

# Product Catalog



**SILICON**  
**GENERAL**

The logo features the word "SILICON" in a bold, black, sans-serif font, positioned above a thick black horizontal bar. Below this bar is the word "GENERAL" in the same font style. The entire logo is framed by a red horizontal bar at the top and a yellow horizontal bar at the bottom.

Solutions for Data Conversion and Power Management





## INTRODUCTION

### THE SILICON GENERAL COMMITMENT

Silicon General Semiconductors has been recognized for many years as a leading supplier of linear power management IC's, providing proprietary semiconductors for regulators, pulse width modulators, servo and other drivers, read/write circuitry, and operational amplifiers. Our roots in power IC technology have led us naturally into the interface area, and CMOS now plays an important role in our product strategy, along with our historically recognized bipolar capability. Our CMOS products, while not represented in this catalog, serve a variety of interface applications and are available on a custom basis.

Silicon General believes a focused product and marketing strategy is best for our chosen marketing base, as well as our customers. We concentrate our resources on serving applications in the Military, Radiation Hard, Industrial Power Supplies, Computer Storage, and Automotive markets. This focused strategy has allowed to us to become the leading supplier to our customers in some of these areas, and we continue to increase our penetration in the others.

Silicon General has been certified by DESC to manufacture microcircuits in conformance with MIL-M-38510, Class B. Certification has also been extended to manufacture devices to MIL-S-19500, JAN, JANTX, and JANTXV. Several devices have been qualified with a growing list of QPL items planned in the future. Many OEM customers have approved Silicon General to manufacture and process devices to their demanding Class S requirements.

We are committed to providing quality products to our customers, on schedule. All our products, whether industrial or military, are processed in the same qualified bipolar fabrication facility. Fab equipment includes the use of projection aligners, dry etch equipment, and ion implantation. Statistical process control is in place and used in daily operations.

Silicon General's offshore and US assembly capability, in combination with one of the broadest package offerings in the industry, provides further flexibility in satisfying the needs of our customers.

We are also committed to providing better technical solutions to your applications problems, and particularly endeavor to provide custom capability wherever practical. Design, product, and applications engineering teams are available in more than one geographical area.

Silicon General supplies the leaders in each of our chosen market areas, and we pride ourselves in this regard. We are a team dedicated to meeting our commitments, and we are a company who values partnership relations with its customers.

We thank you for considering Silicon General as a supplier to your company.

Signed,

A handwritten signature in black ink, appearing to read "Charles C. Thompson", written over a circular stamp or seal.

Charles C. Thompson  
Executive Vice President &  
General Manager



## *PRODUCT STATUS DEFINITIONS*

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The following definitions are used in this catalog to describe the current product production status. Silicon General reserves the right to make changes without further notice to any product to improve reliability, function or design.

**Future Product Release -**

Product is either currently under design or in the conceptual stage, and characteristics are for information only.














**Advanced Data Sheet -**

Product design has been completed and parameters are under evaluation. Data described are design goals, and final device specifications are subject to change.

**(No Definition Noted) -**

Product is in full production.

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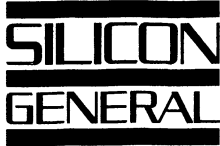
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# PRODUCT SELECTION GUIDE

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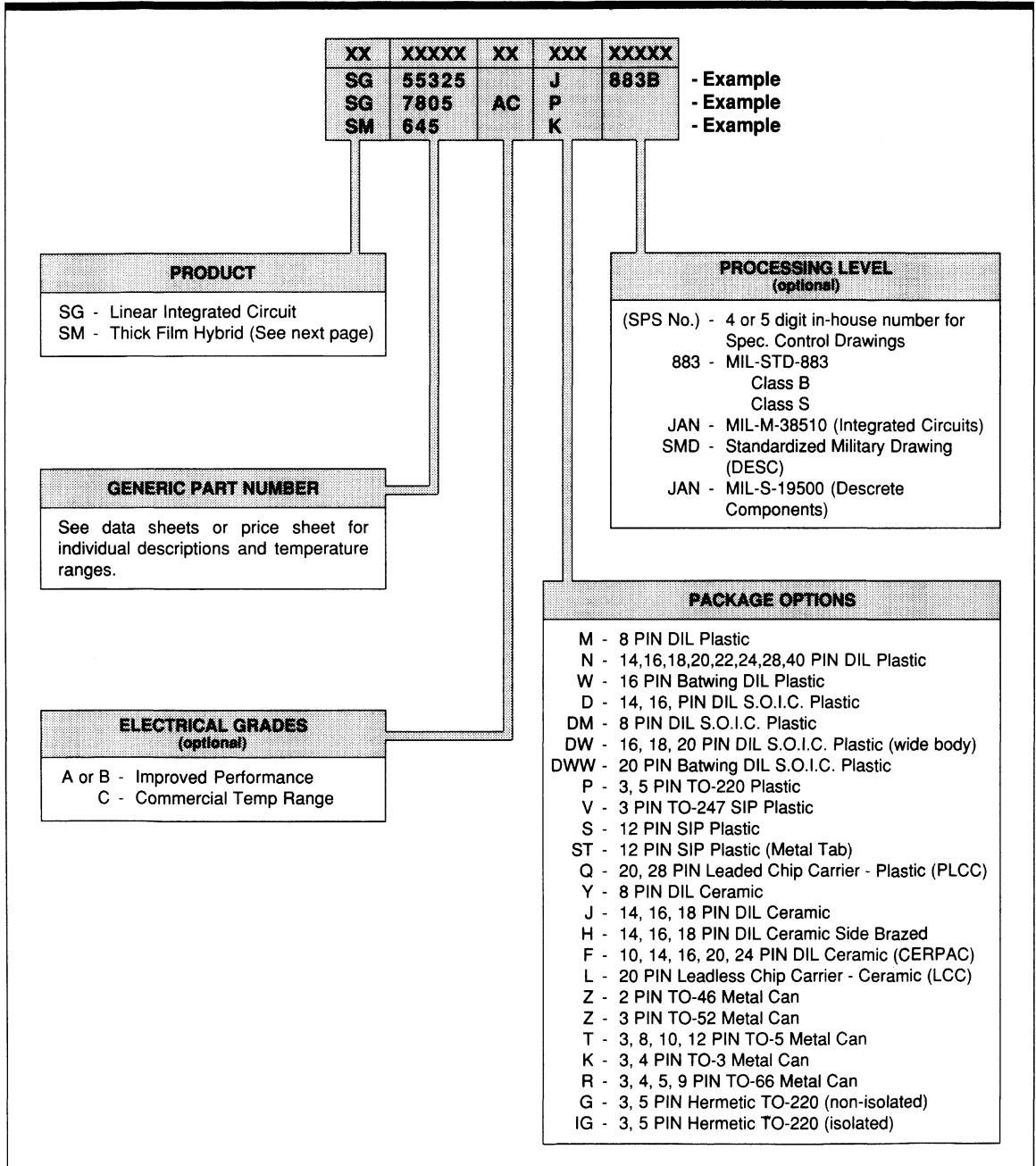
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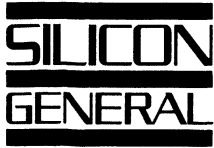


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ULN2003A	SG2003C	ULS2811	SG2811A	SNJ55450B	SG55450B	PIC7535	SM656A	UC7815A	SG7815A
ULN2004A	SG2004C	ULS2812	SG2812A	SNJ55451B	SG55451B	PIC7535	SM657A	UC7815C	SG7815C
ULN2064B	SG2064	ULS2814	SG2814A	SNJ55452B	SG55452B	UC117	SG117	UC7905	SG7905
ULN2065B	SG2065	ULS2821	SG2821A	SNJ55453B	SG55453B	UC120-05	SG120-05	UC7905A	SG7905A
ULN2066B	SG2066	ULS2822	SG2822A	SNJ55454B	SG55454B	UC120-12	SG120-12	UC7905C	SG7905C
ULN2067B	SG2067	ULS2823	SG2823A	SNJ55460	SG55460	UC120-15	SG120-15	UC7905A	SG7905A
ULN2068B	SG2068	ULS2824	SG2824A	SNJ55461	SG55461	UC137	SG137	UC7905C	SG7905C
ULN2069B	SG2069	ULS8124	SG1524	SNJ55462	SG55462	UC140-05	SG140-05	UC7905C	SG7905C
ULN2070B	SG2070	ULS8125A	SG1525A	SNJ55463	SG55463	UC140-12	SG140-12	UC7912	SG7912
ULN2071B	SG2071	ULS8126H	SG1526	SNJ55464	SG55464	UC140-15	SG140-15	UC7912A	SG7912A
ULN2074B	SG2074	ULS8127A	SG1527A	SNJ55470	SG55470	UC150	SG150	UC7912AC	SG7912AC
ULN2075B	SG2075	<b>TEXAS INSTRUMENTS</b>		SNJ55471	SG55471	UC1524	SG1524	UC7912C	SG7912C
ULN2076B	SG2076	TL040	SG040	SNJ55472	SG55472	UC1524A	SG1524B	UC7915	SG7915
ULN2077B	SG2077	LM101A	SG101A	SNJ55473	SG55473	UC1525A	SG1525A	UC7915A	SG7915A
ULN2801A	SG2801A	LM107	SG107	SNJ55474	SG55474	UC1526	SG1526	UC7915C	SG7915C
ULN2802A	SG2802A	LM111	SG111			UC1526A	SG1526B		
ULN2803A	SG2803A	LM137	SG137	TL111	SG111	UC1527A	SG1527A		
ULN2804A	SG2804A	LM207	SG207	TL117	SG117	UC1543	SG1543		
		LM211	SG211	TL1525A	SG1525A	UC1825	SG1825		
		LM217	SG217	TL1527A	SG1527A	UC1544	SG1544		
		LM224	SG224	TL2525A	SG2525A	UC1840	SG1840		
		LM237	SG237	TL2527A	SG2527A	UC1842	SG1842		
		LM748	SG201			UC1843	SG1843		
						UC1844	SG1844		



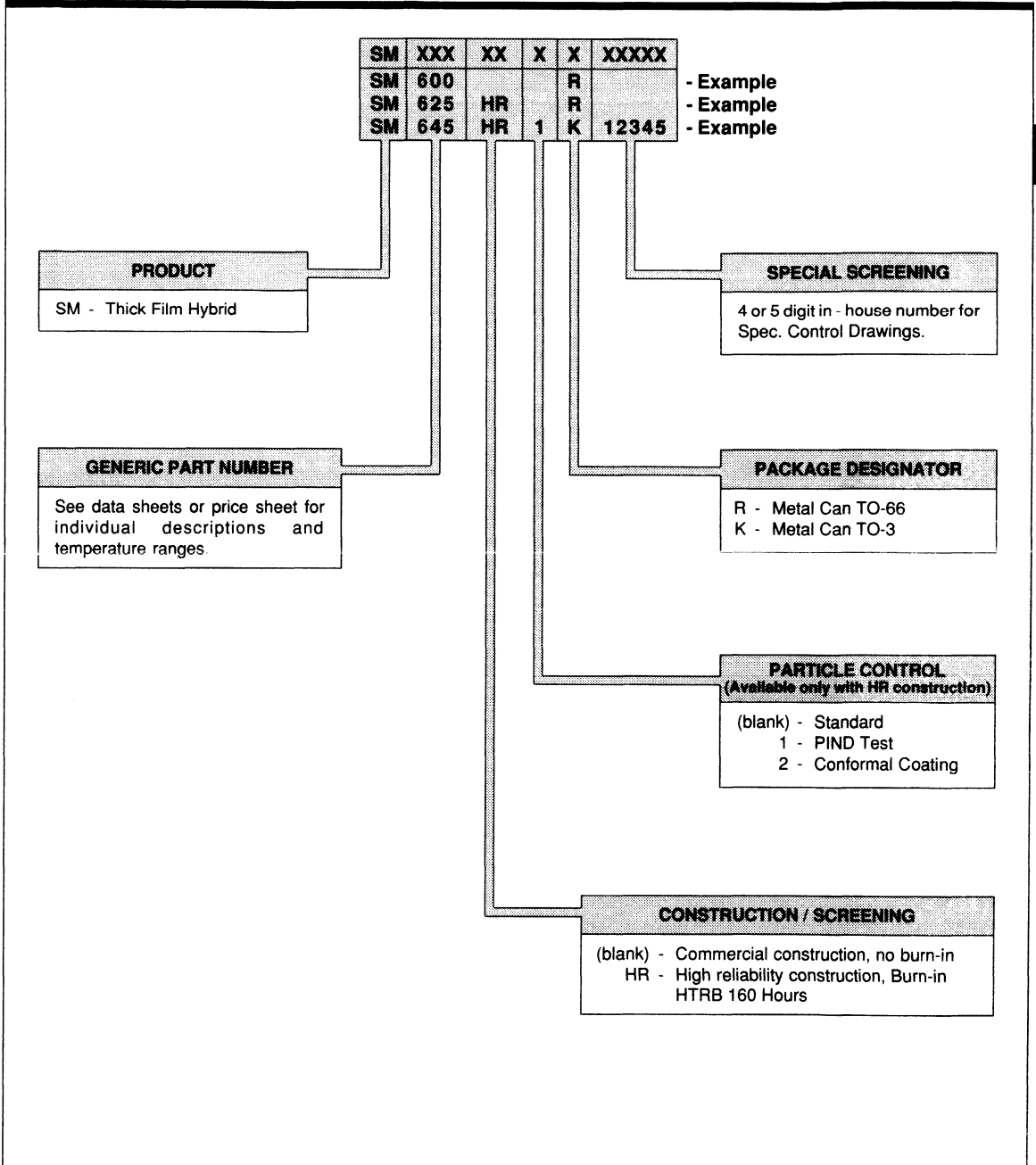




# PRODUCT IDENTIFICATION

LINEAR INTEGRATED CIRCUITS

## POWER HYBRID CIRCUITS





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LINEAR INTEGRATED CIRCUITS

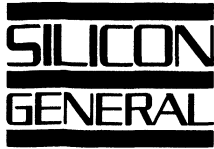
From its beginning in 1969, Silicon General has been committed to excellence in the manufacture of Linear Integrated Circuits.

Over the years, innovative design and the dedication to high quality manufacturing principles has seen the product line expand in scope and grow in customer acceptance.

Silicon General is committed to the concept that the ultimate quality of a device is determined by the company's exacting design and manufacturing process controls. The Statistical Process Control program (SPC) at Silicon General is in effect and has a high management directive to continue to improve. Our dedication to a zero defects program, through process control, has largely been realized through the Total Quality Management concept currently in place.

We understand that satisfaction to the customer is achieved by delivering a high quality product on time. Silicon General assures this through close customer working relationships and a dedication to personal service.

QUALITY ASSURANCE MANAGER



LINEAR INTEGRATED CIRCUITS

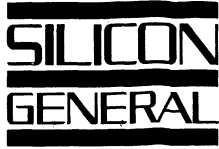
# QUALITY ASSURANCE

## SCREENING PROCEDURES FOR LINEAR INTEGRATED CIRCUITS

Silicon General manufactures hermetic products to the three standard levels of quality assurance processing outlined below. In addition, the company's unique flexibility allows ready accommodations to special customer requirements. The following Class S and Class B screening procedures are in compliance to MIL-M-38510 and all methods are as detailed in MIL-STD-883.

Screen	MIL-M-38510, Class S Method	Reqm't	MIL-M-38510, Class B Method	Reqm't	Standard Product Method	Reqm't
Wafer Lot Acceptance	5007	Sample	N/A		N/A	
Non-Destructive Bond Pull	2023	100%	N/A		N/A	
Internal Visual (Pre-Cap)	2010, Condition A	100%	2010, Condition B	100%	2010, Condition B	100%
Stabilization Bake	1008, Condition C 24 Hours @ 150°C	100%	1008, Condition C 24 Hours @ 150°C	100%	1008, Condition C 24 Hours @ 150°C	100%
Temperature Cycling	1010, Condition C 10 Cycles, -65°C to +150°C	100%	1010, Condition C 10 Cycles, -65°C to +150°C	100%	1010, Condition C 10 Cycles, -65°C to +150°C	100%
Constant Acceleration	2001, Applicable Condition per Package Type	100%	2001, Applicable Condition per Package Type	100%	2001, Applicable Condition per Package Type	100%
Particle Impact Noise Detection (PIND)	2020, Condition A		N/A		N/A	
Hermeticity (Seal)						
a) Fine Leak	1014, Condition B 5 x 10 <sup>-8</sup> atm-cc/sec	100%	1014, Condition B 5 x 10 <sup>-8</sup> atm-cc/sec	100%	1014, Condition B 5 x 10 <sup>-8</sup> atm-cc/sec	100%
b) Gross Leak	1014, Condition C2	100%	1014, Condition C2	100%	1014, Condition C2	100%
Pre-Burn-in Electrical Test	Per Applicable Device Spec. Unit Serialization as required		Per Applicable Device Spec.		Per Applicable Device Spec.	
Burn-in Test	1015, Dynamic 240 Hours @ 125°C Minimum (Note: An additional 72 Hrs HTRB burn-in and interim electrical test as required)	100%	1015, Static or Dynamic 160 Hours @ 125°C Minimum or equivalent	100%	N/A	
Final Electrical Test	Per Applicable Device Spec.		Per Applicable Device Spec.		Per Applicable Device Spec.	
a) DC @ 25°C		100%		100%		100%
b) DC @ Max. and Min. Rated Temp.		100%		100%		100%
c) Dynamic @ 25°C		100%		100%		100%
d) Functional @ 25°C		100%		100%		100%
Hermeticity (Seal)						
a) Fine Leak	1014, Condition B 5 x 10 <sup>-8</sup> atm-cc/sec	100%	N/A		N/A	
b) Gross Leak	1014, Condition C2	100%	N/A		N/A	
Radiography	Method 2012	100%	N/A		N/A	
External Visual	Method 2009	100%	Method 2009	100%	Method 2009	100%
Quality Conformance Testing Group A	5005 DC, AC Parameters	+25°C +125°C -55°C	5005 DC, AC Parameters	+25°C +125°C -55°C	DC, AC Parameters	+25°C
Groups B, C (Class B only), D	5005 Paragraph	3.5	5005 Paragraph	3.5		

December 1988



LINEAR INTEGRATED CIRCUITS

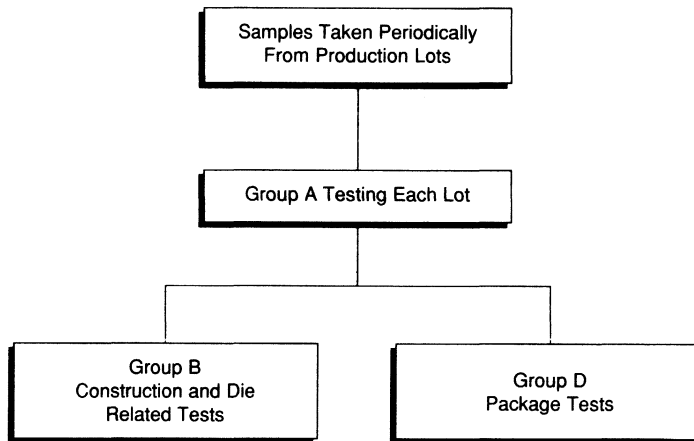
**SCREENING PROCEDURES FOR  
HIGH RELIABILITY POWER HYBRID CIRCUITS**

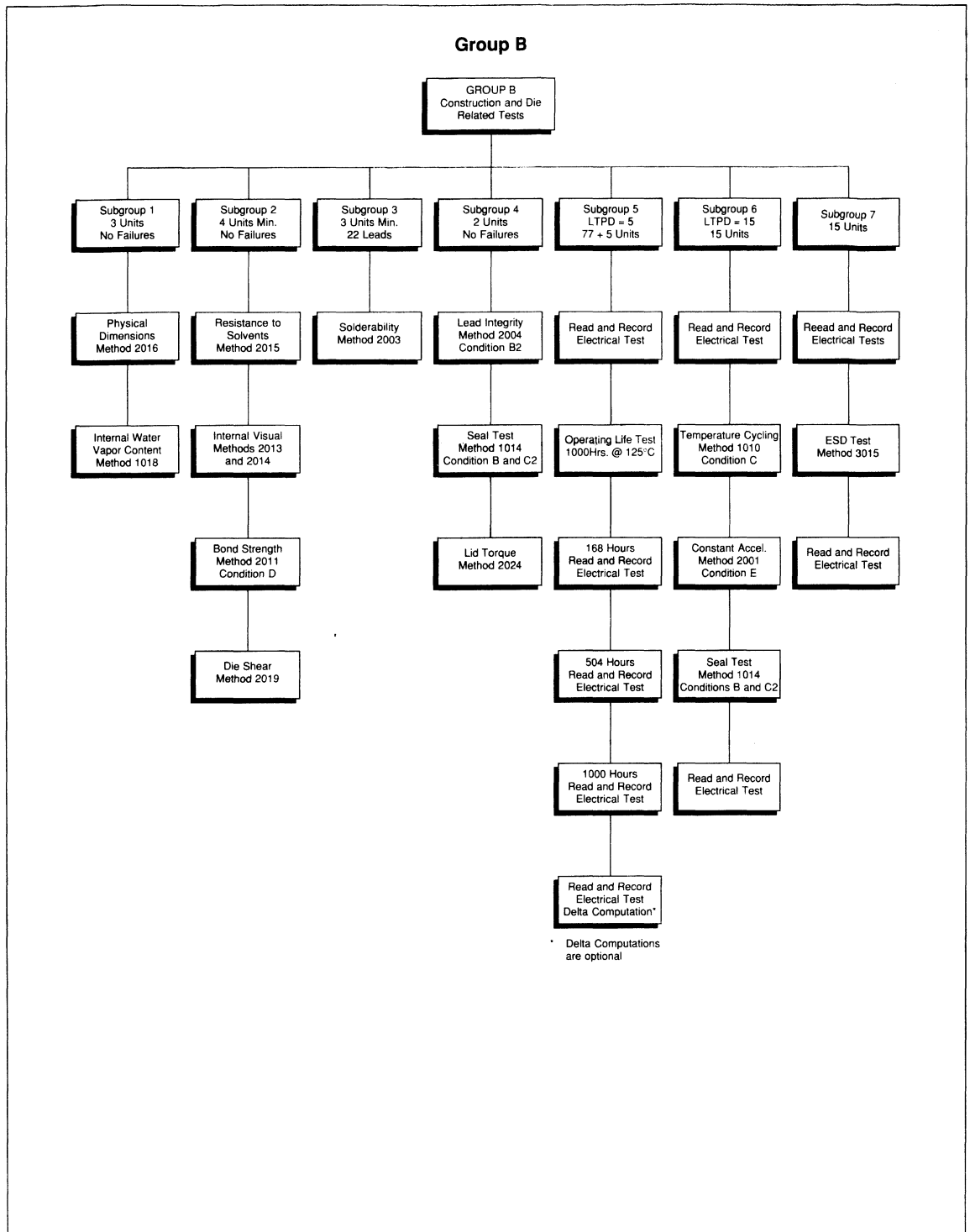
Screen	Method - MIL-STD-883	Requirement	Comments
Internal Visual (Pre-Cap)	2017, Condition B	100%	
Conformal Coating	SG Internal Spec.	(optional)	Per Applicable Device Specification
Stabilization Bake	1008, Condition C 24 Hours @ 150°C	100%	
Temperature Cycling	1010, Condition C 10 Cycles, -65°C to +150°C	100%	
Constant Acceleration	2001, Condition B 20,000 g, Y <sub>1</sub> orientation (R - Pkg.) 5,000 g, Y <sub>1</sub> orientation (K - Pkg.)	100%	
Particle Impact Noise Detection (PIND)	2020, Condition B	(optional)	
Hermeticity (Seal)			
a) Fine Leak	1014, Condition B 5 x 10 <sup>-8</sup> atm-cc/sec	100%	
b) Gross Leak	1014, Condition C2	100%	
Functional Test		100%	Per Applicable Device Specification
Pre-Burn-in Electrical Test	Per Applicable Device Specification	100%	Unit Serialization as required
Burn-in Test	1015, Static Condition A (HTRB) 160 Hours	100%	Consult Factory for Other Screening Procedures
Final Electrical Test	Per Applicable Device Specification		
a) DC @ 25°C		100%	
b) DC @ Max. and Min. Rated Temp.		100%	
c) Dynamic @25°C		100%	
d) Functional @25°C		100%	
e) AC @ 25°C		100%	
Hermeticity (Seal)			
a) Fine Leak	1014, Condition B 5 x 10 <sup>-8</sup> atm-cc/sec	100%	
b) Gross Leak	1014, Condition C2	100%	
External Visual	Method 2009	100%	
Quality Conformance Testing Group A	5008 DC, AC Parameters	+25°C +125°C -55°C	Subgroups 1, 4, 7, 9 Subgroups 2, 8, 10 Subgroups 3, 8, 11
Groups B, C, D	Sample Testing		

December 1988

**QUALITY CONFORMANCE INSPECTION (Q.C.I.)**

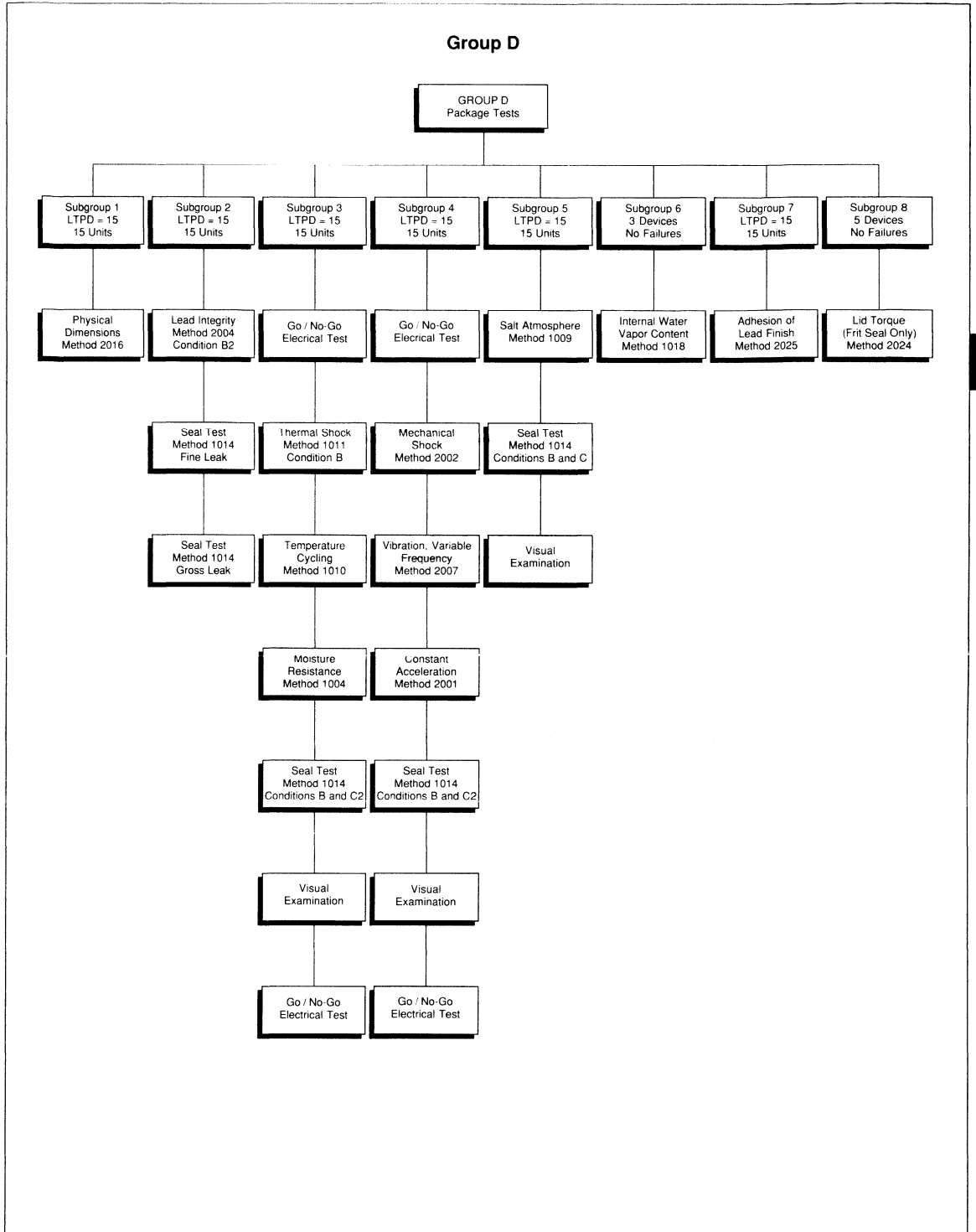
The following Group B and D tests are performed on a periodic basis or when specified by the customer. This testing is in compliance to MIL-M-38510 as detailed in MIL-STD-883, Method 5005.







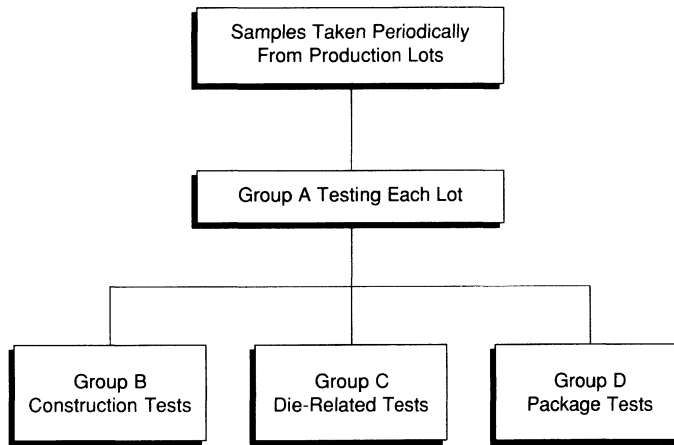
# CLASS S MIL-M-38510 Q.C.I.



**CLASS B MIL-M-38510 Q.C.I.**

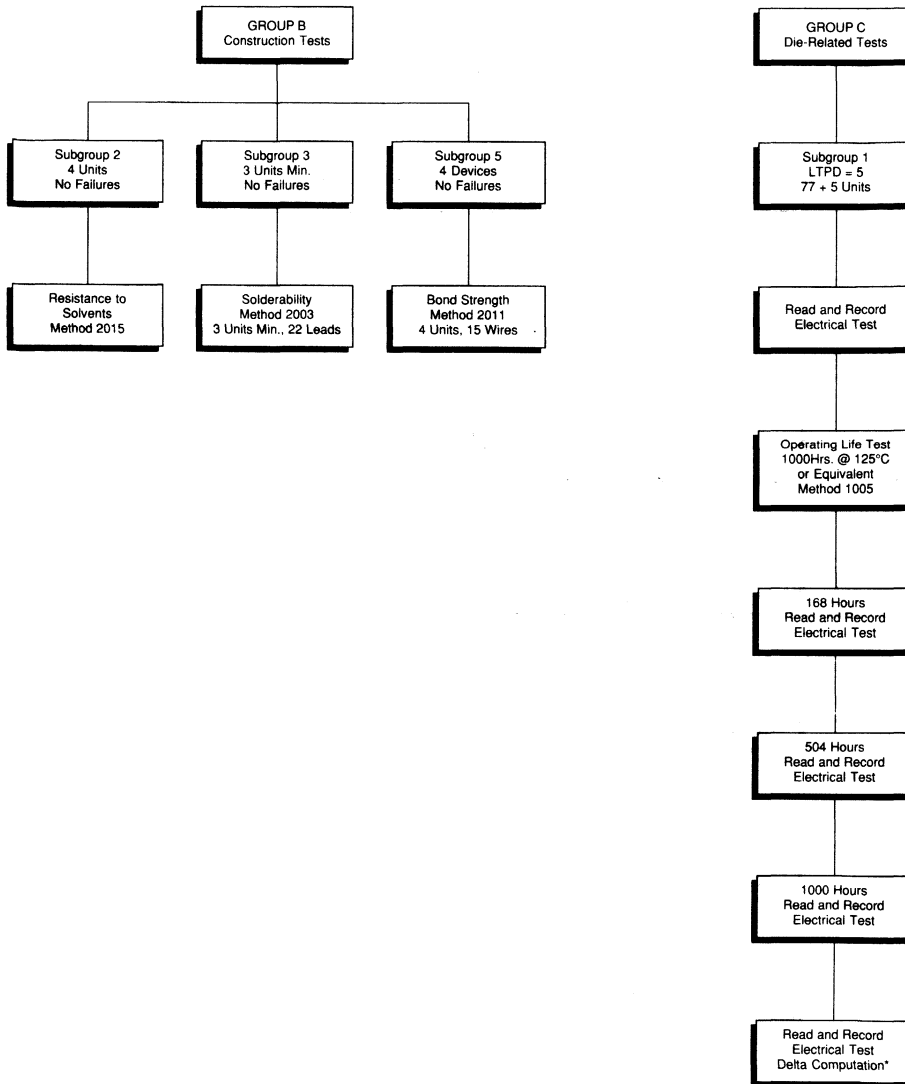
**QUALITY CONFORMANCE INSPECTION (Q.C.I.)**

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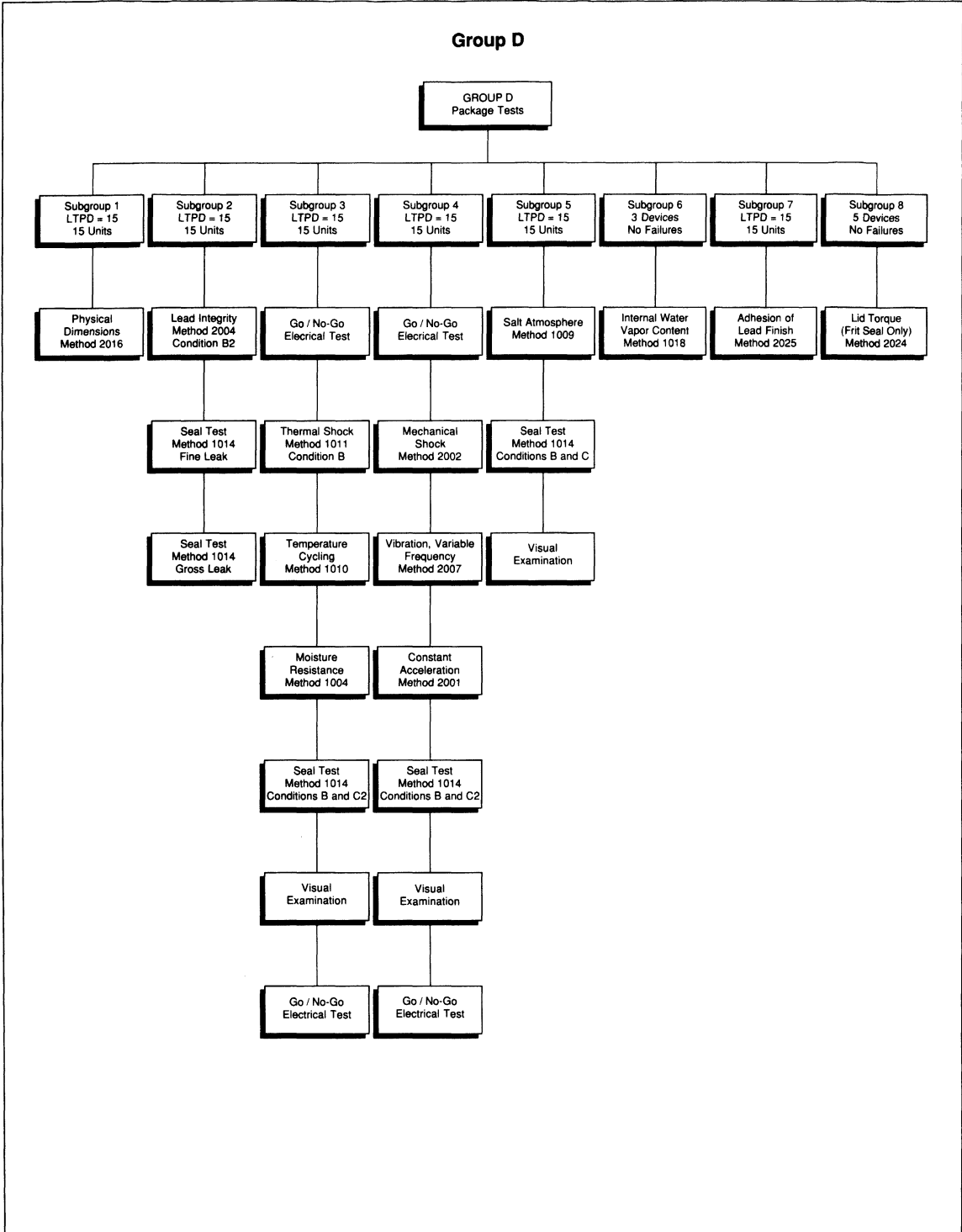
# CLASS B MIL-M-38510 Q.C.I.

## Groups B and C



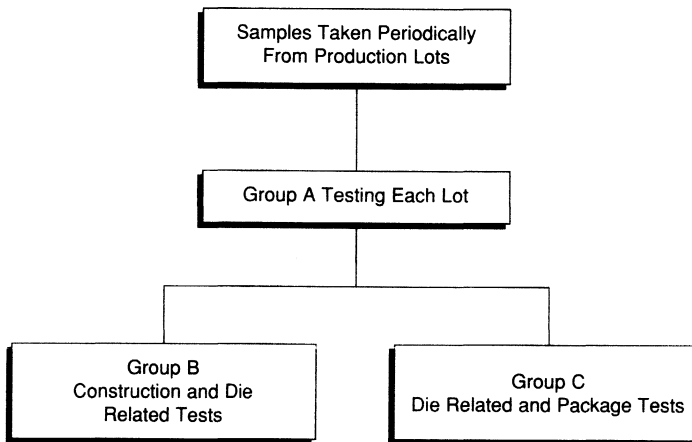
\* Delta Computations are optional

**CLASS B MIL-M-38510 Q.C.I.**



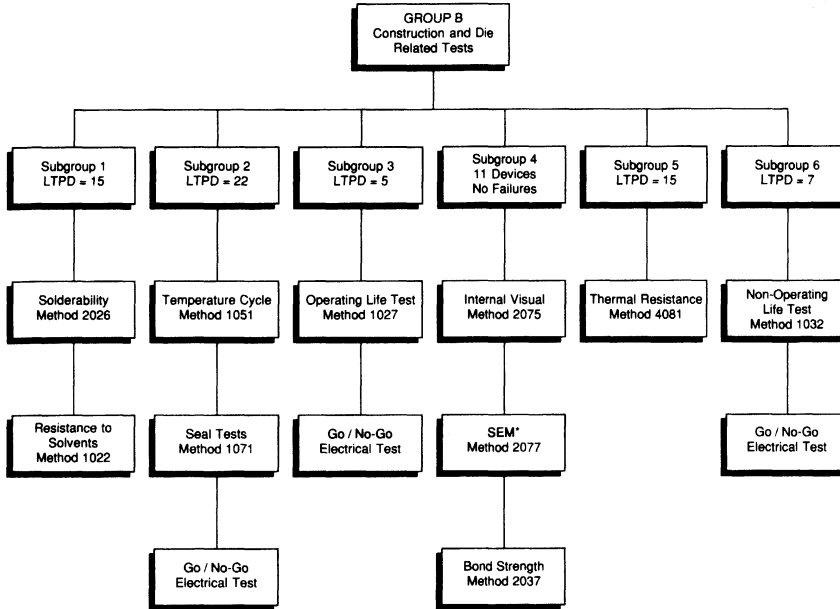
**QUALITY CONFORMANCE INSPECTION**

The following Group B and C tests are performed on a periodic basis or when specified by the customer. This testing is in compliance to MIL-S-19500 Class B quality is shown below.



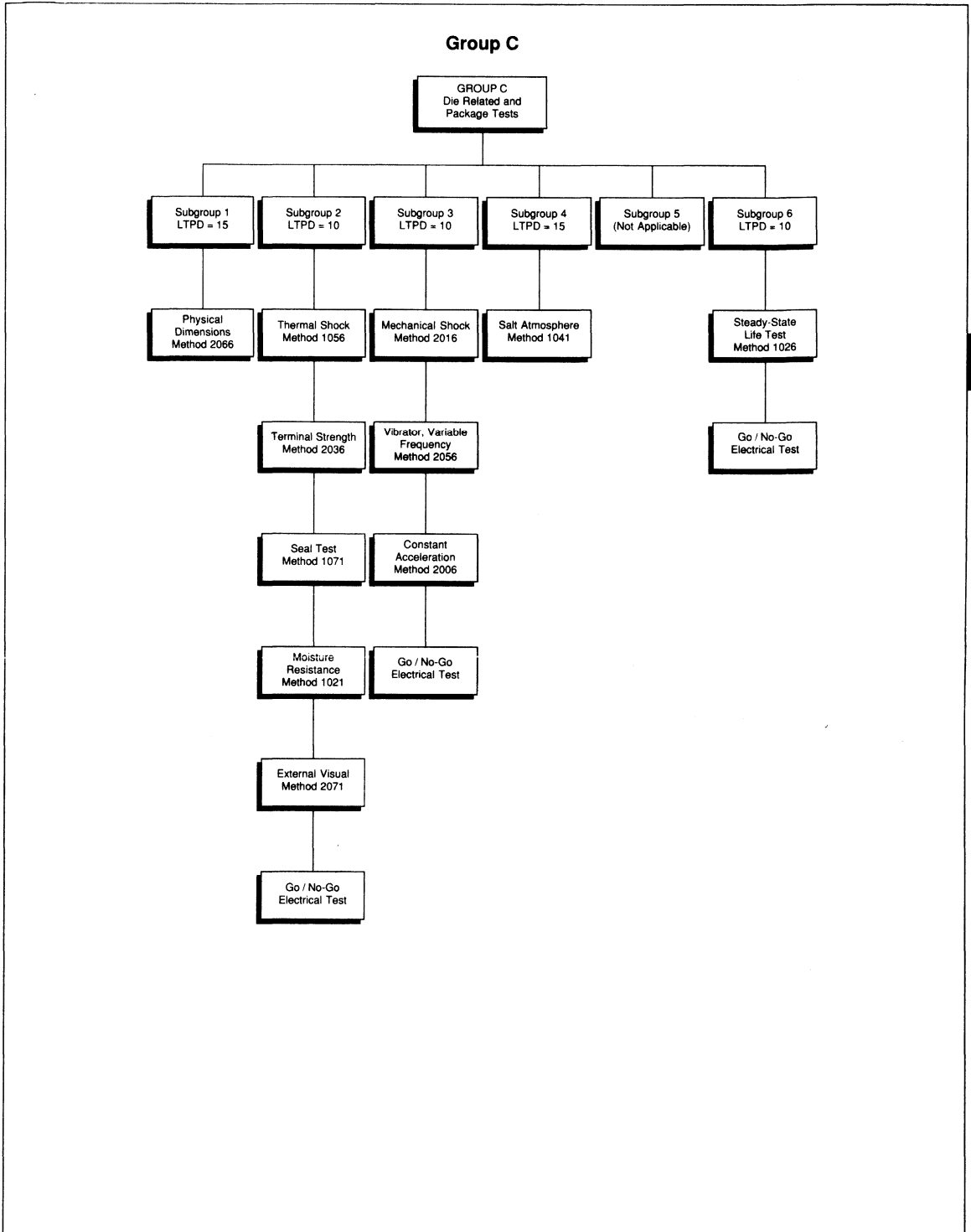
# JAN, JANTX, JANTXV MIL-S-19500 Q.C.I.

## Group B



\* When specifically required

# JAN, JANTX, JANTXV MIL-S-19500 Q.C.I.





LINEAR INTEGRATED CIRCUITS

## *CAPABILITIES*

### *MILITARY PRODUCTS*

#### **PROCESS CAPABILITIES**

Silicon General offers a variety of design, test and processing capabilities that specialize in meeting the specific requirements of the military customer.

This commitment to the military marketplace has led Silicon General to staff and operate a fully certified MIL-M-38510 as well as MIL-S-19500 facility. This unique combination encompassing both discrete and microcircuit components solutions has proven valuable in solving the military customers needs.

The JAN market has become a vital part of our business and Silicon General has introduced a broad offering of components to support it. In addition to our current list of QPL devices we have developed an extensive list of products scheduled for future JAN qualification. These products will help to support the military's thrust for product standardization. Silicon General believes that this understanding of severe environment components has improved the quality of our entire product offering.

#### **SILICON GENERAL SPECIFICATION PROGRAMS**

- MIL-M-38510 - JAN
- MIL-S-19500 - JAN, TX, TXV
- DESC Drawings
- MIL - STD - 883
- MIL - STD - 750
- Source Control Drawings

#### **ADDITIONAL - HIGH RELIABILITY OPTIONS**

In addition to the process capabilities required by our military certification, we also offer the following process options for our space level and Ultra-High Reliability applications.

- PIND Testing
- X - Ray
- Radiation Testing
- SEM Analysis and Wafer Lot Acceptance
- Customer Source Inspection Program
- Custom Data Capability

This combination of small company customer service philosophy with large company capability has enabled Silicon General to become a key supplier in a broad range of High Reliability programs.

Contact Silicon General for a current listing of our JAN QPL and DESC DWG qualifications.





LINEAR INTEGRATED CIRCUITS

# CAPABILITIES

## CUSTOM AND SEMI-CUSTOM INTEGRATED CIRCUITS

### INTRODUCTION

Silicon General offers a wide range of full custom and semi-custom integrated circuits processed in a Mil-M-38510 and Mil-S-19500 certified facility.

### CUSTOM CIRCUIT TECHNOLOGY

Full custom ICs are unique circuit topologies defined by the end user. By contrast, semi-custom ICs are circuit modifications and extrapolations of existing Silicon General devices. This might be as simple as unique electrical test programs or special packaging or as extensive as actually altering the original circuit design.

Silicon General has several circuit technologies to choose from in the design of a custom or semi-custom I.C. This choice can be defined by the end user or recommended by Silicon General. These technologies are shown in Table 1.

TABLE 1 - CUSTOM CIRCUIT TECHNOLOGIES

- |                        |                            |
|------------------------|----------------------------|
| • Bipolar              | • Hybrids                  |
| • Gold - doped Bipolar | • Silicon - on - Insulator |
| • CMOS                 |                            |

### CUSTOM CIRCUIT CAPABILITY

The important characteristics for each of the technologies mentioned above in Table 1 are listed in the following section. These characteristics provide only a baseline as new processing

modules are continually being developed. Please consult the factory for the latest innovations being made.

#### Bipolar

The details in Table 2 show the characteristics of the various junction isolated bipolar processes used at Silicon General.

TABLE 2 - BIPOLAR PROCESS CAPABILITIES

Process	F <sub>T</sub>	Min. HFE	Min. V <sub>CBO</sub>	Min. V <sub>CEO</sub>	Current Rating	Double Layer Metal	Schottky	Gold Doping	Implant Resistor	Polysilicon Resistor
12V	1GHz	50	25V	14V	100mA	Yes	Yes	No	Yes	No
20V	600MHz	50	40V	20V	5A	Yes	Yes	Yes	Yes	Yes
40V	400MHz	50	60V	40V	5A	Yes	Yes	Yes	Yes	Yes
60V	250MHz	50	80V	60V	5A	No	No	Yes	Yes	Yes
Discrete	N/A	50	150V	100V	30A	No	No	Yes	N/A	N/A

Along with the broad bipolar processing capabilities, Silicon General offers proven building blocks with extensive reliability histories and known levels of operational performance. These

blocks can be used as is or modified to accommodate an end users needs. Table 3 details the building blocks used extensively on Silicon General standard and custom/semi-custom circuits.

TABLE 3 - IC BUILDING BLOCKS

- |   |   |
|---|---|
| <ul style="list-style-type: none"> <li>• Pulse Width Modulation techniques for switching power supplies and motor control applications</li> <li>• Bandgap voltage references (tolerance &lt; 1%)</li> <li>• Oscillators</li> <li>• Low dropout output stages (e.g. dropout &lt;1V at 750mA)</li> <li>• Various comparators and op-amps</li> </ul> | <ul style="list-style-type: none"> <li>• Full Logic               <ul style="list-style-type: none"> <li>- Gates, Flip Flops, Schmitt Triggers etc.</li> <li>- TTL, Schottky TTL, EFL, ECL, I<sup>2</sup>L</li> <li>- Gate Delays ≥ 3nsec</li> </ul> </li> <li>• Discrete Transistor / Diode Arrays</li> <li>• High Current, High Voltage Power Stages</li> </ul> |
|---|---|

# CUSTOM AND SEMI-CUSTOM IC's

## CUSTOM CIRCUIT CAPABILITY (continued)

### CMOS

Silicon General has in-house capability to develop Standard Cell or full custom CMOS I.C.'s. These I.C.'s are then processed at qualified outside foundries. This CMOS capability combined with

the broad bipolar background enable Silicon General to aid in the partitioning of many end users applications. Current CMOS capabilities are listed in Table 4.

TABLE 4 - CMOS CAPABILITIES

- |  |   |
|--|---|
| <ul style="list-style-type: none"><li>• Geometries from 2.0<math>\mu</math>m to 1.2<math>\mu</math>m</li><li>• Standard Cell Library that includes:<ul style="list-style-type: none"><li>- 7400 SSI/MSI Logic Family</li><li>- Static RAM to 64K</li></ul></li></ul> | <ul style="list-style-type: none"><li>• CAD tools available:<ul style="list-style-type: none"><li>- Auto Place and Route (Standard Cell and Block)</li><li>- Schematic Capture</li><li>- Schematic Simulation</li><li>- Layout vs. Schematic Checking (LVS)</li><li>- Design Rule Checking (DRC)</li><li>- Electrical Rule Checking (ERC)</li></ul></li></ul> |
|--|---|

### Hybrid

A long history exists in the design and manufacture of thick film hybrids for the military, automotive, and commercial markets. For those applications where a single monolithic approach is not attainable Silicon General can combine a standard, custom or

semi-custom I.C. with other components into a cost-effective, size efficient hybrid. Current thick film hybrid capabilities are listed in Table 5.

TABLE 5 - HYBRID CAPABILITIES

- |   |   |
|---|---|
| <ul style="list-style-type: none"><li>• Surface Mount or Chip and Wire technologies</li><li>• Custom Hybrid Packaging for both low and high power applications</li><li>• Full Military Processing</li></ul> | <ul style="list-style-type: none"><li>• Laser trimmed resistors:<ul style="list-style-type: none"><li>- 0.5% absolute value</li><li>- 0.2% matching</li></ul></li><li>• Conformal Coating</li></ul> |
|---|---|

### Silicon on Insulator (SOI)

Currently under development is a proprietary state of the art SOI process designed specifically to improve the radiation hardening capability of Military I.C.'s produced at Silicon General. First

product introduction will occur in 1989. The details of this process are shown on page 3-18. Target characteristics are listed in Table 6.

TABLE 6 - SOI CHARACTERISTICS

- |   |  |
|---|--|
| <ul style="list-style-type: none"><li>• Transistor isolation to 750V</li><li>• Minimum <math>V_{CBO} = 130V</math>, <math>V_{CEO} = 80V</math></li><li>• Maximum Current Rating to 5A</li></ul> | <ul style="list-style-type: none"><li>• Dual Layer metal, Schottky, and gold doping capability</li><li>• <math>F_T</math> up to 6GHz</li><li>• Implant and Polysilicon resistors</li></ul> |
|---|--|

### PACKAGING ALTERNATIVES

Packaging alternatives are presented in Table 7. These range from the more common DIP to newer packages like the hermetic TO-220 and full custom packages. Trade-offs can be made concerning power handling capability, size, hermeticity and cost.

The  $\theta_{JC}$  and  $\theta_{JA}$  values and package dimensions are given for most of these packages in Section 11 of this catalog. Silicon General product engineers are well equipped to assist in selecting the best package for your particular requirements.

TABLE 7 - PACKAGING ALTERNATIVES

- |  |   |
|--|---|
| <ul style="list-style-type: none"><li>• Ceramic and plastic dual in line</li><li>• Ceramic and plastic leadless and leaded chip carriers (J-lead available)</li><li>• Ceramic flatpacks</li><li>• Plastic S.O.I.C.</li></ul> | <ul style="list-style-type: none"><li>• Metal Can (TO-3, TO-5, TO-39, TO-46, TO-52, TO-66, TO-99)</li><li>• Hermetic TO-220 and plastic TO-220 outline package</li><li>• Power SIP</li><li>• Custom hermetic and plastic packages</li></ul> |
|--|---|

# CUSTOM AND SEMI-CUSTOM IC's

## CUSTOM CIRCUIT PROCESSING LEVELS

Silicon General's custom circuit experience is extensive. We have produced custom ICs for some of the most demanding environments, both military and commercial. Our custom circuits can be found on satellites, radar systems, gyroscopes, automobiles, missile systems, disc drives and catalog power supplies.

Table 8 contains a partial list of the processing levels available for custom circuits. This flexibility in processing combined with a MIL-M-38510, MIL-S-19500 approved facility results in a custom circuit supplier able to handle virtually all special program and end-user requirements.

TABLE 8 - CUSTOM CIRCUIT PROCESSING LEVELS

<ul style="list-style-type: none"><li>• MIL - STD - 883 Class B Class S</li><li>• MIL - STD - 750 JAN JANTX JANTXV</li><li>• Die processing; MIL - STD - 883, Level B, Level S</li></ul>	<ul style="list-style-type: none"><li>• Military (-55°C to 125°C)</li><li>• Automotive (-40°C to 125°C)</li><li>• Industrial (-25°C to 85°C)</li><li>• Commercial (0°C to 70°C)</li><li>• Extended temperature range</li><li>• Wafer traceability, wafer lot acceptance, SEM</li><li>• Special processing (end user defined)</li></ul>
--	--

## CONCLUSION

Silicon General is committed to building long-term customer relationships. To be a valued supplier; we must provide, on time, a quality product, which meets not only the customer specification but the device application as well. Our military certified facility and production capability, both military and commercial, define Silicon General as a custom IC supplier able to support virtually any end-user requirement.

Silicon General has the production resources, technical expertise and commitment to quality to provide a TOTAL SERVICE (end-user defined) custom integrated circuit program.

**RADIATION HARDENED  
INTEGRATED CIRCUITS**

**INTRODUCTION**

Silicon General has formed a division to design and produce radiation hardened linear ICs for strategic military, space-level and specialized applications.

**RAD HARD TECHNOLOGY**

The RAD HARD IC TECHNOLOGIES Division begins the design of a radiation hardened device by studying the customer's system requirements and determining which of the many hardening techniques will be needed.

The two main areas of concern when designing a device for specific radiation performance are design techniques and fabrication processes. Listed below are some of the techniques used by Silicon General.

**DESIGN CAPABILITIES**

- Beta degradation tolerant electrical design ensures the system designer worst case electrical specification after the radiation event.
- Photocurrent compensation is used to minimize the circuit upset during a radiation event.
- In junction isolated devices, NPN and PNP transistors are spaced for maximum radiation tolerance.

**FABRICATION PROCESSES**

- A Silicon General proprietary Silicon-On-Insulator (SOI) process technique called *TISER* (see Figure 1) is used to prevent "latch-up" during single event upset and gamma dot events. This proprietary process has many advantages over older techniques in both electrical and radiation performance.

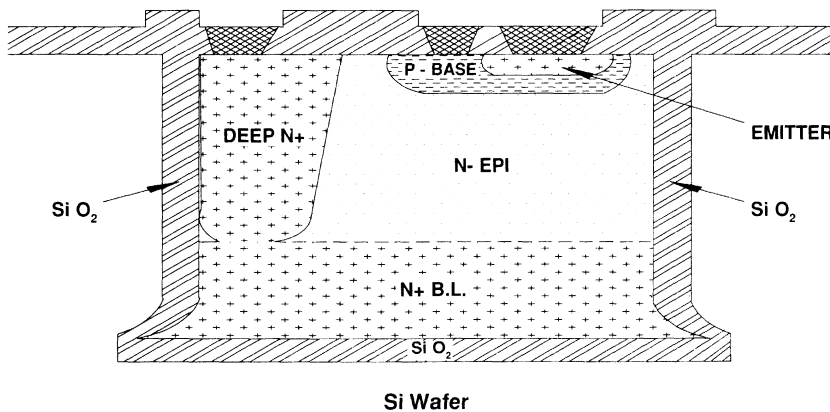


Figure 1. NPN Transistor

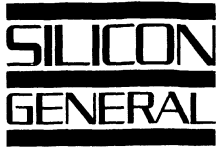
- Buried zener references are used instead of surface zeners to minimize the effect of surface charge build-up.
- Other fabrication processes, such as Submetal Nitride Passivation, Double diffused PNP transistors, and Oxide Isolated resistors, are also used.

In addition to custom radiation hardened designs, Silicon General plans to introduce a line of rad hard "industry standard" linear devices, e.g., LM117, LM137, ...

Please call Silicon General or your local Silicon General representative for more information.

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<b>6</b>	<b>POWER DRIVER AND INTERFACE CIRCUITS</b>
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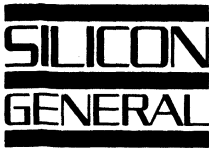
# SELECTION GUIDE POWER SUPPLY CIRCUITS

LINEAR INTEGRATED CIRCUITS

## SWITCHING REGULATOR CONTROL IC's

DEVICE TYPE	PERFORMANCE CHARACTERISTICS													Packages				
	Voltage Reference $\pm 4\%$	Voltage Reference $\pm 1\%$	Soft Start	PWM Latch	Under-Voltage Lockout	Pulse-by-Pulse Current Limiting	Shutdown Terminal	Output Transistor Rating (Vce, Peak Current)	Feed Forward	Maximum Frequency Oscillator	Uncommitted Outputs	Number of Outputs	Totem Pole Outputs		Separate Oscillators	Adjustable Oscillator Sync Terminal	Double Pulse Declaiming Control	Low Current Start Up
<b>Voltage Mode PWM</b>																		
SG1524/2524/3524	•						40V 100mA	300KHz	•	2	•						<50%	J, N, D, F, L
SG1524B/2524B/3524B	•	•	•	•	•	•	60V 200mA	500KHz	•	2	•	•	•				<50%	J, N, DW, F, L
SG1525A/2525A/3525A	•	•	•	•	•	•	35V	500KHz		2	•	•	•				<50%	J, N, DW, F, L
SG1527A/2527A/3527A	•	•	•	•	•	•	0.4A				•	•	•					
SG1526/2526/3526	•	•	•	•	•	•	35V 0.4A	400KHz		2	•	•	•	•			<50%	J, N, DW, F, L
SG1526B/2526B/3526B	•	•	•	•	•	•	35V 0.4A	550KHz		2	•	•	•	•			<50%	J, N, DW, F, L
SG1529/2529/3529	•		•	•	•	•	60V 200mA	500KHz	•	2	•		•				<50%	J, N, DW
SG1840/2840/3840	•	•	•	•	•	•	30V 400mA	500KHz	•	1			N/A	•			<100%	J, N, DW
<b>Current Mode PWM</b>																		
SG1528/2528/3528		•	•	•	•	•	22V	3MHz		1	•	•	N/A	•			<50%	J, N, DW
SG1530/2530/3530		•	•	•	•	•	3A				•	•		•			<100%	
SG1825/2825/3825	•	•	•	•	•	•	30V 1.5A	2MHz		2	•	•	•	•			<50%	J, N, DW, F, L, Q
SG1842/2842/3842	•		•	•	•	•	30V	500KHz		1	•		N/A	•			<100%	J, N, Y, M, D, F, L
SG1843/2843/3843	•		•	•	•	•	1A				•	•	•	•				
SG1844/2844/3844	•		•	•	•	•					•	•	•	•			<50%	J, N, Y, M, D
SG1845/2845/3845	•		•	•	•	•					•	•	•	•				
SG1846/2846/3846	•	•	•	•	•	•	40V	500KHz		2	•	•	•	•			<50%	J, N, DW, F, L
SG1847/2847/3847	•	•	•	•	•	•	500mA				•	•	•	•				

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## SELECTION GUIDE POWER SUPPLY CIRCUITS

LINEAR INTEGRATED CIRCUITS

### POWER SUPPLY SUPPORT FUNCTIONS

Device Type	Description	Key Features	Packages
SG1540/2540/3540	Off-line start up controller. Minimizes the cost and complexity of auxillary power supply.	<ul style="list-style-type: none"> <li>Eliminates bulky 50/60Hz transformer.</li> <li>Minimizes high voltage bleeder current.</li> <li>Usable with primary or secondary PWM control.</li> <li>Programmable start up voltage.</li> <li>Programmable over voltage latch.</li> </ul>	Y, M, DW, F
SG1543/2543/3543 SG1544/2544/3544	Power supply supervisory circuit. Monitors and controls power supply output.	<ul style="list-style-type: none"> <li>Over-voltage, under-voltage, and current sensing circuits are all included</li> <li>Programmable time delays</li> <li>Internal 1% accurate reference available</li> <li>Open collector outputs</li> <li>Remote activation capability</li> <li>SCR "Crowbar" drive of 300mA</li> <li>Optional over voltage latch</li> <li>Uncommitted comparator</li> <li>Inputs for low voltage sensing (SG1544 series only)</li> </ul>	J, N, DW, F, L
SG1548/2548/3548	Quad power fault monitor. Monitors and controls four power supply outputs.	<ul style="list-style-type: none"> <li>Over-voltage and under-voltage sensing on four power supply outputs</li> <li>Programmable time delay</li> <li>Internal 1% accurate reference available</li> <li>Open collector outputs.</li> <li>Adjustable fault window</li> <li>On-chip inverting op-amp for negative voltage</li> <li>Additional input for AC line monitoring</li> </ul>	J, N, DW, L
SG1549/2549/2549	Current sense latch. Monitors power supply output current.	<ul style="list-style-type: none"> <li>Current sense latching circuitry</li> <li>Separate terminals for high and low common mode input sensing</li> <li>Automatic reset from PWM clock</li> <li>Complementary outputs available</li> <li>Low propagation delays (180ns)</li> </ul>	Y, M
SG1557/2557/3557 SG1559/2559/3559 SG1560/2560/3560	Low cost MAG-AMP controller. Controller for magnetic amplifiers or secondary side control applications.	<ul style="list-style-type: none"> <li>Lower cost than combined comparable discrete parts</li> <li>Two independent op-amps (1557/59 series)</li> <li>Two uncommitted open collector comparators (1557/59 series)</li> <li>±2% voltage reference over line, load and temperature</li> <li>Low input voltage operation</li> <li>13V zener for pre-regulating +V<sub>IN</sub> (1557/59 series)</li> <li>Internal 100mV offset voltage built in one of the comparators (1559 series only)</li> </ul>	J, N, Y, M, DW
SG1626/2626/3626 SG1644/2644/3644 SG1627/2627/3627 SG1629/2629/3629	High speed driver (Inv.) High speed driver (N.I.) Dual uncommitted output driver Bipolar driver	SEE POWER DRIVER AND INTERFACE SECTION	
SG103/203/303 SG1503/2503/3503	Voltage reference Voltage reference	SEE OTHER LINEAR CIRCUITS SECTION	

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# SELECTION GUIDE POWER SUPPLY CIRCUITS

LINEAR INTEGRATED CIRCUITS

## VOLTAGE REGULATORS

Device Type	PERFORMANCE CHARACTERISTICS								
	Output Current	Polarity	Fixed	Adjustable	Dual	Low Dropout	Max. Input Voltage	Output Voltage (V)	Package
SG138/138A	5A	Positive		•			35V	1.2V to 38V	K (TO-3)
SG150	3A	Positive		•			35V	1.2V to 33V	K (TO-3), P (TO-220)
SG117/117A	1.5A	Positive		•			35V	1.2V to 37V	K (TO-3), R (TO-66), P (TO-220), G (Hermetic TO-220), IG (Hermetic TO-220)
SG117HV/117AHV				•			60V	1.2V to 57V	
SG140		Positive	•				35V	5, 6, 8, 12, 15, 18, 20, 24	
SG7800			•						
SG109		Positive	•				35V	5V	
SG137/137A		Negative			•		35V	-1.2V to -37V	
SG137HV					•		60V	-1.2V to -57V	
SG120		Negative		•			35V	-5, -5.2, -8, -12, -15, -18, -20	
SG7900/7900A				•					
SG29055/55A*		0.75A	Positive	•		•	•	26V	5V, 5V
SG29085/85A*	Positive		•		•	•	26V	8V, 5V	
SG29125/125A*	Positive		•		•	•	26V	12V, 5V	
SG117/117A	0.5A	Positive		•			35V	1.2V to 37V	T (TO-39)
SG117HV/117AHV				•			60V	1.2V to 57V	
SG140		Positive	•				35V	5, 6, 8, 12, 15, 18, 20, 24	
SG7800/7800A			•						
SG109		Positive	•				35V	5V	
SG137/137A		Negative			•		35V	-1.2V to -37V	
SG137HV					•		60V	-1.2V to -57V	
SG120		Negative		•			35V	-5, -5.2, -8, -12, -15, -18, -20	
SG7900/7900A				•					
SG1532		0.1A	Positive		•			50V	2V to 38V
SG723	Positive			•			50V	2V to 38V	
SG1501A	Negative/ Positive		•			•	±35V	±15V	J, N, T (TO-100)
SG1502	Negative/ Positive				•	•	±30V	±10V to ±28V	J, N
SG1568	Positive/ Negative		•			•	±30V	±15V	J, N, T (TO-100) R (TO-66)
SG105	0.02A		Positive		•			50V	4.5V to 40V
SG104		Negative		•			-50V	-0.015V to -40V	T (TO-100)

\* See Automotive Section





## SELECTION GUIDE POWER SUPPLY CIRCUITS

LINEAR INTEGRATED CIRCUITS

### SWITCHING REGULATOR OUTPUT STAGE

Device Type	PERFORMANCE CHARACTERISTICS									Packages			
	Peak Output Current	Polarity	Input/Output Voltage (V)	Rise Time (ns)		Fall Time (ns)		On-State Voltage					
				Voltage	Current	Voltage	Current	Transistor	Diode				
SM645	20A	Positive	60	60	150	175	300	1.5V @ 7A	1.25V @ 7A	K (TO-3)			
SM646			80										
SM647			100										
SM655		Negative	60	60	175	300	300						
SM656			80										
SM657			100										
SM625	15A	Positive	60	60	150	175	300	1.5V @ 7A	1.25V @ 7A	R (TO-66) Isolated			
SM626			80										
SM627			100										
SM635		Negative	60	60	175	300	300						
SM636			80										
SM637			100										
SM660	10A	Positive	60	60	150	175	300	1.5V @ 5A	1.25V @ 5A	R (TO-66) Isolated			
SM661			80										
SM662			100										
SM670		Negative	60	60	175	300	300						
SM671			80										
SM672			100										
SM600	5A	Positive	60	50	75	75	150	1.5V @ 2A	1.0V @ 2A	R (TO-66) Isolated			
SM601			80										
SM602			100										
SM610		Negative	60	50	75	75	150						
SM611			80										
SM612			100										





LINEAR INTEGRATED CIRCUITS

# SG104/SG204/SG304

## NEGATIVE VOLTAGE REGULATOR

### DESCRIPTION

This circuit is a negative voltage regulator designed for both linear and switching applications. It is a complement of the SG100/200/300, SG105/205/305 and SG723/723C intended for systems requiring regulated negative voltages having a common ground with the unregulated supply. With an input voltage rating of up to 50 volts, this device will deliver load currents to 25 milliamps. Adding external transistors will increase the current capability to greater than 10amps and further improve regulation.

The SG104 will operate over the full military temperature range of -55°C to +125°C. The SG204 operates over the temperature range of -25°C to 85°C while the SG304 is designed for commercial applications of 0°C to 70°C.

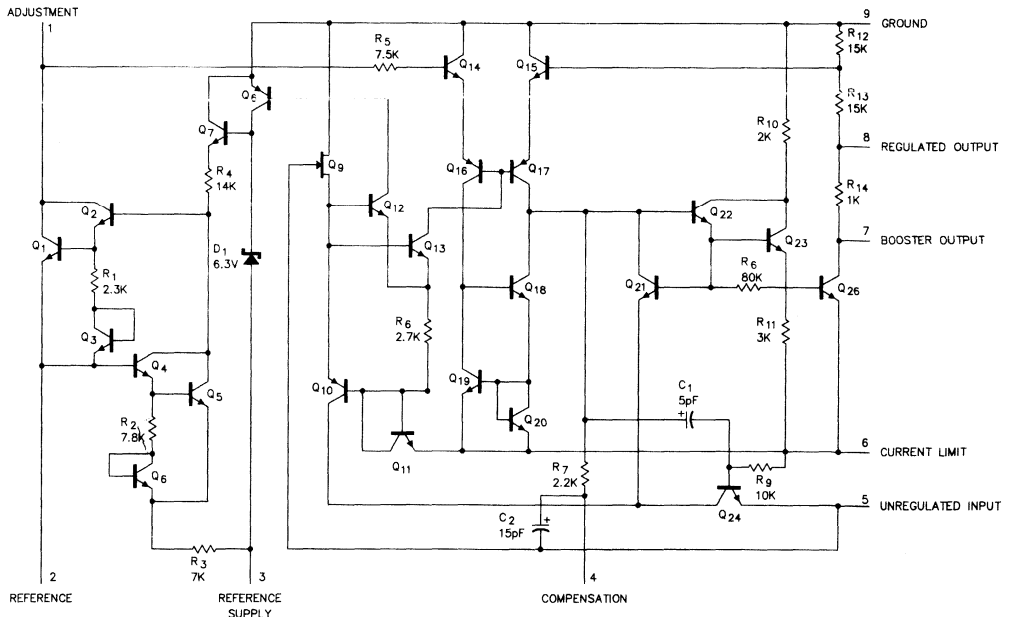
### FEATURES

- Output voltage adjustable from 15mV to 40V
- 1mV regulation no load to full load
- 0.01%/V lin regulation
- 1% maximum temperature variation

### HIGH RELIABILITY FEATURES - SG104

- ◆ Available to MIL-STD-883B
- ◆ SG level "S" processing available

### BLOCK DIAGRAM



# SG104/SG204/SG304

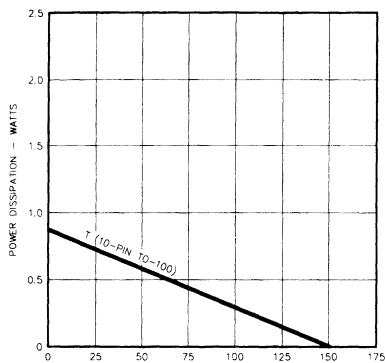
## ABSOLUTE MAXIMUM RATINGS

Input Voltage		Operating Junction Temperature	
SG104, SG204 .....	50V	Hermetic (T-Package) .....	175°C
SG304 .....	40V	Power Dissipation (Note 1) .....	500mW
Input - Output Voltage Differential		Storage Temperature Range .....	-65°C to 150°C
SG104, SG204 .....	50V	Lead Temperature (Soldering, 10 seconds) .....	300°C
SG304 .....	40V		

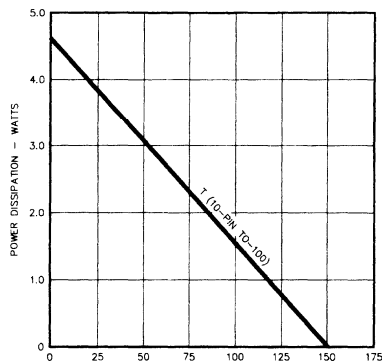
Note 1. Operated at elevated temperatures, the device must be derated based upon the maximum junction temperature (150°C for the SG104, 100°C for the SG204, and 85°C for the SG304) and a thermal resistance of 45°C/W junction to case or 150°C/W junction to ambient.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Input Voltage		Operating Ambient Temperature Range	
SG104, SG204 .....	8V to 48V	SG104 .....	-55°C to 125°C
SG304 .....	8V to 38V	SG204 .....	-25°C to 85°C
Input - Output Voltage Differential		SG304 .....	0°C to 70°C
SG104, SG204 .....	4V to 47V		
SG304 .....	4V to 37V		

Note 2: Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(These specifications apply for over recommended operating temperatures, unless otherwise specified. The load and line regulation specifications are for constant junction temperature. Temperature drift effects must be taken into account separately when the unit is operating under conditions of high dissipation.)

Parameter	Test Conditions	SG104/204			SG304			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Input Voltage Range		-50		-8	-40		-8	V
Output Voltage Range		-40		-0.015	-30		-0.035	V
Output - Input Voltage Differential (Note 2)	$I_o = 20\text{mA}$	2.0		50	2.0		40	V
	$I_o = 5\text{mA}$	0.5		50	0.5		40	V
Load Regulation (Note 3)	$0 \leq I_o \leq 20\text{mA}$ , $R_{SC} = 15\Omega$		1	5		1	5	mV
Line Regulation (Note 4)	$V_{OUT} \leq -5\text{V}$ , $\Delta V_{IN} = 0.1 V_{IN}$		0.056	0.1		0.056	0.1	%
Ripple Rejection	$C_{PINH - PINS} = 10\mu\text{F}$ , $f = 120\text{Hz}$							
	$V_{IN} < -15\text{V}$		0.2	0.5		0.2	0.5	mV/V
	$-7\text{V} \geq V_{IN} \geq -15\text{V}$		0.5	1.0		0.5	1.0	mV/V

Note 2. When external booster transistors are used, the minimum output-input voltage differential is increased, in the worst case, by approximately 1 volt.

Note 3. The output currents given, as well as the load regulation, can be increased by the addition of external transistors. The improvement factor will be roughly equal to the composite current gain of the added transistors.

Note 4. With zero output, the DC line regulation is determined from the ripple rejection. Hence, with output voltages between 0 volts and -5volts, a DC output variation, determined from the ripple rejection, must be added to find the worst-case line regulation.

# SG104/SG204/SG304

## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG104/204			SG304			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage Scale Factor	$R_{PIN2 - PIN3} = 2.4K$	1.8	2.0	2.2	1.8	2.0	2.2	V/KΩ
Temperature Stability	$V_O \leq -1V$		0.3	1.0	0.3	1.0		%
Output Noise Voltage	$10Hz \leq f \leq 10KHz$							
	$V_O \leq -5V, C_{PIN1 - PIN9} = 0$		0.007		0.007			%
	$C_{PIN1 - PIN9} = 10\mu F$		15		15			$\mu V$
Standby Current Drain	$I_L = 5mA, V_O = 0$		1.7	2.5	1.7	2.5		mA
	$V_O = -30V$				3.6	5.0		mA
	$V_O = -40V$		3.6	5.0				mA
Long Term Stability	$V_O \leq -1V$	0.1	1.0		0.1	1.0		%

## APPLICATION CIRCUITS

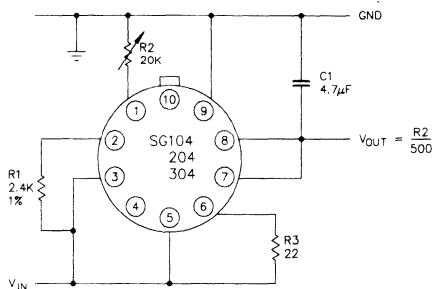


FIGURE 1 - BASIC NEGATIVE REGULATOR CIRCUIT

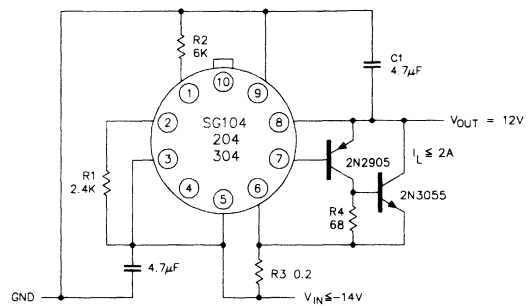


FIGURE 1 - HIGH CURRENT REGULATOR CIRCUIT

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
10-PIN TO-100 METAL CAN T-PACKAGE	SG104T/883B SG104T SG204T SG304T	-55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C	

- Note 1. Contact factory for JAN and DESC product availability.  
 2. All packages are viewed from the top.



**POSITIVE VOLTAGE REGULATOR**

**DESCRIPTION**

This circuit is a positive voltage regulator designed for both linear and switching applications. Inherent component tracking of the monolithic integrated circuit process provides a high degree of stability and accuracy in addition to fast response to both line and load transients. With an input voltage rating of up to 50V, this device will deliver load currents of 20mA (45mA with 305A). Adding external transistors will increase the current capability to greater than 10amps and further improve regulation.

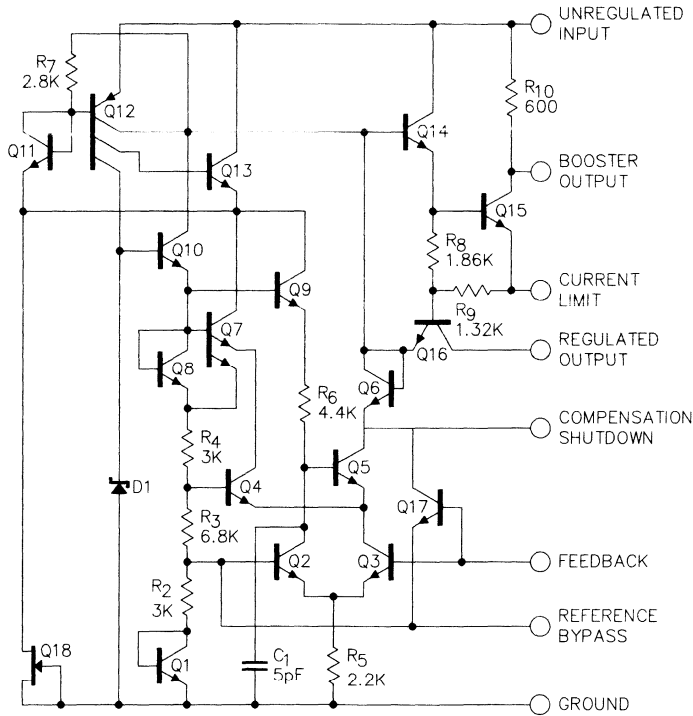
**FEATURES**

- Output voltage adjustable from 4.5V to 40V
- Load regulation better than 0.01%/mA
- Line regulation better than 0.06%/V
- Ripple rejection of 0.01%/V
- 1.0% maximum temperature variation

**HIGH RELIABILITY FEATURES - SG105**

- ◆ Available to MIL-STD-883B
- ◆ SG level "S" processing available

**BLOCK DIAGRAM**



# SG105/SG205/SG305/SG305A

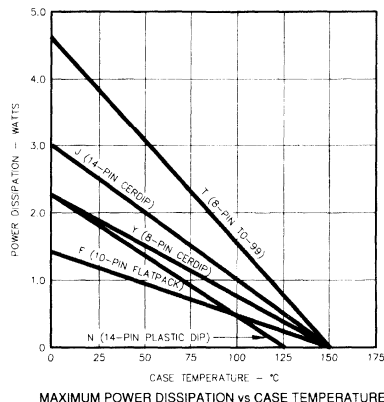
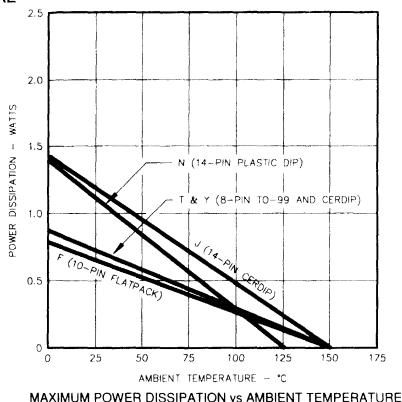
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Input Voltage		Input - Output Voltage Differential	
SG105 .....	50V	SG105 .....	30V
SG205 .....	50V	SG205 .....	30V
SG305 .....	40V	SG305 .....	30V
SG305A .....	50V	SG305A .....	30V
Storage Temperature Range .....	-65°C to 150°C	Operating Junction Temperatures	
Lead Temperature (Soldering, 10 seconds) .....	300°C	Hermetic (T, J, F, Y-Packages) .....	175°C
		Plastic (N-Packages) .....	150°C

Note 1. Values beyond which damage may occur.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



### ELECTRICAL

Input Voltage		Operating Ambient Temperature Range	
SG105, SG205, SG305A .....	10V to 48V	SG105 .....	-55°C to 125°C
SG305 .....	10V to 38V	SG205 .....	-25°C to 85°C
Input - Output Voltage Differential		SG305, SG305A .....	0°C to 70°C
SG105, SG205, SG305, SG305A .....	5V to 28V		

Note 2: Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(These specifications apply for over recommended operating temperatures, unless otherwise specified. The load and line regulation specifications are for constant junction temperature. Temperature drift effects must be taken into account separately when the unit is operating under conditions of high dissipation.)

Parameter	Test Conditions	SG105/205			SG305			SG305A			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
Input Voltage Range		8.5		50	8.0		40	8.5		50	V
Output Voltage Range		4.5		40	4.5		30	4.5		40	V
Input/Output Differential		3.0		30	3.0		30	3.0		30	V
Load Regulation (Note 4)	$I_L < 12\text{mA}$ , $R_{SC} = 10\Omega$			0.1			0.1			0.2	%
Line Regulation	$V_{IN} - V_{OUT} \leq 5\text{V}$ $V_{IN} - V_{OUT} > 5\text{V}$ $C_{REF} = 10\mu\text{F}$ , $f = 120\text{Hz}$			0.06			0.06			0.06	%/V
				0.03			0.03			0.03	%/V
Ripple Feed				0.01			0.01	0.003		0.003	%/V
Temperature Stability (Note 3)				1.0			1.0			1.0	%
Output Noise Voltage	$10\text{Hz} \leq f \leq 10\text{KHz}$ , $C_{REF} = 0$		0.005			0.005			0.005		%
Feedback Sense Voltage		1.55	1.7	1.85	1.55	1.7	1.85	1.55		1.85	V
Standby Current Drain				2.0			2.0			2.0	mA
Load Current		0			0			0			mA
Long Term Stability (Note 3)			0.1	1.0		0.1	1.0		0.1	1.0	%

Note 3. This test is guaranteed but not tested.

Note 4. Applies for constant junction temperature. Temperature drift effects must be taken into account separately when the unit is operating under conditions of high dissipation.



## CHARACTERISTIC CURVES (continued)

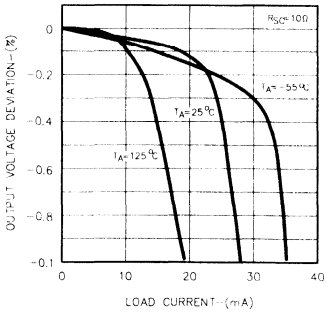


FIGURE 1. LOAD REGULATION

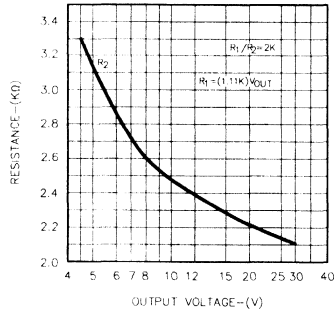


FIGURE 2. OPTIMUM DIVIDER RESISTOR VALUES

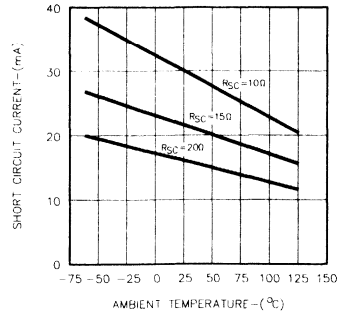


FIGURE 3. CURRENT LIMITING

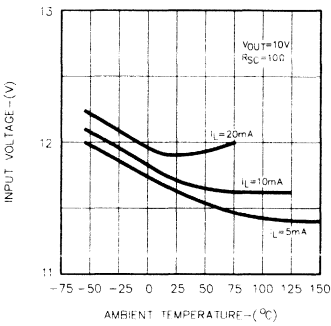


FIGURE 4. DROPOUT VOLTAGE

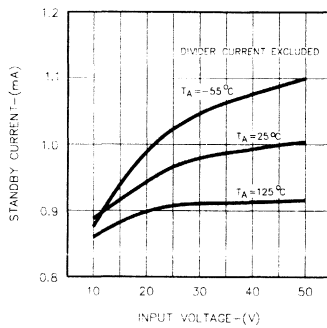


FIGURE 5. STANDBY CURRENT DRAIN

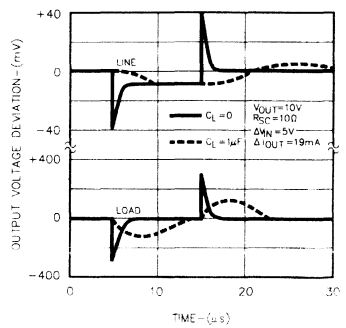


FIGURE 6. TRANSIENT RESPONSE

## APPLICATION CIRCUITS

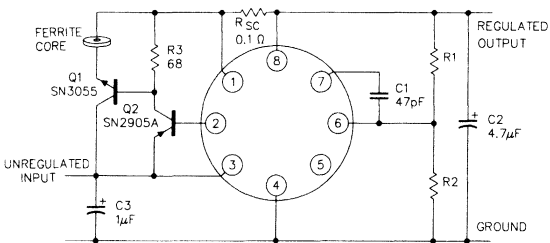


FIGURE 7 - REGULATOR CONNECTED FOR 2 AMP OUTPUT

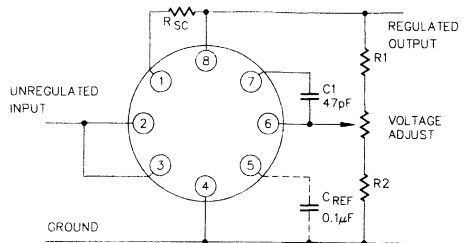


FIGURE 8 - BASIC REGULATOR CIRCUIT

# SG105/SG205/SG305/SG305A

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
8-PIN CERAMIC DIP Y - PACKAGE	SG105Y/883B SG105Y SG205Y SG305Y	-55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C	
14-PIN CERAMIC DIP J - PACKAGE	SG105J/883B SG105J SG205J SG305J	-55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C	
14-PIN PLASTIC DIP N - PACKAGE	SG205N SG305N	-25°C to 85°C 0°C to 70°C	
10-PIN CERAMIC FLATPACK F - PACKAGE	SG105F/883B SG105F	-55°C to 125°C -55°C to 125°C	
8-PIN TO-99 METAL CAN T-PACKAGE	SG105T/883B SG105T SG205T SG305T	-55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C	

Note 1. Contact factory for JAN and DESC product availability.  
 2. All packages are viewed from the top.

**5 -VOLT FIXED VOLTAGE REGULATORS**

**DESCRIPTION**

The SG109/SG309 is a completely self-contained 5V regulator. Designed to provide local regulation at currents up to 1A for digital logic cards, this device is available in the hermetic TO-3, TO-66, TO-39 and hermetic and plastic TO-220.

A major feature of the SG109's design is its built-in protective features which make it essentially blowout proof. These consist of both current limiting to control the peak currents and thermal shutdown to protect against excessive power dissipation. With the only added component being a possible need for an input bypass capacitor, this regulator becomes extremely easy to apply. Utilizing an improved Bandgap reference design, problems have been eliminated that are normally associated with the zener diode references, such as drift in output voltage and large changes in the line and load regulation.

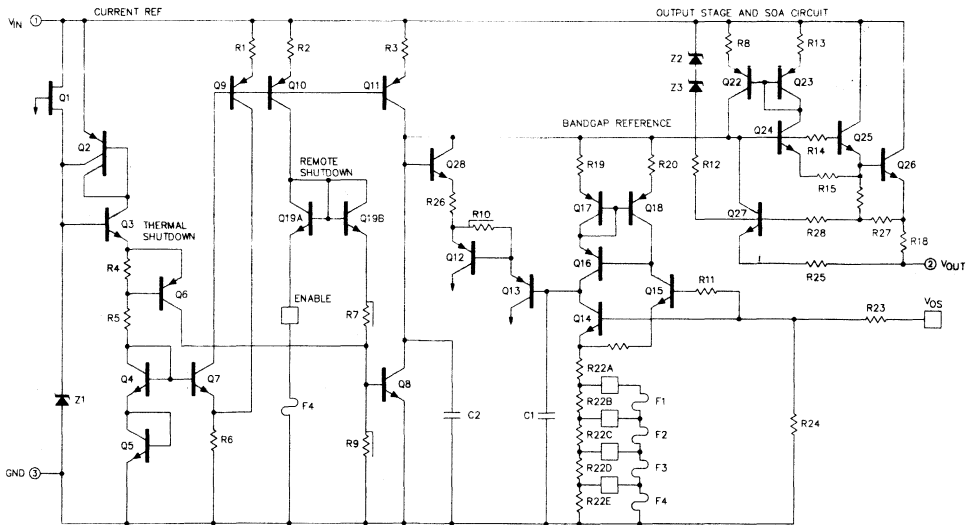
**FEATURES**

- Fully compatible with TTL and DTL
- Output current in excess of 1A
- Internal thermal overload protection
- No additional external components
- Bandgap reference voltage
- Foldback current limiting

**HIGH RELIABILITY FEATURES-SG109**

- ◆ Available to MIL-STD-883
- ◆ Scheduled for MIL-M38510 QPL listing
- ◆ Radiation data available
- ◆ SG level "S" processing available

**SCHEMATIC**



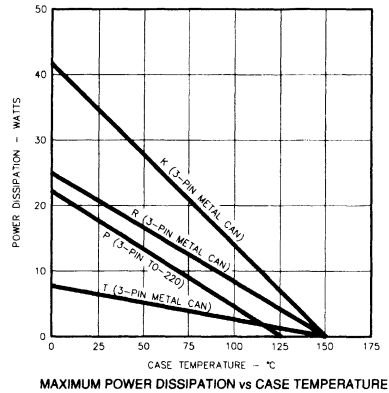
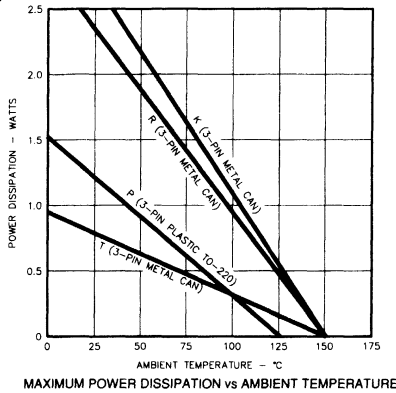
**ABSOLUTE MAXIMUM RATINGS** (Note 1)

Input Voltage .....	35V	Operating Junction Temperature	
Power Dissipation .....	Internally Limited	Hermetic (K, R, T, G, IG-Packages).....	175°C
Storage Temperature Range .....	-65°C to 150°C	Lead Temperature (Soldering, 10 Seconds) .....	300°C

Note 1. Exceeding these ratings could cause damage to the device.

**RECOMMENDED OPERATING CONDITIONS** (Note 2)

**THERMAL**



**ELECTRICAL**

Input Voltage Range .....	7.0V to 25V	Operating Junction Temperature Range	
		SG109 .....	-55°C to 150°C
		SG309 .....	0°C to 125°C

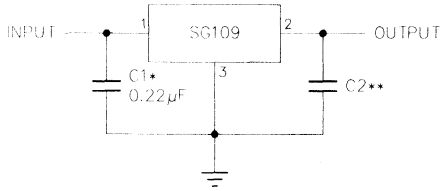
Note 2. Range over which the device is functional.

**ELECTRICAL SPECIFICATIONS**

(Unless otherwise specified, these specifications apply at  $V_{IN} = 10V$ ,  $I_{OUT} = 500mA$  (K, R, G, and IG-Power Packages-),  $I_{OUT} = 100mA$  (T-package) and over recommended  $T_A = T_{MIN}$  to  $T_{MAX}$ .)

Parameter	Test Conditions	SG109			SG309			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_A = 25^\circ C$	4.7	5.05	5.3	4.8	5.05	5.2	V
Line Regulation	$V_{IN} = 7.1V$ to 25V, $T_A = 25^\circ C$		4.0	50		4.0	50	mV
Load Regulation	$T_A = 25^\circ C$ Power Pkgs: $I_{OUT} = 5mA$ to 1.5A T-package: $I_{OUT} = 5mA$ to 500mA		15	100		15	100	mV
Total Output Voltage Tolerance	$V_{IN} = 7.4V$ to 25V Power Pkgs: $I_{OUT} = 5mA$ to 1.0A, $P \leq 20W$ T-package: $I_{OUT} = 5mA$ to 200mA, $P \leq 20W$	4.6	5.0	5.4	4.75	5.00	5.25	V
Quiescent Current	$V_{IN} = 7.4V$ to 25V	4.6	5.0	5.4	4/75	5.00	5.25	V
Quiescent Current Change	With Line: $V_{IN} = 7.4V$ to 25V With Load: Power Pkgs: $I_{OUT} = 5mA$ to 1.0A T-package: $I_{OUT} = 5mA$ to 200mA			0.5			0.5	mA
Output Noise Voltage	$f = 10Hz$ to 100KHz, $T_A = 25^\circ C$		40			40		$\mu V$
Long Term Stability			10			20		mV
Ripple Rejection	$T_A = 25^\circ C$	50			50			dB

APPLICATION CIRCUITS



\* REQUIRED IF REGULATOR IS AN APPRECIABLE DISTANCE FROM POWER SUPPLY FILTER.  
 \*\* ALTHOUGH NO OUTPUT CAPACITOR IS NEEDED FOR STABILITY IT DOES IMPROVE TRANSIENT RESPONSE.

FIGURE 1 - FIXED 5V REGULATOR

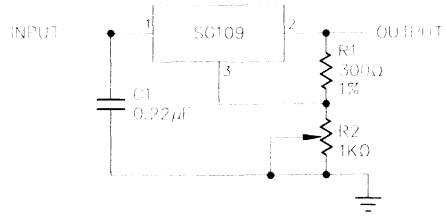


FIGURE 2 - ADJUSTABLE OUTPUT REGULATOR

CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
3-TERMINAL TO-3 METAL CAN K-PACKAGE	SG109K/883B SG109K SG309K	-55°C to 125°C -55°C to 125°C 0°C to 70°C	
3-TERMINAL TO-66 METAL CAN R-PACKAGE	SG109R/883B SG109R SG309R	-55°C to 125°C -55°C to 125°C 0°C to 70°C	
3-PIN HERMETIC TO-220 G-PACKAGE (Non-Isolated)	SG109G/883B SG109G	-55°C to 125°C -55°C to 125°C	
3-PIN HERMETIC TO-220 IG-PACKAGE (Isolated)	SG109IG/883B SG109IG	-55°C to 125°C -55°C to 125°C	
3-PIN TO-39 METAL CAN T-PACKAGE	SG109T/883B SG109T SG109T SG109T/883B SG109T SG317T	-55°C to 125°C -55°C to 125°C 0°C to 70°C -55°C to 125°C -55°C to 125°C 0°C to 70°C	

Note 1. Contact factory for JAN and DESC product availability. 3. Product is also available in leadless chip carrier (LCC) and hermetic flat pack (F).  
 2. All parts are viewed from the top. Contact factory for price and availability.





LINEAR INTEGRATED CIRCUITS

**SG117A/SG217A/SG317A  
SG117/SG217/SG317**

**1.5 AMP THREE TERMINAL  
ADJUSTABLE VOLTAGE REGULATOR**

**DESCRIPTION**

The SG117A Series are 3-terminal positive adjustable voltage regulators which offer improved performance over earlier devices. A major feature of the SG117A is the output voltage tolerance is guaranteed at a maximum of  $\pm 1\%$ , allowing an overall power supply tolerance to be better than 3% using inexpensive 1% resistors. Line and load regulation performance has been improved as well. Additionally, the SG117A reference voltage is guaranteed not to exceed 2% when operating over the full load, line and power dissipation conditions. The SG117A adjustable regulators offer an improved solution for all positive voltage regulator requirements with load currents up to 1.5A.

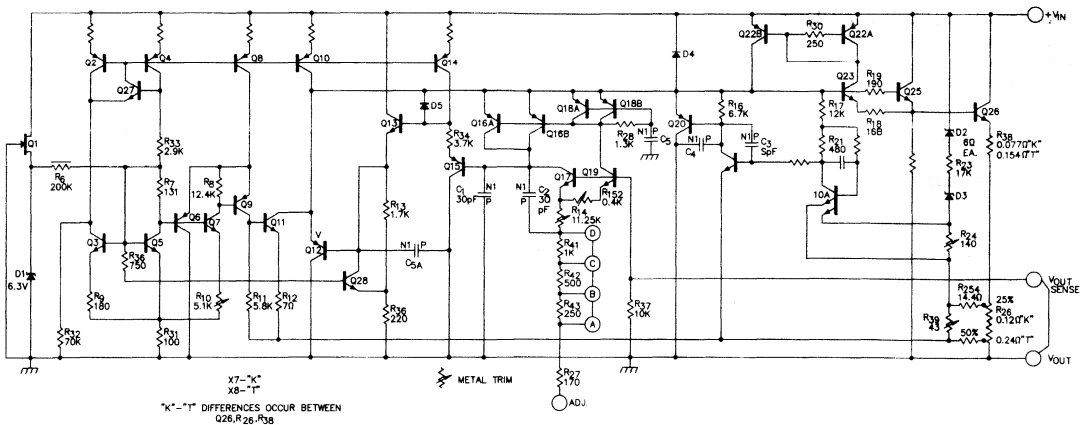
**FEATURES**

- 1% output voltage tolerance
- 0.01%/V line regulation
- 0.3% load regulation
- Min. 1.5A output current
- Available in hermetic TO-220

**HIGH RELIABILITY FEATURES-SG117A/SG117**

- ◆ Available to MIL-STD-883 and DESC SMD
- ◆ MIL-M38510/11704BYA - JAN117K
- ◆ MIL-M38510/11704BXA - JAN117T
- ◆ SG level "S" processing available

**SCHEMATIC**



# SG117A/SG117 SERIES

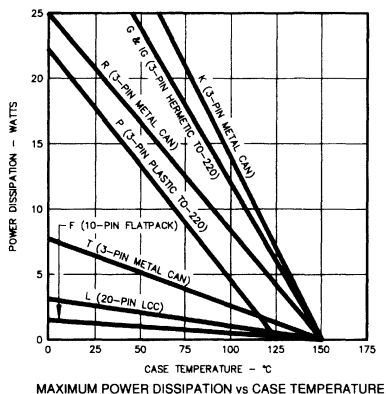
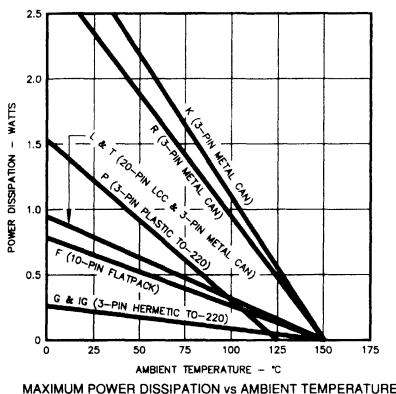
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Power Dissipation ..... Internally Limited  
 Input to Output Voltage Differential ..... 40V  
 Storage Temperature Range ..... -65°C to 150°C  
 Note 1. Exceeding these ratings could cause damage to the device.

Operating Junction Temperature  
 Hermetic (K, R, T, F, L, G, IG-Packages) ..... 175°C  
 Plastic (P-Package) ..... 150°C  
 Lead Temperature (Soldering, 10 Seconds) ..... 300°C

## RECOMMENDED OPERATING CONDITIONS (Note 2 & 3)

### THERMAL



### ELECTRICAL

Input Voltage Range ..... ( $V_{OUT} + 3.5V$ ) to 37V

Operating Junction Temperature Range  
 SG117A/SG117 ..... -55°C to 150°C  
 SG217A/SG217 ..... -25°C to 150°C  
 SG317A/SG317 ..... 0°C to 125°C

Note 2. Range over which the device is functional.

Note 3. These ratings are applicable for junction temperatures of less than 150°C.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise specified, these specifications apply over full operating ambient temperature range,  $V_{IN} - V_{OUT} = 5.0V$ ,  $I_{OUT} = 0.1A$  for the TO-39, F, and L packages, and  $I_{OUT} = 0.5A$  for the TO-3, TO-220, Hermetic TO-220, and TO-66 packages. Although power dissipation is internally limited, these specifications are applicable for power dissipations of 2W for the TO-39, F, and L packages, and 20W for the TO-3, TO-220, Hermetic TO-220, and TO-66 packages.  $I_{MAX}$  is 1.5A for the TO-3, TO-220, Hermetic TO-220, and TO-66 packages and 0.5A for the TO-39, F, and L packages.)

Parameter	Test Conditions	SG117A/SG217A			SG117/SG217			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Reference Voltage	$I_{OUT} = 10mA$ , $T_A = 25^\circ C$ $3V \leq (V_{IN} - V_{OUT}) \leq 40V$ , $P \leq P_{MAX}$	1.238	1.250	1.262				V
Line Regulation (Note 4)	$10mA \leq I_{OUT} \leq I_{MAX}$ $3V \leq (V_{IN} - V_{OUT}) \leq 40V$ , $I_L = 10mA$ $T_A = 25^\circ C$	1.225	1.250	1.270	1.20	1.25	1.30	V
Load Regulation (Note 4)	$T_A = T_{MIN}$ to $T_{MAX}$ $10mA \leq I_{OUT} \leq I_{MAX}$		0.005	0.01	0.01	0.02	0.02	%/V
	$V_{OUT} \leq 5V$ , $T_A = 25^\circ C$		5	15	5	15		mV
	$V_{OUT} \geq 5V$ , $T_A = 25^\circ C$		0.1	0.3	0.1	0.3		%
	$V_{OUT} \leq 5V$ $V_{OUT} \geq 5V$		20	50	20	50		mV
Thermal Regulation (Note 5)	$T_A = 25^\circ C$ , 20ms pulse		0.002	0.02	0.03	0.07		%/W
Ripple Rejection	$V_{OUT} = 10V$ , $f = 120Hz$ $C_{ADJ} = 1\mu F$ , $T_A = 25^\circ C$ $C_{ADJ} = 10\mu F$		65		65			dB
Adjust Pin Current		66	80		66	80		dB
Adjust Pin Current Change	$10mA \leq I_{OUT} \leq I_{MAX}$ , $2.5V \leq (V_{IN} - V_{OUT}) \leq 40V$		50	100	50	100		$\mu A$
			0.2	5	0.2	5		$\mu A$



# SG117A/SG117 SERIES

## ELECTRICAL SPECIFICATIONS (continued)

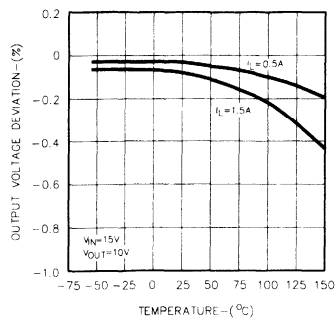
Parameter	Test Conditions	SG117A/SG217A			SG117/SG217			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Minimum Load Current	$(V_{IN} - V_{OUT}) = 40V$		3.5	5		3.5	5	mA
Current Limit	$(V_{IN} - V_{OUT}) \leq 15V$ K, P, R, G, IG Packages	1.5	2.2		1.5	2.2		A
	T, L, F Package	0.5	0.8		0.5	0.8		A
	$(V_{IN} - V_{OUT}) = 40V, T_J = 25^\circ C$ K, P, R, G, IG Packages	0.3	0.4		0.3	0.4		A
	T, L, F Packages	0.15	0.2		0.15	0.2		A
Temperature Stability (Note 5)			1	2		1		%
Long Term Stability (Note 5)	$T_A = 125^\circ C, 1000$ Hours		0.3	1		0.3	1	%
RMS Output Noise (% of $V_{OUT}$ )	$T_A = 25^\circ C, 10Hz \leq f \leq 10$ KHz (Note 5)		0.001			0.001		%

Parameter	Test Conditions	SG317A			SG317			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Reference Voltage	$I_{OUT} = 10mA, T_A = 25^\circ C$ $3V \leq (V_{IN} - V_{OUT}) \leq 40V, P \leq P_{MAX}$	1.238	1.250	1.262				V
Line Regulation (Note 4)	$10mA \leq I_{OUT} \leq I_{MAX}$ $3V \leq (V_{IN} - V_{OUT}) \leq 40V, I_L = 10mA$	1.225	1.250	1.270	1.20	1.25	1.30	V
Load Regulation (Note 4)	$T_A = 25^\circ C$ $T_A = T_{MIN}$ to $T_{MAX}$ $10mA \leq I_{OUT} \leq I_{MAX}$		0.005	0.01		0.01	0.04	%/V
	$V_{OUT} \leq 5V, T_A = 25^\circ C$		0.01	0.02		0.02	0.07	%/V
	$V_{OUT} \geq 5V, T_A = 25^\circ C$		5	25		5	25	mV
	$V_{OUT} \leq 5V$		0.1	0.5		0.1	0.5	%
	$V_{OUT} \geq 5V$		20	50		20	70	mV
Thermal Regulation (Note 5)	$T_A = 25^\circ C, 20ms$ pulse		0.3	1		0.3	1.5	%
Ripple Rejection	$V_{OUT} = 10V, f = 120Hz$ $C_{ADJ} = 1\mu F, T_A = 25^\circ C$		0.002	0.02		0.03	0.07	%/W
	$C_{ADJ} = 10\mu F$		66	80		66	80	dB
Adjust Pin Current	$T_A = 25^\circ C$		50	100		50	100	$\mu A$
Adjust Pin Current Change	$10mA \leq I_{OUT} \leq I_{MAX}, 2.5V \leq (V_{IN} - V_{OUT}) \leq 40V$		0.2	5		0.2	5	$\mu A$
Minimum Load Current	$(V_{IN} - V_{OUT}) = 40V$		3.5	10		3.5	10	mA
Current Limit	$(V_{IN} - V_{OUT}) \leq 15V$ K, P, R, G, IG Packages	1.5	2.2		1.5	2.2		A
	T, L, F Packages	0.5	0.8		0.5	0.8		A
	$(V_{IN} - V_{OUT}) = 40V, T_J = 25^\circ C$ K, P, R, G, IG Packages	0.15	0.4		0.15	0.4		A
	T, L, F Packages	.075	0.2		.075	0.2		A
Temperature Stability (Note 5)			1	2		1		%
Long Term Stability (Note 5)	$T_A = 125^\circ C$		0.3	1		0.3	1	%
RMS Output Noise (% of $V_{OUT}$ )	$T_A = 25^\circ C, 10Hz \leq f \leq 10KHz$ (Note 5)		0.001			0.001		%

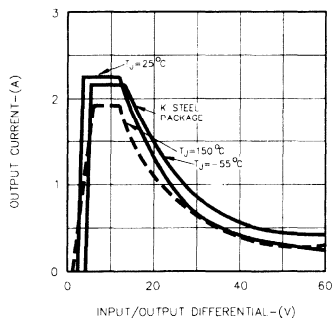
Note 4. Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output voltage due to heating effects are covered under the specification for thermal regulation.

Note 5. These parameters, although guaranteed, are not tested in production.

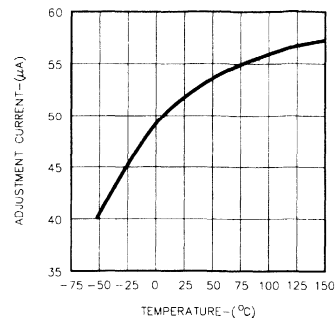
## CHARACTERISTIC CURVES



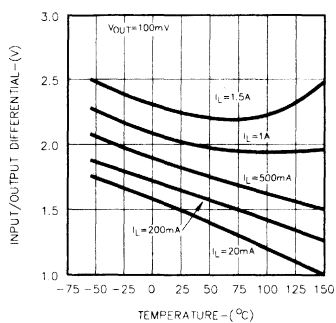
**FIGURE 1.**  
OUTPUT VOLTAGE DEVIATION VS. TEMPERATURE



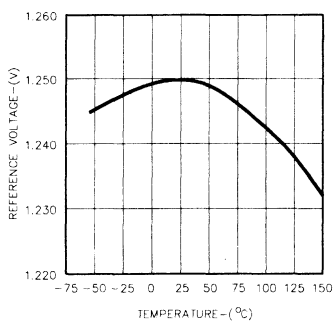
**FIGURE 2.**  
OUTPUT CURRENT VS. INPUT/OUTPUT DIFFERENTIAL



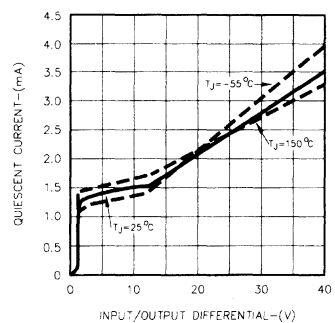
**FIGURE 3.**  
ADJUSTMENT CURRENT VS. TEMPERATURE



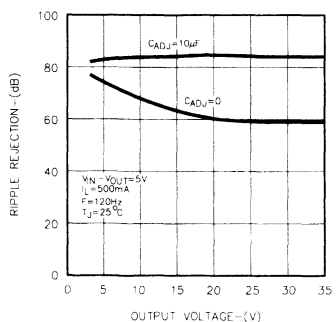
**FIGURE 4.**  
INPUT/OUTPUT DIFFERENTIAL VS. TEMPERATURE



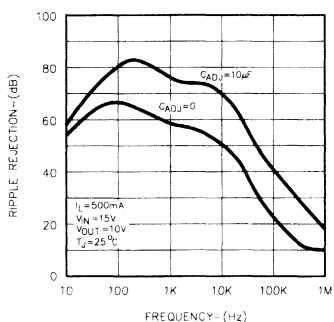
**FIGURE 5.**  
REFERENCE VOLTAGE VS. TEMPERATURE



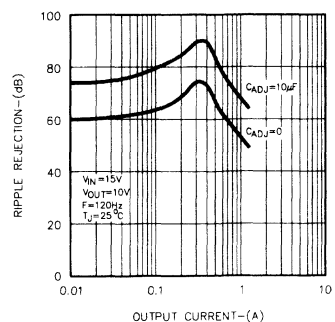
**FIGURE 6.**  
QUIESCENT CURRENT VS. INPUT/OUTPUT DIFFERENTIAL



**FIGURE 7.**  
RIPPLE REJECTION VS. OUTPUT VOLTAGE



**FIGURE 8.**  
RIPPLE REJECTION VS. FREQUENCY



**FIGURE 9.**  
RIPPLE REJECTION VS. OUTPUT CURRENT

## CHARACTERISTIC CURVES (continued)

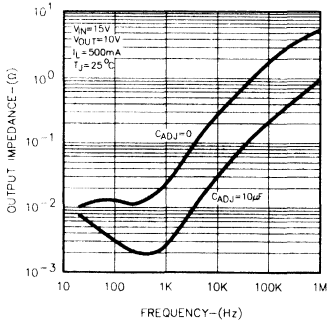


FIGURE 10.  
OUTPUT IMPEDANCE VS. FREQUENCY

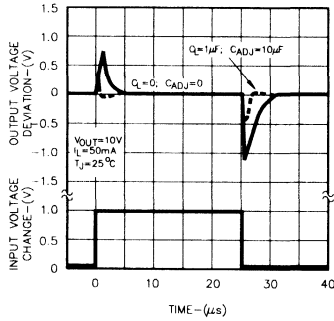


FIGURE 11.  
LINE TRANSIENT RESPONSE

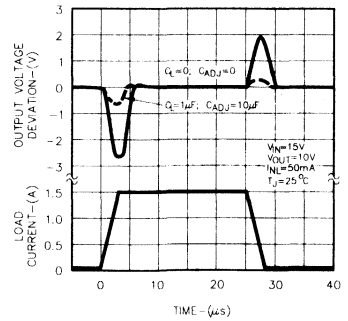


FIGURE 12.  
LOAD TRANSIENT RESPONSE

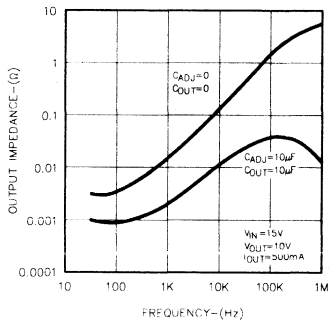


FIGURE 13.  
OUTPUT IMPEDANCE VS. FREQUENCY

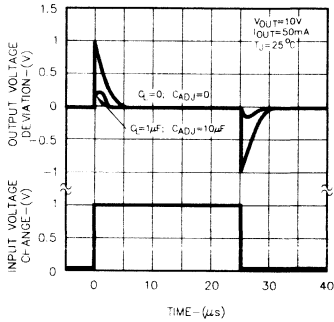


FIGURE 14.  
LINE TRANSIENT RESPONSE

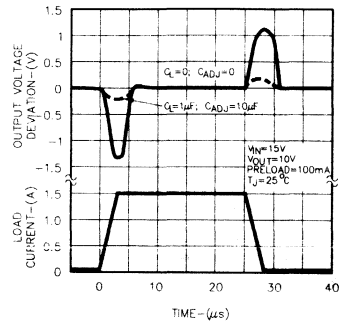


FIGURE 15.  
LOAD TRANSIENT RESPONSE

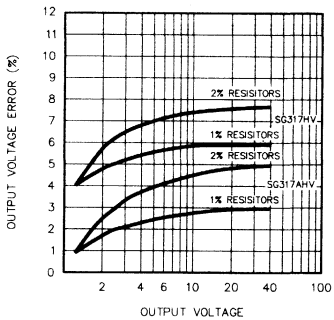
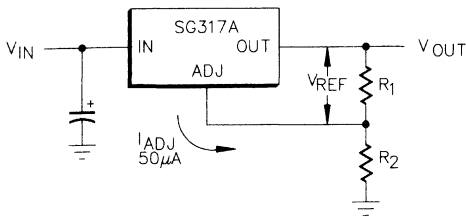


FIGURE 16.  
OUTPUT VOLTAGE ERROR

## APPLICATION INFORMATION

### GENERAL

The SG117A develops a 1.25V reference voltage between the output and the adjustable terminal (see Figure 1). By placing a resistor,  $R_1$ , between these two terminals, a constant current is caused to flow through  $R_1$  and down through  $R_2$  to set the overall output voltage. Normally this current is the specified minimum load current of 5mA or 10mA.



$$V_{OUT} = V_{REF} \left( 1 + \frac{R_2}{R_1} \right) + I_{ADJ} R_2$$

FIGURE 17 - BASIC REGULATOR CIRCUIT

Because  $I_{ADJ}$  is very small and constant when compared with the current through  $R_1$ , it represents a small error and can usually be ignored.

It is easily seen from the above equation, that even if the resistors were of exact value, the accuracy of the output is limited by the accuracy of  $V_{REF}$ . Earlier adjustable regulators had a reference tolerance of  $\pm 4\%$ . This tolerance is dangerously close to the  $\pm 5\%$  supply tolerance required in many logic and analog systems. Further, many 1% resistors can drift  $0.01\%/^{\circ}\text{C}$  adding another 1% to the output voltage tolerance.

For example, using 2% resistors and  $\pm 4\%$  tolerance for  $V_{REF}$ , calculations will show that the expected range of a 5V regulator design would be  $4.66\text{V} \leq V_{OUT} \leq 5.36\text{V}$  or approximately  $\pm 7\%$ . If the same example were used for a 15V regulator, the expected tolerance would be  $\pm 8\%$ . With these results most applications require some method of trimming, usually a trim pot. This solution is expensive and not conducive to volume production.

One of the enhancements of Silicon General's adjustable regulators over existing devices is tightened initial tolerance. This allows relatively inexpensive 1% or 2% film resistors to be used for  $R_1$  and  $R_2$  while setting output voltage within an acceptable tolerance range.

With a guaranteed 1% reference, a 5V power supply design, using  $\pm 2\%$  resistors, would have a worst case manufacturing tolerance of  $\pm 4\%$ . If 1% resistors were used, the tolerance would drop to  $\pm 2.5\%$ . A plot of the worst case output voltage tolerance as a function of resistor tolerance is shown on the front page.

For convenience, a table of standard 1% resistor values is shown below.

Table of 1/2% and 1% Standard Resistance Values

1.00	1.47	2.15	3.16	4.64	6.81
1.02	1.50	2.21	3.24	4.75	6.98
1.05	1.54	2.26	3.32	4.87	7.15
1.07	1.58	2.32	3.40	4.99	7.32
1.10	1.62	2.37	3.48	5.11	7.50
1.13	1.65	2.43	3.57	5.23	7.68
1.15	1.69	2.49	3.65	5.36	7.87
1.18	1.74	2.55	3.74	5.49	8.06
1.21	1.78	2.61	3.83	5.62	8.25
1.24	1.82	2.67	3.92	5.76	8.45
1.27	1.87	2.74	4.02	5.90	8.66
1.30	1.91	2.80	4.12	6.04	8.87
1.33	1.96	2.87	4.22	6.19	9.09
1.37	2.00	2.94	4.32	6.34	9.31
1.40	2.05	3.01	4.42	6.49	9.53
1.43	2.10	3.09	4.53	6.65	9.76

Standard Resistance Values are obtained from the Decade Table by multiplying by multiples of 10. As an example: 1.21 can represent 1.21 $\Omega$ , 12.1 $\Omega$ , 121 $\Omega$ , 1.21K $\Omega$  etc.

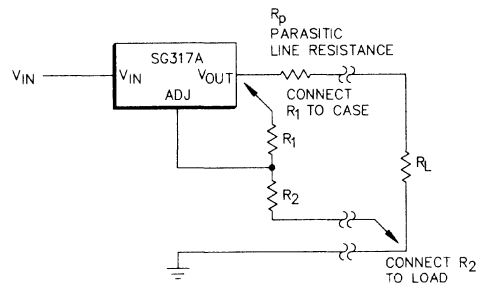
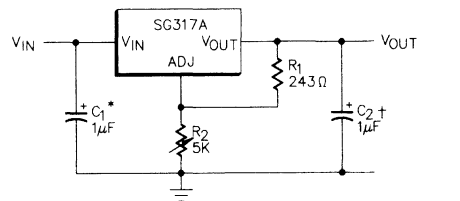


FIGURE 18 - CONNECTIONS FOR BEST LOAD REGULATION



† Optional—improves transient response

\* Needed if device is far from filter capacitors

$$V_{OUT} = 1.25\text{V} \left( 1 + \frac{R_2}{R_1} \right)$$

FIGURE 19 - 1.2V-25V ADJUSTABLE REGULATOR

# SG117A/SG117 SERIES

## APPLICATION INFORMATION (continued)

### BYPASS CAPACITORS

Input bypassing using a 1µF tantalum or 25µF electrolytic is recommended when the input filter capacitors are more than 5 inches from the device. Improved ripple rejection (80dB) can be accomplished by adding a 10µF capacitor from the adjust pin to ground. For improved AC transient response and to prevent the possibility of oscillation due to unknown reactive load, a 1µF capacitor is also recommended at the output. Because of their low impedance at high frequencies, the best type of capacitor to use is solid tantalum.

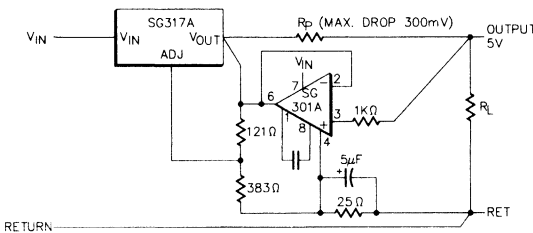


FIGURE 20 - REMOTE SENSING

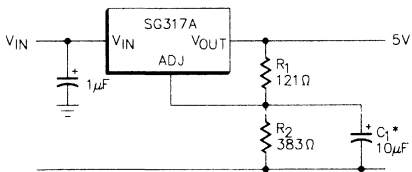


FIGURE 21 - IMPROVING RIPPLE REJECTION

### LOAD REGULATION

Because the SG117A is a three-terminal device, it is not possible to provide true remote load sensing. Load regulation will be limited by the resistance of the wire connecting the regulator to the load. For the data sheet specification, regulation is measured at the bottom of the package. Negative side sensing is a true Kelvin connection, with the bottom of the output divider returned to the negative side of the load. Although it may not be immediately obvious, best load regulation is obtained when the top of the divider is connected directly to the case, not to the load. This is illustrated in Figure 18. If  $R_1$  were connected to the load, the effective resistance between the regulator and the load would be

$$R_p \times \left( \frac{R_2 + R_1}{R_1} \right), R_p = \text{Parasitic Line Resistance.}$$

Connected as shown,  $R_p$  is not multiplied by the divider ratio.  $R_p$  is about 0.004Ω per foot using 16 gauge wire. This translates to 4mV/ft. at 1A load current, so it is important to keep the positive lead between regulator and load as short as possible.

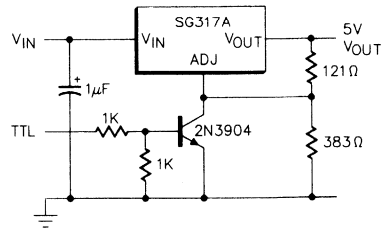


FIGURE 22 - 5V REGULATOR WITH SHUT DOWN

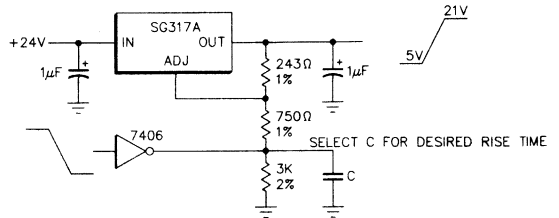


FIGURE 23 - 21V PROGRAMMING SUPPLY FOR UV PROM/EEPROM

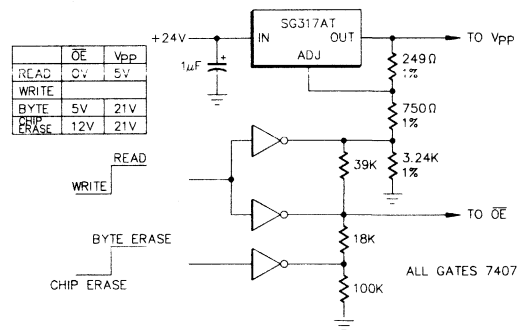


FIGURE 24 - 2816 EEPROM SUPPLY PROGRAMMER FOR READ/WRITE CONTROL

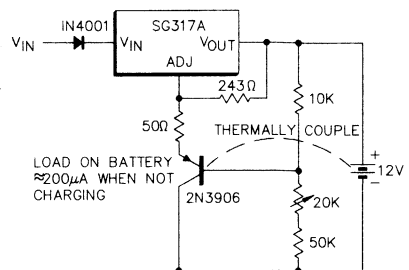


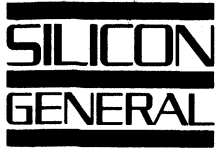
FIGURE 25 - TEMPERATURE COMPENSATED LEAD ACID BATTERY CHARGER

# SG117A/SG117 SERIES

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram																																																																									
3-TERMINAL TO-3 METAL CAN K-PACKAGE	SG117AK/883B	-55°C to 125°C																																																																										
	SG117AK	-55°C to 125°C																																																																										
	SG217AK	-25°C to 85°C																																																																										
	SG317AK	0°C to 70°C																																																																										
	SG117K/883B	-55°C to 125°C																																																																										
	SG117K	-55°C to 125°C																																																																										
	SG217K	-25°C to 85°C																																																																										
3-TERMINAL TO-66 METAL CAN R-PACKAGE	SG117AR/883B	-55°C to 125°C																																																																										
	SG117AR	-55°C to 125°C																																																																										
	SG217AR	-25°C to 85°C																																																																										
	SG317AR	0°C to 70°C																																																																										
	SG117R/883B	-55°C to 125°C																																																																										
	SG117R	-55°C to 125°C																																																																										
	SG217R	-25°C to 85°C																																																																										
3-PIN TO-39 METAL CAN T-PACKAGE	SG117AT/883B	-55°C to 125°C																																																																										
	SG117AT	-55°C to 125°C																																																																										
	SG217AT	-25°C to 85°C																																																																										
	SG317AT	0°C to 70°C																																																																										
	SG117T/883B	-55°C to 125°C																																																																										
	SG117T	-55°C to 125°C																																																																										
	SG217T	-25°C to 85°C																																																																										
3-PIN PLASTIC TO-220 P-PACKAGE	SG317AP	0°C to 70°C																																																																										
	SG317P	0°C to 70°C																																																																										
3-PIN HERMETIC TO-220 G-PACKAGE (Non-Isolated)	SG117AG/883B	-55°C to 125°C																																																																										
	SG117AG	-55°C to 125°C																																																																										
	SG117G/883B	-55°C to 125°C																																																																										
	SG117G	-55°C to 125°C																																																																										
3-PIN HERMETIC TO-220 IG-PACKAGE (Isolated)	SG117AIG/883B	-55°C to 125°C																																																																										
	SG117AIG	-55°C to 125°C																																																																										
	SG117IG/883B	-55°C to 125°C																																																																										
	SG117IG	-55°C to 125°C																																																																										
10-PIN CERAMIC FLAT PACK F - PACKAGE	SG117AF/883B	-55°C to 125°C	(Note 3) <table style="margin-left: 20px; border-collapse: collapse;"> <tr> <td>N.C.</td><td>1</td><td>10</td><td>ADJUST</td> </tr> <tr> <td>N.C.</td><td>2</td><td>9</td><td>V<sub>IN</sub></td> </tr> <tr> <td>N.C.</td><td>3</td><td>8</td><td>V<sub>IN</sub></td> </tr> <tr> <td>V<sub>OUT</sub></td><td>4</td><td>7</td><td>N.C.</td> </tr> <tr> <td>V<sub>OUT</sub></td><td>5</td><td>6</td><td>N.C.</td> </tr> </table>	N.C.	1	10	ADJUST	N.C.	2	9	V <sub>IN</sub>	N.C.	3	8	V <sub>IN</sub>	V <sub>OUT</sub>	4	7	N.C.	V <sub>OUT</sub>	5	6	N.C.																																																					
	N.C.	1		10	ADJUST																																																																							
	N.C.	2		9	V <sub>IN</sub>																																																																							
	N.C.	3		8	V <sub>IN</sub>																																																																							
	V <sub>OUT</sub>	4		7	N.C.																																																																							
V <sub>OUT</sub>	5	6	N.C.																																																																									
SG117AF	-55°C to 125°C																																																																											
SG117F/883B	-55°C to 125°C																																																																											
SG117F	-55°C to 125°C																																																																											
20-PIN CERAMIC (LCC) LEADLESS CHIP CARRIER L- PACKAGE	SG117AL/883B	-55°C to 125°C	(Note 4) <table style="margin-left: 20px; border-collapse: collapse;"> <tr> <td>1. SENSE</td><td>3</td><td>2</td><td>1</td><td>20</td><td>19</td><td>11. N.C.</td> </tr> <tr> <td>2. N.C.</td><td></td><td></td><td></td><td></td><td></td><td>12. N.C.</td> </tr> <tr> <td>3. N.C.</td><td></td><td></td><td></td><td></td><td></td><td>13. N.C.</td> </tr> <tr> <td>4. N.C.</td><td>4</td><td></td><td></td><td></td><td></td><td>14. N.C.</td> </tr> <tr> <td>5. V<sub>IN</sub></td><td>5</td><td></td><td></td><td></td><td></td><td>15. N.C.</td> </tr> <tr> <td>6. N.C.</td><td>6</td><td></td><td></td><td></td><td></td><td>16. N.C.</td> </tr> <tr> <td>7. N.C.</td><td>7</td><td></td><td></td><td></td><td></td><td>17. N.C.</td> </tr> <tr> <td>8. N.C.</td><td>8</td><td></td><td></td><td></td><td></td><td>18. N.C.</td> </tr> <tr> <td>9. N.C.</td><td></td><td></td><td></td><td></td><td></td><td>19. N.C.</td> </tr> <tr> <td>10. ADJUST</td><td></td><td></td><td></td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>20. V<sub>OUT</sub></td> </tr> </table>	1. SENSE	3	2	1	20	19	11. N.C.	2. N.C.						12. N.C.	3. N.C.						13. N.C.	4. N.C.	4					14. N.C.	5. V <sub>IN</sub>	5					15. N.C.	6. N.C.	6					16. N.C.	7. N.C.	7					17. N.C.	8. N.C.	8					18. N.C.	9. N.C.						19. N.C.	10. ADJUST				9	10	11	12	13	20. V <sub>OUT</sub>
	1. SENSE	3		2	1	20	19	11. N.C.																																																																				
	2. N.C.							12. N.C.																																																																				
	3. N.C.							13. N.C.																																																																				
	4. N.C.	4						14. N.C.																																																																				
5. V <sub>IN</sub>	5					15. N.C.																																																																						
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8. N.C.	8					18. N.C.																																																																						
9. N.C.						19. N.C.																																																																						
10. ADJUST				9	10	11	12	13	20. V <sub>OUT</sub>																																																																			
SG117AL	-55°C to 125°C																																																																											
SG117L/883B	-55°C to 125°C																																																																											
SG117L	-55°C to 125°C																																																																											

- Note 1. Contact factory for JAN and DESC product availability.  
 2. All parts are viewed from the top.  
 3. Both inputs and outputs must be externally connected together at the device terminals.  
 4. For normal operation the SENSE pin must be externally connected to the load.



LINEAR INTEGRATED CIRCUITS

# SG117AHV/SG217AHV/SG317AHV SG117HV/SG217HV/SG317HV

## 1.5 AMP THREE TERMINAL ADJUSTABLE VOLTAGE REGULATOR

### DESCRIPTION

The SG117AHV Series are 3-terminal positive adjustable voltage regulators which offer improved performance over earlier devices. A major feature of the SG117AHV is the output voltage tolerance is guaranteed at a maximum of  $\pm 1\%$ , allowing an overall power supply tolerance to be better than 3% using inexpensive 1% resistors. Line and load regulation performance has been improved as well. Additionally, the SG117AHV reference voltage is guaranteed not to exceed 2% when operating over the full load, line and power dissipation conditions. The SG117AHV adjustable regulators offer an improved solution for all positive voltage regulator requirements with load currents up to 1.5 amps.

For application information and characteristic curves see SG117A/117 data sheet.

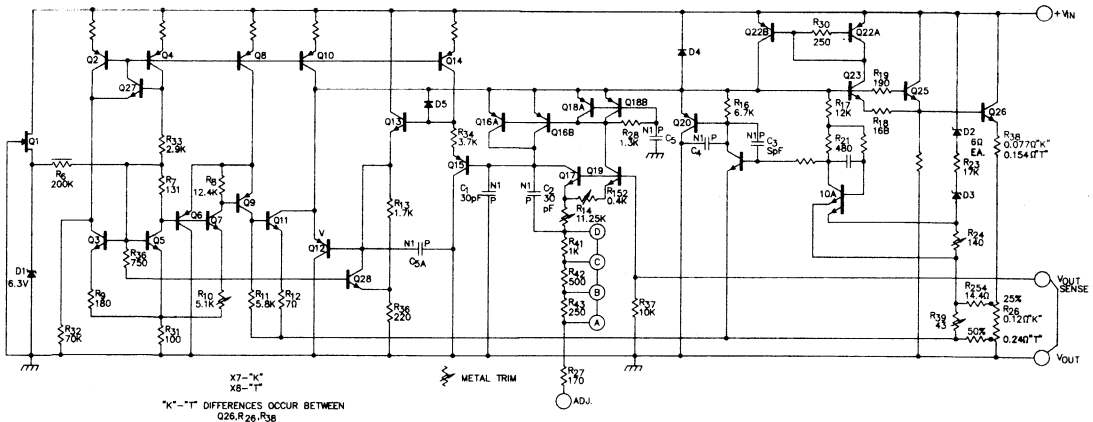
### FEATURES

- 1% output voltage tolerance
- 0.01%/V line regulation
- 0.3% load regulation
- Min. 1.5A output current
- Available in hermetic TO-220

### HIGH RELIABILITY FEATURES -SG117AHV/SG117HV

- ◆ Available to MIL-STD-883
- ◆ SG level "S" processing available

### SCHEMATIC



# SG117AHV/SG117HV SERIES

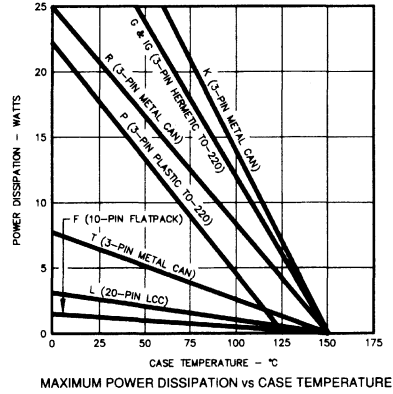
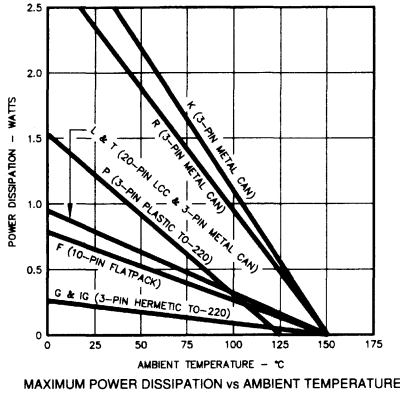
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Power Dissipation ..... Internally Limited  
 Input to Output Voltage Differential ..... 60V  
 Storage Temperature Range ..... -65°C to 150°C  
 Note 1. Exceeding these ratings could cause damage to the device.

Operating Junction Temperature  
 Hermetic (K, R, T, F, L, G, IG-Packages) ..... 175°C  
 Plastic (P-Package) ..... 150°C  
 Lead Temperature (Soldering, 10 Seconds) ..... 300°C

## RECOMMENDED OPERATING CONDITIONS (Note 2 & 3)

### THERMAL



### ELECTRICAL

Input Voltage Range ..... ( $V_{OUT} + 3.5V$ ) to 57V

Operating Junction Temperature Range  
 SG117AHV/SG117HV ..... -55°C to 150°C  
 SG217AHV/SG217HV ..... -25°C to 150°C  
 SG317AHV/SG317HV ..... 0°C to 125°C

Note 2. Range over which the device is functional.  
 Note 3. These ratings are applicable for junction temperatures of less than 150°C.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise specified, these specifications apply over full operating ambient temperature range,  $V_{IN} - V_{OUT} = 5.0V$ ,  $I_{OUT} = 0.1A$  for the TO-39, F, and L packages, and  $I_{OUT} = 0.5A$  for the TO-3, TO-220, Hermetic TO-220, and TO-66 packages. Although power dissipation is internally limited, these specifications are applicable for power dissipations of 2W for the TO-39, F, and L packages, and 20W for the TO-3, TO-220, Hermetic TO-220, and TO-66 packages.  $I_{MAX}$  is 1.5A for the TO-3, TO-220, Hermetic TO-220, and TO-66 packages and 0.5A for the TO-39, F, and L packages.)

Parameter	Test Conditions	SG117AHV/SG217AHV			SG117HV/SG217HV			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Reference Voltage	$I_{OUT} = 10mA$ , $T_A = 25^\circ C$ $3V \leq (V_{IN} - V_{OUT}) \leq 60V$ , $P \leq P_{MAX}$	1.238	1.250	1.262				V
Line Regulation (Note 4)	$10mA \leq I_{OUT} \leq I_{MAX}$ $3V \leq (V_{IN} - V_{OUT}) \leq 60V$ , $I_L = 10mA$ $T_A = 25^\circ C$	1.225	1.250	1.270	1.20	1.25	1.30	V
	$T_A = T_{MIN}$ to $T_{MAX}$		0.005	0.01		0.01	0.02	%/V
Load Regulation (Note 4)	$10mA \leq I_{OUT} \leq I_{MAX}$ $V_{OUT} \leq 5V$ , $T_A = 25^\circ C$		0.01	0.02		0.02	0.05	%/V
	$V_{OUT} \geq 5V$ , $T_A = 25^\circ C$		5	15		5	15	mV
	$V_{OUT} \leq 5V$		0.1	0.3		0.1	0.3	%
	$V_{OUT} \geq 5V$		20	50		20	50	mV
Thermal Regulation (Note 5)	$T_A = 25^\circ C$ , 20msec pulse		0.03	1		0.3	1	%
Ripple Rejection	$V_{OUT} = 10V$ , $f = 120Hz$ $C_{ADJ} = 1\mu F$ , $T_A = 25^\circ C$ $C_{ADJ} = 10\mu F$		0.002	0.02		0.03	0.07	%/W
Adjust Pin Current	$T_A = 25^\circ C$	66	65		66	65		dB
Adjust Pin Current Change	$10mA \leq I_{OUT} \leq I_{MAX}$ , $2.5V \leq (V_{IN} - V_{OUT}) \leq 60V$		50	100		50	100	$\mu A$
			0.2	5		0.2	5	$\mu A$



# SG117AHV/SG117HV SERIES

## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG117AHV/ SG217AHV			SG117HV/ SG217HV			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Minimum Load Current	$(V_{IN} - V_{OUT}) = 60V$		3.5	7		3.5	7	mA
Current Limit	$(V_{IN} - V_{OUT}) \leq 15V$ K, P, R, G, IG Packages	1.5	2.2		1.5	2.2		A
	T, L, F Package	0.5	0.8		0.5	0.8		A
	$(V_{IN} - V_{OUT}) = 60V, T_J = 25^\circ C$ K, P, R, G, IG Packages		0.1			0.1		A
	T, L, F Packages		0.03			0.03		A
Temperature Stability (Note 5)			1	2		1		%
Long Term Stability (Note 5)	$T_A = 125^\circ C, 1000$ Hours		0.3	1		0.3	1	%
RMS Output Noise (% of $V_{OUT}$ )	$T_A = 25^\circ C, 10Hz \leq f \leq 10$ KHz (Note 5)		0.001			0.001		%

Parameter	Test Conditions	SG317AHV			SG317HV			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Reference Voltage	$I_{OUT} = 10mA, T_A = 25^\circ C$ $3V \leq (V_{IN} - V_{OUT}) \leq 60V, P \leq P_{MAX}$	1.238	1.250	1.262				V
Line Regulation (Note 4)	$10mA \leq I_{OUT} \leq I_{MAX}$ $3V \leq (V_{IN} - V_{OUT}) \leq 60V, I_L = 10mA$ $T_A = 25^\circ C$	1.225	1.250	1.270	1.20	1.25	1.30	V
	$T_A = T_{MIN}$ to $T_{MAX}$		0.005	0.01		0.01	0.04	%/V
	$T_A = T_{MIN}$ to $T_{MAX}$		0.01	0.02		0.02	0.07	%/V
Load Regulation (Note 4)	$10mA \leq I_{OUT} \leq I_{MAX}$ $V_{OUT} \leq 5V, T_A = 25^\circ C$		5	25		5	25	mV
	$V_{OUT} \geq 5V, T_A = 25^\circ C$		0.1	0.5		0.1	0.5	%
	$V_{OUT} \leq 5V$		20	50		20	70	mV
	$V_{OUT} \geq 5V$		0.3	1		0.3	1.5	%
Thermal Regulation (Note 5)	$T_A = 25^\circ C, 20ms$ pulse		0.002	0.02		0.04	0.07	%/W
Ripple Rejection	$V_{OUT} = 10V, f = 120Hz$ $C_{ADJ} = 1\mu F, T_A = 25^\circ C$ $C_{ADJ} = 10\mu F$	66	80		66	80		dB
Adjust Pin Current	$T_A = 25^\circ C$		50	100		50	100	$\mu A$
Adjust Pin Current Change	$10mA \leq I_{OUT} \leq I_{MAX}, 2.5V \leq (V_{IN} - V_{OUT}) \leq 60V$		0.2	5		0.2	5	$\mu A$
Minimum Load Current	$(V_{IN} - V_{OUT}) = 60V$		3.5	12		3.5	12	mA
Current Limit	$(V_{IN} - V_{OUT}) \leq 15V$ K, P, R, G, IG Packages	1.5	2.2		1.5	2.2		A
	T, L, F Packages	0.5	0.8		0.5	0.8		A
	$(V_{IN} - V_{OUT}) = 60V, T_J = 25^\circ C$ K, P, R, G, IG Packages		0.1			0.4		A
	T, L, F Packages		0.03			0.03		A
Temperature Stability (Note 5)			1	2		1		%
Long Term Stability (Note 5)	$T_A = 125^\circ C$		0.3	1		0.3	1	%
RMS Output Noise (% of $V_{OUT}$ )	$T_A = 25^\circ C, 10Hz \leq f \leq 10KHz$ (Note 5)		0.001			0.001		%

Note 4. Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output voltage due to heating effects are covered under the specification for thermal regulation.

Note 5. These parameters, although guaranteed, are not tested in production.

# SG117AHV/SG117HV SERIES

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
3-TERMINAL TO-3 METAL CAN K-PACKAGE	SG117AHVK/883B	-55°C to 125°C	
	SG117AHVK	-55°C to 125°C	
	SG217AHVK	-25°C to 85°C	
	SG317AHVK	0°C to 70°C	
	SG117HVK/883B	-55°C to 125°C	
	SG117HVK	-55°C to 125°C	
	SG217HVK	-25°C to 85°C	
3-TERMINAL TO-66 METAL CAN R-PACKAGE	SG117AHVR/883B	-55°C to 125°C	
	SG117AHVR	-55°C to 125°C	
	SG217AHVR	-25°C to 85°C	
	SG317AHVR	0°C to 70°C	
	SG117HVR/883B	-55°C to 125°C	
	SG117HVR	-55°C to 125°C	
	SG217HVR	-25°C to 85°C	
3-PIN TO-39 METAL CAN T-PACKAGE	SG117AHVT/883B	-55°C to 125°C	
	SG117AHVT	-55°C to 125°C	
	SG217AHVT	-25°C to 85°C	
	SG317AHVT	0°C to 70°C	
	SG117HVT/883B	-55°C to 125°C	
	SG117HVT	-55°C to 125°C	
	SG217HVT	-25°C to 85°C	
3-PIN PLASTIC TO-220 P-PACKAGE	SG317AHVP	0°C to 125°C	
	SG317HVP	0°C to 125°C	
3-PIN HERMETIC TO-220 G-PACKAGE (Non-Isolated)	SG117AHVG/883B	-55°C to 125°C	
	SG117AHVG	-55°C to 125°C	
	SG117HVG/883B	-55°C to 125°C	
	SG117HVG	-55°C to 125°C	
3-PIN HERMETIC TO-220 IG-PACKAGE (Isolated)	SG117AHVIG/883B	-55°C to 125°C	
	SG117AHVIG	-55°C to 125°C	
	SG117HVIG/883B	-55°C to 125°C	
	SG117HVIG	-55°C to 125°C	
10-PIN CERAMIC FLAT PACK F - PACKAGE	SG117AHVF/883B	-55°C to 125°C	(Note 3)
	SG117AHVF	-55°C to 125°C	
	SG117HVF/883B	-55°C to 125°C	
	SG117HVF	-55°C to 125°C	
	SG117HVF	-55°C to 125°C	
20-PIN CERAMIC (LCC) LEADLESS CHIP CARRIER L- PACKAGE	SG117AHVL/883B	-55°C to 125°C	(Note 4)
	SG117AHVL	-55°C to 125°C	
	SG117HVL/883B	-55°C to 125°C	
	SG117HVL	-55°C to 125°C	
	SG117HVL	-55°C to 125°C	

- Note 1. Contact factory for JAN and DESC product availability.  
 2. All parts are viewed from the top.  
 3. Both inputs and outputs must be externally connected together at the device terminals.  
 4. For normal operation the SENSE pin must be externally connected to the load.

**NEGATIVE FIXED VOLTAGE REGULATOR**

**DESCRIPTION**

The SG120/320 series of negative regulators offer self-contained, fixed-voltage capability with up to 1.5A of load current. With a variety of output voltages and four package options this regulator series is an optimum complement to the SG7800A/7800/120/320 line of three terminal regulators.

All protective features of thermal shutdown, current limiting, and safe-area control have been designed into these units and since these regulators require only a single output capacitor or a capacitor and 5mA minimum load for satisfactory performance, ease of application is assured.

Although designed as fixed-voltage regulators, the output voltage can be increased through the use of a simple voltage divider. The low quiescent drain current of the device insures good regulation when this method is used, especially for the SG120 series. Utilizing an improved Bandgap reference design, problems have been eliminated that are normally associated with the zener diode references, such as drift in output voltage and large changes in the line and load regulation

These devices are available in hermetically sealed TO-220 (both isolated and non-isolated), TO-3, TO-39 and TO-66 power packages as well as the plastic commercial power TO-220 package.

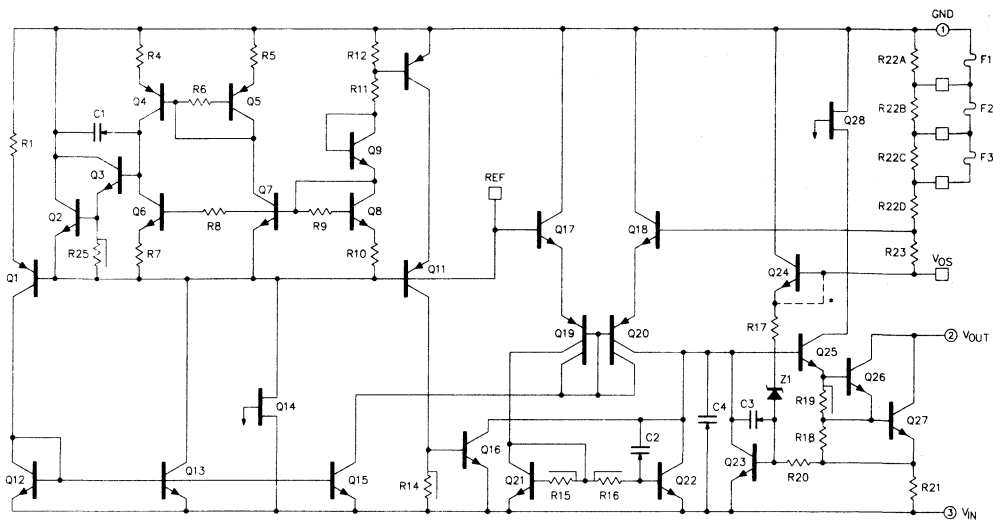
**FEATURES**

- Output current to 1.5A
- Excellent line and load regulation
- Foldback current limiting
- Thermal overload protection
- Voltages available: -5V, -5.2V, -8V, -12V, -15V, -18V, -20V
- Contact factory for other voltage options

**HIGH RELIABILITY FEATURES - SG120**

- ◆ Available to MIL-STD - 883
- ◆ Radiation data available
- ◆ SG level "S" processing available

**SCHEMATIC DIAGRAM**



\* WIRE EXISTS IF 120 TYPE DEVICE.  
WIRE DOES NOT EXIST IF 7900 TYPE DEVICE.  
SELECTABLE BY EMITTER OPTION.

**ABSOLUTE MAXIMUM RATINGS** (Note 1)

Device Output Voltage	Input Voltage	Input Voltage Differential (Output shorted to ground)
-5V	-35V	35V
-5.2V	-35V	35V
-8V	-35V	35V
-12V	-35V	35V
-15V	-40V	35V
-18V	-40V	35V
-20V	-40V	35V

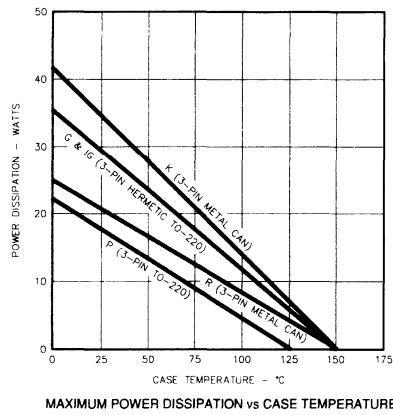
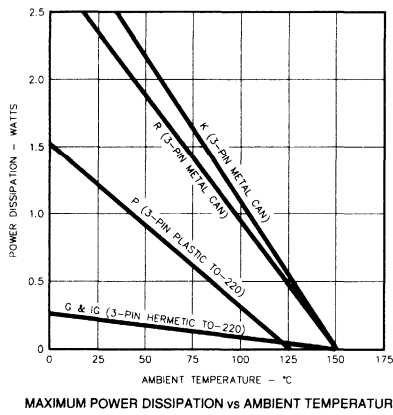
Operating Junction Temperature  
 Hermetic (K, R, G, IG - Packages) ..... 175°C  
 Plastic (P - Package) ..... 150°C

Storage Temperature Range ..... -65°C to 150°C  
 Lead Temperature (Soldering, 10 Seconds) ..... 300°C

Note 1. Values beyond which damage may occur.

**RECOMMENDED OPERATING CONDITIONS** (Note 2)

**THERMAL**



**ELECTRICAL**

Operating Junction Temperature Range:  
 SG120 ..... -55°C to 150°C  
 SG320 ..... 0°C to 125°C

Note 2. Range over which the device is functional.

**CHARACTERISTIC CURVES**

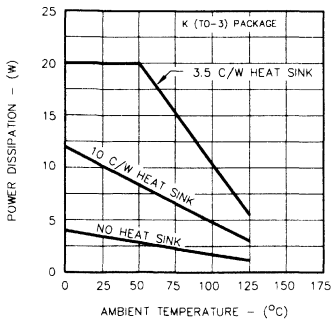


FIGURE 1. MAXIMUM AVERAGE POWER DISSIPATION

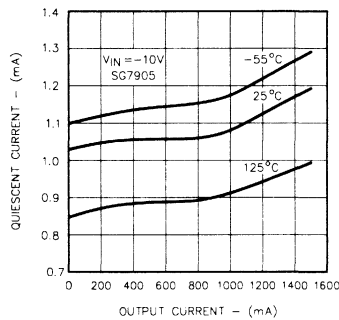


FIGURE 2. QUIESCIENT CURRENT VS. LOAD

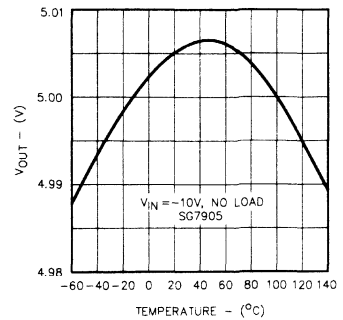


FIGURE 3. TEMPERATURE COEFFICIENT

CHARACTERISTIC CURVES (continued)

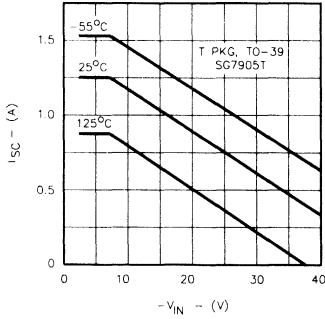


FIGURE 4. SHORTCIRCUIT CURRENT VS.  $V_{IN}$

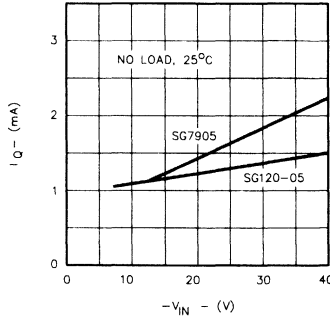


FIGURE 5. QUIESCENT CURRENT VS.  $V_{IN}$

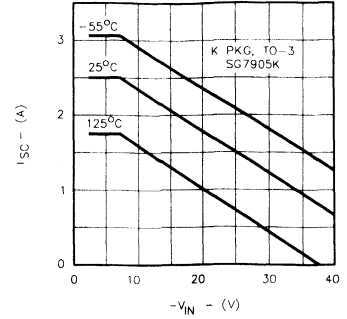


FIGURE 6. SHORT CIRCUIT CURRENT VS.  $V_{IN}$

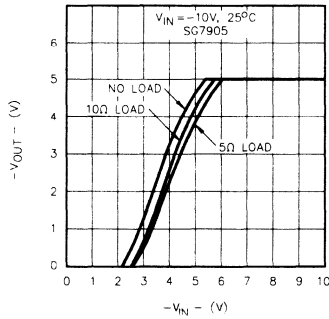


FIGURE 7. DROPOUT CHARACTERISTICS

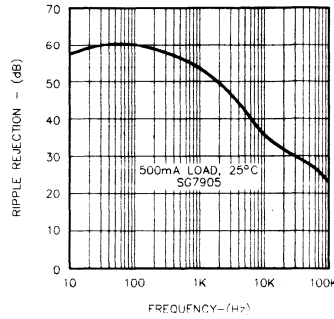


FIGURE 8. RIPPLE REJECTION VS. FREQUENCY

APPLICATIONS

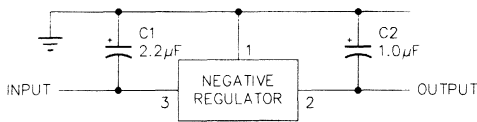


FIGURE 9 - FIXED OUTPUT REGULATOR

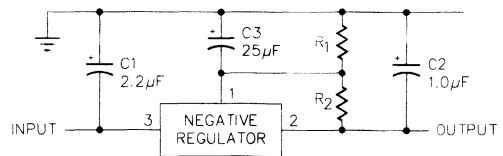


FIGURE 10 - CIRCUIT FOR INCREASING OUTPUT VOLTAGE

- NOTE: 1. C1 is required only if regulator is separated from rectifier filter.  
 2. Both C1 and C2 should be low E.S.R. types such as solid tantalum. If aluminum electrolytics are used, at least 10 times values shown should be selected.  
 3. If large output capacities are used, the regulators must be protected from momentary input shorts. A high current diode from output to input will suffice.

NOTE: C3 optional for improved transient response and ripple rejection.

$$V_{OUT} = V(\text{REGULATOR}) \frac{R_1 + R_2}{R_1} \quad R_2 = \frac{V(\text{REG})}{15\text{mA}}$$

**ELECTRICAL SPECIFICATIONS** (Note 1)

**SG120-05/SG320-05**

(Unless otherwise specified, these specifications apply for  $V_{IN} = -10V$ ,  $I_O = 5mA$ ,  $C_{IN} = 2\mu F$ ,  $C_{OUT} = 1.0\mu F$ , over the recommended operating temperatures, and are applicable for the P, K, R, G, IG -Power Packages- only.)

Parameter	Test Conditions	SG120-05			SG320-05			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_J = 25^\circ C$	-4.9	-5.0	-5.1	-4.8	-5.0	-5.2	V
Line Regulation (Note 1)	$V_{IN} = -7V$ to $-25V$ , $T_J = 25^\circ C$		10	25		10	40	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$		50	75		60	100	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		30	50		30	50	mV
Total Output Voltage Tolerance	$V_{IN} = -7.5V$ to $-25V$ Power Pkgs: $I_O = 5mA$ to $1.5A$ , $P \leq 20W$	-4.8	-5.0	-5.2	-4.75	-5.00	-5.25	V
	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	-4.8	-5.0	-5.2	-4.75	-5.00	-5.25	V
Quiescent Current	$V_{IN} = -7V$ to $-25V$			2			2	mA
Quiescent Current Change	With Line: $V_{IN} = -7V$ to $-25V$ , $T_J = 25^\circ C$			0.4			0.4	mA
	With Load: $T_J = 25^\circ C$ Power Pkgs: $I_O = 5mA$ to $1.5A$			0.4			0.4	mA
	T - Pkg: $I_O = 5mA$ to $500mA$			0.4			0.4	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$							
	Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		1.1	2.3		1.1	2.3	V
Peak Output Current	Power Pkgs: $T_J = 25^\circ C$	1.5		3.3	1.5		3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.5		1.4			1.4	A
Short Circuit Current	Power Pkgs: $V_{IN} = -35V$ , $T_J = 25^\circ C$			1.2			1.2	A
	T - Pkg: $V_{IN} = -35V$ , $T_J = 25^\circ C$			0.6			0.6	A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	54			54			dB
Output Noise Voltage (rms)	$f = 10Hz$ to $100KHz$ (Note 2)		25	80		25	80	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		20			20		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

**SG120-5.2/SG320-5.2**

(Unless otherwise specified, these specifications apply for  $V_{IN} = -10V$ ,  $I_O = 5mA$ ,  $C_{IN} = 2\mu F$ ,  $C_{OUT} = 1.0\mu F$ , over the recommended operating temperatures, and are applicable for the P, K, R, G, IG -Power Packages- only.)

Parameter	Test Conditions	SG120-5.2			SG320-5.2			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_J = 25^\circ C$	-5.1	-5.2	-5.3	-5.0	-5.2	-5.4	V
Line Regulation (Note 1)	$V_{IN} = -7.2V$ to $-25V$ , $T_J = 25^\circ C$		15	25		10	40	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$		50	75		60	100	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		30	50		30	50	mV
Total Output Voltage Tolerance	$V_{IN} = -7.7V$ to $-25V$ Power Pkgs: $I_O = 5mA$ to $1.5A$ , $P \leq 20W$	-5.0	-5.2	-5.4	-4.95	-5.20	-5.45	V
	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	-5.0	-5.2	-5.4	-4.95	-5.20	-5.45	V
Quiescent Current	$V_{IN} = -7.2V$ to $-25V$			2			2	mA
Quiescent Current Change	With Line: $V_{IN} = -7.2V$ to $-25V$ , $T_J = 25^\circ C$			0.4			0.4	mA
	With Load: $T_J = 25^\circ C$ Power Pkgs: $I_O = 5mA$ to $1.5A$			0.4			0.4	mA
	T - Pkg: $I_O = 5mA$ to $500mA$			0.4			0.4	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$							
	Power Pkgs: $I_O = 1.5A$ , T - Pkg: $I_O = 500mA$		1.1	2.3		1.1	2.3	V
Peak Output Current	Power Pkgs: $T_J = 25^\circ C$	1.5		3.3	1.5		3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.5		1.4	0.5		1.4	A
Short Circuit Current	Power Pkgs: $V_{IN} = -35V$ , $T_J = 25^\circ C$			1.2			1.2	A
	T - Pkg: $V_{IN} = -35V$ , $T_J = 25^\circ C$			0.6			0.6	A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	54			54			dB
Output Noise Voltage (rms)	$f = 10Hz$ to $100KHz$ (Note 2)		25	80		25	80	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		20			20		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

Note 1. All regulation tests are made at constant junction temperature with low duty cycle testing.  
2. This test is guaranteed but is not tested in production.

**ELECTRICAL SPECIFICATIONS** (Note 1)

**SG120-08/SG320-08**

(Unless otherwise specified, these specifications apply for  $V_{IN} = -14V$ ,  $I_O = 5mA$ ,  $C_{IN} = 2\mu F$ ,  $C_{OUT} = 1.0\mu F$ , over the recommended operating temperatures, and are applicable for the P, K, R, G, IG -Power Packages- only.)

Parameter	Test Conditions	SG120-8			SG320-8			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_J = 25^\circ C$	-7.8	-8.0	-8.2	-7.7	-8.0	-8.3	V
Line Regulation (Note 1)	$V_{IN} = -10.5V$ to $-25V$ , $T_J = 25^\circ C$		10	25		10	40	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$		20	80		20	100	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		10	25		10	40	mV
Total Output Voltage	$V_{IN} = -10.5V$ to $-25V$							
Tolerance	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $P \leq 20W$	-7.65	-8.00	-8.35	-7.6	-8.0	-8.4	V
	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	-7.65	-8.00	-8.35	-7.6	-8.0	-8.4	V
Quiescent Current	$V_{IN} = -10.5V$ to $-25V$			2			2	mA
Quiescent Current Change	With Line: $V_{IN} = -10.5V$ to $-25V$ , $T_J = 25^\circ C$			0.4			0.4	mA
	With Load: $T_J = 25^\circ C$							
Dropout Voltage	Power Pkgs: $I_O = 5mA$ to $1.5A$			0.4			0.4	mA
	T - Pkg: $I_O = 5mA$ to $500mA$			0.4			0.4	mA
Peak Output Current	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$							
	Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		1.1	2.3		1.1	2.3	V
Short Circuit Current	Power Pkgs: $T_J = 25^\circ C$	1.5		3.3	1.5		3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.5		1.4	0.5		1.4	A
Ripple Rejection	Power Pkgs: $V_{IN} = -35V$ , $T_J = 25^\circ C$			1.2			1.2	A
	T - Pkg: $V_{IN} = -35V$ , $T_J = 25^\circ C$			0.6			0.6	A
Output Noise Voltage (rms)	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	54			54			dB
Long Term Stability	$f = 10Hz$ to $100KHz$ (Note 2)		25	80		25	80	$\mu V/V$
Thermal Shutdown	1000hrs. at $T_J = 125^\circ C$		32			32		mV
	$I_O = 5mA$		175			175		$^\circ C$

**SG120-12/SG320-12**

(Unless otherwise specified, these specifications apply for  $V_{IN} = -17V$ ,  $I_O = 5mA$ ,  $C_{IN} = 2\mu F$ ,  $C_{OUT} = 1.0\mu F$ , over the recommended operating temperatures, and are applicable for the P, K, R, G, IG -Power Packages- only.)

Parameter	Test Conditions	SG120-12			SG320-12			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_J = 25^\circ C$	-11.7	-12.0	-12.3	-11.6	-12.0	-12.4	V
Line Regulation (Note 1)	$V_{IN} = -14V$ to $-32V$ , $T_J = 25^\circ C$		4	10		4	20	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.0A$ , $T_J = 25^\circ C$		30	80		30	80	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		10	25		10	40	mV
Total Output Voltage	$V_{IN} = -14.5V$ to $-32V$							
Tolerance	Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 20W$	-11.5	-12.0	-12.5	-11.4	-12.0	-12.4	V
	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	-11.5	-12.0	-12.5	-11.4	-12.0	-12.4	V
Quiescent Current	$V_{IN} = -14V$ to $-32V$			2			2	mA
Quiescent Current Change	With Line: $V_{IN} = -14V$ to $-32V$ , $T_J = 25^\circ C$			0.4			0.4	mA
	With Load: $T_J = 25^\circ C$							
Dropout Voltage	Power Pkgs: $I_O = 5mA$ to $1.0A$			0.4			0.4	mA
	T - Pkg: $I_O = 5mA$ to $500mA$			0.4			0.4	mA
Peak Output Current	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$							
	Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		1.1	2.3		1.1	2.3	V
Short Circuit Current	Power Pkgs: $T_J = 25^\circ C$	1.5		3.3	1.5		3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.5		1.4	0.5		1.4	A
Ripple Rejection	Power Pkgs: $V_{IN} = -35V$ , $T_J = 25^\circ C$			1.2			1.2	A
	T - Pkg: $V_{IN} = -35V$ , $T_J = 25^\circ C$			0.6			0.6	A
Output Noise Voltage (rms)	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	56			56			dB
Long Term Stability	$f = 10Hz$ to $100KHz$ (Note 2)		25	80		25	80	$\mu V/V$
Thermal Shutdown	1000hrs. at $T_J = 125^\circ C$		48			48		mV
	$I_O = 5mA$		175			175		$^\circ C$

Note 1. All regulation tests are made at constant junction temperature with low duty cycle testing.  
 2. This test is guaranteed but is not tested in production.

**ELECTRICAL SPECIFICATIONS** (Note 1)

**SG120-15/SG320-15**

(Unless otherwise specified, these specifications apply for  $V_{IN} = -20V$ ,  $I_O = 5mA$ ,  $C_{IN} = 2\mu F$ ,  $C_{OUT} = 1.0\mu F$ , over the recommended operating temperatures, and are applicable for the P, K, R, G, IG -Power Packages- only.)

Parameter	Test Conditions	SG120-15			SG320-15			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_J = 25^\circ C$	-14.7	-15.0	-15.3	-14.6	-15.0	-15.4	V
Line Regulation (Note 1)	$V_{IN} = -17V$ to $-35V$ , $T_J = 25^\circ C$		5	10		5	20	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.0A$ , $T_J = 25^\circ C$		30	80		30	80	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		10	25		10	40	mV
Total Output Voltage	$V_{IN} = -17.5V$ to $-35V$							
Tolerance	Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 20W$	-14.5	-15.0	-15.5	-14.4	-15.0	-15.6	V
	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	-14.5	-15.0	-15.5	-14.4	-15.0	-15.6	V
Quiescent Current	$V_{IN} = -17V$ to $-35V$		2	4		2	4	mA
Quiescent Current Change	With Line: $V_{IN} = -17V$ to $-35V$ , $T_J = 25^\circ C$			0.4			0.4	mA
	With Load: $T_J = 25^\circ C$							
Dropout Voltage	Power Pkgs: $I_O = 5mA$ to $1.0A$			0.4			0.4	mA
	T - Pkg: $I_O = 5mA$ to $500mA$			0.4			0.4	mA
	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$							
Peak Output Current	Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		1.1	2.3		1.1	2.3	V
	Power Pkgs: $T_J = 25^\circ C$	1.5		3.3	1.5		3.3	A
Short Circuit Current	T - Pkg: $T_J = 25^\circ C$	0.5		1.4	0.5		1.4	A
	Power Pkgs: $V_{IN} = -35V$ , $T_J = 25^\circ C$			1.2			1.2	A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	56			56			dB
Output Noise Voltage (rms)	$f = 10Hz$ to $100KHz$ (Note 2)		25	80		25	80	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		60			60		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

**SG120-18/SG320-18**

(Unless otherwise specified, these specifications apply for  $V_{IN} = -27V$ ,  $I_O = 5mA$ ,  $C_{IN} = 2\mu F$ ,  $C_{OUT} = 1.0\mu F$ , over the recommended operating temperatures, and are applicable for the P, K, R, G, IG -Power Packages- only.)

Parameter	Test Conditions	SG120-18			SG320-18			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_J = 25^\circ C$	-17.6	-18.0	-18.4	-17.4	-18.0	-18.6	V
Line Regulation (Note 1)	$V_{IN} = -21V$ to $-33V$ , $T_J = 25^\circ C$		5	10		5	20	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.0A$ , $T_J = 25^\circ C$		30	80		30	80	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		10	25		10	40	mV
Total Output Voltage	$V_{IN} = -22V$ to $-33V$							
Tolerance	Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 20W$	-17.4	-18.0	-18.6	-17.1	-18.0	-18.9	V
	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	-17.4	-18.0	-18.6	-17.1	-18.0	-18.9	V
Quiescent Current	$V_{IN} = -21V$ to $-33V$		2	4		2	4	mA
Quiescent Current Change	With Line: $V_{IN} = -21V$ to $-33V$ , $T_J = 25^\circ C$			0.4			0.4	mA
	With Load: $T_J = 25^\circ C$							
Dropout Voltage	Power Pkgs: $I_O = 5mA$ to $1.0A$			0.4			0.4	mA
	T - Pkg: $I_O = 5mA$ to $500mA$			0.4			0.4	mA
	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$							
Peak Output Current	Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		1.1	2.3		1.1	2.3	V
	Power Pkgs: $T_J = 25^\circ C$	1.5		3.3	1.5		3.3	A
Short Circuit Current	T - Pkg: $T_J = 25^\circ C$	0.5		1.4	0.5		1.4	A
	Power Pkgs: $V_{IN} = -35V$ , $T_J = 25^\circ C$			1.2			1.2	A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	56			56			dB
Output Noise Voltage (rms)	$f = 10Hz$ to $100KHz$ (Note 2)		25	80		25	80	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		72			72		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

Note 1. All regulation tests are made at constant junction temperature with low duty cycle testing.  
 2. This test is guaranteed but is not tested in production.



**ELECTRICAL SPECIFICATIONS** (Note 1)

**SG120-20/SG320-20**

(Unless otherwise specified, these specifications apply for  $V_{IN} = -29V$ ,  $I_O = 5mA$ ,  $C_{IN} = 2\mu F$ ,  $C_{OUT} = 1.0\mu F$ , over the recommended operating temperatures, and are applicable for the P, K, R, G, IG -Power Packages- only.)

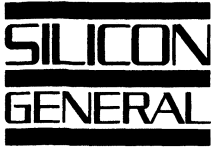
Parameter	Test Conditions	SG120-20			SG320-20			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_J = 25^\circ C$	-19.5	-20.0	-20.5	-19.2	-20.0	-20.8	V
Line Regulation (Note 1)	$V_{IN} = -23V$ to $-35V$ , $T_J = 25^\circ C$		5	10		5	20	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.0A$ , $T_J = 25^\circ C$		30	80		30	80	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		10	25		10	25	mV
Total Output Voltage Tolerance	$V_{IN} = -24V$ to $-35V$ Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 20W$ T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	-19.3	-20.0	-20.7	-19.0	-20.0	-21.0	V
Quiescent Current	$V_{IN} = -23V$ to $-35V$		2	4		2	4	mA
Quiescent Current Change	With Line: $V_{IN} = -23V$ to $-35V$ , $T_J = 25^\circ C$			0.4			0.4	mA
	With Load: $T_J = 25^\circ C$ Power Pkgs: $I_O = 5mA$ to $1.0A$ T - Pkg: $I_O = 5mA$ to $500mA$			0.4			0.4	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$ Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		1.1	2.3		1.1	2.3	V
Peak Output Current	Power Pkgs: $T_J = 25^\circ C$	1.5		3.3	1.5		3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.5		1.4	0.5		1.4	A
Short Circuit Current	Power Pkgs: $V_{IN} = -35V$ , $T_J = 25^\circ C$			1.2			1.2	A
	T - Pkg: $V_{IN} = -35V$ , $T_J = 25^\circ C$			0.6			0.6	A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	56			56			dB
Output Noise Voltage (rms)	$f = 10Hz$ to $100KHz$ (Note 2)		25	80		25	80	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		80			80		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

- Note 1. All regulation tests are made at constant junction temperature with low duty cycle testing.
- 2. This test is guaranteed but is not tested in production.

CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
3-TERMINAL TO-3 METAL CAN K-PACKAGE	SG120-XXK/883B SG120-XXK SG320-XXK	-55°C to 125°C -55°C to 125°C 0°C to 70°C	
3-TERMINAL TO-66 METAL CAN R-PACKAGE	SG120-XXR/883B SG120-XXR SG320-XXR	-55°C to 125°C -55°C to 125°C 0°C to 70°C	
3-PIN PLASTIC TO-220 P-PACKAGE	SG320-XXP	0°C to 70°C	
3-PIN HERMETIC TO-220 G-PACKAGE (Non-Isolated)	SG120-XXG/883B SG120-XXG	-55°C to 125°C -55°C to 125°C	
3-PIN HERMETIC TO-220 IG-PACKAGE (Isolated)	SG120-XXIG/883B SG120-XXIG	-55°C to 125°C -55°C to 125°C	

- Note 1. Contact factory for JAN and DESC product availability.  
 2. All parts are viewed from the top.  
 3. "XX" to be replaced by output voltage of specific fixed regulator.  
 4. Some products will be available in leadless chip carrier (LCC) and hermetic flat pack (F). Consult factory for price and availability



LINEAR INTEGRATED CIRCUITS

# SG137A/SG237A/SG337A SG137/SG237/SG337

## 1.5 AMP NEGATIVE ADJUSTABLE REGULATOR

### DESCRIPTION

The SG137A family of negative adjustable regulators will deliver up to 1.5A output current over an output voltage range of -1.2V to -37V. Silicon General has made significant improvements in these regulators compared to previous devices, such as better line and load regulation, and a maximum output voltage error of 1%. The SG137 family uses the same chip design and guarantees maximum output voltage error of  $\pm 2\%$ .

Every effort has been made to make these devices easy to use and difficult to damage. Internal current and power limiting coupled with true thermal limiting prevents device damage due to overloads or shorts even if the regulator is not fastened to a heat sink.

The SG137A/137 family of products are ideal complements to the SG117A/117 adjustable positive regulators.

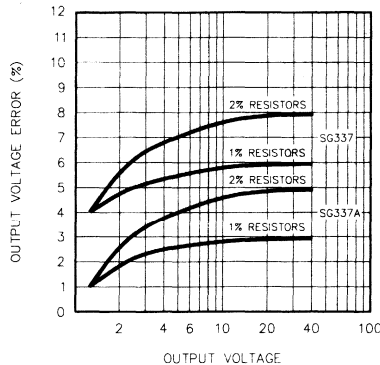
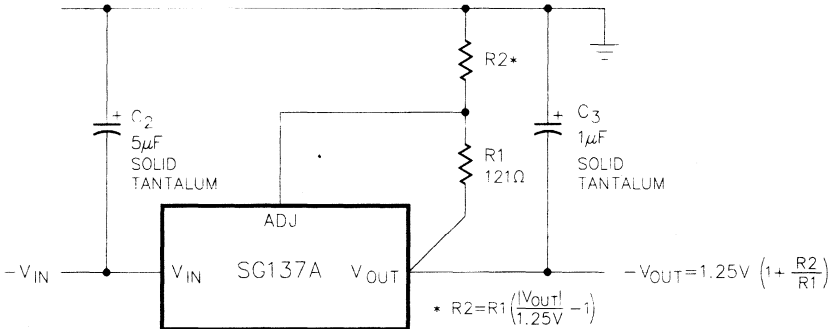
### FEATURES

- 1 % output voltage tolerance
- 0.01%/V line regulation
- 0.5% load regulation
- 0.02%/W thermal regulation
- Available in hermetic TO-220

### HIGH RELIABILITY FEATURES -SG137A/SG137

- ◆ Available to MIL-STD-883 and DESC SMD
- ◆ Scheduled for MIL-M38510 QPL listing
- ◆ SG level "S" processing available

### BLOCK DIAGRAM



# SG137A/SG137 SERIES

## ABSOLUTE MAXIMUM RATINGS (Note 1)

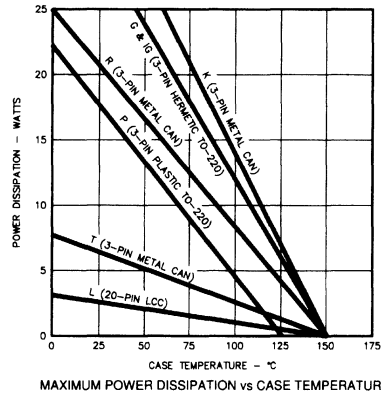
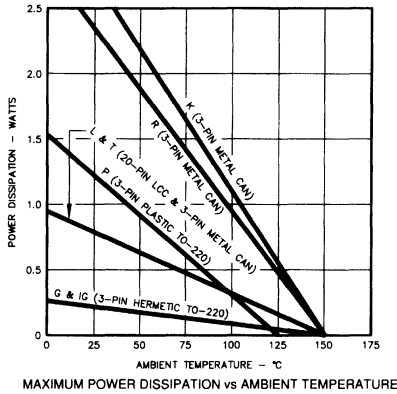
Power Dissipation ..... Internally Limited  
 Input to Output Voltage Differential ..... 40V  
 Storage Temperature Range ..... -65°C to 150°C

Operating Junction Temperature  
 Hermetic (K, R, T, L, G, IG-Packages) ..... 175°C  
 Plastic (P-Package) ..... 150°C  
 Lead Temperature (Soldering, 10 Seconds) ..... 300°C

Note 1. Exceeding these ratings could cause damage to the device.

## RECOMMENDED OPERATING CONDITIONS (Note 2 & 3)

### THERMAL



### ELECTRICAL

Input Voltage Range .....  $-(V_{OUT} + 3.5V)$  to  $-36V$

Operating Junction Temperature Range  
 SG137A/SG137 ..... -55°C to 150°C  
 SG237A/SG237 ..... -25°C to 150°C  
 SG337A/SG337 ..... 0°C to 125°C

Note 2. Range over which the device is functional.

Note 3. These ratings are applicable for junction temperatures of less than 135°C.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise specified, these specifications apply over full operating ambient temperature range,  $|V_{IN} - V_{OUT}| = 5.0V$ ,  $I_{OUT} = 0.1A$  for the TO-39 and L packages, and  $I_{OUT} = 0.5A$  for the TO-3, TO-220, Hermetic TO-220, and TO-66 packages. Although power dissipation is internally limited, these specifications are applicable for power dissipations of 2W for the TO-39 and L packages, and 20W for the TO-3, TO-220, Hermetic TO-220, and TO-66 packages.  $I_{MAX}$  is 1.5A for the TO-3, TO-220, Hermetic TO-220, and TO-66 packages and 0.5A for the TO-39 and L packages.)

Parameter	Test Conditions	SG137A/SG237A			SG137/SG237			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Reference Voltage	$I_{OUT} = 10mA$ , $T_A = 25^\circ C$	-1.238	-1.250	-1.262	-1.225	-1.250	-1.275	V
	$3V \leq  V_{IN} - V_{OUT}  \leq 40V$ , $10mA \leq I_{OUT} \leq I_{MAX}$	-1.220	-1.250	-1.280	-1.200	-1.250	-1.300	V
Line Regulation (Note 4)	$T_A = 25^\circ C$		0.005	0.01	0.01	0.02	%/V	
	$10mA \leq I_{OUT} \leq I_{MAX}$							
Load Regulation (Note 4)	$ V_{OUT}  \leq 5V$ , $T_A = 25^\circ C$		5	25	15	25	mV	
	$ V_{OUT}  \geq 5V$ , $T_A = 25^\circ C$		0.1	0.5	0.3	0.5	%	
	$ V_{OUT}  \leq 5V$		10	50	20	50	mV	
	$ V_{OUT}  \geq 5V$		0.2	1.0	0.3	1.0	%	
Thermal Regulation (Note 5)	$T_A = 25^\circ C$ , 10ms pulse		0.002	0.02	0.002	0.02	%/W	
Ripple Rejection	$V_{OUT} = -10V$ , $f = 120Hz$							
	$C_{ADJ} = 0$ , $T_A = 25^\circ C$	60	66		60		dB	
Adjust Pin Current	$C_{ADJ} = 10\mu F$	70	80		66	77	dB	
	$T_A = 25^\circ C$		65	100	65	100	$\mu A$	
Adjust Pin Current Change	$3V \leq  V_{IN} - V_{OUT}  \leq 40V$		1.0	5	2	5	$\mu A$	
	$10mA \leq I_{OUT} \leq I_{MAX}$		0.2	2	0.5	5	$\mu A$	

# SG137A/SG137 SERIES

## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG137A/SG237A			SG137/SG237			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Minimum Load Current	$ V_{IN} - V_{OUT}  \leq 40V$		2.5	5.0		2.5	5.0	mA
Current Limit	$ V_{IN} - V_{OUT}  \leq 10V$		1.2	3		1.2	3.0	mA
	$ V_{IN} - V_{OUT}  \leq 15V$ K, P, R, G, IG Packages	1.5	2.2	3.2	1.5	2.2		A
	T, L, Packages	0.5	0.8	1.5	0.5	0.8		A
Temperature Stability (Note 5)	$ V_{IN} - V_{OUT}  \leq 40V, T_J = 25^\circ C$							
	K, P, R, G, IG Packages	0.24	0.4	1.0	0.24	0.4		A
	T, L, Packages	0.15	0.25	0.5	0.15	0.25		A
Long Term Stability (Note 5)	$T_A = 125^\circ C, 1000 \text{ Hours}$		0.6	1.5		0.6		%
RMS Output Noise (% of $V_{OUT}$ )	$T_A = 25^\circ C, 10\text{Hz} \leq f \leq 10 \text{ KHz}$ (Note 5)		0.3	1.0		0.3	1.0	%
			0.003			0.003		%

Parameter	Test Conditions	SG337A			SG337			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Reference Voltage	$I_{OUT} = 10\text{mA}, T_A = 25^\circ C$	1.238	1.250	1.262	1.219	1.250	1.287	V
Line Regulation (Note 4)	$3V \leq  V_{IN} - V_{OUT}  \leq 40V, 10\text{mA} \leq I_{OUT} \leq I_{MAX}$	1.220	1.250	1.280	1.200	1.250	1.300	V
	$T_A = 25^\circ C$		0.005	0.01		0.01	0.04	%/V
Load Regulation (Note 4)	$10\text{mA} \leq I_{OUT} \leq I_{MAX}$							
	$ V_{OUT}  \leq 5V, T_A = 25^\circ C$		5	25		15	50	mV
	$ V_{OUT}  \geq 5V, T_A = 25^\circ C$		0.1	0.5		0.3	1.0	%
	$ V_{OUT}  \leq 5V$		10	50		20	70	mV
Thermal Regulation (Note 5)	$ V_{OUT}  \geq 5V$		0.2	1.0		0.3	1.5	%
	$T_A = 25^\circ C, 10\text{ms pulse}$		0.002	0.02		0.003	0.04	%/W
Ripple Rejection	$V_{OUT} = -10V, f = 120\text{Hz}$							
	$C_{ADJ} = 0, T_A = 25^\circ C$	60	66			60		dB
	$C_{ADJ} = 10\mu F$	70	80		66	77		dB
Adjust Pin Current	$T_A = 25^\circ C$		65	100		65	100	$\mu A$
Adjust Pin Current Change	$3V \leq  V_{IN} - V_{OUT}  \leq 40V$		1.0	5		2	5	$\mu A$
	$10\text{mA} \leq I_{OUT} \leq I_{MAX}$		0.2	2		0.5	5	$\mu A$
Minimum Load Current	$ V_{IN} - V_{OUT}  \leq 40V$		2.5	5		2.5	10	mA
Current Limit	$ V_{IN} - V_{OUT}  \leq 10V$		1.2	3		1	6	mA
	$ V_{IN} - V_{OUT}  \leq 15V$ K, P, R, G, IG-Packages	1.5	2.2	3.5	1.5	2.2		A
	T, L-Packages	0.5	0.8	1.5	0.5	0.8		A
Temperature Stability (Note 5)	$ V_{IN} - V_{OUT}  \leq 40V, T_J = 25^\circ C$							
	K, P, R, G, IG-Packages	0.24	0.5	1.0	0.15	0.4		A
	T, L-Packages	0.15	0.25	0.5	0.10	0.17		A
Long Term Stability (Note 5)	$T_A = 125^\circ C, 1000\text{hr}$		0.6	1.5		0.6		%
RMS Output Noise (% of $V_{OUT}$ )	$T_A = 25^\circ C, 10\text{Hz} \leq f \leq 10\text{KHz}$ (Note 5)		0.3	1.0		0.3	1.0	%
			0.003			0.003		%

Note 4. Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output voltage due to heating effects are covered under the specification for thermal regulation.

Note 5. These parameters, although guaranteed, are not tested in production.

## CHARACTERISTIC CURVES

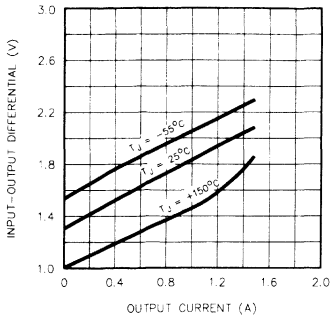


FIGURE 1. INPUT-OUTPUT DIFFERENTIAL VS. OUTPUT CURRENT

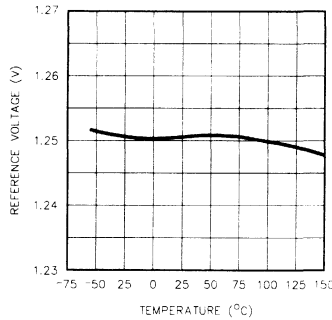


FIGURE 2. REFERENCE VOLTAGE VS. TEMPERATURE

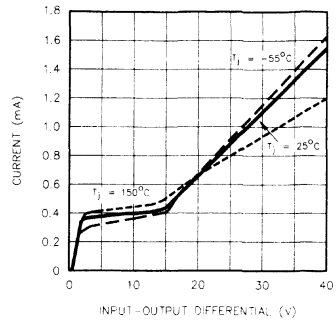


FIGURE 3. CURRENT VS. INPUT/OUTPUT DIFFERENTIAL

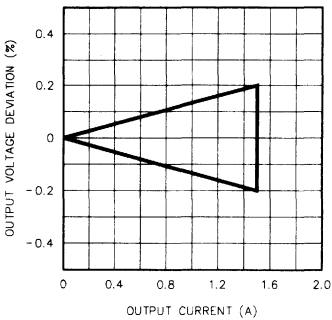


FIGURE 4. \* OUTPUT VOLTAGE DEVIATION VS. OUTPUT CURRENT

\* The SG137A has load regulation compensation which makes the typical unit read close to zero. This band represents the typical production spread.

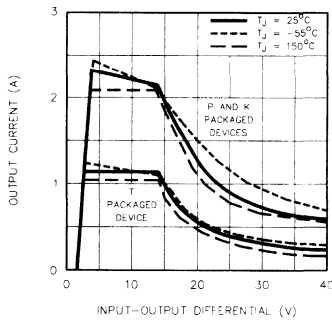


FIGURE 5. INPUT/OUTPUT DIFFERENTIAL VS. OUTPUT CURRENT

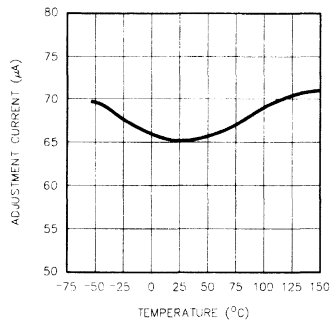


FIGURE 6. ADJUSTMENT CURRENT VS. TEMPERATURE

## APPLICATION INFORMATION

### OUTPUT VOLTAGE

The output voltage is determined by two external resistors,  $R_1$  &  $R_2$  (see Figure 7).

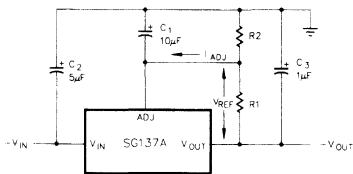


FIGURE 7

The exact formula for the output voltage is:

$$V_{OUT} = V_{REF} \left( \frac{R_2 + R_1}{R_1} \right) + I_{ADJ} (R_2)$$

Where:  $V_{REF}$  = Reference Voltage,  $I_{ADJ}$  = Adjustment Pin Current. In most applications, the second term is small enough to be ignored, typically about 0.5% of  $V_{OUT}$ . In more critical applications, the exact formula should be used, with  $I_{ADJ}$  equal to 65µA. Solving for  $R_2$  yields:

$$R_2 = \frac{V_{OUT} - V_{REF}}{\frac{V_{REF}}{R_1} + I_{ADJ}}$$

Smaller values of  $R_1$  and  $R_2$  will reduce the influence of  $I_{ADJ}$  on the output voltage, but the no-load current drain on the regulator will be increased. Typical values for  $R_1$  are between 100Ω and 300Ω, giving 12.5 mA and 4.2mA no-load current respectively. There is an additional consideration in selecting  $R_1$ , the minimum load current specification of the regulator. The operating current

# SG137A/SG137 SERIES

## APPLICATION INFORMATION (continued)

of the SG137A flows from input to output. If this current is not absorbed by the load, the output of the regulator will rise above the regulated value. The current drawn by  $R_1$  and  $R_2$  is normally high enough to absorb the current, but care must be taken in no-load situations where  $R_1$  and  $R_2$  have high values. The maximum value for the operating current, which must be absorbed, is 5mA for the SG137A. If input-output voltage differential is less than 10V, the operating current that must be absorbed drops to 3mA.

## EXAMPLES:

1. A precision 10V regulator to supply up to 1Amp load current.

a. Select  $R_1 = 100\Omega$  to minimize effect of  $I_{ADJ}$

b. Calculate  $R_2 = \frac{V_{OUT} - V_{REF}}{(V_{REF}/R_1) + I_{ADJ}} = \frac{10V - 1.25V}{(1.25V/100\Omega) + 65\mu A} = 704\Omega$

2. A 15V regulator to run off batteries and supply 50mA.

$V_{IN MAX} = 25V$

a. To minimize battery drain, select  $R_1$  as high as possible

$$R_1 = \frac{1.25V}{3mA} = 417\Omega, \text{ use } 404\Omega, 1\%$$

## TYPICAL APPLICATIONS

The output stability, load regulation, line regulation, thermal regulation, temperature drift, long term drift, and noise, can be improved by a factor of 6.6 over the standard regulator configuration. This assumes a zener whose drift and noise is considerably better than the regulator itself. The LM329B has 20PPM/ $^{\circ}C$  maximum drift and about 10 times lower noise than the regulator.

In the application shown Figure 8, regulators #2 to #N will track regulator #1 to within  $\pm 24mV$  initially, and to  $\pm 60mV$  over all load, line, and temperature conditions. If any regulator output is shorted to ground, all other outputs will drop to -2V. Load regulation of regulators #2 to #N will be improved by  $V_{OUT}/1.25V$  compared to a standard regulator, so regulator #1 should be the one which has the lowest load current.

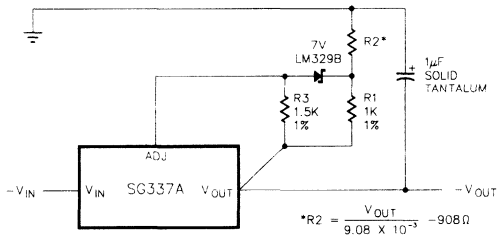
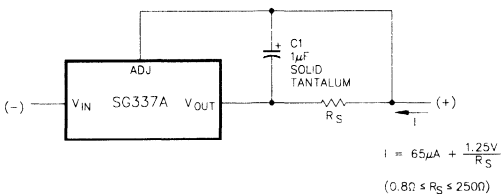


FIGURE 9 - HIGH STABILITY REGULATOR



$$I = 65\mu A + \frac{1.25V}{R_S}$$

$(0.8\Omega \leq R_S \leq 2500)$

FIGURE 10 - CURRENT REGULATOR

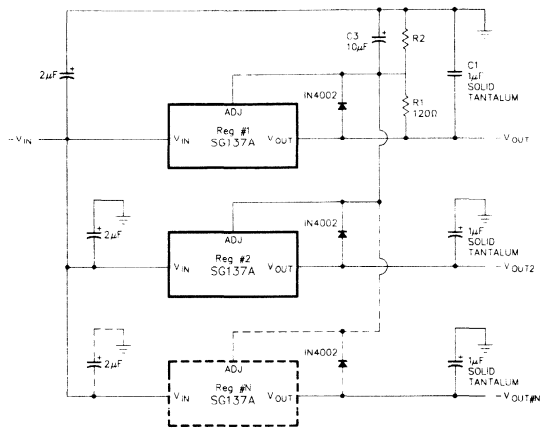
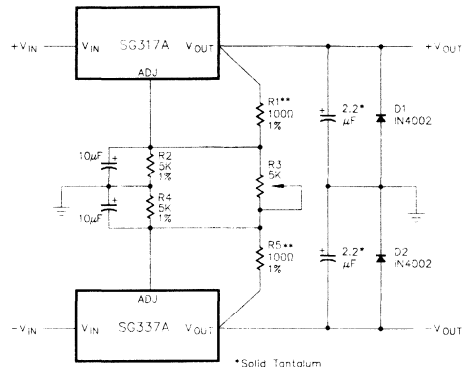


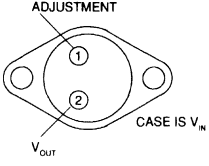
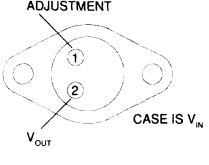
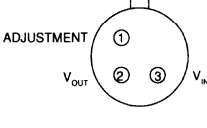



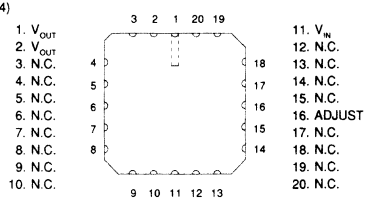
FIGURE 8 - MULTIPLE TRACKING REGULATORS



\*Solid Tantalum  
\*\*R1 or R2 may be trimmed slightly to improve tracking

FIGURE 11 - DUAL TRACKING SUPPLY  $\pm 1.25V$  to  $\pm 20V$

# SG137A/SG137 SERIES

<b>CONNECTION DIAGRAMS &amp; ORDERING INFORMATION</b> (See Notes Below)			
Package	Part No.	Ambient Temperature Range	Connection Diagram
3-TERMINAL TO-3 METAL CAN K-PACKAGE	SG137AK/883B SG137AK SG237AK SG337AK SG137K/883B SG137K SG237K SG337K	-55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C -55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C	
3-TERMINAL TO-66 METAL CAN R-PACKAGE	SG137AR/883B SG137AR SG237AR SG337AR SG137R/883B SG137R SG237R SG337R	-55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C -55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C	
3-PIN TO-39 METAL CAN T-PACKAGE	SG137AT/883B SG137AT SG237AT SG337AT SG137T/883B SG137T SG237T SG337T	-55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C -55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C	
3-PIN PLASTIC TO-220 P-PACKAGE	SG337AP SG337P	0°C to 70°C 0°C to 70°C	
3-PIN HERMETIC TO-220 G-PACKAGE (Non-Isolated)	SG137AG/883B SG137AG SG137G/883B SG137G	-55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C	
3-PIN HERMETIC TO-220 IG-PACKAGE (Isolated)	SG137AIG/883B SG137AIG SG137IG/883B SG137IG	-55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C	
20-PIN CERAMIC (LCC) LEADLESS CHIP CARRIER L-PACKAGE	SG137AL/883B SG137AL SG137L/883B SG137L	-55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C	<p>(Note 4)</p> 

Note 1. Contact factory for JAN and DESC product availability.      3. Product is also available in flatpack. Consult factory for price and delivery.  
 2. All parts are viewed from the top.      4. Both outputs must be externally connected together at the device terminals.





LINEAR INTEGRATED CIRCUITS

**SG138A/SG238A/SG338A**  
**SG138/SG238/SG338**

**5 AMP POSITIVE ADJUSTABLE**  
**VOLTAGE REGULATOR**

**DESCRIPTION**

The SG138A series are 3-terminal positive adjustable voltage regulators capable of supplying in excess of 5A over a 1.25V to 32V output voltage range. These regulators are exceptionally easy to use, requiring only two external resistors to program the output voltage. In addition, a major feature of the "A" version device is the initial output voltage tolerance which is guaranteed to be within  $\pm 1\%$  at room temperature. Over full operating conditions, including load, line, and power dissipation, the reference is guaranteed not to vary more than 2%.

A novel characteristic of the SG138A series is its new current limit circuitry, which allows transient load currents of up to 12A to be safely delivered to the load without additional protection schemes.

The SG138A is an improved version of the popular LM138, and utilizes advanced circuit design, device layout, and processing techniques in order to provide superior performance and reliability.

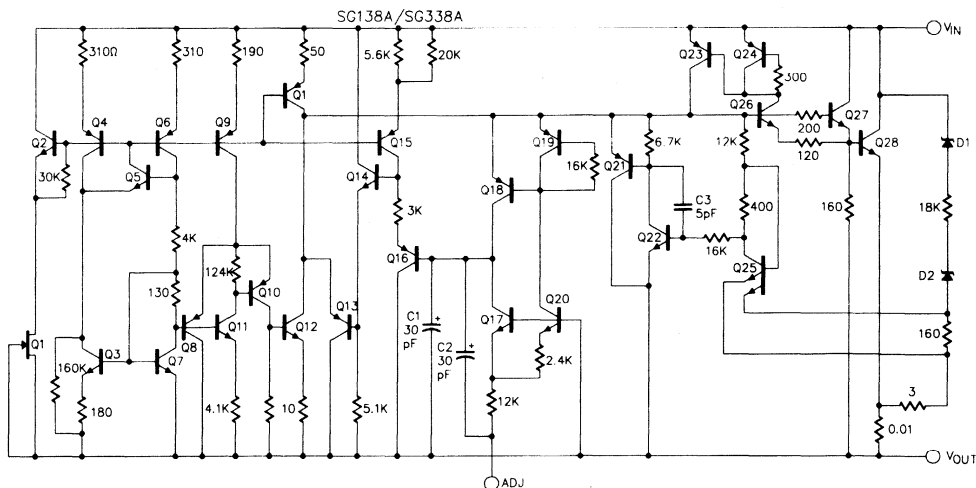
**FEATURES**

- Guaranteed 5A output current
- Guaranteed 1% output voltage tolerance
- Guaranteed 0.3 % load regulation
- Guaranteed 0.01% line regulation
- Low TC internal current limit
- Thermal overload protection
- Improved output transistor safe operating area compensation
- Output adjustable from 1.25V to 32V
- Paralleling regulators for higher output current

**HIGH RELIABILITY FEATURES**  
**-SG138A/SG138**

- ◆ Available to Mil-Std-883
- ◆ SG level "S" processing available

**SCHEMATIC**



# SG138A/SG138 SERIES

## ABSOLUTE MAXIMUM RATINGS (Note 1)

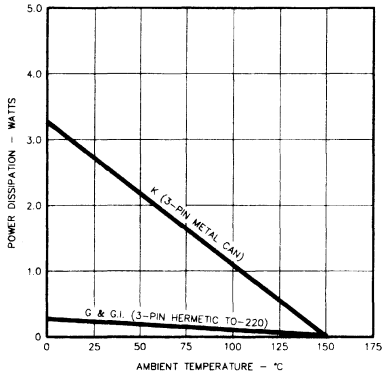
Power Dissipation ..... Internally Limited  
 Input to output Voltage Differential ..... 35V  
 Storage Temperature Range ..... -65°C to 150°C

Operating Junction Temperature  
 Hermetic (K, G, G.I.-Packages) ..... 175°C  
 Lead Temperature (Soldering, 10 Seconds) ..... 300°C

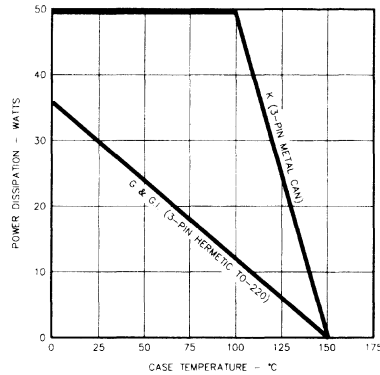
Note 1. Exceeding these ratings could cause damage to the device.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Input to output Voltage Differential ..... 3V to 35V

Operation Junction Temperature Range

SG138A/SG138 ..... -55°C to 150°C  
 SG238A/SG238 ..... -25°C to 150°C  
 SG338A/SG338 ..... 0°C to 125°C

Note 2: Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise specified, these specifications apply:  $V_{IN} - V_{OUT} = 5V$ ,  $I_{OUT} = 2.5A$  and will apply over full operating junction temperature range.)

Parameter	Test Conditions	SG138A/SG238A			SG138/SG238			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Reference Voltage	$I_{OUT} = 10mA$ , $T_A = 25^\circ C$ $3V \leq (V_{IN} - V_{OUT}) \leq 35V$	1.238	1.250	1.262				V
Line Regulation	$10mA \leq I_{OUT} \leq 5A$ , $P \leq 50W$ $3V \leq (V_{IN} - V_{OUT}) \leq 35V$ , (Note 3) $T_A = 25^\circ C$	1.225	1.250	1.270	1.19	1.24	1.29	V
Load Regulation	$T_A = T_{MIN}$ to $T_{MAX}$		0.005	0.01	0.005	0.01		%/V
	$10mA \leq I_{OUT} \leq 5A$ , (Note 3)		0.02	0.04	0.02	0.04		%/V
	$V_{OUT} \leq 5V$ , $T_A = 25^\circ C$		5	15	5	15		mV
	$V_{OUT} \geq 5V$ , $T_A = 25^\circ C$		0.1	0.3	0.1	0.3		%
Thermal Regulation	$V_{OUT} \leq 5V$		20	30	20	30		mV
	$V_{OUT} \geq 5V$		0.3	0.6	0.3	0.6		%
Ripple Rejection	$T_A = 25^\circ C$ , 20msec pulse $V_{OUT} = 10V$ , $f = 120Hz$		0.002	0.01	0.002	0.01		%/W
Adjust Pin Current	$C_{ADJ} = 0$		60		60			dB
Adjust Pin Current Change	$C_{ADJ} = 10\mu F$	60	75		60	75		dB
Adjust Pin Current			45	100	45	100		$\mu A$
Adjust Pin Current Change	$10mA \leq I_{OUT} \leq 5A$ , $3V \leq (V_{IN} - V_{OUT}) \leq 35V$		0.2	5	0.2	5		$\mu A$

## SG138A/SG138 SERIES

### ELECTRICAL SPECIFICATIONS (Continued)

Parameter	Test Conditions	SG138A/SG238A			SG138/SG238			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Minimum Load Current	$(V_{IN} - V_{OUT}) = 35V$		3.5	5		3.5	5	mA
Current Limit	$(V_{IN} - V_{OUT}) \leq 10V$							
	DC	5	8		5	8		A
	0.5ms peak	7	12		7	12		A
Temperature Stability	$(V_{IN} - V_{OUT}) = 30V, T_J = 25^\circ C$		1			1		A
			1	2		1		%
Long Term Stability	$T_A = 125^\circ C, 1000 \text{ Hours}$		0.3	1		0.3	1	%
RMS Output Noise (% of $V_{OUT}$ )	$T_A = 25^\circ C, 10Hz \leq f \leq 10 \text{ KHz}$		0.001			0.003		%
Thermal Resistance	Junction to case			1			1	$^\circ C/W$

Parameter	Test Conditions	SG338A			SG338			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Reference Voltage	$I_{OUT} = 10mA, T_A = 25^\circ C$ $3V \leq (V_{IN} - V_{OUT}) \leq 35V$ $10mA \leq I_{OUT} \leq 5A, P \leq 50W$	1.238	1.250	1.262				V
Line Regulation	$3V \leq (V_{IN} - V_{OUT}) \leq 35V, ( \text{Note } 3)$	1.225	1.250	1.270	1.19	1.24	1.29	V
	$T_A = 25^\circ C$		0.005	0.01		0.005	0.03	%/V
Load Regulation	$T_A = T_{MIN}$ to $T_{MAX}$		0.02	0.04		0.02	0.06	%/V
	$10mA \leq I_{OUT} \leq 5A, ( \text{Note } 3)$							
Thermal Regulation	$V_{OUT} \leq 5V, T_A = 25^\circ C$		5	15		5	25	mV
	$V_{OUT} \geq 5V, T_A = 25^\circ C$		0.1	0.3		0.1	0.5	%
	$V_{OUT} \leq 5V$		20	30		20	50	mV
	$V_{OUT} \geq 5V$		0.3	0.6		0.3	1	%
Ripple Rejection	$T_A = 25^\circ C, 20\text{msec pulse}$ $V_{OUT} = 10V, f = 120Hz$ $C_{ADJ} = 0$ $C_{ADJ} = 10\mu F$		0.002	0.02		0.002	0.02	%/W
Adjust Pin Current			60			60		dB
			60	75		60	75	dB
Adjust Pin Current Change			45	100		45	100	$\mu A$
Adjust Pin Current Change	$10mA \leq I_{OUT} \leq 5A, 3V \leq (V_{IN} - V_{OUT}) \leq 35V$		0.2	5		0.2	5	$\mu A$
Minimum Load Current	$(V_{IN} - V_{OUT}) = 35V$		3.5	10		3.5	10	mA
Current Limit	$(V_{IN} - V_{OUT}) \leq 10V$							
	DC	5	8		5	8		A
	0.5ms peak	7	12		7	12		A
Temperature Stability	$(V_{IN} - V_{OUT}) = 30V, T_J = 25^\circ C$		1			1		A
			1	2		1		%
Long Term Stability	$T_A = 125^\circ C, 1000 \text{ Hours}$		0.3	1		0.3	1	%
RMS Output Noise (% of $V_{OUT}$ )	$T_A = 25^\circ C, 10Hz \leq f \leq 10 \text{ KHz}$		0.001			0.003		%
Thermal Resistance	Junction to case			1			1	$^\circ C/W$

Note 3: See thermal regulation specifications for changes in output voltage due to heating effects. Load and line regulation are measured at a constant junction temperature by low duty cycle pulse testing.

## CHARACTERISTIC CURVES

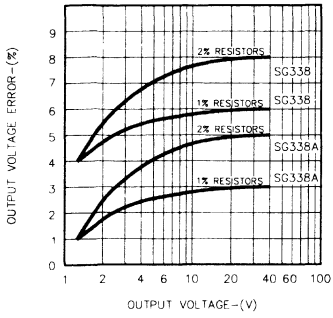


FIGURE 1. OUTPUT VOLTAGE ERROR VS. OUTPUT VOLTAGE

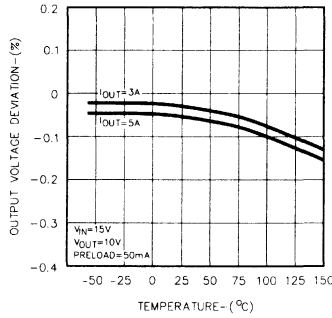


FIGURE 2. LOAD REGULATION VS. TEMPERATURE

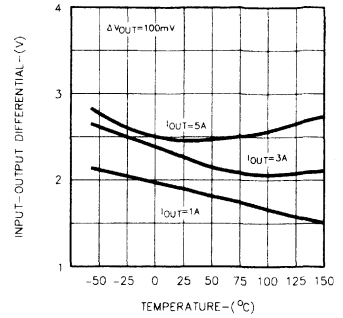


FIGURE 3. DROPOUT VOLTAGE VS. TEMPERATURE

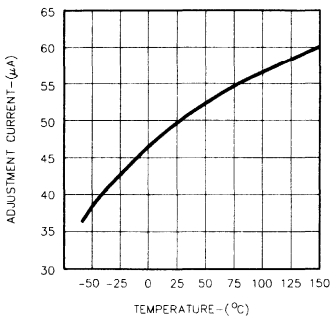


FIGURE 4. ADJUSTMENT CURRENT VS. TEMPERATURE

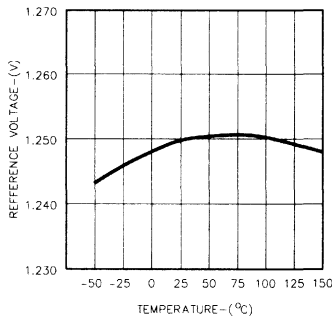


FIGURE 5. TEMPERATURE STABILITY

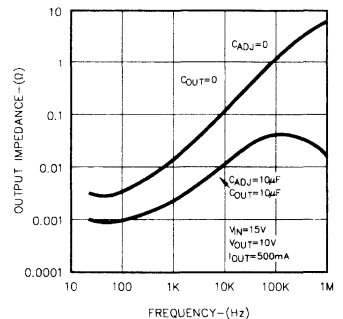


FIGURE 6. OUTPUT IMPEDANCE VS. FREQUENCY

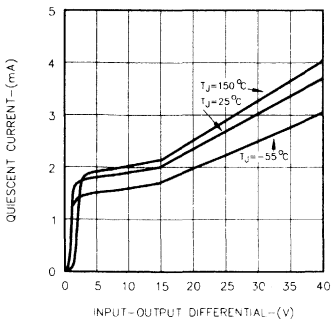


FIGURE 7. MINIMUM OPERATING CURRENT VS. INPUT-OUTPUT DIFFERENTIAL

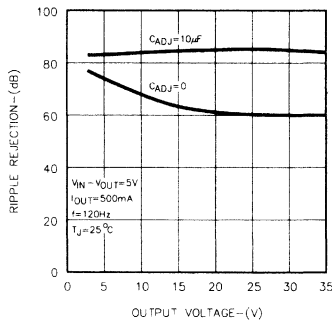


FIGURE 8. RIPPLE REJECTION VS. OUTPUT VOLTAGE

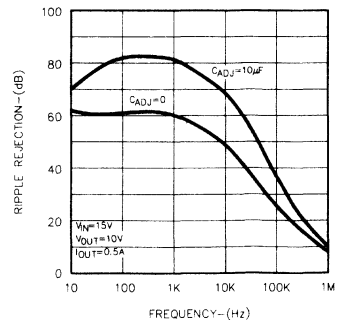


FIGURE 9. RIPPLE REJECTION VS. FREQUENCY

## CHARACTERISTIC CURVES (continued)

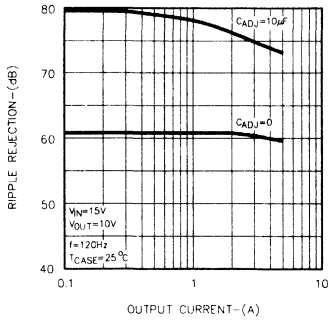


FIGURE 10.  
RIPPLE REJECTION

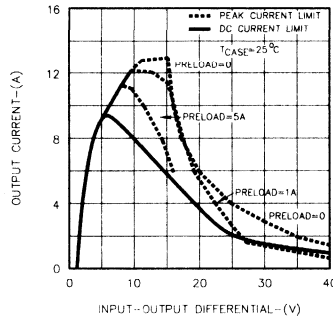


FIGURE 11.  
CURRENT LIMIT VS. INPUT - OUTPUT DIFFERENTIAL

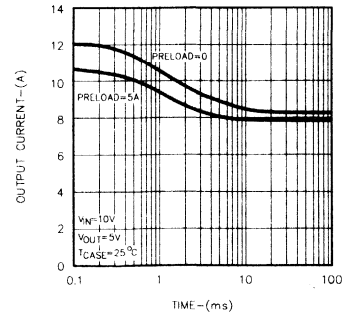


FIGURE 12.  
CURRENT LIMIT VS. PERIOD

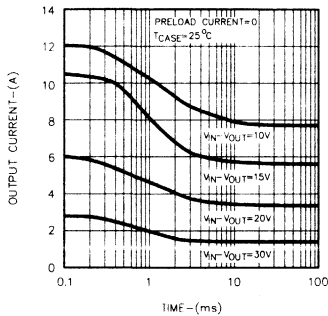


FIGURE 13.  
CURRENT LIMIT VS. PERIOD

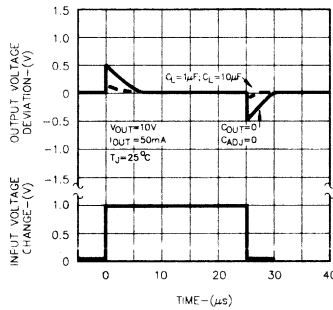


FIGURE 14.  
LINE TRANSIENT RESPONSE VS. PERIOD

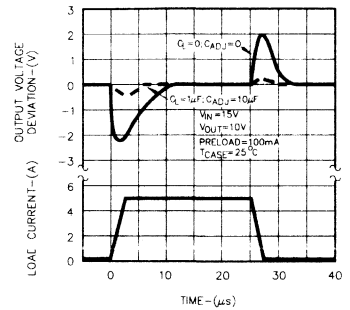
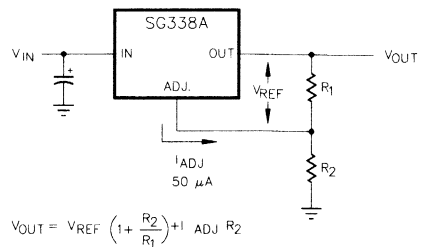


FIGURE 15.  
LOAD TRANSIENT RESPONSE VS. PERIOD

## APPLICATION INFORMATION

### GENERAL

The SG138A develops a 1.25V reference voltage between the output and the adjustable terminal (see Figure 1). By placing a resistor, R1, between these two terminals, a constant current is caused to flow through R1 and down through R2 to set the overall output voltage. Normally this current is the specified minimum load current of 5mA or 10mA. Because  $I_{ADJ}$  is very small and constant when compared with the current through R1, it represents a small error and can usually be ignored. It is easily seen from the output voltage equation, that even if the resistors were of exact value, the accuracy of the output is limited by the accuracy of  $V_{REF}$ . Earlier adjustable regulators had a reference tolerance of  $\pm 4\%$  which is dangerously close to the  $\pm 5\%$  supply tolerance required in many logic and analog systems. Further, even 1% resistors can drift 0.01%/°C, adding additional error to the output voltage tolerance.



$$V_{OUT} = V_{REF} \left( 1 + \frac{R_2}{R_1} \right) + I_{ADJ} R_2$$

FIGURE 16 - BASIC ADJUSTABLE REGULATOR

## APPLICATION INFORMATION (continued)

For example, using 2% resistors and  $\pm 4\%$  tolerance for  $V_{REF}$ , calculations will show that the expected range of a 5V regulator design would be  $4.66V \leq V_{OUT} \leq 5.36V$  or approximately  $\pm 7\%$ . If the same example were used for a 15V regulator, the expected tolerance would be  $\pm 8\%$ . With these results most applications required some method of trimming, usually a trim pot. This solution is both expensive and not conducive to volume production.

One of the enhancements of Silicon General's adjustable regulators over existing devices is the tightened initial tolerance of  $V_{REF}$ . This allows relatively inexpensive 1% or 2% film resistors to be used to R1 and R2 to set the output voltage within an acceptable tolerance.

With a guaranteed 1% reference, a 5V power supply design, using  $\pm 2\%$  resistors, would have a worst case manufacturing tolerance of  $\pm 4\%$ . If 1% resistors are used, the tolerance will drop to  $\pm 2.5\%$ . A plot of the worst case output voltage tolerance as a function of resistor tolerance is shown on the front page.

For convenience, a table of standard 1% resistor values is shown below.

Table of 1/2% and 1% Standard Resistance Values

1.00	1.47	2.15	3.16	4.64	6.81
1.02	1.50	2.21	3.24	4.75	6.98
1.05	1.54	2.26	3.32	4.87	7.15
1.07	1.58	2.32	3.40	4.99	7.32
1.10	1.62	2.37	3.48	5.11	7.50
1.13	1.65	2.43	3.57	5.23	7.68
1.15	1.69	2.49	3.65	5.36	7.87
1.18	1.74	2.55	3.74	5.49	8.06
1.21	1.78	2.61	3.83	5.62	8.25
1.24	1.82	2.67	3.92	5.76	8.45
1.27	1.87	2.74	4.02	5.90	8.66
1.30	1.91	2.80	4.12	6.04	8.87
1.33	1.96	2.87	4.22	6.19	9.09
1.37	2.00	2.94	4.32	6.34	9.31
1.40	2.05	3.01	4.42	6.49	9.53
1.43	2.10	3.09	4.53	6.65	9.76

Standard Resistance Values are obtained from the Decade Table by multiplying by multiples of 10. As an example: 1.21 can represent 1.21 $\Omega$ , 12.1 $\Omega$ , 121 $\Omega$ , 1.21K $\Omega$  etc.

## BYPASS CAPACITORS

Input bypassing using a 1 $\mu$ F tantalum or 25 $\mu$ F electrolytic is recommended when the input filter capacitors are more than 5 inches from the device. Improved ripple rejection (80dB) can be accomplished by adding a 10 $\mu$ F capacitor from the adjust pin to ground. Increasing the size of the capacitor to 20 $\mu$ F will help ripple rejection at low output voltage since the reactance of this capacitor should be small compared to the voltage setting resistor, R2. For improved AC transient response and to prevent the possibility of oscillation due to unknown reactive load, a 1 $\mu$ F capacitor is also recommended at the output. Because of their low impedance at high frequencies, the best type of capacitor to use is solid tantalum.

## PROTECTION DIODES

The SG138A/338A do not require a protection diode from the adjustment terminal to the output (see Figure 17). Improved internal circuitry eliminates the need for this diode when the adjustment pin is bypassed with a capacitor to improve ripple rejection. If a very large output capacitor is used, such as a 100 $\mu$ F shown in Figure 2, the regulator could be damaged or destroyed if the input is accidentally shorted to ground or crowbarred, due to the output capacitor discharging into the output terminal of the regulator. To prevent this, a diode D1 as shown, is recommended to safely discharge the capacitor.

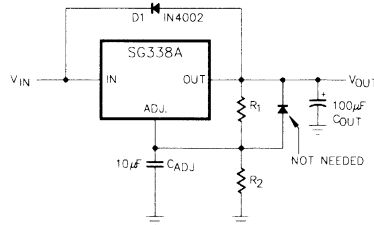


FIGURE 17 - REMOVING PROTECTION DIODE

## LOAD REGULATION

Because the SG138A is a three-terminal device, it is not possible to provide true remote load sensing. Load regulation will be limited by the resistance of the wire connecting the regulator to the load. The data sheet specification for load regulation is measured at the bottom of the package. Negative side sensing is a true Kelvin connection, with the bottom of the output divider returned to the negative side of the load. Although it may not be immediately obvious, best load regulation is obtained when the top of the resistor divider, (R1), is connected directly to the case not to the load. This is illustrated in Figure 18. If R1 were connected to the load, the effective resistance between the regulator and the load would be

$$R_p \times \left( \frac{R_2 + R_1}{R_1} \right), R_p = \text{Parasitic Line Resistance.}$$

Connected as shown,  $R_p$  is not multiplied by the divider ratio.  $R_p$  is about 0.004 $\Omega$  per foot using 16 gauge wire. This translates to 4mV/ft at 1A load current, so it is important to keep the positive lead between regulator and load as short as possible, and use large wire or PC board traces.

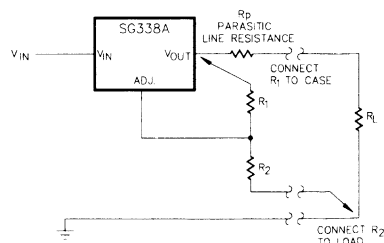


FIGURE 18 - CONNECTIONS FOR BEST LOAD REGULATION

## TYPICAL APPLICATIONS

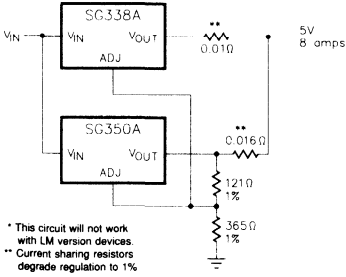


FIGURE 19 - PARALLEL REGULATORS FOR HIGHER CURRENT

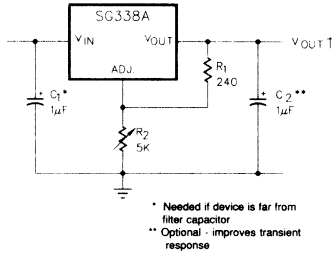


FIGURE 20 - 1.2V - 25V ADJUSTABLE REGULATOR

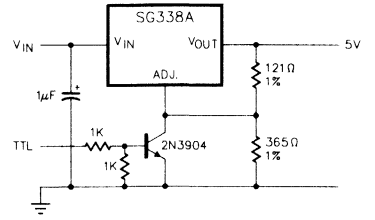


FIGURE 21 - 5V REGULATOR WITH SHUT DOWN

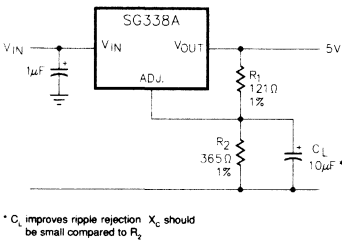


FIGURE 22 - IMPROVING RIPPLE REJECTION

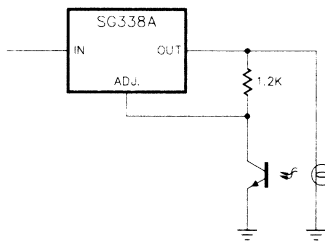


FIGURE 23 - AUTOMATIC LIGHT CONTROL

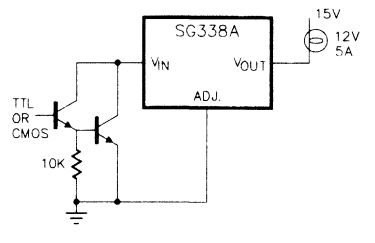


FIGURE 24 - PROTECTED HIGH CURRENT LAMP DRIVER

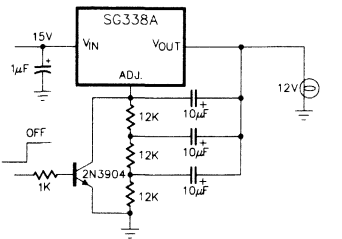


FIGURE 25 - LAMP FLASHER

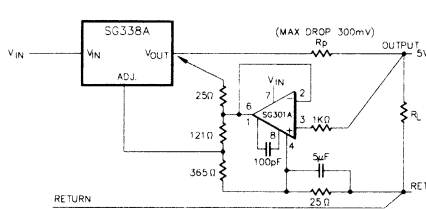


FIGURE 26 - REMOTE SENSING

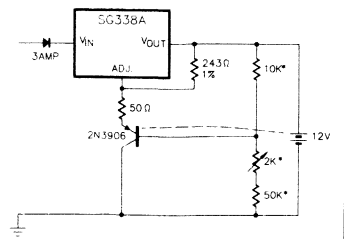
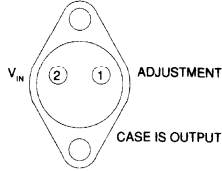




FIGURE 27 - TEMPERATURE COMPENSATED LEAD ACID BATTERY CHARGER

# SG138A/SG138 SERIES

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
3-PIN METAL CAN K-PACKAGE	SG138AK/883B	-55°C to 150°C	
	SG138AK	-55°C to 150°C	
	SG238AK	-25°C to 150°C	
	SG338AK	0°C to 125°C	
	SG138K/883B	-55°C to 150°C	
	SG138K	-55°C to 150°C	
	SG238K	-25°C to 150°C	
SG338K	0°C to 125°C		
3-PIN HERMETIC TO-220 G-PACKAGE (non-Isolated)	SG138AG/883B	-55°C to 150°C	
	SG138AG	-55°C to 150°C	
	SG138G/883B	-55°C to 150°C	
	SG138G	-55°C to 150°C	
3-PIN HERMETIC TO-220 G.I.-PACKAGE (Isolated)	SG138AG.I./883B	-55°C to 150°C	
	SG138AG.I.	-55°C to 150°C	
	SG138G.I./883B	-55°C to 150°C	
	SG138G.I.	-55°C to 150°C	

- Note 1. Contact factory for JAN and DESC product availability.  
 Note 2. All parts are viewed from the top.



**POSITIVE FIXED VOLTAGE REGULATOR**

**DESCRIPTION**

The SG140A/140 series of positive regulators offer self contained, fixed-voltage capability with up to 1.5A of load current and input voltage up to 50V (SG140A series only).

These units feature a unique on-chip trimming system to set the output voltages to within  $\pm 1.5\%$  of nominal on the SG140A series,  $\pm 2.0\%$  on the SG140/240 series, and  $\pm 4.0\%$  on the SG340 series. The SG140A versions also offer much improved line and load regulation characteristics. Utilizing an improved Bandgap reference design, problems have been eliminated that are normally associated with the Zener Diode references, such as drift in output voltage and large changes in the line and load regulation.

All protective features of thermal shutdown, current limiting, and safe-area control have been designed into these units and since these regulators require only a small output capacitor for satisfactory performance, ease of application is assured.

Although designed as fixed-voltage regulators, the output voltage can be increased through the use of a simple voltage divider. The low quiescent drain current of the device insures good regulation when this method is used.

Product is available in hermetically sealed TO-220 (both isolated and non-isolated), TO-3, TO39 and TO-66 power packages as well as the plastic TO-220 package.

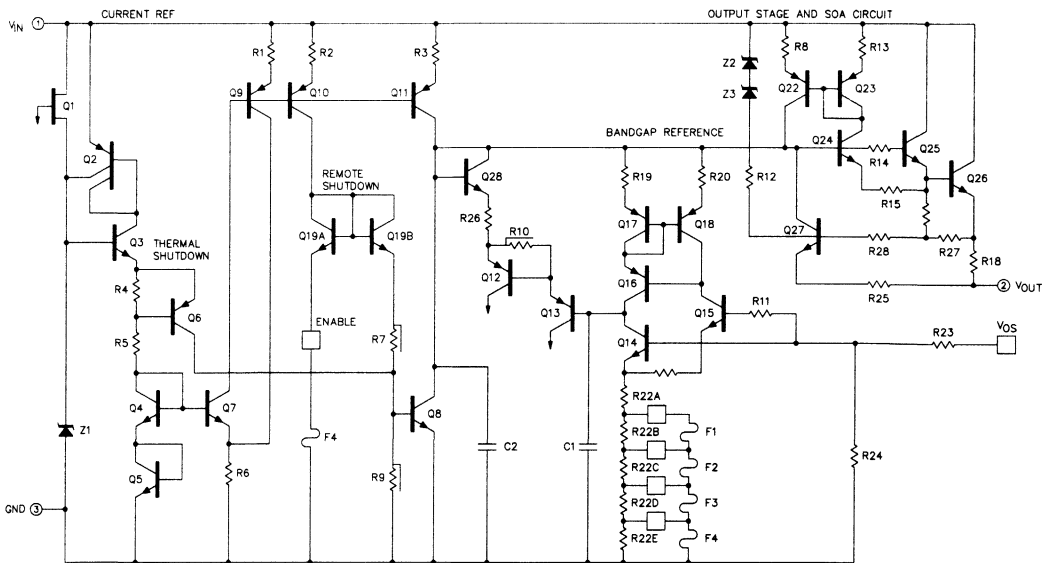
**FEATURES**

- Output voltage set internally to  $\pm 1.5\%$  on SG140A
- Input voltage range to 50V max. on SG140A
- Two volt input-output differential
- Bandgap reference voltage
- Excellent line and load regulation
- Foldback current limiting
- Thermal overload protection
- Voltages available - 5V, 6V, 8V, 12V, 15V, 18V, 24V

**HIGH RELIABILITY FEATURES  
- SG140A/140**

- ◆ Available to MIL-STD - 883
- ◆ Radiation data available
- ◆ SG level "S" processing available

**SCHEMATIC DIAGRAM**



## ABSOLUTE MAXIMUM RATINGS (Note 1)

Device	Input Voltage	Input Voltage (transient) (Note 3)	Input Voltage Differential (Output shorted to ground)
Output Voltage	Input Voltage		
5V	35V	50V	35V
6V	35V	50V	35V
8V	35V	50V	35V
12V	35V	50V	35V
15V	35V	50V	35V
18V	35V	50V	35V
24V	40V	50V	35V

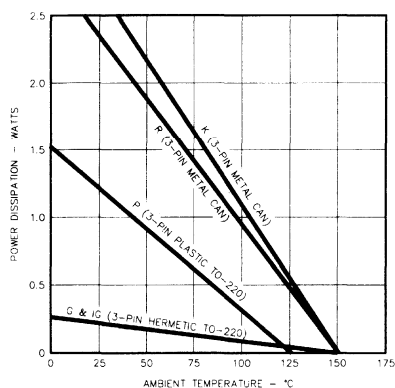
  

Operating Junction Temperature	Storage Temperature Range	-65°C to 150°C
Hermetic (K, R, G, IG - Packages)	Lead Temperature (Soldering, 10 Seconds)	300°C
Plastic (P - Package)		

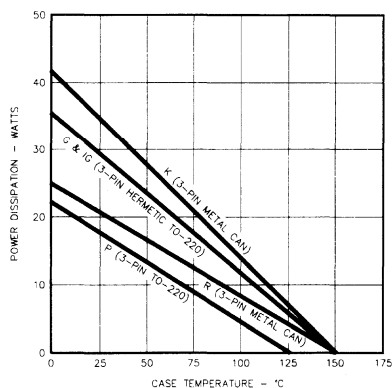
Note 1. Values beyond which damage may occur.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Operating Junction Temperature Range:

SG140A/140	-55°C to 150°C
SG240A/240	0°C to 150°C
SG340A/340	0°C to 125°C

Note 2. Range over which the device is functional.

## CHARACTERISTIC CURVES

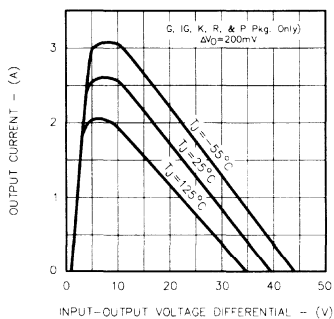
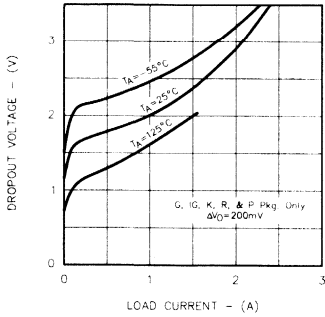


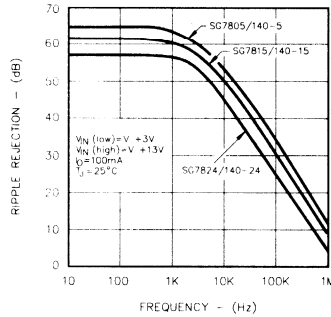
FIGURE 1.  
PEAK OUTPUT CURRENT  
VS. INPUT-OUTPUT DIFFERENTIAL

Note 3. Operation at high input voltages is dependent upon load current. When load current is less than 5mA, output will rise out of regulation as input-output differential increases beyond 30V. Note also from Figure 1, that maximum load current is reduced at high voltages. The 50V input rating of the SG140A series refers to ability to withstand high line or transient conditions without damage. Since the regulator's maximum current capability is reduced, the output may fall out of regulation at high input voltages under nominal loading.

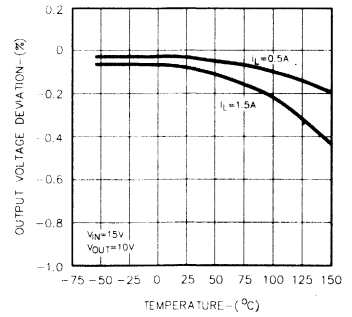
## CHARACTERISTIC CURVES (continued)



**FIGURE 2.**  
MINIMUM INPUT - OUTPUT VOLTAGE  
VS. LOAD CURRENT



**FIGURE 3.**  
RIPPLE REJECTION VS. FREQUENCY



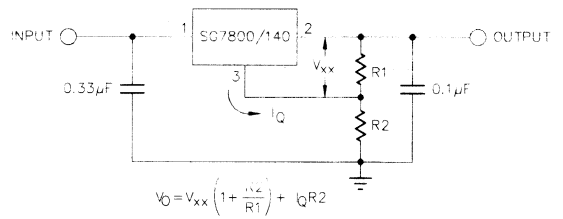
**FIGURE 4.**  
TEMPERATURE COEFFICIENT OF OUTPUT VOLTAGE

## APPLICATIONS

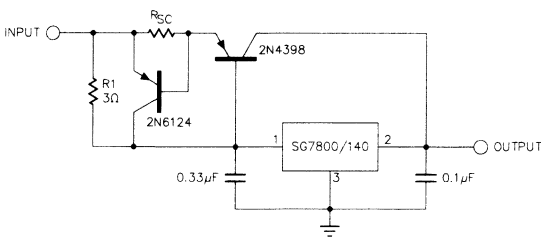


- INCREASING VALUE OF OUTPUT CAPACITOR IMPROVES SYSTEM TRANSIENT RESPONSE
- REQUIRED ONLY IF REGULATOR IS LOCATED AN APPRECIABLE DISTANCE FROM POWER SUPPLY FILTER

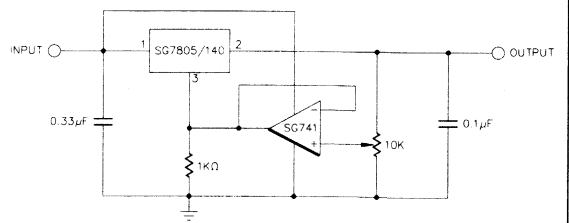
**FIGURE 5 - FIXED OUTPUT REGULATOR**



**FIGURE 6 - CIRCUIT FOR INCREASING OUTPUT VOLTAGE**



**FIGURE 7 - HIGH OUTPUT CURRENT, SHORT CIRCUIT PROTECTED**



**FIGURE 8 - ADJUSTABLE OUTPUT REGULATOR, 7V TO 30V**

**ELECTRICAL SPECIFICATIONS** (Note 1)

**SG140A - 5 / SG340A - 5**

(Unless otherwise specified, these specifications apply for  $V_{IN} = 10V$ ,  $I_O = 1.0A$ ,  $C_{IN} = 0.33\mu F$ ,  $C_{OUT} = 0.1\mu F$ , over the recommended operating temperature, and are applicable for the P, K, R, G and IG -Power Packages- only.)

Parameter	Test Conditions	SG140A-5			SG340A-5			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$I_O = 5mA$ to 1.0A, $T_J = 25^\circ C$	4.9	5.0	5.1	4.9	5.0	5.1	V
Line Regulation (Note 1)	$V_{IN} = 7.5V$ to 20V, $I_O = 500mA$			10			10	mV
	$V_{IN} = 7.5V$ to 20V, $T_J = 25^\circ C$		3	10		3	10	mV
	$V_{IN} = 7.5V$ to 20V			12			12	mV
Load Regulation (Note 1)	$V_{IN} = 8V$ to 12V, $T_J = 25^\circ C$			4			4	mV
	$I_O = 5mA$ to 1.0A			25			25	mV
	$I_O = 5mA$ to 1.5A, $T_J = 25^\circ C$		10	25		10	25	mV
	$I_O = 250mA$ to 750mA, $T_J = 25^\circ C$			15			15	mV
Total Output Voltage Tolerance	$V_{IN} = 7.5V$ to 20V, $I_O = 5mA$ to 1.0A, $P \leq 15W$	4.8	5.0	5.2	4.8	5.0	5.2	V
Quiescent Current	Over Temperature Range			6.5			6.5	mA
	$T_J = 25^\circ C$			6			6	mA
Quiescent Current Change	With Line: $V_{IN} = 7.5V$ to 25V, $I_O = 500mA$			0.8			0.8	mA
	$V_{IN} = 7.5V$ to 20V, $I_O = 1A$ , $T_J = 25^\circ C$			0.8			0.8	mA
	With Load: $I_O = 5mA$ to 1.0A			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $I_O = 1A$ , $T_J = 25^\circ C$		2	2.5		2	2.5	V
Peak Output Current	$T_J = 25^\circ C$		2.4			2.4		A
Short Circuit Current	$T_J = 25^\circ C$		2.1			2.1		A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	68			68			dB
Output Noise Voltage (rms)	$f = 10Hz$ to 100KHz (Note 2)			40			40	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		20			20		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

**SG140 - 5 / SG340 - 5**

(Unless otherwise specified, these specifications apply for  $V_{IN} = 10V$ ,  $I_O = 500mA$ ,  $C_{IN} = 0.33\mu F$ ,  $C_{OUT} = 0.1\mu F$ , over the recommended operating temperature, and are applicable for the P, K, R, G and IG -Power Packages- only.)

Parameter	Test Conditions	SG140-5			SG340-5			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$I_O = 5mA$ to 1.0A, $T_J = 25^\circ C$	4.8	5.0	5.2	4.8	5.0	5.2	V
Line Regulation (Note 1)	$V_{IN} = 8V$ to 20V			50			50	mV
	$V_{IN} = 7V$ to 25V, $T_J = 25^\circ C$			50			50	mV
	$V_{IN} = 8V$ to 12V, $I_O = 1.0A$			25			25	mV
Load Regulation (Note 1)	$V_{IN} = 7.3V$ to 20V, $I_O = 1.0A$ , $T_J = 25^\circ C$			50			50	mV
	$I_O = 5mA$ to 1.0A			50			50	mV
	$I_O = 5mA$ to 1.5A, $T_J = 25^\circ C$			50			50	mV
	$I_O = 250mA$ to 750mA, $T_J = 25^\circ C$			25			25	mV
Total Output Voltage Tolerance	$V_{IN} = 8V$ to 20V, $I_O = 5mA$ to 1.0A, $P \leq 15W$	4.75	5.00	5.25	4.75	5.00	5.25	V
Quiescent Current	$I_O = 1.0A$			7			8.5	mA
	$T_J = 25^\circ C$			6			8	mA
Quiescent Current Change	With Line: $V_{IN} = 8V$ to 25V			0.8			1.0	mA
	$V_{IN} = 8V$ to 20V, $I_O = 1A$ , $T_J = 25^\circ C$			0.8			1.0	mA
	With Load: $I_O = 5mA$ to 1.0A			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $I_O = 1A$ , $T_J = 25^\circ C$		2	2.5		2	2.5	V
Peak Output Current	$T_J = 25^\circ C$		2.4			2.4		A
Short Circuit Current	$T_J = 25^\circ C$		2.1			2.1		A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	68			62			dB
Output Noise Voltage (rms)	$f = 10Hz$ to 100KHz (Note 2)			40			40	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		20			20		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

Note 1. All regulation tests are made at constant junction temperature with low duty cycle testing.  
 2. This test is guaranteed but is not tested in production.

# SG140A/SG140 SERIES

# 6.0V & 8.0V POSITIVE REGULATOR

## ELECTRICAL SPECIFICATIONS (Note 1)

### SG140 - 6 / SG340 - 6

(Unless otherwise specified, these specifications apply for  $V_{IN} = 11V$ ,  $I_O = 500mA$ ,  $C_{IN} = 0.33\mu F$ ,  $C_{OUT} = 0.1\mu F$ , over the recommended operating temperature, and are applicable for the P, K, R, G and IG -Power Packages- only.)

Parameter	Test Conditions	SG140 - 6			SG340 - 6			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$I_O = 5mA$ to 1.0A, $T_J = 25^\circ C$	5.75	6.00	6.25	5.75	6.00	6.25	V
Line Regulation (Note 1)	$V_{IN} = 9V$ to 21V			60			60	mV
	$V_{IN} = 8V$ to 25V, $T_J = 25^\circ C$			60			60	mV
	$V_{IN} = 9V$ to 13V, $I_O = 1.0 A$			30			30	mV
Load Regulation (Note 1)	$V_{IN} = 8.3V$ to 21V, $I_O = 1.0 A$ , $T_J = 25^\circ C$			60			60	mV
	$I_O = 5mA$ to 1.0A			60			60	mV
	$I_O = 5mA$ to 1.5A, $T_J = 25^\circ C$			60			60	mV
Total Output Voltage Tolerance	$I_O = 250mA$ to 750mA, $T_J = 25^\circ C$			30			30	mV
	$V_{IN} = 9V$ to 21V, $I_O = 5mA$ to 1.0A, $P \leq 15W$	5.7	6.0	6.3	5.7	6.0	6.3	V
Quiescent Current	$I_O = 1.0 A$			7			8.5	mA
	$T_J = 25^\circ C$			6			8	mA
Quiescent Current Change	With Line: $V_{IN} = 9V$ to 25V			0.8			1.0	mA
	$V_{IN} = 9V$ to 21V, $I_O = 1A$ , $T_J = 25^\circ C$			0.8			1.0	mA
	With Load: $I_O = 5mA$ to 1.0A			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $I_O = 1A$ , $T_J = 25^\circ C$		2	2.5		2	2.5	V
Peak Output Current	$T_J = 25^\circ C$		2.4			2.4		A
Short Circuit Current	$T_J = 25^\circ C$		2.1			2.1		A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	65			59			dB
Output Noise Voltage (rms)	$f = 10Hz$ to 100KHz (Note 2)			40			40	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		24			24		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

### SG140 - 8 / SG340 - 8

(Unless otherwise specified, these specifications apply for  $V_{IN} = 14V$ ,  $I_O = 500mA$ ,  $C_{IN} = 0.33\mu F$ ,  $C_{OUT} = 0.1\mu F$ , over the recommended operating temperature, and are applicable for the P, K, R, G and IG -Power Packages- only.)

Parameter	Test Conditions	SG140 - 8			SG340 - 8			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$I_O = 5mA$ to 1.0A, $T_J = 25^\circ C$	7.7	8.0	8.3	7.7	8.0	8.3	V
Line Regulation (Note 1)	$V_{IN} = 11V$ to 23V			80			80	mV
	$V_{IN} = 10.5V$ to 25V, $T_J = 25^\circ C$			80			80	mV
	$V_{IN} = 11V$ to 17V, $I_O = 1.0A$			40			40	mV
Load Regulation (Note 1)	$V_{IN} = 10.5V$ to 23V, $I_O = 1.0A$ , $T_J = 25^\circ C$			80			80	mV
	$I_O = 5mA$ to 1.0A			80			80	mV
	$I_O = 5mA$ to 1.5A, $T_J = 25^\circ C$			80			80	mV
Total Output Voltage Tolerance	$I_O = 250mA$ to 750mA, $T_J = 25^\circ C$			40			40	mV
	$V_{IN} = 11.5V$ to 23V, $I_O = 5mA$ to 1.0A, $P \leq 15W$	7.6	8.0	8.4	7.6	8.0	8.4	V
Quiescent Current	$I_O = 1.0A$			7			8.5	mA
	$T_J = 25^\circ C$			6			8	mA
Quiescent Current Change	With Line: $V_{IN} = 11.5V$ to 25V			0.8			1.0	mA
	$V_{IN} = 11.5V$ to 23V, $I_O = 1A$ , $T_J = 25^\circ C$			0.8			1.0	mA
	With Load: $I_O = 5mA$ to 1.0A			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $I_O = 1A$ , $T_J = 25^\circ C$		2	2.5		2	2.5	V
Peak Output Current	$T_J = 25^\circ C$		2.4			2.4		A
Short Circuit Current	$T_J = 25^\circ C$		2.1			2.1		A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	62			56			dB
Output Noise Voltage (rms)	$f = 10Hz$ to 100KHz (Note 2)			40			40	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		32			32		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

Note 1. All regulation tests are made at constant junction temperature with low duty cycle testing.  
 2. This test is guaranteed but is not tested in production.

**ELECTRICAL SPECIFICATIONS** (Note 1)

**SG140A - 12 / SG340A - 12**

(Unless otherwise specified, these specifications apply for  $V_{IN} = 19V$ ,  $I_O = 1.0A$ ,  $C_{IN} = 0.33\mu F$ ,  $C_{OUT} = 0.1\mu F$ , over the recommended operating temperature, and are applicable for the P, K, R, G and IG -Power Packages- only.)

Parameter	Test Conditions	SG140A - 12			SG340A - 12			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$I_O = 5mA$ to $1.0A$ , $T_J = 25^\circ C$	11.75	12.00	12.25	11.75	12.00	12.25	V
Line Regulation (Note 1)	$V_{IN} = 14.8V$ to $27V$ , $I_O = 500mA$			18			18	mV
	$V_{IN} = 14.5V$ to $27V$ , $T_J = 25^\circ C$		4	18		4	18	mV
	$V_{IN} = 16V$ to $22V$			30			30	mV
	$V_{IN} = 16V$ to $22V$ , $T_J = 25^\circ C$			9			9	mV
Load Regulation (Note 1)	$I_O = 5mA$ to $1.0A$			60			60	mV
	$I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$			32			32	mV
	$I_O = 250mA$ to $750mA$ , $T_J = 25^\circ C$			19			19	mV
Total Output Voltage Tolerance	$V_{IN} = 14.8V$ to $27V$ , $I_O = 5mA$ to $1.0A$ , $P \leq 15W$	11.5	12.0	12.5	11.5	12.0	12.5	V
Quiescent Current	Over Temperature Range			6.5			6.5	mA
	$T_J = 25^\circ C$			6			6	mA
Quiescent Current Change	With Line: $V_{IN} = 15V$ to $30V$ , $I_O = 500mA$			0.8			0.8	mA
	$V_{IN} = 14.8V$ to $27V$ , $I_O = 1A$ , $T_J = 25^\circ C$			0.8			0.8	mA
	With Load: $I_O = 5mA$ to $1.0A$			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $I_O = 1A$ , $T_J = 25^\circ C$		2	2.5		2	2.5	V
Peak Output Current	$T_J = 25^\circ C$		2.4			2.4	A	
Short Circuit Current	$T_J = 25^\circ C$		2.1			2.1	A	
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	61			61			dB
Output Noise Voltage (rms)	$f = 10Hz$ to $100KHz$ (Note 2)			40			40	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		48			48		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

**SG140 - 12 / SG340 - 12**

(Unless otherwise specified, these specifications apply for  $V_{IN} = 19V$ ,  $I_O = 500mA$ ,  $C_{IN} = 0.33\mu F$ ,  $C_{OUT} = 0.1\mu F$ , over the recommended operating temperature, and are applicable for the P, K, R, G and IG -Power Packages- only.)

Parameter	Test Conditions	SG140 - 12			SG340 - 12			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$I_O = 5mA$ to $1.0A$ , $T_J = 25^\circ C$	11.5	12.0	12.5	11.5	12.0	12.5	V
Line Regulation (Note 1)	$V_{IN} = 15V$ to $27V$			120			120	mV
	$V_{IN} = 14.5V$ to $30V$ , $T_J = 25^\circ C$			120			120	mV
	$V_{IN} = 16V$ to $22V$ , $I_O = 1.0A$			60			60	mV
	$V_{IN} = 14.6V$ to $27V$ , $I_O = 1.0A$ , $T_J = 25^\circ C$			120			120	mV
Load Regulation (Note 1)	$I_O = 5mA$ to $1.0A$			120			120	mV
	$I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$			120			120	mV
	$I_O = 250mA$ to $750mA$ , $T_J = 25^\circ C$			60			60	mV
Total Output Voltage Tolerance	$V_{IN} = 14.5V$ to $27V$ , $I_O = 5mA$ to $1.0A$ , $P \leq 15W$	11.4	12.0	12.6	11.4	12.0	12.6	V
Quiescent Current	$I_O = 1.0A$			7			8.5	mA
	$T_J = 25^\circ C$			6			8	mA
Quiescent Current Change	With Line: $V_{IN} = 15V$ to $30V$			0.8			1.0	mA
	$V_{IN} = 14.5V$ to $27V$ , $I_O = 1A$ , $T_J = 25^\circ C$			0.8			1.0	mA
	With Load: $I_O = 5mA$ to $1.0A$			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $I_O = 1A$ , $T_J = 25^\circ C$		2	2.5		2	2.5	V
Peak Output Current	$T_J = 25^\circ C$		2.4			2.4	A	
Short Circuit Current	$T_J = 25^\circ C$		2.1			2.1	A	
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	61			55			dB
Output Noise Voltage (rms)	$f = 10Hz$ to $100KHz$ (Note 2)			40			40	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		48			48		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

Note 1. All regulation tests are made at constant junction temperature with low duty cycle testing.  
 2. This test is guaranteed but is not tested in production.

# SG140A/SG140 SERIES

# 15V POSITIVE REGULATOR

## ELECTRICAL SPECIFICATIONS (Note 1)

### SG140A - 15 / SG340A - 15

(Unless otherwise specified, these specifications apply for  $V_{IN} = 23V$ ,  $I_O = 1.0A$ ,  $C_{IN} = 0.33\mu F$ ,  $C_{OUT} = 0.1\mu F$ , over the recommended operating temperature, and are applicable for the P, K, R, G and IG -Power Packages- only.)

Parameter	Test Conditions	SG140A - 15			SG340A - 15			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$I_O = 5mA$ to 1.0A, $T_J = 25^\circ C$	14.7	15.0	15.3	14.7	15.0	15.3	V
Line Regulation (Note 1)	$V_{IN} = 17.9V$ to 30V, $I_O = 500mA$			22			22	mV
	$V_{IN} = 17.5V$ to 30V, $T_J = 25^\circ C$			22			22	mV
	$V_{IN} = 20V$ to 26V			30			30	mV
Load Regulation (Note 1)	$V_{IN} = 20V$ to 26V, $T_J = 25^\circ C$			10			10	mV
	$I_O = 5mA$ to 1.0A			75			75	mV
	$I_O = 5mA$ to 1.5A, $T_J = 25^\circ C$			35			35	mV
Total Output Voltage Tolerance	$I_O = 250mA$ to 750mA, $T_J = 25^\circ C$			21			21	mV
	$V_{IN} = 17.9V$ to 30V, $I_O = 5mA$ to 1.0A, $P \leq 15W$	14.4	15.0	15.6	14.4	15.0	15.6	V
Quiescent Current	Over Temperature Range			6.5			6.5	mA
	$T_J = 25^\circ C$			6			6	mA
Quiescent Current Change	With Line: $V_{IN} = 17.9V$ to 30V, $I_O = 500mA$			0.8			0.8	mA
	$V_{IN} = 17.9V$ to 30V, $I_O = 1A$ , $T_J = 25^\circ C$			0.8			0.8	mA
	With Load: $I_O = 5mA$ to 1.0A			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $I_O = 1A$ , $T_J = 25^\circ C$		2	2.5		2	2.5	V
Peak Output Current	$T_J = 25^\circ C$		2.4			2.4	A	
Short Circuit Current	$T_J = 25^\circ C$		2.1			2.1	A	
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	60			60			dB
Output Noise Voltage (rms)	$f = 10Hz$ to 100KHz (Note 2)			40			40	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		60			60		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

### SG140 - 15 / SG340 - 15

(Unless otherwise specified, these specifications apply for  $V_{IN} = 23V$ ,  $I_O = 500mA$ ,  $C_{IN} = 0.33\mu F$ ,  $C_{OUT} = 0.1\mu F$ , over the recommended operating temperature, and are applicable for the P, K, R, G and IG -Power Packages- only.)

Parameter	Test Conditions	SG140 - 15			SG340 - 15			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$I_O = 5mA$ to 1.0A, $T_J = 25^\circ C$	14.4	15.0	15.6	14.4	15.0	15.6	V
Line Regulation (Note 1)	$V_{IN} = 18.5V$ to 30V			150			150	mV
	$V_{IN} = 17.5V$ to 30V, $T_J = 25^\circ C$			150			150	mV
	$V_{IN} = 20V$ to 26V, $I_O = 1.0A$			75			75	mV
Load Regulation (Note 1)	$V_{IN} = 17.7V$ to 30V, $I_O = 1.0A$ , $T_J = 25^\circ C$			150			150	mV
	$I_O = 5mA$ to 1.0A			150			150	mV
	$I_O = 5mA$ to 1.5A, $T_J = 25^\circ C$			150			150	mV
Total Output Voltage Tolerance	$I_O = 250mA$ to 750mA, $T_J = 25^\circ C$			75			75	mV
	$V_{IN} = 17.5V$ to 30V, $I_O = 5mA$ to 1.0A, $P \leq 15W$	14.25	15.00	15.75	14.25	15.00	15.75	V
Quiescent Current	$I_O = 1.0A$			7			8.5	mA
	$T_J = 25^\circ C$			6			8	mA
Quiescent Current Change	With Line: $V_{IN} = 18.5V$ to 30V			0.8			1.0	mA
	$V_{IN} = 18.5V$ to 30V, $I_O = 1A$ , $T_J = 25^\circ C$			0.8			1.0	mA
	With Load: $I_O = 5mA$ to 1.0A			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $I_O = 1A$ , $T_J = 25^\circ C$		2	2.5		2	2.5	V
Peak Output Current	$T_J = 25^\circ C$		2.4			2.4	A	
Short Circuit Current	$T_J = 25^\circ C$		2.1			2.1	A	
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	60			54			dB
Output Noise Voltage (rms)	$f = 10Hz$ to 100KHz (Note 2)			40			40	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		60			60		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

Note 1. All regulation tests are made at constant junction temperature with low duty cycle testing.  
 2. This test is guaranteed but is not tested in production.

**ELECTRICAL SPECIFICATIONS (Note 1)**

**SG140 - 18 / SG340 - 18**

(Unless otherwise specified, these specifications apply for  $V_{IN} = 27V$ ,  $I_O = 500mA$ ,  $C_{IN} = 0.33\mu F$ ,  $C_{OUT} = 0.1\mu F$ , over the recommended operating temperature, and are applicable for the P, K, R, G and IG -Power Packages- only.)

Parameter	Test Conditions	SG140 - 18			SG340 - 18			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$I_O = 5mA$ to 1.0A, $T_J = 25^\circ C$	17.3	18.0	18.7	17.3	18.0	18.7	V
Line Regulation (Note 1)	$V_{IN} = 21.5V$ to 33V			180			180	mV
	$V_{IN} = 21V$ to 33V, $T_J = 25^\circ C$			180			180	mV
	$V_{IN} = 24V$ to 30V, $I_O = 1.0A$			90			90	mV
	$V_{IN} = 21V$ to 30V, $I_O = 1.0A$ , $T_J = 25^\circ C$			180			180	mV
Load Regulation (Note 1)	$I_O = 5mA$ to 1.0A			180			180	mV
	$I_O = 5mA$ to 1.5A, $T_J = 25^\circ C$			180			180	mV
	$I_O = 250mA$ to 750mA, $T_J = 25^\circ C$			90			90	mV
Total Output Voltage Tolerance	$V_{IN} = 21V$ to 33V, $I_O = 5mA$ to 1.0A, $P \leq 15W$	17.1	18.0	18.9	17.1	18.0	18.9	V
Quiescent Current	$I_O = 1A$			7			8.5	mA
	$T_J = 25^\circ C$			6			8	mA
Quiescent Current Change	With Line: $V_{IN} = 21V$ to 33V			0.8			1.0	mA
	$V_{IN} = 21V$ to 33V, $I_O = 1A$ , $T_J = 25^\circ C$			0.8			1.0	mA
	With Load: $I_O = 5mA$ to 1.0A			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $I_O = 1A$ , $T_J = 25^\circ C$		2	2.5		2	2.5	V
Peak Output Current	$T_J = 25^\circ C$		2.4			2.4		A
Short Circuit Current	$T_J = 25^\circ C$		2.1			2.1		A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	59			53			dB
Output Noise Voltage (rms)	$f = 10Hz$ to 100KHz (Note 2)			40			40	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		72			72		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

**SG140 - 24 / SG340 - 24**

(Unless otherwise specified, these specifications apply for  $V_{IN} = 33V$ ,  $I_O = 500mA$ ,  $C_{IN} = 0.33\mu F$ ,  $C_{OUT} = 0.1\mu F$ , over the recommended operating temperature, and are applicable for the P, K, R, G and IG -Power Packages- only.)

Parameter	Test Conditions	SG140 - 24			SG340 - 24			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$I_O = 5mA$ to 1.0A, $T_J = 25^\circ C$	23	24	25	23	24	25	V
Line Regulation (Note 1)	$V_{IN} = 28V$ to 38V			240			240	mV
	$V_{IN} = 27V$ to 38V, $T_J = 25^\circ C$			240			240	mV
	$V_{IN} = 30V$ to 36V, $I_O = 1.0A$			120			120	mV
	$V_{IN} = 27.1V$ to 35V, $I_O = 1.0A$ , $T_J = 25^\circ C$			240			240	mV
Load Regulation (Note 1)	$I_O = 5mA$ to 1.0A			240			240	mV
	$I_O = 5mA$ to 1.5A, $T_J = 25^\circ C$			240			240	mV
	$I_O = 250mA$ to 750mA, $T_J = 25^\circ C$			120			120	mV
Total Output Voltage Tolerance	$V_{IN} = 27V$ to 38V, $I_O = 5mA$ to 1.0A, $P \leq 15W$	22.8	24.0	25.2	22.8	24.0	25.2	V
Quiescent Current	$I_O = 1.0A$			7			8.5	mA
	$T_J = 25^\circ C$			6			8	mA
Quiescent Current Change	With Line: $V_{IN} = 27V$ to 38V			0.8			1.0	mA
	$V_{IN} = 28V$ to 38V, $I_O = 1A$ , $T_J = 25^\circ C$			0.8			1.0	mA
	With Load: $I_O = 5mA$ to 1.0A			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $I_O = 1A$ , $T_J = 25^\circ C$		2	2.5		2	2.5	V
Peak Output Current	$T_J = 25^\circ C$		2.4			2.4		A
Short Circuit Current	$T_J = 25^\circ C$		2.1			2.1		A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	56			50			dB
Output Noise Voltage (rms)	$f = 10Hz$ to 100KHz (Note 2)			40			40	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		96			96		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

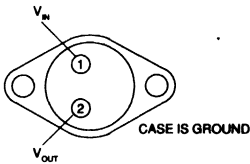
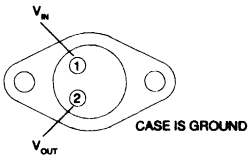
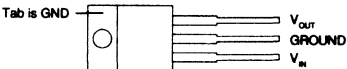
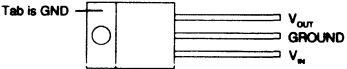
Note 1. All regulation tests are made at constant junction temperature with low duty cycle testing.  
 2. This test is guaranteed but is not tested in production.



# SG140A/SG140 SERIES

# POSITIVE REGULATOR

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
3-TERMINAL TO-3 METAL CAN K-PACKAGE	SG140A-XXK/883B SG140A-XXK SG240A-XXK SG340A-XXK SG140-XXK/883B SG140-XXK SG240-XXK SG340-XXK	-55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C -55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C	
3-TERMINAL TO-66 METAL CAN R-PACKAGE	SG140A-XXR/883B SG140A-XXR SG240A-XXR SG340A-XXR SG140-XXR/883B SG140-XXR SG240-XXR SG340-XXR	-55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C -55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C	
3-PIN PLASTIC TO-220 P-PACKAGE	SG340A-XXP SG340-XXP	0°C to 70°C 0°C to 70°C	
3-PIN HERMETIC TO-220 G-PACKAGE (Non-Isolated)	SG140A-XXG/883B SG140A-XXG SG140-XXG/883B SG140-XXG	-55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C	
3-PIN HERMETIC TO-220 IG-PACKAGE (Isolated)	SG140A-XXIG/883B SG140A-XXIG SG140-XXIG/883B SG140-XXIG	-55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C	

- Note 1. Contact factory for JAN and DESC product availability.  
 2. All parts are viewed from the top.  
 3. "XX" to be replaced by output voltage of specific fixed regulator.  
 4. Some products will be available in leadless chip carrier (LCC) and hermetic flat pack (F). Consult factory for price and availability



**3 AMP POSITIVE ADJUSTABLE REGULATOR**

**DESCRIPTION**

The SG150/150A series are adjustable 3-terminal positive voltage regulators capable of supplying in excess of 3A over a 1.2V to 33V output range. They are exceptionally easy to use and require only 2 external resistors to set the output voltage. The SG150/150A series offers full overload protection available only in IC's. Included on the chip are current limit, thermal overload protection and safe operating area protection.

Since the regulator is "floating" and sees only the input-to-output differential voltage, supplies of several hundred volts can be regulated as long as the maximum input to output differential is not exceeded.

Supplies needing electronic shutdown can be achieved by clamping the adjustment terminal to ground, which programs the output to 1.2V where most loads draw little current. Reference voltage, which is trimmed to be within  $\pm 1\%$  at room temperature, is guaranteed to be within  $\pm 2\%$  over all operating conditions for the "A" version and  $\pm 4\%$  for the standard version. They are packaged in the hermetic TO-3 and TO-220 (Isolated and Non-Isolated) as well as the plastic TO-220.

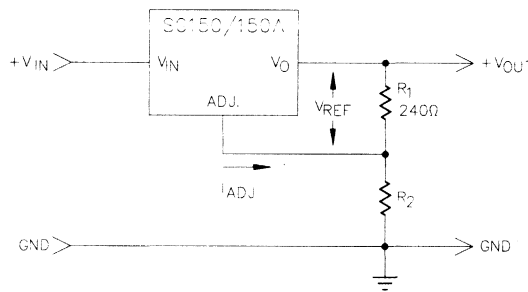
**FEATURES**

- Trimmed  $\pm 1\%$  reference voltage
- Adjustable output down to 1.2V
- Guaranteed 3A output current
- Line Regulation typically 0.1%
- Guaranteed thermal regulation
- Current limit constant with temperature
- 86 dB ripple rejection
- Standard 3-lead transistor package

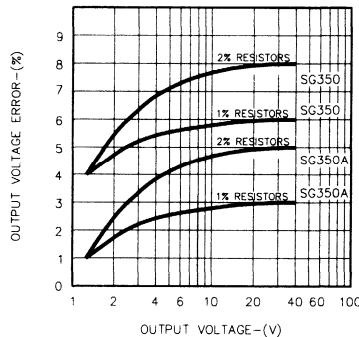
**HIGH RELIABILITY FEATURES**

- SG150A / SG150
- Available to MIL-STD-883 AND DESC SMD
- SG level "S" processing available

**PRECISION REGULATOR**



**OUTPUT VOLTAGE ERROR**



# SG150A/SG150 SERIES

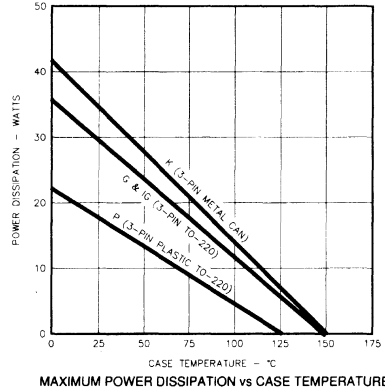
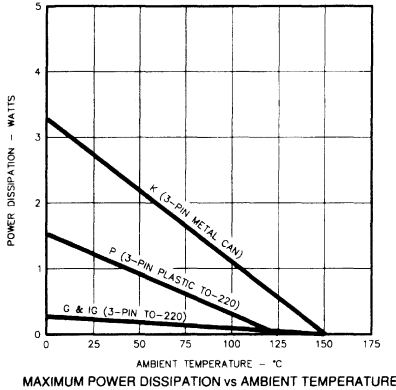
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Power Dissipation ..... Internally Limited  
 Input-Output Voltage Differential ..... 35V  
 Storage Temperature Range ..... -65°C to 150°C  
 Note 1. Exceeding these ratings could cause damage to the device.

Operating Junction Temperature  
 Hermetic (K, G, IG-Packages) ..... 175°C  
 Plastic (P - Package) ..... 150°C  
 Lead Temperature (Soldering, 10 Seconds) ..... 300°C

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



### ELECTRICAL

Input Voltage Range ..... 3.0V to 30V

Operation Junction Temperature Range

SG150A/150 ..... -55°C to 150°C  
 SG250A/250 ..... -25°C to 150°C  
 SG350A/350 ..... 0°C to 125°C

Note 2. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise specified, these specifications apply over the full operating temperature range,  $V_{IN} - V_{OUT} = 5V$  and  $I_{OUT} = 1.5A$ . These specifications are applicable for power dissipations up to 30W for the K package and up to 25W for the P-package. Power dissipation is guaranteed at these values up to 15V input-output differential. Above 15V input-output differential power dissipation is limited by device internal protections circuitry.)

Parameter	Test Conditions	SG150A/SG250A			SG150			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Reference Voltage	$I_{OUT} = 10mA$ , $T_J = 25^\circ C$ $3V \leq (V_{IN} - V_{OUT}) \leq 35V$ , $P \leq 30W$ , $10mA \leq I_{OUT} \leq 3A$	1.238	1.250	1.262				V
Line Regulation	$3V \leq (V_{IN} - V_{OUT}) \leq 35V$ , $I_L = 10mA$ , $T_A = 25^\circ C$	1.225	1.250	1.270	1.20	1.25	1.30	V
Load Regulation (Note 3)	$10mA \leq I_{OUT} \leq 3A$ $V_{OUT} \leq 5V$ , $T_A = 25^\circ C$ $V_{OUT} \geq 5V$ , $T_A = 25^\circ C$ $V_{OUT} \leq 5V$ $V_{OUT} \geq 5V$		0.02 0.005	0.05 0.01		0.02 0.005	0.05 0.01	%/V %/V
Thermal Regulation	$T_A = 25^\circ C$ , 20ms pulse		5	15		5	15	mV
Ripple Rejection	$V_{OUT} = 10V$ , $f = 120Hz$ $C_{ADJ} = 0$ $C_{ADJ} = 10\mu F$		0.1 0.3	0.3 1		0.1 0.3	0.3 1	% %
Adjust Pin Current		66	86		66	86		dB
Adjust Pin Current Change	$10mA \leq I_L \leq 3A$ , $3V \leq (V_{IN} - V_{OUT}) \leq 35V$		50	100		50	100	$\mu A$
Minimum Load Current	$(V_{IN} - V_{OUT}) = 35V$		0.2	5		0.2	5	$\mu A$
Current Limit	$(V_{IN} - V_{OUT}) = 10V$ $(V_{IN} - V_{OUT}) = 30V$	3	3.5	5	3	3.5	5	mA
		0.3	4.5		0.3	4.5		A
			1			1		A

# SG150A/SG150 SERIES

## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG150A/SG250A			SG150			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Temperature Stability (Note 4)			1	2		1		%
Long Term Stability (Note 4)	$T_A = 125^\circ\text{C}$		0.3	1		0.3	1	%
RMS Output Noise (% of $V_{OUT}$ )	$T_A = 25^\circ\text{C}, 10\text{Hz} \leq f \leq 10\text{KHz}$		0.001			0.001		%

Parameter	Test Conditions	SG350A			SG350			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Reference Voltage	$I_{OUT} = 10\text{mA}, T_J = 25^\circ\text{C}$ $3\text{V} \leq (V_{IN} - V_{OUT}) \leq 35\text{V}, P \leq 30\text{W}$ $10\text{mA} \leq I_{OUT} \leq 3\text{A}$	1.238	1.250	1.262				V
Line Regulation	$3\text{V} \leq (V_{IN} - V_{OUT}) \leq 35\text{V}, I_L = 10\text{mA}$ $T_A = 25^\circ\text{C}$	1.225	1.250	1.270	1.20	1.25	1.30	V
Load Regulation (Note 3)	$10\text{mA} \leq I_{OUT} \leq 3\text{A}$ $V_{OUT} \leq 5\text{V}, T_A = 25^\circ\text{C}$ $V_{OUT} \geq 5\text{V}, T_A = 25^\circ\text{C}$ $V_{OUT} \leq 5\text{V}$ $V_{OUT} \geq 5\text{V}$		0.02	0.05	0.02	0.07		%/V
Thermal Regulation	$T_A = 25^\circ\text{C}, 20\text{ms pulse}$		0.005	0.01	0.005	0.03		%/V
Ripple Rejection	$V_{OUT} = 10\text{V}, f = 120\text{Hz}$ $C_{ADJ} = 0$ $C_{ADJ} = 10\mu\text{F}$		5	15	5	25		mV
Adjust Pin Current		66	86		66	86		dB
Adjust Pin Current Change	$10\text{mA} \leq I_L \leq 3\text{A}, 3\text{V} \leq (V_{IN} - V_{OUT}) \leq 35\text{V}$		0.1	0.3	0.1	0.5		%
Minimum Load Current	$(V_{IN} - V_{OUT}) = 35\text{V}$		15	50	20	70		mV
Current Limit	$(V_{IN} - V_{OUT}) \leq 10\text{V}$ $(V_{IN} - V_{OUT}) = 30\text{V}$	3	0.3	1	0.3	1.5		%
Temperature Stability (Note 4)		0.25	1		0.25	1		A
Long Term Stability (Note 4)	$T_A = 125^\circ\text{C}$		1	2		1		%
RMS Output Noise (% of $V_{OUT}$ )	$T_A = 25^\circ\text{C}, 10\text{Hz} \leq f \leq 10\text{KHz}$		0.3	1		0.3	1	%
			0.001			0.001		%

Note 3. Regulation is measured at a constant  $T_A$ . Changes in output due to heating must be taken into account separately. Pulse testing with low duty cycle is used.

Note 4. These parameters, although guaranteed are not tested in production.

## APPLICATIONS INFORMATION

### GENERAL

The SG150A develops a 1.25V reference voltage between the output and the adjustable terminal (see Figure 1). By placing a resistor,  $R_1$ , between these two terminals, a constant current is caused to flow through  $R_1$  and down through  $R_2$  to set the overall output voltage. Normally this current is the specified minimum load current of 5mA or 10mA.

Because  $I_{ADJ}$  is a very small and constant when compared with the current through  $R_1$ , it represents a small error and can usually be ignored. It is easily seen from the equation, that even if the resistors were of exact value, the accuracy of the output is limited by the accuracy of  $V_{REF}$ . Earlier adjustable regulators had a reference tolerance of  $\pm 4\%$  which is dangerously close to the  $\pm 5\%$  supply tolerance required in many logic and analog systems. Further, even 1% resistors can drift 0.01%/°C, adding additional error to the output voltage tolerance.

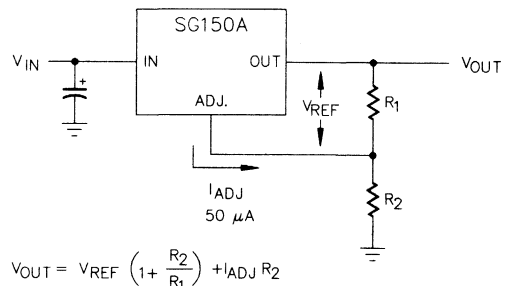


FIGURE 1 - BASIC ADJUSTABLE REGULATOR

## APPLICATIONS INFORMATION

### BYPASS CAPACITORS

Input bypassing using a 1μF tantalum or 25μF electrolytic is recommended when the input filter capacitors are more than 5 inches from the device. Improved ripple rejection (80dB) can be accomplished by adding a 10μF capacitor from the adjust pin to ground. Increasing the size of the capacitor to 20μF will help ripple rejection at low output voltage since the reactance of this capacitor should be small compared to the voltage setting resistor, R<sub>2</sub>. For improved AC transient response and to prevent the possibility of oscillation due to unknown reactive load, a 1μF capacitor is also recommended at the output. Because of their low impedance at high frequencies, the best type of capacitor to use is solid tantalum.

### LOAD REGULATION

Because the SG150A is a three-terminal device, it is not possible to provide true remote load sensing. Load regulation will be limited by the resistance of the wire connecting the regulator to the load. The data sheet specification for load regulation is measured at the bottom of the package. Negative side sensing is a true Kelvin connection, with the bottom of the output divider returned to the negative side of the load. Although it may not be immediately obvious, best load regulation is obtained when the top of the resistor divider (R<sub>2</sub>) is connected directly to the case,

not the load. This is illustrated in Figure 2. If R<sub>1</sub> were connected to the load, the effective resistance between the regulator and the load would be

$$R_p \times \left( \frac{R_2 + R_1}{R_1} \right), R_p = \text{Parasitic Line Resistance.}$$

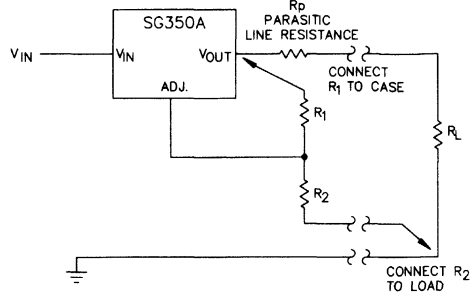
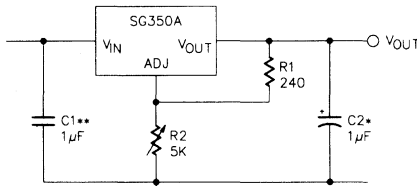


FIGURE 2 - CONNECTIONS FOR BEST LOAD REGULATION

Connected as shown, R<sub>p</sub> is not multiplied by the divider ratio. R<sub>p</sub> is about 0.004Ω per foot using 16 gauge wire. This translates to 4mV/ft. at a 1A load current, so it is important to keep the positive lead between regulator and load as short as possible, and use large wire or PC board traces.

## TYPICAL APPLICATIONS



- \*\* Optional—Improves transient response.
- \* Needed if device is far from filter capacitors.

$$V_{OUT} = 1.25V \left( 1 + \frac{R_2}{R_1} \right)$$

FIGURE 3 - 1.2V - 25V ADJUSTABLE REGULATOR

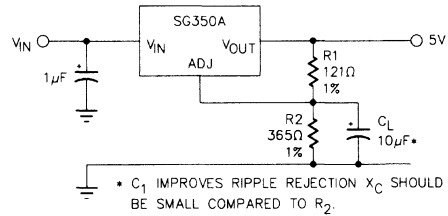
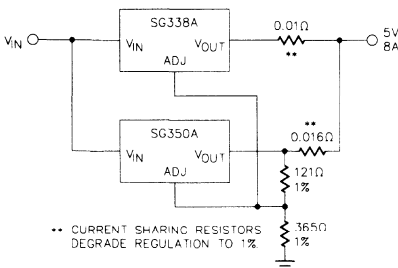


FIGURE 4 - IMPROVING RIPPLE REJECTION



- \*\* CURRENT SHARING RESISTORS DEGRADE REGULATION TO 1%

FIGURE 5 - PARALLEL REGULATORS FOR HIGHER CURRENT  
(This circuit will not work with LM version devices.)

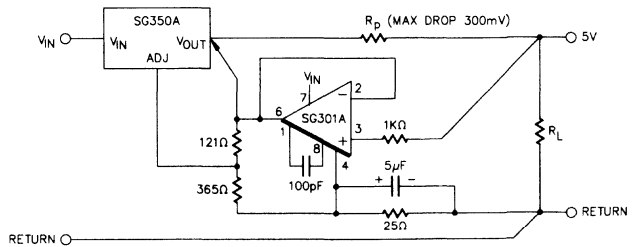


FIGURE 6 - REMOTE SENSING

# SG150A/SG150 SERIES

## TYPICAL APPLICATIONS (continued)

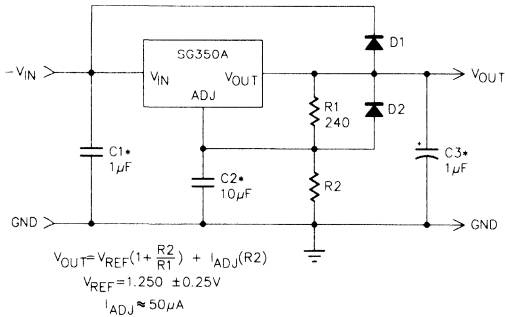


FIGURE 7 - BASIC REGULATOR WITH CAPACITORS\* FOR INCREASED PERFORMANCE

\* No external capacitors are required with the SG150A/150 but in some application, performance may be improved with added capacitance as follows:

- C1. An input capacitor at 0.1µF will protect against problems when high impedance is present. The device can be more sensitive to input impedance when output or adjustment capacitors are used.
- C2. Bypassing the adjustment terminal to ground with a 10µF capacitor will improve the ripple rejection by about 15dB.
- C3. A 1µF tantalum capacitors on the output will improve transient response and keep the regulator from ringing due to tight capacitive loading.

In addition to external capacitors, it is sometimes good practice to add protection diodes D1 and D2 if there is a chance that a capacitor may discharge through the regulator IC.

Diode D1 protects against C3 with an input short.  
Diode D2 protects against C2 with an output short.

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
3-TERMINAL TO-3 METAL CAN K-PACKAGE	SG150AK/883B	-55°C to 125°C	
	SG150AK	-55°C to 125°C	
	SG250AK	-25°C to 85°C	
	SG350AK	0°C to 70°C	
	SG150K/883B	-55°C to 125°C	
	SG150K	-55°C to 125°C	
	SG250K	-25°C to 85°C	
	SG350K	0°C to 70°C	
3-PIN PLASTIC TO-220 P-PACKAGE	SG250P	0°C to 70°C	
	SG350P	0°C to 70°C	
3-PIN HERMETIC TO-220 G-PACKAGE (Non-Isolated)	SG150AG/883B	-55°C to 125°C	
	SG150AG	-55°C to 125°C	
	SG150G/883B	-55°C to 125°C	
	SG150G	-55°C to 125°C	
3-PIN HERMETIC TO-220 IG-PACKAGE (Isolated)	SG150AIG/883B	-55°C to 125°C	
	SG150AIG	-55°C to 125°C	
	SG150IG/883B	-55°C to 125°C	
	SG150IG	-55°C to 125°C	

Note 1. Contact factory for JAN and DESC product availability.  
2. All parts are viewed from the top.





**PRECISION VOLTAGE REGULATOR**

**DESCRIPTION**

This monolithic voltage regulator is designed for use with either positive or negative supplies as a series, shunt, switching, or floating regulator with currents up to 150mA. Higher current requirements may be accommodated through the use of external NPN or PNP power transistors. This device consists of a temperature compensated reference amplifier, error amplifier, power series pass transistor, current limit, and remote shutdown circuitry.

The SG723 will operate over the full military temperature range of -55°C to 125°C while the SG723C is designed for commercial applications of 0°C to 70°C.

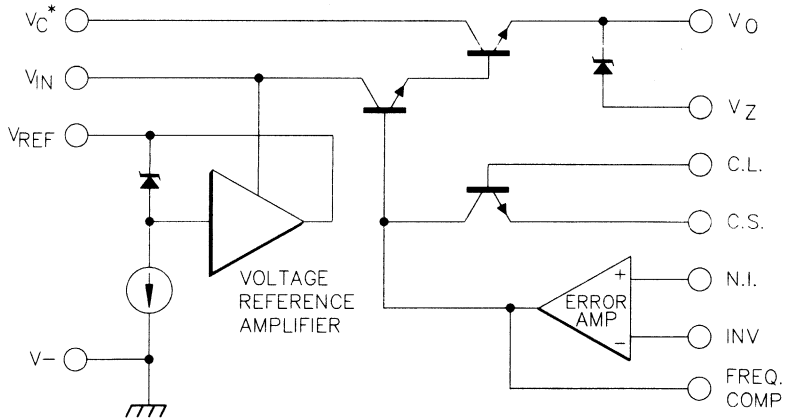
**FEATURES**

- Positive or negative supply operation
- Series, shunt, switching or floating operation
- Low line and load regulation
- Output adjustable from 2V to 37V
- Output current to 150 mA
- Low standby current drain
- 0.002%/°C average temperature variation

**HIGH RELIABILITY FEATURES - SG723**

- ◆ Available to MIL-STD-883 and DESC SMD
- ◆ MIL-M38510/10201BHA - JAN 723F
- ◆ MIL-M38510/10201BIA - JAN 723T
- ◆ SG level "S" processing available

**BLOCK DIAGRAM**



\*  $V_C$  IS INTERNALLY CONNECTED TO  $V_{IN}$  FOR T PACKAGE.

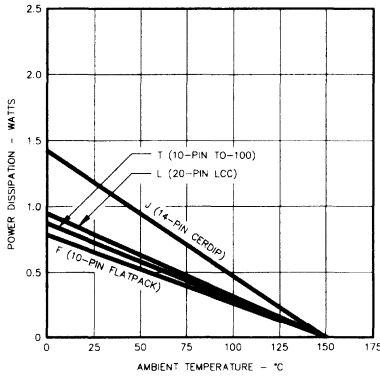
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Pulse (50 ms) Input Voltage from $V_{IN}$ to $V_-$ .....	50V	Current from $V_{REF}$ .....	15mA
Continuous Input Voltage from $V_{IN}$ to $V_-$ .....	40V	Operating Junction Temperature	
Input to Output Voltage Differential .....	40V	Hermetic (T, J, F, L-Packages) .....	175°C
Maximum Output Current .....	150mA	Storage Temperature Range .....	-65°C to 150°C
Current from $V_z$ (J-Package only) .....	25 mA	Lead Temperature (Soldering, 10 Seconds) .....	300°C

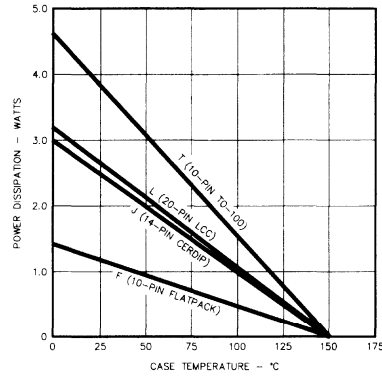
Note 1. Exceeding these ratings could cause damage to the device.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Input Voltage Range .....	( $V_{OUT} + 4.5V$ ) to 38 V	Operating Junction Temperature Range	
Output Current Range .....	5mA to 45mA	SG723 .....	-55°C to 125°C
Reference Current .....	5mA	SG723C .....	0°C to 70°C
Zener Current (J-Package only) .....	5mA		

Note 2. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise specified, these specifications apply for  $T_A = 25^\circ C$ ,  $V_{IN} = V_C = 12V$ ,  $V_- = 0V$ ,  $V_{OUT} = 5V$ ,  $I_L = 1 mA$ ,  $R_{SC} = 0\Omega$ ,  $C_1 = 100pF$ ,  $C_{REF} = 0$ , and divider impedance as seen by error amplifier  $\leq 10K\Omega$ .)

Parameter	Test Conditions	SG723		SG723C			Units
		Min.	Typ. Max.	Min.	Typ.	Max.	
Input Voltage Range		9.5	40	9.5		40	V
Output Voltage Range		2.0	37	2.0		37	V
Input to Output Differential		3.0	38	3.0		38	V
Line Regulation (Note 3)	$V_{IN} = 12V$ to $15V$ $T_A = T_{MIN}$ to $T_{MAX}$		0.01 0.1		0.01	0.1	% $V_{OUT}$
	$V_{IN} = 12V$ to $40V$		0.02 0.2		0.1	0.5	% $V_{OUT}$
Load Regulation (Note 3)	$I_L = 1$ to $50 mA$ $T_A = T_{MIN}$ to $T_{MAX}$		0.03 0.15 0.6		0.03	0.2 0.6	% $V_{OUT}$
Ripple Rejection	$f = 50 Hz$ to $10KHz$ $C_{REF} = 0$		74		74		dB
	$C_{REF} = 5\mu F$		86		86		dB
Temperature Stability (Note 4)	$T_A = T_{MIN}$ to $T_{MAX}$		0.002 0.015		0.003 0.015		%/ $^\circ C$
Short Circuit Current Limit	$R_{SC} = 10\Omega$		65		65		mA
Reference Voltage		6.95	7.15 7.35	6.80	7.15	7.50	V
Output Noise Voltage	$BW = 100Hz$ to $10KHz$ $C_{REF} = 0$		20		20		$\mu V_{rms}$
	$C_{REF} = 5\mu F$		2.5		2.5		$\mu V_{rms}$
Standby Current Drain	$I_L = 0$ , $V_{IN} = 30V$		2.3 3.5		2.3 4.0		mA
Long Term Stability			0.1		0.1		%/Khr

Note 3. Applies for constant junction temperature. Temperature drift effects must be taken into account separately when the unit is operating under conditions of high dissipation.

Note 4. These parameters, although guaranteed, are not tested in production.

CHARACTERISTIC CURVES

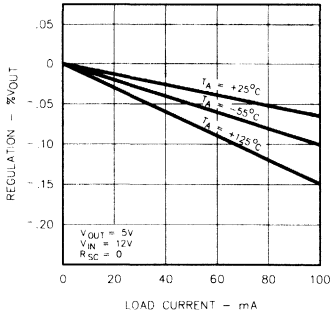


FIGURE 1. LOAD REGULATION

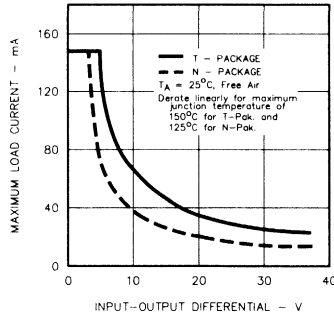


FIGURE 2. MAXIMUM LOAD CURRENT

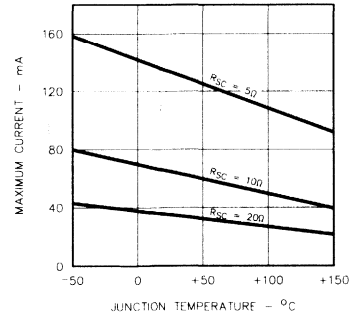


FIGURE 3. CURRENT LIMITING CHARACTERISTICS

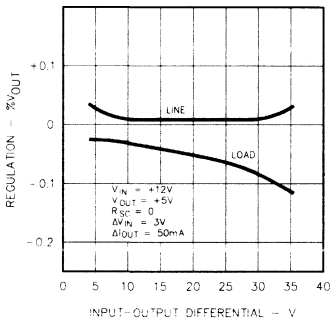


FIGURE 4. REGULATION VS. INPUT-OUTPUT VOLTAGE REGULATION

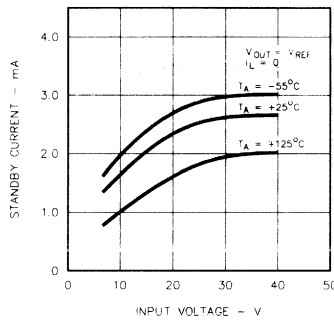


FIGURE 5. STANDBY CURRENT DRAIN

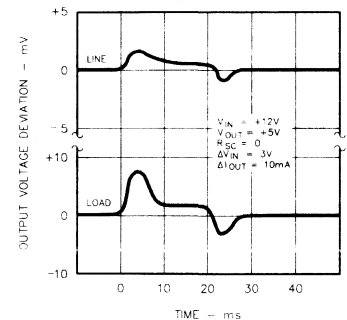


FIGURE 6. TRANSIENT RESPONSE

APPLICATION INFORMATION

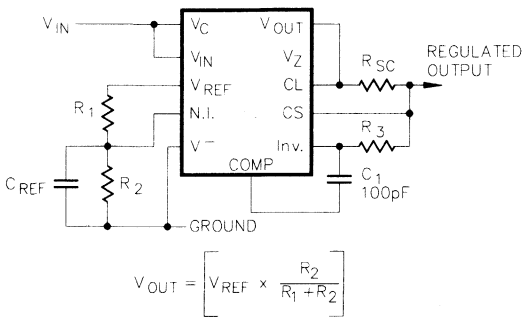


FIGURE 7 - BASIC LOW VOLTAGE REGULATOR  
 $V_{OUT} = 2\text{V TO } 7\text{V}$

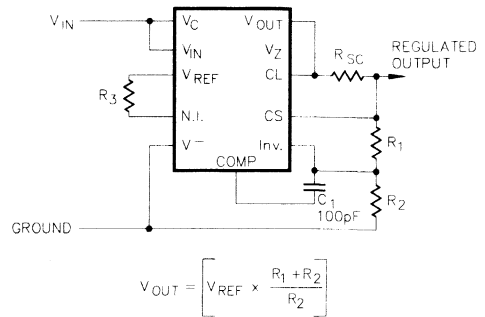
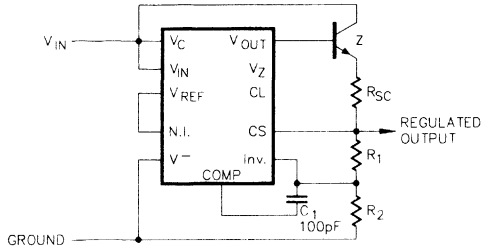


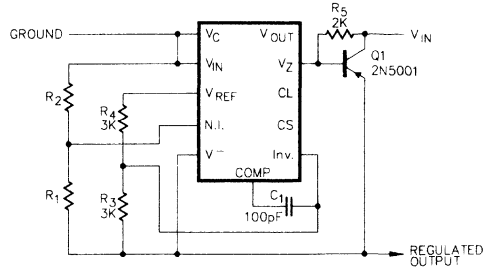
FIGURE 8 - BASIC HIGH VOLTAGE REGULATOR  
 $V_{OUT} = 7\text{V TO } 37\text{V}$

**APPLICATION INFORMATION** (continued)



$$V_{OUT} = \left[ V_{REF} \times \frac{R_1 + R_2}{R_2} \right]$$

FIGURE 9 - HIGH CURRENT REGULATOR  
EXTERNAL NPN TRANSISTOR  $I_L = 1.0A$



$$V_{OUT} = \left[ \frac{V_{REF}}{2} \times \frac{R_1 + R_2}{R_1} \right]; R_3 = R_4$$

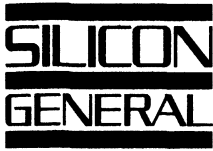
FIGURE 10 - NEGATIVE VOLTAGE REGULATOR

**CONNECTION DIAGRAMS & ORDERING INFORMATION** (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
14-PIN CERAMIC DIP J - PACKAGE	SG723J/883B SG723J SG723CJ	-55°C to 125°C -55°C to 125°C 0°C to 70°C	
10-PIN METAL CAN T - PACKAGE	SG723T/883B SG723T SG723CT	-55°C to 125°C -55°C to 125°C 0°C to 70°C	(Notes 3 & 4) 
10-PIN CERAMIC FLAT PACK F - PACKAGE	SG723F/883B SG723F	-55°C to 125°C -55°C to 125°C	(Note 3) 
20-PIN CERAMIC LEADLESS CHIP CARRIER L - PACKAGE	SG723L/883B SG723L	-55°C to 125°C -55°C to 125°C	

Note 1. Contact factory for JAN and DESC product availability.  
Note 2. All packages are viewed from the top.

Note 3.  $V_Z$  output is not available in T, F-packages.  
Note 4. Pin 5 is connected to case.



LINEAR INTEGRATED CIRCUITS

# SG1501A/SG2501A/SG3501A/SG4501

## DUAL VOLTAGE TRACKING REGULATOR

### DESCRIPTION

This circuit is a dual polarity tracking regulator designed to provide balanced positive and negative output voltages at currents up to 100mA. It is internally set for positive and negative 15 volt outputs but a single external adjustment can be used to change both outputs simultaneously from 10 to 23 volts. This device can be used with input voltages of up to  $\pm 35$  volts and also has provision for adjustable current limiting, and utilization at currents in excess of two amps with the aid of external power transistors. A built-in sensing circuit monitors junction temperature and shuts down the regulator above 170°C eliminating the user's need for concern about power dissipation under short circuit conditions. The SG1501A will operate over the military temperature range of -55°C to 125°C, while the SG2501A, SG3501A, and SG4501 are designed for commercial applications of 0°C to 70°C.

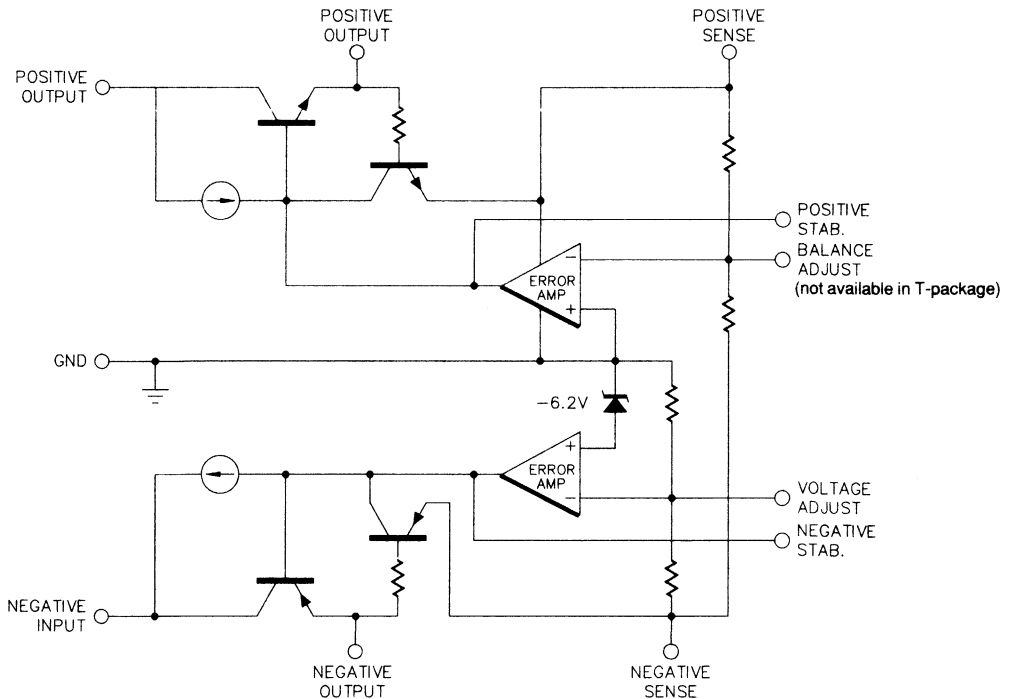
### FEATURES

- $\pm 15V$  tracking outputs
- Output currents to 100mA
- Internal thermal shutdown protection
- Precision line and load regulation
- 1% maximum temperature variation
- Adjustable current limit
- $\pm 35V$  inputs
- Output adjustable from  $\pm 10V$  to  $\pm 23V$

### HIGH RELIABILITY FEATURES - SG1501A

- ◆ Available to MIL-STD-883
- ◆ SG level "S" processing available

### BLOCK DIAGRAM



# SG1501A/SG2501A/SG3501A/SG4501

## ABSOLUTE MAXIMUM RATINGS (Note 1)

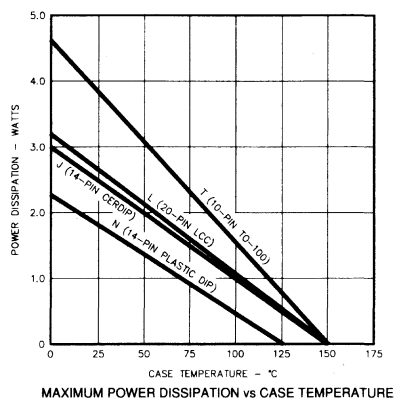
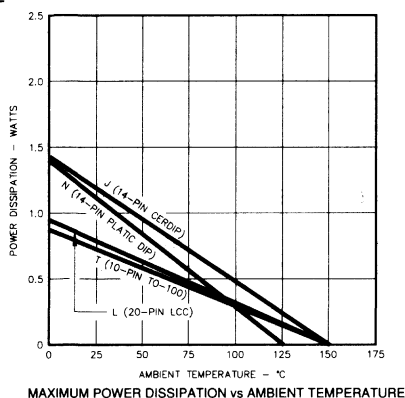
Input Voltage from V+ to V-  
 SG1501A, SG2501A ..... 70V  
 SG3501A, SG4501 ..... 60V  
 Maximum Load Current ..... 100mA

Operating Junction Temperature  
 Hermetic (J, T, L - Packages) ..... 175°C  
 Plastic (N - Packages) ..... 150°C  
 Storage Temperature Range ..... -65°C to 150°C  
 Lead Temperature (Soldering, 10 Seconds) ..... 300°C

Note 1. Exceeding these ratings could cause damage to the device.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



### ELECTRICAL

Input Voltage from V+ to V-  
 SG1501A, SG2501A ..... 60V  
 SG3501A, 4501 ..... 50V  
 Output Current ..... 0 to 50mA

Input - Output Differential (minimum) ..... 4V  
 Operating Ambient Temperature Range (T<sub>A</sub>)  
 SG1501A ..... -55°C to 125°C  
 SG2501A, SG3501A, SG4501 ..... 0°C to 70°C

Note 2. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(All specifications apply to both positive and negative sides of the regulator, either singly or together. Unless otherwise stated, these specifications apply for T<sub>A</sub> = 25°C, V<sub>IN</sub> = ±20V, V<sub>OUT</sub> = ±15V, I<sub>L</sub> = 0, R<sub>SC</sub> = 0Ω, C<sub>1</sub> = C<sub>2</sub> = 0.01μF, C<sub>3</sub> = C<sub>4</sub> = 1.0μF, and Voltage Adjustment pin open.)

Parameter	Test Conditions	SG1501A/2501A			SG3501A			SG4501			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage		14.8	15	15.2	14.5	15	15.5	14.25		15.75	V
Input Voltage				±35			±30			±30	V
Input - Output Differential	R <sub>SC</sub> = 0, I <sub>L</sub> = 50mA	2			2			2			V
Output Voltage Balance			50	150		50	300		50	300	mV
Line Regulation	V <sub>IN</sub> = 17V to V <sub>MAX</sub> , T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub>		4	20		4	20		4	20	mV
Load Regulation	I <sub>L</sub> = 0mA to 50mA, T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub>		5	30		5	30		5	30	mV
Output Voltage Range	Voltage adjust circuit	10		23	10		23	10		23	V
Input Voltage Range	10V Output	12		35	12		30	12		30	V
Ripple Rejection	f = 120Hz		75			75		75			dB
Temperature Stability (Note 3)	T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub>	0.3	1.0		0.3	1.0		0.3	1.0		%
Short Circuit Current Limit	R <sub>SC</sub> = 10Ω	60			60			60			mA
Output Noise Voltage	BW = 100Hz to 10KHz	50			50			50			μV <sub>rms</sub>
Positive Standby Current	I <sub>L</sub> = 0	2	4		2	4		2	4		mA
Negative Standby Current	I <sub>L</sub> = 0	3	5		3	5		3	5		mA
Long Term Stability		0.1			0.1			0.1			%/Khr

Note 3. These parameters, although guaranteed, are not tested in production.

# SG1501A/SG2501A/SG3501A/SG4501

## CHARACTERISTIC CURVES

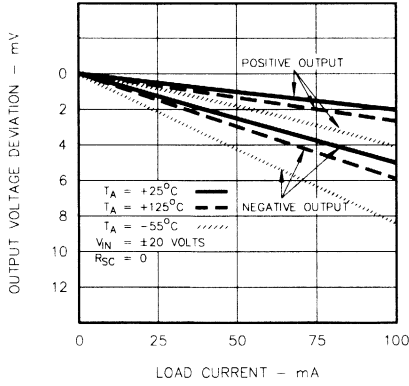


FIGURE 1.  
LOAD REGULATION

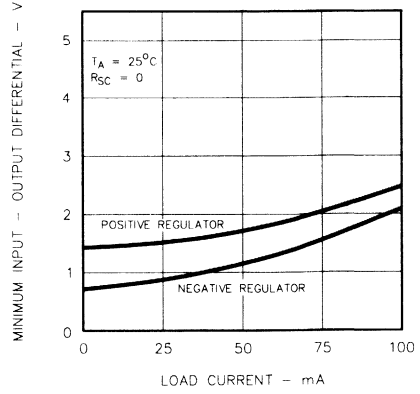


FIGURE 2.  
REGULATOR DROPOUT VOLTAGE

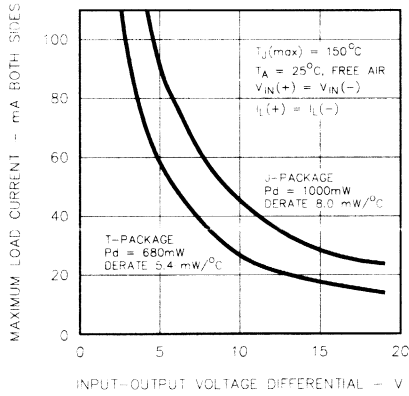


FIGURE 3.  
MAXIMUM CURRENT CAPABILITY

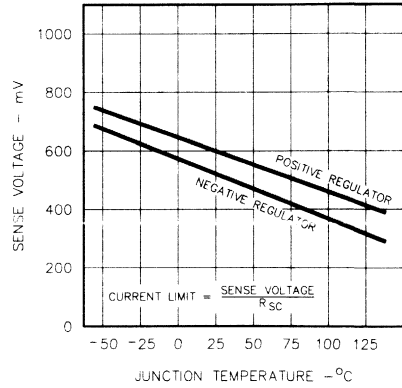


FIGURE 4.  
CURRENT LIMITING CHARACTERISTICS

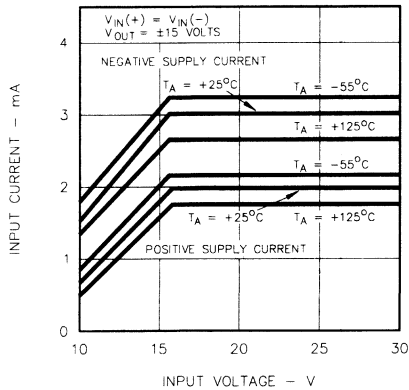


FIGURE 5.  
STANDBY CURRENT DRAIN

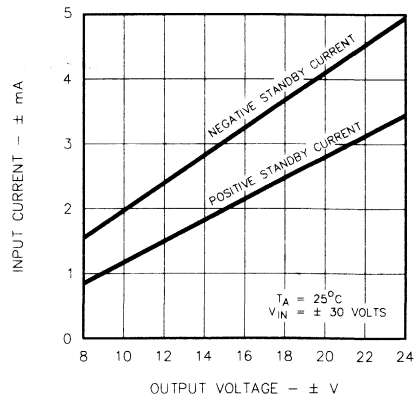


FIGURE 6.  
STANDBY CURRENT DRAIN

CHARACTERISTIC CURVES

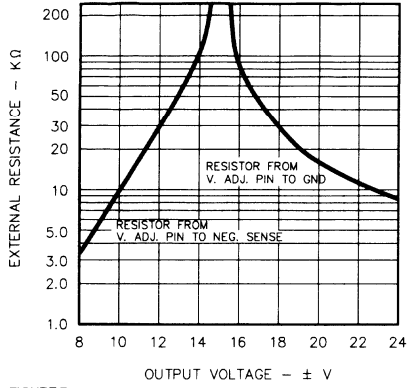


FIGURE 7. EXTERNAL PARALLEL RESISTOR REQUIRED FOR VOLTAGES OTHER THAN  $\pm 15$  VOLTS

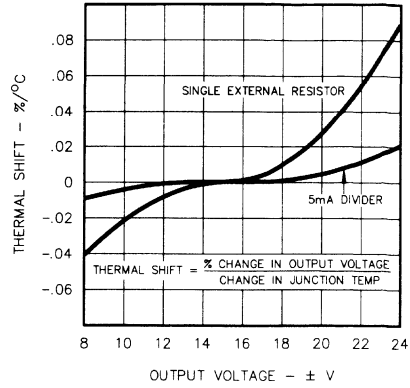


FIGURE 8. TEMPERATURE COEFFICIENT OF OUTPUT VOLTAGE

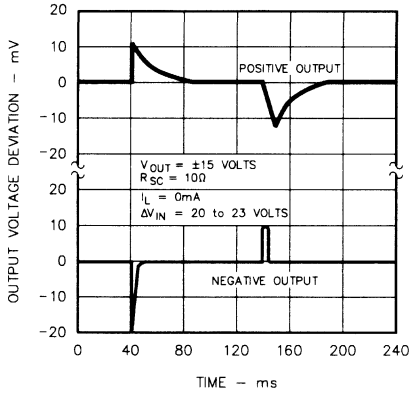


FIGURE 9. LINE TRANSIENT RESPONSE

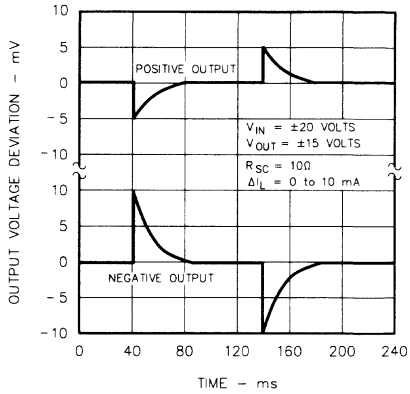


FIGURE 10. LOAD TRANSIENT RESPONSE

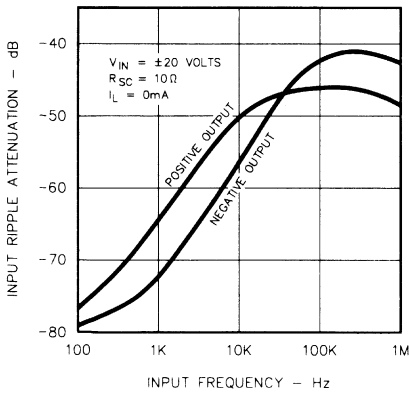


FIGURE 11. RIPPLE REJECTION

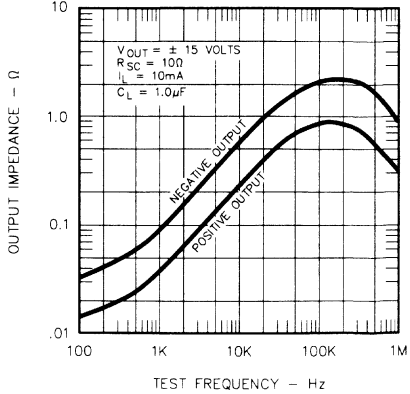


FIGURE 12. OUTPUT IMPEDANCE



# SG1501A/SG2501A/SG3501A/SG4501

## TYPICAL APPLICATIONS

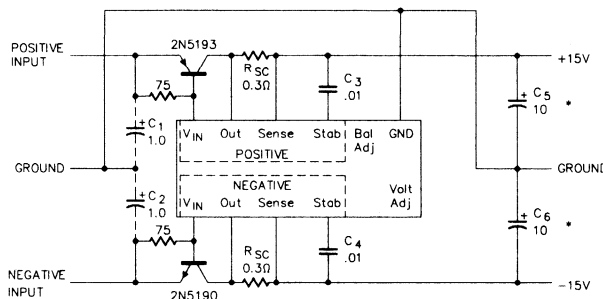


FIGURE 13 - HIGH CURRENT CONFIGURATION, ONE AMP OUTPUT

For full power output, the external transistors must be mounted on adequate heat sinks. Selection of power transistors may be made on the basis of current and voltage capability with low-frequency devices preferred to minimize the risk of oscillation. In this circuit, the value of  $R_{sc}$  is selected in order to protect the pass transistors rather than the IC.  $C_1$  and  $C_2$  are only necessary if high line impedance is present.

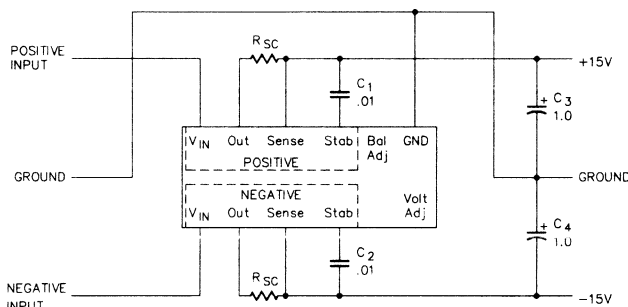


FIGURE 14 - BASIC  $\pm 15$  V, 50mA REGULATOR

Additional reduction in output noise voltage may be achieved with larger values for  $C_1$  and  $C_2$  although there is some loss in frequency response.  $C_3$  and  $C_4$  may also be increased to improve load transient characteristics. Note that the case is common to  $-V_{IN}$ , not ground.

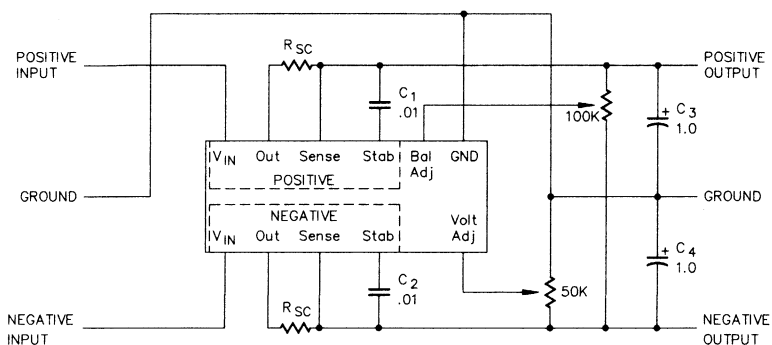


FIGURE 15 - ADJUSTMENT OF VOLTAGE LEVELS

Greater resolution may be achieved by padding each of the potentiometer with fixed resistors. Also, a single resistor, rather than a divider, may be used when adjustment in only one direction is required, but some degradation in temperature coefficient results (see temperature coefficient of output voltage curve).

# SG1501A/SG2501A/SG3501A/SG4501

## APPLICATION NOTE

Although the SG1501A series contains thermal limiting circuitry, the maximum current must still be controlled to allow time for this protection to react. Therefore, without external pass transistors, the minimum value for  $R_{sc}$  is three ohms.  $R_{sc}$  can, of course, have a larger value in order to protect a load.

the negative side when the device goes into current limiting. Should this be a problem, it may be eliminated by by-passing  $R_{sc}$  with a capacitor whose value is such that the time constant,  $R_{sc}C$ , is equal to  $10 \times 10^{-6}$  second. This capacitor, as well as the output capacitors, C3 and C4, must be low ESR types such as solid tantalum.

Under some conditions, a low-level oscillation may be present on

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Note Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
14-PIN CERAMIC DIP J - PACKAGE	SG1501AJ/883B SG1501AJ SG2501AJ SG3501AJ SG4501T	-55°C to 125°C -55°C to 125°C 0°C to 70°C 0°C to 70°C 0°C to 70°C	<p>(Note 2) BALANCE ADJUST □ 2 □ N.C.          POSITIVE STAB. □ 3 □ NEGATIVE STAB.          POSITIVE SENSE □ 4 □ NEGATIVE SENSE          POSITIVE OUTPUT □ 5 □ NEGATIVE OUTPUT          N.C. □ 6 □ N.C.          POSITIVE INPUT V+ □ 7 □ 8 □ NEGATIVE INPUT V-</p>
14-PIN PLASTIC DIP N - PACKAGE	SG2501AN SG3501AN SG4501T	0°C to 70°C 0°C to 70°C 0°C to 70°C	
10-PIN TO-100 METAL CAN T-PACKAGE	SG1501AT/883B SG1501AT SG2501AT SG3501AT SG4501T	-55°C to 125°C -55°C to 125°C 0°C to 70°C 0°C to 70°C 0°C to 70°C	<p>GND          POSITIVE STAB. POSITIVE SENSE POSITIVE OUTPUT POSITIVE INPUT V+ POSITIVE INPUT V+ NEGATIVE OUTPUT NEGATIVE SENSE NEGATIVE INPUT V-          VOLTAGE ADJ. NEGATIVE STAB.</p>
20-PIN CERAMIC LEADLESS CHIP CARRIER L - PACKAGE	SG1501AL/883B SG1501AL	-55°C to 125°C -55°C to 125°C	<p>(Note 3)</p> <p>1. N.C. 2. N.C. 3. GND 4. BALANCE ADJ. 5. POS. STAB. 6. N.C. 7. POS. SENSE 8. POS. OUTPUT 9. POS. INPUT V+ 10. N.C. 11. N.C. 12. N.C. 13. NEG. INPUT V- 14. NEG. OUTPUT 15. N.C. 16. N.C. 17. NEG. SENSE 18. NEG. STAB. 19. VOLTAGE ADJ. 20. N.C.</p>

Note 1. All packages are viewed from the top.

Note 2. The Balance Adjust function is not available in the "T" package.

Note 3. The Negative Input (V-) pin is internally connected to the case.

**ADJUSTABLE DUAL VOLTAGE REGULATOR**

**DESCRIPTION**

This circuit is identical to the SG1501 series of dual polarity tracking regulators except that the internal voltage setting resistors are not included and the current limit inputs have been disconnected from the pass transistors. While this circuit does require external divider resistors, maximum versatility of offered in adjusting the output voltage levels, and additional current-limit inputs ease the application of fold-back current limiting. In all other respects, this circuit performs as the SG1501.

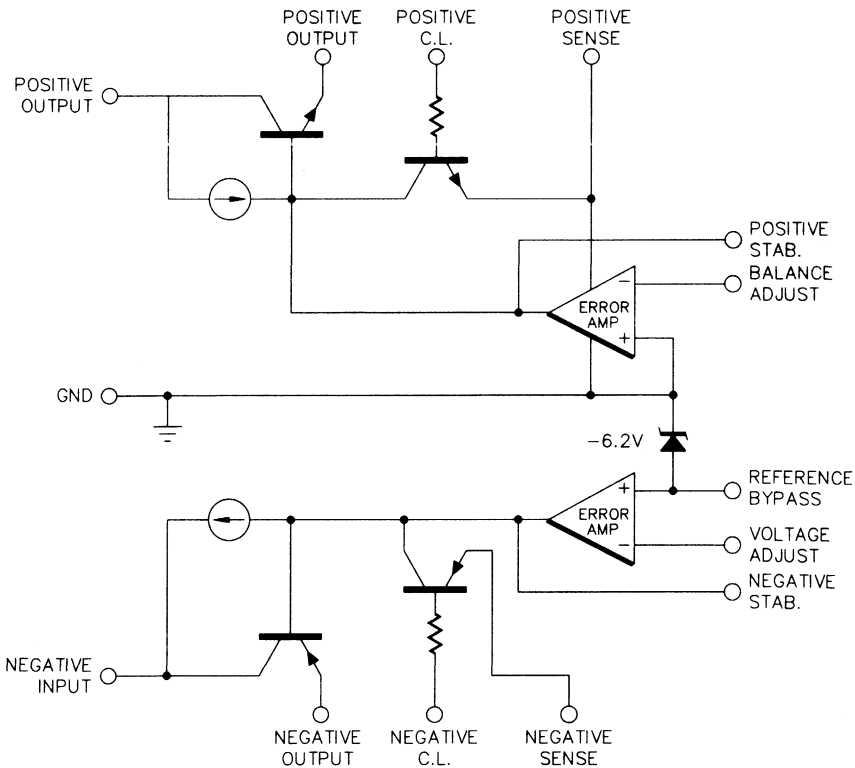
**FEATURES**

- Positive and negative output voltage independently adjustable from 10V to 28V
- Output currents to 100mA
- Line and load regulation of 0.1%
- 1% maximum temperature variation
- Standby current drain only 3mA
- Internal thermal shutdown protection

**HIGH RELIABILITY FEATURES - SG1502**

- ◆ Available to MIL-STD-883
- ◆ SG level "S" processing available

**BLOCK DIAGRAM**



# SG1502/SG2502/SG3502

## ABSOLUTE MAXIMUM RATINGS (Note 1)

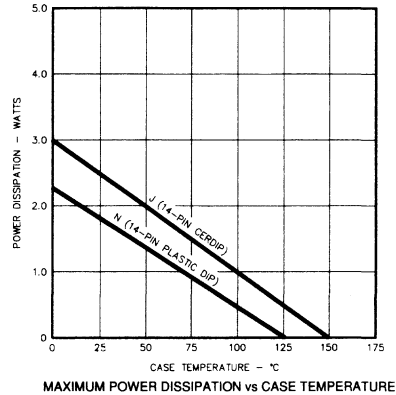
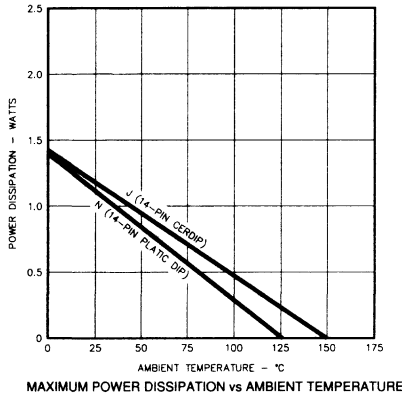
Input Voltage from V+ to V-  
 SG1502, SG2502 ..... 60V  
 SG3502 ..... 50V  
 Maximum Load Current ..... 100mA

Operating Junction Temperature  
 Hermetic (J Package) ..... 175°C  
 Plastic (N Package) ..... 150°C  
 Storage Temperature Range ..... -65°C to 150°C  
 Lead Temperature (Soldering, 10 Seconds) ..... 300°C

Note 1. Exceeding these ratings could cause damage to the device.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



### ELECTRICAL

Input Voltage from V+ to V-  
 SG1502, SG2502 ..... 50V  
 SG3502 ..... 40V  
 Output Current ..... 0 to 50mA

Input - Output Differential (minimum) ..... 4V  
 Operating Ambient Temperature Range (T<sub>A</sub>)  
 SG1502 ..... -55°C to 125°C  
 SG2502, SG3502 ..... 0°C to 70°C

Note 2. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(All specifications apply to both positive and negative sides of the regulator, either singly or together. Unless otherwise stated, these specifications apply for T<sub>A</sub> = 25°C, V<sub>IN</sub> = ±20V, V<sub>OUT</sub> = ±15V, I<sub>L</sub> = 0, R<sub>SC</sub> = 0Ω, C<sub>1</sub> = C<sub>2</sub> = 0.01μF, C<sub>3</sub> = C<sub>4</sub> = 1.0μF.)

Parameter	Test Conditions	SG1502/2502			SG3502			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Input Voltage Range		12		30	12		25	V
Output Voltage Range		10		28	10		23	V
Input - Output Differential		2			2			V
Line Regulation	ΔV <sub>IN</sub> = 10V T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub>		0.02	0.1		0.02	0.1	%V <sub>OUT</sub>
Load Regulation	I <sub>L</sub> = 0mA to 50mA T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub>		0.02	0.1		0.02	0.1	%V <sub>OUT</sub>
Temperature Stability (Note 3)	T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub>		0.03	0.3		0.02	0.3	%V <sub>OUT</sub>
Current Limit Sense Voltage			0.3	1.0		0.3	1.0	%V <sub>OUT</sub>
Reference Voltage		6.3		6.6	6.2		6.8	V
Ripple Rejection	f = 120Hz		75			75		dB
Output Noise Voltage	BW = 100Hz to 10KHz		50			50		μV <sub>rms</sub>
Positive Standby Current	Divider 1 = 0.5mA (Note 4)		2	3		2	3	mA
Negative Standby Current	Divider 1 = 0.5mA (Note 4)		3	4		3	4	mA
Long Term Stability			0.1			0.1		%/Khr

Note 3. These parameters, although guaranteed, they are not tested in production.

Note 4. "Divider 1" refers to R<sub>1</sub>, R<sub>2</sub> resistor divider. (See Figure 7)

CHARACTERISTIC CURVES

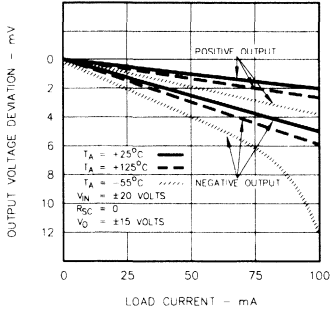


FIGURE 1. LOAD REGULATION

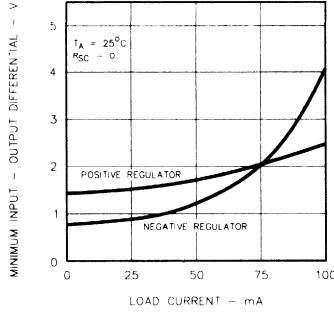


FIGURE 2. REGULATOR DROPOUT VOLTAGE

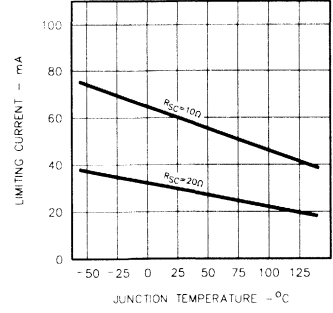


FIGURE 3. CURRENT LIMITING CHARACTERISTICS

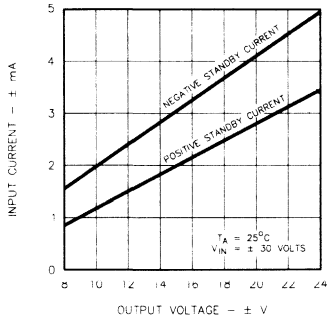


FIGURE 4. STANDBY CURRENT DRAIN

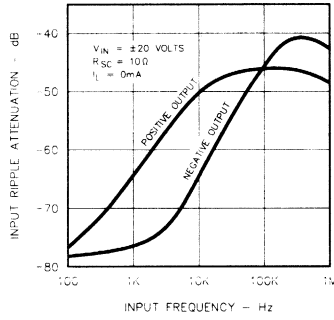


FIGURE 5. RIPPLE REJECTION

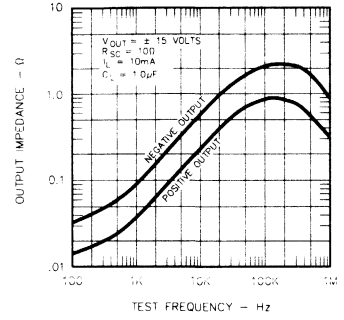


FIGURE 6. OUTPUT IMPEDANCE

TYPICAL APPLICATIONS

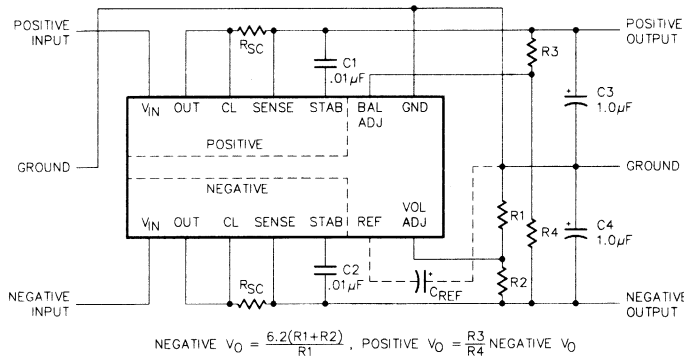


FIGURE 7 - BASIC REGULATOR CIRCUIT

For best temperature performance, the parallel impedance of  $R_1$  and  $R_2$  should be 6.3K ohm while that of  $R_3$  and  $R_4$  should be 10 K. Increasing the value of  $C_1$  and  $C_2$  will reduce the frequency response while transient response may be improved by increasing  $C_3$  and  $C_4$ . For very low-noise applications, a 4.7 $\mu\text{F}$  capacitor for  $C_{REF}$  may be added.  $R_{SC}$  is selected such that a sense voltage of 0.6 volts (at  $T_j = 25^\circ\text{C}$ ) is developed at the maximum load current desired.

**TYPICAL APPLICATIONS** (continued)

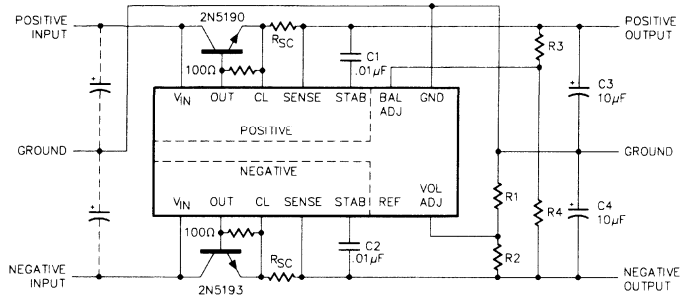


FIGURE 8 - HIGH CURRENT CONFIGURATION

Power transistors should be selected on the basis of current and voltage requirements with low-frequency devices preferred to minimize the risk of oscillation. Input capacitors (0.1µF to 1.0µF) may be required if the circuit is located remote from the power supply filter. The common-collector configuration here has the advantage of allowing the use of separate collector voltages for the pass transistors but the common-emitter configuration shown below may also be used. In fact, one configuration on the positive side and the other on the negative side will allow the use of all NPN or all PNP power transistors.

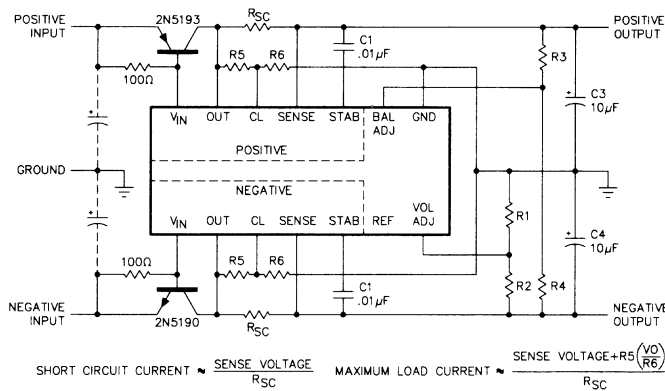


FIGURE 9 - FOLDBACK CURRENT LIMITING

The use of R5 and R6 to provide fold-back current limiting is possible with either common-emitter or common-collector configurations. The values for R5 and R6 are determined by an iterative solution of the equations shown with the trade-off being that a greater amount of fold-back requires a larger voltage drop across R<sub>SC</sub>. Note that in the common-emitter configuration, the 100Ω base - to emitter resistors must provide a path for the regulator stand-by current and should not be increased in value.

**CONNECTION DIAGRAMS & ORDERING INFORMATION** (See Note Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
14-PIN CERAMIC DIP J - PACKAGE	SG1502J/883B	-55°C to 125°C	
	SG1502J	-55°C to 125°C	
	SG2502J	0°C to 70°C	
SG3502J	0°C to 70°C		
14-PIN PLASTIC DIP N - PACKAGE	SG2502N	0°C to 70°C	
	SG3502N	0°C to 70°C	

Note 1. All packages are viewed from the top.

**REGULATING PULSE WIDTH MODULATOR**

**DESCRIPTION**

This monolithic integrated circuit contains all the control circuitry for a regulating power supply inverter or switching regulator. Included in a 16-pin dual-in-line package is the voltage reference, error amplifier, oscillator, pulse width modulator, pulse steering flip-flop, dual alternating output switches and current limiting and shut-down circuitry. This device can be used for switching regulators of either polarity, transformer coupled DC to DC converters, transformerless voltage doublers and polarity converters, as well as other power applications. The SG1524 is specified for operation over the full military ambient temperature range of -55°C to +125°C, the SG2524 for -25°C to +85°C, and the SG3524 is designed for commercial applications of 0°C to +70°C.

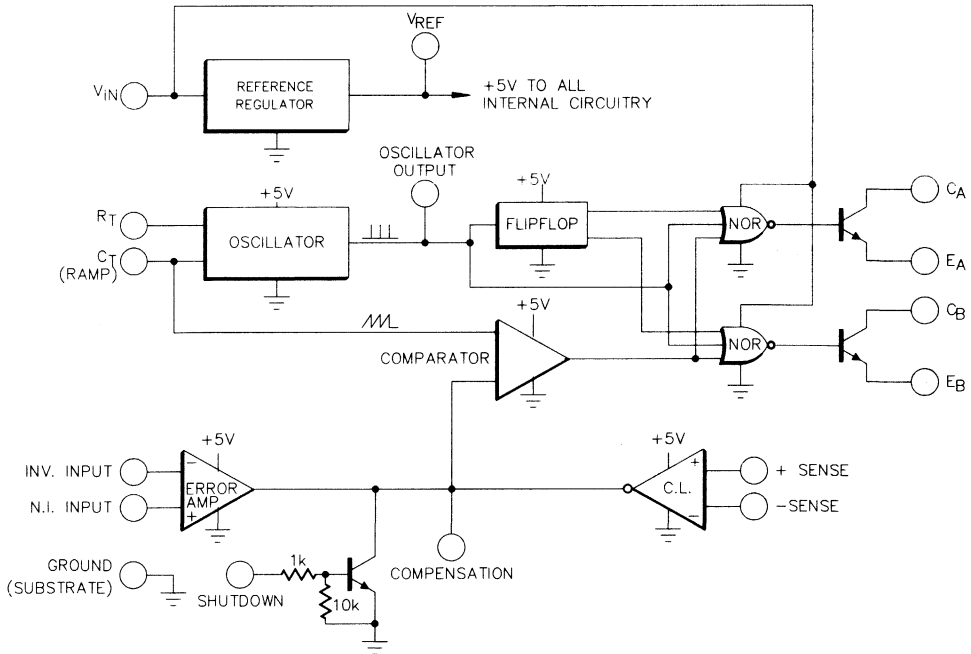
**FEATURES**

- 8V to 40V operation
- 5V reference
- Reference line and load regulation of 0.4%
- Reference temperature coefficient  $< \pm 1\%$
- 100Hz to 300KHz oscillator range
- Excellent external sync capability
- Dual 50mA output transistors
- Current limit circuitry
- Complete PWM power control circuitry
- Single ended or push-pull outputs
- Total supply current less than 10mA

**HIGH RELIABILITY FEATURES - SG1524**

- ◆ Available to MIL-STD-883B and DESC SMD
- ◆ MIL-M-38510/12601BEA - JAN1524J
- ◆ Radiation data available
- ◆ SG level "S" processing available

**BLOCK DIAGRAM**



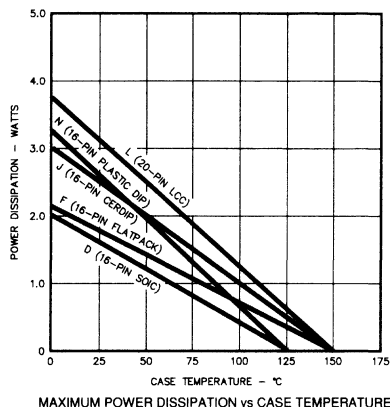
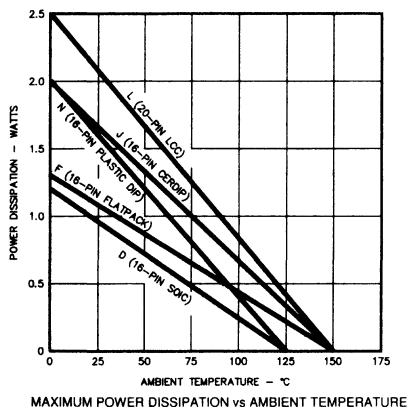
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Input Voltage (+V <sub>IN</sub> ) .....	42V	Oscillator Charging Current .....	5mA
Collector Voltage .....	40V	Operating Junction Temperature	
Logic Inputs .....	-0.3V to 5.5V	Hermetic (J, F, L Packages) .....	175°C
Current Limit Sense Inputs .....	-0.3V to 0.3V	Plastic (N, DW Packages) .....	150°C
Output Current (each transistor) .....	100mA	Storage Temperature Range .....	-65°C to 150°C
Reference Load Current .....	50mA	Lead Temperature (Soldering, 10 seconds) .....	300°C

Note 1. Values beyond which damage may occur.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



### ELECTRICAL

Input Voltage (+V <sub>IN</sub> ) .....	8V to 40V	Oscillator Frequency Range .....	100Hz to 300KHz
Collector Voltage .....	0V to 40V	Oscillator Timing Resistor (R <sub>T</sub> ) .....	1.8KΩ to 100KΩ
Error Amp Common Mode Range .....	1.8V to 3.4V	Oscillator Timing Capacitor (C <sub>T</sub> ) .....	1nF to 1.0μF
Current Limit Sense Common Mode Range .....	-0.3V to 0.3V	Operating Ambient Temperature Range	
Output Current (each transistor) .....	0 to 50mA	SG1524 .....	-55°C to 125°C
Reference Load Current .....	0 to 20mA	SG2524 .....	-25°C to 85°C
Oscillator Charging Current .....	30μA to 2mA	SG3524 .....	0°C to 70°C

Note 2: Range over which the device is functional and parameter limits are guaranteed.

## ELECTRICAL SPECIFICATIONS

(+V<sub>IN</sub> = 20V, and over operating temperature, unless otherwise specified.)

Parameter	Test Conditions	SG1524/2524			SG3524			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Reference Section (Note 3)</b>								
Output Voltage	T <sub>J</sub> = 25°C	4.80	5.00	5.20	4.60	5.00	5.40	V
Line Regulation	V <sub>IN</sub> = 8V to 40V			20			30	mV
Load Regulation	I <sub>L</sub> = 0 to 20mA			50			50	mV
Temperature Stability (Note 7)	Over Operating Temperature Range			50			50	mV
Total Output Voltage Range (Note 7)	Over Line, Load and Temperature	4.80		5.20	4.60		5.40	V
Short Circuit Current	V <sub>REF</sub> = 0V	25	50	150	25	50	150	mA

Note 3. I<sub>L</sub> = 0mA



**ELECTRICAL SPECIFICATIONS** (continued)

Parameter	Test Conditions	SG1524/2524			SG3524			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Oscillator Section</b> (Note 4)								
Initial Accuracy	$T_J = 25^\circ\text{C}$	36	40	44	36	40	44	KHz
	$\text{MIN} \leq T_J \leq \text{MAX}$	34		46	34		46	KHz
Voltage Stability	$V_{IN} = 8\text{V to }40\text{V}$		0.1	1		0.1	1	%
Maximum Frequency	$R_T = 2\text{K}\Omega, C_T = 1\text{nF}$	200	400		200	400		KHz
Sawtooth Peak Voltage	$V_{IN} = 40\text{V}$	3		3.8	3		3.8	V
Sawtooth Valley Voltage	$V_{IN} = 8\text{V}$	0.6	1	1.2	0.6	1	1.2	V
Clock Amplitude		3.2			3.2			V
Clock Pulse Width		0.3		1.5	0.3		1.5	$\mu\text{s}$
<b>Error Amplifier Section</b> (Note 5)								
Input Offset Voltage	$R_S \leq 2\text{K}\Omega$		0.5	5		2	10	mV
Input Bias Current			1	10		1	10	$\mu\text{A}$
Input Offset Current				1			2	$\mu\text{A}$
DC Open Loop Gain	$R_L \geq 10\text{M}\Omega, T_J = 25^\circ\text{C}$	72			60			dB
Output Low Level	$V_{PIN1} - V_{PIN2} \geq 150\text{mV}$		0.2	0.5		0.2	0.5	V
Output High Level	$V_{PIN2} - V_{PIN1} \geq 150\text{mV}$	3.8	4.2		3.8	4.2		V
Common Mode Rejection	$V_{CM} = 1.8\text{V to }3.4\text{V}$	70						dB
Supply Voltage Rejection	$V_{IN} = 8\text{V to }40\text{V}$	55						dB
Gain-Bandwidth Product (Note 7)	$T_J = 25^\circ\text{C}$	1	2		1	2		MHz
<b>P.W.M. Comparator</b> (Note 4)								
Minimum Duty Cycle	$V_{COMP} = 0.5\text{V}$			0			0	%
Maximum Duty Cycle	$V_{COMP} = 3.6\text{V}$	45	49		45	49		%
<b>Current Limit Amplifier Section</b> (Note 6)								
Sense Voltage	$T_J = 25^\circ\text{C}$	190	200	210	180	200	220	mV
Input Bias Current				200			200	$\mu\text{A}$
<b>Shutdown Section</b>								
Threshold Voltage	$T_J = 25^\circ\text{C}$	0.5	0.8	1.2	0.5	0.8	1.2	V
	$\text{MIN} \leq T_J \leq \text{MAX}$	0.2		1.8	0.2		1.8	V
<b>Output Section</b> (each transistor)								
Collector Leakage Current	$V_{CE} = 40\text{V}$			50			50	$\mu\text{A}$
Collector Saturation Voltage	$I_C = 50\text{mA}$			2			2	V
Emitter Output Voltage	$I_E = 50\text{mA}$	17			17			V
Collector Voltage Rise Time	$R_C = 2\text{K}\Omega$			0.4			0.4	$\mu\text{s}$
Collector Voltage Fall Time	$R_C = 2\text{K}\Omega$			0.2			0.2	$\mu\text{s}$
<b>Power Consumption</b>								
Standby Current	$V_{IN} = 40\text{V}$		7	10		7	10	mA

Note 4.  $F_{OSC} = 40\text{KHz}$  ( $R_T = 2.9\text{K}\Omega, C_T = .01\mu\text{F}$ )

Note 5.  $V_{CM} = 2.5\text{V}$

Note 6.  $V_{CM} = 0\text{V}$

Note 7. These parameters, although guaranteed over the recommended operating conditions, are not 100% tested in production.

**APPLICATION NOTES**

**OSCILLATOR**

The oscillator in the SG1524 uses an external resistor  $R_T$  to establish a constant charging current into an external capacitor  $C_T$ . While this uses more current than a series-connected RC, it provides a linear ramp voltage at  $C_T$  which is used as a time-dependent reference for the PWM comparator. The charging current is equal to  $3.6V/R_T$ , and should be restricted to between  $30\mu A$  and  $2mA$ . The equivalent range for  $R_T$  is  $1.8K$  to  $100K$ .

The range of values for  $C_T$  also has limits, as the discharge time of  $C_T$  determines the pulse width of the oscillator output pulse. The pulse is used (among other things) as a blanking pulse to both outputs to insure that there is no possibility of having both outputs on simultaneously during transitions. This output deadtime relationship is shown in Figure 1. A pulse width below  $0.35$  microseconds may cause failure of the internal flip-flop to toggle. This restricts the minimum value of  $C_T$  to  $1000pF$ . (Note: Although the oscillator output is a convenient oscilloscope sync input, the probe capacitance will increase the pulse width and decrease the oscillator frequency slightly.) Obviously, the upper limit to the pulse width is determined by the modulation range required in the power supply at the chosen switching frequency. Practical values of  $C_T$  fall between  $1000pF$  and  $0.1\mu F$ , although successful  $120$  Hz oscillators have been implemented with values up to  $5\mu F$  and a series surge limit resistor of  $100$  ohms.

The oscillator frequency is approximately  $1/R_T \cdot C_T$ ; where  $R$  is in ohms,  $C$  is in microfarads, and the frequency is in Megahertz. For greater accuracy, the chart in Figure 2 may be used for a wide range of operating frequencies.

Note that for buck regulator topologies, the two outputs can be wire-ORed for an effective  $0-90\%$  duty cycle range. With this connection, the output frequency is the same as the oscillator frequency. For push-pull applications, the outputs are used separately; the flip-flop limits the duty cycle range at each output to  $0-45\%$ , and the effective switching frequency at the transformer is  $1/2$  the oscillator frequency.

If it is desired to synchronize the SG1524 to an external clock, a positive pulse may be applied to the clock pin. The oscillator should be programmed with  $R_T$  and  $C_T$  values that cause it to free-run at  $90\%$  of the external sync frequency. A sync pulse with a maximum logic 0 of  $+0.3$  volts and a minimum logic 1 of  $+2.4$  volts applied to Pin 3 will lock the oscillator to the external source. The minimum sync pulsewidth should be  $200$  nanoseconds, and the maximum is determined by the required deadtime. The clock pin should never be driven more negative than  $-0.3$  volts, nor more positive than  $+5.0$  volts. The nominal resistance to ground is  $3.2K$  at the clock pin,  $\pm 25\%$  over temperature.

If two or more SG1524s must be synchronized together, program one master unit with  $R_T$  and  $C_T$  for the desired frequency. Leave the  $R_T$  pins on the slaves open, connect the  $C_T$  pins to the  $C_T$  of the master, and connect the clock pins to the clock pin of the master. Since  $C_T$  is a high-impedance node, this sync technique works best when all devices are close together.

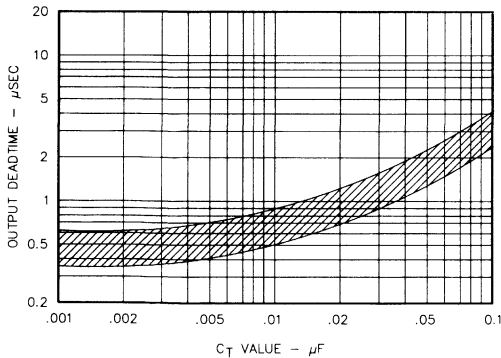


FIGURE 1 - OUTPUT STAGE DEADTIME VS.  $C_T$

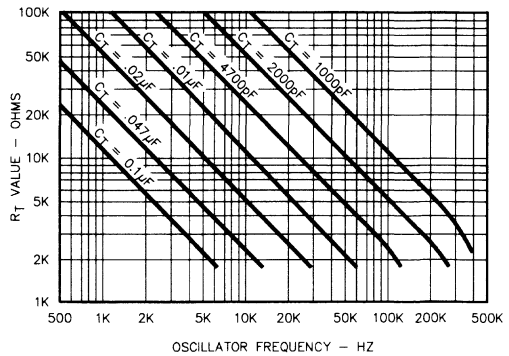


FIGURE 2 - OSCILLATOR FREQUENCY VS.  $R_T$  AND  $C_T$

## APPLICATION NOTES (continued)

### CURRENT LIMITING

The current limiting circuitry of the SG1524 is shown in Figure 3. By matching the base-emitter voltages of Q1 and Q2, and assuming a negligible voltage drop across R1:

$$\begin{aligned} \text{C.L. Threshold} &= V_{BE}(Q1) + I_1 \cdot R_2 - V_{BE}(Q2) = I_1 \cdot R_2 \\ &\sim 200 \text{ mV} \end{aligned}$$

Although this circuit provides a relatively small threshold with a negligible temperature coefficient, there are some limitations to its use because of its simplicity.

The most important of these is the limited common-mode voltage range:  $\pm 0.3$  volts around ground. This requires sensing in the ground or return line of the power supply. Also precautions should be taken to not turn on the parasitic substrate diode of the integrated circuit, even under transient conditions. A Schottky clamp diode at Pin 5 may be required in some configurations to achieve this.

A second factor to consider is that the response time is relatively slow. The current limit amplifier is internally compensated by  $R_1$ ,  $C_1$ , and Q1, resulting in a roll-off pole at approximately 300

Hz.

A third factor to consider is the bias current of the C.L. Sense pins. A constant current of approximately  $150\mu\text{A}$  flows out of Pin 4, and a variable current with a range of  $0\text{-}150\mu\text{A}$  flows out of Pin 5. As a result, the equivalent source impedance seen by the current sense pins should be less than 50 ohms to keep the threshold error less than 5%.

Since the gain of this circuit is relatively low (42 dB), there is a transition region as the current limit amplifier takes over pulse width control from the error amplifier. For testing purposes, threshold is defined as the input voltage required to get 25% duty cycle (+2 volts at the error amplifier output) with the error amplifier signaling maximum duty cycle.

*APPLICATION NOTE: If the current limit function is not used on the SG1524, the common-mode voltage range restriction requires both current sense pins to be grounded.*

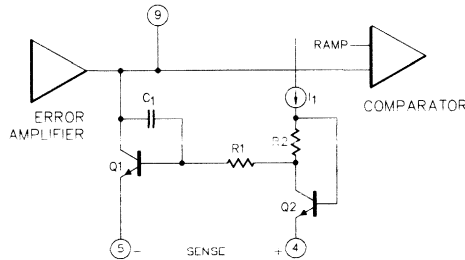
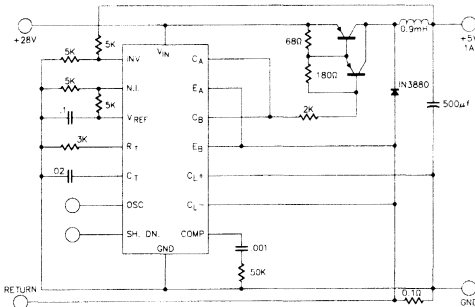
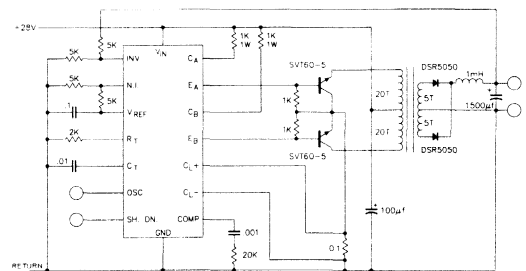


FIGURE 3 - CURRENT LIMITING CIRCUITRY OF THE SG1524



In this conventional single-ended regulator circuit, the two outputs of the SG1524 are connected in parallel for effective 0 - 90% duty-cycle modulation. The use of an output inductor requires and R-C phase compensation network for loop stability.



Push-pull outputs are used in this transformer-coupled DC-DC regulating converter. Note that the oscillator must be set at twice the desired output frequency as the SG1524's internal flip-flop divides the frequency by 2 as it switches the P.W.M. signal from one output to the other. Current limiting is done here in the primary so that the pulse width will be reduced should transformer saturation occur.

# SG1524/SG2524/SG3524

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
16-PIN CERAMIC DIP J - PACKAGE	SG1524J/883B SG1524J SG2524J SG3524J	-55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C	
16-PIN PLASTIC DIP N - PACKAGE	SG2524N SG3524N	-25°C to 85°C 0°C to 70°C	
16-PIN NARROW BODY PLASTIC S.O.I.C. D - PACKAGE	SG2524D SG3524D	-25°C to 85°C 0°C to 70°C	
16-PIN CERAMIC FLAT PACK F - PACKAGE	SG1524F/883B SG1524F	-55°C to 125°C -55°C to 125°C	
20-PIN CERAMIC LEADLESS CHIP CARRIER L - PACKAGE	SG1524L/883B SG1524L	-55°C to 125°C -55°C to 125°C	

Note 1. Contact factory for JAN and DESC product availability.  
 Note 2. All packages are viewed from the top.

**REGULATING PULSE WIDTH MODULATOR**

**DESCRIPTION**

The SG1524B is a pulse width modulator for switching power supplies which features improved performance over industry standards like the SG1524. A direct pin-for-pin replacement for the earlier device, it combines advanced processing techniques and circuit design to provide improved reference accuracy, and extended common mode range at the error amplifier and current limit inputs. A DC-coupled flip-flop eliminates triggering and glitch problems, and a PWM data latch prevents edge oscillations. The circuit incorporates true digital shutdown for high speed response, while an undervoltage lockout circuit prevents spurious outputs when the supply voltage is too low for stable operation. Full double-pulse suppression logic insures alternating output pulses when the Shutdown pin is used for pulse-by-pulse current limiting. The SG1524B is specified for operation over the full military ambient temperature range of -55°C to 125°C. The SG2524B is characterized for the industrial range of -25°C to 85°C, and the SG3524B is designed for the commercial range of 0°C to 70°C.

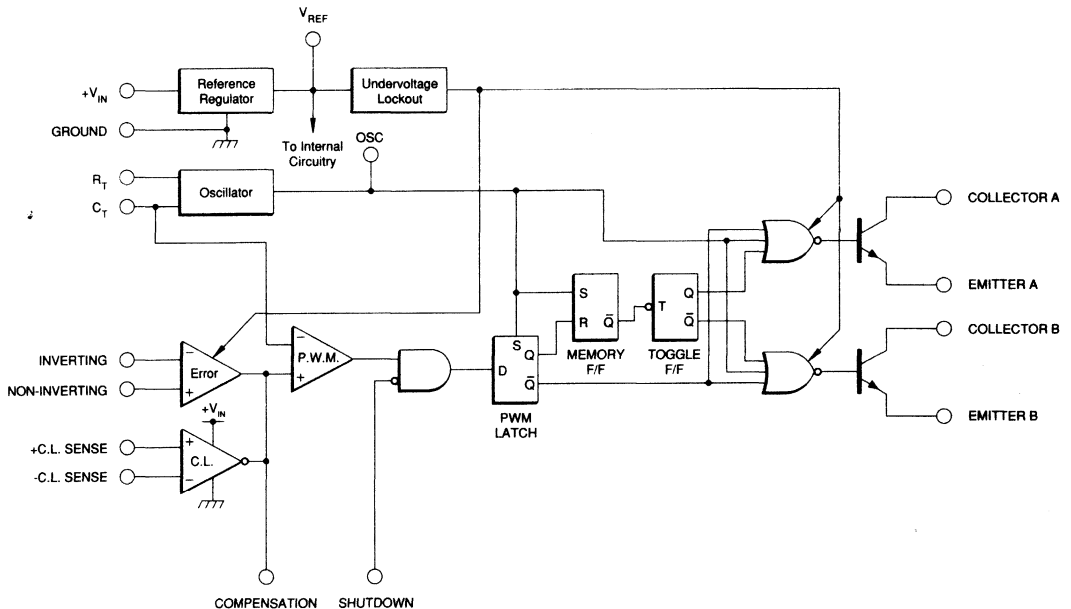
**FEATURES**

- 7V to 40V operation
- 5V reference trimmed to ±1%
- 100Hz to 400KHz oscillator range
- Excellent external sync capability
- Dual 100mA output transistors
- Wide current limit common mode range
- DC-coupled toggle flip-flop
- PWM data latch
- Undervoltage lockout
- Full double-pulse suppression logic
- 60V output collectors

**HIGH RELIABILITY FEATURES  
- SG1524B**

- ◆ Available to MIL-STD-883 and DESC SMD
- ◆ Scheduled for MIL-M-38510 QPL listing
- ◆ Radiation data available
- ◆ SG level "S" processing available

**BLOCK DIAGRAM**



# SG1524B/SG2524B/SG3524B

## ABSOLUTE MAXIMUM RATINGS (Note 1)

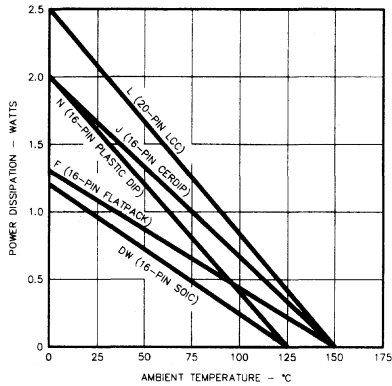
Input Voltage (+V<sub>IN</sub>) ..... 42V  
 Collector Voltage ..... 60V  
 Logic Inputs ..... -0.3V to 5.5V  
 Current Limit Sense Inputs ..... -0.3V to V<sub>IN</sub>  
 Output Current (each transistor) ..... 200mA  
 Reference Load Current ..... 50mA

Oscillator Charging Current ..... 5mA  
 Operating Junction Temperature  
     Hermetic (J, F, L Packages) ..... 175°C  
     Plastic (N, DW Packages) ..... 150°C  
 Storage Temperature Range ..... -65°C to 150°C  
 Lead Temperature (Soldering, 10 seconds) ..... 300°C

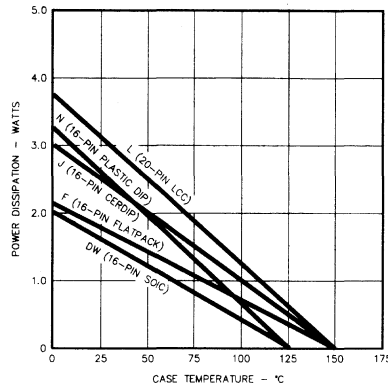
Note 1. Values beyond which damage may occur.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Input Voltage (+V<sub>IN</sub>) ..... 7V to 40V  
 Collector Voltage ..... 0V to 60V  
 Error Amp Common Mode Range ..... 2.3V to V<sub>REF</sub>  
 Current Limit Sense Common Mode Range ..... 0V to V<sub>IN</sub>-2.5V  
 Output Current (each transistor) ..... 0 to 100mA  
 Reference Load Current ..... 0 to 20mA  
 Oscillator Charging Current ..... 25µA to 1.8mA

Oscillator Frequency Range ..... 100Hz to 400KHz  
 Oscillator Timing Resistor (R<sub>T</sub>) ..... 2KΩ to 150KΩ  
 Oscillator Timing Capacitor (C<sub>T</sub>) ..... 1nF to 0.1µF  
 Operating Ambient Temperature Range  
     SG1524B ..... -55°C to 125°C  
     SG2524B ..... -25°C to 85°C  
     SG3524B ..... 0°C to 70°C

Note 2: Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(+V<sub>IN</sub> = 20V, and over operating temperature, unless otherwise specified.)

Parameter	Test Conditions	SG1524B/2524B			SG3524B			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Reference Section (Note 3)</b>								
Output Voltage	T <sub>J</sub> = 25°C	4.95	5.00	5.05	4.90	5.00	5.10	V
Line Regulation	V <sub>IN</sub> = 7V to 40V		3	20		3	30	mV
Load Regulation	I <sub>L</sub> = 0 to 20mA		5	30		5	50	mV
Temperature Stability (Note 7)	Over Operating Temperature Range		15	50		15	50	mV
Total Output Voltage Range	Over Line, Load and Temperature	4.90		5.10	4.80		5.20	V
Short Circuit Current	V <sub>REF</sub> = 0V	25	50	120	25	50	120	mA
<b>Undervoltage Lockout Section</b>								
Threshold Voltage		4.3	4.5	4.7	4.3	4.5	4.7	V

Note 3. I<sub>L</sub> = 0mA

# SG1524B/SG2524B/SG3524B

## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG1524B/2524B			SG3524B			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Oscillator Section (Note 4)</b>								
Initial Accuracy	$T_J = 25^\circ\text{C}$	42	45	48	40	45	50	KHz
Voltage Stability	$V_{IN} = 7\text{V to }40\text{V}$		0.1	1		0.1	1	%
Temperature Stability (Note 9)	Over Operating Range		1	2		1	2	%
Minimum Frequency	$R_T = 150\text{K}\Omega, C_T = 0.1\mu\text{F}$		50	140		50	120	Hz
Maximum Frequency	$R_T = 2\text{K}\Omega, C_T = 470\text{pF}$	400	600		400	600		KHz
Sawtooth Peak Voltage	$V_{IN} = 40\text{V}$		3.5	3.9		3.5	3.9	V
Sawtooth Valley Voltage	$V_{IN} = 7\text{V}$	0.6	1		0.6	1		V
Clock Amplitude		3.0	4.0		3.0	4.0		V
Clock Pulse Width		0.2	0.5	1.2	0.2	0.5	1.2	$\mu\text{s}$
<b>Error Amplifier Section (Note 5)</b>								
Input Offset Voltage	$R_B \leq 2\text{K}\Omega$		0.5	5		2	10	mV
Input Bias Current			1	5		1	10	$\mu\text{A}$
Input Offset Current				1			1	$\mu\text{A}$
DC Open Loop Gain	$R_L \geq 10\text{M}\Omega$	60	78		60	78		dB
Output Low Level	$I_{\text{SINK}} = 100\mu\text{A}; V_{\text{PIN}1} - V_{\text{PIN}2} \geq 150\text{mV}$		0.2	0.5		0.2	0.5	V
Output High Level	$I_{\text{SOURCE}} = 100\mu\text{A}; V_{\text{PIN}2} - V_{\text{PIN}1} \geq 150\text{mV}$	3.8	4.2		3.8	4.2		V
Common Mode Rejection	$V_{\text{CM}} = 2.3\text{V to }V_{\text{REF}}$	70	90		70	90		dB
Supply Voltage Rejection	$V_{IN} = 7\text{V to }40\text{V}$	76	100		76	100		dB
Gain-Bandwidth Product (Note 7)	$T_A = 25^\circ\text{C}$	1	2		1	2		MHz
<b>P.W.M. Comparator (Note 4)</b>								
Minimum Duty Cycle	$V_{\text{COMP}} = 0.5\text{V}$			0			0	%
Maximum Duty Cycle	$V_{\text{COMP}} = 3.9\text{V}$	45	49		45	49		%
<b>Current Limit Amplifier Section (Note 6)</b>								
Sense Voltage		180	200	220	170	200	230	mV
Input Bias Current			-3	-10		-3	-10	$\mu\text{A}$
<b>Shutdown Input Section</b>								
HIGH Input Voltage		2.0			2.0			V
HIGH Input Current	$V_{\text{SHUTDOWN}} = 5.0\text{V}$		0.1	1		0.1	1	mA
LOW Input Voltage				0.6			0.6	V
<b>Output Section (each transistor)</b>								
Collector Leakage Current	$V_{\text{CE}} = 60\text{V}$			50			50	$\mu\text{A}$
Collector Saturation Voltage	$I_C = 10\text{mA}$		0.2	0.4		0.2	0.4	V
	$I_C = 100\text{mA}$		1.0	2.0		1.0	2.0	V
Emitter Output Voltage	$I_E = 10\text{mA}$	17.5	19		17.5	19		V
	$I_E = 100\text{mA}$	17	18		17	18		V
Emitter Voltage Rise Time (Note 7)	$R_E = 2\text{K}\Omega, T_A = 25^\circ\text{C}$		0.2	0.5		0.2	0.5	$\mu\text{s}$
Collector Voltage Fall Time	$R_C = 2\text{K}\Omega, T_A = 25^\circ\text{C}$		0.1	0.2		0.1	0.2	$\mu\text{s}$
<b>Power Consumption</b>								
Standby Current	$V_{IN} = 40\text{V}, V_{\text{SHUTDOWN}} = 2.0\text{V}$		5	12		5	12	mA

Note 4.  $f_{\text{OSC}} = 43\text{KHz}$  ( $R_T = 2700\Omega, C_T = .01\mu\text{F}$ )

Note 5.  $V_{\text{CM}} = 2.3\text{V to }V_{\text{REF}}$

Note 6.  $V_{\text{CM}} = 0\text{V to }17.5\text{V}$

Note 7. These parameters, although guaranteed over the recommended operating conditions, are not tested in production.

# SG1524B/SG2524B/SG3524B

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
16-PIN CERAMIC DIP J - PACKAGE	SG1524BJ/883B SG1524BJ SG2524BJ SG3524BJ	-55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C	
16-PIN PLASTIC DIP N - PACKAGE	SG2524BN SG3524BN	-25°C to 85°C 0°C to 70°C	
16-PIN WIDE BODY PLASTIC S.O.I.C. DW - PACKAGE	SG2524BDW SG3524BDW	-25°C to 85°C 0°C to 70°C	
16-PIN CERAMIC FLAT PACK F - PACKAGE	SG1524BF/883B SG1524BF	-55°C to 125°C -55°C to 125°C	
20-PIN CERAMIC LEADLESS CHIP CARRIER L- PACKAGE	SG1524BL/883B SG1524BL	-55°C to 125°C -55°C to 125°C	

Note 1. Contact factory for JAN and DESC product availability.  
 2. All packages are viewed from the top.



**REGULATING PULSE WIDTH MODULATOR**

**DESCRIPTION**

The SG1525A/1527A series of pulse width modulator integrated circuits are designed to offer improved performance and lower external parts count when used to implement all types of switching power supplies. The on-chip +5.1 volt reference is trimmed to  $\pm 1\%$  initial accuracy and the input common-mode range of the error amplifier includes the reference voltage, eliminating external potentiometers and divider resistors. A Sync input to the oscillator allows multiple units to be slaved together, or a single unit to be synchronized to an external system clock. A single resistor between the  $C_T$  pin and the Discharge pin provides a wide range of deadtime adjustment. These devices also feature built-in soft-start circuitry with only a timing capacitor required externally. A Shutdown pin controls both the soft-start circuitry and the output stages, providing instantaneous turn-off with soft-start recycle for slow turn-on. These functions are also controlled by an undervoltage lockout which keeps the outputs off and the soft-start capacitor discharged for input voltages less than that required for normal operation. Another unique feature of these PWM circuits is a latch following the comparator. Once a PWM pulse has been terminated for any reason, the outputs will remain off for the duration of the period. The latch is reset with each clock pulse. The output stages are totem-pole designs capable of sourcing or sinking in excess of 200mA. The SG1525A output stage features NOR logic, giving a LOW output for an OFF state. The SG1527A utilizes OR logic which results in a HIGH output level when OFF.

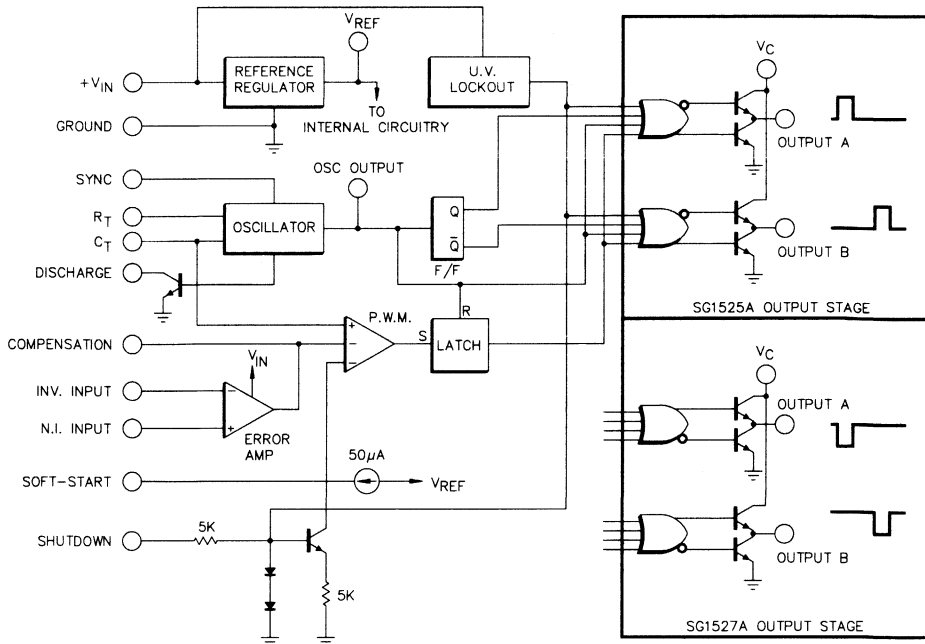
**FEATURES**

- 8V to 35V operation
- 5.1V reference trimmed to  $\pm 1\%$
- 100Hz to 500KHz oscillator range
- Separate oscillator sync terminal
- Adjustable deadtime control
- Internal soft-start
- Input undervoltage lockout
- Latching P.W.M. to prevent multiple pulses
- Dual source/sink output drivers

**HIGH RELIABILITY FEATURES**

- SG1525A, SG1527A
- ◆ Available to MIL-STD-883B
- ◆ Scheduled for MIL-M-38510 QPL listing
- ◆ Radiation data available
- ◆ SG level "S" processing available

**BLOCK DIAGRAM**



# SG1525A/SG1527A SERIES

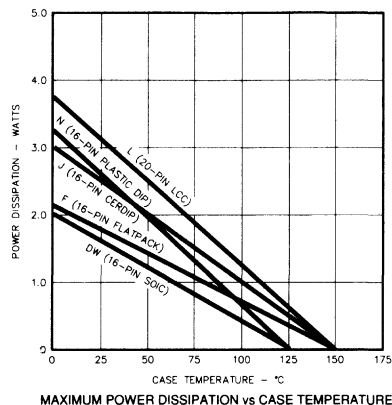
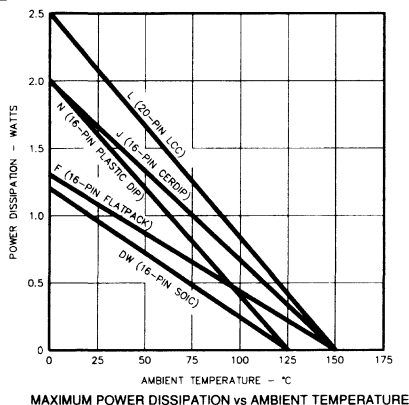
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage (+V <sub>IN</sub> ) .....	40V	Oscillator Charging Current .....	5mA
Collector Supply Voltage (V <sub>C</sub> ) .....	40V	Operating Junction Temperature Range	
Logic Inputs .....	-0.3V to 5.5V	Hermetic (J, F, L Packages) .....	175°C
Analog Inputs .....	-0.3V to V <sub>IN</sub>	Plastic (N, DW Packages) .....	150°C
Output Current, Source or Sink .....	500mA	Storage Temperature Range .....	-65°C to 150°C
Reference Load Current .....	50mA	Lead Temperature (Soldering, 10 seconds) .....	300°C

Note 1. Values beyond which damage may occur.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



### ELECTRICAL

Input Voltage (+V <sub>IN</sub> ) .....	8V to 35V	Deadtime Resistor Range (R <sub>D</sub> ) .....	0Ω to 500Ω
Collector Voltage (V <sub>C</sub> ) .....	4.5V to 35V	Oscillator Timing Capacitor (C <sub>T</sub> ) .....	0.001μF to 0.1μF
Sink/Source Load Current (steady state) .....	0 to 100mA	Operating Ambient Temperature Range	
Sink/Source Load Current (peak) .....	0 to 400mA	SG1525A/SG1527A .....	-55°C to 125°C
Reference Load Current .....	0 to 20mA	SG2525A/SG2527A .....	-25°C to 85°C
Oscillator Frequency Range .....	100Hz to 350KHz	SG3525A/SG3527A .....	0°C to 70°C
Oscillator Timing Resistor (R <sub>T</sub> ) .....	2KΩ to 150KΩ		

Note 2: Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(+V<sub>IN</sub> = 20V, and over operating temperature, unless otherwise specified.)

Parameter	Test Conditions	SG1525A/2525A SG1527A/2527A			SG3525A SG3527A			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Reference Section</b>								
Output Voltage	T <sub>J</sub> = 25°C	5.05	5.10	5.15	5.00	5.10	5.20	V
Line Regulation	V <sub>IN</sub> = 8V to 35V		10	30		10	30	mV
Load Regulation	I <sub>L</sub> = 0 to 20mA		20	50		20	50	mV
Temperature Stability (Note 3)	Over Operating Temperature Range		20	50		20	50	mV
Total Output Voltage Range (Note 3)	Over Line, Load and Temperature	5.00		5.20	4.95		5.25	V
Short Circuit Current	V <sub>REF</sub> = 0V, T <sub>J</sub> = 25°C		80	100		80	100	mA
Output Noise Voltage (Note 3)	10Hz ≤ f ≤ 10KHz, T <sub>J</sub> = 25°C		40	200		40	200	μVrms
Long Term Stability (Note 3)	T <sub>J</sub> = 125°C		20	50		20	50	mV/khr

Note 3. These parameters, although guaranteed over the recommended operating conditions, are not 100% tested in production.

Note 4. F<sub>osc</sub> = 40KHz (R<sub>T</sub> = 3.6KΩ, C<sub>T</sub> = 0.01μF, R<sub>D</sub> = 0Ω)

Note 5. Applies to SG1525A/2525A/3525A only, due to polarity of output pulses.

# SG1525A/SG1527A SERIES

## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG1525A/2525A SG1527A/2527A			SG3525A SG3527A			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Oscillator Section (Note 4)</b>								
Initial Accuracy	$T_J = 25^\circ\text{C}$	37.6	40	42.4	37.6	40	42.4	KHz
Voltage Stability	$V_{IN} = 8\text{V to }35\text{V}$		$\pm 0.3$	$\pm 1$		$\pm 1$	$\pm 2$	%
Temperature Stability (Note 3)	$\text{MIN} \leq T_J \leq \text{MAX}$		$\pm 3$	$\pm 6$		$\pm 3$	$\pm 6$	%
Minimum Frequency (Note 3)	$R_T = 150\text{K}\Omega, C_T = .01\mu\text{F}$			150			150	Hz
Maximum Frequency (Note 3)	$R_T = 2\text{K}\Omega, C_T = 1\text{nF}$	350			350			KHz
Current Mirror	$I_{RT} = 2\text{mA}$	1.7	2.0	2.2	1.7	2.0	2.2	mA
Clock Amplitude		3.0	3.5		3.0	3.5		V
Clock Width	$T_J = 25^\circ\text{C}$	0.3	0.5	1.0	0.3	0.5	1.0	$\mu\text{s}$
Sync Threshold		1.2	2.0	2.8	1.2	2.0	2.8	V
Sync Input Current	Sync Voltage = 3.5V		1.0	2.5		1.0	2.5	mA
<b>Error Amplifier Section (<math>V_{CM} = 5.1\text{V}</math>)</b>								
Input Offset Voltage			0.5	5		2	10	mV
Input Bias Current			1	10		1	10	$\mu\text{A}$
Input Offset Current				1			1	$\mu\text{A}$
DC Open Loop Gain	$R_L \geq 10\text{M}\Omega, T_J = 25^\circ\text{C}$	60	75		60	75		dB
Gain-Bandwidth Product (Note 3)	$A_v = 0\text{dB}, T_J = 25^\circ\text{C}$	1	2		1	2		MHz
Output Low Level			0.2	0.5		0.2	0.5	V
Output High Level		3.8	5.6		3.8	5.6		V
Common Mode Rejection	$V_{CM} = 1.5\text{V to }5.2\text{V}$	60	75		60	75		dB
Supply Voltage Rejection	$V_{IN} = 8\text{V to }35\text{V}$	50	60		50	60		dB
<b>P.W.M. Comparator Section</b>								
Minimum Duty Cycle	$V_{COMP} = 0.6\text{V}$			0			0	%
Maximum Duty Cycle	$V_{COMP} = 3.6\text{V}$	45	49		45	49		%
Input Threshold (Note 4)	Zero Duty Cycle	0.6	0.9		0.6	0.9		V
	Maximum Duty Cycle		3.3	3.6		3.3	3.6	V
Input Bias Current			.05	2.0		.05	2.0	$\mu\text{A}$
<b>Soft-Start Section</b>								
Soft Start Current	$V_{SHUTDOWN} = 0\text{V}$	25	50	80	25	50	80	$\mu\text{A}$
Soft Start Voltage	$V_{SHUTDOWN} = 2\text{V}$		0.4	0.6		0.4	0.6	V
Shutdown Input Current	$V_{SHUTDOWN} = 2.5\text{V}$		0.4	1.0		0.4	1.0	mA
<b>Output Drivers Section (each transistor, <math>V_C = 20\text{V}</math>)</b>								
Output High Level	$I_{SOURCE} = 20\text{mA}$	18	19		18	19		V
	$I_{SOURCE} = 100\text{mA}$	17	18		17	18		V
Output Low Level	$I_{SINK} = 20\text{mA}$		0.2	0.4		0.2	0.4	V
	$I_{SINK} = 100\text{mA}$		1.0	2.2		1.0	2.2	V
Undervoltage Lockout	$V_{COMP}$ and $V_{SS} = \text{High}$	6	7	8	6	7	8	V
Collector Leakage (Note 5)	$V_C = 35\text{V}$			200			200	$\mu\text{A}$
Rise Time	$C_L = 1\text{nF}, T_J = 25^\circ\text{C}$		100	600		100	600	ns
Fall Time	$C_L = 1\text{nF}, T_J = 25^\circ\text{C}$		50	300		50	300	ns
Shutdown Delay (Note 3)	$V_{SD} = 3\text{V}, C_6 = 0, T_J = 25^\circ\text{C}$		0.2	0.5		0.2	0.5	$\mu\text{s}$
<b>Total Standby Current</b>								
Standby Current	$V_{IN} = 35\text{V}$		14	20		14	20	mA

OSCILLATOR SECTION

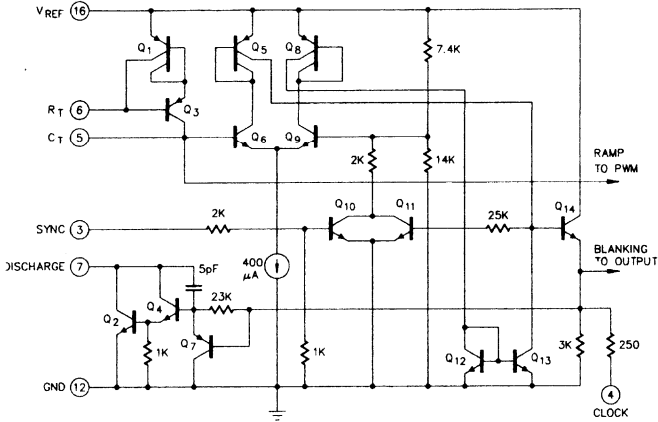


FIGURE 3 - OSCILLATOR SCHEMATIC

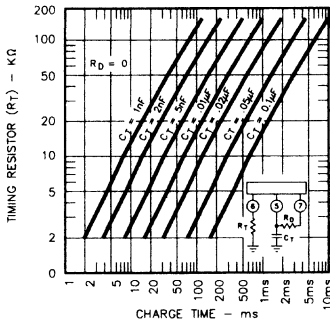


FIGURE 2 - OSCILLATOR CHARGE TIME VS.  $R_T$  AND  $C_T$

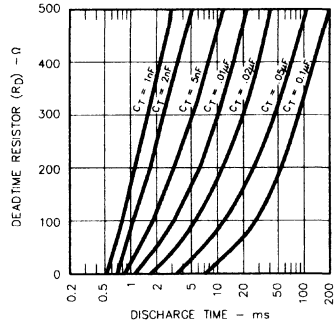


FIGURE 3 - OSCILLATOR DISCHARGE TIME VS.  $R_D$  AND  $C_T$

ERROR AMPLIFIER SECTION

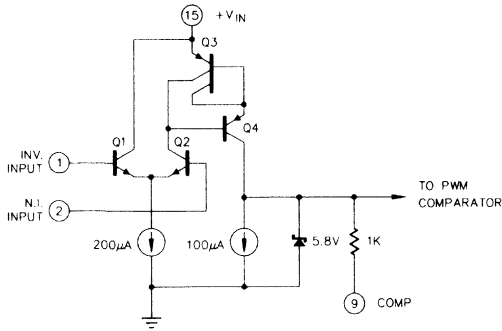


FIGURE 4 - ERROR AMPLIFIER

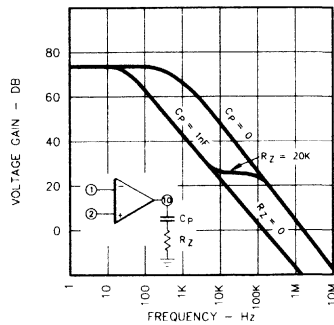


FIGURE 5 - ERROR AMPLIFIER OPEN-LOOP FREQUENCY RESPONSE

# SG1525A/SG1527A SERIES

## OUTPUT SECTION

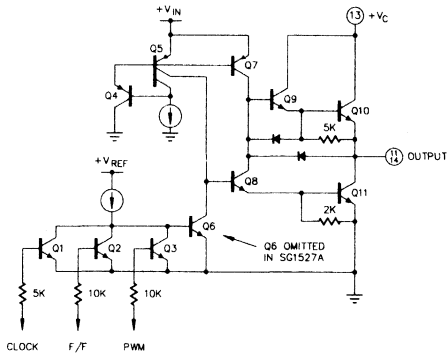


FIGURE 6 - OUTPUT CIRCUIT (1/2 Circuit Shown)

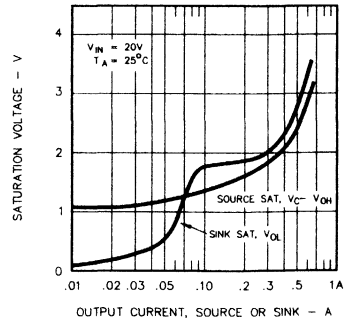
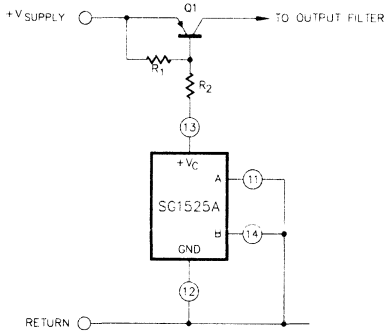
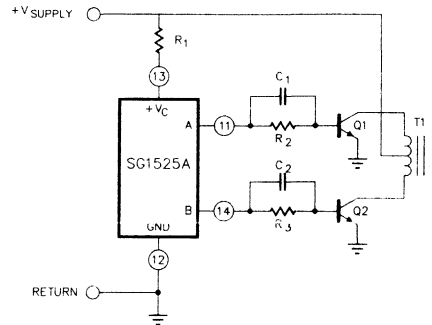


FIGURE 7 - OUTPUT SATURATION CHARACTERISTICS

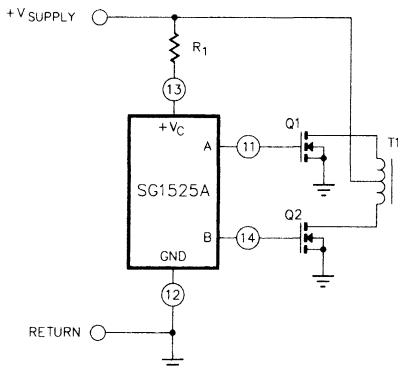
## APPLICATION INFORMATION



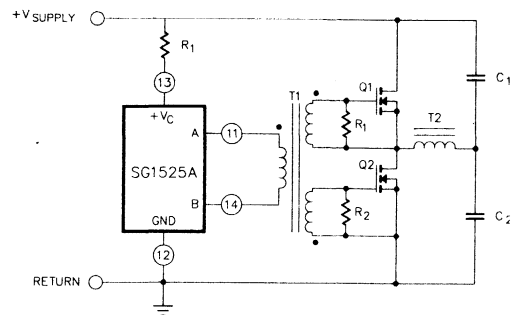
For single-ended supplies, the driver outputs are grounded. The  $V_c$  terminal is switched to ground by the totem-pole source transistors on alternate oscillator cycles.



In conventional push-pull bipolar designs, forward base drive is controlled by  $R_1 - R_3$ . Rapid turn-off times for the power devices are achieved with speed-up capacitors  $C_1$  and  $C_2$ .



The low source impedance of the output drivers provides rapid charging of power FET input capacitance while minimizing external components.



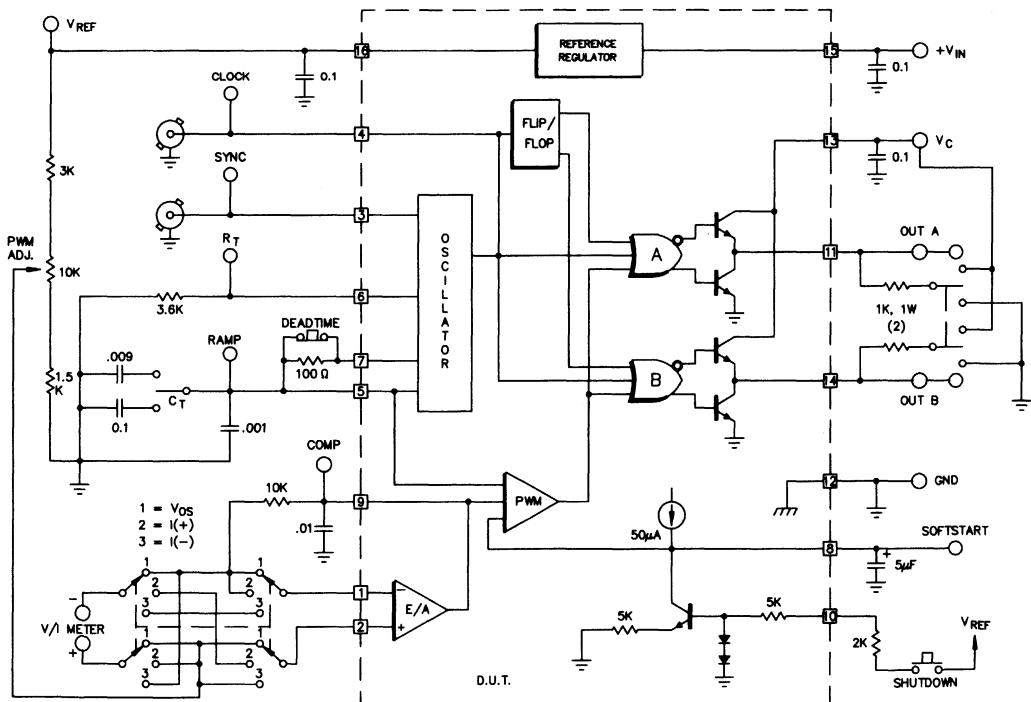
Low power transformers can be driven directly by the SG1525A. Automatic reset occurs during deadtime, when both ends of the primary winding are switched to ground.

## APPLICATION INFORMATION (continued)

### SHUTDOWN OPTIONS

1. Use an external transistor or open-collector comparator to pull down on the Comp terminal. This will set the PWM latch turning off both outputs. If the shutdown signal is momentary, pulse-by-pulse protection can be accomplished as the PWM latch will be reset with each clock pulse.
2. The same results can be accomplished by pulling down on the Soft-Start terminal with the difference that on this pin, shutdown will not affect the amplifier compensation network but must discharge any Soft-Start capacitor.
3. Apply a positive-going signal to the Shutdown terminal. This will provide most rapid shutdown of the outputs but will not immediately set the PWM latch if there is a Soft-Start capacitor. This capacitor will discharge but with a current of approximately twice the charging current.
4. The shutdown terminal can be used to set the PWM latch on a pulse-by-pulse basis if there is no external capacitance on Soft-Start terminal. Slow turn-on may still be accomplished by applying an external capacitor, blocking diode, and charging resistor to the comp terminal. (See SG1524 Application Note).

### SG1525A/1527A LAB TEST FIXTURE



# SG1525A/SG1527A SERIES

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
16-PIN CERAMIC DIP J - PACKAGE	SG1525AJ/883B	-55°C to 125°C	
	SG1525AJ	-55°C to 125°C	
	SG2525AJ	-25°C to 85°C	
	SG3525AJ	0°C to 70°C	
	SG1527AJ/883B	-55°C to 125°C	
	SG1527AJ	-55°C to 125°C	
16-PIN PLASTIC DIP N - PACKAGE	SG2525AN	-25°C to 85°C	
	SG3525AN	0°C to 70°C	
	SG2527AN	-25°C to 85°C	
	SG3527AN	0°C to 70°C	
16-PIN WIDE BODY PLASTIC S.O.I.C. DW - PACKAGE	SG2525ADW	-25°C to 85°C	
	SG3525ADW	0°C to 70°C	
	SG2527ADW	-25°C to 85°C	
	SG3527ADW	0°C to 70°C	
16-PIN CERAMIC FLAT PACK F - PACKAGE	SG1525AF/883B	-55°C to 125°C	
	SG1525AF	-55°C to 125°C	
	SG1527AF/883B	-55°C to 125°C	
	SG1527AF	-55°C to 125°C	
20-PIN CERAMIC LEADLESS CHIP CARRIER L - PACKAGE	SG1525AL/883B	-55°C to 125°C	
	SG1525AL	-55°C to 125°C	
	SG1527AL/883B	-55°C to 125°C	
	SG1527AL	-55°C to 125°C	

Note 1. Contact factory for JAN and DESC product availability.  
 Note 2. All packages are viewed from the top.





**REGULATING PULSE WIDTH MODULATOR**

**DESCRIPTION**

The SG1526 is a high performance monolithic pulse width modulator circuit designed for fixed-frequency switching regulators and other power control applications. Included in an 18-pin dual-in-line package are a temperature compensated voltage reference, sawtooth oscillator, error amplifier, pulse width modulator, pulse metering and steering logic, and two low impedance power drivers. Also included are protective features such as soft-start and undervoltage lockout, digital current limiting, double pulse inhibit, a data latch for single pulse metering, adjustable deadtime, and provision for symmetry correction inputs. For ease of interface, all digital control ports are TTL and B-series CMOS compatible. Active LOW logic design allows wired-OR connections for maximum flexibility. This versatile device can be used to implement single-ended or push-pull switching regulators of either polarity, both transformerless and transformer coupled. The SG1526 is characterized for operation over the full military junction temperature range of -55°C to +150°C. The SG2526 is characterized for operation from -25°C to +150°C, and the SG3526 is characterized for operation from 0°C to +125°C.

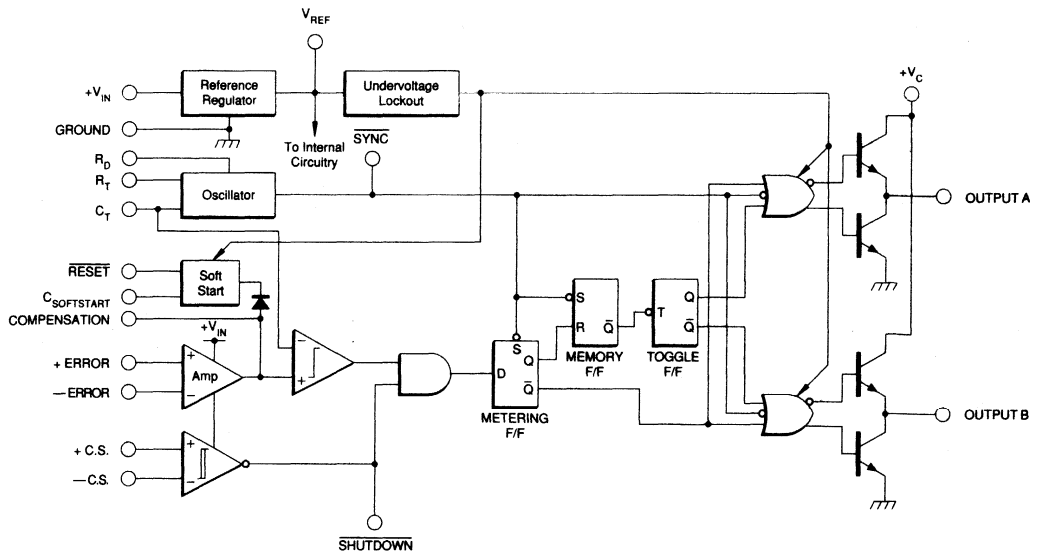
**FEATURES**

- 8 to 35 volt operation
- 5V reference trimmed to ±1%
- 1Hz to 350KHz oscillator range
- Dual 100mA source/sink outputs
- Digital current limiting
- Double pulse suppression
- Programmable deadtime
- Undervoltage lockout
- Single pulse metering
- Programmable soft-start
- Wide current limit common mode range
- TTL/CMOS compatible logic ports
- Symmetry correction capability
- Guaranteed 6 unit synchronization

**HIGH RELIABILITY FEATURES - SG1526**

- ◆ Available to MIL-STD-883B and DESC SMD
- ◆ Radiation data available
- ◆ SG level "S" processing available

**BLOCK DIAGRAM**



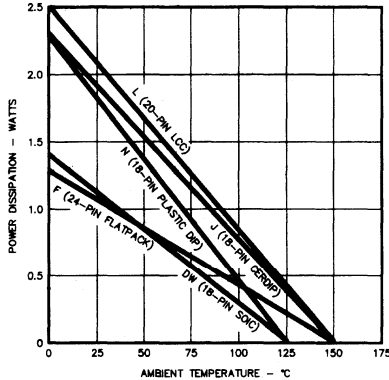
## ABSOLUTE MAXIMUM RATINGS

Input Voltage ( $V_{IN}$ ) .....	40V	Logic Sink Current .....	15mA
Collector Supply Voltage ( $V_C$ ) .....	40V	Operating Junction Temperature	
Logic Inputs .....	-0.3V to 5.5V	Hermetic (J, F, L Packages) .....	175°C
Analog Inputs .....	-0.3V to $V_{IN}$	Plastic (N, DW Packages) .....	150°C
Source/Sink Load Current (each output) .....	200mA	Storage Temperature Range .....	-65°C to 150°C
Reference Load Current .....	50mA	Lead Temperature (Soldering, 10 Seconds) .....	300°C

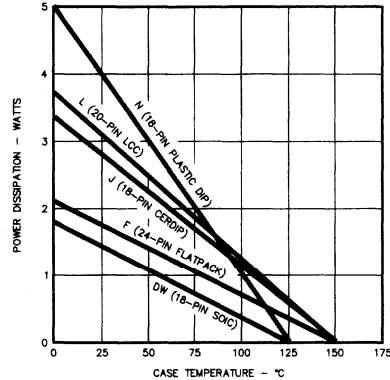
Note 1. Exceeding these ratings could cause damage to the device.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Input Voltage .....	8V to 35V	Oscillator Timing Capacitor .....	1nF to 20 $\mu$ F
Collector Supply Voltage .....	4.5V to 35V	Available Deadtime Range at 40KHz .....	3% to 50%
Sink/Source Load Current (each output) .....	0 to 100mA	Operating Ambient Temperature Range:	
Reference Load Current .....	0 to 20mA	SG1526 .....	-55°C to 125°C
Oscillator Frequency Range .....	1Hz to 350KHz	SG2526 .....	-25°C to 85°C
Oscillator Timing Resistor .....	2K $\Omega$ to 150K $\Omega$	SG3526 .....	0°C to 70°C

Note 2. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

( $V_{IN} = 15V$ , and over operating ambient temperature, unless otherwise specified.)

Parameter	Test Conditions	SG1526/2526			SG3526			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Reference Section (Note 3)</b>								
Output Voltage	$T_J = 25^\circ C$	4.95	5.00	5.05	4.90	5.00	5.10	V
Line Regulation	$V_{IN} = 8$ to 35V		10	30		10	30	mV
Load Regulation	$I_L = 0$ to 20mA		10	30		10	50	mV
Temperature Stability (Note 9)	Over Operating $T_J$		15	50		15	50	mV
Total Output Voltage Range (Note 9)	Over Recommended Operating Conditions	4.90	5.00	5.10	4.85	5.00	5.15	V
Short Circuit Current	$V_{REF} = 0V$		50	125		50	125	mA
<b>Undervoltage Lockout Section</b>								
RESET Output Voltage	$V_{REF} = 3.8V$		0.2	0.4		0.2	0.4	V
RESET Output Voltage	$V_{REF} = 4.8V$	2.4	4.8		2.4	4.8		V

**ELECTRICAL SPECIFICATIONS** (continued)

Parameter	Test Conditions	SG1526/2526			SG3526			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Oscillator Section (Note 4)</b>								
Initial Accuracy	$T_J = 25^\circ\text{C}$		$\pm 3$	$\pm 8$		$\pm 3$	$\pm 8$	%
Voltage Stability	$V_{IN} = 8 \text{ to } 35\text{V}$		0.5	1.0		0.5	1.0	%
Temperature Stability (Note 9)	Over Operating $T_J$		7	10		5	10	%
Minimum Frequency (Note 9)	$R_T = 150\text{K}\Omega$ , $C_T = 20\mu\text{F}$			1.0			1.0	Hz
Maximum Frequency	$R_T = 2\text{K}\Omega$ , $C_T = 1.0\text{nF}$	350			350			KHz
Sawtooth Peak Voltage	$V_{IN} = 35\text{V}$		3.0	3.5		3.0	3.5	V
Sawtooth Valley Voltage	$V_{IN} = 8\text{V}$	0.5	1.0		0.5	1.0		V
<b>Error Amplifier Section (Note 5)</b>								
Input Offset Voltage	$R_S \leq 2\text{K}\Omega$		2	5		2	10	mV
Input Bias Current			-350	-1000		-350	-2000	nA
Input Offset Current			35	100		35	200	nA
DC Open Loop Gain	$R_L \geq 10\text{M}\Omega$ , $T_J = 25^\circ\text{C}$	64	72		60	72		dB
High Output Voltage	$V_{PIN1} - V_{PIN2} \geq 150\text{mV}$ , $I_{SOURCE} = 100\mu\text{A}$	3.6	4.2		3.6	4.2		V
Low Output Voltage	$V_{PIN2} - V_{PIN1} \geq 150\text{mV}$ , $I_{SINK} = 100\mu\text{A}$		0.2	0.4		0.2	0.4	V
Common Mode Rejection	$R_S \leq 2\text{K}\Omega$	70	94		70	94		dB
Supply Voltage Rejection	$V_{IN} = 8\text{V to } 35\text{V}$	66	80		66	80		dB
<b>PWM Comparator Section (Note 4)</b>								
Minimum Duty Cycle	$V_{COMPENSATION} = 0.4\text{V}$			0			0	%
Maximum Duty Cycle	$V_{COMPENSATION} = 3.6\text{V}$	45	49		45	49		%
<b>Digital Ports (SYNC, SHUTDOWN, and RESET)</b>								
HIGH Output Voltage	$I_{SOURCE} = 40\mu\text{A}$	2.4	4		2.4	4		V
LOW Output Voltage	$I_{SINK} = 3.6\text{mA}$		0.2	0.4		0.2	0.4	V
HIGH Input Current	$V_{IN} = 2.4\text{V}$		-125	-300		-125	-300	$\mu\text{A}$
LOW Input Current	$V_{IL} = 0.4\text{V}$		-225	-500		-225	-500	$\mu\text{A}$
<b>Current Limit Comparator Section (Note 6)</b>								
Sense Voltage	$R_S \leq 50\Omega$ , $T_J = 25^\circ\text{C}$	90	100	110	80	100	120	mV
Input Bias Current			-3	-10		-3	-10	$\mu\text{A}$
<b>Soft-Start Section</b>								
Error Clamp Voltage	RESET = 0.4V		0.1	0.4		0.1	0.4	V
$C_S$ Charging Current	RESET = 2.4V	50	100	200	50	100	200	$\mu\text{A}$
<b>Output Drivers (each output) (Note 7)</b>								
HIGH Output Voltage	$I_{SOURCE} = 20\text{mA}$	12.5	13.5		12.5	13.5		V
	$I_{SOURCE} = 100\text{mA}$	12	13		12	13		V
LOW Output Voltage	$I_{SINK} = 20\text{mA}$		0.2	0.3		0.2	0.3	V
	$I_{SINK} = 100\text{mA}$		1.2	2		1.2	2	V
Collector Leakage	$V_C = 40\text{V}$		50	150		50	150	$\mu\text{A}$
Rise Time	$C_L = 1000\text{pF}$		0.3	0.6		0.3	0.6	$\mu\text{s}$
Fall Time	$C_L = 1000\text{pF}$		0.1	0.2		0.1	0.2	$\mu\text{s}$
<b>Power Consumption Section (Note 8)</b>								
Standby Current	SHUTDOWN = 0.4V		18	30		18	30	mA

Note 3.  $I_L = 0\text{mA}$

Note 4.  $F_{OSC} = 40\text{KHz}$  ( $R_T = 4.12\text{K}\Omega \pm 1\%$ ,  $C_T = .01\mu\text{F} \pm 1\%$ ,  $R_D = 0\Omega$ )

Note 5.  $V_{CM} = 0 \text{ to } 5.2\text{V}$

Note 6.  $V_{CM} = 0 \text{ to } 12\text{V}$

Note 7.  $V_C = 15\text{V}$

Note 8.  $V_{IN} = 35\text{V}$

Note 9. These parameters, although guaranteed over the recommended operating conditions, are not tested in production.

CHARACTERISTIC CURVES

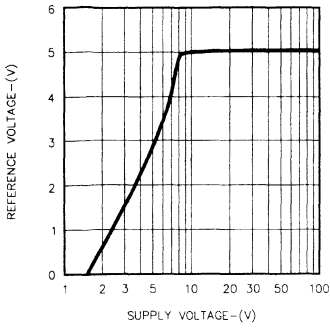


FIGURE 1. REFERENCE VOLTAGE VS. SUPPLY VOLTAGE

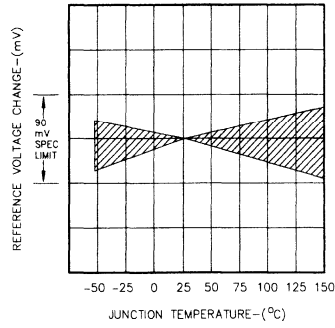


FIGURE 2. REFERENCE TEMPERATURE STABILITY

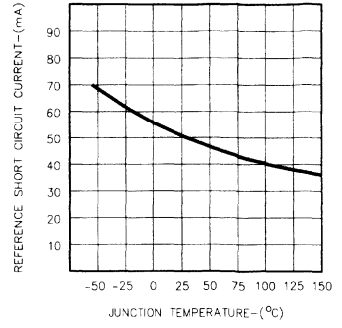


FIGURE 3. REFERENCE SHORT CIRCUIT CURRENT

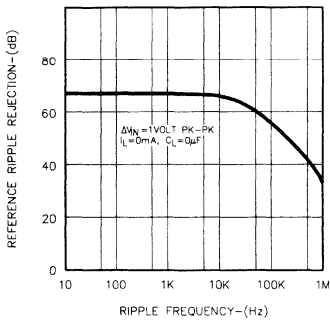


FIGURE 4. REFERENCE RIPPLE REJECTION

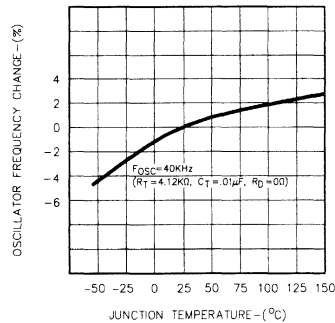


FIGURE 5. OSCILLATOR FREQUENCY TEMPERATURE STABILITY

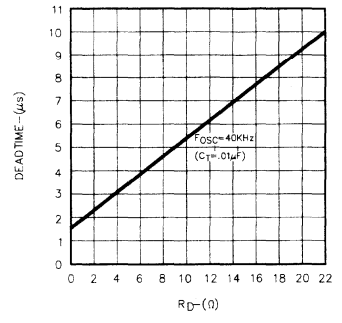


FIGURE 6. OUTPUT DRIVER DEADTIME VS.  $R_D$  VALUE

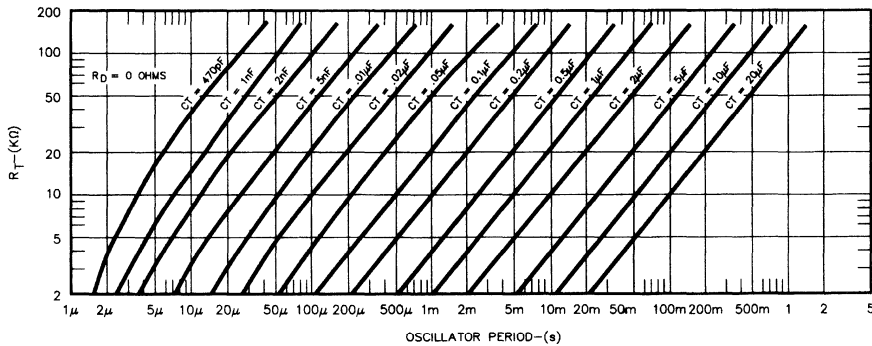


FIGURE 7. OSCILLATOR PERIOD VS.  $R_T$  AND  $C_T$

CHARACTERISTIC CURVES (continued)

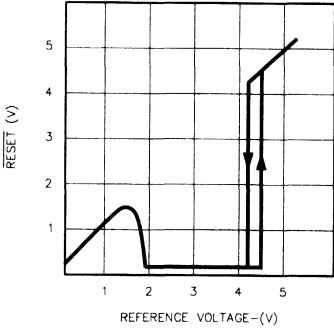


FIGURE 8. UNDERVOLTAGE LOCKOUT CHARACTERISTIC

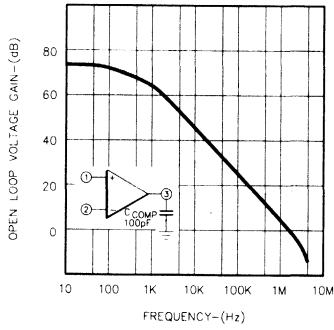


FIGURE 9. ERROR AMPLIFIER OPEN LOOP GAIN VS. FREQUENCY

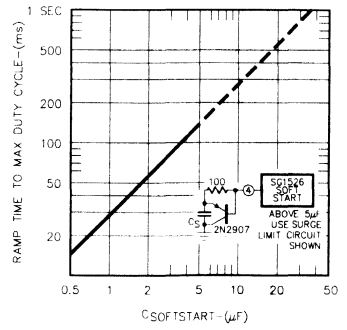


FIGURE 10. SOFTSTART TIME CONSTANT VS.  $C_S$

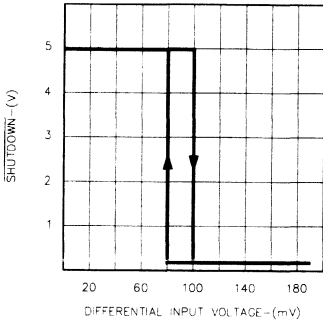


FIGURE 11. CURRENT LIMIT TRANSFER FUNCTION

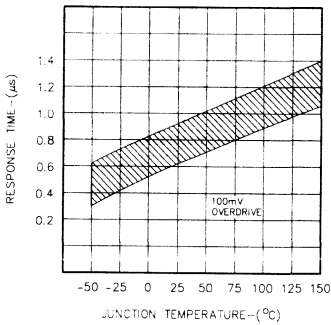


FIGURE 12. COMPARATOR INPUT TO DRIVER OUTPUT DELAY

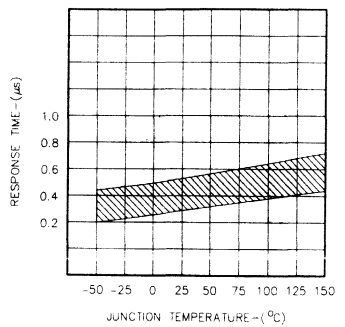


FIGURE 13. SHUTDOWN INPUT TO DRIVER OUTPUT DELAY

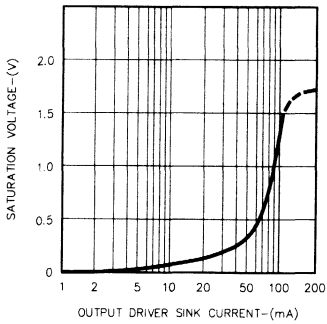


FIGURE 14. OUTPUT DRIVER SATURATION VOLTAGE VS.  $I_{SINK}$

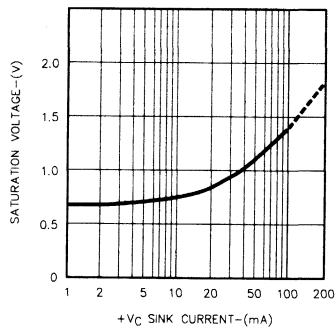


FIGURE 15. OUTPUT SUPPLY SATURATION VOLTAGE VS.  $I_{SINK}$

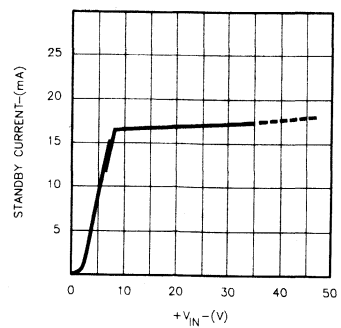


FIGURE 16. STANDBY CURRENT VS. SUPPLY VOLTAGE

**APPLICATION INFORMATION**

**VOLTAGE REFERENCE**

The reference regulator of the SG1526 is based on a temperature compensated zener diode. The circuitry is fully active at supply voltages above +8 volts., and provides up to 20mA of load current to external circuitry at +5.0 volts. In systems where additional current is required, an external PNP transistor can be used to boost the available current. A rugged low frequency audio-type transistor should be used, and lead lengths between the PWM and transistor should be as short as possible to minimize the risk of oscillations. Even so, some types of transistors may require collector-base capacitance for stability. Up to 1 amp of load current can be obtained with excellent regulation if the device selected maintains high current gain.

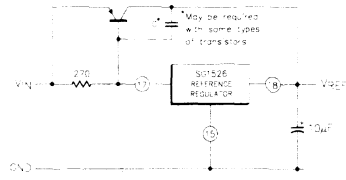


FIGURE 17. EXTENDING REFERENCE OUTPUT CURRENT

**UNDERVOLTAGE LOCKOUT**

The undervoltage lockout circuit protects the SG1526 and the power devices it controls from inadequate supply voltage. If +V<sub>IN</sub> is too low, the circuit disables the output drivers and holds the RESET pin LOW. This prevents spurious output pulses while the control circuitry is stabilizing, and holds the soft-start timing capacitor in a discharged state.

The circuit consists of a +1.2 volt bandgap reference and comparator circuit which is active when the reference voltage has risen to 3V<sub>BE</sub> or 1.8 volts at 25°C. When the reference voltage rises to approximately +4.4 volts, the circuit enables the output drivers and releases the RESET pin, allowing a normal soft-start. The comparator has 200mV of hysteresis to minimize oscillation at the trip point. When +V<sub>IN</sub> to the PWM is removed and the reference drops to +4.2 volts, the undervoltage circuit pulls RESET LOW again. The soft-start capacitor is immediately discharged, and the PWM is ready for another soft-start cycle.

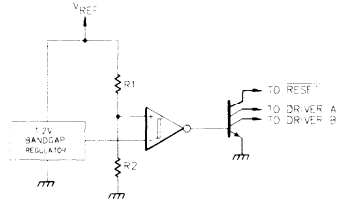


FIGURE 18. SIMPLIFIED UNDERVOLTAGE LOCKOUT

The SG1526 can operate from a +5 volt supply by connecting the V<sub>REF</sub> pin to the +V<sub>IN</sub> pin and maintaining the supply between +4.8 and +5.2 volts.

**SOFT-START CIRCUIT**

The soft-start circuit protects the power transistors and rectifier diodes from high current surges during power supply turn-on. When supply voltage is first applied to the SG1526, the undervoltage lockout circuit holds RESET LOW with Q3. Q1 is turned on, which holds the soft-start capacitor voltage at zero. The second collector of Q1 clamps the output error amplifier to ground, guaranteeing zero duty cycle at the driver outputs. When the supply voltage reaches normal operating range, RESET will go HIGH. Q1 turns off, allowing the internal 100µA current source to charge C<sub>S</sub>. Q2 clamps the error amplifier output to 1V<sub>BE</sub> above the voltage on C<sub>S</sub>. As the soft-start voltage ramps up to +5 volts, the duty cycle of the PWM linearly increases to whatever value the voltage regulation loop requires for an error null. Figure 10 gives the timing relationship between C<sub>S</sub> and ramp time to 100% duty cycle.

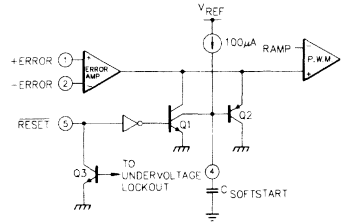


FIGURE 19. SOFT-START CIRCUIT SCHEMATIC

**DIGITAL CONTROL PORTS**

The three digital control ports of the SG1526 are bi-directional. Each pin can drive TTL and 5 volt CMOS logic directly, up to a fan-out of 10 low-power Schottky gates. Each pin can also be directly driven by open-collector voltage comparators; fan-in is equivalent to 1 low-power Schottky gate. Each port is normally HIGH; the pin is pulled LOW to activate the particular function. Driving SYNC LOW initiates a discharge cycle in the oscillator. Pulling SHUTDOWN LOW immediately inhibits all PWM output pulses. Holding RESET LOW discharges the soft-start capacitor. The logic threshold is +1.1 volts at 25°C. Noise immunity can be gained at the expense of fan-out with an external 2K pullup resistor to +5 volts.

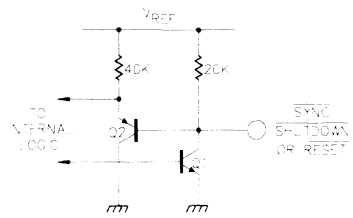


FIGURE 20. DIGITAL CONTROL PORT SCHEMATIC

APPLICATION INFORMATION (continued)

OSCILLATOR

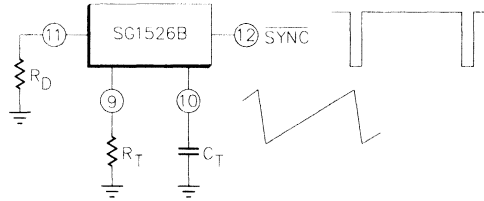


FIGURE 21 · OSCILLATOR CONNECTIONS AND WAVEFORMS

The oscillator is programmed for frequency and deadtime with three components:  $R_T$ ,  $C_T$ , and  $R_D$ . Two waveforms are generated: a sawtooth waveform at pin 10 for pulse width modulation, and a logic clock at pin 12. The following procedure is recommended for choosing timing values:

1. With  $R_D = 0\Omega$  (pin 11 shorted to ground) select values for  $R_T$  and  $C_T$  from Figure 7 to give the desired oscillator period. Remember that the frequency at each driver output is half the oscillator frequency, and the frequency at the  $+V_C$  terminal is the same as the oscillator frequency.
2. If more dead time is required, select a larger value of  $R_D$  using Figure 6 as a guide. At 40kHz dead time increases by 400nSec/ohm.
3. Increasing the dead time will cause the oscillator frequency to decrease slightly. Go back and decrease the value of  $R_T$  slightly to bring the frequency back to the nominal design value.

The SG1526 can be synchronized to an external logic clock by programming the oscillator to free-run at a frequency 10% slower than the sync frequency. A periodic LOW logic pulse approximately 0.5 $\mu$ Sec wide at the SYNC pin will then lock the oscillator to the external frequency.

Multiple devices can be synchronized together by programming one master unit for the desired frequency, and then sharing its sawtooth and clock waveforms with the slave units. All  $C_T$  terminals are connected to the  $C_T$  pin of the master, and all SYNC terminals are likewise connected to the SYNC pin of the master. Slave  $R_T$  terminals should not be left open nor should they be tied to the +5V reference; at least 50K should be connected to each pin. Slave  $R_D$  terminals may be either left open or grounded.

ERROR AMPLIFIER

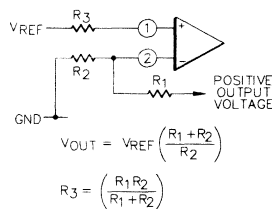


FIGURE 22A

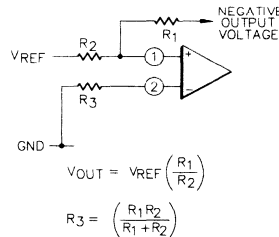


FIGURE 22B

ERROR AMPLIFIER CONNECTIONS

The error amplifier is a transconductance design, with an output impedance of 2 megohms and an effective output capacitance of 100 pF. Since all voltage gain takes place at the output pin, the open-loop gain can be shaped with shunt reactance to ground. For unity gain stability the amplifier requires an additional external 100 pF to ground, resulting in an open-loop pole at 400 Hz.

The input connections to the error amplifier are determined by the polarity of the switching supply output voltage. For positive supplies, the common-mode voltage is +5.0 volts and the feedback connections in Figure 22A are used. With negative supplies, the common-mode voltage is ground and the feedback divider is connected between the negative output and the +5.0 volt reference voltage, as shown in Figure 22B.

APPLICATION INFORMATION (continued)

OUTPUT DRIVERS

The totem-pole output drivers of the SG1526 are designed to source and sink 100mA continuously and 200mA peak. Loads can be driven either from the output pins 13 and 16, or from the +V<sub>C</sub> pin, as required. Curves for the saturation voltage at these outputs as a function of load current are found in Figures 14 and 15.

Since the bottom transistor of the totem-pole is allowed to saturate, there is a momentary conduction path from the +V<sub>C</sub> terminal to ground during switching. To limit the resulting current spikes a small resistor in series with pin 14 is always recommended. The resistor value is determined by the driver supply voltage, and should be chosen for 200mA peak currents, as shown in Figure 25.

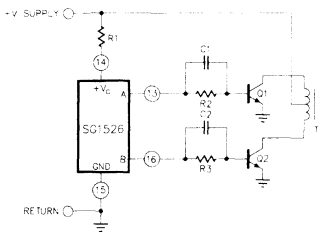


FIGURE 23. PUSH-PULL CONFIGURATION

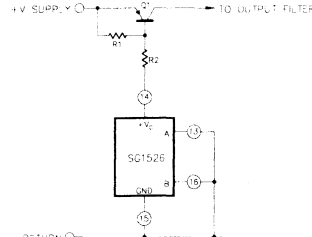


FIGURE 24. SINGLE-ENDED CONFIGURATION

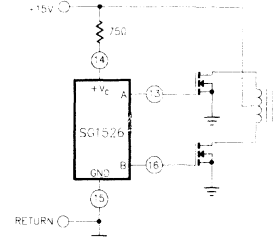
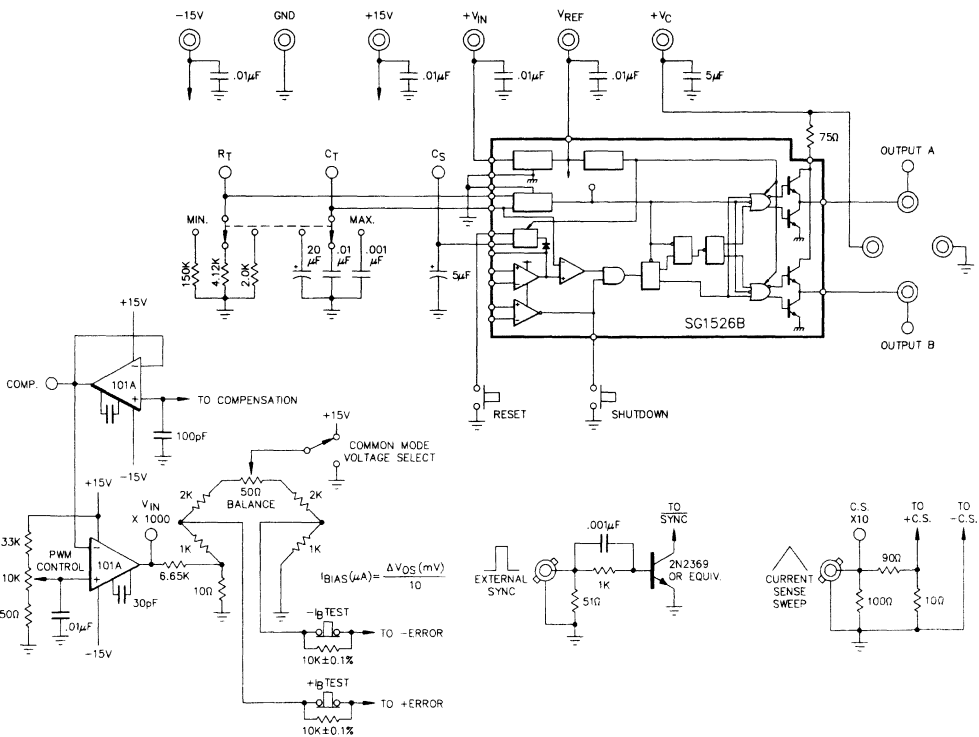


FIGURE 25. DRIVING N-CHANNEL POWER MOSFETS

SG1526 LAB TEST FIXTURE





# SG1526/SG2526/SG3526

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
18-PIN CERAMIC DIP J - PACKAGE	SG1526J/883B SG1526J SG2526J SG3526J	-55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C	
18-PIN PLASTIC DIP N - PACKAGE	SG2526N SG3526N	-25°C to 85°C 0°C to 70°C	
18-PIN WIDE BODY PLASTIC S.O.I.C. DW - PACKAGE	SG2526DW SG3526DW	-25°C to 85°C 0°C to 70°C	
24-PIN CERAMIC FLAT PACK F - PACKAGE	SG1526F/883B SG1526F	-55°C to 125°C -55°C to 125°C	
20-PIN CERAMIC LEADLESS CHIP CARRIER L - PACKAGE	SG1526L/883B SG1526L	-55°C to 125°C -55°C to 125°C	

Note 1. Contact factory for JAN and DESC product availability.  
 2. All parts are viewed from the top.





LINEAR INTEGRATED CIRCUITS

# SG1526B/SG2526B/SG3526B

## REGULATING PULSE WIDTH MODULATOR

### DESCRIPTION

The SG1526B is a high-performance pulse width modulator for switching power supplies which offers improved functional and electrical characteristics over the industry-standard SG1526. A direct pin-for-pin replacement for the earlier device with all its features, it incorporates the following enhancements: a bandgap reference circuit for improved regulation and drift characteristics, improved undervoltage lockout, lower temperature coefficients on oscillator frequency and current-sense threshold, tighter tolerance on softstart time, much faster SHUTDOWN response, improved double-pulse suppression logic for higher speed operation, and an improved output driver design with low shoot-through current, and faster rise and fall times. This versatile device can be used to implement single-ended or push-pull switching regulators of either polarity, both transformerless and transformer-coupled. The SG1526B is specified for operation over the full military junction temperature range of -55°C to 150°C. The SG2526B is characterized for the industrial range of -25°C to 150°C, and the SG3526B is designed for the commercial range of 0°C to 125°C.

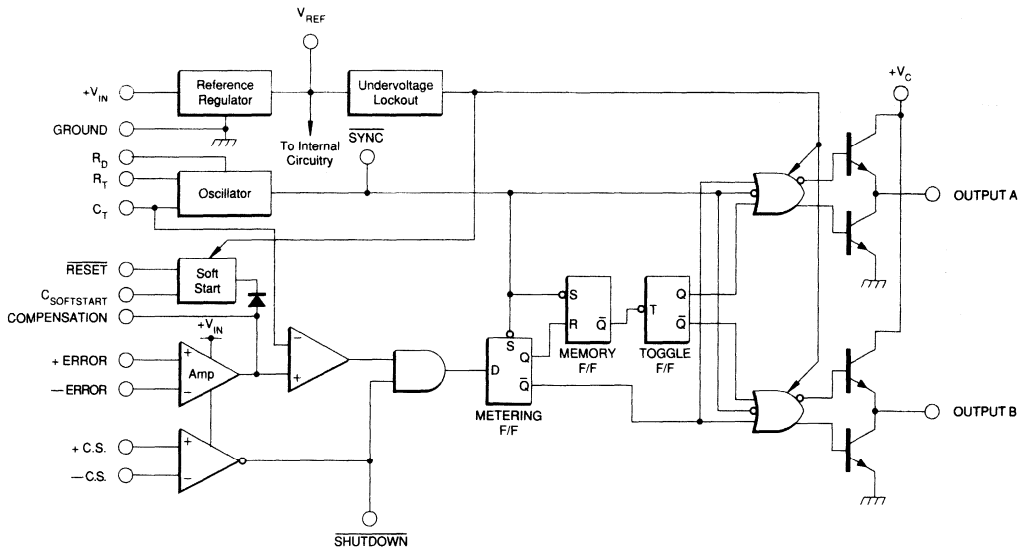
### FEATURES

- 8 to 35 volt operation
- 5V low drift 1% bandgap reference
- 1Hz to 500KHz oscillator range
- Dual 100mA source/sink
- Digital current limiting
- Double pulse suppression
- Programmable deadtime
- Improved undervoltage lockout
- Single pulse metering
- Programmable soft-start
- Wide current limit common mode range
- TTL/CMOS compatible logic ports
- Symmetry correction capability
- Guaranteed 6 unit synchronization
- Shoot thru currents less than 100mA
- Improved shutdown delay
- Improved rise and fall time

### HIGH RELIABILITY FEATURES - SG1526B

- ◆ Available to MIL-STD-883
- ◆ Scheduled for MIL-M38510
- ◆ Radiation data available
- ◆ SG level "S" processing available

### BLOCK DIAGRAM



# SG1526B/SG2526B/SG3526B

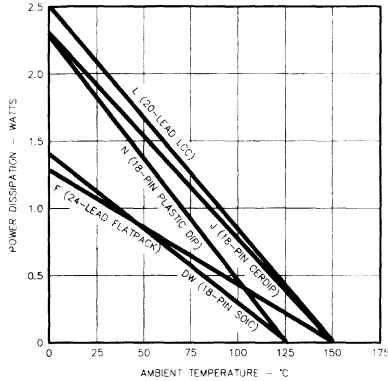
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Input Voltage ( $V_{IN}$ ) .....	40V	Logic Sink Current .....	15mA
Collector Supply Voltage ( $V_C$ ) .....	40V	Operating Junction Temperature	
Logic Inputs .....	-0.3V to 5.5V	Hermetic (J, F, L Packages) .....	175°C
Analog Inputs .....	-0.3V to $V_{IN}$	Plastic (N, DW Packages) .....	150°C
Source/Sink Load Current (each output) .....	200mA	Storage Temperature Range .....	-65°C to 150°C
Reference Load Current .....	50mA	Lead Temperature (Soldering, 10 Seconds) .....	300°C

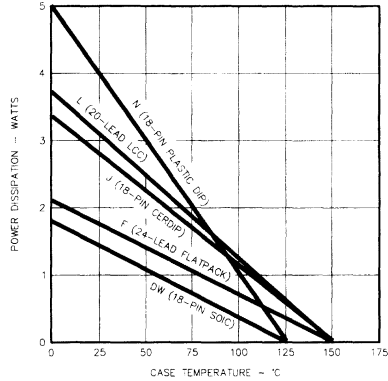
Note 1. Exceeding these ratings could cause damage to the device.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Input Voltage .....	8V to 35V	Oscillator Timing Capacitor .....	470pF to 20μF
Collector Supply Voltage .....	4.5V to 35V	Available Deadtime Range at 40KHz .....	5% to 50%
Sink/Source Load Current (each output) .....	0 to 100mA	Operating Ambient Temperature Range:	
Reference Load Current .....	0 to 20mA	SG1526B .....	-55°C to 125°C
Oscillator Frequency Range .....	1Hz to 500KHz	SG2526B .....	-25°C to 85°C
Oscillator Timing Resistor .....	2KΩ to 150KΩ	SG3526B .....	0°C to 70°C

Note 2. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

( $V_{IN} = 15V$ , and over operating ambient temperature, unless otherwise specified)

Parameter	Test Conditions	SG1526B/2526B			SG3526B			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Reference Section (Note 3)</b>								
Output Voltage	$T_J = 25^\circ C$	4.95	5.00	5.05	4.90	5.00	5.10	V
Line Regulation	$V_{IN} = 8$ to 35V		7	10		10	20	mV
Load Regulation	$I_L = 0$ to 20mA		10	20		10	25	mV
Temperature Stability (Note 9)	Over Operating $T_J$		15	50		15	50	mV
Total Output Voltage Range (Note 9)		4.90	5.00	5.10	4.85	5.00	5.15	V
Short Circuit Current	$V_{REF} = 0V$	25	50	125	25	50	125	mA
<b>Undervoltage Lockout Section</b>								
RESET Output Voltage	$V_{REF} = 3.8V$		0.2	0.4		0.2	0.4	V
RESET Output Voltage	$V_{REF} = 4.8V$	2.4	4.8		2.4	4.8		V

# SG1526B/SG2526B/SG3526B

## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG1526B/2526B			SG3526B			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Oscillator Section (Note 4)</b>								
Initial Accuracy	$T_J = 25^\circ\text{C}$		±3	±8		±3	±8	%
Voltage Stability	$V_{IN} = 8 \text{ to } 35\text{V}$		0.5	1.0		0.5	1.0	%
Temperature Stability (Note 9)	Over Operating $T_J$		7	10		3	5	%
Minimum Frequency (Note 9)	$R_T = 150\text{K}\Omega$ , $C_T = 20\mu\text{F}$			1.0			1.0	Hz
Maximum Frequency	$R_T = 2\text{K}\Omega$ , $C_T = 470\text{pF}$	500			500			KHz
Sawtooth Peak Voltage	$V_{IN} = 35\text{V}$	2.5	3.0	3.5	2.5	3.0	3.5	V
Sawtooth Valley Voltage	$V_{IN} = 8\text{V}$	0.5	1.0	1.1	0.5	1.0	1.1	V
SYNC Pulse Width	$R_T = 2.0\text{K}\Omega$ to $V_{REF}$		1.0	2		1.0	2	μs
<b>Error Amplifier Section (Note 5)</b>								
Input Offset Voltage	$R_S \leq 2\text{K}\Omega$		2	5		2	10	mV
Input Bias Current			-350	-1000		-350	-2000	nA
Input Offset Current			35	100		35	200	nA
DC Open Loop Gain	$R_L \geq 10\text{M}\Omega$	64	72		60	72		dB
High Output Voltage	$V_{PIN1} - V_{PIN2} \geq 150\text{mV}$ , $I_{SOURCE} = 100\mu\text{A}$	3.6	4.2		3.6	4.2		V
Low Output Voltage	$V_{PIN2} - V_{PIN1} \geq 150\text{mV}$ , $I_{SINK} = 100\mu\text{A}$		0.2	0.4		0.2	0.4	V
Common Mode Rejection	$R_S \leq 2\text{K}\Omega$		70	94		70	94	dB
Supply Voltage Rejection	$V_{IN} = 8\text{V}$ to $35\text{V}$	66	80		66	80		dB
<b>PWM Comparator Section (Note 4)</b>								
Minimum Duty Cycle	$V_{COMPENSATION} = 0.4\text{V}$			0			0	%
Maximum Duty Cycle	$V_{COMPENSATION} = 3.6\text{V}$	45	49		45	49		%
<b>Digital Ports (SYNC, SHUTDOWN, and RESET)</b>								
HIGH Output Voltage	$I_{SOURCE} = 40\mu\text{A}$	2.4	4		2.4	4		V
LOW Output Voltage	$I_{SINK} = 3.6\text{mA}$		0.2	0.4		0.2	0.4	V
HIGH Input Current	$V_{IH} = 2.4\text{V}$		-125	-200		-125	-200	μA
LOW Input Current	$V_{IL} = 0.4\text{V}$		-225	-360		-225	-360	μA
SHUTDOWN Delay to Output	(Note 9)			200			200	ns
<b>Current Limit Comparator Section (Note 6)</b>								
Sense Voltage	$R_S \leq 50\Omega$	90	100	110	80	100	120	mV
Input Bias Current			-3	-10		-3	-10	μA
Delay to Output (Note 9)				400			400	ns
<b>Soft-Start Section</b>								
Error Clamp Voltage	RESET = 0.4V		0.1	0.4		0.1	0.4	V
$C_S$ Charging Current	RESET = 2.4V	50	100	150	50	100	150	μA
<b>Output Drivers (each output) (Note 7)</b>								
HIGH Output Voltage	$I_{SOURCE} = 20\text{mA}$	12.5	13.5		12.5	13.5		V
	$I_{SOURCE} = 100\text{mA}$	12	13		12	13		V
LOW Output Voltage	$I_{SINK} = 20\text{mA}$		0.2	0.3		0.2	0.3	V
	$I_{SINK} = 100\text{mA}$		1.2	2		1.2	2	V
Collector Leakage	$V_C = 40\text{V}$		50	150		50	150	μA
Rise Time	$C_L = 1000\text{pF}$		0.3	0.4		0.3	0.4	μs
Fall Time	$C_L = 1000\text{pF}$		0.1	0.15		0.1	0.15	μs
<b>Power Consumption Section (Note 8)</b>								
Standby Current	SHUTDOWN = 0.4V		18	30		18	30	mA

Note 3.  $I_L = 0\text{mA}$

Note 4.  $F_{OSC} = 40\text{KHz}$  ( $R_T = 4.12\text{K}\Omega \pm 1\%$ ,  $C_T = .01\mu\text{F} \pm 1\%$ ,  $R_O = 0\Omega$ )

Note 5.  $V_{CM} = 0$  to  $5.2\text{V}$

Note 6.  $V_{CM} = 0$  to  $12\text{V}$

Note 7.  $V_C = 15\text{V}$

Note 8.  $V_{IN} = 35\text{V}$

Note 9. These parameters, although guaranteed over the recommended operating conditions, are not tested in production.

CHARACTERISTIC CURVES

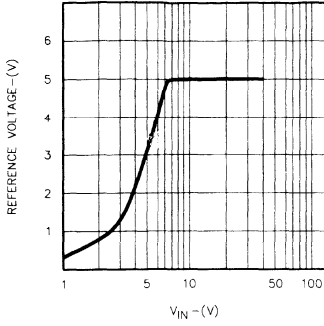


FIGURE 1. REFERENCE VOLTAGE VS. SUPPLY VOLTAGE

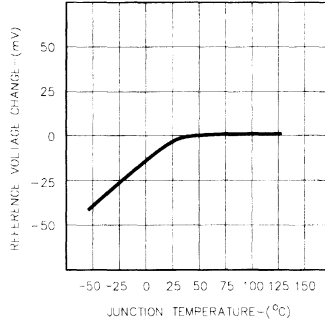


FIGURE 2. REFERENCE TEMPERATURE STABILITY

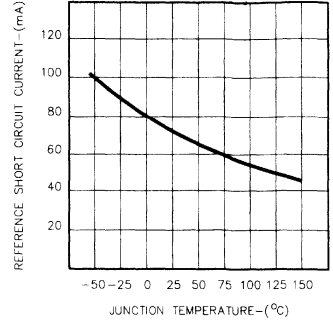


FIGURE 3. REFERENCE SHORT CIRCUIT

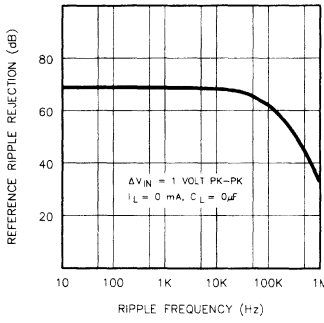


FIGURE 4. REFERENCE RIPPLE REJECTION

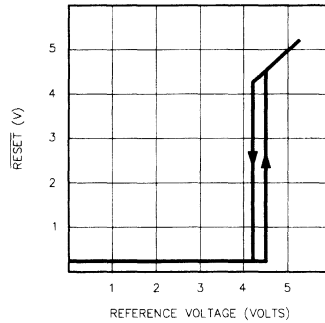


FIGURE 5. UNDER VOLTAGE LOCKOUT

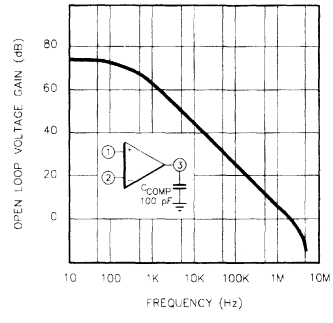


FIGURE 6. ERROR AMPLIFIER OPEN LOOP GAIN VS. FREQUENCY

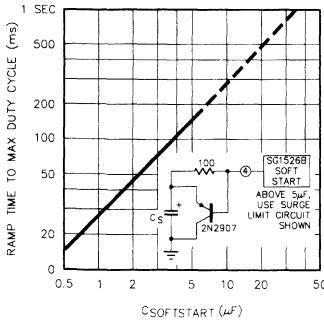


FIGURE 7. SOFTSTART TIME CONSTANT VS.  $C_S$

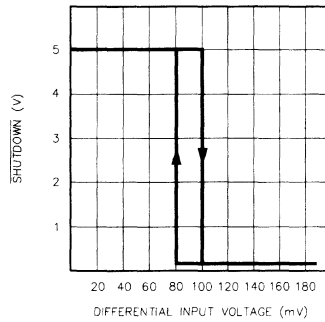


FIGURE 8. CURRENT LIMIT TRANSFER FUNCTION

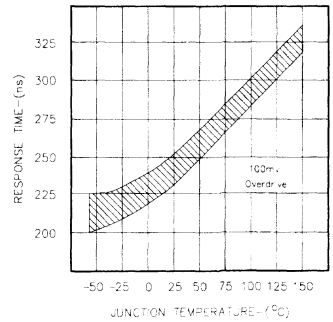


FIGURE 9. COMPARATOR INPUT TO DRIVER OUTPUT DELAY

## CHARACTERISTIC CURVES (continued)

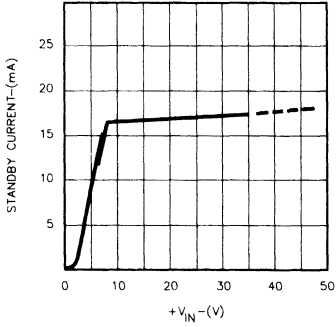


FIGURE 10. STANDBY CURRENT VS. SUPPLY VOLTAGE

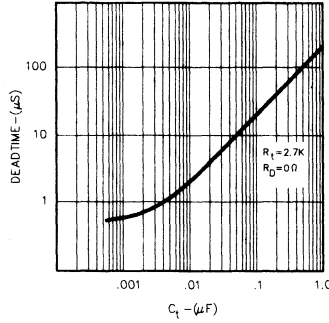


FIGURE 11. OUTPUT DRIVER DEADTIME VS.  $C_T$  VALUE

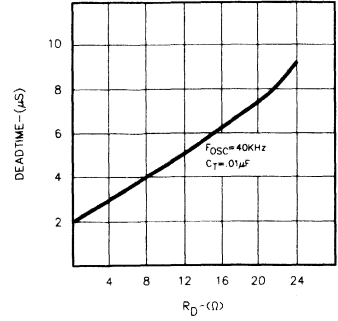


FIGURE 12. OUTPUT DRIVER DEADTIME VS.  $R_D$  VALUE

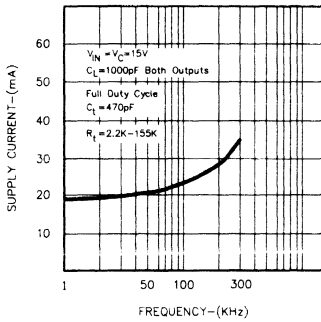


FIGURE 13. SUPPLY CURRENT VS. OUTPUT FREQUENCY

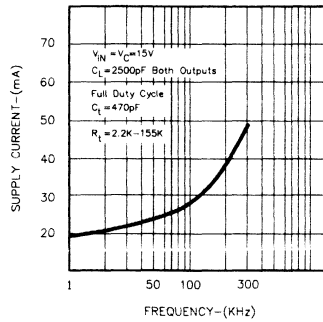


FIGURE 14. SUPPLY CURRENT VS. OUTPUT FREQUENCY

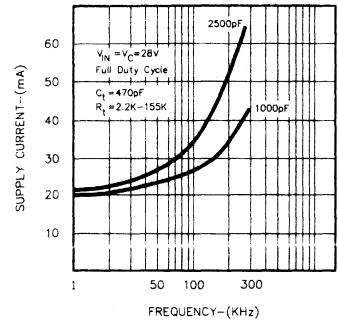


FIGURE 15. SUPPLY CURRENT VS. OUTPUT FREQUENCY

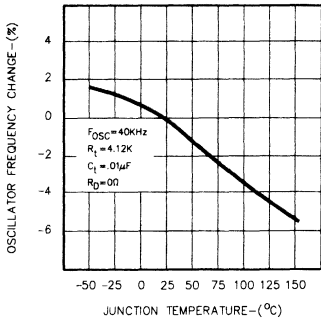


FIGURE 16. OSCILLATOR FREQUENCY TEMPERATURE STABILITY

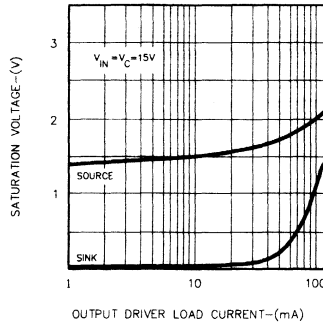


FIGURE 17. OUTPUT DRIVER SATURATION VOLTAGE

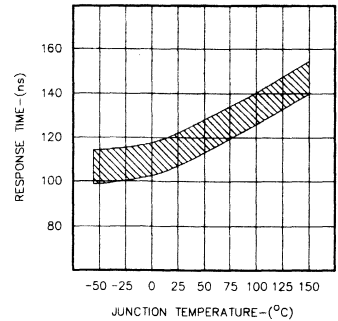


FIGURE 18. SHUTDOWN INPUT TO DRIVER OUTPUT DELAY

**CHARACTERISTIC CURVES** (continued)

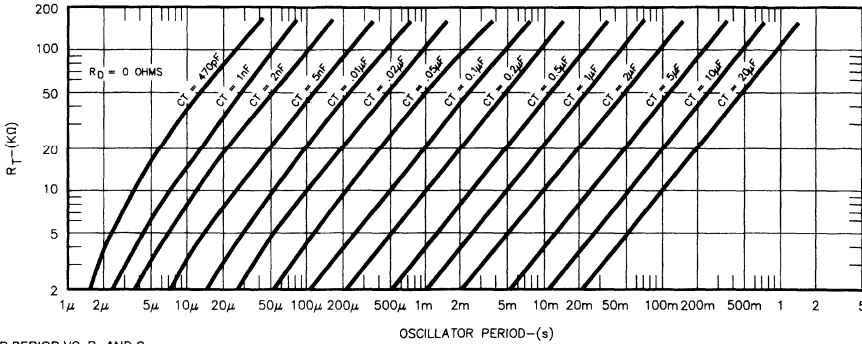


FIGURE 19. OSCILLATOR PERIOD VS.  $R_T$  AND  $C_T$

**APPLICATION INFORMATION**

**VOLTAGE REFERENCE**

The reference regulator of the SG1526B is a "band-gap" type; that is, the precision +5 volt output is derived from the very predictable base-emitter voltage of an NPN transistor. Since this is a sub-surface phenomenon, the resulting output exhibits excellent stability compared to earlier surface-breakdown zener designs. The reference output is stabilized at input voltages as low as +8 volts, and can provide up to 20mA of load current to external circuitry. An external PNP transistor can be used to boost the available current to many hundreds of mA. A rugged low-frequency audio-type transistor should be used, and lead lengths between the PWM and transistor should be as short as possible to minimize the risk of oscillation.

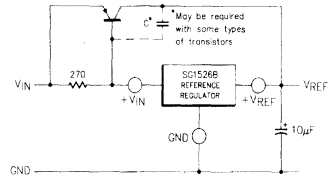


FIGURE 20. EXTENDING REFERENCE OUTPUT CURRENT

**UNDERVOLTAGE LOCKOUT**

The undervoltage lockout circuit protects the SG1526B and the power devices it controls from inadequate supply voltage. If + $V_{IN}$  is too low, the circuit disables the output drivers and holds the RESET pin LOW. This prevents spurious output pulses while the control circuitry is stabilizing, and holds the soft-start timing capacitor in a discharged state.

The circuit consists of a merged bandgap reference and comparator circuit which is active when the reference voltage has risen to  $2V_{BE}$  or 1.2 volts at 25°C. When the reference voltage rises to approximately +4.4 volts, the circuit enables the output drivers and releases the RESET pin, allowing a normal softstart. The comparator has 200mV of hysteresis to minimize oscillation at the trip point. When + $V_{IN}$  to the PWM is removed and the reference drops to +4.2 volts, the undervoltage circuit pulls RESET LOW again. The soft-start capacitor is immediately discharged, and the PWM is ready for another soft-start cycle.

The SG1526B can operate from a +5 volt supply regulated to within  $\pm 4\%$  by connecting the  $V_{REF}$  pin to the + $V_{IN}$  pin.

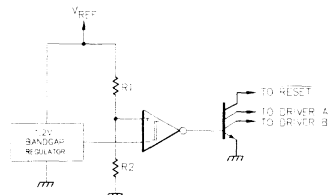


FIGURE 21. SIMPLIFIED UNDERVOLTAGE LOCKOUT

**SOFT-START CIRCUIT**

The soft-start circuit protects the power transistors and rectifier diodes from high current surges during power supply turn-on. When supply voltage is first applied to the SG1526B, the undervoltage lockout circuit holds RESET LOW with Q3. Q1 is turned on, which holds the soft-start capacitor voltage at zero. The second collector of Q1 clamps the output of the error amplifier to ground, guaranteeing zero duty cycle at the driver outputs. When the supply voltage reaches normal operating range, RESET will go HIGH. Q1 turns off, allowing the internal 100μA current source to charge  $C_S$ . Q2 clamps the error amplifier output to  $1.0 V_{BE}$  above the voltage on  $C_S$ . As the soft-start voltage ramps up to +5 volts, the duty cycle of the PWM linearly increases to whatever value the voltage regulation loop requires for an error null. Figure 7 gives the timing relationship between  $C_S$  ramp time to 100% duty cycle.

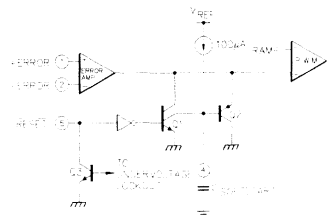


FIGURE 22. SOFT-START CIRCUIT SCHEMATIC



## APPLICATION INFORMATION (continued)

### DIGITAL CONTROL PORTS

The three digital control ports of the SG1526B are bi-directional. Each pin can drive TTL and 5 volt CMOS logic directly, up to a fan-out of 10 low-power Schottky gates. Each pin can also be directly driven by open-collector TTL, open-drain CMOS, and open-collector voltage comparators, fan-in is equivalent to 1 low-power Schottky gate. Each port is normally HIGH; the pin is pulled LOW to activate the particular function. Driving SYNC LOW initiates a discharge cycle in the oscillator. Pulling SHUTDOWN LOW immediately inhibits all PWM output pulses. Holding RESET LOW discharges the soft-start capacitor. The logic threshold is +1.1 volts at +25°C. Noise immunity can be gained at the expense of fan-out with an external 2K pull-up resistor to +5 volts.

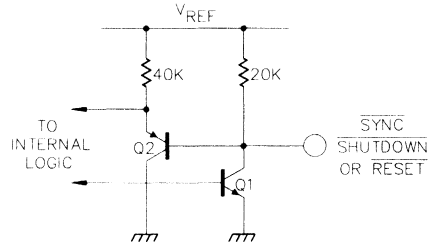


FIGURE 23  
DIGITAL CONTROL PORT SCHEMATIC

### OSCILLATOR

The oscillator is programmed for frequency and dead time with three components:  $R_T$ ,  $C_T$ , and  $R_D$ . Two waveforms are generated: a sawtooth waveform at pin 10 for pulse width modulation, and a logic clock at pin 12. The following procedure is recommended for choosing timing values:

1. With  $R_D = 0\Omega$  (pin 11 shorted to ground) select values for  $R_T$  and  $C_T$  from Figure 19 to give the desired oscillator period. Remember that the frequency at each driver output is half the oscillator frequency, and the frequency at the  $+V_C$  terminal is the same as the oscillator frequency.
2. If more dead time is required, select a larger value of  $R_D$  using Figure 14 as a guide. At 40 KHz dead time increases by 300 ns/ $\Omega$ .
3. Increasing the dead time will cause the oscillator frequency to decrease slightly. Go back and decrease the value of  $R_T$  slightly to bring the frequency back to the nominal design value.

The SG1526B can be synchronized to an external logic clock by programming the oscillator to free-run at a frequency 10% slower than the sync frequency. A periodic LOW logic pulse approximately 0.5  $\mu$ Sec wide at the SYNC pin will then lock the oscillator to the external frequency.

Multiple devices can be synchronized together by programming one master unit for the desired frequency, and then sharing its sawtooth and clock waveforms with the slave units. All  $C_T$  terminals are connected to the  $C_T$  pin of the master, and all SYNC terminals are likewise connected to the SYNC pin of the master. Slave  $R_T$  terminals should be left open; at least 50K should be connected from each pin to ground. Slave  $R_D$  terminals may be either left open or grounded.

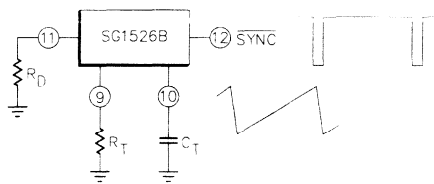


FIGURE 24.  
OSCILLATOR CONNECTIONS AND WAVEFORMS

### ERROR AMPLIFIER

The error amplifier is a transconductance design, with an output impedance of 2 megohms. Since all voltage gain takes place at the output pin, the open-loop gain/frequency characteristics can be controlled with shunt reactance to ground. When compensated for unity-gain stability with 100 pF, the amplifier has an open-loop pole at 400 Hz.

The input connections to the error amplifier and determined by the polarity of the switching supply output voltage. For positive supplies, the common-mode voltage is +5.0 volts and the feedback connections in Figure 25A are used. With negative supplies, the common-mode voltage is ground and the feedback divider is connected between the negative output and the +5.0 volt reference voltage, as shown in Figure 25B.

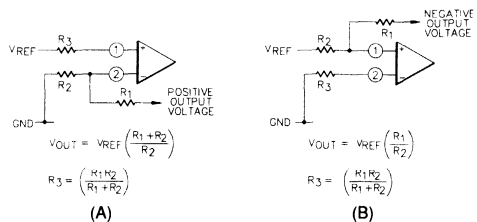


FIGURE 25.  
ERROR AMPLIFIER CONNECTIONS

APPLICATION INFORMATION (continued)

OUTPUT DRIVERS

The totem-pole output drivers of the SG1526B are designed to source and sink 100mA continuously and 200mA peak. Loads can be driven either from the output pins 13 and 16,

or from the +V<sub>C</sub> pin, as required. Curves for the saturation voltage at these outputs as a function of load current are found in Figure 17.

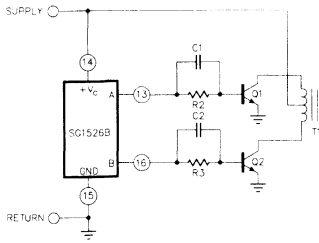


FIGURE 26. PUSH-PULL CONFIGURATION

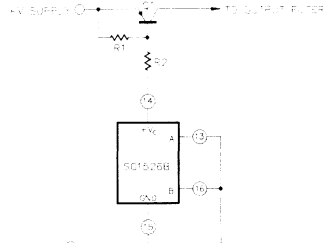


FIGURE 27. SINGLE-ENDED CONFIGURATION

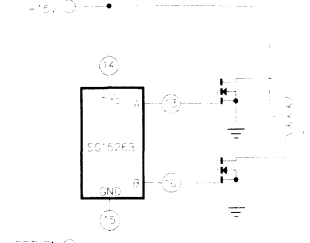
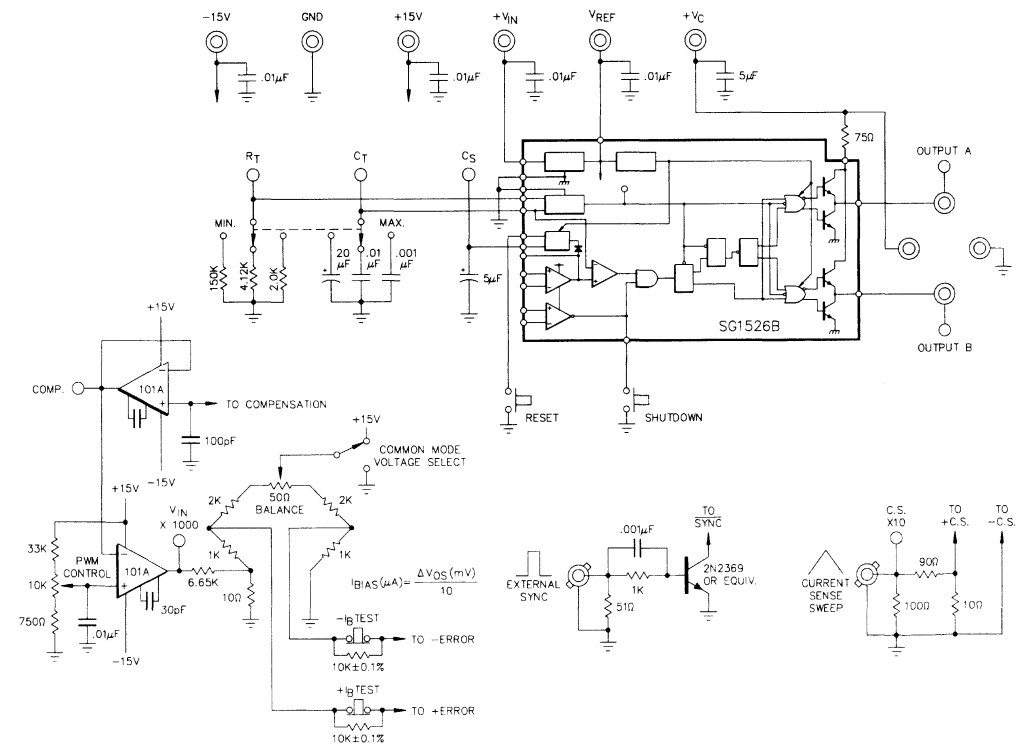


FIGURE 28. DRIVING N-CHANNEL POWER MOSFETS

SG1526B LAB TEST FIXTURE



# SG1526B/SG2526B/SG3526B

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
18-PIN CERAMIC DIP J - PACKAGE	SG1526BJ/883B	-55°C to 125°C	
	SG1526BJ	-55°C to 125°C	
	SG2526BJ	-55°C to 125°C	
18-PIN PLASTIC DIP N - PACKAGE	SG2526BN	-25°C to 85°C	
	SG3526BN	0°C to 70°C	
18-PIN WIDE BODY PLASTIC S.O.I.C. DW - PACKAGE	SG2526BDW	-25°C to 85°C	
	SG3526BDW	0°C to 70°C	
24-PIN CERAMIC FLAT PACK F - PACKAGE	SG1526BF/883B	-55°C to 125°C	
	SG1526BF	-55°C to 125°C	
20-PIN CERAMIC LEADLESS CHIP CARRIER L - PACKAGE	SG1526BL/883B	-55°C to 125°C	
	SG1526BL	-55°C to 125°C	

Note 1. Contact factory for JAN and DESC product availability.  
 Note 2. All parts are viewed from the top.





# SG1528/SG1530 SERIES

LINEAR INTEGRATED CIRCUITS

## HIGH SPEED CURRENT MODE PWM CONTROLLER

### DESCRIPTION

The SG1528/30 family of single-ended pulse width modulators are optimized for high frequency, current mode control of switching power supply applications. The control architecture also allows its use as a unidirectional motor speed controller. The circuit features internally preset start-up and run voltage thresholds compatible with power N-channel MOSFETs. A precision low-drift bandgap reference exhibits excellent long-term stability. Both the voltage error amp and current amp are wideband operational amplifiers for high speed performance and maximum applications flexibility. A high peak-current totem-pole output driver permits direct drive of the power switch. The difference between these two series of controllers is the maximum duty cycle range of the output stage. The SG1530 family can operate to duty cycles approaching 100%, where they are mainly used in non-isolated DC-DC converters whereas the 1528 series has a duty cycle range of zero to <50%, optimized for isolated, primary-side control of switching power supplies. The SG1528/1530 is specified for operation over the full military ambient temperature range of -55°C to 125°C. The SG2528/2530 is characterized for the industrial range of -25°C to 85°C, and the SG3528/3530 is designed for the commercial range of 0°C to 70°C.

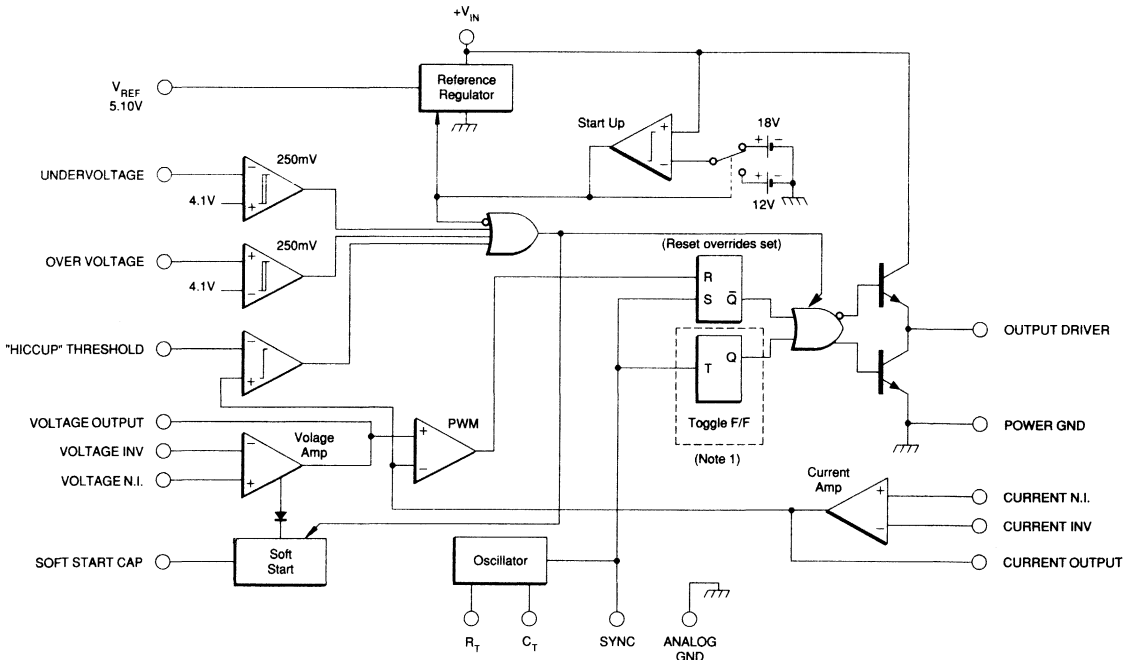
### FEATURES

- Current mode or voltage mode control
- Micropower start-up mode (0.6mA max.)
- $\pm 1\%$  Low-drift reference
- Wideband voltage error amp (6MHz typ.)
- Wideband current differential amp (12MHz typ.)
- Output Frequencies to 2MHz
- Programmable DC Bus O.V. and U.V. sense
- High speed shutdown (C.L. delay to output 25ns)
- Soft start
- Full fault suppression logic
- 2A peak output current drive
- Output driver rise and fall time less than 30ns
- Ideal for using with SENSFETS

### HIGH RELIABILITY FEATURES - SG1528/SG1530

- ◆ Available to MIL-STD-883
- ◆ SG level "S" processing available

### BLOCK DIAGRAM



# SG1528/SG1530 SERIES

## ABSOLUTE MAXIMUM RATINGS (Note 2)

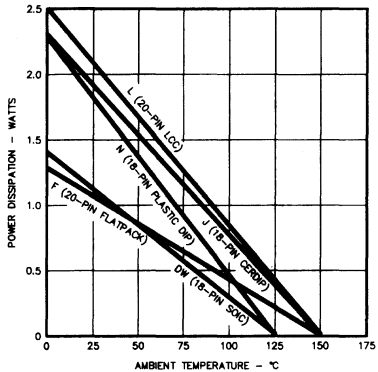
Supply Voltage ( $V_{CC}$ ) ..... 22V  
 Analog Inputs (ERR, CUR, OV, UV) ..... -0.3V to  $V_{IN}$   
 Logic Inputs (SYNC) ..... -0.3V to 5.5V  
 Source / Sink Load Current (continuous) ..... 0.5A  
 Source / Sink Load Current Peak (200ns) ..... 3A  
 Reference Load Current ..... 50mA  
 Soft Start Sink Current ..... 50mA  
 Sync Output Source Current ..... 5mA

Error Amplifier Output Current ..... 5mA  
 Current Sense Amplifier Output Current ..... 5mA  
 Oscillator Discharging Current ..... 5mA  
 Operating Junction Temperature  
   Hermetic (J, F, L Packages) ..... 175°C  
   Plastic (N, DW Packages) ..... 150°C  
 Storage Temperature ..... -65°C to 150°C

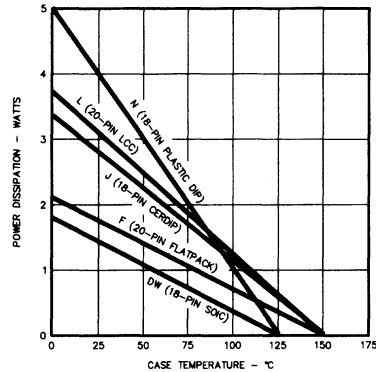
Note 2. Values beyond which damage may occur.

## RECOMMENDED OPERATING CONDITIONS (Note 3)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Supply Voltage Range ..... 13V to 17V  
 Source / Sink Output Current (continuous) ..... 0.3A  
 Source / Sink Output Current Peak (200ns) ..... 1.5A  
 Reference Load Current ..... 0 to 10mA  
 Oscillator Frequency Range ..... 1KHz to 1.5MHz  
 Oscillator Timing Resistor ( $R_T$ ) ..... 10K to 250K $\Omega$

Oscillator Timing Capacitor ( $C_T$ ) ..... 500pF to 0.1 $\mu$ F  
 Operating Ambient Temperature Range  
   SG1528 ..... -55°C to 125°C  
   SG2528 ..... -25°C to 85°C  
   SG3528 ..... 0°C to 70°C

Note 3: Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS (Note 4)

( $V_{CC}$  = 15V, and over operating temperature, unless otherwise specified.)

Parameter	Test Conditions	SG1528/2528 SG1530/2530			SG3528 SG3530			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Reference Section</b>								
Output Voltage	$T_J = 25^\circ\text{C}$ , $I_O = 1\text{mA}$	5.05	5.10	5.15	5.05	5.10	5.15	V
Line Regulation	$V_{IN} = 13\text{V to }17\text{V}$		3	15		3	15	mV
Load Regulation	$I_L = 1\text{ to }10\text{mA}$		2	15		2	15	mV
Temperature Stability (Note 5)			0.1			0.1		mV/ $^\circ\text{C}$
Total Output Variation	Line, Load and Temp	5.0		5.2	5.0		5.2	V
Output Noise Voltage (Note 5)	$T_J = 25^\circ\text{C}$ , $10\text{Hz} < f < 10\text{KHz}$		100			100		$\mu\text{V}$
Long-Term Stability (Note 5)	$T_J = 125^\circ\text{C}$ , 1000Hrs		5			5		mV
Short Circuit Output Current	$V_{REF} = 0\text{V}$	20	50	100	20	50	100	mA

Note 4. Performance data described herein represent design goals. Final device specifications are subject to change.

## SG1528/SG1530 SERIES

### ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG1528/2528 SG1530/2530			SG3528 SG3530			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Oscillator Section</b>								
Initial Accuracy	$T_J = 25^\circ\text{C}$	360	400	440	360	400	440	KHz
Voltage Stability	$V_{IN} = 13\text{V to }17\text{V}$			0.5			0.5	%
Temperature Stability	Over Operating Range		1			1		%
Sync Output High Level	$T_J = 25^\circ\text{C}$	4.2	4.35	4.5	4.2	4.35	4.5	V
Sync Output Low Level	$T_J = 25^\circ\text{C}$	3.35	3.55	3.75	3.35	3.55	3.75	V
Sync Input High Level	$T_J = 25^\circ\text{C}$	4.25			4.25			V
Sync Input Low Level	$T_J = 25^\circ\text{C}$			3.6			3.6	V
Sync Input Current			1			1		mA
Discharge Current Source Variation	$T_J = 25^\circ\text{C}, R_T = 5\text{K}\Omega$	-5		5	-5		5	%
Sync Output Pulse		25	50	100	25	50	100	ns
<b>Error Amplifier Section</b>								
Input Offset Voltage				5			5	mV
Input Bias Current				15			15	$\mu\text{A}$
Input Offset Current				2.5			2.5	$\mu\text{A}$
Common Mode Range		1.7		7	1.7		7	V
Open Loop Gain	$V_{CM} = 2.5\text{V}, \text{Output Voltage } 1 \text{ to } 3\text{V}, R_L = 5\text{K}$	60	64		60	64		dB
Unity Gain Bandwidth (Note 5)			6			6		MHz
Output Voltage Slew Rate (Note 5)		5	10		5	10		V/ $\mu\text{s}$
CMRR		75	100		75	100		dB
PSRR		90			90			dB
Output Sink Current		0.4	0.67		0.4	0.67		mA
Output Source Current		3	6		3	6		mA
Output High Level	$R_L = 10\text{K}$	2.9	3.5		2.9	3.5		V
Output Low Level	$R_L = 10\text{K}$		0.1	0.2		0.1	0.2	V
<b>Current Sense Amplifier (CSA) Section</b>								
Input Offset Voltage				5			5	mV
Input Bias Current				500			500	$\mu\text{A}$
Input Offset Current				50			75	$\mu\text{A}$
Common Mode Range		0		3	0		3	V
Open Loop Gain	$V_{CM} = 2.5\text{V}, \text{Output Voltage } 1 \text{ to } 3\text{V}, R_L = 5\text{K}$	60	64		60	64		dB
Unity Gain Bandwidth (Note 5)		8	12		8	12		MHz
Output Voltage Slew Rate (Note 5)		10	20		10	20		V/ $\mu\text{s}$
CMRR		75	100		75	100		dB
PSRR		90			90			dB
Output Sink Current		0.8	1.33		0.8	1.33		mA
Output Source Current		5	10		5	10		mA
Output High Level	$R_L = 5\text{K}$	3	3.5		3	3.5		V
Output Low Level	$R_L = 5\text{K}$		0.2	0.3		0.2	0.3	V
<b>"Hiccup" Section</b>								
Input Offset Voltage				4			4	mV
Input Bias Current	CSA Output = 2V, "Hiccup" = 2V			10			10	$\mu\text{A}$
Input Offset Current				1			1	$\mu\text{A}$
Common Mode Range		1.7		5	1.7		5	V
Delay to Output (Note 5)	CSA Output = 2.2V, "Hiccup" = 2V		60	250		60	250	ns
<b>Overvoltage/Undervoltage Section</b>								
Overvoltage Threshold Voltage		$V_{REF} - 1.2$		$V_{REF} - 0.8$	$V_{REF} - 1.2$		$V_{REF} - 0.8$	mV
Overvoltage Hysteresis		150	250	350	150	250	350	mV
Undervoltage Threshold Voltage		$V_{REF} - 1.2$		$V_{REF} - 0.8$	$V_{REF} - 1.2$		$V_{REF} - 0.8$	mV
Undervoltage Hysteresis		150	250	350	150	250	350	mV
Delay to Output (Note 5)	$OV = V_{REF} + .2\text{V}$		45	200		45	200	ns
Input Bias Current	Input Voltage = $V_{REF}$			6			6	$\mu\text{A}$
Input Offset Current				1			1	$\mu\text{A}$

# SG1528/SG1530 SERIES

## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG1528/2528 SG1530/2530			SG3528 SG3530			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Output Section</b>								
Collector Leakage Current				0.5			0.5	mA
Output High Level	$I_{SOURCE} = 50mA$	13	13.5		13	13.5		V
	$I_{SOURCE} = 200mA$	12.5	13.5		12.5	13.5		V
Output Low Level	$I_{SINK} = 50mA$		0.3	0.5		0.3	0.5	V
	$I_{SINK} = 200mA$		1	2		1	2	V
Rise Time (Note 5)	$C_L = 1nF, T_J = 25^\circ C$		25	65		25	65	ns
Fall Time (Note 5)	$C_L = 1nF, T_J = 25^\circ C$		20	50		20	50	ns
Cross Conduction Current (Note 5)	$C_L = 1nF$		6	60		6	60	nJ/Hz
<b>Start Up Section</b>								
Start Up Voltage		16	17.5	18	16	17.5	18	V
Shut Down Voltage		12.6	13.0	13.4	12.6	13.0	13.4	V
Soft Start Charging Current		30	45	60	30	45	60	$\mu A$
Soft Start Discharge Current		10			10			mA
Delay to Output on Shut Down	Output Low, $V_{IN} = 12V$ (Note 5)		150	300		150	300	ns
	Tristate Output, $V_{IN} = 12V$ (Note 5)		250	500		250	500	ns
<b>Total Supply Current</b>								
Standby Current	$C_L = 50pF, F_o = 20KHz$		20	30		24	36	mA
Start Up Current	$+V_{IN} = 15.5V$		350	600		350	600	$\mu A$

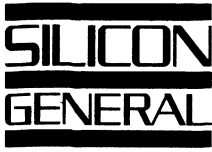
Note 5. The parameters, although guaranteed over the recommended operating conditions, are not tested in production.

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
18-PIN CERAMIC DIP J - PACKAGE	SG1528J/883B	-55°C to 125°C	<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>CURRENT INV. <input type="checkbox"/> 1</p> <p>CURRENT OUTPUT <input type="checkbox"/> 2</p> <p>VOLTAGE N.I. <input type="checkbox"/> 3</p> <p>VOLTAGE INV. <input type="checkbox"/> 4</p> <p>ERROR VOLTAGE <input type="checkbox"/> 5</p> <p>SOFT-START <input type="checkbox"/> 6</p> <p>HICCUP <input type="checkbox"/> 7</p> <p>ANALOG GROUND <input type="checkbox"/> 8</p> <p>POWER GROUND <input type="checkbox"/> 9</p> </div> <div style="width: 45%;"> <p>18 <input type="checkbox"/></p> <p>17 <input type="checkbox"/> <math>V_{REF}</math></p> <p>16 <input type="checkbox"/> SYNC</p> <p>15 <input type="checkbox"/> <math>R_t</math></p> <p>14 <input type="checkbox"/> <math>C_t</math></p> <p>13 <input type="checkbox"/> UNDERVOLTAGE</p> <p>12 <input type="checkbox"/> OVERVOLTAGE</p> <p>11 <input type="checkbox"/> <math>+V_{IN}</math></p> <p>10 <input type="checkbox"/> DRIVER OUTPUT</p> </div> </div>
	SG1528J	-55°C to 125°C	
	SG2528J	-55°C to 125°C	
	SG3528J	0°C to 70°C	
	SG1530J/883B	-55°C to 125°C	
	SG1530J	-55°C to 125°C	
	SG2530J	-55°C to 125°C	
	SG3530J	0°C to 70°C	
18-PIN PLASTIC DIP N - PACKAGE	SG2528N	-25°C to 85°C	<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>CURRENT INV. <input type="checkbox"/> 1</p> <p>CURRENT OUTPUT <input type="checkbox"/> 2</p> <p>VOLTAGE N.I. <input type="checkbox"/> 3</p> <p>VOLTAGE INV. <input type="checkbox"/> 4</p> <p>ERROR VOLTAGE <input type="checkbox"/> 5</p> <p>SOFT-START <input type="checkbox"/> 6</p> <p>HICCUP <input type="checkbox"/> 7</p> <p>ANALOG GROUND <input type="checkbox"/> 8</p> <p>POWER GROUND <input type="checkbox"/> 9</p> </div> <div style="width: 45%;"> <p>18 <input type="checkbox"/></p> <p>17 <input type="checkbox"/> <math>V_{REF}</math></p> <p>16 <input type="checkbox"/> SYNC</p> <p>15 <input type="checkbox"/> <math>R_t</math></p> <p>14 <input type="checkbox"/> <math>C_t</math></p> <p>13 <input type="checkbox"/> UNDERVOLTAGE</p> <p>12 <input type="checkbox"/> OVERVOLTAGE</p> <p>11 <input type="checkbox"/> <math>+V_{IN}</math></p> <p>10 <input type="checkbox"/> DRIVER OUTPUT</p> </div> </div>
	SG3528N	0°C to 70°C	
	SG2530N	-25°C to 85°C	
	SG3530N	0°C to 70°C	
18-PIN WIDE BODY PLASTIC S.O.I.C. DW - PACKAGE	SG2528DW	-25°C to 85°C	<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>CURRENT INV. <input type="checkbox"/> 1</p> <p>CURRENT OUTPUT <input type="checkbox"/> 2</p> <p>VOLTAGE N.I. <input type="checkbox"/> 3</p> <p>VOLTAGE INV. <input type="checkbox"/> 4</p> <p>ERROR VOLTAGE <input type="checkbox"/> 5</p> <p>SOFT-START <input type="checkbox"/> 6</p> <p>HICCUP <input type="checkbox"/> 7</p> <p>ANALOG GROUND <input type="checkbox"/> 8</p> <p>POWER GROUND <input type="checkbox"/> 9</p> </div> <div style="width: 45%;"> <p>18 <input type="checkbox"/></p> <p>17 <input type="checkbox"/> <math>V_{REF}</math></p> <p>16 <input type="checkbox"/> SYNC</p> <p>15 <input type="checkbox"/> <math>R_t</math></p> <p>14 <input type="checkbox"/> <math>C_t</math></p> <p>13 <input type="checkbox"/> UNDERVOLTAGE</p> <p>12 <input type="checkbox"/> OVERVOLTAGE</p> <p>11 <input type="checkbox"/> <math>+V_{IN}</math></p> <p>10 <input type="checkbox"/> DRIVER OUTPUT</p> </div> </div>
	SG3528DW	0°C to 70°C	
	SG2530DW	-25°C to 85°C	
	SG3530DW	0°C to 70°C	

- Notes: 1. Contact factory for JAN and DESC product availability.  
 2. All parts are viewed from the top.  
 3. Product is also available in leadless chip carrier (LCC) and 24-pin hermetic flat pack (F). Contact factory for price and availability.





LINEAR INTEGRATED CIRCUITS

**SG1529/SG2529/SG3529**  
ADVANCED DATA SHEET

**REGULATING PULSE WIDTH MODULATOR**

**DESCRIPTION**

The SG1529 series of pulse width modulator integrated circuits are designed to provide all the operational features of the SG1524B series with the added advantage of an uncommitted input to the PWM comparator. This allows the device to be used in Feed-Forward regulation schemes to achieve better line regulation as well as improved dynamic response. A 5V bandgap reference trimmed to  $\pm 1\%$  tolerance, an error amplifier, and a current limit comparator with a high common mode range are included in the I.C.

A DC coupled flip-flop eliminates triggering and glitch problems, and a PWM data latch prevents edge oscillations. The circuit incorporates true digital shutdown for high speed response while an undervoltage lockout circuit prevents spurious outputs when the supply voltage is too low for stable operation. Full double-pulse suppression logic insures alternating output pulses when the Shutdown pin is used for pulse-by-pulse current limiting. The SG1529 is specified for operation over the full military ambient temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The SG2529 is characterized for the industrial range of  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$  and the SG3529 is designed for the commercial range of  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

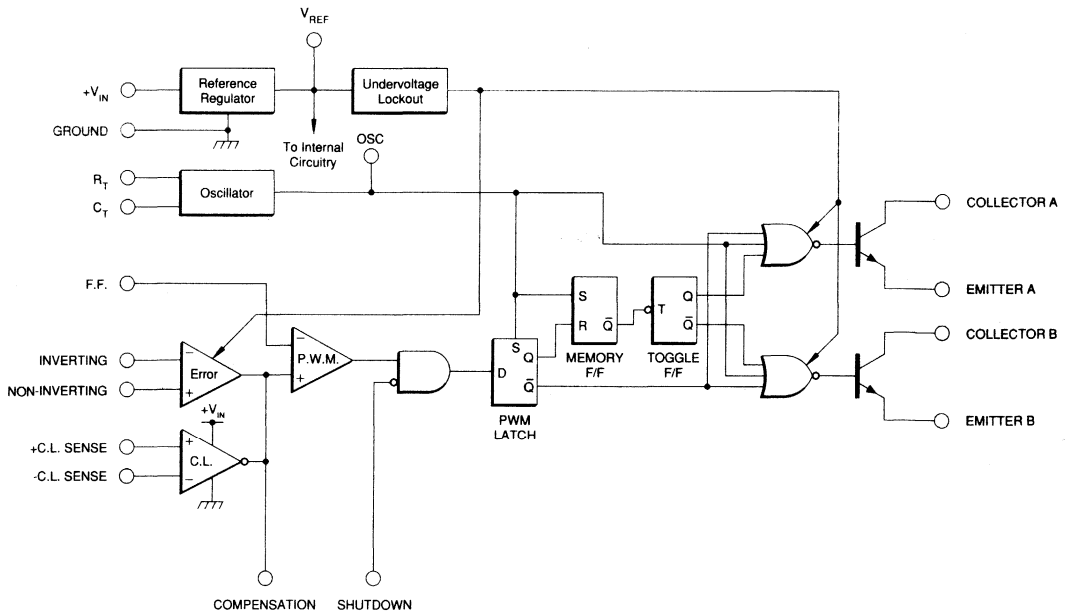
**FEATURES**

- Feed forward capability**
- 7V to 40V operation**
- **5V reference trimmed to  $\pm 1\%$**
- **100Hz to 400KHz oscillator range**
- **Excellent external sync capability**
- **Dual 100mA output transistors**
- **Wide current limit common mode range**
- **DC-coupled toggle flip-flop**
- **PWM data latch**
- **Undervoltage lockout**
- **Full double-pulse suppression logic**
- **60V output collectors**

**HIGH RELIABILITY FEATURES - SG1529**

- ◆ **Available to MIL-STD-883**
- ◆ **SG level "S" processing available**

**BLOCK DIAGRAM**



# SG1529/SG2529/SG3529

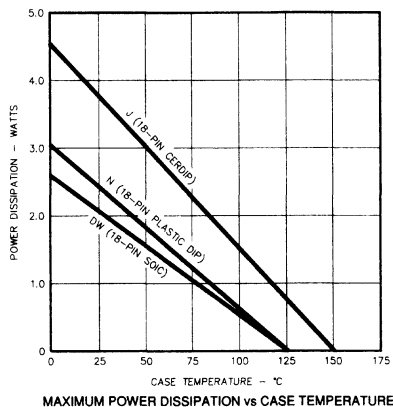
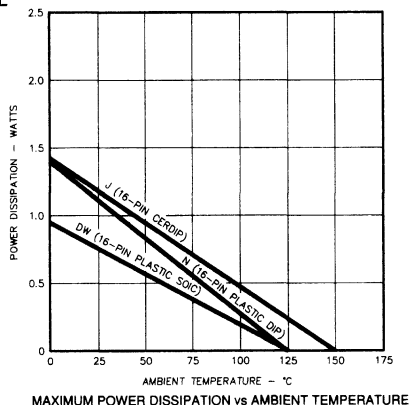
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Input Voltage (+V <sub>IN</sub> ) .....	42V	Oscillator Charging Current .....	5mA
Collector Voltage .....	60V	Operating Junction Temperature	
Logic Inputs .....	-0.3V to 5.5V	Hermetic (J Package) .....	175°C
Current Limit Sense Inputs .....	-0.3V to V <sub>IN</sub>	Plastic (N, DW Packages) .....	150°C
Output Current (each transistor) .....	200mA	Storage Temperature Range .....	-65°C to 150°C
Reference Load Current .....	50mA	Lead Temperature (Soldering, 10 seconds) .....	300°C

Note 1. Values beyond which damage may occur.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



### ELECTRICAL

Input Voltage (+V <sub>IN</sub> ) .....	7V to 40V	Oscillator Frequency Range .....	100Hz to 400KHz
Collector Voltage .....	0V to 60V	Oscillator Timing Resistor (R <sub>T</sub> ) .....	2KΩ to 150KΩ
Error Amp Common Mode Range .....	2.3V to V <sub>REF</sub>	Oscillator Timing Capacitor (C <sub>T</sub> ) .....	1nF to 0.1μF
Current Limit Sense Common Mode Range .....	0V to V <sub>IN</sub> -2.5V	Operating Ambient Temperature Range	
Output Current (each transistor) .....	0 to 100mA	SG1529 .....	-55°C to 125°C
Reference Load Current .....	0 to 20mA	SG2529 .....	-25°C to 85°C
Oscillator Charging Current .....	25μA to 1.8mA	SG3529 .....	0°C to 70°C

Note 2: Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(+V<sub>IN</sub> = 20V, and over operating temperature, unless otherwise specified.)

Parameter	Test Conditions	SG1529/2529			SG3529			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Reference Section (Note 3)</b>								
Output Voltage	T <sub>J</sub> = 25°C	4.95	5.00	5.05	4.90	5.00	5.10	V
Line Regulation	V <sub>IN</sub> = 7V to 40V		3	20		3	30	mV
Load Regulation	I <sub>L</sub> = 0 to 20mA		5	30		5	50	mV
Temperature Stability (Note 7)	Over Operating Temperature Range		15	50		15	50	mV
Total Output Voltage Range	Over Line, Load and Temperature	4.90		5.10	4.80		5.20	V
Short Circuit Current	V <sub>REF</sub> = 0V	25	50	120	25	50	120	mA
<b>Undervoltage Lockout Section</b>								
Threshold Voltage		4.3	4.5	4.7	4.3	4.5	4.7	V

Note 3. I<sub>L</sub> = 0mA

# SG1529/SG2529/SG3529

## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG1529/2529			SG3529			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Oscillator Section (Note 4)</b>								
Initial Accuracy	$T_J = 25^\circ\text{C}$	42	45	48	40	45	50	KHz
Voltage Stability	$V_{IN} = 7\text{V to }40\text{V}$		$\pm 0.1$	$\pm 1$		$\pm 0.1$	$\pm 1$	%
Temperature Stability (Note 7)	Over Operating Range		$\pm 1$	$\pm 2$		$\pm 1$	$\pm 2$	%
Minimum Frequency	$R_T = 150\text{K}\Omega, C_T = 0.1\mu\text{F}$		50	140		50	120	Hz
Maximum Frequency	$R_T = 2\text{K}\Omega, C_T = 470\text{pF}$	400	600		400	600		KHz
Sawtooth Peak Voltage	$V_{IN} = 40\text{V}$		3.5	3.9		3.5	3.9	V
Sawtooth Valley Voltage	$V_{IN} = 7\text{V}$	0.6	1		0.6	1		V
Clock Amplitude		3.0	4.0		3.0	4.0		V
Clock Pulse Width		0.2	0.5	1.2	0.2	0.5	1.2	$\mu\text{s}$
<b>Error Amplifier Section (Note 5)</b>								
Input Offset Voltage	$R_B \leq 2\text{K}\Omega$		0.5	5		2	10	mV
Input Bias Current			1	5		1	10	$\mu\text{A}$
Input Offset Current				1			1	$\mu\text{A}$
DC Open Loop Gain	$R_L \geq 10\text{M}\Omega$	60	78		60	78		dB
Output Low Level	$I_{\text{SINK}} = 100\mu\text{A}; V_{\text{PIN}1} - V_{\text{PIN}2} \geq 150\text{mV}$		0.2	0.5		0.2	0.5	V
Output High Level	$I_{\text{SOURCE}} = 100\mu\text{A}; V_{\text{PIN}2} - V_{\text{PIN}1} \geq 150\text{mV}$	3.8	4.2		3.8	4.2		V
Common Mode Rejection	$V_{\text{CM}} = 2.3\text{V to }V_{\text{REF}}$	70	90		70	90		dB
Supply Voltage Rejection	$V_{IN} = 7\text{V to }40\text{V}$	76	100		76	100		dB
Gain-Bandwidth Product (Note 7)	$T_J = 25^\circ\text{C}$	1	2		1	2		MHz
<b>P.W.M. Comparator (Note 4)</b>								
Minimum Duty Cycle	$V_{\text{COMP}} = 0.5\text{V}$ (Note 8)			0			0	%
Maximum Duty Cycle	$V_{\text{COMP}} = 3.9\text{V}$ (Note 8)	45	49		45	49		%
Input Bias Current	$V_{\text{REF}} = 0.5\text{V to }3.9\text{V}$			2			2	$\mu\text{A}$
<b>Current Limit Amplifier Section (Note 6)</b>								
Sense Voltage		180	200	220	170	200	230	mV
Input Bias Current			-3	-10		-3	-10	$\mu\text{A}$
<b>Shutdown Input Section (Note 6)</b>								
HIGH Input Voltage		2.0			2.0			V
HIGH Input Current	$V_{\text{SHUTDOWN}} = 5.0\text{V}$		0.1	1		0.1	1	mA
LOW Input Voltage				0.6			0.6	V
<b>Output Section (each transistor)</b>								
Collector Leakage Current	$V_{\text{CE}} = 60\text{V}$			50			50	$\mu\text{A}$
Collector Saturation Voltage	$I_C = 10\text{mA}$		0.2	0.4		0.2	0.4	V
	$I_C = 100\text{mA}$		1.0	2.0		1.0	2.0	V
Emitter Output Voltage	$I_E = 10\text{mA}$	17.5	19		17.5	19		V
	$I_E = 100\text{mA}$	17	18		17	18		V
Emitter Voltage Rise Time (Note 7)	$R_E = 2\text{K}\Omega, T_A = 25^\circ\text{C}$		0.2	0.5		0.2	0.5	$\mu\text{s}$
Collector Voltage Fall Time	$R_C = 2\text{K}\Omega, T_A = 25^\circ\text{C}$		0.1	0.2		0.1	0.2	$\mu\text{s}$
<b>Power Consumption</b>								
Standby Current	$V_{IN} = 40\text{V}, V_{\text{SHUTDOWN}} = 2.0\text{V}$		5	12		5	12	mA

Note 4.  $F_{\text{OSC}} = 43\text{KHz}$  ( $R_T = 2700\Omega, C_T = .01\mu\text{F}$ )

Note 5.  $V_{\text{CM}} = 2.3\text{V to }V_{\text{REF}}$

Note 6.  $V_{\text{CM}} = 0\text{V to }17.5\text{V}$

Note 7. These parameters, although guaranteed over the recommended operating conditions, are not 100% tested in production.

Note 8.  $C_T$  connected to FF.

## APPLICATION CIRCUITS

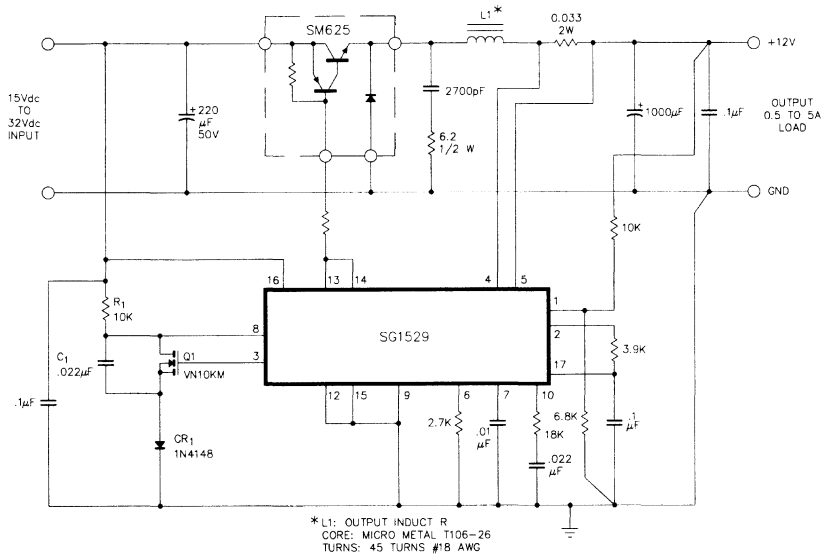


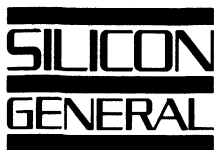
FIGURE 1 - 60V STEP DOWN BUCK CONVERTER

The above schematic describes a 60W step down (Buck) converter where feed forward feature is obtained by generating a ramp with external components R1, C1 and Q1. The slope of the ramp changes with the change in input voltage, which causes the duty cycle to adjust much faster than the conventional fixed slope ramp method resulting in a better line transient response. Rectifier CR1 is used to offset the ramp.

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram																																				
18-PIN CERAMIC DIP J - PACKAGE	SG1529J/883B	-55°C to 125°C	<table style="width: 100%; border: none;"> <tr> <td>INV. INPUT</td><td>1</td><td>18</td><td>N.C.</td> </tr> <tr> <td>N.I. INPUT</td><td>2</td><td>17</td><td>V<sub>REF</sub></td> </tr> <tr> <td>OSC. OUTPUT</td><td>3</td><td>16</td><td>+V<sub>IN</sub></td> </tr> <tr> <td>+C.L. SENSE</td><td>4</td><td>15</td><td>E<sub>B</sub></td> </tr> <tr> <td>-C.L. SENSE</td><td>5</td><td>14</td><td>C<sub>B</sub></td> </tr> <tr> <td>R<sub>T</sub></td><td>6</td><td>13</td><td>C<sub>A</sub></td> </tr> <tr> <td>C<sub>T</sub></td><td>7</td><td>12</td><td>E<sub>A</sub></td> </tr> <tr> <td>F.F.</td><td>8</td><td>11</td><td>SHUTDOWN</td> </tr> <tr> <td>GROUND</td><td>9</td><td>10</td><td>COMPENSATION</td> </tr> </table>	INV. INPUT	1	18	N.C.	N.I. INPUT	2	17	V <sub>REF</sub>	OSC. OUTPUT	3	16	+V <sub>IN</sub>	+C.L. SENSE	4	15	E <sub>B</sub>	-C.L. SENSE	5	14	C <sub>B</sub>	R <sub>T</sub>	6	13	C <sub>A</sub>	C <sub>T</sub>	7	12	E <sub>A</sub>	F.F.	8	11	SHUTDOWN	GROUND	9	10	COMPENSATION
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SG3529DW	0°C to 70°C																																						

Note 1. Contact factory for JAN and DESC product availability.  
 2. All packages are viewed from the top.



LINEAR INTEGRATED CIRCUITS

SG1532/SG2532/SG3532

**PRECISION GENERAL-PURPOSE REGULATOR**

**DESCRIPTION**

This monolithic integrated circuit is a versatile, general-purpose voltage regulator designed as a substantially improved replacement for the popular SG723 device. The SG1532 series regulators retain all the versatility of the SG723 but have the added benefits of operation with input voltages as low as 4.5 volts and as high as 50 volts; a low noise, low voltage reference; temperature compensated, low threshold current limiting; and protective circuits which include thermal shutdown and independent current limiting of both the reference and output voltages. A separate remote shutdown terminal is included. In the dual-in-line package an open collector output is available for low input-output differential applications.

These devices are available in both hermetic 14-pin cerdip and 10-pin TO-96 packages. In the T-package, these units are interchangeable with the LAS-1000 and LAS-1100 regulators. The SG1532 is rated for operation over the temperature range of -55°C to 125°C while the SG2532 and SG3532 are intended for industrial applications of 0°C to 70°C.

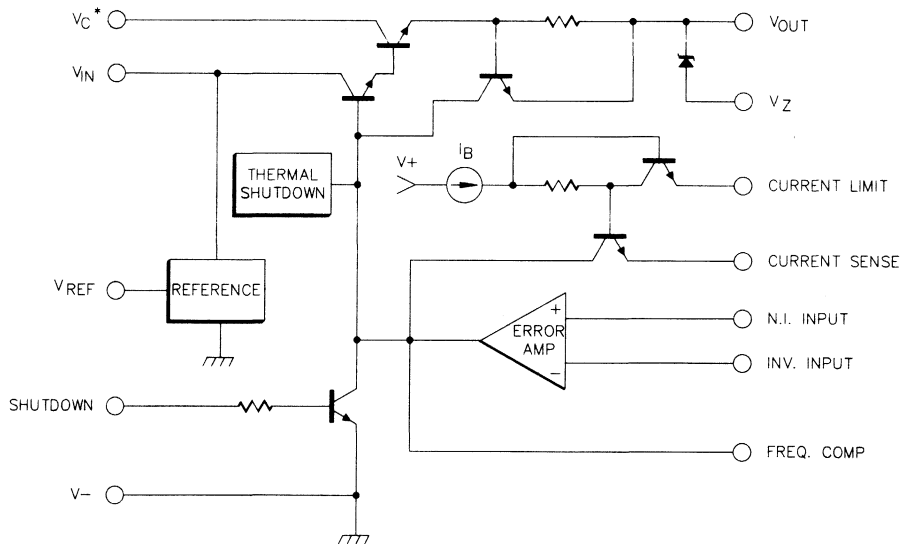
**FEATURES**

- Input voltage range of 4.5V to 50V
- 2.5V low noise reference
- Independent shutdown terminal
- Improved line and load regulation
- 80mV current limit sense voltage
- Fully protected including thermal shutdown
- Useful output current to 150mA

**HIGH RELIABILITY FEATURES -SG1532**

- ♦ Available to MIL-STD-883
- ♦ SG level "S" processing available

**BLOCK DIAGRAM**



\*  $V_C$  IS INTERNALLY CONNECTED TO  $V_{IN}$  FOR T PACKAGE

# SG1532/SG2532/SG3532

## ABSOLUTE MAXIMUM RATINGS (Note 1)

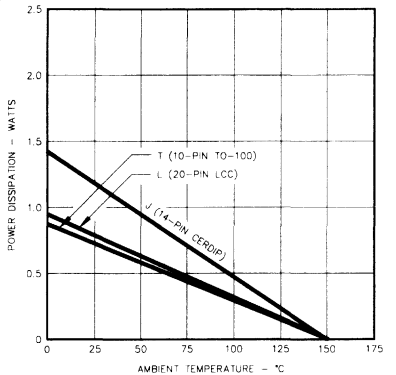
Pulse (50 ms) Input Voltage from  $V_{IN}$  to  $V_-$  ..... 50V  
 Continuous Input Voltage from  $V_{IN}$  to  $V_-$  ..... 40V  
 Input to Output Voltage Differential ..... 40V  
 Maximum Output Current ..... 250mA  
 Current from  $V_2$  (J, L-Package only) ..... 100mA

Current from  $V_{REF}$  ..... 25mA  
 Operating Junction Temperature  
 Hermetic (T, J, L-Packages) ..... 175°C  
 Storage Temperature Range ..... -65°C to 150°C  
 Lead Temperature (Soldering, 10 Seconds) ..... 300°C

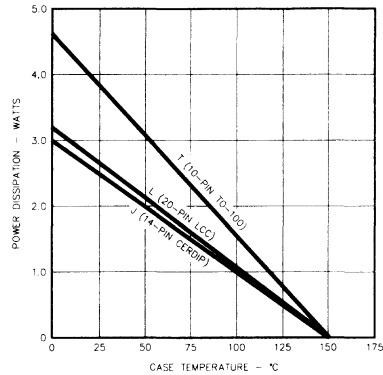
Note 1. Exceeding these ratings could cause damage to the device.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Input Voltage Range  
 SG1532/SG2532 ..... 5V to 45V  
 SG3532 ..... 5V to 36V  
 Output Current Range ..... 5mA

Reference Current ..... 5mA  
 Zener Current (J & L-Packages only) ..... 20mA  
 Operating Junction Temperature Range  
 SG1532 ..... -55°C to 125°C  
 SG2532/SG3532 ..... 0°C to 70°C

Note 2. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise specified, these specifications apply for  $V_{IN} = 10V$ ,  $V_{OUT} = 5V$ ,  $I_{OUT} = 1mA$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ .)

Parameter	Test Conditions	SG1532/SG2532			SG3532			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Input Voltage Range	$T_A = 25^\circ C$	4.5		50	4.5		40	V
		4.7		50	4.7		40	V
Output Voltage Range		2.0		38	2.0		38	V
Max Output Current	$R_{SC} = 0, V_{OUT} = 0, T_A = 25^\circ C$		175	250		175	250	mA
Min ( $V_{IN} - V_{OUT}$ )	$I_{OUT} = 100mA, T_A = 25^\circ C$		1.7	2.0		1.7	2.0	V
Reference Voltage	$T_A = 25^\circ C$	2.40	2.50	2.60	2.40	2.50	2.60	V
		2.35		2.65	2.35		2.65	V
Temperature Stability (Note 4)			0.005	0.015		0.005	0.015	%/°C
Ref Short Circuit Current	$V_{REF} = 0, T_A = 25^\circ C$		15	25		15	25	mA
Line Regulation (Note 3)	$8V \leq V_{IN} \leq 40V$		0.005	0.01		0.005	0.02	%/V
	$8V \leq V_{IN} \leq 20V, I_{OUT} = 25mA$		0.01	0.02		0.01	0.03	%/V
Load Regulation (Note 3)	$1mA \leq I_{OUT} \leq 25mA$		0.002	0.004		0.002	0.004	%/mA
	$1mA \leq I_{OUT} \leq 100mA$		0.002	0.005		0.002	0.005	%/mA
Current Limit Sense Voltage	$R_{SC} = 100\Omega, V_{OUT} = 0V$	0.06	0.08	0.10	0.06	0.08	0.10	V
Shutdown Voltage Threshold		0.40	0.70	1.0	0.40	0.70	1.0	V
Shutdown Source Current	$V_{OUT} = high$	100	200	300	100	200	300	$\mu A$
Zener Voltage	J, L-Packages only	6.0	6.4	7.0	6.0	6.4	7.0	V
Standby Current	$V_{IN} = 40V$		2.5	3.5		2.5	3.5	mA
Error Amplifier Offset Voltage			2.0	10		2.0	15	mV
Error Amplifier Input Bias Current			4.0	15		4.0	20	$\mu A$

**ELECTRICAL SPECIFICATIONS** (continued)

Parameter	Test Conditions	SG1532/SG2532			SG3532			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Open Loop Gain	$T_A = 25^\circ\text{C}$	66	68	72	60	68	72	dB
Ripple Rejection	$f = 120\text{Hz}, T_A = 25^\circ\text{C}$		66			66		dB
Output Noise	$10\text{Hz} \leq f \leq 100\text{KHz}, T_A = 25^\circ\text{C}$		50			50		$\mu\text{V}_{\text{RMS}}$
Long Term Stability (Note 4)	$V_{\text{IN}} = 30\text{V}, T_A = 125^\circ\text{C}$		0.3	1.0		0.3	1.0	%/Khr
Thermal Shutdown			175			175		$^\circ\text{C}$

Note 3. Applies for constant junction temperature. Temperature drift effects must be taken into account separately when the unit is operating under conditions of high dissipation.

Note 4. These parameters, although guaranteed, are not tested in production.

**CHARACTERISTIC CURVES**

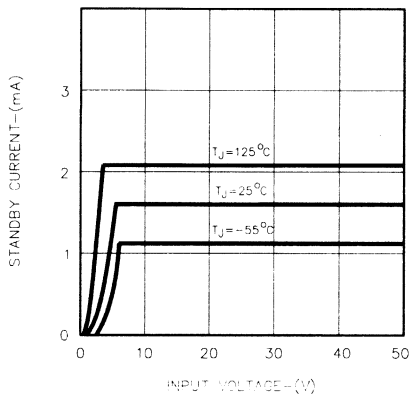


FIGURE 1. STANDBY CURRENT

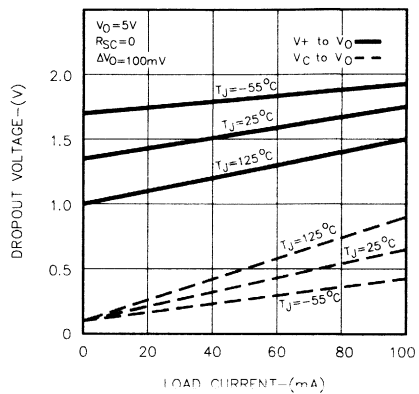


FIGURE 2. MINIMUM INPUT-OUTPUT VOLTAGE

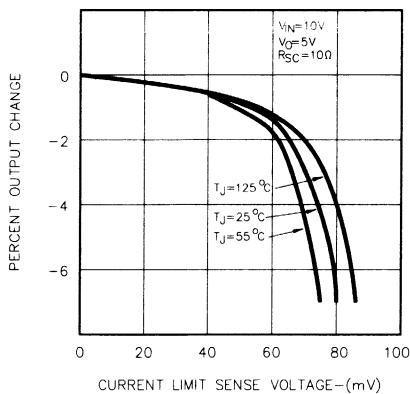


FIGURE 3. CURRENT LIMITING

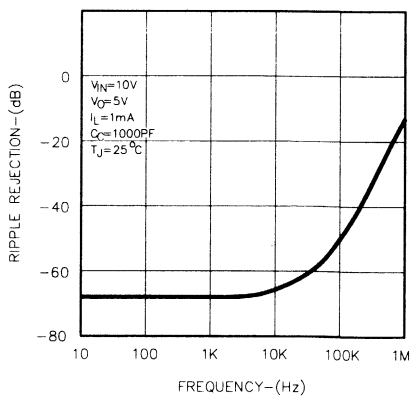


FIGURE 4. RIPPLE REJECTION

CHARACTERISTIC CURVES (continued)

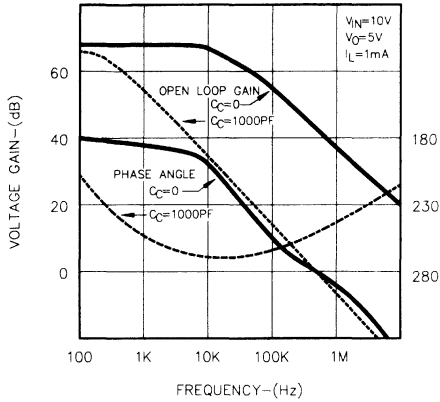


FIGURE 5. FREQUENCY RESPONSE

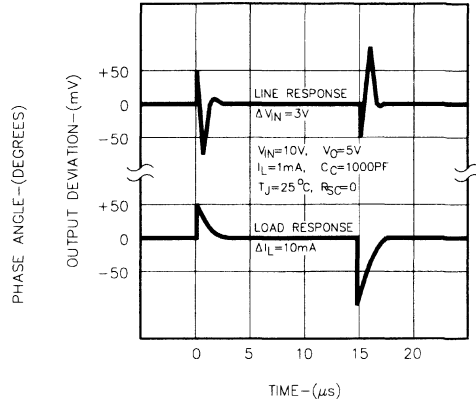


FIGURE 6. TRANSIENT RESPONSE

APPLICATION INFORMATION

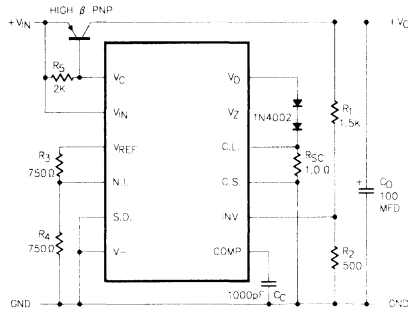


FIGURE 7 - 90% EFFICIENT LINEAR REGULATOR

Output Voltage = 5V  
 Min ( $V_{IN}-V_{OUT}$ ) at 2A = 0.4V  
 Load Reg 0-2A = 20mV  
 Max Output Current = 3A  
 Line Reg 6-30V = 10 mV

Notes:

For output voltages above 8V and load currents which allow PNP base current to be limited to 25mA, the internal zener may be used, eliminating the need for the two external diodes and the divider on  $V_{REF}$ .

$R_{SC}$  can be eliminated if the 200mA current limit on  $V_{OUT}$  is adequate. Overall current limiting is dependent upon PNP Beta. For greater accuracy, load current may be sensed in the ground line.

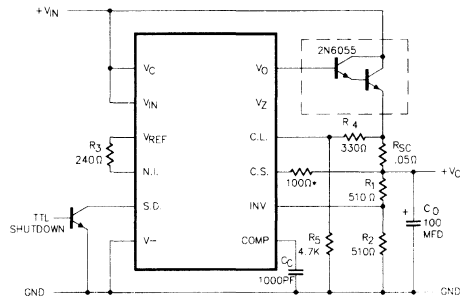


FIGURE 8 - HIGH CURRENT REGULATOR WITH FOLDBACK CURRENT LIMITING AND REMOTE SHUTDOWN

Output Voltage = 5V  
 Max Output Current = 8A  
 Min  $V_{IN}$  at No Load = 6.9V  
 Min  $V_{IN}$  at 5A = 8.2V  
 Line Reg 10-30V = 3mV  
 Load Reg 0-5A = 17mV  
 Short Circuit Current = 1.8A

Note:

\* 100 $\Omega$  surge limiting resistor should be used for output voltages above 8V.



APPLICATION INFORMATION

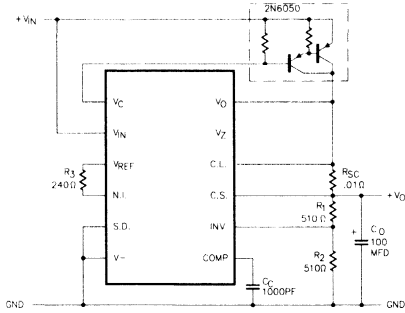


FIGURE 9 - HIGH EFFICIENCY LOW VOLTAGE REGULATOR

Output Voltage = 5V  
 Max Output Current = 9A  
 Min  $V_{in}$  at 5A = 7.0V  
 Line Reg 7-20V = 10mV  
 Load Reg 0-5A = 25mV  
 Constant Current Limiting

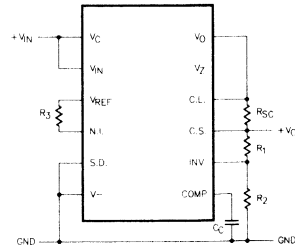


FIGURE 10 - BASIC LOW CURRENT REGULATOR

$$V_{OUT} = V_{REF} \left( 1 + \frac{R_1}{R_2} \right)$$

$$I_{SC} = \frac{\text{Sense Voltage}}{R_{SC}} = \frac{R_1 R_2}{R_1 + R_2}$$

$$C_C = 1000 \text{ pF}$$

$$I_{OUT} \leq 100 \text{ mA}$$

CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
14-PIN CERAMIC DIP J - PACKAGE	SG1532J/883B SG1532J SG2532J SG3532J	-55°C to 125°C -55°C to 125°C 0°C to 70°C 0°C to 70°C	
10-PIN METAL CAN T - PACKAGE	SG1532T/883B SG1532T SG2532T SG3532T	-55°C to 125°C -55°C to 125°C 0°C to 70°C 0°C to 70°C	(Notes 3 & 4) 
20-PIN CERAMIC LEADLESS CHIP CARRIER L - PACKAGE	SG1532L/883B SG1532L	-55°C to 125°C -55°C to 125°C	

Note 1. Contact factory for JAN and DESC product availability.  
 Note 2. All packages are viewed from the top.

Note 3.  $V_z$  output is not available in T-package.  
 Note 4. Pin 5 is connected to case.



**OFF-LINE START-UP CONTROLLER**

**DESCRIPTION**

The SG1540 is an integrated circuit designed to efficiently provide start-up power from a high-voltage DC bus to a PWM control circuit in a switching power supply. When used on the primary side, it reduces start-up current to less than 1mA and allows any standard PWM control circuit to be used as a primary-side controller. When used to power a controller on the secondary side, it efficiently eliminates the need for a heavy 50/60Hz line transformer with its associated low frequency magnetic fields.

The circuit consists of three sections: a micropower bandgap comparator/power switch referenced to 2.5 volts which isolates the start-up capacitor from its load; a high frequency square-wave oscillator with 200mA totem-pole output for driving an isolation transformer; and a second bandgap comparator with latching crowbar to protect against overvoltage faults while starting or running.

The SG1540 is specified for operation over the full military ambient temperature range of -55°C to 125°C. The SG2540 is characterized for the industrial range of -25°C to 85°C, and the SG3540 is designed for the commercial range of 0°C to 70°C.

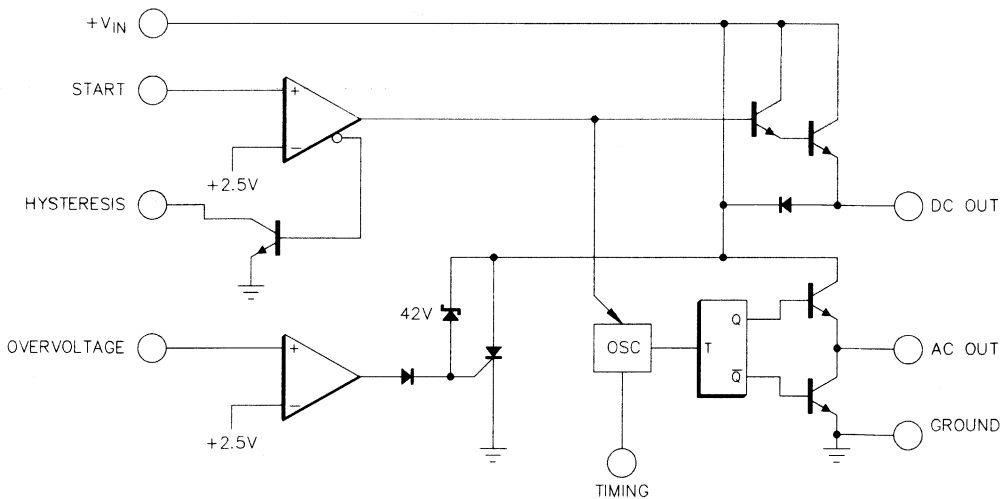
**FEATURES**

- Useable with primary and secondary side PWM controllers
- Micropower comparator / switch
  - Internal 2.5V bandgap reference
  - 50mA power switch
- Squarewave oscillator
  - 500Hz to 200KHz operation
  - 200mA totem pole outputs
- Eliminates bulky, expensive 50/60 Hz transformer
- Minimizes high voltage bleeder current
- Programmable start-up voltage and hysteresis
- Internal and programmable overvoltage crowbar latch
- Available in 8 pin DIP, 10 pin flat pack, and 16 pin widebody SOIC

**HIGH RELIABILITY FEATURES - SG1540**

- ♦ Available to MIL-STD - 883
- ♦ SG level "S" processing available

**BLOCK DIAGRAM**



# SG1540/SG2540/SG3540

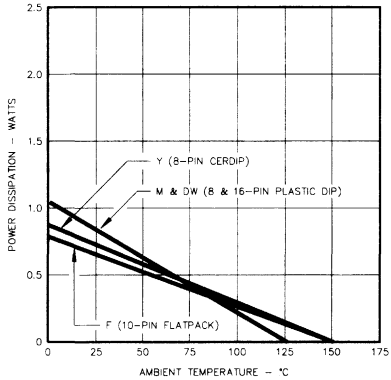
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage (+V <sub>IN</sub> ) .....	+37V	Overshoot Crowbar Energy (½CV²) .....	8mJ
DC Output Current, Continuous (V <sub>OUT</sub> ) .....	100mA	Operating Junction Temperature	
AC Output Current, Continuous .....	200mA	Hermetic (Y Package) .....	175°C
Analog Inputs (Start and Overshoot) .....	-0.3V to 6.0V	Plastic (M, DW Packages) .....	150°C
Analog Input Currents (V>8V) .....	10mA	Storage Temperature Range .....	-65°C to 150°C
Overshoot Crowbar Current, Continuous .....	50mA	Lead Temperature (Soldering, 10 Seconds) .....	300°C

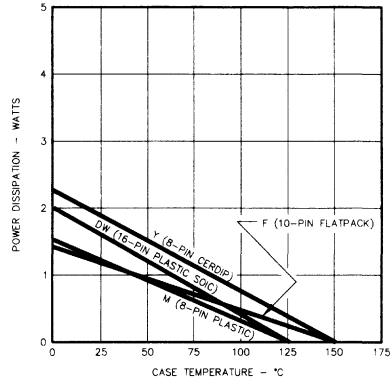
Note 1. Values beyond which damage may occur.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Supply Voltage Range .....	7V to 35V	Timing Capacitor Range .....	1nF to 20µF
DC Output Current, Continuous .....	0 to 50mA	Operating Ambient Temperature Range	
AC Output Current, Continuous .....	0 to 100 mA	SG1540 .....	-55°C to 125°C
Oscillator Frequency Range .....	1KHz to 400KHz	SG2540 .....	-25°C to 85°C
Timing Resistor Range .....	2KΩ to 150KΩ	SG3540 .....	0°C to 70°C

Note 2. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise specified, these specifications apply at +V<sub>IN</sub> = 15V, and over operating ambient temperature. A 0.1µF high frequency bypass capacitor is recommended on V<sub>IN</sub>.)

Parameter	Test Conditions	SG1540/2540/3540			Units
		Min.	Typ.	Max.	
<b>Start-up Section</b>					
Start Current I <sub>CC</sub>	V <sub>START</sub> = 0 to 2.37V		0.2	0.4	mA
Operating Current	V <sub>TIMING</sub> = +V <sub>IN</sub> ; V <sub>OUT</sub> Open		0.3	0.6	mA
	F <sub>OSC</sub> = 50KHz; V <sub>OUT</sub> and AC <sub>OUT</sub> Open		3	6	mA
Start Threshold		2.37	2.50	2.63	V
Start Bias Current	V <sub>PIN1</sub> = 0 to 5V		0.1	1	µA
Start Clamp Voltage	I <sub>PIN1</sub> = 1mA	6	7	8	V
Hysteresis ON Voltage	I <sub>PIN4</sub> = 100µA		0.1	0.2	V
<b>DC Output Section</b>					
V <sub>OUT</sub> Voltage	I <sub>SOURCE</sub> = 10mA	12.5	13.5		V
	I <sub>SOURCE</sub> = 50mA	12.0	13.0		V
Short Circuit Current	V <sub>OUT</sub> = 0V	50	100	225	mA

# SG1540/SG2540/SG3540

## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG1540/2540/3540			Units
		Min.	Typ.	Max.	
<b>Oscillator Section (Note 3)</b>					
Initial Accuracy	$T_J = 25^\circ\text{C}$	46	50	54	KHz
Voltage Stability	$+V_{IN} = 12 \text{ to } 18\text{V}$		5	12	%
Temperature Stability (Note 4)			2	5	%
Oscillator Minimum Frequency	$R_T = 17.8\text{K}, C_T = .068\mu\text{F}$			1	KHz
Oscillator Maximum Frequency	$R_T = 1.5\text{K}, C_T = 470\text{pF}$	400			KHz
<b>AC Output Section</b>					
HIGH Output Voltage	$I_{SOURCE} = 20\text{mA}$	12.5	13.5		V
	$I_{SOURCE} = 100\text{mA}$	12.0	13.0		V
LOW Output Voltage	$I_{SINK} = 20\text{mA}$		0.2	0.3	V
	$I_{SINK} = 100\text{mA}$		1.2	2.0	V
Squarewave Duty Cycle		45	50	55	%
AC Output Risetime	$C_L = 1000\text{pF}$		0.3	0.6	$\mu\text{S}$
AC Output Faltime	$C_L = 1000\text{pF}$		0.1	0.2	$\mu\text{S}$
<b>Overvoltage Crowbar Section</b>					
Overvoltage Threshold		2.37	2.50	2.63	V
Overvoltage Bias Current	$V_{O.V.} = 0 \text{ to } 2.37\text{V}$		0.1	1	$\mu\text{A}$
Overvoltage Clamp Voltage	$I_{O.V.} = 1\text{mA}$	6	7	8	V
$+V_{IN}$ Overvoltage Threshold		37	42	44	V
SCR ON Voltage	$I_{VIN} = 35\text{mA}$		9	12	V
SCR Holding Current	$V_{O.V.} = 0$	0.15	0.35	0.55	mA

Note 3.  $F_{OSC} = 50\text{KHz}$ ,  $R_T = 3.48\text{K}$ ,  $C_T = 4.7\text{nF}$  unless otherwise specified.

Note 4. These parameters, although guaranteed, are not tested in production.

## CHARACTERISTIC CURVES

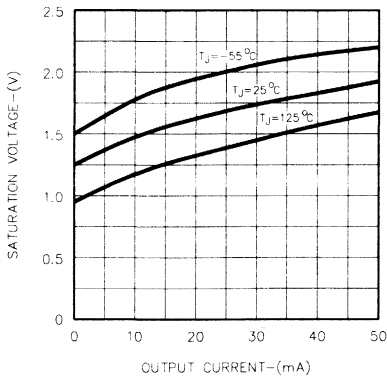


FIGURE 1 - SATURATION VOLTAGE (DC OUT PIN) VS. OUTPUT CURRENT

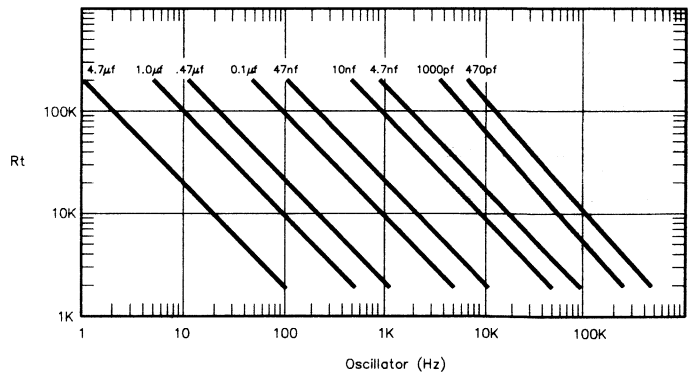


FIGURE 2 - OSCILLATOR FREQUENCY VS.  $R_T$  AND  $C_T$

**APPLICATION INFORMATION**

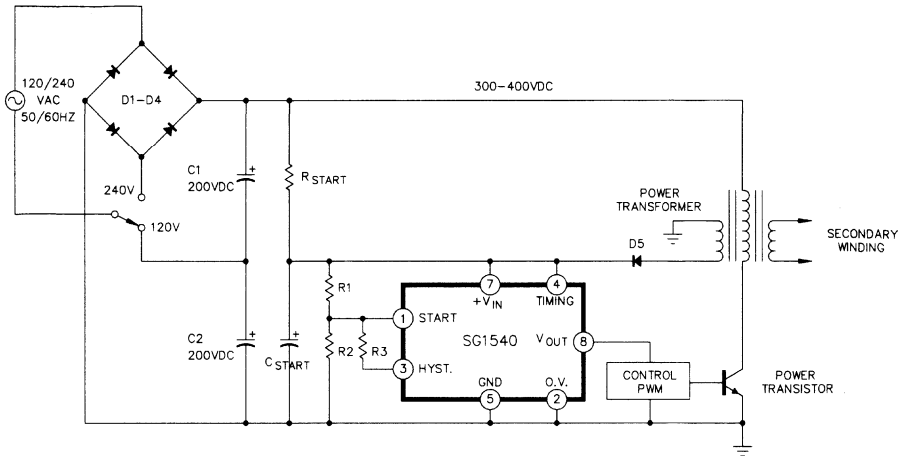


FIGURE 3 - EFFICIENT PRIMARY SIDE START-UP

**PRIMARY SIDE START-UP**

When the design goal is efficient start-up for a control PWM referenced to the primary side of the power transformer, the configuration in Figure 3 is recommended. An energy storage capacitor  $C_{START}$  is trickle-charged from the 300-400 Volt DC bus by resistor  $R_{START}$ . The value of  $R_{START}$  is chosen to provide a constant 1mA charging current, allowing the use of a 1/2 watt resistor. As the voltage on  $C_{START}$  ramps up from zero, the only load current is the standby current of the SG1540 and that of the divider network R1-R3. (Connecting the TIMING pin to  $+V_{IN}$  disables the internal power oscillator and forces the circuitry into a micropower standby model. Since the input bias current at the START pin is 1 $\mu$ A maximum, a divider current of 100 $\mu$ A is adequate).

When the voltage at the START pin reaches +2.5 Volts, the hysteresis transistor turns off, overdriving the START pin. The  $V_{OUT}$  pin is switched to the HIGH state, providing power to the PWM control circuit. As energy flows out of the START capacitor, its voltage decays; but it remains connected to the PWM circuit until the dropout voltage is reached ( $V_{START} - V_{HYSTERESIS}$ ). The bootstrap winding on the power transformer and rectifier diode D5 prevent this from happening. As the PWM control circuit becomes active, the power transistor begins to switch, providing operating current to the PWM circuit through the SG1540.

**RESISTOR CALCULATIONS**

Given that  $V_{START}$  and  $V_{DROPOUT}$  have been chosen, and that the divider current at start-up is 100 $\mu$ A, then the values for R1 through R3 are calculated as follows:

$$1. \text{ For simplification, let } X = \frac{V_{START} - 2.5}{2.5} \quad 2. \text{ Then, } R1 = 2.5 \times 10^4 * X \quad [1]$$

$$\text{and } Y = \frac{V_{DROPOUT} - 2.5}{2.5} \quad R2 = R1/Y \quad [2]$$

$$\text{and } R3 = \frac{R1 * R2}{X * R2 - R1} \quad [3]$$

**DESIGN EXAMPLE**

Suppose we have a power MOSFET device, and so want to start at +18 volts and drop out at +12 volts.

Then  $X = 6.20$   
and  $Y = 3.80$

Therefore  $R1 = 2.5 \times 10^4 * 6.2 = 155K$  (Choose 150K)  
 $R2 = 1.5 \times 10^5 / 3.8 = 39.5K$  (Choose 39K)  
 $R3 = \frac{1.5 \times 10^5 * 3.9 \times 10^4}{6.2 * 3.9 \times 10^4 - 1.5 \times 10^5} = 63.7K$  (Choose 62K)

**APPLICATIONS INFORMATION** (continued)

The voltage waveform at +V<sub>IN</sub> is shown in Figure 4 with these resistor values and with C<sub>START</sub> = 3μF. Notice that two tries are required before the +15 volt bootstrap winding becomes active.

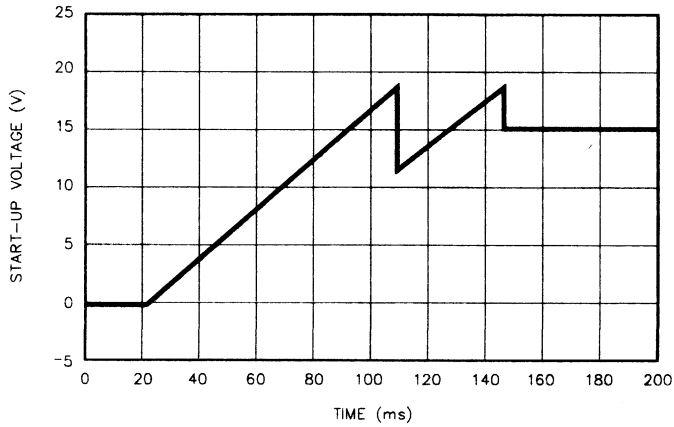


FIGURE 4 - STARTUP VOLTAGE WAVEFORM

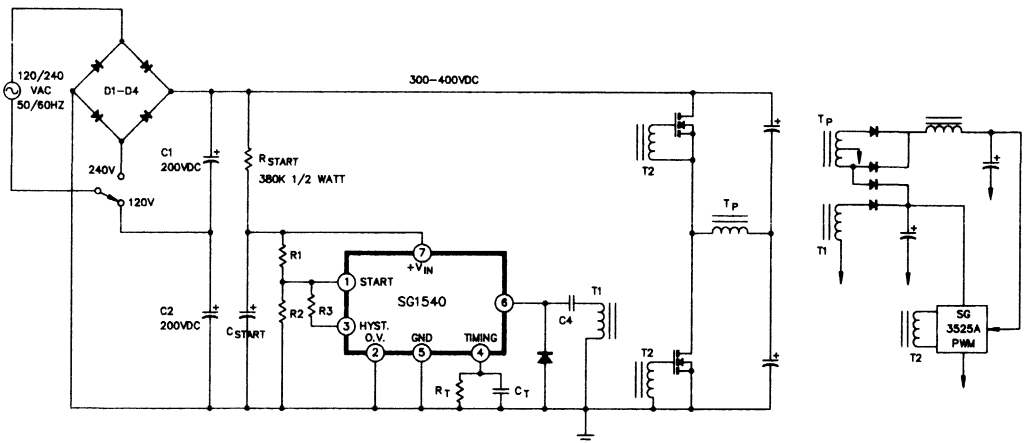


FIGURE 5 - SECONDARY-SIDE START-UP WITHOUT A LINE TRANSFORMER

# SG1540/SG2540/SG3540

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
8-PIN CERAMIC DIP Y - PACKAGE	SG1540Y/883B SG1540Y SG2540Y SG3540Y	-55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C	
8-PIN PLASTIC DIP M - PACKAGE	SG2540M SG3540M	-25°C to 85°C 0°C to 70°C	
16-PIN PLASTIC DIP DW - PACKAGE	SG2540DW SG3540DW	-25°C to 85°C 0°C to 70°C	
10-PIN HERMETIC FLAT PACK F - PACKAGE	SG1540F/883B SG1540F	-55°C to 125°C -55°C to 125°C	

Notes: 1. Contact factory for JAN and DESC part availability.  
2. All parts are viewed from the top.



**POWER SUPPLY OUTPUT SUPERVISORY CIRCUIT**

**DESCRIPTION**

This monolithic integrated circuit contains all the functions necessary to monitor and control the output of a sophisticated power supply system. Over-voltage (O.V.) sensing with provision to trigger an external SCR "crowbar" shutdown; an under-voltage (U.V.) circuit which can be used to monitor either the output or to sample the input line voltage; and a third op amp/comparator usable for current sensing (C.L.) are all included in this IC, together with an independent, accurate reference generator.

Both over and under-voltage sensing circuits can be externally programmed for minimum time duration of fault before triggering. All functions contain open collector outputs which can be used independently or wire-ORed together; and although the SCR trigger is directly connected only to the over-voltage sensing circuit, it may be optionally activated by any of the other outputs, or from an external signal. The O.V. circuit also includes an optional latch and external reset capability.

The current sense circuit may be used with external compensation as a linear amplifier or as a high gain comparator. Although nominally set for zero input offset, a fixed threshold may be added with an external resistor. Instead of current limiting, this circuit may also be used as an additional voltage monitor.

The reference generator circuit is internally trimmed to eliminate the need for external potentiometers and the entire circuit may be powered directly from either the output being monitored or from a separate bias voltage.

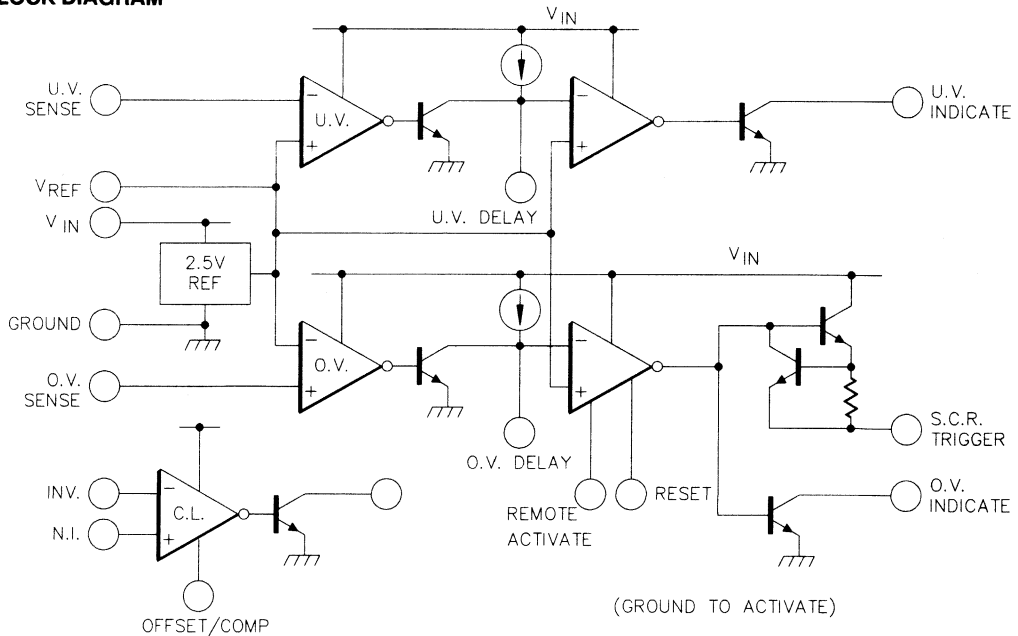
**FEATURES**

- **Over-voltage, under-voltage, and current sensing circuits all included**
- **Reference voltage trimmed to 1% accuracy**
- **SCR "Crowbar" drive of 300mA**
- **Programmable time delays**
- **Open-collector outputs and remote activation capability**
- **Total standby current less than 10mA**

**HIGH RELIABILITY FEATURES - SG1543**

- **Available to MIL-STD-883 and DESC SMD**
- **SG level "S" processing available**

**BLOCK DIAGRAM**



**ABSOLUTE MAXIMUM RATINGS** (Note 1)

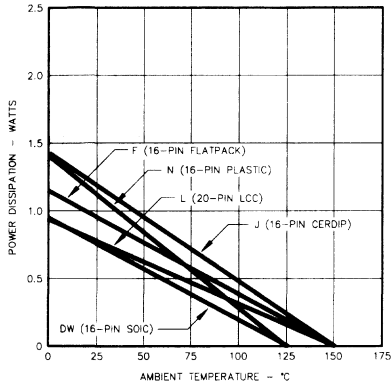
Input Supply Voltage (+V <sub>IN</sub> ).....	40V	Indicator Output Sink Current .....	50mA
Sense Inputs .....	+V <sub>IN</sub>	Operating Junction Temperature	
SCR Trigger Current (Note 2) .....	300mA	Hermetic (J, F, L Packages) .....	175°C
Indicator Output Voltage .....	40V	Plastic (N, DW Packages) .....	150°C
		Storage Temperature Range .....	-65°C to 150°C

Note 1. Values beyond which damage may occur.

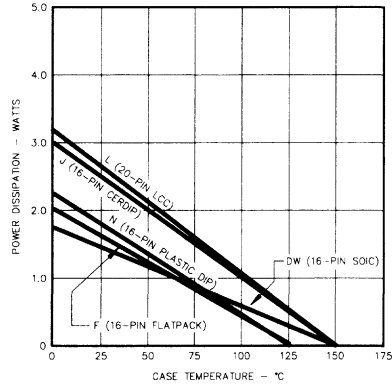
Note 2. At higher input voltages, a dissipation limiting resistor, R<sub>G</sub>, is required. See Figure 1.

**RECOMMENDED OPERATING CONDITIONS** (Note 3)

**THERMAL**



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

**ELECTRICAL**

Input Supply Voltage (+V <sub>IN</sub> ) .....	4.7V to 40V	Delay Timing Capacitor (Note 4) .....	0 to 1μF
Current Limit Common Mode		Operating Ambient Temperature Range	
Input Voltage Range .....	0V to +V <sub>IN</sub> -3V	SG1543 .....	-55°C to 125°C
Reference Load Current .....	0 to 10mA	SG2543 .....	-25°C to 85°C
Indicator Output Voltage .....	4.7V to 40V	SG3543 .....	0°C to 70°C
Indicator Output Current .....	0 to 10mA		

Note 3: Range over which the device is functional.

Note 4. Larger value capacitor may be used with peak current limiting. See Figure 7.

**ELECTRICAL SPECIFICATIONS**

(+V<sub>IN</sub> = 10V. Unless otherwise stated, these specifications apply for T<sub>J</sub> = -55°C to 125°C for the SG1543, -25°C to 85°C for the SG2543, and 0°C to 70°C for the SG3543. Indicator outputs have 2kΩ pull-up to 10V.)

Parameter	Test Conditions	SG1543/2543			SG3543			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Supply Section</b>								
Input Voltage Range	T <sub>J</sub> = 25°C to T <sub>MAX</sub>	4.5		40	4.5		40	V
		4.7		40	4.7		40	V
Supply Current	+V <sub>IN</sub> = 40V, Outputs open, T <sub>J</sub> = 25°C		7	10		7	10	mA
<b>Reference Section</b>								
Output Voltage	T <sub>J</sub> = 25°C	2.48	2.50	2.52	2.45	2.50	2.55	V
		2.45		2.55	2.40		2.60	V
Line Regulation	+V <sub>IN</sub> = 5 to 30V		1	5		1	5	mV
Load Regulation	I <sub>REF</sub> = 0 to 10mA		1	10		1	10	mV
Short Circuit Current	V <sub>REF</sub> = 0V	12	25	40	12	25	40	mA
Temperature Stability			.005			.005		%/°C

ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG1543/2543			SG3543			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Comparator Section</b>								
Input Threshold (Note 5)	$T_J = 25^\circ\text{C}$	2.45	2.50	2.55	2.40	2.50	2.60	V
		2.40		2.60	2.35		2.65	V
Input Hysteresis			25			25		mV
Input Bias Current	Sense input = 0V		0.3	1.0		0.3	1.0	$\mu\text{A}$
Delay Saturation			0.2	0.5		0.2	0.5	V
Delay High Level			6	8		6	8	V
Delay Charging Current	$V_D = 0\text{V}$	200	250	300	200	250	300	$\mu\text{A}$
Indicate Saturation	$I_L = 10\text{mA}$		0.2	0.5		0.2	0.5	V
Indicate Leakage	$V_{IND} = 40\text{V}$		.01	1.0		0.1	1.0	$\mu\text{A}$
Propagation Delay	$V_{O.V. INPUT} = 2.7\text{V}, V_{U.V. INPUT} = 2.3\text{V}, T_J = 25^\circ\text{C}$							ns
	$C_D = 0$		400			400		ns
	$C_D = 1\mu\text{F}$		10			10		ms
<b>SCR Trigger Section</b>								
Peak Output Current	$+V_{IN} = 5\text{V}, R_G = 0, V_O = 0$	100	200	400	100	200	400	mA
Peak Output Voltage	$+V_{IN} = 15\text{V}, I_O = 100\text{mA}$	12	13		12	13		V
Output Off Voltage	$+V_{IN} = 40\text{V}, R_L = 1\text{k}\Omega$		0	0.1		0	0.1	V
Remote Activate Current	REM. ACT. pin = Gnd		0.4	0.8		0.4	0.8	mA
Remote Activate Voltage	REM. ACT. pin open		2	6		2	6	V
Reset Current	RESET pin = Gnd, REM. ACT. = Gnd		0.4	0.8		0.4	0.8	mA
Reset Voltage	RESET pin open, REM. ACT. = Gnd		2	6		2	6	V
Output Current Rise Time	$R_L = 50\Omega, T_J = 25^\circ\text{C}, C_D = 0$		400			400		mA/ $\mu\text{s}$
Prop. Delay from REM. ACT. Pin	$V_{REM. ACT.} = 0.4\text{V}$		300			300		ns
Prop. Delay fom O.V. INPUT Pin	$V_{O.V. INPUT} = 2.7\text{V}$		500			500		ns
<b>Current Limit Section</b>								
Input Voltage Range		0		$V_{IN} - 3\text{V}$	0		$V_{IN} - 3\text{V}$	V
Input Bias Current	OFFSET/COMP pin open, $V_{CM} = 0\text{V}$		0.3	1.0		0.3	1.0	$\mu\text{A}$
Input Offset Voltage	OFFSET/COMP pin open, $V_{CM} = 0\text{V}$		0	10		0	15	mV
	10k $\Omega$ from OFFSET/COMP pin to Gnd	80	100	120	70	100	130	mV
CMRR	$0 \leq V_{CM} \leq 12\text{V}, V_{IN} = 15\text{V}$	60	70		60	70		dB
AVOL	OFFSET/COMP pin open, $V_{CM} = 0\text{V}$	72	80		72	80		dB
Output Saturation	$I_L = 10\text{mA}$		0.2	0.5		0.2	0.5	V
Output Leakage	$V_{IND} = 40\text{V}$		.01	1.0		.01	1.0	$\mu\text{A}$
Small Signal Bandwidth	$A_v = 0\text{dB}, T_J = 25^\circ\text{C}$		5			5		MHz
Propagation Delay	$V_{OVERDRIVE} = 100\text{mV}, T_J = 25^\circ\text{C}$		200			200		ns

Note 5. Input voltage rising on O.V. Input and falling on U.V. Input.

CHARACTERISTIC CURVES

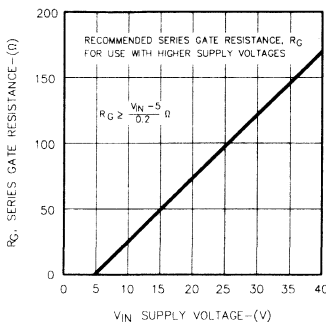


FIGURE 1. SCR TRIGGER POWER LIMITING

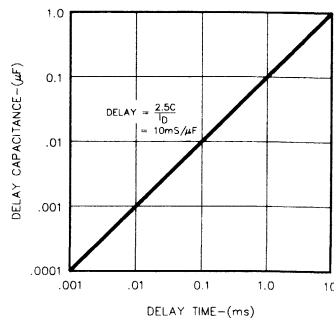


FIGURE 2. ACTIVATION DELAY VS. CAPACITOR VALUE

CHARACTERISTIC CURVES (continued)

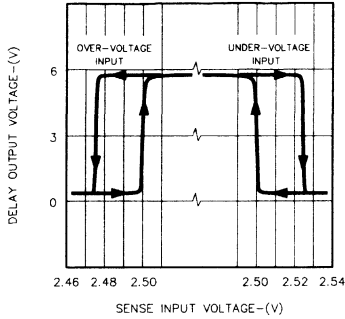


FIGURE 3. COMPARATOR INPUT HYSTERESIS

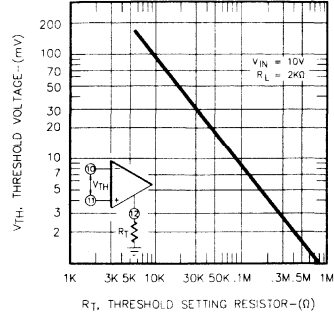


FIGURE 4. CURRENT LIMIT INPUT THRESHOLD

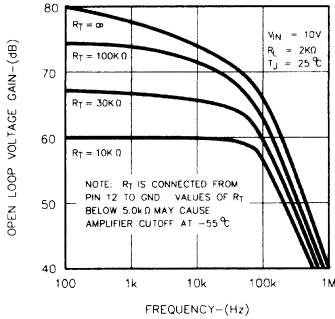


FIGURE 5. CURRENT LIMIT AMPLIFIER GAIN

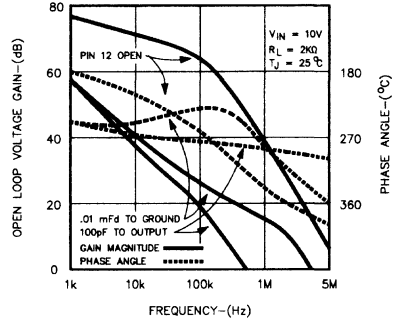


FIGURE 6. CURRENT LIMIT AMPLIFIER FREQUENCY RESPONSE

APPLICATION INFORMATION

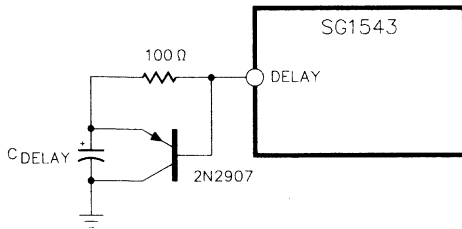


FIGURE 7 - SURGE LIMIT CIRCUIT FOR LARGE DELAY CAPACITORS

The 100 ohm resistor limits the peak discharge current into the SG1543 while the external PNP transistor provides a high peak-current discharge path for the delay capacitor.

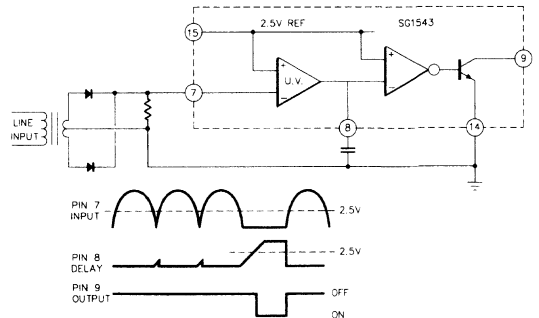


FIGURE 8 - INPUT LINE MONITOR

APPLICATION INFORMATION (continued)

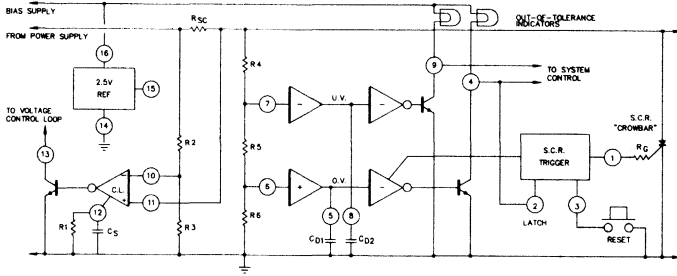


FIGURE 9 - TYPICAL APPLICATION CIRCUIT

The values for the external components are determined as follows:

$$\text{Current limit input threshold, } V_{TH} = \frac{1000}{R_1}$$

$C_5$  is determined by the current loop dynamics

$$\text{Peak current to load, } I_P = \frac{V_{TH}}{R_{SC}} + \frac{V_O}{R_{SC}} \left( \frac{R_2}{R_2 + R_3} \right)$$

$$\text{Short circuit current, } I_{SC} = \frac{V_{TH}}{R_{SC}}$$

$$\text{Low output voltage limit, } V_O (\text{Low}) = \frac{2.5 (R_1 + R_2 + R_3)}{R_1 + R_2}$$

$$\text{High output voltage limit, } V_O (\text{High}) = \frac{2.5 (R_1 + R_2 + R_3)}{R_3}$$

$$\text{Voltage sensing delay, } t_D = 10,000 C_D$$

$$\text{SCR trigger power limiting resistor, } R_3 > \frac{V_{IN} - 5}{0.2}$$

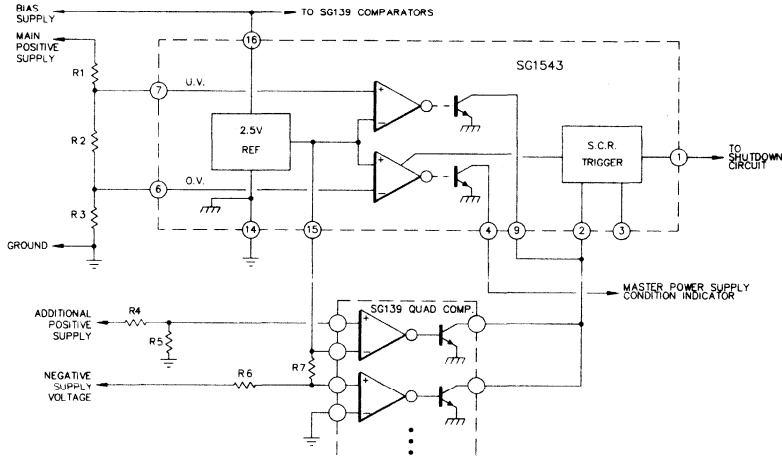


FIGURE 10 - SENSING MULTIPLE SUPPLY VOLTAGES

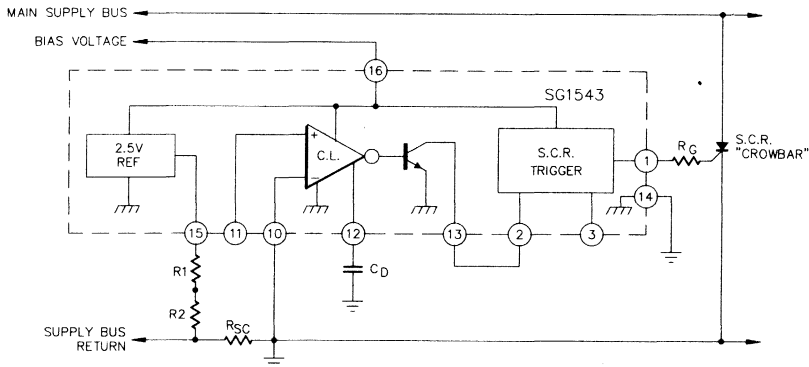


FIGURE 11 - OVERCURRENT SHUTDOWN

## ABSOLUTE MAXIMUM RATINGS (Note 1)

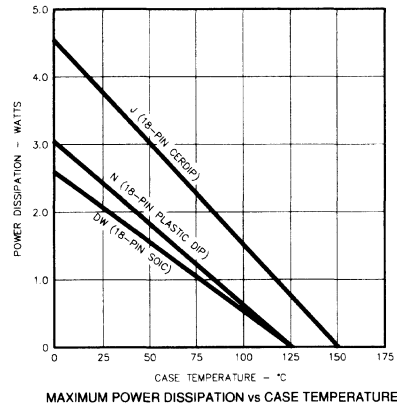
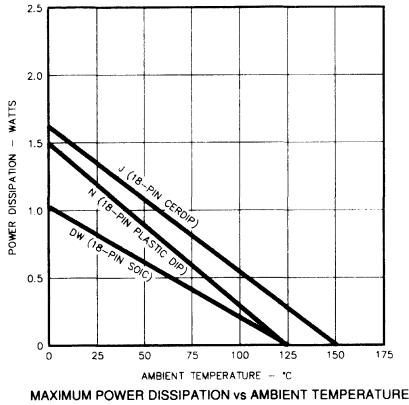
Input Supply Voltage (+V <sub>IN</sub> ) .....	40V	Indicator Output Sink Current .....	50mA
Sense Inputs .....	+V <sub>IN</sub>	Operating Junction Temperature	
SCR Trigger Current (Note 2) .....	300mA	Hermetic (J Package) .....	175°C
Indicator Output Voltage .....	40V	Plastic (N, DW Packages) .....	150°C
		Storage Temperature Range .....	-65°C to 150°C

Note 1. Values beyond which damage may occur.

Note 2. At higher input voltages, a dissipation limiting resistor, R<sub>G</sub>, is required. See Figure 1.

## RECOMMENDED OPERATING CONDITIONS (Note 3)

### THERMAL



### ELECTRICAL

Input Supply Voltage (+V <sub>IN</sub> ) .....	4.7V to 40V	Delay Timing Capacitor (Note 4) .....	0 to 1μF
Current Limit Common Mode		Operating Ambient Temperature Range	
Input Voltage Range .....	0V to +V <sub>IN</sub> -3V	SG1544 .....	-55°C to 125°C
Reference Load Current .....	0 to 10mA	SG2544 .....	-25°C to 85°C
Indicator Output Voltage .....	4.7V to 40V	SG3544 .....	0°C to 70°C
Indicator Output Current .....	0 to 10mA		

Note 3: Range over which the device is functional.

Note 4. Larger value capacitor may be used with peak current limiting. See Figure 1.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise stated, these specifications apply for +V<sub>IN</sub> = 10V; T<sub>J</sub> = -55°C to 125°C for the SG1544, -25°C to 85°C for the SG2544, and 0°C to 70°C for the SG3544. Electrical tests are performed with V<sub>IN</sub> = 10 Volts and 2kΩ pull-up resistors on all indicator outputs. All electrical ratings and specifications are tested with the inverting over-voltage input and the non-inverting under-voltage input externally connected to the 2.5 volt reference.)

Parameter	Test Conditions	SG1544/2544			SG3544			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Supply Section</b>								
Input Voltage Range	T <sub>J</sub> = 25°C to T <sub>MAX</sub>	4.5		40	4.5		40	V
		4.7		40	4.7		40	V
Supply Current	+V <sub>IN</sub> = 40V, Outputs open		7	10		7	10	mA
<b>Reference Section</b>								
Output Voltage	T <sub>J</sub> = 25°C	2.48	2.50	2.52	2.45	2.50	2.55	V
		2.45		2.55	2.40		2.60	V
Line Regulation	+V <sub>IN</sub> = 5 to 30V		1	5		1	5	mV
Load Regulation	I <sub>REF</sub> = 0 to 10mA		1	10		1	10	mV
Short Circuit Current	V <sub>REF</sub> = 0V	12	25	40	12	25	40	mA
Temperature Stability			.005			.005		%/°C

ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG1544/2544			SG3544			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Comparator Section</b>								
Input Threshold (Note 5)	$T_J = 25^\circ\text{C}$	2.45	2.50	2.55	2.40	2.50	2.60	V
		2.40		2.60	2.35		2.65	V
Input Hysteresis			25			25		mV
Input Bias Current	Sense input = 0V		0.3	1.0		0.3	1.0	$\mu\text{A}$
Delay Saturation			0.2	0.5		0.2	0.5	V
Delay High Level			6	8		6	8	V
Delay Charging Current	$V_D = 0\text{V}$	200	250	300	200	250	300	$\mu\text{A}$
Indicate Saturation	$I_I = 10\text{mA}$		0.2	0.5		0.2	0.5	V
Indicate Leakage	$V_{IND} = 40\text{V}$		.01	1.0		0.1	1.0	$\mu\text{A}$
Propagation Delay	$V_{O.V. N.I. IN} = 2.7\text{V}$ , $V_{U.V. INV. IN} = 2.3\text{V}$ , $T_J = 25^\circ\text{C}$							ns
	$C_D = 0$		400			400		ns
	$C_D = 1\mu\text{F}$		10			10		ms
<b>SCR Trigger Section</b>								
Peak Output Current	$+V_{IN} = 5\text{V}$ , $R_G = 0$ , $V_D = 0$	100	200	400	100	200	400	mA
Peak Output Voltage	$+V_{IN} = 15\text{V}$ , $I_O = 100\text{mA}$	12	13		12	13		V
Output Off Voltage	$+V_{IN} = 40\text{V}$ , $R_L = 1\text{K}\Omega$		0	0.1		0	0.1	V
Remote Activate Current	REM. ACT. pin = Gnd		0.4	0.8		0.4	0.8	mA
Remote Activate Voltage	REM. ACT pin open		2	6		2	6	V
Reset Current	RESET pin = Gnd, REM. ACT. = Gnd		0.4	0.8		0.4	0.8	mA
Reset Voltage	RESET pin open, REM. ACT. = Gnd		2	6		2	6	V
Output Current Rise Time	$R_L = 50\Omega$ , $T_J = 25^\circ\text{C}$ , $C_D = 0$		400			400		mA/ $\mu\text{s}$
Prop. Delay from REM. ACT. Pin	$V_{REM. ACT.} = 0.4\text{V}$		300			300		ns
Prop. Delay fom O.V. N.I. IN Pin	$V_{O.V. N.I. INPUT} = 2.7\text{V}$		500			500		ns
<b>Current Limit Section</b>								
Input Voltage Range		0		$V_{IN} - 3\text{V}$	0		$V_{IN} - 3\text{V}$	V
Input Bias Current	OFFSET/COMP pin open, $V_{CM} = 0\text{V}$		0.3	1.0		0.3	1.0	$\mu\text{A}$
Input Offset Voltage	OFFSET/COMP pin open, $V_{CM} = 0\text{V}$		0	10		0	15	mV
	10 $\Omega$ from OFFSET/COMP pin to Gnd, $T_J = 25^\circ\text{C}$	80	100	120	70	100	130	mV
CMRR	$0 \leq V_{CM} \leq 12\text{V}$ , $V_{IN} = 15\text{V}$	60	70		60	70		dB
AVOL	OFFSET/COMP pin open, $V_{CM} = 0\text{V}$	72	80		72	80		dB
Output Saturation	$I_L = 10\text{mA}$		0.2	0.5		0.2	0.5	V
Output Leakage	$V_{IND} = 40\text{V}$		.01	1.0		.01	1.0	$\mu\text{A}$
Small Signal Bandwidth	$A_V = 0\text{dB}$ , $T_J = 25^\circ\text{C}$		5			5		MHz
Propagation Delay	$V_{OVERDRIVE} = 100\text{mV}$ , $T_J = 25^\circ\text{C}$		200			200		ns

Note 5. Input voltage rising on O.V. N.I. INPUT and falling on U.V. INV. INPUT.

APPLICATION INFORMATION

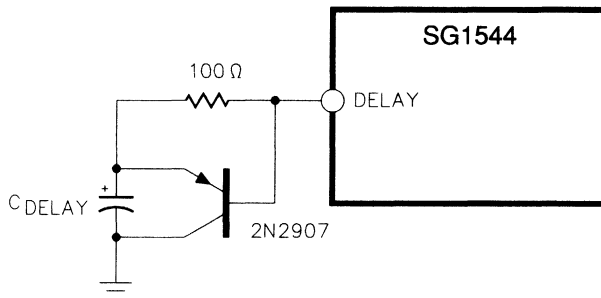


FIGURE 1 - SURGE LIMIT CIRCUIT FOR LARGE DELAY CAPACITORS

The 100 ohm resistor limits the peak discharge current into the SG1544 while the external PNP transistor provides a high peak-current discharge path for the delay capacitor.

# SG1544/SG2544/SG3544

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
18-PIN CERAMIC DIP J - PACKAGE	SG1544J/883B	-55°C to 125°C	
	SG1544J	-55°C to 125°C	
	SG2544J	-25°C to 85°C	
	SG3544J	0°C to 70°C	
18-PIN PLASTIC DIP N - PACKAGE	SG2544N	-25°C to 85°C	
	SG3544N	0°C to 70°C	
18-PIN WIDE BODY PLASTIC S.O.I.C. DW - PACKAGE	SG2544DW	-25°C to 85°C	
	SG3544DW	0°C to 70°C	

Note 1. Contact factory for JAN and DESC product availability.  
 2. All packages are viewed from the top.



**QUAD POWER FAULT MONITOR**

**DESCRIPTION**

The SG1548 is an integrated circuit capable of monitoring up to four positive DC supply voltages simultaneously for overvoltage and undervoltage fault conditions. An on-chip inverting op amp also allows monitoring one negative DC voltage. The fault tolerance window is accurately programmable from  $\pm 5\%$  to  $\pm 40\%$  using a simple divider network on the 2.5V reference. A single external capacitor sets the fault indication delay, eliminating false outputs due to switching noise, logic transition current spikes, and short-term AC line interruptions. An additional comparator referenced to 2.5V allows the AC line to be monitored for undervoltage conditions or for generation of a line clock. The comparator can also be used for programmable undervoltage lockout in a switching power supply. Uncommitted collector and emitter outputs permit both inverting and non-inverting operation. External availability of the precision 2.5V reference and open-collector logic outputs permit expansion to monitor additional voltage using available open-collector quad comparators.

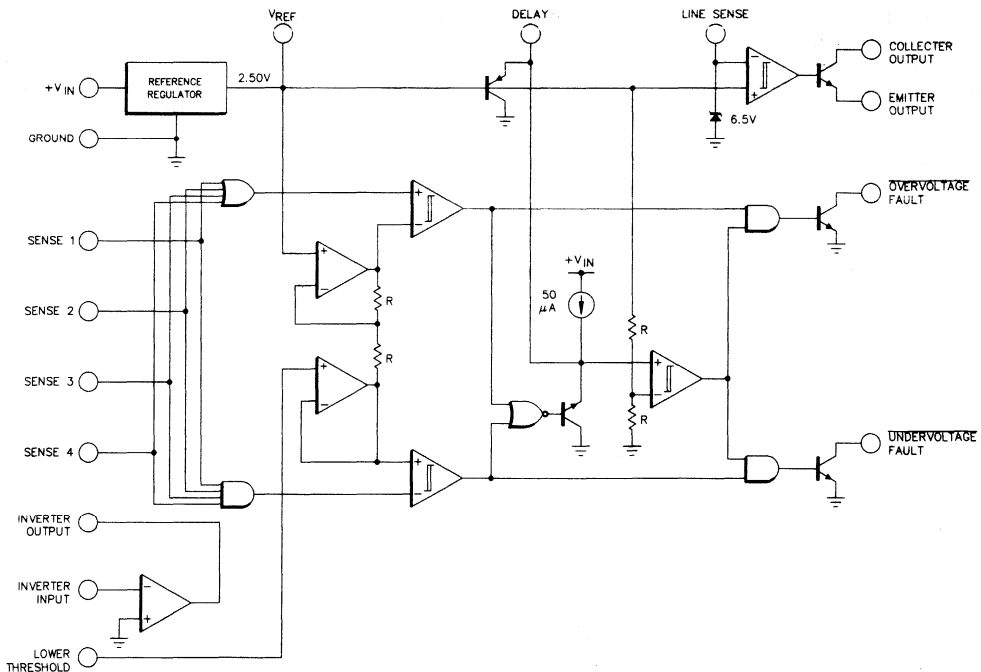
**FEATURES**

- Monitors four DC voltages and the AC line
- Precision 2.5V  $\pm 1\%$  low-drift reference
- Fault tolerance adjustable from  $\pm 5\%$  to  $\pm 40\%$
- $\pm 3\%$  trip threshold tolerance over temperature
- Separate 10mA, 40V overvoltage, undervoltage and AC line fault outputs
- Fault delay programmable with a single capacitor
- 30mV comparator hysteresis to prevent oscillations
- On-chip inverting op amp for negative voltage
- Open-collector output logic or expandability
- Operation from 4.5V to 40V supply

**HIGH RELIABILITY FEATURES - SG1548**

- ◆ Available to MIL-STD-883
- ◆ Radiation data available
- ◆ SG level "S" processing available

**BLOCK DIAGRAM**



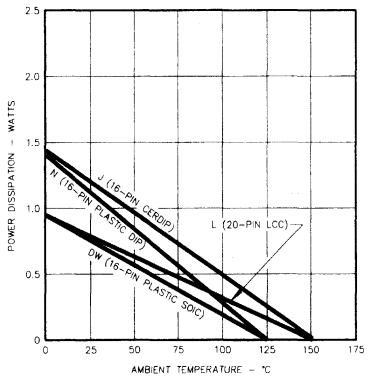
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage (+V <sub>IN</sub> ) .....	40V
Fault Output Collector Voltage .....	40V
Sense Input Voltage Range .....	-0.3V to 6.0V
Fault Output Sink Current .....	20mA
Line Sense Input Current .....	±1mA
Inverting Op Amp Input Current .....	-5mA
Inverting Op Amp Output Current .....	25mA
Operating Junction Temperature	
Hermetic (J, L Packages) .....	175°C
Plastic (N, DW Packages) .....	150°C
Storage Temperature Range .....	-65°C to 150°C
Lead Temperature .....	300°C

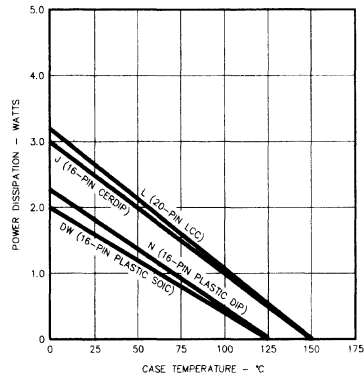
Note 1. Values beyond which damage may occur.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

#### Supply Voltage Range

±25% Maximum Fault Window (Note 3) .....	4.5V to 35V
±40% Maximum Fault Window .....	5.0V to 35V
Lower Threshold Input Range .....	1.5V to 2.45V
Fault Tolerance Window Range .....	±5% to ±40%
Fault Output Sink Current Range .....	0 to 10mA

Line Sense Output Current Range .....

Voltage Reference Output Current .....

Operating Ambient Temperature Range

SG1548 .....

SG2548 .....

SG3548 .....

Note 2. Range over which the device is functional.

Note 3. Limited by inverter amplifier positive swing at -55°C.

## ELECTRICAL SPECIFICATIONS

(+V<sub>IN</sub> = 15V, and over operating temperature, unless otherwise specified.)

Parameter	Test Conditions	SG1548/2548			SG3548			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Supply Section</b>								
Supply Current	+V <sub>IN</sub> = 40V		4.8	10		4.8	10	mA
<b>Reference Section (Note 4)</b>								
Output Voltage	T <sub>J</sub> = 25°C	2.475	2.500	2.525	2.475	2.500	2.525	V
	Over Temperature	2.450		2.550	2.450		2.550	V
Line Regulation	+V <sub>IN</sub> = 4.5V to 35V		1	5		1	5	mV
Load Regulation	I <sub>L</sub> = 0 to 10mA		3	10		3	10	mV
Short Circuit Current	V <sub>REF</sub> = 0V	10	25	40	10	25	40	mA
<b>Fault Window Generator Section</b>								
Input Bias Current	V <sub>PIN1</sub> = 1.5V to 2.45V		-0.4	-2.0		-0.4	-2.0	µA
<b>DC Sense Inputs Section</b>								
Overvoltage Threshold	V <sub>PIN1</sub> = 0.95 × V <sub>REF</sub>	2.547	2.625	2.704				V
	V <sub>PIN1</sub> = 0.60 × V <sub>REF</sub>	3.396	3.500	3.606				V
Undervoltage Threshold	V <sub>PIN1</sub> = 0.95 × V <sub>REF</sub>	2.304	2.375	2.447				V
	V <sub>PIN1</sub> = 0.60 × V <sub>REF</sub>	1.455	1.500	1.545				V
Input Bias Current	V <sub>SENSE</sub> = 1.5V to 3.5V		±0.6	±2.0		±0.6	±2.0	µA
Threshold Supply Rejection	+V <sub>IN</sub> = 4.5V to 35V	60	100		60	100		dB

Note 4. I<sub>L</sub> = 0mA

**ELECTRICAL SPECIFICATIONS** (continued)

Parameter	Test Conditions	SG1548/2548			SG3548			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Fault Delay Section</b>								
Comparator Threshold		1.200	1.250	1.300	1.200	1.250	1.300	V
Comparator Hysteresis			25			25		mV
Delay Charging Current	$V_{PIN8} = 0V$	32.5	50	67.5	32.5	50	67.5	$\mu A$
On Saturation Voltage	$I_{PIN8} = 0mA$		0.1	0.2		0.1	0.2	V
OFF Clamp Voltage	$I_{PIN8} = 0mA$		+3.2	+3.6		+3.2	+3.6	V
<b>Inverting Op Amp Section (Note 5)</b>								
Input Offset Voltage			2	15		2	15	mV
Input Bias Current			-0.3	-1.0		-0.3	-1.0	$\mu A$
Output High Voltage	$I_{SOURCE} = 5mA$	3.2	3.5		3.2	3.5		V
Output Low Voltage	$I_{SINK} = 5mA$		1.0	1.9		1.0	1.9	V
Large Signal Voltage Gain	$R_L = 10K$	72	100		72	100		dB
Output Source Current		5	15	25	5	15	25	mA
Power Supply Rejection Ratio	$+V_{IN} = 4.5V$ to 35V	72	100		72	100		dB
<b>AC Line Sense Section</b>								
Comparator Threshold	$V_{PIN5} = \text{Low to High}$	2.440	2.500	2.560	2.440	2.500	2.560	V
Comparator Hysteresis			25			25		mV
Input Bias Current	$V_{PIN5} = 2.5V$		1	2		1	2	$\mu A$
Collector Leakage Current	$V_{CE} = 40V$		1	10		1	10	$\mu A$
Collector Saturation Voltage	$I_C = 10mA$		0.2	0.5		0.2	0.5	V
Emitter Output Voltage	$I_E = 10mA$	12	13		12	13		V
Diode Clamp Voltage	$I_{PIN5} = 1mA$	6.0		7.5	6.0		7.5	V
	$I_{PIN5} = -1mA$	-0.3		-1.0	-0.3		-1.0	V
<b>Fault Logic Outputs (Each output)</b>								
Collector Leakage Current	$V_C = 40V$		1	10		1	10	$\mu A$
Collector Saturation Voltage	$I_C = 10mA$		0.2	0.5		0.2	0.5	V

Note 5.  $+V_{IN} = 4.5V$ .

**APPLICATION INFORMATION**

**SETTING THE FAULT TOLERANCE WINDOW**

The fault tolerance window is set by applying a voltage less than the +2.50V reference to the Lower Threshold input (Pin 1). The voltage is obtained by a resistor divider from the reference (Pin 3) to ground. If  $\pm 5\%$  tolerance is desired, then 95% of the reference (+2.375V) is applied to Pin 1. If  $\pm 40\%$  is wanted, then 60% of the reference (+1.50V) is applied. In the example on the back page, the tolerance is  $\pm 5\%$ . The nominal overvoltage and undervoltage thresholds are centered about the reference at +2.625V and +2.375V (+2.500V  $\pm 0.125V$ ).

**SCALING THE MONITORED SUPPLY VOLTAGES**

Each positive voltage to be monitored is divided down to +2.50V with a resistor network and connected to one of the Sense inputs. Unused Sense inputs should be connected to the reference. This will not increase the bias current. A variation of the monitored voltages out of the programmed tolerance range will cause the appropriate overvoltage or undervoltage fault output to switch LOW. The effective tolerance on any input may be broadened with an additional resistor to the voltage reference. The example on the back page shows a  $\pm 10\%$  tolerance on the +5V supply although the SG1548 is programmed for a  $\pm 5\%$  tolerance. The procedure for calculating the resistor value is found in the SG1548 Application Note.

**MONITORING A NEGATIVE VOLTAGE**

A negative voltage can be converted to a positive one and simultaneously scaled to +2.50V by using the internal operational amplifier as an inverter. Only an input resistor and feedback resistor are required.

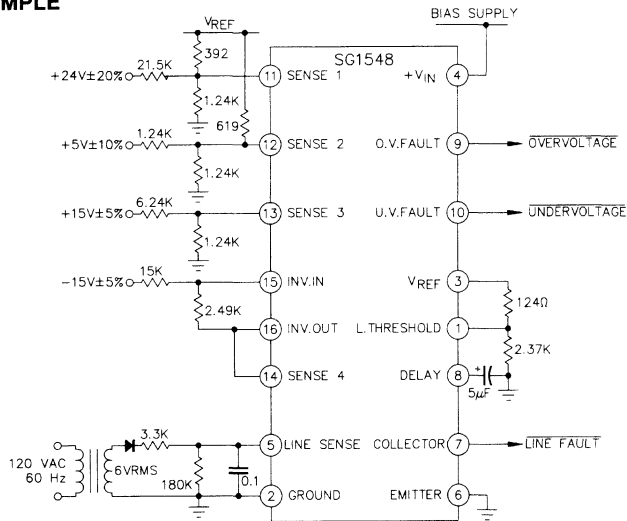
**SETTING THE FAULT DELAY**

A single capacitor at the Delay pin sets the time an out-of-tolerance fault must persist before a fault is actually declared. This feature allows switching noise on the supplies to be rejected. The delay time is given by: Delay = 25ms/ $\mu F$ .

**AC LINE MONITORING**

The AC line voltage can be monitored for single-cycle dropouts with the few components shown in the example. A half-wave rectifier charges the capacitor on positive line cycles. After the positive peak and during the negative line cycle the capacitor discharges from a fixed voltage controlled by the internal Zener diode. If a positive cycle is missing, the capacitor discharges to below the +2.5V trip point of the comparator, causing the output transistor to turn on.

**APPLICATION EXAMPLE**



In this example, the SG1548 simultaneously monitors four DC voltages: +5V, +24V, and ±15V. Three different fault tolerances are programmed: ±5% on the two 15V supplies, ±10% on the +5V supply, and ±20% on the +24V supply. The 5μF delay capacitor provides 125 milliseconds of fault delay.

**CONNECTION DIAGRAMS & ORDERING INFORMATION** (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
16-PIN CERAMIC DIP J - PACKAGE	SG1548J/883B SG1548J SG2548J SG3548J	-55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C	
16-PIN PLASTIC DIP N - PACKAGE	SG2548N SG3548N	-25°C to 85°C 0°C to 70°C	
16-PIN WIDE BODY PLASTIC S.O.I.C. DW - PACKAGE	SG2548DW SG3548DW	-25°C to 85°C 0°C to 70°C	
20-PIN CERAMIC (LCC) LEADLESS CHIP CARRIER L - PACKAGE	SG1548L/883B SG1548L	-55°C to 125°C -55°C to 125°C	

Note 1. Contact factory for JAN and DESC product availability.  
2. All parts are viewed from the top.

**CURRENT SENSE LATCH**

**DESCRIPTION**

This monolithic integrated circuit is an analog latch device with digital reset. It was specifically designed to provide pulse-by-pulse current limiting for switch-mode power supply systems, but many other application are also feasible. Its function is to provide a latching switch action upon sensing an input threshold voltage, with reset accomplished by an external clock signal. This device can be interfaced directly with many kinds of pulse width modulating control IC's, including the SG1524, SG1525A and SG1527A.

The input threshold for the latch circuit is 100mV, which can be referenced either to ground or to a wide-ranging positive voltage. There are high and low-going output signals available, and both the supply voltage and clock signal can be taken directly from an associated PWM control chip.

With delays in the range of 200 nanoseconds, this latch circuit is ideal for fast reaction sensing to provide overall current limiting, short circuit protection, or transformer saturation control.

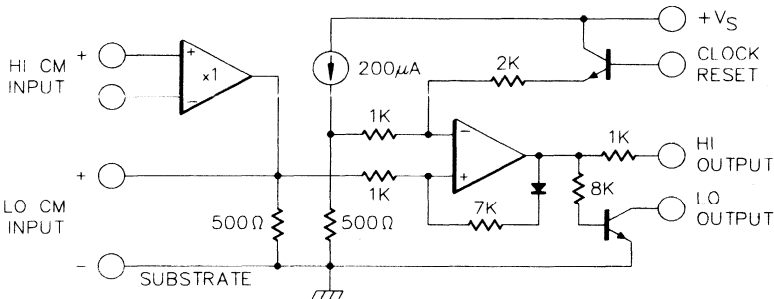
**FEATURES**

- Current sensing with 100mV threshold
- Common-mode input at ground or to 40V
- Complementary outputs
- Automatic reset from PWM clock
- 180ns delay
- Interface direct to SG1524, SG1525A, SG1527A

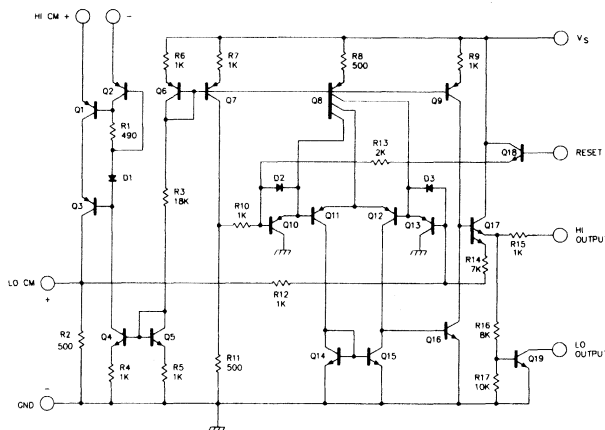
**HIGH RELIABILITY FEATURES - SG1549**

- Available to MIL-STD-883
- SG level "S" processing available

**BLOCK DIAGRAM**



**SCHEMATIC**



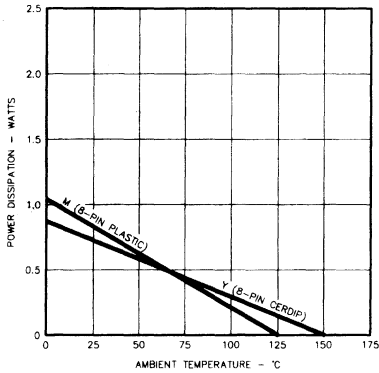
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Input Supply Voltage, $V_S$ .....	25V	Operating Junction Temperature	
HI CM Input Voltage .....	40V	Hermetic (Y Package) .....	175°C
LO Output "off" Voltage .....	40V	Plastic (N Package) .....	150°C
LO Output "on" current .....	25mA	Storage Temperature Range .....	-65°C to 150°C

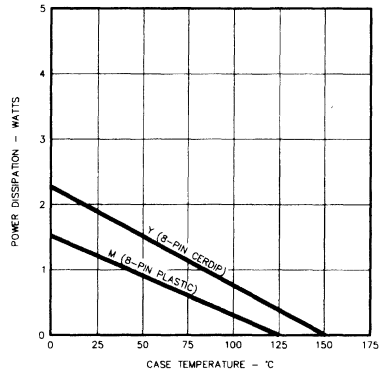
Note 1. Values beyond which damage may occur.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Input Supply Voltage, $V_S$ .....	5.0V	Reset HI Voltage .....	2.5V to 5.0V
HI CM Input Voltage .....	2V to 40V	Operating Ambient Temperature Range	
LO Output "off" Voltage .....	5V to 40V	SG1549Y .....	-55°C to 125°C
LO Output "on" Current .....	0 to 10mA	SG2549Y or M .....	-25°C to 85°C
Reset LO Voltage .....	0V to 0.8V	SG3549Y or M .....	0°C to 70°C

Note 2. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

( $V_S = 5V$ , and over recommended operating temperature, unless otherwise specified.)

Parameter	Test Conditions	SG1549/2549			SG3549			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Supply Section</b>								
Supply Current	$V_{PIN8} = 5V$		2	3		2	5	mA
	$V_{PIN8} = 20V$		10	15		10	15	
<b>LO CM Input Section (Note 3)</b>								
Threshold Voltage	Pin 1 & 2 shorted, $T_A = 25^\circ C$ pin 1 & 2 shorted	80	100	120	80	100	120	mV
		70	100	130	70	100	130	
Input Impedance	$V_{PIN3} = 50mV$ , $T_A = 25^\circ C$ $V_{PIN3} = 50mV$	400	500	600	400	500	600	$\Omega$
		300	500	700	300	500	700	
<b>HI CM Input Section (Note 3)</b>								
Threshold Voltage	$V_{CM} = 2V$ , Pin 3 open, $T_A = 25^\circ C$ $V_{CM} = 40V$ , Pin 3 open, $T_A = 25^\circ C$ $V_{CM} = 2V$ , Pin 3 open $V_{CM} = 40V$ , Pin 3 open	80	100	120	80	100	120	mV
		80	100	120	80	100	120	
		70	100	130	70	100	130	
		70	100	130	70	100	130	
Input Current	$V_{PIN1} = V_{PIN2} = 40V$		200	300		200	300	$\mu A$
<b>Clock Reset Section</b>								
Min. Trigger Voltage			2.0	2.5		2.0	2.5	V
Input Current	$V_{PIN7} = 4V$		20	40		20	40	$\mu A$

Note 3. Input threshold voltages and supply current are directly proportional to supply voltage,  $V_S$ .

**ELECTRICAL SPECIFICATIONS**

( $V_S = 5V$ , and over recommended operating temperature, unless otherwise specified.)

Parameter	Test Conditions	SG1549/2549			SG3549			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>HI Output Section</b>								
Off Voltage			0	0.1		0	0.1	V
On Voltage	$I_L = 1mA$	2.8	3.2		2.8	3.2		V
<b>LO Output</b>								
Off Leakage	$V_{PIN5} = 40V$		.01	1.0		.01	1.0	$\mu A$
On Voltage	$I_L = 5mA$		.3	0.5		.3	0.5	V

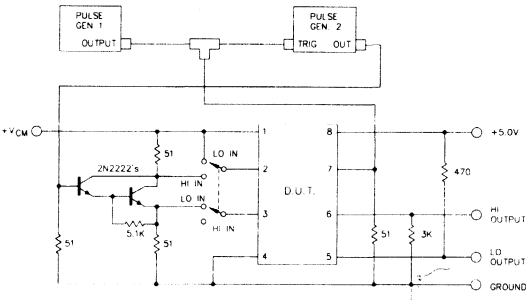
**TYPICAL SWITCHING CHARACTERISTICS (Note 4)**

( $V_S = 5V$ ,  $T_A = 25^\circ C$ )

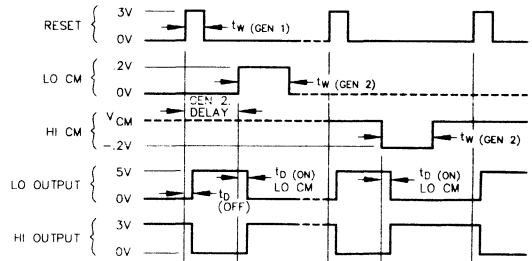
Parameter	Test Conditions	SG1549 Series			Units
		Min.	Typ.	Max.	
Reset Minimum Pulse Width ( $T_{W1}$ )	Amplitude = 3.0V		150	300	ns
Delay from Reset to LO Output ( $T_{D(OFF)}$ )	$R_L = 470\Omega$ to $V_S$		300	600	ns
LO Input Minimum Pulse Width ( $T_{W2}$ )	LO CM Amplitude = 200mV		50	300	ns
Delay from LO Input to LO Output ( $T_{D(ON)}$ )	LO CM Amplitude = 200mV, $R_L = 470\Omega$ to $V_S$		180	360	ns
Delay from HI Input to LO Output ( $T_{D(ON)}$ )	Amplitude = 200mV, $V_{CM} = 5V$		300	900	ns
Delay from HI Output to LO Output	LO CM Input = 200mV		30	60	ns

Note 4: These parameters, although guaranteed, are not tested in production.

**DYNAMIC TEST CIRCUIT**



**SWITCHING WAVEFORMS**



**APPLICATION NOTES**

**HIGH LINE SENSING** - The SG1549 will provide current sensing in the positive supply line in the typical SG1524 single-ended switching regulator application shown in Figure 1. The HI CM sense circuitry can be used with input voltages between 2 and 40 volts.

A value for  $R_{SC}$  is determined by dividing the 100mV input threshold by the peak current desired. High-frequency noise, or switching transients, can usually be eliminated by a small capacitor between pins 3 and 4.

Current control may be accomplished by either the HI OUTPUT pin connected to the SG1524's Shutdown pin, or the LO OUTPUT pin connected directly to the Compensation Terminal. In either case, activation of the current sense latch will tend to discharge the compensation capacitor,  $C_C$ , which may cause slow recovery from pulse limiting. If this feature is desired, the LO OUTPUT pin may be used to discharge a soft-start network instead of coupling directly to the SG1524. If it is not desired, the use of a small value of  $C_C$ , and perhaps a diode across  $R_C$ , will enhance recovery.

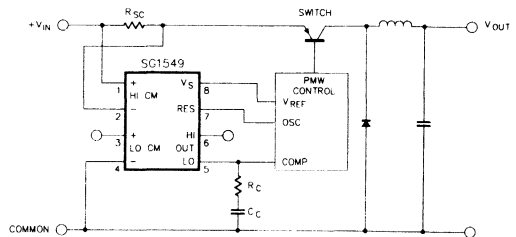


FIGURE 1 — HIGH LINE SENSING WITH THE SG1549 IN CONJUNCTION WITH AN SG1524 PWM CONTROL IC

## APPLICATION NOTES (continued)

Another method of introducing the current shutdown signal is shown in Figure 2 where the SG1524 is used to activate a constant drive current to the high-current switch, in this case an SM600. The 2N2222 forms a constant current generator when driven from the SG1524's 5.0 volt reference through a 1K resistor. This transistor is then switched off by the LO OUTPUT transistor in the SG1549, achieving the fastest response to the output of the regulator.

**LOW LINE SENSING** - In many types of feed-forward or push-pull converters, current protection may be provided by sensing in an emitter resistor referenced to ground on the primary side of an output transformer. The fast-reacting SG1549 can easily sense secondary overload as reflected back to the primary and, additionally, provide protection from unbalanced transformer saturation.

When using the LO CM inputs, the HI CM inputs should be shorted together. While the LO CM inputs may be connected directly across a sense resistor,  $R_{SC}$ , a small low-pass filter as shown in Figure 3 is often required to eliminate high frequency transients. It must be remembered that the 500Ω input impedance at the LO CM terminals will cause the use of R1 to increase the effective threshold; however, this also offers the possibility of an easily adjustable threshold by incorporating a potentiometer at the input.

Coupling the output signal from the SG1549 to the control chip may be done in several ways including the use of either the Compensation or Shutdown pins on the SG1524 as described earlier.

Another convenient way to tie the output of the SG1549 into the PWM control in higher power applications is by using the SG1627 Dual Interface Driver and connecting the LO OUTPUT terminal of the SG1549 directly to the two Non-Inverting inputs of the SG1627 as shown in Figure 4.

And finally, keep in mind that the LO OUTPUT terminal of the SG1549 will easily drive most high-speed optical couplers should some type of isolation between current sense and shutdown control be required.

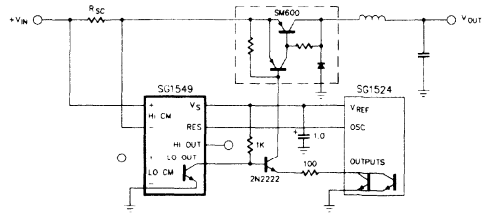


FIGURE 2 — CURRENT CONTROL FOR A BUCK REGULATOR WITH CONSTANT DRIVE CURRENT

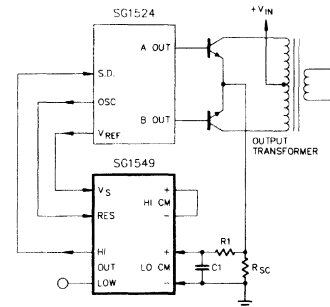


FIGURE 3 — A PUSH-PULL CONVERTER WITH LOW-LINE EMITTER CURRENT SENSING

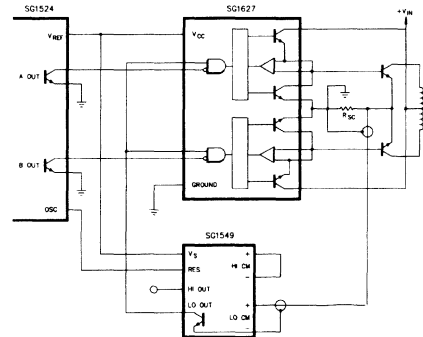


FIGURE 4 — POWER BOOST AND CURRENT CONTROL WITH THE SG1627

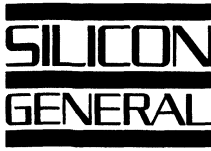
## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
8-PIN CERAMIC DIP Y - PACKAGE	SG1549Y/883B	-55°C to 125°C	
	SG1549Y	-55°C to 125°C	
	SG2549Y	-25°C to 85°C	
	SG3549Y	0°C to 70°C	
8-PIN PLASTIC DIP M - PACKAGE	SG2549M	-25°C to 85°C	
	SG3549M	0°C to 70°C	

Note 1. Contact factory for JAN and DESC product availability.

2. All parts are viewed from the top.





# SG1557/SG1559/SG1560 SERIES

LINEAR INTEGRATED CIRCUITS

## MAG AMP CONTROLLER

### DESCRIPTION

The SG1557, SG1559, and SG1560 family of integrated circuits has been designed to incorporate some of the most commonly used analog functions in one dual in-line package. It includes a  $1.25V \pm 1\%$  band gap reference, guaranteed to operate as low as 4.5V over the entire temperature range. Two independent operational amplifiers with electrical characteristics similar to the industry standard LM324, as well as two uncommitted, open collector comparators similar to LM139 are included in the I.C. This product line provides all the necessary control functions required for magnetic amplifier regulators where they are ideal choices as secondary side regulators requiring high current and high efficiency. It can also be used in power supply applications where PWM is on the primary side and the reference and error amp needs to be on the secondary side to maintain input/output isolation.

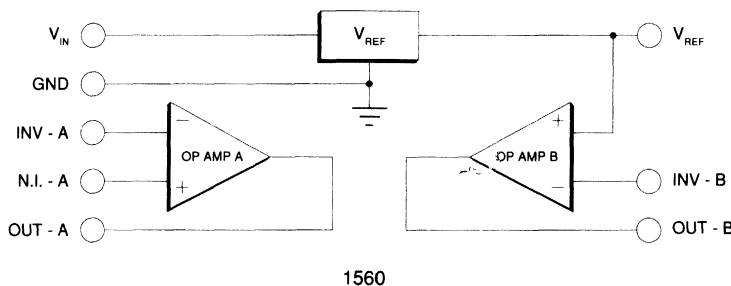
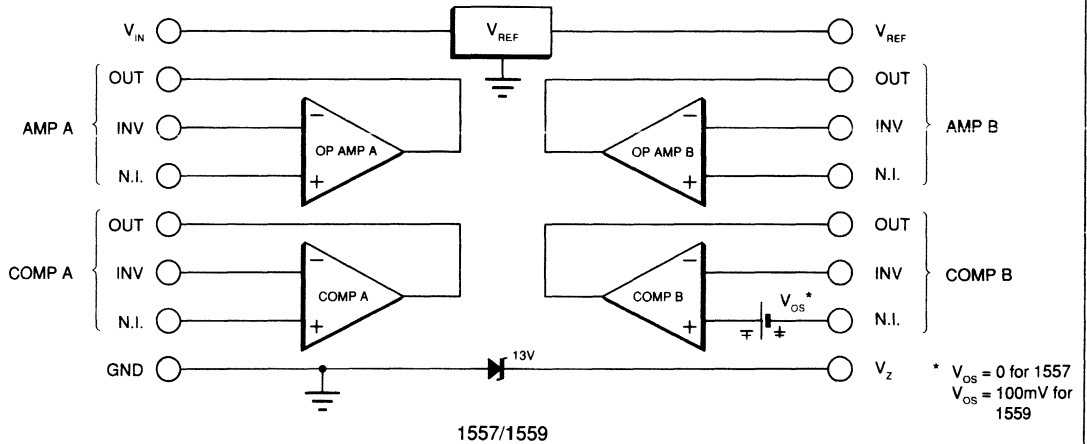
### FEATURES

- Low cost
- Two independent op amps
- Two uncommitted open collector comparators
- 4.5V to 40V input voltage operation over temperature (SG1557 and SG1559 only)
- $\pm 2\%$  voltage reference over load, line and temperature
- 13V zener for pre-regulating  $+V_{IN}$  (SG1557 and SG1559 only)
- Available in SOIC package

### HIGH RELIABILITY FEATURES - SG1557/SG1559/SG1560

♦ Available to MIL-STD-883

### BLOCK DIAGRAM



# SG1557/SG1559/SG1560 SERIES

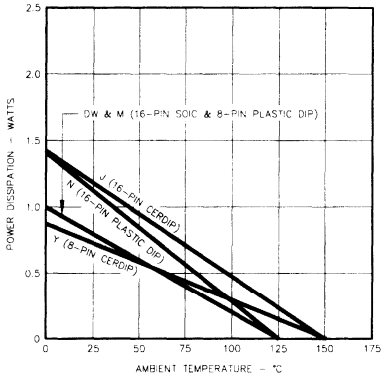
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage ( $V_{CC}$ ) .....	42V	Operating Junction Temperature	
Amplifier Input Voltage .....	-0.3V to $V_{CC}$	Hermetic (J, Y-Packages) .....	175°C
Amplifier Output Current .....	30mA	Plastic (N, M, DW-Packages) .....	150°C
Reference Load Current .....	30mA	Storage Temperature Range .....	-65°C to 150°C
Zener Current .....	25mA	Lead Temperature (Soldering, 10 Seconds) .....	300°C

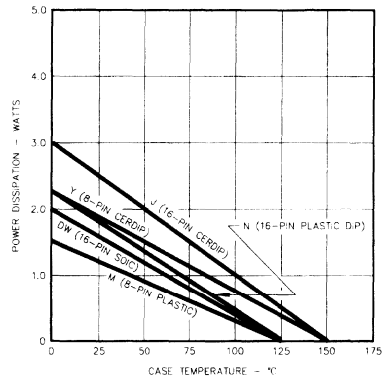
Note 1. Exceeding these ratings could cause damage to the device. All voltages are with respect to ground. All currents are positive into the specified terminal.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Supply Voltage ( $V_{CC}$ ) .....	35V	Operating Ambient Temperature Range	
Amplifier Input Voltage .....	0 to $V_{CC}-2$	SG1557, 1559, 1560 .....	-55°C to 125°C
Amplifier Output Current .....	15mA	SG2557, 2559, 2560 .....	-25°C to 85°C
Reference Load .....	15mA	SG3557, 3559, 3560 .....	0°C to 70°C
Zener Current .....	15mA		

Note 2: Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS \*

( $V_{CC} = 15V$ , and over operating temperature, unless otherwise specified.)

Parameter	Test Conditions	SG1557/2557/3557 SG1559/2559/3559 SG1560/2560/3560			Units
		Min.	Typ.	Max.	
		<b>Reference Section</b>			
Output Voltage	$T_J = 25^\circ C$	1.237	1.250	1.263	V
Temperature Stability		-13		13	mV
Line Regulation	$V_{IN} = 4.5V \text{ to } 40V, T_J = 25^\circ C$	-13		13	mV
Load Regulation	$I_{REF} = 0 \text{ to } 15mA, T_J = 25^\circ C$	-13		13	mV
Total Output Voltage Range		1.225		1.275	V
Short Circuit Current	$V_{REF} = 0V$			100	mA

\* NOTE: Performance data described herein represent design goals. Final device specifications are subject to change.

## SG1557/SG1559/SG1560 SERIES

### ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG1557/2557/3557 SG1559/2559/3559 SG1560/2560/3560			Units
		Min.	Typ.	Max.	
<b>Op-Amp Section</b>					
Input Offset Voltage		-10		10	mV
Input Bias Current				-1000	nA
Input Offset Current				-200	nA
Input Common Mode Range		0		$V_{CC}-2$	V
Open Loop Voltage Gain		80			dB
Unity Gain Bandwidth			1		MHz
Common Mode Rejection Ratio			70		dB
Power Supply Rejection Ratio		65			dB
Output Voltage Level - High	$R_L = 2K\Omega$ to GND	$V_{CC}-1.5$			V
Output Voltage Level - Low	$R_L = 2K\Omega$ to $V_{CC}$			1.2	V
Output Short-circuit Current			30		mA
Slew Rate	$A_V = 1, V_{IN} = 2V$ to 12V		0.5		V/ $\mu$ s
<b>Comparator Section</b> (Applies to SG1557 and SG1559 family only)					
Input Offset Voltage (1557 only)				10	mV
Input Offset Voltage (1559 only)		95	100	110	mV
Input Bias Current	$T_J = 25^\circ C$			1000	nA
Input Offset Current				200	nA
Input Common Mode Range		-0.5		$V_{CC}-2$	V
Output Sink Current	$V_O = 1.5V$	6			mA
Output Saturation Voltage	$I_O = 4mA$			400	mV
Input-Output Propagation Delay	$V_{NI} = 1.4V, V_{INV} = 0.7V$ to 2V			1000	ns
Open Loop Voltage Gain		80			dB
<b>Other Parameters</b>					
Supply Voltage		4.5		40	V
Supply Current				7	mA
Zener Voltage	(1mA to 20mA)	12.4	13.4	14.4	V
Zener Current		1		20	mA

**APPLICATION INFORMATION**

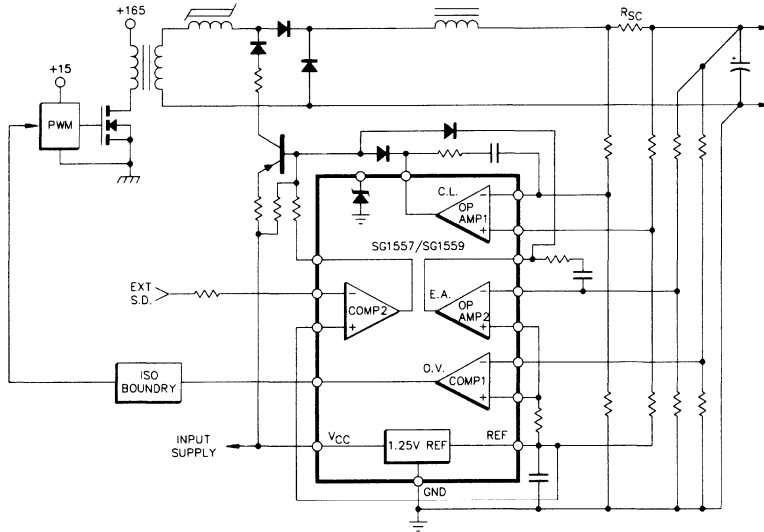


FIGURE 1 - MAGNETIC AMPLIFIER

Magnetic amplifiers are ideal choices where high current, high efficiency secondary regulation is required. Figure 1 shows the application of SG1557 and SG1559 in this Mag-Amp regulator.

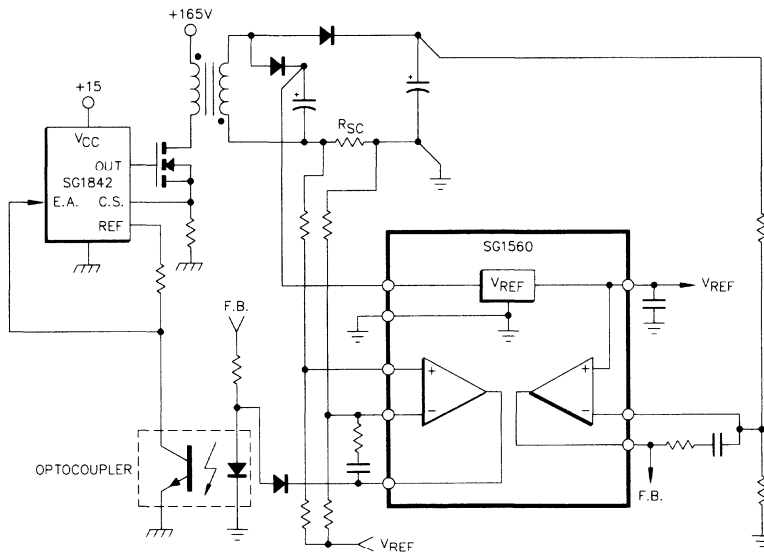
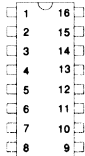
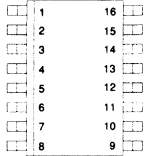



FIGURE 2 - FLYBACK POWER SUPPLY

SG1560 is an ideal choice for the applications where the PWM is in the primary side. Figure 2 shows the application of this device in this flyback power supply using SG1842 as the PWM.

## SG1557/SG1559/SG1560 SERIES

### CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
16-PIN CERAMIC DIP J - PACKAGE	SG1557J/883B	-55°C to 125°C	
	SG1557J	-55°C to 125°C	
	SG2557J	-25°C to 85°C	
	SG3557J	0°C to 70°C	
	SG1559J/883B	-55°C to 125°C	
	SG1559J	-55°C to 125°C	
	SG2559J	-25°C to 85°C	
	SG3559J	0°C to 70°C	
16-PIN PLASTIC DIP N - PACKAGE	SG2557N	-25°C to 85°C	
	SG3557N	0°C to 70°C	
	SG2559N	-25°C to 85°C	
	SG3559N	0°C to 70°C	
16-PIN WIDE BODY PLASTIC S.O.I.C. DW - PACKAGE	SG2557DW	-25°C to 85°C	
	SG3557DW	0°C to 70°C	
	SG2557DW	-25°C to 85°C	
	SG3557DW	0°C to 70°C	
8-PIN CERAMIC DIP Y - PACKAGE	SG1560Y/883B	-55°C to 125°C	
	SG1560Y	-55°C to 125°C	
	SG2560Y/883B	-55°C to 125°C	
	SG3560Y	-55°C to 125°C	
8-PIN PLASTIC DIP M - PACKAGE	SG2560M	-25°C to 85°C	
	SG3560M	0°C to 70°C	

Note 1. Contact factory for JAN and DESC product availability.  
 Note 2. All packages are viewed from the top.  
 Note 3. Consult factory for product availability.



**DUAL-POLARITY TRACKING REGULATORS**

**DESCRIPTION**

The SG1568/SG1468 is a dual-polarity tracking regulator designed to provide balanced positive and negative output voltages at currents to 100mA. The device is set internally for  $\pm 15V$  outputs but a single external adjustment can be used to change both outputs simultaneously from 9V to 20V. Input voltages up to  $\pm 30V$  can be used and there is provision for adjustable current limiting.

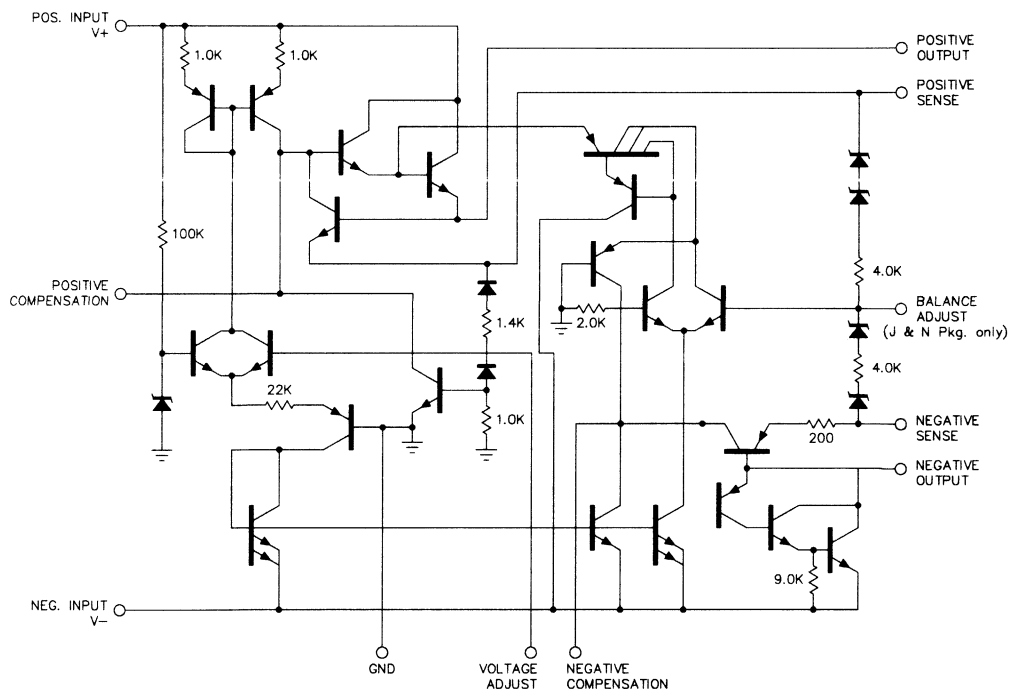
**FEATURES**

- Outputs balanced to within 1% (SG1568)
- Line and load regulation of 0.06%
- 1% maximum output variation due to temperature changes
- Standby current drain of 3.0mA
- Remote sensing provisions

**HIGH RELIABILITY FEATURES - SG1568**

- ◆ Available to MIL-STD-883
- ◆ SG level "S" processing available

**BLOCK DIAGRAM**



## ABSOLUTE MAXIMUM RATINGS (Note 1)

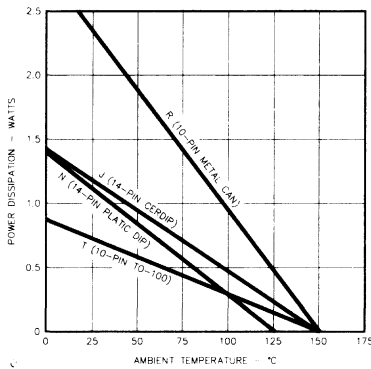
Input Voltage ..... 30V  
 Peak Load Current ..... 100mA  
 Minimum Short-Circuit Resistance ..... 4.0Ω

Operating Junction Temperature  
 Hermetic (J, T, R-Packages) ..... 175°C  
 Plastic (N-Package) ..... 150°C  
 Storage Temperature Range ..... -65°C to 150°C  
 Lead Temperature (Soldering, 10 Seconds) ..... 300°C

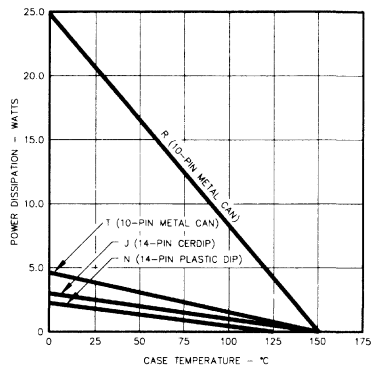
Note 1. Exceeding these ratings could cause damage to the device.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Input Voltage ..... 7.0V to 30V

Operating Ambient Temperature  
 SG1568 ..... -55°C to 125°C  
 SG1468 ..... 0°C to 70°C

Note 2. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise stated, these specifications apply for  $T_A = 25^\circ\text{C}$ ,  $V_{CC} = 20\text{V}$ ,  $V_{EE} = 20\text{V}$ ,  $C_1 = C_2 = 1500\text{pF}$ ,  $C_3 = C_4 = 1.0\mu\text{F}$ ,  $+I_L = -I_L = 0$ , and  $R_{SC} = 4.0\Omega$  for both positive and negative inputs.)

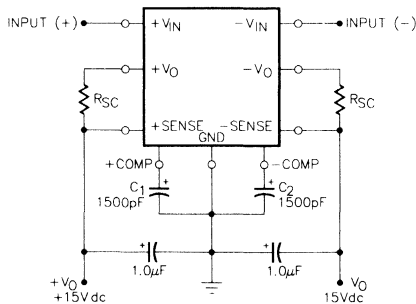
Parameter	Test Conditions	SG1568			SG1468			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage		14.5		15.5	14.5		15.5	V
Input Voltage				30			30	V
Input-Output Voltage Differential				2.0			2.0	V
Output Voltage Balance				±150			±300	mV
Line Regulation Voltage	$V_{IN} = 18\text{V to }30\text{V}$			10			10	mV
	$T_A = T_{MIN} \text{ to } T_{MAX}$			20			20	mV
Load Regulation Voltage (Note 3)	$I_L = 0 \text{ to } 50 \text{ mA}$			10			10	mV
	$T_A = T_{MIN} \text{ to } T_{MAX}$			30			30	mV
Output Voltage Range		9.0		20	9.0		20	V
Ripple Rejection	$f = 120\text{Hz}$		75			75		dB
Output Voltage Temperature Stability (Note 4)	$T_A = T_{MIN} \text{ to } T_{MAX}$			1.0			1.0	%
Short Circuit Current Limit	$R_{SC} = 10\Omega$			60			60	mA
Output Noise Voltage	$BW = 100\text{Hz to }10\text{KHz}$			100			100	$\mu\text{V(rms)}$
Positive Standby Current	$V_{IN} = 30\text{V}$			4.0			4.0	mA
Negative Standby Current	$V_{IN} = -30\text{V}$			3.0			3.0	mA
Long Term Stability			0.2			0.2		%/Khr

Note 3. Applies for constant junction temperature.

Note 4. This parameter, although guaranteed, is not tested in production.



## APPLICATION INFORMATION



C1 and C2 should be located as close to the device as possible. A 0.1µF ceramic capacitor may be required on the input lines if the device is located an appreciable distance from the rectifier filter capacitors.

C3 and C4 may be increased to improve load transient response and to reduce the output noise voltage. At low temperature operation it may be necessary to bypass C4 with a 0.1µF ceramic disc capacitor.

FIGURE 1 - BASIC 50mA REGULATOR

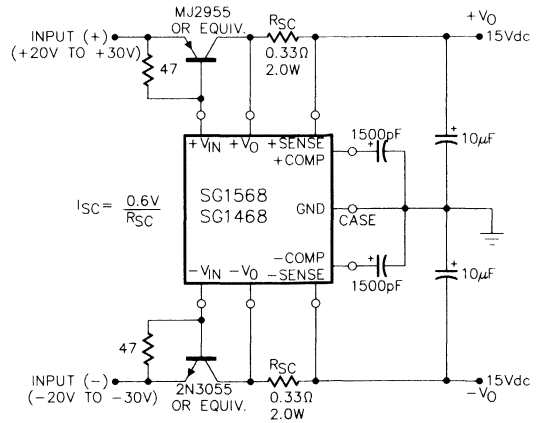


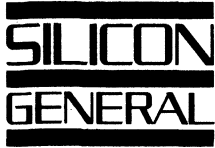
FIGURE 2 - 1.5A REGULATOR SHORT CIRCUIT PROTECTED, WITH PROPER HEATSINKING

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
14-PIN CERAMIC DIP J - PACKAGE	SG1568J/883B SG1568J SG1468J	-55°C to 125°C -55°C to 125°C 0°C to 70°C	
14-PIN PLASTIC DIP N - PACKAGE	SG1468J	0°C to 70°C	
9-PIN METAL CAN R - PACKAGE	SG1568R/883B SG1568R SG1568R	-55°C to 125°C -55°C to 125°C 0°C to 70°C	<p>NOTE: CASE IS GROUND</p>
10-PIN METAL CAN T - PACKAGE	SG1568T/883B SG1568T SG1568T	-55°C to 125°C -55°C to 125°C 0°C to 70°C	

- Note 1. Contact factory for JAN and DESC product availability.  
 Note 2. All packages are viewed from the top.





LINEAR INTEGRATED CIRCUITS

**HIGH-SPEED CURRENT-MODE PWM**

**DESCRIPTION**

The SG1825 is a high-performance pulse width modulator optimized for high frequency current-mode power supplies. Included in the controller are a precision voltage reference, micropower start-up circuitry, soft-start, high-frequency oscillator, wideband error amplifier, fast current-limit comparator, full double-pulse suppression logic, and dual totem-pole output drivers. Innovative circuit design and an advanced linear Schottky process result in very short propagation delays through the current limit comparator, logic, and output drivers. This device can be used to implement either current-mode or voltage-mode switching power supplies. It also is useful as a series-resonant controller to frequencies beyond 1MHz. The SG1825 is specified for operation over the full military junction temperature range of -55°C to 150°C. The SG2825 is characterized for the industrial range of -25°C to 150°C, and the SG3825 is selected for the commercial range of 0°C to 125°C.

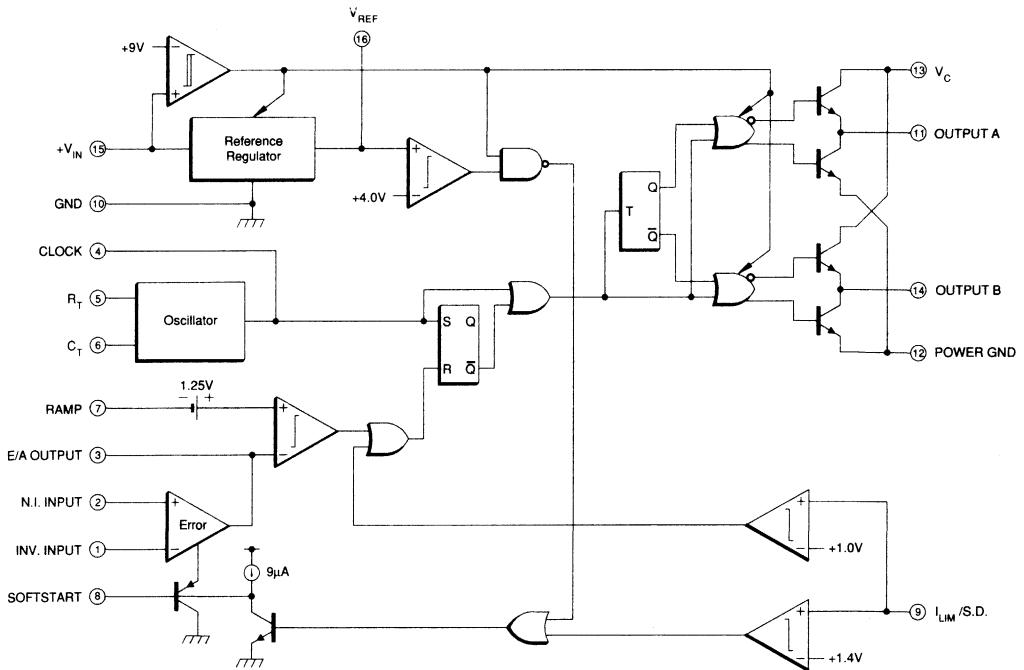
**FEATURES**

- 10 to 30 volt operation
- 5.1V reference trimmed to  $\pm 1\%$
- 2MHz oscillator capability
- 50ns prop delay to outputs
- 1.5A peak totem-pole drivers
- 2mA max start-up current
- U.V. lockout with hysteresis
- Programmable soft start
- Double-pulse suppression logic
- Wideband low-impedance error amp
- Current-mode or voltage-mode control
- Wide choice of high frequency packages

**HIGH RELIABILITY FEATURES - SG1825**

- ◆ Available to MIL-STD-883B
- ◆ Scheduled for MIL-M-38510 QPL listing
- ◆ SG level "S" processing available

**BLOCK DIAGRAM**



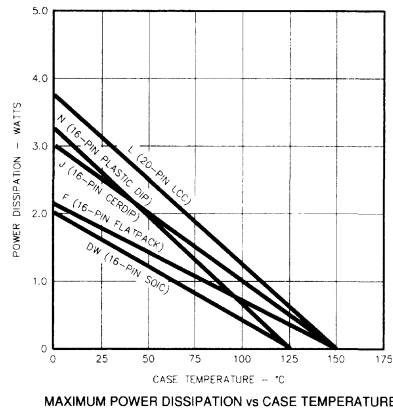
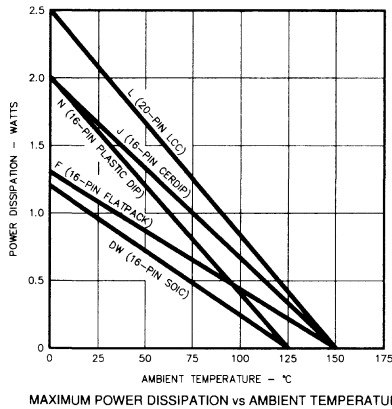
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Input Voltage ( $V_{IN}$ and $V_C$ ) .....	30V
Analog Inputs:	
Error Amplifier and Ramp .....	-0.3V to 7.0V
Soft Start and $I_{LIM}/S.D.$ .....	-0.3V to 6.0V
Digital Input (Clock) .....	1.5V to 6.0V
Driver Outputs .....	-0.3V to $V_C+1.5V$
Source / Sink Output Current (each output):	
Continuous .....	0.5A
Pulse, 500ns .....	2.0A
Soft Start Sink Current .....	20mA
Clock Output Current .....	5mA
Error Amplifier Output Current .....	5mA
Oscillator Charging Current .....	5mA
Operating Junction Temperature:	
Hermetic (F, J, L Packages) .....	175°C
Plastic (DW, N Packages) .....	150°C
Storage Temperature Range .....	-65°C to 150°C
Lead Temperature (soldering, 10 seconds) .....	300°C

Note 1. Exceeding these ratings could cause damage to the device.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



### ELECTRICAL

Supply Voltage Range .....	10V to 30V
Voltage Amp Common Mode Range .....	1.5V to 5.5V
Ramp Input Voltage Range .....	0V to 5.0V
Current Limit / Shutdown Voltage Range .....	0V to 4.0V
Source / Sink Output Current	
Continuous .....	200mA
Pulse, 500ns .....	1.0A
Voltage Reference Output Current .....	1 mA to 10mA
Oscillator Frequency Range .....	4KHz to 1.5MHz
Oscillator Charging Current .....	30μA to 3mA
Oscillator Timing Resistor ( $R_T$ ) .....	1KΩ to 100KΩ
Oscillator Timing Capacitor ( $C_T$ ) .....	470pF to .01μF
Operating Ambient Temperature Range:	
SG1825 .....	-55°C to 125°C
SG2825 .....	-25°C to 85°C
SG3825 .....	0°C to 70°C

Note 2. Range over which the device is functional and parameter limits are guaranteed.

## ELECTRICAL SPECIFICATIONS \*

( $V_{IN} = V_C = 15V$ , and over operating ambient temperature, unless otherwise specified)

Parameter	Test Conditions	SG1825/2825			SG3825			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Reference Section</b>								
Output Voltage	$T_J = 25^\circ C, I_L = 1mA$	5.05	5.10	5.15	5.00	5.10	5.20	V
Line Regulation	$V_{IN} = 10$ to 30V		2	20		2	20	mV
Load Regulation	$I_L = 1$ to 10mA		5	20		5	20	mV
Temperature Stability (Note 3)	Over Operating Temperature			0.2		0.2	0.4	mV/°C
Total Output Range (Note 3)	Over Line, Load, and Temperature	5.00		5.20	4.95		5.25	V
Output Noise Voltage (Note 3)	$f = 10Hz$ to 10KHz, $I_L = 0mA$		50	200		50		μV <sub>RMS</sub>
Long Term Stability (Notes 3 & 4)	$T_J = 125^\circ C, t = 1000hrs$		5	25		5	25	mV
Short Circuit Current	$V_{REF} = 0V$	-15	-50	-100	-15	-50	-100	mA

\* NOTE: Performance data described herein represent design goals. Final device specifications are subject to change.

# SG1825/SG2825/SG3825

## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG1825/2825			SG3825			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Oscillator Section (Note 5)</b>								
Initial Accuracy	$T_J = 25^\circ\text{C}, C_{\text{CLK}} \leq 10\text{pF}$	360	400	440	360	400	440	KHz
Voltage Stability	$V_{\text{IN}} = 10 \text{ to } 30\text{V}$		0.2	2		0.2	2	%
Temperature Stability (Note 3)	Over Rated Operating Temperature		5	8		5	8	%
Total Frequency Limits (Note 3)	Over Line and Temperature	340		460	340		460	KHz
Minimum Frequency	$R_T = 100\text{K}\Omega, C_T = .01\mu\text{F}$			4			4	KHz
Maximum Frequency	$R_T = 1\text{K}\Omega, C_T = 470\text{pF}$	1.5			1.5			MHz
Clock High Level	$I_{\text{CLK}} = -1\text{mA}$	3.9	4.5		3.9	4.5		V
Clock Low Level	$I_{\text{CLK}} = -1\text{mA}$		2.3	2.9		2.3	2.9	V
Ramp Peak Voltage		2.6	2.8	3.0	2.6	2.8	3.0	V
Ramp Valley Voltage		0.7	1.0	1.1	0.7	1.0	1.1	V
Valley-to-Peak Amplitude		1.6	1.8	2.0	1.6	1.8	2.0	V
<b>Error Amplifier Section (Note 6)</b>								
Input Offset Voltage	$R_B \leq 2\text{K}\Omega, V_{\text{ERROR}} = 3\text{V}$			10			15	mV
Input Bias Current	$V_{\text{ERROR}} = 3\text{V}$		0.6	3		0.6	3	$\mu\text{A}$
Input Offset Current	$V_{\text{ERROR}} = 3\text{V}$		0.1	1		0.1	1	$\mu\text{A}$
DC Open Loop Gain	$V_{\text{ERROR}} = 1 \text{ to } 4\text{V}$	60	95		60	95		dB
Common Mode Rejection	Over Rated Voltage Range, $V_{\text{ERROR}} = 3\text{V}$	75	95		75	95		dB
Power Supply Rejection	$V_{\text{IN}} = 10\text{V to } 30\text{V}, V_{\text{ERROR}} = 3\text{V}$	85	110		85	110		dB
Output Sink Current	$V_{\text{ERROR}} = 1\text{V}$	1	2.5		1	2.5		mA
Output Source Current	$V_{\text{ERROR}} = 4\text{V}$	-0.5	-1.3		-0.5	-1.3		mA
Output High Voltage	$I_{\text{ERROR}} = -0.5\text{mA}$	4.0	4.7	5.0	4.0	4.7	5.0	V
Output Low Voltage	$I_{\text{ERROR}} = 1\text{mA}$	0	0.5	1.0	0	0.5	1.0	V
Unity Gain Bandwidth (Note 3)	$A_{\text{VOL}} = 0\text{dB}$	3	5.5		3	5.5		MHz
Slew Rate (Note 3)	$A_{\text{VCL}} = 1, V_O = 2\text{V to } 4\text{V}$	6	12		6	12		V/ $\mu\text{s}$
<b>PWM Comparator Section (Note 5 &amp; 7)</b>								
Ramp Input Bias Current			-1	-5		-1	-5	$\mu\text{A}$
Minimum Duty Cycle	$V_{\text{ERROR}} = 1\text{V}$			0			0	%
Maximum Duty Cycle (Note 8)	$V_{\text{ERROR}} = 4\text{V}$	85			85			%
Zero Duty Cycle Threshold		1.1	1.25		1.1	1.25		V
Delay to Driver Output (Note 3)	$V_{\text{RAMP}} = 0 \text{ to } 2\text{V}, V_{\text{ERROR}} = 2\text{V}$		50	80		50	80	ns
<b>SoftStart Section</b>								
$C_{\text{SS}}$ Charge Current	$V_{\text{SOFTSTART}} = 0.5\text{V}$	3	9	20	3	9	20	$\mu\text{A}$
$C_{\text{SS}}$ Discharge Current	$V_{\text{SOFTSTART}} = 1.0\text{V}$	1			1			mA
<b>Current Limit / Shutdown Section (Note 9)</b>								
$I_{\text{LIM}}$ Input Bias Current				$\pm 10$			$\pm 10$	$\mu\text{A}$
Current Limit Threshold		0.9	1.0	1.1	0.9	1.0	1.1	V
Shutdown Threshold		1.25	1.40	1.55	1.25	1.40	1.55	V
Delay to Driver Output (Note 3)	$V_{\text{SHUTDOWN}} = 0\text{V to } 1.2\text{V}$		50	80		50	80	ns
<b>Output Drivers (each output)</b>								
Output Low Level	$I_{\text{SINK}} = 20\text{mA}$		0.25	0.40		0.25	0.40	V
	$I_{\text{SINK}} = 200\text{mA}$		1.2	2.2		1.2	2.2	V
Output High Level	$I_{\text{SOURCE}} = 20\text{mA}$	13.0	13.5		13.0	13.5		V
	$I_{\text{SOURCE}} = 200\text{mA}$	12.0	13.0		12.0	13.0		V
$V_C$ Standby Current	$V_C = 30\text{V}$		100	200		100	200	$\mu\text{A}$
Output Rise / Fall Time (Note 3)	$C_L = 1000\text{pF}$		30	60		30	60	ns
<b>Undervoltage Lockout Section</b>								
Start Threshold Voltage		8.8	9.2	9.6	8.8	9.2	9.6	V
UV Lockout Hysteresis		0.4	0.8	1.2	0.4	0.8	1.2	V
<b>Supply Current Section (Note 5)</b>								
Start Up Current	$V_{\text{IN}} = 8\text{V}$		1.1	2.5		1.1	2.5	mA
Operating Current	$V_{\text{IN}}, V_{\text{RAMP}}, V(I_{\text{LIM}}/\text{S.D.}) = 0\text{V}, V_{\text{NL}} = 1\text{V}$		22	33		22	33	mA

Note 3. This parameter is guaranteed by design and process control, but is not 100% tested in production.

Note 4. This parameter is non-accumulative, and represents the random fluctuation of the reference voltage within some error band when observed over any 1000 hour period of time.

Note 5.  $F_{\text{OSC}} = 400\text{KHz}$  ( $R_T = 3.65\text{K}\Omega, C_T = 1.0\text{nF}$ )

Note 6.  $V_{\text{CM}} = 1.5\text{V to } 5.5\text{V}$ .

Note 7.  $V_{\text{RAMP}} = 0\text{V}$ , unless otherwise specified.

Note 8. 100% duty cycle is defined as a pulsewidth equal to one oscillator period.

Note 9.  $V(I_{\text{LIM}}/\text{SHUTDOWN}) = 0\text{V to } 4.0\text{V}$ , unless otherwise specified.

CHARACTERISTIC CURVES

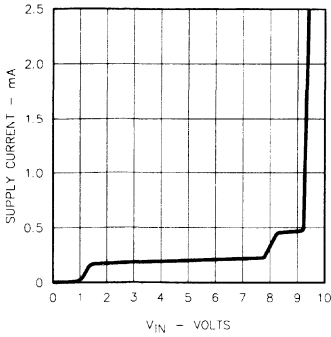


FIGURE 1. SUPPLY CURRENT VS.  $V_{IN}$

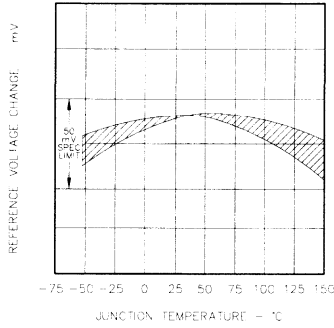


FIGURE 2. REFERENCE TEMPERATURE STABILITY

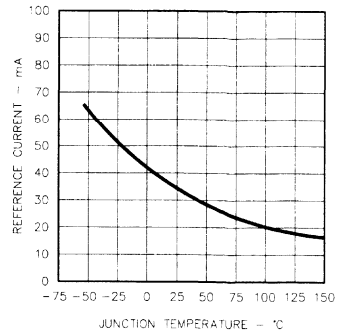


FIGURE 3. REFERENCE SHORT CIRCUIT CURRENT

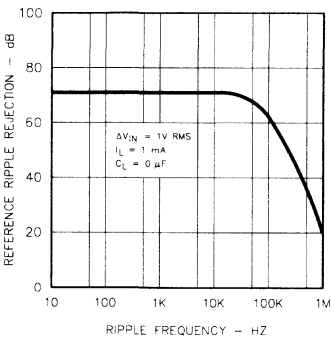


FIGURE 4. REFERENCE RIPPLE REJECTION

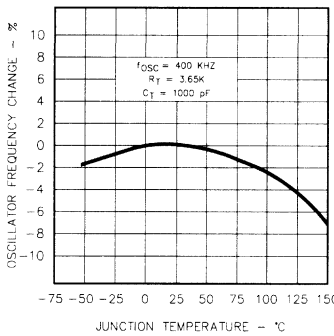


FIGURE 5. OSCILLATOR TEMPERATURE STABILITY

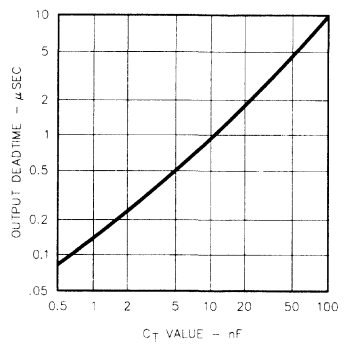


FIGURE 6. OUTPUT DEADTIME VS.  $C_T$  VALUE

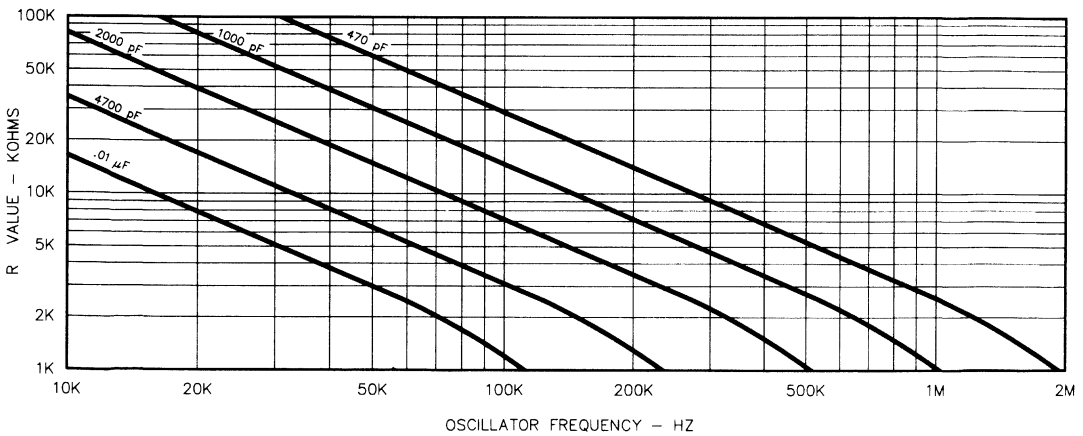


FIGURE 7. OSCILLATOR FREQUENCY VS.  $R_T$  AND  $C_T$

CHARACTERISTIC CURVES

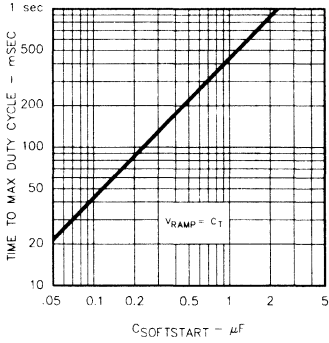


FIGURE 8. SOFTSTART TIME VS.  $C_S$  VALUE

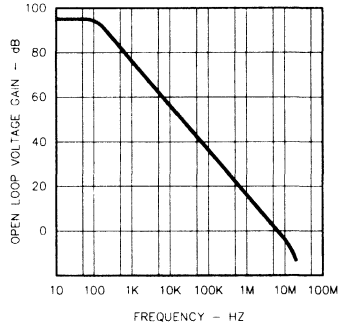


FIGURE 9. ERROR AMP OPEN LOOP GAIN

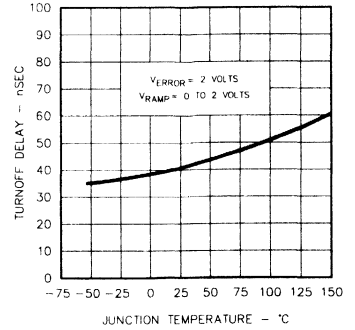


FIGURE 10. RAMP INPUT TO DRIVER OUTPUT DELAY

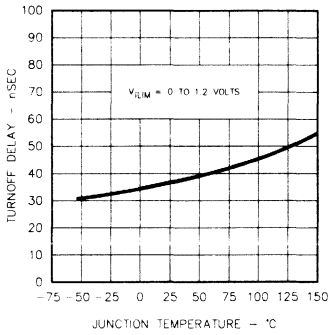


FIGURE 11.  $I_{LIMIT}$  INPUT TO DRIVER OUTPUT DELAY

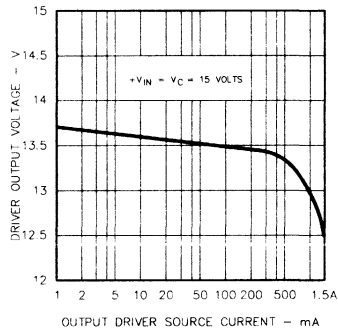


FIGURE 12. OUTPUT DRIVER HIGH VOLTAGE VS.  $I_{SOURCE}$

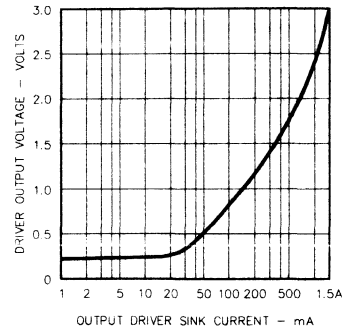


FIGURE 13. OUTPUT DRIVER LOW VOLTAGE VS.  $I_{SINK}$

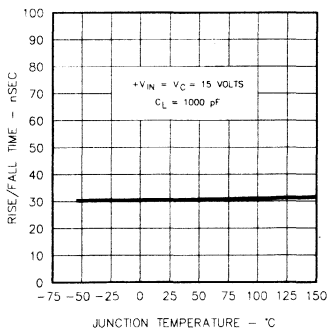


FIGURE 14. OUTPUT RISE/FALL TIME VS. TEMPERATURE

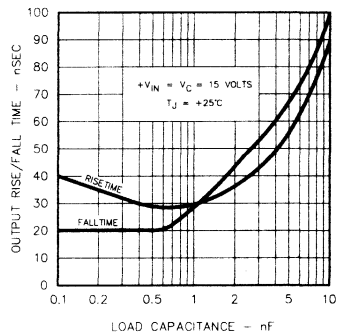


FIGURE 15. OUTPUT RISE/FALL TIME VS. LOAD CAPACITANCE

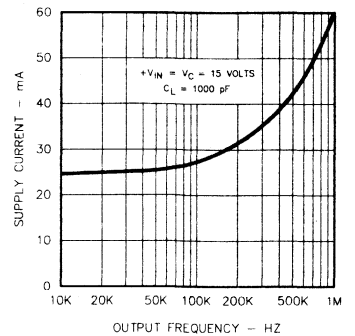


FIGURE 16. SUPPLY CURRENT VS. OUTPUT FREQUENCY

**APPLICATION INFORMATION**

**HIGH-SPEED LAYOUT AND BYPASSING**

The SG1825, like all high-speed circuits, requires extra attention to external conductor and component layout to minimize undesired inductive and capacitive effects. All lead lengths must be as short as possible. The best printed circuit board choice would be a four-layer design, with the two internal planes supplying power and ground. Signal interconnects should be placed on the outside, giving a conductor-over-ground-plane (microstrip) configuration. A two-sided pc board with one side dedicated as a ground plane is next best, and requires careful component placement by a skilled pc designer.

Two supply bypass capacitors should be employed: a low-inductance 0.1  $\mu\text{F}$  ceramic within 0.25 inches of the  $+V_{\text{IN}}$  pin for high frequencies, and a 1 to 5  $\mu\text{F}$  solid tantalum within 0.5 inches of the  $V_{\text{C}}$  pin to provide an energy reservoir for the high peak output currents. A low-inductance .01  $\mu\text{F}$  bypass for the reference output is also recommended.

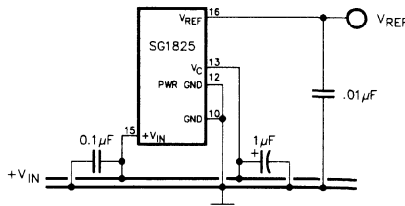


FIGURE 17. HIGH SPEED LAYOUT AND BYPASSING

**MICROPOWER STARTUP**

Since the SG1825 draws less than 2.5 mA of supply current before turning on, a low power bleeder resistor from the rectified AC line supply is all that is required for startup. A start capacitor,  $C_{\text{S}}$ , is charged with the excess current from the bleeder resistor. When the turn-on threshold voltage is reached, the PWM circuit becomes active, energizing the power transistors. The additional operating current required by the PWM is then provided by a bootstrap winding on the main high-frequency power transformer.

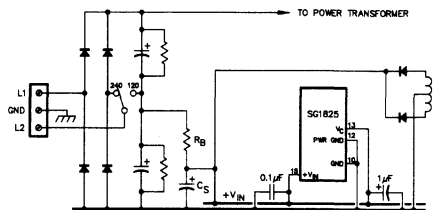


FIGURE 18. MICROPOWER STARTUP

**SOFTSTART CIRCUIT**

The Softstart pin of the SG1825 is held low when either the chip is in the micropower mode, or when a voltage greater than +1.4 volts is present at the  $I_{\text{LIM/S.D.}}$  pin. The maximum positive swing of the voltage error amplifier is clamped to the Softstart pin voltage, providing a ramp-up of peak charging currents in the power semiconductors at turn-on.

In some cases, the duration of the Shutdown signal can be too short to fully discharge the softstart capacitor. The illustrated resistor/discrete PNP transistor configuration can be used to shorten the discharge time by a factor of 50 or more. When the internal discharge transistor in the SG1825 turns on, current will flow through surge limit resistor R1. As the resistor drop approaches 0.6 volts, the external PNP turns on, providing a low resistance discharge path for the energy in the softstart capacitor. The capacitor will be rapidly discharged to +0.7 volts, which corresponds to zero duty cycle in the pulse width modulator.

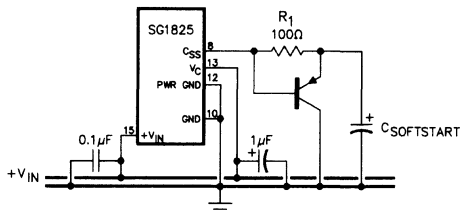


FIGURE 19. SOFTSTART FAST RESET

**FREQUENCY SYNCHRONIZATION**

Two or three SG1825 oscillators may be locked together with the interconnection scheme shown, if the devices are within an inch or so of each other. A master unit is programmed for desired frequency with  $R_{\text{T}}$  and  $C_{\text{T}}$  as usual. The oscillators in the slave units are disabled by grounding  $C_{\text{T}}$  and by connecting  $R_{\text{T}}$  to  $V_{\text{REF}}$ . The logic in the slave units is locked to the clock of the master with the wire-OR connection shown.

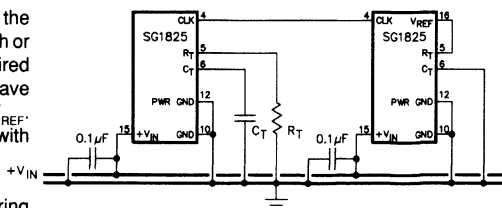


FIGURE 20. OSCILLATOR SYNCHRONIZATION

Many SG1825s can be locked to a master system clock by wiring the oscillators as slave units, and distributing the master clock to each using a tree-fanout geometry.



**APPLICATION INFORMATION**

**OSCILLATOR**

The oscillator frequency is programmed by external timing components  $R_T$  and  $C_T$ . A nominal +3.0 volts appears at the  $R_T$  pin. The current flowing through  $R_T$  is mirrored internally with a 1:1 ratio. This causes an identical current to flow out the  $C_T$  pin, charging the timing capacitor and generating a linear ramp. When the upper threshold of +2.8 volts is reached, a discharge network reduces the ramp voltage to +1.0, where a new charge cycle begins.

The Clock output pin is LOW (+2.3 volts) during the charge cycle, and HIGH (+4.5 volts) during the discharge cycle. The Clock pin is driven by an NPN emitter follower, and so can be wire-ORed. Each Clock pin can drive a 1 mA load. Since the internal current-source pulldown is approximately 400  $\mu$ A, the DC fan-out to other SG1825 Clock pins is at least two.

The type of capacitor selected for  $C_T$  is very important. At high frequencies, non-ideal characteristics such as effective series resistance (ESR), effective series inductance (ESL), dielectric loss and dielectric absorption all affect frequency accuracy and stability. RF capacitors such as silver mica, glass, polystyrene, or COG ceramics are recommended. Avoid high-K ceramics, which work best in DC bypass applications.

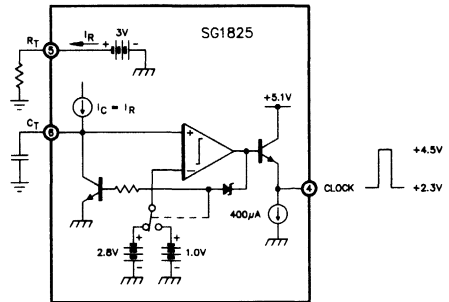


FIGURE 21. OSCILLATOR FUNCTIONAL DIAGRAM

**ERROR AMPLIFIER**

The voltage error amplifier is a true operational amplifier with low-impedance output, and can be gain-stabilized using conventional feedback techniques. The typical DC open-loop gain is 95 dB, with a single low-frequency pole at 100 Hz.

The input connections to the error amplifier are determined by the polarity of the power supply output voltage. For positive supplies, the common-mode voltage is +5.1 volts and the feedback connections in Figure A are used. With negative outputs, the common-mode voltage is half the reference, and the feedback divider is connected between the negative output and the +5.1 volt reference as shown in Figure B.

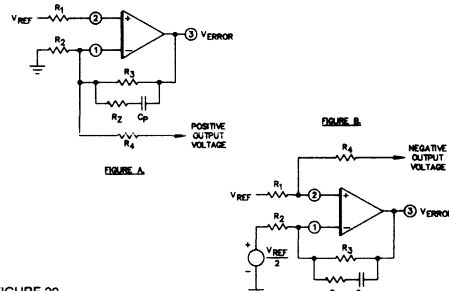


FIGURE 22. VOLTAGE AMP CONNECTIONS

**OUTPUT DRIVERS**

The output drivers are designed to provide up to 1.5 Amps peak output current. To minimize ringing on the output waveform, which can be destructive to both the power MOSFET and the PWM chip, the series inductance seen by the drivers should be as low as possible.

One solution is to keep the distance between the PWM and MOSFET gate as short as possible, and to use carbon composition series damping resistors. A Faraday shield to intercept radiated EMI from the power transistors is usually required with this choice.

A second approach is to place the MOSFETs some distance from the PWM chip, and use a series-terminated transmission line to preserve drive pulse fidelity. This will minimize noise radiated back to the sensitive analog circuitry of the SG1825. A Faraday shield may also be required.

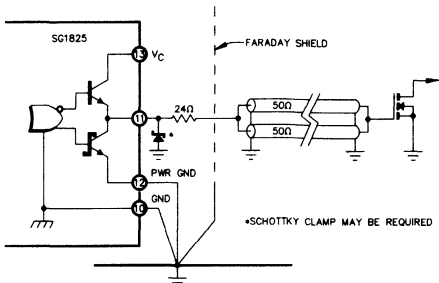


FIGURE 23. DRIVING SHIELDED CABLE

If the drivers are connected to an isolation transformer, or if kickback through  $C_{GD}$  of the MOSFET is severe, clamp diodes may be required. 1 Amp peak Schottky diodes will limit undershoot to less than -0.3 volts.

# SG1825/SG2825/SG3825

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
16-PIN CERAMIC DIP J - PACKAGE	SG1825J/883B	-55°C to 125°C	
	SG1825J	-55°C to 125°C	
	SG2825J	-25°C to 85°C	
	SG3825J	0°C to 70°C	
16-PIN PLASTIC DIP N - PACKAGE	SG2825N	-25°C to 85°C	
SG3825N	0°C to 70°C		
16-PIN WIDE BODY PLASTIC S.O.I.C. DW - PACKAGE	SG2825DW	-25°C to 85°C	
SG3825DW	0°C to 70°C		
16-PIN CERAMIC FLAT PACK F - PACKAGE (Note 3)	SG1825F/883B	-55°C to 125°C	
SG1825F	-55°C to 125°C		
20-PIN CERAMIC LEADLESS CHIP CARRIER L - PACKAGE (Note 3)	SG1825L/883B	-55°C to 125°C	
SG1825L	-55°C to 125°C		
20-PIN PLASTIC LEADLESS CHIP CARRIER Q - PACKAGE (Note 3)	SG2825Q	-25°C to 85°C	
SG3825Q	0°C to 70°C		

- Note 1. Contact factory for JAN and DESC product availability.  
 Note 2. All packages are viewed from the top.  
 Note 3. Contact factory for package availability

**PROGRAMMABLE, OFF-LINE, PWM CONTROLLER**

**DESCRIPTION**

Although containing most of the features required by all types of switching power supply controllers, the SG1840 family has been optimized for highly-efficient boot-strapped primary-side operation in forward or flyback power converters. Two important features for this mode are a starting circuit which requires little current from the second operation over a wide input voltage range.

In addition to startup and normal regulating PWM functions, these devices offer a built-in protection from over-voltage, under-voltage, and over-current fault conditions. This monitoring circuitry contains the added features that any fault will initiate a complete shutdown with provisions for either latch-off or automatic restart. In the latch-off mode, the controller may be started and stopped with external pulsed or steady-state commands.

Other performance features of these devices include a 1% accurate reference, provision for slow-turn-on and duty-cycle limiting, and high-speed pulse-by-pulse current limiting in addition to current fault shutdown.

The SG1840 PWM output stage includes a latch to insure only a single pulse per period and is designed to optimize the turn off of an external switching device by conducting during the "OFF" time with a capability for both high peak current and low saturation voltage. These devices are available in an 18-pin dual-in-line plastic or ceramic package.

The SG1840 is characterised for operation over the full military temperature range or -55°C to 125°C. The SG2840 and SG3840 are designed for operation from -25°C to 85°C and 0°C to 70°C, respectively.

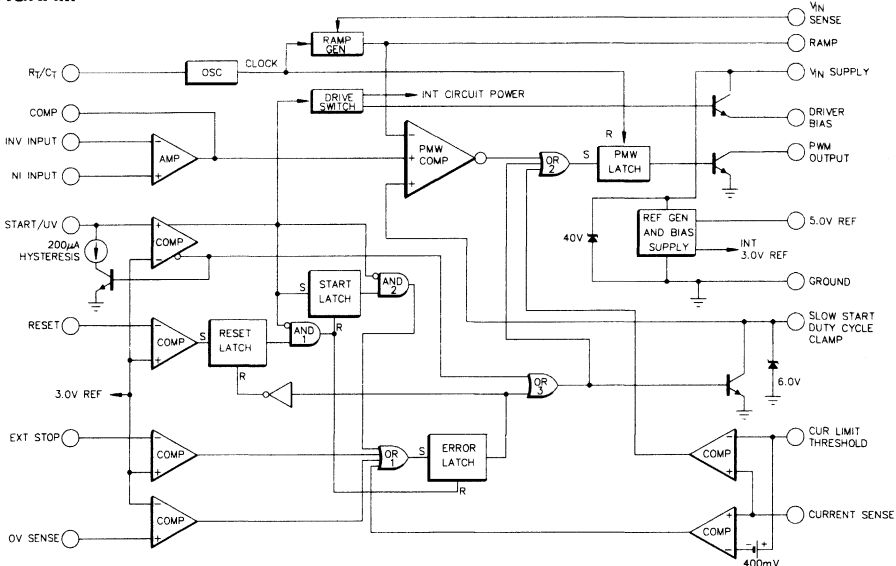
**FEATURES**

- All control, driving, monitoring, and protection functions included
- High Frequency Initial Accuracy
- Low-current, Off-line start circuit
- Feed-forward line regulation over 4 to 1 input range
- PWM latch for single pulse per period
- Pulse-by-pulse current limiting plus shut-down for over-current fault
- No start-up or shutdown transients
- Slow turn-on and maximum duty-cycle clamp
- Shutdown upon over- or under-voltage sensing
- Latch off or continuous retry after fault
- Remote, pulse-commandable start/stop
- PWM output switch usable to 1A peak current
- 1% reference accuracy
- 500kHz operation
- 70dB PSRR
- Linear frequency response

**HIGH RELIABILITY FEATURES-SG1840**

- ♦ Available to MIL-STD-883
- ♦ SG Level "S" processing available

**BLOCK DIAGRAM**



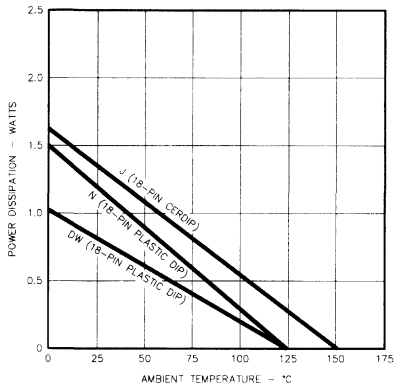
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage (+ V <sub>IN</sub> ) Voltage Driven ..... 32V Current Driven (self-limiting) ..... 100mA PWM Output Voltage (Pin 12) ..... 40V PWM Output Current (continuous) ..... 400mA PWM Output Peak Energy Discharge ..... 20μ Joules Driver Bias Current (Pin 14) ..... -200mA Reference Output Current (Pin 16) ..... -50mA Slow-start Sink Current (Pin 8)..... 20 mA	+ V <sub>IN</sub> Sense Current (Pin 11) ..... 10mA Current Limit Inputs (Pins 6 & 7) ..... -0.5V to 5.5V Comparator Inputs (Pins 2,3,4,5,17,18) ..... -0.3V to V <sub>IN</sub> Operating Junction Temperature Hermetic (J package)..... 175°C Plastic (N, DW packages)..... 150°C Storage Temperature Range ..... -65°C to 150°C Lead Temperature (Soldering, 10 Seconds) ..... 300°C
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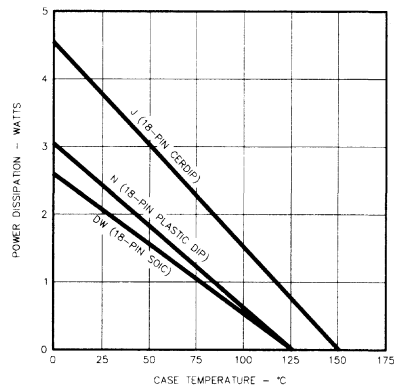
Note 1. Values beyond which damage may occur.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Supply Voltage Range ..... 8V to 30V Error Amp Common Mode Range ..... 1.5V to 5.5V PWM Output Current (continuous) ..... 0 to 200mA Driver Bias Output Current ..... 0 to 50mA Reference Load Current ..... 0 to 20mA + V <sub>IN</sub> Sense Current Range ..... 10μA to 1.0mA Ramp Generator Capacitor Range ..... 620pF to 0.1μF	Oscillator Frequency Range ..... 100Hz to 500KHz Oscillator Timing Resistor (R <sub>T</sub> ) ..... 1KΩ to 100KΩ Oscillator Timing Capacitor (C <sub>T</sub> ) ..... 620pF to 0.1μF Operating Ambient Temperature Range: SG1840 ..... -55°C to 125°C SG2840 ..... -25°C to 85°C SG3840 ..... 0°C to 70°C
--	--

Note 2. Range over which the device is functional and parameter limits are guaranteed.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise stated, these specifications apply for T<sub>A</sub> = -55°C to 125°C for the SG1840; -25°C to 85°C for the SG2840 and 0°C to 70°C for the SG3840; V<sub>IN</sub> = 20V, R<sub>T</sub> = 20K, C<sub>T</sub> = .001μF, C<sub>R</sub> = .001μF, Current Limit Threshold = 200mV.)

Parameter	Test Conditions	SG1840/2840			SG3840			Units	
		Min.	Typ.	Max.	Min.	Typ.	Max.		
<b>Power Inputs Section</b>									
Start-Up Current	V <sub>IN</sub> = 30V, Pin 2 = 2.5V, T <sub>I</sub> = 25°C		5	7		5	7	mA	
Start-Up Current T.C. (Note 3)	V <sub>IN</sub> = 30V, Pin 2 = 2.5V		-0.1	-0.2		-0.1	-0.2	%/°C	
Operating Current	V <sub>IN</sub> = 30V, Pin 2 = 3.5V		5	10	15	5	10	15	mA
Supply OV Clamp	I <sub>IN</sub> = 20mA		33	40	45	33	40	48	V
<b>Reference Section</b>									
Reference Voltage	T <sub>J</sub> = 25°C	4.95	5.0	5.05	4.9	5.0	5.1	V	
Line Regulation	V <sub>IN</sub> = 8 to 30V		10	15		10	20	mV	
Load Regulation	I <sub>L</sub> = 0 to 20mA		10	20		10	30	mV	
Temperature Coefficient (Note 3)	Over operating temperature range			±0.4			±0.4	mV/°C	
Short Circuit Current	V <sub>REF</sub> = 0, T <sub>J</sub> = 25°C		-80	-100		-80	-100	mA	

# SG1840/SG2840/SG3840

## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG1840/2840			SG3840			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Oscillator Section</b>								
Nominal Frequency	$T_J = 25^\circ\text{C}$	47	50	53	45	50	55	KHz
H.F. Initial Accuracy (Note 3)	$R_T = 3\text{K}\Omega$ , $C_T = 910\text{pF}$	270	300	330	270	300	330	KHz
Voltage Stability	$V_{IN} = 8$ to $30\text{V}$		0.5	1		0.5	1	%
Temperature Coefficient (Note 3)	Over operating temperature range			$\pm 0.8$			$\pm 0.8$	$\%/^\circ\text{C}$
Maximum Frequency	$R_T = 2\text{K}\Omega$ , $C_T = 620\text{pF}$	500			500			KHz
<b>Ramp Generator Section</b>								
Ramp Current, Minimum	$I_{\text{SENSE}} = -10\mu\text{A}$		-11	-14		-11	-14	$\mu\text{A}$
Ramp Current, Maximum	$I_{\text{SENSE}} = 1.0\text{mA}$	-0.9	-0.95		-0.9	-0.95		$\text{mA}$
Ramp Valley		0.3	0.5		0.3	0.5		V
Ramp Peak	Clamping Level	3.9	4.2	4.5	3.9	4.2	4.5	V
<b>Error Amplifier Section</b>								
Input Offset Voltage	$V_{CM} = 5.0\text{V}$		0.5	5		2	10	mV
Input Bias Current			0.5	2		1	5	$\mu\text{A}$
Input Offset Current				0.5			0.5	$\mu\text{A}$
Open Loop Gain	$\Delta V_O = 1$ to $3\text{V}$	60	66		60	66		dB
Output Swing (Max. Output $\leq$ Ramp Peak - 100mV)	Minimum Total Range	0.3		3.5	0.3		3.5	V
CMRR	$V_{CM} = 1.5$ to $5.5\text{V}$	70	80		70	80		dB
PSRR	$V_{IN} = 8$ to $30\text{V}$	70	90		70	90		dB
Short Circuit Current	$V_{\text{COMP}} = 0\text{V}$		-4	-10		-4	-10	$\text{mA}$
Gain Bandwidth (Note 3)	$T_J = 25^\circ\text{C}$ , $A_{VOL} = 0\text{dB}$	1	2		1	2		MHz
Slew Rate (Note 3)	$T_J = 25^\circ\text{C}$ , $A_{VOL} = 0\text{dB}$		0.8			0.8		V/ $\mu\text{s}$
<b>PWM Section</b>								
Continuous Duty Cycle Range (other than zero) (Note 3)	Minimum Total Continuous Range, Ramp Peak < 4.2V	5		95	5		95	%
Output Saturation	$I_{\text{OUT}} = 20\text{mA}$		0.2	0.4		0.2	0.4	V
	$I_{\text{OUT}} = 200\text{mA}$		1.7	2.2		1.7	2.2	V
Output Leakage	$V_{\text{OUT}} = 40\text{V}$		0.1	10		0.1	10	$\mu\text{A}$
Comparator Delay (Note 3)	Pin 8 to Pin 12 $T_J = 25^\circ\text{C}$ , $R_L = 1\text{k}\Omega$	300	500		300	500		ns
<b>Sequencing Functions Section</b>								
Comparator Thresholds	Pins 2, 3, 4, 5	2.8	3.0	3.2	2.8	3.0	3.2	V
Input Bias Current	Pins 3, 4, 5 = 0V		-1.0	-3.0		-1.0	-3.0	$\mu\text{A}$
Start/UV Hysteresis Current	Pin 2 = 2.5V	150	200	250	150	200	250	$\mu\text{A}$
Input Leakage	Input V = 20V		0.1	10		0.1	10	$\mu\text{A}$
Driver Bias Saturation Voltage	$I_B = -50\text{mA}$		2	3		2	3	V
Driver Bias Leakage	$V_B = 0\text{V}$		-0.1	-10		-0.1	-10	$\mu\text{A}$
Slow-Start Saturation	$I_S = 2\text{mA}$		0.2	0.5		0.2	0.5	V
Slow-Start Leakage	$V_S = 4.5\text{V}$		0.1	2.0		0.1	2.0	$\mu\text{A}$
<b>Current Control Section</b>								
Current Limit Offset			0	5		0	10	mV
Current Shutdown Offset		370	400	430	360	400	440	mV
Input Bias Current	Pin 7 = 0V		-2	-5		-2	-5	$\mu\text{A}$
Common Mode Range (Note 3)		-0.4		3.0	-0.4		3.0	V
Current Limit Delay (Note 3)	$T_J = 25^\circ\text{C}$ , Pin 7 to 12, $R_L = 1\text{k}$		200	400		200	400	ns

Note 3. These parameters, although guaranteed over the recommended operating condition, are not 100% tested in production.

CHARACTERISTIC CURVES

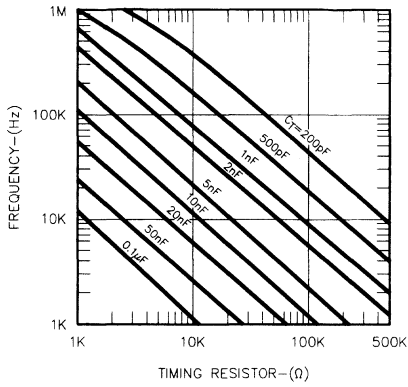


FIGURE 1. OSCILLATOR FREQUENCY

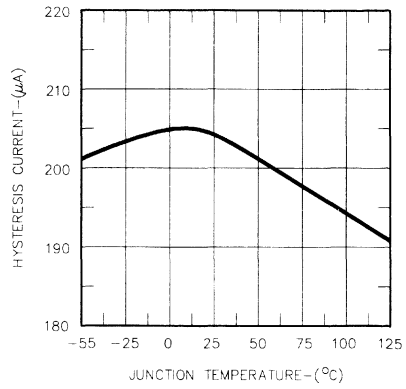


FIGURE 2. START/U.V. HYSTERESIS CURRENT VS. JUNCTION TEMPERATURE

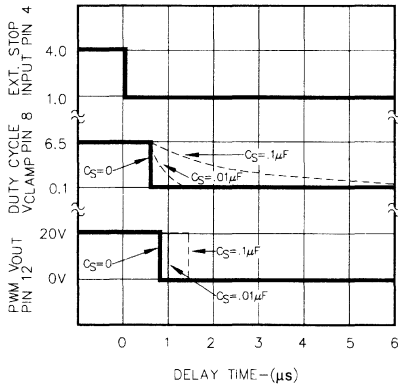


FIGURE 3. SHUTDOWN TIMING

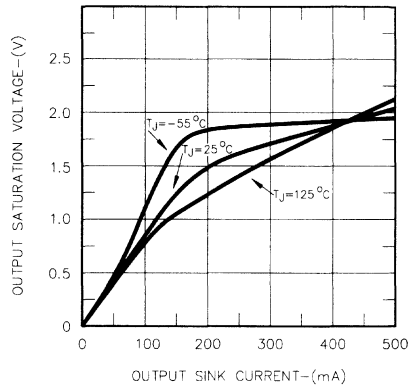


FIGURE 4. PWM OUTPUT SATURATION VOLTAGE VS. SINK CURRENT

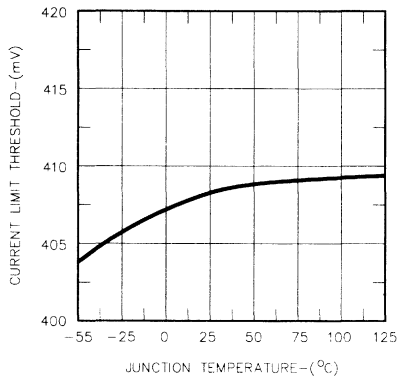
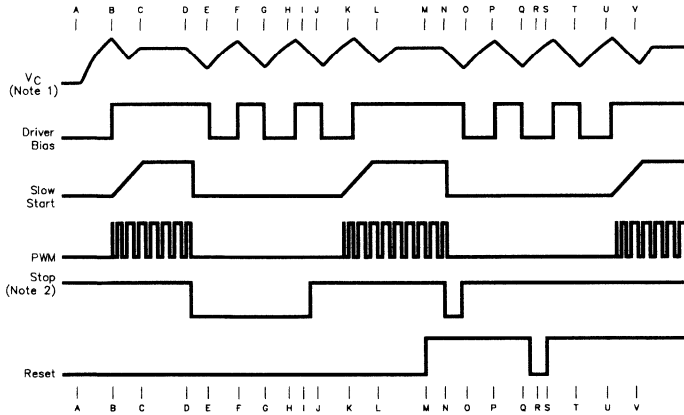


FIGURE 5. CURRENT LIMIT VS. JUNCTION TEMPERATURE

## SG1840 POWER SEQUENCING FUNCTIONS

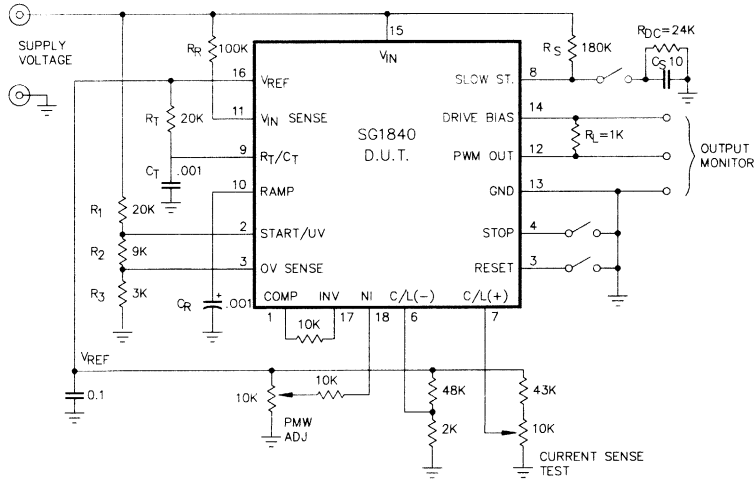


**Note 1.** V<sub>c</sub> represents an analog of the output voltage generated by a primary-referenced secondary winding on the power transformer. It is the voltage monitored by the start/UV comparator and, in most cases, is the supply voltage, V<sub>IN</sub>, for the SG1840.

**Note 2.** Although input to External Stop, Pin 4, is shown, results are the same for any fault input which sets the Error Latch.

TIME	EVENT	TIME	EVENT
A	Initial turn-on. V <sub>c</sub> rises with light load	L	Return to normal run state
B	Start threshold. Driver Bias Loads V <sub>c</sub>	M	Reset Latch set signal removed
C	Operating PWM regulates V <sub>c</sub>	N	Error Latch set with momentary fault
D	Stop input sets Error Latch turning off PWM	O	Error Latch does not reset as Reset Latch is reset
E	UV low threshold. Error Latch remains set	P } Q }	V <sub>c</sub> and Driver Bias recycle with no turn-on
F	Start turns on Driver Bias but Error Latch still set	R	Reset Latch set is set with momentary Reset signal
G } H }	V <sub>c</sub> and Driver Bias continue to cycle	S	V <sub>c</sub> must complete cycle to turn-on
I	Stop command removed	T	Start and Error Latches reset
J	Error Latch reset at UV low threshold	U	Normal start initiated
K	Start threshold now removes slow-start clamp	V	Return to normal run state

## OPEN LOOP TEST CIRCUIT



$$\text{Nominal Frequency} = \frac{1}{R_T C_T} = 50\text{KHz}$$

$$\text{UV Fault Voltage} = 3 \left( \frac{R_1 + R_2 + R_3}{R_2 + R_3} \right) = 8\text{V}$$

$$\text{Current Limit} = 200\text{mV}$$

$$\text{Start Voltage} = 3 \left( \frac{R_1 + R_2 + R_3}{R_2 + R_3} \right) + 0.2R_1 = 12\text{V}$$

$$\text{OV Fault Voltage} = 3 \left( \frac{R_1 + R_2 + R_3}{R_2 + R_3} \right) = 32\text{V}$$

$$\text{Current Fault Voltage} = 600\text{mV}$$

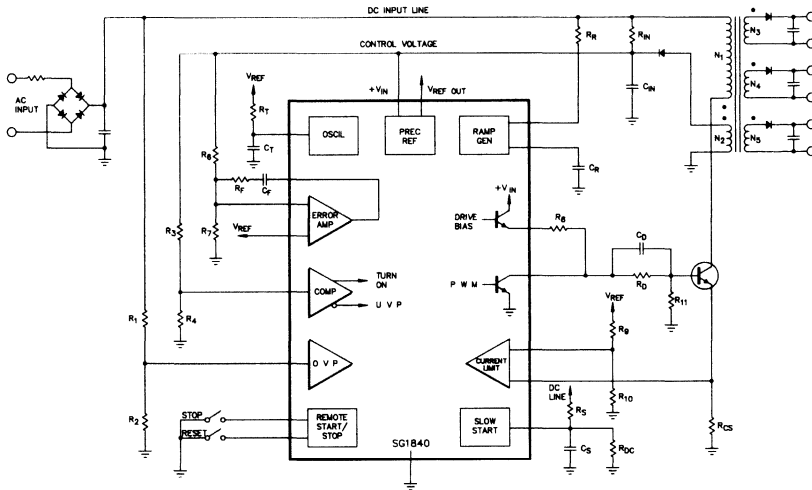
$$\text{Duty Cycle} = 50\%$$

**FUNCTIONAL DESCRIPTION**

<b>PWM Control</b>	
1. Oscillator	Generates a fixed-frequency internal clock from an external $R_T$ and $C_T$ . Frequency = $\frac{1}{R_T C_T}$
2. Ramp Generator	Develops a linear ramp with a slope defined externally by $\frac{dv}{dt} = \frac{\text{sense voltage}}{R_R C_R}$ $C_R$ is normally selected $\leq C_R$ and its value will have some effect upon valley voltage. $C_R$ terminal can be used as an input port for current mode control.
3. Error Amplifier	Conventional operational amplifier for closed-loop gain and phase compensation. Low output impedance; unity-gain stable.
4. Reference Generator	Precision 5.0V for internal and external usage to 50mA. Tracking 3.0V reference for internal usage only with nominal accuracy of $\pm 2\%$ . 40V clamp zener for chip 0V protection. 100mA maximum current.
5. PWM Comparator	Generates output pulse which starts at termination of clock pulse and ends when the ramp input crosses the lowest of two positive inputs.
6. PWM Latch	Terminates the PWM output pulse when set by inputs from either the PWM comparator, the pulse-by-pulse current limit comparator, or the error latch. Resets with each internal clock pulse.
7. PWM Output Switch	Transistor capable of sinking current to ground which is off during the PWM on-time and turns on to terminate the power pulse. Current capacity is 400mA saturated with peak capacitance discharge in excess of one amp.
<b>Sequencing Functions</b>	
1. Start/UV Sense	This comparator performs three functions— With an increasing voltage, it generates a turn-on signal at a start threshold. With a decreasing voltage, it generates a UV fault signal at a lower level separated by a 200 $\mu$ A hysteresis current. At the UV threshold, it also resets the Error Latch if the Reset Latch has been set.
2. Drive Switch	Disables most of the chip to hold internal current consumption low, and Driver Bias OFF, until input voltage reaches start threshold.
3. Driver Bias	Supplies drive current to external power switch to provide turn-on bias.
4. Slow Start	Clamps low to hold PWM OFF. Upon release, rises with rate controlled by $R_S C_S$ for slow increase of output pulse width. Also used to clamp maximum duty cycle with divider $R_S R_{DC}$ .
5. Start Latch	Keeps low input voltage at initial turn-on from being defined as a UV fault. Sets at start level to monitor for UV fault.
6. Reset Latch	When reset, this latch insures no reset signal to either Start or Error latches so that first fault will lock the PWM off. When set, this latch resets the Start and Error latches at the UV low threshold, allowing a restart.
<b>Protection Functions</b>	
1. Error Latch	When set by momentary input, this latch insures immediate PWM shutdown and hold off until reset. Inputs to Error Latch are: a. UV low (after turn-on) b. OV high c. Stop low d. Current Sense 400mV over threshold Error Latch resets at UV threshold if Reset Latch is set.
2. Current Limiting	Differential input comparator terminates individual output pulses each time sense voltage rises above threshold. When sense voltage rises to 400mV above threshold, a shutdown signal is sent to Error Latch.



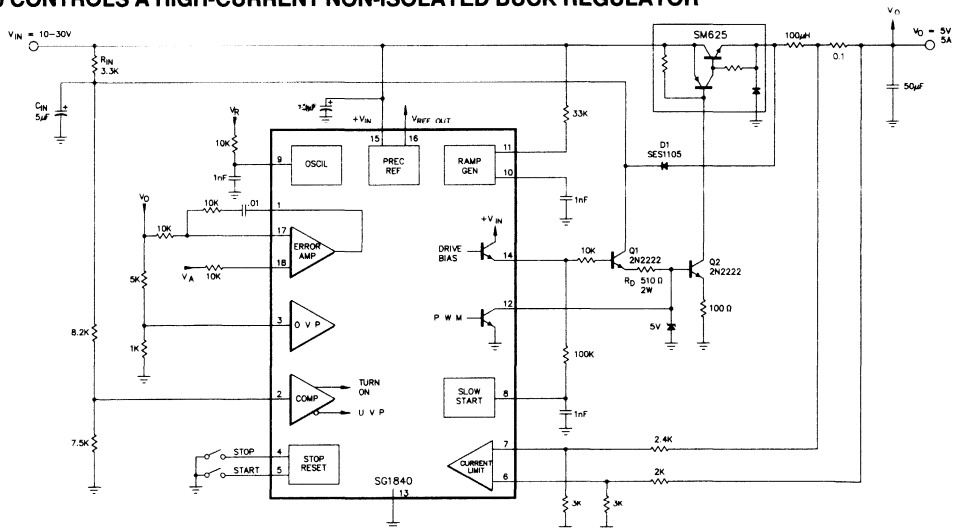
## SG1840 PROGRAMMABLE PWM CONTROLLER IN A SIMPLIFIED FLYBACK REGULATOR



In this application, complete control is maintained on the primary side. Control power is provided by  $R_{IN}$  and  $C_{IN}$  during start-up, and by a primary-referenced low voltage winding, N2, for efficient operation after start. The error amplifier loop is closed to regulate the DC voltage from N2 with other outputs following through their magnetic coupling - a task made even easier with the SG1840's feed-forward line regulation.

Not shown are protective snubbers or additional interface circuitry which may be required by the choice of the high-voltage switch,  $Q_s$ , or the application.

## SG1840 CONTROLS A HIGH-CURRENT NON-ISOLATED BUCK REGULATOR



Although primarily intended for transformer-coupled power systems, the SG1840's advantages of feed-forward for high ripple-rejection, a fully contained fault monitoring system and remote start/stop capability make it worth considering for other types of regulators. Since the fault logic within the SG1840 requires recycling the voltage sensed by the Start/UV Comparator to reset the error latch, a need for automatic restart must be addressed in a manner similar to that shown. In this simple, non-isolated, buck regulator, diode D1 provides a low-impedance bootstrapped drive power source after start-up is achieved through  $R_{IN}$  and  $C_{IN}$ . When a fault shutdown terminates switching action, the loading of Q1 and  $R_D$  will lower the voltage on pin 2 to effect an automatic re-start attempt which will continuously recycle until the fault is removed.

# SG1840/SG2840/SG3840

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram																																				
18-PIN CERAMIC DIP J - PACKAGE	SG1840J/883B	-55°C to 125°C	<table style="width: 100%; border: none;"> <tr> <td>COMPENSATION</td><td>1</td><td>18</td><td>NON-INV INPUT</td></tr> <tr> <td>START UV</td><td>2</td><td>17</td><td>INVERTING INPUT</td></tr> <tr> <td>OV SENSE</td><td>3</td><td>16</td><td>5.0V REF</td></tr> <tr> <td>STOP</td><td>4</td><td>15</td><td>+V<sub>IN</sub> SUPPLY</td></tr> <tr> <td>RESET</td><td>5</td><td>14</td><td>DRIVER BIAS</td></tr> <tr> <td>CURRENT THRESHOLD</td><td>6</td><td>13</td><td>GROUND</td></tr> <tr> <td>CURRENT SENSE</td><td>7</td><td>12</td><td>PWM OUTPUT</td></tr> <tr> <td>SLOW START</td><td>8</td><td>11</td><td>V<sub>IN</sub> SENSE</td></tr> <tr> <td>R<sub>1</sub>C<sub>1</sub></td><td>9</td><td>10</td><td>RAMP</td></tr> </table>	COMPENSATION	1	18	NON-INV INPUT	START UV	2	17	INVERTING INPUT	OV SENSE	3	16	5.0V REF	STOP	4	15	+V <sub>IN</sub> SUPPLY	RESET	5	14	DRIVER BIAS	CURRENT THRESHOLD	6	13	GROUND	CURRENT SENSE	7	12	PWM OUTPUT	SLOW START	8	11	V <sub>IN</sub> SENSE	R <sub>1</sub> C <sub>1</sub>	9	10	RAMP
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SG1840J	-55°C to 125°C																																						
SG2840J	-25°C to 85°C																																						
SG3840J	0°C to 70°C																																						
18-PIN PLASTIC DIP N - PACKAGE	SG2840N	-25°C to 85°C																																					
	SG3840N	0°C to 70°C																																					
18-PIN WIDE BODY PLASTIC S.O.I.C. DW - PACKAGE	SG2840DW	-25°C to 85°C	<table style="width: 100%; border: none;"> <tr> <td>COMPENSATION</td><td>1</td><td>18</td><td>NON-INV INPUT</td></tr> <tr> <td>START UV</td><td>2</td><td>17</td><td>INVERTING INPUT</td></tr> <tr> <td>OV SENSE</td><td>3</td><td>16</td><td>5.0V REF</td></tr> <tr> <td>STOP</td><td>4</td><td>15</td><td>+V<sub>IN</sub> SUPPLY</td></tr> <tr> <td>RESET</td><td>5</td><td>14</td><td>DRIVER BIAS</td></tr> <tr> <td>CURRENT THRESHOLD</td><td>6</td><td>13</td><td>GROUND</td></tr> <tr> <td>CURRENT SENSE</td><td>7</td><td>12</td><td>PWM OUTPUT</td></tr> <tr> <td>SLOW START</td><td>8</td><td>11</td><td>V<sub>IN</sub> SENSE</td></tr> <tr> <td>R<sub>1</sub>C<sub>1</sub></td><td>9</td><td>10</td><td>RAMP</td></tr> </table>	COMPENSATION	1	18	NON-INV INPUT	START UV	2	17	INVERTING INPUT	OV SENSE	3	16	5.0V REF	STOP	4	15	+V <sub>IN</sub> SUPPLY	RESET	5	14	DRIVER BIAS	CURRENT THRESHOLD	6	13	GROUND	CURRENT SENSE	7	12	PWM OUTPUT	SLOW START	8	11	V <sub>IN</sub> SENSE	R <sub>1</sub> C <sub>1</sub>	9	10	RAMP
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R <sub>1</sub> C <sub>1</sub>	9	10	RAMP																																				
SG3840DW	0°C to 70°C																																						

- Note 1. Contact factory for JAN and DESC product availability.  
 Note 2. All parts are viewed from the top.

**CURRENT-MODE PWM CONTROLLER**

**DESCRIPTION**

The SG1842/43 family of control IC's provides all the necessary features to implement off-line fixed frequency, current mode switching power supplies with a minimum number of external components. Current mode architecture demonstrates improved line regulation, improved load regulation, pulse-by-pulse current limiting and inherent protection of the power supply output switch.

The bandgap reference is trimmed to  $\pm 1\%$  over temperature. Oscillator discharge current is trimmed to less than  $\pm 10\%$ . The SG1842/43 has under-voltage lockout, current limiting circuitry and start-up current of less than 1 mA.

The totem pole output is optimized to drive the gate of a power MOSFET. The output is low in the off state to provide direct interface to an N channel device.

The SG1842/43 is specified for operation over the full military temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The SG2842/43 is specified for the industrial range of  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and the SG3842/43 is designed for the commercial range of  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

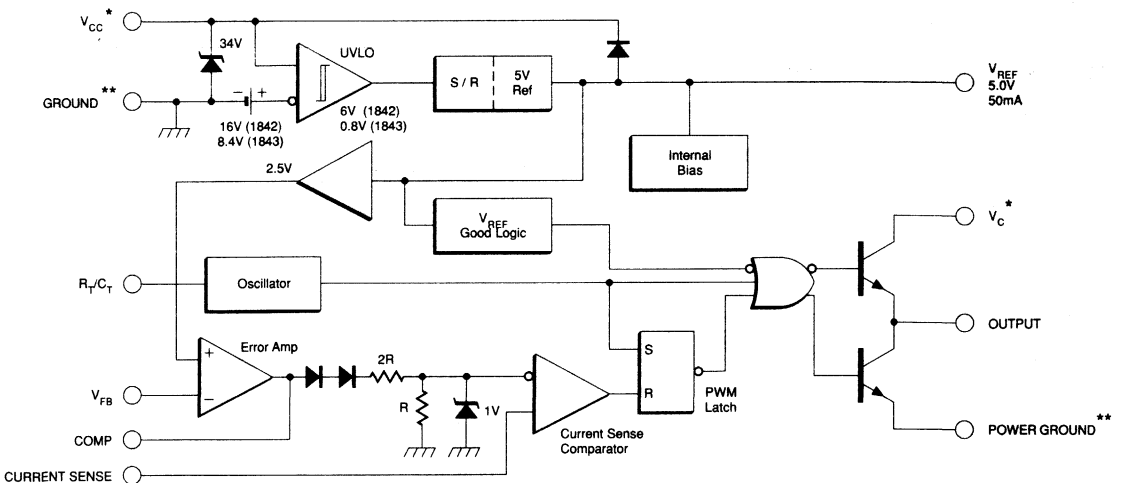
**FEATURES**

- Optimized for off-line control
- Low start-up current ( $< 1\text{mA}$ )
- Automatic feed forward compensation
- Trimmed oscillator discharge current
- Pulse-by-pulse current limiting
- Enhanced load response characteristics
- Under-voltage lockout with 6V hysteresis (SG1842 only)
- Double pulse suppression
- High current totem pole output (1Amp peak)
- Internally trimmed bandgap reference
- 500 KHz operation
- Undervoltage lockout  
SG1842 — 16 volts  
SG1843 — 8.4 volts
- Low shoot-through current  $< 75\text{mA}$  over temperature

**HIGH RELIABILITY FEATURES**  
- SG1842/ 1843

- ◆ Available to MIL-STD-883 and DESC SMD
- ◆ Scheduled for MIL-M38510 QPL listing
- ◆ Radiation data available
- ◆ SG level "S" processing available

**BLOCK DIAGRAM**



\* -  $V_{CC}$  and  $V_C$  are internally connected for 8 pin packages.  
 \*\* - POWER GROUND and GROUND are internally connected for 8 pin packages.

# SG1842/SG1843 SERIES

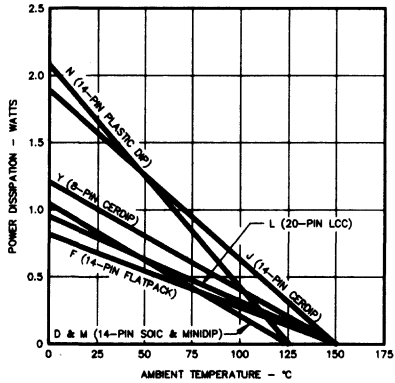
## ABSOLUTE MAXIMUM RATINGS (Notes 1 & 2)

Supply Voltage ( $I_{CC} < 30\text{mA}$ )	Self-limiting	Error Amp Output Sink Current	10mA
Supply Voltage (Low Impedance Source)	30V	Operating Junction Temperature	
Output Current (peak)	$\pm 1\text{A}$	Hermetic (J, Y, F - Packages)	175°C
Output Current (continuous)	350mA	Plastic (N, M, D - Packages)	150°C
Output Energy (Capacitive Load)	5 $\mu\text{J}$	Storage Temperature Range	-65°C to 150°C
Analog Inputs (Pin 2, Pin 3)	-0.3V to $V_{CC}$	Lead Temperature (Soldering, 10 Seconds)	300°C

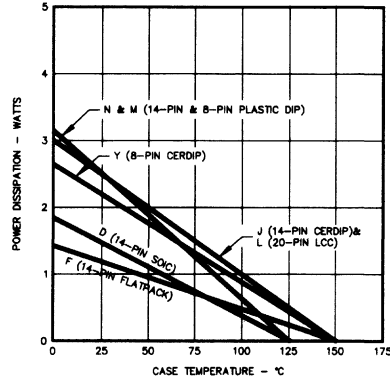
Note 1. Exceeding these ratings could cause damage to the device.  
 Note 2. All voltages are with respect to Pin 5. All currents are positive into the specified terminal.

## RECOMMENDED OPERATING CONDITIONS (Note 3)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Supply Voltage Range	30V	Oscillator Timing Resistor ( $R_T$ )	$520\Omega \leq R_T \leq 150\text{k}\Omega$
Output Current (peak)	•1A	Oscillator Timing Capacitor ( $C_T$ )	$1000\text{pF} \leq C_T \leq 1\mu\text{F}$
Output Current (continuous)	200mA	Operating Ambient Temperature Range:	
Analog Inputs (Pin 2, Pin 3)	-0.3 to $V_{CC}-3$	SG1842/43	-55°C to 125°C
Error Amp Output Sink Current	5mA	SG2842/43	-25°C to 85°C
Oscillator Frequency Range	100Hz to 500KHz	SG3842/43	0°C to 70°C

Note 3. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise stated, these specifications apply for  $-55 \leq T_A \leq 125^\circ\text{C}$  for SG1842/43;  $-25 \leq T_A \leq 85^\circ\text{C}$  for SG2842/43;  $0 \leq T_A \leq 70^\circ\text{C}$  for SG3842/43;  $V_{CC} = 15\text{V}$  (Note 7);  $R_T = 10\text{K}$ ;  $C_T = 3.3\text{nF}$ )

Parameter	Test Conditions	SG1842/43			SG2842/43			SG3842/43			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Reference Section</b>											
Output Voltage	$T_J = 25^\circ\text{C}$ , $I_O = 1\text{mA}$	4.95	5.00	5.05	4.95	5.00	5.05	4.90	5.00	5.10	V
Line Regulation	$12\text{V} \leq V_{IN} \leq 25\text{V}$		6	20		6	20		6	20	mV
Load Regulation	$1 \leq I_O \leq 20\text{mA}$		6	25		6	25		6	25	mV
Temp. Stability (Note 4)			0.2	0.4		.02	0.4		0.2	0.4	mV/°C
Total Output Variation (Note 4)	Line, Load, Temp.	4.90		5.10	4.90		5.10	4.82		5.18	V
Output Noise Voltage (Note 4)	$10\text{Hz} \leq f \leq 10\text{kHz}$ , $T_J = 25^\circ\text{C}$		50			50			50		$\mu\text{V}$
Long Term Stability (Note 4)	$T_A = 125^\circ\text{C}$ , 1000 Hrs.		5	25		5	25		5	25	mV
Output Short Circuit		-30	-100	-180	-30	-100	-180	-30	-100	-180	mA
<b>Oscillator Section</b>											
Initial Accuracy	$T_J = 25^\circ\text{C}$	47	52	57	47	52	57	47	52	57	kHz
Voltage Stability	$12 \leq V_{CC} \leq 25\text{V}$		.02	1		0.2	1		0.2	1	%
Temp. Stability (Note 4)	$T_{MIN} \leq T_A \leq T_{MAX}$		5			5			5		%
Amplitude	$V_{RT/CT}$ (peak to peak)		1.7			1.7			1.7		V
Discharge Current	$T_J = 25^\circ\text{C}$	7.8	8.3	8.8	7.8	8.3	8.8	7.8	8.3	8.8	mA
	$T_{MIN} \leq T_A \leq T_{MAX}$	7.0		9.0	7.5		9.0	7.6		9.0	mA

# SG1842/SG1843 SERIES

## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG1842/43			SG2842/43			SG3842/43			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Error Amp Section</b>											
Input Voltage	$V_{COMP} = 2.5V$	2.45	2.50	2.55	2.45	2.50	2.55	2.42	2.50	2.58	V
Input Bias Current			-0.3	-1		-0.3	1		-0.3	-2	$\mu A$
Open Loop Gain ( $A_{VOL}$ )	$2 \leq V_O \leq 4V$	65	90		65	90		65	90		dB
Unity Gain Bandwidth (Note 4)		0.7	1		0.7	1		0.7	1		MHz
PSRR	$12 \leq V_{CC} \leq 25V$	60	70		60	70		60	70		dB
Output Sink Current	$V_{VFB} = 2.7V, V_{COMP} = 1.1V$	2	6		2	6		2	6		mA
Output Source Current	$V_{VFB} = 2.3V, V_{COMP} = 5V$	-0.5	-0.8		-0.5	-0.8		-0.5	-0.8		mA
$V_{OUT}$ High	$V_{VFB} = 2.3V, R_L = 15K \text{ to } gnd$	5	6		5	6		5	6		V
$V_{OUT}$ Low	$V_{VFB} = 2.7V, R_L = 15K \text{ to } V_{REF}$		0.7	1.1		0.7	1.1		0.7	1.1	V
<b>Current Sense Section</b>											
Gain (Notes 5 & 6)		2.85	3	3.15	2.85	3	3.15	2.85	3	3.15	V/V
Maximum Input Signal (Note 5)	$V_{COMP} = 5V$	0.9	1	1.1	0.9	1	1.1	0.9	1	1.1	V
PSRR (Note 5)	$12 \leq V_{CC} \leq 25V$		70			70			70		dB
Input Bias Current			-2	-10		-2	-10		-2	-10	$\mu A$
Delay to Output (Note 4)			150	300		150	300		150	300	ns
<b>Output Section</b>											
Output Low Level	$I_{SINK} = 20mA$		0.1	0.4		0.1	0.4		0.1	0.4	V
	$I_{SINK} = 200mA$		1.5	2.2		1.5	2.2		1.5	2.2	V
Output High Level	$I_{SOURCE} = 20mA$	13	13.5		13	13.5		13	13.5		V
	$I_{SOURCE} = 200mA$	12	13.5		12	13.5		12	13.5		V
Rise Time	$T_J = 25^\circ C, C_L = 1nF$		50	150		50	150		50	150	ns
Fall Time	$T_J = 25^\circ C, C_L = 1nF$		50	150		50	150		50	150	ns
<b>Under-Voltage Lockout Section</b>											
Start Threshold (1842)		15	16	17	15	16	17	14.5	16	17.5	V
Min. Operating Voltage (1842)	After Turn On	9	10	11	9	10	11	8.5	10	11.5	V
Start Threshold (1843)		7.8	8.4	9.0	7.8	8.4	9.0	7.8	8.4	9.0	V
Min. Operating Voltage (1843)	After Turn On	7.0	7.6	8.2	7.0	7.6	8.2	7.0	7.6	8.2	V
<b>PWM Section</b>											
Max. Duty Cycle		90	95	100	90	95	100	90	95	100	%
Min. Duty Cycle				0			0			0	%
<b>Power Consumption Section</b>											
Start-Up Current			0.5	1		0.5	1		0.5	1	mA
Operating Supply Current	$V_{VFB} = V_{ISENSE} = 0V$		11	17		11	17		11	17	mA
$V_{CC}$ Zener Voltage	$I_{CC} = 25mA$		34			34			34		V

Notes: 4. These parameters, although guaranteed, are not 100% tested in production.

5. Parameter measured at trip point of latch with  $V_{VFB} = 0$ .

6. Gain defined as:  $A = \frac{\Delta V_{COMP}}{\Delta V_{ISENSE}}$ ;  $0 \leq V_{ISENSE} \leq 0.8V$ .

7. Adjust  $V_{CC}$  above the start threshold before setting at 15V.

## CHARACTERISTIC CURVES

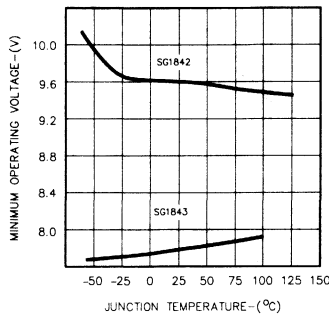


FIGURE 1. DROPOUT VOLTAGE VS. TEMPERATURE

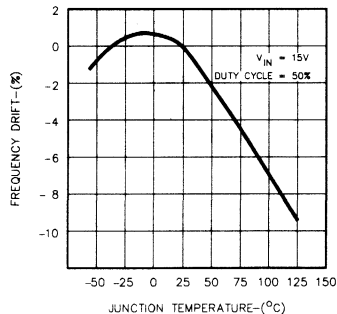


FIGURE 2. OSCILLATOR TEMPERATURE STABILITY

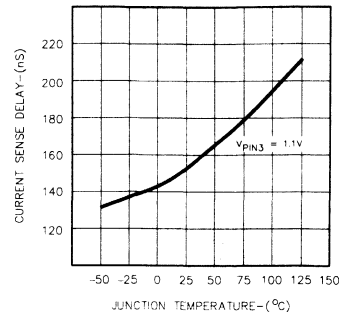
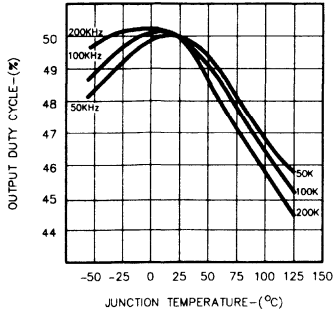
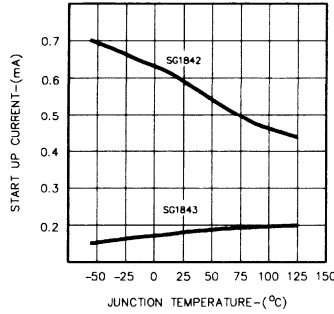


FIGURE 3. CURRENT SENSE TO OUTPUT DELAY VS. TEMP.

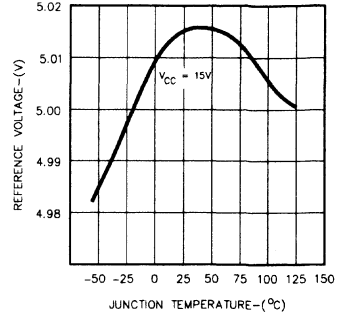
## CHARACTERISTIC CURVES (continued)



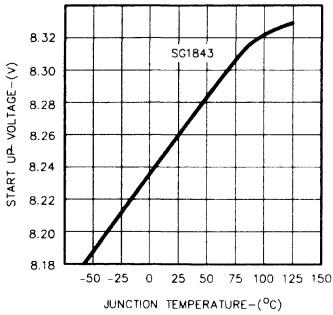
**FIGURE 4.**  
OUTPUT DUTY CYCLE VS. TEMPERATURE



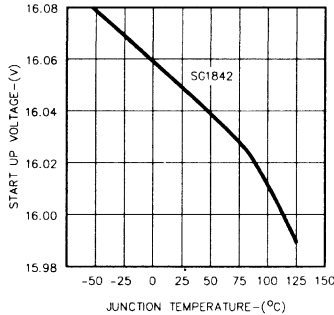
**FIGURE 5.**  
START-UP CURRENT VS. TEMPERATURE



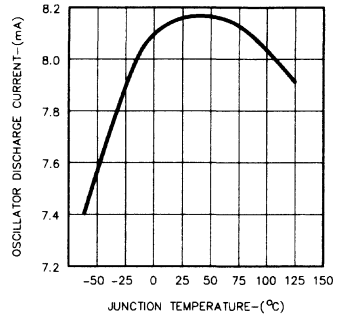
**FIGURE 6.**  
REFERENCE VOLTAGE VS. TEMPERATURE



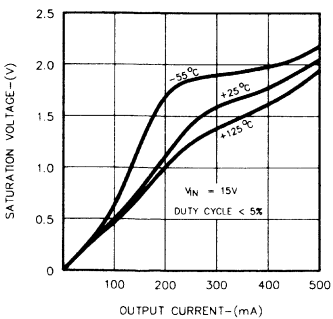
**FIGURE 7.**  
START-UP VOLTAGE THRESHOLD VS. TEMPERATURE



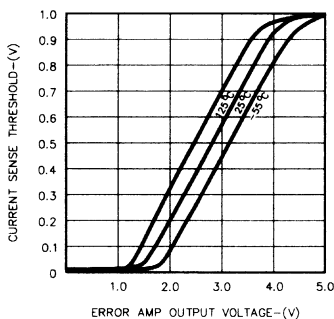
**FIGURE 8.**  
START-UP VOLTAGE THRESHOLD VS. TEMPERATURE



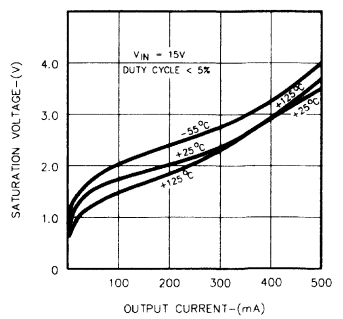
**FIGURE 9.**  
OSCILLATOR DISCHARGE CURRENT VS. TEMPERATURE



**FIGURE 10.**  
OUTPUT SATURATION VOLTAGE VS. OUTPUT CURRENT AND TEMPERATURE (SINK TRANSISTOR)



**FIGURE 11.**  
CURRENT SENSE THRESHOLD VS. ERROR AMPLIFIER OUTPUT



**FIGURE 12.**  
OUTPUT SATURATION VOLTAGE VS. OUTPUT CURRENT AND TEMPERATURE (SOURCE TRANSISTOR)

## APPLICATION INFORMATION

### OSCILLATOR:

The oscillator of the 1842/43 family of PWM's is designed such that many values of  $R_T$  &  $C_T$  will give the same oscillator frequency, but only one combination will yield a specific duty cycle at a given frequency.

A set of formulas are given to determine the values of  $R_T$  &  $C_T$  for a given frequency and maximum duty cycle. (Note: These formulas are less accurate for smaller duty cycles or higher frequencies. This will require trimming of  $R_T$  or  $C_T$  to correct for this error.)

GIVEN: Frequency  $\equiv f$   
Maximum Duty Cycle  $\equiv D_m$

CALCULATE:

$$R_T = 267 \frac{(1.76)^{1/D_m} - 1}{(1.76)^{(1-D_m)/D_m} - 1} (\Omega)$$

where  $.3 < D_m < .95$

$$C_T = \frac{1.86 \times D_m}{f \times R_T} (\mu F)$$

### EXAMPLE:

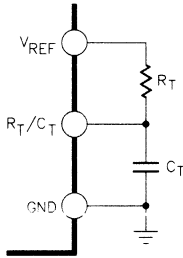
A Flyback power supply requires a maximum of 45% duty cycle at a switching frequency of 50KHz. What are the values of  $R_T$  and  $C_T$ ?

GIVEN:  $f = 50\text{KHz}$   
 $D_m = 0.45$

CALCULATE:  $R_T = 267 \frac{(1.76)^{1/0.45} - 1}{(1.76)^{.55/0.45} - 1} = 674\Omega$

$$C_T = \frac{1.86 \times .45}{50000 \times 674} = .025\mu F$$

For Duty-Cycles above 95% use:



$$F \approx \frac{1.86}{R_T C_T} \text{ WHERE } R_T \geq 5K\Omega$$

FIGURE 13 — OSCILLATOR TIMING CIRCUIT

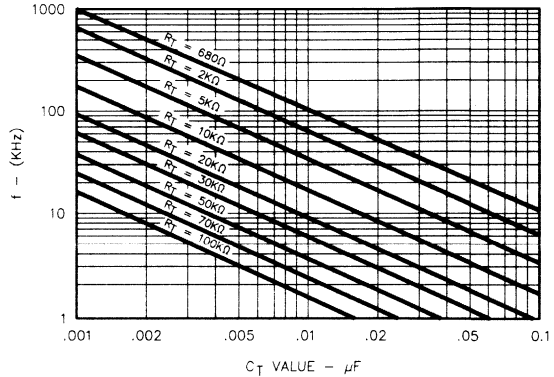


FIGURE 14 — OSCILLATOR FREQUENCY VS.  $R_T$  FOR VARIOUS  $C_T$

## APPLICATION CIRCUITS (Note 8)

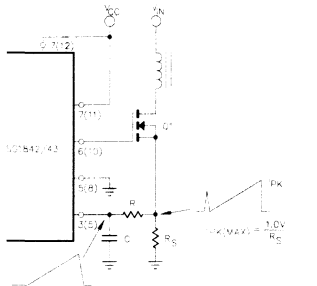


FIGURE 15 — CURRENT SENSE SPIKE SUPPRESSION

The RC low pass filter will eliminate the leading edge current spike caused by parasitics of Power MOSFET.

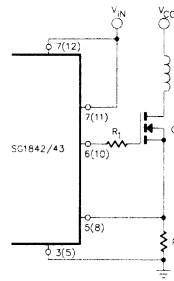


FIGURE 16 — MOSFET PARASITIC OSCILLATIONS

A resistor ( $R_T$ ) in series with the MOSFET gate will reduce overshoot & ringing caused by the MOSFET input capacitance and any inductance in series with the gate drive. (Note: It is very important to have a low inductance ground path to insure correct operation of the I.C. This can be done by making the ground paths as short and as wide as possible.)

## APPLICATION CIRCUITS (continued)

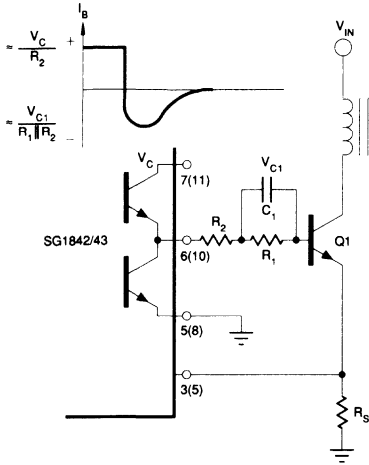


FIGURE 17 — BIPOlar TRANSISTOR DRIVE

The 1842/43 output stage can provide negative base current to remove base charge of power transistor (Q<sub>1</sub>) for faster turn off. This is accomplished by adding a capacitor (C<sub>1</sub>) in parallel with a resistor (R<sub>1</sub>). The resistor (R<sub>1</sub>) is to limit the base current during turn on.

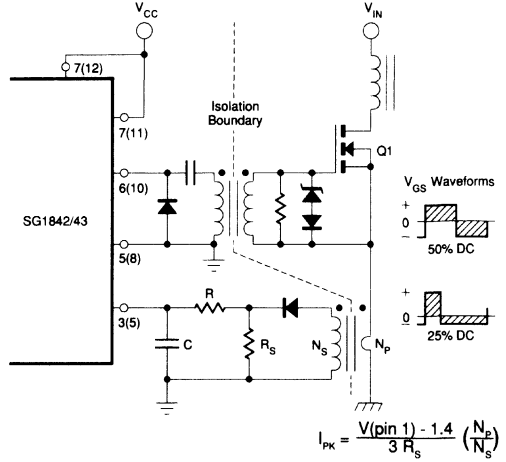


FIGURE 18 — ISOLATED MOSFET DRIVE

Current transformers can be used where isolation is required between PWM and Primary ground. A drive transformer is then necessary to interface the PWM output with the MOSFET.

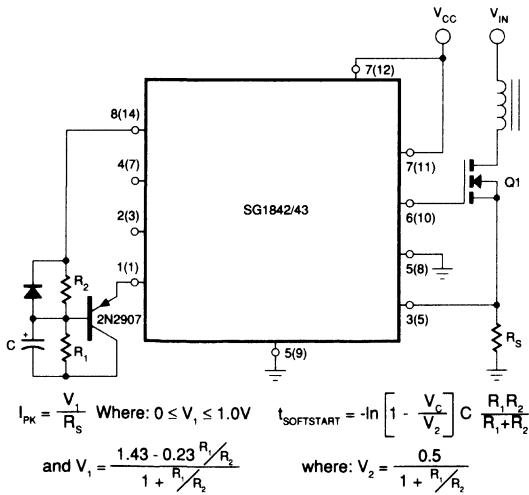


FIGURE 19 — ADJUSTABLE BUFFERED REDUCTION OF CLAMP LEVEL WITH SOFT-START

Soft start and adjustable peak current can be done with the external circuitry shown above.

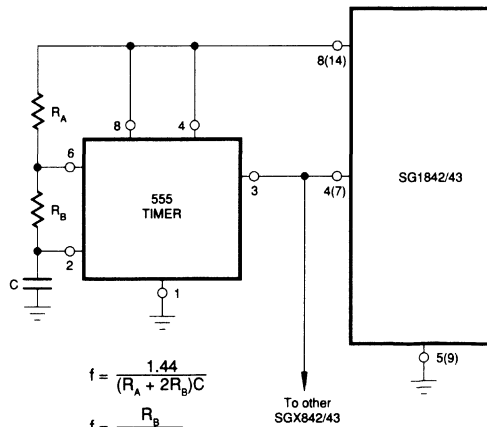


FIGURE 20 — EXTERNAL DUTY CYCLE CLAMP AND MULTI-UNIT SYNCHRONIZATION

Precision duty cycle limiting as well as synchronizing several 1842/43's is possible with the above circuitry.



# SG1842/SG1843 SERIES

## APPLICATION CIRCUITS (continued)

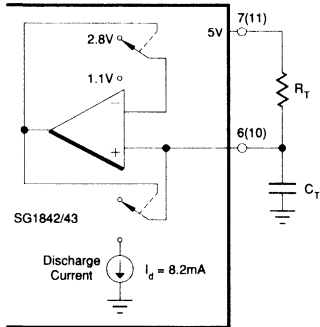


FIGURE 21 — OSCILLATOR CONNECTION

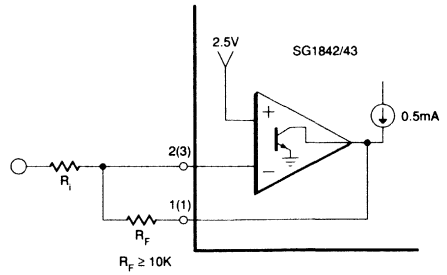


FIGURE 22 — ERROR AMPLIFIER CONNECTION

The oscillator is programmed by the values selected for the timing components  $R_T$  and  $C_T$ . Refer to application information for calculation of the component values.

Error amplifier is capable of sourcing and sinking current up to 0.5mA.

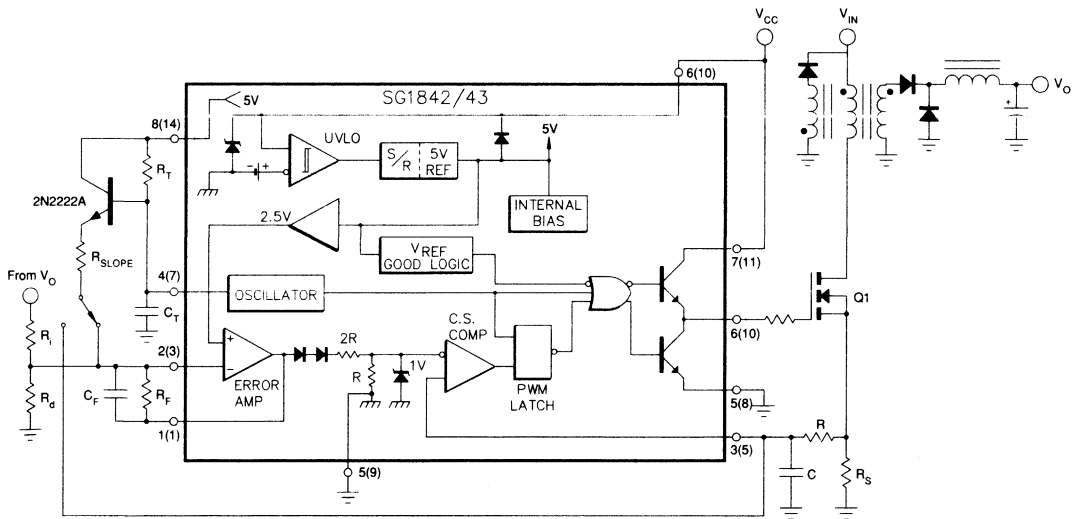


FIGURE 23 — SLOPE COMPENSATION

Due to inherent instability of current mode converters running above 50% duty cycle, a slope compensation should be added to either current sense pin or the error amplifier. Figure 23 shows a typical slope compensation technique.

## APPLICATION CIRCUITS (continued)

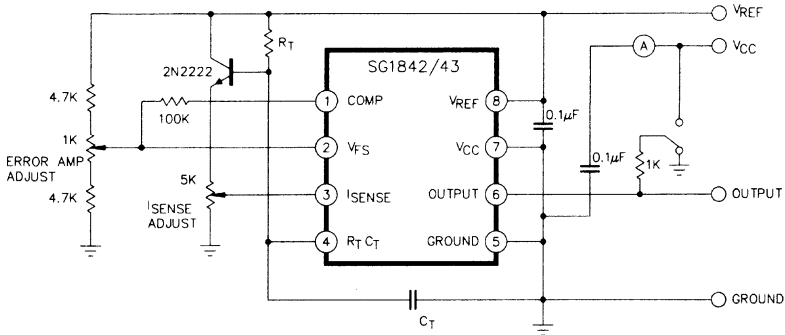


FIGURE 24—OPEN LOOP LABORATORY FIXTURE

High peak currents associated with capacitive loads necessitate careful grounding techniques. Timing and bypass capacitors should be connected to pin 5 in a single point ground. The transistor and 5k potentiometer are used to sample the oscillator waveform and apply an adjustable ramp to pin 3.

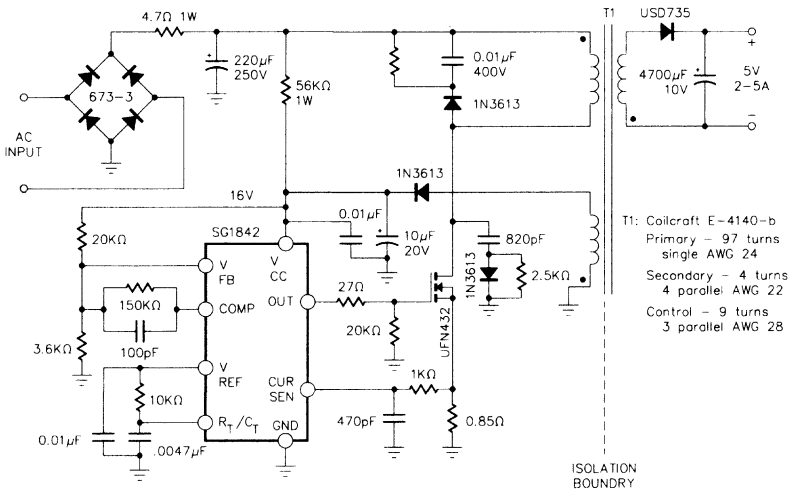


FIGURE 25—OFF-LINE FLYBACK REGULATOR

### SPECIFICATIONS

Input line voltage:	90VAC to 130VAC
Input frequency:	50 or 60Hz
Switching frequency:	40KHz • 10%
Output power:	25W maximum
Output voltage:	5V +5%
Output current:	2 to 5A
Line regulation:	0.01%/V
Load regulation:	8%/A*
Efficiency @ 25 Watts,	
$V_{IN} = 90VAC:$	70%
$V_{IN} = 130VAC:$	65%
Output short-circuit current:	2.5Amp average

\* This circuit uses a low-cost feedback scheme in which the DC voltage developed from the primary-side control winding is sensed by the SG1842 error amplifier. Load regulation is therefore dependent on the coupling between secondary and control windings, and on transformer leakage inductance.

Note 8. Pin numbers referenced are for 8 pin package and pin numbers in parenthesis are for 14 pin packages.

# SG1842/SG1843 SERIES

## CONNECTION DIAGRAM & ORDERING INFORMATION (See notes below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
14-PIN CERAMIC DIP J - PACKAGE	SG1842J/883B	-55°C to 125°C	
	SG1842J	-55°C to 125°C	
	SG2842J	-25°C to 85°C	
	SG3842J	0°C to 70°C	
	SG1843J/883B	-55°C to 125°C	
	SG1843J	-55°C to 125°C	
	SG2843J	-25°C to 85°C	
14-PIN PLASTIC DIP N - PACKAGE	SG2842N	-25°C to 85°C	
	SG3842N	0°C to 70°C	
	SG2843N	-25°C to 85°C	
	SG3843N	0°C to 70°C	
8-PIN CERAMIC DIP Y - PACKAGE	SG1842Y/883B	-55°C to 125°C	
	SG1842Y	-55°C to 125°C	
	SG2842Y	-25°C to 85°C	
	SG3842Y	0°C to 70°C	
	SG1843Y/883B	-55°C to 125°C	
	SG1843Y	-55°C to 125°C	
8-PIN PLASTIC DIP M - PACKAGE	SG2842M	-25°C to 85°C	
	SG3842M	0°C to 70°C	
	SG2843M	-25°C to 85°C	
	SG3843M	0°C to 70°C	
14-PIN PLASTIC S.O.I.C. D - PACKAGE	SG2842D	-25°C to 85°C	
	SG3842D	0°C to 70°C	
	SG2843D	-25°C to 85°C	
	SG3843D	0°C to 70°C	
10-PIN CERAMIC FLAT PACK F - PACKAGE	SG1842F/883B	-55°C to 125°C	
	SG1842F	-55°C to 125°C	
	SG1843F/883B	-55°C to 125°C	
	SG1843F	-55°C to 125°C	
20-PIN CERAMIC LEADLESS CHIP CARRIER L - PACKAGE	SG1842L/883B	-55°C to 125°C	
	SG1842L	-55°C to 125°C	
	SG1843L/883B	-55°C to 125°C	
	SG1843L	-55°C to 125°C	

Note 1. Contact factory for JAN and DESC product availability.  
 2. All packages are viewed from the top.





LINEAR INTEGRATED CIRCUITS

**SG1844/2844/3844**  
**SG1845/2845/3845**

## CURRENT-MODE PWM CONTROLLER

### DESCRIPTION

The SG1844/45 family of control IC's provides all the necessary features to implement off-line fixed frequency, current mode switching power supplies with a minimum number of external components. Current mode architecture demonstrates improved line regulation, improved load regulation, pulse-by-pulse current limiting and inherent protection of the power supply output switch.

The bandgap reference is trimmed to  $\pm 1\%$  over temperature. Oscillator discharge current is trimmed to less than  $\pm 10\%$ . The SG1844/45 has under-voltage lockout, current limiting circuitry and start-up current of less than 1 mA.

The totem pole output is optimized to drive the gate of a power MOSFET. The output is low in the off state to provide direct interface to an N channel device.

Both operate up to a maximum duty cycle range of zero to  $< 50\%$  due to an internal toggle flip flop which blanks the output off every other clock cycle.

The SG1844/45 is specified for operation over the full military ambient temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . The SG2844/45 is specified for the industrial range of  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ , and the SG3844/45 is designed for the commercial range of  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

### FEATURES

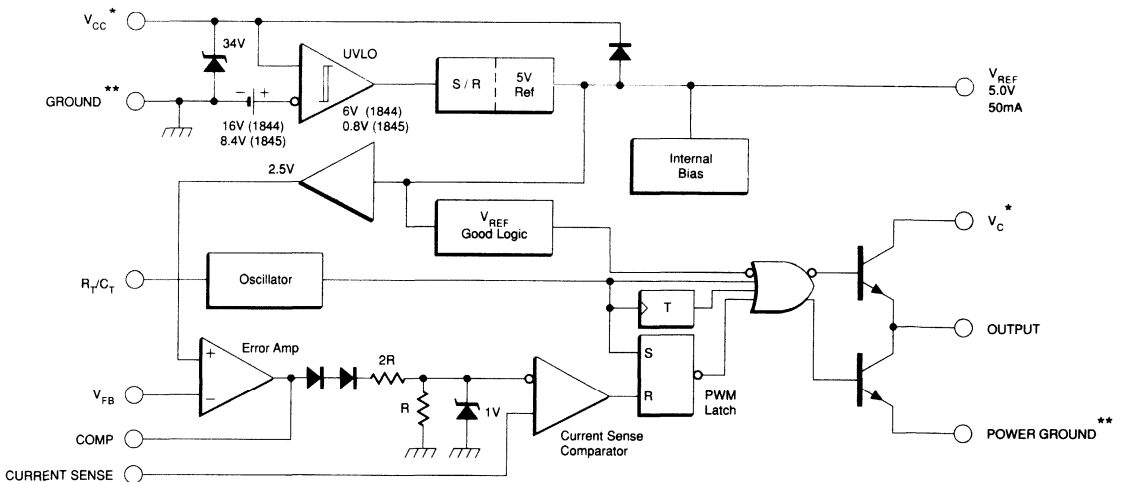
- Optimized for off-line control
- Low start-up current ( $< 1\text{mA}$ )
- Automatic feed forward compensation
- Trimmed oscillator discharge current
- Pulse-by-pulse current limiting
- Enhanced load response characteristics
- Under-voltage lockout with 6V hysteresis (SG1844 only)
- Double pulse suppression
- High current totem pole output
- Internally trimmed bandgap reference
- 500KHz operation
- Undervoltage lockout
- SG1844 — 16 volts
- SG1845 — 8.4 volts
- Low shoot-through current  $< 75\text{mA}$  over temperature

### HIGH RELIABILITY FEATURES

- SG1844/SG1845

- ◆ Available to MIL-STD-883
- ◆ SG level "S" processing available

### BLOCK DIAGRAM



\* -  $V_{CC}$  and  $V_C$  are internally connected for 8 pin packages.

\*\* - POWER GROUND and GROUND are internally connected for 8 pin packages.

# SG1844/SG1845 SERIES

## ABSOLUTE MAXIMUM RATINGS (Note 1 & 2)

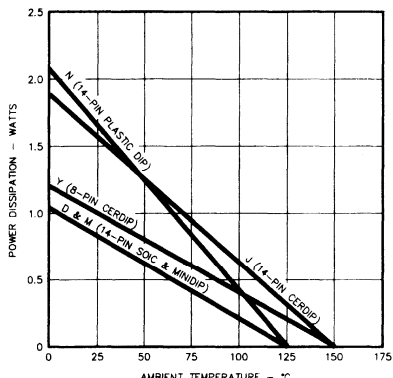
Supply Voltage ( $I_{CC} < 30mA$ )	Self-limiting	Error Amp Output Sink Current	10mA
Supply Voltage (Low Impedance Source)	30V	Operating Junction Temperature	
Output Current (peak)	$\pm 1A$	Hermetic (J, Y Packages)	175°C
Output Current (continuous)	350mA	Plastic (N, M, D Packages)	150°C
Output Energy (Capacitive Load)	5 $\mu$ J	Storage Temperature Range	-65°C to 150°C
Analog Inputs (Pin 2, Pin 3)	-0.3V to $V_{CC}$	Lead Temperature (Soldering, 10 Seconds)	300°C

Note 1. Values beyond which damage may occur.

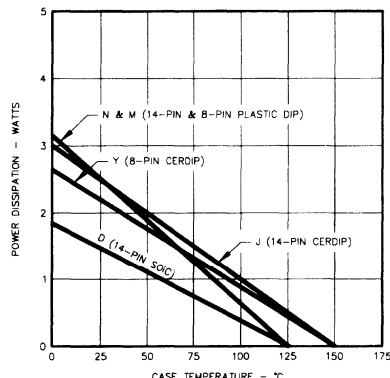
Note 2. All voltages are with respect to Pin 5. All currents are positive into the specified terminal.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Supply Voltage Range	30V	Oscillator Timing Resistor ( $R_T$ )	$520\Omega \leq R_T \leq 150k\Omega$
Output Current (peak)	$\pm 1A$	Oscillator Timing Capacitor ( $C_T$ )	$1000pF \leq C_T \leq 1\mu F$
Output Current (continuous)	200mA	Operating Ambient Temperature Range:	
Analog Inputs (Pin 2, Pin 3)	-0.3 to $V_{CC}-3$	SG1844/45	-55°C to 125°C
Error Amp Output Sink Current	5mA	SG2844/45	-25°C to 85°C
Oscillator Frequency Range	100Hz to 500KHz	SG3844/45	0°C to 70°C

Note 2. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise stated, these specifications apply for  $-55 \leq T_A \leq 125^\circ C$  for SG1844/45;  $-25 \leq T_A \leq 85^\circ C$  for SG2844/45;  $0 \leq T_A \leq 70^\circ C$  for SG3844/45;  $V_{CC} = 15V$  (Note 6);  $R_T = 10K$ ;  $C_T = 3.3nF$ )

Parameter	Test Conditions	SG1844/45			SG2844/45			SG3844/45			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Reference Section</b>											
Output Voltage	$T_J = 25^\circ C, I_O = 1mA$	4.95	5.00	5.05	4.95	5.00	5.05	4.90	5.00	5.10	V
Line Regulation	$12 \leq V_{IN} \leq 25V$		6	20		6	20		6	20	mV
Load Regulation	$1 \leq I_O \leq 20mA$		6	25		6	25		6	25	mV
Temp. Stability (Note 3)			0.2	0.4		.02	0.4		0.2	0.4	mV/ $^\circ C$
Total Output Variation (Note 3)	Line, Load, Temp.	4.90		5.10	4.90		5.10	4.82		5.18	V
Output Noise Voltage (Note 3)	$10Hz \leq f \leq 10kHz, T_J = 25^\circ C$		50			50			50		$\mu V$
Long Term Stability (Note 3)	$T_A = 125^\circ C, 1000 Hrs.$		5	25		5	25		5	25	mV
Output Short Circuit		-30	-100	-180	-30	-100	-180	-30	-100	-180	mA
<b>Oscillator Section</b>											
Initial Accuracy (Note 7)	$T_J = 25^\circ C$	47	52	57	47	52	57	47	52	57	kHz
Voltage Stability	$12V \leq V_{CC} \leq 25V$		.02	1		0.2	1		0.2	1	%
Temp. Stability (Note 3)	$T_{MIN} \leq T_A \leq T_{MAX}$		5			5			5		%
Amplitude	$V_{RT/CT}$ (peak to peak)		1.7			1.7			1.7		V
Discharge Current	$T_J = 25^\circ C$	7.8	8.3	9.1	7.8	8.3	9.1	7.8	8.3	9.1	mA
	$T_{MIN} < T_A < T_{MAX}$	6.8		9.3	7.4		9.3	7.5		9.3	mA

# SG1844/SG1845 SERIES

## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG1844/45			SG2844/45			SG3844/45			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Error Amp Section</b>											
Input Voltage	$V_{COMP} = 2.5V$	2.45	2.50	2.55	2.45	2.50	2.55	2.42	2.50	2.58	V
Input Bias Current			-0.3	-1		-0.3	1		-0.3	-2	$\mu A$
Open Loop Gain ( $A_{VOL}$ )	$2 \leq V_O \leq 4V$	65	90		65	90		65	90		dB
Unity Gain Bandwidth (Note 3)		0.7	1		0.7	1		0.7	1		MHz
PSRR	$12 \leq V_{CC} \leq 25V$	60	70		60	70		60	70		dB
Output Sink Current	$V_{VFB} = 2.7V, V_{COMP} = 1.1V$	2	6		2	6		2	6		mA
Output Source Current	$V_{VFB} = 2.3V, V_{COMP} = 5V$	-0.05	-0.8		-0.5	-0.8		-0.5	-0.8		mA
$V_{OUT}$ High	$V_{VFB} = 2.3V, R_L = 15K$ to gnd	5	6		5	6		5	6		V
$V_{OUT}$ Low	$V_{VFB} = 2.7V, R_L = 15K$ to $V_{REF}$	0.7	1.1		0.7	1.1		0.7	1.1		V
<b>Current Sense Section</b>											
Gain (Notes 4 & 5)		2.85	3	3.15	2.85	3	3.15	2.85	3	3.15	V/V
Maximum Input Signal (Note 4)	$V_{COMP} = 5V$	0.9	1	1.1	0.9	1	1.1	0.9	1	1.1	V
PSRR (Note 4)	$12V \leq V_{CC} \leq 25V$		70		70		70		70		dB
Input Bias Current			-2	-10		-2	-10		-2	-10	$\mu A$
Delay to Output (Note 3)			150	300		150	300		150	300	ns
<b>Output Section</b>											
Output Low Level	$I_{SINK} = 20mA$		0.1	0.4		0.1	0.4		0.1	0.4	V
	$I_{SINK} = 200mA$		1.5	2.2		1.5	2.2		1.5	2.2	V
Output High Level	$I_{SOURCE} = 20mA$	13	13.5		13	13.5		13	13.5		V
	$I_{SOURCE} = 200mA$	12	13.5		12	13.5		12	13.5		V
Rise Time (Note 3)	$T_J = 25^\circ C, C_L = 1nF$		50	150		50	150		50	150	ns
Fall Time (Note 3)	$T_J = 25^\circ C, C_L = 1nF$		50	150		50	150		50	150	ns
<b>Under-Voltage Lockout Section</b>											
Start Threshold (1844)		15	16	17	15	16	17	14.5	16	17.5	V
Min. Operating Voltage (1844)	After Turn On	9	10	11	9	10	11	8.5	10	11.5	V
Start Threshold (1845)		7.8	8.4	9.0	7.8	8.4	9.0	7.8	8.4	9.0	V
Min. Operating Voltage (1845)	After Turn On	7.0	7.6	8.2	7.0	7.6	8.2	7.0	7.6	8.2	V
<b>PWM Section</b>											
Max. Duty Cycle		46	48	50	46	48	50	47	48	50	%
Min. Duty Cycle				0			0			0	%
<b>Power Consumption Section</b>											
Start-Up Current			0.5	1		0.5	1		0.5	1	mA
Operating Supply Current	$V_{VFB} = V_{ISENSE} = 0V$		11	17		11	17		11	17	mA
$V_{CC}$ Zener Voltage	$I_{CC} = 25mA$		34			34			34		V

Notes: 3. These parameters, although guaranteed, are not 100% tested in production.

4. Parameter measured at trip point of latch with  $V_{VFB} = 0$ .

5. Gain defined as:  $A = \frac{\Delta V_{COMP}}{\Delta V_{ISENSE}}$ ;  $0 \leq V_{ISENSE} \leq 0.8V$ .

6. Adjust  $V_{CC}$  above the start threshold before setting at 15V.

7. Output frequency equals one half of oscillator frequency.

## CHARACTERISTIC CURVES

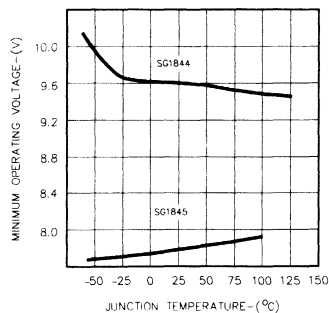


FIGURE 1. DROPOUT VOLTAGE VS. TEMPERATURE

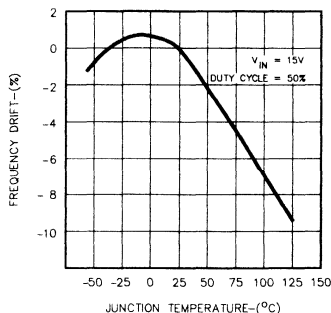


FIGURE 2. OSCILLATOR TEMPERATURE STABILITY

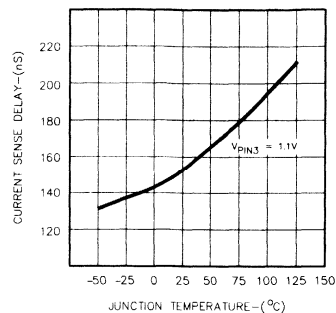


FIGURE 3. CURRENT SENSE TO OUTPUT DELAY VS. TEMP.

## CHARACTERISTIC CURVES (continued)

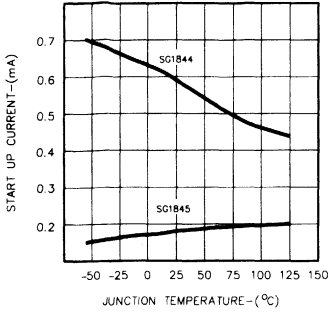


FIGURE 4. START-UP CURRENT VS. TEMPERATURE

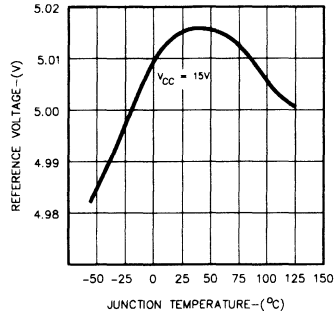


FIGURE 5. REFERENCE VOLTAGE VS. TEMPERATURE

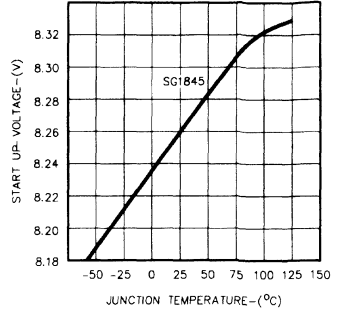


FIGURE 6. START-UP VOLTAGE THRESHOLD VS. TEMPERATURE

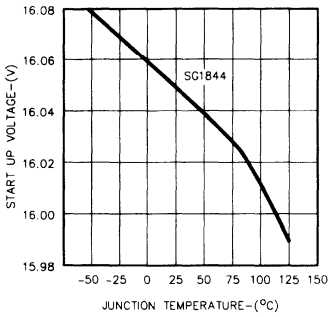


FIGURE 7. START-UP VOLTAGE THRESHOLD VS. TEMPERATURE

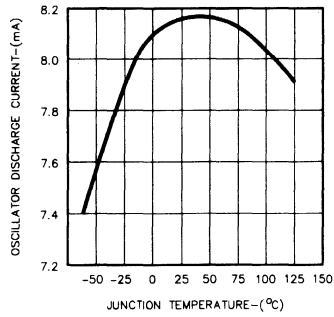


FIGURE 8. OSCILLATOR DISCHARGE CURRENT VS. TEMPERATURE

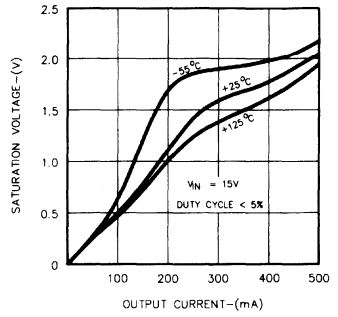


FIGURE 9. OUTPUT SATURATION VOLTAGE VS. OUTPUT CURRENT AND TEMPERATURE (SINK TRANSISTOR)

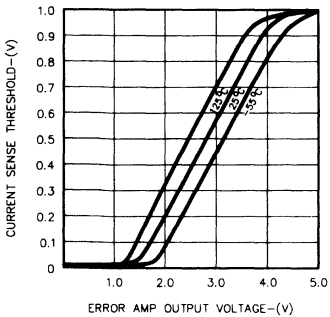


FIGURE 10. CURRENT SENSE THRESHOLD VS. ERROR AMPLIFIER OUTPUT

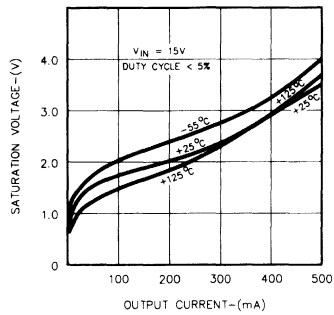


FIGURE 11. OUTPUT SATURATION VOLTAGE VS. OUTPUT CURRENT AND TEMPERATURE (SOURCE TRANSISTOR)



## APPLICATION INFORMATION

### OSCILLATOR

The oscillator of the SG1844/45 PWM's is programmed by the external timing components ( $R_T$ ,  $C_T$ ) as shown in Figure 13.

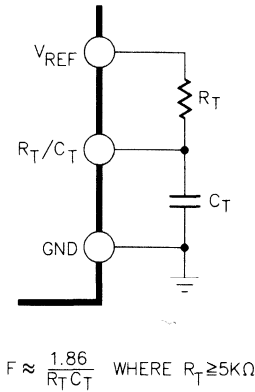


FIGURE 12 - OSCILLATOR TIMING CIRCUIT

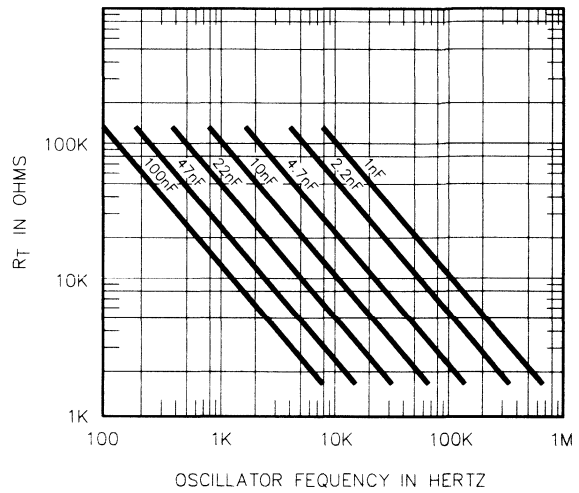


FIGURE 13 - OSCILLATOR FREQUENCY VS.  $R_T$  FOR VARIOUS  $C_T$

## APPLICATION CIRCUITS (Note 8)

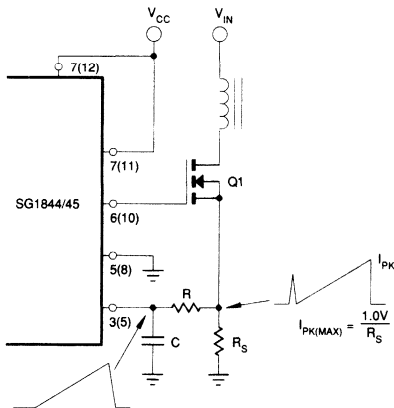


FIGURE 14—CURRENT SENSE SPIKE SUPPRESSION

The RC low pass filter will eliminate the leading edge current spike caused by parasitics of Power MOSFET.

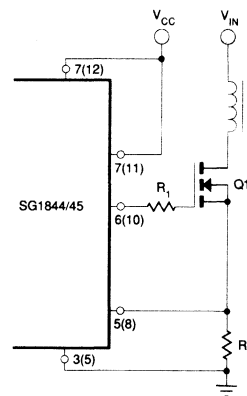


FIGURE 15—MOSFET PARASITIC OSCILLATIONS

A resistor ( $R_T$ ) in series with the MOSFET gate will reduce overshoot & ringing caused by the MOSFET input capacitance and any inductance in series with the gate drive. (Note: It is very important to have a low inductance ground path to insure correct operation of the I.C. This can be done by making the ground paths as short and as wide as possible.)

## APPLICATION CIRCUITS (continued)

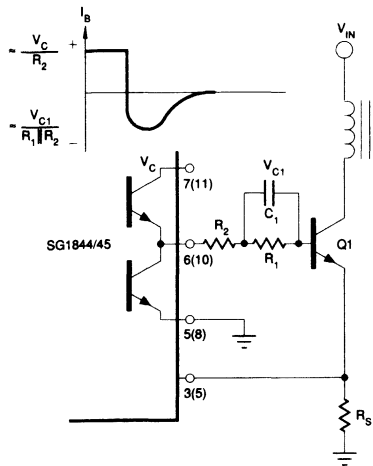


FIGURE 16 — BIPOLAR TRANSISTOR DRIVE

The 1844/45 output stage can provide negative base current to remove base charge of power transistor ( $Q_1$ ) for faster turn off. This is accomplished by adding a capacitor ( $C_1$ ) in parallel with a resistor ( $R_1$ ). The resistor ( $R_1$ ) is to limit the base current during turn on.

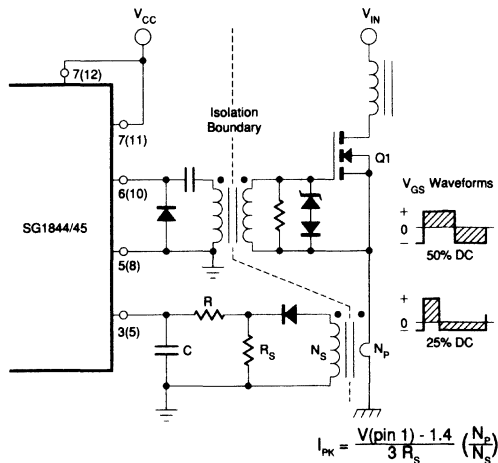


FIGURE 17 — ISOLATED MOSFET DRIVE

Current transformers can be used where isolation is required between PWM and Primary ground. A drive transformer is then necessary to interface the PWM output with the MOSFET.

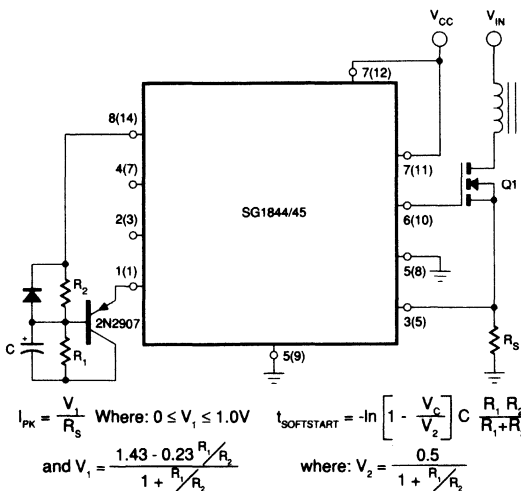


FIGURE 18 — ADJUSTABLE BUFFERED REDUCTION OF CLAMP LEVEL WITH SOFT-START

Soft start and adjustable peak current can be done with the external circuitry shown above.

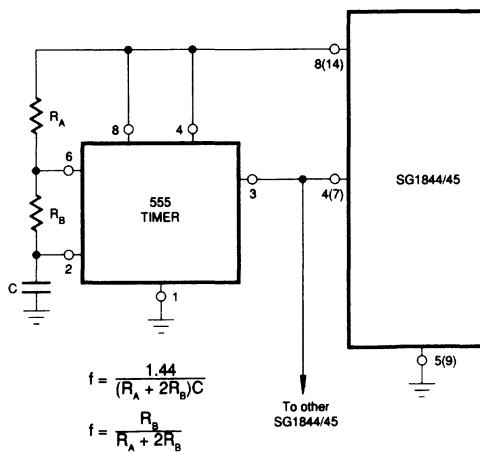


FIGURE 19 — EXTERNAL DUTY CYCLE CLAMP AND MULTI-UNIT SYNCHRONIZATION

Precision duty cycle limiting for a duty cycle of <50%, as well as synchronizing several 1844/45's is possible with the above circuitry.

# SG1844/SG1845 SERIES

## APPLICATION CIRCUITS (continued)

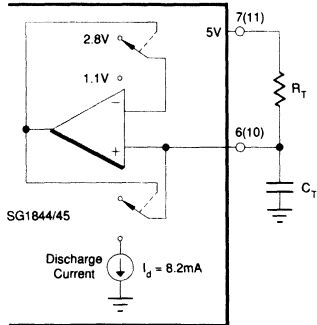


FIGURE 20—OSCILLATOR CONNECTION

The oscillator is programmed by the values selected for the timing components  $R_T$  and  $C_T$ . Refer to application information for calculation of the component values.

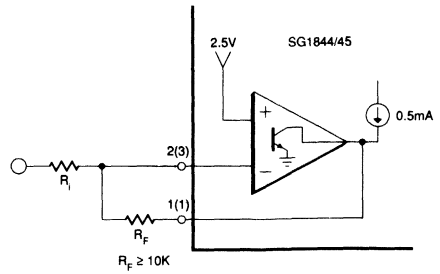


FIGURE 21—ERROR AMPLIFIER CONNECTION

Error amplifier is capable of sourcing and sinking current up to 0.5mA.

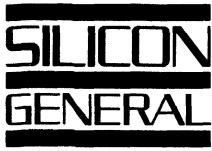
Note 8. Pin numbers referenced are for 8 pin packages and pin numbers in parenthesis are for 14 pin packages.

# SG1844/SG1845 SERIES

## CONNECTION DIAGRAM & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram	
14-PIN CERAMIC DIP J - PACKAGE	SG1844J/883B	-55°C to 125°C		
	SG1844J	-55°C to 125°C		
	SG2844J	-25°C to 85°C		
	SG3844J	0°C to 70°C		
	SG1845J/883B	-55°C to 125°C		
	SG1845J	-55°C to 125°C		
	SG2845J	-25°C to 85°C		
	SG3845J	0°C to 70°C		
	14-PIN PLASTIC DIP N - PACKAGE	SG2844N		-25°C to 85°C
		SG3844N		0°C to 70°C
SG2845N		-25°C to 85°C		
SG3845N		0°C to 70°C		
8-PIN CERAMIC DIP Y - PACKAGE	SG1844Y/883B	-55°C to 125°C		
	SG1844Y	-55°C to 125°C		
	SG2844Y	-25°C to 85°C		
	SG3844Y	0°C to 70°C		
	SG1845Y/883B	-55°C to 125°C		
	SG1845Y	-55°C to 125°C		
	SG2845Y	-25°C to 85°C		
	SG3845Y	0°C to 70°C		
	8-PIN PLASTIC DIP M - PACKAGE	SG2844M		-25°C to 85°C
		SG3844M		0°C to 70°C
SG2845M		-25°C to 85°C		
SG3845M		0°C to 70°C		
14-PIN PLASTIC S.O.I.C. D - PACKAGE	SG2844D	-25°C to 85°C		
	SG3844D	0°C to 70°C		
	SG2845D	-25°C to 85°C		
	SG3845D	0°C to 70°C		

- Note: 1. Contact factory for JAN and DESC product availability.  
 2. All parts are viewed from the top.  
 3. Product is also available in flat pack and leadless chip carrier. Consult factory for price and delivery.



LINEAR INTEGRATED CIRCUITS

# SG1846/SG2846/SG3846 SG1847/SG2847/SG3847

## CURRENT MODE PWM CONTROLLER

### DESCRIPTION

The SG1846/1847 family of control ICs provides all of the necessary features to implement fixed frequency, current mode control schemes while maintaining a minimum external parts count. The superior performance of this technique can be measured in improved line regulation, enhanced load response characteristics, and a simpler, easier-to-design control loop. Topological advantages include inherent pulse-by-pulse current limiting capability, automatic symmetry correction for push-pull converters, and the ability to parallel "power modules" while maintaining equal current sharing.

Protection circuitry includes built-in under-voltage lockout and programmable current limit in addition to soft start capability. A shutdown function is also available which can initiate either a complete shutdown with automatic restart or latch the supply off.

Other features include fully latched operation, double pulse suppression, deadtime adjust capability, and a  $\pm 1\%$  trimmed bandgap reference.

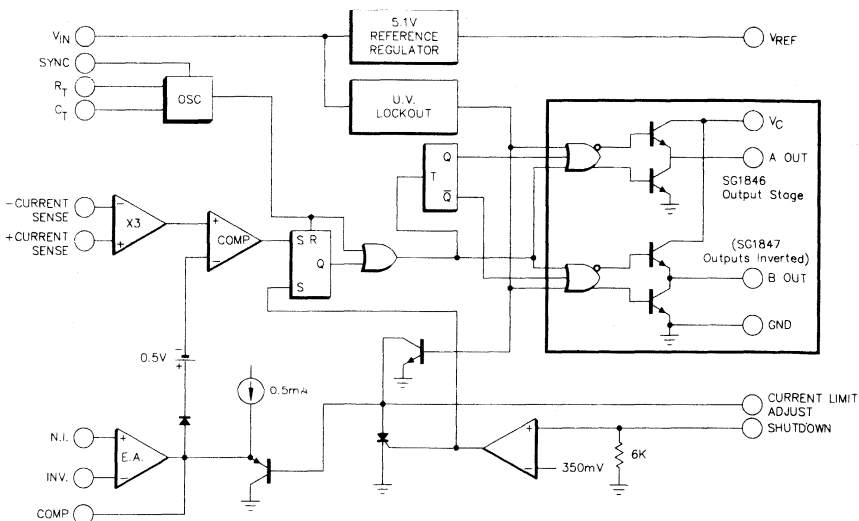
### FEATURES

- Automatic feed forward compensation
- Programmable pulse by pulse current limiting
- Automatic symmetry correction in push-pull configuration
- Enhanced load response characteristics
- Parallel operation capability for modular power systems
- Differential current sense amplifier with wide common mode range
- Double pulse suppression
- 200mA totem-pole outputs
- $\pm 1\%$  bandgap reference
- Under-voltage lockout
- Soft-start capability
- Shutdown capability
- 500KHz operation

### HIGH RELIABILITY FEATURES - SG1846/47

- ◆ Available to MIL-STD - 883
- ◆ Radiation data available
- ◆ SG level "S" processing available

### BLOCK DIAGRAM



# SG1846/SG1847 SERIES

## ABSOLUTE MAXIMUM RATINGS (Note 1 and 2)

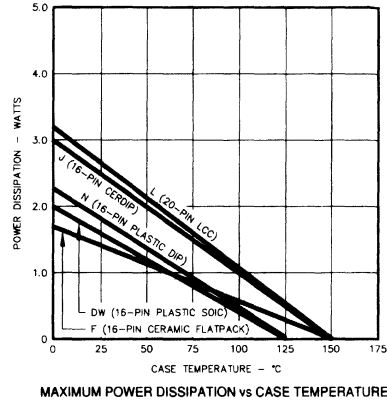
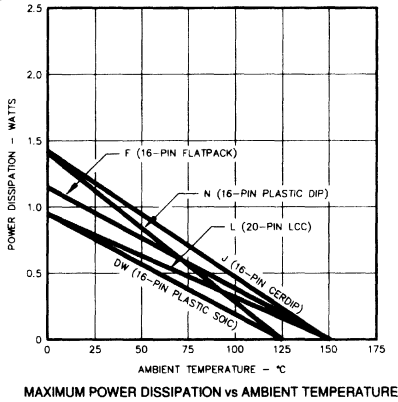
Supply Voltage (+V <sub>IN</sub> ) .....	40V
Collector Supply Voltage(V <sub>C</sub> ) .....	40V
Analog Inputs (Pins 3, 4, 5, 6, & 16) .....	-0.3V to +V <sub>IN</sub>
Logic Input .....	-0.3V to 5.5V
Source/Sink Load current (continuous) .....	200mA
Source/Sink Load Current (peak, 200ns) .....	500mA
Reference Load Current .....	30mA
Soft Start Sink Current .....	50mA

Sync Output Current .....	5mA
Error Amplifier Output Current .....	5mA
Oscillator Charging current (Pin 9) .....	5mA
Operating Junction Temperature	
Hermetic (J, L, F Packages) .....	175°C
Plastic (N, DW Package) .....	150°C
Storage Temperature Range .....	-65°C to 150°C
Lead Temperature (Soldering, 10 Seconds) .....	300°C

Note 1. Values beyond which damage may occur.  
 Note 2. Pin numbers refer to ceramic J package.

## RECOMMENDED OPERATING CONDITIONS (Note 3)

### THERMAL



### ELECTRICAL

Supply Voltage Range .....	8V to 40V
Collector Supply Voltage Range .....	4.5V to 40V
Source/Sink Output Current (continuous) .....	100mA
Source/Sink Output Current (peak 200ns) .....	200mA
Reference Load Current .....	0 to 10mA
Oscillator Frequency Range .....	1KHz to 500KHz

Oscillator Timing Resistor (R <sub>T</sub> ) .....	2KΩ to 100KΩ
Oscillator Timing Capacitor (C <sub>T</sub> ) .....	1000 pF to 0.1•F
Operating Ambient Temperature Range	
SG1846/1847 .....	-55°C to 125°C
SG2846/2847 .....	-25°C to 85°C
SG3846/3847 .....	0°C to 70°C

Note 3. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise specified, these limits apply for +V<sub>IN</sub> = 15 volts, and over operating ambient temperature.)

Parameter	Test Conditions	SG1846/47 SG2846/47			SG3846/47			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Reference Section</b>								
Output Voltage	T <sub>J</sub> = 25°C, I <sub>O</sub> = 1mA	5.05	5.10	5.15	5.00	5.10	5.20	V
Line Regulation	V <sub>IN</sub> = 8V to 40V		5	20		5	20	mV
Load Regulation	I <sub>L</sub> = 1mA to 10mA		3	15		3	15	mV
Temperature Stability (Note 4)			0.4			0.4		mV/°C
Total Output Variation (Note 4)	Line, Load and Temperature	5.00		5.20	4.95		5.25	V
Output Noise Voltage (Note 4)	10Hz ≤ f ≤ 10KHz, T <sub>J</sub> = 25°C		100			100		•V
Long Term Stability (Note 4)	T <sub>J</sub> = 125°C, 1000Hrs.		5			5		mV
Short Circuit Output Current	V <sub>REF</sub> = 0V	-10	-45		-10	-45		mA

# SG1846/SG1847 SERIES

## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG1846/47 SG2846/47			SG3846/47			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Oscillator Section (Note 9)</b>								
Initial Accuracy	$T_J = 25^\circ\text{C}$	39	43	47	39	43	47	KHz
Voltage Stability	$V_{IN} = 8\text{V to }40\text{V}$		1	2		1	2	%
Temperature Stability (Note 4)	Over Operating Range		1			1		%
Sync Output High Level		3.9	4.35		3.9	4.35		V
Sync Output Low Level			2.3	2.5		2.3	2.5	V
Sync Input High Level	Pin 8 = 0V	3.9			3.9			V
Sync Input Low Level	Pin 8 = 0V			2.5			2.5	V
Sync Input Current	Sync Voltage = 5.25V, Pin 8 = 0V		1.2	1.5		1.2	1.5	mA
<b>Error Amp Section</b>								
Input Offset Voltage			0.5	5		0.5	10	mV
Input Bias Current			-0.6	-1		-0.6	-2	$\mu\text{A}$
Input Offset Current			40	250		40	250	nA
Common Mode Range	$V_{IN} = 8\text{V to }40\text{V}$		0	$V_{IN}-2\text{V}$		0	$V_{IN}-2\text{V}$	V
Open Loop Voltage Gain	$V_{DO} = 1.2\text{V to }3\text{V}$ , $V_{CM} = 2\text{V}$	80	105		80	105		dB
Unity Gain Bandwidth (Note 4)	$T_J = 25^\circ\text{C}$	0.7	1.0		0.7	1.0		MHz
CMRR	$V_{CM} = 0\text{V to }38\text{V}$ , $V_{IN} = 40\text{V}$	75	100		75	100		dB
PSRR	$V_{IN} = 8\text{V to }40\text{V}$	80	105		80	105		dB
Output Sink Current	$V_{ID} = -15\text{mV to }-5\text{V}$ , $V_{PIN7} = 1.2\text{V}$	2	6		2	6		mA
Output Source Current	$V_{DO} = 15\text{mV to }5\text{V}$ , $V_{PIN7} = 2.5\text{V}$	-0.4	-0.5		-0.4	-0.5		mA
High Level Output Voltage	$R_L = 15\text{K}\Omega$ (Pin 7)	4.3	4.6		4.3	4.6		V
Low Level Output Voltage	$R_L = 15\text{K}\Omega$ (Pin 7)		0.7	1		0.7	1	V
<b>Current Sense Amplifier Section</b>								
Amplifier Gain (Notes 5 & 6)	$V_{PIN3} = 0\text{V}$ , Pin 1 Open	2.5	2.75	3.0	2.5	2.75	3.0	V
Maximum Differential (Note 6)	Pin 1 Open $R_L = 15\text{K}\Omega$ (Pin 7)							V
Input Signal ( $V_{PIN4} - V_{PIN3}$ ) (Note 5)		1.1	1.2		1.1	1.2		V
Input Offset Voltage (Note 5)	$V_{PIN1} = 0.5\text{V}$ , Pin 7 Open		5	25		5	25	mV
CMRR	$V_{CM} = 1\text{V to }12\text{V}$	60	83		60	83		dB
PSRR	$V_{IN} = 8\text{V to }40\text{V}$	60	84		60	84		dB
Input Bias Current (Note 5)	$V_{PIN1} = 0.5\text{V}$ , Pin 7 Open		-2.5	-10		-2.5	-10	$\mu\text{A}$
Input Offset Current (Note 5)	$V_{PIN1} = 0.5\text{V}$ , Pin 7 Open		0.08	1		0.08	1	$\mu\text{A}$
Input Common Mode Range		0		$V_{IN}-3$	0		$V_{IN}-3$	V
Delay to Outputs (Note 4)	$T_J = 25^\circ\text{C}$		200	500		200	500	ns
<b>Current Limit Adjust Section</b>								
Current Limit Offset Voltage (Note 5)	$V_{PIN3} = 0$ , $V_{PIN4} = 0\text{V}$ , Pin 7 Open	0.45	0.5	0.55	0.45	0.5	0.55	V
Input Bias Current	$V_{PIN5} = V_{REF}$ , $V_{PIN6} = 0\text{V}$		-10	-30		-10	-30	$\mu\text{A}$
<b>Shutdown Terminal Section</b>								
Threshold Voltage		250	350	400	250	350	400	mV
Input Voltage Range		0		$V_{IN}$	0		$V_{IN}$	V
Minimum Latching Current								mA
( $I_{PIN1}$ ) (Note 7)		3.0	1.5		3.0	1.5		mA
Maximum Non-Latching Current								mA
( $I_{PIN1}$ ) (Note 8)			1.5	0.8		1.5	0.8	mA
Delay to Outputs (Note 4)	$T_J = 25^\circ\text{C}$		300	600		300	600	ns
<b>Output Section</b>								
Collector Emitter Voltage		40			40			V
Collector Leakage Current	$V_C = 40\text{V}$			200			200	$\mu\text{A}$
Output Low Level	$I_{SINK} = 20\text{mA}$		0.1	0.4		0.1	0.4	V
	$I_{SINK} = 100\text{mA}$		0.4	2.1		0.4	2.1	V
Output High Level	$I_{SOURCE} = 20\text{mA}$	13	13.5		13	13.5		V
	$I_{SOURCE} = 100\text{mA}$	12	13.5		12	13.5		V
Rise Time (Note 4)	$C_L = 1\text{nF}$ , $T_J = 25^\circ\text{C}$		50	300		50	300	ns
Fall Time (Note 4)	$C_L = 1\text{nF}$ , $T_J = 25^\circ\text{C}$		50	300		50	300	ns

# SG1846/SG1847 SERIES

## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG1846/47 SG2846/47			SG3846/47			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Under-Voltage Lockout Section</b>								
Start-Up Threshold			7.7	8.0		7.7	8.0	V
Threshold Hysteresis			0.75			0.75		V
<b>Total Standby Current</b>								
Supply Current			17	21		17	21	mA

Note 4. These parameters although guaranteed over the recommended operating conditions, are not tested in production.

Note 5. Parameter measured at trip point of latch with  $V_{PIN5} = V_{REF}$ ,  $V_{PIN6} = 0V$ .

Note 6. Amplifier gain defined as:  $G = \frac{\Delta V_{PIN7}}{\Delta V_{PIN4}}$ ;  $V_{PIN4} = 0V$  to  $1.0V$

Note 7. Current into Pin 1 guaranteed to latch circuit in shutdown state.

Note 8. Current into Pin 1 guaranteed not to latch circuit in shutdown state.

Note 9.  $R_T = 10K\Omega$ ,  $C_T = 4.7nF$

## APPLICATION INFORMATION

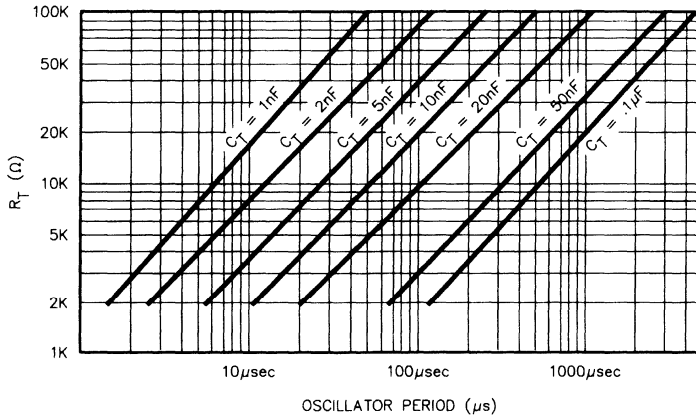
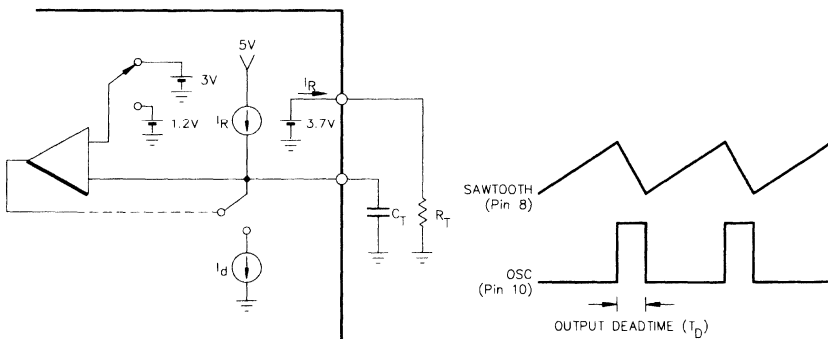


FIGURE 1 - OSCILLATOR FREQUENCY CURVES



Oscillator frequency is approximated by the formula:  $f_T \approx \frac{2.2}{R_T C_T}$

FIGURE 2 - OSCILLATOR CIRCUIT



# SG1846/SG1847 SERIES

## APPLICATION INFORMATION (continued)

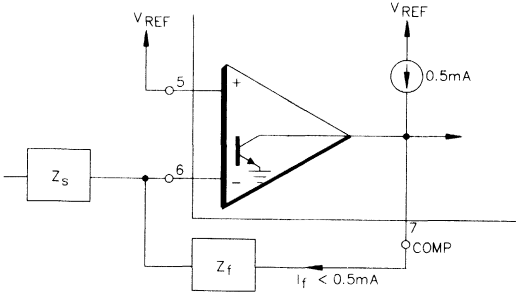


FIGURE 3 - ERROR AMP OUTPUT CONFIGURATION  
(Error amplifier can source up to 0.5mA)

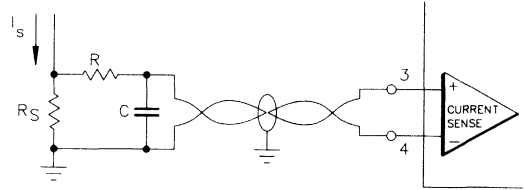


FIGURE 4 - CURRENT SENSE AMP CONNECTIONS

A small RC filter may be required in some applications to reduce switch transients. Differential input allows remote, noise free switching.

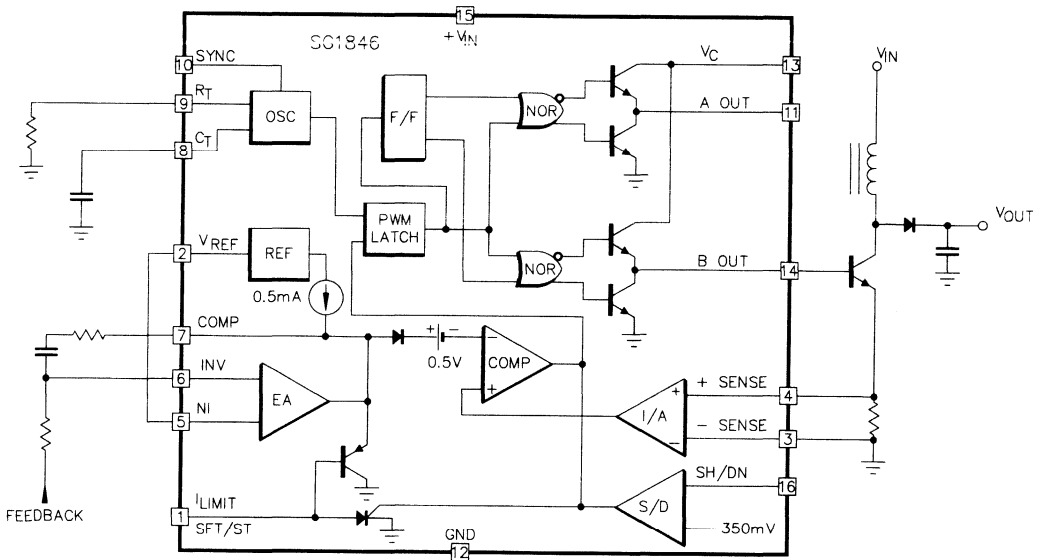


FIGURE 5 - SINGLE ENDED BOOST CONFIGURATION

APPLICATIONS INFORMATION (continued)

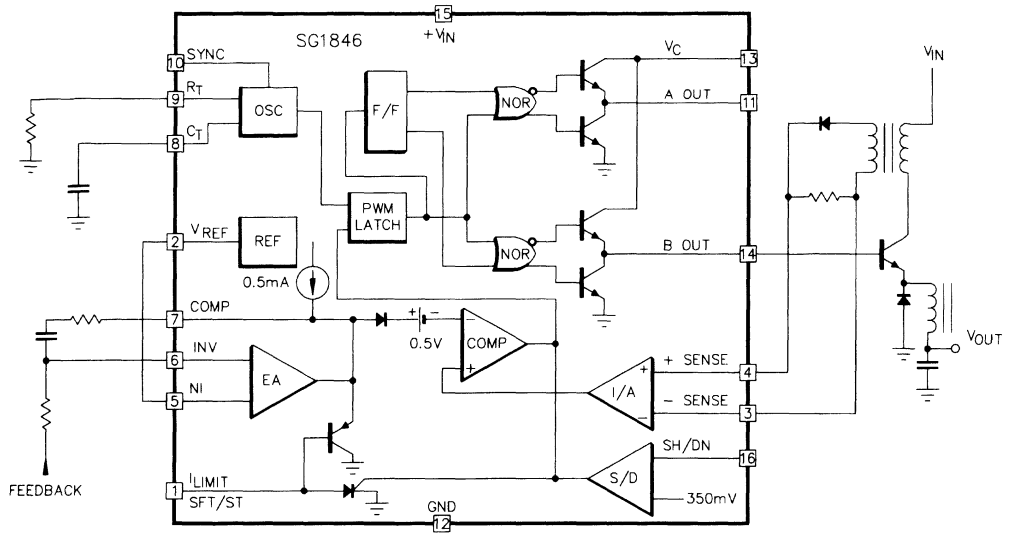


FIGURE 6 - BUCK CONVERTER WITH CURRENT SENSE WINDING

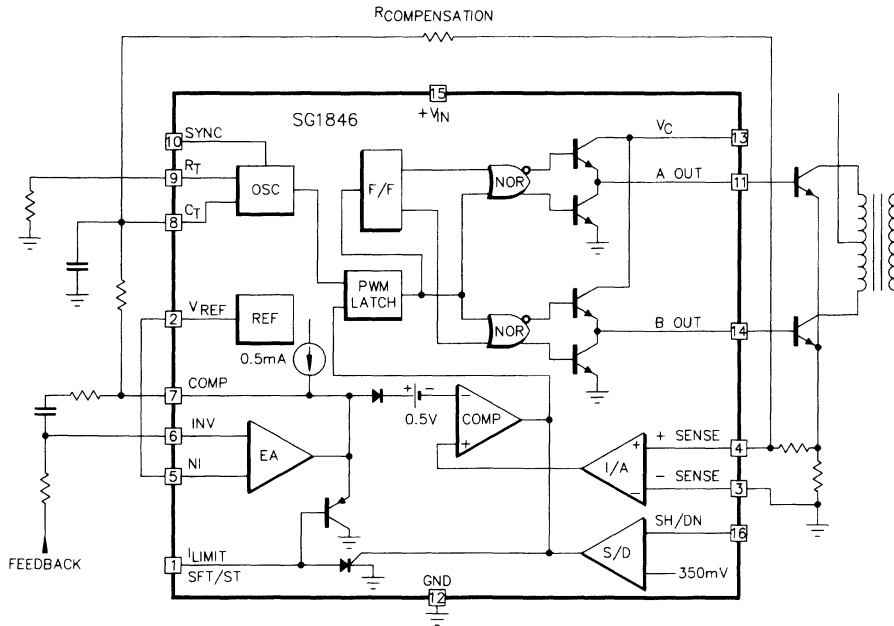


FIGURE 7 - PUSH/PULL CONVERTER WITH SLOPE COMPENSATION

## APPLICATIONS INFORMATION (continued)

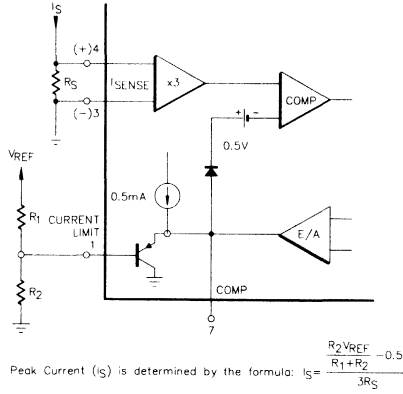


FIGURE 8 - PULSE BY PULSE CURRENT LIMITING

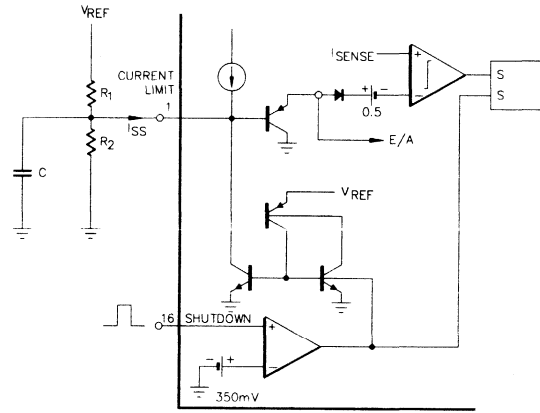


FIGURE 9 - SOFT START AND SHUTDOWN/RESTART FUNCTIONS

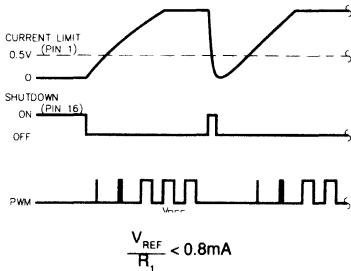


FIGURE 10 - SHUTDOWN WITH AUTO-RESTART

If  $\frac{V_{REF}}{R_1} < 0.8\text{mA}$  the shutdown latch will commutate when  $I_{SS} < 0.8\text{mA}$  and a restart cycle will be initiated.

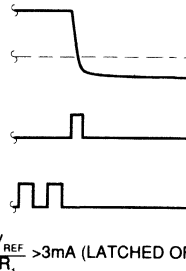


FIGURE 11 - SHUTDOWN WITHOUT AUTO-RESTART (LATCHED)

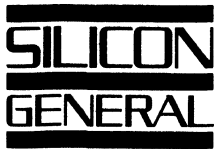
If  $\frac{V_{REF}}{R_1} > 3\text{mA}$  the device will latch off until power is recycled.

# SG1846/SG1847 SERIES

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
16-PIN CERAMIC DIP J - PACKAGE	SG1846J/883B	-55°C to 125°C	
	SG1846J	-55°C to 125°C	
	SG2846J	-25°C to 85°C	
	SG3846J	0°C to 70°C	
	SG1847J/883B	-55°C to 125°C	
	SG1847J	-55°C to 125°C	
	SG2847J	-25°C to 85°C	
16-PIN PLASTIC DIP N - PACKAGE	SG2846N	-25°C to 85°C	
	SG3846N	0°C to 70°C	
	SG2847N	-25°C to 85°C	
	SG3847N	0°C to 70°C	
16-PIN WIDEBODY PLASTIC S.O.I.C DW - PACKAGE	SG2846DW	-25°C to 85°C	
	SG3846DW	0°C to 70°C	
	SG2847DW	-25°C to 85°C	
	SG3847DW	0°C to 70°C	
16-PIN CERAMIC FLAT PACK F - PACKAGE (Note 3)	SG1846F/883B	-55°C to 125°C	
	SG1846F	-55°C to 125°C	
	SG1847F/883B	-55°C to 125°C	
	SG1847F	-55°C to 125°C	
20-PIN CERAMIC LEADLESS CHIP CARRIER L - PACKAGE (Note 3)	SG1846L/883B	-55°C to 125°C	
	SG1846L	-55°C to 125°C	
	SG1847L/883B	-55°C to 125°C	
	SG1847L	-55°C to 125°C	

- Notes:
1. Contact factory for JAN and DESC part availability.
  2. All parts are viewed from the top.
  3. Consult factory for product availability.



# SG7800A/SG7800AC SG7800/SG7800C

LINEAR INTEGRATED CIRCUITS

## POSITIVE FIXED VOLTAGE REGULATOR

### DESCRIPTION

The SG7800A/SG7800 series of positive regulators offer self contained, fixed-voltage capability with up to 1.5A of load current and input voltage up to 50V (SG7800A series only).

These units feature a unique on-chip trimming system to set the output voltages to within  $\pm 1.5\%$  of nominal on the SG7800A series,  $\pm 2.0\%$  on the SG7800 series, and  $\pm 4.0\%$  on the SG7800C/340 series. The SG7800A versions also offer much improved line and load regulation characteristics. Utilizing an improved Bandgap reference design, problems have been eliminated that are normally associated with the Zener diode references, such as drift in output voltage and large changes in the line and load regulation.

All protective features of thermal shutdown, current limiting, and safe-area control have been designed into these units and since these regulators require only a small output capacitor for satisfactory performance, ease of application is assured.

Although designed as fixed-voltage regulators, the output voltage can be increased through the use of a simple voltage divider. The low quiescent drain current of the device insures good regulation when this method is used.

Product is available in hermetically sealed TO-220 (both isolated and non-isolated), TO-3, TO39 and TO-66 power packages as well as the plastic TO-220 package.

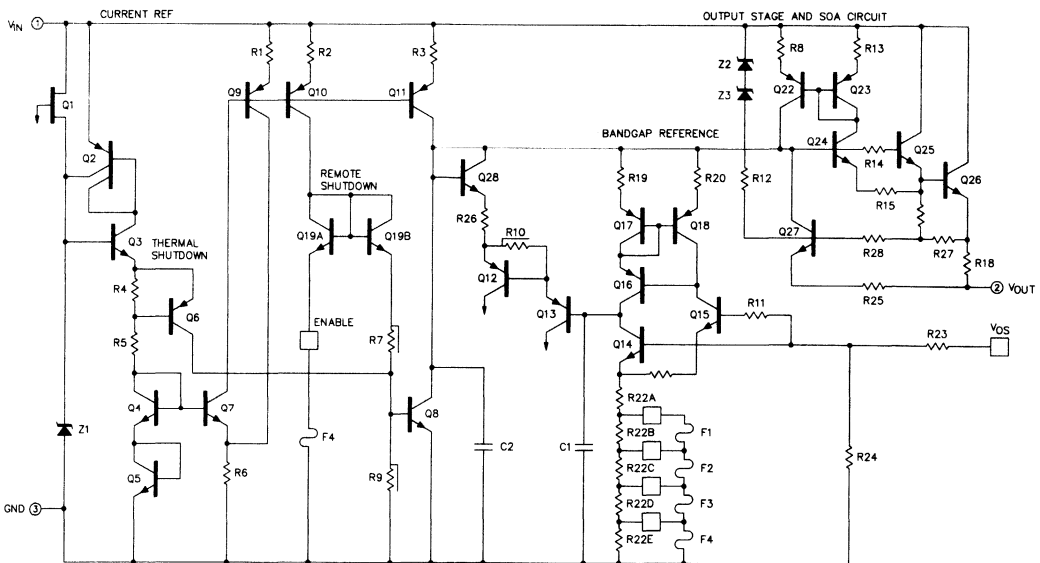
### FEATURES

- Output voltage set internally to  $\pm 1.5\%$  on SG7800A
- Input voltage range to 50V max. on SG7800A
- Two volt input-output differential
- Excellent line and load regulation
- Foldback current limiting
- Thermal overload protection
- Voltages available - 5V, 6V, 8V, 12V, 15V, 18V, 20V, 24V

### HIGH RELIABILITY FEATURES -SG7800A/7800

- ◆ Available to MIL-STD - 883
- ◆ Scheduled for MIL-M-38510 QPL listing
- ◆ Radiation data available
- ◆ SG level "S" processing available

### SCHEMATIC DIAGRAM



**ABSOLUTE MAXIMUM RATINGS** (Note 1)

Device Output Voltage	Input Voltage	Input Voltage (transient) (Note 3)	Input Voltage Differential (Output shorted to ground)
5V	35V	50V	35V
6V	35V	50V	35V
8V	35V	50V	35V
12V	35V	50V	35V
15V	35V	50V	35V
18V	35V	50V	35V
20V	35V	50V	35V
24V	40V	50V	35V

**Operating Junction Temperature**

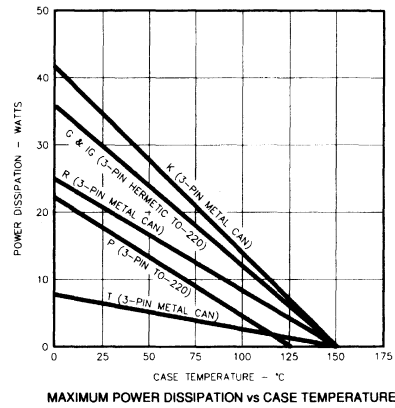
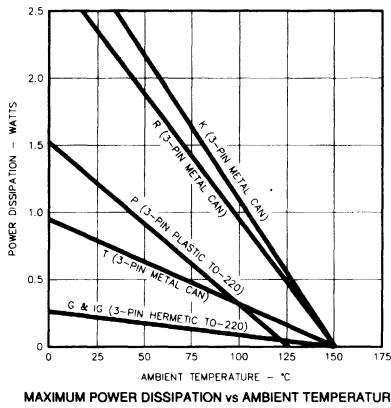
Hermetic (K, R, T, G, IG - Packages) ..... 175°C  
 Plastic (P - Package) ..... 150°C

Storage Temperature Range ..... -65°C to 150°C  
 Lead Temperature (Soldering, 10 Seconds) ..... 300°C

Note 1. Values beyond which damage may occur.

**RECOMMENDED OPERATING CONDITIONS** (Note 2)

**THERMAL**



**ELECTRICAL**

**Operating Junction Temperature Range:**

SG140A/140 ..... -55°C to 150°C  
 SG240A/240 ..... 0°C to 150°C  
 SG340A/340 ..... 0°C to 125°C

Note 2. Range over which the device is functional.

**CHARACTERISTIC CURVES**

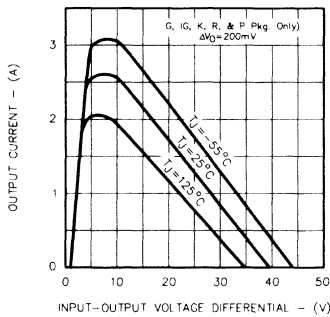
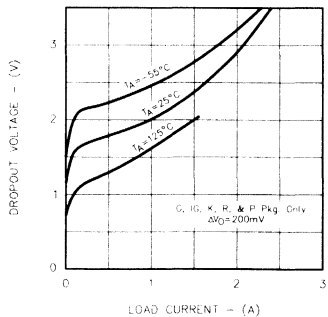


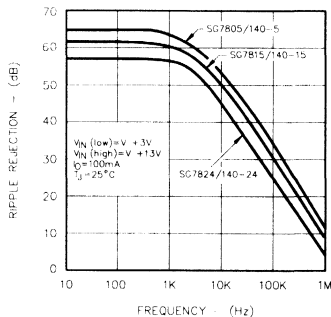
FIGURE 1. PEAK OUTPUT CURRENT VS. INPUT - OUTPUT DIFFERENTIAL

Note 3. Operation at high input voltages is dependent upon load current. When load current is less than 5mA, output will rise out of regulation as input-output differential increases beyond 30V. Note also from Figure 1, that maximum load current is reduced at high voltages. The 50V input rating of the SG140A series refers to ability to withstand high line or transient conditions without damage. Since the regulator's maximum current capability is reduced, the output may fall out of regulation at high input voltages under nominal loading.

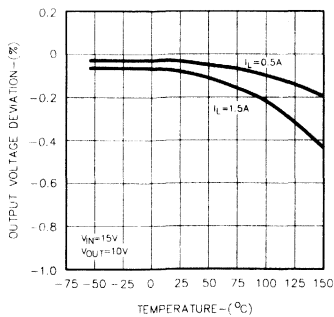
**CHARACTERISTIC CURVES (continued)**



**FIGURE 2.**  
MINIMUM INPUT - OUTPUT VOLTAGE  
VS. LOAD CURRENT

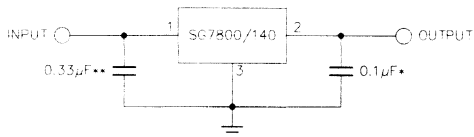


**FIGURE 3.**  
RIPPLE REJECTION VS. FREQUENCY



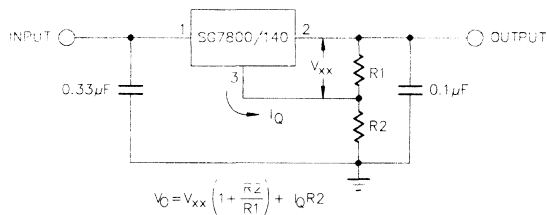
**FIGURE 4.**  
TEMPERATURE COEFFICIENT OF OUTPUT VOLTAGE

**APPLICATIONS**

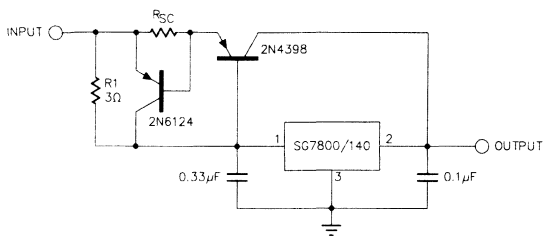


- INCREASING VALUE OF OUTPUT CAPACITOR IMPROVES SYSTEM TRANSIENT RESPONSE
- REQUIRED ONLY IF REGULATOR IS LOCATED AN APPRECIABLE DISTANCE FROM POWER SUPPLY FILTER

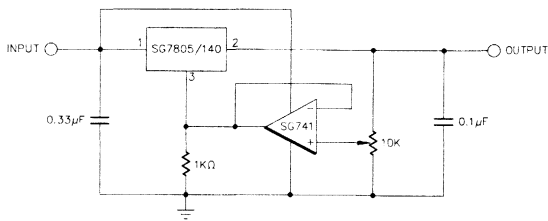
**FIGURE 5 - FIXED OUTPUT REGULATOR**



**FIGURE 6 - CIRCUIT FOR INCREASING OUTPUT VOLTAGE**



**FIGURE 7 - HIGH OUTPUT CURRENT, SHORT CIRCUIT PROTECTED**



**FIGURE 8 - ADJUSTABLE OUTPUT REGULATOR, 7V TO 30V**

# SG7800A/SG7800 SERIES

# 5.0V POSITIVE REGULATOR

## ELECTRICAL SPECIFICATIONS (Note 1)

(Unless otherwise specified, these specifications apply for  $V_{IN} = 10V$ ,  $I_O = 500mA$  for the P, K, R, G and IG -Power Packages- and  $I_O = 100mA$  for the T package,  $C_{IN} = 0.33\mu F$ ,  $C_{OUT} = 0.1\mu F$ , and over the recommended operating temperatures.)

### SG7805A/SG7805

Parameter	Test Conditions	SG7805A			SG7805			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_J = 25^\circ C$	4.92	5.00	5.08	4.80	5.00	5.20	V
Line Regulation (Note 1)	$V_{IN} = 7.5V$ to $20V$ , $T_J = 25^\circ C$		5	25		5	50	mV
	$V_{IN} = 8V$ to $12V$ , $T_J = 25^\circ C$		2	12		2	25	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$		15	50		15	50	mV
	$I_O = 250mA$ to $750mA$ , $T_J = 25^\circ C$		5	25		5	25	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		5	25		20	100	mV
Total Output Voltage Tolerance	$V_{IN} = 8V$ to $20V$							
	Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 20W$	4.85	5.00	5.15	4.65	5.00	5.35	V
	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	4.85	5.00	5.15	4.65	5.00	5.35	V
Quiescent Current	Over Temperature Range			7			7	mA
	$T_J = 25^\circ C$		4	6		4	6	mA
Quiescent Current Change	With Line: $V_{IN} = 8V$ to $25V$			0.8			0.8	mA
	With Load: $I_O = 5mA$ to $1.0A$ (Power Pkgs.)			0.5			0.5	mA
	$I_O = 5mA$ to $500mA$ (T)			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$							
	Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		2	2.5		2	2.5	V
Peak Output Current	Power Pkgs: $V_{IN} = 10V$ , $T_J = 25^\circ C$	1.5	2.0	3.3	1.5	2.0	3.3	A
	T - Pkg: $V_{IN} = 10V$ , $T_J = 25^\circ C$	0.5	1.0	2.0	0.5	1.0	2.0	A
Short Circuit Current	Power Pkgs: $V_{IN} = 35V$ , $T_J = 25^\circ C$			1.2			1.2	A
	T - Pkg: $V_{IN} = 35V$ , $T_J = 25^\circ C$			0.7			0.7	A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	68			68			dB
Output Noise Voltage (rms)	$f = 10Hz$ to $100KHz$ (Note 2)			40			40	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		20			20		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

### SG7805AC/SG7805C

Parameter	Test Conditions	SG7805AC			SG7805C			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_J = 25^\circ C$	4.92	5.00	5.08	4.80	5.00	5.20	V
Line Regulation (Note 1)	$V_{IN} = 7.5V$ to $20V$ , $T_J = 25^\circ C$		5	50		5	100	mV
	$V_{IN} = 8V$ to $12V$ , $T_J = 25^\circ C$		2	25		4	50	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$			50			100	mV
	$I_O = 250mA$ to $750mA$ , $T_J = 25^\circ C$		5	25		10	50	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$			25			100	mV
Total Output Voltage Tolerance	$V_{IN} = 8V$ to $20V$							
	Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 20W$	4.85	5.00	5.15	4.75	5.00	5.25	V
	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	4.85	5.00	5.15	4.75	5.00	5.25	V
Quiescent Current	Over Temperature Range			7			8.5	mA
	$T_J = 25^\circ C$		4	6		4	8	mA
Quiescent Current Change	With Line: $V_{IN} = 8V$ to $25V$			1.0			1.3	mA
	With Load: $I_O = 5mA$ to $1.0A$ (Power Pkgs.)			0.5			0.5	mA
	$I_O = 5mA$ to $500mA$ (T)			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$							
	Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		2	2.5		2	2.5	V
Peak Output Current	Power Pkgs: $T_J = 25^\circ C$	1.5	2.0	3.3	1.5	2.0	3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.5	1.0	2.0	0.5	1.0	2.0	A
Short Circuit Current	Power Pkgs: $V_{IN} = 35V$ , $T_J = 25^\circ C$			1.2			1.2	A
	T - Pkg: $V_{IN} = 35V$ , $T_J = 25^\circ C$			0.7			0.7	A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	68			62			dB
Output Noise Voltage (rms)	$f = 10Hz$ to $100KHz$ (Note 2)			40			40	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		20			20		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

Note 1. All regulation tests are made at constant junction temperature with low duty cycle testing.

2. This test is guaranteed but is not tested in production.



# SG7800A/SG7800 SERIES

# 6.0V POSITIVE REGULATOR

## ELECTRICAL SPECIFICATIONS (Note 1)

(Unless otherwise specified, these specifications apply for  $V_{IN} = 11V$ ,  $I_O = 500mA$  for the P, K, R, G and IG -Power Packages- and  $I_O = 100mA$  for the T package,  $C_{IN} = 0.33\mu F$ ,  $C_{OUT} = 0.1\mu F$ , and over the recommended operating temperatures.)

### SG7806A/SG7806

Parameter	Test Conditions	SG7606A			SG7806			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Output Voltage</b>	$T_J = 25^\circ C$	5.9	6.0	6.1	5.75	6.00	6.25	V
Line Regulation (Note 1)	$V_{IN} = 8.5V$ to 25V, $T_J = 25^\circ C$		6	30		6	60	mV
	$V_{IN} = 9V$ to 13V, $T_J = 25^\circ C$		3	15		3	30	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to 1.5A, $T_J = 25^\circ C$		20	60		20	60	mV
	$I_O = 250mA$ to 750mA, $T_J = 25^\circ C$		6	30		6	30	mV
	T - Pkg: $I_O = 5mA$ to 500mA, $T_J = 25^\circ C$			30			30	mV
<b>Total Output Voltage Tolerance</b>	$V_{IN} = 9V$ to 21V Power Pkgs: $I_O = 5mA$ to 1.0A, $P \leq 20W$ T - Pkg: $I_O = 5mA$ to 500mA, $P \leq 2W$	5.82	6.00	6.18	5.65	6.00	6.35	V
<b>Quiescent Current</b>	Over Temperature Range $T_J = 25^\circ C$			7			7	mA
	$T_J = 25^\circ C$		4	6		4	6	mA
<b>Quiescent Current Change</b>	With Line: $V_{IN} = 8V$ to 25V With Load: $I_O = 5mA$ to 1.0A (Power Pkgs.) $I_O = 5mA$ to 500mA (T)			0.8			0.8	mA
				0.5			0.5	mA
<b>Dropout Voltage</b>	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$ Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		2	2.5		2	2.5	V
<b>Peak Output Current</b>	Power Pkgs: $T_J = 25^\circ C$ T - Pkg: $T_J = 25^\circ C$	1.5	2.0	3.3	1.5	2.0	3.3	A
		0.5	1.0	1.7	0.5	1.0	1.7	A
<b>Short Circuit Current</b>	Power Pkgs: $V_{IN} = 35V$ , $T_J = 25^\circ C$ T - Pkg: $V_{IN} = 35V$ , $T_J = 25^\circ C$			1.2			1.2	A
				0.7			0.7	A
<b>Ripple Rejection</b>	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	65			65			dB
Output Noise Voltage (rms)	$f = 10Hz$ to 100KHz (Note 2)			40			40	$\mu V/V$
<b>Long Term Stability</b>	1000hrs. at $T_J = 125^\circ C$		24			24		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

### SG7806AC/SG7806C

Parameter	Test Conditions	SG7806AC			SG7806C			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Output Voltage</b>	$T_J = 25^\circ C$	5.9	6.0	6.1	5.75	6.00	6.25	V
Line Regulation (Note 1)	$V_{IN} = 8.5V$ to 25V, $T_J = 25^\circ C$		6	60		12	120	mV
	$V_{IN} = 9V$ to 13V, $T_J = 25^\circ C$		3	30		6	60	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to 1.5A, $T_J = 25^\circ C$		15	60		25	120	mV
	$I_O = 250mA$ to 750mA, $T_J = 25^\circ C$		5	30		10	60	mV
	T - Pkg: $I_O = 5mA$ to 500mA, $T_J = 25^\circ C$			30			60	mV
<b>Total Output Voltage Tolerance</b>	$V_{IN} = 9V$ to 21V Power Pkgs: $I_O = 5mA$ to 1.0A, $P \leq 20W$ T - Pkg: $I_O = 5mA$ to 500mA, $P \leq 2W$	5.82	6.00	6.18	5.7	6.0	6.3	V
		5.82	6.00	6.18	5.7	6.0	6.3	V
<b>Quiescent Current</b>	Over Temperature Range $T_J = 25^\circ C$			7			8.5	mA
	$T_J = 25^\circ C$		4	6		4	8	mA
<b>Quiescent Current Change</b>	With Line: $V_{IN} = 8V$ to 25V With Load: $I_O = 5mA$ to 1.0A (Power Pkgs.) $I_O = 5mA$ to 500mA (T)			1.0			1.3	mA
				0.5			0.5	mA
				0.5			0.5	mA
<b>Dropout Voltage</b>	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$ Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		2	2.5		2	2.5	V
<b>Peak Output Current</b>	Power Pkgs: $T_J = 25^\circ C$ T - Pkg: $T_J = 25^\circ C$	1.5	2.0	3.3	1.5	2.0	3.3	A
		0.5	1.0	1.7	0.5	1.0	1.7	A
<b>Short Circuit Current</b>	Power Pkgs: $V_{IN} = 35V$ , $T_J = 25^\circ C$ T - Pkg: $V_{IN} = 35V$ , $T_J = 25^\circ C$			1.2			1.2	A
				0.7			0.7	A
<b>Ripple Rejection</b>	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	62			59			dB
Output Noise Voltage (rms)	$f = 10Hz$ to 100KHz (Note 2)			40			40	$\mu V/V$
<b>Long Term Stability</b>	1000hrs. at $T_J = 125^\circ C$		24			24		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

Note 1. All regulation tests are made at constant junction temperature with low duty cycle testing.

2. This test is guaranteed but is not tested in production.

# SG7800A/SG7800 SERIES

# 8.0V POSITIVE REGULATOR

## ELECTRICAL SPECIFICATIONS (Note 1)

(Unless otherwise specified, these specifications apply for  $V_{IN} = 14V$ ,  $I_O = 500mA$  for the P, K, R, G and IG -Power Packages- and  $I_O = 100mA$  for the T package,  $C_{IN} = 0.33\mu F$ ,  $C_{OUT} = 0.1\mu F$ , and over the recommended operating temperatures.)

### SG7808A/SG7808

Parameter	Test Conditions	SG7808A			SG7808			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_J = 25^\circ C$	7.88	8.00	8.12	7.7	8.00	8.3	V
Line Regulation (Note 1)	$V_{IN} = 10.5V$ to $25V$ , $T_J = 25^\circ C$		8	40		8	80	mV
	$V_{IN} = 16V$ to $22V$ , $T_J = 25^\circ C$		4	20		4	40	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$		24	70		24	80	mV
	$I_O = 250mA$ to $750mA$ , $T_J = 25^\circ C$		8	35		8	40	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		8	35		8	40	mV
Total Output Voltage Tolerance	$V_{IN} = 11.5V$ to $23V$							
	Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 20W$	7.76	8.00	8.24	7.6	8	8.4	V
	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	7.76	8.00	8.24	7.6	8	8.4	V
Quiescent Current	Over Temperature Range			7			7	mA
	$T_J = 25^\circ C$		4	6		4	6	mA
Quiescent Current Change	With Line: $V_{IN} = 11.5V$ to $25V$			0.8			0.8	mA
	With Load: $I_O = 5mA$ to $1.0A$ (Power Pkgs.)			0.5			0.5	mA
	$I_O = 5mA$ to $500mA$ (T)			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$							
	Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		2	2.5		2	2.5	V
Peak Output Current	Power Pkgs: $T_J = 25^\circ C$	1.5	2.0	3.3	1.5	2.0	3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.5	1.0	1.7	0.5	1.0	1.7	A
Short Circuit Current	Power Pkgs: $V_{IN} = 35V$ , $T_J = 25^\circ C$			1.2			1.2	A
	T - Pkg: $V_{IN} = 10V$ , $T_J = 25^\circ C$			0.7			0.7	A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	62			62			dB
Output Noise Voltage (rms)	$f = 10Hz$ to $100KHz$ (Note 2)							$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		32			32		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

### SG7808AC/SG7808C

Parameter	Test Conditions	SG7808AC			SG7808C			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_J = 25^\circ C$	7.88	8.00	8.12	7.7	8.0	8.3	V
Line Regulation (Note 1)	$V_{IN} = 10.5V$ to $25V$ , $T_J = 25^\circ C$		8	80		16	160	mV
	$V_{IN} = 11V$ to $17V$ , $T_J = 25^\circ C$		4	40		8	80	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$		24	80		40	160	mV
	$I_O = 250mA$ to $750mA$ , $T_J = 25^\circ C$		8	40		16	80	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		8	40		16	80	mV
Total Output Voltage Tolerance	$V_{IN} = 11.5V$ to $23V$							
	Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 20W$	7.76	8.00	8.24	7.6	8.0	8.4	V
	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	7.76	8.00	8.24	7.6	8.0	8.4	V
Quiescent Current	Over Temperature Range			7			8.5	mA
	$T_J = 25^\circ C$		4	6		4	8	mA
Quiescent Current Change	With Line: $V_{IN} = 11.5V$ to $25V$			1.0			1.0	mA
	With Load: $I_O = 5mA$ to $1.0A$ (Power Pkgs.)			0.5			0.5	mA
	$I_O = 5mA$ to $500mA$ (T)			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$							
	Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		2	2.5		2	2.5	V
Peak Output Current	Power Pkgs: $T_J = 25^\circ C$	1.5	2.0	3.3	1.5	2.0	3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.5	1.0	1.7	0.5	1.0	1.7	A
Short Circuit Current	Power Pkgs: $V_{IN} = 35V$ , $T_J = 25^\circ C$			1.2			1.2	A
	T - Pkg: $V_{IN} = 35V$ , $T_J = 25^\circ C$			0.7			0.7	A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	62			55			dB
Output Noise Voltage (rms)	$f = 10Hz$ to $100KHz$ (Note 2)			40			40	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		32			32		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

Note 1. All regulation tests are made at constant junction temperature with low duty cycle testing.

2. This test is guaranteed but is not tested in production.

# SG7800A/SG7800 SERIES

# 12V POSITIVE REGULATOR

## ELECTRICAL SPECIFICATIONS (Note 1)

(Unless otherwise specified, these specifications apply for  $V_{IN} = 19V$ ,  $I_O = 500mA$  for the P, K, R, G and IG -Power Packages- and  $I_O = 100mA$  for the T package,  $C_{IN} = 0.33\mu F$ ,  $C_{OUT} = 0.1\mu F$ , and over the recommended operating temperatures.)

### SG7812A/SG7812

Parameter	Test Conditions	SG7812A			SG7812			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_J = 25^\circ C$	11.8	12.0	12.2	11.5	12.0	12.5	V
Line Regulation (Note 1)	$V_{IN} = 14.5V$ to $30V$ , $T_J = 25^\circ C$		12	60		12	120	mV
	$V_{IN} = 16V$ to $22V$ , $T_J = 25^\circ C$		6	30		6	60	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$		28	80		28	120	mV
	$I_O = 250mA$ to $750mA$ , $T_J = 25^\circ C$		10	40		10	60	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		10	40		10	60	mV
Total Output Voltage Tolerance	$V_{IN} = 15.5V$ to $27V$							
	Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 20W$	11.7	12.0	12.3	11.4	12.0	12.6	V
	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	11.7	12.0	12.3	11.4	12.0	12.6	V
Quiescent Current	Over Temperature Range			7			7	mA
	$T_J = 25^\circ C$		4	6		4	6	mA
Quiescent Current Change	With Line: $V_{IN} = 15V$ to $30V$			0.8			0.8	mA
	With Load: $I_O = 5mA$ to $1.0A$ (Power Pkgs.)			0.5			0.5	mA
	$I_O = 5mA$ to $500mA$ (T)			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$							
	Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		2	2.5		2	2.5	V
Peak Output Current	Power Pkgs: $T_J = 25^\circ C$	1.5	2.0	3.3	1.5	2.0	3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.5	1.0	1.7	0.5	1.0	1.7	A
Short Circuit Current	Power Pkgs: $V_{IN} = 35V$ , $T_J = 25^\circ C$			1.2			1.2	A
	T - Pkg: $V_{IN} = 35V$ , $T_J = 25^\circ C$			0.7			0.7	A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	61			61			dB
Output Noise Voltage (rms)	$f = 10Hz$ to $100KHz$ (Note 2)			40			40	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		48			48		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

### SG7812AC/SG7812C

Parameter	Test Conditions	SG7812AC			SG7812C			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_J = 25^\circ C$	11.8	12.0	12.2	11.5	12.0	12.5	V
Line Regulation (Note 1)	$V_{IN} = 14.5V$ to $30V$ , $T_J = 25^\circ C$		12	120		240	240	mV
	$V_{IN} = 16V$ to $22V$ , $T_J = 25^\circ C$		6	60		12	120	mV
Load Regulation (Note1)	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$		28	120		80	240	mV
	$I_O = 250mA$ to $750mA$ , $T_J = 25^\circ C$		10	60		24	120	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		10	60		24	120	mV
Total Output Voltage Tolerance	$V_{IN} = 15.5V$ to $27V$							
	Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 20W$	11.7	12.0	12.3	11.4	12.0	12.6	V
	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	11.7	12.0	12.3	11.4	12.0	12.6	V
Quiescent Current	Over Temperature Range			7			8.5	mA
	$T_J = 25^\circ C$		4	6		4	8	mA
Quiescent Current Change	With Line: $V_{IN} = 15V$ to $30V$			1.0			1.0	mA
	With Load: $I_O = 5mA$ to $1.0A$ (Power Pkgs.)			0.5			0.5	mA
	$I_O = 5mA$ to $500mA$ (T)			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$							
	Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		2	2.5		2	2.5	V
Peak Output Current	Power Pkgs: $T_J = 25^\circ C$	1.5	2.0	3.3	1.5	2.0	3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.5	1.0	1.7	0.5	1.0	1.7	A
Short Circuit Current	Power Pkgs: $V_{IN} = 35V$ , $T_J = 25^\circ C$			1.2			1.2	A
	T - Pkg: $V_{IN} = 35V$ , $T_J = 25^\circ C$			0.7			0.7	A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	61			55			dB
Output Noise Voltage (rms)	$f = 10Hz$ to $100KHz$ (Note 2)			40			40	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		48			48		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

Note 1. All regulation tests are made at constant junction temperature with low duty cycle testing.  
 2. This test is guaranteed but is not tested in production.

**ELECTRICAL SPECIFICATIONS** (Note 1)

(Unless otherwise specified, these specifications apply for  $V_{IN} = 23V$ ,  $I_O = 500mA$  for the P, K, R, G and IG -Power Packages- and  $I_O = 100mA$  for the T package,  $C_{IN} = 0.33\mu F$ ,  $C_{OUT} = 0.1\mu F$ , and over the recommended operating temperatures.)

**SG7815A/SG7815**

Parameter	Test Conditions	SG7815A			SG7815			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_J = 25^\circ C$	14.8	15.0	15.2	14.4	15.0	15.6	V
Line Regulation (Note 1)	$V_{IN} = 17.5V$ to 30V, $T_J = 25^\circ C$		15	75		15	150	mV
	$V_{IN} = 20V$ to 26V, $T_J = 25^\circ C$		8	40		8	75	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to 1.5A, $T_J = 25^\circ C$		30	100		30	150	mV
	$I_O = 250mA$ to 750mA, $T_J = 25^\circ C$		12	50		12	75	mV
	T - Pkg: $I_O = 5mA$ to 500mA, $T_J = 25^\circ C$		12	50		12	75	mV
Total Output Voltage Tolerance	$V_{IN} = 18.5V$ to 30V Power Pkgs: $I_O = 5mA$ to 1.0A, $P \leq 20W$ T - Pkg: $I_O = 5mA$ to 500mA, $P \leq 2W$	14.6	15.0	15.4	14.3	15.0	15.7	V
Quiescent Current	Over Temperature Range $T_J = 25^\circ C$		4	6		4	6	mA
Quiescent Current Change	With Line: $V_{IN} = 18.5V$ to 30V With Load: $I_O = 5mA$ to 1.0A (Power Pkgs.) $I_O = 5mA$ to 500mA (T)			0.8			0.8	mA
				0.5			0.5	mA
				0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$ Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		2	2.5		2	2.5	V
Peak Output Current	Power Pkgs: $T_J = 25^\circ C$	1.5	2.2	3.3	1.5	2.2	3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.5	0.9	1.7	0.5	0.9	1.7	A
Short Circuit Current	Power Pkgs: $V_{IN} = 35V$ , $T_J = 25^\circ C$ T - Pkg: $V_{IN} = 35V$ , $T_J = 25^\circ C$			1.2			1.2	A
				0.7			0.7	A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	60			60			dB
Output Noise Voltage (rms)	$f = 10Hz$ to 100KHz (Note 2)			40			40	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		60			60		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

**SG7815AC/SG7815C**

Parameter	Test Conditions	SG7815AC			SG7815C			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_J = 25^\circ C$	14.8	15.0	15.2	14.4	15.0	15.6	V
Line Regulation (Note 1)	$V_{IN} = 17.5V$ to 30V, $T_J = 25^\circ C$		15	150		30	300	mV
	$V_{IN} = 20V$ to 26V, $T_J = 25^\circ C$		8	75		15	150	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to 1.5A, $T_J = 25^\circ C$		30	150		100	300	mV
	$I_O = 250mA$ to 750mA, $T_J = 25^\circ C$		12	75		30	150	mV
	T - Pkg: $I_O = 5mA$ to 500mA, $T_J = 25^\circ C$		12	75		30	150	mV
Total Output Voltage Tolerance	$V_{IN} = 13.5V$ to 30V Power Pkgs: $I_O = 5mA$ to 1.0A, $P \leq 20W$ T - Pkg: $I_O = 5mA$ to 500mA, $P \leq 2W$	14.6	15.0	15.4	14.3	15.0	15.7	V
Quiescent Current	Over Temperature Range $T_J = 25^\circ C$			7			8.5	mA
			4	6		4	8	mA
Quiescent Current Change	With Line: $V_{IN} = 18.5V$ to 30V With Load: $I_O = 5mA$ to 1.0A (Power Pkgs.) $I_O = 5mA$ to 500mA (T)			1.0			1.0	mA
				0.5			0.5	mA
				0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$ Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		2	2.5		2	2.5	V
Peak Output Current	Power Pkgs: $T_J = 25^\circ C$	1.5	2.2	3.3	1.5	2.2	3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.5	0.9	1.7	0.5	0.9	1.7	A
Short Circuit Current	Power Pkgs: $V_{IN} = 35V$ , $T_J = 25^\circ C$ T - Pkg: $V_{IN} = 35V$ , $T_J = 25^\circ C$			1.2			1.2	A
				0.7			0.7	A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	60			60			dB
Output Noise Voltage (rms)	$f = 10Hz$ to 100KHz (Note 2)			40			40	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		60			60		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

Note 1. All regulation tests are made at constant junction temperature with low duty cycle testing.  
2. This test is guaranteed but is not tested in production.

# SG7800A/SG7800 SERIES

# 18V POSITIVE REGULATOR

## ELECTRICAL SPECIFICATIONS (Note 1)

(Unless otherwise specified, these specifications apply for  $V_{IN} = 27V$ ,  $I_O = 500mA$  for the P, K, R, G and IG - Power Packages- and  $I_O = 100mA$  for the T package,  $C_{IN} = 0.33\mu F$ ,  $C_{OUT} = 0.1\mu F$ , and over the recommended operating temperatures.)

### SG7818A/SG7818

Parameter	Test Conditions	SG7818A			SG7818			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_J = 25^\circ C$	17.7	18.0	18.3	17.3	18.0	18.7	V
Line Regulation (Note 1)	$V_{IN} = 21V$ to $33V$ , $T_J = 25^\circ C$		20	90		20	180	mV
	$V_{IN} = 24V$ to $30V$ , $T_J = 25^\circ C$		10	45		10	90	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$		40	120		40	180	mV
	$I_O = 250mA$ to $750mA$ , $T_J = 25^\circ C$		15	60		15	90	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		15	60		15	90	mV
Total Output Voltage Tolerance	$V_{IN} = 22V$ to $33V$							
	Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 2W$	17.5	18.0	18.5	17.1	18.0	18.9	V
	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	17.5	18.0	18.5	17.1	18.0	18.9	V
Quiescent Current	Over Temperature Range			7			7	mA
	$T_J = 25^\circ C$		4	6		4	6	mA
Quiescent Current Change	With Line: $V_{IN} = 28V$ to $38V$			0.8			0.8	mA
	With Load: $I_O = 5mA$ to $1.0A$ (Power Pkgs.)			0.5			0.5	mA
	$I_O = 5mA$ to $500mA$ (T)			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$							
	Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		2	2.5		2	2.5	V
Peak Output Current	Power Pkgs: $T_J = 25^\circ C$	1.5	2.2	3.3	1.5	2.2	3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.5	0.9	1.7	0.5	0.9	1.7	A
Short Circuit Current	Power Pkgs: $V_{IN} = 35V$ , $T_J = 25^\circ C$			1.2			1.2	A
	T - Pkg: $V_{IN} = 35V$ , $T_J = 25^\circ C$			0.7			0.7	A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	59			59			dB
Output Noise Voltage (rms)	$f = 10Hz$ to $100KHz$ (Note 2)			40			40	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		72			72		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

### SG7818AC/SG7818C

Parameter	Test Conditions	SG7818AC			SG7818C			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_J = 25^\circ C$	17.7	18.0	18.3	17.3	18.0	18.7	V
Line Regulation (Note 1)	$V_{IN} = 21V$ to $33V$ , $T_J = 25^\circ C$		20	180		40	360	mV
	$V_{IN} = 24V$ to $30V$ , $T_J = 25^\circ C$		10	90		20	180	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$		40	180		120	360	mV
	$I_O = 250mA$ to $750mA$ , $T_J = 25^\circ C$		15	90		40	180	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		15	90		40	180	mV
Total Output Voltage Tolerance	$V_{IN} = 22V$ to $33V$							
	Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 2W$	17.5	18.0	18.5	17.1	18.0	18.9	V
	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	17.5	18.0	18.5	17.1	18.0	18.9	V
Quiescent Current	Over Temperature Range			7			8.5	mA
	$T_J = 25^\circ C$		4	6		4	8	mA
Quiescent Current Change	With Line: $V_{IN} = 28V$ to $38V$			1.0			1.0	mA
	With Load: $I_O = 5mA$ to $1.0A$ (Power Pkgs.)			0.5			0.5	mA
	$I_O = 5mA$ to $500mA$ (T)			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$							
	Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		2	2.5		2	2.5	V
Peak Output Current	Power Pkgs: $T_J = 25^\circ C$	1.5	2.2	3.3	1.5	2.2	3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.5	0.9	1.7	0.5	0.9	1.7	A
Short Circuit Current	Power Pkgs: $V_{IN} = 35V$ , $T_J = 25^\circ C$			1.2			1.2	A
	T - Pkg: $V_{IN} = 35V$ , $T_J = 25^\circ C$			0.7			0.7	A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	59			59			dB
Output Noise Voltage (rms)	$f = 10Hz$ to $100KHz$ (Note 2)			40			40	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		72			72		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

Note 1. All regulation tests are made at constant junction temperature with low duty cycle testing.

2. This test is guaranteed but is not tested in production.

**ELECTRICAL SPECIFICATIONS** (Note 1)

(Unless otherwise specified, these specifications apply for  $V_{IN} = 29V$ ,  $I_O = 500mA$  for the P, K, R, G and IG -Power Package- and  $I_O = 100mA$  for the T package,  $C_{IN} = 0.33\mu F$ ,  $C_{OUT} = 0.1\mu F$ , and over the recommended operating temperatures.)

**SG7820A/SG7820**

Parameter	Test Conditions	SG7820A			SG7820			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_J = 25^\circ C$	19.7	20.0	20.3	19.2	20.0	20.8	V
Line Regulation (Note 1)	$V_{IN} = 27V$ to $35V$ , $T_J = 25^\circ C$		22	100		22	200	mV
Load Regulation (Note 1)	$V_{IN} = 26V$ to $32V$ , $T_J = 25^\circ C$		12	50		12	100	mV
	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$		45	140		45	200	mV
	$I_O = 250mA$ to $750mA$ , $T_J = 25^\circ C$		20	70		20	100	mV
Total Output Voltage Tolerance	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		20	70		20	100	mV
	$V_{IN} = 24V$ to $35V$	19.4	20.0	20.6	19.0	20.0	21.0	V
Quiescent Current	Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 20W$	19.4	20.0	20.6	19.0	20.0	21.0	V
	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$			7			7	mA
Quiescent Current Change	Over Temperature Range		4	6		4	6	mA
	$T_J = 25^\circ C$			0.8			0.8	mA
Dropout Voltage	With Line: $V_{IN} = 24V$ to $35V$			0.5			0.5	mA
	With Load: $I_O = 5mA$ to $1.0A$ (Power Pkgs.)			0.5			0.5	mA
Peak Output Current	$I_O = 5mA$ to $500mA$ (T)			0.5			0.5	mA
	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$		2	2.5		2	2.5	V
Short Circuit Current	Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$	1.5	2.2	3.3	1.5	2.2	3.3	A
	Power Pkgs: $T_J = 25^\circ C$	0.5	0.9	1.7	0.5	0.9	1.7	A
Ripple Rejection	T - Pkg: $T_J = 25^\circ C$			1.2			1.2	A
	Power Pkgs: $V_{IN} = 35V$ , $T_J = 25^\circ C$			0.7			0.7	A
Output Noise Voltage (rms)	T - Pkg: $V_{IN} = 35V$ , $T_J = 25^\circ C$							A
Long Term Stability	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	58			58			dB
Thermal Shutdown	$f = 10Hz$ to $100KHz$ (Note 2)			40			40	$\mu V/V$
	1000hrs. at $T_J = 125^\circ C$		96			96		mV
	$I_O = 5mA$		175			175		$^\circ C$

**SG7820AC/SG7820C**

Parameter	Test Conditions	SG7820AC			SG7820C			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_J = 25^\circ C$	19.7	20.0	20.3	19.2	20.0	20.8	V
Line Regulation (Note 1)	$V_{IN} = 27V$ to $35V$ , $T_J = 25^\circ C$		22	200		44	400	mV
Load Regulation (Note 1)	$V_{IN} = 26V$ to $32V$ , $T_J = 25^\circ C$		12	100		24	200	mV
	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$		45	200		150	400	mV
	$I_O = 250mA$ to $750mA$ , $T_J = 25^\circ C$		20	100		50	200	mV
Total Output Voltage Tolerance	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		20	100		50	200	mV
	$V_{IN} = 24V$ to $35V$	19.4	20.0	20.6	19.0	20.0	21.0	V
Quiescent Current	Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 20W$	19.4	20.0	20.6	19.0	20.0	21.0	V
	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$			7			8.5	mA
Quiescent Current Change	Over Temperature Range		4	6		4	8	mA
	$T_J = 25^\circ C$			1.0			1.0	mA
Dropout Voltage	With Line: $V_{IN} = 24V$ to $35V$			0.5			0.5	mA
	With Load: $I_O = 5mA$ to $1.0A$ (Power Pkgs.)			0.5			0.5	mA
Peak Output Current	$I_O = 5mA$ to $500mA$ (T)			0.5			0.5	mA
	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$		2	2.5		2	2.5	V
Short Circuit Current	Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$	1.5	2.2	3.3	1.5	2.2	3.3	A
	Power Pkgs: $T_J = 25^\circ C$	0.5	0.9	1.7	0.5	0.9	1.7	A
Ripple Rejection	T - Pkg: $T_J = 25^\circ C$			1.2			1.2	A
	Power Pkgs: $V_{IN} = 35V$ , $T_J = 25^\circ C$			0.7			0.7	A
Output Noise Voltage (rms)	T - Pkg: $V_{IN} = 35V$ , $T_J = 25^\circ C$							A
Long Term Stability	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	58			58			dB
Thermal Shutdown	$f = 10Hz$ to $100KHz$ (Note 2)			40			40	$\mu V/V$
	1000hrs. at $T_J = 125^\circ C$		96			96		mV
	$I_O = 5mA$		175			175		$^\circ C$

Note 1. All regulation tests are made at constant junction temperature with low duty cycle testing.  
 2. This test is guaranteed but is not tested in production.

# SG7800A/SG7800 SERIES

# 24V POSITIVE REGULATOR

## ELECTRICAL SPECIFICATIONS (Note 1)

(Unless otherwise specified, these specifications apply for  $V_{IN} = 33V$ ,  $I_O = 500mA$  for the P, K, R, G and IG -Power Packages- and  $I_O = 100mA$  for the package,  $C_{IN} = 0.33\mu F$ ,  $C_{OUT} = 0.1\mu F$ , and over the recommended operating temperatures.)

### SG7824A/SG7824

Parameter	Test Conditions	SG7824A			SG7824			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_J = 25^\circ C$	23.6	24.0	24.4	23.0	24.0	25.0	V
Line Regulation (Note 1)	$V_{IN} = 27V$ to $38V$ , $T_J = 25^\circ C$		25	120		50	240	mV
	$V_{IN} = 30V$ to $36V$ , $T_J = 25^\circ C$		14	60		28	120	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$		50	160		180	240	mV
	$I_O = 250mA$ to $750mA$ , $T_J = 25^\circ C$		25	80		70	120	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		25	80		25	120	mV
Total Output Voltage Tolerance	$V_{IN} = 28V$ to $38V$ Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 20W$	23.3	24.0	24.7	22.8	24.0	25.2	V
Quiescent Current	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	23.3	24.0	24.7	22.8	24.0	25.2	V
	Over Temperature Range			7			7	mA
Quiescent Current Change	$T_J = 25^\circ C$		4	6		4	6	mA
	With Line: $V_{IN} = 28V$ to $38V$			0.8			0.8	mA
	With Load: $I_O = 5mA$ to $1.0A$ (Power Pkgs.) $I_O = 5mA$ to $500mA$ (T)			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$ Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		2	2.5		2	2.5	V
Peak Output Current	Power Pkgs: $T_J = 25^\circ C$	1.5	2.2	3.3	1.5	2.2	3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.5	0.9	1.7	0.5	0.9	1.7	A
Short Circuit Current	Power Pkgs: $V_{IN} = 35V$ , $T_J = 25^\circ C$			1.2			1.2	A
	T - Pkg: $V_{IN} = 35V$ , $T_J = 25^\circ C$			0.7			0.7	A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	56			56			dB
Output Noise Voltage (rms)	$f = 10Hz$ to $100KHz$ (Note 2)			40			40	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		96			96		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

### SG7824AC/SG7824C

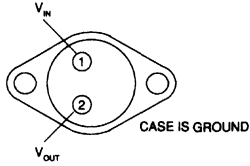
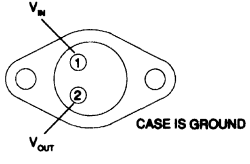
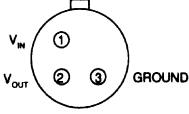
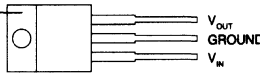
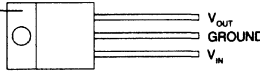
Parameter	Test Conditions	SG7824AC			SG7824C			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_J = 25^\circ C$	23.6	24.0	24.4	23.0	24.0	25.0	V
Line Regulation (Note 1)	$V_{IN} = 27V$ to $38V$ , $T_J = 25^\circ C$		25	240		50	480	mV
	$V_{IN} = 30V$ to $36V$ , $T_J = 25^\circ C$		14	120		28	240	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$		50	240		180	480	mV
	$I_O = 250mA$ to $750mA$ , $T_J = 25^\circ C$		25	120		70	240	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		25	120		25	240	mV
Total Output Voltage Tolerance	$V_{IN} = 28V$ to $38V$ Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 20W$	23.3	24.0	24.7	22.8	24.0	25.2	V
Quiescent Current	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	23.3	24.0	24.7	22.8	24.0	25.2	V
	Over Temperature Range			7			8.5	mA
Quiescent Current Change	$T_J = 25^\circ C$		4	6		4	8	mA
	With Line: $V_{IN} = 28V$ to $38V$			1.0			1.0	mA
	With Load: $I_O = 5mA$ to $1.0A$ (Power Pkgs.) $I_O = 5mA$ to $500mA$ (T)			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$ Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		2	2.5		2	2.5	V
Peak Output Current	Power Pkgs: $T_J = 25^\circ C$	1.5	2.2	3.3	1.5	2.2	3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.7	0.9	1.7	0.7	0.9	1.7	A
Short Circuit Current	Power Pkgs: $V_{IN} = 35V$ , $T_J = 25^\circ C$			1.2			1.2	A
	T - Pkg: $V_{IN} = 35V$ , $T_J = 25^\circ C$			0.7			0.7	A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	56			56			dB
Output Noise Voltage (rms)	$f = 10Hz$ to $100KHz$ (Note 2)			40			40	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		96			96		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

- Note 1. All regulation tests are made at constant junction temperature with low duty cycle testing.  
 2. This test is guaranteed but is not tested in production.

# SG7800A/SG7800 SERIES

# POSITIVE REGULATOR

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
3-TERMINAL TO-3 METAL CAN K-PACKAGE	SG78XXAK/883B SG78XXAK SG78XXACK SG78XXK/883B SG78XXK SG78XXK	-55°C to 125°C -55°C to 125°C 0°C to 70°C -55°C to 125°C -55°C to 125°C 0°C to 70°C	
3-TERMINAL TO-66 METAL CAN R-PACKAGE	SG78XXAR/883B SG78XXAR SG78XXACR SG78XXR/883B SG78XXR SG78XXCR	-55°C to 125°C -55°C to 125°C 0°C to 70°C -55°C to 125°C -55°C to 125°C 0°C to 70°C	
3-PIN TO-39 METAL CAN T-PACKAGE	SG78XXAT/883B SG78XXAT SG78XXACT SG78XXT/883B SG78XXT SG78XXCT	-55°C to 125°C -55°C to 125°C 0°C to 70°C -55°C to 125°C -55°C to 125°C 0°C to 70°C	
3-PIN PLASTIC TO-220 P-PACKAGE	SG78XXACP SG78XXCP	0°C to 70°C 0°C to 70°C	
3-PIN HERMETIC TO-220 G-PACKAGE (Non-Isolated)	SG78XXAG/883B SG78XXAG SG78XXG/883B SG78XXG	-55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C	
3-PIN HERMETIC TO-220 IG-PACKAGE (Isolated)	SG78XXAIG/883B SG78XXAIG SG78XXIG/883B SG78XXIG	-55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C	

- Note 1. Contact factory for JAN and DESC product availability.  
 Note 2. All parts are viewed from the top.  
 Note 3. "XX" to be replaced by output voltage of specific fixed regulator.  
 Note 4. Some products will be available in leadless chip carrier (LCC) and hermetic flat pack (F). Consult factory for price and availability





LINEAR INTEGRATED CIRCUITS

# SG7900A/SG7900AC SG7900/SG7900C

## NEGATIVE FIXED VOLTAGE REGULATOR

### DESCRIPTION

The SG7900A/SG7900 series of negative regulators offer self-contained, fixed-voltage capability with up to 1.5A of load current. With a variety of output voltages and four package options this regulator series is an optimum complement to the SG7800A/SG7800, SG140/SG340 line of three terminal regulators.

These units feature a unique band gap reference which allows the SG7900A series to be specified with an output voltage tolerance of  $\pm 1.5\%$ . The SG7900A versions also offer much improved line regulation characteristics.

All protective features of thermal shutdown, current limiting, and safe-area control have been designed into these units and since these regulators require only a single output capacitor (SG7900 series) or a capacitor and 5mA minimum load (SG120 series) for satisfactory performance, ease of application is assured.

Although designed as fixed-voltage regulators, the output voltage can be increased through the use of a simple voltage divider. The low quiescent drain current of the device insures good regulation when this method is used, especially for the SG120 series.

These devices are available in hermetically sealed TO-220 (both isolated and non-isolated), TO-3, TO-39 and TO-66 power packages as well as the plastic commercial power TO-220 package.

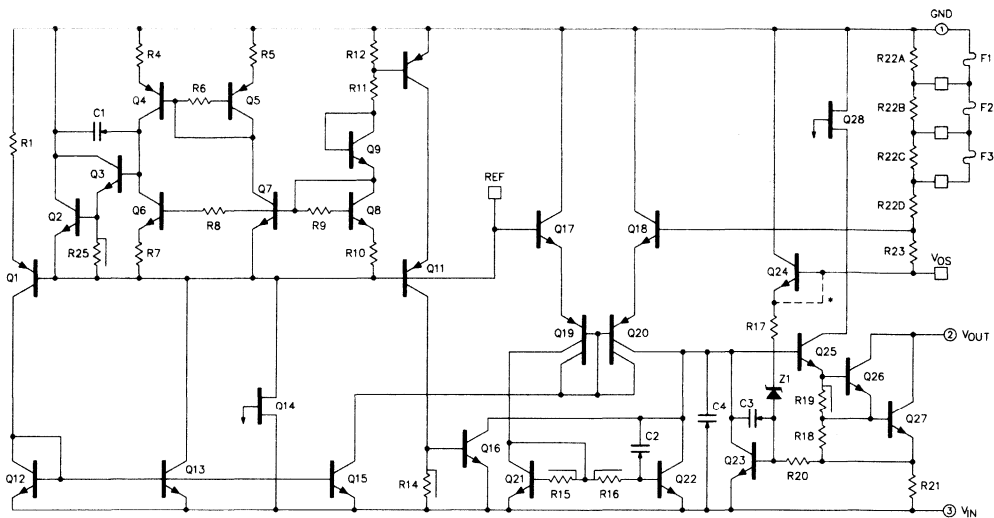
### FEATURES

- Output voltage set internally to  $\pm 1.5\%$  on SG7900A
- Output current to 1.5A
- Excellent line and load regulation
- Foldback current limiting
- Thermal overload protection
- Voltages available: -5V, -5.2V, -8V, -12V, -15V, -18V, -20V
- Contact factory for other voltage options

### HIGH RELIABILITY FEATURES -SG7900A/SG7900

- ◆ Available to MIL-STD - 883
- ◆ MIL-M-38510 / 11505BYA - JAN7905K
- ◆ Scheduled for MIL-M-38510 QPL listing
- ◆ Radiation data available
- ◆ SG level "S" processing available

### SCHEMATIC DIAGRAM



• WIRE EXISTS IF 120 TYPE DEVICE.  
WIRE DOES NOT EXIST IF 7900 TYPE DEVICE.  
SELECTABLE BY EMITTER OPTION.

### ABSOLUTE MAXIMUM RATINGS (Note 1)

Device Output Voltage	Input Voltage	Input Voltage Differential (Output shorted to ground)
-5V	-35V	35V
-5.2V	-35V	35V
-8V	-35V	35V
-12V	-35V	35V
-15V	-40V	35V
-18V	-40V	35V
-20V	-40V	35V

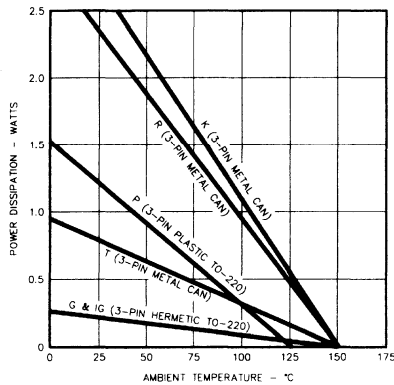
Operating Junction Temperature  
 Hermetic (K, R, T, G, IG - Packages) ..... 175°C  
 Plastic (P - Package) ..... 150°C

Storage Temperature Range ..... -65°C to 150°C  
 Lead Temperature (Soldering, 10 Seconds) ..... 300°C

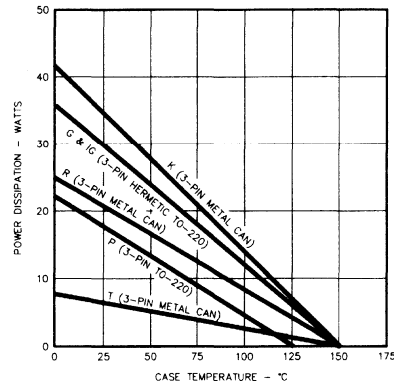
Note 1. Values beyond which damage may occur.

### RECOMMENDED OPERATING CONDITIONS (Note 2)

#### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

#### ELECTRICAL

Operating Junction Temperature Range:  
 SG7900A/7900 ..... -55°C to 150°C  
 SG7900AC/7900C ..... 0°C to 125°C

Note 2. Range over which the device is functional.

### CHARACTERISTIC CURVES

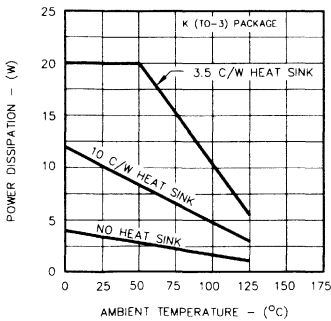


FIGURE 1. MAXIMUM AVERAGE POWER DISSIPATION

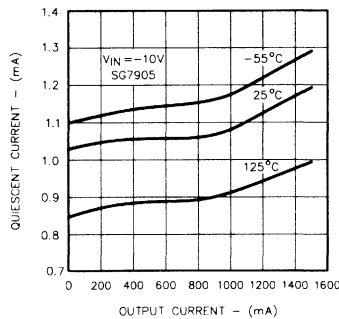


FIGURE 2. QUIESCENT CURRENT vs. LOAD

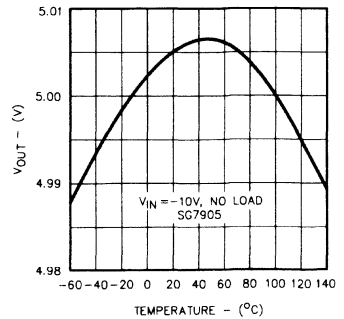


FIGURE 3. TEMPERATURE COEFFICIENT

CHARACTERISTIC CURVES (continued)

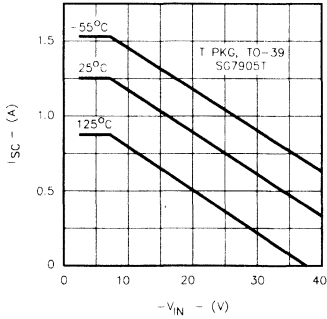


FIGURE 4. SHORTCIRCUIT CURRENT VS.  $V_{IN}$

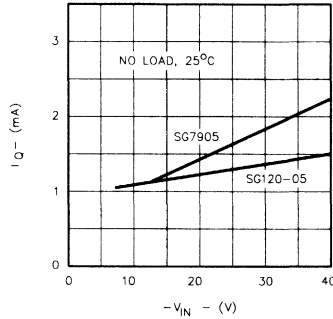


FIGURE 5. QUIESCENT CURRENT VS.  $V_{IN}$

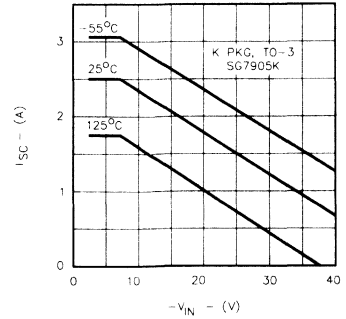


FIGURE 6. SHORT CIRCUIT CURRENT VS.  $V_{IN}$

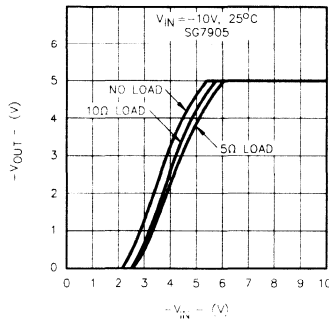


FIGURE 7. DROPOUT CHARACTERISTICS

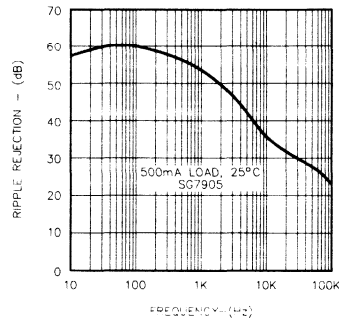


FIGURE 8. RIPPLE REJECTION VS. FREQUENCY

APPLICATIONS

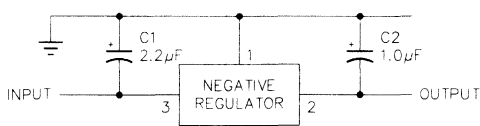


FIGURE 9 - FIXED OUTPUT REGULATOR

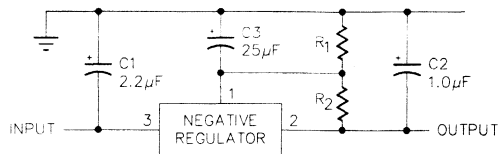


FIGURE 10 - CIRCUIT FOR INCREASING OUTPUT VOLTAGE

- NOTE: 1. C1 is required only if regulator is separated from rectifier filter.  
 2. Both C1 and C2 should be low E.S.R. types such as solid tantalum. If aluminum electrolytics are used, at least 10 times values shown should be selected.  
 3. If large output capacities are used, the regulators must be protected from momentary input shorts. A high current diode from output to input will suffice.

NOTE: C3 optional for improved transient response and ripple rejection.

$$V_{OUT} = V(\text{REGULATOR}) \frac{R_1 + R_2}{R_1} \quad R_2 = \frac{V(\text{REG})}{15\text{mA}}$$

**ELECTRICAL SPECIFICATIONS** (Note 1)

(Unless otherwise specified, these specifications apply for  $V_{IN} = -10V$ ,  $I_O = 500mA$  for the P, K, R, G and IG -Power Packages- and  $I_O = 100mA$  for the T package,  $C_{IN} = 2\mu F$ ,  $C_{OUT} = 1.0\mu F$ , and over the recommended operating temperatures.)

**SG7905A/SG7905**

Parameter	Test Conditions	SG7905A			SG7905			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Output Voltage</b>	$T_J = 25^\circ C$	-4.92	-5.00	-5.08	-4.8	-5.0	-5.2	V
Line Regulation (Note 1)	$V_{IN} = -7.5V$ to $-25V$ , $T_J = 25^\circ C$		5	25		3	50	mV
	$V_{IN} = -8V$ to $-12V$ , $T_J = 25^\circ C$		3	12		1	25	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$		15	75		15	100	mV
	$I_O = 250mA$ to $750mA$ , $T_J = 25^\circ C$		15	25		15	25	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		5	30		5	100	mV
<b>Total Output Voltage Tolerance</b>	$V_{IN} = -8V$ to $-20V$							
	Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 20W$	-4.85	-5.00	-5.15	-4.70	-5.00	-5.30	V
	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	-4.85	-5.00	-5.15	-4.70	-5.00	-5.30	V
Quiescent Current	Over Temperature Range			2.5			2.5	mA
	$T_J = 25^\circ C$			2.0			2.0	mA
Quiescent Current Change	with Line: $V_{IN} = -8V$ to $-25V$			1.3			1.3	mA
	with Load: $I_O = 5mA$ to $1.0A$ (Power Packages)			0.5			0.5	mA
	$I_O = 5mA$ to $500mA$ (T)			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$							
	Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		1.1	2.3		1.1	2.3	V
Peak Output Current	Power Pkgs: $T_J = 25^\circ C$	1.5		3.3	1.5		3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.5		1.4	0.5		1.4	A
Short Circuit Current	Power Pkgs: $V_{IN} = -35V$ , $T_J = 25^\circ C$			1.2			1.2	A
	T - Pkg: $V_{IN} = -35V$ , $T_J = 25^\circ C$			0.6			0.6	A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	54			54			dB
Output Noise Voltage (rms)	$f = 10Hz$ to $100KHz$ (Note 2)		25	80		25	80	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		20			20		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

**SG7905AC/SG7905C**

Parameter	Test Conditions	SG7905AC			SG7905C			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Output Voltage</b>	$T_J = 25^\circ C$	-4.92	-5.00	-5.08	-4.8	-5.0	-5.2	V
Line Regulation (Note 1)	$V_{IN} = -7.5V$ to $-25V$ , $T_J = 25^\circ C$		5	40		3	100	mV
	$V_{IN} = -8V$ to $-12V$ , $T_J = 25^\circ C$		3	25		1	50	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$		15	75		15	100	mV
	$I_O = 250mA$ to $750mA$ , $T_J = 25^\circ C$		5	50		5	50	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		5	50		15	100	mV
<b>Total Output Voltage Tolerance</b>	$V_{IN} = -8V$ to $-20V$							
	Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 20W$	-4.85	-5.00	-5.15	-4.75	-5.00	-5.25	V
	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	-4.85	-5.00	-5.15	-4.75	-5.00	-5.25	V
Quiescent Current	Over Temperature Range			2.5			3.0	mA
	$T_J = 25^\circ C$			2.0			2.0	mA
Quiescent Current Change	with Line: $V_{IN} = -8V$ to $-25V$			1.3			1.3	mA
	with Load: $I_O = 5mA$ to $1.0A$ (Power Packages)			0.5			0.5	mA
	$I_O = 5mA$ to $500mA$ (T)			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$							
	Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		1.1	2.3		1.1	2.3	V
Peak Output Current	Power Pkgs: $T_J = 25^\circ C$	1.5		3.3	1.5		3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.5		1.4	0.5		1.4	A
Short Circuit Current	Power Pkgs: $V_{IN} = -35V$ , $T_J = 25^\circ C$			1.2			1.2	A
	T - Pkg: $V_{IN} = -35V$ , $T_J = 25^\circ C$			0.6			0.6	A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	54			54			dB
Output Noise Voltage (rms)	$f = 10Hz$ to $100KHz$ (Note 2)		25	80		25	80	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		20			20		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

Note 1. All regulation tests are made at constant junction temperature with low duty cycle testing.  
 2. This test is guaranteed but is not tested in production.

# SG7900A/SG7900 SERIES

# -5.2V NEGATIVE REGULATOR

## ELECTRICAL SPECIFICATIONS (Note 1)

(Unless otherwise specified, these specifications apply for  $V_{IN} = -10V$ ,  $I_O = 500mA$  for the P, K, R, G and IG -Power Packages- and  $I_O = 100mA$  for the T package,  $C_{IN} = 2\mu F$ ,  $C_{OUT} = 1.0\mu F$ , and over the recommended operating temperatures.)

### SG7905.2A/SG7905.2

Parameter	Test Conditions	SG7905.2A			SG7905.2			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_J = 25^\circ C$	-5.12	-5.20	-5.28	-5.0	-5.2	-5.4	V
Line Regulation (Note 1)	$V_{IN} = -7.7V$ to $-25V$ , $T_J = 25^\circ C$		5	25		5	50	mV
	$V_{IN} = -8V$ to $-12V$ , $T_J = 25^\circ C$		3	15		3	25	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$		15	75		15	100	mV
	$I_O = 250mA$ to $750mA$ , $T_J = 25^\circ C$		5	25		5	30	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		5	30		5	100	mV
Total Output Voltage Tolerance	$V_{IN} = -8.2V$ to $-20V$							
	Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 20W$	-5.05	-5.20	-5.35	-4.90	-5.20	-5.50	V
	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	-5.05	-5.20	-5.35	-4.90	-5.20	-5.50	V
Quiescent Current	Over Temperature Range			2.5			2.5	mA
	$T_J = 25^\circ C$			2.0			2.0	mA
Quiescent Current Change	with Line: $V_{IN} = -8.2V$ to $-25V$			1.3			1.3	mA
	with Load: $I_O = 5mA$ to $1.0A$ (Power Packages)			0.5			0.5	mA
	$I_O = 5mA$ to $500mA$ (T)			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$							
	Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		1.1	2.3		1.1	2.3	V
Peak Output Current	Power Pkgs: $T_J = 25^\circ C$	1.5		3.3	1.5		3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.5		1.4	0.5		1.4	A
Short Circuit Current	Power Pkgs: $V_{IN} = -35V$ , $T_J = 25^\circ C$			1.2			1.2	A
	T - Pkg: $V_{IN} = -35V$ , $T_J = 25^\circ C$			0.6			0.6	A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	54			54			dB
Output Noise Voltage (rms)	$f = 10Hz$ to $100KHz$ (Note 2)		25	80		25	80	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		24			24		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

### SG7905.2AC/SG7905.2C

Parameter	Test Conditions	SG7905.2AC			SG7905.2C			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_J = 25^\circ C$	-5.12	-5.20	-5.28	-5.0	-5.2	-5.4	V
Line Regulation (Note 1)	$V_{IN} = -7.7V$ to $-25V$ , $T_J = 25^\circ C$		5	40		10	50	mV
	$V_{IN} = -8V$ to $-12V$ , $T_J = 25^\circ C$		3	25		5	25	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$		15	75		15	100	mV
	$I_O = 250mA$ to $750mA$ , $T_J = 25^\circ C$		5	50		5	50	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		5	50		5	100	mV
Total Output Voltage Tolerance	$V_{IN} = -8.2V$ to $-20V$							
	Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 20W$	-5.05	-5.20	-5.35	-4.95	-5.20	-5.45	V
	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	-5.05	-5.20	-5.35	-4.95	-5.20	-5.45	V
Quiescent Current	Over Temperature Range			2.5			3.1	mA
	$T_J = 25^\circ C$			2.0			2.0	mA
Quiescent Current Change	with Line: $V_{IN} = -8.2V$ to $-20V$			1.3			1.3	mA
	with Load: $I_O = 5mA$ to $1.0A$ (Power Packages)			0.5			0.5	mA
	$I_O = 5mA$ to $500mA$ (T)			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$							
	Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		1.1	2.3		1.1	2.3	V
Peak Output Current	Power Pkgs: $T_J = 25^\circ C$	1.5		3.3	1.5		3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.5		1.4	0.5		1.4	A
Short Circuit Current	Power Pkgs: $V_{IN} = -35V$ , $T_J = 25^\circ C$			1.2			1.2	A
	T - Pkg: $V_{IN} = -35V$ , $T_J = 25^\circ C$			0.6			0.6	A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	54			54			dB
Output Noise Voltage (rms)	$f = 10Hz$ to $100KHz$ (Note 2)		25	80		25	80	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		24			24		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

Note 1. All regulation tests are made at constant junction temperature with low duty cycle testing.

2. This test is guaranteed but is not tested in production.

**ELECTRICAL SPECIFICATIONS (Note 1)**

(Unless otherwise specified, these specifications apply for  $V_{IN} = -14V$ ,  $I_O = 500mA$  for the P, K, R, G and IG -Power Packages- and  $I_O = 100mA$  for the T package,  $C_{IN} = 2\mu F$ ,  $C_{OUT} = 1.0\mu F$ , and over the recommended operating temperatures.)

**SG7908A/SG7908**

Parameter	Test Conditions	SG7908A			SG7908			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_J = 25^\circ C$	-7.88	-8.00	-8.12	-7.7	-8.0	-8.3	V
Line Regulation (Note 1)	$V_{IN} = -10.5V$ to $-25V$ , $T_J = 25^\circ C$		6	40	6	80	80	mV
	$V_{IN} = -11V$ to $-17V$ , $T_J = 25^\circ C$		2	20	2	40	40	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$		12	80	12	100	100	mV
	$I_O = 250mA$ to $750mA$ , $T_J = 25^\circ C$		4	30	4	40	40	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		10	30	10	160	160	mV
Total Output Voltage Tolerance	$V_{IN} = -11.5V$ to $-23V$ Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 20W$ T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	-7.76	-8.00	-8.24	-7.6	-8.0	-8.4	V
Quiescent Current	Over Temperature Range			2.5			2.5	mA
	$T_J = 25^\circ C$			2.0			2.0	mA
Quiescent Current Change	with Line: $V_{IN} = -11.5V$ to $-25V$			1.0			1.0	mA
	with Load: $I_O = 5mA$ to $1.0A$ (Power Packages)			0.5			0.5	mA
	$I_O = 5mA$ to $500mA$ (T)			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$ Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		1.1	2.3		1.1	2.3	V
Peak Output Current	Power Pkgs: $T_J = 25^\circ C$	1.5		3.3	1.5		3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.5		1.4	0.5		1.4	A
Short Circuit Current	Power Pkgs: $V_{IN} = -35V$ , $T_J = 25^\circ C$			1.2			1.2	A
	T - Pkg: $V_{IN} = -35V$ , $T_J = 25^\circ C$			0.6			0.6	A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	54			54			dB
Output Noise Voltage (rms)	$f = 10Hz$ to $100KHz$ (Note 2)		25	80		25	80	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		32			32		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

**SG7908AC/SG7908C**

Parameter	Test Conditions	SG7908AC			SG7908C			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_J = 25^\circ C$	-7.88	-8.00	-8.12	-7.7	-8.0	-8.3	V
Line Regulation (Note 1)	$V_{IN} = -10.5V$ to $-25V$ , $T_J = 25^\circ C$		6	40	6	160	160	mV
	$V_{IN} = -11V$ to $-17V$ , $T_J = 25^\circ C$		4	25	2	80	80	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$		12	100	12	160	160	mV
	$I_O = 250mA$ to $750mA$ , $T_J = 25^\circ C$		10	50	4	80	80	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		10	40	10	160	160	mV
Total Output Voltage Tolerance	$V_{IN} = -11.5V$ to $-23V$ Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 20W$ T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	-7.76	-8.00	-8.24	-7.6	-8.0	-8.4	V
Quiescent Current	Over Temperature Range			2.5			3.0	mA
	$T_J = 25^\circ C$			2.0			2.0	mA
Quiescent Current Change	with Line: $V_{IN} = -11.5V$ to $-25V$			1.0			1.0	mA
	with Load: $I_O = 5mA$ to $1.0A$ (Power Packages)			0.5			0.5	mA
	$I_O = 5mA$ to $500mA$ (T)			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$ Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		1.1	2.3		1.1	2.3	V
Peak Output Current	Power Pkgs: $T_J = 25^\circ C$	1.5		3.3	1.5		3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.5		1.4	0.5		1.4	A
Short Circuit Current	Power Pkgs: $V_{IN} = -35V$ , $T_J = 25^\circ C$			1.2			1.2	A
	T - Pkg: $V_{IN} = -35V$ , $T_J = 25^\circ C$			0.6			0.6	A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	54			54			dB
Output Noise Voltage (rms)	$f = 10Hz$ to $100KHz$ (Note 2)		25	80		25	80	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		32			32		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

Note 1. All regulation tests are made at constant junction temperature with low duty cycle testing.  
2. This test is guaranteed but is not tested in production.

# SG7900A/SG7900 SERIES

# -12V NEGATIVE REGULATOR

## ELECTRICAL SPECIFICATIONS (Note 1)

(Unless otherwise specified, these specifications apply for  $V_{IN} = -19V$ ,  $I_O = 500mA$  for the P, K, R, G and IG -Power Packages- and  $I_O = 100mA$  for the T package,  $C_{IN} = 2\mu F$ ,  $C_{OUT} = 1.0\mu F$ , and over the recommended operating temperatures.)

### SG7912A/SG7912

Parameter	Test Conditions	SG7912A			SG7912			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_J = 25^\circ C$	-11.8	-12.0	-12.2	-11.5	-12.0	-12.5	V
Line Regulation (Note 1)	$V_{IN} = -14.5V$ to $-30V$ , $T_J = 25^\circ C$		4	60		10	120	mV
	$V_{IN} = -16V$ to $-22V$ , $T_J = 25^\circ C$		3	30		3	60	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$		20	90		12	120	mV
	$I_O = 250mA$ to $750mA$ , $T_J = 25^\circ C$		10	40		4	60	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		10	40		10	240	mV
Total Output Voltage Tolerance	$V_{IN} = -14.5V$ to $-27V$							
	Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 20W$	-11.7	-12.0	-12.3	-11.4	-12.0	-12.6	V
	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	-11.7	-12.0	-12.3	-11.4	-12.0	-12.6	V
Quiescent Current	Over Temperature Range			4			4	mA
	$T_J = 25^\circ C$			3			3	mA
Quiescent Current Change	with Line: $V_{IN} = -14.5V$ to $-30V$			1.0			1.0	mA
	with Load: $I_O = 5mA$ to $1.0A$ (Power Packages)			0.5			0.5	mA
	$I_O = 5mA$ to $500mA$ (T)			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$							
	Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		1.1	2.3		1.1	2.3	V
Peak Output Current	Power Pkgs: $T_J = 25^\circ C$	1.5		3.3	1.5		3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.5		1.4	0.5		1.4	A
Short Circuit Current	Power Pkgs: $V_{IN} = -35V$ , $T_J = 25^\circ C$			1.2			0.2	A
	T - Pkg: $V_{IN} = -35V$ , $T_J = 25^\circ C$			0.6			0.6	A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	54			54			dB
Output Noise Voltage (rms)	$f = 10Hz$ to $100KHz$ (Note 2)		25	80		25	80	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		60			60		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

### SG7912AC/SG7912C

Parameter	Test Conditions	SG7912AC			SG7912C			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_J = 25^\circ C$	-11.8	-12.0	-12.2	-11.5	-12.0	-12.5	V
Line Regulation (Note 1)	$V_{IN} = -14.5V$ to $-30V$ , $T_J = 25^\circ C$		4	70		10	240	mV
	$V_{IN} = -16V$ to $-22V$ , $T_J = 25^\circ C$		3	40		3	120	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$		20	100		12	240	mV
	$I_O = 250mA$ to $750mA$ , $T_J = 25^\circ C$		10	50		4	120	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		10	50		10	240	mV
Total Output Voltage Tolerance	$V_{IN} = -14.5V$ to $-27V$							
	Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 20W$	-11.7	-12.0	-12.3	-11.4	-12.0	-12.6	V
	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	-11.7	-12.0	-12.3	-11.4	-12.0	-12.6	V
Quiescent Current	Over Temperature Range			4			4	mA
	$T_J = 25^\circ C$			3			3	mA
Quiescent Current Change	with Line: $V_{IN} = -14.5V$ to $-30V$			1.0			1.0	mA
	with Load: $I_O = 5mA$ to $1.0A$ (Power Packages)			0.5			0.5	mA
	$I_O = 5mA$ to $500mA$ (T)			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$							
	Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		1.1	2.3		1.1	2.3	V
Peak Output Current	Power Pkgs: $T_J = 25^\circ C$	1.5		3.3	1.5		3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.5		1.4	0.5		1.4	A
Short Circuit Current	Power Pkgs: $V_{IN} = -35V$ , $T_J = 25^\circ C$			1.2			1.2	A
	T - Pkg: $V_{IN} = -35V$ , $T_J = 25^\circ C$			0.6			0.6	A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	54			54			dB
Output Noise Voltage (rms)	$f = 10Hz$ to $100KHz$ (Note 2)		25	80		25	80	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		60			60		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

Note 1. All regulation tests are made at constant junction temperature with low duty cycle testing.

2. This test is guaranteed but is not tested in production.

**ELECTRICAL SPECIFICATIONS** (Note 1)

(Unless otherwise specified, these specifications apply for  $V_{IN} = -23V$ ,  $I_O = 500mA$  for the P, K, R, G and IG -Power Packages- and  $I_O = 100mA$  for the T package,  $C_{IN} = 2\mu F$ ,  $C_{OUT} = 1.0\mu F$ , and over the recommended operating temperatures.)

**SG7915A/SG7915**

Parameter	Test Conditions	SG7915A			SG7915			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Output Voltage</b>	$T_J = 25^\circ C$	-14.8	-15.0	-15.2	-14.4	-15.0	-15.6	V
Line Regulation (Note 1)	$V_{IN} = -17.5V$ to $-30V$ , $T_J = 25^\circ C$		5	75		11	150	mV
	$V_{IN} = -20V$ to $-25V$ , $T_J = 25^\circ C$		3	40		3	75	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$		30	100		12	150	mV
	$I_O = 250mA$ to $750mA$ , $T_J = 25^\circ C$		4	50		4	75	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		10	50		10	240	mV
<b>Total Output Voltage Tolerance</b>	$V_{IN} = -18.5V$ to $-30V$							
	Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 20W$	-14.6	-15.0	-15.4	-14.25	-15.00	-15.75	V
	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	-14.6	-15.0	-15.4	-14.25	-15.00	-15.75	V
Quiescent Current	Over Temperature Range						4	mA
	$T_J = 25^\circ C$			3			3	mA
Quiescent Current Change	with Line: $V_{IN} = -18.5V$ to $-30V$			1.0			1.0	mA
	with Load: $I_O = 5mA$ to $1.0A$ (Power Packages)			0.5			0.5	mA
	$I_O = 5mA$ to $500mA$ (T)			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$							
	Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		1.1	2.3		1.1	2.3	V
Peak Output Current	Power Pkgs: $T_J = 25^\circ C$	1.5		3.3	1.5		3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.5		1.4	0.5		1.4	A
Short Circuit Current	Power Pkgs: $V_{IN} = -35V$ , $T_J = 25^\circ C$			1.2			1.2	A
	T - Pkg: $V_{IN} = -35V$ , $T_J = 25^\circ C$			0.6			0.6	A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	54			54			dB
Output Noise Voltage (rms)	$f = 10Hz$ to $100KHz$ (Note 2)		25	80		25	80	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		60			60		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

**SG7915AC/SG7915C**

Parameter	Test Conditions	SG7915AC			SG7915C			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Output Voltage</b>	$T_J = 25^\circ C$	-14.8	-15.0	-15.2	-14.4	-15.0	-15.6	V
Line Regulation (Note 1)	$V_{IN} = -17.5V$ to $-30V$ , $T_J = 25^\circ C$		5	90		12	300	mV
	$V_{IN} = -20V$ to $-25V$ , $T_J = 25^\circ C$		4	50		3	150	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$		30	130		12	300	mV
	$I_O = 250mA$ to $750mA$ , $T_J = 25^\circ C$		4	60		4	150	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		10	60		10	240	mV
<b>Total Output Voltage Tolerance</b>	$V_{IN} = -18.5V$ to $-30V$							
	Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 20W$	-14.6	-15.0	-15.4	-14.25	-15.00	-15.75	V
	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	-14.6	-15.0	-15.4	-14.25	-15.00	-15.75	V
Quiescent Current	Over Temperature Range			4			4	mA
	$T_J = 25^\circ C$			3			3	mA
Quiescent Current Change	with Line: $V_{IN} = -18.5V$ to $-30V$			1.0			1.0	mA
	with Load: $I_O = 5mA$ to $1.0A$ (Power Packages)			0.5			0.5	mA
	$I_O = 5mA$ to $500mA$ (T)			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$							
	Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		1.1	2.3		1.1	2.3	V
Peak Output Current	Power Pkgs: $T_J = 25^\circ C$	1.5		3.3	1.5		3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.5		1.4	0.5		1.4	A
Short Circuit Current	Power Pkgs: $V_{IN} = -35V$ , $T_J = 25^\circ C$			1.2			1.2	A
	T - Pkg: $V_{IN} = -35V$ , $T_J = 25^\circ C$			0.6			0.6	A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	54			54			dB
Output Noise Voltage (rms)	$f = 10Hz$ to $100KHz$ (Note 2)		25	80		25	80	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		60			60		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

Note 1. All regulation tests are made at constant junction temperature with low duty cycle testing.  
 2. This test is guaranteed but is not tested in production.



# SG7900A/SG7900 SERIES

# -18V NEGATIVE REGULATOR

## ELECTRICAL SPECIFICATIONS (Note 1)

(Unless otherwise specified, these specifications apply for  $V_{IN} = -27V$ ,  $I_O = 500mA$  for the P, K, R, G and IG -Power Packages- and  $I_O = 100mA$  for the T package,  $C_{IN} = 2\mu F$ ,  $C_{OUT} = 1.0\mu F$ , and over the recommended operating temperatures.)

### SG7918A/SG7918

Parameter	Test Conditions	SG7918A			SG7918			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_J = 25^\circ C$	-17.7	-18.0	-18.3	-17.3	-18.0	-18.7	V
Line Regulation (Note 1)	$V_{IN} = -21V$ to $-33V$ , $T_J = 25^\circ C$		5	90		6	180	mV
	$V_{IN} = -24V$ to $-30V$ , $T_J = 25^\circ C$		3	50		3	75	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$		30	120		12	180	mV
	$I_O = 250mA$ to $750mA$ , $T_J = 25^\circ C$		4	60		4	90	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		10	60		10	240	mV
Total Output Voltage Tolerance	$V_{IN} = -22V$ to $-33V$							
	Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 20W$	-17.5	-18.0	-18.5	-17.1	-18.0	-18.9	V
	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	-17.5	-18.0	-18.5	-17.1	-18.0	-18.9	V
Quiescent Current	Over Temperature Range			4			4	mA
	$T_J = 25^\circ C$			3			3	mA
Quiescent Current Change	with Line: $V_{IN} = -21V$ to $-33V$			1.0			1.0	mA
	with Load: $I_O = 5mA$ to $1.0A$ (Power Packages)			0.5			0.5	mA
	$I_O = 5mA$ to $500mA$ (T)			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$							
	Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		1.1	2.3		1.1	2.3	V
Peak Output Current	Power Pkgs: $T_J = 25^\circ C$	1.5		3.3	1.5		3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.5		1.4	0.5		1.4	A
Short Circuit Current	Power Pkgs: $V_{IN} = -35V$ , $T_J = 25^\circ C$			1.2			1.2	A
	T - Pkg: $V_{IN} = -35V$ , $T_J = 25^\circ C$			0.6			0.6	A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	54			54			dB
Output Noise Voltage (rms)	$f = 10Hz$ to $100KHz$ (Note 2)		25	80		25	80	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		72			72		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

### SG7918AC/SG7918C

Parameter	Test Conditions	SG7918AC			SG7918C			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_J = 25^\circ C$	-17.7	-18.0	-18.3	-17.4	-18.0	-18.6	V
Line Regulation (Note 1)	$V_{IN} = -21V$ to $-33V$ , $T_J = 25^\circ C$		5	100		12	300	mV
	$V_{IN} = -24V$ to $-30V$ , $T_J = 25^\circ C$		4	60		3	150	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$		30	130		12	360	mV
	$I_O = 250mA$ to $750mA$ , $T_J = 25^\circ C$		4	70		4	180	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		10	70		10	300	mV
Total Output Voltage Tolerance	$V_{IN} = -22V$ to $-33V$							
	Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 20W$	-17.5	-18.0	-18.5	-17.1	-18.0	-18.9	V
	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	-17.5	-18.0	-18.5	-17.1	-18.0	-18.9	V
Quiescent Current	Over Temperature Range			4			4	mA
	$T_J = 25^\circ C$			3			3	mA
Quiescent Current Change	with Line: $V_{IN} = -21V$ to $-33V$			1.0			1.0	mA
	with Load: $I_O = 5mA$ to $1.0A$ (Power Packages)			0.5			0.5	mA
	$I_O = 5mA$ to $500mA$ (T)			0.5			0.5	mA
Dropout Voltage	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$							
	Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		1.1	2.3		1.1	2.3	V
Peak Output Current	Power Pkgs: $T_J = 25^\circ C$	1.5		3.3	1.5		3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.5		1.4	0.5		1.4	A
Short Circuit Current	Power Pkgs: $V_{IN} = -35V$ , $T_J = 25^\circ C$			1.2			1.2	A
	T - Pkg: $V_{IN} = -35V$ , $T_J = 25^\circ C$			0.6			0.6	A
Ripple Rejection	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	54			54			dB
Output Noise Voltage (rms)	$f = 10Hz$ to $100KHz$ (Note 2)		25	80		25	80	$\mu V/V$
Long Term Stability	1000hrs. at $T_J = 125^\circ C$		72			72		mV
Thermal Shutdown	$I_O = 5mA$		175			175		$^\circ C$

Note 1. All regulation tests are made at constant junction temperature with low duty cycle testing.

2. This test is guaranteed but is not tested in production.

**ELECTRICAL SPECIFICATIONS** (Note 1)

(Unless otherwise specified, these specifications apply for  $V_{IN} = -29V$ ,  $I_O = 500mA$  for the P, K, R, G and IG -Power Packages- and  $I_O = 100mA$  for the T package,  $C_{IN} = 2\mu F$ ,  $C_{OUT} = 1.0\mu F$ , and over the recommended operating temperatures.)

**SG7920A/SG7920**

Parameter	Test Conditions	SG7920A			SG7920			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Output Voltage</b>	$T_J = 25^\circ C$	-19.7	-20.0	-20.3	-19.2	-20.0	-20.8	V
Line Regulation (Note 1)	$V_{IN} = -23V$ to $-35V$ , $T_J = 25^\circ C$		5	100		11	150	mV
	$V_{IN} = -26V$ to $-32V$ , $T_J = 25^\circ C$		4	60		3	75	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$		30	120		12	200	mV
	$I_O = 250mA$ to $750mA$ , $T_J = 25^\circ C$		4	70		4	100	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		10	70		10	240	mV
<b>Total Output Voltage Tolerance</b>	$V_{IN} = -24V$ to $-35V$							
	Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 20W$	-19.4	-20.0	-20.6	-19.0	-20.0	-21.0	V
<b>Quiescent Current</b>	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	-19.4	-20.0	-20.6	-19.0	-20.0	-21.0	V
	Over Temperature Range			4			4	mA
<b>Quiescent Current Change</b>	$T_J = 25^\circ C$			3			3	mA
	with Line: $V_{IN} = -24V$ to $-35V$			1.0			1.0	mA
<b>Dropout Voltage</b>	with Load: $I_O = 5mA$ to $1.0A$ (Power Packages)			0.5			0.5	mA
	$I_O = 5mA$ to $500mA$ (T)			0.5			0.5	mA
<b>Peak Output Current</b>	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$							
	Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		1.1	2.3		1.1	2.3	V
<b>Short Circuit Current</b>	Power Pkgs: $T_J = 25^\circ C$	1.5		3.3	1.5		3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.5		1.4	0.5		1.4	A
<b>Ripple Rejection</b>	Power Pkgs: $V_{IN} = -35V$ , $T_J = 25^\circ C$			1.2			1.2	A
	T - Pkg: $V_{IN} = -35V$ , $T_J = 25^\circ C$			0.6			0.6	A
<b>Output Noise Voltage (rms)</b>	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	54			54			dB
<b>Long Term Stability</b>	$f = 10Hz$ to $100KHz$ (Note 2)		25	80		25	80	$\mu V/V$
<b>Thermal Shutdown</b>	1000hrs. at $T_J = 125^\circ C$		80			80		mV
	$I_O = 5mA$		175			175		$^\circ C$

**SG7920AC/SG7920C**

Parameter	Test Conditions	SG7920AC			SG7920C			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Output Voltage</b>	$T_J = 25^\circ C$	-19.7	-20.0	-20.3	-19.2	-20.0	-20.8	V
Line Regulation (Note 1)	$V_{IN} = -23V$ to $-35V$ , $T_J = 25^\circ C$		6	120		11	300	mV
	$V_{IN} = -26V$ to $-32V$ , $T_J = 25^\circ C$		4	70		3	150	mV
Load Regulation (Note 1)	Power Pkgs: $I_O = 5mA$ to $1.5A$ , $T_J = 25^\circ C$		30	140		12	400	mV
	$I_O = 250mA$ to $750mA$ , $T_J = 25^\circ C$		4	80		10	200	mV
	T - Pkg: $I_O = 5mA$ to $500mA$ , $T_J = 25^\circ C$		10	80		10	300	mV
<b>Total Output Voltage Tolerance</b>	$V_{IN} = -24V$ to $-35V$							
	Power Pkgs: $I_O = 5mA$ to $1.0A$ , $P \leq 20W$	-19.4	-20.0	-20.6	-19.0	-20.0	-21.0	V
<b>Quiescent Current</b>	T - Pkg: $I_O = 5mA$ to $500mA$ , $P \leq 2W$	-19.4	-20.0	-20.6	-19.0	-20.0	-21.0	V
	Over Temperature Range			4			4	mA
<b>Quiescent Current Change</b>	$T_J = 25^\circ C$			3			3	mA
	with Line: $V_{IN} = -24V$ to $-35V$			1.0			1.0	mA
<b>Dropout Voltage</b>	with Load: $I_O = 5mA$ to $1.0A$ (Power Packages)			0.5			0.5	mA
	$I_O = 5mA$ to $500mA$ (T)			0.5			0.5	mA
<b>Peak Output Current</b>	$\Delta V_O = 100mV$ , $T_J = 25^\circ C$							
	Power Pkgs: $I_O = 1.0A$ , T - Pkg: $I_O = 500mA$		1.1	2.3		1.1	2.3	V
<b>Short Circuit Current</b>	Power Pkgs: $T_J = 25^\circ C$	1.5		3.3	1.5		3.3	A
	T - Pkg: $T_J = 25^\circ C$	0.5		1.4	0.5		1.4	A
<b>Ripple Rejection</b>	Power Pkgs: $V_{IN} = -35V$ , $T_J = 25^\circ C$			1.2			1.2	A
	T - Pkg: $V_{IN} = -35V$ , $T_J = 25^\circ C$			0.6			0.6	A
<b>Output Noise Voltage (rms)</b>	$\Delta V_{IN} = 10V$ , $f = 120Hz$ , $T_J = 25^\circ C$	54			54			dB
<b>Long Term Stability</b>	$f = 10Hz$ to $100KHz$ (Note 2)		25	80		25	80	$\mu V/V$
<b>Thermal Shutdown</b>	1000hrs. at $T_J = 125^\circ C$		80			80		mV
	$I_O = 5mA$		175			175		$^\circ C$

Note 1. All regulation tests are made at constant junction temperature with low duty cycle testing.  
 2. This test is guaranteed but is not tested in production.

# SG7900A/SG7900 SERIES

# NEGATIVE REGULATOR

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
3-TERMINAL TO-3 METAL CAN K-PACKAGE	SG79XXAK/883B SG79XXAK SG79XXACK SG79XXK/883B SG79XXK SG79XXK	-55°C to 125°C -55°C to 125°C 0°C to 70°C -55°C to 125°C -55°C to 125°C 0°C to 70°C	
3-TERMINAL TO-66 METAL CAN R-PACKAGE	SG79XXAR/883B SG79XXAR SG79XXACR SG79XXR/883B SG79XXR SG79XXCR	-55°C to 125°C -55°C to 125°C 0°C to 70°C -55°C to 125°C -55°C to 125°C 0°C to 70°C	
3-PIN TO-39 METAL CAN T-PACKAGE	SG79XXAT/883B SG79XXAT SG79XXACT SG79XXT/883B SG79XXT SG79XXCT	-55°C to 125°C -55°C to 125°C 0°C to 70°C -55°C to 125°C -55°C to 125°C 0°C to 70°C	
3-PIN PLASTIC TO-220 P-PACKAGE	SG79XXACP SG79XXCP	0°C to 70°C 0°C to 70°C	
3-PIN HERMETIC TO-220 G-PACKAGE (Non-Isolated)	SG79XXAG/883B SG79XXAG SG79XXG/883B SG79XXG	-55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C	
3-PIN HERMETIC TO-220 IG-PACKAGE (Isolated)	SG79XXAIG/883B SG79XXAIG SG79XXIG/883B SG79XXIG	-55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C	

- Note 1. Contact factory for JAN and DESC product availability.  
 2. All parts are viewed from the top.  
 3. "XX" to be replaced by output voltage of specific fixed regulator.  
 4. Some products will be available in leadless chip carrier (LCC) and hermetic flat pack (F). Consult factory for price and availability





LINEAR INTEGRATED CIRCUITS

# SM600/SM601/SM602/SM610/SM611/SM612

## SWITCHING REGULATOR POWER OUTPUT STAGES

### DESCRIPTION

The SM600/601/602 and SM610/611/612 series of Power Output Stages are especially designed to be driven with standard PWM integrated circuits to form an efficient switching power supply. The SM600, SM601 and SM602 are optimized for non-isolated Buck and Buck-Boost application, where SM610, SM611 and SM612 are best suited for DC-DC Boost type applications as well as negative output Buck Converters. The hybrid circuit construction utilizes thick film resistors on a beryllia substrate for maximum thermal conductivity and resultant low thermal impedance. All of the active elements in the hybrid are fully passivated.

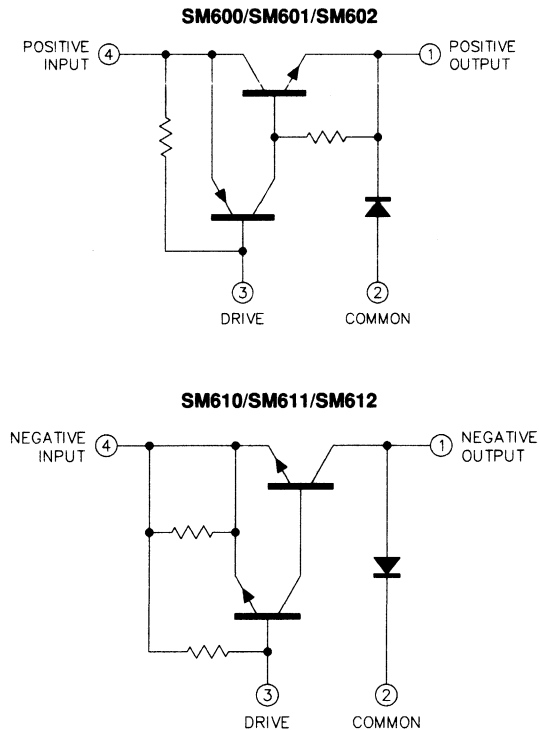
### FEATURES

- Equivalent to the Unitrode PIC 600, 601, 602, 610, 611, 612
- 5A current capability
- Designed and characterized for switching regulator applications such as Buck, Boost, and Buck-Boost type
- Cost saving design reduces size, Improves efficiency, reduces noise and RFI
- High operating efficiency at 2A typical performance - Rise and fall time < 75ns Efficiency > 85%
- Electrically isolated, 4-pin, TO-66 hermetic case

### HIGH RELIABILITY FEATURES

- ◆ Available with high reliability processing

### FUNCTIONAL DIAGRAM



# SM600/SM601/SM602/SM610/SM611/SM612

## ABSOLUTE MAXIMUM RATINGS (Note 1)

	SM600	SM601	SM602	SM610	SM611	SM612
Input Voltage, $V_{4-2}$ .....	60V	80V	100V	-60V	-80V	-100V
Output Voltage, $V_{1-2}$ .....	60V	80V	100V	-60V	-80V	-100V
Drive Input Reverse Voltage, $V_{3-4}$ .....	5V	5V	5V	-5V	-5V	-5V
Output Current, $I_1$ .....	5A	5A	5A	-5A	-5A	-5A
Drive Current, $I_3$ .....	-0.2A	-0.2A	-0.2A	0.2A	0.2A	0.2A

### Thermal Resistance

Power Switch, $\theta_{J-C}$ .....	4.0°C/W
Commutating Diode .....	4.0°C/W
Case to Ambient, $\theta_{C-A}$ .....	60.0°C/W

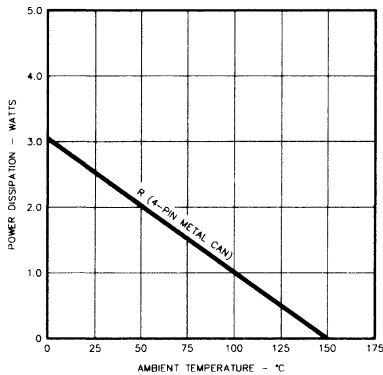
### Operating Junction Temperature

Hermetic (R Package) .....	175°C
Storage Temperature Range .....	-65°C to 150°C
Lead Temperature (Soldering, 10 Seconds) .....	300°C

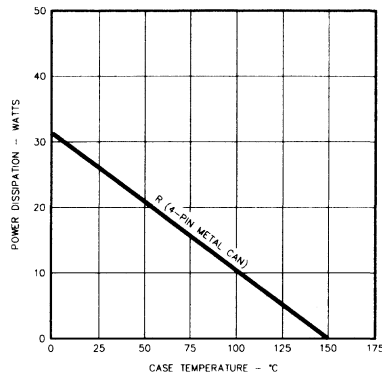
Note 1. Exceeding these ratings could cause damage to the device.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

	SM600	SM601	SM602	SM610	SM611	SM612
Input Voltage, $V_{4-2}$ .....	50V	70V	90V	-50V	-70V	-90V
Output Voltage, $V_{1-2}$ .....	50V	70V	90V	-50V	-70V	-90V
Drive Input Reverse Voltage, $V_{3-4}$ .....	3V	3V	3V	-3V	-3V	-3V
Output Current, $I_1$ .....	4A	4A	4A	-4A	-4A	-4A
Drive Current, $I_3$ .....	-0.1A	-0.1A	-0.1A	0.1A	0.1A	0.1A

### Operating Ambient Temperature Range

SM6XXR .....	0°C to 70°C
SM6XXHRR .....	-55°C to 125°C

Note 2. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS (Unless otherwise stated, these specifications apply for $T_A = 25^\circ\text{C}$ .)

Parameter	Test Conditions	SG600/601/602			SG610/611/612			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
On-State Voltage (Note 3)	$I_A = 2A(-2A), I_3 = -20mA (20mA)$	1.0	1.5		-1.0	-1.5		V
	$I_A = 5A(-5A), I_3 = -20mA (20mA)$	2.5	3.5		-2.5	-3.5		V
Diode Forward Voltage (Note 3)	$I_A = 2A(-2A)$	0.8	1.0		-0.8	-1.0		V
	$I_A = 5A(-5A)$	1.0	1.5		-1.0	-1.5		V
Off-State Current	$V_A = \text{Rated input voltage}$	0.1	10		-0.1	-10		$\mu\text{A}$
	$V_A = \text{Rated input voltage}, T_A = 125^\circ\text{C}$		10			-10		$\mu\text{A}$
Diode Reverse Current	$V_1 = \text{Rated output voltage}$	1.0	10		-1.0	-10		$\mu\text{A}$
	$V_1 = \text{Rated output voltage}, T_A = 125^\circ\text{C}$		500			-500		$\mu\text{A}$

Note 3. Pulse test: Duration = 300 $\mu\text{s}$ , Duty Cycle  $\leq 2\%$ .

# SM600/SM601/SM602/SM610/SM611/SM612

## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG600/601/602			SG610/611/612			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Dynamic Characteristics (See Figures 1 &amp; 2) (Notes 4 &amp; 5)</b>								
Current Delay Time			20	40		20	40	ns
Current Rise Time			50	75		50	75	ns
Voltage Rise Time			30	50		30	50	ns
Voltage Storage Time			450			450		ns
Voltage Fall Time			50	75		50	75	ns
Current Fall Time			70	150		70	150	ns
Efficiency (Note 5)			85			85		%

## AC TEST CIRCUIT AND SWITCHING TIME WAVEFORMS (Note 6)

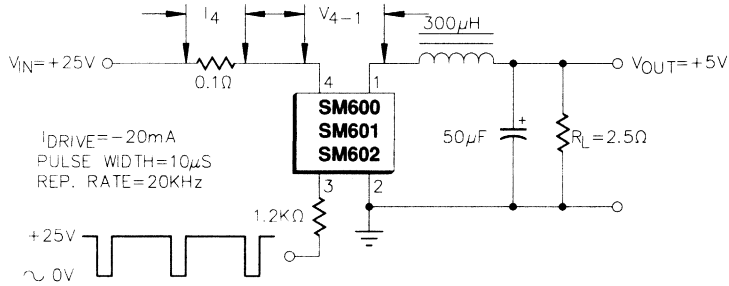


FIGURE 1 - SM600/601/602 SWITCHING SPEED CIRCUIT

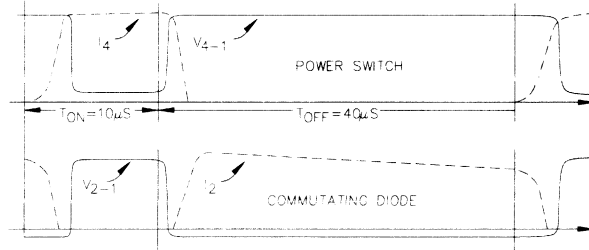


FIGURE 2 - SM600/601/602 SWITCHING WAVEFORMS

Note 4. In switching an inductive load, the current will lead the voltage on turn-on and lag the voltage on turn-off (see Figure 2). Therefore, Voltage Delay Time ( $t_{dv}$ )  $\cong t_d + t_r$  and Current Storage Time ( $t_{cs}$ )  $\cong t_{sv} + t_v$ .

Note 5. The efficiency is a measure of internal power losses and is equal to Output Power divided by Input Power. The switching speed circuit of Figure 1, in which the efficiency measured, is representative of typical operating conditions for the SM600 series switching regulators.

Note 6. SM610/611/612 Test Circuit and waveforms are identical but of opposite polarity ( $V_{IN} = -25V$ ,  $V_{OUT} = -5V$ ,  $I_{DRIVE} = +20mA$ ).

## APPLICATION CIRCUITS

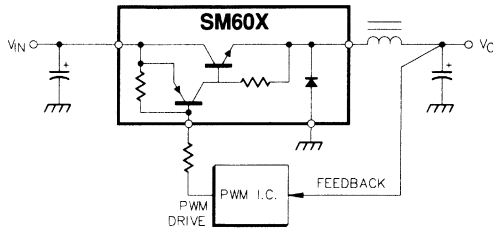


FIGURE 3 - STEP DOWN (BUCK) CONVERTER

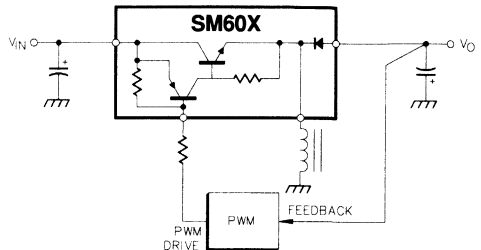


FIGURE 4 - NEGATIVE OUTPUT DOWN/UP (BUCK-BOOST) CONVERTER

# SM600/SM601/SM602/SM610/SM611/SM612

## APPLICATION CIRCUITS (continued)

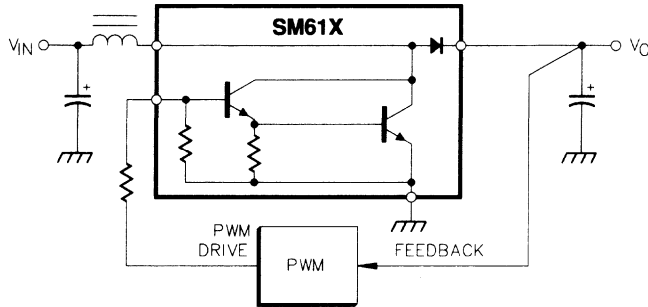


FIGURE 5 - STEP UP (BOOST) CONVERTER

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Note Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
4-PIN TO-66 METAL CAN R - PACKAGE	SM600R	0°C to 70°C	
	SM600HRR	-55°C to 125°C	
	SM601R	0°C to 70°C	
	SM601HRR	-55°C to 125°C	
	SM602R	0°C to 70°C	
	SM602HRR	-55°C to 125°C	
	SM610R	0°C to 70°C	
	SM610HRR	-55°C to 125°C	
	SM611R	0°C to 70°C	
	SM611HRR	-55°C to 125°C	
SM612R	0°C to 70°C		
SM612HRR	-55°C to 125°C		

- Note 1. All packages are viewed from the top.  
 2. Case is electrically isolated.  
 3. Consult factory for additional screening available.





LINEAR INTEGRATED CIRCUITS

# SM625/SM626/SM627/SM635/SM636/SM637

## SWITCHING REGULATOR POWER OUTPUT STAGES

### DESCRIPTION

The SM625/626/627 and SM635/636/637 series of Power Output Stages are especially designed to be driven with standard PWM integrated circuits to form an efficient switching power supply. The SM625, SM626 and SM627 are optimized for non-isolated Buck and Buck-Boost application, where SM635, SM636 and SM637 are best suited for DC-DC Boost type applications as well as negative output Buck Converters. The hybrid circuit construction utilizes thick film resistors on a beryllia substrate for maximum thermal conductivity and resultant low thermal impedance. All of the active elements in the hybrid are fully passivated.

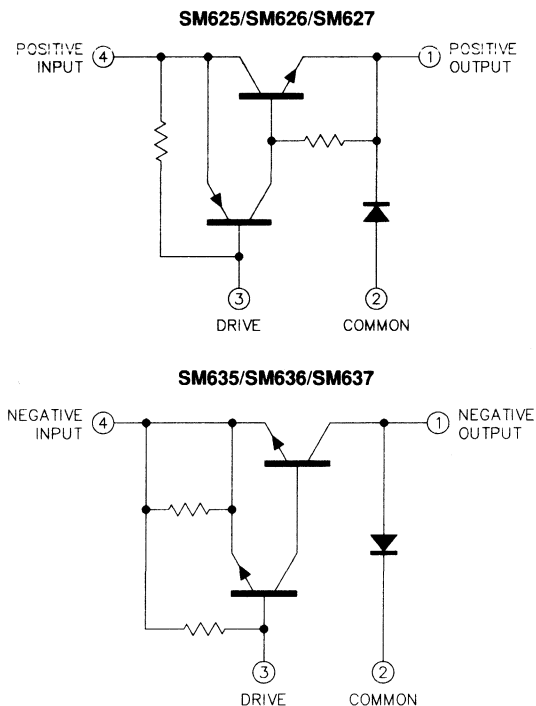
### FEATURES

- Equivalent to the Unitrode PIC 625, 626, 627, 635, 636, 637
- 15A current capability
- Designed and characterized for switching regulator applications such as Buck, Boost, and Buck-Boost type
- Cost saving design reduces size, improves efficiency, reduces noise and RFI
- High operating frequency (to > 100KHz) results in smaller inductor-capacitor filter and improved power supply response time
- High operating efficiency at 7A typical performance - Rise and fall time < 300ns Efficiency > 85%
- Electrically isolated, 4-pin, TO-66 hermetic case

### HIGH RELIABILITY FEATURES

- ◆ Available with high reliability processing

### FUNCTIONAL DIAGRAM



# SM625/SM626/SM627/SM635/SM636/SM637

## ABSOLUTE MAXIMUM RATINGS (Note 1)

	SM625	SM626	SM627	SM635	SM636	SM637
Input Voltage, $V_{1,2}$	60V	80V	100V	-60V	-80V	-100V
Output Voltage, $V_{1,2}$	60V	80V	100V	-60V	-80V	-100V
Drive Input Reverse Voltage, $V_{3,4}$	5V	5V	5V	-5V	-5V	-5V
Output Current, $I_1$	15A	15A	15A	-15A	-15A	-15A
Drive Current, $I_3$	-0.4A	-0.4A	-0.4A	0.4A	0.4A	0.4A

### Thermal Resistance

Power Switch, $\theta_{J-C}$	4.0°C/W
Commutating Diode	4.0°C/W
Case to Ambient, $\theta_{C-A}$	60.0°C/W

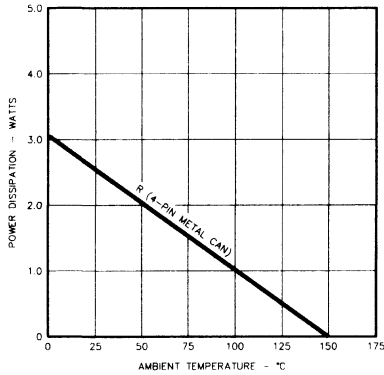
### Operating Junction Temperature

Hermetic (R Package)	175°C
Storage Temperature Range	-65°C to 150°C
Lead Temperature (Soldering, 10 Seconds)	300°C

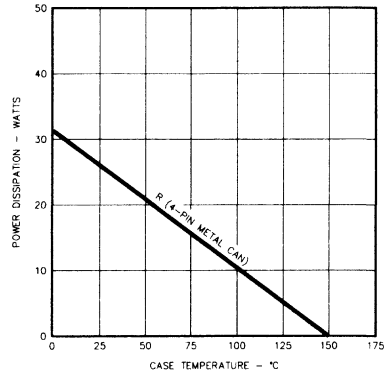
Note 1. Exceeding these ratings could cause damage to the device.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

	SM625	SM626	SM627	SM635	SM636	SM637
Input Voltage, $V_{1,2}$	50V	70V	90V	-50V	-70V	-90V
Output Voltage, $V_{1,2}$	50V	70V	90V	-50V	-70V	-90V
Drive Input Reverse Voltage, $V_{3,4}$	4V	4V	4V	-4V	-4V	-4V
Output Current, $I_1$	13A	13A	13A	-13A	-13A	-13A
Drive Current, $I_3$	-0.3A	-0.3A	-0.3A	0.3A	0.3A	0.3A

### Operating Ambient Temperature Range

SM6XXR ..... 0°C to 70°C

SM6XXHRR ..... -55°C to 125°C

Note 2. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS (Unless otherwise stated, these specifications apply for $T_A = 25^\circ\text{C}$ .)

Parameter	Test Conditions	SG625/626/627			SG635/636/637			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
On-State Voltage (Note 3)	$I_A = 7A(-7A)$ , $I_3 = -30mA(30mA)$		1.0	1.5		-1.0	-1.5	V
	$I_A = 15A(-15A)$ , $I_3 = -30mA(30mA)$		2.5	3.5		-2.5	-3.5	V
Diode Forward Voltage (Note 3)	$I_A = 7A(-7A)$		0.85	1.25		-0.85	-1.25	V
	$I_A = 15A(-15A)$		0.95	1.75		-0.95	-1.75	V
Off-State Current	$V_A = \text{Rated input voltage}$		0.1	10		-0.1	-10	$\mu\text{A}$
	$V_A = \text{Rated input voltage}$ , $T_A = 125^\circ\text{C}$		10			-10		$\mu\text{A}$
Diode Reverse Current	$V_1 = \text{Rated output voltage}$		1.0	10		-1.0	-10	$\mu\text{A}$
	$V_1 = \text{Rated output voltage}$ , $T_A = 125^\circ\text{C}$		500			-500		$\mu\text{A}$

Note 3. Pulse test: Duration = 300 $\mu\text{s}$ , Duty Cycle  $\leq 2\%$ .

# SM625/SM626/SM627/SM635/SM636/SM637

## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG625/626/627			SG635/636/637			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Dynamic Characteristics</b> (See Figures 1 & 2) (Notes 4 & 5)								
Current Delay Time			35	60	35	60		ns
Current Rise Time			65	150	65	175		ns
Voltage Rise Time			40	60	40	60		ns
Voltage Storage Time			700		700			ns
Voltage Fall Time			70	175	100	300		ns
Current Fall Time			175	300	175	300		ns
Efficiency (Note 5)			85		85			%

## AC TEST CIRCUIT AND SWITCHING TIME WAVEFORMS (Note 6)

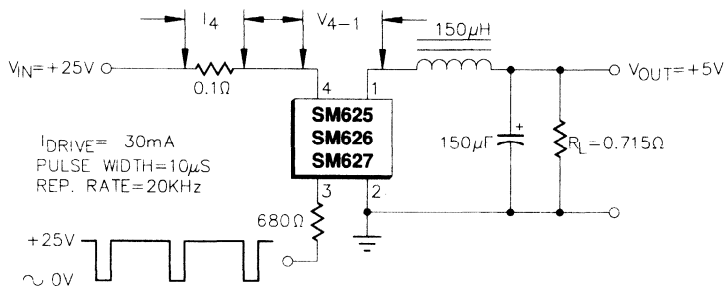


FIGURE 1 - SM625/626/627 SWITCHING SPEED CIRCUIT

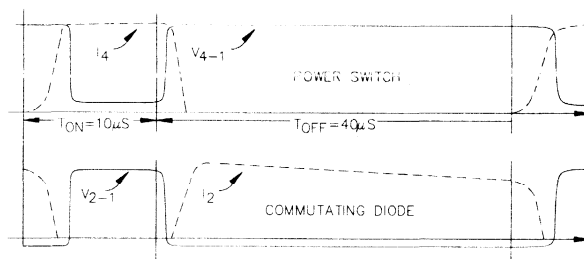


FIGURE 2 - SM625/626/627 SWITCHING WAVEFORMS

Note 4. In switching an inductive load, the current will lead the voltage on turn-on and lag the voltage on turn-off (see Figure 2). Therefore, Voltage Delay Time ( $t_{dv}$ )  $\cong t_d + t_r$  and Current Storage Time ( $t_{cs}$ )  $\cong t_{sv} + t_{fv}$ .

Note 5. The efficiency is a measure of internal power losses and is equal to Output Power divided by Input Power. The switching speed circuit of Figure 1, in which the efficiency measured, is representative of typical operating conditions for the SM600 series switching regulators.

Note 6. SM635/636/637 Test Circuit and waveforms are identical but of opposite polarity ( $V_{IN} = -25V$ ,  $V_{OUT} = -5V$ ,  $I_{DRIVE} = +30mA$ ).

## APPLICATION CIRCUITS

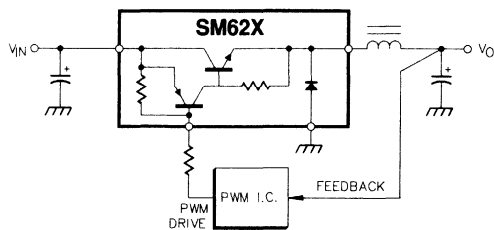


FIGURE 3 - STEP DOWN (BUCK) CONVERTER

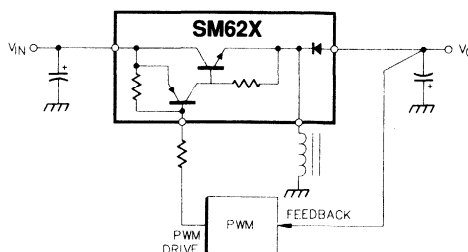


FIGURE 4 - NEGATIVE OUTPUT DOWN/UP (BUCK-BOOST) CONVERTER

# SM625/SM626/SM627/SM635/SM636/SM637

## APPLICATION CIRCUITS (continued)

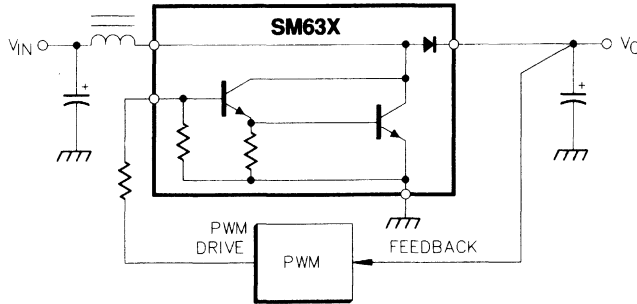


FIGURE 5 - STEP UP (BOOST) CONVERTER

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Note Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
4-PIN TO-66 METAL CAN R - PACKAGE	SM625R	0°C to 70°C	
	SM625HRR	-55°C to 125°C	
	SM626R	0°C to 70°C	
	SM626HRR	-55°C to 125°C	
	SM627R	0°C to 70°C	
	SM627HRR	-55°C to 125°C	
	SM635R	0°C to 70°C	
	SM635HRR	-55°C to 125°C	
	SM636R	0°C to 70°C	
	SM636HRR	-55°C to 125°C	
SM637R	0°C to 70°C		
SM637HRR	-55°C to 125°C		

- Note
1. All packages are viewed from the top.
  2. Case is electrically isolated.
  3. Contact factory for additional screening available.



LINEAR INTEGRATED CIRCUITS

## SM645/SM646/SM647/SM655/SM656/SM657

### SWITCHING REGULATOR POWER OUTPUT STAGES

#### DESCRIPTION

The SM645/646/647 and SM655/656/657 series of Power Output Stages are especially designed to be driven with standard PWM integrated circuits to form an efficient switching power supply. The SM645, SM646 and SM647 are optimized for non-isolated Buck and Buck-Boost application, where SM655, SM656 and SM657 are best suited for DC-DC Boost type applications as well as negative output Buck Converters. The hybrid circuit construction utilizes thick film resistors on a beryllia substrate for maximum thermal conductivity and resultant low thermal impedance. All of the active elements in the hybrid are fully passivated.

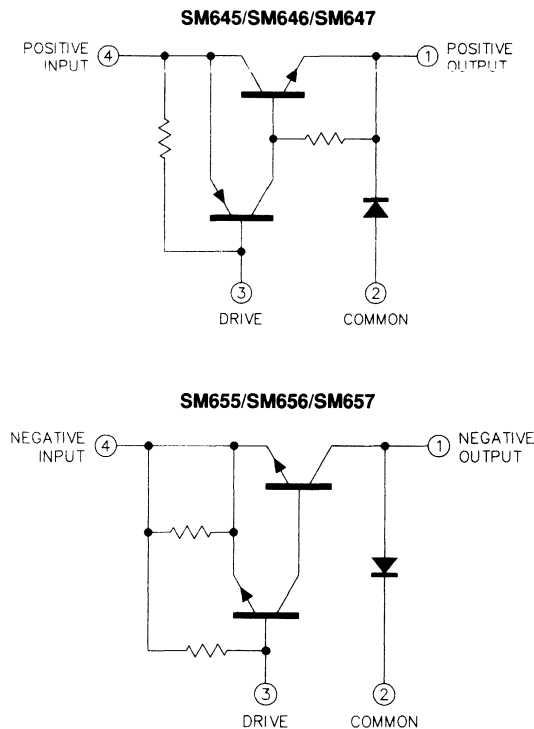
#### FEATURES

- Equivalent to the Unitrode PIC 645, 646, 647, 655, 656, 657
- 15A current capability
- Cost saving design reduces size, improves efficiency, reduces noise and RFI
- High operating frequency (to > 100KHz) results in smaller inductor-capacitor filter and improved power supply response time
- High operating efficiency at 7A typical performance - Rise and fall time < 300ns Efficiency > 85%

#### HIGH RELIABILITY FEATURES

- ◆ Available with high reliability processing

#### FUNCTIONAL DIAGRAM



# SM645/SM646/SM647/SM655/SM656/SM657

## ABSOLUTE MAXIMUM RATINGS (Note 1)

	SM645	SM646	SM647	SM655	SM656	SM657
Input Voltage, $V_{4-2}$ .....	60V	80V	100V	-60V	-80V	-100V
Output Voltage, $V_{1-2}$ .....	60V	80V	100V	-60V	-80V	-100V
Drive Input Reverse Voltage, $V_{3-4}$ .....	5V	5V	5V	-5V	-5V	-5V
Continuous Output Current, $I_1$ .....	15A	15A	15A	-15A	-15A	-15A
Peak Output Current .....	20A	20A	20A	-20A	-20A	-20A
Drive Current, $I_3$ .....	-0.4A	-0.4A	-0.4A	0.4A	0.4A	0.4A

### Thermal Resistance

Power Switch, $\theta_{J-C}$ .....	2.0°C/W
Commutating Diode .....	2.0°C/W
Case to Ambient, $\theta_{C-A}$ .....	30.0°C/W

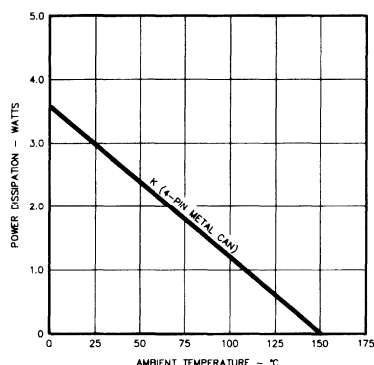
### Operating Junction Temperature

Hermetic (K Package) .....	175°C
Storage Temperature Range .....	-65°C to 150°C
Lead Temperature (Soldering, 10 Seconds) .....	300°C

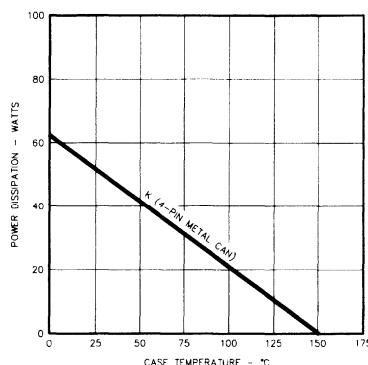
Note 1. Exceeding these ratings could cause damage to the device.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

	SM645	SM646	SM647	SM655	SM656	SM657
Input Voltage, $V_{4-2}$ .....	50V	70V	90V	-50V	-70V	-90V
Output Voltage, $V_{1-2}$ .....	50V	70V	90V	-50V	-70V	-90V
Drive Input Reverse Voltage, $V_{3-4}$ .....	4V	4V	4V	-4V	-4V	-4V
Output Current, $I_1$ .....	13A	13A	13A	-13A	-13A	-13A
Drive Current, $I_3$ .....	-0.3A	-0.3A	-0.3A	0.3A	0.3A	0.3A

### Operating Ambient Temperature Range

SM6XXK ..... 0°C to 70°C

SM6XXHRK ..... -55°C to 125°C

Note 2. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS (Unless otherwise stated, these specifications apply for $T_A = 25^\circ\text{C}$ .)

Parameter	Test Conditions	SG645/646/647			SG655/656/657			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
On-State Voltage (Note 3)	$I_A = 7A(-7A), I_3 = -30mA(30mA)$		1.0	1.5		-1.0	-1.5	V
	$I_A = 15A(-15A), I_3 = -30mA(30mA)$		2.5	3.5		-2.5	-3.5	V
Diode Forward Voltage (Note 3)	$I_A = 7A(-7A)$		0.85	1.25		-0.85	-1.25	V
	$I_A = 15A(-15A)$		0.95	1.75		-0.95	-1.75	V
Off-State Current	$V_A = \text{Rated input voltage}$		0.1	10		-0.1	-10	$\mu\text{A}$
	$V_A = \text{Rated input voltage}, T_A = 125^\circ\text{C}$		10			-10		$\mu\text{A}$
Diode Reverse Current	$V_1 = \text{Rated output voltage}$		1.0	10		-1.0	-10	$\mu\text{A}$
	$V_1 = \text{Rated output voltage}, T_A = 125^\circ\text{C}$		500			-500		$\mu\text{A}$

Note 3. Pulse test: Duration = 300 $\mu\text{s}$ , Duty Cycle  $\leq$  2%.

# SM645/SM646/SM647/SM655/SM656/SM657

## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG645/646/647			SG655/656/657			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Dynamic Characteristics</b> (See Figures 1 & 2) (Notes 4 & 5)								
Current Delay Time			35	60		35	60	ns
Current Rise Time			65	150		65	175	ns
Voltage Rise Time			40	60		40	60	ns
Voltage Storage Time			700			700		ns
Voltage Fall Time			70	175		100	300	ns
Current Fall Time			175	300		175	300	ns
Efficiency (Note 5)			85			85		%

## AC TEST CIRCUIT AND SWITCHING TIME WAVEFORMS (Note 6)

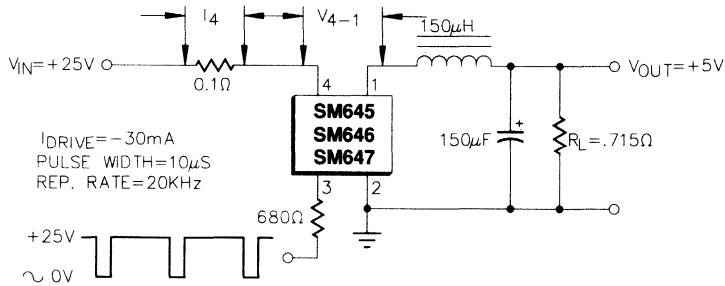


FIGURE 1 - SM645/646/647 SWITCHING SPEED CIRCUIT

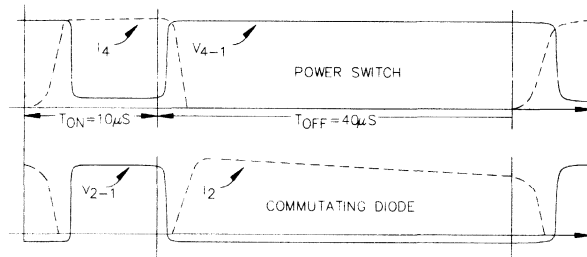


FIGURE 2 - SM645/646/647 SWITCHING WAVEFORMS

Note 4. In switching an inductive load, the current will lead the voltage on turn-on and lag the voltage on turn-off (see Figure 2). Therefore, Voltage Delay Time ( $t_{dv}$ )  $\cong t_d + t_r$  and Current Storage Time ( $t_{ds}$ )  $\cong t_w + t_f$ .

Note 5. The efficiency is a measure of internal power losses and is equal to Output Power divided by Input Power. The switching speed circuit of Figure 1, in which the efficiency measured, is representative of typical operating conditions for the SM600 series switching regulators.

Note 6. SM655/656/657 Test Circuit and waveforms are identical but of opposite polarity ( $V_{IN} = -25V$ ,  $V_{OUT} = -5V$ ,  $I_{DRIVE} = +30mA$ ).

## APPLICATION CIRCUITS

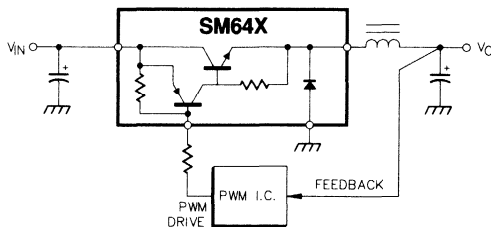


FIGURE 3 - STEP DOWN (BUCK) CONVERTER

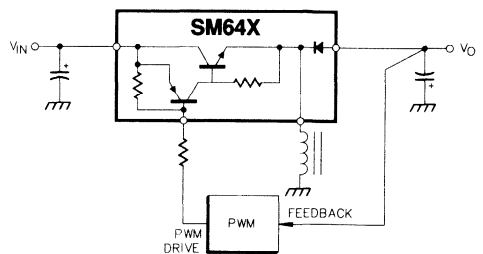


FIGURE 4 - NEGATIVE OUTPUT DOWN/UP (BUCK-BOOST) CONVERTER

# SM645/SM646/SM647/SM655/SM656/SM657

## APPLICATION CIRCUITS (continued)

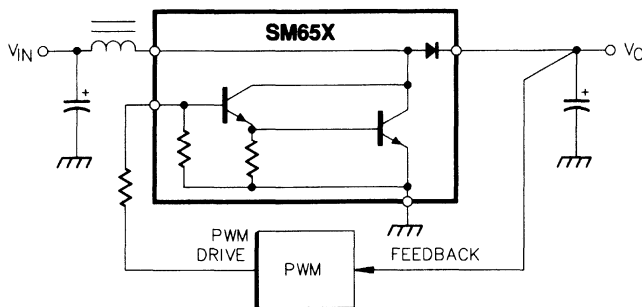


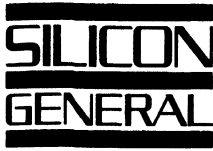
FIGURE 5 - STEP UP (BOOST) CONVERTER

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Note Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
4-TERMINAL TO-3 METAL CAN K - PACKAGE	SM645K	0°C to 70°C	
	SM645HRK	-55°C to 125°C	
	SM646K	0°C to 70°C	
	SM646HRK	-55°C to 125°C	
	SM647K	0°C to 70°C	
	SM647HRK	-55°C to 125°C	
	SM655K	0°C to 70°C	
	SM655HRK	-55°C to 125°C	
	SM656K	0°C to 70°C	
	SM656HRK	-55°C to 125°C	
SM657K	0°C to 70°C		
SM657HRK	-55°C to 125°C		

Note 1. All packages are viewed from the top.  
 Note 2. Consult factory for additional screening available.





LINEAR INTEGRATED CIRCUITS

# SM660/SM661/SM662/SM670/SM671/SM672

## SWITCHING REGULATOR POWER OUTPUT STAGES

### DESCRIPTION

The SM660/661/662 and SM670/671/672 series of Power Output Stages are especially designed to be driven with standard PWM integrated circuits to form an efficient switching power supply. The SM660, SM661 and SM662 are optimized for non-isolated Buck and Buck-Boost application, where SM670, SM671 and SM672 are best suited for DC-DC Boost type applications as well as negative output Buck Converters. The hybrid circuit construction utilizes thick film resistors on a beryllia substrate for maximum thermal conductivity and resultant low thermal impedance. All of the active elements in the hybrid are fully passivated.

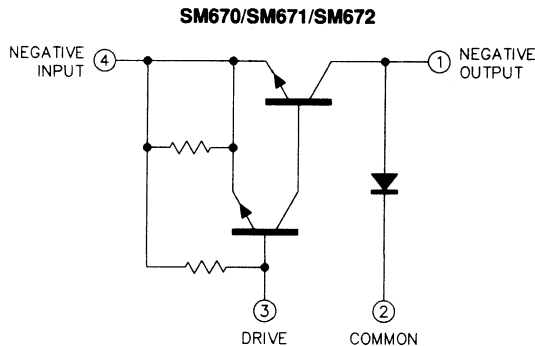
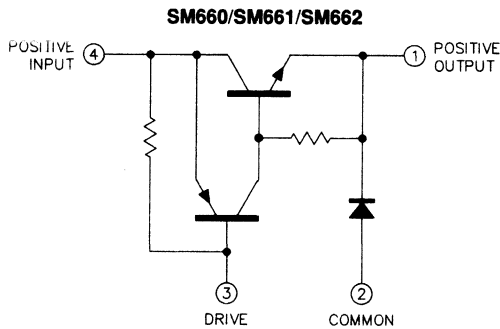
### FEATURES

- Equivalent to the Unitrode PIC 660, 661, 662, 670, 671, 672
- 10A current capability
- Designed and characterized for switching regulator applications such as Buck, Boost, and Buck-Boost type
- Cost saving design reduces size, improves efficiency, reduces noise and RFI
- High operating frequency (to > 100KHz) results in smaller inductor-capacitor filter and improved power supply response time
- High operating efficiency at 7A typical performance - Rise and fall time < 300ns Efficiency > 85%
- Electrically Isolated, 4-pin, TO-66 hermetic case

### HIGH RELIABILITY FEATURES

- ♦ Available with high reliability processing

### FUNCTIONAL DIAGRAM



# SM660/SM661/SM662/SM670/SM671/SM672

## ABSOLUTE MAXIMUM RATINGS (Note 1)

	SM660	SM661	SM662	SM670	SM671	SM672
Input Voltage, $V_{4-2}$ .....	60V	80V	100V	-60V	-80V	-100V
Output Voltage, $V_{1-2}$ .....	60V	80V	100V	-60V	-80V	-100V
Drive Input Reverse Voltage, $V_{3-4}$ .....	5V	5V	5V	-5V	-5V	-5V
Output Current, $I_1$ .....	10A	10A	10A	-10A	-10A	-10A
Drive Current, $I_3$ .....	-0.4A	-0.4A	-0.4A	0.4A	0.4A	0.4A

### Thermal Resistance

Power Switch, $\theta_{j-c}$ .....	4.0°C/W
Commutating Diode .....	4.0°C/W
Case to Ambient, $\theta_{c-a}$ .....	60.0°C/W

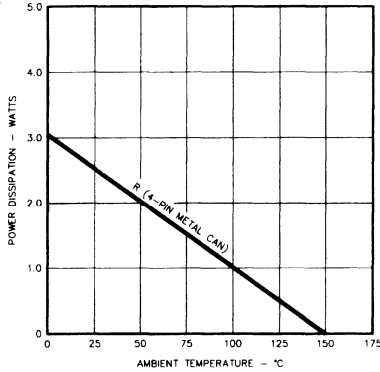
### Operating Junction Temperature

Hermetic (R Package) .....	175°C
Storage Temperature Range .....	-65°C to 150°C
Lead Temperature (Soldering, 10 Seconds) .....	300°C

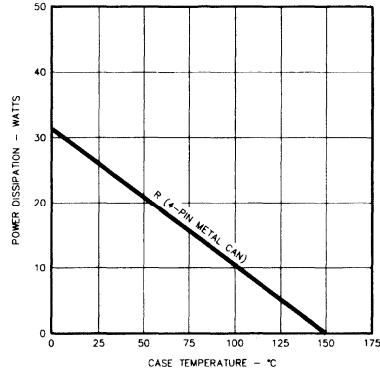
Note 1. Exceeding these ratings could cause damage to the device.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

	SM660	SM661	SM662	SM660	SM661	SM662
Input Voltage, $V_{4-2}$ .....	50V	70V	90V	-50V	-70V	-90V
Output Voltage, $V_{1-2}$ .....	50V	70V	90V	-50V	-70V	-90V
Drive Input Reverse Voltage, $V_{3-4}$ .....	4V	4V	4V	-4V	-4V	-4V
Output Current, $I_1$ .....	9A	9A	9A	-9A	-9A	-9A
Drive Current, $I_3$ .....	-0.3A	-0.3A	-0.3A	0.3A	0.3A	0.3A

### Operating Ambient Temperature Range

SM6XXR .....	0°C to 70°C
SM6XXHRK .....	-55°C to 125°C

Note 2. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise stated, these specifications apply for  $T_A = 25^\circ\text{C}$ .)

Parameter	Test Conditions	SG660/661/662			SG670/671/672			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
On-State Voltage (Note 3)	$I_A = 5A(-5A)$ , $I_3 = -30mA(30mA)$	1.0	1.5		-10	-1.5		V
	$I_A = 10A(-10A)$ , $I_3 = -30mA(30mA)$	2.5	3.5		-2.5	-3.5		V
Diode Forward Voltage (Note 3)	$I_A = 5A(-5A)$	0.85	1.25		-0.85	-1.25		V
	$I_A = 10A(-10A)$	0.95	1.75		-0.95	-1.75		V
Off-State Current	$V_A = \text{Rated input voltage}$	0.1	10		-0.1	-10		$\mu\text{A}$
	$V_A = \text{Rated input voltage}$ , $T_A = 125^\circ\text{C}$	10			-10			$\mu\text{A}$
Diode Reverse Current	$V_1 = \text{Rated output voltage}$	1.0	10		-1.0	-10		$\mu\text{A}$
	$V_1 = \text{Rated output voltage}$ , $T_A = 125^\circ\text{C}$	500			-500			$\mu\text{A}$

Note 3. Pulse test: Duration = 300 $\mu\text{s}$ , Duty Cycle  $\leq$  2%.

# SM660/SM661/SM662/SM670/SM671/SM672

## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG660/661/662			SG670/671/672			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Dynamic Characteristics</b> (See Figures 1 & 2) (Notes 4 & 5)								
Current Delay Time			35	60		35	60	ns
Current Rise Time			65	150		65	175	ns
Voltage Rise Time			40	60		40	60	ns
Voltage Storage Time			700			700		ns
Voltage Fall Time			70	175		100	300	ns
Current Fall Time			175	300		175	300	ns
Efficiency (Note 5)			85			85		%

## AC TEST CIRCUIT AND SWITCHING TIME WAVEFORMS (Note 6)

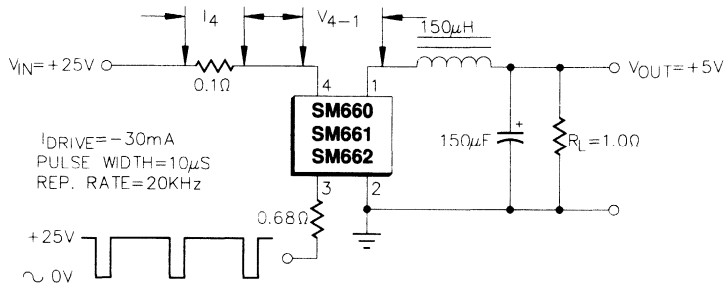


FIGURE 1 - SM660/661/662 SWITCHING SPEED CIRCUIT

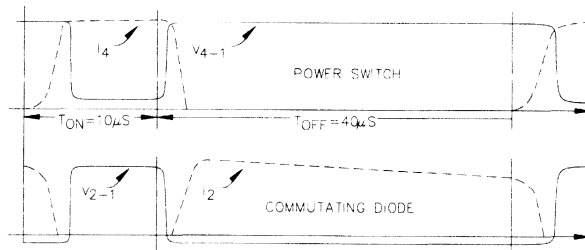


FIGURE 2 - SM660/661/662 SWITCHING WAVEFORMS

Note 4. In switching an inductive load, the current will lead the voltage on turn-on and lag the voltage on turn-off (see Figure 2). Therefore, Voltage Delay Time ( $t_{DV} \cong t_{d} + t_{n}$ ) and Current Storage Time ( $t_{CS} \cong t_{sv} + t_{v}$ ).

Note 5. The efficiency is a measure of internal power losses and is equal to Output Power divided by Input Power. The switching speed circuit of Figure 1, in which the efficiency measured, is representative of typical operating conditions for the SM600 series switching regulators.

Note 6. SM670/671/672 Test Circuit and waveforms are identical but of opposite polarity ( $V_{IN} = -25V$ ,  $V_{OUT} = -5V$ ,  $I_{DRIVE} = +30mA$ ).

## APPLICATION CIRCUITS

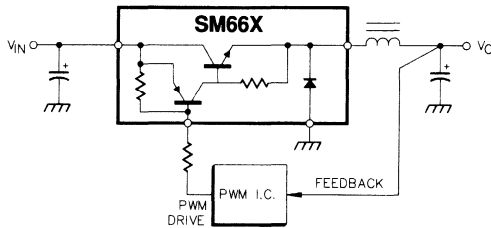


FIGURE 3 - STEP DOWN (BUCK) CONVERTER

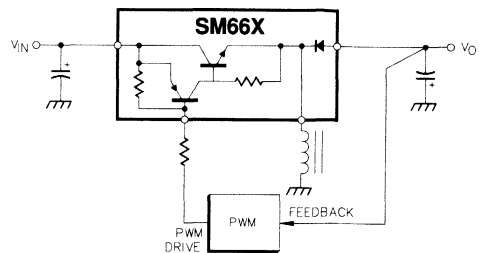


FIGURE 4 - NEGATIVE OUTPUT DOWN/UP (BUCK-BOOST) CONVERTER

# SM660/SM661/SM662/SM670/SM671/SM672

## APPLICATION CIRCUITS (continued)

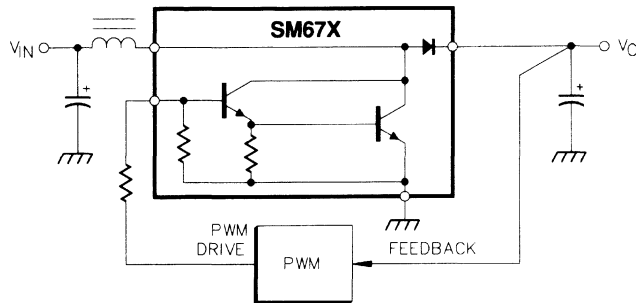


FIGURE 5 - STEP UP (BOOST) CONVERTER

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Note Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
4-PIN TO-66 METAL CAN R - PACKAGE	SM660R	0°C to 70°C	
	SM660HRR	-55°C to 125°C	
	SM661R	0°C to 70°C	
	SM661HRR	-55°C to 125°C	
	SM662R	0°C to 70°C	
	SM662HRR	-55°C to 125°C	
	SM670R	0°C to 70°C	
	SM670HRR	-55°C to 125°C	
	SM671R	0°C to 70°C	
	SM671HRR	-55°C to 125°C	
SM672R	0°C to 70°C		
SM672HRR	-55°C to 125°C		

- Note
1. All packages are viewed from the top.
  2. Case is electrically isolated.
  3. Consult factory for additional screening available.

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## SELECTION GUIDE MOTION CONTROL CIRCUITS

LINEAR INTEGRATED CIRCUITS

Device Type	Description	Typ. Application	I <sub>O(PK)</sub>	I <sub>O(CONT)</sub>	V <sub>C(MAX)</sub>	V <sub>CC(MAX)</sub>	Key Features	Pkgs.
SG1635/3635 SG1635A/3635A SG1650/3650	Half-bridge driver	<ul style="list-style-type: none"> <li>DC motor drivers</li> <li>Stepper motor drive</li> </ul>	5A	2A	35V 40V	35V 40V	<ul style="list-style-type: none"> <li>Single totem-pole output</li> <li>Internal clamp diodes</li> <li>Built-in thermal protection</li> <li>TTL input compatibility</li> </ul>	R, P
SG3645	Quad power driver	<ul style="list-style-type: none"> <li>DC motor drivers</li> <li>Stepper motor drive</li> <li>Lamp driver</li> <li>Relay driver</li> </ul>	3.5A	2.5A	60V	40V	<ul style="list-style-type: none"> <li>Four open collector outputs</li> <li>Internal clamp diodes</li> <li>Thermal shutdown protection</li> <li>TTL input compatibility</li> <li>Common enable pin</li> </ul>	W, DWW
SG3663	Dual solenoid motor driver	<ul style="list-style-type: none"> <li>DC motor drivers</li> <li>Stepper motor drive</li> <li>Solenoid motor drive</li> </ul>	3.5A	3.0A	50V	50V	<ul style="list-style-type: none"> <li>Dual uncommitted totem pole outputs</li> <li>Internal clamp diodes</li> <li>Thermal shutdown protection</li> <li>Current sense comparator with variable threshold and hysteresis</li> <li>Chop or non-chop load current control</li> </ul>	S, ST
SG3700	Dual hammer driver	<ul style="list-style-type: none"> <li>DC motor drivers</li> <li>Hammer coil drive in high speed printers</li> </ul>	1.5A	0.9A	5.25V	40V	<ul style="list-style-type: none"> <li>Dual open collector outputs</li> <li>Internal clamp diodes</li> <li>Thermal shutdown protection</li> <li>Internal op-amp to regulate output current</li> <li>Adjustable output current control</li> <li>Thermal shutdown indicator</li> <li>Logic control of input data</li> </ul>	N
SG1731/2731/3731	DC motor pulse-width modulator	<ul style="list-style-type: none"> <li>DC motor control</li> <li>Electronic micro-stepping of stepper motors</li> </ul>	400mA	200mA	±25V (50V)	±18V (36V)	<ul style="list-style-type: none"> <li>Dual uncommitted totem pole outputs</li> <li>Maximum frequency to 350KHz</li> <li>Adjustable deadband operation</li> <li>High slew rate op-amp</li> <li>Digital SHUTDOWN input</li> </ul>	J, N
SG1173/2173/3173 SG3172 SG3272	Power op-amp	<ul style="list-style-type: none"> <li>Linear DC motor</li> </ul>	5A 3A 1.5A	3.5A 2A 1A	50V 18V 18V		SEE OP-AMP SECTION	
SG2000/2800 Series	Darlington arrays	<ul style="list-style-type: none"> <li>Logic to power interface</li> <li>Lamp driver</li> <li>Motor driver</li> </ul>	0.6A	0.5A	50V & 95V		SEE POWER DRIVER & INTERFACE SECTION	
SG2064 thru 2077	Quad power Darlington arrays	<ul style="list-style-type: none"> <li>Relays</li> <li>Solenoids</li> <li>DC and stepper motor driver</li> <li>Display driver</li> </ul>	1.75A	1.5A	50V & 80V		SEE POWER DRIVER SECTION	

November 1988



# SG1635A/SG3635A, SG1635/SG3635, SG1650/SG3650

LINEAR INTEGRATED CIRCUITS

## 2A, HALF-BRIDGE DRIVER

### DESCRIPTION

The SG1635 and SG1650 are monolithic integrated circuits designed to interface low-level logic signals with high-current, inductive, or capacitive loads. These devices are particularly adept at high-speed pulse width modulation for motor drives or Class D audio amplifiers, and when used in pairs, they can provide full bridge drive for bi-directional control.

With TTL-compatible units, these devices will either source or sink up to 5A of peak current with interlock protection to insure that source and sink cannot be on simultaneously. Additional protection is provided by thermal shutdown of the source output if the chip temperature rises above 160°C. High speed internal commutating diodes are also included.

### FEATURES

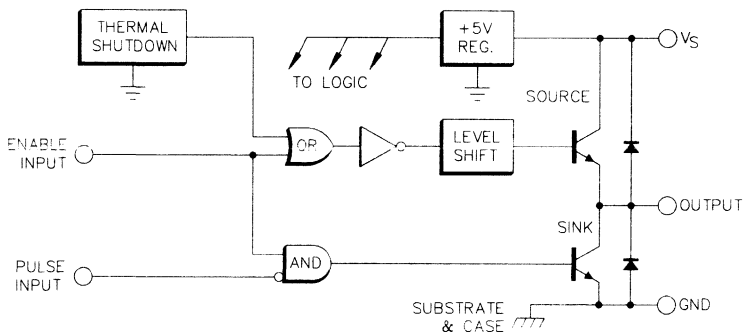
- Source or sink 5A peak
- Half-bridge with internal diodes
- TTL input compatibility
- Either dual- or tri-state output
- Direct PWM motor drive from microprocessor
- Built-in thermal protection
- SG3635P replaces UDN2935Z
- SG3650P replaces UDN2950Z and SN75605

### HIGH RELIABILITY FEATURES

- SG1635A/SG1635/SG1650

- Available to MIL-STD-883
- SG level "S" processing available

### BLOCK DIAGRAM - SG1635/1635A/3635/3635A

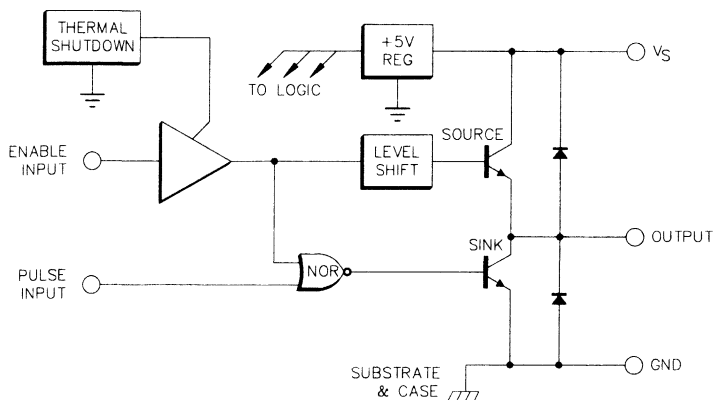


### TRUTH TABLE

Enable	Pulse	Output
0	0	High
0	1	High
1	0	Low
1	1	Off - High Z

1 = Open or High

### BLOCK DIAGRAM - SG1650/3650



### TRUTH TABLE

Enable	Pulse	Output
0	0	Low
0	1	Off - High Z
1	0	Low
1	1	High

1 = Open or High

# SG1635A/SG3635A, SG1635/SG3635, SG1650/SG3650

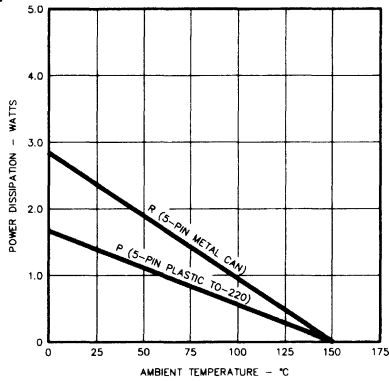
## ABSOLUTE MAXIMUM RATINGS (Note 1)

<b>Supply Voltage (<math>V_s</math>)</b>		<b>Source/Sink Output Current</b>	
SG1635/SG3635, SG1650/SG3650 .....	40V	Continuous .....	3A
SG1635A/SG3635A .....	45V	Peak .....	5A
<b>Input Voltage</b>		<b>Operating Junction Temperature</b>	
Enable and Pulse .....	7V	Hermetic (R - Package) .....	175°C
		Plastic (P - Package) .....	150°C
		Storage Temperature Range .....	-65°C to 150°C
		Lead Temperature (Soldering, 10 Seconds) .....	300°C

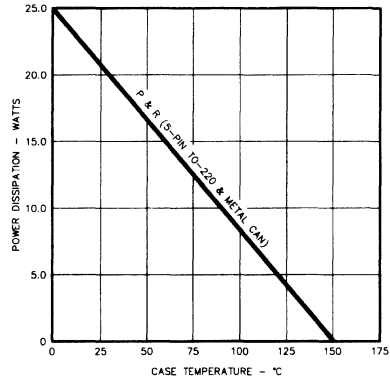
Note 1. Values beyond which damage may occur.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

<b>Supply Voltage (<math>V_s</math>)</b>		<b>Source/Sink Output Current</b>	
SG1635/SG3635, SG1650/SG3650 .....	8V to 35V	Continuous .....	2A
SG1635A/SG3635A .....	8V to 40V	Peak .....	3A
		<b>Operating Ambient Temperature Range</b>	
		SG1635/SG1635A, SG1650 .....	-55°C to 125°C
		SG3635/SG3635A, SG3650 .....	0°C to 70°C

Note 2. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

### SG1635/SG1635A and SG3635/SG3635A

(Unless otherwise specified, these specifications apply at  $+V_s = 24V$  and over  $T_A = T_{MIN}$  to  $T_{MAX}$ .)

Parameter	Test Conditions	SG1635/1635A SG3635/3635A			Units
		Min.	Typ.	Max.	
<b>Static Characteristics</b>					
Logic 1 Input Voltage		2.0			V
Logic 0 Input Voltage			0.8		V
Input High Current	$V_{PULSE} = V_{ENABLE} = 4.5V$		200		mA
Input Low Current	$V_{PULSE} = V_{ENABLE} = 0V$		-3.2		$\mu A$
Output Leakage	$V_{PULSE} = V_{ENABLE} = 2.0V$			50	mA
	$V_{OUT} = 24V$ $V_{OUT} = 0V$			40	$\mu A$
Source Saturation Voltage	$V_{PULSE} = 2.0V, V_{ENABLE} = 0.8V, I_{OUT} = -2A$	2.0	3.0		V
Sink Saturation Voltage	$V_{PULSE} = 0.8V, V_{ENABLE} = 2.0V, I_{OUT} = 2A$		3.0		V
Diode Forward Voltage	$I_{DIODE} = \pm 2A$	2.0	3.0		V
Supply Current	$V_s = 35V$ (SG1635/3635); $V_s = 40V$ (SG1635A/3635A)				
	$V_{PULSE} = 2.0V, V_{ENABLE} = 0.8V$		25		mA
	$V_{PULSE} = 0.8V, V_{ENABLE} = 2.0V$		70		mA



# SG1635A/SG3635A, SG1635/SG3635, SG1650/SG3650

## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Definition	SG1635/1635A SG3635/3635A			Units
		Min.	Typ.	Max.	
<b>Dynamic Characteristics</b> (Notes 3 and 4)					
Pulse Propagation Delay	Turn-On Delay (TPDHL)		50		ns
	Turn-Off Delay (TPDLH)		100		ns
Pulse Transition Time	Turn-On (TPTHL)		200		ns
	Turn-Off (TPTLH)		200		ns
Enable Propagation Delay	Turn-On Delay (TEDLH)		200		ns
	Turn-Off Delay (TEDHL)		100		ns
Enable Transition Time	Turn-On (TETLH)		100		ns
	Turn-Off (TETHL)		100		ns

Note 3.  $T_J = 25^\circ\text{C}$ .

Note 4. Although these parameters are guaranteed, they are not tested in production.

## SG1650/SG1640A

(Unless otherwise specified, these specifications apply at  $+V_S = 24\text{V}$  and over  $T_A = T_{\text{MIN}}$  to  $T_{\text{MAX}}$ .)

Parameter	Test Conditions	SG1650 SG3650			Units
		Min.	Typ.	Max.	
<b>Static Characteristics</b>					
Logic 1 Input Voltage		2.0			V
Logic 0 Input Voltage				0.8	V
Input High Current	$V_{\text{PULSE}} = V_{\text{ENABLE}} = 4.5\text{V}$			200	mA
Input Low Current	$V_{\text{PULSE}} = V_{\text{ENABLE}} = 0\text{V}$			-3.2	$\mu\text{A}$
Output Leakage	$V_{\text{PULSE}} = 2.0\text{V}, V_{\text{ENABLE}} = 0.8\text{V}$				
	$V_{\text{OUT}} = 24\text{V}$			500	mA
Source Saturation Voltage	$V_{\text{OUT}} = 0\text{V}$			40	$\mu\text{A}$
	$V_{\text{ENABLE}} = 0.8\text{V}, I_{\text{OUT}} = -2\text{A}$	2.0	3.0		V
Sink Saturation Voltage	$V_{\text{PULSE}} = V_{\text{ENABLE}} = 0.8\text{V}, I_{\text{OUT}} = 2\text{A}$	2.0	3.0		V
Diode Forward Voltage	$I_{\text{DIODE}} = \pm 2\text{A}$	2.0	3.0		V
Supply Current	$V_S = 35\text{V}$				
	$V_{\text{PULSE}} = 2.0\text{V}, V_{\text{ENABLE}} = 0.8\text{V}$			25	mA
	$V_{\text{PULSE}} = 0.8\text{V}, V_{\text{ENABLE}} = 2.0\text{V}$			70	mA

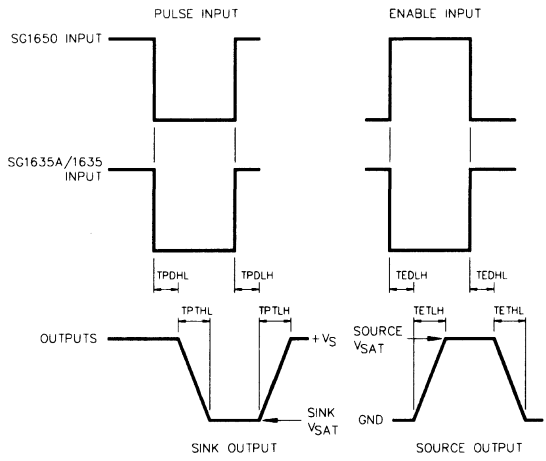
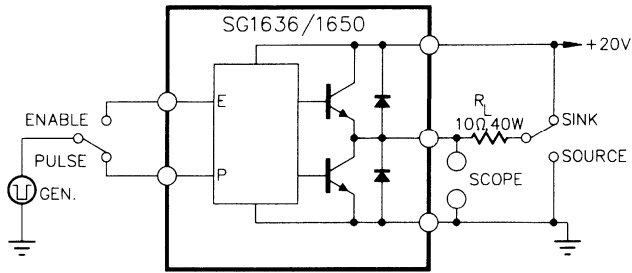
Parameter	Definition	SG1635/1635A SG3635/3635A			Units
		Min.	Typ.	Max.	
<b>Dynamic Characteristics</b> (Notes 5 and 6)					
Pulse Propagation Delay	Turn-On Delay (TPDHL)		300		ns
	Turn-Off Delay (TPDLH)		300		ns
Enable Propagation Delay	Turn-On Delay (TEDLH)		1		$\mu\text{s}$
	Turn-Off Delay (TEDHL)		1		$\mu\text{s}$

Note 5.  $T_J = 25^\circ\text{C}$ .

Note 6. Although these parameters are guaranteed, they are not tested in production.

# SG1635A/SG3635A, SG1635/SG3635, SG1650/SG3650

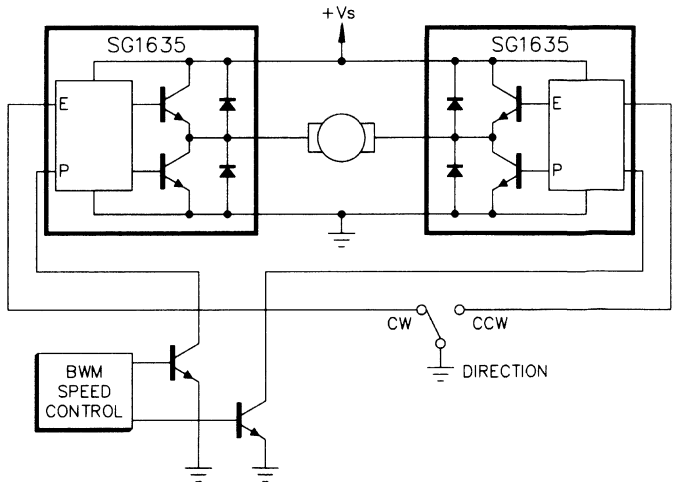
**AC TEST CIRCUIT AND SWITCHING TIME WAVEFORMS - FIGURE 1**



## APPLICATION INFORMATION

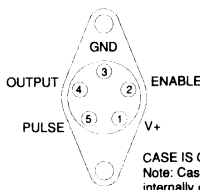
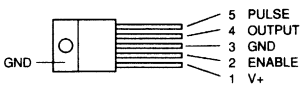
### TYPICAL MOTOR DRIVE APPLICATION

Two SG1635's form a full bridge motor drive circuit with the appropriate Enable Input, determining motor direction, and a PWM signal into the Pulse Inputs, determining speed. Because of the internal Enable interlock, both Pulse Inputs may be connected together to a single-ended PWM signal.



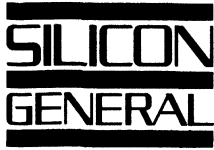
## SG1635A/SG3635A, SG1635/SG3635, SG1650/SG3650

### CONNECTION DIAGRAMS/ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
5-PIN TO-66 METAL CAN R - PACKAGE	SG1635AR/883B	-55°C to 125°C	 <p>CASE IS GROUND Note: Case and tab are internally connected to substrate ground.</p>
	SG1635AR	-55°C to 125°C	
	SG3635AR	0°C to 70°C	
	SG1635R/883B	-55°C to 125°C	
	SG1635R	-55°C to 125°C	
	SG3635R	0°C to 70°C	
	SG1650R/883B	-55°C to 125°C	
	SG1650R	-55°C to 125°C	
5-PIN TO-220 PLASTIC P - PACKAGE	SG3635AP	0°C to 70°C	 <p>Case + Tab are internally connected</p>
	SG3635P	0°C to 70°C	
	SG3650AP	0°C to 70°C	
	SG3650P	0°C to 70°C	

- Notes: 1. Contact factory for JAN and DESC part availability.  
2. All parts are viewed from the top.





DC MOTOR PULSE WIDTH MODULATOR

DESCRIPTION

The SG1731 is a pulse width modulator circuit designed specifically for DC motor control. It provides a bi-directional pulse train output in response to the magnitude and polarity of an analog error signal input. The device is useful as the control element in motor-driven servo systems for precision positioning and speed control, as well as in audio modulators and amplifiers using carrier frequencies to 350 KHz.

The circuit contains a triangle waveform oscillator, a wideband operational amplifier for error voltage generation, a summing/scaling network for level-shifting the triangle waveform, externally programmable PWM comparators and dual  $\pm 100\text{mA}$ ,  $\pm 22\text{V}$  totem pole drivers with commutation diodes for full bridge output. A SHUTDOWN terminal forces the drivers into a floating high-impedance state when driven LOW. Supply voltage to the control circuitry and to the output drivers may be from either dual positive and negative supplies, or single-ended.

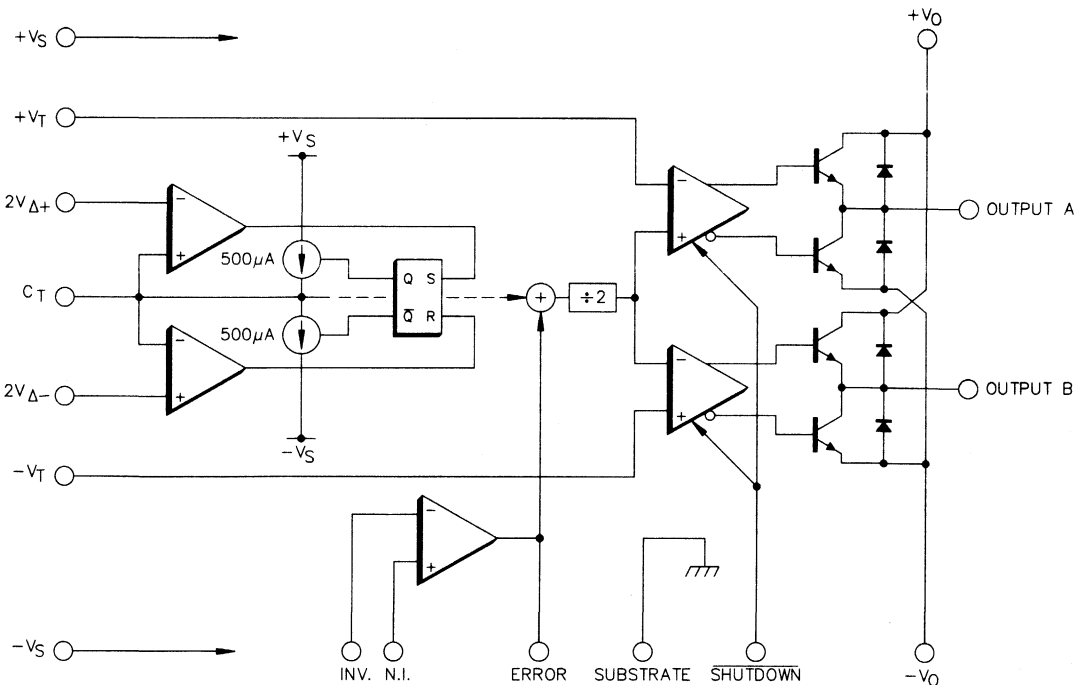
FEATURES

- $\pm 3.5\text{V}$  to  $\pm 15\text{V}$  control supply
- $\pm 2.5\text{V}$  to  $\pm 22\text{V}$  driver supply
- Dual 100mA source/sink output drivers
- 5KHz to 350KHz oscillator range
- High slew rate error amplifier
- Adjustable deadband operation
- Digital SHUTDOWN input

HIGH RELIABILITY FEATURES - SG1731

- ◆ Available to MIL-STD-883
- ◆ SG level "S" processing available

BLOCK DIAGRAM

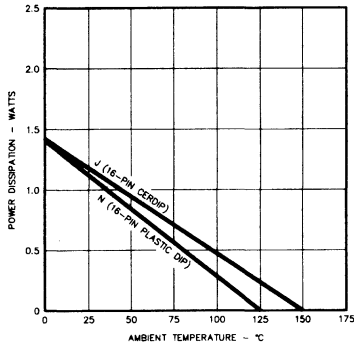


**ABSOLUTE MAXIMUM RATINGS** (Note1)

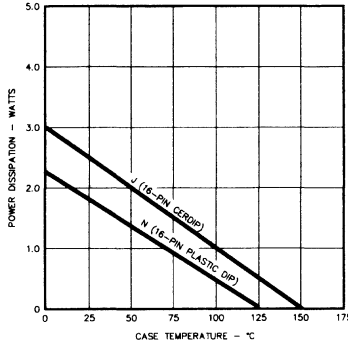
Supply Voltage (+V <sub>S</sub> ) .....	±18V	Output Driver Diode Current (continuous) .....	200mA
Analog Inputs .....	±V <sub>S</sub>	Output Driver Diode Current (peak, 500ns) .....	400mA
Digital Inputs (SHUTDOWN) .....	-V <sub>S</sub> -0.3V to -V <sub>S</sub> +18V	Operating Junction Temperature	
Output Driver Supply Voltage (±V <sub>O</sub> ) .....	±25V	Hermetic (J - Package) .....	175°C
Source/Sink Output Current (continuous) .....	200mA	Plastic (N - Package) .....	150°C
Source/Sink Output Current (peak, 500ns) .....	400mA	Storage Temperature Range .....	-65°C to 150°C
Note 1. Values beyond which damage may occur.		Lead Temperature (Soldering, 10 Seconds) .....	300°C

**RECOMMENDED OPERATING CONDITIONS** (Note 2)

**THERMAL**



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

**ELECTRICAL**

Supply Voltage Range (+V <sub>S</sub> ) .....	±3.5V to ±15V	Oscillator Frequency Range .....	10Hz to 350KHz
Error Amp Common-Mode Range .....	-V <sub>S</sub> + 3V to V <sub>S</sub> - 3V	Oscillator Voltage (Peak-to-Peak) .....	1V to 10V
Output Driver Supply Voltage Range .....	±2.5V to ±22V	Oscillator Timing Capacitor (C <sub>T</sub> ) .....	200pF to 2.5μF
Source/Sink Output Current (continuous) .....	100mA	Operating Ambient Temperature Range	
Source/Sink Output Current (peak, 500ns) .....	200mA	SG1731 .....	-55°C to 125°C
Output Driver Diode Current (continuous) .....	100mA	SG2731 .....	-25°C to 85°C
Output Driver Diode Current (peak, 500ns) .....	200mA	SG3731 .....	0°C to 70°C

Note 2. Range over which the device is functional and parameter limits are guaranteed.

**ELECTRICAL SPECIFICATIONS**

(Unless otherwise specified, these specifications apply over recommended operating ambient temperature range, V<sub>S</sub> = ±15V, and V<sub>O</sub> = ±5V.)

Parameter	Test Conditions	SG1731/2731/3731			Units
		Min.	Typ.	Max.	
<b>Oscillator Section</b>					
C <sub>T</sub> Charging Current	T <sub>A</sub> = 25°C	450	500	550	μA
2VΔ± Input Bias Current	T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub> V <sub>CM</sub> = ±5V	400		600	μA
Initial Oscillator Frequency	C <sub>T</sub> = 1000pF, 2VΔ± = ±5V, T <sub>A</sub> = 25°C	22.5	25.0	27.5	KHz
Temperature Stability (Note 3)	C <sub>T</sub> = 1000pF, 2VΔ± = ±5V			10	%
<b>Error Amplifier Section (Note 5)</b>					
Input Offset Voltage				10	mV
Input Bias Current				3	μA
Input Offset Current				600	nA
Open Loop Voltage Gain	R <sub>L</sub> = 2KΩ	70			dB
Output Voltage Swing	R <sub>L</sub> = 2KΩ	+10			V
Common-Mode Rejection Ratio		70			dB
Slew Rate (Notes 3 and 4)	T <sub>A</sub> = 25°C	5	10		V/μs
Unity Gain Bandwidth (Notes 3 and 4)	T <sub>A</sub> = 25°C	0.7	1		MHz
<b>PWM Comparators</b>					
Input Bias Current	±V <sub>T</sub> = ±3V			6	μA

## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG1731/2731/3731			Units
		Min.	Typ.	Max.	
<b>SHUTDOWN Section</b>					
Logic Threshold	$-V_S = -3.5V \text{ to } -15V$	$V_{S+0.8}$		$V_S - 2.0$	V
SHUTDOWN HIGH Current	$V_{SHUTDOWN} = -V_S + 2.4V$			400	$\mu A$
SHUTDOWN LOW Current	$V_{SHUTDOWN} = -V_S$			-1.0	mA
<b>Output Drivers (Each Output)</b>					
HIGH Output Voltage	$I_{SOURCE} = 20mA$	19.2			V
	$I_{SOURCE} = 100mA$	19.0			V
LOW Output Voltage	$I_{SINK} = 20mA$			-19.2	V
	$I_{SINK} = 100mA$			-19.0	V
Driver Risettime	$C_L = 1000pF$			300	ns
Driver Falltime	$C_L = 1000pF$			300	ns
<b>Total Supply Current</b>					
$V_S$ Supply Current	$V_{SHUTDOWN} = -V_S + 0.8V$			14	mA
$V_O$ Supply Current	$V_{SHUTDOWN} = -V_S + 0.8V$			6	mA

Note 3. These parameters, although guaranteed, are not tested in production.  
 Note 4. Unity Gain Inverting 10K $\Omega$  Feedback Resistance.

Note 5.  $V_{CM} = \pm 12V$ .

## APPLICATION INFORMATION

### SUPPLY VOLTAGE

The SG1731 requires a supply voltage for the control circuitry ( $V_S$ ) and for the power output drivers ( $V_O$ ). Each supply may be either balanced positive and negative with respect to ground, or single-ended. The only restrictions are:

1. The voltage between  $+V_S$  and  $-V_S$  must be at least 7.0V; but no more than 44V.
2. The voltage between  $+V_O$  and  $-V_O$  must be at least 5.0V; but no more than 44V.
3.  $+V_O$  must be at least 5V more positive than  $-V_S$ . This eliminates the combination of a single-ended positive control supply with a single-ended negative driver supply.

### SUBSTRATE CONNECTION

The substrate connection (Pin 10) must always be connected to either  $-V_S$  or  $-V_O$ , whichever is more negative. The substrate must also be well bypassed to ground with a high quality capacitor.

### OSCILLATOR

The triangle oscillator consists of two voltage comparators, a set/reset flip-flop, a bi-directional 500 $\mu A$  current source, and an external timing capacitor  $C_T$ . A positive reference voltage ( $2V_{\Delta+}$ ) applied to Pin 2 determines the positive peak value of the triangle, and a negative reference voltage ( $2V_{\Delta-}$ ) at Pin 7 sets the negative peak value of the triangle waveform.

Since the value of the internal current source is fixed at a nominal  $\pm 500\mu A$ , the oscillator period is a function of the selected peak-to-peak voltage excursion and the value of  $C_T$ . The theoretical expression for the oscillator period is:

$$T_{osc} = \frac{2C_T dV}{5 \times 10^{-4}} \quad (\text{Eq. 1})$$

where  $C_T$  is the timing capacitor in Farads and  $dV$  is  $V_{osc}$  in Volts peak-to-peak.

As a design aid, the solutions to Equation 1 over the recommended range of  $T_{osc}$  and  $V_{osc}$  are given in graphic form in Figure 1. The lower limit on  $T_{osc}$  is 1.85 $\mu s$ , corresponding to a maximum frequency of 350 KHz. The maximum value of  $V_{osc}$ , ( $2V_{\Delta+}$ ) - ( $2V_{\Delta-}$ ), is 10V peak-to-peak for linear waveforms.

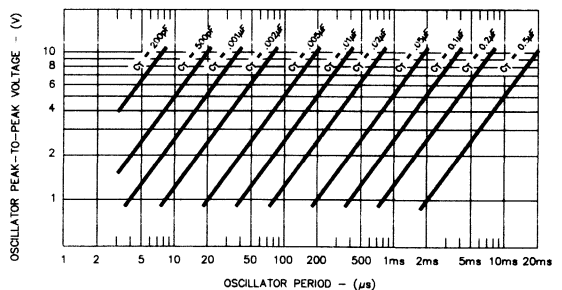


FIGURE 1 - SG1731 OSCILLATOR PERIOD VS.  $V_{osc}$  AND  $C_T$

### ERROR AMPLIFIER

The error amplifier of the SG1731 is a conventional internally-compensated operational amplifier with low output impedance. All of the usual feedback and frequency compensation techniques may be used to control the closed-loop gain characteristics. The control supply voltage  $\pm V_S$  will determine the input common mode range and output voltage swing; both will extend to within 3V of the  $V_S$  supply.

### PULSE WIDTH MODULATION

Pulse width modulation occurs by comparing the triangle waveform to a fixed upper ( $+V_T$ ) and lower ( $-V_T$ ) threshold voltage. A crossing above the upper threshold causes Output A to switch to the HIGH state, and a crossing below the lower threshold causes Output B to switch to the HIGH state.

**APPLICATION INFORMATION** (continued)

If  $\pm V_S$  is less than  $\pm 8V$  then  $\pm V_T$  can be obtained with resistors from  $\pm V_S$ . If  $\pm V_S$  is greater than  $\pm 8V$  use zeners.

Threshold crossings are generated by shifting the triangle waveform up and down with the error voltage (Pin 5). A positive error voltage will result in a pulse width modulated output at Driver A (Pin 13). Similarly, a negative error voltage produces a pulse train at Driver B (Pin 12). Figure 2 illustrates this process for the case where  $V_{\Delta+}$  is greater than  $V_T$ .

It is important to note that the triangle shifting circuit also attenuates the waveform seen at  $C_T$  by a factor of 2. This results in a waveform at the PWM comparators with a positive peak of  $V_{\Delta+}$  and a negative peak of  $V_{\Delta-}$ , and must be taken into account when selecting the values for  $+V_T$  and  $-V_T$ .

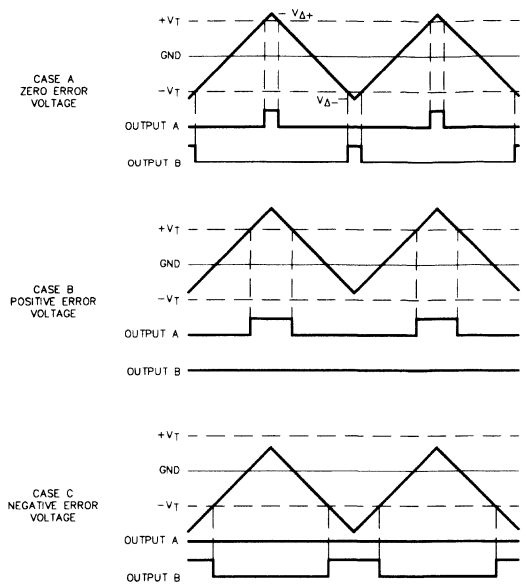


FIGURE 2 - PULSE WIDTH MODULATION WITH NO DEADBAND

**APPLICATION CIRCUITS**

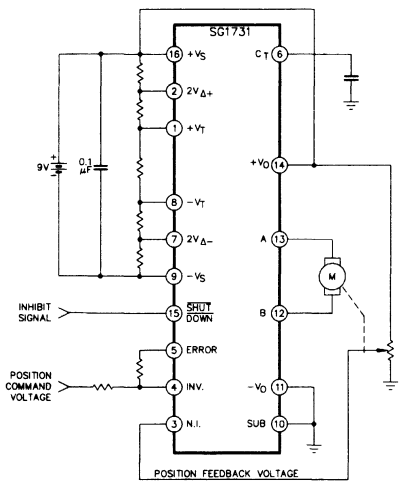


FIGURE 3

In this simple battery-powered position servo, the control supply and driver supply are both single-ended positive with respect to ground.

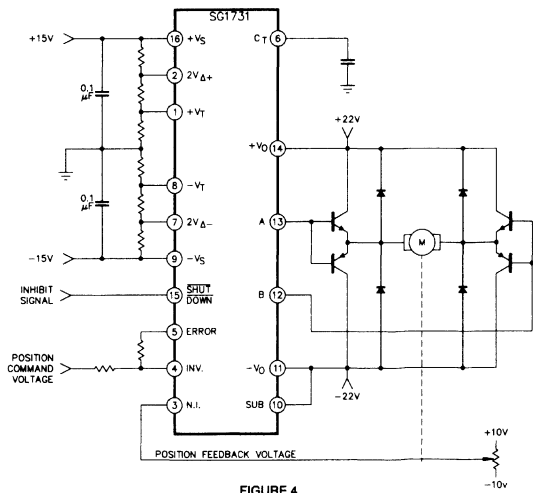


FIGURE 4

A high torque position servo is obtained by buffering the output drivers to obtain higher output current.



APPLICATION CIRCUITS

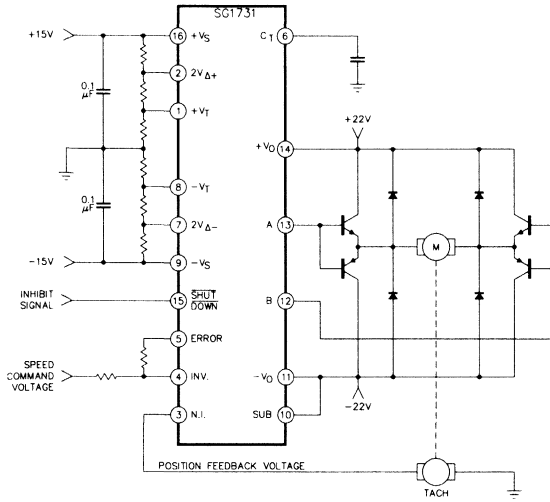


FIGURE 5

Bi-directional speed control results when the feedback voltage transducer is a tachometer.

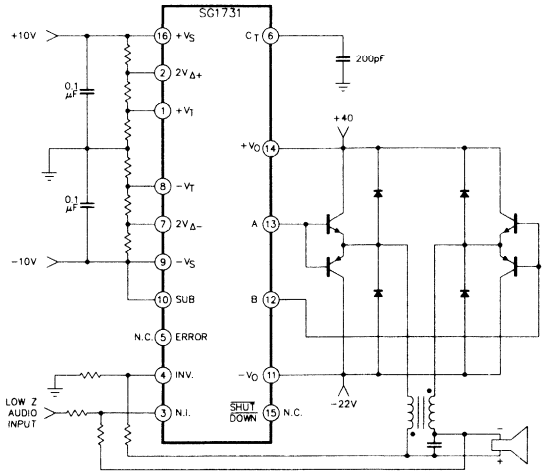


FIGURE 6

The two-quadrant transfer function of the SG1731 is ideal for pulse width modulated audio power amplifiers.

CONNECTION DIAGRAMS & ORDERING INFORMATION (See Note Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
16-PIN CERAMIC DIP J - PACKAGE	SG1731J/883B	-55°C to 125°C	
	SG1731J	-55°C to 125°C	
	SG2731J	-25°C to 85°C	
	SG3731J	0°C to 65°C	
16-PIN CERAMIC DIP N - PACKAGE	SG2731N	-25°C to 85°C	
	SG3731N	0°C to 65°C	

Note 1. All packages are viewed from the top.

Note 2. Contact factory for flatpack and leadless chip carrier availability.



**QUAD 2.5 AMP POWER DRIVER**

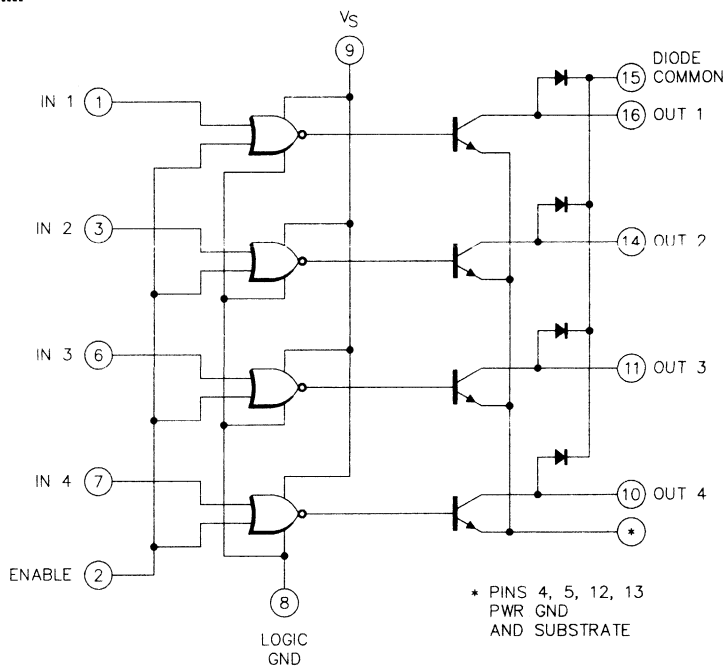
**DESCRIPTION**

The SG3645 is a quad high voltage, high current driver, ideal for driving stepper motors. Each channel consists of TTL compatible inputs and open collector-Darlington outputs with integral transient suppression diodes. A common enable is provided to disable or enable all four outputs simultaneously. The output stages are capable of sinking 2.5 Amps with breakdown voltages in excess of 60 volts. Thermal shutdown is provided to disable the outputs if excessive die heating occurs. The SG3645 is specified for operation over the junction temperature range of 0°C to 125°C and is available in the thermally efficient plastic Batwing package.

**FEATURES**

- Peak output currents to 3.5A
- Output voltages to 60V
- Integral clamp diodes
- Common enable pin
- TTL compatible inputs
- Thermal shutdown protection
- Available in 16 pin Batwing DIP and a 20 pin Batwing SOIC

**BLOCK DIAGRAM**



**TRUTH TABLE**

INPUT	ENABLE	OUTPUT
L	L	ON
L	H	OFF
H	L	OFF
H	H	OFF

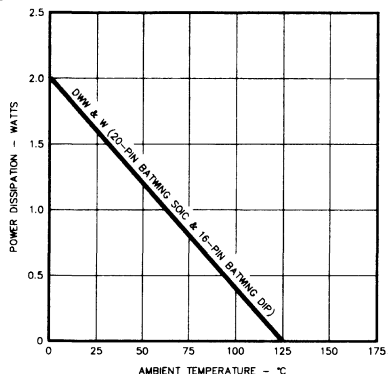
**ABSOLUTE MAXIMUM RATINGS** (Note 1)

Output Voltage .....	70V	Logic Input Voltage .....	7V
Output Current (Each Output)		Logic Supply to Substrate Voltage .....	40V
Continuous (Note 2) .....	3.0A	Operating Junction Temperature	
Peak (1% Duty Cycle, $t_{ON} = 10ms$ ) .....	4.0A	Plastic (W, DWW-Package).....	150°C
Supply Voltage ( $V_S$ ) .....	25V	Storage Temperature Range .....	-65°C to 150°C
		Lead Temperature (Soldering, 10 Seconds) .....	300°C

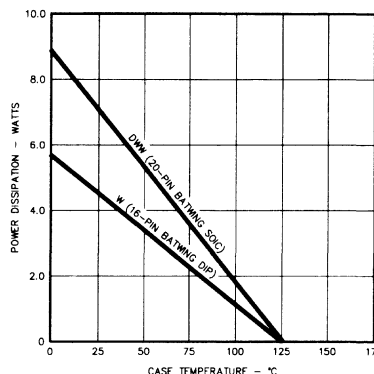
Note 1. Exceeding these ratings could cause damage to the device. All currents are positive into the specified terminal.  
 Note 2. Maximum continuous output current is limited by the thermal resistance of the package-heat sink combination.

**RECOMMENDED OPERATING CONDITIONS** (Note 3)

**THERMAL**



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

**ELECTRICAL**

Supply Voltage ( $V_S$ ) .....	4.5V to 20V	Output Current (Each Output)	
Output Voltage .....	60V	Continuous .....	2.5A
Logic Supply to Substrate Voltage .....	25V	Peak (1% Duty Cycle, $t_{ON} = 10ms$ ) .....	3.5A
		Operating Junction Temperature Range	
		SG3645 .....	0°C to 125°C

Note 3. Range over which the device is functional.

**ELECTRICAL SPECIFICATIONS** (Static and Dynamic)

(Unless otherwise stated, these specifications apply for 0°C ≤  $T_J$  ≤ 125°C,  $V_S = 5V$ . (Note 4))

Parameter	Test Conditions	SG3173			Units
		Min.	Typ.	Max.	
Logic 1 Input Voltage ( $V_{IH}$ )		2			V
Logic 0 Input Voltage ( $V_{IL}$ )				0.8	V
Supply Current ( $I_S$ - OFF)	$V_{IN} = V_{EN} = 5V, V_S = 20V$		8	15	mA
( $I_S$ - ON)	$V_{IN} = V_{EN} = 0V, V_S = 20V$		21	35	mA
Input High Current ( $I_{INH}$ )	$V_{IN} = 5V; V_S = 20V$			10	μA
( $I_{EN(H)}$ )	$V_{EN} = 5V; V_S = 20V$			10	μA
Input Low Current ( $I_{INL}$ )	$V_{IN} = 0V; V_S = 20V$		-50	-250	μA
( $I_{EN(L)}$ )	$V_{EN} = 0V; V_S = 20V$		-70	-250	μA
Output Saturation Voltage ( $V_{SAT}$ )	$V_{IN} = V_{EN} = 0.8V; V_S = 4.5V$				
(Note 5)	$I_{OUT} = 1.5A$		1.2	1.75	V
	$I_{OUT} = 2.5A$		1.8	2.65	V
Output Leakage Current ( $I_{CEX}$ )	(Per Truth Table) $V_S = 20V; V_{CEX} = 60V$			25	μA
	$T_J = 25°C$			250	μA
	$T_J = 0°C$ to 125°C				
Diode Forward Voltage ( $V_F$ )	$I_F = 1.5A$		1.5	2.1	V
(Note 5)	$I_C = 2.5A$		1.8	2.65	V

**ELECTRICAL SPECIFICATIONS** (continued)

Parameter	Test Conditions	SG3663			Units
		Min.	Typ.	Max.	
Diode Leakage Current ( $I_R$ )	$V_R = 60V$ $T_J = 25^\circ C$ $T_J = 125^\circ C$			25	$\mu A$
				250	$\mu A$
Input/Enable, Turn-on Delay ( $t_{ON}$ ) (Note 6)	$T_J = 25^\circ C$ ; $V_S = 5V$ , $I_{OUT} = 1.5A$ , $V_{OUT} = 45V$ , Duty Cycle = 10%		500	1500	ns
Input/Enable, Turn-off Delay ( $t_{OFF}$ ) (Note 6)	$T_J = 25^\circ C$ ; $V_S = 5V$ , $I_{OUT} = 1.5A$ , $V_{OUT} = 45V$ , Duty Cycle = 10%		500	1500	ns
Thermal Shutdown ( $T_{TH}$ ) (Note 6)	Measured at Junction Temperature	125	150		$^\circ C$

Note 4. Although device performance is guaranteed over the recommended junction temperature range, testing is not performed at the temperature extremes.  
 Note 5. These parameters are tested using pulse techniques to minimize device heating.  
 Note 6. These parameters, although guaranteed over the recommended operating conditions, are not tested in production.

**CHARACTERISTIC CURVES**

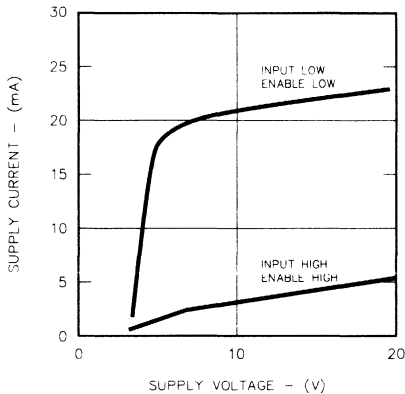


FIGURE 1. SUPPLY CURRENT

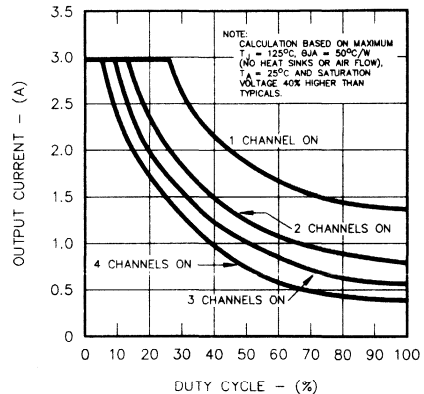


FIGURE 2. RECOMMENDED MAXIMUM PEAK CURRENT VS. DUTY CYCLE

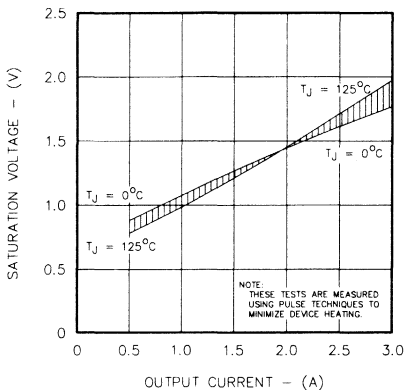


FIGURE 3. SATURATION VOLTAGE VS. OUTPUT CURRENT

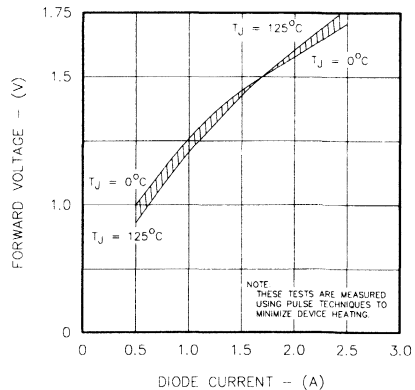


FIGURE 4. DIODE FORWARD VOLTAGE VS. DIODE CURRENT

APPLICATION CIRCUITS

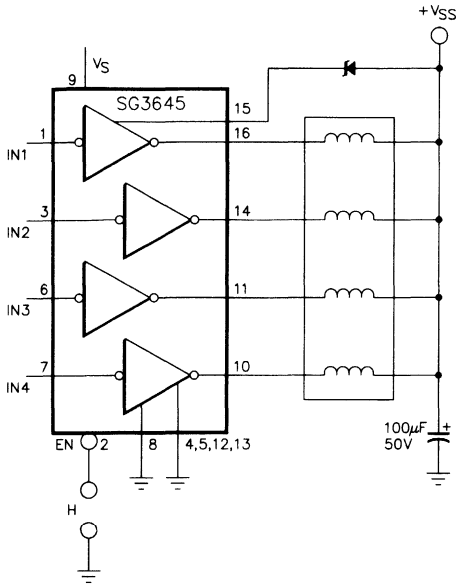
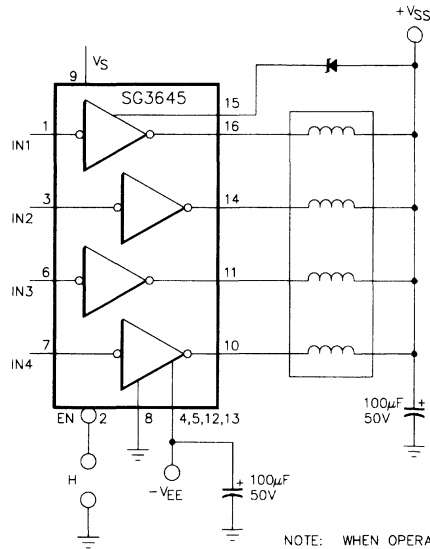


FIGURE 5 - POSITIVE SUPPLY



NOTE: WHEN OPERATING USING A SPLIT SUPPLY, INSURE THAT THE LOGIC GROUND TO NEGATIVE SUPPLY DOES NOT EXCEED 25V.

FIGURE 6 - SPLIT SUPPLY

CONNECTION DIAGRAMS & ORDERING INFORMATION (See Note Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
16-PIN PLASTIC BATWING W - PACKAGE	SG3645W	0°C to 70°C	
20-PIN PLASTIC BATWING S.O.I.C. DWW - PACKAGE	SG3645DWW	0°C to 70°C	

Note 1. All parts are viewed from the top.

## DUAL SOLENOID / MOTOR DRIVER

### DESCRIPTION

The SG3663 is a dual high-voltage, high-current monolithic I.C. recommended for driving solenoids and stepper motors. Each output stage contains sink/source drivers rated to  $\pm 3.5A$  peak currents with breakdowns in excess of 50V. Internal suppression diodes provide protection when switching inductive loads. The output stage can be configured to drive two separate loads or a single load in an H-bridge configuration.

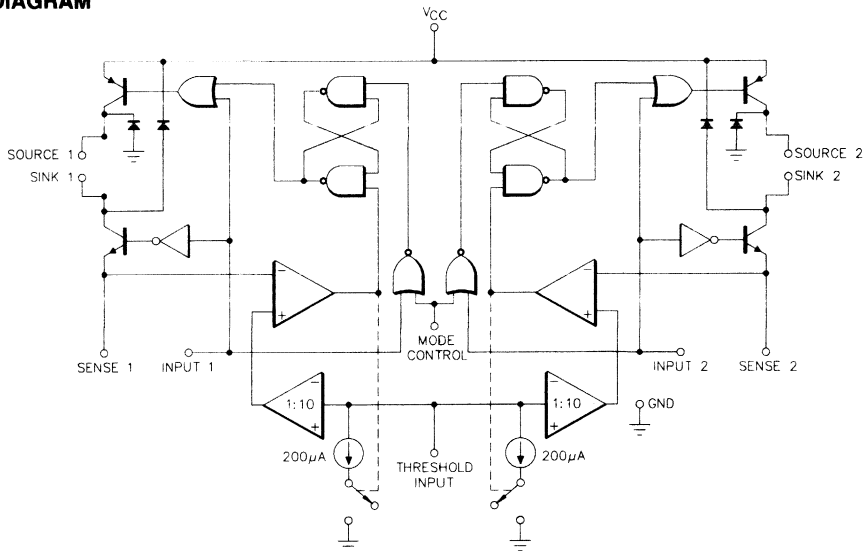
The SG3663 offers load current control through the implementation of an internal current sense comparator to control the high side driver. Peak and average currents are set by controlling the threshold voltage on the sense comparator. A mode select pin determines if the SG3663 is operating in the chop or non-chop mode.

The SG3663 is available in two types of power SIP and is rated to junction temperatures of 0°C to 125°C.

### FEATURES

- Dual outputs rated at  $\pm 3.5A$  peak current
- Chop or non-chop load current control
- Current sense comparator with variable threshold and hysteresis
- Internal clamp diodes for transient suppression
- Single supply operation (8V to 50V)
- Thermal shutdown protection
- Available in two different power SIP's rated at  $\theta_{jc} < 2^\circ C/W$

### BLOCK DIAGRAM



### TRUTH TABLE

INPUT	MODE CONTROL	$V_{SENSE}$	SOURCE DRIVER	SINK DRIVER
0	0 (Non-chop)	$< V_{TH} / 10$	ON	ON
0	0 (Non-chop)	$> V_{TH} / 10$	OFF	ON
0	1 (Chop)	$< V_{TH} / 10$	ON	ON
0	1 (Chop)	$> V_{TH} / 10$	OFF	ON
1	DC	DC	OFF	OFF

DC = Don't care

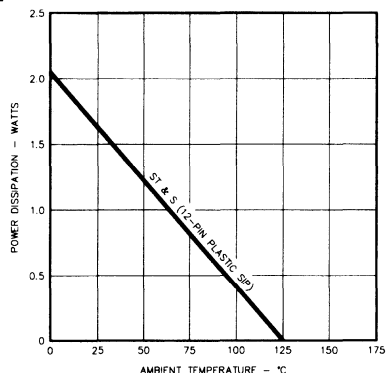
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage ( $V_{CC}$ ) .....	55V	Operating Junction Temperature .....	150°C
Logic Input Voltage .....	7V	Storage Temperature Range .....	-65°C to 150°C
Threshold Input Voltage ( $V_{Th}$ ) .....	5V	Lead Temperature (Soldering, 10 Seconds) .....	300°C
Source/Sink Output Current (Each Output):			
Continuous .....	•3.5A		
Peak .....	•4.4A		

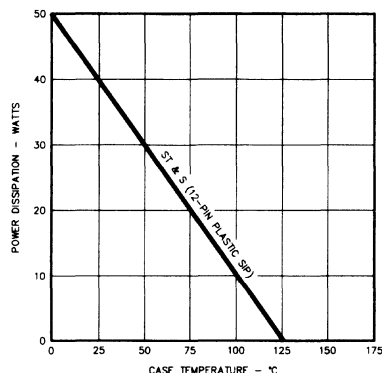
Note 1. Exceeding these ratings could cause damage to the device. All currents are positive into the specified terminal.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Supply Voltage ( $V_{CC}$ ) .....	8V to 50V	Threshold Input Voltage ( $V_{Th}$ ) .....	0.6V to 5.0V
Source/Sink Output Current (Each Output):		Junction Temperature Range ( $T_J$ ) .....	0°C to 125°C
Continuous .....	•3.0A	Ambient Temperature Range ( $T_A$ ) .....	0°C to 70°C
Peak .....	•3.5A		

Note 2. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise stated, these specifications apply for  $T_J = 25^\circ\text{C}$ ,  $V_{CC} = 50\text{V}$ ,  $R_{SENSE} = 0.1\Omega$ .)

Parameter	Test Conditions	SG3173			Units
		Min.	Typ.	Max.	
Supply Current ( $I_{CC(ON)}$ )	$V_{IN} = V_{MODE} = 0\text{V}$ , $I_{OUT} = 0\text{A}$		12	25	mA
( $I_{CC(OFF)}$ )	$V_{IN} = V_{MODE} = 2.7\text{V}$		12	25	mA
Logic 1 Input Voltage ( $V_{IH}$ )	Input / Mode Control	2.0			V
Logic 0 Input Voltage ( $V_{IL}$ )	Input / Mode Control			0.8	V
Logic 1 Input Current ( $I_{IH}$ )	$V_{IN} = V_{MODE} = 2.4\text{V}$			100	$\mu\text{A}$
Logic 0 Input Current ( $I_{IL}$ )	$V_{IN} = V_{MODE} = 0.4\text{V}$			-1.0	mA
Threshold Input Current ( $I_{TH(I)}$ )	$V_{TH} = 0.6\text{V to } 5.0\text{V}$ , $V_{TH} \geq V_{SENSE} \times 10$			-100	$\mu\text{A}$
Threshold Hysteresis Current ( $I_{HYS}$ )	$V_{TH} = 0.6\text{V to } 5.0\text{V}$ , $V_{TH} \geq V_{SENSE} \times 10$	140	200	260	$\mu\text{A}$
Source Output Saturation Voltage ( $V_{SAT}$ ) (Note 3)	$V_{IN} = 0\text{V}$ , $I_{OUT} = -2\text{A}$		1.85	2.2	V
( $V_{SAT}$ ) (Note 3)	$V_{IN} = 0\text{V}$ , $I_{OUT} = -3.5\text{A}$		2.0	2.6	V
Sink Output Saturation Voltage ( $V_{SAT}$ ) (Note 3)	$V_{IN} = 0\text{V}$ , $I_{OUT} = 2\text{A}$		1.3	1.8	V
( $V_{SAT}$ ) (Note 3)	$V_{IN} = 0\text{V}$ , $I_{OUT} = 3.5\text{A}$		2.1	2.6	V
Source/Sink Leakage Current ( $I_{DEX}$ )	$V_{IN} = 2.4\text{V}$ , $V_{SOURCE} = 0\text{V}$			100	$\mu\text{A}$
	$V_{IN} = 2.4\text{V}$ , $V_{SINK} = 50\text{V}$			100	$\mu\text{A}$
Source Diode Forward Voltage ( $V_F$ )	$V_{IN} = 2.4\text{V}$ , $I_{SOURCE} = -2\text{A}$		-1.2	-1.6	V
	$V_{IN} = 2.4\text{V}$ , $I_{SOURCE} = -3.5\text{A}$		-1.4	-2.0	V



**ELECTRICAL SPECIFICATIONS** (continued)

Parameter	Test Conditions	SG3663			Units
		Min.	Typ.	Max.	
Sink Diode Forward Voltage ( $V_p$ )	$V_{IN} = 2.4V, I_{SINK} = 2A$		1.75	2.2	V
	$V_{IN} = 2.4V, I_{SINK} = 3.5A$		2.3	2.8	V
Diode Leakage Current ( $I_R$ )	$V_{IN} = 2.4V, V_{SOURCE} = 50V$			100	$\mu A$
Output Current Regulation ( $I_{REG}$ )	$V_{IN} = 2.4V, V_{SOURCE} = 0V$			100	$\mu A$
	$V_{TH} = 2.0V \text{ to } 3.6V$	-5		5	%
	$V_{TH} = 1.0V \text{ to } 2.0V$	-10		10	%
Propagation Delay (Note 4)	$(T_{PLH})$ $(T_{PHL})$	-25		25	%
	50% $V_{IN}$ to 50% $V_{OUT}$ $I_{OUT} = 2A$ (resistive)			2.5	$\mu s$
Thermal Shutdown ( $T_{TH}$ )				3.0	$\mu s$
			160		$^{\circ}C$

Note 3. These parameters are tested using pulse techniques to minimize device heating.  
 Note 4. These parameters are guaranteed by design but not 100% tested in production.

**CHARACTERISTIC CURVES**

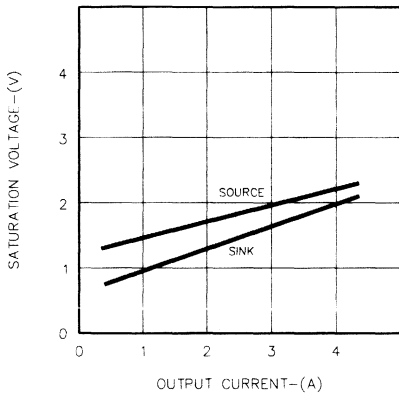


FIGURE 1. OUTPUT SATURATION VOLTAGE VS. OUTPUT CURRENT

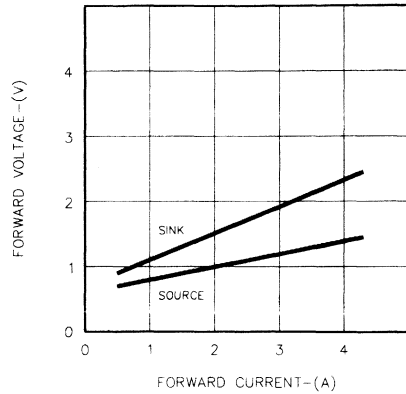


FIGURE 2. DIODE FORWARD VOLTAGE VS. FORWARD CURRENT

**APPLICATION NOTES**

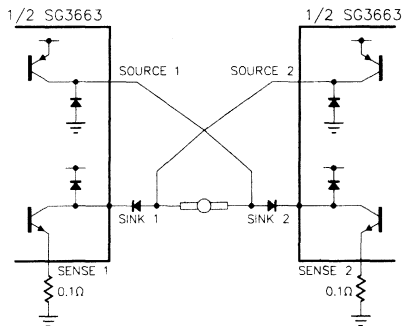


FIGURE 3 - H-BRIDGE CONFIGURATION

1. When using the SG3663 in an H-bridge configuration, external diodes must be used. These diodes must be high speed with voltage ratings above 70V and capable of handling 5A. Care should also be taken not to simultaneously turn on both inputs.
2. PC Board layout - The output current is controlled by both the voltage of the Sense pin and the sense resistor. Because of the large currents and low resistance, it is critical to have extremely good PC board layout to reduce parasitic wiring resistances which could add to the sense resistor and reduce the output current.
3. Decoupling of the  $V_{CC}$  supply with a 10 $\mu F$  electrolytic is recommended.

**FUNCTIONAL DESCRIPTION**

**NON-CHOP MODE**

A logic "0" applied to the Mode Control pin will cause the SG3663 to operate in the non-chop mode. If a logic "0" then appears on the Input pin, both the sink and source transistors will turn-on causing the load current to rise according to:

$$V_{CC} - V_{SAT1} - V_{SAT2} - L \frac{di}{dt} - IR_{SENSE} = 0$$

solving for I(t)

$$1) \quad I(t) = \frac{V_{CC} - V_{SAT1} - V_{SAT2}}{R_{SENSE}} (1 - e^{-(R/L)t})$$

for I(t=0) = 0A

This current will rise exponentially until it reaches a peak value described in Equation 2.

$$2) \quad I_{PEAK} = \frac{V_{TH} / 10}{R_{SENSE}}$$

The comparator then trips, setting the latch and turning off the source transistor.

Since the source transistor has been disabled and the coil current cannot change instantaneously the current flow will be through D2 and will exponentially decay per the following:

$$3) \quad I(t) = -I_{PEAK} e^{-(R/L)(t - T)}$$

The load current will decay to "0" unless the latch is reset by pulling the input high and then low again to activate the source driver.

When the input goes high both the sink and source turn off and the current path is through D2, L, and D1. Figure 5 is a graphical representation of the above discussion.

**CHOP MODE** (Note: Only one section can be used at one time.)

A logic signal "1" on the Mode Control pin will cause the SG3663 to operate in the chop mode. As in the non-chop mode a logic "0" on the Input pin will cause the sink and source transistor to turn on with Equation 4 describing the current in the load.

$$4) \quad I(t) = \frac{V_{CC} - V_{SAT1} - V_{SAT2}}{R_{SENSE}} (1 - e^{-(R/L)t})$$

Once  $I_{PEAK}$  is reached the source transistor turns-off and a current source ( $I_{HYS} \approx +200\mu A$ ) is activated on the threshold pin. This current source lowers the effective threshold voltage by an amount determined by a resistor value  $R_{HYS}$ . The load current will decay until the new threshold is reached at which time the source transistor is activated and the threshold is restored to its original value by turning off the current source. The output current will rise again until the original peak value has been reached. This chopping action will continue until the Input pin is taken high causing the load current to decay to 0A. Figure 6 is a graphical representation of the chop-mode action.

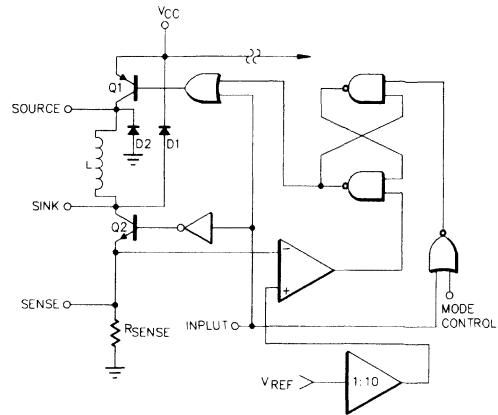


FIGURE 4 - TYPICAL APPLICATION IN NON-CHOP MODE (Refer to Figures 4 & 5)

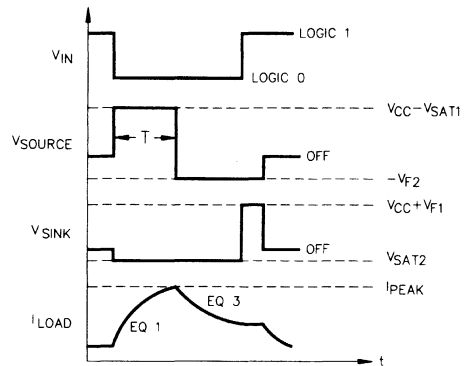


FIGURE 5 - NON-CHOP MODE

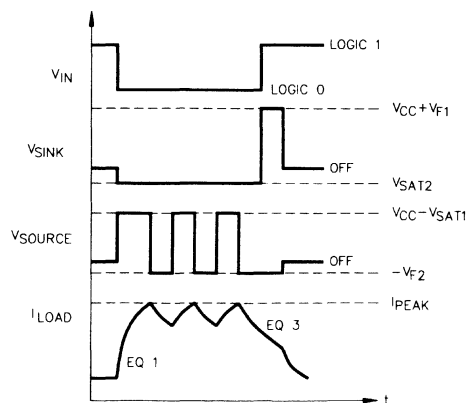


FIGURE 6 - CHOP MODE (Refer to Figure 4)

**DESIGN EXAMPLES - CHOP MODE** (Refer to Figure 4)

**Example 1 -**

Desired: 3.0A Peak, 20KHz Chop Frequency  
 Given:  $V_{CC} = 50V$ ,  $L = 2mH$ ,  $R_{SENSE} = 0.1\Omega$

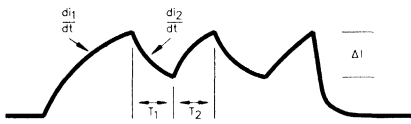


FIGURE 7.

1)  $V_{SENSE} = (3.0A) \times (0.1\Omega) = 300mV$

$V_{TH} = 300mV \times 10 = 3V$

2)  $T = T_1 + T_2 = \frac{1}{20KHz}$

$V = L \frac{dI_1}{dt}$

$\frac{dI_1}{dt} = \frac{V_{CC} - V_{SAT1} - V_{SAT2}}{L}$   
 $= \frac{50V - 2.0V - 2.0V}{2mH}$   
 $= 23A/ms$

$V = L \frac{dI_2}{dt}$

$\frac{dI_2}{dt} = \frac{-V_{SAT2} - V_{R2}}{L}$   
 $= \frac{-2.0V - 2.0V}{2mH}$   
 $= -2.0A/ms$

$\therefore T \cong \frac{\Delta I}{23A/ms} + \frac{\Delta I}{2.0A/ms}$

$\Delta I \cong \frac{1}{\left(\frac{1}{2.0} + \frac{1}{23}\right) \times 10^{-3}} = 92mA$

3) % HYS =  $\frac{\Delta I}{I_{PEAK}}$   
 $= \frac{0.092A}{3A}$   
 $= 3\%$

4)  $\Delta V_{TH} = (3\%) (3V)$   
 $= 90mV$

5)  $R_{HYS} = \frac{\Delta V_{TH}}{200\mu A}$   
 $= \frac{90mV}{200\mu A}$   
 $= 450\Omega$

**Example 2 -**

A voltage divider on the reference supply can be used to establish the necessary peak and hysteresis current.

Desired: 3.0A Peak, 10% Hysteresis Current  
 Given:  $V_{REF} = 5.0V$ ,  $R_{SENSE} = 0.1\Omega$

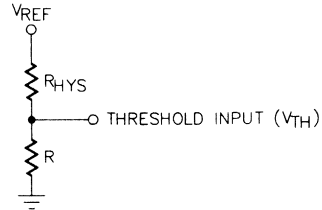


FIGURE 8.

$R_{HYS} = \frac{V_{REF} \times \% \text{ Hysteresis}}{200\mu A}$

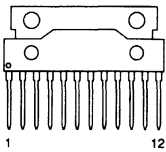
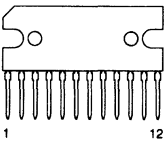
$R = \frac{R_{HYS} \times V_{TH} (\text{peak})}{V_{REF} - V_{TH} (\text{peak})}$

$R = \frac{R_{HYS} (I_{PEAK} \times R_{SENSE} \times 10)}{V_{REF} - (I_{PEAK} \times R_{SENSE} \times 10)}$

$\therefore R_{HYS} = \frac{5.0V \times 10\%}{200\mu A}$   
 $= 2.5K\Omega$

$R = \frac{2.5K\Omega (3.0A \times 0.1\Omega \times 10)}{5.0V - (3.0A \times 0.1\Omega \times 10)}$   
 $= 3.75K\Omega$

**CONNECTION DIAGRAMS & ORDERING INFORMATION** (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
12-PIN PLASTIC SIP ST - PACKAGE	SG3663ST	0°C to 70°C	 <ol style="list-style-type: none"> <li>1. GROUND</li> <li>2. IN 1</li> <li>3. SENSE 1</li> <li>4. SINK 1</li> <li>5. SOURCE 1</li> <li>6. THRESHOLD INPUT</li> <li>7. V<sub>CC</sub></li> <li>8. SOURCE 2</li> <li>9. SINK 2</li> <li>10. SENSE 2</li> <li>11. IN 2</li> <li>12. MODE CONTROL</li> </ol>
12-PIN PLASTIC SIP S - PACKAGE	SG3663S	0°C to 70°C	 <ol style="list-style-type: none"> <li>1. GROUND</li> <li>2. IN 1</li> <li>3. SENSE 1</li> <li>4. SINK 1</li> <li>5. SOURCE 1</li> <li>6. THRESHOLD INPUT</li> <li>7. V<sub>CC</sub></li> <li>8. SOURCE 2</li> <li>9. SINK 2</li> <li>10. SENSE 2</li> <li>11. IN 2</li> <li>12. MODE CONTROL</li> </ol>

Note 1. Contact factory for JAN and DESC product availability.  
 2. All packages are viewed from the top.

**DUAL HAMMER DRIVER**

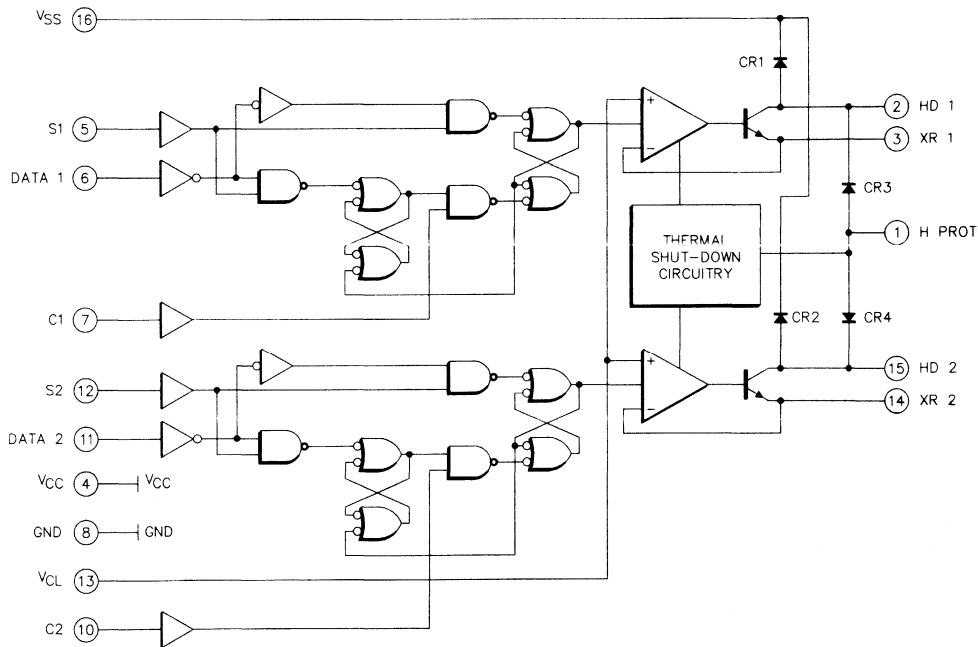
**DESCRIPTION**

The SG3700 is a monolithic integrated circuit that will provide up to 900mA of current to each output. An external sense resistor and an external reference control voltage is required for programming the output current to the desired value. On-chip TTL-compatible logic is provided for timing of the output current pulse duration.

**FEATURES**

- Output current to 900mA
- Output voltage to 40V
- Built-in clamp diodes
- Thermal protection
- Logic control of pulse duration

**BLOCK DIAGRAM**



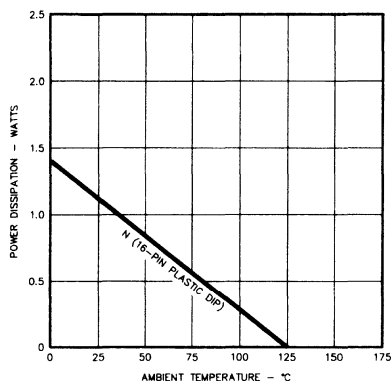
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Driver Supply Voltage ( $V_{SS}$ ) .....	42V	$V_{HPROT}$ .....	$V_{SS}$
TTL Supply Voltage ( $V_{CC}$ ) .....	7V	Operating Junction Temperature	
TTL Logic Input Voltage With Respect To Ground ( $V_{IN}$ ) ..	5.5V	Plastic (N- Package) .....	150°C
Output Current, Each Driver .....	1A	Storage Temperature Range .....	-65°C to 150°C
Control Voltage ( $V_{CL}$ ) .....	2V	Lead Temperature (Soldering, 10 Seconds) .....	300°C

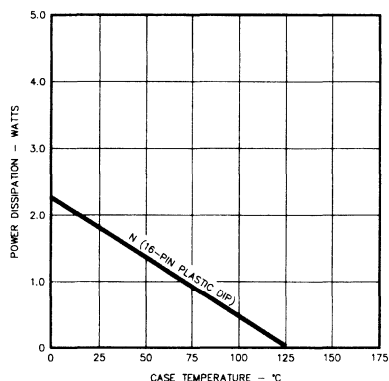
Note 1. Values beyond which damage may occur.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Driver Supply Voltage ( $V_{SS}$ ) .....	40V	Output Current, Continuous .....	900mA
TTL Supply Voltage ( $V_{CC}$ ) .....	4.75V to 5.25V	Operating Ambient Temperature Range	
Control Voltage ( $V_{CL}$ ) (On State) .....	1.2V to 1.8V	SG3700 .....	0°C to 70°C
Control Voltage ( $V_{CL}$ ) (Off State) .....	0V to 0.4V		

Note 2. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise specified, these specifications apply over recommended  $T_A = T_{MIN}$  to  $T_{MAX}$ .)

Parameter	Test Conditions	SG3700			Units
		Min.	Typ.	Max.	
<b>Logic Section</b>					
Low Level Input Voltage ( $V_{IL}$ ) (All Inputs)				0.8	V
Low Level Input Current ( $I_{IL}$ ) (All Inputs)	$V_{CC} = 5.25V, V_{IN} = 0.4V$			-1.6	mA
High Level Input Voltage ( $V_{IH}$ ) (All Inputs)		2.0			V
High Level Input Current ( $I_{IH}$ ) (All Inputs)	$V_{CC} = 5.25V, V_{IN} = 2.4V$			40	$\mu A$
	$V_{CC} = 5.25V, V_{IN} = 5.5V$			1.0	mA
Input Clamp Voltage ( $V_{IK}$ )	$V_{CC} = 4.75V, I_{IN} = 12mA$			-1.5	V
<b>Control Section</b>					
Control Voltage Input Current ( $I_{CL}$ )	$V_{CC} = 0V$ to 1.8V			-0.2	$\mu A$
<b>Protection Section</b>					
HPROT Output Voltage, Low State (Thermal Shutdown) ( $V_{HPROT}$ )	$I_{HPROT} = 1.5mA$			2.0	V
HPROT Leakage to Ground ( $I_{HPROT}$ )	$V_{HPROT} = 0V, V_{SS} = 40V$			-100	$\mu A$
HPROT Leakage from $V_{SS}$ ( $I_{HPROT}$ )	$V_{HPROT} = V_{SS} = V_{HD} = 40V, V_{CC} = 5V$			5	$\mu A$

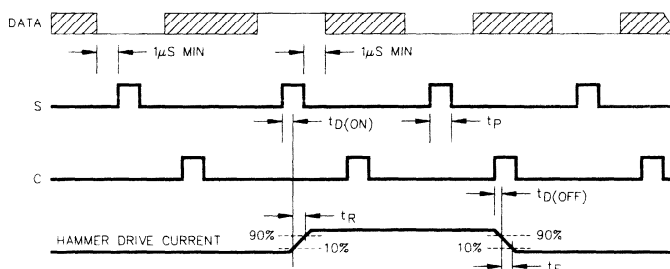
**ELECTRICAL SPECIFICATIONS** (continued)

Parameter	Test Conditions	SG3700			Units
		Min.	Typ.	Max.	
<b>Output Section</b>					
Output Transistor Saturation Voltage ( $V_{CE(SAT)}$ )	$I_C = 900\text{mA}$ , $V_{CL} = 1.2\text{V to } 1.8\text{V}$			1.5	V
Output Current Low, Off State ( $I_{OL}$ )	$V_{SS} = V_{HD} = 40\text{V}$			1.0	mA
$XR_1$ , $XR_2$ Voltage, On State ( $V_{XR}$ )	Driver on, $V_{CL} = 1.2\text{V to } 1.8\text{V}$ , $T_A = 25^\circ\text{C}$	0.97	$V_{CL}$	1.03	V
$XR_1$ , $XR_2$ Voltage, Off State ( $V_{XR}$ ) (Note 3)	Driver on, $V_{CL} = 0\text{V}$			450	mV
Forward Voltage ( $CR_1$ , $CR_2$ ) ( $V_F$ )	$I_F = 900\text{mA}$			3.0	V
Forward Voltage ( $CR_3$ , $CR_4$ ) ( $V_F$ )	$I_F = 1\text{mA}$			1.0	V
Leakage Current ( $CR_1$ , $CR_2$ ) ( $I_h$ )	$V_{SS} = 40\text{V}$ , $V_{HD} = 0\text{V}$			100	$\mu\text{A}$
<b>Supply Section</b>					
Total Supply Current ( $I_{CC}$ )	Outputs in Off State, Logic Inputs Low		50	70	mA

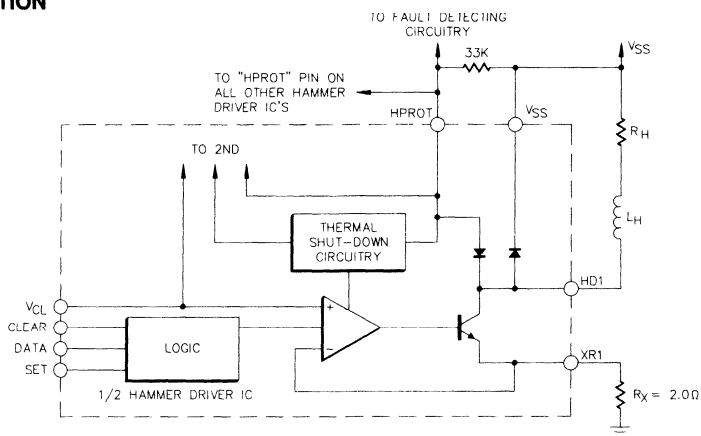
Parameter	Test Conditions	SG3700			Units
		Min.	Typ.	Max.	
<b>Dynamic Characteristics</b> ( $V_{SS} = 40\text{V}$ , $R_x = 2\Omega$ , $R_H = 32\Omega$ , $L_H = 0$ and $T_A = 25^\circ\text{C}$ )					
Pulse Width, S & C Inputs ( $t_p$ )	See Figure 1	1			$\mu\text{s}$
Hammer Drive Current Turn-on Delay ( $t_{D(ON)}$ )			3		$\mu\text{s}$
Hammer Drive Current Turn-off Delay ( $t_{D(OFF)}$ )			3		$\mu\text{s}$
Hammer Drive Rise Time ( $t_R$ )			30		$\mu\text{s}$
Hammer Drive Fall Time ( $t_F$ )			30		$\mu\text{s}$

Note 3.  $V_{XR}$  voltage in off-state shall not exceed specified value when  $V_{CC}$  is changed from +5V to 0V.

**SWITCHING WAVEFORM AND TIMING DIAGRAM - FIGURE 1**



**TYPICAL APPLICATION**



**CONNECTION DIAGRAMS & ORDERING INFORMATION** (See Note Below)

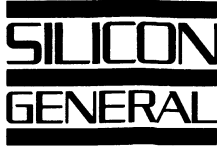
Package	Part No.	Ambient Temperature Range	Connection Diagram
16-PIN PLASTIC DIP N - PACKAGE	SG3700N	0°C to 70°C	

Note: 1. All parts are viewed from the top.



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# SELECTION GUIDE POWER DRIVERS & INTERFACE CIRCUITS

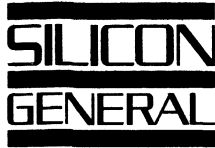
LINEAR INTEGRATED CIRCUITS

## POWER DRIVERS

Device Type	Description	Typ. Application	$I_{O(PK)}$	$I_{O(CCMT)}$	$V_C$ (MAX)	$V_{CC}$ (MAX)	Key Features	Pkgs.
SG1635/2635/3635 SG1635A/2635A/3635A	Half-bridge driver	<ul style="list-style-type: none"> <li>DC motor drivers</li> <li>Stepper motor drive</li> </ul>	5A	2A	35V 40V	35V 40V	SEE MOTION CONTROL CIRCUITS	
SG2000 Series	Darlington arrays	<ul style="list-style-type: none"> <li>Logic to power interface</li> <li>Lamp driver</li> <li>Motor driver</li> </ul>	0.6A	0.5A	50V 95V*		<ul style="list-style-type: none"> <li>Seven open collector Darlington arrays</li> <li>Internal clamp diodes</li> <li>High speed switching</li> <li>Closely matched parameters</li> </ul>	J, N, DW, L
SG2800 Series	Darlington arrays	<ul style="list-style-type: none"> <li>Logic to power interface</li> <li>Lamp driver</li> <li>Motor driver</li> </ul>		0.5A	50V 95V*		<ul style="list-style-type: none"> <li>Eight open collector Darlington arrays</li> <li>Internal clamp diodes</li> <li>High speed switching</li> <li>Closely matched parameters</li> </ul>	J, L
SG2064 thru SG2077	Quad power Darlington arrays	<ul style="list-style-type: none"> <li>Relays</li> <li>Solenoids</li> <li>DC and stepping motors</li> <li>Display drivers</li> </ul>	1.75A	1.5A	50V 80V**		<ul style="list-style-type: none"> <li>Four open collector Darlington arrays</li> <li>Internal clamp diodes</li> <li>1.5V max. saturation at 1.5A</li> <li>Low internal parasitics</li> </ul>	J, W
SG3645	Quad power driver	<ul style="list-style-type: none"> <li>Stepper motor drive</li> <li>DC motor drive</li> <li>Lamp driver</li> <li>Relay driver</li> </ul>	3.5A	2.5A	60V	40V	SEE MOTION CONTROL CIRCUITS	
SG3663	Dual solenoid motor driver	<ul style="list-style-type: none"> <li>DC motor drivers</li> <li>Stepper motor drive</li> <li>Solenoid motor drive</li> </ul>	3.5A	3.0A	50V	50V	SEE MOTION CONTROL CIRCUITS	
SG3700	Dual hammer driver	<ul style="list-style-type: none"> <li>DC motor drivers</li> <li>Hammer coil drive in high speed printers</li> </ul>	1.5A	0.9A	5.25V	40V	SEE MOTION CONTROL CIRCUITS	

\* - SG2021 thru SG2025 only  
SG2821 thru SG2824 only

\*\* - For SG2065, 2067, 2069, 2071, 2075, 2077 only.

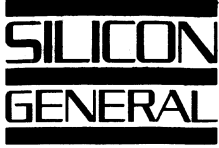


# SELECTION GUIDE POWER DRIVERS & INTERFACE CIRCUITS

LINEAR INTEGRATED CIRCUITS

## INTERFACE CIRCUITS

Device Type	Description	Typ. Application	$I_{O(PK)}$	$I_{O(CONT)}$	$V_C$	$V_{CC}$	Key Features	Pkgs.
SG1488	Quad line-driver	• Data communication interface	10mA	10mA	$\pm 12V$		<ul style="list-style-type: none"> <li>Conformance with specifications of EIA standard No. RS-232C</li> <li>Current limited outputs</li> <li>Power-off source impedance 300<math>\Omega</math> minimum</li> <li>Slew rate control with external capacitor</li> <li>Inputs compatible with DTL and TTL logic</li> </ul>	J
SG1489/SG1489A	Quad line receiver	• Data communication interface	20mA	10mA	10V		<ul style="list-style-type: none"> <li>Conformance with specifications of EIA standard No. RS-232C</li> <li>Input resistance -3K<math>\Omega</math> TO 7K<math>\Omega</math></li> <li>Input threshold hysteresis built in</li> <li>Logic threshold shifting</li> <li>Input noise filtering</li> </ul>	J
SG1626/2626/3626 SG1644/2644/3644	Dual high speed driver Inv. (1626 series) N.I. (1644 series)	<ul style="list-style-type: none"> <li>Driving power MOSFETs</li> <li>Driving high capacitive loads</li> <li>Low voltage motor drive</li> </ul>	3A	0.2A	22V	22V	<ul style="list-style-type: none"> <li>Dual totem pole outputs</li> <li>High speed Schottky logic</li> <li>Frequencies beyond 1MHz</li> <li>TTL input compatibility</li> <li>Rise and fall times less than 25ns</li> <li>Propagation delays less than 20ns</li> <li>Efficient operation at high frequency</li> </ul>	Y, M, J, W, T, R
SG1627/2627/3627	Dual high current output driver	<ul style="list-style-type: none"> <li>Driving bipolar or MOSFETs</li> <li>Low current DC motor drive</li> </ul>	1A	0.5A	30V	30V	<ul style="list-style-type: none"> <li>Dual uncommitted totem-pole outputs</li> <li>Constant current drive capability</li> <li>Inverting and N.I. inputs</li> <li>2V threshold for high noise immunity</li> <li>Full compatibility with 1524 outputs</li> </ul>	J, N
SG1629/2629/3629	Floating switch driver	• Driving high speed bipolar power transistors	2A	0.5A	20V	20V	<ul style="list-style-type: none"> <li>Single uncommitted outputs</li> <li>Self generating positive and negative currents</li> <li>Floating operation</li> <li>Baker clamp input for non-saturated switching</li> <li>Provisions for source and sink gating</li> </ul>	T, R
SG5792	Quad pin diode driver	<ul style="list-style-type: none"> <li>Phase shifters</li> <li>Attenuators</li> </ul>	0.5A	0.3A	50V	6V	<ul style="list-style-type: none"> <li>Four independent pin drivers</li> <li>Shorted diode protection</li> <li>TTL input compatible</li> </ul>	J
SG5793	Quad pin diode driver	<ul style="list-style-type: none"> <li>Phase shifters</li> <li>Attenuators</li> </ul>	0.2A	0.1A	-55V	7V	<ul style="list-style-type: none"> <li>Four independent pin drivers</li> <li>HCMOS compatible</li> <li>Output monitor pin for each output</li> </ul>	J



# SELECTION GUIDE

## POWER DRIVERS & INTERFACE CIRCUITS

LINEAR INTEGRATED CIRCUITS

## PERIPHERAL DRIVERS

Device Type	Description	Typ. Application	$I_{O(PK)}$	$I_{O(AVG)}$	$V_C$	$V_{CC}$	Key Features	Pkgs.
SG508	Quad high voltage NAND driver	<ul style="list-style-type: none"> <li>Lamp drivers</li> <li>Relay driver</li> </ul>	0.5A	0.25A	100V	7V	<ul style="list-style-type: none"> <li>Four NAND gates with open collector outputs</li> <li>Pinning compatible with 54/74 logic series</li> <li>Inputs compatible with DTL/TTL</li> </ul>	H
SG55325 SG55326 SG55327	Memory driver	<ul style="list-style-type: none"> <li>Core memory drivers</li> <li>Relay drivers</li> <li>Lamp drivers</li> </ul>	0.75A	0.6A	25V	7V & 25V	SEE CORE MEMORY CIRCUITS	
SG55450B/75450B	Dual peripheral positive AND driver	<ul style="list-style-type: none"> <li>High speed logic buffers</li> <li>Relay drivers</li> <li>Lamp drivers</li> <li>Memory drivers</li> <li>Line drivers</li> </ul>	0.4A	0.3A	35V	7V	<ul style="list-style-type: none"> <li>Two NAND gates and two uncommitted NPN transistors</li> <li>High speed switching</li> <li>TTL or DTL compatible diode-clamped inputs</li> <li>Can be configured as an AND gate (common emitter configuration) or as a NAND gate (emitter follower configuration)</li> </ul>	J, L
SG55460/75460					40V			
SG55470/75470					70V			
SG55451B/75451B	Dual peripheral positive AND driver	<ul style="list-style-type: none"> <li>High speed logic buffers</li> <li>Relay drivers</li> <li>Lamp drivers</li> <li>Memory drivers</li> <li>Line drivers</li> </ul>	0.4A	0.3A	30V	7V	<ul style="list-style-type: none"> <li>Two AND gates with open collector outputs</li> <li>High speed switching</li> <li>TTL or DTL compatible diode-clamped inputs</li> </ul>	Y, L
SG55461/75461					35V			
SG55471/75471					70V			
SG55452B/75452B	Dual peripheral positive NAND driver	<ul style="list-style-type: none"> <li>High speed logic buffers</li> <li>Relay drivers</li> <li>Lamp drivers</li> <li>Memory drivers</li> <li>Line drivers</li> </ul>	0.4A	0.3A	30V	7V	<ul style="list-style-type: none"> <li>Two NAND gates with open collector outputs</li> <li>High speed switching</li> <li>TTL or DTL compatible diode-clamped inputs</li> </ul>	Y, L
SG55462/75462					35V			
SG55472/75472					70V			
SG55453B/75453B	Dual peripheral positive OR driver	<ul style="list-style-type: none"> <li>High speed logic buffers</li> <li>Relay drivers</li> <li>Lamp drivers</li> <li>Memory drivers</li> <li>Line drivers</li> </ul>	0.4A	0.3A	30V	7V	<ul style="list-style-type: none"> <li>Two OR gates with open collector outputs</li> <li>High speed switching</li> <li>TTL or DTL compatible diode-clamped inputs</li> </ul>	Y, L
SG55463/75463					35V			
SG55473/75473					70V			
SG55454B/75454B	Dual peripheral positive NOR driver	<ul style="list-style-type: none"> <li>High speed logic buffers</li> <li>Relay drivers</li> <li>Lamp drivers</li> <li>Memory drivers</li> <li>Line drivers</li> </ul>	0.4A	0.3A	30V	7V	<ul style="list-style-type: none"> <li>Two NOR gates with open collector outputs</li> <li>High speed switching</li> <li>TTL or DTL compatible diode-clamped inputs</li> </ul>	Y, L
SG55464/75464					35V			
SG55474/75474					70V			

November 1988

**QUAD-NAND DRIVER**

**DESCRIPTION**

The SG508 is a Quad 2-Input NAND Driver with outputs capable of sustaining 100V breakdown voltage. Each TTL-compatible NAND gate controls a 500mA output sink transistor. This combination of a TTL-compatible gate with high current output driver allows the designer to interface low-level logic circuits to power loads. It is also ideal for sense circuit applications.

The high breakdown voltage and current sink capabilities of these devices make them the perfect choice for driving incandescent lamps, relays and other peripheral devices.

The SG508 driver is a direct replacement for the Sprague UHD508 and is available in the side-brazed hermetic package (H-package). The SG508 Quad NAND driver is characterized for operation over the full military temperature range of -55°C to 125°C and can be ordered in custom or other high-reliability screening flows.

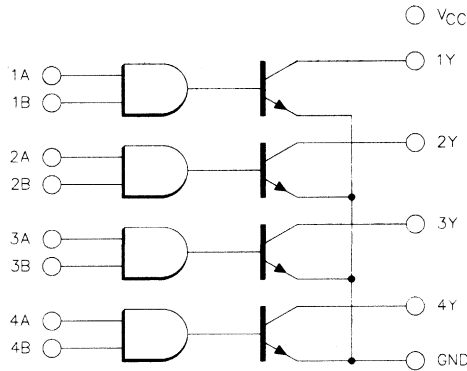
**FEATURES**

- Quad drivers with TTL-compatible logic
- 500mA output sink current
- 100V output breakdown voltage

**HIGH RELIABILITY FEATURES  
- SG508**

- ◆ Available to MIL-STD-883 and DESC SMD
- ◆ SG level "S" processing available

**BLOCK DIAGRAM**



**FUNCTION TABLE (each driver)**

A	B	Y
L	L	H (off-state)
L	H	H (off-state)
H	L	H (off-state)
H	H	L (on-state)

H = High Level, L = Low Level

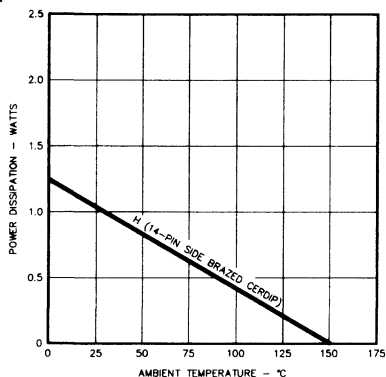
**ABSOLUTE MAXIMUM RATINGS** (Note 1)

Supply Voltage ( $V_{CC}$ ) .....	7.0V DC	Operating Junction Temperature	
Input Voltage .....	5.5V DC	Hermetic (H-package) .....	150°C
Output Off-State Voltage .....	100V DC	Storage Temperature Range .....	-65°C to 150°C
Output On-State Current .....	500mA	Lead Temperature (Soldering, 10 Seconds) .....	300°C

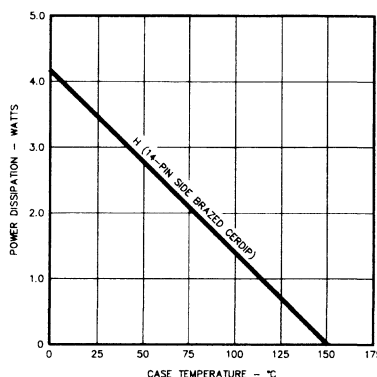
Note 1. Exceeding these ratings could cause damage to the device. All currents are positive into the specified terminal.

**RECOMMENDED OPERATING CONDITIONS** (Note 2)

**THERMAL**



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

**ELECTRICAL**

Supply Voltage ( $V_{CC}$ ) .....	4.5V to 5.5V	Maximum Low Level Input Voltage ( $V_{IL}$ ) .....	0.8V
Maximum Current Into Any Output (On-State) .....	250mA	Operating Ambient Temperature Range ( $T_A$ )	SG508 .....
Minimum High Level Input Voltage ( $V_{IH}$ ) .....	2.0V		-55°C to 125°C

Note 2. Range over which the device is functional.

**ELECTRICAL SPECIFICATIONS**

(Unless otherwise stated, these specifications apply for  $T_A = -55^\circ\text{C}$  to  $125^\circ\text{C}$ .)

Parameter	Test Conditions	SG508			Units
		Min.	Typ.	Max.	
Input Current High ( $I_{IH(1)}$ )	Other input = 0V Driven input = 2.4V			40	$\mu\text{A}$
	Driven input = 5.5V			1000	$\mu\text{A}$
Input Current Low ( $I_{IN(0)}$ )	Other input = 4.5V, Driven input = 0.4V, $V_{CC} = 5.5\text{V}$ , $V_{OUT} = 100\text{V}$			-800	$\mu\text{A}$
Output Reverse Current ( $I_{OFF}$ )	Other input = $V_{CC}$ , Driven input = 0.8V, $V_{CC} = 4.5\text{V}$			100	$\mu\text{A}$
Output Voltage Low ( $V_{ON}$ )	$V_{CC} = 4.5\text{V}$ , All inputs = 2.0V				
	$-55^\circ\text{C} \leq T_A < 25^\circ\text{C}$ , Output = 150mA			0.5	V
	$-55^\circ\text{C} \leq T_A < 25^\circ\text{C}$ , Output = 250mA			0.7	V
	$T_A = 125^\circ\text{C}$ , Output = 150mA			0.6	V
	$T_A = 125^\circ\text{C}$ , Output = 250mA			0.8	V
Level Supply Current, High ( $I_{CC(1)}$ )	$T_A = 25^\circ\text{C}$ , $V_{CC} = 5.5\text{V}$ , All Inputs = 0V			30	mA
Level Supply Current, Low ( $I_{CC(0)}$ )	$T_A = 25^\circ\text{C}$ , $V_{CC} = 5.5\text{V}$ , All Inputs = 5.0V			106	mA
Propagation Delay Time	$V_S = 100\text{V}$ , $C_L = 15\text{pF}$ , $V_{CC} = 5.0\text{V}$ , $R_L = 670\Omega$				
Turn-on ( $t_{PD(ON)}$ )				500	ns
Turn-off ( $t_{PD(OFF)}$ )				750	ns

**CONNECTION DIAGRAMS & ORDERING INFORMATION** (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
14-PIN SIDE-BRAZED DIP H - PACKAGE	SG508H/883B SG508H	-55°C to 125°C -55°C to 125°C	

Note 1. Contact factory for JAN and DESC product availability.  
 Note 2. All packages are viewed from the top.





**QUAD RS-232C LINE DRIVER**

**DESCRIPTION**

The SG1488 is a monolithic quad line driver designed to interface data terminal equipment with data communications equipment in conformance with specifications of EIA standard No. RS-232C.

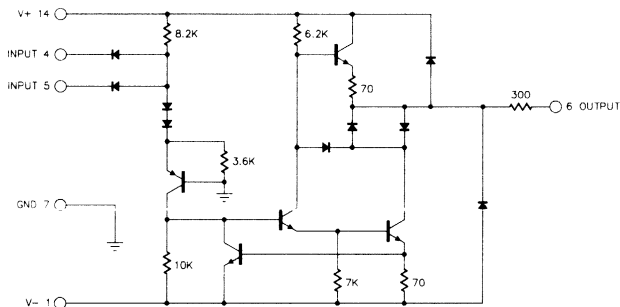
**FEATURES**

- Current limited output 10mA typical
- Power-Off source impedance 300Ω minimum
- Simple slew rate control with external capacitor
- Flexible operating supply range
- Compatible with all DTL and TTL logic families

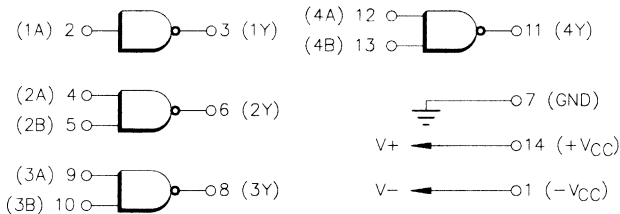
**HIGH RELIABILITY FEATURES - SG1488**

- ◆ Available to MIL-STD-883
- ◆ SG level "S" processing available

**CIRCUIT SCHEMATIC** (1/4 Circuit Shown)



**LOGIC DIAGRAM**



POSITIVE LOGIC:  $Y = \overline{AB}$

**FUNCTION TABLE**

INPUTS		OUTPUT
A	S	Y
H	H	L
L	X	H
X	L	H

H = high level, L = low level,  
X = irrelevant

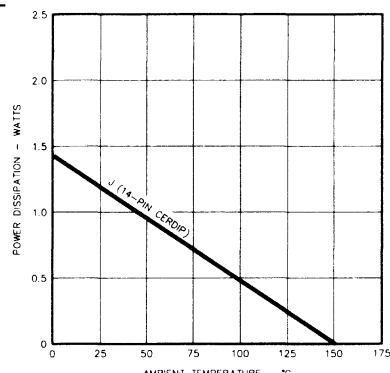
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage .....	±15V	Operating Junction Temperature	
Input Signal Voltage .....	-15V ≤ V <sub>IN</sub> ≤ 7.0V	Hermetic (J-Package) .....	175°C
Output Signal Voltage .....	±15V	Storage Temperature .....	-65°C to 150°C
		Lead Temperature (Soldering, 10 Seconds) .....	300°C

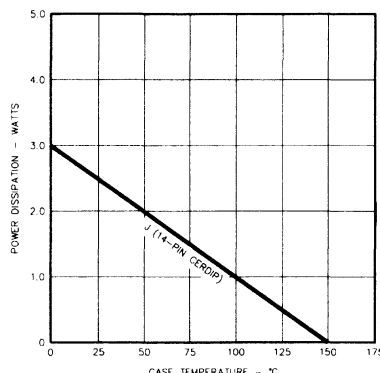
Note 1. Exceeding these ratings could cause damage to the device.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Supply Voltage .....	±12V	Operating Ambient Temperature Range	
Input Signal Voltage .....	V- to 5V	SG1488 .....	0°C to 75°C

Note 2. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise specified, these specifications apply for V<sub>+</sub> = 9.0V ±1%, V<sub>-</sub> = -9.0V ±1%, and T<sub>A</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>.)

Parameter	Test Conditions	SG1489A			Units
		Min.	Typ.	Max.	
<b>Static Characteristics</b>					
Forward Input Current	V <sub>IN</sub> = 0V		1.0	1.6	mA
Reverse Input Current	V <sub>IN</sub> = 5.0V			10	μA
Output Voltage High	V <sub>IN</sub> = 0.8V, R <sub>L</sub> = 3.0KΩ, V <sub>+</sub> = 9.0V, V <sub>-</sub> = -9.0V	6.0	7.0		V
	V <sub>IN</sub> = 0.8V, R <sub>L</sub> = 3.0KΩ, V <sub>+</sub> = 13.2V, V <sub>-</sub> = -13.2V	9.0	10.5		V
Output Voltage Low	V <sub>IN</sub> = 1.9V, R <sub>L</sub> = 3.0KΩ, V <sub>+</sub> = 9.0V, V <sub>-</sub> = -9.0V	-6.0	-7.0		V
	V <sub>IN</sub> = 1.9V, R <sub>L</sub> = 3.0KΩ, V <sub>+</sub> = 13.2V, V <sub>-</sub> = -13.2V	-9.0	-10.5		V
Positive Output Short-Circuit Current (Note 3)		6.0	10	12	mA
Negative Output Short-Circuit Current (Note 3)		-6.0	-10	-12	mA
Output Resistance (Note 4)	V <sub>+</sub> = V <sub>-</sub> = 0V,  V <sub>OUT</sub>   = ±2.0V	300			Ω
Positive Supply Current	R <sub>L</sub> = ∞				
	V <sub>IN</sub> = 0.8V, V <sub>+</sub> = 9.0V		4.5	6.0	mA
	V <sub>IN</sub> = 1.9V, V <sub>+</sub> = 9.0V		15	20	mA
	V <sub>IN</sub> = 0.8V, V <sub>+</sub> = 12V		5.5	7.0	mA
	V <sub>IN</sub> = 1.9V, V <sub>+</sub> = 12V		19	25	mA
	V <sub>IN</sub> = 0.8V, V <sub>+</sub> = 15V			12	mA
	V <sub>IN</sub> = 1.9V, V <sub>+</sub> = 15V			34	mA
Negative Supply Current	R <sub>L</sub> = ∞				
	V <sub>IN</sub> = 0.8V, V <sub>-</sub> = -9.0V			-15	mA
	V <sub>IN</sub> = 1.9V, V <sub>-</sub> = -9.0V			-13	mA
	V <sub>IN</sub> = 0.8V, V <sub>-</sub> = -12V			-15	mA
	V <sub>IN</sub> = 1.9V, V <sub>-</sub> = -12V			-18	mA
	V <sub>IN</sub> = 0.8V, V <sub>-</sub> = -15V			-2.5	mA
V <sub>IN</sub> = 1.9V, V <sub>-</sub> = -15V				mA	

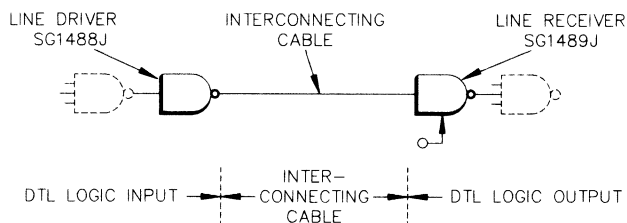
## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG1488			Units
		Min.	Typ.	Max.	
<b>Static Characteristics</b> (continued)					
Power Dissipation	$V_+ = 9.0V, V_- = -9.0V$ $V_+ = 12V, V_- = -12V$			333 576	mW mW
<b>Dynamic Characteristics</b> (Note 4)					
Propagation Delay Time High-Low (TPHL)	$Z_L = 3.0K\Omega, C_L = 15pF, T_A = 25^\circ C$		150	200	ns
Fall Time (TTHL)	$Z_L = 3.0K\Omega, C_L = 15pF, T_A = 25^\circ C$		45	75	ns
Propagation Delay Time Low-High (TPLH)	$Z_L = 3.0K\Omega, C_L = 15pF, T_A = 25^\circ C$		110	175	ns
Rise Time (TTLH)	$Z_L = 3.0K\Omega, C_L = 15pF, T_A = 25^\circ C$		55	100	ns

Note 3. Maximum power dissipation may be exceeded if all outputs are shorted simultaneously.

Note 4. These parameters are not tested in production.

## TYPICAL APPLICATION



## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
14-PIN CERAMIC DIP J - PACKAGE	SG1488J/883B SG1488J	0°C to 75°C 0°C to 75°C	

Note 1. Contact factory for JAN and DESC product availability.  
 Note 2. All packages are viewed from the top.



**QUAD RS-232C LINE RECEIVERS**

**DESCRIPTION**

The SG1489/SG1489A monolithic quad line receivers are designed to interface data terminal equipment with data communications equipment in conformance with specifications of EIA Standard No. RS-232C.

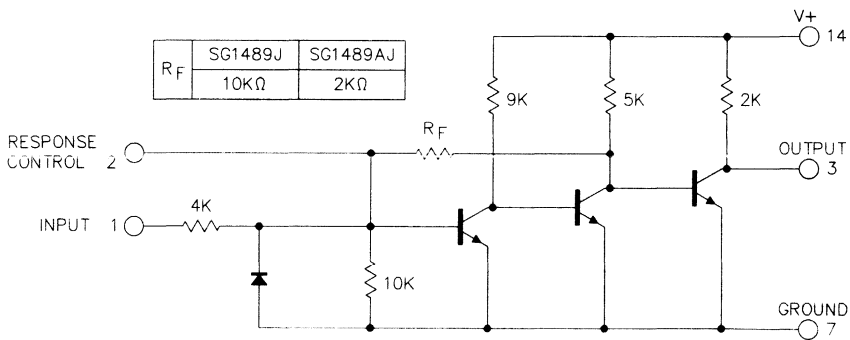
**FEATURES**

- Input resistance 3.0KΩ to 7.0KΩ
- Input signal range ±30V
- Input threshold hysteresis built in
- Response control
  - Logic threshold shifting
  - Input noise filtering

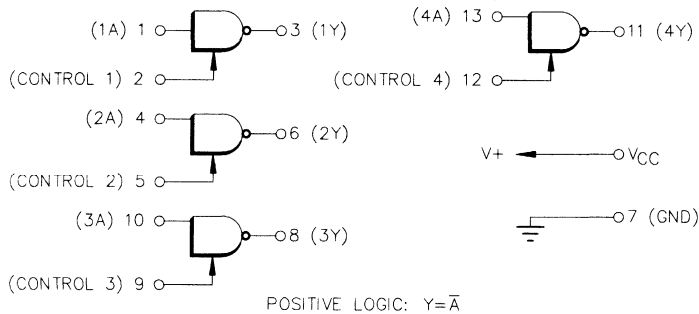
**HIGH RELIABILITY FEATURES  
- SG1489/1489A**

- ◆ Available to MIL-STD-883
- ◆ SG level "S" processing available

**CIRCUIT SCHEMATIC (1/4 Circuit Shown)**



**LOGIC DIAGRAM**



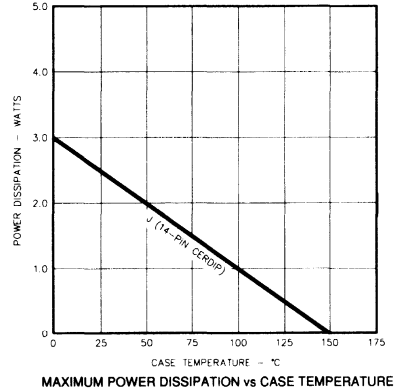
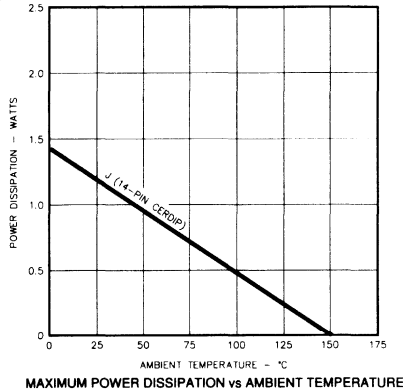
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Power Supply Voltage ..... 10V	Operating Junction Temperature
Input Signal Range ..... $\pm 30V$	Hermetic (J-Package) ..... 175°C
Output Load Current ..... 20mA	Storage Temperature Range ..... -65°C to 150°C
	Lead Temperature (Soldering, 10 Seconds) ..... 300°C

Note 1. Exceeding these ratings could cause damage to the device.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



### ELECTRICAL

Supply Voltage ..... 9V	Operating Ambient Temperature Range
Input Signal Range ..... $\pm 25V$	SG1489/SG1489A ..... 0°C to 75°C

Note 2. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

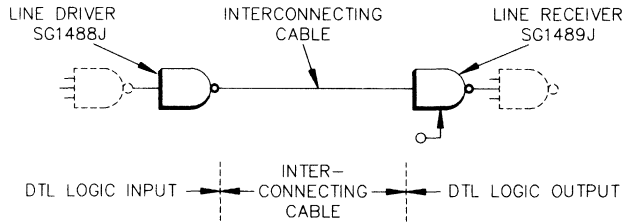
(Unless otherwise specified, these specifications apply for  $V_+ = 5.0V \pm 1\%$  and  $T_A = T_{MIN}$  to  $T_{MAX}$ . Response Control pin is open.)

Parameter	Test Conditions	SG1489			SG1489A			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Static Characteristics</b>								
Positive Input Current	$V_{IN} = 25V$	3.6		8.3	3.6		8.3	mA
	$V_{IN} = 3.0V$	0.43			0.43			mA
Negative Input Current	$V_{IN} = -25V$	-3.6		-8.3	-3.8		8.3	V
	$V_{IN} = -3.0V$	-0.43			-0.43			V
Input Turn-On Threshold Voltage	$V_{OL} \leq 0.45V, T_A = 25^\circ C$	1.0		1.5	1.75	1.95	2.25	V
Input Turn-Off Threshold Voltage	$V_{OH} \geq 2.5V, I_L = -0.5mA, T_A = 25^\circ C$	0.75		1.25	0.75	0.8	1.25	V
Output Voltage High	$V_{IN} = 0.75V, I_L = -0.5mA$	2.6	4.0	5.0	2.6	4.0	5.0	V
	Input open circuit, $I_L = -0.5mA$	2.6	4.0	5.0	2.6	4.0	5.0	V
Output Voltage Low	$V_{IN} = 3.0V, I_L = 10mA$		0.2	0.45		0.2	0.45	V
Output Short-Circuit Current			3.0			3.0		mA
Power Supply Current	$V_{IN} = 5.0V$		20	26		20	26	mA
Power Dissipation	$V_{IN} = 5.0V$		100	130		100	130	mW
<b>Dynamic Characteristics (Note 3)</b>								
Propagation Delay Time High-Low (TPHL)	$R_L = 3.9K\Omega, T_A = 25^\circ C$		25	85		25	85	ns
Fall Time (TTHL)	$R_L = 3.9K\Omega, T_A = 25^\circ C$		120	175		120	175	ns
Propagation Delay Time Low-High (TPLH)	$R_L = 390\Omega, T_A = 25^\circ C$		25	50		25	50	ns
Rise Time (TTLH)	$R_L = 390\Omega, T_A = 25^\circ C$		10	20		10	20	ns

Note 3. These parameters, although guaranteed, are not tested in production.

# SG1489/SG1489A

## TYPICAL APPLICATION



## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
14-PIN CERAMIC DIP J - PACKAGE	SG1489AJ/883B	0°C to 75°C	
	SG1489AJ	0°C to 75°C	
	SG1489J/883B	0°C to 75°C	
	SG1489J	0°C to 75°C	

Note 1. Contact factory for JAN and DESC product availability.  
 2. All packages are viewed from the top.







LINEAR INTEGRATED CIRCUITS

# SG1626/SG2626/SG3626

## DUAL HIGH SPEED DRIVER

### DESCRIPTION

The SG1626, 2626, 3626 is a dual inverting monolithic high speed driver that is pin for pin compatible with the DS0026, TSC426 and ICL7667. This device utilizes high voltage Schottky logic to convert TTL signals to high speed outputs up to 18V. The totem pole outputs have 3A peak current capability, which enables them to drive 1000pF loads in typically less than 25ns. These speeds make it ideal for driving power MOSFETs and other large capacitive loads requiring high speed switching.

In addition to the standard packages, Silicon General offers the 16 pin Batwing (W-package) for commercial and industrial applications and the Hermetic TO-66 (R-package) for military use. These packages offer improved thermal performance for applications requiring high frequencies and/or high peak currents.

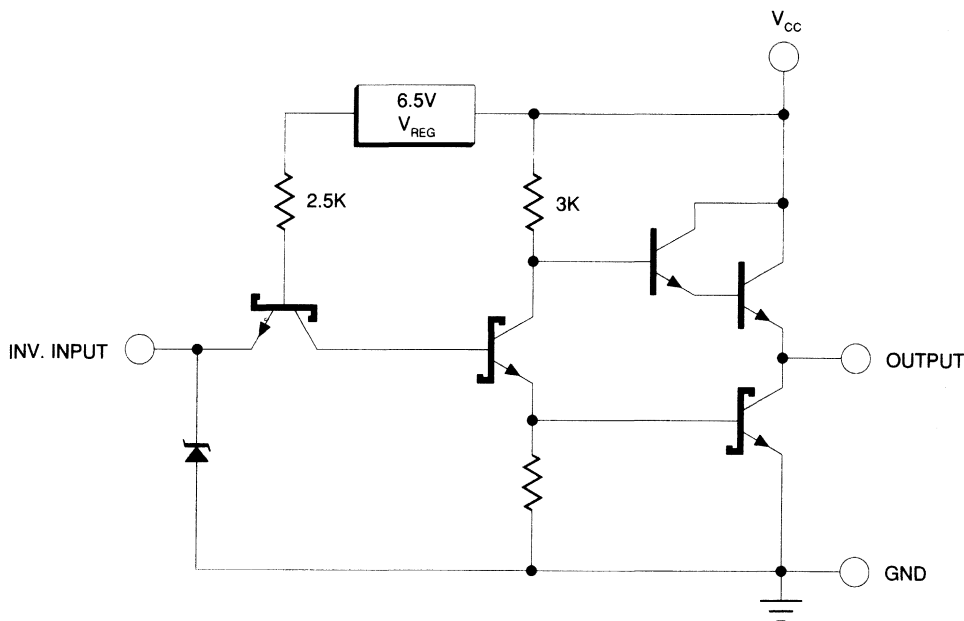
### FEATURES

- Pin for pin compatible with DS0026, TSC426 and ICL7667.
- Totem pole outputs with 3.0A peak current capability.
- Supply voltage to 22V.
- Rise and fall times less than 25ns.
- Propagation delays less than 20ns.
- Inverting high-speed high-voltage Schottky logic.
- Efficient operation at high frequency.
- Available in:
  - 8 Pin Plastic and Ceramic DIP
  - 14 Pin Ceramic DIP
  - 16 Pin Batwing DIP
  - TO-99
  - TO-66

### HIGH RELIABILITY FEATURES - SG1626

- ◆ Available to MIL-STD-883
- ◆ Radiation data available
- ◆ SG level "S" processing available

### EQUIVALENT CIRCUIT SCHEMATIC



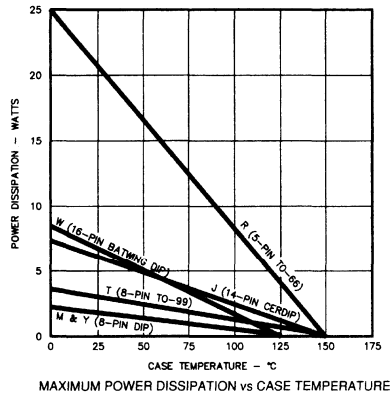
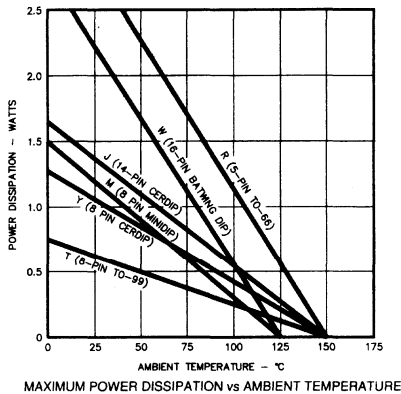
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage ( $V_{CC}$ ) .....	22V	Operating Junction Temperature	
Logic Input Voltage .....	7V	Hermetic (J, T, Y, R-Packages) .....	175°C
Source/Sink Output Current (Each Output)		Plastic (M, W-Packages) .....	150°C
Continuous .....	$\pm 0.5A$	Storage Temperature Range .....	-65°C to 150°C
Pulse, 500ns .....	$\pm 3.0A$	Lead Temperature (Soldering, 10 Seconds) .....	300°C

Note 1. Exceeding these ratings could cause damage to the device. All voltages are with respect to ground. All currents are positive into the specified terminal.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



### ELECTRICAL

Supply Voltage ( $V_{CC}$ ) .....	4.5V to 20V (Note 3)	Operating Ambient Temperature Range ( $T_A$ )	
Frequency Range .....	DC to 1.5MHz	SG1626 .....	-55°C to 125°C
Peak Pulse Current .....	$\pm 3A$	SG2626 .....	-25°C to 85°C
Logic Input Voltage .....	-0.5 to 5.5V	SG3626 .....	0°C to 70°C

Note 2. Range over which the device is functional.

Note 3. AC performance has been optimized for  $V_{CC} = 8V$  to 20V.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise stated, these specifications apply for  $-55 \leq T_A \leq 125^\circ C$  for SG1626;  $-25 \leq T_A \leq 85^\circ C$  for SG2626;  $0 \leq T_A \leq 70^\circ C$  for SG3626;  $V_{CC} = 20V$ .)

Parameter	Test Conditions	SG1626/2626/3626			Units
		Min.	Typ.	Max.	
<b>Static Characteristics</b>					
Logic 1 Input Voltage		2.0			V
Logic 0 Input Voltage				0.7	V
Input High Current	$V_{IN} = 2.4V$			200	$\mu A$
Input High Current	$V_{IN} = 5.5V$			1.0	mA
Input Low Current	$V_{IN} = 0V$			-4	mA
Input Clamp Voltage	$I_{IN} = -10mA$			-1.5	V
Output High Voltage (Note 4)	$I_{OUT} = -200mA$	$V_{CC} \cdot 3$			V
Output Low Voltage (Note 4)	$I_{OUT} = 200mA$			1.0	V
Supply Current Outputs Low	$V_{IN} = 2.4V$ (both inputs)		18	27	mA
Supply Current Outputs High	$V_{IN} = 0V$ (both inputs)		7.5	12	mA

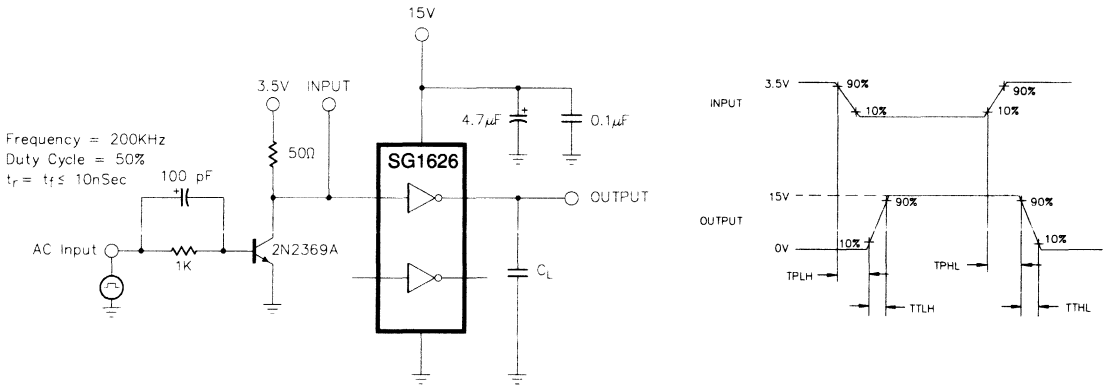
Note 4.  $V_{CC} = 10V$  to 20V.

## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions (Figure 1)	SG1626/2626/3626 T <sub>A</sub> = 25°C			SG1626 T <sub>A</sub> = -55°C to 125°C			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Dynamic Characteristics (Note 6)</b>								
Propagation Delay High-Low (TPHL)	C <sub>L</sub> = 1000pF (Note 5)			<b>18</b>			<b>30</b>	ns
	C <sub>L</sub> = 2500pF		17	25			40	ns
Propagation Delay Low-High (TPLH)	C <sub>L</sub> = 1000pF (Note 5)			<b>25</b>			<b>40</b>	ns
	C <sub>L</sub> = 2500pF		25	35			50	ns
Rise Time (TTLH)	C <sub>L</sub> = 1000pF (Note 5)			<b>30</b>			<b>35</b>	ns
Fall Time (TTHL)	C <sub>L</sub> = 2500pF		30	40			50	ns
	C <sub>L</sub> = 1000pF (Note 5)			<b>20</b>			<b>30</b>	ns
Supply Current (I <sub>CC</sub> ) (both outputs)	C <sub>L</sub> = 2500pF		30	40			50	ns
	C <sub>L</sub> = 2500pF, Freq. = 200KHz Duty Cycle = 50%		30	35			40	mA

Note 5. These parameters, specified at 1000pF, although guaranteed over recommended operating conditions, are not 100% tested in production.  
 Note 6. V<sub>CC</sub> = 15V.

## AC TEST CIRCUIT AND SWITCHING TIME WAVEFORMS - FIGURE 1



## CHARACTERISTIC CURVES

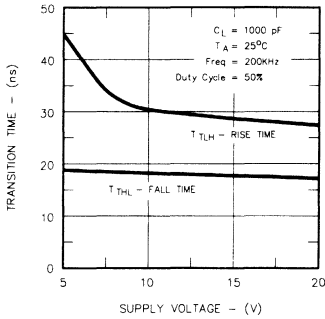


FIGURE 2.  
TRANSITION TIMES VS. SUPPLY VOLTAGE

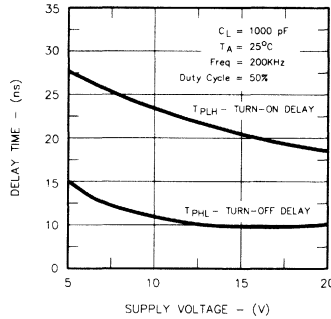


FIGURE 3.  
PROPAGATION DELAY VS. SUPPLY VOLTAGE

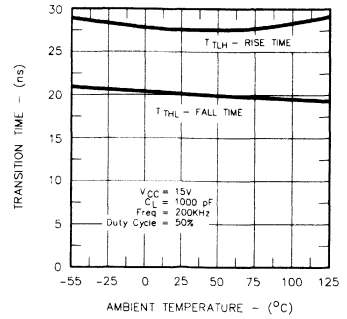
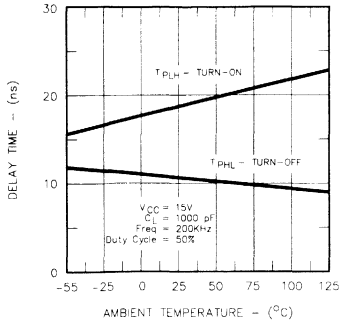
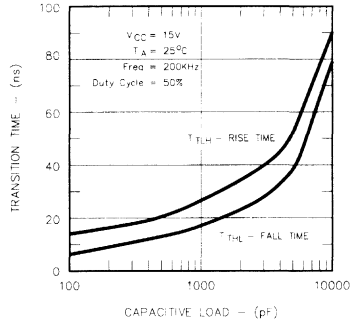


FIGURE 4.  
TRANSITION TIMES VS. AMBIENT TEMPERATURE

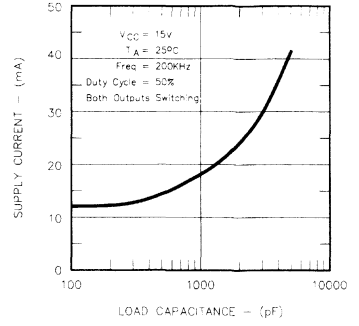
**CHARACTERISTIC CURVES** (continued)



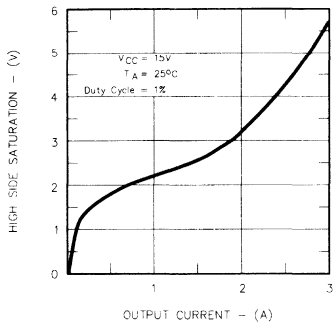
**FIGURE 5.**  
PROPAGATION DELAY VS. AMBIENT TEMPERATURE



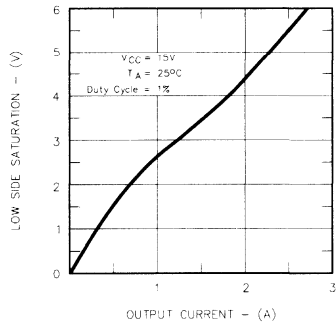
**FIGURE 6.**  
TRANSITION TIMES VS. CAPACITIVE LOAD



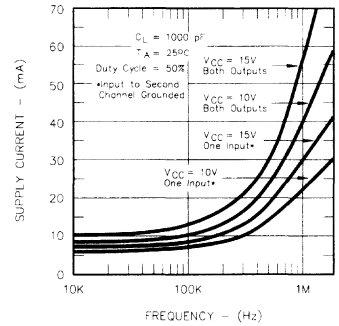
**FIGURE 7.**  
SUPPLY CURRENT VS. CAPACITANCE LOAD



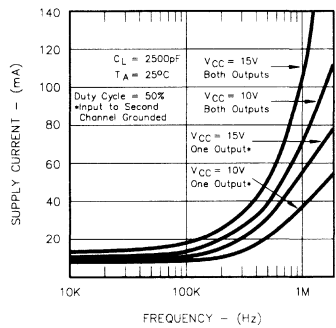
**FIGURE 8.**  
HIGH SIDE SATURATION VS. OUTPUT CURRENT



**FIGURE 9.**  
LOW SIDE SATURATION VS. OUTPUT CURRENT



**FIGURE 10.**  
SUPPLY CURRENT VS. FREQUENCY



**FIGURE 11.**  
SUPPLY CURRENT VS. FREQUENCY

## APPLICATION INFORMATION

### POWER DISSIPATION

The SG1626, while more energy-efficient than earlier gold-doped driver IC's, can still dissipate considerable power because of its high peak current capability at high frequencies. Total power dissipation in any specific application will be the sum of the DC or steady-state power dissipation, and the AC dissipation caused by driving capacitive loads.

The DC power dissipation is given by:

$$P_{DC} = +V_{CC} \cdot I_{CC} \quad [1]$$

where  $I_{CC}$  is a function of the driver state, and hence is duty-cycle dependent.

The AC power dissipation is proportional to the switching frequency, the load capacitance, and the square of the output voltage. In most applications, the driver is constantly changing state, and the AC contribution becomes dominant when the frequency exceeds 100-200KHz.

The SG1626 driver family is available in a variety of packages to accommodate a wide range of operating temperatures and power dissipation requirements. The Absolute Maximums section of the data sheet includes two graphs to aid the designer in choosing an appropriate package for his design.

The designer should first determine the actual power dissipation of the driver by referring to the curves in the data sheet relating operating current to supply voltage, switching frequency, and capacitive load. These curves were generated from data taken on actual devices. The designer can then refer to the Absolute Maximum Thermal Dissipation curves to choose a package type, and to determine if heat-sinking is required.

### DESIGN EXAMPLE

Given: Two 2500 pF loads must be driven push-pull from a +15 volt supply at 100KHz. This is a commercial application where the maximum ambient temperature is +50°C, and cost is important.

1. From Figure 11, the average driver current consumption under these conditions will be 18mA, and the power dissipation will be 15volts x 18mA, or 270mW.

2. From the Ambient Thermal Characteristic curve, it can be seen that the M package, which is an 8-pin plastic DIP with a copper lead frame, has more than enough thermal conductance from junction to ambient to support operation at an ambient temperature of +50°C. The SG3626M driver would be specified for this application.

### SUPPLY BYPASSING

Since the SG1626 can deliver peak currents above 3amps under some load conditions, adequate supply bypassing is essential for proper operation. Two capacitors in parallel are recommended to guarantee low supply impedance over a wide bandwidth: a 0.1µF ceramic disk capacitor for high frequencies, and a 4.7µF solid tantalum capacitor for energy storage. In military

applications, a CK05 or CK06 ceramic capacitor with a CSR-13 tantalum capacitor is an effective combination. For commercial applications, any low-inductance ceramic disk capacitor teamed with a Sprague 150D or equivalent low ESR capacitor will work well. The capacitors must be located as close as physically possible to the  $V_{CC}$  pin, with combined lead and pc board trace lengths held to less than 0.5 inches.

### GROUNDING CONSIDERATIONS

Since ground is both the reference potential for the driver logic and the return path for the high peak output currents of the driver, use of a low-inductance ground system is essential. A ground plane is highly recommended for best performance. In dense, high performance applications a 4-layer pc board works best; the 2 inner planes are dedicated to power and ground distribution, and signal traces are carried by the outside layers. For cost-sensitive designs a 2-layer board can be made to work, with one layer dedicated completely to ground, and the other to power and signal distribution. A great deal of attention to component layout and interconnect routing is required for this approach.

### LOGIC INTERFACE

The logic input of the 1626 is designed to accept standard DC-coupled 5 volt logic swings, with no speed-up capacitors required. If the input signal voltage exceeds 6 volts, the input pin must be protected against the excessive voltage in the HIGH state. Either a high speed blocking diode must be used, or a resistive divider to attenuate the logic swing is necessary.

### LAYOUT FOR HIGH SPEED

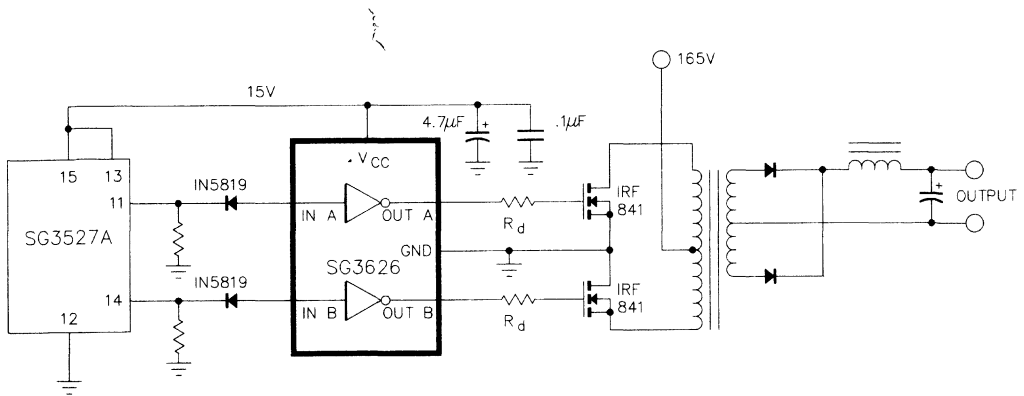
The SG1626 can generate relatively large voltage excursions with rise and fall times around 20-30 nanoseconds with light capacitive loads. A Fourier analysis of these time domain signals will indicate strong energy components at frequencies much higher than the basic switching frequency. These high frequencies can induce ringing on an otherwise ideal pulse if sufficient inductance occurs in the signal path (either the positive signal trace or the ground return). Overshoot on the rising edge is undesirable because the excess drive voltage could rupture the gate oxide of a power MOSFET. Trailing edge undershoot is dangerous because the negative voltage excursion can forward-bias the parasitic PN substrate diode of the driver, potentially causing erratic operation or outright failure.

Ringing can be reduced or eliminated by minimizing signal path inductance, and by using a damping resistor between the drive output and the capacitive load. Inductance can be reduced by keeping trace lengths short, trace widths wide, and by using 2oz. copper if possible. The resistor value for critical damping can be calculated from:

$$R_D = 2\sqrt{L/C_L} \quad [2]$$

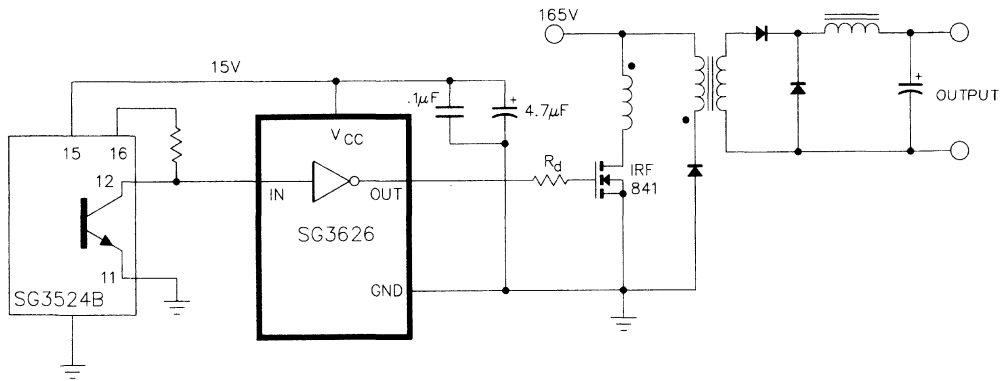
where L is the total signal line inductance, and  $C_L$  is the load capacitance. Values between 10 and 100ohms are usually sufficient. Inexpensive carbon composition resistors are best because they have excellent high frequency characteristics. They should be located as close as possible to the gate terminal of the power MOSFET.

TYPICAL APPLICATIONS



**FIGURE 12.**

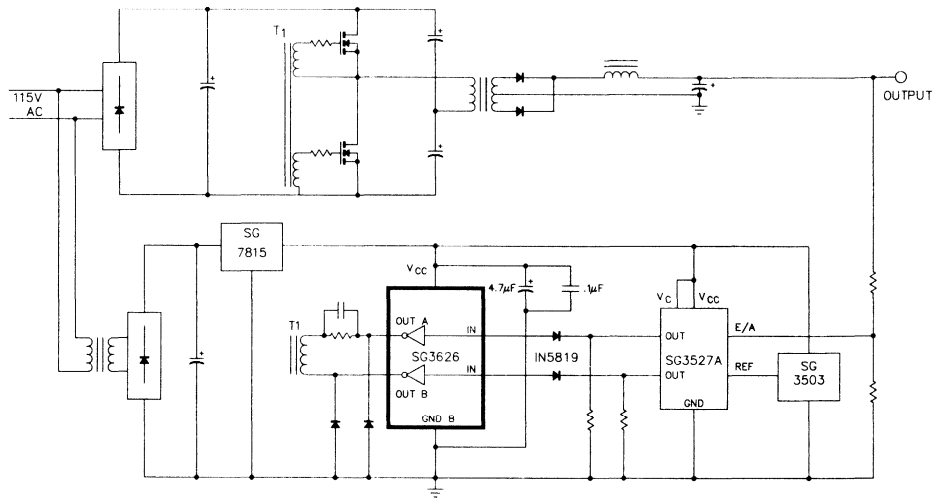
When the SG3626 is driven from a totem-pole source with a peak output greater than 6 volts, a low-current, fast-switching blocking diode is required at each logic input for protection. In this push-pull converter, the inverted logic outputs of the 3527A are ideal control sources for the power driver.



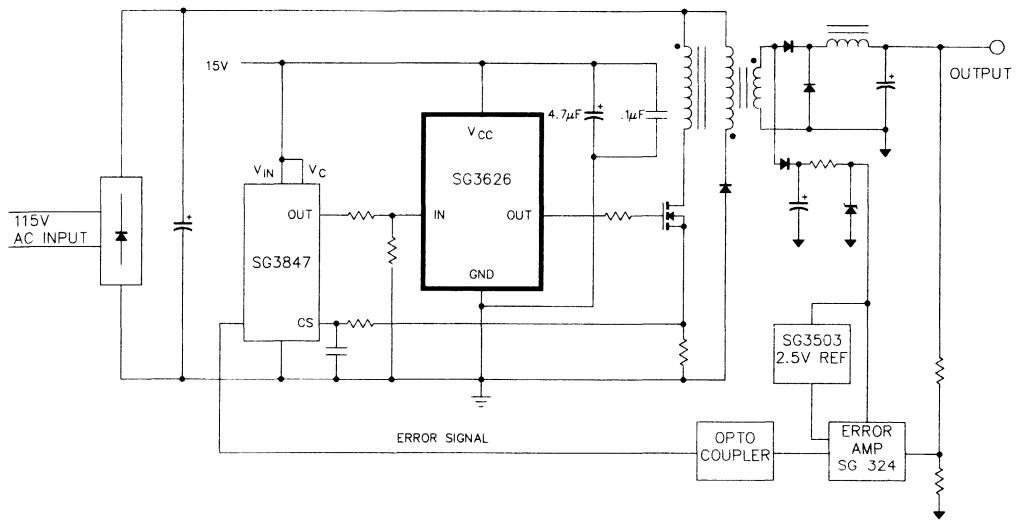
**FIGURE 13.**

In this forward converter circuit, the control capabilities of the SG3524B PWM are combined with the powerful totem-pole drivers found in the SG3626. This inexpensive configuration results in very fast charge and discharge of the power MOSFET gate capacitance for efficient switching.

TYPICAL APPLICATIONS (continued)



**FIGURE 14.** In half or full-bridge power supplies, driving the isolation transformers directly from the PWM can cause excessive IC temperatures, especially above 100KHz. This circuit uses the high drive capacity of the SG3626 to solve the problem.



**FIGURE 15.** A low-impedance resistive divider network can also be used as the interface between the PWM high-voltage logic output and the SG3626 power driver. In this 200KHz current mode converter, the SG3847 provides control, while the SG3626 provides high power drive and minimizes ground spiking in the control IC.

# SG1626/SG2626/SG3626

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
14-PIN CERAMIC DIP J - PACKAGE	SG1626J/883B SG1626J SG2626J SG3626J	-55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C	
8-PIN CERAMIC DIP Y - PACKAGE	SG1626Y/883B SG1626Y SG2626Y SG3626Y	-55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C	
8-PIN PLASTIC DIP M - PACKAGE	SG2626M SG3626M	-25°C to 85°C 0°C to 70°C	
16-PIN BATWING DIP W - PACKAGE	SG2626W SG3626W	-25°C to 85°C 0°C to 70°C	
8-PIN TO-99 METAL CAN T - PACKAGE	SG1626T/883B SG1626T SG2626T SG3626T	-55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C	
5-PIN TO-66 METAL CAN R - PACKAGE	SG1626R/883B SG1626R SG2626R SG3626R	-55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C	

Note 1. Contact factory for JAN and DESC product availability.  
 Note 2. All packages are viewed from the top.



**DUAL HIGH-CURRENT OUTPUT DRIVER**

**DESCRIPTION**

The SG1627 series devices are monolithic, high-speed driver integrated circuits designed to interface digital control logic with high current loads. Each device contains two independent drivers which will either source or sink up to 500mA of current. The sink transistor is designed as a saturating switch while the source transistor can be used either as a switch or as a constant current generator with external resistor programming.

Each half of this device contains both inverting and non-inverting inputs which have two volt thresholds for high noise immunity. Either input can be used alone to switch the output, or one input can be strobed with the other. These units have been designed to directly interface with the SG1524 Regulating Pulse Width Modulator Circuit.

These devices are supplied in ceramic 16-pin D.I.L. packages. The SG1627 is specified for operation over a -55°C to +125°C temperature range while the SG2627 is intended for industrial applications of -25°C to 85°C and the SG3627 for 0°C to 70°C.

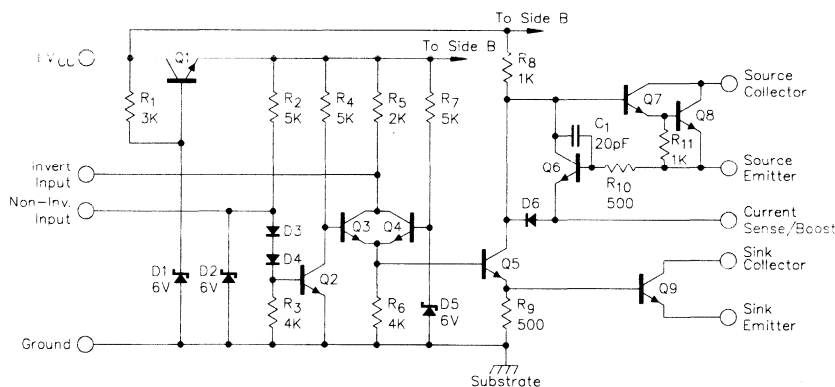
**FEATURES**

- Two independent driver circuits
- Outputs will source or sink currents to 500mA
- 300ns response time
- Full compatibility with SG1524 PWM circuit
- Constant current drive capability
- Two volt threshold for high noise immunity
- Source and sink can be separated for complementary outputs

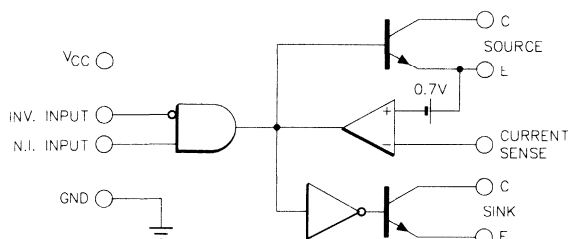
**HIGH RELIABILITY FEATURES - SG1627**

- ♦ Available to MIL-STD-883
- ♦ SG level "S" processing available

**SCHEMATIC** (one-half of total device shown)



**BLOCK DIAGRAM** (one-half of total device shown)



**FUNCTION TABLE**

NON INV.	INV.	SINK	SOURCE
LO	OPEN	ON	OFF
OPEN	LO	OFF	ON
OPEN	OPEN	ON	OFF
LO	LO	ON	OFF

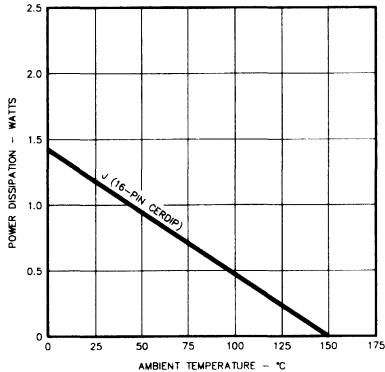
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage, $V_{CC}$	Peak Current (< 2% duty cycle)	1A
SG1627, 2627	Input Voltage Range	-0.3V to 5.5V
SG3627	Input Current	10mA
Output Collector Voltage	Operating Junction Temperature	
SG1627, 2627	Hermetic (J Package)	175°C
SG3627	Storage Temperature Range	-65°C to 150°C
Source or Sink Current, DC	Lead Temperature (Soldering, 10 Seconds)	300°C

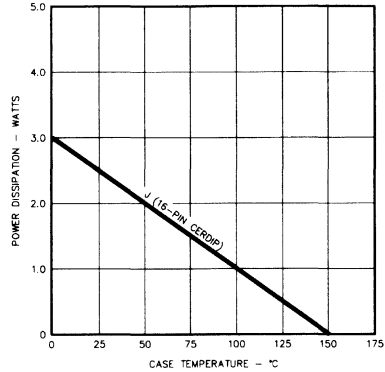
Note 1. Exceeding these ratings could cause damage to the device.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Supply Voltage, $V_{CC}$	Peak Current (<2% duty cycle)	0mA to 750mA
SG1627, 2627	Input Voltage	0V to 5.5V
SG3627	Input Current	0mA to 10mA
Output Collector Voltage	Operating Ambient Temperature Range	
SG1627, 2627	SG1627	-55°C to 125°C
SG3627	SG2627	-25°C to 85°C
Source or Sink Current, DC	SG3627	0°C to 70°C

Note 2. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise specified, these specifications apply for  $V_{CC} = 5V$ , and over recommended operating ambient temperature.)

Parameter	Test Conditions	SG1627/2627/3627			Units
		Min.	Typ.	Max.	
High-Level Input Voltage		2.8		5.5	V
Low-Level Input Voltage		0		1.4	V
Input Threshold			2.0		V
Low-Level Input Current	$V_{IN} = 0V$		-1.0	-2.0	mA
Source Off, Leakage Current	Collector $V = V_{MAX}$		0.3	1.0	mA
Source On, Collector Saturation	$I_{SOURCE} = 50mA$		1.1	1.7	V
(Source Emitter Grounded, $R_{SC} = 0$ )	$I_{SOURCE} = 300mA$		1.2	1.9	V
	$I_{SOURCE} = 500mA$		1.3		V
Source On, Emitter Voltage	$I_{SOURCE} = -50mA$	$(V_{CC} = 3V)$			V
Sink Off, Leakage Current	Collector $V = V_{MAX}$		1.0	100	$\mu A$
Sink On, Collector Saturation	$I_{SINK} = 50mA$		0.2	0.4	V
	$I_{SINK} = 300mA, V_{CC} = 20V$		0.5	0.7	V
	$I_{SINK} = 500mA, I_{BOOST} = 25mA$		0.5		V
Current Limit Sense Voltage	$R_{SC} = 10\Omega, T_A = 25^\circ C$	600	700	900	mV
Sense Voltage Temperature Coefficient	$R_{SC} = 10\Omega$		1.8		mV/°C

ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG1627/2627/3627			Units
		Min.	Typ.	Max.	
Supply Current (both sink transistors on)	$V_{CC} = 5V$		15	22	mA
	$V_{CC} = 20V$		50	73	mA
	$V_{CC} = 30V$ (1627/2627 only)		80	115	mA
Response Time (TRHL)	Fig. 12, $R_L = 24\Omega$ , $T_A = 25^\circ C$		100		ns
Response Time (TRLH)	Fig. 12, $R_L = 24\Omega$ , $T_A = 25^\circ C$		300		ns

CHARACTERISTIC CURVES

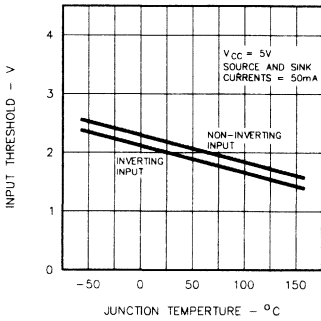


FIGURE 1. INPUT THRESHOLD VS. TEMPERATURE

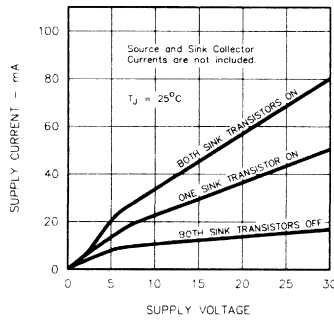


FIGURE 2. SUPPLY CURRENT VS. VOLTAGE

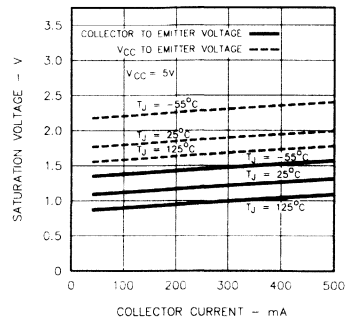


FIGURE 3. SOURCE TRANSISTOR SATURATION

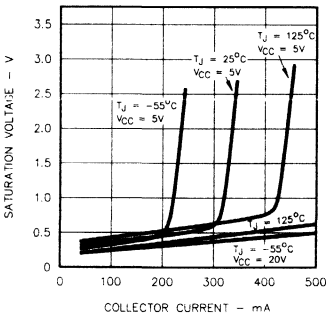


FIGURE 4. SINK TRANSISTOR SATURATION

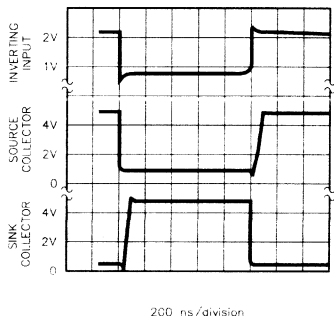


FIGURE 5. DYNAMIC RESPONSE (See Fig. 12 for Test Circuit,  $R_L = 24\Omega$ )

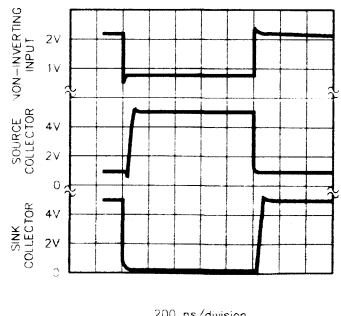


FIGURE 6. DYNAMIC RESPONSE (See Fig. 12 for Test Circuit,  $R_L = 24\Omega$ )

APPLICATION INFORMATION

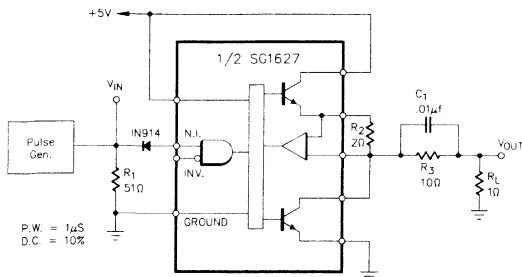


FIGURE 7 - TOTEM POLE OUTPUT SWITCH CIRCUIT

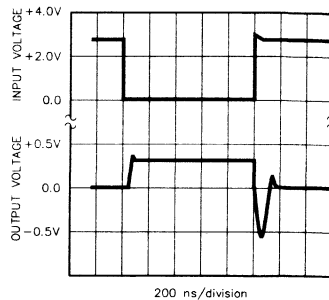


FIGURE 8 - OUTPUT WAVEFORM

APPLICATION CIRCUITS

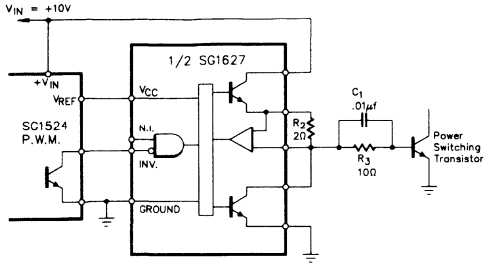


FIGURE 9

Basic 300mA switched drive circuit. If the external output transistor is to be on when the driving transistor is on, use the inverting input with the non-inverting input left open. For opposite phasing, use the non-inverting input with the inverting input grounded.

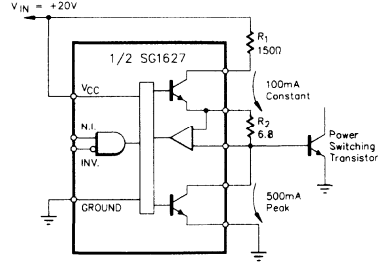


FIGURE 10

Use of higher input voltage provides greater drive for higher sink-transistor peak current while R2 provides constant source current. R1 helps minimize power in the SG1627. Although the sink emitter may be connected to a different ground point from pin 5, any voltage differences between them will directly affect the input threshold level.

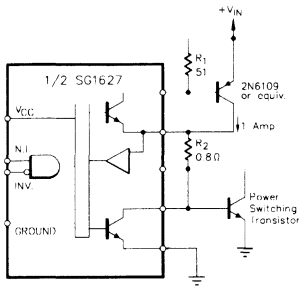


FIGURE 11

Additional source current or power handling capability may be added with the use of an external PNP transistor. For optimum performance, a low storage-time unit should be selected. If current limiting is not required, an NPN emitter follower could also be used for source boost.

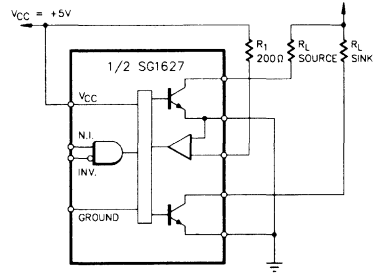


FIGURE 12

Source and sink transistors can be used separately for complementary outputs. At low supply voltages the sink current is limited to approximately 100mA, but if current limiting is not required a sink drive boost may be added with R1. The current in R1 should be .05 times the sink load current to insure saturation.

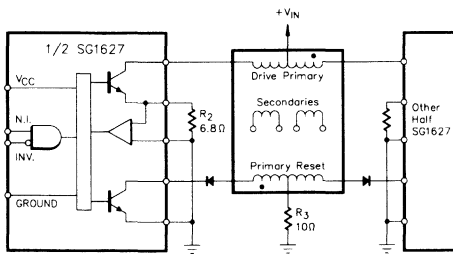


FIGURE 13

Source and sink transistors can be used separately for an efficient transformer driver. Here the source provides constant current drive with magnetic reset accomplished by a flux clamp utilizing the sink transistor. With the source current sense terminal connected to ground, there will be a residual collector current of approximately 300μA. If this is objectionable, insert a diode between current sense and ground.

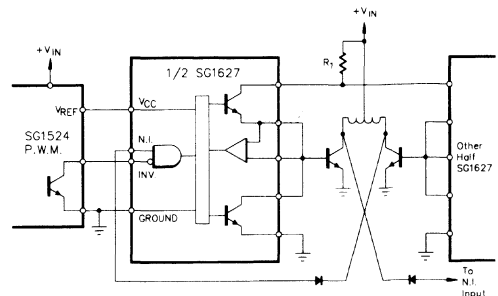
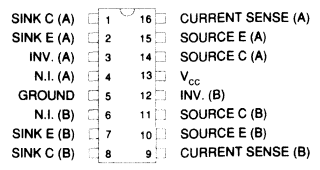


FIGURE 14

Simultaneous conduction of the output switching transistors can be positively prevented by using diodes to cross-couple a gating signal into the non-inverting inputs. For maximum power handling capability, the source transistor is driven into saturation with the current limiting provided by R1.

# SG1627/SG2627/SG3627

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
16-PIN CERAMIC DIP J - PACKAGE	SG1627J/883B	-55°C to 125°C	
	SG1627J	-55°C to 125°C	
	SG2627J	-25°C to 85°C	
	SG3627J	0°C to 70°C	

Note 1. Contact factory for JAN and DESC product availability.  
 2. All packages are viewed from the top.

6



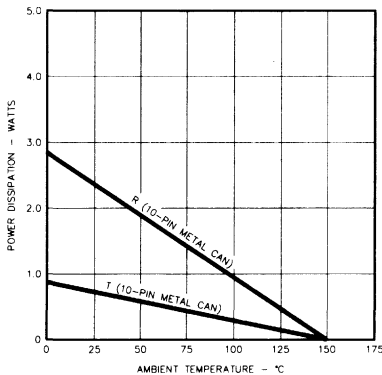
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Input Voltage (+V <sub>IN</sub> or -V <sub>IN</sub> ) .....	20V	Sink Rectifier Current (peak) .....	2.0A
Collector to Emitter Voltage, Source or Sink .....	20V	Operating Junction Temperature	
Source Current .....	2.0A	Hermetic (T, R Packages) .....	175°C
Sink Current .....	3.0A	Storage Temperature Range .....	-65°C to 150°C
		Lead Temperature (Soldering, 10 Seconds) .....	300°C

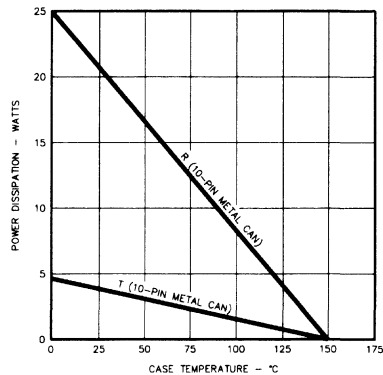
Note 1. Exceeding these ratings could cause damage to the device.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Input Voltage (+V <sub>IN</sub> or -V <sub>IN</sub> ) .....	15V	Sink Rectifier Current (Peak) .....	0A to 1A
Collector to Emitter Voltage, Source or Sink .....	15V	Operating Junction Temperature Range	
Source Current .....	0A to 1A	SG1629 .....	-55°C to 125°C
Sink Current .....	0A to 2A	SG3629 .....	0°C to 70°C

Note 2. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

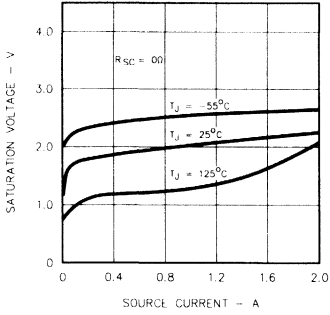
(Unless otherwise specified, these specifications apply over recommended operating ambient temperature.)

Parameter	Test Conditions	SG1629/SG3629			Units
		Min.	Typ.	Max.	
Collector to Emitter Voltage, Source or Sink	V <sub>BE</sub> = 0	20	30		V
Collector to Emitter Leakage, Source or Sink	V <sub>BE</sub> = 0, V <sub>CE</sub> = 15V		5	100	μA
Input Leakage V+ to V-	Input Voltage = +15V		1	100	μA
Input Leakage V- to V+	Input Voltage = -15V		2	4	mA
Standby Current from Sink Emitter Voltage (Note 3)	Sink Emitter = -5V, +V <sub>IN</sub> = -V <sub>IN</sub> = 0V		5	10	mA
Clamp Current	+V <sub>IN</sub> = 15V, V clamp = 0V	10	15	20	mA
Source Saturation Voltage	I <sub>SOURCE</sub> = 100mA		1.7		V
	I <sub>SOURCE</sub> = 500mA		1.8		V
	I <sub>SOURCE</sub> = 1A, T <sub>A</sub> = 25°C		2.0	3	V
Sink Saturation Voltage, Force beta = 100	I <sub>SINK</sub> = 100mA		1.2		V
	I <sub>SINK</sub> = 500mA		1.3		V
	I <sub>SINK</sub> = 1A, T <sub>A</sub> = 25°C		1.5	2	V
Sink Current Gain	I <sub>SINK</sub> = 2A, V <sub>CE</sub> = 3V	300	500		
Current Limit Sense Voltage	R <sub>SC</sub> = 0.7Ω, T <sub>A</sub> = 25°C	0.55	0.65	0.80	V
Sink Rectifier Forward Voltage	I <sub>F</sub> = 1A, T <sub>A</sub> = 25°C		1.0	2.0	V
Sink Gate Output Saturation	Sink Drive = 10mA, Sink Gate I <sub>IN</sub> = 1mA		0.2	0.4	V
Source Response	I <sub>SOURCE</sub> = 1A		100		ns
Sink Response	I <sub>SINK</sub> = 1A		100		ns

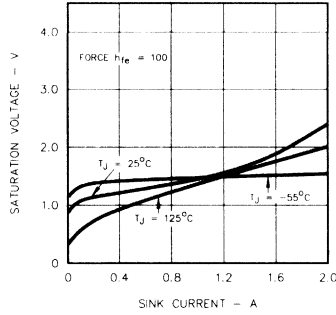
Note 3. 1KΩ from -V<sub>IN</sub> to Sink Drive and Source Emitter connected to Sink Collector.



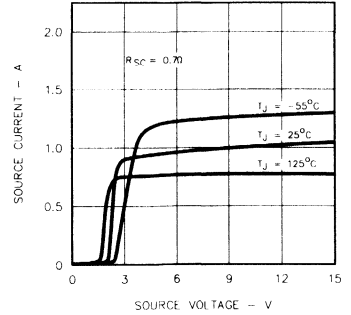
**CHARACTERISTIC CURVES**



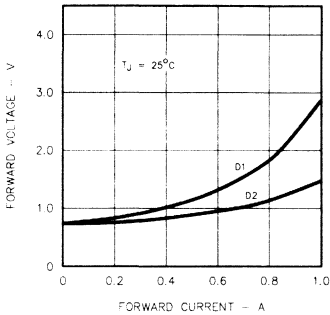
**FIGURE 1.**  
SOURCE SATURATION



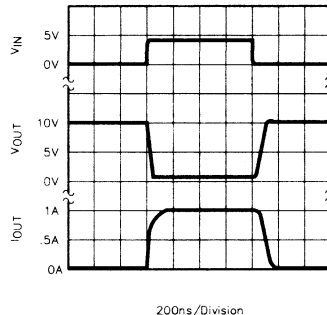
**FIGURE 2.**  
SINK SATURATION



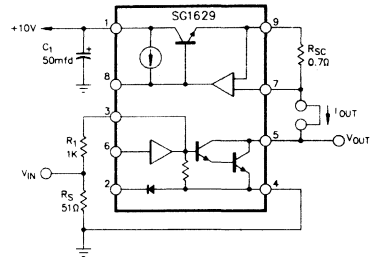
**FIGURE 3.**  
CONSTANT SOURCE CURRENT



**FIGURE 4.**  
RECTIFIER FORWARD VOLTAGE

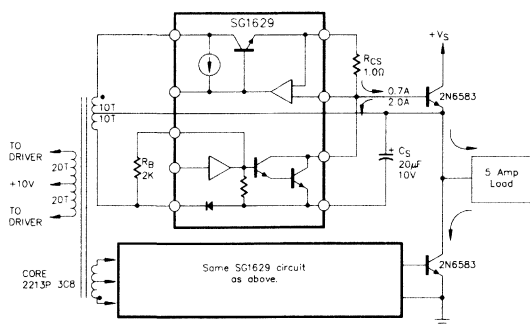


**FIGURE 5.**  
DYNAMIC RESPONSE WAVEFORM



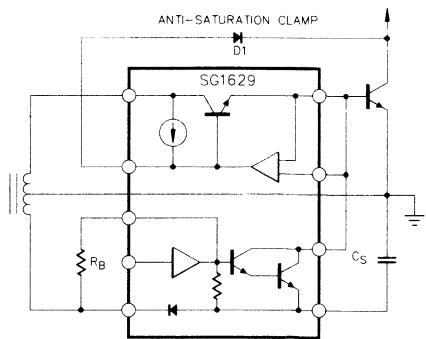
**FIGURE 6.**  
DYNAMIC RESPONSE TEST CIRCUIT

**APPLICATION CIRCUITS**



**FIGURE 6**

Two SG1629 devices can be combined to form the drive signals for the power transistors in a 5A, half-bridge switching supply.



**FIGURE 7**

A load-dependent drive current may be provided by eliminating the current sensing resistor and adding the anti-saturation clamp diode  $D_1$ .



**DUAL HIGH SPEED DRIVER**

**DESCRIPTION**

The SG1644, 2644, 3644 is a dual non-inverting monolithic high speed driver. This device utilizes high voltage Schottky logic to convert TTL signals to high speed outputs up to 18V. The totem pole outputs have 3A peak current capability, which enables them to drive 1000pF loads in typically less than 25ns. These speeds make it ideal for driving power MOSFETs and other large capacitive loads requiring high speed switching.

In addition to the standard packages, Silicon General offers the 16 pin Batwing (W-package) for commercial and industrial applications and the Hermetic TO-66 (R-package) for military use. These packages offer improved thermal performance for applications requiring high frequencies and/or high peak currents.

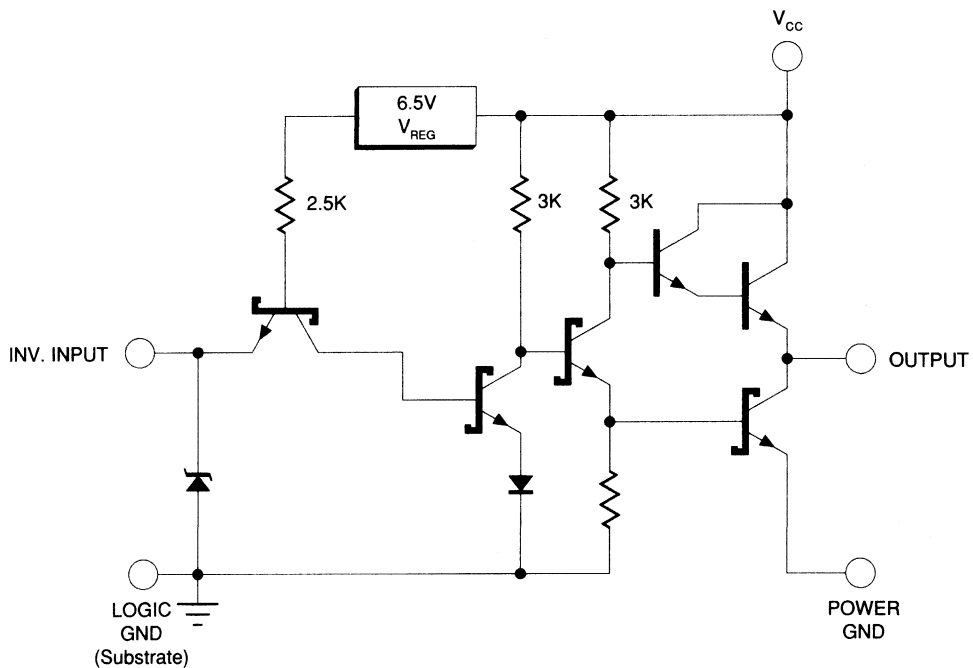
**FEATURES**

- Totem pole outputs with 3.0A peak current capability.
- Supply voltage to 22V.
- Rise and fall times less than 25ns.
- Propagation delays less than 20ns.
- Non-inverting high-speed high-voltage Schottky logic.
- Efficient operation at high frequency.
- Available in:
  - 8 Pin Plastic and Ceramic DIP
  - 14 Pin Ceramic DIP
  - 16 Pin Batwing DIP
  - TO-99
  - TO-66

**HIGH RELIABILITY FEATURES - SG1644**

- ◆ Available to MIL-STD-883
- ◆ Radiation data available
- ◆ SG level "S" processing available

**EQUIVALENT CIRCUIT SCHEMATIC**



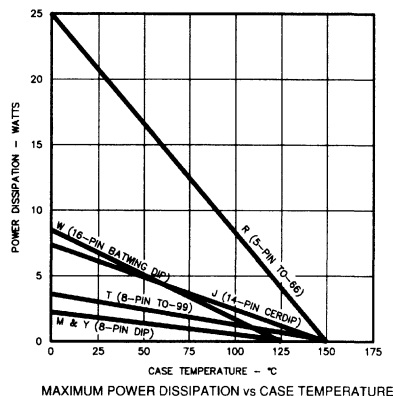
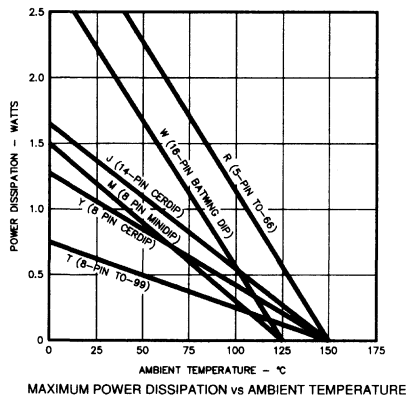
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage ( $V_{CC}$ ) .....	22V	Operating Junction Temperature	
Logic Input Voltage .....	7V	Hermetic (J, T, Y, R-Packages) .....	175°C
Source/Sink Output Current (Each Output)		Plastic (M, W-Packages) .....	150°C
Continuous .....	$\pm 0.5A$	Storage Temperature Range .....	-65°C to 150°C
Pulse, 500ns .....	$\pm 3.0A$	Lead Temperature (Soldering, 10 Seconds) .....	300°C

Note 1. Exceeding these ratings could cause damage to the device. All voltages are with respect to ground. All currents are positive into the specified terminal.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



### THERMAL

Supply Voltage ( $V_{CC}$ ) .....	4.5V to 20V (Note 3)	Operating Ambient Temperature Range ( $T_A$ )	
Frequency Range .....	DC to 1.5MHz	SG1644 .....	-55°C to 125°C
Peak Pulse Current .....	$\pm 3A$	SG2644 .....	-25°C to 85°C
Logic Input Voltage .....	-0.5 to 5.5V	SG3644 .....	0°C to 70°C

Note 2. Range over which the device is functional.

Note 3. AC performance has been optimized for  $V_{CC} = 8V$  to 20V.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise stated, these specifications apply for  $-55 \leq T_A \leq 125^\circ C$  for SG1644;  $-25 \leq T_A \leq 85^\circ C$  for SG2644;  $0 \leq T_A \leq 70^\circ C$  for SG3644;  $V_{CC} = 20V$ .)

Parameter	Test Conditions	SG1644/2644/3644			Units
		Min.	Typ.	Max.	
<b>Static Characteristics</b>					
Logic 1 Input Voltage		2.0			V
Logic 0 Input Voltage				0.7	V
Input High Current	$V_{IN} = 2.4V$			200	$\mu A$
Input High Current	$V_{IN} = 5.5V$			1.0	mA
Input Low Current	$V_{IN} = 0V$			-4	mA
Input Clamp Voltage	$I_{IN} = -10mA$			-1.5	V
Output High Voltage (Note 4)	$I_{OUT} = -200mA$	$V_{CC}-3$			V
Output Low Voltage (Note 4)	$I_{OUT} = 200mA$			1.0	V
Supply Current Outputs Low	$V_{IN} = 0V$ (both inputs)		18	27	mA
Supply Current Outputs High	$V_{IN} = 2.4V$ (both inputs)		7.5	12	mA

Note 4.  $V_{CC} = 10V$  to 20V.

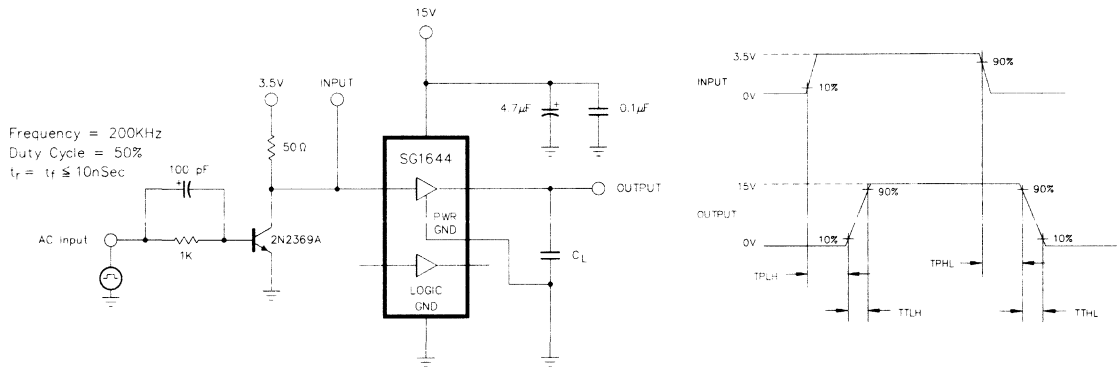
## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions (Figure 1)	SG1644/2644/3644 T <sub>A</sub> = 25°C			SG1644 T <sub>A</sub> = -55°C to 125°C			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Dynamic Characteristics (Note 6)</b>								
Propagation Delay High-Low (TPHL)	C <sub>L</sub> = 1000pF (Note 5)			30			40	ns
	C <sub>L</sub> = 2500pF		26	35			50	ns
Propagation Delay Low-High (TPLH)	C <sub>L</sub> = 1000pF (Note 5)			25			30	ns
	C <sub>L</sub> = 2500pF		18	30			40	ns
Rise Time (TTLH)	C <sub>L</sub> = 1000pF (Note 5)			30			35	ns
	C <sub>L</sub> = 2500pF		30	40			50	ns
Fall Time (TTHL)	C <sub>L</sub> = 1000pF (Note 5)			25			30	ns
	C <sub>L</sub> = 2500pF		30	40			50	ns
Supply Current (I <sub>CC</sub> ) (both outputs)	C <sub>L</sub> = 2500pF, Freq. = 200KHz Duty Cycle = 50%		30	35			40	mA

Note 5. These parameters, specified at 1000pF, although guaranteed over recommended operating conditions, are not tested in production.

Note 6. V<sub>CC</sub> = 15V.

## AC TEST CIRCUIT AND SWITCHING TIME WAVEFORMS - FIGURE 1



## CHARACTERISTIC CURVES

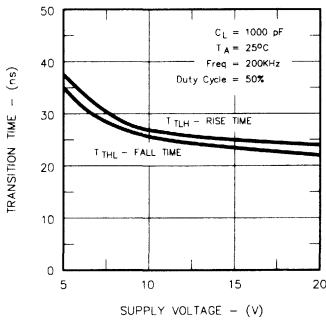


FIGURE 2.  
TRANSITION TIMES VS. SUPPLY VOLTAGE

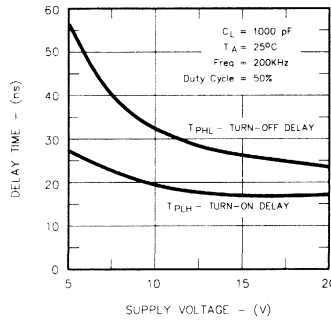


FIGURE 3.  
PROPAGATION DELAY VS. SUPPLY VOLTAGE

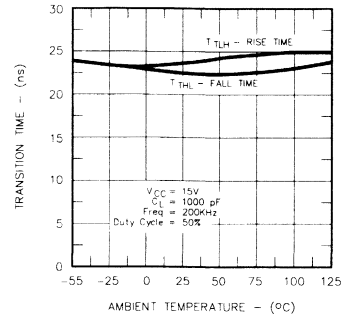


FIGURE 4.  
TRANSITION TIMES VS. AMBIENT TEMPERATURE

CHARACTERISTIC CURVES (continued)

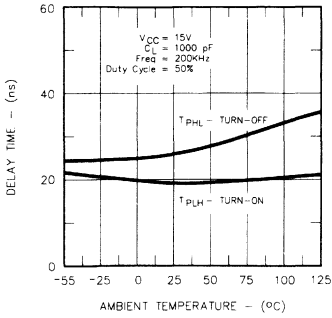


FIGURE 5. PROPAGATION DELAY VS. AMBIENT TEMPERATURE

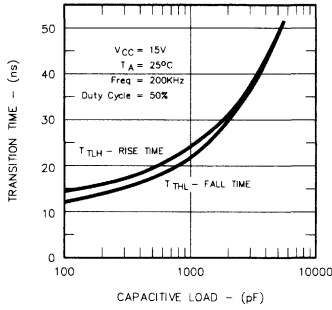


FIGURE 6. TRANSITION TIMES VS. CAPACITIVE LOAD

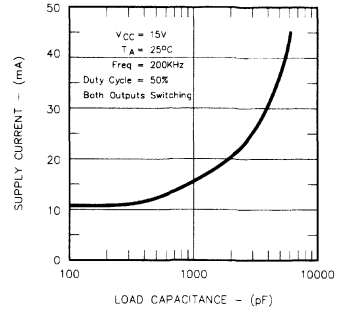


FIGURE 7. SUPPLY CURRENT VS. CAPACITANCE LOAD

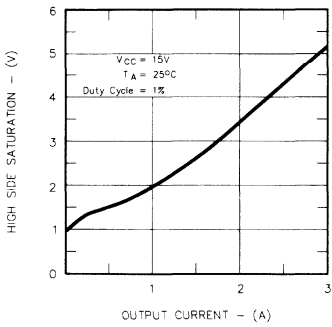


FIGURE 8. HIGH SIDE SATURATION VS. OUTPUT CURRENT

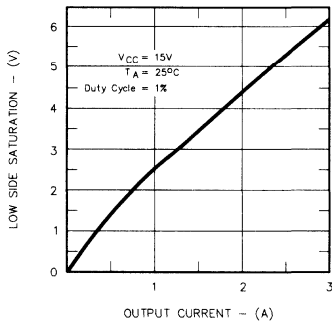


FIGURE 9. LOW SIDE SATURATION VS. OUTPUT CURRENT

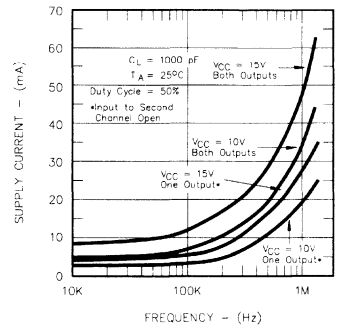


FIGURE 10. SUPPLY CURRENT VS. FREQUENCY

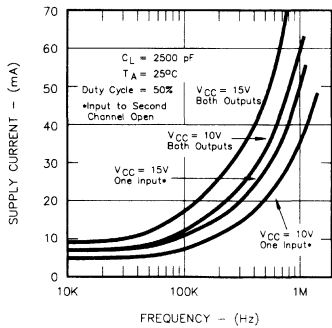


FIGURE 11. SUPPLY CURRENT VS. FREQUENCY

## APPLICATION INFORMATION

### POWER DISSIPATION

The SG1644, while more energy-efficient than earlier gold-doped driver IC's, can still dissipate considerable power because of its high peak current capability at high frequencies. Total power dissipation in any specific application will be the sum of the DC or steady-state power dissipation, and the AC dissipation caused by driving capacitive loads.

The DC power dissipation is given by:

$$P_{DC} = +V_{CC} \cdot I_{CC} \quad [1]$$

where  $I_{CC}$  is a function of the driver state, and hence is duty-cycle dependent.

The AC power dissipation is proportional to the switching frequency, the load capacitance, and the square of the output voltage. In most applications, the driver is constantly changing state, and the AC contribution becomes dominant when the frequency exceeds 100-200KHz.

The SG1644 driver family is available in a variety of packages to accommodate a wide range of operating temperatures and power dissipation requirements. The Absolute Maximums section of the data sheet includes two graphs to aid the designer in choosing an appropriate package for his design.

The designer should first determine the actual power dissipation of the driver by referring to the curves in the data sheet relating operating current to supply voltage, switching frequency, and capacitive load. These curves were generated from data taken on actual devices. The designer can then refer to the Absolute Maximum Thermal Dissipation curves to choose a package type, and to determine if heat-sinking is required.

### DESIGN EXAMPLE

Given: Two 2500pF loads must be driven push-pull from a +15 volt supply at 100KHz. The application is a commercial one in which the maximum ambient temperature is +50°C, and cost is important.

1. From Figure 11, the average driver current consumption under these conditions will be 18mA, and the power dissipation will be 15volts x 18mA, or 270mW.

2. From the ambient thermal characteristic curve, it can be seen that the M package, which is an 8-pin plastic DIP with a copper lead frame, has more than enough thermal conductance from junction to ambient to support operation at an ambient temperature of +50°C. The SG36446M driver would be specified for this application.

### SUPPLY BYPASSING

Since the SG1644 can deliver peak currents above 3amps under some load conditions, adequate supply bypassing is essential for proper operation. Two capacitors in parallel are recommended to guarantee low supply impedance over a wide bandwidth: a 0.1µF ceramic disk capacitor for high frequencies, and

a 4.7µF solid tantalum capacitor for energy storage. In military applications, a CK05 or CK06 ceramic capacitor with a CSR-13 tantalum capacitor is an effective combination. For commercial applications, any low-inductance ceramic disk capacitor teamed with a Sprague 150D or equivalent low ESR capacitor will work well. The capacitors must be located as close as physically possible to the  $V_{CC}$  pin, with combined lead and pc board trace lengths held to less than 0.5 inches.

### GROUNDING CONSIDERATIONS

The ability of the SG1644 to deliver high peak currents into capacitive loads can cause undesirable negative transients on the logic and power grounds. To avoid this, a low inductance ground path should be considered for each output to return the high peak currents back to its own ground point. A ground plane is recommended for best performance. If space for a ground plane is not available, make the paths as short and as wide as possible. The logic ground can be returned to the supply bypass capacitor and be connected at one point to the power grounds.

### LOGIC INTERFACE

The logic input of the 1644 is designed to accept standard DC-coupled 5 volt logic swings, with no speed-up capacitors required. If the input signal voltage exceeds 6 volts, the input pin must be protected against the excessive voltage in the HIGH state. Either a high speed blocking diode must be used, or a resistive divider to attenuate the logic swing is necessary.

### LAYOUT FOR HIGH SPEED

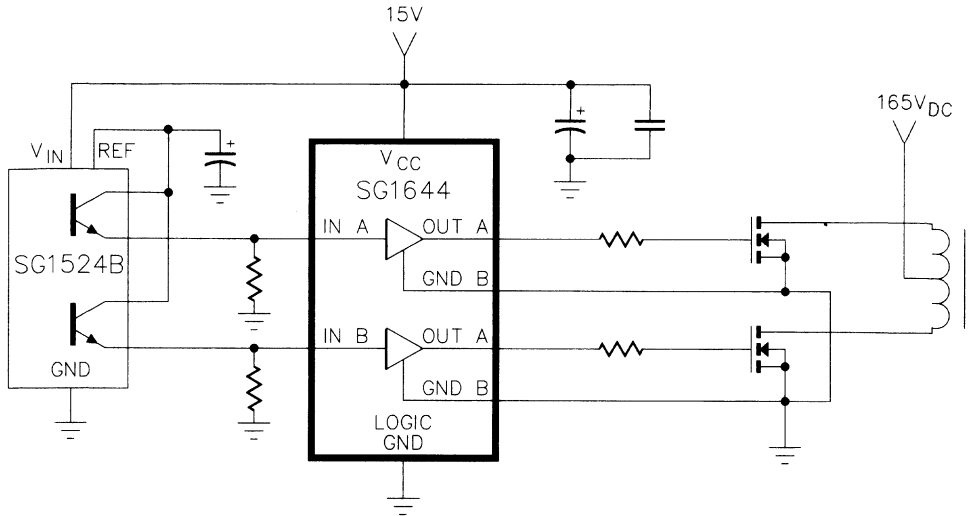
The SG1644 can generate relatively large voltage excursions with rise and fall times around 20-30 nanoseconds with light capacitive loads. A Fourier analysis of these time domain signals will indicate strong energy components at frequencies much higher than the basic switching frequency. These high frequencies can induce ringing on an otherwise ideal pulse if sufficient inductance occurs in the signal path (either the positive signal trace or the ground return). Overshoot on the rising edge is undesirable because the excess drive voltage could rupture the gate oxide of a power MOSFET. Trailing edge undershoot is dangerous because the negative voltage excursion can forward-bias the parasitic PN substrate diode of the driver, potentially causing erratic operation or outright failure.

Ringing can be reduced or eliminated by minimizing signal path inductance, and by using a damping resistor between the drive output and the capacitive load. Inductance can be reduced by keeping trace lengths short, trace widths wide, and by using 2oz. copper if possible. The resistor value for critical damping can be calculated from:

$$R_D = 2\sqrt{L/C_L} \quad [2]$$

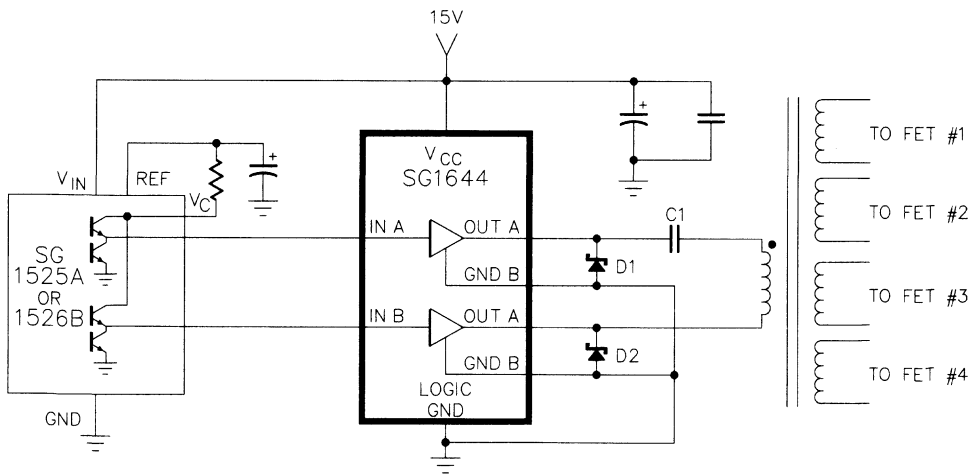
where L is the total signal line inductance, and  $C_L$  is the load capacitance. Values between 10 and 100ohms are usually sufficient. Inexpensive carbon composition resistors are best because they have excellent high frequency characteristics. They should be located as close as possible to the gate terminal of the power MOSFET.

TYPICAL APPLICATIONS



**FIGURE 12.**

In this push pull converter circuit, the control capabilities of the SG1524B PWM are combined with the powerful totem-pole drivers found in the SG1644 (see SG1626 for example). This inexpensive configuration results in very fast charge and discharge of the power MOSFET gate capacitance for efficient switching.



**FIGURE 13.**

When the peak current capabilities of PWM's such as 1525A or 1526B are not sufficient to drive high capacitive loads fast enough, SG1644 is one solution to this problem. This combination is especially suited for full bridge applications where high input capacitance MOSFETs are being used. Diodes D1 and D2 are necessary if the leakage inductance of the drive transformer will drive the output pins negative.



TYPICAL APPLICATIONS (continued)

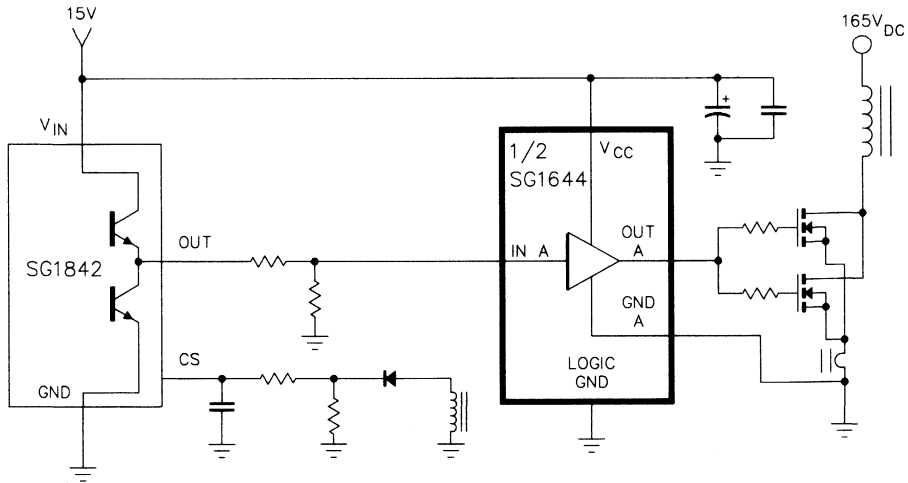


FIGURE 14.

A low cost, yet powerful alternative to the single ended converters with parallel MOSFETs is a combination of SG1842 and SG1644 as shown in Figure 16. This combination will also allow a low noise operation by separating the drive and its associated high peak currents, away from the PWM logic section.

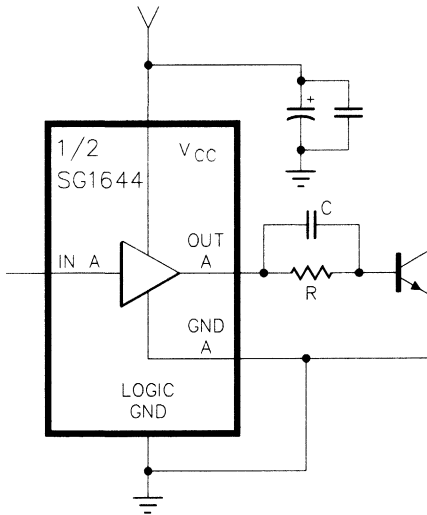


FIGURE 15.

Fast turn off of bipolar transistors is possible by the totem pole output stage of SG1644. The charge on capacitor C will drive the base negative for faster turn off.

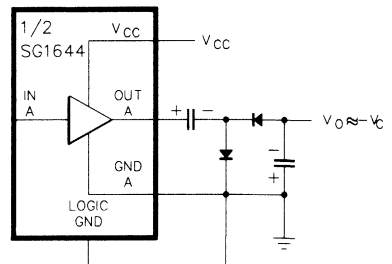
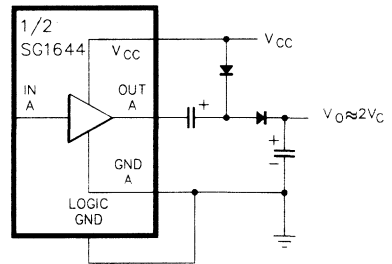


FIGURE 16.

When the inputs are driven with a TTL square wave drive, the high peak current capabilities of SG1644 allow easy implementation of charge pump voltage converters.

# SG1644/SG2644/SG3644

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
14-PIN CERAMIC DIP J - PACKAGE	SG1644J/883B SG1644J SG2644J SG3644J	-55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C	
8-PIN CERAMIC DIP Y - PACKAGE	SG1644Y/883B SG1644Y SG2644Y SG3644Y	-55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C	
8-PIN PLASTIC DIP M - PACKAGE	SG2644M SG3644M	-25°C to 85°C 0°C to 70°C	
16-PIN BATWING DIP W - PACKAGE	SG2644W SG3644W	-25°C to 85°C 0°C to 70°C	
8-PIN TO-99 METAL CAN T - PACKAGE	SG1644T/883B SG1644T SG2644T SG3644T	-55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C	
9-PIN TO-66 METAL CAN R - PACKAGE	SG1644R/883B SG1644R SG2644R SG3644R	-55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C	<p style="font-size: small;">CASE IS LOGIC GROUND Note: Case and tab are internally connected to substrate ground.</p>

Note 1. Contact factory for JAN and DESC product availability.  
 Note 2. All packages are viewed from the top.

**HIGH VOLTAGE MEDIUM  
CURRENT DRIVER ARRAYS**

**DESCRIPTION**

The SG2000 series integrates seven NPN Darlington pairs with internal suppression diodes to drive lamps, relays, and solenoids in many military, aerospace, and industrial applications that require severe environments. All units feature open collector outputs with greater than 50V breakdown voltages combined with 500mA current carrying capabilities. Five different input configurations provide optimized designs for interfacing with DTL, TTL, PMOS, or CMOS drive signals. These devices are designed to operate from -55°C to 125°C ambient temperature in a 16 pin dual in line ceramic (J) package and 20 pin Leadless Chip Carrier (LCC). The plastic dual in-line (N) and S.O.I.C. (DW) are designed to operate over the commercial temperature range of 0°C to 70°C.

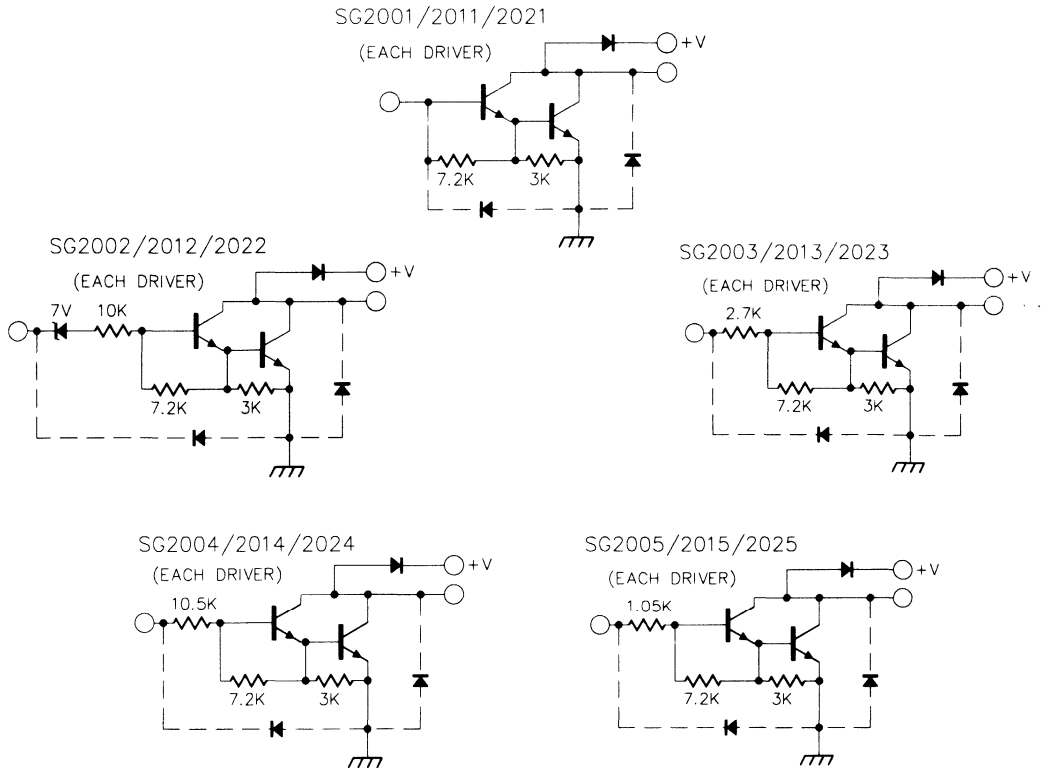
**FEATURES**

- Seven npn Darlington pairs
- -55°C to 125°C ambient operating temperature range
- Collector currents to 600mA
- Output voltages from 50V to 95V
- Internal clamping diodes for inductive loads
- DTL, TTL, PMOS, or CMOS compatible inputs
- Hermetic ceramic package

**HIGH RELIABILITY FEATURES**

- ◆ Available to MIL-STD-883 and DESC SMD
- ◆ MIL-M38510/14103BEA - JAN2003J
- ◆ Radiation data available
- ◆ SG level "S" processing available

**PARTIAL SCHEMATICS**



## ABSOLUTE MAXIMUM RATINGS (Note 1)

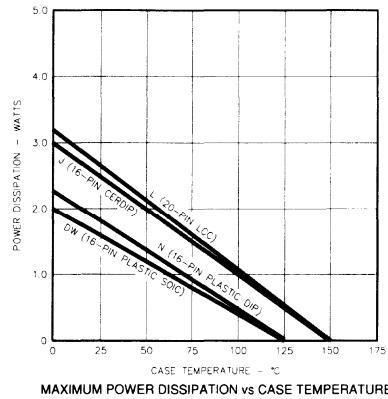
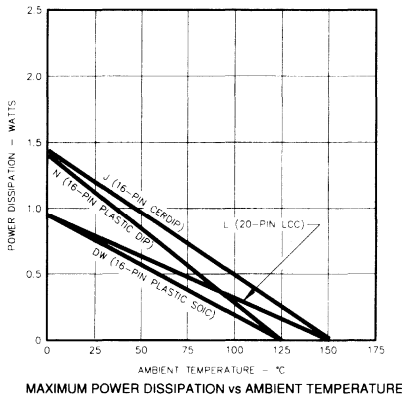
Output Voltage, $V_{CE}$	
(SG2000, 2010 series) .....	50V
(SG2020 series) .....	95V
Input Voltage, $V_{IN}$	
(SG2002,3,4) .....	30V
(SG2005) .....	15V
Continuous Input Current, $I_{IN}$ .....	25mA

Peak Collector Current, $I_C$	
(SG2000, 2020) .....	500mA
(SG2010) .....	600mA
Operating Junction Temperature	
Hermetic (J, L Packages) .....	175°C
Plastic (N, DW Packages) .....	150°C
Storage Temperature Range .....	-65°C to 150°C
Lead Temperature (Soldering 10 sec.) .....	300°C

Note 1. Values beyond which damage may occur.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



### ELECTRICAL

Output Voltage, $V_{CE}$	
SG2000, SG2020 series .....	50V
SG2010 series .....	95V

Peak Collector Current, $I_C$	
SG2000, SG2020 series .....	350mA
SG2010 series .....	500mA
Operating Ambient Temperature Range	
SG2000 Series - Hermetic .....	-55°C to 125°C
SG2000 Series - Plastic .....	0°C to 70°C

Note 2. Range over which the device is functional.

# SG2000 SERIES

## ELECTRICAL SPECIFICATIONS

(Unless otherwise specified, these specifications apply over operating temperature range.)

SG2001 thru SG2005

Parameter	Applicable Devices	Temp.	Test Conditions	Limits			Units
				Min.	Typ.	Max.	
Output Leakage Current ( $I_{CEX}$ )	All		$V_{CE} = 50V$			100	$\mu A$
	SG2002		$V_{CE} = 50V, V_{IN} = 6V$			500	$\mu A$
	SG2004		$V_{CE} = 50V, V_{IN} = 1V$			500	$\mu A$
Collector - Emitter ( $V_{CE(SAT)}$ )	All	$T_A = T_{MIN}$	$I_C = 350mA, I_B = 850\mu A$	1.6		1.8	V
		$T_A = T_{MIN}$	$I_C = 200mA, I_B = 550\mu A$	1.3		1.5	V
		$T_A = T_{MIN}$	$I_C = 100mA, I_B = 350\mu A$	1.1		1.3	V
		$T_A = 25^\circ C$	$I_C = 350mA, I_B = 500\mu A$	1.25		1.6	V
		$T_A = 25^\circ C$	$I_C = 200mA, I_B = 350\mu A$	1.1		1.3	V
		$T_A = 25^\circ C$	$I_C = 100mA, I_B = 250\mu A$	0.9		1.1	V
		$T_A = T_{MAX}$	$I_C = 350mA, I_B = 500\mu A$	1.6		1.8	V
		$T_A = T_{MAX}$	$I_C = 200mA, I_B = 350\mu A$	1.3		1.5	V
		$T_A = T_{MAX}$	$I_C = 100mA, I_B = 250\mu A$	1.1		1.3	V
Input Current ( $I_{IN(ON)}$ )	SG2002		$V_{IN} = 17V$	480	850	1300	$\mu A$
	SG2003		$V_{IN} = 3.85V$	650	930	1350	$\mu A$
	SG2004		$V_{IN} = 5V$	240	350	500	$\mu A$
			$V_{IN} = 12V$	650	1000	1450	$\mu A$
	SG2005		$V_{IN} = 3V$	1180	1500	2400	$\mu A$
Input Voltage ( $V_{IN(OFF)}$ )	All	$T_A = T_{MAX}$	$I_C = 500\mu A$	25	50		$\mu A$
	SG2002	$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 300mA$			18	V
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 300mA$			13	V
	SG2003	$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 200mA$			3.3	V
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 250mA$			3.6	V
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 300mA$			3.9	V
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 200mA$			2.4	V
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 250mA$			2.7	V
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 300mA$			3.0	V
	SG2004	$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 125mA$			6.0	V
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 200mA$			8.0	V
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 275mA$			10	V
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 350mA$			12	V
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 125mA$			5.0	V
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 200mA$			6.0	V
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 275mA$			7.0	V
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 350mA$			8.0	V
	SG2005	$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 350mA$			3.0	V
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 350mA$			2.4	V
	D-C Forward Current	SG2001	$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 350mA$	500		
Transfer Ratio ( $h_{FE}$ )		$T_A = 25^\circ C$	$V_{CE} = 2V, I_C = 350mA$	1000			
Input Capacitance ( $C_{IN}$ ) (Note 3)	All	$T_A = 25^\circ C$			15	25	pF
Turn-On Delay (TPLH)	All	$T_A = 25^\circ C$	$0.5 E_{IN}$ to $0.5 E_{OUT}$		250	1000	ns
Turn-Off Delay (TPHL)	All	$T_A = 25^\circ C$	$0.5 E_{IN}$ to $0.5 E_{OUT}$		250	1000	ns
Clamp Diode Leakage Current ( $I_R$ )	All		$V_R = 50V$			50	$\mu A$
Clamp Diode Forward Voltage ( $V_F$ )	All		$I_F = 350mA$	1.7		2.0	V

Note 3. These parameters, although guaranteed, are not tested in production.

**ELECTRICAL SPECIFICATIONS** (continued)

SG2011 thru SG2015

Parameter	Applicable Devices	Temp.	Test Conditions	Limits			Units
				Min.	Typ.	Max.	
Output Leakage Current ( $I_{CEX}$ )	All		$V_{CE} = 50V$			100	$\mu A$
	SG2012		$V_{CE} = 50V, V_{IN} = 6V$			500	$\mu A$
	SG2014		$V_{CE} = 50V, V_{IN} = 1V$			500	$\mu A$
Collector - Emitter ( $V_{CE(SAT)}$ )	All	$T_A = T_{MIN}$	$I_C = 500mA, I_B = 1100\mu A$	1.8	2.1	V	
		$T_A = T_{MIN}$	$I_C = 350mA, I_B = 850\mu A$	1.6	1.8	V	
		$T_A = T_{MIN}$	$I_C = 200mA, I_B = 550\mu A$	1.3	1.5	V	
		$T_A = 25^\circ C$	$I_C = 500mA, I_B = 600\mu A$	1.7	1.9	V	
		$T_A = 25^\circ C$	$I_C = 350mA, I_B = 500\mu A$	1.25	1.6	V	
		$T_A = 25^\circ C$	$I_C = 200mA, I_B = 350\mu A$	1.1	1.3	V	
		$T_A = T_{MAX}$	$I_C = 500mA, I_B = 600\mu A$	1.8	2.1	V	
		$T_A = T_{MAX}$	$I_C = 350mA, I_B = 500\mu A$	1.6	1.8	V	
		$T_A = T_{MAX}$	$I_C = 200mA, I_B = 350\mu A$	1.3	1.5	V	
		Input Current ( $I_{IN(ON)}$ )	SG2012		$V_{IN} = 17V$	480	850
SG2013			$V_{IN} = 3.85V$	650	930	1350	$\mu A$
SG2014			$V_{IN} = 5V$	240	350	500	$\mu A$
			$V_{IN} = 12V$	650	1000	1450	$\mu A$
SG2015			$V_{IN} = 3V$	1180	1500	2400	$\mu A$
Input Voltage ( $V_{IN(OFF)}$ )	All	$T_A = T_{MAX}$	$I_C = 500\mu A$	25	50	$\mu A$	
	SG2012	$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 500mA$			23.5	V
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 500mA$			17	V
	SG2013	$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 250mA$			3.6	V
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 300mA$			3.9	V
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 500mA$			6.0	V
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 250mA$			2.7	V
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 300mA$			3.0	V
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 500mA$			3.5	V
	SG2014	$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 275mA$			10	V
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 350mA$			12	V
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 500mA$			17	V
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 275mA$			7.0	V
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 350mA$			8.0	V
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 500mA$			9.5	V
	SG2015	$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 350mA$			3.0	V
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 500mA$			3.5	V
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 350mA$			2.4	V
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 500mA$			2.6	V
	D-C Forward Current	SG2011	$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 500mA$	450		
Transfer Ratio ( $h_{FE}$ )		$T_A = 25^\circ C$	$V_{CE} = 2V, I_C = 500mA$	900			
Input Capacitance ( $C_{IN}$ ) (Note 3)	All	$T_A = 25^\circ C$		15	25	pF	
Turn-On Delay (TPLH)	All	$T_A = 25^\circ C$	$0.5 E_{IN}$ to $0.5 E_{OUT}$	250	1000	ns	
Turn-Off Delay (TPHL)	All	$T_A = 25^\circ C$	$0.5 E_{IN}$ to $0.5 E_{OUT}$	250	1000	ns	
Clamp Diode Leakage Current ( $I_R$ )	All		$V_R = 50V$		50	$\mu A$	
Clamp Diode Forward Voltage ( $V_F$ )	All		$I_F = 350mA$	1.7	2.0	V	
			$I_F = 500mA$		2.5	V	

Note 3. These parameters, although guaranteed, are not tested in production.

# SG2000 SERIES

## ELECTRICAL SPECIFICATIONS (continued)

SG2021 thru SG2025

Parameter	Applicable Devices	Temp.	Test Conditions	Limits			Units		
				Min.	Typ.	Max.			
Output Leakage Current ( $I_{CEX}$ )	All		$V_{CE} = 95V$			100	$\mu A$		
	SG2022		$V_{CE} = 95V, V_{IN} = 6V$			500	$\mu A$		
	SG2024		$V_{CE} = 95V, V_{IN} = 1V$			500	$\mu A$		
Collector - Emitter ( $V_{CE(SAT)}$ )	All	$T_A = T_{MIN}$	$I_C = 350mA, I_B = 850\mu A$		1.6	1.8	V		
		$T_A = T_{MIN}$	$I_C = 200mA, I_B = 550\mu A$		1.3	1.5	V		
		$T_A = T_{MIN}$	$I_C = 100mA, I_B = 350\mu A$		1.1	1.3	V		
		$T_A = 25^\circ C$	$I_C = 350mA, I_B = 500\mu A$		1.25	1.6	V		
		$T_A = 25^\circ C$	$I_C = 200mA, I_B = 350\mu A$		1.1	1.3	V		
		$T_A = 25^\circ C$	$I_C = 100mA, I_B = 250\mu A$		0.9	1.1	V		
		$T_A = T_{MAX}$	$I_C = 350mA, I_B = 500\mu A$		1.6	1.8	V		
		$T_A = T_{MAX}$	$I_C = 200mA, I_B = 350\mu A$		1.3	1.5	V		
		$T_A = T_{MAX}$	$I_C = 100mA, I_B = 250\mu A$		1.1	1.3	V		
Input Current ( $I_{IN(ON)}$ )	SG2022		$V_{IN} = 17V$	480	850	1300	$\mu A$		
	SG2023		$V_{IN} = 3.85V$	650	930	1350	$\mu A$		
	SG2024		$V_{IN} = 5V$	240	350	500	$\mu A$		
			$V_{IN} = 12V$	650	1000	1450	$\mu A$		
	SG2025		$V_{IN} = 3V$	1180	1500	2400	$\mu A$		
Input Voltage ( $V_{IN(OFF)}$ ) ( $V_{IN(ON)}$ )	All	$T_A = T_{MAX}$	$I_C = 500\mu A$	25	50		$\mu A$		
	SG2022	$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 300mA$				18	V	
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 300mA$				13	V	
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 200mA$				3.3	V	
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 250mA$				3.6	V	
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 300mA$				3.9	V	
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 200mA$				2.4	V	
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 250mA$				2.7	V	
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 300mA$				3.0	V	
		SG2024	$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 125mA$				6.0	V
			$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 200mA$				8.0	V
	$T_A = T_{MIN}$		$V_{CE} = 2V, I_C = 275mA$				10	V	
	$T_A = T_{MIN}$		$V_{CE} = 2V, I_C = 350mA$				12	V	
	$T_A = T_{MAX}$		$V_{CE} = 2V, I_C = 125mA$				5.0	V	
	SG2025	$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 200mA$				6.0	V	
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 275mA$				7.0	V	
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 350mA$				8.0	V	
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 350mA$				3.0	V	
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 350mA$				2.4	V	
		SG2021	$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 350mA$				500	
$T_A = 25^\circ C$			$V_{CE} = 2V, I_C = 350mA$				1000		
Transfer Ratio ( $h_{FE}$ )		All	$T_A = 25^\circ C$						
Input Capacitance ( $C_{IN}$ ) (Note 3)		All	$T_A = 25^\circ C$				15	pF	
Turn-On Delay (TPLH)		All	$T_A = 25^\circ C$	$0.5 E_{IN}$ to $0.5 E_{OUT}$			250	1000	ns
Turn-Off Delay (TPHL)	All	$T_A = 25^\circ C$	$0.5 E_{IN}$ to $0.5 E_{OUT}$			250	1000	ns	
Clamp Diode Leakage Current ( $I_R$ )	All		$V_R = 95V$			50	$\mu A$		
Clamp Diode Forward Voltage ( $V_F$ )	All		$I_F = 350mA$			1.7	2.0	V	

Note 3. These parameters, although guaranteed, are not tested in production.

## CHARACTERISTIC CURVES

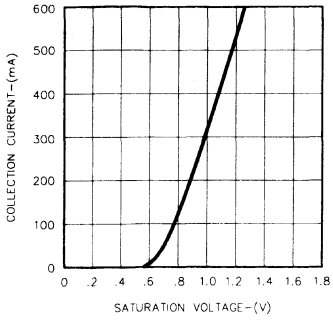


FIGURE 1.  
OUTPUT CHARACTERISTICS

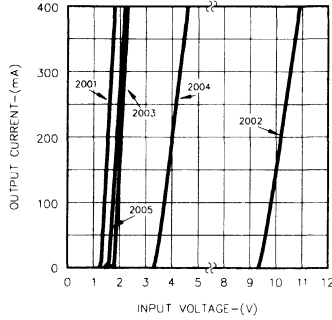


FIGURE 2.  
OUTPUT CURRENT VS. INPUT VOLTAGE

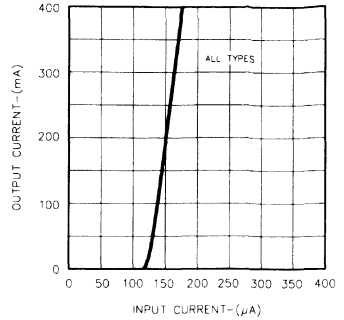


FIGURE 3.  
OUTPUT CURRENT VS. INPUT CURRENT

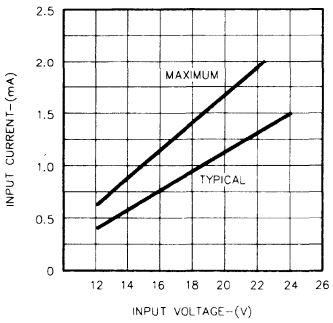


FIGURE 4.  
INPUT CHARACTERISTICS - SG2002

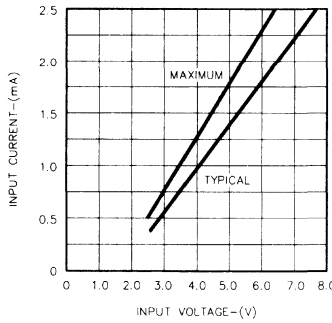


FIGURE 5.  
INPUT CHARACTERISTICS - SG2003

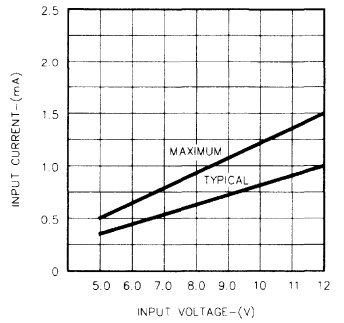


FIGURE 6.  
INPUT CHARACTERISTICS - SG2004

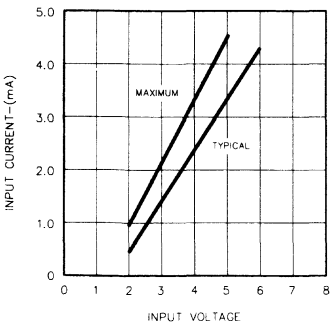


FIGURE 7.  
INPUT CHARACTERISTICS - SG2005

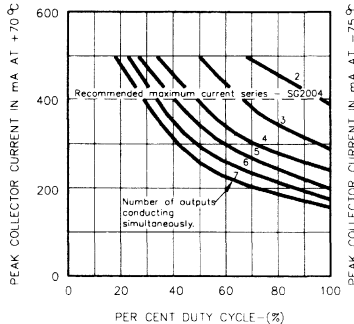


FIGURE 8.  
PEAK COLLECTOR CURRENT VS. DUTY CYCLE



# SG2000 SERIES

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No. (Note 3)	Ambient Temperature Range	Connection Diagram
16-PIN CERAMIC DIP J - PACKAGE	SG2XXXJ/883B SG2XXXJ	-55°C to 125°C -55°C to 125°C	
16-PIN PLASTIC DIP N - PACKAGE	SG2XXXN	0°C to 70°C	
16-PIN WIDE BODY PLASTIC S.O.I.C. DW - PACKAGE	SG2XXXDW	0°C to 70°C	
20-PIN CERAMIC LEADLESS CHIP CARRIER L - PACKAGE	SG2XXXL/883B SG2XXXL	-55°C to 125°C -55°C to 125°C	

- Note 1. Contact factory for JAN and DESC product availability.  
 2. All parts are viewed from the top.  
 3. See selection guide for specific device types.



**QUAD 1.5 AMP DARLINGTON SWITCHES**

**DESCRIPTION**

These high-voltage, high-current Darlington arrays are monolithic bipolar devices especially designed for interfacing low-level control logic and peripheral loads such as relays, solenoids, DC and stepping motors; multiplexed LED and incandescent displays; and heaters. The logic inputs are designed to be compatible with TTL, DTL, LSTTL, CMOS and NMOS logic families. Several of the arrays include integral clamp diodes for driving inductive loads, and breakdown voltage ratings to 80 volts are available.

All devices are supplied in a modified 16-lead plastic dual-in-line package. A copper alloy lead frame with webbing between the central pins provides low thermal resistance to ambient air, and allows a 2.8 watt total power dissipation rating within a standard footprint.

These devices are direct replacements for ULN-2064B thru ULN-2077B devices.

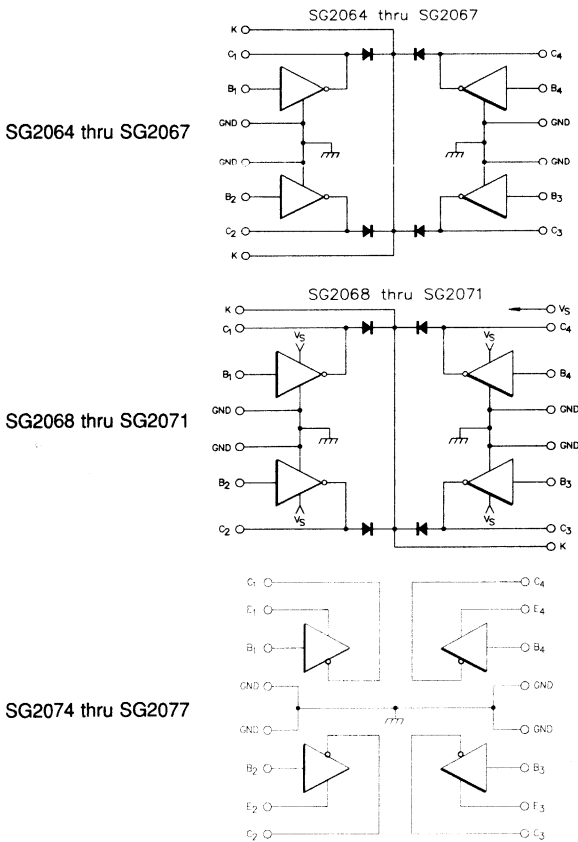
**FEATURES**

- Four power drivers per package
- 1.5 Amp collector currents
- 80V and 50V  $V_{CEX}$  ratings
- Integral clamp diodes for inductive loads
- Compatibility with all popular logic families
- Low internal parasitics

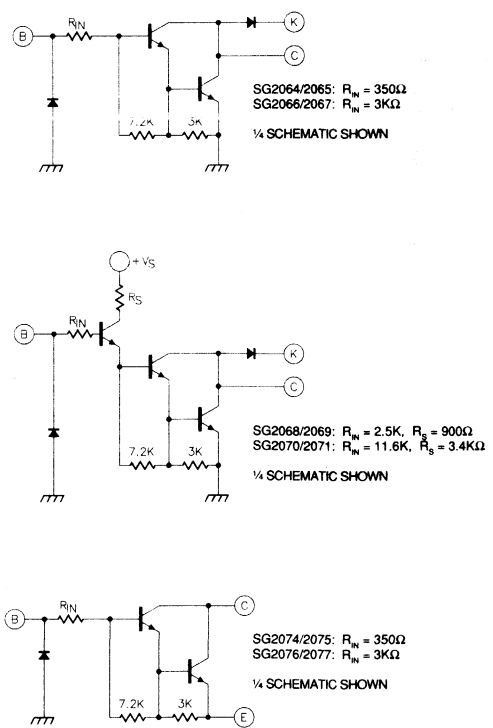
**HIGH RELIABILITY FEATURES  
- SG2069**

- ◆ Available to MIL-STD-883 and DESC SMD

**BLOCK DIAGRAM**



**PARTIAL SCHEMATICS**



# SG2064 THRU SG2077

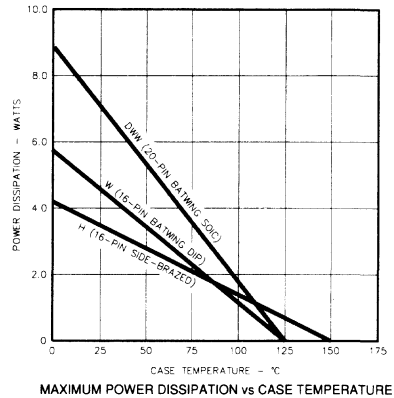
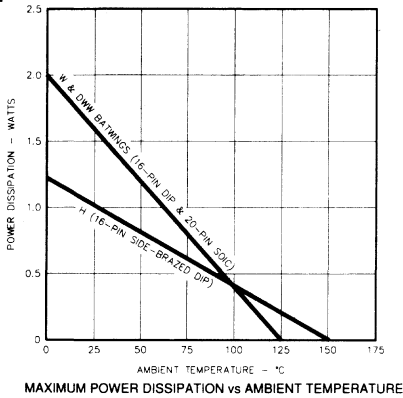
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Logic Input Voltage .....	(Note 2)	Output Current .....	1.75A
Logic Input Current .....	25mA	Operating Junction Temperature	
Supply Voltage		Hermetic (H-Packages) .....	175°C
SG2068/2069 .....	12V	Plastic (W-Packages) .....	150°C
SG2070/2071 .....	22V	Storage Temperature Range .....	-65°C to 150°C
Output Voltage .....	(Note 2)	Lead Temperature (Soldering 10 sec.) .....	300°C

Note 1. Values beyond which damage may occur.  
 Note 2. See Selection Guide located on last page of this data sheet.

## RECOMMENDED OPERATING CONDITIONS (Note 3)

### THERMAL



### ELECTRICAL

Peak Output Current .....	1.5A	Operating Ambient Temperature Range	
Supply Voltage		SG2069 (Side-Brazed) .....	-55°C to 125°C
SG2068/2069 .....	10V	SG2064 thru SG2077 (Batwing) .....	0°C to 70°C
SG2070/2071 .....	20V		

Note 3. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise specified, these specifications apply for  $T_A = 25^\circ\text{C}$ .)  
 SG2064 thru SG2067

Parameter	Applicable Devices	Test Conditions	Limits			Units
			Min.	Typ.	Max.	
Output Leakage Current	SG2064/2066	$V_{CE} = 50V$			100	$\mu\text{A}$
		$V_{CE} = 50V, T_A = T_{MAX}$			500	$\mu\text{A}$
Output Sustaining Voltage (Note 4)	SG2065/2067	$V_{CE} = 80V$			100	$\mu\text{A}$
		$V_{CE} = 80V, T_A = T_{MAX}$			500	$\mu\text{A}$
Collector-Emitter Saturation Voltage	SG2064/2066	$I_C = 100\text{mA}, V_{IN} = 0.4V$	35			V
	SG2065/2067	$I_C = 100\text{mA}, V_{IN} = 0.4V$	50			V
Input Current	All	$I_C = 500\text{mA}, I_B = 625\mu\text{A}$			1.1	V
		$I_C = 750\text{mA}, I_B = 935\mu\text{A}$			1.2	V
	SG2064/2066	$I_C = 1.0A, I_B = 1.25\text{mA}$			1.3	V
	SG2065/2067	$I_C = 1.25A, I_B = 2.0\text{mA}$			1.4	V
	SG2064/2065	$I_C = 1.5A, I_B = 2.25\text{mA}$			1.5	V
Input Current	SG2066/2067	$V_{IN} = 2.4V$	1.4		4.3	mA
		$V_{IN} = 3.75V$	3.3		9.6	mA
		$V_{IN} = 5.0V$	0.6		1.8	mA
		$V_{IN} = 12V$	1.7		5.2	mA

Note 4. These parameters, although guaranteed, are not tested in production.

# SG2064 THRU SG2077

## ELECTRICAL SPECIFICATIONS (continued)

SG2064 thru SG2067

Parameter	Applicable Devices	Test Conditions	Limits			Units
			Min.	Typ.	Max.	
Input Voltage	SG2064/2065	$V_{CE} = 2V, I_C = 1.0A$			2.0	V
		$V_{CE} = 2V, I_C = 1.5A$			2.5	V
	SG2066/2067	$V_{CE} = 2V, I_C = 1.0A$			6.5	V
		$V_{CE} = 2V, I_C = 1.5A$			10	V
Turn-On Delay (Note 4)	All	$0.5 E_{IN}$ to $0.5 E_{OUT}$			1.0	$\mu s$
Turn-Off Delay	All	$0.5 E_{IN}$ to $0.5 E_{OUT}$			1.5	$\mu s$
Clamp Diode Leakage (Note 4) Current	SG2064/2066	$V_R = 50V$			50	$\mu A$
		$V_R = 50V, T_A = T_{MAX}$			100	$\mu A$
	SG2065/2067	$V_R = 80V$			50	$\mu A$
$V_R = 80V, T_A = T_{MAX}$				100	$\mu A$	
Clamp Diode Forward Voltage	All	$I_F = 1.0A$			1.75	V
		$I_F = 1.5A$			2.0	V

SG2068 thru SG2071

Parameter	Applicable Devices	Test Conditions	Limits			Units
			Min.	Typ.	Max.	
Output Leakage Current	SG2068/2070	$V_{CE} = 50V$			100	$\mu A$
		$V_{CE} = 50V, T_A = T_{MAX}$			500	$\mu A$
	SG2069/2071	$V_{CE} = 80V$			100	$\mu A$
		$V_{CE} = 80V, T_A = T_{MAX}$			500	$\mu A$
Output Sustaining Voltage (Note 4)	SG2068/2070	$I_C = 100mA, V_{IN} = 0.4V$	35			V
	SG2069/2071	$I_C = 100mA, V_{IN} = 0.4V$	50			V
Collector-Emitter Saturation Voltage	SG2068/2069	$I_C = 500mA, V_{IN} = 2.75V$			1.1	V
		$I_C = 750mA, V_{IN} = 2.75V$			1.2	V
		$I_C = 1.0A, V_{IN} = 2.75V$			1.3	V
	SG2069	$I_C = 1.25A, V_{IN} = 2.75V$			1.4	V
		$I_C = 1.5A, V_{IN} = 2.75V$			1.5	V
		$I_C = 500mA, V_{IN} = 5.0V$			1.1	V
	SG2070/2071	$I_C = 750mA, V_{IN} = 5.0V$			1.2	V
		$I_C = 1.0A, V_{IN} = 5.0V$			1.3	V
		$I_C = 1.25A, V_{IN} = 5.0V$			1.4	V
		$I_C = 1.5A, V_{IN} = 5.0V$			1.5	V
Input Current	SG2068/2069	$V_{IN} = 2.75V$			550	$\mu A$
		$V_{IN} = 3.75V$			1000	$\mu A$
	SG2070/2071	$V_{IN} = 5.0V$			400	$\mu A$
Input Voltage	SG2068/2069	$V_{CE} = 2V, I_C = 1.5A$			2.75	V
		$V_{CE} = 2V, I_C = 1.5A$			5.0	V
	SG2070/2071	$I_C = 500mA, V_{IN} = 2.4V$			6.0	mA
Supply Current	SG2068/2069	$I_C = 500mA, V_{IN} = 5.0V$			4.5	mA
		$I_C = 500mA, V_{IN} = 5.0V$			4.5	mA
Turn-On Delay (Note 4)	All	$0.5 E_{IN}$ to $0.5 E_{OUT}$			1.0	$\mu s$
Turn-Off Delay (Note 4)	All	$0.5 E_{IN}$ to $0.5 E_{OUT}$			1.5	$\mu s$
Clamp Diode Leakage Current	SG2068/2070	$V_R = 50V$			50	$\mu A$
		$V_R = 50V, T_A = T_{MAX}$			100	$\mu A$
	SG2069/2071	$V_R = 80V$			50	$\mu A$
Clamp Diode Forward Voltage	All	$V_R = 80V, T_A = T_{MAX}$			100	$\mu A$
		$I_F = 1.0A$			1.75	V
		$I_F = 1.5A$			2.0	V

## ELECTRICAL SPECIFICATIONS (continued)

SG2074 thru SG2077

Parameter	Applicable Devices	Test Conditions	Limits			Units
			Min.	Typ.	Max.	
Output Leakage Current	SG2074/2076	$V_{CE} = 50V$ $V_{CE} = 50V, T_A = T_{MAX}$			100	$\mu A$
	SG2075/2077	$V_{CE} = 80V$ $V_{CE} = 80V, T_A = T_{MAX}$			500	$\mu A$
Output Sustaining Voltage (Note 4)	SG2074/2076	$I_C = 100mA, V_{IN} = 0.4V$	35			V
	SG2075/2077	$I_C = 100mA, V_{IN} = 0.4V$	50			V
Collector-Emitter Saturation Voltage	All	$I_C = 500mA, I_B = 625\mu A$			1.1	V
		$I_C = 750mA, I_B = 935\mu A$			1.2	V
	SG2074/2076	$I_C = 1.0A, I_B = 1.25mA$			1.3	V
		$I_C = 1.25A, I_B = 2.0mA$			1.4	V
		$I_C = 1.5A, I_B = 2.25mA$			1.5	V
Input Current	SG2074/2075	$V_{IN} = 2.4V$	2.0		4.3	mA
		$V_{IN} = 3.75V$	4.5		9.6	mA
	SG2076/2077	$V_{IN} = 5.0V$	0.9		1.8	mA
Input Voltage	SG2074/2075	$V_{CE} = 2V, I_C = 1.0A$			2.0	V
		$V_{CE} = 2V, I_C = 1.5A$			2.5	V
	SG2076/2077	$V_{CE} = 2V, I_C = 1.0A$			6.5	V
Turn-On Delay (Note 4)	All	$0.5 E_{IN}$ to $0.5 E_{OUT}$			1.0	$\mu s$
		$0.5 E_{IN}$ to $0.5 E_{OUT}$			1.5	$\mu s$

## CHARACTERISTIC CURVES

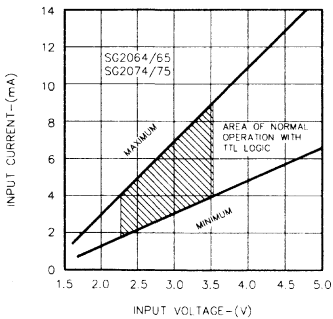


FIGURE 1. LOGIC INPUT CURRENT VS. INPUT VOLTAGE—5V LOGIC

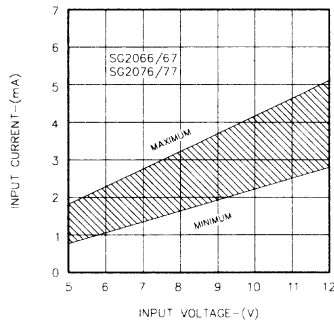


FIGURE 2. LOGIC INPUT CURRENT VS. INPUT VOLTAGE—HIGH LEVEL LOGIC

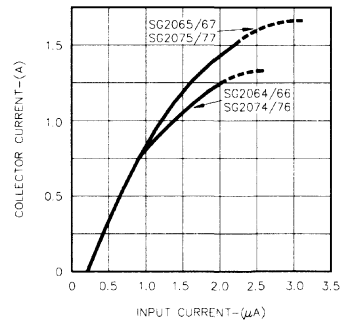


FIGURE 3. MAXIMUM REQUIRED LOGIC INPUT CURRENT VS. COLLECTOR CURRENT

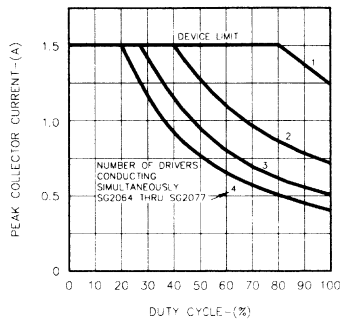


FIGURE 4. PEAK ALLOWABLE COLLECTOR CURRENT VS. DUTY CYCLE AT  $T_a = 70^\circ C$

# SG2064 THRU SG2077

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
16-PIN PLASTIC BATWING W - PACKAGE	SG2064W SG2065W SG2066W SG2067W	0°C to 70°C 0°C to 70°C 0°C to 70°C 0°C to 70°C	
16-PIN PLASTIC BATWING W - PACKAGE	SG2068W SG2069W SG2070W SG2071W	0°C to 70°C 0°C to 70°C 0°C to 70°C 0°C to 70°C	
16-PIN PLASTIC BATWING W - PACKAGE	SG2074W SG2075W SG2076W SG2077W	0°C to 70°C 0°C to 70°C 0°C to 70°C 0°C to 70°C	
16-PIN SIDE-BRAZED DIP H - PACKAGE	SG2069H/883B SG2069H	-55°C to 125°C -55°C to 125°C	
20-PIN PLASTIC BATWING S.O.I.C. DWW - PACKAGE	SG2064DWW SG2065DWW SG2066DWW SG2067DWW	0°C to 70°C 0°C to 70°C 0°C to 70°C 0°C to 70°C	
20-PIN PLASTIC BATWING S.O.I.C. DWW - PACKAGE	SG2068DWW SG2069DWW SG2070DWW SG2071DWW	0°C to 70°C 0°C to 70°C 0°C to 70°C 0°C to 70°C	

- Note 1. Contact factory for JAN and DESC product availability.  
 2. All parts are viewed from the top.  
 3. See selection guide for specific device types.

# SG2064 THRU SG2077

**CONNECTION DIAGRAMS & ORDERING INFORMATION** (continued)

Package	Part No.	Ambient Temperature Range	Connection Diagram
20-PIN PLASTIC BATWING S.O.I.C. DWW - PACKAGE	SG2074DWW	0°C to 70°C	
	SG2075DWW	0°C to 70°C	
	SG2076DWW	0°C to 70°C	
	SG2077DWW	0°C to 70°C	

**SELECTION GUIDE**

Device	V <sub>CEX</sub> Max	V <sub>CE(SUS)</sub> Max	V <sub>IN</sub> Max	Logic Inputs
SG2064	50V	35V	15V	TTL, DTL, Schottky TTL, 5V CMOS and NMOS
SG2065	80V	50V	15V	
SG2066	50V	35V	30V	6V to 15V CMOS and PMOS
SG2067	80V	50V	30V	
SG2068	50V	35V	15V	TTL, DTL, Schottky TTL, 5V CMOS and NMOS
SG2069	80V	50V	15V	
SG2070	50V	35V	30V	6V to 15V CMOS and PMOS
SG2071	80V	50V	30V	
SG2074	50V	35V	30V	General Purpose
SG2075	80V	50V	60V	
SG2076	50V	35V	30V	6V to 15V CMOS and PMOS
SG2077	80V	50V	60V	



**HIGH VOLTAGE MEDIUM  
CURRENT DRIVER ARRAYS**

**DESCRIPTION**

The SG2800 series integrates eight NPN Darlington pairs with internal suppression diodes to drive lamps, relays, and solenoids in many military, aerospace, and industrial applications that require severe environments. All units feature open collector outputs with greater than 50V breakdown voltages combined with 500mA current carrying capabilities. Five different input configurations provide optimized designs for interfacing with DTL, TTL, PMOS, or CMOS drive signals. These devices are designed to operate from -55°C to 125°C ambient temperature in a 16-pin dual in-line ceramic (J) package and 20-pin leadless chip carrier (LCC).

**FEATURES**

- Eight NPN Darlington pairs
- -55°C to 125°C ambient operating temperature range
- Collector currents to 600mA
- Output voltages from 50V to 95V
- Internal clamping diodes for inductive loads
- DTL, TTL, PMOS, or CMOS compatible inputs
- Hermetic ceramic package

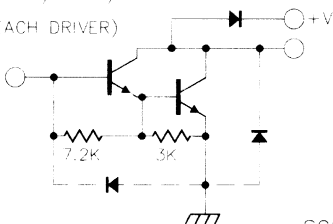
**HIGH RELIABILITY FEATURES**

- ◆ Available to MIL-STD-883 and DESC SMD
- ◆ Scheduled for MIL-M38510 QPL listing
- ◆ Radiation data available
- ◆ SG level "S" processing available

**PARTIAL SCHEMATICS**

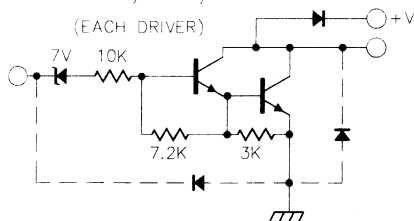
SG2801/2811/2821

(EACH DRIVER)



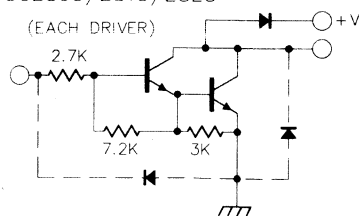
SG2802/2812/2822

(EACH DRIVER)



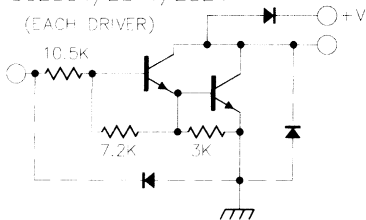
SG2803/2813/2823

(EACH DRIVER)



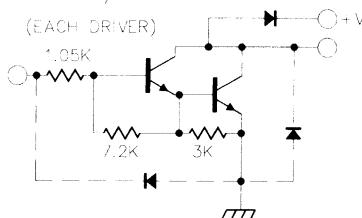
SG2804/2814/2824

(EACH DRIVER)



SG2805/2815

(EACH DRIVER)



# SG2800 SERIES

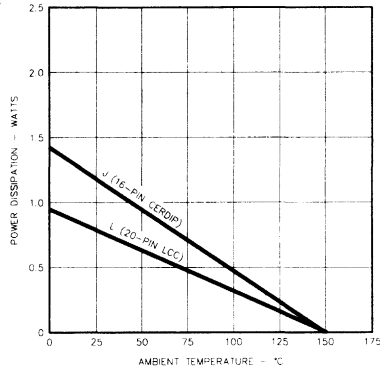
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Output Voltage, $V_{CE}$ (SG2800, 2810 series) .....	50V	Continuous Collector Current, $I_C$ (SG2800, 2820) .....	500mA
(SG2820 series) .....	95V	(SG2810) .....	600mA
Input Voltage, $V_{IN}$ (SG2802,3,4 series) .....	30V	Operating Junction Temperature Hermetic (J, L Packages) .....	175°C
(SG2805 series) .....	15V	Storage Temperature Range .....	-65°C to 150°C
Continuous Input Current, $I_{IN}$ .....	25mA	Lead Temperature (Soldering 10 sec.) .....	300°C

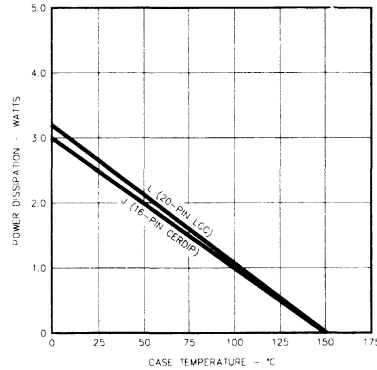
Note 1. Values beyond which damage may occur.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Output Voltage, $V_{CE}$ SG2800, SG2820 series .....	50V	Peak Collector Current, $I_C$ SG2800, SG2820 series .....	350mA
SG2810 series .....	95V	SG2810 series .....	500mA

Note 2. Range over which the device is functional.

## SELECTION GUIDE

Device	$V_{CE}$ Max	$I_C$ Max	Logic Inputs
SG2801	50V	500mA	General Purpose PMOS, CMOS
SG2802	50V	500mA	14V-25V PMOS
SG2803	50V	500mA	5V TTL, CMOS
SG2804	50V	500mA	6V-15V CMOS, PMOS
SG2805	50V	500mA	High Output TTL
SG2811	50V	600mA	General Purpose PMOS, CMOS
SG2812	50V	600mA	14V-25V PMOS

Device	$V_{CE}$ Max	$I_C$ Max	Logic Inputs
SG2813	50V	600mA	5V TTL, CMOS
SG2814	50V	600mA	6V-15V CMOS, PMOS
SG2815	50V	600mA	High Output TTL
SG2821	95V	500mA	General Purpose PMOS, CMOS
SG2822	95V	500mA	14V-25V PMOS
SG2823	95V	500mA	5V TTL, CMOS
SG2824	95V	500mA	6V-15V CMOS, PMOS

# SG2800 SERIES

## ELECTRICAL SPECIFICATIONS

(Unless otherwise specified, these specifications apply over operating temperature range.)  
SG2801 thru SG2805

Parameter	Applicable Devices	Temp.	Test Conditions	Limits			Units
				Min.	Typ.	Max.	
Output Leakage Current ( $I_{CEX}$ )	All		$V_{CE} = 50V$			100	$\mu A$
	SG2802		$V_{CE} = 50V, V_{IN} = 6V$			500	$\mu A$
	SG2804		$V_{CE} = 50V, V_{IN} = 1V$			500	$\mu A$
Collector - Emitter ( $V_{CE(SAT)}$ )	All	$T_A = T_{MIN}$	$I_C = 350mA, I_B = 850\mu A$		1.6	1.8	V
		$T_A = T_{MIN}$	$I_C = 200mA, I_B = 550\mu A$		1.3	1.5	V
		$T_A = T_{MIN}$	$I_C = 100mA, I_B = 350\mu A$		1.1	1.3	V
		$T_A = 25^\circ C$	$I_C = 350mA, I_B = 500\mu A$		1.25	1.6	V
		$T_A = 25^\circ C$	$I_C = 200mA, I_B = 350\mu A$		1.1	1.3	V
		$T_A = 25^\circ C$	$I_C = 100mA, I_B = 250\mu A$		0.9	1.1	V
		$T_A = T_{MAX}$	$I_C = 350mA, I_B = 500\mu A$		1.6	1.8	V
		$T_A = T_{MAX}$	$I_C = 200mA, I_B = 350\mu A$		1.3	1.5	V
		$T_A = T_{MAX}$	$I_C = 100mA, I_B = 250\mu A$		1.1	1.3	V
Input Current ( $I_{IN(ON)}$ )	SG2802		$V_{IN} = 17V$	480	850	1300	$\mu A$
	SG2803		$V_{IN} = 3.85V$	650	930	1350	$\mu A$
	SG2804		$V_{IN} = 5V$	240	350	500	$\mu A$
			$V_{IN} = 12V$	650	1000	1450	$\mu A$
	SG2805		$V_{IN} = 3V$	1180	1500	2400	$\mu A$
$I_{IN(OFF)}$ Input Voltage ( $V_{IN(ON)}$ )	All	$T_A = T_{MAX}$	$I_C = 500\mu A$	25	50		$\mu A$
	SG2802	$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 300mA$			18	V
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 300mA$			13	V
	SG2803	$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 200mA$			3.3	V
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 250mA$			3.6	V
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 300mA$			3.9	V
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 200mA$			2.4	V
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 250mA$			2.7	V
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 300mA$			3.0	V
	SG2804	$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 125mA$			6.0	V
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 200mA$			8.0	V
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 275mA$			10	V
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 350mA$			12	V
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 125mA$			5.0	V
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 200mA$			6.0	V
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 275mA$			7.0	V
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 350mA$			8.0	V
	SG2805	$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 350mA$			3.0	V
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 350mA$			2.4	V
	D-C Forward Current	SG2801	$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 350mA$	500		
Transfer Ratio ( $h_{FE}$ )		$T_A = 25^\circ C$	$V_{CE} = 2V, I_C = 350mA$	1000			
Input Capacitance ( $C_{IN}$ ) (Note 3)	All	$T_A = 25^\circ C$			15	25	pF
Turn-On Delay (TPLH)	All	$T_A = 25^\circ C$	$0.5 E_{IN}$ to $0.5 E_{OUT}$		250	1000	ns
Turn-Off Delay (TPHL)	All	$T_A = 25^\circ C$	$0.5 E_{IN}$ to $0.5 E_{OUT}$		250	1000	ns
Clamp Diode Leakage Current ( $I_R$ )	All		$V_R = 50V$			50	$\mu A$
Clamp Diode Forward Voltage ( $V_F$ )	All		$I_F = 350mA$		1.7	2.0	V

Note 3. These parameters, although guaranteed, are not tested in production.

**ELECTRICAL SPECIFICATIONS** (continued)

SG2811 thru SG2815

Parameter	Applicable Devices	Temp.	Test Conditions	Limits			Units	
				Min.	Typ.	Max.		
Output Leakage Current ( $I_{CEX}$ )	All		$V_{CE} = 50V$			100	$\mu A$	
	SG2812		$V_{CE} = 50V, V_{IN} = 6V$			500	$\mu A$	
Collector - Emitter ( $V_{CE(SAT)}$ )	SG2814		$V_{CE} = 50V, V_{IN} = 1V$			500	$\mu A$	
	All	$T_A = T_{MIN}$	$I_C = 500mA, I_B = 1100\mu A$			1.8	2.1	V
		$T_A = T_{MIN}$	$I_C = 350mA, I_B = 850\mu A$			1.6	1.8	V
		$T_A = T_{MIN}$	$I_C = 200mA, I_B = 550\mu A$			1.3	1.5	V
		$T_A = 25^\circ C$	$I_C = 500mA, I_B = 600\mu A$			1.7	1.9	V
		$T_A = 25^\circ C$	$I_C = 350mA, I_B = 500\mu A$			1.25	1.6	V
		$T_A = 25^\circ C$	$I_C = 200mA, I_B = 350\mu A$			1.1	1.3	V
		$T_A = T_{MAX}$	$I_C = 500mA, I_B = 600\mu A$			1.8	2.1	V
		$T_A = T_{MAX}$	$I_C = 350mA, I_B = 500\mu A$			1.6	1.8	V
		$T_A = T_{MAX}$	$I_C = 200mA, I_B = 350\mu A$			1.3	1.5	V
Input Current ( $I_{IN(ON)}$ )	SG2812		$V_{IN} = 17V$	480	850	1300	$\mu A$	
	SG2813		$V_{IN} = 3.85V$	650	930	1350	$\mu A$	
	SG2814		$V_{IN} = 5V$	240	350	500	$\mu A$	
			$V_{IN} = 12V$	650	1000	1450	$\mu A$	
	SG2815		$V_{IN} = 3V$	1180	1500	2400	$\mu A$	
$(I_{IN(OFF)})$ Input Voltage ( $V_{IN(ON)}$ )	All		$I_C = 500\mu A$	25	50		$\mu A$	
	SG2812	$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 500mA$			23.5	V	
	SG2813	$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 500mA$			17	V	
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 250mA$			3.6	V	
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 300mA$			3.9	V	
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 500mA$			6.0	V	
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 250mA$			2.7	V	
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 300mA$			3.0	V	
	SG2814	$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 500mA$			3.5	V	
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 275mA$			10	V	
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 350mA$			12	V	
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 500mA$			17	V	
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 275mA$			7.0	V	
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 350mA$			8.0	V	
	SG2815	$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 500mA$			9.5	V	
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 350mA$			3.0	V	
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 500mA$			3.5	V	
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 350mA$			2.4	V	
	D-C Forward Current	SG2811	$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 500mA$			2.6	V
			$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 500mA$	450			
	Transfer Ratio ( $h_{FE}$ )		$T_A = 25^\circ C$	$V_{CE} = 2V, I_C = 500mA$	900			
	Input Capacitance ( $C_{IN}$ ) (Note 3)	All	$T_A = 25^\circ C$			15	25	pF
Turn-On Delay (TPLH)	All	$T_A = 25^\circ C$	$0.5 E_{IN}$ to $0.5 E_{OUT}$		250	1000	ns	
Turn-Off Delay (TPHL)	All	$T_A = 25^\circ C$	$0.5 E_{IN}$ to $0.5 E_{OUT}$		250	1000	ns	
Clamp Diode Leakage Current ( $I_R$ )	All		$V_R = 50V$			50	$\mu A$	
Clamp Diode Forward Voltage ( $V_F$ )	All		$I_F = 350mA$		1.7	2.0	V	
			$I_F = 500mA$			2.5	V	

Note 3. These parameters, although guaranteed, are not tested in production.

# SG2800 SERIES

## ELECTRICAL SPECIFICATIONS (continued)

SG2821 thru SG2824

Parameter	Applicable Devices	Temp.	Test Conditions	Limits			Units	
				Min.	Typ.	Max.		
Output Leakage Current ( $I_{CEX}$ )	All		$V_{CE} = 95V$			100	$\mu A$	
	SG2822		$V_{CE} = 95V, V_{IN} = 6V$			500	$\mu A$	
	SG2824		$V_{CE} = 95V, V_{IN} = 1V$			500	$\mu A$	
Collector - Emitter ( $V_{CE(SAT)}$ )	All	$T_A = T_{MIN}$	$I_C = 350mA, I_B = 850\mu A$		1.6	1.8	V	
		$T_A = T_{MIN}$	$I_C = 200mA, I_B = 550\mu A$		1.3	1.5	V	
		$T_A = T_{MIN}$	$I_C = 100mA, I_B = 350\mu A$		1.1	1.3	V	
		$T_A = 25^\circ C$	$I_C = 350mA, I_B = 500\mu A$		1.25	1.6	V	
		$T_A = 25^\circ C$	$I_C = 200mA, I_B = 350\mu A$		1.1	1.3	V	
		$T_A = 25^\circ C$	$I_C = 100mA, I_B = 250\mu A$		0.9	1.1	V	
		$T_A = T_{MAX}$	$I_C = 350mA, I_B = 500\mu A$		1.6	1.8	V	
		$T_A = T_{MAX}$	$I_C = 200mA, I_B = 350\mu A$		1.3	1.5	V	
		$T_A = T_{MAX}$	$I_C = 100mA, I_B = 250\mu A$		1.1	1.3	V	
		Input Current ( $I_{IN(ON)}$ )	SG2822		$V_{IN} = 17V$	480	850	1300
SG2823			$V_{IN} = 3.85V$	650	930	1350	$\mu A$	
SG2824			$V_{IN} = 5V$	240	350	500	$\mu A$	
			$V_{IN} = 12V$	650	1000	1450	$\mu A$	
$(I_{IN(OFF)})$ Input Voltage ( $V_{IN(ON)}$ )	All	$T_A = T_{MAX}$	$I_C = 500\mu A$				$\mu A$	
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 300mA$			18	V	
	SG2822	$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 300mA$			13	V	
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 200mA$			3.3	V	
	SG2823	$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 250mA$			3.6	V	
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 300mA$			3.9	V	
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 200mA$			2.4	V	
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 250mA$			2.7	V	
	SG2824	$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 300mA$			3.0	V	
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 125mA$			6.0	V	
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 200mA$			8.0	V	
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 275mA$			10	V	
		$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 350mA$			12	V	
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 125mA$			5.0	V	
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 200mA$			6.0	V	
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 275mA$			7.0	V	
		$T_A = T_{MAX}$	$V_{CE} = 2V, I_C = 350mA$			8.0	V	
		D-C Forward Current Transfer Ratio ( $h_{FE}$ )	SG2821	$T_A = T_{MIN}$	$V_{CE} = 2V, I_C = 350mA$	500		
	$T_A = 25^\circ C$			$V_{CE} = 2V, I_C = 350mA$	1000			
	Input Capacitance ( $C_{IN}$ ) (Note 3)	All	$T_A = 25^\circ C$			15	25	pF
Turn-On Delay (TPLH)	All	$T_A = 25^\circ C$	$0.5 E_{IN}$ to $0.5 E_{OUT}$	250	1000		ns	
Turn-Off Delay (TPHL)	All	$T_A = 25^\circ C$	$0.5 E_{IN}$ to $0.5 E_{OUT}$	250	1000		ns	
Clamp Diode Leakage Current ( $I_R$ )	All		$V_R = 95V$			50	$\mu A$	
Clamp Diode Forward Voltage ( $V_F$ )	All		$I_F = 350mA$		1.7	2.0	V	

Note 3. These parameters, although guaranteed, are not tested in production.

## CHARACTERISTIC CURVES

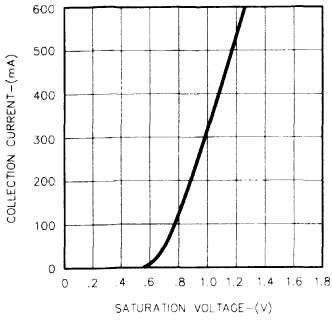


FIGURE 1. OUTPUT CHARACTERISTICS

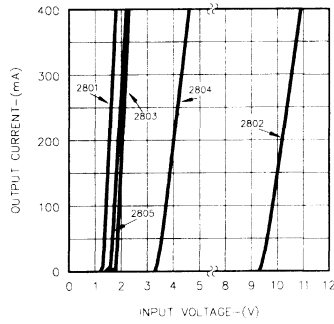


FIGURE 2. OUTPUT CURRENT VS. INPUT VOLTAGE

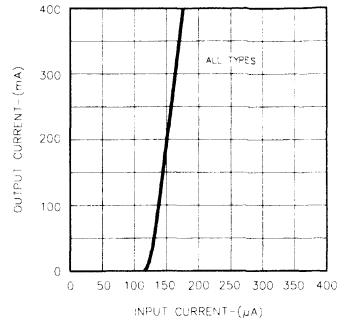


FIGURE 3. OUTPUT CURRENT VS. INPUT CURRENT

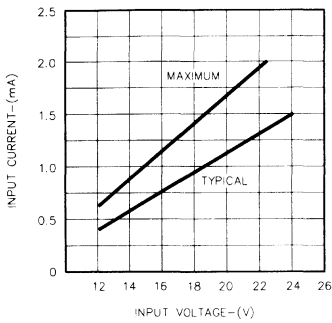


FIGURE 4. INPUT CHARACTERISTICS - SG2802

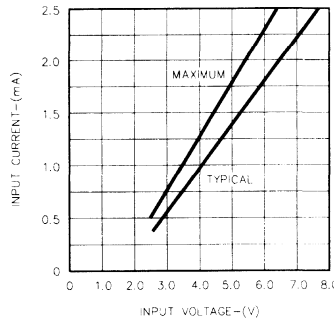


FIGURE 5. INPUT CHARACTERISTICS - SG2803

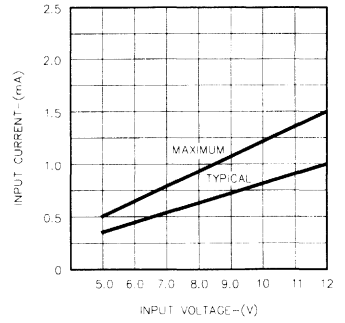


FIGURE 6. INPUT CHARACTERISTICS - SG2804

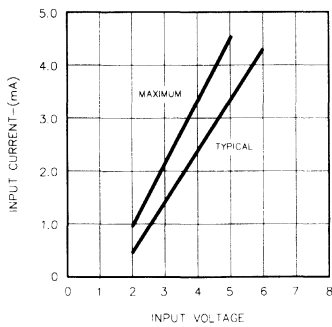


FIGURE 7. INPUT CHARACTERISTICS - SG2805

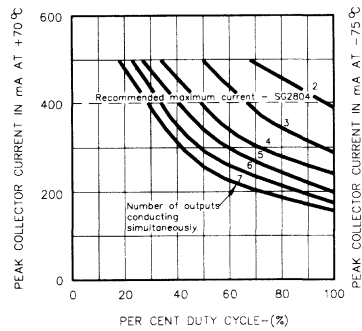
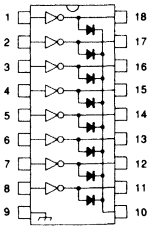
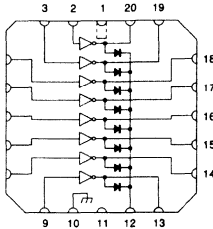


FIGURE 8. PEAK COLLECTOR CURRENT VS. DUTY CYCLE

## SG2800 SERIES

### CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No. (Note 3)	Ambient Temperature Range	Connection Diagram
16-PIN CERAMIC DIP J - PACKAGE	SG28XXJ/883B SG28XXJ	-55°C to 125°C -55°C to 125°C	
20-PIN CERAMIC LEADLESS CHIP CARRIER L - PACKAGE	SG28XXL/883B SG28XXL	-55°C to 125°C -55°C to 125°C	

- Note 1. Contact factory for JAN and DESC product availability.  
 2. All parts are viewed from the top.  
 3. See Selection Guide for specific device types.





**QUAD PIN DIODE DRIVER**

**DESCRIPTION**

This monolithic multiple high-voltage inverting switch is designed to interface between low level digital logic and high-voltage PIN diodes. Each driver stage is self-contained and protected against diode shorts, requiring only a single resistor for determining diode forward current. Reverse operation provides high transient switching current capability for fast diode turnoff. Forward operation is effected when the input is pulled high.

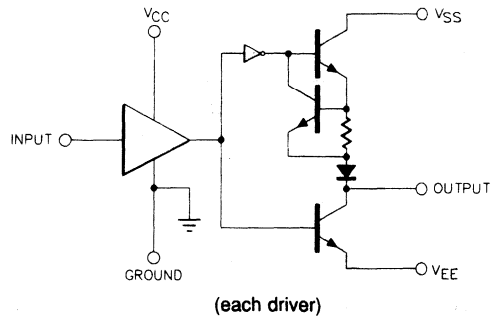
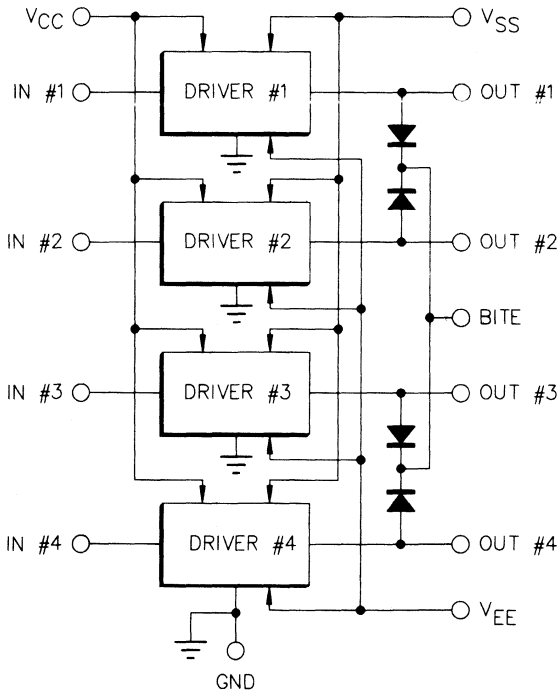
**FEATURES**

- Four independent PIN diode drivers
- 50 volts reverse bias
- 300mA forward current
- Fast diode turnoff
- Shorted diode protection
- Compatible with most logic families
- For 85V or 125V devices contact factory

**HIGH RELIABILITY FEATURES - SG5792**

- ◆ Available to MIL-STD-883
- ◆ SG level "S" processing available

**BLOCK DIAGRAM**



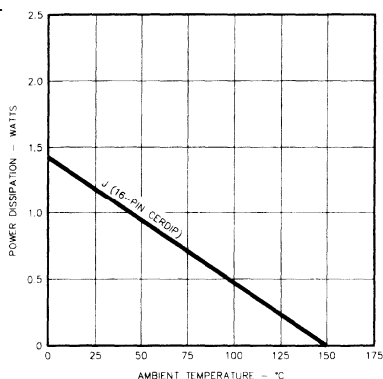
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage ( $V_{CC}$ ) .....	6.0V	Sink Current ( $I_{ON}$ ) .....	500mA
Supply Voltage ( $V_{EE}$ ) .....	-5.0V	Operating Case Temperature ( $T_C$ )	
Supply Voltage ( $V_{SS}$ ) .....	60V	Hermetic (J Package) .....	175°C
Operating Voltage ( $V_{CC} - V_{EE}$ ) .....	9.5V	Storage Temperature Range .....	-65°C to +150°C

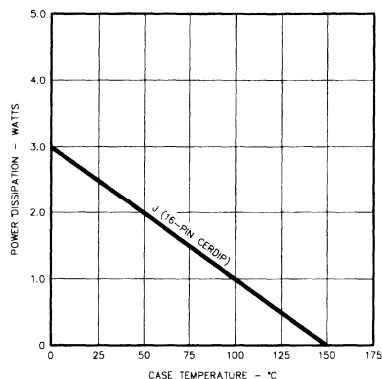
Note 1. Exceeding these ratings could cause damage to the device.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Supply Voltage ( $V_{CC}$ ) .....	4.5V to 5.5V	Operating Ambient Temperature Range	
Supply Voltage ( $V_{EE}$ ) .....	-2.0V to -4.0V	SG5792 .....	-55°C to 125°C
Supply Voltage ( $V_{SS}$ ) .....	$V_{CC}$ to 50V	Current into any output (ON state) .....	300mA (Note 3)
Operating Voltage ( $V_{SS} - V_{EE}$ ) .....	54V		

Note 2. Range over which the device is functional.

Note 3. 300mA into four driver outputs at  $T_A = 125^\circ\text{C}$ . See Thermal Characteristics

## ELECTRICAL SPECIFICATIONS

(Unless otherwise specified, these specifications apply over operating temperature range,  $V_{CC} = 4.5\text{V}$ ,  $V_{EE} = -3.0\text{V}$ , and  $V_{SS} = 50\text{V}$ . All measurements are taken one driver at a time. Output open, unless otherwise specified.)

Parameter	Test Conditions	SG5792			Units
		Min.	Typ.	Max.	
<b>Static Section</b>					
Input Voltage High ( $V_{IH}$ ) (Note 4)		2.0		5.5	V
Input Voltage Low ( $V_{IL}$ ) (Note 4)				0.8	V
Input Current Low ( $I_{IL}$ ) (Note 4)	$V_{CC} = 5.5\text{V}$ , $V_{IN} = 0.4\text{V}$			1.0	mA
Input Current High ( $I_{IH}$ ) (Note 4)	$V_{CC} = 5.5\text{V}$ , $V_{IN} = 5.0\text{V}$	50			$\mu\text{A}$
Output Voltage Low ( $V_{OL}$ ) (Note 5)	$T_A = -55^\circ\text{C}$ , $V_{EE} = 2.4\text{V}$ , $I_O = 300\text{mA}$			0.85	V
	$T_A = 125^\circ\text{C}$ , $V_{EE} = -2.0\text{V}$ , $V_{IN} = 2.4\text{V}$ , $I_O = 300\text{mA}$			1.0	V
	$T_A = 25^\circ\text{C}$ , $V_{EE} = -2.0\text{V}$ , $V_{IN} = 2.4\text{V}$ , $I_O = 300\text{mA}$			0.85	V
	$T_A = -55^\circ\text{C}$ , $V_{IN} = 2.4\text{V}$ , $I_O = 150\text{mA}$			0.5	V
	$T_A = 125^\circ\text{C}$ , $V_{EE} = -2.0\text{V}$ , $V_{IN} = 2.4\text{V}$ , $I_O = 150\text{mA}$			0.6	V
	$T_A = 25^\circ\text{C}$ , $V_{EE} = -2.0\text{V}$ , $V_{IN} = 2.4\text{V}$ , $I_O = 150\text{mA}$			0.5	V
$V_{CC}$ Supply Current - input high ( $I_{CC(1)}$ ) (Note 4)	$V_{CC} = 5.5\text{V}$ , $V_{EE} = -4.0\text{V}$ , $V_{IN} = 2.4\text{V}$ , Total 4 drivers. No load		34	52	mA
$V_{CC}$ Supply Current - input low ( $I_{CC(0)}$ ) (Note 4)	$V_{CC} = 5.5\text{V}$ , $V_{EE} = -4.0\text{V}$ , $V_{IN} = 0.4\text{V}$ , Total 4 drivers. No load		30	40	mA
$V_{EE}$ Supply Current - input low ( $I_{EE(0)}$ ) (Note 4)	$V_{CC} = 5.0\text{V}$ , $V_{IN} = 0.4\text{V}$		20		mA
$V_{EE}$ Supply Current - input high ( $I_{EE(1)}$ ) (Note 4)	$V_{CC} = 5.0\text{V}$ , $V_{IN} = 2.4\text{V}$		120		mA

**ELECTRICAL SPECIFICATIONS** (continued)

Parameter	Test Conditions	SG5792			Units
		Min.	Typ.	Max.	
<b>Static Section</b> (continued)					
Output Short Circuit Current ( $I_{OS}$ )	$V_{IN} = 0.4V, V_{OUT} = 0V, V_{SS} =$	25		60	mA
$V_{SS}$ Supply Current ( $I_{SS}$ )	$T_A = 25^\circ C, V_{IN} = 2.4V$		2.5	4.0	mA
	$T_A = 25^\circ C, V_{IN} = 0.4V$		10	100	$\mu A$
	$T_A = 125^\circ C, V_{IN} = 2.4V$			4.0	mA
	$T_A = 125^\circ C, V_{IN} = 0.4V$			200	$\mu A$
$V_{SS}$ Supply Current ( $I_{SS(SC)}$ )	$T_A = 25^\circ C, V_{IN} = 0.4V, V_{OUT} = 0V$	1.0	3.25	4.0	mA
Output Voltage High ( $V_{OH}$ )	$V_{IN} = 0.4V, I_O = 0.5mA$	45			V
Bite Diodes Reverse Breakdown Voltage ( $P_{IV}$ ) (Note 6 & 8)	$T_A = 125^\circ C$	55			V
	$T_A = 25^\circ C$	55			V
Bite Diodes Forward Voltage Drop ( $V_F$ ) (Note 7 & 8)	$T_A = 125^\circ C$			0.8	V
	$T_A = 25^\circ C$			1.0	V

Parameter	Test Conditions	SG5792			Units
		Min.	Typ.	Max.	
<b>Dynamic Section</b> (See Figure 1)					
Turn-on Time ( $t_{ON}$ ) (Note 9)				0.7	$\mu s$
Turn-off Time ( $t_{OFF}$ ) (Note 9)				5	$\mu s$
Rise Time ( $t_r$ ) (Note 9)				4	$\mu s$

Note 4. Each input.

Note 5. Reference  $V_{EE}$

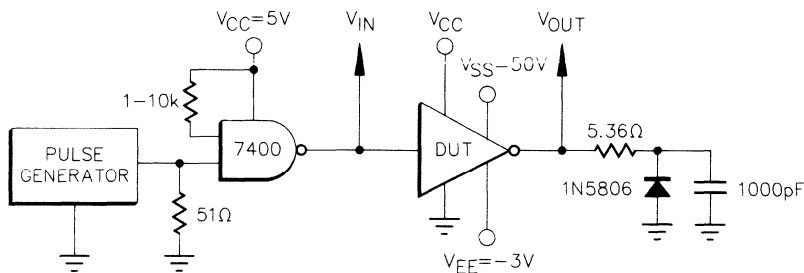
Note 6. Diode output force  $10\mu A$

Note 7. Diode output force  $-100\mu A$

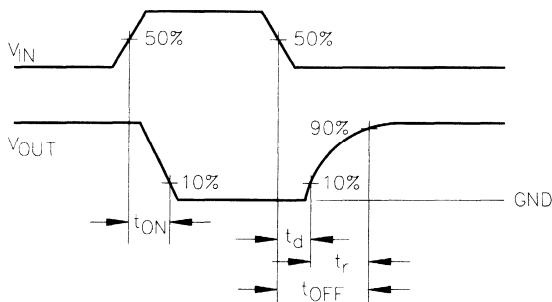
Note 8.  $V_{CC} = \text{Open}, V_{IN} = \text{Open}, V_{OUT} = 0V, V_{SS} = \text{Open}$

Note 9. These tests, although guaranteed, are not tested in production.

**AC TEST CIRCUIT AND SWITCHING TIME WAVEFORMS - FIGURE 1**



PULSE GENERATOR:  
 $P_{RR} = 25KHz$   
 DUTY CYCLE = 0.5  
 $t_f = t_r \leq 7ns$



**CONNECTION DIAGRAMS & ORDERING INFORMATION** (See Note Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
16-PIN CERAMIC DIP J - PACKAGE	SG5792J/883B SG5792J	-55°C to 125°C -55°C to 125°C	<pre> V<sub>ss</sub> 1 16 N.C. BITE 2 15 N.C. OUTPUT #1 3 14 INPUT #1 OUTPUT #2 4 13 INPUT #2 V<sub>EE</sub> 5 12 INPUT #3 OUTPUT #3 6 11 INPUT #4 OUTPUT #4 7 10 V<sub>CC</sub> GND 8 9 N.C. </pre>

Note 1. All packages are viewed from the top.

**QUAD PIN DIODE DRIVER**

**DESCRIPTION**

This monolithic pin diode driver circuit contains four outputs. Each of those is individually controlled by a logic input (HCMOS compatible). A precise current source constant over temperature is implemented, so that an accurate output current driving the pin diode can be obtained when the logic input is high. The circuit is capable of switching the pin diode voltage "on" or "off" fast after detecting and change from the input, it also has four independent polar voltage divider networks to provide an accurate indication of each diode voltage.

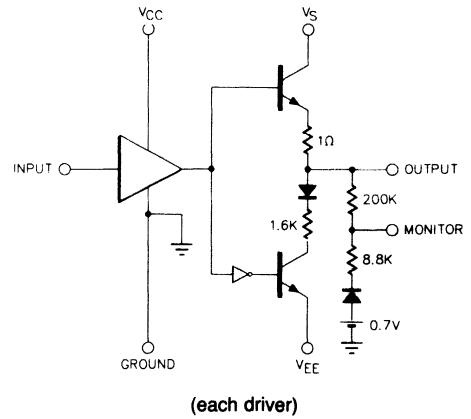
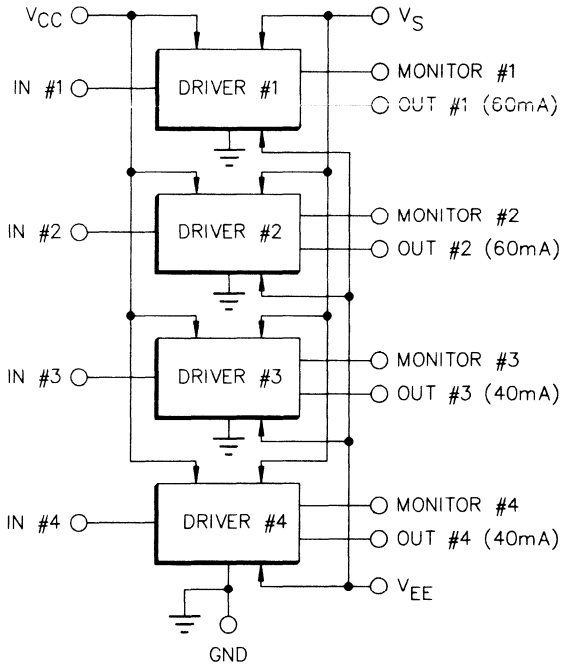
**FEATURES**

- Four independent PIN drivers
- HCMOS compatible
- 200mA forward current capability
- Fast ON or OFF diode switching time
- Accurate monitor output to indicate output voltage
- 55 volts reverse bias

**HIGH RELIABILITY FEATURES - SG5793**

- ◆ Available to MIL-STD-883

**BLOCK DIAGRAM**



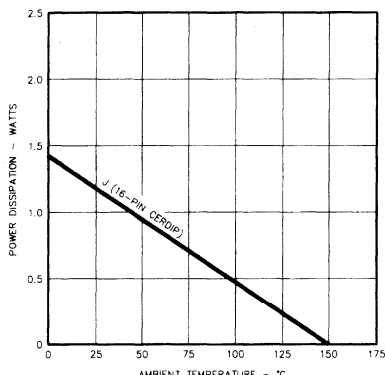
**ABSOLUTE MAXIMUM RATINGS** (Note 1)

Supply Voltage ( $V_{CC}$ ) .....	7.0V	Operating Junction Temperature	
Supply Voltage ( $V_{EE}$ ) .....	-65V	Hermetic (J Package) .....	175°C
Supply Voltage ( $V_S$ ) .....	2.0V	Storage Temperature Range .....	-65°C to +150°C
		Lead Temperature (Soldering, 10 Seconds) .....	300°C

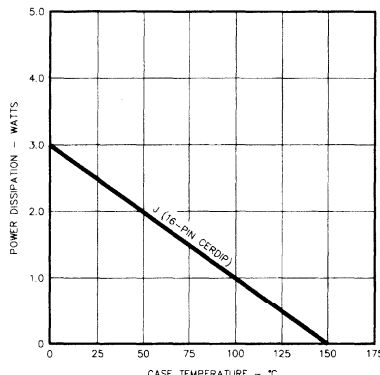
Note 1. Exceeding these ratings could cause damage to the device

**RECOMMENDED OPERATING CONDITIONS** (Note 2)

**THERMAL**



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

**ELECTRICAL**

Supply Voltage ( $V_{CC}$ ) .....	4.75V to 5.25V	Operating Ambient Temperature Range	
Supply Voltage ( $V_{EE}$ ) .....	-47.5V to -52.5V	SG5793 .....	-55°C to 125°C
Supply Voltage ( $V_S$ ) .....	1.45V to 1.55V		

Note 2. Range over which the device is functional.

**ELECTRICAL SPECIFICATIONS**

(Unless otherwise specified, these specifications apply for  $-55^\circ\text{C} \leq T_A \leq 125^\circ\text{C}$ ,  $V_{CC} = 5.0\text{V}$ ,  $V_{EE} = -50\text{V}$ , and  $V_S = 1.5\text{V}$ .)

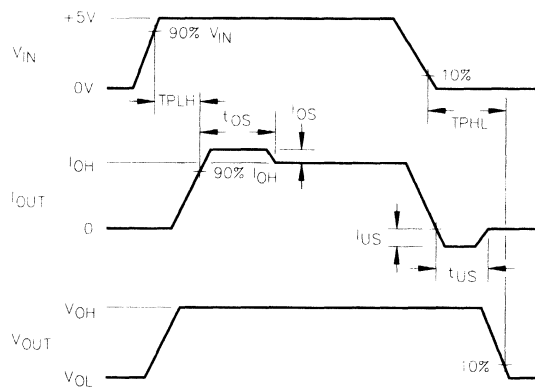
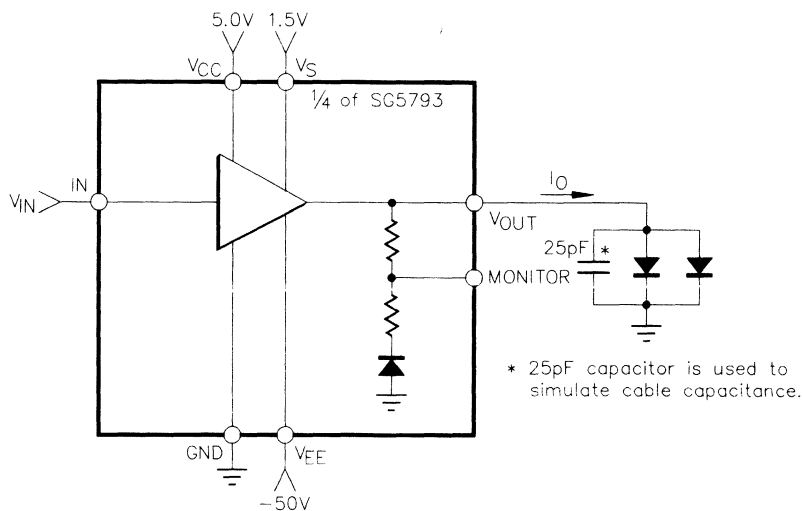
Parameter	Test Conditions	SG5793			Units
		Min.	Typ.	Max.	
<b>Static Section</b>					
<b>Supply Currents</b>					
$I_{CC}$	All four channels are active $V_{IN(1-4)} = 5.0\text{V}$			10.0	mA
$I_{EE}$	$V_{IN(1-4)} = 5.0\text{V}$			-3.0	mA
$I_S$	$V_{IN(1-4)} = 5.0\text{V}$			230	mA
Low Level Input Voltage ( $V_{IL}$ )		-0.5	0	0.4	V
High Level Input Voltage ( $V_{IH}$ )		3.15		5.5	V
Low Level Input Current ( $I_{IL}$ )	$V_{IN} = 0.4\text{V}$			400	$\mu\text{A}$
High Level Input Current ( $I_{IH}$ )	$V_{IN} = 5.5\text{V}$			400	$\mu\text{A}$
Low Level Output Voltage ( $V_{OL}$ )	$V_{CC} = 4.5\text{V}$ , $V_{EE} = -45\text{V}$ , $V_S = 1.4\text{V}$ , $I_O = -500\mu\text{A}$	-36		-55	V
High Level Output Current ( $I_{OH}$ )					
Outputs 1 & 2	$V_{OH} = 0.6\text{V}$	54	60	66	mA
Outputs 3 & 4	$V_{OH} = 0.6\text{V}$	36	40	44	mA
<b>Monitor Voltage</b>					
Output High ( $V_{MH}$ )	Same as for $I_{OH}$	99		102	% $V_{OH}$
Output Low ( $V_{ML}$ )	Same as for $V_{OL}$	5.25		3.25	% $V_{OL}$

**ELECTRICAL CHARACTERISTICS** (continued)

Parameter	Test Conditions	SG5793			Units
		Min.	Typ.	Max.	
<b>Dynamic Section</b> (See Figure 1)					
Propagation Delay (T <sub>PLH</sub> ) (Note 3)				5.0	μs
(T <sub>PHL</sub> ) (Note 3)				5.0	μs
Forward Current Overshoot (I <sub>OS</sub> ) (Note 3)					
Outputs 1 & 2				60	mA
Outputs 3 & 4				40	mA
Overshoot Duration (t <sub>OS</sub> ) (Note 3)				3.0	μs
Reverse Current Undershoot (I <sub>US</sub> ) (Note 3)					
Outputs 1 & 2				-45	mA
Outputs 3 & 4				-30	mA
Undershoot Duration (t <sub>US</sub> ) (Note 3)				2.0	μs

Note 3. Guaranteed by design but not 100% tested.

**TEST CIRCUIT AND SWITCHING TIME WAVEFORMS - FIGURE 1**



**CONNECTION DIAGRAMS & ORDERING INFORMATION** (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram																																
16-PIN CERAMIC DIP J - PACKAGE	SG5793J/883B SG5793J	-55°C to 125°C -55°C to 125°C	<table border="0"> <tr> <td>IN #1</td> <td>1</td> <td>16</td> <td>OUT #1</td> </tr> <tr> <td>IN #2</td> <td>2</td> <td>15</td> <td>MONITOR #1</td> </tr> <tr> <td>V<sub>CC</sub></td> <td>3</td> <td>14</td> <td>OUT #2</td> </tr> <tr> <td>V<sub>S</sub></td> <td>4</td> <td>13</td> <td>MONITOR #2</td> </tr> <tr> <td>V<sub>EE</sub></td> <td>5</td> <td>12</td> <td>MONITOR #3</td> </tr> <tr> <td>GND</td> <td>6</td> <td>11</td> <td>OUT #3</td> </tr> <tr> <td>IN #3</td> <td>7</td> <td>10</td> <td>MONITOR #4</td> </tr> <tr> <td>IN #4</td> <td>8</td> <td>9</td> <td>OUT #4</td> </tr> </table>	IN #1	1	16	OUT #1	IN #2	2	15	MONITOR #1	V <sub>CC</sub>	3	14	OUT #2	V <sub>S</sub>	4	13	MONITOR #2	V <sub>EE</sub>	5	12	MONITOR #3	GND	6	11	OUT #3	IN #3	7	10	MONITOR #4	IN #4	8	9	OUT #4
IN #1	1	16	OUT #1																																
IN #2	2	15	MONITOR #1																																
V <sub>CC</sub>	3	14	OUT #2																																
V <sub>S</sub>	4	13	MONITOR #2																																
V <sub>EE</sub>	5	12	MONITOR #3																																
GND	6	11	OUT #3																																
IN #3	7	10	MONITOR #4																																
IN #4	8	9	OUT #4																																

Note: 1. All packages are viewed from the top.





LINEAR INTEGRATED CIRCUITS

**SG55450B/SG55460/SG55470  
SG75450B/SG75460/SG75470**

**DUAL PERIPHERAL POSITIVE-AND DRIVER**

**DESCRIPTION**

The SG55450B/SG55460/SG55470 (SG75450B/SG75460/SG75470) series of dual peripheral Positive-AND drivers are a family of versatile devices designed for use in systems that employ TTL or DTL logic. This family of drivers are direct replacements for the Texas Instruments SN55450B/60/70 (SN75450B/60/70) series. Diode-clamped inputs simplify circuit design. Typical applications include high-speed logic buffers, power drivers, relay drivers, MOS drivers, line drivers, and memory drivers. These parts are unique general-purpose devices each featuring two standard Series 54/74 TTL gates and two uncommitted, high-current, high-voltage n-p-n transistors and offer the system designer the flexibility of tailoring the circuit to the application. The SG55450B/SG55460/SG55470 drivers are characterized for operation over the full military temperature range of -55°C to 125°C and the SG75450B/SG75460/SG75470 drivers are characterized for operation from 0°C to 70°C

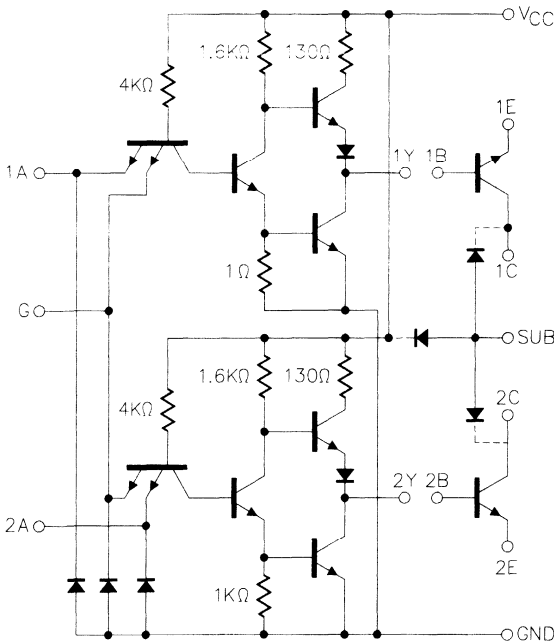
**FEATURES**

- 300mA output current capability
- High-voltage output
- No output latch-up at 20V
- High speed switching
- TTL or DTL compatible diode-clamped inputs
- Standard supply voltages

**HIGH RELIABILITY FEATURES**

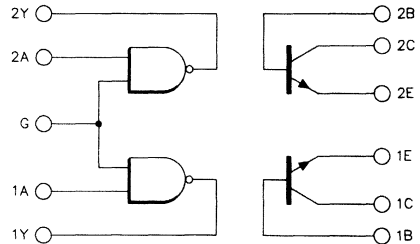
- SG55450B/SG55460/SG55470
- ◆ Available to MIL-STD-883
- ◆ Scheduled for MIL-M-38510 QPL listing
- ◆ SG level "S" processing available

**EQUIVALENT CIRCUIT SCHEMATIC**



**BLOCK DIAGRAM**

Positive Logic:  $Y = \overline{AG}$  (gate only)  
 $C = AG$  (gate and transistor)



**FUNCTION TABLE (each gate)**

A	G	Y
L	L	H (off-state)
L	H	H (off-state)
H	L	H (off-state)
H	H	L (on-state)

H = High Level, L = Low Level

# SG55450B/60/70 SERIES

## ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage ( $V_{CC}$ ) .....	7V
Input Voltage .....	5.5V
Intermitter Voltage (Note 2) .....	5.5V
Emitter-base Voltage .....	5V
Output Current .....	400mA
Operating Junction Temperature	
Hermetic (J, L Packages) .....	175°C

Storage Temperature Range .....	-65°C to 150°C		
Lead Temperature (soldering 60 sec.) .....	300°C		

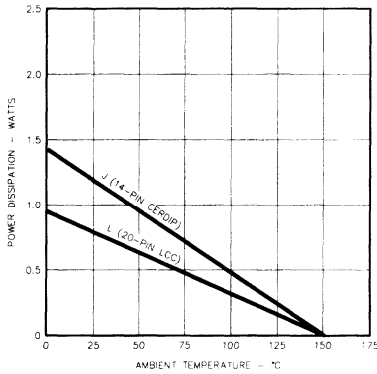
	XX450B Series	XX460 Series	XX470 Series
$V_{CC}$ -to-substrate Voltage .....	35V	40V	70V
Collector-to-substrate Voltage .....	35V	40V	70V
Collector base Voltage .....	35V	40V	70V
Collector-emitter Voltage (Note 3).....	35V	40V	70V

Note 1. Exceeding these ratings could cause damage to the device.  
 Note 2. Voltage between two emitters of a multiple-emitter transistor.

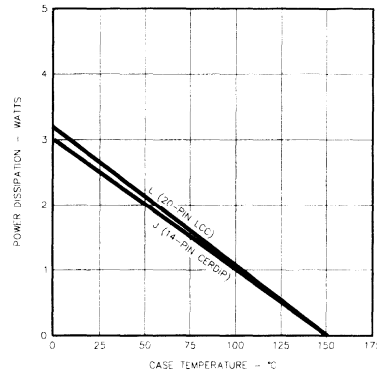
Note 3. Applies when the base-emitter resistance ( $R_{BE}$ ) is equal to or less than 500Ω.

## RECOMMENDED OPERATING CONDITIONS (Notes 4 & 5)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### THERMAL

Supply Voltage ( $V_{CC}$ )	
SG55450B, SG55460, SG55470 .....	4.5V to 5.5V
SG75450B, SG75460, SG75470 .....	4.75V to 5.25V

Operating Ambient Temperature Range	
SG55450B, SG55460, SG55470 .....	-55°C to 125°C
SG75450B, SG75460, SG75470 .....	0°C to 70°C

Note 4. Range over which device is functional.

Note 5. The substrate (pin 8) must always be at the most-negative device voltage for proper operation.

## ELECTRICAL SPECIFICATIONS

TTL Gates - Unless otherwise stated, these specifications and conditions apply using the appropriate recommended operating conditions. Typical values are tested at  $V_{CC} = 5V$ ,  $T_A = 25^\circ C$ .

Parameter	Test Conditions	SG55450B SG55460 SG55470			SG75450B SG75460 SG75470			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>TTL Gates</b>								
High-level Input Voltage ( $V_{IH}$ )		2		0.8	2		0.8	V
Low-level Input Voltage ( $V_{IL}$ )				-1.2			-1.2	V
Input Clamp Voltage ( $V_{IC}$ )	$V_{CC} = \text{MIN}, I_{IN} = -12\text{mA}$			-1.5			-1.5	V
High-level Output Voltage ( $V_{OH}$ )	$V_{CC} = \text{MIN}, V_{IL} = 0.8V, I_{OH} = -400\mu A$	2.4		3.3	2.4		3.3	V
Low-level Output Voltage ( $V_{OL}$ )	$V_{CC} = \text{MIN}, V_{IH} = 2V, I_{OL} = 16\text{mA}$			0.25			0.25	V
Input Current at Max $V_{IN}$	input A $V_{CC} = \text{MAX}, V_{IN} = 5.5V$			1			1	mA
	input G $V_{CC} = \text{MAX}, V_{IN} = 5.5V$			2			2	$\mu A$
High-level Input Current	input A $V_{CC} = \text{MAX}, V_{IN} = 2.4V$			40			40	$\mu A$
	input G $V_{CC} = \text{MAX}, V_{IN} = 2.4V$			80			80	mA
Low-level Input Current	input A $V_{CC} = \text{MAX}, V_{IN} = 0.4V$			-1.6			-1.6	mA
	input G $V_{CC} = \text{MAX}, V_{IN} = 0.4V$			-3.2			-3.2	mA
Short-circuit Output Current (Note 6)	$V_{CC} = \text{MAX}$	-18			-18			mA
Supply Current, Outputs High	$V_{CC} = \text{MAX}, V_{IN} = 0$			4			4	mA
Supply Current, Outputs Low	$V_{CC} = \text{MAX}, V_{IN} = 5V$			11			11	mA

# SG55450B/60/70 SERIES

## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG55450B SG55460 SG55470			SG75450B SG75460 SG75470			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Output Transistors</b>								
Collector-Base Breakdown Voltage ( $V_{(BR)CBO}$ )	$I_C = 100\mu A, I_E = 0$ SG55450B/SG75450B SG55460/SG75460 SG55470/SG75470	35			35			V
		40			40			V
		70			70			V
Collector-Emitter Breakdown Voltage ( $V_{(BR)CEO}$ ) (Note 7)	$I_C = 10mA, I_B = 0$ SG55460/SG75460 SG55470/SG75470	25			25			V
		40			40			V
Collector-Emitter Breakdown Voltage	$I_C = 100\mu A, R_{BE} = 500\Omega$ SG55450B/SG75450B SG55460/SG75460 SG55470/SG75470	30			30			V
		40			40			V
		70			70			V
Emitter-Base Breakdown Voltage ( $V_{(BR)EBO}$ )	$I_E = 100\mu A, I_C = 0$	5			5			V
Static Forward Current Transfer Ratio ( $h_{fe}$ ) (Note 7)	$V_{CE} = 3V, I_C = 100mA, T_A = 25^\circ C$ $V_{CE} = 3V, I_C = 300mA, T_A = 25^\circ C$ $V_{CE} = 3V, I_C = 100mA, T_A = MIN$ $V_{CE} = 3V, I_C = 300mA, T_A = MIN$	25			25			
		30			30			
		10			20			
		15			25			
Base-Emitter Voltage ( $V_{BE}$ ) (Note 7)	$I_B = 10mA, I_C = 100mA$ $I_B = 30mA, I_C = 300mA$		0.85	1.2		0.85	1.0	V
	$I_B = 10mA, I_C = 100mA$		1	1.4		1	1.2	V
Collector-Emitter Saturation Voltage ( $V_{CE(SAT)}$ ) (Note 7)	$I_B = 10mA, I_C = 100mA$ $I_B = 30mA, I_C = 300mA$	0.25	0.5		0.25	0.4		V
		0.45	0.8		0.45	0.7		V

Note 6. Not more than one output should be shorted at a time.

Note 7. These parameters must be measured using pulse techniques ( $t_w = 300\mu s$ , duty cycle  $\leq 2\%$ ).

## SWITCHING SPECIFICATIONS ( $V_{CC} = 5V, T_A = 25^\circ C$ )

Parameter	Test Conditions	SG55450B SG75450B			SG55460 SG75460		SG55470 SG75470		Units			
		Min.	Typ.	Max.	Min.	Typ.	Max.	Min.		Typ.	Max.	
<b>TTL Gates</b>												
Propagation Delay Time, Low- to-High Level Output	$C_L = 15pF, R_L = 400\Omega$		12	22		22		22		ns		
Propagation Delay Time, High- to-Low Level Output			8	15		8		8		ns		
<b>Output Transistors (Note 8)</b>												
Delay Time	$I_L = 200mA, I_{B(1)} = 20mA,$ $I_{B(2)} = -40mA, V_{BE(off)} = -1V,$ $C_L = 15pF, R_L = 50\Omega$		8	15		10		10		ns		
Rise Time			12	20		16		16		ns		
Storage Time			7	15		23		23		ns		
Fall Time			6	15		14		14		ns		
<b>Gate and Transistors Combined</b>												
Propagation Delay Time, Low- to-High Level Output	$I_C = 200mA, C_L = 15pF,$ $R_L \approx 50\Omega$		20	30		45	65		45	65	ns	
Propagation Delay Time, High- to-Low Level Output			20	30		35	50		35	50	ns	
Transition Time, Low-to-High Output				7	12		10	20		10	20	ns
Transition Time, High-to-Low Level Output				9	15		10	20		10	20	ns
High-Level Output Voltage After Switching	$I_C = 300mA, R_{BE} = 500\Omega$ $V_S = 20V$ $V_S = 30V$ $V_S = 55V$				$V_S - 6.5$			$V_S - 10$			mV	
								$V_S - 18$			mV	

Note 8. Voltage and current values shown are nominal; exact values vary slightly with transistor parameters.

## CHARACTERISTIC CURVES

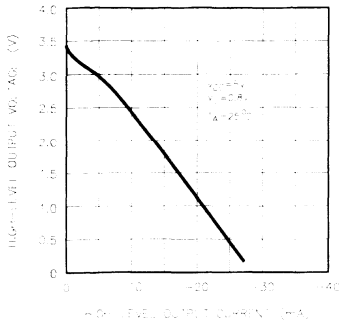


FIGURE 1.  
HIGH-LEVEL OUTPUT VOLTAGE VS. HIGH-LEVEL  
OUTPUT CURRENT

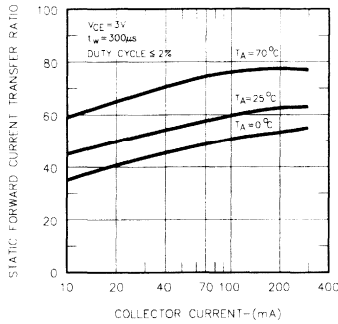


FIGURE 2.  
STATIC FORWARD VS. COLLECTOR CURRENT

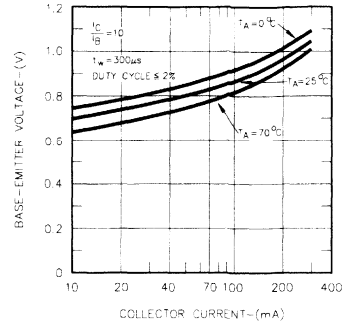


FIGURE 3.  
BASE-EMITTER VOLTAGE VS. COLLECTOR  
VOLTAGE

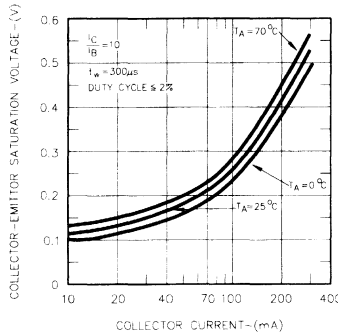


FIGURE 4.  
COLLECTOR-EMITTER SATURATION VOLTAGE  
VS. COLLECTOR CURRENT

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
14-PIN CERAMIC DIP J - PACKAGE	SG55450BJ/883B	-55°C to 125°C	
	SG55450BJ	-55°C to 125°C	
	SG55460J/883B	-55°C to 125°C	
	SG55460J	-55°C to 125°C	
	SG55470J/883B	-55°C to 125°C	
	SG55470J	-55°C to 125°C	
	SG75450BJ	0°C to 70°C	
	SG75460J	0°C to 70°C	
	SG75470J	0°C to 70°C	
	20-PIN CERAMIC LEADLESS CHIP CARRIER L- PACKAGE	SG55450BL/883B	
SSG55450BL		-55°C to 125°C	
SG55460L/883B		-55°C to 125°C	
SG55460L		-55°C to 125°C	
SG55470L/883B		-55°C to 125°C	
SG55470L		-55°C to 125°C	

Note 1. Contact factory for JAN and DESC product availability.  
2. All parts are viewed from the top.

Note 3. Product is also available in flat pack. Consult factory for price and delivery.



LINEAR INTEGRATED CIRCUITS

**SG55451B/SG55461/SG55471  
SG75451B/SG75461/SG75471**

**DUAL PERIPHERAL POSITIVE-AND DRIVER**

**DESCRIPTION**

The SG5541B/SG55461/SG55471 (SG75451B/SG75461/SG75471) series of dual peripheral Positive-AND drivers are a family of versatile devices designed for use in systems that employ TTL or DTL logic. This family of drivers are direct replacements for the Texas Instruments SN55451B/61/71 (SN75451B/61/71) series. Diode-clamped inputs simplify circuit design. Typical applications include high-speed logic buffers, power drivers, relay drivers, MOS drivers, line drivers, and memory drivers. The SG55451B/SG55461/SG55471 drivers are characterized for operation over the full military temperature range of -55°C to 125°C and the SG75451B/SG75461/SG75471 drivers are characterized for operation from 0°C to 70°C.

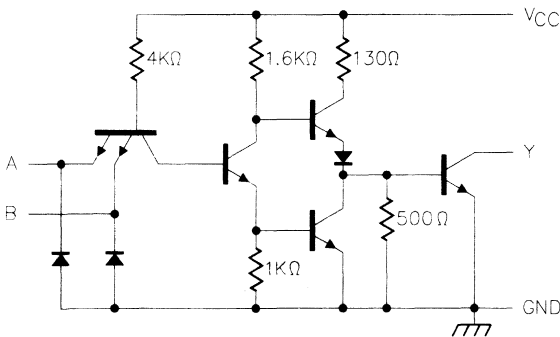
**FEATURES**

- 300mA output current capability
- High-voltage output
- No output latch-up at 20V
- High speed switching
- TTL or DTL compatible diode-clamped inputs
- Standard supply voltages

**HIGH RELIABILITY FEATURES  
- SG55451B/SG55461/SG55471**

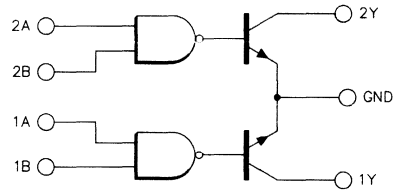
- ◆ Available to MIL-STD-883
- ◆ Scheduled for MIL-M-38510 QPL listing
- ◆ SG level "S" processing available

**EQUIVALENT CIRCUIT SCHEMATIC (each driver)**



**BLOCK DIAGRAM**

Positive Logic:  $Y = AB$



**FUNCTION TABLE (each gate)**

A	B	Y
L	L	L (on-state)
L	H	L (on-state)
H	L	L (on-state)
H	H	H (off-state)

H = High Level, L = Low Level

# SG55451B/61/71 SERIES

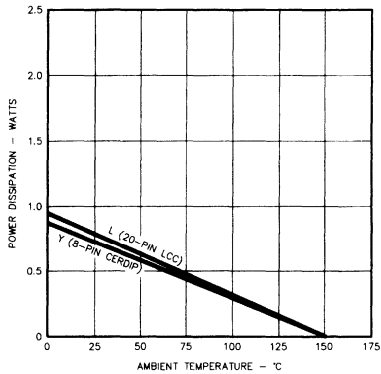
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage ( $V_{CC}$ ) .....	7V	Output Current .....	400mA
Input Voltage .....	5.5V	Continuous Total Dissipation at (or below)	
Intermitter Voltage .....	5.5V	25°C Free-Air Temperature .....	800mW
Off-state Output Voltage		Operating Junction Temperature	
X5451B Series .....	30V	Hermetic (Y, L Packages) .....	175°C
X5461 Series .....	35V	Storage Temperature Range .....	-65°C to 150°C
X5471 Series .....	70V	Lead Temperature (1/16 inch from case	
		for soldering 60 sec.) .....	300°C

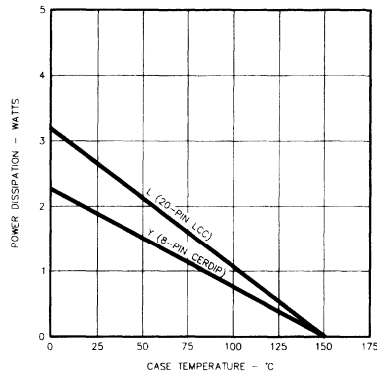
Note 1. Exceeding these ratings could cause damage to the device.

## RECOMMENDED OPERATING CONDITIONS (Notes 2 & 3)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Supply Voltage ( $V_{CC}$ )		Operating Ambient Temperature Range	
SG55451B, SG55461, SG55471 .....	4.5V to 5.5V	SG55451B, SG55461, SG55471 .....	-55°C to 125°C
SG75451B, SG75461, SG75471 .....	4.75V to 5.25V	SG75451B, SG75461, SG75471 .....	0°C to 70°C

Note 2. Range over which device is functional.

Note 3. The substrate (pin 8) must always be at the most-negative device voltage for proper operation.

## ELECTRICAL SPECIFICATIONS

Unless otherwise stated, these specifications and conditions apply for  $-55^{\circ}\text{C} \leq T_A \leq 125^{\circ}\text{C}$  for SG55451B, SG55461, SG55471 and  $0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$  for SG75451B, SG75461, SG75471. Typical values are tested at  $V_{CC} = 5\text{V}$ ,  $T_A = 25^{\circ}\text{C}$ .

Parameter	Test Conditions	SG55451B SG55461 SG55471			SG75451B SG75461 SG75471			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
High-level Input Voltage ( $V_{IH}$ )		2		0.8	2		0.8	V
Low-level Input Voltage ( $V_{IL}$ )				-1.2			-1.2	V
Input Clamp Voltage ( $V_{IK}$ )	$V_{CC} = \text{MIN}$ , $I_{IN} = -12\text{mA}$			-1.5			-1.5	V
High-level Output Current ( $I_{OH}$ )	$V_{CC} = \text{MIN}$ , $V_{IH} = 2\text{V}$ , $V_{OH} = 30\text{V}$ SGX5451B $V_{OH} = 35\text{V}$ SGX5461 $V_{OH} = 70\text{V}$ SGX5471			300			100	$\mu\text{A}$
Low-level Output Voltage ( $V_{OL}$ )	$V_{CC} = \text{MIN}$ , $V_{IL} = 0.8\text{V}$ , $I_{OL} = 100\text{mA}$ $V_{CC} = \text{MIN}$ , $V_{IL} = 0.8\text{V}$ , $I_{OL} = 300\text{mA}$	0.25	0.5		0.25	0.4		V
Input Current at Max $V_{IN}$ ( $I_{IN}$ )	$V_{CC} = \text{MAX}$ , $V_{IN} = 5.5\text{V}$			1.0			1.0	$\text{mA}$
High-level Input Current ( $I_{IH}$ )	$V_{CC} = \text{MAX}$ , $V_{IN} = 2.4\text{V}$			40			40	$\mu\text{A}$
Low-level Input Current ( $I_{IL}$ )	$V_{CC} = \text{MAX}$ , $V_{IN} = 0.4\text{V}$			-1.0			-1.0	$\text{mA}$
Supply Current, Outputs High	$V_{CC} = \text{MAX}$ , $V_{IN} = 5\text{V}$			8			8	$\text{mA}$
Supply Current, Outputs Low	$V_{CC} = \text{MAX}$ , $V_{IN} = 0\text{V}$							
	SGX5451B	52	65		52	65		$\text{mA}$
	SGX5461	56	76		56	76		$\text{mA}$
	SGX5471	56	76		56	76		$\text{mA}$

# SG55451B/61/71 SERIES

## SWITCHING SPECIFICATIONS ( $V_{CC} = 5V, T_A = 25^\circ C$ )

Parameter	Test Conditions	SG55451B SG75451B			SG55461 SG75461			SG55471 SG75471			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
Propagation Delay Time, Low-to-High Level Output	$I_C = 200mA, C_L = 15pF,$ $R_L \approx 50\Omega$		18	25		30	55		30	55	ns
Propagation Delay Time, High-to-Low Level Output			18	25		25	40		25	40	ns
Transition Time, Low-to-High Output			5	8		8	20		8	20	ns
Transition Time, High-to-Low Level Output			7	12		10	20		10	20	ns
High-Level Output Voltage After Switching	$I_C = 300mA,$ $V_S = 20V$ SGX5451B $V_S = 30V$ SGX5461 $V_S = 55V$ SGX5471	$V_S - 6.5$			$V_S - 10$			$V_S - 18$			mV mV mV

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
8-PIN CERAMIC DIP Y - PACKAGE	SG55451BY/883B SG55451BY SG55461Y/883B SG55461Y SG55471Y/883B SG55471Y SG75451BY SG75461Y SG75471Y	-55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C 0°C to 70°C 0°C to 70°C 0°C to 70°C	<p>1A □ 1    8 □ V<sub>CC</sub> 1B □ 2    7 □ 2B 1Y □ 3    6 □ 2A GND □ 4    5 □ 2Y</p>
20-PIN CERAMIC LEADLESS CHIP CARRIER L - PACKAGE	SG55451BL/883B SG55451BL SG55461L/883B SG55461L SG55471L/883B SG55471L	-55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C	<p>1. N.C.    3    2    1    20    19    11. N.C. 2. 1A    4    18    12. 2Y 3. N.C.    5    17    13. N.C. 4. N.C.    6    16    14. N.C. 5. 1B    7    15    15. 2A 6. N.C.    8    14    16. V<sub>CC</sub> 7. 1Y    9    13    17. 2B 8. N.C.    10    12    18. N.C. 9. N.C.    11    11    19. N.C. 10. GND    12    10    20. V<sub>CC</sub></p>

Note 1. Contact factory for JAN and DESC product availability.  
 2. All parts are viewed from the top.  
 3. Product is also available in flat pack. Consult factory for price and delivery.







LINEAR INTEGRATED CIRCUITS

**SG55452B/SG55462/SG55472**  
**SG75452B/SG75462/SG75472**

**DUAL PERIPHERAL POSITIVE-NAND DRIVER**

**DESCRIPTION**

The SG55452B/SG55462/SG55472 (SG75452B/SG75462/SG75472) series of dual peripheral Positive-NAND drivers are a family of versatile devices designed for use in systems that employ TTL or DTL logic. This family of drivers are direct replacements for the Texas Instruments SN55452B/62/72 (SN75452B/62/72) series. Diode-clamped inputs simplify circuit design. Typical applications include high-speed logic buffers, power drivers, relay drivers, MOS drivers, line drivers, and memory drivers. The SG55452B/SG55462/SG55472 drivers are characterized for operation over the full military temperature range of -55°C to 125°C and the SG75452B/SG75462/SG75472 drivers are characterized for operation from 0°C to 70°C.

**FEATURES**

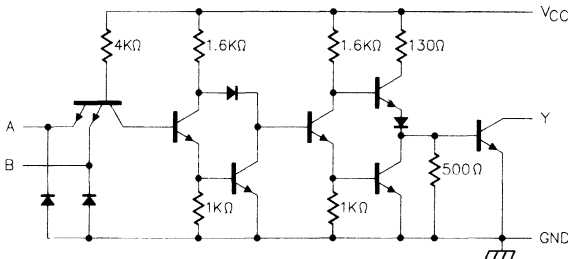
- 300mA output current capability
- High-voltage output
- No output latch-up at 20V
- High speed switching
- TTL or DTL compatible diode-clamped inputs
- Standard supply voltages

**HIGH RELIABILITY FEATURES**

- SG55452B/SG55462/SG55472

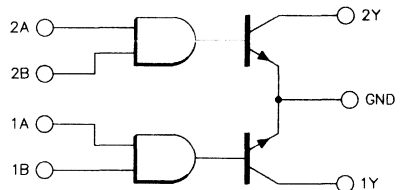
- ◆ Available to MIL-STD-883 and DESC SMD
- ◆ Scheduled for MIL-M-38510 QPL listing
- ◆ SG level "S" processing available

**EQUIVALENT CIRCUIT SCHEMATIC (each driver)**



**BLOCK DIAGRAM**

Positive Logic:  $Y = AB$



**FUNCTION TABLE (each gate)**

A	B	Y
L	L	H (off-state)
L	H	H (off-state)
H	L	H (off-state)
H	H	L (on-state)

H = High Level, L = Low Level

# SG55452B/62/72 SERIES

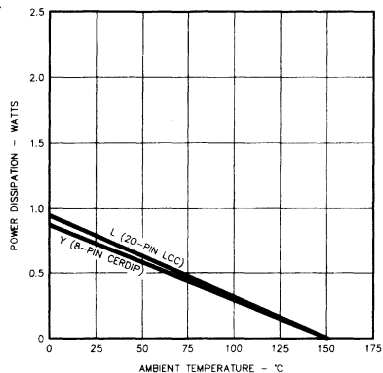
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage ( $V_{CC}$ ) .....	7V	Output Current .....	400mA
Input Voltage .....	5.5V	Continuous Total Dissipation at (or below)	
Intermitter Voltage .....	5.5V	25°C Free-Air Temperature .....	800mW
Off-state Output Voltage		Operating Junction Temperature	
X5452B Series .....	30V	Hermetic (Y, L Packages) .....	175°C
X5462 Series .....	35V	Storage Temperature Range .....	-65°C to 150°C
X5472 Series .....	70V	Lead Temperature (1/16 inch from case	
		for soldering 60 sec.) .....	300°C

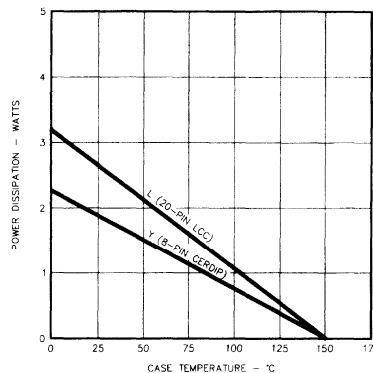
Note 1. Exceeding these ratings could cause damage to the device.

## RECOMMENDED OPERATING CONDITIONS (Notes 2 & 3)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Supply Voltage ( $V_{CC}$ )		Operating Ambient Temperature Range
SG55452B, SG55462, SG55472 .....	4.5V to 5.5V	SG55452B, SG55462, SG55472 .....
SG75452B, SG75462, SG75472 .....	4.75V to 5.25V	SG75452B, SG75462, SG75472 .....

Note 2. Range over which device is functional.

Note 3. The substrate (pin 8) must always be at the most-negative device voltage for proper operation.

## ELECTRICAL SPECIFICATIONS

Unless otherwise stated, these specifications and conditions apply for  $-55^{\circ}\text{C} \leq T_A \leq 125^{\circ}\text{C}$  for SG55452B, SG55462, SG55472 and  $0^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$  for SG75452B, SG75462, SG75472. Typical values are tested at  $V_{CC} = 5\text{V}$ ,  $T_A = 25^{\circ}\text{C}$ .

Parameter	Test Conditions	SG55452B SG55462 SG55472			SG75452B SG75462 SG75472			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
High-level Input Voltage ( $V_{IH}$ )		2			2			V
Low-level Input Voltage ( $V_{IL}$ )				0.8			0.8	V
Input Clamp Voltage ( $V_{IK}$ )			-1.2	-1.5		-1.2	-1.5	V
High-level Output Current ( $I_{OH}$ )	$V_{CC} = \text{MIN}$ , $I_{IN} = -12\text{mA}$ $V_{CC} = \text{MIN}$ , $V_{IH} = 2\text{V}$ $V_{OH} = 30\text{V}$ SGX5452B $V_{OH} = 35\text{V}$ SGX5462 $V_{OH} = 70\text{V}$ SGX5472			300			100	$\mu\text{A}$
Low-level Output Voltage ( $V_{OL}$ )	$V_{CC} = \text{MIN}$ , $V_{IL} = 0.8\text{V}$ , $I_{OL} = 100\text{mA}$ $V_{CC} = \text{MIN}$ , $V_{IL} = 0.8\text{V}$ , $I_{OL} = 300\text{mA}$	0.25	0.5		0.25	0.4		V
Input Current at Max $V_{IN}$ ( $I_{IN}$ )	$V_{CC} = \text{MAX}$ , $V_{IN} = 5.5\text{V}$			1.0			1.0	mA
High-level Input Current ( $I_{IH}$ )	$V_{CC} = \text{MAX}$ , $V_{IN} = 2.4\text{V}$			40			40	$\mu\text{A}$
Low-level Input Current ( $I_{IL}$ )	$V_{CC} = \text{MAX}$ , $V_{IN} = 0.4\text{V}$			-1.0		-1.0	-1.6	mA
Supply Current, Outputs High	$V_{CC} = \text{MAX}$ , $V_{IN} = 0\text{V}$ SGX5452B SGX5462, SGX5472	11	14		11	14		mA
Supply Current, Outputs Low	$V_{CC} = \text{MAX}$ , $V_{IN} = 5\text{V}$ SGX5452B SGX5462, SGX5472	13	17		13	17		mA
		56	71		56	71		mA
		61	76		61	76		mA

## SG55452B/62/72 SERIES

### SWITCHING SPECIFICATIONS ( $V_{CC} = 5V$ , $T_A = 25^\circ C$ )

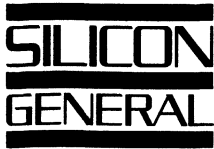
Parameter	Test Conditions	SG55452B SG75452B			SG55462 SG75462			SG55472 SG75472			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
Propagation Delay Time, Low-to-High Level Output	$I_C = 200mA$ , $C_L = 15pF$ , $R_L = 50\Omega$		26	35		45	65		45	65	ns
Propagation Delay Time, High-to-Low Level Output			24	35		30	50		30	50	ns
Transition Time, Low-to-High Output			5	8		13	25		13	25	ns
Transition Time, High-to-Low Level Output			7	12		10	20		10	20	ns
High-Level Output Voltage After Switching	$I_C = 300mA$ , $V_S = 20V$ SGX5452B $V_S = 30V$ SGX5462 $V_S = 55V$ SGX5472	$V_S - 6.5$			$V_S - 10$			$V_S - 18$			mV

### CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
8-PIN CERAMIC DIP Y - PACKAGE	SG55452BY/883B SG55452BY SG55462Y/883B SG55462Y SG55472Y/883B SG55472Y SG75452BY SG75462Y SG75472Y	-55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C 0°C to 70°C 0°C to 70°C 0°C to 70°C	
20-PIN CERAMIC LEADLESS CHIP CARRIER L - PACKAGE	SG55452BL/883B SG55452BL SG55462L/883B SG55462L SG55472L/883B SG55472L	-55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C	

- Note 1. Contact factory for JAN and DESC product availability.  
 2. All parts are viewed from the top.  
 3. Product is also available in flat pack. Consult factory for price and delivery.





LINEAR INTEGRATED CIRCUITS

**SG55453B/SG55463/SG55473  
SG75453B/SG75463/SG75473**

**DUAL PERIPHERAL POSITIVE-OR DRIVER**

**DESCRIPTION**

The SG55453B/SG55463/SG55473 (SG75453B/SG75463/SG75473) series of dual peripheral Positive-OR drivers are a family of versatile devices designed for use in systems that employ TTL or DTL logic. This family of drivers are direct replacements for the Texas Instruments SN55453B/63/73 (SN75453B/63/73) series. Diode-clamped inputs simplify circuit design. Typical applications include high-speed logic buffers, power drivers, relay drivers, MOS drivers, line drivers, and memory drivers. The SG55453B/SG55463/SG55473 drivers are characterized for operation over the full military temperature range of -55°C to 125°C and the SG75453B/SG75463/SG75473 drivers are characterized for operation from 0°C to 70°C.

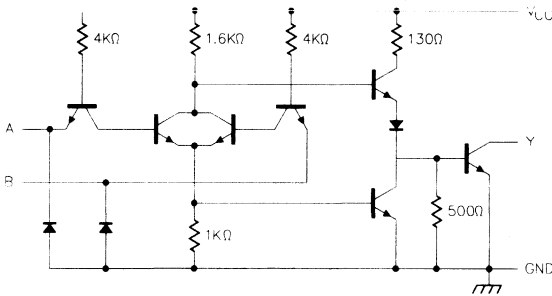
**FEATURES**

- 300mA output current capability
- High-voltage output
- No output latch-up at 20V
- High speed switching
- TTL or DTL compatible diode-clamped inputs
- Standard supply voltages

**HIGH RELIABILITY FEATURES**

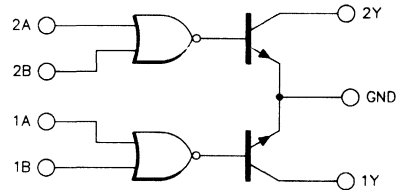
- SG55453B/SG55463/SG55473
- ◆ Available to MIL-STD-883
- ◆ Scheduled for MIL-M-38510 QPL listing
- ◆ SG level "S" processing available

**EQUIVALENT CIRCUIT SCHEMATIC (each driver)**



**BLOCK DIAGRAM**

Positive Logic:  $Y = A + B$



**FUNCTION TABLE (each gate)**

A	B	Y
L	L	L (on-state)
L	H	H (off-state)
H	L	H (off-state)
H	H	H (off-state)

H = High Level, L = Low Level

# SG55453B/63/73 SERIES

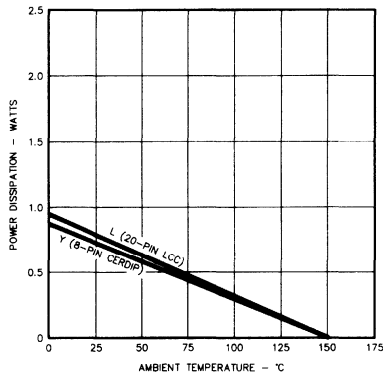
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage ( $V_{CC}$ ) .....	7V	Output Current .....	400mA
Input Voltage .....	5.5V	Continuous Total Dissipation at (or below)	
Intermitter Voltage .....	5.5V	25°C Free-Air Temperature .....	800mW
Off-state Output Voltage		Operating Junction Temperature	
X5453B Series .....	30V	Hermetic (Y, L Packages) .....	175°C
X5463 Series .....	35V	Storage Temperature Range .....	-65°C to 150°C
X5473 Series .....	70V	Lead Temperature (1/16 inch from case	
		for soldering 60 sec.) .....	300°C

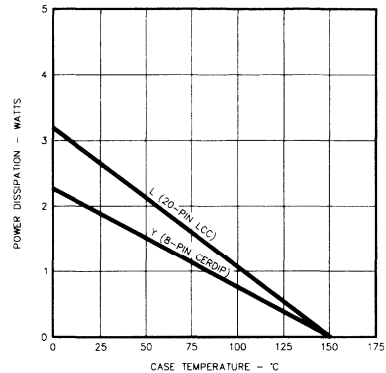
Note 1. Exceeding these ratings could cause damage to the device.

## RECOMMENDED OPERATING CONDITIONS (Notes 2 & 3)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Supply Voltage ( $V_{CC}$ )		Operating Ambient Temperature Range	
SG55453B, SG55463, SG55473 .....	4.5V to 5.5V	SG55453B, SG55463, SG55473 .....	-55°C to 125°C
SG75453B, SG75463, SG75473 .....	4.75V to 5.25V	SG75453B, SG75463, SG75473 .....	0°C to 70°C

Note 2. Range over which device is functional.

Note 3. The substrate (pin 8) must always be at the most-negative device voltage for proper operation.

## ELECTRICAL SPECIFICATIONS

Unless otherwise stated, these specifications and conditions apply for  $-55^\circ\text{C} \leq T_A \leq 125^\circ\text{C}$  for SG55453B, SG55463, SG55473 and  $0^\circ\text{C} \leq T_A \leq 70^\circ\text{C}$  for SG75453B, SG75463, SG75473. Typical values are tested at  $V_{CC} = 5V$ ,  $T_A = 25^\circ\text{C}$ .

Parameter	Test Conditions	SG55453B SG55463 SG55473			SG75453B SG75463 SG75473			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
High-level Input Voltage ( $V_{IH}$ )		2			2			V
Low-level Input Voltage ( $V_{IL}$ )				0.8			0.8	V
Input Clamp Voltage ( $V_{IK}$ )	$V_{CC} = \text{MIN}$ , $I_{IK} = -12\text{mA}$		-1.2	-1.5		-1.2	-1.5	V
High-level Output Current ( $I_{OH}$ )	$V_{CC} = \text{MIN}$ , $V_{IH} = 2V$ , $V_{OH} = 30V$ SGX5453B $V_{OH} = 35V$ SGX5463 $V_{OH} = 70V$ SGX5473			300			100	$\mu\text{A}$
Low-level Output Voltage ( $V_{OL}$ )	$V_{CC} = \text{MIN}$ , $V_{IL} = 0.8V$ , $I_{OL} = 100\text{mA}$ $V_{CC} = \text{MIN}$ , $V_{IK} = 0.8V$ , $I_{IK} = 300\text{mA}$	0.25	0.5		0.25	0.4		V
Input Current at Max $V_{IN}$ ( $I_{IN}$ )	$V_{CC} = \text{MAX}$ , $V_{IN} = 5.5V$	0.5	0.8		0.5	0.7		V
High-level Input Current ( $I_{IH}$ )	$V_{CC} = \text{MAX}$ , $V_{IN} = 2.4V$			1.0			1.0	mA
Low-level Input Current ( $I_{IL}$ )	$V_{CC} = \text{MAX}$ , $V_{IN} = 0.4V$	-1.0	-1.6		-1.0	-1.6		mA
Supply Current, Outputs High	$V_{CC} = \text{MAX}$ , $V_{IN} = 5V$	8	11		8	11		mA
Supply Current, Outputs Low	$V_{CC} = \text{MAX}$ , $V_{IN} = 0V$							
	SGX5453B	54	68		54	68		mA
	SGX5463	58	76		58	76		mA
	SGX5473	58	76		58	76		mA

# SG55453B/63/73 SERIES

## SWITCHING SPECIFICATIONS ( $V_{CC} = 5V, T_A = 25^\circ C$ )

Parameter	Test Conditions	SG55453B SG75453B			SG55463 SG75463			SG55473 SG75473			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
Propagation Delay Time, Low-to-High Level Output	$I_C = 200mA, C_L = 15pF,$ $R_L = 50\Omega$		18	25		30	55		30	55	ns
Propagation Delay Time, High-to-Low Level Output			16	25		25	40		25	40	ns
Transition Time, Low-to-High Output			5	8		8	20		8	20	ns
Transition Time, High-to-Low Level Output			7	12		10	20		10	20	ns
High-Level Output Voltage After Switching	$I_C = 300mA,$ $V_S = 20V$ SGX5453B $V_S = 30V$ SGX5463 $V_S = 55V$ SGX5473	$V_S - 6.5$			$V_S - 10$			$V_S - 18$			mV mV mV

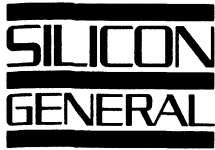
## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
8-PIN CERAMIC DIP Y - PACKAGE	SG55453BY/883B SG55453BY SG55463Y/883B SG55463Y SG55473Y/883B SG55473Y SG75453BY SG75463Y SG75473Y	-55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C 0°C to 70°C 0°C to 70°C 0°C to 70°C	
20-PIN CERAMIC LEADLESS CHIP CARRIER L - PACKAGE	SG55453BL/883B SG55453BL SG55463L/883B SG55463L SG55473L/883B SG55473L	-55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C	

- Note 1. Contact factory for JAN and DESC product availability.  
 2. All parts are viewed from the top.  
 3. Product is also available in flat pack. Consult factory for price and delivery.







LINEAR INTEGRATED CIRCUITS

**SG55454B/SG55464/SG55474  
SG75454B/SG75464/SG75474**

**DUAL PERIPHERAL POSITIVE-NOR DRIVER**

**DESCRIPTION**

The SG55454B/SG55464/SG55474 (SG75454B/SG75464/SG75474) series of dual peripheral Positive-NOR drivers are a family of versatile devices designed for use in systems that employ TTL or DTL logic. This family of drivers are direct replacements for the Texas Instruments SN55454B/64/74 (SN75454B/64/74) series. Diode-clamped inputs simplify circuit design. Typical applications include high-speed logic buffers, power drivers, relay drivers, MOS drivers, line drivers, and memory drivers. The SG55454B/SG55464/SG55474 drivers are characterized for operation over the full military temperature range of -55°C to 125°C and the SG75454B/SG75464/SG75474 drivers are characterized for operation from 0°C to 70°C.

**FEATURES**

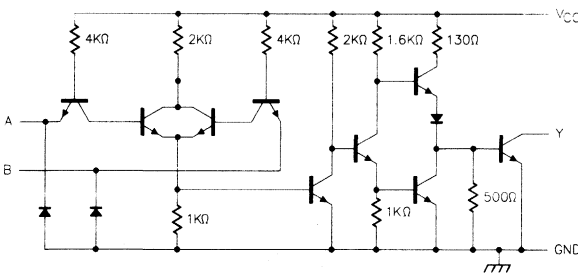
- 300mA output current capability
- High-voltage output
- No output latch-up at 20V
- High speed switching
- TTL or DTL compatible diode-clamped inputs
- Standard supply voltages

**HIGH RELIABILITY FEATURES**

- SG55454B/SG55464/SG55474

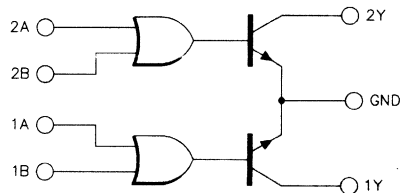
- ◆ Available to MIL-STD-883
- ◆ Scheduled for MIL-M-38510 QPL listing
- ◆ SG level "S" processing available

**EQUIVALENT CIRCUIT SCHEMATIC (each driver)**



**BLOCK DIAGRAM**

Positive Logic:  $Y = \overline{A + B}$



**FUNCTION TABLE (each gate)**

A	B	Y
L	L	H (off-state)
L	H	L (on-state)
H	L	L (on-state)
H	H	L (on-state)

H = High Level, L = Low Level

# SG55454B/64/74 SERIES

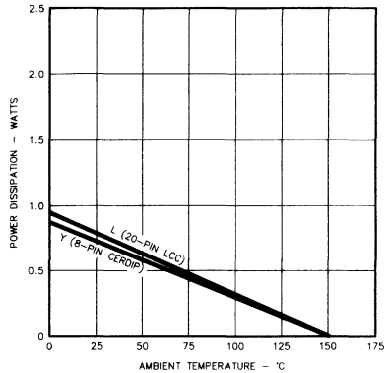
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage ( $V_{CC}$ ) .....	7V	Output Current .....	400mA
Input Voltage .....	5.5V	Continuous Total Dissipation at (or below) 25°C Free-Air Temperature .....	800mW
Intermitter Voltage .....	5.5V	Operating Junction Temperature	
Off-state Output Voltage		Hermetic (Y, L Packages) .....	175°C
X5454B Series .....	30V	Storage Temperature Range .....	-65°C to 150°C
X5464 Series .....	35V	Lead Temperature (1/16 inch from case for soldering 60 sec.) .....	300°C
X5474 Series .....	70V		

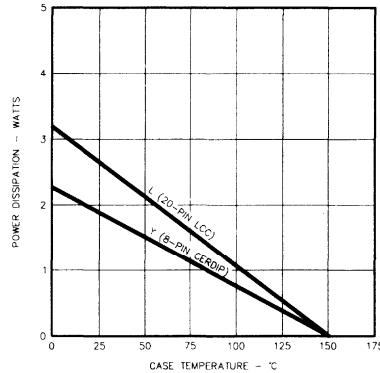
Note 1. Exceeding these ratings could cause damage to the device.

## RECOMMENDED OPERATING CONDITIONS (Notes 2 & 3)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Supply Voltage ( $V_{CC}$ )		Operating Ambient Temperature Range	
SG55454B, SG55464, SG55474 .....	4.5V to 5.5V	SG55454B, SG55464, SG55474 .....	-55°C to 125°C
SG75454B, SG75464, SG75474 .....	4.75V to 5.25V	SG75454B, SG75464, SG75474 .....	0°C to 70°C

Note 2. Range over which device is functional.

Note 3. The substrate (pin 8) must always be at the most-negative device voltage for proper operation.

## ELECTRICAL SPECIFICATIONS

Unless otherwise stated, these specifications and conditions apply for  $-55^\circ\text{C} \leq T_A \leq 125^\circ\text{C}$  for SG55454B, SG55464, SG55474 and  $0^\circ\text{C} \leq T_A \leq 70^\circ\text{C}$  for SG75454B, SG75464, SG75474. Typical values are tested at  $V_{CC} = 5V$ ,  $T_A = 25^\circ\text{C}$ .

Parameter	Test Conditions	SG55454B SG55464 SG55474			SG75454B SG75464 SG75474			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
High-level Input Voltage ( $V_{IH}$ )		2			2			V
Low-level Input Voltage ( $V_{IL}$ )				0.8			0.8	V
Input Clamp Voltage ( $V_{IK}$ )			-1.2	-1.5		-1.2	-1.5	V
High-level Output Current ( $I_{OH}$ )	$V_{CC} = \text{MIN}$ , $V_{IH} = 2V$ , $V_{OH} = 30V$ SGX5454B $V_{OH} = 35V$ SGX5464 $V_{OH} = 70V$ SGX5474			300			100	$\mu\text{A}$
Low-level Output Voltage ( $V_{OL}$ )	$V_{CC} = \text{MIN}$ , $V_{IL} = 0.8V$ , $I_{OL} = 100\text{mA}$ $V_{CC} = \text{MIN}$ , $V_{IL} = 0.8V$ , $I_{OL} = 300\text{mA}$	0.25	0.5		0.25	0.4		V
Input Current at Max $V_{IN}$ ( $I_{IN}$ )	$V_{CC} = \text{MAX}$ , $V_{IN} = 5.5V$		1.0			1.0		$\text{mA}$
High-level Input Current ( $I_{IH}$ )	$V_{CC} = \text{MAX}$ , $V_{IN} = 2.4V$		40			40		$\mu\text{A}$
Low-level Input Current ( $I_{IL}$ )	$V_{CC} = \text{MAX}$ , $V_{IN} = 0.4V$	-1.0	-1.6		-1.0	-1.6		$\text{mA}$
Supply Current, Outputs High	$V_{CC} = \text{MAX}$ , $V_{IN} = 0V$							
	SGX5454B	13	17		13	17		$\text{mA}$
	SGX5464, SGX5474	14	19		14	19		$\text{mA}$
Supply Current, Outputs Low	$V_{CC} = \text{MAX}$ , $V_{IN} = 5V$							
	SGX5452B	61	79		61	79		$\text{mA}$
	SGX5462, SGX5472	67	85		67	85		$\text{mA}$

# SG55454B/64/74 SERIES

## SWITCHING SPECIFICATIONS ( $V_{CC} = 5V, T_A = 25^\circ C$ )

Parameter	Test Conditions	SG55454B SG75454B			SG55464 SG75464			SG55474 SG75474			Units	
		Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.		
Propagation Delay Time, Low-to-High Level Output	$I_C = 200mA, C_L = 15pF,$ $R_L \approx 50\Omega$		26	35		45	65		45	65	ns	
Propagation Delay Time, High-to-Low Level Output			24	35		30	50		30	50	ns	
Transition Time, Low-to-High Output				5	8		13	25		13	25	ns
Transition Time, High-to-Low Level Output				7	12		10	20		10	20	ns
High-Level Output Voltage After Switching	$I_C = 300mA,$ $V_S = 20V$ SGX5454B $V_S = 30V$ SGX5464 $V_S = 55V$ SGX5474	$V_S - 6.5$			$V_S - 10$			$V_S - 18$			mV	
											mV	

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

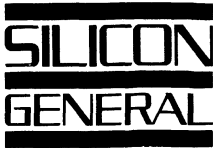
Package	Part No.	Ambient Temperature Range	Connection Diagram
8-PIN CERAMIC DIP Y - PACKAGE	SG55454BY/883B SG55454BY SG55464Y/883B SG55464Y SG55474Y/883B SG55474Y SG75454BY SG75464Y SG75474Y	-55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C 0°C to 70°C 0°C to 70°C 0°C to 70°C	
20-PIN CERAMIC LEADLESS CHIP CARRIER L - PACKAGE	SG55454BL/883B SG55454BL SG55464L/883B SG55464L SG55474L/883B SG55474L	-55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C	

- Note 1. Contact factory for JAN and DESC product availability.  
 2. All parts are viewed from the top.  
 3. Product is also available in flat pack. Consult factory for price and delivery.



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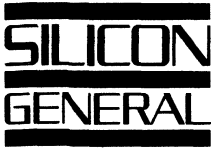
# SELECTION GUIDE OP-AMPS & COMPARATORS

LINEAR INTEGRATED CIRCUITS

## GENERAL PURPOSE

Device Type	Description	Key Features	Packages
SG101A/201A/301A	General purpose Operational Amplifier	<ul style="list-style-type: none"> <li>• <math>\pm 20V</math> supply voltage range</li> <li>• Offset voltage 3mV max. over temperature</li> <li>• Offsets guaranteed over entire common mode range</li> </ul>	J, N, T, F
SG2101A	General purpose dual Operational Amplifier	<ul style="list-style-type: none"> <li>• Two SG101A chips in one package</li> <li>• See SG101A features</li> </ul>	J
SG107/207/307	General purpose Operational Amplifier	<ul style="list-style-type: none"> <li>• <math>\pm 20V</math> supply voltage range</li> <li>• Offset voltage 3mV max. over temperature</li> <li>• Offsets guaranteed over entire common mode range</li> <li>• Internally compensated</li> </ul>	J, N, T, F
SG111/211/311	General purpose comparator	<ul style="list-style-type: none"> <li>• 30V supply voltage range</li> <li>• 50V, 50mA output capability</li> <li>• Single 5V supply operation</li> </ul>	Y, T, F, L
SG2111	General purpose dual comparator	<ul style="list-style-type: none"> <li>• Two SG111 chips in one package</li> <li>• See SG111 features</li> </ul>	J
SG741/741C	General purpose Operational Amplifier	<ul style="list-style-type: none"> <li>• <math>\pm 20V</math> supply voltage range</li> <li>• Complete short circuit protection</li> <li>• High common mode voltage range</li> <li>• Internally compensated</li> </ul>	J, N, T, F
SG143/343	General purpose High Voltage Operational Amplifier	<ul style="list-style-type: none"> <li>• <math>\pm 40V</math> supply voltage range</li> <li>• <math>\pm 37V</math> output voltage swing</li> <li>• <math>\pm 24V</math> common mode voltages</li> <li>• Over voltage protection</li> <li>• Output short circuit protection</li> <li>• Internally compensated</li> </ul>	Y, T
SG1536/1436	General purpose High Voltage Operational Amplifier	<ul style="list-style-type: none"> <li>• <math>\pm 40V</math> supply voltage range</li> <li>• <math>\pm 37V</math> output voltage swing</li> <li>• <math>\pm 24V</math> common mode voltages</li> <li>• Over voltage protection</li> <li>• Output short circuit protection</li> <li>• Internally compensated</li> </ul>	Y, T

December 1988



## SELECTION GUIDE OP-AMPS & COMPARATORS

LINEAR INTEGRATED CIRCUITS

### POWER OPERATIONAL AMPLIFIERS

Device Type	Description	$I_{O(PK)}$	$I_{O(CONT)}$	$V_{CC(MAX)}$	$I_S(MAX)$	Key Features	Packages
SG1173/2173/3173	Single Power Operational Amplifier	5A	3.5A	50V	20mA	<ul style="list-style-type: none"> <li>• Internally compensated</li> <li>• Current limit protection</li> <li>• Thermal shutdown protection</li> </ul>	P, R
SG3172	Single Power Operational Amplifier	3A	2A	18V	14mA	<ul style="list-style-type: none"> <li>• Optimized for low overhead motor drive</li> <li>• Internally compensated</li> <li>• Current limit protection</li> <li>• Thermal shutdown protection</li> </ul>	P, R
SG3272	Dual Power Operational Amplifier	1.5A	1A	18V	15mA	<ul style="list-style-type: none"> <li>• Two Operational Amplifiers in one package</li> <li>• Internal flyback protection diodes</li> <li>• Common mode range includes ground (<math>V_{EE}</math>)</li> <li>• Ideal for driving motors in "H" bridge configuration</li> <li>• Internally compensated</li> <li>• Thermal shutdown protection</li> </ul>	DWW, Y







LINEAR INTEGRATED CIRCUITS

# SG101A/SG201A/SG301A

## OPERATIONAL AMPLIFIERS

### DESCRIPTION

The SG101A/201A/301A is a general purpose internally compensated operational amplifier. It has excellent input bias current and drift characteristics in addition to short circuit protection and is pin compatible with industry standard operational amplifiers.

The SG101A is guaranteed and fully characterized over the full military temperature range of -55°C to 125°C while the SG201A is electrically identical, except its performance is guaranteed from -25°C to 85°C. The 301A is designed for commercial applications of 0°C to 70°C.

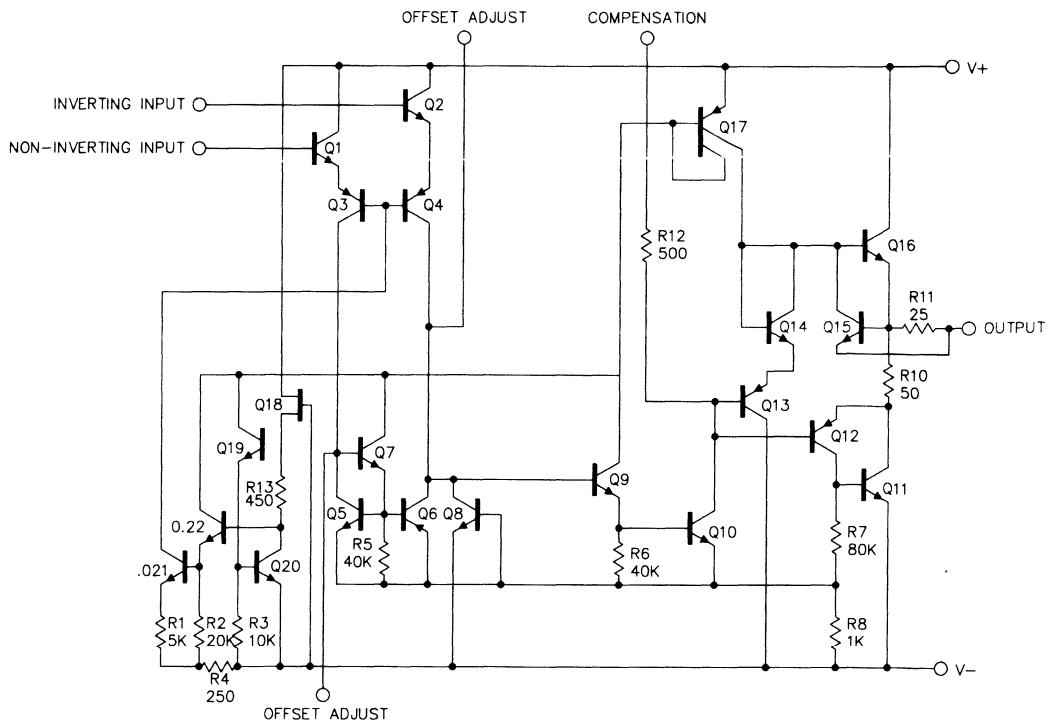
### FEATURES

- Offset voltage 3mV maximum over temperature
- Input bias current 100nA maximum over temperature
- Offset current 20nA maximum over temperature
- Guaranteed drift characteristics
- Offsets guaranteed over entire common mode range

### HIGH RELIABILITY FEATURES - SG101A

- ◆ Available to MIL-STD-883
- ◆ MIL-M38510/10103BGA - JAN101AT
- ◆ SG level "S" processing available

### SCHEMATIC DIAGRAM



# SG101A/SG201A/SG301A

## ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage		Operating Junction Temperature	
SG101A/201A	±22V	Hermetic (T, J, F Packages)	175°C
SG301A	±18V	Plastic (N Package)	150°C
Differential Input Voltage	±30V	Storage Temperature Range	-65°C to 150°C
Input Voltage (Note 2)	±15V	Output Short Circuit Duration (Note 3)	Indefinite
		Lead Temperature (Soldering, 10 Seconds)	300°C

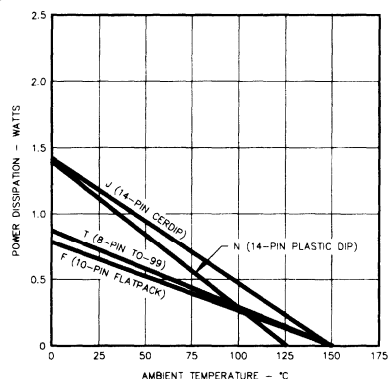
Note 1. Exceeding these ratings could cause damage to the device.

Note 2. For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

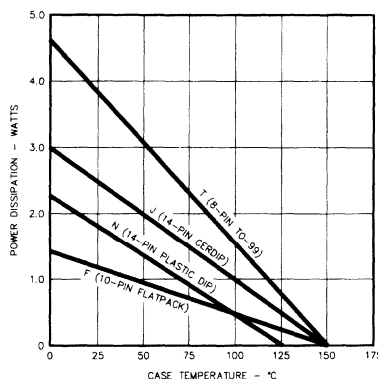
Note 3. Continuous short circuit is allowed for case temperatures to 125° and ambient temperatures to 70°C.

## RECOMMENDED OPERATING CONDITIONS (Note 4 & 5)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Supply Voltage	
SG101A/201A	±5V to ±20V
SG301A	±5V to ±18V

Operating Ambient Temperature Range	
SG101A	-55°C to 125°C
SG201A	-25°C to 85°C
SG301A	0°C to 70°C

Note 4. Range over which the device is functional.

Note 5.  $R_L = 2K\Omega$ ,  $C_L = 100pF$ .

## ELECTRICAL SPECIFICATIONS

(Unless otherwise stated, these specifications apply for  $T_A = 25^\circ C$ ,  $\pm 5V \leq V_S \leq \pm 20V$ , and  $C_L = 30pF$ .)

Parameter	Test Conditions	SG101A/SG201A			SG301A			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Input Offset Voltage	$R_S \leq 50K\Omega$		0.7	2.0		2.0	7.5	mV
Input Offset Current			1.5	10		3.0	50	nA
Input Bias Current	$T_A = T_{MIN}$ to $T_{MAX}$			20		70	70	nA
Input Resistance (Note 5)	$T_A = T_{MIN}$ to $T_{MAX}$		30	75		70	250	nA
Supply Current	$V_S = \pm 20V$ $T_A = 125^\circ C$			100			300	nA
Supply Current	$V_S = \pm 15V$	1.5	4		0.5	2		M $\Omega$
Large Signal Voltage Gain	$V_S = \pm 15V$ , $V_{OUT} = \pm 10V$ , $R_L \geq 2K\Omega$ $V_S = \pm 15V$ , $V_{OUT} = \pm 10V$ , $R_L \geq 2K\Omega$		1.8	3.0		1.8	3.0	mA
Large Signal Voltage Gain	$T_A = T_{MIN}$ to $T_{MAX}$		1.2	2.5				mA
Output Voltage Swing	$V_S = \pm 15V$ , $R_L = 10K\Omega$ $V_S = \pm 15V$ , $R_L = 2K\Omega$	50	±12	±14	25	±12	±14	V/mV
Output Voltage Swing	$T_A = T_{MIN}$ to $T_{MAX}$	25	±10	±13	25	±10	±13	V
Input Voltage Range	$V_S = \pm 20V$ , $T_A = T_{MIN}$ to $T_{MAX}$		±15			±15		V
Common Mode Rejection Ratio	$R_S \leq 10K\Omega$ , $T_A = T_{MIN}$ to $T_{MAX}$	80	96		80	96		dB
Supply Voltage Rejection Ratio	$R_S \leq 10K\Omega$ , $T_A = T_{MIN}$ to $T_{MAX}$	80	96		80	96		dB

## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG107/SG207			SG307			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Average Temperature Coefficient of Input Offset Voltage (Note 5)	$T_A = T_{MIN}$ to $T_{MAX}$		3.0	15		6.0	30	$\mu V/^\circ C$
Average Temperature Coefficient of Input Offset Current (Note 5)	$25^\circ C \leq T_A \leq 125^\circ C$		0.01	0.1				nA/°C
	$-55^\circ C \leq T_A \leq 25^\circ C$		0.02	0.2				nA/°C
	$25^\circ C \leq T_A \leq 70^\circ C$				0.01	0.3		nA/°C
	$0^\circ C \leq T_A \leq 25^\circ C$				0.02	0.6		nA/°C

Note 5. These parameters, although guaranteed, are not tested in production.

## CHARACTERISTIC CURVES

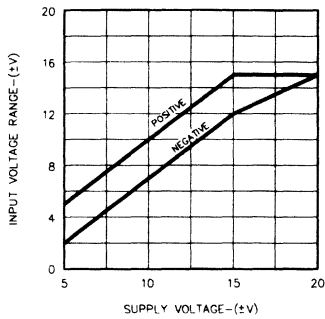


FIGURE 1. INPUT VOLTAGE RANGE VS. SUPPLY VOLTAGE

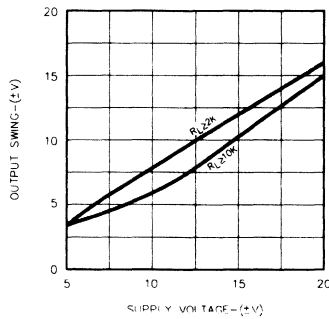


FIGURE 2. OUTPUT SWING VS. SUPPLY VOLTAGE

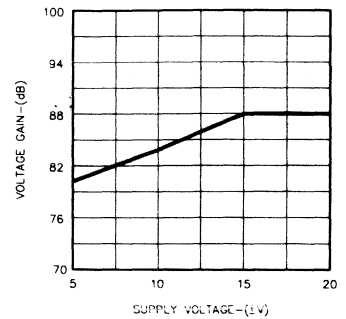


FIGURE 3. MINIMUM VOLTAGE GAIN

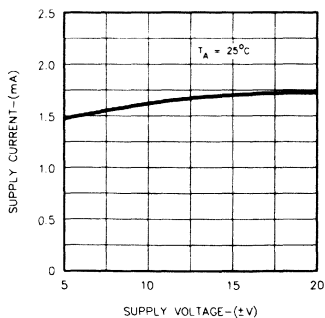


FIGURE 4. SUPPLY CURRENT VS. SUPPLY VOLTAGE

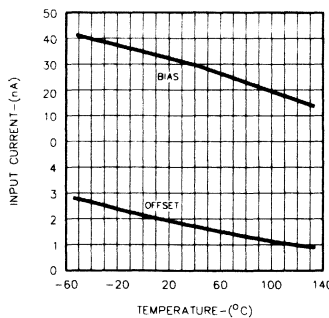


FIGURE 5. INPUT CURRENT VS. TEMPERATURE

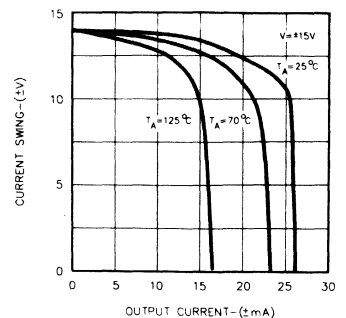


FIGURE 6. CURRENT LIMITING

**CHARACTERISTIC CURVES**

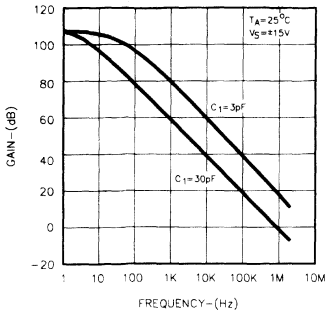


FIGURE 7  
OPEN LOOP FREQUENCY RESPONSE

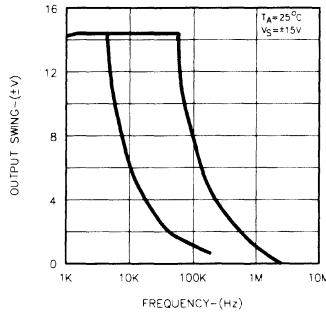


FIGURE 8  
LARGE SIGNAL FREQUENCY RESPONSE

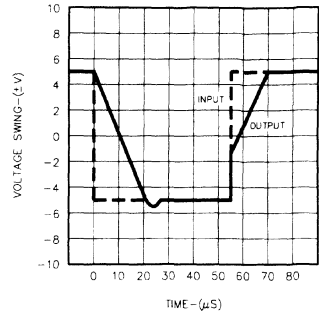


FIGURE 9  
VOLTAGE FOLLOWER PULSE RESPONSE

**CONNECTION DIAGRAMS & ORDERING INFORMATION** (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
14-PIN CERAMIC DIP J - PACKAGE	SG101AJ/883B SG101AJ SG201AJ SG301AJ	-55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C	
14-PIN PLASTIC DIP N - PACKAGE	SG201AN SG301AN	-25°C to 85°C 0°C to 70°C	
8-PIN METAL CAN T - PACKAGE	SG101AT/883B SG101AT SG201AT SG301AT	-55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C	
10-PIN CERAMIC FLAT PACK F - PACKAGE	SG101AF/883B SG101AF	-55°C to 125°C -55°C to 125°C	

Note 1. Contact factory for JAN and DESC product availability.  
 Note 2. All packages are viewed from the top.



LINEAR INTEGRATED CIRCUITS

**SG2101A**  
ADDENDUM TO SG101A DATA SHEET

**DUAL OPERATIONAL AMPLIFIERS**

**DESCRIPTION**

The SG2101A is a dual version of the SG101A Operational Amplifier and consists of two independent dice in the same package.

The SG2101A is a general-purpose internally compensated operational amplifier. It has excellent input bias current and drift characteristics in addition to short circuit protection and is pin compatible with industry standard operational amplifiers.

The SG2101A is guaranteed and fully characterized over the full military temperature range of -55°C to 125°C.

**FEATURES**

- Dual independent SG101A
- Offset voltage 3mV maximum over temperature
- Input bias current 100nA maximum over temperature
- Offset current 20nA maximum over temperature
- Guaranteed drift characteristics
- Offsets guaranteed over entire common-mode range

**HIGH RELIABILITY FEATURES - SG2101A**

- ◆ Available to MIL-STD - 883
- ◆ Scheduled for MIL-M38510 QPL listing
- ◆ SG level "S" processing available

**OPERATING CONDITIONS & ELECTRICAL SPECIFICATIONS**

(All information is identical to the SG101A. Consult data sheet for specifics.)

**CONNECTION DIAGRAMS & ORDERING INFORMATION**

Package	Part No.	Ambient Temperature Range	Connection Diagram
16-PIN CERAMIC DIP J - PACKAGE	SG2101AJ/883B SG2101AJ	-55°C to 125°C -55°C to 125°C	
16-PIN CERAMIC FLAT PACK F - PACKAGE	SG2101AF/883B SG2101AF	-55°C to 125°C -55°C to 125°C	

Note 1. Contact factory for JAN and DESC product availability.  
2. All parts are viewed from the top.



**OPERATIONAL AMPLIFIERS**

**DESCRIPTION**

The SG107/207/307 is a general purpose internally compensated operational amplifier. It has excellent input bias current and drift characteristics in addition to short circuit protection and is pin compatible with industry standard operational amplifiers.

The SG107 is guaranteed and fully characterized over the full military temperature range of -55°C to 125°C while the SG207 is electrically identical, except its performance is guaranteed from -25°C to 85°C. The 307 is designed for commercial applications of 0°C to 70°C.

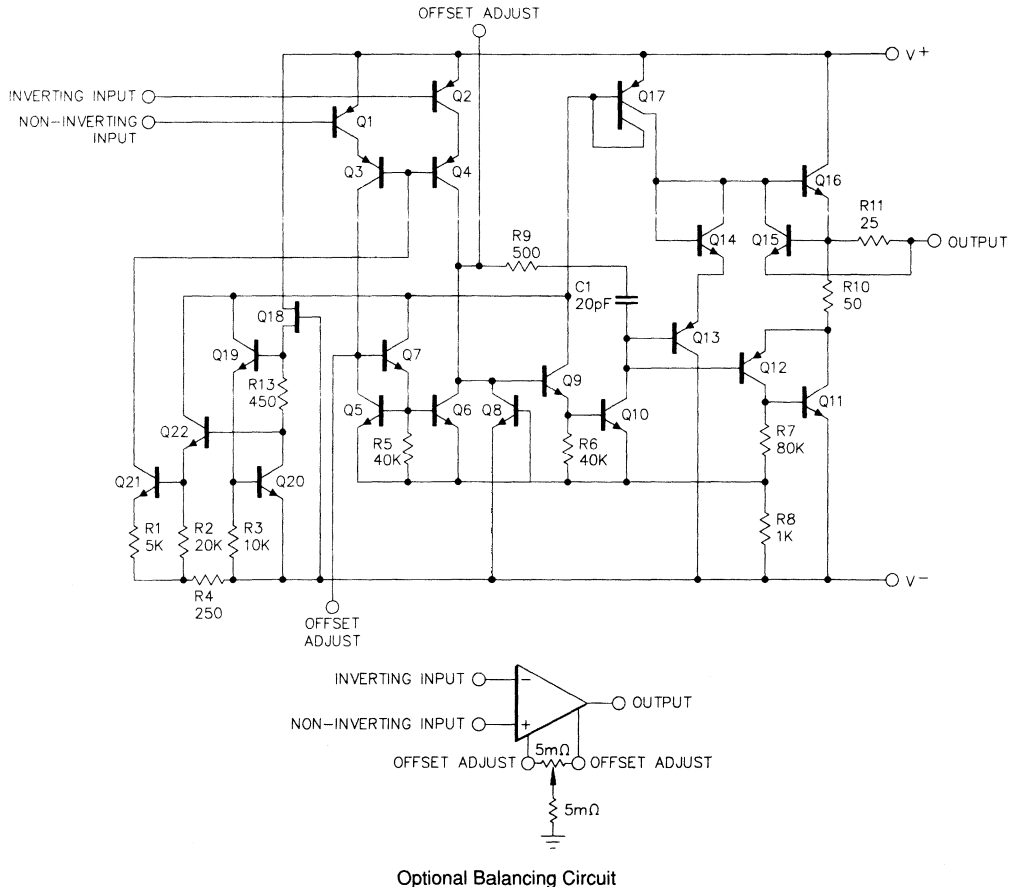
**FEATURES**

- Offset voltage 3mV maximum over temperature
- Input current 100nA maximum over temperature
- Offset current 20nA maximum over temperature
- Guaranteed drift characteristics
- Offsets guaranteed over entire common mode range

**HIGH RELIABILITY FEATURES - SG107**

- ◆ Available to MIL-STD - 883
- ◆ SG level "S" processing available

**SCHEMATIC DIAGRAM**



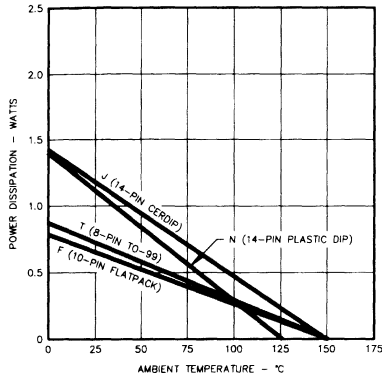
**ABSOLUTE MAXIMUM RATINGS** (Note 1)

Supply Voltage	Operating Junction Temperature
SG107/207 ..... ±22V	Hermetic (T, J, F Packages) ..... 175°C
SG307 ..... ±18V	Plastic (N Package) ..... 150°C
Differential Input Voltage ..... ±30V	Storage Temperature Range ..... -65°C to 150°C
Input Voltage (Note 2) ..... ±15V	Output Short Circuit Duration (Note 3) ..... Indefinite
	Lead Temperature (Soldering, 10 Seconds) ..... 300°C

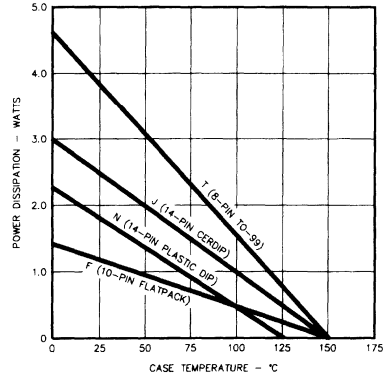
Note 1. Exceeding these ratings could cause damage to the device.  
 Note 2. For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.  
 Note 3. Continuous short circuit is allowed for case temperatures to 125° and ambient temperatures to 70°C.

**RECOMMENDED OPERATING CONDITIONS** (Note 4)

**THERMAL**



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

**ELECTRICAL**

Supply Voltage	Operating Ambient Temperature Range
SG107/207 ..... ±5V to ±20V	SG107 ..... -55°C to 125°C
SG307 ..... ±5V to ±15V	SG207 ..... -25°C to 85°C
	SG307 ..... 0°C to 70°C

Note 4. Range over which the device is functional.

**ELECTRICAL SPECIFICATIONS**

(Unless otherwise stated, these specifications apply for  $T_A = 25^\circ\text{C}$ ,  $\pm 5\text{V} \leq V_S \leq \pm 20\text{V}$  for the SG107/SG207, and  $V_S = \pm 15\text{V}$  for the SG307.)

Parameter	Test Conditions	SG107/SG207			SG307			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Input Offset Voltage	$R_S \leq 50\text{K}\Omega$ $T_A = T_{\text{MIN}}$ to $T_{\text{MAX}}$		0.7	2.0		2.0	7.5	mV
Input Offset Current	$T_A = T_{\text{MIN}}$ to $T_{\text{MAX}}$		1.5	10		3.0	10.0	mV
Input Bias Current	$T_A = T_{\text{MIN}}$ to $T_{\text{MAX}}$			20		70	70	nA
Input Resistance (Note 5)	$T_A = T_{\text{MIN}}$ to $T_{\text{MAX}}$		30	75		70	250	nA
Supply Current	$T_A = T_{\text{MIN}}$ to $T_{\text{MAX}}$	1.5	4	100	0.5	2	300	nA
Large Signal Voltage Gain	$V_S = \pm 20\text{V}$ $V_S = \pm 15\text{V}$ $V_{\text{OUT}} = \pm 10\text{V}$ , $V_S = \pm 15\text{V}$ , $R_L \geq 2\text{K}\Omega$ , $T_A = T_{\text{MIN}}$ to $T_{\text{MAX}}$		1.8	3.0		1.8	3.0	mA
Output Voltage Swing	$V_S = \pm 15\text{V}$ , $R_L = 10\text{K}\Omega$ $V_S = \pm 15\text{V}$ , $R_L = 2\text{K}\Omega$	50	160		25	160		V/mV
Input Voltage Range	$V_S = \pm 20\text{V}$ , $T_A = T_{\text{MIN}}$ to $T_{\text{MAX}}$ $V_S = \pm 15\text{V}$ , $T_A = T_{\text{MIN}}$ to $T_{\text{MAX}}$		±12	±14		±12	±14	V
Common Mode Rejection Ratio	$V_S = \pm 20\text{V}$ , $T_A = T_{\text{MIN}}$ to $T_{\text{MAX}}$ $V_S = \pm 15\text{V}$ , $T_A = T_{\text{MIN}}$ to $T_{\text{MAX}}$		±10	±13		±10	±13	V
Supply Voltage Rejection Ratio	$R_S \leq 10\text{K}\Omega$ , $T_A = T_{\text{MIN}}$ to $T_{\text{MAX}}$	80	96		80	96		dB
		80	96		80	96		dB



# SG107/SG207/SG307

## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG107/SG207			SG307			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Average Temperature Coefficient of Input Offset Voltage (Note 5)	$T_A = T_{MIN}$ to $T_{MAX}$		3.0	15		6.0	15	V/mV
Average Temperature Coefficient of Input Offset Current (Note 5)	$25^{\circ}\text{C} \leq T_A \leq 125^{\circ}\text{C}$		0.01	0.1			$\pm 12$	V
	$-55^{\circ}\text{C} \leq T_A \leq 25^{\circ}\text{C}$		0.02	0.2			$\pm 10$	V
	$25^{\circ}\text{C} \leq T_A \leq 70^{\circ}\text{C}$					0.01	$\pm 12$	V
	$0^{\circ}\text{C} \leq T_A \leq 25^{\circ}\text{C}$					0.02	80	dB
						80	80	dB

Note 5. These parameters, although guaranteed, are not tested in production.

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
14-PIN CERAMIC DIP J - PACKAGE	SG107J/883B SG107J SG207J SG307J	-55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C	
14-PIN PLASTIC DIP N - PACKAGE	SG207N SG307N	-25°C to 85°C 0°C to 70°C	
8-PIN METAL CAN T - PACKAGE	SG107T/883B SG107T SG207T SG307T	-55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C	
10-PIN CERAMIC FLAT PACK F - PACKAGE	SG107F/883B SG107F	-55°C to 125°C -55°C to 125°C	

Note 1. Contact factory for JAN and DESC product availability.  
 Note 2. All packages are viewed from the top.





LINEAR INTEGRATED CIRCUITS

# SG111/SG211/SG311

## VOLTAGE COMPARATOR

### DESCRIPTION

The SG111/SG211/SG311 Voltage Comparators are medium-speed, high-input impedance devices which are especially well suited for use in level detection and low-level voltage sensing applications. Operation may be obtained from supply voltages ranging from  $\pm 15V$  down to a single  $+5V$  source.

The output, an open collector NPN capable of switching 50V and 50mA, can drive RTL, DTL, TTL, MOS logic, relays or lamps. Both input and output can be isolated from ground and the output can drive loads referred to a positive supply, ground or a negative supply. These devices also offer offset balance, strobe capability and pin configuration of the SG710 Comparator.

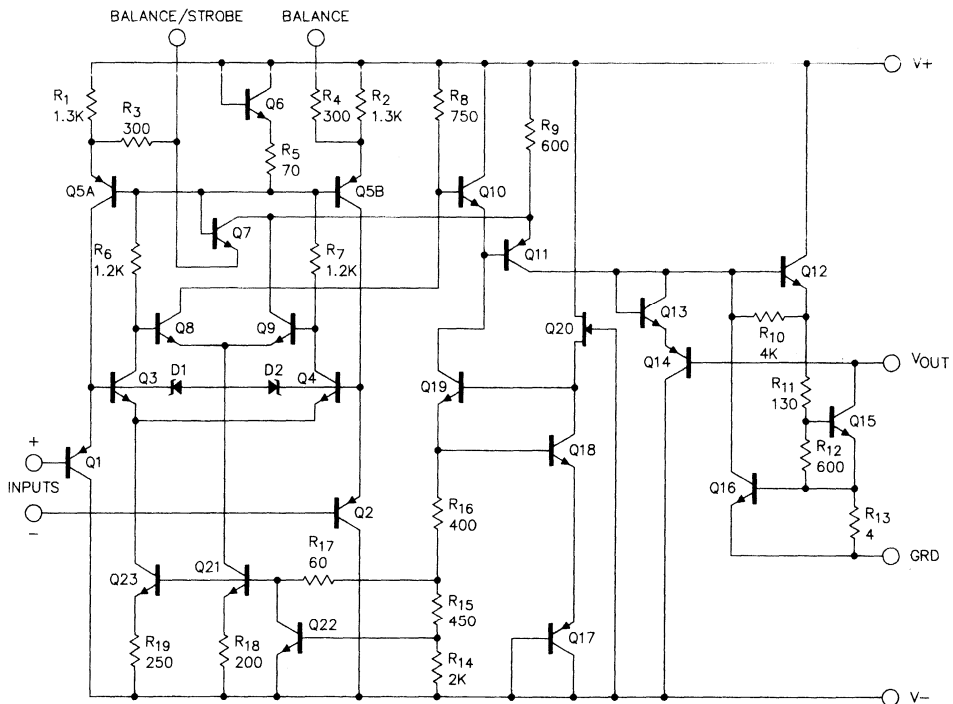
### FEATURES

- Differential input voltage range of  $\pm 30V$
- 150nA maximum bias current
- 50V, 50mA output capability
- Single 5V supply operation
- Consumes 135mW at  $\pm 15V$

### HIGH RELIABILITY FEATURES - SG111

- ♦ Available to MIL-STD - 883 and DESC SMD
- ♦ Scheduled for MIL-M38510 QPL listing
- ♦ SG level "S" processing available
- ♦ Dual version SG2111 also available for military applications

### SCHEMATIC DIAGRAM



## ABSOLUTE MAXIMUM RATINGS (Note 1)

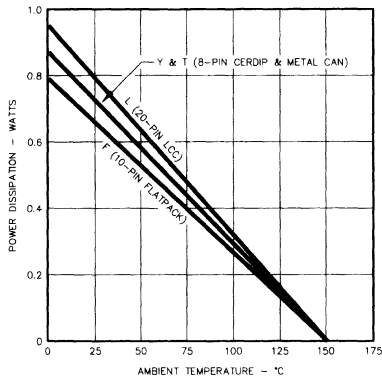
Total Supply Voltage ( $V_{8,4}$ ) .....	36V	Input Voltage (Note 2) .....	±15V
Output to Negative Supply Voltage ( $V_{7,4}$ )		Operating Junction Temperature	
SG111/SG211 .....	50V	Hermetic (Y, T, F, L Packages) .....	175°C
SG311 .....	40V	Storage Temperature Range .....	-65°C to 150°C
Ground to Negative Supply Voltage ( $V_{1,4}$ ) .....	30V	Output Short Circuit Duration .....	10 sec.
Differential Input Voltage .....	±30V	Lead Temperature (Soldering, 10 Seconds) .....	300°C

Note 1. Exceeding these ratings could cause damage to the device.

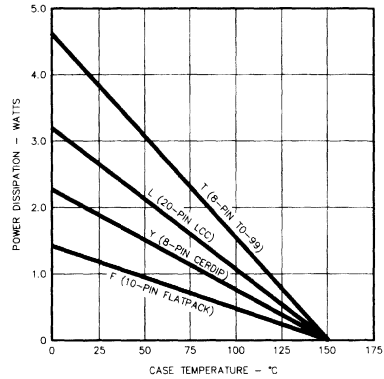
Note 2. Rating for ±15V supplies. The positive input voltage limit is 30V above the negative supply. The negative input voltage limit is equal to the negative supply voltage or 30V below the positive supply, whichever is less.

## RECOMMENDED OPERATING CONDITIONS (Note 3)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Total Supply Voltage .....	5V to 30V
$V_{OUT}$ to Ground Voltage .....	0V to 35V
Input Voltage Range with ±15V Supplies .....	±14V

Operating Ambient Temperature Range	
SG111 .....	-55°C to 125°C
SG211 .....	-25°C to 85°C
SG311 .....	0°C to 70°C

Note 3. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise stated, these specifications apply at  $V_S = \pm 15V$  and over recommended operating ambient temperature. Offset voltage, offset current and bias currents given apply for supply voltages from a single 5V supply to ±15V supplies.)

Parameter	Test Conditions	SG111/SG211			SG311			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Input Offset Voltage (Note 4)	$T_A = 25^\circ C, R_S \leq 50K$		0.7	3.0		2.0	7.5	mV
				4.0			10	mV
Input Offset Current (Note 4)	$T_A = 25^\circ C$		4.0	10		6.0	50	nA
				20			70	nA
Input Bias Current	$T_A = 25^\circ C$		60	100		100	250	nA
				150			300	nA
Voltage Gain	$T_A = 25^\circ C$		200		200		V/mV	
Input Voltage Range			±14		±14		V	
Response Time (Note 5)	$T_A = 25^\circ C$		200		200		nS	
Saturation Voltage	$I_{OUT} = 50mA, V_{IN} \leq -5mV$		0.75	1.5				V
						0.75	1.5	V
	$V_+ \geq 4.5V, V_- = 0$							
	$V_{IN} \leq -6mV, I_{SINK} \leq 8mA$		0.23	0.4			V	
	$V_{IN} \leq -10mV, I_{SINK} \leq 8mA$				0.23	0.4	V	

# SG111/SG211/SG311

## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG111/SG211			SG311			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Strobe on Current (Note 6)	$T_A = 25^\circ\text{C}$		3.0			3.0		mA
Output Leakage Current (Note 7)	$V_{\text{OUT}} = 35\text{V}, V_{\text{IN}} \geq 5\text{mV}$		0.1	0.5				$\mu\text{A}$
	$T_A = 25^\circ\text{C}, V_{\text{IN}} \geq 5\text{mV}$		0.2	10				nA
Short Circuit Current	$T_A = 25^\circ\text{C}, V_{\text{IN}} \geq 10\text{mV}$				0.2		50	nA
	10mS maximum test duration							
	$T_A = -55^\circ\text{C}$	0		250				mA
	$T_A = 125^\circ\text{C}$	0		150				mA
Positive Supply Current	$T_A = 25^\circ\text{C}$	0		200	0		200	mA
Negative Supply Current	$T_A = 25^\circ\text{C}$		5.1	6.0		5.1	7.5	mA
Response Time Low-to-High Level	$T_A = 25^\circ\text{C}$		4.1	5.0		4.1	5.0	mA
Collector Output (Note 7)	Overdrive = -5mV							
	$C_L = 50\text{pF}$ minimum							
	$V_{\text{IN}} = 100\text{mV}$	0		600	0		600	nS
Response Time High-to-Low level (Note 7)	Overdrive = 5mV							
	$C_L = 50\text{pF}$ minimum							
	$V_{\text{IN}} = 100\text{mV}$	0		600	0		600	nS

Note 4. Maximum values drive output within 1 Volt of either supply with 1mA load.

Note 5. Response time specified is for 100mV input step with 5mV overdrive.

Note 6. Do not short the strobe pin to ground; it should be current driven at 3mA to 5mA.

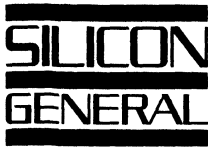
Note 7. These parameters, although guaranteed over the recommended operating conditions, are not tested in production.

# SG111/SG211/SG311

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
8-PIN CERAMIC DIP Y - PACKAGE	SG111Y/883B SG111Y SG211Y SG311Y	-55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C	
8-PIN METAL CAN T - PACKAGE	SG111T/883B SG111T SG211T SG311T	-55°C to 125°C -55°C to 125°C -25°C to 85°C 0°C to 70°C	
10-PIN CERAMIC FLAT PACK F - PACKAGE	SG111F/883B SG111F	-55°C to 125°C -55°C to 125°C	
20-PIN CERAMIC LEADLESS CHIP CARRIER L - PACKAGE	SG111L/883B SG111L	-55°C to 125°C -55°C to 125°C	

Note 1. Contact factory for JAN and DESC product availability.  
 2. All packages are viewed from the top.



LINEAR INTEGRATED CIRCUITS

**SG2111**  
ADDENDUM TO SG111 DATA SHEET

## DUAL VOLTAGE COMPARATOR

### DESCRIPTION

The SG2111 is a dual version of the SG111 Voltage Comparator and consists of two independent die in the same package. The SG111/SG211/SG311 Voltage Comparators are medium-speed, high-input impedance devices which are especially well suited for use in level detection and low-level voltage sensing applications. Operation may be obtained from supply voltages ranging from  $\pm 15V$  down to a single  $+ 5V$  source.

The output, an open collector NPN capable of switching 50V and 50mA, can drive RTL, DTL, TTL, MOS logic, relays or lamps. Both input and output can be isolated from ground and the output can drive loads referred to a positive supply, ground or a negative supply. These devices also offer offset balance, strobe capability and pin configuration of the SG710 Comparator.

### FEATURES

- Dual independent SG111
- Differential input voltage range of  $\pm 30V$
- 150nA maximum bias current
- 50V, 50mA output capability
- Single 5V supply operation

### HIGH RELIABILITY FEATURES - SG2111

- ◆ Available to MIL-STD - 883
- ◆ Scheduled for MIL-M38510 QPL listing
- ◆ SG level "S" processing available

### OPERATING CONDITIONS & ELECTRICAL SPECIFICATIONS

(All information is identical to the SG111. Consult data sheet for specifics.)

### CONNECTION DIAGRAMS & ORDERING INFORMATION

Package	Part No.	Ambient Temperature Range	Connection Diagram
16-PIN CERAMIC DIP J - PACKAGE	SG2111J/883B SG2111J	-55°C to 125°C -55°C to 125°C	<pre> +V<sub>cc</sub> (A) 1 16 N.C. GROUND (A) 2 15 (A) COLLECTOR OUTPUT NON-INV. INPUT (A) 3 14 (A) BAL/STAB. INVERTING INPUT (A) 4 13 (A) BALANCE -V<sub>cc</sub> 5 12 (B) INVERTING INPUT BALANCE (B) 6 11 (B) NON-INV. INPUT BAL/STAB. (B) 7 10 (B) GROUND COLLECTOR OUTPUT (B) 8 9 (B) +V<sub>cc</sub>           </pre>

Note 1. Contact factory for JAN and DESC product availability.  
2. All parts are viewed from the top.

3.  $+V_{cc}$  (A) and  $+V_{cc}$  (B) are not internally connected.  
4.  $-V_{cc}$  is connected to the case on metal packages.





**HIGH-VOLTAGE OPERATIONAL AMPLIFIER**

**DESCRIPTION**

The SG143 is a general-purpose high-voltage operational amplifier featuring operation to  $\pm 40V$  and overvoltage protection up to  $\pm 40V$ . Increased slew rate, together with higher common-mode and supply rejection, insure improved performance at high supply voltages. Operating characteristics are independent of supply voltage and temperature. These devices are intended for use in high voltage applications where common-mode input ranges, high output voltage swings, and low input currents are required. Also, they are internally compensated and are pin compatible with industry standard operational amplifiers.

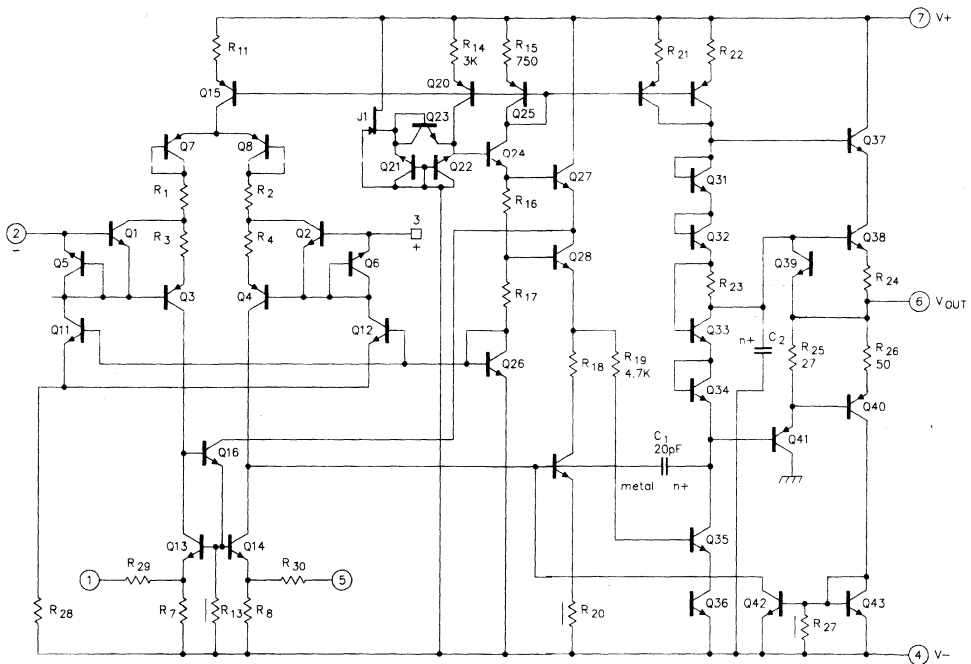
**FEATURES**

- $\pm 4.0V$  to  $\pm 40V$  supply voltage range
- $\pm 37V$  output voltage swing
- $\pm 24V$  common-mode voltages
- Overvoltage protection
- Output short circuit protection

**HIGH RELIABILITY FEATURES-SG143**

- ◆ Available to MIL-STD-883 and DESC SMD
- ◆ SG level "S" processing available

**CIRCUIT SCHEMATIC**



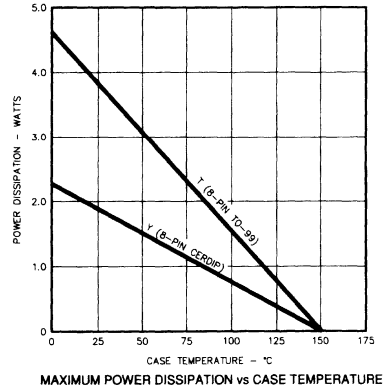
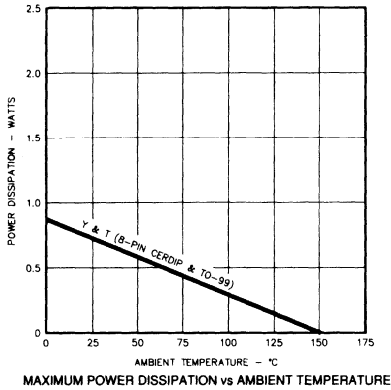
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage		Differential Input Voltage	$\pm(V^+ +  V^-  - 3)$ V
SG143	$\pm 40$ V	Output Short Circuit Duration	5 sec
SG343	$\pm 34$ V	Operating Junction Temperature	
Input Voltage		Hermetic (T, Y-Package)	175°C
SG143	$\pm 40$ V	Storage Temperature Range	-65°C to 150°C
SG343	$\pm 34$ V	Lead Temperature (Soldering, 10 Seconds)	300°C

Note 1. Exceeding these ratings could cause damage to the device.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



### ELECTRICAL

Supply Voltage		Input Voltage	
SG143	$\pm 28$ V	SG143	$\pm 28$ V
SG343	$\pm 15$ V	SG343	$\pm 15$ V
		Operating Ambient Temperature Range ( $T_A$ )	
		SG143	-55°C to 125°C
		SG343	0°C to 75°C

Note 2. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise specified, these specifications apply over recommended supply voltage range and  $T_A = 25^\circ\text{C}$ .)

Parameter	Test Conditions	SG143			SG343			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Input Offset Voltage			2.0	5.0		2.0	8.0	mV
Input Offset Current	$T_A = T_{MIN}$ to $T_{MAX}$			6.0		10		mV
			1.0	3.0		5.0		nA
Input Bias Current	$T_A = T_{MAX}$			4.5		14		nA
	$T_A = T_{MIN}$			7.0		14		nA
Large Signal Voltage Gain	$T_A = T_{MIN}$ to $T_{MAX}$		8.0	20		15		nA
	$R_L = 100\text{K}\Omega$ , $V_{OUT} = \pm 10\text{V}$			35			55	nA
Common-Mode Rejection	$T_A = T_{MIN}$ to $T_{MAX}$	100	180		70	180		V/mV
		50			50			V/mV
Power Supply Rejection		80	110		70	100		dB
Input Common Mode Range (Peak)			15	100		35	200	$\mu\text{V/V}$
Unity Gain Bandwidth		$\pm 24$	$\pm 25$		$\pm 22$	$\pm 25$		V
Slew Rate			1.0			1.0		MHz
Supply Current			2.5			2.5		V/ $\mu\text{s}$
Output Voltage Swing	$R_L = 5\text{K}\Omega$			4.0			5.0	mA
Short Circuit Current		$\pm 22$			$\pm 20$		200	V
			20			20		mA

CHARACTERISTIC CURVES

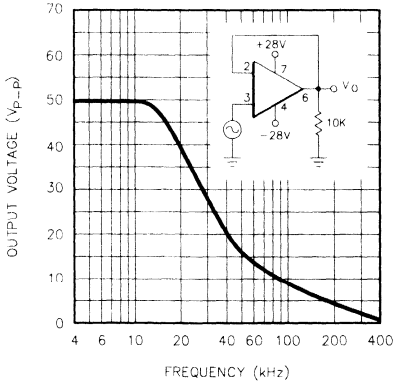


FIGURE 1. POWER BANDWIDTH

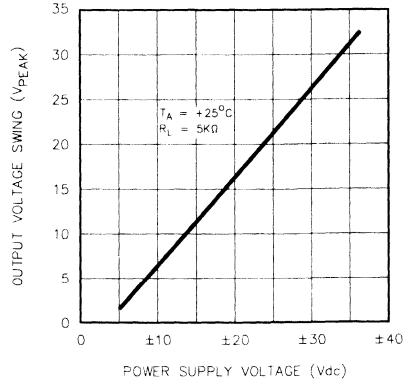


FIGURE 2. PEAK OUTPUT VOLTAGE SWING VS. POWER SUPPLY VOLTAGE

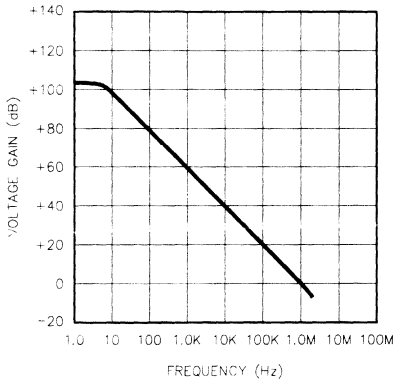


FIGURE 3. OPEN-POOL FREQUENCY RESPONSE

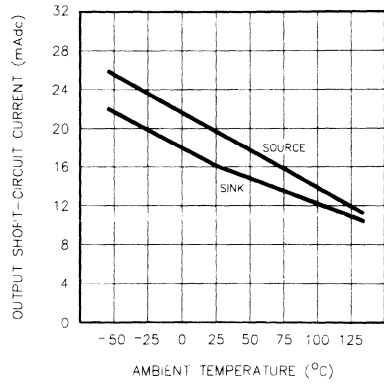


FIGURE 4. OUTPUT SHORT-CIRCUIT CURRENT VS. TEMPERATURE

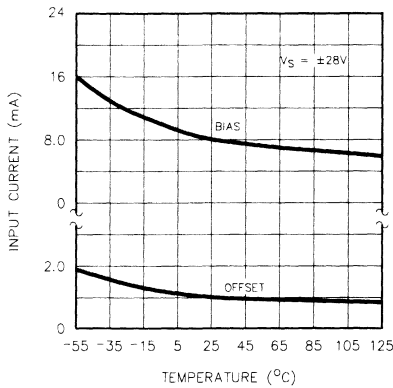


FIGURE 5. INPUT CURRENT

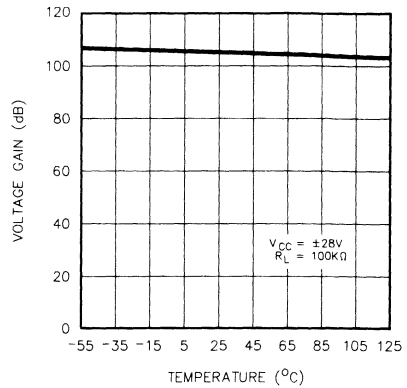


FIGURE 6. VOLTAGE GAIN

CHARACTERISTIC CURVES (continued)

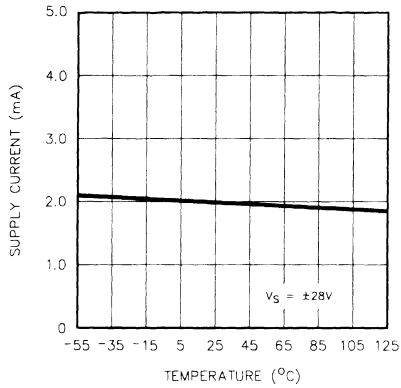


FIGURE 7. SUPPLY CURRENT

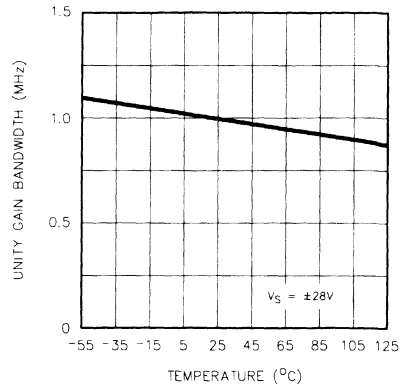


FIGURE 8. UNITY GAIN BANDWIDTH

CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
8-PIN METAL CAN T - PACKAGE	SG143T/883B SG143T SG343T	-55°C to 125°C -55°C to 125°C 0°C to 70°C	
8-PIN CERAMIC DIP Y - PACKAGE	SG143Y/883B SG143Y SG343Y	-55°C to 125°C -55°C to 125°C 0°C to 70°C	

Note 1. Contact factory for JAN and DESC product availability.  
 Note 2. All packages are viewed from the top.

**OPERATIONAL AMPLIFIER**

**DESCRIPTION**

SG741/741C are pin compatible with the most widely accepted operational amplifiers and provide excellent performance for a wide range of applications. The SG741 is characterized for operation over the full military ambient temperature range of -55°C to 125°C and the SG741C is designed for the commercial temperature range of 0°C to 70°C.

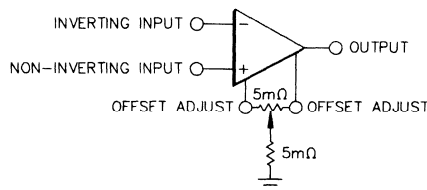
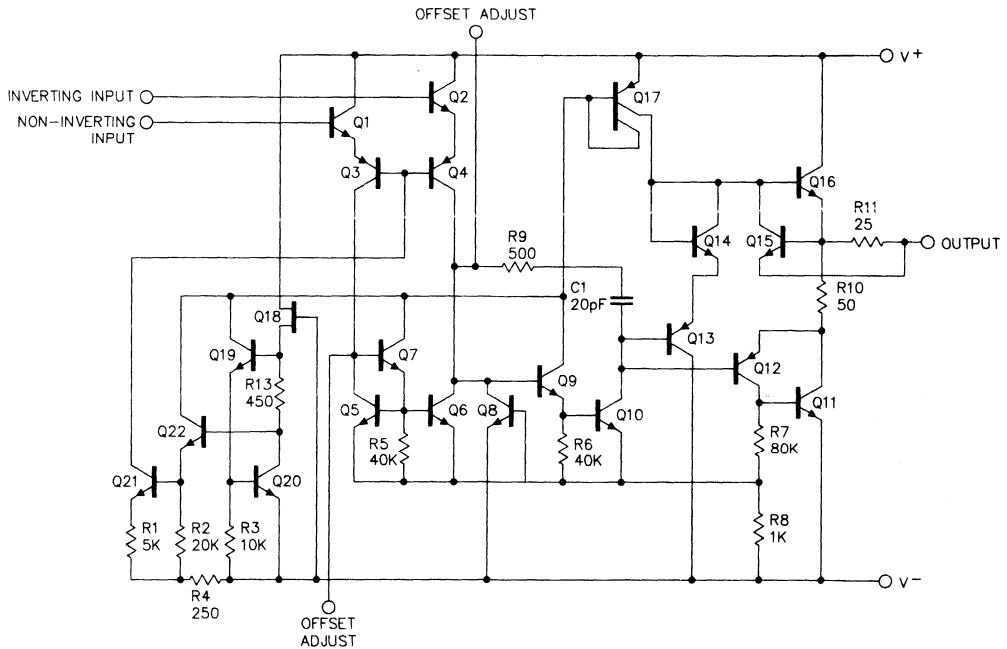
**FEATURES**

- Complete short circuit protection
- Offset voltage null capability
- High common mode voltage range
- High differential input voltage range

**HIGH RELIABILITY FEATURES - SG741**

- ◆ Available to MIL-STD - 883
- ◆ SG level "S" processing available

**SCHEMATIC DIAGRAM**



**Optional Balancing Circuit**

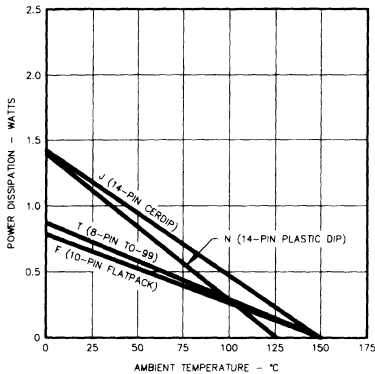
## ABSOLUTE MAXIMUM RATINGS (Note 1)

<b>Supply Voltage</b> SG741 ..... ±22V SG741C ..... ±18V <b>Differential Input Voltage</b> ..... ±30V <b>Input Voltage (Note 2)</b> ..... ±15V	<b>Operating Junction Temperature</b> Hermetic (T, J, F Packages) ..... 175°C Plastic (N Package) ..... 150°C <b>Storage Temperature Range</b> ..... -65°C to 150°C <b>Output Short Circuit Duration (Note 3)</b> ..... Indefinite <b>Lead Temperature (Soldering, 10 Seconds)</b> ..... 300°C
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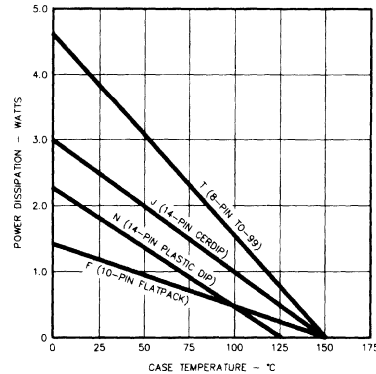
Note 1. Exceeding these ratings could cause damage to the device.  
 Note 2. For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.  
 Note 3. Continuous short circuit is allowed for case temperatures to 125°C and ambient temperatures to 70°C.

## RECOMMENDED OPERATING CONDITIONS (Note 4)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

<b>Supply Voltage</b> SG741 ..... ±5V to ±20V SG741C ..... ±5V to ±15V	<b>Operating Ambient Temperature Range</b> SG741 ..... -55°C to 125°C SG741C ..... 0°C to 70°C
--	--

Note 4. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise stated, these specifications apply for  $V_{CC} = +15V$ ,  $V_{EE} = -15V$  and  $T_A = 25^\circ C$ .)

Parameter	Test Conditions	SG741			SG741C			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Input Offset Voltage	$R_S \leq 10K\Omega$		1	5		2	6	mV
Input Offset Current	$R_S \leq 10K\Omega$ , $T_A = T_{MIN}$ to $T_{MAX}$		20	200		20	200	nA
Input Offset Current	$T_A = 125^\circ C$			200				nA
	$T_A = -55^\circ C$			500				nA
	$0^\circ C \leq T_A \leq 70^\circ C$						300	nA
Input Bias Current			80	500		80	500	nA
Input Bias Current	$T_A = 125^\circ C$			500				nA
	$T_A = -55^\circ C$			1500				nA
	$0^\circ C \leq T_A \leq 70^\circ C$						800	nA
Input Resistance (Note 5)		0.3	2		0.3	2		MΩ
Supply Current			1.7	2.8		1.7		mA
Input Noise Voltage	$f = 10Hz$		$5 \times 10^{-16}$			$5 \times 10^{-16}$		V <sup>2</sup> /Hz
	$f = 100KHz$		$2 \times 10^{-16}$			$2 \times 10^{-16}$		V <sup>2</sup> /Hz

Note 5. These parameters, although guaranteed, are not tested in production.

# SG741/SG741C

## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG741			SG741C			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Large Signal Voltage Gain	$V_S = \pm 15, V_{OUT} = \pm 10V, R_L \geq 2K\Omega$ $T_A = T_{MIN}$ to $T_{MAX}$	25			15			V/mV
Output Voltage Swing	$T_A = 25^\circ C$	50	160		25	160		V/mV
	$V_S = \pm 15, R_L = 10K\Omega$	$\pm 12$	$\pm 14$		$\pm 12$	$\pm 14$		V
Input Voltage Range	$R_L = 2K\Omega$ $T_A = T_{MIN}$ to $T_{MAX}$	$\pm 10$	$\pm 13$		$\pm 10$	$\pm 13$		V
Common Mode Rejection Ratio	$T_A = T_{MIN}$ to $T_{MAX}$	$\pm 12$			$\pm 12$			V
Supply Voltage Rejection Ratio	$R_S \leq 10K\Omega, T_A = T_{MIN}$ to $T_{MAX}$	80	96	150	80	96	150	dB
								$\mu V/V$

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
14-PIN CERAMIC DIP J - PACKAGE	SG741J/883B SG741J SG741CJ	-55°C to 125°C -55°C to 125°C 0°C to 70°C	
14-PIN PLASTIC DIP N - PACKAGE	SG741CN	0°C to 70°C	
8-PIN METAL CAN T - PACKAGE	SG741T/883B SG741T SG741CT	-55°C to 125°C -55°C to 125°C 0°C to 70°C	
10-PIN CERAMIC FLAT PACK F - PACKAGE	SG741F/883B SG741F	-55°C to 125°C -55°C to 125°C	

Note 1. Contact factory for JAN and DESC product availability.  
2. All packages are viewed from the top.







LINEAR INTEGRATED CIRCUITS

# SG1173/SG2173/SG3173

## 3.5 AMP POWER OP AMP

### DESCRIPTION

The SG1173 is a power monolithic operational amplifier capable of operating with loads to 3.5A with a power supply range to  $\pm 24V$ . Thermal shutdown and current limit have been provided to insure reliable operation during heavy loading. In addition, the SG1173's high common mode rejection, low input offsets, and high open loop gain rival those of much lower power op amps. Another important feature not provided by competitive power amps is the low quiescent current enabling significant power savings under no load conditions.

The SG1173 is ideal for use with voice coils in Winchester disk drives and other linear servo applications required by the automotive and military industries.

### FEATURES

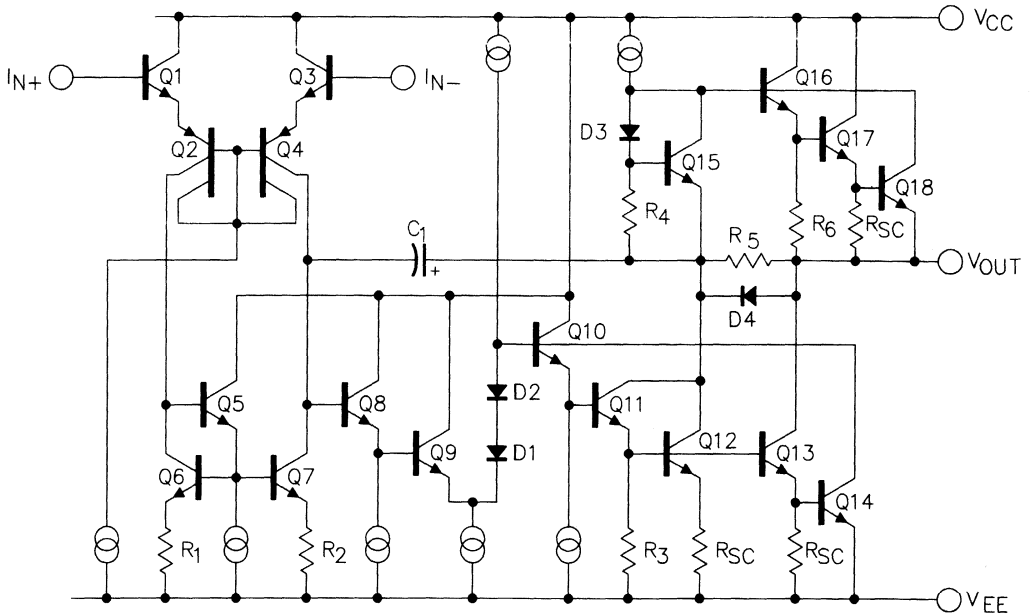
- Low quiescent current
- 3.5A output current
- Supply voltage range from  $\pm 5V$  to  $\pm 24V$
- Internally compensated
- Thermal shutdown protection
- Current limit protection
- Functional replacements for ULN3751, L165, and LM675
- Available in TO-220, TO-66 packages

### HIGH RELIABILITY FEATURES

- SG1173

- ◆ Available to MIL-STD-883
- ◆ SG level "S" processing available

### EQUIVALENT CIRCUIT SCHEMATIC



## ABSOLUTE MAXIMUM RATINGS (Note 1)

Positive Supply Voltage ( $V_{CC}$ )	25V
Negative Supply Voltage ( $V_{EE}$ )	-25V
Differential Input Voltage (Note 2)	$\pm 50V$
Common Mode Voltage (Note 2)	$\pm 25V$
Output Current	$\pm 4A$

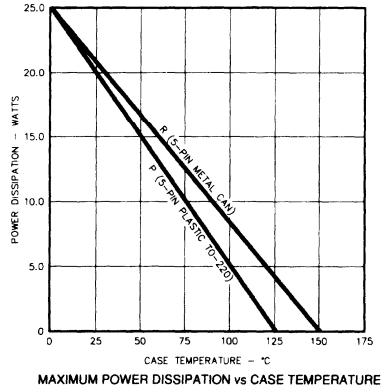
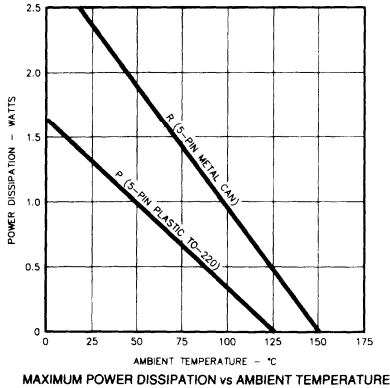
Operating Junction Temperature	
Hermetic (R-Package)	175°C
Plastic (P-Package)	150°C
Storage Temperature Range	-65°C to 150°C
Lead Temperature (Soldering, 10 Seconds)	300°C

Note 1. Exceeding these ratings could cause damage to the device. All voltages are with respect to ground. All currents are positive into the specified terminal.

Note 2. Either or both input voltages must not exceed the magnitude of  $V_{CC}$  or  $V_{EE}$ .

## RECOMMENDED OPERATING CONDITIONS (Note 3)

### THERMAL



### ELECTRICAL

Supply Voltage Range ( $V_{CC}$ )	+5V to +24V
Supply Voltage Range ( $V_{EE}$ )	-5V to -24V
Output Current (Continuous)	$\pm 3.5A$

Operating Ambient Temperature Range	
SG1173	-55°C to 125°C
SG2173	-45°C to 85°C
SG3173	0°C to 70°C

Note 3. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise stated, these specifications apply over operating ambient temperature range,  $V_{CC} = 15V$ , and  $V_{EE} = -15V$ )

Parameter	Test Conditions	SG1173/2173			SG3173			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Supply Voltage Range		$\pm 5$		$\pm 24$	$\pm 5$		$\pm 24$	V
Quiescent Drain Current	$I_{OUT} = 0$		10	20		10	20	mA
Input Offset Voltage	$V_{OUT} = 0V, I_{OUT} = 0$ $T_A = 25^\circ C$		2	6		2	6	mV
Input Bias Current	$V_{OUT} = 0V, I_{OUT} = 0$ $T_A = 25^\circ C$			1000			1000	nA
Input Offset Current	$V_{OUT} = 0V, I_{OUT} = 0$ $T_A = 25^\circ C$			250			250	nA
Output Voltage Swing	$I_{OUT} = -2A$ $T_A = 25^\circ C$			2.8			2.8	V
	$I_{OUT} = +2A$ $T_A = 25^\circ C$			3.5			3.5	V
	$I_{OUT} = 0V$ $T_A = 25^\circ C$			6.5			6.5	V
Current Limit	$V_{OUT} = 0V$		5			5		A
Common Mode Rejection Ratio	$\Delta V_{CM} = \pm 10V$	70			70			dB
Power Supply Rejection Ratio	$\Delta V_{CC} = \Delta V_{EE} = \pm 15V$	74			74			dB
Open Loop Voltage Gain	$I_{OUT} = 2A$ $T_A = 25^\circ C$	75			75			dB
		80			80			dB
Slew Rate			0.5			0.5		V/ $\mu s$
Gain Bandwidth Product			600			600		KHz
Thermal Shutdown			175			175		°C

**CHARACTERISTIC CURVES**

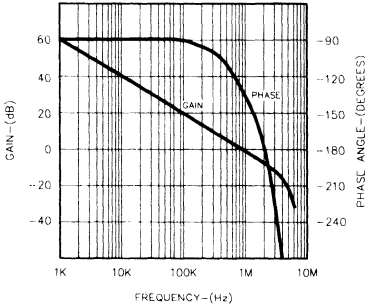


FIGURE 1. FREQUENCY RESPONSE

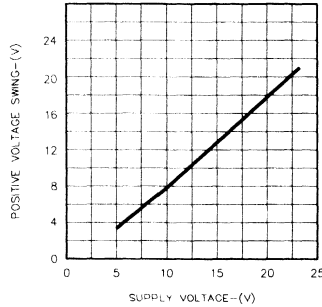


FIGURE 2. POSITIVE VOLTAGE SWING VS. SUPPLY VOLTAGE

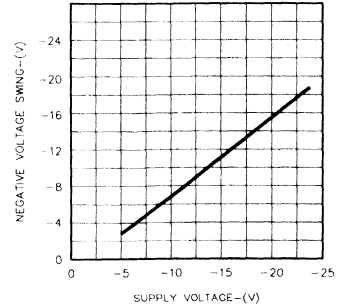


FIGURE 3. NEGATIVE VOLTAGE SWING VS. SUPPLY VOLTAGE

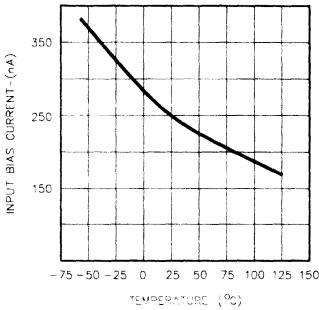


FIGURE 4. INPUT BIAS CURRENT VS. TEMPERATURE

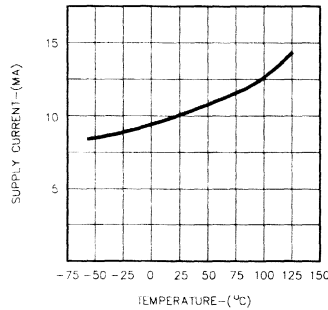


FIGURE 5. SUPPLY CURRENT VS. TEMPERATURE

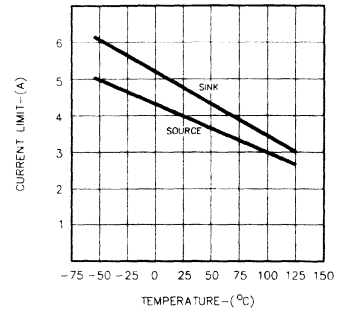


FIGURE 6. CURRENT LIMIT VS. TEMPERATURE

**APPLICATION INFORMATION**

General usage of the SG1173 requires the same design and layout considerations used with other op amps. Power supplies should be adequately bypassed and clamped with Zener diodes if transients are a problem. Leads to high impedance nodes should be kept as short as possible to minimize undesirable input-output coupling or RF pick-up. In addition to these, the high current capability of the SG1173 presents some new challenges that a designer must be aware of. Special care should be taken to avoid spurious feedback due to ground loops or voltage drops in high current paths. Kelvin connections should be used when applicable. When driving inductive loads, protection diode must

be used to clamp the output voltage to the power supplies (Figure 7). This protects the amplifier from high voltage transients caused by the stored energy in the inductor. Some loads may require external load compensation. Examples of this are shown in Figures 8 and 9. Safe operating area (SOA) is another area where extreme care must be used. Simultaneous conditions of high current and high voltage on the part may cause the junction temperature to exceed the maximum rating. In any application, the worst case power dissipations should be calculated and adequate heat sinking must be provided.

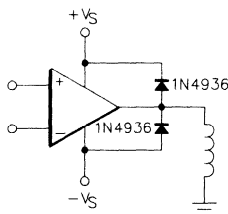


FIGURE 7 - PROTECTION DIODES USED WITH INDUCTIVE LOAD

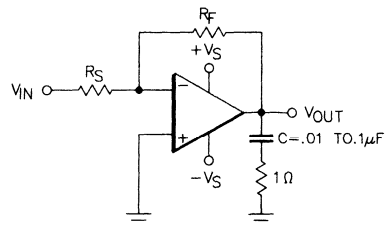


FIGURE 8 - INVERTING AMPLIFIER WITH RC LOAD COMPENSATION

**APPLICATION INFORMATION** (continued)

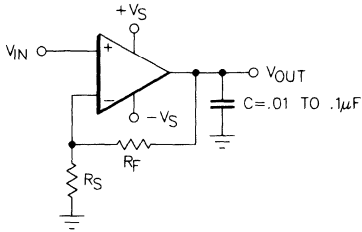


FIGURE 9 - NON-INVERTING AMPLIFIER WITH CAPACITIVE LOAD COMPENSATION

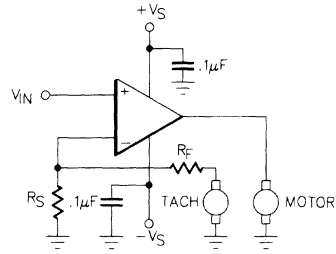


FIGURE 10 - MOTOR SPEED CONTROL WITH TACHOMETER FEEDBACK

A simple motor control loop is shown in Figure 10. This loop regulates the speed of the motor by using a tachometer to generate a voltage proportional to motor speed that is fed back to the amplifier. If the speed of the motor is S rpm and the proportionality constant of the tachometer is K volts/rpm then

$$S = V_{IN} \frac{(1 + R_F/R_S)}{K}$$

The speed of the motor is set by the input voltage  $V_{IN}$  regardless of the load on the motor. This is because the action of the feedback loop forces the voltage on the motor to whatever value is required to maintain the desired speed. If it is shaft position rather than speed that needs to be regulated then the tachometer may be replaced by some type of shaft encoder that generates a voltage proportional to the position of the motor shaft. In this case the input voltage will set the shaft angle according to the relation

$$\omega = V_{IN} \frac{(1 + R_F/R_S)}{H}$$

where  $\omega$  is shaft angle in degrees and H is the proportionality constant of the shaft encoder in volts/degree.

The new op amp has the capability to drive a loudspeaker directly allowing it to be used as an amplifier. Standard op amp configurations can be used to design amplifiers with particular values of closed loop gain or bandwidth. An example of such a circuit is shown in Figure 11. This circuit utilizes the op amp in a non-inverting gain configuration. The midband closed loop gain is set by  $R_F$  and  $R_S$ . The product of  $R_S$  and  $C_S$  set the lower 3dB frequency. The upper 3dB frequency is a function of the op amp's bandwidth and closed loop gain. A capacitor in parallel with  $R_S$  can be used to set the upper 3dB frequency to lower values if desired.

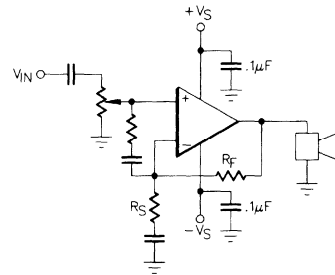


FIGURE 11 - AUDIO AMPLIFIER

**CONNECTION DIAGRAMS & ORDERING INFORMATION** (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
5-PIN TO-220 PLASTIC P - PACKAGE	SG2173P SG3173P	-45°C to 85°C 0°C to 70°C	<p>Case + Tab are internally connected</p>
5-PIN TO-66 METAL CAN R - PACKAGE	SG1173R/883B SG1173R SG2173R SG3173R	-55°C to 125°C -55°C to 125°C -45°C to 85°C 0°C to 70°C	<p>CASE IS GROUND Note: Case and tab are internally connected to substrate ground.</p>

Note 1. Contact factory for JAN and DESC product availability.

Note 2. All packages are viewed from the top.

**HIGH-VOLTAGE OPERATIONAL AMPLIFIER**

**DESCRIPTION**

The SG1536 series of monolithic amplifiers is designed specifically for use in high voltage applications up to  $\pm 40V$  and where high common-mode input ranges, high output voltage swings, and low input currents are required. These devices are internally compensated and are pin compatible with industry standard operational amplifiers.

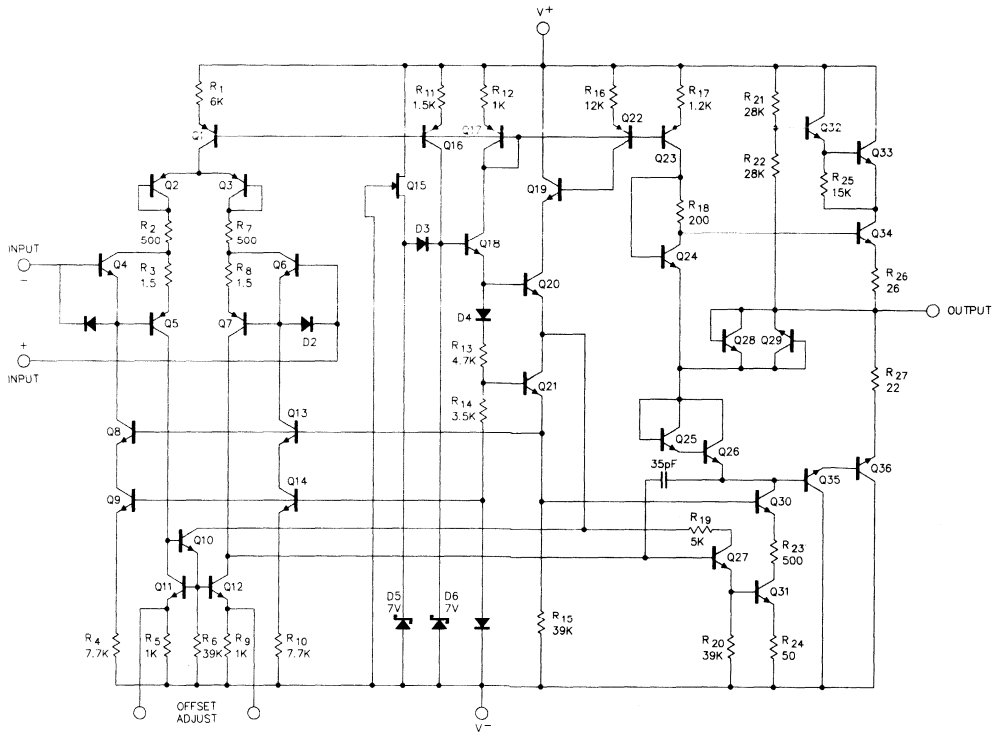
**FEATURES**

- High supply voltage capability
- High output voltage swing
- High common-mode voltage range
- Internal frequency compensation
- Input current 35nA maximum over temperature

**HIGH RELIABILITY FEATURES  
-SG1536**

- ◆ Available to MIL-STD-883 and DESC SMD
- ◆ SG level "S" processing available

**CIRCUIT SCHEMATIC**



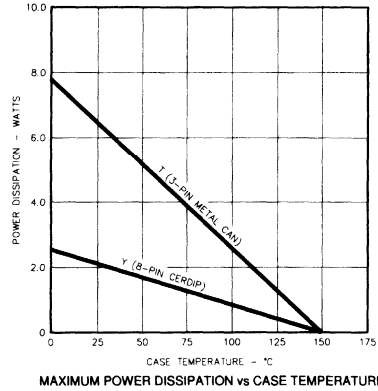
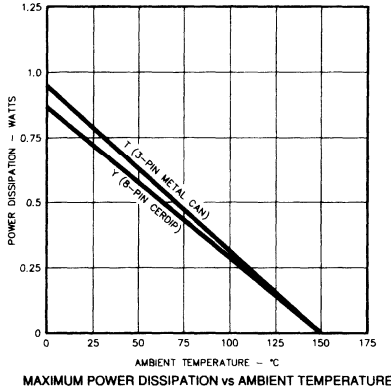
**ABSOLUTE MAXIMUM RATINGS** (Note 1)

Supply Voltage		Output Short Circuit Duration	
SG1536	±40V	( $V^* =  V  = 28V, V_o = 0V$ )	5.0sec
SG1436	±34V	Operating Junction Temperature	
Differential Input Signal	$\pm(V^* +  V  - 3)V$	Hermetic (T, Y-Package)	175°C
Common-Mode Input Swing	$\pm V^*, -(  V  - 3)V$	Storage Temperature Range	-65°C to 150°C
		Lead Temperature (Soldering, 10 Seconds)	300°C

Note 1. Exceeding these ratings could cause damage to the device.

**RECOMMENDED OPERATING CONDITIONS** (Note 2)

**THERMAL**



**ELECTRICAL**

Supply Voltage		Operating Ambient Temperature Range ( $T_A$ )	
SG1536	±28V	SG1536	-55°C to 125°C
SG1436	±15V	SG1436	0°C to 70°C

Note 2. Range over which the device is functional.

**ELECTRICAL SPECIFICATIONS**

(Unless otherwise specified, these specifications apply for  $V_s = \pm 28V$  and  $T_A = 25^\circ C$ .)

Parameter	Test Conditions	SG1536			SG1436			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Input Offset Voltage			2.0	5.0		5.0	10	mV
Input Offset Current	$T_A = T_{MIN}$ to $T_{MAX}$			7.0			14	mV
	$T_A = T_{MAX}$		1.0	3.0		5.0	10	nA
Input Bias Current	$T_A = T_{MIN}$			7.0			14	nA
	$T_A = T_{MAX}$		8.0	20		15	40	nA
Differential Input Impedance	$T_A = T_{MIN}$ to $T_{MAX}$			35			55	nA
Common-Mode Input Impedance	Open loop, $\leq 5.0Hz$		10			10		MΩ
Common-Mode Input Voltage	$f \leq 5.0Hz$		250			250		MΩ
Range (Peak)		±24	±25		±22	±25		V
Common-Mode Rejection Ratio		80	110		70	100		dB
Large Signal Voltage Gain	$R_L = 10K\Omega, V_o = \pm 10V$			200K			200K	V/V
	$R_L = 100K\Omega, V_o = \pm 10V$		100K	500K		70K	500K	V/V
Power Supply Rejection Ratio	$T_A = T_{MIN}$ to $T_{MAX}$			50K			50K	V/V
	$V^*$ constant, $R_S \leq 10K\Omega$		15	100		35	200	μV/V
Output Impedance	$V^*$ constant, $R_S \leq 10K\Omega$		15	100		35	200	μV/V
	$f \leq 5.0Hz$		1.0			1.0		KΩ
Short Circuit Output Current			±17			±17		mA
Output Voltage Swing (Peak)	$R_L = 5.0 K\Omega, V_s = \pm 28V$	±22			±22			V
	$R_L = 5.0 K\Omega, V_s = \pm 36V$	±30			±30			V

**ELECTRICAL SPECIFICATIONS** (continued)

Parameter	Test Conditions	SG1536			SG1436			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Power Bandwidth	$A_v = +1$ , $R_L = 5.0K\Omega$ , THD $\leq 5\%$ , $V_o = 40V$ p-p		23		23			KHz
Unity Gain Crossover Frequency	Open loop		1.0		1.0			MHz
Slew Rate	Unity gain		2.0		2.0			V/ $\mu$ s
Phase Margin	Open loop, unity gain		50		50			deg
Gain Margin			18		18			dB
Equivalent Input Noise	$A_v = 100$ , $R_s = 10K\Omega$ , $f = 1.0KHz$ , $BW = 1.0$ Hz		50		50			nV/ $\sqrt{Hz}$
Power Supply Current			2.2	4.0	2.6	5.0		mA
Power Consumption	$V_o = 0$		124	224	146	280		mW

**CHARACTERISTIC CURVES**

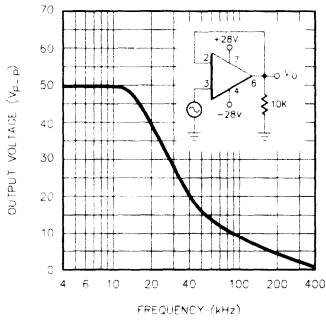


FIGURE 1. POWER BANDWIDTH

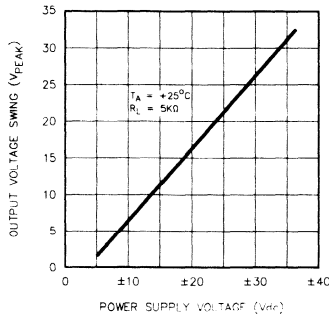


FIGURE 2. PEAK OUTPUT VOLTAGE SWING VS. POWER SUPPLY VOLTAGE

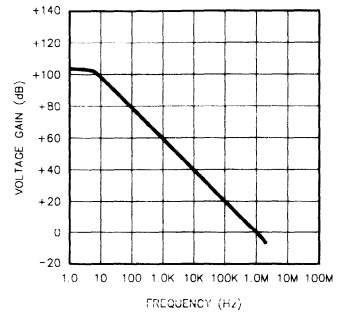


FIGURE 3. OPEN-LOOP FREQUENCY RESPONSE

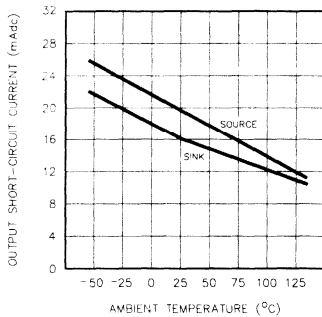


FIGURE 4. OUTPUT SHORT-CIRCUIT CURRENT VS. TEMPERATURE

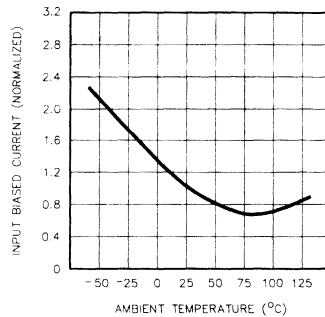


FIGURE 5. INPUT BIAS CURRENT VS. TEMPERATURE

TYPICAL APPLICATIONS

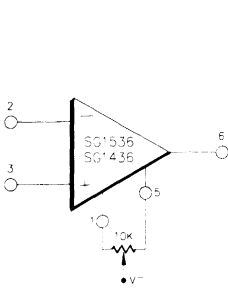


FIGURE 6 - VOLTAGE OFFSET NULL CIRCUIT

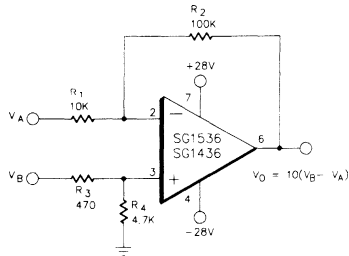


FIGURE 7 - DIFFERENTIAL AMPLIFIER WITH ±20V COMMON-MODE INPUT VOLTAGE RANGE

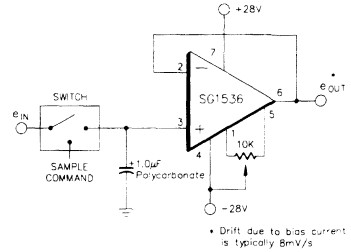


FIGURE 8 - LOW-DRIFT SAMPLE AND HOLD

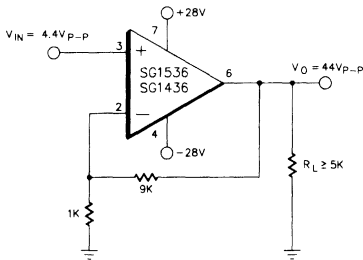


FIGURE 9 - TYPICAL NON-INVERTING X10 VOLTAGE AMPLIFIER

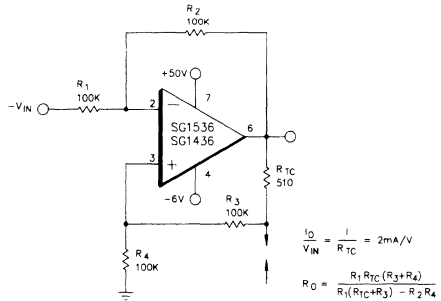


FIGURE 10 - VOLTAGE CONTROLLED CURRENT SOURCE OR TRANSCONDUCTANCE AMPLIFIER WITH 0 TO 40V COMPLIANCE

CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
8-PIN METAL CAN T - PACKAGE	SG1536T/883B SG1536T SG1436T	-55°C to 125°C -55°C to 125°C 0°C to 70°C	
8-PIN CERAMIC DIP Y- PACKAGE	SG1536Y/883B SG1536Y SG1436Y	-55°C to 125°C -55°C to 125°C 0°C to 70°C	

Note 1. Contact factory for JAN and DESC product availability.  
2. All packages are viewed from the top.



**3 AMP POWER OP AMP**

**DESCRIPTION**

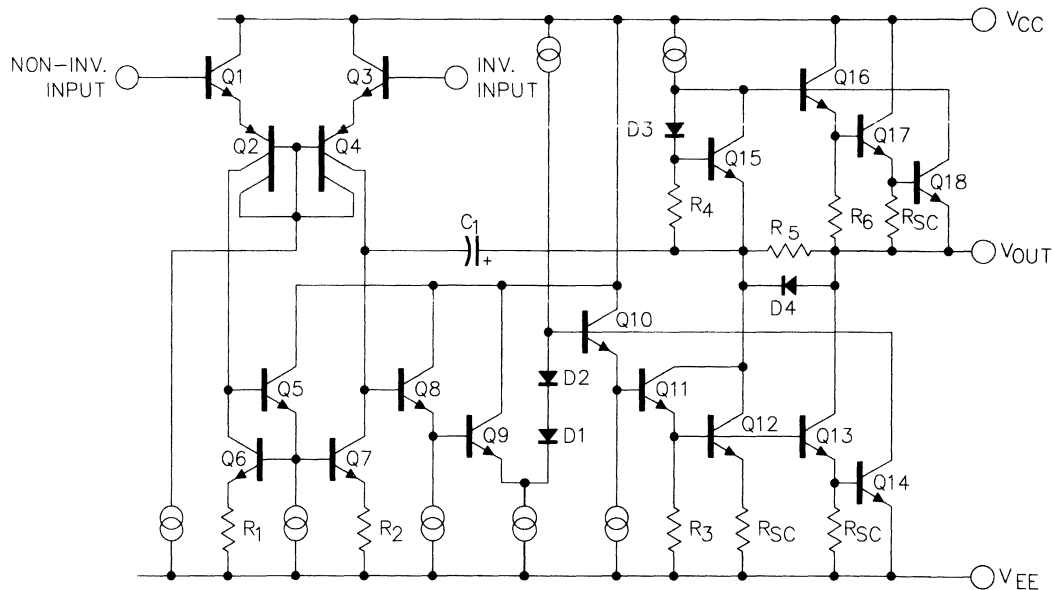
The SG2172/3172 is a power monolithic operational amplifier capable of operating with loads to 3A with a power supply range to 18V. Thermal shutdown and current limit have been provided to insure reliable operation during heavy loading. In addition, the SG2172/3172's high common mode rejection, low input offsets, and high open loop gain rival those of much lower power op amps. Another important feature not provided by competitive power op amps is the low quiescent current (7mA typically) enabling significant power savings under no load conditions.

The SG2172/3172 is ideal for use with voice coils in Winchester disk drives and other linear servo applications.

**FEATURES**

- Low quiescent current
- 3.0A output current
- Supply voltage range from 10V to 18V
- Internally compensated
- Thermal shutdown protection
- Current limit protection
- Functional replacements for ULN3751, L165, and LM675
- Available in TO-220, TO-66 packages

**EQUIVALENT CIRCUIT SCHEMATIC**



**ABSOLUTE MAXIMUM RATINGS** (Note 1)

Supply Voltage ( $V_{CC}-V_{EE}$ ) ..... 20V  
 Differential Input Voltage (Note 2) .....  $\pm 20V$   
 Common Mode Voltage (Note 2) .....  $\pm 10V$   
 Output Current .....  $\pm 3.5A$

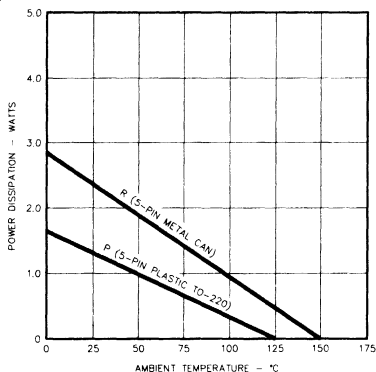
Operating Junction Temperature  
 Hermetic (R-Package) ..... 175°C  
 Plastic (P-Package) ..... 150°C  
 Storage Temperature Range ..... -65°C to 150°C  
 Lead Temperature (Soldering, 10 Seconds) ..... 300°C

Note 1. Exceeding these ratings could cause damage to the device. All voltages are with respect to ground. All currents are positive into the specified terminal.

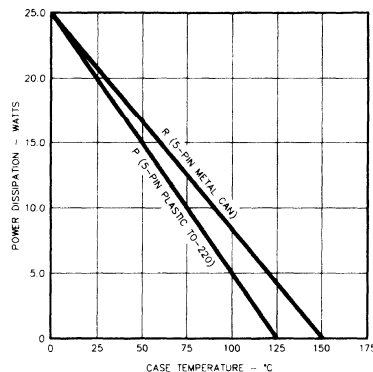
Note 2. Either or both input voltages must not exceed the magnitude of  $V_{CC}$  or  $V_{EE}$ .

**RECOMMENDED OPERATING CONDITIONS** (Note 3)

**THERMAL**



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

**ELECTRICAL**

Supply Voltage Range ( $V_{CC}-V_{EE}$ ) ..... 10V to 18V  
 Output Current (Continuous) .....  $\pm 3.0A$

Operating Ambient Temperature Range  
 SG2172 ..... -45°C to 85°C  
 SG3172 ..... 0°C to 70°C

Note 3. Range over which the device is functional.

**ELECTRICAL SPECIFICATIONS**

(Unless otherwise stated, these specifications apply over operating ambient temperature range,  $V_{CC} = 6V$ , and  $V_{EE} = -6V$ )

Parameter	Test Conditions	SG2172/3172			Units
		Min.	Typ.	Max.	
Supply Voltage Range	$(V_{CC}-V_{EE})$	10		18	V
Quiescent Drain Current	$I_{OUT} = 0$		7	12	mA
Input Offset Voltage	$V_{OUT} = 0V, I_{OUT} = 0$			10	mV
Input Bias Current	$V_{OUT} = 0V, I_{OUT} = 0$			1000	nA
	$T_A = 25^\circ C$			500	nA
Input Offset Current	$V_{OUT} = 0V, I_{OUT} = 0$			250	nA
	$T_A = 25^\circ C$			200	nA
Output Saturation Voltage	$I_{OUT} = -2A, V_{CC} - V_{OUT}$			2.5	V
	$I_{OUT} = +2A, V_{OUT} - V_{EE}$			3.2	V
Current Limit	$V_{OUT} = 0V$		5		A
Common Mode Rejection Ratio	$\Delta V_{CM} = 6V$	70			dB
Power Supply Rejection Ratio	$(V_{CC}-V_{EE}) = 10V$ to 14V	74			dB
Open Loop Voltage Gain	$I_{OUT} = 0$	80	110		dB
Slew Rate			0.5		V/ $\mu s$
Gain Bandwidth Product			600		KHz
Thermal Shutdown			175		$^\circ C$

**CHARACTERISTIC CURVES**

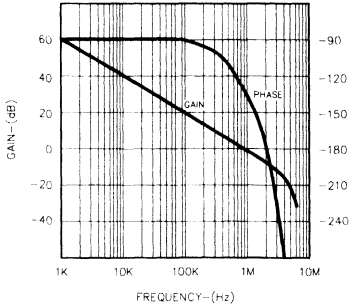


FIGURE 1. FREQUENCY RESPONSE

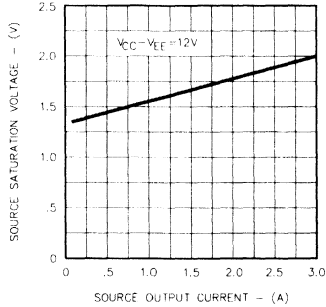


FIGURE 2. SOURCE VOLTAGE VS. OUTPUT CURRENT

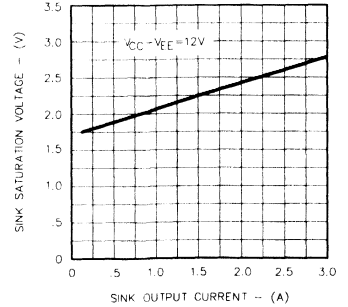


FIGURE 3. SINK SATURATION VOLTAGE VS. OUTPUT CURRENT

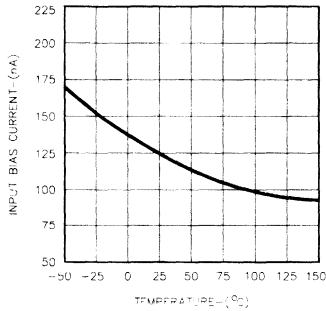


FIGURE 4. INPUT BIAS CURRENT VS. TEMPERATURE

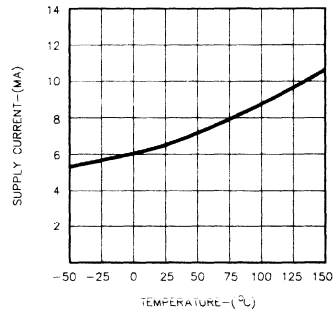


FIGURE 5. SUPPLY CURRENT VS. TEMPERATURE

**APPLICATION INFORMATION**

General usage of the SG2172/3172 requires the same design and layout considerations used with other op amps. Power supplies should be adequately bypassed and clamped with Zener diodes if transients are a problem. Leads to high impedance nodes should be kept as short as possible to minimize undesirable input-output coupling or RF pick-up. In addition to these, the high current capability of the SG2172/3172 presents some new challenges that a designer must be aware of. Special care should be taken to avoid spurious feedback due to ground loops or voltage drops in high current paths. Kelvin connections should be used when applicable. When driving

inductive loads, protection diodes must be used to clamp the output voltage to the power supplies (Figure 7). This protects the amplifier from high voltage transients caused by the stored energy in the inductor. Some loads may require external load compensation. Examples of this are shown in Figures 8 and 9. Safe operating area (SOA) is another area where extreme care must be used. Simultaneous conditions of high current and high voltage on the part may cause the junction temperature to exceed the maximum rating. In any application, the worst case power dissipations should be calculated and adequate heat sinking must be provided.

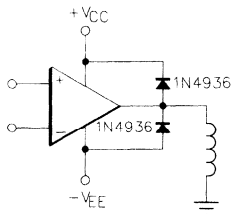


FIGURE 7 - PROTECTION DIODES USED WITH INDUCTIVE LOAD

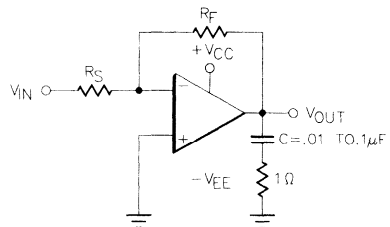


FIGURE 8 - INVERTING AMPLIFIER WITH RC LOAD COMPENSATION

**APPLICATION INFORMATION** (continued)

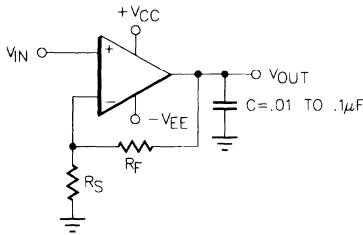


FIGURE 9 - NON-INVERTING AMPLIFIER WITH CAPACITIVE LOAD COMPENSATION

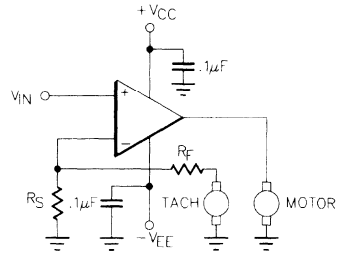


FIGURE 10 - MOTOR SPEED CONTROL WITH TACHOMETER FEEDBACK

A simple motor control loop is shown in Figure 10. This loop regulates the speed of the motor by using a tachometer to generate a voltage proportional to motor speed that is fed back to the amplifier. If the speed of the motor is  $S$  rpm and the proportionality constant of the tachometer is  $K$  volts/rpm then

$$S = V_{IN} \frac{(1 + R_F/R_S)}{K}$$

The speed of the motor is set by the input voltage  $V_{IN}$  regardless of the load on the motor. This is because the action of the feedback loop forces the voltage on the motor to whatever value is required to maintain the desired speed. If it is shaft position rather than speed that needs to be regulated then the tachometer may be replaced by some type of shaft encoder that generates a voltage proportional to the position of the motor shaft. In this case the input voltage will set the shaft angle according to the relation

$$\omega = V_{IN} \frac{(1 + R_F/R_S)}{H}$$

where  $\omega$  is shaft angle in degrees and  $H$  is the proportionality constant of the shaft encoder in volts/degree.

The new op amp has the capability to drive a loudspeaker directly allowing it to be used as an amplifier. Standard op amp configurations can be used to design amplifiers with particular values of closed loop gain or bandwidth. An example of such a circuit is shown in Figure 11. This circuit utilizes the op amp in a non-inverting gain configuration. The midband closed loop gain is set by  $R_F$  and  $R_S$ . The product of  $R_S$  and  $C_S$  set the lower 3dB frequency. The upper 3dB frequency is a function of the op amp's bandwidth and closed loop gain. A capacitor in parallel with  $R_S$  can be used to set the upper 3dB frequency to lower values if desired.

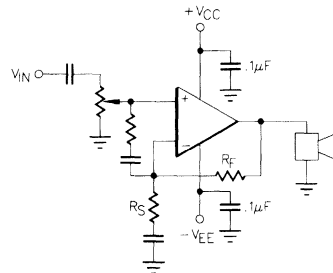


FIGURE 11 - AUDIO AMPLIFIER

**CONNECTION DIAGRAMS & ORDERING INFORMATION** (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
5-PIN TO-220 PLASTIC P - PACKAGE	SG2172P SG3172P	-45°C to 85°C 0°C to 70°C	<p>Case + Tab are internally connected to <math>V_{EE}</math></p>
5-PIN TO-66 METAL CAN R - PACKAGE	SG2172R SG3172R	-45°C to 85°C 0°C to 70°C	<p>CASE IS <math>V_{EE}</math> Note: Case and tab are internally connected to the chip substrate ground, <math>V_{EE}</math>.</p>

Note 1. Contact factory for JAN and DESC product availability.

Note 2. All packages are viewed from the top.

**DUAL POWER OPERATIONAL AMPLIFIER**

**DESCRIPTION**

The SG3272 is a monolithic dual-power operational amplifier which features a high current, low saturation voltage, flyback protected output stage optimized for driving heavy inductive loads. Capable of operation in a single supply mode from as low as 4.5V up to 13.2V, the SG3272 is ideally suited for the computer peripheral environment, driving small motors, solenoids, and linear actuators in an H-bridge configuration.

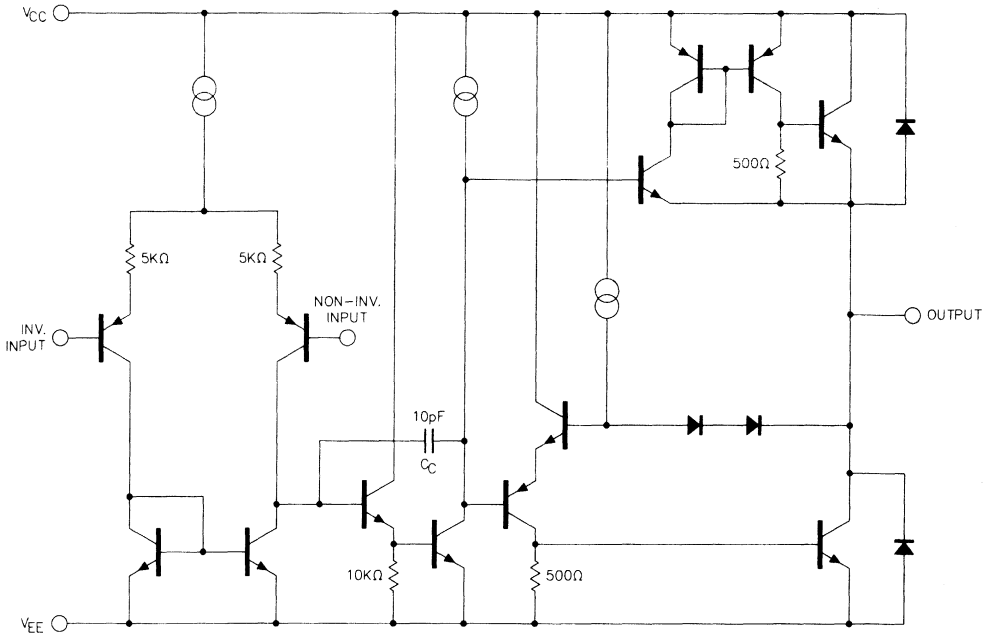
As a general-purpose op amp, the SG3272 exhibits low input offset voltage, high open loop gain, low quiescent current, a large differential input voltage range, and a common-mode input voltage range which includes ground ( $V_{EE}$ ).

Available in either an 8-pin plastic DIP package or a wide-body 20-pin batwing SOIC, the SG3272 provides system designers with a low-cost, convenient way to minimize power dissipation and reduce board area consumption in applications requiring high current inductive load drive capability.

**FEATURES**

- Full output swing at  $\pm 500\text{mA}$
- High inductive load drive capability
- Internal flyback protection diodes
- Low power dissipation
- Single or split supply operation
- Common-mode range includes ground ( $V_{EE}$ )
- High open loop gain
- Low input offset voltage
- Large differential input voltage range
- Thermal shutdown protection
- Available in 8-pin mini-DIP and 20-pin batwing SOIC

**EQUIVALENT CIRCUIT SCHEMATIC**



**ABSOLUTE MAXIMUM RATINGS** (Note 1)

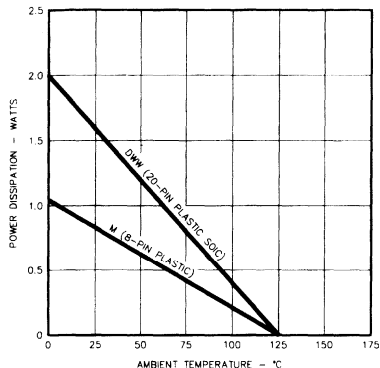
Supply Voltage (Single Supply) ( $V_{CC}$ ) ..... -0.3V to 14V  
 DC Output Current ( $I_{OUT}$ ) .....  $\pm 1.0A$   
 Peak Output Current (Non-Repetitive) ( $I_{OUT}$ ) .....  $\pm 1.5A$   
 Common-Mode Input Voltage ( $V_{ICM}$ ) ..... -0.3V to  $V_{CC}-2V$   
 Differential-Mode Input Voltage ( $V_{IDM}$ ) .....  $\pm V_{CC}$

Operating Junction Temperature  
 Plastic (M-, DW-Packages) ..... 150°C  
 Storage Temperature Range ..... -65°C to 150°C  
 Lead Temperature (Soldering, 10 Seconds) ..... 300°C

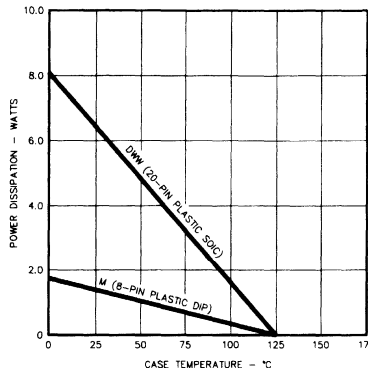
Note 1. Exceeding these ratings could cause damage to the device. All voltages are with respect to ground. All currents are positive into the specified terminal.

**RECOMMENDED OPERATING CONDITIONS** (Note 2)

**THERMAL**



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

**ELECTRICAL**

Supply Voltage (Single Supply) ( $V_{CC}$ ) ..... 4.5V to 13.2V  
 DC Output Current ( $I_{OUT}$ ) .....  $\pm 500mA$   
 Common-Mode Input Voltage ( $V_{ICM}$ ) ..... 0V to  $V_{CC}-2V$

Differential-Mode Input Voltage ( $V_{IDM}$ ) .....  $\pm V_{CC}$   
 Operating Ambient Temperature Range  
 SG3272 ..... 0°C to 70°C

Note 2. Range over which the device is functional.

**ELECTRICAL SPECIFICATIONS**

(Unless otherwise stated, these specifications apply at  $T_A = 25^\circ C$  and  $V_{CC} = 12V$ .)

Parameter	Test Conditions	SG3272			Units
		Min.	Typ.	Max.	
<b>Static Characteristics</b>					
Input Offset Voltage ( $V_{IO}$ )	$T_A = T_{MIN}$ to $T_{MAX}$	-15	0	15	mV
Input Bias Current ( $I_B$ )		-30		30	mV
Input Offset Current ( $I_{OS}$ )	$T_A = T_{MIN}$ to $T_{MAX}$	-1.0	-0.2		$\mu A$
Differential Input Resistance ( $R_D$ )		-50		50	nA
Source Side Output Saturation Voltage ( $+V_{SAT}$ )	$I_{OUT} = -100mA$ $I_{OUT} = -500mA$	-200		200	nA
Sink Side Output Saturation Voltage ( $-V_{SAT}$ )		500			K $\Omega$
Open Loop Voltage Gain ( $A_{VOL}$ )			0.8		mA
Common-Mode Rejection Ratio (CMRR)			1.0	1.5	V
Power Supply Rejection Ratio (PSRR)			0.3		V
Quiescent Drain Current ( $I_{CC}$ )			0.6	1.0	V
Thermal Shutdown Temperature		70	90		dB
		66	90		dB
		60	80		dB
			7	15	mA
			175		$^\circ C$

ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG3272			Units
		Min.	Typ.	Max.	
<b>Dynamic Characteristics</b>					
Gain Bandwidth Product (GBWP)	$R_L = \infty\Omega$		800		KHz
Slew Rate ( $dV_o/dt$ )	$AV = 1$		1.6		V/ $\mu$ s
Power Bandwidth, -3dB (PBW)			200		KHz
Input Noise Voltage ( $E_n$ )	22Hz to 22KHz		10		$\mu$ V
Input Noise Current ( $I_n$ )	22Hz to 22KHz		200		pA
Channel Separation ( $C_s$ )	$f = 1\text{KHz}, R_L = 10\Omega, AV_{CL} = 30\text{dB}$		60		dB

CHARACTERISTIC CURVES

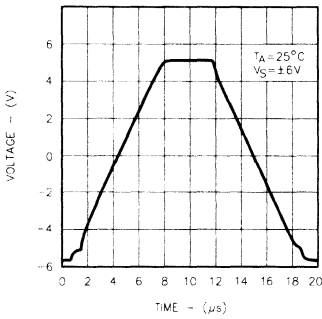


FIGURE 1. LARGE SIGNAL TRANSIENT RESPONSE

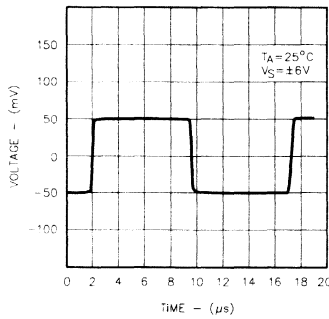


FIGURE 2. SMALL SIGNAL TRANSIENT RESPONSE

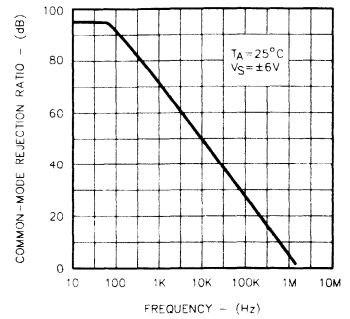


FIGURE 3. COMMON-MODE REJECTION RATIO VS. FREQUENCY

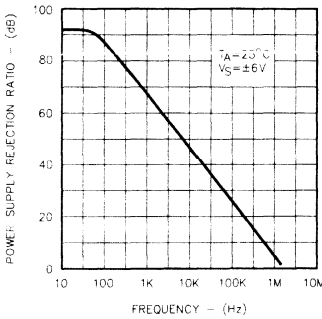


FIGURE 4. POWER SUPPLY REJECTION VS. FREQUENCY

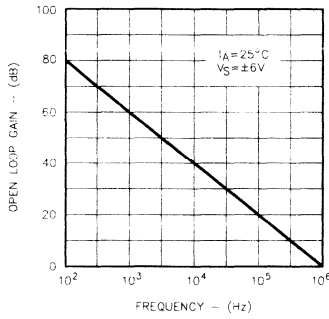


FIGURE 5. OPEN LOOP GAIN VS. FREQUENCY

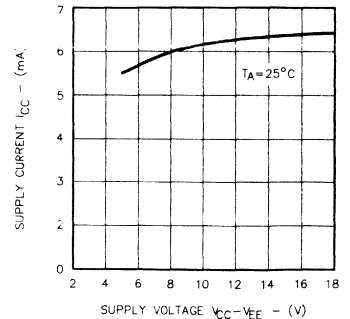


FIGURE 6. SUPPLY CURRENT VS. SUPPLY VOLTAGE

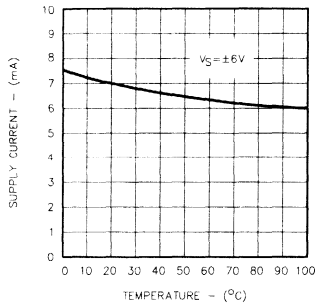


FIGURE 7. SUPPLY CURRENT VS. TEMPERATURE

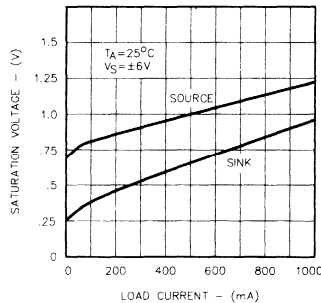


FIGURE 8. SATURATION VOLTAGE VS. LOAD CURRENT

**APPLICATION CIRCUIT**

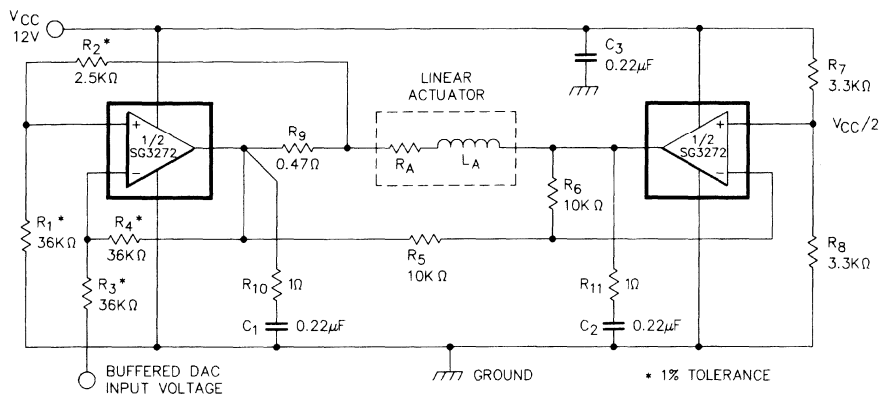


FIGURE 9 - 3.5-INCH WINCHESTER DISK DRIVE HEAD POSITION CONTROL AMPLIFIER

**CONNECTION DIAGRAMS & ORDERING INFORMATION** (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
8-PIN PLASTIC M - PACKAGE	SG3272M	0°C to 70°C	
20-PIN PLASTIC DIP DWW - PACKAGE	SG3272DWW	0°C to 70°C	

Note 1. All packages are viewed from the top.



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LINEAR INTEGRATED CIRCUITS

## SELECTION GUIDE CORE MEMORY

### SENSE AMPLIFIER

Device Type	Description	Key Features	Packages
SG5524	Dual sense amplifier	<ul style="list-style-type: none"> <li>Adjustable input threshold level</li> <li>High speed</li> <li>TTL or DTL drive compatibility</li> <li>Standard logic supply voltage</li> </ul>	J, F
SG55234 SG55234A	Dual sense amplifier	<ul style="list-style-type: none"> <li>Adjustable input threshold level</li> <li>High speed</li> <li>TTL or DTL drive compatibility</li> <li>Standard logic supply voltage</li> <li>Threshold voltage matching (<math>\Delta V_{TH}</math>):                SG55234 3mV                SG55234A 1.5mV             </li> </ul>	J, F
SG55236 SG55236A	Dual sense amplifier / data registers	<ul style="list-style-type: none"> <li>Threshold voltage matching (<math>\Delta V_{TH}</math>):                SG55236 1.5mV                SG55236A 0.8mV</li> <li>Adjustable differential-input threshold voltage</li> <li>Reference amplifier inherently stable with no external frequency compensation required</li> <li>Built-in data buffer drives 450pF load in 15ns</li> <li>Internal reference voltage attenuator makes reference amplifier less sensitive to noise</li> </ul>	F



## SELECTION GUIDE CORE MEMORY

LINEAR INTEGRATED CIRCUITS

## MEMORY DRIVERS

Device Type	Description	$I_{O(PK)}$	$I_{O(COM)}$	$V_C$	$V_{CC} \#1$	$V_{CC} \#2$	Key Features	Packages
SG55325 SG75325	Dual source/ Dual sink memory driver	0.75A	0.6A	24V	7V	24V	<ul style="list-style-type: none"> <li>• Two open emitter, two open collector output stages</li> <li>• Output clamp circuitry on sink transistors</li> <li>• Source base drive externally adjustable</li> <li>• Fast switching time</li> <li>• TTL or DTL compatibility</li> <li>• MIL-M-38510 / 13001 BEA</li> <li>QPL JAN55325J</li> </ul>	J, N, F
SG55326 SG75326	Quad sink memory driver	0.75A	0.6A	24V	7V		<ul style="list-style-type: none"> <li>• Four open collector output stages</li> <li>• Output clamp circuitry on all outputs</li> <li>• Output transistor base drives externally adjustable</li> <li>• Fast switching time</li> <li>• TTL or DTL compatibility</li> <li>• MIL-M-38510 / 13002 BEA</li> <li>QPL JAN 55326J</li> </ul>	J, N, F
SG55327 SG75327	Quad source memory driver	0.75A	0.6A	24V	7V	24V	<ul style="list-style-type: none"> <li>• Four open emitter output stages</li> <li>• Can operate as a sink driver</li> <li>• Output transistor base drives externally adjustable</li> <li>• Fast switching time</li> <li>• TTL or DTL compatibility</li> </ul>	J, N, F



LINEAR INTEGRATED CIRCUITS

# SELECTION GUIDE CORE MEMORY

## DIODE ARRAYS

Device Type	Circuit Diagram	Key Features
SG5768/5768A		<ul style="list-style-type: none"> <li>• 60V minimum breakdown voltage</li> <li>• 500mA current capability per diode</li> <li>• Maximum reverse recovery time (<math>t_r</math>) of 20ns</li> <li>• Maximum forward recovery time (<math>t_f</math>) of 40ns</li> <li>• Reverse current (<math>I_r</math>) &lt; 100nA</li> <li>• JANTXV, JANTX &amp; JAN parts available</li> <li>• SG level "S" processing available</li> <li>• MIL-S-19500/474 QPL parts available               <ul style="list-style-type: none"> <li>1N5768</li> <li>1N5770</li> <li>1N5772</li> </ul> </li> <li>• Available in hermetic ceramic DIP (J) and flat (F) packages</li> </ul>
SG5770/5770A		
SG5772/5772A		
SG5774/5774A		
SG25768		
SG25770		
SG6496/6496A		

December 1988

**DUAL SENSE AMPLIFIER**

**DESCRIPTION**

The SG5524 is a monolithic, dual channel sense amplifier designed for high speed magnetic memory systems. The sense amplifier inputs can detect low-level differential signals. An adjustable input threshold level ( $V_{REF}$ ) allows the designer to tailor the device to suit a specific application. The outputs are TTL/DTL compatible and feature separate strobes for individual channel control.

The SG5524 is characterized over the full military temperature range of -55°C to 125°C and is available in both 16-pin ceramic DIP and 16-pin flatpack packages.

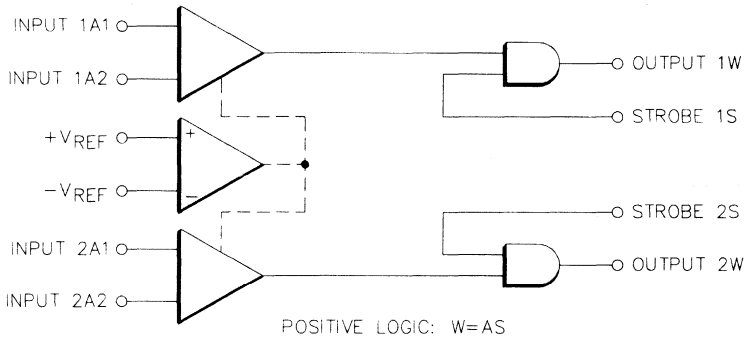
**FEATURES**

- Adjustable input threshold voltage
- High speed
- TTL or DTL drive compatibility
- Standard logic supply voltage

**HIGH RELIABILITY FEATURES - SG5524**

- ◆ Available to MIL-STD-883
- ◆ SG level "S" processing available

**BLOCK DIAGRAM**



**FUNCTION TABLE**

INPUTS		OUTPUT
A	S	W
H	H	H
L	X	L
X	L	L

**Definition of Logic Levels**

INPUT	H	L	X
A*	$V_{ID} \geq V_{T\text{MAX}}$	$V_{ID} \leq V_{T\text{MIN}}$	Irrelevant
S	$V_I \geq V_{IH\text{MIN}}$	$V_I \leq V_{IL\text{MAX}}$	Irrelevant

\* A is a differential voltage ( $V_{ID}$ ) between A1 and A2. For these circuits,  $V_{ID}$  is considered positive regardless of which terminal is positive with respect to the other.

**ABSOLUTE MAXIMUM RATINGS** (Note 1)

Supply Voltage (+V <sub>CC</sub> ) (Note 2) .....	7.0V	Off-state Voltage Applied to Open-Collector Outputs .....	5.5V
Supply Voltage (-V <sub>CC</sub> ) (Note 2) .....	-7.0V	Storage Temperature Range .....	-65°C to 150°C
Differential Input Voltage .....	±5V	Operating Junction Temperature (T <sub>C</sub> )	
Voltage From Any Input to Ground (Note 3) .....	5.5V	Hermetic (J, F-Packages) .....	175°C
		Lead Temperature (Soldering, 10 seconds) .....	300°C

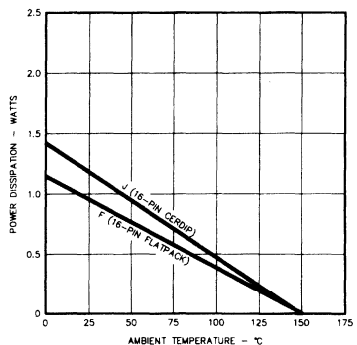
Note 1. Values beyond which damage may occur.

Note 2. Voltage values, except differential voltages, are with respect to network ground terminals.

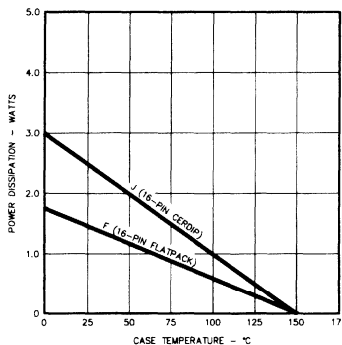
Note 3. Strobe and gate input voltages must be zero or positive with respect to network ground terminal.

**RECOMMENDED OPERATING CONDITIONS** (Note 4)

**THERMAL**



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

**ELECTRICAL**

Supply Voltage (+V <sub>CC</sub> ) .....	4.75V to 5.25V	Operating Ambient Temperature Range:	
Supply Voltage (-V <sub>CC</sub> ) .....	-4.75V to -5.25V	SG5524 .....	-55°C to 125°C
Reference Voltage (V <sub>REF</sub> ) .....	15mV to 40mV		

Note 4. Range over which the device is functional.

**ELECTRICAL SPECIFICATIONS**

(Unless otherwise specified, these specifications apply over operating ambient temperature range, +V<sub>CC</sub> = 5V, and -V<sub>CC</sub> = -5V.

Parameter	Test Conditions	SG5524			Units
		Min.	Typ.	Max.	
<b>Static Section</b>					
Differential Input Threshold Voltage (V <sub>T</sub> )	V <sub>REF</sub> = 15mV	10	15	20	mV
	V <sub>REF</sub> = 40mV	35	40	45	mV
Common Mode Input Firing Voltage (V <sub>ICF</sub> ) (Note 5)	V <sub>REF</sub> = 40 mV, V <sub>HS</sub> = V <sub>HP</sub> , T <sub>A</sub> = 25°C Common Mode input pulse: t <sub>r</sub> ≤ 15ns, t <sub>f</sub> ≤ 15ns, t <sub>w</sub> ≤ 50ns		±2.5		V
Differential Input Bias Current (I <sub>IB</sub> )	+V <sub>CC</sub> = 5.25V, -V <sub>CC</sub> = -5.25V, V <sub>ID</sub> = 0V T <sub>A</sub> = -55°C to 0°C			100	μA
	T <sub>A</sub> = 0°C to 125°C			75	μA
Differential Input Offset Current	+V <sub>CC</sub> = 5.25V, -V <sub>CC</sub> = -5.25V, V <sub>ID</sub> = 0V, T <sub>A</sub> = 25°C		0.5		μA
High Level Input Voltage (Strobe Inputs) (V <sub>IH</sub> )		2			V
Low Level Input Voltage (Strobe Inputs) (V <sub>IL</sub> )				0.8	V
High Level Output Voltage (V <sub>OH</sub> )	+V <sub>CC</sub> = 4.75V, -V <sub>CC</sub> = -4.75V, I <sub>OH</sub> = -0.4 mA	2.4	4.0		V
Low Level Output Voltage (V <sub>OL</sub> )	+V <sub>CC</sub> = 4.75V, -V <sub>CC</sub> = -4.75V, I <sub>OL</sub> = 16 mA	0.25	0.4		V
High Level Input Current (Strobe Inputs) (I <sub>IH</sub> )	+V <sub>CC</sub> = 5.25V, -V <sub>CC</sub> = -5.25V V <sub>IH</sub> = 2.40V			40	μA
	V <sub>HP</sub> = 5.25V			1.0	mA
Low Level Input Current (Strobe Inputs) (I <sub>IL</sub> )	+V <sub>CC</sub> = 5.25V, -V <sub>CC</sub> = -5.25V, V <sub>IL</sub> = 0.4V	-1.0	-1.6		mA

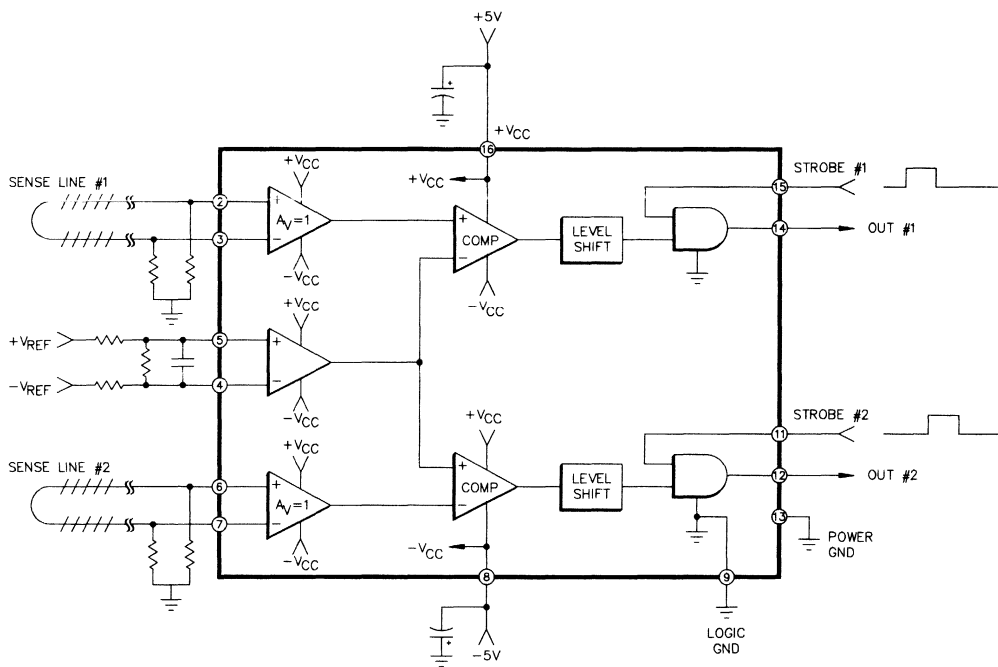
ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG5524			Units
		Min.	Typ.	Max.	
<b>Static Section (continued)</b>					
Short Circuit Output Current ( $I_{OS}$ )	$+V_{CC} = 5.25V, -V_{CC} = -5.25V, T_A = 25^\circ C$	-2.1		-3.5	mA
Supply Current from $+V_{CC}$ ( $+I_{CC}$ )	$+V_{CC} = 5.25V, -V_{CC} = -5.25V, T_A = 25^\circ C$		25	40	mA
Supply Current from $-V_{CC}$ ( $-I_{CC}$ )	$+V_{CC} = 5.25V, -V_{CC} = -5.25V, T_A = 25^\circ C$		-15	-20	mA

Parameter	Test Conditions	SG5524			Units
		Min.	Typ.	Max.	
<b>Dynamic Section</b>					
Propagation Delay Times From A1-A2 to W	$C_L = 15pF, R_L = 288\Omega, C_{EXT} > 100pF, T_A = 25^\circ C$				
Low to High (TPLH)			25	40	ns
High to Low (TPHL)			20		ns
Propagation Delay Times From Strobe to W	$C_L = 15pF, R_L = 288\Omega, C_{EXT} > 100pF, T_A = 25^\circ C$				
Low to High (TPLH)			15	30	ns
High to Low (TPHL)			20		ns

Note 5. Common-mode input firing voltage is the minimum common-mode voltage that will exceed the dynamic range of the input at the specified conditions and cause the logic output to switch. The common-mode input signal is applied when the strobe is high.

TYPICAL APPLICATION



**CONNECTION DIAGRAMS & ORDERING INFORMATION** (See Note Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
16-PIN CERAMIC DIP J - PACKAGE	SG5524J/883B SG5524J	-55°C to 125°C -55°C to 125°C	
16-PIN CERAMIC FLAT PACK F - PACKAGE	SG5524F/883B SG5524F	-55°C to 125°C -55°C to 125°C	

Note 1. All packages are viewed from the top.





**SG5768/68A, SG5770/70A, SG5772/72A, SG5774/74A  
SG25768, SG25770,  
SG6496/96A**

LINEAR INTEGRATED CIRCUITS

**DIODE ARRAY CIRCUITS**

**DESCRIPTION**

The Silicon General series of diode arrays feature high breakdown, high speed diodes in a variety of configurations.

Each array configuration consists of either common anode diodes, common cathode diodes, or a combination of common anode and common cathode diodes.

Individual diodes within the array have 60V minimum breakdown voltage, can handle 500mA of current and typically switch in less than 10 nanoseconds.

Each of the array configurations is available in ceramic DIP or ceramic flatpack and can be processed to JANTXV, JANTX, or JAN flows at Silicon General's MIL-S-19500 facility.

**FEATURES**

- 60V minimum breakdown voltage
- 500mA current capability per diode
- Fast switching speeds: typically less than 10ns
- Low leakage current

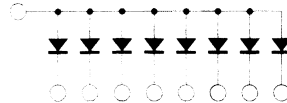
**HIGH RELIABILITY FEATURES**

- ◆ MIL-S-19500/474 QPL - 1N5768  
- 1N5770  
- 1N5772
- ◆ JANTXV, JANTX & JAN available
- ◆ SG level "S" processing available

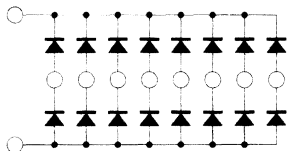
**CIRCUIT DIAGRAMS**



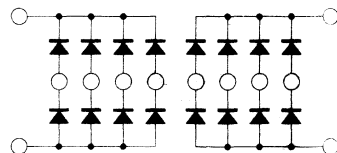
COMMON CATHODE  
SG5768/SG5768A



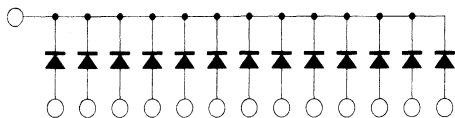
COMMON ANODE  
SG5770/SG5770A



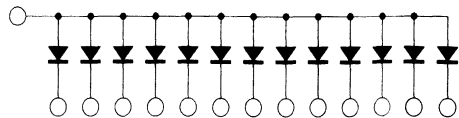
COMMON ANODE / COMMON CATHODE  
SG5772/SG5772A



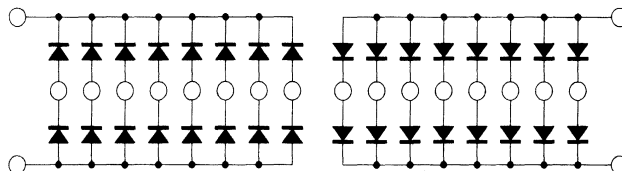
DUAL COMMON ANODE / COMMON CATHODE  
SG5774/SG5774A



COMMON CATHODE  
SG25768



COMMON ANODE  
SG25770



DUAL COMMON ANODE / COMMON CATHODE  
SG6496/SG6496A

# DIODE ARRAY SERIES

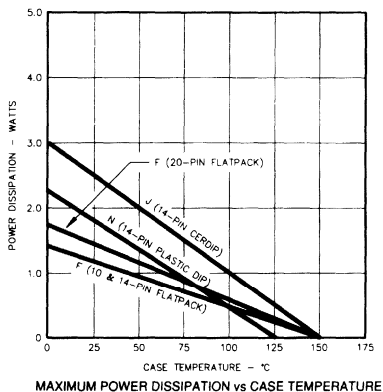
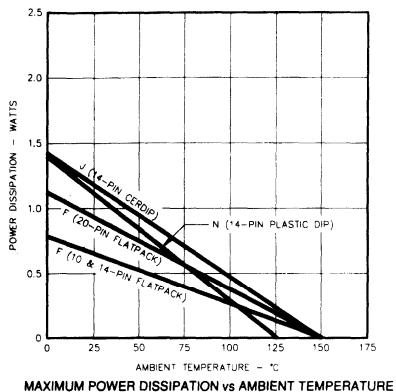
## ABSOLUTE MAXIMUM RATINGS (Note 1 & 2)

Breakdown Voltage ( $V_{BR}$ ) .....	60V	Operating Junction Temperature	
Output Current ( $I_O$ ), $T_C = 25^\circ\text{C}$		Hermetic (J, F Packages) .....	175°C
Continuous .....	500mA	Storage Temperature Range .....	-65°C to 200°C

Note 1. Exceeding these ratings could cause damage to the device.  
 Note 2. Applicable for each diode.

## RECOMMENDED OPERATING CONDITIONS (Note 3)

### THERMAL



### ELECTRICAL

Operating Ambient Temperature Range		Operating Ambient Temperature Range	
SG5768, SG5768A .....	-55°C to 150°C	SG5774, SG5774A .....	-55°C to 150°C
SG5770, SG5770A .....	-55°C to 150°C	SG25768 .....	-55°C to 150°C
SG5772, SG5772A .....	-55°C to 150°C	SG25770 .....	-55°C to 150°C
		SG6496, SG6496A .....	-55°C to 150°C

Note 3. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise stated, these specifications apply for  $T_A = 25^\circ\text{C}$  for each diode.)

Parameter	Test Conditions	SG5768A SG25768			SG5768			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Breakdown Voltage ( $V_{BR}$ )	$I_R = 10\mu\text{A}$	60			60			V
Forward Voltage ( $V_F$ )	Duty Cycle $\leq$ 2%, 300 $\mu\text{s}$ pulse							
		$I_F = 100\text{mA}$		1.0		1.0		V
		$I_F = 200\text{mA}$		1.1		1.1		V
		$I_F = 500\text{mA}$		1.3		1.5		V
		$I_F = 10\text{mA}$ , $T_A = -55^\circ\text{C}$		1.0		1.0		V
Reverse Current ( $I_R$ )	$V_R = 40\text{V}$			100			100	nA
	$V_R = 40\text{V}$ , $T_A = 150^\circ\text{C}$			50			50	$\mu\text{A}$
Capacitance (C) (Note 4)	$V_R = 0\text{V}$ , $f = 1\text{MHz}$ , Pin-to-pin			4			4	pf
Forward Recovery Time ( $t_{fr}$ ) (Note 4)	$I_F = 500\text{mA}$ , $t_r \leq 15\text{ns}$ , $V_R = 1.8\text{V}$ , $R_s = 50\Omega$			40			40	ns
Reverse Recovery Time ( $t_{rr}$ ) (Note 4)	$I_F = I_R = 200\text{mA}$ , $I_R = 20\text{mA}$ , $R_L = 100\Omega$		7	20		7	20	ns

Note 4. The parameters, although guaranteed, are not 100% tested in production.

# DIODE ARRAY SERIES

## ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG5770A SG25770			SG5770			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Breakdown Voltage ( $V_{BR}$ )	$I_R = 10\mu A$ , 100ms pulse, $\leq 20\%$ Duty Cycle	60			60			V
Forward Voltage ( $V_F$ )	Duty Cycle $\leq 2\%$ , 300 $\mu s$ pulse							
	$I_F = 100mA$			1.0		1.0		V
	$I_F = 200mA$			1.1		1.1		V
	$I_F = 500mA$			1.3		1.5		V
Reverse Current ( $I_R$ )	$I_F = 10mA$ , $T_A = -55^\circ C$			1.0		1.0		V
	$V_R = 40V$			100		100		nA
	$V_R = 40V$ , $T_A = 150^\circ C$			50		50		$\mu A$
Capacitance (C) (Note 4)	$V_R = 0V$ , $f = 1MHz$ , Pin-to-pin			8		8		pf
Forward Recovery Time ( $t_r$ )								
(Note 4)	$I_F = 500mA$ , $t_s \leq 15ns$ , $V_R = 1.8V$ , $R_S = 50\Omega$			40		40		ns
Reverse Recovery Time ( $t_{rr}$ )								
(Note 4)	$I_F = I_R = 200mA$ , $i_{rr} = 20mA$ , $R_L = 100\Omega$		7	20		7	20	ns

Parameter	Test Conditions	SG6496A SG5772A SG5774A			SG6496 SG5772 SG5774			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Breakdown Voltage ( $V_{BR}$ )	$I_R = 10\mu A$ , 100ms pulse, $\leq 20\%$ Duty Cycle	60			60			V
Forward Voltage ( $V_F$ )	Duty Cycle $\leq 2\%$ , 300 $\mu s$ pulse							
	$I_F = 100mA$			1.0		1.0		V
	$I_F = 200mA$			1.1		1.1		V
	$I_F = 500mA$			1.3		1.5		V
Reverse Current ( $I_R$ )	$I_F = 10mA$ , $T_A = -55^\circ C$			1.0		1.0		V
	$V_R = 40V$			100		100		nA
	$V_R = 40V$ , $T_A = 150^\circ C$			50		50		$\mu A$
Capacitance (C) (Note 4)	$V_R = 0V$ , $f = 1MHz$ , Pin-to-pin			8		8		pf
Forward Recovery Time ( $t_r$ )								
(Note 4)	$I_F = 500mA$ , $t_s \leq 15ns$ , $V_R = 1.8V$ , $R_S = 50\Omega$			40		40		ns
Reverse Recovery Time ( $t_{rr}$ )								
(Note 4)	$I_F = I_R = 200mA$ , $i_{rr} = 20mA$ , $R_L = 100\Omega$		7	20		7	20	ns

# DIODE ARRAY SERIES

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
14-PIN CERAMIC DIP J - PACKAGE	SG5768AJ SG5768J	-55°C to 150°C -55°C to 150°C	
10-PIN CERAMIC FLATPACK F - PACKAGE	SG5768AF SG5768F	-55°C to 150°C -55°C to 150°C	
14-PIN CERAMIC DIP J - PACKAGE	SG5770AJ SG5770J	-55°C to 150°C -55°C to 150°C	
10-PIN CERAMIC FLATPACK F - PACKAGE	SG5770AF SG5770F	-55°C to 150°C -55°C to 150°C	
14-PIN CERAMIC DIP J - PACKAGE	SG5772AJ SG5772J	-55°C to 150°C -55°C to 150°C	
10-PIN CERAMIC FLATPACK F - PACKAGE	SG5772AF SG5772F	-55°C to 150°C -55°C to 150°C	

- Note 1. Consult factory for other packages available.  
 2. All packages are viewed from the top.  
 3. Consult factory for JAN, JAN TX, and JAN TXV product availability.

# DIODE ARRAY SERIES

## CONNECTION DIAGRAMS & ORDERING INFORMATION (continued)

Package	Part No.	Ambient Temperature Range	Connection Diagram
14-PIN CERAMIC DIP J - PACKAGE	SG5774AJ SG5774J	-55°C to 150°C -55°C to 150°C	
10-PIN CERAMIC FLATPACK F - PACKAGE	SG5774AF SG5774F	-55°C to 150°C -55°C to 150°C	
14-PIN CERAMIC DIP J - PACKAGE	SG25768J SG25768J	-55°C to 150°C -55°C to 150°C	
14-PIN CERAMIC DIP J - PACKAGE	SG25770J SG25770J	-55°C to 150°C -55°C to 150°C	
20-PIN CERAMIC FLATPACK SF - PACKAGE	SG6496AF SG6496F	-55°C to 150°C -55°C to 150°C	





LINEAR INTEGRATED CIRCUITS

# SG55234/SG55234A

## DUAL SENSE AMPLIFIER

### DESCRIPTION

The SG55234/SG55234A is a monolithic, dual channel sense amplifier capable of detecting low-level differential-input signals from high speed magnetic memories. The inputs of the sense amplifier have adjustable threshold levels that allow the designer to customize the device to the application. Also, to eliminate much of the threshold voltage adjustments necessary with competitors' sense amplifiers, the SG55234/SG55234A is tested for  $V_{TH}$  matching. This guarantees the different inputs will trigger within set levels of each other.

The outputs of the sense amplifier are TTL/DTL (logic level) compatible and feature separate strobes for individual channel control.

The SG55234/SG55234A is characterized for operation over the full military temperature range of -55°C to 125°C. The device is available in 16-pin ceramic DIP or 16-pin flatpack.

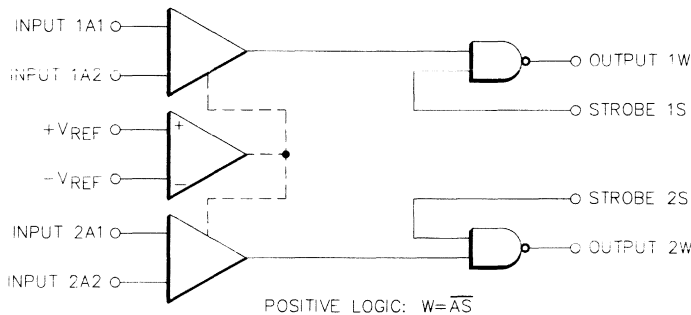
### FEATURES

- Adjustable input threshold voltage
- High speed
- TTL or DTL output compatibility
- Threshold voltage matching ( $\Delta V_{TH}$ ):  
 SG55234A 1.5mV  
 SG55234 3.0mV

### HIGH RELIABILITY FEATURES - SG55234/SG55234A

- ◆ Available to MIL-STD-883
- ◆ SG level "S" processing available

### BLOCK DIAGRAM



### FUNCTION TABLE

INPUTS		OUTPUT
A	S	W
H	H	L
L	X	H
X	L	H

### Definition of Logic Levels

INPUT	H	L	X
A*	$V_{ID} \geq V_{T MAX}$	$V_{ID} \leq V_{T MIN}$	Irrelevant
S	$V_I \geq V_{IH MIN}$	$V_I \leq V_{IL MAX}$	Irrelevant

\* A is a differential voltage ( $V_{ID}$ ) between A1 and A2. For these circuits,  $V_{ID}$  is considered positive regardless of which terminal is positive with respect to the other.

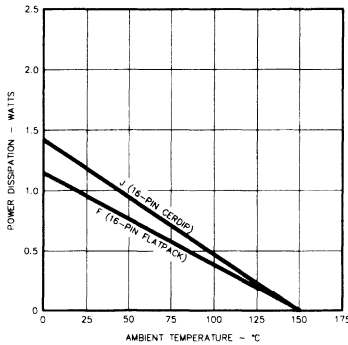
## ABSOLUTE MAXIMUM RATINGS (Note1)

Supply Voltage (+V <sub>CC</sub> ) .....	7.0V	Storage Temperature Range .....	-65°C to 150°C
Supply Voltage (-V <sub>CC</sub> ) .....	-7.0V	Operating Junction Temperature (T <sub>J</sub> )	
Differential Input Voltage .....	±5V	Hermetic (J, F-Packages) .....	175°C
Input Voltage to Ground .....	5.5V	Lead Temperature (Soldering, 10 seconds) .....	300°C

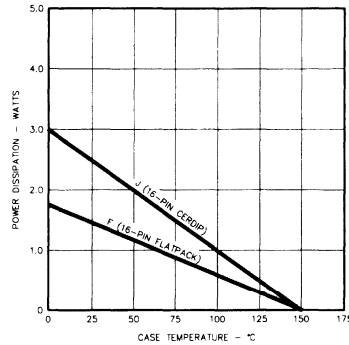
Note 1. Values beyond which damage may occur.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Supply Voltage (+V <sub>CC</sub> ) .....	4.75V to 5.25V
Supply Voltage (-V <sub>CC</sub> ) .....	-4.75V to -5.25V
Reference Voltage (V <sub>REF</sub> ) .....	15mV to 40mV

Operating Ambient Temperature Range:  
SG55234/SG55234A ..... -55°C to 125°C

Note 2. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise specified, these specifications apply over operating ambient temperature range, +V<sub>CC</sub> = 5V, and -V<sub>CC</sub> = -5V.)

Parameter	Test Conditions	SG55234/234A			Units
		Min.	Typ.	Max.	
<b>Static Section</b>					
Differential-Input Threshold Voltage (V <sub>T</sub> ) (Note 3)	V <sub>REF</sub> = 15mV	11	15	19	mV
	SG55234	13	15	17	mV
	V <sub>REF</sub> = 40mV	36	40	44	mV
	SG55234A	38	40	42	mV
Max. Difference Between Any Two Channels (ΔV <sub>T</sub> )	V <sub>REF</sub> = 15mV, T <sub>A</sub> = 25°C				
	SG55234			3.0	mV
	SG55234A			1.5	mV
Differential-Input Bias Current (I <sub>ID</sub> )	+V <sub>CC</sub> = 5.25V, -V <sub>CC</sub> = -5.25V, V <sub>ID</sub> = 0V		30	75	μA
Differential-Input Offset Current (I <sub>IO</sub> )	+V <sub>CC</sub> = 5.25V, -V <sub>CC</sub> = -5.25V, V <sub>ID</sub> = 0V		0.5		μA
High-Level Input Voltage (Strobe Inputs) (V <sub>IH</sub> )		2.0			V
Low-Level Input Voltage (Strobe Inputs) (V <sub>IL</sub> )				0.8	V
High-Level Output Voltage (V <sub>OIH</sub> )	+V <sub>CC</sub> = 4.75V, -V <sub>CC</sub> = -4.75V, I <sub>OIH</sub> = -0.4mA	2.4	4.0		V
Low-Level Output Voltage (V <sub>OIL</sub> )	+V <sub>CC</sub> = 4.75V, -V <sub>CC</sub> = -4.75V, I <sub>OIL</sub> = 16 mA		0.25	0.4	V
High-Level Input Current (Strobe Inputs) (I <sub>IH</sub> )	+V <sub>CC</sub> = 5.25V, -V <sub>CC</sub> = -5.25V				
	V <sub>IH</sub> = 2.40V			40	μA
	V <sub>IH</sub> = 5.25V			1.0	mA
Low-Level Input Current (Strobe Inputs) (I <sub>IL</sub> )	+V <sub>CC</sub> = 5.25V, -V <sub>CC</sub> = -5.25V, V <sub>IL</sub> = 0.4V		-1.0	-1.6	mA



**ELECTRICAL SPECIFICATIONS** (continued)

Parameter	Test Conditions	SG55234/234A			Units
		Min.	Typ.	Max.	
<b>Static Section</b> (continued)					
Short-circuit Output Current ( $I_{OS}$ )	$+V_{CC} = 5.25V, -V_{CC} = -5.25V$	-2.1	-3.5		mA
Supply Current from $+V_{CC}$ ( $+I_{CC}$ )	$+V_{CC} = 5.25V, -V_{CC} = -5.25V, T_A = 25^\circ C$	25	40		mA
Supply Current from $-V_{CC}$ ( $-I_{CC}$ )	$+V_{CC} = 5.25V, -V_{CC} = -5.25V, T_A = 25^\circ C$	-15	-20		mA

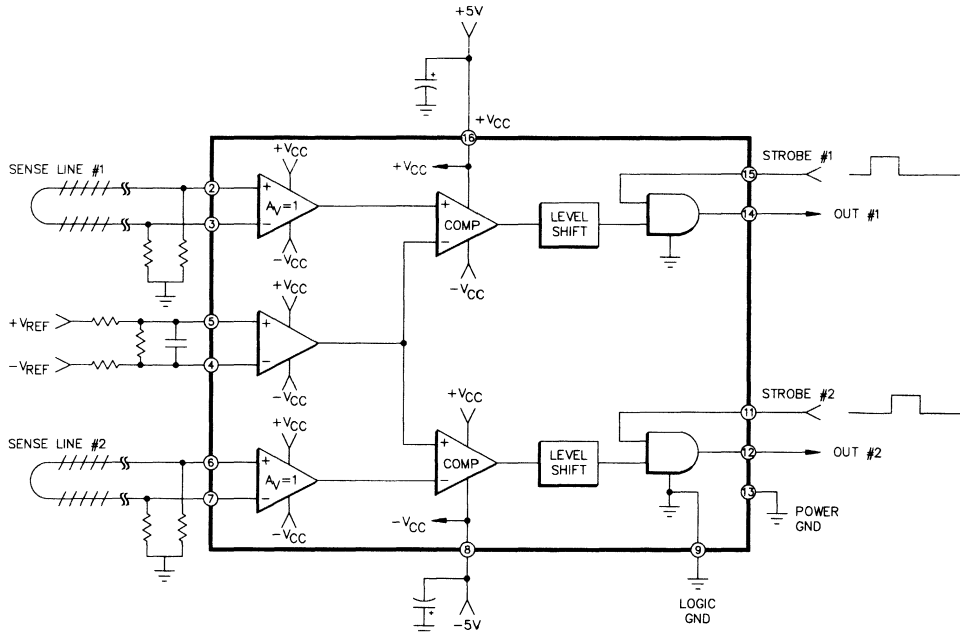
Parameter	Test Conditions	SG55234/234A			Units
		Min.	Typ.	Max.	
<b>Dynamic Section</b>					
<b>Propagation Delay Times From A1-A2 to W</b>		$C_L = 15pF, R_L = 288\Omega, T_A = 25^\circ C$			
Low to High (TPLH)			25		ns
High to Low (TPHL)			25	40	ns
<b>Propagation Delay Times From Strobe to W</b>		$C_L = 15pF, R_L = 288\Omega, T_A = 25^\circ C$			
Low to High (TPLH)			25		ns
High to Low (TPHL)			15	30	ns
<b>Differential-Input Overload Recovery</b>		<b>Differential Input Pulse:</b>			
Time ( $T_{ORD}$ ) (Note 4)	$V_{ID} = 2V, T_R = T_F = 20ns, T_A = 25^\circ C$		20		ns
<b>Common-Mode-Input Overload Recovery</b>		<b>Common-Mode Input Pulse:</b>			
Time ( $T_{ORC}$ ) (Note 5)	$V_{IC} = \pm 2V, T_R = T_F = 20ns, T_A = 25^\circ C$		20		ns
<b>Minimum Cycle Time (<math>T_{CYC(MIN)}</math>)</b>			200		ns

Note 3. The differential-input threshold voltage ( $V_T$ ) is defined as the DC differential-input voltage ( $V_{ID}$ ) required to force the output of the sense amplifier to the logic gate threshold voltage level.

Note 4. Differential-input overload recovery time is the time necessary for the device to recover from the specified differential-input-overload signal prior to the strobe-enable signal.

Note 5. Common-mode-input overload recovery time is the time necessary for the device to recover from the specified common-mode-input overload signal prior to the strobe-enable signal.

**TYPICAL APPLICATIONS**



# SG55234/SG55234A

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Note Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
16-PIN CERAMIC DIP J - PACKAGE	SG55234J/883B SG55234J SG55234AJ/883B SG55234AJ	-55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C	
16-PIN CERAMIC FLAT PACK F - PACKAGE	SG55234F/883B SG55234F SG55234AF/883B SG55234AF	-55°C to 125°C -55°C to 125°C -55°C to 125°C -55°C to 125°C	

Note 1. All packages are viewed from the top.



**DUAL SENSE AMPLIFIER/DATA REGISTERS**

**DESCRIPTION**

The SG55236/SG55236A is a monolithic, dual channel, high speed sense amplifier with independently controlled data registers. The input section features an adjustable differential-input threshold voltage. All four inputs of the sense amplifier have been screened to guarantee threshold matching (see  $\Delta V_{TH}$  in electrical characteristics).

Separate detector outputs for each channel allow the designer the flexibility to use additional output stages if necessary. In addition, each of the data registers has provisions for external data inputs.

The SG55236A was developed to meet the high speed, tight voltage threshold matching requirements of today's fast cycle time magnetic memory systems. Its enhancements are listed in the Electrical Characteristics.

The SG55236/SG55236A is available in a 24-pin flat pack and is characterized over the full military ambient temperature range of -55°C to 125°C.

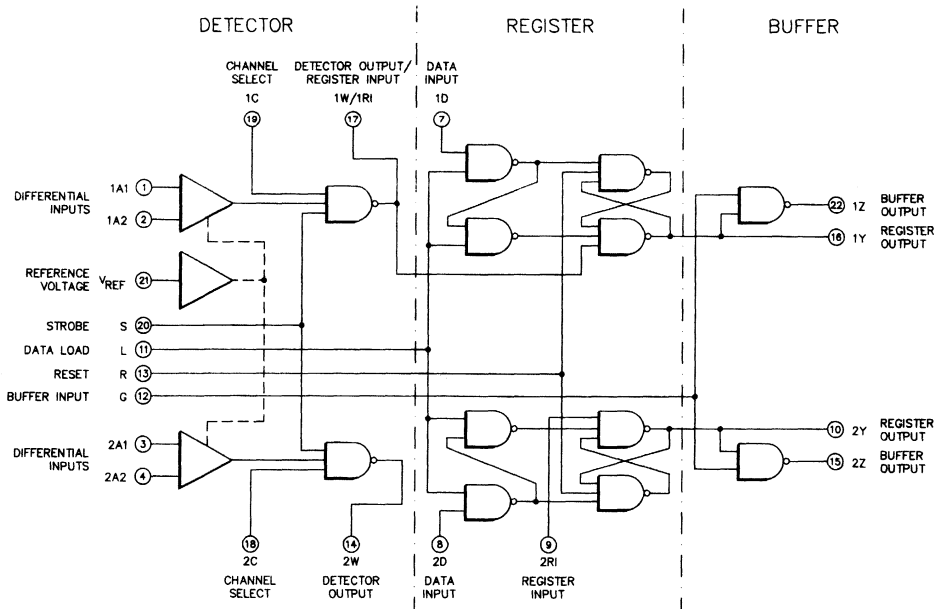
**FEATURES**

- **Threshold voltage matching ( $\Delta V_{TH}$ ):**  
 SG55236 1.5mV  
 SG55236A 0.8mV
- **Adjustable differential-input threshold voltage**
- **Reference amplifier inherently stable with no external frequency compensation required**
- **Built-in data register with provisions for external data inputs**
- **Built-in data buffer drives 450pF load in 15ns**
- **Internal reference voltage attenuator makes reference amplifier less sensitive to noise**

**HIGH RELIABILITY FEATURES - SG55236**

- ◆ **Available to MIL-STD-883**
- ◆ **Radiation data available**
- ◆ **SG level "S" processing available**

**BLOCK DIAGRAM**



See page 4 of this data sheet for Function Tables

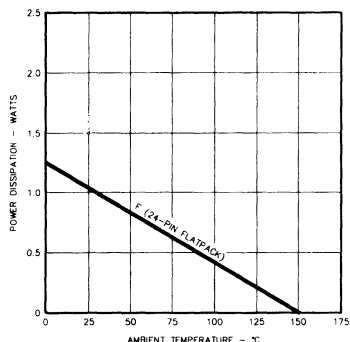
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage (+V <sub>CC</sub> ) .....	7.0V	Storage Temperature Range .....	-65°C to 150°C
Supply Voltage (-V <sub>CC</sub> ) .....	-7.0V	Operating Junction Temperature (T <sub>J</sub> )	
Reference Voltage (V <sub>REF</sub> ) .....	±5.0V	Hermetic (J-Package) .....	175°C
Differential Input Voltage (V <sub>ID</sub> ) .....	±5.0V	Lead Temperature (Soldering, 10 seconds) .....	300°C
Voltage From Any Input to Ground .....	5.25V		

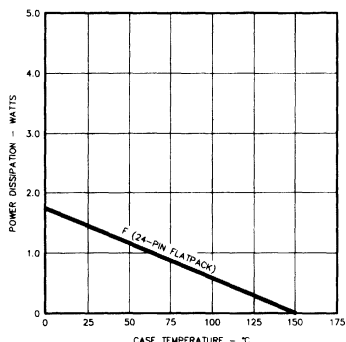
Note 1. Values beyond which damage may occur.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Supply Voltage (+V <sub>CC</sub> ) .....	4.75V to 5.25V	Low-Level Output Current (I <sub>OL</sub> ):	
Supply Voltage (-V <sub>CC</sub> ) .....	-4.75V to -5.25V	Register .....	16mA
Reference Voltage (V <sub>REF</sub> ) .....	±1.5V to ±4.5V	Buffer .....	25mA
High-Level Output Voltage (V <sub>OH</sub> ):		Detector .....	3.2mA
Detector and Buffer .....	V <sub>CC</sub>	Width of Reset Pulse (t <sub>R</sub> ) .....	115ns
High-Level Output Current (I <sub>OH</sub> ):		Operating Ambient Temperature Range:	
Register .....	-400μA	SG55236/SG55236A .....	-55°C to 125°C

Note 2. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise specified, these specifications apply over operating ambient temperature range, +V<sub>CC</sub> = 4.75V, -V<sub>CC</sub> = -4.75V, and V<sub>REF</sub> = ±2.1V.

Parameter	Test Conditions	SG55236A			SG55236			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Static Section</b>								
Differential-Input Threshold Voltage (V <sub>TH</sub> )	+V <sub>CC</sub> = 5V, -V <sub>CC</sub> = -5V, T <sub>A</sub> = 25°C	6.0	7.0	8.0	5.0	7.0	9.0	mV
	+V <sub>CC</sub> = 5V ±5%, -V <sub>CC</sub> = -5V ±5%	5.5	7.0	8.5	4.5	7.0	9.5	mV
Delta Threshold Voltage (ΔV <sub>TH</sub> )	T <sub>A</sub> = 25°C (See Functional Description)			0.8			1.5	mV
Differential-Input Bias Current (I <sub>IB</sub> )	+V <sub>CC</sub> = 5V, -V <sub>CC</sub> = -5V, V <sub>ID</sub> = 0		12	20		20	40	μA
Differential-Input Offset Current (I <sub>IO</sub> )	+V <sub>CC</sub> = 5V, -V <sub>CC</sub> = -5V, V <sub>ID</sub> = 0		0.5	2.0		1.0	5.0	μA
High-Level Input Voltage (V <sub>IH</sub> ) (Strobe and Logic Inputs)		2.0			2.0			V
Low-Level Input Voltage (V <sub>IL</sub> ) (Strobe and Logic Inputs)				0.8			0.8	V
High-Level Output Voltage (V <sub>OH</sub> )								
Register	V <sub>IH</sub> = 2V, V <sub>IL</sub> = 0.8V, I <sub>OH</sub> = -400μA	2.4			2.4			V
Detector	V <sub>IH</sub> = 2V, V <sub>IL</sub> = 0.8V	2.4			2.4			V
High-Level Output Current (I <sub>OH</sub> )								
Buffer	V <sub>IH</sub> = 2V, V <sub>IL</sub> = 0.8V, V <sub>OH</sub> = 4.75V			250			250	μA

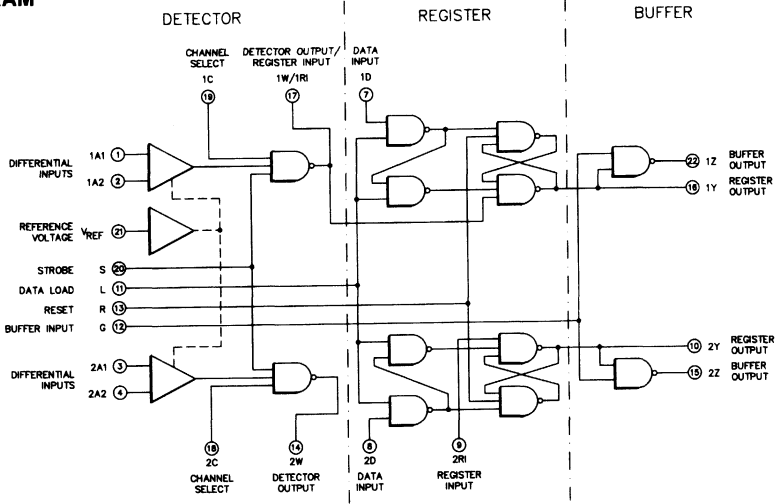
**ELECTRICAL SPECIFICATIONS** (continued)

Parameter	Test Conditions	SG55236A			SG55236			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Static Section</b> (continued)								
Low-Level Output Voltage ( $V_{OL}$ )								
Register	$V_{IH} = 2V, V_{IL} = 0.8V, I_{OL} = 16mA$			0.4			0.4	V
Buffer	$V_{IH} = 2V, V_{IL} = 0.8V, I_{OL} = 25mA$			0.5			0.5	V
Detector	$V_{IH} = 2V, V_{IL} = 0.8V$			0.4			0.4	V
Input Current at Maximum Input Voltage (Logic Inputs) ( $I_{IN}$ )	$+V_{CC} = 5.25V, -V_{CC} = -5.25V, V_{IH} = 5.25V$			1			1	mA
High-Level Input Current ( $I_{IH}$ )	$+V_{CC} = 5.25V, -V_{CC} = -5.25V, V_{IH} = 2.4V$							
Data In or Channel Select				40			40	$\mu A$
Register Input 2RI				-750			-750	$\mu A$
Strobe, Reset, or Buffer Input				80			80	$\mu A$
Data Load				160			160	$\mu A$
Low-Level Input Current ( $I_{IL}$ )	$+V_{CC} = 5.25V, -V_{CC} = -5.25V, V_{IL} = 0.4V$							
Data In				-2.0			-2.0	mA
Channel Select				-1.6			-1.6	mA
Register Input 2RI				-3.0			-3.0	mA
Strobe, Reset, or Buffer Input				-3.2			-3.2	mA
Data Load				-6.4			-6.4	mA
Short-Circuit Output Current ( $I_{OS}$ )								
Register	$+V_{CC} = 5.25V, -V_{CC} = -5.25V, V_{OUT} = 0V$	-20		-60	-20		-60	mA
Reference-Input Current ( $I_{REF}$ )	$+V_{CC} = 5.25V, -V_{CC} = -5.25V, V_{REF} = -2.1V, T_A = 25^\circ C$			0.5			0.5	mA
Supply Current From $+V_{CC}$ ( $+I_{CC}$ )	$+V_{CC} = 5.25V, -V_{CC} = -5.25V, T_A = 25^\circ C$			55			55	mA
Supply Current From $-V_{CC}$ ( $-I_{CC}$ )	$+V_{CC} = 5.25V, -V_{CC} = -5.25V, T_A = 25^\circ C$			18			18	mA

Parameter	Input	Output	SG55236A			SG55236			Units
			Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Dynamic Section</b> (Note 3)									
Propagation Delay Time									
Low to High (TPLH)	1A or 2A	Y	28	40		28	50	ns	
	Strobe	Y	16	25		18	35	ns	
	Data Input	Y	17	30		17	40	ns	
High to Low (TPHL)	Data Load	Y	13	25		15	35	ns	
	Reset	Y	12	20		12	30	ns	
Low to High (TPLH)	Reset	Z	100	200		100	200	ns	
High to Low (TPHL)	Buffer Input	Z	14	35		22	55	ns	
	1A or 2A	Z	42	60		42	90	ns	
Transition Time									
Low to High (TTLH)		Y	10	20		13	35	ns	
High to Low (TTHL)		Y	4	15		7	20	ns	
Low to High (TTLH)		Z	150	185		150	185	ns	
High to Low (TTHL)		Z	15	35		20	50	ns	

Note 3. Unless otherwise specified,  $+V_{CC} = 5V, -V_{CC} = -5V, V_{REF} = -2.1V, T_A = 25^\circ C$

**BLOCK DIAGRAM**



**FUNCTION TABLE**

INPUTS							OUTPUTS		
A	C	S	W/R1*	L	D	R	G	Y	Z
H	H	H	L	X	X	X	H	H	L
H	H	H	L	X	X	X	L	H	H
↓	H	H	↑	L	X	H	H	H	L
↓	H	H	↑	L	X	H	L	H	H
H	↓	H	↑	L	X	H	H	H	L
H	↓	H	↑	L	X	H	L	H	H
H	H	↓	↑	L	X	H	H	H	L
H	H	↓	↑	L	X	H	L	H	H
L	X	X	H	H	H	X	X	L	H
L	X	X	H	H	L	X	H	H	L
L	X	X	H	H	L	X	L	H	H
L	X	X	H	L	X	L	X	L	H
L	X	X	H	L	X	↑	X	L	H
X	L	X	H	H	H	X	X	L	X
X	L	X	H	H	L	X	H	H	L
X	L	X	H	H	L	X	L	H	H
X	L	X	H	L	X	L	X	L	H
X	L	X	H	L	X	↑	X	L	H
X	X	L	H	H	H	X	X	L	X
X	X	L	H	H	L	X	H	H	L
X	X	L	H	H	L	X	L	H	H
X	X	L	H	L	X	L	X	L	H
X	X	L	H	L	X	↑	X	L	H

**FUNCTION TABLE FOR DUAL-CHANNEL DETECTOR OPERATION (2W connected to 1W/1R1)**

INPUTS					OUTPUT
1A	1C	2A	2C	S	1W-2W
H	H	X	X	H	L
X	X	H	H	H	L
↓	H	L	X	H	↑
↓	H	X	L	H	↑
L	X	↓	H	H	↑
X	L	↓	H	H	↑
Any Other Combination					H

H = High level (steady state)  
 L = Low level (steady state)  
 X = Irrelevant (any input, including transitions)  
 ↓ = Transition from high level to low level  
 ↑ = Transition from low level to high level  
 \* The W/R1 column shows the output from the detector resulting from the inputs A, C, and S. In positive logic,  $W = \overline{ACS}$ . For dual operation with 2W connected to 2R1, this column represents an intermediate node and can be ignored.

For independent operation of register 2, this column is an input and the A, C, and S columns should be ignored.

For dual-channel operation with 2W connected to 1W/1R1, this column is the result of  $W = \overline{S(1A \cdot 1C + 2A \cdot 2C)}$ , as shown in the table above.

**Definition of Logic Levels**

INPUT	H	L
A**	$V_{IO} \geq V_{TMAX}$	$V_{IO} \leq V_{TMIN}$
LOGIC	$V_I \geq V_{HMIN}$	$V_I \leq V_{LMAX}$

\*\* A is a differential voltage ( $V_{IO}$ ) between A1 and A2. For these circuits,  $V_{IO}$  is considered positive regardless of which terminal is positive with respect to the other.

# SG55236/SG55236A

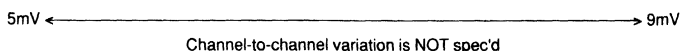
## FUNCTIONAL DESCRIPTION

### SG55236/55236A THRESHOLD VOLTAGE GRADING

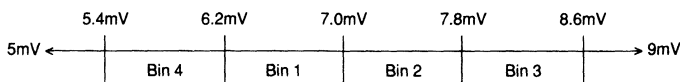
The threshold voltages for each of the four sense amplifier inputs of the SG55236/55236A are compared to ensure that the maximum difference between channels does not exceed 1.5mV (SG55236) or 0.8mV (SG55236A). Devices that exceed this limit are rejected. The four threshold voltage values are

averaged to determine the device's "bin" number (see below). The assigned bin number is marked in the lower right-hand corner of the devices. By using devices from the same bin, system performance is improved and the need for changing out sense amps due to trigger level differences is reduced.

Standard Spec  
for  $V_T$

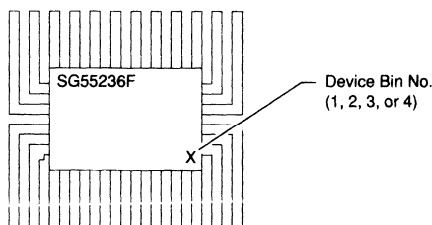


The SG55236/236A  
Spec for  $V_T$



SG55236: Channel-to channel variation  $\leq 1.5\text{mV}$   
SG55236A: Channel-to-channel variation  $\leq 0.8\text{mV}$

Marking Example:



## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Note Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
24-PIN CERAMIC FLAT PACK	SG55236AF/883B	-55°C to 125°C	
	SG55236AF	-55°C to 125°C	
F - PACKAGE	SG55236F/883B	-55°C to 125°C	
	SG55236F	-55°C to 125°C	

Note 1. All packages are viewed from the top.







LINEAR INTEGRATED CIRCUITS

SG55325/SG75325

**DUAL SOURCE / DUAL SINK MEMORY DRIVER**

**DESCRIPTION**

The SG55325/SG75325 is a monolithic dual source/dual sink driver designed to meet the high current and fast switching speed requirements of magnetic memory systems. Each driver can be independently selected through separate input logic. Also, each pair of drivers (sink or source pairs) has a separate strobe input to allow control of either pair of drivers. Each driver of the SG55325/SG75325 can switch 600mA.

Although used extensively in magnetic memory systems, this versatile driver has been used to drive relays, lamps, and small motors as well as being used as the driver in a clock circuit.

The SG55325 is characterized for use over the military ambient temperature range of -55°C to 125°C. The SG75325 has an operating ambient temperature range of 0°C to 70°C.

These devices are available in 16-pin ceramic DIP, 16-pin plastic DIP, and 16-pin flatpack.

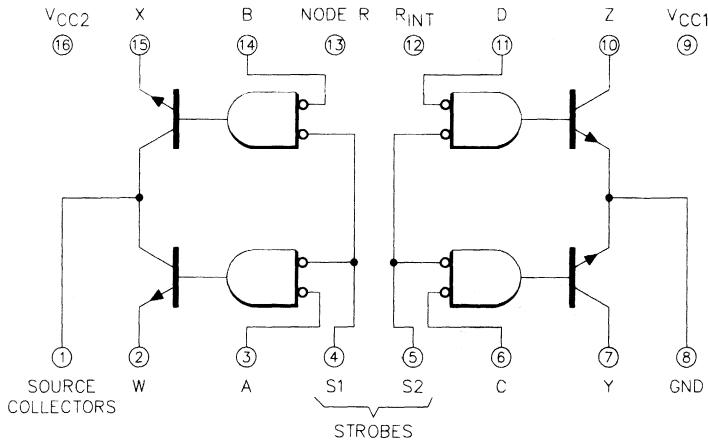
**FEATURES**

- 600mA output capability
- Fast switching times
- Output short-circuit protection
- 24V output capability
- Source base drive externally adjustable
- TTL or DTL compatibility
- Input clamping diodes

**HIGH RELIABILITY FEATURES - SG55325**

- ◆ Available to MIL-STD-883
- ◆ MIL-M-38510/13001BEA - JAN55325J
- ◆ Radiation data available
- ◆ SG level "S" processing available

**BLOCK DIAGRAM**



**ABSOLUTE MAXIMUM RATINGS** (Note 1)

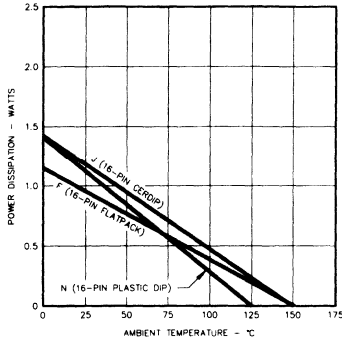
Supply Voltage ( $V_{CC1}$ ) (Note 2) ..... 7.0V  
 Supply Voltage ( $V_{CC2}$ ) (Note 2) ..... 25V  
 Input Voltage (any address or strobe input) ..... 5.5V  
 Storage Temperature Range ..... -65°C to 150°C

Operating Junction Temperature ( $T_J$ )  
 Hermetic (J, F-Packages) ..... 175°C  
 Plastic (N-Package) ..... 150°C  
 Lead Temperature (Soldering, 10 seconds) ..... 300°C

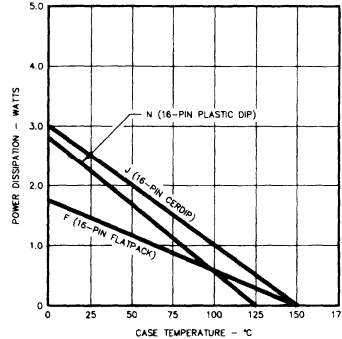
Note 1. Values beyond which damage may occur.  
 Note 2. Voltage values are with respect to network ground terminal.

**RECOMMENDED OPERATING CONDITIONS** (Note 3)

**THERMAL**



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

**ELECTRICAL**

Supply Voltage ( $V_{CC1}$ ) ..... 4.5V to 5.5V  
 Supply Voltage ( $V_{CC2}$ ) ..... 15V to 24V  
 Input Voltage ..... 0.4V to 5V

$R_{EXT}$  ( $V_{CC2} = 24V$ ) ..... 100Ω  
 Operating Ambient Temperature Range:  
 SG55325 ..... -55°C to 125°C  
 SG75325 ..... 0°C to 70°C

Note 3. Range over which the device is functional.

**ELECTRICAL SPECIFICATIONS**

(Unless otherwise specified, these specifications apply over operating ambient temperature range,  $V_{CC1} = 5.5V$ , and  $V_{CC2} = 24V$ .)

Parameter	Test Conditions	SG55325			SG75325			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Static Section</b>								
High-Level Input Voltage ( $V_{IH}$ )		2			2			V
Low-Level Input Voltage ( $V_{IL}$ )				0.8			0.8	V
Input Clamp Voltage ( $V_{ICL}$ )	$V_{CC1} = 4.5V, I_{IN} = -10mA, T_A = 25°C$			-1.3			-1.3	V
Source-Collectors Terminal								
Off-State Current ( $I_{OFF}$ )	$V_{CC1} = 4.5V$			500			200	μA
	$V_{CC1} = 4.5V, T_A = 25°C$			3.0			3.0	200
				150			200	μA
High-Level Sink Output								
Voltage ( $V_{OH}$ )	$V_{CC1} = 4.5V, I_{OUT} = 0$	19	23		19	23		V
Saturation Voltage ( $V_{SAT}$ ) (Note 3)	$V_{CC1} = 4.5V, V_{CC2} = 15V, R_L = 24Ω$							
Source Outputs	$I_{SOURCE} = -600mA$			0.90			0.90	V
	$I_{SOURCE} = -600mA, T_A = 25°C$			0.43		0.43	0.75	V
Sink Outputs	$I_{SINK} = -600mA$			0.90			0.90	V
	$I_{SINK} = -600mA, T_A = 25°C$			0.43		0.43	0.75	V
Input Current ( $I_{IN}$ )	At max. input voltage, $V_{IN} = 5.5V$							
Address Inputs				1			1	mA
Strobe Inputs				2			2	mA

**ELECTRICAL SPECIFICATIONS** (continued)

Parameter	Test Conditions	SG55325			SG75325			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Static Section</b> (continued)								
High-Level Input Current ( $I_{IH}$ )	$V_{IN} = 2.4V$		3	40		3	40	$\mu A$
Address Inputs			6	80		6	80	$\mu A$
Strobe Inputs			-1	-1.6		-1	-1.6	mA
Low-Level Input Current ( $I_{IL}$ )	$V_{IN} = 0.4V$		-2	-3.2		-2	-3.2	mA
Address Inputs								
Strobe Inputs								
Supply Current	All sources and sinks off, $T_A = 25^\circ C$							
From $V_{CC1}$			14	22		14	22	mA
From $V_{CC2}$			7.5	20		7.5	20	mA
Supply Current From $V_{CC1}$	Either sink on, $I_{SINK} = 50mA$ , $T_A = 25^\circ C$		55	70		55	70	mA
Supply Current From $V_{CC2}$ (Note 4)	Either source on, $I_{SOURCE} = -50mA$ , $T_A = 25^\circ C$		32	50		32	50	mA

Parameter	To (Outputs)	Test Conditions	SG55323/75325			Units
			Min.	Typ.	Max.	
<b>Dynamic Section</b> (Note 6)						
Propagation Delay, Low to High (TPLH)	Source Collectors			35	50	ns
	Sink Outputs			20	45	ns
Propagation Delay, High to Low (TPHL)	Source Collectors			35	50	ns
	Sink Outputs			20	45	ns
Transition Time, Low to High (TTLH)	Source Outputs	$V_{CC2} = 20V, R_L = 1K\Omega$		55		ns
	Sink Outputs			7	15	ns
Transition Time, High to Low (TTHL)	Source Outputs	$V_{CC2} = 20V, R_L = 1K\Omega$		7		ns
	Sink Outputs			9	20	ns
Storage Time ( $T_s$ )	Sink Outputs			15	30	ns

Note 4. These parameters must be measured using pulse techniques.  $T_w = 200ms$ , duty cycle  $\leq 2\%$ .

Note 6. Unless otherwise specified.  $V_{CC1} = 5V$ ,  $V_{CC2} = 15V$ ,  $C_L = 25pF$ ,  $R_L = 24\Omega$ , and  $T_A = 25^\circ C$ .

Note 5. Under these conditions, not more than one output is to be on at any one time.

**CONNECTION DIAGRAMS & ORDERING INFORMATION** (See Note Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
16-PIN CERAMIC DIP J - PACKAGE	SG55325J/883B SG55325J SG75325J	-55°C to 125°C -55°C to 125°C 0°C to 70°C	
16-PIN PLASTIC DIP N - PACKAGE	SG75325N	0°C to 70°C	
16-PIN CERAMIC FLAT PACK F - PACKAGE	SG55325F/883B SG55325F	-55°C to 125°C -55°C to 125°C	

Note 1. All packages are viewed from the top.



**QUAD SINK MEMORY DRIVER**

**DESCRIPTION**

The SG55326/SG75326 is a monolithic quad positive-OR sink driver designed to meet the high current and fast switching speed requirements of magnetic memory systems. Each driver is independently controlled and capable of sinking up to 600mA.

Paired with the SG55327 Quad Source Driver, the SG55326/SG75326 provides the current drive necessary for many sink/source applications.

Although designed specifically for magnetic memory applications, the SG55326/SG75326 has been used to drive clock circuits, relays, lamps, and small motors, or any application where a 600mA sink driver is needed.

The SG55326 is characterized for use over the full military operating ambient temperature range of -55°C to 125°C while the SG75326 is characterized over the operating ambient temperature of 0°C to 70°C.

These devices are available in 16-pin ceramic DIP, 16-pin plastic DIP, and 16-pin flatpack.

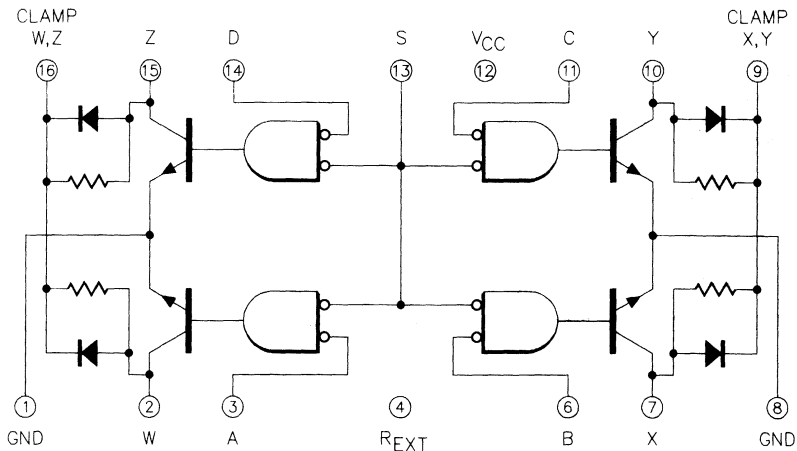
**FEATURES**

- 600mA output current sink capability
- 24V output capability
- Clamp voltage variable to 24V
- High-repetition-rate driver compatible with high-speed magnetic memories
- Inputs compatible with TTL level decoders
- Minimum time skew between strobe and output-current rise
- Pulse-transformer coupling eliminated
- Drive-line lengths reduced

**HIGH RELIABILITY FEATURES - SG55326**

- ◆ Available to MIL-STD-883
- ◆ MIL-M-38510/13002BEA - JAN55326J
- ◆ SG level "S" processing available

**BLOCK DIAGRAM**



**ABSOLUTE MAXIMUM RATINGS** (Note 1)

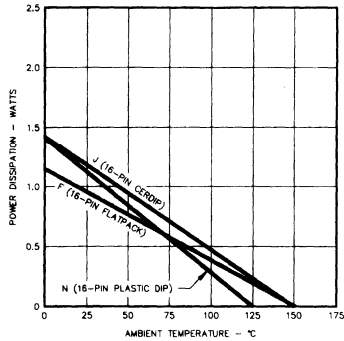
Supply Voltage ( $V_{CC}$ ) (Note 2) ..... 7.0V  
 Input Voltage (any address or strobe input) ..... 5.5V  
 Output Collector Voltage ..... 25V  
 Output Clamp Voltage ..... 25V

Output Collector Current ..... 750mA  
 Storage Temperature Range ..... -65°C to 150°C  
 Operating Junction Temperature ( $T_J$ )  
 Hermetic (J, F-Packages) ..... 175°C  
 Plastic (N-Package) ..... 150°C  
 Lead Temperature (Soldering, 10 seconds) ..... 300°C

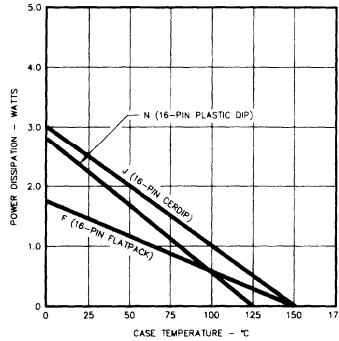
Note 1. Values beyond which damage may occur.  
 Note 2. Voltage values are with respect to network ground terminal.

**RECOMMENDED OPERATING CONDITIONS** (Note 3)

**THERMAL**



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

**ELECTRICAL**

Supply Voltage ( $V_{CC}$ ) ..... 4.5V to 5.5V  
 Output Collector Voltage ..... 24V  
 Output Clamp Voltage ( $V_{CLAMP}$ ) ..... 4.5V to 24V

Output Collector Current ..... 600mA  
 Operating Ambient Temperature Range:  
 SG55326 ..... -55°C to 125°C  
 SG75326 ..... 0°C to 70°C

Note 3. Range over which the device is functional.

**ELECTRICAL SPECIFICATIONS**

(Unless otherwise specified, these specifications apply over operating ambient temperature range. All typical values are measured at  $T_A = 25^\circ\text{C}$ .)

Parameter	Test Conditions	SG55326			SG75326			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Static Section</b>								
High-Level Input Voltage ( $V_{IH}$ )		2			2			V
Low-Level Input Voltage ( $V_{IL}$ )			0.8			0.8		V
Input Clamp Voltage ( $V_{IK}$ )	$V_{CC} = 4.5V, I_{IN} = -10mA, T_A = 25^\circ\text{C}$		-1.0	-1.7		-1.0	-1.7	V
High-Level Output Voltage ( $V_{OH}$ )	$V_{CC} = 4.5V, I_{OUT} = 0$	19	23		19	23		V
Saturation Voltage ( $V_{SAT}$ ) (Note 4)	$V_{CC} = 4.5V, I_{SINK} = 600mA$		0.9			0.9		V
	$V_{CC} = 4.5V, I_{SINK} = 600mA, T_A = 25^\circ\text{C}$		0.43	0.70		0.43	0.75	V
<b>Output-Clamp-Diode Forward</b>								
Voltage ( $V_{F(CLAMP)}$ )	$V_{CLAMP} = 0V, I_{CLAMP} = -10mA, T_A = 25^\circ\text{C}$			1.5			1.5	V
Output-Clamp Current ( $I_{CLAMP}$ )	One Output On, $I_{SINK} = 50mA, T_A = 25^\circ\text{C}$		5	7		5	7	mA
Input Current ( $I_{IN}$ )	$V_{IN} = 5.5V$							
Address				1			1	mA
Strobe				4			4	mA
<b>High-Level Input Current (<math>I_{IH}</math>)</b>								
Address	$V_{IN} = 2.4V$			40			40	$\mu\text{A}$
Strobe				160			160	$\mu\text{A}$

**ELECTRICAL SPECIFICATIONS** (continued)

Parameter	Test Conditions	SG55326			SG75326			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Static Section</b> (continued)								
Low-Level Input Current ( $I_{IL}$ )	$V_{IN} = 0.4V$							
Address		-1.0	-1.6	-1.0	-1.6			mA
Strobe		-4.0	-6.4	-4.0	-6.4			mA
Supply Current	All outputs off, all inputs at 5V, $T_A = 25^\circ C$	18	25	18	25			mA
Supply Current	One output on, $I_{SINK} = 50mA$ , $T_A = 25^\circ C$	58	75	58	75			mA

Parameter	To (Output)	Test Conditions	SG55326/75326			Units
			Min.	Typ.	Max.	
<b>Dynamic Section</b> (Note 5)						
Propagation Delay, Low to High (TPLH)	W, X, Y, or Z			30	50	ns
Propagation Delay, High to Low (TPHL)	W, X, Y, or Z			25	15	ns
Transition Time, Low to High (TTLH)	W, X, Y, or Z			7.0	15	ns
Transition Time, High to Low (TTHL)	W, X, Y, or Z			10	20	ns
Storage Time	W, X, Y, or Z			24	35	ns
High-Level Output Voltage ( $V_{OH}$ )		$V_S = V_{CLAMP} = 24V$ , $I_{SINK} = 500mA$ , $C_L = 25pF$ , $R_L = 47\Omega$		$V_S = 25$		mV

Note 4. Under these conditions, not more than one output is to be on at any one time.

Note 5. Unless otherwise specified,  $V_{CC} = 5V$ ,  $V_S = V_{CLAMP} = 15V$ ,  $C_L = 25pF$ ,  $R_L = 24\Omega$ , and  $T_A = 25^\circ C$ .

**CONNECTION DIAGRAMS & ORDERING INFORMATION** (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
16-PIN CERAMIC DIP J - PACKAGE	SG55326J/883B SG55326J SG75326J	-55°C to 125°C -55°C to 125°C 0°C to 70°C	
16-PIN PLASTIC DIP N - PACKAGE	SG75326N	0°C to 70°C	
16-PIN CERAMIC FLAT PACK F - PACKAGE	SG55326F/883B SG55326F	-55°C to 125°C -55°C to 125°C	

Note 1. All packages are viewed from the top.

Note 2. Contact factory for LCC availability.

Note 3. Pin 8 is in electrical contact with the metal base.







LINEAR INTEGRATED CIRCUITS

SG55327/SG75327

## QUAD SOURCE MEMORY DRIVER

### DESCRIPTION

The SG55327/SG75327 is a monolithic quad source driver designed to meet the high current and fast switching speed requirements of magnetic memory systems. Each driver is independently controlled and capable of sinking up to 600mA.

Paired with the SG55326 Quad Sink Driver, the SG55327/SG75327 provides the current drive necessary for many sink/source applications.

The SG55327/SG75327 has also been used in many non-memory applications: for example, as the driver for a clock circuit, relay, lamp, or small motor, or any application where a 600mA source driver is needed.

The SG55327 is characterized for use over the full military operating ambient temperature range of -55°C to 125°C while the SG75327 is characterized from 0°C to 70°C.

These devices are available in 16-pin ceramic DIP, 16-pin plastic DIP, and 16-pin flatpack.

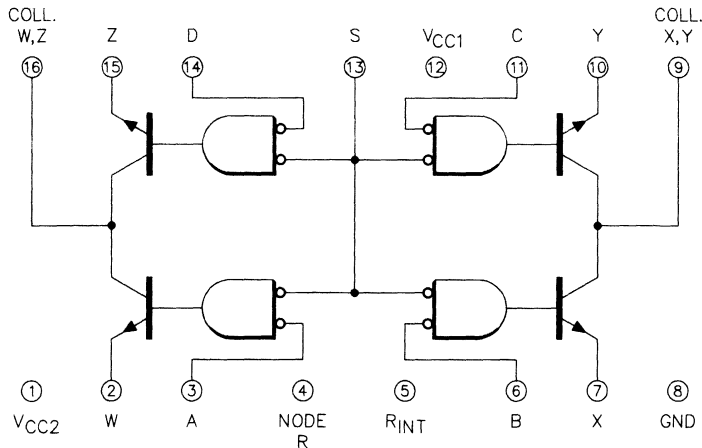
### FEATURES

- Quad source memory drivers
- 600mA output current capability
- $V_{CC2}$  drive voltage variable to 24V
- Output capable of swinging between  $V_{CC2}$  and ground
- High-repetition-rate driver compatible with high-speed magnetic memories
- Inputs compatible with TTL decoders
- Minimum time skew between strobe and output-current rise
- Pulse-transformer coupling eliminated
- Drive-line lengths reduced

### HIGH RELIABILITY FEATURES - SG55327

- ◆ Available to MIL-STD-883
- ◆ Scheduled for MIL-M-38510 QPL listing
- ◆ SG level "S" processing available

### BLOCK DIAGRAM



**ABSOLUTE MAXIMUM RATINGS** (Note1)

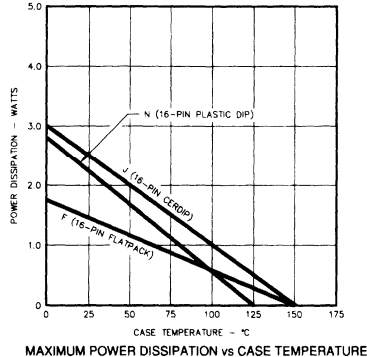
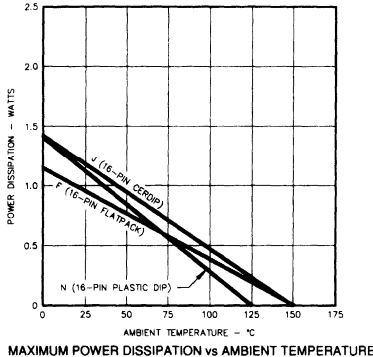
Supply Voltage ( $V_{CC1}$ ) (Note 2) ..... 7.0V  
 Supply Voltage ( $V_{CC2}$ ) ..... 25V  
 Input Voltage (any address or strobe input) ..... 5.5V  
 Output Collector Voltage ..... 25V

Output Collector Current ..... 750mA  
 Storage Temperature Range ..... -65°C to 150°C  
 Operating Junction Temperature ( $T_C$ )  
 Hermetic (J, F-Packages) ..... 175°C  
 Plastic (N-Package) ..... 150°C  
 Lead Temperature (Soldering, 10 seconds) ..... 300°C

Note 1. Values beyond which damage may occur.  
 Note 2. Voltage values are with respect to network ground terminal.

**RECOMMENDED OPERATING CONDITIONS** (Note 3)

**THERMAL**



**ELECTRICAL**

Supply Voltage ( $V_{CC1}$ ) ..... 4.5V to 5.5V  
 Supply Voltage ( $V_{CC2}$ ) ..... 4.5V to 24V  
 Output Collector Voltage ..... 24V

Output Collector Current ..... 600mA  
 Operating Ambient Temperature Range:  
 SG55327 ..... -55°C to 125°C  
 SG75327 ..... 0°C to 70°C

Note 3. Range over which the device is functional.

**ELECTRICAL SPECIFICATIONS**

(Unless otherwise specified, these specifications apply over operating ambient temperature range.)

Parameter	Test Conditions	SG55327			SG75327			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Static Section</b>								
High-Level Input Voltage ( $V_{IH}$ )		2		0.8	2		0.8	V
Low-Level Input Voltage ( $V_{IL}$ )				-1.0			-1.0	V
Input Clamp Voltage ( $V_{IK}$ )	$V_{CC1} = 4.5V, I_{IN} = -10mA, T_A = 25^\circ C$			-1.7			-1.7	V
Collectors Terminal Off-State Current ( $I_{OFF}$ )	$V_{CC1} = 4.5V, V_{COL} = 24V$			500			200	$\mu A$
	$V_{CC1} = 4.5V, V_{COL} = 24V, T_A = 25^\circ C$			150			200	$\mu A$
Saturation Voltage ( $V_{SAT}$ ) (Note 4)	$V_{CC1} = 4.5V, V_{OUT} = 0V, I_{SOURCE} = -600mA$			0.90			0.90	V
	$T_A = 25^\circ C$			0.43			0.75	V
Input Current ( $I_{IN}$ )	$V_{IN} = 5.5V$							
Address				1			1	mA
Strobe				4			4	mA
High-Level Input Current ( $I_{IH}$ )	$V_{IN} = 2.4V$							
Address				40			40	$\mu A$
Strobe				160			160	$\mu A$
Low-Level Input Current ( $I_{IL}$ )	$V_{IN} = 0.4V$							
Address				-1.0			-1.0	mA
Strobe				-4.0			-4.0	mA

**ELECTRICAL SPECIFICATIONS** (continued)

Parameter	Test Conditions	SG55327			SG75327			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Static Section</b> (continued)								
Supply Current ( $I_{CC(OFF)}$ )	All outputs off, all inputs at 5V, $T_A = 25^\circ\text{C}$		7.0	10		7.0	10	mA
From $V_{CC1}$			13	20		13	20	
Supply Current ( $I_{CC(ON)}$ )	One output on, $I_{SOURCE} = -50\text{mA}$ , $V_{COL} = 6\text{V}$ , $T_A = 25^\circ\text{C}$		8.0	12		8.0	12	mA
From $V_{CC1}$			36	55		36	55	

Parameter	To (output)	Test Conditions	SG55327/75327			Units
			Min.	Typ.	Max.	
<b>Dynamic Section</b> (Note 5)						
Propagation Delay, Low to High (TPLH)	Coll. W, Z or X, Y	$V_S = V_{CC2} = 15\text{V}$ , $R_L = 24\Omega$		35	55	ns
Propagation Delay, High to Low (TPHL)	Coll. W, Z or X, Y	$V_S = V_{CC2} = 15\text{V}$ , $R_L = 24\Omega$		30	55	ns
Transition Time, Low to High (TTLH)	W, X, Y, or Z	$V_{COL} = V_{CC2} = 20\text{V}$ , $R_L = 100\Omega$		30		ns
Transition Time, High to Low (TTHL)	W, X, Y, or Z	$V_{COL} = V_{CC2} = 20\text{V}$ , $R_L = 100\Omega$		10		ns
High-Level Output Voltage ( $V_{OH}$ )	Coll. W, Z or X, Y	$V_S = V_{CC2} = 24\text{V}$ , $R_L = 47\Omega$ , $I_{SINK} = 500\text{mA}$	$V_S - 25$			mV

Note 4. Under these conditions, not more than one output is to be on any one time.

Note 5. Unless otherwise specified,  $V_{CC1} = 5\text{V}$ ,  $C_L = 25\text{pF}$ , and  $T_A = 25^\circ\text{C}$ .

**CONNECTION DIAGRAMS & ORDERING INFORMATION** (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
16-PIN CERAMIC DIP J - PACKAGE	SG55327J/883B SG55327J SG75327J	-55°C to 125°C -55°C to 125°C 0°C to 70°C	
16-PIN PLASTIC DIP N - PACKAGE	SG75327N	0°C to 70°C	
16-PIN CERAMIC FLAT PACK F - PACKAGE	SG55327F/883B SG55327F	-55°C to 125°C -55°C to 125°C	

Note 1. All packages are viewed from the top.

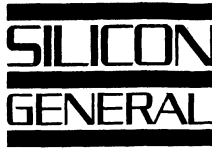
Note 2. Contact factory for LCC.

Note 3. Pin 8 is in electrical contact with the metal base.



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# SELECTION GUIDE AUTOMOTIVE CIRCUITS

LINEAR INTEGRATED CIRCUITS

## LOW DROPOUT VOLTAGE REGULATORS

Device Type	Output Current	Output Voltages	Maximum Input Voltage	Initial Tolerance	Key Features	Packages
SG29055	0.75A	5V, 5V	26V	±5%	<ul style="list-style-type: none"> <li>• Input / output differential less than 0.6V at 0.5A</li> <li>• Dual outputs</li> <li>• 5V / 10mA standby output</li> <li>• Low quiescent current in the standby mode</li> <li>• Reverse battery protection</li> <li>• 60V load dump protection</li> <li>• -50V Reverse transient protection</li> <li>• Thermal shutdown protection</li> <li>• ON/OFF switch for high current output</li> <li>• Available in 5 - pin TO-220 package</li> </ul>	P
SG29055A	0.75A	5V, 5V	26V	±2%		
SG29085	0.75A	8V, 5V	26V	±5%		
SG29085A	0.75A	8V, 5V	26V	±2%		
SG29125	0.75A	12V, 5V	26V	±5%		
SG29125A	0.75A	12V, 5V	26V	±2%		

See General Information Section regarding capabilities for custom automotive circuits

**LOW DROPOUT DUAL REGULATOR**

**DESCRIPTION**

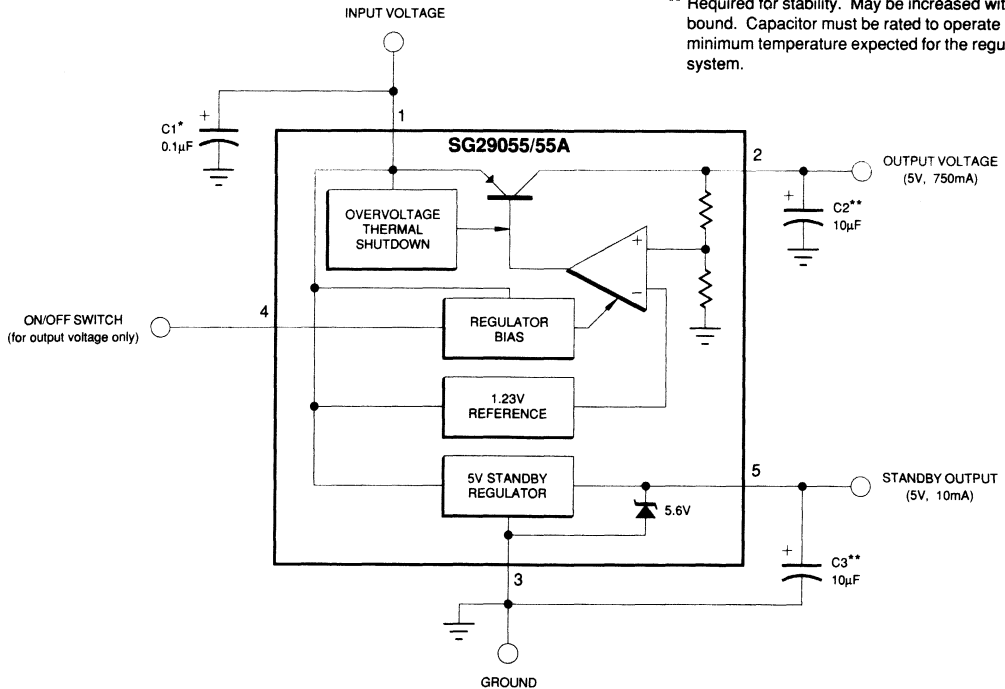
The SG29055/55A is a dual 5V/5V positive voltage regulator. One output is a high current (up to 750 mA) regulator that can be turned on or off by a high impedance low current TTL compatible switch. The second or standby output remains on regardless. The on/off switch not only shuts off the high current output but actually puts the IC in a micropower mode making possible a low quiescent current. This unique characteristic coupled with an extremely low dropout, (.55V for output current of 10mA) makes the SG29055/55A well suited for power systems that require standby memory. The SG29055/55A includes other features which were originally designed for automotive applications. These include protection from reverse battery installations and double battery jumps. The high current regulator has overvoltage shutdown to protect both the internal circuitry and the load during line transients, such as load dump (60V). In addition, the high current regulator design also has built-in protection for short circuit and thermal overload. During these fault conditions of the primary regulator the standby regulator will continue to power its load.

The SG29055 is the 5 volt,  $\pm 5\%$  version of a family of dual regulators with a standby output voltage of 5V. Other high current outputs of 8.2V and 12V are available. Also available is the SG29055A which offers an improved output voltage tolerance of  $\pm 2\%$ . They are available in the plastic TO-220 power package and are designed to function over the automotive temperature range of  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ .

**FEATURES**

- 2% Internally Trimmed Outputs
- Two regulated outputs
- Output current in excess of 750mA
- Low quiescent current standby regulator
- Input-output differential less than 0.6V at 0.5A
- Reverse battery protection
- 60V load dump protection
- -50V reverse transient protection
- Short circuit protection
- Internal thermal overload protection
- Available in plastic TO-220
- ON/OFF switch for high current output

**TYPICAL APPLICATION CIRCUIT**



- \* Required if regulator is located far from power supply filter.
- \*\* Required for stability. May be increased without bound. Capacitor must be rated to operate at the minimum temperature expected for the regulator system.

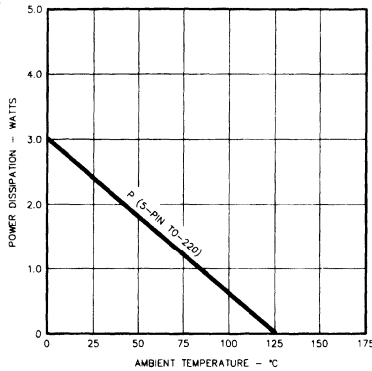
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Input Voltage ( $V_{IN}$ ) ..... -15V to 26V      Storage Temperature Range ( $T_{STG}$ ) ..... -65°C to 150°C  
 ON/OFF Switch ..... -0.3V to  $V_{IN}$       Operating Junction Temperature ( $T_J$ ) ..... 150°C

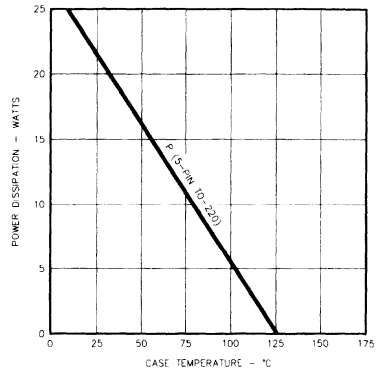
Note 1. Exceeding these values may destroy this part. The SG29055/55A will not function properly at these maximum ratings.

## RECOMMENDED OPERATING CONDITIONS (Notes 2 & 3)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Input Voltage ( $V_{IN}$ ) ..... 6V to 26V      Reverse Polarity D.C. Input Voltage ( $V_{IN}$ )  
 ON/OFF Switch Threshold Voltage ( $V_O \geq -0.6V, 16\Omega$  load) ..... -15V max.  
 Low Level,  $V_{IL}$  ( $V_{OUT}$  is OFF) ..... 0.8V max.      Reverse Polarity Transient Input Voltage ( $V_{IN}$ )  
 High Level,  $V_{IH}$  ( $V_{OUT}$  is ON) ..... 2.0V min.      (1% duty cycle,  $T \leq 100ms, V_O \geq -9V, 16\Omega$  load) ... -50V max.  
 Load Current (with adequate heatsinking) ..... 5mA to 750mA      Output Capacitor with ESR of 10 $\mu$ F max.  
 Maximum Line Transient (Load Dump)  $V_O \leq 5.5V$  .... 60V max.      ( $V_{OUT}$  to GND &  $V_{SB}$  to GND) ..... 10 $\mu$ F min.  
 Input Capacitor ( $V_{IN}$  to GND) ..... 0.1  $\mu$ F min.      Operating Ambient Temperature Range ( $T_A$ )  
 SG29055/55A ..... -40°C to 85°C

Note 2. Range over which the device is functional.

Note 3. During 60V load dump,  $V_{SB}$  shall not be less than 4.75V at  $I_{OUT} = 10mA$ .

## ELECTRICAL SPECIFICATIONS

DC Characteristics:  $T_J = 25^\circ C, V_{IN} = 14V, I_O = 500mA$  for  $V_{OUT}$  and 10mA for  $V_{SB}$ , except where noted.

Parameter	Test Conditions	SG29055/55A			Units
		Min.	Typ.	Max.	
<b>Voltage Output (<math>V_{OUT}</math>) Section</b>					
Output Voltage (Note 4)	$6V \leq V_{IN} \leq 26V, I_O \leq 500mA, -40^\circ C \leq T_A \leq 85^\circ C$ SG29055 SG29055A	4.75 4.90	5.00 5.00	5.25 5.10	V V
Line Regulation	$9V \leq V_{IN} \leq 16V, I_O = 5mA$ $6V \leq V_{IN} \leq 26V, I_O = 5mA$		4 10	25 50	mV mV
Load Regulation	$5mA \leq I_O \leq 500mA$		10	50	mV
Output Impedance	$500mA_{DC}$ and $10mA_{RMS}, 100Hz - 10kHz$		200		$\Omega$
Quiescent Current	$I_O \leq 10mA$ , No Load on Standby $I_O = 500mA$ , No Load on Standby $I_O = 750mA$ , No Load on Standby		3 55 120		mA mA mA
Output Noise Voltage	10Hz - 100kHz		100		$\mu V_{RMS}$
Long Term Stability			20		mV/1000hr
Ripple Rejection	$F_O = 120Hz$		66		dB
Dropout Voltage	$I_O = 500mA$ $I_O = 750mA$		0.45 0.82	0.6	V V
Current Limit		0.75	1.4		A
Maximum Operational Input Voltage		26	31		V
Maximum Line Transient	$V_O \leq 5.5V$	60	70		V
ON/OFF Switch ( $I_{IH}$ )	$I_O = 10mA$ , Pin 4 = 2.4V			10	$\mu A$
ON/OFF Switch ( $I_{IL}$ )	$I_O = 10mA$ , Pin 4 = 0.4V	-10			$\mu A$

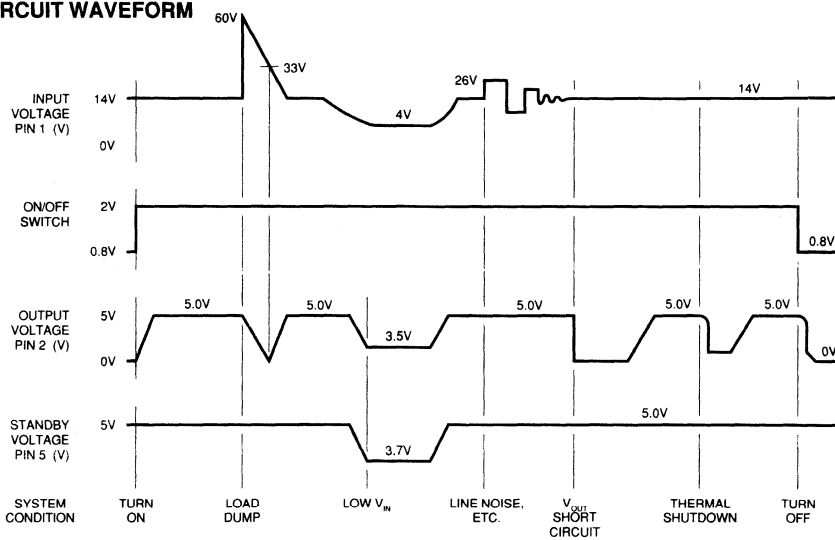


**ELECTRICAL SPECIFICATIONS (continued)**

Parameter	Test Conditions	SG29055/55A			Units
		Min.	Typ.	Max.	
<b>Standby Output (<math>V_{SP}</math>) Section</b>					
Output Voltage (Note 4)	$6V \leq V_{IN} \leq 26V, I_O \leq 10mA, -40^\circ C \leq T_A \leq 85^\circ C$	4.75	5.0	5.25	V
Tracking	$V_{OUT}$ - Standby Output Voltage		50	200	mV
Line Regulation	$6V \leq V_{IN} \leq 26V$	4	50		mV
Load Regulation	$1mA \leq I_O \leq 10mA$	1	50		mV
Output Impedance	$1mA_{DC}$ and $1mA_{RMS}$ , 100Hz - 10kHz	10			$\Omega$
Quiescent Current	$I_O \leq 10mA, V_{OUT,OFF}$	1.2	3		mA
Output Noise Voltage	10Hz - 100kHz		300		$\mu V_{RMS}$
Long Term Stability			20		mV/1000hr
Ripple Rejection	$F_O = 120Hz$		66		dB
Dropout Voltage	$I_O \leq 10mA$		0.55	0.7	V
Current Limit		25	70		mA
Maximum Operational Input Voltage	$4.5V \leq V_O \leq 6V$	60	70		V

Note 4. The temperature extremes are guaranteed but not 100% production tested.

**TYPICAL CIRCUIT WAVEFORM**



**APPLICATION NOTES**

The advantages of using a low-dropout regulator such as the SG29055/55A are the need for less "headroom" for full regulation, and the inherent reverse polarity protection provided by the PNP output device. A typical NPN regulator design requires an input to output differential of approximately two volts minimum. This is due to the  $2V_{be} + V_{cesat}$  of the NPN Darlington used in the output, coupled with the voltage drop across the current limit resistor. In contrast, the "PNP Regulator" uses a single series pass transistor with its single  $V_{cesat}$ , thus the lower input to output voltage differential or dropout voltage.

In addition to a low dropout voltage, an important advantage of the SG29055/55A series is low quiescent current in the standby mode. When the high current or primary regulator is shut off, the

regulator enters a micropower mode. Here all but the most essential circuitry to power the standby output is deactivated. This allows the lowest possible quiescent current (typical around 1.2mA), a vital factor when used in a battery powered system.

In some applications the regulator output voltage is used not only as a power supply but also as a voltage reference for control systems. In such cases not just the temperature stability of the output is important but also the initial accuracy. The SG29055/55A fills this need as the internal bandgap reference is trimmed allowing a typical output voltage tolerance of  $\pm 1\%$ .

## APPLICATION HINTS

### EXTERNAL CAPACITORS

To stabilize the outputs and prevent oscillation (perhaps by many volts) external capacitors are required. The minimum recommended value for the output capacitors is 10 $\mu$ F, although the actual size and type will likely vary according to the particular application, e.g., operating temperature range and load. Another consideration is the effective series resistance (ESR) of the capacitor. Capacitor ESR will vary by manufacturer. Consequently, some evaluation may be required to determine the minimum value of the output capacitors. Generally worst case occurs at the maximum load and minimum ambient temperature.

The size of the output capacitor can be increased to any value above the minimum. One possible advantage of this would be to maintain the output voltage during brief periods of negative input transients

The output capacitors chosen should be rated for the full range of ambient temperature over which the circuit will be exposed and expected to operate. For example, many aluminum type electrolytic capacitors will freeze at -30°C. The effective capacitance is reduced to zero in such a situation. Capacitors rated for -40°C operation must be used in order to maintain regulator stability at that temperature. Tantalum capacitors satisfy this requirement.

### STANDBY OUTPUT

The SG29055/55A differs from most fixed voltage regulators in that it is equipped with two regulator outputs instead of one. The additional output is intended for use in systems requiring standby memory circuits. While the high current regulator output can be controlled with the ON/OFF pin described below, the standby remains on under all conditions as long as sufficient input voltage is applied to the IC. Thus, memory and other circuits powered by this output remain unaffected by positive line transients, thermal shutdown, etc.

The standby regulator circuit is designed so that the quiescent current to the IC is very low (<1.5mA) when the other regulator output is off.

If the standby output is not required it can be disabled. This is accomplished by connecting a resistor from the standby output to the supply voltage, thereby also eliminating the requirement for a more expensive output capacitor to prevent unwanted oscillations. The resistor value depends upon the minimum input voltage expected for a given system.

Since the standby output is shunted with an internal 5.6V zener, the current through the external resistor should be sufficient to bias internal resistors up to this point. Approximately 60 $\mu$ F will suffice, resulting in a 10k external resistor for most applications (Figure 1).

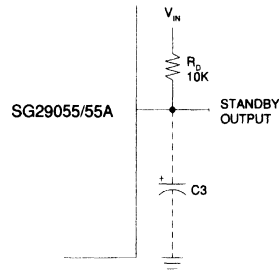


FIGURE 1. Disabling Standby Output to Eliminate C3

### HIGH CURRENT OUTPUT

The high current regulated output features fault protection against overvoltage as well as a thermal shutdown feature. If the input voltage rises above 33V (load dump), the high current output shuts down automatically. The internal circuitry is thus protected and the IC is able to survive higher voltage transients than might otherwise be expected. The thermal shutdown of the high current output effectively guards against overheating of the die since this section of the IC is the principle source of power dissipation on the chip.

### ON/OFF SWITCH

The ON/OFF pin is a high impedance low current switch that controls the main output voltage (pin 2). This is directly compatible with all 5 volt logic families. For use with open collector logic outputs, a 100k resistor from this pin to a 5V supply, such as Pin 5, is required.

## CONNECTION DIAGRAM & ORDERING INFORMATION (See Note Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
5-PIN TO-220 PLASTIC P - PACKAGE	SG29055P SG29055AP	-40°C to 85°C -40°C to 85°C	

Note: 1. All parts are viewed from the top.

**LOW DROPOUT DUAL REGULATOR**

**DESCRIPTION**

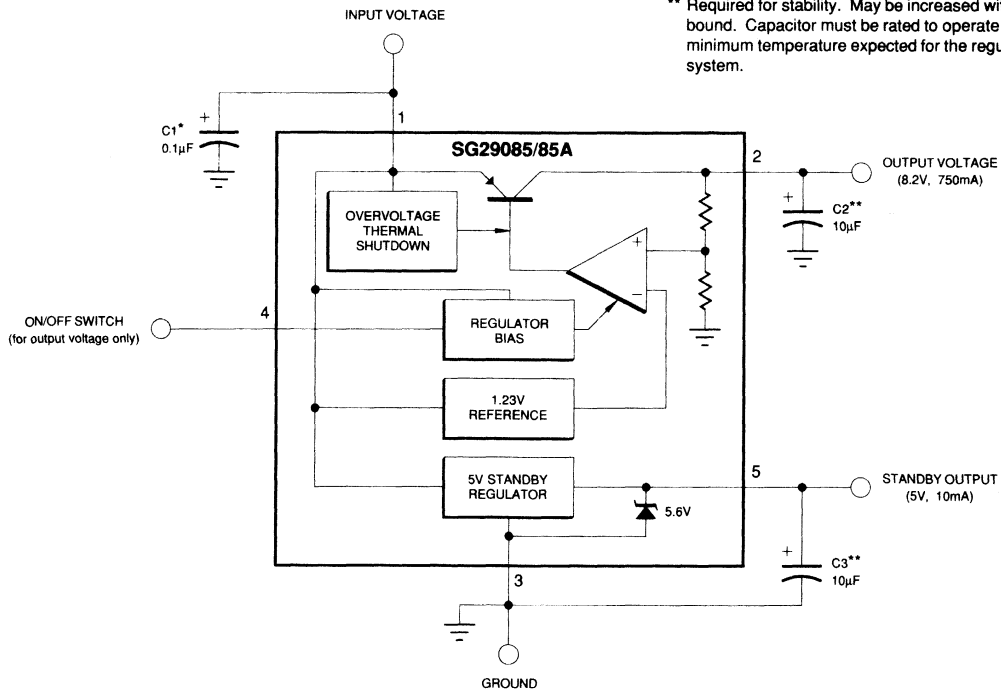
The SG29085/85A is a dual 8.2V/5V positive voltage regulator. One output is a high current (up to 750 mA) regulator that can be turned on or off by a high impedance low current TTL compatible switch. The second or standby output remains on regardless. The on/off switch not only shuts off the high current output but actually puts the IC in a micropower mode making possible a low quiescent current. This unique characteristic coupled with an extremely low dropout, (.55V for output current of 10mA) makes the SG29085/85A well suited for power systems that require standby memory. The SG29085/85A includes other features which were originally designed for automotive applications. These include protection from reverse battery installations and double battery jumps. The high current regulator has overvoltage shutdown to protect both the internal circuitry and the load during line transients, such as load dump (60V). In addition, the high current regulator design also has built-in protection for short circuit and thermal overload. During these fault conditions of the primary regulator the standby regulator will continue to power its load.

The SG29085 is the 8.2 volt,  $\pm 5\%$  version of a family of dual regulators with a standby output voltage of 5V. Other high current outputs of 5 and 12 volts are available. Also available is the SG28085A which offers an improved output voltage tolerance of  $\pm 2\%$ . They are available in the plastic TO-220 power package and are designed to function over the automotive temperature range of  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ .

**FEATURES**

- 2% Internally Trimmed Outputs
- Two regulated outputs
- Output current in excess of 750mA
- Low quiescent current standby regulator
- Input-output differential less than 0.6V at 0.5A
- Reverse battery protection
- 60V load dump protection
- -50V reverse transient protection
- Short circuit protection
- Internal thermal overload protection
- Available in plastic TO-220
- ON/OFF switch for high current output

**TYPICAL APPLICATION CIRCUIT**



- \* Required if regulator is located far from power supply filter.
- \*\* Required for stability. May be increased without bound. Capacitor must be rated to operate at the minimum temperature expected for the regulator system.

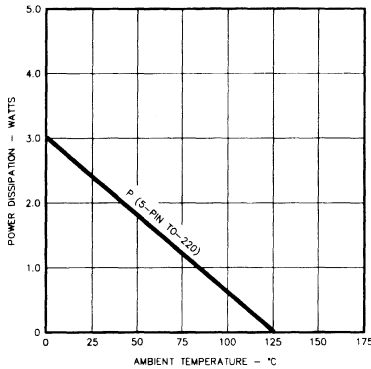
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Input Voltage ( $V_{IN}$ ) ..... -15V to 26V      Storage Temperature Range ( $T_{STG}$ ) ..... -65°C to 150°C  
 ON/OFF Switch ..... -0.3V to  $V_{IN}$       Operating Junction Temperature ( $T_J$ ) ..... 150°C

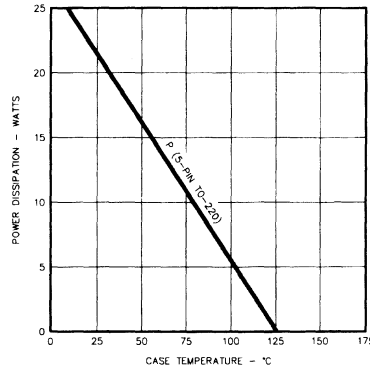
Note 1. Exceeding these values may destroy this part. The SG29085 and SG29085A will not function properly at these maximum ratings.

## RECOMMENDED OPERATING CONDITIONS (Notes 2 & 3)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Input Voltage ( $V_{IN}$ ) ..... 9V to 26V  
 ON/OFF Threshold Voltage  
     Low Level,  $V_{IL}$  ( $V_{OUT}$  is OFF) ..... 0.8V max.  
     High Level,  $V_{IH}$  ( $V_{OUT}$  is ON) ..... 2.0V min.  
 Load Current (with adequate heatsinking) ..... 5mA to 750mA  
 Maximum Line Transient (Load Dump)  $V_O \leq 5.5V$  ..... 60V max.  
 Input Capacitor ( $V_{IN}$  to GND) ..... 0.1  $\mu F$  min.

Reverse Polarity D.C. Input Voltage ( $V_{IN}$ )  
 ( $V_O \geq -0.6V$ , 16 $\Omega$  load) ..... -15V max.  
 Reverse Polarity Transient Input Voltage ( $V_{IN}$ )  
 (1% duty cycle,  $T \leq 100ms$ ,  $V_O \geq -9V$ , 16 $\Omega$  load) .. -50V max.  
 Output Capacitor with ESR of 10 $\Omega$  max.  
 ( $V_{OUT}$  to GND &  $V_{SB}$  to GND) ..... 10 $\mu F$  min.  
 Operating Ambient Temperature Range - ( $T_A$ )  
 SG29085/85A ..... -40°C to 85°C

Note 2. Range over which the device is functional.

Note 3. During 60V load dump,  $V_{SB}$  shall not be less than 4.75V at  $I_{OUT} = 10mA$ .

## ELECTRICAL SPECIFICATIONS

DC Characteristics:  $T_J = 25^\circ C$ .  $V_{IN} = 14V$ .  $I_O = 500mA$  for  $V_{OUT}$  and 10mA for  $V_{SB}$ , except where noted.

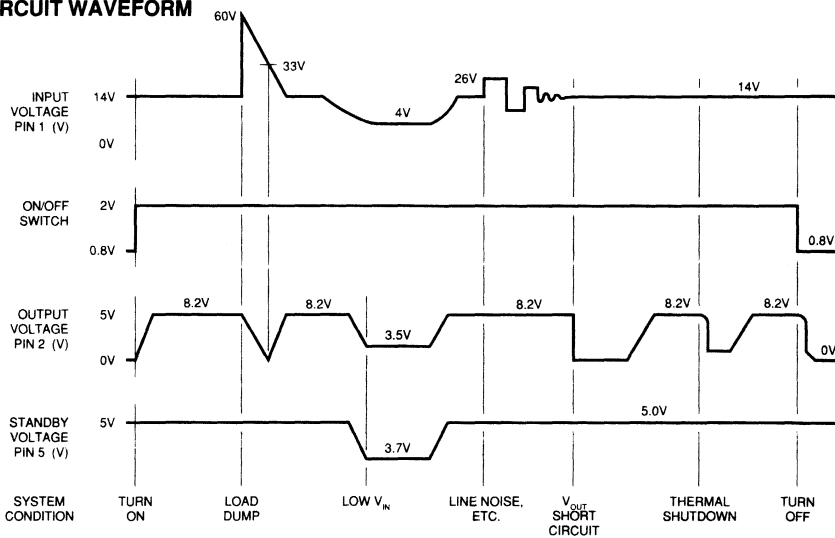
Parameter	Test Conditions	SG29085/85A			Units
		Min.	Typ.	Max.	
<b>Voltage Output (<math>V_{OUT}</math>) Section</b>					
Output Voltage (Note 4)	$9V \leq V_{IN} \leq 26V$ , $I_O \leq 500mA$ , $-40^\circ C \leq T_A \leq 85^\circ C$ SG29085	7.8	8.2	8.6	V
	SG29085A	8.0	8.2	8.4	V
Line Regulation	$9V \leq V_{IN} \leq 16V$ , $I_O = 5mA$		4	25	mV
	$9V \leq V_{IN} \leq 26V$ , $I_O = 5mA$		10	50	mV
Load Regulation	$5mA \leq I_O \leq 500mA$		10	50	mV
Output Impedance	$500mA_{DC}$ and $10mA_{RMS}$ , 100Hz - 10kHz		200		$\Omega$
Quiescent Current	$I_O \leq 10mA$ , No Load on Standby		3		mA
	$I_O = 500mA$ , No Load on Standby		55	100	mA
	$I_O = 750mA$ , No Load on Standby		120		mA
Output Noise Voltage	10Hz - 100kHz		100		$\mu V_{RMS}$
Long Term Stability			20		mV/1000hr
Ripple Rejection	$F_O = 120Hz$		66		dB
Dropout Voltage	$I_O = 500mA$		0.45	0.6	V
	$I_O = 750mA$	0.75	0.82		V
Current Limit		26	1.4		A
Maximum Operational Input Voltage		60	31		V
Maximum Line Transient	$V_O \leq 9V$		70		V
ON/OFF Switch ( $I_{IN}$ )	$I_O = 10mA$ , Pin 4 = 2.4V			10	$\mu A$
ON/OFF Switch ( $I_{IL}$ )	$I_O = 10mA$ , Pin 4 = 0.4V	-10			$\mu A$

**ELECTRICAL SPECIFICATIONS (continued)**

Parameter	Test Conditions	SG29085/85A			Units
		Min.	Typ.	Max.	
<b>Standby Output (<math>V_{SB}</math>) Section</b>					
Output Voltage (Note 4)	$6V \leq V_{IN} \leq 26V, I_O \leq 10mA, -40^\circ C \leq T_A \leq 85^\circ C$	4.75	5.0	5.25	V
Tracking	$V_{OUT}$ - Standby Output Voltage		50	200	mV
Line Regulation	$6V \leq V_{IN} \leq 26V$	4	50		mV
Load Regulation	$1mA \leq I_O \leq 10mA$	10	50		mV
Output Impedance	$1mA_{DC}$ and $1mA_{RMS}, 100Hz - 10kHz$	1			$\Omega$
Quiescent Current	$I_O \leq 10mA, V_{OUT} OFF$		1.2	3	mA
Output Noise Voltage	$10Hz - 100kHz$		300		$\mu V_{RMS}$
Long Term Stability			20		mV/1000hr
Ripple Rejection	$F_O = 120Hz$		66		dB
Dropout Voltage	$I_O \leq 10mA$		0.55	0.7	V
Current Limit		25	70		mA
Maximum Operational Input Voltage	$4.5V \leq V_O \leq 6V$	60	70		V

Note 4. The temperature extremes are guaranteed but not 100% production tested.

**TYPICAL CIRCUIT WAVEFORM**



**APPLICATION NOTES**

The advantages of using a low-dropout regulator such as the SG29085/85A are the need for less "headroom" for full regulation, and the inherent reverse polarity protection provided by the PNP output device. A typical NPN regulator design requires an input to output differential of approximately two volts minimum. This is due to the  $2V_{be} + V_{cesat}$  of the NPN Darlington used in the output, coupled with the voltage drop across the current limit resistor. In contrast, the "PNP Regulator" uses a single series pass transistor with its single  $V_{cesat}$ , thus the lower input to output voltage differential or dropout voltage.

In addition to a low dropout voltage, an important advantage of the SG29085/85A series is low quiescent current in the standby mode. When the high current or primary regulator is shut off, the

regulator enters a micropower mode. Here all but the most essential circuitry to power the standby output is deactivated. This allows the lowest possible quiescent current (typical around 1.2mA), a vital factor when used in a battery powered system.

In some applications the regulator output voltage is used not only as a power supply but also as a voltage reference for control systems. In such cases not just the temperature stability of the output is important but also the initial accuracy. The SG29085/85A fills this need as the internal bandgap reference is trimmed allowing a typical output voltage tolerance of  $\pm 1\%$ .

## APPLICATION HINTS

### EXTERNAL CAPACITORS

To stabilize the outputs and prevent oscillation (perhaps by many volts) external capacitors are required. The minimum recommended value for the output capacitors is 10µF, although the actual size and type will likely vary according to the particular application, e.g., operating temperature range and load. Another consideration is the effective series resistance (ESR) of the capacitor. Capacitor ESR will vary by manufacturer. Consequently, some evaluation may be required to determine the minimum value of the output capacitors. Generally worst case occurs at the maximum load and minimum ambient temperature.

The size of the output capacitor can be increased to any value above the minimum. One possible advantage of this would be to maintain the output voltage during brief periods of negative input transients

The output capacitors chosen should be rated for the full range of ambient temperature over which the circuit will be exposed and expected to operate. For example, many aluminum type electrolytic capacitors will freeze at -30°C. The effective capacitance is reduced to zero in such a situation. Capacitors rated for -40°C operation must be used in order to maintain regulator stability at that temperature. Tantalum capacitors satisfy this requirement.

### STANDBY OUTPUT

The SG29085/85A differs from most fixed voltage regulators in that it is equipped with two regulator outputs instead of one. The additional output is intended for use in systems requiring standby memory circuits. While the high current regulator output can be controlled with the ON/OFF pin described below, the standby remains on under all conditions as long as sufficient input voltage is applied to the IC. Thus, memory and other circuits powered by this output remain unaffected by positive line transients, thermal shutdown, etc.

The standby regulator circuit is designed so that the quiescent current to the IC is very low (<1.5mA) when the other regulator output is off.

If the standby output is not required it can be disabled. This is accomplished by connecting a resistor from the standby output to the supply voltage, thereby also eliminating the requirement for a more expensive output capacitor to prevent unwanted oscillations. The resistor value depends upon the minimum input voltage expected for a given system.

Since the standby output is shunted with an internal 5.6V zener, the current through the external resistor should be sufficient to bias internal resistors up to this point. Approximately 60µA will suffice, resulting in a 10k external resistor for most applications (Figure 1).

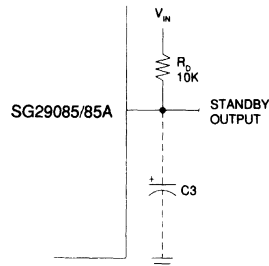


FIGURE 1. Disabling Standby Output to Eliminate C3

### HIGH CURRENT OUTPUT

The high current regulated output features fault protection against overvoltage as well as a thermal shutdown feature. If the input voltage rises above 33V (load dump), the high current output shuts down automatically. The internal circuitry is thus protected and the IC is able to survive higher voltage transients than might otherwise be expected. The thermal shutdown of the high current output effectively guards against overheating of the die since this section of the IC is the principle source of power dissipation on the chip.

### ON/OFF SWITCH

The ON/OFF pin is a high impedance low current switch that controls the main output voltage (pin 2). This is directly compatible with all 5 volt logic families. For use with open collector logic outputs, a 100k resistor from this pin to a 5V supply, such as Pin 5, is required.

## CONNECTION DIAGRAM & ORDERING INFORMATION (See Note Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
5-PIN TO-220 PLASTIC P - PACKAGE	SG29085P SG29085AP	-40°C to 85°C -40°C to 85°C	

Note: 1. All packages are viewed from the top.

**LOW DROPOUT DUAL REGULATOR**

**DESCRIPTION**

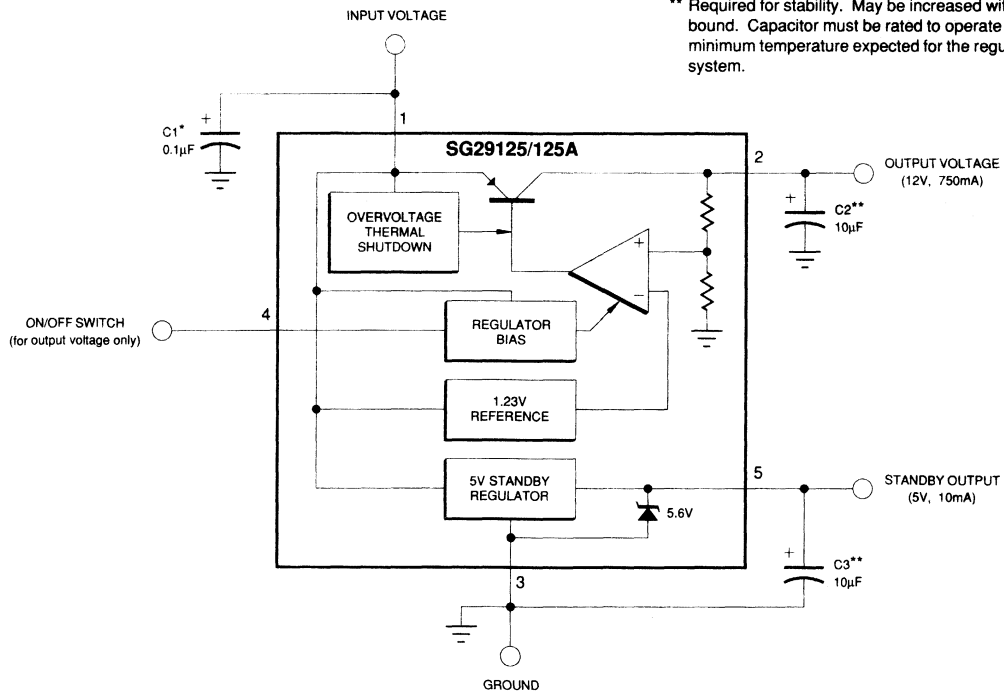
The SG29125/125A is a dual 12V/5V positive voltage regulator. One output is a high current (up to 750 mA) regulator that can be turned on or off by a high impedance low current TTL compatible switch. The second or standby output remains on regardless. The on/off switch not only shuts off the high current output but actually puts the IC in a micropower mode making possible a low quiescent current. This unique characteristic coupled with an extremely low dropout, (.55V for output current of 10mA) makes the SG29125/125A well suited for power systems that require standby memory. The SG29125/125A includes other features which were originally designed for automotive applications. These include protection from reverse battery installations and double battery jumps. The high current regulator has overvoltage shutdown to protect both the internal circuitry and the load during line transients, such as load dump (60V). In addition, the high current regulator design also has built-in protection for short circuit and thermal overload. During these fault conditions of the primary regulator the standby regulator will continue to power its load.

The SG29125 is the 12 volt,  $\pm 5\%$  version of a family of dual regulators with a standby output voltage of 5V. Other high current outputs of 5 and 8.2 volts are available. Also available is the SG29125A which offers an improved output voltage tolerance of  $\pm 2\%$ . They are available in the plastic TO-220 power package and are designed to function over the automotive temperature range of  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ .

**FEATURES**

- 2% Internally Trimmed Outputs
- Two regulated outputs
- Output current in excess of 750mA
- Low quiescent current standby regulator
- Input-output differential less than 0.6V at 0.5A
- Reverse battery protection
- 60V load dump protection
- -50V reverse transient protection
- Short circuit protection
- Internal thermal overload protection
- Available in plastic TO-220
- ON/OFF switch for high current output

**TYPICAL APPLICATION CIRCUIT**



- \* Required if regulator is located far from power supply filter.
- \*\* Required for stability. May be increased without bound. Capacitor must be rated to operate at the minimum temperature expected for the regulator system.

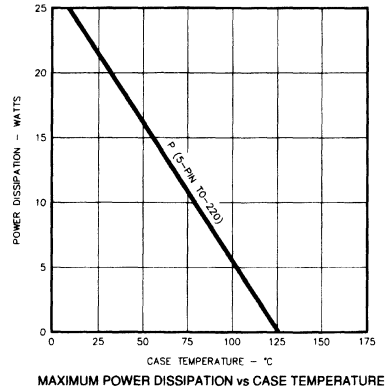
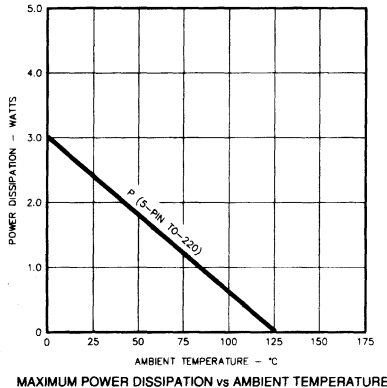
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Input Voltage ( $V_{IN}$ ) ..... -15V to 26V      Storage Temperature Range ( $T_{STG}$ ) ..... -65°C to 150°C  
 ON/OFF Switch ..... -0.3V to  $V_{IN}$       Operating Junction Temperature ( $T_J$ ) ..... 150°C

Note 1. Exceeding these values may destroy this part. The SG29125 and SG29125A will not function properly at these maximum ratings.

## RECOMMENDED OPERATING CONDITIONS (Note 2 & 3)

### THERMAL



### ELECTRICAL

Input Voltage ( $V_{IN}$ ) ..... 13V to 26V  
 ON/OFF Threshold Voltage  
     Low Level,  $V_{IL}$  ( $V_{OUT}$  is OFF) ..... 0.8V max.  
     High Level,  $V_{IH}$  ( $V_{OUT}$  is ON) ..... 2.0V min.  
 Load Current (with adequate heatsinking) ..... 5mA to 750mA  
 Maximum Line Transient (Load Dump)  $V_O \leq 5.5V$  ..... 60V max.  
 Input Capacitor ( $V_{IN}$  to GND) ..... 0.1  $\mu F$  min.

Reverse Polarity D.C. Input Voltage ( $V_{IN}$ )  
 ( $V_O \geq -0.6V$ , 16 $\Omega$  load) ..... -15V max.  
 Reverse Polarity Transient Input Voltage ( $V_{IN}$ )  
 (1% duty cycle,  $T \leq 100ms$ ,  $V_O \geq -9V$ , 16 $\Omega$  load) .. -50V max.  
 Output Capacitor with ESR of 10 $\Omega$  max.  
 ( $V_{OUT}$  to GND &  $V_{SB}$  to GND) ..... 10 $\mu F$  min.  
 Operating Ambient Temperature Range ( $T_A$ )  
 SG29125/125A ..... -40°C to 85°C

Note 2. Range over which the device is functional.

Note 3. During 60V load dump,  $V_{SB}$  shall not be less than 4.75V at  $I_{OUT} = 10mA$ .

## ELECTRICAL SPECIFICATIONS

DC Characteristics:  $T_J = 25^\circ C$ ,  $V_{IN} = 14V$ ,  $I_O = 500mA$  for  $V_{OUT}$  and 10mA for  $V_{SB}$ , except where noted.

Parameter	Test Conditions	SG29125/125A			Units
		Min.	Typ.	Max.	
<b>Voltage Output (<math>V_{OUT}</math>) Section</b>					
Output Voltage (Note 4)	$13V \leq V_{IN} \leq 26V$ , $I_O \leq 500mA$ , $-40^\circ C \leq T_A \leq 85^\circ C$ SG29125	11.2	12	12.8	V
	SG29125A	11.75	12	12.25	V
Line Regulation	$13V \leq V_{IN} \leq 16V$ , $I_O = 5mA$ $13V \leq V_{IN} \leq 26V$ , $I_O = 5mA$		4	25	mV
Load Regulation	$5mA \leq I_O \leq 500mA$		10	50	mV
Output Impedance	$500mA_{DC}$ and $10mA_{RMS}$ , 100Hz - 10kHz		10	50	mV
Quiescent Current	$I_O \leq 10mA$ , No Load on Standby		3		mA
	$I_O = 500mA$ , No Load on Standby		55	100	mA
	$I_O = 750mA$ , No Load on Standby		120		mA
Output Noise Voltage	10Hz - 100kHz		100		$\mu V_{RMS}$
Long Term Stability			20		mV/1000hr
Ripple Rejection	$F_O = 120Hz$		66		dB
Dropout Voltage	$I_O = 500mA$ $I_O = 750mA$		0.45	0.6	V
Current Limit		0.75	0.82		V
Maximum Operational Input Voltage		26	1.4		A
Maximum Line Transient	$V_O \leq 13V$	60	31		V
ON/OFF Switch ( $I_{IN}$ )	$I_O = 10mA$ , Pin 4 = 2.4V		70		V
ON/OFF Switch ( $I_{IN}$ )	$I_O = 10mA$ , Pin 4 = 0.4V	-10		10	$\mu A$

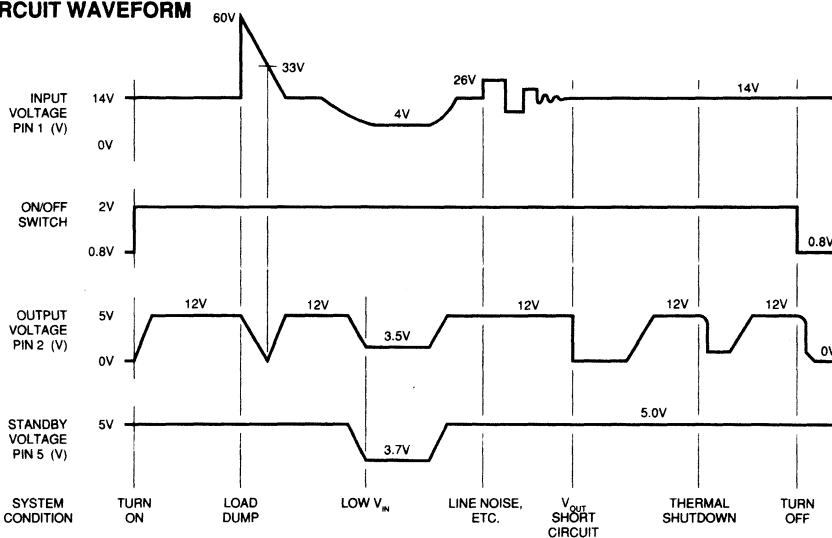


**ELECTRICAL SPECIFICATIONS** (continued)

Parameter	Test Conditions	SG29125/125A			Units
		Min.	Typ.	Max.	
<b>Standby Output (<math>V_{SB}</math>) Section</b>					
Output Voltage (Note 4)	$6V \leq V_{IN} \leq 26V, I_O \leq 10mA, -40^\circ C \leq T_A \leq 85^\circ C$	4.75	5.0	5.25	V
Tracking	$V_{OUT}$ - Standby Output Voltage		50	200	mV
Line Regulation	$6V \leq V_{IN} \leq 26V$		4	50	mV
Load Regulation	$1mA \leq I_O \leq 10mA$		10	50	mV
Output Impedance	$1mA_{DC}$ and $1mA_{RMS}$ , 100Hz - 10kHz		1		$\Omega$
Quiescent Current	$I_O \leq 10mA, V_{OUT\_OFF}$		1.2	3	mA
Output Noise Voltage	10Hz - 100kHz		300		$\mu V_{RMS}$
Long Term Stability			20		mV/1000hr
Ripple Rejection	$F_O = 120Hz$		66		dB
Dropout Voltage	$I_O \leq 10mA$		0.55	0.7	V
Current Limit		25	70		mA
Maximum Operational Input Voltage	$4.5V \leq V_O \leq 6V$	60	70		V

Note 4. The temperature extremes are guaranteed but not 100% production tested.

**TYPICAL CIRCUIT WAVEFORM**



**APPLICATION NOTES**

The advantages of using a low-dropout regulator such as the SG29125/125A are the need for less "headroom" for full regulation, and the inherent reverse polarity protection provided by the PNP output device. A typical NPN regulator design requires an input to output differential of approximately two volts minimum. This is due to the  $2V_{be} + V_{cesat}$  of the NPN Darlington used in the output, coupled with the voltage drop across the current limit resistor. In contrast, the "PNP Regulator" uses a single series pass transistor with its single  $V_{cesat}$ , thus the lower input to output voltage differential or dropout voltage.

In addition to a low dropout voltage, an important advantage of the SG29125/125A series is low quiescent current in the standby mode. When the high current or primary regulator is shut off, the

regulator enters a micropower mode. Here all but the most essential circuitry to power the standby output is deactivated. This allows the lowest possible quiescent current (typical around 1.2mA), a vital factor when used in a battery powered system.

In some applications the regulator output voltage is used not only as a power supply but also as a voltage reference for control systems. In such cases not just the temperature stability of the output is important but also the initial accuracy. The SG29125/125A fills this need as the internal bandgap reference is trimmed allowing a typical output voltage tolerance of  $\pm 1\%$ .

## APPLICATION HINTS

### EXTERNAL CAPACITORS

To stabilize the outputs and prevent oscillation (perhaps by many volts) external capacitors are required. The minimum recommended value for the output capacitors is 10 $\mu$ F, although the actual size and type will likely vary according to the particular application, e.g., operating temperature range and load. Another consideration is the effective series resistance (ESR) of the capacitor. Capacitor ESR will vary by manufacturer. Consequently, some evaluation may be required to determine the minimum value of the output capacitors. Generally worst case occurs at the maximum load and minimum ambient temperature.

The size of the output capacitor can be increased to any value above the minimum. One possible advantage of this would be to maintain the output voltage during brief periods of negative input transients

The output capacitors chosen should be rated for the full range of ambient temperature over which the circuit will be exposed and expected to operate. For example, many aluminum type electrolytic capacitors will freeze at -30 $^{\circ}$ C. The effective capacitance is reduced to zero in such a situation. Capacitors rated for -40 $^{\circ}$ C operation must be used in order to maintain regulator stability at that temperature. Tantalum capacitors satisfy this requirement.

### STANDBY OUTPUT

The SG29125/125A differs from most fixed voltage regulators in that it is equipped with two regulator outputs instead of one. The additional output is intended for use in systems requiring standby memory circuits. While the high current regulator output can be controlled with the ON/OFF pin described below, the standby remains on under all conditions as long as sufficient input voltage is applied to the IC. Thus, memory and other circuits powered by this output remain unaffected by positive line transients, thermal shutdown, etc.

The standby regulator circuit is designed so that the quiescent current to the IC is very low (<1.5mA) when the other regulator output is off.

If the standby output is not required it can be disabled. This is accomplished by connecting a resistor from the standby output to the supply voltage, thereby also eliminating the requirement for a more expensive output capacitor to prevent unwanted oscillations. The resistor value depends upon the minimum input voltage expected for a given system.

Since the standby output is shunted with an internal 5.6V zener, the current through the external resistor should be sufficient to bias internal resistors up to this point. Approximately 60 $\mu$ F will suffice, resulting in a 10k external resistor for most applications (Figure 1).

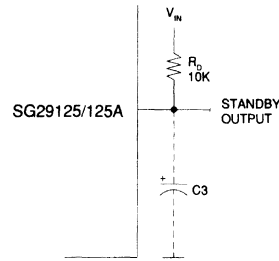


FIGURE 1. Disabling Standby Output to Eliminate C3

### HIGH CURRENT OUTPUT

The high current regulated output features fault protection against overvoltage as well as a thermal shutdown feature. If the input voltage rises above 33V (load dump), the high current output shuts down automatically. The internal circuitry is thus protected and the IC is able to survive higher voltage transients than might otherwise be expected. The thermal shutdown of the high current output effectively guards against overheating of the die since this section of the IC is the principle source of power dissipation on the chip.

### ON/OFF SWITCH

The ON/OFF pin is a high impedance low current switch that controls the main output voltage (pin 2). This is directly compatible with all 5 volt logic families. For use with open collector logic outputs, a 100k resistor from this pin to a 5V supply, such as Pin 5, is required.

## CONNECTION DIAGRAM & ORDERING INFORMATION (See Note Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
5-PIN TO-220 PLASTIC P - PACKAGE	SG29125P SG29125AP	-40 $^{\circ}$ C to 85 $^{\circ}$ C -40 $^{\circ}$ C to 85 $^{\circ}$ C	

Note: 1. All parts are viewed from the top.

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## SELECTION GUIDE OTHER LINEAR CIRCUITS

LINEAR INTEGRATED CIRCUITS

Device Type	Description	Typical Application	Key Features	Pkgs.
SG103/203/303	Voltage Reference	<ul style="list-style-type: none"> <li>Power supplies</li> <li>Signal conditioners</li> <li>Communications</li> </ul>	<ul style="list-style-type: none"> <li>±10% initial tolerance (for tighter tolerance contact factory)</li> <li>Bandgap design</li> <li>Low dynamic impedance from 10μA to 10mA (improved over LM103)</li> <li>-1mV/°C temperature coefficient</li> <li>Output voltages: 1.8V, 2.0V, 2.2V, 2.4V, 2.7V, 3.0V, 3.3V, 3.6V, 3.9V, 4.3V, 4.7V, 5.1V, 5.6V</li> <li>Two terminal device</li> </ul>	Z
SG1503/2503/3503	2.5V Precision Voltage Reference	<ul style="list-style-type: none"> <li>Power supplies</li> <li>Signal conditioners</li> <li>Communications</li> </ul>	<ul style="list-style-type: none"> <li>Bandgap design</li> <li>Output voltage trimmed to ±1%</li> <li>Input voltage range of 4.5V to 40V</li> <li>Temperature coefficient of 10ppm/°C</li> <li>Output current in excess of 10mA</li> <li>Interchangeable with MC1503 and AD580</li> </ul>	Y, T, M
SG040	Dual Video Amplifier	<ul style="list-style-type: none"> <li>Tape drives</li> <li>Low level audio stage</li> </ul>	<ul style="list-style-type: none"> <li>Two selectable independent channels</li> <li>Wide bandwidth (20MHz) and low noise (5nV/√Hz)</li> <li>Input stages each with variable gain adjustment</li> <li>No frequency compensation required</li> <li>Internal bias supply provided to user</li> <li>TTL compatible channel select</li> <li>Replaces TL040</li> <li>Available in SOIC and DIP packages</li> </ul>	J, N, D
SG1401/2401/3401	High Frequency Video Amplifier	<ul style="list-style-type: none"> <li>IF and RF amplifiers</li> <li>Symmetrical non-saturating limiters</li> <li>Oscillators</li> <li>Automatic Gain Control</li> <li>Pulse and video amplification</li> <li>Low-level audio stages</li> </ul>	<ul style="list-style-type: none"> <li>20dB voltage gain at 100MHz</li> <li>5ns rise and fall times</li> <li>Fixed or variable gain</li> <li>Single power supply voltage</li> <li>Minimum external components</li> <li>Symmetrical limiting</li> </ul>	T, J
SG1402	Wideband Amplifier/Multiplier	<ul style="list-style-type: none"> <li>High frequency amplifiers</li> <li>Modulators</li> <li>Automatic gain control</li> </ul>	<ul style="list-style-type: none"> <li>Single power supply voltage</li> <li>Self-contained biasing</li> <li>25dB voltage gain</li> <li>Differential or single ended inputs and outputs</li> <li>Large bandwidth</li> <li>Low power dissipation</li> </ul>	T, J
SG1595/1495	4 - Quadrant Multiplier	<ul style="list-style-type: none"> <li>Multipliers</li> <li>Dividers</li> <li>Square root functions</li> <li>Phase detectors</li> <li>Frequency doublers</li> </ul>	<ul style="list-style-type: none"> <li>Excellent linearity</li> <li>Adjustable scale factor</li> <li>Excellent temperature stability</li> <li>Wide bandwidth</li> <li>High input voltage range</li> <li>Wide supply voltage operation</li> </ul>	J
SG1596/1496	Balanced Modulator/Demodulator	<ul style="list-style-type: none"> <li>AM, SSB, DSB, FSK, and FM modulation or demodulation</li> <li>Phase detection</li> <li>Linear mixing and choppings</li> </ul>	<ul style="list-style-type: none"> <li>Excellent carrier suppression</li> <li>Fully balanced inputs and outputs</li> <li>Low Offsets and Drift</li> <li>High common mode rejection</li> <li>Adjustable gain and signal handling</li> <li>Useful to 100MHz</li> </ul>	J, T, F

November 1988



LINEAR INTEGRATED CIRCUITS

## SELECTION GUIDE OTHER LINEAR CIRCUITS

### TRANSISTOR ARRAYS

Device Type	Description	Typical Application	Key Features	Pkgs.
SG3049	Dual High-Frequency Differential Amplifiers	<ul style="list-style-type: none"> <li>VHF amplifiers</li> <li>VHF mixers</li> <li>IF amplifiers</li> <li>Balanced quadrature detectors</li> <li>Sense amplifiers</li> </ul>	<ul style="list-style-type: none"> <li>Two differential amplifiers on a common substrate</li> <li>Independently accessible inputs and outputs</li> <li>Full military temperature range capability</li> </ul>	J
SG3045/3046/3821	Transistor Arrays	<ul style="list-style-type: none"> <li>High Frequency Amplifiers</li> <li>Comparators</li> <li>Relay drivers</li> <li>Lamp drivers</li> </ul>	<ul style="list-style-type: none"> <li>Two NPN matched transistor pairs to <math>\pm 0.5\text{mV } V_{BE}</math></li> <li>3 uncommitted matched NPN transistors</li> <li>Operation from DC to 300MHz</li> <li>High current gain</li> <li>High voltage capabilities (3821/3045)</li> </ul>	J, N
SG3183/3183A	Transistor Arrays	<ul style="list-style-type: none"> <li>High Frequency Amplifiers</li> <li>Comparators</li> <li>Relay drivers</li> <li>Lamp drivers</li> </ul>	<ul style="list-style-type: none"> <li>Five closely matched NPN transistors</li> <li>50V <math>V_{CE}</math> voltage (3183A)</li> <li>Collector current to 100mA</li> <li>Low saturation voltage</li> </ul>	J, N



**TWO CHANNEL SELECTABLE VIDEO AMPLIFIER**

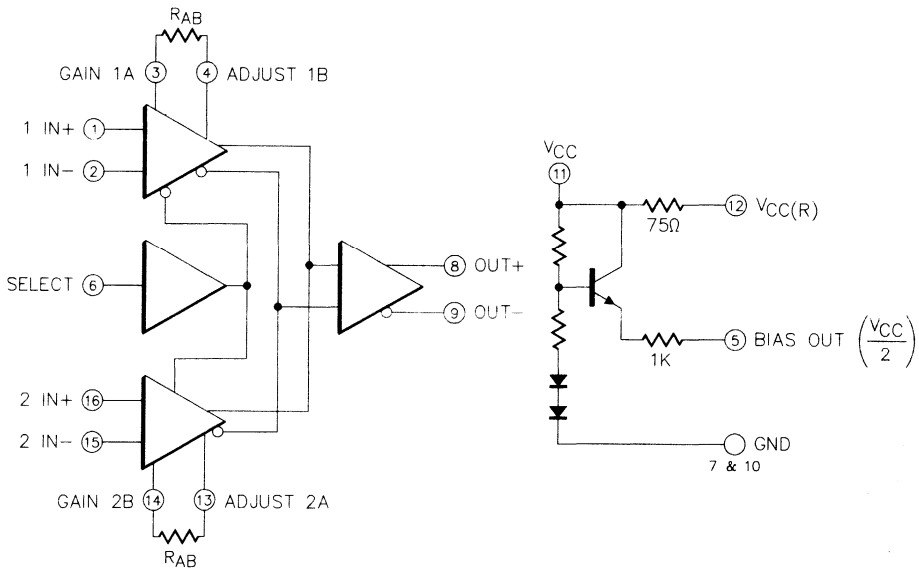
**DESCRIPTION**

The SG040 is a two-channel selectable video amplifier intended for use as a pre-amplifier in the read chain of streaming tape drives. It offers two selectable, wide bandwidth (20MHz), low noise (5nV/√Hz) differential input/differential output pre-stages. Each pre-stage offers variable gain adjustment through the use of an external resistor or potentiometer. Channel multiplexing occurs based on a logic "1" or "0" to the SELECT input pin. Special care has been taken to provide sufficient channel separation between the two input stages. The SG040 typically dissipates less than 150mW and offers a bias supply for the center tapped magnetic read heads. The SG040 is available in a 16-pin DIP or a 16-pin SOIC package.

**FEATURES**

- Wide bandwidth (20MHz) and low noise (5nV/√Hz)
- Input stages each with variable gain adjustment
- No frequency compensation required
- Internal bias supply provided to user
- TTL compatible channel select
- Replaces TL040
- Available in SOIC and DIP packages

**BLOCK DIAGRAM**



**CHANNEL SELECT TABLE**

SELECT	CHANNEL
0	1
1	2

**ABSOLUTE MAXIMUM RATINGS** (Notes 1 & 2)

Supply Voltage ( $V_{CC}$ ) ..... 14V  
 Differential Input Voltage .....  $\pm 5V$   
 Input Voltage Range .....  $-0.2V$  to  $V_{CC} + 0.2V$

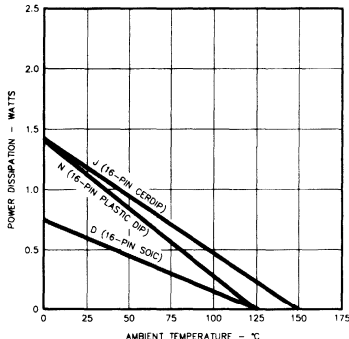
Storage Temperature .....  $-65^{\circ}C$  to  $150^{\circ}C$   
 Operating Junction Temperature  
 Hermetic (J - Package) .....  $175^{\circ}C$   
 Plastic (D, N-Package) .....  $150^{\circ}C$

Note 1. Values beyond which damage may occur.

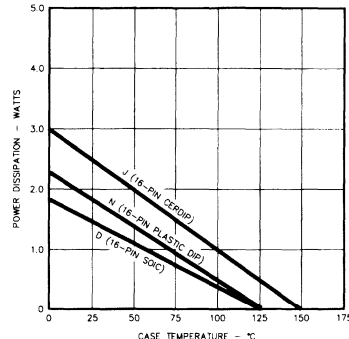
Note 2. All voltages are with respect to Pin 7. All currents are positive into the specified terminal.

**RECOMMENDED OPERATING CONDITIONS** (Note 3)

**THERMAL**



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

**ELECTRICAL**

Supply Voltage ..... 5.0V to 13.2V  
 Common Mode Input Voltage ..... 5V to 7V  
 Differential Output Sink Current .....  $\pm 1.5$  mA

Operating Ambient Temperature Range:  
 SG040 .....  $0^{\circ}C$  to  $70^{\circ}C$

Note 3. Range over which the device is functional.

**ELECTRICAL SPECIFICATIONS**

(Unless otherwise stated, these specifications apply for  $10.8V \leq V_{CC} \leq 13.2V$ ;  $T_A = 25^{\circ}C$ ;  $R_{AB} = 0\Omega$ ;  $R_L = 2K$ . Pins 3 & 4 and Pins 13 & 14 are shorted together.)

Parameter	Test Conditions	SG040			Units
		Min.	Typ.	Max.	
Supply Current	$V_{CC} = 13.2V$ , $V_{CM} = 6V$		8	12	mA
Logic 1 Input Voltage	SELECT (Pin 6)	2.0			V
Logic 0 Input Voltage	SELECT (Pin 6)			0.8	V
High Input Current	$V_{SELECT} = 2.7V$	-0.4			mA
Low Input Current	$V_{SELECT} = 0.4V$			20	$\mu A$
Bias Voltage	$V_{CC} = 12V$ , $I_{BIAS} = 100\mu A$	5		7	V
Differential Voltage Gain	$\Delta V_{OUT} = 3V$	300		600	V/V
Bandwidth (Note 4)	At -3dB	15	20		MHz
Propagation Delay	$\Delta V_{OUT} = 1V$		30		ns
Rise Time	$\Delta V_{OUT} = 1V$		25		ns
Large Signal Differential Voltage Attenuation	$\Delta V_{INPUT} = 50mV$ on unselected input	50			dB
Voltage Swing		3	5		V
Common-Mode Output Voltage	Output open	7	8	9	V
Differential Output Voltage	$V_{ID} = 0V$ , Output open			.75	V
Input Bias Current				17	$\mu A$
Input Offset Current				3	$\mu A$
Common Mode Rejection Ratio	$V_{CM} = 5V$ to $7V$	75	100		dB
Power Supply Rejection Ratio	$V_{CC} = 10.8V$ to $13.2V$	50	80		dB
Input Noise Voltage			5		nV/ $\sqrt{Hz}$
Input Resistance (Note 4)		3			K $\Omega$
Channel Separation		50	60		dB

Note 4. These parameters, although guaranteed, are not tested in production.



CHARACTERISTIC CURVES

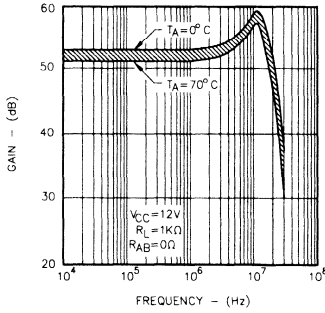


FIGURE 1. GAIN VS. FREQUENCY AS A FUNCTION OF TEMPERATURE

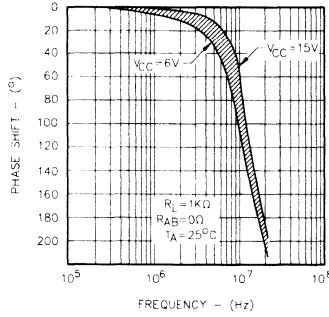


FIGURE 2. PHASE VS. FREQUENCY AS A FUNCTION OF SUPPLY VOLTAGE

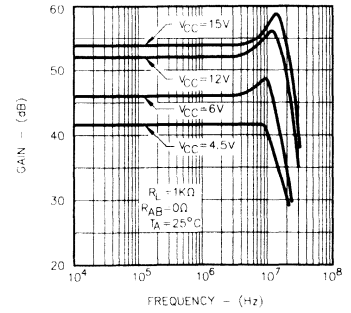


FIGURE 3. GAIN VS. FREQUENCY AS A FUNCTION OF SUPPLY VOLTAGE

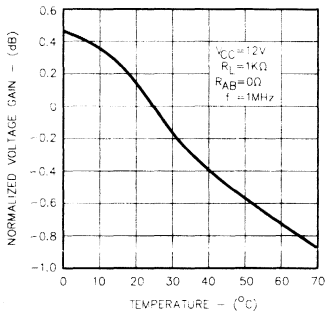


FIGURE 4. VOLTAGE GAIN VS. TEMPERATURE

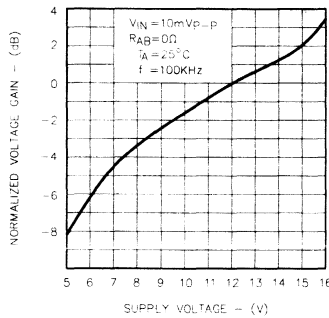


FIGURE 5. VOLTAGE GAIN VS. SUPPLY VOLTAGE

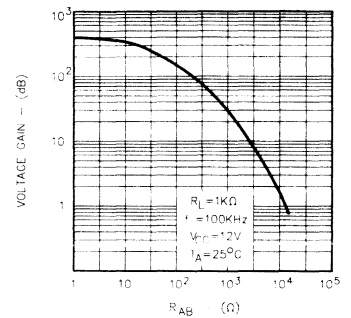


FIGURE 6. VOLTAGE GAIN VS.  $R_{AB}$

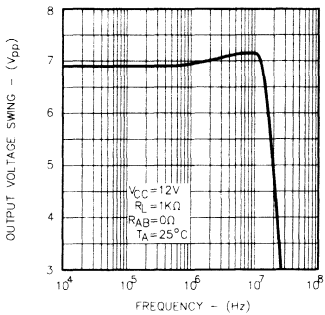


FIGURE 7. OUTPUT VOLTAGE SWING VS. FREQUENCY

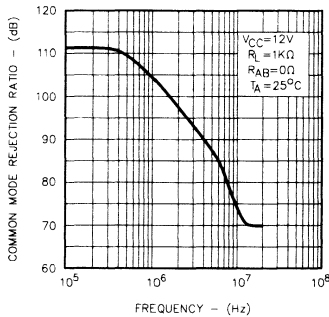


FIGURE 8. COMMON MODE REJECTION RATIO VS. FREQUENCY

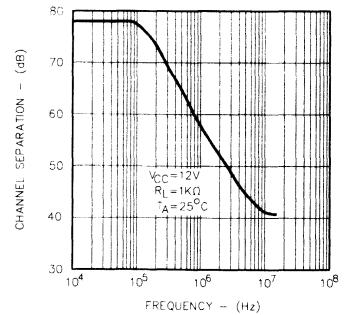


FIGURE 9. CHANNEL SEPARATION VS. FREQUENCY

**CHARACTERISTIC CURVES** (continued)

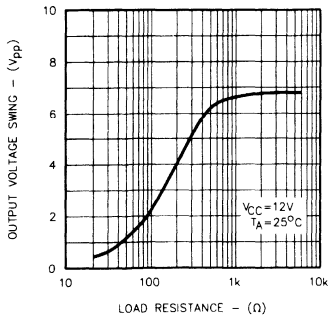


FIGURE 10. OUTPUT VOLTAGE SWING VS. LOAD RESISTANCE

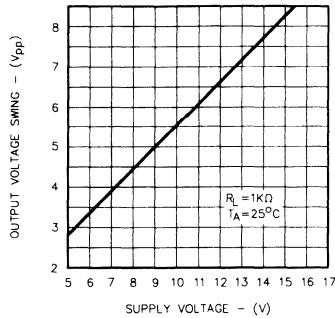


FIGURE 11. OUTPUT VOLTAGE SWING VS. SUPPLY VOLTAGE

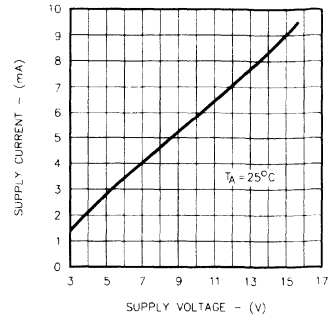


FIGURE 12. SUPPLY CURRENT VS. SUPPLY VOLTAGE

**CONNECTION DIAGRAMS & ORDERING INFORMATION** (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
16-PIN CERAMIC DIP J - PACKAGE	SG040J	0°C to 70°C	
16-PIN PLASTIC DIP N - PACKAGE	SG040N	0°C to 70°C	
16-PIN NARROW BODY PLASTIC S.O.I.C. D - PACKAGE	SG040D	0°C to 70°C	

Note 1. Contact factory for JAN and DESC product availability.  
 Note 2. All packages are viewed from the top.

**VOLTAGE REFERENCES**

**DESCRIPTION**

The SG103 is a two-terminal integrated circuit designed for analog and/or digital applications requiring precision voltage reference. The SG103 is an improved version of the National LM103 voltage reference. The design uses the band-gap voltage of the silicon as an internal reference for a tightly regulated output voltage. The advantages of this method over single junction zener diodes are: lower turn on drift, better temperature coefficient, sharper breakdown characteristics (line regulation) and lower dynamic impedance (load regulation). The I.C. is available in thirteen different voltages ranging from 1.8V to 5.6V (See Table 1). The SG103 is packaged in a hermetically sealed, modified TO-46 header and is specified for operation over the full military ambient temperature range of -55° C to +125° C.

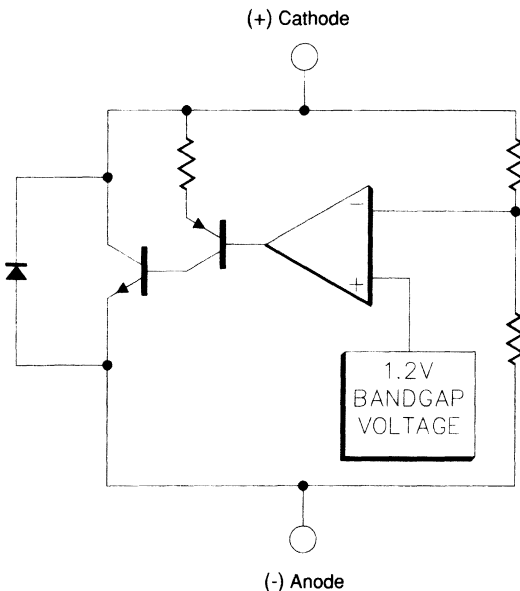
**FEATURES**

- Precision band gap design
- Exceptionally sharp breakdown
- Low dynamic impedance from 10 $\mu$ A to 10mA (improved over LM103)
- Improved temperature coefficient
- Low capacitance
- Performance guaranteed over full military temperature range

**HIGH RELIABILITY FEATURES -SG103**

- ♦ Available to MIL-STD - 883 and DESC SMD
- ♦ SG level "S" processing available

**BLOCK DIAGRAM**



**REFERENCE VOLTAGES**

**TABLE 1**

Measured at  $I_R = 1\text{mA}$

- SG103 - 1.8\*
- SG103 - 2.0
- SG103 - 2.2
- SG103 - 2.4
- SG103 - 2.7\*
- SG103 - 3.0
- SG103 - 3.3
- SG103 - 3.6
- SG103 - 3.9
- SG103 - 4.3
- SG103 - 4.7\*
- SG103 - 5.1
- SG103 - 5.6

\* These are the voltages that are currently available. Contact factory for product availability for additional voltages.

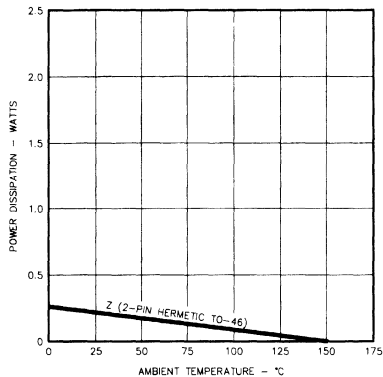
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Reference Current ..... 20mA	Operating Junction Temperature ..... 175°C
Forward Current ..... 100mA	Storage Temperature Range ..... -65°C to +150°C
	Lead Temperature (Soldering, 10 Seconds) ..... 300°C

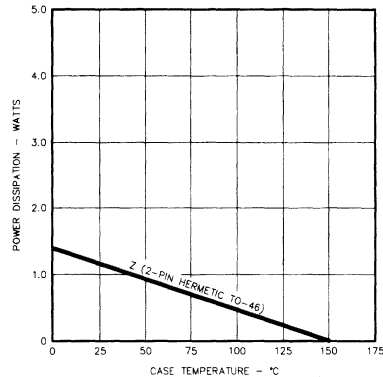
Note 1. Exceeding these ratings could cause damage to the device. All voltages are with respect to ground. All currents are positive into the specified terminal.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Reference Current ..... <10mA	Operating Ambient Temperature Range
Forward Current ..... <30mA	SG103 ..... -55°C to 125°C
	SG203 ..... -25°C to 85°C
	SG303 ..... 0°C to 70°C

Note 2. Range over which the device is functional

## SPECIFICATIONS

Typical specifications apply for  $T_A = 25^\circ\text{C}$  and  $1.8\text{V} < V_Z < 5.6\text{V}$  unless stated otherwise. The diode should not be operated with shunt capacitances between 100 pF and 0.01  $\mu\text{F}$ , unless isolated by at least a 300 $\Omega$  resistor, as it may oscillate at some currents. For voltages between 4.3V and 5.6V, the maximum shunt capacitance is 50pF rather than 100pF.)

Parameter	Test Conditions	SG103/203/303			Units
		Min.	Typ.	Max.	
Reference Voltage Change	$10\mu\text{A} \leq I_R \leq 100\mu\text{A}$		60	120	mV
	$100\mu\text{A} \leq I_R \leq 1\text{mA}$		15	50	mV
	$1\text{mA} \leq I_R \leq 10\text{mA}$		50	150	mV
Reverse Dynamic Impedance (Note 3)	$I_R = 3\text{mA}$		5	25	$\Omega$
	$I_R = 0.3\text{mA}$		15	60	$\Omega$
Reverse Leakage Current	$V_R = V_Z - 0.2\text{V}$		2	5	$\mu\text{A}$
Forward Voltage Drop	$I_F = 10\text{mA}$	0.7	0.8	1.0	V
Peak-to-Peak Broadband Noise Voltage	$10\text{Hz} \leq f \leq 100\text{kHz}, I_R = 1\text{mA}$		300		$\mu\text{V}$
Reference Voltage Change with Current (Note 4)	$10\mu\text{A} \leq I_R \leq 100\mu\text{A}$			200	mV
	$100\mu\text{A} \leq I_R \leq 1\text{mA}$			60	mV
	$1\text{mA} \leq I_R \leq 10\text{mA}$			200	mV
Reference Voltage Temperature Coefficient (Note 4)	$100\mu\text{A} \leq I_R \leq 1\text{mA}$		-1.0		mV/°C

Note 3. Measured with the peak-to-peak change of reverse current equal to 10% of the DC reverse current.

Note 4. These specifications apply for  $-55^\circ\text{C} < T_A < +125^\circ\text{C}$ .

CHARACTERISTIC CURVES

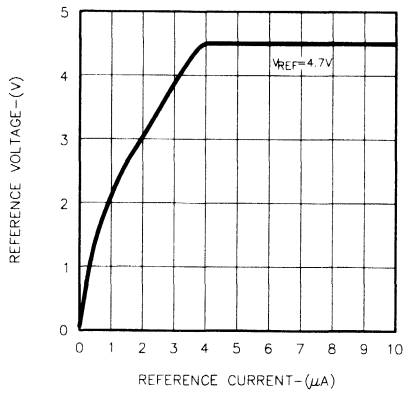


FIGURE 1. REFERENCE VOLTAGE VS. CURRENT

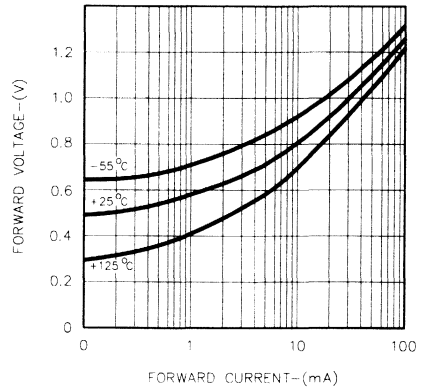


FIGURE 2. FORWARD DIODE CHARACTERISTICS

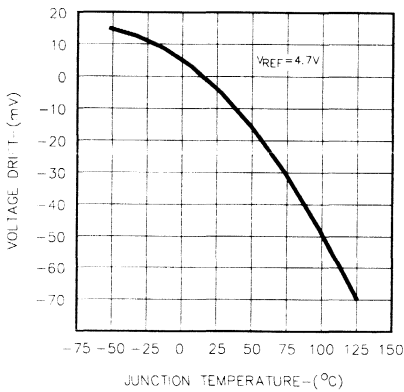


FIGURE 3. TEMPERATURE DRIFT

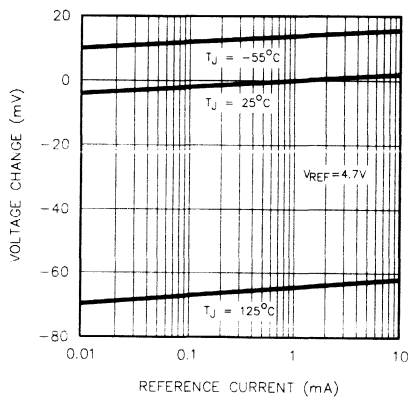
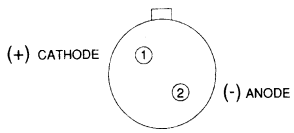


FIGURE 4. REFERENCE VOLTAGE CHANGE VS. CURRENT

# SG103/SG203/SG303

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.                      Ambient Temperature Range	Connection Diagram
2-PIN TO-46 METAL CAN Z - PACKAGE	SG103-x.xZ/883B   -55°C to 125°C SG103-x.xZ        -55°C to 125°C SG203-x.xZ        -25°C to 85°C SG303-x.xZ        0°C to 70°C  x.x = See first page of data sheet for reference voltages available.	

- Note 1. Contact factory for JAN and DESC product availability.  
 Note 2. All packages are viewed from the top.

**HIGH FREQUENCY VIDEO AMPLIFIER**

**DESCRIPTION**

A monolithic integrated voltage amplifier useful over a frequency range from DC to 200 MHz. Internal emitter followers are used to achieve high input and low output impedances, allowing simple capacitor coupling. Biasing and gain-setting resistors are internally diffused, eliminating external resistor networks. The gain may be externally varied through the use of AGC diodes which are included in the circuit.

The SG1401 will operate over the full military temperature range of -55°C to 125°C while the SG2401 and SG3401 are designed for 0°C to 70°C applications.

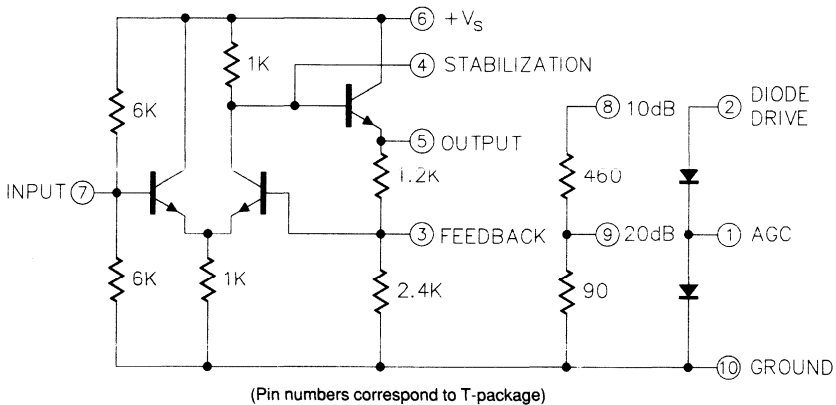
**FEATURES**

- 20dB voltage gain at 100MHz
- 5ns rise and fall times
- Fixed or variable gain
- Single power supply voltage
- Minimum external components
- Symmetrical limiting

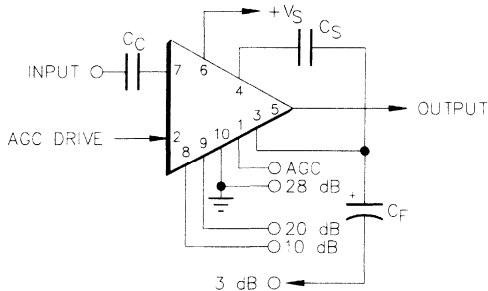
**HIGH RELIABILITY FEATURES  
-SG1401**

- ♦ Available to MIL-STD-883
- ♦ SG level "S" processing available

**SCHEMATIC DIAGRAM**



**BLOCK DIAGRAM**



(Pin numbers correspond to T-package)

$$C_f = \frac{1}{2\pi f_c R}$$

where  $f_c$  is Low Frequency corner and R is the Gain setting.

$C_s = 0$  to 10pF to minimize high frequency peaking.

# SG1401/SG2401/SG3401

## ABSOLUTE MAXIMUM RATINGS (Note 1)

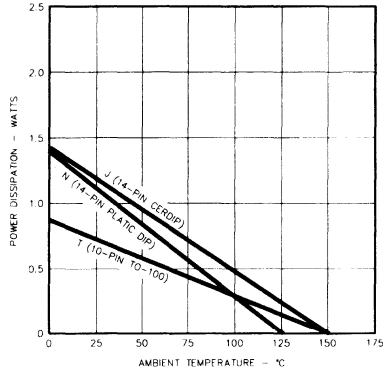
Supply Voltage ..... 20V  
 AGC Diode Current ..... 5mA  
 Lead Temperature (Soldering, 10 Seconds) ..... 300°C

Operating Junction Temperature  
 Hermetic (J, T-Packages)..... 175°C  
 Plastic (N-Packages) ..... 150°C  
 Storage Temperature Range ..... -65°C to 150°C

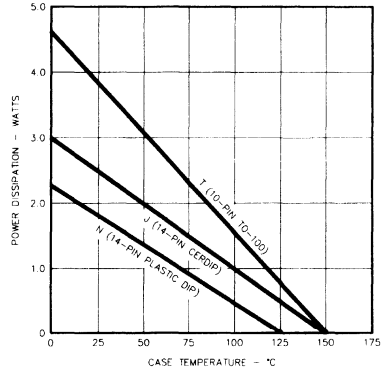
Note 1. Exceeding these ratings could cause damage to the device.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Supply Voltage ..... 8V to 18V

Operation Junction Temperature Range

SG1401 ..... -55°C to 125°C  
 SG2401/SG3401 ..... 0°C to 70°C

Note 2. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise specified, these specifications apply for  $T_A = 25^\circ\text{C}$ ,  $V_S = +12\text{V}$ ,  $f = 1\text{MHz}$ .)

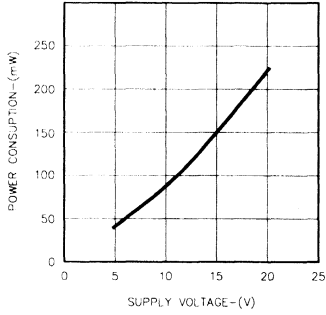
Parameter	Test Conditions	SG1401/SG2401			SG3401			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Supply Voltage		6	12	20	6	12	20	V
Power Consumption	No AGC Voltage		90	110		90	120	mW
DC Output Voltage			8.7			8.7		V
Peak-to-Peak Output Voltage	Pin 3(4) to AC Ground (Note 3)		4			3		V
Voltage Gain	Pin 3(4) open (Note 3)	2.2	2.7	3.2	2.2	2.7	3.2	dB
	Pin 3(4) coupled to pin 8(11) (Note 3)	9	10	11	9	10	11	dB
	Pin 3(4) coupled to pin 9(12) (Note 3)	18	20	21	18	20	21	dB
	Pin 3(4) to AC Ground (Note 3)	26	28	31	24	26	31	dB
Unity Gain Frequency	Pin 3(4) to AC Ground (Note 3)		200			200		MHz
Input Resistance	20dB Gain		2.5			2.5		K $\Omega$
Output Resistance	20dB Gain		25			50		$\Omega$
Input Capacitance	20dB Gain		5			5		pF
Maximum Power Gain	20dB Gain, $R_L = 50\Omega$		30			30		dB
Temperature Stability (Note 4)	20dB Gain, $T_A = T_{MIN}$ to $T_{MAX}$		$\pm 0.5$	$\pm 1$		$\pm 1$	$\pm 2$	dB
AGC Range	20dB Gain, $R_S = 1K$		20	22		22		dB
Noise Figure			6	8		6		dB

Note 3. Numbers in parenthesis refer to dual-in-line package.

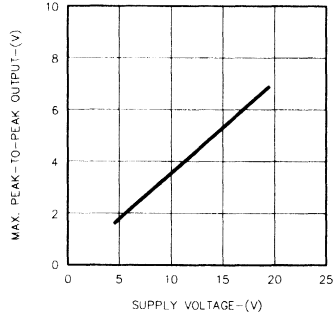
Note 4. These parameters, although guaranteed, are not tested in production.



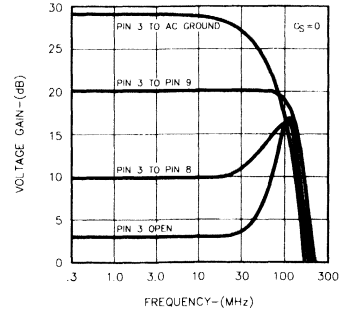
**CHARACTERISTIC CURVES** (Pin Numbers correspond to T - Package)



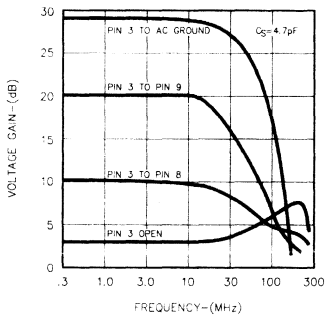
**FIGURE 1.**  
POWER CONSUMPTION VS. SUPPLY VOLTAGE



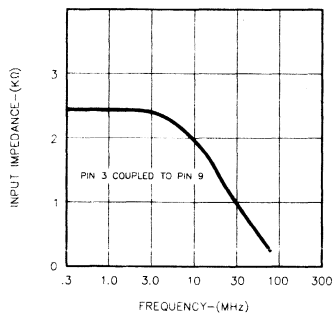
**FIGURE 2.**  
MAXIMUM OUTPUT VS. SUPPLY VOLTAGE



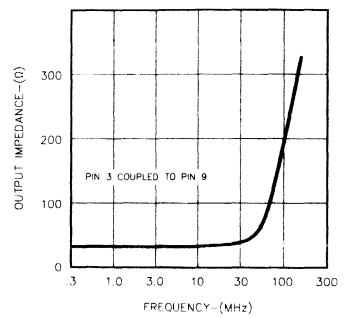
**FIGURE 3.**  
FREQUENCY RESPONSE



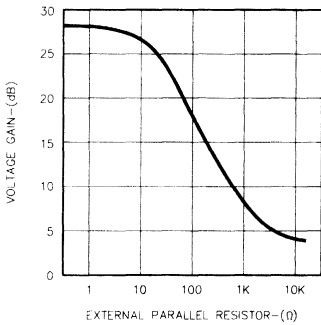
**FIGURE 4.**  
STABILIZED FREQUENCY RESPONSE



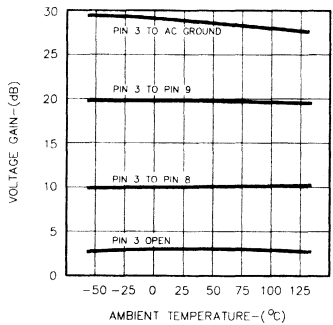
**FIGURE 5.**  
INPUT IMPEDANCE VS. FREQUENCY



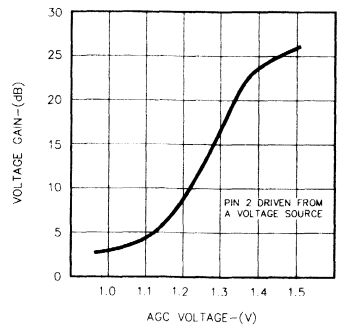
**FIGURE 6.**  
OUTPUT IMPEDANCE VS. FREQUENCY



**FIGURE 7.**  
EXTERNAL GAIN CONTROL



**FIGURE 8.**  
TEMPERATURE STABILITY



**FIGURE 9.**  
GAIN VS. AGC DIODE VOLTAGE

**CHARACTERISTIC CURVES** (continued)

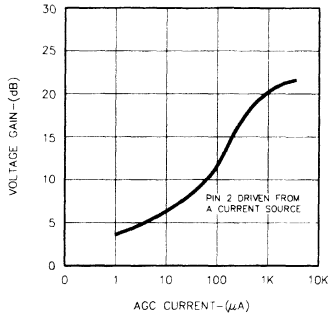


FIGURE 10. GAIN VS. AGC DIODE CURRENT

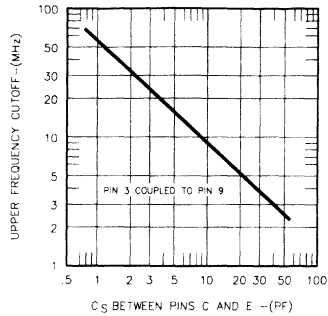


FIGURE 11. UPPER CUTOFF FREQUENCY VS. Q VALUE

**APPLICATION INFORMATION**

The SG1401 series has been designed to provide maximum versatility as a general-purpose, single-ended amplifier. With its broad frequency capability, this circuit will be useful in a wide range of applications provided that the usual considerations for high frequency circuit designs are observed. The following information is presented toward aiding in the optimization of the many possible configurations of this device.

**FIXED GAIN**

In the circuit configurations shown in Figure 12, the overall voltage gain is approximated by resistors R<sub>1</sub> and the parallel combination of R<sub>2</sub> and R<sub>3</sub>, as

$$A_v \approx 1 + \frac{R_1}{R} \text{ where } R = \frac{R_2 R_3}{R_2 + R_3}$$

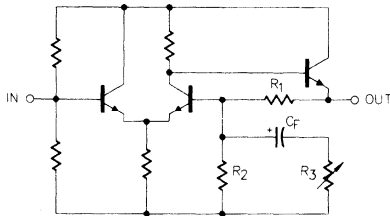


FIGURE 12

With no external connections, the voltage gain is determined solely by R<sub>1</sub> and R<sub>2</sub> and is 1½ or 3 dB. Decreasing the effective value of R<sub>2</sub> by capacitively coupling a lower resistor in parallel, raises the gain. Four fixed gain settings are provided internal to the circuit; however, any other setting within the maximum gain of the amplifier is possible with external resistors as shown in Figure 7.

The value of the coupling capacitor, C<sub>f</sub> is determined by the low frequency response desired, as its capacitive reactance will add to the value of the resistance it couples. Therefore, the lower cutoff frequency will be

$$f_c \approx 2 \frac{1}{R_3 C_f}$$

Utilizing the internal 90 or 460 ohm resistors for higher gain settings provides the added advantage of maximum temperature stability since the close tracking of adjacent diffused resistors keeps their ratio constant. Typical temperature variation of this circuit is shown in Figure 8.

**VARIABLE GAIN**

Since the dynamic impedance of a forward-biased diode is inversely proportional to the current through it, a convenient gain control can be achieved by using a pair of diodes as a variable impedance. In the circuit of Figure 13, R<sub>3</sub> has been replaced by two diodes whose impedances act in parallel due to the decoupling of C<sub>D</sub>. If the diodes are driven from a voltage source, a logarithmic relationship between gain and control signal is achieved (see Figure 9); while if a current source is used, the relationship is linear as shown in Figure 10.

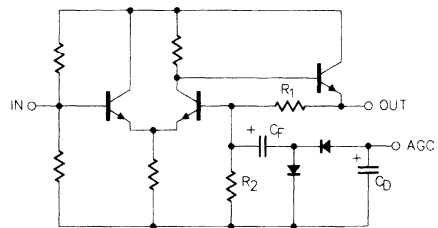


FIGURE 13

There are two limitations on this form of gain control. First, the diodes' capacitance limits their effectiveness to frequencies below 20MHz and, secondly, the signal voltage across the diodes should be held to less than 50 millivolts RMS to minimize self-modulation of amplifier gain. Additionally, the AGC current should be limited to 3mA maximum to keep the diodes out of saturation.

# SG1401/SG2401/SG3401

## APPLICATION INFORMATION (continued)

### HIGH FREQUENCY STABILITY

With the capability of operation at 100MHz, the SG1401 series also has some susceptibility to external stray reactances; however, with reasonable care, complete stability may be assured. Some general precautions which should be considered include the following:

1. Power supply decoupling close to the circuit terminals (a 0.1 $\mu$ F capacitor is usually adequate).
2. Maintain separation of input and output lines.
3. Minimize load capacitance or insert a series resistor (up to 50 $\Omega$ ) in the output.
4. Purposely limit the high frequency response with a stabilizing capacitor  $C_s$  between pins 3 and 4.

Since the gain of this circuit is reduced by increasing the amount of feedback, the potential for instability is greatest when the gain is at its minimum value. This characteristic and the stabilizing effects of a 4.7 picofared capacitor between pins 4 and 3 are illustrated in the frequency response curves presented in Figures 3 & 4. The relationship between the value of  $C_s$  and the upper cutoff frequency of a 20dB gain setting is shown in Figure 11.

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
14-PIN CERAMIC DIP J - PACKAGE	SG1401J/883B SG1401J SG2401J SG3401J	-55°C to 125°C -55°C to 125°C 0°C to 70°C 0°C to 70°C	
14-PIN CERAMIC DIP N - PACKAGE	SG2401N SG3401N	0°C to 70°C 0°C to 70°C	
10-PIN METAL CAN T - PACKAGE	SG1401T/883B SG1401T SG2401T SG3401T	-55°C to 125°C -55°C to 125°C 0°C to 70°C 0°C to 70°C	

- Note 1. Contact factory for JAN and DESC product availability.  
2. All packages are viewed from the top.





LINEAR INTEGRATED CIRCUITS

# SG1402/SG2402/SG3402

## VARIABLE GAIN, WIDEBAND AMPLIFIER / MULTIPLIER

### DESCRIPTION

The SG1402 is a monolithic four quadrant multiplier offering excellent frequency response and provision for use as a variable gain amplifier with both non-inverting and inverting outputs available. In addition to linear amplification, the device is also ideal for balanced modulation, pulse or gated amplification, and coincidence detection.

The SG1402 will operate over the full military temperature range of -55°C to 125°C while the SG2402 and SG3402 are designed for 0°C to 70°C applications.

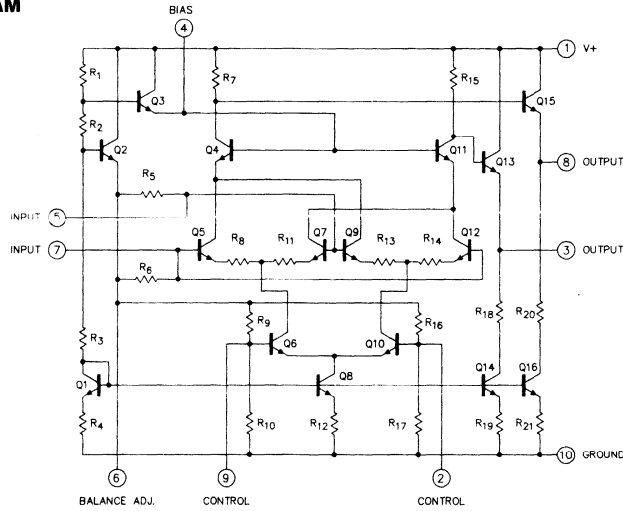
### FEATURES

- Single power supply voltage
- Self-contained biasing
- 25dB voltage gain
- Differential or single ended inputs and outputs
- Large bandwidth
- Low power dissipation

### HIGH RELIABILITY FEATURES -SG1402

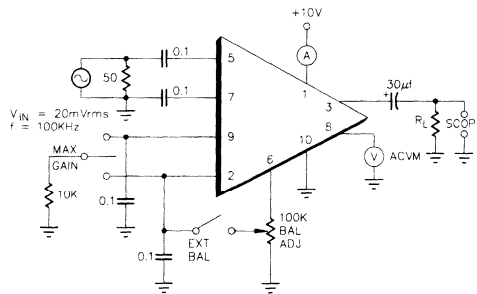
- ◆ Available to MIL-STD-883
- ◆ SG level "S" processing available

### SCHEMATIC DIAGRAM



(Pin numbers correspond to T-package)

### TEST CIRCUIT



(Pin numbers correspond to T-package)

# SG1402/SG2402/SG3402

## ABSOLUTE MAXIMUM RATINGS (Note 1)

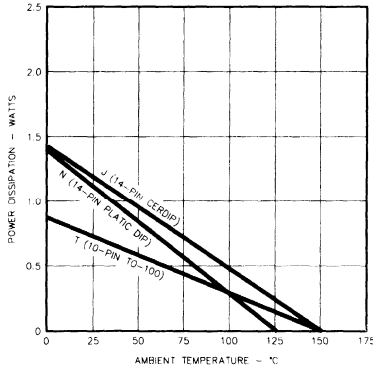
Supply Voltage ..... 18V  
 Load Current ..... 15mA  
 Lead Temperature (Soldering, 10 Seconds) ..... 300°C

Operating Junction Temperature  
 Hermetic (J, T-Packages) ..... 175°C  
 Plastic (N-Packages) ..... 150°C  
 Storage Temperature Range ..... -65°C to 150°C

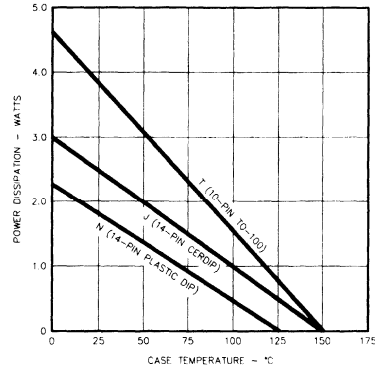
Note 1. Exceeding these ratings could cause damage to the device.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Supply Voltage ..... 16V (Note 3)

Operation Junction Temperature Range

SG1402 ..... -55°C to 125°C  
 SG2402/SG3402 ..... 0°C to 70°C

Note 2. Range over which the device is functional.

Note 3. See Figure 6.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise specified, these specifications apply for  $T_A = 25^\circ\text{C}$ ,  $V_+ = +10\text{V}$ ,  $f = 100\text{MHz}$ .)

Parameter	Test Conditions	SG1402/SG2402			SG3402			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Maximum Voltage Gain	Single ended	23	25		20	25		dB
Variable Gain Range	With external balance	55	60		40	50		dB
Frequency Response	f at 3dB	40	50			50		MHz
Input Impedance			1.2			1.2		K $\Omega$
			1.8			1.8		K $\Omega$
Output Impedance			100			100		$\Omega$
Output Voltage Swing	$R_L = 100\text{K}$	3	4		3	4		V <sub>pp</sub>
	$R_L = 1\text{K}$	1.3	1.6		1.3	1.6		V <sub>pp</sub>
Quiescent DC Levels	Inputs and Balance Adjust		3.6			3.6		V
	Control Inputs		1.8			1.8		V
	Outputs	6.5	7.0	7.5	7.0			V
Output Offset Voltage	Minimum Gain			100			300	mV
	Maximum Gain			200			500	mV
	With max. gain change			100			200	mV
Differential Control Voltage	For max. gain change		200			200		mV
Maximum Gain Variation with temperature			1	2		1	3	dB
	$T_A = T_{\text{MIN}}$ to $T_{\text{MAX}}$							
Equivalent Input Noise	BW = 10MHz, $R_S = 50\Omega$		25			25		$\mu\text{Vrms}$
Power Consumption	$V_+ = 10\text{V}$		65	85		65	85	mW

CHARACTERISTIC CURVES

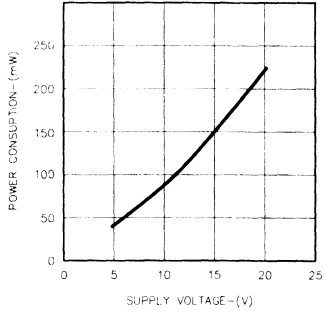


FIGURE 1. MULTIPLIER TRANSFER FUNCTION

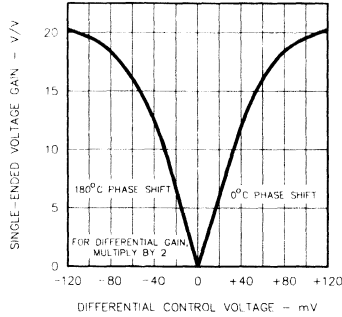


FIGURE 2. SINGLE-ENDED GAIN CONTROL

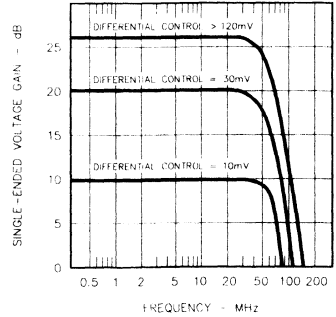


FIGURE 3. FREQUENCY RESPONSE

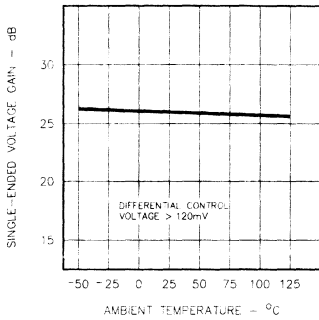


FIGURE 4. MAXIMUM GAIN VS. TEMPERATURE

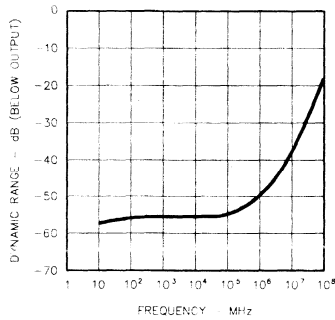


FIGURE 5. DYNAMIC GAIN RANGE

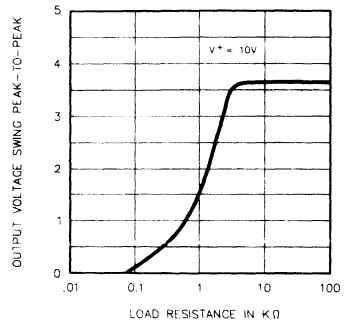


FIGURE 6. MAXIMUM OUTPUT VOLTAGE

TYPICAL APPLICATIONS (Pin Numbers correspond to T - Package)

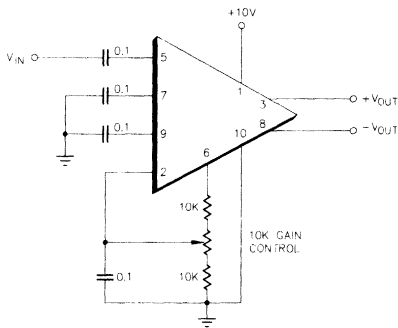


FIGURE 7

Single-ended or differential output variable gain amplifier with manual gain control for output of either phase.

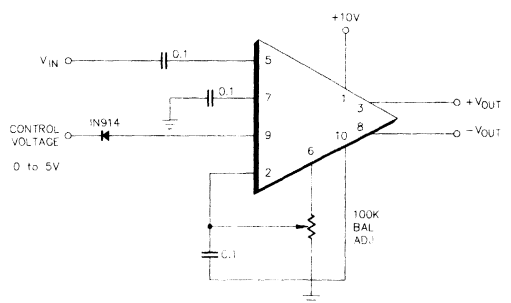


FIGURE 8

Gated amplifier for gain control without phase change. Balance control may be eliminated if maximum attenuation is not needed.

## TYPICAL APPLICATIONS (continued) (Pin Numbers correspond to T - Package)

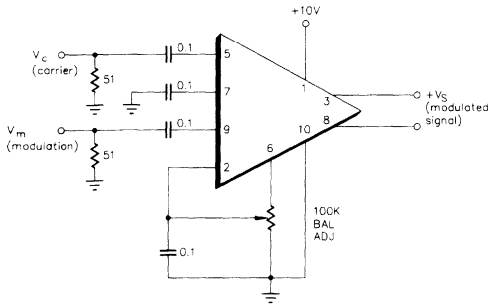


FIGURE 9

Modulator circuit with potentiometer adjustable for either amplitude or balanced modulation.

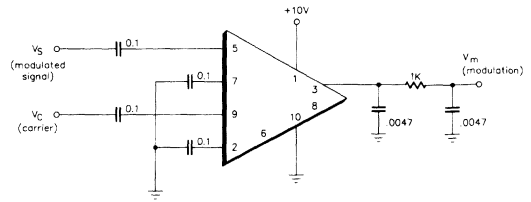


FIGURE 10

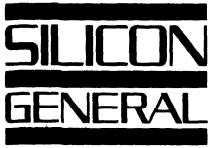
Balanced demodulator with output filter eliminating need for external balance.

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
14-PIN CERAMIC DIP J - PACKAGE	SG1402J/883B	-55°C to 125°C	
	SG1402J	-55°C to 125°C	
	SG2402J	0°C to 70°C	
	SG3402J	0°C to 70°C	
14-PIN CERAMIC DIP N - PACKAGE	SG2402N	0°C to 70°C	
	SG3402N	0°C to 70°C	
10-PIN METAL CAN T - PACKAGE	SG1402T/883B	-55°C to 125°C	
	SG1402T	-55°C to 125°C	
	SG2402T	0°C to 70°C	
	SG3402T	0°C to 70°C	

Note 1. Contact factory for JAN and DESC product availability.  
 Note 2. All packages are viewed from the top.





LINEAR INTEGRATED CIRCUITS

## SG1503/SG2503/SG3503

### PRECISION 2.5-VOLT REFERENCE

#### DESCRIPTION

This monolithic integrated circuit is a fully self-contained precision voltage reference generator, internally trimmed for  $\pm 1\%$  accuracy. Requiring less than 2mA in quiescent current, this device can deliver in excess of 10mA with total load- and line-induced tolerances of less than 0.5%. In addition to voltage accuracy, internal trimming achieves a temperature coefficient of output voltage of typically 10 ppm/ $^{\circ}\text{C}$ . As a result, these references are excellent choices for application to critical instrumentation and D-to-A converter systems.

The SG1503 is specified for operation over the full military ambient temperature range of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ , while the SG2503 is designed for  $-25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$  and the SG3503 for commercial applications of  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .

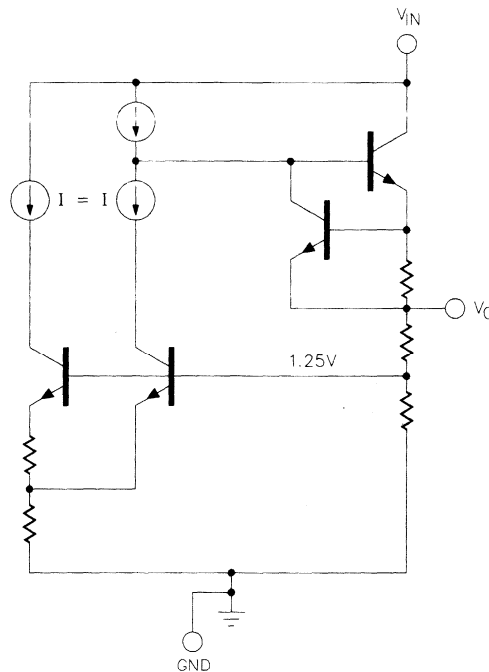
#### FEATURES

- Output voltage trimmed to  $\pm 1\%$
- Input voltage range of 4.5 to 40V
- Temperature coefficient of 10ppm/ $^{\circ}\text{C}$
- Quiescent current typically 1.5mA
- Output current in excess of 10mA
- Interchangeable with MC1503 and AD580

#### HIGH RELIABILITY FEATURES - SG1503

- ◆ Available to MIL-STD-883 and DESC SMD
- ◆ Radiation data available
- ◆ SG level "S" processing available

#### FUNCTIONAL DIAGRAM



## ABSOLUTE MAXIMUM RATINGS (Note 1)

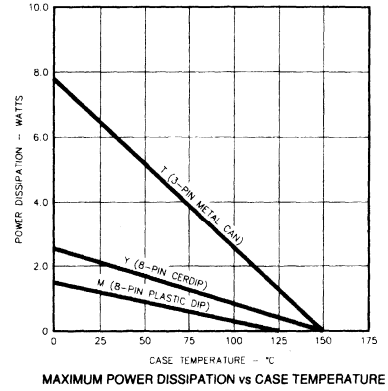
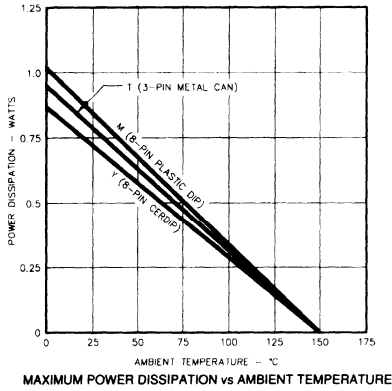
Input Voltage ..... 40V  
 Storage Temperature Range ..... -65°C to 150°C

Operating Junction Temperature  
 Hermetic (J, Y - Package) ..... 175°C  
 Plastic (M-Package) ..... 150°C  
 Lead Temperature (Soldering, 10 Seconds) ..... 300°C

Note 1. Exceeding these ratings could cause damage to the device.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



### ELECTRICAL

Input Voltage ..... 4.5V to 40V

Operating Ambient Temperature Range  
 SG1503 ..... -55°C to 125°C  
 SG2503/SG3503 ..... 0°C to 70°C

Note 2. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise specified, these specifications apply for  $V_{IN} = 15V$ ,  $I_L = 0mA$ , and  $T_A = T_{MIN}$  to  $T_{MAX}$ .)

Parameter	Test Conditions	SG1503/2503			SG3503			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Output Voltage	$T_A = 25^\circ C$	2.485	2.500	2.515	2.475	2.500	2.525	V
Input Voltage		4.7		40	4.7		40	V
Line Regulation	$T_A = 25^\circ C$ $V_{IN} = 5V$ to $15V$		1	3		1	3	mV
	$V_{IN} = 15V$ to $40V$		3	5		3	10	mV
Load Regulation	$\Delta I_L = 10mA$		3	5		3	10	mV
	$\Delta I_L = 10mA$ , $V_{IN} = 30V$		4	8		4	15	mV
Temperature Regulation	(SG1503 only)		15	20				mV
	(SG2503/3503 only)		2.5	5		5	10	mV
Quiescent Current	$V_{IN} = 40V$		1.5	2.0		1.5	2.0	mA
Short Circuit Current	$T_A = 25^\circ C$	15	20	30	15	20	30	mA
Ripple Rejection	$f = 120Hz$ , $T_A = 25^\circ C$		76			76		dB
Output Noise	$BW = 10KHz$ , $T_A = 25^\circ C$		100			100		$\mu V$ rms
Voltage Stability			250			250		$\mu V/Khr$

**CHARACTERISTIC CURVES**

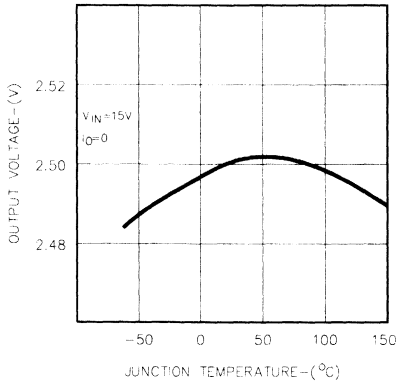


FIGURE 1. OUTPUT VOLTAGE VS. TEMPERATURE

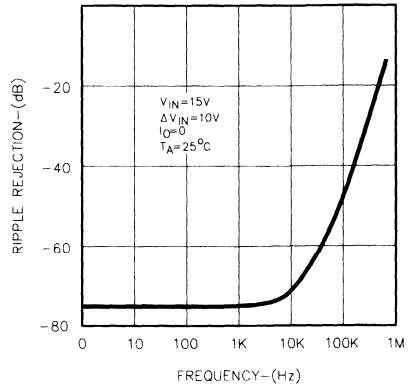


FIGURE 2. RIPPLE REJECTION

**CONNECTION DIAGRAMS & ORDERING INFORMATION** (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
8-PIN CERAMIC DIP Y - PACKAGE	SG1503Y/883B	-55°C to 125°C	
	SG1503Y	-55°C to 125°C	
	SG2503Y	0°C to 70°C	
	SG3503Y	0°C to 70°C	
8-PIN PLASTIC DIP M - PACKAGE	SG2503M	0°C to 70°C	
	SG3503M	0°C to 70°C	
3-PIN TO-39 METAL CAN T - PACKAGE	SG1503T/883B	-55°C to 125°C	
	SG1503T	-55°C to 125°C	
	SG2503T	0°C to 70°C	
	SG3503T	0°C to 70°C	

Note 1. Contact factory for JAN and DESC product availability.  
 Note 2. All packages are viewed from the top.



**FOUR-QUADRANT MULTIPLIER**

**DESCRIPTION**

The SG1595 and SG1495 four-quadrant analog multipliers are designed for applications where the output voltage required is a linear product of two input voltages. Both types provide excellent linearity and operation over a wide supply range and input voltage range. Applications include use as multipliers, dividers, squarers, phase detectors, frequency doublers, and as balanced modulators.

The SG1595 is rated for military applications over the -55°C to 125°C range; the SG1495 offers identical performance for 0°C to 70°C requirements.

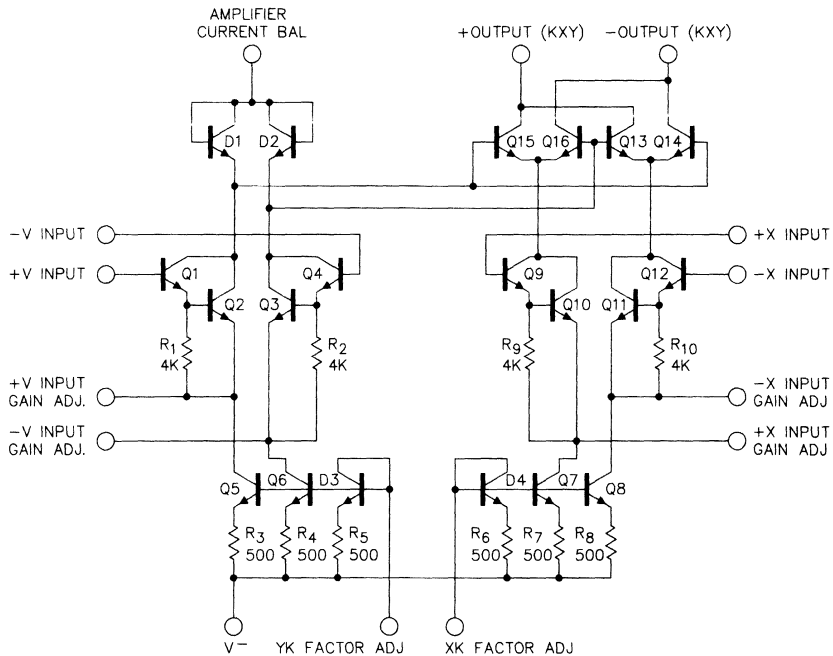
**FEATURES**

- Excellent linearity
- Adjustable scale factor
- Excellent temperature stability
- Wide bandwidth
- High input voltage range
- Wide supply voltage operation

**HIGH RELIABILITY FEATURES  
-SG1595**

- ◆ Available to MIL-STD-883
- ◆ SG level "S" processing available

**CIRCUIT SCHEMATIC**



## ABSOLUTE MAXIMUM RATINGS (Note 1)

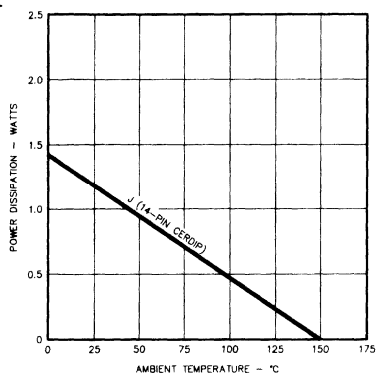
Applied Voltage (Note 2) .....	30V	Operating Junction Temperature	
Differential Input Signal .....	$V_9 - V_{12} = \pm(6 + I_{13} R_x)$	Hermetic (J-Package) .....	175°C
	$V_4 - V_8 = \pm(6 + I_3 R_y)$	Storage Temperature Range .....	-65°C to 150°C
Factor Adjust Current .....	10mA	Lead Temperature (Soldering, 10 Seconds) .....	300°C

Note 1. Exceeding these ratings could cause damage to the device.

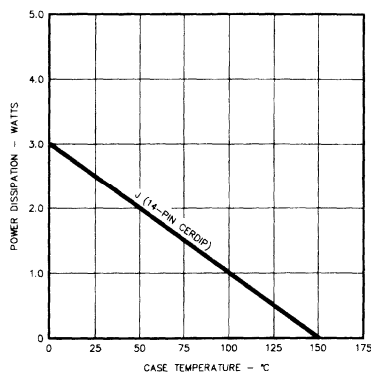
Note 2. Voltage applied between pins 2-1, 14-1, 1-9, 1-12, 1-4, 1-8, 12-7, 9-7, 8-7, 4-7.

## RECOMMENDED OPERATING CONDITIONS (Note 3)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### ELECTRICAL

Applied Voltage .....	28V	Operating Ambient Temperature Range	
Differential Input Signal .....	$V_9 - V_{12} = \pm(5 + I_{13} R_x)$	SG1595 .....	-55°C to 125°C
	$V_4 - V_8 = \pm(5 + I_3 R_y)$	SG1495 .....	0°C to 70°C
Factor Adjust Current ( $I_3$ ), ( $I_{13}$ ) .....	5mA		

Note 3. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise specified, these specifications apply for  $T_A = 25^\circ\text{C}$ )

Parameter	Test Conditions	SG1595			SG1495			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Linearity Error (% of Full Scale)	$-10 < V_x < 10$ ( $V_y = \pm 10\text{V}$ )		0.5	2.0		1.0	4.0	%
	$-10 < V_y < 10$ ( $V_x = \pm 10\text{V}$ )		1.0	4.0		2.0	8.0	%
Squaring Mode Error (Note 4)	$T_A = T_{\text{MIN}}$ to $T_{\text{MAX}}$							
	$-10 < V_x < 10$ ( $V_y = \pm 10\text{V}$ )		0.75	2.0		1.5	4.0	%
	$-10 < V_y < 10$ ( $V_x = \pm 10\text{V}$ )		1.50	4.0		3.0	8.0	%
	$T_A = T_{\text{MIN}}$ to $T_{\text{MAX}}$		0.50			0.75		%
Scale Factor (adjustable) (Note 4 and 5)	$T_A = T_{\text{MIN}}$ to $T_{\text{MAX}}$		0.75			1.00		%
Input Resistance (Note 4)	$f = 20\text{Hz}$		0.1			0.1		$\text{M}\Omega$
Differential Output Resistance (Note 4)	$f = 20\text{Hz}$		35			20		$\text{K}\Omega$
Input Bias Current (Note 4)	$T_A = T_{\text{MIN}}$ to $T_{\text{MAX}}$		2.0	8.0		2.0	12	$\mu\text{A}$
Input Offset Current (Note 4)	$T_A = T_{\text{MIN}}$ to $T_{\text{MAX}}$		0.2	1.0		0.4	2.0	$\mu\text{A}$
Common-Mode Gain (Note 4)	$T_A = T_{\text{MIN}}$ to $T_{\text{MAX}}$	-50	-60		-40	-50		dB
Output Common-Mode Voltage			21			21		V
Differential Output Voltage Swing (Note 4)	$V_x = V_y = 10\text{V}$ , $T_A = T_{\text{MIN}}$ to $T_{\text{MAX}}$	$\pm 8$	$\pm 14$		$\pm 8$	$\pm 14$		V
Positive Supply Voltage Rejection Ratio			5			5		mV/V
Negative Supply Voltage Rejection Ratio			10			10		mV/V
Negative Supply Current (Note 4)	$T_A = T_{\text{MIN}}$ to $T_{\text{MAX}}$		6.0	7.0		6.0	7.0	mA

ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG1595			SG1495			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Power Consumption (Note 4)			135	170		135	170	mW
Average Temperature Coefficient of Input Offset Current	$T_A = T_{MIN}$ to $T_{MAX}$		2.5		2.5			nA/°C
Frequency Response	-3dB bandwidth		3.0		3.0			MHz
	3° relative phase shift		750		750			KHz
	1% absolute error due to input-output phase shift		30		30			KHz

Note 4. These parameters are guaranteed by design and process control but are not tested in production.

Note 5.  $K = \frac{2R_L}{I_3 R_X R_Y}$

CHARACTERISTIC CURVES

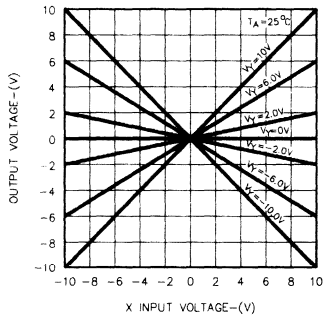


FIGURE 1. STANDBY CURRENT

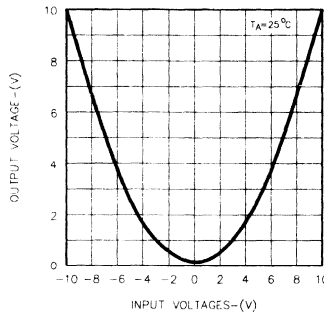


FIGURE 2. MINIMUM INPUT-OUTPUT VOLTAGE

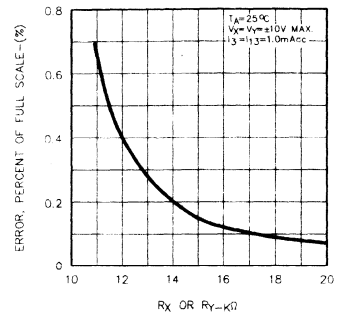


FIGURE 3. MINIMUM INPUT-OUTPUT VOLTAGE

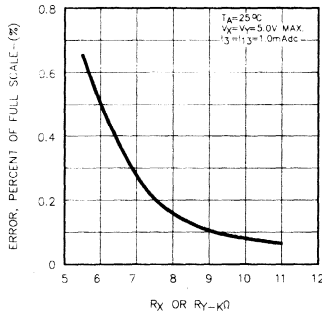


FIGURE 4. CURRENT LIMITING

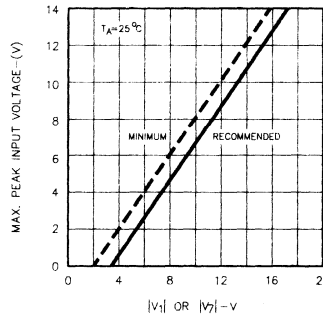


FIGURE 5. RIPPLE REJECTION

APPLICATION INFORMATION

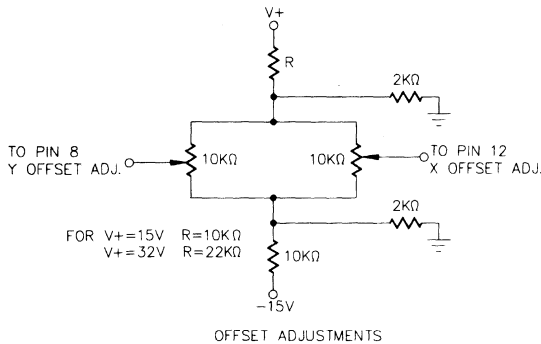


FIGURE 6

For best output accuracy, use above network and follow procedure at right.

RECOMMENDED ZERO ADJUSTMENT AND SCALE SETTING PROCEDURE

With  $V_x = V_y = 0V$  adjust the output offset adjustment until the output of the external amplifier reads  $0V$ . Set  $V_x = 5.000V$ ,  $V_y = 0.000V$ , and adjust the Y-input offset control until the output amplifier reads  $0V$ . Repeat this procedure for  $V_x = 0.000V$ ,  $V_y = 5.000V$  and adjust the X-input offset control until the output amplifier reads  $0V$ . This procedure should be repeated until complete null is achieved.

Next, set  $V_x = V_y = 5.000V$  and adjust the K-factor potentiometer until the output reads the desired output.

$$V_{OUT} = 2.500V = K V_x V_y \text{ for a K-factor of } 0.100.$$

When a high degree of accuracy is unnecessary for small output signals, the above procedure may be simplified by eliminating the output offset adjustment.

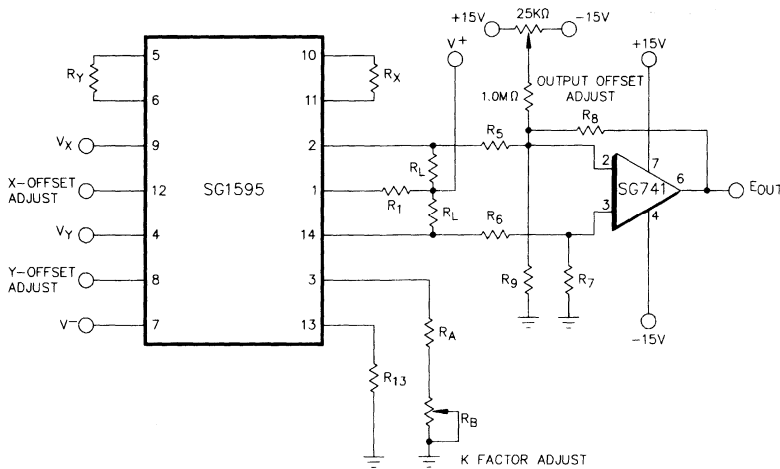


FIGURE 7 - MULTIPLY WITH OP AMP LEVEL SHIFT

SET UP	RESISTOR*	$R_1$	$R_5$	$R_6$	$R_7$	$R_8$	$R_9$	$R_{13}$	$R_A$	$R_B$	$R_L$	$R_x$	$R_y$
	TOLERANCE	5%	1%	1%	1%	1%	1%	1%	5%	20%	0.5%	5%	5%
1	$V_+ = 32V, V_- = -15V,$ $-10V \leq V_x \leq 10V,$ $-10V \leq V_y \leq 10V$	9.1	121	100	11	121	15	13.7	12	5.0	11	15	15
2	$V_+ = 15V, V_- = -15V,$ $-5V \leq V_x \leq 5V,$ $-5V \leq V_y \leq 5V$	3.0	300	100	100	300		13.7	12	5.0	3.4	8.2	8.2
3	$V_+ = 15V, V_- = -15V,$ $-10V \leq V_x \leq 10V,$ $-10V \leq V_y \leq 10V$	1.2	121	100	11	910	13.7	13.7	12	5.0	1.5	15	15

\* All resistor values are in  $k\Omega$







**BALANCED MODULATOR/DEMODULATOR**

**DESCRIPTION**

The SG1596 and SG1496 are monolithic double-balanced modulator/demodulator devices designed for use where the output voltage is a product of an input voltage (signal) and a switching function (carrier). Typical applications include modulation and demodulation of AM, SSB, DSB, FSK, FM and phase encoded signals. Additional uses include frequency doubling, linear mixing, and chopping.

The SG1596 will operate over the full military temperature range of -55°C to 125°C; the SG1496 commercial counterpart is intended for application of 0°C to 70°C.

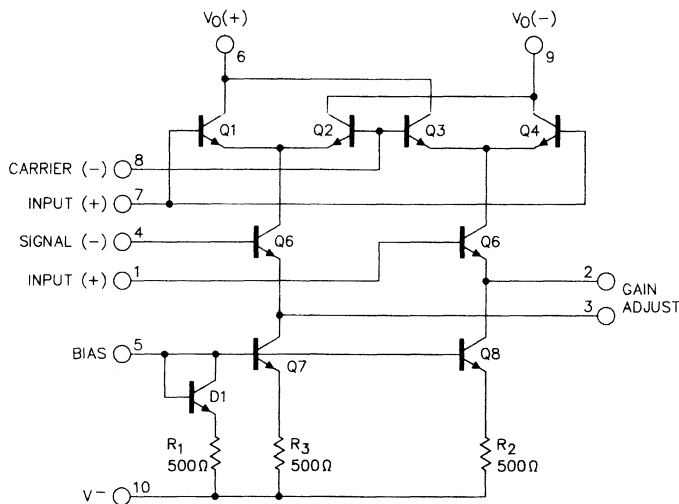
**FEATURES**

- Excellent carrier suppression
- Fully balanced inputs and outputs
- Low offsets and drift
- High common-mode rejection
- Adjustable gain and signal handling
- Useful to 100MHz

**HIGH RELIABILITY FEATURES  
-SG1596**

- ◆ Available to MIL-STD-883
- ◆ SG level "S" processing available

**CIRCUIT SCHEMATIC**



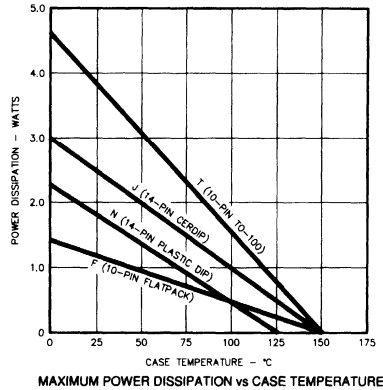
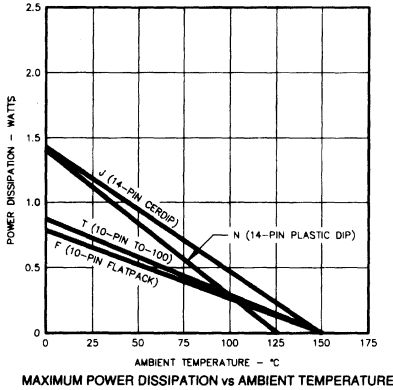
**ABSOLUTE MAXIMUM RATINGS** (Note 1)

Applied Voltage (Note 2) .....	30V	Maximum Bias Current .....	10mA
Differential Input Signal		Operating Junction Temperature	
( $V_7 - V_9$ ) .....	$\pm 5.0V$	Hermetic (J, T, F-Packages) .....	175°C
( $V_4 - V_1$ ) .....	$\pm(5 + I_5 R_E)V$	Plastic (N-Package) .....	150°C
Input Signal ( $V_2 - V_1, V_3 - V_4$ ) .....	5.0V	Storage Temperature Range .....	-65°C to 150°C
		Lead Temperature (Soldering, 10 Seconds) .....	300°C

Note 1. Exceeding these ratings could cause damage to the device.  
 Note 2. Voltage applied between pins 6-7, 8-1, 9-7, 9-8, 7-4, 7-1, 8-4, 6-8, 2-5, 3-5.

**RECOMMENDED OPERATING CONDITIONS** (Note 3)

**THERMAL**



**ELECTRICAL**

Applied Voltage .....	28V	Bias Current ( $I_5$ ) .....	5mA
Differential Input Signal		Operating Ambient Temperature Range	
( $V_7 - V_9$ ) .....	$\pm 4.0V$	SG1596 .....	-55°C to 125°C
( $V_4 - V_1$ ) .....	$\pm(4 + I_5 R_E)V$	SG1496 .....	0°C to 70°C

Note 3. Range over which the device is functional.

**ELECTRICAL SPECIFICATIONS**

(Unless otherwise specified, these specifications apply for  $T_A = 25^\circ C$ .)

Parameter	Test Conditions	SG1596			SG1496			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Carrier Feedthrough (Note 4)	$V_c = 60mV$ (rms) sine wave							
	$f_c = 1.0KHz$ , offset adjusted		40		40			$\mu V(rms)$
	$f_c = 10MHz$ , offset adjusted		140		140			$\mu V(rms)$
	$V_c = 300mV$ (p-p) square wave							
Carrier Suppression (Note 4)	$f_c = 1.0KHz$ , offset adjusted		0.04	0.2	0.04	0.2		mV(rms)
	$f_c = 1.0KHz$ , offset not adjusted		20	100	20	200		mV(rms)
	$f_s = 10KHz$ , 300mV (rms)							
	$f_c = 500KHz$ , 60mV (rms) sine wave offset adjusted	50	65		50	65		dB
Transadmittance Bandwidth	$f_s = 10KHz$ , 300mV (rms)							
	$f_c = 10MHz$ , 60mV (rms) sine wave offset adjusted		50		50			dB
	Carrier Input Port, $R_i = 50\Omega$						-50	
	$V_c = 60mV$ (rms) sine wave,							
$f_s = 1.0KHz$ , 300mV (rms) sine wave		300		300			MHz	
Signal Input Port, $V_s = 300mV$ (rms)		80		80			MHz	

ELECTRICAL SPECIFICATIONS (continued)

Parameter	Test Conditions	SG1595			SG1495			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
Voltage Gain, Signal Channel	$V_S = 100\text{mV (rms)}, f = 1.0\text{KHz}$ $V_7 - V_8 = 0.5\text{V}, T_A = T_{\text{MIN}} \text{ to } T_{\text{MAX}}$	2.5	3.5		2.5	3.5		V/V
Input Resistance, Signal Port	$f = 5.0\text{MHz}, V_7 - V_8 = 0.5\text{V}$		200			200		$\text{K}\Omega$
Input Capacitance, Signal Port	$f = 5.0\text{MHz}, V_7 - V_8 = 0.5\text{V}$		2.0			2.0		pF
Single-Ended Output Resistance	$f = 10\text{MHz}$		40			40		$\text{K}\Omega$
Single-Ended Output Capacitance	$f = 10\text{MHz}$		5.0			5.0		pF
Input Bias Current	$(I_1 + I_2)/2, T_A = T_{\text{MIN}} \text{ to } T_{\text{MAX}}$ $(I_7 + I_8)/2, T_A = T_{\text{MIN}} \text{ to } T_{\text{MAX}}$		12	25		12	30	$\mu\text{A}$
Input Offset Current	$(I_1 - I_2), T_A = T_{\text{MIN}} \text{ to } T_{\text{MAX}}$ $(I_7 - I_8), T_A = T_{\text{MIN}} \text{ to } T_{\text{MAX}}$		0.7	5.0		0.7	7.0	$\mu\text{A}$
Average Temperature Coefficient of Input Offset Current	$T_A = T_{\text{MIN}} \text{ to } T_{\text{MAX}}$		2.0			2.0		$\text{nA}/^\circ\text{C}$
Output Offset Current	$(I_6 - I_9), T_A = T_{\text{MIN}} \text{ to } T_{\text{MAX}}$		14	50		14	80	$\mu\text{A}$
Average Temperature Coefficient of Output Offset Current	$T_A = T_{\text{MIN}} \text{ to } T_{\text{MAX}}$		90			90		$\text{nA}/^\circ\text{C}$
Signal Port Common-Mode Input Voltage Range	$f_S = 1.0\text{KHz}$		5.0			5.0		V p-p
Signal Port Common-Mode Rejection Ratio	$V_7 - V_8 = 0.5\text{V}$		-85			-85		dB
Common-Mode Quiescent Output Voltage			8.0			8.0		V
Differential Output Swing Capability			8.0			8.0		V p-p
Positive Supply Current	$(I_6 + I_9), T_A = T_{\text{MIN}} \text{ to } T_{\text{MAX}}$		2.0	3.0		2.0	4.0	mA
Negative Supply Current	$(I_{10}), T_A = T_{\text{MIN}} \text{ to } T_{\text{MAX}}$		3.0	4.0		3.0	5.0	mA
Power Dissipation			33			33		mW

Note 4. These parameters are guaranteed by design and process control but are not tested in production.

CHARACTERISTIC CURVES

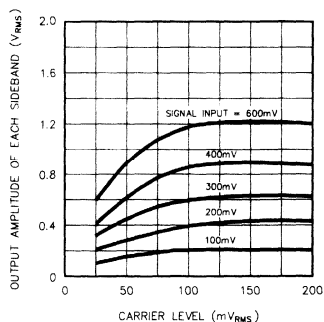


FIGURE 1. SIDEBAND OUTPUT VS. CARRIER LEVELS

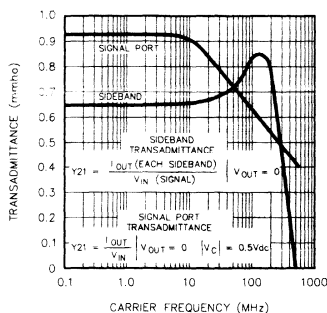


FIGURE 2. SIDEBAND AND SIGNAL PORT TRANSMITTANCES VS. CARRIER LEVELS

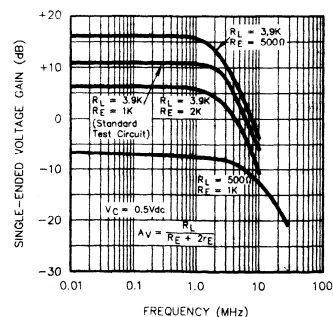


FIGURE 3. SIGNAL-PORT FREQUENCY RESPONSE

**CHARACTERISTIC CURVES** (continued)

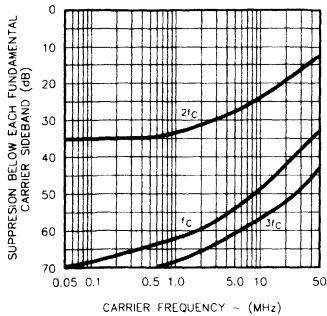


FIGURE 4. CARRIER SUPPRESSION VS. FREQUENCY

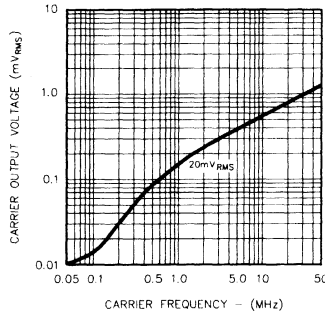


FIGURE 5. CARRIER FEEDTHROUGH VS. FREQUENCY

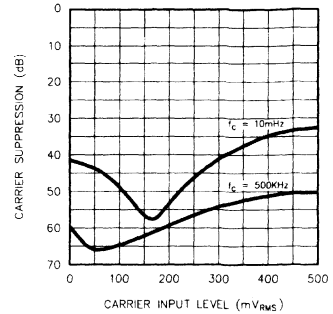
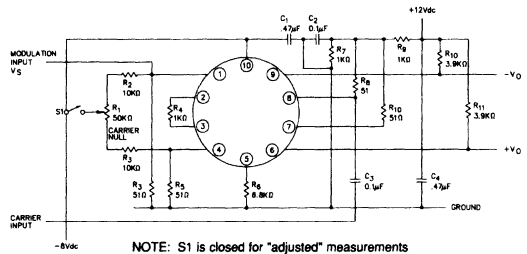


FIGURE 6. CARRIER SUPPRESSION VS. CARRIER INPUT LEVEL

**APPLICATION INFORMATION**

**TYPICAL MODULATOR CIRCUIT**

Under certain values of driving source impedance, oscillation may occur. In this event, an RC suppression network should be connected directly to each input using short leads. This will reduce the Q of the source-tuned circuits that cause the oscillation.



NOTE: S1 is closed for "adjusted" measurements

FIGURE 7 - TYPICAL MODULATOR CIRCUIT

**PRODUCT DETECTOR**

This figure shows the SG1596 used as a single sideband suppressed carrier demodulator (Product Detector). The carrier signal is applied to the carrier input port with sufficient amplitude for switching operation. A carrier input level of 300 mV (rms) is optimum. The composite SSB signal is applied to the signal input port with an amplitude of 5.0 to 500mV (rms). All output signal components except the desired demodulated audio are filtered out, so that an offset adjustment is not required. This circuit may also be used as an AM detector by applying composite and carrier signals in the same manner as described for product detector operation.

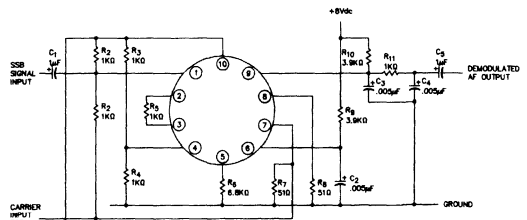


FIGURE 8 - PRODUCT DETECTOR

**FREQUENCY DOUBLER**

The frequency doubler circuit shown will double low-level signals with low distortion. The value of C should be chosen for low reactance at the operating frequency.

Signal level at the carrier input must be less than 25mV peak to maintain operation in the linear region of the switching differential amplifier. Levels to 50mV peak may be used with some distortion of the output waveform. If a large input signal is available a resistive divider may be used at the carrier input, with full signal applied to the signal input.

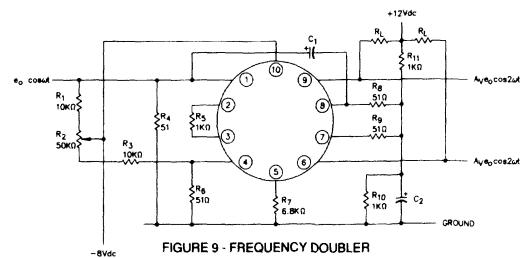


FIGURE 9 - FREQUENCY DOUBLER

## APPLICATION INFORMATION (continued)

### SIGNAL PORT STABILITY

Under certain values of driving source impedance, oscillation may occur. In this event, an RC suppression network should be connected directly to each input using short leads. This will reduce the Q of the source-tuned circuits that cause the oscillation.

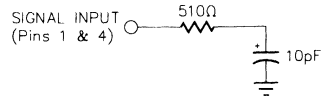


FIGURE 10 - SIGNAL PORT STABILITY

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
10-PIN METAL CANT - PACKAGE	SG1596T/883B SG1596T SG1496T	-55°C to 125°C -55°C to 125°C 0°C to 70°C	
14-PIN CERAMIC DIP J - PACKAGE	SG1596J/883B SG1596J SG1496J	-55°C to 125°C -55°C to 125°C 0°C to 70°C	
14-PIN PLASTIC DIP N - PACKAGE	SG1496N	0°C to 70°C	
10-PIN CERAMIC FLAT PACK F - PACKAGE	SG1596F/883B SG1596F	-55°C to 125°C -55°C to 125°C	

Note 1. Contact factory for JAN and DESC product availability.  
 Note 2. All packages are viewed from the top.





**DUAL HIGH-FREQUENCY  
OPERATIONAL AMPLIFIER**

**DESCRIPTION**

The SG3049 consists of dual high-frequency differential amplifiers with associated constant-current transistors on a common monolithic substrate. The monolithic construction provides close electrical and thermal matching of the amplifiers. The transistors which comprise the amplifiers are general-purpose devices with  $f_T$  in excess of 600MHz. Bias and load resistors have been omitted to provide maximum application flexibility.

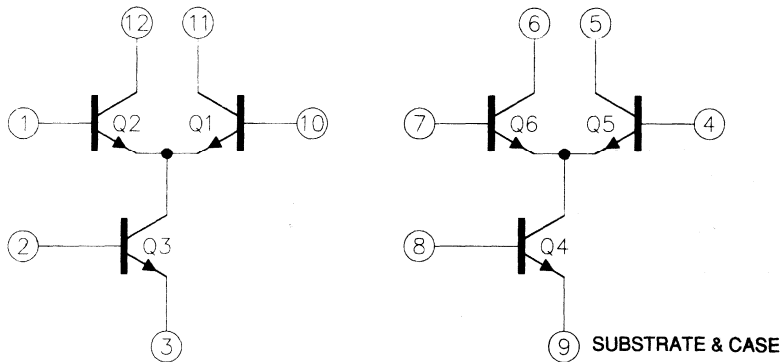
**FEATURES**

- $V_{SO}$  matching typically 200 $\mu$ V over operating current and voltage
- Two differential amplifiers on a common substrate
- Independently accessible inputs and outputs
- Full military temperature range capability

**HIGH RELIABILITY FEATURES**

- ◆ Available to MIL-STD-883
- ◆ SG level "S" processing available

**SCHEMATIC DIAGRAM**



## ABSOLUTE MAXIMUM RATINGS (Notes 1 and 2)

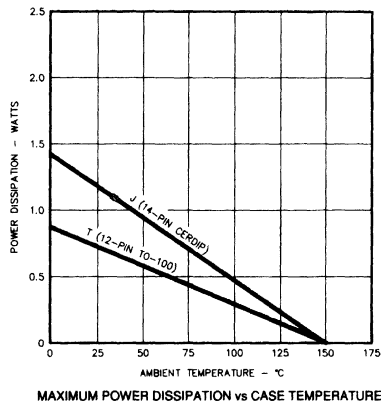
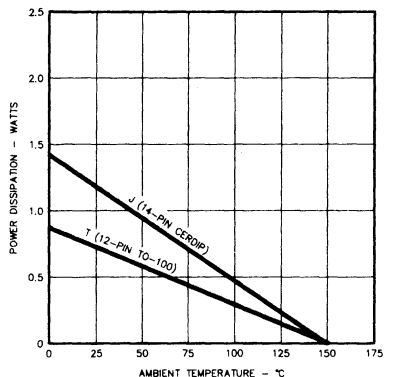
Collector to Emitter Voltage ( $V_{CE0}$ ) .....	15V
Collector to Base Voltage ( $V_{CBO}$ ) .....	20V
Collector to Substrate Voltage ( $V_{CIC}$ ) .....	20V
Emitter to Base Voltage ( $V_{EBO}$ ) .....	5V
Collector Current ( $I_C$ ) .....	50mA

Operating Junction Temperature	
Hermetic (J, T-Packages) .....	175°C
Storage Temperature Range .....	-65°C to 150°C
Lead Temperature (Soldering, 10 Seconds) .....	300°C

Note 1. Electrical values apply for each transistor.  
 Note 2. Exceeding these ratings could cause damage to the device.

## RECOMMENDED OPERATING CONDITIONS (Notes 1 and 3)

### THERMAL



### THERMAL

Operating Ambient Temperature Range  
 SG3049 ..... -55°C to 125°C

Note 3. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise stated, these specifications apply for  $T_A = T_{MIN}$  to  $T_{MAX}$ .)

Parameter	Test Conditions	SG3049			Units
		Min.	Typ.	Max.	
<b>Static Characteristics (Each Transistor)</b>					
<b>Breakdown Voltages</b>					
Collector-Base ( $V_{(BR)CBO}$ )	$I_C = 10\mu A, I_E = 0$	20	60		V
Collector-Substrate ( $V_{(BR)CIC}$ )	$I_C = 10\mu A, I_B = 0, I_E = 0$	20	60		V
Collector-Emitter ( $V_{(BR)CEO}$ )	$I_C = 1mA, I_B = 0$	15	24		V
Emitter-Base ( $V_{(BR)EBO}$ )	$I_E = 10\mu A, I_C = 0$	5	7		V
Collector Cutoff Current ( $I_{CBO}$ )	$V_{CB} = 10V, I_E = 0$			100	nA
Base-Emitter Voltage ( $V_{BE}$ )	$V_{CE} = 3V, I_C = 1mA$				
	$T_A = 25^\circ C$	0.60	0.70	0.80	V
	$T_A = T_{MIN}$	0.72	0.80	0.92	V
	$T_A = T_{MAX}$	0.50	0.60	0.70	V
<b>Static Characteristics (Each Differential Amplifier)</b>					
Input Offset Voltage ( $V_{IO}$ )	$I_E(Q_3) = I_E(Q_4) = 2mA, V_{CB} = 3V$		0.45	5.0	mV
Input Offset Current ( $I_{IO}$ )	$I_E(Q_3) = I_E(Q_4) = 2mA, V_{CB} = 3V$		0.30	3.0	$\mu A$
Input Bias Current ( $I_{IB}$ )	$I_E(Q_3) = I_E(Q_4) = 2mA, V_{CB} = 3V$		10	45	$\mu A$
DC Gain ( $h_{FE}$ )					
$Q_3$	$I_E(Q_3) / I_B(Q_3)$	35	150	300	
$Q_4$	$I_E(Q_4) / I_B(Q_4)$	35	150	300	

**ELECTRICAL SPECIFICATIONS** (continued)

Parameter	Test Conditions	SG3049			Units
		Min.	Typ.	Max.	
<b>Dynamic Characteristics (T<sub>A</sub> = 25°C)</b>					
<b>Common-Mode Rejection Ratio (CMRR)</b> (Each Amplifier)	V <sub>CC</sub> = 12V, V <sub>EE</sub> = -6V, V <sub>X</sub> = 3.3V, f = 1KHz (See Figure 2)	80			dB
<b>Automatic Gain Control Range (AGC)</b> (Single Stage)	V <sub>CC</sub> = 12V, V <sub>EE</sub> = -6V, V <sub>X</sub> = 3.3V, f = 1KHz (See Figure 3)	75			dB
<b>Voltage Gain (A<sub>v</sub>)</b> (Single Stage, Double-Ended Output)	V <sub>CC</sub> = 12V, V <sub>EE</sub> = -6V, V <sub>X</sub> = 3.3V, f = 1KHz (See Figure 3)	35			dB
<b>Gain Bandwidth Product (f<sub>T</sub>)</b> (Single Transistor)	I <sub>C</sub> = 3mA, V <sub>CE</sub> = 3V	600			MHz
<b>Noise Figure (NF)</b> (Single Transistor)	V <sub>CE</sub> = 3V, I <sub>C</sub> = 100μA, R <sub>X</sub> = 1KΩ, f = 1KHz, BW = 15.7KHz	3.25			dB
<b>(Each Amplifier)</b>	f = 100MHz	8			dB

**TEST CIRCUITS**

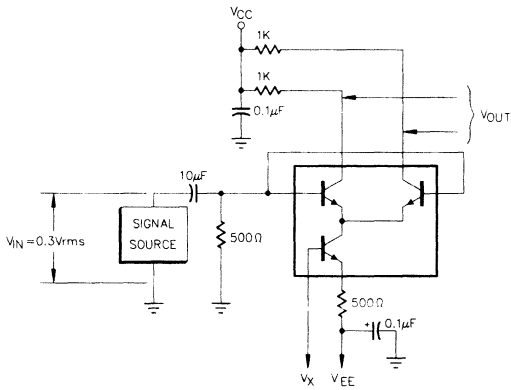


FIGURE 2 - COMMON-MODE REJECTION RATIO

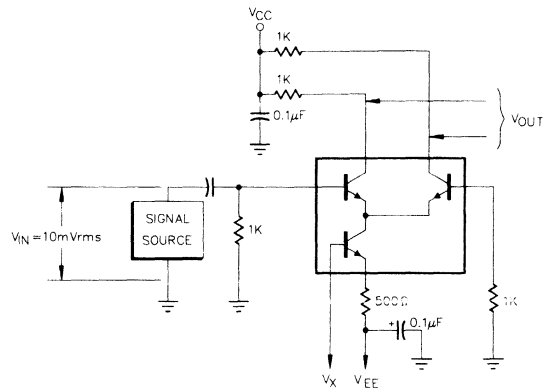


FIGURE 3 - SINGLE-STAGE VOLTAGE GAIN

**CHARACTERISTIC CURVE**

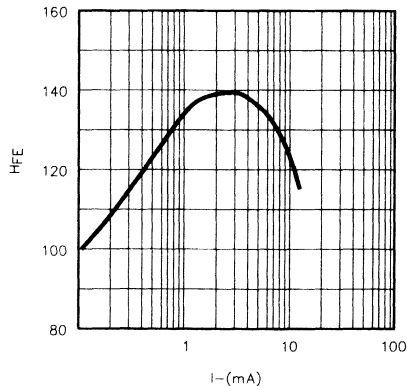


FIGURE 1 - DC GAIN VS. CURRENT

**CONNECTION DIAGRAMS & ORDERING INFORMATION** (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
14-PIN CERAMIC DIP J - PACKAGE	SG3049J/883B SG3049J	-55°C to 125°C -55°C to 125°C	
12-PIN METAL CAN T - PACKAGE	SG3049T/883B SG3049T	-55°C to 125°C -55°C to 125°C	

Note 1. Contact factory for JAN and DESC product availability.  
 2. All packages are viewed from the top.

***HIGH-CURRENT NPN TRANSISTOR ARRAYS***

**DESCRIPTION**

The SG 3183 series of arrays consists of five, closely-matched, high-current NPN transistors. Although sharing a common monolithic substrate, the transistors are connected such that all terminals are independent, including the substrate bias connector. With current capability to 100mA per transistor, these arrays are ideally suited for all types of driving applications including relays, lamps, and thyristors.

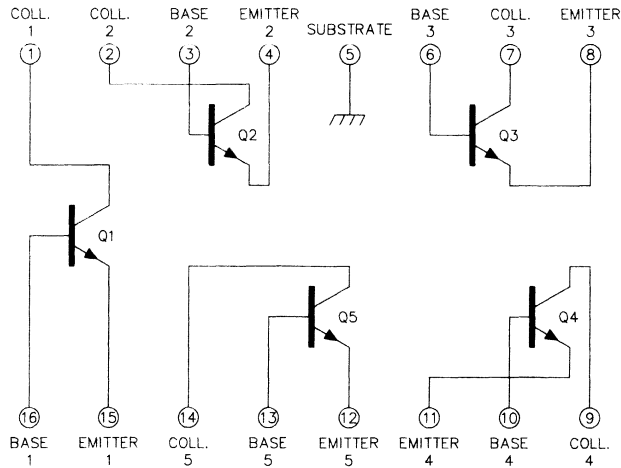
**FEATURES**

- High voltage capability
- Collector current to 100mA
- Low saturation voltage
- Closely matched parameters

**HIGH RELIABILITY FEATURES - SG3183**

- ◆ Available to MIL-STD-883
- ◆ SG level "S" processing available

**BLOCK DIAGRAM**



**ABSOLUTE MAXIMUM RATINGS** (Note 1)

Maximum Collector Current ..... 100mA  
 Maximum Base Current ..... 20mA  
 Power Dissipation  
   Any One Transistor ..... 500mW  
   Total Package ..... 750mW

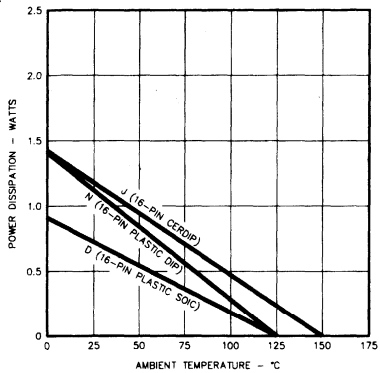
Operating Junction Temperature

Hermetic (J-Packages) ..... 175°C  
 Plastic (N, D-Package) ..... 150°C  
 Storage Temperature Range ..... -65°C to 150°C  
 Lead Temperature (Soldering, 10 Seconds) ..... 300°C

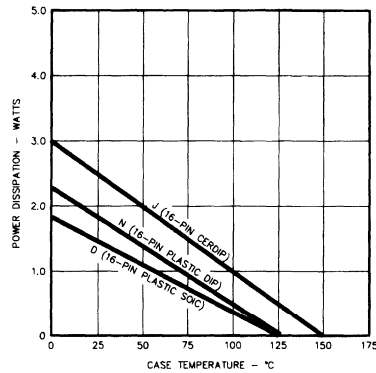
Note 1. Exceeding these ratings could cause damage to the device.

**RECOMMENDED OPERATING CONDITIONS** (Note 2)

THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

ELECTRICAL

Operating Ambient Temperature

SG3183 (J-Package) ..... -55°C to 125°C  
 SG3183 (N, D-Package) ..... 0°C to 70°C

Note 2. Range over which the device is functional.

**ELECTRICAL SPECIFICATIONS**

(Unless otherwise stated, these specifications apply over recommended  $T_A = T_{MIN}$  to  $T_{MAX}$ .)

Parameter	Test Conditions	SG3183			Units
		Min.	Typ.	Max.	
<b>Breakdown Voltage</b>					
Collector-Substrate ( $BV_{CSO}$ )	$I_C = 100\mu A$	40	70		V
Collector-Base ( $BV_{CBQ}$ )	$I_C = 100\mu A$	40	70		V
Collector-Emitter ( $BV_{CEO}$ )	$I_C = 1mA$	30	40		V
Emitter-Base ( $BV_{EBQ}$ )	$I_E = 100\mu A$	5.0	6.9		V
Collector Cutoff Current ( $I_{CEO}$ )	$V_{CE} = 10V$			10	$\mu A$
Collector Cutoff Current ( $I_{CBO}$ )	$V_{CB} = 10V$			1	$\mu A$
<b>DC Forward Current Transfer Ratio (<math>h_{FE}</math>)</b>					
	$V_{CE} = 3V, I_C = 10mA$	40			
	$T_A = 25^\circ C$	50	100		
	$V_{CE} = 3V, I_C = 10mA$	35			
	$T_A = 25^\circ C$	40	75		
Collector-Emitter Saturation Voltage ( $V_{CE(SAT)}$ )	$I_C = 50mA, I_B = 5mA$		1.7	3.0	V
Base-to-Emitter Voltage ( $V_{BE}$ )	$V_{CE} = 3V, I_C = 10mA$	0.50		0.95	V
	$T_A = 25^\circ C$	0.65	0.75	0.85	V
For $Q_1$ and $Q_2$ Matched Pair:					
Input Offset Voltage ( $V_{IO}$ )	$V_{CE} = 3V, I_C = 1mA$			10	mV
	$T_A = 25^\circ C$			1.2	5.0
Input Offset Current ( $I_{IO}$ )	$T_A = 25^\circ C$			5.0	$\mu A$
				0.7	2.5

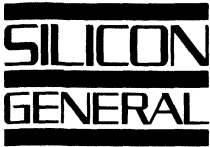
**CONNECTION DIAGRAMS & ORDERING INFORMATION** (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
16-PIN CERAMIC DIP J - PACKAGE	SG3183J/883B SG3183J	-55°C to 125°C -55°C to 125°C	
16-PIN PLASTIC DIP N - PACKAGE	SG3183N	0°C to 70°C	
16-PIN SOIC D - PACKAGE	SG3183D	0°C to 70°C	

Note 1. Contact factory for JAN and DESC product availability.  
 2. All packages are viewed from the top.







LINEAR INTEGRATED CIRCUITS

SG3821/SG3045/SG3046

**MATCHED NPN TRANSISTOR ARRAYS**

**DESCRIPTION**

These five matched transistors are general purpose NPN transistors configured with two internally connected to form a differential amplifier, each with its own associated source transistor. They are well suited to a wide variety of applications in low power systems in the DC through VHF range. In addition to being used as discrete transistors in conventional circuits, they also provide the very significant inherent integrated circuit advantages of close electrical and thermal matching. These transistor arrays offer  $V_{BE}$  typically matched to  $\pm 0.5mV$ , less than 10% variation in  $h_{FE}$ , operation from DC to 300MHz, high current gain from  $10\mu A$  to 10mA, and high voltage capability.

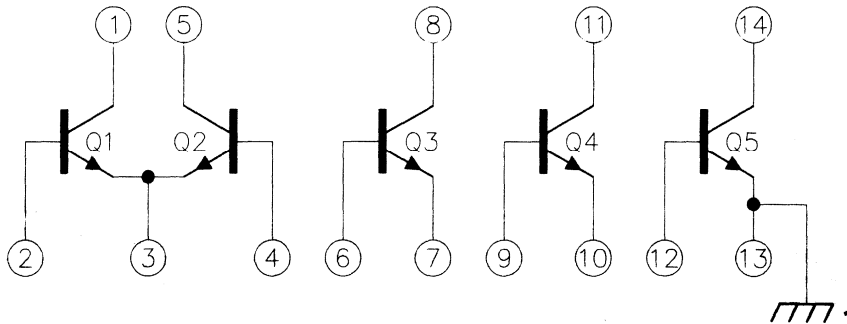
**FEATURES**

- Two matched transistor pairs  $\pm 0.5mV$
- Five general purpose matched transistors
- Operation from DC to 300MHz
- High current gain
- High voltage capabilities

**HIGH RELIABILITY FEATURES - SG3821**

- ◆ Available to MIL-STD-883
- ◆ SG level "S" processing available

**SCHEMATIC DIAGRAM**



\* Substrate pin must be connected to the most negative DC potential - which should also be a good AC ground - for proper isolation between transistors.

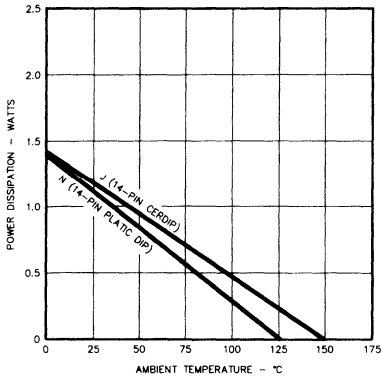
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Collector to Substrate Voltage .....	40V	Operating Junction Temperature	
Collector to Base Voltage .....	40V	Hermetic (J-Package) .....	175°C
Collector to Emitter Voltage .....	25V	Plastic (N-Package) .....	150°C
Storage Temperature Range .....	-65°C to 150°C	Lead Temperature (Soldering, 10 Seconds) .....	300°C

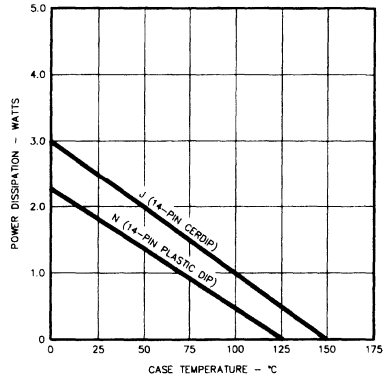
Note 1. Exceeding these ratings could cause damage to the device.

## RECOMMENDED OPERATING CONDITIONS (Note 2)

### THERMAL



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

### Operating Ambient Temperature Range

SG3045, SG3821 .....	-55°C to 125°C
SG3046 .....	0°C to 70°C

Note 2. Range over which the device is functional.

## ELECTRICAL SPECIFICATIONS

(Unless otherwise stated, these specifications apply for  $T_A = 25^\circ\text{C}$ .)

Parameter	Test Conditions	SG3821/3046			SG3045			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
<b>Breakdown Voltage:</b>								
Collector-Substrate ( $BV_{CSO}$ )	$I_C = 10\mu\text{A}, I_B = 0$	40			20			V
Collector-Base ( $BV_{CSB}$ )	$I_C = 10\mu\text{A}, I_E = 0$	40			20			V
Collector-Emitter ( $BV_{CEO}$ )	$I_C = 100\mu\text{A}, I_B = 0$	25			15			V
Emitter-Base ( $BV_{EBB}$ )	$I_E = 10\mu\text{A}, I_C = 0$	5			5			V
<b>Leakage Current</b>								
Collector-Substrate ( $I_{CSO}$ )	$V_{CE} = 20\text{V}, I_B = 0$			80			80	nA
Collector-Base ( $I_{CSB}$ )	$V_{CB} = 20\text{V}, I_E = 0$			40			40	nA
Collector-Emitter ( $I_{CEO}$ )	$V_{CE} = 20\text{V}, I_B = 0$			500			500	nA
<b>Forward Current-Transfer Ratio (<math>h_{FE}</math>)</b>								
	$V_{CE} = 5\text{V}, I_C = 10\mu\text{A}$		80		80			
	$V_{CE} = 5\text{V}, I_C = 1\text{mA}$	50		400	50		400	
	$V_{CE} = 5\text{V}, I_C = 10\text{mA}$		80		80			
	$V_{CE} = 5\text{V}, I_E = 10\text{mA}$		0.5		0.5			
<b>Base-to-Emitter Voltage (<math>V_{BE}</math>)</b>	$I_C = 10\text{mA}, I_B = 1\text{mA}$	0.5		0.9	0.5		0.9	V
<b>Collector-Emitter Saturation (<math>V_{CE(SAT)}</math>)</b>	$V_{CE} = 5\text{V}, I_C = 3\text{mA}$		500		500			MHz
<b>Gain-Bandwidth Product</b>	$V_{CE} = 5\text{V}, I_C = 0$		2.0		2.0			pF
<b>Collector-Substrate Capacitance</b>	$V_{CE} = 5\text{V}, I_C = 0$		0.4		0.4			pF
<b>Collector-Base Capacitance</b>	$f = 1\text{KHz}, V_{CE} = 5\text{V}, I_C = 100\text{mA}, R_S = 1\text{k}\Omega$		4		4			dB
<b>Noise Figure</b>	$V_{CE} = 5\text{V}, I_C = 1\text{mA}$		5		5			mV
<b>Input Offset Voltage (<math>V_{IO}</math>)</b>	$V_{CE} = 5\text{V}, I_C = 1\text{mA}$		4		2			$\mu\text{A}$
<b>Input Offset Current (<math>I_{IO}</math>)</b>								

# SG3821/SG3045/SG3046

## CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
14-PIN CERAMIC DIP J - PACKAGE	SG3821J/883B	-55°C to 125°C	<p style="text-align: center;">COMMON EMITTER Q1, Q2</p>
	SG3821J	-55°C to 125°C	
	SG3821N	0°C to 70°C	
	SG3045J/883B	-55°C to 125°C	
	SG3045J	-55°C to 125°C	
14-PIN PLASTIC DIP N - PACKAGE	SG3046N	0°C to 70°C	

Note 1. Contact factory for JAN and DESC product availability.  
 Note 2. All packages are viewed from the top.



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<b>4</b>	<b>POWER SUPPLY CIRCUITS</b>
<b>5</b>	<b>MOTION CONTROL CIRCUITS</b>
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<b>11</b>	<b>PACKAGE INFORMATION</b>
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<b>13</b>	<b>SALES OFFICES</b>



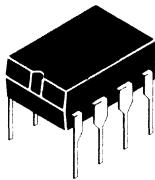
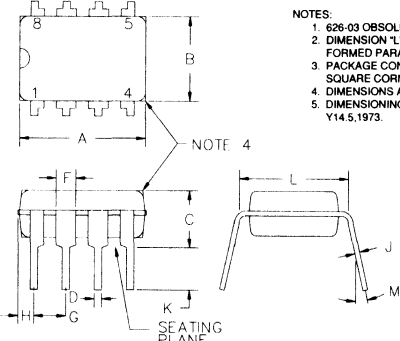
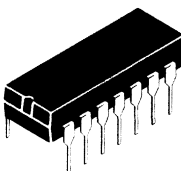
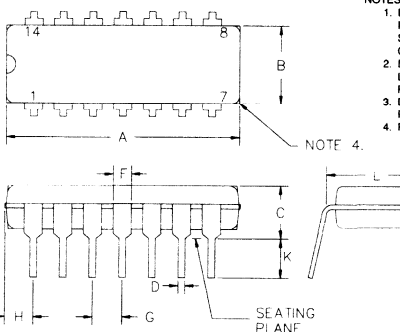
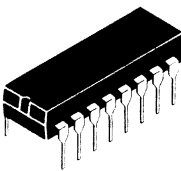
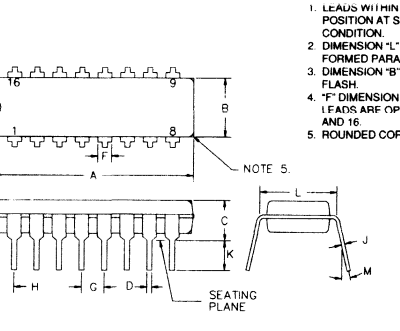
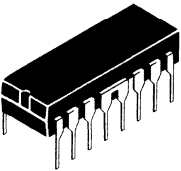
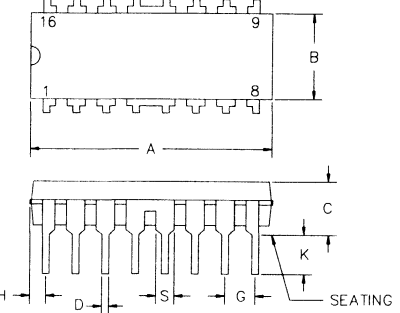
# THERMAL CHARACTERISTICS

LINEAR INTEGRATED CIRCUITS

No. of Pins	Pkg. Symbol	JEDEC No.	$\theta_{JA}$ ( $^{\circ}\text{C}/\text{W}$ )	$\theta_{JC}$ ( $^{\circ}\text{C}/\text{W}$ )	$P_D$ 25 $^{\circ}\text{C}$ (mW)	Derate > 25 $^{\circ}$ (mW/ $^{\circ}\text{C}$ )	No. of Pins	Pkg. Symbol	JEDEC No.	$\theta_{JA}$ ( $^{\circ}\text{C}/\text{W}$ )	$\theta_{JC}$ ( $^{\circ}\text{C}/\text{W}$ )	$P_D$ 25 $^{\circ}\text{C}$ (mW)	Derate > 25 $^{\circ}$ (mW/ $^{\circ}\text{C}$ )
<b>PLASTIC DUAL-IN-LINE (DIP)</b>							<b>CERAMIC LEADLESS CHIP CARRIER</b>						
8	M		95	60	1050	10.5	20	L	(LCC)	120	35	1040	8.3
14	N		65	40	1540	15.4	<b>METAL CANS</b>						
16	N		65	40	1540	15.4	2	T	TO-46	440	80	200	2.3
16	W	(Batwing)	45	15*	2220	22.2	3	T	TO-52	440	80	280	2.3
18	N		60	30	1670	16.7	3	T	TO-39	120	15	1040	8.3
20	N		60	30	1670	16.7	3	K	TO-3	35	3.0	3570	28.6
22	N		55	27	1820	18.2	3	R	TO-66	40	5.0	3120	25.0
24	N	(Wide)	52	25	1920	19.2	4	R	TO-66 (SM)	40	4.0	3120	25.0
24	N	(Narrow)	58	29	1720	17.2	4	K	TO-3 (SM)	35	2.0	3570	28.6
28	N		45	20	2220	22.2	5	R	TO-66	40	5.0	3120	25.0
40	N		40	15	2500	25.0	8	T	TO-99	130	2.5	960	7.7
<b>PLASTIC SMALL OUTLINE (S.O.I.C.)</b>							<b>HERMETIC TO-220</b>						
8	D		165	55	610	6.1	3	G	(Non-Iso)	42	3.5*	2980	23.8
14	D		120	50	830	8.3	3	IG	(Isolated)	42	3.5*	2980	23.8
16	D		120	50	830	8.3	<b>* = <math>\theta_{JT}</math> (Junction to Tab)</b>						
16	DW		95	40	1050	10.5	<b>Note: This data is for reference only as it does not account for thermal transfer characteristics of variable die sizes.</b>						
18	DW		90	35	1110	11.1							
20	DW		86	32	1160	11.6							
20	DWW	(Batwing)	50	12*	2000	20.0							
<b>PLASTIC (POWER)</b>													
3	P	TO-220	60	4.5*	1670	16.7							
3	V	TO-247	50	1.5*	2000	20.0							
5	P	TO-220	55	4.0*	1820	18.2							
12	S	(SIP)	45	2.0*	2220	22.2							
12	ST	(SIP)	45	2.0*	2220	22.2							
<b>PLASTIC LEADED CHIP CARRIER</b>													
20	Q	(PLCC)	80	35	1250	12.5							
28	Q	(PLCC)	70	20	1430	14.3							
<b>CERAMIC DUAL-IN-LINE</b>													
8	Y		130	50	960	7.7							
14	J		80	30	1560	12.5							
16	J	TO-116	80	30	1560	12.5							
18	J		70	25	1790	14.3							
<b>CERAMIC SIDE BRAZED (DIP)</b>													
14	H		100	30	1250	10.0							
16	H		100	30	1250	10.0							
18	H		85	25	1470	11.8							
<b>CERAMIC FLAT PACK (CERPAC)</b>													
10	F		145	80	860	6.9							
14	F		140	80	890	7.1							
16	F		115	70	1090	8.7							
20	F		115	70	1090	8.7							
24	F		110	70	1140	9.1							

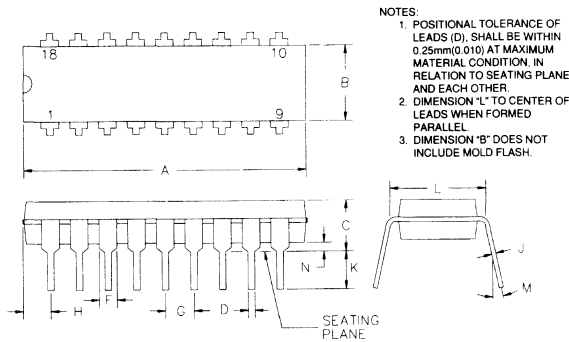
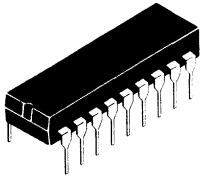
December 1988

# MECHANICAL DIMENSIONS

<p><b>PLASTIC MINI-DIP</b> <b>8-PIN</b> <b>"M" SUFFIX</b></p> 	 <p><b>NOTES:</b></p> <ol style="list-style-type: none"> <li>626-03 OBSOLETE NEW STD 626-04.</li> <li>DIMENSION "L" TO CENTER OF LEADS WHEN FORMED PARALLEL.</li> <li>PACKAGE CONTOUR OPTIONAL (ROUND OR SQUARE CORNERS).</li> <li>DIMENSIONS A AND B ARE DATUMS.</li> <li>DIMENSIONING AND TOLERANCING PER ANSI Y14.5, 1973.</li> </ol> <table border="1"> <thead> <tr> <th rowspan="2">DIM</th> <th colspan="2">MILLIMETERS</th> <th colspan="2">INCHES</th> </tr> <tr> <th>MIN</th> <th>MAX</th> <th>MIN</th> <th>MAX</th> </tr> </thead> <tbody> <tr> <td>A</td> <td>—</td> <td>10.16</td> <td>—</td> <td>0.400</td> </tr> <tr> <td>B</td> <td>6.10</td> <td>6.60</td> <td>0.240</td> <td>0.260</td> </tr> <tr> <td>C</td> <td>—</td> <td>5.08</td> <td>—</td> <td>0.200</td> </tr> <tr> <td>D</td> <td>0.38</td> <td>0.51</td> <td>0.015</td> <td>0.020</td> </tr> <tr> <td>F</td> <td>0.76</td> <td>1.52</td> <td>0.030</td> <td>0.060</td> </tr> <tr> <td>G</td> <td>2.54</td> <td>BSC</td> <td>0.100</td> <td>BSC</td> </tr> <tr> <td>H</td> <td>0.76</td> <td>1.83</td> <td>0.030</td> <td>0.072</td> </tr> <tr> <td>J</td> <td>0.20</td> <td>0.38</td> <td>0.008</td> <td>0.015</td> </tr> <tr> <td>K</td> <td>3.18</td> <td>—</td> <td>0.125</td> <td>—</td> </tr> <tr> <td>L</td> <td>7.62</td> <td>BSC</td> <td>0.300</td> <td>BSC</td> </tr> <tr> <td>M</td> <td>—</td> <td>15°</td> <td>—</td> <td>15°</td> </tr> </tbody> </table>	DIM	MILLIMETERS		INCHES		MIN	MAX	MIN	MAX	A	—	10.16	—	0.400	B	6.10	6.60	0.240	0.260	C	—	5.08	—	0.200	D	0.38	0.51	0.015	0.020	F	0.76	1.52	0.030	0.060	G	2.54	BSC	0.100	BSC	H	0.76	1.83	0.030	0.072	J	0.20	0.38	0.008	0.015	K	3.18	—	0.125	—	L	7.62	BSC	0.300	BSC	M	—	15°	—	15°
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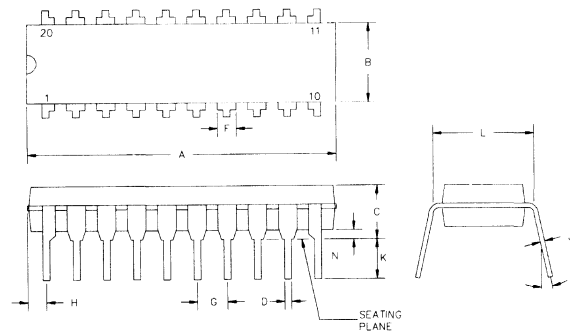
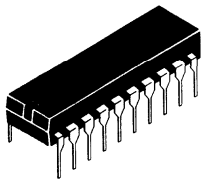
# MECHANICAL DIMENSIONS

## PLASTIC DIP 18-PIN "N" SUFFIX



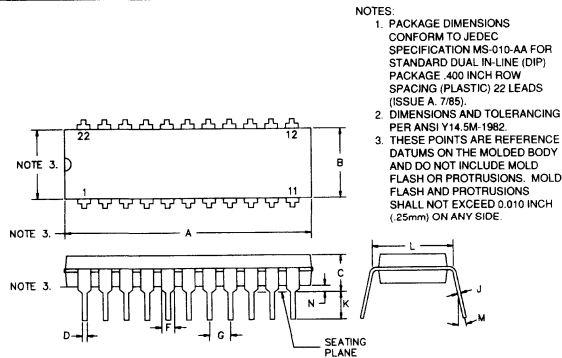
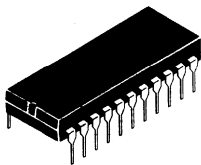
DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	22.61	23.11	0.890	0.910
B	6.10	6.60	0.240	0.260
C	3.56	4.57	0.140	0.180
D	0.36	0.56	0.014	0.022
F	1.27	1.78	0.050	0.070
G	2.54	BSC	0.100	BSC
H	1.02	1.52	0.040	0.060
J	0.20	0.30	0.008	0.012
K	3.18	-	0.125	-
L	7.62	BSC	0.300	BSC
M	-	15°	-	15°
N	0.38	0.64	0.015	0.025

## PLASTIC DIP 20-PIN "N" SUFFIX



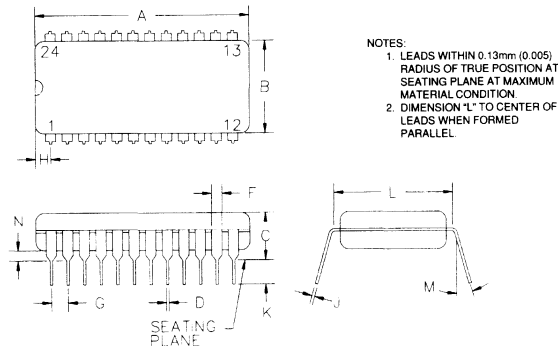
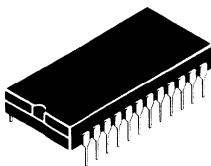
DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	25.91	26.42	1.020	1.040
B	6.10	6.60	0.240	0.260
C	3.56	4.57	0.140	0.180
D	0.38	0.53	0.015	0.021
F	1.27	1.78	0.050	0.070
G	2.54	BSC	0.100	BSC
H	1.02	1.52	0.040	0.060
J	0.20	0.36	0.008	0.014
K	3.18	-	0.125	-
L	7.62	BSC	0.300	BSC
M	-	15°	-	15°
N	0.38	0.64	0.015	0.025

## PLASTIC DIP 22-PIN "N" SUFFIX



DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	27.81	28.19	1.095	1.110
B	13.21	13.72	0.520	0.540
C	4.19	4.83	0.165	0.190
D	0.43	0.56	0.017	0.022
F	1.14	1.63	0.045	0.064
G	2.54	BSC	0.100	BSC
J	0.25	0.035	0.010	0.015
K	3.05	3.51	0.120	0.138
L	10.16	10.72	0.400	0.422
M	-	15°	-	15°
N	0.51	0.89	0.020	0.035

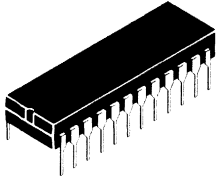
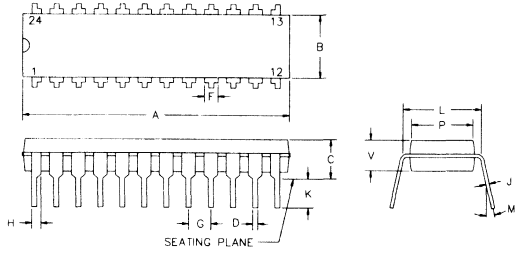
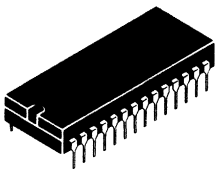
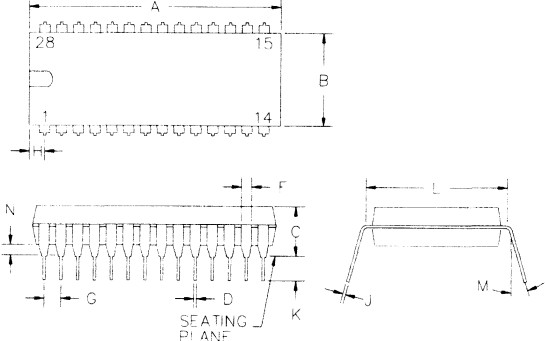
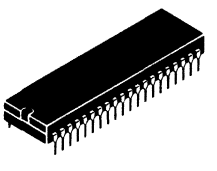
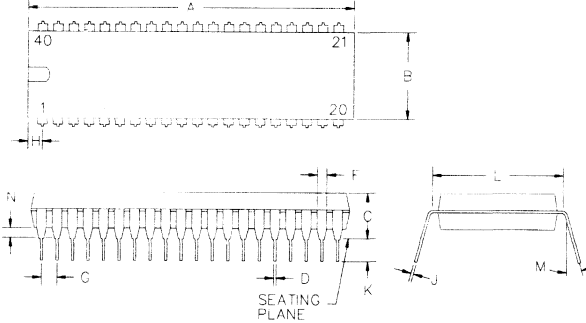
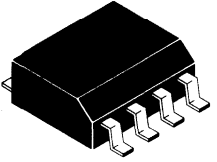
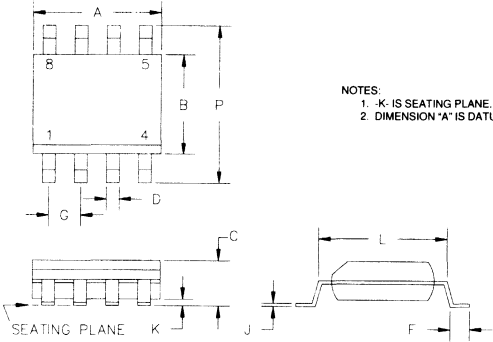
## PLASTIC DIP (WIDE) 24-PIN "N" SUFFIX



DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	-	31.50	-	1.240
B	-	13.72	-	0.540
C	3.56	4.57	0.140	0.180
D	0.38	0.53	0.015	0.021
F	1.27	1.78	0.050	0.070
G	2.54	BSC	0.100	BSC
H	1.02	1.52	0.040	0.060
J	0.20	0.36	0.008	0.014
K	3.18	-	0.125	-
L	15.24	BSC	0.600	BSC
M	-	15°	-	15°
N	0.38	0.64	0.015	0.025

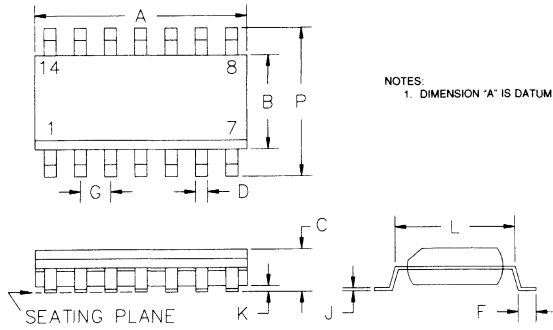
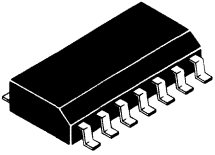


# MECHANICAL DIMENSIONS

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<p><b>PLASTIC S.O.I.C.</b> <b>8-PIN</b> <b>"D" SUFFIX</b></p> 	<p>NOTES: 1. -K- IS SEATING PLANE. 2. DIMENSION "A" IS DATUM.</p> 	<table border="1"> <thead> <tr> <th rowspan="2">DIM</th> <th colspan="2">MILLIMETERS</th> <th colspan="2">INCHES</th> </tr> <tr> <th>MIN</th> <th>MAX</th> <th>MIN</th> <th>MAX</th> </tr> </thead> <tbody> <tr> <td>A</td> <td>4.85</td> <td>5.73</td> <td>0.193</td> <td>0.222</td> </tr> <tr> <td>B</td> <td>3.66</td> <td>4.14</td> <td>0.144</td> <td>0.163</td> </tr> <tr> <td>C</td> <td>1.73</td> <td>1.88</td> <td>0.068</td> <td>0.074</td> </tr> <tr> <td>D</td> <td>0.25</td> <td>0.46</td> <td>0.010</td> <td>0.018</td> </tr> <tr> <td>E</td> <td>0.38</td> <td>0.89</td> <td>0.015</td> <td>0.035</td> </tr> <tr> <td>F</td> <td>1.27</td> <td>BSC</td> <td>0.050</td> <td>BSC</td> </tr> <tr> <td>G</td> <td>0.19</td> <td>0.25</td> <td>0.007</td> <td>0.010</td> </tr> <tr> <td>H</td> <td>0.13</td> <td>0.25</td> <td>0.005</td> <td>0.010</td> </tr> <tr> <td>L</td> <td>4.80</td> <td>5.21</td> <td>0.189</td> <td>0.205</td> </tr> <tr> <td>P</td> <td>5.79</td> <td>6.20</td> <td>0.228</td> <td>0.244</td> </tr> </tbody> </table>	DIM	MILLIMETERS		INCHES		MIN	MAX	MIN	MAX	A	4.85	5.73	0.193	0.222	B	3.66	4.14	0.144	0.163	C	1.73	1.88	0.068	0.074	D	0.25	0.46	0.010	0.018	E	0.38	0.89	0.015	0.035	F	1.27	BSC	0.050	BSC	G	0.19	0.25	0.007	0.010	H	0.13	0.25	0.005	0.010	L	4.80	5.21	0.189	0.205	P	5.79	6.20	0.228	0.244															
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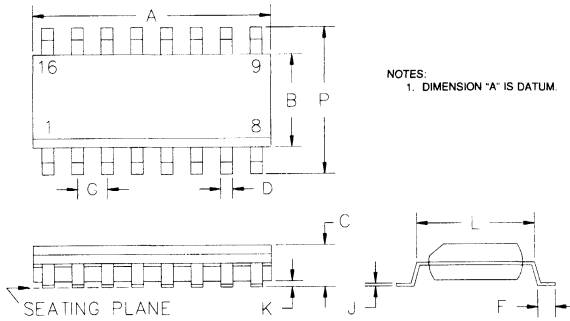
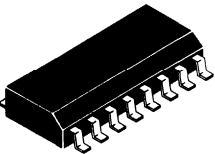
# MECHANICAL DIMENSIONS

**PLASTIC S.O.I.C.  
14-PIN  
"D" SUFFIX**



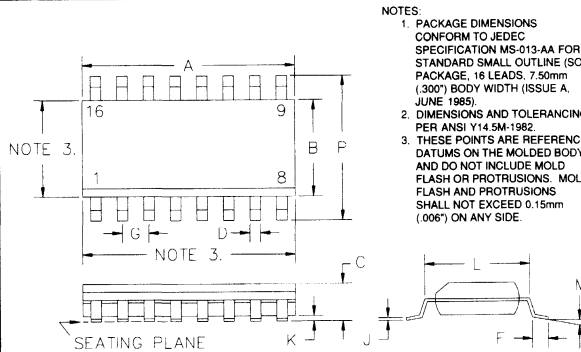
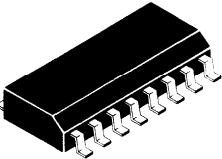
DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	8.54	8.74	0.336	0.344
B	3.81	4.01	0.150	0.158
C	1.35	1.75	0.053	0.069
D	0.35	0.46	0.014	0.018
F	0.67	0.77	0.026	0.030
G	1.27	BSC	0.050	BSC
J	0.19	0.25	0.007	0.010
K	0.10	0.20	0.004	0.008
L	4.82	5.21	0.189	0.205
P	5.79	6.20	0.228	0.244

**PLASTIC S.O.I.C.  
16-PIN  
"D" SUFFIX**



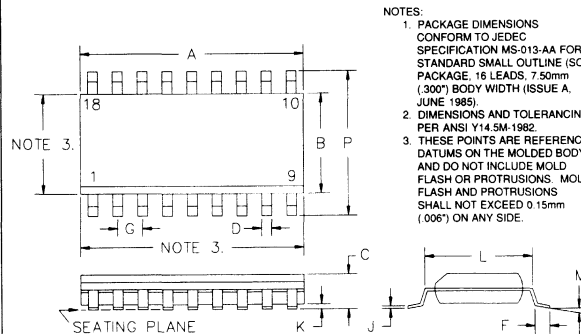
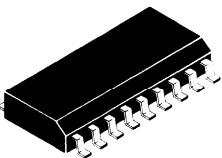
DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	9.78	10.01	0.385	0.394
B	3.81	4.01	0.150	0.158
C	1.35	1.75	0.053	0.069
D	0.35	0.46	0.014	0.018
F	0.57	0.77	0.020	0.030
G	1.27	BSC	0.050	BSC
J	0.19	0.25	0.007	0.010
K	0.10	0.20	0.004	0.008
L	4.82	5.21	0.189	0.205
P	5.79	6.20	0.228	0.244

**PLASTIC S.O.I.C.  
16-PIN WIDEBODY  
"DW" SUFFIX**



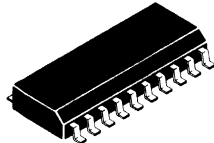
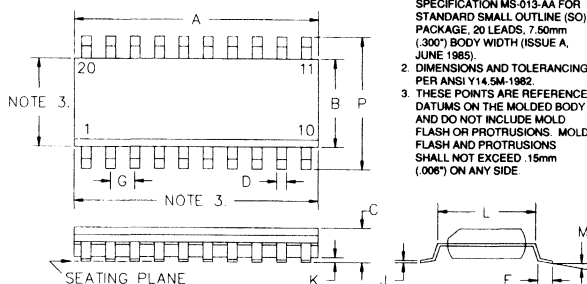
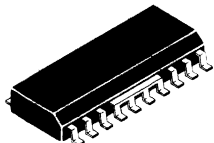
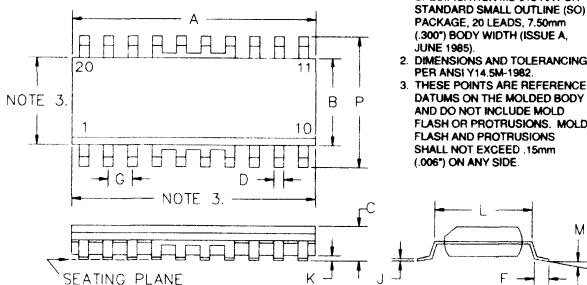
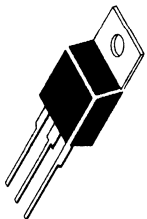
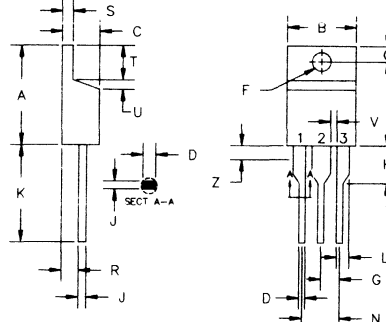

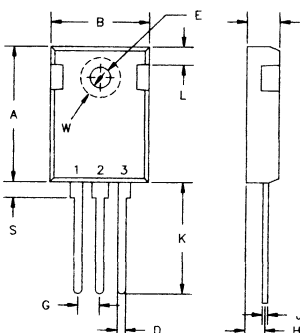
DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	-	10.67	-	0.420
B	7.49	7.75	0.295	0.305
C	2.35	2.65	0.093	0.104
D	0.25	0.46	0.010	0.018
F	0.64	0.89	0.025	0.035
G	1.27	BSC	0.050	BSC
J	0.23	0.32	0.009	0.013
K	0.10	0.30	0.004	0.012
L	8.13	8.64	0.320	0.340
M	0°	8°	0°	8°
P	10.26	10.65	0.404	0.419

**PLASTIC S.O.I.C.  
18-PIN WIDEBODY  
"DW" SUFFIX**

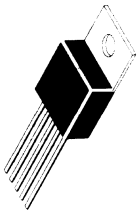
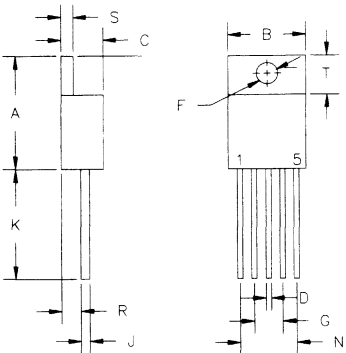
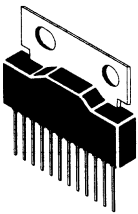
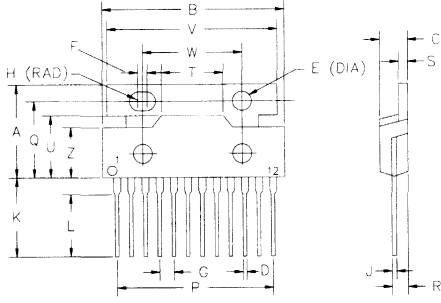
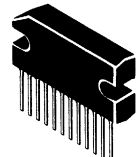
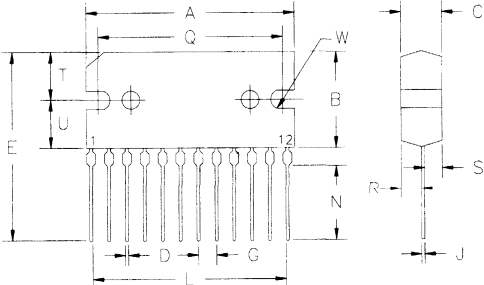
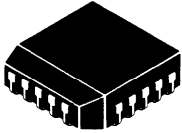
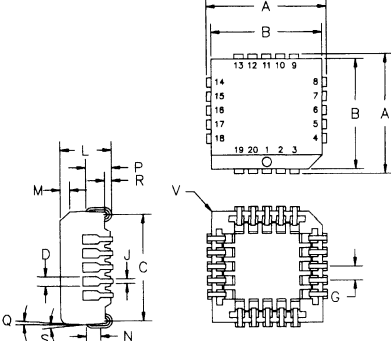


DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	-	13.21	-	0.520
B	7.49	7.75	0.295	0.305
C	2.35	2.65	0.093	0.104
D	0.25	0.46	0.010	0.018
F	0.64	0.89	0.025	0.035
G	1.27	BSC	0.050	BSC
J	0.23	0.32	0.009	0.013
K	0.10	0.30	0.004	0.012
L	8.13	8.64	0.320	0.340
M	0°	8°	0°	8°
P	10.26	10.65	0.404	0.419

# MECHANICAL DIMENSIONS

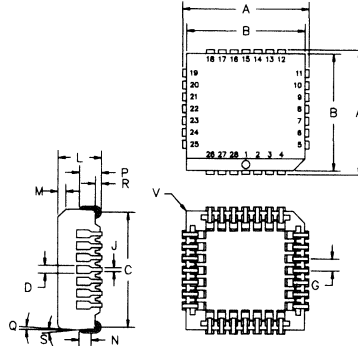
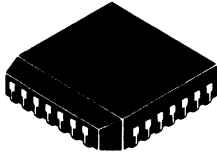
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# MECHANICAL DIMENSIONS

<p><b>PLASTIC TO-220</b> <b>5-PIN</b> <b>"P" SUFFIX</b></p> 	 <p>NOTES: 1. LEAD SPACING TOLERANCE IS NON-CUMULATIVE 2. EXACT BODY CONFIGURATION AT VENDOR'S OPTION WITHIN LIMITS SHOWN 3. LEAD GAUGE PLANE IS 0.030" (0.76mm) MAX. BELOW SEATING PLANE.</p>	<table border="1"> <thead> <tr> <th rowspan="2">DIM</th> <th colspan="2">MILLIMETERS</th> <th colspan="2">INCHES</th> </tr> <tr> <th>MIN</th> <th>MAX</th> <th>MIN</th> <th>MAX</th> </tr> </thead> <tbody> <tr> <td>A</td> <td>14.23</td> <td>16.51</td> <td>0.560</td> <td>0.650</td> </tr> <tr> <td>B</td> <td>9.66</td> <td>10.66</td> <td>0.380</td> <td>0.420</td> </tr> <tr> <td>C</td> <td>3.56</td> <td>4.82</td> <td>0.140</td> <td>0.190</td> </tr> <tr> <td>D</td> <td>0.46</td> <td>0.89</td> <td>0.018</td> <td>0.035</td> </tr> <tr> <td>F</td> <td>3.56</td> <td>4.06</td> <td>0.140</td> <td>0.160</td> </tr> <tr> <td>G</td> <td>3.40</td> <td>-</td> <td>0.134</td> <td>-</td> </tr> <tr> <td>J</td> <td>0.31</td> <td>1.14</td> <td>0.012</td> <td>0.045</td> </tr> <tr> <td>K</td> <td>12.70</td> <td>14.73</td> <td>0.500</td> <td>0.580</td> </tr> <tr> <td>N</td> <td>6.80</td> <td>TYP</td> <td>0.268</td> <td>TYP</td> </tr> <tr> <td>R</td> <td>2.04</td> <td>2.92</td> <td>0.080</td> <td>0.115</td> </tr> <tr> <td>S</td> <td>1.14</td> <td>1.39</td> <td>0.045</td> <td>0.055</td> </tr> <tr> <td>T</td> <td>5.85</td> <td>6.85</td> <td>0.230</td> <td>0.270</td> </tr> </tbody> </table>	DIM	MILLIMETERS		INCHES		MIN	MAX	MIN	MAX	A	14.23	16.51	0.560	0.650	B	9.66	10.66	0.380	0.420	C	3.56	4.82	0.140	0.190	D	0.46	0.89	0.018	0.035	F	3.56	4.06	0.140	0.160	G	3.40	-	0.134	-	J	0.31	1.14	0.012	0.045	K	12.70	14.73	0.500	0.580	N	6.80	TYP	0.268	TYP	R	2.04	2.92	0.080	0.115	S	1.14	1.39	0.045	0.055	T	5.85	6.85	0.230	0.270																																								
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J	0.36	0.46	0.014	0.018																																																																																																											
K	-	27.94	-	1.100																																																																																																											
N	6.10	6.86	0.240	0.270																																																																																																											
Q	23.62	24.38	0.930	0.960																																																																																																											
R	2.03	2.54	0.080	0.100																																																																																																											
S	1.78	2.29	0.070	0.090																																																																																																											
T	6.60	7.11	0.260	0.280																																																																																																											
U	6.60	7.11	0.260	0.280																																																																																																											
W	-	1.80	-	0.070																																																																																																											
<p><b>PLASTIC LEADED CHIP CARRIER (PLCC)</b> <b>20-PIN "Q" SUFFIX</b></p> 		<table border="1"> <thead> <tr> <th rowspan="2">DIM</th> <th colspan="2">MILLIMETERS</th> <th colspan="2">INCHES</th> </tr> <tr> <th>MIN</th> <th>MAX</th> <th>MIN</th> <th>MAX</th> </tr> </thead> <tbody> <tr> <td>A</td> <td>9.70</td> <td>10.03</td> <td>0.382</td> <td>0.395</td> </tr> <tr> <td>B</td> <td>8.89</td> <td>9.04</td> <td>0.350</td> <td>0.356</td> </tr> <tr> <td>C</td> <td>8.08</td> <td>8.38</td> <td>0.318</td> <td>0.330</td> </tr> <tr> <td>D</td> <td>0.66</td> <td>0.81</td> <td>0.026</td> <td>0.032</td> </tr> <tr> <td>G</td> <td>1.19</td> <td>1.35</td> <td>0.047</td> <td>0.053</td> </tr> <tr> <td>J</td> <td>0.36</td> <td>0.46</td> <td>0.014</td> <td>0.018</td> </tr> <tr> <td>L</td> <td>4.06</td> <td>4.78</td> <td>0.160</td> <td>0.188</td> </tr> <tr> <td>M</td> <td>1.27</td> <td>-</td> <td>0.050</td> <td>-</td> </tr> <tr> <td>N</td> <td>1.52</td> <td>-</td> <td>0.060</td> <td>-</td> </tr> <tr> <td>P</td> <td>2.41</td> <td>-</td> <td>0.095</td> <td>-</td> </tr> <tr> <td>Q</td> <td>-</td> <td>3°</td> <td>-</td> <td>3°</td> </tr> <tr> <td>R</td> <td>0.63</td> <td>1.14</td> <td>0.025</td> <td>0.045</td> </tr> <tr> <td>S</td> <td>-</td> <td>3°</td> <td>-</td> <td>3°</td> </tr> <tr> <td>V</td> <td>-</td> <td>0.25</td> <td>-</td> <td>0.010</td> </tr> </tbody> </table>	DIM	MILLIMETERS		INCHES		MIN	MAX	MIN	MAX	A	9.70	10.03	0.382	0.395	B	8.89	9.04	0.350	0.356	C	8.08	8.38	0.318	0.330	D	0.66	0.81	0.026	0.032	G	1.19	1.35	0.047	0.053	J	0.36	0.46	0.014	0.018	L	4.06	4.78	0.160	0.188	M	1.27	-	0.050	-	N	1.52	-	0.060	-	P	2.41	-	0.095	-	Q	-	3°	-	3°	R	0.63	1.14	0.025	0.045	S	-	3°	-	3°	V	-	0.25	-	0.010																														
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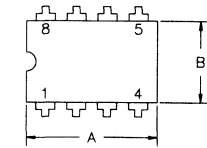
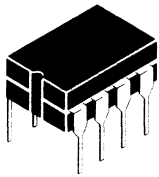
# MECHANICAL DIMENSIONS

**PLASTIC LEADED CHIP CARRIER (PLCC)  
28-PIN "Q" SUFFIX**

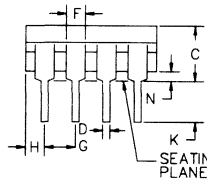


DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	12.19	12.70	0.480	0.500
B	11.43	11.56	0.450	0.455
C	10.54	10.92	0.415	0.430
D	0.64	0.89	0.025	0.035
E	1.27	TYP	0.050	TYP
F	0.36	0.46	0.014	0.018
G	4.06	4.83	0.160	0.190
H	1.14	—	0.045	—
I	0.76	1.27	0.030	0.050
J	2.41	—	0.095	—
K	3°	6°	3°	6°
L	0.63	1.14	0.025	0.045
M	3°	6°	3°	6°
N	—	0.25	—	0.010

**CERAMIC MINI DIP  
8-PIN "Y" SUFFIX**

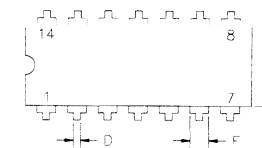
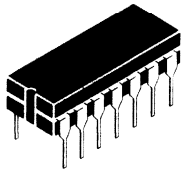


NOTES:  
1. LEADS WITHIN 0.13mm (0.005) RAD OF TRUE POSITION AT SEATING PLANE AT MAXIMUM MATERIAL CONDITION.  
2. DIMENSION 'L' TO CENTER OF LEADS WHEN FORMED PARALLEL.

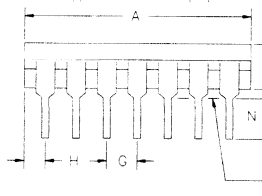


DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	9.91	10.92	0.390	0.430
B	5.59	7.11	0.220	0.280
C	4.32	5.08	0.170	0.200
D	0.38	0.51	0.015	0.020
E	1.02	1.78	0.040	0.070
F	2.54	BSC	0.100	BSC
G	1.14	1.65	0.045	0.065
H	0.20	0.30	0.008	0.012
I	3.18	4.06	0.125	0.160
J	7.37	7.87	0.290	0.310
K	—	15°	—	15°
L	0.51	1.02	0.020	0.040

**CERAMIC DIP  
14-PIN "J" SUFFIX**

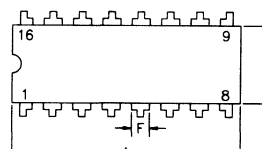
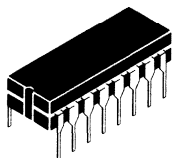


NOTES:  
1. ALL RULES AND NOTES ASSOCIATED WITH MO-001 AA OUTLINE SHALL APPLY.  
2. DIMENSION 'L' TO CENTER OF LEADS WHEN FORMED PARALLEL.  
3. LEADS WITHIN 0.25mm (0.010) DIA OF TRUE POSITION AT SEATING PLANE AND MAXIMUM MATERIAL CONDITION.

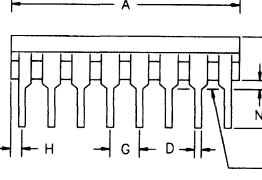


DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	18.80	19.94	0.740	0.785
B	5.59	7.11	0.220	0.280
C	—	5.08	—	0.200
D	0.38	0.51	0.015	0.020
E	1.02	1.77	0.040	0.070
F	2.54	BSC	0.100	BSC
G	0.20	0.30	0.008	0.012
H	3.18	4.06	0.125	0.160
I	7.37	7.87	0.290	0.310
J	—	15°	—	15°
K	0.51	0.76	0.020	0.030

**CERAMIC DIP  
16-PIN "J" SUFFIX**



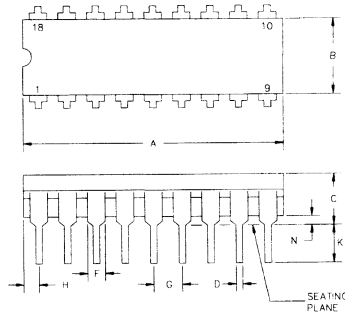
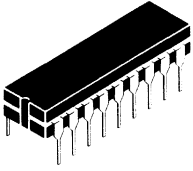
NOTES:  
1. LEADS WITHIN 0.13mm (0.005) RADIUS OF TRUE POSITION AT SEATING PLANE AT MAXIMUM MATERIAL CONDITION.  
2. PKG. INDEX: NOTCH IN LEAD IN CERAMIC OR INK DOT.  
3. DIMENSION 'L' TO CENTER OF LEADS WHEN FORMED PARALLEL.



DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	18.80	19.94	0.740	0.785
B	5.59	7.11	0.220	0.280
C	—	5.08	—	0.200
D	0.38	0.51	0.015	0.020
E	1.02	1.77	0.040	0.070
F	2.54	BSC	0.100	BSC
G	0.20	0.30	0.008	0.012
H	3.18	4.06	0.125	0.160
I	7.37	7.87	0.290	0.310
J	—	15°	—	15°
K	0.51	0.76	0.020	0.030

# MECHANICAL DIMENSIONS

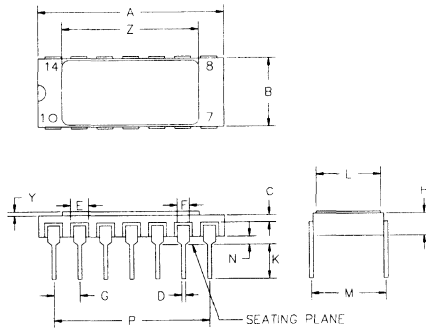
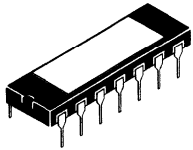
## CERAMIC DIP 18-PIN "J" SUFFIX



- NOTES:
- LEADS, TRUE POSITIONED WITHIN 0.25mm (0.010) DIA. AT SEATING PLANE, AT MAXIMUM MATERIAL CONDITION
  - DIMENSION 'L' TO CENTER OF LEADS WHEN FORMED PARALLEL.
  - DIM 'A' & 'B' INCLUDES MENISCUS.

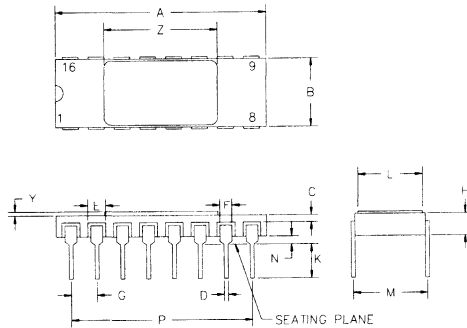
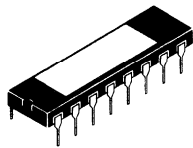
DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	—	24.38	—	0.960
B	5.59	7.11	0.220	0.280
C	—	5.08	—	0.200
D	0.38	0.51	0.15	0.020
F	0.76	1.78	0.030	0.070
G	2.54	BSC	0.100	BSC
H	—	2.03	—	0.080
J	0.20	0.30	0.008	0.012
K	3.18	5.08	0.125	0.200
L	7.37	7.87	0.290	0.310
M	—	15°	—	15°
N	0.51	0.76	0.020	0.030

## CERAMIC SIDE BRAZED (DIP) 14-PIN "H" SUFFIX



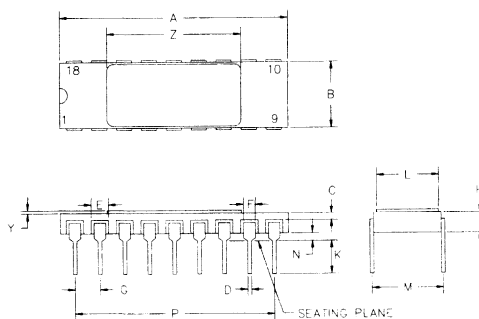
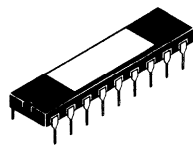
DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	18.54	19.81	0.730	0.780
B	7.11	8.13	0.280	0.320
C	0.18	—	0.007	—
D	0.38	0.53	0.015	0.021
E	1.78	TYP	0.070	TYP
F	1.02	1.40	0.040	0.055
G	2.54	TYP	0.100	TYP
H	1.78	3.05	0.070	0.120
K	3.18	—	0.125	—
L	—	7.37	—	0.290
M	7.11	8.13	0.280	0.320
N	0.64	1.14	0.025	0.045
P	15.00	15.49	0.590	0.610
Y	—	0.76	—	0.030
Z	11.81	12.32	0.465	0.485

## CERAMIC SIDE BRAZED (DIP) 16-PIN "H" SUFFIX



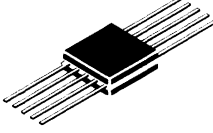
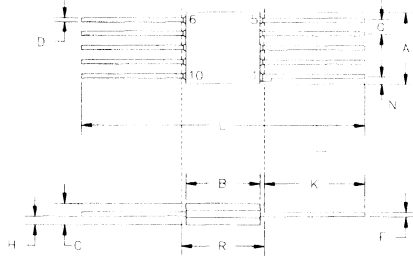
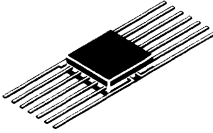
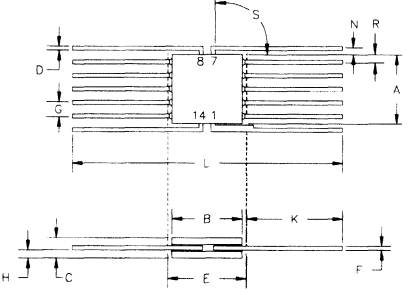
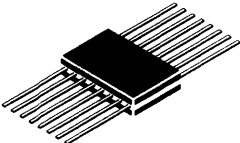
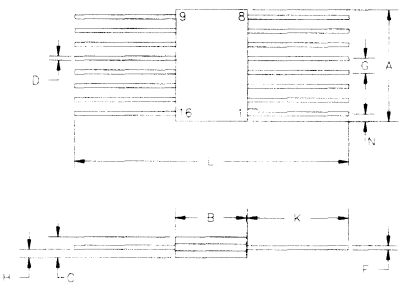
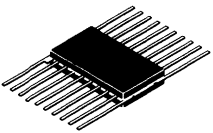
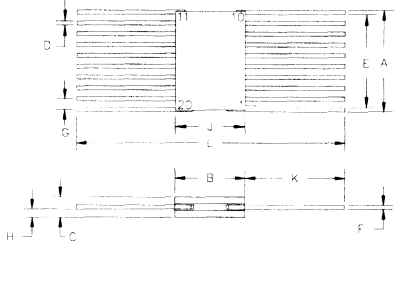
DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	19.81	20.32	0.780	0.800
B	7.11	8.13	0.280	0.320
C	0.18	—	0.007	—
D	0.38	0.53	0.015	0.021
E	1.78	TYP	0.070	TYP
F	1.02	1.40	0.040	0.055
G	2.54	TYP	0.100	TYP
H	1.78	3.05	0.070	0.120
K	3.18	—	0.125	—
L	—	7.37	—	0.290
M	7.11	8.13	0.280	0.320
N	0.64	1.14	0.025	0.045
P	17.53	18.03	0.690	0.710
Y	—	0.76	—	0.030
Z	11.81	12.32	0.465	0.485

## CERAMIC SIDE BRAZED (DIP) 18-PIN "H" SUFFIX



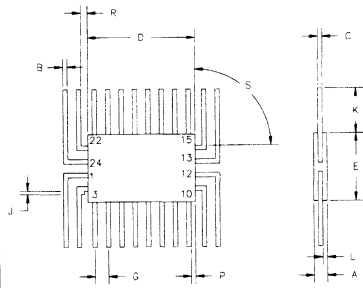
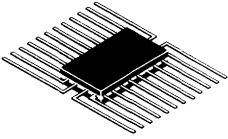
DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	22.35	23.37	0.880	0.920
B	7.11	8.13	0.280	0.320
C	0.18	—	0.007	—
D	0.38	0.53	0.015	0.021
E	1.78	TYP	0.070	TYP
F	1.02	1.40	0.040	0.055
G	2.54	TYP	0.100	TYP
H	1.78	3.05	0.070	0.120
K	3.18	—	0.125	—
L	—	7.37	—	0.290
M	7.11	8.13	0.280	0.320
N	0.64	1.14	0.025	0.045
P	20.07	20.57	0.790	0.810
Y	—	0.76	—	0.030
Z	11.81	12.32	0.465	0.485

# MECHANICAL DIMENSIONS

<p><b>CERAMIC FLATPACK</b> <b>10-PIN</b> <b>"F" SUFFIX</b></p> 	<p><b>NOTES:</b></p> <ol style="list-style-type: none"> <li>LEADS ARE WITHIN 0.13(0.005) RADIUS OF TRUE POSITION (TP) AT MAXIMUM MATERIAL CONDITION.</li> <li>DIMENSION "G" DETERMINES A ZONE WITHIN WHICH ALL BODY AND LEAD IRREGULARITIES LIE.</li> </ol>  <table border="1"> <thead> <tr> <th rowspan="2">DIM</th> <th colspan="2">MILLIMETERS</th> <th colspan="2">INCHES</th> </tr> <tr> <th>MIN</th> <th>MAX</th> <th>MIN</th> <th>MAX</th> </tr> </thead> <tbody> <tr> <td>A</td> <td>—</td> <td>7.37</td> <td>—</td> <td>0.290</td> </tr> <tr> <td>B</td> <td>6.04</td> <td>6.40</td> <td>0.238</td> <td>0.252</td> </tr> <tr> <td>C</td> <td>1.45</td> <td>1.70</td> <td>0.057</td> <td>0.067</td> </tr> <tr> <td>D</td> <td>0.25</td> <td>0.483</td> <td>0.010</td> <td>0.019</td> </tr> <tr> <td>F</td> <td>0.076</td> <td>0.153</td> <td>0.003</td> <td>0.006</td> </tr> <tr> <td>G</td> <td>1.27</td> <td>BSC</td> <td>0.050</td> <td>BSC</td> </tr> <tr> <td>H</td> <td>0.51</td> <td>1.02</td> <td>0.020</td> <td>0.040</td> </tr> <tr> <td>K</td> <td>6.35</td> <td>9.40</td> <td>0.250</td> <td>0.370</td> </tr> <tr> <td>L</td> <td>18.74</td> <td>25.4</td> <td>0.738</td> <td>1.000</td> </tr> <tr> <td>N</td> <td>0.20</td> <td>0.38</td> <td>0.008</td> <td>0.015</td> </tr> <tr> <td>R</td> <td>—</td> <td>6.91</td> <td>—</td> <td>0.272</td> </tr> </tbody> </table>	DIM	MILLIMETERS		INCHES		MIN	MAX	MIN	MAX	A	—	7.37	—	0.290	B	6.04	6.40	0.238	0.252	C	1.45	1.70	0.057	0.067	D	0.25	0.483	0.010	0.019	F	0.076	0.153	0.003	0.006	G	1.27	BSC	0.050	BSC	H	0.51	1.02	0.020	0.040	K	6.35	9.40	0.250	0.370	L	18.74	25.4	0.738	1.000	N	0.20	0.38	0.008	0.015	R	—	6.91	—	0.272										
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<p><b>CERAMIC FLATPACK</b> <b>14-PIN</b> <b>"F" SUFFIX</b></p> 	<p><b>NOTES:</b></p> <ol style="list-style-type: none"> <li>DIMENSION "E" ALLOWS FOR OFF-CENTER LID, MENISCUS AND GLASS OVERRUN.</li> <li>DIMENSION "N" APPLIES TO LEADS 1, 7, 8, AND 14.</li> <li>DIMENSION "H" IS MEASURED AT THE POINT OF EXIT OF THE LEAD FROM THE BODY.</li> <li>DIMENSION "R" APPLIES TO ALL FOUR CORNERS.</li> <li>DIMENSION "G" IS THE BASIC PIN SPACING BETWEEN CENTER LINES IN TWELVE POSITIONS.</li> </ol>  <table border="1"> <thead> <tr> <th rowspan="2">DIM</th> <th colspan="2">MILLIMETERS</th> <th colspan="2">INCHES</th> </tr> <tr> <th>MIN</th> <th>MAX</th> <th>MIN</th> <th>MAX</th> </tr> </thead> <tbody> <tr> <td>A</td> <td>—</td> <td>7.11</td> <td>—</td> <td>0.280</td> </tr> <tr> <td>B</td> <td>6.10</td> <td>6.40</td> <td>0.240</td> <td>0.252</td> </tr> <tr> <td>C</td> <td>1.45</td> <td>1.70</td> <td>0.057</td> <td>0.067</td> </tr> <tr> <td>D</td> <td>0.25</td> <td>0.48</td> <td>0.010</td> <td>0.019</td> </tr> <tr> <td>F</td> <td>—</td> <td>6.91</td> <td>—</td> <td>0.272</td> </tr> <tr> <td>F</td> <td>0.08</td> <td>0.15</td> <td>0.003</td> <td>0.006</td> </tr> <tr> <td>G</td> <td>1.27</td> <td>BSC</td> <td>0.050</td> <td>BSC</td> </tr> <tr> <td>H</td> <td>0.51</td> <td>1.02</td> <td>0.020</td> <td>0.040</td> </tr> <tr> <td>K</td> <td>6.35</td> <td>9.40</td> <td>0.250</td> <td>0.370</td> </tr> <tr> <td>L</td> <td>19.0</td> <td>25.4</td> <td>0.750</td> <td>1.000</td> </tr> <tr> <td>N</td> <td>0.10</td> <td>—</td> <td>0.004</td> <td>—</td> </tr> <tr> <td>R</td> <td>0.13</td> <td>—</td> <td>0.005</td> <td>—</td> </tr> <tr> <td>S</td> <td>30°</td> <td>90°</td> <td>30°</td> <td>90°</td> </tr> </tbody> </table>	DIM	MILLIMETERS		INCHES		MIN	MAX	MIN	MAX	A	—	7.11	—	0.280	B	6.10	6.40	0.240	0.252	C	1.45	1.70	0.057	0.067	D	0.25	0.48	0.010	0.019	F	—	6.91	—	0.272	F	0.08	0.15	0.003	0.006	G	1.27	BSC	0.050	BSC	H	0.51	1.02	0.020	0.040	K	6.35	9.40	0.250	0.370	L	19.0	25.4	0.750	1.000	N	0.10	—	0.004	—	R	0.13	—	0.005	—	S	30°	90°	30°	90°
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# MECHANICAL DIMENSIONS

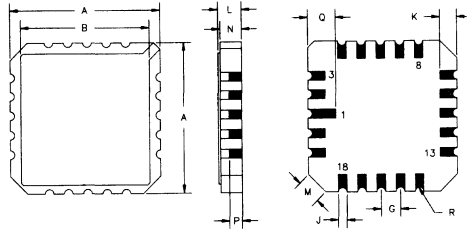
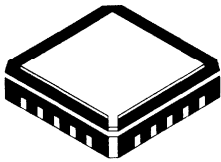
## CERAMIC FLAT PACK 24-PIN "F" SUFFIX



- NOTES:
1. DIMENSION "L" SHALL BE MEASURED AT THE POINT OF EXIT OF THE LEAD FROM THE BODY.
  2. DIMENSION "D" ALLOWS FOR OFF-CENTER LID, MENISCUS AND GLASS OVERRUN.
  3. THE BASIC PIN SPACING IS 0.050" (1.27mm) BETWEEN CENTERLINES. EACH PIN CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.005$  (0.13mm) OF ITS EXACT LONGITUDINAL POSITION RELATIVE TO PINS 1 AND 24.
  4. DIMENSION "PP" APPLIES TO ALL FOUR CORNERS (LEADS NUMBER 3, 10, 15, AND 22).
  5. DIMENSION "R" APPLIES TO LEADS NUMBER 2, 11, 14, AND 23.
  6. DIMENSION "S" APPLIES TO LEADS NUMBER 1, 2, 11, 12, 13, 14, 23, AND 24.

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	1.650	1.900	0.065	0.075
B	0.380	0.480	0.015	0.019
C	0.080	0.150	0.003	0.006
D	-	11.18	-	0.440
E	6.27	6.63	0.247	0.261
G	1.27	BSC	0.050	BSC
J	0.200	0.380	0.008	0.015
K	6.350	9.400	0.250	0.370
L	0.510	1.020	0.020	0.040
P	0.130	-	0.005	-
R	0.100	-	0.004	-
S	30°	90°	30°	90°

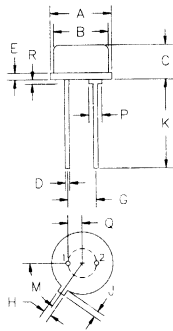
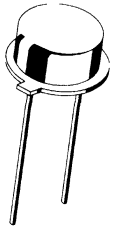
## CERAMIC LEADLESS CHIP CARRIER (LCC) 20-PIN "L" SUFFIX



- NOTES:
1. ALL EXPOSED METALLIZED AREA SHALL BE GOLD PLATED 60 MICRO-INCH MINIMUM THICKNESS OVER NICKEL PLATED UNLESS OTHERWISE SPECIFIED PURCHASE ORDER.

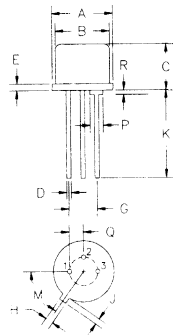
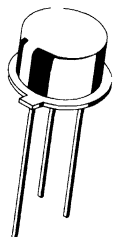
DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	8.64	9.14	0.340	0.360
B	-	8.128	-	0.320
G	1.270	TYP	0.050	TYP
J	0.635	TYP	0.025	TYP
K	1.02	1.52	0.040	0.060
L	1.626	2.286	0.064	0.090
M	1.016	TYP	0.040	TYP
N	1.372	1.68	0.054	0.066
P	-	1.168	-	0.046
Q	1.91	2.41	0.075	0.095
R	0.203R	-	0.008R	-

## METAL CAN TO-46 2-PIN "Z" SUFFIX



DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	5.207	5.842	0.205	0.230
B	4.521	4.953	0.178	0.195
C	-	2.667	-	0.105
D	0.406	0.533	0.016	0.021
E	-	0.381	-	0.015
G	2.54	BSC	0.100	BSC
H	0.914	1.14	0.036	0.045
J	0.711	1.092	0.028	0.043
K	12.70	-	0.500	-
M	42°	48°	42°	48°
P	-	1.143	-	0.045
Q	1.27	TYP	0.050	TYP
R	-	0.381	-	0.015

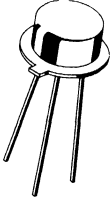
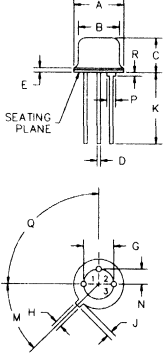
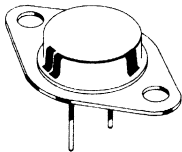
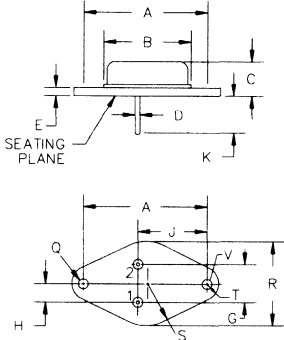
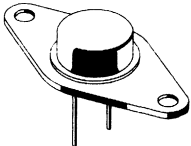
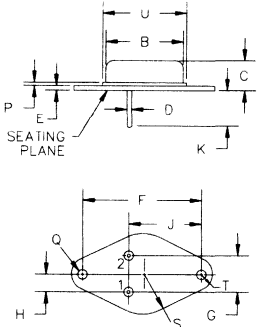
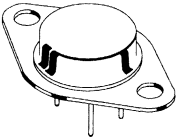
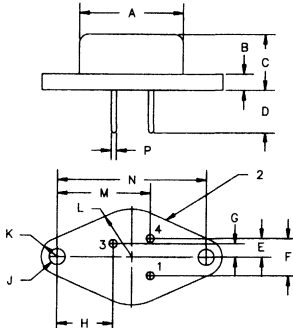
## METAL CAN TO-52 3-PIN "Z" SUFFIX



DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	5.207	5.842	0.205	0.230
B	4.521	4.953	0.178	0.195
C	-	4.064	-	0.160
D	0.406	0.533	0.016	0.021
E	-	0.381	-	0.015
G	2.54	BSC	0.100	BSC
H	0.914	1.14	0.036	0.045
J	0.711	1.092	0.028	0.043
K	12.70	-	0.500	-
M	42°	48°	42°	48°
P	-	1.143	-	0.045
Q	1.27	TYP	0.050	TYP
R	-	0.381	-	0.015

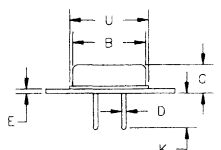
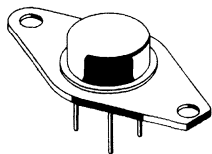


# MECHANICAL DIMENSIONS

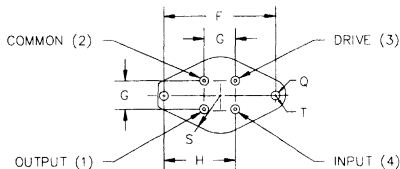
<p><b>METAL CAN TO-39</b> <b>3-PIN</b> <b>"T" SUFFIX</b></p> 		<table border="1"> <thead> <tr> <th rowspan="2">DIM</th> <th colspan="2">MILLIMETERS</th> <th colspan="2">INCHES</th> </tr> <tr> <th>MIN</th> <th>MAX</th> <th>MIN</th> <th>MAX</th> </tr> </thead> <tbody> <tr> <td>A</td> <td>8.89</td> <td>9.40</td> <td>0.350</td> <td>0.370</td> </tr> <tr> <td>B</td> <td>8.00</td> <td>8.51</td> <td>0.315</td> <td>0.335</td> </tr> <tr> <td>C</td> <td>4.19</td> <td>4.70</td> <td>0.165</td> <td>0.185</td> </tr> <tr> <td>D</td> <td>0.406</td> <td>0.533</td> <td>0.016</td> <td>0.021</td> </tr> <tr> <td>E</td> <td>—</td> <td>1.02</td> <td>—</td> <td>0.040</td> </tr> <tr> <td>G</td> <td>5.08</td> <td>TYP</td> <td>0.200</td> <td>TYP</td> </tr> <tr> <td>H</td> <td>0.711</td> <td>0.864</td> <td>0.028</td> <td>0.034</td> </tr> <tr> <td>J</td> <td>0.74</td> <td>1.14</td> <td>0.029</td> <td>0.045</td> </tr> <tr> <td>K</td> <td>12.70</td> <td>—</td> <td>0.500</td> <td>—</td> </tr> <tr> <td>M</td> <td>45°</td> <td>TYP</td> <td>45°</td> <td>TYP</td> </tr> <tr> <td>N</td> <td>2.54</td> <td>TYP</td> <td>0.100</td> <td>TYP</td> </tr> <tr> <td>P</td> <td>—</td> <td>1.143</td> <td>—</td> <td>0.045</td> </tr> <tr> <td>Q</td> <td>90°</td> <td>TYP</td> <td>90°</td> <td>TYP</td> </tr> <tr> <td>R</td> <td>—</td> <td>0.635</td> <td>—</td> <td>0.025</td> </tr> </tbody> </table>	DIM	MILLIMETERS		INCHES		MIN	MAX	MIN	MAX	A	8.89	9.40	0.350	0.370	B	8.00	8.51	0.315	0.335	C	4.19	4.70	0.165	0.185	D	0.406	0.533	0.016	0.021	E	—	1.02	—	0.040	G	5.08	TYP	0.200	TYP	H	0.711	0.864	0.028	0.034	J	0.74	1.14	0.029	0.045	K	12.70	—	0.500	—	M	45°	TYP	45°	TYP	N	2.54	TYP	0.100	TYP	P	—	1.143	—	0.045	Q	90°	TYP	90°	TYP	R	—	0.635	—	0.025
DIM	MILLIMETERS			INCHES																																																																													
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# MECHANICAL DIMENSIONS

**METAL CAN (SM)**  
**4-PIN**  
**"R" SUFFIX**

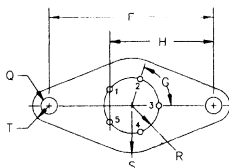
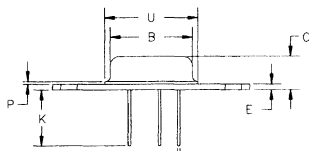
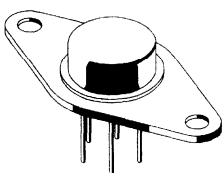


- NOTES:  
 1. CASE IS ELECTRICALLY ISOLATED.  
 2. LOADS MAY BE SOLDERED TO WITHIN 1/16" OF BASE PROVIDED TEMPERATURE-TIME EXPOSURE IS LESS THAN 260 C FOR 10 SECONDS.



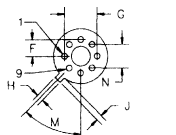
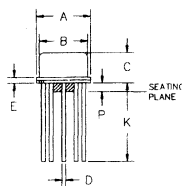
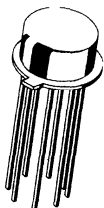
DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
B	11.94	12.70	0.470	0.500
C	6.35	8.636	0.250	0.340
D	0.711	0.864	0.028	0.034
E	1.270	1.905	0.050	0.075
F	24.13	24.64	0.950	0.970
G	5.08	TYP	0.200	TYP
H	14.48	14.99	0.570	0.590
K	9.398	9.906	0.370	0.390
Q	3.607	3.861	0.142	0.152
S	-	8.89R	-	0.350R
T	-	3.68R	-	0.145R
U	-	15.75	-	0.620

**METAL CAN TO-66**  
**5-PIN**  
**"R" SUFFIX**



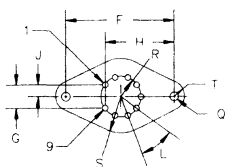
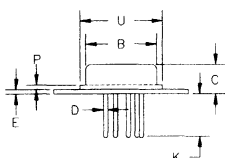
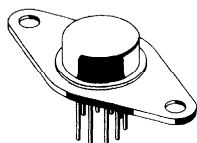
DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
B	11.94	12.70	0.470	0.500
C	6.35	8.64	0.250	0.340
D	0.71	0.86	0.028	0.034
E	1.27	1.90	0.050	0.075
F	24.33	24.43	0.958	0.962
G	7.25	TYP	7.25	TYP
H	14.48	14.99	0.570	0.590
K	9.14	-	0.360	-
P	-	1.27	-	0.050
Q	3.61	3.86	0.142	0.152
R	-	4.11R	-	0.162R
S	-	8.89R	-	0.350R
T	-	3.68R	-	0.145R
U	-	15.75	-	0.620

**METAL CAN TO-99**  
**8-PIN**  
**"T" SUFFIX**



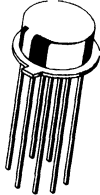
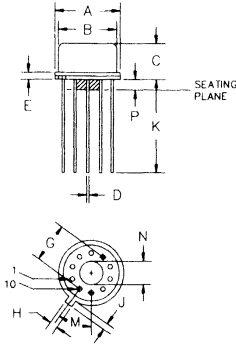
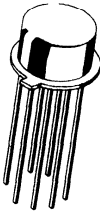
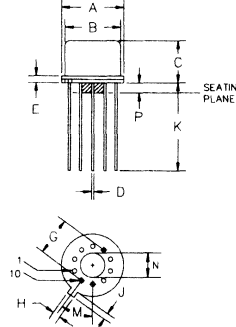
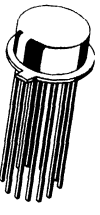
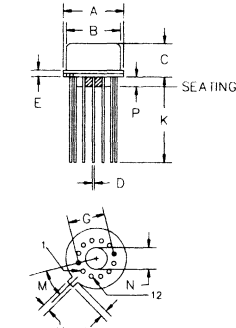
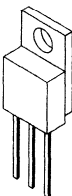
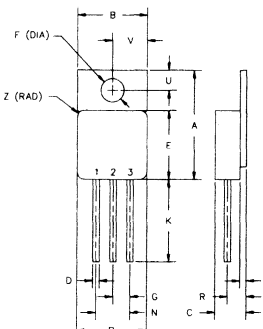
DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	8.509	9.398	0.335	0.370
B	7.772	8.509	0.306	0.335
C	4.191	4.699	0.165	0.185
D	0.406	0.533	0.016	0.021
E	-	1.016	-	0.040
F	2.54	TYP	0.100	TYP
G	5.08	TYP	0.200	TYP
H	0.711	0.864	0.028	0.034
J	0.737	1.14	0.029	0.045
K	12.70	14.48	0.500	0.570
M	4.57	TYP	0.180	TYP
N	3.556	4.064	0.140	0.160
P	0.254	1.016	0.010	0.040

**METAL CAN TO-66**  
**9-PIN**  
**"R" SUFFIX**



DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
B	11.94	12.70	0.470	0.500
C	6.35	8.636	0.250	0.340
D	0.711	0.863	0.028	0.034
E	1.270	1.905	0.050	0.075
F	24.33	24.43	0.958	0.962
G	4.826	5.334	0.190	0.210
H	14.47	14.99	0.570	0.590
J	2.362	2.718	0.093	0.107
K	9.14	-	0.360	-
L	36°	TYP	36°	TYP
M	-	1.270	-	0.050
N	3.607	3.861	0.142	0.152
Q	-	4.11R	-	0.162R
R	-	8.89R	-	0.350R
S	-	3.68R	-	0.145R
T	-	15.75	-	0.620

# MECHANICAL DIMENSIONS

<p><b>METAL CAN TO-100</b> <b>10-PIN</b> <b>"T" SUFFIX</b></p> 		<table border="1"> <thead> <tr> <th rowspan="2">DIM</th> <th colspan="2">MILLIMETERS</th> <th colspan="2">INCHES</th> </tr> <tr> <th>MIN</th> <th>MAX</th> <th>MIN</th> <th>MAX</th> </tr> </thead> <tbody> <tr> <td>A</td> <td>8.890</td> <td>9.398</td> <td>0.350</td> <td>0.370</td> </tr> <tr> <td>B</td> <td>8.001</td> <td>8.509</td> <td>0.315</td> <td>0.335</td> </tr> <tr> <td>C</td> <td>4.191</td> <td>4.699</td> <td>0.165</td> <td>0.185</td> </tr> <tr> <td>D</td> <td>0.406</td> <td>0.533</td> <td>0.016</td> <td>0.021</td> </tr> <tr> <td>E</td> <td>-</td> <td>1.016</td> <td>-</td> <td>0.040</td> </tr> <tr> <td>G</td> <td>5.842</td> <td>TYP</td> <td>0.230</td> <td>TYP</td> </tr> <tr> <td>H</td> <td>0.711</td> <td>0.864</td> <td>0.028</td> <td>0.034</td> </tr> <tr> <td>J</td> <td>0.737</td> <td>1.143</td> <td>0.029</td> <td>0.045</td> </tr> <tr> <td>K</td> <td>12.70</td> <td>14.48</td> <td>0.500</td> <td>0.570</td> </tr> <tr> <td>M</td> <td>36°</td> <td>TYP</td> <td>36°</td> <td>TYP</td> </tr> <tr> <td>N</td> <td>3.556</td> <td>4.064</td> <td>0.140</td> <td>0.160</td> </tr> <tr> <td>P</td> <td>0.254</td> <td>1.016</td> <td>0.010</td> <td>0.040</td> </tr> </tbody> </table>	DIM	MILLIMETERS		INCHES		MIN	MAX	MIN	MAX	A	8.890	9.398	0.350	0.370	B	8.001	8.509	0.315	0.335	C	4.191	4.699	0.165	0.185	D	0.406	0.533	0.016	0.021	E	-	1.016	-	0.040	G	5.842	TYP	0.230	TYP	H	0.711	0.864	0.028	0.034	J	0.737	1.143	0.029	0.045	K	12.70	14.48	0.500	0.570	M	36°	TYP	36°	TYP	N	3.556	4.064	0.140	0.160	P	0.254	1.016	0.010	0.040										
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December 1988

**THE SG1401 VIDEO AMPLIFIER**

**ABSTRACT**

The SG1401-SG3401 has been designed to provide maximum versatility as a general-purpose, single-ended amplifier. With its broad frequency capability, this circuit will be useful in a wide range of applications provided that the usual considerations for high frequency circuit designs are observed. The following information is presented toward aiding in the optimization of the many possible configurations of this device.

**FIXED GAIN**

In the circuit configurations shown in Figure 1, the overall voltage gain is approximated by resistors R1 and the parallel combination of R2 and R3, as

$$A_v \approx 1 + \frac{R_1}{R} \text{ , where } R = \frac{R_2 R_3}{R_2 + R_3}$$

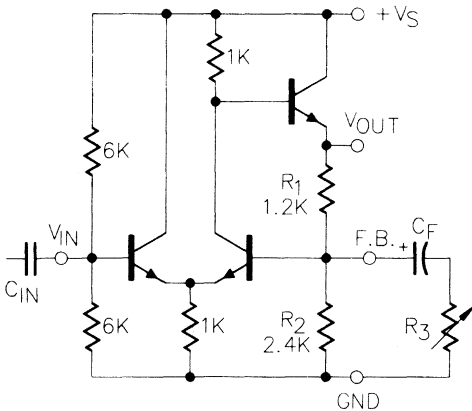


Figure 1.

With no external connections, the voltage gain is determined solely by R1 and R2 and is 1½ or 3 dB. Decreasing the effective value of R2 by capacitively coupling a lower resistor in parallel, raises the gain. Four fixed gain settings are provided internal to the circuit; however, any other setting within the maximum gain of the amplifier is possible with external resistors as shown in Figure 2.

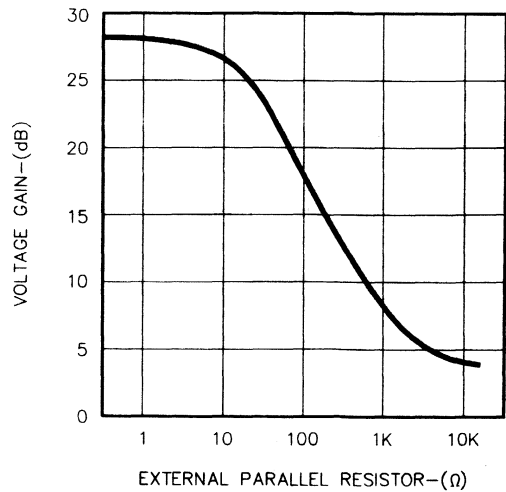


Figure 2. External Gain Control

# APPLICATION NOTES – SG1401

The value of the coupling capacitor,  $C_F$  is determined by the low frequency response desired, as its capacitive reactance will add to the value of the resistance it couples. Therefore, the lower cutoff frequency will be

$$f_c \approx \frac{1}{2\pi R_3 C_F}$$

Utilizing the internal 90 or 460 ohm resistors for higher gain settings provides the added advantage of maximum temperature stability since the close tracking of adjacent diffused resistors keeps their ratio constant. Typical temperature variation of this circuit is shown below:

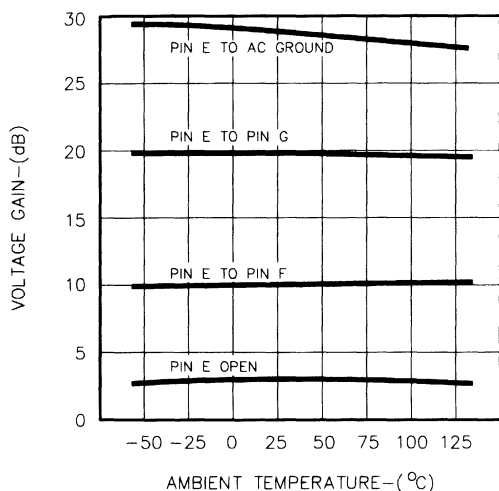


Figure 3. Temperature Stability

## VARIABLE GAIN

Since the dynamic impedance of a forward-biased diode is inversely proportional to the current through it, a convenient gain control can be achieved by using a pair of diodes as a variable impedance. In the circuit of Figure 4,  $R_3$  has been replaced by two diodes whose impedances act in parallel due to the decoupling of  $C_D$ . If the diodes are driven from a voltage source, a logarithmic relationship between gain and control signal is achieved (see Figure 5); while if a current source is used, the relationship is linear as shown in Figure 6.

There are two limitations on this form of gain control. First, the diodes' capacitance limits their effectiveness to frequencies below 20MHz and, secondly, the signal voltage across the diodes should be held to less than 50 mV RMS to minimize self-modulation of amplifier gain. Additionally, the AGC current should be limited to 3mA maximum to keep the diodes out of saturation.

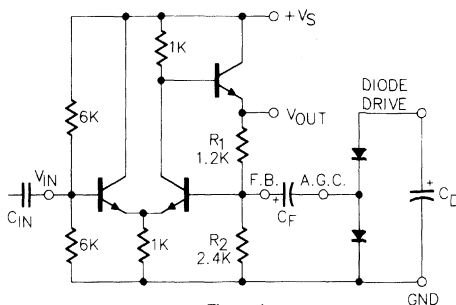


Figure 4.

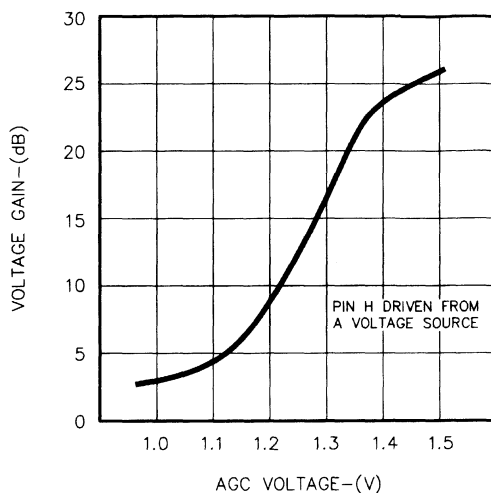


Figure 5. Gain vs. AGC Diode Voltage

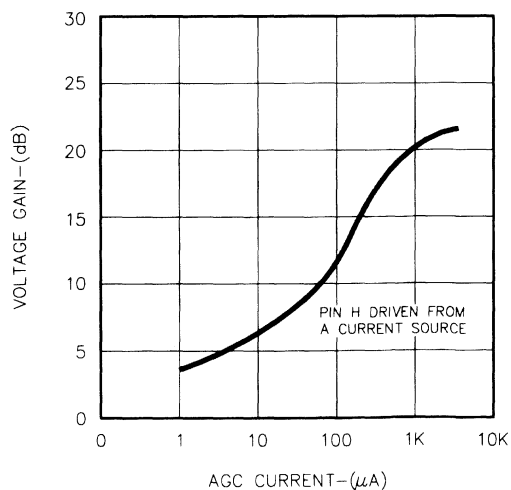


Figure 6. Gain vs. AGC Diode Current



# APPLICATION NOTES – SG1401

## HIGH FREQUENCY STABILITY

With the capability of operation at 100MHz, the SG1401-SG3401 also has some susceptibility to external stray reactances; however, with reasonable care, complete stability may be assured. Some general precautions which should be considered include the following:

1. Power supply decoupling close to the circuit terminals (a 0.1 $\mu$ F capacitor is usually adequate).
2. Maintain separation of input and output lines.
3. Minimize load capacitance or insert a series resistor (up to 50 ohms) in the output.
4. Purposely limit the high frequency response with a stabilizing capacitor  $C_s$  between pins 3 and 4.

Since the gain of this circuit is reduced by increasing the amount of feedback, the potential for instability is greatest when the gain is at its minimum value. This characteristic and the stabilizing effects of a 4.7 pF capacitor between pins 4 and 3 are illustrated in the frequency response curves presented in Figure 5 and 8. The relationship between the value of  $C_s$  and the upper cutoff frequency of a 20dB gain setting is shown in Figure 9 below.

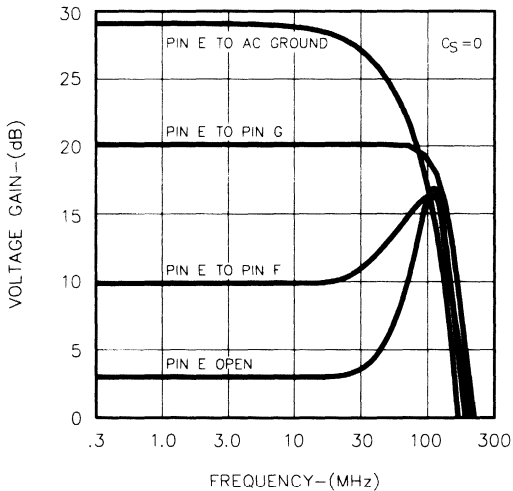


Figure 7. Frequency Response

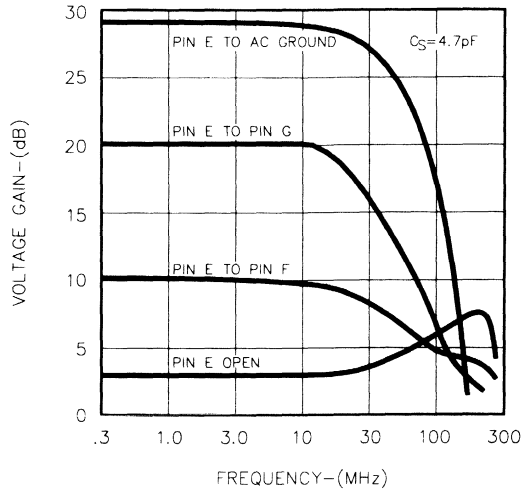


Figure 8. Frequency Response

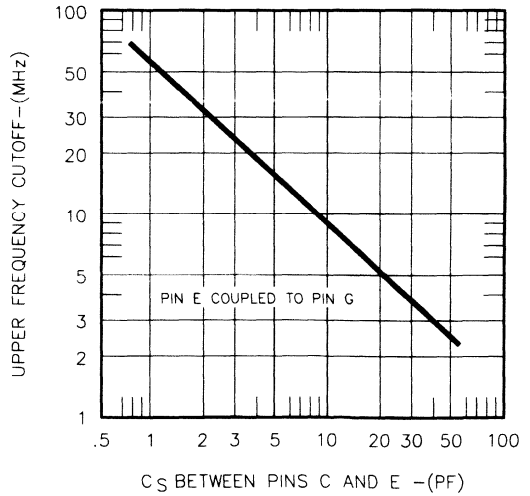


Figure 9. Upper Cutoff Frequency vs.  $C_s$  Value



**SG1402 WIDEBAND AMPLIFIER/MULTIPLIER**

**INTRODUCTION**

Rapid advances in the state-of-the-art of processing monolithic linear integrated circuits have made the use of tightly matched components a practical reality. This in turn has opened the doors to a new class of circuit characterized by its utility, versatility, and ease of application. It is now possible to include on a monolithic chip, many of the components which, because of relatively poor tolerances, were formerly required to be external to the circuit. The SG1402, shown schematically in Figure 1, illustrates this capability both by its inclusion of all necessary biasing networks and by the nature of the circuit itself which requires extremely well matched component parameters for successful operation.

tion of the way in which the above diff amps are cross-coupled will show that while the collector load resistors receive a portion of their current from each diff amp, the signals will arrive out of phase with respect to each other. This is because the input voltage,  $v_c$ , is amplified common emitter - with  $180^\circ$  phase shift - through Q9 and summed at resistor R7 with the signal which has gone common collector-common base - with  $0^\circ$  phase shift - through Q7 and Q5. Therefore, with the circuit perfectly balanced, the two signals completely cancel out and the output has zero signal. This can be shown mathematically as follows:

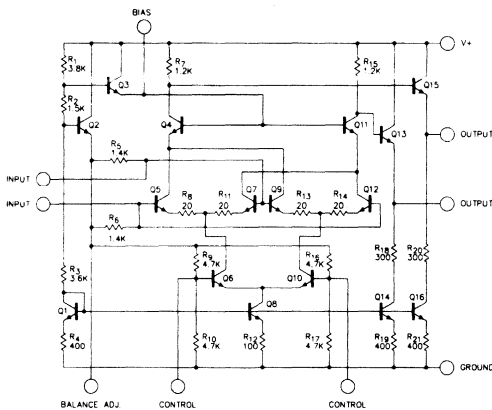


Figure 1. SG1402 Schematic Diagram

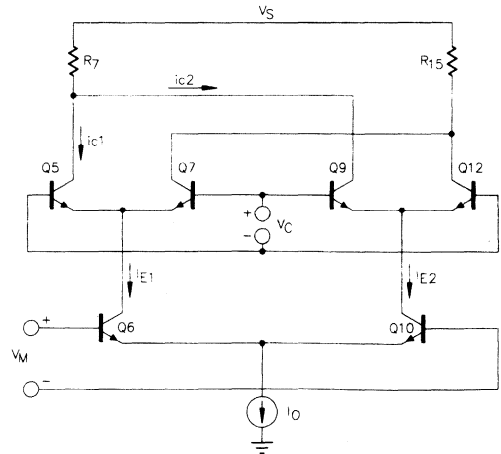


Figure 2. Simplified Schematic of the Multiplier Section of the SG1402

**HOW IT WORKS**

The heart of the SG1402 is a four quadrant multiplier consisting of two cross-coupled differential amplifiers which are jointly controlled by a third differential amplifier. This part of the circuit is shown in simplified form as Figure 2. The constant current,  $I_0$ , is divided by Q6 and Q10 and divided again by each of the upper diff amps such that, for balanced operation, transistors Q5, Q7, Q9, and Q12 each have  $\frac{1}{4} I_0$  flowing through them. An examina-

The collector current in one side of a simple differential amplifier (Q5 and Q7, for example) is:

$$i_{c1} = \frac{I_{E1}}{1 + \exp\left(\frac{q}{kT}\right)v_c}$$

where:  $I_{E1}$  = sum of currents in each collector

$$\frac{kT}{q} = 26 \text{ mV at } 25^\circ\text{C}$$

$V_c$  = different input voltage

This equation can be differentiated to obtain the transconductance which, for small values of  $v_c$ , is:

$$gm = \frac{di_{C1}}{dv_c} = \frac{qI_{E1}}{4kT}$$

In a similar manner, the transconductance through Q9 is:

$$gm = \frac{di_{C2}}{dv_c} = \frac{qI_{E2}}{4kT}$$

and the total voltage gain,  $Av$  is:

$$\begin{aligned} Av &= R_L \frac{di_{C1}}{dv_c} + \frac{di_{C2}}{dv_c} \\ &= \frac{R_L q}{4kT} (I_{E2} - I_{E1}) \end{aligned}$$

Since  $I_{E1} + I_{E2} = I_O$ , it can be seen that when  $v_m = 0$ ,  $I_{E1} = I_{E2} = \frac{1}{2}I_O$  and  $Av = 0$ . With  $I_{E1}$  and  $I_{E2}$  being collector currents of another differential amplifier, the total small-signal gain equation may be written:

$$Av = \frac{v_o}{v_c} = \frac{R_L I_O q}{4kT} \left[ \frac{1}{1 + \exp\left(\frac{q}{kT} v_m\right)} - \frac{1}{1 + \exp\left(-\frac{q}{kT} v_m\right)} \right]$$

The circuit gain of the SG1402 is less than that predicted by the above equation due to the local feedback offered by the 20ohm emitter resistors. The actual relationship between  $Av$  and  $v_m$  is shown in Figure 3 while Figure 4 graphs the full four-quadrant transfer function between the input voltage,  $v_c$ , the control voltage,  $v_m$ , and the output voltage. Note that the 20ohm emitter resistors provide linearity for  $\pm 60$  millivolts of input voltage while the modulating voltage is only linear for approximately half that value. It should be recognized from Figure 4 that output limiting occurs at a constant input voltage regardless of the modulating voltage. In other words, reducing the gain reduces the maximum peak-to-peak output swing.

### BIASING CIRCUITRY

Key to the utility of the SG1402 is the inclusion of all the biasing and level shifting circuitry normally required as external components. This is provided by matched current sources and low impedance voltage sources.

Resistors R1, R2, R3 and R4 are directly across the supply voltage and establish a current:

$$I_b = \frac{V_S - V_{BEQ1}}{R1 + R2 + R3 + R4} = 1 \text{ mA at } 10 \text{ volts}$$

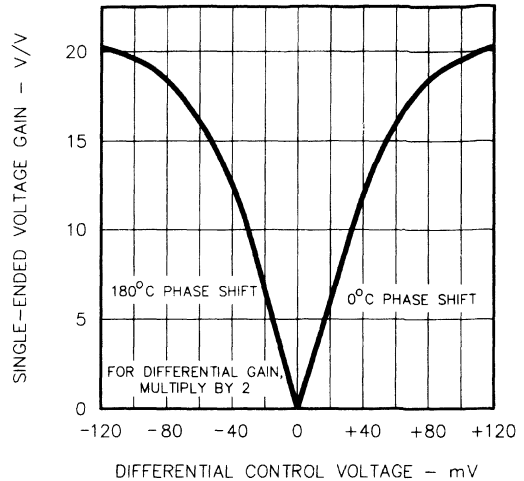


Figure 3. Differential Gain Control

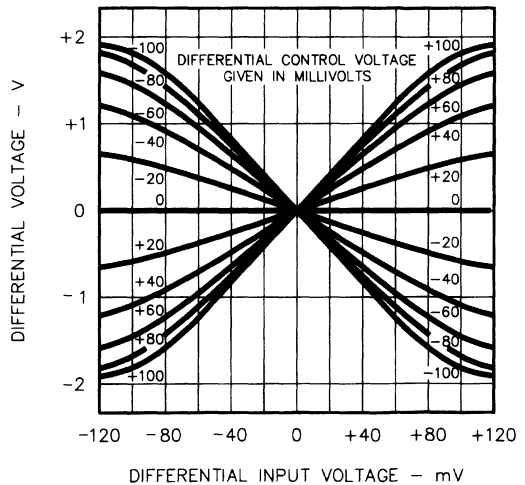


Figure 4. Multiplier Transfer Function

Transistors Q14 and Q16 have the same geometries and emitter resistors as Q1 and therefore, with the same base voltage, they each are also conducting one milliamp and provide the loads for the output emitter followers, Q13 and Q15. This saves chip area as a transistor requires less space than a resistor which would establish the same current.

Transistor Q8 has four times the emitter area and  $\frac{1}{4}$  the emitter resistor as Q1 and thus defines a current level  $I_O$  of 4 milliamps.

The bias voltage levels required at different points in the circuit are all defined by the same resistors which set the current

# APPLICATION NOTES – SG1402

levels but there is no mutual interaction due to the insertion of Q2 and Q3 which act as low-impedance isolators.

Transistors Q4 and Q11 serve only as common-base stages to isolate the load resistor from the collector capacitance of the parallel diff-amp transistors. Thus, frequency response is improved with only slight increase in circuit complexity.

## VARIABLE GAIN AMPLIFICATION

The circuit of Figure 5 shows the simplest application of the SG1402 as a single-ended, variable-gain amplifier. The signals at the two outputs are always equal in magnitude and opposite in phase. As the gain control potentiometer is moved from one end to the other, each output will start with a maximum signal, reduce to a minimum when the pot is centered, and increase to maximum again in the opposite phase as the wiper gets to the other end of the potentiometer.

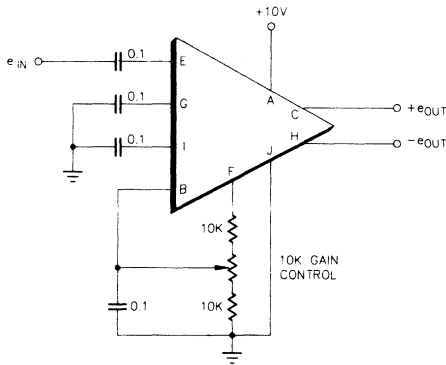


Figure 5. Single-Ended Variable-Gain Amplifier Configuration with Manual Control to provide Maximum Output of Either Phase.

For applications where a phase change is not desired, the incorporation of a diode as shown in Figure 6 will allow a DC control voltage to vary the input-output transfer function from a gain of +25dB to an attenuation of -25dB. This relationship is plotted in the graph of Figure 7.

Since this change in transfer function is accomplished with no net change in either operating currents or bias levels, it is transient-free and extremely fast-reacting. Thus, the circuit of Figure 6 may also be used as a gated amplifier with the control requirements compatible with 0 to 5 volt logic levels. The waveform in Figure 8 shows a 1MHz signal controlled with a 10 microsecond pulse.

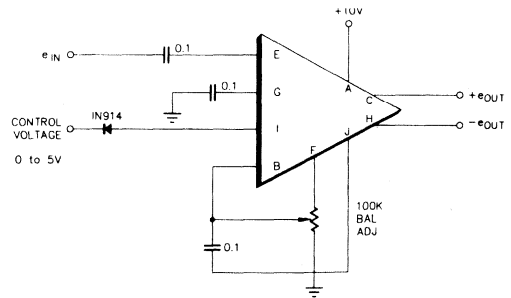


Figure 6. Addition of Diode Provides Gain Control Without Phase Change. Balance May Be Eliminated if Maximum Attenuation is not Required.

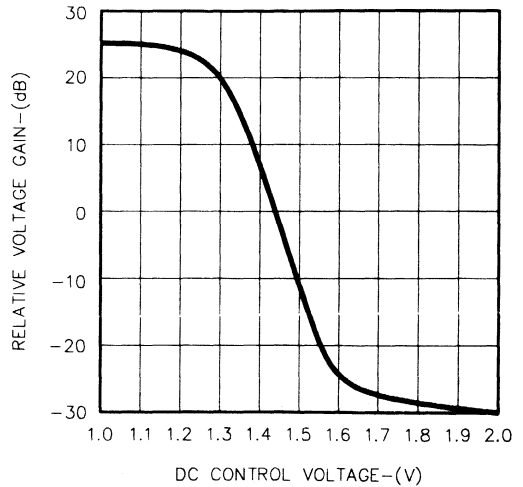


Figure 7. Gain Variation as a Function of Control Voltage with Diode Coupled Input.

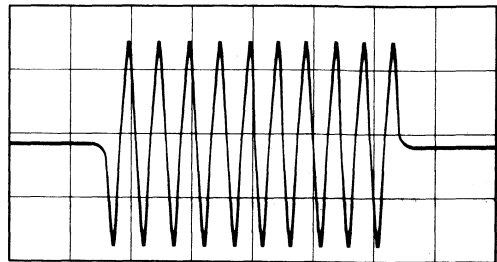


Figure 8. Gate Amplifier or Pulse Modulator Response. Input is 10 mVrms, 1 MHz and Control Voltage is 0 to 5 Volt Square Wave with  $f = 50$  kHz.

## MODULATION

The multiplying function of the SG1402 can be used to provide both balanced and amplitude modulation utilizing the basic circuit shown in Figure 9. With the potentiometer adjusted for optimum balance, the carrier signal is balanced out producing a double sideband waveform at the output. Depending on the amplitude of the carrier signal, higher frequency harmonics can also be generated; however, if only the lower sideband is used, filtering of the upper sideband will also eliminate all the harmonics. It should be noted that this balanced modulation is achieved without the need for the usual transformers and only capacitive coupling is required. Typical waveforms are shown in Figure 10.

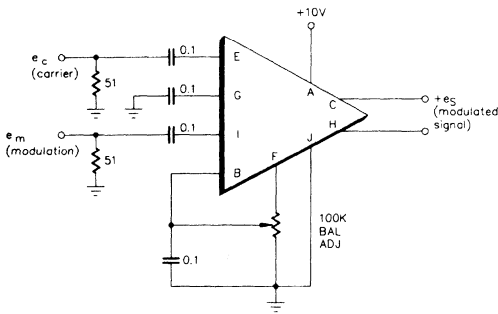


Figure 9. Balanced Modulator

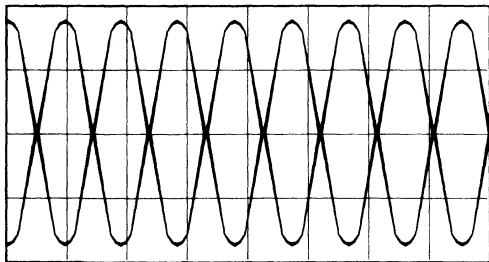


Figure 10. Balanced Modulator Output Waveform.  
(0.1V/cm, 50 µs/cm,  $f_c=1$  MHz,  $f_m=10$  KHz)

If the potentiometer is adjusted so that the circuit is unbalanced, then the carrier is included in the output signal and amplitude modulation as shown in Figure 11 results. The optimum adjustment can most readily be made while observing the output waveform on an oscilloscope. Care should be taken that neither signal overdrive the circuit.

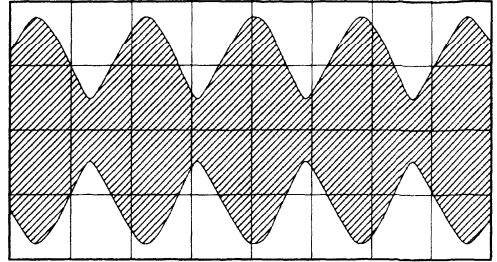


Figure 11. Amplitude Modulator Output Waveform.  
(0.2V/cm, 50 µs/div,  $f_c=1$  MHz,  $f_m=10$  KHz)

By using a signal to modulate itself with the circuit shown in Figure 12, the input is squared and since

$$\cos^2 \omega t = \frac{1}{2} [1 + \cos 2\omega t]$$

the output frequency is twice that of the input. Typical waveforms for this frequency doubler application are shown in Figure 13.

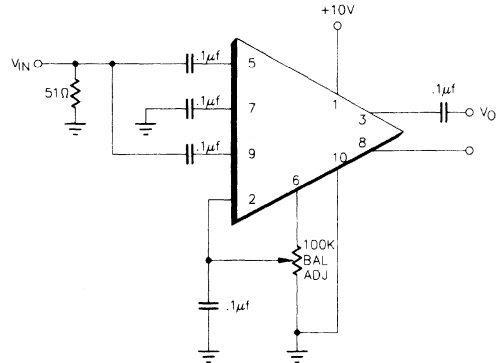


Figure 12. Frequency Doubler

## APPLICATION NOTES – SG1402

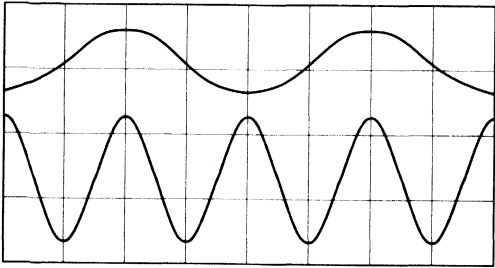


Figure 13. Frequency Doubler Input and Output Waveform.  
(50mV/cm, 0.2 $\mu$ s/div,  $f_1 = 1$  MHz,  $f_2 = 2$  MHz)

### DEMODULATORS

The same features which make the SG1402 an excellent modulator provide superior performance when the circuit is used as a single or double sideband demodulator. The circuit of Figure 14 illustrates the simplicity of this application. The balance pot is not necessary since the inserted carrier is eliminated by the low-pass filter at the output.

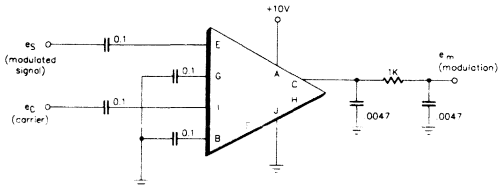


Figure 14. Balanced Demodulator

The same general approach may be used for amplitude modulation and a block diagram of a simple AM detector is shown in Figure 15. Thus, the SG1402 can be used in receivers which combine SSB and AM to provide complete signal transformation in either mode of operation.

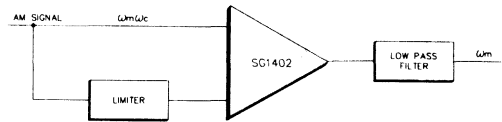


Figure 15. AM Detector Block Diagram

### CONCLUSIONS

With the introduction of the SG1402, Silicon General has provided a powerful tool to the communications engineer and all others working with information processing. Because of its versatility and capability, this device opens the way to a much greater utilization of carrier transmission schemes for data handling in applications ranging from outer space to home kitchens.





**SG1501A DUAL - POLARITY TRACKING REGULATORS**

**CIRCUIT OPERATION**

The first IC to combine a positive and negative voltage regulator on a single chip was the SG1501, and this device has since been supplemented with three new tracking regulator designs - the SG1502, the SG1501A, and the SG1568.

All four of these tracking regulators operate in a similar manner which is best visualized through the block diagram shown in Figure 1. This circuit is fundamentally a tracking regulator. That is, the negative voltage is regulated and the positive output tracks the negative. (Note: In the SG1568, the circuit is reversed in that the negative side tracks the regulated positive output; however, the principle is the same.) Negative regulation is accomplished by providing a constant-voltage reference for the negative error amplifier, but the reference input to the positive error amplifier is grounded. This amplifier forces its other input, which is the center-tap between equal resistors, to also be at zero volts, thus requiring the positive output to be equal in magnitude but opposite in polarity to the negative output.

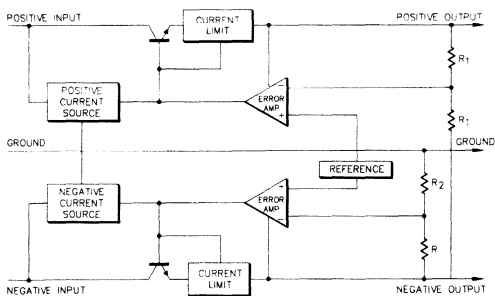


Figure 1. Block Diagram

With this technique, a single adjustment of the negative voltage divider - which changes the negative output level - will also provide exactly the same change to the positive output voltage. This tracking will hold all the way from approximately one volt above the reference voltage to a maximum value of about two volts less than the input supply voltage.

**DESIGNER'S CHOICE**

With four IC's to choose from some discussion of the significant features of each type is in order. Three of the devices, the SG1501A, the SG1501 and the SG1568 are factory set at  $\pm 15V$  regulators while the fourth, the SG1502, is user-adjusted to provide outputs from  $\pm 8V$  to  $\pm 28V$ .

The SG1501 and the SG1501A are interchangeable and both can be used by themselves to provide load currents to the maximum defined by package dissipation, or can be combined with external pass transistors for currents in excess of two amps. Both devices feature constant current limiting with the value set by external resistor. The SG1568 is similar in all respects to the SG1501 except that it is frequency compensated in a slightly different way.

The SG1502 uses the same basic circuit as the SG1501 but has two important differences. First, the voltage setting resistors are external to the device providing greater flexibility in adjusting the output voltage levels to other than  $\pm 15V$ . Secondly, the current limit circuitry has been changed to allow its use in a foldback mode. Foldback current limiting provides for a short circuit current value less than the maximum load current and is a significant feature when the major power dissipation is in external pass transistors rather than the IC.

Self-contained thermal shutdown is the primary improvement offered by the SG1501A although increases in both the maximum input voltage and load current have also been made. With thermal shutdown, temperature sensing circuitry on the chip is designed to turn off the output current when the junction temperature exceeds a safe limit - typically  $170^{\circ}C$ . The significance of this feature is that the designer now need not design around short-circuit power dissipation limits - the device will take care of itself. Since short-circuit power is typically more than twice as much as maximum operating power, this means a two-times, or better, improvement in load current is possible. It should be noted that even with thermal limiting circuitry, the maximum current must be controlled to allow time for this protection to react.

# APPLICATION NOTES – SG1501A

## APPLICATIONS

The simplest way to use SG1501 and the SG1501A is in the basic circuit shown in Figure 2. In this form, the device will handle 50 to 100mA, depending on the heat sinking (more about this later) and will provide  $\pm 15V$  outputs with typically less than two millivolts of sensitivity to either line or load variations. Because of this excellent line regulation, there is no need for symmetrical input supply voltage levels. The only requirement is that each level be greater than its associated output and that the total voltage between positive and negative supplies be less than 60V (70V for the SG1501A). The minimum input voltage is defined by the regulator dropout characteristics shown in Figure 3.

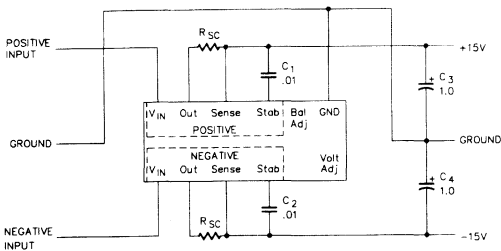


Figure 2. Basic  $\pm 15V$ , 50 mA Regulator

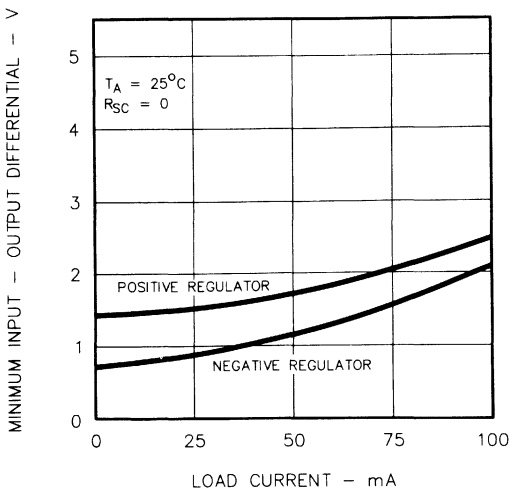


Figure 3. Regulator Dropout Voltage

When operating from a single voltage source, an ungrounded supply is required. An artificial ground can be provided as shown in Figure 4. In this circuit, the external transistors will conduct as necessary to accommodate unbalanced load requirements and

while the outputs will float between the two input levels, they will be held constant with respect to this artificial ground.

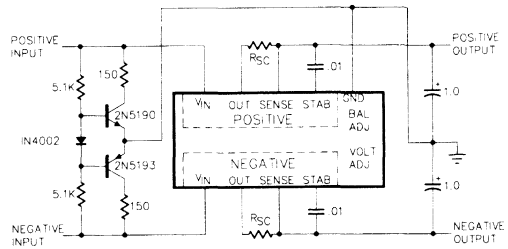


Figure 4. Artificial Ground for use with an Ungrounded or Single Level Voltage

## CURRENT LIMITING

Current sensing is provided by transistors Q12 and Q13 (see schematic, Figure 5) which are normally held off by an external base-to-emitter resistor,  $R_{sc}$ . When the load current passing through this resistor develops enough voltage, the transistor turns on and diverts drive current away from the series pass

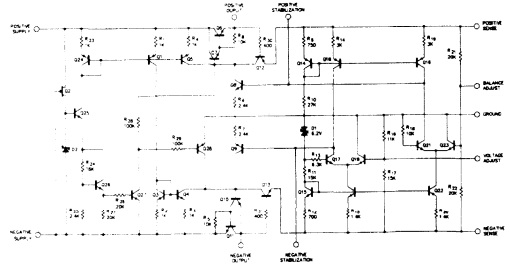


Figure 5. SG1501A Schematic Diagram

transistors. The sense voltage is equal to approximately 0.6V at  $T_j = 25^\circ C$ , but it is temperature dependent decreasing to 0.4V at  $125^\circ C$  as shown in Figure 6. Note that it is junction temperature that determines the sense level, and thus increasing the power dissipation within the circuit can lower the value at which limiting will occur. The value of the limiting resistor,  $R_{sc}$ , should be selected by:

$$R_{sc} = \frac{\text{Sense Voltage at Maximum } T_j}{\text{Allowable Short Circuit Current}}$$

where, for maximum regulation, the allowable short circuit current should be at least 20% more than the maximum expected load current.

## APPLICATION NOTES – SG1501A

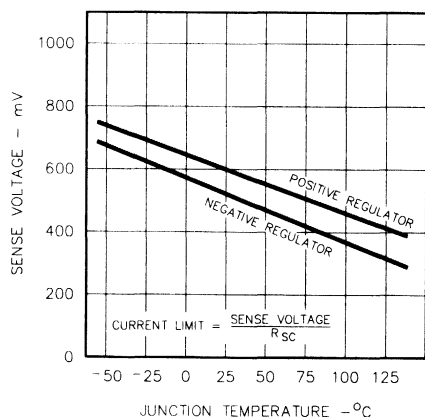


Figure 6. Current Limiting Characteristics

Under some conditions, a low-level oscillation may be present on the negative side when the device goes into current limiting. Should this be a problem, it may be eliminated by by-passing  $R_{sc}$  with a capacitor whose value is such that the time constant,  $R_{sc} C$ , is equal to  $10 \times 10^{-6}$  second. This capacitor, as well as the output capacitors, C3 and C4, must be low ESR types such as solid tantalum.

### POWER CONSIDERATIONS

Although these dual regulators are designed to handle large load currents and high input voltages, the product of the two can easily exceed the maximum total device dissipation allowed by the package. The functional limitation which should be considered for each application is that for maximum reliability the junction temperature of the chip should not exceed  $170^{\circ}\text{C}$ . This is usually derated to give a maximum design operating  $T_j$  of  $150^{\circ}\text{C}$ .

To evaluate the maximum junction temperature possible in a given application, the following three parameters must be known:

1. The power dissipation within the chip
2. The thermal resistance from junction to ambient (or heat sink)
3. The ambient (or heat sink) temperature

The power dissipation within the chip is equal to the sum of the input voltage times the standby current plus the input-output voltage differential times the load current, for each side of the regulator. For example, the total power dissipation for  $\pm 20\text{V}$  inputs,  $\pm 15\text{V}$  outputs, and  $50\text{mA}$  load currents is:

$$\begin{aligned} P_d &= 20(2) + 20(3) + 5(50) + 5(50) \\ &= 100\text{mW standby} + 500\text{mW load current} \\ &= 600\text{mW} \end{aligned}$$

The thermal resistance is the resistance to heat flow from the junction to the ultimate heat sink. For parts mounted in the open, still air, the thermal resistance ( $\theta_jA$ ) is equal to  $185^{\circ}\text{C/watt}$  for the T0-100 metal can and  $125^{\circ}\text{C/watt}$  for the T0-116 ceramic DIP. Blowing air across the package, or the use of some form of heat radiator can significantly reduce these numbers. For example, the use of IERC's model TXBF-032-025B top hat radiator on the T0-100 package, reduces  $\theta_jA$  to  $130^{\circ}\text{C/watt}$ , while their model LIC-2144-2B radiator for the T0-116 will give an  $\theta_jA$  of  $50^{\circ}\text{C/watt}$  for that package. Finally, a perfect heat sink reduces  $\theta_jA$  to  $\theta_jC$  which is  $50^{\circ}\text{C/watt}$  for the T0-100 and  $20^{\circ}\text{C/watt}$  for the T0-116.

With the above information, the maximum power handling capability of the package can be determined as follows:

1. Calculate the maximum allowable junction temperature rise:

$$\Delta T_j = 150^{\circ}\text{C} - T_A (\text{max})$$

2. Calculate the power availability:

$$P_d = \Delta T_j / \theta_jA$$

3. From this number, subtract the maximum standby dissipation:

$$P_{sb} = (V + \text{max})(I_{sb+}) + (V - \text{max})(I_{sb-})$$

4. The remainder can be used to determine the maximum load current as a function of input-output voltage differential.

The curves of Figure 7 show these relationships for each package under the assumptions of  $25^{\circ}\text{C}$  ambient, and symmetrical input and output voltages and load currents.

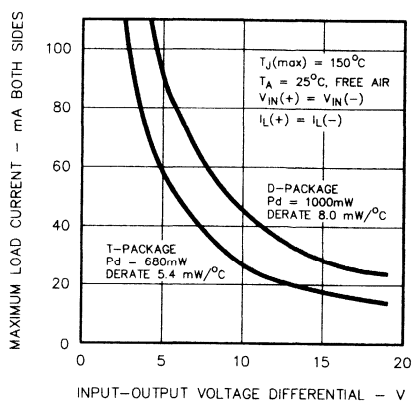


Figure 7. Maximum Current Capability

## EXTERNAL POWER TRANSISTORS

Additional current handling capability may be provided through the use of external power transistors in the configuration shown in Figure 8. In this circuit, the 75ohm base-to-emitter resistors provide a path for the regular standby current and should not be increased in value. An additional consideration is the use of solid tantalum output capacitors as most common electrolytic types have too high an equivalent series resistance particularly at high frequencies.

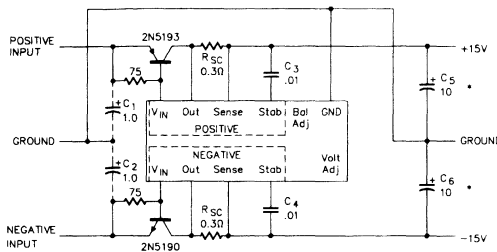


Figure 8. High Current Configuration, One Amp Output

The power transistors are not critical and can be selected on the basis of current and voltage capability, and on mechanical requirements for practical heat sinking. Note that only one transistor need be used if only one side has excessive load current. Although low-frequency devices will minimize the risk of oscillation, unique transistor characteristics may require a small capacitor (0.1µF) from base to ground or a larger value (5µF) from base to emitter for complete stability.

## FOLDBACK CURRENT LIMITING

With constant-current limiting as shown in Figure 8, the power dissipation in the pass transistors under short circuit conditions can be substantial. Here, the thermal limiting feature of the SG1501A can't do much good since it senses the IC temperature rather than the external transistors. To eliminate the problem of having to heat sink a short circuit power two to three times normal operating levels, the use of the SG1502 in the circuit of Figure 9 should be considered. The dividers of R5 and R6 pre-bias the current limiting such that when the output is shorted, the maximum current is substantially reduced from its normal operating level. The values for R5 and R6 are most easily determined from an iterative solution of the equations below with the trade-off being that a greater amount of foldback requires a larger voltage drop across Rsc:

$$\text{Max Load Current} \approx \frac{\text{Sense Voltage} + \frac{R5}{R6} V_o}{R_{sc}}$$

$$\text{Short Circuit Current} \approx \frac{\text{Sense Voltage}}{R_{sc}}$$

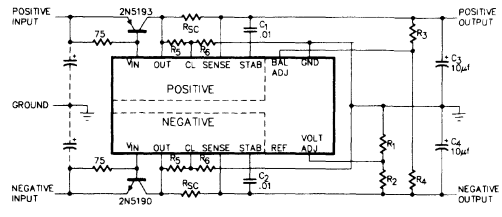


Figure 9. Foldback Current Limiting

## VOLTAGE ADJUSTMENTS

With both output voltage levels internally set for 15V (±200mV for the SG1501/2501 and ±500mV for the SG3501) these devices require no additional resistors for many applications. It is possible, however, to externally vary the output voltages from ±10 to ±23V by using external resistors to shunt one or both of the internal resistors which set the negative output level. The positive output will, of course, track the negative value.

The simplest way of changing the output levels is to use a single resistor in parallel with R17 (see Figure 5) for voltages less than 15V and in parallel with R16 for voltages above 15V. The graph of Figure 10 shows the approximate value to use in either case.

This method of adjusting output levels has one disadvantage, however. Diffused resistors have a positive temperature coefficient and while they can be made to track each other extremely well, with one of them shunted this tracking becomes degraded. A method offering greater temperature stability is the use of a pair of resistors with values low enough to swamp out the internal divider. By shunting R16 with 1.2k, and R17 with a resistor selected by:

$$R17 = \frac{1.2(V_o - 6.2)}{6.2} k\Omega$$

where  $V_o$  is the desired output voltage, a four-fold improvement in temperature performance is achieved at the expense of the additional divider current. Figure 11 shows that temperature variation which may be expected both with a single shunt resistor

# APPLICATION NOTES – SG1501A

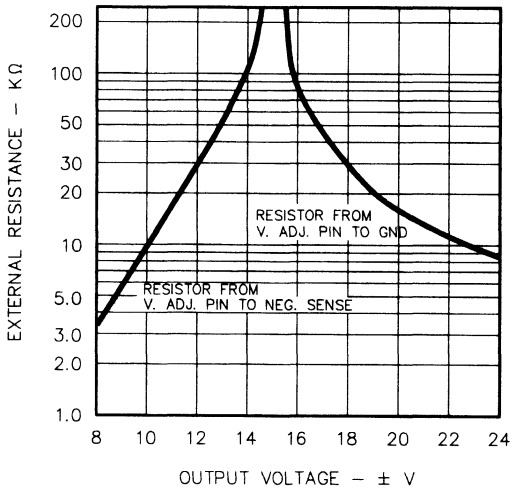


Figure 10. External parallel resistor required for voltages other than ±15V.

and with a divider drawing approximately five milliamps of current. Note that these temperature shifts are caused by changes in chip temperature which could result from variations of either ambient temperature or internal power dissipation.

In the 14 pin dual-in-line package, a connection is provided to the junction of R21 and R22. An external resistor divider can be used here in the same manner to either balance the two outputs so that they are exactly equal in magnitude or to unbalance them for non-symmetrical output levels.

Although all of these dual regulator types have provisions for adjustment of the output voltage levels, with its user-supplied voltage setting resistors, the SG1502 is the best choice for applications very far from ±15V. The divider resistors (see Figure 9) are selected as follows:

$$\text{Negative } V_o = \frac{6.2 (R1+R2)}{R1}$$

$$\text{Positive } V_o = \frac{R3}{R4} (\text{Negative } V_o)$$

One common application for positive and negative voltages is as a power source for the widely used 710 and 711 IC voltage comparators. Since these devices are designed for +12 and -6V operation, it takes a circuit as shown in Figure 12 to get around the ±8 minimum output limitation of these regulators. Here, the

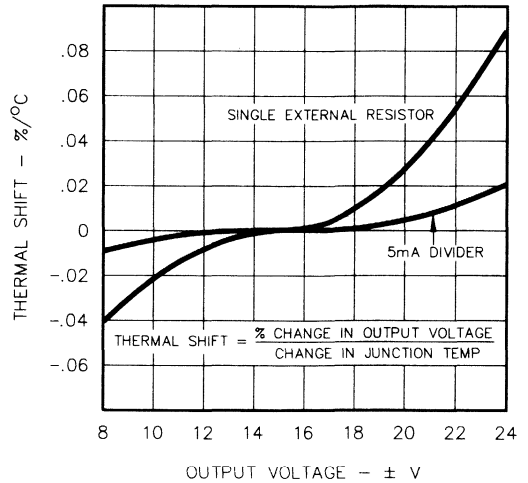


Figure 11. Temperature Coefficient of Output Voltage

nominal ±15V output of the SG1501 has been reduced to ±12V by the 2.0k and 1.8k voltage divider. Six volts are then subtracted from the negative output by the IN4735 zener diode. Because the diode is outside the feedback loop, some minor variations in the -6V output may be observed due to its temperature coefficient or dynamic impedance. These variations have negligible effect on the comparators, however, as the negative voltage is used only to bias high impedance current sources.

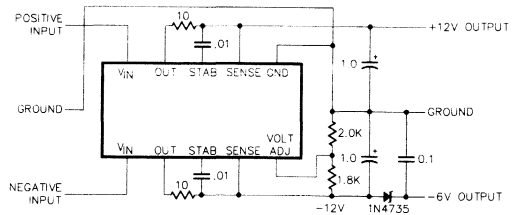


Figure 12. Using the SG 1501 to Provide +12 and -6 Outputs

Zener diodes can also be put to use in applications requiring high input voltages. In the circuit in Figure 13, the small signal zener diodes reduce the voltage applied to the IC while allowing the easily heat-sinked power transistors to absorb the added power dissipation caused by a large input-output differential.

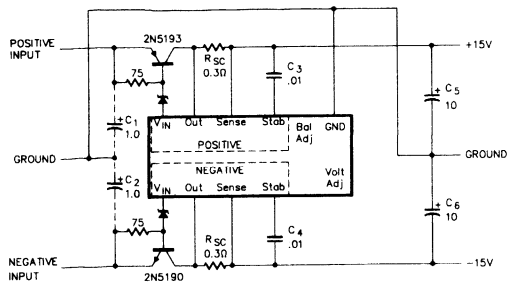


Figure 13. Zener Diodes Used to Prevent High Input Voltages from Appearing Across the Device.

## CONCLUSIONS

With two complete regulators in a single IC, these new regulators offer an improved approach to power distribution. Their high degree of performance and freedom from large numbers of external components make "on-card," or distributed regulation a practical reality. By regulating at the point of use, the system designer has eliminated many knotty problems such as lead inductance, decoupling, line drop through connectors, etc. In addition, since each circuit card or module can now regulate its own voltage, complete interchangeability is more nearly assured and the problems of equipment maintenance are greatly eased.

***SIMPLIFYING CONVERTER DESIGN WITH A NEW  
INTEGRATED REGULATING PULSE WIDTH MODULATOR***

Edited by Stan Dendinger  
Manager, Advanced Product Development  
Silicon General, Inc.

**ABSTRACT**

A new monolithic integrated circuit is described which contains all the control circuitry for a regulating power supply converter or switching regulator. Included in this 16-pin dual-in-line package is the voltage reference, error amplifier, oscillator, pulse width modulator, pulse steering flip-flop, dual alternating output switches, and current limiting and shutdown circuitry. This device can be used for switching regulators of either polarity, transformer coupled DC to DC converters, transformer-less voltage doublers and polarity converters, as well as other power control applications.

**INTRODUCTION**

Implementing a switching power supply has just become significantly easier with the introduction of the SG1524 series of Regulating Pulse Width Modulator integrated circuits. Long recognized as offering greatly improved efficiencies, the development of switching supplies has been hampered by the complexity of the low-level circuitry required to provide the proper signals for adequate control of the switching transistors. As a result, these supplies have tended to be more costly, larger in size, and with proper reliability than could be justified by their improved efficiency. Even when threats of higher energy costs and potential brown-outs have made switching supplies mandatory, their complexity has made the engineering design task a formidable undertaking.

With the introduction of the SG1524, a major portion of the complex low-level control circuit has been integrated into a single LSI linear integrated circuit. This monolithic chip, packaged in a 16-pin dual-in-line outline, implements the entire block diagram shown in Figure 1.

It is the integration of all these different functions into a single IC that qualifies the SG1524 as one of the best examples to date of large scale integration as applied to analog circuits. The remainder of this paper will describe each of the individual blocks in the following diagram in considerable detail and then offer a few basic application suggestions.

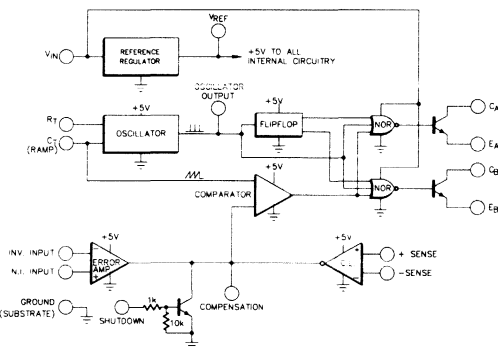


Figure 1. SG1524 Block Diagram

**VOLTAGE REFERENCE**

The reference circuit of the SG1524 is shown in Figure 2. This is a complete linear regulator designed to provide a constant 5 volt output with input voltage variations of 8 to 40 volts. It is internally compensated and short circuit protected. It is used both to generate a reference voltage and as the regulated source for all the internal timing and controlling circuitry. This regular may be bypassed for operation from a fixed 5 volt source by

# APPLICATION NOTES – SG1524

connecting pins 15 and 16 together to the input voltage. In this configuration, the maximum input voltage is 6 volts. While discussing input power, it should be mentioned that the entire SG1524 IC draws less than 10mA of current, regardless of input voltage.

This reference may be used as a 5 volt source for other circuitry. It will provide up to 20mA of output current itself and can easily be expanded to higher currents with an external PNP transistor as shown in Figure 3.

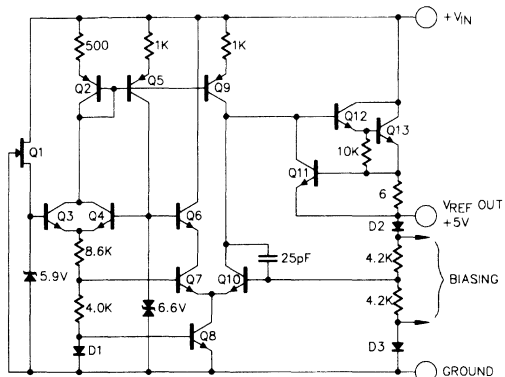


Figure 2. SG1524 Reference Circuit

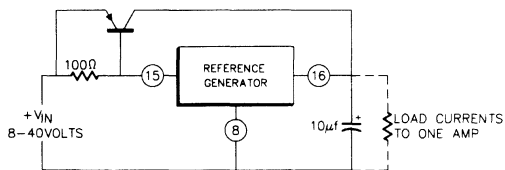


Figure 3. SG1524 Expanded Current Source

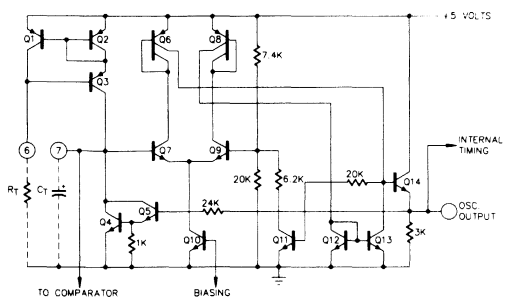


Figure 4. SG1524 Oscillator Circuit

## OSCILLATOR

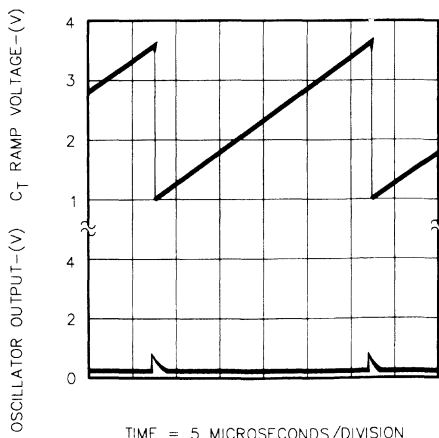
The oscillator in the SG1524 uses an external resistor ( $R_T$ ) to establish a constant charging current into an external capacitor

( $C_T$ ). This constant-current charging gives a linear ramp voltage which provides an overall linear relationship between error voltage and output pulse width. The SG1524 oscillator circuit is shown in Figure 4.

A second output from the oscillator is a narrow clock pulse which occurs each time  $C_T$  is discharged. This output pulse is used for several functions as outlined below:

1. As a blanking pulse to both outputs to insure that there is no possibility of having both outputs on simultaneously during transitions. The width of this blanking pulse can be controlled to some extent by the value selected for  $C_T$ .
2. As a trigger for an internal flip-flop which directs the PWM signal to alternate between the two outputs. Note that for single-ended applications, the two outputs can be connected in parallel and the frequency of the output is the frequency of the oscillator. For push-pull applications, the outputs are separated and the action of the flip-flop provides an output frequency  $\frac{1}{2}$  that of the oscillator.
3. As a convenient place to synchronize an oscilloscope for system de-bugging and maintenance.
4. As a bi-directional port for external timing synchronization. The output pulse from this oscillator - which is stable to within 2% over variations in both input voltage and temperature - can be used as a master clock for other circuitry, including other SG1524's. It thus follows that a positive pulse applied to this terminal can synchronize the SG1524 to an external clock signal.

The waveforms of the two outputs from the oscillator are shown in Figure 5.



TIME = 5 MICROSECONDS/DIVISION

Figure 5. SG1524 Oscillator Waveforms



# APPLICATION NOTES – SG1524

## ERROR AMPLIFIER

The error amplifier circuit, shown in Figure 6, is a simple differential input, transconductance amplifier. Both inputs and the output are available for maximum versatility. The gain of the amplifier is nominally 10,000 (80dB) but can be easily reduced by either feedback or by shunting the output to ground with an external resistor. The overall frequency response of this amplifier which, by the way, is not internally compensated but yet is stable with unity gain feedback, is plotted with various values of external load resistance in Figure 7.

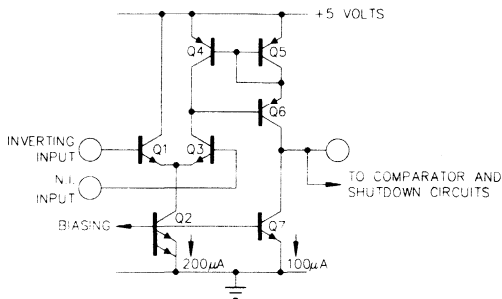


Figure 6. SG1524 Error Amplifier Schematic

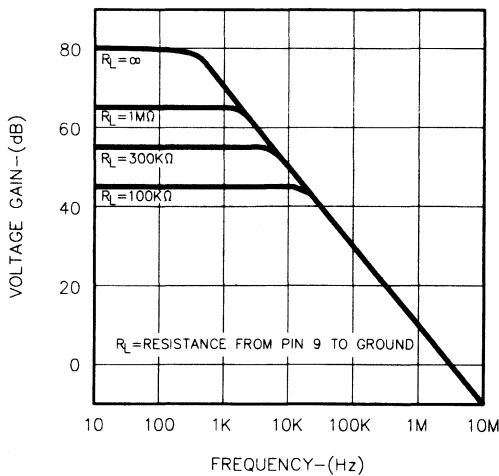


Figure 7. SG1524 Error Amp Frequency Response

Phase shifting to compensate for an output filter pole may readily be accomplished with an external series R-C combination at the output terminal of the amplifier.

Since the error amplifier is powered by the 5-volt reference voltage, the acceptable common-mode input voltage range is restricted to 1.8 to 3.4 volts. This means the reference must be divided down to be compatible with the amplifier input, but yet provides the advantage of being able to be used to regulate negative output voltages. Required input dividers are shown in Figure 8.

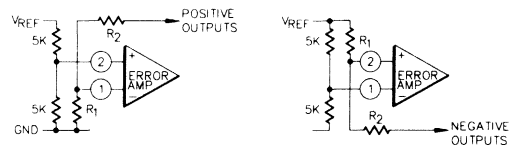


Figure 8. Error Amplifier Connections

Since this amplifier is a transconductance design, the output is a very high impedance (approximately 5MΩ) and can source or sink only 100µA. This makes the output terminal (Pin 9) a very convenient place to insert any programming signal which is to override the error amplifier. Internal shutdown and current limit circuits are connected here, but any other circuit which can sink 100µA can pull this point to ground, thereby shutting off both outputs.

For example, the soft start circuit of Figure 9 can be used to hold Pin 9 to ground - and thus both outputs off - when power is first applied. As the capacitor charges, the output pulse slowly increases from zero to the point where the feedback loop takes control. The diode then isolates this turn-on circuit from whatever frequency stabilizing network might also be connected to Pin 9.

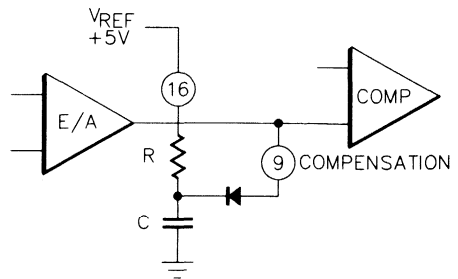


Figure 9. SG1524 Soft Start Circuitry

## CURRENT LIMITING

The current limiting circuit, while shown in the block diagram as op amp, is really only a single transistor amplifier as shown in Figure 10. It is frequency compensated and has a second transistor to provide temperature compensation and a reduction of input threshold to 200mV. When this threshold is exceeded, the amplifying transistor turns on and, by pulling the output of the error amplifier toward ground, linearly decreases the output pulse width.

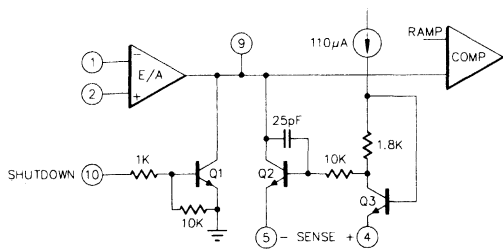


Figure 10. SG1524 Current Limiting

One consideration in using this circuit is that the sense terminals have a  $\pm 0.3$  volt common mode range which requires sensing in the ground line. However, since differential inputs are available, foldback current limiting can be implemented as shown in Figure 11.

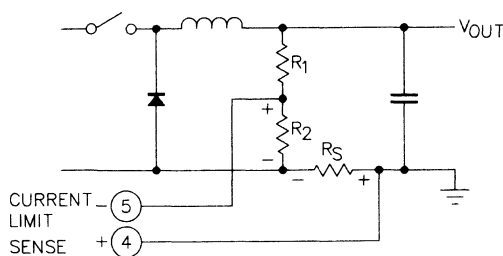


Figure 11. Foldback Current Limiting

While on the subject of protection circuitry, although overvoltage protection is not built into the SG1524, it is relatively easy to add by using the internal shutdown circuit in conjunction with a few external components as shown in Figure 12.

This circuit will provide a low level sensing and latching function and while it won't protect against a shorted output transistor, it will remove the drive signals with no power dissipation.

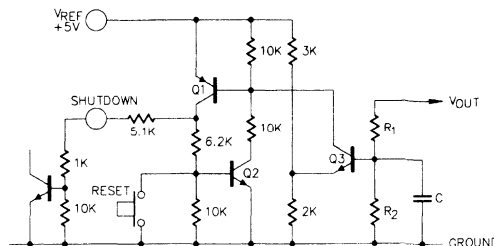


Figure 12. SG1524 Over Voltage Protection

## OUTPUT STAGES

The outputs of the SG1524 are two identical NPN transistors with both collectors and emitters uncommitted. These circuits are as shown in Figure 13 and include an antisaturation network for fast response and current limiting set for a output current of approximately 100mA.

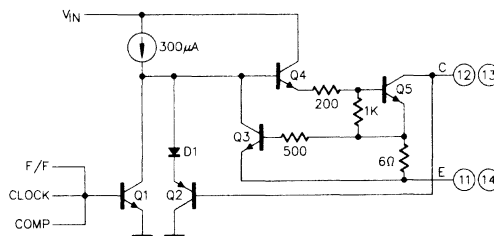


Figure 13. SG1524 Output Stage

The availability of both collectors and emitters allows a maximum versatility to enable driving either NPN or PNP external transistors; however, it must be remembered that this is only a switch which closes and opens. Power transistor turn-off drive must be developed externally. Some suggestions for output drive circuits are shown in Figure 14.

## APPLICATIONS

In considering applications for the SG1524, it appears that there are three general classifications of switching power supply systems. Included in the first are the transformerless voltage multiplier circuits shown in Figure 15. These circuits are primarily used for low level applications but can step up, step down, or change the polarity of an input voltage. The switches shown can be either the output stages of the SG1524 or external transistors.

## APPLICATION NOTES – SG1524

Note that one extra diode is required to protect the emitter-base junction of switch  $S_A$  during the times when both switches are open.

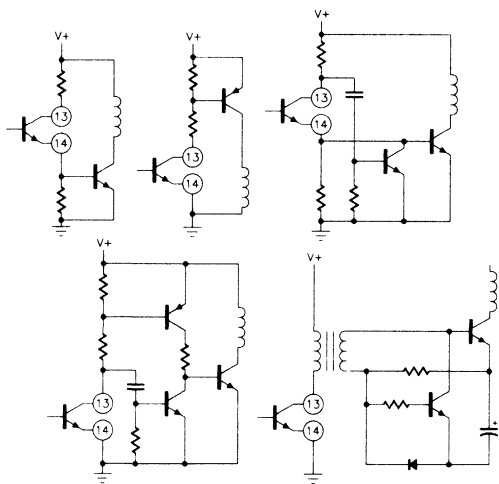


Figure 14. Driving External Transistors

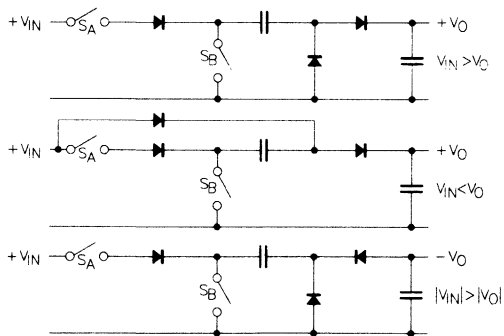


Figure 15. Capacitor/Diode Output Circuits

For higher current applications, the single-ended inductor circuits of Figure 16 represent another classification. Here, the two outputs of the SG1524 are connected in parallel, but note that this does not give twice the current as the switches are alternating internally. This does not affect external performance, however, and the SG1524 can be used to provide 0-90% duty cycle modulation in any of the configurations shown.

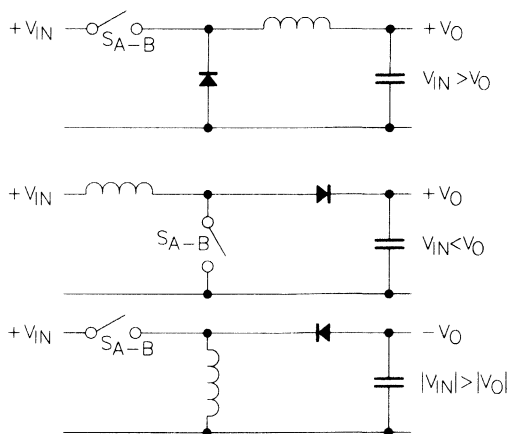


Figure 16. Single-Ended Inductor Circuits

The third general classification of power supply systems are transformer coupled, two types of which are shown in Figure 17.

The push-pull circuit represents the conventional DC to DC converter with each switch being controlled for 0-45% duty cycle modulation. The second transformer circuit is a single-ended flyback converter, useful at light loads without a separate output inductor.

To illustrate the use of the SG1524 in each of the above general classifications, the following simple, but practical, circuits are presented:

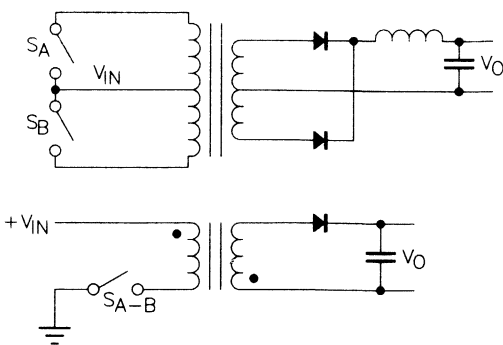


Figure 17. Transformer Coupled Circuits

# APPLICATION NOTES – SG1524

Figure 18 shows the use of the SG1524 as a low current polarity converter providing a regulated -5volt output at currents up to 20mA from a single positive input voltage. The external components required include the divider resistors to interface the reference and output voltages with the error amplifier, a resistor/capacitor to set the operating frequency, and the output diodes and capacitors. The combination of the built-in current limiting of the SG1524 output stages and the capacitor coupling of the output signal provide full protection against short circuits and the current limit amplifier is more than enough to stabilize the regulating loop and no additional compensation is required.

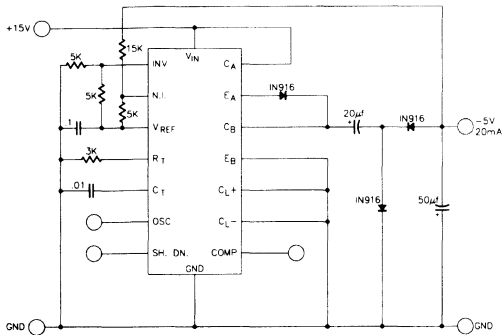


Figure 18. Low Current Polarity

Another low-level circuit is the flyback converter shown in Figure 19.

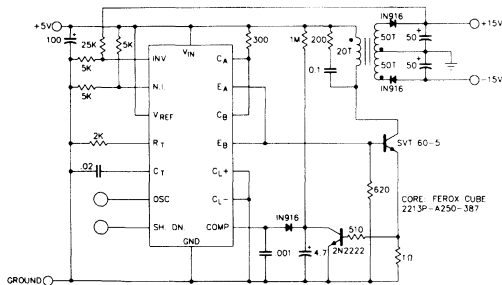


Figure 19. +5 to ±15 Volt, Flyback Converter

The circuit is designed to develop a regulated ±15volt supply from a single +5 volt source. Note that the reference terminal is tied to the input, disabling the internal regulator. The error amplifier resistors are also tied to the input line so that the output regulation can be no better than the input; however, an external reference could just as easily have been used.

In this application, the two output stages are connected in parallel and used as emitter followers to drive a single external

transistor. Since the currents in the secondary of a flyback transformer are out of phase with the primary current, current limiting is very difficult to achieve. In this circuit, protection was provided through the use of a soft-start circuit. If either output is shorted, the transformer will saturate, providing more current through the drive transistor. This current is sensed and used to turn on the 2N2222 which resets the soft-start circuit and turn off the drive signal. If the short remains, the regulator will repetitively try to start up and reset with a time constant set by the soft-start circuit. Removing the short will then allow the regulating loop to re-establish control.

For higher current applications, the single-ended conventional switching regulator of Figure 20 is shown.

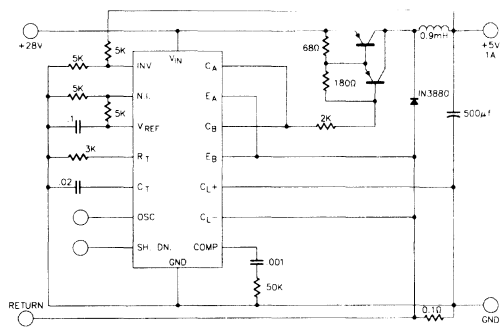


Figure 20. 1 Amp, Single-Ended Switching

In this case, an external PNP Darlington is used to provide a 1-amp current switch. The SG1524 has the two outputs in parallel, connected as a grounded emitter amplifier. The current sense resistor is inserted in the ground line and the voltage across it used for constant current limiting. Note that in addition to the divider resistors and frequency setting  $R_1, C_1$ , a phase compensation resistor and capacitor is used to stabilize the loop now that an inductor has been added.

A fourth application would have to be a push-pull, DC to DC regulating converter as shown in Figure 21.

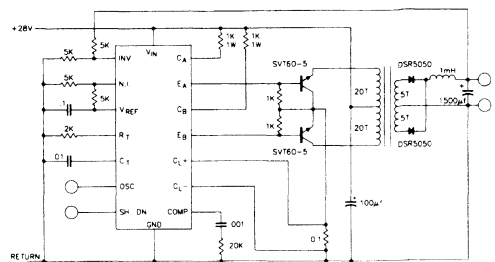


Figure 21. 5V, 25W, DC to DC Converter

## APPLICATION NOTES – SG1524

Here the outputs of the SG1524 are connected as separate emitter followers driving external transistors. Current limiting in this application is done in the primary for several reasons: First, it's easier to live within the  $\pm 0.3$  volt common mode limits of the current limit amplifier; second, since this is a step-down application, the current - and therefore the power in the sense resistor - is lower; and third, if the output drive were to become non-symmetrical causing the transformer to approach saturation, the resultant current spikes will shorten the pulse width on a pulse-by-pulse basis, providing a first order correction. Note that the oscillator is set to run at 40kHz to obtain a 20kHz signal at the transformer.

The application as shown does not provide input-output isolation and, of course, that feature is difficult to achieve within a single IC. There are a couple of ways the SG1524 can be used with isolated power supply systems, however. The first is shown in Figure 22 where the SG1524 is direct coupled on the secondary side of the output transformer. The outputs from the IC are transformer-coupled back to the primary side to drive the switching transistors. Of course, a separate start-up power source is needed for the SG1524 but that shouldn't present much of a problem remembering that the IC draws less than 10mA of supply current.

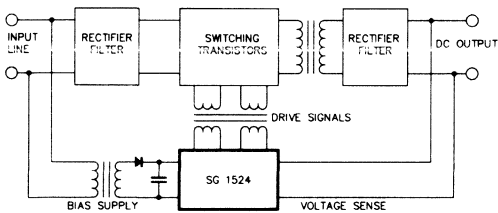


Figure 22. Input/Output Isolation

A different method of providing isolation is shown in Figure 23 where the IC is direct coupled on the primary side. Here a separate reference error amplifier (most easily implemented with a SG1532 regulator IC) is connected on the secondary and then optically coupled back to the primary side.

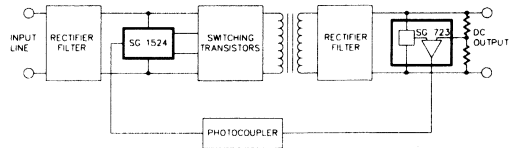


Figure 23. Input/Output Isolation

As should be evident from the above, the SG1524 was designed as the first of what will undoubtedly become a larger family of regulator IC's specifically designed for switching power supplies. As such, versatility was the primary design goal of this device and hopefully this goal has been achieved to the degree that will allow the SG1524 to find application to a wide range of power control systems.

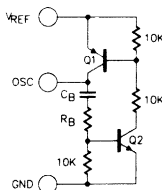


## DEADBAND WITH THE SG1524 REGULATING PULSE WIDTH

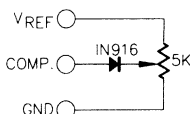
### ABSTRACT

The SG1524 Regulating P.W.M. integrated circuit provides two outputs which alternate in turning on for push-pull inverter applications. The internal oscillator sends a momentary blanking pulse to both outputs at the beginning of each period to provide a deadband so that there cannot be a condition where both output transistors are on at the same time. The deadtime duration is determined by the width of the blanking pulse appearing on Pin 3, as measured at the  $\pm 0.7$  volt level, and can be controlled by three techniques:

1. For the 0.3 to 1.0 microseconds, the deadband is controlled by the timing capacitor,  $C_T$ , on Pin 7. The relationship between  $C_T$  and deadband is shown in Figure 3 on the SG1524 data sheet. Of course, since  $C_T$  also determines the oscillator frequency, the range of control is somewhat limited.
2. Above 1.0 microsecond, a simple one-shot latch similar to the circuit shown below should be used.  
When this circuit is triggered by the positive-going pulse from the oscillator output, it will latch for a period determined by  $C_B R_B$ , providing a well-defined deadtime.



3. Another way of providing greater deadband is just to limit the maximum pulse width. This can be done by using a clamp to limit the output voltage of the error amplifier. A simple way of achieving this clamp is with the circuit below:



This circuit will limit the error amplifier's voltage range since its current source output will supply only  $100\mu\text{a}$ . Another advantage of this circuit is that it does not change the programmed-oscillator frequency.

In general, it is not recommended to stretch the deadtime by using external capacitors on Pin 3. There are several reasons for this:

- a. It is difficult to obtain well-controlled, repeatable deadtimes with this approach, since the logic threshold is  $+0.7$  volts. The normal exponential fall of the pulse trailing edge due to the external capacitor and internal  $3\text{K}$  pull-down resistor results in a poorly defined crossing of the logic threshold.
- b. The external capacitor degrades the rise and fall times of the clock to the internal flip-flop. For sufficiently high values of capacitance, the flip-flop will cease to toggle properly, especially at higher temperatures.

In general, if a simple means of stretching deadtime is required, the best solution is to use the SG1524B device instead of the earlier 1524. Up to  $1000\text{pF}$  can be connected to the OSC pin with no degradation of the flip-flop operation, since the clock to the toggle flip-flop in the 1524B is generated by the internal double-pulse suppression logic.





## **IMPROVING SWITCHING REGULATOR DYNAMIC RESPONSE**

Edited by Stan Dendinger  
 Manager, Advanced Product Development  
 Silicon General, Inc.

### **ABSTRACT**

Recent introductions of LSI integrated circuits for P.W.M. control have offered considerable simplification to the job of optimizing the design of switching regulators. In addition to greatly reducing the necessary circuitry, the linear transfer function of these devices eases the task of stabilizing the feedback loop and offers several possibilities for improved response. Experimental methods for evaluating the response characteristics of the P.W.M. switching and output stages can be used to confirm simplifying assumptions of linear operation. With this data, several approaches to equalization networks can be compared for performance optimization.

### **INTRODUCTION**

The past few years have seen a major revolution take place in the field of power supply design. Whether forced upon us by the need for energy conservation or finally made practical thru recent advances in semiconductor technology, switching regulators are now the name of the game in voltage control. Novices soon learn, however, that the implementation of a well-designed switching supply involves a little more skill than that required for a linear regulator.

Although the theory of switching regulation has long been known, there is much practical technology - or art - in designing efficient and reliable systems. This is still true even though recently introduced semiconductor devices have made the job at least a little easier. It is the purpose of this discussion to cover a few of the practical aspects of implementing and stabilizing switching regulators using these newer devices.

### **INTEGRATED P.W.M. CONTROL CIRCUITS**

Recognizing a rapidly growing market, many component suppliers have introduced new devices designed specifically for switching regulator applications. These include faster power transistors with improved S.O.A., low E.S.R. electrolytic capacitors, hybrid power devices which include a matched commutating diode, and monolithic IC control devices such as the SG124<sup>(1)</sup> which contain all of the P.W.M. control circuitry in a single 16-pin, dual-in-line package.

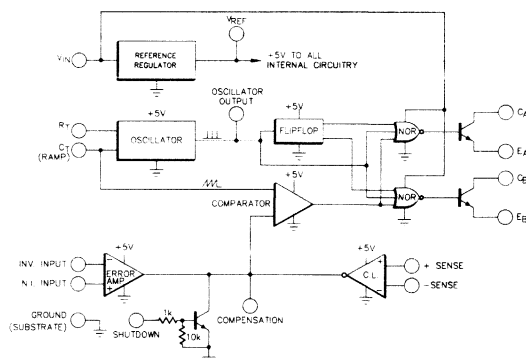


Figure 1. SG1524 Block Diagram

From the block diagram shown in Figure 1, it can be seen that the SG1524 contains the elements necessary to implement either single-ended switching regulators or DC to DC converters of several different configurations. This device includes a voltage reference, error amplifier, constant frequency oscillator, pulse width modulator, pulse steering logic, dual alternating output switches, and current limiting and shutdown circuitry. Since many of the different types of applications for this IC have been discussed earlier<sup>(1)</sup> it should suffice to review only two of the more common usages as shown in Figures 2 and 3.

The single-sided regulator of Figure 2 is unique because of its simplicity. This circuit combines an SG1524 with an SM625 hybrid to build a 5 volt, 5amp regulator with all the semiconductor devices contained in only two packages. This circuit has an efficiency of over 70% with an input voltage range of 20 to 30 volts, 0.1% line and load regulation, and some added benefits of constant frequency operation and short circuit protection.

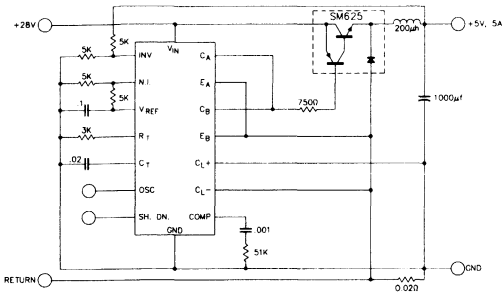


Figure 2. SG1524 Single-Ended Switching Regulator

Figure 3 shows the same 5-volt, 5amp output requirement met this time with a DC to DC converter. The use of high speed transistors and Schottky rectifiers keep the efficiency more than 80% - significant for a low-voltage output - while maintaining all the other benefits included in the single-ended circuit.

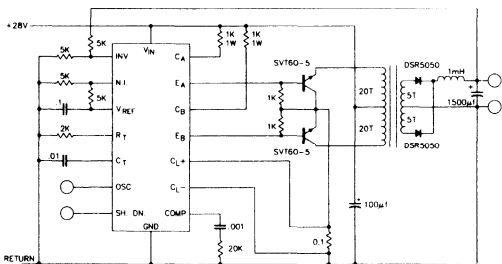


Figure 3. SG1524 Regulating DC - DC Converter

It should be recognized that the above circuits represent very basic applications of an IC control chip. Most practical power supply systems would probably incorporate many other features which may be accomplished by interfacing these IC's with a small amount of external circuitry to add characteristics such as: soft start, oscillator synchronization, dead-band controls, additional current and/or voltage step-up stages, input-output isolation, remote overvoltage or overload shutdown, and response modifying circuitry. It is this latter subject we wish to explore more fully below.

## SWITCHING REGULATOR CONTROL

The basic switching regulator control loop which applies to the most common forms of implementation is illustrated in Figure 4. In analyzing this control loop stability, the obvious immediate problem is the transfer function of the P.W.M. and output stage. A detailed and accurate analysis of the nonlinear characteristics of this stage is an extremely difficult and complex task if one is to account for all the parameters which could possibly be a factor. (2,3,4) On the other hand, if this stage could be assumed to have a linear transfer function, analysis becomes a relatively simple application of basic feedback theory.

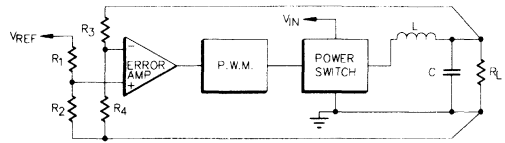


Figure 4. Basic Regulating Control Loop

A significance of the SG1524 is that it uses a design approach which makes a linear assumption accurate enough for most applications. The fact that this device features constant frequency operation, a linear-slope ramp for P.W.M., and fast-response logic and output circuitry all contribute to minimizing the errors associated with a linear assumption. Of course, there are factors external to the IC which could destroy this assumption. Such things as excessive delay in the switching transistors, parasitic ringing or oscillation in the power stages, or nonlinear operation of the magnetics could all cause a resultant nonlinear performance. A first exercise for the designer, then, is to confirm linear operation of the P.W.M. and output stages of his regulator by evaluating his early breadboard models.

## OUTPUT STAGE ANALYSIS

The pulse width modulation is accomplished in the SG1524 by comparing the output of the error amplifier with a linear ramp, or saw-tooth signal from the oscillator. Because the comparator has both high gain and high output impedance, and the error amplifier has a high output impedance, this node (pin-9) becomes a very convenient place for inserting a test signal. A voltage source applied as shown in Figure 5 will completely override the error amplifier and essentially open the loop without actually breaking any connections. In addition, the test signal is easily managed because the voltage gain from this point to the output is relatively low. (A voltage level on pin 9 of from 1 to 4 volts will change the pulse width from zero to maximum which will yield zero to maximum output voltage.)

# APPLICATION NOTES – SG1524

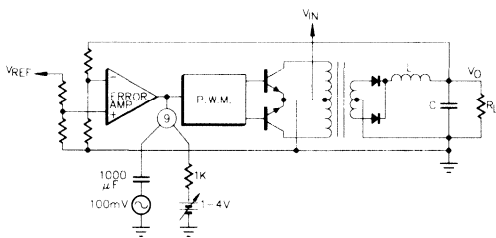


Figure 5. Measuring Output Stage Transfer Function

In experimentally attempting to confirm satisfactory operation of the output stages, the designer hopes to prove that a linear equivalent circuit model is valid for reasonable analysis. One such model as proposed by Middlebrook<sup>(9)</sup> is shown in Figure 6. This model describes the overall AC and DC transfer function and input and output impedances in terms of the duty cycle and modulation constant. This model assumes that the effects of operating frequency, switching delays, and parasitic elements are well above the frequencies of interest as defined by the output LC filter.

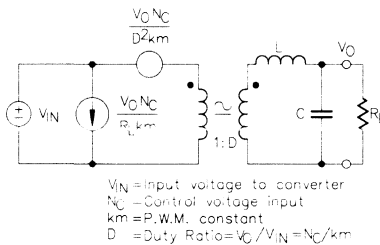


Figure 6. Linear Equivalent Circuit

Values for the inductor and capacitor are normally calculated on the basis of output ripple current and voltage as follows

$$L = \frac{V_{IN} f(\Delta_L)}{V_O (V_{IN} - V_O)}$$

and

$$C = \frac{V_{IN} f(\Delta_V)}{8L f^2 V_{IN} (\Delta V_O)}$$

where:

- $V_{IN}$  = peak input voltage to the inductor
- $V_O$  = output across the capacitor
- $f$  = switching frequency
- $\Delta I_L$  = peak - to - peak current variation in the inductor
- $\Delta V_O$  = peak - to - peak ripple voltage across the capacitor

Note that the actual ripple voltage at the output of the filter will be  $\Delta V_O$ , plus  $\Delta I_L$  times the capacitor E. S. R.

Regardless of the requirements for minimizing the output ripple, an additional requirement on the filter is that its cutoff frequency will be well below the switching frequency if our original goal of simple linear analysis is to be met. Specifically, the switching operation introduces a second order lag at one-half the switching frequency and for the output filter to dominate, its cutoff should be at least an order of magnitude below that number or

$$\frac{1}{2\pi\sqrt{LC}} \leq \frac{f}{20}$$

To verify the performance of the resultant hardware, a Bode plot of the output stage response can be most meaningful. Ideally, a plot as shown in Figure 7 should show a flat response to the filter cutoff and then a linear 12dB/octave rolloff with a

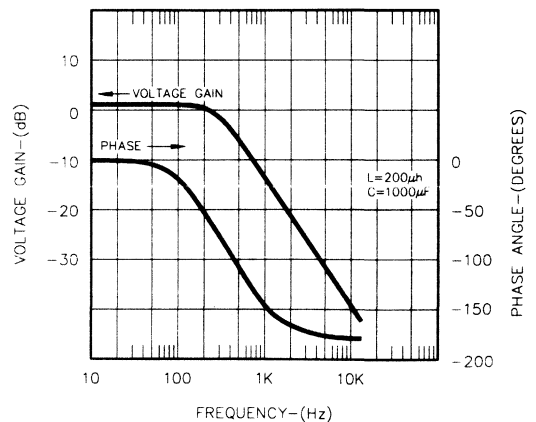


Figure 7. Linear Output Stage Response

180° phase shift. By making these plots with varying input voltage and load current, factors affecting stability such as leakage inductance, capacitor E.S.R., and either saturation or discontinuous operation of the magnetics may be evaluated over the operating conditions of interest. Figure 8 shows typical plots with less than ideal component parameters. With the characteristics of the output stage defined, attention can be turned to the error amplifier to develop an equalizing network which will allow satisfactory closing of the loop.

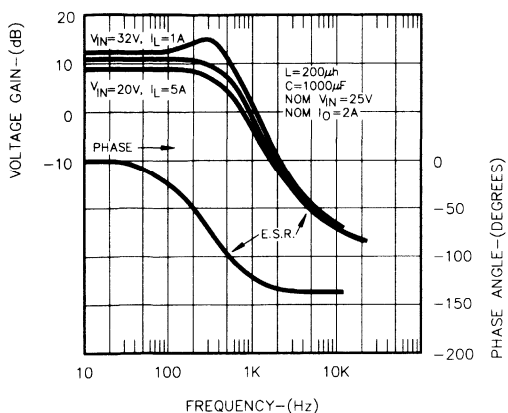


Figure 8. Measured Output Stage Response

## ERROR AMPLIFIER COMPENSATION

The error amplifier contained within the SG1524 is a transconductance amplifier in that it has a high-impedance, current source output. The gain is a function of the output loading and can be reduced from a nominal 80dB by shunt resistance as shown in Figure 9. Note also in Figure 9 that the uncompen-

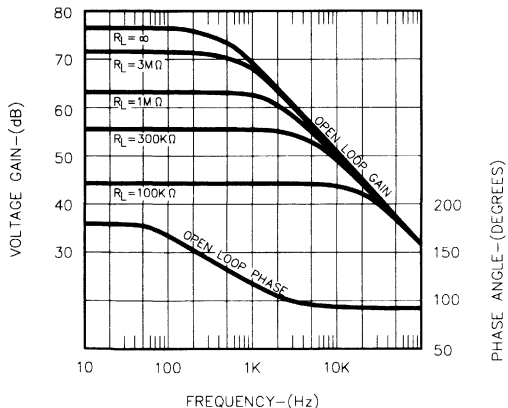


Figure 9. SG1524 Single-Ended Switching Regulator

sated amplifier has a single pole at 300Hz and 90° of phase shift. The unity gain cross-over frequency is 3MHz and the large scale slew rate is 0.5 volt per microsecond.

This type of amplifier can be compensated in two ways: The compensation network can go from the output to ground so it can

be connected from output back to the inverting input.<sup>(6)</sup> In the first case the voltage gain is:

$$A_V = gmZ_C = \frac{2kT}{8I_C Z_C} \approx 0.002Z_C$$

where  $Z_c$  is the complex compensation network impedance. If a feedback approach is used, the gain is:

$$AV = \frac{Z_C}{Z_S}$$

where  $Z_s$  is the source impedance driving the input. In cases where relatively low impedances are desired in a feedback network, it may be necessary to buffer the high output impedance of the error amplifier. Figure 10c shows the use of an external emitter follower to provide a low driving impedance for the feedback network.

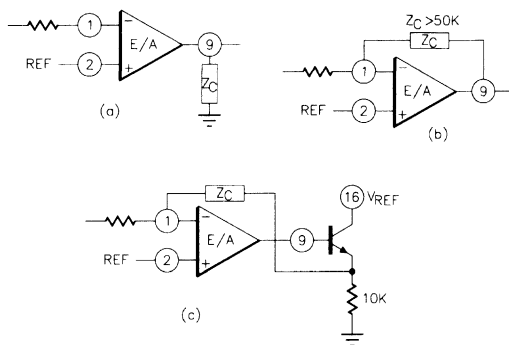


Figure 10. Error Amplifier Compensation Networks

To stabilize the overall regulator feedback loop of Figure 4, it should be apparent that the uncompensated loop contains at least two poles in the output filter and one more in the error amplifier, a situation which typically results in significant gain remaining when the total loop phase equals 360°. One of the simplest compensation schemes is to convert the error amplifier to an integrator by adding a single dominate pole at a frequency so low that the loop gain falls below unity well before the cutoff frequency of the output filter. While this approach yields a stable closed loop gain as shown in Figure 11, the response to disturbances is very slow. For example, the waveforms of Figure 12 show the response to a 20%, or one amp, step change in load to the circuit of Figure 3 when compensated with a 0.2µF capacitor around the error amplifier.

If instead of slowing down the error amplifier, a zero, or lead network is added to cancel one of the output filter poles, we can keep the total loop phase less than 360° to well beyond the output filter cutoff.

# APPLICATION NOTES – SG1524

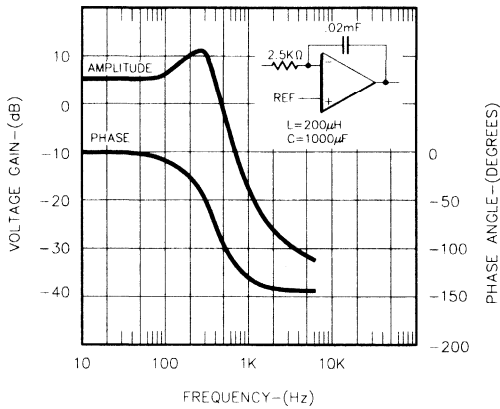


Figure 11. Closed Loop Frequency Response

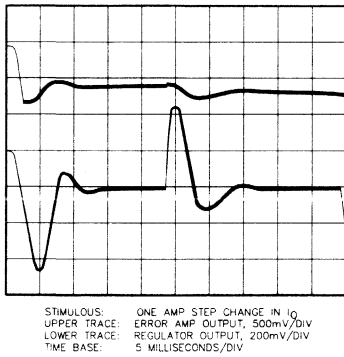


Figure 12. Integrator Compensation Step Response

Figure 13 shows a circuit for accomplishing this by moving the amplifier pole lower in frequency and adding a zero at the output filter cutoff frequency. Figure 14 shows the effects of this network on the Bode plot of the error amplifier, and Figure 15 indicates the improvement in recovery from the same one-amp load change. Note how the output of the error amplifier overshoots to give a boost to the output.

Even faster response can be achieved by providing additional lead networks. For example, another zero may be added by bypassing the sense feedback resistor. As can be seen in Figure 16, this greatly improves loop response but offers the hazard of coupling ripple noise directly into the error amplifier.

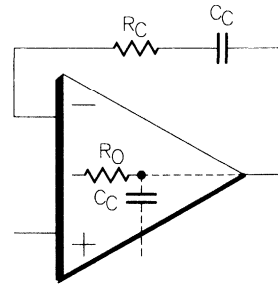


Figure 13. Series RC Phase Compensation

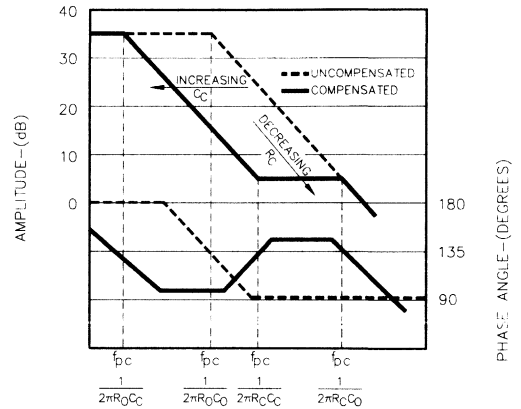


Figure 14. Phase Compensated Bode Plot

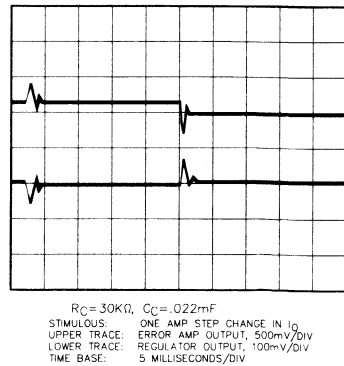
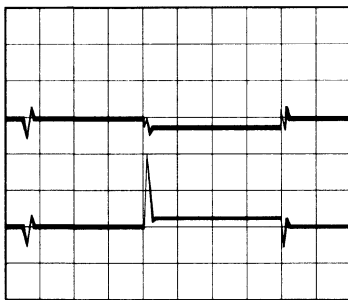
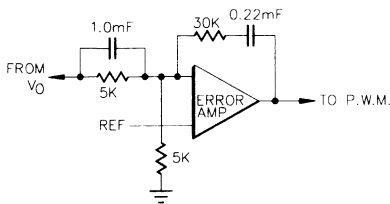


Figure 15. Phase Compensated Step Response

## TWO LOOP CONTROL

From the examples presented above, it should be apparent that the integration method of error amplifier compensation provides good stability by making the dominate pole so low in frequency that variations in all other circuit parameters become inconsequential. This technique also provides high accuracy at DC where high gain can be used and is the type of feedback one would want to take directly from the output of a regulator since a user might add additional external capacitance, thereby changing the output filter characteristics. Another reason for using single-pole compensation is to accommodate the use of a two-stage output filter which can add phase shifts well beyond 180°.



STIMULOUS: ONE AMP STEP CHANGE IN  $I_o$   
 UPPER TRACE: ERROR AMP OUTPUT, 500mV/DIV  
 LOWER TRACE: REGULATOR OUTPUT, 50mV/DIV  
 TIME BASE: 2 MILLISECOND/DIV

Figure 16. Double Zero Compensated Step Response

The problem of poor response can then be accommodated by adding a differentiated signal taken from somewhere else in the loop. If the time constants and gain factors are properly selected, the differentiated signal can compensate for the error in the integrated signal taken from the regulated output.

## SUMMARY

Although integrated circuit controllers for switching supplies have removed much of the circuit complexity from this type of regulator, the dynamic analysis of the control loop must still be optimized for each application. This optimization is made easier,

however, if a linear approximation of the switching stages can be shown to be valid. The SG1524 controller offers benefits in this regard as it does provide a linear transfer function through its pulse width modulation scheme. Therefore, experimental techniques can be used to simply confirm proper operation of the power switches and output filter.

With a linear output stage, conventional feedback analysis can be used to define the best equalizing network achieving a compromise between stability and fast response. In some cases it may even be desirable to provide separate signal paths for these two parameters but this, too, can be adapted to the SG1524 controller with a minimum of external circuitry.

Obviously, no recipes for optimum performance have been provided herein. Only a few directions which, it is hoped, will point the way toward the development of specific solutions for specific applications.

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**CONVERTING 1524 SWITCHING POWER SUPPLY  
DESIGNS TO THE SG1524B**

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Manager, Advanced Product Development  
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**INTRODUCTION**

Many power control engineers have designed successful switching power supplies around the SG1524 Pulse Width Modulator integrated circuit. This application note explains the differences between this earlier device and the more sophisticated SG1524B. While the functional pinouts are identical for the two devices, there are some distinct operational differences which the user should be aware of when designing new supplies or when updating an existing design. In many cases design changes are minimal (such as adjustment of frequency compensation) or not required at all. At the same time the improvements in control architecture and circuit design of the SG1524B allow the designer to obtain levels of performance in new power supply designs not possible with the older device.

**GENERAL COMPARISON**

Figures 1 and 2 show respectively the block diagrams of the SG1524 and the SG1524B. Both devices were designed for voltage-mode control, but both can be used to implement current-mode control as well with the addition of an external dual op amp. For further details see the Silicon General Application Note "Current Mode Control with the SG1524B."

The main functional difference between the two circuits is in the action of the shutdown pin. In the SG1524, a voltage at Pin 10 greater than +0.7 volts will turn on an internal transistor which pulls the error amplifier output to ground. In the SG1524B, a voltage greater than +1.2 volts at Pin 10 activates a logic gate which inhibits the pulse output of the PWM comparator. The error amplifier output-voltage is not affected directly.

Other improvements include the addition of an undervoltage lockout function and fault suppression logic. These provide protection against inadequate supply voltage to the control IC

and insure constant-frequency alternating output pulses to the power devices.

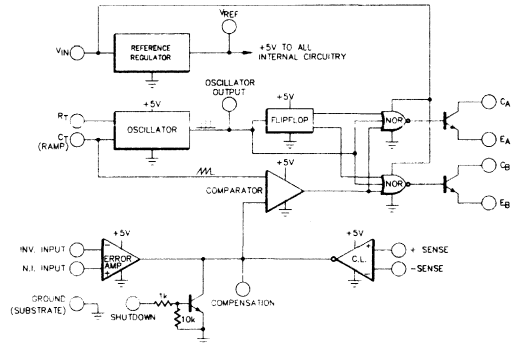


Figure 1. SG1524 Block Diagram

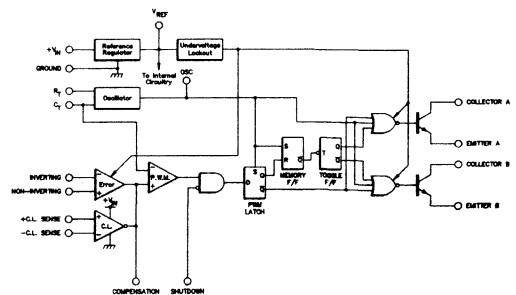


Figure 2. SG1524B Block Diagram

## INDIVIDUAL SECTION DIFFERENCES

### Voltage Reference

The voltage reference is a low-drift bandgap design which provides a precision +5.0 volt references for the control loop. Initial accuracy is  $\pm 1\%$  for the SG1524B/2524B, and  $\pm 2\%$  for the SG3524B. This is a factor of four improvements over the original reference. Line regulation is typically better by a factor of 3:3mV instead of 10mV. Load regulation is better by a factor of 4:5mV rather than 20mV. The temperature coefficient is also lower and more uniform from device to device. All these features translate directly into tighter tolerances on the switcher output voltage.

At 25°C the differential drop across the regulator is only 1.2 volts, as opposed to 2.7 volts for the 1524. Figure 3 shows the relationship between  $V_{IN}$  and  $V_{REF}$  for both devices. As a result, the SG1524B is fully functional with a 6.2 volt supply. Under worse case conditions of  $I_{LOAD} = 20mA$  and  $T_A = -55^\circ C$ , all devices also guaranteed to function at  $V_{IN} = 7$  volts.

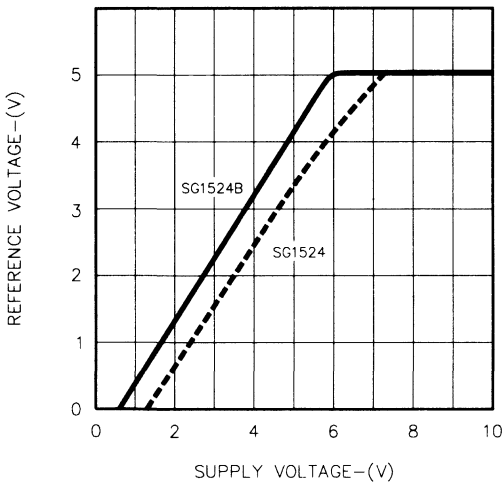


Figure 3. Reference Voltage vs. Supply Voltage

### Undervoltage Lockout

This circuit has two sections: a controlled current source which forces the error amp low and the output transistors off, and a bandgap comparator which overrides the lockout source. The current source is fully active when  $V_{IN}$  is +1.2 volts. Since the error amp and output driver cannot function until  $V_{IN}$  is approximately 3 volts, it is impossible for spurious output pulses to occur when the supply voltage is too low for normal operation.

The bandgap comparator monitors the reference voltage. It enables the SG1524B when the reference rises to +4.3 volts. This arrangement allows operation from a +5 volt  $\pm 5\%$  supply by connecting  $V_{IN}$  and  $V_{REF}$  together.

The action of the undervoltage lockout can be observed with the test circuit of Figure 4. A 100K pull-up resistor is connected from Compensation to  $V_{IN}$ .  $V_{IN}$  is swept from 0 to +6.5 volts with 5Hz triangle waveform from a function generator. An oscilloscope in XY Mode displaying  $V_{IN}$  horizontally and Compensation vertically will generate the display shown in Figure 5.

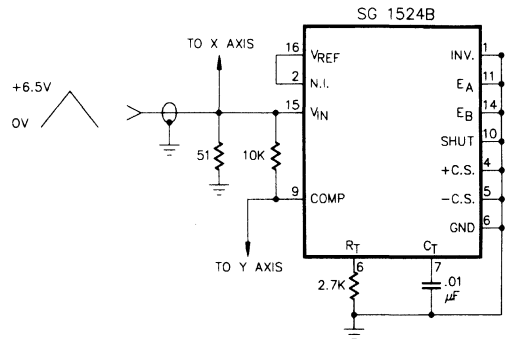


Figure 4. Undervoltage Lockout Test Circuit

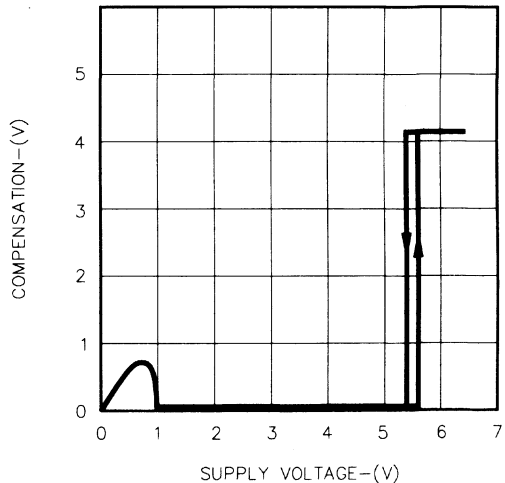


Figure 5 - Undervoltage Lockout At The Error Amp



# APPLICATION NOTES – SG1524B

As  $V_{IN}$  slowly sweeps from 0 to 1 volt, the lockout current source becomes active and pulls the error amp to ground, guaranteeing 0% duty cycle from the controller. From 1 volt to approximately 5.5 volts the controller is inhibited while the internal circuitry stabilizes. At 5.5 volts the bandgap comparator overrides the lockout current, releasing the output of the error amp. The reverse portion of the voltage sweep is identical, except that approximately 200mV of hysteresis can be observed at the comparator trip point.

## Oscillator

The oscillator of the SG1524 is programmed for frequency with an external  $R_T$  and  $C_T$  in the same manner as the SG1524. Both initial accuracy and temperature coefficient have been improved with the "B" version.

There are two methods to synchronize multiple units together.

- Program master unit with  $R_T$  and  $C_T$  for the desired frequency. Connect the  $C_T$  terminal (Pin 7) of the master to the  $C_T$  terminal of the slave. Connect the OSC terminal (Pin 3) of the master to the OSC terminal of the slave. Leave the slave  $R_T$  terminal (Pin 6) open or tied to the reference. This is the recommended approach if the PWM controllers are close together (on the same printed circuit board and within six inches of each other).
- Program a master unit for the desired frequency. Select  $R_T$  and  $C_T$  for the slave units such that they free-run at a frequency 10% slower than the master. Connect all the oscillator terminals together. This method is recommended if the PWM controllers are not close together, since it avoids routing a high impedance line ( $C_T$ ) around a noisy environment.

To synchronize one or more devices to an external clock frequency, one of the connections shown in Figure 6 should be used. The device(s) to be synchronized should free-run 10% slower than the clock. Pulse width of the external clock should be at least 200nsec, but not longer than the desired deadtime.

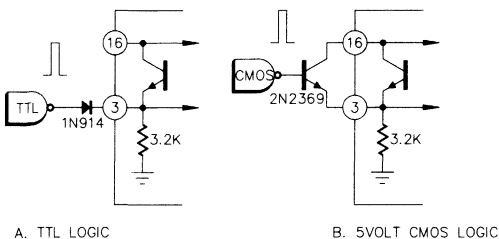


Figure 6. Oscillator Sync to an External Clock

## Error Amplifier

The error amplifier of the SG1524B is, like its predecessor, a transconductance design with an output impedance of approximately 4 megaohms. This allows use of external clamp circuitry to obtain soft-start and duty cycle limit, as on the original 1524. Since all the voltage gain takes place at the output pin, open-loop gain/frequency characteristics are easily controlled by shunt reactance from Pin 9 to ground (Figure 7). Also, this type of amplifier has a very predictable 1/T variation of open-loop gain with absolute temperature as shown in Figure 8.

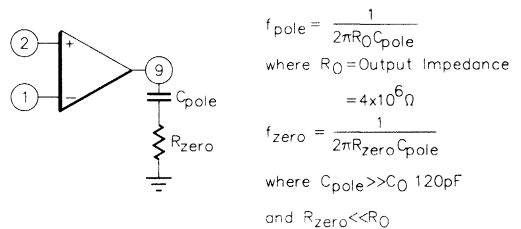


Figure 7. Frequency Compensation of the Error Amplifier

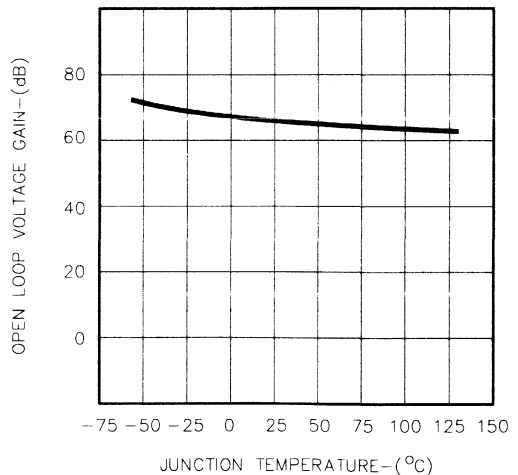


Figure 8. Open Loop Gain vs. Temperature

The input common mode range is +2.3 to +5.2 volts, so that existing designs at +2.5 volts will function with no modifications. For new designs the +5 volt reference may be applied directly to the non-inverting input, eliminating the necessity for two divider resistors.

Since the lower common mode limit is +2.3 volts for the 1524B and +1.8 volts for the 1524, neither amplifier should ever be used

# APPLICATION NOTES – SG1524B

in the non-inverting unity-gain configuration shown in Figure 9. The error voltage must swing down to +5 volts to guarantee 0% duty cycle from the pulse width modulator, and this violates the common mode range specification.

In general, any frequency compensation for the voltage control loop which works with the SG1524 can also be used with the SG1524B with no modification.

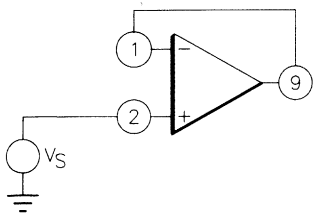


Figure 9. Non-Inverting Unity-Gain Connection (Not Recommended)

## Current Limit Amplifier

The current limit amplifier of the SG1524B is one of the most significant areas of change from an applications viewpoint. Like the original circuit, there is a fixed 200mV threshold designed into Pins 4 and 5 to permit direct sensing across a current sampling resistor. Differences in the "B" circuit affect the input bias current, allowable common mode range, and stability in current-limit.

## Input Bias Current

In the SG1524, there is a constant 130μA flowing out of Pin 4, while the current out of Pin 5 is variable from 0 to 100μA depending on the differential input voltage. Because of this characteristic, the current limit sense terminals must be driven from source impedances less than 20 ohms to avoid modulating the current limit threshold. The "B" device features bias currents which are identical at each pin, are independent of current sense voltage, and are a factor of 10 lower. This allows predictable foldback current limiting without wasteful low-resistance divider networks.

## Common Mode Range

The guaranteed common mode range of the current sense inputs is 0 volts to  $V_{IN} - 2.5$  volts. Current sensing in a supply ground line is possible, but the configuration of Figure 10 should be used to avoid damaging the IC. The 100ohm resistor is required because of delays through the controller and storage time in any bipolar device. The SG1524B will reduce the pulse width as Pin 5 is driven 200mV below ground, but in practice it is

overdriven due to the aforementioned delays. If Pin 5 is driven below -0.3v at  $T_A = +125^\circ\text{C}$  the substrate diode will conduct. The 100ohm resistor will limit the peak substrate current to a safe value without shifting the C.L. threshold.

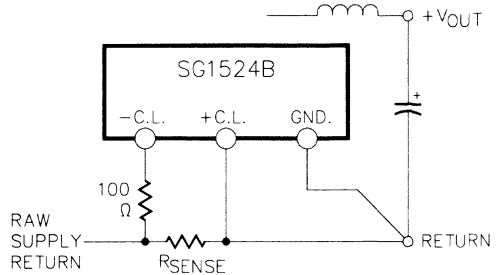


Figure 10. Current Sensing in the Ground Line

Current sensing may also be accomplished with a common emitter or source resistor to ground as shown in Figure 11; or it may be placed in the supply output line, as indicated in Figure 12. At -55°C the value of  $V_{IN}$  must be at least 2.5 volts greater than the switcher output voltage.

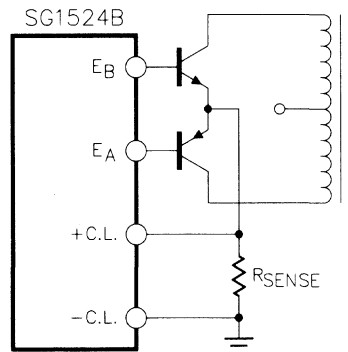


Figure 11. Sensing Primary Current With an Emitter Resistor

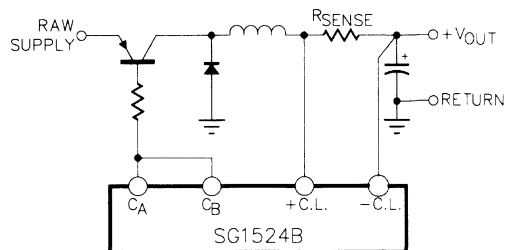


Figure 12. Current Sensing in the Output Line

# APPLICATION NOTES – SG1524B

## Frequency Compensation

The original SG1524 current limit amplifier had a typical open loop gain of 44dB and was internally compensated to produce a single-pole rolloff above 300Hz. The SG1524B exhibits 75dB of gain and has no internal compensation. The circuit may be used as a moderate speed comparator, or it may be used as an analog gain block to override the error amplifier.

Because of the higher gain and bandwidth, designers may find that the control loop will oscillate when the supply goes into current limiting. The cure is to add frequency compensation externally to the current limit circuit or to rework the existing voltage loop compensation. See the Silicon General Application Note "A New, Versatile P.W.M. Control Circuit for Switching Power Supplies."

## Shutdown

The shutdown circuit of the "B" is illustrated in Figure 13. It has the following differences compared to the 1524:

- Logic threshold is +1.2 volts instead of +0.7 volts for compatibility with TTL logic and improved noise immunity.
- Input current is very low (usually under 100nA) even at +5 volts input. The pin may be driven directly from TTL logic (all families) to TTL-output comparators.
- Response time is very fast, between 35 and 100 nanoseconds depending on output transistor loading.

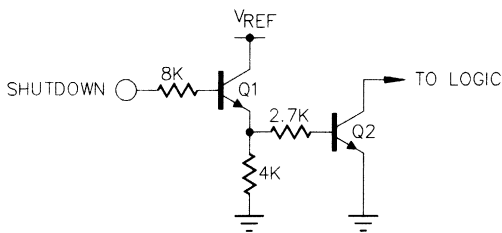


Figure 13. Shutdown Circuitry of the SG1524B

**The shutdown pin should never be left floating.** If not used, the pin should be grounded. If the shutdown function is used, the pin should be driven from a low impedance source to prevent noise pickup. The internal logic is very fast, and will respond readily to spurious pickup from the normally noisy environment of a switcher.

## Output Transistors

The output devices have been redesigned to provide 100mA continuous and typically 200mA peak, with  $BV_{CEX}$  ratings of 60 volts. Saturation voltage is guaranteed both at 10m and 100mA to ease the interface with external power devices.

## Bipolar Drive

For driving bipolar devices the circuit in Figure 14 is recommended. The output transistor is used as a phase-splitter to generate the necessary base drive. Figure 15 illustrates forward and reverse base current, and collector current of a PMD 20K 120 volt, 14amp Darlington using this driver configuration.

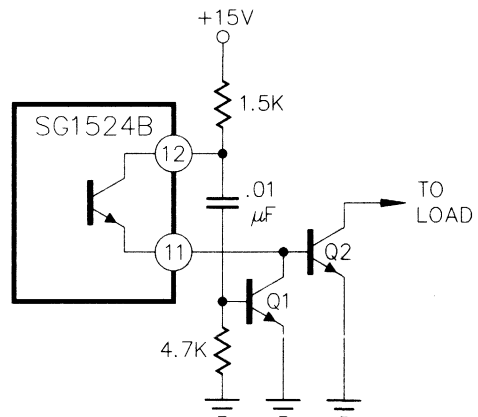


Figure 14. Driving Power Bi-Polar Transistors with the SG1524

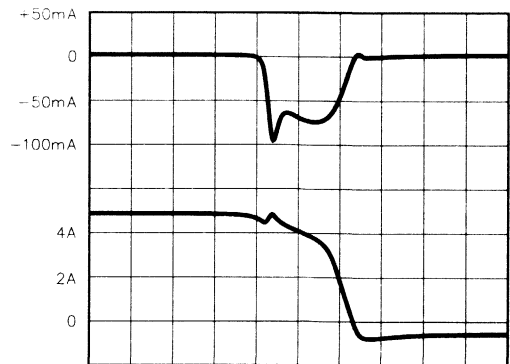


Figure 15. Bipolar Turn-Off Waveforms.  
Upper Trace: Darlington Base Current @ 200 Nsec/Div.  
Lower Trace: Collector Current @200 Nsec/Div.

# APPLICATION NOTES – SG1524B

## Mosfet Drive

Highly capacitive loads such as presented by the gated of power MOSFET's can be readily driven with the circuit in Figure 16. At turn-on, 200mA of charging current is conducted by D1. During turn-off D1 becomes back-biased by the pull-down resistor. Q1 turns on and provides 500mA of discharge current. Figure 17 shows the turn-off gate voltage and drain current of an IRF130 100 volt, 14amp power MOSFET driven directly with this circuit.

## CONCLUSION

A designer who is familiar with the SG1524 will find it relatively easy to adapt his designs to use the SG1524B. The immediate benefits are higher levels of power supply performance, worthwhile reductions in total component count, a greater degree of protection for the power devices, and lower overall costs.

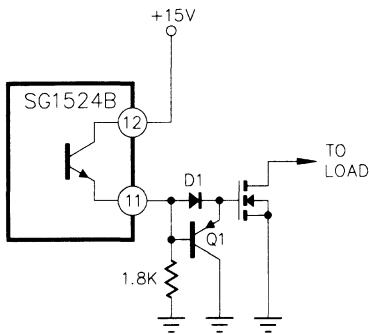


Figure 16. Driving Power Mosfets With the SG1524B

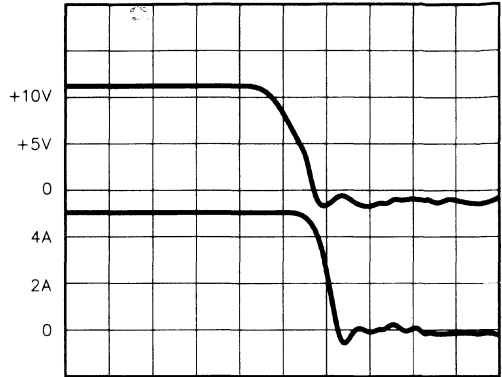


Figure 17. Mosfets Turn-Off Waveforms.  
Upper Trace: Gate Voltage @ 100 Nsec/Div.  
Lower Trace: Drain Current @ 100 Nsec/Div.

## **A NEW, VERSATILE P.W.M. CONTROL CIRCUIT FOR SWITCHING POWER SUPPLIES**

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### **ABSTRACT**

A new control circuit for pulse-width-modulated switchmode power supplies is described. This device offers improved electrical and functional performance over earlier designs, while retaining the familiar pin-out of the industry-standard SG1524. Innovative circuit design techniques and optimized control architecture result in improved reference accuracy, protection against inadequate supply voltage, elimination of harmful output switching transients, improved current limiting, and higher voltage and current capabilities from the output transistors. A 50kHz power supply utilizing the new controller is described, and performance characteristics are analyzed.

### **INTRODUCTION**

Since the introduction in 1976 of the first monolithic control chip for switchmode power supplies, and its subsequent wide acceptance as the basic building block for high-efficiency regulator designs, the semiconductor industry has found itself in a bit of quandry when attempting to define an improved device. On the one hand, the initial device, being rather simple and straightforward, had a number of deficiencies when its capabilities were compared with the total requirements of most switchers. As a result, new, more complex controllers were introduced with improved reference accuracy, protection against inadequate or fluctuating supply voltage, improved current limit circuitry, fault suppression logic, and a host of other features.

On the other hand, the new controllers, while enthusiastically accepted first by aerospace designers for sophisticated high-performance supplies and later by major computer and instrumentation manufacturers, lacked the familiar pin-out of the earlier device. As a result it has not been possible until recently to easily upgrade the performance of an existing design by simply plugging in a more intelligent pin-for-pin substitute.

The circuit to be described has been under development at Silicon General for more than two years, and represents an attempt to fit as much function as possible within the constraints of the original device pin-out. Designated the SG1524B, the device block diagram is shown in Figure 1.

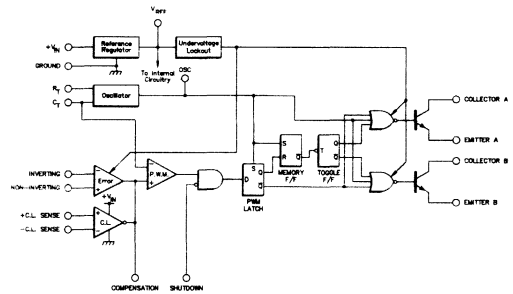


Figure 1. Block Diagram of the SG1524B Pulse Width Modulator

### **FUNCTIONAL DESCRIPTION**

A precision +5.00V reference trimmed to an initial  $\pm 1\%$  accuracy provides a voltage standard for the regulation loop. It also powers most of the internal control circuitry, eliminating adverse effects due to fluctuating supply voltage. A high gain error amplifier compares the reference voltage with the switchmode supply output voltage, and generates a PWM control voltage at Pin 9. This voltage is compared against a periodic linear ramp

# APPLICATION NOTES – SG1524B

generated by the oscillator circuit. Oscillator frequency is determined by an external timing resistor and capacitor,  $R_T$  and  $C_T$ . The comparator output is a fixed-frequency, variable pulse-width logic signal which passes through routine logic to one of the two high current output transistors if the Shutdown pin is LOW. A current limit amplifier within the IC overrides the PWM control voltage when the voltage differential at the Current Limit Sense inputs reaches 200mV. This built-in threshold permits direct sensing across an external current sampling resistor. On-chip undervoltage lockout circuitry protects the power semiconductors in the switchmode supply by guaranteeing orderly start-ups and shutdowns as supply voltage is switched on and off. Each control section of this new PWM controller has been either redesigned for improved performance, or is a completely new function compared to the original SG1524 design. A detailed description of each section follows to highlight the major improvements.

## Bandgap Reference Regulator

The precision reference uses the predictable base-emitter voltage of NPN transistors to generate the +5V reference voltage, rather than a zener diode<sup>(1,2)</sup>. The advantages of this design approach are: lower noise due to elimination of the shot noise associated with an avalanche device, low turn-on drift, better log term stability, and operation from a lower supply voltage. The primary disadvantages are that the bandgap requires more components, and thermal matching of key devices is necessary for realizing low thermal drift.

	ZENER REFERENCE	BANDGAP REFERENCE
Minimum Supply Voltage	8V	7V
Output Noise Voltage	75 $\mu$ Vrms	25 $\mu$ Vrms
Long Term Stability	20 mV/1000hrs	5 mV/1000hrs
Turn-on Drift	5-35 mV	2 mV

Table 1. Comparison of Zener and Bandgap Reference Typical Parameters

The ability of the PWM controller to be fully functional with a 7V supply enhances its usefulness in portable instrumentation applications, where six-cell Ni-Cad battery voltage is defined as end-of-life before recharge.

## Undervoltage Lockout

The undervoltage lockout circuitry prevents spurious turn-on commands to the external power transistors when the supply voltage to the integrated circuit is too low for proper operation. When the reference voltage is less than +4.5V, the output transistors are forced to an OFF or nonconducting state. Additionally, the output of the error amplifier is clamped to ground. When the supply voltage rises to +7V, the output drivers are enabled and the amplifier output is released. Since compensation capacitance is usually present at Pin 9, this provides a

measure of built-in soft start.

During the power-up period of the controller, when the undervoltage lockout is achieved, bias current is freely supplied to all the internal control circuitry. This insures that all control functions have stabilized in the proper state when the turn-on voltage is reached, and it prevents the possibility of start-up glitches.

The lockout circuitry monitors the reference voltage rather than  $+V_{IN}$  to allow the SG1524B to be used with +5V supplies in the same manner as the original SG1524. If the  $+V_{IN}$  pin is connected to the  $V_{REF}$  pin and  $+5V \pm 10\%$  is applied, the control chip will function normally. When the undervoltage sense circuitry monitors the  $+V_{IN}$  pin, this type of operation is not possible due to the 2-3V drop across the internal regulator.

To provide jitter-free turn-on and turn-off points, the lockout circuitry has been designed with approximately 500mV of hysteresis. This provides rejection of 120Hz ripple on the  $+V_{IN}$  line and reduces capacitive filtering requirements on the controller supply voltage.

## Error Amplifier

The error amplifier of the SG1524B was designed with three principle goals in mind: a common-mode range extending from +2.5V to  $+V_{REF}$ , excellent supply voltage and common-mode noise rejection characteristics, and a minimum voltage gain of 60dB at +125°C. Like its predecessor, it is a transconductance amplifier with a high-impedance output to permit external soft-start circuitry.

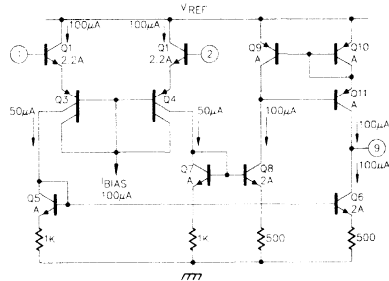


Figure 2. Schematic Diagram of the SG1524B Error Amplifier

Input transistors Q1 and Q2 are connected as emitter-followers with their collectors tied to the +5V reference supply. This configuration provides the required common-mode range, even with  $+V_{IN}$  connected to  $V_{REF}$  for operation from a +5V supply. It also provides current gain to reduce input bias current, and produces a low impedance source to drive level shifters Q3 and Q4. These PNP devices operate at a forced beta of 1.0, and are connected common base to maximize frequency response.

# APPLICATION NOTES – SG1524B

Input stage operating current is set up by the 100µA bias supply to the common base. Frequency response is further improved by the low impedance collector loads Q5 and Q7. These two devices are diode-connected and form the input sides of two precision 2-to-1 current mirrors, which provide additional current gain. The output current of Q6 provides the pull-down or sink current for the amplifier output. The collector current of Q8 is referenced to the +5V supply rail by the Wilson current mirror consisting of Q9, Q20, and Q11. The collector current of Q11 provides the pull-up or source current for the amplifier output. It can be seen from the symmetry of the circuit that a differential input voltage is converted to an output current, with a maximum of ±200µA available. The open-loop voltage gain can be shown to be<sup>(3)</sup>

$$A_v = gm R_L = I_s \frac{q}{kT} R_L = .001 R_L \text{ at } +25^\circ\text{C}$$

Since  $R_L$  is the parallel combination of the output impedances of Q6 and Q11, and is typically 4MΩ an open-loop voltage gain of 72dB is obtained.

The circuit design of the output stage insures that the maximum positive output swing never exceeds +4.3V. This is important when considering loop recovery from momentary overloads which drive the PWM to maximum duty cycle. The peak value of the sawtooth oscillator waveform is +3.4V, and the error amplifier must slew from positive full scale to less than this voltage to reduce the duty cycle from maximum. Some error amplifier designs clamp the output voltage with a 6.3V zener diode, nearly tripling the recovery time from overload. Since all the voltage gain of the error amplifier takes place at the output pin, the amplifier can be easily frequency compensated at this node with shunt reactance to ground. The uncompensated amplifier exhibits an open loop pole at 350Hz and a typical unity-gain bandwidth of 2MHz.

## Current Limit

The current limit amplifier has been redesigned to eliminate the two most common complaints about the original SG1524: limited input voltage range and slow response time. In the original design the ±1V common-mode range restricted current sensing to the supply return line only. In many systems, ground returns cannot be separated, making the current limit function unusable. Also, the internal frequency compensation provided freedom from oscillation at the expense of response time.

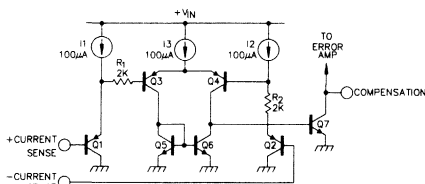


Figure 3. High-Gain Current Limit Amplifier

In the new design, input transistors Q1 and Q2 allow common mode voltages as low as -0.3V over the operating temperature range, allowing sensing in the ground line for configurations that require it. The upper limit is restrained only by the value of  $+V_{IN}$ , to which the level-shifter current sources I1 and I2 are referenced. The voltage drop across R2 creates a 200mV offset voltage at the amplifier input which provides the current sense threshold. The positive 0.2%/°C temperature coefficient of  $R_2$  is balanced by a negative tempco for I2, effectively canceling effects of temperature on the current sense threshold.

Since both the allowable common-mode and differential voltages are much greater with this design, higher current foldback ratios can be achieved compared to the maximum of 3 or 4 possible with the earlier part. Also, the bias currents are a factor of 10 lower, resulting in more consistent limiting thresholds from unit-to-unit when foldback is employed.

Because there is no internal compensation capacitor, stability in the current limit mode will depend on external components. Due to the controller architecture, in which the output of the current limit amplifier overrides the error amplifier, these external frequency compensation networks may either be shared with the error amplifier or optimized for the current limit amplifier. The two choices are shown in the figures. In either case, the designer now has the freedom to optimize bandwidth for his particular switcher configuration.

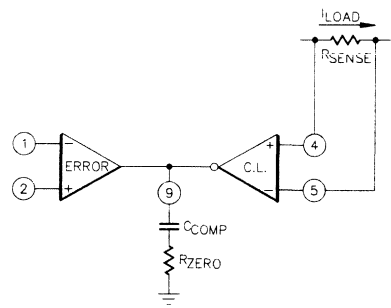


Figure 4. Current Limit Compensation in Common With Error Amp

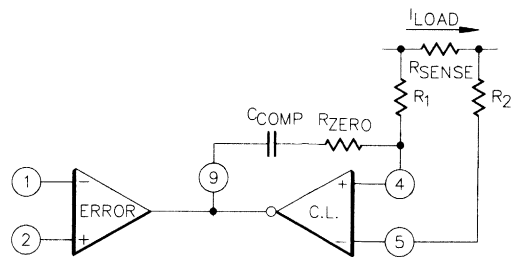


Figure 5. Current Limit With Optimized Frequency Compensation

# APPLICATION NOTES – SG1524B

## Oscillator

The sawtooth oscillator circuitry of the SG1524B incorporates the same design improvements recently applied to the SG1524. These result in greatly improved external drive and synchronization capability, together with reduced sawtooth undershoot at high frequencies. In the original SG1524 design, an external synchronization pulse applied to the OSC pin did not generate a self-sustaining discharge cycle. The extent of the discharge of  $C_T$  depended on both the amplitude and duration of the external pulse. As a result, it was possible to generate erratic sawtooth waveforms with partial discharge cycles and pulse-to-pulse modulation of waveform endpoints. The frequency result was audible noise from subharmonics, transformer saturation, and destruction of the power transistors.

In the improved design, an external sync pulse which meets the minimum threshold requirements triggers a positive feedback circuit. This circuit drives the oscillator to end-of-discharge even if the external pulse is very narrow. Due to the feedback, there exists no in-between or quasi-synchronized state; the oscillator switches smoothly between free-running and synchronized modes as the external pulse amplitude is varied through the trigger threshold.

The positive feedback also effectively bootstraps the comparator gain, providing enhanced voltage swing and output current at Pin 3 to drive peripheral circuits. The improved oscillator design, together with a fast, DC-coupled toggle flip-flop, permits operation beyond 500kHz. However, the limitations associated with single-transistor outputs put a practical upper limit of 400kHz on the device.

## Full Double-Pulse Suppression Logic

The PWM logic in the SG1524B insures that the output pulses always alternate from side to side, regardless of the action of the shutdown circuit. This is very important in push-pull switcher configurations where two pulses in succession on one side of the power transformer primary will cause core saturation and instantaneous failure of the power transistor.

The logic consists of two sections: a PWM latch circuit and a memory flip-flop. The latch allows only one pulse through per oscillator cycle. Once a PWM pulse is terminated, whether due to the normal PWM process or due to SHUTDOWN going high, the pulse cannot start again until the beginning of the next oscillator cycle. Pulse-by-pulse current limiting is easily accomplished now because of the latch feature and the completely digital (and therefore very fast) shutdown circuitry.

The memory flip-flop insures that output pulses always alternate from the output transistors. This is accomplished by generating a clock to the toggle flip-flop only if a PWM pulse was generated during the previous cycle. In the original 1524, the toggle flip-flop changes state with every oscillator pulse, irrespective of what the outputs are doing.

Figure 6 and 7 illustrate the difference in performance between two PWM control ICs, one with only a data latch and the other with the full double-pulse suppression logic described above. The triple-trace photos in each example show an alternating output pulse sequence interrupted by a SHUTDOWN command, followed a short time later by resumption of outputs from Emitters A and B. Oscillator frequency is 40kHz for each device, so 20kHz is obtained at the output transistors.

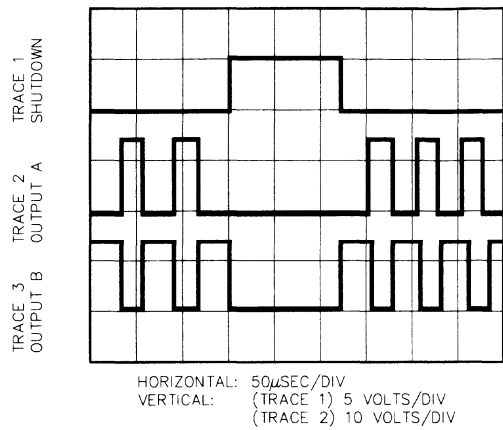


Figure 6. Output Sequence Without Double Pulse Suppression

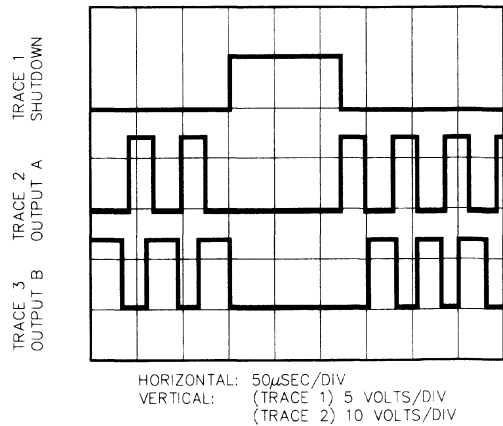


Figure 7. Output Sequence With Double Pulse Suppression

In the first case, the PWM pulses are alternating can BABAB when a SHUTDOWN signal inhibits the outputs for five oscillator cycles. When output resumes, the output sequence begins



# APPLICATION NOTES – SG1524B

BABAB...Two pulses have occurred in succession from Emitter B.

With the second control IC, the PWM pulses are again alternating BABAB when a SHUTDOWN signal is received, again inhibiting output for five oscillator cycles. When SHUTDOWN is removed, output resumes but with an ABABA...sequence. The potential double-pulse from Emitter B has been eliminated by the internal pulse-steering logic.

This side-by-side pulse-routing problem exists for any PWM control IC with push-pull architecture and a fully digital shutdown function. In the original 1524 design, recovery from shutdown was fairly slow since the error amplifier output was pulled to ground for turn-off. Turn-on was limited by the  $100\mu\text{A}$  output current of the error amp, the internal compensation capacitor in the current limit circuitry, and any external frequency compensation components. This created an inherent soft-start characteristic. With digital shutdown, the error amp voltage is not immediately affected; the first pulse out after shutdown can be the same width as before shutdown, making pulse-routing logic an absolute necessity to guarantee the safety of the power switches.

## Output Transistors

In response to requests for greater output drive capability, the output transistors were redesigned for both higher breakdown voltage and more current.

In a PWM controller with a single-transistor output structure, the load driven is frequently one end of a center-tapped transformer primary winding. Since the maximum collector voltage is  $2 \times V_{CC}$ , the absolute maximum rating of 40V for the earlier device restricted the supply voltage to 20V. Consideration given to the effects of transformer leakage reactance would reduce this voltage still further. The SG1524B output transistors carry  $BV_{CEX}$  ratings of 60V, high enough for use on a standard +28V supply bus.

Output device geometry was scaled up to allow reliable operation at continuous collector currents of 100mA. This represents a factor of two improvement over the earlier device, which was characterized at only 50mA. As a further aid to the designer, the data sheet for the new device specifies maximum saturation voltage at two continuous current levels: 10mA and 100mA. The maximum peak current capability of the output transistors is 200mA for  $1\mu\text{S}$ .

The anti-saturation clamp circuit around the output transistors found in the earlier PWM controller has been retained in the SG1524B to enhance switching speed. Each output transistor is also guarded against excessive current by protective circuitry which limits the maximum continuous current to 150mA at  $+25^\circ\text{C}$ .

## DESIGN EXAMPLE

The functional usefulness of a new device is best demonstrated by study of an actual switcher design. The circuit described illustrates full control of a power supply with a single integrated circuit, resulting in reduction of overall cost and an increase in supply reliability through reduction of component count.

The circuit illustrated in Figure 8 is a push-pull, +28V to +5V converter operating at 50kHz. The power supply is unique in that the only active component is the SG1524B regulating pulse width modulator; the only other semiconductors required are diodes.

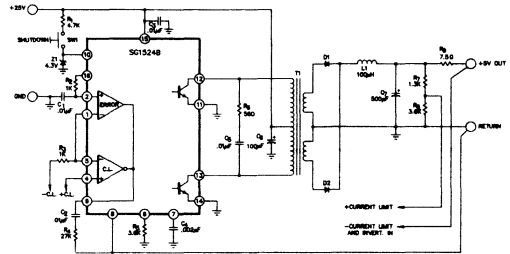


Figure 8. A Single IC 50 kHz Push-Pull Converter

The DC-coupled push-pull configuration was chosen because it is most sensitive to PWM controller anomalies which cause side-to-side imbalance. These include start-up problems such as output from only one driver until the toggle flip-flop begins to be correctly clocked by the oscillator. During normal operation, side-to-side imbalance of volt-second product due to unequal propagation delays in the IC can cause the onset of core saturation. Finally, as outlined earlier, when the digital Shutdown control is activated, double-pulse sequencing can drive the excursion of the transformer core flux past the saturation knee of the BH loop.

Capacitor C3 acts as a high-frequency bypass for the IC supply line, while C6 is the high current reservoir for the power stage. The oscillator is set for 100kHz with C4 and R5. When divided by two by the action of the internal toggle flip-flop, this becomes 50kHz at the power transformer. The +5V reference is filtered against high frequency noise pick-up by R2 and C1, and applied to the non-inverting input of the error amp. The inverting input is connected to the power supply output terminals to form the negative feedback loop required for regulation. R3 minimizes the effects of input offset bias current by equalizing the source impedance seen by each error amp input terminal. Closed loop stability is provided by frequency compensation components R4

## APPLICATION NOTES – SG1524B

and C2, using the common technique of cancelling one of the two poles of the LC output filter with an open-loop zero in the error amplifier.<sup>(4)</sup>

In the power section of the supply, the two output transistors are used to directly drive a center-tapped transformer. A snubber network consisting of C5 and R6 modifies the inductive load line seen by each transistor. The transformer itself is wound on a small ferrite core; turns ratio is 3:1. Rectifier diodes D1 and D2 are Schottky junction devices to maximize efficiency at +5V output. Filtering is provided by L1, wound on a permalloy powder toroid, and C7.

The improved common mode range of the current limit amp is used to good advantage here; current sensing is done directly in the output line. A foldback ratio of 7.5 to 1 is obtained with the given values R7, R8, and R9. The divider formed by R7 and R8 applies a back-bias of 1.3 volts, or 6.5 times current limit threshold, when the supply output is at +5.0V. Peak output current before onset of current limiting is 200mA, and short-circuit current is only 25mA. Rapid turn-off of the control circuit is accomplished by closing SW1. R1 and Z1 limit the maximum voltage applied to the Shutdown terminal to less than +5V.

While capable of only limited output power due to thermal limitations of the 16 pin Cerdip package, the supply amply illustrates the controller ability to perform all the major control functions required both during start-up, normal regulation, and overload.

### CONCLUSION

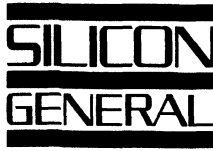
In the past it was often necessary to incorporate additional components around the 1524 pulse-width modulator to enhance its capabilities, and to guard against various functional anomalies. Economically this was feasible due to the relative cost of the control device compared to the cost of the peripheral components.

With the occurrence of the usual price decline characteristic of most integrated circuits, the economic balance has shifted. Many users now pay more for the necessary support circuitry than for the 1524 itself.

The availability of the SG1524B now gives the designer another option. In many instances costly additional support components can be eliminated and a functionally superior device may be plugged directly into an existing design, with the benefit of simplicity, greater reliability, and reduced overall cost.

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LINEAR INTEGRATED CIRCUITS

## APPLICATION NOTES – SG1525

### *SYNCHRONIZING THE SG1525A PWM*

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#### 1. Synchronizing One Device to an External Clock

- A. Program the SG1525A oscillator with  $R_T$  and  $C_T$  to free-run at a frequency 10% slower than the external clock frequency.
- B. Drive the SG1525A SYNC terminal (pin 3) with the external clock. Input impedance is 2K. The clock amplitude should be greater than 2 volts and less than 5 volts. Pulse width should be at least 300nsec. for reliable triggering, but it should not exceed the free-running oscillator clock pulse width by more than 200nsec.

#### 2. Synchronizing Multiple Devices to an External Clock

Two different methods are recommended, depending on the distance between the various SG1525A PWMs. Use method A if the ICs are within 3 inches of each other and on the same printed circuit board. Otherwise, use method B.

- A. Designate one of the SG1525A PWMs as the master unit and select  $R_T$ ,  $C_T$ , and  $R_D$  to free-run 10% slower than the external sync frequency. Connect all pins together and all OSC pins together, leaving  $R_T$  pins and DISCHARGE pins open on the slave units. Drive the SYNC pin of the master with a clock pulse as described in Section 1B above.
- B. Program each of the separate devices with  $R_T$ ,  $C_T$ , and  $R_D$  to free-run 10% slower than the external sync frequency. Drive each of the SYNC pins with the clock described in Section 1B. (This arrangement avoids routing a high-impedance line [ $C_T$ ] around a noisy environment.)

#### 3. Synchronizing One Slave Unit to a Master SG1525

As in Section 2, two methods are advised, depending on the distance between the master unit and the slave. Use method A for short distances, and method B otherwise.

- A. Program the master unit for desired frequency with  $R_T$ ,  $C_T$ , and  $R_D$ . Connect the  $C_T$  pin of the master to the  $C_T$  pin of the slave, and the OSC pin of the master to the OSC pin of the slave. Leave the  $R_T$  and DISCHARGE pins of the slave open.

- B. Program the master unit for desired frequency. Program the slave unit to free-run 10% slower than the master. This is best done by choosing  $C_T$  and  $R_D$  to be the same as the master, and by increasing the value of  $R_T$ . Drive the SYNC pin of the slave with the OSC pin of the master.

#### 4. Synchronizing Multiple SG1525A to a Master SG1525A

Again, different techniques are recommended depending on the physical and electrical distances between the various PWM circuits. If all of the devices are separated by no more than 3 inches each, and on the same pc board, then the "cluster" technique described in section 3A (i.e. sharing a master unit's  $C_T$  and OSC waveforms with adjacent slave units) will give good results.

If one or more of the devices are remote from the master so that the  $C_T$  node cannot be distributed without the possibility of noise pick-up, then each remote unit must be synchronized as described in Section 3B above. Note that it is possible to cluster remote units to decrease the required number of timing components. In other words, if two or more units are close together at one remote location, one of them can be programmed for the required 10% slower free-run frequency, and its  $C_T$  and OSC waveforms can be shared with its neighbors.

This description covers all the possibilities normally encountered. NOTE THAT IT IS ALWAYS GOOD ENGINEERING PRACTICE TO GROUND ANY UNUSED SYNC PINS TO ELIMINATE THE POSSIBILITY OF NOISE PICK-UP.



## ***DIGITAL CURRENT LIMITING TECHNIQUES FOR SWITCHING POWER SUPPLIES***

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Silicon General, Inc.

### **ABSTRACT**

This paper explores the performance benefits gained by digital techniques for current limiting in switch-mode power supplies. The necessary control architecture is described along with the several possible modes of operation. Characteristics of several actual supplies using these techniques are presented.

### **SUMMARY**

Techniques for protecting switching power supplies against excessive output current demands have traditionally borrowed the analog approaches of linear voltage regulators. In many instances, the resulting performance has been unsatisfactory. Problems such as degraded load regulation, poor response to overloads, and oscillation at the crossover point between constant voltage and constant current output are frequently encountered.

A brief analysis of the properties of two coupled closed-loop control systems provides some insight into the basic limitations of the analog approach to current limiting. Specific examples using several currently available pulse width modulator circuits are shown.

An evaluation of the benefits of a digital approach shows that with the proper control architecture, all of the limitation imposed by analog techniques can be removed, with subsequent benefits to the power semiconductors. The impact on power device load lines and improvement in current limit characteristics are examined. Waveforms from operational switching supplies illustrate the practical applications of the principles discussed in this paper.

### **BACKGROUND**

The architecture of almost all fixed-frequency, constant output voltage switch-mode power supplies can be reduced to the simple configuration in Figure 1. A sawtooth waveform is compared with the output voltage from an error amplifier, which

in turn continuously compares a fraction of the supply output voltage with a precision reference voltage. The comparator output is a fixed-frequency, variable duty cycle pulse which drives a power switch. The power switch in turn chops the DC input voltage at some ultrasonic frequency. An output filter smooths the bursts of energy into a low ripple DC voltage at the output terminals.

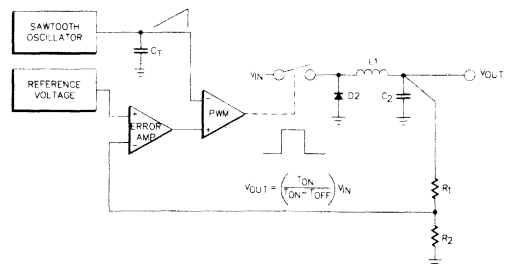


Figure 1. Basic Architecture of a Constant Voltage Switching Power Supply.

Under heavy loading, the voltage control loop forces the pulse width modulator to maximum duty cycle. In order to limit the maximum current flow and reduce operating stresses on the power components, it is necessary to limit the energy transfer through the power switch. The usual method in the past has been to establish a second feedback control loop. An overcurrent condition is sensed and the pulse width is reduced by

overriding the voltage control amplifier, as shown in Figure 2.

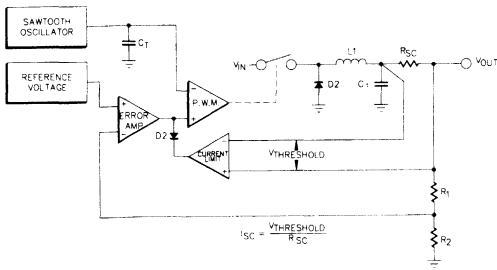


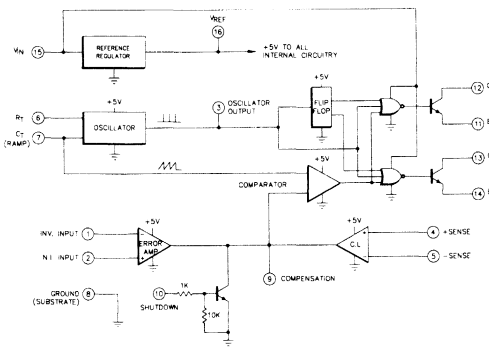
Figure 2. The Basic Switching Supply Modified for Analog Current Limiting.

In this configuration, a voltage amplifier with a fixed threshold or offset voltage derives a differential input signal from a current sense resistor in series with the supply output terminal. As the output current approaches the pre-determined limit, the amplifier enters its linear gain region, and its output voltage becomes increasingly negative. Diode D2 begins to conduct, clamping the error amp voltage to a low value and reducing the duty cycle of the pulse width modulator.

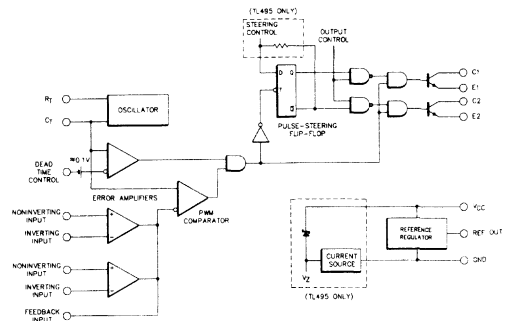
### Examples

This method has been a popular solution to the problem of providing overcurrent protection. Figure 3 shows the control architecture of four integrated PWM circuits, all of which employ this analog approach.

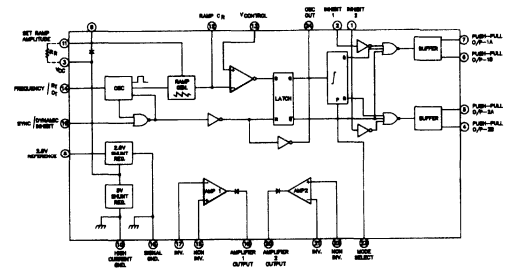
Despite the popularity of this technique, experience has shown



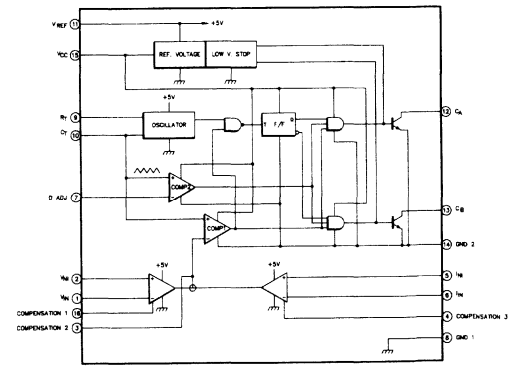
A. Silicon General SG1524



B. Texas Instruments TL494



C. Ferranti ZN1066



D. NEC Electron μPC1042C

Figure 3. Four Pulse Width Modulator Circuits with Analog Current Limiting

that there are significant problems which result in degraded output regulation when compared to ideal current limiting characteristics. As shown in Figure 4, the supply voltage should be constant over the full range of rated output current. At some excess current level, the supply should make a sharp transition

# APPLICATION NOTES – SG1526

to a current source. In actual practice with an analog current loop, load regulation is degraded as the output current approaches the maximum rating. Furthermore once transition to current limiting has occurred, appreciable excess current can flow under short circuit conditions.

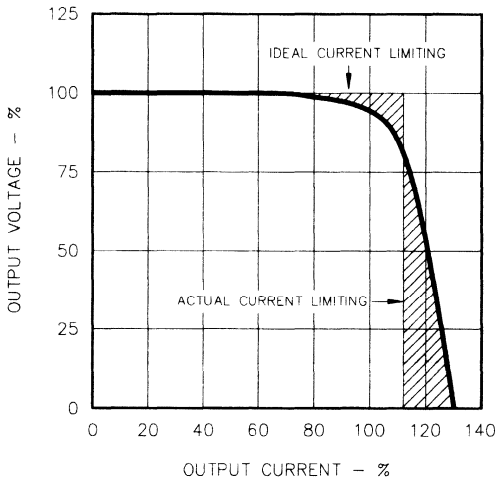


Figure 4. Load Regulation Characteristics of Supplies with Analog Current Limiting.

The reason for this non-ideal behavior is found in the finite loop gain of the current limit amplifier. Not only must the loop gain of the voltage control be opposed, but also the non-abrupt conduction of the clamp diode must be compensated. Higher gain can narrow the difference between actual and ideal performance, but at the risk of oscillation at the crossover point between constant voltage and constant current. To understand why this is true, we must analyze the frequency behavior of the gain elements in the two control loops.

### Analysis of the Stability Problem

The three gain elements are the error amplifier, pulse width modulator, and current limit amplifier. The following notation is used: open-loop gains and frequencies are designated by lower case letters ( $a(s)$ ,  $s_c$ ). Closed-loop gains and frequencies are denoted by upper case letters ( $T(O)$ ,  $S_1$ ). The frequency compensation connections shown apply to the SG1524 and other transconductance amplifiers. The same compensation principles, however, also apply to low-impedance output amplifiers, where the feedback network is connected between the output and the inverting input terminal.

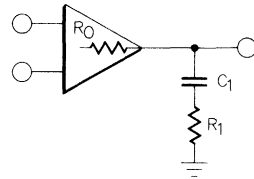
If the ratio of chopper frequency to the cutoff frequency of the output filter is at least 20, then the pulse width modulator may be

modeled simply as a linear gain block. Its transfer function is given by

$$a(s) = \frac{a(0)}{(1-s/s_c)^2} \quad (\text{Eq. 1})$$

where  $s$  is the complex frequency variable  $\sigma + j\omega$   
 $a(0)$  is the DC open-loop voltage gain

$$s_c \text{ is a double pole at } s = -\frac{1}{\sqrt{LC}}$$

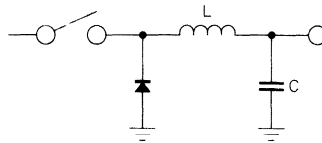


A. ERROR AMPLIFIER

$$a(s) = a(0) \frac{(1-s/s_B)}{(1-s/s_A)}$$

$$\text{WHERE } s_A \text{ IS A POLE AT } s = -\frac{1}{R_0 C_1}$$

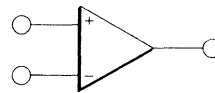
$$\text{WHERE } s_B \text{ IS A ZERO AT } s = -\frac{1}{R_1 C_1}$$



B. PULSE WIDTH MODULATOR

$$a(s) = \frac{a(0)}{(1-s/s_c)^2}$$

$$\text{WHERE } s_c \text{ IS A DOUBLE POLE AT } s = -\frac{1}{\sqrt{LC}}$$



C. CURRENT LIMIT AMPLIFIER

$$a(s) = \frac{a(0)}{(1-s/s_D)}$$

WHERE  $s_D$  IS THE SINGLE DOMINANT OPEN-LOOP POLE

Figure 5. Open-loop Gain Characteristics of the Three Gain Elements.

The error amplifier open-loop response is determined by external components C1 and R1 (Figure 5), since it is a transconductance amp with output impedance  $R_o$ . To obtain maximum closed-loop bandwidth for the voltage control loop, the designer must compensate the amplifier so that it exhibits an open-loop zero which cancels one of the poles of the low pass filter in the pulse width modulator.

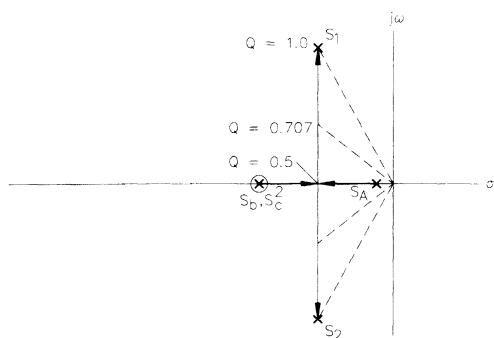


Figure 6. Trajectories in Complex Frequency Space of the Open-loop Poles and Zeros of the Error Amplifier and Pulse Width Modulator as the Feedback Loop Gain is Increased.

The locations of the open-loop poles and zero for the voltage regulation loop appear in complex frequency space as shown in Figure 6. The dominant (lowest frequency) pole of the error amplifier ( $s_a$ ), the open loop zero ( $s_b$ ), and the two pulse width modulator poles ( $s_c$ ) all lie on the negative real axis. Since there is a pole-zero cancellation, the net open-loop frequency characteristic is that of a two pole system, i.e.

$$a'(s) = \frac{a'(0)}{(1-s's_a)(1-s/s_b)} = \frac{a'(0)}{1+a_s s+a_s^2 s^2} \quad (\text{Eq. 2})$$

When feedback is applied around the regulator, the poles move in complex frequency space along the trajectory shown. For low values of loop gain, the dominant poles remain real. When the loop gain  $T(O)$  exceeds  $(a_s^2/4a_s)-1$ , the poles become complex. They then follow a path parallel to the  $j\omega$  axis as  $T(O)$  increases. Note that the poles of the closed-loop transfer function always lie on the left hand plane, and so there is no stability problem. However if  $Q$  is much greater than unity the transient response may be unacceptable because of severe ringing.

At the transition point between voltage regulation and current regulation, the situation is quite different. The two feedback loops are now coupled together and oppose one another. A three pole system now exists, since the current limit amplifier now contributes a pole at  $s_d$ , so the positions of the poles in the  $s$ -plane are altered. If the bandwidth of the current limit amplifier is designed to be large (and ideally it should be to obtain rapid

response time) then the paths of the poles  $s_a$  and  $s_c$  in the voltage loop will curve towards the  $j\omega$  axis, as shown in Figure 7. It can be seen that the net effect of coupling is that, for sufficiently high loop gain, the closed-loop poles  $S_1$  and  $S_2$  will cross over into the right hand plane, resulting in oscillation at the supply output.

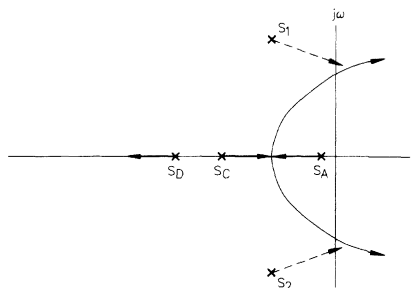


Figure 7. Movement of the Closed-loop Poles of the Voltage Regulation Loop Towards the Right Hand  $s$ -plane due to "Pole Mingling"

One method frequently used to stabilize the supply is to narrow-band the current limit amplifier. For the case where

$$s_d < \frac{2}{s_a + s_c} \quad (\text{Eq. 3})$$

the closed-loop poles are forced away from the  $j\omega$  axis as the loops become coupled together, and no instability occurs. This condition is shown in Figure 8.

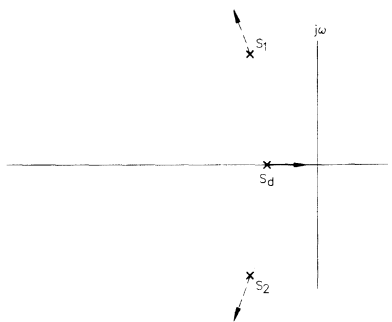


Figure 8. Movement of the Closed-loop Poles

$$\text{for } s_d < \frac{2}{s_a + s_c}$$

To summarize the situation, the switching power supply designer is faced with a dilemma. He can design the current limit circuitry for high gain to obtain a sharp limiting knee, and large bandwidth to obtain fast response time, at a substantial risk of oscillation.



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Alternately he can avoid instability by designing for low gain, with resulting poor limiting characteristics: or he can slow the amplifier and risk destruction of the power switching devices. Clearly a new approach to the problem of current limiting is necessary to obtain better performance.

## ANALOG CURRENT LIMITING

- Slow
- Degrades Load Regulation
- Potential Oscillation at Crossover
- Inflexible

## A Digital Approach

A solution that bypasses all these difficulties is to monitor output current on a pulse-by-pulse basis. If an overcurrent condition is sensed during power switch conduction, the pulse is immediately terminated. The process is repeated at the beginning of each conduction cycle. To obtain the fastest possible reaction time, a digital node within the PWM architecture is chosen to inhibit the output pulse. Figure 9 illustrates one realization.

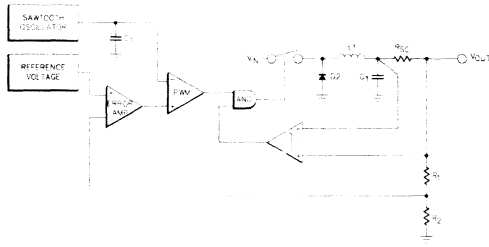


Figure 9. Current Limiting by Inhibiting the Output from the PWM Comparator.

A voltage comparator with fixed input offset voltage switches from a logical HIGH state to a LOW state when the selected current threshold is exceeded. Since both logic inputs to the AND gate must be HIGH to enable the output pulse, the pulse width can be narrowed by the current limit comparator independently of the voltage control loop.

One further refinement is necessary to ensure that multiple pulses cannot occur during one oscillator period. The block diagram as presently defined only *inhibits* the output during overloads, but does not prevent the pulse from turning on again when the overcurrent condition is removed. Switching noise could cause the comparator output to switch back and forth erratically, forcing the power semiconductors to switch many times through a high-power-dissipation load line during one oscillator cycle. The insertion of a data latch which is reset by a clock pulse from the sawtooth oscillator solves this difficulty. The data latch is designed so that a PWM pulse may ripple through

asynchronously, but the trailing edge will lock up the flip-flop and prevent any further output until reset at the beginning of the next oscillator period. This final configuration is shown in Figure 10.

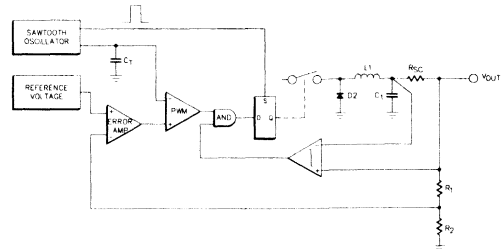


Figure 10. Addition of a Data Latch to Obtain Pulse-by-Pulse Current Limiting.

The theoretical performance of this configuration is shown in Figure 11. As load current increases from no-load to maximum load, no triggering of the current limit comparator occurs. The output voltage is affected only by the regulation of the voltage control loop. When the current limit threshold is reached, the comparator terminates each output pulse and the output voltage begins to decrease. As the load on the output increases, the overcurrent threshold point is reached earlier in each oscillator cycle. The pulse width will decrease to a minimum value determined by the propagation delay through the current limit loop. The storage time of the power switch is usually the dominant factor in this delay. Switch mode supplies which utilize power MOSFETs will exhibit the smallest pulsewidth due to the lack of any appreciable storage time. When the minimum pulse width is reached, the output current will increase as the load resistance decreases, since constant energy is being delivered to the LC output filter.

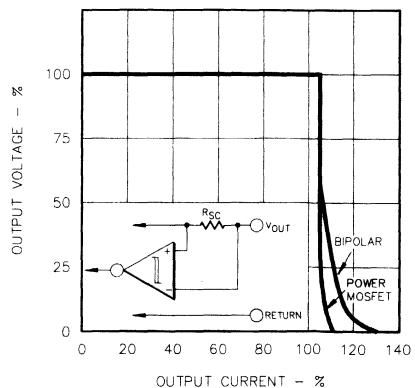


Figure 11. Theoretical Current Limiting with Bipolar and Power MOSFET Devices.

The excess current “tail” may easily be eliminated by foldback current limiting. This technique pre-biases the current limit comparator away from the threshold point with a fraction of the supply output voltage (Figure 12). As the supply voltage goes into current limit, the output voltage falls, reducing the bias on the comparator. Less current is then required through  $R_{SC}$  to maintain limiting. Finally, at full short circuit only a fraction of the full output current is available, even with the “tailing” phenomenon.

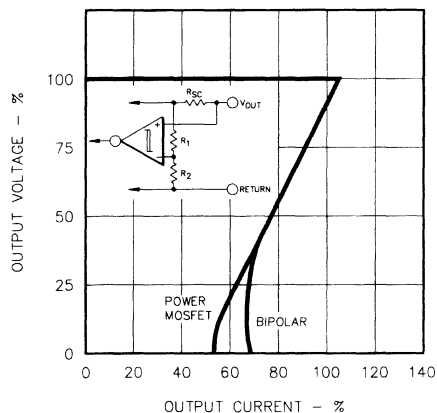


Figure 12. Reduction of Maximum Current Using Foldback Current Limiting.

The design equations for foldback limiting are straightforward:

$$I_{MAX} = \frac{V_{TH} + V_{OUT} R_1 / (R_1 + R_2)}{R_{SC}} \quad (\text{Eq. 4})$$

where  $V_{TH}$  is the comparator threshold voltage

$$I_{SC} = \frac{V_{TH}}{R_{SC}} \quad (\text{Eq. 5})$$

### Impact on Load Lines

Pulse-by-pulse current limiting also has a beneficial effect on switching device load lines. Data was collected on load line excursions of a 40kHz forward converter, with line results shown in Figure 13. The forward configuration was chosen rather than a flyback design because the output current is always in phase with the conduction of the principal power transistor. Thus load changes at the supply output are instantaneously reflected back to the load line excursion.

The normal load line trajectory indicates some deviation from the theoretical path due to non-ideal transformer characteristics. During turn-on, distributed capacitance in the transformer pri-

mary winding causes current overshoot. During turn-off, leakage reactance contributes some collector voltage overshoot.

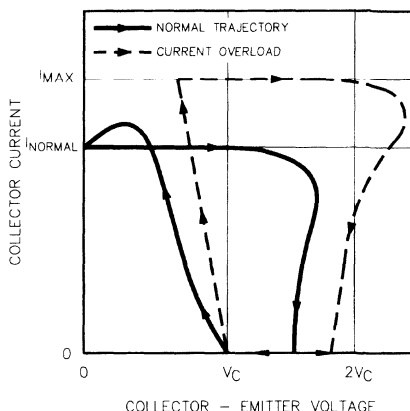


Figure 13. Prevention of Overcurrent in the Power Switch During Cycle-by-Cycle Current Limiting.

During a switching cycle where an overload exists, the collector current rises rapidly due to the low collector load impedance reflected from the power transformer secondary. Before the current can reach a destructive level, the conduction cycle is terminated, protecting the switching device from catastrophic failure due to damaged metalization or vaporized wire bonds. However, the collector voltage overshoot during turn-off is now greater due to the increased energy stored in the leakage reactance at higher current levels.

It can be concluded from the foregoing that pulse-by-pulse current limiting will protect the power devices from failure due to excessive current levels, but it offers no protection against abnormal leakage reactance voltage spikes. Their magnitude may be limited due to the imposition of a maximum value of current at turn-off, but some type of snubber network or other transient suppressor may still be required.

It is also apparent that device power dissipation is higher than normal during overload conditions. To avoid thermal damage an eventual transition from pulse-by-pulse limiting to “hiccup” mode current limiting may be desirable. “Hiccup” mode limiting occurs by discharging the PWM soft-start timing capacitor, causing the controller to turn off for several hundred milliseconds before resuming operation. An elegant method for controlling this transition by “fault counting” will be described at the end of this paper.

### A Bipolar Example

To verify the actual limiting characteristics of a switch mode

# APPLICATION NOTES – SG1526

supply with digital current limiting, the 30kHz buck converter in Figure 14 was constructed. Almost all the control circuitry is contained within two integrated circuits and a power hybrid. The SM625 is a 60 volt, 15amp bipolar switch with matched commutating diode. It is controlled by an SG1524 pulse width modulator. The 2N2222 transistor provides constant current drive to the power switch over a wide range of input voltage.

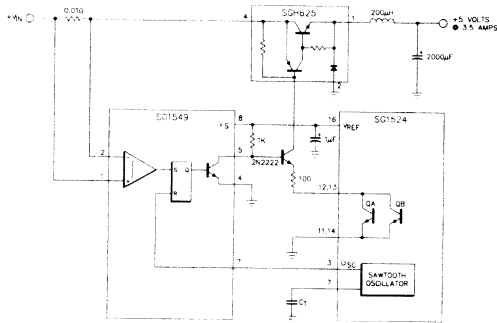


Figure 14. Buck Converter with Digital Current Limiting Using an SG1524 PWM and SG1549 Current Sense Latch.

Pulse-by-pulse current limiting is provided by an SG1549 Current Sense Latch. This circuit consists of two voltage comparators and a set/reset latch with Q and  $\bar{Q}$  digital outputs. Both comparators have a 100mV threshold voltage. One device has full differential inputs with a common mode range from +2 to +40 volts. The second comparator has its 100mV threshold referred to ground, and is intended for sensing the voltage in an emitter resistor. This current sense configuration is desirable in forward and push-pull converters where secondary current overloads can be sensed by the reflection to the primary of the transformer. The two comparator outputs are ORed together at the SET terminal of the latch. A clock pulse from the oscillator output of the SG1524 is used to reset the latch. Maximum turn-off speed is obtained in this circuit by disabling the 2N2222 at its base with the open-collector LOW output of the SG1549.

Figure 15 shows the output voltage/current curve obtained with this regulator. The data points agree remarkably well with the theoretical curve for bipolar devices shown in Figure 11. The supply exhibits excellent load regulation (20mV) all the way to maximum load current, with a sharp, well-controlled transition to current limiting.

## A MOSFET Example

To further illustrate the performance obtainable with present high performance switch mode power supply components, a 100kHz off-mains supply was designed with full input-output isolation, power MOSFETS, and an SG1526 pulse width modulator IC

which incorporates the digital current limiting principles discussed earlier.

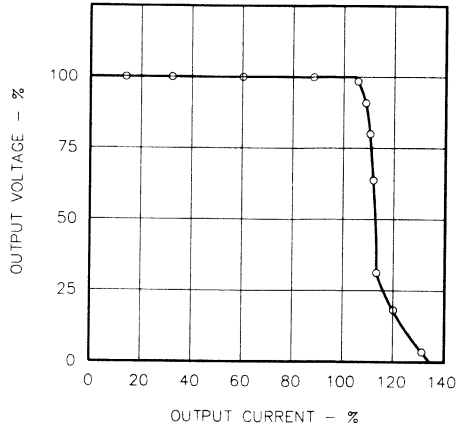


Figure 15. Output Characteristics of the Buck Regulator in Figure 14.

The block diagram of the PWM circuit (Figure 16) illustrates the differential voltage comparator, AND gate, and data latch that comprise the components for pulse-by-pulse current limiting. The comparator has a 100mV threshold and 20mV of hysteresis to minimize jitter at the decision point. The data latch allows only one pulse to pass through per each oscillator cycle. The memory flip-flop provides the double-pulse suppression logic. If the PWM pulse is gated off for more than one cycle, the flip-flop remembers which driver was the source for the last pulse. When the output is again enabled, the first pulse is automatically routed to the other driver. This prevents two pulses in succession from one driver, minimizing the possibility of transformer core saturation in push-pull configurations.

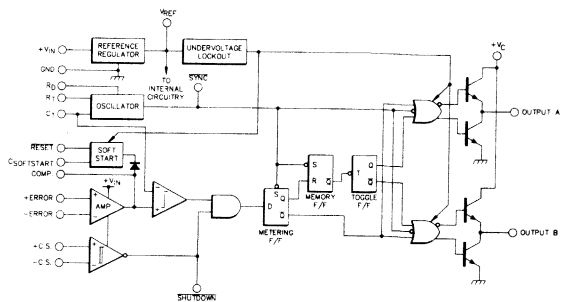


Figure 16. Block Diagram of the SG1526 Pulse Width Modulator

The complete schematic of the power supply is shown in Figure 17. A half-bridge configuration was chosen to minimize the drain-source breakdown voltage requirements on the power MOSFETs when operating from the rectified 220 volt European mains. Power for the SG1526 pulse width modulator is derived from a small (3 Watt) 50Hz power transformer. This arrangement maximizes supply efficiency and allows the voltage regulation loop to be referenced to the output ground. The two MOSFETs are driven from the secondary of a small ferrite pot core isolation transformer. The primary of the transformer is connected directly to the totem-pole output drivers of the SG1526. The oscillator is programmed for 200kHz by  $R_T$  and  $C_T$  and the current sense network is designed to give a 7 to 1 foldback ratio.

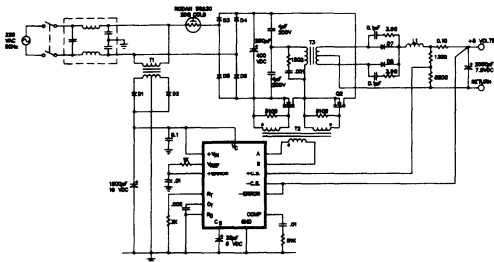
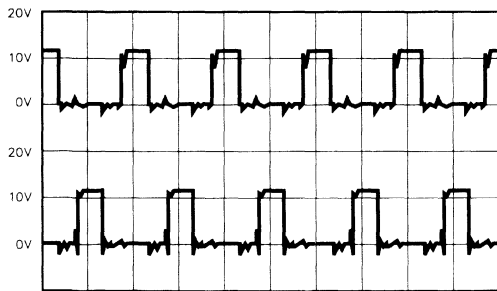


Figure 17. A 100 KHz Oof-line Power Supply Using the SG1526 for Digital Current Limiting.

Operational waveforms for the supply when operating under partial load are shown in Figure 18. The two traces show the unipolar gate drive signals at the pulse width modulator; these become bipolar when observed on the secondary of the isolation transformer. Transition edges are sharp and clean due to the totem-poles' ability to source or sink 200mA peak for charging and discharging the power MOSFET gate capacitance.

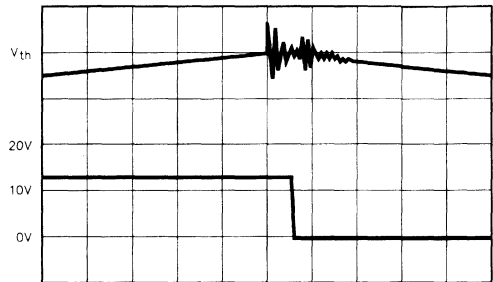


TIME BASE: 5μSEC/DIVISION  
UPPER WAVEFORM: DRIVER A OUTPUT  
LOWER WAVEFORM: DRIVER B OUTPUT

Figure 18

The propagation delay through the overcurrent control loop is of major importance when attempting pulse-by-pulse limiting at 100kHz. As Figure 19 indicates, the response time through the SG1526 from comparator to driver output is only 300 nanoseconds. Since this represents only 6% of the maximum duty cycle at 100kHz, a large foldback ratio is possible.

Data taken on the current limiting characteristics of this supply are shown in Figure 20. As expected, the output voltage regulation was completely unaffected by the current limit circuit until maximum load current had been exceeded. Also, the available output current steadily decreased as the overload increased, as would be expected from Figure 12. However, there was no current "tailing" effect from the loop propagation delay. The explanation appears to be that under prolonged



TIME BASE: 5 nSEC/DIVISION  
UPPER WAVEFORM: OVERCURRENT SIGNAL TO  
CURRENT SENSE COMPARATOR  
LOWER WAVEFORM: SG1526 DRIVER OUTPUT

Figure 19

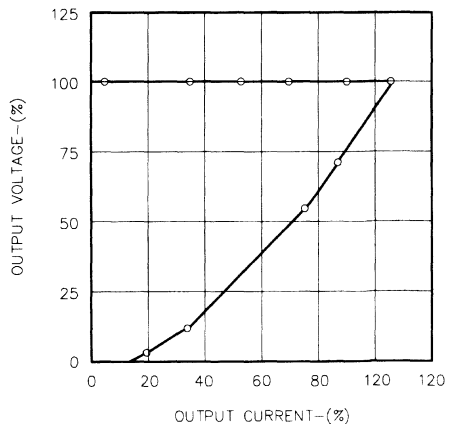


Figure 20. Measured Output Characteristics of the 100KHz Switching Supply in Figure 17.

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pulse-by-pulse current limiting the power dissipation in the power MOSFETs is sufficient for the negative temperature coefficient of transconductance to override the effect of loop delay.

### Fault Counting Technique

Fault counting may be utilized to reduce power dissipation in the power switch during prolonged current limiting. One implementation is illustrated in Figure 21, using an inexpensive CMOS ripple counter and an even less expensive timer circuit. The 14-bit binary counter accumulates pulse-terminating commands from the SG1526 comparator. The output of the 14th stage will go high after  $2^{13}$  or 8192 counts have been accumulated. At 200kHz (an overcurrent SHUTDOWN pulse can occur during either phase of the output) this represents 41 milliseconds of delay. When the counter output goes HIGH, the soft-start timing capacitor of the SG1526 is discharged. The SG555 timer is connected as an oscillator to periodically reset the accumulated count in the MC14020B, which allows a soft-start cycle to begin. A period greater than 41 milliseconds should be used.

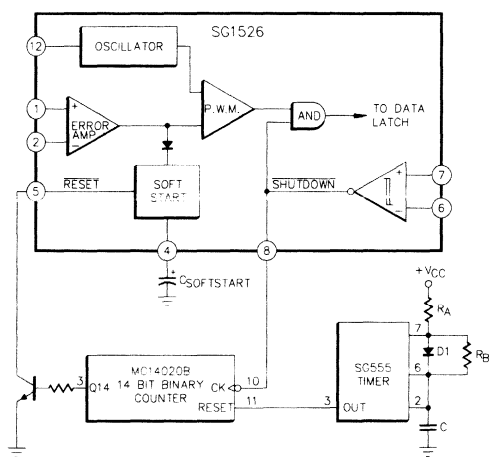


Figure 21. Using CMOS Logic as a Fault Counter to Control Transition from Pulse-by-Pulse Current Limiting to "Hiccup" Mode Current Limiting

Obviously this technique can be extended even further. A second counter could accumulate "hiccup" cycles and shut the supply off until manual reset or power re-cycle. This is easily accomplished with the SG1526 since the SHUTDOWN and RESET terminals are compatible with both TTL and CMOS logic.

### DIGITAL CURRENT LIMITING

- Fast
- No Load Regulation Degradation
- Clean Crossover from Voltage to Current Output
- Multiple Current Limiting Modes Possible

### Conclusions

The use of digital current limiting techniques provides enhanced load regulation, a sharp transition to constant current, and faster protection to the power semiconductors in a switch-mode power supply when compared to analog methods. It also offers the designer flexibility in the choice of crossover criteria from pulse-by-pulse mode to "hiccup" mode to total shutdown. The net benefit to users will be enhanced reliability and increased performance from switch-mode power supplies.

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much lower level than that associated with similarly-rated bipolar devices.

## MODIFICATIONS

The power MOSFET is not directly compatible with the bipolar power transistor and cannot be used in a switched mode circuit without modification.

Irrespective of the power switching device used, be it a MOSFET or a bipolar power transistor, the associated pulse-width modulated switcher cannot normally be left on for more than 50 per cent of the total duty cycle. Under normal circumstances, a 50 per cent on time occurs only when the input voltage is very low and the output current is high. Conversely, the shortest on times occur when the input voltage is near to its peak and the output current is minimal.

Ideally, the pulse-width modulator should operate over a very wide duty cycle range to ensure close regulation with wide line and load extremes. Unfortunately, it has been impracticable to implement this approach in bipolar designs, since the gain of bipolar transistors decreases rapidly when operated in the short-pulse, high-current mode.

A power MOSFET's transconductance, on the other hand, does not vary so widely with current changes. This makes it much easier to drive a MOSFET directly, using a short duty cycle. Furthermore, the short conduction time at high input voltage leaves a relatively long time to reset the associated transformer and thus reduce the peak voltage across the MOSFET. Also the designer is able to use 500V rated devices in mains driven supplies in contrast to the usual 800V rating often needed for circuits featuring bipolar devices.

## PROTECTION

Some protection is of course necessary. The MOSFET shown in Fig. 1, for example, features clamping diodes (Zener diodes 1 and 2) to limit the circuit's maximum gate voltage to 18V. Zener 3 which comprises four series-connected 120V diodes, restricts the source/drain swing to 450V to give a safe working margin.

The resistor/capacitor/diode snubber formed by  $R_1/C_2/D_3$  conforms in the principle to the approach outlined in the earlier article, except that it is allowed to float. For more details on this and other related topics, refer to International Rectifier's application note AN-939.

Trials have shown that worst-case efficiency occurs at virtually maximum input voltage with minimum loading. Here efficiency drops to just under 70 percent, compared with 76 percent at maximum output. Dissipation is thus around 8W at maximum output and slightly higher than this value when the supply is lightly loaded.

## OPERATION

The off-screen photographs show how the circuit functions. Fig. 2 demonstrates how the pulse-width modulator controls the MOSFET's conduction time with respect to various load and line conditions. At one extreme, the input voltage is down to 85V, while output is at 20A. Fig. 2a shows the MOSFET on for 4 $\mu$ s which gives a duty cycle of approximately 44 percent. When operating at the other extreme, ie 265V input and 5A output, the MOSFET is on for approximately 1 $\mu$ s, which corresponds to a 10 percent duty cycle. Note how the gate/source waveforms which are depicted in Fig. 3 relate to the operating levels shown in Fig. 2.

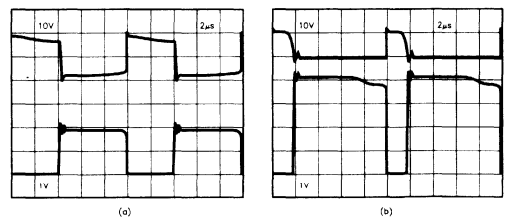


Figure 3. Gate/Source Waveforms. These Were Recorded with the Unit Under Full Load, (a) with a Line Voltage of 85V and (b) with a Line Voltage of 265V. The Upper Traces Show Gate/Source Voltage While the Lower Show Drain Voltage.

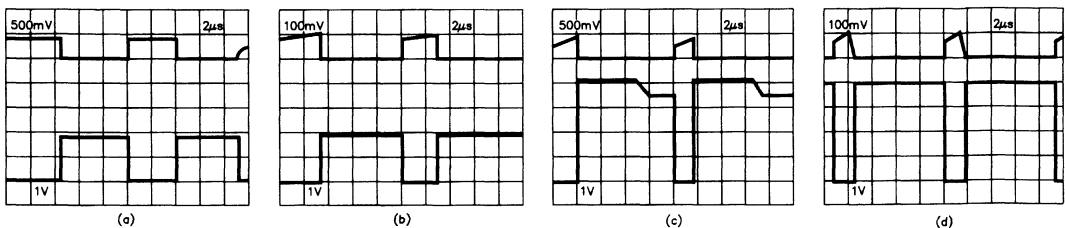
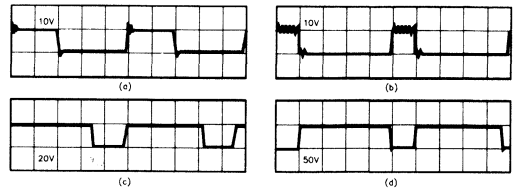


Figure 2. Switching Waveforms. With an 85V Line and a 20A Load (a) Shows Drawn Current on the Upper Trace and Drain Voltage on the Lower. The Load is Cut to 5A in (b), While (c) and (d) Show the Same Parameters at a 265V Line Voltage with Respective Loads of 20A and 5A.



## APPLICATION NOTES – SG1526

Typical voltage waveforms across the output rectifiers are shown in Fig. 4. Note that while the forward rectifier D1 blocks a peak voltage (including the commutation transient) of about 12V, D2 has to withstand around 75V for a 5V output, due to the short conduction cycle. Both of these diodes contribute to the system's net losses. Indeed, these devices dissipate some 30 to 50 percent of the switching energy, and represent a major problem in designing low output voltage power supplies. Losses from the rectifier diodes are approximately the same for both the 5 and 15V supply designs.



TRACE	PARAMETER	CONDITIONS	VERTICAL	HORIZONTAL
a	D <sub>1</sub> VOLTAGE	35V LINE	10V/DIV	2μ SEC/DIV
b	D <sub>2</sub> VOLTAGE	5A LOAD	20V/DIV	
c	D <sub>1</sub> VOLTAGE	265V LINE	20V/DIV	50V/DIV
d	D <sub>2</sub> VOLTAGE	5A LOAD	50V/DIV	

Figure 4. Output Circuit Waveforms. The Upper Traces Show the Voltage Waveform Appearing Across D1, While the Lower Covers Rectifier D2. In Both Cases, Load is at 5A; (a) with the Input Voltage at 85V and (b) at 265V.



## POWER SUPPLY CIRCUITS HEAD FOR SIMPLICITY BY INTEGRATION

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### SUMMARY

The benefits obtained from switching power supplies have become universally recognized by power systems engineers in the past several years. However, there has been a simultaneous realization that, too frequently, gains in efficiency and reductions in weight have been accompanied by an escalating component count and a decrease in reliability and predictability of performance. To effectively solve these problems, integrated circuit manufacturers have recently designed new products specifically for switchers. These devices offer the proven advantages of monolithic technology: compactness, accuracy, reproducibility, higher performance through reduction of parasitics, and the economies of mass production.

This paper reviews the circuit simplifications made possible by these specialized devices, as typified by the first practical switching regulator control chip, the SG1524 Pulse Width Modulator, and later by other circuits such as the ZN1066, the TL494A, and the MC3420. A second potential area of power supply simplification is the interface between the control circuit and the high power switching transistors. Two specialized driver circuits, the SG1627 and the SG1629 are described which provide high-level turn-on and turn-off signals for efficient switching. Finally, some second and third generation pulse width modulator designs will be discussed. These later devices, designated the SG1525/27 series and the SG1526, offer even higher levels of control function integration compared to earlier designs. The SG1526 in particular integrates a number of protective control features which substantially increase the reliability of the power semiconductors in "real world" switching power supplies.

### HISTORICAL PERSPECTIVE

A basic pulse width modulated switching power supply requires only four control elements: a precision reference voltage, a ramp oscillator, an error amplifier, and a differential voltage compara-

tor. Each of these elements has been available in integrated circuit form for years, with the well-established benefits of reduced physical size, greater reliability, and increased performance. In light of this background, the development of a single monolithic circuit for switching power supply control appears to be a logical progression.

One of the first devices available to power supply designers was the SG1524 Pulse Width Modulator from Silicon General. This circuit, shown in Figure 1, contained all of the basic control elements required for a switching regulator. In addition to providing the four basic control elements, the device allowed for push-pull configurations by inclusion of a toggle flip-flop and dual alternately-gated output transistors. Finally, provision was made for some abnormal power supply operating conditions. An analog current limit circuit and a digital shutdown control were included to provide protection against short circuits and other load faults.

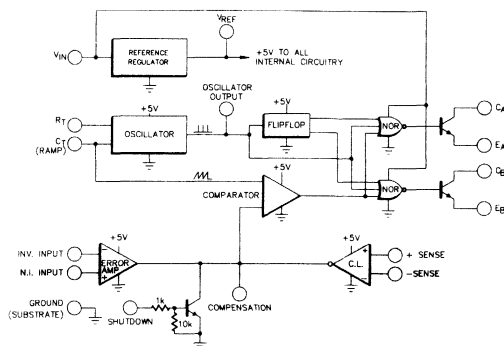


Figure 1. SG1524B Pulse Width Modulator Block Diagram

# APPLICATION NOTES – SG1525A/SG1526/SG1527A

Despite this level of complexity, the device was easy to understand and was quite flexible. As a result, since its introduction in 1976, the SG1524 has been very widely accepted within the power supply industry, finding its way into a majority of new designs, including exotic applications in communications satellites and the space shuttle program.

## POWER DRIVER INTEGRATION - SG1627

As experience was gained in applying the SG1524, it became apparent that there was a gap between output power capabilities of the control integrated circuit and the drive levels required by the power semiconductors. Two areas were identified within most supply configurations where specialized driver functions could be successfully implemented with monolithic technology.

### An integrated Source/Sink Driver

The first design is a dual 500mA totem pole driver with externally programmable current sourcing. Both inverting and noninverting logic inputs are available, and may be driven by either an open-collector control circuit or (with a diode) by TTL logic. Connections to the high current output transistors are brought out separately, allowing maximum flexibility when interfacing with standard bipolar transistors, the new VMOS power FET's, and transformers.

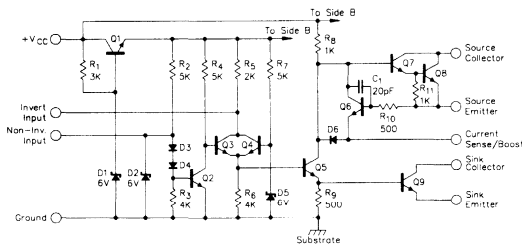


Figure 2. Partial Schematic Diagram SG1627 Driver Circuit

Power Bipolar Drive is accomplished with the connection shown in Figure 3. R2 controls the magnitude of forward base drive, and is selected to develop a voltage drop of one  $V_{BE}$  when the output Darlington pair is sourcing 350mA. At the same time R3 develops a 3.5 volt differential, which is stored by C1. During turn-off, sink transistor Q9 saturates, pulling the output terminal to ground. The emitter-base junction becomes reverse biased from a low impedance source, allowing stored base charge to be rapidly extracted.

Power FET Drive is possible with a minimum of external components. The source/sink capability of the SG1627, together with its fast edge speeds, makes it an ideal driver for power MOSFET

devices. Although MOSFETs have negligible DC gate current, input capacitances of 800,-1000pF exist in the higher current units. Since this capacitance must be charged and discharged by 10 or 12 volts in 10 to 20 nanoseconds, high peak currents are required. At switching frequencies of 200kHz, considerable dynamic power dissipation is required of the drive circuit to obtain the high speed switching benefits of these devices.

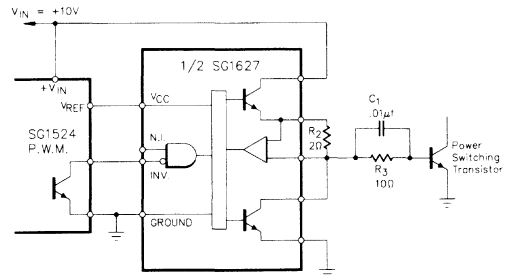


Figure 3. Driving Bipolar Junction Transistors With a Totem-Pole Switch Driver

In Figure 4, peak currents in the output stage are limited by  $R_2$ , while  $R_1$  helps minimize power in the SG1627. With some power FETs, a 100ohm resistor in series with the gate lead may also be necessary to eliminate device oscillations.

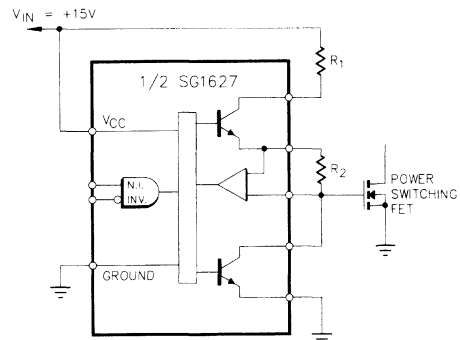


Figure 4. A Source/Sink Driver Provides the Peak Currents Required by Power Fet's at High Switching Frequencies

Transformer Drive is the third interface area where an integrated power driver can eliminate components. Most bi-phase transformer drive circuits using grounded emitter transistors require additional components to reset the magnetic flux to zero every half cycle. This is necessary to insure that no net DC excitation is applied to the transformer primary over many cycles of operation, thereby avoiding core saturation. These additional

# APPLICATION NOTES – SG1525A/SG1526/SG1527A

components may include extra transformer windings, clamp diodes, and anti-phase driven clamp resistors. A much less complex circuit can be achieved with the SG1627, as shown in Figure 5.

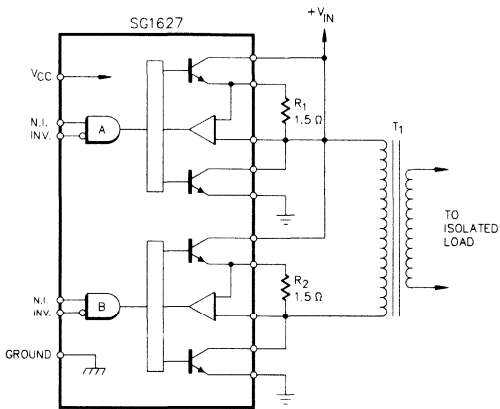


Figure 5. The Low Impedance of the SG1627 in Both On and Off States Allows Direct Transformer Drive With a Minimum of External Components

In this circuit the transformer primary voltage-driven by the source/sink output structure of the SG1627. Core reset to zero occurs automatically during deadtime, when both ends of the primary winding are switched to ground. Resistors  $R_1$  and  $R_2$  serve as over-current protection for the driver in case of control malfunction or onset of core saturation due to load faults on the secondary. No center tap is required, resulting in elimination of winding balance problems.

## AN INTEGRATED FLOATING SWITCH DRIVER - SG1629

The second interface considered was that between the secondary winding of a drive transformer and the base-emitter junction of an NPN power transistor. This configuration is frequently found in off-line converters, where a half or full bridge design is chosen because of the high input supply voltage. In this case the design problem consisted of providing controlled forward base drive to the power device during the positive polarity of the secondary voltage, and a fast negative peak current for rapid switch-off during the negative portion of the cycle. No power other than that provided by the transformer secondary should be required, so that the power device can be floated above ground by several hundred volts.

The circuit shown in Figure 6 is a modification of a discrete design developed by Pete Wood while at TRW semiconductors<sup>1</sup>. During a positive cycle, base current flows from the drive transformer secondary winding through a source transistor which can be

programmed for current limiting. A center tap on the secondary completes the circuit for returning base drive current. At the same time, external storage capacitor  $C_S$  is charged to a negative value through the high current rectifier diode in the switch driver. When the secondary voltage is driven to zero, the rectifier diode becomes reverse biased. The resulting positive drive turns on the Darlington sink transistors, which reverse-biases the base-emitter junction of the power device through the storage capacitor. A large negative current spike results, minimizing the turn-off time and power loss in the switching transistors.

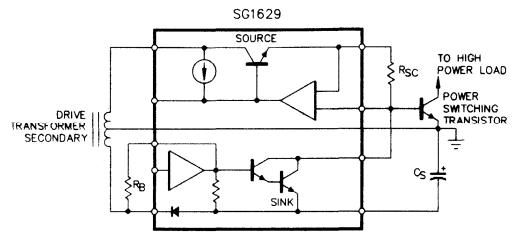


Figure 6. SG1629 Floating Switch Driver Block Diagram

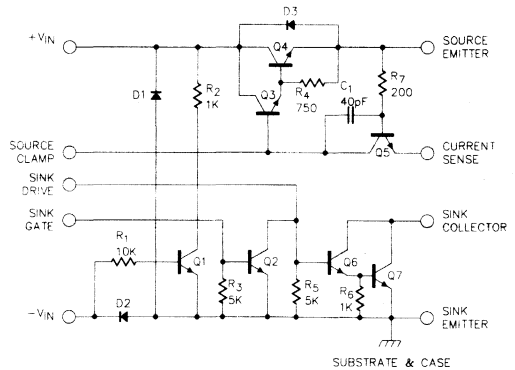


Figure 7. SG1629 Floating Switch Driver Schematic Diagram

As the detailed schematic of the SG1629 in Figure 7 indicated, in addition to the high current Darlington source and sink transistors the circuit also contains several gating options for the sink or turn-off section of the driver. Source transistors Q3-Q4 and sink transistors Q6-Q7 are designed to 2 Amp collector currents. Base drive to the source is provided by  $R_2$ , while Q5 provides current limiting. On the sink side of the circuit, base

# APPLICATION NOTES – SG1525A/SG1526/SG1527A

drive to Q6-Q7 is normally provided by a resistor connected to Pin 3. Q1 senses the polarity of the input voltage and gates the source transistor off between each drive current pulse. This action allows the external storage capacitor to be charged even at very low duty cycles, since the discharge current during the "off" portion of the drive cycle becomes negligible. The sink gate input is used when the risetime of base turn-on current is important, and transformer inductance is a significant limiting factor. Methods for using this feature are found in the SG1629 application note<sup>(2)</sup>.

## Power Drive Summary

Two integrated power drive circuits designed specifically for use in switch-mode power supplies have been reviewed. These devices provide the necessary power gain between a complex low-power control circuit and high voltage, high current switching semiconductors, while offering greater performance in a reduced volume compared to discrete component design. Monolithic technology will provide even higher levels of voltage and current handling capability in the future as soon as semiconductor packaging technology solves the problem of providing large pin-outs in a high power dissipation package.

## A SECOND GENERATION PULSE WIDTH MODULATOR CONTROL CIRCUIT - SG1525A/SG1527A

As switch-mode power supplies gained in popularity, a demand was made by power supply design engineers for an integrated circuit that offered all of the functions of a control device and the interface capabilities of a power driver. The SG1525A series of pulse width modulators represents a combination control IC and power drive. The control section is based upon the time-proven architecture of the SG1524, while the output stage of this device combines many of the elements of the previously discussed 1627 power driver. At the same time, improvements were made within the architecture of the control chip to include even more functions than were originally available on the 1524.

The internal reference regulator on the chip is trimmed to an accuracy of  $\pm 1\%$  compared to the original  $\pm 4\%$ . Secondly, the chip now contains on-chip shutdown and soft start circuitry. The only external components required are an external timing capacitor. A third area of improvement is in the common mode range of the error amplifier. By designing the error amplifier so the common mode range now includes the 5.1V of the reference, a reference divider network is no longer necessary, thus eliminating two external resistors. The oscillator circuitry has been redesigned to make deadtime control easier and multiple device synchronization easier. Finally, the output stage has been redesigned so that, instead of a single transistor which is periodically turned on for pulse width modulation, an output source/sink driver or totem-pole type design is used. Since this particular driver has the characteristic of low impedance in both

the on and off states, it becomes much easier now to interface the control circuits with external power transistors including standard bipolar junction devices, the new power FETs, and also drive transformers.

The new family of regulating pulse width modulators is designated the SG1525A/1527Av series of devices, and the device block diagram is illustrated in Figure 8.

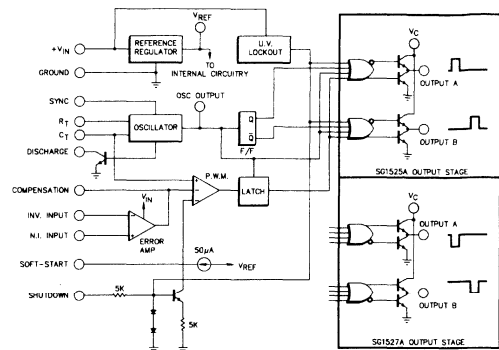


Figure 8. Block Diagram of a "Second Generation" Pulse Width Modulator Family: The SG1525A/1527A Series

The trimmed reference regulator, which has an output voltage of 5.1V, not only acts as the reference terminal for the error amplifier control loop, but it acts as a power source for all the internal circuitry, with the exception of the error amplifier and the output drivers. The oscillator determines the basic operating frequency of the pulse width modulator circuit. An external  $R_T$  and  $C_T$  are the components that are fixed to set this frequency. Additionally, deadtime is controlled by the insertion of a small amount of resistance between the discharge terminal (Pin 7) and the  $C_T$  terminal (Pin 5) on the oscillator. The oscillator circuit has two outputs: the ramp waveform, which is applied to the positive input of the pulse width modulation comparator, and a periodic positive-going pulse at the oscillator output pin which acts as the toggle signal for the flip-flop. It is also used as the deadtime control pulse for the output gating logic.

The totem-pole output drivers are designed to easily interface with either single ended or push-pull types of switching power supply configurations. There are two output polarities available with this series of pulse width modulators. In the 1525A series, the output gating is designed with NOR logic, which results in a positive-going output pulse during active time. The 1527A series uses OR logic, so that the active state is a low ground state. This particular polarity of output is useful in certain types of proportional base drive circuits in which feedback from the power

# APPLICATION NOTES – SG1525A/SG1526/SG1527A

transformer is used to provide base current, thereby compensating for variations in transistor beta.

## Soft Start Circuit

The equivalent of the SG1525A/1527A soft start circuitry is shown in Figure 9. An external capacitor  $C_{\text{SOFTSTART}}$  provides the timing element for the soft start cycle. This capacitor is charged via a 50microamp current source internal to the chip. The P.W.M. comparator has two inverting inputs, and the more negative of the two voltages determines the duty cycle. During undervoltage conditions on the  $V_{\text{IN}}$  line, current is forced through the two diodes in Q1's base circuit. A voltage of approximately  $1V_{\text{BE}}$  appears across Q1's emitter resistor, resulting in a collector current of approximately  $100\mu\text{A}$ . Since the charging current available is only  $50\mu\text{A}$ , the soft start capacitor is held in a discharged state. Because the voltage at pin 8 is 0, the PWM comparator ignores the signal from the error amplifier, and zero duty cycle is obtained. When the controller supply rises to 8 volts the discharge current is turned off, and the voltage on pin 8 rises linearly, resulting in gradually increasing duty cycle. Eventually the capacitor charges up very close to the reference voltage and the duty cycle is controlled by the error amplifier. If the voltage on the shutdown pin is raised above  $\pm 1.5$  volts the capacitor is slowly discharged at the same rate it is normally charged.

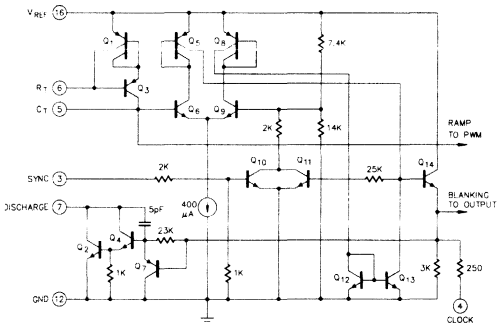


Figure 9. SG1525A/1527A Softstart Circuit

## Oscillator Description

The circuit for generating of the timing ramp waveform is shown in Figure 10. The timing capacitor  $C_T$  receives a constant charge current from the compound current mirror formed by Q1 and Q2. The  $R_T$  terminal voltage is two  $V_{\text{BE}}$  less than the reference voltage, so that a resistor tied from Pin 6 to ground sets up the charging current for  $C_T$ . Transistors Q5 through Q10 form a voltage comparator which constantly compares the voltage at  $C_T$  to either a +3.3V or +1V reference, depending on the state of the comparator. The timing capacitor  $C_T$  is discharged via the Darlington formed by Q3 and Q4.

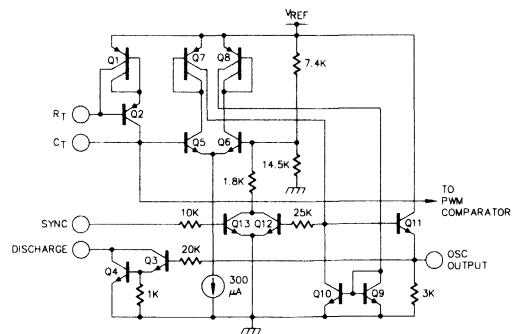


Figure 10. SG1525A/1527A Oscillator Schematic Diagram

When the voltage on  $C_T$  is less than +3.3V, the discharge network does not conduct and  $C_T$  receives a constant charge via the current mirror, resulting in a linear increasing voltage. When the +3.3V trigger level is reached, the comparator changes state and turns on the discharge network. This rapidly removes charge from  $C_T$  so that voltage falls towards +1V, at which time the comparator changes state again and another cycle begins. The discharge time of  $C_T$  is used to generate the blanking pulse at the oscillator output pin. The deadtime or pulse width at the oscillator output pin may be increased from its minimum value of approximately 400 to 500 nanoseconds by a resistor between the discharge pin and Pin 5, which lengthens the discharge time of  $C_T$  during the second half of the oscillator cycle.

A positive pulse at the sync pin will initiate a discharge cycle in the oscillator. This pin then forms a convenient connection for synchronizing the IC to a frequency supplied by an external system clock.

## Output Driver

A simplified schematic of the output gating and the power output stage of the 1525A is shown in Figure 11. Transistors Q1, Q2, and Q3, together with a 500 microamp current source, from a logical NOR gate where the pulse width modulation signal from the pulse width modulation comparator, the deadtime pulse from the oscillator, and one side of the toggle flip-flop are combined. Q4 is an amplifier with active load which inverts the output signal from the NOR gate. Q5, in turn, acts as the phase-splitter transistor for the push-pull output. When Q5 is on, its emitter current drives the base of Q8, holding the output low. At the same time, the collector of Q5 is also low, thereby back-biasing Q6 and Q7, the output pull-up devices. When Q5 turns off, its collector voltage rises, turning on the output Darlington. At the same time, Q8 turns off and the output terminal is pulled up towards the  $V_C$  supply. Diode D1 acts to protect the base emitter junction of the upper Darlington against reverse breakdown. D2

# APPLICATION NOTES – SG1525A/SG1526/SG1527A

acts to provide extra base drive current to Q8 during turn off. If a capacitive load is present on the output terminal, D2 will turn on and the extra collector current of Q5 will then be routed to Q8 so that Q8 in turn will be turned on harder, thus discharging the output capacitance and enabling the output to fall rapidly to zero.

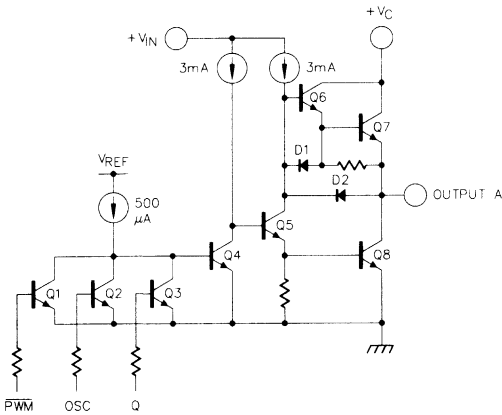


Figure 11. SG1525A Pulse Width Modulator Power Output Stage

The source and sink transistors Q7 and Q8 in this driver are designed to provide more than 100mA of current handling capability. In most cases, the full current capability will not be used in a steady state condition to drive an external load but rather the peak current capability can be used to provide rapid charging of external capacitance loads, thereby providing very fast rise and fall times at the output driver.

Figures 12 and 13 illustrate the speed capabilities of the output drivers when driving power MOSFETs, in this case a pair of Siliconix VN64GA devices. The upper traces show the driver output voltage swing for a collector supply of +12 volts. The lower waveforms are the 0-5amp drain currents of the FETs. Switching times of 100 nanoseconds were achieved by driving the gates directly from the totem pole outputs, and by limiting peak currents to 200mA with a 62ohm resistor at the +V<sub>c</sub> terminal. Faster times can be obtained with the higher current SG1627 Power Driver.

The ultimate frequency capabilities of the output drivers as a function of ambient temperature for a given VMOS load is shown in Figure 14. For this graph, a +V<sub>c</sub> supply of 12 volts was assumed. An effective power FET input capacitance of 1000pF on each driver was also assumed. A thermocouple attached to the ceramic dual-in-line package allowed junction temperature to be calculated based on a worst case  $\theta_{JC}$  of 60°C/W and a  $\theta_{JA}$  of 100°C/W maximum.

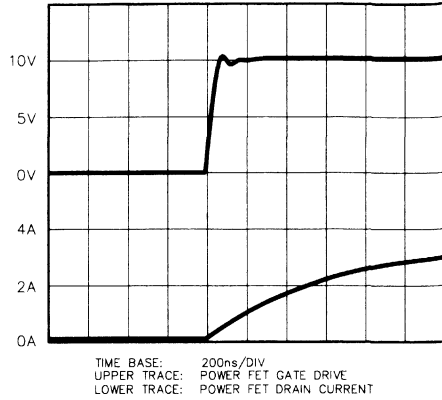


Figure 12. SG1525A/Power Fet Turn-On Wave Forms

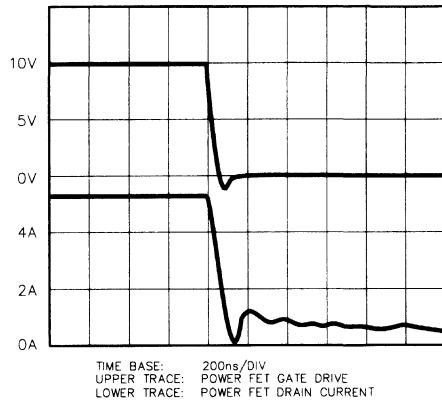


Figure 13. SG1525A/Power Fet Turn-Off Wave Forms

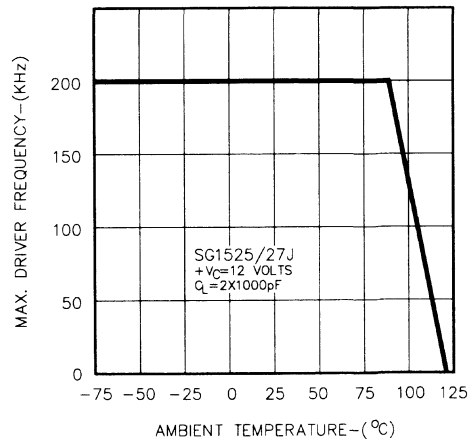


Figure 14. SG1525A/1527A Power Fet Drive Capability



# APPLICATION NOTES – SG1525A/SG1526/SG1527A

For ambient temperatures below 90°C, the maximum frequency allowable is determined by the maximum possible oscillator frequency of 400kHz. Above 90°C operating frequency and dynamic power dissipation must be reduced to keep the junction temperature from exceeding +150°C. Different supply voltages, capacitive loads, and heat sinking will result in other temperature limits.

It will be noticed in comparing the block diagram of the SG1525A/1527A family to that of the SG1524 that there is no provision made directly for current limiting on the 1525A/1527A. The reason for this is that this chip is designed to interface with a new output supervisory circuit, the SG1543. This device has an extra comparator with adjustable offset which can be used for providing the current limit function in conjunction with the SG1525A/1527A. Additionally, this particular chip has the capability for providing under and overvoltage protection for the remainder of the power supply.

## A THIRD GENERATION SWITCHING POWER SUPPLY CONTROL CIRCUIT - SG1526

- Supply operation to 40 volts
- Reference trimmed to  $\pm 1\%$
- Sawtooth oscillator with deadband control
- PWM comparator with hysteresis
- Undervoltage lockout
- Programmable soft start
- Wide error amp common mode range
- Wide current limit common mode range
- Two modes of digital current limiting
- Double pulse suppression logic
- Single pulse metering logic
- Symmetry correction capability
- TTL/CMOS compatible logic
- Dual 100mA source/sink output drivers

Table 1. Desirable Features of a High-Performance Pulse Width Modulator

An ideal circuit for switching power supplies should include not only the elements necessary for normal pulse modulation operation, but also the full range of abnormal operations. Ideally, the circuit should contain as many protective features as possible for the power semiconductors. If a table of parameters were constructed for such device, it would look much like that shown in Table 1. Analysis of the features in the table would show that most of the new features are control related and are therefore ideally suited for inclusion in an integrated circuit, where a great deal of complexity can be easily compressed into a very small area. Just such a device has been designed by Silicon General, and the block diagram of that device is shown in Figure 15.

As can be seen, the four basic elements of the pulse modulator are present: a reference regulator, error amplifier, sawtooth

oscillator, and a pulse width modulation comparator. Of particular interest are some new features in the block diagram: an undervoltage lockout, soft start circuitry, digital current limit comparator and digital signal processing logic between the pulse width modulation comparator and the output power drivers.

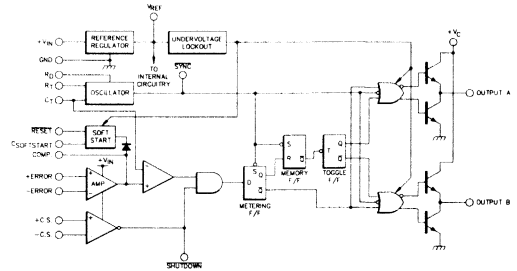


Figure 15. SG1526 High Performance Pulse Width Modulator Block Diagram

The operation of the circuit is as follows: An on-chip regulator trimmed to 1% is both reference voltage for the error amplifier, and also the stabilized power source for all the internal circuitry, with the exception of the error amplifier, the current limit comparator, and the output drivers.

The sawtooth oscillator is programmed for a specific frequency and deadband by values of  $R_T$ ,  $C_T$ , and  $R_D$ . The resulting ramp waveform is applied to one side of the pulse width modulation comparator, which has been designed with a very small amount of hysteresis to prevent oscillations at the comparison point. The other terminal of the PWM comparator is connected to the output of an error amplifier which has been designed with a common mode range that includes both ground and the 5V reference.

Also associated with the amplifier is on-chip soft start circuitry. This soft start circuitry is controlled not only by an external RESET terminal, but also by the undervoltage lockout circuitry. If the reference voltage should be less than the 5V required for normal linear operation of the control circuitry, the RESET terminal in the soft start is held low by the undervoltage lockout, thus preventing the soft start capacitor from charging. At the same time, the power output drivers of the device are inhibited, thus making it impossible for spurious output pulses to occur during undervoltage conditions.

The digital output of the pulse width modulation comparator is ANDed with the output of the current limit comparator. This provides very fast response to overcurrent conditions. The current limit comparator has a fixed input offset of 100mV plus a slight hysteresis of 20mV to eliminate indecision at the threshold point. The PWM signal from the AND gate is followed by three levels of pulse processing logic. It first passes through a

## APPLICATION NOTES – SG1525A/SG1526/SG1527A

metering flip-flop whose function is to allow only one output pulse per oscillator cycle, thus eliminating oscillations and permitting pulse-by-pulse current limiting. The second element is a memory flip-flop. This flip-flop is part of the double pulse suppression logic and prevents two pulses in succession from one output driver, independent of conditions on the SHUTDOWN terminal, RESET terminal or error amplifier inputs. Also included is a toggle flip-flop which alternately gates first one driver and then the other in the presence of a PWM signal.

The final elements in the block diagram are the source/sink output drivers, with a separate collector supply voltage terminal brought out for additional flexibility.

A simplified version of the undervoltage lockout circuitry is shown in Figure 16. The circuitry consists of a 1.2V bandgap reference and a voltage comparator which are fully operational for reference voltages greater than 2.1V. When the reference voltage is greater than 2.1V, the output transistor is turned on, inhibiting both power output drivers. It also holds the RESET line controlling the soft start circuitry in the low state, thus preventing the soft start capacitor from charging, and guaranteeing zero duty cycle.

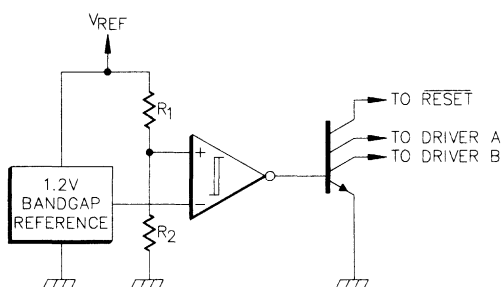


Figure 16. The Undervoltage Lockout Circuit Contains a Bandgap Reference and Comparator Which Becomes Active at  $V_{REF}=3 V_{BE}\approx 2.1$  Volts

Resistive divider  $R_1$  and  $R_2$  is scaled so that when the reference voltage reaches 4.5 v the comparator changes state, thus releasing the soft start capacitor and also enabling the power drivers. Approximately 200mV hysteresis is built into the comparator so that the transition from lockout to fully on is not accompanied by indecision and jitter.

Monitoring the reference voltage rather than the input terminal voltage has an additional benefit. With this particular configuration, this chip can operate on +5V by connecting the  $V_{IN}$  terminal to the  $V_{REFERENCE}$  terminal and then regulating the input voltage between 4.5 and 5.5 volts. This is a desirable feature where other supply voltages must be generated from a regulated +5V source.

A simplified schematic of the oscillator of the 1526 is shown in Figure 17. A new approach is taken for controlling deadtime in the circuit. The principle of operation is similar to the 1524 and 1525 oscillator. A timing capacitor is charged via a constant current programmed by an external resistance  $R_T$ . When the capacitor has charged linearly up to a nominal 3.2V, a voltage comparator changes state, thereby turning on a discharge network which reduces the capacitor voltage very rapidly to the +1V level. The distinctive difference between the oscillator in the 1525 and that in the 1526 is that the discharge network is a current source instead of a semi-saturating Darlington. In the 1526, the discharge circuit is formed by a compound current mirror, Q3, Q4, and Q5. The output current of this current mirror is ratioed to the current charging in  $C_T$  by a ratio of 30:1. This results in a charge time to discharge time ratio of approximately 29:1 independent of the value of  $C_T$ . This ratio can be modified to give longer deadtimes by insertion of a small amount of resistance from Pin 11 to ground. With this technique, deadtimes up to 50% or more are easily obtainable. The oscillator configuration has the advantage that the minimum deadtime for the oscillator is now fixed at approximately 3% independently of the frequency of the circuit.

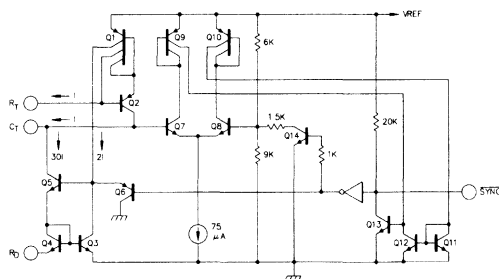


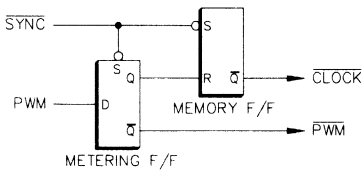
Figure 17. The SG1526 Oscillator Provides Deadband Control By Ratioing The Charging Currents to  $C_T$

The remainder of the oscillator circuit functions similarly to that of the 1525. One notable exception is the TLL compatible buffer gate between the SYNC output pin and the remainder of the circuit. This enables the port to be bi-directional, driven either by open-collector TTL or by open-drain CMOS, or to itself drive other TTL or CMOS logic.

Figure 18 contains a brief explanation of the pulse processing logic in the 1526. The logic consists of two specialized flip-flops: a metering or data latch flip-flop, and a set/reset or memory flip-flop. The metering flip-flop is basically an asynchronous data latch which is enabled by a sync pulse from the oscillator during the beginning of every oscillator cycle. Once the metering flip-flop is enabled, a PWM signal may pass asynchronously through the device. However,

# APPLICATION NOTES – SG1525A/SG1526/SG1527A

once the signal is terminated for any reason, no new pulse can propagate through the data latch until a new sync pulse is received at the beginning of the next oscillator cycle. This feature allows each individual pulse to be terminated either by the action of the current limit comparator or by external circuitry which pulls the SHUTDOWN pin low. This feature allows the SHUTDOWN pin to be a convenient input port for a strobe pulse from symmetry correction circuitry.



### METERING FLIP-FLOP

**DESCRIPTION:** ASYNCHRONOUS DATA LATCH  
**FUNCTION:** ALLOWS ONLY ONE PWM PULSE PER OSCILLATOR PERIOD  
**BENEFIT:** SUPPRESSES HIGH FREQUENCY OSCILLATIONS

### MEMORY FLIP-FLOP

**DESCRIPTION:** SET-RESET FLIP-FLOP  
**FUNCTION:** REMEMBERS WHICH OUTPUT PRODUCED LAST PULSE  
**BENEFIT:** INHIBITS DOUBLE PULSING IN PUSH-PULL CONFIGURATION

Figure 18. SG1526 Pulse Processing Logic

The function of the memory flip-flop is to generate the clock pulse for the toggle flip-flop, which alternately gates the two output power drivers. It operates as follows: Let us assume that the flip-flop begins operation in the reset state. When a sync pulse is received from the oscillator, the Q terminal is then driven low, generating a clock pulse for the toggle flip-flop, which then changes state. If a PWM signal is generated during the oscillator cycle, then the flip-flop is reset, thus enabling it to generate another clock at the beginning of the next oscillator cycle. If no pulse width modulation signal is generated because the duty cycle has gone to zero or SHUTDOWN has been pulled low, then the memory flip-flop will not be reset, and when the next sync pulse occurs, no clock will be generated. In this way, the output flip-flop is toggled only upon generation of pulse width modulation signals, thus rendering it impossible for two successive pulses to be obtained from one output driver.

The operation of the metering logic in the 1526 is shown in more detail in the timing diagram in Figure 19. The top waveform, Waveform A, shows the SYNC pulse train from the oscillator. This pulse train divides four timing periods,  $T_1$  through  $T_4$ , as shown at the bottom of the timing diagram. Waveform B represents the ramp signal from the master oscillator, while Waveform C represents the analog output signal from the error amplifier. These two waveforms are differentially compared in the pulse width modulation comparator, whose output is shown as Waveform D. It can be seen that the error amplifier output voltage is just slightly less than the peak of the ramp signal

approaching nearly full duty cycle. Waveform E is a SHUTDOWN signal from the current limit comparator. Alternately, this line could also show a digital input signal from other control logic. The waveform at line F represents the ANDed output of the PWM comparator and the SHUTDOWN signal. This acts as the data input to the metering logic flip-flop, whose output is shown as Waveform G.

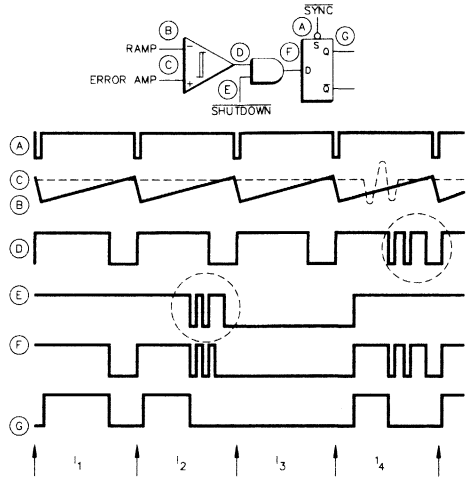


Figure 19. Timing Diagram of the Pulse Processing Logic Over Four Oscillator Cycles

The first time frame,  $T_1$ , illustrates a normal period of operation. The error amplifier calls for nearly full duty cycle; the SHUTDOWN pin stays high, and this output signal then passes unaltered through the metering logic flip-flop. During the second time frame, the SHUTDOWN pin is pulled low for several times during the active pulse period. This results in a series of pulses being applied to the data input of the metering logic flip-flop, but as can be shown in Waveform G, once the first pulse is terminated no other pulse can begin until the next oscillator cycle. During time frame  $T_3$ , the SHUTDOWN pin is low, thus preventing and PWM signals from reaching the metering flip-flop. In the fourth time frame, the disturbance at the output of the error amplifier causes multiple ramp crossings, which generates multiple PWM signals during one oscillator cycle. These signals reach the data input of the metering flip-flop, but as before, once the first pulse is terminated, the remainder of the pulses cannot propagate through the device to the output drivers.

The combination of source/sink drivers with a separate collector supply voltage terminal allows the output drivers to be easily interfaced with all the circuit configurations found in mot switching power supplies. Figure 20 illustrates the connections for a common emitter push-pull configuration. In this circuit, the

# APPLICATION NOTES – SG1525A/SG1526/SG1527A

collector supply to the output source/sink drivers is tied to the supply voltage through  $R_1$ , which limits the voltage swing of each driver output, preventing emitter-base breakdown. During the turn-off cycle, an additional spike of reverse base current is generated by the speed-up capacitor  $C_1$  or  $C_2$ .

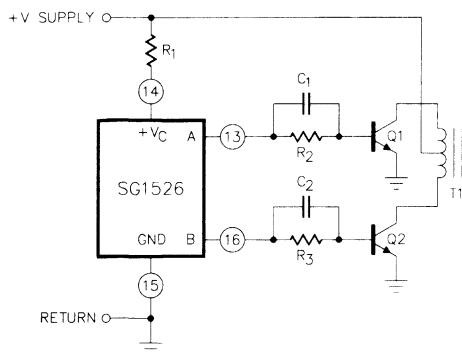


Figure 20. Basic Connections for a Push-Pull Grounded-Emitter Configuration

Buck-type converters are easily interfaced to the totempole output devices. For this mode of operation it is necessary only to ground the output terminals A and B, and drive the base of the switching device with the collector supply terminal. In this configuration, the upper Darlington resistors are alternately turned on and pull Pin 14 to ground, thus providing up to 100mA of current drive capability on alternate oscillator cycles.

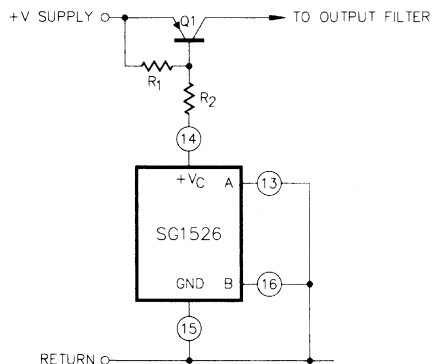


Figure 21. For Single-Ended Configurations the  $V_c$  Terminal is Alternately Switched to Ground by the Driver Pull-Up Transistors

The totem-pole outputs can also drive a transformer directly, as illustrated in Figure 22. Since each output driver exhibits a low impedance, no center tap winding is required on the transformer

primary. In this example, the transformer drive capability is used to interface the control device with the power transistors in a half bridge configuration.

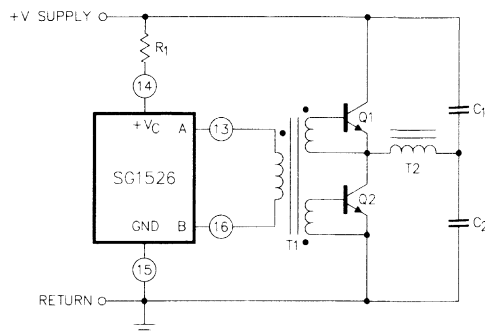


Figure 22. Low Power Transformers are Driven Directly by the Output Terminals

If an additional current drive capability beyond that available in the 1526 is necessary, it is very easy to interface the output totem-pole drivers with the 1627 dual 500mA driver circuit. This is shown in Figure 23.

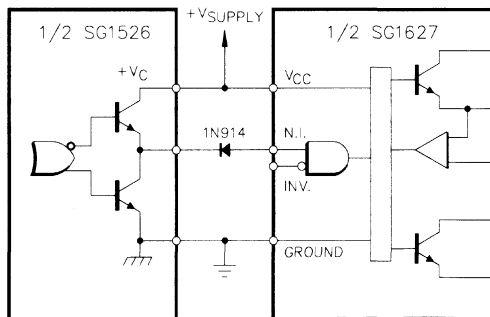


Figure 23. The Totem-Pole Outputs of the SG1526 can be Interfaced to the SG1627 Power Driver With a High-Speed Switching Diode

The logic threshold of the 1627 is a nominal +2V, while the sink current in the low state is about 1mA. A fast silicon switching diode such as a 1N914 can be used to provide a sink current path in the low state, while blocking excessive input current to the power driver during the control circuit's high state.

The ability of one control port of the 1526 to drive another control port enables a good deal of flexibility from the chip. The flyback converter in Figure 24 illustrates this point. Current limiting in a flyback converter is difficult because the overcurrent signal from

## APPLICATION NOTES – SG1525A/SG1526/SG1527A

the current sense resistor is always out of phase with the conduction of the principle power transistor. In this circuit, the output of the current limit comparator in the 1526 is used to re-trigger the soft start circuitry. By choosing the value of the soft start capacitor so that the recovery time of the soft start circuitry is of the order of one or two cycles, it is possible to provide current limiting with a minimal number of external components. This same technique can be used in a push-pull converter where it is desirable for the pulse width modulation signal to be turned off for multiple oscillator cycles rather than for a single cycle. This allows overstressed output semiconductors a cool-off period before returning to normal operation.

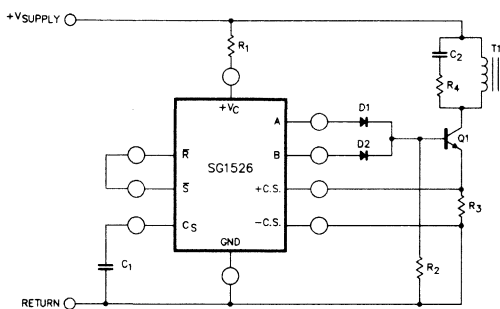


Figure 24. Using the SG1526 in a Flyback Converter With Current Limiting

### CONCLUSION

Several integrated circuits designed specifically for switch-mode power supply control have been described. A brief review has been made of past approaches to the integration of switching power supply control and driver circuitry. A description of a newly available family of control/driver integrated circuits, the SG1525/1527 series, has been given. Finally, a sketch of a future high performance controller circuit, the SG1526, has been drawn.

The future of integrated circuits for switching power supplies clearly involves greater complexity in the control circuitry to account for all possible modes of supply operation. The benefits for the power supply designer will be greater performance and reliability from switchers with reduced component count and greater overall manufacturing economies.

### REFERENCES

1. Peter N. Wood, "Design of a 5 Volt 1000 Watt Power Supply," TRW Power Semiconductors Application Note 122A, February, 1976.
2. Robert A. Mammano, "Power Switch Drivers: New IC Interface Building Blocks for Switched-Mode Converters," Powercon 5 Proceedings, May, 1978.



## A CURRENT MODE I.C. OPTIMIZED FOR SINGLE ENDED CONVERTERS

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### INTRODUCTION

Recent advances in switched mode power supply (SMPS) technologies have resulted in rapid developments of more advanced pulsed width modulator (PWM) integrated circuits. Conventional PWM techniques are now losing some of their market share to the newer PWM circuits that are using current mode technology. One of these current mode PWM integrated circuits optimized for low cost, low to mid range output power supplies (15W-250W), is the SG1842/43/44/45 family of PWM controls. This application note includes a brief review of voltage mode technique vs. current mode (constant frequency type), their advantages and disadvantages, that is followed by a functional description of the SG1842/43/44/45 family of PWM controllers.

### CURRENT MODE VS. VOLTAGE MODE CONTROL

Let us briefly review the conventional control approach (voltage mode technique) by referring to Figure 1.

In this method, the small differential voltage between output voltage ( $V_O$ ) and reference voltage ( $V_R$ ) is being amplified by the high DC gain of the error amplifier, resulting in an error voltage ( $V_E$ ). This voltage is then compared to a fixed frequency sawtooth with a finite peak to peak magnitude ( $V_M$ ). The output of the comparator stage is now a fixed frequency, variable duty cycle square wave that controls switch element (Q1) according to the variations in the magnitude of error voltage. This type of a converter where a single loop system is incorporated and only output voltage is being monitored and regulated, is called voltage mode technique. It is possible to vary the slope of the ramp signal in proportion to variation of input voltage, in order to improve line regulation and output dynamic response. This scheme is an improved version of voltage mode which is referred to as feed forward technique.

Now let us examine current mode method by referring to Figure 2. Notice that unlike the voltage mode, this scheme consists of two loops; a current loop which detects the switch current, inside another loop regulating the output voltage, called voltage loop.

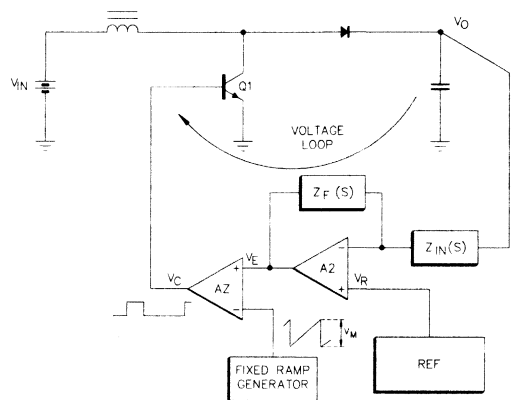


Figure 1. Typical Application of a Voltage mode regulator

The operation is as follows. A clock signal running at a fixed frequency sets the output of the latch circuitry to go high, turning on the switch (Q1). Once the voltage across the sense resistor ( $R_S$ ) reaches a threshold set by the error signal ( $V_E$ ), the output of the comparator (A2) switches low. This resets the latch, resulting in termination of the next output pulse and keeping it low until arrival of the next clock pulse.

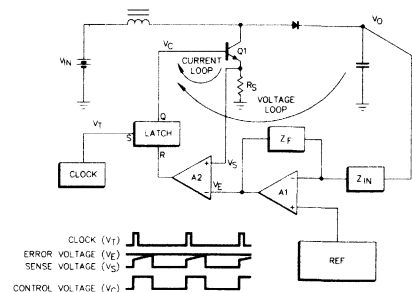


Figure 2. Typical Application of Current Mode Regulator

# APPLICATION NOTES – SG1842/43/44/45

As a result of this two loop control scheme, current mode controllers offer several performance advantages. The first advantage over voltage mode is the inherent feed forward capability. Recall that in the current loop, the ramp voltage ( $V_s$ ) across sense resistor was generated by the inductor current during switch "on-time", which was also directly proportional to the input voltage ( $V_{in}$ ). Therefore, as  $V_{in}$  increases, the slope of the ramp also increases, which causes a shorter duration of the switch "on-time". This results in the control loop quickly adjusting itself to any line perturbations since it does not have to wait for a command from the output. As a result of this, current mode regulators have excellent line regulation and transient response.

Second, pulse-by-pulse current limiting is inherently achieved whenever using this method. This is because the error signal sets a limit on inductor peak current. This means that maximum current or current limit knee point can easily be set by simply clamping the output of error amplifier. This feature of current mode controllers is especially important whenever push-pull center tapped topologies are used, where any imbalance in the power transistors can cause a net DC current flow in the transformer. This problem sometimes causes transformer saturation and failure of the power transistors.

Third, current mode regulators are easier to stabilize and require simpler compensation circuitries. This is due to the fact that by controlling the inductor current, the double poles of control to output transfer function associated with conventional approach, are separated with two single poles. As a result, less phase shift is generated and the required phase boost is less critical for a stable operation. In fact, many current mode regulators are often compensated such that the overall loop gain is crossing zero db gain at a frequency prior to reaching the second pole frequency.

Finally, current mode controlled regulators can operate in parallel with equal current sharing, due to their inherent current regulating feature. One big advantage of paralleling converters is their redundant operation for the applications requiring high reliability power systems.

## DESCRIPTION

The 1842/3/4/5 family of PWM controlled ICs are designed for low cost switched mode power supply applications utilizing current mode techniques. While they can be used in most DC-DC applications, they are optimized for single-ended designs such as Flyback and Forward converters. 1842/44 series are best suited for off-line applications, whereas 1843/45s are mostly used in power supplies with low input voltages. The IC can be divided into six main sections as shown in Figure 3: undervoltage lockout and start up; reference oscillator; current sense and PWM latch; error amplifier; and the output stage. The operation of each section is described and the differences between the members of this family are summarized in Table 1 and explained in each related section.

PART #	UVLO		MAXIMUM DUTY CYCLE
	Start-up Voltage ( $V_{ST}$ )	Hysterise Voltage ( $V_{HYS}$ )	
SG1842	16V	6V	<100%
SG1843	8.4V	0.8V	<100%
SG1844	16V	6V	<50%
SG1845	8.4V	0.8V	<50%

TABLE 1

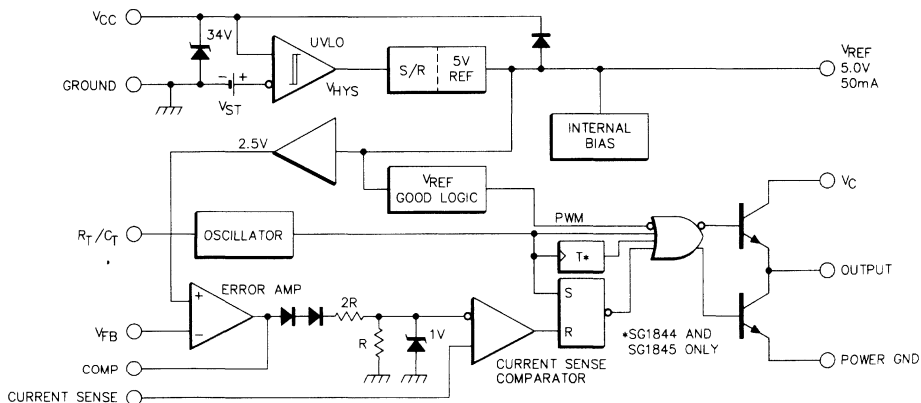


Figure 3. Device Block Diagram



# APPLICATION NOTES – SG1842/43/44/45

## UNDERVOLTAGE LOCKOUT

The purpose of undervoltage lockout is to maintain a low quiescent current of less than 1mA and to guarantee that the IC is fully functional before the output stage is activated. Both input voltage ( $V_{IN}$ ) and reference are monitored by separate comparators with built-in hysteresis. The input voltage comparator upper and lower thresholds for 1842/44 is 16V/10V and 1843/45 has 8.4V/7.6V nominal threshold levels. The combination of low start-up current and large hysteresis make them ideally suited in off line converter applications. Referring to Figure 4, an efficient start-up circuitry is implemented using 1842 PWM IC in conjunction with a bootstrap winding off of the power transformer. The operation of the circuitry is as follows.

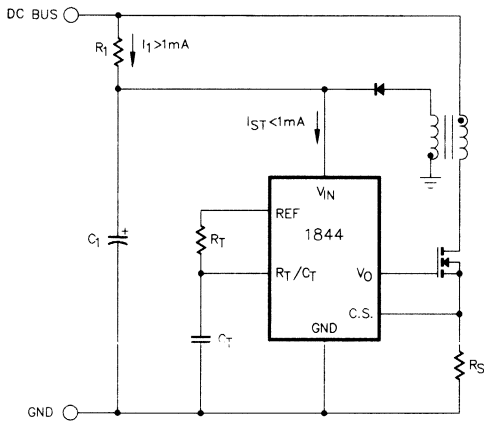


Figure 4. Typical Application of Start-Up Circuitry

The start-up capacitor ( $C_1$ ) is being charged by the current through resistor ( $R_1$ ) from the high voltage DC bus. Resistor ( $R_1$ ) is designed such that it provides more than 1mA of current. As the voltage across capacitor ramps up from zero, the only load current is the standby current of the IC. Once voltage reaches the start-up threshold, PWM IC starts operating, turning on the converter which causes the capacitor to discharge quickly, ramping down toward the drop-out thresholds. During this time, the auxiliary winding with ( $CR_1$ ) and ( $C_1$ ) provides the necessary voltage to continue to operate the IC and support its required supply current. (NOTE: The start-up capacitor must be large enough such that during the discharge period, the bootstrap voltage will reach above the shutdown threshold.)

## VOLTAGE REFERENCE

The voltage reference is a low drift bandgap design which provides +5.0V to supply charging current to the oscillator timing capacitor, as well as supporting internal circuitries. Initial accu-

racy of 184X/284X is  $\pm 1\%$ , and 384X series has  $\pm 2\%$  over their specified ambient temperature range. The reference is capable of providing in excess of 20mA for powering any external control circuitries and has built-in short circuit protection.

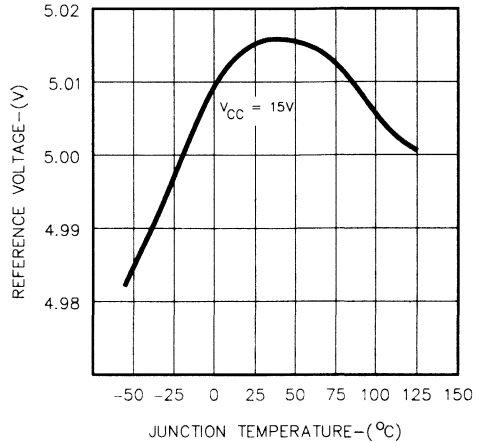


Figure 5. Reference Voltage vs. Temperature

## OSCILLATOR

The oscillator is programmed by the values selected for the timing components ( $R_T$ ) and ( $C_T$ ). A simplified schematic of the oscillator is shown in Figure 6. The operation is as follows. Capacitor ( $C_T$ ) is charged from the 5V reference with resistor ( $R_T$ ) to a peak voltage of 2.8V nominally. Once this threshold is

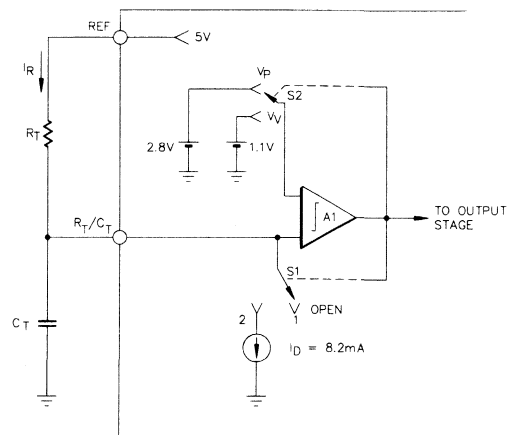


Figure 6. Simplified Schematic of Oscillator Section.

# APPLICATION NOTES – SG1842/43/44/45

reached, comparator (A1) changes state, causing (S1) to switch to position (2) and (S2) to ( $V_V$ ) position. This will allow the capacitor to discharge with a current equal to the difference between a constant current ( $I_D$ ) and current through charging resistor ( $I_R$ ), until the voltage drops down to  $\approx 1.1V$  nominally and the comparator changes state again repeating the cycle. Oscillator charge time results in the output to be in a high state (on time) and discharge time sets it to a low state (off time). Since the oscillator period is the sum of the charge and discharge time, any variations in either of them will ultimately affect the stability of the output frequency and the maximum duty cycle. In fact, this variation is more pronounced when the maximum duty cycle has to be limited to less than 50%. This is due to the fact that for longer output off time, capacitor discharge current ( $I_D - I_R$ ) must be decreased by increasing  $I_R$  current. (NOTE:  $R_T$  value should always be greater than  $520\Omega$  or the oscillator may stop functioning). Consequently, this increases the sensitivity of the frequency and duty cycle to any small variations of internal current source ( $I_D$ ), making this parameter more critical under those conditions. As a result, this parameter is trimmed to a nominal current value of  $8.2\pm 0.5mA$  at room temperature, and guaranteed to a maximum range of 7 to 9mA over the specified ambient temperature range. Figure 7 shows the variations of  $I_D$  over temperature.

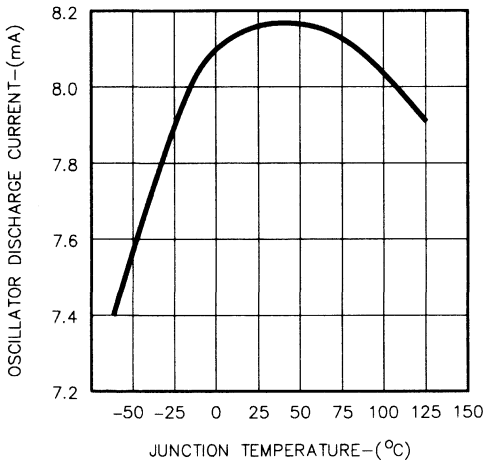


Figure 7. Oscillator Current vs. Temperature

The oscillator is designed such that many values of  $R_T$  and  $C_T$  will give the same frequency, but only one combination will yield a specific duty cycle at a given frequency (see Figure 8). A set of formulas are given to determine the values of timing components for a given frequency and duty cycle. (NOTE: The following formulas are less accurate at shorter duty cycles and/or higher frequencies. This will require some adjustment of timing components to correct for this error).

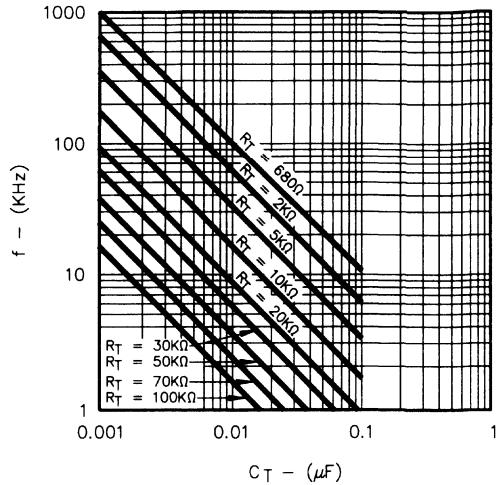


Figure 8. Oscillator Timing Diagram

Given: frequency  $\equiv f$ ; maximum duty-cycle  $\equiv Dm$   
Calculate:

$$R_T = 267 \frac{\left[ (1.76)^{\frac{1}{Dm}} - 1 \right]}{\left[ (1.76)^{\frac{1-Dm}{Dm}} - 1 \right]} \quad (\Omega), \quad 0.3 \leq Dm \leq 0.95$$

$$C_T = \frac{1.86 \cdot Dm}{f \cdot R_T} \quad (\mu f)$$

for duty cycles above 95% use:

$$f \approx \frac{1.86}{R_T \cdot C_T} \quad \text{where } R_T \geq 5K\Omega$$

Example: A flyback power supply design requires the duty cycle to be limited to less than 45%. If the switching frequency is designed to be 50kHz, what are the values of  $R_T$  and  $C_T$ ?

Given:  $f = 50KHZ$   
 $Dm = 0.45$

$$R_T = 267 \frac{\left[ (1.76)^{\frac{1}{.45}} - 1 \right]}{\left[ (1.76)^{\frac{.55}{.45}} - 1 \right]} = 674\Omega$$

$$C_T = \frac{1.86 \times 0.45}{50 \times 10^3 \times 674} = .025 \mu f$$

# APPLICATION NOTES – SG1842/43/44/45

## CURRENT SENSE COMPARATOR AND PWM LATCH

Referring back to the operation of current mode PWM, recall that the switch peak current is established by the output of the error amplifier. This current is sensed by an external sense resistor (or a current transformer), monitored by a C.S. pin and compared internally with a voltage from the output of the error amplifier. The output of comparator then goes to a PWM latch that will insure only a single pulse to appear at the output during any given oscillator cycle. SG1844/5 series have an additional flip flop stage that will limit the output to less than 50% duty cycle range as well as reducing its frequency to half of the oscillator frequency. The current sense comparator threshold is internally clamped to 1V nominally which would limit maximum peak switch current to:

$$(1) I_{SPMAX} = \frac{V_z}{R_s} \quad \text{where: } \begin{array}{l} I_{SP} \equiv \text{Peak switch current} \\ V_z \equiv \text{internal zener} \\ 0.9V \leq V_z \leq 1.1V \end{array}$$

Equation 1 is used to calculate the value of sense resistor during the current limit condition where switch current reaches its maximum level. In normal operation of the converter, the relationship between peak switch current and error voltage (voltage at pin 1) is given by:

$$I_{SP} = \frac{V_E - 2V_F}{3 \cdot R_s} \quad \text{where: } \begin{array}{l} V_E \equiv \text{Voltage at pin 1} \\ V_F \equiv \text{Diode Forward volt.} \\ 0.7V \text{ at } T_j = 25c \end{array}$$

The above equation is plotted in Figure 9. Notice that the gain becomes non-linear above current sense voltages greater than  $\approx 0.88$  volts. It is therefore recommended to operate below this range during the normal operation. This would insure that overall closed loop gain of the system will not be affected by the change in the gain of the current sense stage.

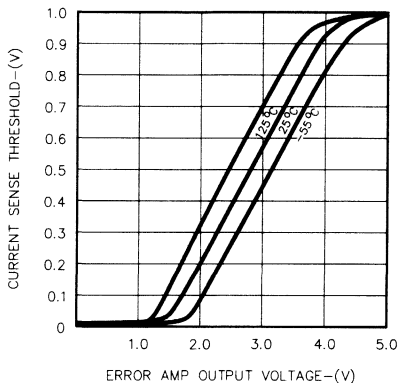


Figure 9. Current Sense Threshold vs. Error Amplifier Output

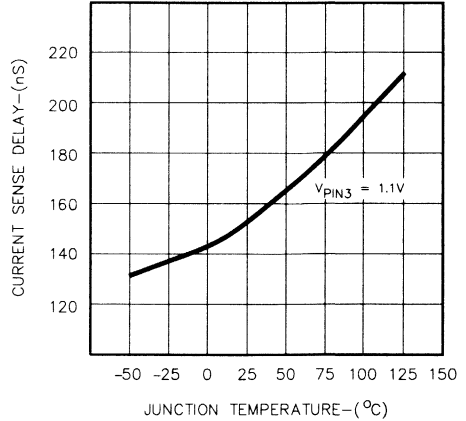


Figure 10. Current Sense to Output Delay vs. Temperature

## ERROR AMPLIFIER

The error amplifier has a PNP input differential stage with access to the Inverting input and the output pin. The N.I. input is internally biased to 2.5 volts and is not available for any external connections. The amplifier is internally compensated with a bandwidth of  $\approx 1$ MHz and a typical DC open loop gain of  $\approx 90$ dB. The maximum input bias current for 384X series is  $2\mu A$ , while 184X/284X devices are rated for  $1\mu A$  maximum over their specified range of ambient temperature. Low value resistor dividers should be used in order to avoid output voltage errors caused by the input bias current. The error amplifier can source 0.5mA and sink 2mA of current. A minimum value of feedback resistor ( $R_F$ ) is given by:

$$R_{FMIN} = \frac{3(1.1) + 1.8}{0.5 \text{ mA}} = 10K$$

Figure 11 shows the open loop gain and phase response of the error amplifier for all devices.

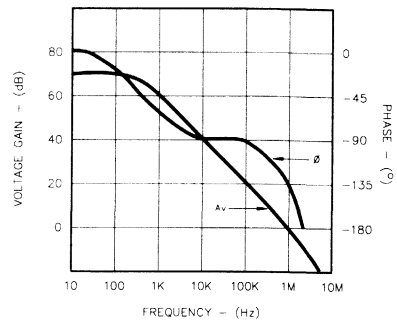


Figure 11. Error Amplifier Open-Loop Frequency Response

# APPLICATION NOTES – SG1842/43/44/45

## OUTPUT TRANSISTOR

The output section has been specifically designed for direct drive of power MOSFETs. It has a totempole configuration which is capable of up to  $\pm 1A$  of peak current. This will typical result in a rise and fall time of 50ns into a 1000pf capacitive load. Each output transistor (source and sink) is capable of supplying 200mA of continuous current with typical saturation voltages of less than 2.5 volts over  $-55^{\circ}C$  to  $+125^{\circ}C$  junction temperature range. (See Figure 12 and 13) All parts are designed to minimize the amount of shoot-thru current which is a result of momentary overlap of output transistors. This allows a more efficient usage of the IC at higher frequencies, as well as improving the noise susceptibility of the device.

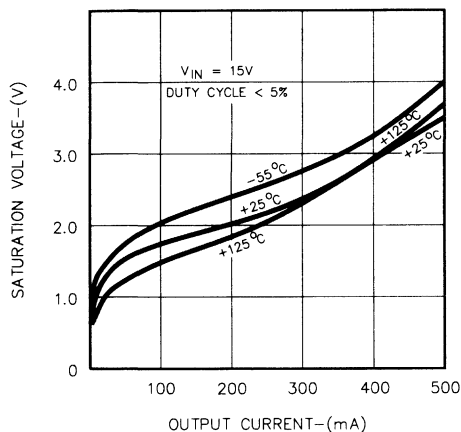


Figure 12. Output Saturation Voltage vs. Output Current and Temperature

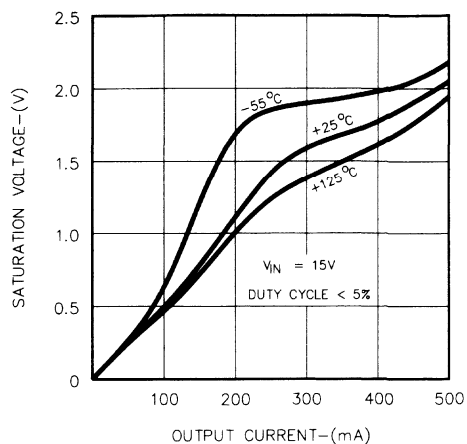


Figure 13. Output Saturation Voltage vs. Output Current and Temperature

## **OUTPUT SUPERVISORY CIRCUITS: A NEW FAMILY OF POWER SUPPLY CONTROL DEVICES**

Stan Dendinger  
Manager, Advanced Product Development  
Silicon General, Inc.

### **ABSTRACT**

This paper describes a series of new monolithic integrated circuits designed to perform all the functions necessary to monitor and control the outputs of sophisticated power supply systems. Beginning with a simple over-voltage sensing circuit, these devices range through more versatile and accurate single-function units, to all-inclusive devices which contain sensing circuits for both over and under-voltage conditions, current sensing, SCR crowbar firing, logic outputs, and an accurate independent reference generator. A description of the operation of each individual element is given together with several applications which demonstrate their utility.

### **INTRODUCTION**

Recent years have seen the introduction of many sophisticated integrated circuits for use in controlling the voltage regulation function of both linear and switching power supply systems. While these circuits have provided a high degree of performance with a side benefit of considerable increases in both reliability and cost savings, they have all addressed the basic function of maintaining the output voltage constant. Most power supply systems, however, require additional circuitry for monitoring satisfactory performance and providing protection in the event of a fault condition. These requirements have led to the development of a new class of power supply element - an Output Supervisory Control Circuit.

### **SUPERVISORY CONTROL FAMILY MEMBERS**

The first integrated circuit developed specifically as a power supply monitoring device was Motorola's MC3523 available also as an SG3523 from Silicon General. This device, which is packaged as an 8-pin minidip, was designed to sense an over-voltage condition, provide an adjustable time delay, and then fire a high-current SCR crowbar for power supply shutdown. An improved and interchangeable device, the SG3523A, was later introduced to provide more tightly specified performance, greater threshold accuracy, and improved temperature stability. Block diagrams of these two devices are shown in Figure 1.

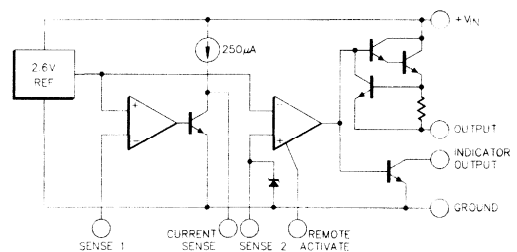


Figure 1. SG3523 Over-Voltage Sensing Circuit. The SG3523 and 3523A contain an independent reference generator, an input comparator designed to initiate a settable time delay, and a second comparator which activates both a crowbar firing current and a low-level indication signal.

It was soon recognized that with the addition of a few more access points to this circuit, significant increases in versatility could be achieved. This led to the development of the SG1542 device shown in Figure 2. With 14 pins in this DIL package the following additional features could be offered:

1. Access to the reference generator's output so that one could take advantage of its 1% accuracy and 50 ppm T.C.

# APPLICATION NOTES – SG1542/SG1543/SG1544/SG3523

- Uncommitted inputs to the sensing comparator allowing use for either under or over-voltage sensing as well as the ability to set threshold levels below 2.6 volts.
- The addition of a logic level output active when the sensed voltage is within tolerance, as well as the one which indicates out-of-tolerance.
- A separate supply terminal for the high current SCR trigger allowing greater utilization of this output.

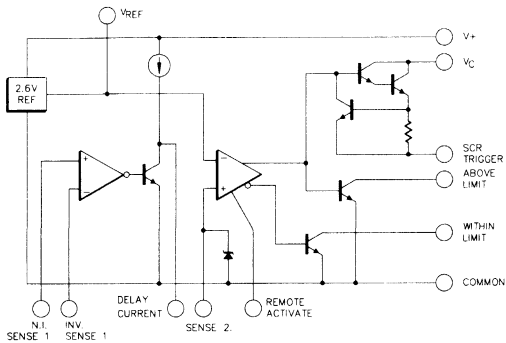


Figure 2. SG1542 Voltage Sensing and Protection Circuit. The use of a 14-pin package for the SG1542 provides greater access to the circuit elements and thus greatly expanded versatility.

Finally, it was decided to build an all-encompassing device which would include both over and under-voltage sensing as well as a means for current limiting, all in one integrated circuit. This resulted in the 16-pin SG1543, the main subject of this paper. The circuitry of the SG3523, 3523A, and 1542 is equivalent to the OVP portion of the SG1543 and thus need not be described separately.

Before proceeding with a discussion of the SG1543, however, there is one more member of this family worth mentioning. The SG1544 is identical to the SG1543, but uses an 18-pin DIL package to keep the voltage-sensing comparator inputs uncommitted. This adds the ability to sense voltage levels below the reference voltage to the lengthy list of features offered by the SG1543. Now, on to a more complete description.

## THE SG1543 OUTPUT SUPERVISORY CIRCUIT

To fill the need for this output monitoring and controlling function, the SG1543 output supervisory circuit shown in Figure 3 was developed. This device contains an operational amplifier, a voltage reference circuit, several comparators, and a high-current SCR trigger circuit. The functions performed by this

device include over-voltage and under-voltage sensing, current limiting, and provisions for triggering an external SCR crowbar shutdown. All the functions provide open collector outputs for maximum flexibility in interfacing with either the power supply or the system load and, although the SCR trigger is directly connected only to the over-voltage sensing circuit, it may be optionally activated by any of the other outputs or by an external shutdown command. The SCR trigger circuit also includes an optional latch with external reset capability. External capacitors may be used to accurately program the sensing circuits for a minimum time duration of fault before triggering.

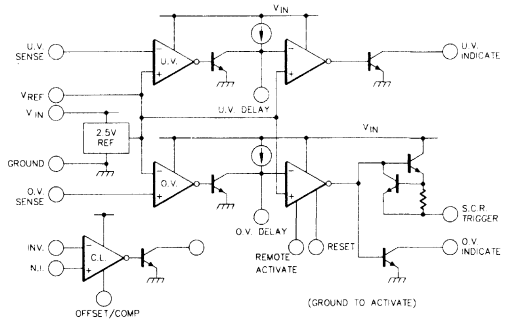


Figure 3. The block diagram of the SG1543 Output Supervisory Circuit includes over-voltage and under-voltage sensing as well as the capability for current limiting and SCR crowbar triggering.

The SG1543 circuit may be powered by either the output voltage to be monitored or a separate bias voltage at any level between 4.5 and 40 volts with a standby current of less than 10mA.

This device is packaged in a standard 16-pin hermetically sealed ceramic package and is available in both commercial and military temperature ranges. Before describing in greater detail the overall functions that this device can perform, it is worth discussing the individual circuits which go into its makeup.

## VOLTAGE REFERENCE CIRCUIT

The precision 2.50V reference circuit of the SG1543 is shown in Figure 4. This regulator is based upon the well-known band-gap reference circuit which has the capability of providing very stable performance over an input voltage range from as low as 4.5V to as high as 40V. The output is nominally set at 2.5V, but in addition, is trimmed to remove all effects of production manufacturing tolerances from the output voltage. In fact, this trimming not only adjusts the output voltage to within 1% of 2.5V, but in the process, as shown in Figure 5, also trims the temperature coefficient of output voltage to better than 50 parts per million per degree C. The trimming is performed at water probe by using controlled energy sources to blow fusible metal links which short

# APPLICATION NOTES – SG1542/SG1543/SG1544/SG3523

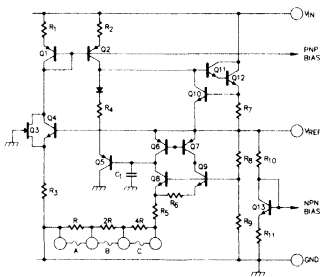


Figure 4. This precision 2.50 volt band-gap reference source is internally trimmed for  $\pm 1\%$  accuracy in order to eliminate the need for adjustment potentiometers.

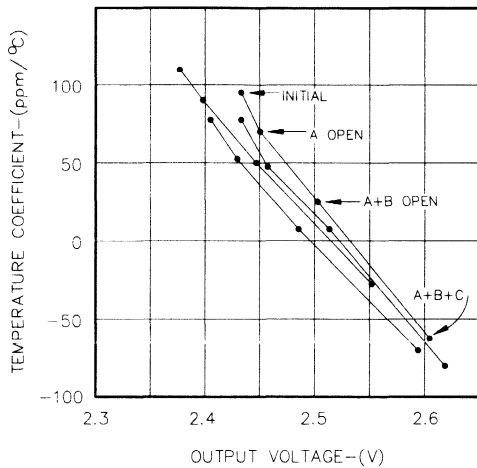


Figure 5. Temperature Coefficient vs. Voltage TrimAs successive links are opened in the reference voltage trimming network, the output voltage increases and the temperature coefficient becomes less positive.

out incremental values of resistance in the voltage setting network. These resistors are binary coded so that three values give eight bits of resolution and allow trimming to better than  $\pm 12$  millivolts. With this accuracy in all but the most precise applications, the need for adjustment or trimming potentiometers is effectively eliminated.

The output of this reference circuit is current limited for protection and will provide up to 10 milliamps of current for use as a reference for other functions that may be required along with the SG1543. In addition to stable temperature performance, this regulator also maintains its output voltage to within 10mV for all line and load changes. Additional benefits of the band gap reference circuit include a low noise performance, instant turn-on, and a high degree of long-term stability.

## COMPARATOR SECTION

Over and under-voltage sensing circuits are identical with only the input polarity changed between them. The under-voltage circuit is shown schematically in Figure 6. This configuration is made up of two comparators in series, each referenced to 2.50 volts, with the delay terminal at their juncture. The first comparator activates a current source upon sensing an out-of-tolerance condition and that current is used to charge an externally selected capacitor to provide a delay. The second comparator then activates the output indicating circuit. The overall time delay from input sense to output indicate, with no external capacitor, is approximately 0.5 microsecond. By adding a capacitor at the delay terminal, the fault must exist for an interval defined by the time it takes the voltage on the capacitor to charge from zero to 2.5V before the output comparator can switch. The charging current for this capacitor is a constant 250 microamps which provides for a delay of approximately 10 milliseconds per microfarad of capacitance. Since the comparator can discharge in excess of 10mA, the capacitor is reset in a fraction of its charge time.

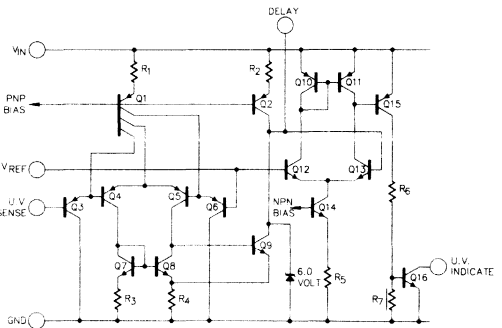


Figure 6. Voltage Sensing Comparators. Voltage level sensing is done with a high input impedance comparator with built-in hysteresis. When switched, the input comparator allows a constant current source to trigger the output comparator.

The input comparator has PNP transistor inputs which provide both high input impedance with less than one microamp bias current, and a wide input voltage range which includes ground and goes to within 2V of the positive supply voltage. Because the input PNP operates as an emitter follower, the input impedance to that comparator remains high throughout the input range. To eliminate the tendency to oscillate at threshold, a hysteresis of approximately 25mV is built into the input comparator.

The output indicating transistor, Q18, is designed to sink 10mA of current with a saturation voltage of less than 0.4 volt. Its open

# APPLICATION NOTES – SG1542/SG1543/SG1544/SG3523

collector allows several outputs to be connected together to provide a single indicating signal.

## SCR TRIGGER SECTION

While the under-voltage sensing circuit has only the 10mA, or low current, open-collector output, the over-voltage section contains additionally, an SCR crowbar triggering circuit good for 200mA. This stage also includes provision for remote activation of the output as well as a reset terminal. From the schematic shown in Figure 7, it can be seen that the output voltage comparator drives a PNP transistor, Q6, with two collectors, one of which drives the low-current, open collector indicating signal similar to the under-voltage circuit. The other collector of Q6 drives a Darlington amplifier which will provide 200mA to activate an external high current SCR crowbar device. Note that these two outputs are complements of each other; i.e. when pin 4 switches to ground, pin 1 goes positive.

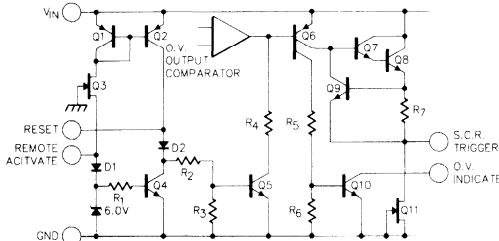


Figure 7. Over-Voltage Circuit. Either the over-voltage output comparator or the remote activation terminal will energize both the SCR trigger and the O.V. indicating transistor. Connecting pins 4 and 2 form a latch.

Since in many cases it is desired to activate the crowbar under other than over-voltage conditions, a remote activation circuit is also included. This consists of transistors Q1 through Q5 as shown in Figure 7. The functioning of this circuit is as follows: Q3 provides a controlled current source of approximately 300 microamps to saturate transistor Q4. With Q4 saturated, transistor Q5 is held in the off condition. When the remote activation terminal, pin 2, is grounded, it diverts the current away from the input of Q4, turning it off and turning Q5 on, which activates the output circuitry in the same manner as the over-voltage comparator.

An additional function of this circuit is to provide the capability to latch the outputs on after a fault is sensed, by externally connecting the over-voltage indicating terminal, pin 4, to the remote activation terminal, pin 2. With this configuration, an over-voltage condition which turns on Q10 will pull pin 2 to ground activating the remote activation signal which, in turn, holds the circuit in the on condition until the reset terminal is externally grounded, removing the latch and turning off the

output. Thus, the user has the capability to either activate the high current output only as long as a fault condition exists, or to latch it on upon the occurrence of a fault requiring external action by an operator to reset the circuit to its initial condition. Thresholds for both remote activation and reset terminals are approximately 1.2 volts.

## CURRENT SENSING AMPLIFIER

The amplifier in SG1543 designated for current sensing actually has much wider application. It is basically a high-gain, non-compensated operational amplifier with an open collector output; i.e., pull-up on the output must be provided externally. From the schematic shown in Figure 8, it can be seen that this circuit also has a PNP front end which gives it a wide common-mode range extending from slightly below ground to within 2 volts of the supply voltage. With a pull-up resistor of 2k $\Omega$ , the open loop voltage gain is greater than 72dB with a unity gain bandwidth beyond 5MHz. When used as a comparator, the response time is less than 200nanoseconds, and if linear amplification is required, external compensation may be added for stable performance over a wide frequency range or a unique frequency response.

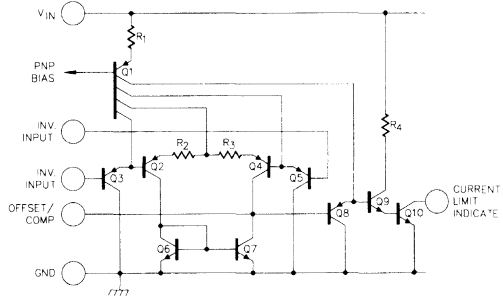


Figure 8. Current-Sensing Amplifier. PNP inputs give the current limit amplifier a common-mode input voltage range of from below ground to within 2 volts of the supply voltage.

The input to this amplifier is balanced for zero offset voltage but a fixed offset or threshold of up to 200mV may be incorporated by adding or subtracting current at the offset/compensation pin 12. For most current sensing application the required threshold polarity calls for a positive voltage on the inverting input. This can be accomplished with a resistor, R<sub>7</sub>, to ground as shown in Figure 9.

Reducing the impedance at pin 12 also lowers the gain of the amplifier somewhat as shown in Figure 8. This fact allows pin 12 to do double-duty as a point to apply frequency compensation as well. Due to the excess phase shift of the internal PNP trans-



# APPLICATION NOTES – SG1542/SG1543/SG1544/SG3523

tors, this amplifier requires compensation for stable closed-loop, linear applications but this can be accomplished easily with either  $C_1$  to the output or  $C_2$  to ground as shown in Figures 9 and 10.

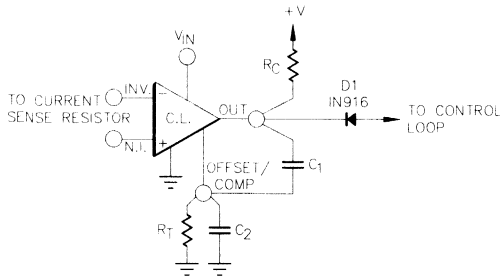


Figure 9. Current Sense Compensation. External components can be used with the current sense amplifier to establish an input offset or threshold, define the frequency response, and buffer the output.

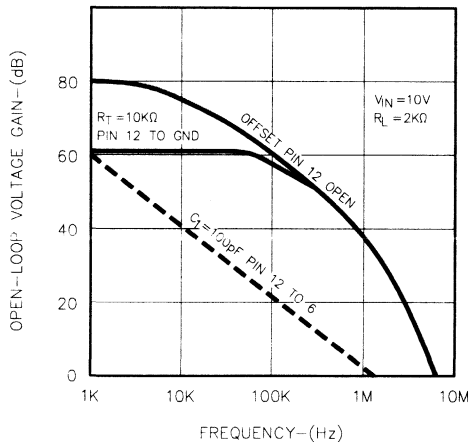


Figure 10. C.L. Amplifier Frequency Response. With 80dB gain and 5MHz bandwidth, the current sense amplifier provides a wide dynamic response, even when modified with external passive components.

Diode D1 and resistor  $R_C$  are used only if it is necessary to increase the frequency response by operating the output transistor at higher current and/or isolating the load from  $R_C$  and  $C_1$  when the amplifier is off.

## Applications

Figure 11 shows a typical application of the SG 1543 as used

to monitor a single power supply output voltage for both high and low voltage operation as well as current limiting. The data accompanying Figure 11 indicates how the values for the external components are selected. This circuit is driven from an external bias supply which must provide a standby current of 10mA maximum plus the activation current for the SCR trigger. The application in Figure 11 shows a single resistor divider string,  $R_4$ ,  $R_5$ , and  $R_6$ , which sets the thresholds for both the under and over-voltage activation levels. The external capacitors  $C_{D1}$  and  $C_{D2}$  are used to provide time delays before activation of the output circuitry. The output of the comparators can be used for many different functions; in this case, they are shown driving indicators. They can also provide signals to the system under power to give information that an out-of-tolerance condition exists. Additionally, by the external connection between pin 2 and pin 4, a latch has been provided such that an over-voltage condition will activate and hold that control signal until positive reset action at pin 3 is performed.

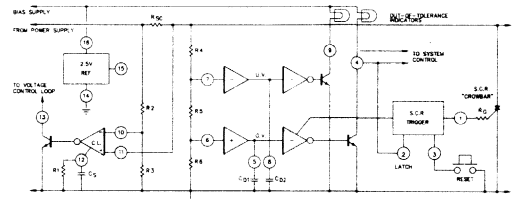


Figure 11. This typical application for the SG1543 provides linear foldback current limiting as well as over and under-voltage protection.

In firing an SCR with supply voltages above 5 volts an external resistor,  $R_G$ , is used on pin 1 to provide power dissipation limiting for the SG1543. While the SG1543 will provide up to 400mA of trigger current, the power limitation of the 16-pin-dual-in-line package should be held to less than one watt.

In this application, current limiting is performed by sensing the current in the positive supply line with fold-back provided by the action of  $R_2$  and  $R_3$ . A fixed threshold for the amplifier is set by  $R_1$  which is connected between pin 12 and ground.

Although the SG1543 could have been driven from the output voltage to be monitored, it would lose control when that output voltage fell to approximately 3V. This would, of course, preclude the use of the current limit function where short circuit protection must be provided.

# APPLICATION NOTES – SG1542/SG1543/SG1544/SG3523

The values for the external components used in conjunction with the SG1543 application of Figure 11 are determined as follows:

$$\text{Current limit input threshold, } V_{TH} \approx \frac{1000}{R_9}$$

Cs is determined by the current loop dynamics

$$\text{Peak current to load, } I_p \approx \frac{V_{TH}}{R_{SC}} + \frac{V_O}{R_{SC}} \left( \frac{R_2}{R_2 + R_3} \right)$$

$$\text{Short circuit current, } I_{SC} = \frac{V_{TH}}{R_{SC}}$$

$$\text{Low output voltage limit, } V_O (\text{Low}) = \frac{2.5 (R_4 + R_5 + R_6)}{R_5 + R_6}$$

$$\text{High output voltage limit, } V_O (\text{High}) = \frac{2.5 (R_4 + R_5 + R_6)}{R_6}$$

$$\text{Voltage sensing delay, } t_d = 10,000 C_d$$

$$\text{SRC trigger power limiting resistor, } R_G > \frac{V_{IN} - 5}{0.2}$$

## CURRENT SENSING OPTIONS

It is important to remember that all the features of the SG1543 apply equally to either linear or switching power supplies. Figure 12, for example, shows the current sensing amplifier in the SG1543 used to provide foldback current limiting for a linear regulator utilizing the SG723. To answer the question of why one would use the SG1543 for current limiting when that capability is built into the SG723, there are two important benefits: low sensing threshold voltage (whatever is selected vs. a fixed 700mV) and much higher gain for a very sharp transition from voltage to current feedback.

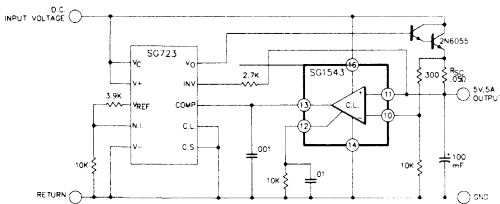


Figure 12. Linear Foldback Current Limiting. The SG1543 is equally adaptable to either linear or switching supplies. The circuit above shows a substantially improved current limit function for a linear SG723 voltage regulator.

Output current limiting for a switching supply which gets its control from an SG1524 regulating pulse width modulator is shown in Figure 13. Here, foldback is not included but an optical coupler for isolation has been added. It should be noted that all the low-current outputs of the SG1543 are equally well suited for driving optical couplers.

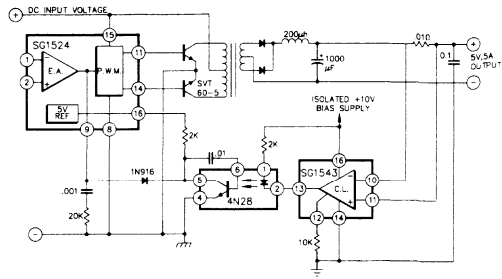


Figure 13. DC Converter With Isolated Current Limiting. Current limiting for a switching inverter is readily accomplished, even with a requirement for input-output isolation.

The last application suggests another use for the current sense amplifier completely dissociated with current. This is shown in Figure 14 where it is used in conjunction with the very excellent characteristic of the 2.50 volt reference contained within the SG1543 to provide an isolated voltage feedback signal. The SG1543's amplifier provides the gain and the overall loop compensation network, and drives a high-frequency opto-coupler which feeds into the unity-gain configured error amplifier of the SG1524. A designer should recognize that there are many possible variations on this theme, including taking the error signal from the collector of the opto-coupler, feeding into the output of the SG1524's error amplifier such that this amplifier provides a startup signal. Then the SG1543 may be powered directly from the output eliminating the need for an isolated bias supply.

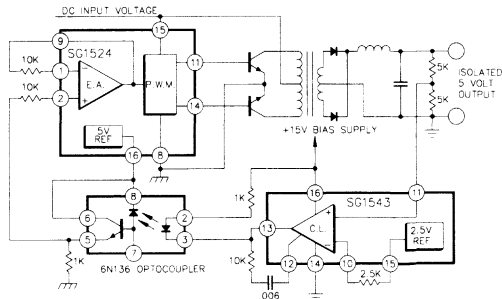


Figure 14. The current sense amplifier can also be used in conjunction with the SG1543's reference to provide a stable, isolated voltage feedback signal.

One final possible use for the current limit amplifier is to provide complete shutdown of the power supply rather than linear voltage reduction upon sensing an over-current condition. This function is shown in Figure 15 where the current limit amplifier is used as a comparator with the output terminal connected to the remote activation terminal for the SCR trigger. In this case,

# APPLICATION NOTES – SG1542/SG1543/SG1544/SG3523

sensing is done in the ground line. There is no offset added to the current limit amplifier but instead a threshold is provided by the action of  $R_1$  and  $R_2$  from the 2.50V reference signal. When an over-current condition is sensed and maintained for a period of time determined by a capacitor  $C_D$  on pin 12, then the output transistor will conduct, activating the SCR trigger and shutting down the power supply.

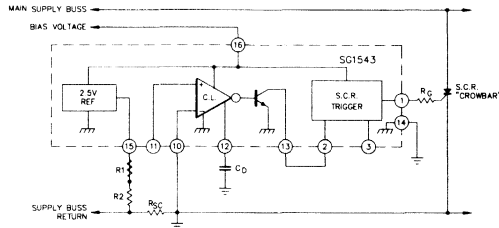


Figure 15. Overcurrent Shutdown. The current sense amplifier may also be used as a high-gain comparator to shut down the supply upon over-current.

## SENSING MULTIPLE OUTPUT VOLTAGES

Many power supply systems have several output voltages which need to be monitored. This is easily done with the SG1543 because of the capability for remote activation and the availability of the reference voltage for use with external circuitry. A quad comparator like the SG139 which also has open collector outputs can be used to monitor several additional output voltages. As shown in Figure 16, the SG1543 is used to provide both over and under-voltage protection on a main positive supply. The additional comparators within the SG139 which also has open collector outputs can be used to monitor either positive or negative supply voltages depending on whether one uses the 2.5V signal or ground as the reference potential. The output comparators of each collector are tied together to the remote activation terminal such that the operation of any single comparator in either the SG1543 or the SG139 will activate the SCR trigger shutdown circuit. Note that grounding the remote activation terminal also provides an output on the over-voltage indicating circuit; therefore, this output on pin 4 can be used as a master power supply-condition indicator which will provide a low signal if any output voltage that is being monitored is outside its allowable tolerance.

## UNDER-VOLTAGE SENSING

In addition to normal low-output voltage monitoring, the under-voltage sensing circuit has considerable possibilities in monitoring the input voltage to a power supply system. For example, in Figure 17, this circuit is used to measure the input DC voltage to an SG723 regulator and keep the output completely off whenever the input is lower than the minimum required for satisfactory operation of the SG723. The same protective feature when applied to a switch-mode regulator, is even more important since it keeps the switching transistors off until the oscillator stabilizes.

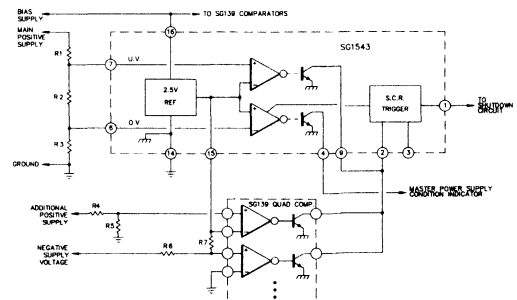


Figure 16. Sensing Multiple Supply Voltages. Addition of a simple quad comparator allows multiple voltage sensing of positive or negative levels.

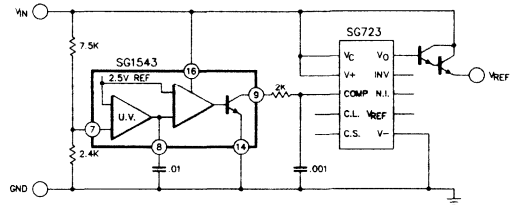


Figure 17. Under Voltage Shutdown. In addition to output monitoring, the under-voltage circuit can be used to inhibit the output if the input voltage is too low for satisfactory performance.

As shown in figure 18, the under-voltage circuit can be used to monitor the AC input voltage to a power supply. An isolation transformer and rectifier are used to provide a rectified AC signal to the input of the under-voltage comparator. The signal is compared with the 2.50V reference, activating the first stage of the comparator with each transition toward zero. With proper selection of the delay capacitor, no output is provided unless some number of input pulses are missing at which time the first comparator allows the charging of the capacitor to 2.50 volts

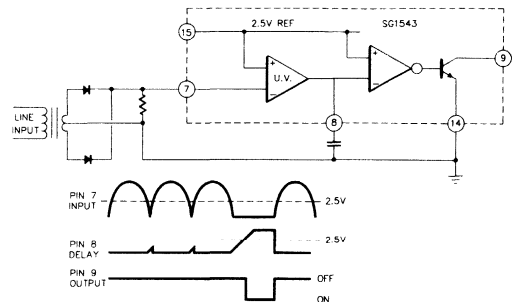


Figure 18. SG1543 Input Line Monitor The under-voltage sensing circuit can also be used to monitor the AC input voltage and provide a power failure signal before the power supply output voltage begins to fall.

## APPLICATION NOTES – SG1542/SG1543/SG1544/SG3523

which activates the output circuit. In this way, the under-voltage circuit provides an immediate indication of failure, even for one or two cycles. This provides an early warning indication that the power supply output voltage is going to drop while taking advantage of the holdup capability provided by normal electrolytic capacitor storage within the power supply system.

Like other parts of the SG1543, the under-voltage circuit is not limited to its primary function. Figure 19 demonstrates its use as an over-temperature indicator by using the well-defined temperature coefficient of a Darlington transistor's  $V_{BE}$  as a sensor. Divider  $R_1$ - $R_2$  establishes a fixed threshold equal to the 2N2723's  $V_{BE}$  at the desired temperature limit. Below that limit, the transistor is off and  $R_C$  back-biases the input to the U.V. sensor. Many other transistors could be used; however, the small case of the 2N2723 makes good thermal coupling relatively easy.

By providing all of these diagnostic and protective features within one integrated circuit, a new class of control device has been generated to provide overall performance monitoring and control of sophisticated power supply systems. Thus, the SG1543 further enhances the inventory of building block components available to the power supply system designer providing new options in implementing increased performance at lower cost.

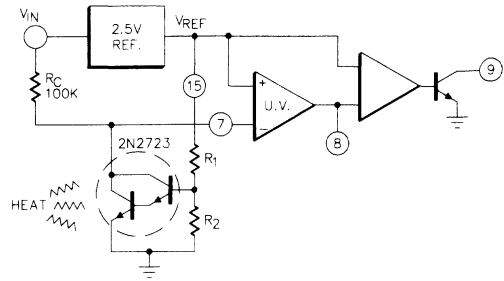


Figure 19. Over-Temperature Indication. Another use of the under-voltage circuit is to provide an over-temperature indication using the  $-4\text{mV}/^\circ\text{C}$   $V_{BE}$  tempco of the 2N2723 as a sensor.

## A CONCEPTUALLY NEW QUAD POWER FAULT MONITOR CIRCUIT

by Stan Dendinger  
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### ABSTRACT

A comprehensive fault monitoring system in a single 16-pin IC is described. The new circuit provides overvoltage and undervoltage supervision of four DC power supplies simultaneously. In addition a uniquely flexible pin-out permits AC line voltage monitoring, real-time line clock generation, or programmable switching supply undervoltage lockout protection. All fault thresholds are adjustable to a high degree of accuracy using a minimum of external passive components. A number of typical application examples are given to clarify the concepts discussed.

### INTRODUCTION

As the complexity of modern electronic systems grows, the number of supply voltages necessary to support the circuitry has also increased. Even the simplest home computer typically requires +5 volts for the logic,  $\pm 12$  or  $\pm 15$  volts for the analog circuits, and perhaps +24 or +28 volts for the printer or disk drive. The task of supervising these multiple voltages for proper tolerance has traditionally required a substantial number of precision components: a voltage reference, resistors, timing capacitors, op amps, comparators, and logic gates. An addi-

tional penalty was paid in board space consumption. Consequently, in an attempt to shave costs, the supervisory function was often eliminated entirely. While this action resulted in meeting budget for the supply, the money saved was often given out again many times over when a system malfunction occurred in the field and a service engineer had to tediously check each supply voltage.

The availability of a new integrated circuit which can monitor four DC supplies and the AC line simultaneously now allows the power systems designer to implement fault monitoring at lower cost and with much reduced board space. This new device utilizes the strengths of monolithic linear technology to create precisely-matched components at high density on a silicon chip. Called the SG1548 Quad Power Fault Monitor, its functional block diagram is shown in Figure 1.

### FUNCTIONAL DESCRIPTION

The circuit consists of a precision reference regulator, a fault window generator, analog OR and AND circuitry for selecting most positive and most negative voltages, threshold comparators, delay logic, open-collector output drivers, an inverting amplifier, and a multipurpose line sense comparator with uncommitted collector and emitter outputs.

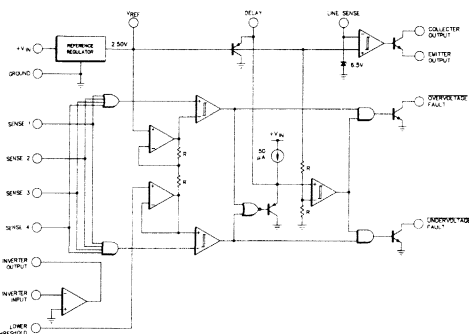


Figure 1. Block Diagram of the SG1548 Quad Power Fault Monitor

The most positive voltage at the four Sense inputs is compared with the upper or overvoltage threshold, and the most negative input is routed to the undervoltage comparator. The comparator outputs are connected to their respective output drivers and two AND logic gates. The drivers are inhibited by the delay logic, which requires that either an overvoltage fault or undervoltage fault persists for a pre-set time interval. A single capacitor at the Delay pin sets the time interval, which is  $C \times 2.5 \times 10^4$  seconds. If a negative voltage must be monitored, it can be mirrored into a positive voltage using the inverter amplifier. Special clamp circuitry inside the SG1548 prevents the amplifier from locking up if Pin 15 is pulled below ground. Now let's look at the operation of each subset in detail.

## VOLTAGE REFERENCE

The reference circuit is a low-drift bandgap design which generates a precise +2.50 volts  $\pm 1\%$  at Pin 3. It is fully functional at input voltages as low as +4.5 volts, and provides up to 10mA of output current. Special  $\beta$ -compensation circuitry provides immunity to process variations and achieves typical 1mV line and 3mV load regulation. Internal current limiting protects the IC against accidental shorts to ground.

## FAULT WINDOW GENERATOR

The fault window generator is the heart of the Quad Power Fault Monitor. This section generates an upper overvoltage and lower undervoltage threshold centered about the +2.5 reference. A precision tracking regulator utilizing two operational amplifiers and a pair of ratioed resistors produce the tracking action, as shown in Figure 2.

An external voltage derived from the reference is applied to Pin 1. This voltage represents the lower boundary of the tolerance window. Op amp A1 is connected as a unity-gain buffer, providing a low input bias current and a low impedance output for driving the remaining circuitry. The transfer function through A1 is simply:

$$V_{\text{LOWER}} = V_{\text{REF}} - \Delta V \pm V_{\text{OS1}} \quad [1]$$

where  $V_{\text{OS1}}$  is the input offset voltage of A1, and  $\Delta V$  is some small

percentage of  $V_{\text{REF}}$ . Op amp A2 is connected as an inverter working at a common mode voltage equal to  $V_{\text{REF}}$ . Its transfer function is given by:

$$V_{\text{UPPER}} = \frac{R_2}{R_1} \{ \Delta V \pm V_{\text{OS1}} \pm V_{\text{OS2}} \} + V_{\text{REF}} \pm V_{\text{OS2}} \quad [2]$$

where  $V_{\text{OS2}}$  is the input offset voltage of A2, and bias current errors are assumed to be very small.

If  $\frac{R_2}{R_1}$  is nearly 1, then

$$V_{\text{UPPER}} = V_{\text{REF}} + \Delta V \pm V_{\text{OS1}} \pm 2V_{\text{OS2}} \quad [3]$$

Since  $R_1 = R_2 = 2K$  and the resistor match very well over the temperature, then the above assumptions about bias current error and resistor ratio are correct. Therefore the limit as to how small  $\Delta V$  can be is approximately 3 times the offset voltage, neglecting comparator offsets. If a worst case value of 8mV is assumed, the smallest value of  $\Delta V$  is 24mV, corresponding to a fault tolerance of  $\pm 1\%$ . Since this is the same order as the initial accuracy of the reference,  $\pm 2\%$  is recommended as the tightest setting for the tolerance window.

## DUAL CHANNEL DELAY WITH A SINGLE CAPACITOR

In supervisory circuits, delay is frequently required to reject false fault reports which could result from switching supply spikes or transients due to step load changes. The delay circuit in the SG1548 requires only one capacitor to implement the delay function for both the overvoltage and undervoltage channels.

The circuit depends on two factors for low false alarm rates:

1. Reports due to noise are of short duration compared to the program delay.
2. Noise causing false threshold crossings in each channel is essentially uncorrelated.

When all four voltages at the Sense pins fall within the set fault tolerance band, the output of each fault comparator is LOW. The

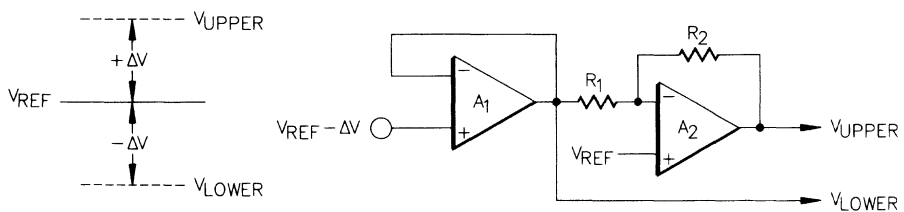


Figure 2. Generating a Precision Fault Tolerance Window

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output of the 2-input NOR gate is HIGH, turning on the discharge transistor Q1. The Delay pin is held at ground. This is below the +1.25 volt trip threshold of the delay comparator, resulting in a LOW logic level to each of the output AND gates. Since both inputs must be HIGH to turn on the output drivers, no fault indication is possible.

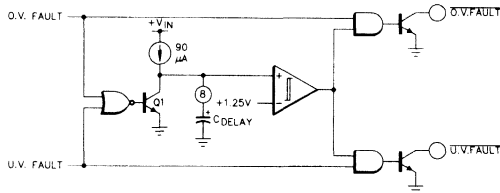


Figure 3. False Alarm Rejection Using a Single Capacitor

When one of the sensed voltages crosses a fault threshold, the fault comparator switches HIGH, turning off Q1. The delay pin voltage rises linearly from 0 volts as the 50μA current source charges the delay capacitor. If the fault condition persists long enough, the capacitor will charge to +1.25 volts, tripping the delay comparator, which has hysteresis to eliminate jitter due to the slow ramp. The HIGH output level from the comparator enables both output drivers, permitting an overvoltage and/or undervoltage indication as appropriate.

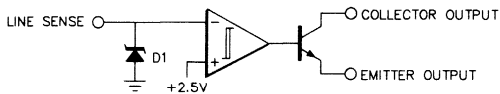


Figure 4. Block Diagram of the AC Line Sense Circuit

## AC LINE SENSE COMPARATOR

The line Sense section of the SG1548 is a high-gain comparator with 25mV of hysteresis referenced to the precision +2.5 volt threshold voltage. The output transistor is rated at 40 volts and 10mA, and has uncommitted collector and emitter connections for either inverting or non-inverting operation. A unique clamp diode structure (D1) on the input adds to the versatility of this section, since it is specified for both forward and reverse conduction at 1mA. (Most junction-isolated integrated circuits can behave strangely or self-destruct if any pin is driven negative with respect to the substrate. The AC Line Sense pin was specifically designed to operate in this mode, thereby eliminating the need for an external clamp diode).

## ON-CHIP INVERTING AMPLIFIER

The operational amplifier provided for converting a negative

voltage to a positive one is optimized for inverter operation with the summing node at ground. The amplifier has a minimum open loop gain of 72dB, and is internally compensated for unity gain stability.

Like the AC line Sense input pin, the Inverting Input pin can be pulled below ground by nature of the external circuitry. To prevent the possibility of latch-up under these conditions, clamp circuitry as illustrated in Figure 5 exists at the pin. These protective components clamp negative excursions to  $-0.5V_{BE}$  or approximately -0.3 volts at +25°C. This prevents the substrate diode from conducting and activating any parasitic SCRs in the IC. An additional diode limits the maximum positive input voltage to  $1V_{BE}$  to eliminate the possibility of latch up in the direction.

Input offset characteristics are further improved with a special Kelvin grounding scheme for the non-inverting input. Separate bounding pads exist at the periphery of the chip for power ground and the op amp input. The bond wires become common only at the IC package pin itself, eliminating the errors due to ground drops in the circuit metalization.

A performance factor called "inversion error" can be defined from the amplifier's electrical parameters which quantizes the total deviation from ideal inversion. It includes the effects of input offset voltage, input bias current, input offset current, and finite open-loop voltage gain. For unity-gain operation with perfect 10K/10K gain setting resistors, the maximum inversion error for the SG1548 is 26.5mV or 1.06% referred to the +2.5 volts fault window center. In most applications the error will be less. For example, if -15 volts is converted to +2.5 volts, the closed loop gain will be -1/6. The output stage can source at least 5mA, so 6K/1K gain resistors can be used. With these values the maximum inversion error falls to 13.5mV or 0.5%. The actual resistor tolerances will, of course, degrade this further.

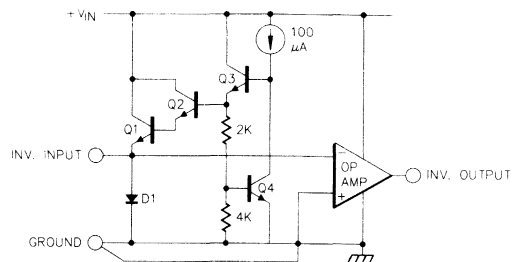


Figure 5. Protective Circuitry at the Inverter Input Terminals

## SETTING THE FAULT TOLERANCE

The fault tolerance window is set by applying a voltage slightly less than the +2.50 volt reference to the Lower Threshold pin. In

the example shown in Figure 6, a  $\pm 2\%$  window is programmed with the divider network formed by  $R_A$  and  $R_B$ . The maximum input bias current at Pin 1 is  $1.0\mu\text{A}$ , so the divider current is chosen to be three orders of magnitude greater to minimize threshold shifts. With the resistor values shown,  $+2.450$  volts is applied to Pin 1, setting up nominal  $\pm 50\text{mV}$  threshold values about the  $+2.500$  reference. Resistors should be of the same type so that temperature coefficients will track, maintaining a constant divider ratio. The allowable voltage range on the adjustment pin is  $+2.45$  volts to  $+1.50$  volts, corresponding to  $\pm 2\%$  and  $\pm 40\%$  fault tolerance bands.

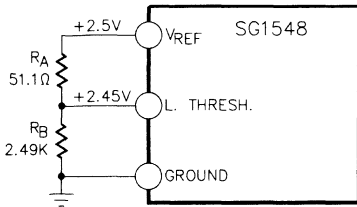


Figure 6. Programming the Fault Tolerance Window

## IMPLEMENTING MULTIPLE TOLERANCES

In actual practice, some power supply tolerances may be more critical than others. For example, most  $+5$  volt logic can withstand  $\pm 10\%$  variations without malfunction, whereas the analog circuitry might require  $\pm 5\%$  accuracy. Multiple tolerances can easily be obtained with the SG1548 using the technique shown in Figure 7.

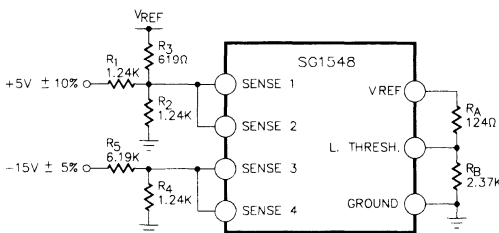


Figure 7. Implementing Multiple Tolerances

The Quad Power Fault Monitor is first programmed for the tightest tolerance required. In this case the  $+15$  volt supply must be held within  $\pm 5\%$  of its nominal value, so  $R_A$  and  $R_B$  are chosen such that  $\pm 125\text{mV}$  window edges are set at Pin 1, and pin 13 is set at  $2.5\text{v}$  by  $R_4$  and  $R_5$  divider network. Next, the required tolerance of  $\pm 10\%$  for the  $+5\text{v}$  input is set by adding a resistor  $R_3$  from the sense pin to the  $2.5\text{v}$  reference. In this section a set of formulas are derived to calculate  $R_1$ ,  $R_2$ , and  $R_3$  considering the effect of the sink current capability of the reference voltage.

- Given:
1. Nominal Input Voltage -  $V_{\text{NOM}}$
  2. A programmed window tolerance -  $X\%$
  3. A desired fault tolerance -  $Y\%$

1. Calculate:  $P = (V_{\text{NOM}} - 2.5)/2.5$

2. Choose  $R_2$  such that:

$$R_2 \geq (5) (Y-X) \left( \frac{P+1}{P} \right)$$

3. Calculate  $R_1$  and  $R_3$  by:

$$R_1 = PR_2$$

$$R_3 = \left( \frac{X}{Y-X} \right) \left( \frac{PR_2}{P+1} \right)$$

4. Calculate reference sink current:

$$I_{\text{SINK}} = \frac{(2.5)(X)}{R_3}$$

$I_{\text{SINK}}$  calculated should be less than  $500\mu\text{A}$ .

5. Check your calculation by calculating fault tolerance  $Y$ :

$$Y = \left( 1 + \frac{R_1/R_3}{1+R_1/R_2} \right) (X) \quad [\%]$$

This value should be very close to your desired value of  $Y$ .

### EXAMPLE:

- Given:
1.  $V_{\text{NOM}} = 5\text{V}$
  2.  $X = 5\%$
  3.  $Y = 10\%$

1. Calculate  $P$ :

$$P = \frac{5-2.5}{2.5} = 1$$

2. Choose  $R_2$ :

$$R_2 \geq (5) \left( \frac{10-5}{100} \right) (2) = .50 \text{ K}\Omega$$

Choose  $R_2 = 1.24\text{K}$

3. Calculate  $R_1$  and  $R_3$ :

$$R_1 = R_2 = 1.24\text{K}$$

$$R_3 = \left( \frac{5}{10-5} \right) \left( \frac{1.24}{2} \right) = 620 \Omega$$

Choose  $R_3 = 619\Omega$

4. Calculate reference sink current:

$$I_{\text{SINK}} = \frac{(2.5 \times .05)}{619} = 202 \mu\text{A}$$

5. Check Calculation:

$$Y = \left( 1 + \frac{1.24/619}{1 + 1.24/1.24} \right) (5) = 10.008\%$$

## INVERTING A NEGATIVE SUPPLY

Conversion of a negative source to  $+2.50$  volts is straightforward, as shown in Figure 8. The op amp is operated at a closed loop gain less than unity. However, since the amplifier is internally compensated for unity gain, it is possible to monitor



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voltages less than 2.5 volts (gain greater than unity) without additional components for stability.

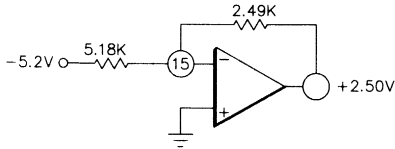


FIGURE 8. Inverting and Scaling a Negative Voltage

## DETERMINING FAULT DELAY

Fault delay as a function of delay capacitor on Pin 8 is given by the graph in Figure 9. The line reflects the time required to charge a given capacitor to +1.25 volts with a nominal 50 $\mu$ A current source. Delays beyond several hundred milliseconds can be obtained, but for capacitor values beyond 5 $\mu$ F, the surge limiting circuit shown in Figure 10 is recommended. The 100ohm resistor limits the peak discharge current into the SG1548, while the external PNP transistor provides a high peak-current discharge path for the delay capacitor.

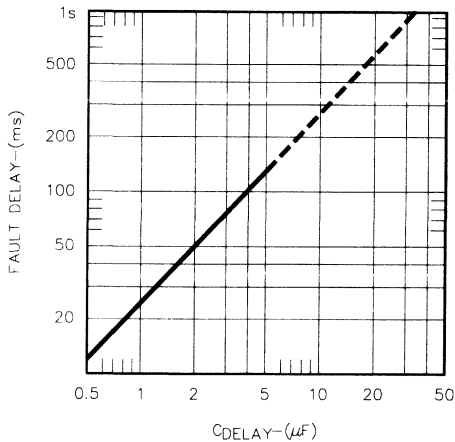


FIGURE 9. Graph of Fault Delay vs. Delay Capacitor

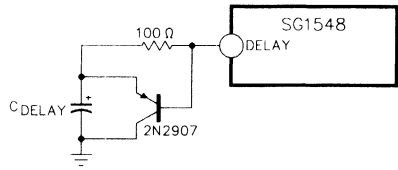
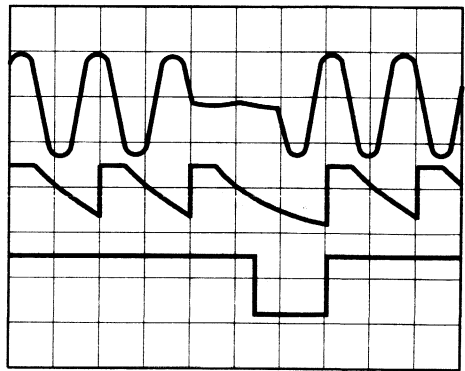


FIGURE 10. Suge Limit Circuit for Large Delay Capacitors

## MONITORING THE AC LINE

Single-cycle AC line dropouts can be detected with the circuit shown in Figure 11. A positive half cycle is clipped to a precise level using the internal Zener and a 3K source resistor. The discharge circuit consisting of 180K and the 0.1 $\mu$ F capacitor control the voltage decay so that the +2.5 volt trip point is not reached with normal sinusoidal line conditions. A single-cycle dropout will provide an extra 16.7 milliseconds discharge time, as shown in Figure 12, causing the Line Fault output to switch LOW.



HORIZONTAL: 10mSEC/DIV.  
UPPER TRACE: AC LINE  
MIDDLE TRACE: PIN 5 AT 5V/DIV.  
LOWER TRACE: LINE SENSE OUTPUT AT 5V/DIV.

FIGURE 12. Response to a Single-Cycle Line Dropout

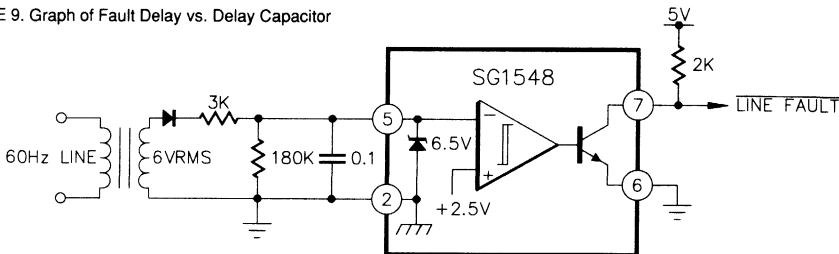


FIGURE 11. Monitoring the AC Line for Single-Cycle Dropout

## LINE CLOCK GENERATION

A logic clock derived from the line frequency can be obtained with a minimal number of components, as illustrated in Figure 13. The internal clamp diode is used in both forward and reverse conduction modes, with the 10K input resistor limiting peak input current to less than 1mA. Waveforms obtained with this circuit are shown in Figure 14.

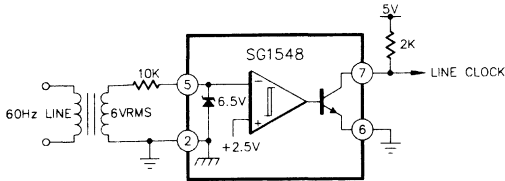
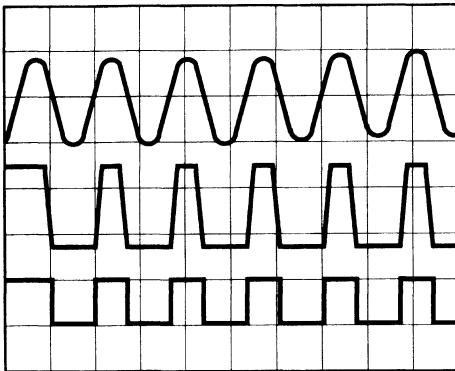


FIGURE 13. Generating an AC Line Clock



HORIZONTAL: 10mSEC/DIV.  
UPPER TRACE: AC LINE  
MIDDLE TRACE: PIN 5 AT 5V/DIV.  
LOWER TRACE: LINE SENSE OUTPUT AT 5V/DIV.

FIGURE 14. Waveforms Produced by the Line Clock

## UNDERVOLTAGE LOCKOUT

Figure 15A and B shows two methods of using the Line Sense comparator for inhibiting power supply start-up until some minimum supply voltage has been reached. In the first case a HIGH-going shutdown signal to the PWM control is generated until  $V_{IN}$  causes the voltage at Pin 5 to exceed +2.5 volts. If the PWM is on the primary side of the power transformer, the Line Sense Output can directly drive an optocoupler. In the second case the line sense comparator is used to gate a bias supply ON when the proper working voltage has been reached.

## EXPANDING THE QUAD POWER FAULT MONITOR

The SG1548 is readily expandable to include additional positive and negative supplies. One half of an inexpensive quad comparator IC is required for each supply, as shown in Figure 16.

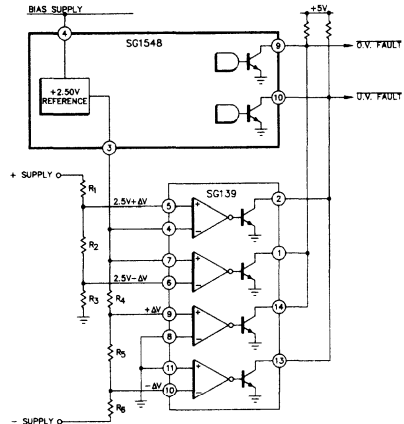


FIGURE 16. Expanding the SG1548 to Monitor Additional Supplies

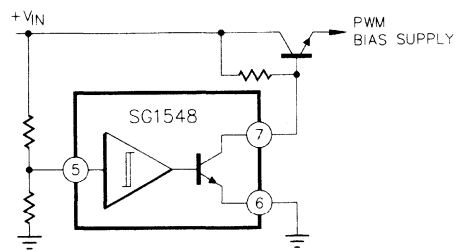
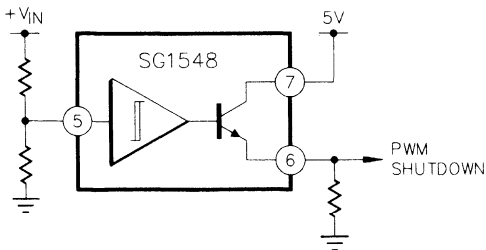


FIGURE 15A & 15B. Using the Line Sense for Undervoltage Lockout

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For an additional positive supply, the comparators are referenced to the +2.5 volt regulator of the SG1548. The monitored supply is divided down by resistors R1 through R3. When the supply drops a given percent, the upper comparator switches LOW. Since the fault outputs of the SG1548 are active LOW, the indication from the quad comparator can be wire-ORed to the undervoltage fault output line. Similarly, if the supply voltage increases beyond a preset limit, the overvoltage fault line will be pulled LOW by the second comparator.

The negative supply is handled similarly, except that the comparators are referenced to ground, and the resistive divider R4 through R6 is returned to the +2.5 volt reference. The 139 quad comparator will work correctly as long as the inputs are not pulled below -0.3 volts. If this possibility exists, a Schottky clamp diode should be used at Pin 10 to preserve the overvoltage indication in case of a massive negative overdrive at the divider input.

## A COMPREHENSIVE EXAMPLE

Each section of the SG1548 Quad Power Fault Monitor has been described in detail. Now it is time to put all the pieces together and show power supply supervision in an actual system. For our example we will use the hypothetical personal computer mentioned at the beginning of this paper. Figure 17 shows all the components required.

In this case, four DC voltages are monitored: three positive and one negative. Three different fault tolerances are mechanized, and the AC line is checked for single-cycle dropout.

The  $\pm 15$  volt supplies are the most critical, requiring  $\pm 5\%$  accuracy. The 124ohm/2.37K divider from the reference sets this tolerance in the fault window generator. The -15 volt supply is converted to +2.50 volts with the inversion amplifier on the chip and applied to one of the Sense inputs. The +5 and +24 volt supplies are not as critical, requiring  $\pm 10\%$  and  $\pm 20\%$  respectively. Divider resistors to the reference are used to scale the effective windows accordingly. The single 5 $\mu$ F capacitor provides 125 milliseconds of delay before an out-of-tolerance fault is reported.

All this is accomplished with one 16-pin integrated circuit and 14 resistors, 2 capacitors, a low-current diode, and a line isolation transformer, which can be part of the bias supply.

## CONCLUSION

The opportunity to realize comprehensive power supply fault monitoring with low component count is a reality with the introduction of the SG1548 Quad Power Fault Monitor. A combination of flexible architecture combined with innovative circuit design techniques has resulted in a supervisory function with excellent accuracy and repeatability over the full military temperature range of -55°C to +125°C.

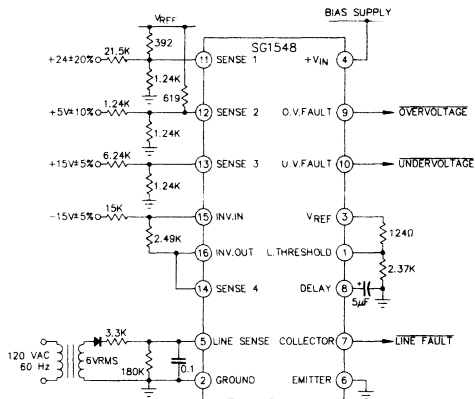


FIGURE 17. Monitoring Four DC Supplies and the AC Line

## APPENDIX - A

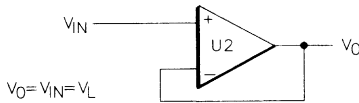
Derivation of over voltage trip in terms of  $R_1, R_2, R_3, R_4, R_5$   
Looking at Figure 1:

Lower Threshold voltage is calculated by:

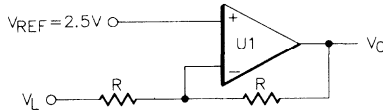
$$V_L = \frac{R_B}{R_B + R_A} V_{REF} = V_{REF} - \Delta V \quad (1)$$

$$\text{where } \Delta V = \frac{R_A}{R_A + R_B} V_{REF} \quad (2)$$

Op-amp (U2) is configured as a unity gain follower, therefore:



UPPER THRESHOLD IS CALCULATED AS:



$$V_O = \left(1 + \frac{R}{R}\right) V_{REF} - \frac{R}{R} V_L = 2V_{REF} - V_L$$

But  $V_L$  was calculated to be:

$$V_L = V_{REF} - \Delta V \quad (2-a)$$

$$V_O = 2V_{REF} - (V_{REF} - \Delta V) = V_{REF} + \Delta V$$

We will call the output of U1 op-amp upper threshold UMIT and designate it by  $V_U$ , so:

$$V_U = V_{REF} + \Delta V \quad (3)$$

Next we will analyze the circuitry associate with O.V sensing circuit. We also assume, it is required to have higher threshold voltage setting than the one being programmed by  $R_4, R_5$  divider.

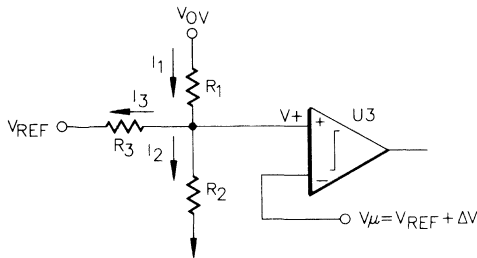


Figure 2

From the schematic of figure 2, we have:

$$V_T = V_U = V_{REF} + \Delta V$$

and writing K.C.L. for  $V_T$  node, we get:

$$I_1 = I_2 + I_3$$

$$\frac{V_{OV} - V_T}{R_1} = \frac{V_T}{R_2} + \frac{V_T - V_{REF}}{R_3}$$

$$\text{or: } V_{OV} = \left(1 + \frac{R_1}{R_2}\right)(V_{REF} + \Delta V) + \frac{R_1}{R_3} \Delta V \quad (4)$$

$$\text{where } \Delta V = \frac{R_A}{R_A + R_B} V_{REF}$$

Equation (4) can only hold if the following is true:

$$(4-a) \quad I_2 \gg I_{BIAS} \quad \text{where: } I_{BIAS} \text{ is the bias current of } U_3 \text{ comparator}$$

and

$$(4-b) \quad I_3 < I_{SINK\ MAX} \quad \text{where: } I_{SINK\ MAX} \text{ is the maximum sink current capability of the reference voltage.}$$

Derivation of equation for  $R_3$ :

Assumption:

$V_{OV1} \cong 0.V$  trip point set by  $R_4, R_5$  (lower threshold)

$V_{OV2} \cong 0.V$  trip point desired ( $V_{OV2} > V_{OV1}$ )

$x \cong$  percent voltage above nominal for  $V_{OV1}$

$y \cong$  percent voltage above nominal for  $V_{OV2}$

From the definitions of  $x$  and  $y$  we get:

$$\left. \begin{array}{l} ] \\ ] \end{array} \right\} V_{OV1} = (x + 1) V_{NOM} \quad (7)$$

$$\left. \begin{array}{l} ] \\ ] \end{array} \right\} V_{OV2} = (y + 1) V_{NOM} \quad (8)$$

We also know that:

$$V_{OV1} = (V_{REF} + \Delta V) \left(1 + \frac{R_1}{R_2}\right) \quad (9)$$

and from equation (4)

$$V_{OV2} = (V_{REF} + \Delta V) \left(1 + \frac{R_1}{R_2}\right) + \frac{R_1}{R_3} \Delta V \quad (10)$$

Replacing (7) and (8) into (9) and (10) and subtracting (9) from (10) we get:

$$(y - x) V_{NOM} = \frac{R_1}{R_3} \Delta V \quad (11)$$

or

$$R_3 = \frac{R_1 R_2}{R_1 + R_2} \times \frac{1}{y - x} \times \frac{\Delta V}{V_{REF}} \quad (12)$$

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We also know that the relation between  $V_L$  and  $V_{REF}$  is:

$$V_L = (1 - x) V_{REF} \quad (13)$$

Since  $V_L$  is  $x$  percentage lower than  $V_{REF}$  by  $R_3$ ,  $R_4$  divider, putting (13) into equation (2-a) we get:

$$\Delta V = x V_{REF} \quad (14)$$

Replacing (14) into (12) we get the result:

$$R_3 = \left( \frac{R_1 R_2}{R_1 + R_2} \right) \left( \frac{x}{y - x} \right) \quad (15)$$

Deriving a set of formulas for  $R_1$ ,  $R_2$ ,  $R_3$  calculation:

From the inequality of 4-b we get:

$$R_3 > \frac{\Delta V}{10^{-3}} = \Delta V \text{ (KR)} \quad (16)$$

$I_{BIAS}$  maximum for 1548 comparator is 1mA.

we know that:

$$V_{NOM} = \frac{R_2}{R_1 + R_2} \quad (16-a)$$

$$R_1 = \left( \frac{V_{NOM} - V_{REF}}{V_{REF}} \right) R_2 = P R_2 \quad (17)$$

$$\text{if } P \equiv \frac{V_{NOM} - V_{REF}}{V_{REF}}$$

From equation (15), (16) and (17) we get:

$$\left( \frac{x}{y - x} \right) \left( \frac{P R_2}{P + 1} \right) > \Delta V$$

$$\text{or } R_2 > (\Delta V) \left( \frac{P + 1}{P} \right) \left( \frac{y - x}{x} \right) \text{ where } R_2 \text{ [KR]} \quad (18)$$

From equation (14) we have:

$$\Delta V = x V_{REF}$$

and replacing  $V_{REF}$  by 2.5 in equation 18) we get:

$$R_2 > (2.5)(y - x) \left( \frac{P + 1}{P} \right) \quad (19)$$

Using equations (17), (19) and (15) we can calculate  $R_1$ ,  $R_2$ , and  $R_3$  values.

To calculate the reference sink current we use:

$$I_{SINK} = \frac{\Delta V}{R_3} = \frac{x V_{REF}}{R_3} = \frac{2.5x}{R_3}$$

To derive the equation for checking we start by equation (4):

$$V_{OV} = (V_{REF} + \Delta V) \left( 1 + \frac{R_1}{R_2} \right) + \frac{R_1}{R_3} \Delta V$$

or

$$V_{OV} = V_{REF} \left( 1 + \frac{R_1}{R_2} \right) + \Delta V \left( 1 + \frac{R_1}{R_2} + \frac{R_1}{R_3} \right) \quad (20)$$

putting equation (8) in (20) we get:

$$V_{NOM} + y V_{NOM} = V_{REF} \left( 1 + \frac{R_1}{R_2} \right) + \Delta V \left( 1 + \frac{R_1}{R_2} + \frac{R_1}{R_3} \right) \quad (21)$$

Replacing 16-a) into (21) we get :

$$y = \frac{\Delta V}{V_{NOM}} \left( 1 + \frac{R_1}{R_2} + \frac{R_1}{R_3} \right) \quad (22)$$

Replacing (14) and (16-a) into (22) we get:

$$y = \frac{x}{\left( 1 + \frac{R_1}{R_2} \right)} \left( 1 + \frac{R_1}{R_2} + \frac{R_1}{R_3} \right)$$

or

$$y = \left( 1 + \frac{\frac{R_1}{R_3}}{1 + \frac{R_1}{R_2}} \right) x$$



## **PROTECT YOUR SWITCHERS WITH DIGITAL CURRENT LIMITING**

*A New Current Sense Latch IC Provides Pulse-by-Pulse Current Control*

Stan Dendinger  
Manager, Advanced Product Development  
Silicon General, Inc.

### **INTRODUCTION**

Another new class of integrated circuits, designed specifically to ease the plight of the switch-mode power supply designer, has just been established with the introduction of the SG1549 Current Sense Latch IC. Although there have been many IC products developed over the past few years to provide simple methods of voltage control for switching supplies, the SG1549 is the first to specifically address and take a fresh approach to the problem of current control. Almost all existing PWM chips have included some type of circuit for current limiting, but these have all used the same techniques as linear regulators; that is, a current sense amplifier generates an error signal linearly proportional to load current which, after reaching an established threshold, takes command away from a voltage control amplifier. Thus, upon overload, the power supply switches from a voltage feedback loop to a separate current feedback path. Each loop must be stabilized separately and, because of the output filter, stable performance along with a reaction fast enough to protect the high-speed switching transistors is difficult to achieve. What is needed for optimum protection is a circuit which operates at the switching frequency and immediately turns off the main current-carrying switching transistors upon current overload. Turn-off must be rapid, without allowing the transistors any appreciable time in their linear operating region, and with no oscillation or multiple-pulsing.

### **A DIGITAL CURRENT LIMITER**

The optimum approach to switch-mode current limiting is to treat each on-cycle as a separate problem. That is, pulse-by-pulse current limiting. This is implemented by a device-monitoring current build-up each time the power supply's switching transistor conducts and, upon sensing an overcurrent condition, immediately turning the transistor off and holding it off for the duration of that normally on period. Such a circuit must have a latch, as once turn-off is achieved, the removal of the overcurrent signal

would otherwise allow the transistor to return to conduction. Including a latch means a provision for reset must also be provided.

All of this and more is offered by the SG1549 Current Sense Latch IC. From the block diagram of this device, it can be seen that the circuit includes a comparator with positive feedback, a means for establishing an input threshold of 100mV, a reset circuit, complementary outputs, and a high voltage level-shifting circuit. This device is designed to be completely compatible with many commonly-used Regulating PWM control IC's such as the SG1524, MC3420, and the TL494. Requiring only 2mA of supply current, the entire circuit can be operated from the reference voltage available with these chips, with reset accomplished by their clock output signals.

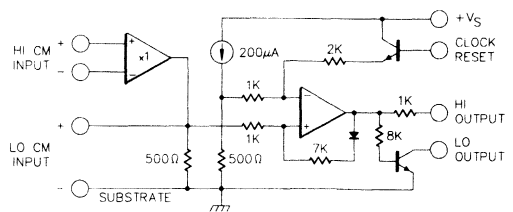


Figure 1. The SG1549 Current Sense Latch IC contains provision for sensing a current threshold over a wide voltage range. Complementary outputs and a latch with reset are also a part of this new protection circuit.

Although obviously designed for use with switch-mode power supplies, the SG1549 has broader application as a general purpose, low-threshold latch. A clock signal is not the only way to provide reset; that function may also be accomplished by any operation which will momentarily pull the reset pin high.

## CIRCUIT OPERATION

For a detailed understanding of the operation of this device, refer to the schematic of Figure 2. With a +5 volt supply, a threshold reference is established by a current through R3. This current is mirrored by Q7 to provide a constant 200 $\mu$ A through R11, thereby holding one input to the comparator at 100mV above ground. That same current is mirrored through Q4 to the floating threshold circuit of Q1-Q3, D1, and R1. This portion of the circuit will convert a differential voltage between pins 1 and 2 into an identical voltage across R2. It will do this accurately while allowing the absolute voltage on pins 1 and 2 to range from 2 to 40 volts with respect to ground.

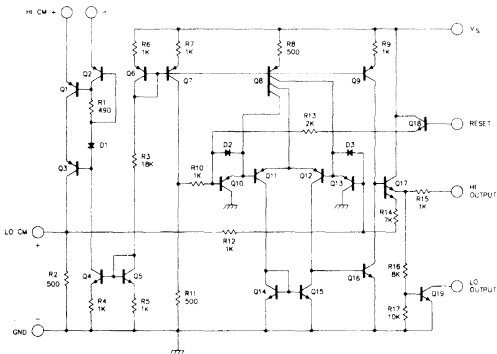


Figure 2. The heart of the SG1549 is a high-speed comparator together with an input threshold level-shifting circuit.

Since the other input to the comparator is tied to pin 3, it can be seen that the comparator will switch when the voltage on pin 3 rises to 100mV, regardless of whether that voltage is applied to pin 3 directly or differentially between pins 1 and 2.

Once the comparator switches, positive feedback provided by Q17 and R14 will hold it latched until a reset signal, effected by raising pin 7 above 2 volts, momentarily increases the threshold returning the circuit to its initial state.

Transistor Q17 also provides two outputs: a high-going signal on pin 6 which can source 2mA and a open-collector saturating transistor on pin 5 which can sink more than 10mA. With complementary outputs, a variety of shutdown options are offered. Typical delay times for the SG1549 are 180nSec from the LO CM input and 300nSec from HI CM to the outputs.

## HIGH LINE SENSING

A very straightforward application of the SG1549 is its use for current sensing in the input line. This switching regulator is shown in Figure 3. The switching regulator is shown imple-

mented with the SG1524 PWM control IC and it can be seen that interfacing between these two chips couldn't be easier. The value for R<sub>SC</sub> is determined by dividing the 100mV input threshold by the peak current desired. High frequency noise, or switching transients can usually be eliminated by a small capacitor between pins 3 and 4.

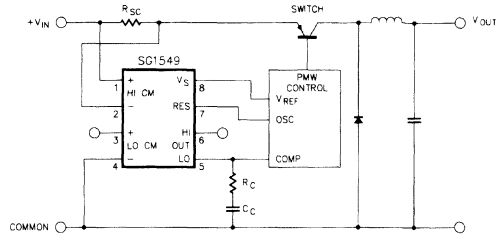


Figure 3. Using the SG1549 to sense input current to a simple buck converter and interface directly to a PWM control IC such as the SG1524.

The current shutdown command can be coupled into the SG1524 by either connecting the HI-OUT, pin 6 to the SG1524's shutdown pin or, as shown here, using the LO-OUT pin to pull the compensation terminal low. In either case, activation of the current sense latch will tend to discharge the compensation capacitor, C<sub>c</sub> which may cause slow recovery from pulse limiting. Keeping the value of C<sub>c</sub> as small as possible within the requirements of voltage loop stability will minimize this effect; however, slow turn-on from current limit is often desirable and can be optimized by using the LO-OUT signal to discharge a soft-start network instead of coupling directly into the SG1524.

Where minimizing turn-off delay is important, the command from the SG1549 may be taken directly to the output stage of a switching regulator. A practical means of accomplishing this is shown in Figure 4 where the power switch consists of an SM625 15-amp hybrid circuit containing both the power switch and the commutating diode. This switch is driven by using the SG1524 to switch a constant current source formed by the 2N2222 transistor connected with its base to the 5 volt V<sub>REF</sub> line through a 1k resistor. By connecting the LO-OUT terminal of the SG1549 to the base of the 2N2222, drive current to the output stage can be interrupted without the delays inherent in the SG1524.

## LOW LINE SENSING

In many types of feed-forward or push-pull converters, current protection may be provided by sensing through an emitter resistor referenced to ground on the primary side of an output









LINEAR INTEGRATED CIRCUITS

### **MINIMIZING THE COST AND COMPLEXITY OF START-UP CIRCUITS FOR SWITCHING POWER SUPPLIES**

Reza Amirani  
Applications Manager  
Silicon General, Inc.

#### **INTRODUCTION**

Power supply designers are often faced with choosing an optimum circuit topology based on a specific set of requirements. Though the hypothetical optimum design may vary substantially from one set of specifications to another, some of the most important criteria in many power supply applications are cost, size, weight, reliability and efficiency. Based on such parameters, designers often will choose between operating the pulse-width modulation (PWM) control IC referenced to either the primary- or secondary-side return. In either case, they must provide the dc power needed to operate that IC. Although a number of ways to generate this auxiliary supply voltage exist, some of the most common methods used are a 60-Hz transformer, linear regulator, self-oscillating dc chopper or an internal bootstrap.

Auxiliary 60-Hz transformers are used in off-line switchers to step down the input ac line voltage, which is then rectified and filtered to power the control IC. Although it is straightforward, this approach requires the use of low-frequency magnetics that are relatively heavy and occupy a considerable amount of pc-board real estate.

The size of the auxiliary 60-Hz power transformer can be a big factor in low-power switchers, which are typically very small. In these instances, the transformer can easily approach 30% of the total volume occupied by the supply. To accommodate the transformer, the supply's overall size would have to be increased, thus increasing its cost as well. Because of this, the PWM control circuits are not usually powered from an auxiliary 60-Hz transformer unless they must be referenced to the secondary side return.

Linear Regulators are typically used in dc/dc converters operating on inputs of less than 60 volts. If the input voltage is less than 30 volts, the designer often chooses a three-terminal voltage regulator. If the input is greater than 30 volts, a discrete series-pass regulator is usually used, with a zener diode providing the reference voltage.

Unfortunately, both of these approaches are inherently inefficient because of the power being dissipated in the series-pass element. Moreover, as the input voltage increases, the power dissipation also increases, with a corresponding decrease in efficiency. And since the input power is derived from the primary side of the switcher's power transformer, the PWM control circuit must be referenced to the primary-side return. As a result, the supply must include additional analog circuits on the secondary side and provide primary-to-secondary isolation through an optocoupler or isolation transformer.

Self-oscillating dc choppers can be used in either off-line switches or in dc/dc converters. In either case, the dc applied to the switching circuit is also applied to a self-oscillating chopper built around a saturable core. The chopper converts the dc into a high-frequency ac square wave that is stepped down, rectified and filtered to provide the dc power required by the PWM control circuits.

Since the frequency of operation is often above the 20-KHz range, the selected magnetics are much smaller than a comparable 60-Hz transformer. The chief disadvantage of this approach is the need for two high-voltage switching transistors, the cost of which more than offsets any savings achieved by use of smaller magnetics. Because of this, choppers are usually used only in dc/dc converters intended for use in telecommunications, aerospace and other high-reliability applications.

Bootstrapping employs an auxiliary startup power supply and a special winding on the main power transformer. Once the supply's operation has stabilized, this winding provides all the power required to operate the PWM control circuits. However, when ac power is first applied to the supply, the bootstrap winding provides no output. Instead, the PWM control circuits are powered entirely by the auxiliary startup supply. But as the switching transistors begin to function, voltage appears across the bootstrap winding. Eventually this winding, with its associated rectifier/filter circuit, takes over the task of powering the

PWM control circuits, and the startup circuit shuts down.

Because the startup circuit must provide power for only the period required for the switch-mode regulator to stabilize the supply's turn-on delay-very little power is dissipated in the start-up circuitry. But this approach requires a relatively large number of discrete components, especially when the design calls for the PWM control circuit to be referenced to the secondary-side return. With the availability of monolithic bootstrapping startup circuits, however, these components can be replaced with a single integrated circuit. Figures 1 and 2 show block diagrams of the bootstrap method for primary and secondary side operation.

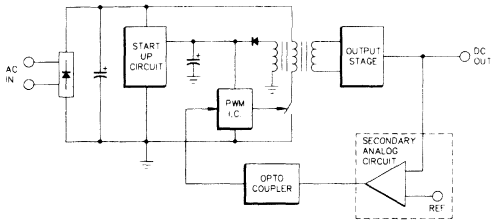


Figure 1. Primary Side Start-up Circuit

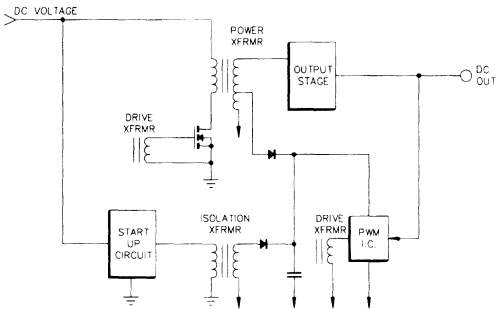


Figure 2. Secondary Side Start-up Circuit

## A MONOLITHIC BOOTSTRAPPING STARTUP

A simplified schematic diagram showing how the monolithic startup circuit, an SG1540 is connected into a typical power supply, can be found in Figure 3. As can be seen, the PWM control IC, an SG1526 in this case, receives power from two sources logically "ORed" at pin 14.

When ac power is first applied, capacitor C3 is charged through resistor R2. When its voltage reaches the turn-on threshold, a self-contained chopper in the SG1540 is turned on with the resulting high-frequency ac being applied to the primary winding of transformer T2. The resulting voltage appearing across the secondary is rectified, filtered and applied to the dc input of the

PWM control IC at pin 14. With the application of dc power at pin 14, the PWM control IC turns on the switching transistors and power is soon applied to the primary of transformer T1, the main power transformer. As a result, voltage is induced in the bootstrap winding, AB. This voltage is rectified, filtered and applied to pin 14 of the PWM control IC. Because its voltage is higher than that provided by the SG1540 through transformer T2, it provides all the power used by the PWM control IC.

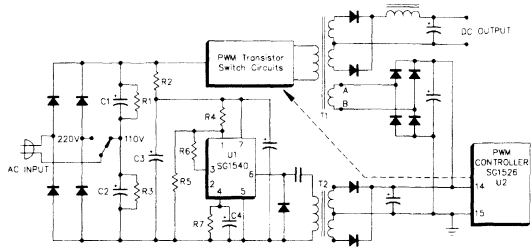


Figure 3. Schematic Diagram of the Bootstrap Start-up-power Circuits

During the period of time that has elapsed for this to occur, energy has been drawn out of capacitor C3 to power the control circuits through the SG1540. As a result, the voltage across C3 has decreased. As energy continues to be withdrawn, the voltage eventually falls below the SG1540's turn-off threshold and its self-contained chopper turns off. When this happens, transformer T2 no longer provides power to the rectifier connected to its secondary winding. This has no effect on T2 or the SG1540, because the diodes in the rectifier isolate them from voltage being produced by the bootstrap winding.

Of course, once the SG1540 turns off, energy is no longer withdrawn from C3 and, as a result, its voltage increases and the SG1540 is again turned on. However, because the bootstrap voltage is higher, the SG1540 does not supply any power to the PWM control circuits. Instead, it simply alternates between being on in an idling mode and being tuned off as the voltage across C3 rises and falls. The primary side operation is the same except the AB winding is wound on the primary side. (See Figure 5 in the comparator section.)

## EXPLANATION OF THE INTEGRATED CIRCUIT

The SG1540 consists of three main sections, as shown in Figure 4; a micropower bandgap comparator/power switch, a high-frequency square wave oscillator with a 200-milliamp totem-pole output stage, and a second bandgap comparator with latching crowbar to protect against overvoltage faults while starting or running.

# APPLICATION NOTES – SG1540

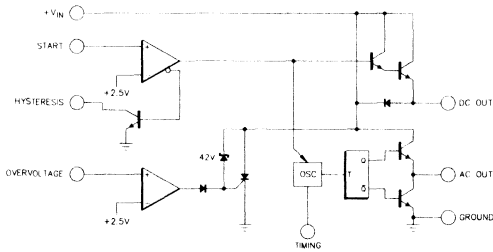


Figure 4. 1540 Block Diagram

## The Comparator Circuit

The operation of the circuit is best explained by referring to Figure 5. A micropower comparator (U1) is referenced to an internal low-drift bandgap source that provides +2.5 volts to one input of both the startup and overvoltage comparators. The overall tolerance of this reference voltage, over the full operating temperature range, is  $\pm 130$  millivolts. However, this reference is not available for any external connections. Also included is a hysteresis transistor (Q1) facilitating external programming of turn-on and turn-off voltage thresholds.

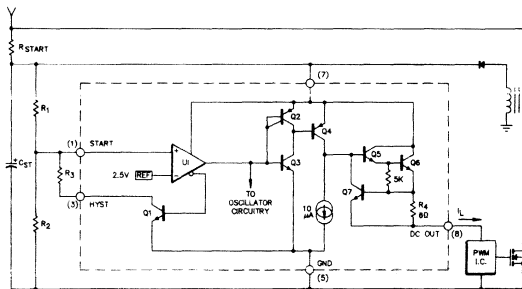


Figure 5. Simplified Schematic Diagram of the Comparator Circuit

When voltage is first applied to the IC, pin 2 is set lower than 2.5 volts by the voltage divider composed of R1 and R2. This causes the output of the comparator to be switched low. When this happens, transistors Q3, Q4, Q5 and Q6 are biased off, isolating startup capacitor  $C_{START}$  from its load. At the same time, transistor Q1 is turned on, placing R3 in parallel with R2 and forcing the voltage at pin 2 to drop even lower. During this time, the quiescent current drawn by the IC is less than 1 milliamp, which allows the startup capacitor voltage to ramp up towards the high-voltage dc supply through startup resistor  $R_{START}$ .

Once the startup threshold is reached, the base of Q1 transistor switches low and causes Q1 to be turned off. This raises the voltage at pin 2 to a higher value, determined by the R1-R2 voltage divider. At the same time, the other output of the

comparator activates the oscillator circuitry and through Q3, Q4 transistors turns the Darlington pair (Q5-Q6) on. When the Darlington pair is turned on, they provide a path through which the energy stored in the startup capacitor  $C_{START}$  can flow to the PWM control circuit. During the discharge time, the voltage induced in the flyback winding will be rectified and filtered by D1 and  $C_{ST}$  to provide the DC voltage. Note that the startup capacitor must be large enough to store sufficient energy to generate a bootstrap voltage that can meet all power requirements of the control circuits in the supply.

The Q5-Q6 Darlington pair is protected against any load transients or short-circuit conditions by internal current limiting. The maximum allowable output current is determined by the ratio of base-emitter voltage of transistor Q7 to the voltage across resistor R4. A typical value for the short-circuit current is 100 milliamps at 25°C, but as the temperature increases the current-limit threshold decreases. Figure 6 shows the Darlington saturation voltage vs load current.

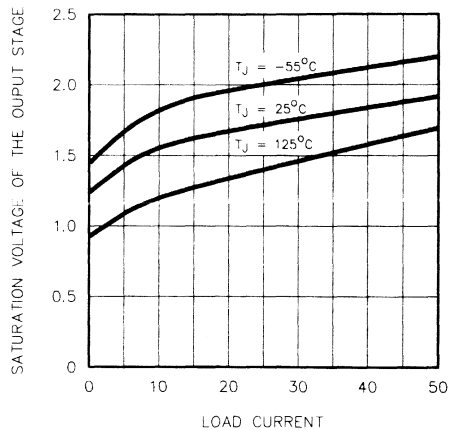


Figure 6. Output Transistor Voltage v.s. Load Current

## Oscillator and AC Output

A simplified schematic block diagram of the oscillator is shown in Figure 7. The oscillator's frequency is determined by the values of an external resistor,  $R_T$ , and capacitor,  $C_T$  (R7 and C4 in Figure 3). Their values can be obtained from the chart in Figure 8. When voltage is first applied to the IC, capacitor  $C_T$  is completely discharged and switch S1 remains open. Even though the input voltage rises, switch S1 remains open until the startup threshold is reached. When it is reached, the startup comparator (see Figure 5) changes its output state, causing switch S1 to close. As soon as it closes, capacitor  $C_T$  rapidly charges through resistor R1 towards input voltage  $V_{IN}$ . Once the voltage across  $C_T$  reaches 0.7 volts, the output of comparator U1 changes state.

Despite the change of U1's output state, switch S1 remains closed due to the action of a latch circuit, and the voltage across  $C_T$  continues to rise towards  $V_{IN}$ . When it reaches approximately 2.1 volts, the output of comparator U2 goes high. This resets the latch circuit and opens switch S1. When switch S1 opens, capacitor  $C_T$  is isolated from  $V_{IN}$  and begins to discharge through resistor  $R_T$ . As the discharge continues, the voltage across  $C_T$  decreases and when it finally falls to 0.7 volts, the output of comparator U2 goes low, closing switch S1 and beginning the cycle again.

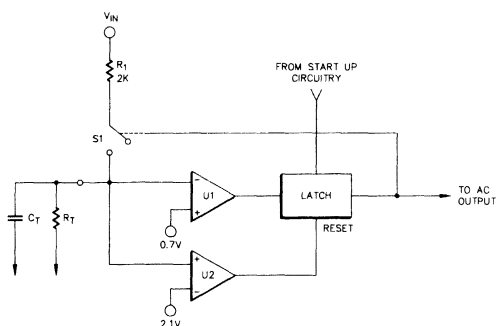


Figure 7. Block Diagram of the Internal Oscillator used to Drive the SG1540's Chopper Circuit

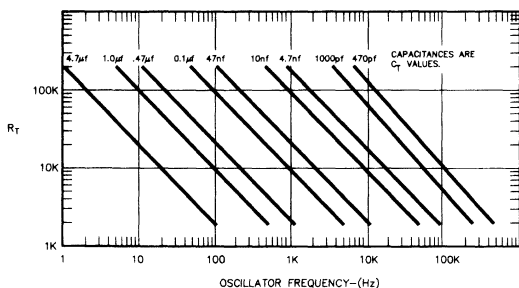


Figure 8. 1540 Oscillator Frequency Chart

A square-wave ac output is generated by driving a flip-flop from the output of the latch circuit. The flip-flop's output is applied to a totem-pole output stage. The output transistors have maximum peak-current capabilities of 200 milliamps, which is enough to power the control circuits of most switching power supplies during the startup period. Note that if the oscillator circuit is not being used, pin 4 should be connected to pin 7.

### Overvoltage Circuit

The overvoltage circuitry is intended to protect the IC against any overvoltage faults during startup and any period it is active. The circuit is shown schematically in Figure 9 and consists of a

comparator, composed of Q2 and Q3 referenced to 2.5 volts, a latching crowbar circuit, composed of Q6 and Q7, and a zener diode, Z1. When the voltage at pin 7 exceeds the threshold set by the R1-R2 voltage divider, pin 2 rises above 2.5 volts, causing transistor Q5 to turn on. This, in turn, turns off output transistors Q9 and Q10 and activates an SCR crowbar. When pin 2 is not used to program the overvoltage condition, the SCR can still be activated by allowing the voltage at pin 7 to exceed the zener diode's nominal 42-volt avalanche voltage. Note that when the overvoltage circuit is not being used, pin 2 should be tied to ground.

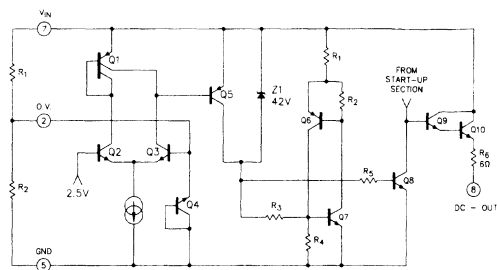


Figure 9. Simplified Schematic Diagram of the Overvoltage Protection Circuit in the SG1540

### DESIGN EXAMPLE

The power supply design discussed in this section uses a fairly common, straight forward circuit. It is intended to show the application of the SG1540 I.C. in one of the modes of its application, namely secondary side PWM operation. This mode of operation was chosen over the primary side, simply to show the dramatic reduction in the size and weight of the auxiliary supply compared to applications where 60Hz transformers are being used.

### Circuit Description

A general description of the SG1540 in a typical power supply was given in section "A MONOLITHIC BOOTSTRAPPING STARTUP". We will now design a complete power supply using the same circuit topology of Figure 3 with an SG1540 as the start up controller. As can be seen from Figure 10, the input rectifier bridge is arranged for connection either to 117 Vac or 220 Vac line. The circuit uses a pair of 400 volts MOSFET's in a Half Bridge circuitry and a pair of high speed rectifiers for the output stage. The MOSFET's are driven directly from the totem-pole output stages of an SG1526 control chip through an isolation transformer. This provides the fast current turn-on and turn-off pulses needed for MOSFET gates.

Current limiting is done with current transformer (T4) in series with the primary of the power transformer. The signal is rectified



## APPLICATION NOTES – SG1540

and lightly filtered, then fed to the current limit comparator terminal pin 7 of the SG1526 control chip, where it is being compared to the threshold voltage at pin 6 by R26, R27 divider network.

### Start-up Circuit Calculations

Suppose we want our power MOSFETS (Q1, Q2) to start at +15 volts and drop out at +10 volts. This would require the secondary start up and drop out voltages to be 15V and 10V respectively. If the isolation transformer (T2) has a 1:1 turns ratio, then the voltage out of (pin 6) of SG1540 needs to be a squarewave of 0 to 30 volts P-P output, since capacitor C5 blocks the DC component, converting it to a waveform of  $\pm 15$  volts peak amplitude signal. Knowing this, we proceed with calculations of R1-R3 resistors as follows:

Refer to Figure 5 for this section.

Given  $V_{START}$ ,  $V_{DROP}$ , and that the divider current at start up is 100uA, then the resistor values are calculated as follows:

$$1. \quad \text{Let } X = \frac{V_{START} - 2.5}{2.5}$$

and

$$Y = \frac{V_{DROP} - 2.5}{2.5}$$

Calculate:

$$R_1 = 25 * X$$

$$R_2 = \frac{R_1}{Y}$$

$$R_3 = \frac{R_1 * R_2}{X * R_2 - R_1}$$

Now, based on these formulas we will work out the values of R1-R3 for our converter design:

$$\text{Given: } V_{START} = 30V, V_{DROP} = 20V$$

$$X = 11.0$$

$$Y = 7.0$$

$$R_1 = 275K \quad \text{Choose } \underline{R1 = 274K}, 1\%$$

$$R_2 = 39.1K \quad \text{Choose } \underline{R2 = 39.2K}, 1\%$$

$$R_3 = 68.3K \quad \text{Choose } \underline{R3 = 68.1K}, 1\%$$

2. Calculation of start up resistor ( $R_{ST}$ ) and start up capacitor ( $C_{ST}$ ) are as follows:

$$R_{ST} \leq \frac{V_{DCMIN} - V_{START}}{I_{ST}}$$

and

$$P_R = \frac{(V_{DCMAX})^2}{R_{ST}}$$

Calculation of  $C_{ST}$ :

$$\frac{I * \Delta T}{\Delta V} < C_{ST} < \frac{T_{ST}}{R_{ST} * \text{Ln} \left( \frac{V_{DCMIN}}{V_{DCMIN} - V_{START}} \right)}$$

$I_{ST}$  = total start up current including the resistor divider.  
( $I_{ST} \geq 1\text{mA}$  is a good choice).

$I$  = Total rms current of control circuitry plus 1540 I.C.

$\Delta T$  = Discharge time (Time allowed for the auxiliary winding to reach start up voltage).

$\Delta V$  = The difference between start-up voltage and drop-out voltage.

$T_{ST}$  = Time to charge up capacitor to start up voltage threshold (power supply start up time).

$V_{DC}$  = Rectified DC BUS at minimum AC input.

A numerical example for our converter design is as follows:

First, assume that we have following specs for power supply start up time and power dissipation allowed in the start up resistor.

$$T_{ST} \leq 700 \text{ ms}$$

$$P_R \leq 1 \text{ watt}$$

Based on the formulas given, we find:

$$R_{ST} \leq \frac{100 \sqrt{2} - 30}{10^{-3}} = 111K \quad \text{Choose } \underline{R_{ST} = 47K}$$

$$P_R = \frac{(134 \sqrt{2})^2}{47 * 10^3} = 0.764 \text{ watts} \quad \text{Choose } \underline{1W \text{ Resistor}}$$

If  $I = 40\text{mA}$  and  $\Delta T = 5\text{ms}$ , then  $40\mu\text{f} < C_{ST} < 62\mu\text{f}$

Next, we calculate the start up time of the converter by the formula:

$$T_{ST} = R_{ST} C_{ST} \text{Ln} \left( \frac{V_{DC}}{V_{DC} - V_{ST}} \right)$$



## APPLICATION NOTES – SG1540

A tabulation of start up time vs input voltage based on the above equation for the converter is given:

Va	Start up time
100 Vrms	526 mS
117 Vrms	442 mS
134 Vrms	381 mS

3. Finally, to complete our start up circuitry, we need to design an isolation transformer. We start by writing the equation:

$$N_p = \frac{V_p}{4 B_m A_c F_s}$$

Where:  $V_p$  = Transformer primary voltage  
 $B_m$  = Maximum flux density of core material  
 $A_c$  = Cross sectional area of the core  
 $F_s$  = Frequency of transformer input voltage

For our design we choose a Ferroxcube Pot Core, 905PL00-3B9 with  $A_c = 0.101 \text{ cm}^2$ . Looking at 3B9 material we choose  $B_m = 0.1\text{T}$ , and we calculate  $N_p$  as follows:

$$N_p = \frac{15}{(4)(0.1)(0.101 \times 10^{-4})(200 \times 10^3)} = 19 \text{ Turns}$$

Choose  $N_p = 25\text{T}$

Note: R7 and C4 are chosen such that oscillator frequency is at 400KHz, therefore providing an output frequency of 200KHz.

Since transformer has a 1:1 turns ratio, both the primary and secondary turns are chosen to be equal.  $N_p = N_s = 25$  turns of #32 AWG wire.

Figure 11 shows the start up time at 117Vac input.

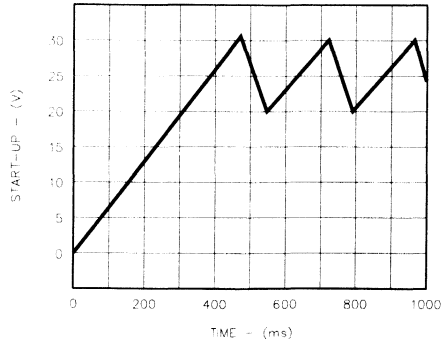


Figure 11. Power Supply Start-up Time v.s. Start-up Voltage

### CONCLUSION

Considerable savings in size, weight, and/ or cost can be achieved by using a bootstrap startup circuit in switch-mode power supplies. Empirical evidence has shown that bootstrapping a PWM control IC on the primary side results in a startup current of about 1 milliamp, which means just about any standard PWM control IC can be used as a primary-side controller. Bootstrapping a secondary-side controller results in a significant reduction in the size and weight of the auxiliary power transformer by substituting high-frequency magnetics for the 60-Hz magnetics that would otherwise be required. Moreover, the use of a monolithic startup circuit, such as the SG1540, in a bootstrap circuit minimizes both real estate and component requirements.

### PERFORMANCE

A summary of the test results of some of the parameters is tabulated here:

Parameter	Condition	5V Output	Aux output
Line and load regulation	100<Vac<134.5A<l<20A	± 3mV	12V<Vaux<16V
Ripple & noise	100<Vac<134.5A<l<20A	90mV p-p	
Current limit knee	Vac = 100V	22.4A	
	Vac = 134V	23 A	
Short circuit current	Vac = 100V	16A	12.5V
	Vac = 134V	20A	17.6V

Parameter	Condition	Test Result
Efficiency at full load	Vac = 100V	77%
	Vac = 134V	70%
Output load transient	100<Vac<134V	Overshoot = 500mV Rcvry time = 300nsec
Start up time	Vac = 100V	520 ms
	Vac = 134V	380 ms



## **USING THE SG3626/3644 FET DRIVERS IN THE 16-PIN SOIC PACKAGE**

Stan Dendinger  
Advanced Product Development  
Silicon General, Inc.

### **INTRODUCTION**

The use of surface-mount integrated circuits is becoming more popular as the trend to miniaturize electronic systems continues. Consequently, designers are requesting more types of ICs to be available in these packages, particularly the Phillips Small Outline Integrated Circuit (SOIC) configuration. To accommodate this need, Silicon General offers the SG3626 (inverting) and SG3644 (non-inverting) Dual High-speed MOSFET Drivers in the wide body 16-pin copper-lead SOIC package (DW suffix).

This combination of potentially high-dissipation die in a very small package requires special attention on the designer's part to thermal management techniques. The net effect of average IC power dissipation and the resulting heat flow from the die to the outside world should be an operating junction temperature which never rises above +125°C for acceptable device reliability. This application brief is intended to provide enough information for the designer to avoid major pitfalls and to achieve a successful thermal design.

### **EFFECT OF JUNCTION TEMPERATURE ON RELIABILITY**

The undesirable effect of high junction temperatures on long-term reliability of semiconductors has long been known. The Military Handbook, Reliability Prediction of Electronic Equipment (MIL-HDBK-2170) published by the U.S. Defense Department, contains a formula for calculating the Mean-Time-Before-Failure (MTBF). The actual failure rate is dependent on many factors; but assuming all other variables are constant, the relative failure rate will increase with higher junction temperatures.

The curve plotted in Figure 1 is based upon the handbook tables for the temperature acceleration factor of the failure rate model. It can be used to estimate the change in reliability for a given linear bipolar IC as its operating junction temperature increases.

For Example, the SG3626 is rated for a maximum junction temperature of +125°C, and will exhibit a certain failure rate in

actual operation dependent on the other factors that influence reliability. If the junction temperature is allowed to go to +150°C, the failure rate will triple. At +175°C, the expected lifetime will be reduced by a factor of 9! On the other hand, if heatsinking lowers the maximum junction temperature from +125°C to +100°C, the reliability will improve by a factor of 3.5. From these numbers, it is easy to see the importance of controlling the junction temperature if reasonable lifetime is a design goal.

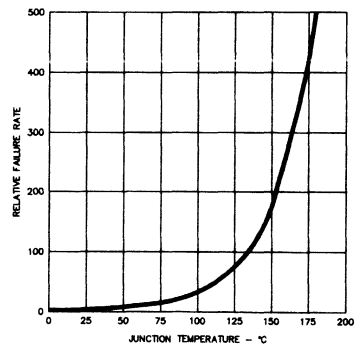


Figure 1. Linear IC Failure Rate vs Junction Temperature (MIL-HDBK 217D)

### **FREE-AIR OPERATION**

Figure 2 shows the maximum allowable power dissipation as a function of ambient temperature for the SG3626DW and 3644DW. Power dissipation capabilities of the 16-pin copper-lead SOIC package ( $\theta_{JA} = 105^\circ\text{C/W}$ ) are compared with the popular 8-pin copper-lead-frame plastic DIP ( $\theta_{JA} = 78^\circ\text{C/W}$ ).

For free-air operation, the maximum allowable dissipation at  $T_A = +70^\circ\text{C}$  is 500mW for the SG3626/3644DW. From the data

sheet, the worst-case DC current consumption is 27mA with both drivers continuously in the LOW state. If no heat sink is used, a maximum supply voltage of 500mW + 27mA, or 18.5 volts should be allowed to keep the junction temperature below +125°C. This is just for safe DC operation.

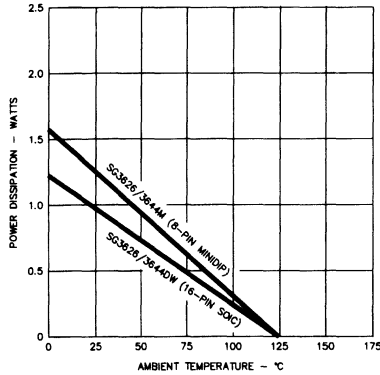


Figure 2. Maximum Power Dissipation vs Ambient Temperature

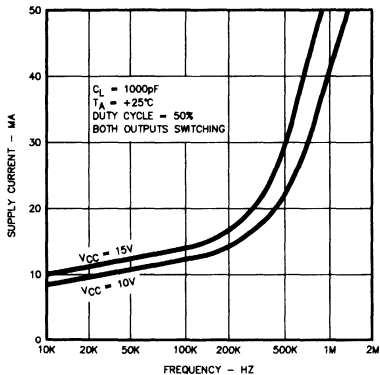


Figure 3. Supply Current vs Switching Frequency

Figures 3 and 4 which are re-printed from the data sheet, can be used to estimate the AC current consumption. The data, taken on actual devices, shows that the current consumption can exceed the worst-case DC value at high frequencies, or with a sufficiently large capacitive load. In the case of a switching power supply, the worst-case dissipation will occur at high line voltage and light load: the driver pulse-width will narrow to a small value, and the power dissipation of the driver will approach the sum of the worst-case DC value plus the AC contribution.

The designer will have to determine the exact power dissipation given the chosen switching frequency and equivalent input capacitance of the power devices; he may conclude that the supply voltage to the driver will have to be reduced even further.

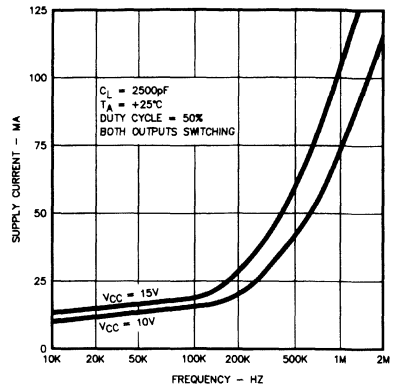


Figure 4. Supply Current vs Switching Frequency

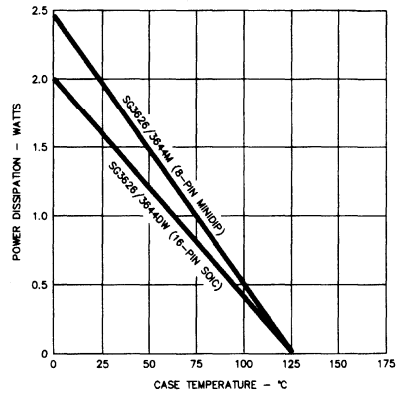


Figure 5. Maximum Power Dissipation vs Case Temperature

### OPERATION WITH A HEATSINK

Since most power MOSFETs require gate enhancement voltages of 10 to 15 volts, the idea of heatsinking the SOIC may begin to appear attractive since it offers the beleaguered designer another degree of freedom. From Figure 5, if the case of the SOIC package (the bottom, which is closest to the internal copper die-flag of the lead frame) can be held below +80°C, the driver can dissipate 750mW rather than the previous 500mW. The additional 50% gain in power dissipation capability may be adequate to meet the original design goals.

The thermal resistance is best minimized by designing a wide pc board trace under the SOIC package, and by eliminating the air gap with thermal grease or a high thermal-conductivity rubber gasket with double-sided adhesive. More elegant schemes, such as using a metal-core board of alumina substrate, will allow even higher dissipation. Finally, airflow across the package in the range of 200-800 LFPM will reduce the thermal resistance by 15 to 30%, if the goal of miniaturization is not compromised by the addition of a fan.

**POWER SWITCH DRIVERS: NEW IC INTERFACE BUILDING  
BLOCKS FOR SWITCHED-MODE CONVERTERS**

Stan Dendinger  
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Silicon General, Inc.

**ABSTRACT**

This paper describes the characteristics and performance of two new integrated circuit products designed to interface between the control circuitry for switch mode converters and their high power output stages. The first device develops the high level turn-on and turn-off commands directly from the outputs of a low power P.W.M. control circuit while the second is designed as a floating switch to control a high current switching transistor directly from the secondary of a drive transformer.

**INTRODUCTION**

Recent years have seen significant developments by component suppliers which have resulted in the ready availability of many high performance power transistors and sophisticated control integrated circuits for switching power supply design. There existed a gap, however, between the control circuit and the power switching transistors where a considerable amount of circuitry was required to adequately condition and amplify the control signal in such a way as to provide the proper turn-on and turn-off commands to the power switch. This gap has now been filled with two new integrated power switch drivers, the SG1627 Dual Output Driver and the SG1629 High Current Floating Switch Driver.

**SG1627 DUAL OUTPUT DRIVER**

The SG1627 was designed to directly interface between low level control circuitry and the high current handling devices required in switching power supplies. As shown in Figure 1, this is a dual circuit containing both channels that are required for a push-pull system. It accepts the P.W.M. signals from a control circuit such as the SG1524 and provides the conditioning necessary to develop both turn-on and turn-off commands at currents up to 500mA. Its outputs can be used to directly control an external power transistor or to interface with driver transformers for additional power amplification. Another feature of this circuit is the optional ability to provide a constant drive current.

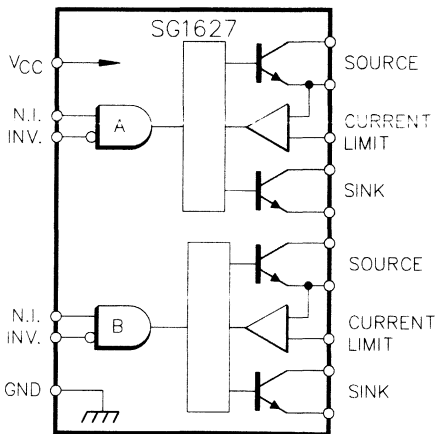


Figure 1. The SG1627 Dual Output Driver is Packaged in a 16-Pin Cerdip D.I.L. Package.

**CIRCUIT DESCRIPTION**

Figure 2 shows the schematic for one-half of an SG1627 dual output driver. It must be remembered that there are two identical circuits in each 16-pin dual-in-line package. The inputs to this circuit are switch closures to ground with both inverting and non-inverting logic configurations available. The input threshold level

# APPLICATION NOTES – SG1627/SG1629

of both logic inputs is 2V, and the logic is powered by an internal voltage regulator so that input characteristics are unaffected by power supply voltage which can range from 5 to 30 volts.

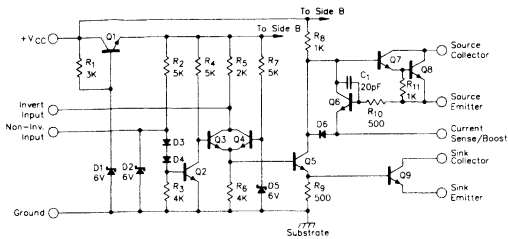


Figure 2. Schematic Diagram for One-Half of the SG1627

The output sections of the SG1627 contain both source and sink transistors, each capable of 500mA, 30V operation. In addition, the source transistor has the capability of constant current operation by using an external sense resistor between the source emitter and the current sense terminals. The source transistor is in a Darlington configuration which can easily deliver currents to 500mA under all operating conditions but at the cost, however, of a higher saturation voltage. The sink transistor is designed for very low saturation voltage: approximately 0.5 volts at 500mA. It does, however, need greater base drive to meet those high currents. This can be provided by either raising the supply voltage above 5V, or by adding a boost drive current through D6. The saturation characteristics of both source and sink are shown in Figures 3 and 4.

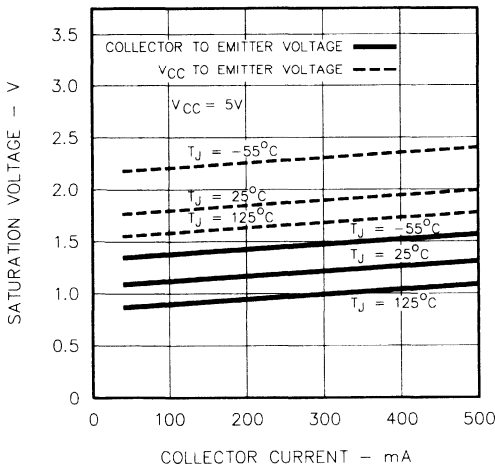


Figure 3. Saturation Characteristics of the SG1627 Source Transistor

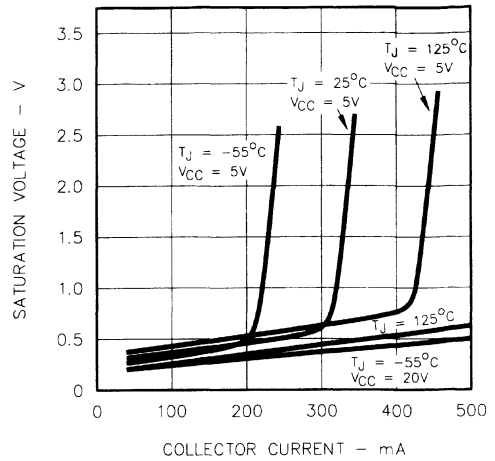


Figure 4. Saturation Characteristics of the SG1627 Sink Transistor

## THE TOTEM-POLE OUTPUT CONFIGURATION

One of the simplest uses of the SG1627 is illustrated in Figure 5 where the output is configured to provide a constant 300mA turn-on command to an external switching transistor together with a high peak turn-off current. Note that the logic on the SG1627 is being driven directly from the 5V reference terminal of an SG1524 P.W.M. control I.C. The logic inputs are directly connected to the open collector output transistors of the SG1524 with no additional interfacing components. The output current of the SG1627 comes from the input voltage, which in this case is approximately 10V, but the use of  $R_2$  provides a constant source drive regardless of input voltage variations.

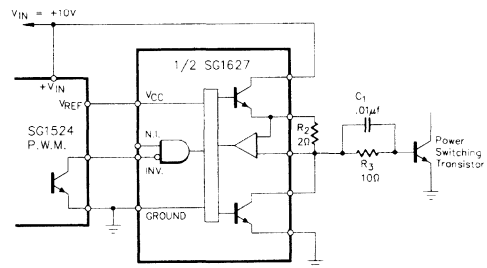


Figure 5. In a 300mA Output "Totem Pole" Configuration, The SG1627 Interfaces Directly With the SG1524 Regulating P.W.M. Control Circuit.

Resistor  $R_3$  is used to build up a voltage drop across capacitor  $C_1$ . At turn-off, the energy stored in  $C_1$  provides both a negative voltage to the base of the power switching transistor and the

# APPLICATION NOTES – SG1627/SG1629

boost drive current necessary to saturate the sink transistor during peak discharge currents of approximately 500mA. With this magnitude of reverse base current (Ib2), transistor turn-off is greatly accelerated.

There are two considerations to remember in this configuration. The first is that the maximum output voltage will be less than the value of  $V_{CC}$  because the source transistor operates as an emitter follower. With  $V_{CC} = 5$  volts in this case, the peak output voltage is approximately 3 volts. The other consideration is power dissipation in the source transistor when using it in the constant current mode since it will absorb any excess voltage after current limiting.

The performance of this application is illustrated in Figure 6 which shows the base current into the external switching transistor. One can see both the constant drive current of about 300mA and the rapid, peak negative turn-off current in excess of 500mA. Note that the delays through the SG1627 are less than 50 nanoseconds making a very fast responding circuit.

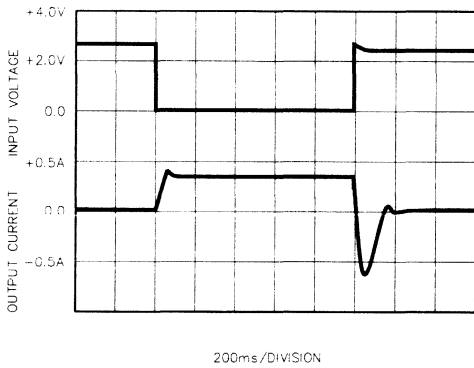


Figure 6. Output Current Transfer Function

An alternate configuration shown in Figure 7 pictures the SG1627 with a higher value of supply voltage. This offers at least two advantages: first of all, it allows the output voltage swing to rise considerably higher remembering that the source as an emitter follower can rise to approximately 2V below the input supply voltage. The other benefit is in providing greater drive current for the sink transistor allowing 500mA saturation without the need for additional boost current. Because of the large power supply voltage across the source transistor, power dissipation can be a problem. This probably means a reduced source current if current limiting is required, although the use of resistor  $R_1$  to absorb some of the voltage drop will reduce the power dissipation within the SG1627.

Recognizing the potential for package power limitations, it is important to consider the use of the SG1627 with various types

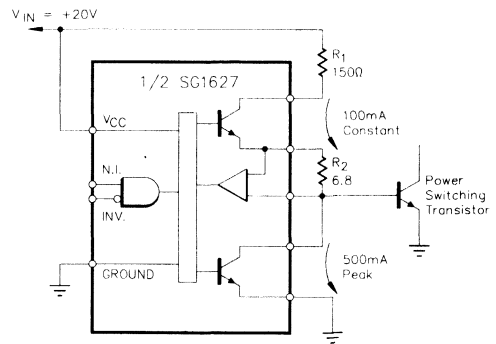


Figure 7. Higher Input Voltages Can be Used to Provide Drive for Higher Sink-Transistor Currents

of power boosting circuitry. Maximum flexibility for the use of external current boosting transistors is maintained by the uncommitted availability of both the collector and emitter terminals of both the source and sink transistors. Figure 8, for example, shows the use of an external PNP transistor to boost the source current to 1amp. The use of the PNP transistor in this configuration still allows current sensing to be used for constant current operation. If constant current operation is not required, an NPN emitter follower booster could also be used. The use of a single boost transistor as shown in Figure 8 makes a powerful drive circuit as one can now drive one amp of turn-on current into a switching power transistor and still have a 500mA of turn-off current through the sink transistor.

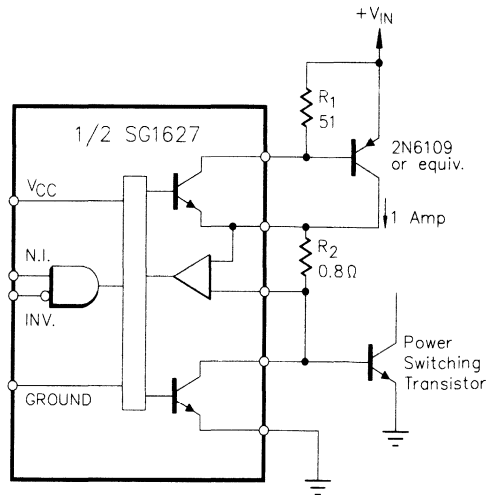


Figure 8. Increased Source Current With the Use of an External Boost Transistor

# APPLICATION NOTES – SG1627/SG1629

## DUAL PHASE OUTPUTS

The SG1627 does not need to be committed to totem pole operation. The source and sink transistors can be separated and used independently for dual opposite-phase outputs. Figure 9 shows the operation with both source and sink transistor emitters grounded and each used as a common emitter amplifier driving an external load resistor. Figure 9 also shows the use of an external resistor  $R_1$  to provide additional drive current boost to the sink transistor. This will allow the sink transistor to provide full 500mA operation with only a 5 volt supply. The response characteristics of this type of configuration are shown in Figure 10, which pictures the response of both source and sink with 24ohm load resistors to inputs at both the inverting and the non-inverting logic inputs. Note again the minimum delay of both outputs; less than 100 nanoseconds from input to output on both source and sink.

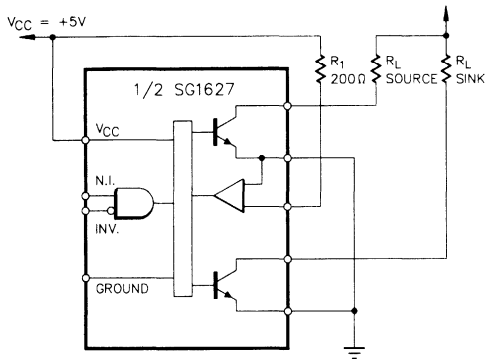


Figure 9. Separate Dual-Phase Outputs With Additional Drive Current for 500mA Sink Transistor Operation

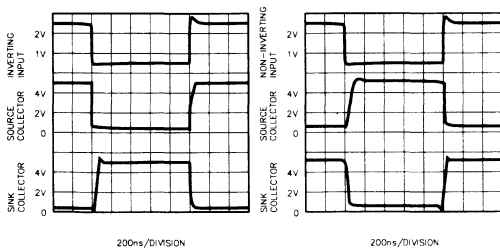


Figure 10. Source and Sink Response Characteristics

The use of the source and sink as separate outputs provides significant benefit for driving a transformer, as illustrated in Figure 11. In this example, the primary winding of the transformer is driven by the source transistor with its emitter grounded. Constant current operation is shown with the inclu-

sion of the sense resistor,  $R_2$ , but voltage switching could as easily be accomplished by merely shorting together the sense terminals. To provide greater efficiency in the magnetic design, a reset winding is added and shown being driven by the sink transistor. This ensures the magnetic flux is reset to zero between each pulse. Of course, the sink transistor opens up every time the source transistor drives the primary winding.

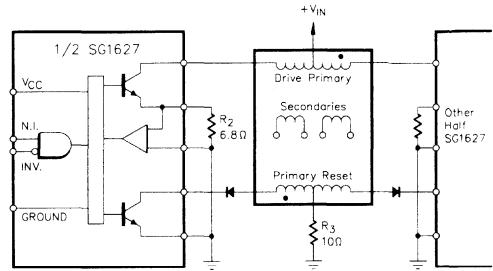


Figure 11. Driving an Outside Transformer With the SG1627

An additional illustration of the versatility of the SG1627 is shown in Figure 12, where the non-inverting logic input is used to provide a positive guarantee that both sides of a push-pull inverter can be on at the same time. This circuit is shown using the inverting input as the primary drive path, which will force the source transistor to be on when the control circuit transistor is conducting. The non-inverting input is then diode-coupled to the opposite side of the inverter and senses saturation of the external power switch. If the collector of the opposite transistor is low, holding the non-inverting input low, then regardless of what happens at the inverting input terminal, the output source on that side cannot be turned on. The sink will remain on, holding the output low until a rising collector voltage on the opposite side removes the non-inverting input at which time the command

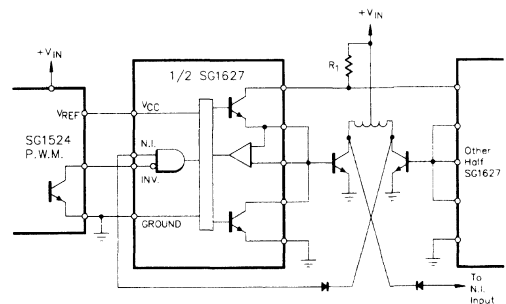


Figure 12. Simultaneous Conduction of the Two Output Transistors is Prevented by Gating With the Non-Inverting Inputs



# APPLICATION NOTES – SG1627/SG1629

signal will then come through the SG1627 and turn on the correct side. This circuit is particularly useful as a protection against cross-conduction of the output transistors during transient conditions at power-on or overload.

The above examples have been chosen to illustrate the versatility and performance of this new device designed to interface between a low level pulse width modulating control circuit and the high power switching transistors used in all modern-day switching power supply designs.

## THE SG1629 HIGH CURRENT FLOATING SWITCH DRIVER

A second interface circuit to be discussed in this paper is the SG1629 illustrated in Figure 13. This device has been designed to provide an interface between a drive transformer secondary winding and a high power switching transistor, and again provide the proper signal conditioning to adequately deliver both turn-on and turn-off current into the base of that switching transistor. More importantly, its design is such that it requires no external power connection but develops all the power for both turn-on and turn-off from the drive transformer and an external storage capacitor. With this capability, the SG1629 can be used in floating operation for bridge inverters at voltages in excess of 300V with respect to ground. This circuit also contains the capability for constant current drive operation with a similar type of current sensing circuit and an external current sensing resistor.

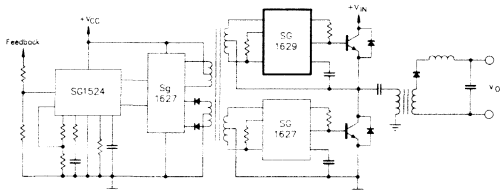


Figure 13. The SG1629 High-Current, Floating Switch Driver

## CIRCUIT OPERATION

The SG1629 functions with a center-tapped drive transformer secondary winding such that when a turn-on command is present and current is flowing in the upper half of the secondary winding through the source transistor and into the base of the power switching transistor, a current is also flowing in the lower portion of the transformer secondary through the high current rectifier to charge the external capacitor  $C_s$  to a negative voltage. When the drive command terminates, this negative voltage is used to turn on the sink transistor which then pulls a negative  $I_{b2}$  current from the base of the switching power transistor down to the negative voltage on the capacitor providing again a high peak turn-off current to speed the response and minimize the power

losses in the switching transistor. For maximum versatility, this circuit also contains several gating options.

In Figure 14, the schematic of the SG1629 shows two power Darlington transistor structures, each capable of handling an excess of 2amps of current: Q3/Q4 as the source, and Q6/Q7 forming the sink. Transistor Q5 provides current sensing with feedback to provide constant current operation. The source transistor is turned on by conduction of drive current through resistor  $R_2$ . The drive current for the source transistor is gated on and off through the action of Q1 which senses the input voltage and provide a turn-off of the source transistor between each drive current pulse.

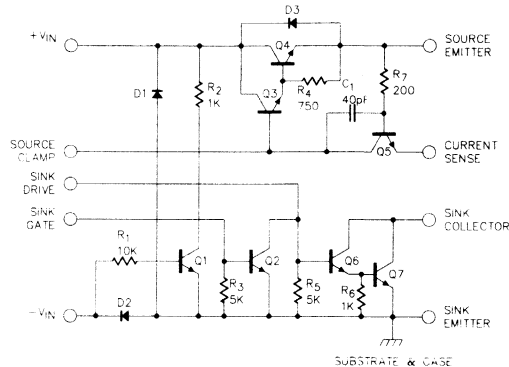


Figure 14. The Schematic of the SG1629. Transistors Q4 and Q7 are Designed for Two-Amp Operation.

The Darlington sink transistor has its input brought out as a separate sink drive terminal which gives the user several driving options. In addition, the sink driving current can be gated by the use of Q2, which has its own input terminal. The diodes D1 and D2 are high current rectifiers which provide the charging current for the external capacitor attached to the sink emitter terminal. The action of transistor Q1 to gate the source transistor insures that there is negligible discharge current (less than 10mA) from the external capacitor during the off periods of the circuit. This allows the capacitor to be charged with very narrow drive pulses separated by relatively long off periods.

The SG1629 is packaged in both a multi-pin TO-66 power package and an 8-pin minidip. Having no sensitive, low current circuitry, this device can be operated with a maximum junction temperature of 175° which, coupled with a low  $\theta_{JC}$  thermal resistance of 5°C/W, gives the TO-66 package a 3 Watt capability in free air and 10 Watts or more with some heat sinking. Because of the versatility of this device, it was felt that there may be applications for lower power requirements and thus the SG1629 will also be available in an 8-pin ceramic minidip package which, of course, has a power dissipation of only

# APPLICATION NOTES – SG1627/SG1629

800mW. With one pin less in the 8-pin minidip package, the sink gate function is sacrificed.

## SG1629 APPLICATIONS

The use of the SG1629 can best be demonstrated in an application as shown in Figure 15 where two SG1629's are used to provide the drive signals for the power transistors in a 5 amp one-half bridge switching supply. The drive transformer is shown with 10 volt drive signals on the primary winding which, with a 2:1 transformer turns ratio, provides a 5V peak signal on each half of the secondary. When the drive command is present on one secondary, it is translated into a constant current through the source transistor by the use of the sense resistor,  $R_{CS}$ , which in this case provides a constant 700mA into the base of the external NPN transistor. At the same time, the 20 microfarad external capacitor is being charged with a current through the rectifier in the SG1629 and the lower half of the secondary winding. While this is occurring, the opposite phase signal is being applied to the lower SG1629 circuit which serves to further enhance the charge on its external capacitor while maintaining the power switch in the off state.

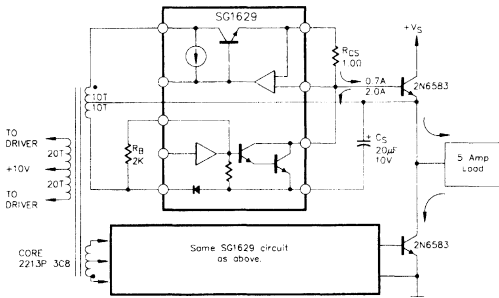


Figure 15. Use of the SG1629 in a 5-Amp Half-Bridge Converter

When the drive command terminates, the voltage at both ends of the secondary winding goes to zero. Since there is approximately -4V at the emitter of the sink transistor while its base is being driven through the external drive resistor,  $R_B$ , to zero volts, the sink transistor then immediately turns on and pulls a high current  $I_{b2}$  pulse out of the external transistor and through the capacitor. This current, of course, only flows as long as it is available from the stored charge within the base of the external transistor as the source has been gated off. After that charge is depleted, the sink transistor remains on insuring a negative reverse voltage at the base of the switch transistor.

The performance of the SG1629 can be illustrated by the waveform photographs in Figures 16 through 18. In figure 16, the command signal from one channel of the control circuitry and

the waveform of the drive transformer primary voltage are shown. The voltage on the secondary winding, referenced to the centertap and the power transistor emitter, is pictured in Figure 17. Also shown in this photograph is the input voltage at the base of the external NPN transistor. Note that at the very first portion of this waveform, when the opposite side is on, there is an additional negative charge supplied to the capacitor so that we have a maximum reverse base-to-emitter voltage of close to -4V. During the off time, the action of the sink transistor maintains a negative voltage bias of approximately -3V on the base of the power transistor. When the drive command is given to turn on, the base voltage goes positive to the 0.7 or so volts necessary to turn it on and at turn-off, goes negative again. The important action is shown in Figure 18 which pictures the actual base current of the power transistor with a scale of one amp per division. Both the constant turn-on  $I_{b1}$  of about 3/4 amp and the peak  $I_{b2}$  of close to -2amps can be seen along with the collector voltage waveform with a 5amp resistive load. Remembering that the time base of all these waveform photographs is 5 microseconds per division, one can see approximately one microsecond delay between the turn-off signal at the base and the actual turn-off of the collector of the output transistor. Although this turn-off response is primarily a function of the transistor design, it is safe to say that any power switching transistor should perform faster with this form of base drive.

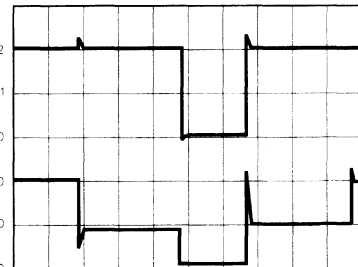


Figure 16. Input Control to the Drive Transformer

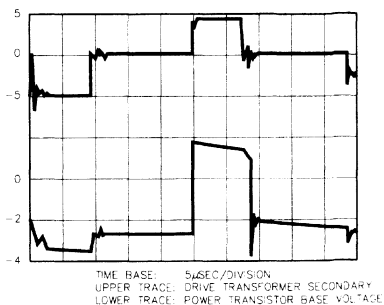


Figure 17. The Base Voltage Delivered to the External Power Switching Transistor by the SG1629

# APPLICATION NOTES – SG1627/SG1629

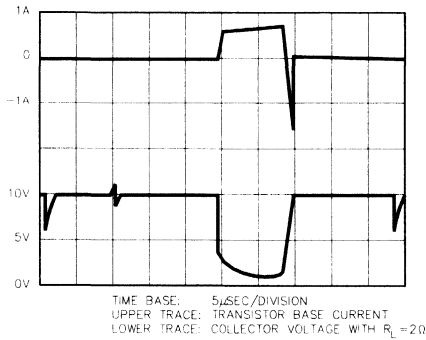


Figure 18. Base Current and Collector Voltage of the External Switching Transistor

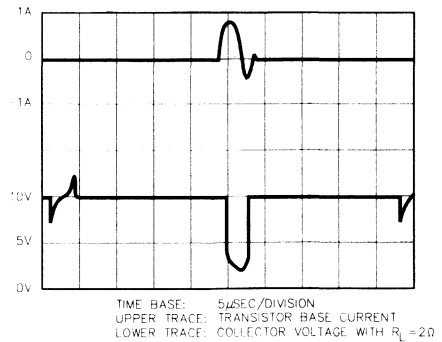


Figure 19. Operation With Narrow Pulse Widths

Note that one can also see in the collector waveform a soft knee at turn-on where the power transistor is not saturated instantaneously. This is partially because of the turn-on characteristics of the transistor and partially because of the finite rise time of the base current through the driving circuitry. The rise time is primarily a function of the leakage inductance of the drive transformer which opposes a sudden change in current from zero to maximum value. It is an exercise in transformer design to configure the transformer to minimize to the greatest extent possible the leakage inductance. This can be done with a minimum number of turns and a maximum coupling between turns. In the illustration, a ferrite pot core of approximately 3/4" in diameter was used to configure the drive transformer. More will be said about turn-on rise time later, but first let's discuss one additional characteristic of concern in the turn-off circuitry: The operation with very narrow pulse command.

Since the charge on the external capacitor is developed during the turn-on command, narrow pulse widths accomplish the transfer of a minimum amount of energy. As the drive command pulse widths get narrower, there is a point where the voltage on the external capacitor begins to fall off. With the circuit components as shown earlier, this loss of  $I_{b2}$  occurs at approximately 2 microsecond pulse widths. Figure 19 shows the base current and collector voltage waveforms at narrow pulse widths where the  $I_{b2}$  has diminished from 2amps down to approximately 3/4 of an amp. Further reductions in pulse width bring the  $I_{b2}$  current ultimately to zero. This characteristic is, of course, a function of the time constants in the total circuit and some compromise or optimization can be achieved by appropriate selection of capacitor values and secondary drive voltages.

The above circuit incorporated constant current drive which is an advantage if the load current happens to be relatively constant but in many applications this is not the case. The SG1629 may also be used to provide a base drive proportional to load demand

by adding an anti-saturation clamp diode as shown in Figure 20. With the current sense terminals shorted, there are two  $V_{BE}$  voltage drops between the clamp and the source emitter terminals. Therefore, the clamp diode D1 will hold the collector on voltage to approximately one diode drop above the base. This will keep the switching transistor right at the threshold of saturation, regardless of load current variations.

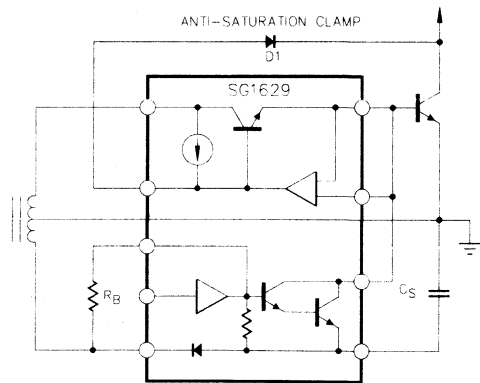


Figure 20. Use of the SG1629 in a Load-Dependent Drive Configuration

## IMPROVING TURN-ON RESPONSE

In applications where maximizing base current rise time is important and secondary transformer inductance is a significant consideration, the use of the gating functions in the SG1629 can provide significant benefits. Figure 21 shows the addition of an external transistor Q1 to drive the sink transistor's gate circuit. To explain the operation of this circuit, note that the sink

# APPLICATION NOTES – SG1627/SG1629

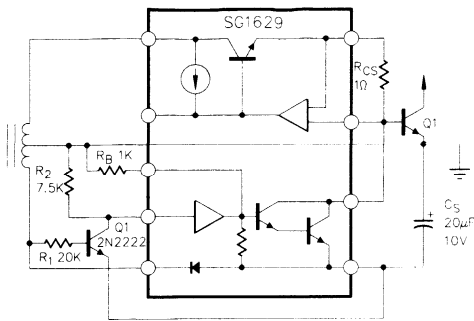


Figure 21. Improving Base Current Turn-On Rise Time

transistor's base drive is now being generated with  $R_B$  connected to the common or center tap of the drive transformer secondary instead of the negative input terminal. This is essentially zero volts and since the emitter of the sink transistor is attached to the capacitor which has a negative voltage on it, the sink transistor would normally be on continuously. Transistor Q1 is selected as a relatively slow non-gold-doped transistor which has a finite storage time. Its action is to turn the sink transistor off during the drive command signals, but to delay that off signal for some increment in time. Note that before the commencement of a drive command, the sink transistor is on by the action of  $R_B$ . Transistor Q1 is also saturated by its base resistor being connected to the end of the transformer which is also at zero volts prior to the command signal.

When the drive command is initiated, current begins to build up in the secondary circuit and the first flow of current is through the source transistor, through the current limiting resistor, down through the sink transistor which is still conducting, and back to the negative terminal on the transformer secondary. The switching transistor is still back-biased while this occurs. Because the input to transistor Q1 is now at a negative voltage, it turns off, but since it has a finite storage time, that time is used to delay the rise of the input to the sink gate. Additional delay can be added with a small capacitor at the sink gate input terminal. When the input to the sink gate goes high, its output goes low, forcing the sink transistor to turn off. Since the source current is already flowing, turn-off of the sink diverts that current to the base of the output transistor producing base currents in Q1 with rise times of less than 100 nanoseconds.

When the action is reversed at turn-off, there is negligible increase in delay time between the turn-off signal and the actual turn on of the sink transistor. This is because Q1 is the only device with a long storage time and it is turning on so storage is not a factor.

Another method of spreading up the rise time of current into the base is the use of some reactive components to differentiate the drive current signal. A simple approach is a capacitor by-pass around the current sense resistor,  $R_{SC}$ , providing an initial boost in turn-on current.

## GETTING IT ALL TOGETHER

The overall simplifications which Silicon General has offered to the design of switch mode power converters can best be illustrated by Figure 22 which shows the total command signal flow from the feedback error information to the output of a high current half-bridge regulating inverter. The SG1524 was designed to provide all of a switching regulator's P.W.M. control signals with the only external components required being the divider resistors to interface with the error amplifier, the overall loop compensation network, and the resistor and capacitor to set the operating frequency. The SG1524 drives the SG1627 directly which, in turn, provides the signal conditioning to develop the drive and reset commands to an interstage drive transformer. The secondary windings of that drive transformer are directly coupled into a pair of SG1629 floating drivers which are then used to command the external 5amp switching transistors which form the high power output stage of the power supply.

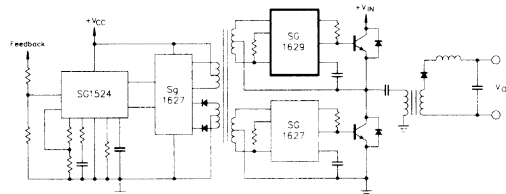


Figure 22. Three IC Types Form a Major Portion of the Control Electronics for a Switch-Mode Half-Bridge Converter.

These circuits have all been designed to offer a maximum degree of flexibility while incorporating what would otherwise be a substantial amount of discrete circuitry.

Thus, all these new IC's greatly ease the design and manufacturing problems typically inherent in switching power supplies and, at the same time, provide greater repeatability and reliability at significantly reduced costs.

**USE MOTOR-DRIVE IC TO SOLVE TRICKY  
DESIGN PROBLEMS**

*An IC Driver's Logic-Control Features and High Output Capability Suggest  
Elegant Ways to Handle a Variety of Difficult-to-Drive Loads*

Stan Dendinger  
Manager, Advanced Product Development  
Silicon General, Inc.

**INTRODUCTION**

You can use the SG3635 driver IC in a wide range of applications, ranging from a switched-mode motor-speed controller to a data-communications line driver. The device's input configuration simplifies interfacing between low-level circuitry (eg, a  $\mu$ P or logic blocks) and the high-power load. And its output stage (see "Anatomy of a driver IC), capable of driving 40V, 2A loads with peaks as high as 5A (including reactive loads), provides sinking and sourcing capability as well as commutation diodes.

**CONTROL MOTOR SPEED WITH MINIMUM PARTS COUNT**

Fig 1 shows one application of the device in a self-clocking switched-mode speed-control loop. The mechanically coupled tachometer detects the motor's speed; its output, scaled and

filtered by the RC network, drives the 311 comparator, which compares the output with the speed-setting input and biases the SG3635 to complete the loop.

When the motor slows down, the SG3635's output switches on (Fig 2, trace A), forcing current into the motor (trace B) until the comparator's inputs balance. Under these conditions, the circuit oscillates in a controlled manner around setpoint. The 10-k $\Omega$ , 0.1- $\mu$ F pair provides positive ac feedback to ensure clean transitions.

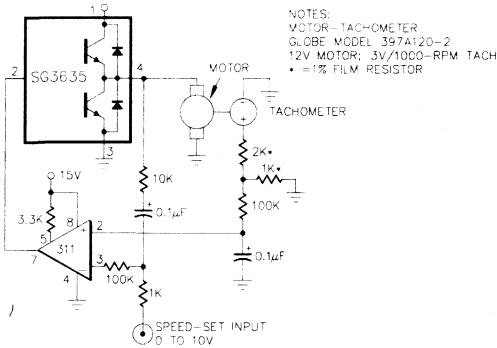


Figure 1. Used in a Closed-Loop Configuration, the SG3635 Self-Clocking Driver IC Controls Motor Speed in Proportion to 0 to 10 V Input. The Comparator Weighs the Tachometer's Output Against the Input Setting, Then Commands the SG3635 to Either Speed up or Slow Down the Motor



TRACE	VERTICAL	HORIZONTAL
A	5V/DIV	5mSEC/DIV
B	0.5V/DIV	5mSEC/DIV

Figure 2. Switching on in Discrete Increments (trace A), Fig 1's Driver IC Forces Current (traces B) into the Motor to Speed it up. Upon Reaching Equilibrium, the Circuit Oscillates Around the Setpoint

The 3.3-kΩ resistor from the comparator's offset pin to the 15V supply provides enough offset to prevent motor turn-on with a 0V speed setting. In this application the driver only sources current: The sink transistor is never enabled. You could turn the sink device on to dynamically brake the motor, but the motor's back EMF would cause considerable power dissipation. The back EMF appears after the initial inductive spike (clamped by the internal commutation diode), which appears when the IC's output switches LOW.

## IC's HIGH-CURRENT OUTPUT YIELDS FAST MOTOR REVERSAL

What about motor-reversing capability? Fig 3's single-supply circuit uses two SG3635s in a bridge configuration. The flip flop generates the necessary complementary instructions to the ICs' Enable inputs. In this example, the SG3635s' Pulse inputs are grounded; you could instead pulse-width modulate them to control motor speed.

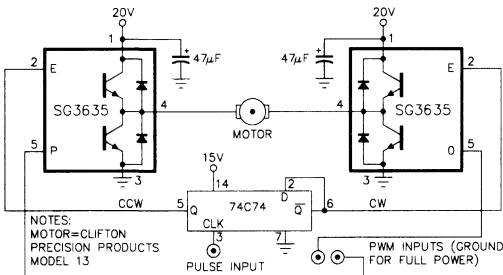


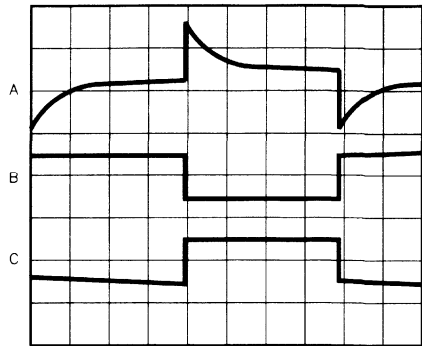
Figure 3. This Push/Pull Bridge Configuration Allows Two Driver IC's to Provide Bidirectional Motor Drive. A Command to the Flip Flop's Clock Input Causes Instantaneous Reversal. Ground the SG3635's Pulse Inputs for Full Speed; Apply a Pulse-Width-Modulated Input to Control the Speed

Fig 3's circuit is a good test of the IC's peak current capabilities, because motors present a very difficult load during instantaneous reversal. Fig 4, trace A shows the current; traces B and C represent the SG3635's voltage outputs. The motor draws 200mA during a reversal because of the armature's stored energy.

## Servoed motor makes position clear

In addition to controlling speed and direction, you can use the SG3635 in a simple circuit to control a shaft's position (Fig 5). In this configuration, the motor drives a mechanical scanner in either direction between a set of programmed limits. The driver IC's ground pin is biased at -15V, allowing the device's output to swing symmetrically about 0V.

The 5-kΩ pickoff potentiometer detects the scanner's position, then trips a pair of limit comparators; these comparators in turn



TRACE	VERTICAL	HORIZONTAL
A	2A/DIV	50 mSEC/DIV
B	20V/DIV	50 mSEC/DIV
C	20V/DIV	50 mSEC/DIV

Figure 4. Large Peak-Reversal Current in Fig 3's Motor is Evident in Trace A. Traces B and C Show the Drivers' Output Reversal; the Outputs Handle the 3A Motor Peaks Cleanly

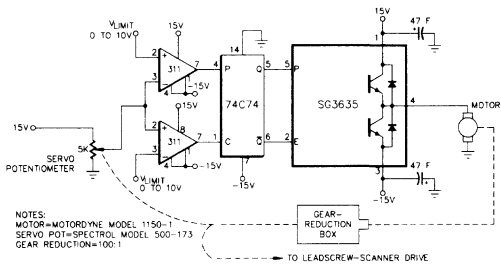


Figure 5. Control a Shaft's Angular with This Servo-Loop Circuit. Select the Position by Applying Limits to the Comparator Inputs. The Circuit Uses Supplies Shifted 15V Negative to Provide a Ground-Level Bipolar Output to the Motor

bias the RS flip flop that controls the SG3635. To provide logic level compatibility with the driver, the flip flop uses 0V and -15V supplies instead of the usual +15V and 0V configuration. This circuit forces the scanner to run continuously between the limits defined by the  $V_{LIMIT}$  inputs. You could control speed by summing pulse-width modulated signals at the comparator inputs or by gating the SG3635's inputs.

## DRIVE LONG CABLES WITH TOTAL DATA RECOVERY

You can also use the driver IC in applications other than motor control. Consider, for example, the problem of driving long cables at high data rates - a difficult task because of the rapid buildup of parasitic capacitance with increasing cable length. In a remote data-monitoring application, for instance, a 10,000-ft cable displays 0.1-μF capacitance - a brutal load at high speed, making receiver-end data recovery difficult.

# APPLICATION NOTES – SG3635

**Fig 6's** circuit provides the drive for this difficult load: the V/F converter presents a serial, 100-kHz square-wave data format to the SG3635. The driver's output (**Fig 7, trace A**) - somewhat distorted because of the load - drives the line. Trace B shows the IC's output current: The 5A peaks at the waveforms's edges clearly reflect the heavy capacitance.

The square wave's distortion is relatively minor, allowing easy data recovery. The 311 comparator uses a simple RC network to set an adaptive amplitude threshold against which to compare the line output. Because the threshold is derived from the signal, power-supply shifts produce no undesirable effects.

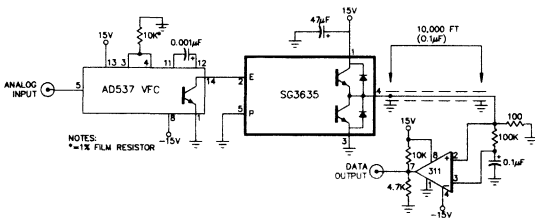
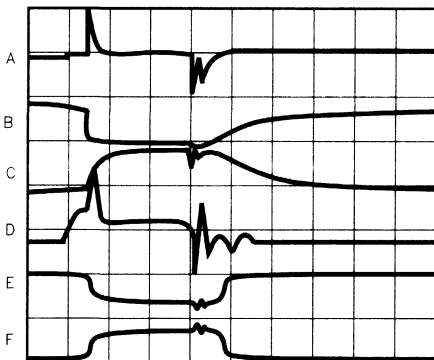


Figure 6. Driving a Brutal Capacitive Load Presents Little Problem to the SG3635 Driver. In This Circuit, the IC Drives a 10,000 ft Data-Communications Cable Having 0.1µF Capacitance. The Driver Transmits Serial 100-kHz Data to the Receiving Comparator.



TRACE	VERTICAL	HORIZONTAL
A	5V/DIV	500 nSEC/DIV
B	200V/DIV	500 nSEC/DIV
C	3A/DIV	500 nSEC/DIV
D	5V/DIV	500 nSEC/DIV
E	200V/DIV	500 nSEC/DIV
F	3A/DIV	500 nSEC/DIV

Figure 7. The Effects of Fig 6's Glutinous Capacitive Load are Evident in Traces A and B. The 10,000 ft. Line Absorbs 5A Current Peaks During the IC's Switching Transitions. The Receiving-End Comparator Uses an Adaptive Amplitude Threshold to Produce a Clean Output.

## VALVE-CONTROL CIRCUIT MAINTAINS CONSTANT pH

In another nonmotor-related application, you can use the SG3635 in conjunction with a pH probe as a 3-mode controller (**Fig 8**). The FET op amp unloads the probe and routes the signal - via an RC filter - to the two comparators. The comparators, configured as a double-ended limit detector, bias the SG3635; the IC then drives valves that feed either acidic or basic solutions to the chemical vessel.

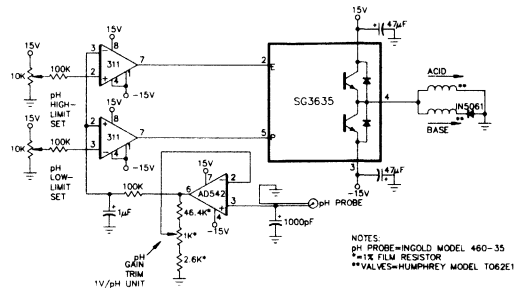


Figure 8. Regulate a Chemical Solution's Acidity with this 3-mode Controller Circuit. The SG3635 Drives the Valves that add Either Acidic or Basic Solution to the Bath. Set the Desired pH with Potentiometer-Determined Comparator Limits.

If pH is correct, both comparator's outputs remain HIGH and neither valve energizes: The appropriate LOW-switching comparator redresses eventual pH imbalance by turning the necessary valve on.

In a final example of the driver IC's versatility, consider its use as a high power-transistor driver. Driving these devices at high speed requires active turn-off techniques to sweep charges from the base-emitter junction. Moreover, many high-voltage power transistors need negative base bias to guarantee breakdown ratings.

Assume, for example, the use of unipolar base drive (**Fig 9a**) for a high-power 2N6308. **Fig 10, trace A** shows the transistor's base waveform; traces B and C display collector voltage and current, respectively. Because the base drive is unipolar, the collector turns off slowly: Voltage and current require about 1.5µsec to settle. What's more, the transistor dissipates considerable power during turnoff, increasing its vulnerability to secondary breakdown. Inductive loads (eg. flyback transformers) can exacerbate the situation.

The solution? **Fig 9b's** circuit uses an SG3635 to provide bipolar base drive, thereby shortening turn-off time. The 311 comparator shifts the TLL-command level to bias the driver's Enable input; shifting is necessary because the SG3635's ground pin is returned to -15V. The 25\_ resistor to ground limits the transistor's reverse bias. Traces D, E and F show the @N6308's base

voltage and collector voltage and current, respectively - you can see that collector turn-off time decreases to 200nsec, greatly reducing the likelihood of secondary breakdown.

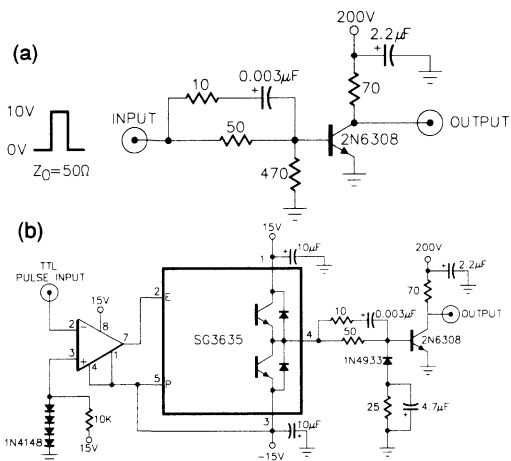
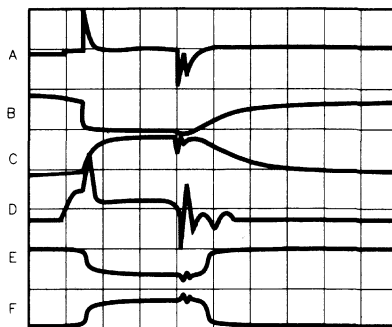


Figure 9. Using Unipolar Base Drive (a) for a High-Power Transistor can Result in Slow Collector Turn-Off. A Bipolar-Drive Circuit (b) Shortens Turn-Off Time Considerably by Sweeping out Base-Emitter Change. Moreover, the Negative Base Bias Improves the Transistor's Breakdown Characteristics



TRACE	VERTICAL	HORIZONTAL
A	5V/DIV	500 nSEC/DIV
B	200V/DIV	500 nSEC/DIV
C	3A/DIV	500 nSEC/DIV
D	5V/DIV	500 nSEC/DIV
E	200V/DIV	500 nSEC/DIV
F	3A/DIV	500 nSEC/DIV

Figure 10. Dramatic Turn-Off-Time Differences Between Unipolar and Bipolar-Base-Drive Circuits (Figs 9a and 9b) are Evident in This Photo. Long Collector-Voltage (trace B) and -Current (trace C) ON-to-OFF Transitions Result From the Unipolar Drive (trace A); the Bipolar Drive (trace D) Increases Turn-Off Speed More Than Sevenfold.

## ANATOMY OF A DRIVER IC

Figure 11(a) shows the SG3635 driver IC's internal organization. The main consideration in the IC's design is to make logic-level/power-load interfacing as straightforward as possible. The logic-compatible Enable and Pulse inputs operate according to the truth table shown: Accepting drive from 74C Series circuits operating at 10V or more, they're compatible with all TLL forms except 54L. You can allow the inputs to float to the HIGH state, but you must force them to ground to produce ZERO.

Negative supply voltages are permissible at the ground pin, but you must restrict the chip's total rail-to-rail voltage to 40V. The internal regulator stabilizes the IC against supply variations; the level-shift and interlock features provide proper drive levels and prevent simultaneous output-device conduction. The output sinks or sources 2A continuously (5A pk) with  $\pm 40V$  output swing; the commutating diodes handle 5A pk. Finally, the thermal-shutdown circuit disables the upper output device if chip temperature exceeds 160°C.

Why the interlock circuitry? It's important to prevent simultaneous conduction of a source/sink pair's devices (b). This condition

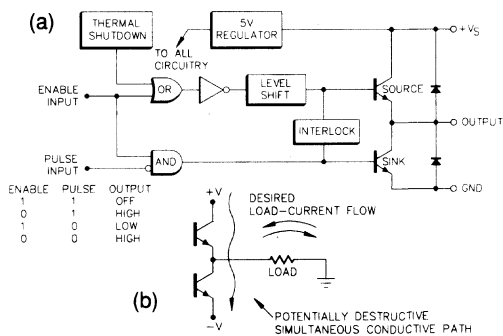


Figure 11. Providing Logic-to-Power-Drive Translation, the SG3635 (a) contains both low and high-level circuitry. The interlock circuitry-an important feature-allows only one power device to conduct at a time, thus avoiding transitional power-supply short circuits (b) An IC without the interlock can produce large current pulses (c) during switching. A test circuit (d) verifies the IC's interlock circuitry; (e) shows no common current flows in the output devices during switching.

usually arises during switching, when the respective devices are interchanging OFF and ON states. During this interval, substan-

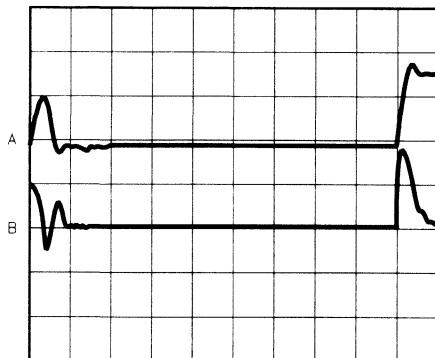


## APPLICATION NOTES – SG3635

tial supply current flows through both devices, effectively shorting the supplies. A common approach to alleviating the problem is to make the stage switch quickly, minimizing concurrent ON time.

The widely used 555 timer furnishes this simple solution. However, it still generates considerable supply glitches (c). Trace B shows the large supply-current spike the IC's output pair produces when switching (trace A). Such a current spike, in conjunction with a supply bus's impedance, can result in unacceptable system noise or device destruction.

(c)



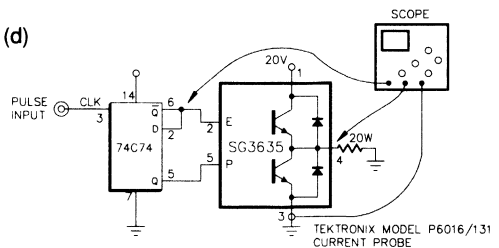
TRACE	VERTICAL	HORIZONTAL
A	20V/DIV	200nSEC/DIV
B	500mA/DIV	200nSEC/DIV

The SG3635's interlock circuitry ensures complete turn-off of one output device before the other begins to turn on. This provision eliminates supply shorts during switching, even when controlling high power. To verify this section, use the figure's test circuit (d). Part (e), trace A shows one phase (Q) of the 74C74's output; trace b depicts the driver's output.

When Q switches LOW, the SG3635 unclamps its sink transistor, then allows the source device to turn on. The reverse holds

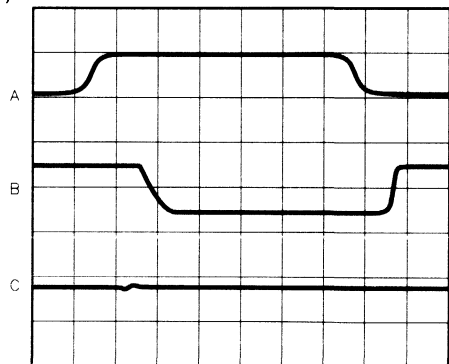
true when Q switches HIGH. These intentional turn-on delays account for the 200-nsec output-timing skew. Note in trace C - the ground-pin-current - that no current ever flows directly through the source/sink pair.

(d)



NOTES:  
RETURN SG3635 LOAD AND GROUND-PIN LEADS SEPARATELY TO SUPPLY

(e)



TRACE	VERTICAL	HORIZONTAL
A	10V/DIV	200nSEC/DIV
B	20V/DIV	200nSEC/DIV
C	100mA/DIV	200nSEC/DIV



***SIMPLIFIED HIGH-EFFICIENCY MOTOR DRIVE SYSTEMS  
WITH NEW PWM INTEGRATED CIRCUITS***

Edited by Stan Dendinger  
Manager, Advanced Product Development  
Silicon General, Inc.

**ABSTRACT**

This paper describes a new pulse width modulator circuit designed specifically for DC motor control. It provides a bi-directional pulse train output in response to the magnitude and polarity of an analog error signal input. The device is useful as the control element in motor-driven servo systems for precision positioning and speed control, as well as in audio modulators and amplifiers using carrier frequencies to 350kHz.

**INTRODUCTION**

Power management engineers have been aware for a number of years of the efficiency advantages of switching power supplies over linear designs. In response to growing production of switchers, the semiconductor industry has spawned a number of pulse width modulator (PWM) integrated circuits of varying degrees of complexity for the control of these power supplies.

Perceptive designers soon realized that the same efficiency advantages apply to motor control. Unfortunately, when they attempted to utilize existing PWM circuits, they found that the architecture was not optimized for motor control. so many auxiliary components had to be added to work around the restrictions of the PWM circuit that totally discrete designs were frequently found to be more economical.

The main difficulty has been that PWM controllers for switching power supplies were designed to be one quadrant power conditioners; i.e., the polarity of DC output voltage is fixed and proportional to a unipolar reference voltage. A second difficulty has been that power supply controllers attempt to produce an AC waveform of variable energy content, since power must be transferred through a high frequency transformer. This requires that PWM pulses alternate from side to side with a dual-driver architecture.

The requirements for PWM motor control are different: The integrated pulse train must have a DC component proportional to the magnitude of the applied reference voltage, and a polarity

determined by the sign of the reference to accomplish bi-directional rotation. All of the necessary control elements for two quadrant operation are found in the PWM circuit to be described, which is designated the SG1731.

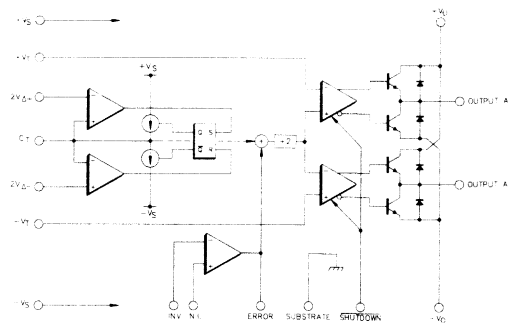


Figure 1. SG1731 Block Diagram

**BLOCK DIAGRAM**

The SG1731 contains a triangle waveform oscillator, a wideband operational amplifier for error voltage generation, a summing/scaling network for level-shifting the oscillator waveform, externally programmable PWM comparators, and dual  $\pm 100\text{mA}$ ,  $\pm 32$

volt totem pole drivers with commutating diodes for full bridge output drive. A TTL-compatible SHUTDOWN terminal forces the output drivers into a floating high-impedance state when driven LOW. Supply voltage to the circuit may be either from dual positive and negative supplies, or single-ended.

## PULSE WIDTH MODULATION

Pulse width modulation occurs by adding an error voltage to the triangle waveform, attenuating the resulting signal by a factor of 2, and comparing it to threshold voltages  $+V_T$  and  $-V_T$ , which are applied to pins 1 and 8 respectively. Figure 2 illustrates the case for  $V_{\Delta} < +V_T$ . When the error voltage is zero, no threshold crossings occur, and the output drivers remain in the LOW state. If the error voltage is sufficiently positive, the upper threshold will be periodically crossed by the shifted triangle waveform and output driver A will switch to the HIGH state. As the error voltage becomes larger, the duty cycle of driver A will linearly increase towards 100%. The same action occurs at output driver B for negative error voltages.

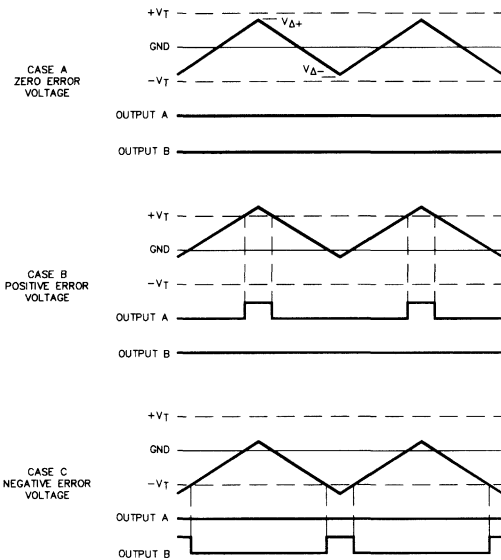


Figure 2. Deadband Operation

A motor connected across the full bridge formed by drivers A and B will receive a high frequency pulse train which, when integrated by the LR time constant of the armature, will result in a voltage drive proportional to the magnitude of the error signal. The polarity of the drive signal will be the same as the polarity of the error voltage.

With deadband operation, there is a small region around the null point of the servo loop where no power is applied to the motor. This conserves power, which may be desirable in some applications, but it also results in loss of both positioning accuracy and mechanical stiffness.

The other possible mode of operation is shown in Figure 3, where  $V_{\Delta} > V_T$ . At the loop null point the motor still receives drive pulses, which provides resistance to armature movement by external forces. The integrated drive voltage is still zero, since the drive pulses alternate in polarity with identical pulse widths at the null point.

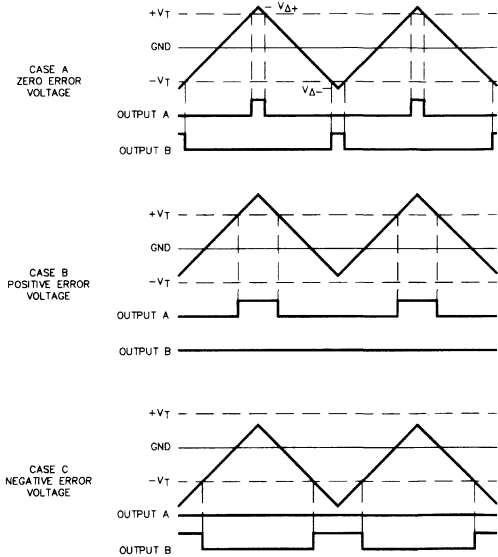


Figure 3. Non-Deadband Operation

This is the preferred mode of control in a missile fin actuator system where aerodynamic forces on the airfoil attempt to move the motor armature away from the null position. A second example where deadband operation is not desirable is a switching, or "Class D," audio amplifier. Cross-over distortion would be unacceptable, and poor speaker damping would also result.

## 4. OSCILLATOR CIRCUIT

The triangle oscillator consists of two voltage comparators, a set/reset flip-flop, a bi-directional  $500\mu A$  current source, and an external timing capacitor  $C_T$ . A positive reference voltage applied to pin 2 ( $2V_{\Delta+}$ ) sets the peak value of the triangle., and a negative reference voltage at pin 7 ( $2V_{\Delta-}$ ) determines the valley of the



# APPLICATION NOTES – SG1731

5K emitter resistors. Transistors Q8, Q11 and Q12 form a compound current mirror which converts the full differential voltage gain of the input stage into a single-ended gain referred to  $-V_S$ . A Darlington gain stage formed by Q18 and Q20 provides the large voltage swing required for the amplifier output. When the differential input voltage is not zero, that voltage appears across the 5K resistors of the input stage, increasing the operating current. Simultaneously this increased current is sensed by Q1, and current supply to the output stage is increased proportionally. Since more current is available to charge the 30pF compensation capacitor, the amplifier output voltage slews at a much higher rate. When equilibrium is again reached, the bias currents return to their normal quiescent levels.

As shown in Figure 7, the error amplifier is capable of excellent power bandwidth. Full output swing to 200kHz is available, with slew rates exceeding 15 volts/microsecond. These dynamic characteristics allow application to audio modulation circuits with very low transient distortion.

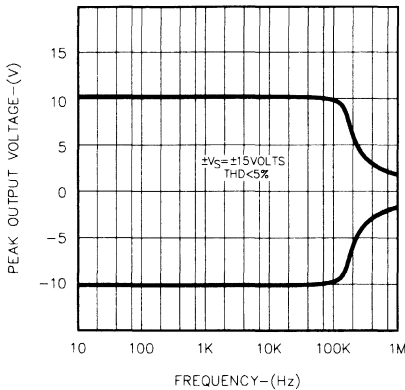


Figure 7. Error Amp Power Bandwidth

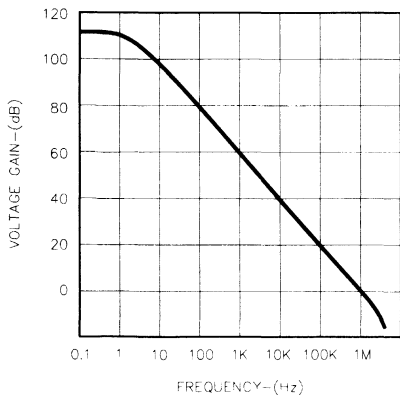


Figure 8. Error Amp Open-Loop Frequency Response

The amplifier frequency-gain plot is a constant 6dB/octave roll-off to unity gain, resulting both in unity gain stability and good transient response. Typical DC voltage gain is 110dB into a 2K load, and unity gain crossover frequency is 1 megahertz.

## OUTPUT DRIVERS

The output stage is a non-saturating quasi-complementary high current switch for efficient high frequency operation. Transistors Q3, Q4, Q5 and Q6 form a high voltage Schmitt trigger input stage. The positive feedback produces fast switching times and jitter-free pulse width modulation. Q7 and Q9 provide output current sourcing, and Q8, Q10 and Q11 provide current sinking. Commutation diodes D1 and D2 clamp inductive loads to the supply rails. Their current capability is the same as the output transistors: 200mA peak.

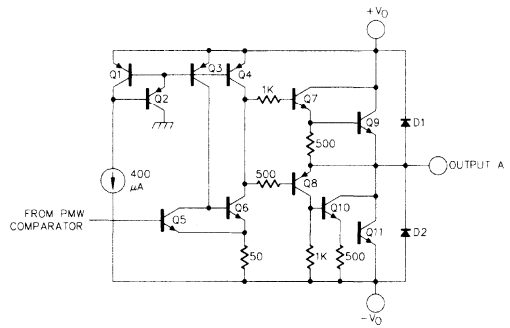


Figure 9. Half-Bridge Output Driver Schematic

## TYPICAL APPLICATIONS

### Simple Position Servo

A simple, low-voltage battery-powered position servo is illustrated in Figure 10. A resistive divider network sets up the

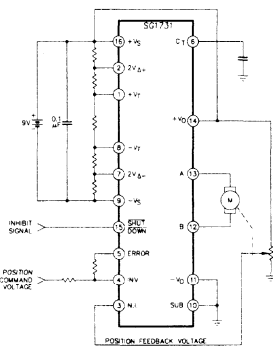


Figure 10. Error Amp Power Bandwidth

# APPLICATION NOTES – SG1731

reference voltages for triangle waveform amplitude and PWM thresholds. Since the circuit is powered by battery,  $V_{\Delta}$  is designed to be less than  $+V_T$  (deadband) to conserve power. The 9 volt DC motor is driven directly from the output drivers, and it in turn drives a position feedback potentiometer through a geartrain. The position feedback voltage is subtracted from the external position command voltage in the on-chip error amplifier. The difference between commanded position and actual position generates an error voltage which in turn generates a series of PWM pulses to the motor to correct the difference. Once null has been reached, no further power is applied to the motor until a new position command voltage is received, or the wiper is moved out of position by external forces.

## High Torque Position Servo

Figure 11 illustrates a high power version of the previous position servo loop. The control circuit is powered from balanced positive and negative supply voltages, and the output drivers switch the load between  $\pm 32$  volt supply rails for maximum output power. Complimentary emitter follower buffers on each output provide increased current gain and power handling capability.

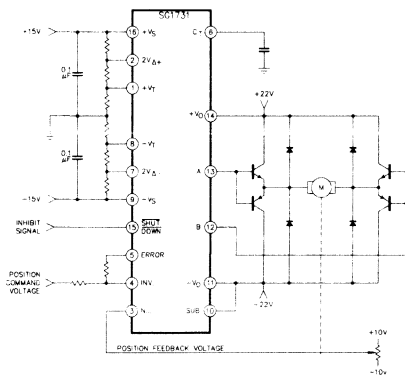


Figure 11. High Torque Position Servo

## Motor Speed Control

In Figure 12, a bi-directional motor speed control circuit is derived from the previous circuit by substituting a tachometer for the position pot in the motor feedback circuit. The external command voltage now represents a speed rather than a position, with direction of motor rotation a function of command voltage polarity. Magnetic tape drives are an example of this configuration, with the velocity feedback voltage frequently derived from an encoded bit pattern on the tape.

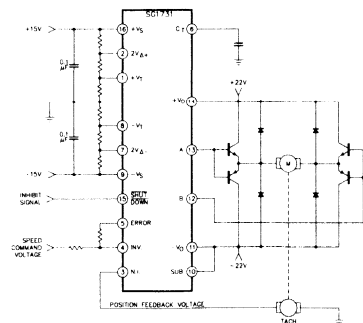


Figure 12. High Torque Bi-Directional Motor Speed Control Circuit

## PWM Audio Power Amplifier

A complete PWM power audio amplifier is illustrated in this last application. The circuit reconstructs an amplified version of the audio input voltage by deriving the feedback signal from the speaker voice coil. An oscillator frequency of 300kHz was chosen to maintain a ratio of at least 15 to 1 between the carrier frequency and the highest modulation frequency (20kHz).

Ratios of at least 10 to 1 are necessary for acceptable linearity, low distortion and good transient response. An LC output filter smooths the pulse width modulated output to the speaker; its design is critical for low distortion. This circuit, consisting of one integrated circuit and four power transistors, can deliver 150 watts RMS of power into a 4ohm load.

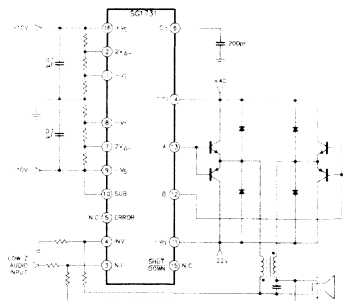


Figure 13. P.W.M. Audio Power Amplifier

## CONCLUSION

A new pulse width modulator integrated circuit designed for motor control has been described which includes all the circuitry necessary for implementing high efficiency bi-directional controllers. Inputs and outputs have been designed for maximum flexibility, allowing the device to be useful in a wide range of position and speed servo systems.





## **SIMPLIFY FEEDBACK CONTROLLERS WITH A 2-QUADRANT PWM IC**

*A 2-Quadrant Pulse-Width-Modulator IC Eliminates Many of the Problems  
Arising With Unipolar Devices in Feedback-Control Applications.*

Stan Dendinger  
Manager, Advanced Product Development  
Silicon General, Inc.

### **INTRODUCTION**

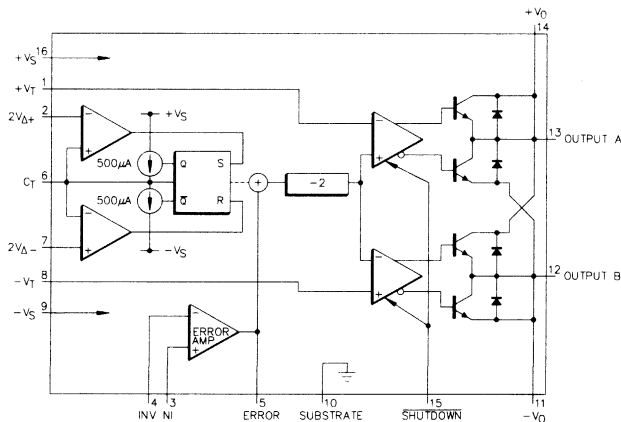
The SG1731 pulse-width modulator (PWM) IC brings to motor controllers and similar applications the efficiency previously limited to switching-power-supply circuitry. As a result, you can use it to design motor-controller circuits having parts counts smaller than previously achievable.

Switching-power-supply PWM controllers are designed to be 1-quadrant power conditioners, furnishing a dc output voltage with fixed polarity and amplitude proportional to a unipolar reference voltage. Motor controllers, on the other hand, require an integrated pulse train with a dc component proportional to the magnitude of an applied reference voltage and polarity determined by the reference's sign. Otherwise, they can't produce bidirectional rotation.

In addition, the architecture of power-supply PWM ICs often proves inappropriate for motor-control tasks, requiring so many auxiliary circuits that totally discrete designs often prove more economical.

PWM power-supply controllers attempt to produce a variable-energy-content ac waveform, because power must be transferred via a high-frequency transformer. Unlike those from a PWM motor control IC, the PWM pulses produced by these devices must alternate and are therefore produced by a dual-driver architecture.

**Fig 1** shows the SG1731's structure. The device contains a triangle-waveform oscillator whose frequency is determined by



**Figure 1.** A DC-Motor Pulse-Width-Modulator IC. The SG1731 features 50Hz to 350kHz oscillator range, adjustable deadband operation, a high-slew-rate error amplifier, a Shutdown input providing floating outputs, and dual 100mA source/sink output drivers capable of operating from supplies to +32V.

an external capacitance at pin 6 and whose amplitude can be set through resistor or voltage programming at pins 2 and 7. The IC also contains a wide-band op amp for error voltage generation, a summing/scaling network for level-shifting the oscillator waveform, externally programmable PWM comparators and dual  $\pm 100\text{mA}$  continuous ( $\pm 200\text{mA}$  pk),  $\pm 32\text{V}$  totem-pole drivers with commutation diodes for full-bridge output drive. Typical supply voltages are  $\pm 15\text{V}$ , although the device can function at values as low as  $\pm 3.5\text{V}$ . You can use dual- or single-polarity supply voltages. Pin 15, the Shutdown terminal, forces the output drivers into high-impedance states when LOW.

## ERROR VOLTAGE CONTROLS PULSE-WIDTH MODULATION

Pulse-width modulation occurs when an error voltage gets added to the triangle waveform, attenuating the resulting signal by a factor of two and comparing it with threshold voltages  $+V_T$  and  $-V_T$  (pins 1 and 8). Fig 2 illustrates the case for  $V < V_T$ . When the error is 0V, no threshold crossings occur, and the output drivers remain at  $-V_O$  (Fig 2a). As the error voltage goes positive, the upper threshold gets periodically crossed by the shifted waveform, and the output driver A switches to  $+V_O$  (Fig 2b). As the error voltage becomes larger, the duty cycle of driver A increases linearly toward 100%. The same action occurs at output B (Fig 2c) for negative error voltages.

A motor connected across the full bridge formed by drivers A and

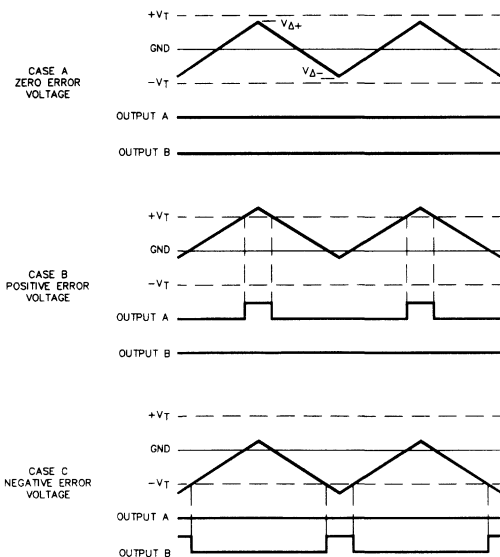


Figure 2. With Oscillator Voltage Less Than Threshold Voltage, the SG1731's Outputs Switch LOW to HIGH When the Error Voltage Shifts Oscillator Output Outside the Threshold

B receives a high-frequency pulse train. When integrated by the armature's L/R time constant, the pulse train results in a voltage drive proportional to the error signal's magnitude. Drive-signal and error-voltage polarities are identical.

## NO MOTOR POWER REQUIRED WITH DEADBAND OPERATION

With this deadband operation, no motor power gets applied in a small region around the servo loop's null point. Although this action conserves power (desirable in some applications), it results in a loss of both positioning accuracy and mechanical stiffness. Deadband operation is also not desirable in switching (Class D) audio amplifiers. There, crossover distortion is unacceptable and poor speaker damping results (see "Class D amplifiers for audio applications").

The other SG1731 mode of operation is shown in Fig 3, where  $V > V_T$ . At the loop null point, the motor receives drive pulses that resist externally produced armature movement. The integrated drive voltage is 0V with no error voltage (Fig 3a) because the drive pulses alternate in polarity and have identical widths at the null point. Figs 3b and 3c show the effects of error voltages on the oscillator signal.

This is the preferred control mode in a missile-finactuator system, for example, where aerodynamic forces on the airfoil attempt to move the motor armature away from the null position.

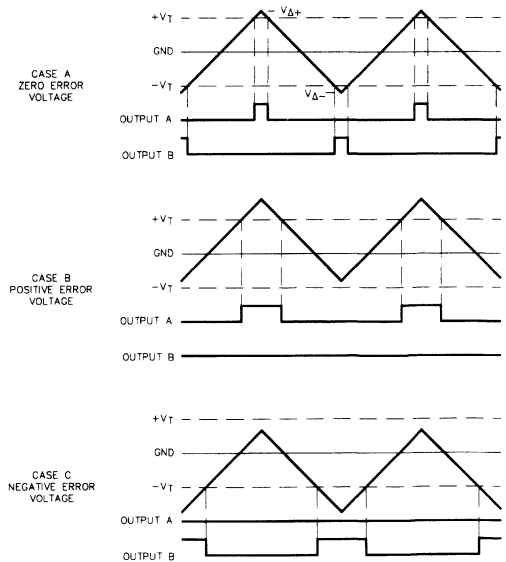


Figure 3. With Oscillator Voltage Greater Than Threshold Voltage in the SG1731, Lack of a Deadband Provides Resistance to Motor Movement Caused by External Forces.

## APPLICATION NOTES – SG1731

You can configure the SG1731 as a bidirectional motor-speed controller as shown in Fig 4. The motor specified runs directly from the device's outputs, and the tachometer produces an output directly proportional to the motor's speed and direction. This high-level signal gets divided down and filtered by the discrete components associated with the tachometer, then applied to the SG1731's error-amplifier input. The 1731 internally compares this signal with the speed-control input's value and provides output drive of the appropriate phase and magnitude, completing a speed-control loop. Set the comparator voltages for nondeadband operation. The lowest rotation speed depends on the motor's friction characteristics.

Instantaneous-direction-reversing applications might require an optional current-limiting circuit rather than  $\pm 15V$  applied directly to pins 11 and 14. At the time of direction reversing, the motor draws peak currents that could damage the 1731's output drivers.  $Q_1$ 's ability to supply current is controlled by  $Q_2$ 's state, which in turn depends on the voltage across the  $4\Omega$  current-sensing resistor. If the motor current exceeds 200 to 250mA,  $Q_2$  turns on and  $Q_1$  shuts off.

### EXTEND CONTROL CAPABILITY WITH HIGH-CURRENT DRIVERS

Another bidirectional speed-control loop appears in Fig 5. Here, SG1635 drivers control higher motor power and eliminate the need for a speed-monitoring tachometer; instead, back EMF produced by the motor serves as a feedback signal. This arrangement entails some increase in circuit complexity but eliminates the tachometer's cost.

The circuit's basic servo mode is similar to that of Fig 4. The 311 comparator ( $IC_1$ ) senses the polarity of the input command signal. Its output goes to the 1635s via a diode and inverter, allowing both 1635s to be OFF, neither sinking nor sourcing current, when the 1731 is not producing output pulses. Fig 6 shows the circuit waveforms. When either 1731 output is HIGH, the other output is LOW, and the motor is driven. When both outputs are LOW, the 1635s are OFF and the motor is electrically floating.

The motor's inductive turn-off spike gets damped by the 1635s'

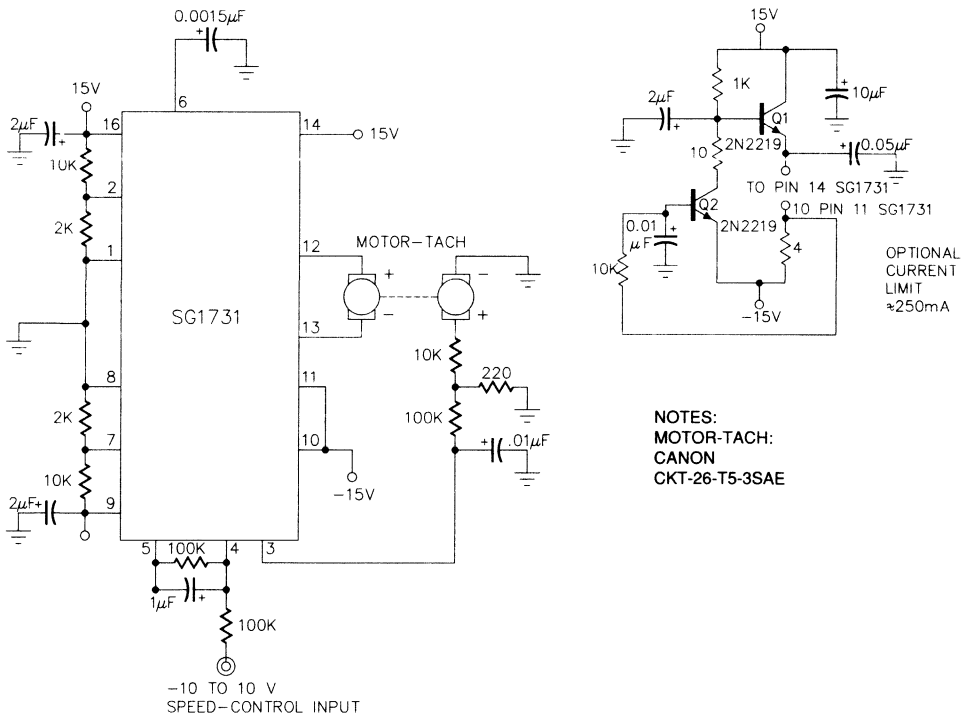


Figure 4. In This Bidirectional Motor-Speed Controller, the Tachometer Provides Feedback While the Current-Limiting Circuit Protects the Outputs From Surge Currents.

# APPLICATION NOTES – SG1731

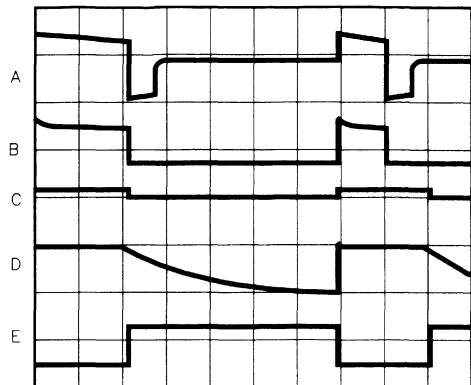
internal diodes. After turn-off, the waveform returns to a dc level determined by the back EMF of the undriven motor, now functioning as a tachometer. This level gets differentially picked off by the 301A op amp ( $IC_3$ ), whose output feeds a switched synchronous filter. This filter, composed of the FET and the  $100\text{-k}\Omega/0.01\text{-}\mu\text{F}$  combination, samples the back-EMF value during the motor's powered interval.

A 311 ( $IC_2$ ) gates the FET switch synchronously with the 1731's output. The diode-RC network feeding  $IC_2$  allows either output to actuate the filter. The  $10\text{-k}\Omega/0.02\text{-}\mu\text{F}$  network's decay time length (Fig 6, trace D) ensures that the FET drive (trace E) remains OFF until well after the inductive spike has settled out.

The pure dc filter output feeds back to the 1731's amplifier to complete the speed-control loop. The zener-diode bridge clamps all inputs above approximately  $\pm 10\text{V}$ ; otherwise the 1731's outputs would saturate at dc and the switched feedback loop would never operate.

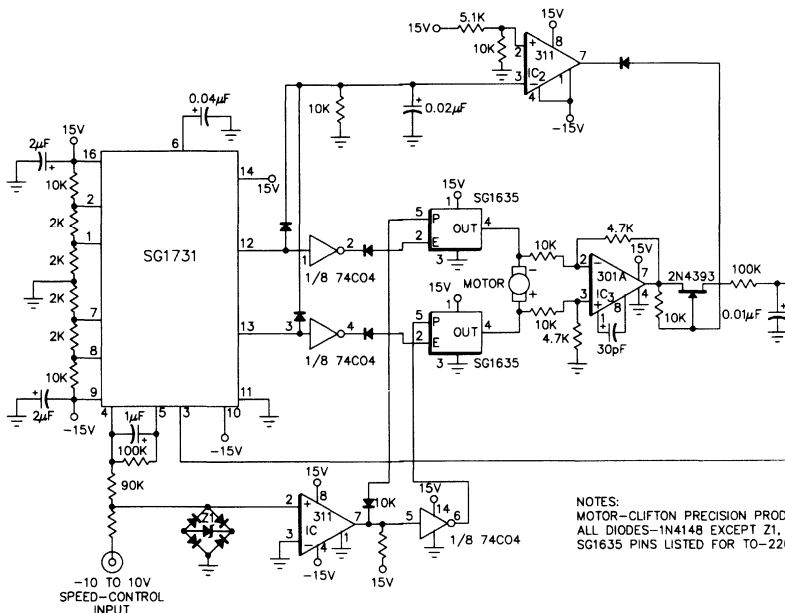
Another SG1731 application appears in Fig 7. Here, two 1731's bidirectionally control the speed and shaft position of a printed-circuit-type motor.

The shaft position gets sensed at the output of a geardown



TRACE	VERTICAL	HORIZONTAL
A	5V/DIV	200 $\mu\text{SEC}/\text{DIV}$
B	20V/DIV	200 $\mu\text{SEC}/\text{DIV}$
C	10V/DIV	200 $\mu\text{SEC}/\text{DIV}$
D	20V/DIV	200 $\mu\text{SEC}/\text{DIV}$
E	20V/DIV	200 $\mu\text{SEC}/\text{DIV}$

Figure 6. Waveforms for Fig 5's Tachless Controller Include the Controller's Outputs (traces B and C) and the Voltage Across the motor (trace A). The  $10\text{-k}\Omega/0.02\mu\text{F}$  Network's Decay Time (trace D) Ensures that the FET Drive (trace E) Remains off Until After the Inductive Spike has Settled out.



NOTES:  
 MOTOR—CLIFTON PRECISION PRODUCTS—TYPE 13  
 ALL DIODES—1N4148 EXCEPT Z1, 1N1960, 10V  
 SG1635 PINS LISTED FOR TO-220 CASE

## APPLICATION NOTES – SG1731

transmission. Slave the 1731s together to avoid producing frequency beating from separate oscillators; take the triangle waveform of SG1731<sub>A</sub> through a 301A follower and use the output to drive the capacitor pin of SG1731<sub>B</sub>. This is an effective way to slave 1731s together because the follower's low-impedance output overrides whatever state the unbiased internal oscillator of SG1731<sub>B</sub> might take. Control the shaft position by sensing it with a potentiometer that feeds a signal back to SG1731<sub>A</sub>. This signal then gets compared with the Position input, and the outputs of SG1731<sub>A</sub> drive the shaft to the position required to balance the error amplifier's inputs.

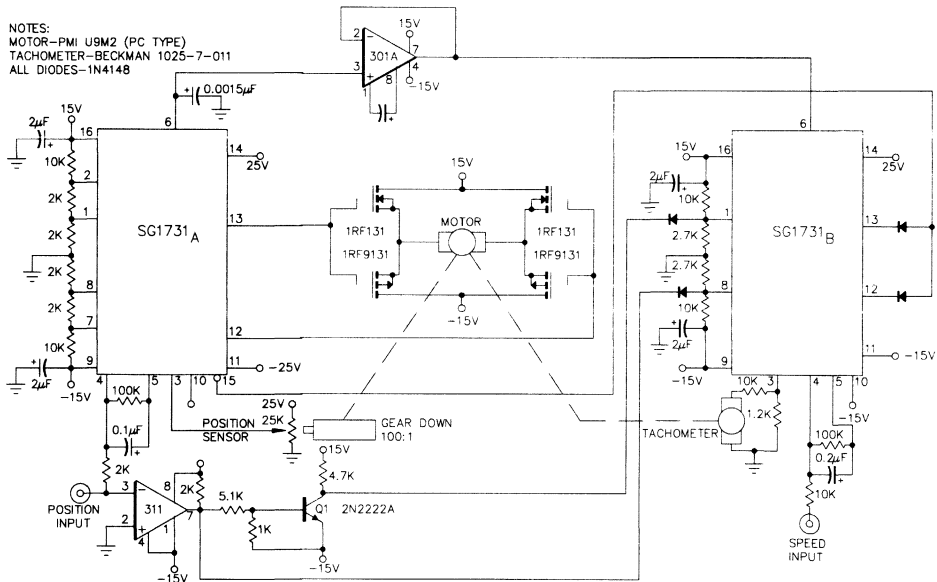
SG1731<sub>B</sub> functions in a speed-control loop similar to that described in Fig 4. It controls speed by using its output pins, via a diode OR gate, to pulse-width-modulate SG1731<sub>A</sub>'s Shutdown pin. The 311 comparator prevents either SG1731<sub>B</sub> output from going LOW on a dc basis by synchronously gating signals into the device's output comparators, forcing the appropriate output HIGH.

Consider SG1731<sub>A</sub> to be a position servo; SG1731<sub>B</sub>'s controls how quickly the position is acquired. Deadzone control results from voltage-modulating SG1731<sub>B</sub>'s comparator thresholds.

### Fan-temperature control safeguards instruments

You can also use a 1731 to control a fan motor's speed, regulating instrument temperature and extending fan life (Fig 8). At least one oscilloscope manufacturer uses this approach, and it has also found use in several military applications.

When power is applied, the thermistor, located near the fan, has a high resistive value. This condition unbalances the amplifier-driven bridge, sending pin 12 LOW. Q<sub>1</sub> and the fan motor are off. But as the instrument warms, thermistor resistance decreases, producing PWM signals at pin 12 and turning Q<sub>1</sub> and the fan motor on.



# APPLICATION NOTES – SG1731

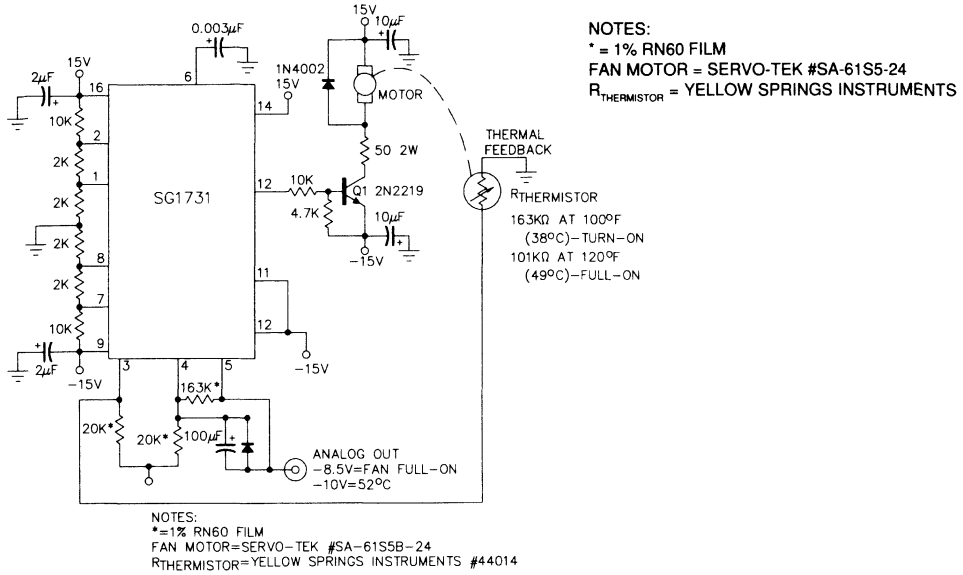


Figure 8. A Fan-Temperature Controller's Error-Amplifier Output (pin 5) Warns of an Overtemperature Condition

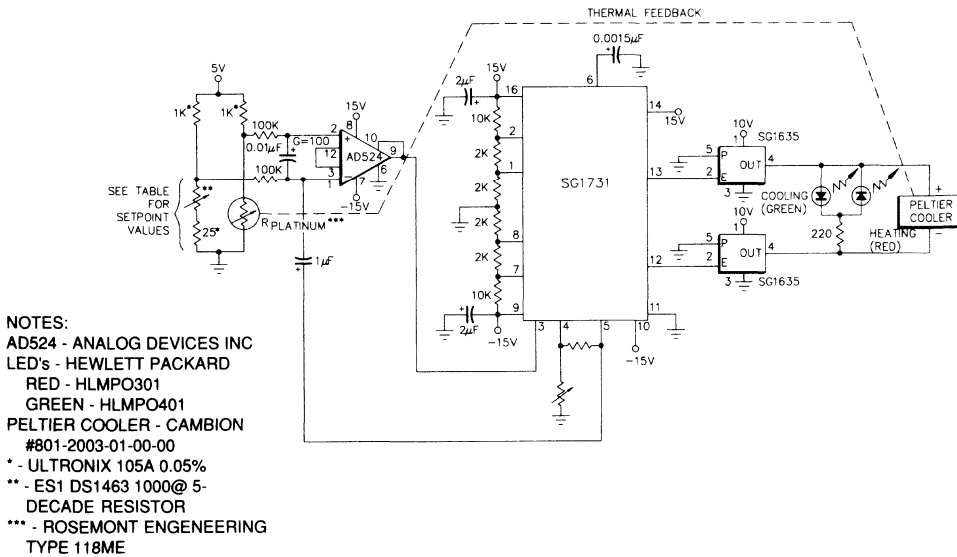


Figure 9. A Well-Insulated Peltier Cooler With Good Heat Removal on its Normally Hot Side Specs Stability Better Than 0.02°C typ.

## APPLICATION NOTES – SG1731

### ELIMINATE SERVO HUNTING WITH LONG TIME CONSTANTS

The 100- $\mu$ F capacitor determines the time constant across the error amplifier; a short time constant produces audibly annoying hunting in the servo. The 50 $\Omega$  resistor limits motor current, and the IN4002 diode dampens motor spikes.

The SG1731 can function in nonmotor applications, too. The freezing point of water serves as a reference point for the calibration of various types of temperature sensors, such as platinum RTDs and thermocouples. In such applications, an ice slurry in a Styrofoam container or a Dewar bottle is usually used to achieve the 0°C condition. Although inexpensive, this approach requires constant ice replenishment and water removal and tends to be messy. As an alternative, you can use the SG1731 to provide 2-quadrant control for a Peltier-junction-type thermoelectric cooler.

Current flow in a Peltier device cools one side of the junction and heats the other; reversing the applied current causes the cold side of the junction to heat and the hot side to cool. Commercial devices use a large number of junctions to achieve high thermal capacity and are about the size of a postage stamp. They are

optimized for one direction of current flow but can work both ways.

### TEMPERATURE REFERENCE IS BIDIRECTIONAL

Fig 9's circuit capitalizes on this characteristic to achieve a very precise temperature reference that cools to 0°C and then settles out very quickly. Most thermal control loops settle slowly because energy can only be removed (as in a refrigerator) or added (as in a crystal oven). But because the Peltier device is thermodynamically bidirectional, it's an ideal choice for use in a low-temperature servo.

When power is applied, the platinum sensor (at a high resistive value) unbalances the bridge and causes the AD524 instrumentation amplifier to saturate negatively. This action turns the 1731 and its 1635 drivers on, resulting in current flow through the Peltier device in the cooling direction. When the temperature reaches 0°C, the 1731 tends to cut off, causing loop overshoot. However, the heat-pump reversal in the Peltier device forces short thermal settling times.

The 100-k $\Omega$  potentiometer adjusts loop gain; the 1- $\mu$ F capacitor sets bandwidth. The 100-k $\Omega$  resistors and the 0.01- $\mu$ F capacitor

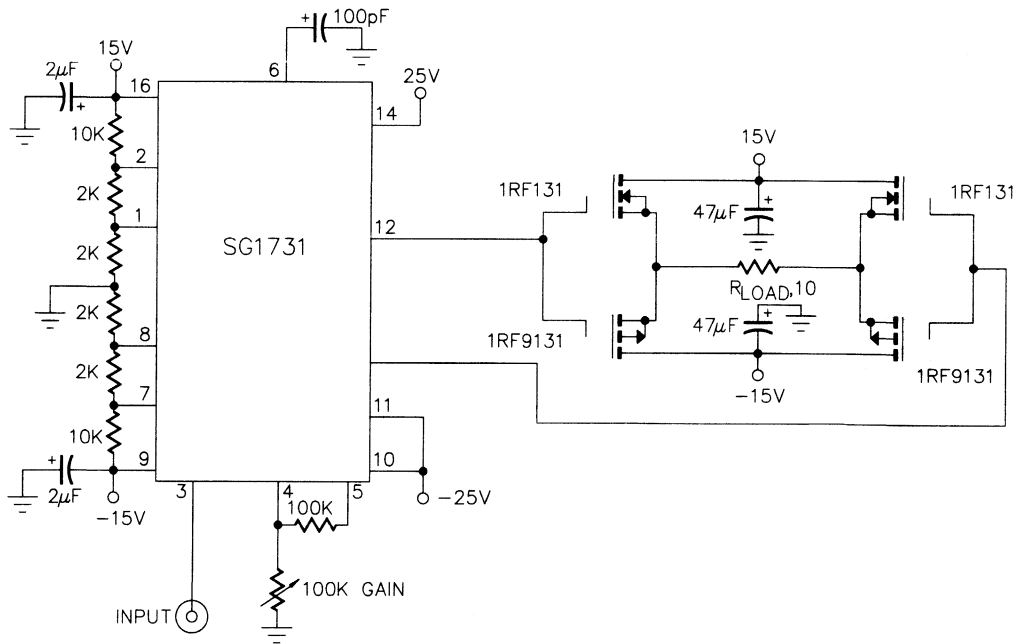


Figure 10. A Switched-Mode Power Amplifier Using a 25-kHz Carrier Transmits a 400-Hz Waveform to a Load

# APPLICATION NOTES – SG1731

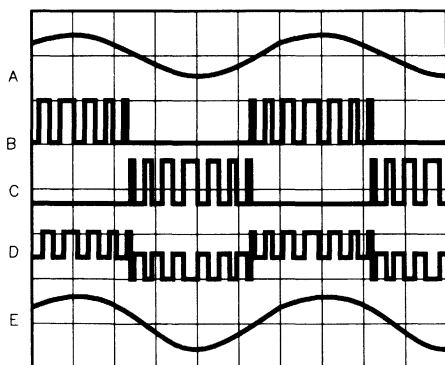
across the instrumentation amplifier filter out the fast chopping noise the platinum sensor, a wiresound device, picks up.

If you use the resistance decade shown, you can control the junction at any desired temperature around 0°C. For an ideal 1000Ω sensor at 0°C, the table values shown in Fig 9 apply. You can substitute the actual 0°C value for the platinum sensor used, biasing all values by the difference between the sensor resistance at 0°C and 1000Ω. The bidirectional thermal control and high loop gain produce very rapid response to any shift in temperature setpoint, plus high stability.

## MOTORS ADAPT EASILY TO CLASS D OPERATION, SPEAKERS DON'T

Finally, the SG1731's 2-quadrant capability allows its use as a switched-mode (Class D) power amplifier. Motors and other devices that can integrate the time-power spectrum of Class D amplifier output are obvious loads. The design can also serve audio applications but requires careful attention to output filtering to achieve acceptable distortion levels.

Fig 10 shows the 1731 set up to deliver high power to a 10Ω load via complementary power FETs. The device's output stage swings ±25V, providing a 10V enhancement for turning on the FETs. The active 1731 outputs are ideal for driving power FETs because they can both source and sink the relatively high gate currents caused by the FETs' input capacitances. Fig 11 shows the waveforms associated with this circuit.



TRACE	VERTICAL	HORIZONTAL
A	10V/DIV	500μSEC/DIV
B	50V/DIV	500μSEC/DIV
C	50V/DIV	500μSEC/DIV
D	50V/DIV	500μSEC/DIV
E	20V/DIV	500μSEC/DIV

Figure 11. In These Waveforms for Fig. 10's Amplifier, Trace A is the Amplifier's Input, Traces B and C the 1731's Outputs and Trace D the Waveform Across the Load. Trace E, a 3-kHz Filtered Version of Trace D, Shows That Power Density Approximates Input Signal

## CLASS D AMPLIFIERS FOR AUDIO APPLICATIONS

Almost all amplifiers use some form of output pass element to deliver power to a load. Because the amplifier controls this pass element, and because the amount of power delivered to the load varies, dissipation is inevitable. And at high power, substantial dissipation losses place limits on packaging, power consumption and efficiency.

One form of amplifier, the Class D stage, largely circumvents these problems by using a switch-mode output stage to deliver power to the load. Because the amplifier's output is either ON or OFF, efficiency is higher than that of a linear stage, and heat dissipation is low. In Fig 12, the output of such a stage is represented by a series of width modulated pulses whose power-time spectrum is related to the input signal.

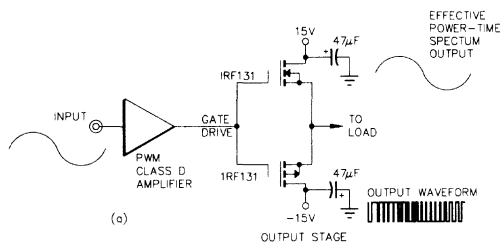


Figure 12. A Switched-Mode PWM Class D Amplifier Coupled to an FET Output Stage Provides Efficient Operation

In theory, this type of stage can serve in an efficient audio amplifier. And recently, designers have expressed a great deal of interest in developing such an amplifier. However, practical problems have made a workable switching design for audio difficult to achieve.

Historically, switched-mode-amplifier designs called for complex circuitry and expensive output devices. Producing a pulse-width modulator that provides 2-quadrant response with high linearity and wide bandwidth was difficult. In addition, even if available, low-loss output switches that operated at high carrier frequencies were expensive, and the drive circuitry quite complex.

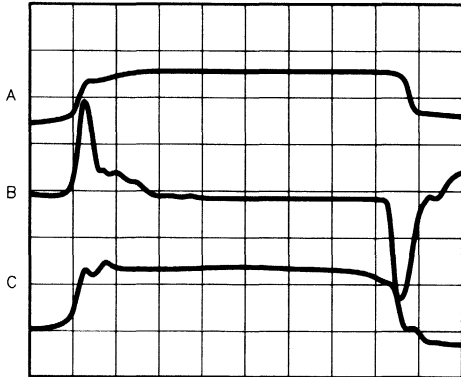
The introduction of power-FET devices has reduced design-cost and complexity problems in the output stage. But although such components make the job easier, designers still must deal with several issues to achieve optimum performance.

One unpleasant surprise is the combination of the high-frequency carrier and the FET's input capacitance. The FET gate drive (Fig 13, trace A) causes the current drawn through the input capacitances (trace B) to peak at 400mA on both edges as the FETs switch. Although the FETs have a high impedance at dc, the high carrier frequency required for audio calls for sub-



## APPLICATION NOTES – SG1731

stantial average gate current. This requirement in turn calls for some form of preceding driver.



TRACE	VERTICAL	HORIZONTAL
A	50V/DIV	200nSEC/DIV
B	200mA/DIV	200nSEC/DIV
C	20V/DIV	200nSEC/DIV

Figure 13. Fig 12's FET Output Stage Draws 400mA pk Gate Current When the FET's Switch (trace B). Trace A is the Gate Drive Signal; Trace C, the FET's Source Lines.

A more serious problem centers on filtering the carrier at the load (a speaker in audio applications). Filter design is complicated by the uncertain characteristics of the lead wire and speaker that connect to the amplifier. Even if these parameters are fixed by specification, the speaker's reactive nature complicates the design.

Even assuming the filter can be built, the waveform across the speaker is well out of the phase with the input because of carrier-induced phase shift as well as filter phase shift. As a result, closing a feedback loop from the load proves difficult. It might be possible to use a complementary phase-shift network to correct for this shortcoming, but the design of this type of an audio-grade compensation scheme is difficult. Without feedback, the problem goes away, but nonlinearities in the pulse-width modulator then contribute to output distortion.

Finally, the high-frequency harmonics in the switching stage pose a difficult RFI-suppression problem. The same fast switching that yields efficiency and wide-range audio bandwidth also qualifies as a potential broadband radio transmitter and must be suppressed. This need mandates careful layout, expensive and complex packaging and RFI suppression on both power and speaker connections.



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<b>2</b>	<b>PART NUMBER INFORMATION</b>
<b>3</b>	<b>GENERAL INFORMATION</b>
<b>4</b>	<b>POWER SUPPLY CIRCUITS</b>
<b>5</b>	<b>MOTION CONTROL CIRCUITS</b>
<b>6</b>	<b>POWER DRIVER AND INTERFACE CIRCUITS</b>
<b>7</b>	<b>OPERATION AMPLIFIERS AND COMPARATORS</b>
<b>8</b>	<b>CORE MEMORY CIRCUITS</b>
<b>9</b>	<b>AUTOMOTIVE CIRCUITS</b>
<b>10</b>	<b>OTHER CIRCUITS</b>
<b>11</b>	<b>PACKAGE INFORMATION</b>
<b>12</b>	<b>APPLICATION INFORMATION</b>
<b>13</b>	<b>SALES OFFICES</b>

### ALABAMA

**R.O. Whitesell & Assoc.**  
P.O. Box 1797  
2227 Drake Ave.  
Suite 10-F  
Huntsville, AL 35807  
(205)883-5110  
TWX: 810-726-2112  
FAX: 205-882-9626  
EZ: 62925545

### ARIZONA

**ISDS**  
3101 E. Shea Blvd.  
Suite 110  
Phoenix, AZ 85028  
(602)971-6250  
FAX: 602-971-6252

### ARKANSAS

**TMI**  
3120 Wiley Post Rd.  
Carrollton, TX 75006  
(214)387-3601  
FAX: 214-387-3605

### CALIFORNIA (Northern)

**Brooks Technical Group**  
883 Stierlin Rd.  
Suite C200  
Mountain View, CA 94043  
(415)960-3880  
TWX: 910-379-5061  
FAX: 415-960-3615

### CALIFORNIA (Southern)

**First Rep**  
22024 Lassen Street  
Suite 112  
Chatsworth, CA 91311  
(818)718-6155  
(714)447-9344  
FAX: 818-718-1559

### (San Diego County Only)

**Cerco**  
5230 Carroll Canyon Rd.  
Suite 214  
San Diego, CA 92121  
(619)450-1754  
FAX: 619-450-3681

### COLORADO

**Lange Sales, Inc.**  
1500 W. Canal Ct.  
Building A, Suite 100  
Littleton, CO 80120  
(303)795-3600  
TELEX: 450017  
FAX: 303-795-0373

**Lange Sales, Inc.**  
1864 S. State St.  
Suite 195  
Salt Lake City, UT 84115  
(801)487-0843  
TELEX: 910-925-4006  
FAX: 801-484-5408

**Lange Sales, Inc.**  
760 Center Ave.  
P.O. Box 5145  
Woodland Park,  
CO 80866  
(303)687-1346

### CONNECTICUT

### (Contact Factory)

### DELAWARE

**T.A.I. Corp.**  
12 Blackhorse Pike  
Belmawr, NJ 08031  
(609)933-2600  
(215)627-6615  
FAX: 609-933-3329

### FLORIDA

**SEC**  
776 South Military Trail  
Deerfield Beach,  
FL 33442  
(305)426-4601  
FAX: 305-427-7338

**SEC**  
901 Douglas Ave.  
Suite 200  
Altamonte Springs,  
FL 32714  
(407)682-4800  
FAX: 407-682-6491

**SEC**  
15202 Race Track Rd.  
Tampa, FL 33626  
(813)854-2859  
FAX: 813-854-3127

### GEORGIA

**R.O. Whitesell & Assoc.**  
3091 Holcomb Bridge Rd.  
Suite N1  
Norcross, GA 30071-1320  
(404)449-9190  
EZ: 62926741  
FAX: 404-449-9197

### HAWAII

### (Contact Factory)

### IDAHO

**N.R. Schultz Company**  
1365 N. Orchard St.  
Suite 303  
P.O. Box 4545  
Boise, ID 83704  
(208)377-8686

### ILLINOIS (Northern)

**KMA Sales Co.**  
1040 S. Arlington  
Heights Rd.  
Arlington Heights,  
IL 60005  
(312)398-5300  
FAX: 312-398-5708  
TWX: 910-687-0263

### ILLINOIS (Southern)

**Spectrum Sales**  
47 Village Sq. Center  
Suite P  
Hazelwood, MO 63042  
(314)731-5151  
FAX: 314-731-0950

### INDIANA

**R.O. Whitesell & Assoc.**  
6691 E. Washington St.  
P.O. Box 19904  
Indianapolis, IN 46219  
(317)359-9283  
TWX: 810-341-3320  
FAX: 317-359-2091

**R.O. Whitesell & Assoc.**  
3426 Taylor St.  
Fort Wayne, IN 46804  
(219)432-5591  
EZ: 62925204  
FAX: 219-432-8823

### R.O. Whitesell & Assoc.

1800 S. Plate St.  
Suite A  
Kokomo, IN 46902  
(317)457-9127  
FAX: 317-456-1234  
EZ: 62925205

### IOWA

**Rep Associates Corp.**  
4905 Lakeside Dr. N.E.  
Cedar Rapids, IA 52402  
(319)373-0152  
FAX: 319-373-0217  
EZ: 62904706

### KANSAS

**Spectrum Sales**  
3879 W. 95th St.  
Overland Park, KS 66206  
(913)648-6811  
FAX: 913-648-6823

### KENTUCKY

**R.O. Whitesell & Assoc.**  
313 La Grange Rd.  
Suite 201  
P.O. Box 797  
Pewee Valley, KY 40056  
(502)241-1441  
EZ: 62913061

### LOUISIANA

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2227 Drake Ave.  
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TWX: 810-726-2112  
FAX: 205-882-9626

### MAINE

**Professional  
Component Sales**  
1049 East St.  
Tewksbury, MA 01876  
(508)858-0100  
TWX: 910-380-9030  
FAX: 508-858-0110

### MARYLAND

**Burgin Kreh**  
7000 Security Blvd.  
Suite 330  
Baltimore, MD 21207  
(301)265-8500  
FAX: 301-265-8536

### MASSACHUSETTS

**Professional  
Component Sales**  
1049 East St.  
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(508)858-0100  
TWX: 910-380-9030  
FAX: 508-858-0110

### MICHIGAN

**R.O. Whitesell & Assoc.**  
18444 W. Ten Mile Rd.  
Southfield, MI 48075  
(313)559-5454  
FAX: 313-559-9643  
EZ: 62925297  
TWX: 510-601-2458

**R.O. Whitesell & Assoc.**  
8332 Office Park Dr.  
Suite A  
Grand Blanc, MI 48439  
(313)695-0770  
FAX: 313-695-2732  
EZ: 62925199

**R.O. Whitesell & Assoc.**  
1822 Hilltop Rd.  
St. Joseph, MI 49085  
(616)983-7337  
TWX: 810-270-3180  
EZ: 62913060

**R.O. Whitesell & Assoc.**  
688 Cascade W. Pkwy. S.E.  
Grand Rapids, MI 49506  
(616)942-5420  
EZ: 62913056

### MINNESOTA

**Comstrand**  
2852 Anthony Ln. S.  
Minneapolis, MN 55418  
(612)788-9234  
TWX: 62953437  
FAX: 612-788-7218

# REPRESENTATIVE

## MISSISSIPPI

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Huntsville, AL 35807  
(205)883-5110  
TWX: 810-726-2112  
FAX: 205-882-9626

## MISSOURI (Western)

**Spectrum Sales**  
3879 W. 95th St.  
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(913)648-6811  
FAX: 913-648-6823

## MISSOURI (Eastern)

**Spectrum Sales**  
47 Village Sq. Center  
Suite P  
Hazelwood, MO 63042  
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FAX: 314-731-0950

## MONTANA

**N.R. Schultz Company**  
300 120th Ave. N.E.  
Bellevue, WA 98009  
(206)454-0300  
TWX: 910-240-3969

## NEBRASKA

**Spectrum Sales**  
3879 W. 95th St.  
Overland Park, KS 66206  
(913)648-6811  
FAX: 913-648-6823

## NEVADA

(Contact Factory)

## NEW HAMPSHIRE

**Professional  
Component Sales**  
1049 East St.  
Tewksbury, MA 01876  
(508)858-0100  
FAX: 508-858-0110

## NEW JERSEY (Northern)

**Technical Marketing  
Group**  
175 Fairfield Ave  
Unit 3-C  
West Caldwell, NJ 07006  
(201)226-3300  
TWX: 710-990-5086  
FAX: 201-226-9518

## NEW JERSEY (Southern)

**T.A.I. Corp.**  
12 S. Blackhorse Pike  
Belmawr, NJ 08031  
(609)933-2600  
(215)627-6615  
FAX: 609-933-3329

## NEW MEXICO

**Quatra Associates**  
9704 Admiral Dewey N.E.  
Albuquerque, NM 87111  
(505)821-1455  
TWX: 910-950-1153  
FAX: 602-820-7054

## NEW YORK (except NYC)

**Nycom Inc.**  
10 Adler Dr.  
East Syracuse, NY 13057  
(315)437-8343  
FAX: 315-437-1208  
EZ: 5016019211

(New York City)

**Technical Marketing  
Group**  
20 Broad Hollow Rd.  
Melville, NY 11747  
(516)351-8833  
TWX: 910-997-3030  
FAX: 516-351-8667

## NORTH CAROLINA

**R.O. Whitesell & Assoc.**  
1515 Cornwallis Dr.  
Suite G-103  
Greensboro, NC 27408  
(919)273-1945  
TWX: 510-600-3075  
FAX: 919-273-8768

## NORTH DAKOTA

**Comstrand**  
2852 Anthony Ln. S.  
Minneapolis, MN 55418  
(612)788-9234  
TWX: 910-576-0924  
FAX: 612-788-7218

## OHIO

**R.O. Whitesell & Assoc.**  
4133 S. Dixie Ave.  
Dayton, OH 45439  
(513)298-9546  
TWX: 510-601-2416  
EZ: 62925197  
FAX: 513-298-2586

**R.O. Whitesell & Assoc.**  
1172 W. Galbraith  
Cincinnati, OH 45231  
(513)521-2290  
EZ: 62913063

**R.O. Whitesell & Assoc.**  
6000 W. Creek Rd.  
Suite 21  
Cleveland, OH 44131  
(216)447-9020  
TWX: 810-427-2211  
FAX: 216-447-0260

**R.O. Whitesell & Assoc.**  
6161 Bush Blvd.  
Suite 304  
Columbus, OH 43229  
(614)888-9396  
EZ: 62925202  
FAX: 614-888-8792

## OKLAHOMA

**TMI**  
3320 Wiley Post Rd.  
Carrollton, TX 75006  
(214)387-3601  
FAX: 214-387-3605

## OREGON

**N.R. Schultz Company**  
13095 S.W. Hall Blvd.  
Beaverton, OR 95075  
(503)643-1644  
TWX: 910-467-8707  
FAX: 503-641-0595

## PENNSYLVANIA (Eastern)

**T.A.I. Corp.**  
12 S. Blackhorse Pike  
Belmawr, NJ 08031  
(609)933-2600  
(215)627-6615  
FAX: 609-933-3329

## PENNSYLVANIA (Western)

**R.O. Whitesell & Assoc.**  
1360 Old Freeport Rd.  
Pittsburgh, PA 15238  
(412)963-6161  
EZ: 62913064  
FAX: 412-963-0620

## PUERTO RICO

**M. Anderson Co., Inc.**  
Edificio El Monte Wall  
Suite 18, 3rd Floor  
Hato Rey, PR 00918  
(809)751-2026  
FAX: 809-751-0725  
TLX: 3450551

## RHODE ISLAND

**Professional  
Component Sales**  
1049 East St.  
Tewksbury, MA 01876  
(508)858-0100  
TWX: 910-380-9030  
FAX: 508-858-0110

## SOUTH CAROLINA

**R.O. Whitesell & Assoc.**  
1515 Cornwallis Dr.  
Suite G-103  
Greensboro, NC 27408  
(919)273-1945  
TWX: 510-600-3075  
EZ: 62901672

## SOUTH DAKOTA

**Comstrand**  
2852 Anthony Ln. S.  
Minneapolis, MN 55418  
(612)788-9234  
TWX: 910-576-0924  
FAX: 612-788-7218

## TENNESSEE

**R.O. Whitesell & Assoc.**  
9208 Kingston Pike  
Suite 358  
Knoxville, TN 37922  
(615)694-9476  
FAX: 615-693-3716  
EZ: 62913062

**R.O. Whitesell & Assoc.**  
5600 Brookwood Terrace  
Suite 357  
Nashville, TN 37205  
(615)352-4760  
FAX: 615-352-1511

## TEXAS

**TMI**  
3320 Wiley Post Rd.  
Carrollton, TX 75006  
(214)387-3601  
FAX: 214-387-3605

**TMI**  
2901 Wilcrest Dr.  
Suite 139  
Houston, TX 77042  
(713)783-4497  
(713)783-5307

**TMI**  
1315 Sam Bass Cr.  
Suite B3  
Round Rock, TX 78681  
(512)244-2291  
(512)388-1596

## TEXAS

(El Paso County only)

**Quatra Associates**  
9704 Admiral Dewey N.E.  
Albuquerque, NM 87111  
(505)821-1455  
TWX: 910-950-1153  
FAX: 602-820-7054

## UTAH

**Lange Sales, Inc.**  
1864 S. State St.  
Suite 195  
Salt Lake City, UT 84115  
(801)487-0843  
TWX: 910-925-4006  
FAX: 801-484-5408

## VERMONT

**Professional  
Component Sales**  
1049 East St.  
Tewksbury, MA 01876  
(508)858-0100  
TWX: 910-380-9030  
FAX: 508-858-0110

## VIRGINIA

**Burgin Kreh**  
8314 Timberlake Rd.  
P.O. Box 4455  
Lynchburg, VA 24502  
(804)239-2626  
FAX: 804-239-1333

# REPRESENTATIVE

## WASHINGTON

**N.R. Schultz Company**  
300-120th St. N.E.  
Bellevue, WA 98009  
(206)454-0300  
TWX: 910-240-3969  
FAX: 206-455-1601

## WEST VIRGINIA

**R.O. Whitesell & Assoc.**  
1360 Old Freeport Rd.  
Pittsburgh, PA 15238  
(412)963-6161  
TWX: 710-795-3144

## WISCONSIN (Northern)

**Comstrand**  
2852 Anthony Ln. S.  
Minneapolis, MN 55418  
(612)788-9234  
TWX: 910-576-0924  
FAX: 612-788-7218

## WISCONSIN (Southern)

**KMA Sales Co.**  
2360 N. 124th St.  
Milwaukee, WI 53226  
(414)259-1771  
FAX: 414-259-0246  
TWX: 910-262-3315

## WYOMING

**Lange Sales, Inc.**  
1500 W. Canal Ct.  
Building A, Suite 100  
Littleton, CO 80120  
(303)795-3600  
TWX: 910-935-0824

### ALABAMA

**Pioneer/Huntsville**  
4825 University Sq.  
Huntsville, AL 35805  
(205)837-9300  
TWX: 810-726-2197  
FAX: 205-837-9358

### ARIZONA

**Anthem Electronics**  
1727 E. Weber Dr.  
Tempe, AZ 85281  
(602)966-6600  
TWX: 910-950-0110  
FAX: 602-966-4286

### CALIFORNIA (Northern)

**All American**  
2360 Curme Dr.  
Suite C  
San Jose, CA 95131  
(408)943-1200  
FAX: 408-943-1393

**Anthem Electronics**  
1040 E. Brokaw Rd.  
San Jose, CA 95134  
(408)295-4200  
TWX: 910-338-2038  
FAX: 408-282-1597

**Anthem Electronics**  
580 Menlo Dr.  
Rocklin, CA 95677  
(916)624-9744  
FAX: 916-624-9750

**Future Electronics Corp.**  
575 River Oaks Pkwy.  
San Jose, CA 95134  
(408)434-1122  
FAX: 408-433-0684

**Jaco**  
2880 Zanker Rd  
Suite 202  
San Jose, CA 95134  
(408)432-9290  
FAX: 408-432-9298

**Zeus**  
1580 Old Oakland Rd.  
Suite C-205  
San Jose, CA 95131  
(408)998-5121  
FAX: 408-998-0285  
EZ: 62896083

### CALIFORNIA (Southern)

**All American**  
369 Van Ness Wy.  
Suite 701  
Torrance, CA 90501  
(213)320-0240  
FAX: 213-320-7207

**Anthem Electronics**  
9296 Carrol Park Dr.  
San Diego, CA 92121  
(619)453-9005  
TWX: 910-335-1515  
FAX: 619-546-7893

**Anthem Electronics**  
1 Oldfield Dr.  
Irvine, CA 92718  
(714)768-4444  
FAX: 714-380-4747

**Anthem Electronics**  
20640 Bahama St.  
Chatsworth, CA 91311  
(818)700-1000  
TWX: 910-493-2083  
FAX: 818-709-7639

**Distel (Jaco)**  
2260 Townsgate  
Westlake Village,  
CA 91361  
(805)495-9998  
FAX: 805-494-3864

**Future Electronics**  
1692 Browning Ave.  
Irvine, CA 92714  
(714)250-4141  
FAX: 714-250-4185

**Future Electronics**  
21730 Nordhoff St.  
Chatsworth, CA 91311  
(818)700-0914  
FAX: 818-700-0826

**Future Electronics**  
3940 Ruffin Rd.  
Unit E  
San Diego, CA 92123  
(619)278-5020  
FAX: 619-576-8564

**Jaco**  
23441 S. Pointe Dr.  
Suite 140  
Laguna Hills, CA 92653  
(714)837-8966  
FAX: 714-837-8974

**Milgray Electronics**  
912 C Pancho Rd.  
Camarillo, CA 93010  
(805)484-4055  
FAX: 805-388-8169

**Zeus Components West**  
22700 Savi Ranch Pkwy. W.  
Yorba Linda, CA 92686  
(714)921-9000  
FAX: 714-921-2715

### COLORADO

**Anthem Electronics**  
373 Inverness Dr. S.  
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**Future Electronics Corp.**  
9046 Marshall Ct.  
Westminster, CO 80030  
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**Anthem Electronics**  
170 Research Parkway  
Meriden, CT 06450  
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FAX: 203-237-6026

**Falcon Electronics**  
5 Higgins Dr.  
Milford, CT 06460  
(203)878-5272  
FAX: 203-877-2010

**Future Electronics Corp.**  
24 Stony Hill Road  
Bethel, CT 06801  
(203)743-9594  
FAX: 203-798-9745

**Milgray Electronics**  
326 W. Main St.  
P.O. Box 418  
Milford, CT 06460  
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FAX: 203-878-6970

### FLORIDA

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**All American**  
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Sunrise, FL 33351  
(305)572-7999  
FAX: 305-749-9229

**Future Electronics Corp.**  
4900 M. Creekside Dr.  
Clearwater, FL 33520  
(813)578-2770  
FAX: 813-576-7600

**Future Electronics Corp.**  
380 S. North Lake Blvd.  
Altamonte Springs,  
FL 32701  
(407)767-8414  
FAX: 407-834-9318

**Milgray Electronics**  
1850 Lee Rd.  
Winter Park, FL 32789  
(407)647-5747  
FAX: 407-629-0757

**Pioneer/Fort  
Lauderdale**  
674 S. Military Trail  
Deerfield Beach,  
FL 33442  
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TWX: 510-955-9653  
FAX: 305-481-2950

**Pioneer/Oriando**  
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Altamonte Springs,  
FL 32701  
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FAX: 407-834-0865

**Zeus Components**  
1750 W. Broadway  
Suite 114  
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FAX: 407-365-2356

### GEORGIA

**Future Electronics Corp.**  
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FAX: (404)446-7580

**Milgray Electronics, Inc.**  
3000 Northwoods Pkwy.  
Suite 270  
Norcross, GA 30071  
(404)446-9777  
FAX: 404-446-1186

**Pioneer/Atlanta**  
3100 F Northwoods Pl.  
Norcross, GA 30071  
(404)448-1711  
TWX: 810-766-4515  
FAX: 404-446-8270

### ILLINOIS

**Anthem Electronics**  
180 Crossen Ave.  
Elk Grove, IL 60007  
(312)640-6066  
FAX: 312-640-6302

**Future Electronics Corp.**  
1000 East State Pkwy.  
Suite B  
Schaumburg, IL 60195  
(312)882-1255  
FAX: 312-490-9290

**Milgray Electronics, Inc.**  
765 Route 83  
Suite 123  
Bensenville, IL 60106  
(312)350-0490  
FAX: 312-350-0587

### KANSAS

**Milgray Electronics**  
6400 Glenwood  
Suite 313  
Overland Park, KS 66202  
(913)236-8800  
FAX: 913-384-6825

## MARYLAND

### All American

14636 Rothgeb Dr.  
Rockville, MD 20850  
(301)251-1205  
FAX: 301-251-8574

### Anthem Electronics

9020A Mendenhall Court  
Columbia, MD 21045  
(301)995-6640  
FAX: 301-389-4371

### Falcon Electronics, Inc

Caton Research Center  
1520 Caton Center Dr.  
Suite Q  
Baltimore, MD 21277  
(301)247-5800  
FAX: 301-247-5893

### Future Electronics Corp.

Oakland Center  
8980 N. Route 108  
Columbia, MD 21045  
(301)995-1222  
FAX: 301-730-0509

### Milgray Electronics, Inc.

9801 Broken Land Pkwy.  
Suite 103  
Columbia, MD 21046  
(301)621-8169  
FAX: 301-381-3066

### Pioneer/Washington

9100 Gaither Rd.  
Gaithersburg, MD 20877  
(301)921-0660  
FAX: 301-921-4255

## MASSACHUSETTS

### Anthem Electronics

36 Jonspin Rd.  
Wilmington, MA 01887  
(508)657-5170  
FAX: 508-657-6008

### Falcon Electronics, Inc

38 Pond St.  
Franklin, MA 02038  
(508)520-0323  
FAX: 508-528-2626

### Future Electronics Corp.

133 Flanders Rd.  
Westborough, MA 01581  
(508)366-2400  
TLX: 755917  
FAX: 508-366-1195

## Jaco

222 Andover St.  
Wilmington, MA 01887  
(617)273-1860  
FAX: 617-273-1942

## Milgray Electronics

187 Ballardvale St.  
Wilmington, MA 01887  
(508)657-5900  
FAX: 508-658-7989

## Nu Horizon

151 Andover St.  
Danvers, MA 01923  
(508)777-8800  
FAX: 508-777-8800

## Zeus

429 Marrett Rd.  
Lexington, MA 02173  
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## MICHIGAN

### Future Electronics Corp.

35200 Schoolcraft Rd.  
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Livonia, MI 48150  
(313)261-5270  
FAX: 313-261-8175

## MINNESOTA

### All American

8053 E. Bloomington Fwy.  
Suite 102  
Minneapolis, MN 55420  
(612)884-2220  
FAX: 612-884-7516

### Anthem Electronics

10025 Valley View Rd.  
Suite 162  
Eden Prairie, MN 55344  
(612)944-5454  
FAX: 612-944-3045

### Future Electronics Corp.

10025 Valley View Rd.  
Suite 196  
Eden Prairie, MN 55344  
(612)944-2200  
FAX: 612-944-2520

## NEW JERSEY (Northern)

### Anthem Electronics

311 Route 46 West  
Fairfield, NJ 07006  
(201)227-7960  
FAX: 201-227-9246

### Future Electronics Corp.

122 Fairfield Rd.  
Fairfield, NJ 07006  
(201)227-4346  
FAX: 201-227-5305

## Nu Horizon

39 Route 46  
Pinebrook, NJ 07058  
(201)882-8300  
FAX: (201)882-8398

## Vantage

23 Sebago St.  
Clifton, NJ 07013  
(201)777-4100  
FAX: 201-777-6194

## NEW JERSEY (Southern)

### Future Electronics Corp.

520 Fellowship Rd.  
Suite A101  
Mount Laurel, NJ 08054  
(609)778-7600  
FAX: 609-778-4621

### Milgray Electronics

3001 Greentree  
Executive Campus  
Marlton, NJ 08053  
(609)983-5010  
FAX: 609-985-1607

## NEW MEXICO

### Alliance

11030 Cochiti S.E.  
Albuquerque, NM 87123  
(505)292-3360  
TWX: 910-989-1151  
FAX: 505-292-6537

### Bell Industries

11728 Linn Ave. N.E.  
Albuquerque, NM 87123  
(505)292-2700  
FAX: 505-275-2819

## NEW YORK

### All American

711-2 Koehler Ave.  
Ronkonkoma, NY 11779  
(516)981-3935  
FAX: 516-981-3947

### Anthem Electronics

400 Oser Ave.  
Hauppauge, NY 11787  
(516)273-1660  
FAX: 516-273-1823

### Falcon Electronics

1383-18 Veteran  
Memorial Hwy.  
Hauppauge, NY 11788  
(516)724-0980  
FAX: 516-7224-0993

### Future Electronics Corp.

7453 Morgan Rd.  
Liverpool, NY 13090  
(315)451-2371  
FAX: 315-451-7258

### Future Electronics Corp.

333 Metro Park  
Rochester, NY 14623  
(716)272-1120  
FAX: 716-272-7182

### Future Electronics Corp.

801 Motorparkway  
Hauppauge, NY 11788  
(516)234-4000  
FAX: 516-234-6183

### Jaco Electronics

145 Oser Ave.  
Hauppauge, NY 11788  
(516)273-5500  
TWX: 510-227-6232  
FAX: 516-273-5528

### Milgray Electronics

77 Schmitt Blvd.  
Farmingdale, NY 11735  
(516)420-9800  
TWX: 510-225-3673  
FAX: 516-752-9870

### Milgray Electronics

1200 A Scottsville Rd.  
Rochester, NY 14624  
(716)235-0830  
FAX: 716-436-3647

### Nu Horizon

6000 New Horizons Blvd.  
N. Amityville, NY 11701  
(516)226-6000  
FAX: 516-226-6140

### Summit Electronics

916 Main St.  
Buffalo, NY 14202  
(716)887-2800  
FAX: 716-887-2866

### Summit Electronics

292 Commerce Dr.  
Rochester, NY 14623  
(716)334-8110  
FAX: 716-334-8224

### Zeus Components, Inc.

100 Midland Ave.  
Post Chester, NY 10573  
(914)937-7400  
TELEX: 646610  
FAX: 914-937-2553

## NORTH CAROLINA

### Future Electronics Corp.

4701 Hedgemore Dr.  
Suite 812  
Charlotte, NC 28209  
(704)529-5500  
FAX: 704-527-2222

### Pioneer/Charlotte

9801 A Southern Pine  
Blvd.  
Charlotte, NC 28210  
(704)527-8188  
FAX: 704-522-8564

## OHIO

### Milgray Electronics, Inc.

6155 Rockside Rd.  
Cleveland, OH 44131  
(216)447-1520  
FAX: 216-447-1761

## OKLAHOMA

### Quality Components

3158 S. 108 East Ave.  
Suite 274  
Tulsa, OK 74146  
(918)664-8812  
FAX: 918-664-8515

## OREGON

### Anthem Electronics

9705 S.W. Sunshine Ct.  
Suite 900  
Beaverton, OR 97005  
(503)643-1114  
FAX: 503-626-7928

### Future Electronics Corp.

Cornell Oaks Corp. Center  
15236 N.W. Greenbrier  
Pkwy  
Phase IIIA, Building A  
Beaverton, OR 97006  
(503)645-9454  
(503)644-1559  
FAX: 503-645-1555



## PENNSYLVANIA

**Anthem Electronics**  
3555 Business Center Dr.  
Horsham, PA 19044  
(215)443-5150  
FAX: 215-675-9875

## Pioneer/Delaware Valley

261 Gibraltar Rd.  
Horsham, PA 19044  
(215)674-4000  
TWX: 510-665-6778  
FAX: 215-674-3107

## TEXAS

**Future Electronics Corp.**  
1900 Firman Dr.  
Suite 150  
Richardson, TX 75081  
(214)437-2437  
FAX: 214-669-2347

**Milgray Electronics**  
16610 Dallas Pkwy.  
Suite 1300  
Dallas, TX 75248  
(214)248-1603  
FAX: 214-248-0218

**Quality Components**  
2120 M Baker Ln.  
Austin, TX 78758  
(512)835-0220  
FAX: 512-339-9252

**Quality Components**  
4257 Kellway Circle  
Addison, TX 75001  
(214)733-4300  
FAX: 214-250-0216

**Quality Components**  
1005 Industrial Blvd.  
Sugarland, TX 77478  
(713)240-2255  
FAX: 713-240-6988

**Zeus Components, Inc.**  
1800 N. Glenville  
Suite 120  
Richardson, TX 75081  
(214)783-7010  
FAX: 214-234-4385

## UTAH

**Anthem Electronics**  
1279 W. 2200 S.  
Suite A  
Salt Lake City, UT 84119  
(801)973-8555  
FAX: 801-973-8909

## Future Electronics Corp.

2250 So. Redwood Rd.  
Salt Lake City, UT 84119  
(801)972-8489  
FAX: 801-972-3602

## WASHINGTON

**Anthem Electronics**  
5020 148th Ave. N.E.  
Redmond, WA 98052  
(206)881-0850  
FAX: 206-885-4041

**Future Electronics Corp.**  
4038 148th Avenue N.E.  
Redmond, WA 98052  
(206)881-8199  
FAX: 206-881-5232

## WISCONSIN

**Marsh Electronics**  
1563 S. 101 St.  
Milwaukee, WI 53214  
(414)475-6000  
TWX: 910-262-3321  
FAX: 414-771-2847

## CANADA

**Future Electronics Corp.**  
82 St. Regis Crescent N.  
Downsview, Ontario  
Canada M3J 1Z3  
(416)638-4771  
FAX: 416-638-2936

**Future Electronics Corp.**  
237 Hymus Blvd.  
Pointe Claire (Montreal)  
Quebec  
Canada H9R 5C7  
(514)694-7710  
TWX: 610-421-3251  
FAX: 514-695-3707  
TLX: 05-823599

**Future Electronics Corp.**  
Baxter Center  
1050 Baxter Rd.  
Ottawa, Ontario  
Canada K2C 3P2  
(613)820-8313  
FAX: 613-820-3271

**Future Electronics Corp.**  
106 King Edward  
Winnipeg, Manitoba  
Canada R3H 0N8  
(204)786-7711  
FAX: 204-783-8133

## Future Electronics Corp.

1695 Boundary Rd.  
Vancouver, B.C.  
Canada V5K 4X7  
(604)294-1166  
FAX: 604-294-1206

## Future Electronics Corp.

3220 5th Ave. N.E.  
Calgary, Alberta  
Canada T2A 5N1  
(403)235-5325  
FAX: (403) 248-0750

## Future Electronics Corp.

1990 Charest Blvd. W.  
Suite 190  
St. Foy, Quebec  
Canada G1N 4K8  
(418)682-8092  
(418)682-8303

## Future Electronics Corp.

5312 Calgary Trail S.  
Edmonton, Alberta  
Canada T6H 4J8  
(403)438-2858  
FAX: 403-434-0812

## AUSTRALIA

**A.J. Distributor Pty. Ltd.**  
44 Prospect Rd.  
Prospect, S. Australia  
5082  
TEL: (08)2691244  
TELEX: 79082635  
FAX: 61-8-2696743

## AUSTRIA

**Moor Lackner GMBH**  
Lamezanstr. 10  
1232 Wien  
Austria  
TEL: 011-43-1-610620  
TELEX: 135701  
FAX: 011-43-1-61062-151

## BELGIUM

**Trade Mark Electronics  
P.V.H.A.**  
Bisschoppenhoflaan  
357/359  
2100 Antwerpen  
Belgium  
TEL: 03-3251910  
TELEX: 72713

## CANADA (Except B.C.)

**Vitel Electronics**  
2235 Onesime Gagnon  
Lachine, Quebec  
Canada H8J 9Z7  
TEL: (514)636-5951  
FAX: (514)636-1341  
TELEX: 05821762

**Vitel Electronics**  
5925 Airport Rd.  
Suite 610  
Mississauga, Ontario  
Canada L4V 1W1  
TEL: (416)676-9720  
TWX: 610-492-0055  
FAX: 416-676-1798

**Vitel Electronics**  
300 March Rd.  
Suite 301  
Kanata, Ontario  
Canada K2K 2E2  
TEL: (613)592-0090  
FAX: 613-592-0182

**Vitel Electronics**  
10601 South Port Rd. S.W.  
Suite 324  
Calgary, Alberta  
Canada T2W 3M6  
TEL: (403)278-5833  
FAX: 403-278-6128

## CANADA (B.C. Only)

**N.R. Schultz Company**  
300 12th St. N.E.  
Bellevue, WA 98009  
TEL: (206)454-0300  
TWX: 910-443-2329

## DENMARK

**Inotec A/S**  
Hoerkaer 14  
2730 Herlev  
Denmark  
TEL: 452-948033  
TELEX: 35194

## FINLAND

**Flinkenberg Oy**  
Bulevardi 28  
SF00120  
Helsinki 12  
Finland  
TEL: 358-0647311  
TELEX: 57124533  
FAX: 358-0-604-758

## FRANCE

**Radio Equipment  
Antares**  
79 Rue Pierre Semard  
92320 Chatillon  
France  
TEL: 47-460246  
TELEX: 632777  
FAX: 47-460516

## GERMANY

**Alfatron GMBH**  
Scheissheimer Str. 87  
D-8046 Graching, Munich  
West Germany  
TEL: (89)32 90 99-0  
TELEX: 5 216 935 alfa d  
FAX: (89)32 90 99-59

**Astronic GMBH**  
Grunwalder Weg 30  
8024 Delsenhofen  
West Germany  
TEL: 089-6130303  
TELEX: 5216187  
FAX: 089-6131668

**Eurocomp Elektronik  
GMBH**  
(Silicon General  
Sales Office)  
Im Muehlfeld 20  
D-6360 Friedberg/Hessen  
West Germany  
TEL: 6031-61076  
TELEX: 6031948  
FAX: 6031-61788

**Migray Electronics  
GMBH**  
Industriegebiet OST  
Hielbronner Str. 23  
Postfach 848  
7320 Goepfingen  
West Germany  
TEL: 7161-73054  
TELEX: 727269  
FAX: 7161-76855

## HONG KONG

**Tektron Electronics, Ltd.**  
1702 Bank Center  
636 Nathan Rd.  
Kowloon, Hong Kong  
TEL: 3-880629  
TELEX: 780-38513  
FAX: 3-7805871

## ISRAEL

**Boran Technologies Ltd.**  
P.O. Box 4058  
6 Zahud Street  
Petah Tikva 49130  
Israel  
TEL: 972-3-9345171  
TELEX: 341167  
FAX: 972-3-9344235

## ITALY

**Exhibo s.p.a.**  
Via F. Frisi 22  
20052 Monza  
Italy  
TEL: 39-738021  
TELEX: 333315  
FAX: 39-360280

## JAPAN

**Hakuto Company, Ltd.**  
C.P.O. Box 25  
Tokyo 100-91, Japan  
TEL: 03-502-2211  
TELEX: 22912  
FAX: 81-3-5978975

## KOREA

**Kumoh Electronic Co. Ltd.  
Alpha Engineering Co.**  
187, 2nd Floor, 21st Bldg  
16-1, Hangang-Ro 2-Ka  
Yongsan-Ku  
Seoul, Korea  
TEL: 701-5011/8  
TELEX: 23575  
FAX: 701-5019

## NETHERLANDS

**Techmaton Manudax  
Electronics  
B.V. - T.M.E.B.V.**  
Meerstraat 7a  
P.O. Box 100  
5473 ZJ Heeswijk-Dinther  
Netherlands  
TEL: (31)41398895  
TELEX: 74488  
FAX: (31)41392902

## NORWAY

**Henaco A/S**  
Trondheimsveien 436  
Ammerud  
Oslo  
Norway  
TEL: 02-162110  
TELEX: 76716  
FAX: 02-257780

## PORTUGAL

**Componenta  
Componentes  
Electronicos LTDA**  
Rua Luis de  
Carnoes 128B  
1300 Lisboa  
Portugal

## PUERTO RICO

**M. Anderson  
Company, Inc.**  
Edisifio El Monte Hall  
3rd Floor, Suite 18  
Hato Ray,  
Puerto Rico 00918  
TEL: (809)751-2026  
TELEX: 345 0531  
FAX: 886-2-706-0465

## REPUBLIC OF CHINA

**Helm Engineering  
& Trading**  
4F, 658 Tun Hua S. Rd.  
Taipei, Taiwan  
R.O.C.  
TEL: (02)706-1888  
TELEX: 28204  
FAX: (02)706-0465

**Irtronic Corp.**  
13-5 Fl., No. 112 Sec  
2 Chung Shan N. Road  
Taipei, Taiwan  
R.O.C.  
TEL: (02)531-5467  
TELEX: 26966  
FAX: (02)571-4715

## SINGAPORE

**Taiga Electronics  
PTE Ltd.**  
126 Joo Sang Rd. #09-14  
Gold Pine Industrial Bldg.  
Singapore 1336  
TEL: 2861980  
TELEX: 22974  
FAX: (65)2881255

## SOUTH AFRICA

**Electronics Bldg.  
Elements**  
South Africa (PTY) Ltd.  
P.O. Box 912-1222,  
Silverton 0127  
176 Eresmus St.  
Meyerspark  
Pretoria 0184  
Republic of South Africa  
TEL: (27)12-8037680/93  
TELEX: 322786  
FAX: (27)12-8038294

## SPAIN

**Amtron S.A.**  
Avenida de  
Valledolid, 47-A  
28008 Madrid  
Spain  
TEL: 34-1-2415402  
TELEX: 45550  
FAX: 34-1-2487958

## SWEDEN

**Nexab**  
P.O. Box 4115  
S-171-04 Solna  
Sweden  
TEL: 08-985140  
TELEX: 17912  
FAX: 46-8-7645451

## SWITZERLAND

**Kontron Electronics**  
Bernerstr. Sud 1697  
8048 Zurich  
Switzerland  
TEL: 01-435-4428  
TELEX: 822196  
FAX: 01-621118

## UNITED KINGDOM

**Norbein Technology**  
Bulton Rd.  
Reading, Berkshire  
England RG20LT  
FAX: (734)864411  
TELEX: 847203  
FAX: 734-751464

**Sillicon General Ltd.**  
**European Headquarters**  
17 Bridge St.  
Leatherhead, Surrey  
England KT228BL  
TEL: (372)377779  
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FAX: 372-376848





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