

**Linear Circuits
Data Book
1992**

**Volume 3
Voltage Regulators/Supervisors, Comparators,
Special Functions, and Building Blocks**



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INTRODUCTION

Texas Instruments offers an extensive line of industry-standard integrated circuits designed to provide highly reliable power supply regulators, supervisors, comparators, special functions, and building blocks. These circuits represent processes from standard bipolar through BIFET, BIFET, IMPACT™, LinCMOS™, Advanced LinCMOS™, and Schottky technologies.

This data book (Volume 3 of 3) provides information on the following types of products:

- Supervisory Circuits
- Switch-Capacitance Voltage Converters
- Shunt Voltage Regulators and Voltage References
- Adjustable Series-Pass Voltage Regulators
- Switching Power Supply and Pulse-Width-Modulated (PWM) Controllers and Regulators
- Fixed Output Series-Pass Voltage Regulators (Positive and Negative)
- Voltage Comparators, Timers, Disk Drive Circuits
- Current Mirrors, Sonar Circuits, Sound Generators
- Video Amplifiers

These products provide critical functions in analog and digital systems that:

- Utilize a wide range of voltages
- Require a constant output voltage regardless of changes in input voltage, output current, and ambient temperature
- Demand high input-output isolation where analog circuitry must be connected independently of digital ground
- Need low voltage (i.e., battery) regulation

New surface-mount packages (3 to 20 leads) include the thin, small-outline packages (PW) and SOT-89 (PK) plastic packages that optimize board density with minimum impact of power dissipation capabilities. Test equipment with handlers and automated assembly bonders strengthen the production capabilities that provide a lower cost-to-performance ratio. TI continues to enhance quality and reliability of integrated circuits by improvements in materials, processes, test methods, and test equipment. In addition, specifications and programs are continuously updated. Quality and performance are monitored throughout all phases of manufacturing.

The alphanumeric listing in this data book includes all devices contained in Volumes 1, 2, and 3. Products in this book are shown in **BOLD** type. Thus, the reader can easily find the particular volume for a given device. Also included are those new products added to this volume as indicated by a dagger(†). The selection guide includes a functional description of each device by providing key parametric information and packaging options. Ordering information and mechanical data are in the last section of the book.

Complete technical data for all TI semiconductor products are available from your nearest TI Field Sales Office, local authorized TI distributor, or by writing directly to:

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Dallas, Texas 75380-9066

We sincerely feel that this new 1992 Linear Circuits Data Book, Volume 3, will be a significant addition to your technical literature from Texas Instruments.

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†New devices added to this volume.



VOLTAGE REGULATORS/SUPERVISORS AND BUILDING BLOCKS SELECTION GUIDE

power supply supervisors

(values specified for $T_A = 25^\circ\text{C}$)

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| | 5 V | — | 4.55 | | | TL7705A | | |
| | 9 V | — | 7.6 | | | TL7709A | | |
| | 12 V | — | 10.8 | | | TL7712A | | |
| | 15 V | — | 13.5 | | | TL7715A | | |
| Undervoltage Monitor | † | — | 7.53 | 1 | Open Collector | TL7702B | D, P | 2-351 |
| | 5 V | | 4.55 | | | TL7705B | | |
| Undervoltage Monitor | 5 V | — | 4.55 | 2.6 | Open Collector | TL7757 | D, LP, PK, Y‡ | 2-359 |
| | | | | | | TL7759C | D, P | 2-373 |
| Dual Undervoltage/ Overvoltage | 5 V | † | 4.55 | 1 | Open Collector | TL7770-5 | DW, N | 2-377 |
| | 12 V | † | 10.9 | | | TL7770-12 | | |
| | 15 V | † | 13.64 | | | TL7770-15 | | |

† Programmable

‡ Y package is in chip form

switched-capacitor voltage converters

(values specified for $T_A = 25^\circ\text{C}$)

| CONTROL TOPOLOGY | OUTPUT SWITCH | SUPPLY VOLTAGE RANGE (V) | QUIESCENT CURRENT (NO LOAD) | MAXIMUM CONTINUOUS I/O | MAXIMUM FREQUENCY (kHz) | TYPICAL CONVERSION EFFICIENCY (%) | TYPE | PACKAGE | PAGE NO. |
|------------------|---------------|--------------------------|-----------------------------|------------------------|-------------------------|-----------------------------------|--------|-----------|----------|
| Voltage Mode | Single | 3.5 - 15 | 150 μA | 300 mA | 35 | 90 | LT1054 | DW, JG, P | 2-55 |

shunt voltage regulators/references

(values specified for $T_A = 25^\circ\text{C}$)

| REGULAR VOLTAGE RANGE (V) | MINIMUM SHUNT CURRENT TO MAINTAIN REG | MAXIMUM SHUNT CURRENT | TOLERANCE (%) | TEMPERATURE COEFFICIENT (TYP) | DEVICE | PACKAGE | PAGE NO. |
|---------------------------|---------------------------------------|-----------------------|---------------|-------------------------------|------------|---------------------|----------|
| 1.2 Typ | 10 μA | 20 mA | 1 | 20 PPM/ $^\circ\text{C}$ | LM185-1.2 | D, LP | 2-3 |
| | | | 2 | | LM285-1.2 | | |
| 1 | LM385B-1.2 | | | | | | |
| 2.5 Typ | 20 μA | | 1.5 | | LT1004-2.5 | | 2-35 |
| | | | 3 | | LM185-2.5 | | 2-9 |
| | 400 μA Typ | | 2 | | LM285-2.5 | | |
| | | 1 | LM385B-2.5 | | | | |
| 400 μA | 10 mA | 2 | LM385-2.5 | 2-17 | | | |
| | | 1 | LM236 | | | | |
| 2.5 to 30 | 500 μA Typ | 150 mA | 0.2 | 15 PPM/ $^\circ\text{C}$ | LM336 | LP | 2-185 |
| | | | 4 | 120 PPM/ $^\circ\text{C}$ | TL430 | | |
| 2.5 to 36 | 400 μA Typ | | 2 | 25 PPM/ $^\circ\text{C}$ | TL431 | D, JG, LP, P, PK | 2-189 |
| | | | 1 | | TL431A | | |
| 2.5 to 36 | 450 μA Typ | | 0.4 | 25 PPM/ $^\circ\text{C}$ | TL1431 | D, LP, PK, Y‡ | 2-303 |

‡ Y package is in chip form

VOLTAGE REGULATORS/SUPERVISORS AND BUILDING BLOCKS SELECTION GUIDE

adjustable series-pass voltage regulators (values specified over operating temperature range)

| OUTPUT VOLTAGE | OUTPUT CURRENT | OUTPUT VOLTAGE RANGE (V) | TOLERANCE (%) | MAXIMUM (V _I - V _O) DIFFERENCE | DEVICE | PACKAGE | PAGE NO. |
|-----------------------------|----------------|--------------------------|---------------|---|--------|------------|----------|
| Positive Output | 100 mA | 1.2 to 32 | 5 | 35 V | TL317 | D, JG, LP | 2-173 |
| | 750 mA | 1.25 to 125 | 5 | 125 V | TL783 | KC | 2-291 |
| Positive Output | 5 A | 1.25 to 35 | 2 | 30 V | LT1084 | | 2-133 |
| Negative Output | 1.5 A | -1.2 to -37 | 4 | -40 V | LM337 | | 2-21 |
| Positive or Negative Output | 150 mA | 2 to 37 | 5 | 38 V | uA723 | D, J, N, U | 2-417 |

virtual grounds (values specified over operating temperature range)

| OUTPUT VOLTAGE (V) | OUTPUT CURRENT (mA) | OUTPUT IMPEDANCE (Ω) | TOLERANCE (%) | TEMPERATURE COEFFICIENT (TYP) | DEVICE | PACKAGE | PAGE NO. |
|--------------------|---------------------|----------------------|---------------|-------------------------------|---------|-----------|----------|
| 2.5 | ±20 | 0.0075 | 0.8 | 20 PPM/°C | TLE2425 | D, LP, Y† | 2-385 |
| 1.5 V _I | | 0.025 | | | TLE2426 | | 2-399 |

† Y package is in chip form

VOLTAGE REGULATORS/SUPERVISORS AND BUILDING BLOCKS SELECTION GUIDE

switching power supply controllers and regulators

(values specified for $T_A = 25^\circ\text{C}$)

| CONTROL TOPOLOGY | SINGLE ENDED | FIXED PUSH-PULL | SINGLE SWITCH OUTPUTS | TOTEM-POLE OUTPUTS | OUTPUT CURRENT PER SWITCH | MAXIMUM FREQUENCY PER SWITCH (mA) | VOLTAGE FREQUENCY (kHz) | VOLTAGE REFERENCE TOLERANCE (%) | PULSE-BY-PULSE CURRENT LIMITING | OUTPUT STEERING CONTROL | PROGRAMMABLE OUTPUTS | DEAD-TIME CONTROL | UNDERVOLTAGE LOCKOUT | SOFT START | ON-BOARD AMPLIFIERS | CURRENT-SENSE AMPLIFIERS | 50% MAXIMUM DUTY CYCLE | TYPE | PKGS | PAGE NO. |
|--|--------------|-----------------|-----------------------|--------------------|---------------------------|-----------------------------------|-------------------------|---------------------------------|---------------------------------|-------------------------|----------------------|-------------------|----------------------|------------|---------------------|--------------------------|------------------------|---------|-------------|----------|
| | | | | | | | | | | | | | | | | | | | | |
| Voltage-Mode Pulse-Width Modulated Controllers | X | - | X | - | 200 | 5 | - | - | - | X | X | - | - | 2 | - | - | - | MC34060 | D, N | 2-149 |
| | - | X | - | - | 250 | 300 | - | - | - | - | - | - | - | 1 | 1 | - | - | TL494 | D, FK, J, N | 2-207 |
| | - | X | - | - | 250 | 300 | - | - | - | - | - | - | - | 1 | 1 | - | - | SG2524 | D, N | 2-161 |
| | - | X | - | - | 250 | 300 | - | - | - | - | - | - | - | 2 | - | - | - | SG3524 | | 2-241 |
| | - | X | - | X | ±250 | 300 | 1 | - | - | X | X | X | - | 2 | - | - | - | TL594 | D, FK, J, N | 2-251 |
| | X | - | Dual | - | 21 | 500 | 4 | - | - | - | X | X | - | - | X | - | - | TL598 | D, N | 2-319 |
| | X | - | - | - | 21 | 500 | 4 | - | - | - | X | X | - | - | X | - | - | TL1451A | D, N | 2-319 |
| Current-Mode Pulse-Width Modulated Controllers | X | - | - | X | ±1000 | 500 | 1 | X | - | - | - | X | - | 1 | X | - | - | UC2842 | D, P | 2-475 |
| | - | - | - | - | ±1000 | 500 | 1 | X | - | - | - | X | - | 1 | X | - | - | UC2843 | | |
| | - | - | - | - | ±1000 | 500 | 1 | X | - | - | - | X | - | 1 | X | - | - | UC2842 | | |
| | - | - | - | - | ±1000 | 500 | 1 | X | - | - | - | X | - | 1 | X | - | - | UC3842 | | |
| | - | - | - | - | ±1000 | 500 | 1 | X | - | - | - | X | - | 1 | X | - | - | UC3843 | | |
| | X | - | - | - | ±1000 | 500 | 1 | X | - | - | - | X | - | 1 | X | - | - | UC2844 | D, P | 2-475 |
| | X | - | - | - | ±1000 | 500 | 1 | X | - | - | - | X | - | 1 | X | - | - | UC2845 | | |
| X | - | - | - | ±1000 | 500 | 1 | X | - | - | - | X | - | 1 | X | - | - | UC3844 | | | |
| X | - | X | - | - | 5000 | 40 | 2 | X | - | - | - | - | 1 | X | - | - | UC3845 | KC, KV | 2-77 | |
| X | - | X | - | - | 2500 | 40 | 2 | X | - | - | - | - | 1 | X | - | - | LT1070 | | | |
| X | - | X | - | - | 1250 | 40 | 2 | X | - | - | - | - | 1 | X | - | - | LT1071 | | | |
| Fixed On-Time Voltage Mode | X | - | X | - | 1200 | 40 | 10 | - | - | - | - | - | 1 | - | - | - | - | LT1072 | KC, KV, P | 2-117 |
| | X | - | X | - | 1200 | 40 | 5 | - | - | - | - | - | 1 | - | - | - | - | TL496 | D, P | 2-223 |
| | X | - | X | - | 700 | 50 | 5 | - | - | - | - | - | 1 | - | - | - | - | TL499A | D, P | 2-35 |
| X | - | X | - | 700 | 50 | 5 | - | - | - | - | - | - | 1 | - | - | - | - | TL497A | D, J, N | 2-227 |

X Applicable data
- Nonapplicable data



VOLTAGE REGULATORS/SUPERVISORS AND BUILDING BLOCKS SELECTION GUIDE

positive fixed output series-pass voltage regulators

(values specified over operating temperature range)

| OUTPUT VOLTAGE (V) | OUTPUT CURRENT RATING | OUTPUT VOLTAGE TOLERANCE ($\pm\%$) | MINIMUM DIFFERENTIAL VOLTAGE (V) | TYPE | PACKAGE | PAGE NO. |
|--------------------|-----------------------|--------------------------------------|----------------------------------|---------------|--------------|----------|
| 2 | 1.5 A | 3 | 2.5 | TL782 | KC | 2-87 |
| 2.6 | 100 mA | 5 | 2 | μ A78L02A | D, LP | 2-437 |
| | | 10 | | μ A78L02 | | |
| 5 | 100 mA | 5 | 2 | μ A78L05A | D, JG, LP | |
| | | 10 | | μ A78L05 | | |
| | 150 mA | 10 | 0.6 | LM2930-5 | KC, LP | 2-25 |
| | | 5 | | TL750L05 | D, KC, LP, P | 2-267 |
| | 500 mA | 1 | 2 | TL751L05 | D, P | 2-267 |
| | 750 mA | | | μ A78M05 | JG, KC | 2-447 |
| | 1.5 A | 2 | 0.6 | TL750M05 | KC | 2-273 |
| | | | | TL751M05 | | 2-281 |
| 6 | 500 mA | 5 | TL780-5 | 2-427 | | |
| | | | μ A7805 | | | |
| 6.2 | 100 mA | 10 | μ A78M06 | D, LP | 2-447 | |
| | | | μ A78L06A | | | |
| 8 | 100 mA | 5 | 2 | μ A78L06 | D, LP | 2-437 |
| | | 10 | | μ A78L08A | | |
| | 150 mA | 10 | 0.6 | μ A78L08 | D, LP | 2-437 |
| | | | | 5 | | |
| | 500 mA | 1 | 2 | TL750L08 | D, KC, LP, P | 2-267 |
| | 750 mA | | | TL751L08 | D, P | 2-267 |
| | 1.5 A | 5 | 0.6 | μ A78M08 | KC | 2-447 |
| | | | | TL750M08 | | 2-273 |
| 8.5 | 1.5 A | 5 | TL751M08 | 2-427 | | |
| | | | μ A7808 | | | |
| 9 | 100 mA | 10 | μ A7885 | D, LP | 2-437 | |
| | | | μ A78L09A | | | |
| | 500 mA | 5 | 2 | μ A78L09 | D, LP | 2-437 |
| 10 | 100 mA | 5 | 2 | μ A78M09 | KC | 2-447 |
| | | 10 | | μ A78L10A | D, LP | 2-437 |
| | 150 mA | 5 | 0.6 | μ A78L10 | K, KC, LP, P | 2-267 |
| | | | | TL750L10 | | |
| | 500 mA | 1 | 2 | TL751L10 | D, P | 2-267 |
| | 750 mA | | | μ A78M10 | KC | 2-447 |
| | 1.5 A | 5 | 0.6 | TL750M10 | 2-273 | |
| TL751M10 | | | | | | |
| 12 | 100 mA | 5 | 2 | μ A7810 | D, JG, LP | 2-427 |
| | | 10 | | μ A78L12A | | |
| | | | | μ A78L12 | | 2-437 |



VOLTAGE REGULATORS/SUPERVISORS AND BUILDING BLOCKS SELECTION GUIDE

positive fixed output series-pass voltage regulators (continued)
(values specified over operating temperature range)

| OUTPUT VOLTAGE (V) | OUTPUT CURRENT RATING | OUTPUT VOLTAGE TOLERANCE (±%) | MINIMUM DIFFERENTIAL VOLTAGE (V) | TYPE | PACKAGE | PAGE NO. |
|--------------------|-----------------------|-------------------------------|----------------------------------|------------|--------------|----------|
| 12 | 150 mA | 5 | 0.6 | TL750L12 | D, KC, LP, D | 2-267 |
| | 500 mA | | | TL751L12 | D, P | |
| | 750 mA | 1 | 0.6 | TL750M12 | KC | 2-273 |
| | 1.5 A | | | TL751M12 | | 2-281 |
| | | | TL780-12 | 2-427 | | |
| | | | | uA7812 | | |
| 15 | 100 mA | 5 | 2 | uA78L15A | D, LP | 2-437 |
| | 500 mA | | | uA78L15 | JG, KC | 2-447 |
| | 1.5 A | | | TL780-15 | 2-281 | |
| | | | | uA7815 | KC | 2-427 |
| | | | | uA7818 | | |
| 18 | 500 mA | 5 | uA78M20 | KC | 2-447 | |
| 20 | | | uA78M24 | | 2-427 | |
| 24 | | | uA7824 | | | |
| 2.85 | 620 mA | 1 | 0.6 | TLSCSI285 | KC, N, PW | 2-179 |
| | 500 mA | 1.5 | 1 | TL2217-285 | | 2-337 |

VOLTAGE REGULATORS/SUPERVISORS AND BUILDING BLOCKS SELECTION GUIDE

negative fixed output series-pass voltage regulators

(values specified over operating temperature range)

| OUTPUT VOLTAGE (V) | OUTPUT CURRENT RATING | OUTPUT VOLTAGE TOLERANCE (±%) | MINIMUM DIFFERENTIAL VOLTAGE (V) | TYPE | PACKAGE | PAGE NO. |
|--------------------|-----------------------|-------------------------------|----------------------------------|----------|---------|----------|
| 5 | 100 mA | 5 | 1.7 | MC79L05A | D, LP | 2-157 |
| | | 10 | | MC79L05 | | |
| 5.2 | 1.5 A | 5 | 2 | uA79M05 | JG, KC | 2-465 |
| | | | | uA7905 | KC | 2-457 |
| 6 | 500 mA | 5 | 2 | uA7952 | | KC |
| | | | | uA79M06 | 2-457 | |
| 8 | 500 mA | 5 | 2 | uA7906 | JG, KC | 2-465 |
| | | | | uA79M08 | | |
| 12 | 100 mA | 10 | 1.7 | MC79L12A | D, LP | 2-157 |
| | | 5 | | MC79L12 | | |
| 15 | 500 mA | 5 | 2 | uA79M12 | JG, KC | 2-465 |
| | | | | uA7912 | KC | 2-457 |
| 18 | 100 mA | 10 | 1.7 | MC79L15A | D, LP | 2-157 |
| | | 5 | | MC79L15 | | |
| 20 | 500 mA | 5 | 2 | uA79M15 | KC | 2-465 |
| | | | | uA7915 | KC | 2-457 |
| 24 | 1.5 A | 5 | 2 | uA7918 | | KC |
| | | | | uA79M20 | 2-457 | |
| 24 | 1.5 A | 5 | 2 | uA79M24 | KC | 2-465 |
| | | | | uA7924 | | |

VOLTAGE REGULATORS/SUPERVISORS AND BUILDING BLOCKS CROSS-REFERENCE GUIDE

Replacements are based on similarity of electrical and mechanical characteristics shown in currently published data. Interchangeability in particular applications is not guaranteed. Before using a device as a substitute, compare the specifications of the substitute device with the specifications of the original.

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Manufacturers are arranged in alphabetical order.

| LINEAR TECHNOLOGY | DIRECT TI REPLACEMENT | SUGGESTED TI REPLACEMENT | PAGE NO. |
|----------------------|-----------------------------|--------------------------------|-------------|
| LM185-2.5 | LM185-2.5 | | 2-9 |
| LM285-2.5 | LM285-2.5 | | 2-9 |
| LM336-2.5 | LM336-2.5 | | 2-17 |
| LM337 | LM337 | | 2-21 |
| LM385-2.5 | LM385-2.5 | | 2-9 |
| LT1004-2.5 | LT1004-2.5 | | 2-35 |
| LT1009 | LT1009 | | 2-47 |
| LT1070 (HV) | LT1070 (HV) | | 2-77 |
| LT1071 (HV) | LT1071 (HV) | | 2-101 |
| LT1072 (HV) | LT1072 (HV) | | 2-117 |
| LT1004-1.2 | LT1004-1.2 | | 2-35 |
| LT1054 | LT1054 | | 2-55 |
| LT1084 | LT1084 | | 2-133 |
| LT1117-285 | | TL2217-285 | 2-337 |
| LT1431 | | TL1431 | 2-303 |
| SG3524 | SG3524 | | 2-161 |

| MOTOROLA | DIRECT TI REPLACEMENT | SUGGESTED TI REPLACEMENT | PAGE NO. |
|----------------|-----------------------------|--------------------------------|-------------|
| LM237, LM337 | LM237, LM337 | | 2-21 |
| MC1723 | uA723 | | 2-417 |
| MC3423 | MC3423 | | 2-147 |
| MC34060 | MC34060 | | 2-149 |
| MC34063 | TL497 | | 2-227 |
| MC34064 | | TL7757 | 2-359 |
| MC34164 | | TL7757 | 2-359 |
| MC78L00 Series | uA78L00 Series | | 2-437 |
| MC78M00 Series | uA78M00 Series | | 2-447 |
| MC79L00 Series | MC79L00 Series | | 2-157 |
| TL431 | TL431 | | 2-189 |
| TL431A | TL431A | | 2-189 |
| TL494 | TL494 | | 2-207 |
| TL780-5 | TL780-5 | | 2-281 |
| TL780-12 | TL780-12 | | 2-281 |
| TL780-15 | TL780-15 | | 2-281 |

VOLTAGE REGULATORS/SUPERVISORS AND BUILDING BLOCKS CROSS-REFERENCE GUIDE

| NATIONAL | DIRECT TI REPLACEMENT | SUGGESTED TI REPLACEMENT | PAGE NO. |
|----------------------------|-----------------------------|--------------------------------|-------------|
| LM237, LM337 | LM237, LM337 | | 2-21 |
| LM317L | TL317 | | 2-173 |
| LM336-2.5 | LM336-2.5 | LT1009 | 2-17 / 2-47 |
| LM385-2.5 | LM385-2.5 | LT1004-2.5 | 2-9 / 2-35 |
| LM723 | uA723 | | 2-417 |
| LM2930-5 | LM2930-5 | | 2-25 |
| LM2930-8 | LM2930-8 | | 2-25 |
| LM3524 | SG3524 | | 2-161 |
| LM7800 Series | uA7800 Series | | 2-427 |
| LM78L00 Series | uA78L00 Series | | 2-437 |
| LM78M00 Series | uA78M00 Series | | 2-447 |
| LM7900 Series | uA7900 Series | | 2-457 |
| LM79L00 Series | MC79L00 Series | | 2-157 |
| LM79M00 Series | uA79M00 Series | | 2-465 |
| | DIRECT TI REPLACEMENT | SUGGESTED TI REPLACEMENT | PAGE NO. |
| SILICON GENERAL | | | |
| SG3524 | SG3524 | | 2-161 |
| SG3842/3/4/5 | UC3842/3/4/5 | | 2-475 |
| | DIRECT TI REPLACEMENT | SUGGESTED TI REPLACEMENT | PAGE NO. |
| SPRAGUE | | | |
| ULN8194 | TL594 | | 2-241 |
| | DIRECT TI REPLACEMENT | SUGGESTED TI REPLACEMENT | PAGE NO. |
| UNITRODE | | | |
| TL431 | TL431 | | 2-185 |
| UC337 | LM337 | | 2-21 |
| UC494 | TL494 | | 2-207 |
| UC494A | TL594 | | 2-241 |
| UC2842/3/4/5 | UC2842/3/4/5 | | 2-475 |
| UC3842/3/4/5 | UC3842/3/4/5 | | 2-475 |
| UC7800 Series | uA7800 Series | | 2-427 |
| UC7800A Series | | TL780-00 Series | 2-281 |
| UC7900 Series | uA7900 Series | | 2-457 |

SERIES REGULATORS

Bias Current

The difference between input and output currents.

NOTE: This is sometimes referred to as quiescent current.

Current-Limit Sense-Voltage

The voltage that is a function of the load current and is normally used for control of the current-limiting circuitry. This is the current-sense voltage at which current limiting occurs.

Dropout Voltage

The low input-to-output differential voltage at which the circuit ceases to regulate against further reductions in input voltage.

Feedback Sense Voltage

The voltage that is a function of the output voltage and is used for feedback control of the regulator.

Input Regulation

The change in output voltage, often expressed as a percentage of output voltage, for a change in input voltage from one level to another level.

NOTE: Sometimes this characteristic is normalized with respect to the input voltage change.

Output Noise Voltage

The rms output noise voltage, sometimes expressed as a percentage of the dc output voltage, with constant load and no input ripple.

Output Regulation

The change in output voltage, often expressed as a percentage of output voltage, for a change in load current from one level to another level.

Output Voltage Change With Temperature

The percentage change in the output voltage for a change in temperature. This is the net change over the total temperature range.

Output Voltage Long-Term Drift

The change in the output voltage over a long period of time.

Peak Output Current

The maximum output current that can be obtained from the regulator due to limiting circuitry within the regulator.

Reference Voltage

The voltage that is compared with the feedback sense voltage to control the regulator.

Ripple Rejection

The ratio of the peak-to-peak input ripple voltage to the peak-to-peak output ripple voltage.

NOTE: This is the reciprocal of ripple sensitivity.

Ripple Sensitivity

The ratio of the peak-to-peak output ripple voltage, sometimes expressed as a percentage of output voltage, to the peak-to-peak input ripple voltage.

NOTE: This is the reciprocal of ripple rejection.

Short-Circuit Output Current

The output current of the regulator with the output shorted to ground.

Standby Current

The input current drawn by the regulator with no output load and no reference voltage load.

Temperature Coefficient of Output Voltage (α_{VO})

The ratio of the change in output voltage, usually expressed as a percentage of output voltage, to the change in temperature. This is the average value for the total temperature change.

$$\alpha_{VO} = \pm \left[\frac{V_O \text{ at } T_2 - V_O \text{ at } T_1}{V_O \text{ at } 25^\circ\text{C}} \right] \left[\frac{100\%}{T_2 - T_1} \right]$$

GLOSSARY

VOLTAGE REGULATOR TERMS AND DEFINITIONS

SHUNT REGULATORS

NOTE: These terms and symbols are based on JEDEC and IEC standards for voltage regulator diodes.

Anode

The electrode to which the regulator current flows within the regulator when it is biased for regulation.

Cathode

The electrode from which the regulator current flows within the regulator when it is biased for regulation.

Dynamic Impedance $|z_{KA}|$

The quotient of a change in voltage across the regulator and the corresponding change in current through the regulator when it is biased for regulation.

Noise Voltage (V_{nz})

The rms noise voltage with the regulator biased for regulation and with no input ripple.

Reference Input Voltage (V_{ref}) (of an adjustable shunt regulator)

The voltage at the reference input terminal with respect to the anode terminal.

Regulator Current (I_Z)

The dc current through the regulator when it is biased for regulation.

Regulator Current near Lower Knee of Regulation Range (I_{ZK})

The regulator current near the lower limit of the region within which regulation occurs; this corresponds to the breakdown knee of a regulator diode.

Regulator Current at Maximum Limit of Regulation Range (I_{ZM})

The regulator current above which the differential resistance of the regulator significantly increases.

Regulator Voltage (V_Z)

The dc voltage across the regulator.

Shunt Regulator

A device having a voltage-current characteristic similar to that of a voltage-regulator diode. It is normally biased to operate in a region of low differential resistance (corresponding to the breakdown region of a regulator diode) and develops across its terminals an essentially constant voltage throughout a specified current range.

Temperature Coefficient of Reference Voltage ($\alpha_{V_{ref}}$)

The ratio of the change in reference voltage to the change in temperature. This is the average value for the total temperature change.

To obtain a value in ppm/°C:

$$\alpha_{V_{ref}} = \left[\frac{V_{ref} \text{ at } T_2 - V_{ref} \text{ at } T_1}{V_{ref} \text{ at } 25^\circ\text{C}} \right] \left[\frac{10^6}{T_2 - T_1} \right]$$

SWITCHING REGULATORS

Current-Mode PWM Control

A PWM control technique in which a second feedback loop is incorporated to accomplish pulse-by-pulse switch current control.

Dead Time

A fixed, load independent off time between output pulses of a switching regulator.

NOTE: This is sometimes referred to as blanking time.

Duty Cycle

The ratio of on time to off time of a switching output, usually expressed as a percentage equal to:
$$\frac{\text{On Time}}{\text{On Time} + \text{Off Time}}$$

Parallel Operation

A dual output switching configuration in which both output stages conduct simultaneously.

Pulse-Width-Modulation (PWM) Control

A switching regulation technique in which a fixed frequency is maintained, and regulation is accomplished by changing the output pulse width to vary the duty cycle.

Push-Pull Operation

A dual output switching configuration in which each output stage conducts alternately.

Single-Ended Operation

A single output switching configuration.

Soft Start

A protection circuit that prevents current surges during power up and protects against false signals that might be generated by the control circuit when power is applied.

Undervoltage Lockout (UVLO)

A protection circuit that prevents switching outputs from turning on until a certain supply voltage threshold is reached.

Variable Frequency Control

A switching regulation technique in which a fixed output on time or off time is maintained. Regulation is accomplished by changing the output frequency to vary the duty cycle.

COMPARATORS SELECTION GUIDE

commercial temperature range

(values specified at $T_A = 25^\circ\text{C}$)

| DESCRIPTION | POWER SUPPLY | | V_{IO} MAX (mV) | I_{IB} MAX (μA) | I_{OL} MIN (mA) | RESPONSE TIME TYP (ns) | TYPE | PACKAGE | PAGE NO. |
|-------------|-------------------------|-------------------------|-------------------------|--------------------------------------|-------------------------|---------------------------------|------|---------|-------------|
| | V_{CC+} NOM (V) | V_{CC-} NOM (V) | | | | | | | |

single channel

| | | | | | | | | | |
|---------------------|------|------|---------|------|--------|--------|---------|----------------------|------|
| Strobe | 12 | -6 | 5 | 40 | 100 | 28 | LM306 | D, P | 3-33 |
| Strobe | 4-30 | 0 | 7.5 | 0.25 | 8 | 115 | LM311 | D, P, Y [‡] | 3-3 |
| Low-Power, Strobe | 4-30 | 0 | 7.5 | 0.1 | 1.6 | 1200 | LP311 | D, P | 3-45 |
| Output Enable | 5 | 0 | ± 1 | - | Max 16 | 25 | TL712 | D, P | 3-53 |
| High-Speed | 5 | 0 | - | - | Max 16 | 7 | TL714C | D, P | 3-57 |
| High-Speed | 0 | -5.2 | ± 1 | - | Max 16 | Max 12 | TL721 | D, P | 3-61 |
| High-Speed, LinCMOS | 3-16 | 0 | 3 | † | 6 | 200 | TLC371C | D, P | 3-97 |

dual channel

| | | | | | | | | | |
|---|--------|---|----|------|---|------|----------|---------------------------------|-------|
| Low-Power, Bipolar | 4-30 | 0 | 5 | 0.25 | 6 | 300 | LM393 | D, DB, P, PW, Y [‡] | 3-27 |
| Precision Input | 4-30 | 0 | 2 | 0.25 | 6 | 300 | LM393A | D, P | |
| Ultra Low-Supply, LinCMOS | 1.4-18 | 0 | 10 | † | 6 | 200 | TLC352C | D, P | 3-81 |
| High-Speed, LinCMOS | 3-16 | 0 | 5 | † | 6 | 200 | TLC372C | D, P | 3-109 |
| Ultra Low-Power, Open-Drain Output, CMOS | 3-18 | 0 | 5 | † | 6 | 1100 | TLC393C | D, P | 3-129 |
| Ultra Low-Power, Push-Pull Output, CMOS | 3-18 | 0 | 5 | † | 4 | 1300 | TLC3702C | D, P | 3-145 |

quad channel

| | | | | | | | | | |
|---|--------|---|---------|--------|---|------|----------|---------------------------------|-------|
| Low-Power, Bipolar | 4-30 | 0 | 5 | -0.25 | 6 | 300 | LM339 | D, DB, N, PW, Y [‡] | 3-19 |
| Precision Input | 4-30 | 0 | 2 | -0.25 | 6 | 300 | LM339A | D, N | |
| Ultra Low-Power, Bipolar | 4-30 | 0 | ± 5 | -0.025 | 6 | 8000 | LP339 | D, N | 3-49 |
| Ultra Low-Power, Open-Drain Output, CMOS | 3-18 | 0 | 5 | † | 6 | 1100 | TLC339C | D, N | 3-65 |
| Ultra Low-Supply, LinCMOS | 1.4-18 | 0 | 10 | † | 6 | 200 | TLC354C | D, N | 3-89 |
| High-Speed, CMOS | 3-18 | 0 | 10 | † | 6 | 200 | TLC374C | D, N | 3-119 |
| Ultra Low-Power, Push-Pull Output, CMOS | 3-18 | 0 | 5 | † | 4 | 1300 | TLC3704C | D, N | 3-167 |

† Typically 5 pA

‡ Y package is in chip form

COMPARATORS SELECTION GUIDE

industrial temperature range

(values specified at $T_A = 25^\circ\text{C}$)

| DESCRIPTION | POWER SUPPLY | | V_{IO} MAX (mV) | I_{IB} MAX (μA) | I_{OL} MIN (mA) | RESPONSE TIME TYP (ns) | TYPE | PACKAGE | PAGE NO. |
|-------------|-------------------------|-------------------------|-------------------------|--------------------------------------|-------------------------|---------------------------------|------|---------|-------------|
| | V_{CC+} NOM (V) | V_{CC-} NOM (V) | | | | | | | |

single channel

| | | | | | | | | | |
|-------------------|------|---|-----|-----|-----|------|-------|------|------|
| Strobe | 4-30 | 0 | 3 | 0.1 | 8 | 115 | LM211 | D, P | 3-3 |
| Low-Power, Strobe | 4-30 | 0 | 7.5 | 0.1 | 1.6 | 1200 | LP211 | D, P | 3-45 |

dual channel

| | | | | | | | | | |
|---------------------------------------|--------|---|----|------|---|------|----------|------|-------|
| Industrial LM393 | 4-30 | 0 | 5 | 0.25 | 6 | 300 | LM293 | D, P | 3-27 |
| Industrial LM393, Low Offset | 4-30 | 0 | 2 | 0.25 | 6 | 300 | LM293A | D, P | |
| Ultra Low-Supply, LinCMOS | 1.4-18 | 0 | 10 | † | 6 | 200 | TLC352I | D, P | 3-81 |
| High-Speed, LinCMOS | 3-16 | 0 | 5 | † | 6 | 200 | TLC371I | D, P | 3-97 |
| High-Speed, LinCMOS | 3-16 | 0 | 5 | † | 6 | 200 | TLC372I | D, P | 3-109 |
| Ultra Low-Power, Open-Drain Output | 3-18 | 0 | 5 | † | 6 | 1100 | TLC393I | D, P | 3-129 |
| Ultra Low-Power, Push-Pull Output | 3-18 | 0 | 5 | † | 4 | 1300 | TLC3702I | D, P | 3-145 |

quad channel

| | | | | | | | | | |
|---|--------|---|---------|--------|----|------|----------|------|-------|
| Industrial LM339 | 4-30 | 0 | 5 | -0.25 | 6 | 300 | LM239 | D, N | 3-19 |
| Industrial LM339, Low Offset | 4-30 | 0 | 2 | -0.25 | 6 | 300 | LM239A | D, N | |
| Ultra Low-Power, Industrial LP339, Bipolar | 4-30 | 0 | ± 5 | -0.025 | 20 | 8000 | LP239 | D, N | 3-49 |
| Ultra Low-Power, Open-Drain Output | 3-18 | 0 | 5 | † | 6 | 1100 | TLC339I | D, N | 3-65 |
| Ultra Low-Supply, LinCMOS | 1.4-18 | 0 | 10 | † | 6 | 200 | TLC354I | D, N | 3-89 |
| High-Speed, LinCMOS | 3-18 | 0 | 10 | † | 6 | 200 | TLC374I | D, N | 3-119 |
| Ultra Low-Power, Push-Pull Output | 3-18 | 0 | 5 | † | 4 | 1300 | TLC3704I | D, N | 3-167 |

† Typically 5 pA

automotive temperature range

 (values specified at $T_A = 25^\circ\text{C}$)

| DESCRIPTION | POWER SUPPLY | | V _{IO} MAX (mV) | I _{IB} MAX (μA) | I _{OL} MIN (mA) | RESPONSE TIME TYP (ns) | TYPE | PACKAGE | PAGE NO. |
|-------------|--------------------------------|--------------------------------|--------------------------------|---|--------------------------------|---------------------------------|------|---------|-------------|
| | V _{CC+} NOM (V) | V _{CC-} NOM (V) | | | | | | | |

dual channel

| | | | | | | | | | |
|---------------------------------------|--------|---|----|------|---|------|--------------------|-----------------|-------|
| Automotive LM393 | 4–30 | 0 | 7 | 0.25 | 6 | 300 | LM2903, LM2903Q | D, DB, P, PW | 3–27 |
| Ultra Low-Supply, LinCMOS | 1.4–18 | 0 | 10 | † | 6 | 200 | TLC352I | D, P | 3–81 |
| High-Speed, LinCMOS | 3–16 | 0 | 5 | † | 6 | 200 | TLC372Q | D, P | 3–109 |
| Ultra Low-Power, Open-Drain Output | 3–18 | 0 | 5 | † | 6 | 1100 | TLC393I | D, P | 3–129 |
| Ultra Low-Power, Push-Pull Output | 3–18 | 0 | 5 | † | 4 | 1300 | TLC3702Q | JG | 3–145 |

quad channel

| | | | | | | | | | |
|---|--------|---|----|--------|----|------|--------------------|-----------------|-------|
| Automotive LM339 | 4–30 | 0 | 7 | –0.25 | 6 | 300 | LM2901, LM2901Q | D, DB, N, PW | 3–19 |
| Low-Cost LM2901 | 4–26 | 0 | 20 | 0.5 | 6 | 300 | LM3302 | D, N | 3–41 |
| Ultra Low-Power, Automotive LP339, Bipolar | 5 | 0 | ±5 | –0.025 | 20 | 8000 | LP2901 | D, N | 3–49 |
| Ultra Low-Supply, LinCMOS | 1.4–18 | 0 | 10 | † | 6 | 200 | TLC354I | D, N | 3–89 |
| Open-Drain Output | 3–18 | 0 | 5 | † | 6 | 1100 | TLC339Q | D, N | 3–65 |
| High-Speed, LinCMOS | 3–18 | 0 | 10 | † | 6 | 200 | TLC374Q | D, N | 3–119 |
| Push-Pull Output | 3–18 | 0 | 5 | † | 4 | 1300 | TLC3704Q | J | 3–167 |

† Typically 5 pA

COMPARATORS SELECTION GUIDE

military temperature range

(values specified at $T_A = 25^\circ\text{C}$)

| DESCRIPTION | POWER SUPPLY | | V_{IO} MAX (mV) | I_{IB} MAX (μA) | I_{OL} MIN (mA) | RESPONSE TIME TYP (ns) | TYPE | PACKAGE | PAGE NO. |
|-------------|-------------------------|-------------------------|-------------------------|--------------------------------------|-------------------------|---------------------------------|------|---------|-------------|
| | V_{CC+} NOM (V) | V_{CC-} NOM (V) | | | | | | | |

single channel

| | | | | | | | | | |
|-------------------|------|---|-----|-----|-----|------|-------|-----------------|------|
| Strobe | 4-30 | 0 | 3 | 0.1 | 8 | 115 | LM111 | FK, J, JG, U | 3-3 |
| Low-Power, Strobe | 4-30 | 0 | 7.5 | 0.1 | 1.6 | 1200 | LP111 | FK, JG | 3-45 |

dual channel

| | | | | | | | | | |
|---------------------------------------|--------|---|----|-----|---|------|----------|-----------------|-------|
| Low-Power, Bipolar | 4-30 | 0 | 5 | 0.1 | 6 | 300 | LM193 | D, FK, JG, P | 3-27 |
| Ultra Low-Supply, LinCMOS | 1.4-18 | 0 | 10 | † | 6 | 200 | TLC352M | FK, JG | 3-81 |
| High-Speed, LinCMOS | 4-16 | 0 | 5 | † | 6 | 200 | TLC371M | D, P | 3-97 |
| High-Speed, LinCMOS | 4-16 | 0 | 5 | † | 6 | 200 | TLC372M | FK, JG | 3-109 |
| Ultra Low-Power, Open-Drain Output | 4-18 | 0 | 5 | † | 6 | 1100 | TLC393M | FK, JG | 3-129 |
| Ultra Low-Power, Push-Pull Output | 4-18 | 0 | 5 | † | 4 | 1300 | TLC3702M | FK, JG | 3-145 |

quad channel

| | | | | | | | | | |
|---------------------------------------|--------|---|----|------|---|------|----------|-------------|-------|
| Low-Power, Bipolar | 4-30 | 0 | 5 | -0.1 | 6 | 300 | LM139 | D, FK, J, N | 3-19 |
| Precision Input | 4-30 | 0 | 2 | -0.1 | 6 | 300 | LM139A | D, FK, J, N | |
| Ultra Low-Power, Open-Drain Output | 4-18 | 0 | 5 | † | 6 | 1100 | TLC339M | D, FK, J, N | 3-65 |
| Ultra Low-Supply, LinCMOS | 1.4-18 | 0 | 10 | † | 6 | 200 | TLC354M | FK, J | 3-89 |
| High Speed, LinCMOS | 4-18 | 0 | 10 | † | 6 | 200 | TLC374M | FK, J | 3-119 |
| Ultra Low-Power, Push-Pull Output | 4-18 | 0 | 5 | † | 4 | 1300 | TLC3704M | FK, J | 3-167 |

† Typically 5 pA



COMPARATORS CROSS-REFERENCE GUIDE

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Manufacturers are arranged in alphabetical order.

LINEAR TECHNOLOGY

LT1017
LT1018

SUGGESTED TI REPLACEMENT

TLC352 or TLC3702
TLC352, or TLC3702

PAGE NO.

3-81 / 3-145
3-81 / 3-145

NATIONAL

LM311
LM339
LM393
LM2901
LM3302
LP339

DIRECT TI REPLACEMENT

LM311
LM339
LM393
LM2901
LM3302
LP339

SUGGESTED TI REPLACEMENT

TLC339
TLC393
TLC339
TLC339

PAGE NO.

3-3
3-19 / 3-65
3-27 / 3-129
3-19 / 3-65
3-41
3-49 / 3-65

PMI

CMP04F

DIRECT TI REPLACEMENT

SUGGESTED TI REPLACEMENT

LM339, LM3302,
LM2901, or TLC339

PAGE NO.

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3-65

Average Temperature Coefficient of Input Offset Current ($\alpha_{I_{IO}}$)

The ratio of the change in input offset current to the change in free-air temperature. This is an average value for the specified temperature range.

$$\alpha_{I_{IO}} = \frac{I_{IO \text{ at } T_{A(1)}} - I_{IO \text{ at } T_{A(2)}}}{T_{A(1)} - T_{A(2)}}$$

where $T_{A(1)}$ and $T_{A(2)}$ are the specified temperature extremes.

Average Temperature Coefficient of Input Offset Voltage ($\alpha_{V_{IO}}$)

The ratio of the change in input offset current to the change in free-air temperature. This is an average value for the specified temperature range.

$$\alpha_{V_{IO}} = \frac{V_{IO \text{ at } T_{A(1)}} - V_{IO \text{ at } T_{A(2)}}}{T_{A(1)} - T_{A(2)}}$$

where $T_{A(1)}$ and $T_{A(2)}$ are the specified temperature extremes.

Common-Mode Input Voltage (V_{IC})

The average of the two input voltages.

Common-Mode Input Voltage Range (V_{ICR})

The range of common-mode input voltage that if exceeded will cause the comparator to cease functioning properly.

Common-Mode Rejection Ratio (k_{CMR} , CMRR)

The ratio of differential voltage amplification to common-mode voltage amplification.

NOTE: This is measured by determining the ratio of a change in input common-mode voltage to the resulting change in input offset voltage.

Differential Input Voltage (V_{ID})

The voltage at the noninverting input with respect to the inverting input.

Differential Input Voltage Range (V_{IDR})

The range of voltage between the two input terminals that if exceeded will cause the comparator to cease functioning properly.

Differential Voltage Amplification (A_{VD})

The ratio of the change in output to the change in differential input voltage producing it with the common-mode input voltage held constant.

High-Level Output Current (I_{OH})

The current into an output with input conditions applied that according to the product specification will establish a high level at the output.

High-Level Output Voltage (V_{OH})

The voltage at an output with input conditions applied that according to the product specification will establish a high level at the output.

High-Level Strobe Current ($I_{IH(S)}$)

The current flowing into or out of† the strobe at a high-level voltage.

High-Level Strobe Voltage ($V_{IH(S)}$)

For a device having an active-low strobe, a voltage within that range is guaranteed not to interfere with the operation of the comparator.

Input Bias Current (I_{IB})

The average of the currents into the two input terminals with the output at the specified level.

Input Offset Current (I_{IO})

The difference between the currents into the two input terminals with the output at the specified level.

† Current out of a terminal is given as a negative value.

GLOSSARY COMPARATORS

Input Offset Voltage (V_{IO})

The dc voltage that must be applied between the input terminals to force the quiescent dc output voltage to the specified level.

Input Voltage Range (V_I)

The range of voltage that if exceeded at either input terminal will cause the comparator to cease functioning properly.

Low-Level Output Current (I_{OL})

The current into an output with input conditions applied that according to the product specification will establish a low level at the output.

Low-Level Output Voltage (V_{OL})

The voltage at an output with input conditions applied that according to the product specification will establish a low level at the output.

Low-Level Strobe Current ($I_{IL(S)}$)

The current flowing out of † the strobe at a low-level voltage.

Low-Level Strobe Voltage ($V_{IL(S)}$)

For a device having an active-low strobe, a voltage within the range that is guaranteed to force the output high or low, as specified, independently of the differential inputs.

Output Resistance (r_o)

The resistance between an output terminal and ground.

Response Time

The interval between the application of an input step function and the instant the output crosses the logic threshold voltage.

NOTE: The input step drives the comparator from some initial condition sufficient to saturate the output (or in the case of high-to-low-level response time, to turn the output off) to an input level just barely in excess of that required to bring the output back to the logic threshold voltage. This excess is referred to as the voltage overdrive.

Strobe Release Time

The time required for the output to rise to the logic threshold voltage after the strobe terminal has been driven from its active logic level to its inactive logic level.

Supply Current (I_{CC+} , I_{CC-})

The current into the V_{CC+} or V_{CC-} terminal of an integrated circuit.

Total Power Dissipation (P_D)

The total dc power supplied to the device less any power delivered from the device to a load.

NOTE: At no load: $P_D = V_{CC+} \cdot I_{CC+} + V_{CC-} \cdot I_{CC-}$.

† Current out of a terminal is given as a negative value.

precision timers

commercial temperature range

(values specified for $T_A = 25^\circ\text{C}$)

| DESCRIPTION | OUTPUT CURRENT | TIMING | | TYPE | PACKAGES | PAGE NO. |
|---|------------------|------------------|-------|---------|----------|----------|
| | | FROM | TO | | | |
| Single Timer, Bipolar | ± 200 mA | 10 μs | Hours | NE555 | D, P, Y† | 4-11 |
| Dual Timer, Bipolar | ± 200 mA | 10 μs | Hours | NE556 | D, N | 4-33 |
| LinCMOS, Single High-Speed Timer, 1-V Operation | 100 mA -10 mA | 1 μs | Hours | TLC551 | D, P, Y† | 4-123 |
| LinCMOS, Dual High-Speed Timer, 1-V Operation | 100 mA -10 mA | 1 μs | Hours | TLC552C | D, N | 4-135 |
| LinCMOS, Single High-Speed Timer | 100 mA -10 mA | 1 μs | Hours | TLC555C | D, P | 4-143 |
| | | | | TLC555Y | Y† | |
| LinCMOS, Dual High-Speed Timer | 100 mA -10 mA | 1 μs | Hours | TLC556C | D, N | 4-153 |
| Programmable Timer/Counter | 4 mA | 10 μs | Days | uA2240C | N | 4-173 |

† Y package is in chip form

automotive temperature range

(values specified for $T_A = 25^\circ\text{C}$)

| DESCRIPTION | OUTPUT CURRENT | TIMING | | TYPE | PACKAGES | PAGE NO. |
|----------------------------------|------------------|------------------|-------|---------|----------|----------|
| | | FROM | TO | | | |
| Single Timer, Bipolar | ± 200 mA | 10 μs | Hours | SA555 | D, P | 4-11 |
| Dual Timer, Bipolar | ± 200 mA | 10 μs | Hours | SA556 | D, N | 4-33 |
| LinCMOS, Single High-Speed Timer | 100 mA -10 mA | 1 μs | Hours | TLC555I | D, P | 4-143 |
| LinCMOS, Dual High-Speed Timer | 100 mA -10 mA | 1 μs | Hours | TLC556I | D, N | 4-153 |

military temperature range

(values specified for $T_A = 25^\circ\text{C}$)

| DESCRIPTION | OUTPUT CURRENT | TIMING | | TYPE | PACKAGES | PAGE NO. |
|----------------------------------|------------------|-----------------|-------|---------|--------------|----------|
| | | FROM | TO | | | |
| Single Timer, Bipolar | ± 200 mA | 1 μs | Hours | SE555 | D, FK, JG, P | 4-11 |
| Single Timer, Bipolar | ± 200 mA | 1 μs | Hours | SE555C | D, FK, JG, P | |
| Dual Timer, Bipolar | ± 200 mA | 1 μs | Hours | SE556 | D, FK, J, N | 4-33 |
| Dual Timer, Bipolar | ± 200 mA | 1 μs | Hours | SE556C | D, FK, J, N | |
| LinCMOS, Single High-Speed Timer | 100 mA -10 mA | 1 μs | Hours | TLC555M | D, FK, JG, P | 4-143 |
| LinCMOS, Dual High-Speed Timer | 100 mA -10 mA | 1 μs | Hours | TLC556M | D, FK, J, N | 4-153 |

SPECIAL FUNCTIONS SELECTION GUIDE

current mirrors

(values specified for $T_A = 25^\circ\text{C}$)

| DESCRIPTION | TEMPERATURE RANGE | CURRENT RATIO INPUT TO OUTPUT | INPUT CURRENT RANGE | TYPE | PACKAGES | PAGE NO. |
|--------------|-------------------|-------------------------------|-------------------------|---------|----------|----------|
| Programmable | 0°C to 70°C | 3:1 to 1:15 | Variable | TL010C | P | 4-45 |
| Programmable | -40°C to 85°C | 3:1 to 1:15 | Variable | TL010I | P | |
| Fixed | 0°C to 70°C | 1:1 | 1 μA to 1 mA | TL011C | LP | 4-49 |
| Fixed | -40°C to 85°C | 1:1 | 1 μA to 1 mA | TL011I | LP | |
| Fixed | 0°C to 70°C | 1:2 | 1 μA to 1 mA | TL012C | LP | |
| Fixed | -40°C to 85°C | 1:2 | 1 μA to 1 mA | TL012I | LP | |
| Fixed | 0°C to 70°C | 1:4 | 1 μA to 1 mA | TL014AC | LP | |
| Fixed | 0°C to 70°C | 1:2 | 2 μA to 2 mA | TL021C | LP | |
| Fixed | -40°C to 85°C | 1:2 | 2 μA to 2 mA | TL021I | LP | |

sonar ranging functions

(values specified for $T_A = 25^\circ\text{C}$)

| DESCRIPTION | | TYPE | PACKAGES | PAGE NO. |
|--------------------|---|-------|----------|----------|
| Controller Circuit | Control integrated circuit for use in a sonar ranging module, capable of driving 50-kHz transducers with a simple interface | TL851 | N | 4-109 |
| Receiver Circuit | Receiver integrated circuit for use in a sonar ranging module | TL852 | N | 4-113 |
| Control Circuit | Control integrated circuit for use in a sonar ranging module, capable of driving 40-kHz transducers With a simple interface | TL853 | N | 4-119 |

floppy-disk control circuits

(values specified for $T_A = 25^\circ\text{C}$)

| DESCRIPTION | | TYPE | PACKAGES | PAGE NO. |
|--|--|---------|----------|----------|
| Tape-Read Signal Conditioner | | TL041AC | DW, NT | 4-77 |
| Disk-Memory Read-Chain Data Comparator | | TL712 | D, JG, P | 3-53 |
| Disk-Memory Read-Chain Data Comparator With MECL III and MECL 1000 | | TL721 | D, JG, P | 3-61 |

differential video amplifiers

commercial temperature range

(values specified for $T_A = 25^\circ\text{C}$)

| DESCRIPTION | BANDWIDTH (MHz) | GAIN | TYPICAL NOISE, V_n | TYPE | PACKAGES | PAGE NO. |
|---|-----------------|--------------|----------------------|--------|----------|----------|
| Amplifier With 2 Multiplexed Inputs and Wide AGC Range | 60 | 100 Max | 25 μV | MC1445 | J, N | 4-9 |
| Amplifier With Internal Frequency Compensation and Adjustable/Selectable Gain Options | 90 | 600 Max | 12 μV | NE592 | D, N | 4-25 |
| Amplifier With a Wide AGC Range | 50 | 100 | 12 μV | TL026C | D, P | 4-55 |
| Amplifier With a Wide AGC Range | 50 | 400 Max | 12 μV | TL027C | D, J, N | 4-63 |
| 2-Channel Multiplexed Video Amp | 20 | 600 Max | <5 μV | TL040C | D, N | 4-71 |
| Similar to NE592 but in an 8-Pin Package | 90 | 600 Max | 12 μV | TL592 | D, P | 4-99 |
| Low-Noise Version of NE592 and TL592 | 90 | 600 Max | 3 μV | TL592B | D, N, P | 4-103 |
| Amplifier With Internal Frequency Compensation | 200 | 10, 100, 400 | 12 μV | uA733C | D, N | 4-165 |

military temperature range

(values specified for $T_A = 25^\circ\text{C}$)

| DESCRIPTION | BANDWIDTH (MHz) | GAIN | TYPICAL NOISE, V_n | TYPE | PACKAGES | PAGE NO. |
|---|-----------------|--------------|----------------------|--------|----------|----------|
| Amplifier With Internal Frequency Compensation and Adjustable/Selectable Gain Options | 90 | 600 Max | 12 μV | SE592 | J | 4-25 |
| Amplifier With Internal Frequency Compensation | 200 | 10, 100, 400 | 12 μV | uA733M | J, U | 4-165 |



SPECIAL FUNCTIONS SELECTION GUIDE

logarithmic amplifiers

(values specified for military temperature range)

| DESCRIPTION | BANDWIDTH | GAIN | TYPE | PACKAGES | PAGE NO. |
|-----------------------|-----------|-------------------|---------|----------|----------|
| Logarithmic Amplifier | 40 MHz | Logarithmic Curve | TL441AM | J, FK | 4-85 |

programmable tone/noise generators

(values specified for $T_A = 25^\circ\text{C}$)

| DESCRIPTION | TYPE | PACKAGES | PAGE NO. |
|---|--|----------|----------|
| Complex Sound Generators Designed to Provide Low-Cost Digital Tones or Noise Programmable White-Noise and Attenuation Functions, and Simultaneous Sounds Under Microprocessor Control TTL Compatible | SN76494/ SN76494A SN76496/ SN76496A | N | 4-37 |

frequency-to-voltage-converters

(values specified for $T_A = 25^\circ\text{C}$)

| DESCRIPTION | TYPE | PACKAGES | PAGE NO. |
|---|------------------|----------|----------|
| Output Swings to Ground for Zero-Frequency Input Only One RC Network Provides Frequency Doubling for Low Ripple 8-Pin Version Interfaces Directly to Variable Reluctance Magnetic Pickups | LM2907 LM2917 | D, N, P | 4-3 |

SPECIAL FUNCTIONS CROSS-REFERENCE GUIDE

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| MC1733 | | uA733 | 4-165 |
| NE555 | NE555 | | 4-11 |
| NE592 | NE592 | | 4-25 |
| | DIRECT TI REPLACEMENT | SUGGESTED TI REPLACEMENT | PAGE NO. |
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| NE556 | NE556 | TLC556 | 4-33 / 4-153 |
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| SA556 | SA556 | TLC556 | 4-33 / 4-153 |
| SE555 | SE555 | TLC555 | 4-11 / 4-143 |
| SE555C | SE555C | TLC555 | 4-11 / 4-143 |
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| SE556C | SE556C | TLC556 | 4-33 / 4-153 |
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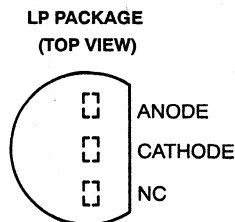
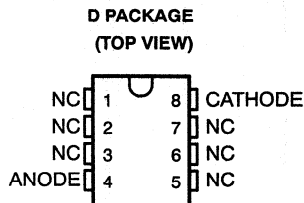
| | |
|--|----------|
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| VRegs/Supervisors and Bldg Blocks | 2 |
| Comparators | 3 |
| Special Functions | 4 |
| Thermal Design Considerations | 5 |
| Mechanical Data | 6 |

2 VRegs/Supervisors and Bidg Blocks

LM185-1.2, LM285-1.2, LM385-1.2, LM385B-1.2 MICROPOWER VOLTAGE REFERENCES

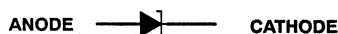
D3268, APRIL 1989—REVISED AUGUST 1991

- **Operating Current Range . . . 10 μ A to 20 mA**
- **1% and 2% Initial Voltage Tolerance**
- **Reference Impedance**
 LM185 . . . 0.6 Ω Max at 25°C
 LM385 . . . 1 Ω Max at 25°C
 All Devices . . . 1.5 Ω Max Over Full Temperature Range
- **Very Low Power Consumption**
- **Applications:**
 Portable Meter References
 Portable Test Instruments
 Battery-Operated Systems
 Current-Loop Instrumentation
 Panel Meters
- **Designed to Be Interchangeable With National LM185-1.2, LM285-1.2, and LM385-1.2**



NC—No internal connection

symbol



description

These micropower terminal band-gap voltage references operate over a 10- μ A to 20-mA current range and feature exceptionally low dynamic impedance and good temperature stability. On-chip trimming provides tight voltage tolerance. The LM185-1.2 series band-gap reference has low noise and good long-term stability.

Careful design of the LM185-1.2 series has made the device exceptionally tolerant of capacitive loading, making it easy to use in almost any reference application. The wide dynamic operating temperature range allows its use with widely varying supplies with excellent regulation.

The extremely low-power drain of the LM185-1.2 series makes it useful for micropower circuitry. These voltage references can be used to make portable meters, regulators, or general-purpose analog circuitry with battery life approaching shelf life. Further, the wide operating current range allows them to replace older references with a tighter tolerance part.

The LM185-1.2 is characterized for operation over the full military temperature range of -55°C to 125°C . The LM285-1.2 is characterized for operation from -40°C to 85°C . The LM385-1.2 and LM385B-1.2 are characterized for operation from 0°C to 70°C .

AVAILABLE OPTIONS

| T _A | V _Z TOLERANCE | PACKAGE | |
|----------------|-----------------------------|----------------------|-----------------|
| | | SMALL OUTLINE (D) | PLASTIC (LP) |
| 0°C to 70°C | 2% | LM385D-1.2 | LM385LP-1.2 |
| | 1% | LM385BD-1.2 | LM385BLP-1.2 |
| -40°C to 85°C | 1% | LM285D-1.2 | LM285LP-1.2 |
| -55°C to 125°C | 1% | LM185D-1.2 | LM185LP-1.2 |

The D package is available taped and reeled. Add the suffix R to the device type (e.g., LM385DR-1.2).

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

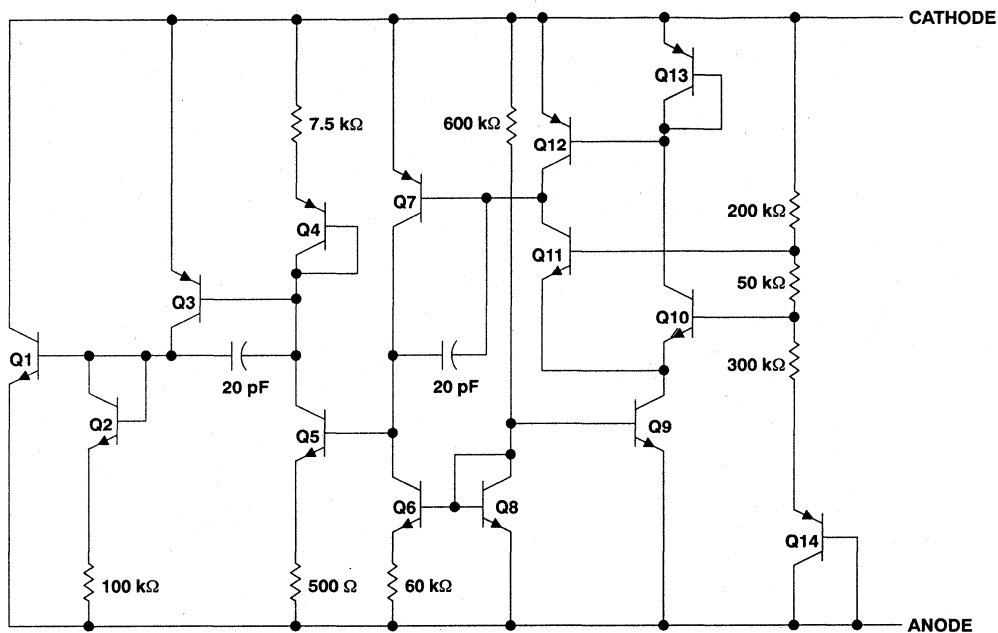
**TEXAS
INSTRUMENTS**

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LM185-1.2, LM285-1.2, LM385-1.2, LM385B-1.2 MICROPOWER VOLTAGE REFERENCES

schematic



Component values shown are nominal.

TEXAS
INSTRUMENTS

POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

LM185-1.2, LM285-1.2, LM385-1.2, LM385B1-1.2 MICROPOWER VOLTAGE REFERENCES

absolute maximum ratings over operating free-air temperature range

| | |
|--|----------------|
| Reverse current, I_R | 30 mA |
| Forward current, I_F | 10 mA |
| Operating free-air temperature range: LM185-1.2 | -55°C to 125°C |
| LM285-1.2 | -40°C to 85°C |
| LM385-1.2, LM385B-1.2 | 0°C to 70°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

recommended operating conditions

| | | MIN | MAX | UNIT |
|---|-----------------------|-----|-------|---------|
| Reference current, I_Z | | 10 | 20000 | μ A |
| Operating free-air temperature range, T_A | LM185-1.2 | -55 | 125 | °C |
| | LM285-1.2 | -40 | 85 | |
| | LM385-1.2, LM385B-1.2 | 0 | 70 | |

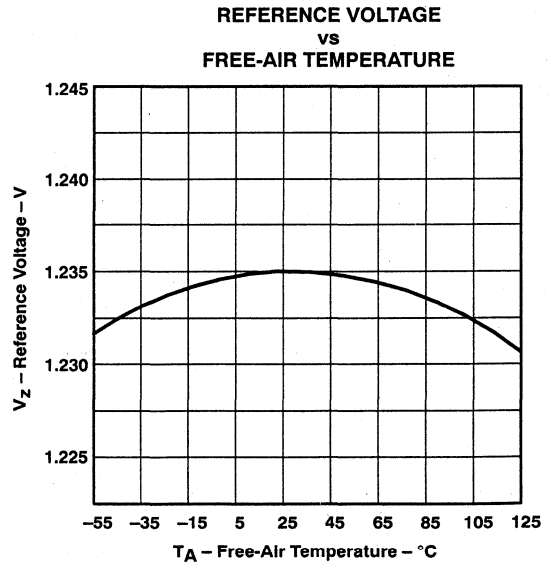
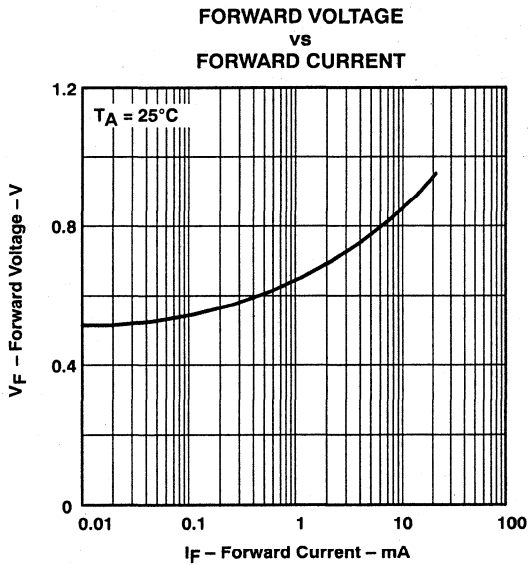
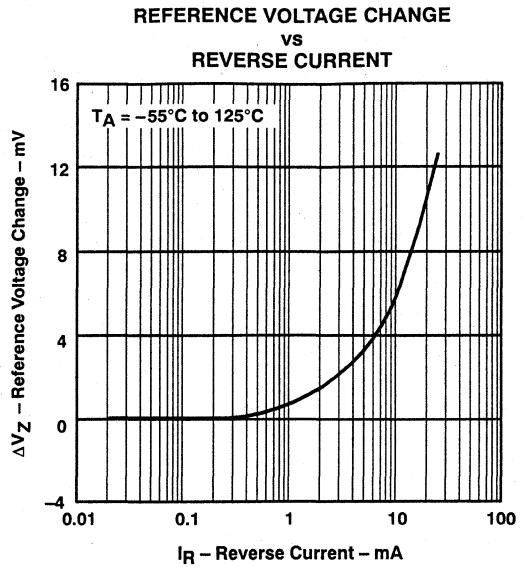
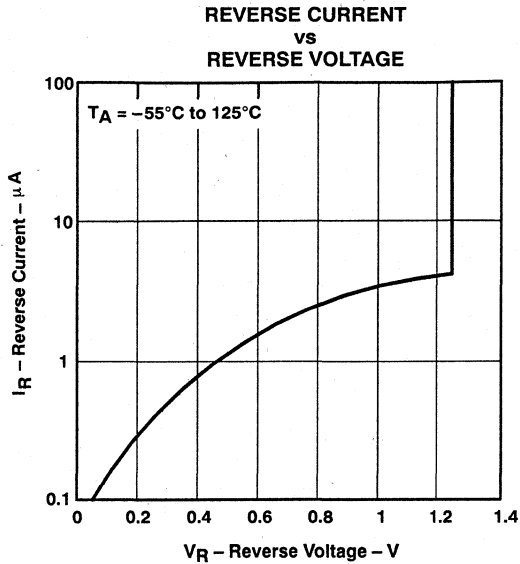
electrical characteristics at specified free-air temperature

| PARAMETER | TEST CONDITIONS | T_A † | LM185-1.2 LM285-1.2 | | | LM385-1.2 | | | LM385B-1.2 | | | UNIT |
|---|---|------------|------------------------|-------|-------|-----------|-------|-------|------------|-------|-------|----------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| V_Z Reference voltage | $I_Z = 10 \mu$ A to 20 mA | 25°C | 1.223 | 1.235 | 1.247 | 1.210 | 1.235 | 1.260 | 1.223 | 1.235 | 1.247 | V |
| α_{VZ} Average temperature coefficient of reference voltage‡ | $I_Z = 10 \mu$ A to 20 mA | 25°C | ± 20 | | | ± 20 | | | ± 20 | | | ppm/°C |
| ΔV_Z Change in reference voltage with current | $I_Z = 10 \mu$ A to 1 mA | 25°C | 1 | | | 1 | | | 1 | | | mV |
| | | Full range | 1.5 | | | 1.5 | | | 1.5 | | | |
| | $I_Z = 1$ mA to 20 mA | 25°C | 10 | | | 20 | | | 20 | | | |
| | | Full range | 20 | | | 25 | | | 25 | | | |
| $\Delta V_Z/\Delta t$ Long-term change in reference voltage | $I_Z = 100 \mu$ A | 25°C | ± 20 | | | ± 20 | | | ± 20 | | | ppm/khr |
| $I_Z(\text{min})$ Minimum reference current | | Full range | 8 10 | | | 8 15 | | | 8 15 | | | μ A |
| Z_Z Reference impedance | $I_Z = 100 \mu$ A | 25°C | 0.2 0.6 | | | 0.4 1 | | | 0.4 1 | | | Ω |
| | | Full range | 1.5 | | | 1.5 | | | 1.5 | | | |
| V_n Broadband noise voltage | $I_Z = 100 \mu$ A, $f = 10$ Hz to 10 kHz | 25°C | 60 | | | 60 | | | 60 | | | μ V |

† Full range is -55°C to 125°C for the LM185-1.2, -40°C to 85°C for the LM285-1.2, and 0°C to 70°C for the LM385-1.2 and LM385B-1.2.

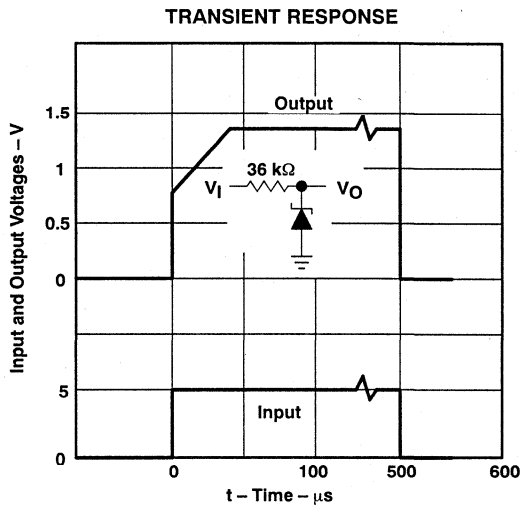
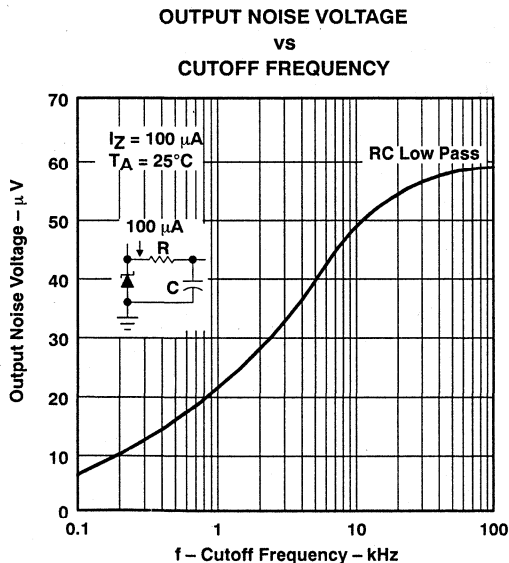
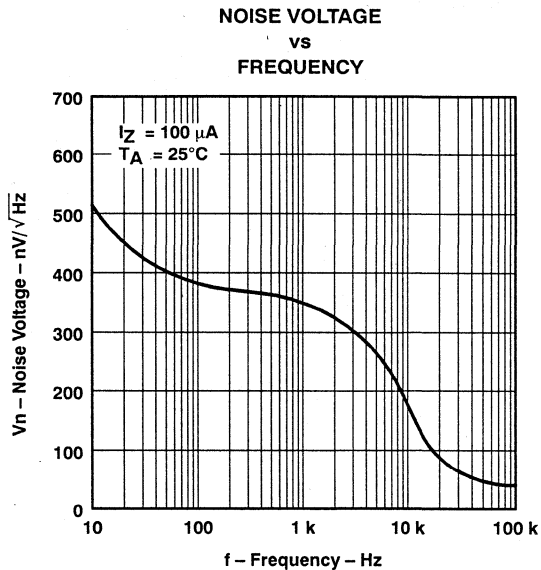
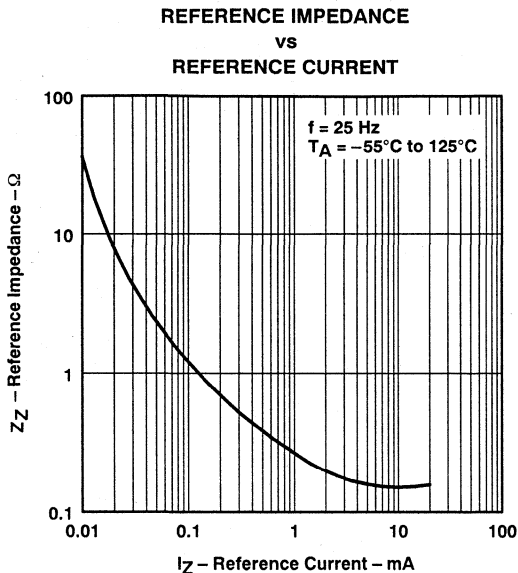
‡ The average temperature coefficient of reference voltage is defined as the total change in reference voltage divided by the specified temperature range.

TYPICAL CHARACTERISTICS†



† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS†



† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

APPLICATION INFORMATION

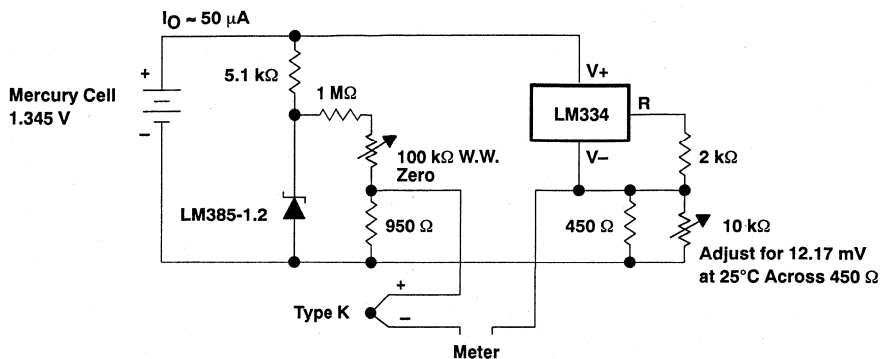


Figure 9. Thermocouple Cold-Junction Compensator

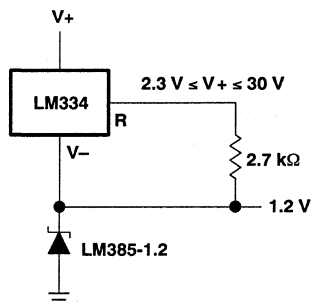


Figure 10. Operation Over a Wide Supply Range

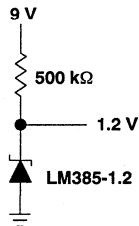
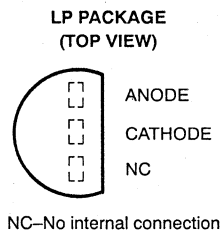
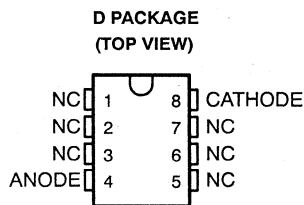


Figure 11. Reference From a 9-V Battery

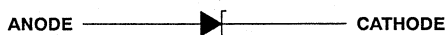
LM185-2.5, LM285-2.5, LM385-2.5, LM385B-2.5 MICROPOWER VOLTAGE REFERENCE

D3189, JANUARY 1989—REVISED JANUARY 1992

- Operating Current Range . . . 20 μ A to 20 mA
- 1.5% and 3% Initial Voltage Tolerance
- Reference Impedance
 LM185 . . . 0.6 Ω Max at 25°C
 LM385 . . . 1 Ω Max at 25°C
 All Devices . . . 1.5 Ω Max Over Full Temperature Range
- Very Low Power Consumption
- Applications:
 Portable Meter References
 Portable Test Instruments
 Battery-Operated Systems
 Current-Loop Instrumentation
 Panel Meters
- Designed to Be Interchangeable With National LM185-2.5, LM285-2.5, and LM385-2.5



symbol



description

These micropower terminal band-gap voltage references operate over a 10- μ A to 20-mA current range and feature exceptionally low dynamic impedance and good temperature stability. On-chip trimming provides tight voltage tolerance. The LM185-2.5 series band-gap reference has low noise and good long-term stability.

Careful design of the LM185-2.5 series has made these devices exceptionally tolerant of capacitive loading, making them easy to use in almost any reference application. The wide dynamic operating temperature range allows their use with widely varying supplies with excellent regulation.

The extremely low power drain of the LM185-2.5 series makes it useful for micropower circuitry. These voltage references can be used to make portable meters, regulators, or general-purpose analog circuitry with battery life approaching shelf life. Further, the wide operating current range allows them to replace older references with a tighter tolerance part.

The LM385-2.5 and LM385B-2.5 are characterized for operation from 0°C to 70°C. The LM285-2.5 is characterized for operation from -40°C to 85°C. The LM185-2.5 is characterized for operation over the full military temperature range of -55°C to 125°C.

AVAILABLE OPTIONS

| T _A | V _Z TOLERANCE | PACKAGE | |
|----------------|-----------------------------|----------------------|-----------------|
| | | SMALL OUTLINE (D) | PLASTIC (LP) |
| 0°C to 70°C | 3% | LM385D-2.5 | LM385LP-2.5 |
| | 1.5% | LM385BD-2.5 | LM385BLP-2.5 |
| -40°C to 85°C | 1.5% | LM285D-2.5 | LM285LP-2.5 |
| -55°C to 125°C | 1.5% | LM185D-2.5 | LM185LP-2.5 |

The D package is available taped and reeled. Add the suffix R to the device type (e.g., LM385DR-2.5).

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

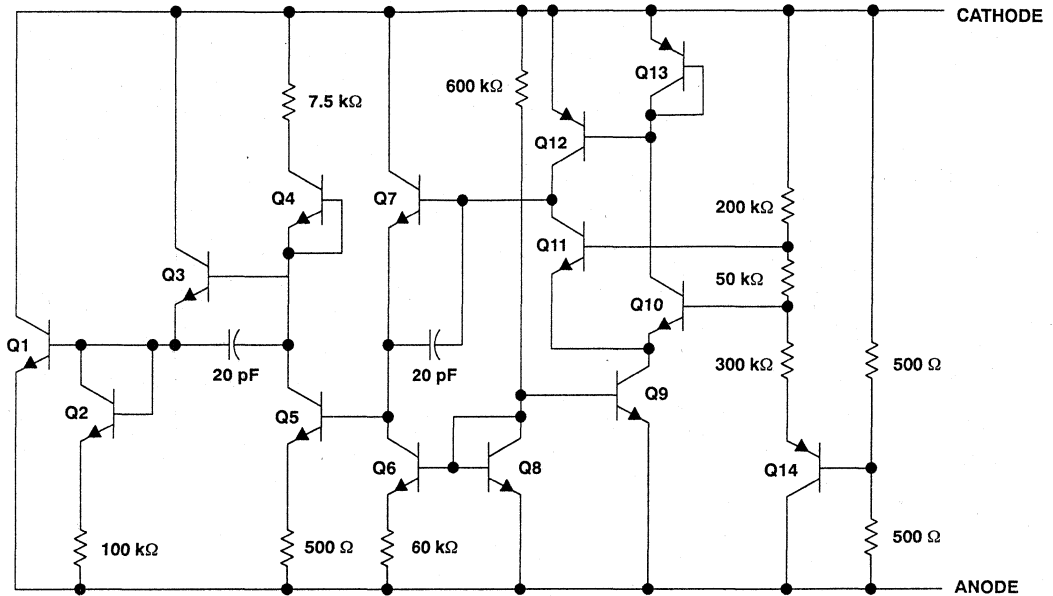
**TEXAS
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LM185-2.5, LM285-2.5, LM385-2.5, LM385B-2.5 MICROPOWER VOLTAGE REFERENCES

schematic



All component values shown are nominal.

absolute maximum ratings over operating free-air temperature range

| | |
|---|----------------|
| Reverse current, I_R | 30 mA |
| Forward current, I_F | 10 mA |
| Operating free-air temperature range: | |
| LM185-2.5 | -55°C to 125°C |
| LM285-2.5 | -40°C to 85°C |
| LM385-2.5, LM385B-2.5 | 0°C to 70°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from cases for 10 seconds | 260°C |

recommended operating conditions

| | MIN | MAX | UNIT |
|---|-----------------------|-------|---------|
| Reference current, I_Z | 20 | 20000 | μ A |
| Operating free-air temperature range, T_A | LM185-2.5 | -55 | 125 |
| | LM285-2.5 | -40 | 85 |
| | LM385-2.5, LM385B-2.5 | 0 | 70 |

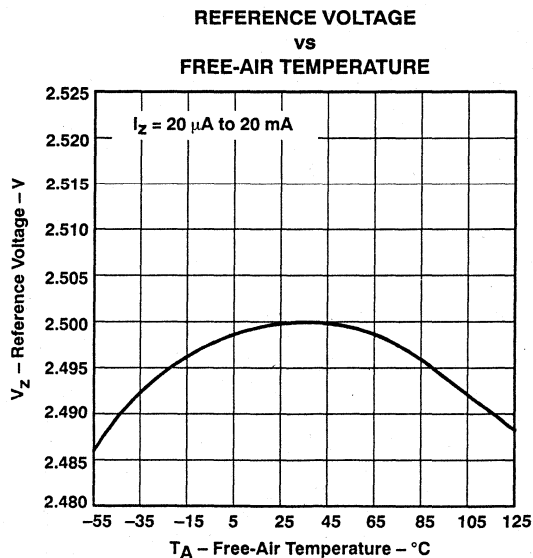
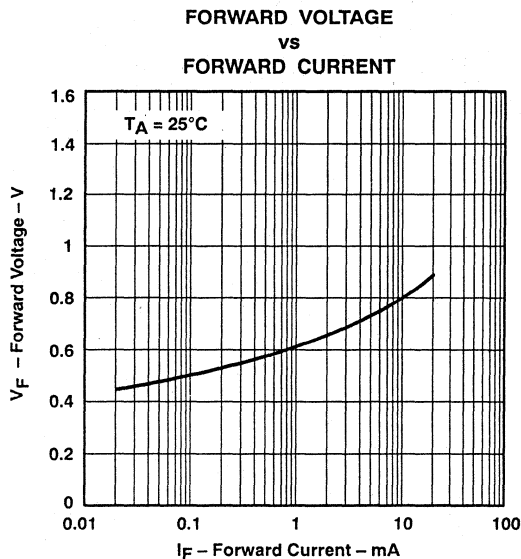
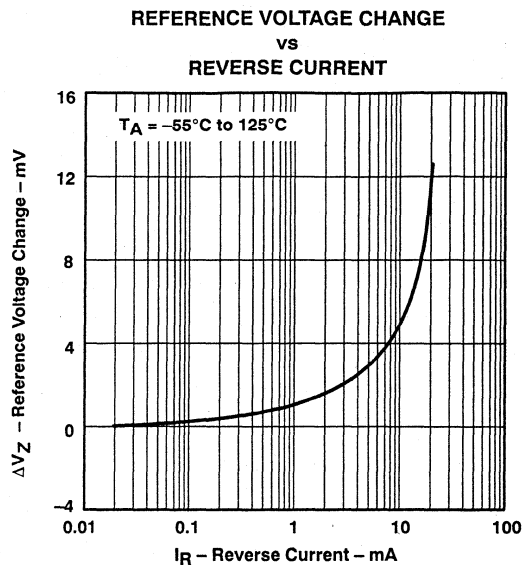
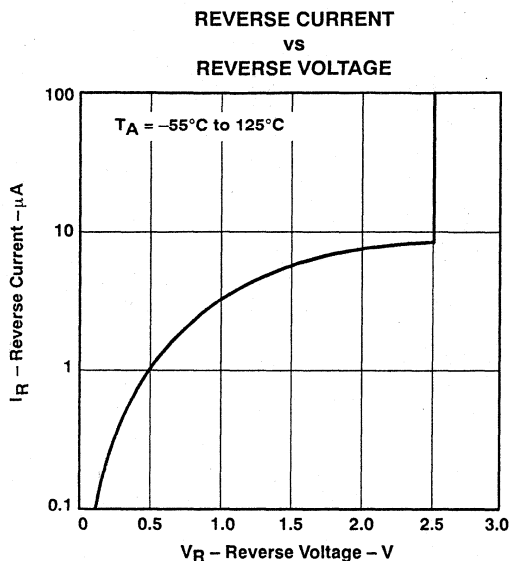
electrical characteristics at specified free-air temperature

| PARAMETER | TEST CONDITIONS | T _A † | LM185-2.5 LM285-2.5 | | | LM385-2.5 | | | LM385B-2.5 | | | UNIT |
|---------------------|---|---------------------------------|---------------------------|-----|-------|-----------|-----|-------|------------|-----|-------|---------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| V _Z | Reference voltage | I _Z = 20 μA to 20 mA | 2.462 | 2.5 | 2.538 | 2.425 | 2.5 | 2.575 | 2.462 | 2.5 | 2.538 | V |
| α _{VZ} | Average temperature coefficient of reference voltage‡ | I _Z = 20 μA to 20 mA | ±20 | | | | | | | | | ppm/°C |
| ΔV _Z | Change in reference voltage with current | I _Z = 20 μA to 1 mA | 25°C | | | | | | | | | 2 |
| | | Full range | 25°C | | | | | | | | | 2 |
| | | I _Z = 1 μA to 20 mA | 25°C | | | | | | | | | 20 |
| ΔV _Z /Δt | Long-term change in reference voltage | I _Z = 100 μA | ±20 | | | | | | | | | ppm/khr |
| | | I _Z (min) | Minimum reference current | | | | | | | | | 25 |
| Z _Z | Reference impedance | I _Z = 100 μA | 25°C | | | 25°C | | | 25°C | | | Ω |
| V _n | Broadband noise voltage | I _Z = 100 μA | 25°C | | | | | | | | | 120 |
| | | f = 10 Hz to 10 kHz | 25°C | | | | | | | | | 120 |

† Full range is 0°C to 70°C for the LM385-2.5 and LM385B-2.5, -40°C to 85°C for the LM285-2.5, and -55°C to 125°C for the LM185-2.5.

‡ The average temperature coefficient of reference voltage is defined as the total change in reference voltage divided by the specified temperature range.

TYPICAL CHARACTERISTICS†



† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS†

REFERENCE IMPEDANCE
vs
REFERENCE CURRENT

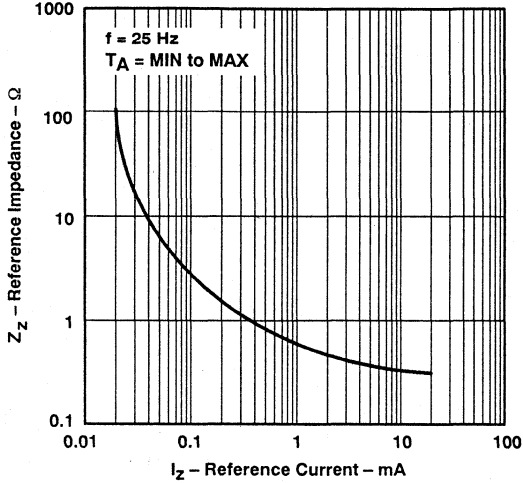


Figure 5

REFERENCE IMPEDANCE
vs
FREQUENCY

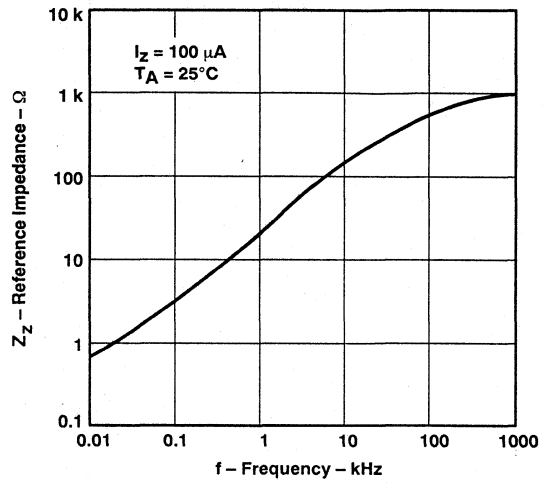


Figure 6

NOISE VOLTAGE
vs
FREQUENCY

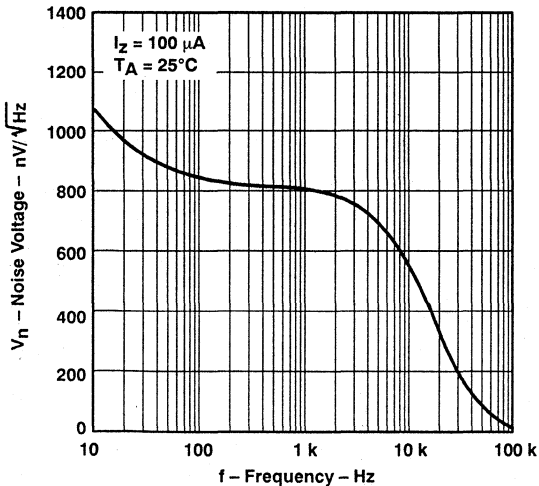


Figure 7

FILTERED RMS OUTPUT NOISE VOLTAGE
vs
FREQUENCY

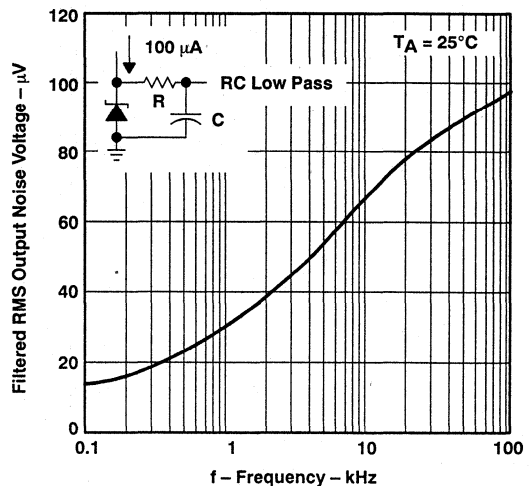


Figure 8

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS†

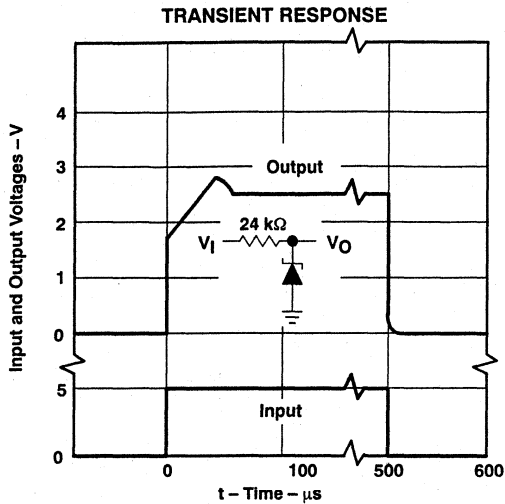


Figure 9

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

APPLICATION INFORMATION

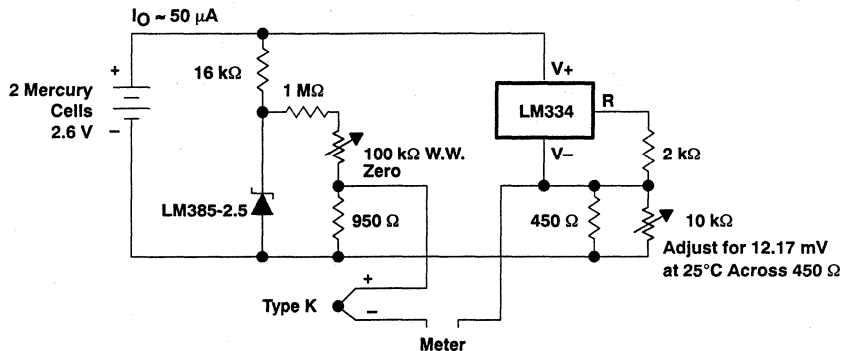


Figure 10. Thermocouple Cold-Junction Compensator

TYPICAL CHARACTERISTICS

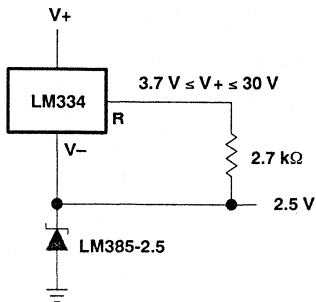


Figure 11. Operation Over a Wide Supply Range

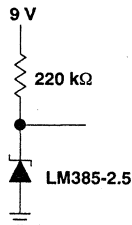


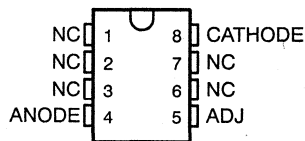
Figure 12. Reference From a 9-V Battery

LM236-2.5, LM336-2.5 2.5-V INTEGRATED REFERENCE CIRCUITS

D3289, NOVEMBER 1988—REVISED AUGUST 1991

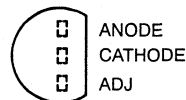
- Low Temperature Coefficient
- Wide Operating Current . . . 400 μ A to 10 mA
- 0.2- Ω Dynamic Impedance
- $\pm 1\%$ Tolerance Available
- Specified Temperature Stability
- Easily Trimmed for Minimum Temperature Drift
- Fast Turn-On
- Three-Lead Transistor Package

D PACKAGE
(TOP VIEW)



NC—No internal connection

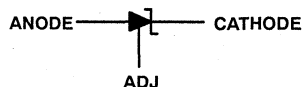
LP PACKAGE
(TOP VIEW)



description

The LM236-2.5 and LM336-2.5 integrated circuits are precision 2.5-V shunt regulator diodes. These monolithic references operate as a low-temperature coefficient 2.5-V zener with a 0.2- Ω dynamic impedance. A third terminal provided on the circuits allows the reference voltage and temperature coefficient to be easily trimmed.

symbol



The series are useful as a precision 2.5-V low-voltage reference (V_Z) for digital voltmeters, power supplies, or operational amplifier circuitry. The 2.5-V voltage reference makes it convenient to obtain a stable reference from 5-V logic supplies. Since the series operate as shunt regulators, they can be used as either positive or negative voltage references.

The LM236-2.5 is characterized for operation from -25°C to 85°C . The LM336-2.5 is characterized for operation from 0°C to 70°C .

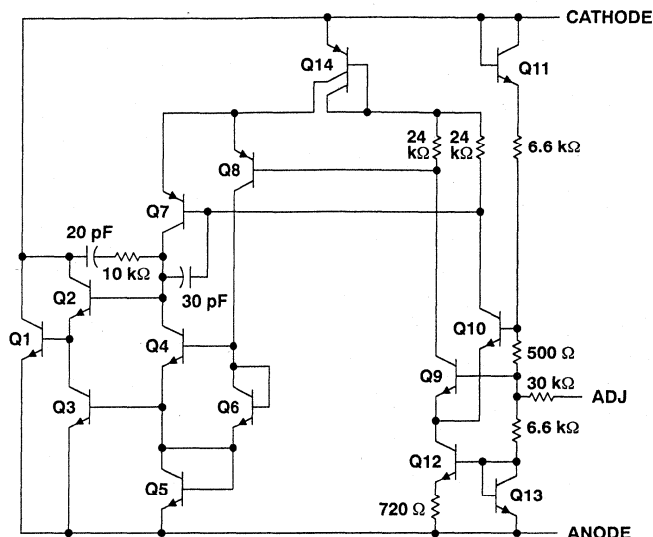
AVAILABLE OPTIONS

| T _A | PACKAGE | |
|---------------------|----------------------|-----------------|
| | SMALL OUTLINE (D) | PLASTIC (LP) |
| 0°C to 70°C | LM336D-2.5 | LM336LP-2.5 |
| -25°C to 85°C | LM236D-2.5 | LM236LP-2.5 |

The D package is available taped and reeled. Add the suffix R to the device type (i.e., LM336DR-2.5).

LM236-2.5, LM336-2.5 2.5-V INTEGRATED REFERENCE CIRCUITS

schematic diagram



All component values are nominal

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|----------------|
| Reverse current | 20 mA |
| Forward current | 10 mA |
| Operating free-air temperature range: | |
| LM236-2.5 | -25°C to 85°C |
| LM336-2.5 | 0°C to 70°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or LP package | 260°C |

electrical characteristics at specified free-air temperature (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T _A [†] | LM236-2.5 | | | LM336-2.5 | | | UNIT | |
|----------------------|---|---|----------------|------------|------|-----------|------------|------|------|---------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | | |
| V _Z | Reference voltage | I _Z = 1 mA | LM236, LM336 | 2.44 | 2.49 | 2.54 | 2.39 | 2.49 | 2.59 | V |
| | | | LM236A, LM336B | 2.465 | 2.49 | 2.515 | 2.44 | 2.49 | 2.54 | |
| ΔV _Z (ΔT) | Change in reference voltage with temperature‡ | V _Z adjusted to 2.490 V, I _Z = 1 mA | Full range | 3.5 9 | | | 1.8 6 | | | mV |
| ΔV _Z (ΔI) | Change in reference voltage with current | I _Z = 400 μA to 10 mA | 25°C | 2.6 6 | | | 2.6 10 | | | mV |
| | | | Full range | 3 10 | | | 3 12 | | | |
| ΔV _Z /Δt | Long-term change in reference voltage | I _Z = 1 mA | 25°C | 20 | | | 20 | | | ppm/khr |
| Z _Z | Reference impedance | I _Z = 1 mA, f = 1 kHz | 25°C | 0.2 0.6 | | | 0.2 1 | | | Ω |
| | | | Full range | 0.4 1 | | | 0.4 1.4 | | | |

[†] Full range is -25°C to 85°C for the LM236-2.5 and 0°C to 70°C for the LM336-2.5.

[‡] Temperature stability (change in reference voltage with temperature) for these devices is ensured by design. Design limits are specified over the indicated temperature and supply voltage ranges. These limits are not used to calculate outgoing quality levels.



TYPICAL CHARACTERISTICS

CHANGE IN REFERENCE VOLTAGE
vs
REFERENCE CURRENT

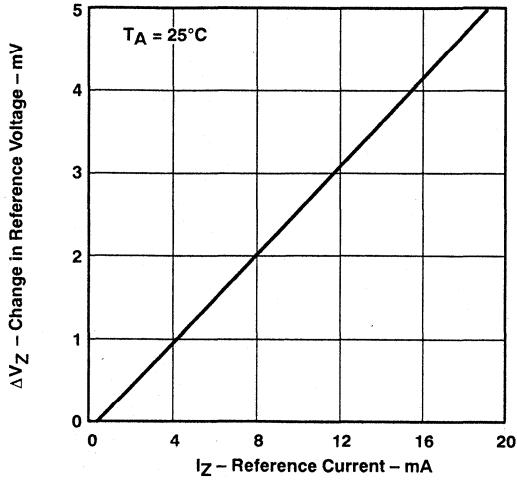


Figure 1

NOISE VOLTAGE
vs
FREQUENCY

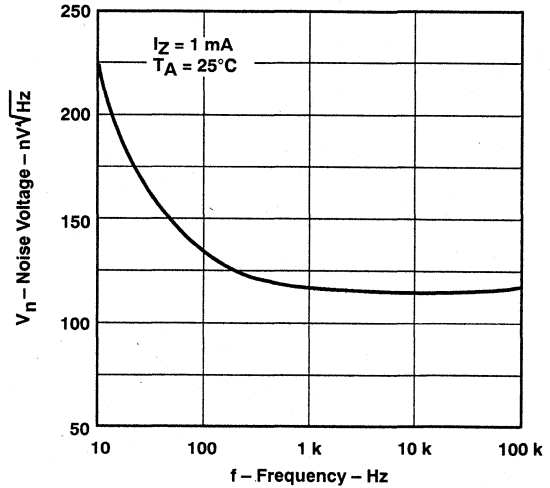


Figure 2

REFERENCE IMPEDANCE
vs
FREQUENCY

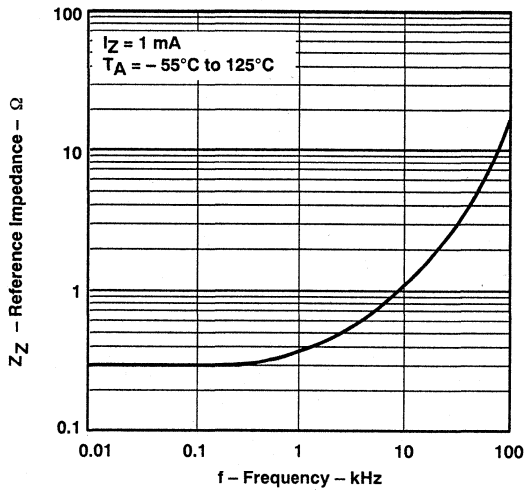
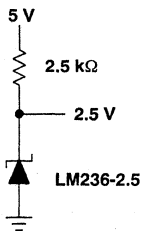


Figure 3

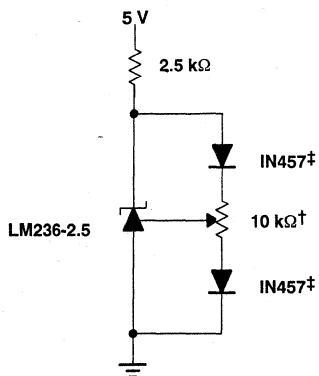
LM236-2.5, LM336-2.5 2.5-V INTEGRATED REFERENCE CIRCUITS

APPLICATION INFORMATION

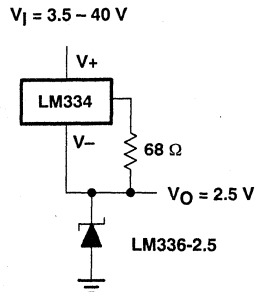
2.5-V REFERENCE



2.5-V REFERENCE WITH MINIMUM
TEMPERATURE COEFFICIENT



WIDE INPUT RANGE REFERENCE



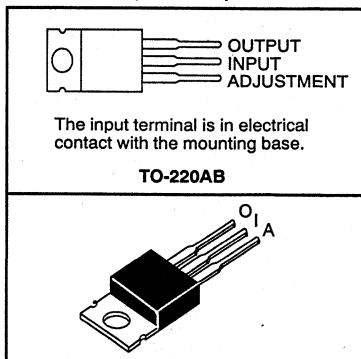
† Adjust to 2.49 V
‡ Any silicon signal diode

LM237, LM337 3-TERMINAL ADJUSTABLE REGULATORS

D2640, NOVEMBER 1981—REVISED NOVEMBER 1991

- Output Voltage Range Adjustable From -1.2 V to -37 V
- I_O Capability of 1.5 A Max
- Input Regulation Typically 0.01% Per Input-Voltage Change
- Output Regulation Typically 0.3%
- Peak Output Current Constant Over Temperature Range of Regulator
- Ripple Rejection Typically 77 dB
- Direct Replacement for National Semiconductor LM237, LM337

LM237, LM337 . . . KC PACKAGE
(TOP VIEW)

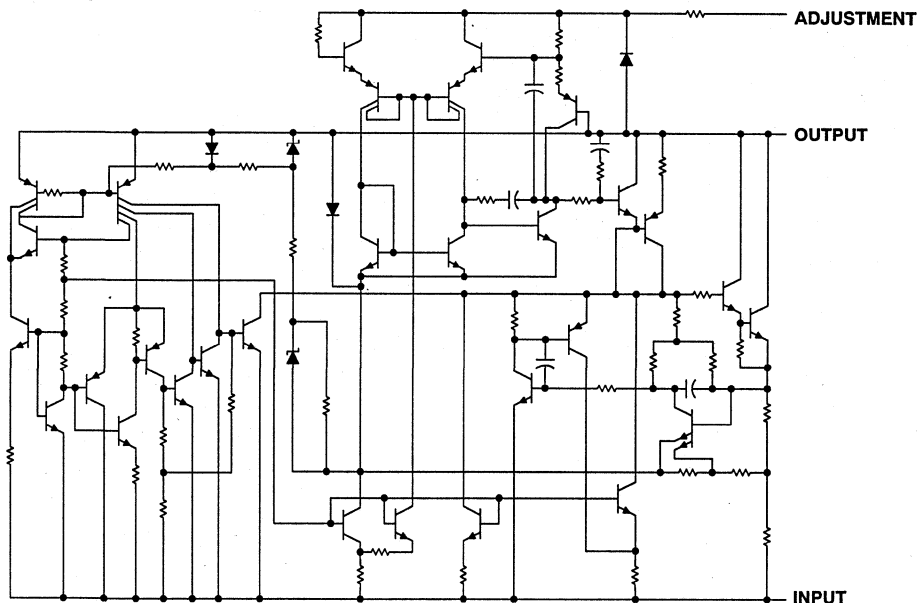


description

The LM237 and LM337 are adjustable 3-terminal negative-voltage regulators capable of supplying in excess of -1.5 A over an output voltage range of -1.2 V to -37 V . They are exceptionally easy to use, requiring only two external resistors to set the output voltage and one output capacitor for frequency compensation. The current design has been optimized for excellent regulation and low thermal transients. In addition, the LM237 and LM337 feature internal current limiting, thermal shutdown, and safe-area compensation, making them virtually immune to blowout by overloads.

The LM237 and LM337 serve a wide variety of applications including local on-card regulation, programmable output voltage regulation, or precision current regulation.

schematic diagram



PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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LM237, LM337

3-TERMINAL ADJUSTABLE REGULATORS

absolute maximum ratings over operating temperature ranges (unless otherwise noted)

| | |
|---|----------------|
| Input-to-output differential voltage, $V_I - V_O$ | -40 V |
| Continuous total dissipation at (or below) 25°C free-air temperature (see Note 1) | 2 W |
| Continuous total dissipation at (or below) 90°C case temperature (see Note 1) | 15 W |
| Operating free-air, case, or virtual junction temperature range: LM237 | -25°C to 150°C |
| LM337 | 0°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 1: For operation above 25°C operating free-air or 90°C case temperature, refer to Figures 1 and 2. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

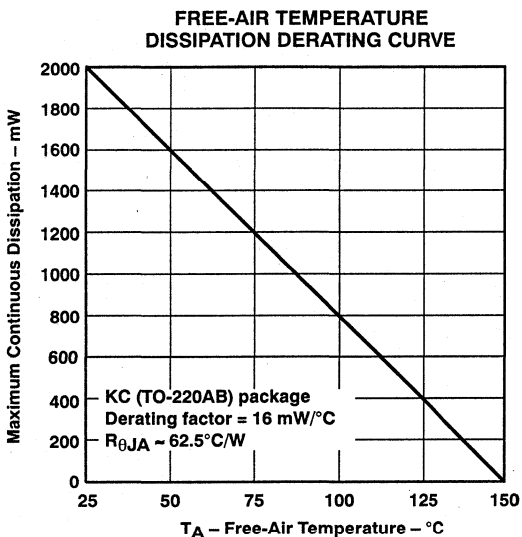


Figure 1

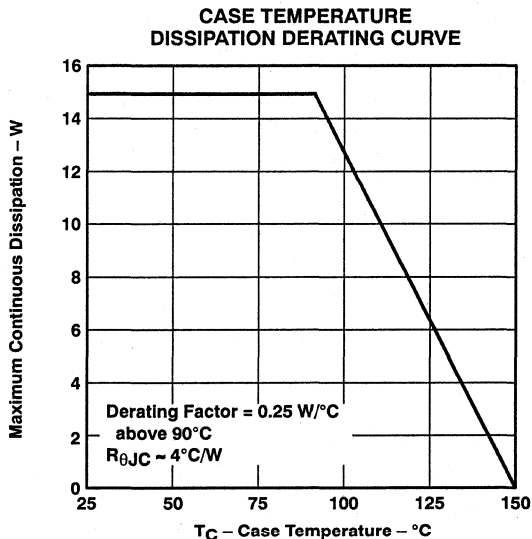


Figure 2

LM237, LM337 3-TERMINAL ADJUSTABLE REGULATORS

recommended operating conditions

| | | LM237 | | LM337 | | UNIT |
|---|--|-------|------|-------|------|------|
| | | MIN | MAX | MIN | MAX | |
| Output current, I_O | $ V_I - V_O \leq 40 \text{ V}$, $P \leq 15 \text{ W}$ | 10 | 1500 | 10 | 1500 | mA |
| | $ V_I - V_O \leq 10 \text{ V}$, $P \leq 15 \text{ W}$ | 6 | 1500 | 6 | 1500 | |
| Operating virtual junction temperature, T_J | | -25 | 150 | 0 | 125 | °C |

electrical characteristics over recommended ranges of operating virtual junction temperature (unless otherwise noted)

| PARAMETER | TEST CONDITIONS [†] | | LM237 | | | LM337 | | | UNIT |
|---|--|----------------------------|--------|--------|--------|--------|-------|---------------|------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| Input regulation [‡] | $V_I - V_O = -3 \text{ V to } -40 \text{ V}$ | $T_J = 25^\circ\text{C}$ | 0.01 | 0.02 | | 0.01 | 0.04 | %V | |
| | | $T_J = \text{MIN to MAX}$ | | 0.02 | 0.05 | | 0.02 | | 0.07 |
| Ripple rejection | $V_O = -10 \text{ V}$, | $f = 120 \text{ Hz}$ | 60 | | | 60 | | | dB |
| | $V_O = -10 \text{ V}$, $C_{ADJ} = 10 \mu\text{F}$ | $f = 120 \text{ Hz}$ | 66 | 77 | | 66 | 77 | | |
| Output regulation | $I_O = 10 \text{ mA to } 1.5 \text{ A}$, $T_J = 25^\circ\text{C}$ | $ V_O \leq 5 \text{ V}$ | 25 | | | 50 | | | mV |
| | | $ V_O \geq 5 \text{ V}$ | 0.3% | 0.5% | | 0.3% | 1% | 1% | |
| | $I_O = 10 \text{ mA to } 1.5 \text{ A}$ | $ V_O \leq 5 \text{ V}$ | 50 | | | 70 | | | mV |
| | | $ V_O \geq 5 \text{ V}$ | 1% | | | 1.5% | | | |
| Output voltage change with temperature | $T_J = \text{MIN to MAX}$ | | 0.6% | | | 0.6% | | | |
| Output voltage long-term drift (see Note 2) | After 1000 h at $T_J = \text{MAX}$ and $V_I - V_O = -40 \text{ V}$ | | 0.3% | 1% | | 0.3% | 1% | | |
| Output noise voltage | $f = 10 \text{ Hz to } 10 \text{ kHz}$, | $T_J = 25^\circ\text{C}$ | 0.003% | | | 0.003% | | | |
| Minimum output current to maintain regulation | $ V_I - V_O \leq 40 \text{ V}$ | | 2.5 | 5 | | 2.5 | 10 | mA | |
| | $ V_I - V_O \leq 10 \text{ V}$ | | 1.2 | 3 | | 1.5 | 6 | | |
| Peak output current | $ V_I - V_O \leq 15 \text{ V}$ | | 1.5 | 2.2 | | 1.5 | 2.2 | A | |
| | $ V_I - V_O \leq 40 \text{ V}$, | $T_J = 25^\circ\text{C}$ | 0.24 | 0.4 | | 0.15 | 0.4 | | |
| Adjustment-terminal current | | | 65 | 100 | | 65 | 100 | μA | |
| Change in adjustment-terminal current | $V_I - V_O = -2.5 \text{ V to } -40 \text{ V}$, | $T_J = 25^\circ\text{C}$, | 2 | 5 | | 2 | 5 | μA | |
| Reference voltage (output to ADJ) | $V_I - V_O = -3 \text{ V to } -40 \text{ V}$, $I_O = 10 \text{ mA to } 1.5 \text{ A}$, $P \leq \text{rated dissipation}$ | $T_J = 25^\circ\text{C}$ | -1.225 | -1.250 | -1.275 | -1.213 | -1.25 | -1.287 | V |
| | | $T_J = \text{MIN to MAX}$ | -1.2 | -1.25 | -1.3 | -1.2 | -1.25 | -1.3 | |
| Thermal regulation | Initial $T_J = 25^\circ\text{C}$, 10-ms pulse | | 0.002 | 0.02 | | 0.003 | 0.04 | %/W | |

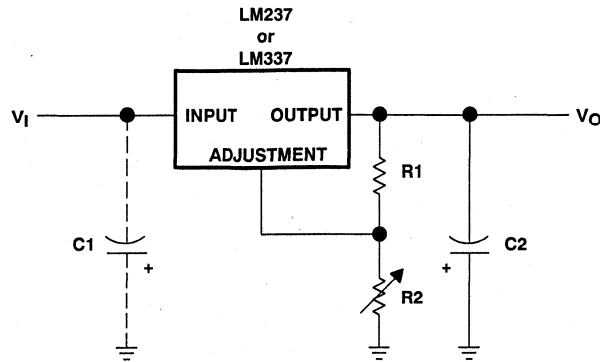
[†] Unless otherwise noted, these specifications apply for the following test conditions $|V_I - V_O| = 5 \text{ V}$ and $I_O = 0.5 \text{ A}$. For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions. All characteristics are measured with a 0.1- μF capacitor across the input and a 1- μF capacitor across the output. Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

[‡] Input regulation is expressed here as the percentage change in output voltage per 1-V change at the input.

NOTE 2: Since long-term drift cannot be measured on the individual devices prior to shipment, this specification is not intended to be a warranty. It is an engineering estimate of the average drift to be expected from lot to lot.

LM237, LM337 3-TERMINAL ADJUSTABLE REGULATORS

APPLICATION INFORMATION



R1 is typically 120 Ω .

$$R2 = R1 \left(\frac{-V_O}{-1.25} - 1 \right) \text{ where } V_O \text{ is the output in volts.}$$

C1 is a 1- μ F solid tantalum capacitor required only if the regulator is more than 10 cm (4 in.) from the power supply filter capacitor.
C2 is a 1- μ F solid tantalum or 10- μ F aluminum electrolytic capacitor required for stability.

Figure 3. Adjustable Negative-Voltage Regulator

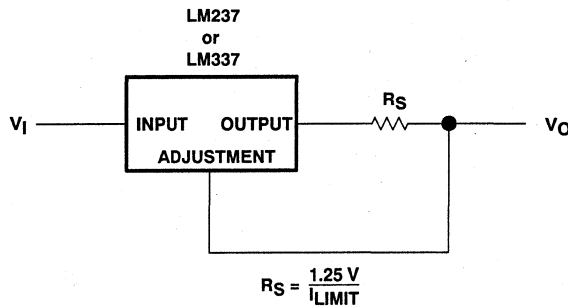


Figure 4. Current-Limiting Circuit

LM2930-5, LM2930-8 3-TERMINAL POSITIVE REGULATORS

D2733, APRIL 1983—REVISED AUGUST 1991

- Input-Output Differential Less Than 0.6 V
- Output Current of 150 mA
- Reverse Battery Protection
- Line Transient Protection
- 40-V Load-Dump Protection
- Internal Short Circuit Current Limiting
- Internal Thermal Overload Protection
- Mirror-Image Insertion Protection
- Direct Replacement for National LM2930 Series

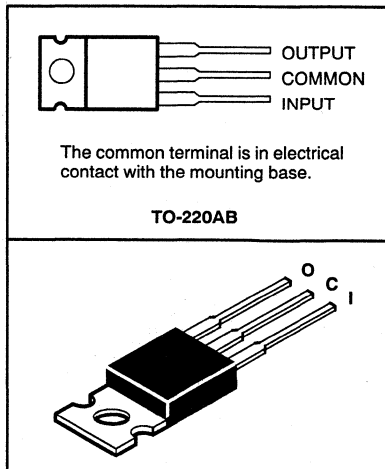
description

The LM2930-5 and LM2930-8 are 3-terminal positive regulators that provide fixed 5-V and 8-V regulated outputs. Each features the ability to source 150 mA of output current with an input-output differential of 0.6 V or less. Familiar regulator features such as current limit and thermal overload protection are also provided.

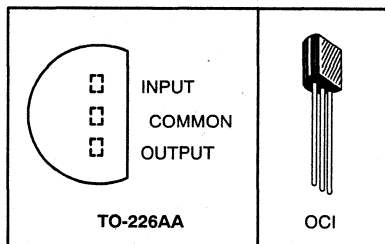
The LM2930 series has low voltage dropout, making it useful for certain battery applications. For example, the low voltage dropout feature allows a longer battery discharge before the output falls out of regulation; the battery supplying the regulator input voltage may discharge to 5.6 V and still properly regulate the system and load voltage. Supporting this feature, the LM2930 series protects both itself and the regulated system from reverse battery installation or 2-battery jumps.

Other protection features include line transient protection for load dump of up to 40 V. In this case, the regulator shuts down to avoid damaging internal and external circuits. The LM2930 series regulator cannot be harmed by temporary mirror-image insertion.

KC PACKAGE
(TOP VIEW)



LP
SILECT PACKAGE
(TOP VIEW)



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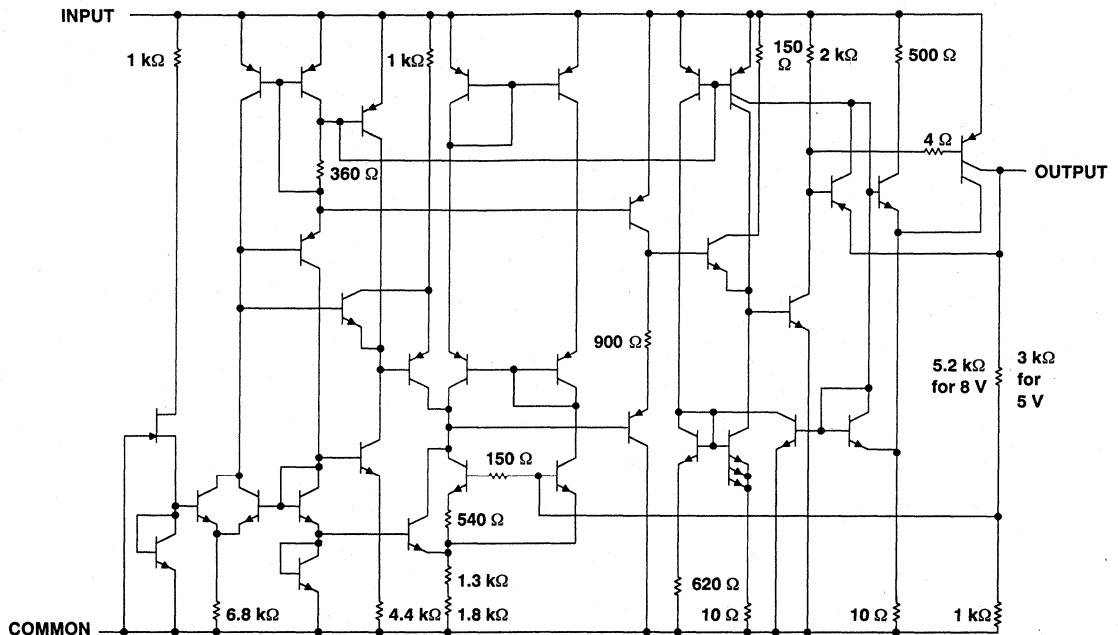
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LM2930-5, LM2930-8 3-TERMINAL POSITIVE REGULATORS

schematic diagram



All component values are nominal.

absolute maximum ratings over operating free-air temperature ranges (unless otherwise noted)

| | |
|--|---------------------------------------|
| Continuous input voltage | 26 V |
| Transient input voltage: $t = 1 \text{ s}$ | 40 V |
| Continuous reverse input voltage | -6 V |
| Transient reverse input voltage: $t = 100 \text{ ms}$ | -12 V |
| Continuous total dissipation (see Note 1) | See Dissipation Rating Tables 1 and 2 |
| Operating free-air, case, or virtual junction temperature | -40°C to 150°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 1: To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variation in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

LM2930-5, LM2930-8 3-TERMINAL POSITIVE REGULATORS

DISSIPATION RATING TABLE 1 – FREE-AIR TEMPERATURE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR | DERATE ABOVE T_A | $T_A = 70^\circ\text{C}$ POWER RATING |
|---------|---|--------------------------|-----------------------|--|
| KC | 2000 mW | 16 mW/ $^\circ\text{C}$ | 25 $^\circ\text{C}$ | 1280 mW |
| LP | 775 mW | 6.2 mW/ $^\circ\text{C}$ | 25 $^\circ\text{C}$ | 496 mW |

DISSIPATION RATING TABLE 2 – CASE TEMPERATURE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR | DERATE ABOVE T_C | $T_C = 125^\circ\text{C}$ POWER RATING |
|---------|---|---------------------------|-----------------------|---|
| KC | 20 W | 0.25 W/ $^\circ\text{C}$ | 70 $^\circ\text{C}$ | 6.25 W |
| LP | 1600 mW | 28.6 mW/ $^\circ\text{C}$ | 94 $^\circ\text{C}$ | 715 mW |

recommended operating conditions

| | MIN | MAX | UNIT |
|--|-----|-----|------------------|
| I_O Output current | | 150 | mA |
| T_J Operating virtual junction temperature | -40 | 125 | $^\circ\text{C}$ |

LM2930-5 electrical characteristics at 25 $^\circ\text{C}$ virtual junction temperature, $V_I = 14\text{ V}$, $I_O = 150\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS [†] | MIN | TYP | MAX | UNIT |
|---|--|------|------|-----|---------------|
| Output voltage | $V_I = 6\text{ V to } 26\text{ V}$, $T_J = -40^\circ\text{C to } 125^\circ\text{C}$ $I_O = 5\text{ mA to } 150\text{ mA}$ | 4.5 | 5 | 5.5 | V |
| Input regulation | $I_O = 5\text{ mA}$ $V_I = 9\text{ V to } 16\text{ V}$ $V_I = 6\text{ V to } 26\text{ V}$ | | 7 | 25 | mV |
| | | | 30 | 80 | |
| Ripple rejection | $f = 120\text{ Hz}$ | | 56 | | dB |
| Output regulation | $I_O = 5\text{ mA to } 150\text{ mA}$ | | 14 | 50 | mV |
| Output voltage long-term drift [‡] | After 1000 hours at $T_J = 125^\circ\text{C}$ | | 20 | | mV |
| Dropout voltage | $I_O = 150\text{ mA}$ | | 0.32 | 0.6 | V |
| Output noise voltage | $f = 10\text{ Hz to } 100\text{ kHz}$ | | 60 | | μV |
| Output voltage during line transients | $V_I = -12\text{ V to } 40\text{ V}$, $R_L = 100\ \Omega$ | -0.3 | | 5.5 | V |
| Output impedance | $I_O = 100\text{ mA}$, $I_O = 10\text{ mA (rms)}$, 100 Hz to 10 kHz | | 200 | | m Ω |
| Bias current | $I_O = 10\text{ mA}$ | | 4 | 7 | mA |
| | $I_O = 150\text{ mA}$ | | 18 | 40 | |
| Peak output current | | 150 | 300 | 700 | mA |

[†] Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.1- μF capacitor across the input and a 10- μF capacitor across the output.

[‡] Since long-term drift cannot be measured on the individual devices prior to shipment, this specification is intended to be an engineering estimate of the average drift to be expected from lot to lot.

LM2930-5, LM2930-8 3-TERMINAL POSITIVE REGULATORS

LM2930-8 electrical characteristics at 25°C virtual junction temperature, $V_I = 14\text{ V}$, $I_O = 150\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS† | MIN | TYP | MAX | UNIT |
|---------------------------------------|---|-------------------------------------|------|-----|------------------|
| Output voltage | $V_I = 6\text{ V to }26\text{ V}$, $T_J = -40^\circ\text{C to }125^\circ\text{C}$ | | | | |
| | $I_O = 5\text{ mA to }150\text{ mA}$ | 7.2 | 8 | 8.8 | V |
| Input regulation | $I_O = 5\text{ mA}$ | $V_I = 9.4\text{ V to }16\text{ V}$ | 12 | 50 | mV |
| | | $V_I = 9.4\text{ V to }26\text{ V}$ | 50 | 100 | |
| Ripple rejection | $f = 120\text{ Hz}$ | | 52 | | dB |
| Output regulation | $I_O = 5\text{ mA to }150\text{ mA}$ | | 25 | 50 | mV |
| Output voltage long-term drift‡ | After 1000 h at $T_J = 125^\circ\text{C}$ | | 30 | | mV |
| Dropout voltage | $I_O = 150\text{ mA}$ | | 0.32 | 0.6 | V |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | | 90 | | μV |
| Output voltage during line transients | $V_I = -12\text{ V to }40\text{ V}$, $R_L = 100\ \Omega$ | -0.3 | | 8.8 | V |
| Output impedance | $I_O = 100\text{ mA}$, $I_O = 10\text{ mA (rms)}$, $f = 100\text{ Hz to }10\text{ kHz}$ | | 300 | | $\text{m}\Omega$ |
| Bias current | $I_O = 10\text{ mA}$ | | 4 | 7 | mA |
| | $I_O = 150\text{ mA}$ | | 18 | 40 | |
| Peak output current | | 150 | 300 | 700 | mA |

† Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a $0.1\text{-}\mu\text{F}$ capacitor across the input and a $10\text{-}\mu\text{F}$ capacitor across the output.

‡ Since long-term drift cannot be measured on the individual devices prior to shipment, this specification is intended to be an engineering estimate of the average drift to be expected from lot to lot.

TYPICAL CHARACTERISTICS

table of graphs

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TYPICAL CHARACTERISTICS

NORMALIZED OUTPUT VOLTAGE
vs
VIRTUAL JUNCTION TEMPERATURE

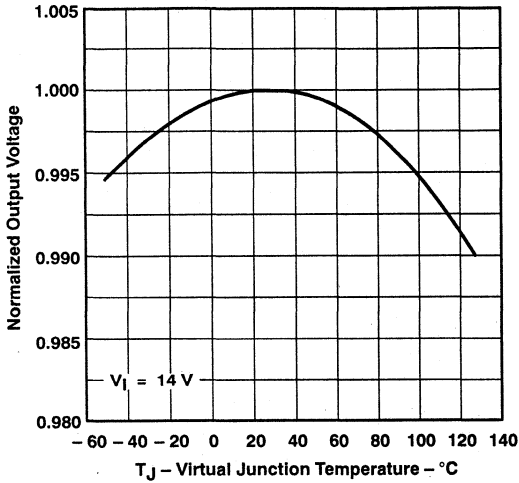


Figure 1

LM2930-5
OUTPUT VOLTAGE
vs
INPUT VOLTAGE

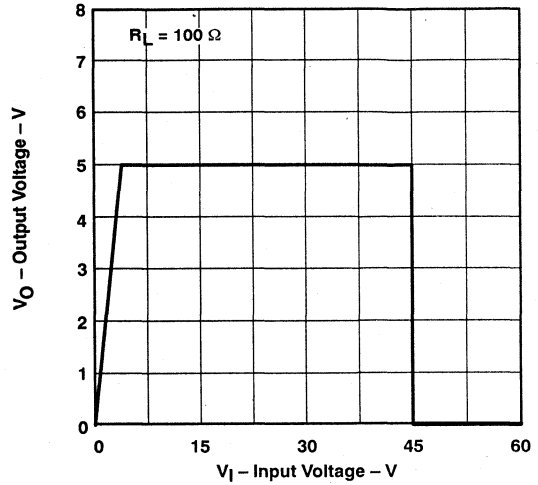


Figure 2

LM2930-5
OUTPUT VOLTAGE
vs
INPUT VOLTAGE

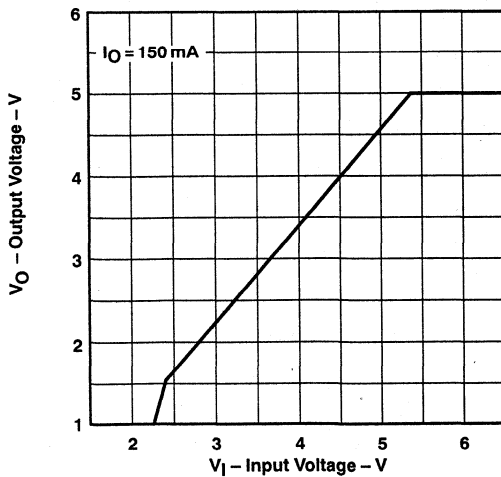


Figure 3

RIPPLE REJECTION
vs
FREQUENCY

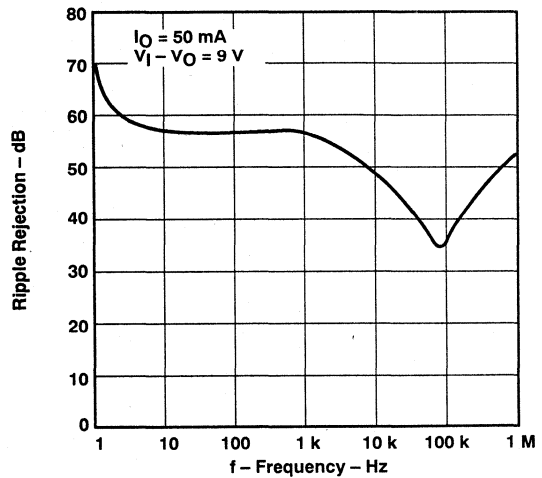


Figure 4

TYPICAL CHARACTERISTICS

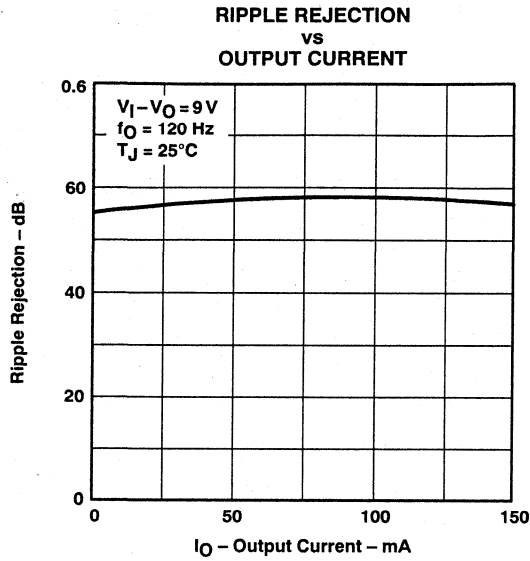


Figure 5

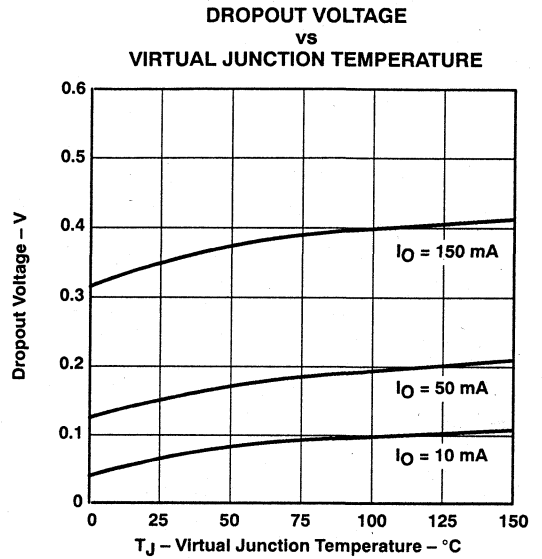


Figure 6

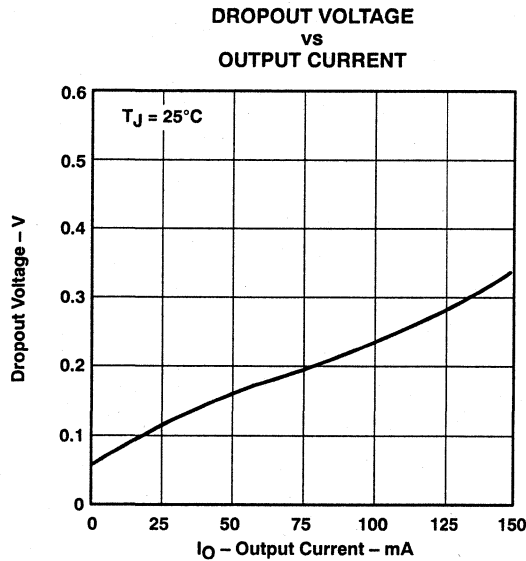


Figure 7

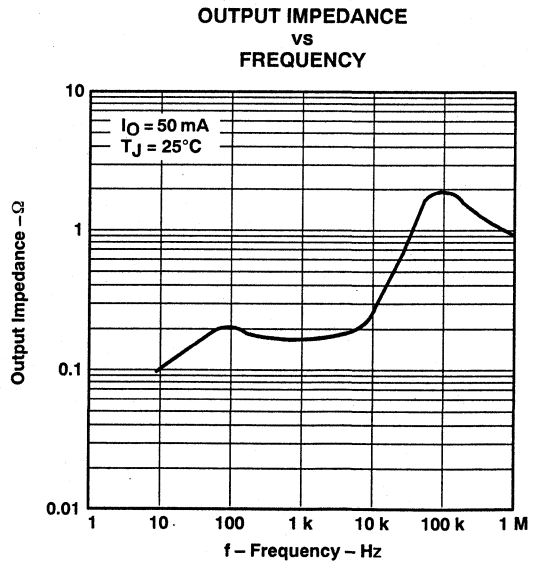


Figure 8

TYPICAL CHARACTERISTICS

INPUT CURRENT
vs
INPUT VOLTAGE

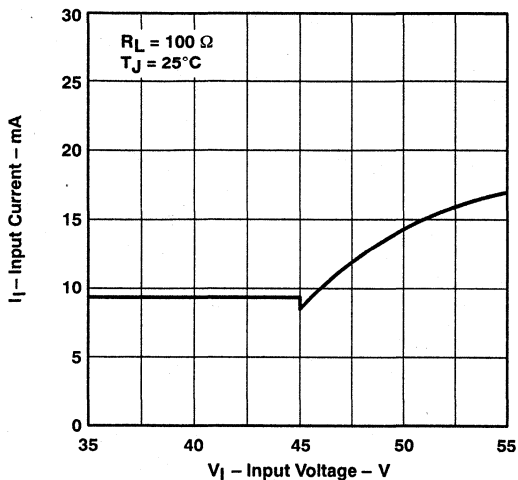


Figure 9

LINE TRANSIENT RESPONSE

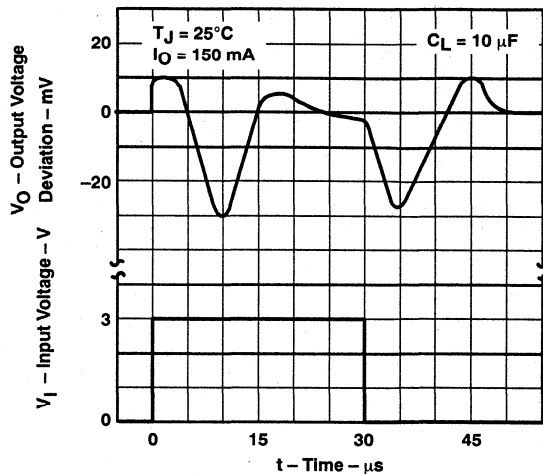


Figure 10

INPUT CURRENT
vs
REVERSE INPUT VOLTAGE

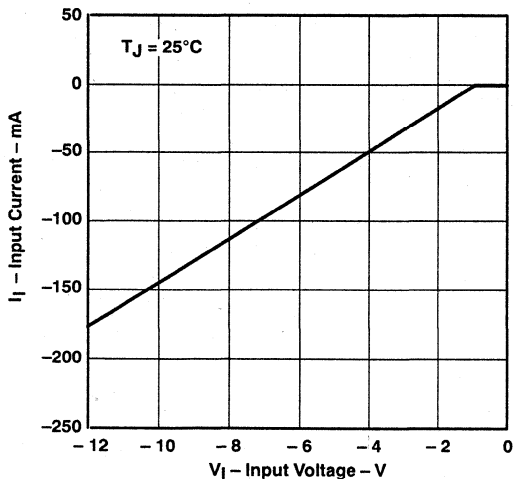


Figure 11

OUTPUT VOLTAGE
vs
REVERSE INPUT VOLTAGE

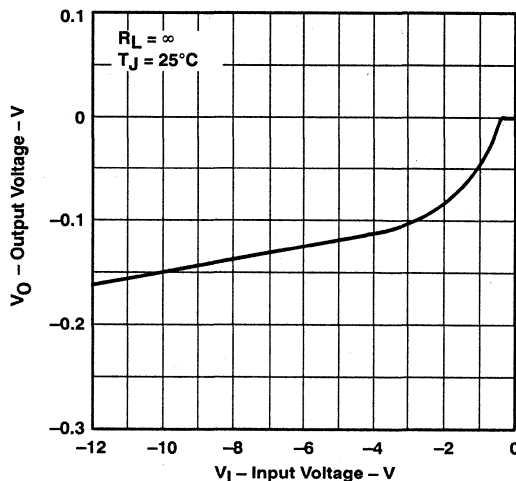


Figure 12

TYPICAL CHARACTERISTICS

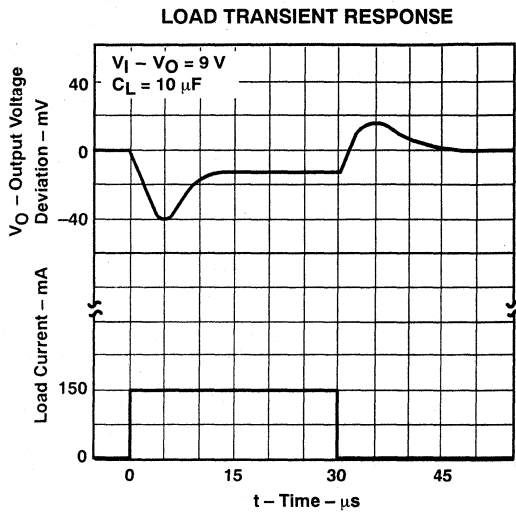


Figure 13

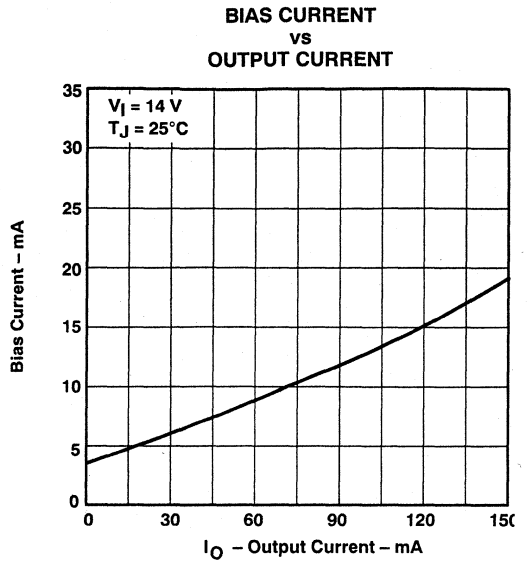


Figure 14

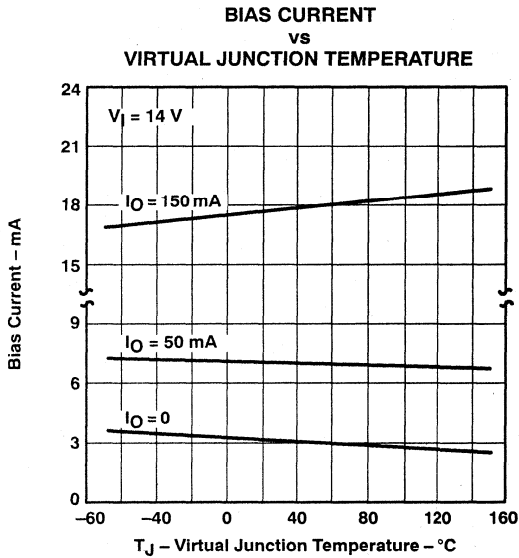


Figure 15

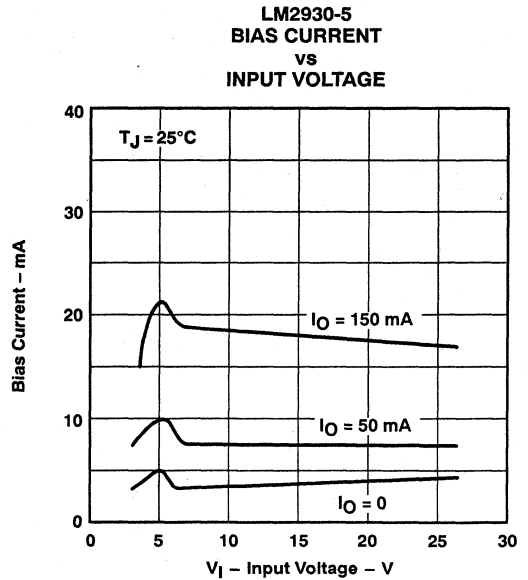
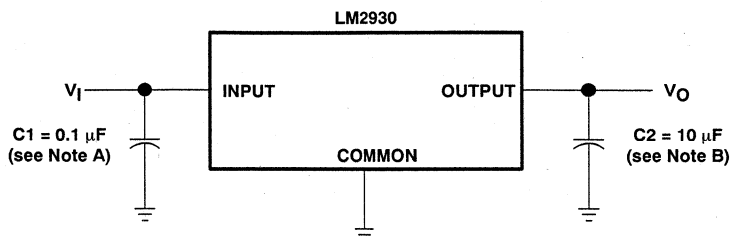


Figure 16

APPLICATION INFORMATION



- NOTES: A. Use of C1 is required if the regulator is not located in close proximity to the supply filter.
B. Capacitor C2 must be located as close as possible to the regulator and may be an aluminum or tantalum-type capacitor. The minimum value required for stability is $10 \mu\text{F}$. The capacitor must be rated for operation at -40°C to guarantee stability to that extreme.

Figure 17

LT1004

MICROPOWER INTEGRATED VOLTAGE REFERENCE

D3190, JANUARY 1989—REVISED JULY 1991

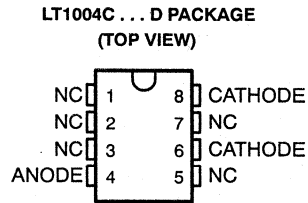
- **Initial Accuracy**
 ± 4 mV for LT1004-1.2
 ± 20 mV for LT1004-2.5
- **Micropower Operation**
- **Operates Up to 20 mA**
- **Very Low Reference Impedance**
- **Applications:**
Portable Meter Reference
Portable Test Instruments
Battery-Operated Systems
Current-Loop Instrumentation

description

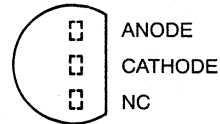
The LT1004 micropower voltage reference is a 2-terminal band-gap reference diode designed to provide high accuracy and excellent temperature characteristics at very low operating currents. Optimizing the key parameters in the design, processing and testing of the device results in specifications previously attainable only with selected units.

The LT1004 is a pin-for-pin replacement for the LM185 series of references with improved specifications. The LT1004 is an attractive device for use in systems in which accuracy was previously attained at the expense of power consumption and trimming.

The LT1004C is characterized for operation from 0°C to 70°C. The LT1004M is characterized for operation over the full military temperature range of -55°C to 125°C.



LT1004C . . . LP PACKAGE
(TOP VIEW)



NC—No internal connection

symbol



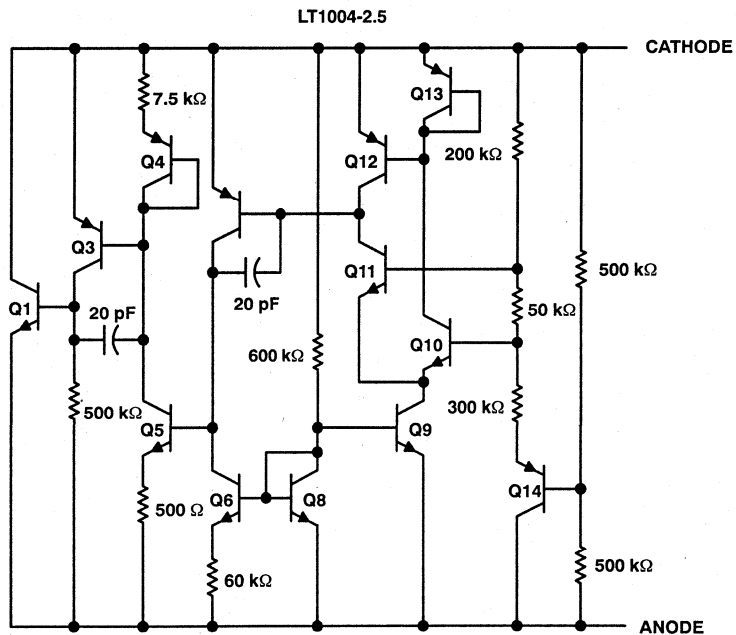
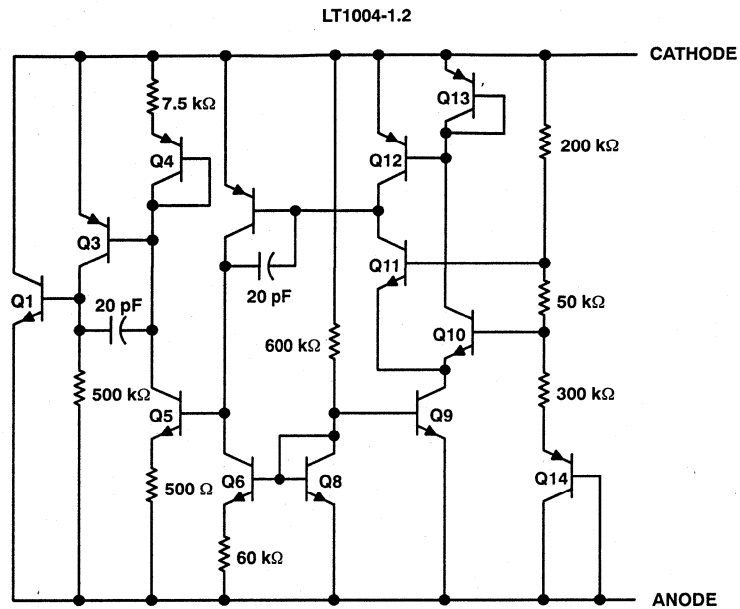
AVAILABLE OPTIONS

| T _A | NOM V _Z | PACKAGE | |
|----------------|-----------------------|----------------------|-----------------|
| | | SMALL OUTLINE (D) | PLASTIC (LP) |
| 0°C to 70°C | 1.2 V | LT1004CD-1.2 | LT1004CLP-1.2 |
| | 2.5 V | LT1004CD-2.5 | LT1004CLP-2.5 |
| -55°C to 125°C | 1.2 V | LT1004MD-1.2 | LT1004MLP-1.2 |
| | 2.5 V | LT1004MD-2.5 | LT1004MLP-2.5 |

The D and LP packages are available taped and reeled. Add suffix R to the device type (i.e., LT1004CDR).

LT1004 MICROPOWER INTEGRATED VOLTAGE REFERENCE

schematic



All component values shown are nominal.

TEXAS
INSTRUMENTS

POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

LT1004

MICROPOWER INTEGRATED VOLTAGE REFERENCE

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|----------------|
| Reverse current, I_R | 30 mA |
| Forward current, I_F | 10 mA |
| Operating free-air temperature range: LT1004C | 0°C to 70°C |
| LT1004M | -55°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

electrical characteristics at specified free-air temperature

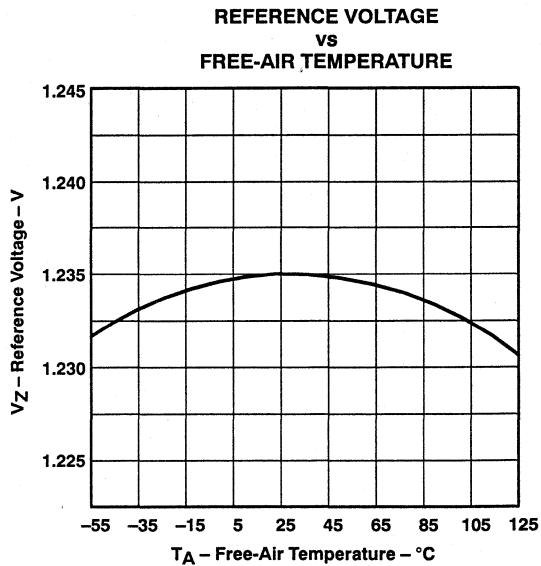
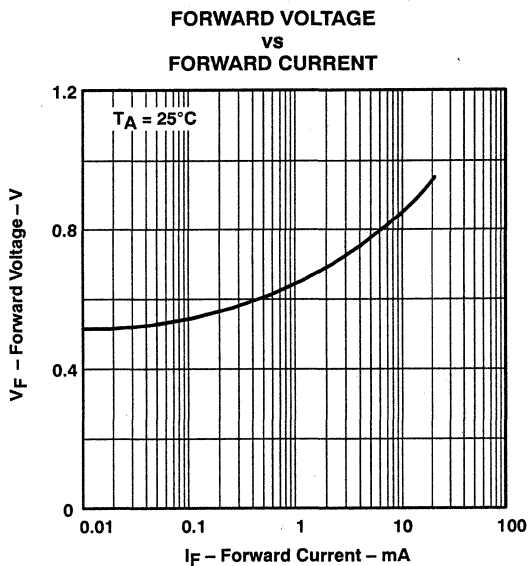
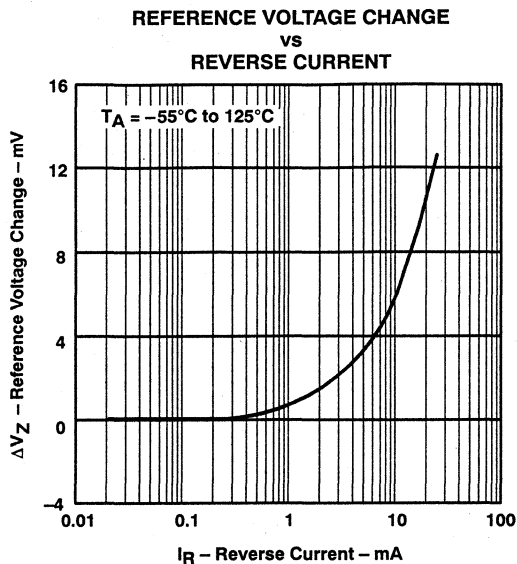
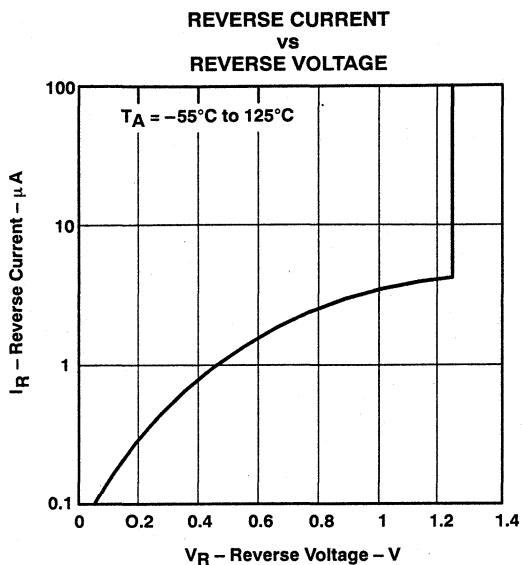
| PARAMETER | TEST CONDITIONS | T_A † | LT1004-1.2 | | | LT1004-2.5 | | | UNIT |
|--|--|------------|------------|-------|---------|------------|-------|------|----------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| V_Z Reference voltage | $I_Z = 100 \mu A$ | 25°C | 1.231 | 1.235 | 1.239 | 2.48 | 2.5 | 2.52 | V |
| | | Full range | LT1004C | 1.225 | 1.245 | 2.47 | 2.53 | | |
| | | | LT1004M | 1.22 | 1.245 | 2.46 | 2.535 | | |
| αV_Z Average temperature coefficient of reference voltage‡ | $I_Z = 10 \mu A$ | 25°C | 20 | | | | | | ppm/°C |
| | $I_Z = 20 \mu A$ | | | | | 20 | | | |
| ΔV_Z Change in reference voltage with current | $I_Z = I_{Z(\min)}$ to 1 mA | 25°C | 1 | | | 1 | | | mV |
| | | Full range | 1.5 | | | 1.5 | | | |
| | $I_Z = 1$ mA to 20 mA | 25°C | 10 | | | 10 | | | |
| | | Full range | 20 | | | 20 | | | |
| $\Delta V_Z/\Delta t$ Long-term change in reference voltage | $I_Z = 100 \mu A$ | 25°C | 20 | | | 20 | | | ppm/khr |
| $I_{Z(\min)}$ Minimum reference current | | Full range | 8 10 | | 12 20 | | | | μA |
| Z_Z Reference impedance | $I_Z = 100 \mu A$ | 25°C | 0.2 0.6 | | 0.2 0.6 | | | | Ω |
| | | Full range | 1.5 | | 1.5 | | | | |
| V_n Broadband noise voltage | $I_Z = 100 \mu A$, $f = 10$ Hz to 10 kHz | 25°C | 60 | | 120 | | | | μV |

† Full range is 0°C to 70°C for the LT1004C and -55°C to 125°C for the LT1004M.

‡ The average temperature coefficient of reference voltage is defined as the total change in reference voltage divided by the specified temperature range.



TYPICAL CHARACTERISTICS†



† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS†

REFERENCE IMPEDANCE
vs
REFERENCE CURRENT

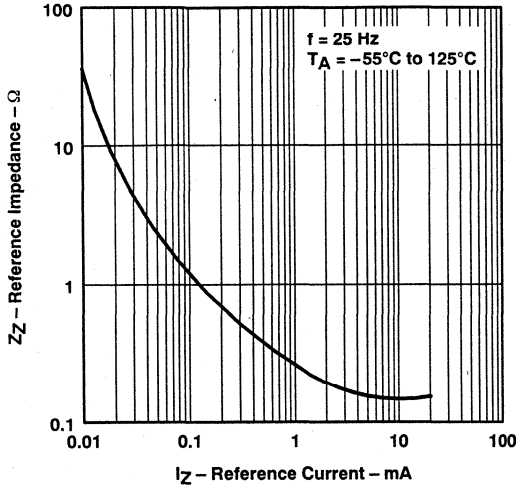


Figure 5

NOISE VOLTAGE
vs
FREQUENCY

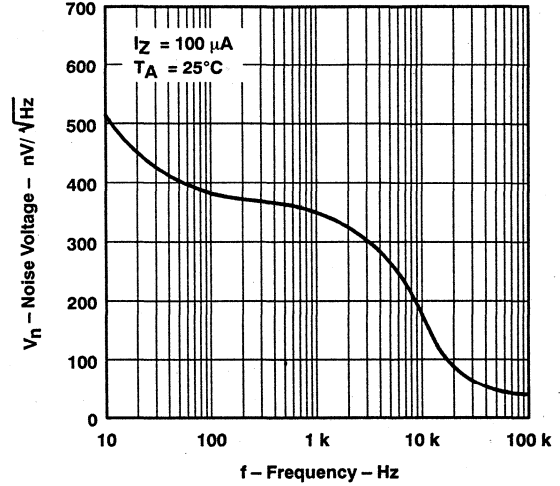


Figure 6

OUTPUT NOISE VOLTAGE
vs
CUTOFF FREQUENCY

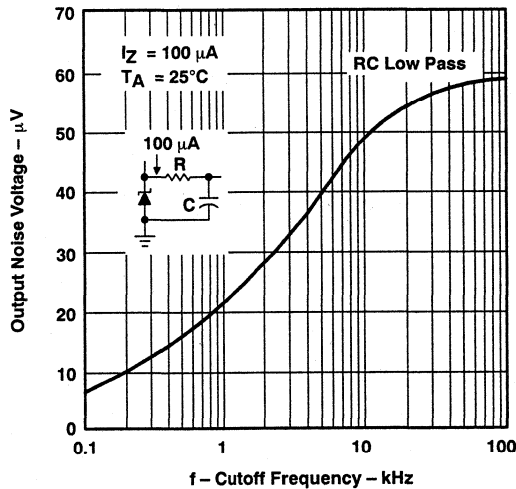
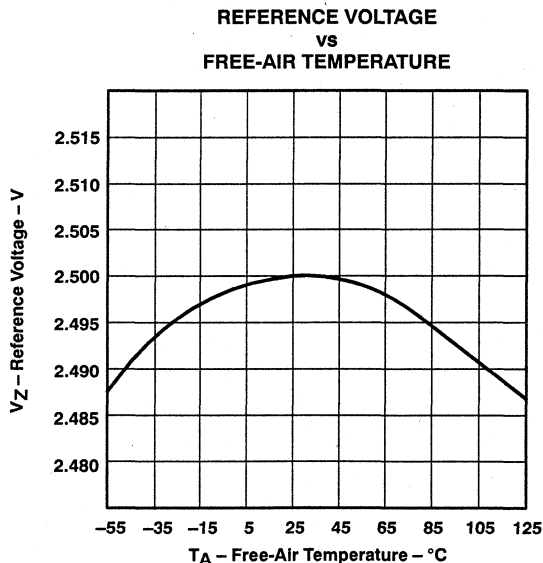
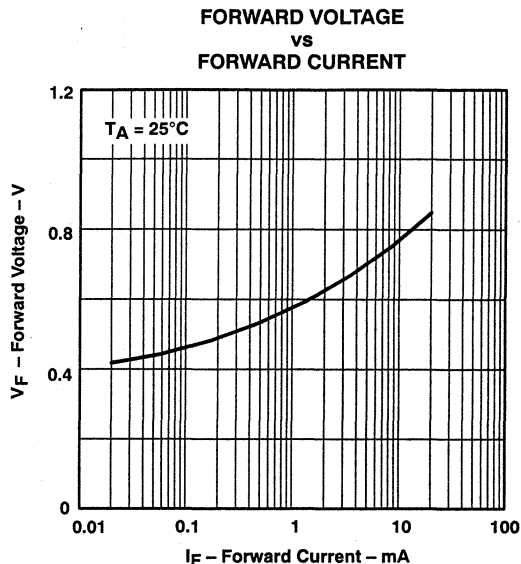
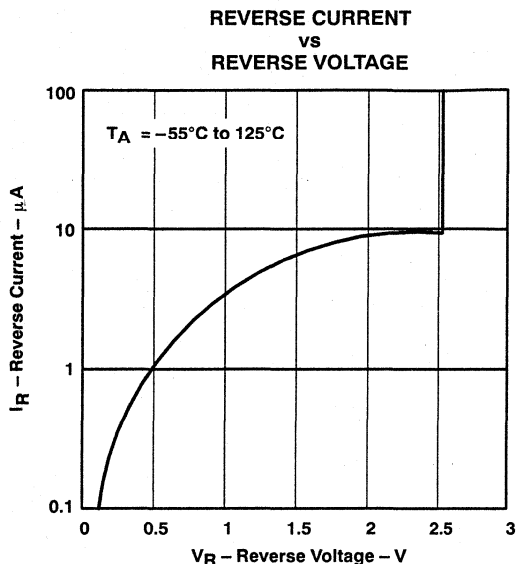


Figure 7

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS†



† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS†

REFERENCE IMPEDANCE
vs
REFERENCE CURRENT

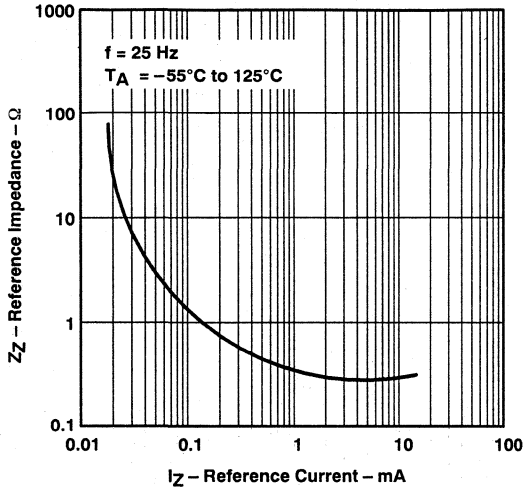


Figure 11

NOISE VOLTAGE
vs
FREQUENCY

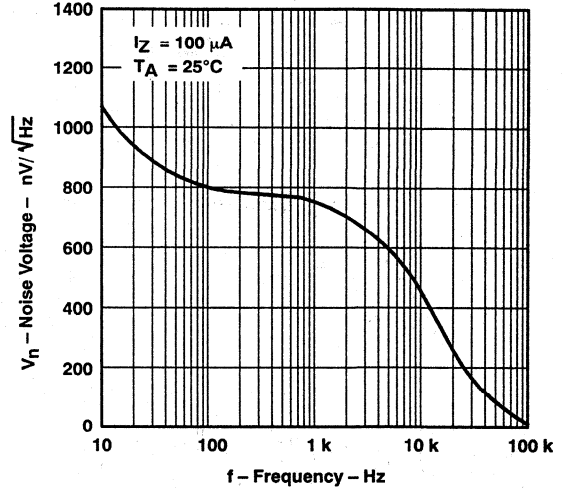


Figure 12

FILTERED OUTPUT NOISE VOLTAGE
vs
OUTPUT FREQUENCY

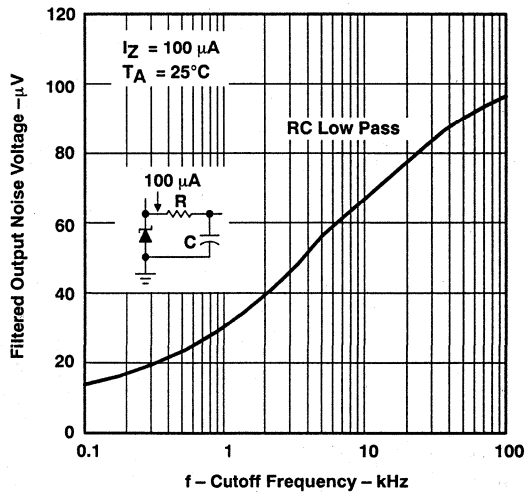
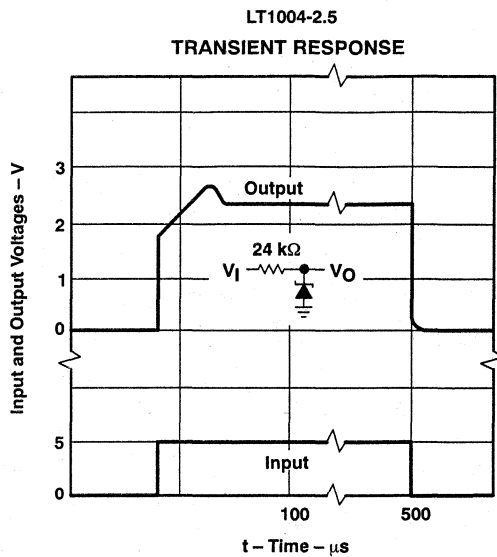
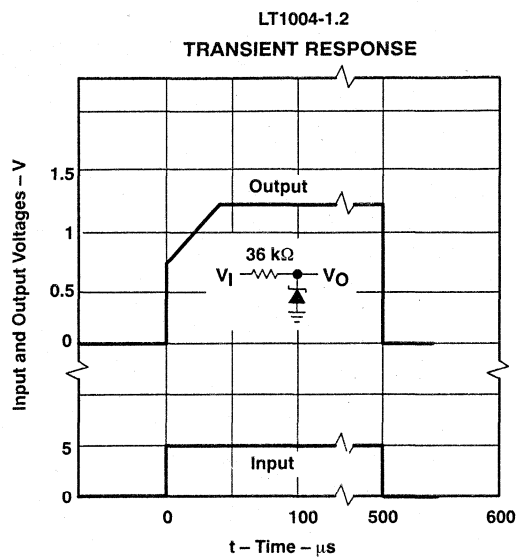


Figure 13

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

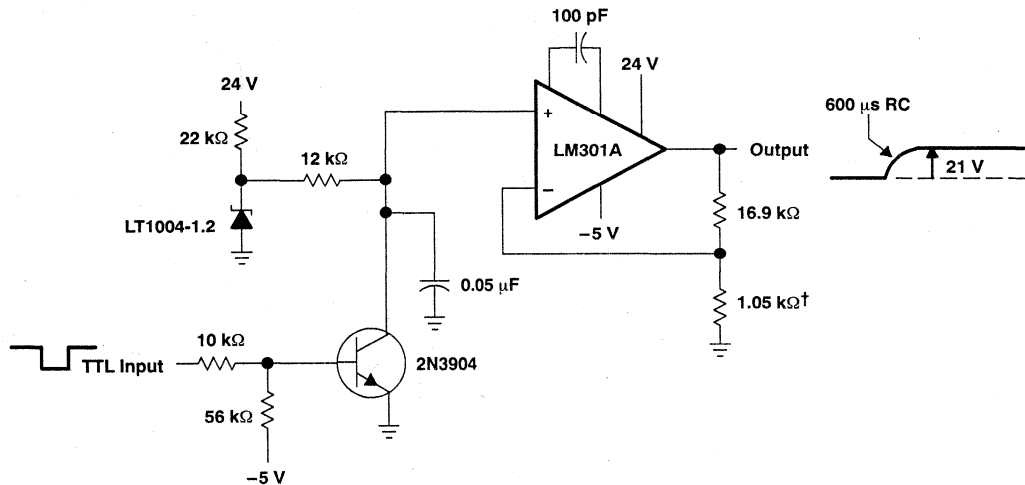
LT1004 MICROPOWER INTEGRATED VOLTAGE REFERENCE

TYPICAL CHARACTERISTICS†



† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

APPLICATION INFORMATION



† 1% metal film resistors

Figure 16. Vpp Generator for EPROMs (no trim required)

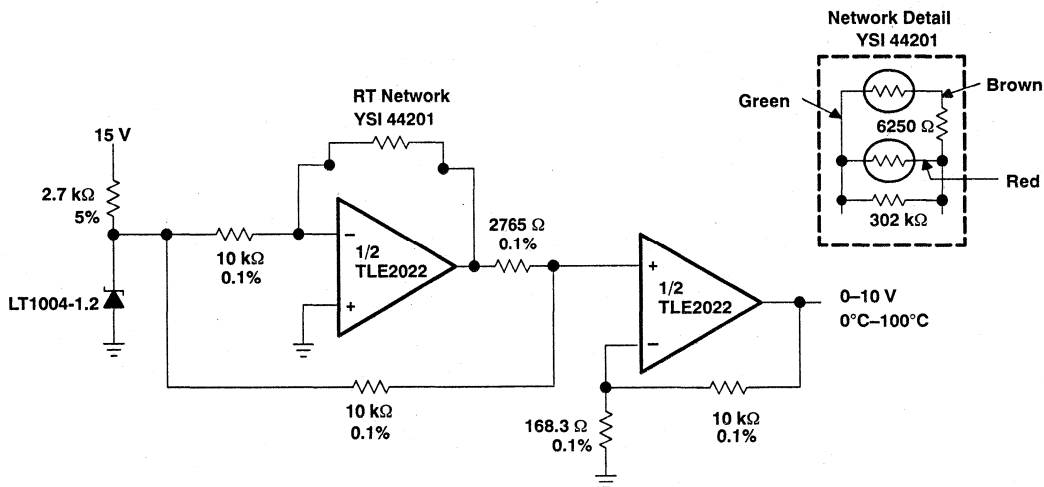


Figure 17. 0°C to 100°C Linear Output Thermometer

LT1004 MICROPOWER INTEGRATED VOLTAGE REFERENCE

APPLICATION INFORMATION

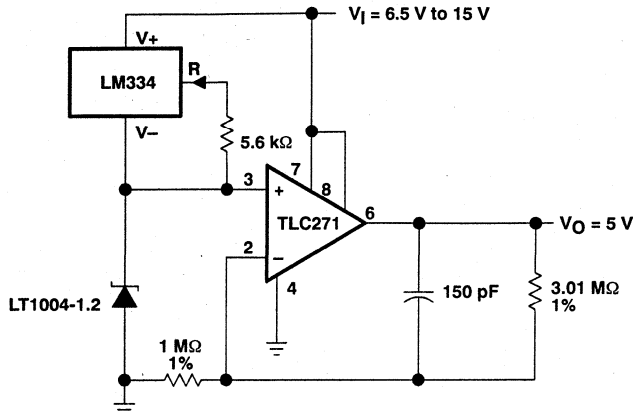


Figure 18. Micropower 5-V Reference

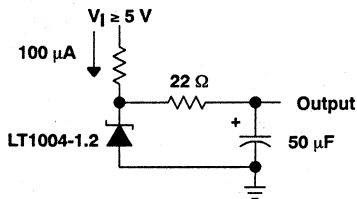


Figure 19. Low-Noise Reference

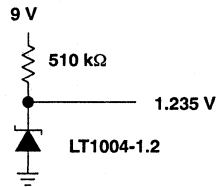
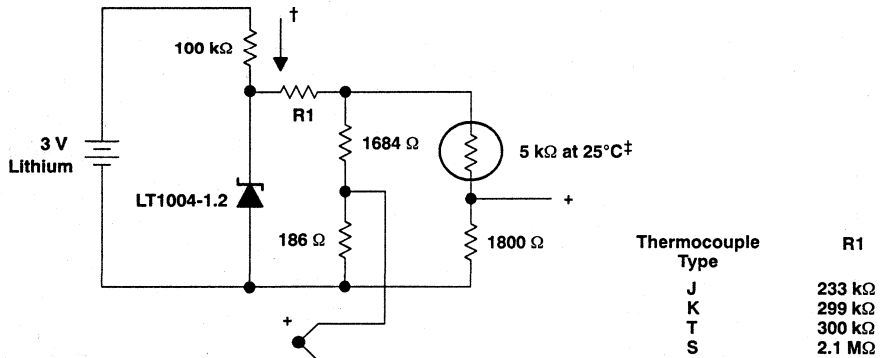


Figure 20. Micropower Reference From 9-V Battery



† Quiescent current = 15 μA

‡ Yellow Springs Inst. Co., Part #44007

NOTE: This application compensates within ±1°C from 0°C to 60°C.

Figure 21. Micropower Cold-Junction Compensation for Thermocouples

APPLICATION INFORMATION

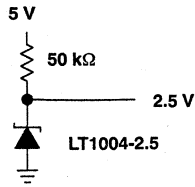


Figure 22. 2.5-V Reference

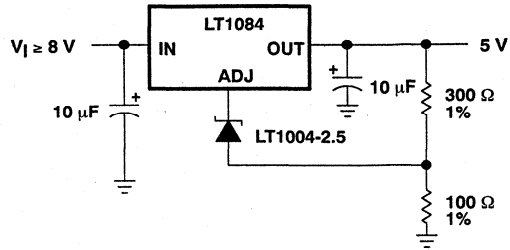
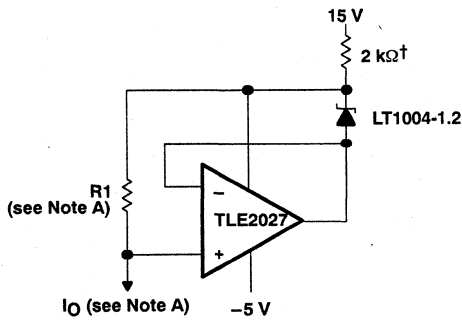


Figure 23. High-Stability 5-V Regulator



† May be increased for small output currents.

NOTE A: $R1 \approx \frac{2V}{I_O + 10\mu A}$, $I_O = \frac{1.235V}{R1}$

Figure 24. Ground-Referenced Current Source

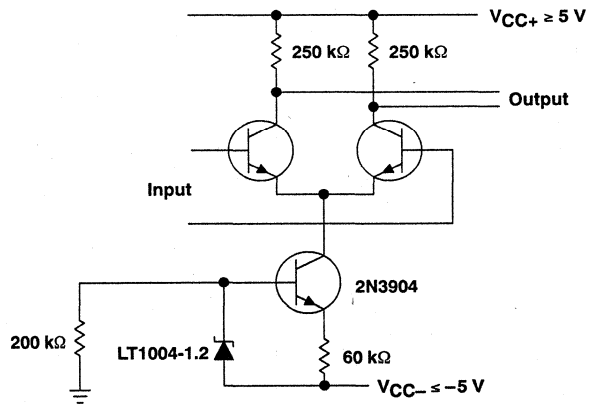
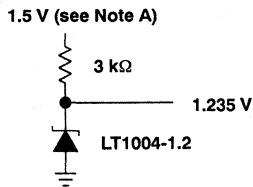


Figure 25. Amplifier With Constant Gain Over Temperature



NOTE A: Output regulates down to 1.285 V for $I_O = 0$.

Figure 26. 1.2-V Reference From 1.5-V Battery

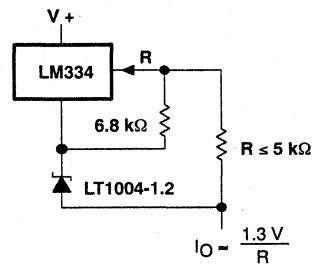
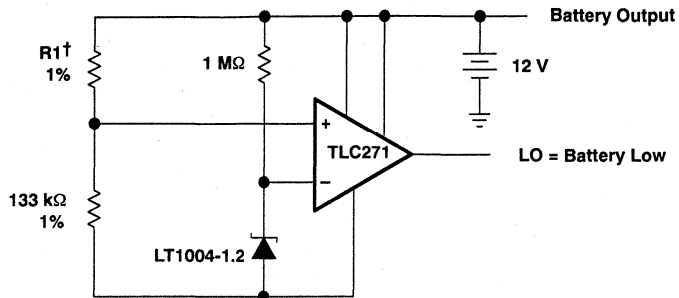


Figure 27. Terminal Current Source With Low Temperature Coefficient

LT1004 MICROPOWER INTEGRATED VOLTAGE REFERENCE

APPLICATION INFORMATION



†R1 sets trip point, 60.4 kΩ per cell for 1.8 V per cell.

Figure 28. Lead-Acid Low-Battery-Voltage Detector

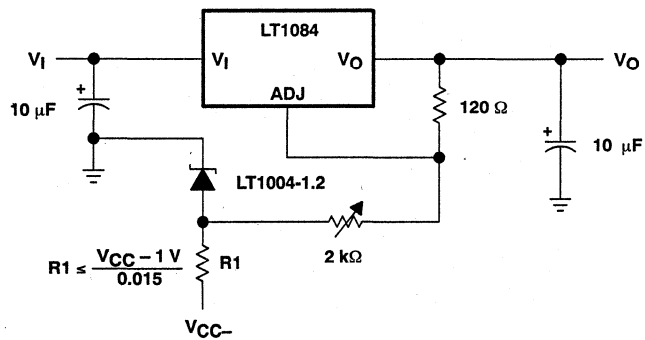


Figure 29. Variable-Voltage Supply

LT1009 2.5-V INTEGRATED REFERENCE CIRCUIT

D3191, MAY 1987—REVISED AUGUST 1991

- Excellent Temperature Stability
- Initial Tolerance . . . 0.2% Max
- Dynamic Impedance . . . 0.6 Ω Max
- Wide Operating Current Range
- Directly Interchangeable With LM136
- Needs No Adjustment for Minimum Temperature Coefficient

description

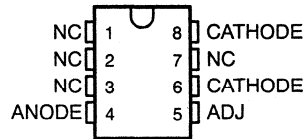
The LT1009 is a precision trimmed 2.5-V shunt regulator featuring low dynamic impedance and a wide operating current range. A maximum initial tolerance of ± 5 mV is available in the FK, JG, or LP package and ± 10 mV in the D package. The reference tolerance is achieved by on-chip trimming, which minimizes the initial voltage tolerance and the temperature coefficient α_{VZ} .

Even though the LT1009 needs no adjustments, a third terminal allows the reference voltage to be adjusted $\pm 5\%$ to eliminate system errors. In many applications, the LT1009 can be used as a pin-for-pin replacement for the LM136-2.5, which eliminates the external trim network.

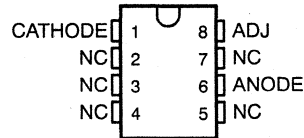
The uses of the LT1009 include a 5-V system reference, an 8-bit ADC and DAC reference, or a power supply monitor. The LT1009 can also be used in applications such as digital voltmeters and current-loop measurement and control systems.

The LT1009C is characterized for operation from 0°C to 70°C. The LT1009I is characterized for operation from -40°C to 85°C. The LT1009M is characterized for operation over the full military temperature range of -55°C to 125°C.

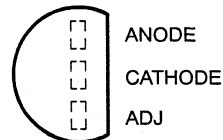
LT1009C, LT1009I . . . D PACKAGE
(TOP VIEW)



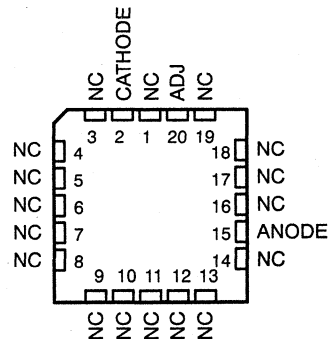
LT1009M . . . JG PACKAGE
(TOP VIEW)



LT1009C, LT1009I . . . LP PACKAGE
(TOP VIEW)

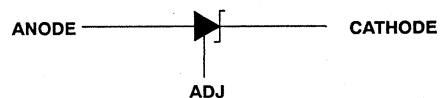


FK PACKAGE
(TOP VIEW)



NC—No internal connection

symbol



PRODUCTION DATA Information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

**TEXAS
INSTRUMENTS**

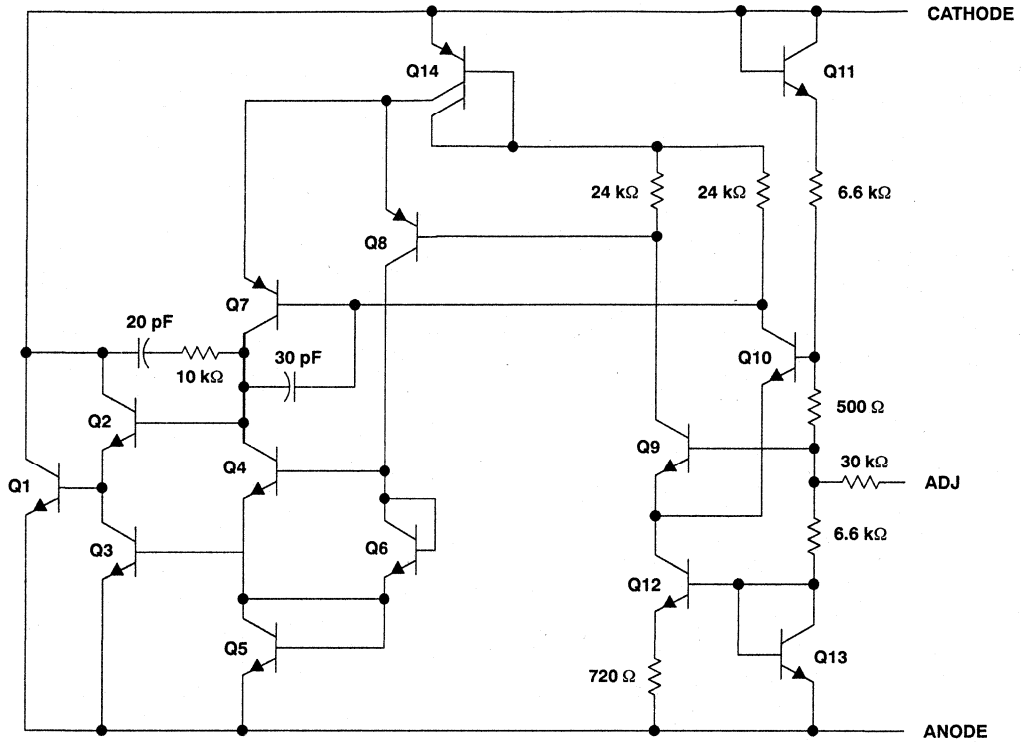
POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

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On products compliant to MIL-STD-883, Class B, all parameters are tested unless otherwise noted. On all other products, production processing does not necessarily include testing of all parameters.

LT1009 2.5-V INTEGRATED REFERENCE CIRCUIT

schematic



All component values shown are nominal.

absolute maximum ratings over operating free-air temperature range

| | |
|--|----------------|
| Reverse current | 20 mA |
| Forward current | 10 mA |
| Operating free-air temperature range: LT1009C | 0°C to 70°C |
| LT1009I | -40°C to 85°C |
| LT1009M | -55°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D and LP package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package | 300°C |

DISSIPATION RATING TABLE

| PACKAGE | DERATING FACTOR | | TA = 25°C | | TA = 70°C | | TA = 85°C | | TA = 125°C | |
|---------|-----------------|------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| | ABOVE TA | 25°C | POWER RATING | POWER RATING | POWER RATING | POWER RATING | POWER RATING | POWER RATING | POWER RATING | POWER RATING |
| D | 5.8 mW/°C | | 725 mW | 464 mW | 377 mW | 145 mW | | | | |
| FK | 11.0 mW/°C | | 1375 mW | 880 mW | 715 mW | 275 mW | | | | |
| JG | 8.4 mW/°C | | 1050 mW | 672 mW | 546 mW | 210 mW | | | | |
| LP | 6.2 mW/°C | | 775 mW | 496 mW | 403 mW | 155 mW | | | | |

electrical characteristics at specified free-air temperature

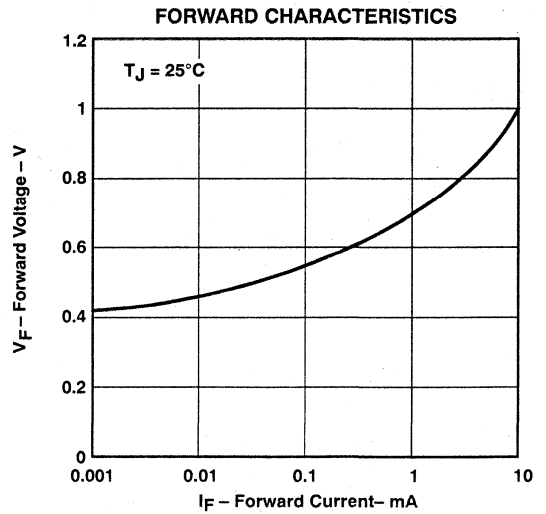
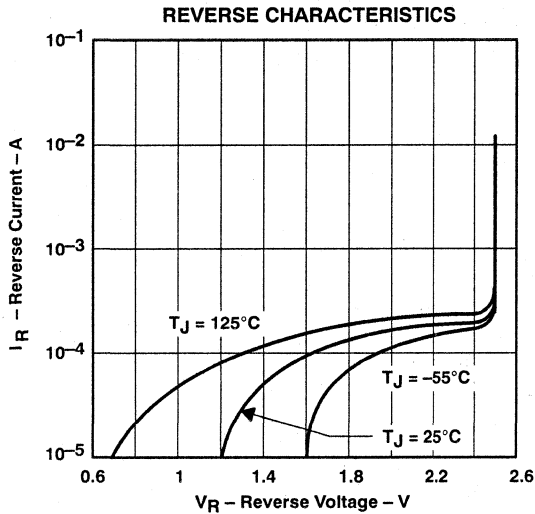
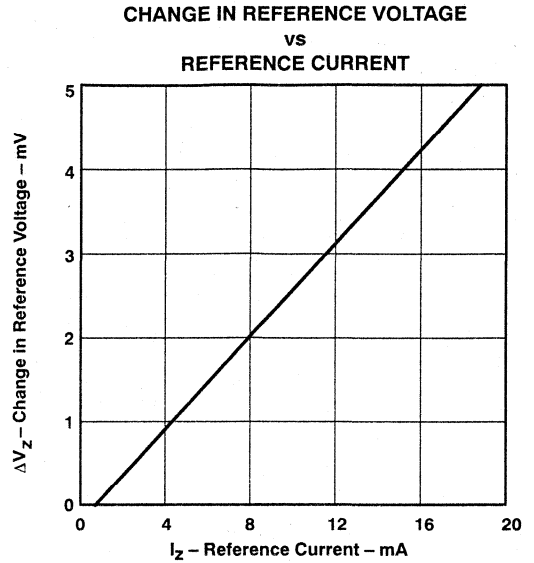
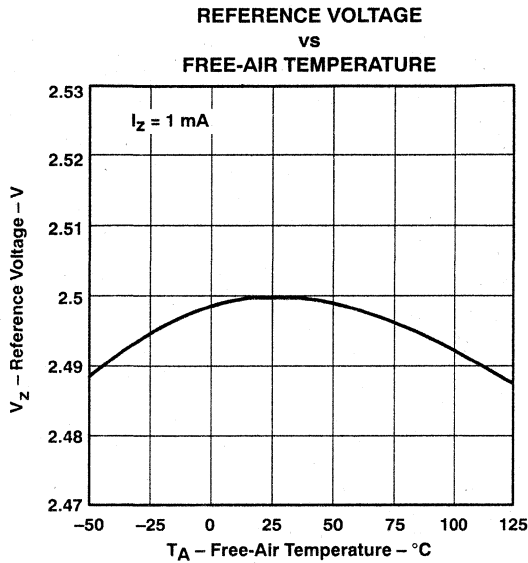
| PARAMETER | TEST CONDITIONS | TA† | LT1009C | | | LT1009I | | | LT1009M | | | UNIT |
|-----------|--|------------|--|-----|-----|---------|-----|-----|---------|-----|-----|---------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| Vz | Reference voltage Iz = 1 mA | 25°C | FK, JG, LP package | | | | | | | | | V |
| | | | D package | | | | | | | | | |
| | | | FK, JG, LP package | | | | | | | | | |
| VF | Forward voltage If = 2 mA | 25°C | D package | | | | | | | | | V |
| | | | Iz = 1 mA, VADJ = GND to Vz | | | | | | | | | |
| | | | Iz = 1 mA, VADJ = 0.6 V to Vz - 0.6 V | | | | | | | | | |
| ΔVz(temp) | Change in reference voltage with temperature | Full range | FK, JG, LP package | | | | | | | | | mV |
| | | | D package | | | | | | | | | |
| | | | Iz = 1 mA, VADJ = 0.6 V to Vz - 0.6 V | | | | | | | | | |
| αvz | Average coefficient of reference voltage‡ | Full range | FK, JG, LP package | | | | | | | | | ppm/°C |
| | | | D package | | | | | | | | | |
| | | | Iz = 1 mA, VADJ = 0.6 V to Vz - 0.6 V | | | | | | | | | |
| ΔVz | Change in reference voltage with current | 25°C | 0°C to 70°C | | | | | | | | | mV |
| | | | -40°C to 85°C | | | | | | | | | |
| | | | -55°C to 125°C | | | | | | | | | |
| ΔVz/Δt | Long-term change in reference voltage | Full range | 25°C | | | | | | | | | ppm/kyr |
| | | | Iz = 400 μA to 10 mA | | | | | | | | | |
| | | | Iz = 1 mA | | | | | | | | | |
| Zz | Reference impedance | Full range | 25°C | | | | | | | | | Ω |
| | | | Iz = 1 mA | | | | | | | | | |
| | | | Iz = 1 mA | | | | | | | | | |

* On products compliant to MIL-STD-883, Class B, this parameter is not production tested.

† Full range is 0°C to 70°C for the LT1009C, -40°C to 85°C for the LT1009I, and -55°C to 125°C for the LT1009M.

‡ The average temperature coefficient of reference voltage is defined as the total change in reference voltage divided by the specified temperature range.

TYPICAL CHARACTERISTICS†



† Data at the high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

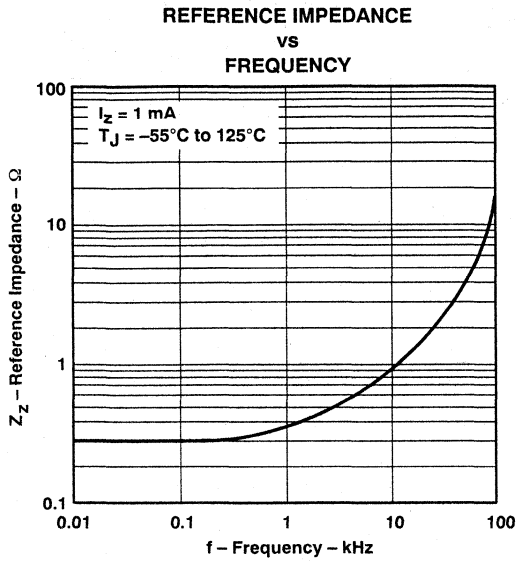


Figure 5

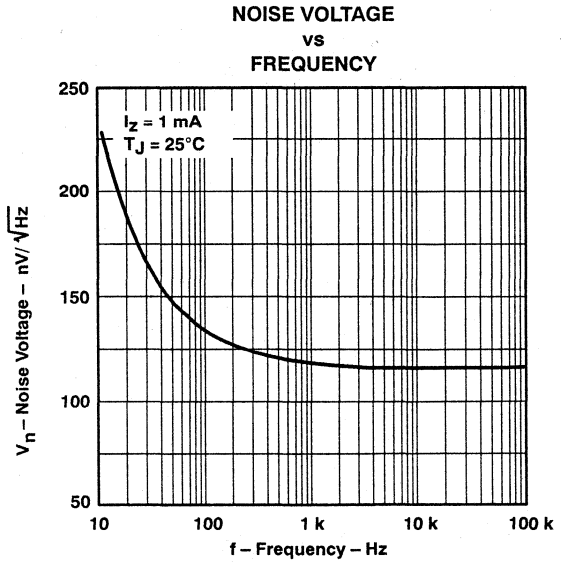


Figure 6

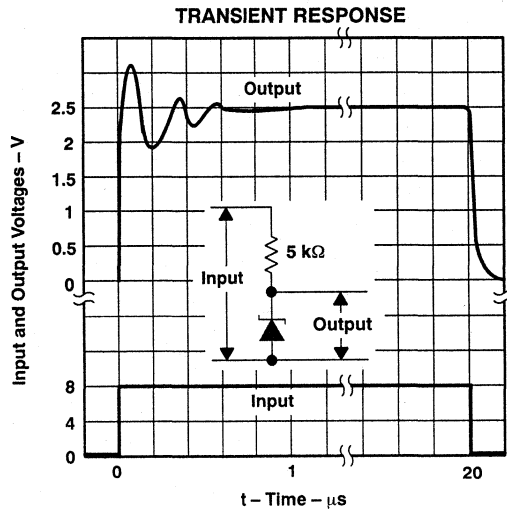
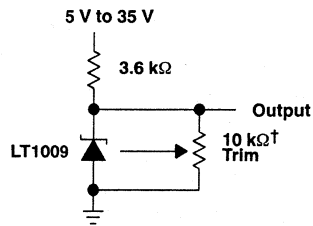


Figure 7

APPLICATION INFORMATION



†Does not affect temperature coefficient. Provides $\pm 5\%$ trim range.

Figure 8. 2.5-V Reference

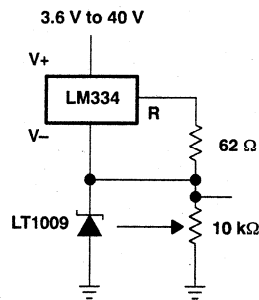


Figure 9. Adjustable Reference With Wide-Supply Range

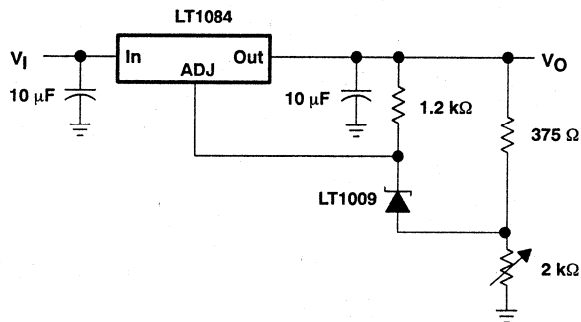


Figure 10. Power Regulator With Low Temperature Coefficient

APPLICATION INFORMATION

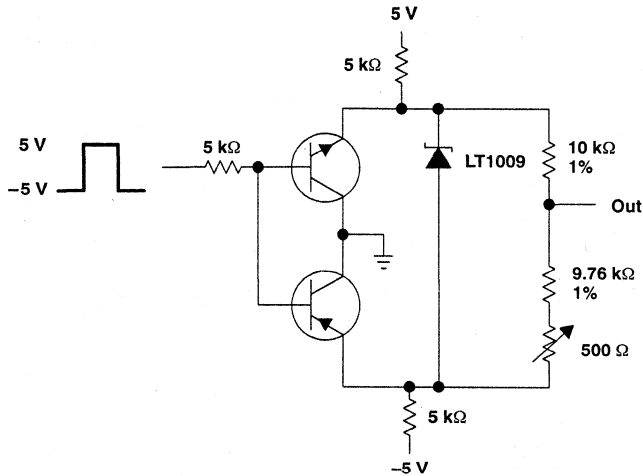


Figure 11. Switchable ± 1.25 -V Bipolar Reference

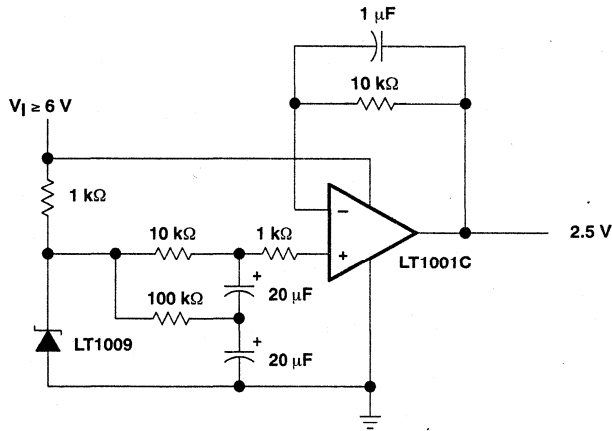


Figure 12. Low-Noise 2.5-V Buffered Reference

LT1054 SWITCHED-CAPACITOR VOLTAGE CONVERTER WITH REGULATOR

D3202, FEBRUARY 1990—REVISED AUGUST 1991

- Output Current . . . 100 mA
- Low Loss . . . 1.1 V at 100 mA
- Operating Range . . . 3.5 V to 15 V
- Reference and Error Amplifier for Regulation
- External Shutdown
- External Oscillator Synchronization
- Devices Can Be Paralleled
- Pin Compatible With the LTC1044/7660

description

The LT1054 is a monolithic, bipolar, switched-capacitor voltage converter with regulator. It provides higher output current and significantly lower voltage losses than previously available converters. An adaptive switch drive scheme optimizes efficiency over a wide range of output currents. Total voltage drop at 100-mA output current is typically 1.1 V. This holds true over the full supply voltage range of 3.5 V to 15 V. Quiescent current is typically 2.5 mA.

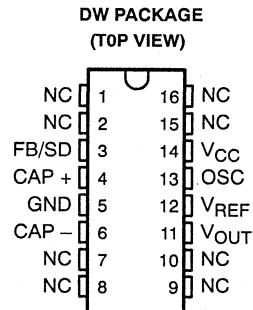
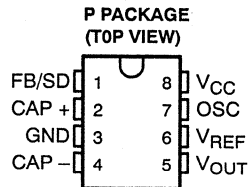
The LT1054 also provides regulation, a feature not previously available in switched-capacitor voltage converters. By adding an external resistive divider, a regulated output can be obtained. This output is regulated against changes in both input voltage and output current. The LT1054 can also be shut down by grounding the feedback pin. Supply current in shut-down is typically 100 μ A.

The internal oscillator of the LT1054 runs at a nominal frequency of 25 kHz. The oscillator pin can be used to adjust the switching frequency or to externally synchronize the LT1054.

AVAILABLE OPTIONS

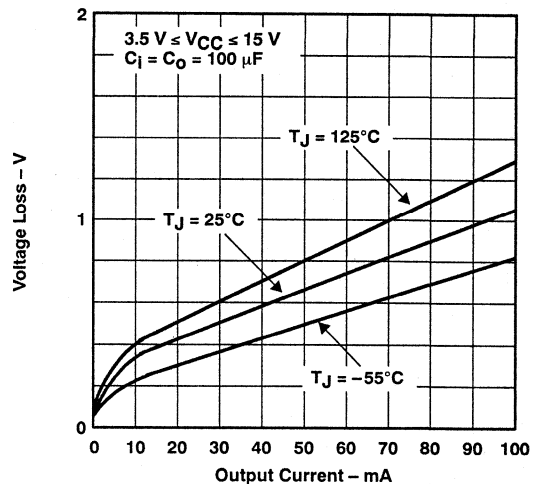
| T _A | PACKAGE | |
|----------------|--------------------|-----------------|
| | SMALL OUTLINE (DW) | PLASTIC DIP (P) |
| 0°C to 70°C | LT1054CDW | LT1054CP |
| -40°C to 85°C | LT1054IDW | LT1054IP |

The DW package is available taped and reeled. Add the suffix R to the device type, (i.e., LT1054CDWR).



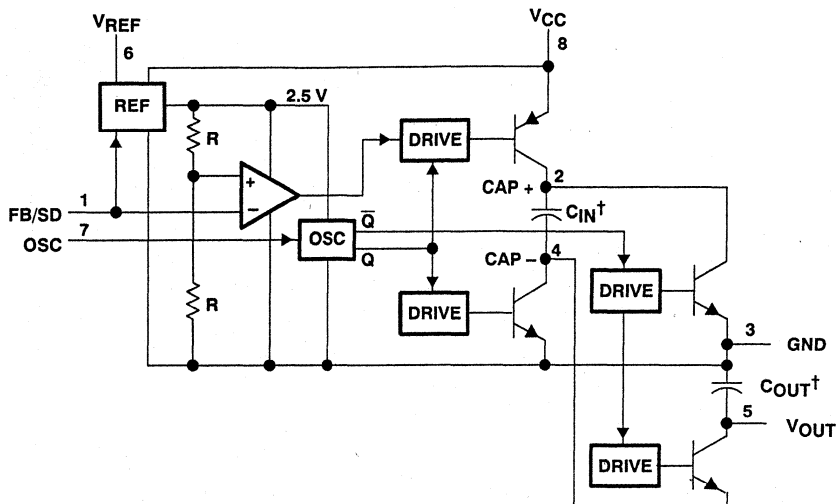
NC – No internal connection

VOLTAGE LOSS vs OUTPUT CURRENT



LT1054 SWITCHED-CAPACITOR VOLTAGE CONVERTER WITH REGULATOR

functional block diagram



† External capacitors

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|------------------|
| Supply voltage, V_{CC} (see Note 1) | 16 V |
| Input voltage range, FB/SD terminal | 0 V to V_{CC} |
| Input voltage range, OSC terminal | 0 V to V_{ref} |
| Junction temperature (see Note 2): LT1054C | 125°C |
| LT1054I | 135°C |
| Operating free-air temperature range: LT1054C | 0°C to 70°C |
| LT1054I | -40°C to 85°C |
| Storage temperature range | -55°C to 150°C |
| Lead temperature, 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTES: 1. The absolute maximum supply voltage rating of 16 V is for unregulated circuits. For regulation mode circuits with $V_{OUT} \leq 15$ V, this rating may be increased to 20 V.

2. The devices are functional up to the absolute maximum junction temperature.

recommended operating conditions

| | | MIN | MAX | UNIT |
|---|---------|-----|-----|------|
| Supply voltage, V_{CC} | | 3.5 | 15 | V |
| Operating free-air temperature range, T_A | LT1054C | 0 | 70 | °C |
| | LT1054I | -40 | 85 | |

LT1054

SWITCHED-CAPACITOR VOLTAGE CONVERTER WITH REGULATOR

electrical characteristics

| PARAMETER | TEST CONDITIONS | T_A † | MIN | TYP‡ | MAX | UNIT |
|--|---|-------------------------|------------|------|------|---------------|
| Regulated output voltage, V_O | $V_{CC} = 7\text{ V}$, $T_J = 25^\circ\text{C}$, $R_L = 500\ \Omega$, See Note 3 | 25°C | -4.7 | -5 | -5.2 | V |
| Input regulation | $V_{CC} = 7\text{ V to }12\text{ V}$, $R_L = 500\ \Omega$, See Note 3 | Full range | | 5 | 25 | mV |
| Output regulation | $V_{CC} = 7\text{ V}$, $R_L = 100\ \Omega\text{ to }500\ \Omega$, See Note 3 | Full range | | 10 | 50 | mV |
| Voltage loss, $V_{CC} - V_O $ (see Note 4) | $C_1 = C_O = 100\ \mu\text{F}$ tantalum | $I_O = 10\text{ mA}$ | Full range | 0.35 | 0.55 | V |
| | | $I_O = 100\text{ mA}$ | Full range | 1.1 | 1.6 | |
| Output resistance | $\Delta I_O = 10\text{ mA to }100\text{ mA}$, See Note 5 | Full range | | 10 | 15 | Ω |
| Oscillator frequency | $V_{CC} = 3.5\text{ V to }15\text{ V}$ | Full range | 15 | 25 | 35 | kHz |
| Reference voltage, V_{ref} | $I_{ref} = 60\ \mu\text{A}$ | 25°C | 2.35 | 2.5 | 2.65 | V |
| | | Full range | 2.25 | | 2.75 | |
| Maximum switch current | | 25°C | | 300 | | mA |
| Supply current, I_{CC} | $I_O = 0$ | $V_{CC} = 3.5\text{ V}$ | Full range | 2.5 | 3.5 | mA |
| | | $V_{CC} = 15\text{ V}$ | Full range | 3 | 4.5 | |
| Supply current in shutdown | $V_{FB}/SD = 0\text{ V}$ | Full range | 100 | 150 | | μA |

† Full range is 0°C to 70°C for the LT1054C and -40°C to 85°C for the LT1054I.

‡ All typical values are at $T_A = 25^\circ\text{C}$.

- NOTES: 3. All regulation specifications are for a device connected as a positive to negative converter/regulator with $R_1 = 20\text{ k}\Omega$, $R_2 = 102.5\text{ k}\Omega$, $C_1 = 10\ \mu\text{F}$ (tantalum), $C_O = 100\ \mu\text{F}$ (tantalum) and $C_1 = 0.002\ \mu\text{F}$.
4. For voltage-loss tests, the device is connected as a voltage inverter, with pins 1, 6, and 7 unconnected. The voltage losses may be higher in other configurations.
5. Output resistance is defined as the slope of the curve (ΔV_O vs ΔI_O) for output currents of 10 mA to 100 mA. This represents the linear portion of the curve. The incremental slope of the curve will be higher at currents less than 10 mA due to the characteristics of the switch transistors.

LT1054 SWITCHED-CAPACITOR VOLTAGE CONVERTER WITH REGULATOR

TYPICAL CHARACTERISTICS

table of graphs

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| I_{OSC} | Oscillator Frequency | vs T_A Free-Air Temperature | 3 |
| | Supply Current in Shutdown | vs V_{CC} Input Voltage | 4 |
| I_{avg} | Average Supply Current | vs I_O Output Current | 5 |
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| | Output Voltage Loss | vs f_{osc} Oscillator Frequency (10 μ F) | 7 |
| | Output Voltage Loss | vs f_{osc} Oscillator Frequency (100 μ F) | 8 |
| V_O | Regulated Output Voltage | vs T_A Free-Air Temperature | 9 |
| ΔV_{ref} | Reference Voltage Change | vs T_A Free-Air Temperature | 10 |

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TYPICAL CHARACTERISTICS†

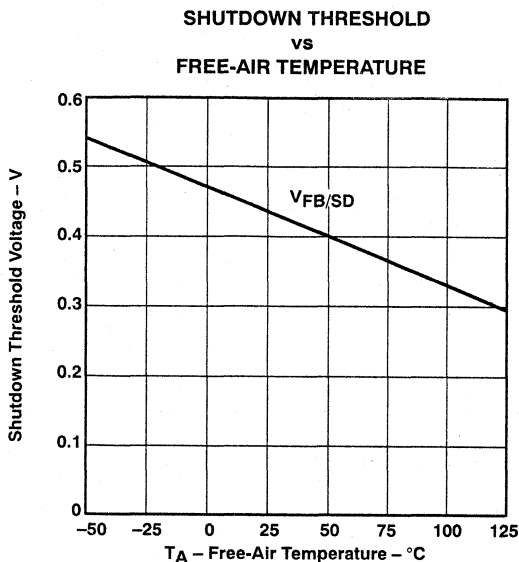


Figure 1

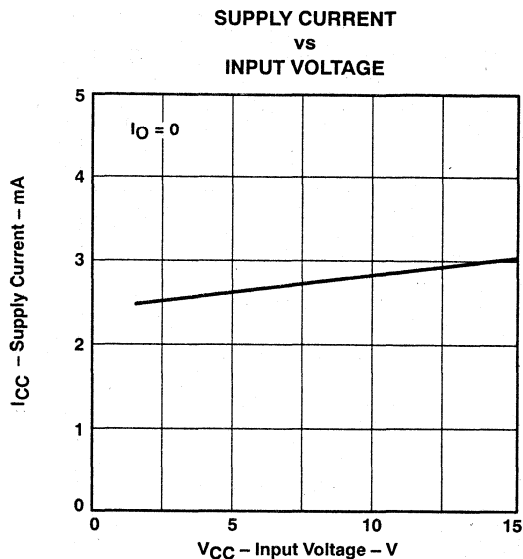


Figure 2

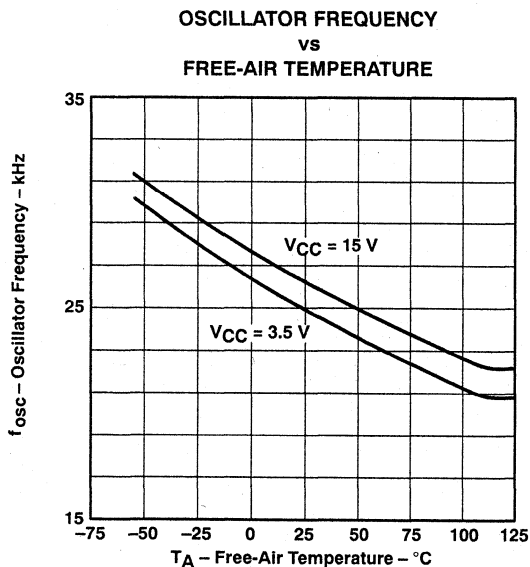


Figure 3

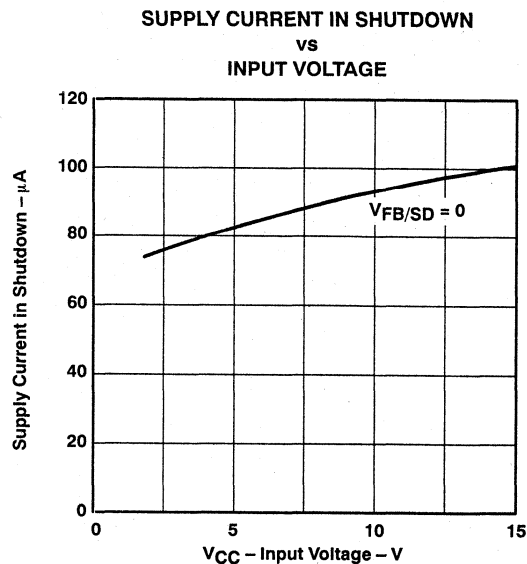


Figure 4

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

LT1054
SWITCHED-CAPACITOR VOLTAGE CONVERTER
WITH REGULATOR

TYPICAL CHARACTERISTICS

AVERAGE SUPPLY CURRENT
vs
OUTPUT CURRENT

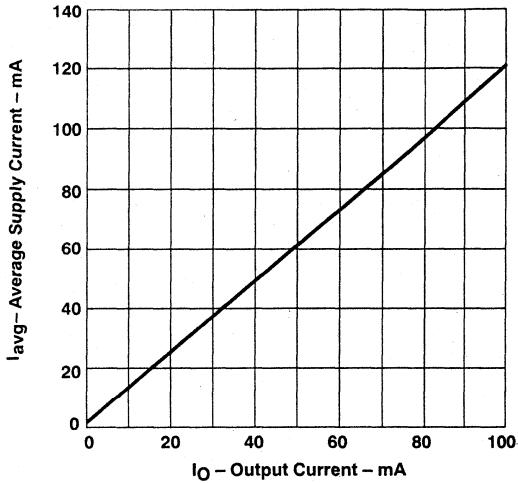


Figure 5

OUTPUT VOLTAGE LOSS
vs
INPUT CAPACITANCE

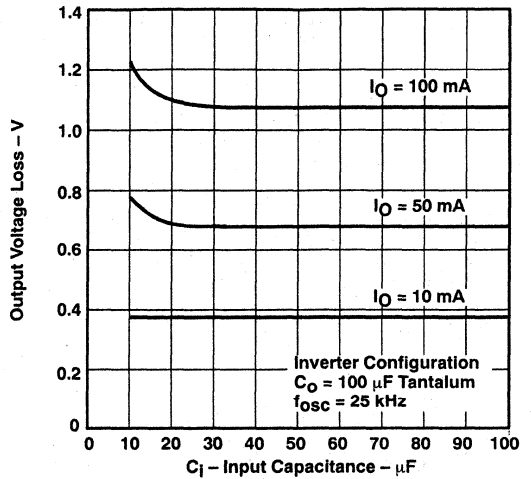


Figure 6

OUTPUT VOLTAGE LOSS
vs
OSCILLATOR FREQUENCY

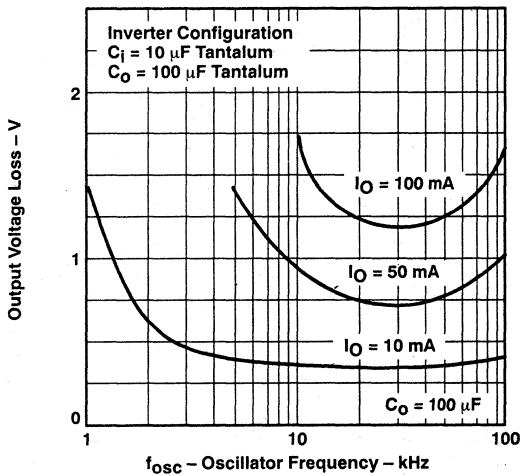


Figure 7

OUTPUT VOLTAGE LOSS
vs
OSCILLATOR FREQUENCY

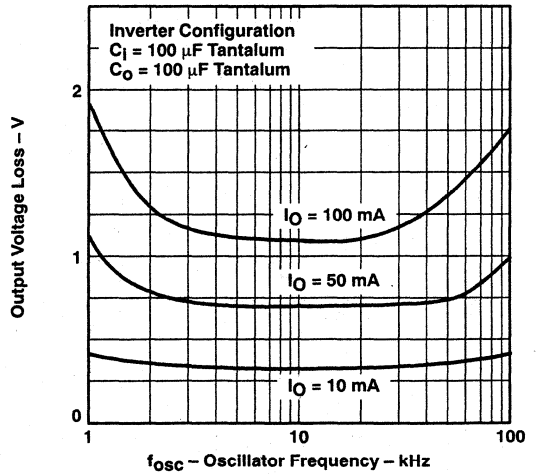


Figure 8

LT1054 SWITCHED-CAPACITOR VOLTAGE CONVERTER WITH REGULATOR

TYPICAL CHARACTERISTICS†

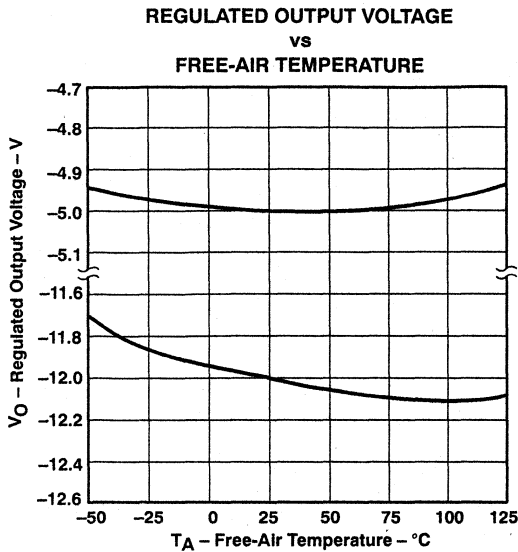


Figure 9

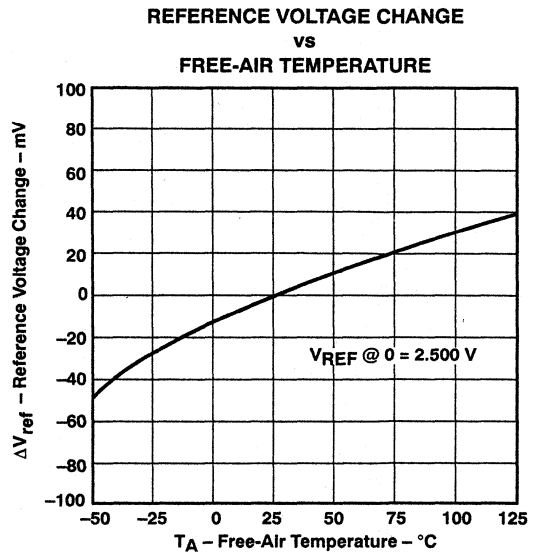


Figure 10

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

PRINCIPLES OF OPERATION

A review of a basic switched-capacitor building block is helpful in understanding the operation of the LT1054. When the switch shown in Figure 11 is in the left position, capacitor C1 charges to the voltage at V1. The total charge on C1 is $q_1 = C1V_1$. When the switch is moved to the right, C1 is discharged to the voltage at V2. After this discharge time, the charge on C1 is $q_2 = C1V_2$. The charge has been transferred from the source V1 to the output V2. The amount of charge transferred is as shown in equation 1.

$$\Delta q = q_1 - q_2 = C1(V_1 - V_2) \tag{1}$$

If the switch is cycled f times per second, the charge transfer per unit time (i.e., current) is as shown in equation 2.

$$I = f \times \Delta q = f \times C1(V_1 - V_2) \tag{2}$$

To obtain an equivalent resistance for a switched-capacitor network, this equation can be rewritten in terms of voltage and impedance equivalence as shown in equation 3.

$$I = \frac{V_1 - V_2}{(1/fC1)} = \frac{V_1 - V_2}{R_{EQUIV}} \tag{3}$$

**LT1054
SWITCHED-CAPACITOR VOLTAGE CONVERTER
WITH REGULATOR**

PRINCIPLES OF OPERATION

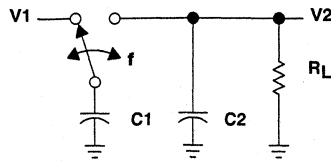


Figure 11. Switched-Capacitor Building Block

A new variable, R_{EQUIV} , is defined as $R_{EQUIV} = 1 + fC1$. The equivalent circuit for the switched-capacitor network is as shown in Figure 12. The LT1054 has the same switching action as the basic switched-capacitor building block. Even though this simplification does not include finite switch-on resistance and output-voltage ripple, it provides an insight into how the device operates.

These simplified circuits explain voltage loss as a function of oscillator frequency (see Figure 7). As oscillator frequency is decreased, the output impedance is eventually dominated by the $1/fC1$ term and voltage losses rise.

Voltage losses also rise as oscillator frequency increases. This is caused by internal switching losses that occur due to some finite charge being lost on each switching cycle. This charge loss per-unit-cycle, when multiplied by the switching frequency, becomes a current loss. At high frequency, this loss becomes significant and voltage losses again rise.

The oscillator of the LT1054 is designed to run in the frequency band where voltage losses are at a minimum.

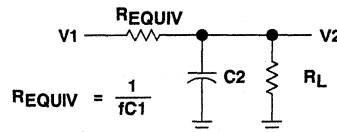


Figure 12. Switched-Capacitor Equivalent Circuit

APPLICATION INFORMATION

pin functions (see functional block diagram)

Supply voltage V_{CC} (pin 8) alternately charges C_{IN} to the input voltage when C_{IN} is switched in parallel with the input supply, and then transfers charge to C_{OUT} when C_{IN} is switched in parallel with C_{OUT} . Switching occurs at the oscillator frequency. During the time that C_{IN} is charging, the peak supply current is approximately 2.2 times the output current. During the time that C_{IN} is delivering a charge to C_{OUT} , the supply current drops to approximately 0.2 times the output current. An input supply bypass capacitor supplies part of the peak input current drawn by the LT1054, and averages out the current drawn from the supply. A minimum input supply bypass capacitor of 2 μ F, preferably tantalum or some other low-ESR type, is recommended. A larger capacitor is desirable in some cases. An example is when the actual input supply is connected to the LT1054 through long leads or when the pulse currents drawn by the LT1054 might affect other circuits through supply coupling.

In addition to being the output pin, V_{OUT} (pin 5) is tied to the substrate of the device. Special care must be taken in LT1054 circuits to avoid making V_{OUT} positive with respect to any of the other pins. For circuits with the output load connected from V_{CC} to V_{OUT} or from some external positive supply voltage to V_{OUT} , an external transistor must be added (see Figure 13). This transistor prevents V_{OUT} from being pulled above the GND pin (pin 3) during start-up. Any small general-purpose transistor such as a 2N2222 or a 2N2219 device can be used. Resistor R1 should be chosen to provide enough base drive to the external transistor so that it is saturated under nominal output voltage and maximum output current conditions.

$$R1 \leq \frac{(|V_{OUT}|) \beta}{I_{OUT}} \tag{4}$$

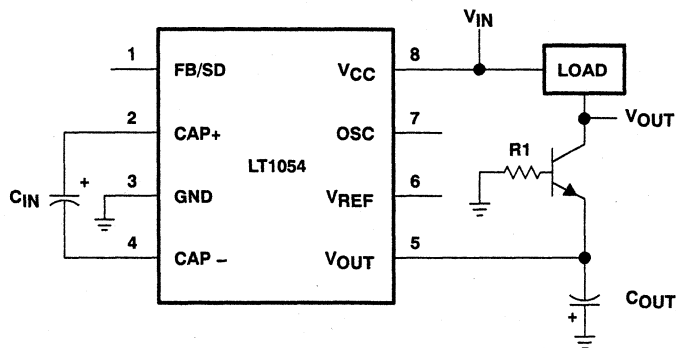


Figure 13. Circuit with Load Connected from V_{CC} to V_{OUT}

LT1054 SWITCHED-CAPACITOR VOLTAGE CONVERTER WITH REGULATOR

APPLICATION INFORMATION

The voltage reference (V_{ref}) output (pin 6) provides a 2.5-V reference point for use in LT1054-based regulator circuits. The temperature coefficient (TC) of the reference voltage has been adjusted so that the TC of the regulated output voltage is near zero. As seen in the typical performance curves, this requires the reference output to have a positive TC. This non-zero drift is necessary to offset a drift term inherent in the internal reference divider and comparator network tied to the feedback pin. The overall result of these drift terms is a regulated output that has a slight positive TC at output voltages below 5 V and a slight negative TC at output voltages above 5 V. For regulator feedback networks, reference output current should be limited to approximately 60 μA . V_{ref} draws approximately 100 μA when shorted to ground and does not affect the internal reference/regulator. This pin can also be used as a pullup for LT1054 circuits that require synchronization.

CAP+ (pin 2) is the positive side of input capacitor C_{IN} and is alternately driven between V_{CC} and ground. When driven to V_{CC} , CAP+ sources current from V_{CC} . When driven to ground, CAP+ sinks current to ground. CAP- (Pin 4) is the negative side of the input capacitor and is driven alternately between ground and V_{OUT} . When driven to ground, CAP- sinks current to ground. When driven to V_{OUT} , CAP- sources current from C_{OUT} . In all cases, current flow in the switches is unidirectional, as should be expected when using bipolar switches.

The OSC (pin 7) can be used to raise or lower the oscillator frequency or to synchronize the device to an external clock. Internally, OSC is connected to the oscillator timing capacitor ($C_t \approx 150 \text{ pF}$), which is alternately charged and discharged by current sources of $\pm 7 \mu\text{A}$, so that the duty cycle is approximately 50%. The LT1054 oscillator is designed to run in the frequency band where switching losses are minimized. However, the frequency can be raised, lowered, or synchronized to an external system clock if necessary.

The frequency can be increased by adding an external capacitor (C_2 in Figure 14) in the range of 5 pF - 20 pF from CAP+ to OSC. This capacitor couples a charge into C_t at the switch transitions. This shortens the charge and discharge time and raises the oscillator frequency. Synchronization can be accomplished by adding an external pullup resistor from OSC to V_{ref} . A 20-k Ω pullup resistor is recommended. An open-collector gate or an NPN transistor can then be used to drive OSC at the external clock frequency as shown in Figure 14.

The frequency can be lowered by adding an external capacitor (C_1 in Figure 14) from OSC to ground. This increases the charge and discharge times, which lowers the oscillator frequency.

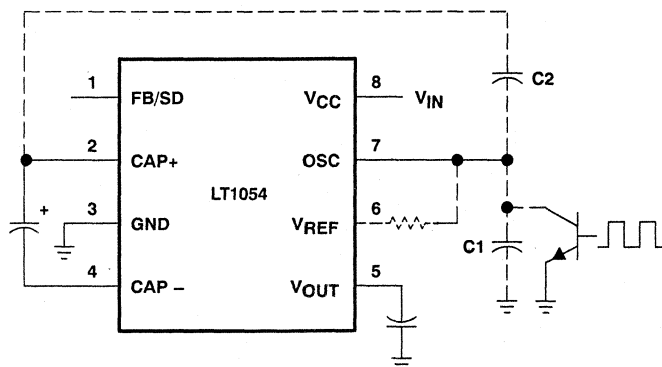


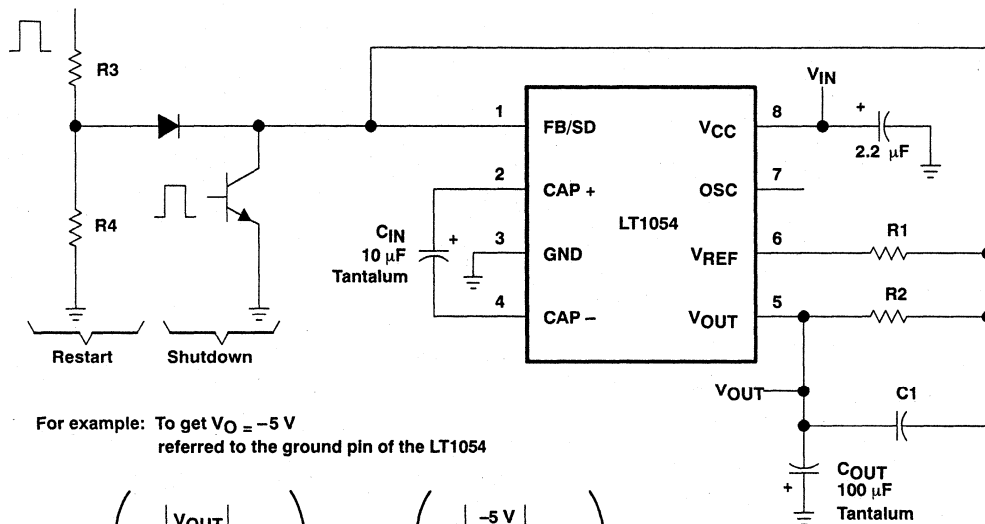
Figure 14. External Clock System

LT1054 SWITCHED-CAPACITOR VOLTAGE CONVERTER WITH REGULATOR

APPLICATION INFORMATION

The feedback/shutdown (FB/SD) pin has two functions. Pulling FB/SD below the shutdown threshold (≈ 0.45 V) puts the device into shutdown. In shutdown, the reference/regulator is turned off and switching stops. The switches are set such that both C_{IN} and C_{OUT} are discharged through the output load. Quiescent current in shutdown drops to approximately $100 \mu\text{A}$. Any open-collector gate can be used to put the LT1054 into shutdown. For normal (unregulated) operation, the device will restart when the external gate is shut off. In LT1054 circuits that use the regulation feature, the external resistor divider can provide enough pullup to keep the device in shutdown until the output capacitor (C_{OUT}) has fully discharged. For most applications where the LT1054 is run intermittently, this does not present a problem because the discharge time of the output capacitor is short compared to the off time of the device. In applications where the device has to start-up before the output capacitor (C_{OUT}) has fully discharged, a restart pulse must be applied to FB/SD of the LT1054. Using the circuit shown in Figure 15, the restart signal can be either a pulse ($t_p > 100 \mu\text{s}$) or a logic high. Diode coupling the restart signal into FB/SD allows the output voltage to rise and regulate without overshoot. The resistor divider $R3/R4$ shown in Figure 15 should be chosen to provide a signal level at FB/SD of 0.7 V - 1.1 V.

FB/SD is also the inverting input of the LT1054 error amplifier, and as such can be used to obtain a regulated output voltage.



For example: To get $V_O = -5$ V referred to the ground pin of the LT1054

$$R2 = R1 \left(\frac{|V_{OUT}|}{\frac{V_{REF}}{2} - 40 \text{ mV}} + 1 \right) = 20 \text{ k}\Omega \left(\frac{|-5 \text{ V}|}{\frac{2.5 \text{ V}}{2} - 40 \text{ mV}} + 1 \right) = 102.6 \text{ k}\Omega^\dagger$$

Where: $R1 = 20 \text{ k}\Omega$
 $V_{REF} = 2.5 \text{ V Nominal}$

† Choose the closest 1% value

Figure 15. Basic Regulation Configuration

LT1054 SWITCHED-CAPACITOR VOLTAGE CONVERTER WITH REGULATOR

APPLICATION INFORMATION

regulation

The error amplifier of the LT1054 drives the PNP switch to control the voltage across the input capacitor (C_{IN}), which determines the output voltage. When the reference and error amplifier of the LT1054 is used, an external resistive divider is all that is needed to set the regulated output voltage. Figure 15 shows the basic regulator configuration and the formula for calculating the appropriate resistor values. R1 should be 20 k Ω or greater because the reference current is limited to $\pm 100 \mu\text{A}$. R2 should be in the range of 100 k Ω to 300 k Ω . Frequency compensation is accomplished by adjusting the ratio of C_{IN} to C_{OUT} .

For best results, this ratio should be approximately 1 to 10. Capacitor C1, required for good load regulation, should be 0.002 μF for all output voltages.

The functional block diagram shows that the maximum regulated output voltage is limited by the supply voltage. For the basic configuration, $|V_{OUT}|$ referred to the ground pin of the LT1054, must be less than the total of the supply voltage minus the voltage loss due to the switches. The voltage loss versus output current due to the switches can be found in the typical performance curves. Other configurations, such as the negative doubler can provide higher voltages at reduced output currents.

capacitor selection

While the exact values of C_{IN} and C_{OUT} are non-critical, good-quality low-ESR capacitors, such as solid tantalum are necessary to minimize voltage losses at high currents. For C_{IN} , the effect of the equivalent series resistance (ESR) of the capacitor is multiplied by four, since switch currents are approximately two times higher than output current. Losses occur on both the charge and discharge cycle, which means that a capacitor with 1 Ω of ESR for C_{IN} has the same effect as increasing the output impedance of the LT1054 by 4 Ω . This represents a significant increase in the voltage losses. C_{OUT} is alternately charged and discharged at a current approximately equal to the output current. The ESR of the capacitor causes a step function to occur in the output ripple at the switch transitions. This step function degrades the output regulation for changes in output load current and should be avoided. A technique is used to parallel a smaller tantalum capacitor with a large aluminum electrolytic capacitor to gain both low ESR and reasonable cost.

output ripple

The peak-to-peak output ripple is determined by the output capacitor and the output current values. Peak-to-peak output ripple is approximated as shown:

$$\Delta V = \frac{I_{OUT}}{2 f C_{OUT}} \quad (5)$$

where:

$$\begin{aligned} \Delta V &= \text{p-p ripple} \\ f_{OSC} &= \text{oscillator frequency} \end{aligned}$$

For output capacitors with significant ESR, a second term must be added to account for the voltage step at the switch transitions. This step is approximately equal to:

$$(2I_{OUT}) (\text{ESR of } C_{OUT}) \quad (6)$$

power dissipation

The power dissipation of any LT1054 circuit must be limited so that the junction temperature of the device does not exceed the maximum junction temperature ratings. The total power dissipation is calculated from two components, the power loss due to voltage drops in the switches, and the power loss due to drive current losses. The total power dissipated by the LT1054 is calculated as shown.

APPLICATION INFORMATION

$$P \approx (V_{CC} - |V_{OUT}|) I_{OUT} + (V_{CC}) (I_{OUT}) \quad (7)$$

where both V_{CC} and V_{OUT} refer to the ground pin. The power dissipation is equivalent to that of a linear regulator. Limited power handling capability of the LT1054 packages causes limited output current requirements or steps can be taken to dissipate power external to the LT1054 for large input or output differentials. This is accomplished by placing a resistor in series with C_{IN} as shown in Figure 16. A portion of the input voltage is dropped across this resistor without affecting the output regulation. Since switch current is approximately 2.2 times the output current and the resistor causes a voltage drop when C_{IN} is both charging and discharging, the resistor chosen is as shown.

$$R_X = V_X / (4.4 I_{OUT})$$

where:

$$V_X \approx V_{CC} - [(LT1054 \text{ voltage loss}) (1.3) + |V_{OUT}|] \quad (8)$$

and I_{OUT} = maximum required output current. The factor of 1.3 allows some operating margin for the LT1054. When using a 12-V to -5-V converter at 100-mA output current, calculate the power dissipation without an external resistor.

$$P = (12 \text{ V} - |-5 \text{ V}|) (100 \text{ mA}) + (12 \text{ V}) (100 \text{ mA}) \quad (0.2)$$

$$P = 700 \text{ mW} + 240 \text{ mW} = 940 \text{ mW}$$

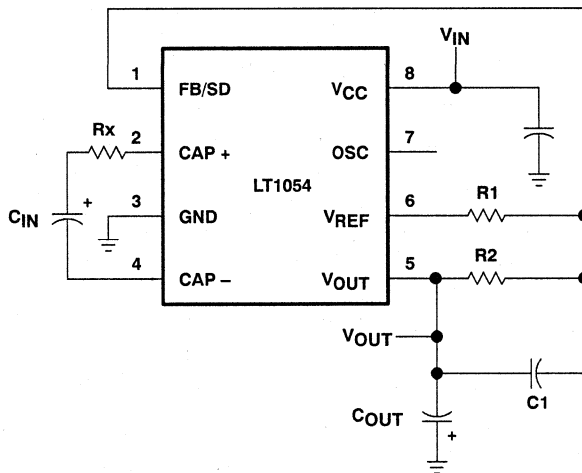


Figure 16. Power-Dissipation-Limiting Resistor in Series with C_{IN}

At θ_{JA} of 130°C/W for a commercial plastic device, a junction temperature rise of 122°C is seen. The device exceeds the maximum junction temperature at an ambient temperature of 25°C. To calculate the power dissipation with an external-resistor (R_X), determine how much voltage can be dropped across R_X . The maximum voltage loss of the LT1054 in the standard regulator configuration at 100 mA output current is 1.6 V.

$$V_X = 12 \text{ V} - [(1.6 \text{ V}) (1.3) + |-5 \text{ V}|] = 4.9 \text{ V} \quad \text{and}$$

$$R_X = 4.9 \text{ V} / (4.4) (100 \text{ mA}) = 11 \Omega$$

LT1054 SWITCHED-CAPACITOR VOLTAGE CONVERTER WITH REGULATOR

APPLICATION INFORMATION

The resistor reduces the power dissipated by the LT1054 by $(4.9 \text{ V}) (100 \text{ mA}) = 490 \text{ mW}$. The total power dissipated by the LT1054 is equal to $(940 \text{ mW} - 490 \text{ mW}) = 450 \text{ mW}$. The junction temperature rise is 58°C . Although commercial devices are functional up to a junction temperature of 125°C , the specifications are tested to a junction temperature of 100°C . In this example, this means limiting the ambient temperature to 42°C . To allow higher ambient temperatures, the thermal resistance numbers for the LT1054 packages represent worst-case numbers with no heat-sinking and still air. Small clip-on heat sinks can be used to lower the thermal resistance of the LT1054 package. Airflow in some systems helps to lower the thermal resistance. Wide PC board traces from the LT1054 leads helps to remove heat from the device. This is especially true for plastic packages.

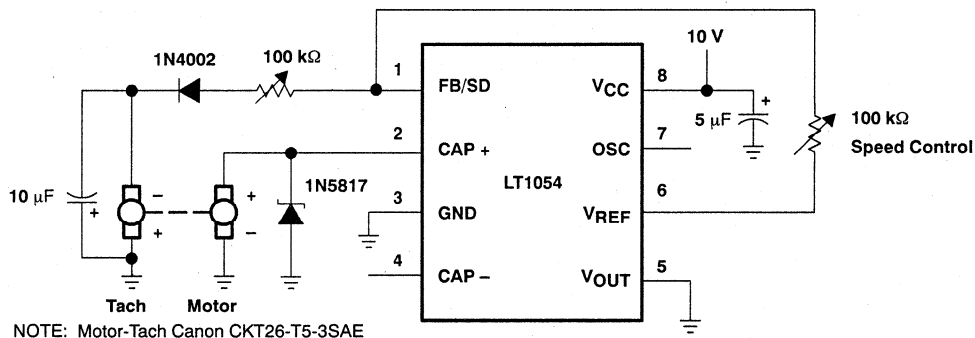


Figure 17. Motor Speed Servo

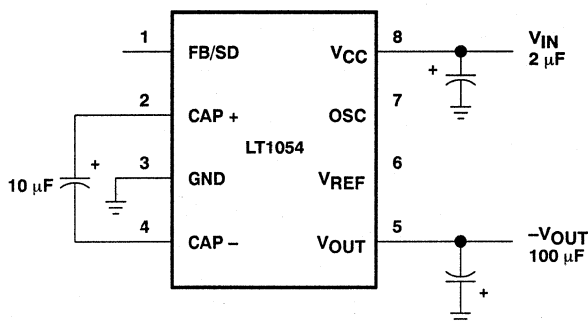
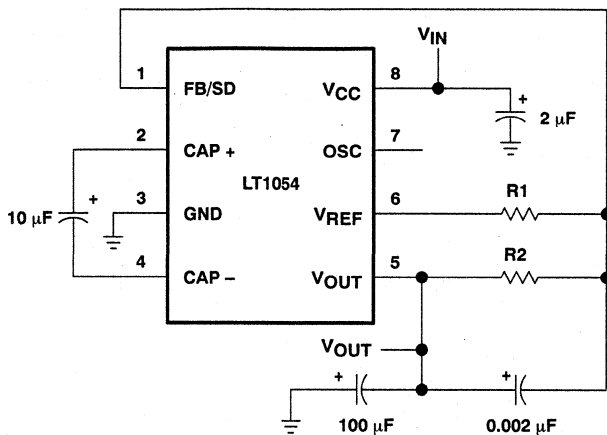


Figure 18. Basic Voltage Inverter

APPLICATION INFORMATION



$$R2 = R1 \left(\frac{|V_{OUT}|}{\frac{V_{REF}}{2} - 40 \text{ mV}} + 1 \right) = 20 \text{ k}\Omega \left(\frac{|V_{OUT}|}{1.21 \text{ V}} + 1 \right)$$

Figure 19. Basic Voltage Inverter/Regulator

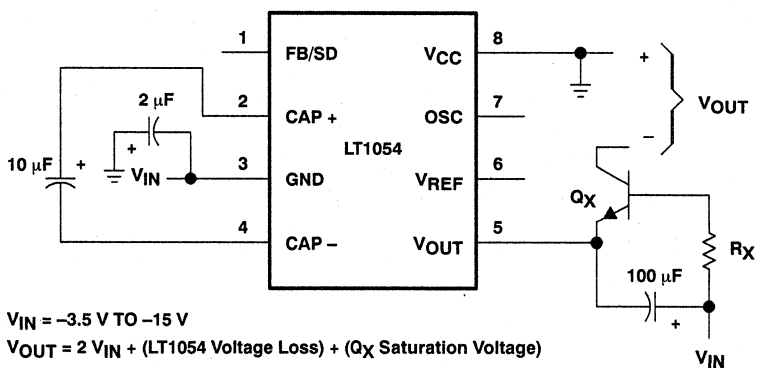


Figure 20. Negative Voltage Doubler

**LT1054
SWITCHED-CAPACITOR VOLTAGE CONVERTER
WITH REGULATOR**

APPLICATION INFORMATION

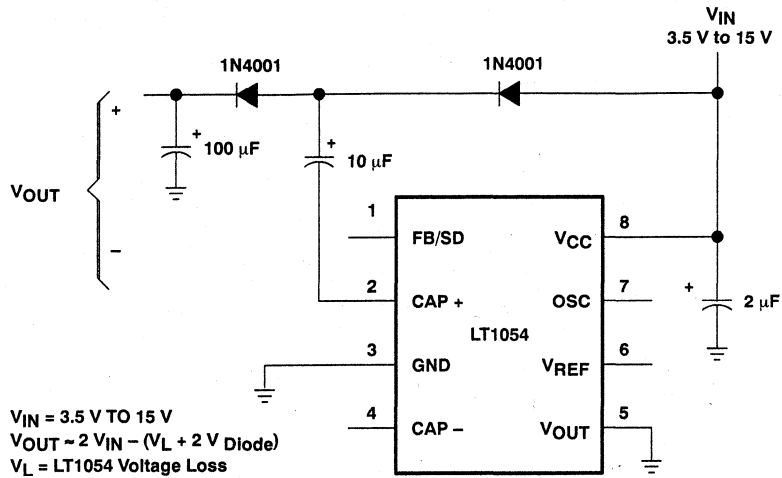
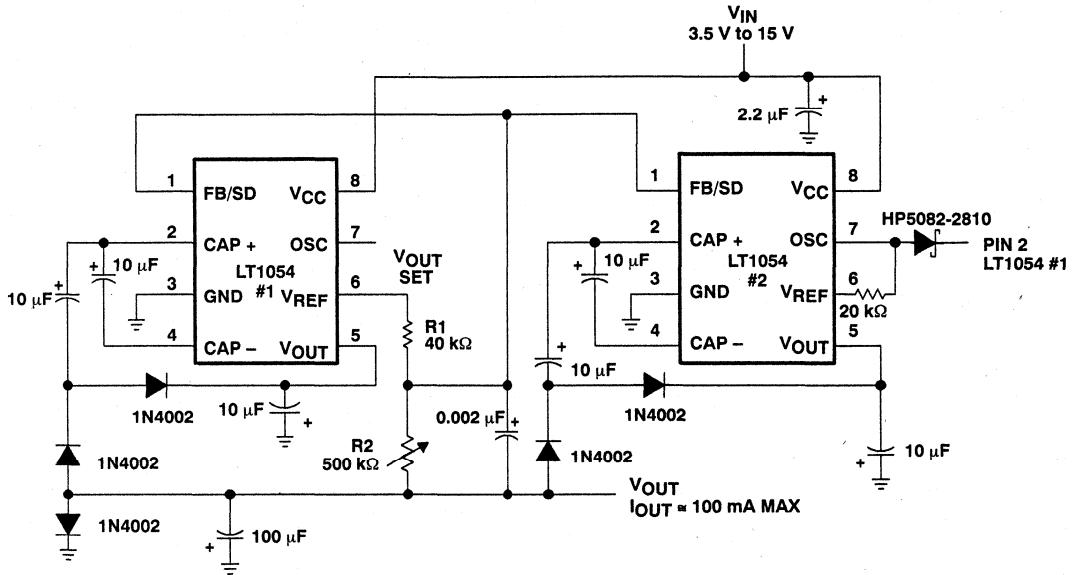


Figure 21. Positive Doubler

LT1054 SWITCHED-CAPACITOR VOLTAGE CONVERTER WITH REGULATOR

APPLICATION INFORMATION



$V_{IN} = 3.5 \text{ to } 15 \text{ V}$
 $V_{OUT \text{ MAX}} \approx -2 V_{IN} + [\text{LT1054 Voltage Loss} + 2 (V_{D\text{Iode}})]$

$$R2 = R1 \left(\frac{|V_{OUT}|}{\frac{V_{REF}}{2} - 40 \text{ mV}} + 1 \right) = R1 \left(\frac{|V_{OUT}|}{1.21 \text{ V}} + 1 \right)$$

Figure 22. 100-mA Regulating Negative Doubler

LT1054
SWITCHED-CAPACITOR VOLTAGE CONVERTER
WITH REGULATOR

APPLICATION INFORMATION

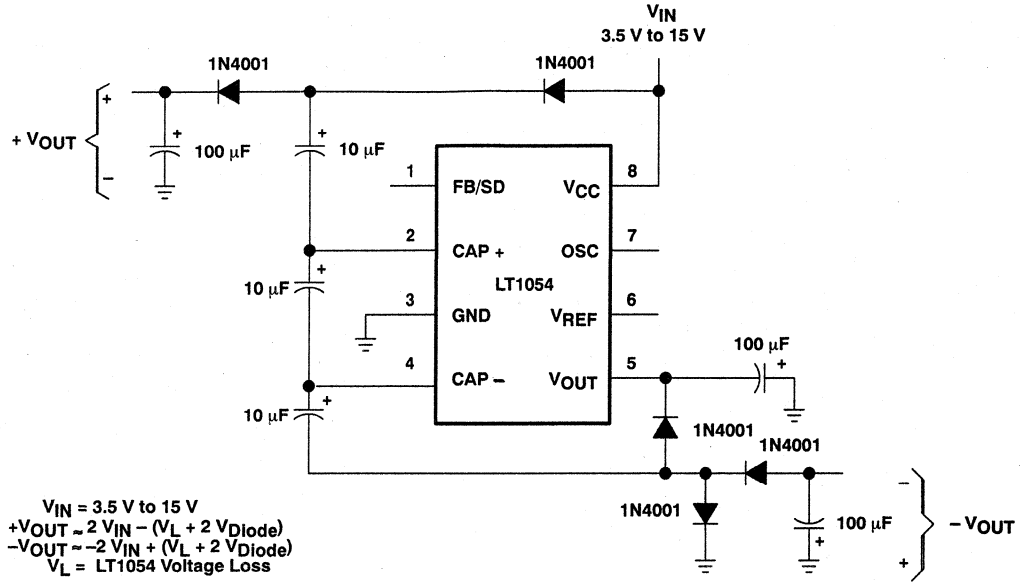


Figure 23. Dual Output Voltage Doubler

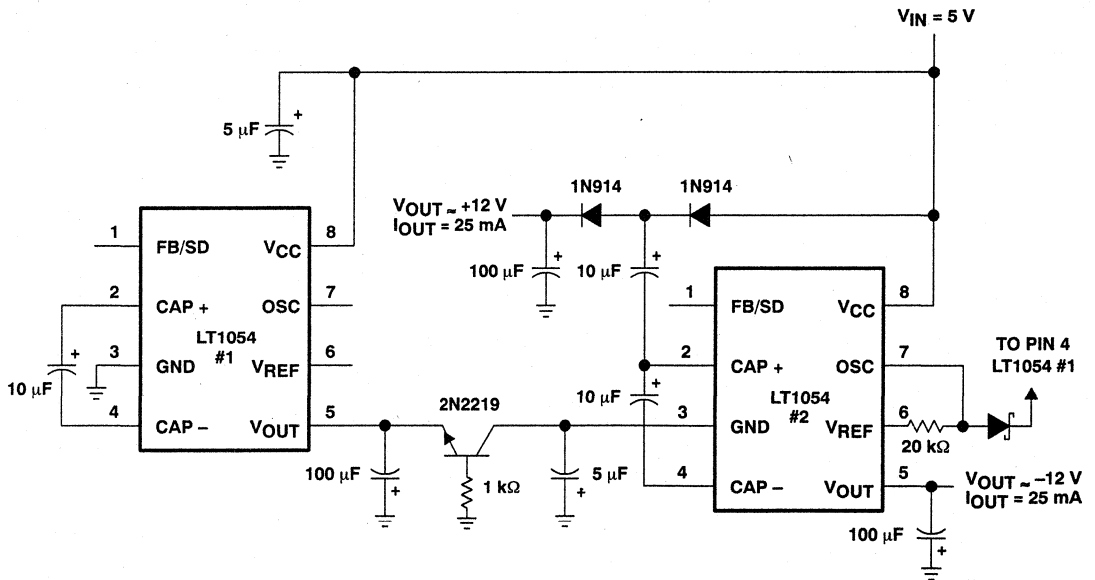


Figure 24. 5-V to ±12-V Converter

LT1054 SWITCHED-CAPACITOR VOLTAGE CONVERTER WITH REGULATOR

APPLICATION INFORMATION

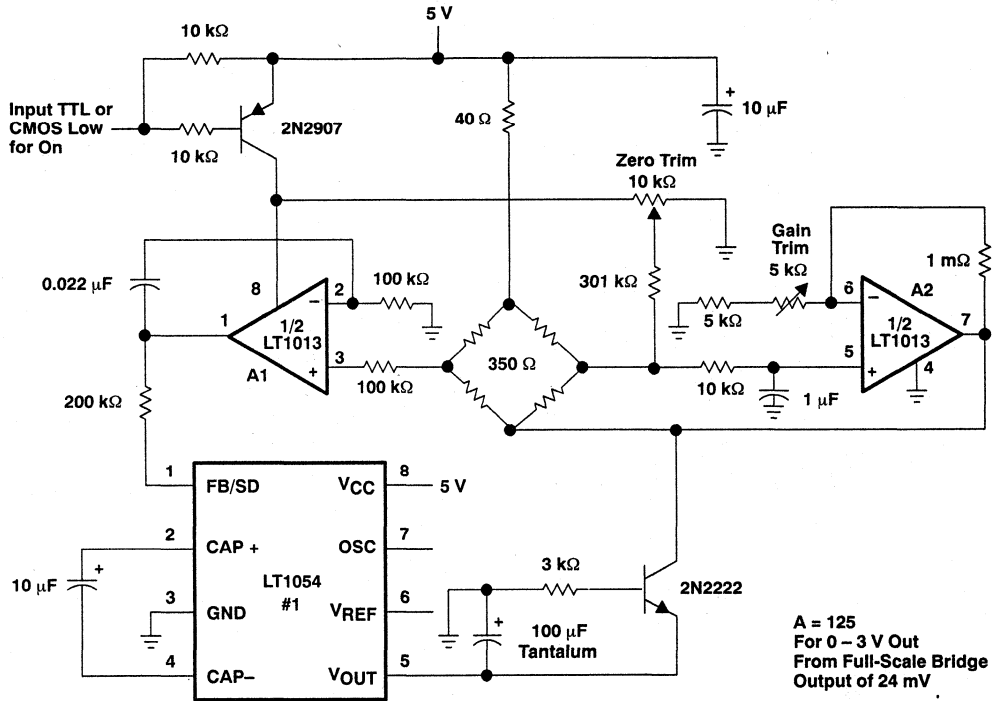


Figure 25. Strain Gage Bridge Signal Conditioner

LT1054 SWITCHED-CAPACITOR VOLTAGE CONVERTER WITH REGULATOR

APPLICATION INFORMATION

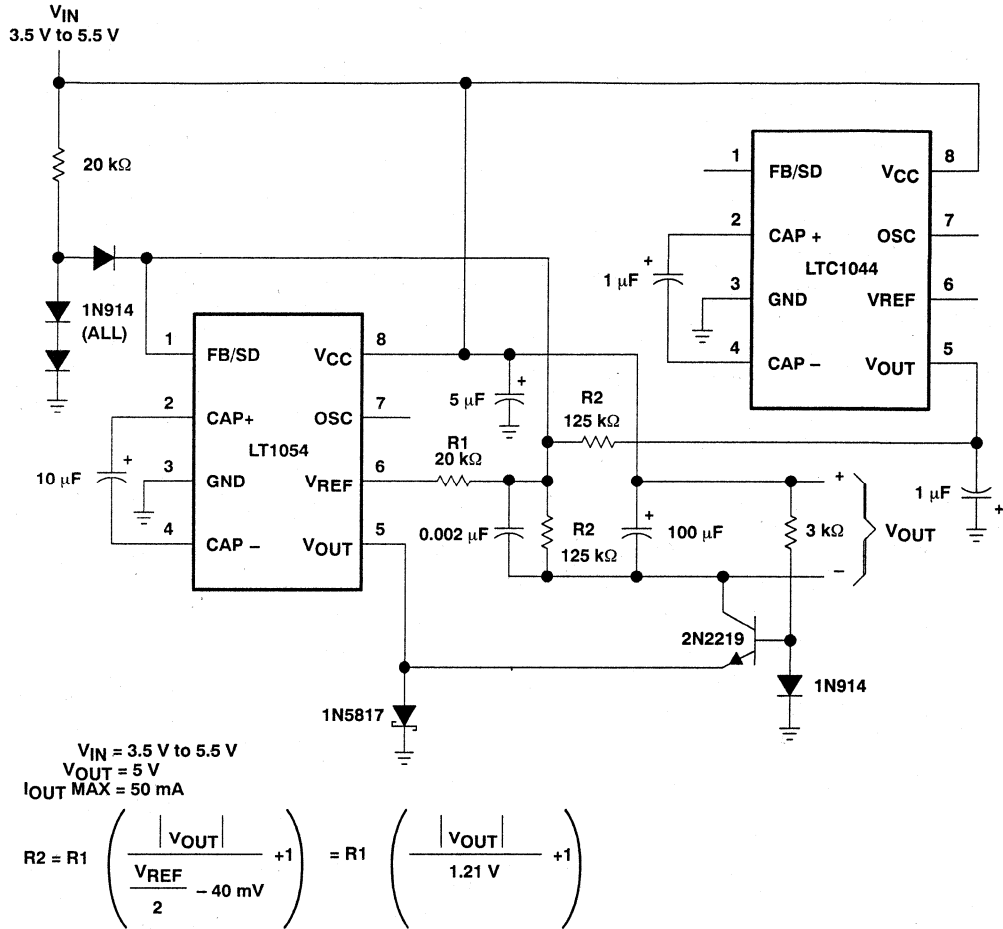


Figure 26. 3.5-V to 5-V Regulator

APPLICATION INFORMATION

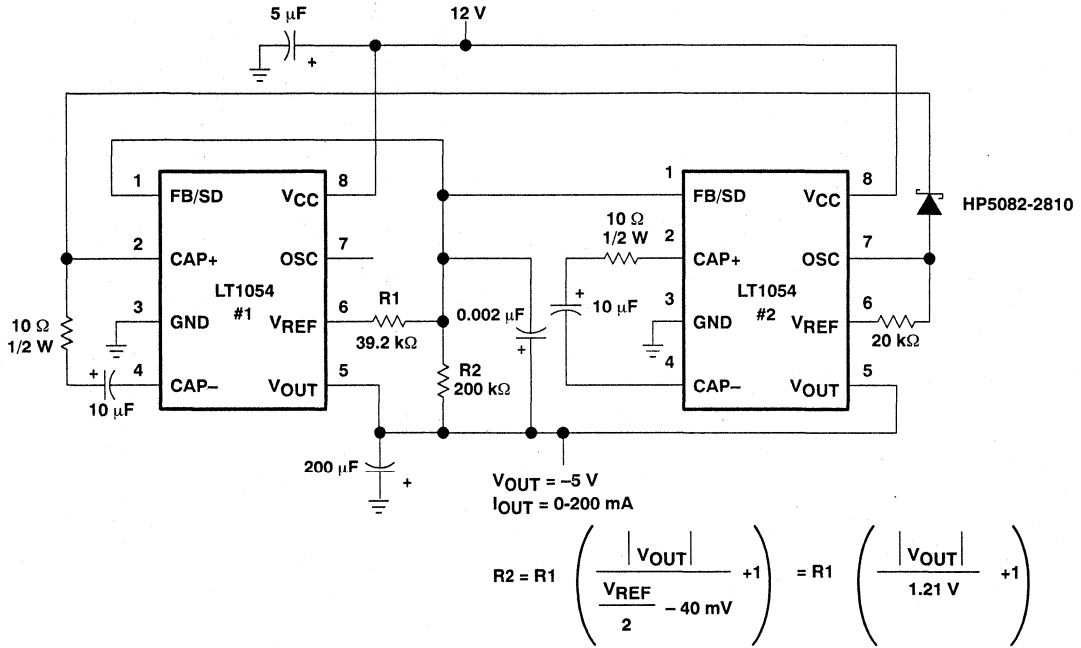


Figure 27. Regulating 200-mA + 12-V to -5-V Converter

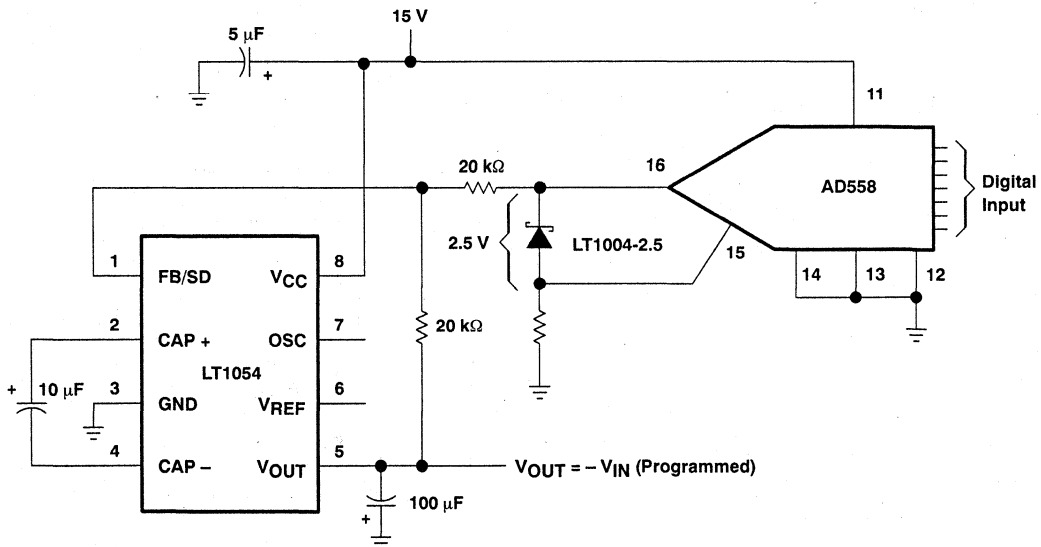


Figure 28. Digitally Programmable Negative Supply

LT1054 SWITCHED-CAPACITOR VOLTAGE CONVERTER WITH REGULATOR

APPLICATION INFORMATION

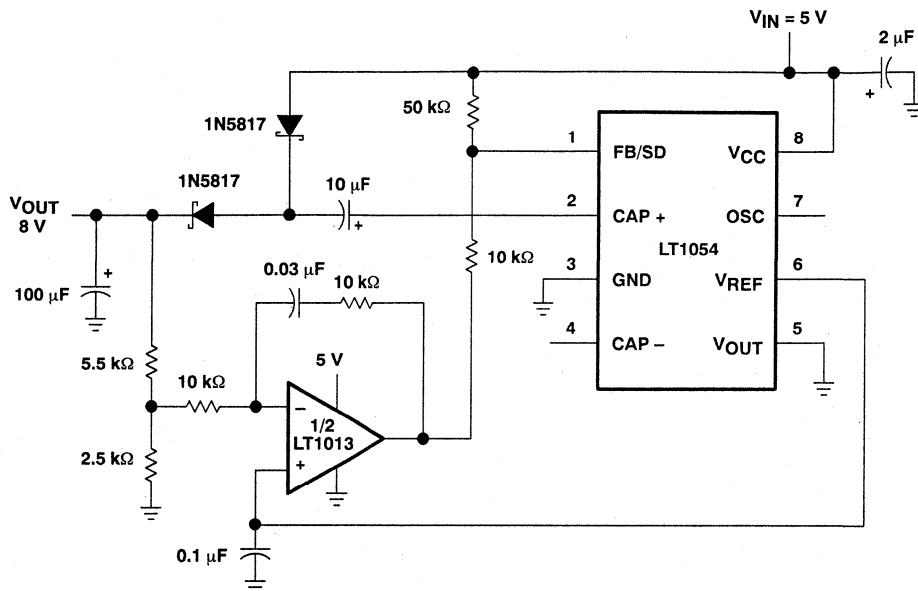


Figure 29. Positive Doubler with Regulation (5-V to 8-V Converter)

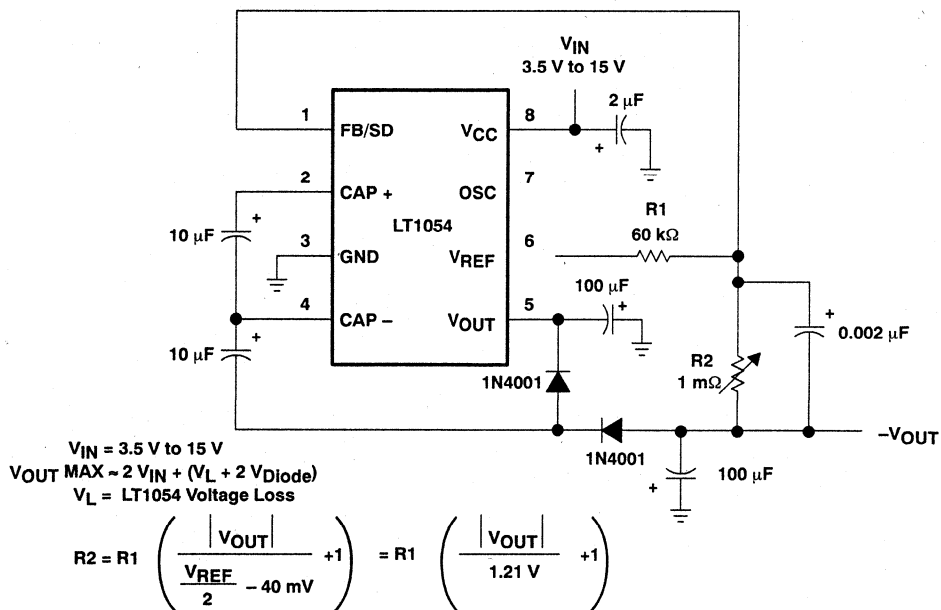


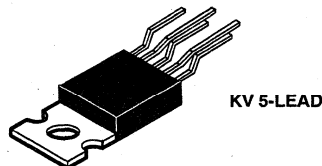
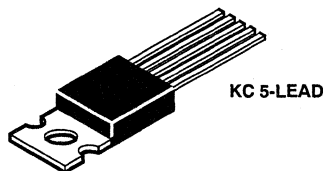
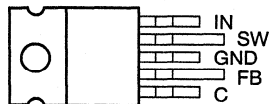
Figure 30. Negative Doubler with Regulator

LT1070, LT1070HV 5-A HIGH-EFFICIENCY SWITCHING REGULATORS

D3222, OCTOBER 1988—REVISED OCTOBER 1991

- **Wide Supply Voltage Range:**
LT1070HV . . . 3 V to 60 V
LT1070 . . . 3 V to 40 V
- **Low Quiescent Current . . . 6 mA Typ**
- **Self-Protected Against Overloads**
- **Operates in Most Switching Configurations**
- **Low Shutdown-Mode Supply Current**
- **Floating Outputs in Flyback-Regulated Mode**
- **Available in Standard KC and KV Packages**
- **Can Be Externally Synchronized**

KC AND KV PACKAGE
(KV Package Used for Illustration)
(TOP VIEW)



AVAILABLE OPTIONS

| T _J | MAX INPUT VOLTAGE | KC PACKAGE | KV PACKAGE |
|----------------|-------------------|-------------|-------------|
| 0°C to 100°C | 60 V | LT1070HVCKC | LT1070HVCKV |
| | 40 V | LT1070CKC | LT1070CKV |
| -40°C to 125°C | 60 V | LT1070HVIKC | LT1070HVIKV |
| | 40 V | LT1070IKC | LT1070IKV |

description

The LT1070 is a monolithic, high-efficiency switching regulator. It can be operated in all standard switching configurations including: step-down (buck), step-up (boost), flyback, forward, inverting, and Cuk[†]. A high-current, high-efficiency switch is included in the package along with all oscillator, control, and protection circuitry. Integration of all functions allows the LT1070 to be built in a standard 5-pin KC or KV package. This makes it extremely easy to use and provides reliable operation similar to that obtained with 3-pin linear regulators.

The LT1070 operates with supply voltages from 3 V to 40 V. The LT1070HV, a high-voltage version of the LT1070, operates with supply voltages from 3 V to 60 V. These devices draw only 6 mA of quiescent current, deliver load power up to 100 W with no external power devices, and by utilizing current-mode switching techniques, they provide excellent ac and dc input and output regulation.

The LT1070 is much easier to use than the low-power control chips that are presently available and has many unique features that are not found on these chips. It uses an adaptive saturation-preventing switch drive to allow very-wide-ranging load currents with no loss in efficiency. An externally activated shutdown mode reduces total supply current to 50 μA typical for standby operation. Totally isolated and regulated outputs can be generated by using the optional flyback-regulation mode built into the LT1070 without the need for optocouplers or extra transformer windings.

[†]A boost-buck-derived regulator circuit patented by Slobodan Ćuk.

PRODUCTION DATA Information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

**TEXAS
INSTRUMENTS**

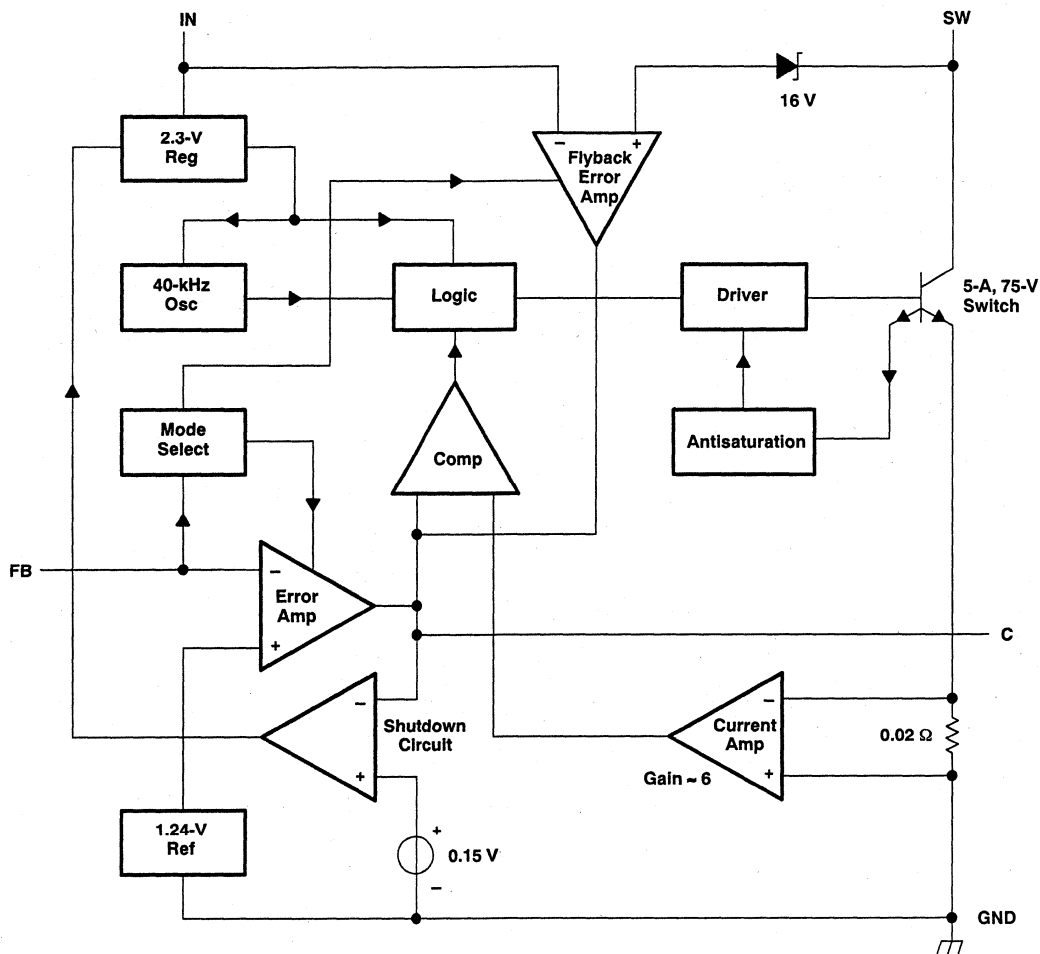
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2-77

LT1070, LT1070HV 5-A HIGH-EFFICIENCY SWITCHING REGULATORS

functional block diagram



Resistor value shown is nominal.

LT1070, LT1070HV 5-A HIGH-EFFICIENCY SWITCHING REGULATORS

absolute maximum ratings over operating virtual junction temperature range (unless otherwise noted)

| | |
|--|---------------------------------------|
| Supply voltage, V_{IN} (see Note 1): LT1070 | 40 V |
| LT1070HV | 60 V |
| Switch output voltage: LT1070 | 65 V |
| LT1070HV | 75 V |
| Feedback input voltage, V_{FB} (transient, 1 ms) | ± 15 V |
| Continuous total dissipation | See Dissipation Rating Tables 1 and 2 |
| Operating virtual-junction temperature range: | |
| LT1070C, LT1070HVC (normal operation) | 0°C to 100°C |
| LT1070C, LT1070HVC (short-circuit operation) | 0°C to 125°C |
| LT1070I, LT1070HVI | -40°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 300°C |

NOTE 1: Minimum switch-on time for the LT1070 in current limit is $\approx 1 \mu\text{s}$. This limits the maximum input voltage during short-circuit conditions, in the step-down and inverting modes only, to ≈ 35 V. Normal (unshorted) conditions are not affected. If the LT1070 is being operated in the step-down or inverting mode at high input voltages and short-circuit conditions are expected, a resistor must be placed in series with the inductor.

**DISSIPATION RATING TABLE 1
FREE-AIR TEMPERATURE**

| PACKAGE | T _A = 25°C POWER RATING | DERATING FACTOR ABOVE T _A = 25°C | T _A = 100°C POWER RATING | T _A = 125°C POWER RATING |
|-----------|---------------------------------------|--|--|--|
| KC and KV | 2000 mW | 16 mW/°C | 800 mW | 400 mW |

**DISSIPATION RATING TABLE 2
CASE TEMPERATURE**

| PACKAGE | T _C = 70°C POWER RATING | OPERATING FACTOR ABOVE T _C = 70°C | T _C = 125°C POWER RATING |
|-----------|---------------------------------------|---|--|
| KC and KV | 20 mW | 250 mW/°C | 6.25 mW |

recommended operating conditions

| | | MIN | MAX | UNIT |
|--|----------------------|-----|-----|------|
| Input voltage, V_{IN} | LT1070C, LT1070I | 3 | 40 | V |
| | LT1070HVC, LT1070HVI | 3 | 60 | |
| Virtual-junction temperature, T _J | LT1070C, LT1070HVC | 0 | 100 | °C |
| | LT1070I, LT1070HVI | -40 | 125 | |

LT1070, LT1070HV

5-A HIGH-EFFICIENCY SWITCHING REGULATORS

electrical characteristics at specified virtual-junction temperature, $V_{IN} = 15\text{ V}$, $V_{FB} = V_{ref}$, with SW output open (unless otherwise noted)

reference section

| PARAMETER | TEST CONDITIONS† | T_J ‡ | MIN | TYP§ | MAX | UNIT |
|------------------------------------|---|------------|-------|-------|-------|------|
| V_{ref} Reference voltage | Measured at FB input, $V_C = 0.6\text{ V}$ | 25°C | 1.224 | 1.244 | 1.264 | V |
| | | Full range | 1.214 | | 1.274 | |
| Reference voltage input regulation | $V_{IN} = 3\text{ V to MAX}$, $V_C = 0.6\text{ V}$ | Full range | | | 0.03 | %/V |

error amplifier section

| PARAMETER | TEST CONDITIONS† | T_J ‡ | MIN | TYP§ | MAX | UNIT |
|--------------------------------------|--|------------|------|------|------|-----------------|
| I_{FB} Feedback input current | $V_{FB} = V_{ref}$ | 25°C | | 380 | 750 | nA |
| | | Full range | | | 1100 | |
| g_m Transconductance | $\Delta I_C = \pm 25\ \mu\text{A}$ | 25°C | 3000 | 4200 | 6000 | μmho |
| | | Full range | 2400 | | 7000 | |
| Source current | $V_C = 1.5\text{ V}$, $V_{FB} = 0.8\text{ V}$ | 25°C | 150 | 200 | 350 | μA |
| | | Full range | 120 | | 400 | |
| Sink current | $V_C = 1.5\text{ V}$, $V_{FB} = 1.5\text{ V}$ | 25°C | 150 | 200 | 350 | μA |
| | | Full range | 120 | | 400 | |
| $V_{O(C)}$ Output voltage | High state, $V_{FB} = 1\text{ V}$ | 25°C | | | 2.3 | V |
| | Low state, $V_{FB} = 1.5\text{ V}$ | | 0.25 | 0.38 | 0.52 | |
| A_V Voltage amplification | $V_C = 0.7\text{ V to }1.4\text{ V}$ | Full range | 500 | 800 | 2000 | V/V |
| $V_{T(C)}$ Control threshold voltage | Duty cycle = 0 | 25°C | 0.8 | 0.9 | 1.08 | V |
| | | Full range | 0.6 | | 1.25 | |

flyback amplifier section

| PARAMETER | TEST CONDITIONS† | T_J ‡ | MIN | TYP§ | MAX | UNIT |
|---|--|------------|--------|------|------|-----------------|
| $V_{T(FB)}$ Normal-flyback-mode threshold voltage | $I_{FB} = 50\ \mu\text{A}$ | 25°C | 0.4 | 0.45 | 0.54 | V |
| V_Z Flyback reference voltage | $V_C = 0.6\text{ V}$, $I_{FB} = 50\ \mu\text{A}$, $I_C = -1\ \mu\text{A to }1\ \mu\text{A}$ | 25°C | 15 | 16.3 | 17.6 | V |
| | | Full range | 14 | | 18 | |
| ΔV_Z Change in flyback reference | $V_C = 0.6\text{ V}$, $I_{FB} = 0.05\text{ to }1\text{ mA}$, $I_C = -1\ \mu\text{A to }1\ \mu\text{A}$ | 25°C | 4.5 | 6.8 | 8.5 | V |
| Flyback reference voltage input regulation | $V_C = 0.6\text{ V}$, $I_{FB} = 50\ \mu\text{A}$, $I_C = -1\ \mu\text{A to }1\ \mu\text{A}$, $V_{IN} = 3\text{ V to MAX}$ | 25°C | | 0.01 | 0.03 | %/V |
| g_m Transconductance | $\Delta I_C = \pm 10\ \mu\text{A}$, $I_{FB} = 50\ \mu\text{A}$ | 25°C | 150 | 300 | 500 | μmho |
| | | Full range | Source | 15 | 32 | |
| Source or sink current | $V_C = 1.5\text{ V}$, $I_{FB} = 50\ \mu\text{A}$, $V_{(SW)} = V_Z + V_{IN} \pm 1\text{ V}$ | | Sink | 25 | 40 | 70 |

†. For conditions shown as MIN or MAX, use the appropriate value specified under the recommended operating conditions.

‡ Full range virtual junction temperature is 0°C to 100°C for LT1070C and LT1070HVC and -40°C to 125°C for LT1070I and LT1070HVH

§ All typical values are $T_A = 25^\circ\text{C}$.



LT1070, LT1070HV 5-A HIGH-EFFICIENCY SWITCHING REGULATORS

electrical characteristics at specified virtual junction temperature, $V_{IN} = 15\text{ V}$, $V_{FB} = V_{ref}$ with SW output open (unless otherwise noted)

output section

| PARAMETER | | TEST CONDITIONS† | T_J ‡ | MIN | TYP§ | MAX | UNIT | |
|-------------------------------|--|--|------------|------------|------|-----|---------------|---|
| $V_{(BR)SW}$ | Switch breakdown voltage | $V_{FB} = 1.5\text{ V}$, $I_{SW} = 5\text{ mA}$ | LT1070 | Full range | | | 65 | V |
| | | | LT1070HV | Full range | | | 75 | |
| R_{on} | Switch on-state resistance | $V_{FB} = 0.8\text{ V}$, $I_{SW} = 5\text{ A}$ | Full range | 0.15 | 0.24 | | Ω | |
| g_m | Control-to-switch transconductance | | 25°C | 8 | | | mho | |
| $I_{SW(lim)}$ | Switch current limit | Duty cycle = 50%, $V_{FB} = 0.8\text{ V}$ Duty cycle = 80%, $V_{FB} = 0.8\text{ V}$ | Full range | 5 | | 13 | A | |
| | | | | | | | | |
| $\Delta I_{IN}/\Delta I_{SW}$ | Input current increase during switch turn-on | $V_{FB} = 0.8\text{ V}$ | 25°C | 25 | 35 | | mA/A | |
| f | Frequency | | 25°C | 35 | 40 | 45 | kHz | |
| | | | Full range | 33 | | 47 | | |
| | Maximum duty cycle | $V_{FB} = 1\text{ V}$ | 25°C | 90% | 92% | 97% | | |
| t_d | Flyback sense delay time | | 25°C | 1.5 | | | μs | |

shutdown section

| PARAMETER | | TEST CONDITIONS† | T_J ‡ | MIN | TYP§ | MAX | UNIT |
|---------------|---------------------------|--|------------|-----|------|-----|---------------|
| $I_{IN(off)}$ | Input current | $V_{IN} = 3\text{ V to MAX}$, $V_C = 50\text{ mV}$ | 25°C | 100 | | 250 | μA |
| $V_{T(off)}$ | Control threshold voltage | $V_{IN} = 3\text{ V to MAX}$ | 25°C | 100 | 150 | 250 | mV |
| | | | Full range | 50 | | 300 | |

total device

| PARAMETER | | TEST CONDITIONS† | T_J ‡ | MIN | TYP§ | MAX | UNIT |
|---------------|-----------------------|--|------------|-----|------|-----|------|
| $V_{IN(min)}$ | Minimum input voltage | | Full range | 2.6 | | 3 | V |
| I_{IN} | Input current | $V_{IN} = 3\text{ V to MAX}$, $V_C = 0.6\text{ V}$ | 25°C | 6 | 9 | | mA |

† For conditions shown as MIN or MAX, use the appropriate value specified under the recommended operating conditions.

‡ Full range virtual junction temperature is 0°C to 100°C for LT1070C and LT1070HVC and -40°C to 125°C for LT1070I and LT1070HVI.

§ All typical values are $T_A = 25^\circ\text{C}$.

LT1070, LT1070HV

5-A HIGH-EFFICIENCY SWITCHING REGULATORS

theory of operation

The LT1070 is a current-mode switcher. This means that the switch duty cycle is directly controlled by switch current rather than by output voltage. Referring to the functional block diagram, the switch is turned on at the start of each oscillator cycle. It is turned off when the switch current reaches a predetermined level. Control of output voltage is obtained by using the output of a voltage-sensing error amplifier to set the current trip level. This technique has several advantages. First, it has immediate response to input-voltage variations, which is unlike ordinary switchers that have poor input transient response. Second, it reduces the 90° phase shift at midfrequencies in the energy-storage inductor. This greatly simplifies closed-loop frequency compensation under widely varying input-voltage or output-load conditions. Finally, it allows simple pulse-by-pulse current limiting to provide maximum switch protection under output overload or short conditions. A low-dropout internal regulator provides a 2.3-V supply for all internal circuitry on the LT1070. This low-dropout design allows input voltage to vary from 3 V to 60 V with virtually no change in device performance. A 40-kHz oscillator is the basic clock for all internal timing. It turns on the output switch via the logic and driver circuitry. Special adaptive antisaturation circuitry detects the onset of saturation in the power switch and adjusts driver current instantaneously to limit switch saturation. This minimizes driver dissipation and provides very rapid turn off of the switch.

A 1.2-V band-gap reference biases the positive input of the error amplifier. The negative input is brought out for output-voltage sensing. This feedback pin has a second function when pulled low with an external resistor. It programs the LT1070 to disconnect the main error-amplifier output and connects the output pulse with respect to the supply voltage. This flyback pulse is directly proportional to output voltage in the traditional transformer-coupled flyback-topology regulator. By regulating the amplitude of the flyback pulse, the output voltage can be regulated with no direct connection between input and output. The output is fully floating up to the breakdown voltage of the transformer windings. Multiple floating outputs are easily obtained with additional windings. A special delay network inside the LT1070 ignores the leakage inductance spike at the leading edge of the flyback pulse to improve output regulation.

The error signal developed at the comparator input is brought out externally. This pin (C) has four different functions. It is used for frequency compensation, current limit adjustment, soft starting, and total regulator shutdown. During normal regulator operation, this pin sits at a voltage between 0.9 V (low output current) and 2 V (high output current). The error amplifiers are current-output (g_m) types, so this voltage can be externally clamped for adjusting current limit. Likewise, a capacitor-coupled external clamp will provide soft start. Switch duty cycle goes to zero if the C pin is pulled to ground through a diode. This places the LT1070 in an idle mode. Pulling the C pin below 0.15 V causes total regulator shutdown, with only 50- μ A supply current for shutdown-circuitry biasing.

TYPICAL CHARACTERISTICS

table of graphs

| | | | | FIGURE |
|----------------------|---|----|------------------------|--------|
| P _{OM} | Maximum output power | vs | Input voltage | 1 |
| V _{ref} | Reference voltage | vs | Junction temperature | 2 |
| ΔV _{ref} | Reference voltage change | vs | Input voltage | 3 |
| I _{FB} | Feedback input current | vs | Junction temperature | 4 |
| g _m | Error amplifier transconductance | vs | Junction temperature | 5 |
| I _C | Control current | vs | Control voltage | 6 |
| V _{T(FB)} | Normal-/flyback-mode threshold voltage | vs | Junction temperature | 7 |
| I _{FB} | Feedback input current | vs | Junction temperature | 7 |
| V _Z | Flyback-mode reference voltage | vs | Junction temperature | 8 |
| t _d | Flyback sense delay time | vs | Junction temperature | 9 |
| I _{O(SW)} | Switch output current (with switch off) | vs | Switch voltage | 10 |
| | Driver base current | vs | Switch output current | 11 |
| V _{sat(SW)} | Switch saturation voltage | vs | Switch output current | 12 |
| I _{O(SW)} | Switch output current limit | vs | Duty cycle | 13 |
| | Maximum duty cycle | vs | Junction temperature | 14 |
| I _{IN(off)} | Shutdown-mode input current | vs | Control voltage | 15 |
| I _{IN(off)} | Shutdown-mode input current | vs | Input voltage | 16 |
| V _{T(off)} | Shutdown-mode control threshold voltage | vs | Junction temperature | 17 |
| V _{T(off)} | Shutdown-mode control threshold current | vs | Junction temperature | 17 |
| V _{FB} | Feedback input voltage | vs | Feedback input current | 18 |
| V _{IN(min)} | Minimum input voltage | vs | Junction temperature | 19 |
| I _{IN} | Input current | vs | Junction temperature | 20 |
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TYPICAL CHARACTERISTICS

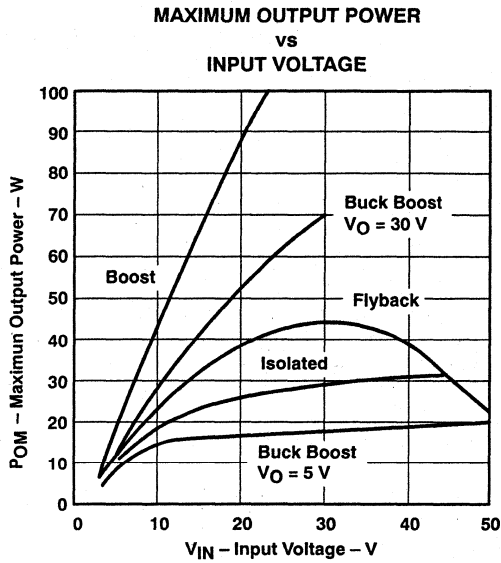


Figure 1

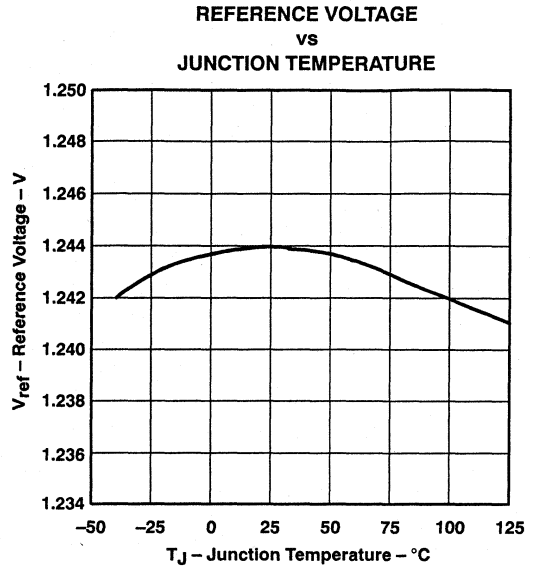


Figure 2

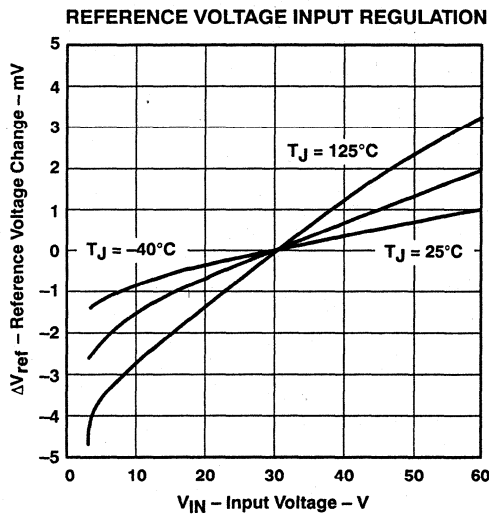


Figure 3

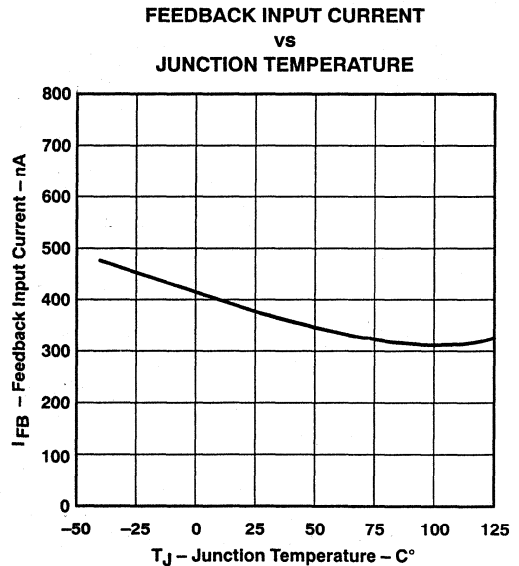


Figure 4

TYPICAL CHARACTERISTICS

ERROR AMPLIFIER TRANSCONDUCTANCE
vs
JUNCTION TEMPERATURE

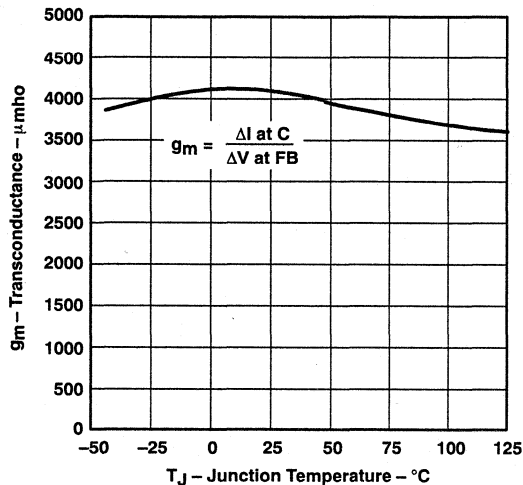


Figure 5

CONTROL CURRENT
vs
CONTROL VOLTAGE

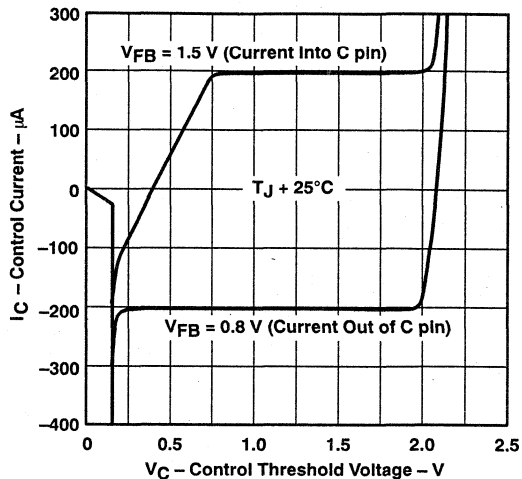


Figure 6

NORMAL/FLYBACK-MODE THRESHOLD VOLTAGE
AND FEEDBACK INPUT CURRENT
vs
JUNCTION TEMPERATURE

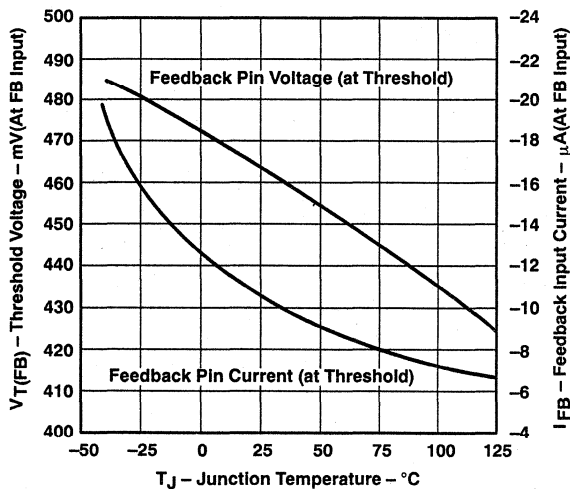


Figure 7

FLYBACK-MODE REFERENCE VOLTAGE
vs
JUNCTION TEMPERATURE

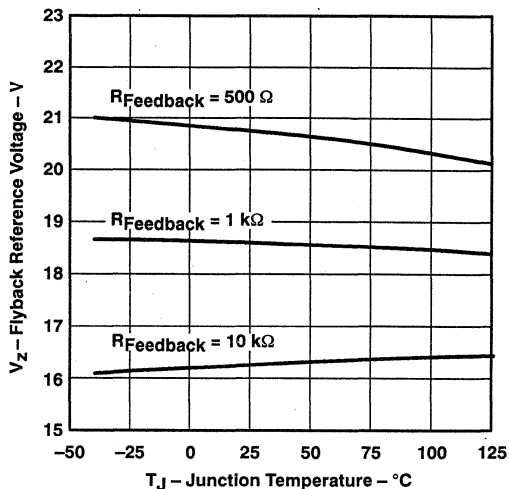


Figure 8

TYPICAL CHARACTERISTICS

FLYBACK SENSE DELAY TIME
vs
JUNCTION TEMPERATURE

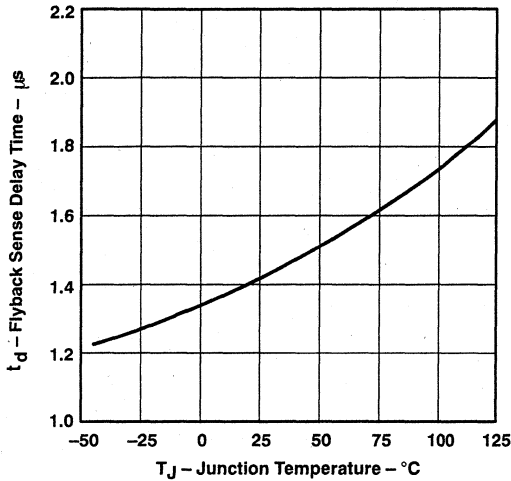


Figure 9

SWITCH OUTPUT CURRENT
vs
SWITCH VOLTAGE and INPUT VOLTAGE
(WITH SWITCH OFF)

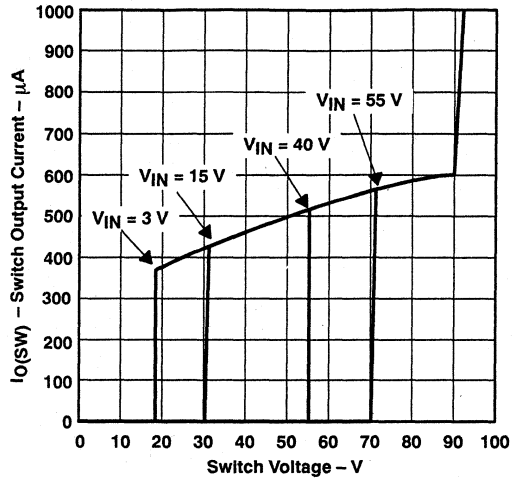


Figure 10

DRIVER BASE CURRENT†
vs
SWITCH OUTPUT CURRENT

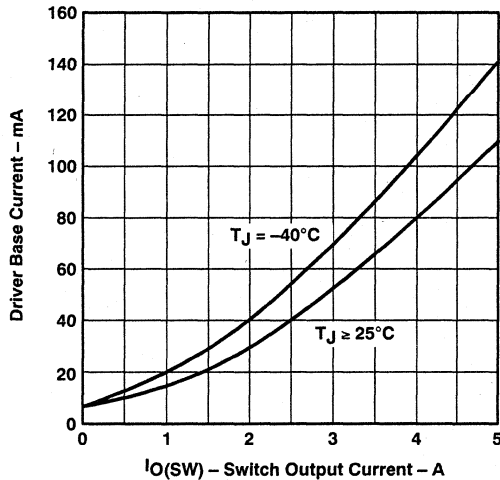


Figure 11

SWITCH SATURATION VOLTAGE
vs
SWITCH CURRENT

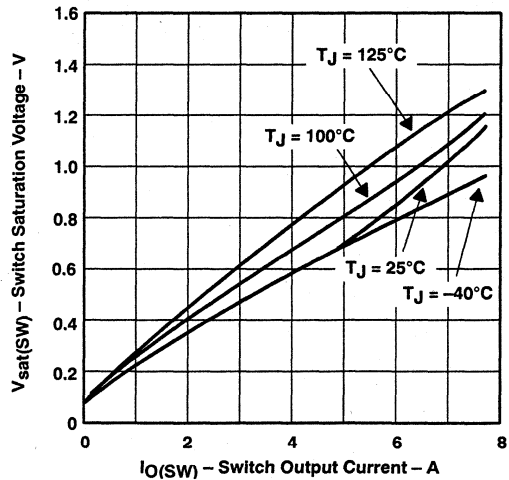


Figure 12

† Average input current is found by multiplying driver base current by duty cycle plus quiescent current.

TYPICAL CHARACTERISTICS

SWITCH OUTPUT CURRENT LIMIT
vs
DUTY CYCLE

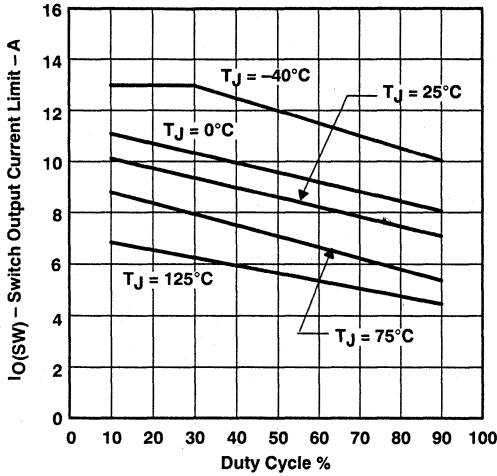


Figure 13

MAXIMUM DUTY CYCLE
vs
JUNCTION TEMPERATURE

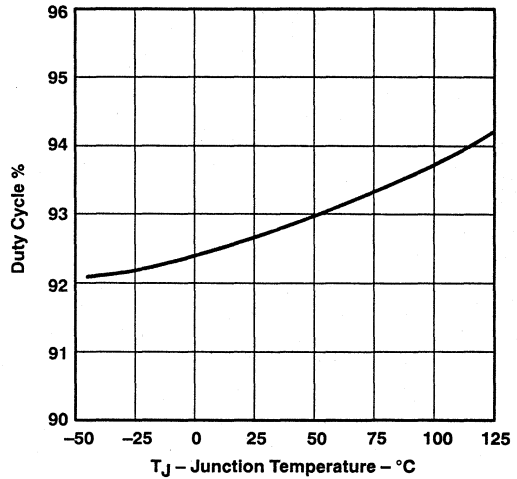


Figure 14

SHUTDOWN-MODE INPUT CURRENT
vs
CONTROL VOLTAGE

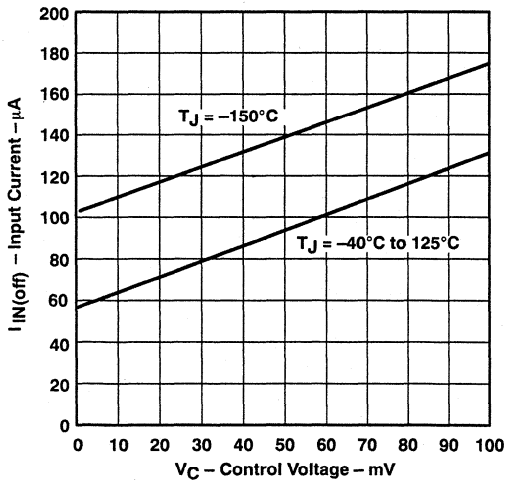


Figure 15

SHUTDOWN-MODE INPUT CURRENT
vs
INPUT CURRENT

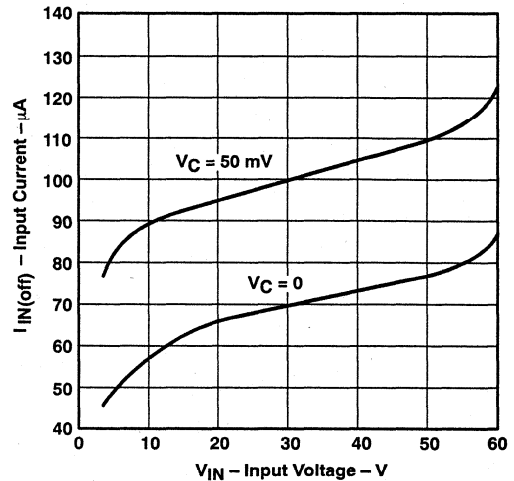


Figure 16

TYPICAL CHARACTERISTICS

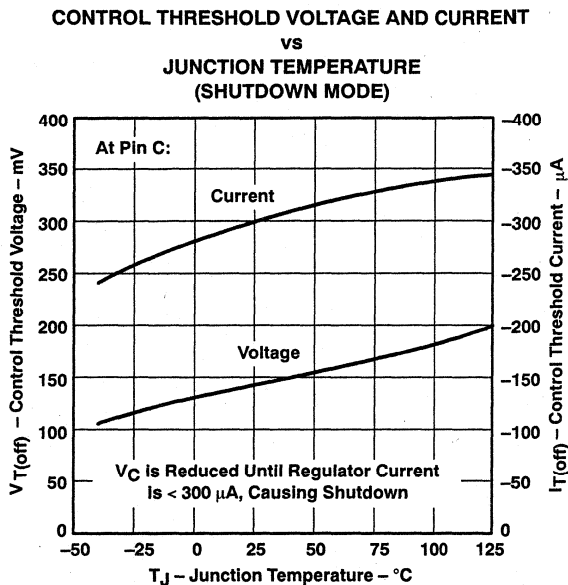


Figure 17

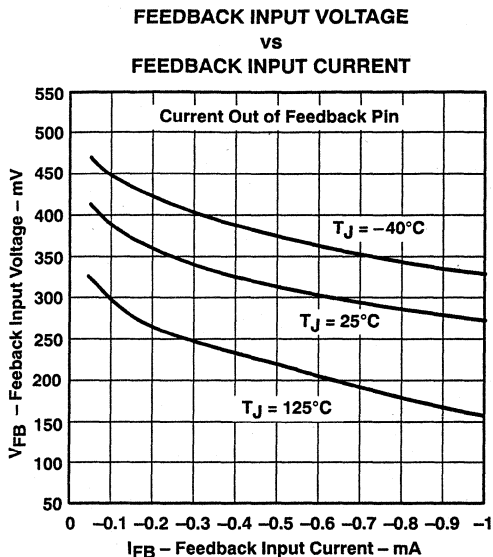


Figure 18

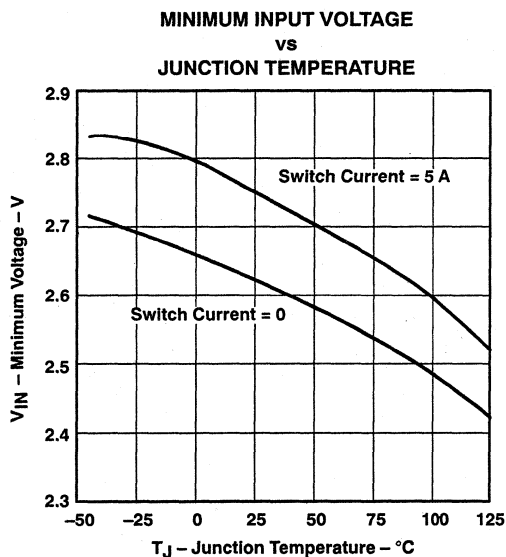


Figure 19

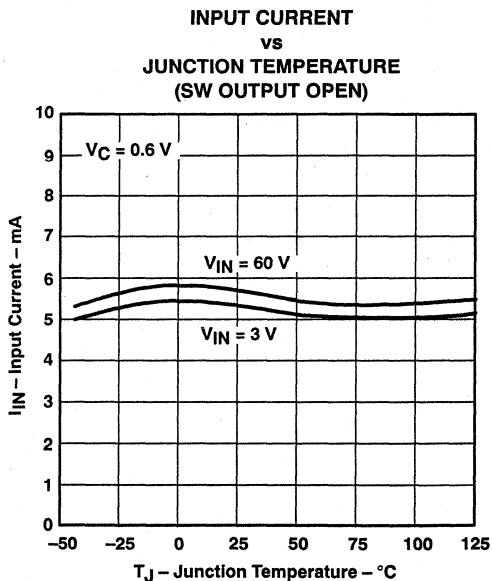
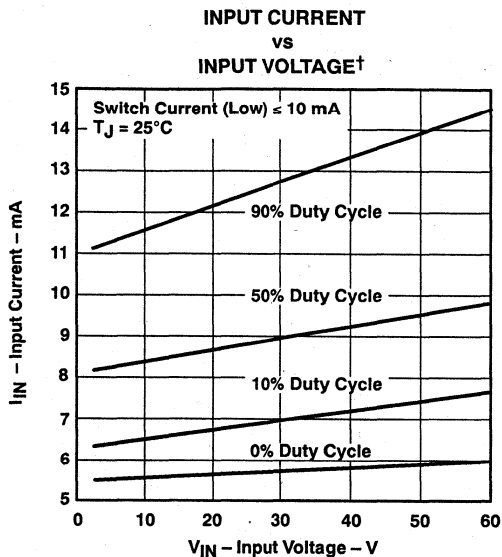


Figure 20

TYPICAL CHARACTERISTICS

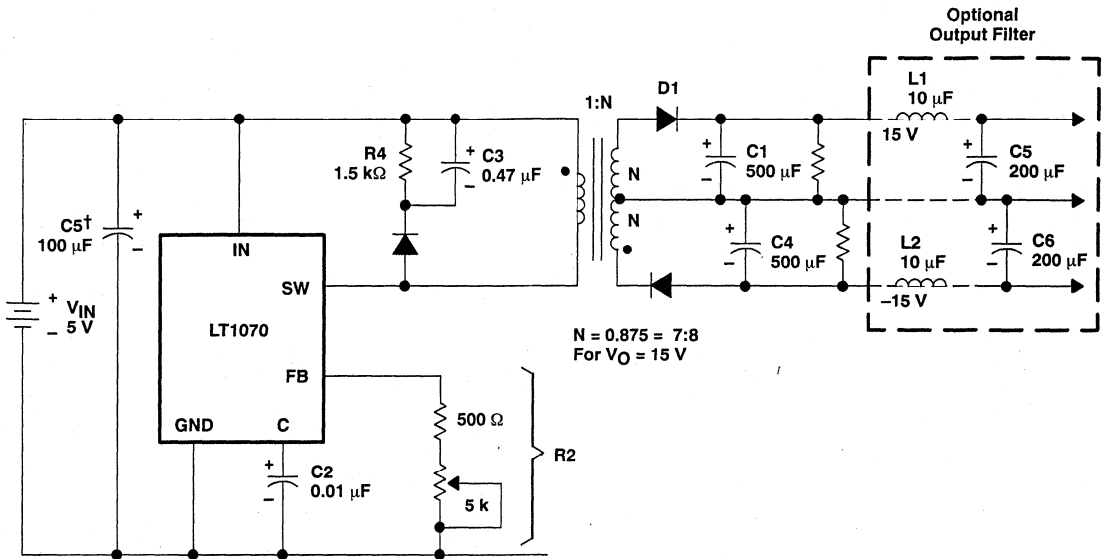


† Under very low output current conditions, duty cycle for most circuits will approach 10% or less.

Figure 21

LT1070, LT1070HV 5-A HIGH-EFFICIENCY SWITCHING REGULATORS

APPLICATION INFORMATION



†Capacitors are required if input lead length exceeds 2 inches.

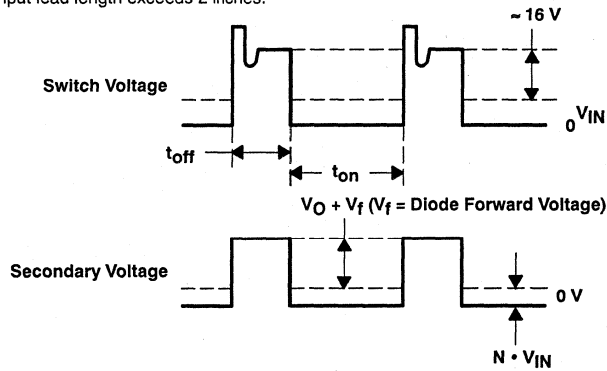
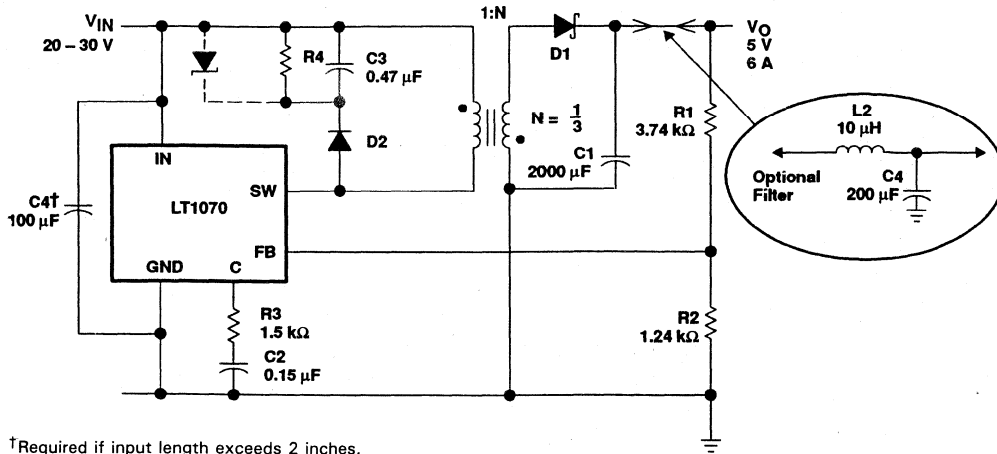


Figure 22. Totally Isolated Converter

APPLICATION INFORMATION



†Required if input length exceeds 2 inches.

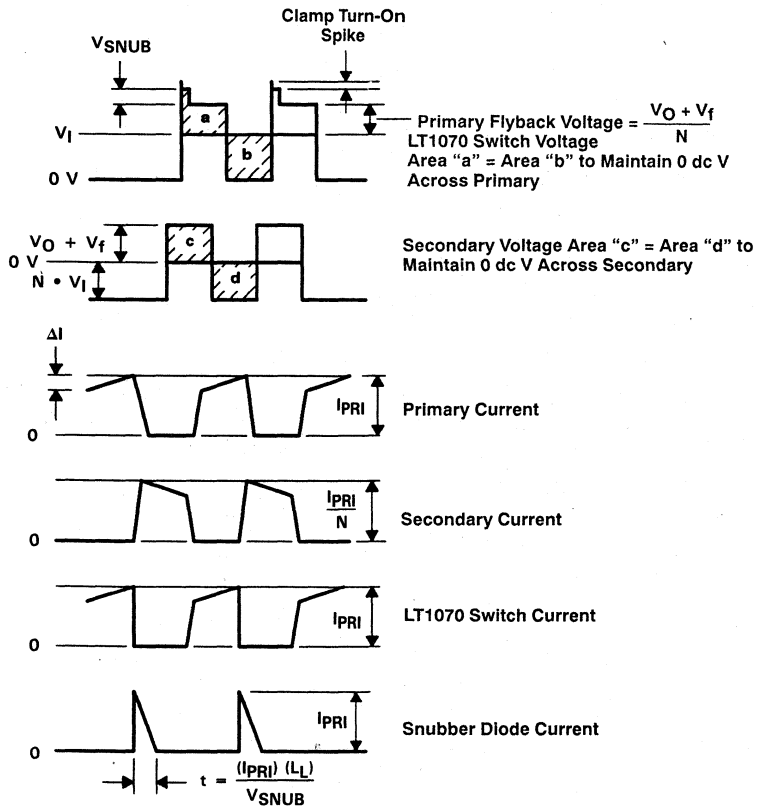


Figure 23. Flyback Converter

LT1070, LT1070HV
5-A HIGH-EFFICIENCY SWITCHING REGULATORS

APPLICATION INFORMATION

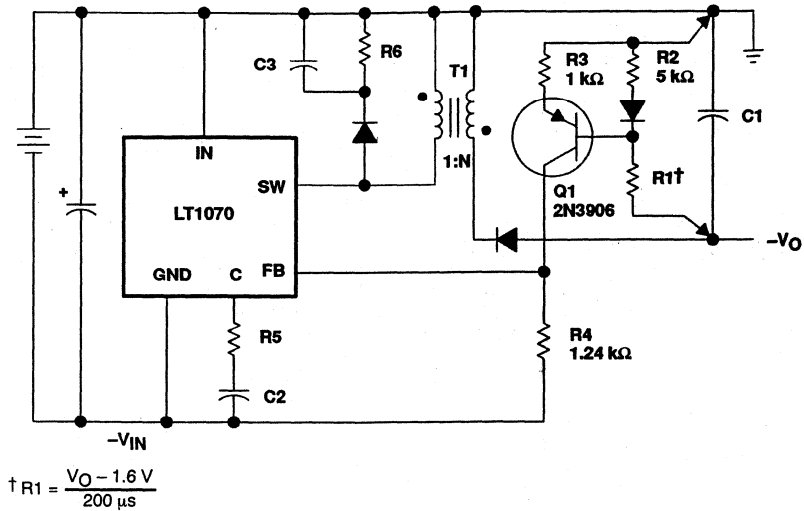


Figure 24. Negative Input - Negative Output Flyback Converter

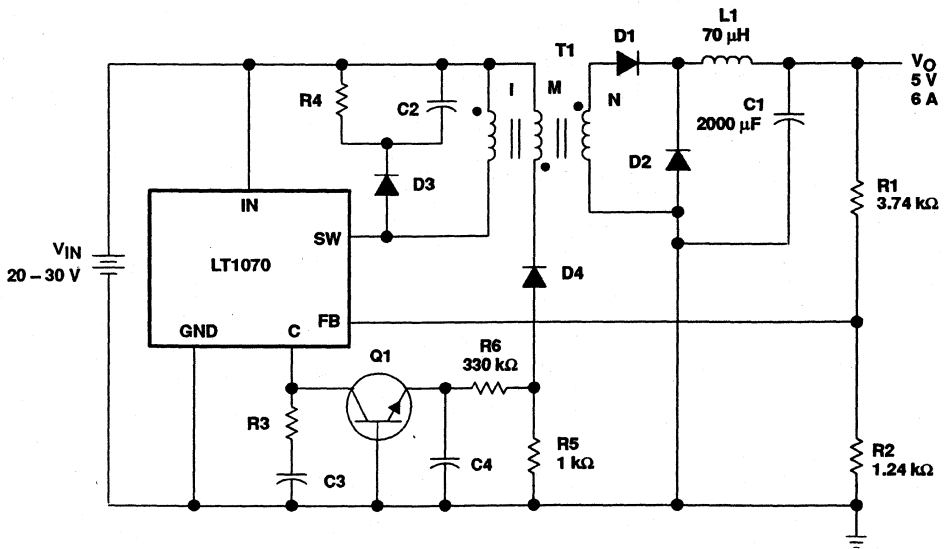


Figure 25. Forward Converter

APPLICATION INFORMATION

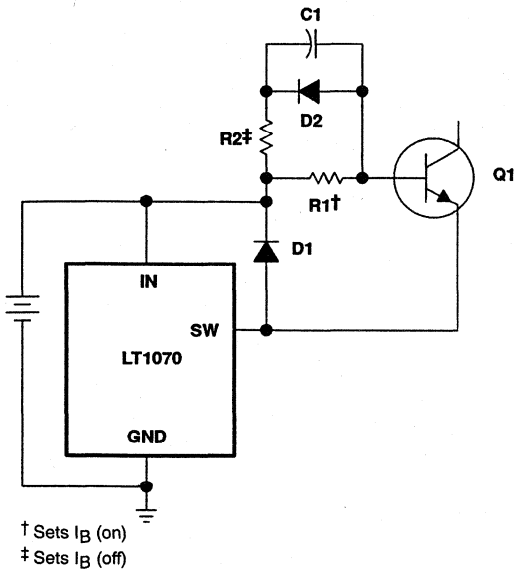


Figure 26. Driving High-Voltage NPN Transistor

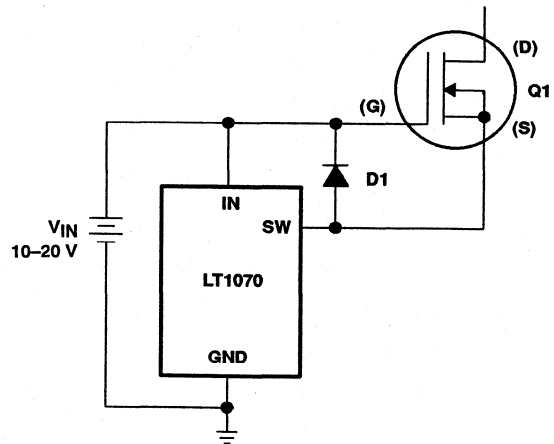


Figure 27. Driving High-Voltage FET

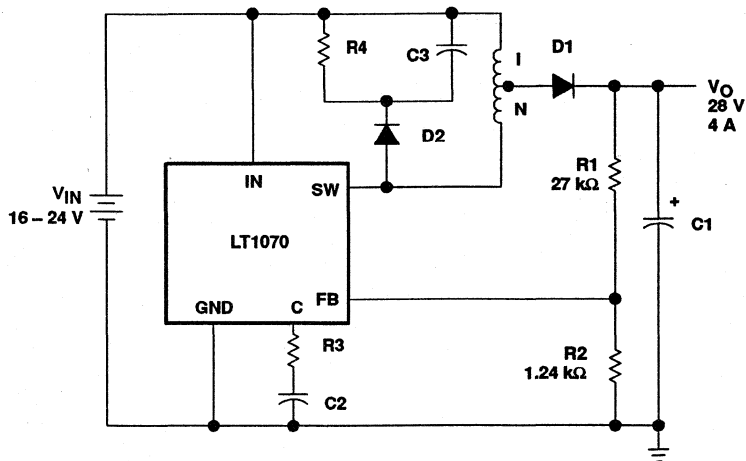


Figure 28. Current-Boosted Boost Converter

LT1070, LT1070HV
5-A HIGH-EFFICIENCY SWITCHING REGULATORS

APPLICATION INFORMATION

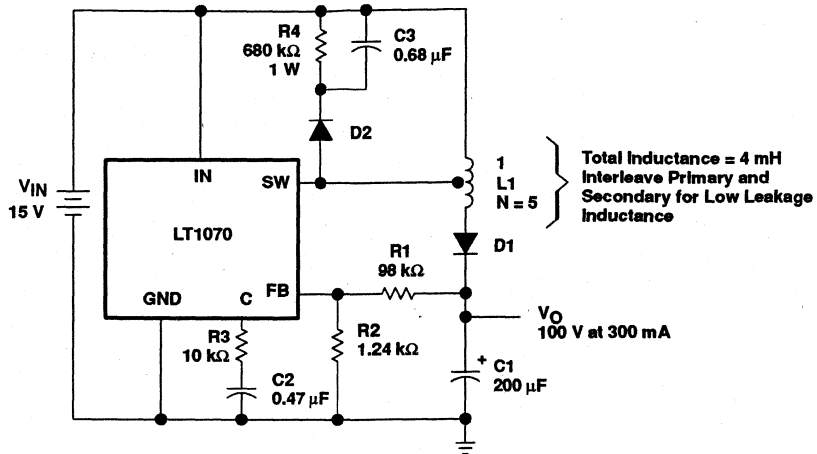
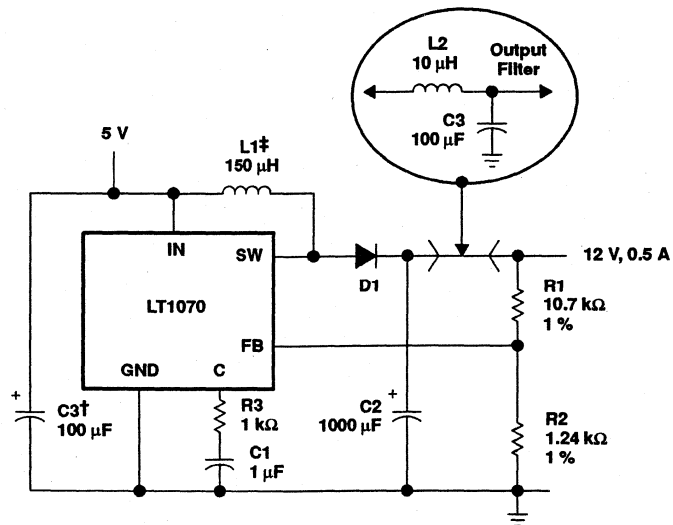


Figure 29. Voltage-Boosted Boost Converter

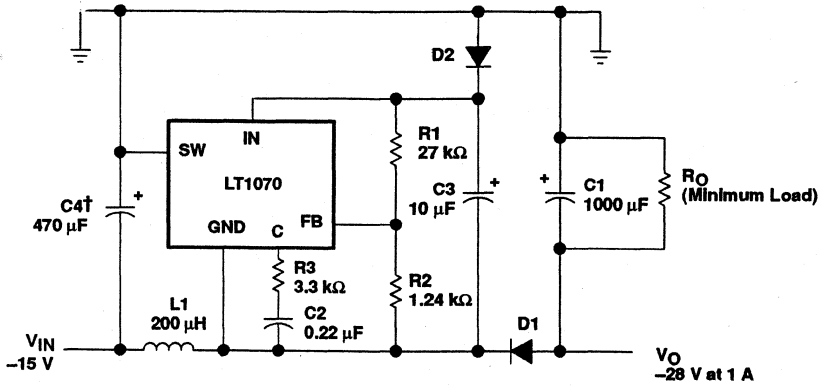


† Capacitors are required if input lead length exceeds 2 inches.

‡ Pulse Engineering 92113.

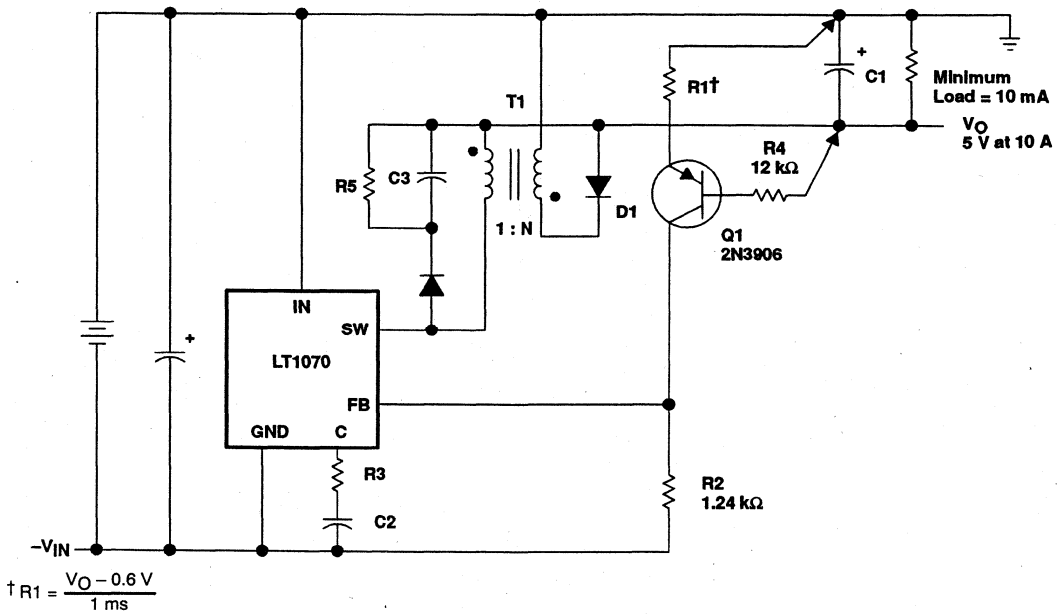
Figure 30. Boost Converter (5 V to 12 V)

APPLICATION INFORMATION



† Required if input lead length exceeds 2 inches.

Figure 31. Negative Boost Regulator

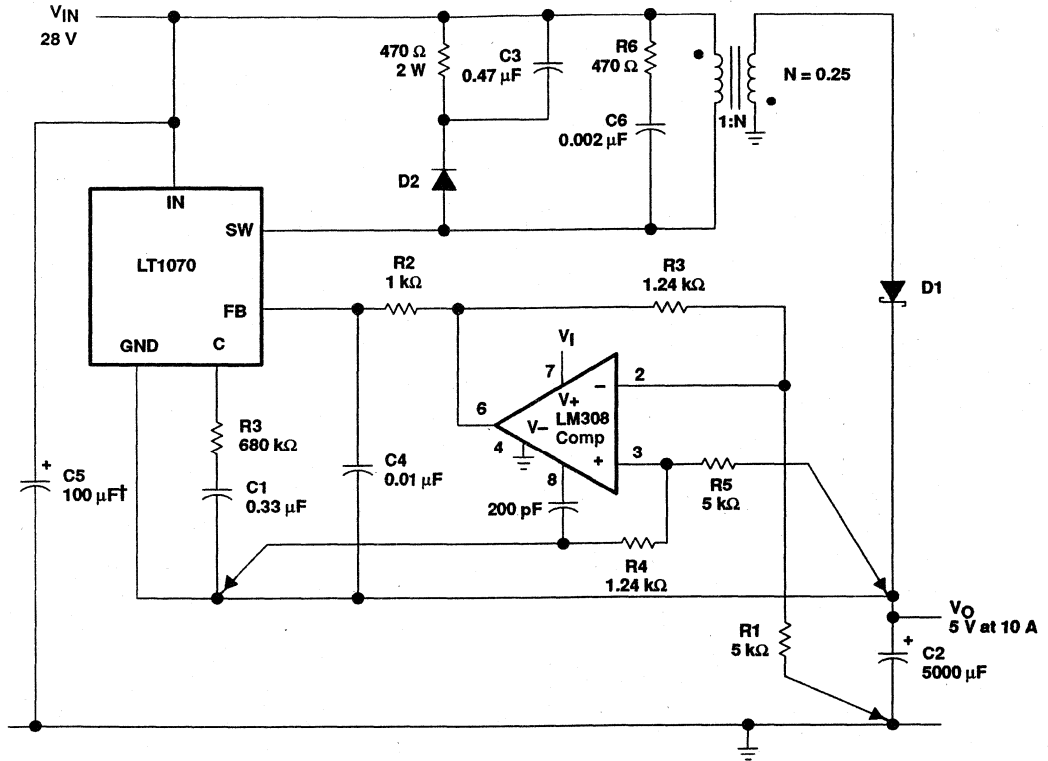


$$\dagger R1 = \frac{V_O - 0.6V}{1ms}$$

Figure 32. Negative Current-Boosted Buck Converter

LT1070, LT1070HV
5-A HIGH-EFFICIENCY SWITCHING REGULATORS

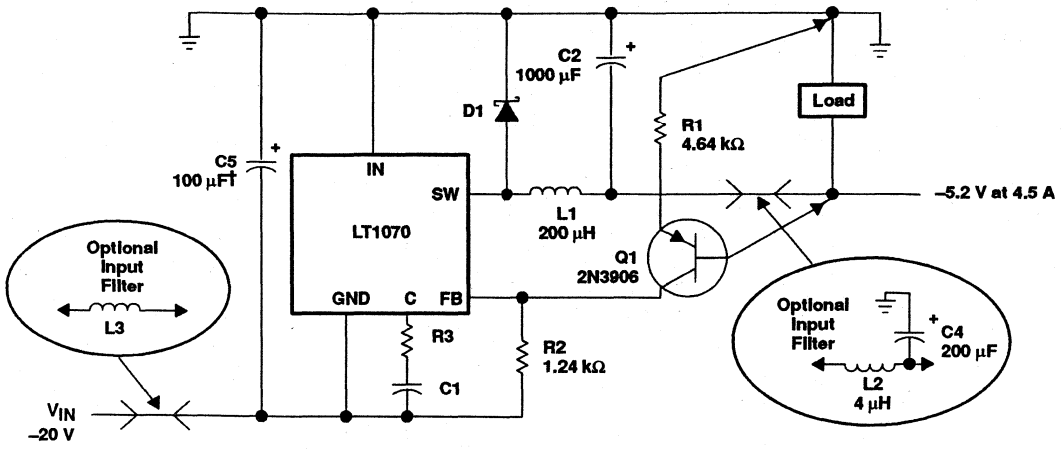
APPLICATION INFORMATION



† Required if input lead length exceeds 2 inches.

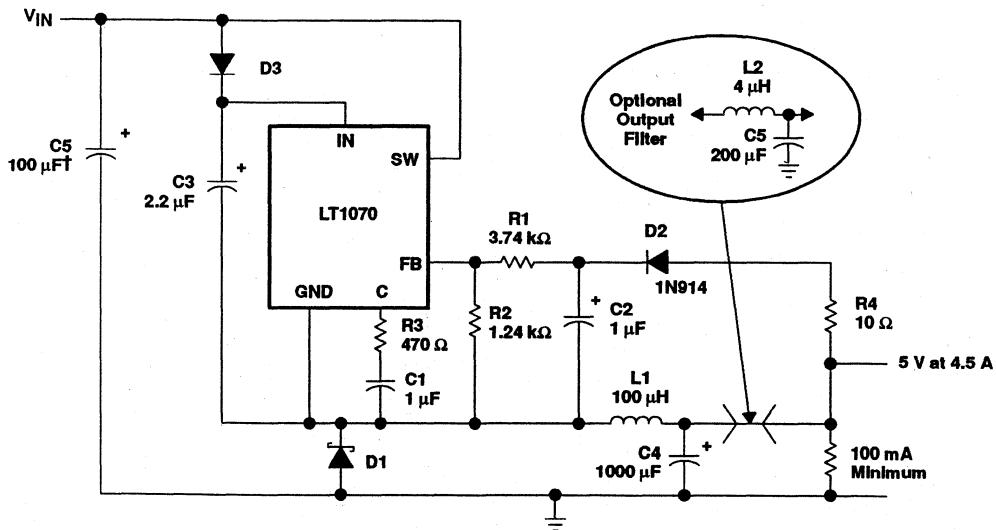
Figure 33. Positive Current-Boosted Buck Converter

APPLICATION INFORMATION



† Required if input lead length exceeds 2 inches.

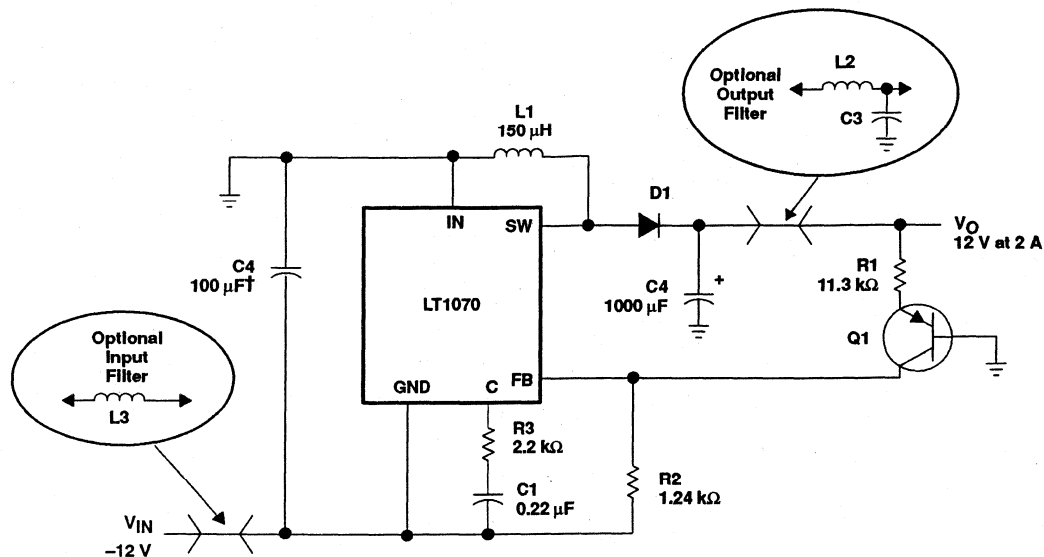
Figure 34. Negative Buck Converter



† Required if input lead length exceeds 2 inches.

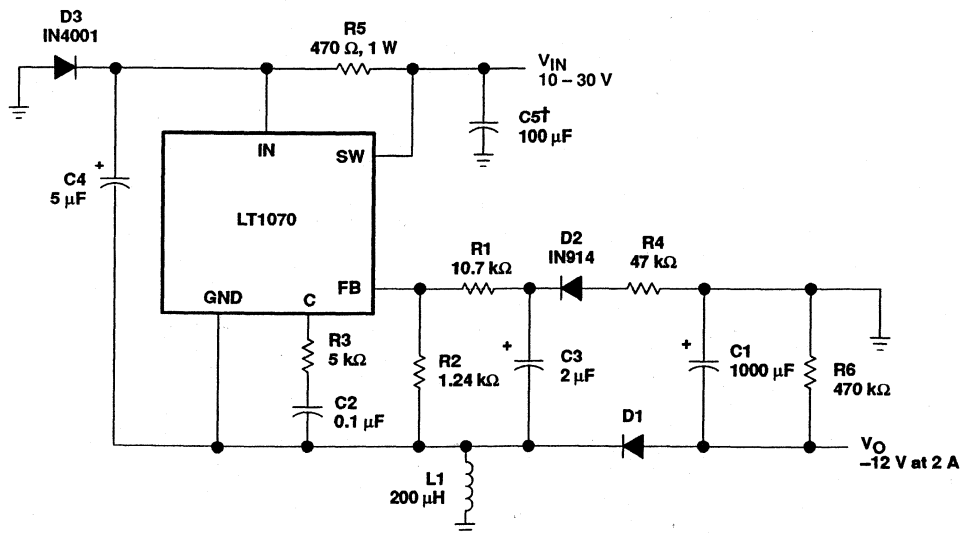
Figure 35. Positive Buck Converter

APPLICATION INFORMATION



† Required if input lead length exceeds 2 inches.

Figure 36. Negative-to-Positive Buck-Boost Converter



† Required if input lead length exceeds 2 inches.

Figure 37. Positive-to-Negative Buck-Boost Converter

APPLICATION INFORMATION

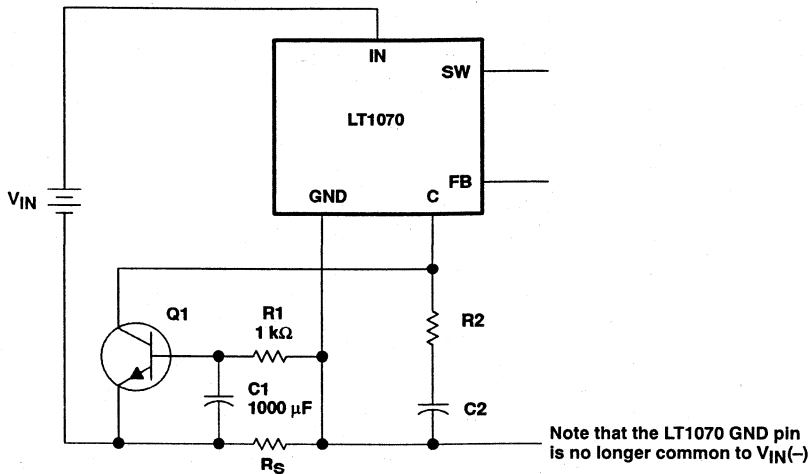


Figure 38. External Current Limit

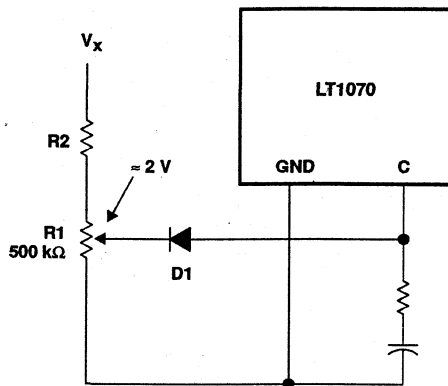


Figure 39. External Current Limit (Adjustable)

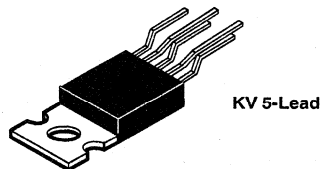
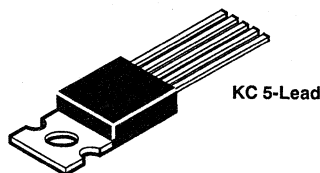
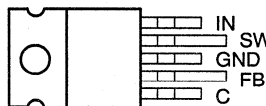
LT1071, LT1071HV

2.5-A HIGH-EFFICIENCY SWITCHING REGULATORS

D3344, JULY 1989—REVISED AUGUST 1991

- **Wide Supply-Voltage Range:**
 LT1071HV . . . 3 V to 60 V
 LT1071 . . . 3 V to 40 V
- **Low Quiescent Current . . . 6 mA Typ**
- **Internal 2.5-A Switch**
- **Few External Parts Required**
- **Self-Protected Against Overloads**
- **Operates in Most Switching Configurations**
- **Low Shutdown-Mode Supply Current**
- **Floating Outputs in Flyback-Regulated Mode**
- **Available in Standard KC and KV Packages**
- **Can Be Externally Synchronized**

KC AND KV PACKAGE
 (KV Package Used for Illustration)
 (TOP VIEW)



AVAILABLE OPTIONS

| T _J | MAX INPUT VOLTAGE | KC PACKAGE | KV PACKAGE |
|----------------|-------------------|-------------|-------------|
| 0°C to 100°C | 60 V | LT1071HVCKC | LT1071HVCKV |
| | 40 V | LT1071CKC | LT1071CKV |
| -40°C to 125°C | 60 V | LT1071HVIKC | LT1071HVIKV |
| | 40 V | LT1071IKC | LT1071IKV |

description

The LT1071 is a monolithic, high-efficiency switching regulator. It can be operated in all standard switching configurations including: step-down (buck), step-up (boost), flyback, forward, inverting, and Cuk[†]. A high-current, high-efficiency switch is included in the package along with all oscillator, control, and protection circuitry. Integration of all functions allows the LT1071 to be built in a standard 5-pin KC or KV package. This makes it extremely easy to use and provides reliable operation similar to that obtained with 3-pin linear regulators.

The LT1071 operates with supply voltages from 3 V to 40 V. The LT1071HV, a high-voltage version of the LT1071, operates with supply voltages from 3 V to 60 V. These devices draw only 6 mA of quiescent current, deliver load power up to 100 W with no external power devices, and by utilizing current-mode switching techniques, provide excellent ac and dc input and output regulation.

The LT1071 is much easier to use than the low-power control chips that are presently available and has many unique features that are not found on these chips. It uses an adaptive saturation-preventing switch drive to allow very-wide-ranging load currents with no loss in efficiency. An externally activated shutdown mode reduces total supply current to 50 μA typical for standby operation. Totally isolated and regulated outputs can be generated by using the optional flyback-regulation mode built into the LT1071 without using optocouplers or extra transformer windings.

[†] A boost-buck-derived regulator circuit patented by Slobodan Cuk.

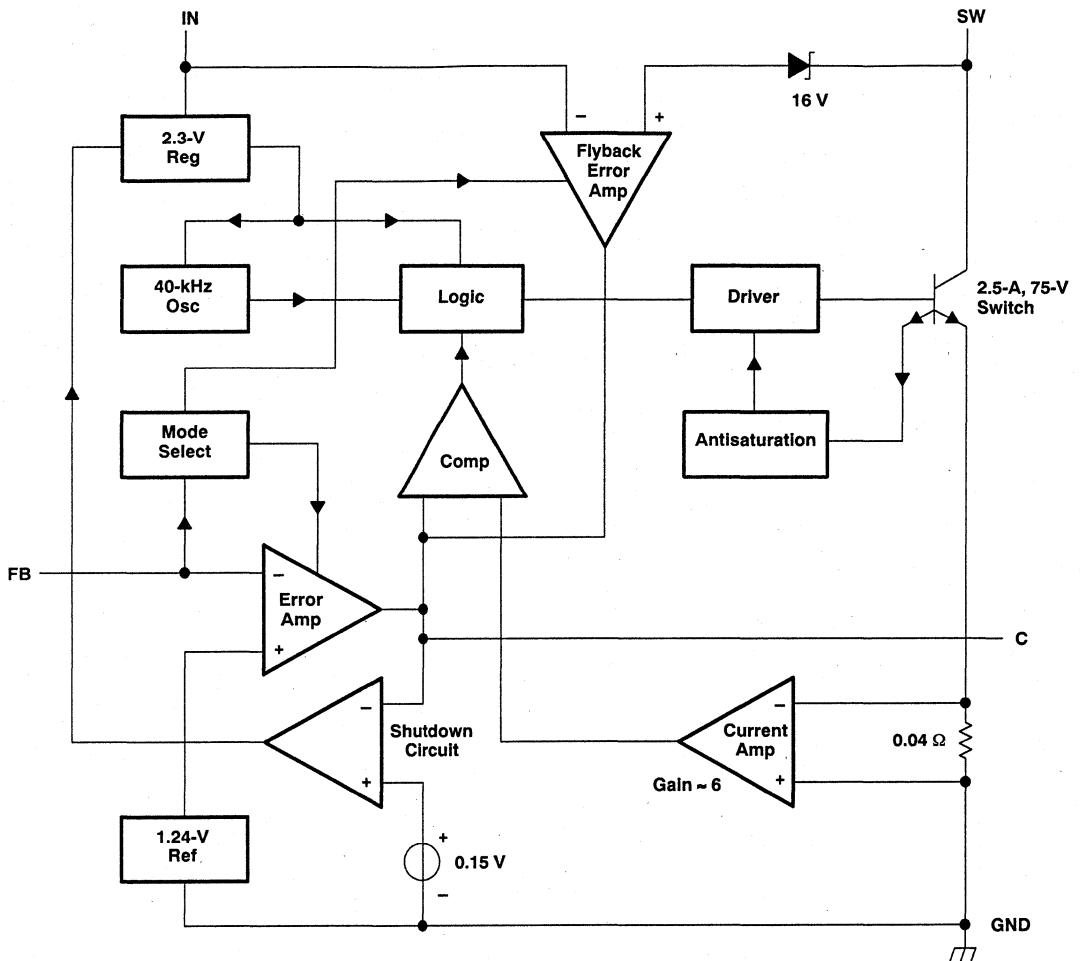
PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.



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LT1071, LT1071HV
2.5-A HIGH-EFFICIENCY SWITCHING REGULATORS

functional block diagram



Resistor value shown is nominal.

LT1071, LT1071HV

2.5-A HIGH-EFFICIENCY SWITCHING REGULATORS

absolute maximum ratings over operating virtual junction temperature range (unless otherwise noted)

| | |
|--|--|
| Supply voltage, V_{IN} (see Note 1): LT1071 | 40 V |
| LT1071HV | 60 V |
| Switch output voltage: LT1071 | 65 V |
| LT1071HV | 75 V |
| Feedback input voltage, V_{FB} (transient, 1 ms) | ± 15 V |
| Continuous total dissipation | See Dissipation Rating Tables 1 and 2 |
| Operating virtual-junction temperature range: LT1071C, LT1071HVC | 0°C to 125°C |
| LT1071I, LT1071HVI | -40°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 300°C |

NOTE 1: Minimum switch-on time for the LT1071 in current limit is $\approx 1 \mu\text{s}$. This limits the maximum input voltage during short-circuit conditions, in the step-down and inverting modes only, to ≈ 35 V. Normal (unshorted) conditions are not affected. If the LT1071 is being operated in the step-down or inverting mode at high input voltages and short-circuit conditions are expected, a resistor must be placed in series with the inductor.

DISSIPATION RATING TABLE 1 – FREE-AIR TEMPERATURE

| PACKAGE | $T_A \leq 25^{\circ}\text{C}$ | DERATING | $T_A = 125^{\circ}\text{C}$ |
|---------|-------------------------------|---|-----------------------------|
| | POWER RATING | FACTOR ABOVE $T_A = 25^{\circ}\text{C}$ | POWER RATING |
| KC | 2000 mW | 16 mW/ $^{\circ}\text{C}$ | 400 mW |
| KV | 2000 mW | 16 mW/ $^{\circ}\text{C}$ | 400 mW |

DISSIPATION RATING TABLE 2 – CASE TEMPERATURE

| PACKAGE | $T_C \leq 70^{\circ}\text{C}$ | DERATING | $T_C = 125^{\circ}\text{C}$ |
|---------|-------------------------------|---|-----------------------------|
| | POWER RATING | FACTOR ABOVE $T_C = 70^{\circ}\text{C}$ | POWER RATING |
| KC | 20 W | 250 mW/ $^{\circ}\text{C}$ | 6.25 W |
| KV | 20 W | 250 mW/ $^{\circ}\text{C}$ | 6.25 W |

recommended operating conditions

| | | MIN | MAX | UNIT |
|-------------------------------------|----------------------|-----|-----|--------------------|
| Input voltage, V_{IN} | LT1071C, LT1071I | 3 | 40 | V |
| | LT1071HVC, LT1071HVI | 3 | 60 | |
| Virtual-junction temperature, T_J | LT1071C, LT1071HVC | 0 | 100 | $^{\circ}\text{C}$ |
| | LT1071I, LT1071HVI | -40 | 125 | |

LT1071, LT1071HV

2.5-A HIGH-EFFICIENCY SWITCHING REGULATORS

electrical characteristics at specified virtual junction temperature, $V_{IN} = 15\text{ V}$, $V_{FB} = V_{ref}$ with SW output open (unless otherwise noted)

reference section

| PARAMETER | | TEST CONDITIONS† | T_J ‡ | MIN | TYP§ | MAX | UNIT |
|-----------|------------------|---|------------|-------|-------|-------|------|
| V_{ref} | Output voltage | Measured at FB input, $V_C = 0.6\text{ V}$ | 25°C | 1.224 | 1.244 | 1.264 | V |
| | | | Full range | 1.214 | | 1.274 | |
| | Input regulation | $V_{IN} = 3\text{ V to MAX}$, $V_C = 0.6\text{ V}$ | Full range | | | 0.03 | %/V |

error amplifier section

| PARAMETER | | TEST CONDITIONS† | T_J ‡ | MIN | TYP§ | MAX | UNIT |
|------------|---------------------------|--|------------|------|------|------|-----------------|
| I_{FB} | Feedback input current | $V_{FB} = V_{ref}$ | 25°C | | 350 | 750 | nA |
| | | | Full range | | | 1100 | |
| g_m | Transconductance | $\Delta I_C = \pm 25\ \mu\text{A}$ | 25°C | 3000 | 4400 | 6000 | μmho |
| | | | Full range | 2400 | | 7000 | |
| | Source current | $V_C = 1.5\text{ V}$, $V_{FB} = 0.8\text{ V}$ | 25°C | 150 | 200 | 350 | μA |
| | | | Full range | 120 | | 400 | |
| | Sink current | $V_C = 1.5\text{ V}$, $V_{FB} = 1.5\text{ V}$ | 25°C | 150 | 200 | 350 | μA |
| | | | Full range | 120 | | 400 | |
| $V_{O(C)}$ | Output voltage | High state, $V_{FB} = 1\text{ V}$ | 25°C | | | 1.8 | V |
| | | Low state, $V_{FB} = 1.5\text{ V}$ | | 0.25 | 0.38 | 0.52 | |
| A_V | Voltage amplification | $V_C = 0.7\text{ V to }1.4\text{ V}$ | Full range | 500 | 800 | 2000 | V/V |
| $V_{T(C)}$ | Control threshold voltage | Duty cycle = 0 | 25°C | 0.8 | 0.9 | 1.08 | V |
| | | | Full range | 0.6 | | 1.25 | |

flyback amplifier section

| PARAMETER | | TEST CONDITIONS† | T_J ‡ | MIN | TYP§ | MAX | UNIT |
|--------------|------------------------------------|---|------------|------------|------|------|-----------------|
| $V_{T(FB)}$ | Flyback threshold voltage | $I_{FB} = 50\ \mu\text{A}$ | 25°C | 0.4 | 0.45 | 0.54 | V |
| V_Z | Flyback reference | $I_{FB} = 50\ \mu\text{A}$, $I_C = -1\text{ to }+1\ \mu\text{A}$, $V_C = 0.6\text{ V}$ | 25°C | 15 | 16.3 | 17.6 | V |
| | | | Full range | 14 | | 18 | |
| ΔV_Z | Change in flyback reference | $I_{FB} = 0.05\text{ to }1\text{ mA}$, $I_C = -1\text{ to }+1\ \mu\text{A}$, $V_C = 0.6\text{ V}$ | 25°C | 4.5 | 6.8 | 8.5 | V |
| | Flyback reference input regulation | $I_{FB} = 50\ \mu\text{A}$, $I_C = -1\text{ to }+1\ \mu\text{A}$, $V_{IN} = 3\text{ V to MAX}$, $V_C = 0.6\text{ V}$ | 25°C | | 0.01 | 0.03 | %/V |
| g_m | Transconductance | $I_{FB} = 50\ \mu\text{A}$, $\Delta I_C \leq \pm 10\ \mu\text{A}$ | 25°C | 150 | 300 | 500 | μmho |
| | Sink or source current | $V_C = 1.5\text{ V}$, $I_{FB} = 50\ \mu\text{A}$, $V(SW) = V_Z + V_{IN} \pm 1\text{ V}$ | Source | | | 15 | μA |
| | | | Sink | Full range | 25 | 40 | |

† For conditions shown as MIN or MAX, use the appropriate value specified under the recommended operating conditions.

‡ Full range virtual junction temperature is 0°C to 100°C for LT1071C and LT1071HVC and -40°C to 125°C for LT1071I and LT1071HVI.

§ All typical values are $T_A = 25^\circ\text{C}$.



LT1071, LT1071HV

2.5-A HIGH-EFFICIENCY SWITCHING REGULATORS

electrical characteristics at specified virtual junction temperature, $V_{IN} = 15\text{ V}$, $V_{FB} = V_{ref}$ with SW output open (unless otherwise noted)

output section

| PARAMETER | | TEST CONDITIONS† | T_J ‡ | MIN | TYP§ | MAX | UNIT |
|-------------------------------|--|---|------------|-------------------------|------|-----|---------------|
| $V_{(BR)SW}$ | Switch breakdown voltage | $V_{FB} = 1.5\text{ V}$, $I_{SW} = 5\text{ mA}$ | Full range | | | 65 | V |
| | | | | LT1071 | | | |
| R_{on} | Switch on-state resistance | $V_{FB} = 0.8\text{ V}$, $I_{SW} = 2\text{ A}$ | Full range | | 0.3 | 0.5 | Ω |
| g_m | Control-to-switch transconductance | | 25°C | | 4 | | mho |
| $I_{SW(lim)}$ | Switch current limit | $V_{FB} = 0.8\text{ V}$, See Note 2 | Full range | $\geq 25^\circ\text{C}$ | 2.5 | 5 | A |
| | | | | $< 25^\circ\text{C}$ | 2.5 | 5.5 | |
| | | | | Duty cycle = 80% | 2 | 5 | |
| $\Delta I_{IN}/\Delta I_{SW}$ | Input current increase during switch turn-on | $V_{FB} = 0.8\text{ V}$ | 25°C | | 25 | 35 | mA/A |
| f | Frequency | | 25°C | 35 | 40 | 45 | kHz |
| | | | Full range | 33 | | 47 | |
| | Maximum duty cycle | $V_{FB} = 1\text{ V}$ | 25°C | 90% | 92% | 97% | |
| t_d | Flyback sense delay time | | 25°C | | 1.5 | | μs |

shutdown section

| PARAMETER | | TEST CONDITIONS† | T_J ‡ | MIN | TYP§ | MAX | UNIT |
|---------------|-----------------------------|---|------------|-----|------|-----|---------------|
| $I_{IN(off)}$ | Shutdown mode input current | $V_{IN} = 3\text{ V to MAX}$, $V_C = 0.05\text{ V}$ | 25°C | | 100 | 250 | μA |
| $V_C(off)$ | Control threshold voltage | $V_{IN} = 3\text{ V to MAX}$, | 25°C | 100 | 150 | 250 | mV |
| | | | Full range | 50 | | 300 | |

total device

| PARAMETER | | TEST CONDITIONS† | T_J ‡ | MIN | TYP§ | MAX | UNIT |
|---------------|-----------------------|--|------------|-----|------|-----|------|
| $V_{IN(min)}$ | Minimum input voltage | | Full range | | 2.6 | 3 | V |
| I_{IN} | Input current | $V_{IN} = 3\text{ V to MAX}$, $V_C = 0.6\text{ V}$ | 25°C | | 6 | 9 | mA |

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

‡ Full range virtual junction temperature is 0°C to 100°C for LT1071C and LT1071HVC and -40°C to 125°C for LT1071I and LT1071HVI.

§ All typical values are $T_A = 25^\circ\text{C}$.

NOTE 2: For duty cycles between 50% and 80%, minimum switch output current is given by $I_{SW(lim)} = 1.67$ (2-duty cycle).

LT1071, LT1071HV

2.5-A HIGH-EFFICIENCY SWITCHING REGULATORS

theory of operation

The LT1071 is a current-mode switcher. This means that the switch duty cycle is directly controlled by switch current rather than by output voltage. Referring to the functional block diagram, the switch is turned on at the start of each oscillator cycle. It is turned off when the switch current reaches a predetermined level. Control of output voltage is obtained by using the output of a voltage-sensing error amplifier to set the current trip level. This technique has several advantages. First, it has immediate response to input-voltage variations, which is unlike ordinary switchers that have poor input transient response. Second, it reduces the 90° phase shift at midfrequencies in the energy-storage inductor. This greatly simplifies closed-loop frequency compensation under widely varying input-voltage or output-load conditions. Finally, it allows simple pulse-by-pulse current limiting to provide maximum switch protection under output overload or short conditions. A low-dropout internal regulator provides a 2.3-V supply for all internal circuitry on the LT1071. This low-dropout design allows input voltage to vary from 3 V to 60 V with virtually no change in device performance. A 40-kHz oscillator is the basic clock for all internal timing. It turns on the output switch via the logic and driver circuitry. Special adaptive antisaturation circuitry detects the onset of saturation in the power switch and adjusts driver current instantaneously to limit switch saturation. This minimizes driver dissipation and provides very rapid turn off of the switch.

A 1.2-V band-gap reference biases the positive input of the error amplifier. The negative input is brought out for output-voltage sensing. This feedback pin has a second function when pulled low with an external resistor. It programs the LT1071 to disconnect the main error-amplifier output and connects the output of the flyback amplifier to the comparator input. The LT1071 will then regulate the value of the flyback pulse with respect to the supply voltage. This flyback pulse is directly proportional to output voltage in the traditional transformer-coupled flyback-topology regulator. By regulating the amplitude of the flyback pulse, the output voltage can be regulated with no direct connection between input and output. The output is fully floating up to the breakdown voltage of the transformer windings. Multiple floating outputs are easily obtained with additional windings. A special delay network inside the LT1071 ignores the leakage inductance spike at the leading edge of the flyback pulse to improve output regulation.

The error signal developed at the comparator input is brought out externally. This pin (C) has four different functions. It is used for frequency compensation, current limit adjustment, soft starting, and total regulator shutdown. During normal regulator operation, this pin sits at a voltage between 0.9 V (low output current) and 2 V (high output current). The error amplifiers are current-output (g_m) types, so this voltage can be externally clamped for adjusting current limit. Likewise, a capacitor-coupled external clamp will provide soft start. Switch duty cycle goes to zero if the C pin is pulled to ground through a diode. This places the LT1071 in an idle mode. Pulling the C pin below 0.15 V causes total regulator shutdown, with only 50- μ A supply current for shutdown-circuitry biasing.



TYPICAL CHARACTERISTICS

table of graphs

| | | | FIGURE |
|---------------|---|------------------------------|---------------|
| P_{OM} | Maximum output power | vs Input voltage | 1 |
| f | Switching frequency | vs Junction temperature | 2 |
| V_{ref} | Reference voltage | vs Junction temperature | 2 |
| | Reference voltage change | vs Input voltage | 3 |
| I_{FB} | Feedback input current | vs Junction temperature | 4 |
| g_m | Error amplifier transconductance | vs Junction temperature | 5 |
| g_m | Error amplifier transconductance | vs Frequency | 6 |
| | Error amplifier phase shift | vs Frequency | 6 |
| I_C | Control current | vs Control voltage | 7 |
| $V_{T(FB)}$ | Normal-flyback-mode threshold voltage | vs Junction temperature | 8 |
| I_{FB} | Feedback input current | vs Junction temperature | 8 |
| V_z | Flyback reference voltage | vs Junction temperature | 9 |
| t_d | Flyback sense delay time | vs Junction temperature | 10 |
| $I_{O(SW)}$ | Switch (output with switch off) current | vs Switch voltage | 11 |
| | Driver base current | vs Switch output current | 12 |
| $V_{sat(SW)}$ | Switch saturation voltage | vs Switch output current | 13 |
| $I_{O(SW)}$ | Switch output current limit | vs Duty cycle | 14 |
| | Maximum duty cycle | vs Junction temperature | 15 |
| I_{IN} | Shutdown-mode input current | vs Control threshold voltage | 16 |
| I_{IN} | Shutdown-Mode input current | vs Input voltage | 17 |
| $V_{T(C)}$ | Shutdown-mode control threshold voltage | vs Junction temperature | 18 |
| $I_{T(C)}$ | Shutdown-mode control threshold current | vs Junction temperature | 18 |
| V_{FB} | Feedback input voltage | vs Feedback input current | 19 |
| | Minimum input voltage | vs Junction temperature | 20 |
| I_{IN} | Input current | vs Junction temperature | 21 |
| I_{IN} | Input current | vs Input voltage | 22 |

table of application circuits

| APPLICATION | FIGURE |
|-------------------------------|--------|
| Totally isolated converter | 23 |
| Boost converter (5 V to 12 V) | 24 |

TYPICAL CHARACTERISTICS

MAXIMUM OUTPUT POWER
vs
INPUT VOLTAGE

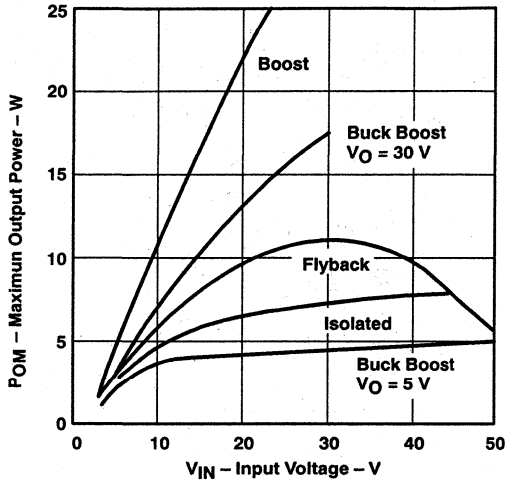


Figure 1

REFERENCE VOLTAGE AND
SWITCHING FREQUENCY
vs
JUNCTION TEMPERATURE

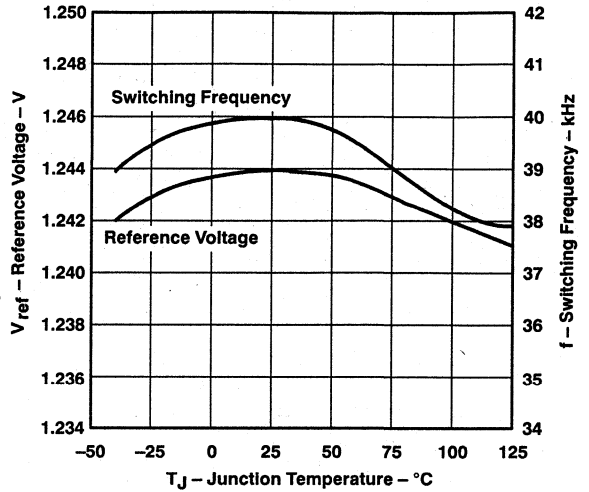


Figure 2

REFERENCE VOLTAGE INPUT REGULATION

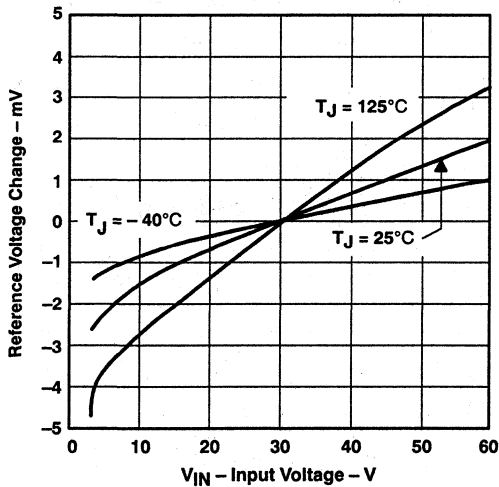


Figure 3

FEEDBACK INPUT CURRENT
vs
JUNCTION TEMPERATURE

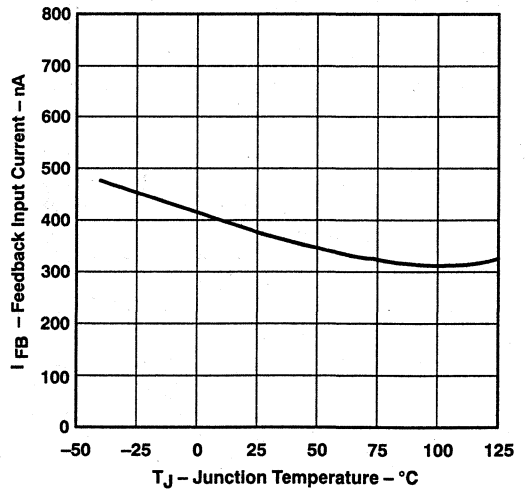


Figure 4

TYPICAL CHARACTERISTICS

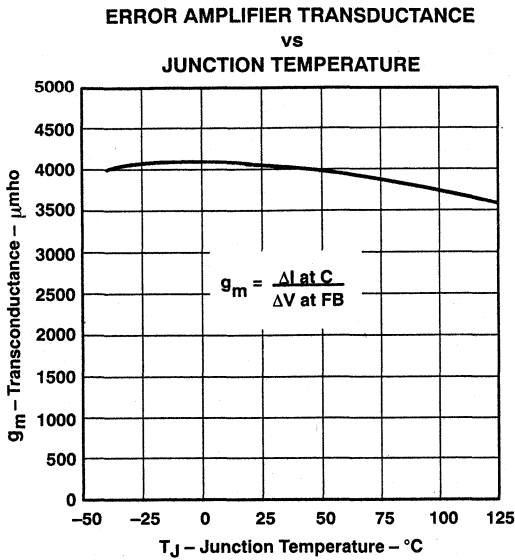


Figure 5

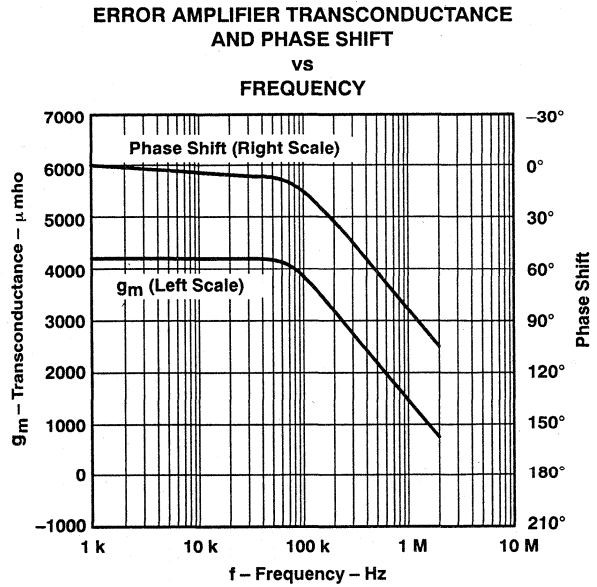


Figure 6

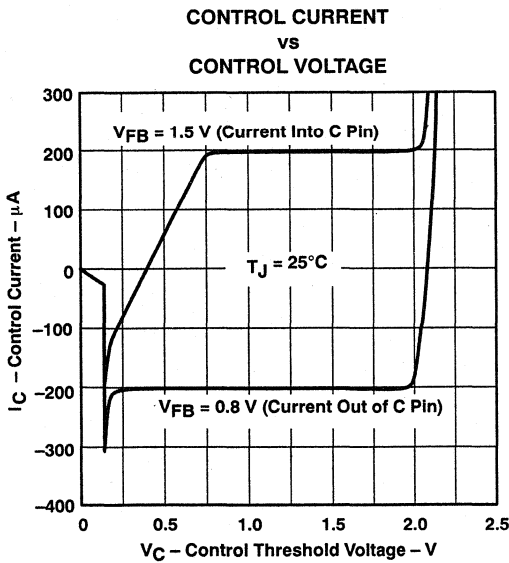


Figure 7

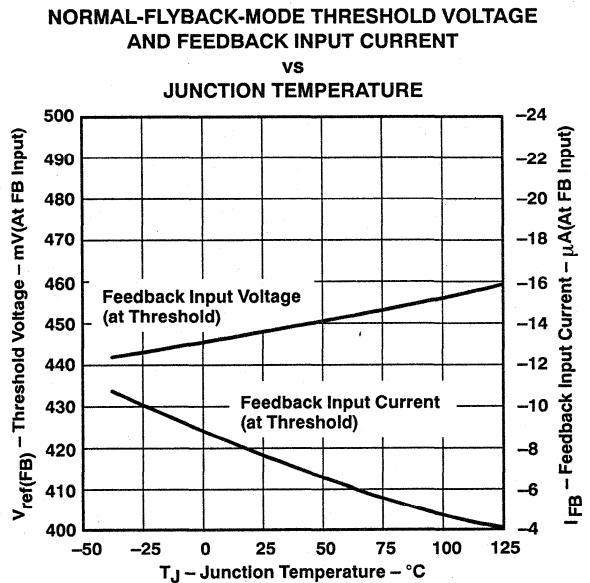


Figure 8

TYPICAL CHARACTERISTICS

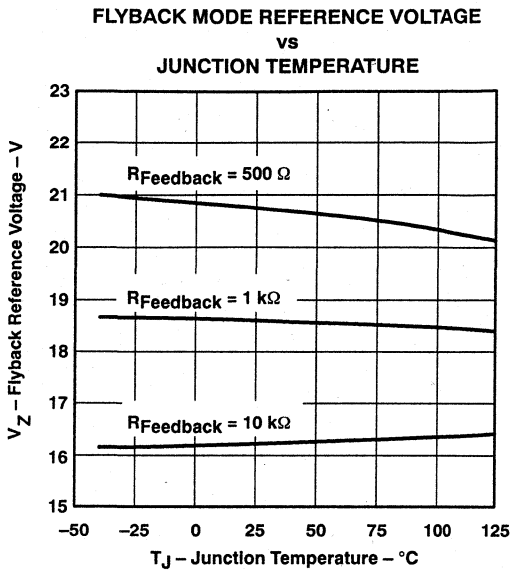


Figure 9

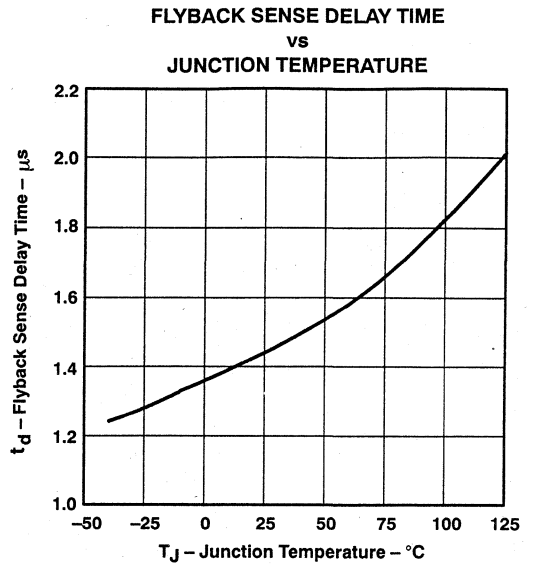


Figure 10

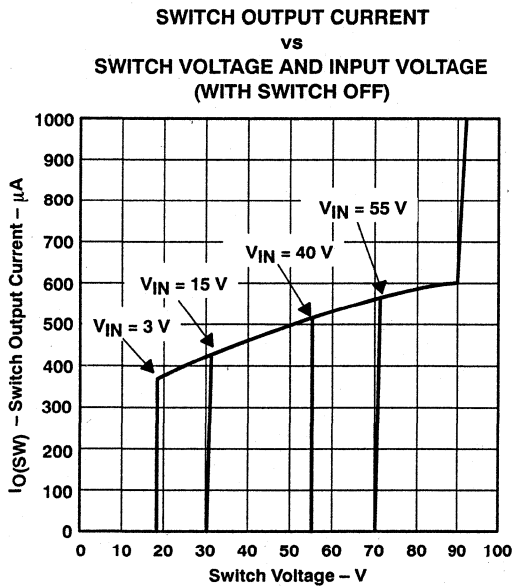


Figure 11

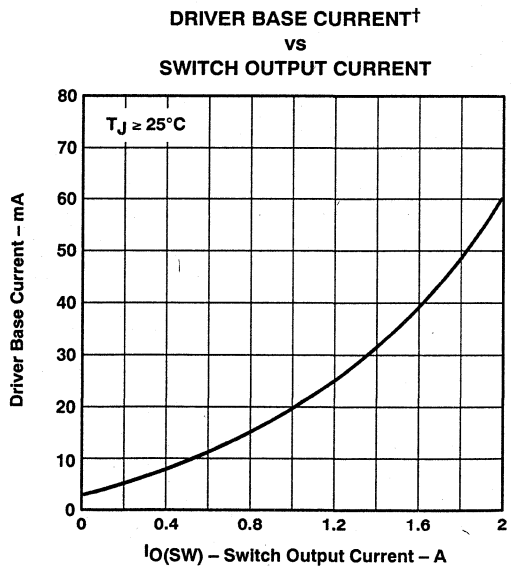


Figure 12

† Average power driver base current is found by multiplying driver base current by duty cycle plus quiescent current.

TYPICAL CHARACTERISTICS

SWITCH SATURATION VOLTAGE
vs
SWITCH CURRENT

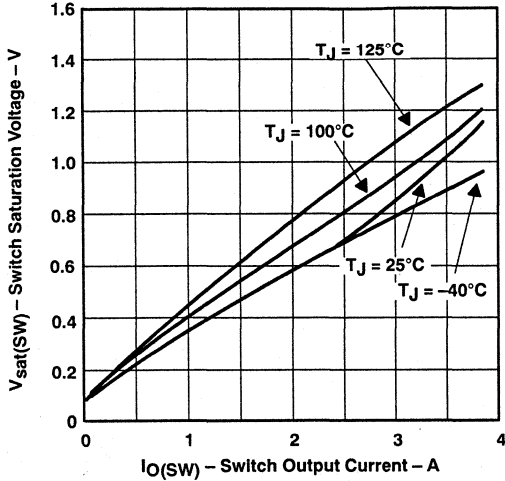


Figure 13

SWITCH OUTPUT CURRENT LIMIT
vs
DUTY CYCLE

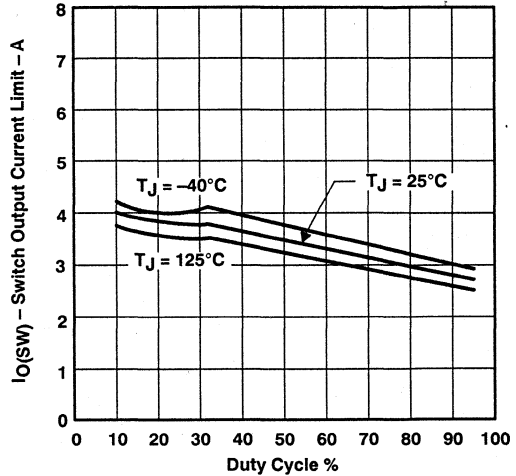


Figure 14

DUTY CYCLE (MAX)
vs
JUNCTION TEMPERATURE

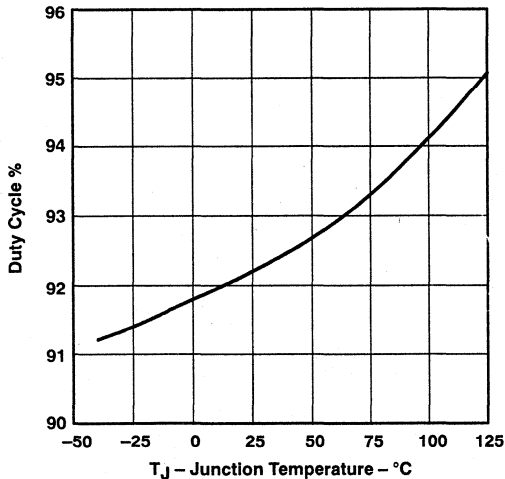


Figure 15

SHUTDOWN MODE
INPUT CURRENT
vs
CONTROL THRESHOLD VOLTAGE

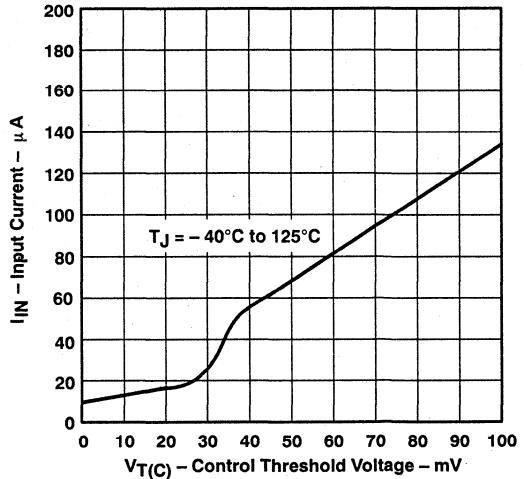


Figure 16

TYPICAL CHARACTERISTICS

SHUTDOWN MODE
INPUT CURRENT
vs
INPUT VOLTAGE

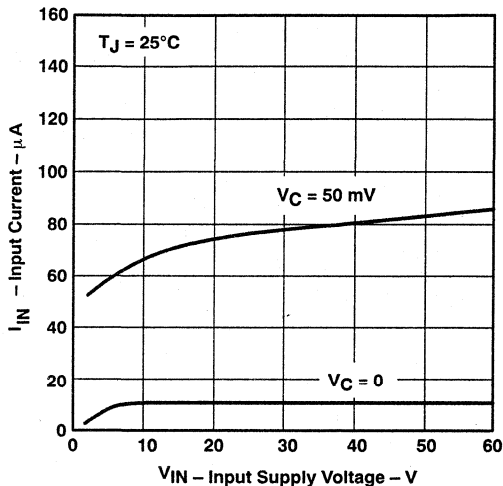


Figure 17

SHUTDOWN MODE
CONTROL THRESHOLD VOLTAGE AND CURRENT
vs
JUNCTION TEMPERATURE

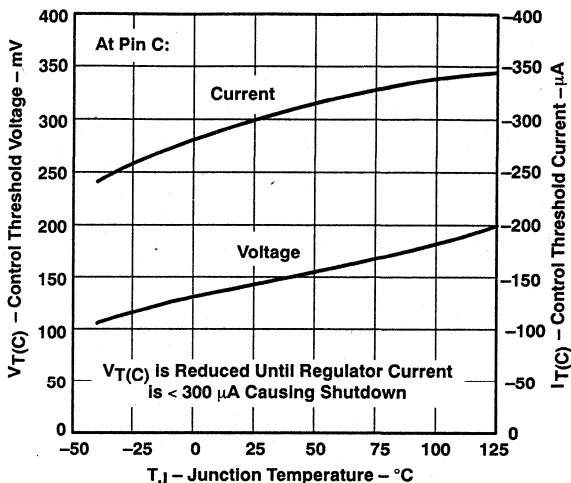


Figure 18

FEEDBACK INPUT VOLTAGE
vs
FEEDBACK INPUT CURRENT

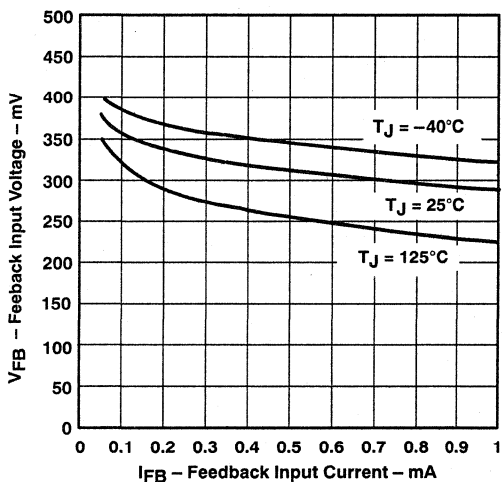


Figure 19

MINIMUM INPUT VOLTAGE
vs
JUNCTION TEMPERATURE

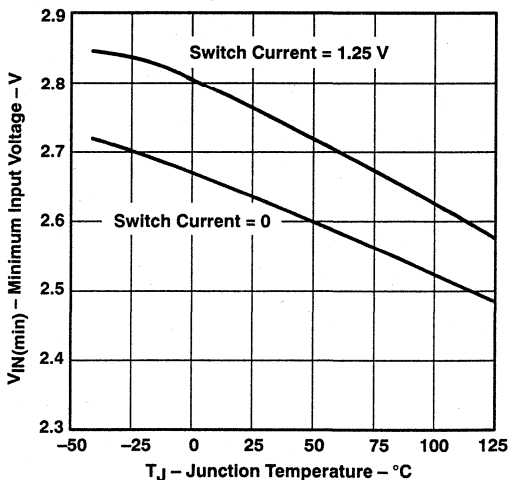


Figure 20

TYPICAL CHARACTERISTICS

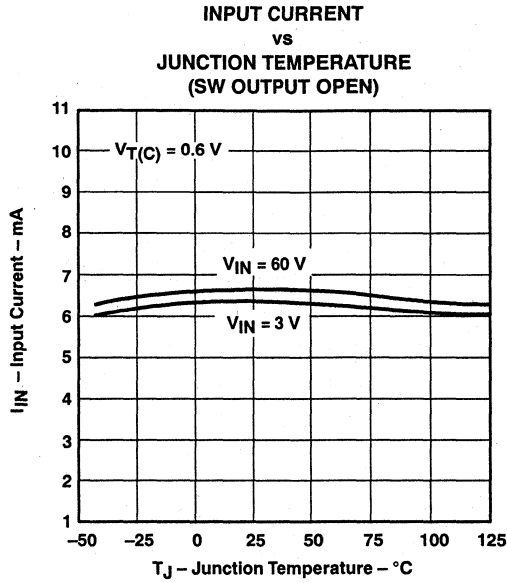
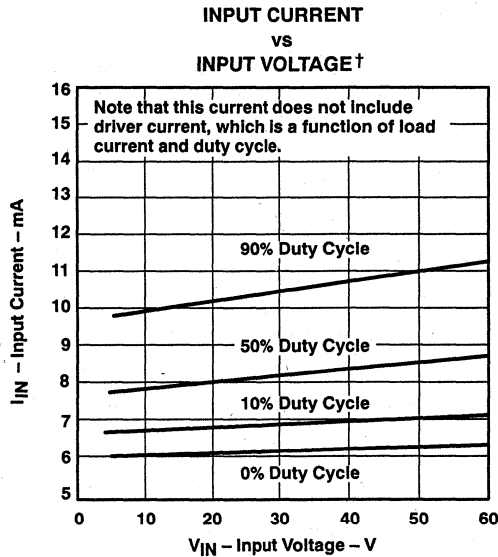


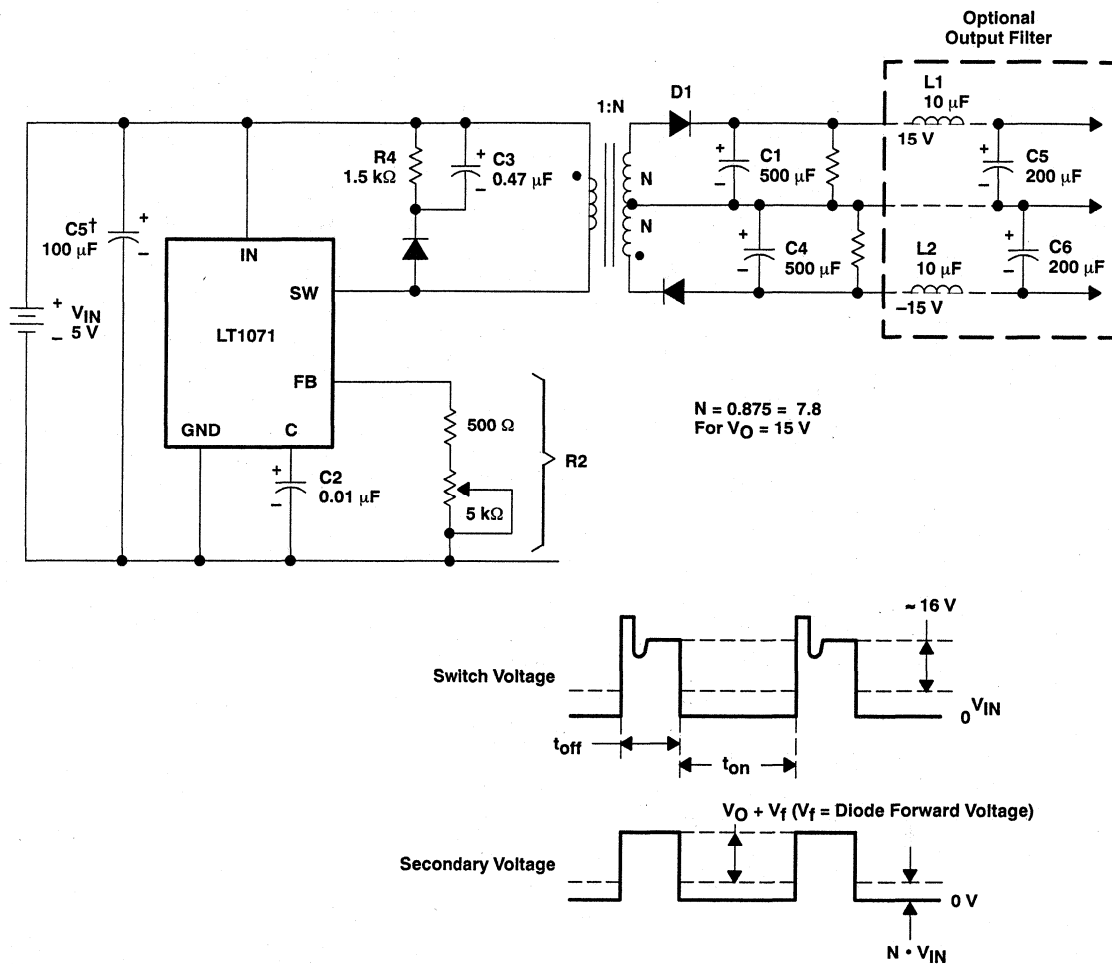
Figure 21



[†] Under very low output current conditions, duty cycle for most circuits will approach 10% or less.

Figure 22

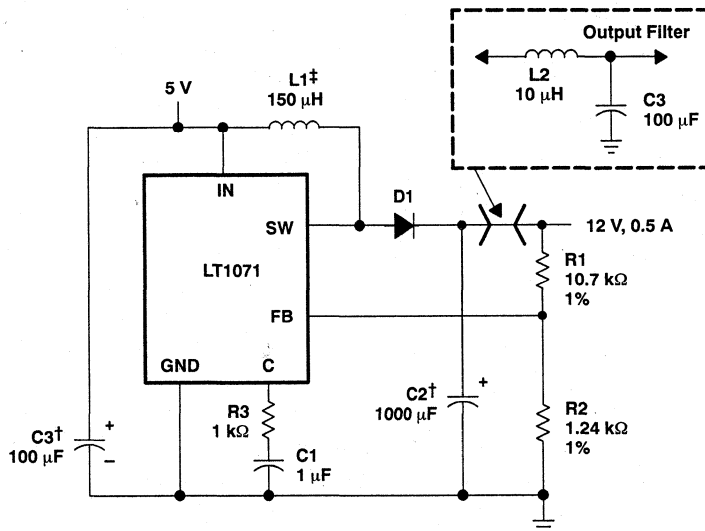
APPLICATION INFORMATION



† Capacitors are required if input leads ≥ 2 inches.

Figure 23. Totally Isolated Converter

APPLICATION INFORMATION



† Capacitors are required if input leads ≥ 2 inches.

‡ Pulse Engineering 92113

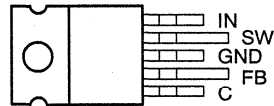
Figure 24. Boost Converter (5 V to 12 V)

LT1072, LT1072HV 1.25-A HIGH-EFFICIENCY SWITCHING REGULATORS

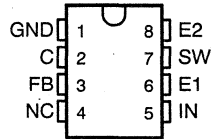
D3369, NOVEMBER 1989—REVISED AUGUST 1991

- **Wide Supply-Voltage Range:**
LT1072HV . . . 3 V to 60 V
LT1072 . . . 3 V to 40 V
- **Low Quiescent Current . . . 6 mA Typ**
- **Internal 1.25-A Switch**
- **Few External Parts Required**
- **Self-Protected Against Overloads**
- **Operates in Most Switching Configurations**
- **Low Shutdown-Mode Supply Current**
- **Floating Outputs in Flyback-Regulated Mode**
- **Can Be Externally Synchronized**

KC AND KV PACKAGE
(KV Package Used for Illustration)
(TOP VIEW)



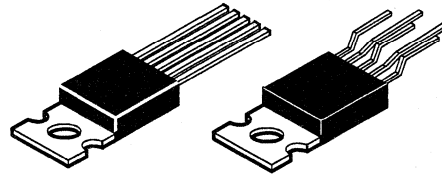
P Package
(TOP VIEW)



NC = No internal connection

AVAILABLE OPTIONS

| T _J | MAX INPUT VOLTAGE | KC PACKAGE | KV PACKAGE | P PACKAGE |
|----------------|-------------------|-------------|-------------|------------|
| 0°C to 100°C | 60 V | LT1072HVCKC | LT1072HVCKV | LT1072HVCP |
| | 40 V | LT1072CKC | LT1072CKV | LT1072CP |
| -40°C to 125°C | 60 V | LT1072HVIKC | LT1072HVIKV | LT1072HVIP |
| | 40 V | LT1072IKC | LT1072IKV | LT1072IP |



KC 5-Lead

KV 5-Lead

description

The LT1072 is a monolithic, high-efficiency switching regulator. It can be operated in all standard switching configurations including: step-down (buck), step-up (boost), flyback, forward, inverting, and Cuk[†]. A high-current, high-efficiency switch is included in the package along with all oscillator, control, and protection circuitry. Integration of all functions allows the LT1072 to be built in standard 5-pin KC or a KV packages and the 8-pin P package. This makes it extremely easy to use and provides reliable operation similar to that obtained with 3-pin linear regulators.

The LT1072 operates with supply voltages from 3 V to 40 V. The LT1072HV, a high-voltage version of the LT1072, operates with supply voltages from 3 V to 60 V. These devices draw only 6 mA of quiescent current, deliver load power up to 20 W with no external power devices, and by utilizing current-mode switching techniques, provide excellent ac and dc input and output regulation.

The LT1072 is much easier to use than the low-power control chips that are presently available and has many unique features that are not found on these chips. It uses an adaptive saturation-preventing switch drive to allow very-wide-ranging load currents with no loss in efficiency. An externally activated shutdown mode reduces total supply current to 50 μ A typical for standby operation. Totally isolated and regulated outputs can be generated by using the optional flyback-regulation mode built into the LT1072 without using optocouplers or extra transformer windings.

[†]A boost-buck-derived regulator circuit patented by Slobodan Cuk.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

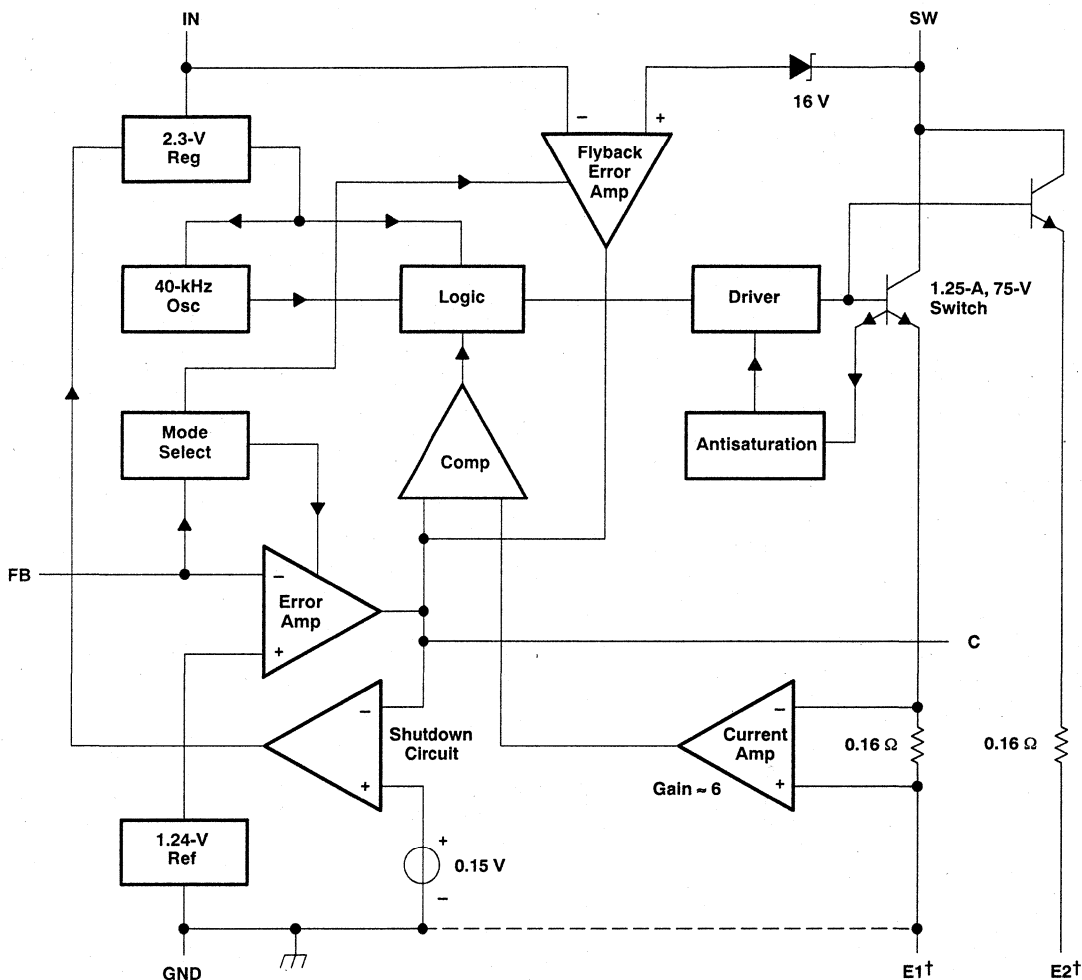


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LT1072, LT1072HV 1.25-A HIGH-EFFICIENCY SWITCHING REGULATORS

functional block diagram



All resistor values shown are nominal.

† Always connect E1 to ground when using the P package. The emitters (E1 and E2) are tied internally to ground on the KC and KV packages.

LT1072, LT1072HV 1.25-A HIGH-EFFICIENCY SWITCHING REGULATORS

absolute maximum ratings over operating virtual junction temperature range (unless otherwise noted)

| | |
|--|--|
| Supply voltage, V_{IN} (see Note 1): LT1072 | 40 V |
| LT1072HV | 60 V |
| Switch output voltage: LT1072 | 65 V |
| LT1072HV | 75 V |
| Feedback input voltage, V_{FB} (transient, 1 ms) | ± 15 V |
| Continuous total dissipation | See Dissipation Rating Tables 1 and 2 |
| Operating virtual-junction temperature range: LT1072C, LT1072HVC | 0°C to 125°C |
| LT1072I, LT1072HVI | -40°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 1: Minimum switch-on time for the LT1072 in current limit is ≈ 0.7 μs . This limits the maximum input voltage during short-circuit conditions, in the step-down and inverting modes only, to ≈ 40 V. Normal (unshorted) conditions are not affected. If the LT1072 is being operated in the step-down or inverting mode at high input voltages and short-circuit conditions are expected, a resistor must be placed in series with the inductor.

DISSIPATION RATING TABLE 1 – FREE-AIR TEMPERATURE

| PACKAGE | $T_A \leq 25^{\circ}\text{C}$ | DERATING | $T_A = 125^{\circ}\text{C}$ |
|---------|-------------------------------|---|-----------------------------|
| | POWER RATING | FACTOR ABOVE $T_A = 25^{\circ}\text{C}$ | POWER RATING |
| KC | 2000 mW | 16 mW/ $^{\circ}\text{C}$ | 400 mW |
| KV | 2000 mW | 16 mW/ $^{\circ}\text{C}$ | 400 mW |
| P | 1000 mW | 8 mW/ $^{\circ}\text{C}$ | 200 mW |

DISSIPATION RATING TABLE 2 – CASE TEMPERATURE

| PACKAGE | $T_C \leq 25^{\circ}\text{C}$ | DERATING | $T_C = 125^{\circ}\text{C}$ |
|---------|-------------------------------|---|-----------------------------|
| | POWER RATING | FACTOR ABOVE $T_C = 70^{\circ}\text{C}$ | POWER RATING |
| KC | 20 W | 250 mW/ $^{\circ}\text{C}$ | 6.25 W |
| KV | 20 W | 250 mW/ $^{\circ}\text{C}$ | 6.25 W |

recommended operating conditions

| | | MIN | MAX | UNIT |
|-------------------------------------|----------------------|-----|-----|--------------------|
| Input voltage, V_{IN} | LT1072C, LT1072I | 3 | 40 | V |
| | LT1072HVC, LT1072HVI | 3 | 60 | |
| Virtual-junction temperature, T_J | LT1072C, LT1072HVC | 0 | 100 | $^{\circ}\text{C}$ |
| | LT1072I, LT1072HVI | -40 | 125 | |

LT1072, LT1072HV

1.25-A HIGH-EFFICIENCY SWITCHING REGULATORS

electrical characteristics at specified virtual junction temperature, $V_{IN} = 15\text{ V}$, $V_{FB} = V_{ref}$ with SW output open (unless otherwise noted)

reference section

| PARAMETER | | TEST CONDITIONS† | T_J ‡ | MIN | TYP§ | MAX | UNIT |
|-----------|------------------|---|------------|-------|-------|-------|------|
| V_{ref} | Output voltage | Measured at FB input, $V_C = 0.6\text{ V}$ | 25°C | 1.224 | 1.244 | 1.264 | V |
| | | | Full range | 1.214 | 1.274 | | |
| | Input regulation | $V_{IN} = 3\text{ V to MAX}$, $V_C = 0.6\text{ V}$ | Full range | | | 0.03 | %/V |

error amplifier section

| PARAMETER | | TEST CONDITIONS† | T_J ‡ | MIN | TYP§ | MAX | UNIT |
|------------|---------------------------|--|------------|------|------|------|-----------------|
| I_{FB} | Feedback input current | $V_{FB} = V_{ref}$ | 25°C | | 350 | 750 | nA |
| | | | Full range | | | 1100 | |
| g_m | Transconductance | $\Delta I_C = \pm 25\ \mu\text{A}$ | 25°C | 3000 | 4400 | 6000 | μmho |
| | | | Full range | 2400 | | 7000 | |
| | Source current | $V_C = 1.5\text{ V}$, $V_{FB} = 0.8\text{ V}$ | 25°C | 150 | 200 | 350 | μA |
| | | | Full range | 120 | | 400 | |
| | Sink current | $V_C = 1.5\text{ V}$, $V_{FB} = 1.5\text{ V}$ | 25°C | 150 | 200 | 350 | μA |
| | | | Full range | 120 | | 400 | |
| $V_{O(C)}$ | Output voltage | High state, $V_{FB} = 1\text{ V}$ | 25°C | 1.8 | | 2.3 | V |
| | | Low state, $V_{FB} = 1.5\text{ V}$ | | 0.25 | 0.38 | 0.52 | |
| A_V | Voltage amplification | $V_C = 0.7\text{ V to }1.4\text{ V}$ | Full range | 500 | 800 | 2000 | V/V |
| $V_{T(C)}$ | Control threshold voltage | Duty cycle = 0 | 25°C | 0.8 | 0.9 | 1.08 | V |
| | | | Full range | 0.6 | | 1.25 | |

flyback amplifier section

| PARAMETER | | TEST CONDITIONS† | T_J ‡ | MIN | TYP§ | MAX | UNIT |
|--------------|------------------------------------|---|------------|-----|------|------|-----------------|
| $V_{T(FB)}$ | Flyback threshold voltage | $I_{FB} = 50\ \mu\text{A}$ | 25°C | 0.4 | 0.45 | 0.54 | V |
| | | | Full range | 15 | 16.3 | 17.6 | |
| V_Z | Flyback reference | $I_{FB} = 50\ \mu\text{A}$, $I_C = -1\text{ to }+1\ \mu\text{A}$, $V_C = 0.6\text{ V}$ | 25°C | 15 | 16.3 | 17.6 | V |
| | | | Full range | 14 | | 18 | |
| ΔV_Z | Change in flyback reference | $I_{FB} = 0.05\text{ to }1\text{ mA}$, $I_C = -1\text{ to }+1\ \mu\text{A}$, $V_C = 0.6\text{ V}$ | 25°C | 4.5 | 6.8 | 8.5 | V |
| | Flyback reference input regulation | $I_{FB} = 50\ \mu\text{A}$, $I_C = -1\text{ to }+1\ \mu\text{A}$, $V_{IN} = 3\text{ V to MAX}$, $V_C = 0.6\text{ V}$ | 25°C | | 0.01 | 0.03 | %/V |
| g_m | Transconductance | $I_{FB} = 50\ \mu\text{A}$, $\Delta I_C = \pm 10\ \mu\text{A}$ | 25°C | 150 | 300 | 500 | μmho |
| | | | Full range | 15 | 32 | 50 | |
| | Sink or source current | $V_C = 1.5\text{ V}$, $I_{FB} = 50\ \mu\text{A}$, $V_{(SW)} = V_Z + V_{IN} \pm 1\text{ V}$ | Source | 25 | 40 | 70 | μA |
| | | Sink | | | | | |

† For conditions shown as MIN or MAX, use the appropriate value specified under the recommended operating conditions.

‡ Full range virtual junction temperature is 0°C to 100°C for LT1072C and LT1072HVC and -40°C to 125°C for LT1072I and LT1072HVI.

§ All typical values are $T_A = 25^\circ\text{C}$.



LT1072, LT1072HV

1.25-A HIGH-EFFICIENCY SWITCHING REGULATORS

electrical characteristics at specified virtual junction temperature, $V_{IN} = 15\text{ V}$, $V_{FB} = V_{ref}$ with SW output open (unless otherwise noted)

output section

| PARAMETER | | TEST CONDITIONS† | T_J ‡ | MIN | TYP§ | MAX | UNIT |
|-------------------------------|--|--|------------------------|-------------------------|------|-----|---------------|
| $V_{(BR)SW}$ | Switch breakdown voltage | $V_{FB} = 1.5\text{ V}$, $I_{SW} = 5\text{ mA}$ | LT1072 | Full range | 65 | | V |
| | | | LT1072HV | | 75 | | |
| R_{on} | Switch on-state resistance | $V_{FB} = 0.8\text{ V}$, $I_{SW} = 1.25\text{ mA}$ | Full range | | 0.6 | 1 | Ω |
| g_m | Control-to-switch transconductance | | 25°C | | 2 | | mho |
| $I_{SW(lim)}$ | Switch current limit | $V_{FB} = 0.8\text{ V}$, See Note 2 | Duty cycle $\leq 50\%$ | $\geq 25^\circ\text{C}$ | 1.25 | 3 | A |
| | | | Duty cycle $\leq 50\%$ | $< 25^\circ\text{C}$ | 1.25 | 3.5 | |
| | | | Duty cycle = 80% | Full range | 1 | 2.5 | |
| $\Delta I_{IN}/\Delta I_{SW}$ | Input current increase during switch turn-on | $V_{FB} = 0.8\text{ V}$ | 25°C | | 25 | 35 | mA/A |
| f | Frequency | | 25°C | 35 | 40 | 45 | kHz |
| | | | Full range | | 33 | | |
| | Maximum duty cycle | $V_{FB} = 1\text{ V}$ | 25°C | 90% | 92% | 97% | |
| t_d | Flyback sense delay time | | 25°C | | 1.5 | | μs |

shutdown section

| PARAMETER | | TEST CONDITIONS† | T_J ‡ | MIN | TYP§ | MAX | UNIT |
|---------------|-----------------------------|---|------------|-----|------|-----|---------------|
| $I_{IN(off)}$ | Shutdown mode input current | $V_{IN} = 3\text{ V to MAX}$, $V_C = 0.05\text{ V}$ | 25°C | | 100 | 250 | μA |
| $V_{C(off)}$ | Control threshold voltage | $V_{IN} = 3\text{ V to MAX}$, | 25°C | 100 | 150 | 250 | mV |
| | | | Full range | 50 | | 300 | |

total device

| PARAMETER | | TEST CONDITIONS† | T_J ‡ | MIN | TYP§ | MAX | UNIT |
|---------------|-----------------------|--|------------|-----|------|-----|------|
| $V_{IN(min)}$ | Minimum input voltage | | Full range | | 2.6 | 3 | V |
| I_{IJN} | Input current | $V_{IN} = 3\text{ V to MAX}$, $V_C = 0.6\text{ V}$ | 25°C | | 6 | 9 | mA |

† For conditions shown as MIN or MAX, use the appropriate value specified under the recommended operating conditions.

‡ Full range virtual junction temperature is 0°C to 100°C for LT1072C and LT1072HVC and -40°C to 125°C for LT1072I and LT1072HVI.

§ All typical values are $T_A = 25^\circ\text{C}$.

NOTE 2: For duty cycles between 50% and 80%, minimum switch output current is given by $I_{SW(lim)} = 0.833$ (2-duty cycle).

LT1072, LT1072HV

1.25-A HIGH-EFFICIENCY SWITCHING REGULATORS

theory of operation

The LT1072 is a current-mode switcher. This means that the switch duty cycle is directly controlled by switch current rather than by output voltage. Referring to the functional block diagram, the switch is turned on at the start of each oscillator cycle. It is turned off when the switch current reaches a predetermined level. Control of output voltage is obtained by using the output of a voltage-sensing error amplifier to set the current trip level. This technique has several advantages. First, it has immediate response to input-voltage variations, which is unlike ordinary switchers that have poor input transient response. Second, it reduces the 90° phase shift at midfrequencies in the energy-storage inductor. This greatly simplifies closed-loop frequency compensation under widely varying input-voltage or output-load conditions. Finally, it allows simple pulse-by-pulse current limiting to provide maximum switch protection under output overload or short conditions. A low-dropout internal regulator provides a 2.3-V supply for all internal circuitry on the LT1072. This low-dropout design allows input voltage to vary from 3 V to 60 V with virtually no change in device performance. A 40-kHz oscillator is the basic clock for all internal timing. It turns on the output switch via the logic and driver circuitry. Special adaptive antisaturation circuitry detects the onset of saturation in the power switch and adjusts driver current instantaneously to limit switch saturation. This minimizes driver dissipation and provides very rapid turn off of the switch.

A 1.2-V band-gap reference biases the positive input of the error amplifier. The negative input is brought out for output-voltage sensing. This feedback pin has a second function when pulled low with an external resistor. It programs the LT1072 to disconnect the main error-amplifier output and connects the output of the flyback amplifier to the comparator input. The LT1072 will then regulate the value of the flyback pulse with respect to the supply voltage. This flyback pulse is directly proportional to output voltage in the traditional transformer-coupled flyback-topology regulator. By regulating the amplitude of the flyback pulse, the output voltage can be regulated with no direct connection between input and output. The output is fully floating up to the breakdown voltage of the transformer windings. Multiple floating outputs are easily obtained with additional windings. A special delay network inside the LT1072 ignores the leakage inductance spike at the leading edge of the flyback pulse to improve output regulation.

The error signal developed at the comparator input is brought out externally. This pin (C) has four different functions. It is used for frequency compensation, current limit adjustment, soft starting, and total regulator shutdown. During normal regulator operation, this pin sits at a voltage between 0.9 V (low output current) and 2 V (high output current). The error amplifiers are current-output (g_m) types, so this voltage can be externally clamped for adjusting current limit. Likewise, a capacitor-coupled external clamp will provide soft start. Switch duty cycle goes to zero if the C pin is pulled to ground through a diode. This places the LT1072 in an idle mode. Pulling the C pin below 0.15 V causes total regulator shutdown, with only 50- μ A supply current for shutdown-circuitry biasing.

In the P package, the emitters of the power transistors are brought out separately from the ground pin. This eliminates errors due to ground-pin voltage drops and allows the user to reduce the switch-current limit (2:1) by leaving the second emitter (E2) disconnected. The first emitter (E1) should always be connected to the ground pin. Note that switch on-state resistance doubles when E2 is left open, so efficiency will suffer somewhat when switch currents exceed 100 mA. Also, note that chip dissipation will actually *increase* with E2 open during normal load operations, even though dissipation in current-limit mode will *decrease*.



LT1072, LT1072HV
1.25-A HIGH-EFFICIENCY SWITCHING REGULATORS

TYPICAL CHARACTERISTICS

table of graphs

| | | | FIGURE |
|---------------|---|---------------------------|---------------|
| P_{OM} | Maximum output power | vs Input voltage | 1 |
| V_{ref} | Reference voltage | vs Junction temperature | 2 |
| f | Switching frequency | vs Junction temperature | 2 |
| | Reference voltage change | vs Input voltage | 3 |
| I_{FB} | Feedback input current | vs Junction temperature | 4 |
| g_m | Error amplifier transconductance | vs Junction temperature | 5 |
| g_m | Error amplifier transconductance | vs Frequency | 6 |
| | Error amplifier phase shift | vs Frequency | 6 |
| I_C | Control current | vs Control voltage | 7 |
| $V_T(FB)$ | Normal/flyback mode threshold voltage | vs Junction temperature | 8 |
| I_{FB} | Feedback input current | vs Junction temperature | 8 |
| V_Z | Flyback reference voltage | vs Junction temperature | 9 |
| t_d | Flyback sense delay time | vs Junction temperature | 10 |
| $I_{O(SW)}$ | Switch output current (with switch off) | vs Switch voltage | 11 |
| | Driver base current | vs Switch output current | 12 |
| $V_{sat(SW)}$ | Switch saturation voltage | vs Switch output current | 13 |
| $I_{O(SW)}$ | Switch output current limit | vs Duty cycle | 14 |
| | Maximum duty cycle | vs Junction temperature | 15 |
| I_{IN} | Shutdown-mode input current | vs Control voltage | 16 |
| I_{IN} | Shutdown-mode input current | vs Input voltage | 17 |
| $V_T(C)$ | Shutdown-mode control threshold voltage | vs Junction temperature | 18 |
| $I_T(C)$ | Shutdown-mode control threshold current | vs Junction temperature | 18 |
| V_{FB} | Feedback input voltage at normal/flyback mode threshold | vs Feedback input current | 19 |
| | Minimum input voltage | vs Junction temperature | 20 |
| I_{IN} | Input current (SW output open) | vs Junction temperature | 21 |
| I_{IN} | Input current | vs Input voltage | 22 |

table of application circuits

| APPLICATION | FIGURE |
|-------------------------------|---------------|
| Totally isolated converter | 23 |
| Boost converter (5 V to 12 V) | 24 |

TYPICAL CHARACTERISTICS

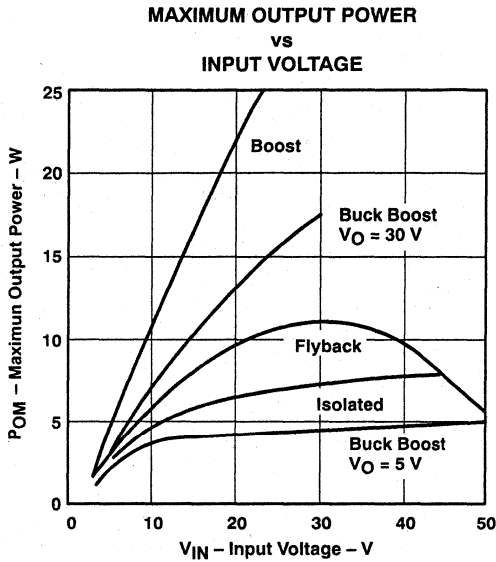


Figure 1

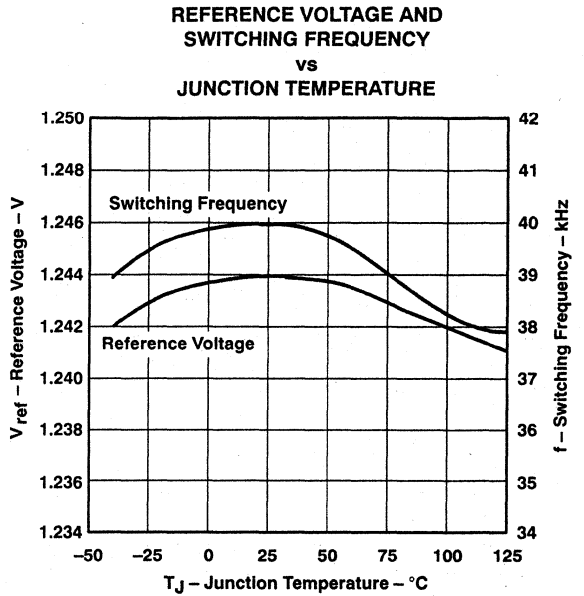


Figure 2

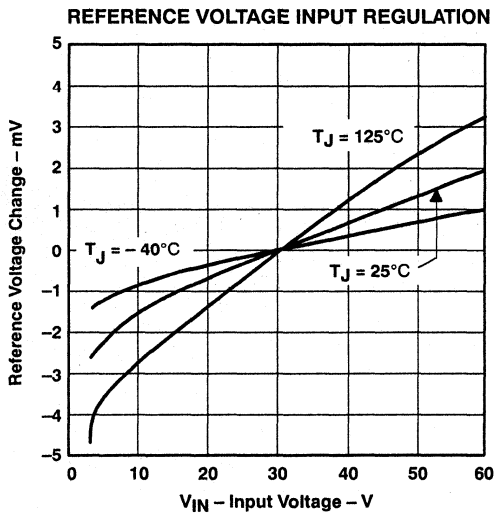


Figure 3

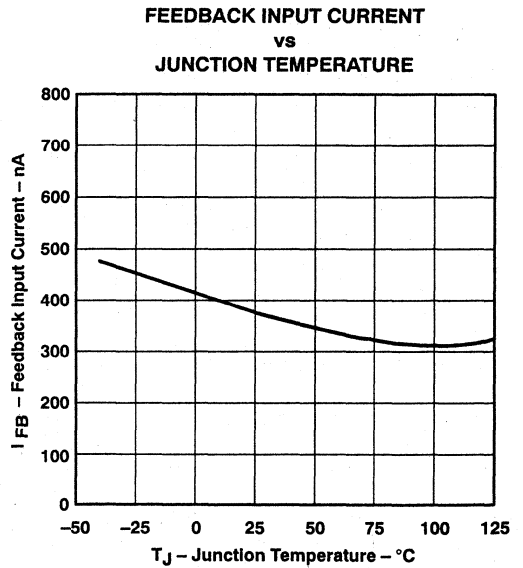


Figure 4

TYPICAL CHARACTERISTICS

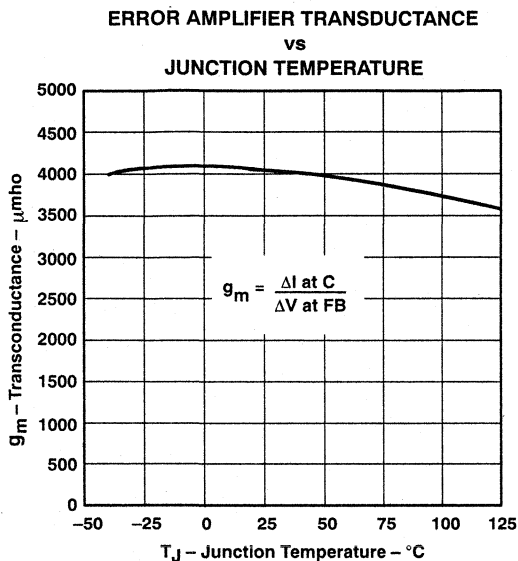


Figure 5

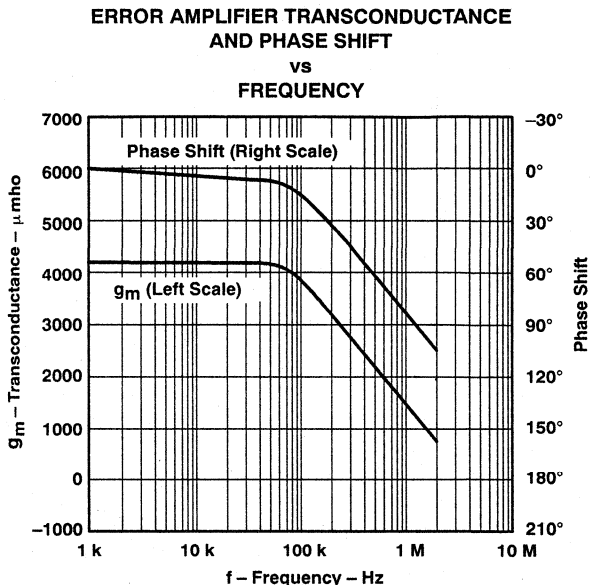


Figure 6

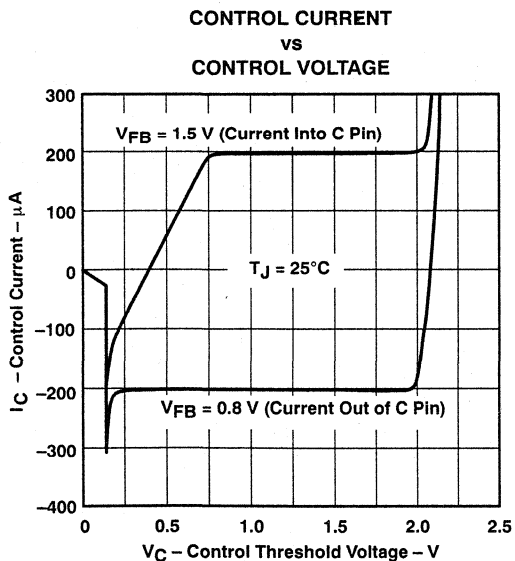


Figure 7

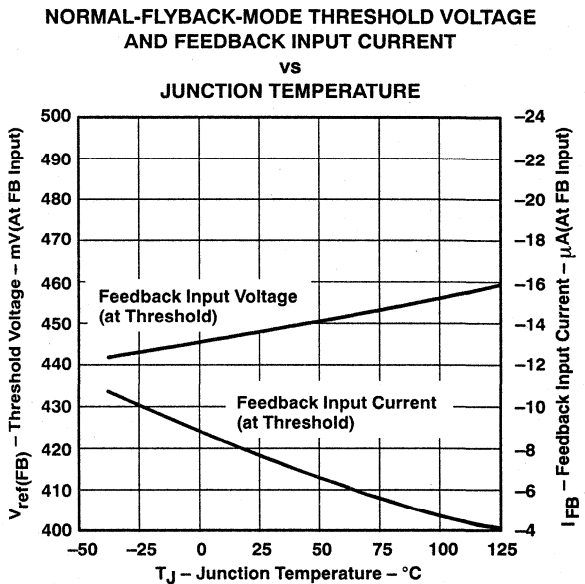


Figure 8

LT1072, LT1072HV
1.25-A HIGH-EFFICIENCY SWITCHING REGULATORS

TYPICAL CHARACTERISTICS

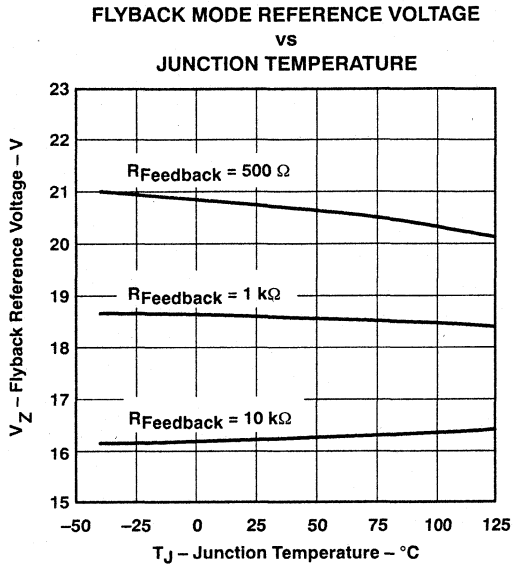


Figure 9

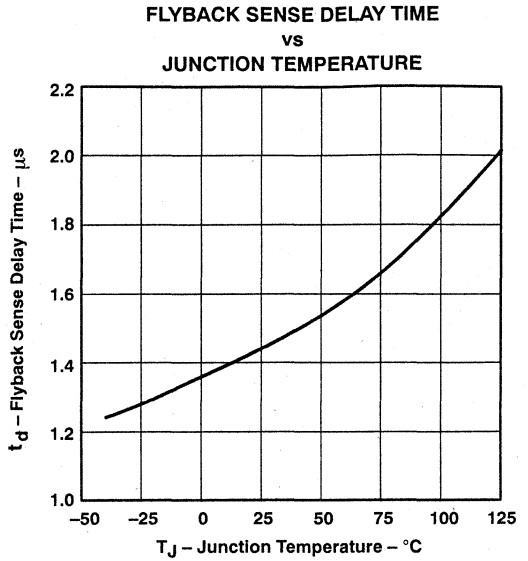


Figure 10

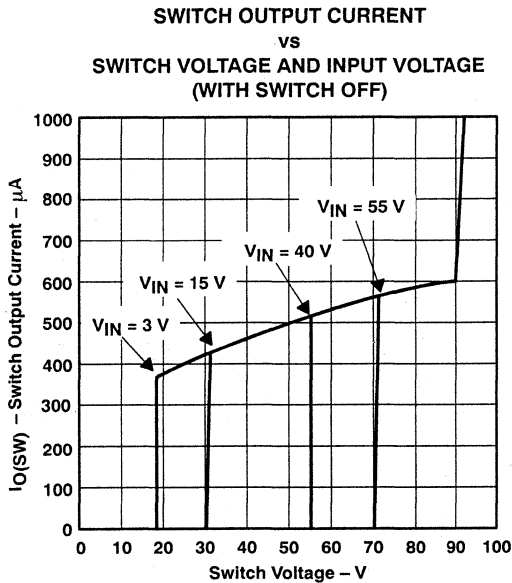


Figure 11

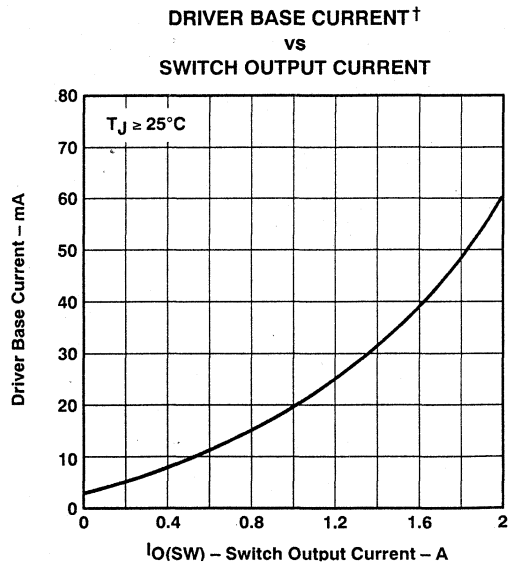


Figure 12

† Average input current is found by multiplying driver base by duty cycle plus quiescent current.

TYPICAL CHARACTERISTICS

SWITCH SATURATION VOLTAGE
vs
SWITCH CURRENT

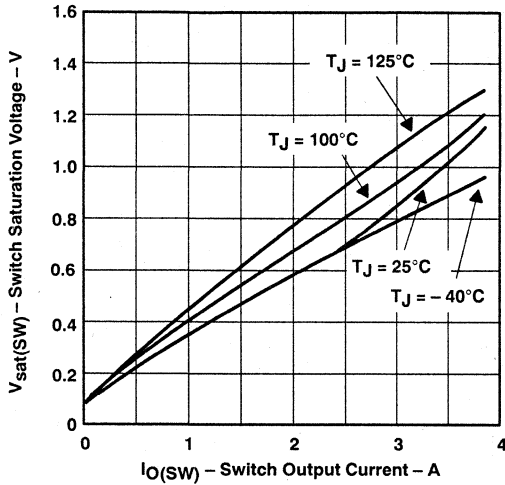


Figure 13

SWITCH OUTPUT CURRENT LIMIT
vs
DUTY CYCLE

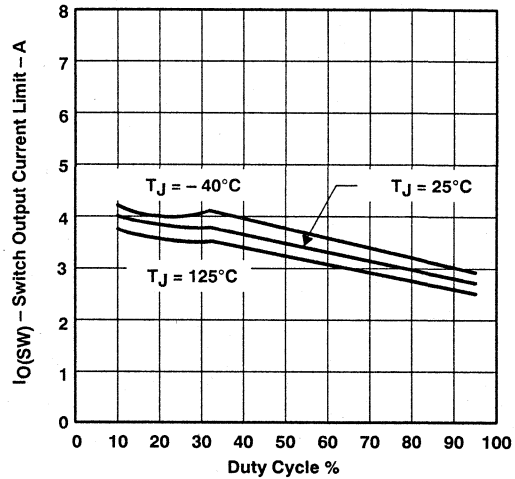


Figure 14

DUTY CYCLE (MAX)
vs
JUNCTION TEMPERATURE

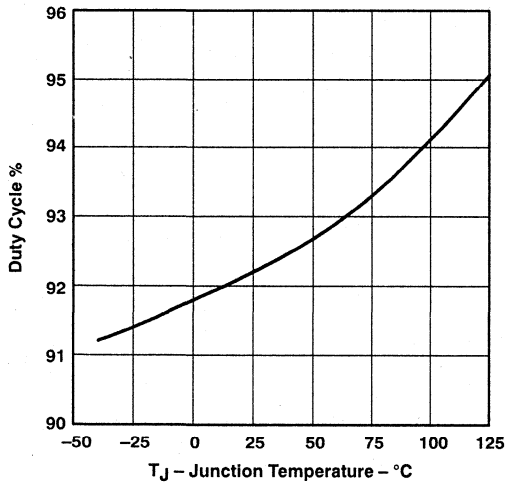


Figure 15

SHUTDOWN MODE
INPUT CURRENT
vs
CONTROL THRESHOLD VOLTAGE

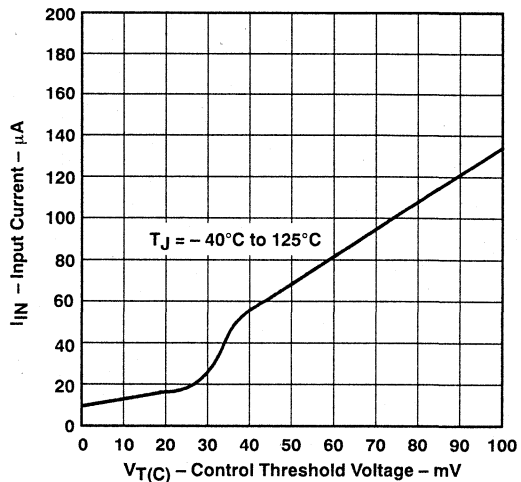


Figure 16

TYPICAL CHARACTERISTICS

SHUTDOWN MODE
INPUT CURRENT
vs
INPUT VOLTAGE

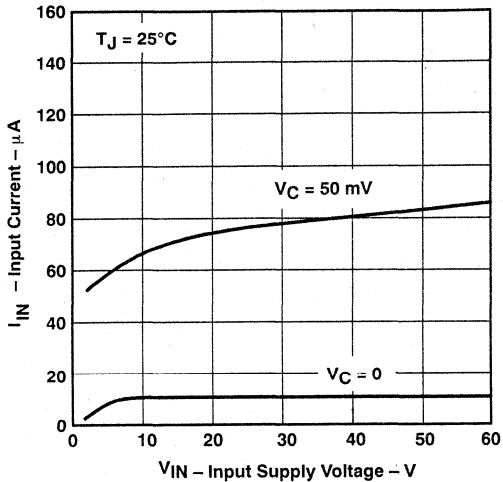


Figure 17

SHUTDOWN MODE
CONTROL THRESHOLD VOLTAGE AND CURRENT
vs
JUNCTION TEMPERATURE

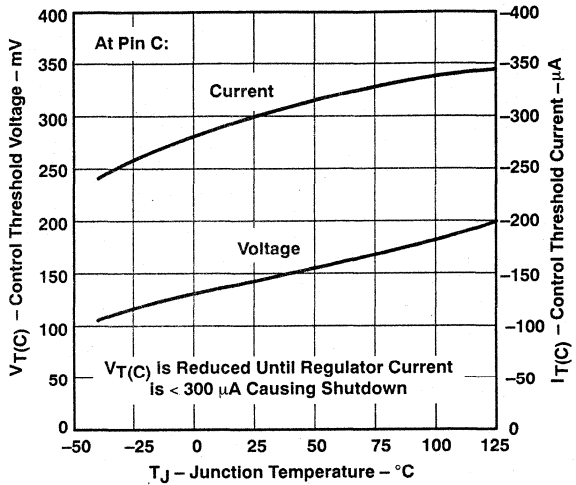


Figure 18

FEEDBACK INPUT VOLTAGE
vs
FEEDBACK INPUT CURRENT

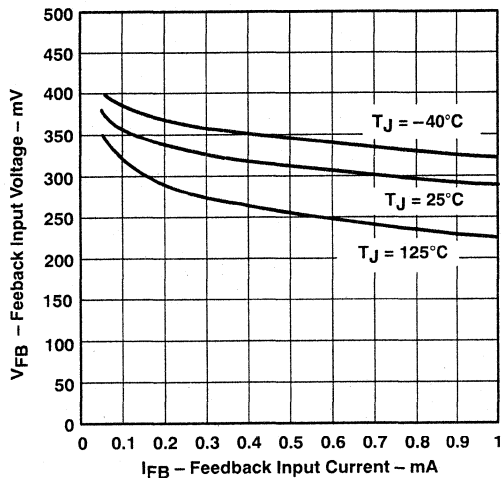


Figure 19

MINIMUM INPUT VOLTAGE
vs
JUNCTION TEMPERATURE

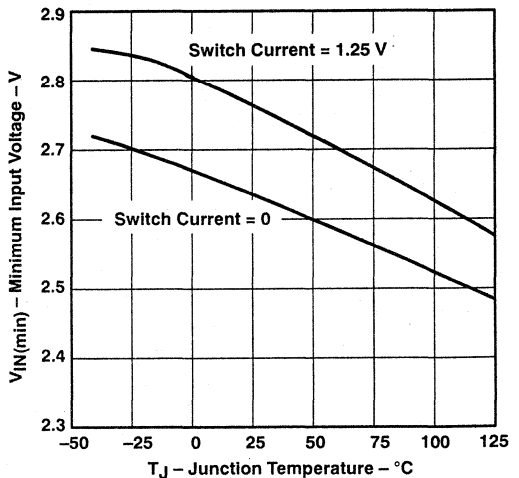


Figure 20

TYPICAL CHARACTERISTICS

INPUT CURRENT
vs
JUNCTION TEMPERATURE
(SW OUTPUT OPEN)

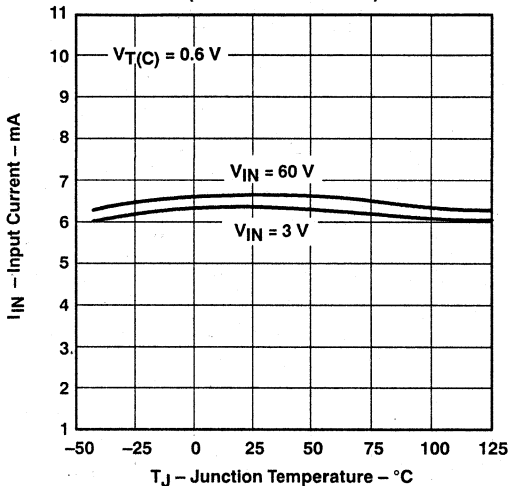
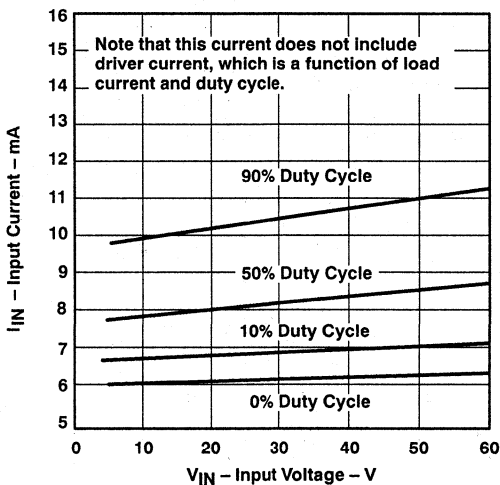


Figure 21

INPUT CURRENT
vs
INPUT VOLTAGE †



† Under very low output current conditions, duty cycle for most circuits will approach 10% or less.

Figure 22

LT1072, LT1072HV
1.25-A HIGH-EFFICIENCY SWITCHING REGULATORS

APPLICATION INFORMATION

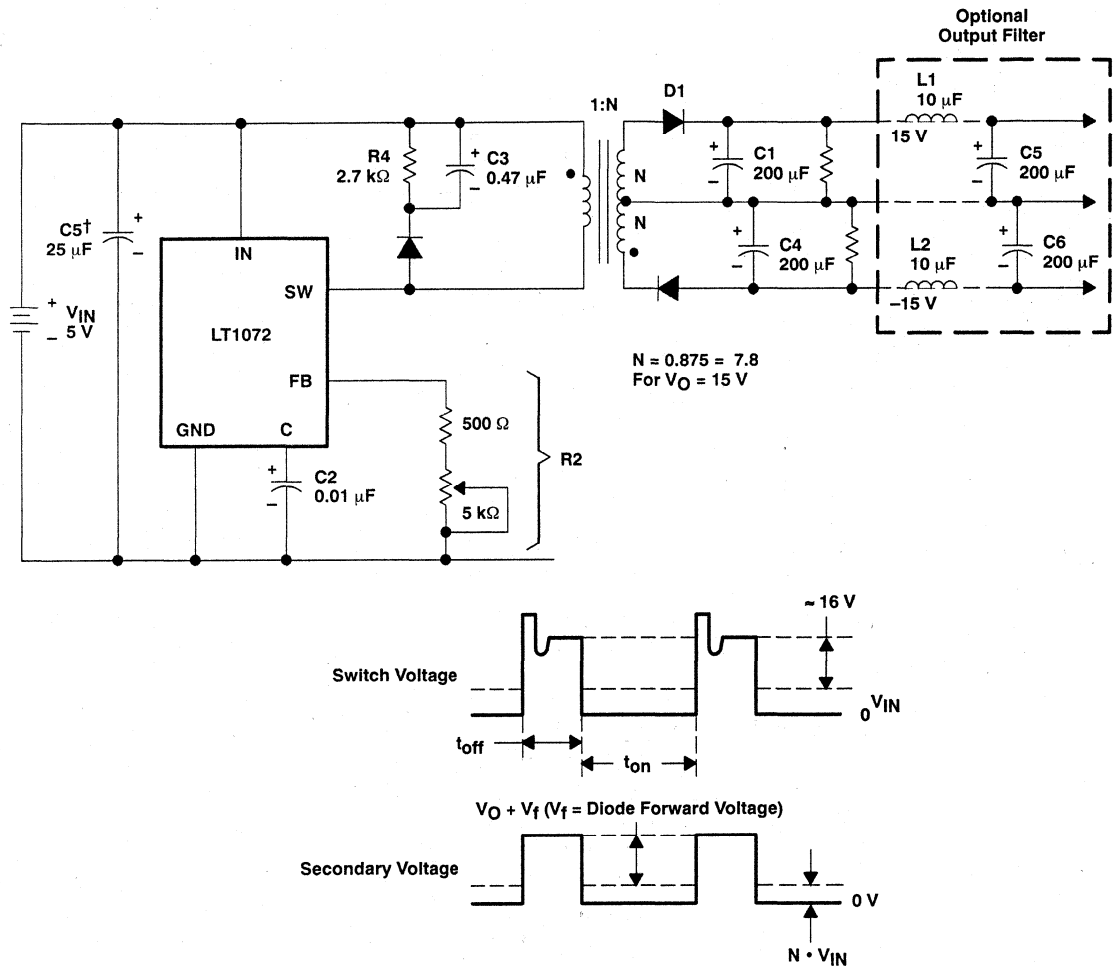
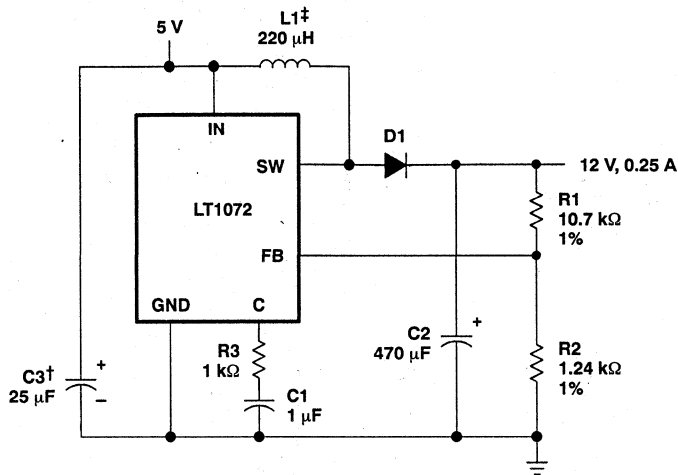


Figure 23. Totally Isolated Converter

APPLICATION INFORMATION



† Capacitor is required if input leads ≥ 2 inches.

‡ Pulse Engineering 52626

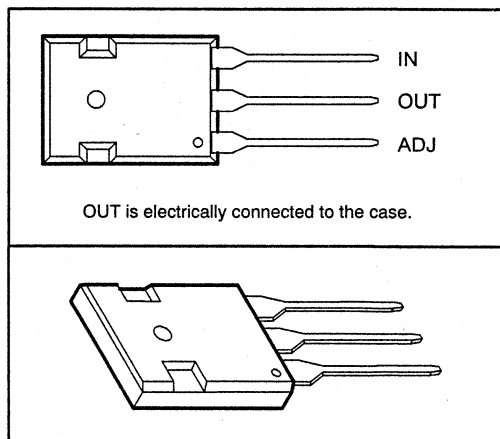
Figure 24. Boost Converter (5 V to 12 V)

LT1084C 5-A, LOW-DROPOUT, ADJUSTABLE POSITIVE REGULATOR

D3118, JULY 1988 -- REVISED JANUARY 1992

- Adjustable Output . . . 1 V to 35 V
- 5-A Output Capability
- Dropout Voltage
1.5 V at Maximum Current
1 V at Minimum Current
- Input Regulation . . . 0.015% Typ
- Output Regulation . . . 0.01% Typ
- 100% Thermal Limit Burn-In

KK PACKAGE
(TOP VIEW)



description

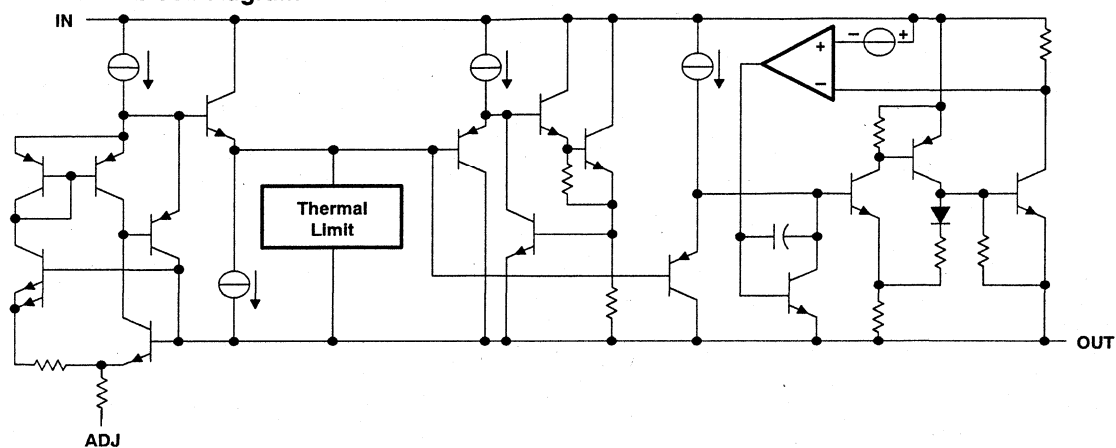
The LT1084C is a 3-terminal low-dropout adjustable positive regulator that operates with higher efficiency than currently available devices with output loads up to 5 A. Internal circuitry is designed to operate with a small input-to-output differential voltage of 1.3 V (typical) and all dropout voltages are specified as a function of output current. Dropout voltage reaches a maximum of 1.5 V at maximum output current. On-chip circuitry holds the reference voltage constant to within 1%. Current limiting is used to minimize the stress on both the regulator and power source circuits under overload conditions.

The LT1084C is terminal compatible with older 3-terminal regulators. A 10- μ F output capacitor is required, as in most regulator designs. In P-N-P regulators, up to 10% of the output current is lost as bias (quiescent) current, but the LT1084C bias current flows into the load, which improves power efficiency.

Typical applications include high-efficiency linear regulators, post regulators for switching power supplies, constant-current regulators, and battery chargers.

LT1084C
5-A, LOW-DROPOUT, ADJUSTABLE POSITIVE REGULATOR

functional block diagram



absolute maximum ratings over operating temperature range (unless otherwise noted)

| | |
|---|-------------------------|
| Input-to-output differential voltage | 30 V |
| Output current, I_O | 8 A |
| Power dissipation | Internally self-limited |
| Operating virtual-junction temperature range: Control section | 0°C to 125°C |
| Power transistor | 0°C to 150°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

recommended operating conditions

| | MIN | MAX | UNIT |
|---|------------------|-----|------|
| Output current, I_O | | 5 | A |
| Operating virtual-junction temperature, T_J | Control section | 0 | 125 |
| | Power transistor | 0 | 150 |



LT1084C

5-A, LOW-DROPOUT, ADJUSTABLE POSITIVE REGULATOR

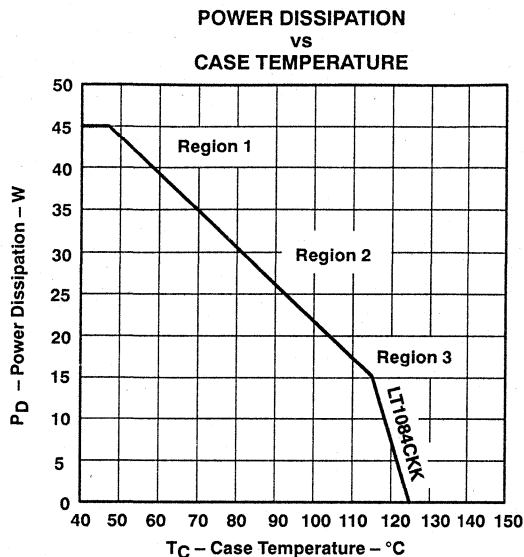
electrical characteristics at specified virtual-junction temperature (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T _J [†] | MIN | TYP | MAX | UNIT |
|--|---|-----------------------------|-------|--------|-------|------|
| | | | | | | |
| Input regulation | V _I - V _O = 1.5 V to 15 V, I _O = 10 mA | 25°C | | 0.015% | 0.2% | |
| | | Full range | | 0.035% | 0.2% | |
| | V _I - V _O = 15 V to 30 V, See Notes 1 and 2 | Full range | | 0.05% | 0.5% | |
| Ripple rejection | V _I - V _O = 3 V, f = 120 Hz, I _O = 5 A (full load), See Notes 3 and 4 | Full range | 60 | 75 | | dB |
| Output regulation | V _I - V _O = 3 V, I _O = 10 mA to 5 A (full load), See Notes 1, 2, and 3 | 25°C | | 0.1% | 0.3% | |
| | | Full range | | 0.2% | 0.4% | |
| Output voltage change with temperature | | Full range | | 0.5% | | |
| Thermal regulation | t _w = 30 ms | T _A = 25°C | | 0.003 | 0.015 | %/W |
| Output voltage long-term drift | After 1000 hours at T _J = 125°C | 25°C | | 0.3% | 1% | |
| Output noise voltage (% of V _O) | f = 10 Hz to 10 kHz | 25°C | | 0.003% | | |
| Minimum output operating current | V _I - V _O = 25 V | Full range | | 5 | 10 | mA |
| Current limit | V _I - V _O = 5 V | Full range | | 5.5 | 6.5 | A |
| | V _I - V _O = 25 V | | | 0.3 | 0.6 | |
| Dropout voltage | ΔV _{ref} = 1%, I _O = full load | Full range | | 1.3 | 1.5 | V |
| ADJ current | | 25°C | | 55 | | μA |
| | | Full range | | | 120 | |
| Change in ADJ current | V _I - V _O = 1.5 V to 25 V, I _O = 10 mA to 5 A (full load), See Note 3 | Full range | | 0.2 | 5 | μA |
| Reference voltage, V _O - V _{ADJ} | V _I - V _O = 1.5 V to 25 V, I _O = 10 mA to 5 A (full load), See Note 3 | Full range | 1.225 | 1.250 | 1.270 | V |

[†] Full range is 0°C to 125°C.

- NOTES: 1. Input regulation is expressed as the percentage change in output voltage per 1-V change at the input. See thermal regulation specifications for changes in output voltage due to heating effects. Input and output regulation are measured at a constant junction temperature by low-duty-cycle pulse testing. Use pulses (t_w ≤ 10 μs, duty cycle ≤ 5%) to limit changes in average internal dissipation. Output voltage changes due to large changes in internal dissipation must be taken into account separately.
2. Input and output regulation are specified up to the maximum power dissipation of 45 W. Power dissipation is determined by the product of input-to-output differential voltage and output current. Maximum power dissipation is not available over the full input-to-output voltage range. See Figure 2.
3. I_O (full load) is defined on the current-limit graph (Figure 2) as the minimum value of current limiting as a function of input-to-output differential voltage. Note that 45-W power dissipation is achievable, but only over a limited range of input-to-output differential voltage.
4. Ripple rejection is measured with a 25-μF capacitor between ADJ and ground and a 25-μF tantalum capacitor between OUT and ground.

TYPICAL CHARACTERISTICS



Region 1 is limited by the full load current, see Figure 2 and Notes 2 and 3.

Region 2 is limited by the maximum junction temperature of the power transistor. The slope is based on the thermal resistance $R_{\theta JC}$, which is 2.3°C/W .

Region 3 is limited by the maximum junction temperature of the control section. The slope is based on the thermal resistance $R_{\theta JC}$, which is 0.65°C/W .

Figure 1

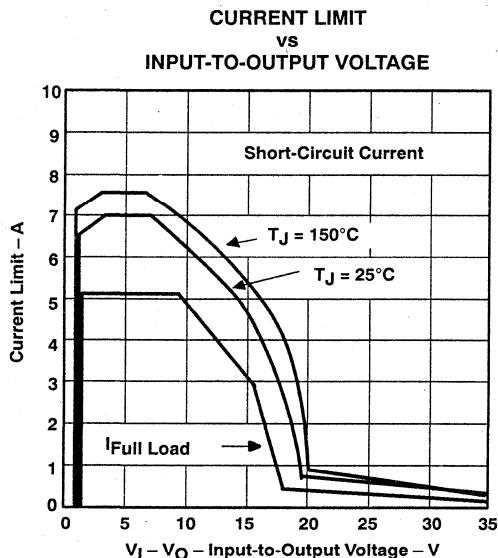


Figure 2

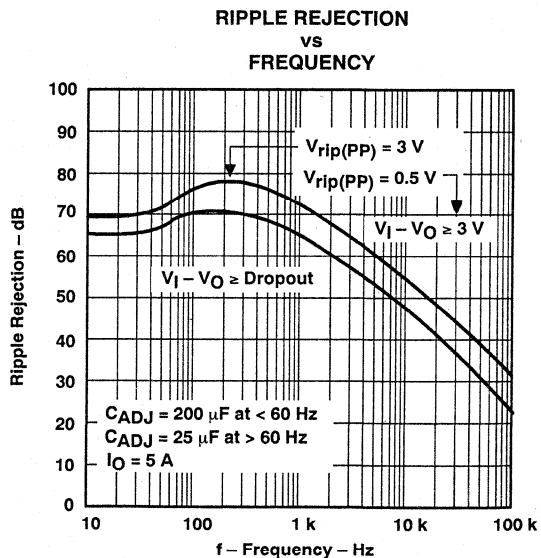


Figure 3

TYPICAL CHARACTERISTICS

RIPPLE REJECTION
 vs
 OUTPUT CURRENT

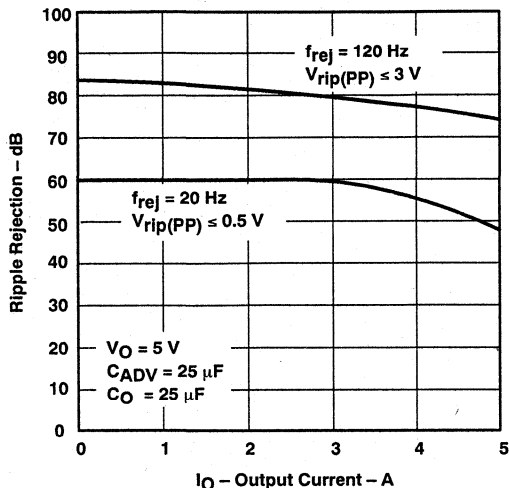


Figure 4

OUTPUT REGULATION
 vs
 JUNCTION TEMPERATURE

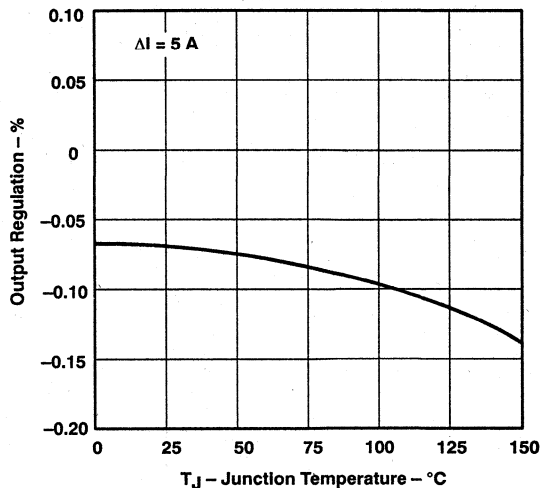


Figure 5

MINIMUM OPERATING CURRENT
 vs
 INPUT-TO-OUTPUT VOLTAGE

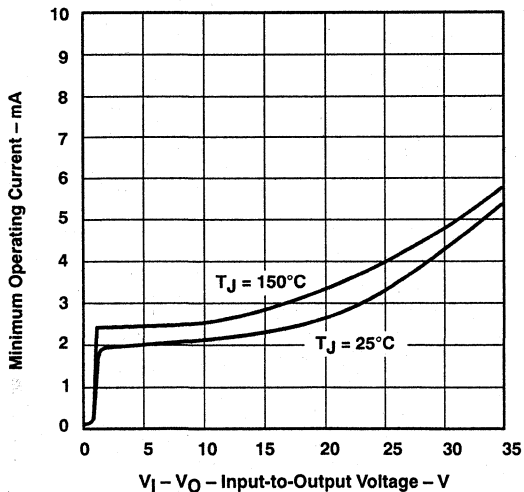


Figure 6

DROPOUT VOLTAGE
 vs
 OUTPUT CURRENT

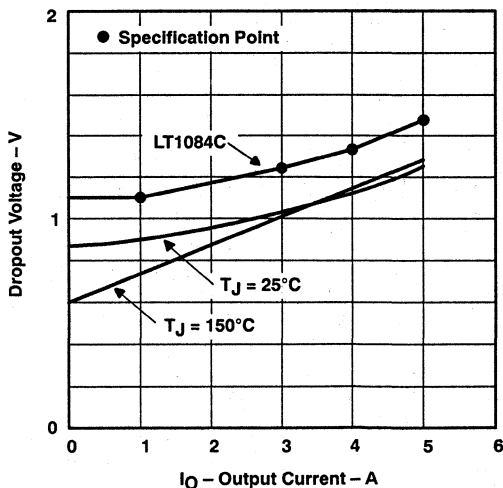


Figure 7

TYPICAL CHARACTERISTICS

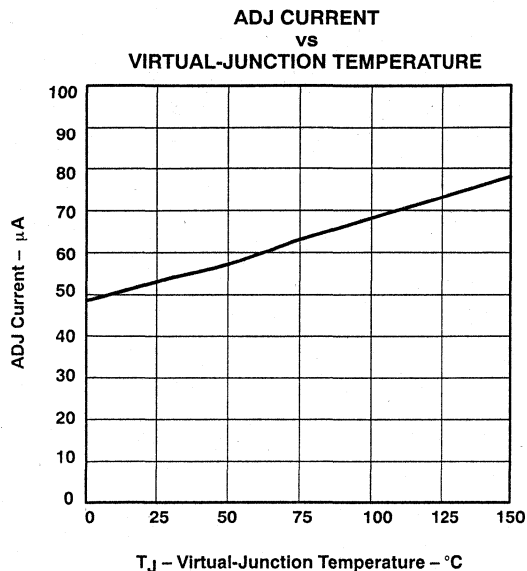


Figure 8

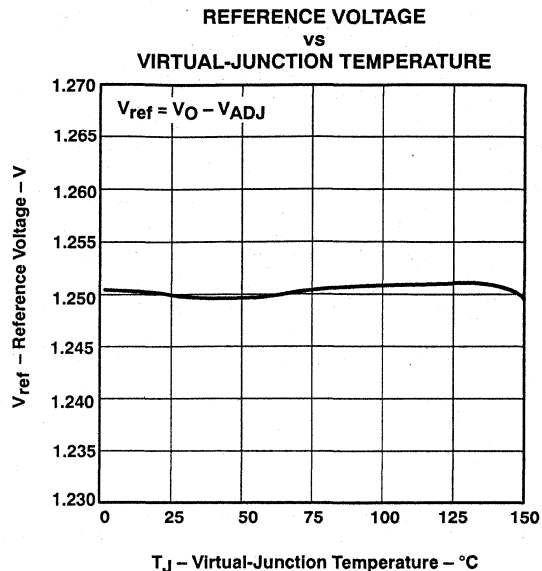


Figure 9

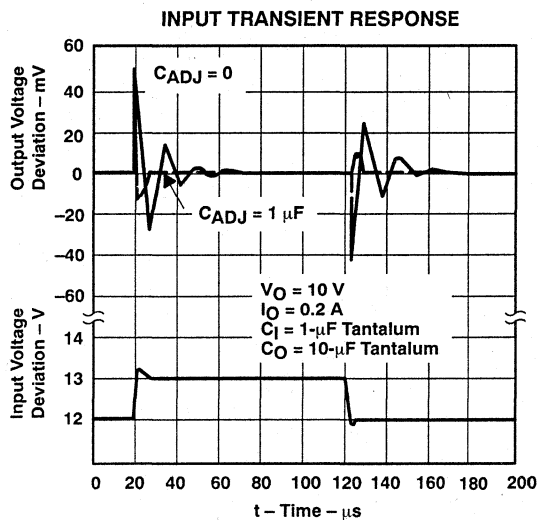


Figure 10

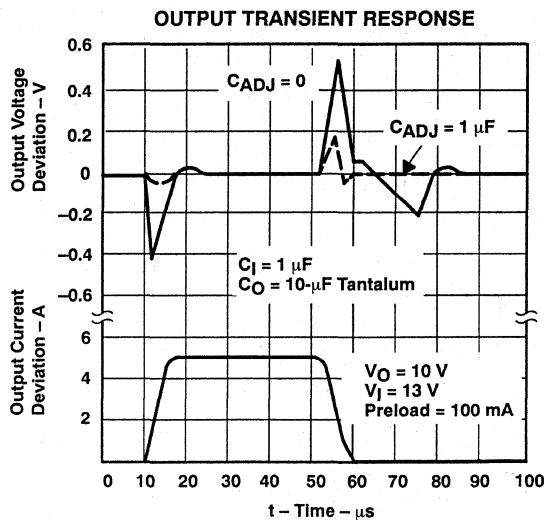


Figure 11

APPLICATION INFORMATION

The LT1084C 3-terminal adjustable regulator is easy to use and has all the protection features that are expected in high-performance voltage regulators. It is short-circuit protected. Safe-area protection and thermal shutdown turn off the regulator when the junction temperature exceeds approximately 165°C.

The regulator is terminal compatible with older 3-terminal adjustable devices and offers lower dropout voltage and voltage reference tolerance. The reference voltage-versus-temperature stability is improved. The only circuit difference between using the LT1084C and older regulators is the need for an output capacitor for more stability.

stability

The circuit design used in the LT1084C requires the use of an output capacitor as part of the device frequency compensation. For all operating conditions, the addition of 150- μ F aluminum electrolytic or a 22- μ F solid tantalum capacitor on the output ensures stability. Typically, capacitors that are much smaller in value can be used with the LT1084C. Many different types of capacitors, with widely varying characteristics, are available that differ in capacitor tolerance (up to plus or minus 100%), equivalent series resistance, and capacitor temperature coefficient. The 150- μ F or 22- μ F values will ensure stability.

When ADJ bypassed to improve ripple rejection, the requirement for an output capacitor increases. The 22- μ F tantalum or 150- μ F electrolytic capacitor values cover all cases of bypassing ADJ. Without bypassing ADJ, smaller capacitors can be used with good results. The recommended capacitors needed to ensure stability are listed in the following table:

RECOMMENDED OUTPUT CAPACITOR VALUES

| IN | OUT | ADJ |
|------------|---|------------|
| 10 μ F | 10- μ F Tantalum or 50- μ F Aluminum | None |
| 10 μ F | 22- μ F Tantalum or 150- μ F Aluminum | 20 μ F |

Typically, capacitor values of 100 μ F are used on the output of many regulators to ensure good transient response with large load-current changes. Output capacitance can be increased without limit to improve the stability and transient response of the LT1084C regulator.

Another stability problem that can occur in monolithic regulators is current-limit oscillations. This problem occurs during current limiting when the safe-area protection exhibits a negative impedance. The safe-area protection decreases the current limit as the input-to-output voltage increases. This acts as a negative resistance since increasing voltage causes current to decrease. Negative resistance during current limiting is not unique to the LT1084C and is present on all power IC regulators. The value of negative resistance is a function of how fast the current limit is folded back as input-to-output voltage increases. This negative resistance can react with capacitors or inductors on the input to cause oscillation during current limiting. Depending on the value of series resistance, the overall circuitry may be unstable. This system problem is not necessarily easy to solve; however, it does not cause any problems with the IC regulator and can usually be ignored.

protection diodes

In normal operation, the LT1084C does not need any protection diodes. Older adjustable regulators required protection diodes between ADJ and OUT and from OUT to IN to prevent overstressing the IC. The internal current paths on the LT1084C ADJ are limited by the internal resistors. Therefore, no protection diode is needed to ensure device safety under short-circuit conditions even with capacitors on ADJ. See Figure 12.

LT1084C

5-A, LOW-DROPOUT, ADJUSTABLE POSITIVE REGULATOR

APPLICATION INFORMATION

Diodes between IN and OUT are usually not needed. The internal diode between IN and OUT of the LT1084C can handle microsecond surge currents of 50 A to 100 A. Even with large output capacitances, it is difficult to obtain those values of surge currents in normal operations. Damage can occur only when using high values of output capacitance (1000 μF to 5000 μF) with IN instantaneously shorted to ground. A crowbar circuit at IN can generate those kinds of currents, and a diode from output-to-input is then recommended. Normal power supply on-off cycling or even connecting and disconnecting in the system will not generate a large enough current to cause damage. ADJ can be driven, on a transient basis, plus or minus 25 V with respect to OUT without device degradation. As with any IC regulator, exceeding the maximum input-to-output differential voltage causes the internal transistors to break down, and the protection circuitry does not prevent this.

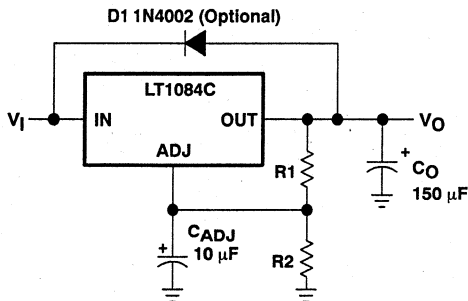


Figure 12

overload recovery

The LT1084C regulator has safe-area protection that decreases the current limit as input-to-output voltage increases, so the power transistor operates inside a safe region for all values of input-to-output voltage. This protection is designed to provide some output current at all values of input-to-output voltage up to the device breakdown.

When power is turned on and IN voltage rises, the OUT follows IN and the input-to-output differential voltage remains small to allow a large current demand on the regulator to be supplied. With high input voltage and low output voltage, a problem occurs that is common to older regulators (such as the 7800 series) as well as the LT1084C. OUT voltage will not recover after removal of an output short. The load line for such a large load may intersect the OUT current curve at two points. If this happens, there are two stable OUT operating points for the regulator. With a double intersection, the power supply may need to be cycled to zero and brought up again to make OUT recover.

ripple rejection

The typical curves for ripple rejection reflect values for a bypassed ADJ. This curve will be true for all values of output voltage. For proper bypassing and ripple rejection near the values shown, the impedance of the ADJ capacitor at the ripple frequency should equal the value of resistor R_1 (normally 100 Ω to 120 Ω). The capacitance of the required ADJ capacitor is a function of the input ripple frequency. The ADJ capacitor should be 13 μF with R_1 equal to 100 Ω at a frequency of 120 Hz. Only 0.16 μF is needed at 10 kHz. See Figure 16.

APPLICATION INFORMATION

Ripple rejection is a function of OUT voltage for circuits without an ADJ bypass capacitor. The output ripple will increase directly as a ratio of the OUT voltage to the reference voltage (V_O/V_{ref}). For example, the output ripple will be higher by the ratio of 5 V/1.25 V or four times larger with OUT voltage equal to 5 V and with no ADJ capacitor. Ripple rejection would be degraded 12 dB from the value shown on the typical curve.

output voltage

The LT1084C develops a 1.25-V reference voltage between OUT and ADJ (see Figure 13). When resistor R1 is placed between these two terminals, a constant current flows through R1 and through R2 to set the overall OUT voltage. Normally this current is the specified minimum output current of 10 mA. Since I_{ADJ} is very small and constant when compared with the current through R1, I_{ADJ} can usually be ignored and represents a small error.

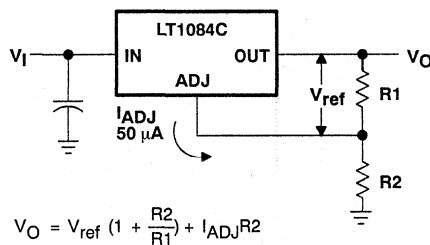


Figure 13

output regulation

The LT1084C is not able to provide true remote-load sensing with only three terminals. Output regulation will be limited by the resistance of the wire connecting the regulator to the load. The data-sheet specification for output regulation is measured at the bottom of the package. Negative-side sensing is a true Kelvin connection that has the bottom of the output divider returned to the negative side of the load. The best output regulation is obtained when the top of the resistor divider R1 is connected directly to the case or OUT, not to the load. This is illustrated in Figure 14. If resistor R1 were connected to the load, the effective resistance between the regulator and the load would be as shown:

$$R_{eff} = R_P \times (R_2 + R_1)/R_1$$

Assuming $R_P = 0.004 \Omega$ per foot (16-gauge wire), this calculation gives 4 mV per foot at a load current of 1 A. It is important to keep the positive lead between regulator and load as short as possible and use large wire or circuit-board traces to minimize this problem. Connected as shown in Figure 14, R_P is not multiplied by the divider ratio.

thermal considerations

The LT1084C regulator has internal power and thermal-limiting circuitry designed to protect the device under overload conditions. For continuous normal-load conditions, maximum junction temperature ratings must not be exceeded. It is important to give careful consideration to all sources of thermal resistance from device junction to ambient. This includes junction-to-case, case-to-heat-sink interface, and heat-sink resistance. New

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thermal-resistance specifications have been developed to more accurately reflect device temperature and ensure safe operating temperatures. The maximum ratings table and the explanation with Figure 1 provide maximum junction temperature and thermal resistance for the control section and separately for the power transistor. Previous regulators used a single junction-to-case thermal resistance specification that was an average of the two values. This method could allow excessive junction temperatures under certain conditions of ambient temperature and heat-sink resistance. To avoid this possibility, calculations should be made for both sections of the device to ensure that both thermal limits are met.

Junction-to-case thermal resistance is specified from the IC junction to the bottom of the case directly below the die. This is the lowest resistance path for heat flow. Proper mounting is required to ensure the best possible thermal flow from this area of the package to the heat sink. Thermal compound at the case-to-heat-sink interface is strongly recommended. If the case of the device must be electrically isolated, a thermally-conductive spacer can be used, but the added contribution to thermal resistance must be considered. The KK package is electrically connected to OUT.

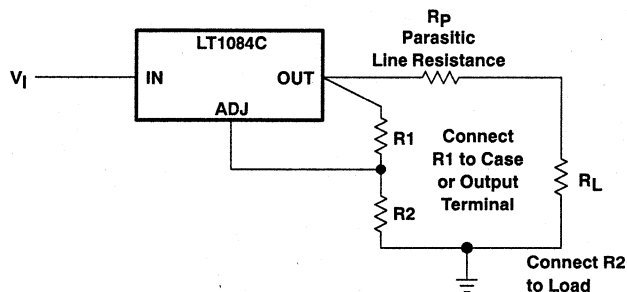


Figure 14

thermal example

Using an LT1084CCKK regulator (KK plastic package and commercial temperature) and assuming:

$$V_I = 9 \text{ V (maximum continuous)}, V_O = 5 \text{ V}, I_O = 5 \text{ A},$$

$$T_A = 75^\circ\text{C}, R_{\theta\text{HSA}} = 1^\circ\text{C/W}, R_{\theta\text{CHS}} = 0.2^\circ\text{C/W}$$

Maximum thermal resistances: (see Figure 1)

$$\text{Control section } R_{\theta\text{JC}} = 0.65^\circ\text{C/W},$$

$$\text{Power transistor } R_{\theta\text{JC}} = 2.3^\circ\text{C/W}$$

Power dissipation under these conditions is equal to:

$$P_D = (V_I - V_O) (I_O) = (9 - 5) (5) = 20 \text{ W}$$

Junction temperature is calculated using:

$$T_J = T_A + P_D(R_{\theta\text{HSA}} + R_{\theta\text{CHS}} + R_{\theta\text{JC}})$$

Junction temperature for control section:

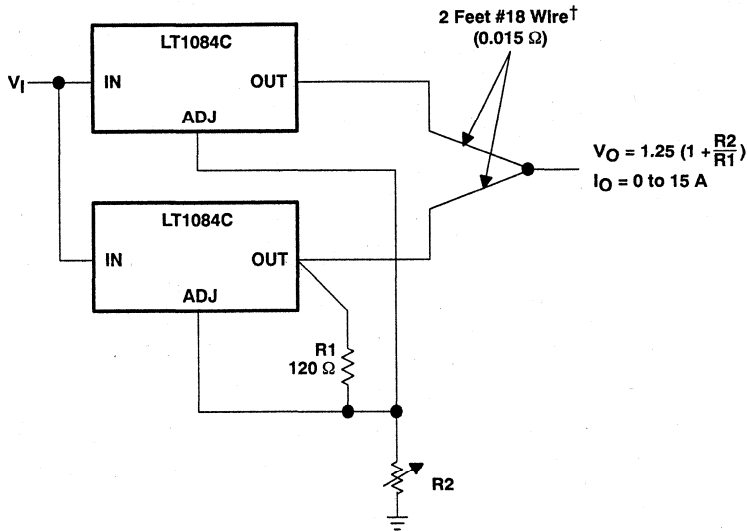
$$T_J = 75 + 20(1 + 0.2 + 0.65) = 112^\circ\text{C}$$

Junction temperature for power transistor:

$$T_J = 75 + 20(1 + 0.2 + 2.3) = 145^\circ\text{C}$$

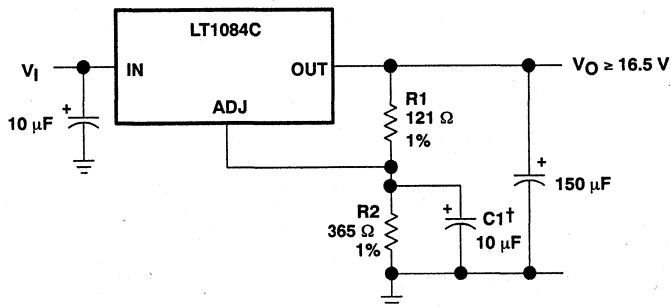
In both cases, the junction temperature is below the maximum rating for the respective sections.

APPLICATION INFORMATION



† The # 18 wire acts as ballast resistance, insuring current sharing between both devices.

Figure 15. Paralleling Regulators



† C1 improves ripple rejection. X_C should be equal to R_1 at ripple frequency.

Figure 16. Improving Ripple Rejection

LT1084C
5-A, LOW-DROPOUT, ADJUSTABLE POSITIVE REGULATOR

APPLICATION INFORMATION

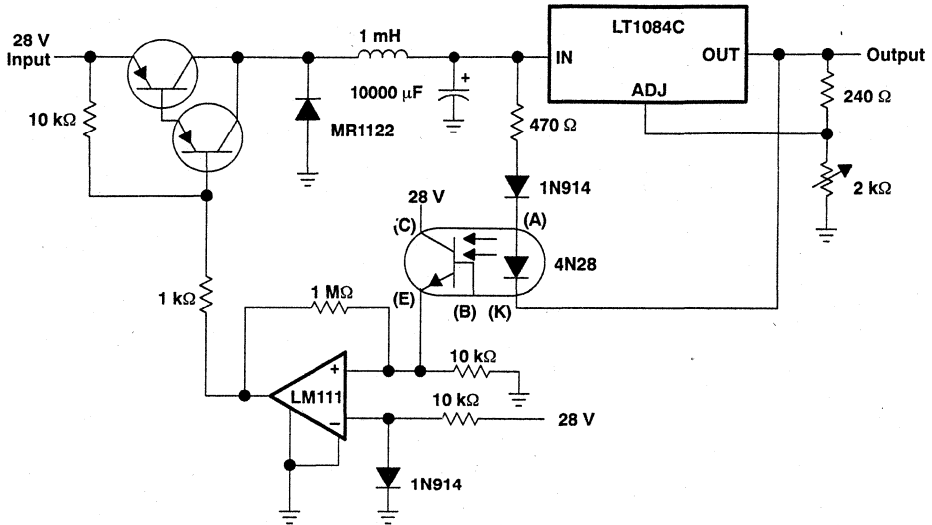


Figure 17. High-Efficiency Regulator

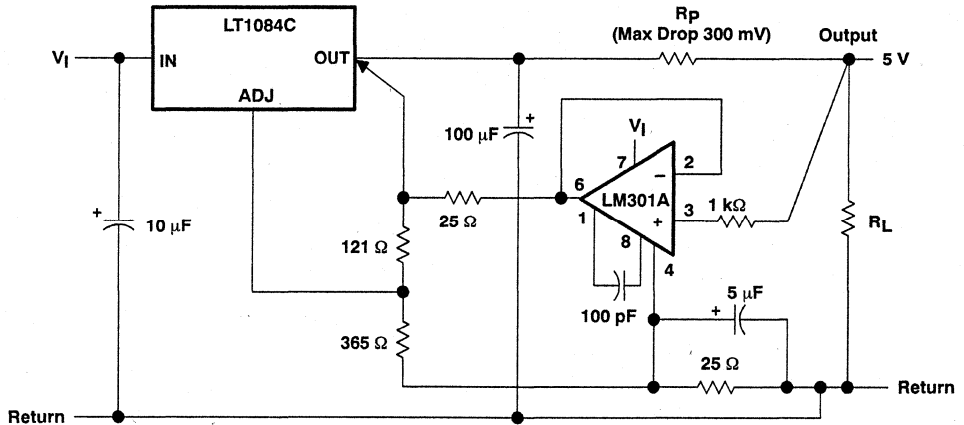
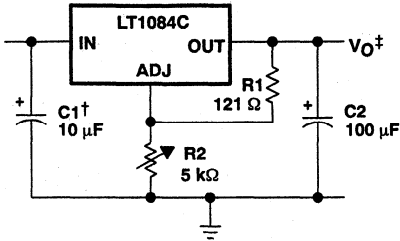


Figure 18. Remote Sensing

APPLICATION INFORMATION



† Needed if device is far from filter capacitors.

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

Figure 19. 1.2-V to 15-V Adjustable Regulator

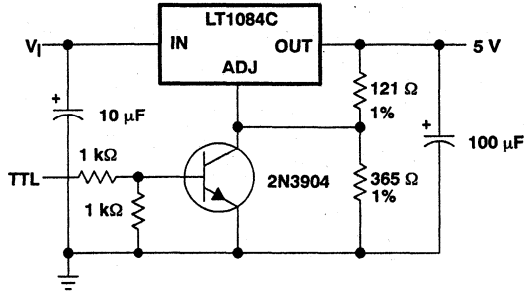


Figure 20. 5-V Regulator With Shutdown

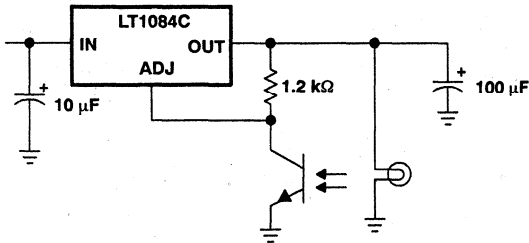


Figure 21. Automatic Light Control

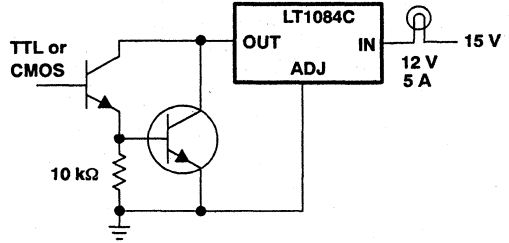


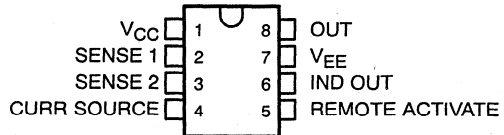
Figure 22. Protected High-Current Lamp Driver

MC3423 OVERVOLTAGE-SENSING CIRCUIT

D2439, APRIL 1978—REVISED MARCH 1988

- Separate Outputs for Crowbar and Logic Circuitry
- Programmable Time Delay to Eliminate Noise Triggering
- TTL-Level Activation Isolated From Voltage-Sensing Inputs
- 2.6-V Internal Voltage Reference With Temperature Coefficient Typically 0.06%/°C

D OR P PACKAGE
(TOP VIEW)

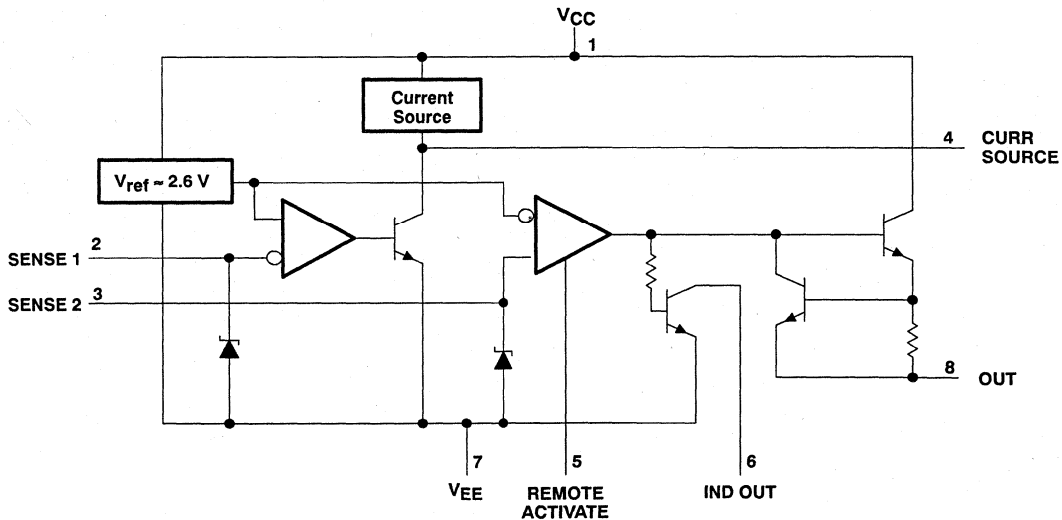


description

The MC3423 overvoltage-sensing circuit is designed to protect sensitive electronic circuitry by monitoring the supply rail and triggering an external crowbar SCR in the event of a voltage transient or loss of regulation. The protective mechanism may be activated by an overvoltage condition at the SENSE 2 input or by application of a TTL-high level to REMOTE ACTIVATE. Separate outputs are available to trigger the crowbar circuit and to provide a logic pulse to indicator or power supply control circuitry. The SENSE 2 input provides a direct control of the output circuitry. The SENSE 1 input controls an internal current source that may be utilized to implement a delayed trigger by connecting its output to an external capacitor and the SENSE 2 input. This protects against false triggering due to noise at the SENSE 1 input.

The MC3423 is characterized for operation from 0°C to 70°C.

functional block diagram



PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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OVERVOLTAGE-SENSING CIRCUIT

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Supply voltage, V_{CC} (see Note 1) | 40 V |
| Input voltage, SENSE 1 | 6.5 V |
| Input voltage, SENSE 2 | 6.5 V |
| Input voltage, REMOTE ACTIVATE | 7 V |
| Output current, I_O | 300 mA |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range | 0°C to 70°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 1: Voltage values are measured with respect to the V_{EE} terminal.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | OPERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$ | $T_A = 70^\circ\text{C}$ POWER RATING |
|---------|---|--|--|
| D | 725 mW | 5.8 mW/°C | 464 mW |
| P | 1000 mW | 8.0 mW/°C | 640 mW |

recommended operating conditions

| | MIN | MAX | UNIT |
|---|-----|-----|------|
| Supply voltage, V_{CC} | 4.5 | 40 | V |
| High-level input voltage, REMOTE ACTIVATE | 2 | | V |
| Low-level input voltage, REMOTE ACTIVATE | | 0.5 | V |

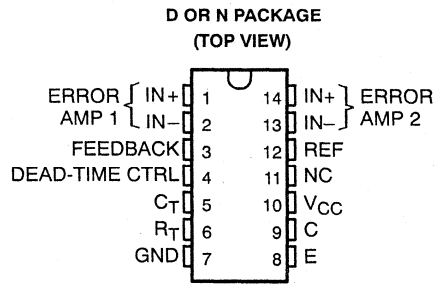
electrical characteristics over operating free-air temperature range, $V_{CC} = 5\text{ V to }36\text{ V}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|--|--------------|--------------|------|-------------------|
| Output voltage | REMOTE ACTIVATE input voltage at 2 V, $I_O = 100\text{ mA}$ | $V_{CC}-2.2$ | $V_{CC}-1.8$ | | V |
| Indicator low-level output voltage | REMOTE ACTIVATE input voltage at 2 V, $I_O = 1.6\text{ mA}$ | | 0.1 | 0.4 | V |
| Threshold voltage of either sense input | $T_A = 25^\circ\text{C}$ | 2.45 | 2.6 | 2.75 | V |
| Temperature coefficient of input threshold voltage | | | 0.06 | | %/°C |
| I_O Output current, CURR SOURCE | SENSE 1 input voltage at 3 V, CURR SOURCE input voltage at 1.3 V | 0.1 | 0.22 | 0.3 | mA |
| High-level input current, REMOTE ACTIVATE | $V_{CC} = 5\text{ V}$, $V_I = 2\text{ V}$ | | 5 | 40 | μA |
| Low-level input current, REMOTE ACTIVATE | $V_{CC} = 5\text{ V}$, $V_I = 0.8\text{ V}$ | | -120 | -180 | μA |
| Supply current | Outputs open | | 6 | 10 | mA |
| Propagation delay time, REMOTE ACTIVATE to output | $T_A = 25^\circ\text{C}$ | | 0.5 | | μs |
| Output current rate of rise | $T_A = 25^\circ\text{C}$ | | 400 | | mA/ μs |

MC34060 PULSE-WIDTH-MODULATION CONTROL CIRCUIT

D2714, MARCH 1983—REVISED FEBRUARY 1988

- Complete PWM Power Control Circuitry
- Uncommitted Output for 200-mA Sink or Source Current
- Variable Dead Time Provides Control Over Total Range
- Internal Regulator Provides a Stable 5-V Reference Supply
- Circuit Architecture Provides Easy Synchronization
- Direct Replacement for Motorola MC34060



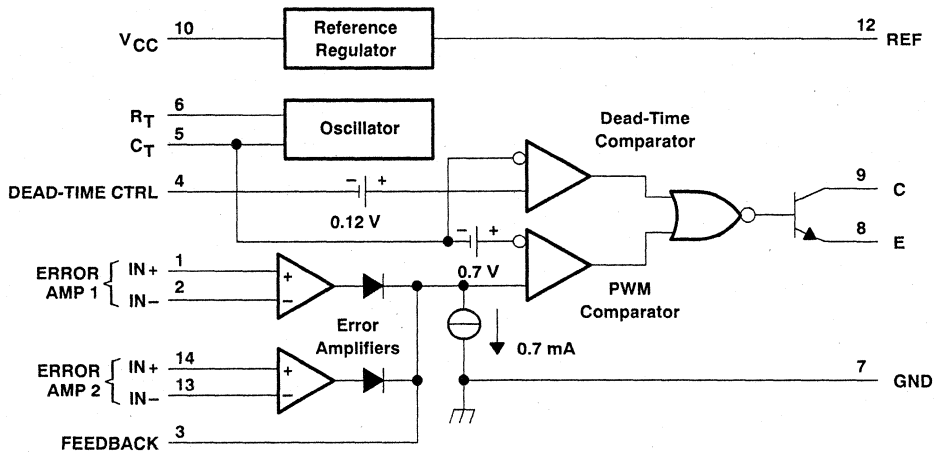
NC — No internal connection

description

The MC34060 incorporates on a single monolithic chip all the functions required in the construction of a pulse-width-modulation control circuit. Designed primarily for power supply control, the device contains an on-chip 5-V regulator, two error amplifiers, an adjustable oscillator, and a dead-time control comparator. The uncommitted output transistor provides either common-emitter or emitter-follower output capability. The internal amplifiers exhibit a common-mode voltage range from -0.3 V to $V_{CC} - 2\text{ V}$. The dead-time control comparator has a fixed offset that provides approximately 5% dead time unless externally altered. The on-chip oscillator may be bypassed by terminating R_T (pin 6) to the reference output and providing a sawtooth input to C_T (pin 5), or it may be used to drive the common MC34060 circuitry and provide a sawtooth input for associated control circuitry in multiple rail power supplies.

The MC34060 is characterized for operation from 0°C to 70°C .

functional block diagram



All voltage and current values shown are nominal.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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MC34060 PULSE-WIDTH-MODULATION CONTROL CIRCUIT

absolute maximum ratings over operating temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Supply voltage, V_{CC} (see Note 1) | 42 V |
| Amplifier input voltage | $V_{CC} + 0.3$ V |
| Collector output voltage | 42 V |
| Collector output current | 250 mA |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range, T_A | 0°C to 70°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 1: All voltage values except differential voltages are with respect to the network ground terminal.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR | DERATE ABOVE T_A | $T_A = 70^\circ\text{C}$ POWER RATING |
|---------|---|--------------------|-----------------------|--|
| D | 900 mW | 7.6 mW/°C | 31°C | 606 mW |
| N | 1000 mW | 9.2 mW/°C | 41°C | 736 mW |

recommended operating conditions

| | MIN | MAX | UNIT |
|--|------|--------------|------------|
| Supply voltage, V_{CC} | 7 | 40 | V |
| Amplifier input voltages, V_I | -0.3 | $V_{CC} - 2$ | V |
| Collector output voltage, V_O | | 40 | V |
| Collector output current (each transistor) | | 200 | mA |
| Reference output current | | 10 | mA |
| Current into feedback terminal | | 0.3 | mA |
| Timing capacitor, C_T | 0.47 | 10000 | nF |
| Timing resistor, R_T | 1.8 | 500 | k Ω |
| Oscillator frequency, f_{osc} | 1 | 200 | kHz |
| Operating free-air temperature, T_A | 0 | 70 | °C |

MC34060 PULSE-WIDTH-MODULATION CONTROL CIRCUIT

electrical characteristics over recommended operating free-air temperature range, $V_{CC} = 15\text{ V}$, $f = 25\text{ kHz}$ (unless otherwise noted)

reference section

| PARAMETER | TEST CONDITIONS† | MIN | TYP‡ | MAX | UNIT |
|--|---|------|------|------|------|
| Output voltage (REF) | $I_O = 1\text{ mA}$ | 4.75 | 5 | 5.25 | V |
| Input regulation | $V_{CC} = 7\text{ V to }40\text{ V}$, $T_A = 25^\circ\text{C}$ | | 2 | 25 | mV |
| Output regulation | $I_O = 1\text{ to }10\text{ mA}$, $T_A = 25^\circ\text{C}$ | | 1 | 15 | mV |
| Output voltage change with temperature | $\Delta T_A = \text{MIN to MAX}$ | | 0.2% | 2.6% | |
| Short-circuit output current§ | REF = 0, $T_A = 25^\circ\text{C}$ | | 35 | | mA |

oscillator section

| PARAMETER | TEST CONDITIONS† | MIN | TYP‡ | MAX | UNIT |
|-----------------------------------|--|-----|------|-----|------|
| Frequency | $C_T = 0.001\ \mu\text{F}$, $R_T = 47\text{ k}\Omega$ | | 25 | | kHz |
| Standard deviation of frequency¶ | $C_T = 0.001\ \mu\text{F}$, $R_T = 47\text{ k}\Omega$ | | 3% | | |
| Frequency change with voltage | $V_{CC} = 7\text{ V to }40\text{ V}$, $T_A = 25^\circ\text{C}$ | | 0.1% | | |
| Frequency change with temperature | $C_T = 0.001\ \mu\text{F}$, $R_T = 47\text{ k}\Omega$, $\Delta T_A = \text{MIN to MAX}$ | | | ±2% | |

dead-time control section (see Figure 1)

| PARAMETER | TEST CONDITIONS | MIN | TYP‡ | MAX | UNIT |
|--|-----------------------------------|--|------|-----|---------------|
| Input bias current (DEAD-TIME CTRL) | $V_I = 0\text{ to }5.25\text{ V}$ | | -2 | -10 | μA |
| Maximum duty cycle | V_I (DEAD-TIME CTRL) = 0 | $C_T = 0.1\ \mu\text{F}$, $R_T = 12\text{ k}\Omega$ | 90% | 96% | 100% |
| | | $C_T = 0.001\ \mu\text{F}$, $R_T = 47\text{ k}\Omega$ | | 92% | 100% |
| Input threshold voltage (DEAD-TIME CTRL) | Zero duty cycle | | 3 | 3.3 | V |
| | Maximum duty cycle | 0 | | | |

error-amplifier section

| PARAMETER | TEST CONDITIONS | MIN | TYP‡ | MAX | UNIT |
|----------------------------------|---|-----|------|--------------------------|---------------|
| Input offset voltage | V_O (FEEDBACK) = 2.5 V | | 2 | 10 | mV |
| Input offset current | V_O (FEEDBACK) = 2.5 V | | 25 | 250 | nA |
| Input bias current | V_O (FEEDBACK) = 2.5 V | | 0.2 | 1 | μA |
| Common-mode input voltage range | $V_{CC} = 7\text{ V to }40\text{ V}$ | | | -0.3 to $V_{CC}-2$ | V |
| Open-loop voltage amplification | $\Delta V_O = 3\text{ V}$, $R_L = 2\text{ k}\Omega$, $V_O = 0.5\text{ V to }3.5\text{ V}$ | 70 | 95 | | dB |
| Unity-gain bandwidth | $V_O = 0.5\text{ V to }3.5\text{ V}$, $R_L = 2\text{ k}\Omega$ | | 800 | | kHz |
| Phase margin at unity gain | $V_O = 0.5\text{ V to }3.5\text{ V}$, $R_L = 2\text{ k}\Omega$ | | 65° | | |
| Common-mode rejection ratio | $V_{CC} = 40\text{ V}$ | 65 | 80 | | dB |
| Output sink current (FEEDBACK) | $V_{ID} = -15\text{ mV to }-5\text{ V}$, V (FEEDBACK) = 0.7 V | 0.3 | 0.7 | | mA |
| Output source current (FEEDBACK) | $V_{ID} = 15\text{ mV to }5\text{ V}$, V (FEEDBACK) = 3.5 V | -2 | | | mA |

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

‡ All typical values except "output voltage" characteristics are at $T_A = 25^\circ\text{C}$.

§ Duration of the short circuit should not exceed one second.

¶ Standard deviation is a measure of the statistical distribution about the mean as derived from the formula: $\sigma = \sqrt{\frac{\sum_{n=1}^N (x_n - \bar{X})^2}{N-1}}$



MC34060 PULSE-WIDTH-MODULATION CONTROL CIRCUIT

electrical characteristics over recommended operating free-air temperature range, $V_{CC} = 15\text{ V}$, $f = 25\text{ kHz}$ (unless otherwise noted) (continued)

output section

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|--------------------------------------|---|-----|------|------|---------------|
| Collector off-state current | $V_C = 40\text{ V}$, $V_E = 0\text{ V}$, $V_{CC} = 40\text{ V}$ | | 2 | 100 | μA |
| Emitter off-state current | $V_{CC} = V_C = 40\text{ V}$, $V_E = 0$ | | | -100 | μA |
| Collector-emitter saturation voltage | Common emitter $V_E = 0$, $I_C = 200\text{ mA}$ | | 1.1 | 1.3 | V |
| | Emitter follower $V_C = 15\text{ V}$, $I_E = -200\text{ mA}$ | | 1.5 | 2.5 | |

pwm comparator section (see Figure 1)

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|------------------------------------|-------------------------------------|-----|------|-----|------|
| Input threshold voltage (FEEDBACK) | Zero duty cycle | | 4 | 4.5 | V |
| Input sink current (FEEDBACK) | $V(\text{FEEDBACK}) = 0.7\text{ V}$ | 0.3 | 0.7 | | mA |

total device

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|------------------------|---|------------------------|------|-----|------|
| Standby supply current | R_T at REF, All other inputs and outputs open | $V_{CC} = 15\text{ V}$ | 6 | 10 | mA |
| | | $V_{CC} = 40\text{ V}$ | 9 | 15 | |
| Average supply current | $V(\text{DEAD-TIME CTRL}) = 2\text{ V}$, $R_T = 47\text{ k}\Omega$, See Figure 1 | | 7.5 | | mA |

switching characteristics, $T_A = 25^\circ\text{C}$

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|--------------------------|--|-----|------|-----|------|
| Output voltage rise time | Common-emitter configuration, See Figure 3 | | 100 | 200 | ns |
| Output voltage fall time | | | 25 | 100 | |
| Output voltage rise time | Emitter-follower configuration, See Figure 4 | | 100 | 200 | ns |
| Output voltage fall time | | | 40 | 100 | |

† All typical values are at $T_A = 25^\circ\text{C}$.



PARAMETER MEASUREMENT INFORMATION

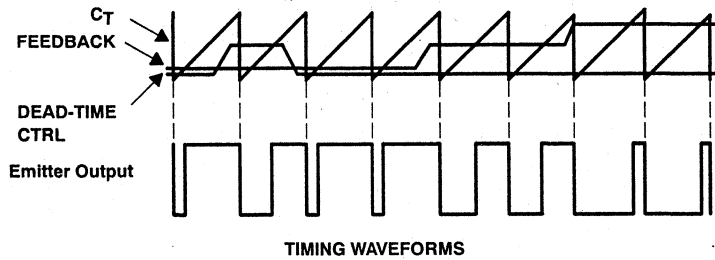
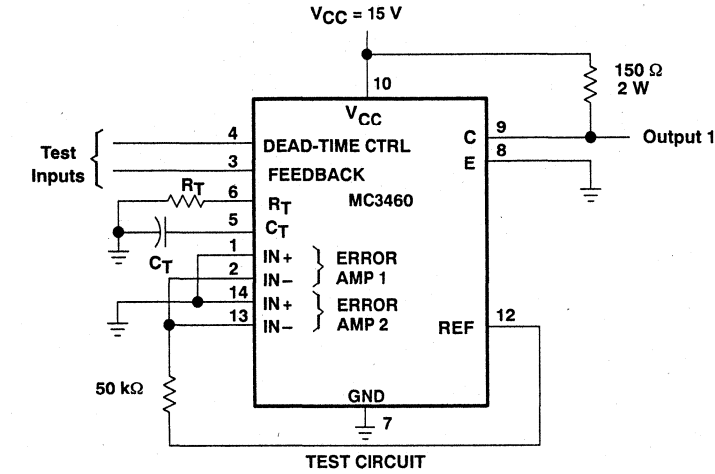


Figure 1. Dead-Time and Feedback Controls

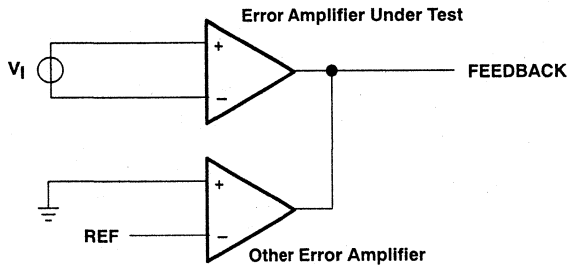


Figure 2. Error-Amplifier Characteristics

PARAMETER MEASUREMENT INFORMATION

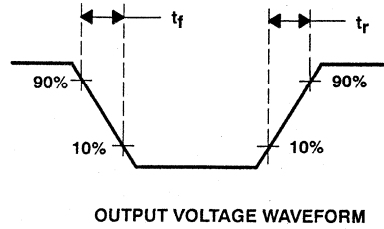
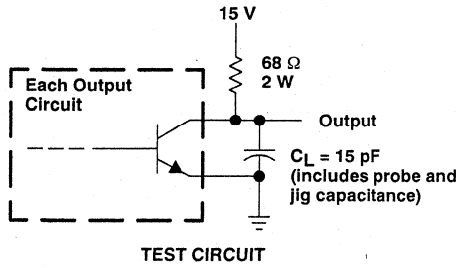


Figure 3. Common-Emitter Configuration

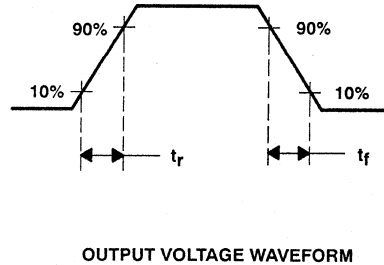
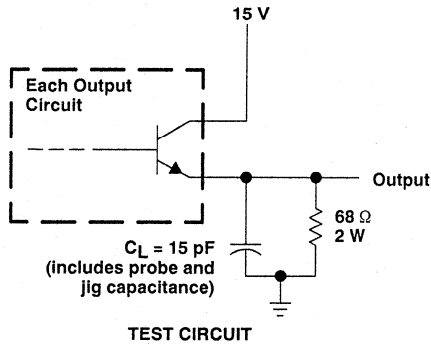
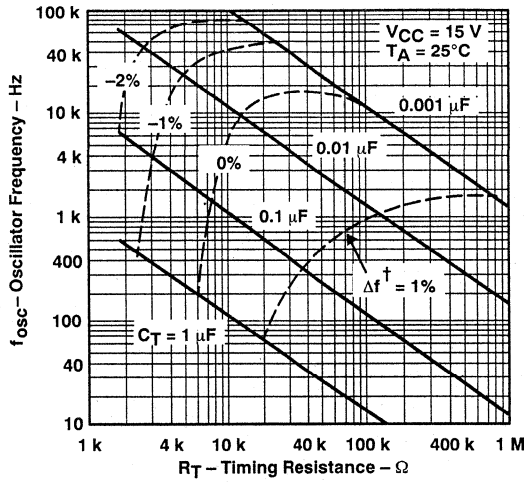


Figure 4. Emitter-Follower Configuration

TYPICAL CHARACTERISTICS

**OSCILLATOR FREQUENCY AND
FREQUENCY VARIATION[†]
vs
TIMING RESISTANCE**



[†] Frequency variation (Δf) is the change in oscillator frequency that occurs over the full temperature range.

Figure 5

**AMPLIFIER VOLTAGE AMPLIFICATION
vs
FREQUENCY**

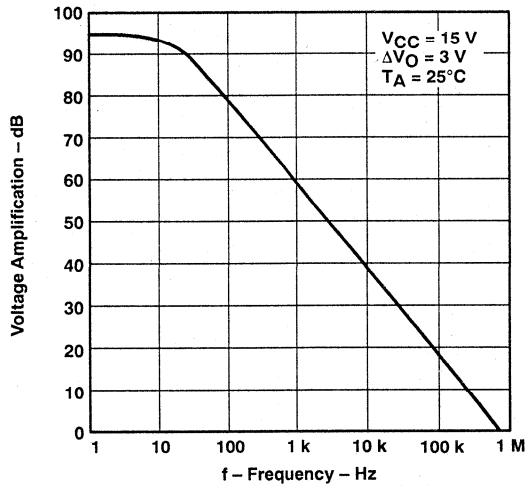


Figure 6

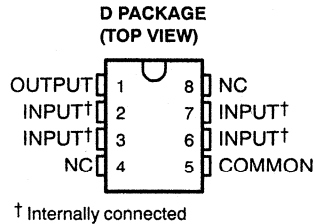
MC79L00 SERIES NEGATIVE-VOLTAGE REGULATORS

D2565, OCTOBER 1982—REVISED NOVEMBER 1991

- 3-Terminal Regulators
- Output Current Up to 100 mA
- No External Components Required
- Internal Thermal Overload Protection
- Internal Short-Circuit Current Limiting
- Direct Replacement for Motorola MC79L00 Series
- Available in 5% or 10% Selections

description

This series of fixed negative-voltage monolithic integrated-circuit voltage regulators is designed for a wide range of applications. These include on-card regulation for elimination of noise and distribution problems associated with single-point regulation. In addition, they can be used to control series pass elements to make high-current voltage-regulator circuits. One of these regulators can deliver up to 100 mA of output current. The internal current-limiting and thermal-shutdown features make them essentially immune to overload. When used as a replacement for a zener diode and resistor combination, these devices can provide an effective improvement in output impedance of two orders of magnitude and lower bias current.



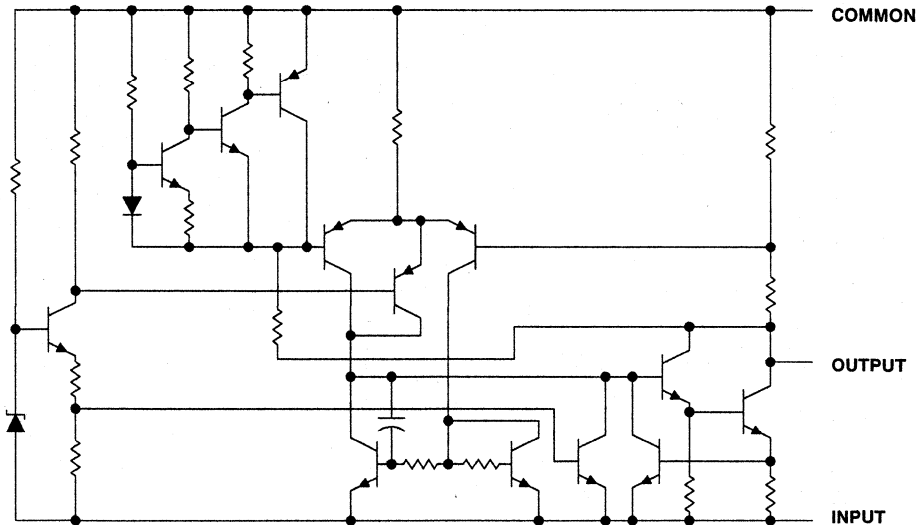
**LP SILENT PACKAGE
(TOP VIEW)**



NC—No internal connection

| NOMINAL OUTPUT VOLTAGE | 5% OUTPUT VOLTAGE TOLERANCE | 10% OUTPUT VOLTAGE TOLERANCE |
|------------------------|-----------------------------|------------------------------|
| -5 V | MC79L05AC | MC79L05C |
| -12 V | MC79L12AC | MC79L12C |
| -15 V | MC79L15AC | MC79L15C |

equivalent schematic



PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

**TEXAS
INSTRUMENTS**

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MC79L00 SERIES NEGATIVE-VOLTAGE REGULATORS

absolute maximum ratings over operating temperature ranges (unless otherwise noted)

| | MC79L05 | MC79L12 MC79L15 | UNIT |
|---|---------------------------------------|--------------------|------|
| Input voltage | -30 | -35 | V |
| Continuous total dissipation | See Dissipation Rating Tables 1 and 2 | | |
| Operating free-air, case, or virtual junction temperature range | 0 to 150 | 0 to 150 | °C |
| Storage temperature range | -65 to 150 | -65 to 150 | °C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260 | 260 | °C |

DISSIPATION RATING TABLE 1 – FREE-AIR TEMPERATURE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR | DERATE ABOVE T_A | $T_A = 70^\circ\text{C}$ POWER RATING |
|---------|---|--------------------|-----------------------|--|
| D | 825 mW | 6.6 mW/°C | 25°C | 528 mW |
| LP† | 775 mW | 6.2 mW/°C | 25°C | 496 mW |

† The LP package dissipation rating is based on thermal resistance measured in still air with the device mounted in an Augat socket. The bottom of the package was 10 mm (0.375 in.) above the socket.

DISSIPATION RATING TABLE 2 – CASE TEMPERATURE

| PACKAGE | $T_C \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR | DERATE ABOVE T_C | $T_C = 125^\circ\text{C}$ POWER RATING |
|---------|---|--------------------|-----------------------|---|
| D | 1600 mW | 29.0 mW/°C | 95°C | 725 mW |
| LP | 1600 mW | 28.6 mW/°C | 94°C | 715 mW |

recommended operating conditions

| | | MIN | MAX | UNIT |
|---|---------|-------|-----|------|
| Input voltage, V_I | MC79L05 | -7 | -20 | V |
| | MC79L12 | -14.5 | -27 | |
| | MC79L15 | -17.5 | -30 | |
| Output current, I_O | | | 100 | mA |
| Operating virtual junction temperature, T_J | | 0 | 125 | °C |



MC79L00 SERIES NEGATIVE-VOLTAGE REGULATORS

electrical characteristics at specified virtual junction temperature, $V_I = -10\text{ V}$, $I_O = 40\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS† | T_J ‡ | MC79L05C | | | MC79L05AC | | | UNIT |
|----------------------|--|------------|----------|-----|------|-----------|-----|-------|---------------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| Output voltage§ | | 25°C | -4.6 | -5 | -5.4 | -4.8 | -5 | -5.2 | V |
| | $V_I = -7\text{ V to }-20\text{ V}$, $I_O = 1\text{ mA to }40\text{ mA}$ | Full range | -4.5 | | -5.5 | -4.75 | | -5.25 | |
| | $V_I = -10\text{ V}$, $I_O = 1\text{ mA to }70\text{ mA}$ | Full range | -4.5 | | -5.5 | -4.75 | | -5.25 | |
| Input regulation | $V_I = -7\text{ V to }-20\text{ V}$ | 25°C | | | | 200 | | | mV |
| | $V_I = -8\text{ V to }-20\text{ V}$ | | | | | 150 | | | |
| Ripple rejection | $V_I = -8\text{ V to }-18\text{ V}$, $f = 120\text{ Hz}$ | 25°C | 40 | 49 | | 41 | 49 | | dB |
| Output regulation | $I_O = 1\text{ mA to }100\text{ mA}$ | 25°C | | | | 60 | | | mV |
| | $I_O = 1\text{ mA to }40\text{ mA}$ | | | | | 30 | | | |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | | | 40 | | | μV |
| Dropout voltage | $I_O = 40\text{ mA}$ | 25°C | | | | 1.7 | | | V |
| Bias current | | 25°C | | | | 6 | | | mA |
| | | 125°C | | | | 5.5 | | | |
| Bias current change | $V_I = -8\text{ V to }-20\text{ V}$ | Full range | | | | 1.5 | | | mA |
| | $I_O = 1\text{ mA to }40\text{ mA}$ | | | | | 0.2 | | | |

electrical characteristics at specified virtual junction temperature, $V_I = -19\text{ V}$, $I_O = 40\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS† | T_J ‡ | MC79L12C | | | MC79L12AC | | | UNIT |
|----------------------|---|------------|----------|-----|-------|-----------|-----|-------|---------------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| Output voltage§ | | 25°C | -11.1 | -12 | -12.9 | -11.5 | -12 | -12.5 | V |
| | $V_I = -14.5\text{ V to }-27\text{ V}$, $I_O = 1\text{ mA to }40\text{ mA}$ | Full range | -10.8 | | -13.2 | -11.4 | | -12.6 | |
| | $V_I = -19\text{ V}$, $I_O = 1\text{ mA to }70\text{ mA}$ | Full range | -10.8 | | -13.2 | -11.4 | | -12.6 | |
| Input regulation | $V_I = -14.5\text{ V to }-27\text{ V}$ | 25°C | | | | 250 | | | mV |
| | $V_I = -16\text{ V to }-27\text{ V}$ | | | | | 200 | | | |
| Ripple rejection | $V_I = -15\text{ V to }-25\text{ V}$, $f = 120\text{ Hz}$ | 25°C | 36 | 42 | | 37 | 42 | | dB |
| Output regulation | $I_O = 1\text{ mA to }100\text{ mA}$ | 25°C | | | | 100 | | | mV |
| | $I_O = 1\text{ mA to }40\text{ mA}$ | | | | | 50 | | | |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | | | 80 | | | μV |
| Dropout voltage | $I_O = 40\text{ mA}$ | 25°C | | | | 1.7 | | | V |
| Bias current | | 25°C | | | | 6.5 | | | mA |
| | | 125°C | | | | 6 | | | |
| Bias current change | $V_I = -16\text{ V to }-27\text{ V}$ | Full range | | | | 1.5 | | | mA |
| | $I_O = 1\text{ mA to }40\text{ mA}$ | | | | | 0.2 | | | |

† All characteristics are measured with a 0.33- μF capacitor across the input and a 0.1- μF capacitor across the output. Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

‡ Full range virtual junction temperature is 0°C to 125°C.

§ This specification applies only for dc power dissipation permitted by absolute maximum ratings.



MC79L00 SERIES NEGATIVE-VOLTAGE REGULATORS

electrical characteristics at specified virtual junction temperature, $V_I = -23$ V, $I_O = 40$ mA (unless otherwise noted)

| PARAMETER | TEST CONDITIONS† | T_J ‡ | MC79L15C | | | MC79L15AC | | | UNIT |
|----------------------|--|------------|----------|-----|-------|-----------|-----|--------|---------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| Output voltage§ | | 25°C | -13.8 | -15 | -16.2 | -14.4 | -15 | -15.6 | V |
| | $V_I = -17.5$ V to -30 V, $I_O = 1$ mA to 40 mA | Full range | -13.5 | | -16.5 | -14.25 | | -15.75 | |
| | $V_I = -23$ V, $I_O = 1$ mA to 70 mA | Full range | -13.5 | | -16.5 | -14.25 | | -15.75 | |
| Input regulation | $V_I = -17.5$ V to -30 V | 25°C | | | | 300 | | | mV |
| | $V_I = -17.5$ V to -30 V | | | | | 250 | | | |
| Ripple rejection | $V_I = -18.5$ V to -28.5 V, $f = 120$ Hz | 25°C | 33 | 39 | | 34 | 39 | | dB |
| Output regulation | $I_O = 1$ mA to 100 mA | 25°C | | | | 150 | | | mV |
| | $I_O = 1$ mA to 40 mA | | | | | 75 | | | |
| Output noise voltage | $f = 10$ Hz to 100 kHz | 25°C | 90 | | | 90 | | | μ V |
| Dropout voltage | $I_O = 40$ mA | 25°C | 1.7 | | | 1.7 | | | V |
| Bias current | | 25°C | | | | 6.5 | | | mA |
| | | 125°C | | | | 6 | | | |
| Bias current change | $V_I = -20$ V to -30 V | Full range | | | | 1.5 | | | mA |
| | $I_O = 1$ mA to 40 mA | | | | | 0.1 | | | |

† All characteristics are measured with a 0.33- μ F capacitor across the input and a 0.1- μ F capacitor across the output. Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

‡ Full range virtual junction temperature is 0°C to 125°C.

§ This specification applies only for dc power dissipation permitted by absolute maximum ratings.

SG2524, SG3524 REGULATING PULSE-WIDTH MODULATORS

D2294, APRIL 1977—REVISED DECEMBER 1991

- Complete PWM Power Control Circuitry
- Uncommitted Outputs for Single-Ended or Push-Pull Applications
- Low Standby Current . . . 8 mA Typ
- Interchangeable With Silicon General SG2524 and SG3524

N PACKAGE
(TOP VIEW)

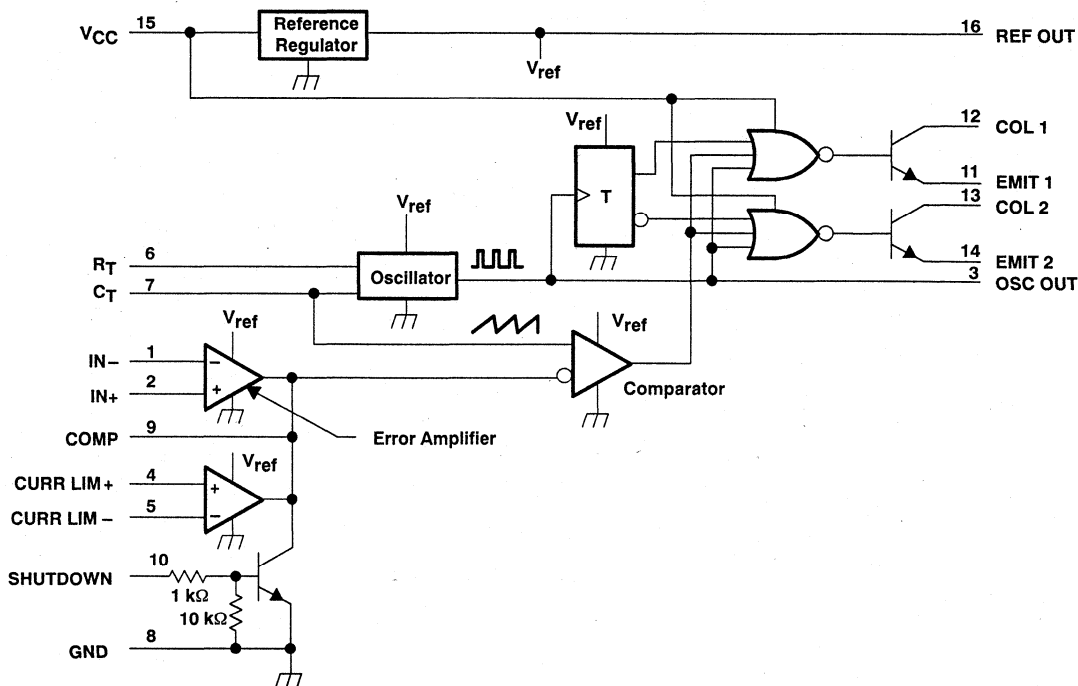
| | | | |
|----------------|---|----|-----------------|
| IN- | 1 | 16 | REF OUT |
| IN+ | 2 | 15 | V _{CC} |
| OSC OUT | 3 | 14 | EMIT 2 |
| CURR LIM+ | 4 | 13 | COL 2 |
| CURR LIM- | 5 | 12 | COL 1 |
| R _T | 6 | 11 | EMIT 1 |
| C _T | 7 | 10 | SHUTDOWN |
| GND | 8 | 9 | COMP |

description

The SG2524 and SG3524 incorporate on single monolithic chips all the functions required in the construction of a regulating power supply, inverter, or switching regulator. They can also be used as the control element for high-power-output applications. The SG2524 and SG3524 were designed for switching regulators of either polarity, transformer-coupled dc-to-dc converters, transformerless voltage doublers, and polarity converter applications employing fixed-frequency, pulse-width-modulation techniques. The complementary output allows either single-ended or push-pull application. Each device includes an on-chip regulator, error amplifier, programmable oscillator, pulse-steering flip-flop, two uncommitted pass transistors, a high-gain comparator, and current-limiting and shut-down circuitry.

The SG2524 is characterized for operation from -25°C to 85°C, and the SG3524 is characterized for operation from 0°C to 70°C.

functional block diagram



Resistor values shown are nominal.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

**TEXAS
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SG2524, SG3524 REGULATING PULSE-WIDTH MODULATORS

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Supply voltage, V_{CC} (see Notes 1 and 2) | 40 V |
| Collector output current | 100 mA |
| Reference output current | 50 mA |
| Current through C_T terminal | -5 mA |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range: SG2524 | -25°C to 85°C |
| SG3524 | 0°C to 70°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

- NOTES: 1. All voltage values are with respect to network ground terminal.
 2. The reference regulator may be bypassed for operation from a fixed 5-V supply by connecting the V_{CC} and reference output pins both to the supply voltage. In this configuration, the maximum supply voltage is 6 V.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR | DERATE ABOVE T_A | $T_A = 70^\circ\text{C}$ POWER RATING | $T_A = 85^\circ\text{C}$ POWER RATING |
|---------|---|-----------------|-----------------------|--|--|
| N | 1000 mW | 9.2 mW/°C | 41°C | 736 mW | 598 mW |

recommended operating conditions

| | SG2524 | | SG3524 | | UNIT |
|--------------------------------|--------|-----|--------|-----|---------------|
| | MIN | MAX | MIN | MAX | |
| Supply voltage, V_{CC} | 8 | 40 | 8 | 40 | V |
| Reference output current | 0 | 50 | 0 | 50 | mA |
| Current through C_T terminal | -0.03 | -2 | -0.03 | -2 | mA |
| Timing resistor, R_T | 1.8 | 100 | 1.8 | 100 | k Ω |
| Timing capacitor, C_T | 0.001 | 0.1 | 0.001 | 0.1 | μF |
| Operating free-air temperature | -25 | 85 | 0 | 70 | °C |

electrical characteristics over recommended operating free-air temperature range, $V_{CC} = 20\text{ V}$ (unless otherwise noted)

reference section

| PARAMETER | TEST CONDITIONS† | SG2524 | | | SG3524 | | | UNIT |
|--|--------------------------------------|--------|------|-----|--------|------|-----|------|
| | | MIN | TYP‡ | MAX | MIN | TYP‡ | MAX | |
| Output voltage | | 4.8 | 5 | 5.2 | 4.6 | 5 | 5.4 | V |
| Input regulation | $V_{CC} = 8\text{ V to }40\text{ V}$ | 10 | | 20 | 10 | | 30 | mV |
| Ripple rejection | $f = 120\text{ Hz}$ | 66 | | | 66 | | | dB |
| Output regulation | $I_O = 0\text{ mA to }20\text{ mA}$ | 20 | | 50 | 20 | | 50 | mV |
| Output voltage change with temperature | $T_A = \text{MIN to MAX}$ | 0.3% | | 1% | 0.3% | | 1% | |
| Short-circuit output current§ | $V_{\text{ref}} = 0$ | 100 | | | 100 | | | mA |

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

‡ All typical values, except output voltage change with temperature, are at $T_A = 25^\circ\text{C}$.

§ Duration of the short circuit should not exceed one second.



SG2524, SG3524 REGULATING PULSE-WIDTH MODULATORS

electrical characteristics over recommended operating free-air temperature range, $V_{CC} = 20\text{ V}$, $f = 20\text{ kHz}$ (unless otherwise noted)

oscillator section

| PARAMETER | | TEST CONDITIONS† | MIN | TYP‡ | MAX | UNIT |
|------------------|--|--|-----|------|-----|---------------|
| f_{osc} | Oscillator frequency | $C_T = 0.001\ \mu\text{F}$, $R_T = 2\ \text{k}\Omega$ | | 450 | | kHz |
| | Standard deviation of frequency§ | All values of voltage, temperature, resistance, and capacitance constant | | 5% | | |
| Δf_{osc} | Frequency change with voltage | $V_{CC} = 8\text{ V to }40\text{ V}$, $T_A = 25^\circ\text{C}$ | | | 1% | |
| Δf_{osc} | Frequency change with temperature | $T_A = \text{MIN to MAX}$ | | | 2% | |
| | Output amplitude at OSC OUT | $T_A = 25^\circ\text{C}$ | | 3.5 | | V |
| t_w | Output pulse duration (width) at OSC OUT | $C_T = 0.01\ \mu\text{F}$, $T_A = 25^\circ\text{C}$ | | 0.5 | | μs |

error amplifier section

| PARAMETER | TEST CONDITIONS† | SG2524 | | | SG3524 | | | UNIT |
|-----------|---------------------------------|--------------------------|------------------|-----|------------------|------|-----|---------------|
| | | MIN | TYP‡ | MAX | MIN | TYP‡ | MAX | |
| V_{IO} | Input offset voltage | $V_{IC} = 2.5\text{ V}$ | 0.5 | 5 | 2 | 10 | | mV |
| I_{IB} | Input bias current | $V_{IC} = 2.5\text{ V}$ | | 2 | 10 | 2 | 10 | μA |
| | Open-loop voltage amplification | | 72 | 80 | 60 | 80 | | dB |
| V_{ICR} | Common-mode input voltage range | $T_A = 25^\circ\text{C}$ | 1.8 to 3.4 | | 1.8 to 3.4 | | | V |
| CMMR | Common-mode rejection ratio | | | 70 | | 70 | | dB |
| B_1 | Unity-gain bandwidth | | | 3 | | 3 | | MHz |
| | Output swing | $T_A = 25^\circ\text{C}$ | 0.5 | 3.8 | 0.5 | 3.8 | | V |

output section

| PARAMETER | | TEST CONDITIONS | MIN | TYP‡ | MAX | UNIT |
|--------------|--------------------------------------|---|-----|------|-----|---------------|
| $V_{(BR)CE}$ | Collector-emitter breakdown voltage | | 40 | | | V |
| | Collector off-state current | $V_{CE} = 40\text{ V}$ | | 0.01 | 50 | μA |
| V_{sat} | Collector-emitter saturation voltage | $I_C = 50\text{ mA}$ | | 1 | 2 | V |
| V_O | Emitter output voltage | $V_C = 20\text{ V}$, $I_E = -250\ \mu\text{A}$ | 17 | 18 | | V |
| t_r | Turn-off voltage rise time | $R_C = 2\ \text{k}\Omega$ | | 0.2 | | μs |
| t_f | Turn-on voltage fall time | $R_C = 2\ \text{k}\Omega$ | | 0.1 | | μs |

comparator section

| PARAMETER | | TEST CONDITIONS | MIN | TYP‡ | MAX | UNIT |
|-----------|---------------------------------|--------------------|-----|------|-----|---------------|
| | Maximum duty cycle, each output | | 45% | | | |
| V_T | Input threshold voltage at COMP | Zero duty cycle | | 1 | | V |
| | | Maximum duty cycle | | 3.5 | | |
| I_{IB} | Input bias current | | | -1 | | μA |

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

‡ All typical values, except for temperature coefficients, are at $T_A = 25^\circ\text{C}$

§ Standard deviation is a measure of the statistical distribution about the mean as derived from the formula:

$$\sigma = \sqrt{\frac{\sum_{n=1}^N (X_n - \bar{X})^2}{N-1}}$$

SG2524, SG3524 REGULATING PULSE-WIDTH MODULATORS

electrical characteristics over recommended operating free-air temperature range, $V_{CC} = 20\text{ V}$, $f = 20\text{ kHz}$ (unless otherwise noted)

current limiting section

| PARAMETER | TEST CONDITIONS | SG2524 | | | SG3524 | | | UNIT |
|---|---|---------------|------|-----|---------------|------|-----|-------|
| | | MIN | TYP† | MAX | MIN | TYP† | MAX | |
| V_I Input voltage range (either input) | | -1 to 1 | | | -1 to 1 | | | V |
| $V(\text{sense})$ Sense voltage at $T_A = 25^\circ\text{C}$ | $V(\text{IN}+) - V(\text{IN}-) \geq 50\text{ mV}$, | 190 | 200 | 210 | 180 | 200 | 220 | mV |
| Temperature coefficient of sense voltage | $V(\text{COMP}) = 2\text{ V}$ | | 0.2 | | | 0.2 | | mV/°C |

total device

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|--------------------------|--|-----|------|-----|------|
| I_{st} Standby current | $V_{CC} = 40\text{ V}$, $\text{IN}-$, CURR LIM+, C_T , GND, COMP, EMIT 1, EMIT 2 grounded $\text{IN}+$ at 2 V, All other inputs and outputs open | | 8 | 10 | mA |

† All typical values, except for temperature coefficients, are at $T_A = 25^\circ\text{C}$.

PARAMETER MEASUREMENT INFORMATION

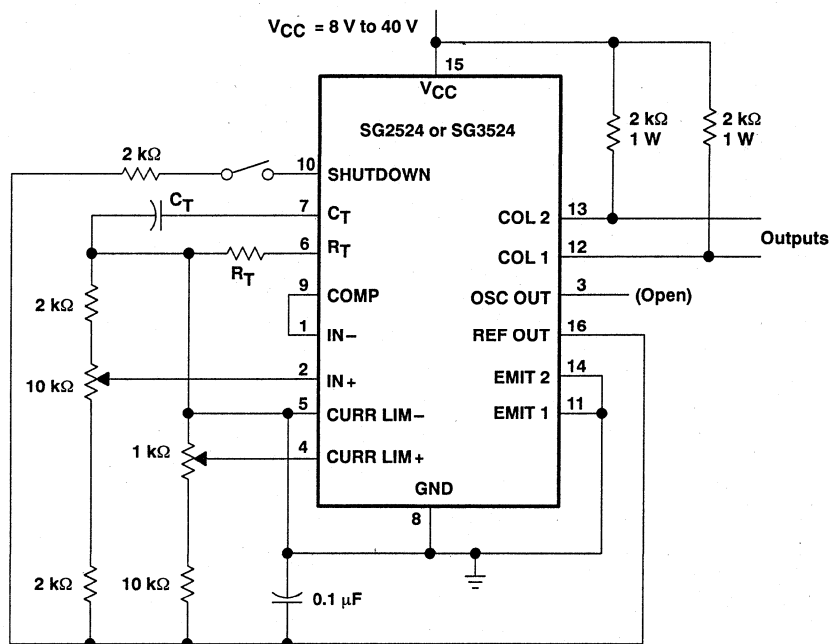


Figure 1. General Test Circuit

PARAMETER MEASUREMENT INFORMATION

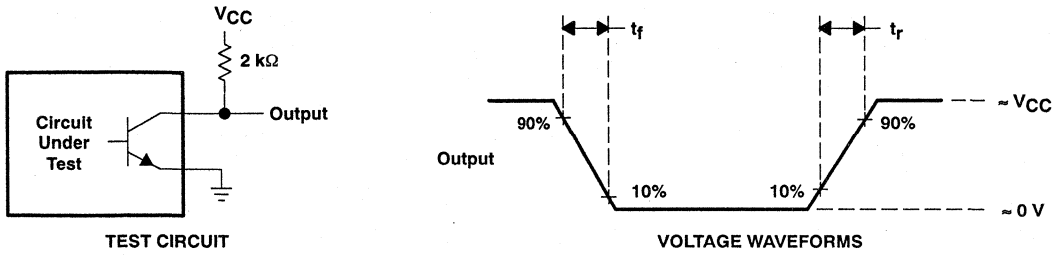


Figure 2. Switching Times

TYPICAL CHARACTERISTICS

OPEN-LOOP VOLTAGE AMPLIFICATION
OF ERROR AMPLIFIER
vs
FREQUENCY

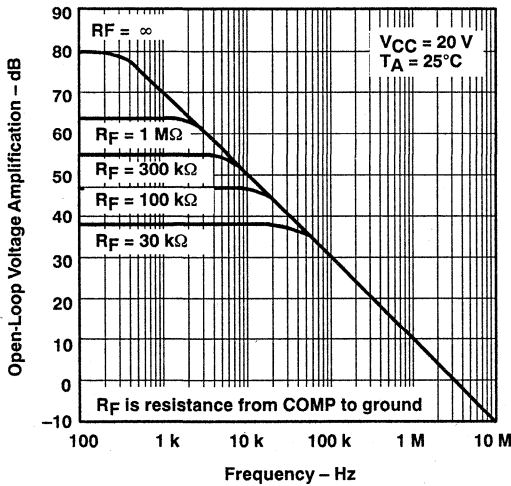


Figure 3

OSCILLATOR FREQUENCY
vs
TIMING RESISTANCE

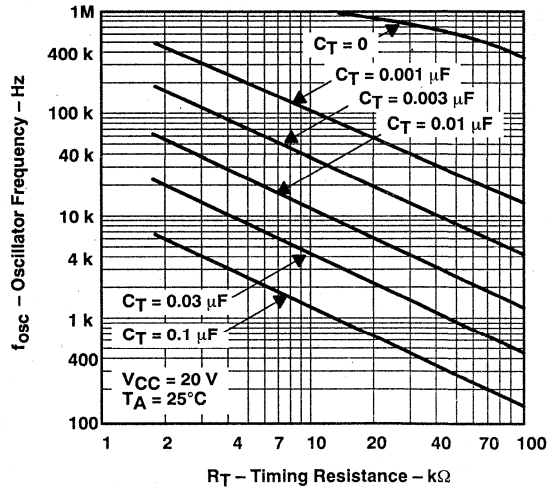


Figure 4

TYPICAL CHARACTERISTICS

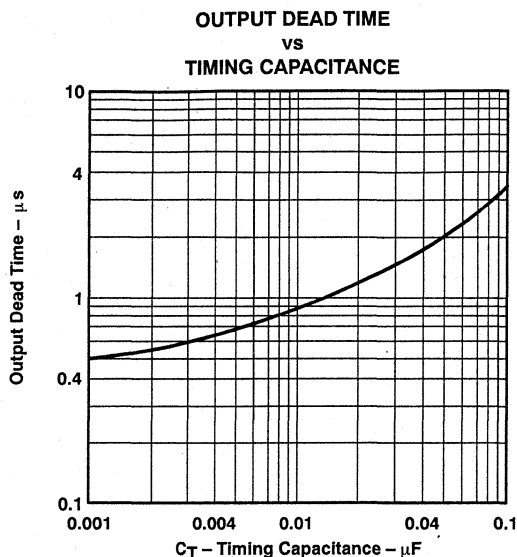


Figure 5

PRINCIPLES OF OPERATION†

The SG2524 is a fixed-frequency pulse-width-modulation voltage-regulator control circuit. The regulator operates at a fixed frequency that is programmed by one timing resistor R_T and one timing capacitor C_T . R_T establishes a constant charging current for C_T . This results in a linear voltage ramp at C_T , which is fed to the comparator providing linear control of the output pulse duration (width) by the error amplifier. The SG2524 contains an on-board 5-V regulator that serves as a reference as well as supplying the SG2524 internal regulator control circuitry. The internal reference voltage is divided externally by a resistor ladder network to provide a reference within the common-mode range of the error amplifier as shown in Figure 6, or an external reference may be used. The output is sensed by a second resistor divider network and the error signal is amplified. This voltage is then compared to the linear voltage ramp at C_T . The resulting modulated pulse out of the high-gain comparator is then steered to the appropriate output pass transistor (Q1 or Q2) by the pulse-steering flip-flop, which is synchronously toggled by the oscillator output. The oscillator output pulse also serves as a blanking pulse to ensure both outputs are never on simultaneously during the transition times. The duration of the blanking pulse is controlled by the value of C_T . The outputs may be applied in a push-pull configuration in which their frequency is half that of the base oscillator, or paralleled for single-ended applications in which the frequency is equal to that of the oscillator. The output of the error amplifier shares a common input to the comparator with the current-limiting and shut-down circuitry and can be overridden by signals from either of these inputs. This common point is also available externally and may be employed to control the gain of, to compensate the error amplifier, or to provide additional control to the regulator.

† Throughout these discussions, references to the SG2524 apply also to the SG3524.

APPLICATION INFORMATION†

oscillator

The oscillator controls the frequency of the SG2524 and is programmed by R_T and C_T as shown in Figure 4.

$$f \approx \frac{1.30}{R_T C_T}$$

where R_T is in $k\Omega$
 C_T is in μF
 f is in kHz

Practical values of C_T fall between 0.001 and 0.1 μF . Practical values of R_T fall between 1.8 and 100 $k\Omega$. This results in a frequency range typically from 140 Hz to 500 kHz.

blanking

The output pulse of the oscillator is used as a blanking pulse at the output. This pulse duration is controlled by the value of C_T as shown in Figure 5. If small values of C_T are required, the oscillator output pulse duration may still be maintained by applying a shunt capacitance from OSC OUT to ground.

synchronous operation

When an external clock is desired, a clock pulse of approximately 3 V can be applied directly to the oscillator output terminal. The impedance to ground at this point is approximately 2 $k\Omega$. In this configuration, $R_T C_T$ must be selected for a clock period slightly greater than that of the external clock.

If two or more SG2524 regulators are to be operated synchronously, all oscillator output terminals should be tied together. The oscillator programmed for the minimum clock period will be the master from which all the other SG2524s operate. In this application, the $C_T R_T$ values of the slaved regulators must be set for a period approximately 10% longer than that of the master regulator. In addition, C_T (master) = 2 C_T (slave) to ensure that the master output pulse, which occurs first, has a longer pulse duration and will subsequently reset the slave regulators.

† Throughout these discussions, references to the SG2524 apply also to the SG3524.

APPLICATION INFORMATION†

voltage reference

The 5-V internal reference may be employed by use of an external resistor divider network to establish a reference within the error amplifiers common-mode voltage range (1.8 V to 3.4 V) as shown in Figure 6, or an external reference may be applied directly to the error amplifier. For operation from a fixed 5-V supply, the internal reference may be bypassed by applying the input voltage to both the V_{CC} and V_{REF} terminals. In this configuration, however, the input voltage is limited to a maximum of 6 V.

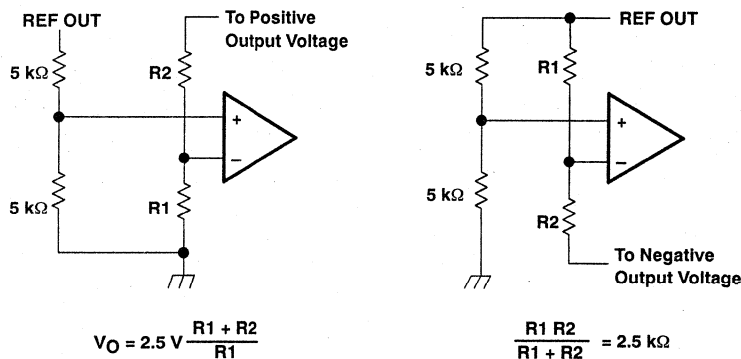


Figure 6. Error Amplifier Bias Circuits

error amplifier

The error amplifier is a differential-input transconductance amplifier. The output is available for dc gain control or ac phase compensation. The compensation node (COMP) is a high-impedance node ($R_L = 5 M\Omega$). The gain of the amplifier is $A_V = (0.002 \Omega^{-1})R_L$ and can easily be reduced from a nominal 10,000 by an external shunt resistance from COMP to ground. Refer to Figure 3 for data.

compensation

COMP, as discussed above, is made available for compensation. Since most output filters will introduce one or more additional poles at frequencies below 200 Hz, which is the pole of the uncompensated amplifier, introduction of a zero to cancel one of the output filter poles is desirable. This can best be accomplished with a series RC circuit from COMP to ground in the range of 50 kΩ and 0.001 μF. Other frequencies can be canceled by use of the formula $f \approx 1/RC$.

shut-down circuitry

COMP can also be employed to introduce external control of the SG2524. Any circuit that can sink 200 μA can pull the compensation terminal to ground and thus disable the SG2524.

In addition to constant-current limiting, CURR LIM+ and CURR LIM– may also be used in transformer-coupled circuits to sense primary current and shorten an output pulse should transformer saturation occur. CURR LIM– may also be grounded to convert CURR LIM+ into an additional shut-down terminal.

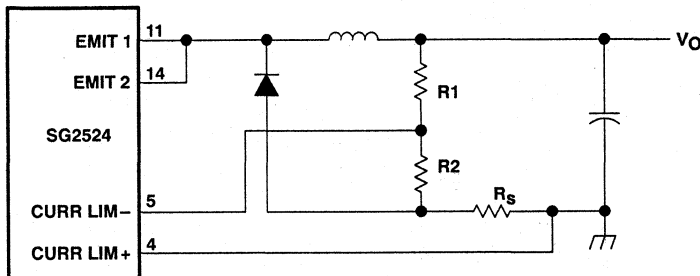
† Throughout these discussions, references to the SG2524 apply also to the SG3524.

APPLICATION INFORMATION†

current limiting

A current-limiting sense amplifier is provided in the SG2524. The current-limiting sense amplifier exhibits a threshold of 200 mV and must be applied in the ground line since the voltage range of the inputs is limited to +1 V to -1 V. Caution should be taken to ensure the -1 V limit is not exceeded by either input, otherwise damage to the device may result.

Foldback current limiting can be provided with the network shown in Figure 7. The current-limit schematic is shown in Figure 8.



$$I_{O(max)} = \frac{1}{R_s} \left(V_{(sense)} + \frac{V_O R_2}{R_1 + R_2} \right)$$

$$I_{OS} = \frac{V_{(sense)}}{R_s} \text{ where } V_{(sense)} = 20 \text{ mV}$$

Figure 7. Foldback Current Limiting for Shorted Output Conditions

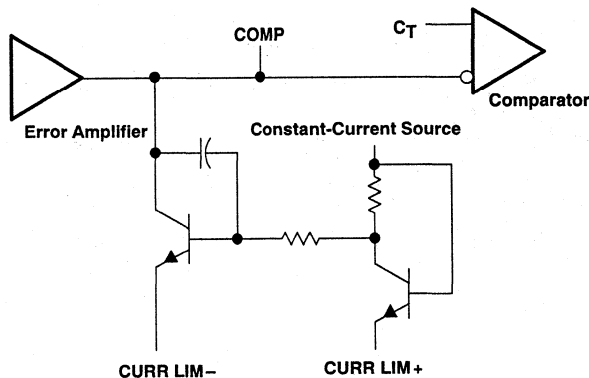


Figure 8. Current-Limit Schematic

output circuitry

The SG2524 contains two identical n-p-n transistors, the collectors and emitters of which are uncommitted. Each transistor has antisaturation circuitry that limits the current through that transistor to a maximum of 100 mA for fast response.

† Throughout these discussions, references to the SG2524 apply also to the SG3524.

SG2524, SG3524 REGULATING PULSE-WIDTH MODULATORS

APPLICATION INFORMATION†

general

There are a wide variety of output configurations possible when considering the application of the SG2524 as a voltage regulator control circuit. They can be segregated into three basic categories:

1. Capacitor-diode-coupled voltage multipliers
2. Inductor-capacitor-implemented single-ended circuits
3. Transformer-coupled circuits

Examples of these categories are shown in Figures 9, 10 and 11, respectively. Detailed diagrams of specific applications are shown in Figures 12 through 15.

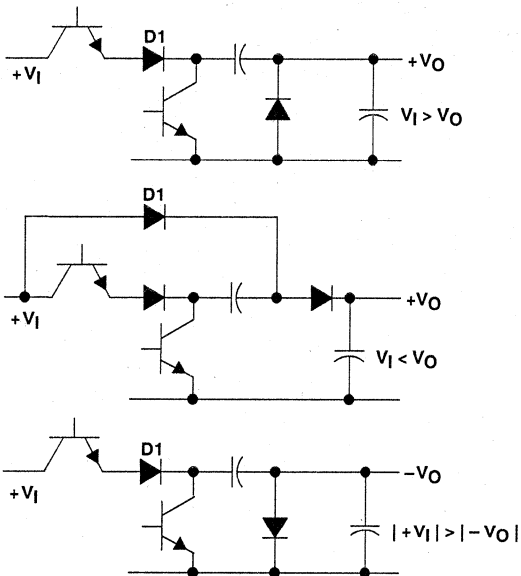


Figure 9. Capacitor-Diode-Coupled Voltage-Multiplier Output Stages

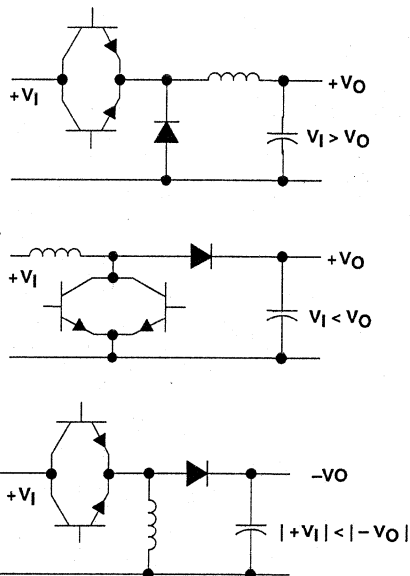


Figure 10. Single-Ended Inductor Circuit

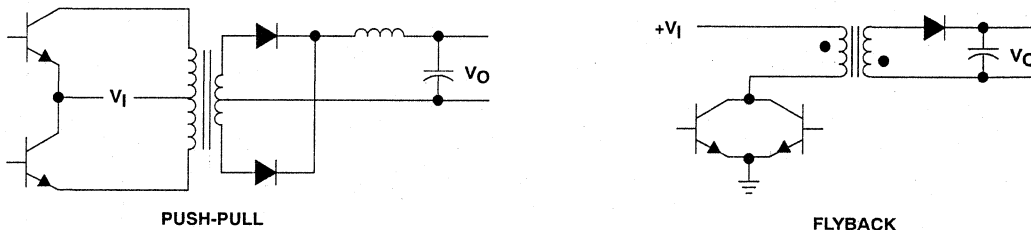


Figure 11. Transformer-Coupled Outputs

† Throughout these discussions, references to the SG2524 apply also to the SG3524.

APPLICATION INFORMATION†

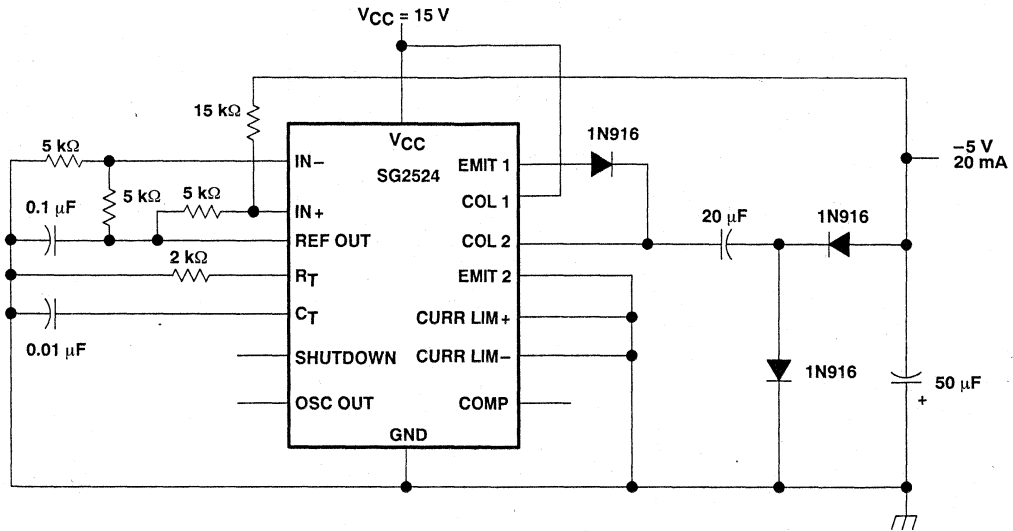


Figure 12. Capacitor-Diode Output Circuit

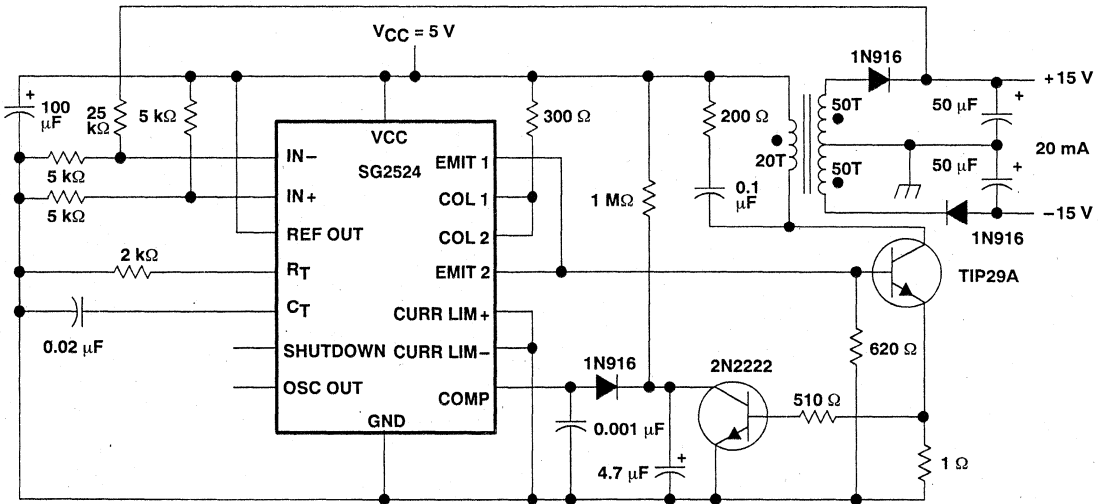


Figure 13. Flyback Converter Circuit

† Throughout these discussions, references to the SG2524 apply also to the SG3524.

SG2524, SG3524 REGULATING PULSE-WIDTH MODULATORS

APPLICATION INFORMATION†

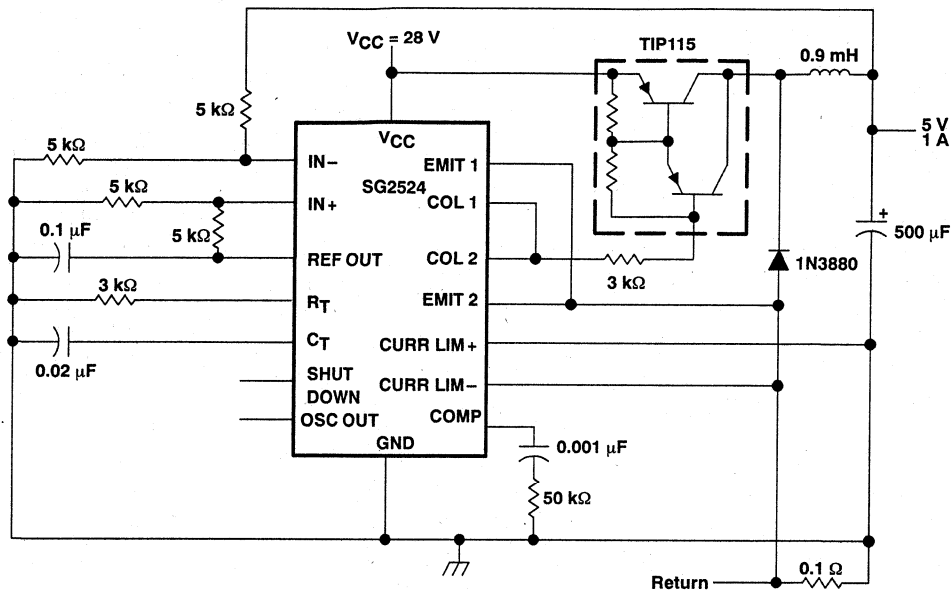


Figure 14. Single-Ended LC Circuit

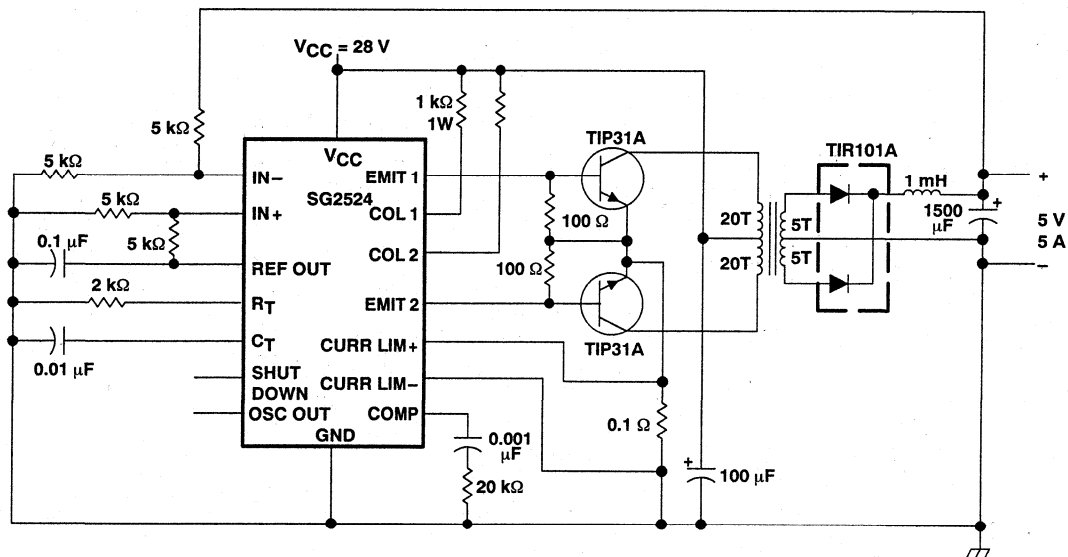


Figure 15. Push-Pull Transformer-Coupled Circuit

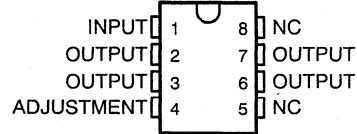
†Throughout these discussions, references to the SG2524 apply also to the SG3524.

TL317C 3-TERMINAL ADJUSTABLE REGULATOR

D2527, APRIL 1979—REVISED AUGUST 1991

- Output Voltage Range Adjustable From 1.2 V to 32 V When Used With an External Resistor Divider
- Output Current Capability of 100 mA
- Input Regulation Typically 0.01% Per Input-Voltage Change
- Output Regulation Typically 0.5%
- Ripple Rejection Typically 80 dB

D PACKAGE
(TOP VIEW)



NOTE: OUTPUT terminals are all internally connected.

description

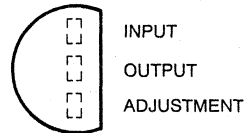
The TL317C is an adjustable 3-terminal positive-voltage regulator capable of supplying 100 mA over an output-voltage range of 1.2 V to 32 V. It is exceptionally easy to use and requires only two external resistors to set the output voltage. Both input and output regulation are better than standard fixed regulators. The device is packaged in standard packages that are easily mounted and handled.

In addition to higher performance than fixed regulators, this regulator offers full overload protection available only in integrated circuits. Included on the chip are current-limiting and thermal-overload protection. All overload protection circuitry remains fully functional even if ADJUSTMENT is disconnected. Normally, no capacitors are needed unless the device is situated far from the input filter capacitors, in which case an input bypass is needed. An optional output capacitor can be added to improve transient response. ADJUSTMENT can be bypassed to achieve very high ripple rejection, which is difficult to achieve with standard 3-terminal regulators.

In addition to replacing fixed regulators, the TL317C regulator is useful in a wide variety of other applications. 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. Its primary application is that of a programmable output regulator, but by connecting a fixed resistor between ADJUSTMENT and OUTPUT, this device can be used as a precision current regulator. Supplies with electronic shutdown can be achieved by clamping ADJUSTMENT to ground, programming the output to 1.2 V where most loads draw little current.

The TL317C is characterized for operation from 0°C to 125°C.

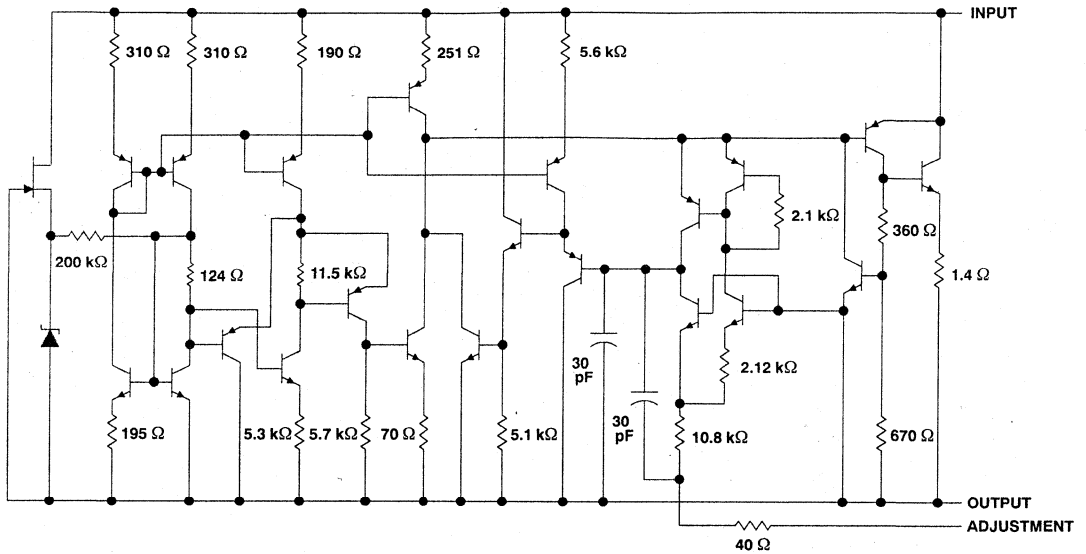
LP SILECT PACKAGE
(TOP VIEW)



NC—No internal connection

TL317C 3-TERMINAL ADJUSTABLE REGULATOR

schematic



All component values shown are nominal.

absolute maximum ratings over operating temperature range (unless otherwise noted)

| | |
|---|---------------------------------------|
| Input-to-output differential voltage, $V_I - V_O$ | 35 V |
| Continuous total dissipation | See Dissipation Rating Tables 1 and 2 |
| Operating free-air, case, or virtual-junction temperature range | 0°C to 150°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

DISSIPATION RATING TABLE 1 - FREE-AIR TEMPERATURE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$ | $T_A = 125^\circ\text{C}$ POWER RATING |
|---------|---|---|---|
| D | 725 mW | 5.8 mW/°C | 145 mW |
| LP† | 775 mW | 6.2 mW/°C | 155 mW |

† The LP package dissipation rating is based on thermal resistance measured in still air with the device mounted in an Augat socket. The bottom of the package is 10 mm (0.375 in.) above the socket.

DISSIPATION RATING TABLE 2 - CASE TEMPERATURE

| PACKAGE | $T_C \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR | DERATE ABOVE T_C | $T_C = 125^\circ\text{C}$ POWER RATING |
|---------|---|--------------------|-----------------------|---|
| D | 1600 mW | 29.6 mW/°C | 96°C | 740 mW |
| LP | 1600 mW | 28.6 mW/°C | 94°C | 715 mW |

recommended operating conditions

| | MIN | MAX | UNIT |
|---|-----|-----|------|
| Input-to-output voltage differential, $V_I - V_O$ | | 35 | V |
| Output current, I_O | 2.5 | 100 | mA |
| Operating virtual-junction temperature, T_J | 0 | 125 | °C |

electrical characteristics over recommended operating virtual-junction temperature range (unless otherwise noted)

| PARAMETER | TEST CONDITIONS† | MIN | TYP | MAX | UNIT |
|---|---|-----------------------|--------|------|---------------|
| Input regulation (see Note 1) | $V_I - V_O = 3\text{ V to }35\text{ V}$ $T_J = 25^\circ\text{C}$ $I_O = 2.5\text{ mA to }100\text{ mA}$ | | 0.01 | 0.02 | %V |
| | | | 0.02 | 0.05 | |
| Ripple regulation | $V_O = 10\text{ V}$, $f = 120\text{ Hz}$ $V_O = 10\text{ V}$, $f = 120\text{ Hz}$, 10- μF capacitor between ADJUSTMENT and ground | | 65 | | dB |
| | | | 66 | 80 | |
| Output regulation | $I_O = 2.5\text{ mA to }100\text{ mA}$, $T_J = 25^\circ\text{C}$ | $V_O \leq 5\text{ V}$ | 25 | | mV |
| | | $V_O \geq 5\text{ V}$ | 0.5% | | |
| | $I_O = 2.5\text{ mA to }100\text{ mA}$ | $V_O \leq 5\text{ V}$ | 50 | | mV |
| | | $V_O \geq 5\text{ V}$ | 1% | | |
| Output voltage change with temperature | $T_J = 0^\circ\text{C to }125^\circ\text{C}$ | | 1% | | |
| Output voltage long-term drift (see Note 2) | After 1000 hours at $T_J = 125^\circ\text{C}$ and $V_I - V_O = 35\text{ V}$ | | 0.3% | 1% | |
| Output noise voltage | $f = 10\text{ Hz to }10\text{ kHz}$, $T_J = 25^\circ\text{C}$ | | 0.003% | | |
| Minimum output current to maintain regulation | $V_I - V_O = 35\text{ V}$ | | 1.5 | 2.5 | mA |
| Peak output current | $V_I - V_O \leq 35\text{ V}$ | 100 | 200 | | mA |
| ADJUSTMENT current | | | 50 | 100 | μA |
| Change in ADJUSTMENT current | $V_I - V_O = 2.5\text{ V to }35\text{ V}$, $I_O = 2.5\text{ mA to }100\text{ mA}$ | | 0.2 | 5 | μA |
| Reference voltage (output to ADJUSTMENT) | $V_I - V_O = 3\text{ V to }35\text{ V}$, $P \leq$ rated dissipation | 1.2 | 1.25 | 1.3 | V |

† Unless otherwise noted, these specifications apply for the following test conditions: $V_I - V_O = 5\text{ V}$ and $I_O = 40\text{ mA}$. Pulse-testing techniques must be used that will maintain the junction temperature as close to the ambient temperature as possible. All characteristics are measured with a 0.1- μF capacitor across the input and a 1- μF capacitor across the output.

- NOTES: 1. Input regulation is expressed here as the percentage change in output voltage per 1-V change at the input
 2. Since long-term drift cannot be measured on the individual devices prior to shipment, this specification is not intended to be a guarantee or warranty. It is an engineering estimate of the average drift to be expected from lot to lot.

TL317C 3-TERMINAL ADJUSTABLE REGULATOR

APPLICATION INFORMATION

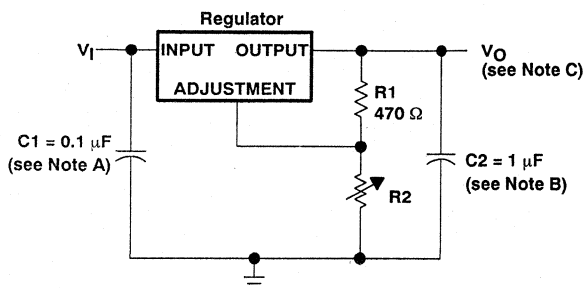


Figure 1. Adjustable Voltage Regulator

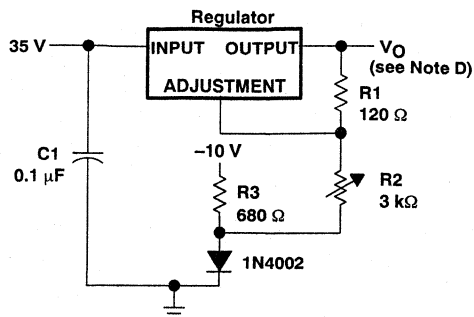
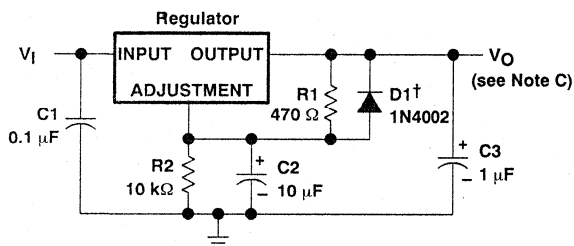


Figure 2. 0-V to 30-V Regulator Circuit



† D1 discharges C2 if output is shorted to ground.

Figure 3. Regulator Circuit
With Improved Ripple Rejection

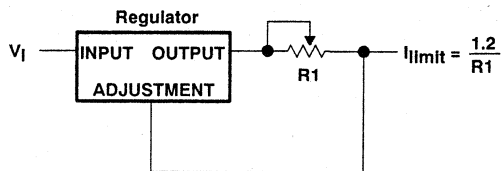


Figure 4. Precision Current-Limiter Circuit

NOTES: A. Use of an input bypass capacitor is recommended if regulator is far from the filter capacitors.
B. Use of an output capacitor improves transient response but is optional.

C. Output voltage is calculated from the equation: $V_O = V_{ref} \left(1 + \frac{R2}{R1} \right)$

where: V_{ref} equals the difference between OUTPUT and ADJUSTMENT voltages.

D. Output voltage is calculated from the equation: $V_O = V_{ref} \left(1 + \frac{R2 + R3}{R1} \right) - 10 \text{ V}$

where: V_{ref} equals the difference between OUTPUT and ADJUSTMENT voltages.

APPLICATION INFORMATION

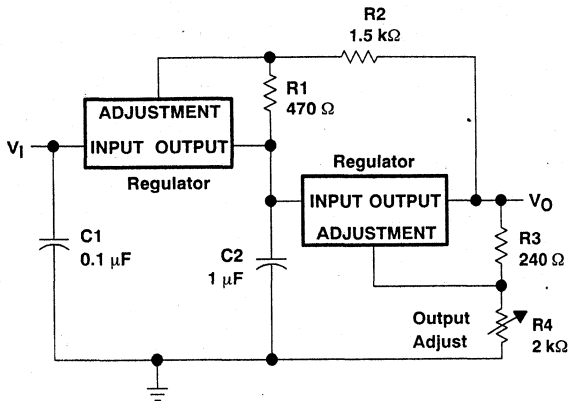


Figure 5. Tracking Preregulator Circuit

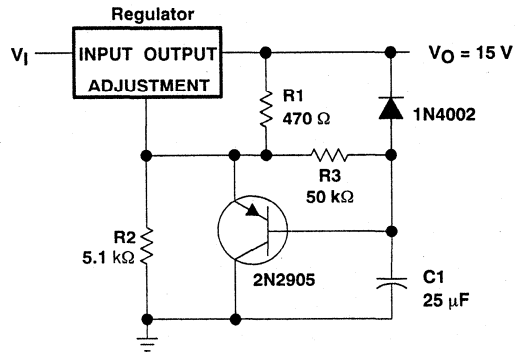


Figure 6. Slow-Turn-On 15-V Regulator Circuit

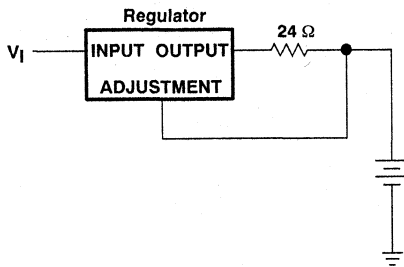
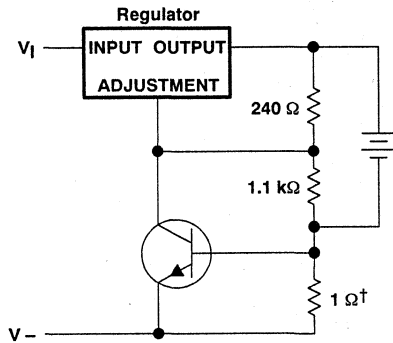


Figure 7. 50-mA Constant-Current Battery Charger Circuit

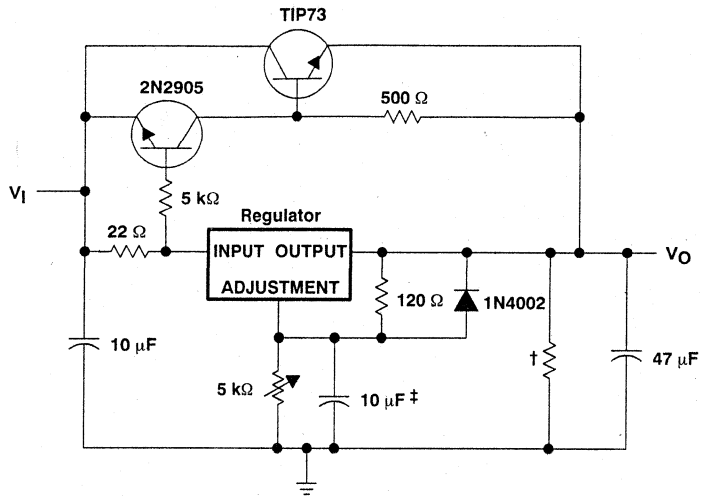


† This resistor sets peak current (100 mA for 6 Ω).

Figure 8. Current-Limited 6-V Charger

TL317C 3-TERMINAL ADJUSTABLE REGULATOR

APPLICATION INFORMATION



† Minimum load current is 30 mA.

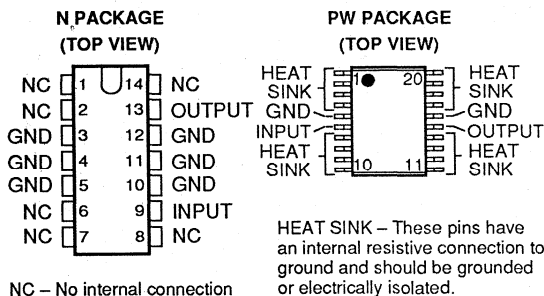
‡ Optional capacitor improves ripple rejection

Figure 9. High-Current Adjustable Regulator

TL-SCSI285 FIXED VOLTAGE REGULATOR FOR SCSI ACTIVE TERMINATION

D3943, NOVEMBER 1991

- Fully Matches Parameters for Alternative 2 SCSI Active Termination
- Fixed 2.85-V Output
- $\pm 1\%$ Maximum Output Tolerance at $T_J = 25^\circ\text{C}$
- 0.6-V Maximum Dropout Voltage
- 620-mA Output Current
- $\pm 2\%$ Absolute Output Variation
- Internal Overcurrent Limiting Circuitry
- Internal Thermal Overload Protection
- Internal Overvoltage Protection

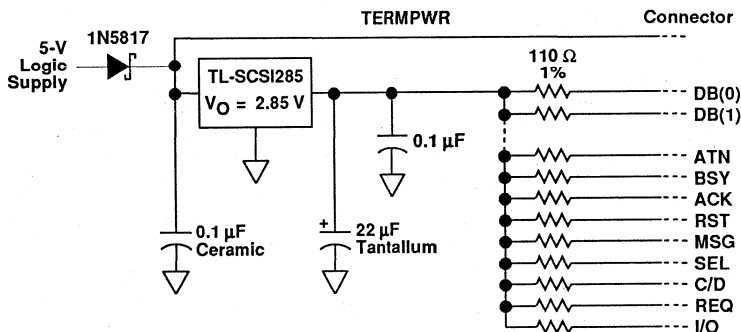


description

The TL-SCSI285 is a low-dropout (0.6-V) fixed voltage regulator specifically designed for Small Computer Systems Interface (SCSI) alternative 2 active signal termination. The TL-SCSI285's 0.6-V maximum dropout ensures compatibility with existing SCSI systems, while providing a wide TERMPWR voltage range. At the same time, the $\pm 1\%$ initial tolerance on its 2.85-V output voltage ensures a tighter line driver current tolerance, thereby increasing system noise margin.

The fixed 2.85-V output voltage of the TL-SCSI285 supports the SCSI alternative 2 termination standard while reducing system power consumption. The 0.6-V maximum dropout voltage brings increased TERMPWR isolation, making the device ideal for battery-powered systems. The TL-SCSI285, with internal current limiting,

typical application schematic



AVAILABLE OPTIONS

| T _J | PACKAGE | | |
|----------------|--------------------|-----------------|---------------------------------|
| | PLASTIC POWER (KC) | PLASTIC DIP (N) | SURFACE MOUNT (PW) [†] |
| 0°C to 125°C | TL-SCSI285KC | TL-SCSI285N | TL-SCSI285PWLE |

[†]The PW package is only available left-end taped and reeled.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

**TEXAS
INSTRUMENTS**
POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

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TL-SCSI285 FIXED VOLTAGE REGULATOR FOR SCSI ACTIVE TERMINATION

description (continued)

overvoltage protection, ESD protection, and thermal protection, offers designers enhanced system protection and reliability.

When configured as a SCSI active terminator, the TL-SCSI285 low-dropout regulator eliminates the 220- Ω and 330- Ω resistors required for each transmission line with a passive termination scheme, reducing significantly the continuous system power drain. When placed in series with 110- Ω resistors, the device matches the impedance level of the transmission cable and eliminates reflections.

The TL-SCSI285 is characterized for operation from 0°C to 125°C virtual junction temperature.

TL-SCSI285 FIXED VOLTAGE REGULATOR FOR SCSI ACTIVE TERMINATION

absolute maximum ratings over operating temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Continuous input voltage | 7.5 V |
| Continuous total dissipation (see Note 1) | See Dissipation Rating Table |
| Operating virtual junction temperature range | -55°C to 150°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 1: Refer to Figures 1 and 2 to avoid exceeding the design maximum virtual junction temperature; these ratings should not be exceeded. Due to variation in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

DISSIPATION RATING TABLE

| PACKAGE | POWER RATING | | DERATING FACTOR | | | |
|---------|--------------|---|------------------------------|--|--|---|
| | AT | $T_A \leq 25^\circ\text{C}$ POWER RATING | ABOVE $T = 25^\circ\text{C}$ | $T = 70^\circ\text{C}$ POWER RATING | $T = 85^\circ\text{C}$ POWER RATING | $T = 125^\circ\text{C}$ POWER RATING |
| KC | T_A | 2000 mW | 16 mW/°C | 1280 mW | 1040 mW | 400 mW |
| | T_C | 20000 mW | 182 mW/°C | 14540 mW | 11810 mW | 4645 mW |
| N | T_A | 2250 mW | 18.0 mW/°C | 1440 mW | 1170 mW | 450 mW |
| | T_C | 11850 mW | 94.8 mW/°C | 7584 mW | 6162 mW | 2370 mW |
| PW | T_A | 775 mW | 6.4 mW/°C | 520 mW | 423 mW | 161 mW |

Derate above 40°C

**DISSIPATION DERATING CURVE
vs
FREE-AIR TEMPERATURE**

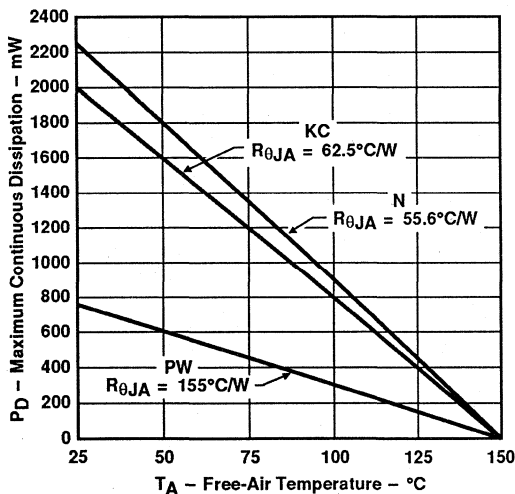


Figure 1

**DISSIPATION DERATING CURVE
vs
CASE TEMPERATURE**

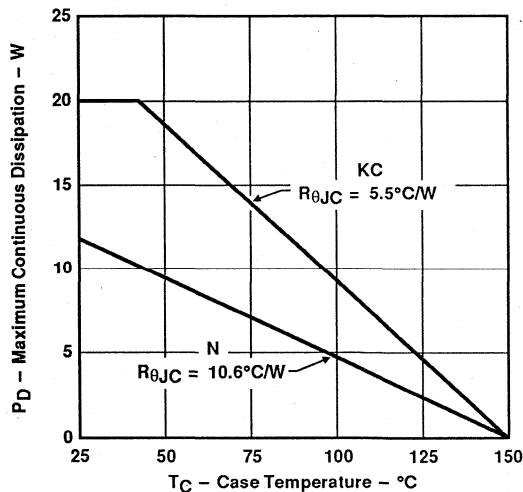


Figure 2

recommended operating conditions

| | MIN | MAX | UNIT |
|---|-------------------|-----|--------|
| Input voltage, V_i | 3.45 | 5.5 | V |
| Output current, I_O | KC and N packages | 0 | 620 mA |
| | PW package | 0 | 500 mA |
| Operating virtual junction temperature range, T_J | 0 | 125 | °C |

TL-SCSI285 FIXED VOLTAGE REGULATOR FOR SCSI ACTIVE TERMINATION

TL-SCSI285KC, TL-SCSI285N electrical characteristics at, $V_I = 4.5\text{ V}$, $I_O = 500\text{ mA}$, $T_J = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS† | MIN | TYP | MAX | UNIT | |
|----------------------|--|---------------------------------------|------|------|---------------|---|
| Output voltage | $I_O = 20\text{ mA to }620\text{ mA}$, $V_I = 3.45\text{ V to }5.5\text{ V}$ | $T_A = T_J = 25^\circ\text{C}$ | 2.82 | 2.85 | 2.88 | V |
| | | $T_J = 0\text{ to }125^\circ\text{C}$ | 2.79 | | 2.91 | |
| Input regulation | $V_I = 3.45\text{ V to }5.5\text{ V}$ | | 5 | 15 | mV | |
| Ripple rejection | $f = 120\text{ Hz}$, $V_{\text{ripple}} = 1\text{ V}_{\text{pp}}$ | | -62 | | dB | |
| Output regulation | $I_O = 20\text{ mA to }620\text{ mA}$ | | 5 | 30 | mV | |
| | $I_O = 20\text{ mA to }500\text{ mA}$ | | 5 | 30 | | |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | | 500 | | μV | |
| Dropout voltage | $I_O = 500\text{ mA}$ | | | 0.6 | V | |
| | $I_O = 620\text{ mA}$ | | | 0.8 | | |
| Bias current | $I_O = 0$ | | 2 | 5 | mA | |
| | $I_O = 27\text{ mA}$, equivalent 1 line asserted | | 3 | 6 | | |
| | $I_O = 500\text{ mA}$, equivalent 18 line asserted (8 bit) | | 26 | 49 | | |
| | $I_O = 620\text{ mA}$ | | 37 | 62 | | |

TL-SCSI285PW electrical characteristics at, $V_I = 4.5\text{ V}$, $I_O = 500\text{ mA}$, $T_J = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS† | MIN | TYP | MAX | UNIT | |
|----------------------|--|---------------------------------------|------|------|---------------|---|
| Output voltage | $I_O = 20\text{ mA to }500\text{ mA}$, $V_I = 3.55\text{ V to }5.5\text{ V}$ | $T_A = T_J = 25^\circ\text{C}$ | 2.82 | 2.85 | 2.88 | V |
| | | $T_J = 0\text{ to }125^\circ\text{C}$ | 2.79 | | 2.91 | |
| Input regulation | $V_I = 3.55\text{ V to }5.5\text{ V}$ | | 5 | 15 | mV | |
| Ripple rejection | $f = 120\text{ Hz}$, $V_{\text{ripple}} = 1\text{ V}_{\text{pp}}$ | | -62 | | dB | |
| Output regulation | $I_O = 20\text{ mA to }500\text{ mA}$ | | 5 | 30 | mV | |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | | 500 | | μV | |
| Dropout voltage | $I_O = 500\text{ mA}$ | | | 0.7 | V | |
| Bias current | $I_O = 0$ | | 2 | 5 | mA | |
| | $I_O = 27\text{ mA}$, equivalent 1 line asserted | | 3 | 6 | | |
| | $I_O = 500\text{ mA}$, equivalent 18 line asserted (8 bit) | | 26 | 49 | | |

Pulse-testing techniques are used to maintain the virtual junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.1- μF capacitor across the input and a 22- μF tantalum capacitor with equivalent series resistance of 1.5 Ω on the output.

COMPENSATION CAPACITOR SELECTION INFORMATION

The TL-SCSI285 is a low-dropout regulator. This means that the capacitance loading is important to the performance of the regulator because it is a vital part of the control loop. The capacitor value and the equivalent series resistance (ESR) both affect the control loop and must be defined for the load range and the temperature range. Figures 3 and 4 can be used to establish the capacitance value and ESR range for best regulator performance.

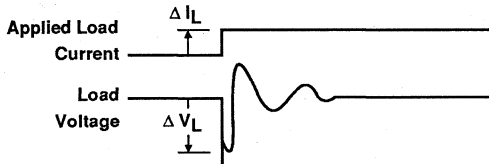
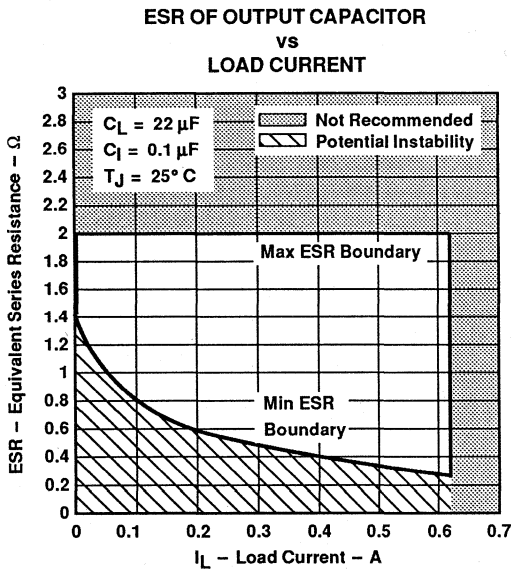


Figure 3

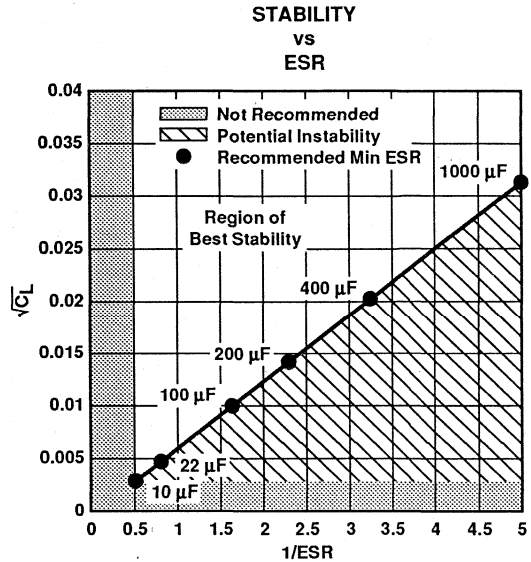


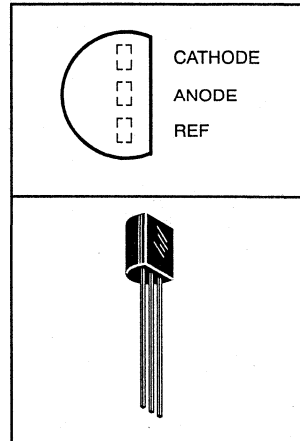
Figure 4

TL430C, TL430I ADJUSTABLE SHUNT REGULATORS

D2165, JUNE 1976—REVISED AUGUST 1991

- Temperature Compensated
- Programmable Output Voltage
- Low Output Resistance
- Low Output Noise
- Sink Capability to 100 mA

LP PACKAGE
(TOP VIEW)



description

The TL430 is a 3-terminal adjustable shunt regulator featuring excellent temperature stability, wide operating current range, and low output noise. The output voltage may be set by two external resistors to any desired value between 3 V and 30 V. The TL430 can replace zener diodes in many applications providing improved performance.

The TL430C is characterized for operation from 0°C to 70°C. The TL430I is characterized for operation from -40°C to 85°C.

symbol



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|----------------|
| Regulator voltage (see Note 1) | 30 V |
| Continuous regulator current | 150 mA |
| Continuous dissipation at (or below) 25°C free-air temperature (see Note 2) | 775 mW |
| Operating free-air temperature range: TL430C | 0°C to 70°C |
| TL430I | -40°C to 85°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

- NOTES: 1. All voltage values are with respect to the anode terminal.
2. For operation above 25°C free-air temperature, derate at 6.2 mW/°C.

recommended operating conditions

| | MIN | MAX | UNIT |
|---------------------------------------|-----------|-----|------|
| Regulator voltage, V_Z | V_{ref} | 30 | V |
| Regulator current, I_Z | 2 | 100 | mA |
| Operating free-air temperature, T_A | TL430C | 0 | °C |
| | TL430I | -40 | |

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

**TEXAS
INSTRUMENTS**

POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

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TL430C, TL430I ADJUSTABLE SHUNT REGULATORS

electrical characteristics at 25°C free-air temperature (unless otherwise noted)

| PARAMETER | TEST FIGURE | TEST CONDITIONS | TL430C | | | TL430I | | | UNIT | | |
|-------------------|--|-----------------|--|-----------------------|------|--------|-----|------|------|--------|----|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | | | |
| V _{ref} | Reference input voltage | 1 | V _Z = V _{ref} , I _Z = 10 mA | 2.5 | 2.75 | 3 | 2.6 | 2.75 | 2.9 | V | |
| αV _{ref} | Temperature coefficient of reference input voltage | 1 | V _Z = V _{ref} , T _A = full range† | 120 | | | 120 | 200 | | ppm/°C | |
| I _{ref} | Reference input current | 2 | I _Z = 10 mA, R1 = 10 kΩ, R2 = ∞ | 3 | | | 3 | | 10 | μA | |
| I _{ZK} | Regulator current near lower knee of regulation range | 1 | V _Z = V _{ref} | 0.5 | | | 0.5 | | 2 | mA | |
| I _{ZM} | Regulator current at maximum limit of regulation range | 1 | V _Z = V _{ref} | 50 | | | 50 | | | mA | |
| | | 2 | V _Z = 5 V to 30 V, See Note 3 | 100 | | | 100 | | | | |
| r _Z | Differential regulator resistance (see Note 4) | 1 | V _Z = V _{ref} , ΔI _Z = (52 - 2) mA | 1.5 | | | 1.5 | | 3 | Ω | |
| V _{nz} | Noise voltage | 2 | f = 0.1 Hz to 10 Hz | V _Z = 3 V | 50 | | | 50 | | | μV |
| | | | | V _Z = 12 V | 200 | | | 200 | | | |
| | | | | V _Z = 30 V | 650 | | | 650 | | | |

† Full temperature range is 0°C to 70°C for the TL430C and -40°C to 85°C for the TL430I.

NOTES: 3. The average power dissipation, V_Z • I_Z • duty cycle, must not exceed the maximum continuous rating in any 10-ms interval.

4. The regulator resistance for V_Z > V_{ref}, r_Z, is given by:

$$r_Z' = r_Z \left(1 + \frac{R1}{R2} \right)$$

PARAMETER MEASUREMENT INFORMATION

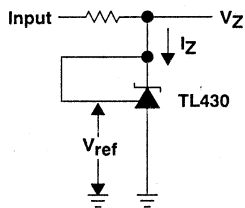
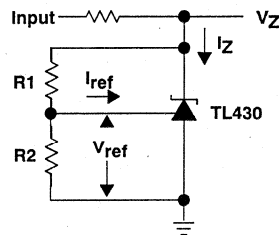


Figure 1. Test Circuit for V_Z = V_{ref}



$$V_Z = V_{ref} \left(1 + \frac{R1}{R2} \right) + I_{ref} \times R1$$

Figure 2. Test Circuit for V_Z > V_{ref}

TYPICAL CHARACTERISTICS

SMALL-SIGNAL REGULATOR IMPEDANCE
vs
FREQUENCY

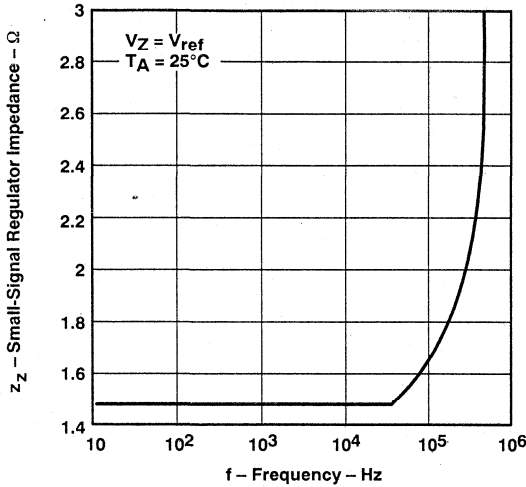


Figure 3

CURRENT
vs
VOLTAGE

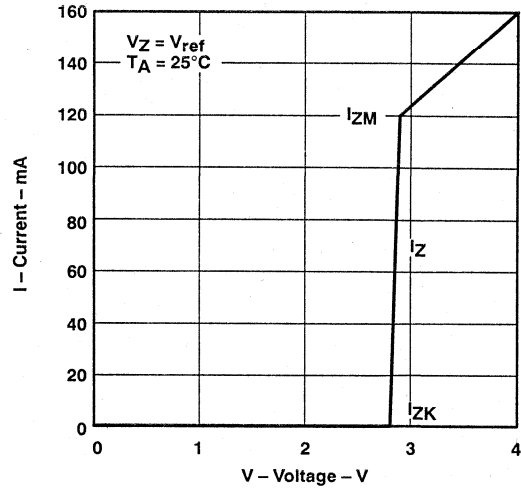


Figure 4

APPLICATION INFORMATION

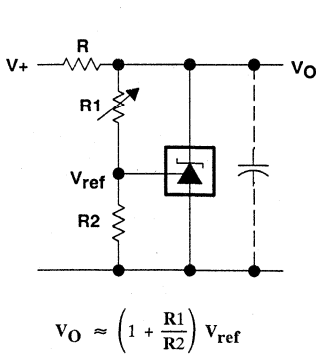


Figure 5. Shunt Regulator

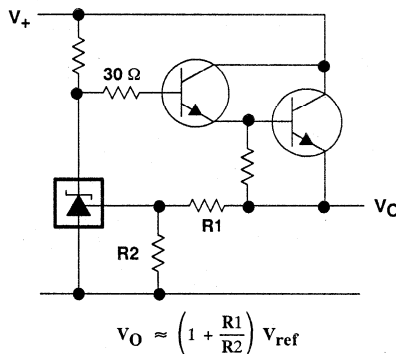


Figure 6. Series Regulator

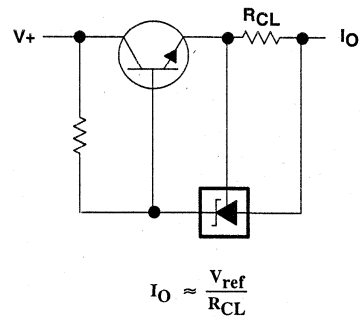
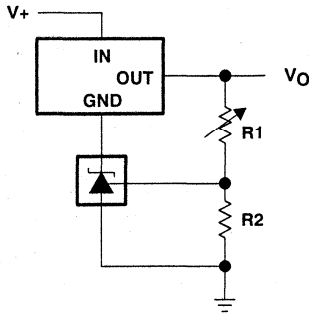


Figure 7. Current Limiter

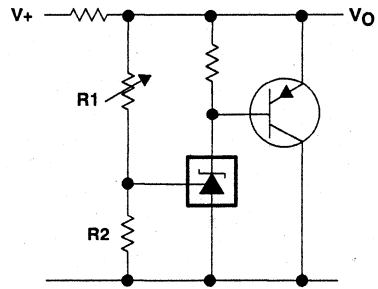
APPLICATION INFORMATION



$$V_O = \left(1 + \frac{R_1}{R_2}\right) V_{ref}$$

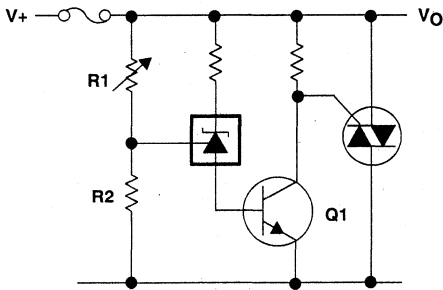
$$\text{Min } V_O = V_{ref} + 5$$

Figure 8. Output Control of a 3-Terminal Fixed Regulator



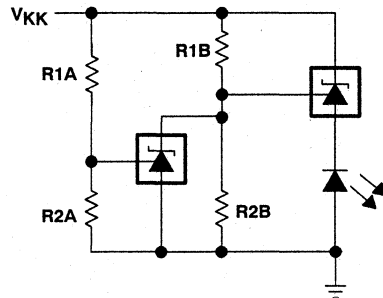
$$V_O \approx \left(1 + \frac{R_1}{R_2}\right) V_{ref}$$

Figure 9. Higher-Current Applications



$$V_{limit} \approx \left(1 + \frac{R_1}{R_2}\right) (V_{ref} + V_{BE}(Q_1))$$

Figure 10. Crowbar



$$\text{Low limit} \approx V_{ref} \left(1 + \frac{R_{1B}}{R_{2B}}\right) + V_{BE}$$

$$\text{High limit} \approx V_{ref} \left(1 + \frac{R_{1A}}{R_{2A}}\right)$$

Figure 11. V_{CC} Monitor

TL431C, TL431AC, TL431I, TL431AI, TL431M ADJUSTABLE PRECISION SHUNT REGULATORS

D2410, JULY 1978—REVISED AUGUST 1991

- Equivalent Full-Range Temperature Coefficient . . . 30 ppm/°C
- 0.2 Ω Typical Output Impedance
- Sink Current Capability . . . 1 mA to 100 mA
- Low Output Noise
- Adjustable Output Voltage . . . V_{ref} to 36 V
- Available in a Wide Range of High Density Packaging Options:
 - Small Outline (D)
 - TO-226AA (LP)
 - SOT-89 (PK)

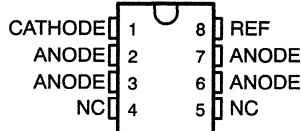
description

The TL431 and TL431A are 3-terminal adjustable shunt regulators with specified thermal stability over applicable automotive, commercial, and military temperature ranges. The output voltage may be set to any value between V_{ref} (approximately 2.5 V) and 36 V with two external resistors (see Figure 16). These devices have a typical output impedance of 0.2 Ω. Active output circuitry provides a very sharp turn-on characteristic, making these devices excellent replacements for zener diodes in many applications like on-board regulation, adjustable power supplies, and switching power supplies.

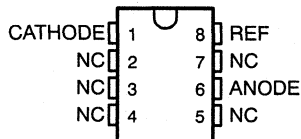
The TL431 is offered in a wide variety of high-density packaging options that includes an SOT-89-type package (suffix PK).

The TL431C and TL431AC are characterized for operation from 0°C to 70°C, and the TL431I and TL431AI are characterized for operation from -40°C to 85°C. The TL431M is characterized for operation over the full military temperature range of -55°C to 125°C.

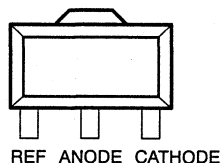
**D PACKAGE
(TOP VIEW)**



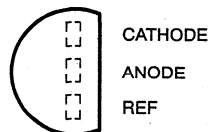
**JG AND P PACKAGE
(TOP VIEW)**



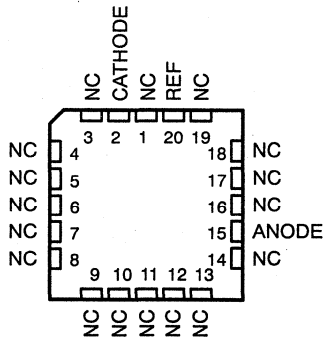
**PK PACKAGE
(TOP VIEW)**



**LP PACKAGE
(TOP VIEW)**



**FK PACKAGE
(TOP VIEW)**



NC—No internal connection

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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On products compliant to MIL-STD-883, Class B, all parameters are tested unless otherwise noted. On all other products, production processing does not necessarily include testing of all parameters.

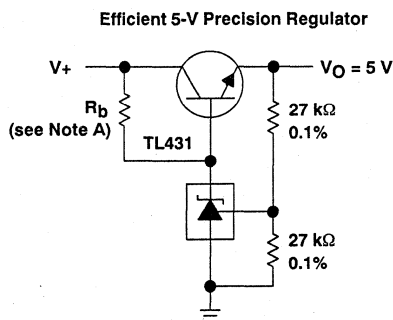
TL431C, TL431AC, TL431I, TL431AI, TL431M ADJUSTABLE PRECISION SHUNT REGULATORS

AVAILABLE OPTIONS

| T _A | PACKAGE | | | | | |
|----------------|----------------------|----------------------|---------------------|-----------------------|---------------------|-----------------------|
| | SMALL OUTLINE (D) | CHIP CARRIER (FX) | CERAMIC DIP (JG) | TO-226AA (LP) | PLASTIC DIP (P) | SOT-89 (PK) |
| 0°C to 70°C | TL431CD TL431ACD | | | TL431CLP TL431ACLP | TL431CP TL431ACP | TL431CPK TL431ACPK |
| -40°C to 85°C | TL431ID TL431AID | | | TL431ILP TL431AILP | TL431IP TL431AIP | TL431IPK TL431AIPK |
| -55°C to 125°C | | TL431MFK | TL431MJG | | | |

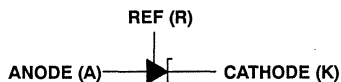
D and LP packages are available taped and reeled. Add "R" suffix to device type (e.g., TL431CDR). PK package is only available taped and reeled. No "R" suffix required.

application schematic

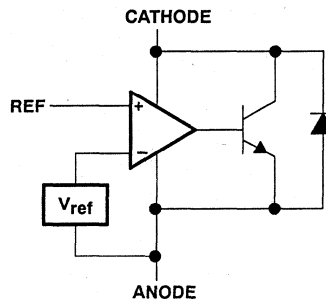


NOTE A: R_b should provide ≥ 1 mA cathode current to the TL431.

symbol

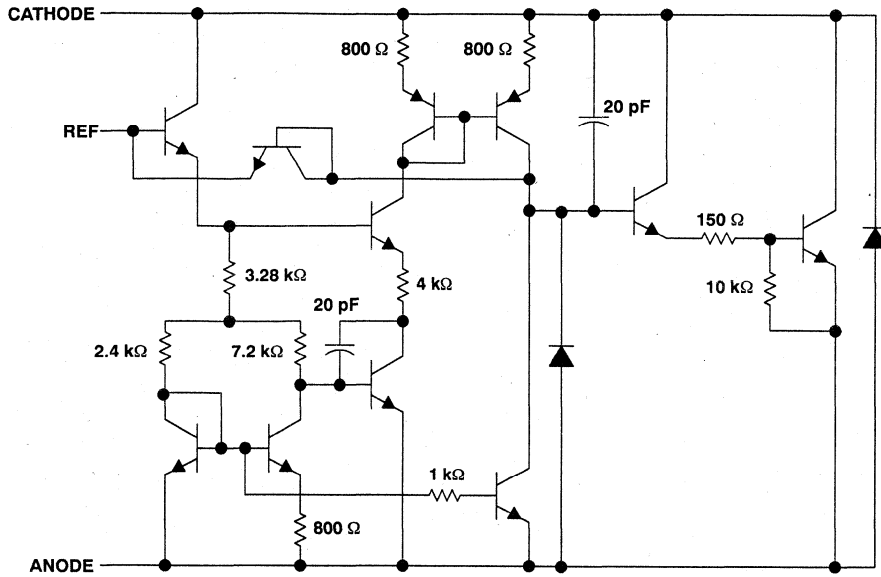


functional block diagram



TL431C, TL431AC, TL431I, TL431AI, TL431M ADJUSTABLE PRECISION SHUNT REGULATORS

equivalent schematic



All component values are nominal.

TL431C, TL431AC, TL431I, TL431AI, TL431M ADJUSTABLE PRECISION SHUNT REGULATORS

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|---------------------------------------|
| Cathode voltage (see Note 1) | 37 V |
| Continuous cathode current range | -100 mA to 150 mA |
| Reference input current range | -50 μ A to 10 mA |
| Continuous power dissipation | See Dissipation Rating Tables 1 and 2 |
| Operating free-air temperature range, T_A : | |
| C-suffix | 0°C to 70°C |
| I-suffix | -40°C to 85°C |
| M-suffix | -55°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG, LP or PK package | 300°C |

NOTE 1: Voltage values are with respect to the anode terminal unless otherwise noted.

DISSIPATION RATING TABLE 1 – FREE-AIR TEMPERATURE

| PACKAGE | DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$ | $T_A = 25^\circ\text{C}$ POWER RATING | $T_A = 70^\circ\text{C}$ POWER RATING | $T_A = 85^\circ\text{C}$ POWER RATING | $T_A = 125^\circ\text{C}$ POWER RATING |
|---------|---|--|--|--|---|
| D | 5.8 mW/ $^\circ\text{C}$ | 725 mW | 464 mW | 429 mW | |
| FK | 11 mW/ $^\circ\text{C}$ | 1375 mW | 880 mW | 715 mW | 275 mW |
| JG | 8.4 mW/ $^\circ\text{C}$ | 1050 mW | 672 mW | 546 mW | 210 mW |
| LP | 6.2 mW/ $^\circ\text{C}$ | 775 mW | 496 mW | 403 mW | |
| P | 8.0 mW/ $^\circ\text{C}$ | 1000 mW | 640 mW | 520 mW | |
| PK | 4.0 mW/ $^\circ\text{C}$ | 500 mW | 320 mW | 266 mW | |

DISSIPATION RATING TABLE 2 – CASE TEMPERATURE

| PACKAGE | DERATING FACTOR ABOVE $T_C = 25^\circ\text{C}$ | $T_C = 25^\circ\text{C}$ POWER RATING | $T_C = 70^\circ\text{C}$ POWER RATING | $T_C = 85^\circ\text{C}$ POWER RATING |
|---------|---|--|--|--|
| PK | 25 mW/ $^\circ\text{C}$ | 3125 mW | 2000 mW | 2625 mW |

recommended operating conditions

| | MIN | MAX | UNIT |
|---------------------------|-----------|-----|------|
| Cathode voltage, V_{KA} | V_{ref} | 36 | V |
| Cathode current, I_K | 1 | 100 | mA |



TL431C, TL431AC, TL431I, TL431AI, TL431M ADJUSTABLE PRECISION SHUNT REGULATORS

electrical characteristics at 25 °C free-air temperature (unless otherwise noted)

| PARAMETER | TEST CIRCUIT | TEST CONDITIONS | TL431M | | TL431I | | TL431C | | UNIT |
|--|---|---|--------|------|--------|------|--------|------|------------------------------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| V _{ref} | Reference input voltage | V _K A = V _{ref} ; I _K = 10 mA | 2400 | 2495 | 2600 | 2440 | 2495 | 2550 | mV |
| V _{ref(dev)} | Deviation of reference input voltage over full temperature range [†] | V _K A = V _{ref} ; I _K = 10 mA, T _A = full range [†] | 22 | 5 | 30 | 2440 | 2495 | 2550 | mV |
| $\frac{\Delta V_{ref}}{\Delta V_{KA}}$ | Ratio of change in reference input voltage to the change in cathode voltage | $\frac{\Delta V_{KA}}{I_K} = 10 \text{ V} - V_{ref}$ $\frac{\Delta V_{KA}}{I_K} = 36 \text{ V} - 10 \text{ V}$ | -1.4 | -3 | -1.4 | -2.7 | -1.4 | -2.7 | $\frac{\text{mV}}{\text{V}}$ |
| I _{ref} | Reference input current | I _K = 10 mA, R1 = 10 kΩ, R2 = ∞ | 2 | 8* | 4 | 2 | 4 | 4 | μA |
| I _{ref(dev)} | Deviation of reference input current over full temperature range [†] | I _K = 10 mA, R1 = 10 kΩ, R2 = ∞, T _A = full range [†] | 1 | 0.8 | 2.5 | 0.4 | 1 | 0.4 | μA |
| I _{min} | Minimum cathode current for regulation | V _K A = V _{ref} | 0.4 | 1.5 | 1 | 0.4 | 1 | 0.4 | mA |
| I _{off} | Off-state cathode current | V _K A = 36 V, V _{ref} = 0 | 0.1 | 3 | 1 | 0.1 | 1 | 0.1 | μA |
| z _{ka} | Dynamic impedance [§] | V _K A = V _{ref} ; I _K = 1 mA to 100 mA, f ≤ 1 kHz | 0.2 | 0.9* | 0.5 | 0.2 | 0.5 | 0.2 | Ω |

*On products compliant to MIL-STD-883, Class B, this parameter is not production tested.

[†] Full temperature range is -55 °C to 125 °C for the TL431M, -40 °C to 85 °C for the TL431I and TL431AI, and 0 °C to 70 °C for the TL431C and TL431AC.

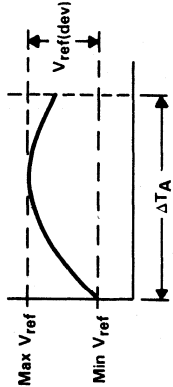
[‡] The deviation parameters V_{ref(dev)} and I_{ref(dev)} are defined as the differences between the maximum and minimum values obtained over the rated temperature range. The average full-range temperature coefficient of the reference input voltage, αV_{ref}, is defined as:

$$|\alpha V_{ref}| \left(\frac{\text{ppm}}{^\circ\text{C}} \right) = \frac{\left(\frac{V_{ref(dev)}}{V_{ref}} \right) \times 10^6}{\Delta T_A}$$

where ΔT_A is the rated operating free-air temperature range of the device.

αV_{ref} can be positive or negative depending on whether minimum V_{ref} or maximum V_{ref}, respectively, occurs at the lower temperature.

Example: Max V_{ref} = 2496 mV at 30 °C, Min V_{ref} = 2492 mV at 0 °C, V_{ref} = 2495 mV at 25 °C, ΔT_A = 70 °C for TL431C



$$|\alpha V_{ref}| = \frac{\left(\frac{4 \text{ mV}}{2495 \text{ mV}} \right) \times 10^6}{70 ^\circ\text{C}} \approx 23 \text{ ppm}/^\circ\text{C}$$

Because minimum V_{ref} occurs at the lower temperature, the coefficient is positive.

[§]The dynamic impedance is defined as: |z_{ka}| = $\frac{\Delta V_{KA}}{\Delta I_K}$

When the device is operating with two external resistors, (see Figure 2), the total dynamic impedance of the circuit is given by:

$$|z'| = \frac{\Delta V}{\Delta I} \approx |z_{ka}| \left(1 + \frac{R1}{R2} \right)$$



TL431C, TL431AC, TL431I, TL431AI, TL431M ADJUSTABLE PRECISION SHUNT REGULATORS

electrical characteristics at 25 °C free-air temperature (unless otherwise noted)

| PARAMETER | TEST CIRCUIT | TEST CONDITIONS | TL431AI | | | TL431AC | | | UNIT |
|---------------------------------------|---|--|---------|------|------|---------|------|------|---------------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| V _{ref} | Reference input voltage | V _{KA} = V _{ref} , I _K = 10 mA | 2470 | 2495 | 2520 | 2470 | 2495 | 2520 | mV |
| V _{ref(dev)} | Deviation of reference input voltage over full temperature range † | V _{KA} = V _{ref} , I _K = 10 mA, T _A = full range † | | 5 | 25 | | 4 | 15 | mV |
| $\frac{\Delta V_{ref}}{V_{ref}}$ | Ratio of change in reference input voltage to the change in cathode voltage | $\Delta V_{KA} = 10 \text{ V} - V_{ref}$ I _K = 10 mA | | -1.4 | -2.7 | | -1.4 | -2.7 | mV |
| $\frac{\Delta V_{KA}}{\Delta I_{KA}}$ | Reference input current | $\Delta I_{KA} = 36 \text{ V} - 10 \text{ V}$ | | -1 | -2 | | -1 | -2 | V |
| I _{ref} | Reference input current | I _K = 10 mA, R1 = 10 k Ω , R2 = ∞ | | 2 | 4 | | 2 | 4 | μA |
| I _{ref(dev)} | Deviation of reference input current over full temperature range † | I _K = 10 mA, R1 = 10 k Ω , R2 = ∞ , T _A = full range † | | 0.8 | 2.5 | | 0.8 | 1.2 | μA |
| I _{min} | Minimum cathode current for regulation | V _{KA} = V _{ref} | | 0.4 | 0.7 | | 0.4 | 0.6 | mA |
| I _{off} | Off-state cathode current | V _{KA} = 36 V, V _{ref} = 0 | | 0.1 | 0.5 | | 0.1 | 0.5 | μA |
| z _{ka} | Dynamic impedance [§] | V _{KA} = V _{ref} , I _K = 1 mA to 100 mA, f \leq 1 kHz | | 0.2 | 0.5 | | 0.2 | 0.5 | Ω |

† Full temperature range is 0 °C to 70 °C for TL431AC and -40 °C to 85 °C for TL431AI.

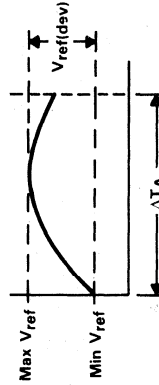
‡ The deviation parameters V_{ref(dev)} and I_{ref(dev)} are defined as the differences between the maximum and minimum values obtained over the rated temperature range. The average full-range temperature coefficient of the reference input voltage, αV_{ref} , is defined as:

$$|\alpha V_{ref}| \left(\frac{\text{ppm}}{^\circ\text{C}} \right) = \frac{\left(\frac{V_{ref(\text{dev})}}{V_{ref \text{ at } 25^\circ\text{C}}} \right) \times 10^6}{\Delta T_A}$$

where ΔT_A is the rated operating free-air temperature range of the device.

αV_{ref} can be positive or negative depending on whether minimum V_{ref} or maximum V_{ref}, respectively, occurs at the lower temperature.

Example: Max V_{ref} = 2496 mV at 30 °C, Min V_{ref} = 2492 mV at 0 °C, V_{ref} = 2495 mV at 25 °C, $\Delta T_A = 70^\circ\text{C}$ for TL431C



$$|\alpha V_{ref}| = \frac{\left(\frac{4 \text{ mV}}{2495 \text{ mV}} \right) \times 10^6}{70^\circ\text{C}} \approx 23 \text{ ppm}/^\circ\text{C}$$

Because minimum V_{ref} occurs at the lower temperature, the coefficient is positive.

§ The dynamic impedance is defined as: $|z_{ka}| = \frac{\Delta V_{KA}}{\Delta I_K}$

When the device is operating with two external resistors, (see Figure 2), the total dynamic impedance of the circuit is given by:

$$|z'| = \frac{\Delta V}{\Delta I} \approx |z_{ka}| \left(1 + \frac{R1}{R2} \right)$$

PARAMETER MEASUREMENT INFORMATION

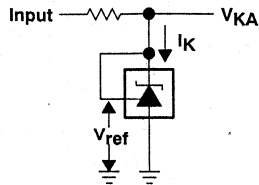


Figure 1. Test Circuit for $V_{KA} = V_{ref}$

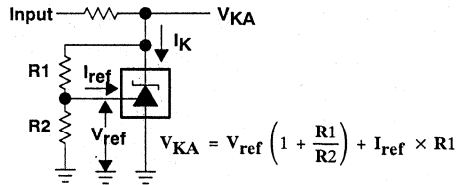


Figure 2. Test Circuit for $V_{KA} > V_{ref}$

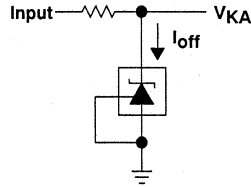


Figure 3. Test Circuit for I_{off}

TL431C, TL431AC, TL431I, TL431AI, TL431M
ADJUSTABLE PRECISION SHUNT REGULATORS

TYPICAL CHARACTERISTICS

table of graphs

| | | | FIGURE |
|------------------|--|---|---------------|
| V_{ref} | Reference voltage | vs Temperature | 4 |
| I_{ref} | Reference current | vs Temperature | 5 |
| I_K | Cathode current | vs Cathode voltage | 6 and 7 |
| I_{off} | Off-State cathode current | vs Temperature | 8 |
| ΔV_{ref} | Change in reference voltage to change in cathode voltage | vs Temperature | 9 |
| V_n | Noise voltage | vs Frequency over a 10-second time-period | 10 and 11 |
| A_v | Voltage amplification | vs Frequency | 12 |
| $\ z_{ka}\ $ | Reference impedance | vs Frequency | 13 |
| | Pulse response | | 14 |
| | Stability boundary conditions | | 15 |

table of application circuits

| | APPLICATION | FIGURE |
|--|---|---------------|
| | Precision shunt regulator | 16 |
| | Single-supply comparator with temperature-compensated threshold | 17 |
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TYPICAL CHARACTERISTICS†

REFERENCE INPUT VOLTAGE
vs
FREE-AIR TEMPERATURE †

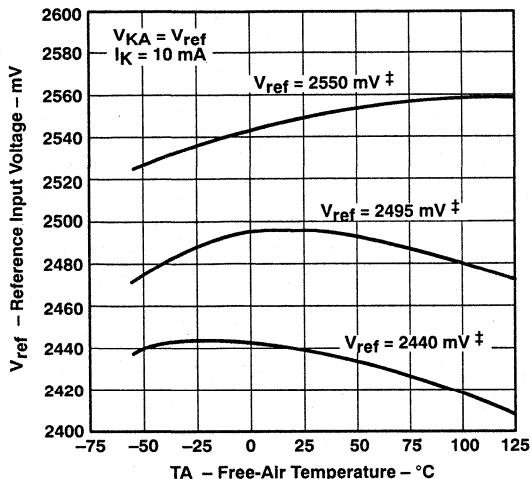


Figure 4

REFERENCE INPUT CURRENT
vs
FREE-AIR TEMPERATURE †

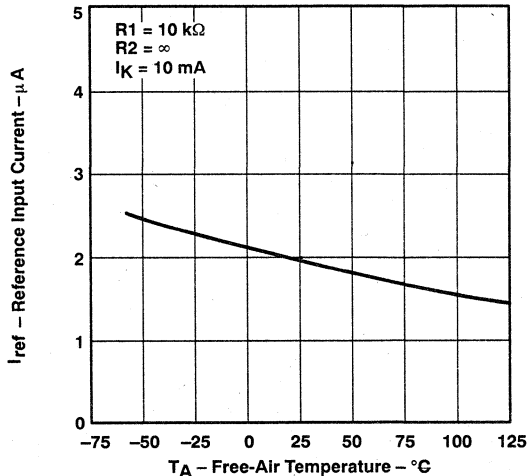


Figure 5

CATHODE CURRENT
vs
CATHODE VOLTAGE

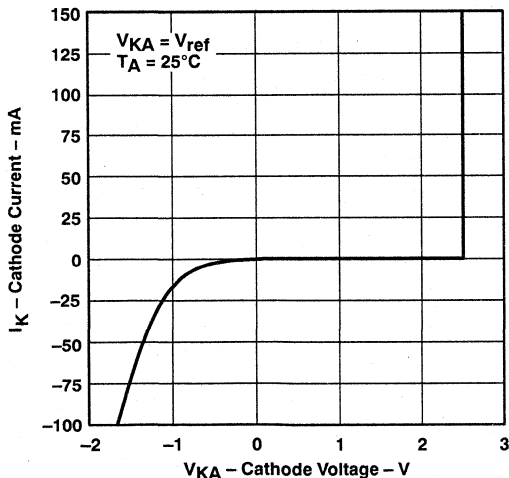


Figure 6

CATHODE CURRENT
vs
CATHODE VOLTAGE

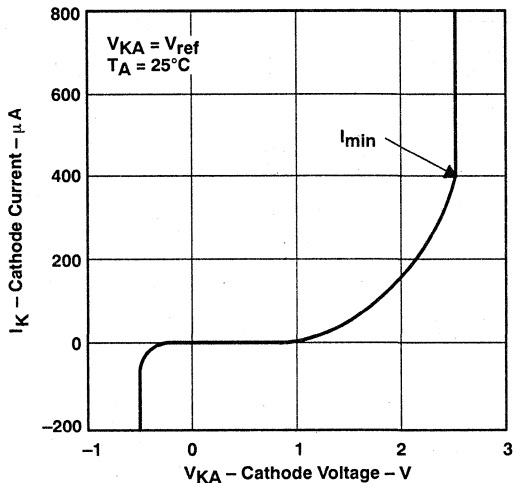


Figure 7

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

‡ Data is for devices having the indicated value of V_{ref} at $I_K = 10$ mA, $T_A = 25^\circ\text{C}$.

TYPICAL CHARACTERISTICS†

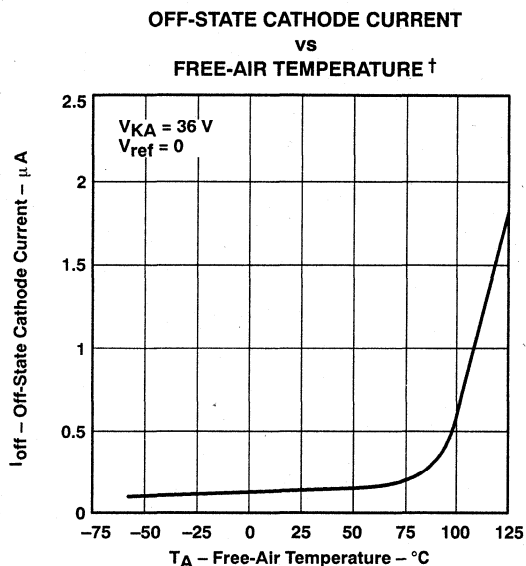


Figure 8

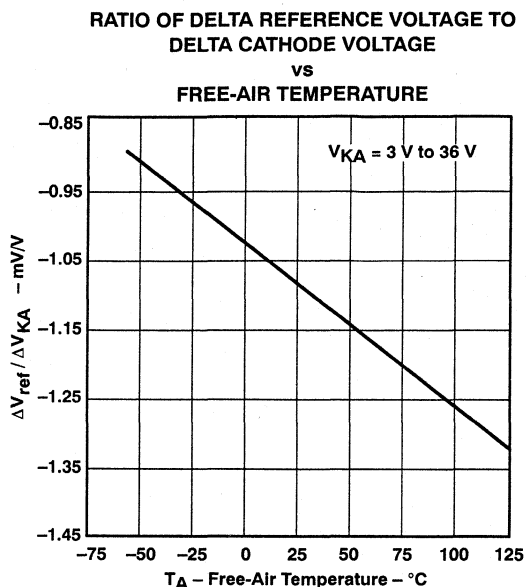


Figure 9

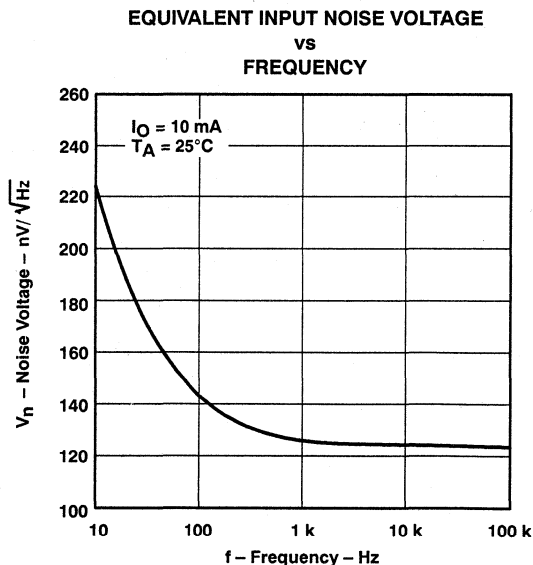


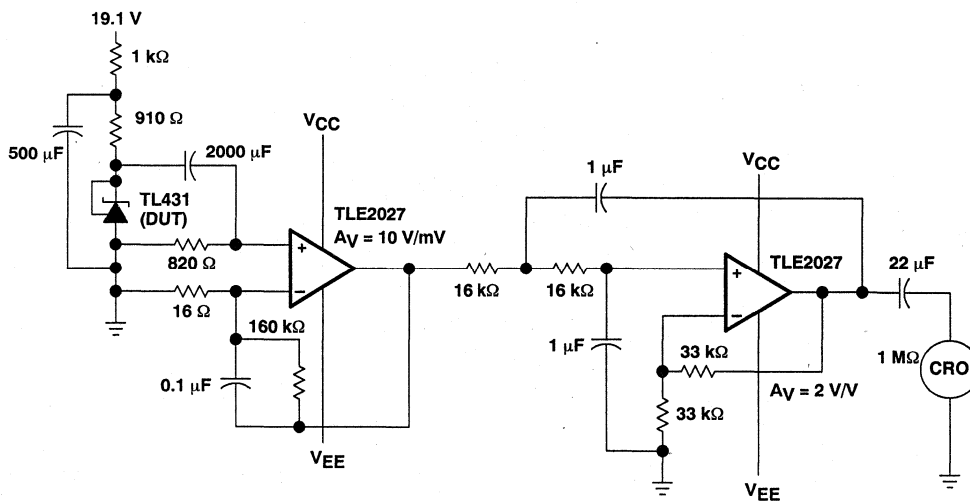
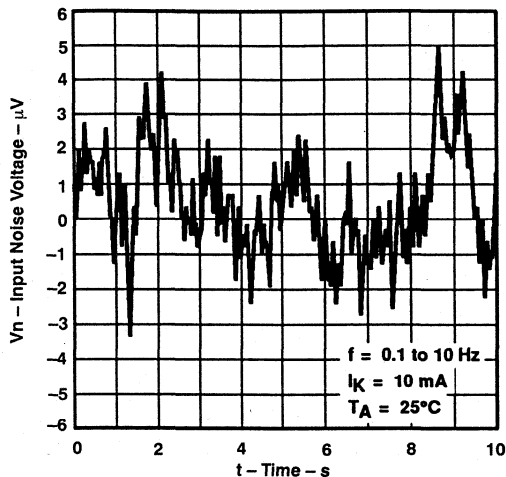
Figure 10

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TL431C, TL431AC, TL431I, TL431AI, TL431M ADJUSTABLE PRECISION SHUNT REGULATORS

TYPICAL CHARACTERISTICS

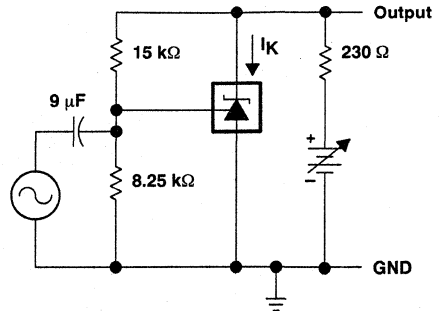
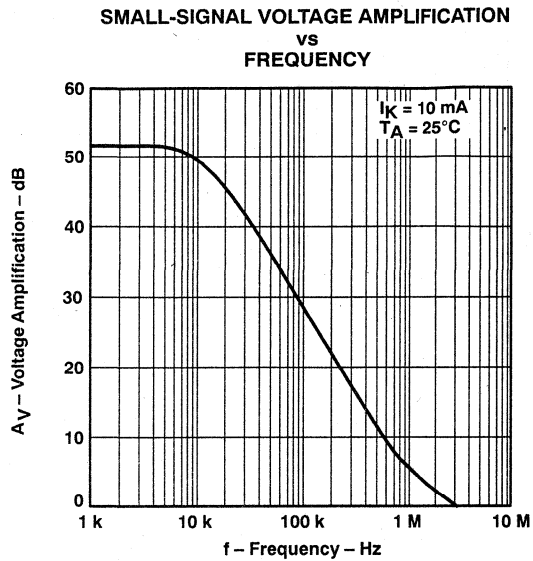
EQUIVALENT INPUT NOISE VOLTAGE
OVER A 10-SECOND PERIOD



TEST CIRCUIT

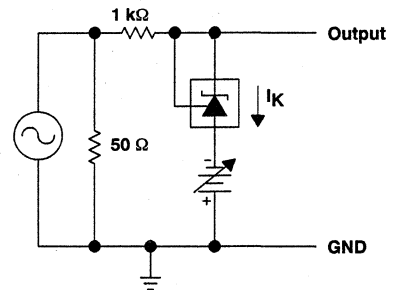
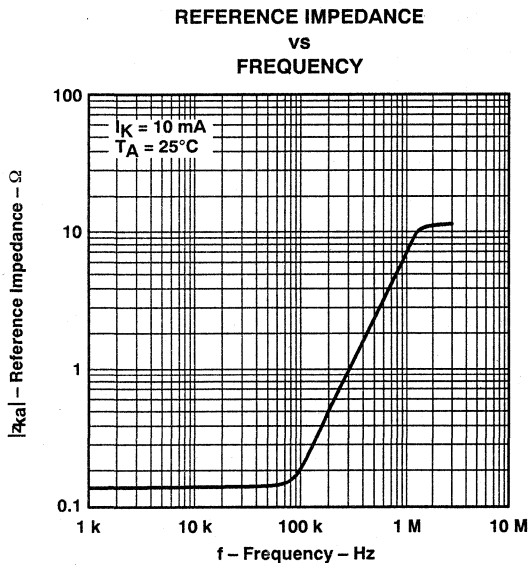
Figure 11

TYPICAL CHARACTERISTICS



TEST CIRCUIT FOR VOLTAGE AMPLIFICATION

Figure 12



TEST CIRCUIT FOR REFERENCE IMPEDANCE

Figure 13

TL431C, TL431AC, TL431I, TL431AI, TL431M ADJUSTABLE PRECISION SHUNT REGULATORS

TYPICAL CHARACTERISTICS

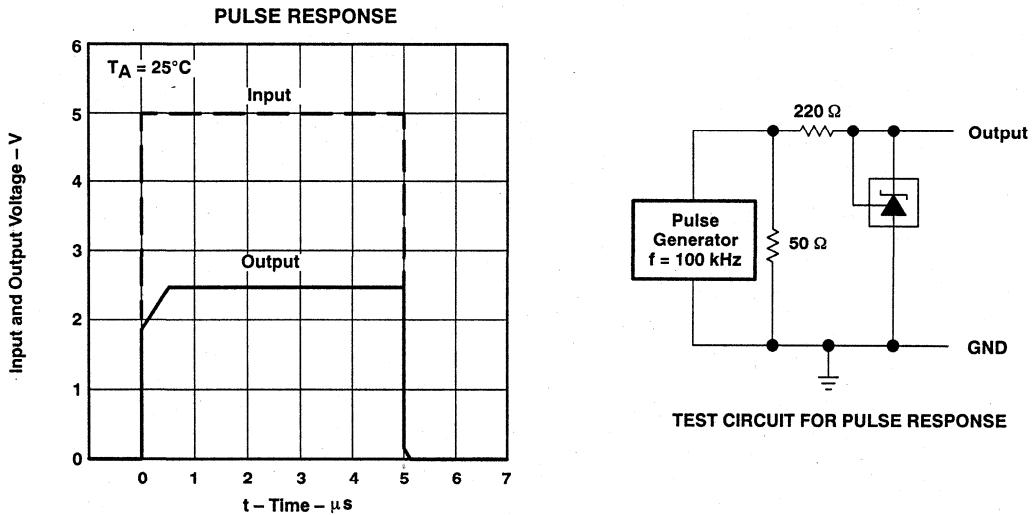


Figure 14

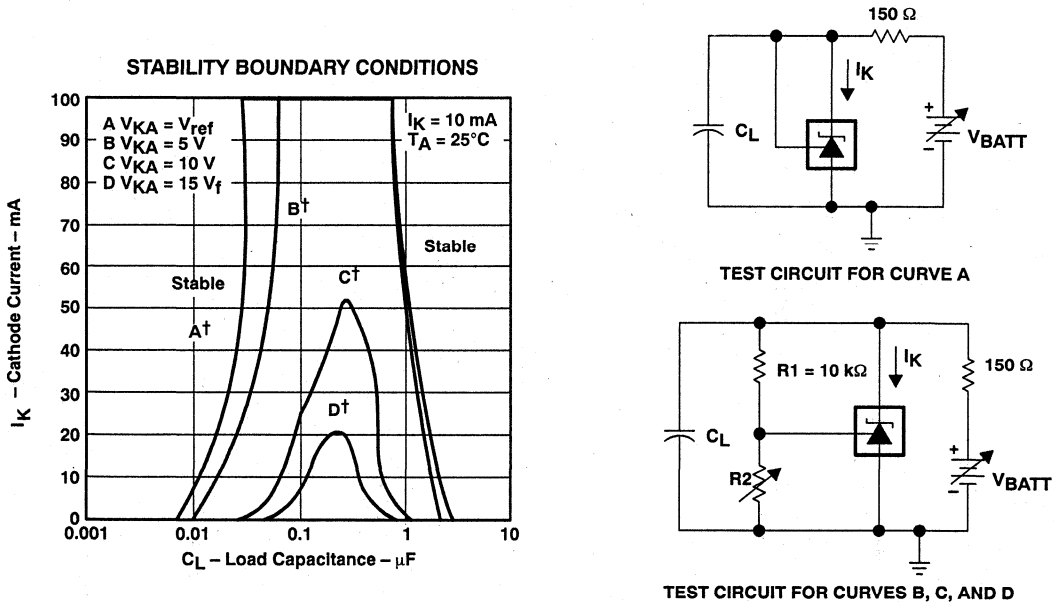
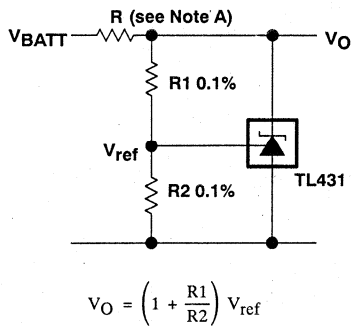


Figure 15

[†] The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R2 and V_{BATT} were adjusted to establish the initial V_{KA} and I_K conditions with C_L = 0. V_{BATT} and C_L were then adjusted to determine the ranges of stability.

TL431C, TL431AC, TL431I, TL431AI, TL431M ADJUSTABLE PRECISION SHUNT REGULATORS

APPLICATION INFORMATION



NOTE A: R should provide ≥ 1 mA cathode current to the TL431 at minimum V_{BATT} .

Figure 16. Shunt Regulator

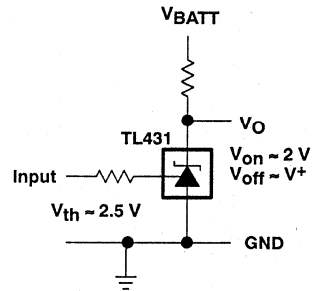
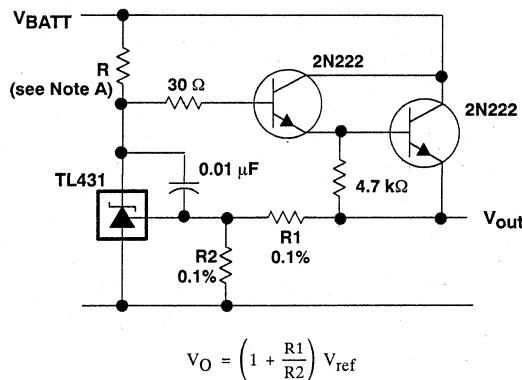


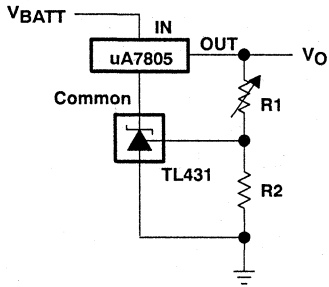
Figure 17. Single-Supply Comparator With Temperature-Compensated Threshold



NOTE A: R should provide ≥ 1 mA cathode current to the TL431 at minimum V_{BATT} .

Figure 18. Precision High-Current Series Regulator

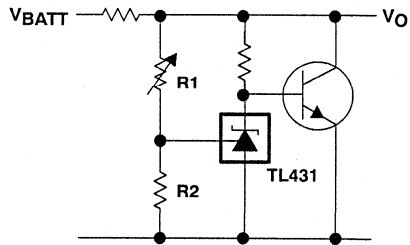
APPLICATION INFORMATION



$$V = \left(1 + \frac{R1}{R2}\right) + V_{ref}$$

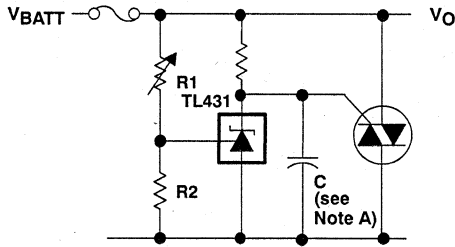
$$\text{Min } V = V_{ref} + 5 \text{ V}$$

Figure 19. Output Control of a 3-Terminal Fixed Regulator



$$V_O = \left(1 + \frac{R1}{R2}\right) V_{ref}$$

Figure 20. High Current Shunt Regulator



NOTE A: Refer to the stability boundary conditions in Figure 15 to determine allowable values for C.

Figure 21. Crowbar Circuit

TL431C, TL431AC, TL431I, TL431AI, TL431M
ADJUSTABLE PRECISION SHUNT REGULATORS

APPLICATION INFORMATION

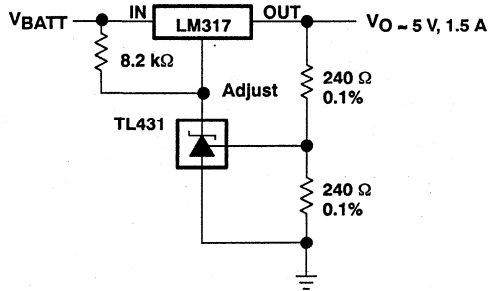
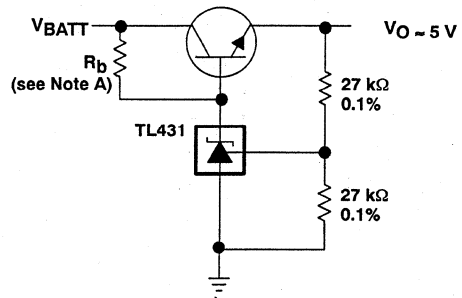


Figure 22. Precision 5-V, 1.5-A Regulator



NOTE A: R_b should provide ≥ 1 -mA cathode current to the TL431.

Figure 23. Efficient 5-V Precision Regulator

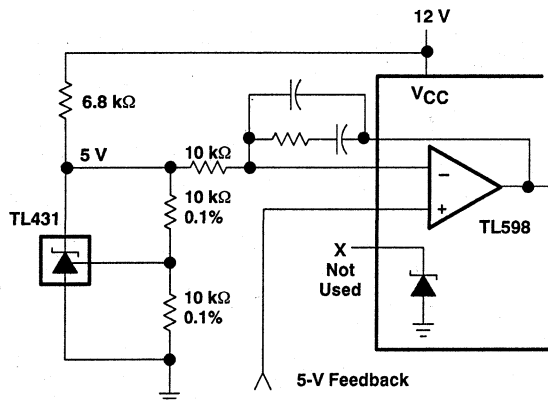
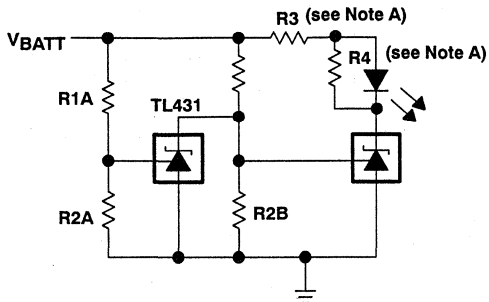


Figure 24. PWM Downconverter With Reference

TL431C, TL431AC, TL431I, TL431AI, TL431M ADJUSTABLE PRECISION SHUNT REGULATORS

APPLICATION INFORMATION

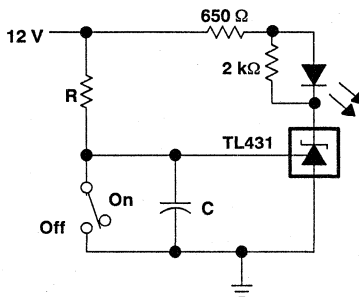


$$\text{Low Limit} = \left(1 + \frac{R1B}{R2B}\right) V_{\text{ref}} \quad \text{LED On When}$$

$$\text{High Limit} = \left(1 + \frac{R1B}{R2B}\right) V_{\text{ref}} \quad \text{Low Limit} < V_{\text{BATT}} < \text{High Limit}$$

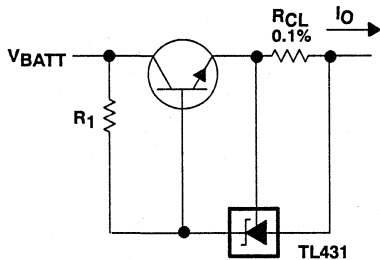
NOTE A: R3 and R4 are selected to provide the desired LED intensity and ≥ 1 mA cathode current to the TL431 at the available V_+ .

Figure 25. Voltage Monitor



$$\text{Delay} = R \times C \times I_n \left(\frac{12 \text{ V}}{12 \text{ V} - V_{\text{ref}}} \right)$$

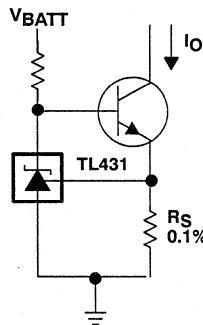
Figure 26. Delay Timer



$$I_{\text{out}} = \frac{V_{\text{ref}}}{R_{\text{CL}}} + I_{\text{K}}$$

$$R_1 = \frac{V_+}{\frac{I_{\text{O}}}{h_{\text{FE}}} + I_{\text{K}}}$$

Figure 27. Precision Current Limiter



$$I_{\text{O}} = \frac{V_{\text{ref}}}{R_{\text{S}}}$$

Figure 28. Precision Constant-Current Sink

TL494 PULSE-WIDTH-MODULATION CONTROL CIRCUIT

D2535, JANUARY 1983—REVISED SEPTEMBER 1991

- Complete PWM Power Control Circuitry
- Uncommitted Outputs for 200-mA Sink or Source Current
- Output Control Selects Single-Ended or Push-Pull Operation
- Internal Circuitry Prohibits Double Pulse at Either Output
- Variable Dead Time Provides Control Over Total Range
- Internal Regulator Provides a Stable 5-V Reference Supply With 5% Tolerance
- Circuit Architecture Allows Easy Synchronization

description

The TL494 incorporates on a single monolithic chip all the functions required in the construction of a pulse-width-modulation control circuit. Designed primarily for power supply control, this device offers the systems engineer the flexibility to tailor the power supply control circuitry to a specific application.

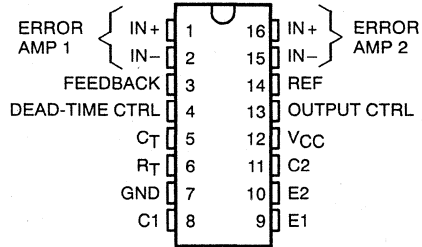
The TL494 contains two error amplifiers, an on-chip adjustable oscillator, a dead-time control comparator, a pulse-steering control flip-flop, a 5-V, 5%-precision regulator, and output-control circuits.

The error amplifiers exhibit a common-mode voltage range from -0.3 V to $V_{CC} - 2\text{ V}$. The dead-time control comparator has a fixed offset that provides approximately 5% dead time when externally altered. The on-chip oscillator may be bypassed by terminating R_T to the reference output and providing a sawtooth input to C_T , or it may be used to drive the common circuits in synchronous multiple-rail power supplies.

The uncommitted output transistors provide either common-emitter or emitter-follower output capability. The TL494 provides for push-pull or single-ended output operation, which may be selected through the output-control function. The architecture of this device prohibits the possibility of either output being pulsed twice during push-pull operation.

The TL494C is characterized for operation from 0°C to 70°C . The TL494I is characterized for operation from -40°C to 85°C .

TL494C, TL494I . . . D OR N PACKAGE
(TOP VIEW)



AVAILABLE OPTIONS

| T _A | PACKAGE | |
|---|-------------------|-----------------|
| | SURFACE MOUNT (D) | PLASTIC DIP (N) |
| 0°C to 70°C | TL494CD | TL494CN |
| -40°C to 85°C | TL494ID | TL494IN |

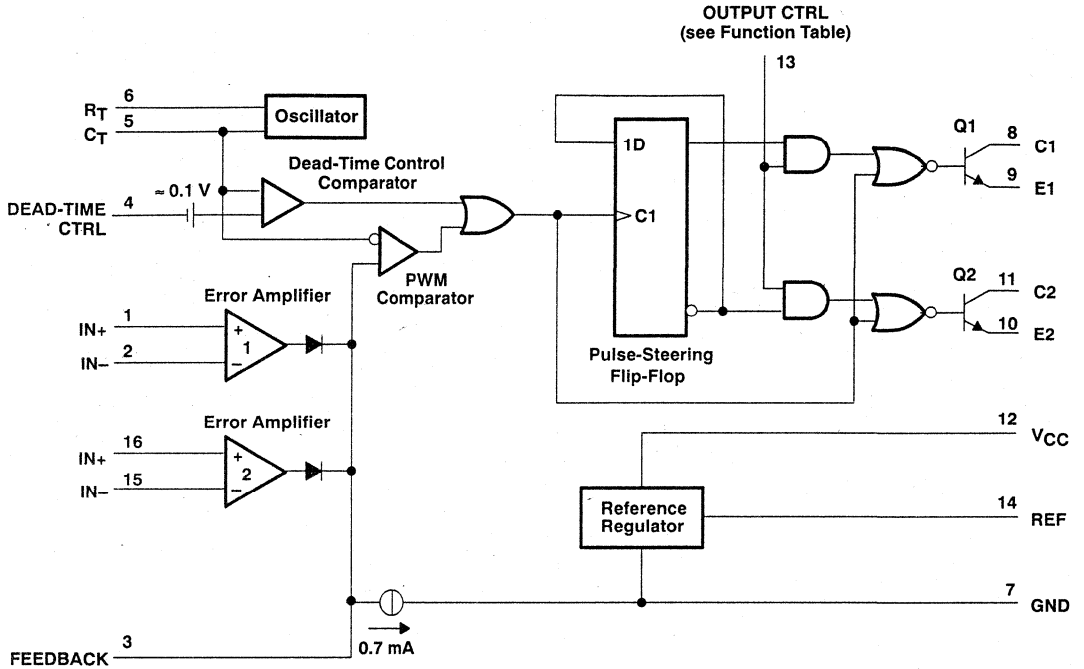
The D package is available taped and reeled. Add "R" suffix to device type (e.g., TL494CDR).

FUNCTION TABLE

| INPUT | OUTPUT FUNCTION |
|-----------------------|---------------------------------|
| OUTPUT CTRL | |
| $V_I \leq 0$ | Single-ended or parallel output |
| $V_I \leq \text{REF}$ | Normal push-pull operation |

TL494 PULSE-WIDTH-MODULATION CONTROL CIRCUIT

functional block diagram



TL494 PULSE-WIDTH-MODULATION CONTROL CIRCUIT

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | TL494C | TL494I | UNIT |
|--|------------------------------|----------------|------|
| Supply voltage, V_{CC} (see Note 1) | 41 | 41 | V |
| Amplifier input voltage | $V_{CC} + 0.3$ | $V_{CC} + 0.3$ | V |
| Collector output voltage | 41 | 41 | V |
| Collector output current | 250 | 250 | mA |
| Continuous total dissipation | See Dissipation Rating Table | | |
| Operating free-air temperature range | 0 to 70 | -40 to 85 | °C |
| Storage temperature range | -65 to 150 | -65 to 150 | °C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or N package | 260 | 260 | °C |

NOTE 1: All voltage values, except differential voltages, are with respect to the network ground terminal.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR | DERATE ABOVE T_A | $T_A = 70^\circ\text{C}$ POWER RATING | $T_A = 85^\circ\text{C}$ POWER RATING |
|---------|---|--------------------|-----------------------|--|--|
| D | 900 mW | 7.6 mW/°C | 25°C | 608 mW | 494 mW |
| N | 1000 mW | 9.2 mW/°C | 41°C | 736 mW | 598 mW |

recommended operating conditions

| | TL494C | | TL494I | | UNIT |
|--|--------|--------------|--------|--------------|------|
| | MIN | MAX | MIN | MAX | |
| Supply voltage, V_{CC} | 7 | 40 | 7 | 40 | V |
| Amplifier input voltage, V_I | -0.3 | $V_{CC} - 2$ | -0.3 | $V_{CC} - 2$ | V |
| Collector output voltage, V_O | 40 | | 40 | | V |
| Collector output current (each transistor) | 200 | | 200 | | mA |
| Current into feedback terminal | 0.3 | | 0.3 | | mA |
| Oscillator frequency | 1 | 300 | 1 | 300 | kHz |
| Timing capacitor, C_T | 0.47 | 10000 | 0.47 | 10000 | nF |
| Timing resistor, R_T | 1.8 | 500 | 1.8 | 500 | kΩ |
| Operating free-air temperature, T_A | 0 | 70 | -40 | 85 | °C |

TL494 PULSE-WIDTH-MODULATION CONTROL CIRCUIT

electrical characteristics over recommended operating free-air temperature range, $V_{CC} = 15\text{ V}$, $f = 10\text{ kHz}$ (unless otherwise noted)

reference section

| PARAMETER | TEST CONDITIONS† | TL494C, TL494I | | | UNIT |
|--|--------------------------------------|----------------|------|------|------|
| | | MIN | TYP‡ | MAX | |
| Output voltage (REF) | $I_O = 1\text{ mA}$ | 4.75 | 5 | 5.25 | V |
| Input regulation | $V_{CC} = 7\text{ V to }40\text{ V}$ | | 2 | 25 | mV |
| Output regulation | $I_O = 1\text{ mA to }10\text{ mA}$ | | 1 | 15 | mV |
| Output voltage change with temperature | $\Delta T_A = \text{MIN to MAX}$ | | 0.2% | 1% | |
| Short-circuit output current§ | REF = 0 | | 35 | | mA |

oscillator section $C_T = 0.01\ \mu\text{F}$, $R_T = 12\text{ k}\Omega$ (see Figure 1)

| PARAMETER | TEST CONDITIONS† | TL494C, TL494I | | | UNIT |
|------------------------------------|--|----------------|------|-----|------|
| | | MIN | TYP‡ | MAX | |
| Frequency | $C_T = 0.01\ \mu\text{F}$, $R_T = 12\text{ k}\Omega$ | | 10 | | kHz |
| Standard deviation of frequency¶ | All values of V_{CC} , C_T , R_T , and T_A constant | | 10% | | |
| Frequency change with voltage | $V_{CC} = 7\text{ V to }40\text{ V}$, $T_A = 25^\circ\text{C}$ | | 0.1% | | |
| Frequency change with temperature# | $C_T = 0.01\ \mu\text{F}$, $R_T = 12\text{ k}\Omega$, $\Delta T_A = \text{MIN to MAX}$ | | | 1% | |

error amplifier section (see Figure 2)

| PARAMETER | TEST CONDITIONS | MIN | TYP‡ | MAX | UNIT |
|---------------------------------|---|-----|--------------------|-----|---------------|
| Input offset voltage | $V_O (\text{pin } 3) = 2.5\text{ V}$ | | 2 | 10 | mV |
| Input offset current | $V_O (\text{pin } 3) = 2.5\text{ V}$ | | 25 | 250 | nA |
| Input bias current | $V_O (\text{pin } 3) = 2.5\text{ V}$ | | 0.2 | 1 | μA |
| Common-mode input voltage range | $V_{CC} = 7\text{ V to }40\text{ V}$ | | -0.3 to $V_{CC}-2$ | | V |
| Open-loop voltage amplification | $\Delta V_O = 3\text{ V}$, $R_L = 2\text{ k}\Omega$, $V_O = 0.5\text{ V to }3.5\text{ V}$ | 70 | 95 | | dB |
| Unity-gain bandwidth | $V_O = 0.5\text{ V to }3.5\text{ V}$, $R_L = 2\text{ k}\Omega$ | | 800 | | kHz |
| Common-mode rejection ratio | $\Delta V_O = 40\text{ V}$, $T_A = 25^\circ\text{C}$ | 65 | 80 | | dB |
| Output sink current (pin 3) | $V_{ID} = -15\text{ mV to }-5\text{ V}$, $V (\text{pin } 3) = 0.7\text{ V}$ | 0.3 | 0.7 | | nA |
| Output source current (pin 3) | $V_{ID} = 15\text{ mV to }5\text{ V}$, $V (\text{pin } 3) = 3.5\text{ V}$ | -2 | | | nA |

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

‡ All typical values except for parameter changes with temperature are at $T_A = 25^\circ\text{C}$.

§ Duration of the short circuit should not exceed one second.

¶ Standard deviation is a measure of the statistical distribution about the mean as derived from the formula:

Temperature coefficient of timing capacitor and timing resistor not taken into account.

$$\sigma = \sqrt{\frac{\sum_{n=1}^N (x_n - \bar{X})^2}{N-1}}$$

TL494
PULSE-WIDTH-MODULATION CONTROL CIRCUIT

electrical characteristics over recommended operating free-air temperature range, $V_{CC} = 15\text{ V}$, $f = 10\text{ kHz}$ (unless otherwise noted)

output section

| PARAMETER | TEST CONDITIONS | TL494C, TL494I | | | UNIT |
|--------------------------------------|--|----------------|------|------|---------------|
| | | MIN | TYP† | MAX | |
| Collector off-state current | $V_{CE} = 40\text{ V}$, $V_{CC} = 40\text{ V}$ | | 2 | 100 | μA |
| Emitter off-state current | $V_{CC} = V_C = 40\text{ V}$, $V_E = 0$ | | | -100 | μA |
| Collector-emitter saturation voltage | Common emitter $V_E = 0$, $I_C = 200\text{ mA}$ | | 1.1 | 1.3 | V |
| | Emitter follower $V_C = 15\text{ V}$, $I_E = -200\text{ mA}$ | | 1.5 | 2.5 | |
| Output control input current | $V_I = V_{ref}$ | | | 3.5 | mA |

dead-time control section (see Figure 1)

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|---------------------------------|---|-----|------|-----|---------------|
| Input bias current (pin 4) | $V_I = 0$ to 5.25 V | | -2 | -10 | μA |
| Maximum duty cycle, each output | V_I (pin 4) = 0, $C_T = 0.1\ \mu\text{F}$, $R_T = 12\text{ k}\Omega$ | | 45% | | |
| Input threshold voltage (pin 4) | Zero duty cycle | | 3 | 3.3 | V |
| | Maximum duty cycle | 0 | | | |

pwm comparator section (see Figure 1)

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|---------------------------------|------------------------------|-----|------|-----|------|
| Input threshold voltage (pin 3) | Zero duty cycle | | 4 | 4.5 | V |
| Input sink current (pin 3) | V (pin 3) = 0.7 V | 0.3 | 0.7 | | mA |

total device

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|------------------------|--|------------------------|------|-----|------|
| Standby supply current | Pin 6 at REF, All other inputs and outputs open | | 6 | 10 | mA |
| | | $V_{CC} = 15\text{ V}$ | | | |
| | | | 9 | 15 | |
| Average supply current | V_I (pin 4) = 2 V , See Figure 1 | | 7.5 | | mA |

switching characteristics, $T_A = 25^\circ\text{C}$

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|--------------------------|--|-----|------|-----|------|
| Output voltage rise time | Common-emitter configuration, See Figure 3 | | 100 | 200 | ns |
| Output voltage fall time | | | 25 | 100 | |
| Output voltage rise time | Emitter-follower configuration, See Figure 4 | | 100 | 200 | ns |
| Output voltage fall time | | | 40 | 100 | |

† All typical values except for temperature coefficient are at $T_A = 25^\circ\text{C}$.

PARAMETER MEASUREMENT INFORMATION

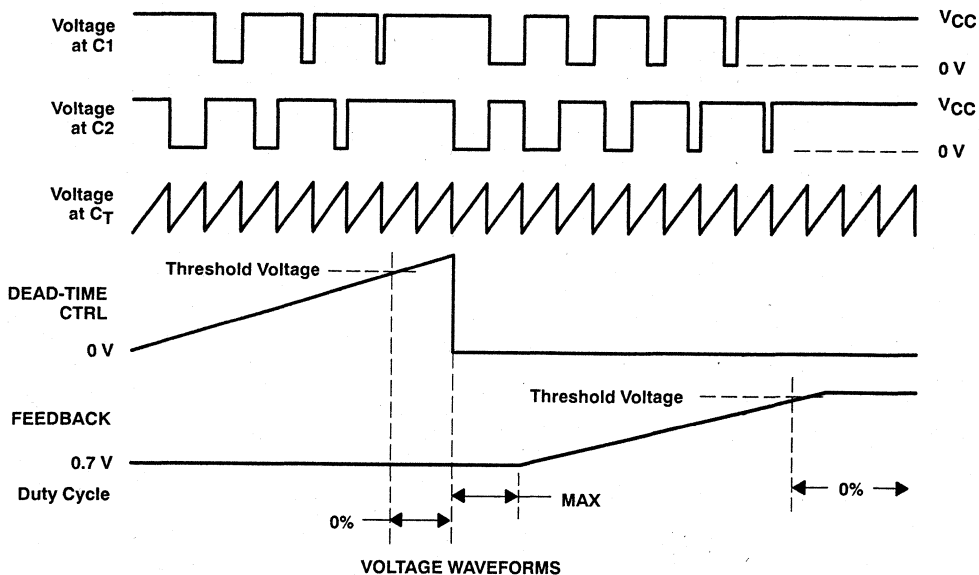
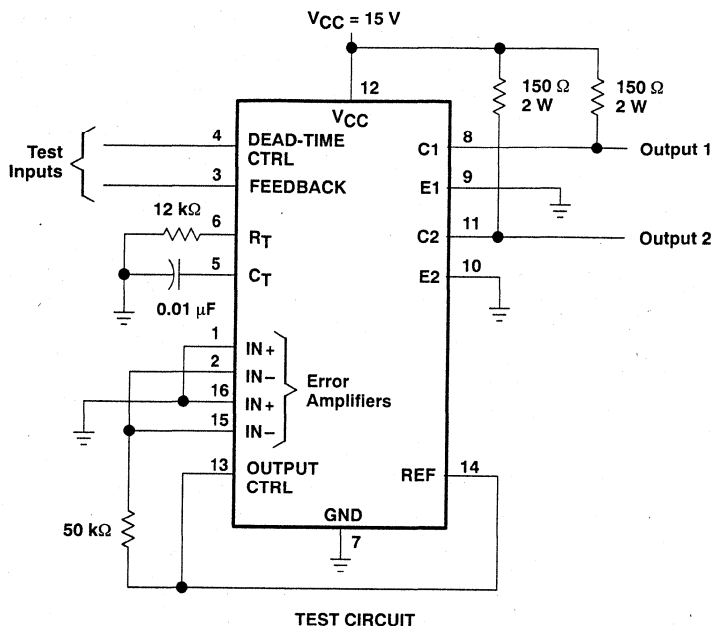


Figure 1. Operational Test Circuit and Waveforms

PARAMETER MEASUREMENT INFORMATION

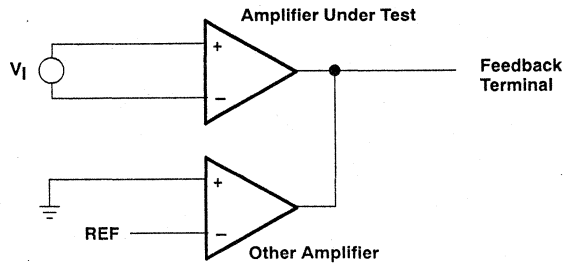


Figure 2. Amplifier Characteristics

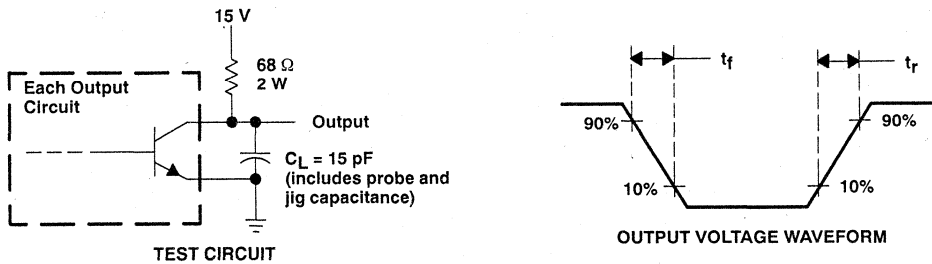


Figure 3. Common-Emitter Configuration

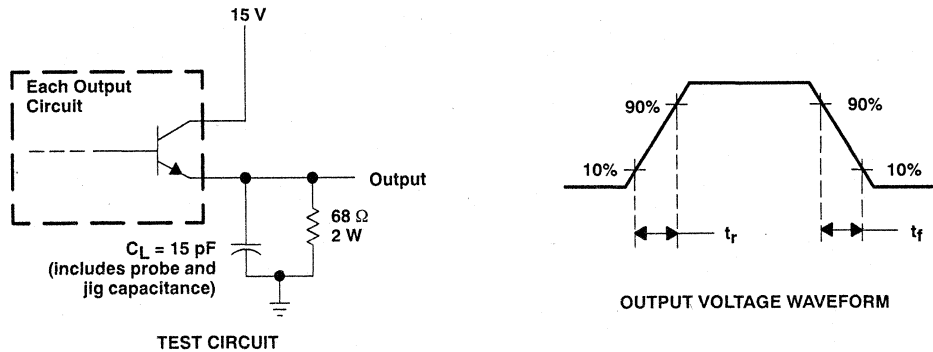


Figure 4. Emitter-Follower Configuration

TL494
PULSE-WIDTH-MODULATION CONTROL CIRCUIT

TYPICAL CHARACTERISTICS

**OSCILLATOR FREQUENCY AND
 FREQUENCY VARIATION†
 vs
 TIMING RESISTANCE**

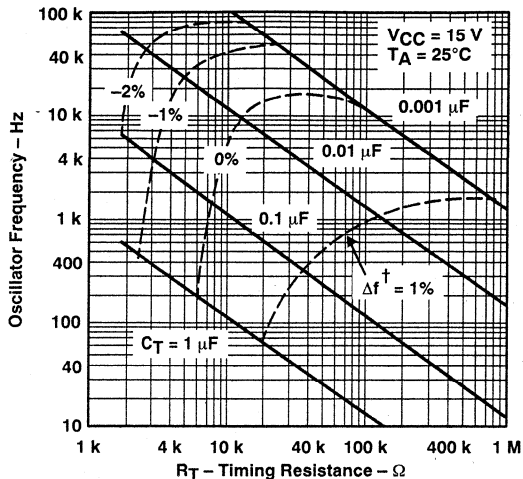


Figure 5

† Frequency variation (Δf) is the change in oscillator frequency that occurs over the full temperature range.

**AMPLIFIER VOLTAGE AMPLIFICATION
 vs
 FREQUENCY**

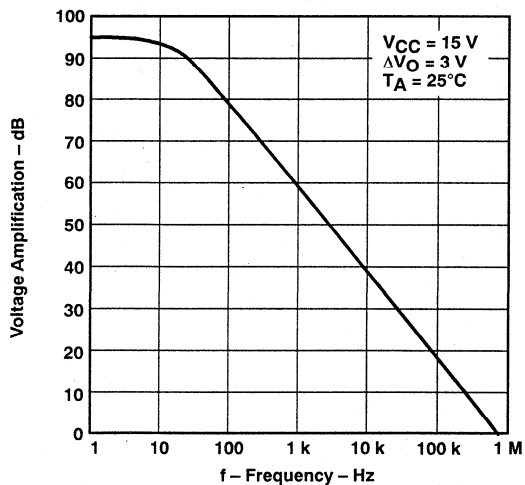


Figure 6

TL494M PULSE-WIDTH-MODULATION CONTROL CIRCUIT

D3883, SEPTEMBER 1991

- Complete PWM Power Control Circuitry
- Uncommitted Outputs for 200-mA Sink or Source Current
- Output Control Selects Single-Ended or Push-Pull Operation
- Internal Circuitry Prohibits Double Pulse at Either Output
- Variable Dead Time Provides Control Over Total Range
- Internal Regulator Provides a Stable 5-V Reference Supply With 5% Tolerance
- Circuit Architecture Allows Easy Synchronization

description

The TL494M incorporates on a single monolithic chip all the functions required in the construction of a pulse-width-modulation control circuit. Designed primarily for power supply control, these devices offer the systems engineer the flexibility to tailor the power supply control circuitry to a specific application.

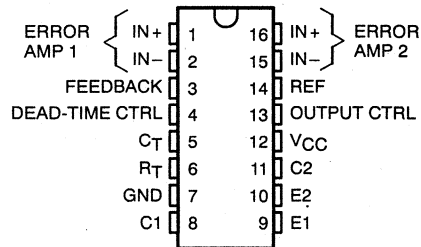
The TL494M contains two error amplifiers, an on-chip adjustable oscillator, a dead-time control comparator, a pulse-steering control flip-flop, a 5-V 5%-precision regulator, and output-control circuits.

The error amplifiers exhibit a common-mode voltage range from -0.3 V to $V_{CC} - 2\text{ V}$. The dead-time control comparator has a fixed offset that provides approximately 5% dead time when externally altered. The on-chip oscillator may be bypassed by terminating R_T to the reference output and providing a sawtooth input to C_T , or it may be used to drive the common circuits in synchronous multiple-rail power supplies.

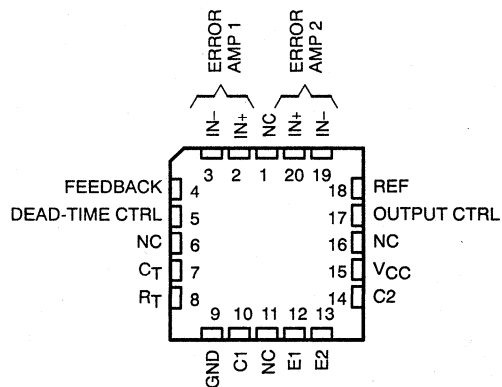
The uncommitted output transistors provide either common-emitter or emitter-follower output capability. Each device provides for push-pull or single-ended output operation, which may be selected through the output-control function. The architecture of these devices prohibits the possibility of either output being pulsed twice during push-pull operation.

The TL494M is characterized for operation from -55°C to 125°C .

J PACKAGE
(TOP VIEW)



FK PACKAGE
(TOP VIEW)



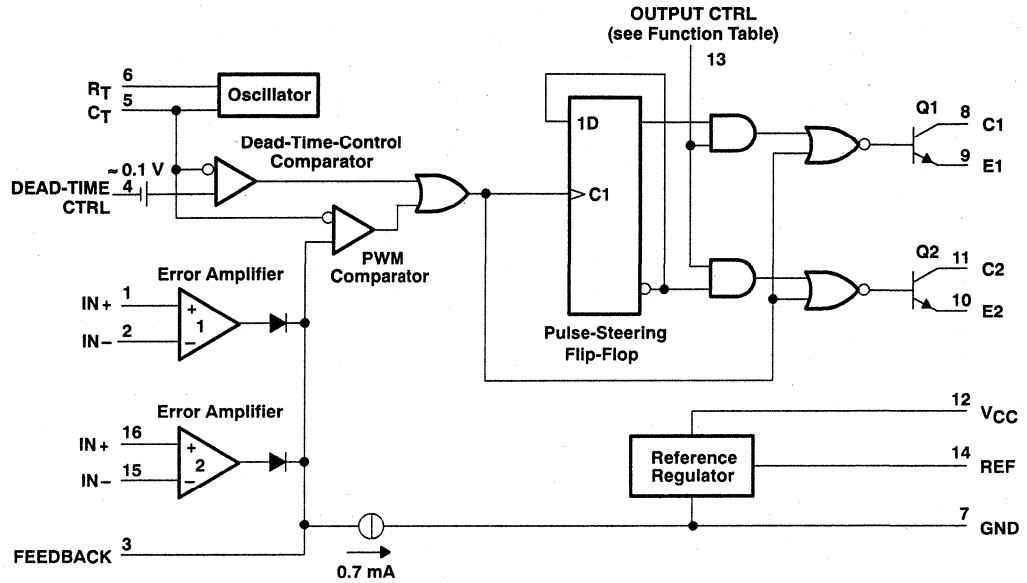
NC – No internal connection

FUNCTION TABLE

| INPUT OUTPUT CTRL | OUTPUT FUNCTION |
|-------------------------|---------------------------------|
| $V_I = 0$ | Single-ended or parallel output |
| $V_I = \text{REF}$ | Normal push-pull operation |

TL494M PULSE-WIDTH-MODULATION CONTROL CIRCUIT

functional block diagram



Pin numbers shown are for J package.

TL494M PULSE-WIDTH-MODULATION CONTROL CIRCUIT

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|------------------|
| Supply voltage, V_{CC} (see Note 1) | 41 V |
| Amplifier input voltage | $V_{CC} + 0.3$ V |
| Collector output voltage | 41 V |
| Collector output current | 250 mA |
| Continuous total dissipation (see Note 2) | 1375 mW |
| Operating free-air temperature range | -55°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package | 300°C |

NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.
 2. For operation above 25°C free-air temperature, derate linearly to 275 mW at the rate of 11 mW/°C.

recommended operating conditions

| | MIN | MAX | UNIT |
|--|------|--------------|------|
| Supply voltage, V_{CC} | 7 | 40 | V |
| Amplifier input voltage, V_I | -0.3 | $V_{CC} - 2$ | V |
| Collector output voltage, V_O | | 40 | V |
| Collector output current (each transistor) | | 200 | mA |
| Current into feedback terminal | | 0.3 | mA |
| Timing capacitor, C_T | 0.47 | 10000 | nF |
| Timing resistor, R_T | 1.8 | 500 | kΩ |
| Oscillator frequency, f_{osc} | 1 | 300 | kHz |
| Operating free-air temperature, T_A | -55 | 125 | °C |

TL494M

PULSE-WIDTH-MODULATION CONTROL CIRCUIT

electrical characteristics over recommended operating free-air temperature range, $V_{CC} = 15\text{ V}$, $f = 10\text{ kHz}$ (unless otherwise noted)

reference section

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|---|---|------|------|------|------|
| Output voltage (REF) | $I_O = 1\text{ mA}$ | 4.75 | 5 | 5.25 | V |
| Input regulation | $V_{CC} = 7\text{ V to }40\text{ V}$ | | 2 | 25 | mV |
| Output regulation | $I_O = 1\text{ to }10\text{ mA}$ | | 1 | 15 | mV |
| Output voltage change with temperature | $\Delta T_A = \text{MIN to MAX}^\ddagger$ | | 0.2% | 3%* | |
| Short-circuit output current [§] | REF = 0 | | 35 | | mA |

oscillator section, $C_T = 0.01\ \mu\text{F}$, $R_T = 12\text{ k}\Omega$ (see Figure 1)

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|--|---|-----|------|-----|------|
| Frequency | $C_T = 0.01\ \mu\text{F}$, $R_T = 12\text{ k}\Omega$ | | 10 | | kHz |
| Standard deviation of frequency [¶] | All values of V_{CC} , C_T , R_T , and T_A constant | | 10% | | |
| Frequency change with voltage | $V_{CC} = 7\text{ V to }40\text{ V}$, $T_A = 25^\circ\text{C}$ | | 0.1% | | |
| Frequency change with temperature [#] | $C_T = 0.01\ \mu\text{F}$, $R_T = 12\text{ k}\Omega$, $\Delta T_A = \text{MIN to MAX}^\ddagger$ | | | 1%* | |

error amplifier section (see Figure 2)

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|---------------------------------|---|-----|-------------------------|-----|---------------|
| Input offset voltage | $V_O (\text{pin } 3) = 2.5\text{ V}$ | | 2 | 10 | mV |
| Input offset current | $V_O (\text{pin } 3) = 2.5\text{ V}$ | | 25 | 250 | nA |
| Input bias current | $V_O (\text{pin } 3) = 2.5\text{ V}$ | | 0.2 | 1 | μA |
| Common-mode input voltage range | $V_{CC} = 7\text{ V to }40\text{ V}$ | | 0.3 to $V_{CC}-2$ | | V |
| Open-loop voltage amplification | $\Delta V_O = 3\text{ V}$, $R_L = 2\text{ k}\Omega$, $V_O = 0.5\text{ V to }3.5\text{ V}$ | 70 | 95 | | dB |
| Unity-gain bandwidth | $V_O = 0.5\text{ V to }3.5\text{ V}$, $R_L = 2\text{ k}\Omega$ | | 800 | | kHz |
| Common-mode rejection ratio | $\Delta V_O = 40\text{ V}$, $T_A = 25^\circ\text{C}$ | 65 | 80 | | dB |
| Output sink current (pin 3) | $V_{ID} = -15\text{ mV to }-5\text{ V}$, $V (\text{pin } 3) = 0.7\text{ V}$ | 0.3 | 0.7 | | mA |
| Output source current (pin 3) | $V_{ID} = 15\text{ mV to }5\text{ V}$, $V (\text{pin } 3) = 3.5\text{ V}$ | -2 | | | mA |

* This parameter is not production tested.

† All typical values except for parameter changes with temperature are at $T_A = 25^\circ\text{C}$.

‡ For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

§ Duration of the short circuit should not exceed one second.

¶ Standard deviation is a measure of the statistical distribution about the mean as derived from the formula:

Temperature coefficient of timing capacitor and timing resistor not taken into account.

$$\sigma = \sqrt{\frac{\sum_{n=1}^N (x_n - \bar{X})^2}{N-1}}$$



TL494M PULSE-WIDTH-MODULATION CONTROL CIRCUIT

electrical characteristics over recommended operating free-air temperature range, $V_{CC} = 15\text{ V}$, $f = 10\text{ kHz}$ (unless otherwise noted)

output section

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|--------------------------------------|--|-----|------|------|---------------|
| Collector off-state current | $V_{CE} = 40\text{ V}$, $V_{CC} = 40\text{ V}$ | | 2 | 100 | μA |
| Emitter off-state current | $V_{CC} = V_C = 40\text{ V}$, $V_E = 0$ | | | -100 | μA |
| Collector-emitter saturation voltage | Common-emitter $V_E = 0$, $I_C = 200\text{ mA}$ | | 1.1 | 1.3 | V |
| | Emitter-follower $V_C = 15\text{ V}$, $I_E = -200\text{ mA}$ | | 1.5 | 2.5 | |
| Output control input current | $V_I = \text{REF}$ | | | 3.5 | mA |

dead-time control section (see Figure 1)

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|---------------------------------|---|-----|------|------|---------------|
| Input bias current (pin 4) | $V_I = 0\text{ to }5.25\text{ V}$ | | -2 | -10 | μA |
| Maximum duty cycle, each output | V_I (pin 4) = 0, $C_T = 0.1\ \mu\text{F}$, $R_T = 12\text{ k}\Omega$ | | 45% | 50%* | |
| Input threshold voltage (pin 4) | Zero duty cycle | | 3 | 3.3 | V |
| | Maximum duty cycle | | 0* | | |

pwm comparator section (see Figure 1)

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|---------------------------------|---------------------|-----|------|-----|------|
| Input threshold voltage (pin 3) | Zero duty cycle | | 4 | 4.5 | V |
| Input sink current (pin 3) | V (pin 3) = 0.7 V | 0.3 | 0.7 | | mA |

total device (see Figure 1)

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|------------------------|--|------------------------|------|-----|------|
| Standby supply current | Pin 6 at REF, All other inputs and outputs open | $V_{CC} = 15\text{ V}$ | 6 | 21 | mA |
| | | $V_{CC} = 40\text{ V}$ | 9 | 26 | |
| Average supply current | V_I (pin 4) = 2 V, See Figure 1 | | 7.5 | | mA |

switching characteristics, $T_A = 25^\circ\text{C}$

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|--------------------------|--|-----|------|------|------|
| Output voltage rise time | Common-emitter configuration, See Figure 3 | | 100 | 200* | ns |
| Output voltage fall time | | | 25 | 100* | |
| Output voltage rise time | Emitter-follower configuration, See Figure 4 | | 100 | 200* | ns |
| Output voltage fall time | | | 40 | 100* | |

* This parameter is not production tested.

† All typical values except for temperature coefficient are at $T_A = 25^\circ\text{C}$.

**TL494M
PULSE-WIDTH-MODULATION CONTROL CIRCUIT**

PARAMETER MEASUREMENT INFORMATION

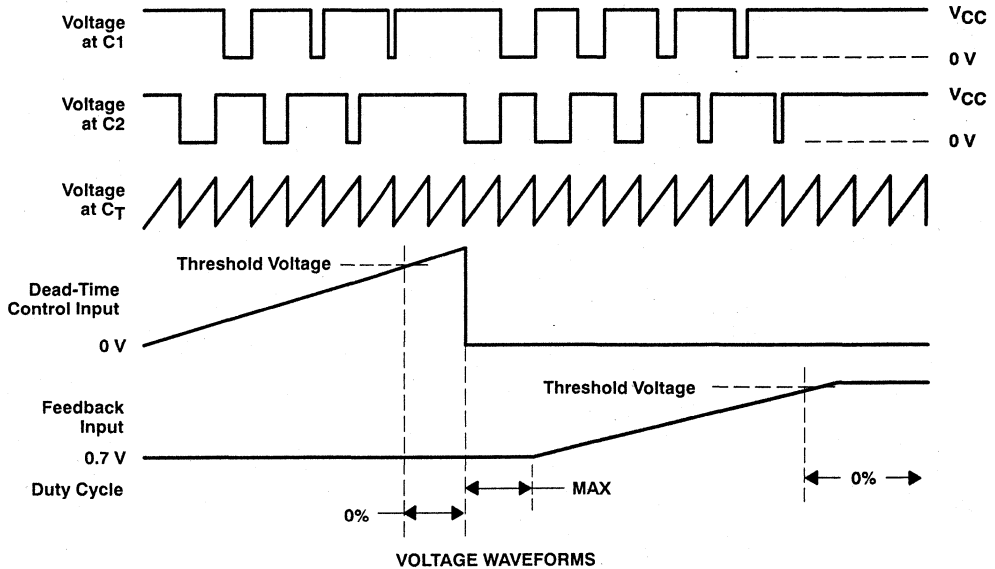
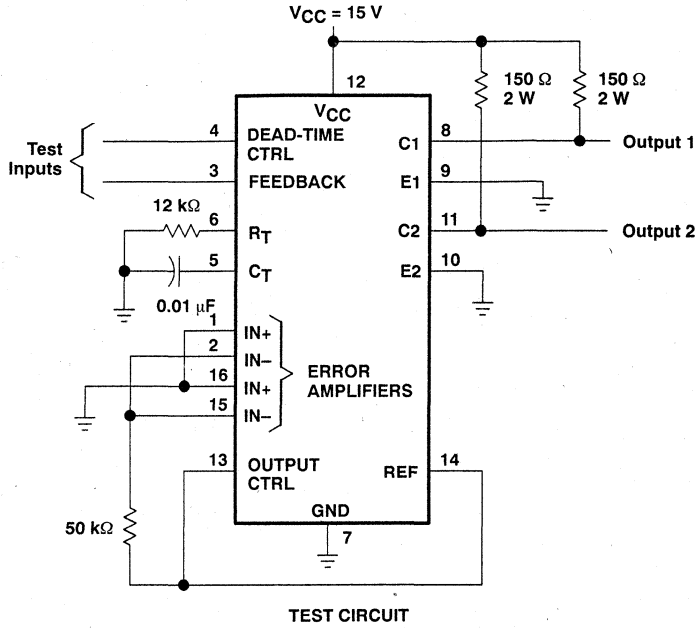


Figure 1. Operational Test Circuit and Waveforms

PARAMETER MEASUREMENT INFORMATION

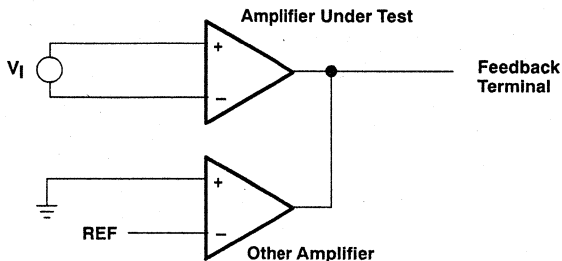


Figure 2. Amplifier Characteristics

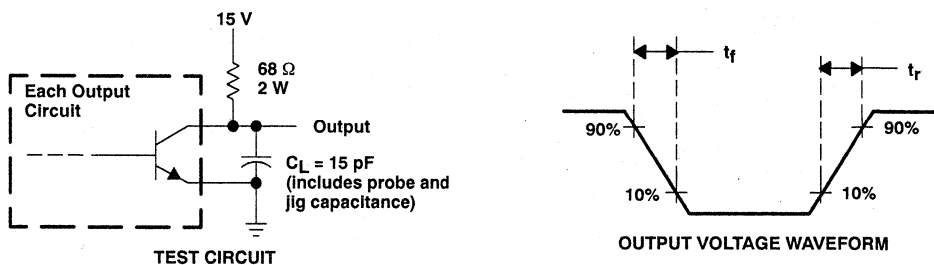


Figure 3. Common-Emitter Configuration

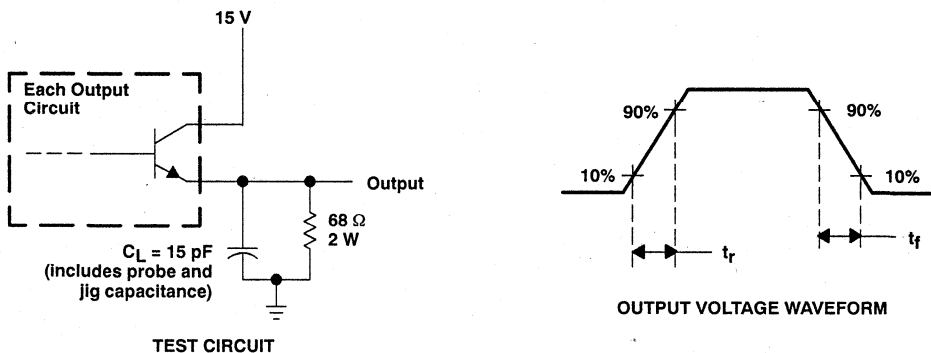


Figure 4. Emitter-Follower Configuration

TYPICAL CHARACTERISTICS

**OSCILLATOR FREQUENCY AND
 FREQUENCY VARIATION[†]
 vs
 TIMING RESISTANCE**

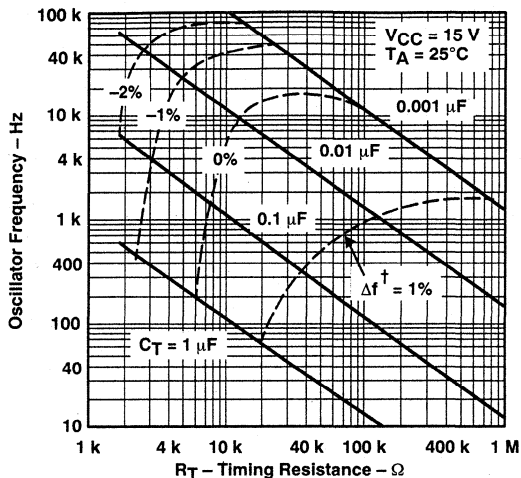


Figure 5

**AMPLIFIER VOLTAGE AMPLIFICATION
 vs
 FREQUENCY**

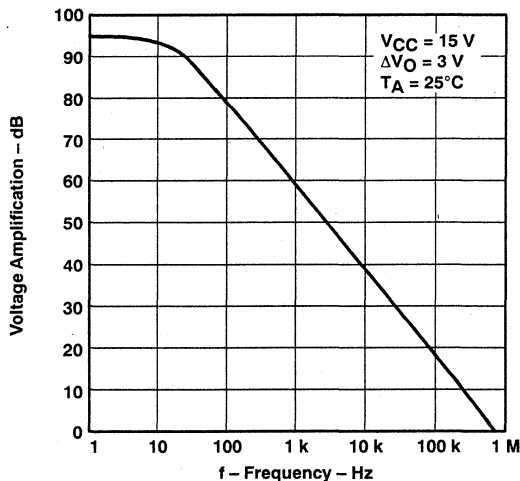


Figure 6

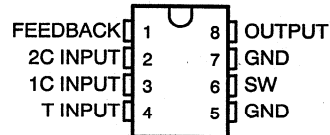
[†] Frequency variation (Δf) is the change in oscillator frequency that occurs over the full temperature range.

TL496C 9-V POWER-SUPPLY CONTROLLER

D2486, AUGUST 1978—REVISED NOVEMBER 1991

- Internal Step-Up Switching Regulator
- Fixed 9-V Output
- Charges Battery Source During Transformer-Coupled-Input Operation
- Minimum External Components Required (1 Inductor, 1 Capacitor, 1 Diode)
- 1- or 2-Cell-Input Operation

D OR P PACKAGE
(TOP VIEW)



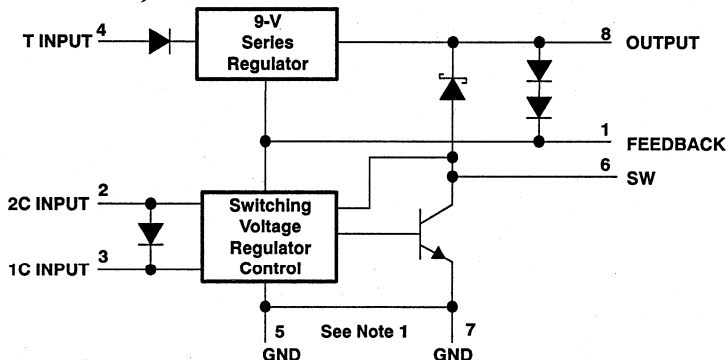
Pins 5 and 7 are connected together internally.

description

The TL496C power-supply control circuit is designed to provide a 9-V regulated supply from a variety of input sources. Operable from a 1- or 2-cell battery input, the TL496C performs as a switching regulator with the addition of a single inductor and filter capacitor. When ac coupled with a step-down transformer, the TL496C operates as a series regulator to maintain the regulated output voltage and, with the addition of a single catch diode, time shares to recharge the input batteries.

The design of the TL496C allows minimal supply current drain during standby operation (125 μ A typical). With most battery sources, this allows a constant bias to be maintained on the power supply. This makes power instantly available to the system, thus eliminating power-up sequencing problems.

functional block diagram



NOTE 1: Pins 5 and 7, though connected together internally, must both be terminated to ground to ensure proper circuit operation.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Input voltage: 2C INPUT | 3.5 V |
| 1C INPUT | 2.5 V |
| T INPUT | 20 V |
| Output voltage, SW | 12 V |
| Diode reverse voltage, OUTPUT | 12 V |
| Switch current, SW | 1.2 A |
| Diode current, OUTPUT | 1.2 A |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range | 0°C to 70°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.


**TEXAS
INSTRUMENTS**

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TL496C

9-V POWER-SUPPLY CONTROLLER

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR | $T_A = 70^\circ\text{C}$ POWER RATING |
|---------|---|--------------------------|--|
| D | 725 mW | 5.8 mW/ $^\circ\text{C}$ | 464 mW |
| P | 1000 mW | 8.0 mW/ $^\circ\text{C}$ | 640 mW |

recommended operating conditions

| | MIN | MAX | UNIT |
|---|-----------|-----|------|
| Input voltage, one-cell operation (2C and 1C INPUTS to ground) | 1.1 | 1.5 | V |
| Input voltage, two-cell operation (2C INPUT to ground) | 2.3 | 3 | V |
| Input voltage, one-cell or two-cell operation (T INPUT to ground) | $V_O + 2$ | 20 | V |

electrical characteristics at $T_A = 25^\circ\text{C}$

series regulator section (T INPUT)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT | |
|---------------------------------|---|--------------------------------|-----|------|---------------|---|
| Dropout voltage | $V_I = 5\text{ V}$, $I_O = -50\text{ mA}$ | | 1.5 | 2 | V | |
| Regulated output voltage | $V_I = 20\text{ V}$ | $I_O = -50\text{ }\mu\text{A}$ | 9.5 | 10.1 | 11.2 | V |
| | | $I_O = -80\text{ mA}$ | 9 | 10 | 11 | |
| | $V_I = 20\text{ V}$, FEEDBACK shorted to OUTPUT | $I_O = -50\text{ }\mu\text{A}$ | 8.5 | 9 | 9.7 | |
| | | $I_O = -80\text{ mA}$ | 6.7 | 8.6 | 9.5 | |
| Standby current, T INPUT | $V_I = 20\text{ V}$, OUTPUT at 12 V | | | 400 | μA | |
| Reverse current through T INPUT | $V_I = -1.5\text{ V}$, 1 mA into OUTPUT | | | -25 | μA | |

output switch

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|------------------------------------|-----|------|-----|------|
| $V_{CE(\text{sat})}$ Collector-emitter saturation voltage | 800 mA into SW, 2C INPUT at 2.25 V | | 0.35 | 0.6 | V |

diode (SW to OUTPUT)

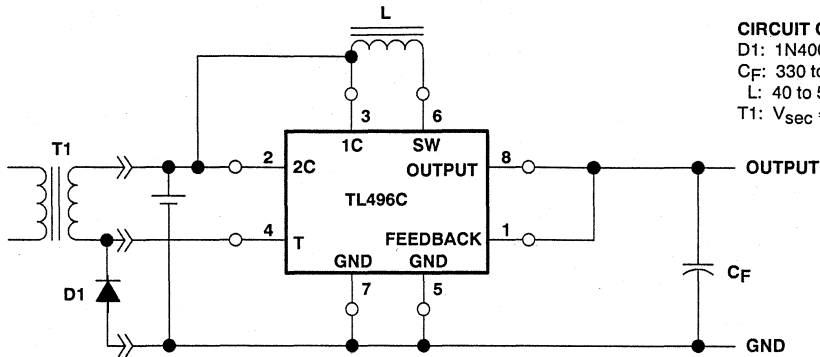
| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|----------------------------------|-----------------------------|-----|-----|-----|---------------|
| V_F Forward voltage | $I_F = 1.5\text{ A}$ | | 1.6 | 2.5 | V |
| I_R Reverse current through SW | SW at 0 V, 1 mA into OUTPUT | | | -20 | μA |

control section

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|--|-----|-----|-----|---------------|
| On-state current (2C INPUT) | FEEDBACK and OUTPUT at 0 V, 2C INPUT at 3 V | | 60 | 100 | mA |
| Standby current (FEEDBACK) | FEEDBACK at 8.65 V, 2C INPUT and SW at 3 V | | | 40 | μA |
| Standby current (2C INPUT and SW) | FEEDBACK at 8.65 V, 2C INPUT and SW at 3 V | | | 400 | μA |
| Start-up current (current into SW to initiate cycle) | FEEDBACK, 2C INPUT, SW, and OUTPUT at 2.25 V | 16 | | | mA |

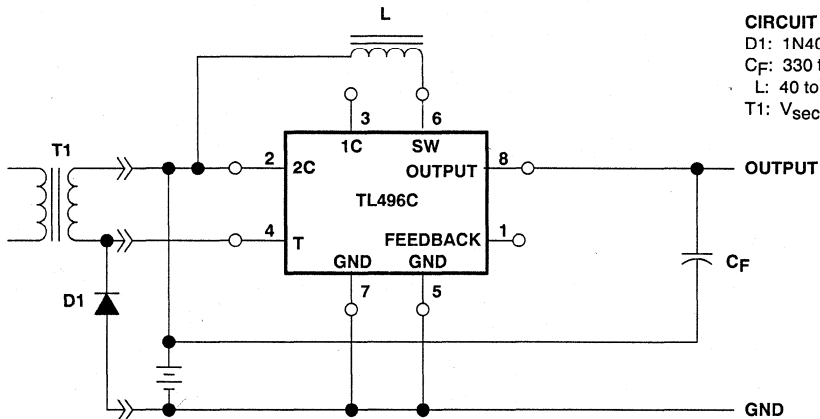


APPLICATION INFORMATION



CIRCUIT COMPONENT INFORMATION
 D1: 1N4001
 CF: 330 to 470 μ F, 10 V, electrolytic
 L: 40 to 50 μ H, Q \approx 3, R < 0, 15 Ω
 T1: V_{sec} = 6.8 V RMS typ, R_{sec} = 11 Ω typ

Figure 1. One-Cell Operation



CIRCUIT COMPONENT INFORMATION
 D1: 1N4001
 CF: 330 to 470 μ F, 10 V, electrolytic
 L: 40 to 50 μ H, Q \approx 3, R < 0, 15 Ω
 T1: V_{sec} = 6.8 V RMS typ, R_{sec} = 11 Ω typ

Figure 2. Two-Cell Operation

electrical characteristics for one- and two-cell input operations

| PARAMETER | | ONE-CELL OPERATION (see Figure 1) | TWO-CELL OPERATION (see Figure 2) |
|---------------------------------|--------------------|--------------------------------------|--------------------------------------|
| Input current | No load | 125 μ A | 125 μ A |
| | $R_L = 120 \Omega$ | 525 mA | 405 mA |
| Output voltage | Without T1 | 7.2 V | 8.6 V |
| | With T1 | 8.6 V | 10 V |
| Output current capability | | 40 mA | 80 mA |
| Efficiency | | 66% | 66% |
| Battery life (AA NiCad) no load | | 60 days | 166 days |

TL496C

9-V POWER-SUPPLY CONTROLLER

functional description

The TL496C is designed to operate from either a single-cell or two-cell source. To operate the device from a single cell (1.1 V to 1.5 V), the source must be connected to both inputs 1C and 2C as shown in Figure 1. For a two-cell operation (2.3 V to 3 V), the input is applied to the 2C input only and the 1C input is left open (see Figure 2).

battery operation

The TL496C operates as a switching regulator from a battery input. The cycle is initiated when a low-voltage condition is sensed by the internal feedback (the thresholds at pin 1 and pin 8 are approximately 7.2 and 8.6 V, respectively). An internal latch is set and the output transistor is turned on. This causes the current in the external inductor (L) to increase linearly until it reaches a peak value of approximately 1 A. When the peak current is sensed, the internal latch is reset and the output transistor is turned off. The energy developed in the inductor is then delivered to the output storage capacitor through the blocking diode. The latch remains in the off state until the feedback signal indicates the output voltage is again deficient.

transformer-coupled operation

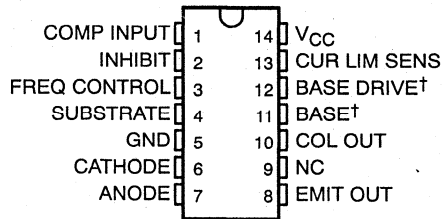
The TL496C operates on alternate half cycles of the ac input during transformer-coupled operation to first sustain the output voltage and second, recharge the batteries. The TL496C performs like a series regulator to supply charge to the output filter/storage capacitor during the first half cycle. The output voltage of the series regulator is slightly higher voltage than that created by the switching circuit; this maintains the feedback voltage above the switching regulator control circuit threshold, effectively inhibiting the switching control circuitry. During the second half cycle, an external diode (1N4001) is used to clamp the negative-going end of the transformer secondary to ground, thus allowing the positive-going end (end connected to V+ side of battery) to pump a charge into the standby batteries.

TL497AC, TL497AI SWITCHING VOLTAGE REGULATORS

D2225, JUNE 1976 – REVISED AUGUST 1991

- High Efficiency . . . 60% or Greater
- Output Current . . . 500 mA
- Input Current Limit Protection
- TTL-Compatible Inhibit
- Adjustable Output Voltage
- Input Regulation . . . 0.2% Typ
- Output Regulation . . . 0.4% Typ
- Soft Start-Up Capability

TL497AC, TL497AI . . . D OR N PACKAGE
(TOP VIEW)



NC - No internal connection

† The BASE pin (#11) and BASE DRIVE pin (#12) are used for device testing only. They are not normally used in circuit applications of the device.

description

The TL497AC and TL497AI incorporate on a single monolithic chip all the active functions required in the construction of switching voltage regulators. They can also be used as the control element to drive external components for high-power-output applications. The TL497AC and TL497AI were designed for ease of use in step-up, step-down, or voltage inversion applications requiring high efficiency.

The TL497AC and TL497AI are fixed-on-time variable-frequency switching voltage regulator control circuits. The on time is programmed by a single external capacitor connected between the FREQ CONTROL pin and GND. This capacitor, C_T , is charged by an internal constant-current generator to a predetermined threshold. The charging current and the threshold vary proportionally with V_{CC} . Thus, the on time remains constant over the specified range of input voltage (4.5 V to 12 V). Typical on times for various values of C_T are as follows:

| TIMING CAPACITOR, C_T (pF) | 200 | 250 | 350 | 400 | 500 | 750 | 1000 | 1500 | 2000 |
|------------------------------|-----|-----|-----|-----|-----|-----|------|------|------|
| ON TIME (μ s) | 19 | 22 | 26 | 32 | 44 | 56 | 80 | 120 | 180 |

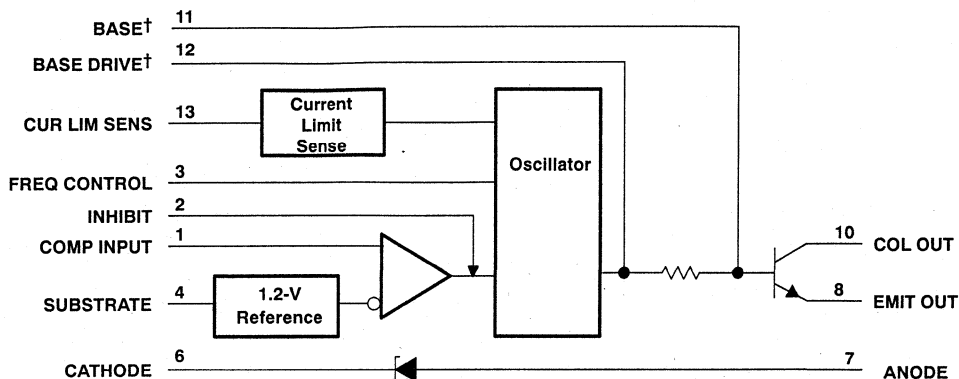
The output voltage is controlled by an external resistor ladder network (R_1 and R_2 in Figures 1, 2, and 3) that provides a feedback voltage to the comparator input. This feedback voltage is compared to the reference voltage of 1.2 V (relative to the SUBSTRATE pin) by the high-gain comparator. When the output voltage decays below the value required to maintain 1.2 V at the comparator input, the comparator enables the oscillator circuit, which charges and discharges C_T as described above. The internal pass transistor is driven on during the charging of C_T . The internal transistor may be used directly for switching currents up to 500 mA. Its collector and emitter are uncommitted, and it is current driven to allow operation from the positive supply voltage or ground. An internal Schottky diode matched to the current characteristics of the internal transistor is also available for blocking or commutating purposes. The TL497AC and TL497AI also have on-chip current-limit circuitry that senses the peak currents in the switching regulator and protects the inductor against saturation and the pass transistor against overstress. The current limit is adjustable and is programmed by a single sense resistor, R_{CL} , connected between V_{CC} and CUR LIM SENS. The current-limit circuitry is activated when 0.7 V is developed across R_{CL} . External gating is provided by the INHIBIT input. When the INHIBIT input is high, the output is turned off.

Simplicity of design is a primary feature of the TL497AC and TL497AI. With only six external components (three resistors, two capacitors, and one inductor), the TL497AC and TL497AI will operate in numerous voltage conversion applications (step-up, step-down, invert) with as much as 85% of the source power delivered to the load. The TL497AC and TL497AI replace the TL497 in all applications.

The TL497AC is characterized for operation from 0°C to 70°C, and the TL497AI is characterized for operation from -40°C to 85°C.

TL497AC, TL497AI SWITCHING VOLTAGE REGULATORS

functional block diagram



† The BASE pin (#11) and BASE DRIVE pin (#12) are used for device testing only. They are not normally used in circuit applications of the device.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Supply voltage, V_{CC} (see Note 1) | 15 V |
| Output voltage, V_O | 35 V |
| Comparator input voltage | 5 V |
| Inhibit input voltage | 5 V |
| Diode reverse voltage | 35 V |
| Power switch current | 750 mA |
| Diode forward current | 750 mA |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range: TL497AC | 0°C to 70°C |
| TL497AI | -40°C to 85°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds | 260°C |

NOTE 1: All voltage values except diode voltages are with respect to network ground terminal.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR | DERATE ABOVE T_A | $T_A = 70^\circ\text{C}$ POWER RATING | $T_A = 85^\circ\text{C}$ POWER RATING |
|---------|---|--------------------|-----------------------|--|--|
| D | 950 mW | 7.6 mW/°C | 25°C | 608 mW | 494 mW |
| N | 1000 mW | 9.2 mW/°C | 41°C | 736 mW | 598 mW |

TL497AC, TL497AI SWITCHING VOLTAGE REGULATORS

recommended operating conditions

| | | MIN | MAX | UNIT | |
|--|--|------------|-----------|------|----|
| Supply voltage, V_{CC} | | 4.5 | 12 | V | |
| High-level input voltage, V_{IH} , INHIBIT | | 2.5 | | V | |
| Low-level input voltage, V_{IL} , INHIBIT | | | 0.8 | V | |
| Output voltage | Step-up configuration (see Figure 1) | $V_I + 2$ | 30 | V | |
| | Step-down configuration (see Figure 2) | V_{ref} | $V_I - 1$ | | |
| | Inverting regulator (see Figure 3) | $-V_{ref}$ | -25 | | |
| Power switch current | | | 500 | mA | |
| Diode forward current | | | 500 | mA | |
| Operating free-air temperature, T_A | | TL497AC | 0 | 70 | °C |
| | | TL497AI | -40 | 85 | |

electrical characteristics at specified free-air temperature, $V_{CC} = 6\text{ V}$ (unless otherwise noted)

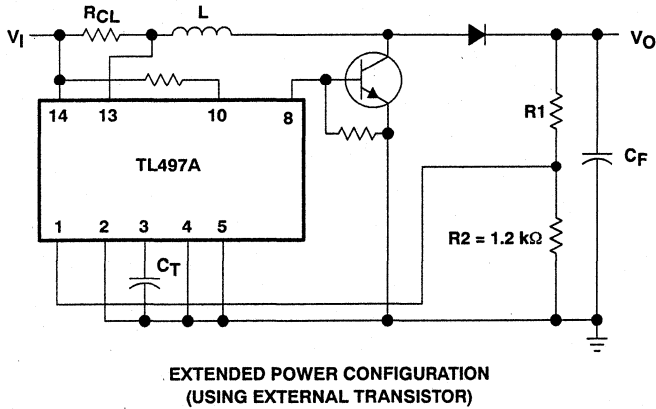
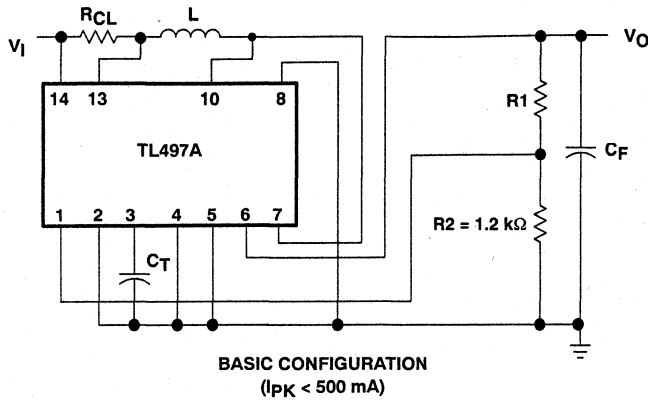
| PARAMETER | TEST CONDITIONS | T_A^\dagger | TL497AC | | | TL497AI | | | UNIT |
|----------------------------------|---|-----------------------|------------|------|------|---------|------|------|---------------|
| | | | MIN | TYP‡ | MAX | MIN | TYP‡ | MAX | |
| High-level inhibit input current | $V_{I(I)} = 5\text{ V}$ | Full range | | 0.8 | 1.5 | | 0.8 | 1.5 | mA |
| Low-level inhibit input current | $V_{I(I)} = 0\text{ V}$ | Full range | | | 5 | | 5 | 20 | μA |
| Comparator reference voltage | $V_I = 4.5\text{ V to }6\text{ V}$ | Full range | 1.08 | 1.2 | 1.32 | 1.14 | 1.2 | 1.26 | V |
| Comparator input bias current | $V_I = 6\text{ V}$ | Full range | | 40 | 100 | | 40 | 100 | μA |
| Switch on-state voltage | $V_I = 4.5\text{ V}$ | $I_O = 100\text{ mA}$ | 25°C | 0.13 | 0.2 | | 0.13 | 0.2 | V |
| | | $I_O = 500\text{ mA}$ | Full range | | 0.85 | | | 1 | |
| Switch off-state current | $V_I = 4.5\text{ V}, V_O = 30\text{ V}$ | 25°C | | 10 | 50 | | 10 | 50 | μA |
| | | Full range | | | 200 | | | 500 | |
| Current-limit sense voltage | $V_I = 6\text{ V}$ | 25°C | 0.45 | | 1 | 0.45 | | 1 | V |
| Diode forward voltage | $I_O = 10\text{ mA}$ | Full range | | 0.75 | 0.85 | | 0.75 | 0.95 | V |
| | $I_O = 100\text{ mA}$ | Full range | | 0.9 | 1 | | 0.9 | 1.1 | |
| | $I_O = 500\text{ mA}$ | Full range | | 1.33 | 1.55 | | 1.33 | 1.75 | |
| Diode reverse voltage | $I_O = 500\text{ }\mu\text{A}$ | Full range | | | | 30 | | | V |
| | $I_O = 200\text{ }\mu\text{A}$ | Full range | 30 | | | | | | |
| On-state supply current | | 25°C | | 11 | 14 | | 11 | 14 | mA |
| | | Full range | | | 15 | | | 16 | |
| Off-state supply current | | 25°C | | 6 | 9 | | 6 | 9 | mA |
| | | Full range | | | 10 | | | 11 | |

† Full range for the TL497AC is 0°C to 70°C and full range for the TL497AI is -40°C to 85°C.

‡ All typical values are at $T_A = 25^\circ\text{C}$.

TL497AC, TL497AI SWITCHING VOLTAGE REGULATORS

APPLICATION INFORMATION



DESIGN EQUATIONS

- $I_{PK} = 2 I_O \max \left[\frac{V_O}{V_I} \right]$

- $L (\mu\text{H}) = \frac{V_I}{I_{PK}} t_{on} (\mu\text{s})$

Choose L (50 to 500 μH), calculate t_{on} (25 to 150 μs)

- $C_T (\text{pF}) \approx 12 t_{on} (\mu\text{s})$

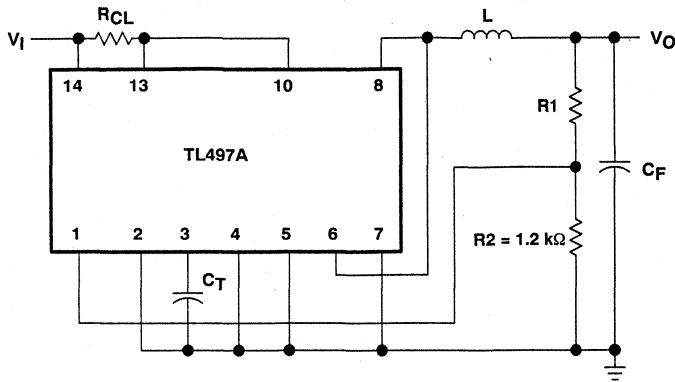
- $R_1 = (V_O - 1.2) \text{ k}\Omega$

- $R_{CL} = \frac{0.5 \text{ V}}{I_{PK}}$

- $C_F (\mu\text{F}) \approx t_{on} (\mu\text{s}) \frac{\left[\frac{V_I}{V_O} I_{PK} + I_O \right]}{\text{Ripple (PK)}}$

Figure 1. Positive Regulator, Step-Up Configurations

APPLICATION INFORMATION



BASIC CONFIGURATION
($I_{PK} < 500 \text{ mA}$)

DESIGN EQUATIONS

- $I_{PK} = 2 I_{O \text{ max}}$
- $L (\mu\text{H}) = \frac{V_I - V_O}{I_{PK}} t_{on}(\mu\text{s})$

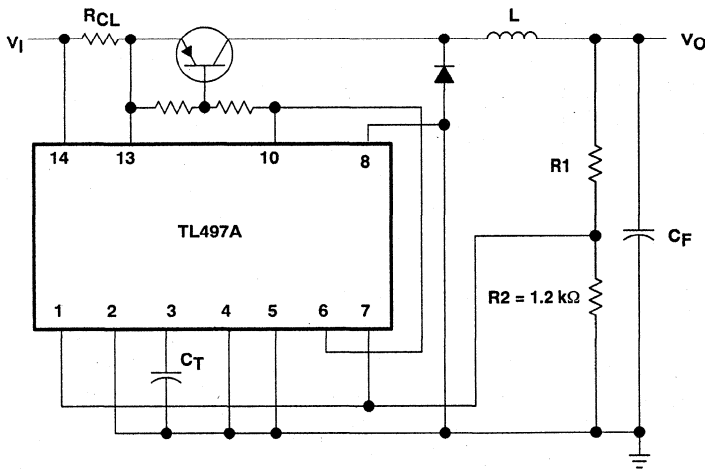
Choose L (50 to 500 μH), calculate t_{on} (10 to 150 μs)

- $C_T(\text{pF}) \approx 12 t_{on}(\mu\text{s})$

- $R_1 = (V_O - 1.2) \text{ k}\Omega$

$$R_{CL} = \frac{0.5 \text{ V}}{I_{PK}}$$

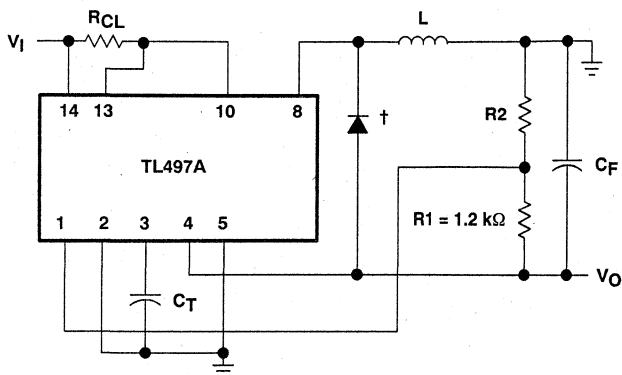
- $C_F (\mu\text{F}) \approx t_{on}(\mu\text{s}) \frac{\left[\frac{V_I}{V_O} I_{PK} + I_O \right]}{V_{\text{ripple}} (\text{PK})}$



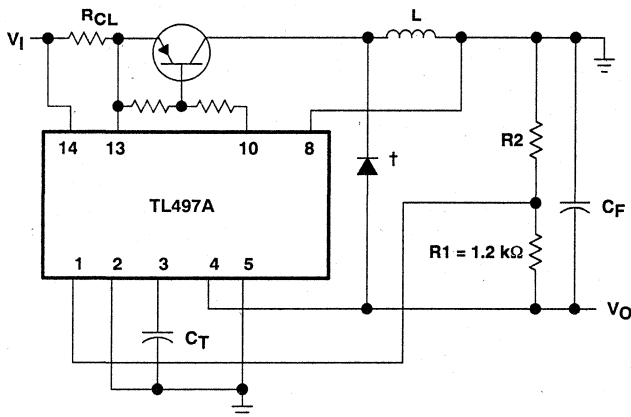
EXTENDED POWER CONFIGURATION
(USING EXTERNAL TRANSISTOR)

Figure 2. Positive Regulator, Step-Down Configurations

APPLICATION INFORMATION



BASIC CONFIGURATION
 ($I_{PK} < 500 \text{ mA}$)



EXTENDED POWER CONFIGURATION
 (USING EXTERNAL TRANSISTOR)

† Use external catch-diode, e.g., 1N4001, when building an inverting supply with the TL497A.

Figure 3. Inverting Applications

DESIGN EQUATIONS

- $I_{PK} = 2 I_O \max \left[1 + \frac{|V_O|}{V_I} \right]$

- $L (\mu\text{H}) = \frac{V_I}{I_{PK}} t_{on}(\mu\text{s})$

Choose L (50 to 500 μH), calculate t_{on} (10 to 150 μs)

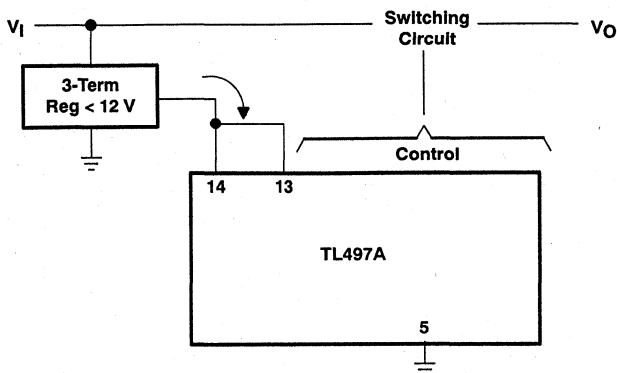
- $C_T(\text{pF}) \approx 12 t_{on}(\mu\text{s})$

- $R_1 = (V_O - 1.2) \text{ k}\Omega$

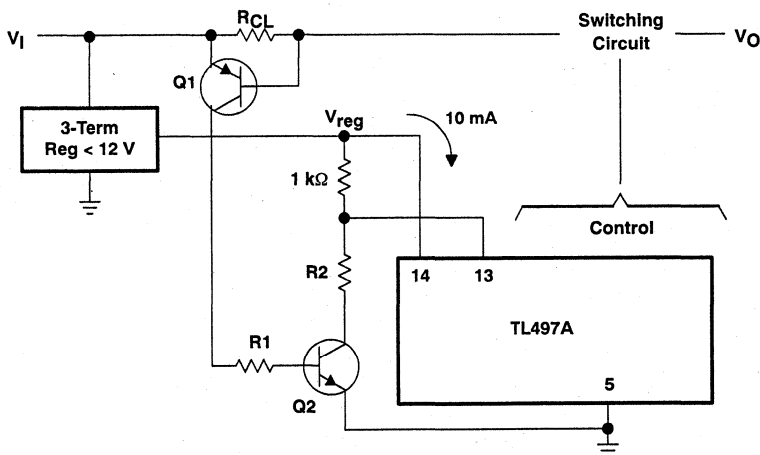
$$R_{CL} = \frac{0.5 \text{ V}}{I_{PK}}$$

- $C_F (\mu\text{F}) \approx t_{on}(\mu\text{s}) \frac{\left[\frac{V_I}{V_O} I_{PK} + I_O \right]}{V_{\text{ripple}} (\text{PK})}$

APPLICATION INFORMATION



EXTENDED INPUT CONFIGURATION WITHOUT CURRENT LIMIT



DESIGN EQUATIONS

- $R_{CL} = \frac{V_{BE}(Q1)}{I_{limit} (PK)}$
- $R1 = \frac{V1}{I_B(Q2)}$
- $R2 = (V_{reg} - 1) 10 \text{ k}\Omega$

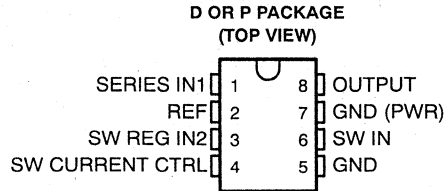
CURRENT LIMIT FOR EXTENDED INPUT CONFIGURATION

Figure 4. Extended Input Voltage Range ($V1 > 12 \text{ V}$)

TL499AC WIDE-RANGE POWER SUPPLY CONTROLLER

D2762, JANUARY 1984—REVISED NOVEMBER 1991

- Internal Series-Pass and Step-Up Switching Regulator
- Output Adjustable From 2.9 V to 30 V
- 1-V to 10-V Input for Switching Regulator
- 4.5-V to 32-V Input for Series Regulator
- Externally-Controlled Switching Current
- No External Rectifier Required



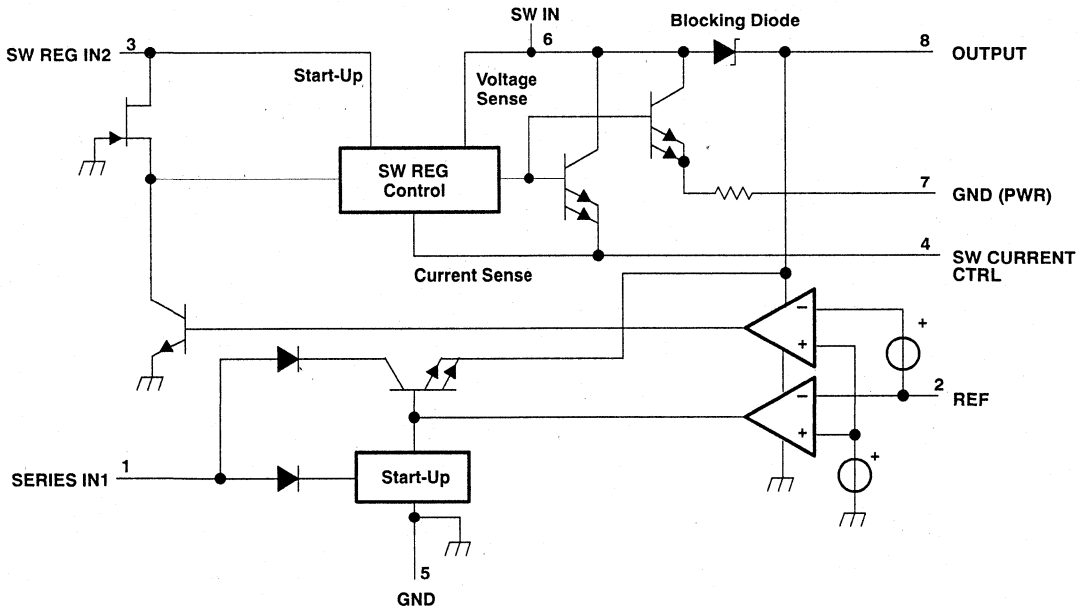
description

The TL499AC is a monolithic integrated circuit designed to provide a wide range of adjustable regulated supply voltages. The regulated output voltage is adjustable from 2.9 V to 30 V by adjusting two external resistors. When the TL499AC is ac-coupled to line power through a step-down transformer, it operates as a series dc voltage regulator to maintain the regulated output voltage. With the addition of a battery from 1.1 V to 10 V, an inductor, a filter capacitor, and two resistors, the TL499AC operates as a step-up switching regulator during an ac-line failure.

The adjustable regulated output voltage makes the TL499AC useful for a wide range of applications. Providing backup power during an ac-line failure makes the TL499AC extremely useful as backup power in microprocessor memory applications.

The TL499AC is designed for operation from -20°C to 85°C .

functional block diagram



PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

**TEXAS
INSTRUMENTS**

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2-235

TL499AC

WIDE-RANGE POWER SUPPLY CONTROLLER

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Output voltage, V_O (see Note 1) | 35 V |
| Input voltage, series regulator, V_{I1} | 35 V |
| Input voltage, switching regulator, V_{I2} | 10 V |
| Blocking diode reverse voltage | 35 V |
| Blocking diode forward current | 1 A |
| Power switch current (at SW IN) | 1 A |
| Continuous total power dissipation | See Dissipation Rating Table |
| Operating free-air temperature range | -20°C to 85°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 1: All voltage values are with respect to network ground terminal.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$ | $T_A = 85^\circ\text{C}$ POWER RATING |
|---------|---|---|--|
| D | 825 mW | 6.6 mW/°C | 429 mW |
| P | 1000 mW | 8 mW/°C | 520 mW |

recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|--|-----|-----|------|---------------|
| Output voltage, V_O | 2.9 | | 30 | V |
| Input voltage, SERIES IN1, V_{I1} | 4.5 | | 32 | V |
| Input voltage, SW REG IN2, V_{I2} | 1.1 | | 10 | V |
| Output-to-input differential voltage, switching regulator, $V_O - V_{I2}$ (see Note 2) | 1.2 | | 28.9 | V |
| Continuous output current, I_O | | | 100 | mA |
| Power switch current (at SW IN) | | | 500 | mA |
| Current-limiting resistor, R_{CL} | 150 | | 1000 | Ω |
| Filter capacitor | 100 | | 470 | μF |
| Pass capacitor | | 0.1 | | μF |
| Inductor, L ($r_l \leq 0.1 \Omega$) | 50 | | 150 | μH |
| Operating free-air temperature, T_A | -20 | | 85 | °C |

NOTE 2: When operating temperature range is $T_A \leq 70^\circ\text{C}$, minimum $V_O - V_{I2}$ is ≥ 1.2 V. When operating temperature range is $T_A \leq 85^\circ\text{C}$, minimum $V_O - V_{I2}$ is ≥ 1.9 V.



TL499AC WIDE-RANGE POWER SUPPLY CONTROLLER

electrical characteristics over recommended operating free-air temperature range (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---------------------|--|-----|------|------|---------------|
| Voltage deviation (see Note 3) | | | | 2% | 3% | |
| Dropout voltage | Switching regulator | $T_A = -20^\circ\text{C}$ to 70°C | | | 1.2 | V |
| | | $T_A = -20^\circ\text{C}$ to 85°C | | | 1.9 | V |
| | Series regulator | $V_{I1} = 15\text{ V}$, $I_O = 50\text{ mA}$ | | | 1.8 | V |
| Reference voltage (internal) | | $V_{I2} = 5\text{ V}$, $V_O = 3\text{ V}$, $I_O = 1\text{ mA}$ | 1.2 | 1.26 | 1.32 | V |
| Reference voltage change with temperature | | $T_A = -20^\circ\text{C}$ to 85°C | | 0.5% | 1% | |
| Output regulation (of reference voltage) | | $I_O = 1\text{ mA}$ to 50 mA | | 1% | 3% | |
| Output current (see Figure 1) | Switching regulator | $V_{I2} = 1.1\text{ V}$, $V_O = 12\text{ V}$, $R_{CL} = 150\ \Omega$, $T_A = 25^\circ\text{C}$ | | 10 | | mA |
| | | $V_{I2} = 1.5\text{ V}$, $V_O = 15\text{ V}$, $R_{CL} = 150\ \Omega$, $T_A = 25^\circ\text{C}$ | | 15 | | |
| | | $V_{I2} = 6\text{ V}$, $V_O = 30\text{ V}$, $R_{CL} = 150\ \Omega$, $T_A = 25^\circ\text{C}$ | | 65 | | |
| | Series regulator | | | 100 | | |
| Standby current | Switching regulator | $V_{I2} = 3\text{ V}$, $V_O = 9\text{ V}$, $T_A = 25^\circ\text{C}$ | | 15 | 80 | μA |
| | Series regulator | $V_{I1} = 15\text{ V}$, $V_O = 9\text{ V}$, $R_{E2} = 4.7\text{ k}\Omega$ | | 0.8 | 1.2 | mA |

NOTE 3: Voltage deviation is the output voltage change in percent that occurs in a change from series regulation to switching regulation.

$$\text{voltage deviation} = \frac{V_O(\text{series reg}) - (\text{switching reg})}{V_O(\text{series reg})} \times 100\%$$

TL499AC WIDE-RANGE POWER SUPPLY CONTROLLER

APPLICATION INFORMATION

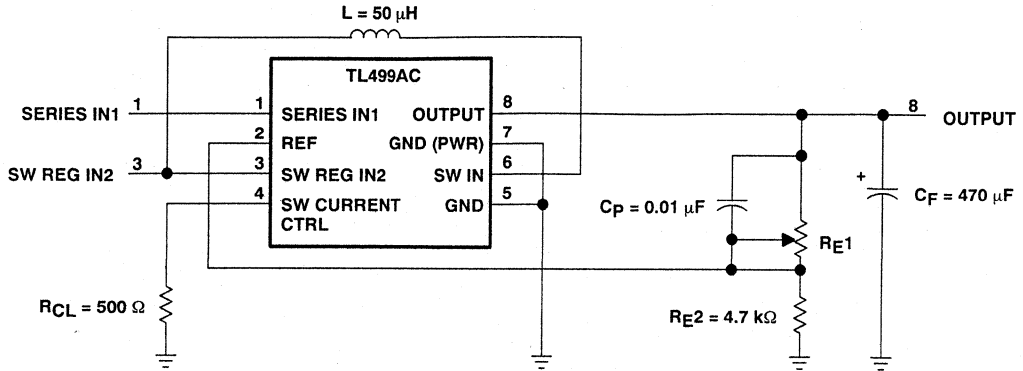


Figure 1. TL499AC Basic Configuration

Table 1. Output Current vs Input and Output Voltages
for Step-Up Switching Regulator With $R_{CL} = 150 \Omega$

| V_O , OUTPUT VOLTAGE (V) | V_I2 , SWITCHING REGULATOR INPUT VOLTAGE (V) | | | | | | | | | | |
|----------------------------|--|-----------------|-----------------|------------------|------------------|----|-----|------------------|--|-----|-----|
| | 1.1 | 1.2 | 1.3 | 1.5 | 1.7 | 2 | 2.5 | 3 | 5 | 6 | 9 |
| | I_O , OUTPUT CURRENT (mA) | | | | | | | | | | |
| 30 | | | | | | | | | | 65 | 90 |
| 25 | | | | | | | | | 50 | 80 | 100 |
| 20 | | | | | | 20 | 25 | 30 | 80 | 100 | 100 |
| 15 | | | | 15 | 20 | 30 | 45 | 55 | 100 | 100 | 100 |
| 12 | 10 | 15 | 20 | 25 | 30 | 40 | 55 | 70 | 100 | 100 | 100 |
| 10 | 15 | 20 | 25 | 30 | 35 | 45 | 65 | 80 | 100 | 100 | |
| 9 | 20 | 25 | 25 | 35 | 40 | 50 | 70 | 90 | 100 | 100 | |
| 6 | 30 | 35 | 40 | 45 | 55 | 75 | 95 | 100 | | | |
| 5 | 35 | 40 | 45 | 55 | 70 | 85 | 100 | 100 | | | |
| 4.5 | 35 | 45 | 50 | 60 | 75 | 95 | 100 | 100 [†] | Circuit of Figure 1 except: $R_{CL} = 150 \Omega$ $C_F = 330 \mu F$ $C_p = 0.1 \mu F$ | | |
| 3 | 55 | 65 [†] | 75 [†] | 95 [†] | 100 [†] | | | | | | |
| 2.9 | 60 [†] | 70 [†] | 75 [†] | 100 [†] | 100 [†] | | | | | | |

[†] The difference between the output and input voltage for these combinations is greater than the minimum output-to-input differential voltage specification at 70°C (1.2 V), but less than the minimum at 85°C (1.9 V).

APPLICATION INFORMATION

**Table 2. Output Current vs Input and Output Voltages
for Step-Up Switching Regulator With $R_{CL} = 200 \Omega$**

| V_O , OUTPUT VOLTAGE (V) | V_I , SWITCHING REGULATOR INPUT VOLTAGE (V) | | | | | | | | | | |
|----------------------------|---|-----|-----|-----|------|----|-----|------|--|-----|-----|
| | 1.1 | 1.2 | 1.3 | 1.5 | 1.7 | 2 | 2.5 | 3 | 5 | 6 | 9 |
| | I_O , OUTPUT CURRENT (mA) | | | | | | | | | | |
| 30 | | | | | | | | | | 50 | 100 |
| 25 | | | | | | | | | 50 | 70 | 100 |
| 20 | | | | | | 15 | 25 | 30 | 70 | 90 | 100 |
| 15 | | | | 10 | 15 | 25 | 35 | 45 | 90 | 100 | 100 |
| 12 | 10 | 10 | 15 | 20 | 25 | 35 | 45 | 60 | 100 | 100 | 100 |
| 10 | 15 | 20 | 20 | 25 | 30 | 40 | 55 | 70 | 100 | 100 | |
| 9 | 20 | 20 | 25 | 30 | 35 | 45 | 60 | 80 | 100 | | |
| 6 | 25 | 30 | 35 | 45 | 50 | 65 | 90 | 100 | | | |
| 5 | 30 | 35 | 40 | 55 | 60 | 75 | 100 | 100 | | | |
| 4.5 | 35 | 40 | 45 | 55 | 65 | 85 | 100 | 100† | Circuit of Figure 1 except: $R_{CL} = 200 \Omega$ $C_F = 330 \mu F$ $C_P = 0.1 \mu F$ | | |
| 3 | 50 | 55† | 65† | 80† | 90† | | | | | | |
| 2.9 | 50† | 60† | 65† | 85† | 100† | | | | | | |

† The difference between the output and input voltage for these combinations is greater than the minimum output-to-input differential voltage specification at 70°C (1.2 V), but less than the minimum at 85°C (1.9 V).

**Table 3. Output Current vs Input and Output Voltages
for Step-Up Switching Regulator With $R_{CL} = 300 \Omega$**

| V_O , OUTPUT VOLTAGE (V) | V_I , SWITCHING REGULATOR INPUT VOLTAGE (V) | | | | | | | | | | |
|----------------------------|---|-----|-----|-----|-----|----|-----|------|--|-----|-----|
| | 1.1 | 1.2 | 1.3 | 1.5 | 1.7 | 2 | 2.5 | 3 | 5 | 6 | 9 |
| | I_O , OUTPUT CURRENT (mA) | | | | | | | | | | |
| 30 | | | | | | | | | | 40 | 70 |
| 25 | | | | | | | | | 40 | 55 | 100 |
| 20 | | | | | | 10 | 15 | 20 | 55 | 70 | 100 |
| 15 | | | | 10 | 10 | 20 | 30 | 35 | 75 | 95 | 100 |
| 12 | 10 | 10 | 10 | 15 | 20 | 25 | 35 | 45 | 95 | 100 | 100 |
| 10 | 15 | 15 | 15 | 20 | 25 | 30 | 45 | 55 | 100 | 100 | |
| 9 | 15 | 15 | 20 | 25 | 30 | 35 | 50 | 60 | 100 | 100 | |
| 6 | 25 | 25 | 30 | 35 | 45 | 55 | 70 | 90 | | | |
| 5 | 30 | 30 | 35 | 45 | 50 | 65 | 85 | 100 | | | |
| 4.5 | 30 | 35 | 40 | 45 | 55 | 70 | 95 | 100† | Circuit of Figure 1 except: $R_{CL} = 300 \Omega$ $C_F = 330 \mu F$ $C_P = 0.1 \mu F$ | | |
| 3 | 45 | 50† | 55† | 70† | 90† | | | | | | |
| 2.9 | 45† | 50† | 60† | 75† | 95† | | | | | | |

† The difference between the output and input voltage for these combinations is greater than the minimum output-to-input differential voltage specification at 70°C (1.2 V), but less than the minimum at 85°C (1.9 V).

APPLICATION INFORMATION

Table 4. Output Current vs Input and Output Voltages for Step-Up Switching Regulator With $R_{CL} = 510 \Omega$

| V _O , OUTPUT VOLTAGE (V) | V _{I2} , SWITCHING REGULATOR INPUT VOLTAGE (V) | | | | | | | | | | |
|-------------------------------------|---|-----------------|-----------------|-----------------|-----------------|----|-----|-----------------|--|-----|-----|
| | 1.1 | 1.2 | 1.3 | 1.5 | 1.7 | 2 | 2.5 | 3 | 5 | 6 | 9 |
| | I _O , OUTPUT CURRENT (mA) | | | | | | | | | | |
| 30 | | | | | | | | | | 30 | 50 |
| 25 | | | | | | | | | 25 | 40 | 75 |
| 20 | | | | | | | | 40 | 55 | 90 | |
| 15 | | | | | | 15 | 20 | 55 | 70 | 100 | |
| 12 | | | | | 10 | 15 | 25 | 35 | 65 | 80 | 100 |
| 10 | | | | 10 | 20 | 25 | 30 | 40 | 70 | 85 | |
| 9 | 10 | 10 | 10 | 15 | 20 | 25 | 35 | 45 | 75 | 100 | |
| 6 | 15 | 20 | 20 | 25 | 30 | 35 | 50 | 60 | | | |
| 5 | 20 | 20 | 25 | 30 | 35 | 45 | 55 | 70 | Circuit of Figure 1 except: $R_{CL} = 510 \Omega$ $C_F = 330 \mu F$ $C_p = 0.1 \mu F$ | | |
| 4.5 | 20 | 25 | 30 | 35 | 40 | 50 | 65 | 90 [†] | | | |
| 3 | 35 | 35 [†] | 40 [†] | 50 [†] | 75 [†] | | | | | | |
| 2.9 | 35 [†] | 35 [†] | 40 [†] | 55 [†] | 80 [†] | | | | | | |

[†] The difference between the output and input voltage for these combinations is greater than the minimum output-to-input differential voltage specification at 70°C (1.2 V), but less than the minimum at 85°C (1.9 V).

Table 5. Output Current vs Input and Output Voltages for Step-Up Switching Regulator With $R_{CL} = 1 k\Omega$

| V _O , OUTPUT VOLTAGE (V) | V _{I2} , SWITCHING REGULATOR INPUT VOLTAGE (V) | | | | | | | | | | |
|-------------------------------------|---|-----------------|-----------------|-----------------|-----------------|----|-----|-----------------|---|----|----|
| | 1.1 | 1.2 | 1.3 | 1.5 | 1.7 | 2 | 2.5 | 3 | 5 | 6 | 9 |
| | I _O , OUTPUT CURRENT (mA) | | | | | | | | | | |
| 30 | | | | | | | | | | | 35 |
| 25 | | | | | | | | | | 35 | 50 |
| 20 | | | | | | | | | | 35 | 60 |
| 15 | | | | | | | | 10 | 30 | 45 | 65 |
| 12 | | | | | | | | 20 | 40 | 45 | 85 |
| 10 | | | | | | | 15 | 25 | 40 | 55 | |
| 9 | | | | 10 | 10 | 15 | 25 | 30 | 45 | 60 | |
| 6 | 10 | 10 | 10 | 15 | 20 | 20 | 30 | 35 | Circuit of Figure 1 except: $R_{CL} = 1 k\Omega$ $C_F = 330 \mu F$ $C_p = 0.1 \mu F$ | | |
| 5 | 10 | 10 | 15 | 20 | 20 | 25 | 35 | 40 | | | |
| 4.5 | 15 | 15 | 15 | 20 | 25 | 30 | 40 | 45 [†] | | | |
| 3 | 20 | 25 [†] | 25 [†] | 30 [†] | 35 [†] | | | | | | |
| 2.9 | 20 [†] | 25 [†] | 25 [†] | 30 [†] | 45 [†] | | | | | | |

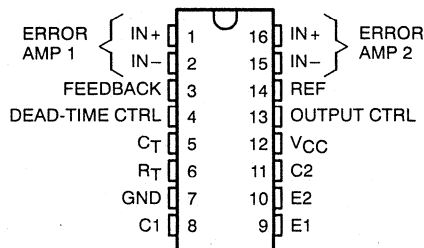
[†] The difference between the output and input voltage for these combinations is greater than the minimum output-to-input differential voltage specification at 70°C (1.2 V), but less than the minimum at 85°C (1.9 V).

TL594C, TL594I PULSE-WIDTH-MODULATION CONTROL CIRCUITS

D2712, APRIL 1988—REVISED NOVEMBER 1991

- Complete PWM Power Control Circuitry
- Uncommitted Outputs for 200-mA Sink or Source Current
- Output Control Selects Single-Ended or Push-Pull Operation
- Internal Circuitry Prohibits Double Pulse at Either Output
- Variable Dead Time Provides Control Over Total Range
- Internal Regulator Provides a Stable 5-V Reference Supply Trimmed to 1%
- Circuit Architecture Allows Easy Synchronization
- Undervoltage Lockout for Low V_{CC} Conditions

D OR N PACKAGE
(TOP VIEW)



AVAILABLE OPTIONS

| T _A | PACKAGE | |
|----------------|-------------------|-----------------|
| | SURFACE MOUNT (D) | PLASTIC DIP (N) |
| 0°C to 70°C | TL594CD | TL594CN |
| -40°C to 85°C | TL594ID | TL594IN |

The D package is available taped and reeled. Add "R" suffix to device type (e.g., TL594CDR).

FUNCTION TABLE

| INPUT | OUTPUT FUNCTION |
|-----------------------|---------------------------------|
| OUTPUT CTRL | |
| $V_I \leq 0$ | Single-ended or parallel output |
| $V_I \leq \text{REF}$ | Normal push-pull operation |

description

The TL594 incorporates on a single monolithic chip all the functions required in the construction of a pulse-width-modulation control circuit. Designed primarily for power supply control, these devices offer the systems engineer the flexibility to tailor the power supply control circuitry to a specific application.

The TL594 contains two error amplifiers, an on-chip adjustable oscillator, a dead-time control comparator, a pulse-steering control flip-flop, a 5-V regulator with a precision of 1%, an undervoltage lockout control circuit, and output control circuitry.

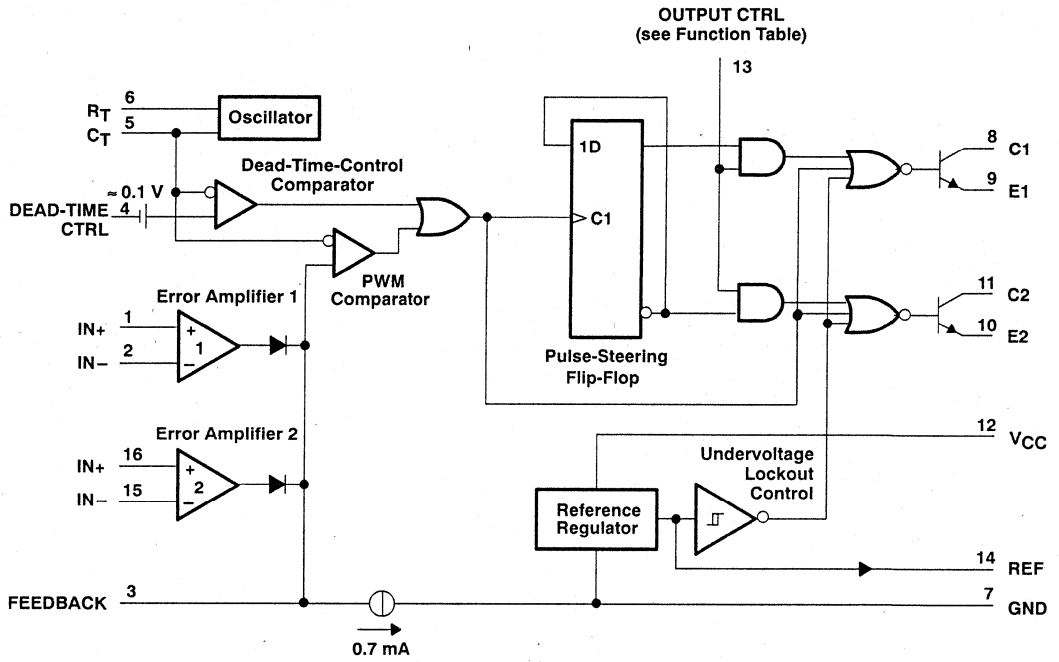
The error amplifiers exhibit a common-mode voltage range from -0.3 V to $V_{CC} - 2 \text{ V}$. The dead-time control comparator has a fixed offset that provides approximately 5% dead time when externally altered. The on-chip oscillator may be bypassed by terminating R_T to the reference output and providing a sawtooth input to C_T , or it may be used to drive the common circuitry in synchronous multiple-rail power supplies.

The uncommitted output transistors provide either common-emitter or emitter-follower output capability. Each device provides for push-pull or single-ended output operation with selection by means of the output-control function. The architecture of these devices prohibits the possibility of either output being pulsed twice during push-pull operation. The undervoltage lockout control circuit locks the outputs off until the internal circuitry is operational.

The TL594C is characterized for operation from 0°C to 70°C. The TL594I is characterized for operation from -40°C to 85°C.

TL594C, TL594I PULSE-WIDTH-MODULATION CONTROL CIRCUITS

functional block diagram



TL594C, TL594I PULSE-WIDTH-MODULATION CONTROL CIRCUITS

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | TL594C | TL594I | UNIT |
|--|------------------------------|--------------|------|
| Supply voltage, V_{CC} (see Note 1) | 41 | 41 | V |
| Amplifier input voltage | $V_{CC}+0.3$ | $V_{CC}+0.3$ | V |
| Collector output voltage | 41 | 41 | V |
| Collector output current | 250 | 250 | mA |
| Continuous total dissipation | See Dissipation Rating Table | | |
| Operating free-air temperature range | 0 to 70 | -40 to 85 | °C |
| Storage temperature range | -65 to 150 | -65 to 150 | °C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260 | 260 | °C |

NOTE 1: All voltage values, except differential voltages, are with respect to the network ground terminal.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ | DERATING FACTOR | DERATE ABOVE T_A | $T_A = 70^\circ\text{C}$ | $T_A = 85^\circ\text{C}$ |
|---------|-----------------------------|--------------------|-----------------------|--------------------------|--------------------------|
| | POWER RATING | | | POWER RATING | POWER RATING |
| D | 950 mW | 7.6 mW/°C | 25°C | 608 mW | 494 mW |
| N | 1000 mW | 9.2 mW/°C | 41°C | 736 mW | 598 mW |

recommended operating conditions

| | TL594C | | TL594I | | UNIT |
|--|--------|------------|--------|------------|------|
| | MIN | MAX | MIN | MAX | |
| Supply voltage, V_{CC} | 7 | 40 | 7 | 40 | V |
| Amplifier input voltage, V_i | -0.3 | $V_{CC}-2$ | -0.3 | $V_{CC}-2$ | V |
| Collector output voltage, V_O | | 40 | | 40 | V |
| Collector output current (each transistor) | | 200 | | 200 | mA |
| Current into feedback terminal | | 0.3 | | 0.3 | mA |
| Timing capacitor, C_T | 0.47 | 10000 | 0.47 | 10000 | nF |
| Timing resistor, R_T | 1.8 | 500 | 1.8 | 500 | kΩ |
| Oscillator frequency, f_{osc} | 1 | 300 | 1 | 300 | kHz |
| Operating free-air temperature, T_A | 0 | 70 | -40 | 85 | °C |

TL594C, TL594I

PULSE-WIDTH-MODULATION CONTROL CIRCUITS

electrical characteristics over recommended operating free-air temperature range, $V_{CC} = 15\text{ V}$, (unless otherwise noted)

reference section

| PARAMETER | TEST CONDITIONS† | MIN | TYP‡ | MAX | UNIT |
|--|---|------|------|------|------|
| Output voltage (REF) | $I_O = 1\text{ mA}$, $T_A = 25^\circ\text{C}$ | 4.95 | 5 | 5.05 | V |
| Input regulation | $V_{CC} = 7\text{ V to }40\text{ V}$, $T_A = 25^\circ\text{C}$ | | 2 | 25 | mV |
| Output regulation | $I_O = 1\text{ to }10\text{ mA}$, $T_A = 25^\circ\text{C}$ | | 14 | 35 | mV |
| Output voltage change with temperature | $\Delta T_A = \text{MIN to MAX}$ | | 0.2% | 1%* | |
| Short-circuit output current§ | $V_{\text{ref}} = 0$ | 10 | 35 | 50 | mA |

oscillator section, $C_T = 0.01\ \mu\text{F}$, $R_T = 12\ \text{k}\Omega$ (see Figure 2)

| PARAMETER | TEST CONDITIONS† | MIN | TYP‡ | MAX | UNIT |
|------------------------------------|---|-----|------|-----|------|
| Frequency | | | 10 | | kHz |
| Standard deviation of frequency¶ | All values of V_{CC} , C_T , R_T , and T_A constant | | 10% | | |
| Frequency change with voltage | $V_{CC} = 7\text{ V to }40\text{ V}$, $T_A = 25^\circ\text{C}$ | | 0.1% | | |
| Frequency change with temperature# | $\Delta T_A = \text{MIN to MAX}$ | | | 5% | |

amplifier section (see Figure 1)

| PARAMETER | TEST CONDITIONS | MIN | TYP‡ | MAX | UNIT |
|--|--|-----|-------------------------|-----|---------------|
| Input offset voltage, error amplifier | FEEDBACK at 2.5 V | | 2 | 10 | mV |
| Input offset current | FEEDBACK at 2.5 V | | 25 | 250 | nA |
| Input bias current | FEEDBACK at 2.5 V | | 0.2 | 1 | μA |
| Common-mode input voltage range, error amplifier | $V_{CC} = 7\text{ V to }40\text{ V}$ | | 0.3 to $V_{CC}-2$ | | V |
| Open-loop voltage amplification, error amplifier | $\Delta V_O = 3\text{ V}$, $R_L = 2\ \text{k}\Omega$, $V_O = 0.5\text{ V to }3.5\text{ V}$ | 70 | 95 | | dB |
| Unity-gain bandwidth | $V_O = 0.5\text{ V to }3.5\text{ V}$, $R_L = 2\ \text{k}\Omega$ | | 800 | | kHz |
| Common-mode rejection ratio, error amplifier | $V_{CC} = 40\text{ V}$, $T_A = 25^\circ\text{C}$ | 65 | 80 | | dB |
| Output sink current (pin 3) | $V_{ID} = -15\text{ mV to }-5\text{ V}$, FEEDBACK at 0.5 V | 0.3 | 0.7 | | mA |
| Output source current (pin 3) | $V_{ID} = 15\text{ mV to }5\text{ V}$, FEEDBACK at 3.5 V | -2 | | | mA |

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

‡ All typical values except for parameter changes with temperature are at $T_A = 25^\circ\text{C}$.

§ Duration of the short circuit should not exceed one second.

¶ Standard deviation is a measure of the statistical distribution about the mean as derived from the formula:

$$\sigma = \sqrt{\frac{\sum_{n=1}^N (x_n - \bar{X})^2}{N-1}}$$

Temperature coefficient of timing capacitor and timing resistor not taken into account.

TL594C, TL594I

PULSE-WIDTH-MODULATION CONTROL CIRCUITS

electrical characteristics over recommended operating free-air temperature range, $V_{CC} = 15\text{ V}$, (unless otherwise noted)

dead-time control section (see Figure 2)

| PARAMETER | TEST CONDITIONS | MIN | TYP [‡] | MAX | UNIT |
|---------------------------------|--------------------------------|-----|------------------|-----|---------------|
| Input bias current | $V_I = 0$ to 5.25 V | | -2 | -10 | μA |
| Maximum duty cycle, each output | DEAD-TIME CTRL at 0 V | 45% | | | |
| Input threshold voltage | Zero duty cycle | | 3 | 3.3 | V |
| | Maximum duty cycle | | 0 | | |

output section

| PARAMETER | TEST CONDITIONS | MIN | TYP [‡] | MAX | UNIT |
|--------------------------------------|--|-----|------------------|------|---------------|
| Collector off-state current | $V_C = 40\text{ V}$, $V_E = 0\text{ V}$, $V_{CC} = 40\text{ V}$ | | 2 | 100 | μA |
| | $V_C = 15\text{ V}$, $V_E = 0\text{ V}$, $V_{CC} = 1$ to 3 V , DEAD-TIME CTRL and OUTPUT CTRL at 0 V | | 4 | 200 | |
| Emitter off-state current | $V_{CC} = V_C = 40\text{ V}$, $V_E = 0$ | | | -100 | μA |
| Collector-emitter saturation voltage | Common emitter $V_E = 0$, $I_C = 200\text{ mA}$ | | 1.1 | 1.3 | V |
| | Emitter follower $V_C = 15\text{ V}$, $I_E = -200\text{ mA}$ | | 1.5 | 2.5 | |
| Output control input current | $V_I = \text{REF}$ | | | 3.5 | mA |

pwm comparator section (see Figure 2)

| PARAMETER | TEST CONDITIONS | MIN | TYP [‡] | MAX | UNIT |
|-----------------------------------|---------------------------|-----|------------------|-----|-------------|
| Input threshold voltage, FEEDBACK | Zero duty cycle | | 4 | 4.5 | V |
| Input sink current, FEEDBACK | FEEDBACK = 0.5 V | 0.3 | 0.7 | | mA |

undervoltage lockout section (see Figure 2)

| PARAMETER | TEST CONDITIONS [†] | MIN | MAX | UNIT |
|-------------------------|----------------------------------|-----|-----|-------------|
| Threshold voltage | $T_A = 25^\circ\text{C}$ | | 6 | V |
| | $\Delta T_A = \text{MIN to MAX}$ | 3.5 | 6.9 | |
| Hysteresis [§] | | 100 | | mV |

total device (see Figure 2)

| PARAMETER | TEST CONDITIONS | MIN | TYP [‡] | MAX | UNIT |
|------------------------|--|------------------------|------------------|-----|-------------|
| Standby supply current | R_T at REF, All other inputs and outputs open | | 9 | 15 | mA |
| | | $V_{CC} = 15\text{ V}$ | | | |
| | | | 11 | 18 | |
| Average supply current | DEAD-TIME CTRL at 2 V , See Figure 2 | | 12.4 | | mA |

switching characteristics, $T_A = 25^\circ\text{C}$

| PARAMETER | TEST CONDITIONS | MIN | TYP [‡] | MAX | UNIT |
|--------------------------|--|-----|------------------|-----|------|
| Output voltage rise time | Common-emitter configuration, See Figure 3 | | 100 | 200 | ns |
| Output voltage fall time | | | 30 | 100 | |
| Output voltage rise time | Emitter-follower configuration, See Figure 4 | | 200 | 400 | |
| Output voltage fall time | | | 45 | 100 | |

[†] For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

[‡] All typical values except for parameter changes with temperature are at $T_A = 25^\circ\text{C}$.

[§] Hysteresis is the difference between the positive-going input threshold voltage and the negative-going input threshold voltage.

PARAMETER MEASUREMENT INFORMATION

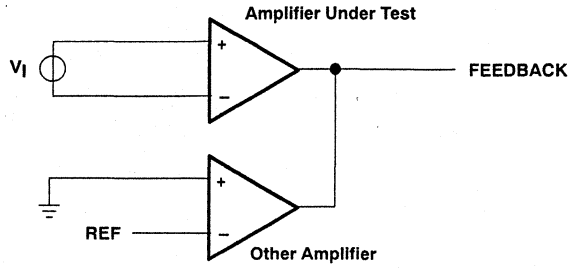


Figure 1. Amplifier Characteristics Test Circuit

PARAMETER MEASUREMENT INFORMATION

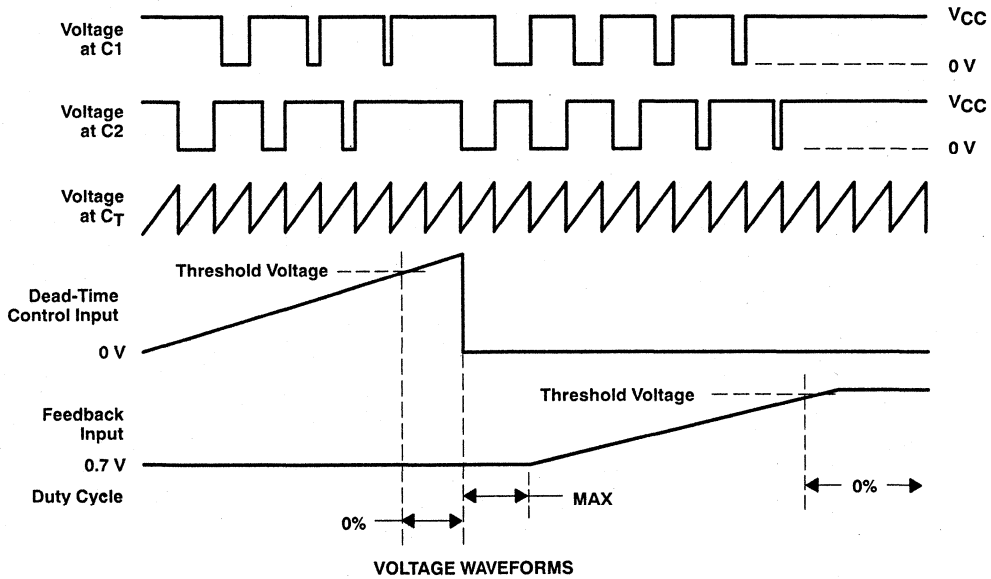
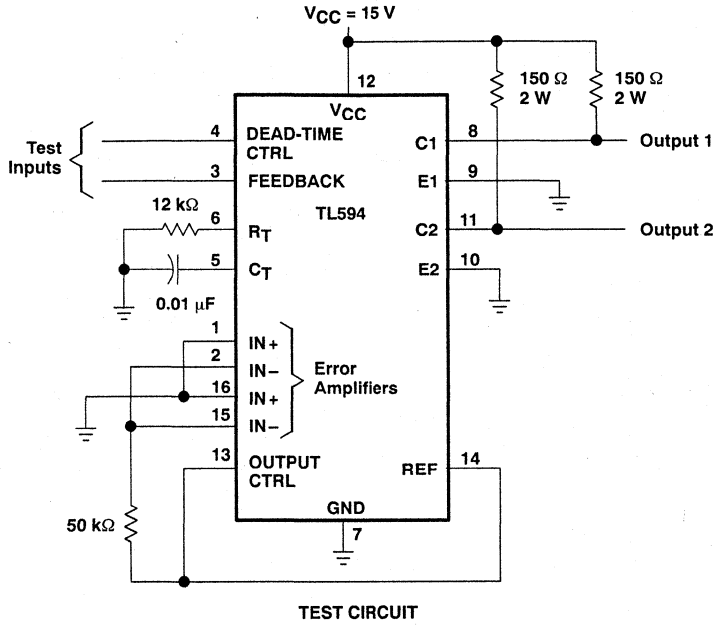


Figure 2. Operational Test Circuit and Waveforms

PARAMETER MEASUREMENT INFORMATION

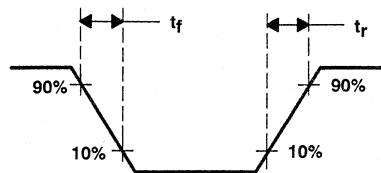
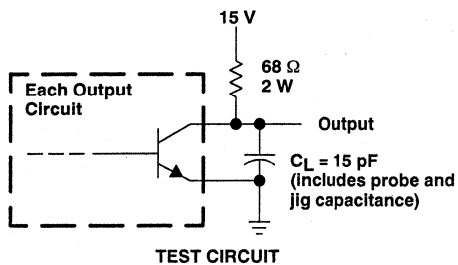


Figure 3. Common-Emitter Configuration

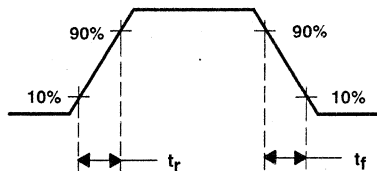
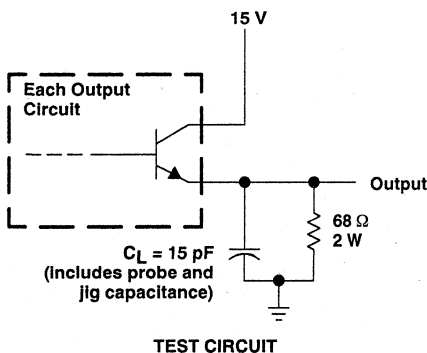


Figure 4. Emitter-Follower Configuration

TYPICAL CHARACTERISTICS

OSCILLATOR FREQUENCY AND
FREQUENCY VARIATION[†]

vs
TIMING RESISTANCE

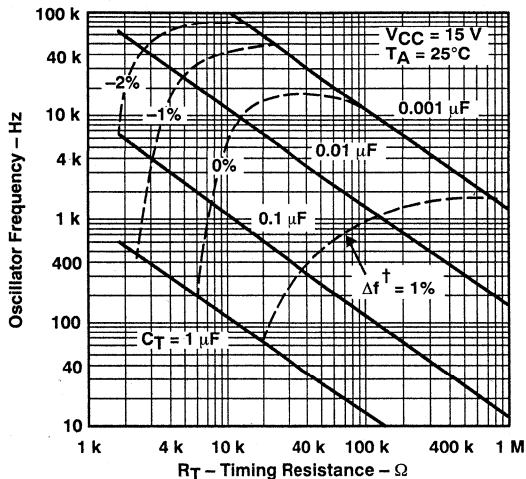


Figure 5

AMPLIFIER VOLTAGE AMPLIFICATION
vs
FREQUENCY

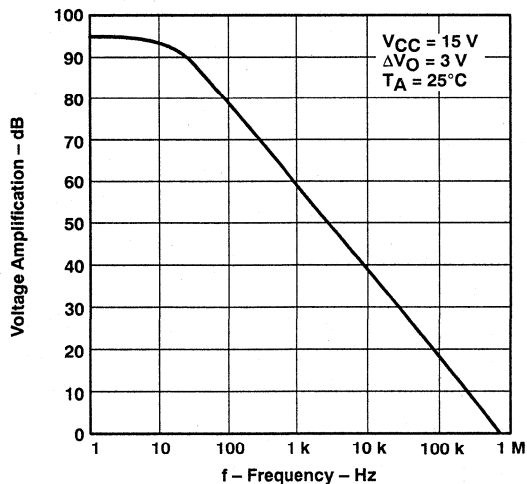


Figure 6

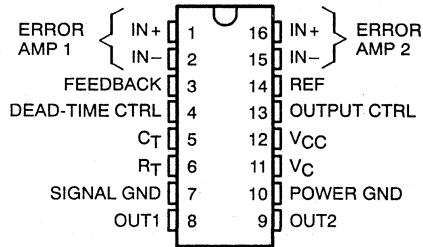
[†] Frequency variation (Δf) is the change in oscillator frequency that occurs over the full temperature range.

TL598 PULSE-WIDTH-MODULATION CONTROL CIRCUIT

D3026, FEBRUARY 1988—REVISED SEPTEMBER 1991

- Complete PWM Power Control Function
- Totem-Pole Outputs for 200-mA Sink or Source Current
- Output Control Selects Parallel or Push-Pull Operation
- Internal Circuitry Prohibits Double Pulse at Either Output
- Variable Dead-Time Provides Control Over Total Range
- Internal Regulator Provides a Stable 5-V Reference Supply, Trimmed to 1% Tolerance
- On-Board Output Current-Limiting Protection
- Undervoltage Lockout for Low V_{CC} Conditions
- Separate Power and Signal Grounds
- TL598Q Has Extended Temperature Range . . . -40°C to 125°C

D OR N PACKAGE
(TOP VIEW)



FUNCTION TABLE

| INPUT OUTPUT CTRL | OUTPUT FUNCTION |
|-------------------------|---------------------------------|
| $V_I = \text{GND}$ | Single-ended or parallel output |
| $V_I = \text{REF}$ | Normal push-pull operation |

description

The TL598 incorporates all the functions required in the construction of pulse-width-modulated controlled systems on a single monolithic chip. Designed primarily for power supply control, the TL598 provides the systems engineer with the flexibility to tailor the power supply control circuits to a specific application.

The TL598 contains two error amplifiers, an internal oscillator (externally adjustable), a dead-time control comparator, a pulse-steering flip-flop, a 5-V precision reference, an undervoltage lockout control, and output control circuits. Two totem-pole outputs provide exceptional rise and fall time performance for power FET control. The outputs share a common source supply and common power ground pins, which allow system designers to eliminate errors caused by high, current-induced voltage drops and common-mode noise.

The error amplifier has a common-mode voltage range from 0 V to $V_{CC} - 2\text{V}$. The dead-time control comparator has a fixed offset that prevents overlap of the outputs during push-pull operation. Synchronous multiple supply operation may be achieved by connecting pin 6 to the reference output and providing a sawtooth input to pin 5.

The TL598 device provides an output control function to select either push-pull or parallel operation. Circuit architecture prevents either output from being pulsed twice during push-pull operation. The output frequency

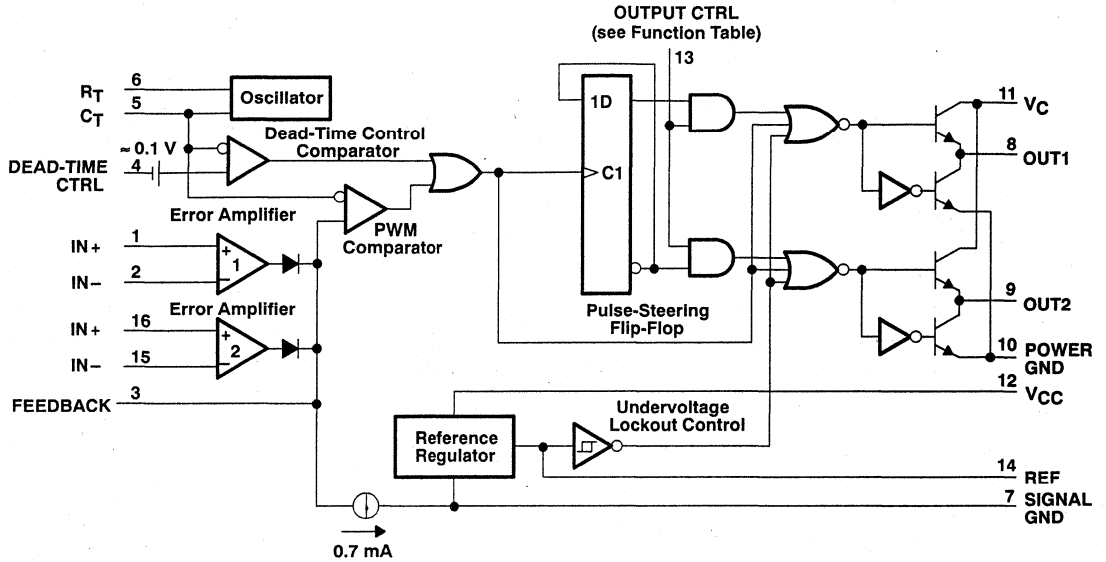
for push-pull applications is one-half the oscillator frequency ($f_o = \frac{1}{2 R_T C_T}$). For single-ended applications:

$$f_o = \frac{1}{R_T C_T}$$

The TL598C is characterized for operation from 0°C to 70°C . The TL598Q is characterized for operation from -40°C to 125°C .

TL598 PULSE-WIDTH-MODULATION CONTROL CIRCUIT

logic diagram (positive logic)



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Supply voltage, V_{CC} (see Note 1) | 41 V |
| Amplifier input voltage, V_I | $V_{CC} + 0.3$ V |
| Collector voltage | 41 V |
| Output current (each output), sink or source, I_O | 250 mA |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating virtual junction temperature range, T_J : TL598C | 0°C to 150°C |
| TL598Q | -40°C to 150°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 1: All voltage values, except differential voltages, are with respect to the signal ground terminal.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ | DERATING FACTOR | $T_A = 70^\circ\text{C}$ | $T_A = 125^\circ\text{C}$ |
|---------|-----------------------------|--------------------------------|--------------------------|---------------------------|
| | POWER RATING | ABOVE $T_A = 25^\circ\text{C}$ | POWER RATING | POWER RATING |
| D | 950 mW | 7.6 mW/°C | 6.8 mW | 190 mW |
| N | 1150 mW | 9.2 mW/°C | 736 mW | 230 mW |

recommended operating conditions

| | MIN | MAX | UNIT |
|---|---------|--------------|------|
| Supply voltage, V_{CC} | 7 | 40 | V |
| Amplifier input voltage, V_I | 0 | $V_{CC} - 2$ | V |
| Collector voltage | | 40 | V |
| Output current (each output), sink or source, I_O | | 200 | mA |
| Current into feedback terminal, I_{FL} | | 0.3 | mA |
| Timing capacitor, C_T | 0.00047 | 10 | μF |
| Timing resistor, R_T | 1.8 | 500 | kΩ |
| Oscillator frequency, f_{OSC} | 1 | 300 | kHz |
| Operating free-air temperature, T_A | TL598C | 0 | 70 |
| | TL598Q | -40 | 125 |

TL598 PULSE-WIDTH-MODULATION CONTROL CIRCUIT

electrical characteristics over recommended operating free-air temperature range, $V_{CC} = 15\text{ V}$ (unless otherwise noted) (see Note 2)

reference section

| PARAMETER | TEST CONDITIONS† | | TL598C | | | TL598Q | | | UNIT |
|--|--------------------------------------|---------------------------|--------|------|------|--------|------|------|------|
| | | | MIN | TYP‡ | MAX | MIN | TYP‡ | MAX | |
| Output voltage (REF) | $I_O = 1\text{ mA}$ | $T_A = 25^\circ\text{C}$ | 4.95 | 5 | 5.05 | 4.95 | 5 | 5.05 | V |
| | | $T_A = \text{MIN to MAX}$ | 4.9 | | 5.1 | 4.9 | | 5.1 | |
| Input regulation | $V_{CC} = 7\text{ V to }40\text{ V}$ | $T_A = 25^\circ\text{C}$ | | | 2 | 25 | | | mV |
| Output regulation | $I_O = 1\text{ to }10\text{ mA}$ | $T_A = 25^\circ\text{C}$ | | | 1 | 15 | | | mV |
| | | $T_A = \text{MIN to MAX}$ | | | 50 | | 80 | | |
| Output voltage change with temperature | $\Delta T_A = \text{MIN to MAX}$ | | | | 0.2% | 1% | | | |
| Short-circuit output current§ | REF = 0 | | -10 | -48 | | | -10 | -48 | mA |

oscillator section, $C_T = 0.001\ \mu\text{F}$, $R_T = 12\ \text{k}\Omega$ (see Figure 1)

| PARAMETER | TEST CONDITIONS† | MIN | TYP‡ | MAX | UNIT |
|------------------------------------|---|------|------|-----|------|
| Frequency | | 100 | | | kHz |
| Standard deviation of frequency¶ | All values of V_{CC} , C_T , R_T , T_A constant | 10% | | | |
| Frequency change with voltage | $V_{CC} = 7\text{ V to }40\text{ V}$, $T_A = 25^\circ\text{C}$ | 0.1% | 1% | | |
| Frequency change with temperature# | $\Delta T_A = \text{MIN to MAX}$ | 7% | 12% | | |
| | $\Delta T_A = \text{MIN to MAX}$, $C_T = 0.01\ \mu\text{F}$ | 5% | 8% | | |

error amplifier section

| PARAMETER | TEST CONDITIONS | MIN | TYP‡ | MAX | UNIT | |
|---------------------------------|--|-----------------------|------|-----|------|---------------|
| Input offset voltage | Feedback pin at 2.5 V | 2 | | | 10 | mV |
| Input offset current | Feedback pin at 2.5 V | 25 | | | 250 | nA |
| Input bias current | Feedback pin at 2.5 V | 0.2 | | | 1 | μA |
| Common-mode input voltage range | $V_{CC} = 7\text{ V to }40\text{ V}$ | 0 to $V_{CC}-2$ | | | | V |
| Open-loop voltage amplification | ΔV_O (pin 3) = 3 V, V_O (pin 3) = 0.5 V to 3.5 V | 70 | 95 | | | dB |
| Unity-gain bandwidth | | 800 | | | | kHz |
| Common-mode rejection ratio | $V_{CC} = 40\text{ V}$, $\Delta V_{IC} = 6.5\text{ V}$, $T_A = 25^\circ\text{C}$ | 65 | 80 | | | dB |
| Output sink current (pin 3) | Feedback pin at 0.5 V | 0.3 | 0.7 | | | mA |
| Output source current (pin 3) | Feedback pin at 3.5 V | -2 | | | | mA |
| Phase margin at unity gain | Feedback pin at 0.5 V to 3.5 V, $R_L = 2\ \text{k}\Omega$ | 65° | | | | |
| Supply voltage rejection ratio | Feedback pin at 2.5 V, $\Delta V_{CC} = 33\text{ V}$, $R_L = 2\ \text{k}\Omega$ | 100 | | | | dB |

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

‡ All typical values except for parameter changes with temperature are at $T_A = 25^\circ\text{C}$.

§ Duration of the short circuit should not exceed one second.

¶ Standard deviation is a measure of the statistical distribution about the mean as derived from the formula: $\sigma = \sqrt{\frac{\sum_{n=1}^N (x_n - X)^2}{N-1}}$

Effects of temperature on external R_T and C_T are not taken into account.

NOTE 2: Pulse-testing techniques that will maintain the junction temperature as close to the ambient temperature as possible must be used.



TL598 PULSE-WIDTH-MODULATION CONTROL CIRCUIT

electrical characteristics over recommended operating free-air temperature range, $V_{CC} = 15\text{ V}$ (unless otherwise noted) (see Note 2)

undervoltage lockout section

| PARAMETER | TEST CONDITIONS† | TL598C | | TL598Q | | UNIT |
|-------------------|----------------------------------|--------|-----|--------|-----|------|
| | | MIN | MAX | MIN | MAX | |
| Threshold voltage | $T_A = 25^\circ\text{C}$ | 4 | 6 | 4 | 6 | V |
| | $\Delta T_A = \text{MIN to MAX}$ | 3.5 | 6.9 | 3 | 6.9 | |
| Hysteresis‡ | $T_A = 25^\circ\text{C}$ | 100 | | 100 | | mV |
| | $T_A = \text{MIN to MAX}$ | 50 | | 30 | | |

output section

| PARAMETER | TEST CONDITIONS | | MIN | TYP§ | MAX | UNIT |
|------------------------------|---|-----------------------------------|-----|------|---------------|---------------|
| Collector off-state current | $V_{CE} = 40\text{ V}$, $V_{CC} = 40\text{ V}$ | Dead-time pin is connected to 0 V | | 2 | 100 | μA |
| High-level output voltage | $V_{CC} = 15\text{ V}$, $V_C = 15\text{ V}$ | $I_O = -200\text{ mA}$ | 12 | | V | |
| | | $I_O = -20\text{ mA}$ | 13 | | | |
| Low-level output voltage | $V_{CC} = 15\text{ V}$, $V_C = 15\text{ V}$ | $I_O = 200\text{ mA}$ | 2 | | V | |
| | | $I_O = 20\text{ mA}$ | 0.4 | | | |
| Output control input current | $V_I = \text{REF}$ | | 3.5 | | mA | |
| | $V_I = 0.4\text{ V}$ | | 100 | | μA | |

dead-time control section (see Figure 1)

| PARAMETER | TEST CONDITIONS | TL598C | | | TL598Q | | | UNIT |
|---------------------------------|-----------------------------------|--------|------|-----|--------|------|-----|---------------|
| | | MIN | TYP§ | MAX | MIN | TYP§ | MAX | |
| Input bias current (pin 4) | $V_I = 0\text{ to }5.25\text{ V}$ | | -2 | -10 | | -2 | -25 | μA |
| Maximum duty cycle, each output | Dead-time control at 0 V | 45% | | | 45% | | | |
| Input threshold voltage (pin 4) | Zero duty cycle | | 3 | 3.3 | | 3 | 3.2 | V |
| | Maximum duty cycle | 0 | | | 0 | | | |

pwm comparator section

| PARAMETER | TEST CONDITIONS | MIN | TYP§ | MAX | UNIT |
|---------------------------------|--------------------------------------|-----|------|-----|------|
| Input threshold voltage (pin 3) | Dead-time control = 0 V | | 3.75 | 4.5 | V |
| Input sink current (pin 3) | $V_{(\text{pin } 3)} = 0.5\text{ V}$ | 0.3 | 0.7 | | mA |

total device (see Figure 1)

| PARAMETER | TEST CONDITIONS | | MIN | TYP§ | MAX | UNIT |
|------------------------|--|------------------------|-----|------|-----|------|
| Standby supply current | Pin 6 at REF, All other inputs and outputs open | $V_{CC} = 15\text{ V}$ | | 15 | 21 | mA |
| | | $V_{CC} = 40\text{ V}$ | | 20 | 26 | |
| Average supply current | Dead-time control at 2 V | | | 15 | | mA |

switching characteristics, $T_A = 25^\circ\text{C}$

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--------------------------|--|-----|-----|-----|------|
| Output voltage rise time | $C_L = 1500\text{ pF}$, $V_C = 15\text{ V}$, $V_{CC} = 15\text{ V}$, See Figure 2 | | 60 | 150 | ns |
| Output voltage fall time | | | 35 | 75 | |

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

‡ Hysteresis is the difference between the positive-going input threshold voltage and the negative-going input threshold voltage.

§ All typical values except for parameter changes with temperature are at $T_A = 25^\circ\text{C}$.

NOTE 2: Pulse-testing techniques must be used that will maintain the junction temperature as close to the ambient temperature as possible.

PARAMETER MEASUREMENT INFORMATION

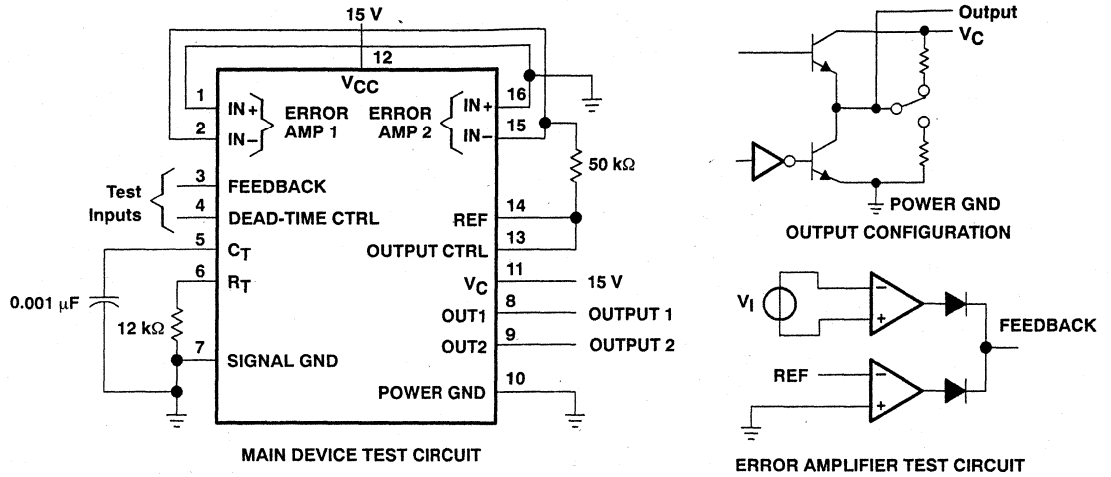


Figure 1. Test Circuits

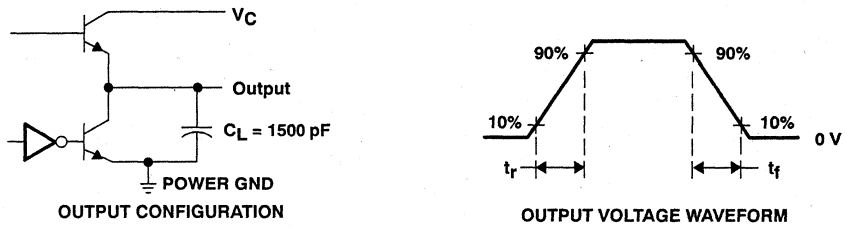
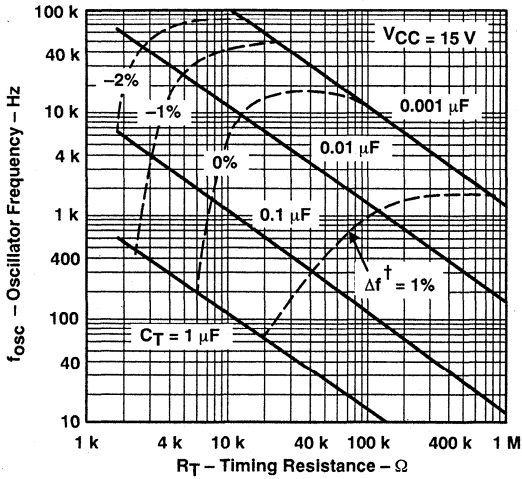


Figure 2. Switching Output Configuration and Voltage Waveform

TYPICAL CHARACTERISTICS

OSCILLATOR FREQUENCY AND
FREQUENCY VARIATION[†]
vs
TIMING RESISTANCE



[†] Frequency variation (Δf) is the change in oscillator frequency that occurs over the full temperature range.

Figure 3

AMPLIFIER VOLTAGE AMPLIFICATION
vs
FREQUENCY

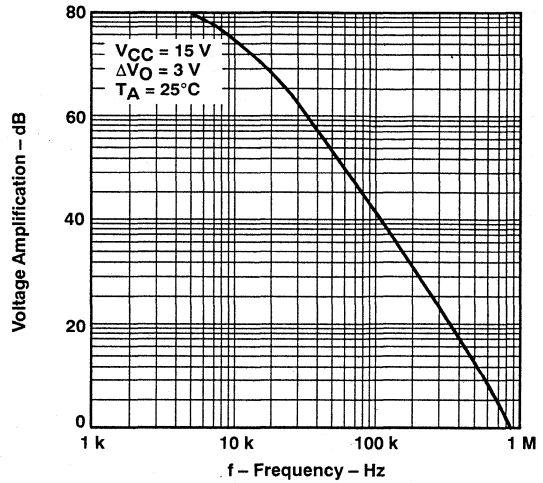


Figure 4

TL598M

PULSE-WIDTH-MODULATION CONTROL CIRCUIT

D3726, APRIL 1991—REVISED SEPTEMBER 1991

- Complete PWM Power Control Function
- Totem-Pole Outputs for 200-mA Sink or Source Current
- Output Control Selects Parallel or Push-Pull Operation
- Internal Circuitry Prohibits Double Pulse at Either Output
- Variable Dead Time Provides Control Over Total Range
- Internal Regulator Provides a Stable 5-V Reference Supply, Trimmed to 1% Tolerance
- On-Board Output Current-Limiting Protection
- Undervoltage Lockout for Low V_{CC} Conditions
- Separate Power and Signal Grounds

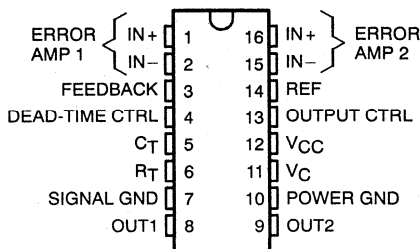
description

The TL598M incorporates all the functions required in the construction of pulse-width-modulated controlled systems on a single monolithic chip. Designed primarily for power supply control, the TL598M provides the systems engineer with the flexibility to tailor the power supply control circuits to a specific application.

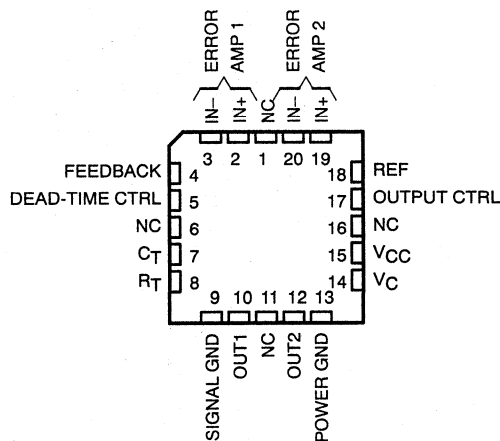
The TL598M contains two error amplifiers, an internal oscillator (externally adjustable), a dead-time control comparator, a pulse-steering flip-flop, a 5-V precision reference, an undervoltage lockout control, and output control circuits. Two totem-pole outputs provide exceptional rise and fall time performance for power FET control. The outputs share common source supply and power ground pins, which allow system designers to eliminate errors caused by high current-induced voltage drops and common-mode noise.

The error amplifier has a common-mode voltage range from 0.3 V to $V_{CC} - 2$ V. The dead-time control comparator has a fixed offset that prevents overlap of the outputs during push-pull operation. Synchronous multiple supply operation may be achieved by connecting pin 6 to the reference output and providing a sawtooth input to pin 5.

**J PACKAGE
(TOP VIEW)**



**FK PACKAGE
(TOP VIEW)**



NC—No internal connection

FUNCTION TABLE

| INPUT | OUTPUT FUNCTION |
|--------------------|---------------------------------|
| OUTPUT CTRL | |
| $V_I = \text{GND}$ | Single-ended or parallel output |
| $V_I = \text{REF}$ | Normal push-pull operation |

TL598M PULSE-WIDTH-MODULATION CONTROL CIRCUIT

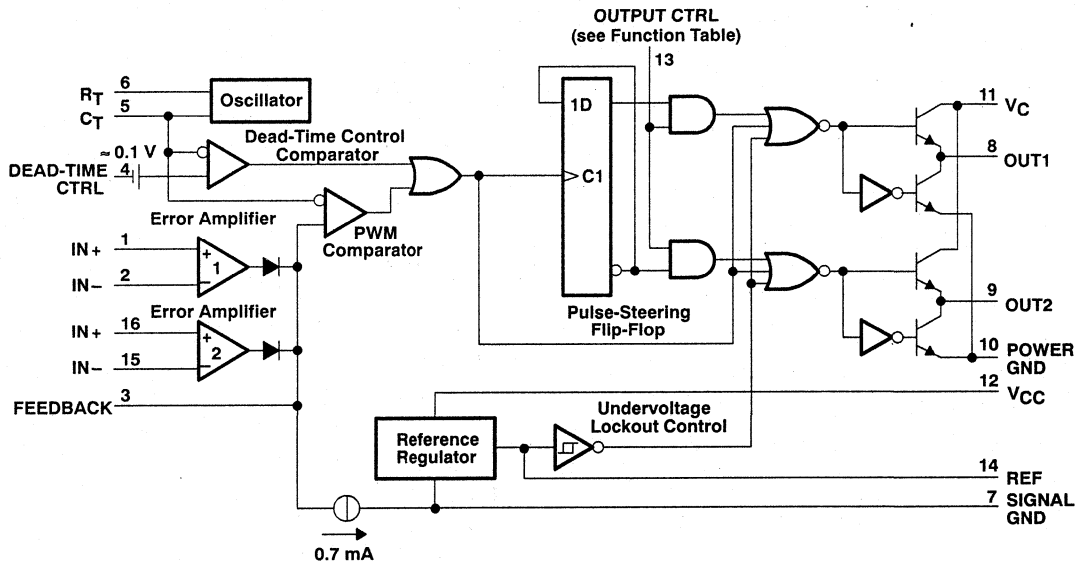
description (continued)

The TL598M device provides an output control function to select either push-pull or parallel operation. Circuit architecture prevents either output from being pulsed twice during push-pull operation. The output frequency for push-pull applications is one-half the oscillator frequency ($f_o = \frac{1}{2 R_T C_T}$). For single-ended applications:

$$f_o = \frac{1}{R_T C_T}$$

The TL598M is characterized for operation from -55°C to 125°C .

logic diagram (positive logic)



Pin numbers shown are for the J package.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|------------------|
| Supply voltage, V_{CC} (see Note 1) | 41 V |
| Amplifier input voltage, V_I | $V_{CC} + 0.3$ V |
| Collector voltage | 41 V |
| Output current (each output), sink or source, I_O | 250 mA |
| Continuous total dissipation (see Note 2) | 1375 mW |
| Operating virtual junction temperature range, T_J | -55°C to 150°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package | 300°C |
| Case temperature for 60 seconds: FK package | 260°C |

- NOTES: 1. All voltage values, except differential voltages, are with respect to the signal ground terminal.
 2. For operation above 25°C free-air temperature, derate linearly to 275 mW at the rate of 11 mW/°C.

recommended operating conditions

| | MIN | MAX | UNIT |
|---|---------|--------------|------|
| Supply voltage, V_{CC} | 7 | 40 | V |
| Amplifier input voltage, V_I | 0.3 | $V_{CC} - 2$ | V |
| Collector voltage | | 40 | V |
| Output current (each output), sink or source, I_O | | 200 | mA |
| Current into FEEDBACK terminal, I_{FL} | | 0.3 | mA |
| Timing capacitor, C_T | 0.00047 | 10 | μF |
| Timing resistor, R_T | 1.8 | 500 | kΩ |
| Oscillator frequency, f_{osc} | 1 | 300 | kHz |
| Operating free-air temperature, T_A | -55 | 125 | °C |

TL598M

PULSE-WIDTH-MODULATION CONTROL CIRCUIT

electrical characteristics over recommended operating free-air temperature range, $V_{CC} = 15\text{ V}$, (unless otherwise noted) (see Note 3)

reference section

| PARAMETER | TEST CONDITIONS† | | MIN | TYP‡ | MAX | UNIT |
|--|--------------------------------------|---------------------------|------|------|------|------|
| Output voltage (REF) | $I_O = 1\text{ mA}$ | $T_A = 25^\circ\text{C}$ | 4.95 | 5 | 5.05 | V |
| | | $T_A = \text{MIN to MAX}$ | 4.9 | | 5.1 | |
| Input regulation | $V_{CC} = 7\text{ V to }40\text{ V}$ | $T_A = 25^\circ\text{C}$ | | 2 | 22 | mV |
| Output regulation | $I_O = 1\text{ to }10\text{ mA}$ | $T_A = 25^\circ\text{C}$ | | 1 | 15 | mV |
| | | $T_A = \text{MIN to MAX}$ | | | 80 | |
| Output voltage change with temperature | $\Delta T_A = \text{MIN to MAX}$ | | | 0.5% | | |
| Short-circuit output current§ | REF = 0 V | | -10 | -48 | | mA |

oscillator section, $C_T = 0.001\ \mu\text{F}$, $R_T = 12\ \text{k}\Omega$ (see Figure 1)

| PARAMETER | TEST CONDITIONS† | MIN | TYP‡ | MAX | UNIT |
|------------------------------------|---|-----|------|------|------|
| Frequency | | | 100 | | kHz |
| Standard deviation of frequency¶ | T_A constant at any value within recommended operating conditions | | 10% | | |
| Frequency change with voltage | $V_{CC} = 7\text{ V to }40\text{ V}$, $f_{\text{OSC}} = 28.06\text{ kHz}$, $T_A = 25^\circ\text{C}$ | | 0.1% | 1% | |
| Frequency change with temperature# | $\Delta T_A = \text{MIN to MAX}$ | | 7% | 15%* | |

error amplifier section

| PARAMETER | TEST CONDITIONS | MIN | TYP‡ | MAX | UNIT |
|---------------------------------|---|-----|-------------------------|-----|---------------|
| Input offset voltage | FEEDBACK at 2.5 V | | 2 | 10 | mV |
| Input offset current | FEEDBACK at 2.5 V | | 25 | 250 | nA |
| Input bias current | FEEDBACK at 2.5 V | | 0.2 | 1 | μA |
| Common-mode input voltage range | $V_{CC} = 7\text{ V to }40\text{ V}$, $T_A = 25^\circ\text{C}$ | | 0.3 to $V_{CC}-2$ | | V |
| Open-loop voltage amplification | ΔV_O FEEDBACK = 3 V, V_O FEEDBACK = 0.5 V to 3.5 V | 70 | 95 | | dB |
| Unity-gain bandwidth | | | 800 | | kHz |
| Common-mode rejection ratio | $V_{CC} = 40\text{ V}$, $\Delta V_{IC} = 37.7\text{ V}$, $T_A = 25^\circ\text{C}$ | 65 | 80 | | dB |
| Output sink current (pin 3) | FEEDBACK at 0.5 V | 0.3 | 0.7 | | mA |
| Output source current (pin 3) | FEEDBACK at 3.5 V | -2 | | | mA |
| Phase margin at unity gain | FEEDBACK at 0.5 V to 3.5 V, $R_L = 2\ \text{k}\Omega$ | | 65° | | |
| Supply voltage rejection ratio | FEEDBACK at 2.5 V, $\Delta V_{CC} = 33\text{ V}$, $R_L = 2\ \text{k}\Omega$ | | 100 | | dB |

* This parameter is not production tested.

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

‡ All typical values except for parameter changes with temperature are at $T_A = 25^\circ\text{C}$.

§ Duration of the short-circuit should not exceed one second.

¶ Standard deviation is a measure of the statistical distribution about the mean as derived from the formula:

$$\sigma = \sqrt{\frac{\sum_{n=1}^N (x_n - \bar{X})^2}{N-1}}$$

Effects of temperature on external R_T and C_T are not taken into account.

NOTE 3: Pulse-testing techniques that will maintain the junction temperature as close to the ambient temperature as possible must be used.

TL598M PULSE-WIDTH-MODULATION CONTROL CIRCUIT

electrical characteristics over recommended operating free-air temperature range, $V_{CC} = 15\text{ V}$, (unless otherwise noted) (see Note 3)

undervoltage lockout section

| PARAMETER | TEST CONDITIONS† | MIN | MAX | UNIT |
|-------------------|----------------------------------|-----|-----|------|
| Threshold voltage | $T_A = 25^\circ\text{C}$ | 4 | 6 | V |
| | $\Delta T_A = \text{MIN to MAX}$ | 3 | 6.9 | |
| Hysteresis‡ | $T_A = 25^\circ\text{C}$ | 100 | | mV |
| | $T_A = \text{MIN to MAX}$ | 30 | | |

output section

| PARAMETER | TEST CONDITIONS | MIN | TYP§ | MAX | UNIT |
|------------------------------|--|-----|------|-----|---------------|
| Collector off-state current | $V_C = 40\text{ V}$, $V_{CC} = 40\text{ V}$, DEAD-TIME CTRL at 0 V | | 2 | 100 | μA |
| High-level output voltage | $V_{CC} = 15\text{ V}$, $I_O = -200\text{ mA}$ | 12 | | | V |
| | $V_C = 15\text{ V}$, $I_O = -20\text{ mA}$ | 13 | | | |
| Low-level output voltage | $V_{CC} = 15\text{ V}$, $I_O = 200\text{ mA}$ | | | 2 | V |
| | $V_C = 15\text{ V}$, $I_O = 20\text{ mA}$ | | | 0.4 | |
| Output control input current | $V_I = \text{REF}$ | | | 3.5 | mA |
| | $V_I = 0.4\text{ V}$ | | | 100 | |

dead-time control section (see Figure 1)

| PARAMETER | TEST CONDITIONS | MIN | TYP§ | MAX | UNIT |
|---------------------------------|---|------|------|-----|---------------|
| Input bias current | $V_I = 0\text{ to }5.25\text{ V}$ | | -2 | -25 | μA |
| Maximum duty cycle, each output | DEAD-TIME CTRL at 0 V, $T_A = 25^\circ\text{C}$ | 45%* | | | |
| Input threshold voltage | Zero duty cycle | | 3 | 3.2 | V |
| | Maximum duty cycle | 0* | | | |

pwm comparator section

| PARAMETER | TEST CONDITIONS | MIN | TYP§ | MAX | UNIT |
|-----------------------------------|----------------------|-----|------|-----|------|
| Input threshold voltage, FEEDBACK | DEAD-TIME CTRL = 0 V | | 3.75 | 4.5 | V |
| Input sink current, FEEDBACK | FEEDBACK = 0.5 V | 0.3 | 0.7 | | mA |

total device (see Figure 1)

| PARAMETER | TEST CONDITIONS | MIN | TYP§ | MAX | UNIT |
|------------------------|-----------------------------------|------------------------|------|-----|------|
| Standby supply current | R_T at REF, | | 15 | 21 | mA |
| | All other inputs and outputs open | $V_{CC} = 15\text{ V}$ | | | |
| Average supply current | DEAD-TIME CTRL at 2 V | | 20 | 26 | mA |

switching characteristics, $T_A = 25^\circ\text{C}$

| PARAMETER | TEST CONDITIONS | MIN | TYP§ | MAX | UNIT |
|--------------------------|--|-----|------|------|------|
| Output voltage rise time | $V_{CC} = 15\text{ V}$, $V_C = 15\text{ V}$, $C_L = 1500\text{ pF}$, See Figure 2 | | 60 | 150* | ns |
| Output voltage fall time | | | 35 | 75* | |

* This parameter is not production tested.

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

‡ Hysteresis is the difference between the positive-going input threshold voltage and the negative-going input threshold voltage.

§ All typical values except for parameter changes with temperature are at $T_A = 25^\circ\text{C}$.

NOTE 3. Pulse-testing techniques must be used that will maintain the junction temperature as close to the ambient temperature as possible.

PARAMETER MEASUREMENT INFORMATION

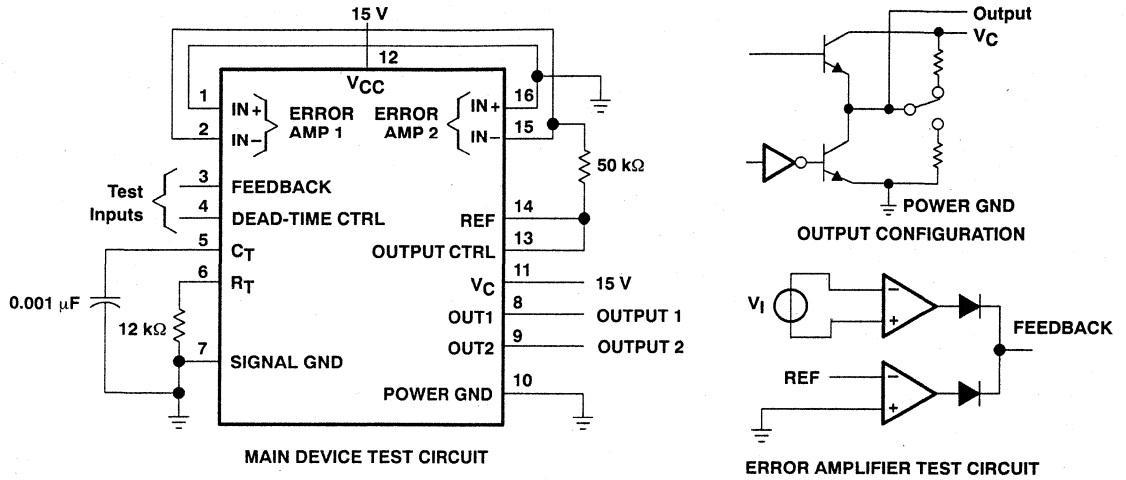


Figure 1. Test Circuits

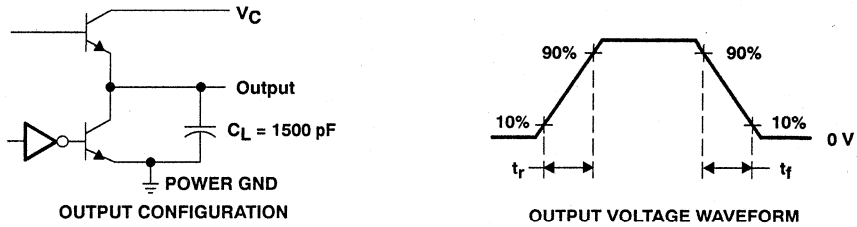
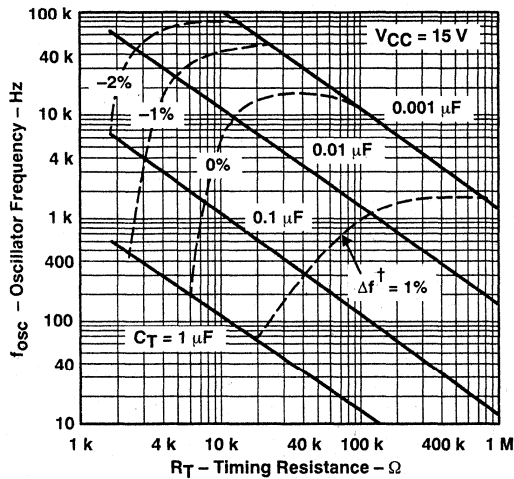


Figure 2. Switching Output Configuration and Voltage Waveform

TYPICAL CHARACTERISTICS

OSCILLATOR FREQUENCY AND
FREQUENCY VARIATION[†]
vs
TIMING RESISTANCE



[†] Frequency variation (Δf) is the change in oscillator frequency that occurs over the full temperature range.

Figure 3

AMPLIFIER VOLTAGE AMPLIFICATION
vs
FREQUENCY

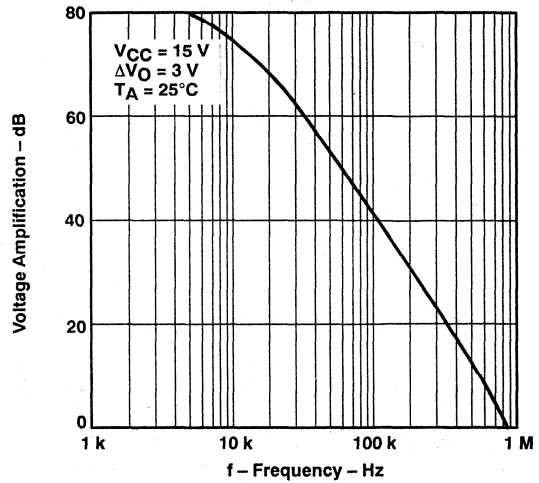


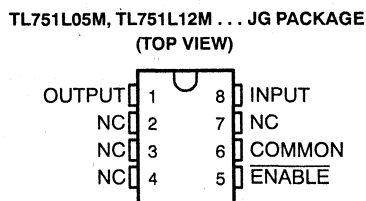
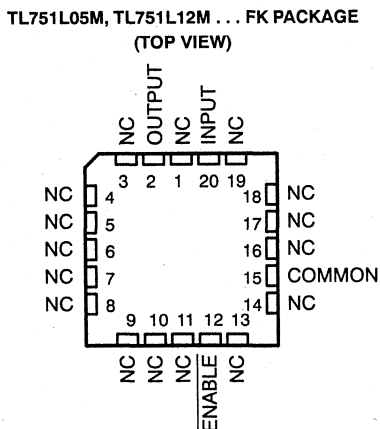
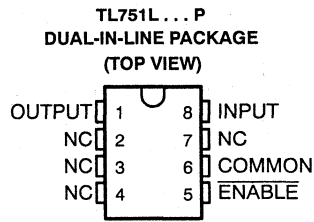
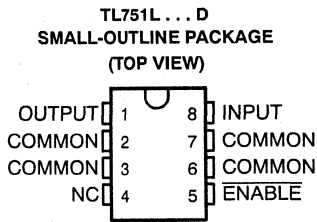
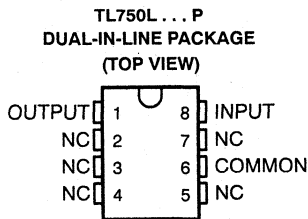
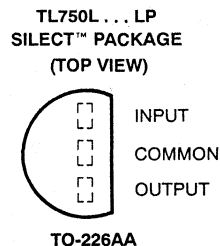
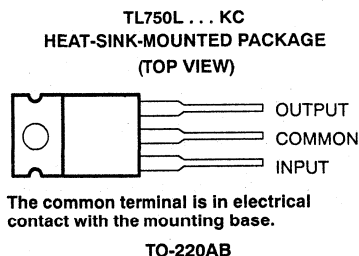
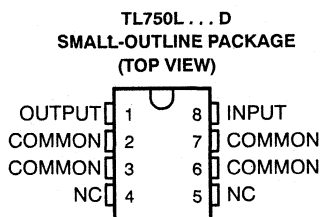
Figure 4

TL750L, TL751L SERIES, TL751L05M, TL751L12M LOW-DROPOUT VOLTAGE REGULATORS

D3017, SEPTEMBER 1987—REVISED FEBRUARY 1991

- Very Low Dropout Voltage, Less Than 0.6 V at 150 mA
- Very Low Quiescent Current
- TTL- and CMOS-Compatible Enable on TL751L Series, TL751L05M, and TL751L12M
- 60-V Load-Dump Protection
- Reverse Transient Protection to -50 V
- Internal Thermal Overload Protection
- Overvoltage Protection
- Internal Overcurrent Limiting Circuitry
- Less Than $500\text{-}\mu\text{A}$ Disable (TL751L Series, TL751L05M, and TL751L12M)

terminal assignments



NC—No internal connection

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PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.



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On products compliant to MIL-STD-883, Class B, all parameters are tested unless otherwise noted. On all other products, production processing does not necessarily include testing of all parameters.

TL750L, TL751L SERIES, TL751L05M, TL751L12M LOW-DROPOUT VOLTAGE REGULATORS

description

The TL750L and TL751L series and the TL751L05M and TL751L12M are low-dropout positive voltage regulators specifically designed for battery-powered systems. These devices incorporate overvoltage and current-limiting protection circuitry along with internal reverse-battery protection circuitry to protect both itself and the regulated system. Both series and the TL751L05M and TL751L12M are fully protected against 60-V load-dump and reverse-battery conditions. Extremely low quiescent current during full-load conditions makes these devices ideal for standby power systems.

The TL750L series of fixed-output voltage regulators offer 5-V, 8-V, 10-V, and 12-V options. They are available in TO-226AA (formerly TO-92) (LP) packages, TO-220AB (KC) packages, 8-pin small-outline plastic packages (D), and 8-pin plastic dual-in-line packages (P).

The TL751L series of fixed-output voltage regulators offer 5-V, 8-V, 10-V, and 12-V options with the addition of an enable input. The enable input, when taken high, places the regulator output in a high-impedance state. This gives the designer complete control over power up, power down, or emergency shut down. This series is offered in the 8-pin small-outline plastic package and the 8-pin plastic dual-in-line package.

The TL751L05M and TL751L12M fixed-output voltage regulators also offer 5-V and 12-V options with an enable input. The enable input, when taken high, places the regulator output in a high-impedance state. This gives the designer complete control over power up, power down, or emergency shut down. This TL751L_M is offered in the FK and JG package.

absolute maximum ratings over operating junction temperature range (unless otherwise noted)

| | TL750L | TL751L TL751L_M | UNIT | |
|--|------------|--------------------|------------------|------|
| Continuous input voltage | 26 | 26 | V | |
| Transient input voltage, $T_A = 25^\circ\text{C}$ (see Note 1) | 60 | 60 | V | |
| Continuous reverse input voltage | -15 | -15 | V | |
| Transient reverse input voltage: $t \leq 100$ ms | -50 | -50 | V | |
| Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2): | D package | 825 | mW | |
| | FK package | | | 1375 |
| | JG package | | | 1050 |
| | KC package | 2000 | | |
| | LP package | 775 | | |
| | P package | 1000 | | 1000 |
| Operating virtual junction temperature range | -40 to 150 | -40 to 150 | $^\circ\text{C}$ | |
| Storage temperature range | -65 to 150 | -65 to 150 | $^\circ\text{C}$ | |
| Lead temperature 1,6 mm (1/16 inch) for 10 seconds | 260 | 260 | $^\circ\text{C}$ | |

NOTES: 1. The transient input voltage rating applies for the waveform described in Figure 1.

2. For operation above 25°C free-air temperature, linearly derate the D package at the rate of $6.6\text{ mW}/^\circ\text{C}$, the FK package at $11\text{ mW}/^\circ\text{C}$, the JG package at $8.4\text{ mW}/^\circ\text{C}$, the KC package at $15.2\text{ mW}/^\circ\text{C}$, the LP package at $6.2\text{ mW}/^\circ\text{C}$, and the P package at $8\text{ mW}/^\circ\text{C}$.



TL750L, TL751L SERIES, TL751L05M, TL751L12M LOW-DROPOUT VOLTAGE REGULATORS

recommended operating conditions over recommended operating junction temperature range (unless otherwise noted)

| | | MIN | MAX | UNITS |
|---|--|-------|-----|------------------|
| Input voltage, V_I | TL75_L05 and TL751L05M | 6 | 26 | V |
| | TL75_L08 | 9 | 26 | |
| | TL75_L10 | 11 | 26 | |
| | TL75_L12 and TL751L12M | 13 | 26 | |
| High-level $\overline{\text{ENABLE}}$ input voltage, V_{IH} | | 2 | 15 | V |
| Low-level $\overline{\text{ENABLE}}$ input voltage | V_{IL}^\dagger , $T_A = 25^\circ\text{C}$ | -0.3 | 0.8 | V |
| | V_{IL}^\dagger , $T_A = \text{Full range}$ | -0.15 | 0.8 | V |
| Output current range, I_O | | 0 | 150 | mA |
| Operating virtual junction temperature, T_J | TL75_L_C | 0 | 125 | $^\circ\text{C}$ |
| | TL75_L_Q | -40 | 125 | |
| | TL751L_M | -55 | 125 | |

† The algebraic convention, in which the least positive (most negative) value is designated minimum, is used in this data sheet for $\overline{\text{ENABLE}}$ voltage levels and temperature only.

TL750L05, TL751L05, and TL751L05M electrical characteristics at 25°C virtual junction temperature, $V_I = 14\text{ V}$, $I_O = 10\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS ‡ | | MIN | TYP | MAX | UNIT |
|----------------------|---|---|------|-----|------|---------------|
| Output voltage | $V_I = 6\text{ V to } 26\text{ V}$, $I_O = 0\text{ to } 150\text{ mA}$ | $T_J = 25^\circ\text{C}$ | 4.80 | 5 | 5.2 | V |
| | | $T_J = T_{J\text{min to } 125^\circ\text{C}}$ | 4.75 | | 5.25 | |
| Input regulation | $V_I = 9\text{ V to } 16\text{ V}$ | | | 5 | 10 | mV |
| | $V_I = 6\text{ V to } 26\text{ V}$ | | | 6 | 30 | |
| Ripple rejection | $V_I = 8\text{ V to } 18\text{ V}$, $f = 120\text{ Hz}$ | | 60* | 65 | | dB |
| Output regulation | $I_O = 5\text{ mA to } 150\text{ mA}$ | | | 20 | 50 | mV |
| Dropout voltage | $I_O = 10\text{ mA}$ | | | | 0.2 | V |
| | $I_O = 150\text{ mA}$ | | | | 0.6 | |
| Output noise voltage | $f = 10\text{ Hz to } 100\text{ kHz}$ | | | 500 | | μV |
| Bias current | $I_O = 150\text{ mA}$ | | | 10 | 12 | mA |
| | $V_I = 6\text{ V to } 26\text{ V}$, $I_O = 10\text{ mA}$, $T_J = T_{J\text{min to } 125^\circ\text{C}}$ | | | 1 | 2 | |

TL750L08 and TL751L08 electrical characteristics at 25°C virtual junction temperature, $V_I = 14\text{ V}$, $I_O = 10\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS ‡ | | MIN | TYP | MAX | UNIT |
|----------------------|---|---|------|-----|------|---------------|
| Output voltage | $V_I = 9\text{ V to } 26\text{ V}$, $I_O = 0\text{ to } 150\text{ mA}$ | $T_J = 25^\circ\text{C}$ | 7.68 | 8 | 8.32 | V |
| | | $T_J = T_{J\text{min to } 125^\circ\text{C}}$ | 7.6 | | 8.4 | |
| Input regulation | $V_I = 10\text{ V to } 17\text{ V}$ | | | 10 | 20 | mV |
| | $V_I = 9\text{ V to } 26\text{ V}$ | | | 25 | 50 | |
| Ripple rejection | $V_I = 11\text{ V to } 21\text{ V}$, $f = 120\text{ Hz}$ | | 60* | 65 | | dB |
| Output regulation | $I_O = 5\text{ mA to } 150\text{ mA}$ | | | 40 | 80 | mV |
| Dropout voltage | $I_O = 10\text{ mA}$ | | | | 0.2 | V |
| | $I_O = 150\text{ mA}$ | | | | 0.6 | |
| Output noise voltage | $f = 10\text{ Hz to } 100\text{ kHz}$ | | | 500 | | μV |
| Bias current | $I_O = 150\text{ mA}$ | | | 10 | 12 | mA |
| | $V_I = 9\text{ V to } 26\text{ V}$, $I_O = 10\text{ mA}$, $T_J = T_{J\text{min to } 125^\circ\text{C}}$ | | | 1 | 2 | |

* On products compliant to MIL-STD-883, Class B, this parameter is not production tested.

‡ Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a $0.1\text{-}\mu\text{F}$ capacitor across the input and a $10\text{-}\mu\text{F}$ capacitor, with equivalent series resistance of less than $1\ \Omega$ across the output.



TL750L, TL751L SERIES, TL751L12M LOW-DROPOUT VOLTAGE REGULATORS

TL750L10 and TL751L10 electrical characteristics at 25°C virtual junction temperature, $V_I = 14\text{ V}$, $I_O = 10\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS† | MIN | TYP | MAX | UNIT | |
|----------------------|--|--|-----|-----|---------------|---|
| Output voltage | $V_I = 11\text{ V to }26\text{ V}$, $I_O = 0\text{ to }150\text{ mA}$ | $T_J = 25^\circ\text{C}$ | 9.6 | 10 | 10.4 | V |
| | | $T_J = T_{Jmin}\text{ to }125^\circ\text{C}$ | 9.5 | | 10.5 | |
| Input regulation | $V_I = 12\text{ V to }19\text{ V}$ | | 10 | 25 | mV | |
| | $V_I = 11\text{ V to }26\text{ V}$ | | 30 | 60 | | |
| Ripple rejection | $V_I = 12\text{ V to }22\text{ V}$, $f = 120\text{ Hz}$ | 60* | 65 | | dB | |
| Output regulation | $I_O = 5\text{ mA to }150\text{ mA}$ | | 50 | 100 | mV | |
| Dropout voltage | $I_O = 10\text{ mA}$ | | | 0.2 | V | |
| | $I_O = 150\text{ mA}$ | | | 0.6 | | |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | | 700 | | μV | |
| Bias current | $I_O = 150\text{ mA}$ | | 10 | 12 | mA | |
| | $V_I = 11\text{ V to }26\text{ V}$, $I_O = 10\text{ mA}$, $T_J = T_{Jmin}\text{ to }125^\circ\text{C}$ | | 1 | 2 | | |

TL750L12, TL751L12, and TL751L12M electrical characteristics at 25°C virtual junction temperature, $V_I = 14\text{ V}$, $I_O = 10\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS† | MIN | TYP | MAX | UNIT | |
|----------------------|--|--|-------|-----|---------------|---|
| Output voltage | $V_I = 13\text{ V to }26\text{ V}$, $I_O = 0\text{ to }150\text{ mA}$ | $T_J = 25^\circ\text{C}$ | 11.52 | 12 | 12.48 | V |
| | | $T_J = T_{Jmin}\text{ to }125^\circ\text{C}$ | 11.4 | | 12.6 | |
| Input regulation | $V_I = 14\text{ V to }19\text{ V}$ | | 15 | 30 | mV | |
| | $V_I = 13\text{ V to }26\text{ V}$ | | 20 | 40 | | |
| Ripple rejection | $V_I = 13\text{ V to }23\text{ V}$, $f = 120\text{ Hz}$ | 50* | 55 | | dB | |
| Output regulation | $I_O = 5\text{ mA to }150\text{ mA}$ | | 50 | 120 | mV | |
| Dropout voltage | $I_O = 10\text{ mA}$ | | | 0.2 | V | |
| | $I_O = 150\text{ mA}$ | | | 0.6 | | |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | | 700 | | μV | |
| Bias current | $I_O = 150\text{ mA}$ | | 10 | 12 | mA | |
| | $V_I = 13\text{ V to }26\text{ V}$, $I_O = 10\text{ mA}$, $T_J = T_{Jmin}\text{ to }125^\circ\text{C}$ | | 1 | 2 | | |

* On products compliant to MIL-STD-883, Class B, this parameter is not production tested.

† Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.1- μF capacitor across the input and a 10- μF capacitor, with equivalent series resistance of less than 1 Ω across the output.

TYPICAL CHARACTERISTICS

TRANSIENT INPUT VOLTAGE
vs
TIME

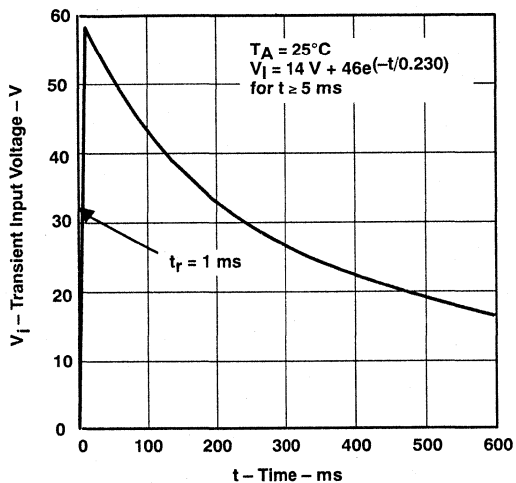


Figure 1

TL750M, TL751M SERIES LOW-DROPOUT VOLTAGE REGULATORS

D3017, JANUARY 1988—REVISED SEPTEMBER 1990

- Very Low Dropout Voltage, Less Than 0.6 V at 750 mA
- Low Quiescent Current
- TTL- and CMOS-Compatible Enable on TL751M Series
- 60-V Load-Dump Protection
- Overvoltage Protection
- Internal Thermal Overload Protection
- Internal Overcurrent Limiting Circuitry

description

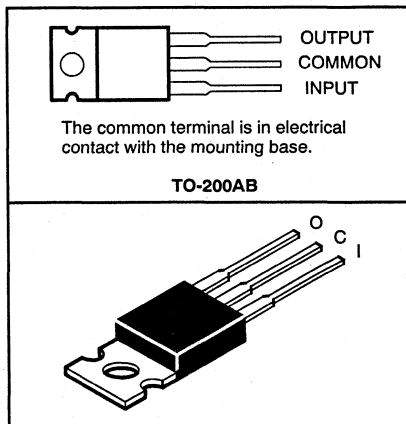
The TL750M and TL751M series are low-dropout positive voltage regulators specifically designed for battery-powered systems. The TL750M and TL751M incorporate on-board overvoltage and current-limit protection circuitry to protect both themselves and the regulated system. Both series are fully protected against 60-V load-dump and reverse battery conditions. Extremely low quiescent current, even during full-load conditions, makes the TL750M and TL751M series ideal for standby power systems.

The TL750M series of fixed-output voltage regulators offer 5-V, 8-V, 10-V, and 12-V options available in 3-lead KC (TO-220AB) plastic packages.

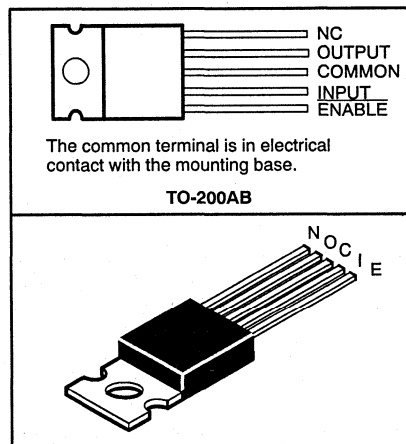
The TL751M series of fixed-output voltage regulators also offer 5-V, 8-V, 10-V, and 12-V options with the addition of an enable input. The enable input gives the designer complete control over power-up, allowing sequential power up or emergency shutdown. When taken high, the enable input places the regulator output in a high-impedance state. It is completely TTL- and CMOS-compatible. The TL751M series is offered in 5-lead KC plastic packages.

The TL750M_C and TL751M_C are characterized for operation from 0°C to 125°C virtual junction temperature, and the TL750M_Q and TL751M_Q series are characterized for operation from -40°C to 125°C virtual junction temperature.

3-LEAD KC PACKAGE
(TOP VIEW)



5-LEAD KC PACKAGE
(TOP VIEW)



NC—No internal connection

TL750M, TL751M SERIES LOW-DROPOUT VOLTAGE REGULATORS

absolute maximum ratings over virtual junction temperature range (unless otherwise noted)

| | |
|---|----------------|
| Continuous input voltage | 26 V |
| Transient input voltage (see Figure 1) | 60 V |
| Continuous reverse input voltage | -15 V |
| Transient reverse input voltage: $t = 100$ ms | -50 V |
| Continuous total dissipation at (or below) 25°C free-air temperature (see Note 1) | 2 W |
| Continuous total dissipation at (or below) 40°C case temperature (see Note 1) | 20 W |
| Operating free-air, case, or virtual junction temperature range | -40°C to 150°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 1: For operation above $T_A = 25^\circ\text{C}$ and $T_C = 40^\circ\text{C}$, refer to Figures 2 and 3. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variation in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

recommended operating conditions over recommended virtual junction temperature range (unless otherwise noted)

| | DEVICE | MIN | MAX | UNIT |
|---|----------|-----|-----|------|
| Input voltage range, V_I | TL75_M05 | 6 | 26 | V |
| | TL75_M08 | 9 | 26 | |
| | TL75_M10 | 11 | 26 | |
| | TL75_M12 | 13 | 26 | |
| High-level $\overline{\text{ENABLE}}$ input voltage, V_{IH} | TL751M_ | 2 | 15 | V |
| Low-level $\overline{\text{ENABLE}}$ input voltage, V_{IL} | TL751M_ | 0 | 0.8 | |
| Output current range, I_O | TL75_M | | 750 | mA |
| Operating virtual junction temperature range, T_J | TL75_M_C | 0 | 125 | °C |
| | TL75_M_Q | -40 | 125 | |

TL750M05 and TL751M05 electrical characteristics, $V_I = 14$ V, $I_O = 300$ mA, $\overline{\text{ENABLE}}$ at 0 V for TL751M05, $T_J = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS (see Note 2) | | MIN | TYP | MAX | UNIT |
|----------------------|--|-----------------------------------|------|-----|------|---------------|
| Output voltage | $V_I = 6$ V to 26 V, $I_O = 0$ to 750 mA | $T_J = 25^\circ\text{C}$ | 4.95 | 5 | 5.05 | V |
| | | $T_J = \text{MIN to MAX}^\dagger$ | 4.9 | | 5.1 | |
| Input regulation | $V_I = 9$ V to 16 V, $I_O = 250$ mA | | | 10 | 25 | mV |
| | $V_I = 6$ V to 26 V, $I_O = 250$ mA | | | 12 | 50 | |
| Ripple rejection | $V_I = 8$ V to 18 V, $f = 120$ Hz | | 50 | 55 | | dB |
| Output regulation | $I_O = 5$ mA to 750 mA | | | 20 | 50 | mV |
| Dropout voltage | $I_O = 500$ mA | | | | 0.5 | V |
| | $I_O = 750$ mA | | | | 0.6 | |
| Output noise voltage | $f = 10$ Hz to 100 kHz | | | 500 | | μV |
| Bias current | $I_O = 750$ mA | | | 60 | 75 | mA |
| | $I_O = 10$ mA | | | | 5 | |
| Bias current | $\overline{\text{ENABLE}} V_{IH} \geq 2$ V | | | | 200 | μA |

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

NOTE 2: Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.1- μF capacitor across the input and a 10- μF tantalum capacitor on the output with equivalent series resistance within the guidelines shown in Figure 4.



TL750M, TL751M SERIES LOW-DROPOUT VOLTAGE REGULATORS

TL750M08 and TL751M08 electrical characteristics, $V_I = 14\text{ V}$, $I_O = 300\text{ mA}$, $\overline{\text{ENABLE}}$ at 0 V for TL751M08, $T_J = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS (see Note 2) | MIN | TYP | MAX | UNIT | |
|----------------------|---|-----------------------------------|------|-----|---------------|---|
| Output voltage | $V_I = 9\text{ V to } 26\text{ V}$, $I_O = 0\text{ to } 750\text{ mA}$ | $T_J = 25^\circ\text{C}$ | 7.92 | 8 | 8.08 | V |
| | | $T_J = \text{MIN to MAX}^\dagger$ | 7.84 | | 8.16 | |
| Input regulation | $V_I = 10\text{ V to } 17\text{ V}$, $I_O = 250\text{ mA}$ | | 12 | 40 | mV | |
| | $V_I = 9\text{ V to } 26\text{ V}$, $I_O = 250\text{ mA}$ | | 15 | 68 | | |
| Ripple rejection | $V_I = 11\text{ V to } 21\text{ V}$, $f = 120\text{ Hz}$ | 50 | 55 | | dB | |
| Output regulation | $I_O = 5\text{ mA to } 750\text{ mA}$ | | 24 | 80 | mV | |
| Dropout voltage | $I_O = 500\text{ mA}$ | | | 0.5 | V | |
| | $I_O = 750\text{ mA}$ | | | 0.6 | | |
| Output noise voltage | $f = 10\text{ Hz to } 100\text{ kHz}$ | | 500 | | μV | |
| Bias current | $I_O = 750\text{ mA}$ | | 60 | 75 | mA | |
| | $I_O = 10\text{ mA}$ | | | 5 | | |
| Bias current | $\overline{\text{ENABLE}} V_{IH} \geq 2\text{ V}$ | | | 200 | μA | |

TL750M10 and TL751M10 electrical characteristics, $V_I = 14\text{ V}$, $I_O = 300\text{ mA}$, $\overline{\text{ENABLE}}$ at 0 V for TL751M10, $T_J = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS (see Note 2) | MIN | TYP | MAX | UNIT | |
|----------------------|--|-----------------------------------|------|-----|---------------|---|
| Output voltage | $V_I = 11\text{ V to } 26\text{ V}$, $I_O = 0\text{ to } 750\text{ mA}$ | $T_J = 25^\circ\text{C}$ | 9.9 | 10 | 10.1 | V |
| | | $T_J = \text{MIN to MAX}^\dagger$ | 9.8 | | 10.2 | |
| Input regulation | $V_I = 12\text{ V to } 18\text{ V}$, $I_O = 250\text{ mA}$ | | 15 | 43 | mV | |
| | $V_I = 11\text{ V to } 26\text{ V}$, $I_O = 250\text{ mA}$ | | 20 | 75 | | |
| Ripple rejection | $V_I = 13\text{ V to } 23\text{ V}$, $f = 120\text{ Hz}$ | 50 | 55 | | dB | |
| Output regulation | $I_O = 5\text{ mA to } 750\text{ mA}$ | | 30 | 100 | mV | |
| Dropout voltage | $I_O = 500\text{ mA}$ | | | 0.5 | V | |
| | $I_O = 750\text{ mA}$ | | | 0.6 | | |
| Output noise voltage | $f = 10\text{ Hz to } 100\text{ kHz}$ | | 1000 | | μV | |
| Bias current | $I_O = 750\text{ mA}$ | | 60 | 75 | mA | |
| | $I_O = 10\text{ mA}$ | | | 5 | | |
| Bias current | $\overline{\text{ENABLE}} V_{IH} \geq 2\text{ V}$ | | | 200 | μA | |

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

NOTE 2: Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.1- μF capacitor across the input and a 10- μF tantalum capacitor on the output with equivalent series resistance within the guidelines shown in Figure 4.



TL750M, TL751M SERIES LOW-DROPOUT VOLTAGE REGULATORS

TL750M12 and TL751M12 electrical characteristics, $V_I = 14\text{ V}$, $I_O = 300\text{ mA}$, $\overline{\text{ENABLE}}$ at 0 V for TL751M12, $T_J = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS (see Note 2) | MIN | TYP | MAX | UNIT | |
|----------------------|--|-----------------------------------|-------|-----|---------------|---|
| Output voltage | $V_I = 13\text{ V to } 26\text{ V}$, $I_O = 0\text{ to } 750\text{ mA}$ | $T_J = 25^\circ\text{C}$ | 11.88 | 12 | 12.12 | V |
| | | $T_J = \text{MIN to MAX}^\dagger$ | 11.76 | | 12.24 | |
| Input regulation | $V_I = 14\text{ V to } 19\text{ V}$, $I_O = 250\text{ mA}$ | | 15 | 43 | mV | |
| | $V_I = 13\text{ V to } 26\text{ V}$, $I_O = 250\text{ mA}$ | | 20 | 78 | | |
| Ripple rejection | $V_I = 13\text{ V to } 23\text{ V}$, $f = 120\text{ Hz}$ | 50 | 55 | | dB | |
| Output regulation | $I_O = 5\text{ mA to } 750\text{ mA}$ | | 30 | 120 | mV | |
| Dropout voltage | $I_O = 500\text{ mA}$ | | | 0.5 | V | |
| | $I_O = 750\text{ mA}$ | | | 0.6 | | |
| Output noise voltage | $f = 10\text{ Hz to } 100\text{ kHz}$ | | 1000 | | μV | |
| Bias current | $I_O = 750\text{ mA}$ | | 60 | 75 | mA | |
| | $I_O = 10\text{ mA}$ | | | 5 | | |
| Bias current | $\overline{\text{ENABLE}} V_{IH} \geq 2\text{ V}$ | | | 200 | μA | |

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

NOTE 2: Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.1- μF capacitor across the input and a 10- μF tantalum capacitor on the output with equivalent series resistance within the guidelines shown in Figure 4.

TL751Mxx electrical characteristics, $V_I = 14\text{ V}$, $I_O = 300\text{ mA}$, $T_J = 25^\circ\text{C}$

| | MIN | TYP | MAX | UNIT |
|---|-----|-----|-----|---------------|
| Response time, $\overline{\text{ENABLE}}$ to output | | 50 | | μs |

TYPICAL CHARACTERISTICS

TRANSIENT INPUT VOLTAGE
vs
TIME

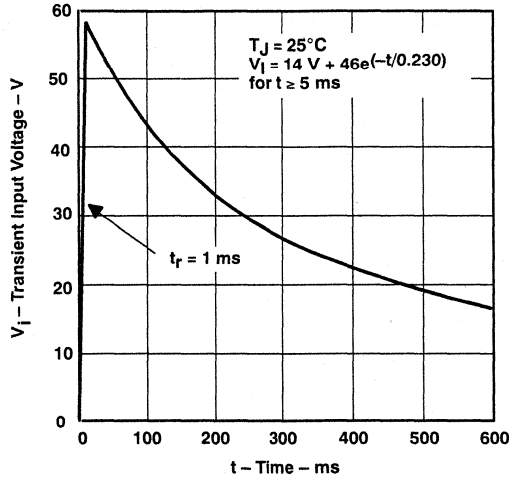


Figure 1

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

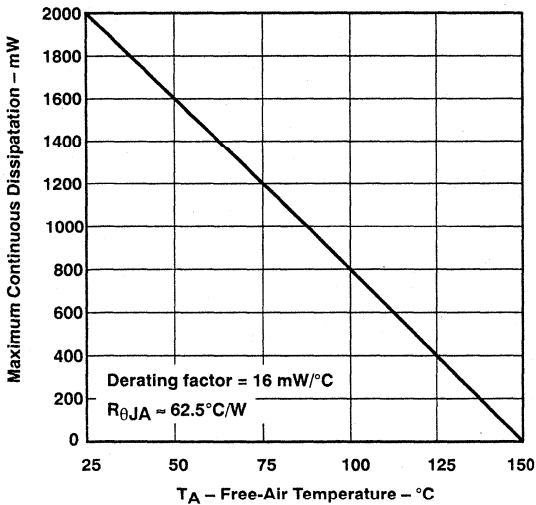


Figure 2

CASE TEMPERATURE
DISSIPATION DERATING CURVE

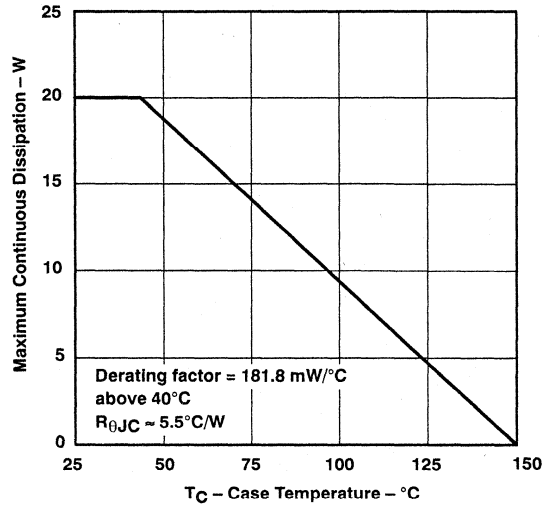


Figure 3

PARAMETER MEASUREMENT INFORMATION

The TL751MXX is a low-dropout regulator. This means that the capacitance loading is important to the performance of the regulator because it is a vital part of the control loop. The capacitor value and the equivalent series resistance (ESR) both affect the control loop and must be defined for the load range and the temperature range. Figures 4 and 5 can be used to establish the capacitance value and ESR range for best regulator performance.

Figure 4 shows the recommended range of ESR for a given load with a 10- μF capacitor on the output. This figure shows a maximum ESR limit of 2 Ω and a load-dependent minimum ESR limit. For applications with varying loads, the lightest load condition should be chosen since it is the worst case. Figure 5 shows the relationship of the reciprocal of ESR to the square root of the capacitance with a minimum capacitance limit of 10 μF and a maximum ESR limit of 2 Ω . This figure is used to establish the amount that the minimum ESR limit shown in Figure 4 can be adjusted for different capacitor values. For example, if the minimum load needed is 200 mA, Figure 4 suggests an ESR range of 0.8 Ω to 2 Ω for 10 μF . Figure 5 shows that changing the capacitor from 10 μF to 400 μF can change the ESR minimum by greater than 3/0.5 (or 6). Therefore, the new minimum ESR value is 0.8/6 (or 0.13 Ω). This now allows an ESR range of 0.13 Ω to 2 Ω , achieving an expanded ESR range by using a larger capacitor at the output.

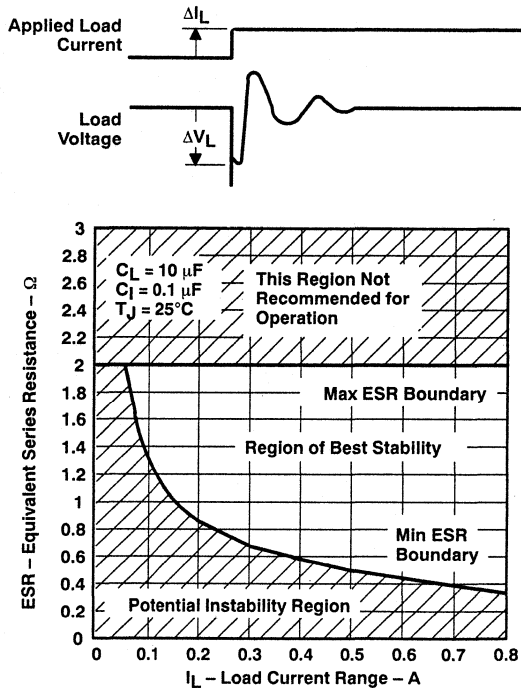


Figure 4. Output Capacitor ESR vs Load Current

PARAMETER MEASUREMENT INFORMATION

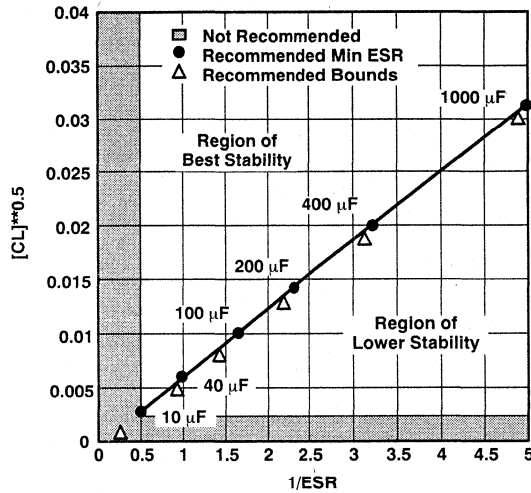


Figure 5. TL751M10 Stability vs ESR

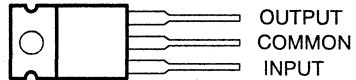
TL780 SERIES POSITIVE VOLTAGE REGULATORS

D2643, APRIL 1981—REVISED AUGUST 1991

- $\pm 1\%$ Output Tolerance at 25°C
- $\pm 2\%$ Output Tolerance Over Full Operating Range
- Thermal Shutdown
- Internal Short-Circuit Current Limiting
- Pinout Identical to uA7800 Series
- Improved Version of uA7800 Series

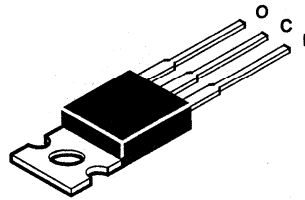
| NOMINAL OUTPUT VOLTAGE | REGULATOR |
|------------------------|-----------|
| 5 V | TL780-05C |
| 12 V | TL780-12C |
| 15 V | TL780-15C |

KC PACKAGE
(TOP VIEW)



The common terminal is in electrical contact with the mounting base.

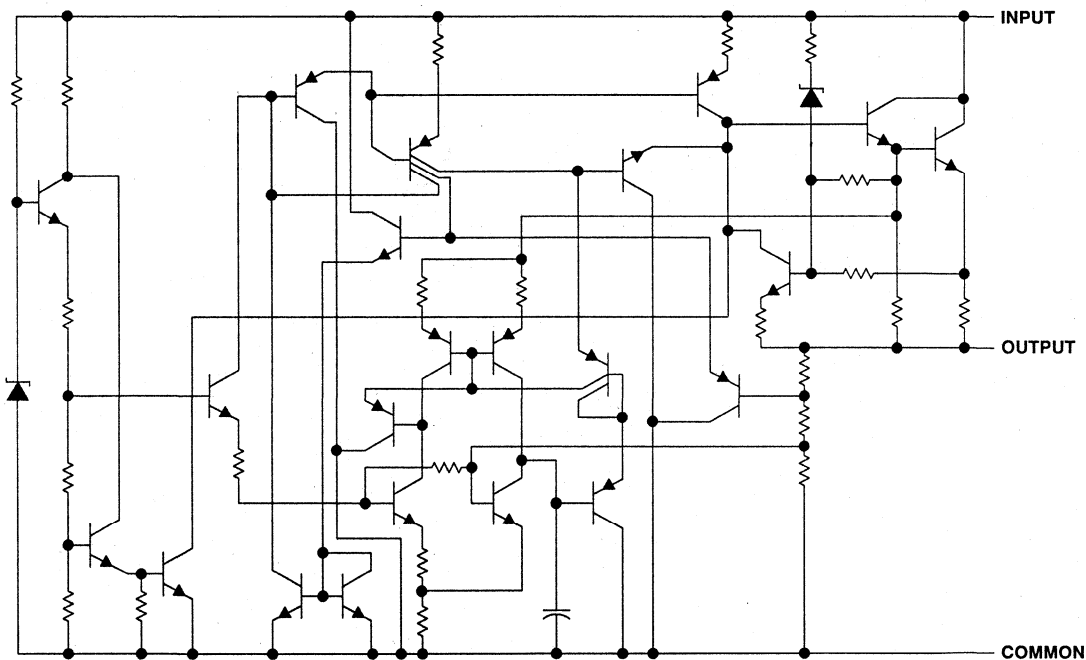
TO-200AB



description

Each fixed-voltage precision regulator in this series is capable of supplying 1.5 A of load current. A unique temperature-compensation technique coupled with an internally trimmed band-gap reference has resulted in improved accuracy when compared to other 3-terminal regulators. Advanced layout techniques provide excellent line, load, and thermal regulation. The internal current limiting and thermal shutdown features make the devices essentially immune to overload.

schematic



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TL780 SERIES POSITIVE VOLTAGE REGULATORS

absolute maximum ratings over operating temperature range (unless otherwise noted)

| | |
|---|----------------|
| Input voltage | 35 V |
| Continuous total dissipation at 25°C free-air temperature (see Note 1) | 2 W |
| Continuous total dissipation at (or below) 25°C case temperature (see Note 1) | 15 W |
| Operating free-air, case, or virtual junction temperature range | 0°C to 150°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 1: For operation above 25°C free-air or case temperature, refer to Figures 1 and 2. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

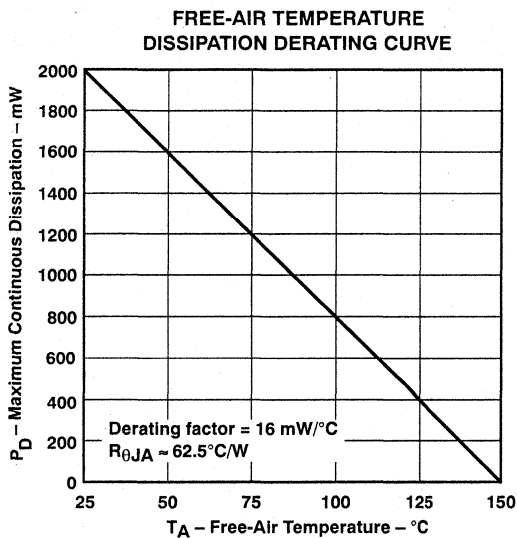


Figure 1

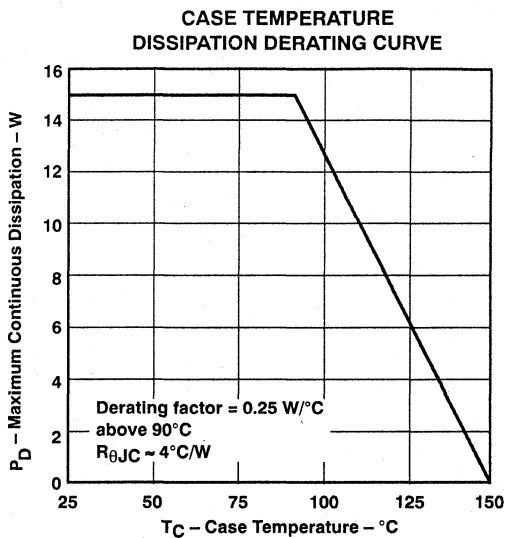


Figure 2

recommended operating conditions

| | | MIN | MAX | UNIT |
|---|-----------|------|-----|------|
| Input voltage, V_i | TL780-05C | 7 | 25 | V |
| | TL780-12C | 14.5 | 30 | |
| | TL780-15C | 17.5 | 30 | |
| Output current, I_O | | | 1.5 | A |
| Operating virtual junction temperature, T_J | | 0 | 125 | °C |

TL780 SERIES POSITIVE VOLTAGE REGULATORS

TL780-05C electrical characteristics at specified virtual junction temperature, $V_I = 10\text{ V}$, $I_O = 500\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J † | MIN | TYP | MAX | UNIT |
|---|---|--------------|------|--------|------|---------------|
| Output voltage | $I_O = 5\text{ mA to }1\text{ A}$, $P \leq 15\text{ W}$, $V_I = 7\text{ V to }20\text{ V}$ | 25°C | 4.95 | 5 | 5.05 | V |
| | | 0°C to 125°C | 4.9 | | 5.1 | |
| Input regulation | $V_I = 7\text{ V to }25\text{ V}$ | 25°C | | 0.5 | 5 | mV |
| | $V_I = 8\text{ V to }12\text{ V}$ | | | 0.5 | 5 | |
| Ripple rejection | $V_I = 8\text{ V to }18\text{ V}$, $f = 120\text{ Hz}$ | 0°C to 125°C | 70 | 85 | | dB |
| Output regulation | $I_O = 5\text{ mA to }1.5\text{ A}$ | 25°C | | 4 | 25 | mV |
| | $I_O = 250\text{ mA to }750\text{ mA}$ | | | 1.5 | 15 | |
| Output resistance | $f = 1\text{ kHz}$ | 0°C to 125°C | | 0.0035 | | Ω |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | 0°C to 125°C | | 0.25 | | mV/°C |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | 75 | | μV |
| Dropout voltage | $I_O = 1\text{ A}$ | 25°C | | 2 | | V |
| Bias current | | 25°C | | 5 | 8 | mA |
| Bias current change | $V_I = 7\text{ V to }25\text{ V}$ | 0°C to 125°C | | 0.7 | 1.3 | mA |
| | $I_O = 5\text{ mA to }1\text{ A}$ | | | 0.003 | 0.5 | |
| Short-circuit output current | $V_I = 35\text{ V}$ | 25°C | | 750 | | mA |
| Peak output current | | 25°C | | 2.2 | | A |

TL780-12C electrical characteristics at specified virtual junction temperature, $V_I = 19\text{ V}$, $I_O = 500\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J † | MIN | TYP | MAX | UNIT |
|---|--|--------------|-------|--------|-------|---------------|
| Output voltage | $I_O = 5\text{ mA to }1\text{ A}$, $P \leq 15\text{ W}$, $V_I = 14.5\text{ V to }27\text{ V}$ | 25°C | 11.88 | 12 | 12.12 | V |
| | | 0°C to 125°C | 11.76 | | 12.24 | |
| Input regulation | $V_I = 14.5\text{ V to }30\text{ V}$ | 25°C | | 1.2 | 12 | mV |
| | $V_I = 16\text{ V to }22\text{ V}$ | | | 1.2 | 12 | |
| Ripple rejection | $V_I = 15\text{ V to }25\text{ V}$, $f = 120\text{ Hz}$ | 0°C to 125°C | 65 | 80 | | dB |
| Output regulation | $I_O = 5\text{ mA to }1.5\text{ A}$ | 25°C | | 6.5 | 60 | mV |
| | $I_O = 250\text{ mA to }750\text{ mA}$ | | | 2.5 | 36 | |
| Output resistance | $f = 1\text{ kHz}$ | 0°C to 125°C | | 0.0035 | | Ω |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | 0°C to 125°C | | 0.6 | | mV/°C |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | 180 | | μV |
| Dropout voltage | $I_O = 1\text{ A}$ | 25°C | | 2 | | V |
| Bias current | | 25°C | | 5.5 | 8 | mA |
| Bias current change | $V_I = 14.5\text{ V to }30\text{ V}$ | 0°C to 125°C | | 0.4 | 1.3 | mA |
| | $I_O = 5\text{ mA to }1\text{ A}$ | | | 0.03 | 0.5 | |
| Short-circuit output current | $V_I = 35\text{ V}$ | 25°C | | 350 | | mA |
| Peak output current | | 25°C | | 2.2 | | A |

† Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.33- μF capacitor across the input and a 0.22- μF capacitor across the output.

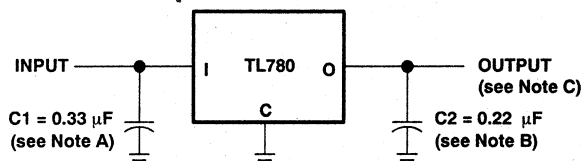
TL780 SERIES POSITIVE VOLTAGE REGULATORS

TL780-15C electrical characteristics at specified virtual junction temperature, $V_I = 23\text{ V}$, $I_O = 500\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J^\dagger | MIN | TYP | MAX | UNIT |
|---|--|---------------|--------|------|-------|---------------|
| Output voltage | $I_O = 5\text{ mA to }1\text{ A}$, $P \leq 15\text{ W}$, $V_I = 17.5\text{ V to }30\text{ V}$ | 25°C | 14.85 | 15 | 15.15 | V |
| | | 0°C to 125°C | 14.7 | | 15.3 | |
| Input regulation | $V_I = 17.5\text{ V to }30\text{ V}$ | 25°C | | 1.5 | 15 | mV |
| | $V_I = 20\text{ V to }26\text{ V}$ | | | 1.5 | 15 | |
| Ripple rejection | $V_I = 18.5\text{ V to }28.5\text{ V}$, $f = 120\text{ Hz}$ | 0°C to 125°C | 60 | 75 | | dB |
| Output regulation | $I_O = 5\text{ mA to }1.5\text{ A}$ | 25°C | | 7 | 75 | mV |
| | $I_O = 250\text{ mA to }750\text{ mA}$ | | | 2.5 | 45 | |
| Output resistance | $f = 1\text{ kHz}$ | 0°C to 125°C | 0.0035 | | | Ω |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | 0°C to 125°C | 0.62 | | | mV/°C |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | 225 | | | μV |
| Dropout voltage | $I_O = 1\text{ A}$ | 25°C | 2 | | | V |
| Bias current | | 25°C | 5.5 | 8 | | mA |
| Bias current change | $V_I = 17.5\text{ V to }30\text{ V}$ | 0°C to 125°C | | 0.4 | 1.3 | mA |
| | $I_O = 5\text{ mA to }1\text{ A}$ | | | 0.02 | 0.5 | |
| Short-circuit output current | $V_I = 35\text{ V}$ | 25°C | 230 | | | mA |
| Peak output current | | 25°C | 2.2 | | | A |

† Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.33- μF capacitor across the input and a 0.22- μF capacitor across the output.

PARAMETER MEASUREMENT INFORMATION



- NOTES: A. C1 is required if the regulator is far from the power supply filter.
 B. C2 is not required for stability; however, transient response is improved.
 C. Permanent damage can occur if output is pulled below ground.

Figure 3. Test Circuit

APPLICATION INFORMATION

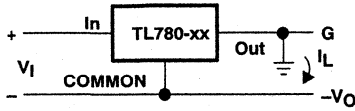
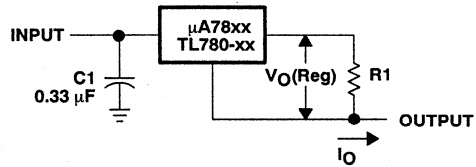


Figure 4. Positive Regulator in Negative Configuration (V_I Must Float)



$$I_O = (V_O/R_1) + I_O \text{ Bias Current}$$

Figure 5. Current Regulator

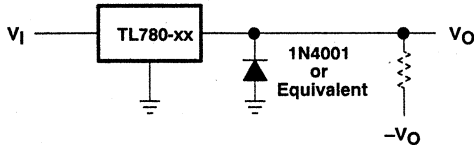


Figure 6. Output Polarity Reversal Protection Circuit

operation with a load common to a voltage of opposite polarity

In many cases, a regulator powers a load that is not connected to ground but instead is connected to a voltage source of opposite polarity (e.g., op amps, level-shifting circuits, etc.). In these cases, a clamp diode should be connected to the regulator output as shown in Figure 6. This protects the regulator from output polarity reversals during startup and short-circuit operation.

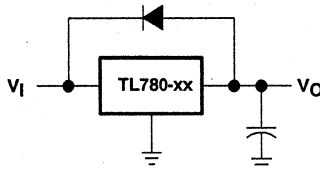


Figure 7. Reverse-Bias Protection Circuit

reverse-bias protection

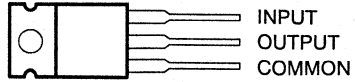
Occasionally, there exists the possibility that the input voltage to the regulator can collapse faster than the output voltage. This could occur, for example, if the input supply is crowbarred during an output overvoltage condition. If the output voltage is greater than approximately 7 V, the emitter-base junction of the series pass element (internal or external) could break down and be damaged. To prevent this, a diode shunt can be employed, as shown in Figure 7.

TL782C, TL782Q 2-V FIXED POSITIVE VOLTAGE REGULATORS

D3022, SEPTEMBER 1987—REVISED NOVEMBER 1991

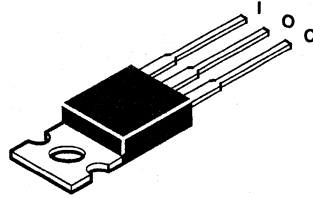
- Overvoltage Protection
- Thermal Shutdown Protection
- Internal Short-Circuit Current Limiting
- Peak Output Current Constant Over Temperature Range
- TL782Q Has Extended Temperature Range of -40°C to 125°C

KC PACKAGE
(TOP VIEW)



The common terminal is in electrical contact with the mounting base.

TO-220AB



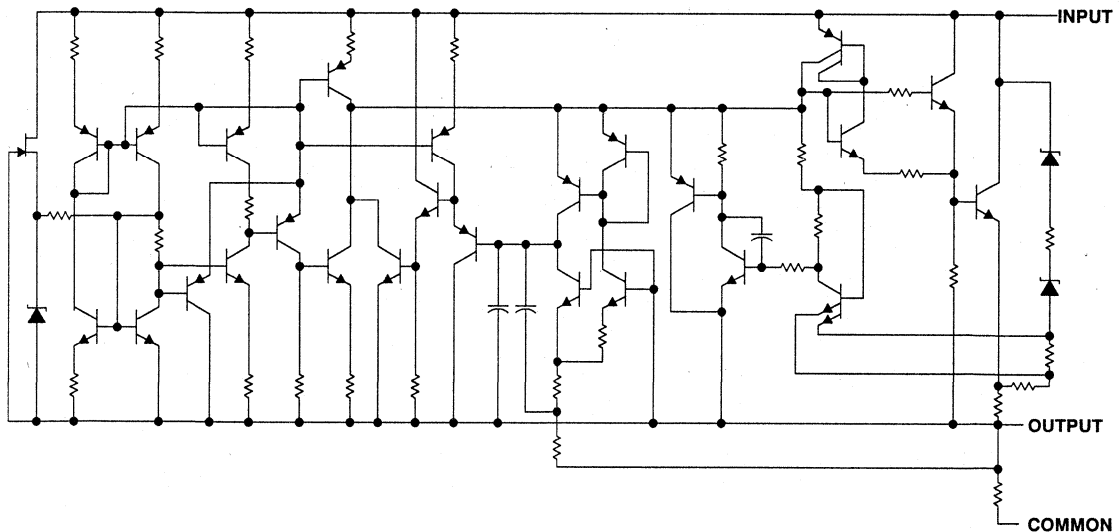
description

The TL782C and the TL782Q are fixed 2-V positive voltage regulators designed to address industry needs. With superior input and output regulation, they can regulate input voltages of 4.5 V to 30 V and are capable of supplying up to 1.5 A of load current.

In addition to high performance, the TL782C and TL782Q feature on-board overvoltage and thermal overload protection circuitry, and the output is current-limit protected.

The TL782C is characterized for operation from 0°C to 125°C virtual temperature range. The TL782Q is characterized for operation from -40°C to 125°C virtual temperature range.

schematic



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TL782C, TL782Q 2-V FIXED POSITIVE VOLTAGE REGULATORS

absolute maximum ratings over operating temperature range (unless otherwise noted)

| | |
|---|----------------|
| Input voltage | 40 V |
| Continuous total dissipation at (or below) 25°C free-air temperature (see Note 1) | 2 W |
| Continuous total dissipation at (or below) 70°C case temperature (see Note 1) | 20 W |
| Operating free-air, case, or virtual junction temperature range: TL782C | 0°C to 125°C |
| TL782Q | -40°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 1: For operation above 25°C free-air or 70°C case temperature, refer to Figures 1 and 2. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

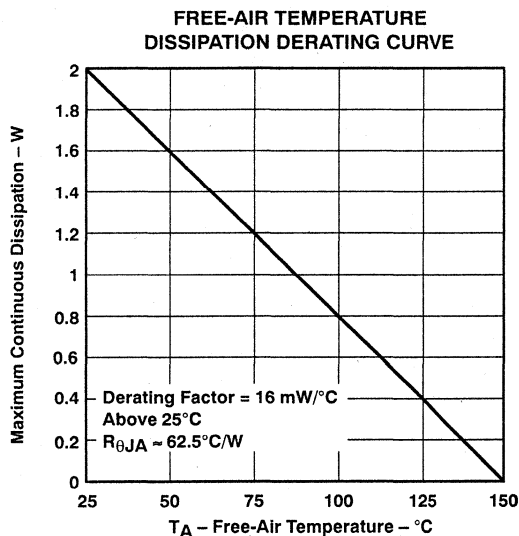


Figure 1

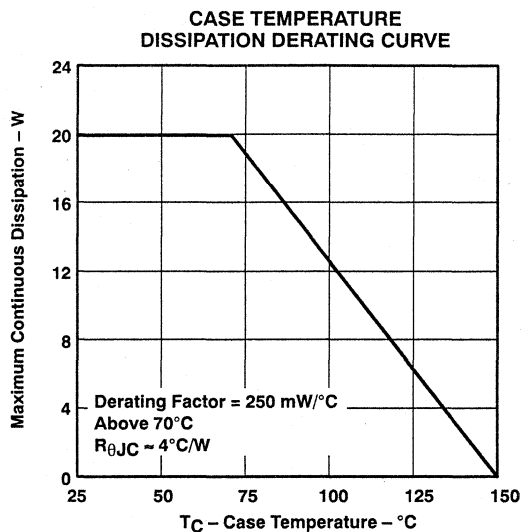


Figure 2

recommended operating conditions

| | | MIN | MAX | UNIT |
|--|--------|-----|-----|------|
| Input voltage, VI | | 4.5 | 30 | V |
| Output current, IO | | | 1.5 | A |
| Operating virtual junction temperature, TJ | TL782C | 0 | 125 | °C |
| | TL782Q | -40 | 125 | |

TL782C, TL782Q

2-V FIXED POSITIVE VOLTAGE REGULATORS

electrical characteristics at specified virtual junction temperature, $V_I = 5\text{ V}$, $I_O = 500\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS† | T_J ‡ | MIN TYP MAX | | | UNIT |
|---|---|------------|-------------|-----|------|-------|
| | | | | | | |
| Output voltage | $I_O = 5\text{ mA to }1\text{ A}$, $P_D \leq 15\text{ W}$, $V_I = 4.5\text{ V to }30\text{ V}$ | 25°C | 1.94 | 2 | 2.06 | V |
| | | Full range | 1.9 | | 2.1 | |
| Input regulation | $V_I = 5\text{ V to }20\text{ V}$ | 25°C | | | 25 | mV |
| | $V_I = 8\text{ V to }12\text{ V}$ | | | | 15 | |
| | $V_I = 5\text{ V to }20\text{ V}$ | Full range | | | 35 | |
| | $V_I = 8\text{ V to }12\text{ V}$ | | | | 25 | |
| Ripple rejection | $V_I(\text{AV}) = 10\text{ V}$, $V_{PP} = 10\text{ V}$, $f = 120\text{ Hz}$ | 25°C | 60 | | | dB |
| Output regulation | $I_O = 5\text{ mA to }1.5\text{ A}$ | 25°C | | | 25 | mV |
| | $I_O = 250\text{ mA to }750\text{ mA}$ | | | | 15 | |
| | $I_O = 5\text{ mA to }1.5\text{ A}$ | Full range | | | 70 | |
| | $I_O = 250\text{ mA to }750\text{ mA}$ | | | | 35 | |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | Full range | 0.25 | | | mV/°C |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | 75 | | μV |
| Bias current | | 25°C | | 8 | 9 | mA |
| | | Full range | | | 10 | |
| Bias current change | $V_I = 5\text{ V to }20\text{ V}$ | Full range | | | 1.4 | mA |
| | $I_O = 5\text{ mA to }1\text{ A}$ | | | | 0.5 | |
| Short-circuit output current | $V_I = 2.5\text{ V}$ | 25°C | | 750 | | mA |
| Peak output current | | 25°C | | 2.2 | | A |

† Pulse-testing techniques are used to maintain the virtual junction temperature as close to the free-air temperature as possible. All characteristics are measured with a 0.33-μF capacitor across the input and a 1-μF capacitor across the output.

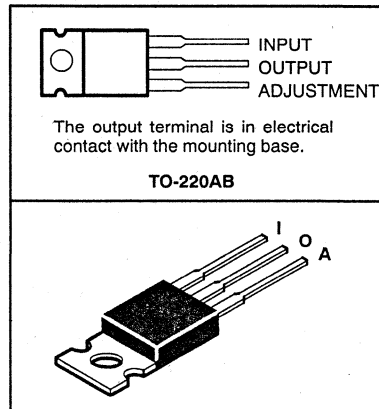
‡ For the TL782C, full range is 0°C to 125°C, and for the TL782Q, full range is -40°C to 125°C.

TL783C HIGH-VOLTAGE ADJUSTABLE REGULATOR

D2659, SEPTEMBER 1981—REVISED DECEMBER 1991

- Output Adjustable From 1.25 V to 125 V, When Used With an External Resistor Divider
- 700-mA Output Current
- Full Short-Circuit, Safe-Operating-Area, and Thermal Shutdown Protection
- 0.001%/V Typical Input Regulation
- 0.15% Typical Output Regulation
- 76-dB Typical Ripple Rejection
- Standard TO-220AB Package

KC PACKAGE
(TOP VIEW)



description

The TL783C is an adjustable 3-terminal high-voltage regulator with an output range of 1.25 V to 125 V and a DMOS output transistor capable of sourcing more than 700 mA. It is designed for use in high-voltage applications where standard bipolar regulators cannot be used. Excellent performance specifications, superior to those of most bipolar regulators, are achieved through circuit design and advanced layout techniques.

As a state-of-the-art regulator, the TL783C combines standard bipolar circuitry with high-voltage double-diffused MOS transistors on one chip to yield a device capable of withstanding voltages far higher than standard bipolar integrated circuits. Because of its lack of secondary breakdown and thermal runaway characteristics usually associated with bipolar outputs, the TL783C maintains full overload protection while operating at up to 125 V from input to output. Other features of the device include current limiting, safe-operating-area (SOA) protection, and thermal shutdown. Even if the adjustment terminal is inadvertently disconnected, the protection circuitry remains functional.

Only two external resistors are required to program the output voltage. An input bypass capacitor is necessary only when the regulator is situated far from the input filter. An output capacitor, although not required, will improve transient response and protection from instantaneous output short circuits. Excellent ripple rejection can be achieved without a bypass capacitor at the adjustment terminal.

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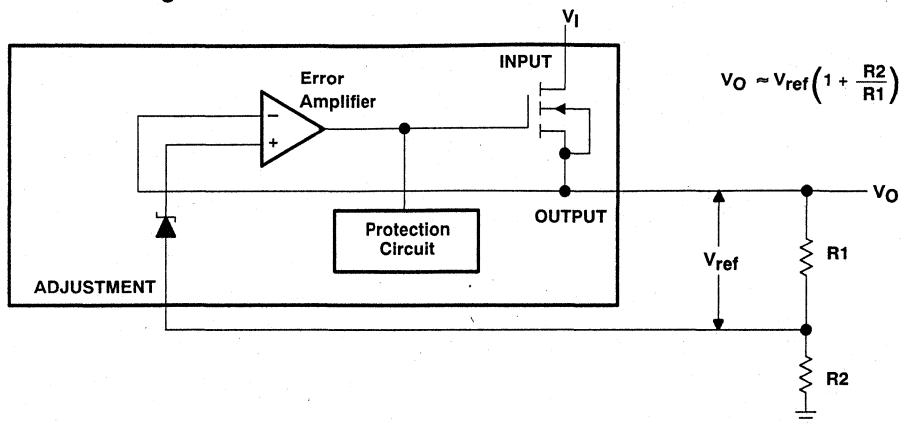
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TL783C HIGH-VOLTAGE ADJUSTABLE REGULATOR

functional block diagram



absolute maximum ratings over operating temperature range (unless otherwise noted)

| | |
|---|--------------|
| Input-to-output differential voltage, $V_I - V_O$ | 125 V |
| Continuous total dissipation at (or below) 25°C free-air temperature (see Note 1) | 2 W |
| Continuous total dissipation at (or below) 70°C case temperature (see Note 1) | 20 W |
| Operating free-air, case, or virtual junction temperature range | 0°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 1: For operation above 25°C free-air or 70°C case temperature, refer to Figures 1 and 2, respectively. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation

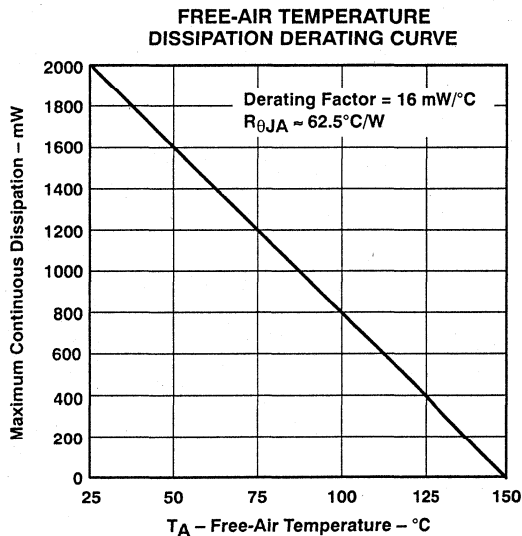


Figure 1

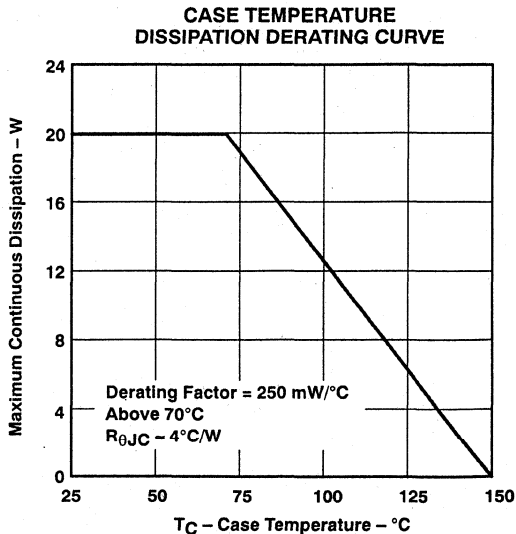


Figure 2



TL783C HIGH-VOLTAGE ADJUSTABLE REGULATOR

recommended operating conditions

| | MIN | MAX | UNIT |
|---|-----|-----|------|
| Input-to-output voltage differential, $V_I - V_O$ | | 125 | V |
| Output current, I_O | 15 | 700 | mA |
| Operating virtual junction temperature, T_J | 0 | 125 | °C |

electrical characteristics at $V_I - V_O = 25$ V, $I_O = 0.5$ A, $T_J = 0^\circ\text{C}$ to 125°C (unless otherwise noted)

| PARAMETER | TEST CONDITIONS† | MIN | TYP | MAX | UNIT |
|---|--|--|--------|------|---------------|
| Input regulation‡ | $V_I - V_O = 20$ V to 125 V, $P \leq$ rated dissipation | $T_J = 25^\circ\text{C}$ | 0.001 | 0.01 | %V |
| | | $T_J = 0^\circ\text{C}$ to 125°C | 0.004 | 0.02 | |
| Ripple rejection | $\Delta V_I(\text{pp}) = 10$ V, $V_O = 10$ V, $f = 120$ Hz | 66 | 76 | | dB |
| Output regulation | $I_O = 15$ mA to 700 mA, $T_J = 25^\circ\text{C}$ | $V_O \leq 5$ V | 7.5 | 25 | mV |
| | | $V_O \geq 5$ V | 0.15% | 0.5% | |
| | $I_O = 15$ mA to 700 mA, $P \leq$ rated dissipation | $V_O \leq 5$ V | 20 | 70 | mV |
| | | $V_O \geq 5$ V | 0.3% | 1.5% | |
| Output voltage change with temperature | | | 0.4% | | |
| Output voltage long-term drift | 1000 hours at $T_J = 125^\circ\text{C}$, $V_I - V_O = 125$ V, See Note 2 | | 0.2% | | |
| Output noise voltage | $f = 10$ Hz to 10 kHz, $T_J = 25^\circ\text{C}$ | | 0.003% | | |
| Minimum output current to maintain regulation | $V_I - V_O = 125$ V | | | 15 | mA |
| Peak output current | $V_I - V_O = 25$ V, $t = 1$ ms | | 1100 | | mA |
| | $V_I - V_O = 15$ V, $t = 30$ ms | | 715 | | |
| | $V_I - V_O = 25$ V, $t = 30$ ms | 700 | 900 | | |
| | $V_I - V_O = 125$ V, $t = 30$ ms | 100 | 250 | | |
| Adjustment-terminal current | | | 83 | 110 | μA |
| Change in adjustment-terminal current | $V_I - V_O = 15$ V to 125 V, $I_O = 15$ mA to 700 mA, $P \leq$ rated dissipation | | 0.5 | 5 | μA |
| Reference voltage (OUTPUT to ADJUSTMENT) | $V_I - V_O = 10$ V to 125 V, $I_O = 15$ mA to 700 mA, $P \leq$ rated dissipation, See Note 3 | 1.2 | 1.27 | 1.3 | V |

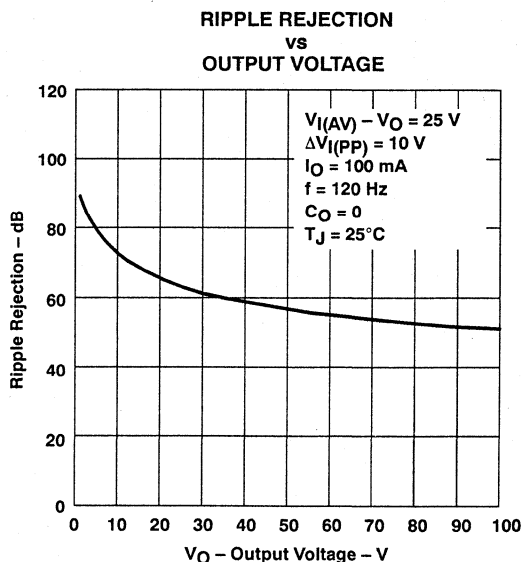
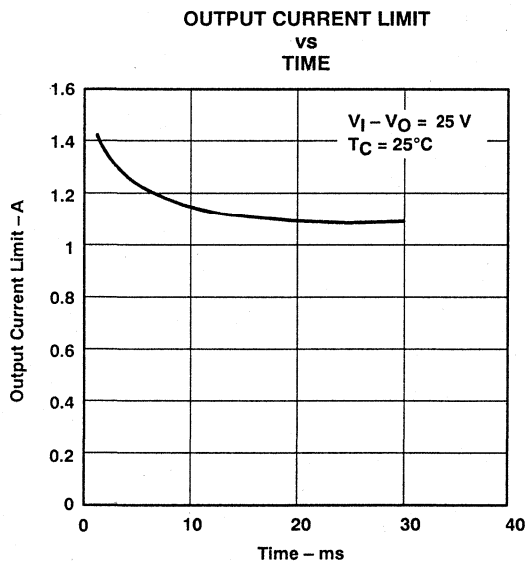
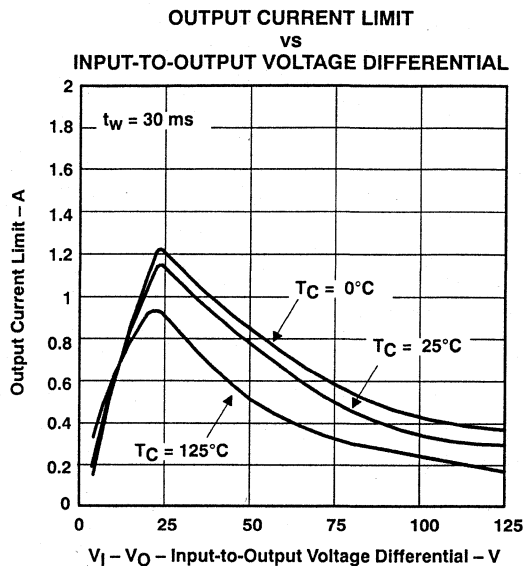
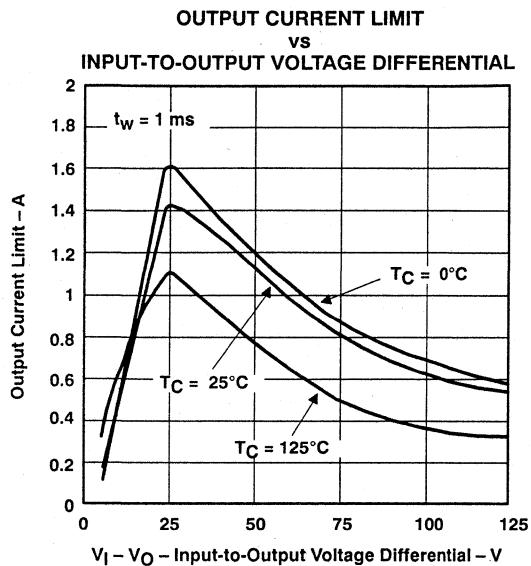
† Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

‡ Input regulation is expressed here as the percentage change in output voltage per 1-V change at the input.

NOTES: 2. Since long-term drift cannot be measured on the individual devices prior to shipment, this specification is not intended to be a guarantee or warranty. It is an engineering estimate of the average drift to be expected from lot to lot.

3. Due to the dropout voltage and output current limiting characteristics of this device, output current is limited to less than 700 mA at input-to-output voltage differentials of less than 25 V.

TYPICAL CHARACTERISTICS



TYPICAL CHARACTERISTICS

RIPPLE REJECTION
 vs
 OUTPUT CURRENT

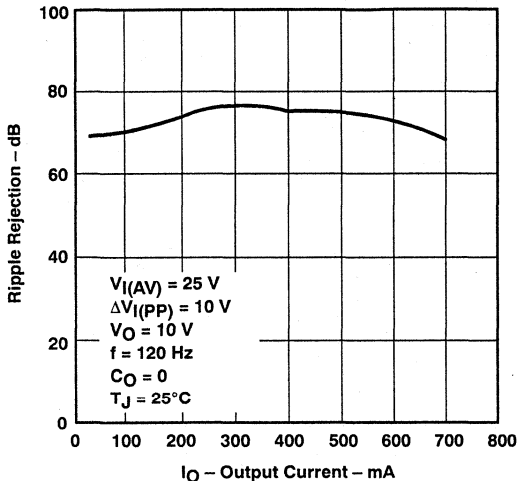


Figure 7

RIPPLE REJECTION
 vs
 FREQUENCY

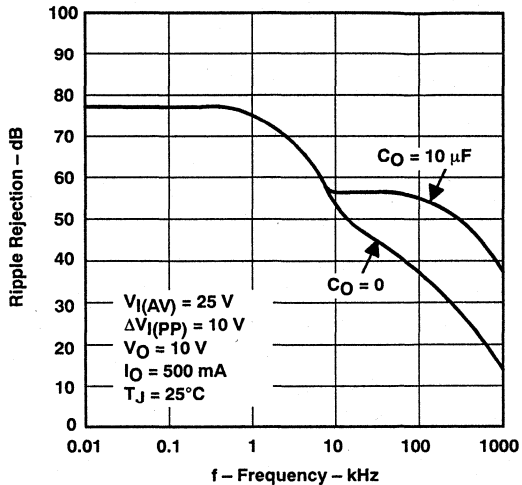


Figure 8

OUTPUT IMPEDANCE
 vs
 FREQUENCY

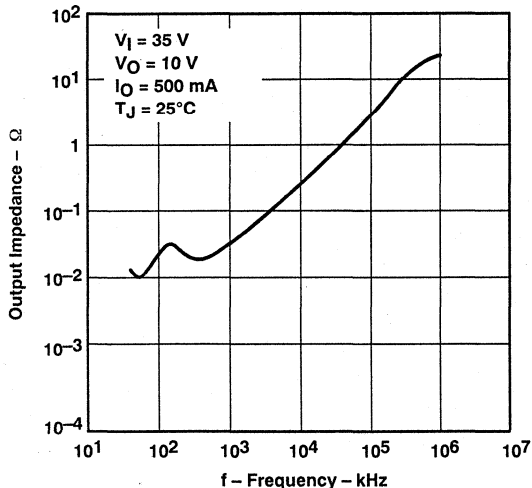


Figure 9

REFERENCE VOLTAGE
 vs
 VIRTUAL JUNCTION TEMPERATURE

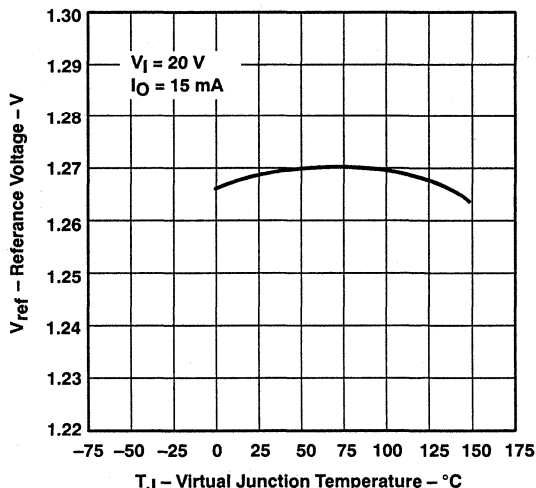
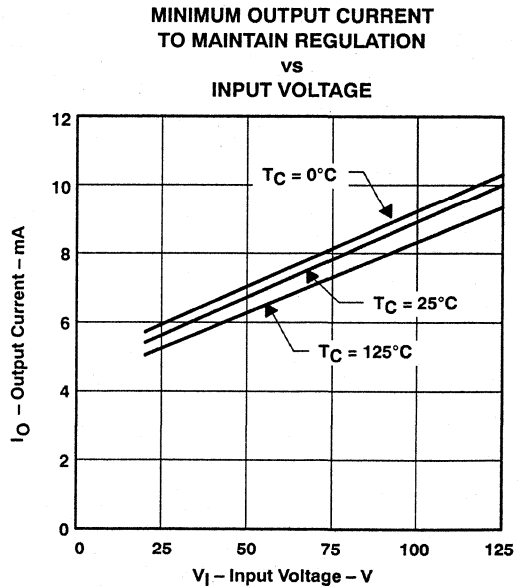
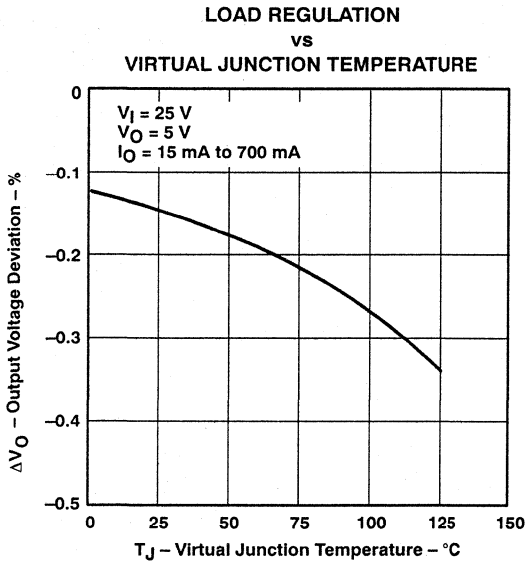
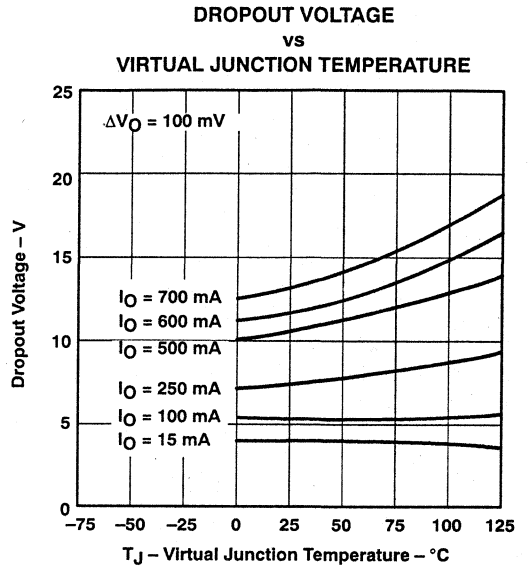
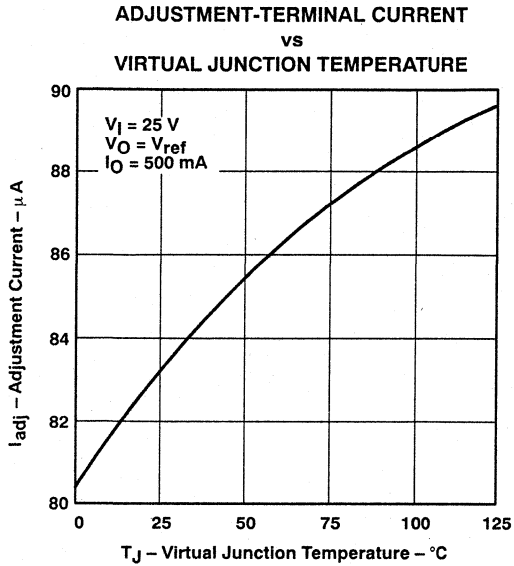


Figure 10

TYPICAL CHARACTERISTICS



TYPICAL CHARACTERISTICS

LINE TRANSIENT RESPONSE

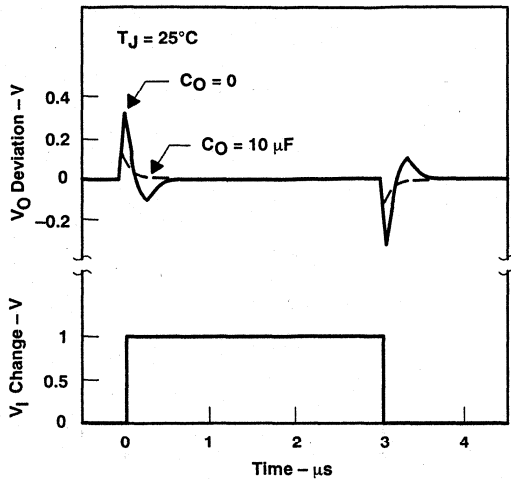


Figure 15

LOAD TRANSIENT RESPONSE

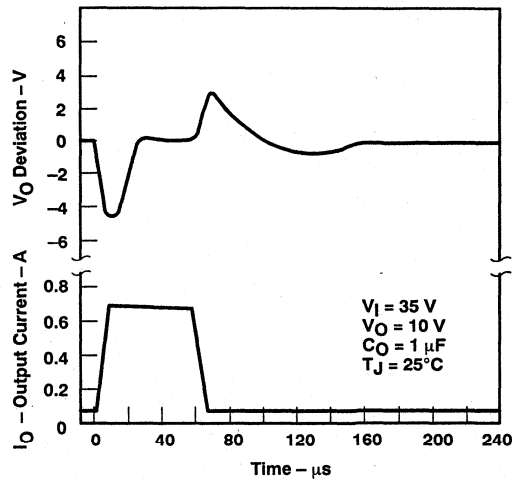


Figure 16

DESIGN CONSIDERATIONS

The internal reference (see functional block diagram) is used to generate 1.25 V nominal (V_{ref}) between the output and adjustment terminals. This voltage is developed across R1 and causes a constant current to flow through R1 and the programming resistor R2, giving an output voltage of:

$$V_O = V_{ref} (1 + R2/R1) + I_{adj} (R2)$$

or

$$V_O \sim V_{ref} (1 + R2/R1).$$

The TL783C was designed to minimize I_{adj} and maintain consistency over line and load variations, thereby minimizing the $I_{adj} (R2)$ error term.

To maintain I_{adj} at a low level, all quiescent operating current is returned to the output terminal. This quiescent current must be sunk by the external load and is the minimum load current necessary to prevent the output from rising. The recommended R1 value of 82 Ω will provide a minimum load current of 15 mA. Larger values may be used if the input-to-output differential voltage is less than 125 V (see minimum operating current curve) or if the load will sink some portion of the minimum current.

bypass capacitors

The TL783C regulator is stable without bypass capacitors; however, any regulator will become unstable with certain values of output capacitance if an input capacitor is not used. Therefore, the use of input bypassing is recommended whenever the regulator is located more than four inches from the power-supply filter capacitor. A 1- μ F tantalum or electrolytic capacitor is usually sufficient.

TL783C HIGH-VOLTAGE ADJUSTABLE REGULATOR

Adjustment-terminal capacitors are not recommended for use on the TL783C because they can seriously degrade load transient response as well as create a need for extra protection circuitry. Excellent ripple rejection is presently achieved without this added capacitor.

Due to the relatively low gain of the MOS output stage, output voltage dropout may occur under large load transient conditions. Addition of an output bypass capacitor will greatly enhance load transient response as well as prevent dropout. For most applications, it is recommended that an output bypass capacitor be used with a minimum value of:

$$C_O (\mu\text{F}) = 15/V_O$$

Larger values will provide proportionally better transient response characteristics.

protection circuitry

The TL783C regulator includes built-in protection circuits capable of guarding the device against most overload conditions encountered in normal operation. These protective features are current limiting, safe-operating-area protection, and thermal shutdown. These circuits are meant to protect the device under occasional fault conditions only. Continuous operation in the current limit or thermal shutdown mode is not recommended.

The internal protection circuits of the TL783C will protect the device up to maximum-rated V_I as long as certain precautions are taken. If V_I is instantaneously switched on, transients exceeding maximum input ratings may occur, which can destroy the regulator. These are usually caused by lead inductance and bypass capacitors causing a ringing voltage on the input. In addition, if rise times in excess of 10 V/ns are applied to the input, a parasitic n-p-n transistor in parallel with the DMOS output can be turned on causing the device to fail. If the device is operated over 50 V and the input is switched on rather than ramped on, a low-Q capacitor, such as tantalum or electrolytic should be used rather than ceramic, paper, or plastic bypass capacitors. A Q factor of 0.015 or greater will usually provide adequate damping to suppress ringing. Normally, no problems occur if the input voltage is allowed to ramp upward through the action of an ac line rectifier and filter network.

Similarly, if an instantaneous short circuit is applied to the outputs, both ringing and excessive fall times can result. A tantalum or electrolytic bypass capacitor is recommended to eliminate this problem. However, if a large output capacitor is used and the input is shorted, addition of a protection diode may be necessary to prevent capacitor discharge through the regulator. The amount of discharge current delivered is dependent on output voltage, size of capacitor, and fall time of V_I . A protective diode (see Figure 17) is required only for capacitance values greater than:

$$C_O (\mu\text{F}) = 3 \times 10^4 / (V_O)^2.$$

Care should always be taken to prevent insertion of regulators into a socket with power on. Power should be turned off before removing or inserting regulators.

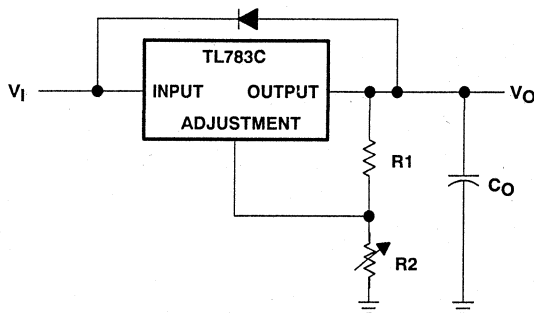


Figure 17. Regulator With Protective Diode

load regulation

The current set resistor (R1) should be located close to the regulator output terminal rather than near the load. This eliminates long line drops from being amplified through the action of R1 and R2 to degrade load regulation. To provide remote ground sensing, R2 should be near the load ground.

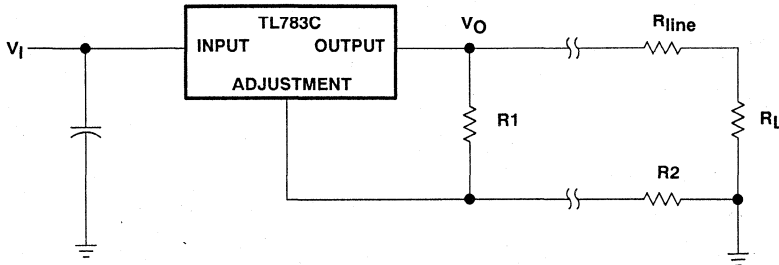
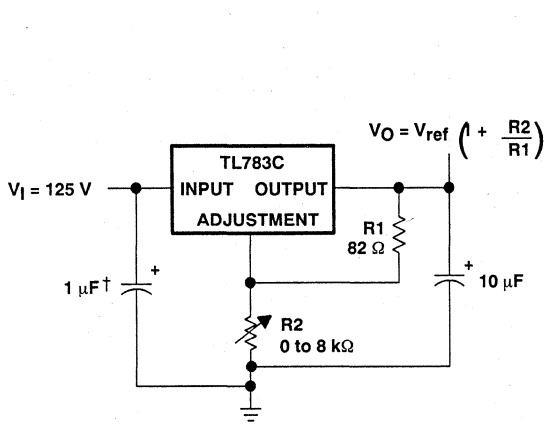


Figure 18. Regulator With Current-Set Resistor

APPLICATION INFORMATION



† Needed if device is more than 4 inches from filter capacitor

Figure 19. 1.25-V to 115-V Adjustable Regulator

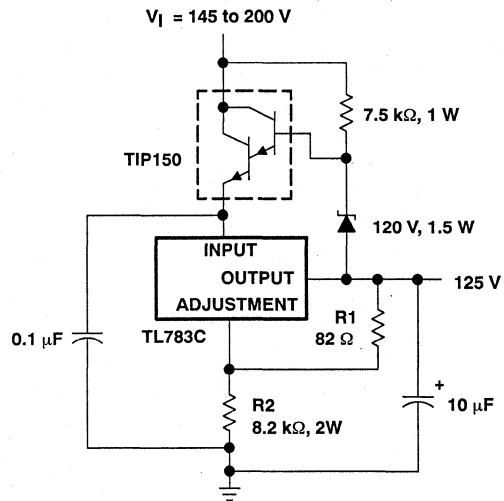


Figure 20. 125-V Short-Circuit-Protected Off-Line Regulator

TL783C HIGH-VOLTAGE ADJUSTABLE REGULATOR

APPLICATION INFORMATION

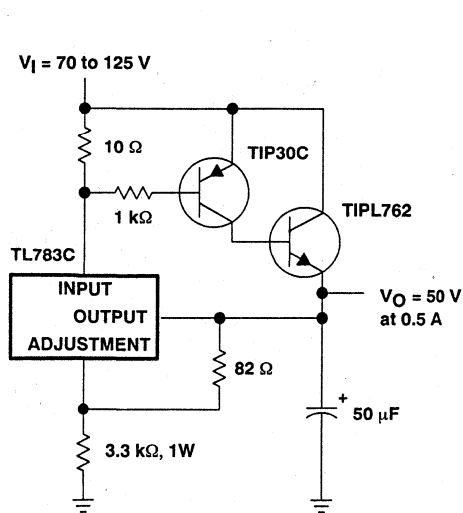


Figure 21. 50-V Regulator With Current Boost

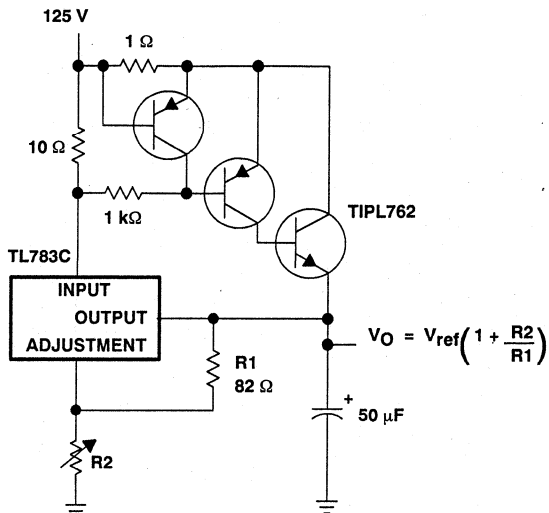


Figure 22. Adjustable Regulator With Current Boost and Current Limit

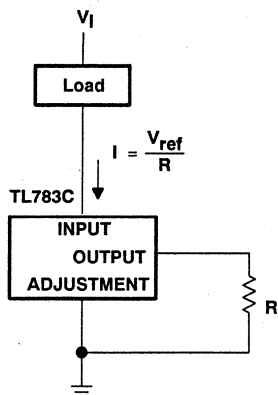


Figure 23. Current-Sinking Regulator

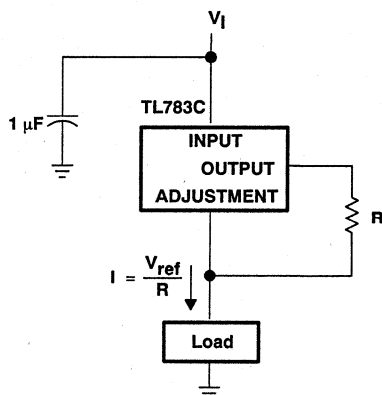


Figure 24. Current-Sourcing Regulator

APPLICATION INFORMATION

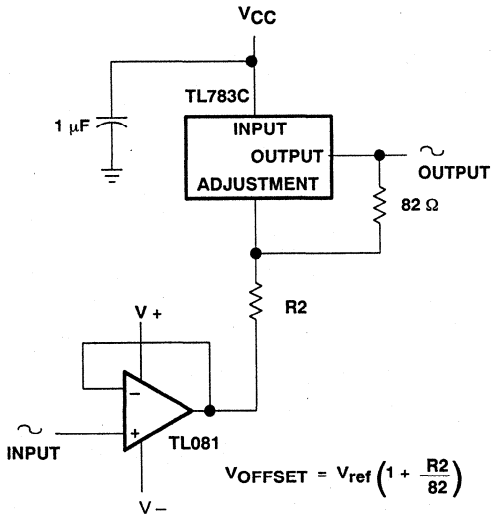


Figure 25. High-Voltage Unity-Gain Offset Amplifier

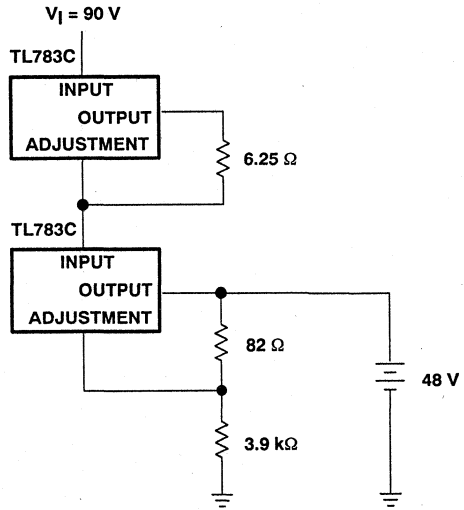


Figure 26. 48-V, 200-mA Float Charger

TL1431C, TL1431Q, TL1431Y PRECISION PROGRAMMABLE REFERENCE

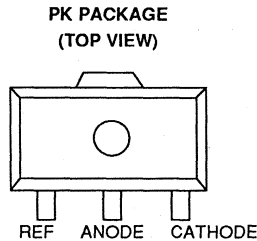
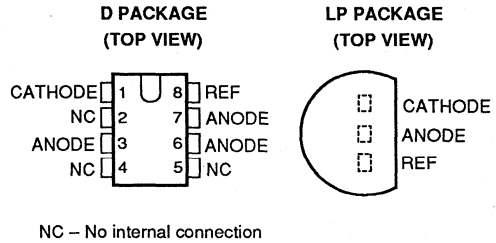
D3858, DECEMBER 1991

- 0.4% Initial Voltage Tolerance
- 0.1-Ω Typical Output Impedance
- Fast Turn-On . . . 500 ns
- Sink Current Capability . . . 1 mA to 100 mA
- Low Ref Pin Current
- Adjustable Output Voltage . . . V_{ref} to 36 V
- Available in a Wide Range of High Density Packaging Options:
 - Small Outline (D)
 - TO-226AA (LP)
 - SOT-89 (PK)

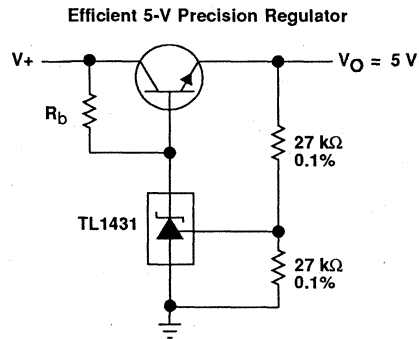
description

The TL1431 is a 3-terminal precision programmable reference with specified thermal stability over applicable automotive and commercial temperature ranges. The output voltage may be set to any value between V_{ref} (approximately 2.5 V) and 36 V with two external resistors (see Figure 16). These devices have a typical output impedance of 0.1 Ω. Active output circuitry provides a very sharp turn-on characteristic, making these devices excellent replacements for zener diodes and other types of references in many applications like on-board regulation, adjustable power supplies, and switching power supplies.

The TL1431 is offered in a wide variety of high-density packaging options that includes an SOT-89-type package (suffix PK). It is also offered in both the automotive temperature range and the commercial temperature range. The TL1431Q is characterized for operation over the automotive temperature range of -40°C to 125°C. The TL1431C is characterized for operation over the commercial temperature range of 0°C to 70°C.



application schematic



Note: R_b should provide ≥ 1 mA cathode current to the TL1431.

AVAILABLE OPTIONS

| T _A | PACKAGE | | | CHIP FORM (Y) |
|----------------|-------------------|---------------|-------------|---------------|
| | SMALL OUTLINE (D) | TO-226AA (LP) | SOT-89 (PK) | |
| 0°C to 70°C | TL1431CD | TL1431CLP | TL1431CPK | TL1431Y |
| -40°C to 125°C | TL1431QD | TL1431QLP | — | |

D and LP packages are available taped and reeled. Add "R" suffix to device type (e.g., TL1431CDR). PK package is only available taped and reeled. No "R" suffix required. Chips are tested at 25°C.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

TEXAS
INSTRUMENTS

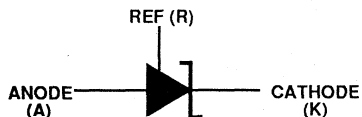
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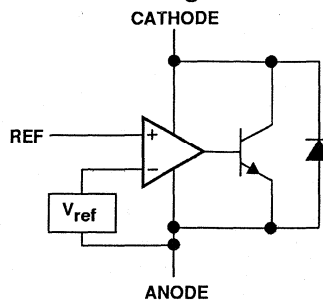
2-303

TL1431C, TL1431Q, TL1431Y PRECISION PROGRAMMABLE REFERENCE

symbol

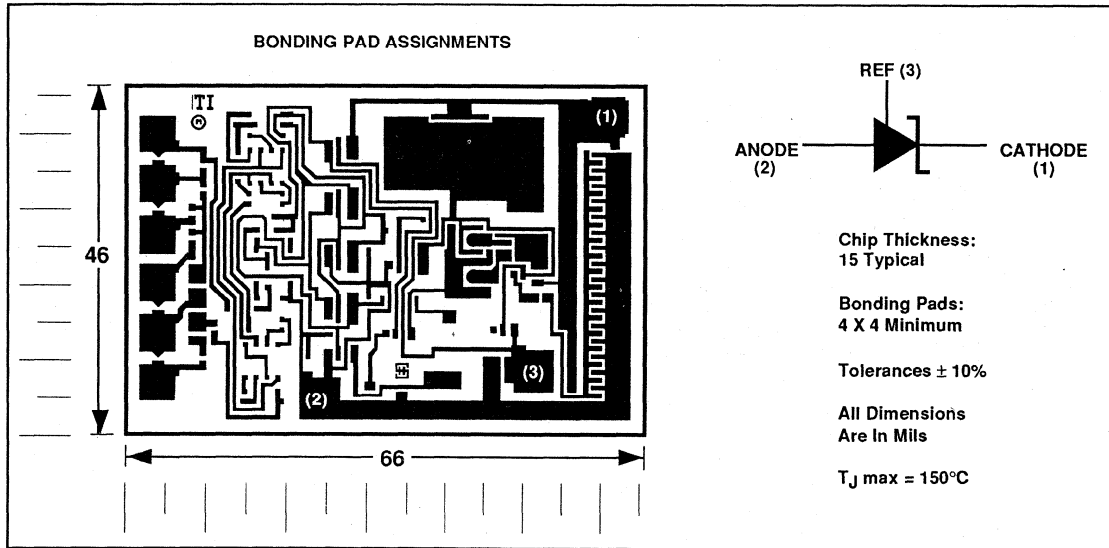


functional block diagram



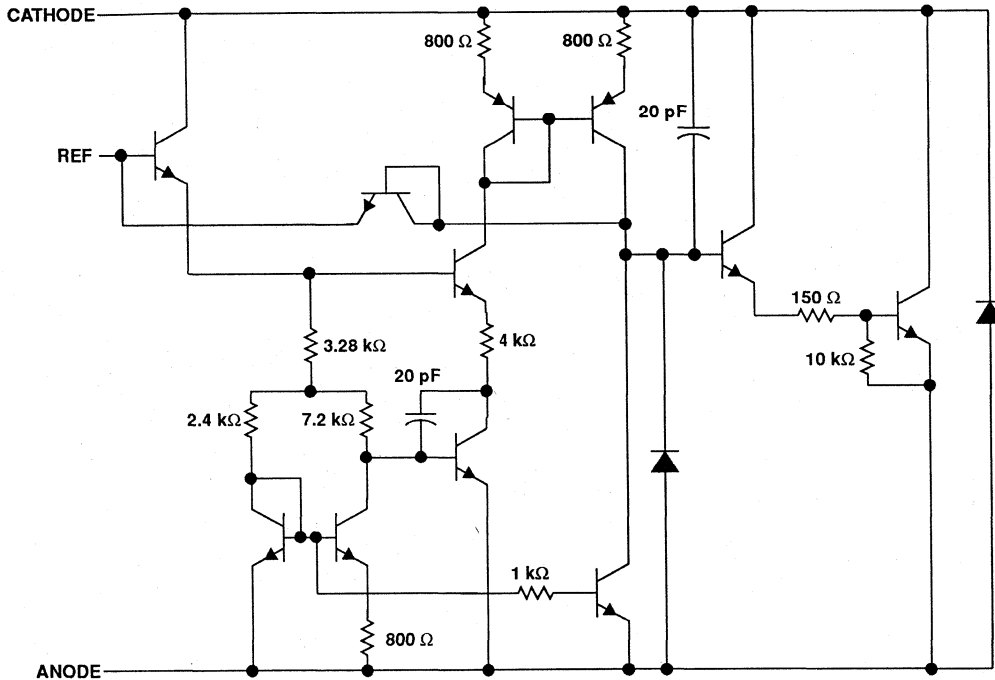
TL1431Y chip information

These chips, properly assembled, display characteristics similar to the TL1431 (see electrical table for TL1431Y). Thermal compression or ultrasonic bonding may be used on the doped aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



TL1431C, TL1431Q, TL1431Y PRECISION PROGRAMMABLE REFERENCE

equivalent schematic



All component values are nominal.

TL1431C, TL1431Q PRECISION PROGRAMMABLE REFERENCE

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|---------------------------------------|
| Cathode voltage (see Note 1) | 37 V |
| Continuous cathode current range | -100 mA to 150 mA |
| Reference input current range | -50 μ A to 10 mA |
| Continuous power dissipation | See Dissipation Rating Tables 1 and 2 |
| Operating free-air temperature range, T_A : C-suffix | 0°C to 70°C |
| Q-suffix | -40°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 1: All voltage values are with respect to the anode terminal unless otherwise noted.

TABLE 1. DISSIPATION RATING TABLE
FREE-AIR TEMPERATURE

| PACKAGE | DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$ | $T_A \leq 25^\circ\text{C}$ POWER RATING | $T_A = 70^\circ\text{C}$ POWER RATING | $T_A = 105^\circ\text{C}$ POWER RATING | $T_A = 125^\circ\text{C}$ POWER RATING |
|---------|---|---|--|---|---|
| D | 5.8 mW/ $^\circ\text{C}$ | 725 mW | 464 mW | 261 mW | 145 mW |
| LP | 6.2 mW/ $^\circ\text{C}$ | 775 mW | 496 mW | 279 mW | 155 mW |
| PK | 4.0 mW/ $^\circ\text{C}$ | 500 mW | 320 mW | 180 mW | 100 mW |

TABLE 2. DISSIPATION RATING TABLE
CASE TEMPERATURE

| PACKAGE | DERATING FACTOR ABOVE $T_C = 25^\circ\text{C}$ | $T_C \leq 25^\circ\text{C}$ POWER RATING | $T_C = 70^\circ\text{C}$ POWER RATING | $T_C = 105^\circ\text{C}$ POWER RATING | $T_C = 125^\circ\text{C}$ POWER RATING |
|---------|---|---|--|---|---|
| PK | 25 mW/ $^\circ\text{C}$ | 3125 mW | 2000 mW | 1125 mW | 625 mW |

recommended operating conditions

| | C-SUFFIX | | Q-SUFFIX | | UNIT |
|---------------------------------------|-----------|-----|-----------|-----|------------------|
| | MIN | MAX | MIN | MAX | |
| Cathode to anode voltage, V_{KA} | V_{ref} | 36 | V_{ref} | 36 | V |
| Cathode current, I_K | 1 | 100 | 1 | 100 | mA |
| Operating free-air temperature, T_A | 0 | 70 | -40 | 125 | $^\circ\text{C}$ |

TL1431C, TL1431Q PRECISION PROGRAMMABLE REFERENCE

electrical characteristics at specified free-air temperature, $I_K = 10 \text{ mA}$ (unless otherwise noted)

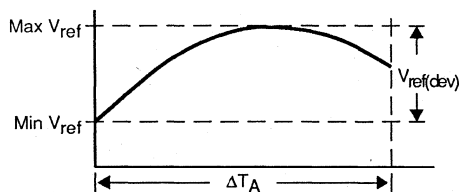
| PARAMETER | TEST CONDITIONS | T_A | TEST CIRCUIT | TL1431C | | | TL1431Q | | | UNIT |
|--|---|------------|--------------|---------|------|------|---------|------|------|---------------|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| V_{ref} Reference input voltage | $V_{KA} = V_{ref}$ | 25°C | 1 | 2490 | 2500 | 2510 | 2490 | 2500 | 2510 | mV |
| | | Full range | | 2480 | | 2520 | 2470 | | 2530 | |
| $V_{ref(dev)}$ Deviation of reference input voltage over full temperature range | $V_{KA} = V_{ref}$ | Full range | 1 | 4 | | 15 | 17 | | 30 | mV |
| $\frac{\Delta V_{ref}}{\Delta V_{KA}}$ Ratio of change in reference input voltage to the change in cathode voltage | $\Delta V_{KA} = 3 \text{ V to } 36 \text{ V}$ | Full range | 2 | -1.1 | | -2 | -1.1 | | -2 | mV/V |
| I_{ref} Reference input current | $R1 = 10 \text{ k}\Omega, R2 = \infty$ | 25°C | 2 | 1.5 | | 1.9 | 1.5 | | 1.9 | μA |
| | | Full range | | 2.3 | | | 2.3 | | | |
| $I_{ref(dev)}$ Deviation of reference input current over full temperature range | $R1 = 10 \text{ k}\Omega, R2 = \infty$ | Full range | 2 | 0.2 | | 1.2 | 0.5 | | 1.2 | μA |
| I_{min} Minimum cathode current for regulation | $V_{KA} = V_{ref} \text{ to } 36 \text{ V}$ | 25°C | 1 | 0.45 | | 1 | 0.45 | | 1 | mA |
| I_{off} Off-state cathode current | $V_{KA} = 36 \text{ V}, V_{ref} = 0$ | 25°C | 3 | 0.18 | | 0.5 | 0.18 | | 0.5 | μA |
| | | Full range | | 2 | | | 2 | | | |
| $ z_{ka} $ Output impedance [§] | $V_{KA} = V_{ref}, f \leq 1 \text{ kHz}, I_K = 1 \text{ mA to } 100 \text{ mA}$ | 25°C | 1 | 0.1 | | 0.2 | 0.1 | | 0.2 | Ω |

† Full range is 0°C to 70°C for C-suffix devices and -40°C to 125°C for Q-suffix devices.

The deviation parameters $V_{ref(dev)}$ and $I_{ref(dev)}$ are defined as the differences between the maximum and minimum values obtained over the rated temperature range. The average full-range temperature coefficient of the reference input voltage $\alpha_{V_{ref}}$ is defined as:

$$\alpha_{V_{ref}} \left(\frac{\text{ppm}}{^\circ\text{C}} \right) = \frac{\left(\frac{V_{ref(dev)}}{V_{ref \text{ at } 25^\circ\text{C}}} \right) \times 10^6}{\Delta T_A}$$

where ΔT_A is the rated operating temperature range of the device.



$\alpha_{V_{ref}}$ can be positive or negative depending on whether minimum V_{ref} or maximum V_{ref} , respectively, occurs at the lower temperature.

§ The output impedance is defined as: $|z_{ka}| = \frac{\Delta V_{KA}}{\Delta I_K}$

When the device is operating with two external resistors (see Figure 2), the total dynamic impedance of the circuit is given by:

$$|z'| = \frac{\Delta V}{\Delta I}, \text{ which is approximately equal to } |z_{ka}| \left(1 + \frac{R1}{R2} \right)$$

TL1431C, TL1431Q, TL1431Y PRECISION PROGRAMMABLE REFERENCE

electrical characteristics at 25°C free-air temperature, $I_K = 10 \text{ mA}$

| PARAMETER | TEST CONDITIONS | TEST CIRCUIT | TL1431Y | | | UNIT |
|---|--|--------------|---------|------|------|---------------|
| | | | MIN | TYP | MAX | |
| V_{ref} Reference input voltage | $V_{KA} = V_{\text{ref}}$ | 1 | 2490 | 2500 | 2510 | mV |
| $\frac{\Delta V_{\text{ref}}}{\Delta V_{KA}}$ Ratio of change in reference input voltage to the change in cathode voltage | $\Delta V_{KA} = 3 \text{ V to } 36 \text{ V}$ | 2 | | -1.1 | -2 | mV/V |
| I_{ref} Reference input current | $R1 = 10 \text{ k}\Omega, R2 = \infty$ | 2 | | 1.44 | 1.9 | μA |
| I_{min} Minimum cathode current for regulation | $V_{KA} = V_{\text{ref}} \text{ to } 36 \text{ V}$ | 1 | | 0.45 | 1 | mA |
| I_{off} Off-state cathode current | $V_{KA} = 36 \text{ V}, V_{\text{ref}} = 0$ | 3 | | .18 | 0.5 | μA |
| $ z_{ka} $ Output impedance ^s | $V_{KA} = V_{\text{ref}}, f \leq 1 \text{ kHz}, I_K = 1 \text{ mA to } 100 \text{ mA}$ | 1 | | 0.1 | 0.2 | Ω |

^sThe output impedance is defined as: $|z_{ka}| = \frac{\Delta V_{KA}}{\Delta I_K}$

When the device is operating with two external resistors (see Figure 2), the total dynamic impedance of the circuit is given by:

$$|z'| = \frac{\Delta V}{\Delta I}, \text{ which is approximately equal to } |z_{ka}| \left(1 + \frac{R1}{R2} \right)$$

PARAMETER MEASUREMENT INFORMATION

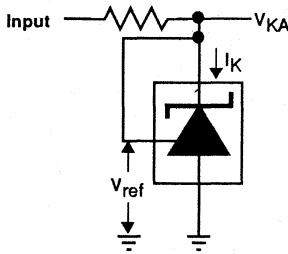


Figure 1. Test Circuit for $V_{KA} = V_{\text{ref}}$

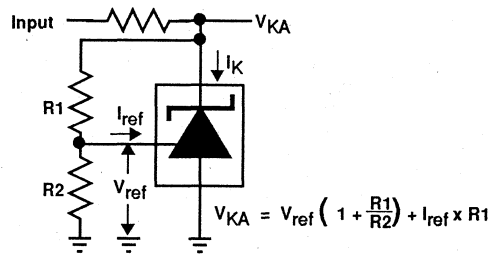


Figure 2. Test Circuit for $V_{KA} > V_{\text{ref}}$

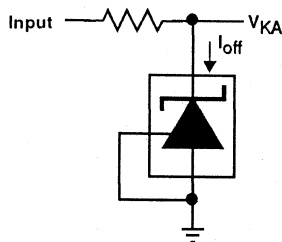


Figure 3. Test Circuit for I_{off}

TL1431C, TL1431Q, TL1431Y PRECISION PROGRAMMABLE REFERENCE

TYPICAL CHARACTERISTICS

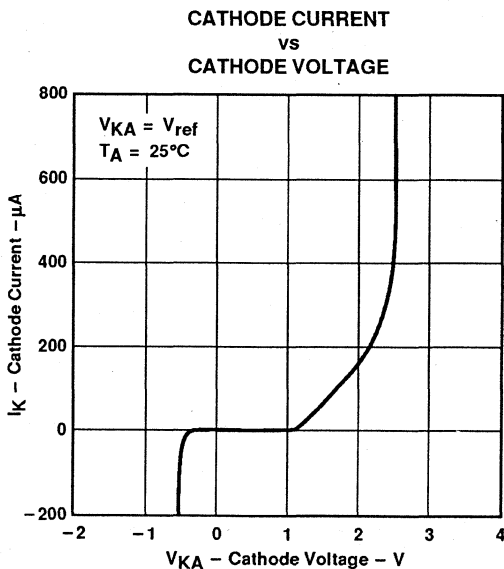
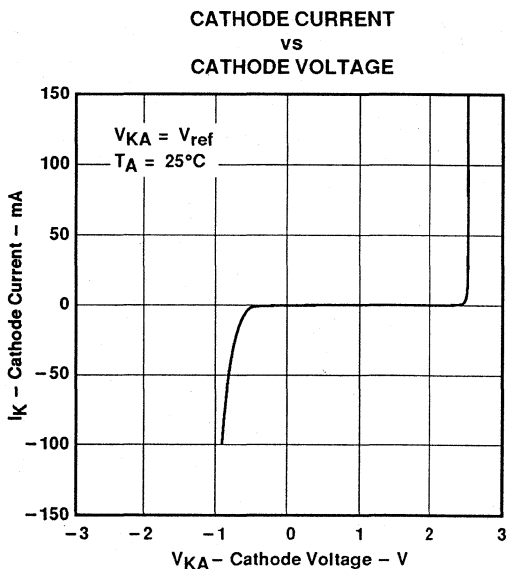
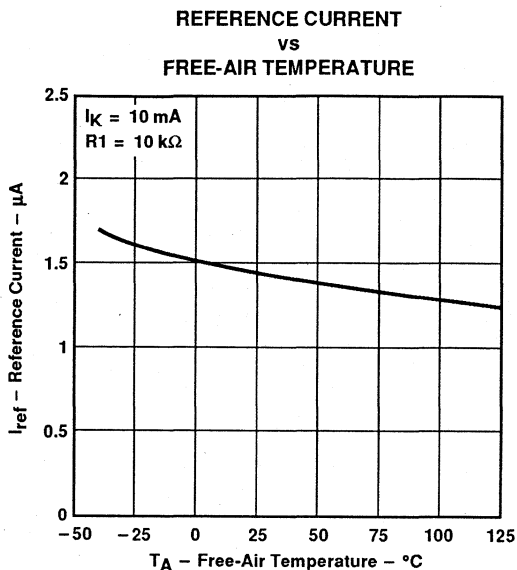
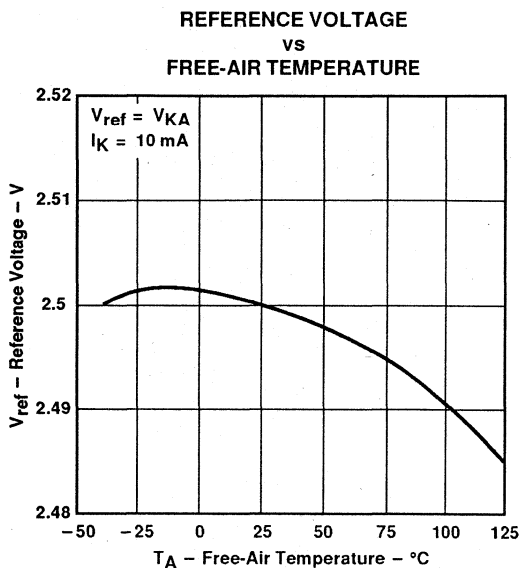
table of graphs

| | | | FIGURE |
|------------------|---|--|----------|
| V_{ref} | Reference voltage | vs Temperature | 4 |
| I_{ref} | Reference current | vs Temperature | 5 |
| I_K | Cathode current | vs Cathode voltage | 6 and 7 |
| I_{off} | Off-state cathode current | vs Temperature | 8 |
| ΔV_{ref} | Ratio of delta reference voltage to delta cathode voltage | vs Temperature | 9 |
| V_n | Noise voltage | vs Frequency over a 10-second time-period | 10 11 |
| A_v | Voltage amplification | vs Frequency | 12 |
| $ z_{ka} $ | Reference impedance | vs Frequency | 13 |
| | Pulse response | | 14 |
| | Stability boundary conditions | | 15 |

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TYPICAL CHARACTERISTICS†



†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS†

OFF-STATE CATHODE CURRENT
vs
FREE-AIR TEMPERATURE

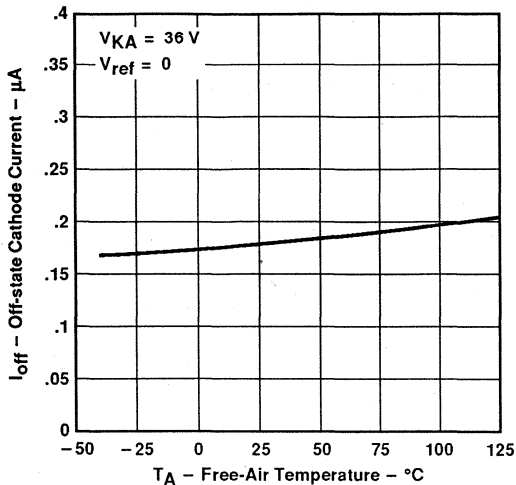


Figure 8

RATIO OF DELTA REFERENCE VOLTAGE TO
DELTA CATHODE VOLTAGE
vs
FREE-AIR TEMPERATURE

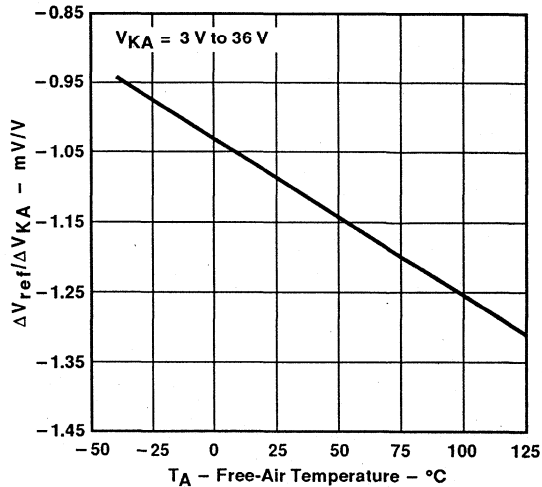


Figure 9

EQUIVALENT INPUT NOISE VOLTAGE
vs
FREQUENCY

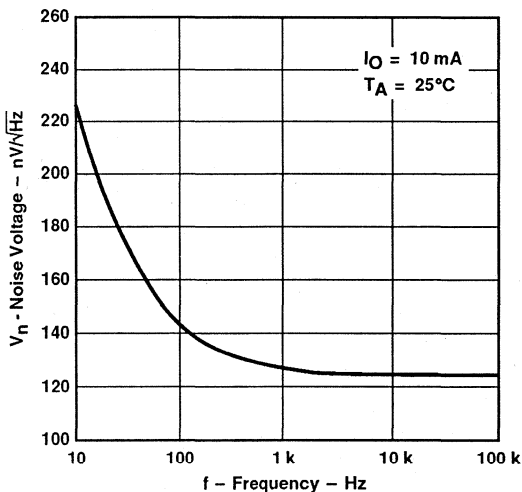
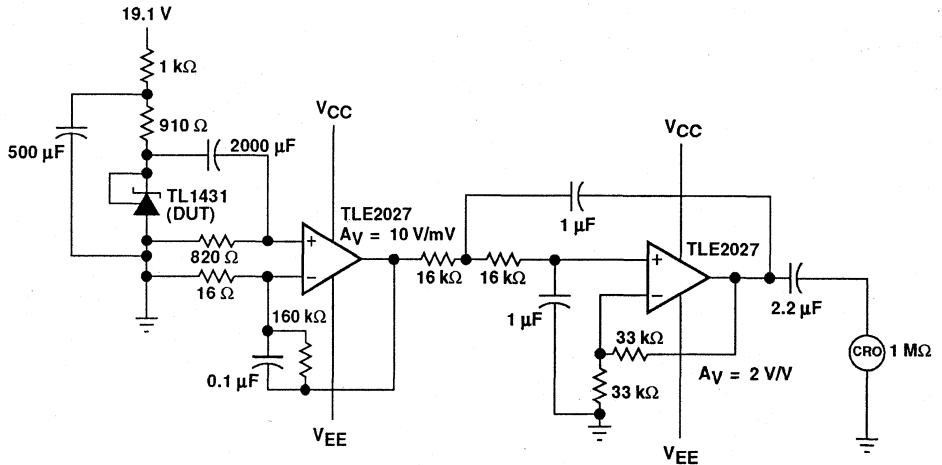
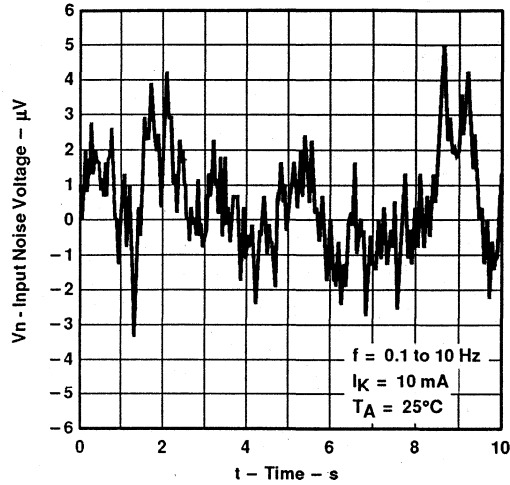


Figure 10

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

EQUIVALENT INPUT NOISE VOLTAGE
 OVER A 10-SECOND PERIOD

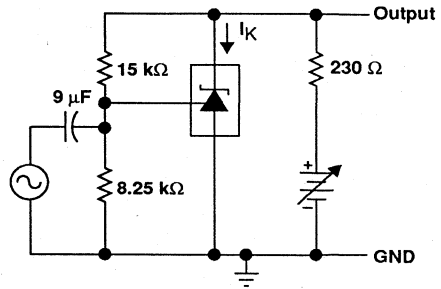
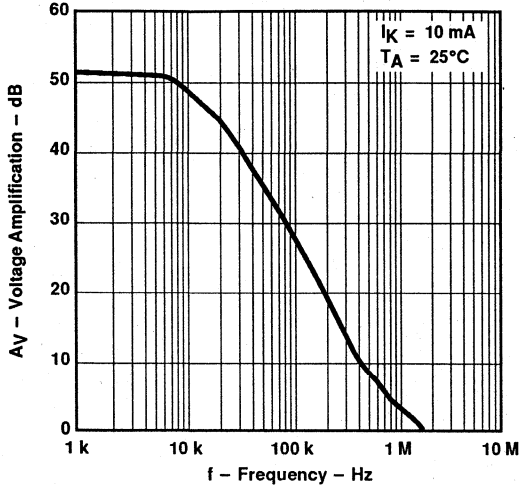


Test Circuit for 0.1-Hz to 10-Hz Equivalent Input Noise Voltage

Figure 11

TYPICAL CHARACTERISTICS

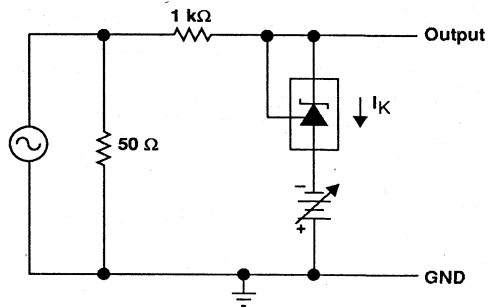
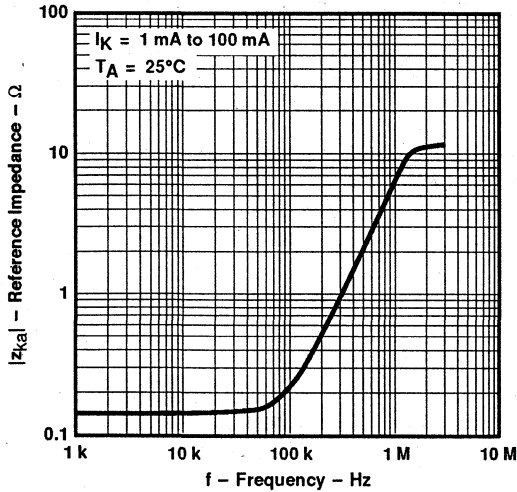
SMALL-SIGNAL VOLTAGE AMPLIFICATION
vs
FREQUENCY



Test Circuit for Voltage Amplification

Figure 12

REFERENCE IMPEDANCE
vs
FREQUENCY



Test Circuit for Reference Impedance

Figure 13

TYPICAL CHARACTERISTICS

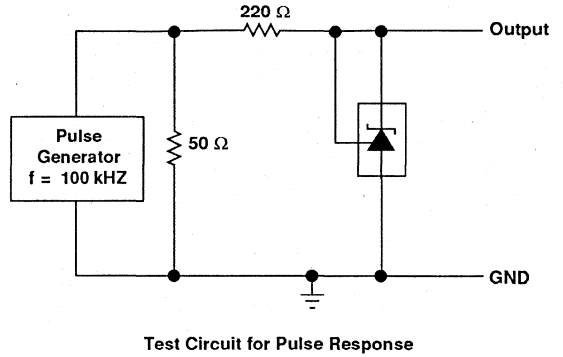
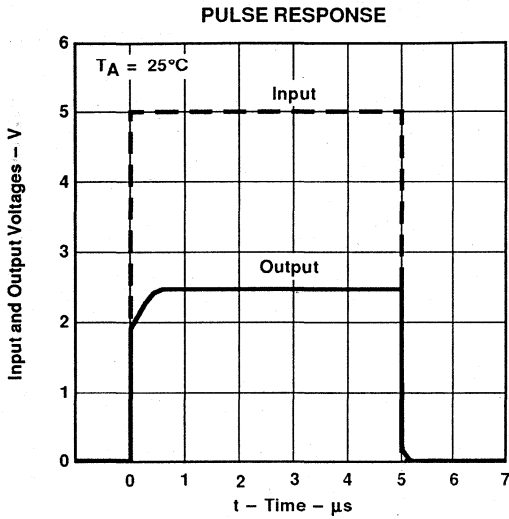
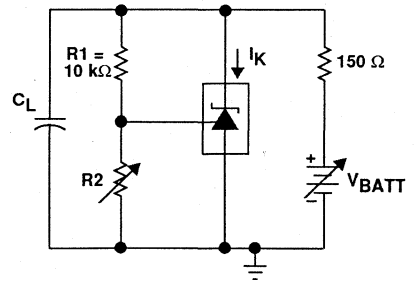
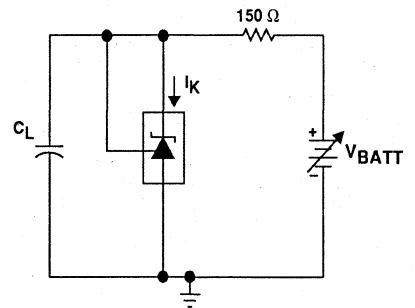
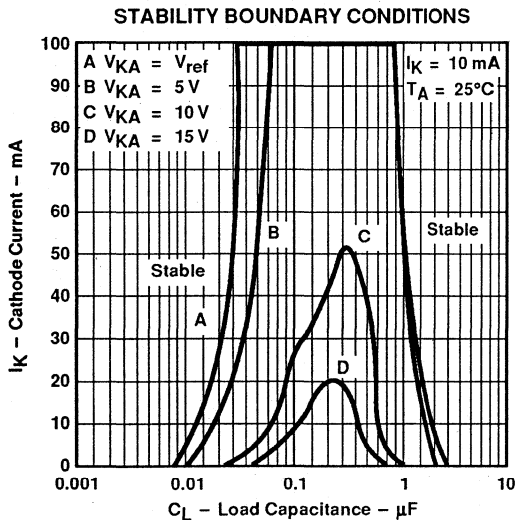


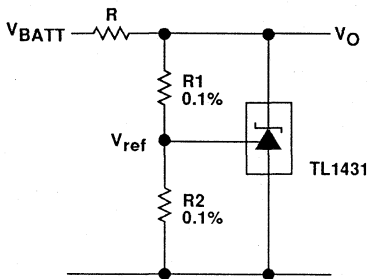
Figure 14



†The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R2 and V+ were adjusted to establish the initial V_{KA} and I_K conditions with $C_L = 0$. V_{BATT} and C_L were then adjusted to determine the ranges of stability.

Figure 15

APPLICATION INFORMATION



$$V_O = \left(1 + \frac{R1}{R2}\right)V_{ref}$$

NOTE: R should provide ≥ 1 -mA cathode current to the TL1431 at minimum V_{BATT} .

Figure 16. Shunt Regulator

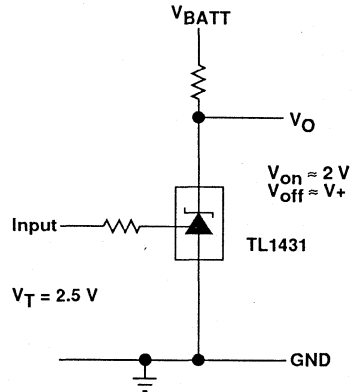
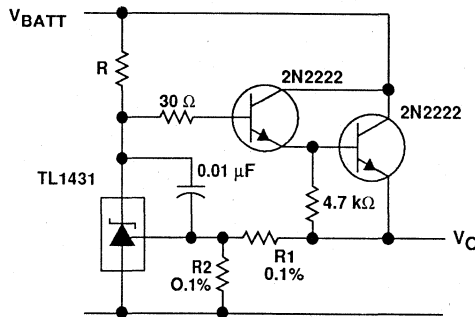


Figure 17. Single-Supply Comparator With Temperature-Compensated Threshold



$$V_O = \left(1 + \frac{R1}{R2}\right)V_{ref}$$

NOTE: R should provide ≥ 1 -mA cathode current to the TL1431 at minimum V_{BATT} .

Figure 18. Precision High-Current Series Regulator

APPLICATION INFORMATION

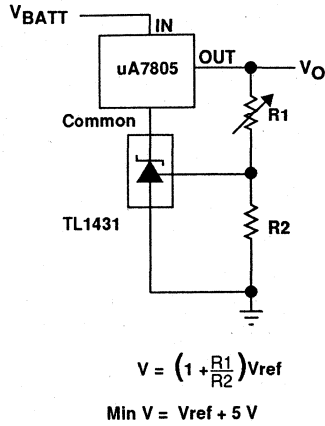


Figure 19. Output Control of a 3-Terminal Fixed Regulator

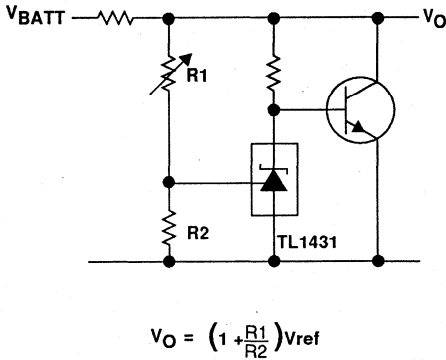
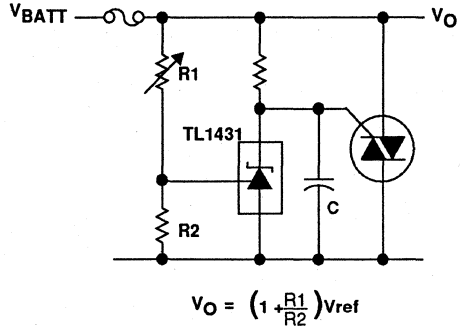


Figure 20. Higher-Current Shunt Regulator



Note: Refer to the stability boundary conditions on Figure 15 to determine allowable values for the capacitor.

Figure 21. Crowbar

APPLICATION INFORMATION

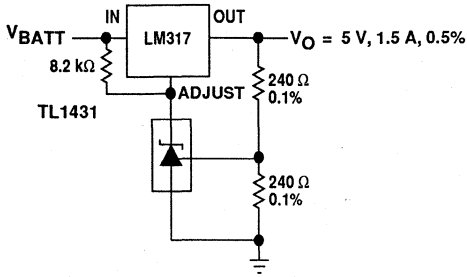
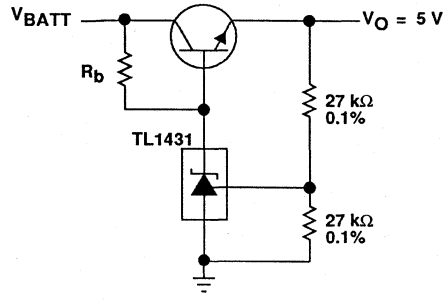


Figure 22. Precision 5-V, 1.5-A, 0.5% Regulator



Note: R_b should provide ≥ 1 -mA cathode current to the TL1431.

Figure 23. Efficient 5-V, Precision Regulator

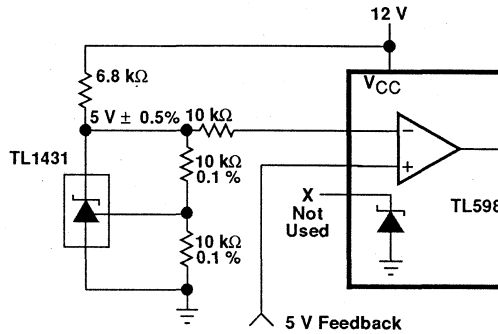


Figure 24. PWM Down Converter With 0.5% Reference

APPLICATION INFORMATION

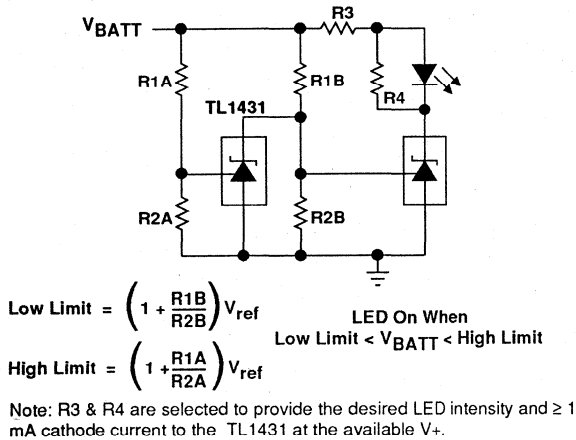


Figure 25. Voltage Monitor

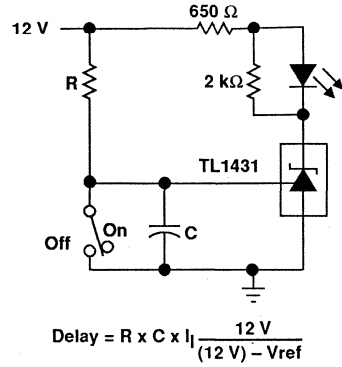


Figure 26. Delay Timer

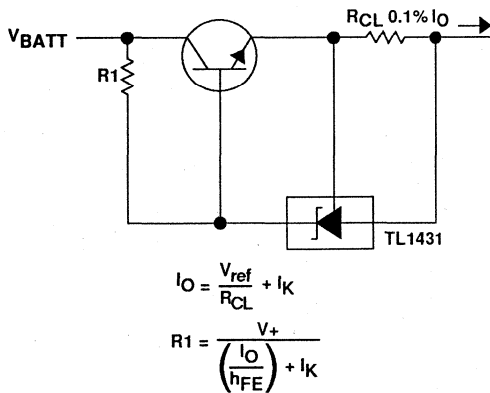


Figure 27. Precision Current Limiter

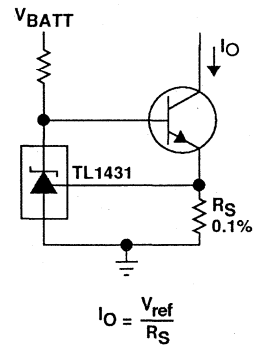


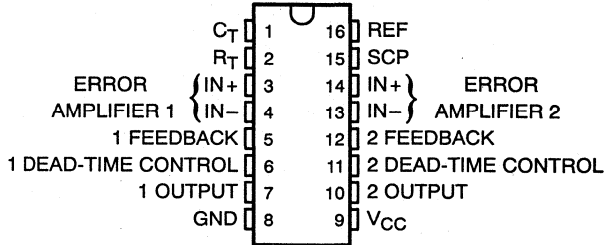
Figure 28. Precision Constant-Current Sink

TL1451AC DUAL PULSE-WIDTH-MODULATION CONTROL CIRCUIT

D2730, FEBRUARY 1983—REVISED AUGUST 1991

- Complete PWM Power Control Circuitry
- Completely Synchronized Operation
- Internal Undervoltage Lockout Protection
- Wide Supply Voltage Range
- Internal Short-Circuit Protection
- Oscillator Frequency . . . 500 kHz Max
- Variable Dead Time Provides Control Over Total Range
- Internal Regulator Provides a Stable 2.5-V Reference Supply

DB†, N, NS, OR PW† PACKAGE
(TOP VIEW)



† The DB and PW packages are only available left-end taped and reeled (add LE suffix, i.e., TL1451ACPWLE)

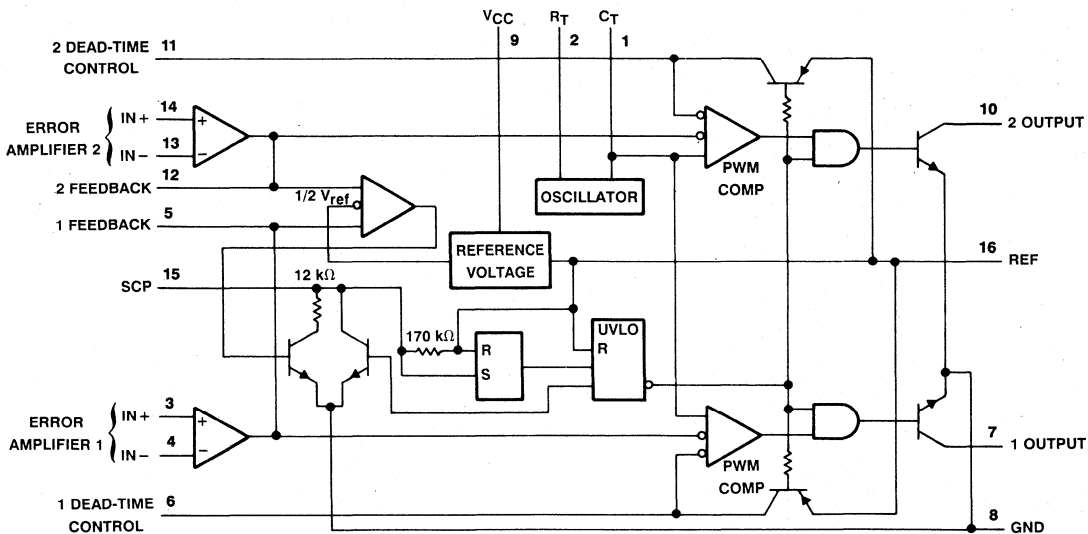
description

The TL1451AC incorporates on a single monolithic chip all the functions required in the construction of two pulse-width-modulation control circuits. Designed primarily for power supply control, the TL1451AC contains an on-chip 2.5-V regulator, two error amplifiers, an adjustable oscillator, two dead-time comparators, undervoltage lockout circuitry, and dual common-emitter output transistor circuits.

The uncommitted output transistors provide common-emitter output capability for each controller. The internal amplifiers exhibit a common-mode voltage range from 1.04 V to 1.45 V. The dead-time control comparator has no offset unless externally altered and may be used to provide 0% to 100% dead time. The on-chip oscillator may be operated by terminating R_T and C_T . During low V_{CC} conditions, the undervoltage lockout control circuit feature locks the outputs off until the internal circuitry is operational.

The TL1451AC is characterized for operation from -20°C to 85°C .

functional block diagram



PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

**TEXAS
INSTRUMENTS**

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2-319

TL1451AC

DUAL PULSE-WIDTH-MODULATION CONTROL CIRCUIT

absolute maximum ratings over operating free-air temperature range

| | |
|--|------------------------------|
| Supply voltage, V_{CC} | 51 V |
| Amplifier input voltage | 20 V |
| Collector output voltage | 51 V |
| Collector output current | 21 mA |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range | -20°C to 85°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$ | $T_A = 70^\circ\text{C}$ POWER RATING | $T_A = 85^\circ\text{C}$ POWER RATING |
|---------|---|---|--|--|
| DB | 775 mW | 6.2 mW/°C | 496 mW | 403 mW |
| N | 1000 mW | 8.0 mW/°C | 640 mW | 520 mW |
| NS | 500 mW | 4.0 mW/°C | 320 mW | 260 mW |
| PW | 700 mW | 5.6 mW/°C | 448 mW | 364 mW |

recommended operating conditions

| | MIN | MAX | UNIT |
|---------------------------------------|------|-------|---------------|
| Supply voltage, V_{CC} | 3.6 | 50 | V |
| Amplifier input voltage, V_I | 1.05 | 1.45 | V |
| Collector output voltage, V_O | | 50 | V |
| Collector output current | | 20 | mA |
| Current into feedback terminal | | 45 | μA |
| Feedback resistor, R_F | 100 | | k Ω |
| Timing capacitor, C_T | 150 | 15000 | pF |
| Timing resistor, R_T | 5.1 | 100 | k Ω |
| Oscillator frequency | 1 | 500 | kHz |
| Operating free-air temperature, T_A | -20 | 85 | °C |

electrical characteristics over recommended operating free-air temperature range, $V_{CC} = 6\text{ V}$, $f = 200\text{ kHz}$ (unless otherwise noted)

reference section

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|--|---|-----|-------|-----------|------|
| Output voltage (pin 16) | $I_O = 1\text{ mA}$ | 2.4 | 2.5 | 2.6 | V |
| Output voltage change with temperature | $T_A = -20^\circ\text{C}$ to 25°C | | -0.1% | $\pm 1\%$ | |
| | $T_A = 25^\circ\text{C}$ to 85°C | | -0.2% | $\pm 1\%$ | |
| Input regulation | $V_{CC} = 3.6\text{ V}$ to 40 V | | 2 | 12.5 | mV |
| Output regulation | $I_O = 0.1\text{ mA}$ to 1 mA | | 1 | 7.5 | mV |
| Short-circuit output current | $V_O = 0$ | 3 | 10 | 30 | mA |

undervoltage lockout section

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|---------------------------------|---|-----|------|-----|------|
| Upper threshold voltage (pin 9) | $I_{Oref} = 0.1\text{ mA}$, $T_A = 25^\circ\text{C}$ | | 2.72 | | V |
| Lower threshold voltage (pin 9) | | | 2.6 | | V |
| Hysteresis (pin 9) | | 80 | 120 | | mV |
| Reset threshold voltage (pin 9) | | 1.5 | 1.9 | | V |

† All typical values are at $T_A = 25^\circ\text{C}$.



TL1451AC

DUAL PULSE-WIDTH-MODULATION CONTROL CIRCUIT

electrical characteristics over recommended operating free-air temperature range, $V_{CC} = 6\text{ V}$, $f = 200\text{ kHz}$ (unless otherwise noted) (continued)

protection control section

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|--|---|------|------|------|---------------|
| Input threshold voltage (pin 15) | $T_A = 25^\circ\text{C}$ | 0.65 | 0.7 | 0.75 | V |
| Standby voltage (pin 15) | No pullup | 140 | 185 | 230 | mV |
| Latched input voltage (pin 15) | No pullup | | 60 | 120 | mV |
| Input (source) current | $V_I = 0.7\text{ V}$, $T_A = 25^\circ\text{C}$ | -10 | -15 | -20 | μA |
| Comparator threshold voltage (pins 5 and 12) | | | 1.18 | | V |

oscillator section

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|-----------------------------------|---|-----|-------|-----------|------|
| Frequency | $C_T = 330\text{ pF}$, $R_T = 10\text{ k}\Omega$ | | 200 | | kHz |
| Standard deviation of frequency | $C_T = 330\text{ pF}$, $R_T = 10\text{ k}\Omega$ | | 10% | | |
| Frequency change with voltage | $V_{CC} = 3.6\text{ V to }40\text{ V}$ | | 1% | | |
| Frequency change with temperature | $T_A = -20^\circ\text{C to }25^\circ\text{C}$ | | -0.4% | $\pm 2\%$ | |
| | $T_A = 25^\circ\text{C to }85^\circ\text{C}$ | | -0.2% | $\pm 2\%$ | |

dead-time control section

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|--|-------------------------------|-----|------|------|---------------|
| Input bias current (pins 6 and 11) | | | | 1 | μA |
| Latch mode (source) current (pins 6 and 11) | $T_A = 25^\circ\text{C}$ | -80 | -145 | | μA |
| Latched input voltage (pins 6 and 11) | $I_O = 40\text{ }\mu\text{A}$ | 2.3 | | | V |
| Input threshold voltage at $f = 10\text{ kHz}$ (pins 6 and 11) | Zero duty cycle | | 2.05 | 2.25 | V |
| | Maximum duty cycle | 1.2 | 1.45 | | |

error-amplifier section

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|---|--|-----------------|------|-----------|---------------|
| Input offset voltage | V_O (pins 5 and 12) = 1.25 V | | | ± 6 | mV |
| Input offset current | V_O (pins 5 and 12) = 1.25 V | | | ± 100 | nA |
| Input bias current | V_O (pins 5 and 12) = 1.25 V | | 160 | 500 | nA |
| Common-mode input voltage range | $V_{CC} = 3.6\text{ V to }40\text{ V}$ | 1.05 | | | V |
| | | to 1.45 | | | |
| Open-loop voltage amplification | $R_F = 200\text{ k}\Omega$ | 70 | 80 | | dB |
| Unity-gain bandwidth | | | 1.5 | | MHz |
| Common-mode rejection ratio | | | 60 | 80 | dB |
| Positive output voltage swing | | $V_{ref} - 0.1$ | | | V |
| Negative output voltage swing | | | | 1 | V |
| Output (sink) current (pins 5 and 12) | $V_{ID} = -0.1\text{ V}$, $V_O = 1.25\text{ V}$ | 0.5 | 1.6 | | mA |
| Output (source) current (pins 5 and 12) | $V_{ID} = 0.1\text{ V}$, $V_O = 1.25\text{ V}$ | -45 | -70 | | μA |

† All typical values are at $T_A = 25^\circ\text{C}$.

TL1451AC

DUAL PULSE-WIDTH-MODULATION CONTROL CIRCUIT

electrical characteristics over recommended operating free-air temperature range, $V_{CC} = 6\text{ V}$, $f = 200\text{ kHz}$ (unless otherwise noted) (continued)

output section

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|------------------------------|----------------------|-----|------|-----|---------------|
| Collector off-state current | $V_O = 50\text{ V}$ | | | 10 | μA |
| Output saturation voltage | $I_O = 10\text{ mA}$ | | 1.2 | 2 | V |
| Short-circuit output current | $V_O = 6\text{ V}$ | | 90 | | mA |

pwm comparator section

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|--|--------------------|-----|------|------|------|
| Input threshold voltage at $f = 10\text{ kHz}$ (pins 5 and 12) | Zero duty cycle | | 2.05 | 2.25 | V |
| | Maximum duty cycle | 1.2 | 1.45 | | |

total device

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|------------------------|---------------------------|-----|------|-----|------|
| Standby supply current | Off-state | | 1.3 | 1.8 | mA |
| Average supply current | $R_T = 10\text{ k}\Omega$ | | 1.7 | 2.4 | mA |

† All typical values are at $T_A = 25^\circ\text{C}$.

PARAMETER MEASUREMENT INFORMATION

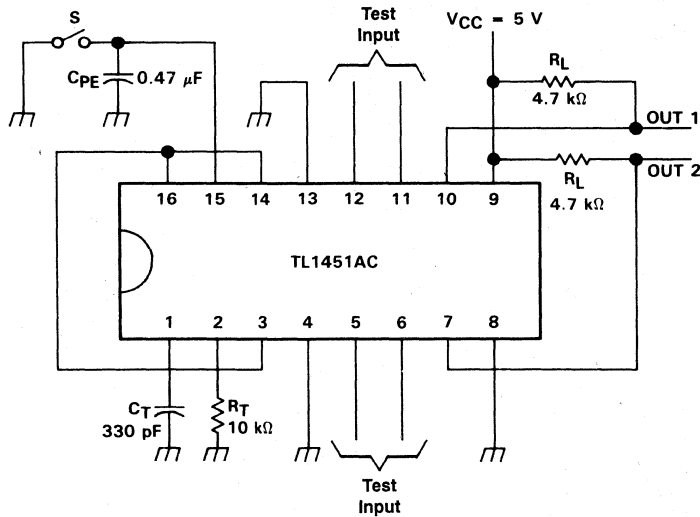


Figure 1. Test Circuit

PARAMETER MEASUREMENT INFORMATION

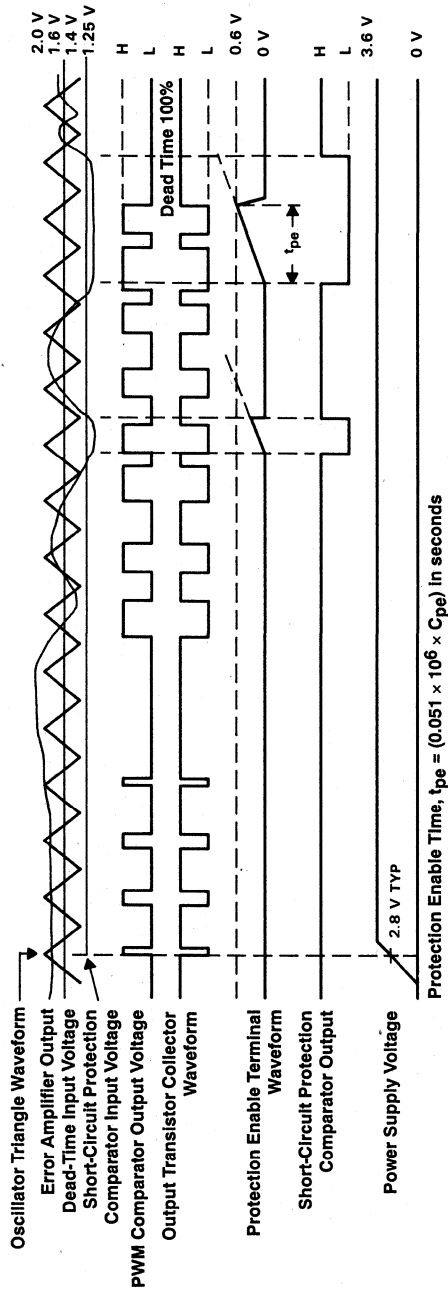


Figure 2. TL1451AC Timing Diagram

TYPICAL CHARACTERISTICS

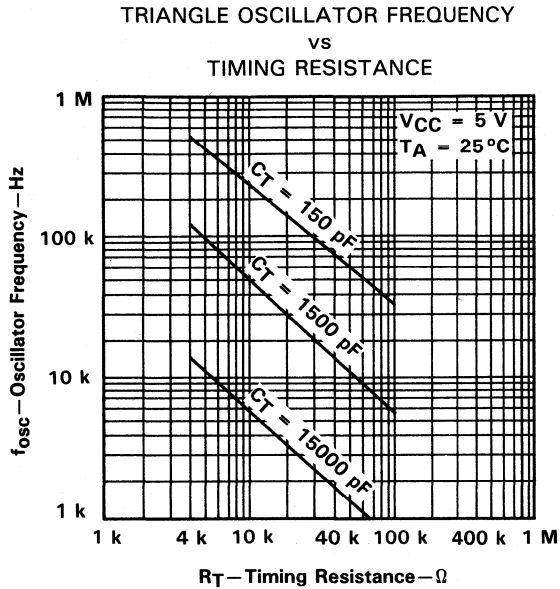


Figure 3

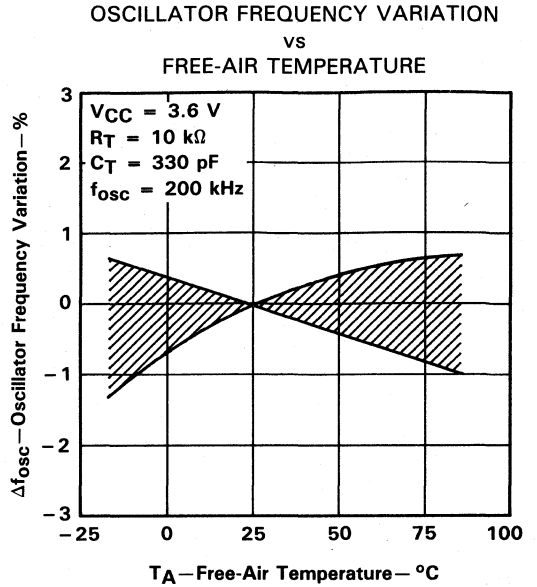


Figure 4

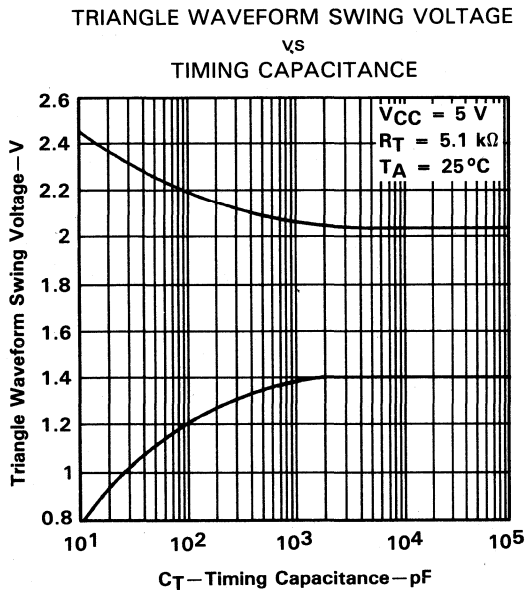


Figure 5

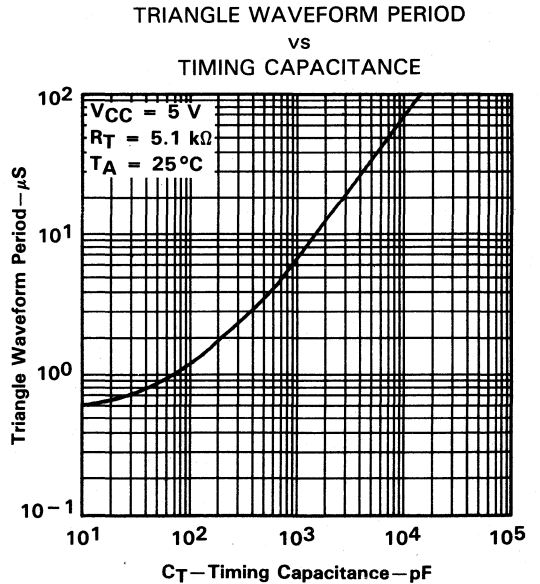


Figure 6

TYPICAL CHARACTERISTICS

REFERENCE OUTPUT VOLTAGE VARIATION
 vs
 FREE-AIR TEMPERATURE

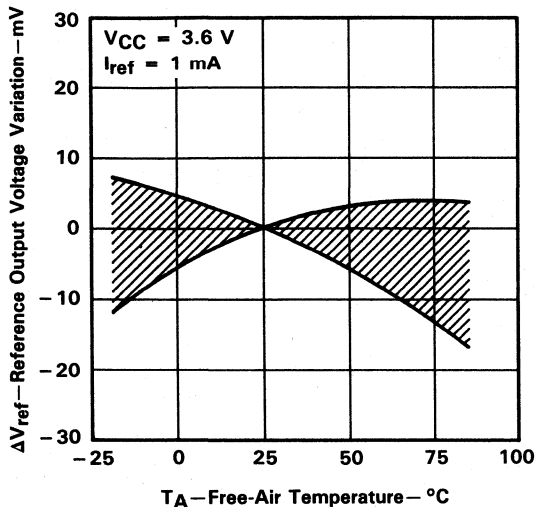


Figure 7

REFERENCE OUTPUT VOLTAGE VARIATION
 vs
 FREE-AIR TEMPERATURE

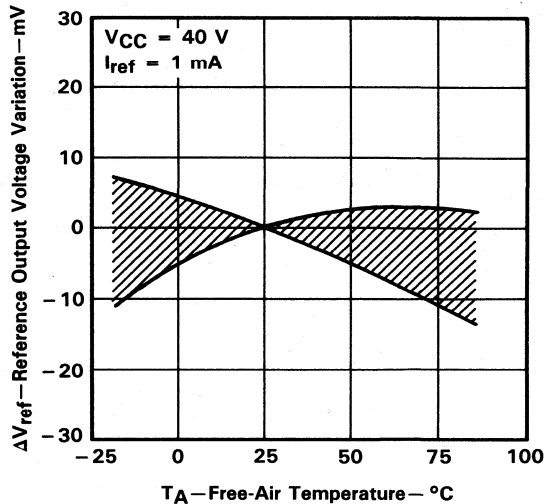


Figure 8

REFERENCE OUTPUT VOLTAGE
 vs
 SUPPLY VOLTAGE

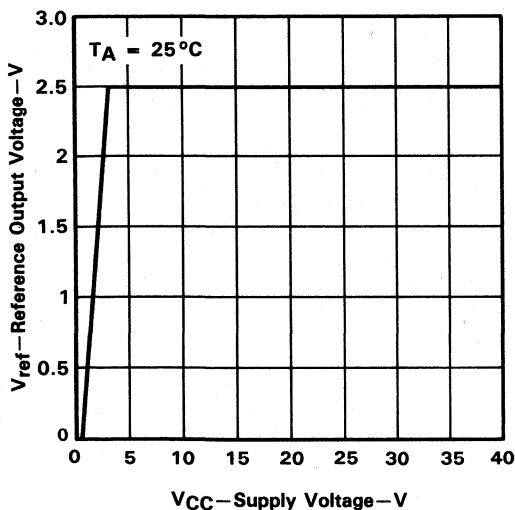


Figure 9

DROP-OUT VOLTAGE VARIATION
 vs
 FREE-AIR TEMPERATURE

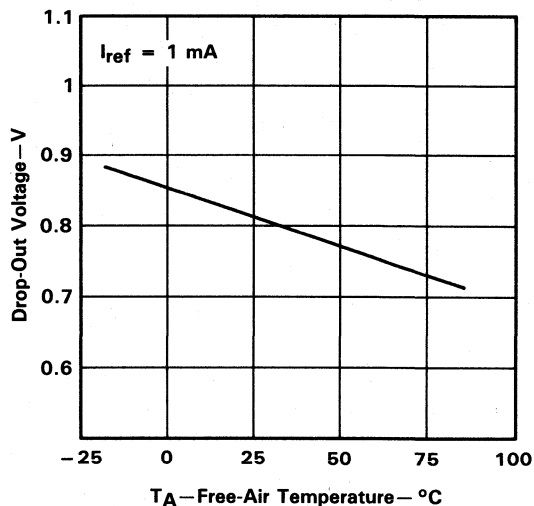


Figure 10

TYPICAL CHARACTERISTICS

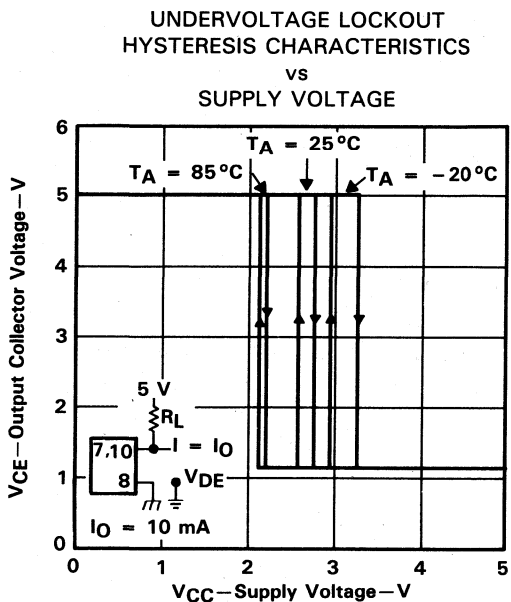


Figure 11

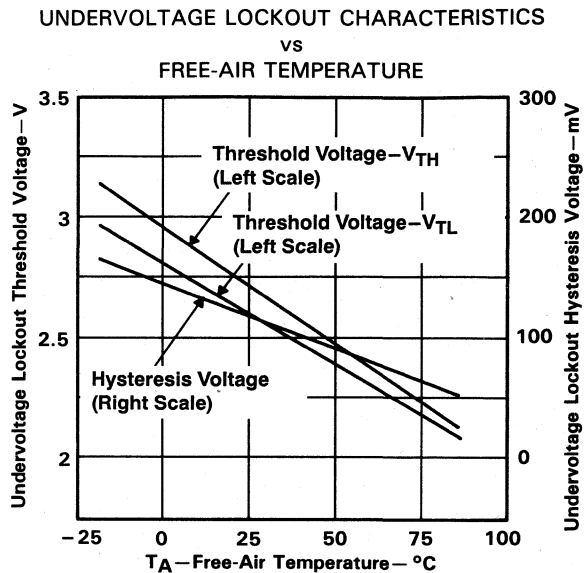


Figure 12

SHORT-CIRCUIT PROTECTION CHARACTERISTICS
 vs
 FREE-AIR TEMPERATURE

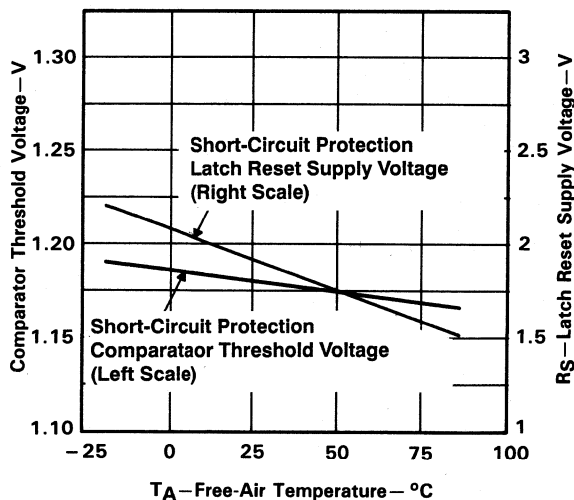


Figure 13

TYPICAL CHARACTERISTICS

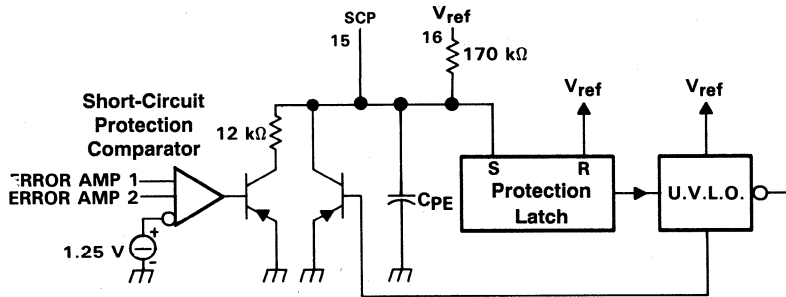
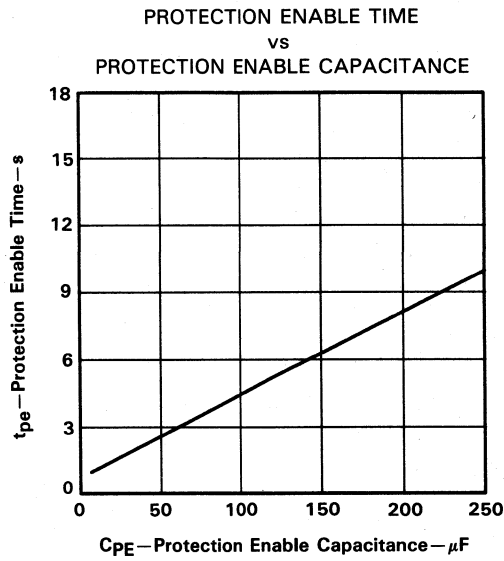


Figure 14

TL1451AC DUAL PULSE-WIDTH-MODULATION CONTROL CIRCUIT

TYPICAL CHARACTERISTICS

ERROR AMP MAXIMUM OUTPUT VOLTAGE SWING

vs
FREQUENCY

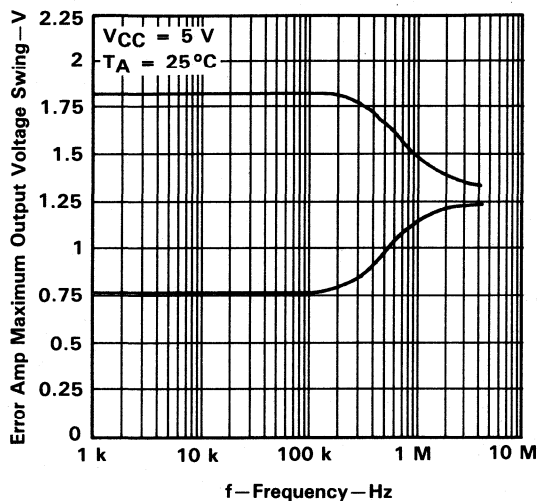


Figure 15

OPEN-LOOP VOLTAGE AMPLIFICATION

vs
FREQUENCY

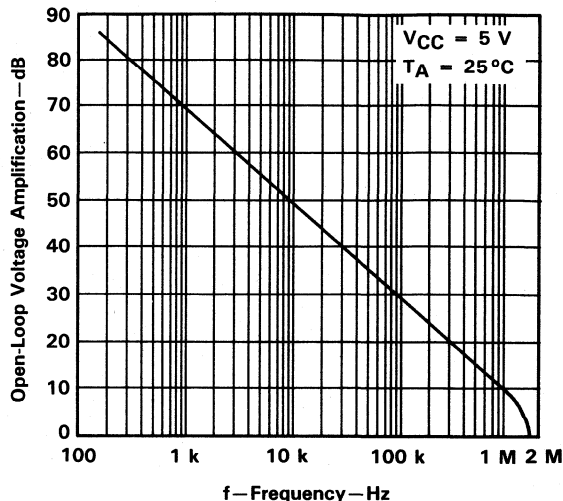


Figure 16

GAIN OF AN AMPLIFIER
IN UNITY-GAIN CONFIGURATION

vs
FREQUENCY

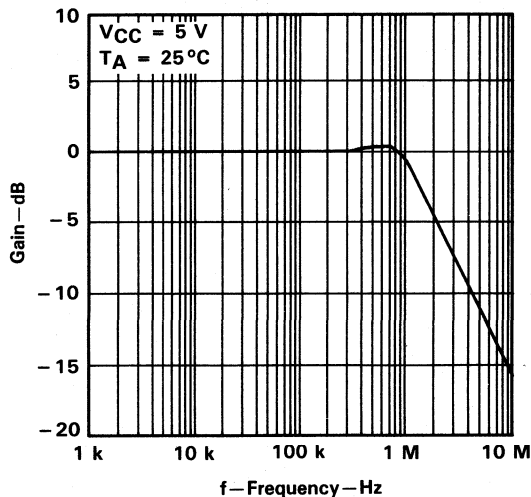
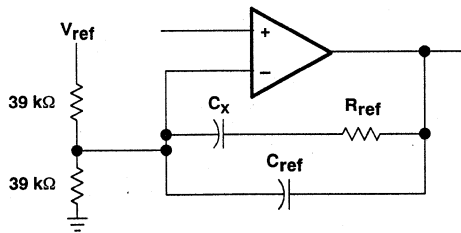
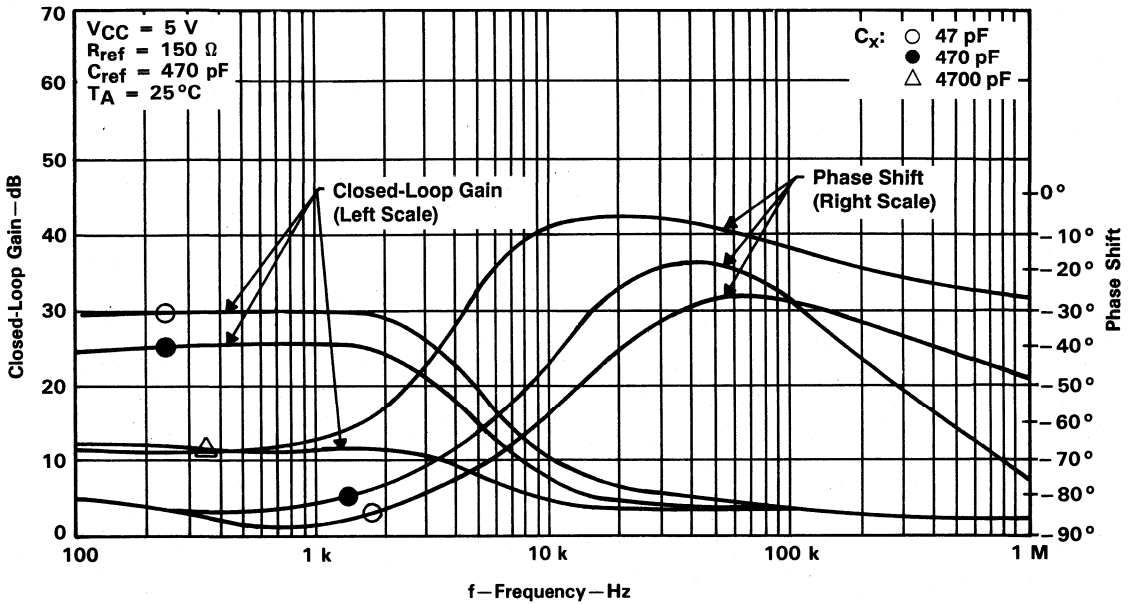


Figure 17

TYPICAL CHARACTERISTICS

CLOSED-LOOP GAIN AND PHASE SHIFT
 VS
 FREQUENCY



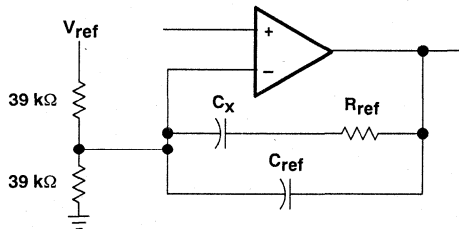
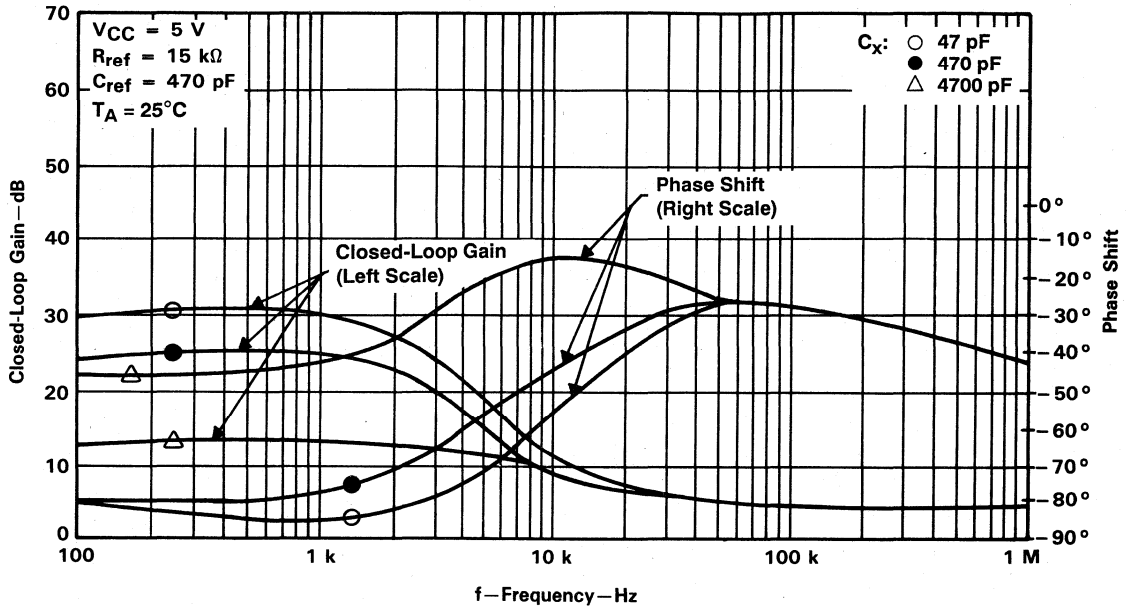
TEST CIRCUIT

Figure 18

TL1451AC
DUAL PULSE-WIDTH-MODULATION CONTROL CIRCUIT

TYPICAL CHARACTERISTICS

CLOSED-LOOP GAIN AND PHASE SHIFT
 VS
 FREQUENCY

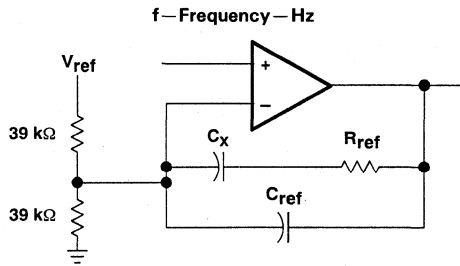
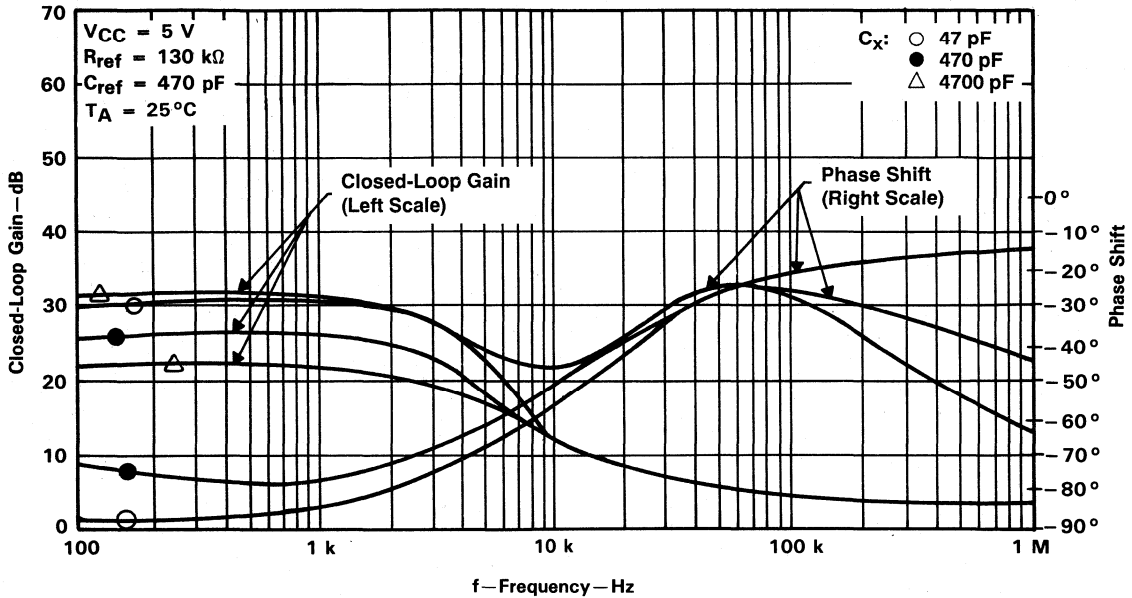


TEST CIRCUIT

Figure 19

TYPICAL CHARACTERISTICS

CLOSED-LOOP GAIN AND PHASE SHIFT
 VS
 FREQUENCY



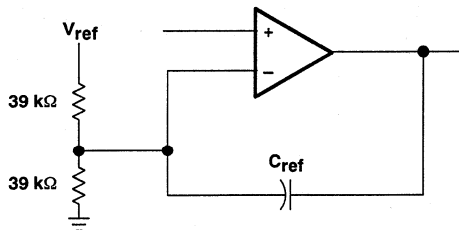
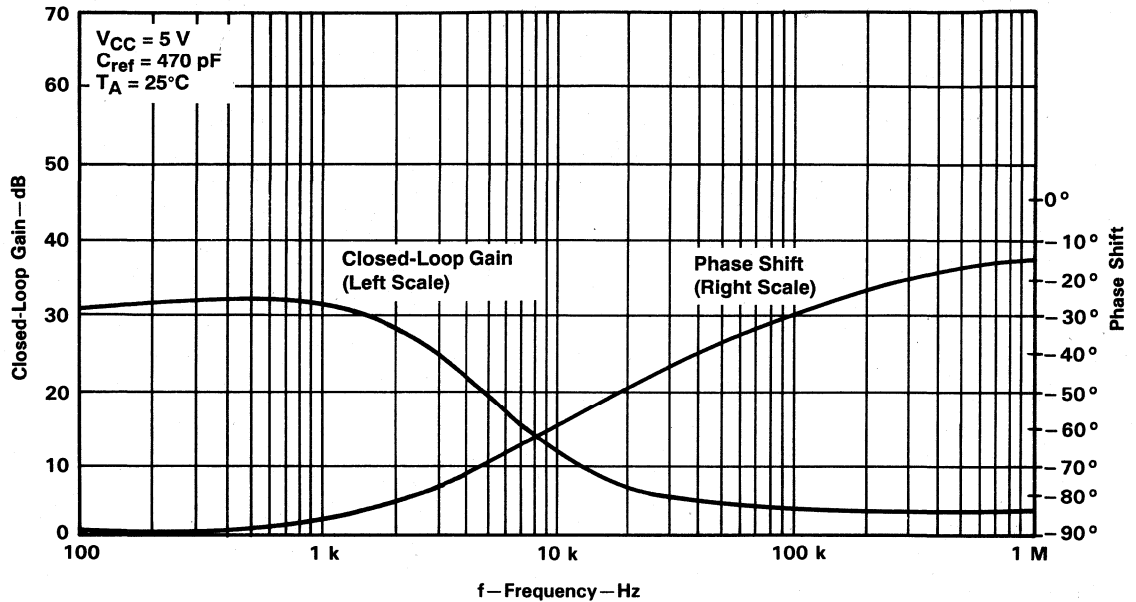
TEST CIRCUIT

Figure 20

TL1451AC
DUAL PULSE-WIDTH-MODULATION CONTROL CIRCUIT

TYPICAL CHARACTERISTICS

CLOSED-LOOP GAIN AND PHASE SHIFT
 vs
 FREQUENCY



TEST CIRCUIT

Figure 21

TYPICAL CHARACTERISTICS

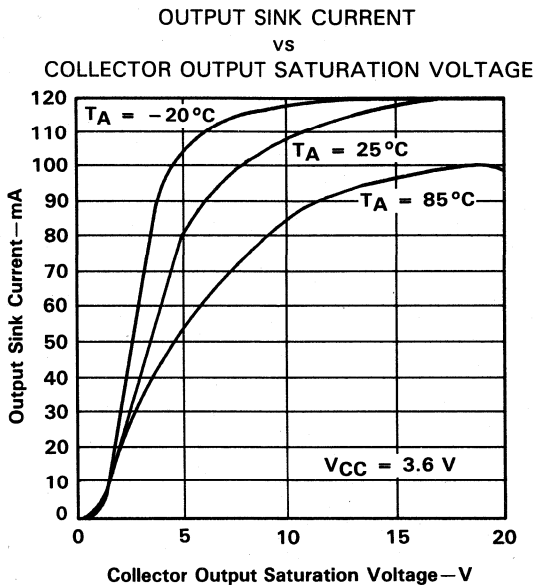


Figure 22

MAXIMUM OUTPUT VOLTAGE SWING
vs
FREE-AIR TEMPERATURE

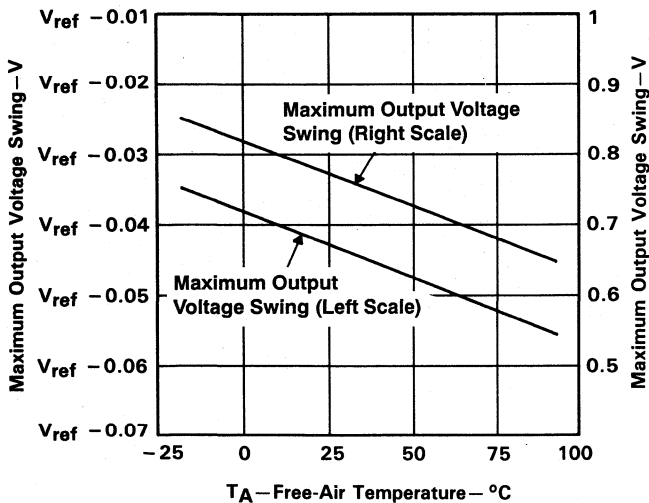
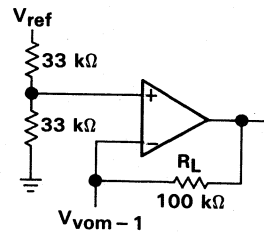


Figure 23



$V_{CC} = 3.6\text{ V}$
 $R_L = 100\text{ k}\Omega$
 $V_{vom} +1 = 1.25\text{ V}$
 $V_{vom} -1 = 1.15\text{ V}$ (Right Scale)
 $V_{vom} -1 = 1.35\text{ V}$ (Left Scale)

TEST CIRCUIT

TL1451AC DUAL PULSE-WIDTH-MODULATION CONTROL CIRCUIT

TYPICAL CHARACTERISTICS

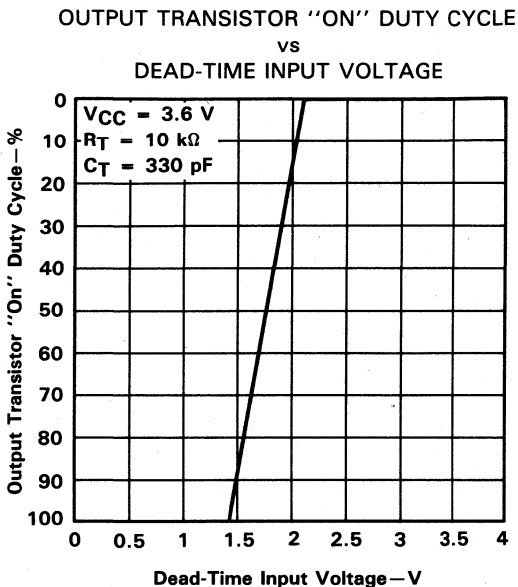


Figure 24

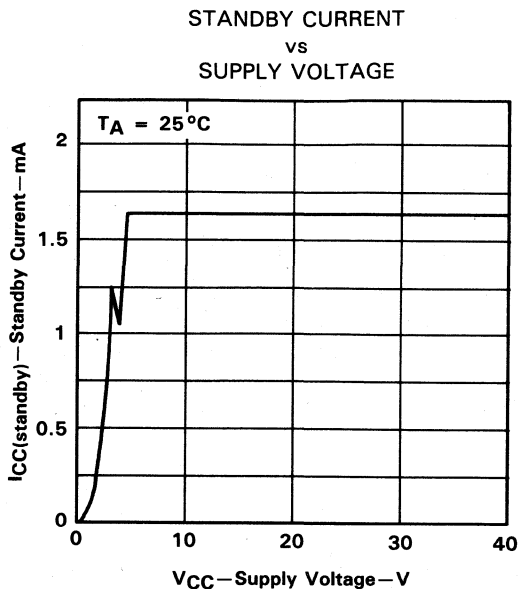


Figure 25

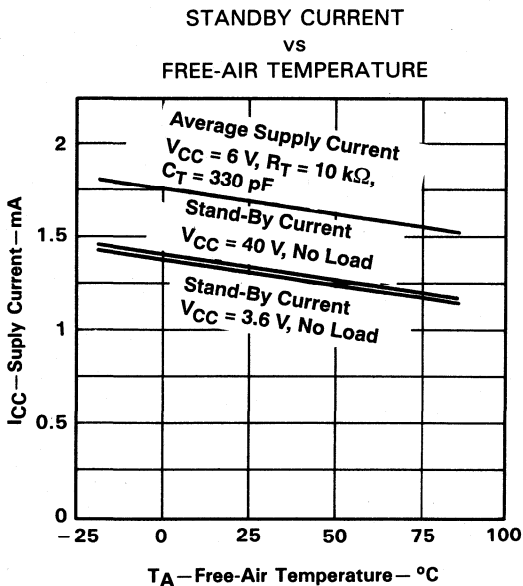


Figure 26

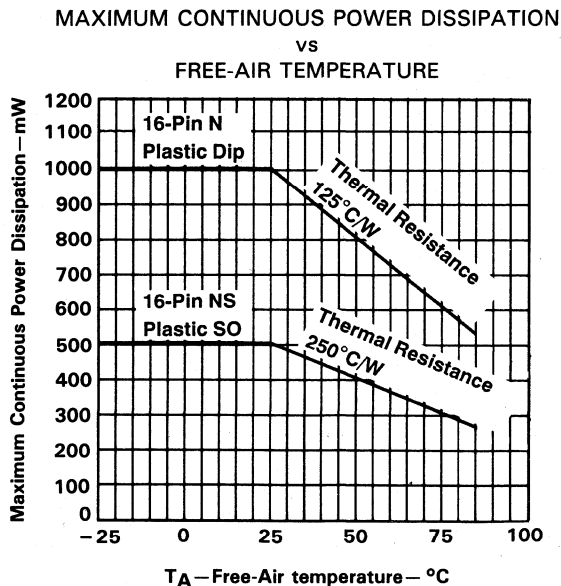
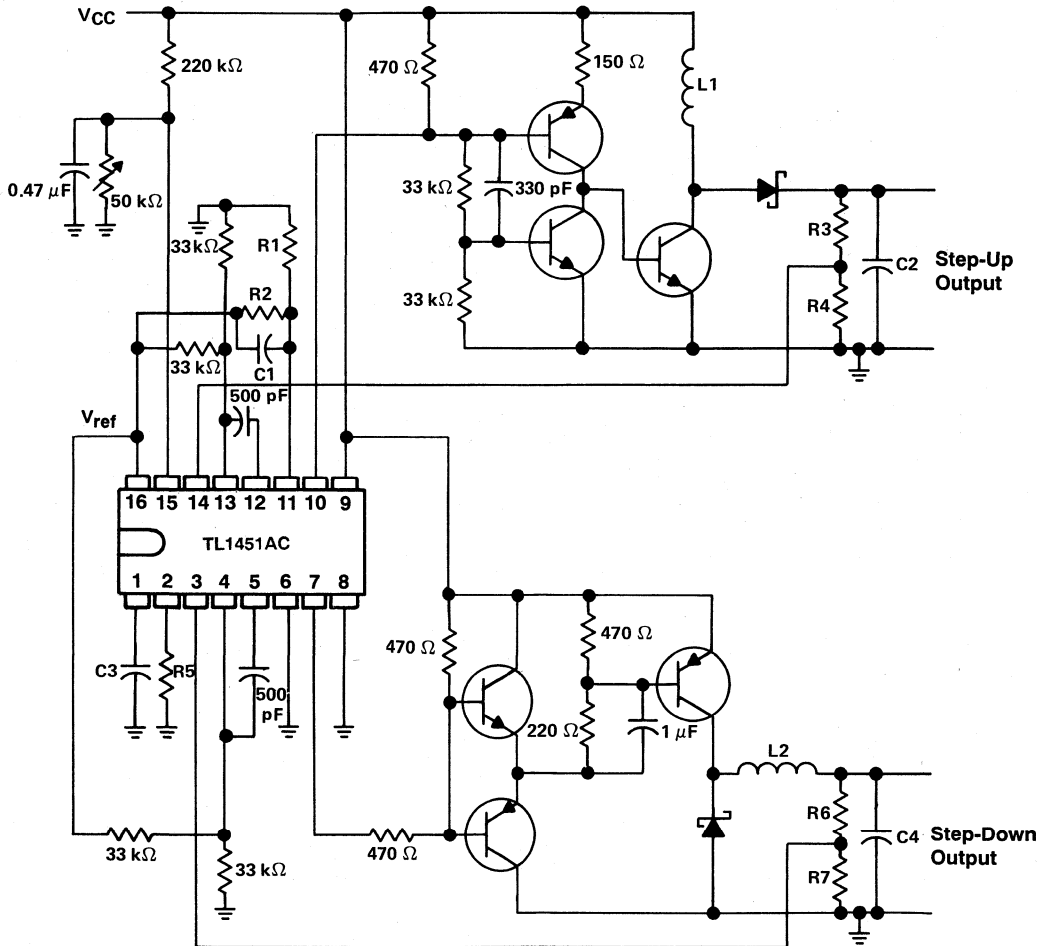


Figure 27

TL1451AC DUAL PULSE-WIDTH-MODULATION CONTROL CIRCUIT

APPLICATION INFORMATION



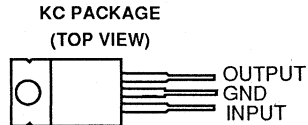
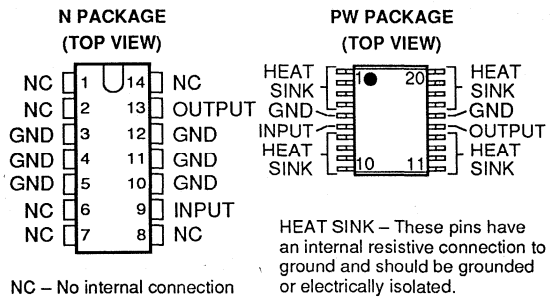
Values for R1 through R7, C1 through C4, and L1 and L2 depend upon individual application.

Figure 28. High-Speed Dual Switching Regulator

TL2217-285 FIXED VOLTAGE REGULATOR FOR SCSI ACTIVE TERMINATION

D3942, NOVEMBER 1991

- Fully Matches Parameters for Alternative 2 SCSI Active Termination
- Fixed 2.850-V Output
- $\pm 1.5\%$ Maximum Output Tolerance at $T_J = 25^\circ\text{C}$
- 1-V Maximum Dropout Voltage
- 500-mA Output Current
- $\pm 3\%$ Absolute Output Variation
- Internal Overcurrent Limiting
- Internal Thermal Overload Protection
- Internal Overvoltage Protection

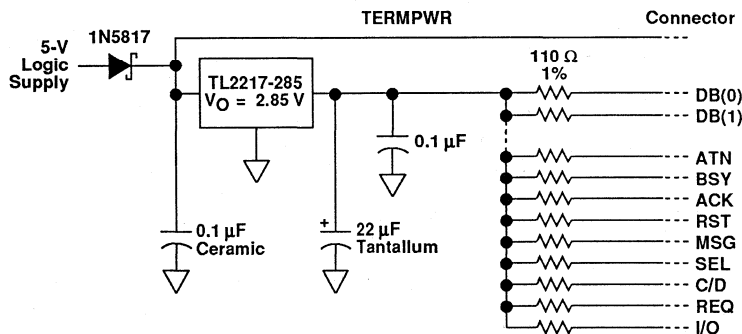


description

The TL2217-285 is a low-dropout (1-V) fixed voltage regulator specifically designed for Small Computer Systems Interface (SCSI) alternative 2 active signal termination. The TL2217-285's 1-V maximum dropout ensures compatibility with existing SCSI systems, while providing a wide TERMPWR voltage range. At the same time, the $\pm 1.5\%$ initial tolerance on its 2.85-V output voltage ensures a tighter line driver current tolerance, thereby increasing system noise margin.

The fixed 2.85-V output voltage of the TL2217-285 supports the SCSI alternative 2 termination standard while reducing system power consumption. The 1-V maximum dropout voltage brings increased TERMPWR isolation, making the device ideal for battery-powered systems. The TL2217-285, with internal current limiting,

typical application schematic



AVAILABLE OPTIONS

| T_J | PACKAGE | | |
|--------------|--------------------|-----------------|---------------------------------|
| | PLASTIC POWER (KC) | PLASTIC DIP (N) | SURFACE MOUNT (PW) [†] |
| 0°C to 125°C | TL2217-285KC | TL2217-285N | TL2217-285PWLE |

[†]The PW package is only available left-end taped and reeled.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

TEXAS INSTRUMENTS

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TL2217-285 FIXED VOLTAGE REGULATOR FOR SCSI ACTIVE TERMINATION

description (continued)

overvoltage protection, ESD protection, and thermal protection, offers designers enhanced system protection and reliability.

When configured as a SCSI active terminator, the TL2217-285 low-dropout regulator eliminates the 220- Ω and 330- Ω resistors required for each transmission line with a passive termination scheme, reducing significantly the continuous system power drain. When placed in series with 110- Ω resistors, the device matches the impedance level of the transmission cable and eliminates reflections.

The TL2217-285 is characterized for operation from 0°C to 125°C virtual junction temperature.

TL2217-285 FIXED VOLTAGE REGULATOR FOR SCSI ACTIVE TERMINATION

absolute maximum ratings over operating temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Continuous input voltage | 7.5 V |
| Continuous total dissipation (see Note 1) | See Dissipation Rating Table |
| Operating virtual junction temperature range | -55°C to 150°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 1: Refer to Figures 1 and 2 to avoid exceeding the design maximum virtual junction temperature; these ratings should not be exceeded. Due to variation in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

DISSIPATION RATING TABLE

| PACKAGE | POWER RATING AT | $T_A \leq 25^\circ\text{C}$ | DERATING FACTOR ABOVE $T = 25^\circ\text{C}$ | $T = 70^\circ\text{C}$ | $T = 85^\circ\text{C}$ | $T = 125^\circ\text{C}$ |
|---------|-----------------|-----------------------------|--|------------------------|------------------------|-------------------------|
| | | POWER RATING | | POWER RATING | POWER RATING | POWER RATING |
| KC | T_A | 2000 mW | 16 mW/°C | 1280 mW | 1040 mW | 400 mW |
| | T_C | 20000 mW | 182 mW/°C | 14540 mW | 11810 mW | 4645 mW |
| N | T_A | 2250 mW | 18.0 mW/°C | 1440 mW | 1170 mW | 450 mW |
| | T_C | 11850 mW | 94.8 mW/°C | 7584 mW | 6162 mW | 2370 mW |
| PW | T_A | 775 mW | 6.4 mW/°C | 520 mW | 423 mW | 161 mW |

Derate above 40°C

**DISSIPATION DERATING CURVE
vs
FREE-AIR TEMPERATURE**

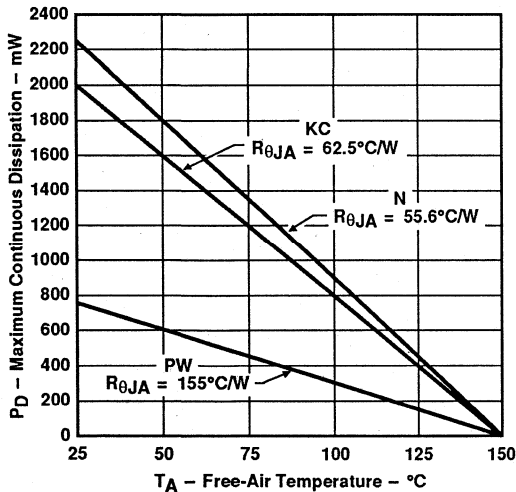


Figure 1

**DISSIPATION DERATING CURVE
vs
CASE TEMPERATURE**

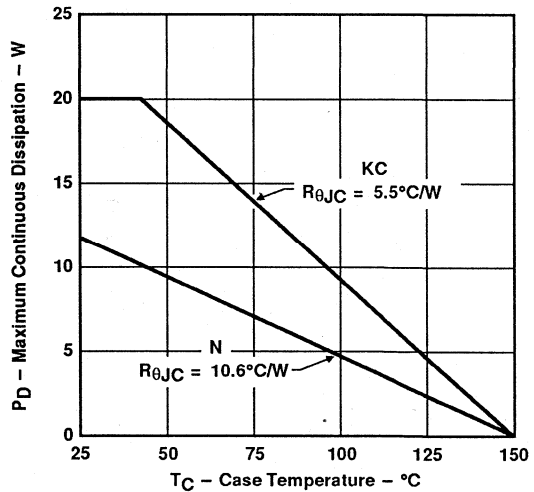


Figure 2

recommended operating conditions

| | MIN | MAX | UNIT |
|---|------|-----|------|
| Input voltage, V_I | 3.85 | 5.5 | V |
| Output current, I_O | 0 | 500 | mA |
| Operating virtual junction temperature range, T_J | 0 | 125 | °C |

TL2217-285

FIXED VOLTAGE REGULATOR FOR SCSI ACTIVE TERMINATION

electrical characteristics at $V_I = 4.5\text{ V}$, $I_O = 500\text{ mA}$, $T_J = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|----------------------|--|---|------|-------|---------------|
| Output voltage | $I_O = 20\text{ mA to }500\text{ mA}$, $V_I = 3.85\text{ V to }5.5\text{ V}$ | $T_A = T_J = 25^\circ$ 2.81 | 2.85 | 2.89 | V |
| | | $T_J = 0^\circ\text{C to }125^\circ\text{C}$ 2.765 | | 2.935 | |
| Input regulation | $V_I = 3.85\text{ V to }5.5\text{ V}$, $I_O = 500\text{ mA}$ | | 5 | 15 | mV |
| Ripple rejection | $f = 120\text{ Hz}$, $V_{\text{ripple}} = 1\text{ V}_{\text{pp}}$ | | -62 | | dB |
| Output regulation | $I_O = 20\text{ mA to }500\text{ mA}$ | | 5 | 30 | mV |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | | 500 | | μV |
| Dropout voltage | $I_O = 500\text{ mA}$ | | | 1 | V |
| | $I_O = 0$ | | 2 | 5 | |
| Bias current | $I_O = 27\text{ mA}$, equivalent 1 line asserted | | 3 | 6 | mA |
| | $I_O = 500\text{ mA}$, equivalent 18 line asserted (8 bit) | | 26 | 49 | |
| | | | | | |

Pulse-testing techniques are used to maintain the virtual junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.1- μF capacitor across the input and a 22- μF tantalum capacitor with equivalent series resistance of 1.5 Ω on the output.

COMPENSATION CAPACITOR SELECTION INFORMATION

The TL2217-285 is a low-dropout regulator. This means that the capacitance loading is important to the performance of the regulator because it is a vital part of the control loop. The capacitor value and the equivalent series resistance (ESR) both affect the control loop and must be defined for the load range and the temperature range. Figures 3 and 4 can be used to establish the capacitance value and ESR range for best regulator performance.

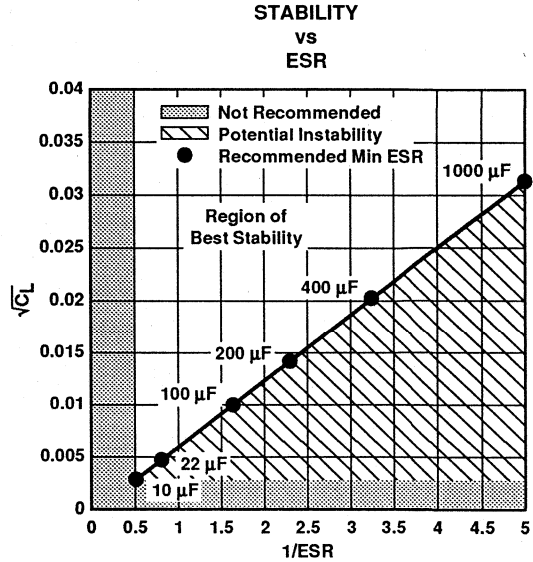
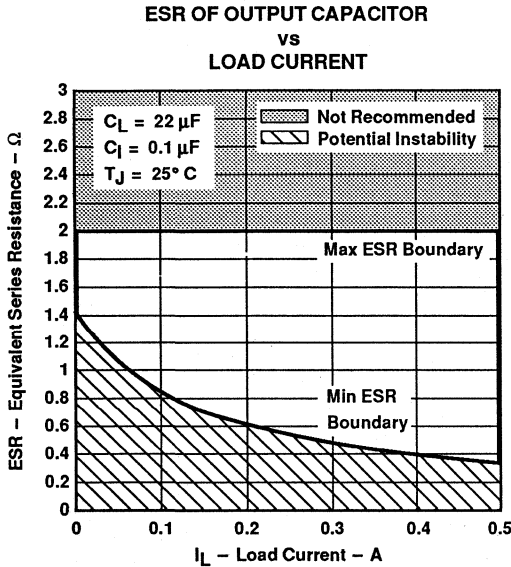


Figure 4

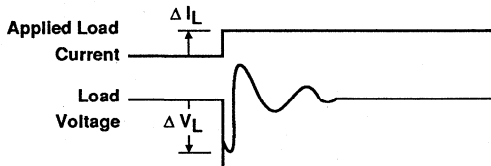


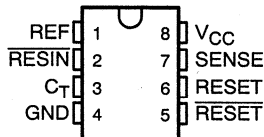
Figure 3

TL7702A, TL7705A, TL7709A, TL7712A, TL7715A SUPPLY VOLTAGE SUPERVISORS

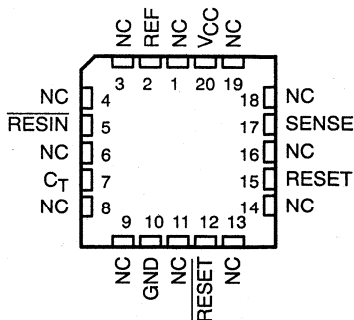
D2722, APRIL 1983—REVISED NOVEMBER 1991

- Power-On Reset Generator
- Automatic Reset Generation After Voltage Drop
- Wide Supply Voltage Range
- Precision Voltage Sensor
- Temperature-Compensated Voltage Reference
- True and Complement Reset Outputs
- Externally Adjustable Pulse Duration

D, JG, OR P PACKAGE
(TOP VIEW)



FK PACKAGE
(TOP VIEW)



NC—No internal connection

description

The TL77__A series are monolithic integrated circuit supply voltage supervisors specifically designed for use as reset controllers in micro-computer and microprocessor systems. The supply voltage supervisor monitors the supply for undervoltage conditions at the SENSE input. During power up, the $\overline{\text{RESET}}$ output becomes active (low) when V_{CC} attains a value approaching 3.6 V. At this point (assuming that SENSE is above V_{T+}), the delay timer function activates a time delay after which outputs $\overline{\text{RESET}}$ and RESET go inactive (high and low, respectively). If an undervoltage condition occurs during normal operation, outputs $\overline{\text{RESET}}$ and RESET go active. To ensure that a complete reset occurs, the reset outputs remain active for a time delay after the voltage at the SENSE input exceeds the positive-going threshold value. The time delay is determined by the value of the external capacitor C_T : $t_d = 1.3 \times 10^4 \times C_T$, where C_T is in farads (F) and t_d is in seconds (s).

During power down (assuming that SENSE is below V_{T-}), the outputs remain active until the V_{CC} falls below a maximum of 2 V. After this, the outputs are undefined.

An external capacitor (typically 0.1 μF for the TL77__AC and TL77__AI and typically 0.02 μF for the TL77__AM) must be connected to REF to reduce the influence of fast transients in the supply voltage.

The TL77__AC series are characterized for operation from 0°C to 70°C. The TL77__AI series are characterized for operation from -25°C to 85°C. The TL7702AM and TL7705AM are characterized for operation over the full military range of -55°C to 125°C.

AVAILABLE OPTIONS

| T _A | PACKAGE | | | |
|----------------|--------------------------|--------------------------|--------------------------|--------------------------|
| | SMALL OUTLINE (D) | CHIP CARRIER (FK) | CERAMIC DIP (JG) | PLASTIC DIP (P) |
| 0°C to 70°C | TL7702ACD thru TL7715ACD | | | TL7702ACP thru TL7715ACP |
| -25°C to 85°C | TL7702AID thru TL7715AID | | | TL7702AIP thru TL7715AIP |
| -55°C to 125°C | | TL7702AMFK TL7705AMFK | TL7702AMJG TL7705AMJG | |

PRODUCTION DATA Information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.



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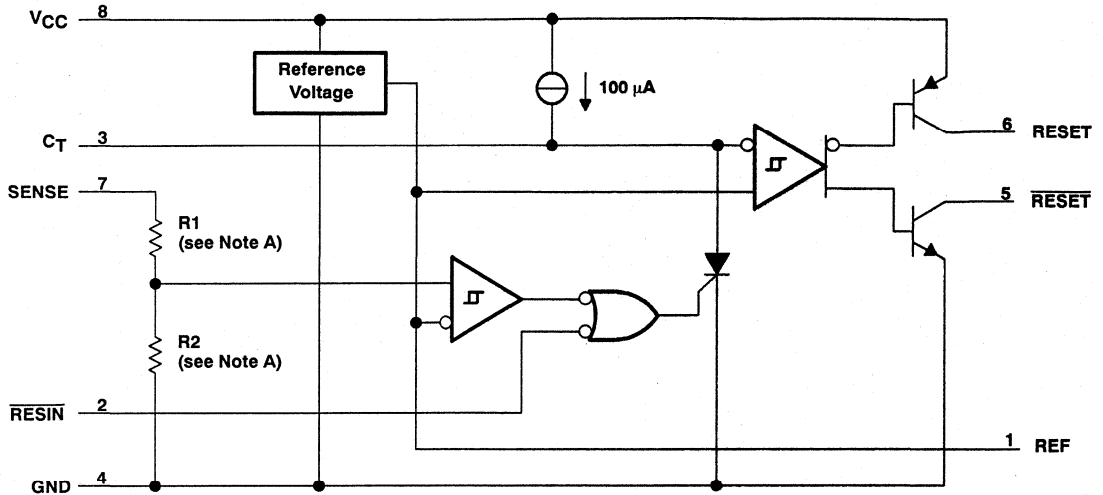
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On products compliant to MIL-STD-883, Class B, all parameters are tested unless otherwise noted. On all other products, production processing does not necessarily include testing of all parameters.

2-343

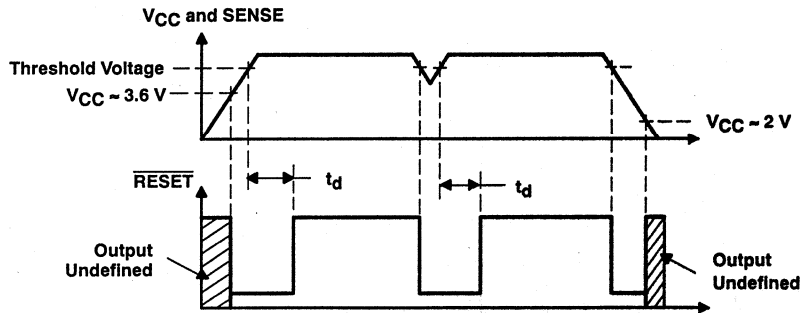
TL7702A, TL7705A, TL7709A, TL7712A, TL7715A SUPPLY VOLTAGE SUPERVISORS

functional block diagram



NOTE A: TL7702A: R1 = 0 Ω , R2 = open
 TL7705A: R1 = 7.8 k Ω , R2 = 10 k Ω
 TL7709A: R1 = 19.7 k Ω , R2 = 10 k Ω
 TL7712A: R1 = 32.7 k Ω , R2 = 10 k Ω
 TL7715A: R1 = 43.4 k Ω , R2 = 10 k Ω
 Pin numbers shown are for the D, JG, or P package.

timing diagram



TL7702A, TL7705A, TL7709A, TL7712A, TL7715A SUPPLY VOLTAGE SUPERVISORS

absolute maximum ratings over operating free-air temperature (unless otherwise noted)

| | |
|--|------------------------------|
| Supply voltage, V_{CC} (see Note 1) | 20 V |
| Input voltage range, RESIN | -0.3 V to 20 V |
| Input voltage range, SENSE: | |
| TL7702A (see Note 2) | -0.3 V to 6 V |
| TL7705A | -0.3 V to 10 V |
| TL7709A | -0.3 V to 15 V |
| TL7712A, TL7715A | -0.3 V to 20 V |
| High-level output current, RESET | -30 mA |
| Low-level output current, RESET | 30 mA |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range: | |
| TL77__AC | 0°C to 70°C |
| TL77__AI | -25°C to 85°C |
| TL7702AM, TL7705AM | -55°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Case temperature for 60 second: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package | 300°C |

NOTE 1: All voltage values are with respect to the network ground terminal.

DISSIPATION RATING TABLE

| PACKAGE | $T_A = 25^\circ\text{C}$ | DERATING FACTOR | $T_A = 70^\circ\text{C}$ | $T_A = 85^\circ\text{C}$ | $T_A = 125^\circ\text{C}$ |
|---------|--------------------------|--------------------------------|--------------------------|--------------------------|---------------------------|
| | POWER RATING | ABOVE $T_A = 25^\circ\text{C}$ | POWER RATING | POWER RATING | POWER RATING |
| D | 725 mW | 5.8 mW/°C | 464 mW | 377 mW | 145 mW |
| FK | 1375 mW | 11.0 mW/°C | 888 mW | 715 mW | 275 mW |
| JG | 1050 mW | 8.4 mW/°C | 672 mW | 546 mW | 210 mW |
| P | 1000 mW | 8.0 mW/°C | 640 mW | 520 mW | 200 mW |

recommended operating conditions

| | TL77__AC and TL77__AI | | TL77__AM | | UNIT | |
|---|-----------------------|-----|------------|-----|------------|-----|
| | MIN | MAX | MIN | MAX | | |
| Supply voltage, V_{CC} | 3.6 | 18 | 3.6 | 10 | V | |
| High-level input voltage at RESIN, V_{IH} | 2 | | 2 | | V | |
| Low-level input voltage at RESIN, V_{IL} | | | 0.6 | 0.6 | V | |
| Input voltage, SENSE, V_I | TL7702A | 0 | See Note 2 | 0 | See Note 2 | V |
| | TL7705A | 0 | 10 | 0 | 10 | |
| | TL7709A | 0 | 15 | | | |
| | TL7712A | 0 | 20 | | | |
| | TL7715A | 0 | 20 | | | |
| High-level output current, RESET, I_{OH} | | | -16 | -16 | mA | |
| Low-level output current, RESET, I_{OL} | | | 16 | 16 | mA | |
| Operating free-air temperature range, T_A | TL77__AC | 0 | 70 | | °C | |
| | TL77__AI | -25 | 85 | | | |
| | TL7702AM, TL7705AM | | | -55 | | 125 |

NOTE 2: For proper operation of the TL7702A, the voltage applied to the SENSE terminal should not exceed $V_{CC}-1$ V or 6 V, whichever is less.



TL7702AC, TL7705AC, TL7709AC, TL7712AC, TL7715AC
TL7702AI, TL7705AI, TL7709AI, TL7712AI, TL7715AI
SUPPLY VOLTAGE SUPERVISORS

electrical characteristics over recommended operating conditions (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS† | MIN | TYP | MAX | UNIT | |
|------------------|--|---|---|------|------|------|----|
| V _{OH} | High-level output voltage, RESET | I _{OH} = -16 mA | V _{CC} -1.5 | | | V | |
| V _{OL} | Low-level output voltage, RESET | I _{OL} = 16 mA | 0.4 | | | V | |
| V _{ref} | Reference voltage | T _A = 25°C | 2.48 | 2.53 | 2.58 | V | |
| V _{T-} | Negative-going threshold voltage, SENSE | T _A = 25°C | TL7702A | 2.48 | 2.53 | 2.58 | V |
| | | | TL7705A | 4.5 | 4.55 | 4.6 | |
| | | | TL7709A | 7.5 | 7.6 | 7.7 | |
| | | | TL7712A | 10.6 | 10.8 | 11 | |
| | | | TL7715A | 13.2 | 13.5 | 13.8 | |
| V _{hys} | Hysteresis, SENSE (V _{T+} - V _{T-}) | T _A = 25°C | TL7702A | 10 | | mV | |
| | | | TL7705A | 15 | | | |
| | | | TL7709A | 20 | | | |
| | | | TL7712A | 35 | | | |
| | | | TL7715A | 45 | | | |
| I _I | Input current, $\overline{\text{RESIN}}$ | V _I = 2.4 V to V _{CC} | 20 | | | μA | |
| | | V _I = 0.4 V | -100 | | | | |
| I _I | Input current, SENSE | TL7702A | V _{ref} < V _I < V _{CC} - 1.5 V | | 0.5 | 2 | μA |
| I _{OH} | High-level output current, $\overline{\text{RESET}}$ | V _O = 18 V | 50 | | | μA | |
| I _{OL} | Low-level output current, RESET | V _O = 0 | -50 | | | μA | |
| I _{CC} | Supply current | All inputs and outputs open | 1.8 | | 3 | mA | |

† All electrical characteristics are measured with 0.1-μF capacitors connected at REF, C_T, and V_{CC} to GND.

switching characteristics over recommended operating conditions (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS‡ | MIN | TYP | MAX | UNIT |
|----------------------|--|---|-----|-----|-----|------|
| t _{wS(min)} | Minimum pulse duration at SENSE input to switch outputs | V _{IH} = V _{T-} + 200 mV, V _{IL} = V _{T-} - 200 mV | 2 | | | μs |
| t _{pd} | Propagation delay time from $\overline{\text{RESIN}}$ to RESET | V _{CC} = 5 V | 1.5 | | | μs |
| t _r | RESET | V _{CC} = 5 V, See Note 3 | 0.2 | | | μs |
| | $\overline{\text{RESET}}$ | | 3.5 | | | |
| t _f | RESET | | 3.5 | | | μs |
| | $\overline{\text{RESET}}$ | | 0.2 | | | |

‡ All switching characteristics are measured with 0.1-μF capacitors connected at REF and V_{CC} to GND.

NOTE 3: The rise and fall times are measured with a 4.7-kΩ load resistor at RESET and $\overline{\text{RESET}}$.



TL7702AM, TL7705AM SUPPLY VOLTAGE SUPERVISORS

electrical characteristics over recommended operating conditions (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS† | MIN | TYP | MAX | UNIT |
|------------------|---|---|----------------------|------|------|------|
| V _{OH} | High-level output voltage, $\overline{\text{RESET}}$ | I _{OH} = -16 mA | V _{CC} -1.5 | | | V |
| V _{OL} | Low-level output voltage, $\overline{\text{RESET}}$ | I _{OL} = 16 mA | 0.4 | | | V |
| V _{ref} | Reference voltage | | 2.38 | 2.53 | 2.63 | V |
| V _{T-} | Negative-going threshold voltage, SENSE | TL7702AM | 2.38 | 2.53 | 2.63 | V |
| | | TL7705AM | 4.25 | 4.55 | 4.7 | |
| V _{hys} | Hysteresis SENSE (V _{T+} - V _{T-}) | TL7702AM | 10 | | | mV |
| | | TL7705AM | 15 | | | |
| I _I | Input current, $\overline{\text{RESIN}}$ | V _I = 2.4 V to V _{CC} | 20 | | | μA |
| | | V _I = 0.4 V | -100 | | | |
| I _I | Input current, SENSE | TL7702AM | 0.5 | | 2 | μA |
| I _{OH} | High-level output current, $\overline{\text{RESET}}$ | V _O = 10 V | 50 | | | μA |
| I _{OL} | Low-level output current, $\overline{\text{RESET}}$ | V _O = 0 | -50 | | | μA |
| I _{CC} | Supply current | All inputs and outputs open | 1.8 | | 3 | mA |

† All electrical characteristics are measured with 0.02-μF capacitors connected at REF, C_T, and V_{CC} to GND.

switching characteristics over recommended operating conditions (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS‡ | MIN | TYP | MAX | UNIT |
|----------------------|--|---|------|-----|-----|------|
| t _{WS(min)} | Minimum pulse duration at SENSE input to switch outputs | V _{IH} = V _{T-} + 200 mV, V _{IL} = V _{T-} - 200 mV | 2* | | | μs |
| t _{pd} | Propagation delay time, $\overline{\text{RESIN}}$ to $\overline{\text{RESET}}$ | V _{CC} = 5 V | 1.5 | | | μs |
| t _r | $\overline{\text{RESET}}$ | V _{CC} = 5 V, See Note 3 | 0.2* | | | μs |
| | $\overline{\text{RESET}}$ | | 3.5* | | | |
| t _f | $\overline{\text{RESET}}$ | | 3.5* | | | μs |
| | $\overline{\text{RESET}}$ | | 0.2* | | | |

* On products compliant to MIL-STD-883, Class B, this parameter is not production tested.

† All switching characteristics are measured with 0.02-μF capacitors connected at REF and V_{CC} to GND.

NOTE 3: The rise and fall times are measured with a 4.7-kΩ load resistor at $\overline{\text{RESET}}$ and RESET.

PARAMETER MEASUREMENT INFORMATION

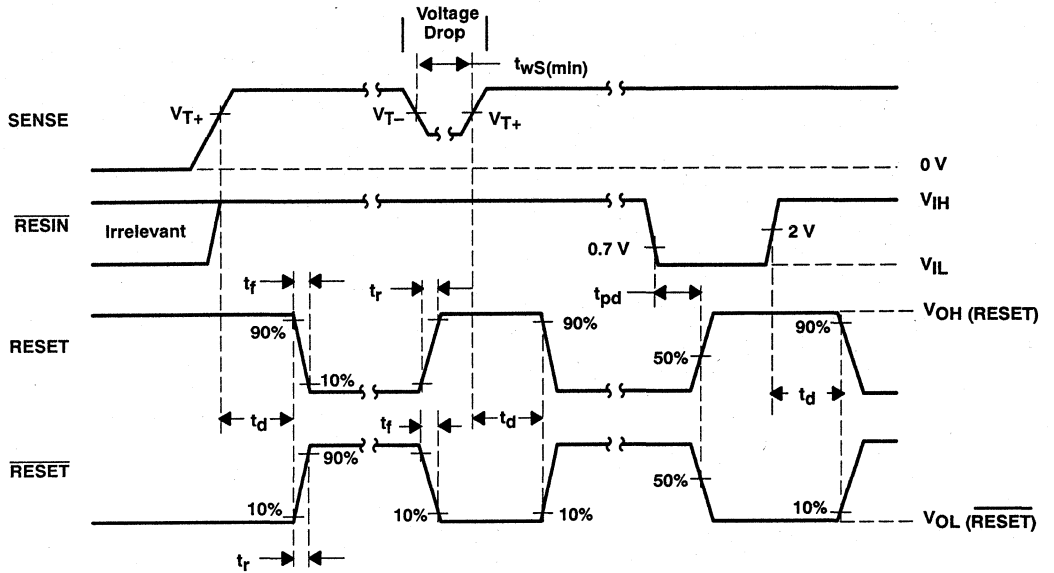


Figure 1. Voltage Waveforms

APPLICATION INFORMATION

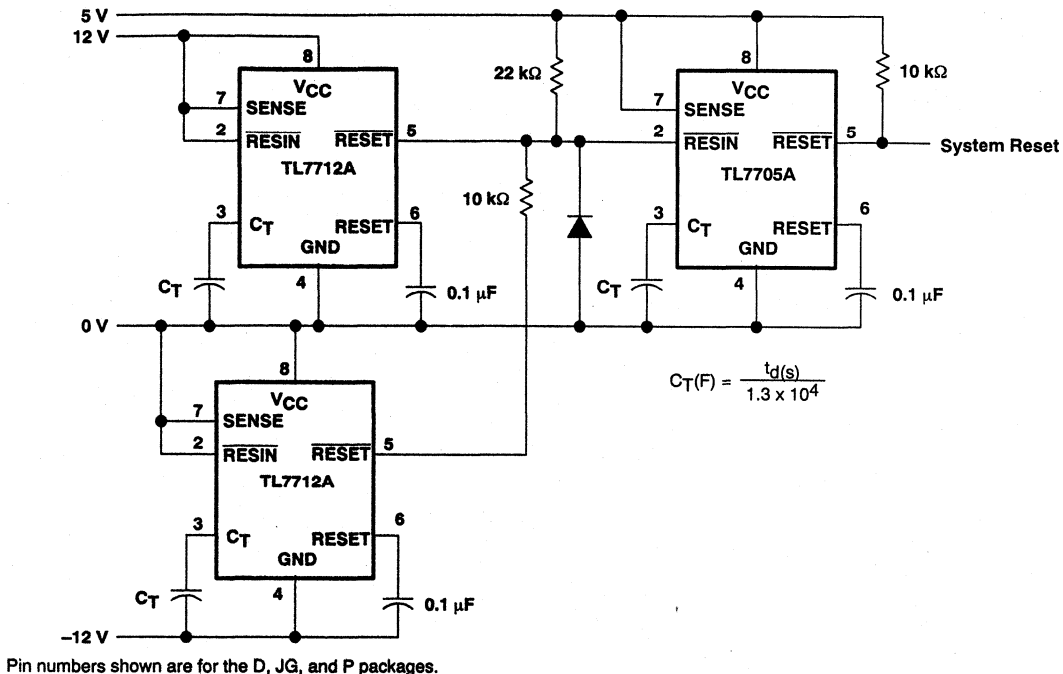


Figure 2. Multiple Power Supply System Reset Generation

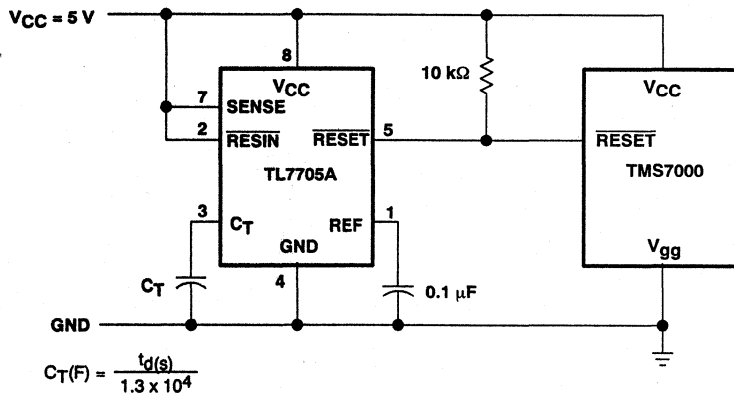


Figure 3. Reset Controller for TMS7000 System

APPLICATION INFORMATION

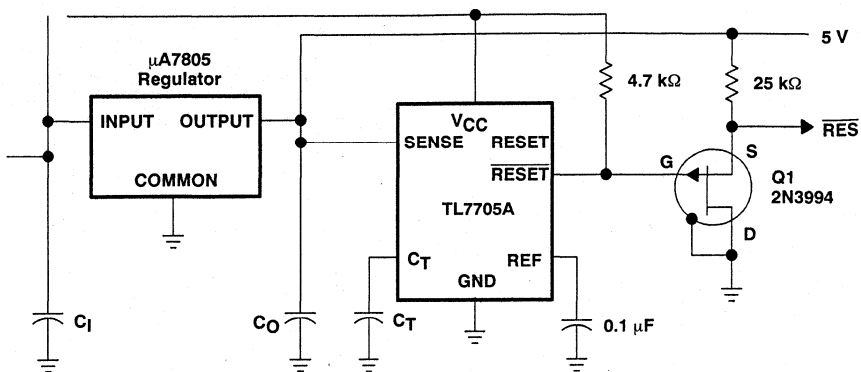


Figure 4. Eliminating Undefined States Using a P-Channel JFET

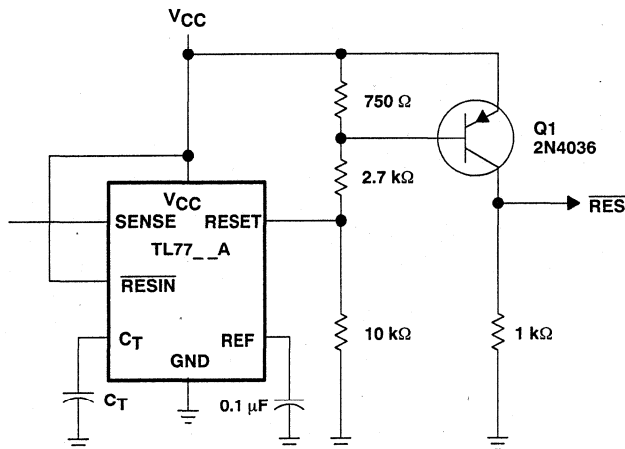


Figure 5. Eliminating Undefined States Using a P-N-P Transistor

TL7702B, TL7705B SUPPLY VOLTAGE SUPERVISORS

D3303, SEPTEMBER 1989—REVISED DECEMBER 1991

- Power-On Reset Generator
- Automatic Reset Generation After Voltage Drop
- Defined Output From $V_{CC} \geq 1\text{ V}$
- Precision Voltage Sensor
- Temperature-Compensated Voltage Reference
- True and Complement Reset Outputs
- Externally Adjustable Pulse Duration

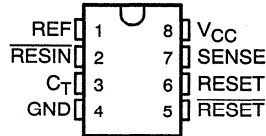
description

The TL7702B and TL7705B are monolithic integrated circuit voltage supervisors designed for use as reset controllers in microcomputer and microprocessor systems. The supply voltage supervisor monitors the supply for undervoltage conditions at the SENSE input. During power up, the $\overline{\text{RESET}}$ output becomes active (low) when V_{CC} attains a value approaching 1 V. As V_{CC} approaches 3 V (assuming that SENSE is above V_{T+}), the delay timer function activates a time delay after which outputs $\overline{\text{RESET}}$ and RESET go inactive (high and low, respectively). If an undervoltage condition occurs during normal operation, outputs $\overline{\text{RESET}}$ and RESET go active. To ensure that a complete reset occurs, the reset outputs remain active for a time delay after the voltage at the SENSE input exceeds the positive-going threshold value. The time delay is determined by the value of the external capacitor C_T : $t_d = 1.3 \times 10^4 \times C_T$, where C_T is in farads (F) and t_d is in seconds (s).

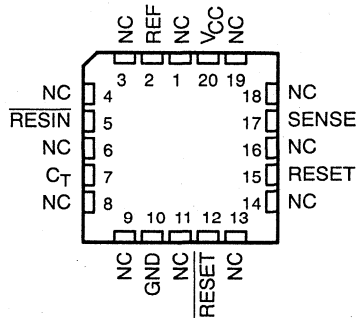
An external capacitor (typically 0.1 μF) must be connected to REF to reduce the influence of fast transients in the supply voltage.

The TL7702BC and TL7705BC are characterized from 0°C to 70°C. The TL7702BI and TL7705BI are characterized for operation from -40°C to 85°C. The TL7702BQ and TL7705BQ are characterized for operation from -40°C to 125°C. The TL7702BM and TL7705BM are characterized for operation from -55°C to 125°C.

D, JG, OR P PACKAGE
(TOP VIEW)



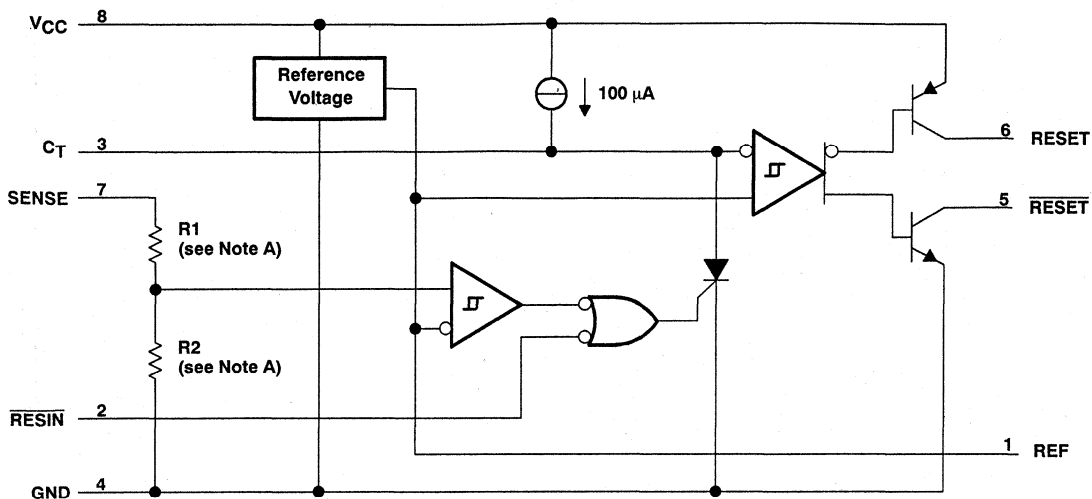
FK PACKAGE
(TOP VIEW)



NC—No internal connection

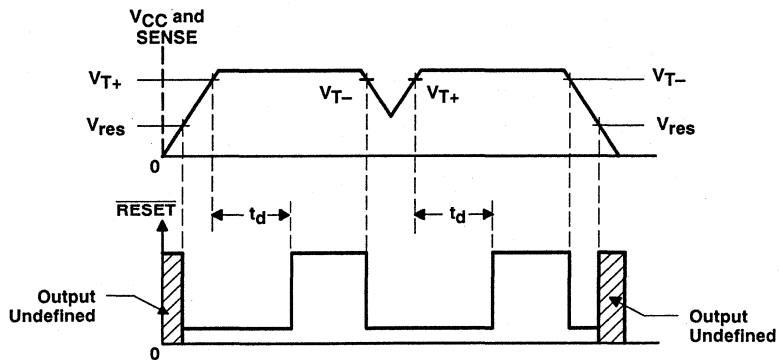
TL7702B, TL7705B SUPPLY VOLTAGE SUPERVISORS

functional block diagram



NOTE A: TL7702B: R1 = 0 Ω, R2 = open
 TL7705B: R1 = 16 kΩ, R2 = 8 kΩ

typical timing diagram



TL7702B, TL7705B SUPPLY VOLTAGE SUPERVISORS

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Supply voltage, V_{CC} (see Note 1) | 20 V |
| Input voltage range at \overline{RESIN} | -0.3 V to 20 V |
| Input voltage range at SENSE: TL7702B | -0.3 V to 20 V |
| TL7705B | -0.3 V to 20 V |
| High-level output current at RESET | -30 mA |
| Low-level output current at RESET | 30 mA |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range: TL77_BC | 0°C to 70°C |
| TL77_BI | -40°C to 85°C |
| TL77_BQ | -40°C to 125°C |
| TL77_BM | -55°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package | 300°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package | 260°C |

NOTE 1: All voltage values are with respect to the network ground terminal.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$ | $T_A = 70^\circ\text{C}$ POWER RATING | $T_A = 85^\circ\text{C}$ POWER RATING | $T_A = 125^\circ\text{C}$ POWER RATING |
|---------|---|---|--|--|---|
| D | 725 mW | 5.8 mW/°C | 464 mW | 377 mW | 145 mW |
| FK | 1375 mW | 11.0 mW/°C | 880 mW | 715 mW | 275 mW |
| JG | 1050 mW | 8.4 mW/°C | 672 mW | 546 mW | 210 mW |
| P | 1000 mW | 8.0 mW/°C | 640 mW | 520 mW | 200 mW |

recommended operating conditions

| | MIN | MAX | UNIT |
|---|---------|-----|------|
| Supply voltage, V_{CC} | 3.6 | 18 | V |
| High-level input voltage at \overline{RESIN} , V_{IH} | 2 | 18 | V |
| Low-level input voltage at \overline{RESIN} , V_{IL} | 0 | 0.8 | V |
| Input voltage at SENSE, V_I | 0 | 18 | V |
| High-level output current at RESET, I_{OH} | | -16 | mA |
| Low-level output current at RESET, I_{OL} | | 16 | mA |
| Operating free-air temperature range, T_A | TL77_BC | 0 | 70 |
| | TL77_BI | -40 | 85 |
| | TL77_BQ | -40 | 125 |
| | TL77_BM | -55 | 125 |



TL7702BC, TL7702BI, TL7702BQ, TL7705BC, TL7705BI, TL7705BQ SUPPLY VOLTAGE SUPERVISORS

electrical characteristics over recommended operating conditions (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS† | MIN | TYP | MAX | UNIT | | |
|-------------------|---|---|---|------|-------|------|----|----|
| V _{OH} | High-level output voltage, RESET | I _{OH} = -16 mA | V _{CC} -1.5 | | | V | | |
| V _{OL} | Low-level output voltage, RESET | I _{OL} = 16 mA | 0.4 | | | V | | |
| V _{ref} | Reference voltage | I _{ref} = 500 μA, T _A = 25°C | 2.48 | 2.53 | 2.58 | V | | |
| V _{T-} | Negative-going threshold voltage, SENSE | TL7702B | 2.505 | 2.53 | 2.555 | | | |
| | | TL7705B | 4.5 | 4.55 | 4.6 | | | |
| | | TL7702B | 2.48 | 2.53 | 2.58 | | | |
| | TL7705B | 4.45 | 4.55 | 4.65 | | | | |
| V _{hys} | Hysteresis SENSE (V _{T+} - V _{T-}) | TL7702B | V _{CC} = 3.6 V to 18 V, | | | mV | | |
| | | TL7705B | T _A = 25°C | | | | | |
| I _I | Input current, $\overline{\text{RESIN}}$ | V _I = 0.4 V to V _{CC} | -10 | | | μA | | |
| I _I | Input current, SENSE | TL7702B | V _I = V _{ref} to 18 V | | | -0.1 | -2 | μA |
| I _{OH} | High-level output current, $\overline{\text{RESET}}$ | V _O = 18 V, See Figure 1 | 50 | | | μA | | |
| I _{OL} | Low-level output current, RESET | V _O = 0 V, See Figure 1 | -50 | | | μA | | |
| V _{res‡} | Power-up reset voltage | I _{OL} (RESET) = 2 mA, T _A = 25°C | 1 | | | V | | |
| I _{CC} | Supply current | V _{SENSE} = 15 V, RESIN ≈ 2 V | 1.8 | | | 3 | mA | |

† All electrical characteristics are measured with 0.1-μF capacitors connected at REF, C_T, and V_{CC} to GND.

‡ This is the lowest voltage at which $\overline{\text{RESET}}$ becomes active.

switching characteristics, V_{CC} = 5 V, C_T open, T_A = 25°C

| PARAMETER | FROM (INPUT) | TO (OUTPUT) | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---------------------|--|-------------|---------------------------|-------------------------|-----|-----|------|
| t _{PLH} | PROPAGATION DELAY TIME FROM LOW-TO-HIGH-LEVEL OUTPUT | RESIN | RESET | See Figures 1, 2, and 3 | 270 | 500 | ns |
| t _{PHL} | PROPAGATION DELAY TIME FROM LOW-TO-HIGH-LEVEL OUTPUT | RESIN | RESET | | 270 | 500 | |
| t _{w(min)} | PULSE DURATION, MINIMUM EFFECTIVE | RESIN | | See Figure 2(a) | 150 | ns | |
| | | SENSE | | See Figure 2(b) | 100 | | |
| t _r | Rise time | | $\overline{\text{RESET}}$ | See Figures 1, 2, and 3 | 75 | ns | |
| t _f | Fall time | | $\overline{\text{RESET}}$ | | 150 | | 200 |
| t _r | Rise time | | RESET | | 75 | 150 | ns |
| t _f | Fall time | | RESET | | 50 | | |

TL7702BM, TL7705BM SUPPLY VOLTAGE SUPERVISORS

electrical characteristics over recommended operating conditions (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS† | MIN | TYP | MAX | UNIT | | |
|--------------------|--|---|--|-------|------|------|---------|---------|
| V _{OH} | High-level output voltage, $\overline{\text{RESET}}$ | I _{OH} = -16 mA | V _{CC} - 1.5 | | | V | | |
| V _{OL} | Low-level output voltage, $\overline{\text{RESET}}$ | I _{OL} = 16 mA | 0.4 | | | V | | |
| V _{ref} | Reference voltage | I _{ref} = 500 μ A, T _A = 25°C | 2.48 | 2.53 | 2.58 | V | | |
| V _{T-} | Negative-going threshold voltage at SENSE input | TL7702B | T _A = 25°C | 2.505 | 2.53 | | 2.555 | |
| | | TL7705B | | 4.5 | 4.55 | | 4.6 | |
| | | TL7702B | | 2.48 | 2.53 | | 2.58 | |
| | | TL7705B | | 4.45 | 4.55 | 4.65 | | |
| V _{hys} | Hysteresis, SENSE (V _{T+} - V _{T-}) | TL7702B | V _{CC} = 3.6 V to 18 V, T _A = 25°C | | | 10 | mV | |
| | | TL7705B | | | | 30 | | |
| I _I | Input current, $\overline{\text{RESIN}}$ | V _I = 0.4 V to V _{CC} | | | | -10 | μ A | |
| I _I | Input current, SENSE | TL7702B | V _I = V _{ref} to V _{CC} - 1.5 V | | | -0.1 | -2 | μ A |
| I _{OH} | High-level output current, $\overline{\text{RESET}}$ | V _O = 18 V | | | | 50 | μ A | |
| I _{OL} | Low-level output current, $\overline{\text{RESET}}$ | V _O = 0 | | | | -50 | μ A | |
| I _{CC} | Supply current | V _{SENSE} = 15 V, RESIN \geq 2 V | | | | 1.8 | 3 | mA |
| V _{res} ‡ | Power-up reset voltage | I _{OL} $\overline{\text{RESET}}$ = 2 mA, T _A = 25°C | 1 | | | | V | |

† All electrical characteristics are measured with 0.1- μ F capacitors connected at REF, C_T, and V_{CC} to GND.

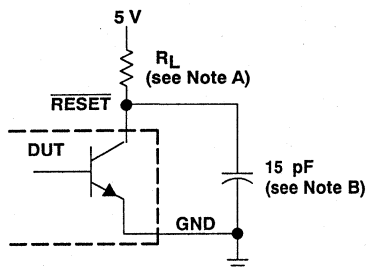
‡ This is the lowest value at which $\overline{\text{RESET}}$ becomes active.

switching characteristics, V_{CC} = 5 V, C_T open, T_A = 25°C

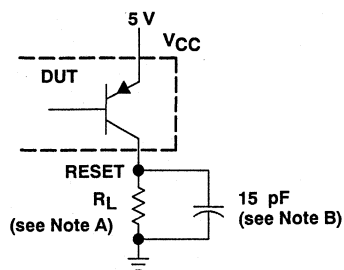
| PARAMETER | FROM (INPUT) | TO (OUTPUT) | TEST CONDITIONS | MIN | TYP | MAX | UNIT | |
|----------------------|--------------|---------------------------|-------------------------|-----|-----|------|------|----|
| t _{PLH} | RESIN | RESET | See Figures 1, 2, and 3 | | 270 | 500* | ns | |
| t _{PHL} | RESIN | $\overline{\text{RESET}}$ | | | 270 | 500* | ns | |
| t _w (min) | RESIN | | See Figure 2(a) | | 150 | | ns | |
| | SENSE | | See Figure 2(b) | | 100 | | | |
| t _r | | $\overline{\text{RESET}}$ | See Figures 1, 2, and 3 | | | 75* | ns | |
| t _f | | | | | 150 | 200* | | |
| t _r | | RESET | | | | 75 | 150* | ns |
| t _f | | | | | | | 50* | |

*For products compliant to MIL-STD-883, Class B, these parameters are not production tested.

PARAMETER MEASUREMENT INFORMATION



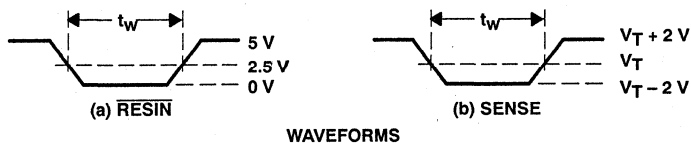
$\overline{\text{RESET}}$ OUTPUT CONFIGURATION



RESET OUTPUT CONFIGURATION

NOTES: A. For I_{OL} and I_{OH} , $R_L = 10\text{ k}\Omega$. For all switching characteristics, $R_L = 511\ \Omega$.
 B. Includes jig and probe capacitance.

Figure 1. $\overline{\text{RESET}}$ and RESET Output Configurations



WAVEFORMS

Figure 2. Input Pulse Definition

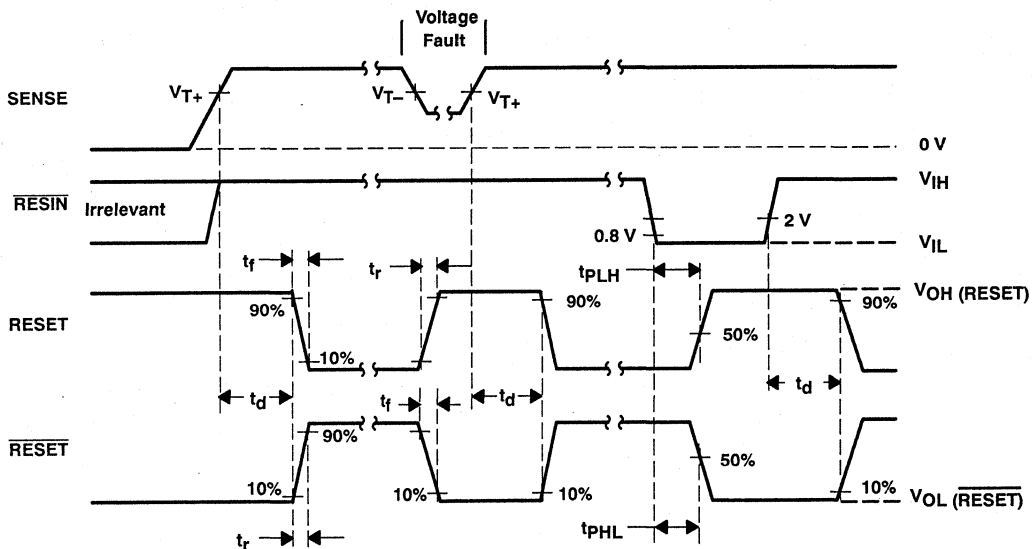
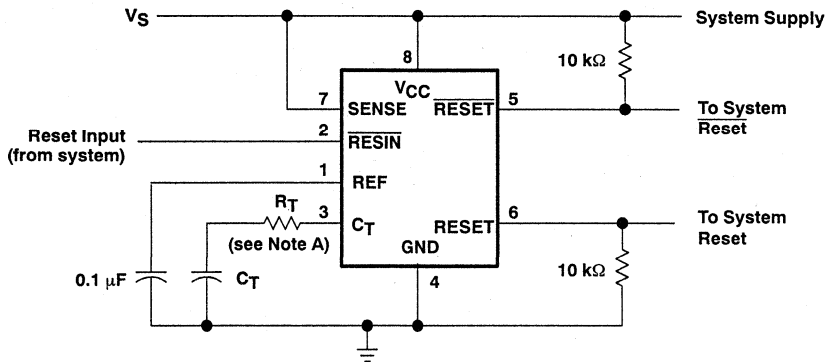


Figure 3. Voltage Waveforms

APPLICATION INFORMATION



NOTE A: When V_{CC} and SENSE are connected to the same point, it is recommended that series resistance (R_T) be added between the time delay programming capacitor (C_T) and the voltage supervisor device pin (C_T).

The suggested R_T value is given by:

$$R_T > \frac{V_I - V_{T-}}{1 \times 10^{-3}}, \text{ where } V_I = (\text{the lesser of } 7.1 \text{ V or } V_S)$$

When this series resistor is used, the t_d calculation is as follows:

$$t_d = \frac{1.3 - [(1 \times 10^{-4}) \times R_T]}{1 \times 10^{-4}} \times C_T$$

Figure 4. System Reset Controller With Undervoltage Sensing

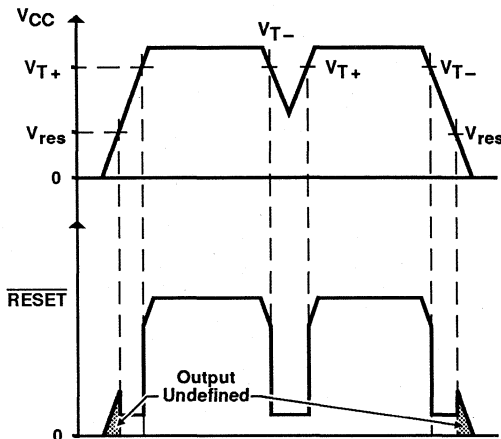
TL7757 SUPPLY VOLTAGE SUPERVISOR AND PRECISION VOLTAGE DETECTOR

D3897, SEPTEMBER 1991

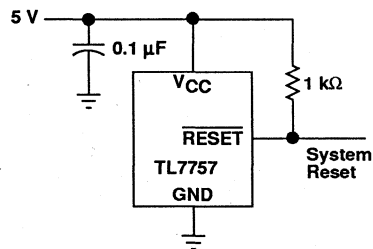
available features

- Power-On Reset Generator
- Automatic Reset Generation After Voltage Drop
- Low Standby Current . . . 20 μ A
- Reset Output Defined When V_{CC} Exceeds 1 V
- Complementary Reset Output
- Precision Threshold Voltage
4.55 V \pm 120 mV
- High Output Sink Capability . . . 20 mA
- Comparator Hysteresis Prevents Erratic Resets

TYPICAL TIMING DIAGRAM



TYPICAL APPLICATION DIAGRAM



description

The TL7757 is a monolithic supply voltage supervisor designed for use in microcomputer and microprocessor systems. The supervisor monitors the supply voltage for undervoltage conditions. During power-up, when the supply voltage, V_{CC} , attains a value approaching 1 V, the RESET output becomes active (low) to prevent undefined operation. If at any time the supply voltage drops below threshold voltage level (V_{T-}), the RESET output goes to the active (low) level until the supply undervoltage fault condition is eliminated.

The C-suffix device is characterized for operation from 0°C to 70°C. The I-suffix device is characterized for operation from -40°C to 85°C. The M-suffix device is characterized for operation from -55°C to 125°C.

AVAILABLE OPTIONS

| T_A | PACKAGE | | | CHIP FORM (Y) |
|----------------|-------------------|---------------|-------------|---------------|
| | SMALL-OUTLINE (D) | TO-226AA (LP) | SOT-89 (PK) | |
| 0°C to 70°C | TL7757CD | TL7757CLP | TL7757CPK | TL7757Y |
| -40°C to 85°C | TL7757ID | TL7757ILP | TL7757IPK | |
| -55°C to 125°C | TL7757MD | TL7757MLP | — | |

D and LP packages are available taped and reeled. Add "R" suffix to device type (e.g., TL7757CDR). Chips are tested at 25°C.

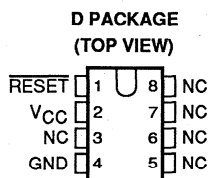
PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

**TEXAS
INSTRUMENTS**

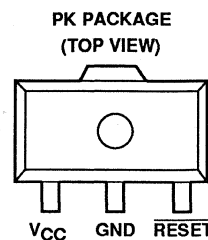
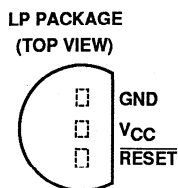
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TL7757 SUPPLY VOLTAGE SUPERVISOR AND PRECISION VOLTAGE DETECTOR



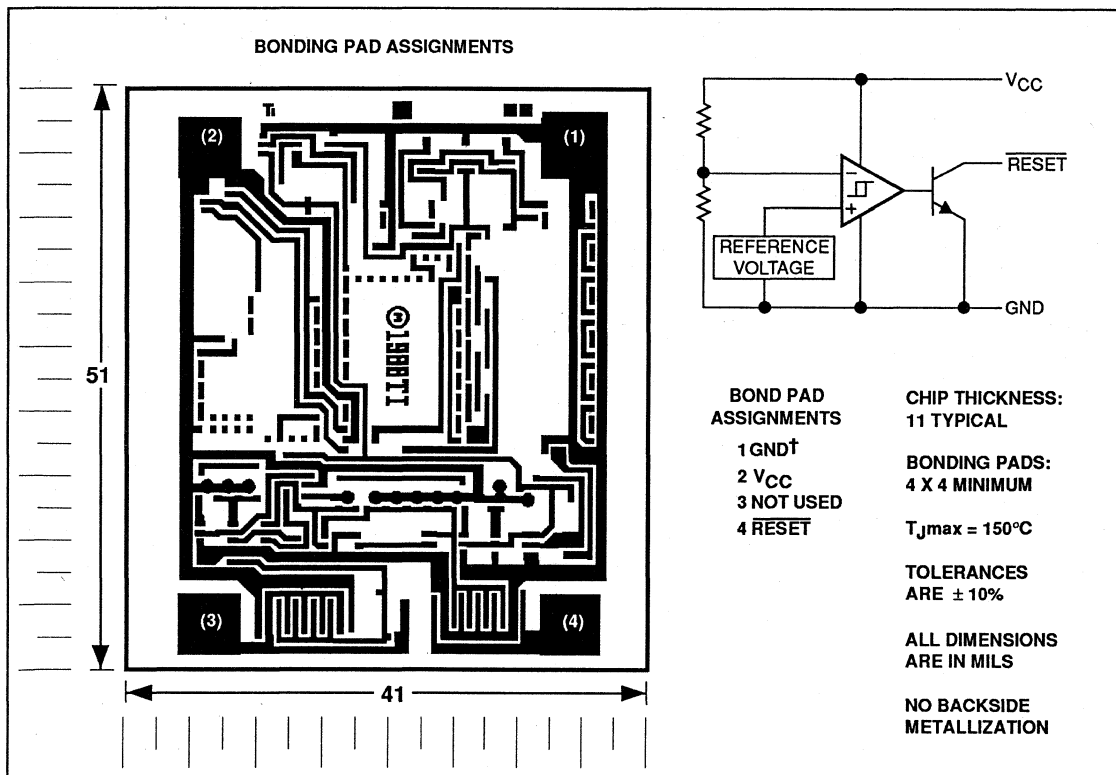
NC - No internal connection



GND is in electrical contact with the tab.

TL7757Y chip information

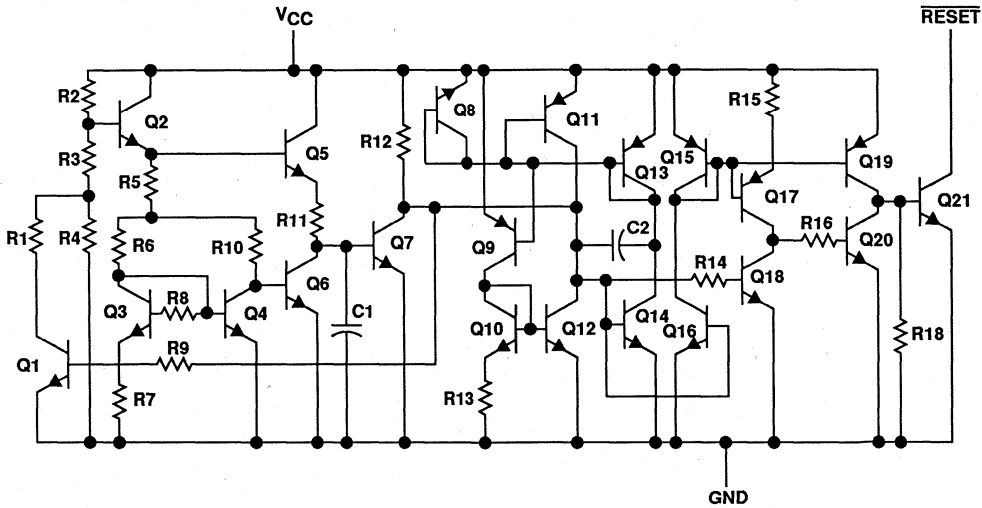
These chips, properly assembled, display characteristics similar to the TL7757. Thermal compression or ultrasonic bonding may be used on the doped aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



† Backside of chip has an internal electrical connection to pad 1.

TL7757 SUPPLY VOLTAGE SUPERVISOR AND PRECISION VOLTAGE DETECTOR

equivalent schematic



| ACTUAL DEVICE COMPONENT COUNT | |
|-------------------------------|----|
| Transistors | 27 |
| Resistors | 20 |
| Capacitors | 2 |

TL7757 SUPPLY VOLTAGE SUPERVISOR AND PRECISION VOLTAGE DETECTOR

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Supply voltage range, V_{CC} (see Note 1) | - 0.3 V to 20 V |
| Offstate output voltage range (see Note 1) | - 0.3 V to 20 V |
| Output current | 30 mA |
| Operating free-air temperature range, T_A : C-suffix | 0°C to 70°C |
| I-suffix | - 40°C to 85°C |
| M-suffix | - 55°C to 125°C |
| Continuous total power dissipation | See Dissipation Rating Table |
| Storage temperature range | - 65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 1: All voltage values are with respect to network terminal ground.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR | DERATE ABOVE | $T_A = 70^\circ\text{C}$ | $T_A = 85^\circ\text{C}$ | $T_A = 125^\circ\text{C}$ |
|---------|---|--------------------|--------------------------|--------------------------|--------------------------|---------------------------|
| D | 725 mW | 5.8 mW/°C | $T_A = 25^\circ\text{C}$ | 464 mW | 377 mW | 145 mW |
| LP | 775 mW | 6.2 mW/°C | $T_A = 25^\circ\text{C}$ | 496 mW | 403 mW | 155 mW |
| PK | 500 mW | 4.0 mW/°C | $T_A = 25^\circ\text{C}$ | 320 mW | 260 mW | 100 mW |
| PK | 3125 mW | 25 mW/°C | $T_C = 25^\circ\text{C}$ | 2000 mW | 1625 mW | 625 mW |

recommended operating conditions

| | C-SUFFIX | | I-SUFFIX | | M-SUFFIX | | UNIT |
|---------------------------------------|----------|-----|----------|-----|----------|-----|------|
| | MIN | MAX | MIN | MAX | MIN | MAX | |
| Supply voltage, V_{CC} | 1 | 7 | 1 | 7 | 1 | 7 | V |
| High-level output voltage, V_{OH} | | 15 | | 15 | | 15 | V |
| Low-level output current, I_{OL} | | 20 | | 20 | | 20 | mA |
| Operating free-air temperature, T_A | 0 | 70 | -40 | 85 | -55 | 125 | °C |

TL7757C
SUPPLY VOLTAGE SUPERVISOR
AND PRECISION VOLTAGE DETECTOR

electrical characteristics at specified free-air temperature

| PARAMETER | TEST CONDITIONS | T _A † | MIN | TYP | MAX | UNIT |
|--------------------|---|--|------|------|------|------|
| V _{T-} | Threshold voltage (negative-going V _{CC}) | 25°C | 4.43 | 4.55 | 4.67 | V |
| | | Full range | 4.4 | | 4.7 | |
| V _{hys} ‡ | Hysteresis at V _{CC} input | 25°C | 40 | 50 | 60 | mV |
| | | Full range | 30 | | 70 | |
| V _{OL} | Low-level output voltage | I _{OL} = 20 mA, V _{CC} = 4.3 V | | 0.1 | 0.8 | V |
| | | | | | 0.8 | |
| I _{OH} | High-level output current | V _{CC} = 4.7 to 7 V, V _{OL} = 15 V, See Figure 1 | | | 1 | µA |
| | | | | | 1 | |
| V _{res} § | Power-up reset voltage | R _L = 2.2 K, V _{CC} slew rate ≤ 5 V/µs | | 0.8 | 1 | V |
| | | | | | 1.2 | |
| I _{CC} | Supply current | V _{CC} = 4.3 V | | 1400 | 2000 | µA |
| | | | | | 2000 | |
| | | V _{CC} = 4.7 V to 7 V | | | 40 | |
| | | | | | 45 | |

switching characteristics at T_A = 25°C (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T _A † | MIN | TYP | MAX | UNIT |
|---------------------|---|---|-----|------|-----|------|
| t _{PLH} | Propagation delay time, low-to-high-level output | See Figures 2 and 3, V _{CC} slew rate ≤ 5 V/µs | | 3.4 | 5 | µs |
| | | | | | 5 | |
| t _{PHL} | Propagation delay time, high-to-low-level output | See Figures 2 and 3 | | 2 | 5 | µs |
| | | | | | 5 | |
| t _r | Rise time | See Figures 2 and 3, V _{CC} slew rate ≤ 5 V/µs | | 0.4 | 1 | µs |
| | | | | | 1 | |
| t _f | Fall time | See Figures 2 and 3 | | 0.05 | 1 | µs |
| | | | | | 1 | |
| t _{w(min)} | Minimum pulse duration at V _{CC} for output response | | | 5 | | µs |
| | | | | 5 | | |

† Full range is 0°C to 70°C.

‡ This is the difference between positive-going input threshold voltage, V_{T+}, and negative-going input threshold voltage, V_{T-}.

§ This is the lowest voltage at which RESET becomes active.

TL77571 SUPPLY VOLTAGE SUPERVISOR AND PRECISION VOLTAGE DETECTOR

electrical characteristics at specified free-air temperature

| PARAMETER | TEST CONDITIONS | T _A [†] | MIN | TYP | MAX | UNIT | |
|-------------------------------|---|--|------------|------|------|------|--|
| V _{T-} | Threshold voltage (negative-going V _{CC}) | 25°C | 4.43 | 4.55 | 4.67 | V | |
| | | Full range | 4.4 | | 4.7 | | |
| V _{hys} [‡] | Hysteresis at V _{CC} input | 25°C | 40 | 50 | 60 | mV | |
| | | Full range | 30 | | 70 | | |
| V _{OL} | Low-level output voltage | I _{OL} = 20 mA, V _{CC} = 4.3 V | 25°C | 0.1 | 0.8 | V | |
| | | | Full range | | 0.8 | | |
| I _{OH} | High-level output current | V _{CC} = 4.7 to 7 V, V _{OL} = 15 V, See Figure 1 | 25°C | | 1 | μA | |
| | | | Full range | | 1 | | |
| V _{res} [§] | Power-up reset voltage | R _L = 2.2 K, V _{CC} slew rate ≤ 5 V/μs | 25°C | 0.8 | 1 | V | |
| | | | Full range | | 1.2 | | |
| I _{CC} | Supply current | V _{CC} = 4.3 V | 25°C | 1400 | 2000 | μA | |
| | | | Full range | | 2100 | | |
| | | V _{CC} = 4.7 V to 7 V | 25°C | | 40 | | |
| | | | Full range | | 45 | | |

switching characteristics at T_A = 25°C (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T _A [†] | MIN | TYP | MAX | UNIT |
|---------------------|---|---|------------|------|-----|------|
| t _{PLH} | Propagation delay time, low-to-high-level output | See Figures 2 and 3, V _{CC} slew rate ≤ 5 V/μs | 25°C | 3.4 | 5 | μs |
| | | | Full range | | 5 | |
| t _{PHL} | Propagation delay time, high-to-low-level output | See Figures 2 and 3 | 25°C | 2 | 5 | μs |
| | | | Full range | | 5 | |
| t _r | Rise time | See Figures 2 and 3, V _{CC} slew rate ≤ 5 V/μs | 25°C | 0.4 | 1 | μs |
| | | | Full range | | 1 | |
| t _f | Fall time | See Figures 2 and 3 | 25°C | 0.05 | 1 | μs |
| | | | Full range | | 1 | |
| t _{w(min)} | Minimum pulse duration at V _{CC} for output response | | 25°C | 5 | | μs |
| | | | Full range | 5 | | |

[†] Full range is -40°C to 85°C.

[‡] This is the difference between positive-going input threshold voltage, V_{T+}, and negative-going input threshold voltage, V_{T-}.

[§] This is the lowest voltage at which RESET becomes active.

TL7757M
SUPPLY VOLTAGE SUPERVISOR
AND PRECISION VOLTAGE DETECTOR

electrical characteristics at specified free-air temperature

| PARAMETER | | TEST CONDITIONS | T _A † | MIN | TYP | MAX | UNIT |
|--------------------|---|--|------------------|------|------|------|------|
| V _{T-} | Threshold voltage (negative-going V _{CC}) | | 25°C | 4.43 | 4.55 | 4.67 | V |
| | | | Full range | 4.35 | | 4.7 | |
| V _{hys} ‡ | Hysteresis at V _{CC} input | | 25°C | 40 | 50 | 60 | mV |
| | | | Full range | 30 | | 70 | |
| V _{OL} | Low-level output voltage | I _{OL} = 20 mA, V _{CC} = 4.3 V | 25°C | | 0.1 | 0.8 | V |
| | | | Full range | | | 0.8 | |
| I _{OH} | High-level output current | V _{CC} = 4.7 to 7 V, V _{OL} = 15 V, See Figure 1 | 25°C | | | 1 | µA |
| | | | Full range | | | 1 | |
| V _{res} § | Power-up reset voltage | R _L = 2.2 K, V _{CC} slew rate ≤ 5 V/µs | 25°C | | 0.8 | 1 | V |
| | | | Full range | | | 1.2 | |
| I _{CC} | Supply current | V _{CC} = 4.3 V | 25°C | | 1400 | 2000 | µA |
| | | | Full range | | | 2500 | |
| | | V _{CC} = 4.7 V to 7 V | 25°C | | | 40 | |
| | | | Full range | | | 45 | |

switching characteristics at T_A = 25°C (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | T _A † | MIN | TYP | MAX | UNIT |
|---------------------|---|---|------------------|-----|------|-----|------|
| t _{PLH} | Propagation delay time, low-to-high-level output | See Figures 2 and 3, V _{CC} slew rate ≤ 5 V/µs | 25°C | | 3.4 | 5* | µs |
| | | | Full range | | | 6* | |
| t _{PHL} | Propagation delay time, high-to-low-level output | See Figures 2 and 3 | 25°C | | 2 | 5* | µs |
| | | | Full range | | | 5* | |
| t _r | Rise time | See Figures 2 and 3, V _{CC} slew rate ≤ 5 V/µs | 25°C | | 0.4 | 1* | µs |
| | | | Full range | | | 1* | |
| t _f | Fall time | See Figures 2 and 3 | 25°C | | 0.05 | 1* | µs |
| | | | Full range | | | 1 | |
| t _{w(min)} | Minimum pulse duration at V _{CC} for output response | | 25°C | | 5* | | µs |
| | | | Full range | | | 6* | |

*On products compliant to MIL-STD-883, Class B, this parameter is not production tested.

† Full range is -55°C to 125°C.

‡ This is the difference between positive-going input threshold voltage, V_{T+}, and negative-going input threshold voltage, V_{T-}.

§ This is the lowest voltage at which RESET becomes active.

TL7757Y

SUPPLY VOLTAGE SUPERVISOR AND PRECISION VOLTAGE DETECTOR

electrical characteristics at specified free-air temperature

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT | |
|----------------------|--|---|------|------|------|---------------|
| V_{T-} | Threshold voltage (negative-going V_{CC}) | 4.43 | 4.55 | 4.67 | V | |
| V_{hys}^{\dagger} | Hysteresis at V_{CC} input | 40 | 50 | 60 | mV | |
| V_{OL} | Low-level output voltage | $I_{OL} = 20 \text{ mA}$, $V_{CC} = 4.3 \text{ V}$ | | 0.1 | 0.8 | V |
| I_{OH} | High-level output current | $V_{CC} = 4.7 \text{ to } 7 \text{ V}$, $V_{OL} = 15 \text{ V}$, See Figure 1 | | | 1 | μA |
| V_{res}^{\ddagger} | Power-up reset voltage | $R_I = 2.2 \text{ K}$, V_{CC} slew rate $\leq 5 \text{ V}/\mu\text{s}$ | | 0.8 | 1 | V |
| I_{CC} | Supply current | $V_{CC} = 4.3 \text{ V}$ | | 1400 | 2000 | μA |
| | | $V_{CC} = 4.7 \text{ V to } 7 \text{ V}$ | | 40 | | |

switching characteristics at $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT | |
|-------------------|--|--|-----|------|------|---------------|
| t_{PLH} | Propagation delay time, low-to-high-level output | See Figures 2 and 3, V_{CC} slew rate $\leq 5 \text{ V}/\mu\text{s}$ | | 3.4 | 5 | μs |
| t_{PHL} | Propagation delay time, high-to-low-level output | See Figures 2 and 3 | | 2 | 5 | μs |
| t_r | Rise time | See Figures 2 and 3, V_{CC} slew rate $\leq 5 \text{ V}/\mu\text{s}$ | | 0.4 | 1 | μs |
| t_f | Fall time | See Figures 2 and 3 | | 0.05 | 1 | μs |
| $t_w(\text{min})$ | Minimum pulse duration at V_{CC} for output response | | | 5 | | μs |

\dagger This is the difference between positive-going input threshold voltage, V_{T+} , and negative-going input threshold voltage, V_{T-} .

\ddagger This is the lowest voltage at which RESET becomes active.

PARAMETER MEASUREMENT INFORMATION

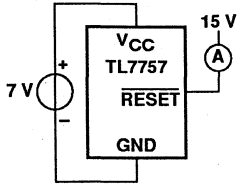
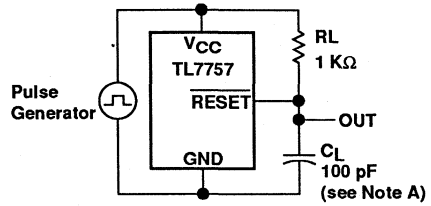
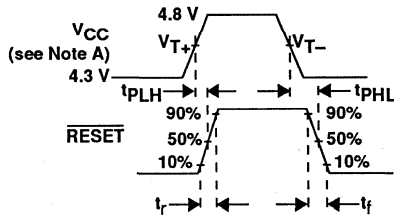


Figure 1. Test Circuit for Output Leakage Current



NOTE A: Includes jig and probe capacitance.

Figure 2. Test Circuit for RESET Output Switching Characteristics



NOTE A: V_{CC} slew rate $\leq 5 \mu s$

Figure 3. Switching Diagram

TL7757
SUPPLY VOLTAGE SUPERVISOR
AND PRECISION VOLTAGE DETECTOR

TYPICAL CHARACTERISTICS

table of graphs

| | | | FIGURE |
|-----------|--|-------------------|---------------|
| V_{CC} | Supply voltage | vs Output voltage | 1 |
| I_{CC} | Supply current | vs Supply voltage | 2 |
| | | vs Temperature | 3 |
| V_{OL} | Low-level output voltage | vs Output current | 4 |
| | | vs Temperature | 5 |
| I_{OL} | Output current | vs Supply voltage | 6 |
| V_{T-} | Threshold voltage (negative-going V_{CC}) | vs Temperature | 7 |
| V_{res} | Power-up reset voltage | vs Temperature | 8 |
| | | | 9 |
| t_{PLH} | Propagation delay time low to high | | 10 |
| t_{PHL} | Propagation delay time high to low | | |

TYPICAL CHARACTERISTICS†

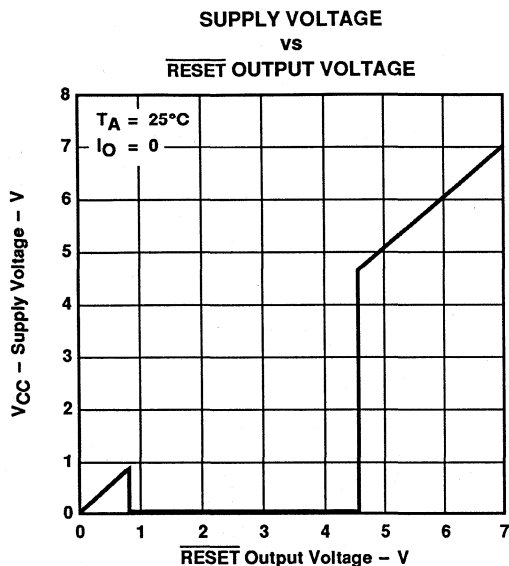


Figure 1

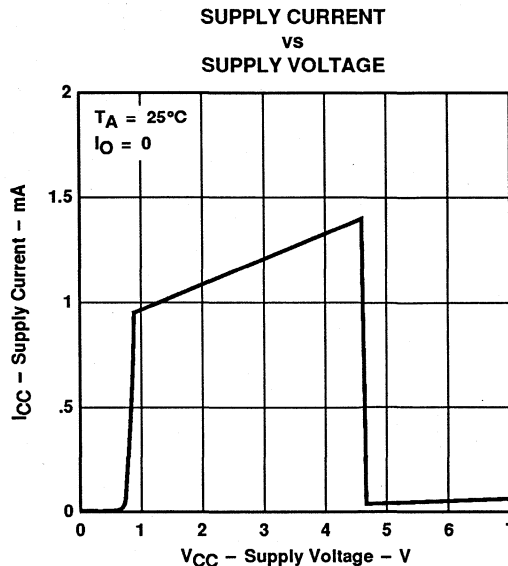


Figure 2

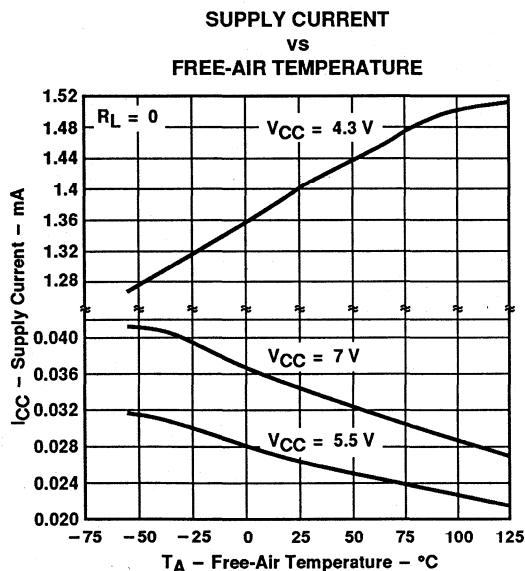


Figure 3

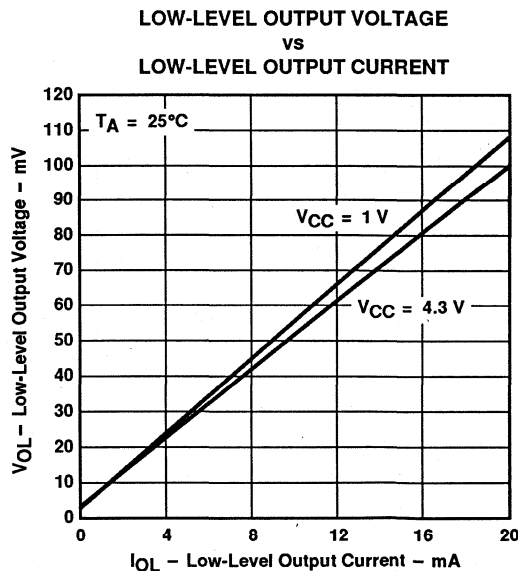


Figure 4

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TL7757 SUPPLY VOLTAGE SUPERVISOR AND PRECISION VOLTAGE DETECTOR

TYPICAL CHARACTERISTICS†

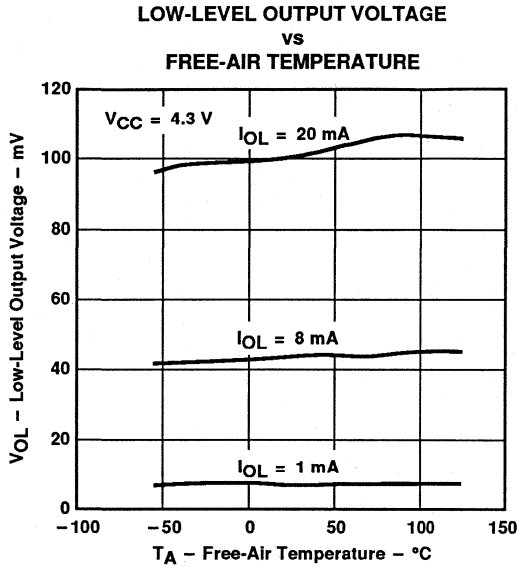


Figure 5

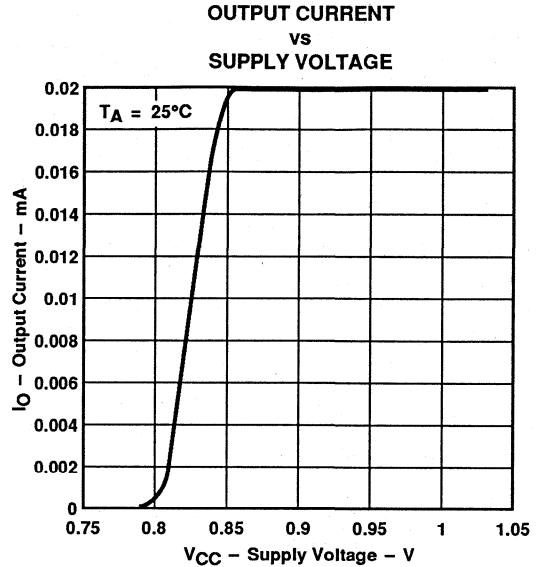


Figure 6

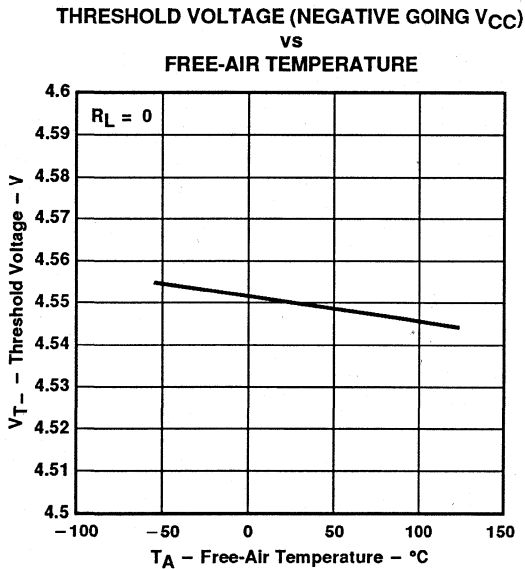


Figure 7

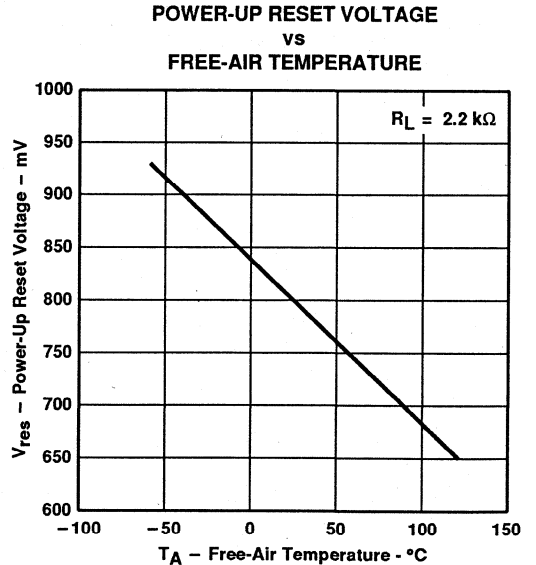


Figure 8

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

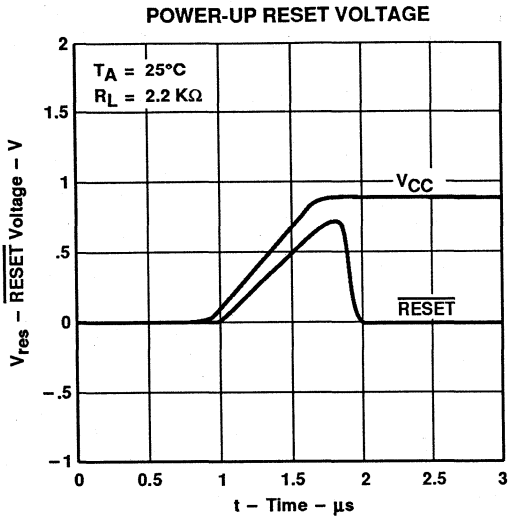


Figure 9

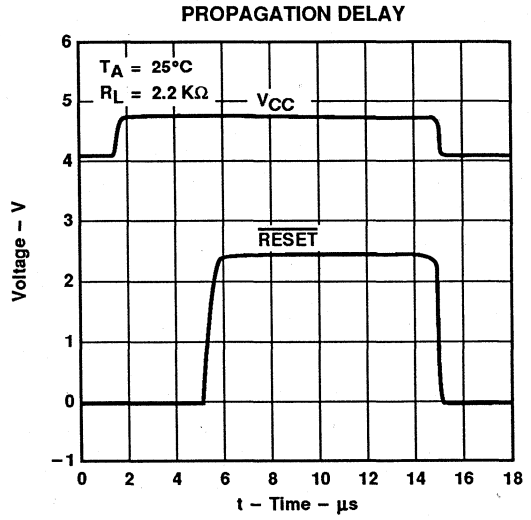


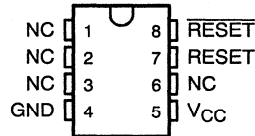
Figure 10

TL7759C SUPPLY VOLTAGE SUPERVISOR

D3905, JANUARY 1991—REVISED SEPTEMBER 1991

- Power-On Reset Generator
- Automatic Reset Generation After Voltage Drop
- Precision Threshold Voltage
4.55 V \pm 120 mV
- Low Standby Current . . . 20 μ A
- Reset Outputs Defined When V_{CC} Exceeds 1 V
- True and Complementary Reset Outputs
- Wide Operating Temperature Range
0°C to 70°C
- Wide Supply Voltage Range . . . 1 V to 7 V

D OR P PACKAGE
(TOP VIEW)



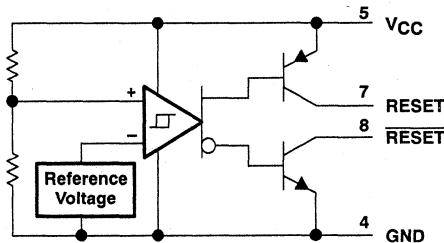
NC — No internal connection

description

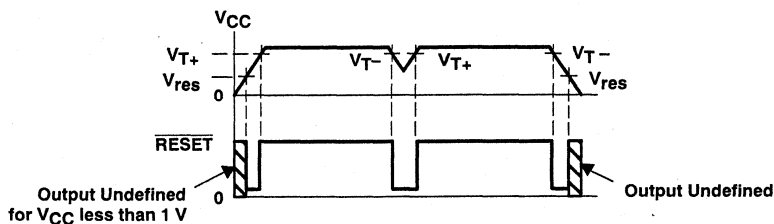
The TL7759C is a monolithic supply voltage supervisor designed for use as a reset controller in microcomputer and microprocessor systems. The supervisor monitors the supply voltage for undervoltage conditions. During power-up, when the supply voltage, V_{CC} , attains a value approaching 1 V, the $\overline{\text{RESET}}$ and RESET outputs become active (high and low, respectively) to prevent undefined operation. If at any time the supply voltage drops below the threshold voltage level (V_{T-}), the reset outputs go to the reset active state until the supply voltage has returned to its nominal value.

The TL7759C is characterized for operation from 0°C to 70°C.

functional block diagram



timing diagram



PRODUCTION DATA Information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.


**TEXAS
INSTRUMENTS**

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2-373

TL7759C SUPPLY VOLTAGE SUPERVISOR

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|------------------------------|
| Supply voltage, V_{CC} (see Note 1) | 20 V |
| Off-state output voltage range: $\overline{\text{RESET}}$ voltage | -0.3 V to 20 V |
| $\overline{\text{RESET}}$ voltage | -0.3 V to 20 V |
| Low-level output current, I_{OL} ($\overline{\text{RESET}}$) | 30 mA |
| High-level output current, I_{OH} ($\overline{\text{RESET}}$) | -10 mA |
| Continuous total power dissipation | See Dissipation Rating Table |
| Operating free-air temperature range, T_A | 0°C to 70°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 1: All voltage values are with respect to the network ground terminal.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$ | $T_A = 70^\circ\text{C}$ POWER RATING | $T_A = 85^\circ\text{C}$ POWER RATING |
|---------|---|---|--|--|
| D | 725 mW | 5.8 mW/°C | 464 mW | 377 mW |
| P | 1000 mW | 8.0 mW/°C | 640 mW | 520 mW |

recommended operating conditions

| | MIN | MAX | UNIT |
|---------------------------------------|--|-----|------|
| Supply voltage, V_{CC} | 1 | 7 | V |
| Output voltage, V_O (see Note 2) | Transistor off $\overline{\text{RESET}}$ voltage | | 15 |
| | Transistor off $\overline{\text{RESET}}$ voltage | | 0 |
| Low-level output current, I_{OL} | $\overline{\text{RESET}}$ | | 24 |
| High-level output current, I_{OH} | $\overline{\text{RESET}}$ | | -8 |
| Operating free-air temperature, T_A | 0 | 70 | °C |

NOTE 2: $\overline{\text{RESET}}$ output must not be pulled down below GND potential.

electrical characteristics over recommended operating free-air temperature range (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|---|---|-------------------------|------|------|---------------|
| V_{OL} Low-level output voltage | $\overline{\text{RESET}}$ $V_{CC} = 4.3\text{ V}$ $I_{OL} = 24\text{ mA}$ | | 0.4 | 0.8 | V |
| V_{OH} High-level output voltage | $\overline{\text{RESET}}$ $I_{OH} = -8\text{ mA}$ | $V_{CC}-1$ | | | |
| V_{T-} Threshold voltage (negative-going V_{CC}) | $T_A = 25^\circ\text{C}$ | 4.43 | 4.55 | 4.67 | V |
| | $T_A = 0^\circ\text{C}$ to 70°C | 4.4 | | 4.7 | |
| V_{res}^\ddagger Power-up reset voltage | $R_L = 2.2\text{ k}\Omega$ $T_A = 25^\circ\text{C}$ | | 0.8 | 1 | V |
| | $T_A = 0^\circ\text{C}$ to 70°C | | | 1.2 | |
| V_{hys}^\S Hysteresis at V_{CC} input | $T_A = 25^\circ\text{C}$ | 40 | 50 | 60 | mV |
| | $T_A = 0^\circ\text{C}$ to 70°C | 30 | | 70 | |
| I_{OH} High-level output current | $\overline{\text{RESET}}$ $V_{CC} = 7\text{ V}$ $V_{OH} = 15\text{ V}$ | | | 1 | μA |
| I_{OL} Low-level output current | $\overline{\text{RESET}}$ See Figure 1 $V_{OL} = 0\text{ V}$ | | | -1 | |
| I_{CC} Supply current | No load | $V_{CC} = 4.3\text{ V}$ | 1400 | 2000 | μA |
| | | $V_{CC} = 5.5\text{ V}$ | | 40 | |

† Typical values are at $T_A = 25^\circ\text{C}$.

‡ This is the lowest voltage at which $\overline{\text{RESET}}$ becomes active, V_{CC} slew rate $\geq 5\text{ V}/\mu\text{s}$.

§ This is the difference between positive-going input threshold voltage, V_{T+} , and negative-going input threshold voltage, V_{T-} .



switching characteristics at $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | FROM (INPUT) | TO (OUTPUT) | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|--------------|-------------|----------------------|-----|-----|-----|------|
| t_{PLH} Propagation delay time, low-to-high-level output | VCC | RESET | See Figures 2 and 3† | | | 5 | μs |
| t_{PHL} Propagation delay time, high-to-low-level output | VCC | RESET | See Figures 2 and 4 | | | 5 | |
| t_r Rise time | | RESET | See Figures 2 and 4† | | | 1 | |
| t_f Fall time | | RESET | See Figures 2 and 4 | | | 1 | |
| $t_{w(\min)}$ Minimum pulse duration | VCC | RESET | See Figures 2 and 4 | 5 | | | |

† VCC slew rate > 5 V/μs.

PARAMETER MEASUREMENT INFORMATION

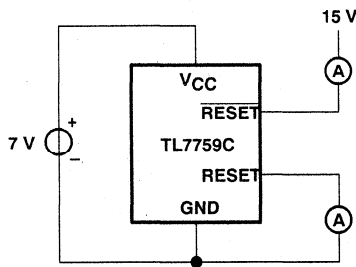
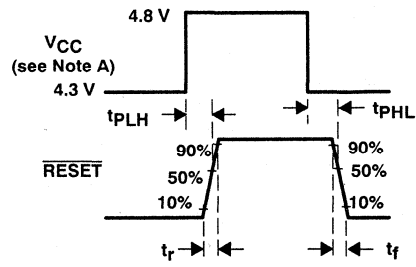
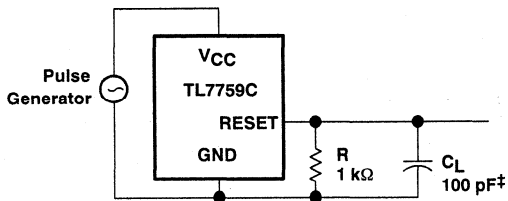


Figure 1. Test Circuit for Output Leakage Current



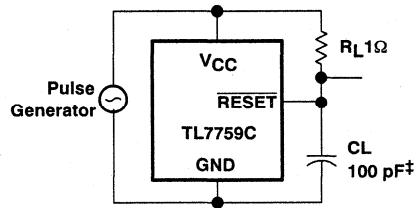
NOTE A: VCC slew rate > 5 V/μs.

Figure 2. Switching Diagram



‡ Includes jig and probe capacitance

Figure 3. Test Circuit for RESET Output Switching Characteristics



‡ Includes jig and probe capacitance

Figure 4. Test Circuit for RESET Output Switching Characteristics

TL7759C SUPPLY VOLTAGE SUPERVISOR

APPLICATION INFORMATION

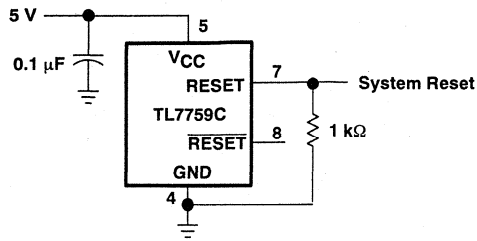


Figure 5. Power Supply System Reset Generation

TL7770-5, TL7770-12, TL7770-15 DUAL POWER-SUPPLY SUPERVISORS

D3035, OCTOBER 1987—REVISED NOVEMBER 1991

- Power-On Reset Generator
- Automatic Reset Generation After Voltage Drop
- $\overline{\text{RESET}}$ Defined When V_{CC} Exceeds 1 V
- Wide Supply Voltage Range . . . 3.5 V to 18 V
- Precision Overvoltage and Undervoltage Sensing
- 250-mA Peak Output Current for Driving SCR Gates
- 2-mA Active-Low SCR Gate Drive for False Trigger Protection
- Temperature-Compensated Voltage Reference
- True and Complementary Reset Outputs
- Externally Adjustable Output Pulse Duration

description

The TL7770 is a monolithic integrated circuit system supervisor designed for use as a reset controller in microcomputer and microprocessor power supply systems. This device contains two independent supply-voltage supervisors that monitor the supplies for overvoltage and undervoltage conditions at the VSO and VSU pins, respectively. When V_{CC} attains the minimum voltage of 1 V during power-up, the $\overline{\text{RESET}}$ output becomes active (low). As V_{CC} approaches 3.5 V, the delay timer function activates latching $\overline{\text{RESET}}$ and $\overline{\text{RESET}}$ active (high and low, respectively) for a time delay, t_d , after system voltages have achieved normal levels. Above $V_{CC} = 3.5$ V, taking $\overline{\text{RESIN}}$ low activates the time delay function, $\overline{\text{RESET}}$ and $\overline{\text{RESET}}$, during normal system voltage levels. To ensure that the microcomputer system has reset, the outputs remain active until the voltage at VSU exceeds the threshold value V_{T+} for a time delay, t_d , which is determined by an external timing capacitor such that:

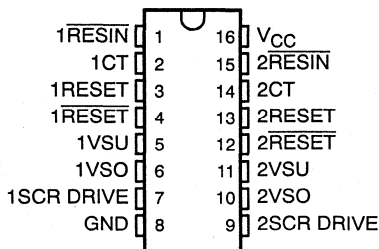
$$t_d \approx 20 \times 10^3 \times \text{capacitance}$$

where t_d is in seconds and capacitance is in farads.

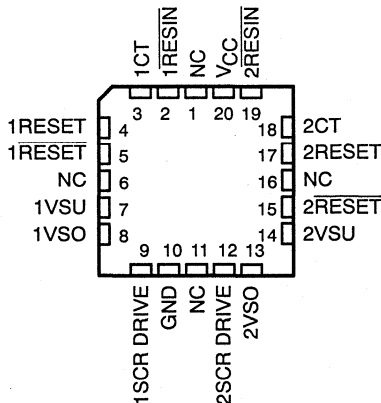
The overvoltage-detection circuit is programmable for a wide range of user designs. During an overvoltage condition, an internal SCR is triggered, providing 250-mA peak instantaneous current and 25-mA continuous current to the SCR gate drive pin, which can be used to drive an external high-current SCR gate or an overvoltage warning circuit.

The TL7770C is characterized for operation from 0°C to 70°C. The TL7770M series is characterized for operation from -55°C to 125°C. The TL7770Q series is characterized for operation from -40°C to 125°C.

DW, J, OR N PACKAGE
(TOP VIEW)



FK PACKAGE
(TOP VIEW)



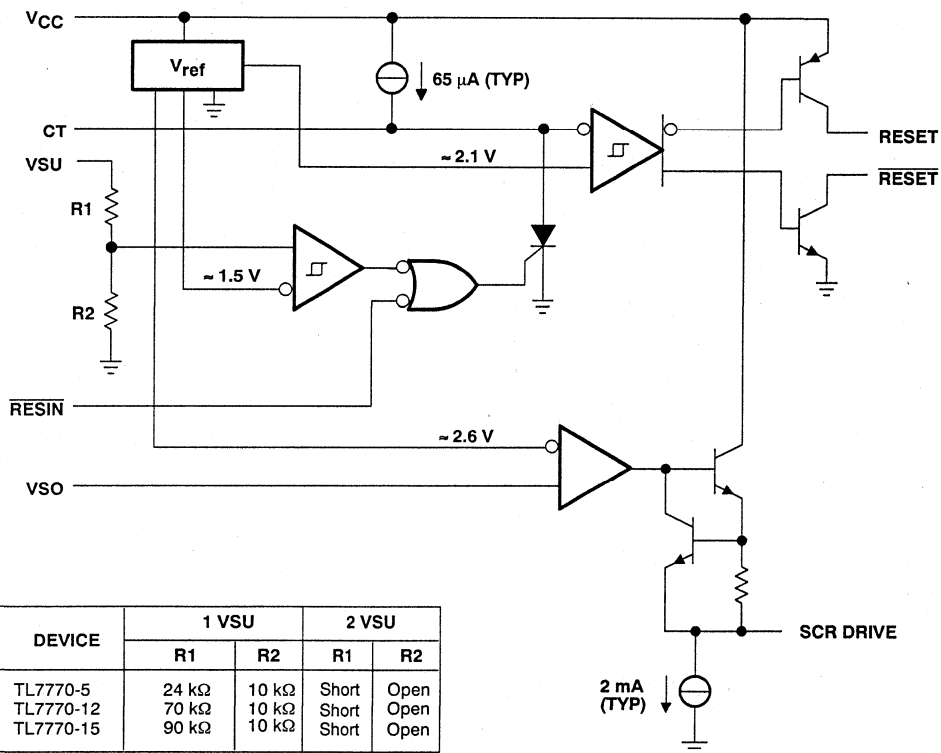
NC—No internal connection

TL7770-5, TL7770-12, TL7770-15 DUAL POWER-SUPPLY SUPERVISORS

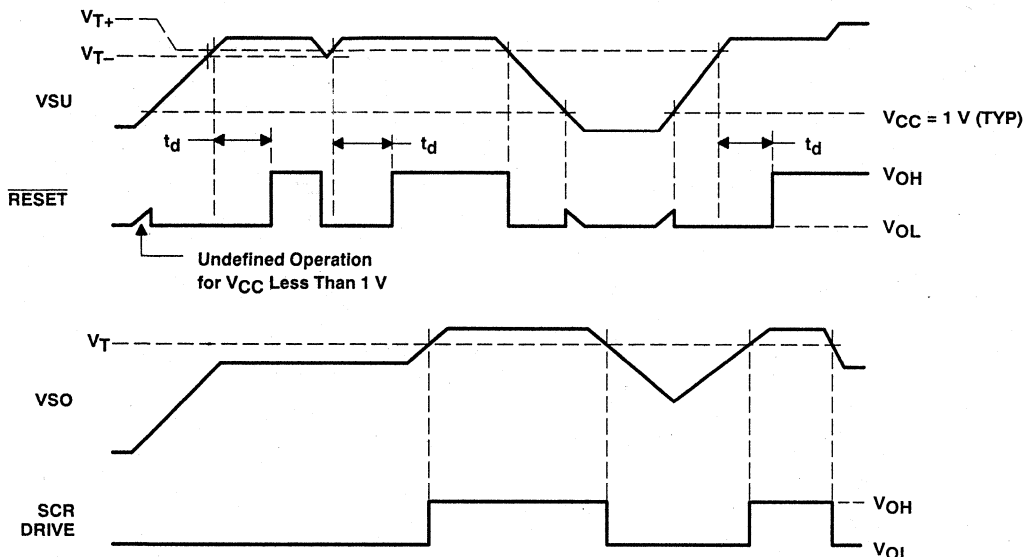
AVAILABLE OPTIONS

| T _A | PACKAGE | | | |
|----------------|---|---|--|--|
| | SMALL OUTLINE (DW) | CHIP CARRIER (FK) | CERAMIC DIP (J) | PLASTIC DIP (N) |
| 0°C to 70°C | TL7770-5CDW TL7770-12CDW TL7770-15CDW | | | TL7770-5CN TL7770-12CN TL7770-15CN |
| -40°C to 125°C | TL7770-5QDW TL7770-12QDW TL7770-15QDW | | | TL7770-5QN TL7770-12QN TL7770-15QN |
| -55°C to 125°C | | TL7770-5MFK TL7770-12MFK TL7770-15MFK | TL7770-5MJ TL7770-12MJ TL7770-15MJ | |

logic diagram (each channel)



typical timing diagram



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|------------------------------|
| Supply voltage, V_{CC} (see Note 1) | 20 V |
| Input voltage range, V_I : 1VSU, 2VSU, 1VSO, and 2VSO | -0.3 V to 18 V |
| Low-level output current (1RESET and 2RESET), I_{OL} | 20 mA |
| High-level output current (1RESET and 2RESET), I_{OH} | -20 mA |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range: TL7770_C | 0°C to 70°C |
| TL7770_M | -55°C to 125°C |
| TL7770-Q | -40°C to 125°C |
| Operating virtual junction temperature range | -40°C to 150°C |
| Storage temperature range | -65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 in) from case for 10 seconds: DW or N package | 260°C |
| Lead temperature 1,6 mm (1/16 in) from case for 60 seconds: J package | 300°C |

NOTE 1: All voltage values are with respect to the network ground terminal.

DISSIPATION RATING TABLE

| PACKAGE | $T_A = 25^\circ\text{C}$ POWER RATING | DERATING FACTOR | $T_A = 70^\circ\text{C}$ POWER RATING | $T_A = 85^\circ\text{C}$ POWER RATING | $T_A = 125^\circ\text{C}$ POWER RATING |
|---------|--|--------------------|--|--|---|
| DW | 1025 mW | 8.2 mW/°C | 656 mW | 533 mW | 205 mW |
| FK | 1375 mW | 11.0 mW/°C | 880 mW | 715 mW | 275 mW |
| J | 1375 mW | 11.0 mW/°C | 880 mW | 715 mW | 275 mW |
| N | 1150 mW | 9.2 mW/°C | 736 mW | 598 mW | 230 mW |

TL7770-5, TL7770-12, TL7770-15 DUAL POWER-SUPPLY SUPERVISORS

recommended operating conditions

| | | MIN | MAX | UNIT |
|--|------------------------|-----|-----|---------|
| Supply voltage, V_{CC} | | 3.5 | 18 | V |
| Input voltage range, V_I (see Note 2) | 1VSU, 2VSU, 2VSO, 1VSO | 0 | 18 | V |
| Output voltage (1CT and 2CT), V_O | | | 5 | V |
| High-level input voltage range, V_{IH} , 1RESIN, 2RESIN | | 2 | 18 | V |
| Low-level input voltage range, V_{IL} , 1RESIN, 2RESIN | | 0 | 0.8 | V |
| Output sink current (1CT and 2CT), I_O | | | 50 | μ A |
| High-level output current (1RESET and 2RESET), I_{OH} | | | -16 | mA |
| Low-level output current (1RESET and 2RESET), I_{OL} | | | 16 | mA |
| Continuous output current (1SCR DRIVE and 2SCR DRIVE), I_O | | | 25 | mA |
| Operating free-air temperature, T_A | TL7770C Series | 0 | 70 | °C |
| | TL7770M Series | -55 | 125 | |
| | TL7770Q Series | -40 | 125 | |

NOTE 2: The algebraic convention, in which the least positive (most negative) value is designated minimum, is used in this data sheet for logic voltage levels only.

**TL7770-5C, TL7770-12C, TL7770-15C
TL7770-5Q, TL7770-12Q, TL7770-15Q
DUAL POWER-SUPPLY SUPERVISORS**

electrical characteristics over recommended ranges of supply voltage, input voltage, output current, and free-air temperature (unless otherwise noted)

supply supervisor section

| PARAMETER | | TEST CONDITIONS† | MIN | TYP‡ | MAX | UNIT | |
|------------------|--|---|---------------------------------|-------|-------|-------|----|
| V _{OH} | High-level output voltage | RESET | V _{CC} -1.5 | | | V | |
| | | SCR DRIVE | V _{CC} -1.5 | | | | |
| V _{OL} | Low-level output voltage | RESET | 0.4 | | | V | |
| V _{T-} | Undervoltage threshold at VSU (negative-going) | TL7770-5 (5-V sense, 1VSU) | T _A = 25°C | 4.5 | 4.55 | 4.6 | V |
| | | TL7770-12 (12-V sense, 1VSU) | | 10.8 | 10.9 | 11.02 | |
| | | TL7770-15 (15-V sense, 1VSU) | | 13.5 | 13.64 | 13.77 | |
| | | TL7770-5, TL7770-12, TL7770-15 (programmable sense, 2VSU) | | 1.485 | 1.5 | 1.515 | |
| | | TL7770-5 (5-V sense, 1VSU) | | 4.46 | | 4.64 | |
| | | TL7770-12 (12-V sense, 1VSU) | | 10.68 | | 11.12 | |
| | | TL7770-15 (15-V sense, 1VSU) | | 13.36 | | 13.91 | |
| V _{hys} | Hysteresis at VSU (V _{T+} - V _{T-}) | TL7770-5 (5-V sense, 1VSU) | T _A = 25°C | 15 | | mV | |
| | | TL7770-12 (12-V sense, 1VSU) | | 36 | | | |
| | | TL7770-15 (15-V sense, 1VSU) | | 45 | | | |
| | | TL7770-5, TL7770-12, TL7770-15 (programmable sense, 2VSU) | | 5 | | | |
| V _T | Overvoltage threshold at VSO | TL7770-5, TL7770-12, TL7770-15 (VSO) | T _A = 25°C | 2.53 | 2.58 | 2.63 | V |
| | | | T _A = MIN to MAX | 2.48 | | 2.68 | |
| I _I | Input current | RESIN | V _I = 5.5 V or 0.4 V | | | -10 | μA |
| | | VSO | V _I = 2.4 V | | | 0.5 | |
| I _{OH} | High-level output current | RESET | V _O = 18 V | | | 50 | μA |
| I _{OL} | Low-level output current | RESET | V _O = 0 | | | -50 | μA |
| I _{OH} | Peak output current | SCR DRIVE | Duration = 1 ms | | | 250 | mA |

total device

| PARAMETER | | TEST CONDITIONS† | MIN | TYP‡ | MAX | UNIT | | |
|--------------------|------------------------|--|---|-----------------------------|-----|------|----|-----|
| V _{res} § | Power-up reset voltage | V _{CC} | V _{OL} = 0.4 V, I _{OL} = 1 mA | | | 0.8 | 1 | V |
| I _{CC} | Supply current | 1VSU = 18 V, 2VSU = 2 V, 1RESIN and 2RESIN at V _{CC} , 1VSO and 2VSO at 0 V | T _A = 25°C | | | 5 | mA | |
| | | | | T _A = MIN to MAX | | | | 6.5 |

† For conditions shown as MIN or MAX, use the appropriate value specified in the recommended operating conditions.

‡ Typical values are at V_{CC} = 5 V, T_A = 25°C.

§ This is the lowest voltage at which RESET becomes active.



TL7770-5M, TL7770-12M, TL7770-15M DUAL POWER-SUPPLY SUPERVISORS

electrical characteristics over recommended ranges of supply voltage, input voltage, output current, and free-air temperature (unless otherwise noted)

supply supervisor section

| PARAMETER | | TEST CONDITIONS† | MIN | TYP‡ | MAX | UNIT | |
|------------------|--|--|----------------------------------|-------|-------|--------|---|
| V _{OH} | High-level output voltage | RESET | V _{CC} -1.5 | | | V | |
| | | SCR DRIVE | V _{CC} -1.5 | | | | |
| V _{OL} | Low-level output voltage | RESET | 0.4 | | | V | |
| | | | I _{OL} = 15 mA | | | | |
| V _{T-} | Undervoltage threshold at VSU (negative-going) | TL7770-5M (5-V sense, 1VSU) | T _A = 25°C | 4.5 | 4.55 | 4.632 | V |
| | | TL7770-12M (12-V sense, 1VSU) | | 10.8 | 10.9 | 11.07 | |
| | | TL7770-15M (15-V sense, 1VSU) | | 13.5 | 13.64 | 13.866 | |
| | | TL7770-5M, TL7770-12M, TL7770-15M (programmable sense, 2VSU) | T _A = -55°C TO 125°C | 1.485 | 1.5 | 1.527 | |
| | | TL7770-5M (5-V sense, 1VSU) | | 4.4 | | 4.646 | |
| | | TL7770-12M (12-V sense, 1VSU) | | 10.62 | | 11.12 | |
| | | TL7770-15M (15-V sense, 1VSU) | | 13.36 | | 13.916 | |
| | | TL7770-5M, TL7770-12M, TL7770-15M (programmable sense, 2VSU) | | 1.47 | | 1.542 | |
| V _{hys} | Hysteresis at VSU (V _{T+} - V _{T-}) | TL7770-5M (5-V sense, 1VSU) | T _A = 25°C | 15 | | mV | |
| | | TL7770-12M (12-V sense, 1VSU) | | 36 | | | |
| | | TL7770-15M (15-V sense, 1VSU) | | 45 | | | |
| | | TL7770-5M, TL7770-12M, TL7770-15M (programmable sense, 2VSU) | | 5 | | | |
| V _T | Overvoltage threshold at VSO | TL7770-5M, TL7770-12M, TL7770-15M (VSO) | T _A = 25°C | 2.53 | 2.58 | 2.63 | V |
| | | | T _A = MIN to MAX | 2.48 | | 2.68 | |
| I _I | Input current | RESIN | V _I = 5.5 V or 0.4 V | | | μA | |
| | | VSO | V _I = 2.4 V | | | | |
| I _{OH} | High-level output current | RESET | V _O = V _{CC} | | | μA | |
| I _{OL} | Low-level output current | RESET | V _O = 1 | | | μA | |
| I _{OH} | Peak output current | SCR DRIVE | Duration = 1 ms | | | mA | |

total device

| PARAMETER | TEST CONDITIONS† | | MIN | TYP‡ | MAX | UNIT |
|--------------------------------|--|-----------------------------|-----|------|-----|------|
| I _{CC} Supply current | 1VSU 18 V, 2 VSU = 2 V, 1RESIN and 2RESIN at V _{CC} , | T _A = 25°C | 5 | | | mA |
| | 1VSO and 2VSO at 0 V | T _A = MIN to MAX | 6.5 | | | |

† For conditions shown as MIN or MAX, use the appropriate value specified in the recommended operating conditions.

‡ Typical values are at V_{CC} = 5 V, T_A = 25°C.

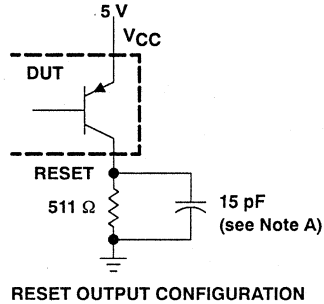
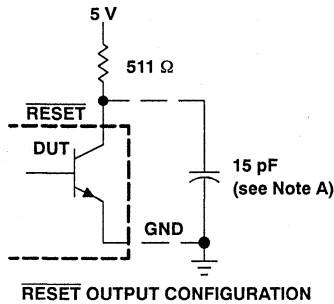


switching characteristics, $V_{CC} = 5\text{ V}$, CT open, $T_A = 25^\circ\text{C}$

| PARAMETER | FROM (INPUT) | TO (OUTPUT) | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-------------------|---------------------------|---------------------------|-----------------|-----|-----|------|------|
| t_{PLH} | RESET | RESET | See Figure 1 | | 270 | 500* | ns |
| t_{PLH} | $\overline{\text{RESET}}$ | $\overline{\text{RESET}}$ | | | 270 | 500* | ns |
| t_r | | RESET | | | | 75* | ns |
| t_f | | RESET | | | 150 | | |
| t_r | | $\overline{\text{RESET}}$ | | | | 75 | ns |
| t_f | | $\overline{\text{RESET}}$ | | | | 50* | |
| $t_w(\text{min})$ | RESET | | See Figure 2(a) | | 150 | ns | |
| | VSU | | See Figure 2(b) | | 100 | | |

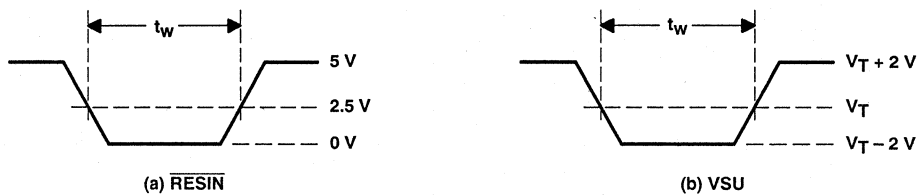
*On products compliant to MIL-STD-883, Class B, parameters are not production tested.

PARAMETER MEASUREMENT INFORMATION



NOTE A: Include jig and probe capacitance.

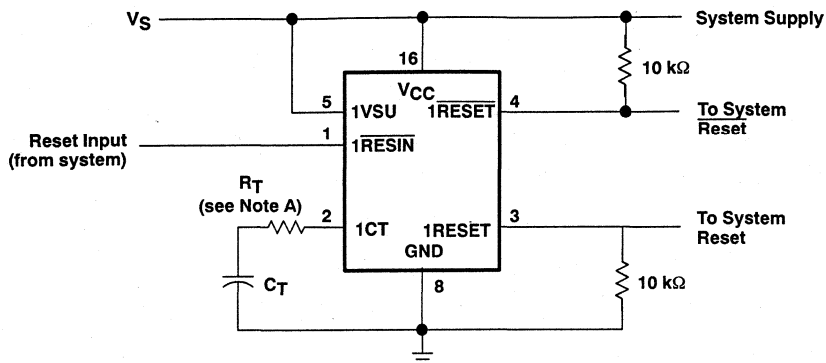
Figure 1. RESET and $\overline{\text{RESET}}$ Output Configurations



WAVEFORMS

Figure 2. Input Pulse Definition

APPLICATION INFORMATION



Pin numbers shown are for the DW, J, and N packages.

NOTE A: When V_{CC} and 1VSU are connected to the same point, it is recommended that series resistance (R_T) be added between the time delay programming capacitor (C_T) and the voltage supervisor device pin (1CT).

The suggested R_T value is given by:

$$R_T > \frac{V_I - V_{T-}}{1 \times 10^{-3}}, \text{ where } V_I = (\text{the lesser of } 7.1 \text{ V or } V_S)$$

When this series resistor is used, the t_d calculation is as follows:

$$t_d = \frac{1.3 - [(1 \times 10^{-4}) \times R_T]}{6.5 \times 10^{-4}} \times C_T$$

Figure 3. System Reset Controller With Undervoltage Sensing

TLE2425C, TLE2425I, TLE2425M, TLE2425Y PRECISION VIRTUAL GROUND

D3824, MARCH 1991, REVISED JUNE 1991

- 2.5-V Virtual Ground for 5-V/GND Analog Systems
- Self-Contained in Small Outline, Dual-In-Line or 3-Terminal TO-226AA Packages
- High Output-Current Capability Sink or Source . . . 20 mA Typ
- Micropower Operation . . . 170 μ A Typ
- Excellent Regulation Characteristics Output Regulation = $\pm 45 \mu$ V Typ, $I_O = 0$ to ± 10 mA Input Regulation = 1.5 μ V/V Typ
- Low-Impedance Output . . . 0.0075 Ω Typ
- Macromodel Included

description

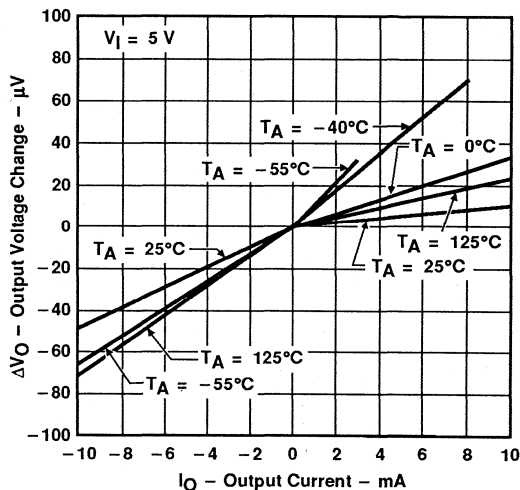
In signal-conditioning applications using a single power source, a reference voltage is required for termination of all signal grounds. To accomplish this, engineers have typically used solutions consisting of resistors, capacitors, operational amplifiers, and voltage references. Texas Instruments has eliminated all of those components with one easy-to-use 3-terminal device. That device is the TLE2425 precision virtual ground.

Use of the TLE2425 over other typical circuit solutions gives the designer increased dynamic signal range, improved signal-to-noise ratio, lower distortion, improved signal accuracy, and easier interfacing to ADCs and DACs. These benefits are the result of combining a precision micropower voltage reference and a high-performance precision operational amplifier in a single silicon chip. It is the precision and performance of these two circuit functions together that yield such dramatic system-level performance.

The TLE2425 improves input regulation as well as output regulation, and in addition reduces output impedance and power dissipation in a majority of virtual-ground-generation circuits. Both input regulation and load regulation exceed 12 bits of accuracy on a single 5-V system. Signal-conditioning front-ends of data acquisition systems that push 12 bits and beyond can use the TLE2425 to eliminate a major source of system error.

The TLE2425C is characterized for operation from 0°C to 70°C. The TLE2425I is characterized for operation from -40°C to 85°C. The TLE2425M is characterized for operation over the full military temperature range of -55°C to 125°C.

OUTPUT REGULATION



AVAILABLE OPTIONS

| T _A | PACKAGE | | | |
|----------------|-------------------|------------------|-----------------------|---------------|
| | SMALL OUTLINE (D) | CERAMIC DIP (JG) | PLASTIC TO-226AA (LP) | CHIP FORM (Y) |
| 0°C to 70°C | TLE2425CD | — | TLE2425CLP | TLE2425Y |
| -40°C to 85°C | TLE2425ID | — | TLE2425ILP | |
| -55°C to 125°C | TLE2425MD | TLE2425MJG | TLE2425MLP | |

D and LP packages are available taped and reeled in the commercial temperature range only. Add "R" suffix to device type (e.g., TLE2425CDR).

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

**TEXAS
INSTRUMENTS**

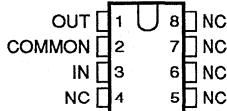
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Copyright © 1991, Texas Instruments Incorporated

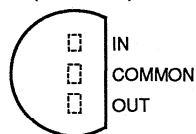
2-385

TLE2425C, TLE2425I, TLE2425M, TLE2425Y PRECISION VIRTUAL GROUND

**D OR JG PACKAGE
(TOP VIEW)**



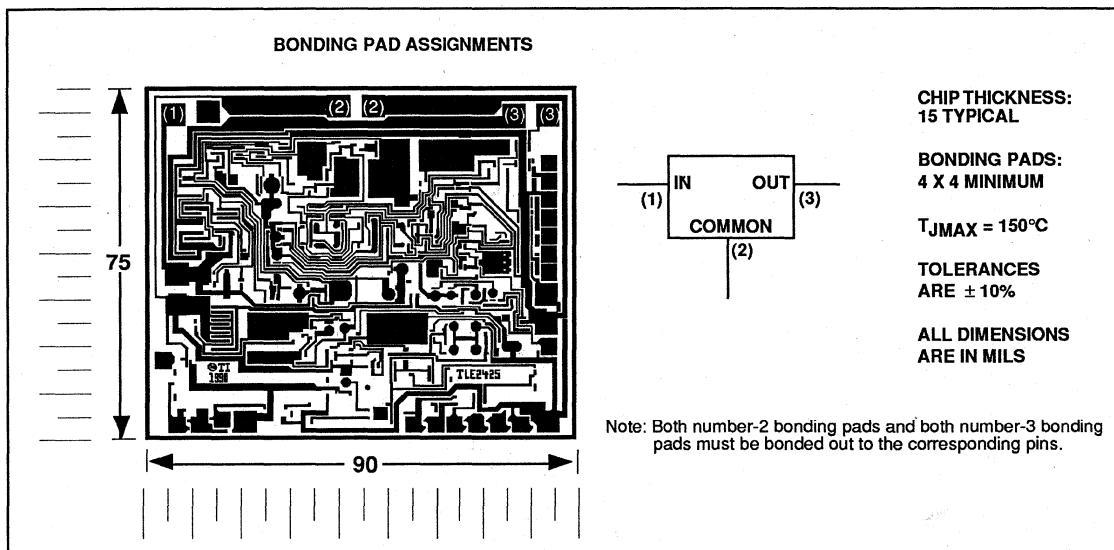
**LPPACKAGE
(TOP VIEW)**



NC – No internal connection

TLE2425Y chip information

These chips, properly assembled, display characteristics similar to the TLE2425, (see electrical table on TLE2425Y). Thermal compression or ultrasonic bonding may be used on the doped aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



TLE2425C, TLE2425I, TLE2425M, TLE2425Y PRECISION VIRTUAL GROUND

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Continuous input voltage | 40 V |
| Output current, I_O | ± 80 mA |
| Duration of short-circuit current at (or below) 25°C (see Note 1) | unlimited |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range, T_A : C-suffix | 0°C to 70°C |
| I-suffix | -40°C to 85°C |
| M-suffix | -55°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG or LP package | 300°C |

NOTE 1: The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ | DERATING FACTOR | $T_A = 70^\circ\text{C}$ | $T_A = 85^\circ\text{C}$ | $T_A = 125^\circ\text{C}$ |
|---------|-----------------------------|--------------------------------|--------------------------|--------------------------|---------------------------|
| | POWER RATING | ABOVE $T_A = 25^\circ\text{C}$ | POWER RATING | POWER RATING | POWER RATING |
| D | 725 mW | 5.8 mW/°C | 464 mW | 377 mW | 145 mW |
| JG | 1050 mW | 8.4 mW/°C | 672 mW | 546 mW | 210 mW |
| LP | 775 mW | 6.2 mW/°C | 496 mW | 403 mW | 155 mW |

recommended operating conditions

| | C-SUFFIX | | I-SUFFIX | | M-SUFFIX | | UNIT |
|---------------------------------------|----------|-----|----------|-----|----------|-----|------|
| | MIN | MAX | MIN | MAX | MIN | MAX | |
| Input voltage, V_I | 4 | 40 | 4 | 40 | 4 | 40 | V |
| Operating free-air temperature, T_A | 0 | 70 | -40 | 85 | -55 | 125 | °C |

TLE2425C PRECISION VIRTUAL GROUND

electrical characteristics at specified free-air temperature, $V_I = 5\text{ V}$, $I_O = 0$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_A † | MIN | TYP | MAX | UNIT |
|--|---|-----------------------|-----------------------|------|------|--------|
| | | 25°C | 2.48 | 2.5 | 2.52 | |
| Output voltage | | 25°C | 2.48 | 2.5 | 2.52 | V |
| | | Full range | 2.47 | | 2.53 | |
| Temperature coefficient of output voltage | | 25°C | | 20 | | ppm/°C |
| Bias current | $I_O = 0$ | 25°C | | 170 | 250 | μA |
| | | Full range | | | 250 | |
| Input regulation | $V_I = 4.5\text{ V to }5.5\text{ V}$ | 25°C | | 1.5 | 20 | μV |
| | | Full range | | | 25 | |
| | $V_I = 4\text{ V to }40\text{ V}$ | 25°C | | 1.5 | 20 | μV/V |
| | | Full range | | | 25 | |
| Ripple rejection | $f = 120\text{ Hz}$, $\Delta V_I(\text{PP}) = 1\text{ V}$ | 25°C | | 80 | | dB |
| Output regulation‡ (source current) | $I_O = 0\text{ to }-10\text{ mA}$ | 25°C | -160 | -45 | 160 | μV |
| | Full range | | -250 | | 250 | |
| Output regulation‡ (sink current) | $I_O = 0\text{ to }-20\text{ mA}$ | 25°C | -450 | -150 | 450 | μV |
| | Full range | | | | | |
| Output regulation‡ (sink current) | $I_O = 0\text{ to }10\text{ mA}$ | 25°C | -160 | 15 | 160 | μV |
| | Full range | | -250 | | 250 | |
| Long-term drift of output voltage | $I_O = 0\text{ to }20\text{ mA}$ | 25°C | -235 | 65 | 235 | μV |
| Long-term drift of output voltage | $\Delta t = 1000\text{ h}$, Noncumulative | 25°C | | 15 | | ppm |
| Output impedance | | 25°C | | 7.5 | 22.5 | mΩ |
| Short-circuit output current | Sink current, $V_O = 5\text{ V}$ | 25°C | | 30 | 55 | mA |
| | Source current, $V_O = 0$ | | | -30 | -50 | |
| Output noise voltage, rms | $f = 10\text{ Hz to }10\text{ kHz}$ | 25°C | | 100 | | μV |
| Output voltage response to output current step | $V_O\text{ to }0.1\%$, $I_O = \pm 10\text{ mA}$ | 25°C | $C_L = 0$ | | 110 | μs |
| | | | $C_L = 100\text{ pF}$ | | 115 | |
| | $V_O\text{ to }0.01\%$, $I_O = \pm 10\text{ mA}$ | $C_L = 0$ | | 180 | | |
| | | $C_L = 100\text{ pF}$ | | 180 | | |
| Output voltage response to input voltage step | $V_I = 4.5\text{ to }5.5\text{ V}$, $V_O\text{ to }0.1\%$ | 25°C | | 12 | | μs |
| | $V_I = 4.5\text{ to }5.5\text{ V}$, $V_O\text{ to }0.01\%$ | | | 30 | | |
| Output voltage turn-on response | $V_I = 0\text{ to }5\text{ V}$, $V_O\text{ to }0.1\%$ | 25°C | | 125 | | μs |
| | $V_I = 0\text{ to }5\text{ V}$, $V_O\text{ to }0.01\%$ | | | 210 | | |

†Full range is 0°C to 70°C.

‡Sample tested. Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

electrical characteristics at specified free-air temperature, $V_I = 5\text{ V}$, $I_O = 0$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_A^\dagger | MIN | TYP | MAX | UNIT |
|--|---|-----------------------|-----------------------|-----|------|-----------------|
| | | 25°C | | | | |
| Output voltage | | 25°C | 2.48 | 2.5 | 2.52 | V |
| | | Full range | 2.47 | | 2.53 | |
| Temperature coefficient of output voltage | | 25°C | 20 | | | ppm/°C |
| Bias current | $I_O = 0$ | 25°C | 170 250 | | | μA |
| | | Full range | 250 | | | |
| Input regulation | $V_I = 4.5\text{ V to }5.5\text{ V}$ | 25°C | 1.5 20 | | | μV |
| | | Full range | 75 | | | |
| | $V_I = 4\text{ V to }40\text{ V}$ | 25°C | 1.5 20 | | | $\mu\text{V/V}$ |
| | | Full range | 75 | | | |
| Ripple rejection | $f = 120\text{ Hz}$, $\Delta V_I(\text{pp}) = 1\text{ V}$ | 25°C | 80 | | | dB |
| Output regulation [‡] (source current) | $I_O = 0\text{ to }-10\text{ mA}$ | 25°C | -160 | -45 | 160 | μV |
| | | Full range | -250 | | 250 | |
| Output regulation [‡] (sink current) | $I_O = 0\text{ to }8\text{ mA}$ | 25°C | -160 | 15 | 160 | μV |
| | | Full range | -250 | | 250 | |
| | $I_O = 0\text{ to }20\text{ mA}$ | 25°C | -235 | 65 | 235 | |
| Long-term drift of output voltage | $\Delta t = 1000\text{ h}$, Noncumulative | 25°C | 15 | | | ppm |
| Output impedance | | 25°C | 7.5 22.5 | | | m Ω |
| Short-circuit output current | Sink current, $V_O = 5\text{ V}$ | 25°C | 30 55 | | | mA |
| | Source current, $V_O = 0$ | | -30 -50 | | | |
| Output noise voltage, rms | $f = 10\text{ Hz to }10\text{ kHz}$ | 25°C | 100 | | | μV |
| Output voltage response to output current step | $V_O\text{ to }0.1\%$, $I_O = \pm 10\text{ mA}$ | 25°C | $C_L = 0$ | 110 | | μs |
| | | | $C_L = 100\text{ pF}$ | 115 | | |
| | $V_O\text{ to }0.01\%$, $I_O = \pm 10\text{ mA}$ | $C_L = 0$ | 180 | | | |
| | | $C_L = 100\text{ pF}$ | 180 | | | |
| Output voltage response to input voltage step | $V_I = 4.5\text{ to }5.5\text{ V}$, $V_O\text{ to }0.1\%$ | 25°C | 12 | | | μs |
| | $V_I = 4.5\text{ to }5.5\text{ V}$, $V_O\text{ to }0.01\%$ | | 30 | | | |
| Output voltage turn-on response | $V_I = 0\text{ to }5\text{ V}$, $V_O\text{ to }0.1\%$ | 25°C | 125 | | | μs |
| | $V_I = 0\text{ to }5\text{ V}$, $V_O\text{ to }0.01\%$ | | 210 | | | |

[†]Full range is -40°C to 85°C.

[‡]Sample tested. Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

TLE2425M PRECISION VIRTUAL GROUND

electrical characteristics at specified free-air temperature, $V_I = 5\text{ V}$, $I_O = 0$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_A^\dagger | MIN | TYP | MAX | UNIT |
|--|---|-----------------------|------|-----------------------|------|-----------------|
| | | 25°C | 2.48 | 2.5 | 2.52 | |
| Output voltage | | 25°C | 2.48 | 2.5 | 2.52 | V |
| | | Full range | 2.47 | | 2.53 | |
| Temperature coefficient of output voltage | | 25°C | | 20 | | ppm/°C |
| Bias current | $I_O = 0$ | 25°C | | 170 | 250 | μA |
| | | Full range | | | 250 | |
| Input regulation | $V_I = 4.5\text{ V to } 5.5\text{ V}$ | 25°C | | 1.5 | 20 | μV |
| | | Full range | | | 100 | |
| | $V_I = 4.5\text{ V to } 40\text{ V}$ | 25°C | | 1.5 | 20 | $\mu\text{V/V}$ |
| | | Full range | | | 100 | |
| Ripple rejection | $f = 120\text{ Hz}$, $\Delta V_I(\text{pp}) = 1\text{ V}$ | 25°C | | 80 | | dB |
| Output regulation [‡] (source current) | $I_O = 0\text{ to } -10\text{ mA}$ | 25°C | -160 | -45 | 160 | μV |
| | | Full range | -250 | | 250 | |
| Output regulation [‡] (sink current) | $I_O = 0\text{ to } 3\text{ mA}$ | 25°C | -160 | 15 | 160 | μV |
| | | Full range | -250 | | 250 | |
| Output regulation [‡] (sink current) | $I_O = 0\text{ to } 20\text{ mA}$ | 25°C | -235 | 65 | 235 | μV |
| | | Full range | -250 | | 250 | |
| Long-term drift of output voltage | $\Delta t = 1000\text{ h}$, Noncumulative | 25°C | | 15 | | ppm |
| Output impedance | | 25°C | | 7.5 | 22.5 | m Ω |
| Short-circuit output current | Sink current, $V_O = 5\text{ V}$ | 25°C | | 30 | 55 | mA |
| | Source current, $V_O = 0$ | | | -30 | -50 | |
| Output noise voltage, rms | $f = 10\text{ Hz to } 10\text{ kHz}$ | 25°C | | 100 | | μV |
| Output voltage response to output current step | $V_O\text{ to } 0.1\%$, $I_O = \pm 10\text{ mA}$ | 25°C | | $C_L = 0$ | 110 | μs |
| | | | | $C_L = 100\text{ pF}$ | 115 | |
| | $V_O\text{ to } 0.01\%$, $I_O = \pm 10\text{ mA}$ | $C_L = 0$ | 180 | | | |
| | | $C_L = 100\text{ pF}$ | 180 | | | |
| Output voltage response to input voltage step | $V_I = 4.5\text{ to } 5.5\text{ V}$, $V_O\text{ to } 0.1\%$ | 25°C | | | 12 | μs |
| | $V_I = 4.5\text{ to } 5.5\text{ V}$, $V_O\text{ to } 0.01\%$ | | | | 30 | |
| Output voltage turn-on response | $V_I = 0\text{ to } 5\text{ V}$, $V_O\text{ to } 0.1\%$ | 25°C | | | 125 | μs |
| | $V_I = 0\text{ to } 5\text{ V}$, $V_O\text{ to } 0.01\%$ | | | | 210 | |

[†]Full range is -55°C to 125°C .

[‡]Sample tested. Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

TLE2425Y PRECISION VIRTUAL GROUND

electrical characteristics at $V_I = 5V$, $I_O = 0$, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|-----------------------|------|------|-----------------------|
| Output voltage | | 2.48 | 2.5 | 2.52 | V |
| Temperature coefficient of output voltage | | | 20 | | ppm/ $^\circ\text{C}$ |
| Bias current | $I_O = 0$ | | 170 | 250 | μA |
| Input regulation | $V_I = 4.5\text{ V to }5.5\text{ V}$ | | 1.5 | 20 | μV |
| | $V_I = 4\text{ V to }40\text{ V}$ | | 1.5 | 20 | $\mu\text{V/V}$ |
| Ripple rejection | $f = 120\text{ Hz}$, $\Delta V_I(\text{PP}) = 1\text{ V}$ | | 80 | | dB |
| Output regulation (source current) [‡] | $I_O = 0\text{ to }-10\text{ mA}$ | -160 | -45 | 160 | μV |
| | $I_O = 0\text{ to }-20\text{ mA}$ | -450 | -150 | 450 | |
| Output regulation (sink current) [‡] | $I_O = 0\text{ to }10\text{ mA}$ | -160 | 15 | 160 | μV |
| | $I_O = 0\text{ to }20\text{ mA}$ | -235 | 65 | 235 | |
| Output impedance | | | 7.5 | 22.5 | m Ω |
| Short-circuit output current | Sink current, $V_O = 5\text{ V}$ | 30 | 55 | | mA |
| | Source current, $V_O = 0$ | -30 | -50 | | |
| Output noise voltage, rms | $f = 10\text{ Hz to }10\text{ kHz}$ | | 100 | | μV |
| Output voltage response to output current step | $V_O\text{ to }0.1\%$, $I_O = \pm 10\text{ mA}$ | $C_L = 0$ | 110 | | μs |
| | | $C_L = 100\text{ pF}$ | 115 | | |
| | $V_O\text{ to }0.01\%$, $I_O = \pm 10\text{ mA}$ | $C_L = 0$ | 180 | | |
| | | $C_L = 100\text{ pF}$ | 180 | | |
| Output voltage response to input voltage step | $V_I = 4.5\text{ to }5.5\text{ V}$, $V_O\text{ to }0.1\%$ | | 12 | | μs |
| | $V_I = 4.5\text{ to }5.5\text{ V}$, $V_O\text{ to }0.01\%$ | | 30 | | |
| Output voltage turn-on response | $V_I = 0\text{ to }5\text{ V}$, $V_O\text{ to }0.1\%$ | | 125 | | μs |
| | $V_I = 0\text{ to }5\text{ V}$, $V_O\text{ to }0.01\%$ | | 210 | | |

[‡]Sample tested. Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

TYPICAL CHARACTERISTICS

table of graphs

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| Output voltage | .Distribution | 1 |
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| Output regulation | | 8 |
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TYPICAL CHARACTERISTICS†

DISTRIBUTION OF
OUTPUT VOLTAGE

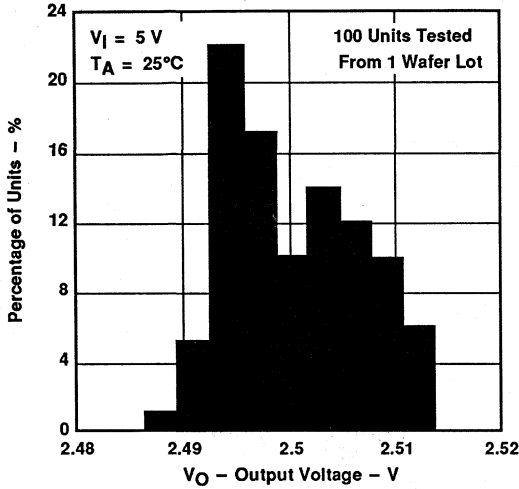


Figure 1

OUTPUT VOLTAGE
vs
FREE-AIR TEMPERATURE

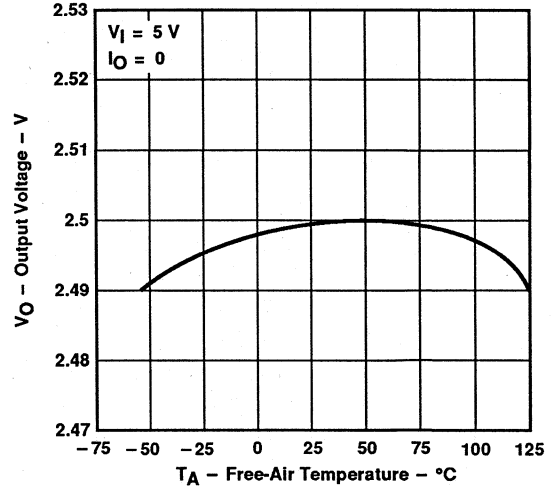


Figure 2

OUTPUT VOLTAGE HYSTERESIS
vs
FREE-AIR TEMPERATURE

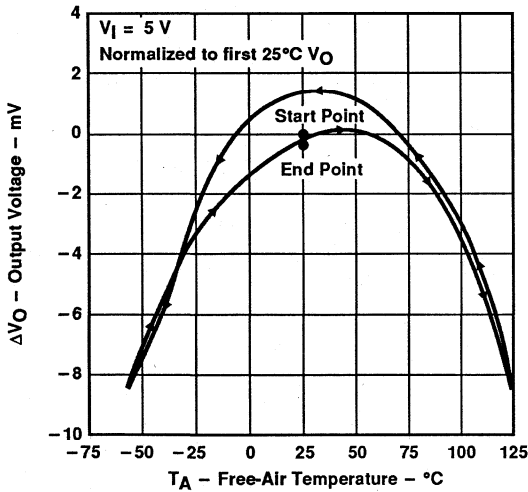


Figure 3

BIAS CURRENT
vs
INPUT VOLTAGE

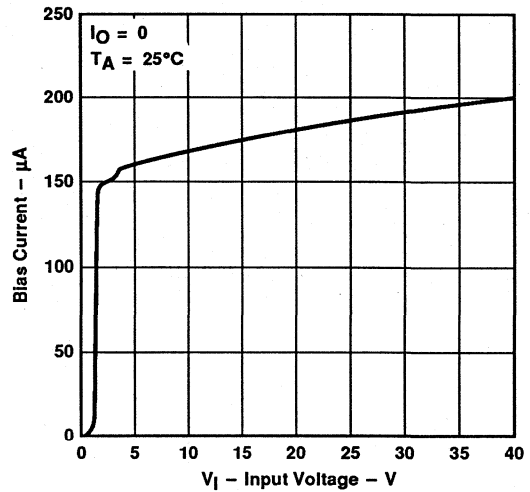
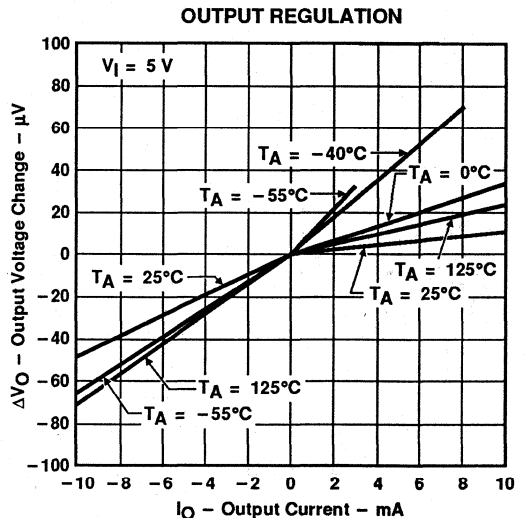
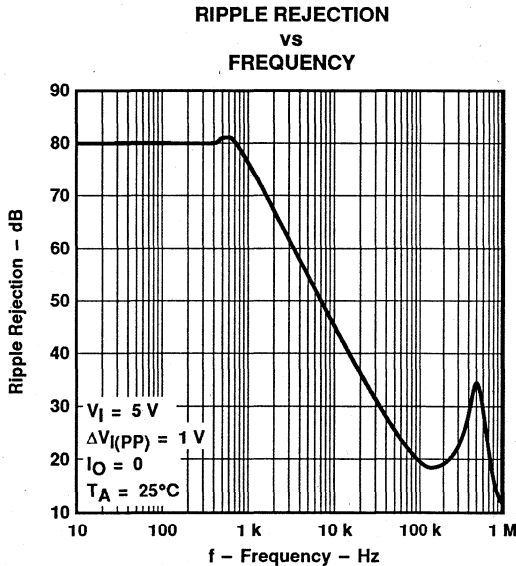
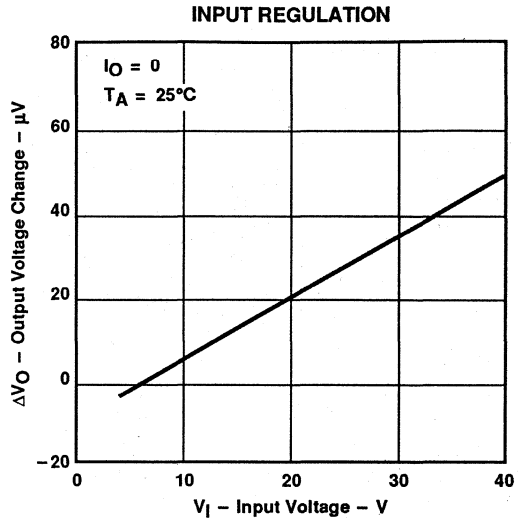
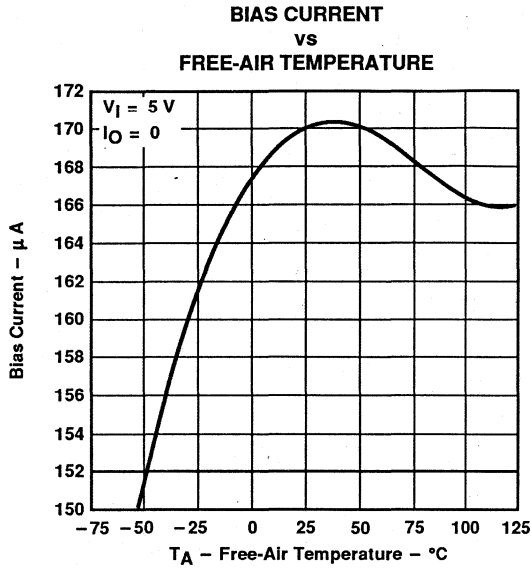


Figure 4

†Data at high and low temperatures are applicable within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS†



†Data at high and low temperatures are applicable within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS†

OUTPUT IMPEDANCE
vs
FREQUENCY

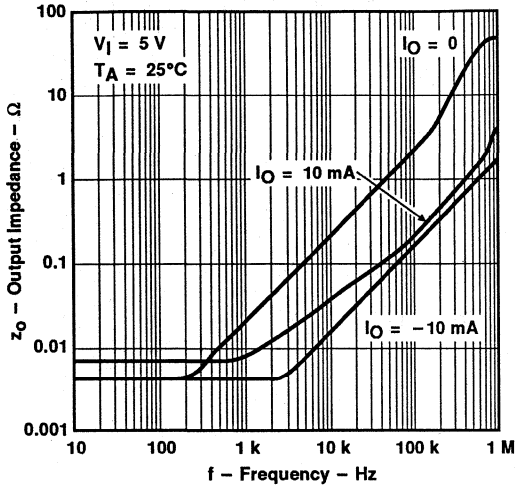


Figure 9

SHORT-CIRCUIT OUTPUT CURRENT
vs
FREE-AIR TEMPERATURE

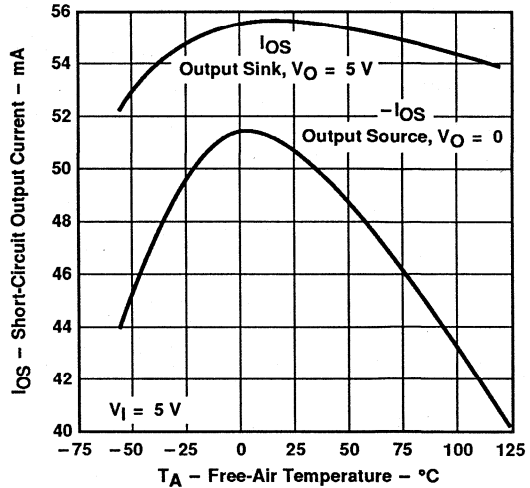


Figure 10

SPOT NOISE VOLTAGE
vs
FREQUENCY

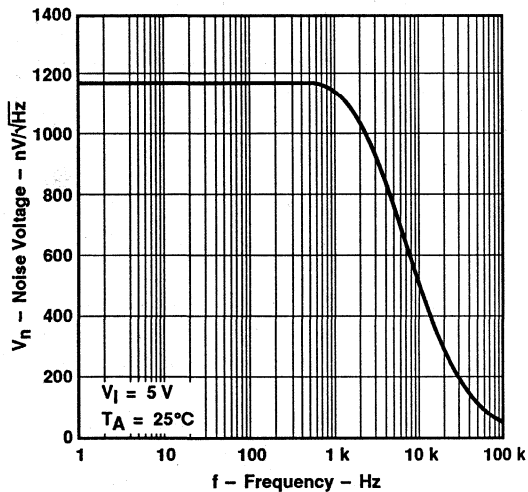


Figure 11

WIDEBAND NOISE VOLTAGE
vs
FREQUENCY

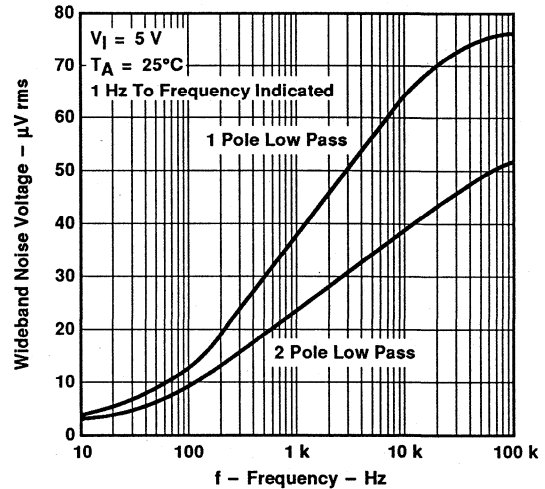


Figure 12

†Data at high and low temperatures are applicable within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

OUTPUT VOLTAGE RESPONSE TO OUTPUT CURRENT STEP vs TIME

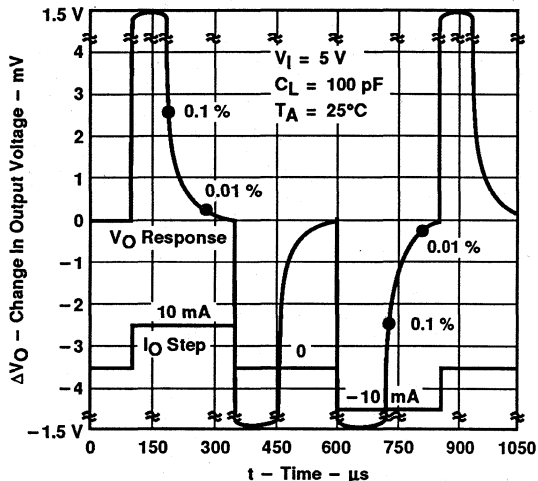


Figure 13

OUTPUT VOLTAGE RESPONSE TO INPUT VOLTAGE STEP vs TIME

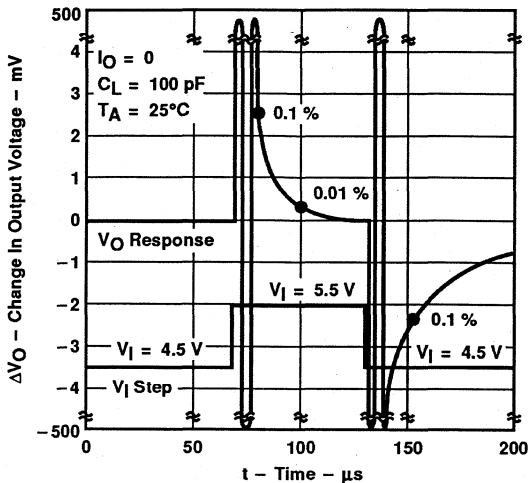


Figure 14

OUTPUT VOLTAGE POWER-UP RESPONSE vs TIME

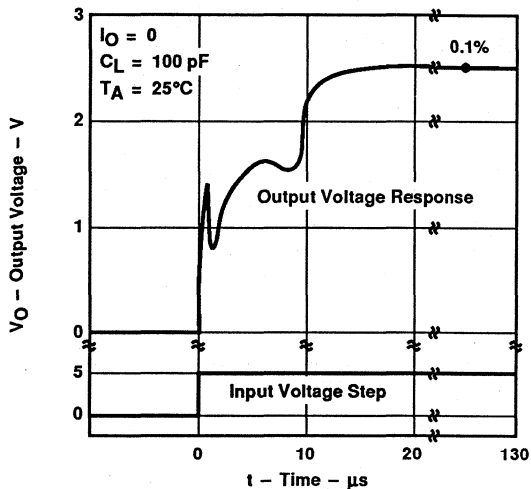


Figure 15

STABILITY RANGE vs LOAD CAPACITANCE

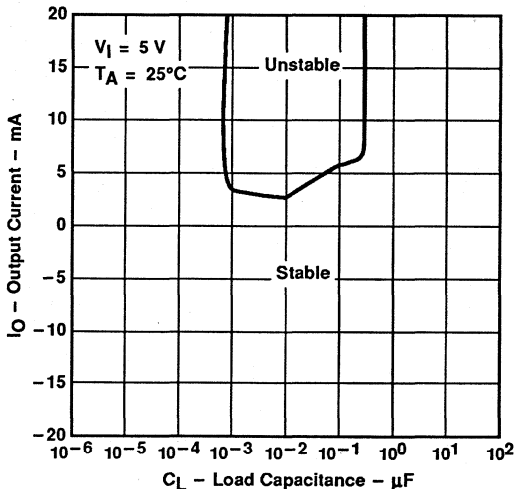


Figure 16

macromodel information

* TLE2425 OPERATIONAL AMPLIFIER "MACROMODEL" SUBCIRCUIT
 * CREATED USING PARTS RELEASE 4.03 ON 08/21/90 AT 13:51
 * REV (N/A) SUPPLY VOLTAGE: 5 V
 * CONNECTIONS: INPUT
 * | COMMON
 * | | OUTPUT
 * | | |
 .SUBCKT TLE2425 3 4 5
 *

* OPAMP SECTION

| | | | |
|------|----|----|--|
| C1 | 11 | 12 | 21.66E-12 |
| C2 | 6 | 7 | 30.00E-12 |
| C3 | 87 | 0 | 10.64E-9 |
| CPSR | 85 | 86 | 15.9E-9 |
| DCM+ | 81 | 82 | DX |
| DCM- | 83 | 81 | DX |
| DC | 5 | 53 | DX |
| DE | 54 | 5 | DX |
| DLP | 90 | 91 | DX |
| DLN | 92 | 90 | DX |
| DP | 4 | 3 | DX |
| ECMR | 84 | 99 | (2,99) 1 |
| EGND | 99 | 0 | POLY(2) (3,0) (4,0) 0 .5 .5 |
| EPSR | 85 | 0 | POLY(1) (3,4) -16.22E-6 3.24E-6 |
| ENSE | 89 | 2 | POLY(1) (88,0) 120E-6 1 |
| FB | 7 | 99 | POLY(6) VB VC VE VLP VLN VPSR 0 74.8E6 -10E6 10E6 10E6 |

+ -10E6 74E6

| | | | |
|------|----|----|-----------------------------|
| GA | 6 | 0 | 11 12 320.4E-6 |
| GCM | 0 | 6 | 10 99 1.013E-9 |
| GPSR | 85 | 86 | (85,86) 100E-6 |
| GRC1 | 4 | 11 | (4,11) 3.204E-4 |
| GRC2 | 4 | 12 | (4,12) 3.204E-4 |
| GRE1 | 13 | 10 | (13,10) 1.038E-3 |
| GRE2 | 14 | 10 | (14,10) 1.038E-3 |
| HLIM | 90 | 0 | VLIM 1K |
| HCMR | 80 | 1 | POLY(2) VCM+ VCM- 0 1E2 1E2 |
| IRP | 3 | 4 | 146E-6 |
| IEE | 3 | 10 | DC 24.05E-6 |
| IIO | 2 | 0 | .2E-9 |
| I1 | 88 | 0 | 1E-21 |
| Q1 | 11 | 89 | 13 QX |
| Q2 | 12 | 80 | 14 QX |
| R2 | 6 | 9 | 100.0E3 |
| RCM | 84 | 81 | 1K |
| REE | 10 | 99 | 8.316E6 |
| RN1 | 87 | 0 | 2.55E8 |
| RN2 | 87 | 88 | 11.67E3 |

TLE2425C, TLE2425I, TLE2425M
PRECISION VIRTUAL GROUND

macromodel information (continued)

| | | | |
|------------------------------------|----|----|-------------------------------|
| RO1 | 8 | 5 | 63 |
| RO2 | 7 | 99 | 62 |
| VCM+ | 82 | 99 | 1.0 |
| VCM- | 83 | 99 | -2.3 |
| VB | 9 | 0 | DC 0 |
| VC | 3 | 53 | DC 1.400 |
| VE | 54 | 4 | DC 1.400 |
| VLIM | 7 | 8 | DC 0 |
| VLP | 91 | 0 | DC 30 |
| VLN | 0 | 92 | DC 30 |
| VPSR | 0 | 86 | DC 0 |
| RFB | 5 | 2 | 1K |
| RIN | 30 | 1 | 1K |
| RCOM | 34 | 4 | .1 |
| *REGULATOR SECTION | | | |
| RG1 | 30 | 0 | 20MEG |
| RG2 | 30 | 31 | .2 |
| RG3 | 31 | 35 | 400K |
| RG4 | 35 | 34 | 411K |
| RG5 | 31 | 36 | 25MEG |
| HREG | 31 | 32 | POLY(2) VPSET VNSET 0 1E2 1E2 |
| VREG | 32 | 33 | DC 0V |
| EREG | 33 | 34 | POLY(1) (36,34) 1.23 1 |
| VADJ | 36 | 34 | 1.27V |
| HPSET | 37 | 0 | VREG 1.030E3 |
| VPSET | 38 | 0 | DC 20V |
| HNSET | 39 | 0 | VREG 6.11E5 |
| VNSET | 40 | 0 | DC -20V |
| DSUB | 4 | 34 | DX |
| DPOS | 37 | 38 | DX |
| DNNEG | 40 | 39 | DX |
| .MODEL DX D(IS=800.0E-18) | | | |
| .MODEL QX PNP(IS=800.0E-18 BF=480) | | | |
| .ENDS | | | |

TLE2426 THE "RAIL SPLITTER" PRECISION VIRTUAL GROUND

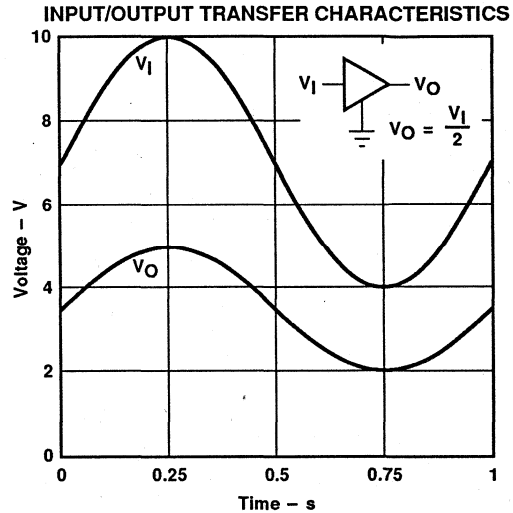
D3878, AUGUST 1991

- 1/2 V_I Virtual Ground for Analog Systems
- Self-Contained 3-terminal TO-226AA Package
- Micropower Operation . . . 170 μ A Typ, $V_I = 5$
- Wide V_I Range . . . 4 V to 40 V
- High Output-Current Capability
Sink . . . 20 mA Typ
Source . . . 20 mA Typ
- Excellent Output Regulation . . . $\pm 45 \mu$ V Typ
 $I_O = -10$ mA to 10 mA
- Low-Impedance Output . . . 0.0075 Ω Typ
- Noise Reduction Pin (D, JG, and P Packages Only)

description

In signal-conditioning applications utilizing a single power source, a reference voltage equal to one-half the supply voltage is required for termination of all analog signal "grounds". Texas Instruments introduces a precision virtual ground whose output voltage is always equal to one-half the input voltage, the TLE2426 "rail splitter".

The unique combination of a high-performance, micropower operational amplifier and a precision-trimmed divider on a single silicon chip results in a precise V_O/V_I ratio of 0.5 while sinking and sourcing current. The TLE2426 provides a low impedance output with 20 mA of sink and source capability while quiescently drawing less than 280 μ A of supply current over the full input range of 4 to 40 V. A designer need not pay the price in terms of board space for a conventional signal ground solution consisting of resistors, capacitors, operational amplifiers, and voltage references. The performance and precision of the TLE2426 is available in an easy-to-use, space saving, 3-terminal LP package. For increased performance, the optional 8-pin packages provide a noise-reduction pin. With the addition of an external capacitor (C_{NR}), peak-to-peak noise is reduced while line ripple rejection is improved.



AVAILABLE OPTIONS

| T _A | PACKAGE | | | | CHIP FORM (Y) |
|----------------|-------------------|------------------|--------------|-----------------|---------------|
| | SMALL-OUTLINE (D) | CERAMIC DIP (JG) | PLASTIC (LP) | PLASTIC DIP (P) | |
| 0°C to 70°C | TLE2426CD | — | TLE2426CLP | TLE2426CP | TLE2426Y |
| -40°C to 85°C | TLE2426ID | — | TLE2426ILP | TLE2426IP | |
| -55°C to 125°C | TLE2426MD | TLE2426MJG | TLE2426MLP | TLE2426MP | |

D and LP packages are available taped and reeled in the commercial temperature range only. Add "R" suffix to device type (e.g., TLC2426CDR). Chips are tested at 25°C.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

**TEXAS
INSTRUMENTS**

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TLE2426 THE "RAIL SPLITTER" PRECISION VIRTUAL GROUND

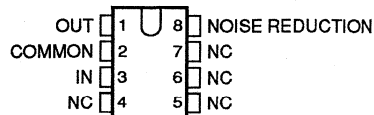
description (continued)

Initial output tolerance for a single 5-V or 12-V system is better than 1% with 3.6% over the full 40-V input range. Load rejection exceeds 12 bits of accuracy. Whether the application is for a data acquisition front-end, analog signal termination, or simply a precision voltage reference, the TLE2426 eliminates a major source of system error. The C-suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized from -40°C to 85°C. The M-suffix devices are characterized over the full military temperature range of -55°C to 125°C.

TLE2426Y chip information

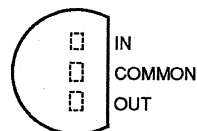
These chips, properly assembled, display characteristics similar to the TLE2426. (see electrical table on TLE2426Y). Thermal compression or ultrasonic bonding may be used on the doped aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.

D, P, OR JG PACKAGE (TOP VIEW)

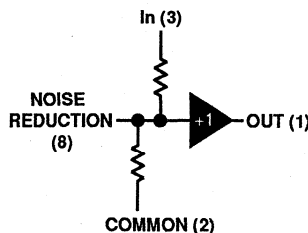
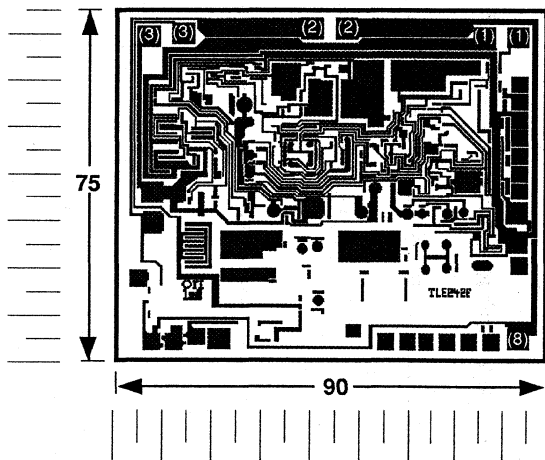


NC - No internal connection.

LP PACKAGE (TOP VIEW)



BONDING PAD ASSIGNMENTS



CHIP THICKNESS:
15 TYPICAL

BONDING PADS:
4 X 4 MINIMUM

T_{JMAX} = 150°C

TOLERANCES
ARE ±10%

ALL DIMENSIONS
ARE IN MILS

Note: Both bonding pads number 1, both number 2, and both number 3, must be bonded out to the corresponding functions pin.

TLE2426
THE "RAIL SPLITTER"
PRECISION VIRTUAL GROUND

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Continuous input voltage | 40 V |
| Continuous filter trap voltage | 40 V |
| Output current, I_O | ± 80 mA |
| Duration of short-circuit current at (or below) 25°C (see Note 1) | unlimited |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range, T_A : C-suffix | 0°C to 70°C |
| I-suffix | -40°C to 85°C |
| M-suffix | -55°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG or LP package | 300°C |

NOTE 1: The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ | DERATING FACTOR | $T_A = 70^\circ\text{C}$ | $T_A = 85^\circ\text{C}$ | $T_A = 125^\circ\text{C}$ |
|---------|-----------------------------|--------------------------------|--------------------------|--------------------------|---------------------------|
| | POWER RATING | ABOVE $T_A = 25^\circ\text{C}$ | POWER RATING | POWER RATING | POWER RATING |
| D | 725 mW | 5.8 mW/°C | 464 mW | 377 mW | 145 mW |
| JG | 1050 mW | 8.4 mW/°C | 672 mW | 546 mW | 270 mW |
| LP | 775 mW | 6.2 mW/°C | 496 mW | 403 mW | 155 mW |
| P | 1000 mW | 8.0 mW/°C | 640 mW | 520 mW | 200 mW |

recommended operating conditions

| | C-SUFFIX | | I-SUFFIX | | M-SUFFIX | | UNIT |
|---------------------------------------|----------|-----|----------|-----|----------|-----|------|
| | MIN | MAX | MIN | MAX | MIN | MAX | |
| Input voltage, V_I | 4 | 40 | 4 | 40 | 4 | 40 | V |
| Operating free-air temperature, T_A | 0 | 70 | -40 | 85 | -55 | 125 | °C |

TLE2426C THE "RAIL SPLITTER" PRECISION VIRTUAL GROUND

electrical characteristics at specified free-air temperature, $V_I = 5V$, $I_O = 0$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | | T_A † | MIN | TYP | MAX | UNIT |
|---|-----------------------------------|--------------------|------------|-------|-------|-------|--------|
| Output voltage | $V_I = 4V$ | | 25°C | 1.975 | 1.995 | 2.015 | V |
| | $V_I = 5V$ | | | 2.48 | 2.5 | 2.52 | |
| | $V_I = 40V$ | | | 20.5 | 20.7 | 20.9 | |
| | $V_I = 5V$ | | Full range | 2.475 | | 2.525 | |
| Temperature coefficient of output voltage | | | Full range | 25 | | | ppm/°C |
| Supply current | No load | $V_I = 5V$ | 25°C | 170 | 250 | | μA |
| | | $V_I = 4$ to 40 V | Full range | 350 | | | |
| Output regulation (sourcing current)‡ | $I_O = 0$ to -10 mA | | 25°C | -45 | ±160 | | μV |
| | $I_O = 0$ to -20 mA | | Full range | ±250 | | | |
| Output regulation (sinking current)‡ | $I_O = 0$ to 10 mA | | 25°C | 15 | ±160 | | μV |
| | $I_O = 0$ to 20 mA | | Full range | ±250 | | | |
| Output impedance | | | 25°C | 7.5 | 22.5 | | mΩ |
| Noise-reduction impedance | | | 25°C | 110 | | | kΩ |
| Short-circuit current | Sinking current, $V_O = 5V$ | | 25°C | 20 | 26 | | mA |
| | Sourcing current, $V_O = 0$ | | | -20 | -47 | | |
| Output noise voltage, rms | $f = 10$ Hz to 10 kHz | $C_{NR} = 0$ | 25°C | 120 | | | μV |
| | | $C_{NR} = 1 \mu F$ | | 30 | | | |
| Output voltage current step response | V_O to 0.1%, $I_O = \pm 10$ mA | $C_L = 0$ | 25°C | 290 | | | μs |
| | | $C_L = 100$ pF | | 275 | | | |
| | V_O to 0.01%, $I_O = \pm 10$ mA | $C_L = 0$ | 25°C | 400 | | | |
| | | $C_L = 100$ pF | | 390 | | | |
| Step response | $V_I = 0$ to 5 V, V_O to 0.1% | $C_L = 100$ pF | 25°C | 20 | | | μs |
| | $V_I = 0$ to 5 V, V_O to 0.01% | | | 160 | | | |

†Full range is 0°C to 70°C.

‡Sample tested. Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

TLE2426C THE "RAIL SPLITTER" PRECISION VIRTUAL GROUND

electrical characteristics at specified free-air temperature, $V_I = 12\text{V}$, $I_O = 0$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | | T_A † | MIN | TYP | MAX | UNIT |
|---|---|--------------------------------|------------|-------|-------|-------|--------|
| Output voltage | $V_I = 4\text{V}$ | | 25°C | 1.975 | 1.995 | 2.015 | V |
| | $V_I = 12\text{V}$ | | | 6 | 6.05 | 6.1 | |
| | $V_I = 40\text{V}$ | | | 20.5 | 20.7 | 20.9 | |
| | $V_I = 12\text{V}$ | | Full range | 5.995 | | 6.105 | |
| Temperature coefficient of output voltage | | | Full range | 35 | | | ppm/°C |
| Supply current | No load | $V_I = 12\text{V}$ | 25°C | 195 | 250 | | µA |
| | | $V_I = 4\text{ to }40\text{V}$ | Full range | 350 | | | |
| Output regulation (sourcing current)‡ | $I_O = 0\text{ to }-10\text{mA}$ | | 25°C | -45 | ±160 | | µV |
| | | | Full range | ±250 | | | |
| Output regulation (sinking current)‡ | $I_O = 0\text{ to }-20\text{mA}$ | | 25°C | -150 | ±450 | | µV |
| | | | Full range | ±250 | | | |
| Output regulation (sinking current)‡ | $I_O = 0\text{ to }10\text{mA}$ | | 25°C | 15 | ±160 | | µV |
| | | | Full range | ±250 | | | |
| Output impedance | | | 25°C | 7.5 | 22.5 | | mΩ |
| | | | 25°C | 110 | | | |
| Noise-reduction impedance | | | 25°C | 110 | | | kΩ |
| Short-circuit current | Sinking current, $V_O = 12\text{V}$ | | 25°C | 20 | 31 | | mA |
| | Sourcing current, $V_O = 0$ | | | -20 | -70 | | |
| Output noise voltage, rms | $f = 10\text{Hz to }10\text{kHz}$ | $CNR = 0$ | 25°C | 120 | | | µV |
| | | $CNR = 1\text{µF}$ | | 30 | | | |
| Output voltage current step response | $V_O\text{ to }0.1\%$, $I_O = \pm 10\text{mA}$ | $C_L = 0$ | 25°C | 290 | | | µs |
| | | $C_L = 100\text{pF}$ | | 275 | | | |
| | $V_O\text{ to }0.01\%$, $I_O = \pm 10\text{mA}$ | $C_L = 0$ | 25°C | 400 | | | |
| | | $C_L = 100\text{pF}$ | | 390 | | | |
| Step response | $V_I = 0\text{ to }12\text{V}$, $V_O\text{ to }0.1\%$ | $C_L = 100\text{pF}$ | 25°C | 12 | | | µs |
| | $V_I = 0\text{ to }12\text{V}$, $V_O\text{ to }0.01\%$ | | | 120 | | | |

†Full range is 0°C to 70°C.

‡Sample tested. Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

TLE2426I

THE "RAIL SPLITTER" PRECISION VIRTUAL GROUND

electrical characteristics at specified free-air temperature, $V_I = 5\text{ V}$, $I_O = 0$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | | T_A^\dagger | MIN | TYP | MAX | UNIT |
|---|---|---------------------------------|---------------|-------|-------|--------|------|
| Output voltage | $V_I = 4\text{ V}$ | | 25°C | 1.975 | 1.995 | 2.015 | V |
| | $V_I = 5\text{ V}$ | | | 2.48 | 2.5 | 2.52 | |
| | $V_I = 40\text{ V}$ | | | 20.5 | 20.7 | 20.9 | |
| | $V_I = 5\text{ V}$ | | Full range | 2.47 | | 2.53 | |
| Temperature coefficient of output voltage | | | Full range | 25 | | ppm/°C | |
| Supply current | No load | $V_I = 5\text{ V}$ | 25°C | 170 | 250 | μA | |
| | | $V_I = 4\text{ to }40\text{ V}$ | Full range | 350 | | | |
| Output regulation (sourcing current) [‡] | $I_O = 0\text{ to }-10\text{ mA}$ | | 25°C | -45 | ±160 | μV | |
| | | | Full range | ±250 | | | |
| Output regulation (sinking current) [‡] | $I_O = 0\text{ to }-20\text{ mA}$ | | 25°C | -150 | ±450 | μV | |
| | $I_O = 0\text{ to }10\text{ mA}$ | | 25°C | 15 | ±160 | | |
| | $I_O = 0\text{ to }8\text{ mA}$ | | Full range | ±250 | | | |
| | $I_O = 0\text{ to }20\text{ mA}$ | | 25°C | 65 | ±235 | | |
| Output impedance | | | 25°C | 7.5 | 22.5 | mΩ | |
| Noise-reduction impedance | | | 25°C | 110 | | kΩ | |
| Short-circuit current | Sinking current, $V_O = 5\text{ V}$ | | 25°C | 20 | 26 | mA | |
| | Sourcing current, $V_O = 0$ | | | -20 | -47 | | |
| Output noise voltage, rms | $f = 10\text{ Hz to }10\text{ kHz}$ | $C_{NR} = 0$ | 25°C | 120 | | μV | |
| | | $C_{NR} = 1\text{ μF}$ | | 30 | | | |
| Output voltage current step response | $V_O\text{ to }0.1\%$, $I_O = \pm 10\text{ mA}$ | $C_L = 0$ | 25°C | 290 | | μs | |
| | | $C_L = 100\text{ pF}$ | | 275 | | | |
| | $V_O\text{ to }0.01\%$, $I_O = \pm 10\text{ mA}$ | $C_L = 0$ | 25°C | 400 | | | |
| | | $C_L = 100\text{ pF}$ | | 390 | | | |
| Step response | $V_I = 0\text{ to }5\text{ V}$, $V_O\text{ to }0.1\%$ | | 25°C | 20 | | μs | |
| | $V_I = 0\text{ to }5\text{ V}$, $V_O\text{ to }0.01\%$ | | | 160 | | | |

[†]Full range is -40°C to 85°C.

[‡]Sample tested. Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

TLE2426I
THE "RAIL SPLITTER" PRECISION
VIRTUAL GROUND

electrical characteristics at specified free-air temperature, $V_I = 12\text{ V}$, $I_O = 0$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | | T_A^\dagger | MIN | TYP | MAX | UNIT |
|---|---|---------------------------------|---------------|-------|-------|--------|------|
| Output voltage | $V_I = 4\text{ V}$ | | 25°C | 1.975 | 1.995 | 2.015 | V |
| | $V_I = 12\text{ V}$ | | | 6 | 6.05 | 6.1 | |
| | $V_I = 40\text{ V}$ | | | 20.5 | 20.7 | 20.9 | |
| | $V_I = 12\text{ V}$ | | Full range | 5.985 | | 6.115 | |
| Temperature coefficient of output voltage | | | Full range | 35 | | ppm/°C | |
| Supply current | No load | $V_I = 12\text{ V}$ | 25°C | 195 | 250 | μA | |
| | | $V_I = 4\text{ to }40\text{ V}$ | Full range | 350 | | | |
| Output regulation (sourcing current)‡ | $I_O = 0\text{ to }-10\text{ mA}$ | | 25°C | -45 | ±160 | μV | |
| | | | Full range | ±250 | | | |
| Output regulation (sinking current)‡ | $I_O = 0\text{ to }-20\text{ mA}$ | | 25°C | -150 | ±450 | μV | |
| | $I_O = 0\text{ to }10\text{ mA}$ | | 25°C | 15 | ±160 | | |
| | $I_O = 0\text{ to }8\text{ mA}$ | | Full range | ±250 | | | |
| | $I_O = 0\text{ to }20\text{ mA}$ | | 25°C | 65 | ±235 | | |
| Output impedance | | | 25°C | 7.5 | 22.5 | mΩ | |
| Noise-reduction impedance | | | 25°C | 110 | | kΩ | |
| Short-circuit current | Sinking current, $V_O = 12\text{ V}$ | | 25°C | 20 | 31 | mA | |
| | Sourcing current, $V_O = 0$ | | | -20 | -70 | | |
| Output noise voltage, rms | $f = 10\text{ Hz to }10\text{ kHz}$ | $C_{NR} = 0$ | 25°C | 120 | | μV | |
| | | $C_{NR} = 1\text{ μF}$ | | 30 | | | |
| Output voltage current step response | $V_O\text{ to }0.1\%, I_O = \pm 10\text{ mA}$ | $C_L = 0$ | 25°C | 290 | | μs | |
| | | $C_L = 100\text{ pF}$ | | 275 | | | |
| | $V_O\text{ to }0.01\%, I_O = \pm 10\text{ mA}$ | $C_L = 0$ | 25°C | 400 | | | |
| | | $C_L = 100\text{ pF}$ | | 390 | | | |
| Step response | $V_I = 0\text{ to }12\text{ V}, V_O\text{ to }0.1\%$ | | 25°C | 12 | | μs | |
| | $V_I = 0\text{ to }12\text{ V}, V_O\text{ to }0.01\%$ | | | 120 | | | |

†Full range is -40°C to 85°C.

‡Sample tested. Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

TLE2426M THE "RAIL SPLITTER" PRECISION VIRTUAL GROUND

electrical characteristics at specified free-air temperature, $V_I = 5\text{ V}$, $I_O = 0$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | | T_A^\dagger | MIN | TYP | MAX | UNIT |
|---|--|---------------------------------|---------------|-------|-------|--------|------|
| Output voltage | $V_I = 4\text{ V}$ | | 25°C | 1.975 | 1.995 | 2.015 | V |
| | $V_I = 5\text{ V}$ | | | 2.48 | 2.5 | 2.52 | |
| | $V_I = 40\text{ V}$ | | | 20.5 | 20.7 | 20.9 | |
| | $V_I = 5\text{ V}$ | | Full range | 2.465 | | 2.535 | |
| Temperature coefficient of output voltage | | | Full range | 25 | | ppm/°C | |
| Supply current | No load | $V_I = 5\text{ V}$ | 25°C | 170 | 250 | µA | |
| | | $V_I = 4\text{ to }40\text{ V}$ | Full range | 350 | | | |
| Output regulation (sourcing current)‡ | $I_O = 0\text{ to }-10\text{ mA}$ | | 25°C | -45 | ±160 | µV | |
| | | | Full range | ±250 | | | |
| Output regulation (sinking current)‡ | $I_O = 0\text{ to }-20\text{ mA}$ | | 25°C | -150 | ±450 | µV | |
| | $I_O = 0\text{ to }10\text{ mA}$ | | 25°C | 15 | ±160 | | |
| | $I_O = 0\text{ to }3\text{ mA}$ | | Full range | ±250 | | | |
| | $I_O = 0\text{ to }20\text{ mA}$ | | 25°C | 65 | ±235 | | |
| Output impedance | | | 25°C | 7.5 | 22.5 | mΩ | |
| Noise-reduction impedance | | | 25°C | 110 | | kΩ | |
| Short-circuit current | Sinking current, $V_O = 5\text{ V}$ | | 25°C | 20 | 26 | mA | |
| | Sourcing current, $V_O = 0$ | | | -20 | -47 | | |
| Output noise voltage, rms | $f = 10\text{ Hz to }10\text{ kHz}$ | $C_{NR} = 0$ | 25°C | 120 | | µV | |
| | | $C_{NR} = 1\text{ µF}$ | | 30 | | | |
| Output voltage current step response | $V_O\text{ to }0.1\%, I_O = \pm 10\text{ mA}$ | $C_L = 0$ | 25°C | 290 | | µs | |
| | | $C_L = 100\text{ pF}$ | | 275 | | | |
| | $V_O\text{ to }0.01\%, I_O = \pm 10\text{ mA}$ | $C_L = 0$ | 25°C | 400 | | | |
| | | $C_L = 100\text{ pF}$ | | 390 | | | |
| Step response | $V_I = 0\text{ to }5\text{ V}, V_O\text{ to }0.1\%$ | | 25°C | 20 | | µs | |
| | $V_I = 0\text{ to }5\text{ V}, V_O\text{ to }0.01\%$ | | | 120 | | | |

†Full range is -55°C to 125°C.

‡Sample tested. Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

TLE2426M THE "RAIL SPLITTER" PRECISION VIRTUAL GROUND

electrical characteristics at specified free-air temperature, $V_I = 12\text{V}$, $I_O = 0$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | | T_A^\dagger | MIN | TYP | MAX | UNIT |
|---|---|-------------------------------------|---------------|-------|------|--------|------|
| Output voltage | $V_I = 4\text{V}$ | | 25°C | 1.975 | | 2.015 | V |
| | $V_I = 12\text{V}$ | | | 6 | 6.05 | 6.1 | |
| | $V_I = 40\text{V}$ | | | 20.5 | 20.7 | 20.9 | |
| | $V_I = 12\text{V}$ | | Full range | 5.975 | | 6.125 | |
| Temperature coefficient of output voltage | | | Full range | 35 | | ppm/°C | |
| Supply current | No load | $V_I = 12\text{V}$ | 25°C | 195 | 250 | μA | |
| | | $V_I = 4\text{ to }40\text{V}$ | Full range | 350 | | | |
| Output regulation (sourcing current) [‡] | $I_O = 0\text{ to }-10\text{mA}$ | | 25°C | -45 | ±160 | μV | |
| | | | Full range | ±250 | | | |
| Output regulation (sinking current) [‡] | $I_O = 0\text{ to }-20\text{mA}$ | | 25°C | -150 | ±450 | μV | |
| | $I_O = 0\text{ to }10\text{mA}$ | | 25°C | 15 | ±160 | | |
| | $I_O = 0\text{ to }8\text{mA}$ | | Full range | ±250 | | | |
| | $I_O = 0\text{ to }20\text{mA}$ | | 25°C | 65 | ±235 | | |
| Output impedance | | | 25°C | 7.5 | 22.5 | mΩ | |
| Noise-reduction impedance | | | 25°C | 110 | | kΩ | |
| Short-circuit current | Sinking current, $V_O = 12\text{V}$ | | 25°C | 20 | 31 | mA | |
| | Sourcing current, $V_O = 0$ | | | -20 | -70 | | |
| Output noise voltage, rms | $f = 10\text{Hz to }10\text{kHz}$ | $\text{CNR} = 0$ | 25°C | 120 | | μV | |
| | | $\text{CNR} = 1\text{ }\mu\text{F}$ | | 30 | | | |
| Output voltage current step response | $V_O\text{ to }0.1\%$, $I_O = \pm 10\text{mA}$ | $C_L = 0$ | 25°C | 290 | | μs | |
| | | $C_L = 100\text{pF}$ | | 275 | | | |
| | $V_O\text{ to }0.01\%$, $I_O = \pm 10\text{mA}$ | $C_L = 0$ | 25°C | 400 | | | |
| | | $C_L = 100\text{pF}$ | | 390 | | | |
| Step response | $V_I = 0\text{ to }12\text{V}$, $V_O\text{ to }0.1\%$ | $C_L = 100\text{pF}$ | 25°C | 12 | | μs | |
| | $V_I = 0\text{ to }12\text{V}$, $V_O\text{ to }0.01\%$ | | | 120 | | | |

[†]Full range is -55°C to 125°C.

[‡]Sample tested. Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

TLE2426Y

THE "RAIL SPLITTER" PRECISION VIRTUAL GROUND

electrical characteristics at specified free-air temperature, $V_I = 5V$, $I_O = 0$, $T_A = 25^\circ C$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---------------------------------------|---------------------------------------|--------------------|-------|-----------|-----------|
| Output voltage | $V_I = 4V$ | 1.975 | 1.995 | 2.015 | V |
| | $V_I = 5V$ | 2.48 | 2.5 | 2.52 | |
| | $V_I = 40V$ | 20.5 | 20.7 | 20.9 | |
| Supply current | No load | | 170 | 250 | μA |
| Output regulation (sourcing current)† | $I_O = 0$ to -10 mA | | -45 | ± 160 | μV |
| | $I_O = 0$ to -20 mA | | -150 | ± 450 | |
| Output regulation (sinking current)† | $I_O = 0$ to 10 mA | | 15 | ± 160 | μV |
| | $I_O = 0$ to 20 mA | | 65 | ± 235 | |
| Output impedance | | | 7.5 | 22.5 | $m\Omega$ |
| Noise-reduction impedance | | | 110 | | $k\Omega$ |
| Short-circuit current | Sinking current, $V_O = 5V$ | | 20 | 26 | mA |
| | Sourcing current, $V_O = 0$ | | -20 | -47 | |
| Output noise voltage, rms | $f = 10$ Hz to 10 kHz | $C_{NR} = 0$ | | 120 | μV |
| | | $C_{NR} = 1 \mu F$ | | 30 | |
| Output voltage current step response | V_O to 0.1% , $I_O = \pm 10$ mA | $C_L = 0$ | | 290 | μs |
| | | $C_L = 100$ pF | | 275 | |
| | V_O to 0.01% , $I_O = \pm 10$ mA | $C_L = 0$ | | 400 | |
| | | $C_L = 100$ pF | | 390 | |
| Step response | $V_I = 0$ to $5V$, V_O to 0.1% | | | 20 | μs |
| | $V_I = 0$ to $5V$, V_O to 0.01% | | | 160 | |

electrical characteristics at specified free-air temperature, $V_I = 12V$, $I_O = 0$, $T_A = 25^\circ C$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---------------------------------------|--|--------------------|-------|-----------|-----------|
| Output voltage | $V_I = 4V$ | 1.975 | 1.995 | 2.015 | V |
| | $V_I = 12V$ | 6 | 6.05 | 6.1 | |
| | $V_I = 40V$ | 20.5 | 20.7 | 20.9 | |
| Supply current | No load | | 195 | 250 | μA |
| Output regulation (sourcing current)‡ | $I_O = 0$ to -10 mA | | -45 | ± 160 | μV |
| | $I_O = 0$ to -20 mA | | -150 | ± 450 | |
| Output regulation (sinking current)‡ | $I_O = 0$ to 3 mA | | 15 | ± 160 | μV |
| | $I_O = 0$ to 20 mA | | 65 | ± 235 | |
| Output impedance | | | 7.5 | 22.5 | $m\Omega$ |
| Noise-reduction impedance | | | 110 | | $k\Omega$ |
| Short-circuit current | Sinking current, $V_O = 12V$ | | 20 | 31 | mA |
| | Sourcing current, $V_O = 0$ | | -20 | -70 | |
| Output noise voltage, rms | $f = 10$ Hz to 10 kHz | $C_{NR} = 0$ | | 120 | μV |
| | | $C_{NR} = 1 \mu F$ | | 30 | |
| Output voltage current step response | V_O to 0.1% , $I_O = \pm 10$ mA | $C_L = 0$ | | 290 | μs |
| | | $C_L = 100$ pF | | 275 | |
| | V_O to 0.01% , $I_O = \pm 10$ mA | $C_L = 0$ | | 400 | |
| | | $C_L = 100$ pF | | 390 | |
| Step response | $V_I = 0$ to $12V$, V_O to 0.1% | | | 12 | μs |
| | $V_I = 0$ to $12V$, V_O to 0.01% | | | 120 | |

†Sample tested. Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

TYPICAL CHARACTERISTICS

table of graphs

| | | FIGURE |
|--|-------------------------|---------------|
| Output voltage | Distribution | 1,2 |
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| Bias current | vs Input voltage | 5 |
| | vs Free-air temperature | 6 |
| Output regulation | vs Output current | 7 |
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TLE2426
THE "RAIL SPLITTER" PRECISION
VIRTUAL GROUND

TYPICAL CHARACTERISTICS†

DISTRIBUTION OF OUTPUT VOLTAGE

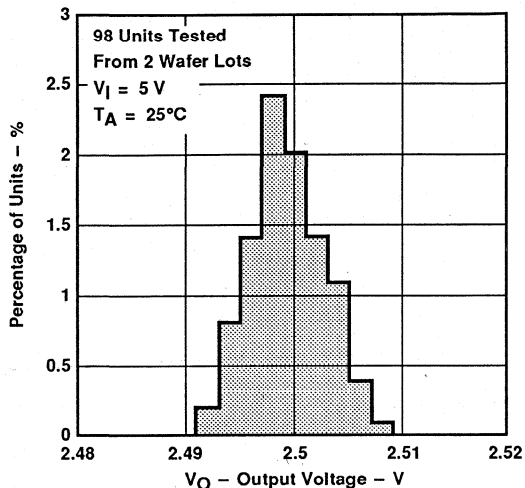


Figure 1

DISTRIBUTION OF OUTPUT VOLTAGE

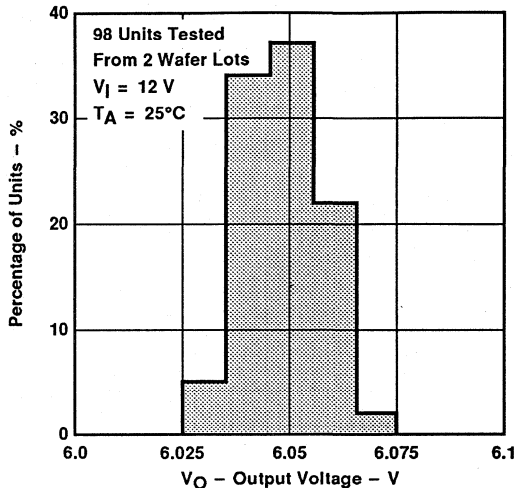


Figure 2

OUTPUT VOLTAGE CHANGE vs FREE-AIR TEMPERATURE

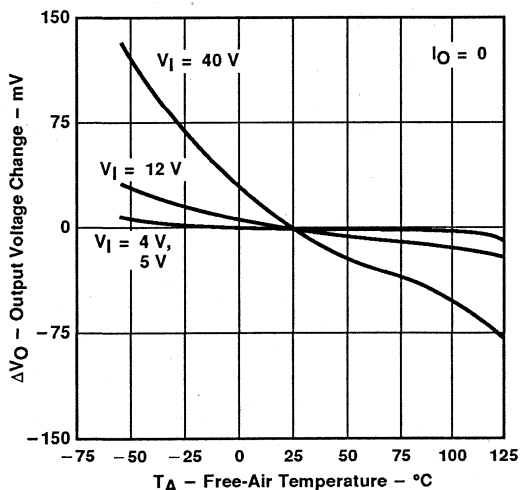


Figure 3

OUTPUT VOLTAGE ERROR vs INPUT VOLTAGE

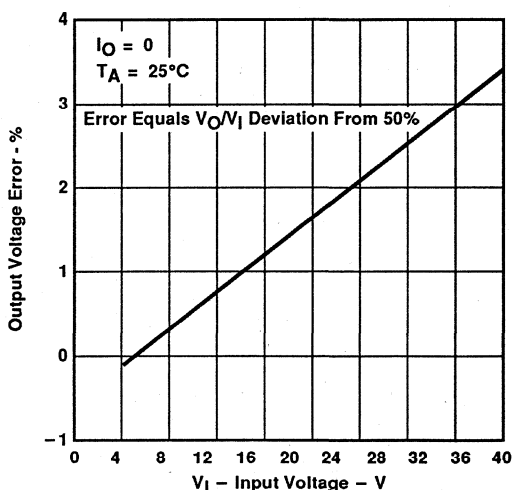


Figure 4

†Data at high and low temperatures are applicable within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS†

BIAS CURRENT
vs
INPUT VOLTAGE

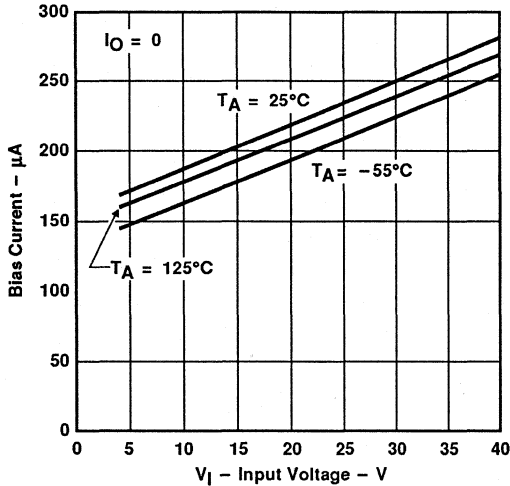


Figure 5

BIAS CURRENT
vs
FREE-AIR TEMPERATURE

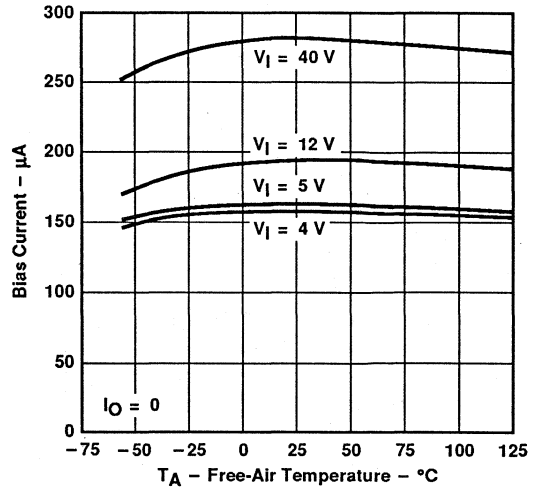


Figure 6

OUTPUT REGULATION
vs
OUTPUT CURRENT

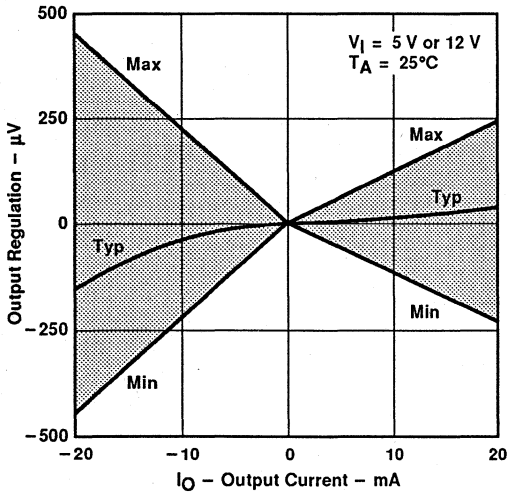


Figure 7

OUTPUT IMPEDANCE
vs
FREQUENCY

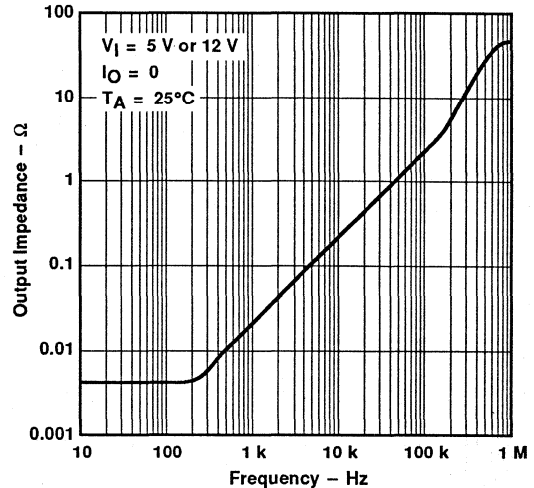


Figure 8

†Data at high and low temperatures are applicable within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS†

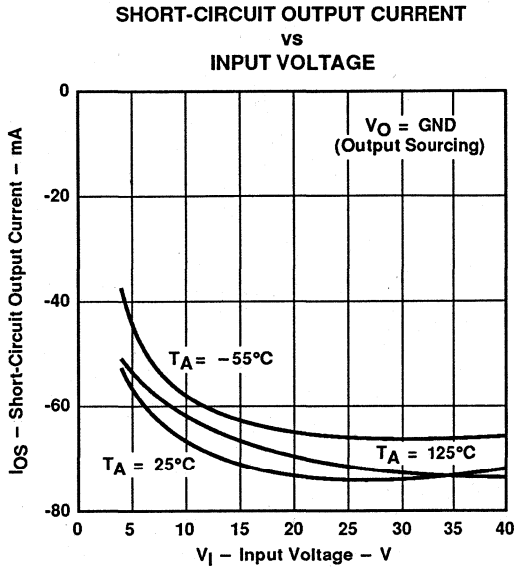


Figure 9

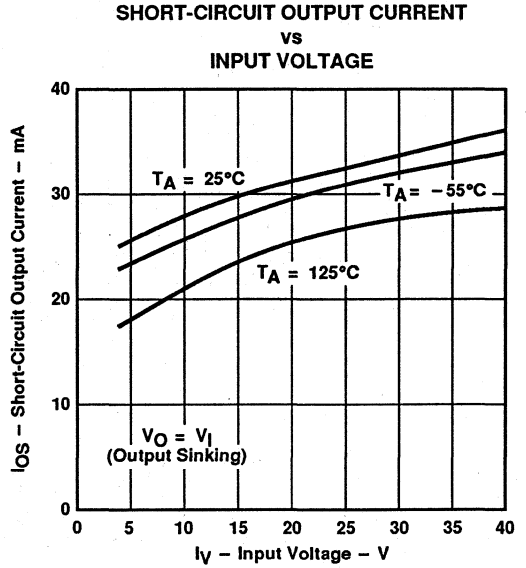


Figure 10

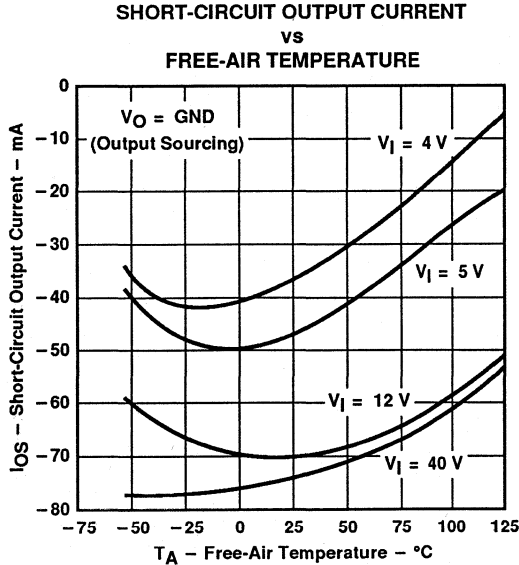


Figure 11

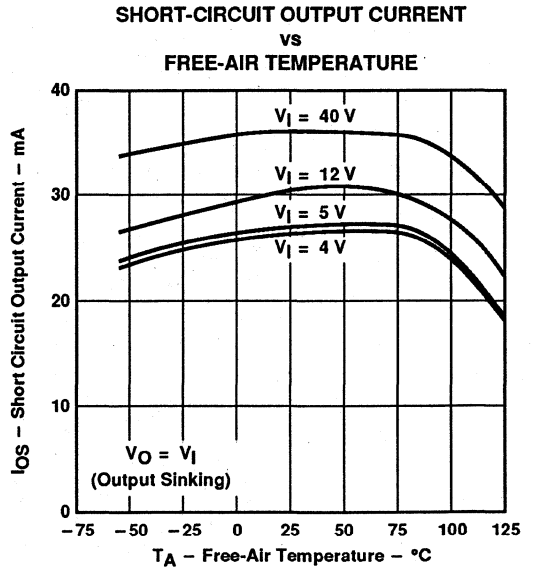


Figure 12

†Data at high and low temperatures are applicable within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

RIPLLE REJECTION
vs
FREQUENCY

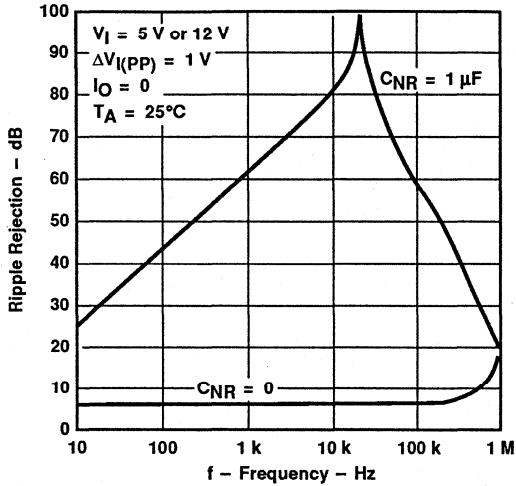


Figure 13

OUTPUT VOLTAGE RESPONSE
TO OUTPUT CURRENT STEP
vs
TIME

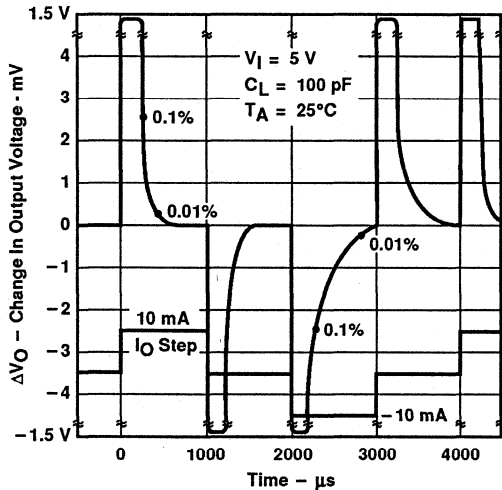


Figure 15

SPOT NOISE
vs
FREQUENCY

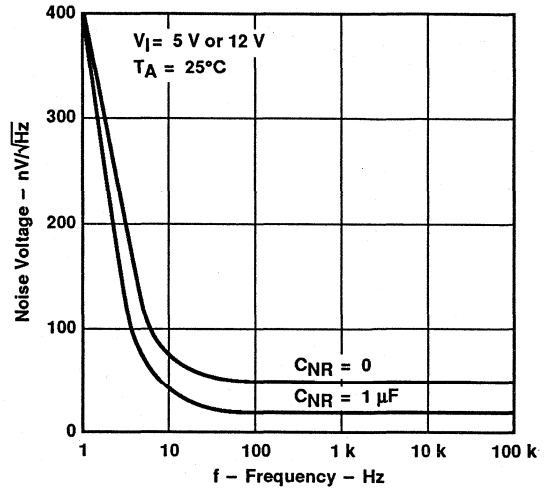


Figure 14

OUTPUT VOLTAGE POWER-UP RESPONSE
vs
TIME

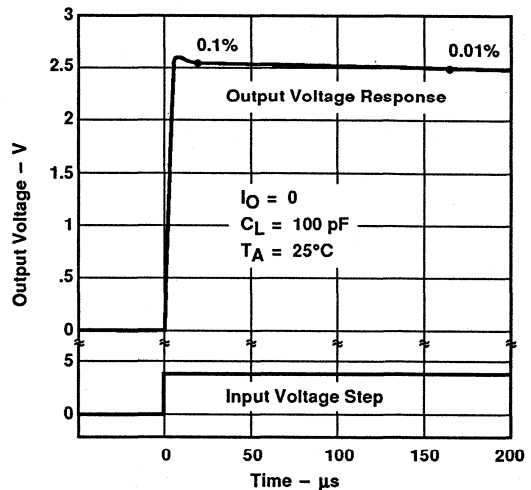


Figure 16

TLE2426
THE "RAIL SPLITTER" PRECISION
VIRTUAL GROUND

TYPICAL CHARACTERISTICS†

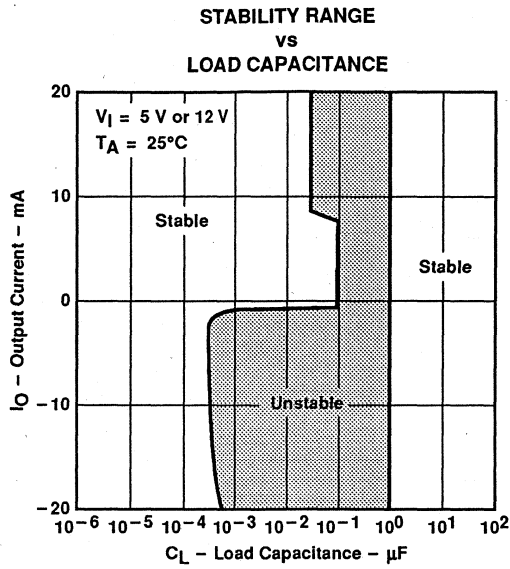


Figure 17

macromodel information

* TLE2426 OPERATIONAL AMPLIFIER "MACROMODEL" SUBCIRCUIT
 * CREATED USING PARTS RELEASE 4.03 ON 08/21/90 AT 13:51
 * REV (N/A) SUPPLY VOLTAGE: 5 V

* CONNECTIONS: FILTER
 | INPUT
 * | | COMMON
 * | | | OUTPUT
 * | | | |
 .SUBCKT TLE2426 1 3 4 5

| | | | |
|------|----|----|---|
| C1 | 11 | 12 | 21.66E-12 |
| C2 | 6 | 7 | 30.00E-12 |
| C3 | 87 | 0 | 10.64E-9 |
| CPSR | 85 | 86 | 15.9E-9 |
| DCM+ | 81 | 82 | DX |
| DCM- | 83 | 81 | DX |
| DC | 5 | 53 | DX |
| DE | 54 | 5 | DX |
| DLP | 90 | 91 | DX |
| DLN | 92 | 90 | DX |
| DP | 4 | 3 | DX |
| ECMR | 84 | 99 | (2,99) 1 |
| EGND | 99 | 0 | POLY(2) (3,0) (4,0) 0 .5 .5 |
| EPSR | 85 | 0 | POLY(1) (3,4) -16.22E-6 3.24E-6 |
| ENSE | 89 | 2 | POLY(1) (88,0) 120E-6 1 |
| FB | 7 | 99 | POLY(6) VB VC VE VLP VLN VPSR 0 74.8E6 -10E6 10E6 10E6 -10E6 74E6 |
| GA | 6 | 0 | 11 12 320.4E-6 |
| GCM | 0 | 6 | 10 99 1.013E-9 |
| GPSR | 85 | 86 | (85,86) 100E-6 |
| GRC1 | 4 | 11 | (4,11) 3.204E-4 |
| GRC2 | 4 | 12 | (4,12) 3.204E-4 |
| GRE1 | 13 | 10 | (13,10) 1.038E-3 |
| GRE2 | 14 | 10 | (14,10) 1.038E-3 |
| HLIM | 90 | 0 | VLIM 1K |
| HCMR | 80 | 1 | POLY(2) VCM+ VCM- 0 1E2 1E2 |
| IRP | 3 | 4 | 146E-6 |
| IEE | 3 | 10 | DC 24.05E-6 |
| IIO | 2 | 0 | .2E-9 |
| I1 | 88 | 0 | 1E-21 |
| Q1 | 11 | 89 | 13 QX |
| Q2 | 12 | 80 | 14 QX |
| R2 | 6 | 9 | 100.0E3 |
| RCM | 84 | 81 | 1K |
| REE | 10 | 99 | 8.316E6 |
| RN1 | 87 | 0 | 2.55E8 |
| RN2 | 87 | 88 | 11.67E3 |
| RO1 | 8 | 5 | 63 |
| R02 | 7 | 99 | 62 |
| VCM+ | 82 | 99 | 1.0 |
| VCM- | 83 | 99 | -2.3 |
| VB | 9 | 0 | DC 0 |

TLE2426 THE "RAIL SPLITTER" PRECISION VIRTUAL GROUND

macromodel information (continued)

| | | | |
|------|----|----|----------|
| VC | 3 | 53 | DC 1.400 |
| VE | 54 | 4 | DC 1.400 |
| VLIM | 7 | 8 | DC 0 |
| VLP | 91 | 0 | DC 30 |
| VLN | 0 | 92 | DC 30 |
| VPSR | 0 | 86 | DC 0 |
| RFB | 5 | 2 | 1K |
| RIN1 | 3 | 1 | 220K |
| RIN2 | 1 | 4 | 220K |

.MODEL DX D(IS=800.OE-18)
.MODEL QX PNP(IS=800.OE-18 BF=480)
.ENDS

†Data at high and low temperatures are applicable within the rated operating free-air temperature ranges of the various devices.

μA723C, μA723M PRECISION VOLTAGE REGULATORS

D1063, AUGUST 1972—REVISED SEPTEMBER 1991

- 150-mA Load Current Without External Power Transistor
- Typically 0.02% Input Regulation and 0.03% Load Regulation (μA723M)
- Adjustable Current Limiting Capability
- Input Voltages to 40 V
- Output Adjustable From 2 V to 37 V
- Direct Replacement for Fairchild μA723C and μA723M

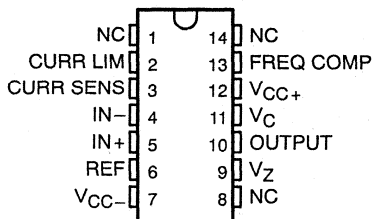
description

The μA723C and μA723M are precision monolithic integrated circuit voltage regulators featuring high ripple rejection, excellent input and load regulation, excellent temperature stability, and low standby current. The circuit consists of a temperature-compensated reference voltage amplifier, an error amplifier, a 150-mA output transistor, and an adjustable output current limiter.

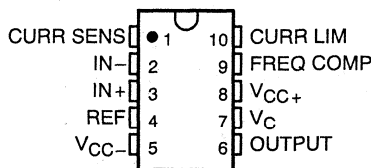
The μA723C and μA723M are designed for use in positive or negative power supplies as a series, shunt, switching, or floating regulator. For output currents exceeding 150 mA, additional pass elements may be connected as shown in Figures 4 and 5.

The μA723C is characterized for operation from 0°C to 70°C. The μA723M is characterized for operation over the full military temperature range of -55°C to 125°C.

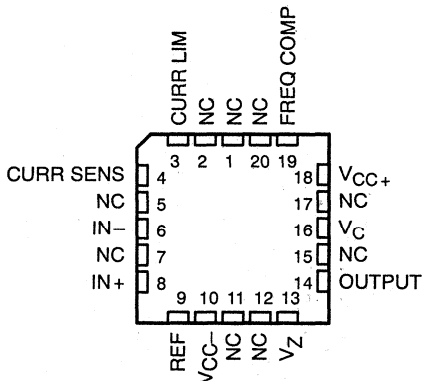
μA723C . . . D OR N PACKAGE
μA723M . . . J PACKAGE
(TOP VIEW)



μA723M . . . U PACKAGE
(TOP VIEW)



μA723M . . . FK PACKAGE
(TOP VIEW)



NC — No internal connection

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

**TEXAS
INSTRUMENTS**

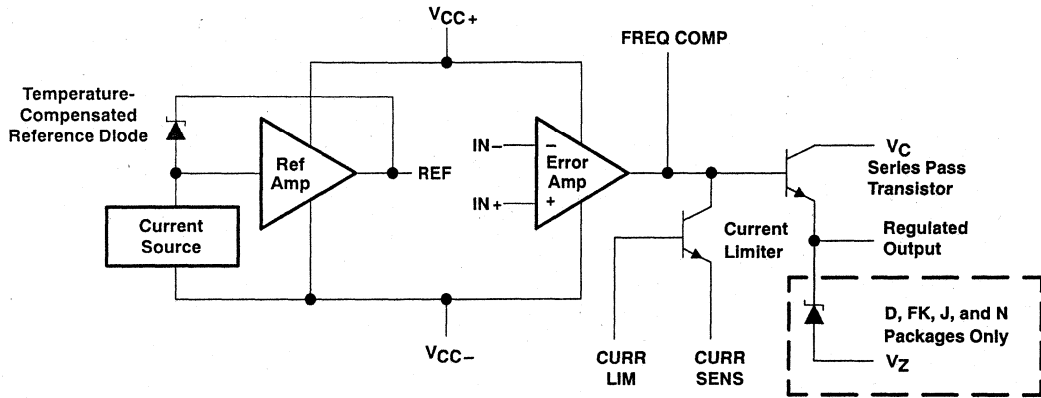
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On products compliant to MIL-STD-883, Class B, all parameters are tested unless otherwise noted. On all other products, production processing does not necessarily include testing of all parameters.

μA723C, μA723M PRECISION VOLTAGE REGULATORS

functional block diagram



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|--|
| Peak voltage from V_{CC+} to V_{CC-} ($t_w \leq 50$ ms) | 50 V |
| Continuous voltage from V_{CC+} to V_{CC-} | 40 V |
| Input-to-output voltage differential | 40 V |
| Differential input voltage to error amplifier | ± 5 V |
| Voltage between noninverting input and V_{CC-} | 8 V |
| Current from V_Z | 25 mA |
| Current from REF | 15 mA |
| Continuous total dissipation (see Note 1) | See Dissipation Rating Table |
| Operating free-air temperature range: $\mu A723C$ | 0°C to 70°C |
| $\mu A723M$ | -55°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J or U package | 300°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or N package | 260°C |

NOTE 1: Power dissipation = $[I_{(\text{standby})} + I_{(\text{ref})}] V_{CC} + [V_C - V_O] I_O$

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR | DERATE ABOVE T_A | $T_A = 70^\circ\text{C}$ POWER RATING | $T_A = 125^\circ\text{C}$ POWER RATING |
|----------|--|---------------------------|--------------------|---------------------------------------|--|
| D | 950 mW | 7.6 mW/ $^\circ\text{C}$ | 25°C | 608 mW | |
| FK and J | 1000 mW | 11.0 mW/ $^\circ\text{C}$ | 59°C | 880 mW | 275 mW |
| N | 1000 mW | 9.2 mW/ $^\circ\text{C}$ | 41°C | 736 mW | |
| U | 675 mW | 5.4 mW/ $^\circ\text{C}$ | 25°C | 432 mW | 135 mW |

recommended operating conditions

| | MIN | MAX | UNIT |
|---|-----|-----|------|
| Input voltage, V_I | 9.5 | 40 | V |
| Output voltage, V_O | 2 | 37 | V |
| Input-to-output voltage differential, $V_C - V_O$ | 3 | 38 | V |
| Output current, I_O | | 150 | mA |



uA723C, uA723M PRECISION VOLTAGE REGULATORS

electrical characteristics at specified free-air temperature (see Notes 2 and 3)

| PARAMETER | TEST CONDITIONS | T _A [†] | uA723C | | | uA723M | | | UNIT |
|---|--|-----------------------------|--------|--------|-------|--------|--------|--------|------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| Input regulation | V _I = 12 V to V _I = 15 V | 25°C | 0.01% | 0.1% | | 0.01% | 0.1% | | |
| | V _I = 12 V to V _I = 40 V | 25°C | | 0.1% | 0.5% | | 0.02% | 0.2% | |
| | V _I = 12 V to V _I = 15 V | Full range | | | 0.3% | | | 0.3% | |
| Ripple rejection | f = 50 Hz to 10 kHz, C _{ref} = 0 | 25°C | | 74 | | | 74 | | |
| | f = 50 Hz to 10 kHz, C _{ref} = 5 μF | 25°C | | 86 | | | 86 | | |
| Output regulation | I _O = 1 mA to 50 mA | 25°C | | -0.03% | -0.2% | | -0.03% | -0.15% | |
| | | Full range | | | -0.6% | | | -0.6% | |
| Reference voltage, V _{ref} | | 25°C | 6.8 | 7.15 | 7.5 | 6.95 | 7.15 | 7.35 | V |
| Standby current | V _I = 30 V, I _O = 0 | 25°C | | 2.3 | 4 | | 2.3 | 3.5 | mA |
| Temperature coefficient of output voltage | | Full range | | 0.003 | 0.015 | | 0.002 | 0.015* | %/°C |
| Short-circuit output current | R _{SC} = 10 Ω, V _O = 0 | 25°C | | 65 | | | 65 | | mA |
| | BW = 100 Hz to 10 kHz, C _{ref} = 0 | 25°C | | 20 | | | 20 | | |
| Output noise voltage | BW = 100 Hz to 10 kHz, C _{ref} = 5 μF | 25°C | | 2.5 | | | 2.5 | | μV |

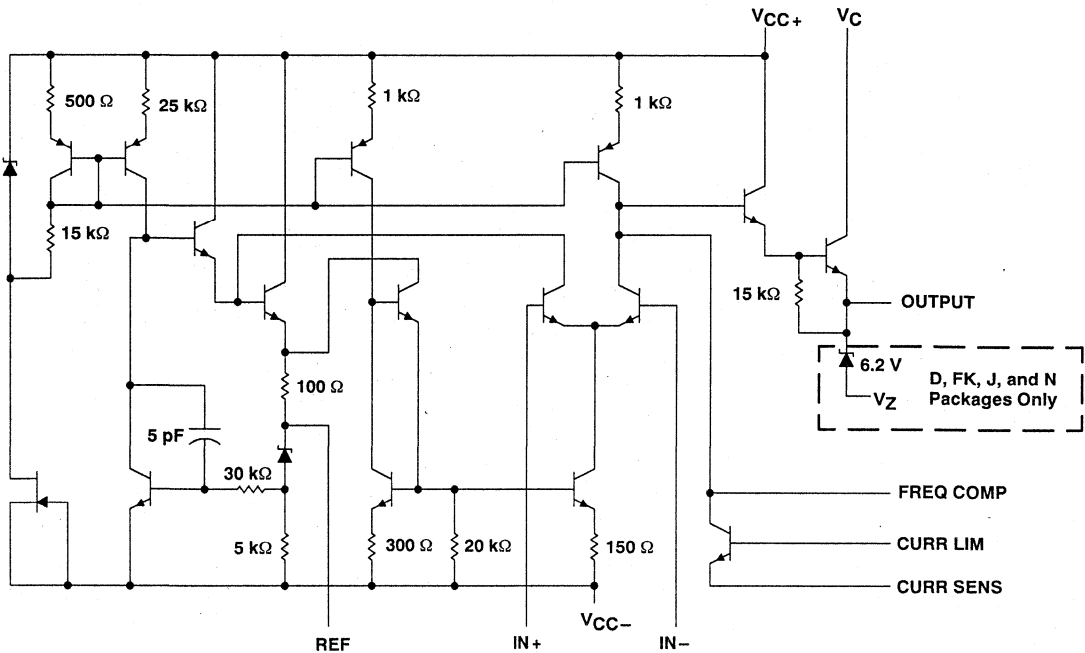
*On products compliant to MIL-STD-883, Class B, this parameter is not production tested.

† Full range for uA723C is 0°C to 70°C and for uA723M is -55°C to 125°C.

NOTES: 2. For all values in this table, the device is connected as shown in Figure 1 with the divider resistance as seen by the error amplifier ≤ 10 kΩ. Unless otherwise specified, V_I = V_{CC+} = V_C = 12 V, V_{CC-} = 0, V_O = 5 V, I_O = 1 mA, R_{SC} = 0, and C_{ref} = 0.

3. Pulse-testing techniques must be used that will maintain the junction temperature as close to the ambient temperature as possible.

schematic



Resistor and capacitor values shown are nominal.

**TEXAS
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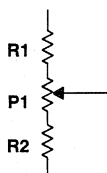
2-419

APPLICATION INFORMATION

Table 1. Resistor Values (kΩ) for Standard Output Voltages

| OUTPUT VOLTAGE (V) | APPLICABLE FIGURES (SEE NOTE 4) | FIXED OUTPUT ±5% | | OUTPUT ADJUSTABLE ±10% (SEE NOTE 5) | | | OUTPUT VOLTAGE (V) | APPLICABLE FIGURES (SEE NOTE 4) | FIXED OUTPUT ±5% | | OUTPUT ADJUSTABLE ±10% (SEE NOTE 5) | | |
|--------------------|---------------------------------|------------------|---------|-------------------------------------|---------|---------|--------------------|---------------------------------|------------------|---------|-------------------------------------|---------|---------|
| | | R1 (kΩ) | R2 (kΩ) | R1 (kΩ) | P1 (kΩ) | P2 (kΩ) | | | R1 (kΩ) | R2 (kΩ) | R1 (kΩ) | P1 (kΩ) | R2 (kΩ) |
| 3.0 | 1,5,6,9,11, 12 (4) | 4.12 | 3.01 | 1.8 | 0.5 | 1.2 | 100 | 7 | 3.57 | 105 | 2.2 | 10 | 91 |
| 3.6 | 1,5,6,9,11, 12 (4) | 3.57 | 3.65 | 1.5 | 0.5 | 1.5 | 250 | 7 | 3.57 | 255 | 2.2 | 10 | 240 |
| 5.0 | 1,5,6,9,11, 12 (4) | 2.15 | 4.99 | 0.75 | 0.5 | 2.2 | -6 (Note 6) | 3, 10 | 3.57 | 2.43 | 1.2 | 0.5 | 0.75 |
| 6.0 | 1,5,6,9,11, 12 (4) | 1.15 | 6.04 | 0.5 | 0.5 | 2.7 | -9 | 3, 10 | 3.48 | 5.36 | 1.2 | 0.5 | 2.0 |
| 9.0 | 2,4,(5,6, 9,12) | 1.87 | 7.15 | 0.75 | 1.0 | 2.7 | -12 | 3, 10 | 3.57 | 8.45 | 1.2 | 0.5 | 3.3 |
| 12 | 2,4,(5,6, 9,12) | 4.87 | 7.15 | 2.0 | 1.0 | 3.0 | -15 | 3, 10 | 3.57 | 11.5 | 1.2 | 0.5 | 4.3 |
| 15 | 2,4,(5,6, 9,12) | 7.87 | 7.15 | 3.3 | 1.0 | 3.0 | -28 | 3, 10 | 3.57 | 24.3 | 1.2 | 0.5 | 10 |
| 28 | 2,4,(5,6, 9,12) | 21.0 | 7.15 | 5.6 | 1.0 | 2.0 | -45 | 8 | 3.57 | 41.2 | 2.2 | 10 | 33 |
| 45 | 7 | 3.57 | 48.7 | 2.2 | 10 | 39 | -100 | 8 | 3.57 | 95.3 | 2.2 | 10 | 91 |
| 75 | 7 | 3.57 | 78.7 | 2.2 | 10 | 68 | -250 | 8 | 3.57 | 249 | 2.2 | 10 | 240 |

NOTES: 4. The R1/R2 divider may be across either V_O or $V_{(ref)}$. If the divider is across $V_{(ref)}$, use the figure numbers without parentheses. If the divider is across V_O , use the figure numbers in parentheses.
5. To make the voltage adjustable, the R1/R2 divider shown in the figures must be replaced by the divider shown below.



Adjustable Output Circuit

6. For Figures 3, 8, and 10, the device requires a minimum of 9 V between V_{CC+} and V_{CC-} when V_O is equal to or more positive than -9 V.

APPLICATION INFORMATION

Table 2. Formulas for Intermediate Output Voltages

| | | |
|---|--|---|
| <p>Outputs from 2 V to 7 V See Figures 1,5,6,9, 11, 12 (4) and Note 4</p> $V_O = V_{(ref)} \times \frac{R_2}{R_1 + R_2}$ | <p>Outputs from 4 V to 250 V See Figure 7 and Note 4</p> $V_O = \frac{V_{(ref)}}{2} \times \frac{R_2 - R_1}{R_1};$ <p>$R_3 = R_4$</p> | <p>Current Limiting</p> $I_{(limit)} \approx \frac{0.65 \text{ V}}{R_{SC}}$ |
| <p>Outputs from 7 V to 37 V See Figures 2,4,(5,6,9, 11, 12) and Note 4</p> $V_O = V_{(ref)} \times \frac{R_1 + R_2}{R_2}$ | <p>Outputs from -6 V to -250 V See Figures 3, 8, 10 and Notes 4 and 6</p> $V_O = -\frac{V_{(ref)}}{2} \times \frac{R_1 + R_2}{R_1};$ <p>$R_3 = R_4$</p> | <p>Foldback Current Limiting See Figure 6</p> $I_{(knee)} \approx \frac{V_O R_3 + (R_3 + R_4) 0.65 \text{ V}}{R_{SC} R_4};$ $I_{OS} \approx \frac{0.65 \text{ V}}{R_{SC}} \times \frac{R_3 + R_4}{R_4}$ |

NOTES: 4. The R1/R2 divider may be across either V_O or $V_{(ref)}$. If the divider is across $V_{(ref)}$, use figure numbers without parentheses. If the divider is across V_O , use the figure numbers in parentheses.

6. For Figures 3, 8, and 10, the device requires a minimum of 9 V between V_{CC+} and V_{CC-} when V_O is equal to or more positive than -9 V.

APPLICATION INFORMATION

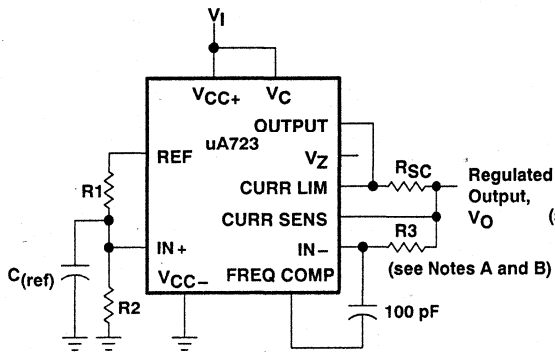


Figure 1. Basic Low-Voltage Regulator
 ($V_O = 2 \text{ V to } 7 \text{ V}$)

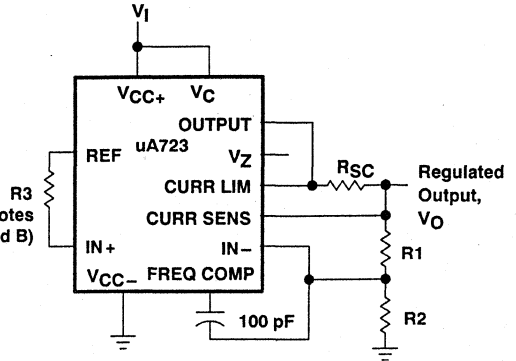


Figure 2. Basic High-Voltage Regulator
 ($V_O = 7 \text{ V to } 37 \text{ V}$)

NOTES: A. $R_3 = \frac{R_1 \cdot R_2}{R_1 + R_2}$ for minimum αV_O .

B. R_3 may be eliminated for minimum component count. Use direct connection (i.e., $R_3 = 0$).

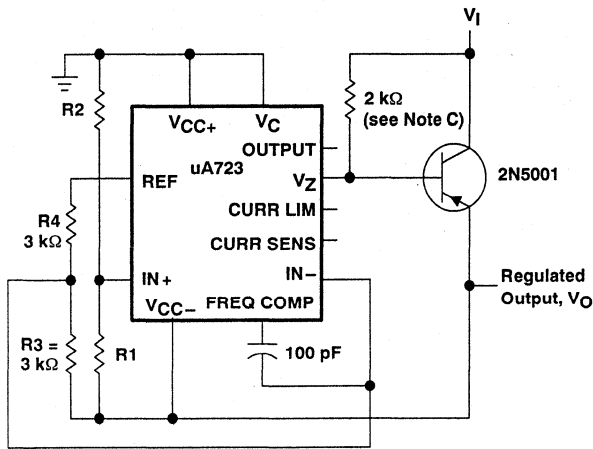


Figure 3. Negative-Voltage Regulator

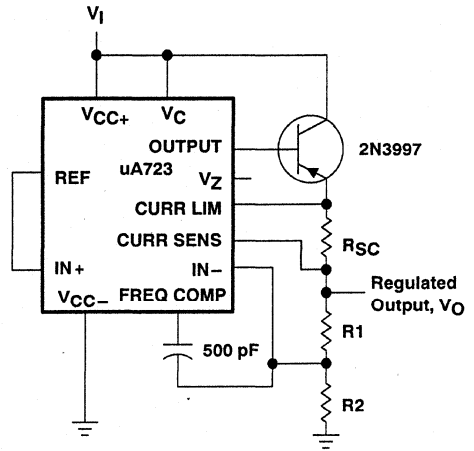
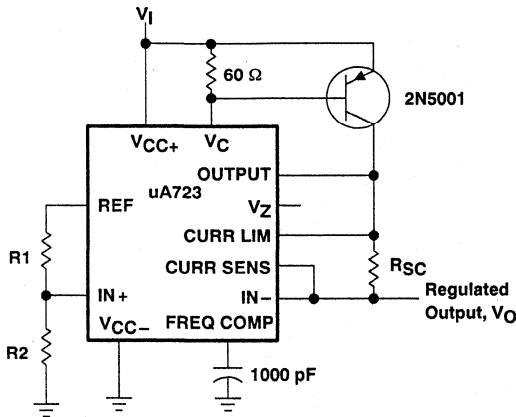


Figure 4. Positive-Voltage Regulator
 (External N-P-N Pass Terminator)

NOTE C: When 10-lead uA723U devices are used in applications requiring V_Z , an external 6.2-V regulator diode must be connected in series with OUTPUT.

APPLICATION INFORMATION



**Figure 5. Positive-Voltage Regulator
(External P-N-P Pass Transistor)**

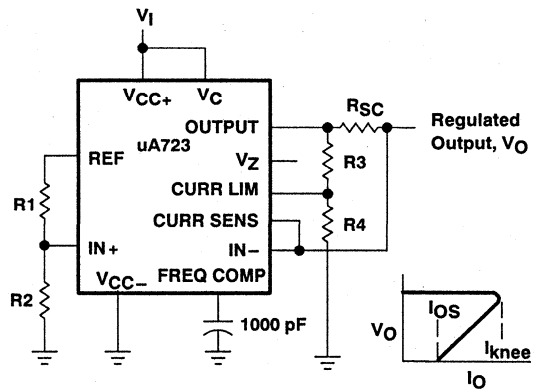


Figure 6. Foldback Current Limiting

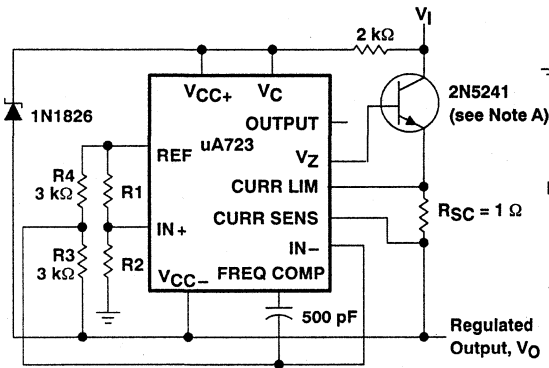


Figure 7. Positive Floating Regulator

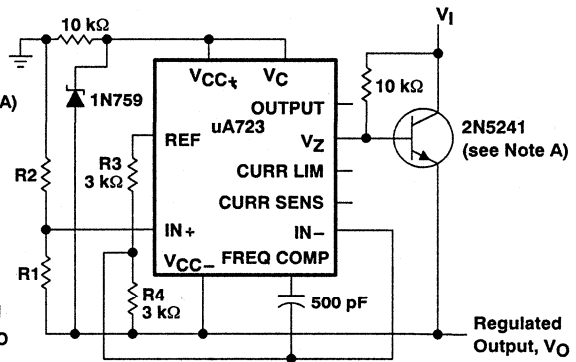


Figure 8. Negative Floating Regulator

NOTE A: When 10-lead uA723U devices are used in applications requiring V_Z , an external 6.2-V regulator diode must be connected in series with OUTPUT.

APPLICATION INFORMATION

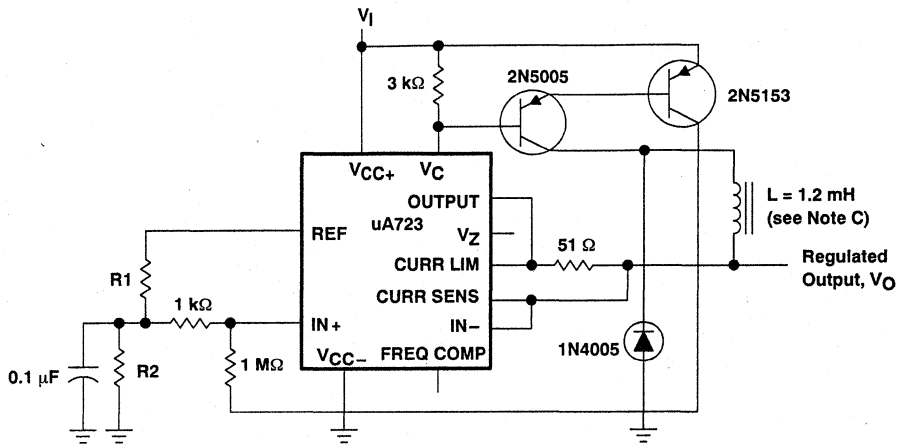


Figure 9. Positive Switching Regulator

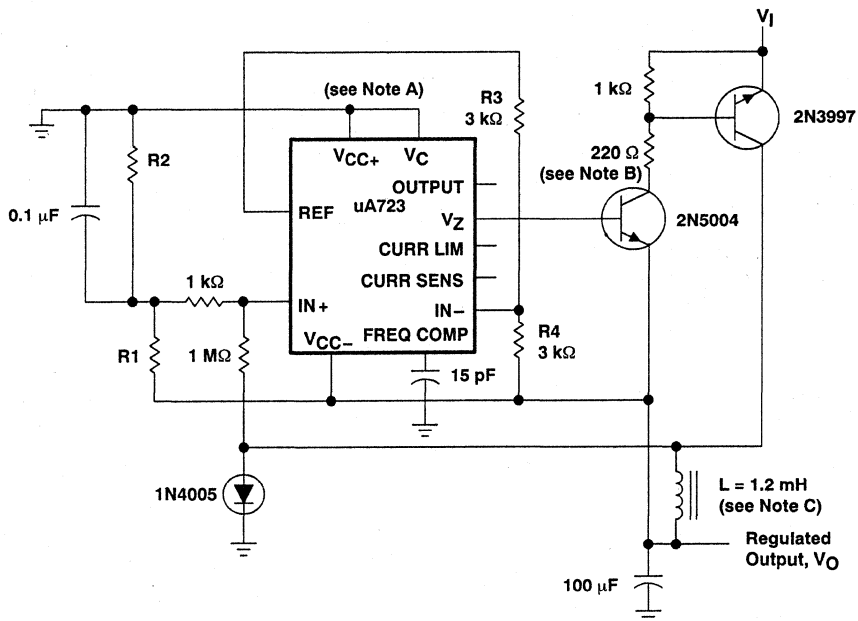
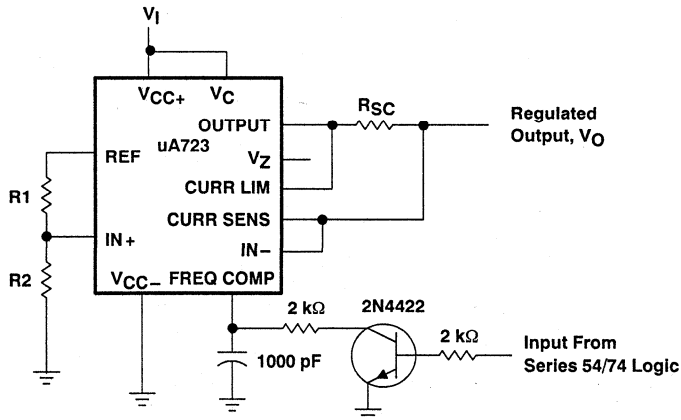


Figure 10. Negative Switching Regulator

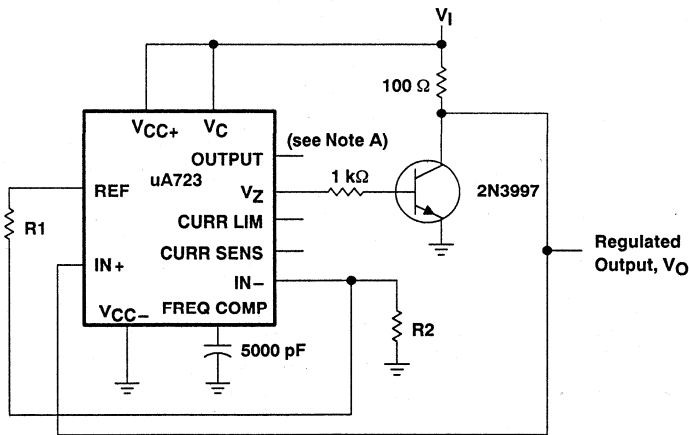
- NOTES: A. The device requires a minimum of 9 V between V_{CC+} and V_{CC-} when V_O is equal to or more positive than -9 V.
 B. When 10-lead uA723U devices are used in applications requiring V_Z , an external 6.2-V regulator diode must be connected in series with OUTPUT.
 C. L is 40 turns of No. 20 enameled copper wire wound on Ferroxcube P36/22-3B7 potted core or equivalent, with a 0.009-inch air gap.

APPLICATION INFORMATION



NOTE A: A current-limit transistor may be used for shutdown if current limiting is not required.

Figure 11. Remote Shutdown Regulator With Current Limiting



NOTE A: When 10-lead uA723U devices are used in applications requiring V_Z , an external 6.2-V regulator diode must be connected in series with OUTPUT.

Figure 12. Shunt Regulator

uA7800 SERIES POSITIVE-VOLTAGE REGULATORS

D2154, MAY 1976—REVISED AUGUST 1991

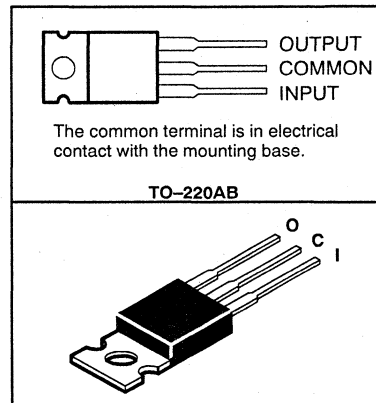
- **3-Terminal Regulators**
- **Output Current Up to 1.5 A**
- **Internal Thermal Overload Protection**
- **High Power Dissipation Capability**
- **Internal Short-Circuit Current Limiting**
- **Output Transistor Safe-Area Compensation**
- **Direct Replacements for Fairchild μ A7800 Series**

| NOMINAL OUTPUT VOLTAGE | REGULATOR |
|------------------------|-----------|
| 5 V | uA7805C |
| 5 V | uA7805Q |
| 6 V | uA7806C |
| 8 V | uA7808C |
| 8.5 V | uA7885C |
| 10 V | uA7810C |
| 12 V | uA7812C |
| 12 V | uA7812Q |
| 15 V | uA7815C |
| 18 V | uA7818C |
| 24 V | uA7824C |

description

This series of fixed-voltage monolithic integrated-circuit voltage regulators is designed for a wide range of applications. These applications include on-card regulation for elimination of noise and distribution problems associated with single-point regulation. Each of these regulators can deliver up to 1.5 A of output current. The internal current limiting and thermal shutdown features of these regulators make them essentially immune to overload. In addition to use as fixed-voltage regulators, these devices can be fused with external components to obtain adjustable output voltages and currents and also as the power-pass element in precision regulators. The uA7800C series is characterized for operation over the virtual junction temperature range of 0°C to 125°C. The uA7805Q and uA7812Q are characterized for operation over the virtual junction temperature range of -40°C to 125°C.

**KC PACKAGE
(TOP VIEW)**



PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

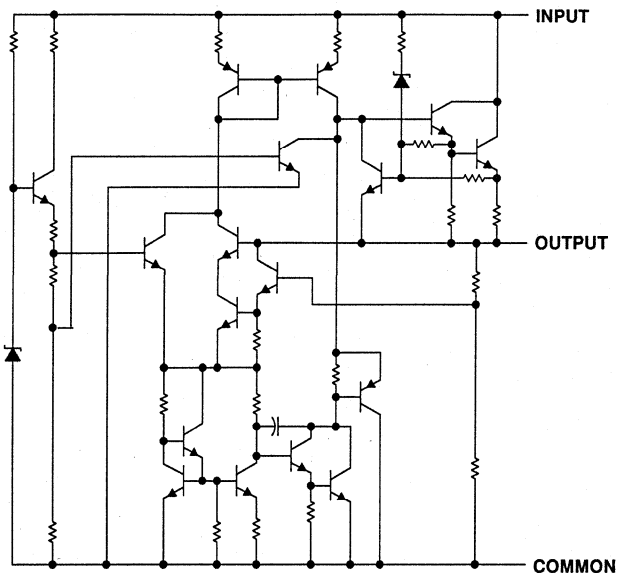
**TEXAS
INSTRUMENTS**

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uA7800 SERIES POSITIVE-VOLTAGE REGULATORS

schematic



absolute maximum ratings over operating temperature ranges (unless otherwise noted)

| | |
|---|--------------|
| Input voltage: uA7824C | 40 V |
| All others | 35 V |
| Continuous total dissipation at (or below) 25°C free-air temperature (see Note 1) | 2 W |
| Continuous total dissipation at (or below) 90°C case temperature (see Note 1) | 15 W |
| Operating free-air, case, or virtual junction temperature range | -40 to 150°C |
| Storage temperature range | -65 to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 1: For operation above 25°C free-air or 90°C case temperature, refer to Figures 1 and 2. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

uA7800 SERIES POSITIVE-VOLTAGE REGULATORS

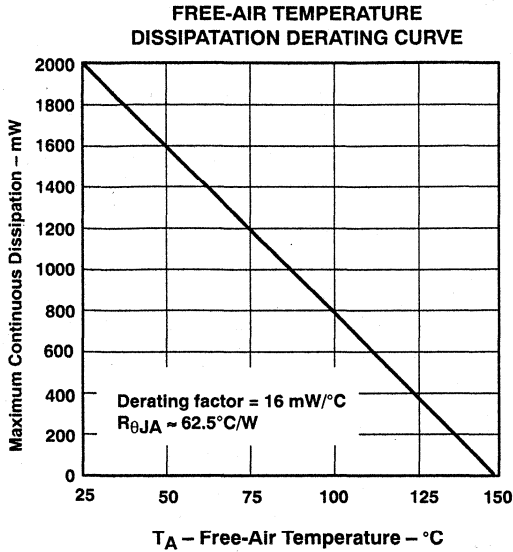


Figure 1

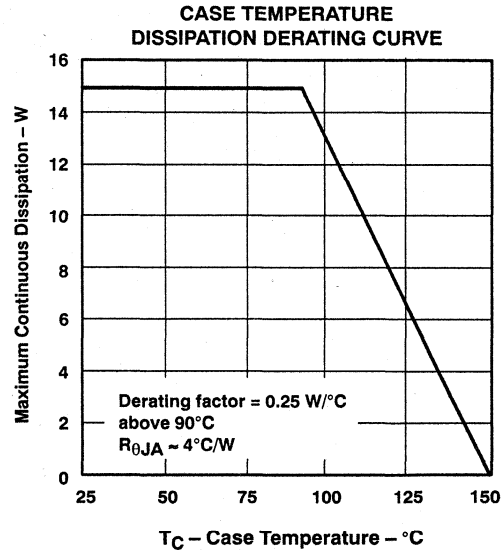


Figure 2

recommended operating conditions

| | | MIN | MAX | UNIT |
|---|------------------|------|-----|------|
| Input voltage, V_I | uA7805C | 7 | 25 | V |
| | uA7806C | 8 | 25 | |
| | uA7808C | 10.5 | 25 | |
| | uA7885C | 10.5 | 25 | |
| | uA7810C | 12.5 | 28 | |
| | uA7812C | 14.5 | 30 | |
| | uA7815C | 17.5 | 30 | |
| | uA7818C | 21 | 33 | |
| | uA7824C | 27 | 38 | |
| Output current, I_O | | | 1.5 | A |
| Operating virtual junction temperature, T_J | uA7800C Series | 0 | 125 | °C |
| | uA7805Q, uA7812Q | -40 | 125 | |

uA7800 SERIES POSITIVE-VOLTAGE REGULATORS

uA7805C and uA7805Q electrical characteristics at specified virtual junction temperature, $V_I = 10\text{ V}$, $I_O = 500\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J^\dagger | MIN | TYP | MAX | UNIT |
|---|---|-------------------------|------|-------|------|---------------|
| Output voltage [‡] | | 25°C | 4.8 | 5 | 5.2 | V |
| | $I_O = 5\text{ mA to }1\text{ A}$, $P \leq 15\text{ W}$ | Full range [§] | 4.75 | | 5.25 | |
| Input regulation | $V_I = 7\text{ V to }25\text{ V}$ | 25°C | | 3 | 100 | mV |
| | $V_I = 8\text{ V to }12\text{ V}$ | | | 1 | 50 | |
| Ripple rejection | $V_I = 8\text{ V to }18\text{ V}$, $f = 120\text{ Hz}$ | Full range [§] | 62 | 78 | | dB |
| Output regulation | $I_O = 5\text{ mA to }1.5\text{ A}$ | 25°C | | 15 | 100 | mV |
| | $I_O = 250\text{ mA to }750\text{ mA}$ | | | 5 | 50 | |
| Output resistance | $f = 1\text{ kHz}$ | Full range [§] | | 0.017 | | Ω |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | Full range [§] | | -1.1 | | mV/°C |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | 40 | | μV |
| Dropout voltage | $I_O = 1\text{ A}$ | 25°C | | 2 | | V |
| Bias current | | 25°C | | 4.2 | 8 | mA |
| Bias current change | $V_I = 7\text{ V to }25\text{ V}$ | Full range [§] | | | 1.3 | mA |
| | $I_O = 5\text{ mA to }1\text{ A}$ | | | | 0.5 | |
| Short-circuit output current | | 25°C | | 750 | | mA |
| Peak output current | | 25°C | | 2.2 | | A |

uA7806C electrical characteristics at specified virtual junction temperature, $V_I = 11\text{ V}$, $I_O = 500\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J^\dagger | MIN | TYP | MAX | UNIT |
|---|---|---------------|------|-------|------|---------------|
| Output voltage [‡] | | 25°C | 5.75 | 6 | 6.25 | V |
| | $I_O = 5\text{ mA to }1\text{ A}$, $P \leq 15\text{ W}$ | 0°C to 125°C | 5.7 | | 6.3 | |
| Input regulation | $V_I = 8\text{ V to }25\text{ V}$ | 25°C | | 5 | 120 | mV |
| | $V_I = 9\text{ V to }13\text{ V}$ | | | 1.5 | 60 | |
| Ripple rejection | $V_I = 9\text{ V to }19\text{ V}$, $f = 120\text{ Hz}$ | 0°C to 125°C | 59 | 75 | | dB |
| Output regulation | $I_O = 5\text{ mA to }1.5\text{ A}$ | 25°C | | 14 | 120 | mV |
| | $I_O = 250\text{ mA to }750\text{ mA}$ | | | 4 | 60 | |
| Output resistance | $f = 1\text{ kHz}$ | 0°C to 125°C | | 0.019 | | Ω |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | 0°C to 125°C | | -0.8 | | mV/°C |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | 45 | | μV |
| Dropout voltage | $I_O = 1\text{ A}$ | 25°C | | 2 | | V |
| Bias current | | 25°C | | 4.3 | 8 | mA |
| Bias current change | $V_I = 8\text{ V to }25\text{ V}$ | 0°C to 125°C | | | 1.3 | mA |
| | $I_O = 5\text{ mA to }1\text{ A}$ | | | | 0.5 | |
| Short-circuit output current | | 25°C | | 550 | | mA |
| Peak output current | | 25°C | | 2.2 | | A |

[†] Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.33- μF capacitor across the input and a 0.1- μF capacitor across the output.

[‡] This specification applies only for dc power dissipation permitted by absolute maximum ratings.

[§] Full range virtual junction temperature is 0°C to 125°C for the uA7805C and -40°C to 125°C for the uA7805Q.



uA7800 SERIES POSITIVE-VOLTAGE REGULATORS

uA7808C electrical characteristics at specified virtual junction temperature, $V_I = 14\text{ V}$, $I_O = 500\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J^\dagger | MIN | TYP | MAX | UNIT |
|---|---|---------------|-----|-------|-----|---------------|
| Output voltage ‡ | | 25°C | 7.7 | 8 | 8.3 | V |
| | $I_O = 5\text{ mA to }1\text{ A}$, $V_I = 10.5\text{ V to }23\text{ V}$, $P \leq 15\text{ W}$ | 0°C to 125°C | 7.6 | | 8.4 | |
| Input regulation | $V_I = 10.5\text{ V to }25\text{ V}$ | 25°C | | 6 | 160 | mV |
| | $V_I = 11\text{ V to }17\text{ V}$ | | | 2 | 80 | |
| Ripple rejection | $V_I = 11.5\text{ V to }21.5\text{ V}$, $f = 120\text{ Hz}$ | 0°C to 125°C | 55 | 72 | | dB |
| Output regulation | $I_O = 5\text{ mA to }1.5\text{ A}$ | 25°C | | 12 | 160 | mV |
| | $I_O = 250\text{ mA to }750\text{ mA}$ | | | 4 | 80 | |
| Output resistance | $f = 1\text{ kHz}$ | 0°C to 125°C | | 0.016 | | Ω |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | 0°C to 125°C | | -0.8 | | mV/°C |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | 52 | | μV |
| Dropout voltage | $I_O = 1\text{ A}$ | 25°C | | 2 | | V |
| Bias current | | 25°C | | 4.3 | 8 | mA |
| Bias current change | $V_I = 10.5\text{ V to }25\text{ V}$ | 0°C to 125°C | | | 1 | mA |
| | $I_O = 5\text{ mA to }1\text{ A}$ | | | | 0.5 | |
| Short-circuit output current | | 25°C | | 450 | | mA |
| Peak output current | | 25°C | | 2.2 | | A |

uA7885C electrical characteristics at specified virtual junction temperature, $V_I = 15\text{ V}$, $I_O = 500\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J^\dagger | MIN | TYP | MAX | UNIT |
|---|---|---------------|------|-------|------|---------------|
| Output voltage ‡ | | 25°C | 8.15 | 8.5 | 8.85 | V |
| | $I_O = 5\text{ mA to }1\text{ A}$, $V_I = 11\text{ V to }23.5\text{ V}$, $P \leq 15\text{ W}$ | 0°C to 125°C | 8.1 | | 8.9 | |
| Input regulation | $V_I = 10.5\text{ V to }25\text{ V}$ | 25°C | | 6 | 170 | mV |
| | $V_I = 11\text{ V to }17\text{ V}$ | | | 2 | 85 | |
| Ripple rejection | $V_I = 11.5\text{ V to }21.5\text{ V}$, $f = 120\text{ Hz}$ | 0°C to 125°C | 54 | 70 | | dB |
| Output regulation | $I_O = 5\text{ mA to }1.5\text{ A}$ | 25°C | | 12 | 170 | mV |
| | $I_O = 250\text{ mA to }750\text{ mA}$ | | | 4 | 85 | |
| Output resistance | $f = 1\text{ kHz}$ | 0°C to 125°C | | 0.016 | | Ω |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | 0°C to 125°C | | -0.8 | | mV/°C |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | 55 | | μV |
| Dropout voltage | $I_O = 1\text{ A}$ | 25°C | | 2 | | V |
| Bias current | | 25°C | | 4.3 | 8 | mA |
| Bias current change | $V_I = 10.5\text{ V to }25\text{ V}$ | 0°C to 125°C | | | 1 | mA |
| | $I_O = 5\text{ mA to }1\text{ A}$ | | | | 0.5 | |
| Short-circuit output current | | 25°C | | 450 | | mA |
| Peak output current | | 25°C | | 2.2 | | A |

† Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.33- μF capacitor across the input and a 0.1- μF capacitor across the output.

‡ This specification applies only for dc power dissipation permitted by absolute maximum ratings.



uA7800 SERIES POSITIVE-VOLTAGE REGULATORS

uA7810C electrical characteristics at specified virtual junction temperature, $V_I = 17\text{ V}$, $I_O = 500\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J^\dagger | MIN | TYP | MAX | UNIT |
|---|---|---------------|-----|-------|------|---------------|
| Output voltage‡ | | 25°C | 9.6 | 10 | 10.4 | V |
| | $I_O = 5\text{ mA to }1\text{ A}$, $V_I = 12.5\text{ V to }25\text{ V}$, $P \leq 15\text{ W}$ | 0°C to 125°C | 9.5 | 10 | 10.5 | |
| Input regulation | $V_I = 12.5\text{ V to }28\text{ V}$ | 25°C | | 7 | 200 | mV |
| | $V_I = 14\text{ V to }20\text{ V}$ | | | 2 | 100 | |
| Ripple rejection | $V_I = 13\text{ V to }23\text{ V}$, $f = 120\text{ Hz}$ | 0°C to 125°C | 55 | 71 | | dB |
| Output regulation | $I_O = 5\text{ mA to }1.5\text{ A}$ | 25°C | | 12 | 200 | mV |
| | $I_O = 250\text{ mA to }750\text{ mA}$ | | | 4 | 100 | |
| Output resistance | $f = 1\text{ kHz}$ | 0°C to 125°C | | 0.018 | | Ω |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | 0°C to 125°C | | -1 | | mV/°C |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | 70 | | μV |
| Dropout voltage | $I_O = 1\text{ A}$ | 25°C | | 2 | | V |
| Bias current | | 25°C | | 4.3 | 8 | mA |
| Bias current change | $V_I = 12.5\text{ V to }28\text{ V}$ | 0°C to 125°C | | | 1 | mA |
| | $I_O = 5\text{ mA to }1\text{ A}$ | | | | 0.5 | |
| Short-circuit output current | | 25°C | | 400 | | mA |
| Peak output current | | 25°C | | 2.2 | | A |

uA7812C electrical characteristics at specified virtual junction temperature, $V_I = 19\text{ V}$, $I_O = 500\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J^\dagger | MIN | TYP | MAX | UNIT |
|---|---|---------------|------|-------|------|---------------|
| Output voltage‡ | | 25°C | 11.5 | 12 | 12.5 | V |
| | $I_O = 5\text{ mA to }1\text{ A}$, $V_I = 14.5\text{ V to }27\text{ V}$, $P \leq 15\text{ W}$ | Full range§ | 11.4 | | 12.6 | |
| Input regulation | $V_I = 14.5\text{ V to }30\text{ V}$ | 25°C | | 10 | 240 | mV |
| | $V_I = 16\text{ V to }22\text{ V}$ | | | 3 | 120 | |
| Ripple rejection | $V_I = 15\text{ V to }25\text{ V}$, $f = 120\text{ Hz}$ | Full range§ | 55 | 71 | | dB |
| Output regulation | $I_O = 5\text{ mA to }1.5\text{ A}$ | 25°C | | 12 | 240 | mV |
| | $I_O = 250\text{ mA to }750\text{ mA}$ | | | 4 | 120 | |
| Output resistance | $f = 1\text{ kHz}$ | Full range§ | | 0.018 | | Ω |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | Full range§ | | -1 | | mV/°C |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | 75 | | μV |
| Dropout voltage | $I_O = 1\text{ A}$ | 25°C | | 2 | | V |
| Bias current | | 25°C | | 4.3 | 8 | mA |
| Bias current change | $V_I = 14.5\text{ V to }30\text{ V}$ | Full range§ | | | 1 | mA |
| | $I_O = 5\text{ mA to }1\text{ A}$ | | | | 0.5 | |
| Short-circuit output current | | 25°C | | 350 | | mA |
| Peak output current | | 25°C | | 2.2 | | A |

† Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.33- μF capacitor across the input and a 0.1- μF capacitor across the output.

‡ This specification applies only for dc power dissipation permitted by absolute maximum ratings.

§ Full range virtual junction temperature is 0°C to 125°C for the uA7812C and -40°C to 125°C for the uA7812Q.



uA7800 SERIES POSITIVE-VOLTAGE REGULATORS

uA7815C electrical characteristics at specified virtual junction temperature, $V_I = 23\text{ V}$, $I_O = 500\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J^\dagger | MIN | TYP | MAX | UNIT |
|---|---|---------------|-------|-------|-------|---------------|
| Output voltage‡ | | 25°C | 14.4 | 15 | 15.6 | V |
| | $I_O = 5\text{ mA to }1\text{ A}$, $V_I = 17.5\text{ V to }30\text{ V}$ $P \leq 15\text{ W}$ | 0°C to 125°C | 14.25 | | 15.75 | |
| Input regulation | $V_I = 17.5\text{ V to }30\text{ V}$ | 25°C | | 11 | 300 | mV |
| | $V_I = 20\text{ V to }26\text{ V}$ | | | 3 | 150 | |
| Ripple rejection | $V_I = 18.5\text{ V to }28.5\text{ V}$, $f = 120\text{ Hz}$ | 0°C to 125°C | 54 | 70 | | dB |
| Output regulation | $I_O = 5\text{ mA to }1.5\text{ A}$ | 25°C | | 12 | 300 | mV |
| | $I_O = 250\text{ mA to }750\text{ mA}$ | | | 4 | 150 | |
| Output resistance | $f = 1\text{ kHz}$ | 0°C to 125°C | | 0.019 | | Ω |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | 0°C to 125°C | | -1 | | mV/°C |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | 90 | | μV |
| Dropout voltage | $I_O = 1\text{ A}$ | 25°C | | 2 | | V |
| Bias current | | 25°C | | 4.4 | 8 | mA |
| Bias current change | $V_I = 17.5\text{ V to }30\text{ V}$ | 0°C to 125°C | | | 1 | mA |
| | $I_O = 5\text{ mA to }1\text{ A}$ | | | | 0.5 | |
| Short-circuit output current | | 25°C | | 230 | | mA |
| Peak output current | | 25°C | | 2.1 | | A |

uA7818C electrical characteristics at specified virtual junction temperature, $V_I = 27\text{ V}$, $I_O = 500\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J^\dagger | MIN | TYP | MAX | UNIT |
|---|---|---------------|------|-------|------|---------------|
| Output voltage‡ | | 25°C | 17.3 | 18 | 18.7 | V |
| | $I_O = 5\text{ mA to }1\text{ A}$, $V_I = 21\text{ V to }33\text{ V}$, $P \leq 15\text{ W}$ | 0°C to 125°C | 17.1 | | 18.9 | |
| Input regulation | $V_I = 21\text{ V to }33\text{ V}$ | 25°C | | 15 | 360 | mV |
| | $V_I = 24\text{ V to }30\text{ V}$ | | | 5 | 180 | |
| Ripple rejection | $V_I = 22\text{ V to }32\text{ V}$, $f = 120\text{ Hz}$ | 0°C to 125°C | 53 | 69 | | dB |
| Output regulation | $I_O = 5\text{ mA to }1.5\text{ A}$ | 25°C | | 12 | 360 | mV |
| | $I_O = 250\text{ mA to }750\text{ mA}$ | | | 4 | 180 | |
| Output resistance | $f = 1\text{ kHz}$ | 0°C to 125°C | | 0.022 | | Ω |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | 0°C to 125°C | | -1 | | mV/°C |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | 110 | | μV |
| Dropout voltage | $I_O = 1\text{ A}$ | 25°C | | 2 | | V |
| Bias current | | 25°C | | 4.5 | 8 | mA |
| Bias current change | $V_I = 21\text{ V to }33\text{ V}$ | 0°C to 125°C | | | 1 | mA |
| | $I_O = 5\text{ mA to }1\text{ A}$ | | | | 0.5 | |
| Short-circuit output current | | 25°C | | 200 | | mA |
| Peak output current | | 25°C | | 2.1 | | A |

† Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.33- μF capacitor across the input and a 0.1- μF capacitor across the output.

‡ This specification applies only for dc power dissipation permitted by absolute maximum ratings.

uA7824C SERIES POSITIVE-VOLTAGE REGULATOR

uA7824C electrical characteristics at specified virtual junction temperature, $V_I = 33\text{ V}$, $I_O = 500\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J^\dagger | MIN | TYP | MAX | UNIT |
|---|---|---------------|------|-------|------|---------------|
| | | 25°C | 23 | 24 | 25 | |
| Output voltage‡ | $I_O = 5\text{ mA to }1\text{ A}, V_I = 27\text{ V to }38\text{ V}, P \leq 15\text{ W}$ | 0°C to 125°C | 22.8 | | 25.2 | V |
| | | 25°C | | 18 | 480 | |
| Input regulation | $V_I = 27\text{ V to }38\text{ V}$ | 25°C | | 6 | 240 | mV |
| | $V_I = 30\text{ V to }36\text{ V}$ | | | | | |
| Ripple rejection | $V_I = 28\text{ V to }38\text{ V}, f = 120\text{ Hz}$ | 0°C to 125°C | 50 | 66 | | dB |
| Output regulation | $I_O = 5\text{ mA to }1.5\text{ A}$ | 25°C | | 12 | 480 | mV |
| | $I_O = 250\text{ mA to }750\text{ mA}$ | | | 4 | 240 | |
| Output resistance | $f = 1\text{ kHz}$ | 0°C to 125°C | | 0.028 | | Ω |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | 0°C to 125°C | | -1.5 | | mV/°C |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | 170 | | μV |
| Dropout voltage | $I_O = 1\text{ A}$ | 25°C | | 2 | | V |
| Bias current | | 25°C | | 4.6 | 8 | mA |
| Bias current change | $V_I = 27\text{ V to }38\text{ V}$ | 0°C to 125°C | | | 1 | mA |
| | $I_O = 5\text{ mA to }1\text{ A}$ | | | | 0.5 | |
| Short-circuit output current | | 25°C | | 150 | | mA |
| Peak output current | | 25°C | | 2.1 | | A |

† Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.33- μF capacitor across the input and a 0.1- μF capacitor across the output.

‡ This specification applies only for dc power dissipation permitted by absolute maximum ratings.



APPLICATION INFORMATION

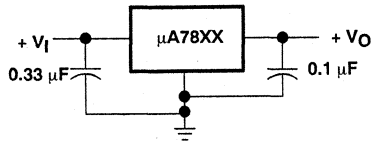


Figure 3. Fixed Output Regulator

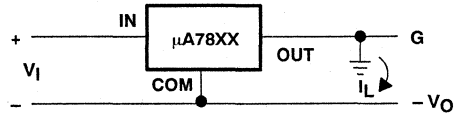


Figure 4. Positive Regulator in Negative Configuration (V_1 Must Float)

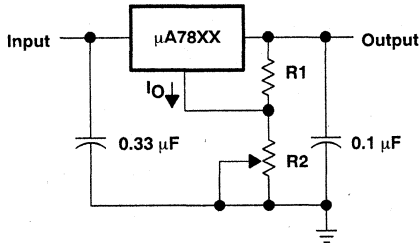
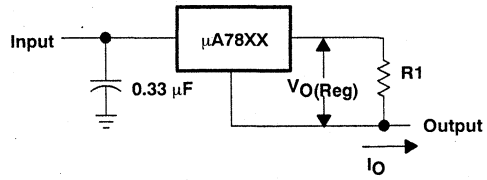


Figure 5. Adjustable Output Regulator



$$I_O = (V_O/R_1) + I_O \text{ Bias Current}$$

Figure 6. Current Regulator

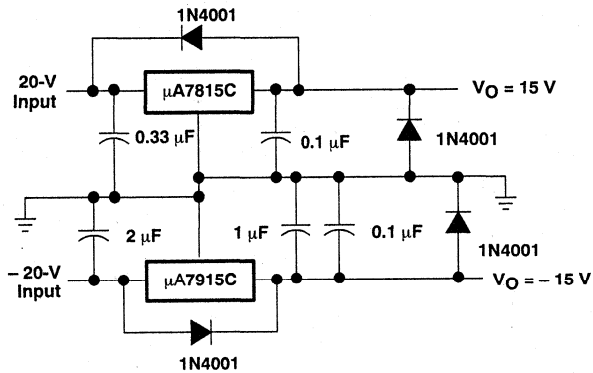


Figure 7. Regulated Dual Supply

APPLICATION INFORMATION

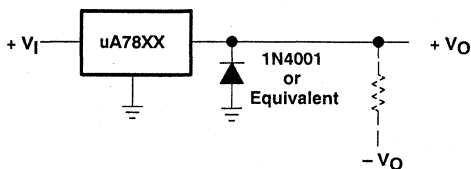


Figure 8. Output Polarity-Reversal Protection Circuit

operation with a load common to a voltage of opposite polarity

In many cases, a regulator powers a load that is not connected to ground but instead is connected to a voltage source of opposite polarity (e.g., op amps, level-shifting circuits, etc.). In these cases, a clamp diode should be connected to the regulator output as shown in Figure 8. This protects the regulator from output polarity reversals during startup and short-circuit operation.

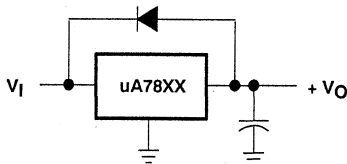


Figure 9. Reverse-Bias Protection Circuit

reverse-bias protection

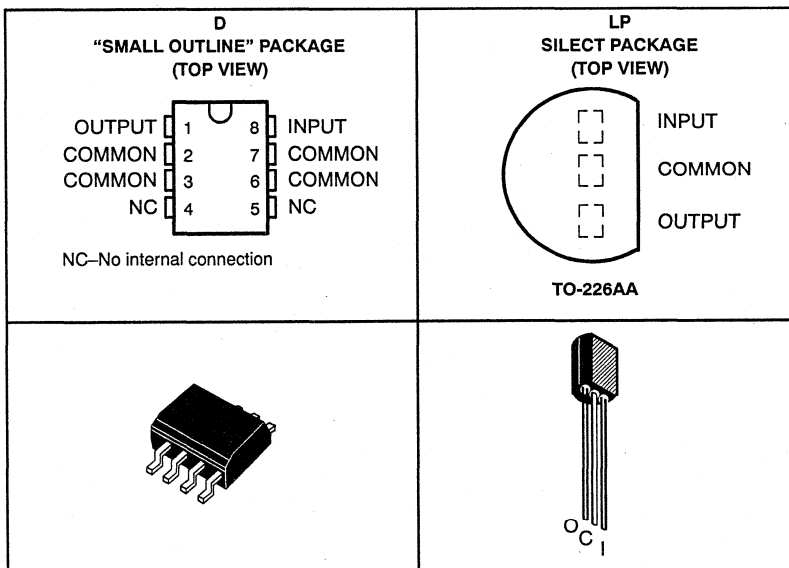
Occasionally, there exists the possibility that the input voltage to the regulator can collapse faster than the output voltage. This could occur, for example, if the input supply is crowbarred during an output overvoltage condition. If the output voltage is greater than approximately 7 V, the emitter-base junction of the series pass element (internal or external) could break down and be damaged. To prevent this, a diode shunt can be employed, as shown in Figure 9.

μA78L00 SERIES POSITIVE-VOLTAGE REGULATORS

D2203, JANUARY 1976—REVISED NOVEMBER 1991

- 3-Terminal Regulators
- Output Current Up to 100 mA
- No External Components
- Internal Thermal Overload Protection
- Internal Short-Circuit Limiting
- Direct Replacements for Fairchild μA78L00 Series

| NOMINAL OUTPUT VOLTAGE | 5% OUTPUT VOLTAGE TOLERANCE | 10% OUTPUT VOLTAGE TOLERANCE |
|------------------------|-----------------------------|------------------------------|
| 2.6 V | μA78L02AC | μA78L02C |
| 5 V | μA78L05AC | μA78L05C |
| 5 V | μA78L05AQ | μA78L05Q |
| 6.2 V | μA78L06AC | μA78L06C |
| 8 V | μA78L08AC | μA78L08C |
| 9 V | μA78L09AC | μA78L09C |
| 10 V | μA78L10AC | μA78L10C |
| 12 V | μA78L12AC | μA78L12C |
| 12 V | μA78L12AQ | μA78L12Q |
| 15 V | μA78L15AC | μA78L15C |



D and LP packages are available taped and reeled. Add "R" suffix to device type (e.g., μA78L05ACDR).

description

This series of fixed-voltage monolithic integrated-circuit voltage regulators is designed for a wide range of applications. These applications include on-card regulation for elimination of noise and distribution problems associated with single-point regulation. In addition, they can be used with power-pass elements to make high-current voltage regulators. One of these regulators can deliver up to 100 mA of output current. The internal limiting and thermal shutdown features of these regulators make them essentially immune to overload. When used as a replacement for a Zener diode-resistor combination, an effective improvement in output impedance can be obtained together with lower-bias current.

PRODUCTION DATA Information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

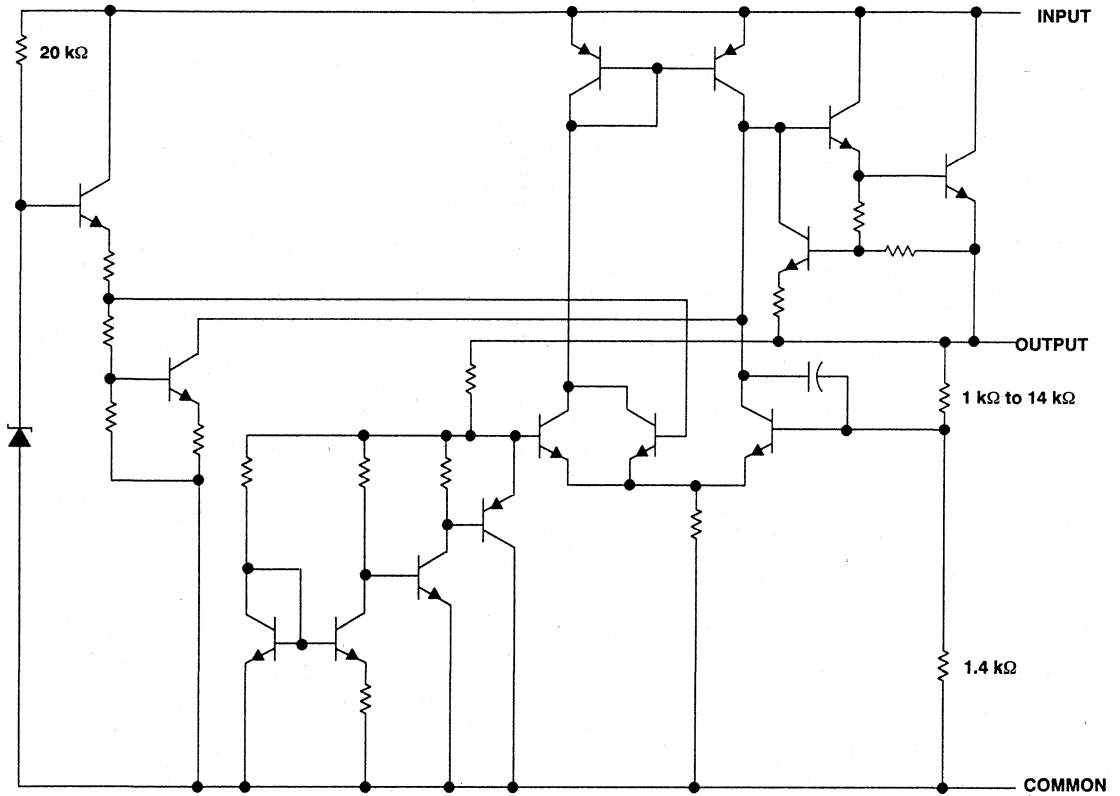

**TEXAS
INSTRUMENTS**

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μA78L00 SERIES POSITIVE-VOLTAGE REGULATORS

schematic



uA78L00 SERIES POSITIVE-VOLTAGE REGULATORS

absolute maximum ratings over operating temperature ranges (unless otherwise noted)

| | uA78L02C, uA78L02AC THRU uA78L10C, uA78L10AC, uA78L05Q, uA78L05AQ | uA78L12C, uA78L12AC, uA78L12Q, uA78L12AQ AND uA78L15C, uA78L15AC | UNIT |
|---|--|---|------|
| Input voltage | 30 | 35 | V |
| Continuous total dissipation (see Note 1) | See Dissipation Rating Tables 1 and 2 | | |
| Operating free-air, case, or virtual junction temperature range | -40 to 150 | -40 to 150 | °C |
| Storage temperature range | -65 to 150 | -65 to 150 | °C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260 | 260 | °C |

NOTE 1: To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

DISSIPATION RATING TABLE 1 – FREE-AIR TEMPERATURE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR | DERATE ABOVE T_A | $T_A = 70^\circ\text{C}$ POWER RATING |
|---------|---|--------------------|-----------------------|--|
| D | 725 mW | 5.8 mW/°C | 25°C | 464 mW |
| LP† | 775 mW | 6.2 mW/°C | 25°C | 496 mW |

† The LP package dissipation rating is based on thermal resistance $R_{\theta JA}$ measured in still air with the device mounted in an Augat socket. The bottom of the package is 10 mm (0.375 in) above the socket.

DISSIPATION RATING TABLE 2 – CASE TEMPERATURE

| PACKAGE | $T_C \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR | DERATE ABOVE T_C | $T_C = 125^\circ\text{C}$ POWER RATING |
|---------|---|--------------------|-----------------------|---|
| D | 1600 mW | 19.6 mW/°C | 65°C | 490 mW |
| LP | 1600 mW | 28.6 mW/°C | 94°C | 715 mW |

recommended operating conditions

| | | MIN | MAX | UNIT |
|---|---|------|-----|------|
| Input voltage, V_I | uA78L02C, uA78L02AC | 4.75 | 20 | V |
| | uA78L05C, uA78L05AC, uA78L05Q, uA78L05AQ | 7 | 20 | |
| | uA78L06C, uA78L06AC | 8.5 | 20 | |
| | uA78L08C, uA78L08AC | 10.5 | 23 | |
| | uA78L09C, uA78L09AC | 11.5 | 24 | |
| | uA78L10C, uA78L10AC | 12.5 | 25 | |
| | uA78L12C, uA78L12AC, uA78L12Q, uA78L12AQ | 14.5 | 27 | |
| | uA78L15C, uA78L15AC | 17.5 | 30 | |
| Output current, I_O | | | 100 | mA |
| Operating virtual junction temperature, T_J | uA78LxxC, uA78LxxAC, uA78LxxQ, uA78LxxAQ | 0 | 125 | °C |
| | | -40 | 125 | |

uA78L00 SERIES POSITIVE-VOLTAGE REGULATORS

electrical characteristics at specified virtual junction temperature, $V_I = 9\text{ V}$, $I_O = 40\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J † | uA78L02C | | | uA78L02AC | | | UNIT |
|----------------------|---|-------------|----------|-----|------|-----------|-----|------|------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| Output voltage‡ | $V_I = 4.75\text{ V to }20\text{ V}$, $I_O = 1\text{ mA to }40\text{ mA}$ $I_O = 1\text{ mA to }70\text{ mA}$ | 25°C | 2.4 | 2.6 | 2.8 | 2.5 | 2.6 | 2.7 | V |
| | | Full range§ | 2.35 | | 2.85 | 2.45 | | 2.75 | |
| | | | 2.35 | | 2.85 | 2.45 | | 2.75 | |
| Input regulation | $V_I = 4.75\text{ V to }20\text{ V}$ | 25°C | | 20 | 125 | | 20 | 100 | mV |
| | $V_I = 5\text{ V to }20\text{ V}$ | | | 16 | 100 | | 16 | 75 | |
| Ripple rejection | $V_I = 6\text{ V to }16\text{ V}$, $f = 120\text{ Hz}$ | 25°C | 42 | 51 | | 43 | 51 | dB | |
| Output regulation | $I_O = 1\text{ mA to }100\text{ mA}$ | 25°C | | 12 | 50 | | 12 | 50 | mV |
| | $I_O = 1\text{ mA to }40\text{ mA}$ | | | 6 | 25 | | 6 | 25 | |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | 30 | | 30 | | µV | |
| Dropout voltage | | 25°C | | 1.7 | | 1.7 | | V | |
| Bias current | | 25°C | | 3.6 | 6 | | 3.6 | 6 | mA |
| | | 125°C | | | 5.5 | | | 5.5 | |
| Bias current change | $V_I = 5\text{ V to }20\text{ V}$ | Full range§ | | | 2.5 | | | 2.5 | mA |
| | $I_O = 1\text{ mA to }40\text{ mA}$ | | | | 0.2 | | | 0.1 | |

electrical characteristics at specified virtual junction temperature, $V_I = 10\text{ V}$, $I_O = 40\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J † | uA78L05C, uA78L05Q | | | uA78L05AC, uA78L05AQ | | | UNIT |
|----------------------|--|-------------|-----------------------|-----|-----|-------------------------|-----|------|------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| Output voltage‡ | $V_I = 7\text{ V to }20\text{ V}$, $I_O = 1\text{ mA to }40\text{ mA}$ $I_O = 1\text{ mA to }70\text{ mA}$ | 25°C | 4.6 | 5 | 5.4 | 4.8 | 5 | 5.2 | V |
| | | Full range§ | 4.5 | | 5.5 | 4.75 | | 5.25 | |
| | | | 4.5 | | 5.5 | 4.75 | | 5.25 | |
| Input regulation | $V_I = 7\text{ V to }20\text{ V}$ | 25°C | | 32 | 200 | | 32 | 150 | mV |
| | $V_I = 8\text{ V to }20\text{ V}$ | | | 26 | 150 | | 26 | 100 | |
| Ripple rejection | $V_I = 8\text{ V to }18\text{ V}$, $f = 120\text{ Hz}$ | 25°C | 40 | 49 | | 41 | 49 | dB | |
| Output regulation | $I_O = 1\text{ mA to }100\text{ mA}$ | 25°C | | 15 | 60 | | 15 | 60 | mV |
| | $I_O = 1\text{ mA to }40\text{ mA}$ | | | 8 | 30 | | 8 | 30 | |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | 42 | | 42 | | µV | |
| Dropout voltage | | 25°C | | 1.7 | | 1.7 | | V | |
| Bias current | | 25°C | | 3.8 | 6 | | 3.8 | 6 | mA |
| | | 125°C | | | 5.5 | | | 5.5 | |
| Bias current change | $V_I = 8\text{ V to }20\text{ V}$ | Full range§ | | | 1.5 | | | 1.5 | mA |
| | $I_O = 1\text{ mA to }40\text{ mA}$ | | | | 0.2 | | | 0.1 | |

† Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.33-µF capacitor across the input and a 0.1-µF capacitor across the output.

‡ This specification applies only for dc power dissipation permitted by absolute maximum ratings.

§ Full range virtual junction temperature is 0°C to 125°C for uA78L02, uA78L02AC, uA78L05C, and uA78L05AC and -40°C to 125°C for uA78L05Q and uA78L05AQ.



uA78L00 SERIES POSITIVE-VOLTAGE REGULATORS

electrical characteristics at specified virtual junction temperature, $V_I = 12\text{ V}$, $I_O = 40\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J^\dagger | uA78L06C | | | uA78L06AC | | | UNIT |
|-----------------------------|---|-------------------------|----------|-----|-----|-----------|-----|---------------|------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| Output voltage [‡] | $V_I = 8.5\text{ V to }20\text{ V}$, $I_O = 1\text{ mA to }40\text{ mA}$ | 25°C | 5.7 | 6.2 | 6.7 | 5.95 | 6.2 | 6.45 | V |
| | | Full range [§] | 5.6 | | 6.8 | 5.9 | | 6.5 | |
| | | | 5.6 | | 6.8 | 5.9 | | 6.5 | |
| Input regulation | $V_I = 8.5\text{ V to }20\text{ V}$ | 25°C | | 35 | 200 | | 35 | 175 | mV |
| | $V_I = 9\text{ V to }20\text{ V}$ | | | 29 | 150 | | 29 | 125 | |
| Ripple rejection | $V_I = 10\text{ V to }20\text{ V}$, $f = 120\text{ Hz}$ | 25°C | 39 | 48 | | 40 | 48 | dB | |
| Output regulation | $I_O = 1\text{ mA to }100\text{ mA}$ | 25°C | | 16 | 80 | | 16 | 80 | mV |
| | $I_O = 1\text{ mA to }40\text{ mA}$ | | | 9 | 40 | | 9 | 40 | |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | 46 | | 46 | | μV | |
| Dropout voltage | | 25°C | | 1.7 | | 1.7 | | V | |
| Bias current | | 25°C | | 3.9 | 6 | | 3.9 | 6 | mA |
| | | 125°C | | | 5.5 | | | 5.5 | |
| Bias current change | $V_I = 9\text{ V to }20\text{ V}$ | Full range [§] | | | 1.5 | | | 1.5 | mA |
| | $I_O = 1\text{ mA to }40\text{ mA}$ | | | | 0.2 | | | 0.1 | |

electrical characteristics at specified virtual junction temperature, $V_I = 14\text{ V}$, $I_O = 40\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J^\dagger | uA78L06C | | | uA78L06AC | | | UNIT |
|-----------------------------|--|-------------------------|----------|-----|------|-----------|-----|---------------|------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| Output voltage [‡] | $V_I = 10.5\text{ V to }23\text{ V}$, $I_O = 1\text{ mA to }40\text{ mA}$ | 25°C | 7.36 | 8 | 8.64 | 7.7 | 8 | 8.3 | V |
| | | Full range [§] | 7.2 | | 8.8 | 7.6 | | 8.4 | |
| | | | 7.2 | | 8.8 | 7.6 | | 8.4 | |
| Input regulation | $V_I = 10.5\text{ V to }23\text{ V}$ | 25°C | | 42 | 200 | | 42 | 175 | mV |
| | $V_I = 11\text{ V to }23\text{ V}$ | | | 36 | 150 | | 36 | 125 | |
| Ripple rejection | $V_I = 13\text{ V to }23\text{ V}$, $f = 120\text{ Hz}$ | 25°C | 36 | 46 | | 37 | 46 | dB | |
| Output regulation | $I_O = 1\text{ mA to }100\text{ mA}$ | 25°C | | 18 | 80 | | 18 | 80 | mV |
| | $I_O = 1\text{ mA to }40\text{ mA}$ | | | 10 | 40 | | 10 | 40 | |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | 54 | | 54 | | μV | |
| Dropout voltage | | 25°C | | 1.7 | | 1.7 | | V | |
| Bias current | | 25°C | | 4 | 6 | | 4 | 6 | mA |
| | | 125°C | | | 5.5 | | | 5.5 | |
| Bias current change | $V_I = 5\text{ V to }20\text{ V}$ | Full range [§] | | | 1.5 | | | 1.5 | mA |
| | $I_O = 1\text{ mA to }40\text{ mA}$ | | | | 0.2 | | | 0.1 | |

[†] Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.33- μF capacitor across the input and a 0.1- μF capacitor across the output.

[‡] This specification applies only for dc power dissipation permitted by absolute maximum ratings.

[§] Full range virtual junction temperature is 0°C to 125°C for uA78L06C and uA78L06AC.

uA78L00 SERIES POSITIVE-VOLTAGE REGULATORS

electrical characteristics at specified virtual junction temperature, $V_I = 16\text{ V}$, $I_O = 40\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J^\dagger | uA78L09C | | | uA78L09AC | | | UNIT |
|-----------------------------|---|-------------------------|----------|-----|-----|-----------|------|-----|------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| Output voltage [‡] | $V_I = 12\text{ V to }24\text{ V}$, $I_O = 1\text{ mA to }40\text{ mA}$ | 25°C | 8.3 | 9 | 9.7 | 8.6 | 9 | 9.4 | V |
| | | Full range [§] | 8.1 | 9.9 | | 8.55 | 9.45 | | |
| | | | 8.1 | 9.9 | | 8.55 | 9.45 | | |
| Input regulation | $V_I = 12\text{ V to }24\text{ V}$ | 25°C | 45 | | 225 | | 45 | 175 | mV |
| | $V_I = 13\text{ V to }24\text{ V}$ | | 40 | | 175 | | 40 | 125 | |
| Ripple rejection | $V_I = 15\text{ V to }25\text{ V}$, $f = 120\text{ Hz}$ | 25°C | 36 | 45 | | 38 | 45 | | dB |
| Output regulation | $I_O = 1\text{ mA to }100\text{ mA}$ | 25°C | 19 | | 90 | | 19 | 90 | mV |
| | $I_O = 1\text{ mA to }40\text{ mA}$ | | 11 | | 40 | | 11 | 40 | |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | 58 | | | 58 | | | µV |
| Dropout voltage | | 25°C | 1.7 | | | 1.7 | | | V |
| Bias current | | 25°C | 4.1 | | 6 | | 4.1 | 6 | mA |
| | | 125°C | | | 5.5 | | 5.5 | | |
| Bias current change | $V_I = 13\text{ V to }24\text{ V}$ | Full range [§] | | | 1.5 | | 1.5 | | mA |
| | $I_O = 1\text{ mA to }40\text{ mA}$ | | | | 0.2 | | 0.1 | | |

electrical characteristics at specified virtual junction temperature, $V_I = 14\text{ V}$, $I_O = 40\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J^\dagger | uA78L10C | | | uA78L10AC | | | UNIT |
|-----------------------------|---|-------------------------|----------|-----|------|-----------|------|------|------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| Output voltage [‡] | $V_I = 13\text{ V to }25\text{ V}$, $I_O = 1\text{ mA to }40\text{ mA}$ | 25°C | 9.2 | 10 | 10.8 | 9.6 | 10 | 10.4 | V |
| | | Full range [§] | 9 | 11 | | 9.5 | 10.5 | | |
| | | | 9 | 11 | | 9.5 | 10.5 | | |
| Input regulation | $V_I = 13\text{ V to }25\text{ V}$ | 25°C | 51 | | 225 | | 51 | 175 | mV |
| | $V_I = 14\text{ V to }25\text{ V}$ | | 42 | | 175 | | 42 | 125 | |
| Ripple rejection | $V_I = 15\text{ V to }25\text{ V}$, $f = 120\text{ Hz}$ | 25°C | 36 | 44 | | 37 | 44 | | dB |
| Output regulation | $I_O = 1\text{ mA to }100\text{ mA}$ | 25°C | 20 | | 90 | | 20 | 90 | mV |
| | $I_O = 1\text{ mA to }40\text{ mA}$ | | 11 | | 40 | | 11 | 40 | |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | 62 | | | 62 | | | µV |
| Dropout voltage | | 25°C | 1.7 | | | 1.7 | | | V |
| Bias current | | 25°C | 4.2 | | 6 | | 4.2 | 6 | mA |
| | | 125°C | | | 5.5 | | 5.5 | | |
| Bias current change | $V_I = 14\text{ V to }25\text{ V}$ | Full range [§] | | | 1.5 | | 1.5 | | mA |
| | $I_O = 1\text{ mA to }40\text{ mA}$ | | | | 0.2 | | 0.1 | | |

[†] Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.33-µF capacitor across the input and a 0.1-µF capacitor across the output.

[‡] This specification applies only for dc power dissipation permitted by absolute maximum ratings.

[§] Full range virtual junction temperature is 0°C to 125°C for uA78L09C, uA78L09AC, uA78L10C, and uA78L10AC.

uA78L00 SERIES POSITIVE-VOLTAGE REGULATORS

electrical characteristics at specified virtual junction temperature, $V_I = 19\text{ V}$, $I_O = 40\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J^\dagger | uA78L12C, uA78L12Q | | | uA78L12AC, uA78L12AQ | | | UNIT |
|-----------------------------|---|-------------------------|-----------------------|------|------|-------------------------|------|---------------|------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| Output voltage [‡] | $V_I = 14\text{ V to }27\text{ V}$, $I_O = 1\text{ mA to }40\text{ mA}$ | 25°C | 11.1 | 12 | 12.9 | 11.5 | 12 | 12.5 | V |
| | | Full range [§] | | 10.8 | 13.2 | 11.4 | 12.6 | | |
| | | | | 10.8 | 13.2 | 11.4 | 12.6 | | |
| Input regulation | $V_I = 14.5\text{ V to }27\text{ V}$ $V_I = 16\text{ V to }27\text{ V}$ | 25°C | | 55 | 250 | 55 | 250 | mV | |
| | | | | 49 | 200 | 49 | 200 | | |
| Ripple rejection | $V_I = 15\text{ V to }25\text{ V}$, $f = 120\text{ Hz}$ | 25°C | 36 | 42 | | 37 | 42 | dB | |
| Output regulation | $I_O = 1\text{ mA to }100\text{ mA}$ $I_O = 1\text{ mA to }40\text{ mA}$ | 25°C | | 22 | 100 | 22 | 100 | mV | |
| | | | | 13 | 50 | 13 | 50 | | |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | 70 | | 70 | | μV | |
| Dropout voltage | | 25°C | | 1.7 | | 1.7 | | V | |
| Bias current | | 25°C | | 4.3 | 6.5 | 4.3 | 6.5 | mA | |
| | | 125°C | | | 6 | | 6 | | |
| Bias current change | $V_I = 16\text{ V to }27\text{ V}$ $I_O = 1\text{ mA to }40\text{ mA}$ | Full range [§] | | | 1.5 | | 1.5 | mA | |
| | | | | | 0.2 | | 0.1 | | |

electrical characteristics at specified virtual junction temperature, $V_I = 23\text{ V}$, $I_O = 40\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J^\dagger | uA78L15C | | | uA78L15AC | | | UNIT |
|-----------------------------|---|-------------------------|----------|------|------|-----------|-------|---------------|------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| Output voltage [‡] | $V_I = 17.5\text{ V to }30\text{ V}$, $I_O = 1\text{ mA to }40\text{ mA}$ | 25°C | 13.8 | 15 | 16.2 | 14.4 | 15 | 15.6 | V |
| | | Full range [§] | | 13.5 | 16.5 | 14.25 | 15.75 | | |
| | | | | 13.5 | 16.5 | 14.25 | 15.75 | | |
| Input regulation | $V_I = 17.5\text{ V to }30\text{ V}$ $V_I = 20\text{ V to }30\text{ V}$ | 25°C | | 65 | 300 | 65 | 300 | mV | |
| | | | | 58 | 250 | 58 | 250 | | |
| Ripple rejection | $V_I = 18.5\text{ V to }28.5\text{ V}$, $f = 120\text{ Hz}$ | 25°C | 33 | 39 | | 34 | 39 | dB | |
| Output regulation | $I_O = 1\text{ mA to }100\text{ mA}$ $I_O = 1\text{ mA to }40\text{ mA}$ | 25°C | | 25 | 150 | 25 | 150 | mV | |
| | | | | 15 | 75 | 15 | 75 | | |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | 82 | | 82 | | μV | |
| Dropout voltage | | 25°C | | 1.7 | | 1.7 | | V | |
| Bias current | | 25°C | | 4.6 | 6.5 | 4.6 | 6.5 | mA | |
| | | 125°C | | | 6 | | 6 | | |
| Bias current change | $V_I = 10\text{ V to }30\text{ V}$ $I_O = 1\text{ mA to }40\text{ mA}$ | Full range [§] | | | 1.5 | | 1.5 | mA | |
| | | | | | 0.2 | | 0.1 | | |

[†] Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.33- μF capacitor across the input and a 0.1- μF capacitor across the output.

[‡] This specification applies only for dc power dissipation permitted by absolute maximum ratings.

[§] Full range virtual junction temperature is 0°C to 125°C for uA78L12C, uA78L12AC, uA78L15C, and uA78L15AC.



APPLICATION INFORMATION

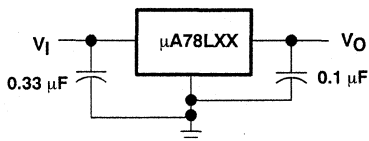


Figure 1. Fixed Output Regulator

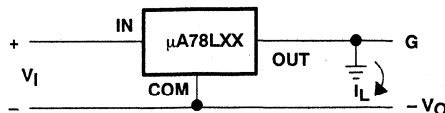


Figure 2. Positive Regulator in Negative Configuration (V_I Must Float)

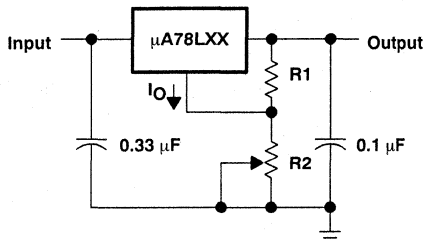
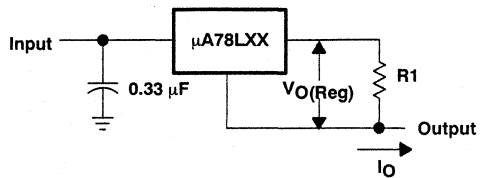


Figure 3. Adjustable Output Regulator



$$I_O = (V_O/R1) + I_O \text{ Bias Current}$$

Figure 4. Current Regulator

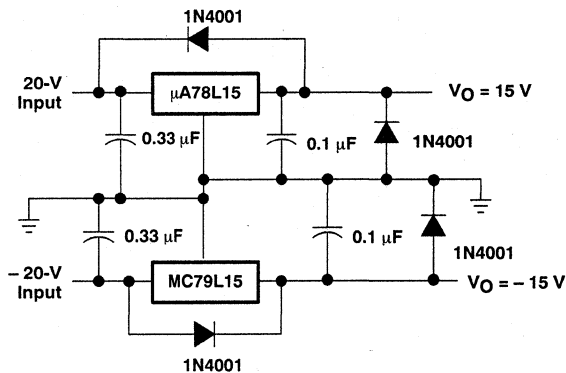


Figure 5. Regulated Dual Supply

APPLICATION INFORMATION

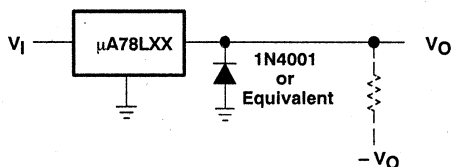


Figure 6. Output Polarity Reversal Protection Circuit

operation with a load common to a voltage of opposite polarity

In many cases, a regulator powers a load that is not connected to ground but instead is connected to a voltage source of opposite polarity (e.g., op amps, level-shifting circuits, etc.). In these cases, a clamp diode should be connected to the regulator output as shown in Figure 6. This protects the regulator from output polarity reversals during startup and short-circuit operation.

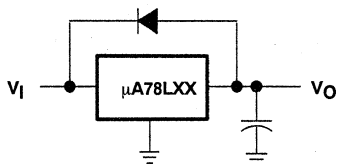


Figure 7. Reverse-Bias Protection Circuit

reverse-bias protection

Occasionally, there exists the possibility that the input voltage to the regulator can collapse faster than the output voltage. This could occur, for example, if the input supply is crowbarred during an output overvoltage condition. If the output voltage is greater than approximately 7 V, the emitter-base junction of the series pass element (internal or external) could break down and be damaged. To prevent this, a diode shunt can be employed, as shown in Figure 7.

SERIES μ A78M00 POSITIVE-VOLTAGE REGULATORS

D2214, JUNE 1976—REVISED SEPTEMBER 1991

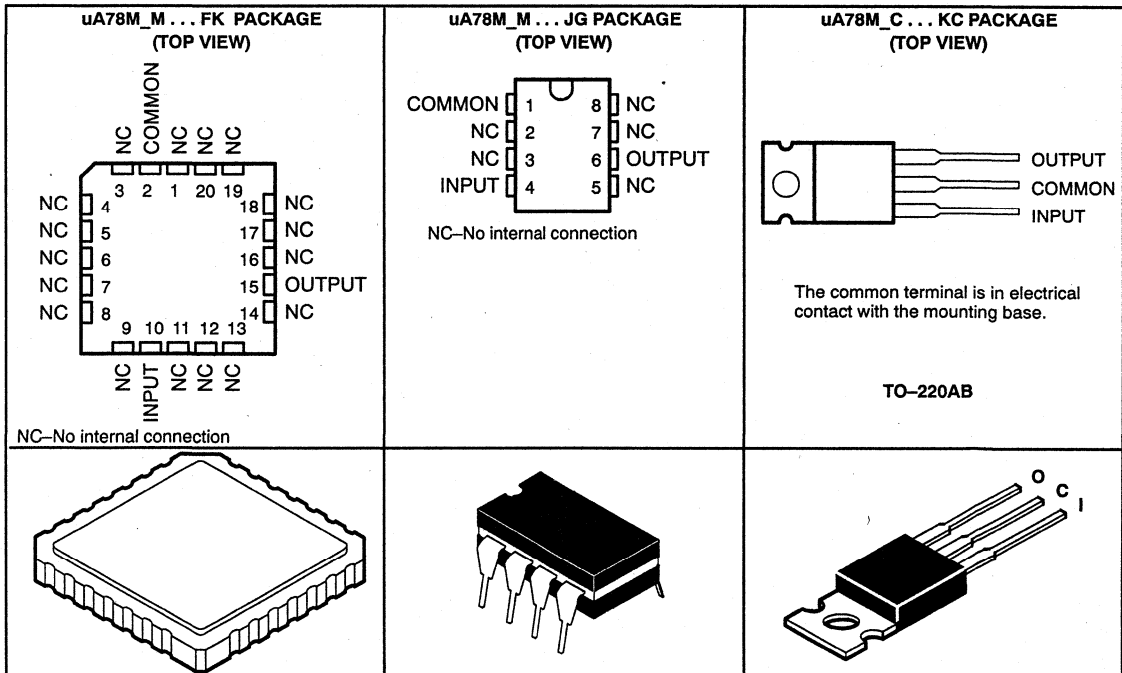
- 3-Terminal Regulators
- Output Current Up to 500 mA
- No External Components
- Internal Thermal Overload Protection
- High Power Dissipation Capability
- Internal Short-Circuit Current Limiting
- Output Transistor Safe-Area Compensation
- Direct Replacements for Fairchild μ A78M00 Series

| NOMINAL OUTPUT VOLTAGE | 0°C TO 125°C OPERATING TEMPERATURE RANGE | -55°C TO 150°C OPERATING TEMPERATURE RANGE |
|------------------------|--|--|
| 5 V | μ A78M05C | μ A78M05M |
| 6 V | μ A78M06C | |
| 8 V | μ A78M08C | |
| 9 V | μ A78M09C | |
| 10 V | μ A78M10C | |
| 12 V | μ A78M12C | |
| 15 V | μ A78M15C | μ A78M12M |
| 20 V | μ A78M20C | |
| 24 V | μ A78M24C | |
| Packages | KC | FK, JG |

description

This series of fixed-voltage monolithic integrated-circuit voltage regulators is designed for a wide range of applications. These applications include on-card regulation for elimination of noise and distribution problems associated with single-point regulation. Each of these regulators can deliver up to 500 mA of output current. The internal current limiting and thermal shutdown features of these regulators make them essentially immune to overload. In addition to use as fixed-voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents and also as the power pass element in precision regulators.

terminal assignments



PRODUCTION DATA Information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

**TEXAS
INSTRUMENTS**

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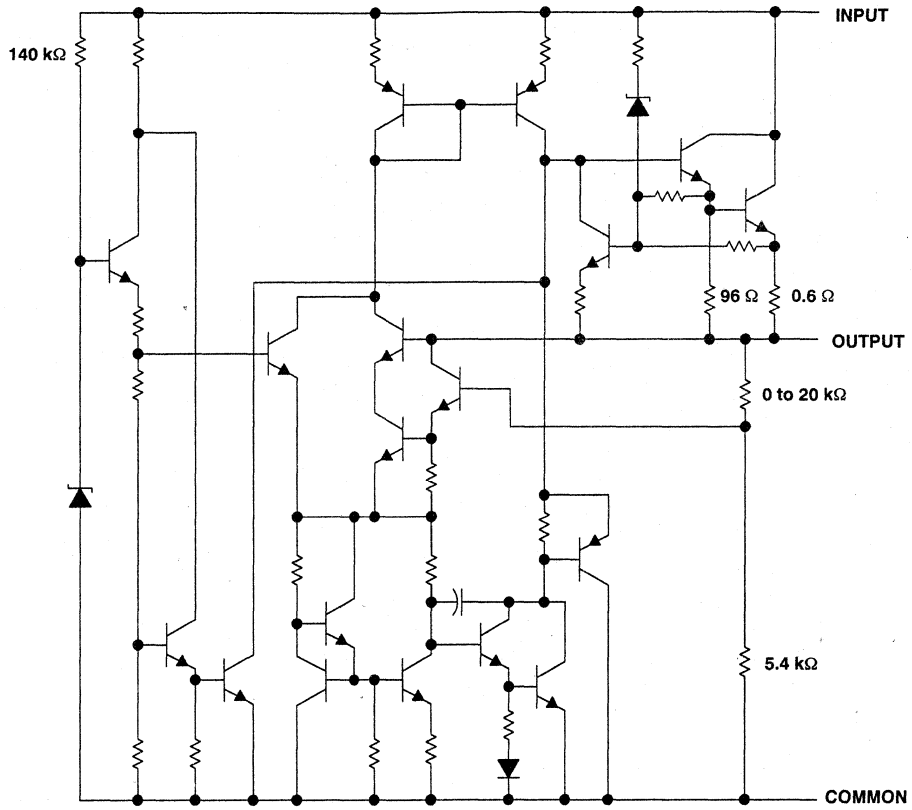
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On products compliant to MIL-STD-883, Class B, all parameters are tested unless otherwise noted. On all other products, production processing does not necessarily include testing of all parameters.

2-447

SERIES μ A78M00 POSITIVE-VOLTAGE REGULATORS

schematic



Resistor values shown are nominal.

TEXAS
INSTRUMENTS

POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

SERIES μ A78M00 POSITIVE-VOLTAGE REGULATORS

absolute maximum ratings over operating temperature range (unless otherwise noted)

| | | μ A78M05C THRU μ A78M24C | μ A78M05M μ A78M12M | UNIT |
|---|----------------------------|--|--------------------------------|--------------|
| Input voltage | μ A78M20, μ A78M24 | -40 | | V |
| | All others | 35 | 35 | |
| Continuous total dissipation (see Note 1) | | See Dissipation Rating Tables 1 and 2 | | |
| Operating free-air, case, or virtual junction temperature range | | 0 to 150 | -55 to 150 | $^{\circ}$ C |
| Storage temperature range | | -65 to 150 | -65 to 150 | $^{\circ}$ C |
| Case temperature for 60 seconds | FK package | | 260 | $^{\circ}$ C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds | JG package | | 300 | $^{\circ}$ C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | KC package | 260 | | $^{\circ}$ C |

NOTE 1: To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

DISSIPATION RATING TABLE 1 – FREE-AIR TEMPERATURE

| PACKAGE | $T_A \leq 25^{\circ}$ C POWER RATING | DERATING FACTOR ABOVE $T_A = 25^{\circ}$ C | $T_A = 70^{\circ}$ C POWER RATING |
|---------|---|---|--------------------------------------|
| FK | 1375 mW | 11.0 mW/ $^{\circ}$ C | 880 mW |
| JG | 1050 mW | 8.4 mW/ $^{\circ}$ C | 672 mW |
| KC | 2000 mW | 16 mW/ $^{\circ}$ C | 1280 mW |

DISSIPATION RATING TABLE 2 – CASE TEMPERATURE

| PACKAGE | $T_C \leq 50^{\circ}$ C POWER RATING | DERATING FACTOR ABOVE $T_C = 50^{\circ}$ C | $T_C = 125^{\circ}$ C POWER RATING |
|---------|---|---|---------------------------------------|
| KC | 20 W | 200 mW/ $^{\circ}$ C | 5 W |

recommended operating conditions

| | | MIN | MAX | UNIT |
|---|----------------------------------|------|-----|--------------|
| Input voltage, V_I | μ A78M05C, μ A78M05M | 7 | 25 | V |
| | μ A78M06C | 8 | 25 | |
| | μ A78M08C | 10.5 | 25 | |
| | μ A78M09C | 11.5 | 26 | |
| | μ A78M10C | 12.5 | 28 | |
| | μ A78M12C, μ A78M12M | 14.5 | 30 | |
| | μ A78M15C | 17.5 | 30 | |
| | μ A78M20C | 23 | 35 | |
| | μ A78M24C | 27 | 38 | |
| Output current, I_O | All devices | | 500 | mA |
| Operating virtual junction temperature, T_J | μ A78M05C thru μ A78M24C | 0 | 125 | $^{\circ}$ C |
| | μ A78M05M and μ A78M12M | -55 | 150 | |

μA78M05C, μA78M05M
POSITIVE-VOLTAGE REGULATORS

μA78M05C, μA78M05M electrical characteristics at specified virtual junction temperature, $V_I = 10\text{ V}$, $I_O = 350\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | $T_{J†}$ | μA78M05C | | | μA78M05M | | | UNIT |
|---|--|----------------|----------|-----|------|----------|-----|-------|-------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| Output voltage † | $I_O = 5\text{ mA to }350\text{ mA}$ $V_I = 8\text{ V to }20\text{ V}$ $V_I = 7\text{ V to }20\text{ V}$ | 25°C | 4.8 | 5 | 5.2 | 4.8 | 5 | 5.2 | V |
| | | -55°C to 150°C | | | | 4.7 | | 5.3 | |
| | | 0°C to 125°C | 4.75 | | 5.25 | | | | |
| Input regulation | $I_O = 200\text{ mA}$ $V_I = 7\text{ V to }25\text{ V}$ $V_I = 8\text{ V to }20\text{ V}$ $V_I = 8\text{ V to }25\text{ V}$ | 25°C | | | | | 3 | 50 | mV |
| | | | | | | 1 | 25 | | |
| | | | | | | | | | |
| Ripple rejection | $V_I = 8\text{ V to }18\text{ V}$, $f = 120\text{ Hz}$ $I_O = 100\text{ mA}$ | -55°C to 150°C | | | | 62* | | | dB |
| | | 0°C to 125°C | 62 | | | | | | |
| | | 25°C | 62 | 80 | | 62* | 80 | | |
| Output regulation | $I_O = 5\text{ mA to }500\text{ mA}$ $I_O = 5\text{ mA to }200\text{ mA}$ | 25°C | | | | | 20 | 50 | mV |
| | | | | | | 10 | 25 | | |
| | | | | | | | | | |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | -55°C to 25°C | | | | | | -2* | mV/°C |
| | | 25°C to 150°C | | | | | | -1.5* | |
| | | 0°C to 125°C | | | | | | | |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | | | | 40 | 200* | μV |
| | | | | | | 2 | 2.5 | | |
| | | | | | | | | | |
| Dropout voltage | | 25°C | | | | | 4.5 | 6 | mV |
| | | | | | | | | | |
| | | | | | | | | | |
| Bias current | $I_O = 200\text{ mA}$, $V_I = 8\text{ V to }25\text{ V}$ | -55°C to 150°C | | | | | | 0.8 | mA |
| | | 0°C to 125°C | | | | | | 0.8 | |
| | | 25°C | | | | | | | |
| Bias current change | $I_O = 5\text{ mA to }350\text{ mA}$ | -55°C to 150°C | | | | | | 0.5 | mA |
| | | 0°C to 125°C | | | | | | 0.5 | |
| | | 25°C | | | | | | | |
| Short-circuit output current | $V_I = 35\text{ V}$ | 25°C | 300 | | | 300 | 600 | 600 | mA |
| Peak output current | | 25°C | 0.7 | | | 0.5* | 0.7 | 1.4* | A |

* On products compliant to MIL-STD-883, Class B, this parameter is not production tested.

† All characteristics are measured with a 0.33-μF capacitor across the input and a 0.1-μF capacitor across the output. Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

‡ This specification applies only for dc power dissipation permitted by absolute maximum ratings.



uA78M06C, uA78M08C
POSITIVE-VOLTAGE REGULATORS

uA78M06C electrical characteristics at specified virtual junction temperature, $V_I = 11\text{ V}$, $I_O = 350\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J^\dagger | MIN | TYP | MAX | UNIT |
|---|--|-----------------------------------|--------------|-----|------|---------------|
| Output voltage ‡ | | 25°C | 5.75 | 6 | 6.25 | V |
| | $I_O = 5\text{ mA to }350\text{ mA}$ | $V_I = 8\text{ V to }21\text{ V}$ | 0°C to 125°C | 5.7 | 6.3 | |
| Input regulation | $I_O = 200\text{ mA}$ | $V_I = 8\text{ V to }25\text{ V}$ | 25°C | 5 | 100 | mV |
| | | $V_I = 9\text{ V to }25\text{ V}$ | | 1.5 | 50 | |
| Ripple rejection | $V_I = 9\text{ V to }19\text{ V}$, $f = 120\text{ Hz}$ | $I_O = 100\text{ mA}$ | 0°C to 125°C | 59 | | dB |
| | | $I_O = 300\text{ mA}$ | 25°C | 59 | 80 | |
| Output regulation | $I_O = 5\text{ mA to }500\text{ mA}$ | 25°C | | 20 | 120 | mV |
| | $I_O = 5\text{ mA to }200\text{ mA}$ | | | 10 | 60 | |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | 0°C to 125°C | | -1 | | mV/°C |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | 45 | | μV |
| Dropout voltage | | 25°C | | 2 | | V |
| Bias current | | 25°C | | 4.5 | 6 | mA |
| Bias current change | $I_O = 200\text{ mA}$, $V_I = 9\text{ V to }25\text{ V}$ | 0°C to 125°C | | | 0.8 | mA |
| | $I_O = 5\text{ mA to }350\text{ mA}$ | 0°C to 125°C | | | 0.5 | |
| Short-circuit output current | $V_I = 35\text{ V}$ | 25°C | | 270 | | mA |
| Peak output current | | 25°C | | 0.7 | | A |

uA78M08C electrical characteristics at specified virtual junction temperature, $V_I = 14\text{ V}$, $I_O = 350\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J^\dagger | MIN | TYP | MAX | UNIT |
|---|---|--------------------------------------|--------------|-----|-----|---------------|
| Output voltage ‡ | | 25°C | 7.7 | 8 | 8.3 | V |
| | $I_O = 5\text{ mA to }350\text{ mA}$ | $V_I = 10.5\text{ V to }23\text{ V}$ | 0°C to 125°C | 7.6 | 8.4 | |
| Input regulation | $I_O = 200\text{ mA}$ | $V_I = 10.5\text{ V to }25\text{ V}$ | 25°C | 6 | 100 | mV |
| | | $V_I = 11\text{ V to }25\text{ V}$ | | 2 | 50 | |
| Ripple rejection | $V_I = 11.5\text{ V to }21.5\text{ V}$, $f = 120\text{ Hz}$ | $I_O = 100\text{ mA}$ | 0°C to 125°C | 56 | | dB |
| | | $I_O = 300\text{ mA}$ | 25°C | 56 | 80 | |
| Output regulation | $I_O = 5\text{ mA to }500\text{ mA}$ | 25°C | | 25 | 160 | mV |
| | $I_O = 5\text{ mA to }200\text{ mA}$ | | | 10 | 80 | |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | 0°C to 125°C | | -1 | | mV/°C |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | 52 | | μV |
| Dropout voltage | | 25°C | | 2 | | V |
| Bias current | | 25°C | | 4.6 | 6 | mA |
| Bias current change | $I_O = 200\text{ mA}$, $V_I = 10.5\text{ V to }25\text{ V}$ | 0°C to 125°C | | | 0.8 | mA |
| | $I_O = 5\text{ mA to }350\text{ mA}$ | 0°C to 125°C | | | 0.5 | |
| Short-circuit output current | $V_I = 35\text{ V}$ | 25°C | | 250 | | mA |
| Peak output current | | 25°C | | 0.7 | | A |

† All characteristics are measured with a 0.33- μF capacitor across the input and a 0.1- μF capacitor across the output. Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

‡ This specification applies only for dc power dissipation permitted by absolute maximum ratings.

uA78M09C, uA78M10C POSITIVE-VOLTAGE REGULATORS

uA78M09C electrical characteristics at specified virtual junction temperature, $V_I = 16$ V, $I_O = 350$ mA (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | | T_J † | MIN | TYP | MAX | UNIT |
|---|--|------------------------|--------------|-----|-----|-----|-------|
| Output voltage ‡ | | | 25°C | 8.6 | 9 | 9.4 | V |
| | $I_O = 5$ mA to 350 mA | $V_I = 11.5$ V to 24 V | 0°C to 125°C | 8.5 | | 9.5 | |
| Input regulation | $I_O = 200$ mA | $V_I = 11.5$ V to 26 V | 25°C | 6 | | 100 | mV |
| | | $V_I = 12$ V to 26 V | | 2 | | 50 | |
| Ripple rejection | $V_I = 13$ V to 23 V, $f = 120$ Hz | $I_O = 100$ mA | 0°C to 125°C | 56 | | | dB |
| | | $I_O = 300$ mA | 25°C | 56 | 80 | | |
| Output regulation | $I_O = 5$ mA to 500 mA | | 25°C | 25 | | 180 | mV |
| | $I_O = 5$ mA to 200 mA | | | 10 | | 90 | |
| Temperature coefficient of output voltage | $I_O = 5$ mA | | 0°C to 125°C | -1 | | | mV/°C |
| Output noise voltage | $f = 10$ Hz to 100 kHz | | 25°C | 58 | | | μV |
| Dropout voltage | | | 25°C | 2 | | | V |
| Bias current | | | 25°C | 4.6 | | 6 | mA |
| Bias current change | $I_O = 200$ mA, $V_I = 11.5$ V to 26 V | | 0°C to 125°C | | | 0.8 | mA |
| | $I_O = 5$ mA to 350 mA | | 0°C to 125°C | | | 0.5 | |
| Short-circuit output current | $V_I = 35$ V | | 25°C | 250 | | | mA |
| Peak output current | | | 25°C | 0.7 | | | A |

uA78M10C electrical characteristics at specified virtual junction temperature, $V_I = 17$ V, $I_O = 350$ mA (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | | T_J † | MIN | TYP | MAX | UNIT |
|---|---------------------------------------|------------------------|--------------|-----|-----|------|-------|
| Output voltage ‡ | | | 25°C | 9.6 | 10 | 10.4 | V |
| | $I_O = 5$ mA to 350 mA | $V_I = 12.5$ V to 25 V | 0°C to 125°C | 9.5 | | 10.5 | |
| Input regulation | $I_O = 200$ mA | $V_I = 12.5$ V to 28 V | 25°C | 7 | | 100 | mV |
| | | $V_I = 14$ V to 28 V | | 2 | | 50 | |
| Ripple rejection | $V_I = 15$ V to 25 V, $f = 120$ Hz | $I_O = 100$ mA | 0°C to 125°C | 59 | | | dB |
| | | $I_O = 300$ mA | 25°C | 55 | 80 | | |
| Output regulation | $I_O = 5$ mA to 500 mA | | 25°C | 25 | | 200 | mV |
| | $I_O = 5$ mA to 200 mA | | | 10 | | 100 | |
| Temperature coefficient of output voltage | $I_O = 5$ mA | | 0°C to 125°C | -1 | | | mV/°C |
| Output noise voltage | $f = 10$ Hz to 100 kHz | | 25°C | 64 | | | μV |
| Dropout voltage | | | 25°C | 2 | | | V |
| Bias current | | | 25°C | 4.7 | | 6 | mA |
| Bias current change | $I_O = 200$ mA | | 0°C to 125°C | | | 0.8 | mA |
| | $I_O = 5$ mA to 350 mA | | | | | 0.5 | |
| Short-circuit output current | $V_I = 35$ V | | 25°C | 245 | | | mA |
| Peak output current | | | 25°C | 0.7 | | | A |

† All characteristics are measured with a 0.33-μF capacitor across the input and a 0.1-μF capacitor across the output. Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

‡ This specification applies only for dc power dissipation permitted by absolute maximum ratings.



uA78M12C, uA78M12M
 POSITIVE-VOLTAGE REGULATORS

uA78M12C, uA78M12M electrical characteristics at specified virtual junction temperature, $V_I = 9\text{ V}$, $I_O = 350\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | $T_{J†}$ | uA78M12C | | | uA78M12M | | | UNIT | |
|---|--|--|----------|-----|------|----------|------|-------|---------------|---|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | | |
| Output voltage † | $I_O = 5\text{ mA}$ to 350 mA | 25°C | 11.5 | 12 | 12.5 | 11.5 | 12 | 12.5 | V | |
| | | -55°C to 150°C | | | | 11.4 | | 12.6 | | |
| | | 0°C to 125°C | 11.4 | | 12.6 | | | | | |
| Input regulation | $I_O = 200\text{ mA}$ | 25°C | | 8 | 100 | | 8 | 60 | mV | |
| | | -55°C to 150°C | | | | | 2 | 30 | | |
| | | 0°C to 125°C | | 2 | 50 | | | | | |
| Ripple rejection | $V_I = 15\text{ V}$ to 25 V , $f = 120\text{ Hz}$ | 25°C | | | | | | | dB | |
| | | -55°C to 150°C | | | | 55* | | | | |
| | | 0°C to 125°C | 55 | | | | | | | |
| Output regulation | $I_O = 5\text{ mA}$ to 500 mA $I_O = 5\text{ mA}$ to 200 mA | 25°C | | | | | | | mV | |
| | | -55°C to 150°C | | | | | | | | |
| | | 0°C to 125°C | 55 | 80 | 240 | 55* | 80 | | | |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | 25°C | | 10 | 120 | | 10 | 60 | mV/°C | |
| | | -55°C to 150°C | | | | | | -4.8* | | |
| | | 0°C to 125°C | | | | | | -3.6* | | |
| Output noise voltage | $f = 10\text{ Hz}$ to 100 kHz | 25°C | | 75 | | | 75 | 480* | μV | |
| Dropout voltage | | 25°C | | 2 | | | 2 | 2.5 | V | |
| | | 25°C | | 4.8 | 6 | | 4.8 | 7 | mA | |
| Bias current | $I_O = 200\text{ mA}$ | 25°C | | | | | | | mA | |
| | | -55°C to 150°C | | | | | | | | |
| | | 0°C to 125°C | | | 0.8 | | | | | |
| Bias current change | $I_O = 5\text{ mA}$ to 350 mA | 25°C | | | | | | | mA | |
| | | -55°C to 150°C | | | | | | 0.5 | | |
| | | 0°C to 125°C | | | 0.5 | | | | | |
| Short-circuit output current | $V_I = 35\text{ V}$ | 25°C | | 240 | | | 240 | 600 | mA | |
| Peak output current | | 25°C | | 0.7 | | | 0.5* | 0.7 | 1.4* | A |

* On products compliant to MIL-STD-883, Class B, this parameter is not production tested.

† All characteristics are measured with a $0.33\text{-}\mu\text{F}$ capacitor across the input and a $0.1\text{-}\mu\text{F}$ capacitor across the output. Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

‡ This specification applies only for dc power dissipation permitted by absolute maximum ratings.



uA78M15C, uA78M24C POSITIVE-VOLTAGE REGULATORS

uA78M15C electrical characteristics at specified virtual junction temperature, $V_I = 23\text{ V}$, $I_O = 350\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | | T_J^\dagger | MIN | TYP | MAX | UNIT |
|---|---|--------------------------------------|---------------|-------|-----|-------|---------------|
| Output voltage ‡ | | | 25°C | 14.4 | 15 | 15.6 | V |
| | $I_O = 5\text{ mA to }350\text{ mA}$ | $V_I = 17.5\text{ V to }30\text{ V}$ | 0°C to 125°C | 14.25 | | 15.75 | |
| Input regulation | $I_O = 200\text{ mA}$ | $V_I = 17.5\text{ V to }30\text{ V}$ | 25°C | | | 10 | 100 |
| | | $V_I = 20\text{ V to }30\text{ V}$ | | | | 3 | 50 |
| Ripple rejection | $V_I = 18.5\text{ V to }28.5\text{ V}$, $f = 120\text{ Hz}$ | $I_O = 100\text{ mA}$ | 0°C to 125°C | | | 54 | dB |
| | | $I_O = 300\text{ mA}$ | 25°C | 54 | 70 | | |
| Output regulation | $I_O = 5\text{ mA to }500\text{ mA}$ | | 25°C | | | 25 | 300 |
| | $I_O = 5\text{ mA to }200\text{ mA}$ | | | | | 10 | 150 |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | | 0°C to 125°C | | | -1 | mV/°C |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | | 25°C | | | 90 | μV |
| Dropout voltage | | | 25°C | | | 2 | V |
| Bias current | | | 25°C | | | 4.8 | 6 |
| Bias current change | $I_O = 200\text{ mA}$, $V_I = 17.5\text{ V to }30\text{ V}$ | | 0°C to 125°C | | | | 0.8 |
| | $I_O = 5\text{ mA to }350\text{ mA}$ | | 0°C to 125°C | | | | 0.5 |
| Short-circuit output current | $V_I = 35\text{ V}$ | | 25°C | | | 240 | mA |
| Peak output current | | | 25°C | | | 0.7 | A |

uA78M20C electrical characteristics at specified virtual junction temperature, $V_I = 29\text{ V}$, $I_O = 350\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | | T_J^\dagger | MIN | TYP | MAX | UNIT |
|---|---|------------------------------------|---------------|------|-----|------|---------------|
| Output voltage ‡ | | | 25°C | 19.2 | 20 | 20.8 | V |
| | $I_O = 5\text{ mA to }350\text{ mA}$ | $V_I = 23\text{ V to }35\text{ V}$ | 0°C to 125°C | 19 | | 21 | |
| Input regulation | $I_O = 200\text{ mA}$ | $V_I = 23\text{ V to }35\text{ V}$ | 25°C | | | 10 | 100 |
| | | $V_I = 24\text{ V to }35\text{ V}$ | | | | 5 | 50 |
| Ripple rejection | $V_I = 24\text{ V to }34\text{ V}$, $f = 120\text{ Hz}$ | $I_O = 100\text{ mA}$ | 0°C to 125°C | | | 53 | dB |
| | | $I_O = 300\text{ mA}$ | 25°C | 53 | 70 | | |
| Output regulation | $I_O = 5\text{ mA to }500\text{ mA}$ | | 25°C | | | 30 | 400 |
| | $I_O = 5\text{ mA to }200\text{ mA}$ | | | | | 10 | 200 |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | | 0°C to 125°C | | | -1.1 | mV/°C |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | | 25°C | | | 110 | μV |
| Dropout voltage | | | 25°C | | | 2 | V |
| Bias current | | | 25°C | | | 4.9 | 6 |
| Bias current change | $I_O = 200\text{ mA}$, $V_I = 23\text{ V to }35\text{ V}$ | | 0°C to 125°C | | | | 0.8 |
| | $I_O = 5\text{ mA to }350\text{ mA}$ | | 0°C to 125°C | | | | 0.5 |
| Short-circuit output current | $V_I = 35\text{ V}$ | | 25°C | | | 240 | mA |
| Peak output current | | | 25°C | | | 0.7 | A |

† All characteristics are measured with a 0.33- μF capacitor across the input and a 0.1- μF capacitor across the output. Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

‡ This specification applies only for dc power dissipation permitted by absolute maximum ratings.



uA78M24C
POSITIVE-VOLTAGE REGULATOR

uA78M24C electrical characteristics at specified virtual junction temperature, $V_I = 33\text{ V}$, $I_O = 350\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | | T_J^\dagger | MIN | TYP | MAX | UNIT |
|---|---|------------------------------------|---------------|------|-----|------|-------|
| | | | 25°C | 23 | 24 | 25 | |
| Output voltage ‡ | | | 25°C | 23 | 24 | 25 | V |
| | $I_O = 5\text{ mA to }350\text{ mA}$ | $V_I = 27\text{ V to }38\text{ V}$ | 0°C to 125°C | 22.8 | | 25.2 | |
| Input regulation | $I_O = 200\text{ mA}$ | $V_I = 27\text{ V to }38\text{ V}$ | 25°C | | 10 | 100 | mV |
| | | $V_I = 28\text{ V to }38\text{ V}$ | | | 5 | 50 | |
| Ripple rejection | $V_I = 28\text{ V to }38\text{ V}$, $f = 120\text{ Hz}$ | $I_O = 100\text{ mA}$ | 0°C to 125°C | 50 | | | dB |
| | | $I_O = 300\text{ mA}$ | 25°C | 50 | 70 | | |
| Output regulation | $I_O = 5\text{ mA to }500\text{ mA}$ | | 25°C | | 30 | 480 | mV |
| | $I_O = 5\text{ mA to }200\text{ mA}$ | | | | 10 | 240 | |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | | 0°C to 125°C | -1.2 | | | mV/°C |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | | 25°C | 170 | | | µV |
| Dropout voltage | | | 25°C | 2 | | | V |
| Bias current | | | 25°C | 5 | | 6 | mA |
| Bias current change | $I_O = 200\text{ mA}$, $V_I = 27\text{ V to }38\text{ V}$ | | 0°C to 125°C | | | 0.8 | mA |
| | $I_O = 5\text{ mA to }350\text{ mA}$ | | 0°C to 125°C | | | 0.5 | |
| Short-circuit output current | $V_I = 35\text{ V}$ | | 25°C | 240 | | | mA |
| Peak output current | | | 25°C | 0.7 | | | A |

† All characteristics are measured with a 0.33-µF capacitor across the input and a 0.1-µF capacitor across the output. Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

‡ This specification applies only for dc power dissipation permitted by absolute maximum ratings.

μA7900 SERIES NEGATIVE-VOLTAGE REGULATORS

D2215, JUNE 1976—REVISED NOVEMBER 1991

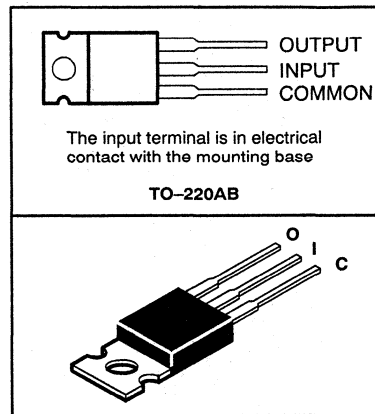
- 3-Terminal Regulators
- Output Current Up to 1.5 A
- No External Components
- Internal Thermal Overload Protection
- High-Power Dissipation Capability
- Internal Short-Circuit Current Limiting
- Output Transistor Safe-Area Compensation
- Essentially Equivalent to National LM320 Series

| NOMINAL OUTPUT VOLTAGE | REGULATOR |
|------------------------|-----------|
| -5 V | μA7905C |
| -5.2 V | μA7952C |
| -6 V | μA7906C |
| -8 V | μA7908C |
| -12 V | μA7912C |
| -15 V | μA7915C |
| -18 V | μA7918C |
| -24 V | μA7924C |

description

This series of fixed-negative-voltage monolithic integrated-circuit voltage regulators is designed to complement Series μA7800 in a wide range of applications. These applications include on-card regulation for elimination of noise and distribution problems associated with single-point regulation. Each of these regulators can deliver up to 1.5 A of output current. The internal current limiting and thermal shutdown features of these regulators make them essentially immune to overload. In addition to use as fixed-voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents and also as the power pass element in precision regulators.

KC PACKAGE
(TOP VIEW)



PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

TEXAS
INSTRUMENTS

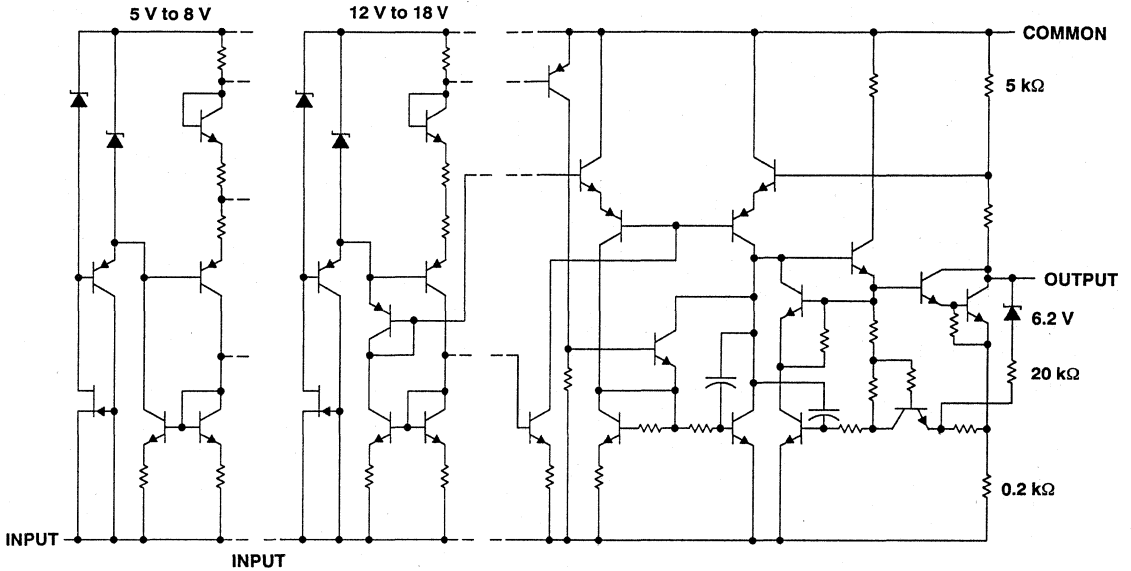
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2-457

uA7900 SERIES NEGATIVE-VOLTAGE REGULATORS

schematic



All component values are nominal.

absolute maximum ratings over operating temperature range (unless otherwise noted)

| | |
|---|--------------|
| Input voltage, V_i : uA7924C | -40 V |
| All others | -35 V |
| Continuous total dissipation at (or below) 25°C free-air temperature (see Note 1) | 2 W |
| Continuous total dissipation at (or below) 90°C case temperature (see Note 1) | 15 W |
| Operating free-air, case, or virtual junction temperature range | 0 to 150°C |
| Storage temperature range | -65 to 150°C |
| Lead temperature 3.2 mm (1/8 inch) from case for 10 seconds | 260°C |

NOTE 1: For operation above 25°C free-air or 90°C case temperature, refer to Figures 1 and 2. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

uA7900 SERIES NEGATIVE-VOLTAGE REGULATORS

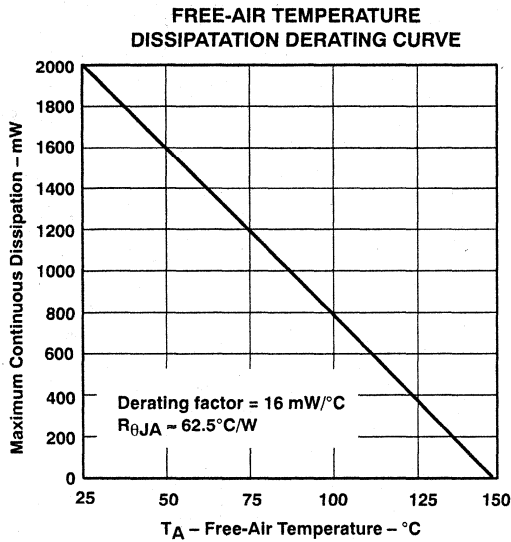


Figure 1

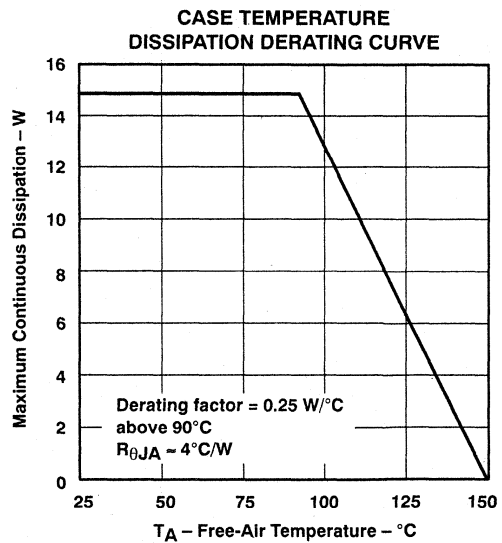


Figure 2

recommended operating conditions

| | | MIN | MAX | UNIT |
|--|---------|-------|-----|------|
| Input voltage, V _I | uA7905C | -7 | -25 | V |
| | uA7952C | -7.2 | -25 | |
| | uA7906C | -8 | -25 | |
| | uA7908C | -10.5 | -25 | |
| | uA7912C | -14.5 | -30 | |
| | uA7915C | -17.5 | -30 | |
| | uA7918C | -21 | -33 | |
| | uA7924C | -27 | -28 | |
| Output current, I _O | | | 1.5 | A |
| Operating virtual junction temperature, T _J | | 0 | 125 | °C |

uA7905C, uA7952C NEGATIVE-VOLTAGE REGULATORS

electrical characteristics at specified virtual junction temperature, $V_I = -10\text{ V}$, $I_O = 500\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J^\dagger | uA7905C | | | UNIT |
|---|---|---------------|---------|------|-------|-------|
| | | | MIN | TYP | MAX | |
| Output voltage [‡] | $I_O = 5\text{ mA to }1\text{ A}$, $P \leq 15\text{ W}$, $V_I = -7\text{ V to }-20\text{ V}$ | 25°C | -4.8 | -5 | -5.2 | V |
| | | 0°C to 125°C | -4.75 | | -5.25 | |
| Input regulation | $V_I = -7\text{ V to }-25\text{ V}$ | 25°C | | 12.5 | 50 | mV |
| | $V_I = -8\text{ V to }-12\text{ V}$ | | | 4 | 15 | |
| Ripple rejection | $V_I = -8\text{ V to }-18\text{ V}$, $f = 120\text{ Hz}$ | 0°C to 125°C | 54 | 60 | | dB |
| Output regulation | $I_O = 5\text{ mA to }1.5\text{ A}$ | 25°C | | 15 | 100 | mV |
| | $I_O = 250\text{ mA to }750\text{ mA}$ | | | 5 | 50 | |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | 0°C to 125°C | | -0.4 | | mV/°C |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | 125 | | µV |
| Dropout voltage | $I_O = 1\text{ A}$ | 25°C | | 1.1 | | V |
| Bias current | | 25°C | | 1.5 | 2 | mA |
| Bias current change | $V_I = -7\text{ V to }-25\text{ V}$ | 0°C to 125°C | | 0.15 | 0.5 | mA |
| | $I_O = 5\text{ mA to }1\text{ A}$ | | | 0.08 | 0.5 | |
| Peak output current | | 25°C | | 2.1 | | A |

electrical characteristics at specified virtual junction temperature, $V_I = -10\text{ V}$, $I_O = 500\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J^\dagger | uA7952C | | | UNIT |
|---|---|---------------|---------|------|-------|-------|
| | | | MIN | TYP | MAX | |
| Output voltage [‡] | $I_O = 5\text{ mA to }1\text{ A}$, $P \leq 15\text{ W}$, $V_I = -7.2\text{ V to }-20\text{ V}$ | 25°C | -5 | -5.2 | -5.4 | V |
| | | 0°C to 125°C | -4.95 | | -5.45 | |
| Input regulation | $V_I = -7.2\text{ V to }-25\text{ V}$ | 25°C | | 12.5 | 100 | mV |
| | $V_I = -8.2\text{ V to }-12\text{ V}$ | | | 4 | 50 | |
| Ripple rejection | $V_I = -8.2\text{ V to }-18\text{ V}$, $f = 120\text{ Hz}$ | 0°C to 125°C | 54 | 60 | | dB |
| Output regulation | $I_O = 5\text{ mA to }1.5\text{ A}$ | 25°C | | 15 | 100 | mV |
| | $I_O = 250\text{ mA to }750\text{ mA}$ | | | 5 | 50 | |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | 0°C to 125°C | | -0.4 | | mV/°C |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | 125 | | µV |
| Dropout voltage | $I_O = 1\text{ A}$ | 25°C | | 1.1 | | V |
| Bias current | | 25°C | | 1.5 | 2 | mA |
| Bias current change | $V_I = -7.2\text{ V to }-25\text{ V}$ | 0°C to 125°C | | 0.15 | 1.3 | mA |
| | $I_O = 5\text{ mA to }1\text{ A}$ | | | 0.08 | 0.5 | |
| Peak output current | | 25°C | | 2.1 | | A |

† Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 2-µF capacitor across the input and a 1-µF capacitor across the output.

‡ This specification applies only for dc power dissipation permitted by absolute maximum ratings.



uA7906C, uA7908C
NEGATIVE-VOLTAGE REGULATORS

electrical characteristics at specified virtual junction temperature, $V_I = -11$ V, $I_O = 500$ mA (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J^\dagger | uA7906C | | | UNIT |
|---|---|---------------|---------|------|-------|---------|
| | | | MIN | TYP | MAX | |
| Output voltage ‡ | | 25°C | -5.75 | -6 | -6.25 | V |
| | $I_O = 5$ mA to 1 A, $V_I = -8$ V to -21 V, $P \leq 15$ W | 0°C to 125°C | -5.7 | | -6.3 | |
| Input regulation | $V_I = -8$ V to -25 V | 25°C | | 12.5 | 120 | mV |
| | $V_I = -9$ V to -13 V | | | 4 | 60 | |
| Ripple rejection | $V_I = -9$ V to -19 V, $f = 120$ Hz | 0°C to 125°C | 54 | 60 | | dB |
| Output regulation | $I_O = 5$ mA to 1.5 A | 25°C | | 15 | 120 | mV |
| | $I_O = 250$ mA to 750 mA | | | 5 | 60 | |
| Temperature coefficient of output voltage | $I_O = 5$ mA | 0°C to 125°C | | -0.4 | | mV/°C |
| Output noise voltage | $f = 10$ Hz to 100 kHz | 25°C | | 150 | | μ V |
| Dropout voltage | $I_O = 1$ A | 25°C | | 1.1 | | V |
| Bias current | | 25°C | | 1.5 | 2 | mA |
| Bias current change | $V_I = -8$ V to -25 V | 0°C to 125°C | | 0.15 | 1.3 | mA |
| | $I_O = 5$ mA to 1 A | | | 0.08 | 0.5 | |
| Peak output current | | 25°C | | 2.1 | | A |

electrical characteristics at specified virtual junction temperature, $V_I = -14$ V, $I_O = 500$ mA (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J^\dagger | uA7908C | | | UNIT |
|---|--|---------------|---------|------|------|---------|
| | | | MIN | TYP | MAX | |
| Output voltage ‡ | | 25°C | -7.7 | -8 | -8.3 | V |
| | $I_O = 5$ mA to 1 A, $V_I = -10.5$ V to -23 V, $P \leq 15$ W | 0°C to 125°C | -7.6 | | -8.4 | |
| Input regulation | $V_I = -10.5$ V to -25 V | 25°C | | 12.5 | 160 | mV |
| | $V_I = -11$ V to -17 V | | | 4 | 80 | |
| Ripple rejection | $V_I = -11.5$ V to -21.5 V, $f = 120$ Hz | 0°C to 125°C | 54 | 60 | | dB |
| Output regulation | $I_O = 5$ mA to 1.5 A | 25°C | | 15 | 160 | mV |
| | $I_O = 250$ mA to 750 mA | | | 5 | 80 | |
| Temperature coefficient of output voltage | $I_O = 5$ mA | 0°C to 125°C | | -0.6 | | mV/°C |
| Output noise voltage | $f = 10$ Hz to 100 kHz | 25°C | | 200 | | μ V |
| Dropout voltage | $I_O = 1$ A | 25°C | | 1.1 | | V |
| Bias current | | 25°C | | 1.5 | 2 | mA |
| Bias current change | $V_I = -10.5$ V to -25 V | 0°C to 125°C | | 0.15 | 1 | mA |
| | $I_O = 5$ mA to 1 A | | | 0.08 | 0.5 | |
| Peak output current | | 25°C | | 2.1 | | A |

† Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 2- μ F capacitor across the input and a 1- μ F capacitor across the output.

‡ This specification applies only for dc power dissipation permitted by absolute maximum ratings.

uA7912C, uA7915C NEGATIVE-VOLTAGE REGULATORS

electrical characteristics at specified virtual junction temperature, $V_I = -19\text{ V}$, $I_O = 500\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J † | uA7912C | | | UNIT |
|---|--|--------------|---------|------|-------|-------|
| | | | MIN | TYP | MAX | |
| Output voltage‡ | $I_O = 5\text{ mA to }1\text{ A}$, $V_I = -14.5\text{ V to }-27\text{ V}$, $P \leq 15\text{ W}$ | 25°C | -11.5 | -12 | -12.5 | V |
| | | 0°C to 125°C | -11.4 | | -12.6 | |
| Input regulation | $V_I = -14.5\text{ V to }-30\text{ V}$ | 25°C | | 5 | 80 | mV |
| | $V_I = -16\text{ V to }-22\text{ V}$ | | | 3 | 30 | |
| Ripple rejection | $V_I = -15\text{ V to }-25\text{ V}$, $f = 120\text{ Hz}$ | 0°C to 125°C | 54 | 60 | | dB |
| Output regulation | $I_O = 5\text{ mA to }1.5\text{ A}$ | 25°C | | 15 | 200 | mV |
| | $I_O = 250\text{ mA to }750\text{ mA}$ | | | 5 | 75 | |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | 0°C to 125°C | | -0.8 | | mV/°C |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | 300 | | µV |
| Dropout voltage | $I_O = 1\text{ A}$ | 25°C | | 1.1 | | V |
| Bias current | | 25°C | | 2 | 3 | mA |
| Bias current change | $V_I = -14.5\text{ V to }-30\text{ V}$ | 0°C to 125°C | | 0.04 | 0.5 | mA |
| | $I_O = 5\text{ mA to }1\text{ A}$ | | | 0.06 | 0.5 | |
| Peak output current | | 25°C | | 2.1 | | A |

electrical characteristics at specified virtual junction temperature, $V_I = -23\text{ V}$, $I_O = 500\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J † | uA7915C | | | UNIT |
|---|--|--------------|---------|------|--------|-------|
| | | | MIN | TYP | MAX | |
| Output voltage‡ | $I_O = 5\text{ mA to }1\text{ A}$, $V_I = -17.5\text{ V to }-30\text{ V}$, $P \leq 15\text{ W}$ | 25°C | -14.4 | -15 | -15.6 | V |
| | | 0°C to 125°C | -14.25 | | -15.75 | |
| Input regulation | $V_I = -17.5\text{ V to }-30\text{ V}$ | 25°C | | 5 | 100 | mV |
| | $V_I = -20\text{ V to }-26\text{ V}$ | | | 3 | 50 | |
| Ripple rejection | $V_I = -18.5\text{ V to }-28.5\text{ V}$, $f = 120\text{ Hz}$ | 0°C to 125°C | 54 | 60 | | dB |
| Output regulation | $I_O = 5\text{ mA to }1.5\text{ A}$ | 25°C | | 20 | 300 | mV |
| | $I_O = 250\text{ mA to }750\text{ mA}$ | | | 8 | 150 | |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | 0°C to 125°C | | -1 | | mV/°C |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | 375 | | µV |
| Dropout voltage | $I_O = 1\text{ A}$ | 25°C | | 1.1 | | V |
| Bias current | | 25°C | | 2 | 3 | mA |
| Bias current change | $V_I = -17.5\text{ V to }-30\text{ V}$ | 0°C to 125°C | | 0.04 | 0.5 | mA |
| | $I_O = 5\text{ mA to }1\text{ A}$ | | | 0.06 | 0.5 | |
| Peak output current | | 25°C | | 2.1 | | A |

† Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 2-µF capacitor across the input and a 1-µF capacitor across the output.

‡ This specification applies only for dc power dissipation permitted by absolute maximum ratings.



uA7918C, uA7924C
NEGATIVE-VOLTAGE REGULATORS

electrical characteristics at specified virtual junction temperature, $V_I = -27\text{ V}$, $I_O = 500\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J^\dagger | uA7918C | | | UNIT |
|---|---|---------------|---------|------|-------|-------|
| | | | MIN | TYP | MAX | |
| Output voltage ‡ | | 25°C | -17.3 | -18 | -18.7 | V |
| | $I_O = 5\text{ mA to }1\text{ A}$, $V_I = -21\text{ V to }-33\text{ V}$, $P \leq 15\text{ W}$ | 0°C to 125°C | -17.1 | | -18.9 | |
| Input regulation | $V_I = -21\text{ V to }-33\text{ V}$ | 25°C | | 5 | 360 | mV |
| | $V_I = -24\text{ V to }-30\text{ V}$ | | | 3 | 180 | |
| Ripple rejection | $V_I = -22\text{ V to }-32\text{ V}$, $f = 120\text{ Hz}$ | 0°C to 125°C | 54 | 60 | | dB |
| Output regulation | $I_O = 5\text{ mA to }1.5\text{ A}$ | 25°C | | 30 | 360 | mV |
| | $I_O = 250\text{ mA to }750\text{ mA}$ | | | 10 | 180 | |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | 0°C to 125°C | | -1 | | mV/°C |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | 450 | | μV |
| Dropout voltage | $I_O = 1\text{ A}$ | 25°C | | 1.1 | | V |
| Bias current | | 25°C | | 2 | 3 | mA |
| Bias current change | $V_I = -21\text{ V to }-33\text{ V}$ | 0°C to 125°C | | 0.04 | 1 | mA |
| | $I_O = 5\text{ mA to }1\text{ A}$ | | | 0.06 | 0.5 | |
| Peak output current | | 25°C | | 2.1 | | A |

electrical characteristics at specified virtual junction temperature, $V_I = -33\text{ V}$, $I_O = 500\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J^\dagger | uA7924C | | | UNIT |
|---|---|---------------|---------|------|-------|-------|
| | | | MIN | TYP | MAX | |
| Output voltage ‡ | | 25°C | -23 | -24 | -25 | V |
| | $I_O = 5\text{ mA to }1\text{ A}$, $V_I = -27\text{ V to }-38\text{ V}$, $P \leq 15\text{ W}$ | 0°C to 125°C | -22.8 | | -25.2 | |
| Input regulation | $V_I = -27\text{ V to }-38\text{ V}$ | 25°C | | 5 | 480 | mV |
| | $V_I = -30\text{ V to }-36\text{ V}$ | | | 3 | 240 | |
| Ripple rejection | $V_I = -28\text{ V to }-38\text{ V}$, $f = 120\text{ Hz}$ | 0°C to 125°C | 54 | 60 | | dB |
| Output regulation | $I_O = 5\text{ mA to }1.5\text{ A}$ | 25°C | | 85 | 480 | mV |
| | $I_O = 250\text{ mA to }750\text{ mA}$ | | | 25 | 240 | |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | 0°C to 125°C | | -1 | | mV/°C |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | 600 | | μV |
| Dropout voltage | $I_O = 1\text{ A}$ | 25°C | | 1.1 | | V |
| Bias current | | 25°C | | 2 | 3 | mA |
| Bias current change | $V_I = -27\text{ V to }-38\text{ V}$ | 0°C to 125°C | | 0.04 | 1 | mA |
| | $I_O = 5\text{ mA to }1\text{ A}$ | | | 0.06 | 0.5 | |
| Peak output current | | 25°C | | 2.1 | | A |

† Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 2-μF capacitor across the input and a 1-μF capacitor across the output.

‡ This specification applies only for dc power dissipation permitted by absolute maximum ratings.

μA79M00 SERIES NEGATIVE-VOLTAGE REGULATORS

D2216, JUNE 1976 – REVISED SEPTEMBER 1991

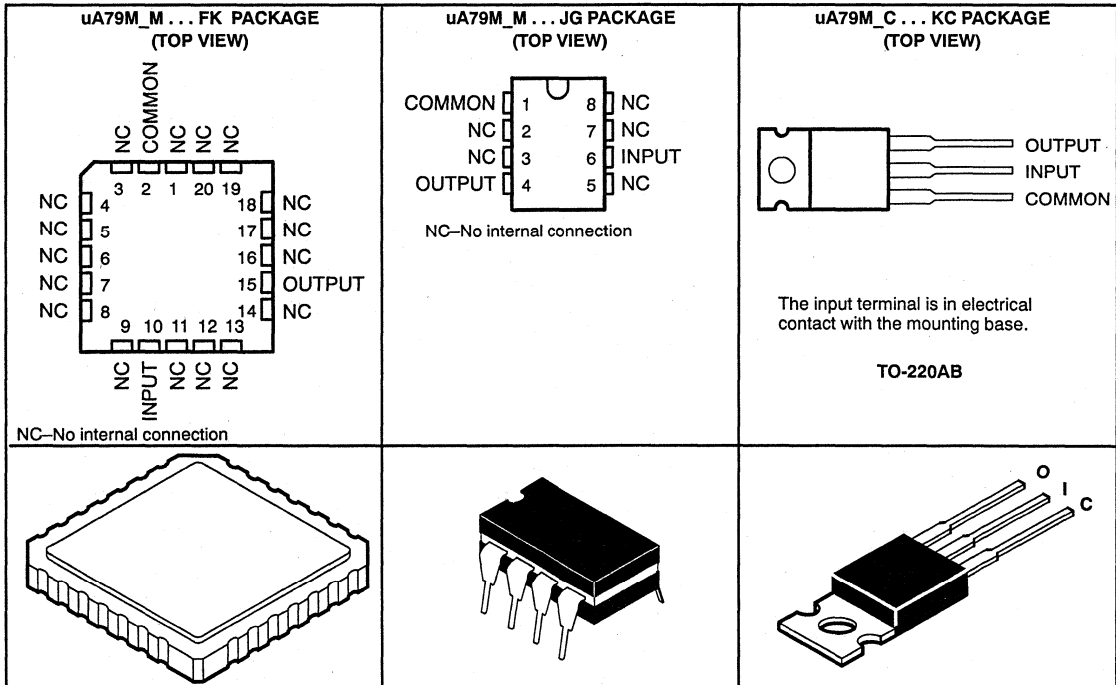
- 3-Terminal Regulators
- Output Current Up to 500 mA
- No External Components
- High Power Dissipation Capability
- Internal Short-Circuit Current Limiting
- Output Transistor Safe-Area Compensation
- Direct Replacements for Fairchild μA79M00 Series

| NOMINAL OUTPUT VOLTAGE | 0°C TO 125°C OPERATING TEMPERATURE RANGE | -55°C TO 150°C OPERATING TEMPERATURE RANGE |
|------------------------|--|--|
| -5 V | μA79M05C | μA79M05M |
| -6 V | μA79M06C | |
| -8 V | μA79M08C | |
| -12 V | μA79M12C | μA79M12M |
| -15 V | μA79M15C | |
| -20 V | μA79M20C | |
| -24 V | μA79M24C | |
| Package | KC | FK, JG |

description

This series of fixed-negative-voltage monolithic integrated-circuit voltage regulators is designed to complement the μA78M00 series in a wide range of applications. These applications include on-card regulation for elimination of noise and distribution problems associated with single-point regulation. Each of these regulators can deliver up to 500 mA of output current. The internal current limiting and thermal shutdown features of these regulators make them essentially immune to overload. In addition to use as fixed-voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents and also as the power pass element in precision regulators.

terminal assignments



PRODUCTION DATA Information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

**TEXAS
INSTRUMENTS**

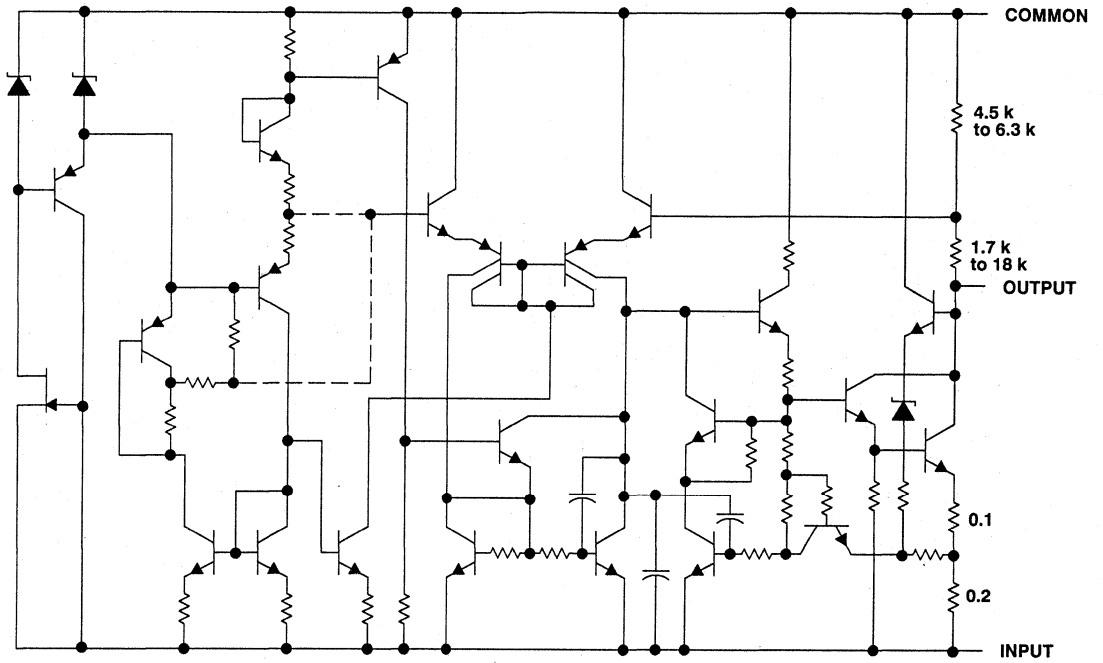
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On products compliant to MIL-STD-883, Class B, all parameters are tested unless otherwise noted. On all other products, production processing does not necessarily include testing of all parameters.

uA79M24C NEGATIVE-VOLTAGE REGULATORS

schematic



Resistor values shown are nominal and in Ω .

TEXAS
INSTRUMENTS

uA79M20C NEGATIVE-VOLTAGE REGULATORS

absolute maximum ratings over operating temperature range (unless otherwise noted)

| | | uA79M05C THRU uA79M12C | uA79M05M AND uA79M12M | UNIT |
|---|------------------|---------------------------------------|-----------------------------|------|
| Input voltage | uA79M20, uA79M24 | -40 | | V |
| | All others | -35 | -35 | |
| Continuous total dissipation (see Note 1) | | See Dissipation Rating Tables 1 and 2 | | |
| Operating free-air, case, or virtual junction temperature range | | 0 to 150 | -55 to 150 | °C |
| Storage temperature range | | -65 to 150 | -65 to 150 | °C |
| Case temperature for 60 seconds | FK package | | 260 | °C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds | JG package | | 300 | °C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | KC package | 260 | | °C |

NOTE 1: To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

DISSIPATION RATING TABLE 1—FREE-AIR TEMPERATURE

| PACKAGE | T _A = 25°C POWER RATING | DERATING FACTOR ABOVE T _A = 25°C | T _A = 70°C POWER RATING | T _A = 125°C POWER RATING |
|---------|---------------------------------------|--|---------------------------------------|--|
| FK | 1375 mW | 11 mW/°C | 880 mW | 275 mW |
| JG | 1050 mW | 8.4 mW/°C | 672 mW | 210 mW |
| KC | 2000 mW | 16 mW/°C | 1280 mW | 400 mW |

DISSIPATION RATING TABLE 2—CASE TEMPERATURE

| PACKAGE | T _C ≤ 120°C POWER RATING | DERATING FACTOR ABOVE T _C = 120°C | T _C = 125°C POWER RATING |
|---------|--|---|--|
| KC | 7.5 W | 250 mW/°C | 6.25 W |

recommended operating conditions

| | | MIN | MAX | UNIT |
|--|------------------------|-------|-----|------|
| Input voltage, V _I | uA79M05C, uA79M05M | -7 | -25 | V |
| | uA79M06C | -8 | -25 | |
| | uA79M08C | -10.5 | -25 | |
| | uA79M12C, uA79M12M | -14.5 | 30 | |
| | uA79M15C | -17.5 | -30 | |
| | uA79M20C | -23 | -35 | |
| | uA79M24C | -27 | -38 | |
| Output current, I _O | | | 500 | mA |
| Operating virtual junction temperature, T _J | uA79M05C thru uA79M24C | 0 | 125 | °C |
| | uA79M05M, uA79M12M | -55 | 150 | |

uA79M24C NEGATIVE-VOLTAGE REGULATORS

electrical characteristics at specified virtual junction temperature, $V_I = -10$ V, $I_O = 350$ mA (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J^\dagger | uA79M05C | | | uA79M05M | | | UNIT |
|---|--|----------------|----------------|-----|-------|---------------|-----|-------|-------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| Output voltage [‡] | $I_O = 5$ mA to 350 mA, $V_I = -7$ V to -25 V | 25°C | -4.8 | -5 | -5.2 | -4.8 | -5 | -5.2 | V |
| | | -55°C to 150°C | | | | -4.75 | | -5.25 | |
| | | 0°C to 125°C | -4.75 | | -5.25 | | | | |
| Input regulation | $V_I = -7$ V to -25 V | 25°C | | 7 | 50 | | 7 | 50 | mV |
| | $V_I = -8$ V to -18 V | | | 3 | 30 | | 3 | 30 | |
| Ripple rejection | $V_I = -8$ V to -18 V, $f = 120$ Hz | $I_O = 100$ mA | -55°C to 150°C | | | 50* | | | dB |
| | | $I_O = 300$ mA | 0°C to 125°C | | | 50 | | | |
| | | | 25°C | 54 | 60 | 54* | 60 | | |
| Output regulation | $I_O = 5$ mA to 500 mA | 25°C | | 75 | 100 | | 75 | 100 | mV |
| | $I_O = 5$ mA to 350 mA | | | 50 | | | 50 | | |
| Temperature coefficient of output voltage | $I_O = 5$ mA | -55°C to 150°C | | | | -1.5* | | | mV/°C |
| | | 0°C to 125°C | | | | -0.4 | | | |
| Output noise voltage | $f = 10$ Hz to 100 kHz | 25°C | 125 | | | 125 400* | | | μV |
| Dropout voltage | | 25°C | 1.1 | | | 1.1 2.3 | | | V |
| Bias current | | 25°C | 1 2 | | | 1 2 | | | mA |
| Bias current change | $V_I = -8$ V to -25 V | -55°C to 150°C | | | | 0.4 | | | mA |
| | | 0°C to 125°C | | | | 0.4 | | | |
| | $I_O = 5$ mA to 350 mA | -55°C to 150°C | | | | 0.4 | | | |
| | | 0°C to 125°C | | | | 0.4 | | | |
| Short-circuit output current | $V_I = -30$ V | 25°C | 140 | | | 600 | | | mA |
| Peak output current | | 25°C | 0.65 | | | 0.5 0.65 1.4* | | | A |

*On products compliant to MIL-STD-883, Class B, this parameter is not production tested.

† Pulse-testing techniques are used to maintain the virtual junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 2-μF capacitor across the input and a 1-μF capacitor across the output.

‡ This specification applies only for dc power dissipation permitted by absolute maximum ratings.



uA79M20C NEGATIVE-VOLTAGE REGULATOR

electrical characteristics at specified virtual junction temperature, $V_I = -11\text{ V}$, $I_O = 350\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J^\dagger | MIN | TYP | MAX | UNIT |
|---|---|---------------------------------------|-------|------|-------|-------|
| Output voltage [‡] | | 25°C | -5.75 | -6 | -6.25 | V |
| | $I_O = 5\text{ mA to } 350\text{ mA}$, $V_I = -8\text{ V to } -25\text{ V}$ | 0°C to 125°C | -5.7 | | -6.3 | |
| Input regulation | $V_I = -8\text{ V to } -25\text{ V}$ | 25°C | | 7 | 60 | mV |
| | $V_I = -9\text{ V to } -19\text{ V}$ | | | 3 | 40 | |
| Ripple rejection | $V_I = -9\text{ V to } -19\text{ V}$, $f = 120\text{ Hz}$ | $I_O = 100\text{ mA}$ 0°C to 125°C | | 50 | | dB |
| | | $I_O = 300\text{ mA}$ 25°C | | 54 | 60 | |
| Output regulation | $I_O = 5\text{ mA to } 500\text{ mA}$ | 25°C | | 80 | 120 | mV |
| | $I_O = 5\text{ mA to } 350\text{ mA}$ | | | 55 | | |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | 0°C to 125°C | | -0.4 | | mV/°C |
| Output noise voltage | $f = 10\text{ Hz to } 100\text{ kHz}$ | 25°C | | 150 | | μV |
| Dropout voltage | | 25°C | | 1.1 | | V |
| Bias current | | 25°C | | 1 | 2 | mA |
| Bias current change | $V_I = -9\text{ V to } -25\text{ V}$ | 0°C to 125°C | | | 0.4 | mA |
| | $I_O = 5\text{ mA to } 350\text{ mA}$ | 0°C to 125°C | | | 0.4 | |
| Short-circuit output current | $V_I = -30\text{ V}$ | 25°C | | 140 | | mA |
| Peak output current | | 25°C | | 0.65 | | A |

† Pulse-testing techniques are used to maintain the virtual junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 2-μF capacitor across the input and a 1-μF capacitor across the output.

‡ This specification applies only for dc power dissipation permitted by absolute maximum ratings.

uA79M24C NEGATIVE-VOLTAGE REGULATOR

electrical characteristics at specified virtual junction temperature, $V_I = -19\text{ V}$, $I_O = 350\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITONS | T_J † | MIN | TYP | MAX | UNIT |
|---|---|-----------------------|--------------|-----|-------|-------|
| Output voltage‡ | | 25°C | -7.7 | -8 | -8.3 | V |
| | $I_O = 5\text{ mA to }350\text{ mA}$, $V_I = -10.5\text{ V to }-25\text{ V}$ | 0°C to 125°C | -7.6 | | -8.4 | |
| Input regulation | $V_I = -10.5\text{ V to }-25\text{ V}$ | 25°C | | 8 | 80 | mV |
| | $V_I = -11\text{ V to }-21\text{ V}$ | | | 4 | 50 | |
| Ripple rejection | $V_I = -11.5\text{ V to }-21.5\text{ V}$, $f = 120\text{ Hz}$ | $I_O = 100\text{ mA}$ | 0°C to 125°C | | 50 | dB |
| | | $I_O = 300\text{ mA}$ | 25°C | | 54 59 | |
| Output regulation | $I_O = 5\text{ mA to }500\text{ mA}$ | 25°C | | 90 | 160 | mV |
| | $I_O = 5\text{ mA to }350\text{ mA}$ | | | 60 | | |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | 0°C to 125°C | | | -0.6 | mV/°C |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | | 200 | μV |
| Dropout voltage | $I_O = 5\text{ mA}$ | 25°C | | | 1.1 | V |
| Bias current | | 25°C | | | 1 2 | mA |
| Bias current change | $V_I = -10.5\text{ V to }-25\text{ V}$ | 0°C to 125°C | | | 0.4 | mA |
| | $I_O = 5\text{ mA to }350\text{ mA}$ | 0°C to 125°C | | | 0.4 | |
| Short-circuit output current | $V_I = -30\text{ V}$ | 25°C | | | 140 | mA |
| Peak output current | | 25°C | | | 0.65 | A |

† Pulse-testing techniques are used to maintain the virtual junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 2-μF capacitor across the input and a 1-μF capacitor across the output.

‡ This specification applies only for dc power dissipation permitted by absolute maximum ratings.

uA79M20C NEGATIVE-VOLTAGE REGULATORS

electrical characteristics at specified virtual junction temperature, $V_I = -19\text{ V}$, $I_O = 350\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J^\dagger | uA79M12C | | | uA79M12M | | | UNIT |
|---|--|-----------------------|----------------|------|-------|----------|------|-------|-------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| Output voltage‡ | $I_O = 5\text{ mA to }350\text{ mA}$, $V_I = -14.5\text{ V to }-30\text{ V}$ | 25°C | -11.5 | -12 | -12.5 | -11.5 | -12 | -12.5 | V |
| | | -55°C to 150°C | | | | -11.4 | | -12.6 | |
| | | 0°C to 125°C | -11.4 | | -12.6 | | | | |
| Input regulation | $V_I = -14.5\text{ V to }-30\text{ V}$ | 25°C | | 9 | 80 | | 9 | 80 | mV |
| | $V_I = -15\text{ V to }-25\text{ V}$ | | | 5 | 50 | | 5 | 50 | |
| Ripple rejection | $V_I = -15\text{ V to }-25\text{ V}$, $f = 120\text{ Hz}$ | $I_O = 100\text{ mA}$ | -55°C to 150°C | | | | 50* | | dB |
| | | | 0°C to 125°C | 50 | | | | | |
| | | $I_O = 300\text{ mA}$ | 25°C | 54 | 60 | | 54* | 60 | |
| Output regulation | $I_O = 5\text{ mA to }500\text{ mA}$ | 25°C | | 65 | 240 | | 65 | 240 | mV |
| | $I_O = 5\text{ mA to }350\text{ mA}$ | | | 45 | | | 45 | | |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | -55°C to 150°C | | | | | | -3.6* | mV/°C |
| | | 0°C to 125°C | -0.8 | | | | | | |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | 300 | | 300 | 960* | µV | |
| Dropout voltage | | 25°C | | 1.1 | | 1.1 | 2.3 | V | |
| Bias current | | 25°C | | 1.5 | 3 | | 1.5 | 3 | mA |
| Bias current change | $V_I = -14.5\text{ V to }-30\text{ V}$ | -55°C to 150°C | | | | | | 0.4 | mA |
| | | 0°C to 125°C | | | 0.4 | | | | |
| | $I_O = 5\text{ mA to }350\text{ mA}$ | -55°C to 150°C | | | | | | 0.4 | |
| | | 0°C to 125°C | | | 0.4 | | | | |
| Short-circuit output current | $V_I = -30\text{ V}$ | 25°C | | 140 | | | 600 | mA | |
| Peak output current | | 25°C | | 0.65 | | 0.5* | 0.65 | 1.4* | A |

*On products compliant to MIL-STD-883, Class B, this parameter is not production tested.

† Pulse-testing techniques are used to maintain the virtual junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 2-µF capacitor across the input and a 1-µF capacitor across the output.

‡ This specification applies only for dc power dissipation permitted by absolute maximum ratings.

uA79M24C NEGATIVE-VOLTAGE REGULATOR

electrical characteristics at specified virtual junction temperature, $V_I = -23\text{ V}$, $I_O = 350\text{ mA}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J † | MIN | TYP | MAX | UNIT |
|---|---|-----------------------|--------------|------|--------|-------|
| Output voltage‡ | | 25°C | -14.4 | -15 | -15.6 | V |
| | $I_O = 5\text{ mA to }350\text{ mA}$, $V_I = -17.5\text{ V to }-30\text{ V}$ | 0°C to 125°C | -14.25 | | -15.75 | |
| Input regulation | $V_I = -17.5\text{ V to }-30\text{ V}$ | 25°C | | 9 | 80 | mV |
| | $V_I = -18\text{ V to }-28\text{ V}$ | | | 7 | 50 | |
| Ripple rejection | $V_I = -18.5\text{ V to }-28.5\text{ V}$, $f = 120\text{ Hz}$ | $I_O = 100\text{ mA}$ | 0°C to 125°C | | 50 | dB |
| | | $I_O = 300\text{ mA}$ | 25°C | | 54 59 | |
| Output regulation | $I_O = 5\text{ mA to }500\text{ mA}$ | 25°C | | 65 | 240 | mV |
| | $I_O = 5\text{ mA to }350\text{ mA}$ | | | 45 | | |
| Temperature coefficient of output voltage | $I_O = 5\text{ mA}$ | 0°C to 125°C | | -1 | | mV/°C |
| Output noise voltage | $f = 10\text{ Hz to }100\text{ kHz}$ | 25°C | | 375 | | μV |
| Dropout voltage | $I_O = 5\text{ mA}$ | 25°C | | 1.1 | | V |
| Bias current | | 25°C | | 1.5 | 3 | mA |
| Bias current change | $V_I = -17.5\text{ V to }-30\text{ V}$ | 0°C to 125°C | | | 0.4 | mA |
| | $I_O = 5\text{ mA to }350\text{ mA}$ | 0°C to 125°C | | | 0.4 | |
| Short-circuit output current | $V_I = -30\text{ V}$ | 25°C | | 140 | | mA |
| Peak output current | | 25°C | | 0.65 | | A |

† Pulse-testing techniques are used to maintain the virtual junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 2-μF capacitor across the input and a 1-μF capacitor across the output.

‡ This specification applies only for dc power dissipation permitted by absolute maximum ratings.

uA79M20C
NEGATIVE-VOLTAGE REGULATOR

electrical characteristics at specified virtual junction temperature, $V_I = -29$ V, $I_O = 350$ mA (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J † | MIN | TYP | MAX | UNIT |
|---|--|----------------|--------------|------|-------|-------|
| Output voltage‡ | $I_O = 5$ mA to 350 mA, $V_I = -23$ V to -35 V | 25°C | -19.2 | -20 | -20.8 | V |
| | | 0°C to 125°C | -19 | | -21 | |
| Input regulation | $V_I = -23$ V to -35 V | 25°C | | 12 | 80 | mV |
| | $V_I = -24$ V to -34 V | | | 10 | 70 | |
| Ripple rejection | $V_I = -24$ V to -34 V, $f = 120$ Hz | $I_O = 100$ mA | 0°C to 125°C | 50 | | dB |
| | | $I_O = 300$ mA | 25°C | 54 | 58 | |
| Output regulation | $I_O = 5$ mA to 500 mA | 25°C | | 75 | 300 | mV |
| | $I_O = 5$ mA to 350 mA | | | 50 | | |
| Temperature coefficient of output voltage | $I_O = 5$ mA | 0°C to 125°C | | -1 | | mV/°C |
| Output noise voltage | $f = 10$ Hz to 100 kHz | 25°C | | 500 | | μV |
| Dropout voltage | | 25°C | | 1.1 | | V |
| Bias current | | 25°C | | 1.5 | 3.5 | mA |
| Bias current change | $V_I = -23$ V to -35 V | 0°C to 125°C | | | 0.4 | mA |
| | $I_O = 5$ mA to 350 mA | | | | 0.4 | |
| Short-circuit output current | $V_I = -30$ V | 25°C | | 140 | | mA |
| Peak output current | | 25°C | | 0.65 | | A |

† Pulse-testing techniques are used to maintain the virtual junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 2-μF capacitor across the input and a 1-μF capacitor across the output.

‡ This specification applies only for dc power dissipation permitted by absolute maximum ratings.

uA79M24C NEGATIVE-VOLTAGE REGULATOR

uA79M24C electrical characteristics at specified virtual junction temperature, $V_I = -33$ V, $I_O = 350$ mA (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_J^\dagger | MIN TYP MAX | | | UNIT |
|---|--|----------------|-----------------|-----|-------|-------|
| | | | MIN | TYP | MAX | |
| Output voltage‡ | $I_O = 5$ mA to 350 mA, $V_I = -27$ V to -38 V | 25°C | -23 | -24 | -25 | V |
| | | 0°C to 125°C | -22.8 | | -25.2 | |
| Input regulation | $V_I = -27$ V to -38 V | 25°C | 12 80 | | | mV |
| | $V_I = -28$ V to -38 V | | 12 70 | | | |
| Ripple rejection | $V_I = -28$ V to -38 V, $f = 120$ Hz | $I_O = 100$ mA | 0°C to 125°C 50 | | | dB |
| | | $I_O = 300$ mA | 25°C 54 58 | | | |
| Output regulation | $I_O = 5$ mA to 500 mA | 25°C | 75 300 | | | mV |
| | $I_O = 5$ mA to 350 mA | | 50 | | | |
| Temperature coefficient of output voltage | $I_O = 5$ mA | 0°C to 125°C | -1 | | | mV/°C |
| Output noise voltage | $f = 10$ Hz to 100 kHz | 25°C | 600 | | | μV |
| Dropout voltage | | 25°C | 1.1 | | | V |
| Bias current | | 25°C | 1.5 3.5 | | | mA |
| Bias current change | $V_I = -27$ V to -38 V | 0°C to 125°C | 0.4 | | | mA |
| | $I_O = 5$ mA to 350 mA | | 0.4 | | | |
| Short-circuit output current | $V_I = -30$ V | 25°C | 140 | | | mA |
| Peak output current | | 25°C | 0.65 | | | A |

† Pulse-testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 2-μF capacitor across the input and a 1-μF capacitor across the output.

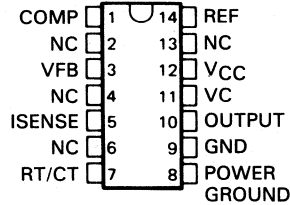
‡ This specification applies only for dc power dissipation permitted by absolute maximum ratings.

UC2842, UC2843, UC2844, UC2845 UC3842, UC3843, UC3844, UC3845 CURRENT-MODE PWM CONTROLLERS

D3175, JANUARY 1989—REVISED AUGUST 1991

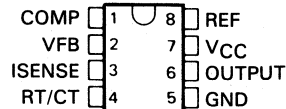
- Optimized for Off-Line and DC-to-DC Converters
- Low Start-Up Current (< 1 mA)
- Automatic Feed-Forward Compensation
- Pulse-by-Pulse Current Limiting
- Enhanced Load-Response Characteristics
- Undervoltage Lockout With Hysteresis
- Double Pulse Suppression
- High-Current Totem-Pole Output
- Internally Trimmed Bandgap Reference
- 500-kHz Operation
- Error Amplifier With Low Output Resistance
- Designed to Be Interchangeable With Unitrode UC2842 and UC3842 Series

**D PACKAGE
(TOP VIEW)**



NC—No internal connection

**P PACKAGE
(TOP VIEW)**



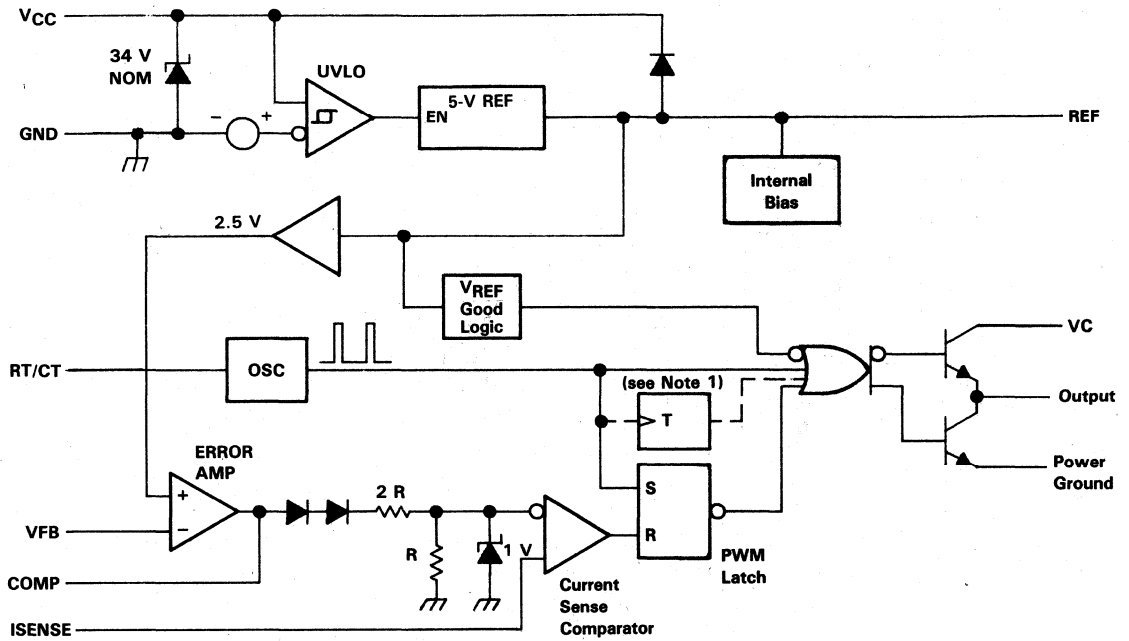
description

The UC2842 and UC3842 series of control integrated circuits provide the features that are necessary to implement off-line or dc-to-dc fixed-frequency current-mode control schemes with a minimum number of external components. Internally implemented circuits include: undervoltage lockout (UVLO) featuring a start-up current of less than 1 mA, a precision reference trimmed for accuracy at the error amplifier input, logic to ensure latched operation, a pulse-width modulation (PWM) comparator (which also provides current-limit control), and a totem-pole output stage designed to source or sink high-peak current. The output stage, suitable for driving N-channel MOSFETs, is low when it is in the off state.

The primary difference between the UC2842-series devices and the UC3842-series devices is the ambient operating temperature range. The UC2842-series devices operate between -25°C and 85°C ; the UC3842-series devices operate between 0°C and 70°C . Major differences between members of these series are the undervoltage lockout (UVLO) thresholds and maximum duty cycle ranges. Typical UVLO thresholds of 16 V (on) and 10 V (off) on the UC__842 and UC__844 devices make them ideally suited to off-line applications. The corresponding typical thresholds for the UC__843 and UC__845 devices are 8.4 V on and 7.6 V off. The UC__842 and UC__843 devices can operate to duty cycles approaching 100%. A duty cycle range of 0 to 50% is obtained by the UC__844 and UC__845 by the addition of an internal toggle flip-flop, which blanks the output off every other clock cycle.

**UC2842, UC2843, UC2844, UC2845
UC3842, UC3843, UC3844, UC3845
CURRENT-MODE PWM CONTROLLERS**

functional block diagram



NOTE 1. The toggle flip-flop is present only in UC2844, UC2845, UC3844, and UC3845.

**UC2842, UC2843, UC2844, UC2845
UC3842, UC3843, UC3844, UC3845
CURRENT-MODE PWM CONTROLLERS**

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|------------------------------|
| Supply voltage (see Note 2) ($I_{CC} < 30$ mA) | Self Limiting |
| Analog input voltage (VFB and ISENSE terminals) | -0.3 V to 6.3 V |
| Voltage on output pin | 35 V |
| Voltage on VC pin (14-pin package) | 35 V |
| Supply current, I_{CC} | 30 mA |
| Output current | ± 1 A |
| Error amplifier output sink current | 10 mA |
| Continuous power dissipation | see Dissipation Rating Table |
| Output energy (capacitive load) | 5 μ J |
| Operating free-air temperature range, T_A : UC284__ | -25°C to 85°C |
| UC384__ | 0°C to 70°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature, 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 2: All voltages are with respect to the device GND terminal.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ | DERATING FACTOR | $T_A = 70^\circ\text{C}$ | $T_A = 85^\circ\text{C}$ |
|---------|-----------------------------|--------------------------------|--------------------------|--------------------------|
| | POWER RATING | ABOVE $T_A = 25^\circ\text{C}$ | POWER RATING | POWER RATING |
| D | 950 mW | 7.6 mW/°C | 608 mW | 494 mW |
| P | 1000 mW | 8.0 mW/°C | 640 mW | 520 mW |

recommended operating conditions

| | UC284__ | | | UC384__ | | | UNIT |
|--|---------|-----|-----|---------|-----|-----|------|
| | MIN | NOM | MAX | MIN | NOM | MAX | |
| Supply voltage, V_{CC} and V_C^\dagger | | | 30 | | | 30 | V |
| Voltage on RT/CT input | 0 | | 5.5 | 0 | | 5.5 | V |
| Voltage on VFB and ISENSE inputs | 0 | | 5.5 | 0 | | 5.5 | V |
| Voltage on OUTPUT | 0 | | 30 | 0 | | 30 | V |
| Voltage on POWER GROUND [†] | -0.1 | | 1 | -0.1 | | 1 | V |
| Supply current, externally limited, I_{CC} | | | 25 | | | 25 | mA |
| Average output current, I_O | | | 200 | | | 200 | mA |
| Reference output current | | | -20 | | | -20 | mA |
| Timing capacitance, C_T | 1 | | | 1 | | | nF |
| Oscillator frequency | | 100 | 500 | | 100 | 500 | kHz |
| Operating free-air temperature, T_A | -25 | | 85 | 0 | | 70 | °C |

[†]These recommended voltages for V_C and POWER GROUND apply only to the D package.

**UC2842, UC2843, UC2844, UC2845
UC3842, UC3843, UC3844, UC3845
CURRENT-MODE PWM CONTROLLERS**

electrical characteristics, $V_{CC} = 15\text{ V}$ (see Note 3), $R_T = 10\text{ k}\Omega$, $C_T = 3.3\text{ nF}$, $T_A = \text{full range}$ (unless otherwise specified)

reference section

| PARAMETER | TEST CONDITIONS | UC284__ | | | UC384__ | | | UNIT |
|---|--|---------|------------------|------|---------|------------------|------|----------------------|
| | | MIN | TYP [†] | MAX | MIN | TYP [†] | MAX | |
| Output voltage | $I_O = 1\text{ mA}$, $T_J = 25^\circ\text{C}$ | 4.95 | 5 | 5.05 | 4.9 | 5 | 5.1 | V |
| Line regulation | $V_{CC} = 12\text{ V to }25\text{ V}$ | | 6 | 20 | | 6 | 20 | mV |
| Load regulation | $I_O = 1\text{ mA to }20\text{ mA}$ | | 6 | 25 | | 6 | 25 | mV |
| Temperature coefficient of output voltage | | | 0.2 | 0.4 | | 0.2 | 0.4 | mV/ $^\circ\text{C}$ |
| Output voltage with worst-case variation | $V_{CC} = 12\text{ V to }25\text{ V}$, $I_O = 1\text{ mA to }20\text{ mA}$ | | 4.9 | 5.1 | | 4.82 | 5.18 | V |
| Output noise voltage | $f = 10\text{ Hz to }10\text{ kHz}$, $T_J = 25^\circ\text{C}$ | | 50 | | | 50 | | μV |
| Output voltage long-term drift | After 1000 h at $T_A = 125^\circ\text{C}$ | | 5 | 25 | | 5 | 25 | mV |
| Short-circuit output current | | -30 | -100 | -180 | -30 | -100 | -180 | mA |

oscillator section

| PARAMETER | TEST CONDITIONS | UC284__ | | | UC384__ | | | UNIT |
|--------------------------------------|---|---------|------------------|-----|---------|------------------|-----|------|
| | | MIN | TYP [†] | MAX | MIN | TYP [†] | MAX | |
| Oscillator frequency (see Note 4) | $T_J = 25^\circ\text{C}$ | 47 | 52 | 57 | 47 | 52 | 57 | kHz |
| Frequency change with supply voltage | $V_{CC} = 12\text{ V to }25\text{ V}$ | | 0.2% | 1% | | 0.2% | 1% | |
| Frequency change with temperature | $T_A = T_{\text{MIN to }T_{\text{MAX}}$ | | 5% | | | 5% | | |
| Peak-to-peak amplitude at RT/CT | | | 1.7 | | | 1.7 | | V |

error amplifier section

| PARAMETER | TEST CONDITIONS | UC284__ | | | UC384__ | | | UNIT |
|---------------------------------|--|---------|------------------|------|---------|------------------|------|---------------|
| | | MIN | TYP [†] | MAX | MIN | TYP [†] | MAX | |
| Feedback input voltage | COMP at 2.5 V | 2.45 | 2.50 | 2.55 | 2.42 | 2.50 | 2.58 | V |
| Input bias current | | | -0.3 | -1 | | -0.3 | -2 | μA |
| Open-loop voltage amplification | $V_O = 2\text{ V to }4\text{ V}$ | | 65 | 90 | | 65 | 90 | dB |
| Gain-bandwidth product | | | 0.7 | 1 | | 0.7 | 1 | MHz |
| Supply voltage rejection ratio | $V_{CC} = 12\text{ V to }25\text{ V}$ | | 60 | 70 | | 60 | 70 | dB |
| Output sink current | VFB at 2.7 V, COMP at 1.1 V | | 2 | 6 | | 2 | 6 | mA |
| Output source current | VFB at 2.3 V, COMP at 5 V | | -0.5 | -0.8 | | -0.5 | -0.8 | mA |
| High-level output voltage | VFB at 2.3 V, $R_L = 15\text{ k}\Omega$ to GND | | 5 | 6 | | 5 | 6 | V |
| Low-level output voltage | VFB at 2.7 V, $R_L = 15\text{ k}\Omega$ to pin 8 | | 0.7 | 1.1 | | 0.7 | 1.1 | V |

[†]All typical values are at $T_J = 25^\circ\text{C}$.

NOTES: 3. Adjust V_{CC} above the start threshold before setting it to 15 V.

4. Output frequency equals oscillator frequency for the UC__842 and UC__843. Output frequency is one-half oscillator frequency for the UC__844 and UC__845.

UC2842, UC2843, UC2844, UC2845
UC3842, UC3843, UC3844, UC3845
CURRENT-MODE PWM CONTROLLERS

electrical characteristics, $V_{CC} = 15\text{ V}$ (see Note 3), $R_T = 10\text{ k}\Omega$, $C_T = 3.3\text{ nF}$, $T_A = \text{full range}$ (unless otherwise specified) (continued)

current sense section

| PARAMETER | TEST CONDITIONS | UC284__ | | | UC384__ | | | UNIT |
|------------------------------------|--|---------|------|------|---------|------|------|---------------|
| | | MIN | TYP† | MAX | MIN | TYP† | MAX | |
| Voltage amplification | See Notes 5 and 6 | 2.85 | 3 | 3.13 | 2.85 | 3 | 3.15 | V/V |
| Current sense comparator threshold | COMP at 5 V, See Note 5 | 0.9 | 1 | 1.1 | 0.9 | 1 | 1.1 | V |
| Supply voltage rejection ratio | $V_{CC} = 12\text{ V}$ to 25 V , See Note 5 | 70 | | | 70 | | | dB |
| Input bias current | | -2 -10 | | | -2 -10 | | | μA |
| Delay time to output | | 150 300 | | | 150 300 | | | ns |

output section

| PARAMETER | TEST CONDITIONS | UC284__ | | | UC384__ | | | UNIT |
|---------------------------|--|---------|------|-----|---------|------|-----|------|
| | | MIN | TYP† | MAX | MIN | TYP† | MAX | |
| High-level output voltage | $I_{OH} = -20\text{ mA}$ | 13 | 13.5 | | 13 | 13.5 | | V |
| | $I_{OH} = -200\text{ mA}$ | 12 | 13.5 | | 12 | 13.5 | | |
| Low-level output voltage | $I_{OL} = 20\text{ mA}$ | | 0.1 | 0.4 | | 0.1 | 0.4 | V |
| | $I_{OL} = 200\text{ mA}$ | | 1.5 | 2.2 | | 1.5 | 2.2 | |
| Rise time | $C_L = 1\text{ nF}$, $T_J = 25^\circ\text{C}$ | | 50 | 150 | | 50 | 150 | ns |
| Fall time | $C_L = 1\text{ nF}$, $T_J = 25^\circ\text{C}$ | | 50 | 150 | | 50 | 150 | ns |

undervoltage lockout section

| PARAMETER | TEST CONDITIONS | UC284__ | | | UC384__ | | | UNIT |
|--|------------------|---------|------|-----|---------|------|------|------|
| | | MIN | TYP† | MAX | MIN | TYP† | MAX | |
| Start threshold voltage | UC__842, UC__844 | 15 | 16 | 17 | 14.5 | 16 | 17.5 | V |
| | UC__843, UC__845 | 7.8 | 8.4 | 9 | 7.8 | 8.4 | 9 | |
| Minimum operating voltage after start-up | UC__842, UC__844 | 9 | 10 | 11 | 8.5 | 10 | 11.5 | V |
| | UC__843, UC__845 | 7 | 7.6 | 8.2 | 7 | 7.6 | 8.2 | |

pulse-width-modulator section

| PARAMETER | TEST CONDITIONS | UC284__ | | | UC384__ | | | UNIT |
|--------------------|------------------|---------|------|------|---------|------|------|------|
| | | MIN | TYP† | MAX | MIN | TYP† | MAX | |
| Maximum duty cycle | UC__842, UC__843 | 95% | 97% | 100% | 95% | 97% | 100% | |
| | UC__844, UC__845 | 46% | 48% | 50% | 46% | 48% | 50% | |
| Minimum duty cycle | | 0 | | | 0 | | | |

supply voltage

| PARAMETER | TEST CONDITIONS | UC284__ | | | UC384__ | | | UNIT |
|--------------------------|-------------------------|---------|------|-----|---------|------|-----|------|
| | | MIN | TYP† | MAX | MIN | TYP† | MAX | |
| Start-up current | | 0.5 1 | | | 0.5 1 | | | mA |
| Operating supply current | VFB and ISENSE at 0 V | 11 17 | | | 11 17 | | | mA |
| Limiting voltage | $I_{CC} = 25\text{ mA}$ | 34 | | | 34 | | | V |

†All typical values are at $T_J = 25^\circ\text{C}$.

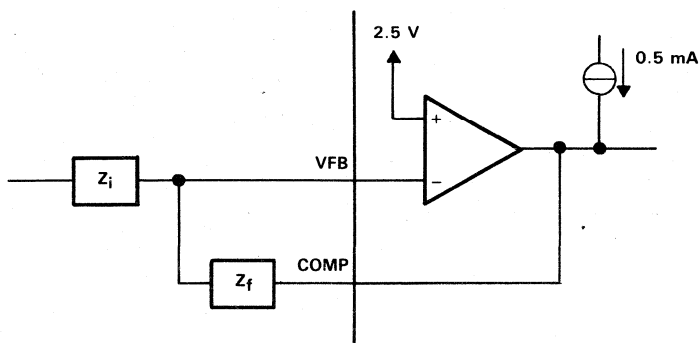
NOTES: 3. Adjust V_{CC} above the start threshold before setting it to 15 V.

5. These parameters are measured at the trip point of the latch with VFB at 0 V.

6. Voltage amplification is measured between the input at ISENSE and the output at COMP with the input changing from 0 V to 0.8 V.

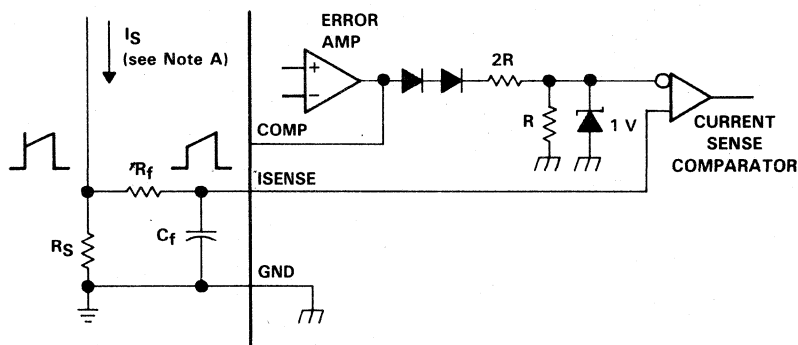


APPLICATION INFORMATION



Note: Error amplifier can source or sink up to 0.5 mA

Figure 1. Error Amplifier Configuration



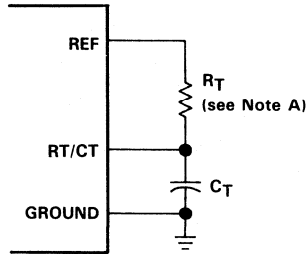
Note A: Peak current (I_S) is determined by the formula:

$$I_{Smax} \approx \frac{1 \text{ V}}{R_S}$$

A small RC filter formed by resistor R_f and capacitor C_f may be required to suppress switch transients.

Figure 2. Current Sense Circuit

APPLICATION INFORMATION



Note A: For $R_T > 5 \text{ k}\Omega$ $f \approx \frac{1.72}{R_T C_T}$

Figure 3. Oscillator Section

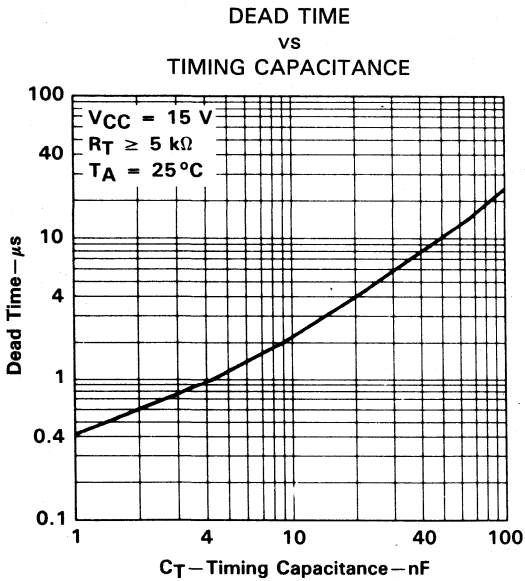


Figure 4

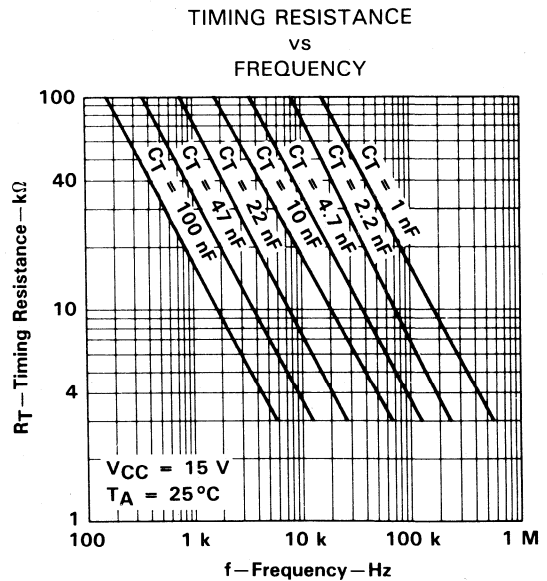


Figure 5

APPLICATION INFORMATION

open-loop laboratory test fixture

In the open-loop laboratory test fixture shown in Figure 6, high-peak currents associated with loads necessitate careful grounding techniques. Timing and bypass capacitors should be connected close to the GND terminal in a single point ground. The transistor and 5-k Ω potentiometer are used to sample the oscillator waveform and apply an adjustable ramp to the ISENSE terminal.

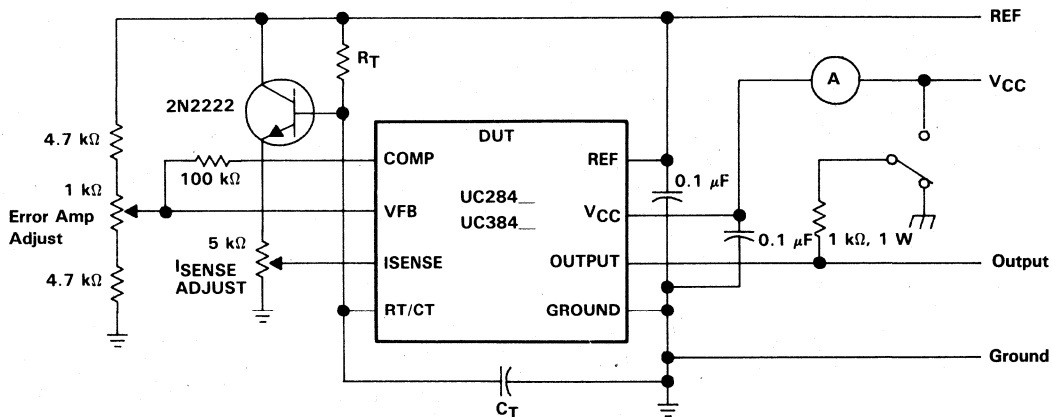


Figure 6. Open-Loop Laboratory Test Fixture

shutdown technique

Shutdown of the PWM controller (see Figure 7) can be accomplished by two methods: either raise the voltage at ISENSE above 1 V or pull the COMP terminal below a voltage two diode drops above ground. Either method causes the output of the PWM comparator to be high (refer to block diagram). The PWM latch is reset dominant so that the output will remain low until the next clock cycle after the shutdown condition at the COMP or ISENSE terminal is removed. In one example, an externally latched shutdown may be accomplished by adding an SCR that will be reset by cycling V_{CC} below the lower UVLO threshold. At this point the reference turns off, allowing the SCR to reset.

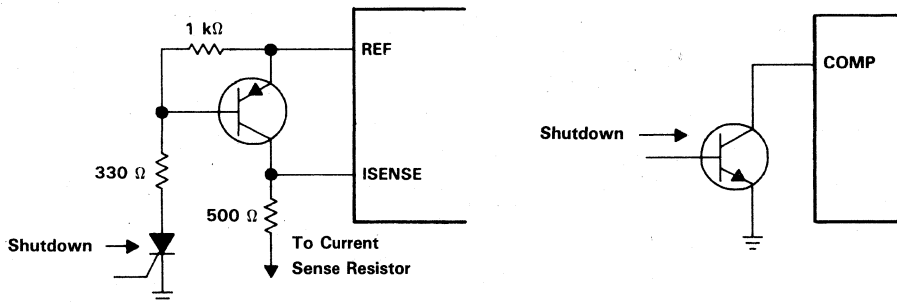


Figure 7. Shutdown Techniques

APPLICATION INFORMATION

A fraction of the oscillator ramp can be resistively summed with the current sense signal to provide slope compensation for converters requiring duty cycles over 50% (see Figure 8). Note that capacitor C forms a filter with R2 to suppress the leading-edge spikes.

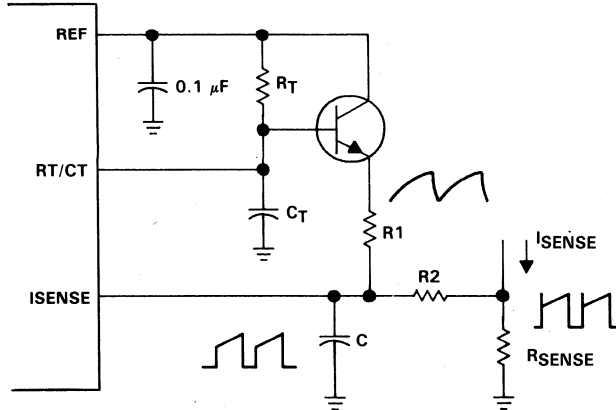


Figure 8. Slope Compensation

| | |
|--|----------|
| General Information | 1 |
| VRegs/Supervisors and Bldg Blocks | 2 |
| Comparators | 3 |
| Special Functions | 4 |
| Thermal Design Considerations | 5 |
| Mechanical Data | 6 |



Comparators

LM111, LM211, LM311, LM311Y DIFFERENTIAL COMPARATORS WITH STROBES

D1312, SEPTEMBER 1973—REVISED FEBRUARY 1992

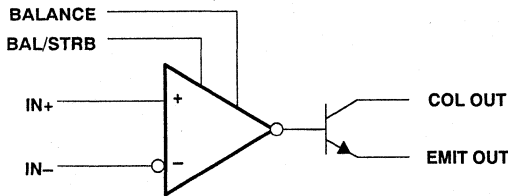
- **Fast Response Times**
- **Strobe Capability**
- **Maximum Input Bias Current . . . 300 nA**
- **Maximum Input Offset Current . . . 70 nA**
- **Can Operate From Single 5-V Supply**
- **Designed to Be Interchangeable With National Semiconductor LM111, LM211, and LM311**

description

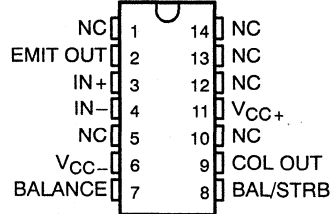
The LM111, LM211, and LM311 are single high-speed voltage comparators. These devices are designed to operate from a wide range of power supply voltages, including ± 15 -V supplies for operational amplifiers and 5-V supplies for logic systems. The output levels are compatible with most TTL and MOS circuits. These comparators are capable of driving lamps or relays and switching voltages up to 50 V at 50 mA. All inputs and outputs can be isolated from system ground. The outputs can drive loads referenced to ground, V_{CC+} or V_{CC-} . Offset balancing and strobe capabilities are available, and the outputs can be wire-OR connected. If the strobe is low, the output will be in the off state regardless of the differential input.

The LM111 is characterized for operation over the full military range of -55°C to 125°C . The LM211 is characterized for operation from -40°C to 85°C , and the LM311 is characterized for operation from 0°C to 70°C .

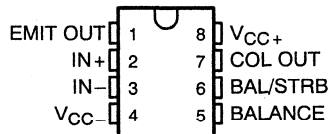
functional block diagram



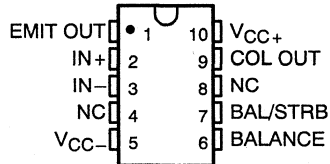
LM111 . . . J PACKAGE
(TOP VIEW)



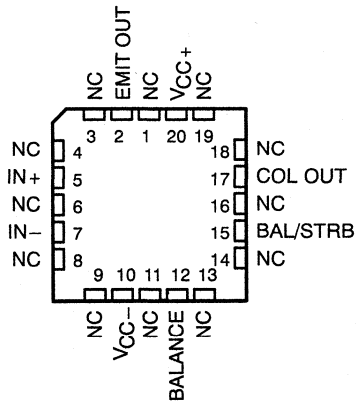
LM111 . . . JG PACKAGE
LM211, LM311 . . . D, DB, P, OR PW PACKAGE
(TOP VIEW)



LM111 . . . U PACKAGE
(TOP VIEW)



LM111 . . . FK PACKAGE
(TOP VIEW)



NC—No internal connection

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

**TEXAS
INSTRUMENTS**

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LM111, LM211, LM311, LM311Y DIFFERENTIAL COMPARATORS WITH STROBES

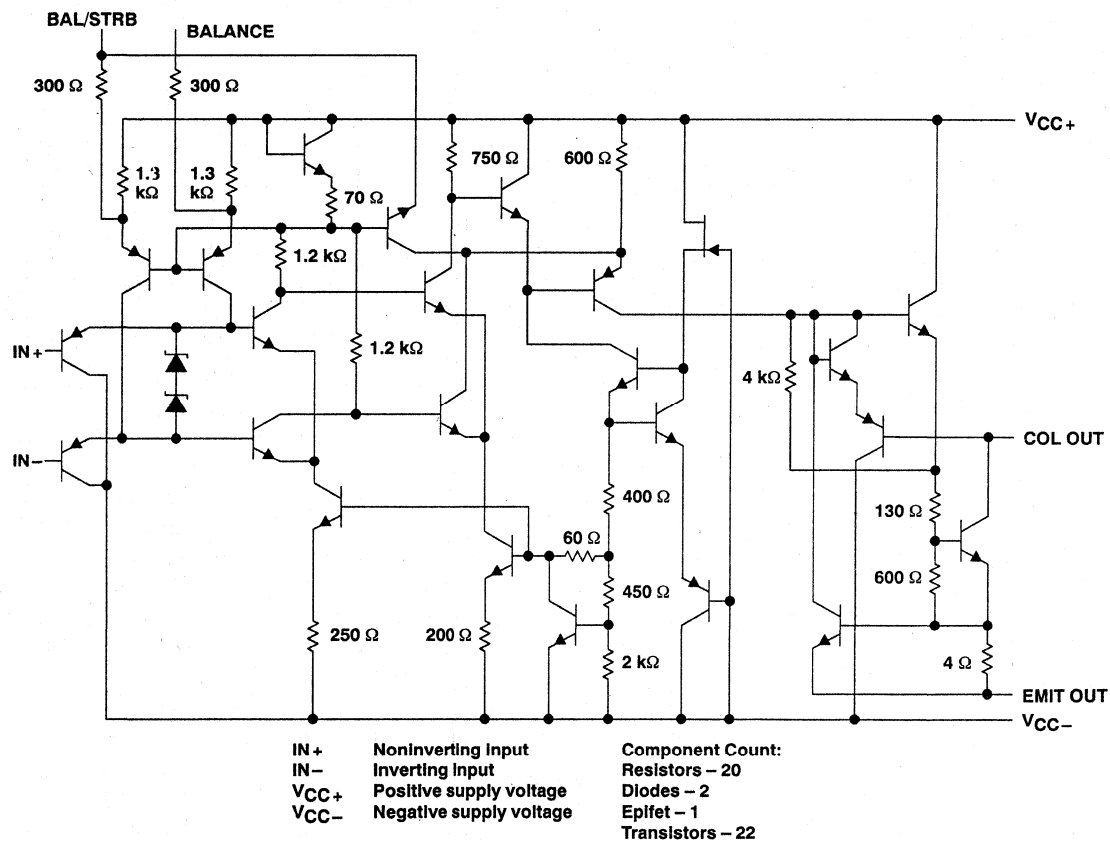
AVAILABLE OPTIONS

| T _A | V _{IO} max at 25°C | PACKAGE | | | | | | | | |
|----------------|-----------------------------|--------------------------------|-----------|-------------------|-----------------|------------------|-----------------|------------|--------------|----------------------------|
| | | SMALL OUTLINE (D) [†] | SSOP (DB) | CHIP CARRIER (FK) | CERAMIC DIP (J) | CERAMIC DIP (JG) | PLASTIC DIP (P) | TSSOP (PW) | FLATPACK (U) | CHIP FORM (Y) [‡] |
| 0°C to 70°C | 7.5 mV | LM311D | LM311DBLE | | | | LM311P | LM311PWLE | | LM311Y |
| -40°C to 85°C | 3 mV | LM211D | | | | | LM211P | | | |
| -55°C to 125°C | 3 mV | | | LM111FK | LM111J | LM111JG | | | LM111U | |

[†] The D package is available taped and reeled. Add the suffix R (e.g., LM311DR). The DB and PW packages are only available left-end taped and reeled.

[‡] Chips are tested at 25°C.

schematic



All resistor values shown are nominal.

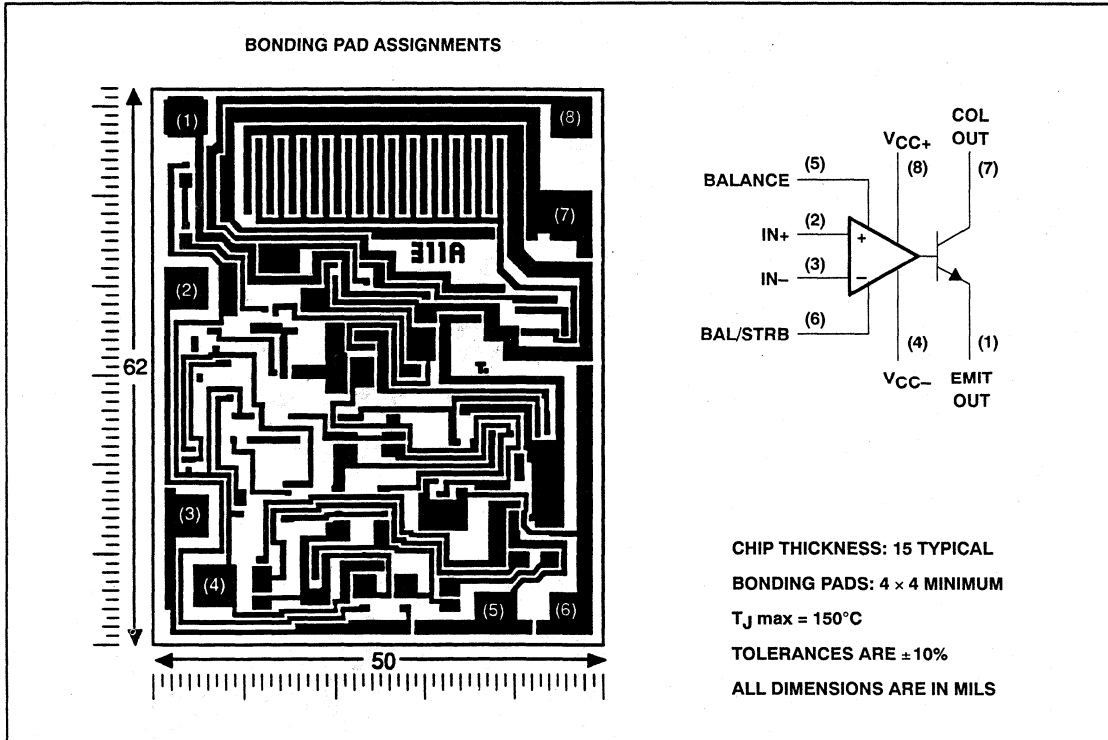
TEXAS
INSTRUMENTS

POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

LM311Y DIFFERENTIAL COMPARATOR WITH STROBES

chip information

These chips, properly assembled, display characteristics similar to the LM311 (see electrical table). Thermal compression or ultrasonic bonding may be used on the doped aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



LM111, LM211, LM311 DIFFERENTIAL COMPARATORS WITH STROBES

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|------------------------------|
| Supply voltage, V_{CC+} , (see Note 1) | 18 V |
| Supply voltage, V_{CC-} , (see Note 1) | -18 V |
| Supply voltage, $V_{CC+} - V_{CC-}$ | 36 V |
| Differential input voltage (see Note 2) | ± 30 V |
| Input voltage (either input, see Notes 1 and 3) | ± 15 V |
| Voltage from emitter output to V_{CC-} | 30 V |
| Voltage from collector output to V_{CC-} : | |
| LM111 | 50 V |
| LM211 | 50 V |
| LM311 | 40 V |
| Duration of output short circuit (see Note 4) | 10 s |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range: | |
| LM111 | -55°C to 125°C |
| LM211 | -40°C to 85°C |
| LM311 | 0°C to 70°C |
| Storage temperature range | -65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: J, JG, or U package | 300°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: D, DB, P, or PW package | 260°C |

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between V_{CC+} and V_{CC-} .
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or ± 15 V, whichever is less.
 4. The output may be shorted to ground or either power supply.

DISSIPATION RATING TABLE

| PACKAGE | $T_A = 25^\circ\text{C}$ POWER RATING | DERATING FACTOR | DERATE ABOVE T_A | $T_A = 70^\circ\text{C}$ POWER RATING | $T_A = 85^\circ\text{C}$ POWER RATING | $T_A = 125^\circ\text{C}$ POWER RATING |
|----------|--|--------------------|-----------------------|--|--|---|
| D | 500 mW | 5.8 mW/°C | 64°C | 464 mW | 377 mW | - |
| DB or PW | 500 mW | 4.2 mW/°C | 31°C | 336 mW | - | - |
| FK | 500 mW | 11.0 mW/°C | 105°C | 500 mW | 500 mW | 275 mW |
| J | 500 mW | 11.0 mW/°C | 105°C | 500 mW | 500 mW | 275 mW |
| JG | 500 mW | 8.4 mW/°C | 90°C | 500 mW | 500 mW | 210 mW |
| P | 500 mW | 8.0 mW/°C | 88°C | 500 mW | 500 mW | - |
| U | 500 mW | 5.4 mW/°C | 57°C | 432 mW | 351 mW | 135 mW |

recommended operating conditions

| | MIN | MAX | UNIT |
|---|-----------------|-----------------|------|
| Supply voltage, $V_{CC+} - V_{CC-}$ | 3.5 | 30 | V |
| Input voltage ($ V_{CC\pm} \leq 15$ V) | $V_{CC-} + 0.5$ | $V_{CC+} - 1.5$ | V |
| Operating free-air temperature range, T_A | LM111 | -55 | 125 |
| | LM211 | -40 | 85 |
| | LM311 | 0 | 70 |
| | | | °C |



LM111, LM211, LM311

DIFFERENTIAL COMPARATORS WITH STROBES

electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15\text{ V}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_A^\dagger | LM111, LM211 | | | LM311 | | | UNIT | |
|--|--|--------------------------|--------------|------------------|-----|-------------|------------------|-----|---------------|--|
| | | | MIN | TYP [‡] | MAX | MIN | TYP [‡] | MAX | | |
| V_{IO} Input offset voltage | See Note 5 | 25°C | 0.7 | | | 2 | | | mV | |
| | | Full range | 4 | | | 10 | | | | |
| I_{IO} Input offset current | See Note 5 | 25°C | 4 | | | 6 | | | nA | |
| | | Full range | 20 | | | 70 | | | | |
| I_{IB} Input bias current | $V_O = 1\text{ V to }14\text{ V}$ | 25°C | 75 | | | 100 | | | nA | |
| | | Full range | 150 | | | 300 | | | | |
| $I_{IL(S)}$ Low-level strobe current (see Note 6) | $V_{(\text{strobe})} = 0.3\text{ V}, V_{ID} \leq -10\text{ mV}$ | 25°C | -3 | | | -3 | | | mA | |
| V_{ICR} Common-mode input voltage range | | Full range | 13 to -14.5 | 13.8 to -14.7 | | 13 to -14.5 | 13.8 to -14.7 | | V | |
| A_{VD} Large-signal differential voltage amplification | $V_O = 5\text{ V to }35\text{ V}, R_L = 1\text{ k}\Omega$ | 25°C | 40 | 200 | | 40 | 200 | | V/mV | |
| I_{OH} High-level (collector) output current | $I_{\text{strobe}} = -3\text{ mA}, V_{ID} = 5\text{ mV}, V_{OH} = 35\text{ V}$ | 25°C | 0.2 | | | 10 | | | nA | |
| | | Full range | 0.5 | | | 50 | | | μA | |
| | | 25°C | 0.2 | | | 50 | | | nA | |
| V_{OL} Low-level (collector-to-emitter) output voltage | $I_{OL} = 50\text{ mA}$ | $V_{ID} = -5\text{ mV}$ | 0.75 | | | 1.5 | | | V | |
| | | $V_{ID} = -10\text{ mV}$ | 0.75 | | | 1.5 | | | | |
| | $V_{CC+} = 4.5\text{ V}, V_{CC-} = 0, I_{OL} = 8\text{ mA}$ | $V_{ID} = -6\text{ mV}$ | Full range | 0.23 | | | 0.4 | | | |
| | | $V_{ID} = -10\text{ mV}$ | Full range | 0.23 | | | 0.4 | | | |
| I_{CC+} Supply current from V_{CC+} , output low | $V_{ID} = -10\text{ mV},$ No load | 25°C | 5.1 | | | 6 | | | mA | |
| I_{CC-} Supply current from V_{CC-} , output high | $V_{ID} = 10\text{ mV},$ No load | 25°C | -4.1 | | | -5 | | | mA | |

[†] Unless otherwise noted, all characteristics are measured with BALANCE and BAL/STRB open and the emitter output grounded.

Full range for LM111 is -55°C to 125°C , for LM211 is -40°C to 85°C , and for LM311 is 0°C to 70°C .

[‡] All typical values are at $T_A = 25^\circ\text{C}$.

NOTES: 5. The offset voltages and offset currents given are the maximum values required to drive the collector output up to 14 V or down to 1 V with a pullup resistor of 7.5 k Ω to V_{CC+} . These parameters actually define an error band and take into account the worst-case effects of voltage gain and input impedance.

6. The strobe should not be shorted to ground; it should be current driven at -3 mA to -5 mA , see Figures 13 and 27.

switching characteristics, $V_{CC\pm} = \pm 15\text{ V}, T_A = 25^\circ\text{C}$

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|--|-----|-----|-----|------|
| Response time, low-to-high-level output | $R_C = 500\ \Omega$ to 5 V, $C_L = 5\text{ pF}$, See Note 7 | 115 | | | ns |
| Response time, high-to-low-level output | | 165 | | | ns |

NOTE 7: The response time specified is for a 100-mV input step with 5-mV overdrive and is the interval between the input step function and the instant when the output crosses 1.4 V.

LM311Y

DIFFERENTIAL COMPARATORS WITH STROBES

electrical characteristics at $V_{CC\pm} = \pm 15\text{ V}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS† | MIN | TYP | MAX | UNIT |
|--|--|-------------------|---------------------|-----|------|
| V_{IO} Input offset voltage | See Note 5 | | 2 | 7.5 | mV |
| I_{IO} Input offset current | See Note 5 | | 6 | 50 | nA |
| I_{IB} Input bias current | $V_O = 1\text{ V to } 14\text{ V}$ | | 100 | 250 | nA |
| $I_{IL(S)}$ Low-level strobe current (see Note 6) | $V_{\text{strobe}} = 0.3\text{ V}, V_{ID} \leq -10\text{ mV}$ | | -3 | | mA |
| V_{ICR} Common-mode input voltage range | | 13 to -14.5 | 13.8 to -14.7 | | V |
| A_{VD} Large-signal differential voltage amplification | $V_O = 5\text{ V to } 35\text{ V}, R_L = 1\text{ k}\Omega$ | 40 | 200 | | V/mV |
| I_{OH} High-level (collector) output current | $I_{\text{strobe}} = -3\text{ mA}, V_{ID} = 5\text{ mV}, V_{OH} = 35\text{ V}$ | | 0.2 | 50 | nA |
| V_{OL} Low-level (collector-to-emitter) output voltage | $I_{OL} = 50\text{ mA}, V_{ID} = -10\text{ mV}$ | | 0.75 | 1.5 | V |
| I_{CC+} Supply current from V_{CC+} , output low | $V_{ID} = -10\text{ mV}, \text{ No load}$ | | 5.1 | 7.5 | mA |
| I_{CC-} Supply current from V_{CC-} , output low | $V_{ID} = 10\text{ mV}, \text{ No load}$ | | -4.1 | -5 | mA |

† Unless otherwise noted, all characteristics are measured with BALANCE and BAL/STRB open and the emitter output grounded.

NOTES: 5. The offset voltages and offset currents given are the maximum values required to drive the collector output up to 14 V or down to 1 V with a pullup resistor of 7.5 k Ω to V_{CC+} . These parameters actually define an error band and take into account the worst-case effects of voltage gain and input impedance.

6. The strobe should not be shorted to ground; it should be current driven at -3 mA to -5 mA, see Figures 13 and 27.

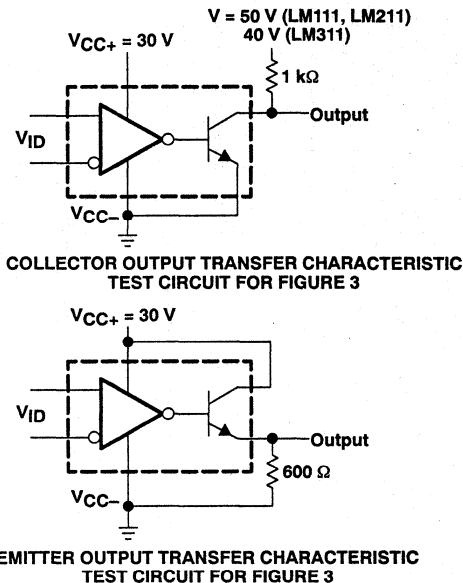
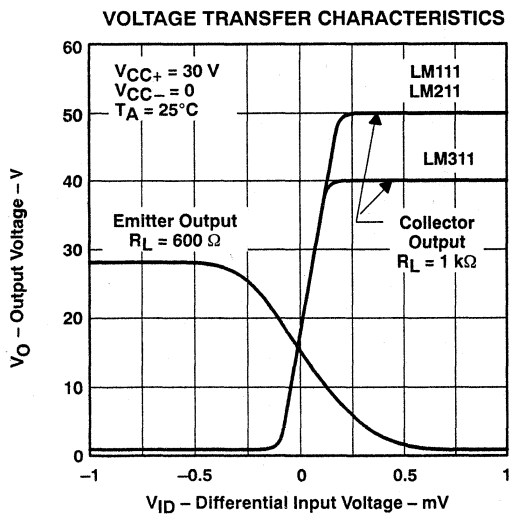
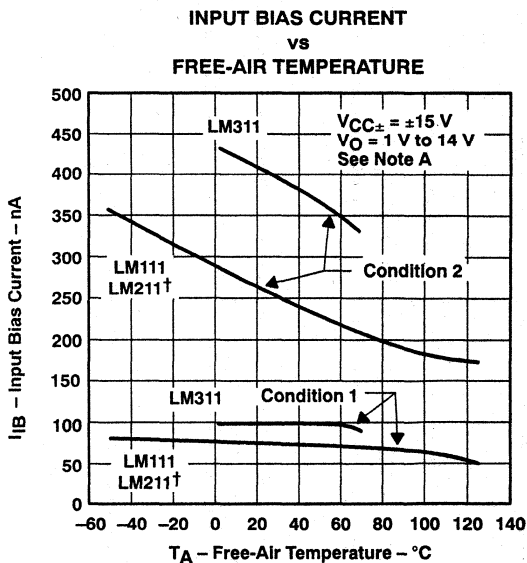
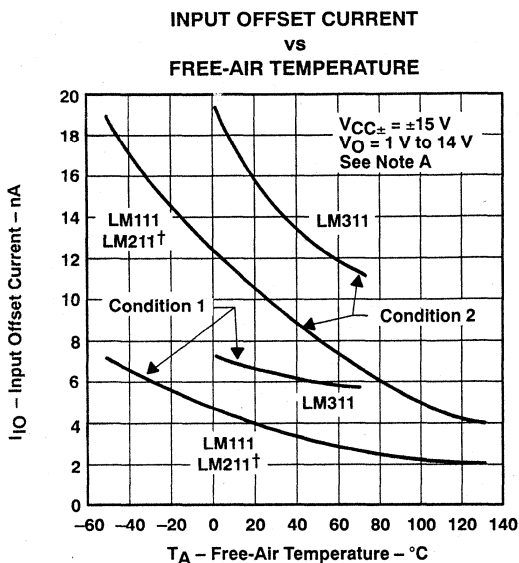
switching characteristics, $V_{CC\pm} = \pm 15\text{ V}, T_A = 25^\circ\text{C}$

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|-----|-----|-----|------|
| Response time, low-to-high-level output | $R_C = 500\ \Omega \text{ to } 5\text{ V}, C_L = 5\text{ pF}, \text{ See Note 7}$ | | 115 | | ns |
| Response time, high-to-low-level output | | | 165 | | ns |

NOTE 7: The response time specified is for a 100-mV input step with 5-mV overdrive and is the interval between the input step function and the instant when the output crosses 1.4 V.

LM111, LM211, LM311 DIFFERENTIAL COMPARATORS WITH STROBES

TYPICAL CHARACTERISTICS†



† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.
NOTE A: Condition 1 is with BALANCE and BAL/STRB open. Condition 2 is with BALANCE and BAL/STRB connected to VCC+.

TYPICAL CHARACTERISTICS

OUTPUT RESPONSE FOR
VARIOUS INPUT OVERDRIVES

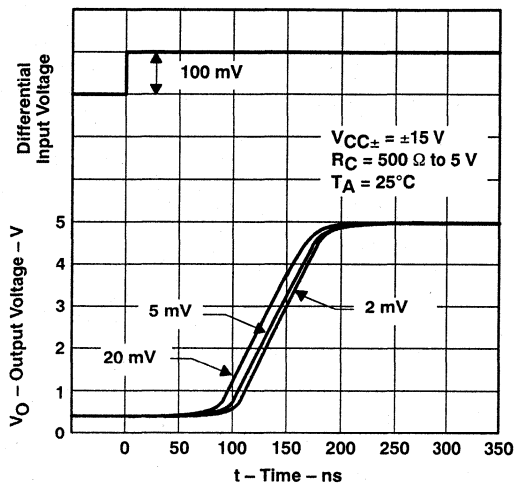


Figure 4

OUTPUT RESPONSE FOR
VARIOUS INPUT OVERDRIVES

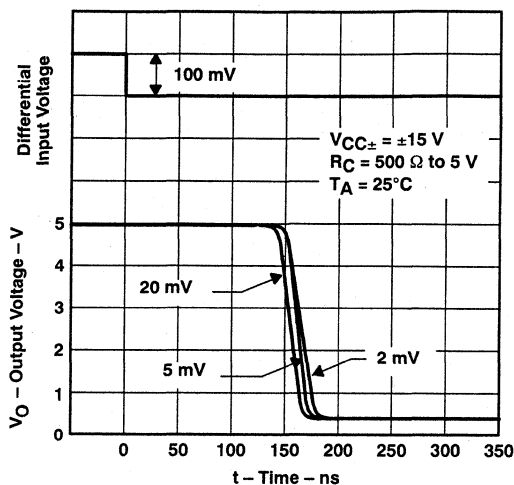
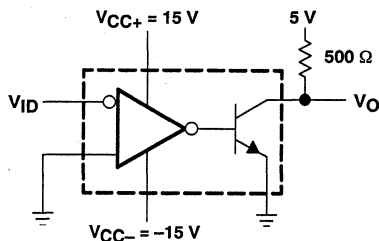


Figure 5



TEST CIRCUIT FOR FIGURES 4 AND 5

TYPICAL CHARACTERISTICS

OUTPUT RESPONSE FOR
VARIOUS INPUT OVERDRIVES

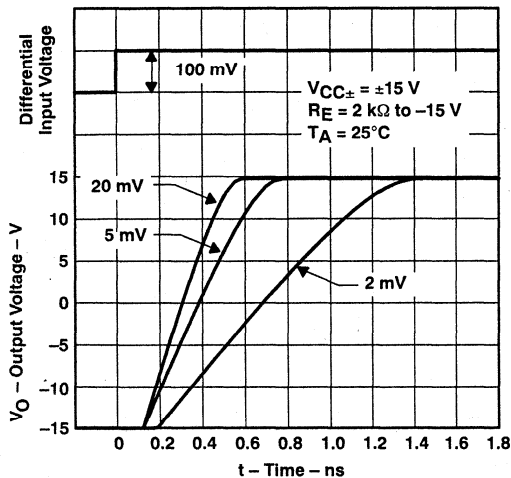


Figure 6

OUTPUT RESPONSE FOR
VARIOUS INPUT OVERDRIVES

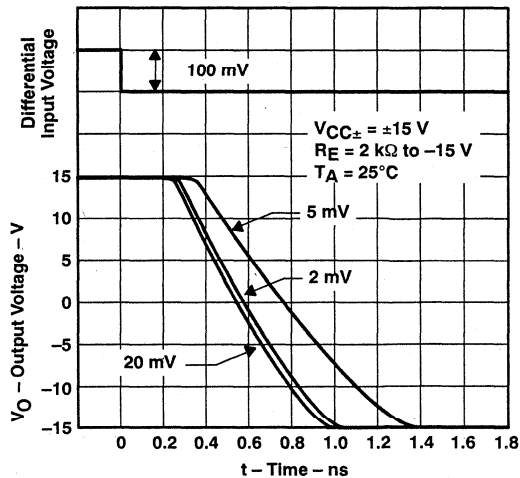
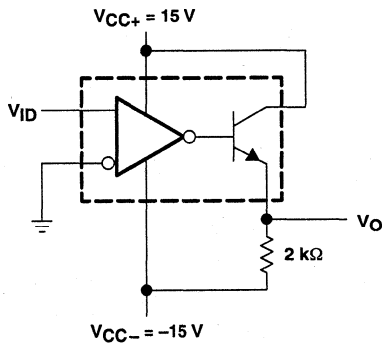


Figure 7



TEST CIRCUIT FOR FIGURES 6 AND 7

TYPICAL CHARACTERISTICS

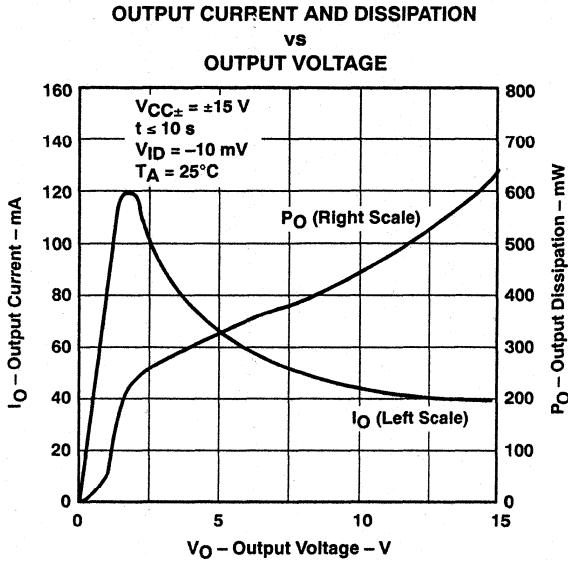


Figure 8

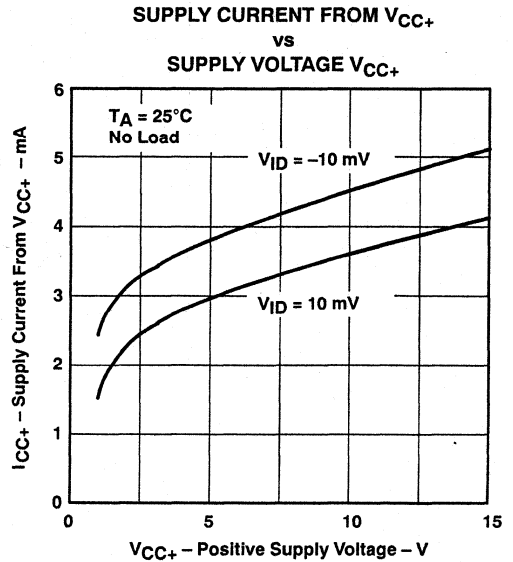


Figure 9

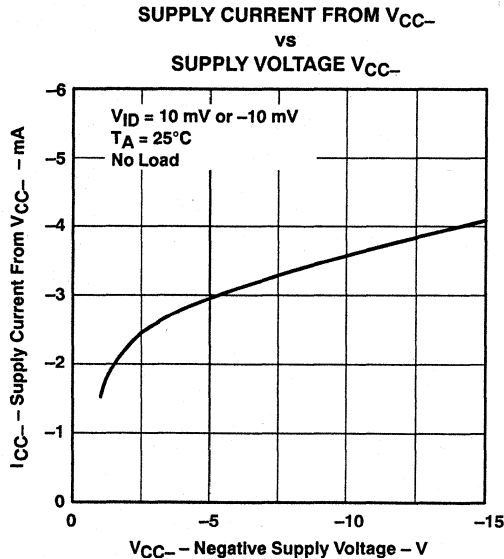


Figure 10

APPLICATION INFORMATION

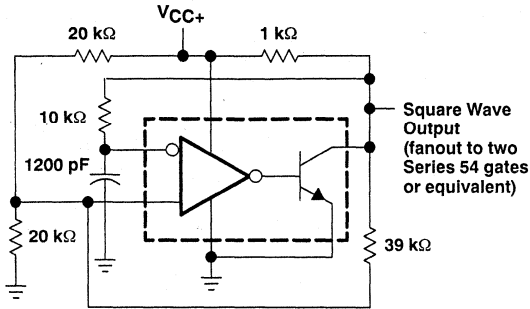


Figure 11. 100-kHz Free-Running Multivibrator

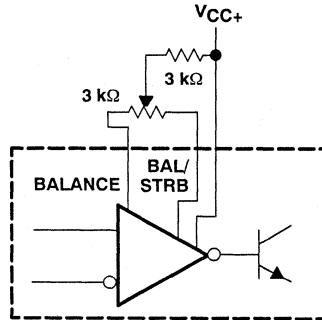


Figure 12. Offset Balancing

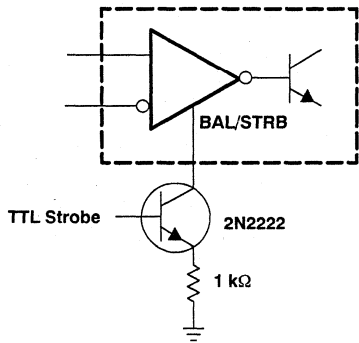


Figure 13. Strobing

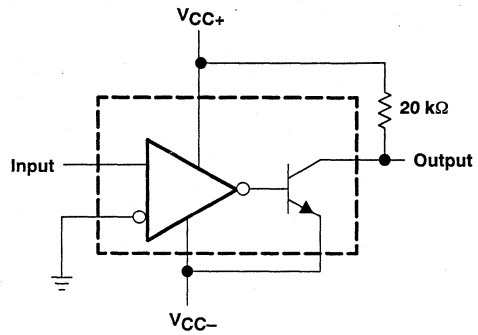
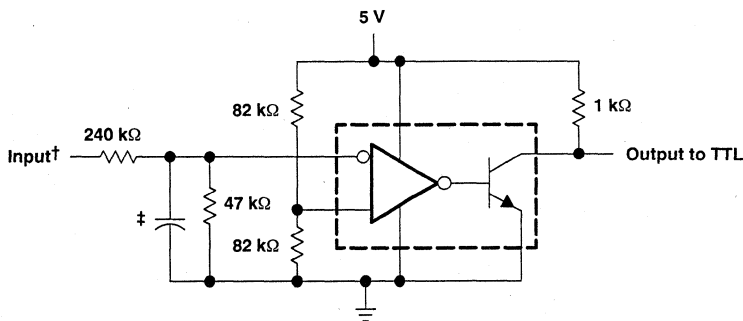


Figure 14. Zero-Crossing Detector



† Resistor values shown are for a 0-to-30-V logic swing and a 15-V threshold.
‡ May be added to control speed and reduce susceptibility to noise spikes.

Figure 15. TTL Interface With High-Level Logic

APPLICATION INFORMATION

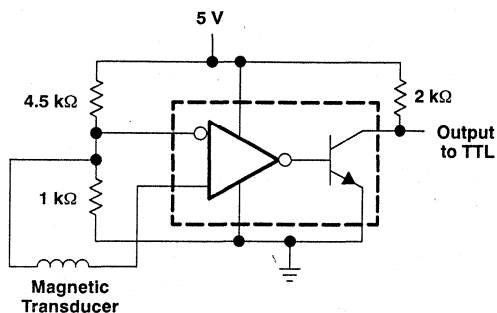


Figure 16. Detector for Magnetic Transducer

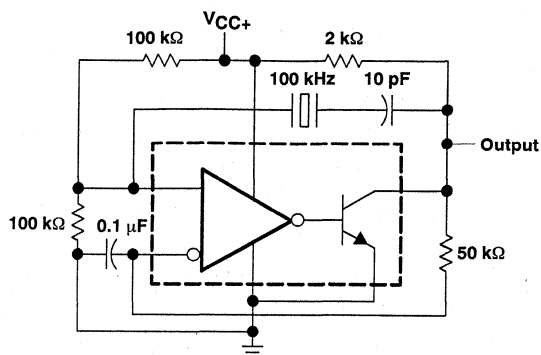


Figure 17. 100-kHz Crystal Oscillator

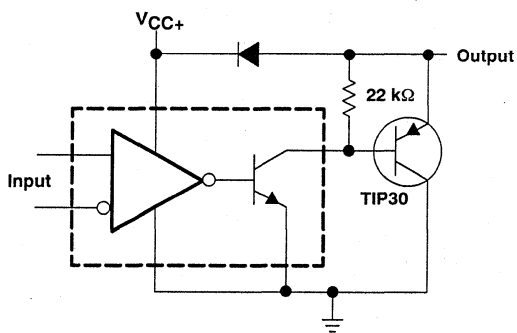
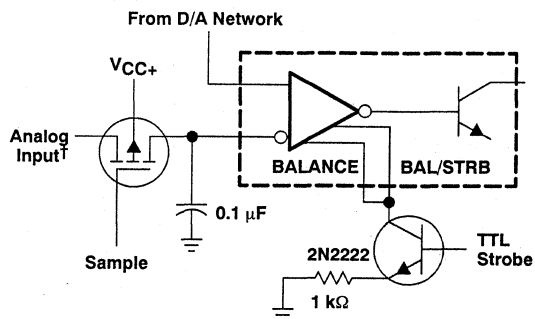


Figure 18. Comparator and Solenoid Driver



†Typical input current is 50 pA with inputs strobed off.

Figure 19. Strobing Both Input and Output Stages Simultaneously

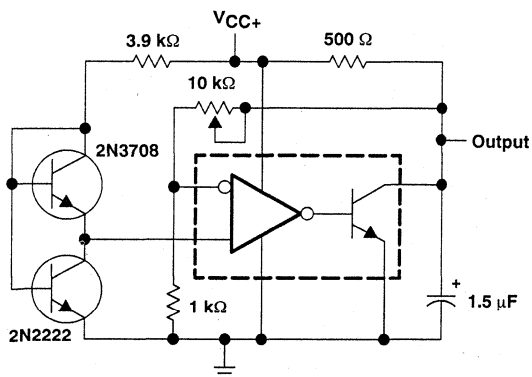


Figure 20. Low-Voltage Adjustable Reference Supply

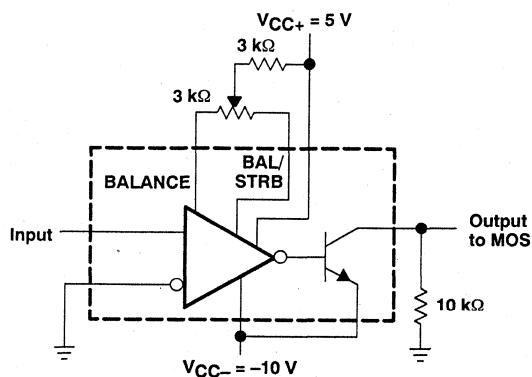


Figure 21. Zero-Crossing Detector Driving MOS Logic

APPLICATION INFORMATION

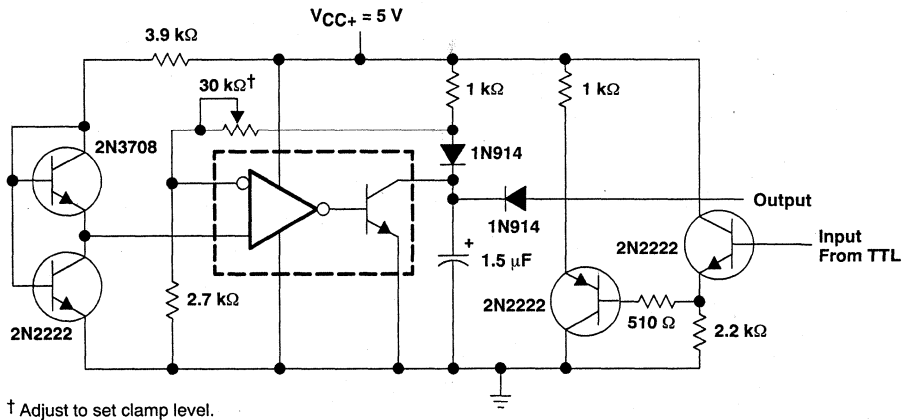


Figure 22. Precision Squarer

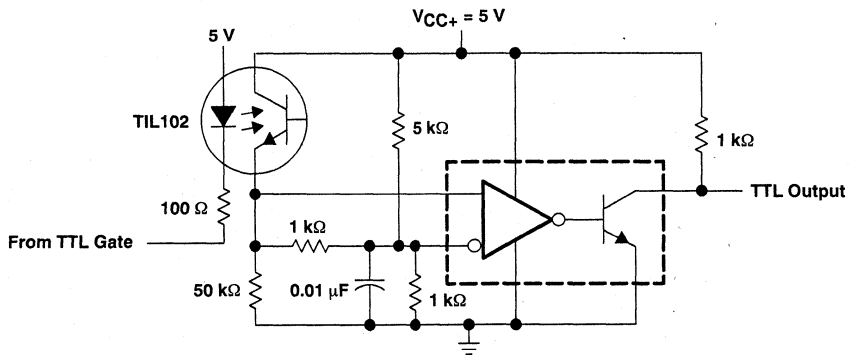


Figure 23. Digital Transmission Isolator

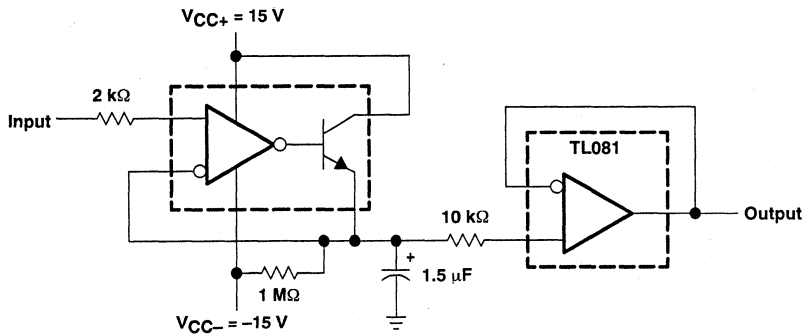


Figure 24. Positive-Peak Detector

APPLICATION INFORMATION

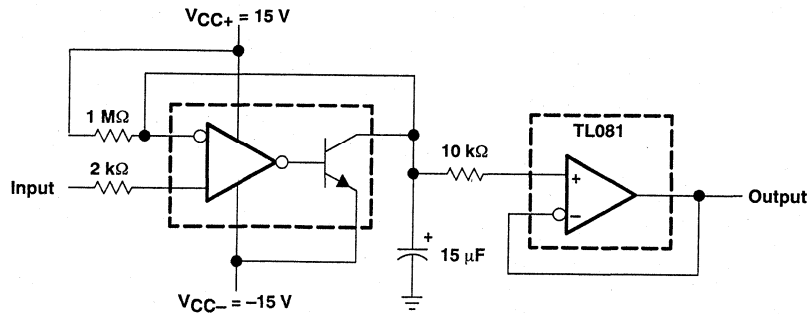
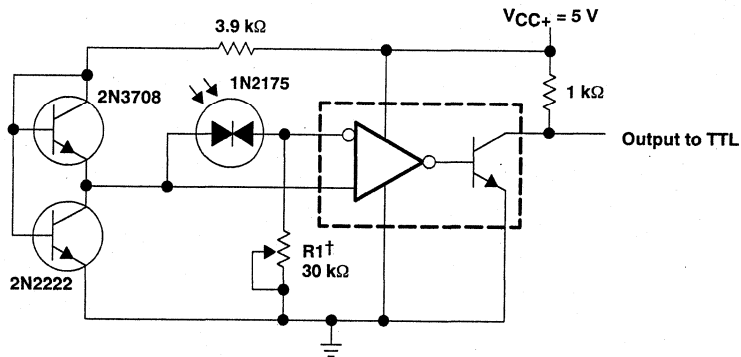
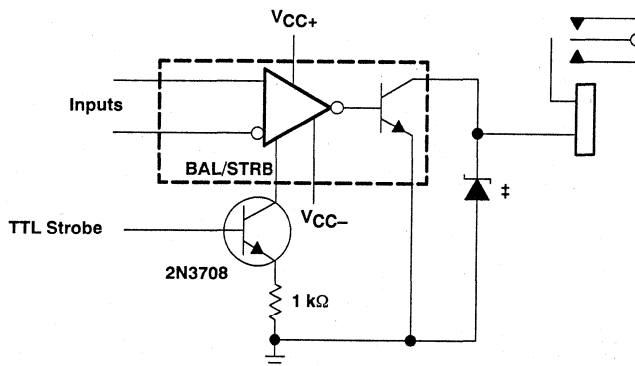


Figure 25. Negative-Peak Detector



† R1 sets the comparison level. At comparison, the photodiode has less than 5 mV across it decreasing dark current by an order of magnitude.

Figure 26. Precision Photodiode Comparator



‡ Transient voltage and inductive kickback protection

Figure 27. Relay Driver With Strobe

APPLICATION INFORMATION

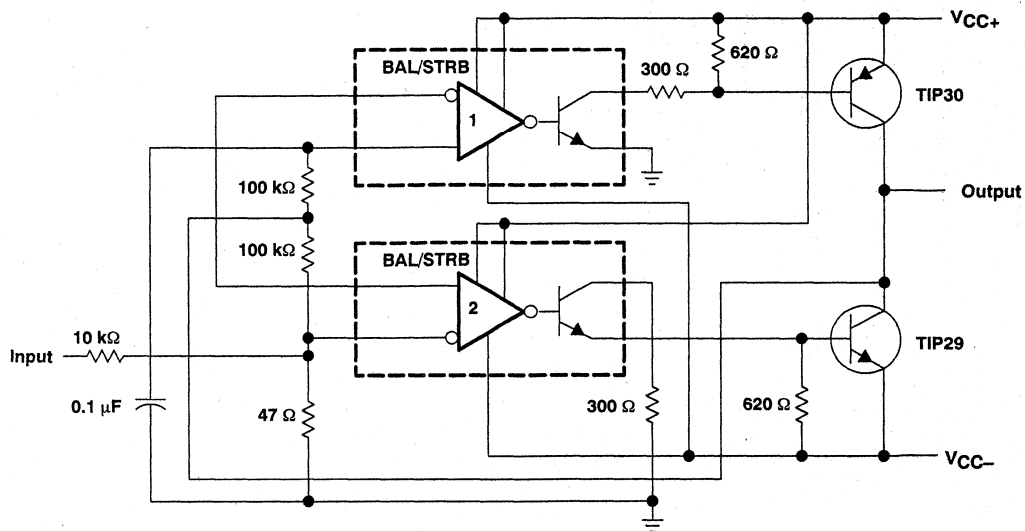


Figure 28. Switching Power Amplifier

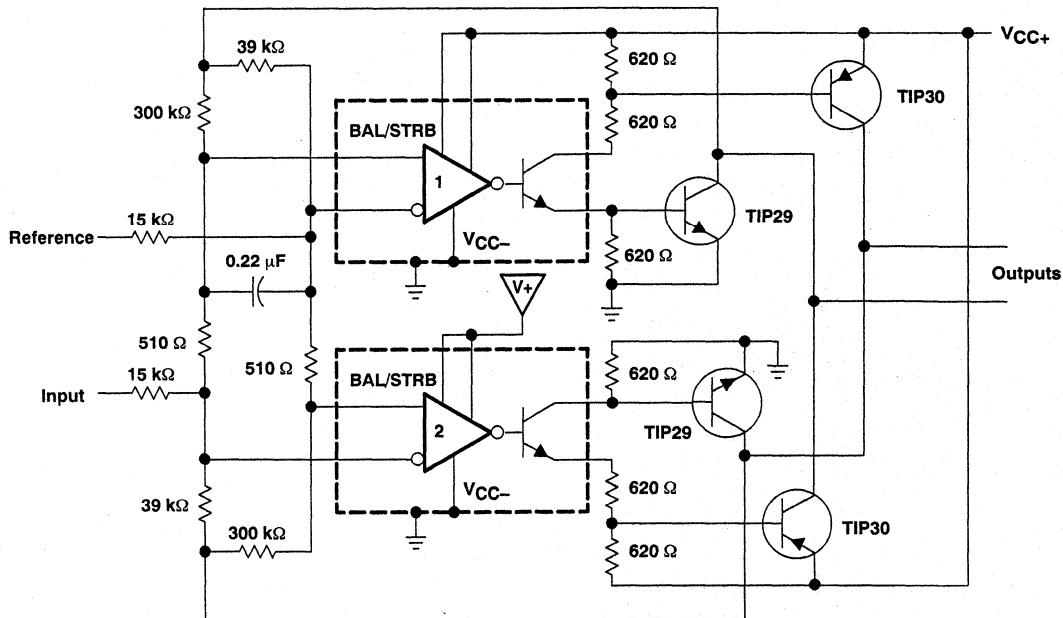


Figure 29. Switching Power Amplifiers

LM139, LM239, LM339, LM139A LM239A, LM339A, LM339Y, LM2901, LM2901Q QUADRUPLE DIFFERENTIAL COMPARATORS

D1979, OCTOBER 1979—REVISED NOVEMBER 1991

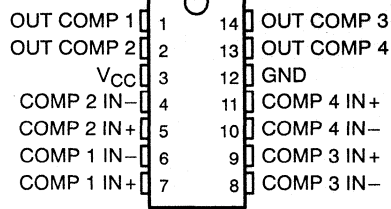
- **Single Supply or Dual Supplies**
- **Wide Range of Supply Voltage**
2 V to 36 V
- **Low Supply Current Drain Independent of Supply Voltage . . . 0.8 mA Typ**
- **Low Input Bias Current . . . 25 nA Typ**
- **Low Input Offset Current . . . 3 nA Typ (LM139)**
- **Low Input Offset Voltage . . . 2 mV Typ**
- **Common-Mode Input Voltage Range Includes Ground**
- **Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage . . . ± 36 V**
- **Low Output Saturation Voltage**
- **Output Compatible With TTL, MOS, and CMOS**

description

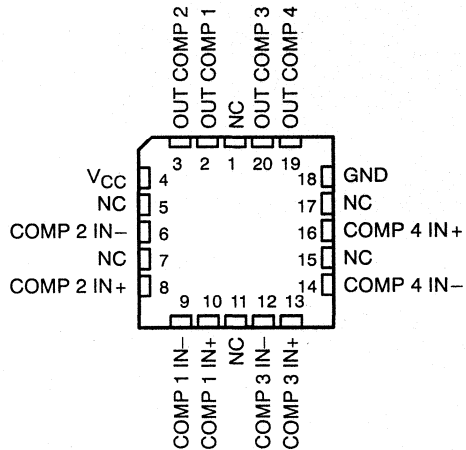
These devices consist of four independent voltage comparators that are designed to operate from a single power supply over a wide range of voltages. Operation from dual supplies is also possible as long as the difference between the two supplies is 2 V to 36 V and V_{CC} is at least 1.5 V more positive than the input common-mode voltage. Current drain is independent of the supply voltage. The outputs can be connected to other open-collector outputs to achieve wire-AND relationships.

The LM139 and LM139A are characterized for operation from -55°C to 125°C . The LM239 and LM239A are characterized for operation from -25°C to 125°C . The LM339 and LM339A are characterized for operation from 0°C to 70°C . The LM2901 and LM2901Q are characterized for operation from -40°C to 85°C .

D, DB, J, N, OR PW PACKAGE
(TOP VIEW)

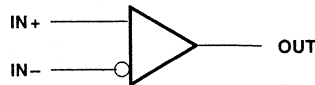


FK PACKAGE
(TOP VIEW)



NC—No internal connection

symbol (each comparator)



**LM139, LM239, LM339, LM139A
LM239A, LM339A, LM339Y, LM2901, LM2901Q
QUADRUPLE DIFFERENTIAL COMPARATORS**

AVAILABLE OPTIONS

| T _A | V _{IO} max at 25°C | PACKAGE | | | | | | CHIP FORM (V) [§] |
|-------------------|--------------------------------|-----------------------------------|---------------------------|----------------------|--------------------|---------------------|----------------------------|-------------------------------|
| | | SMALL OUTLINE (D) [†] | SSOP (DB) [‡] | CHIP CARRIER (FK) | CERAMIC DIP (J) | PLASTIC DIP (N) | TSSOP (PW) [‡] | |
| 0°C to 70°C | 5 mV 2 mV | LM339D LM339AD | LM339DBLE | | | LM339N LM339AN | LM339PWLE | LM339Y |
| -25°C to 85°C | 5 mV 2 mV | LM239D LM239AD | | | | LM239N LM239AN | | |
| -40°C to 125°C | 7 mV | LM2901D LM2901QD | LM2901DBLE | | | LM2901N LM2901QN | LM2901PWLE | |
| -55°C to 125°C | 5 mV 2 mV | LM139D LM139AD | | LM139FK LM139AFK | LM139J LM139AJ | LM139N LM139AN | | |

[†] The D package is available taped and reeled. Add the suffix R to the device type (e.g., LM339DR).

[‡] The DB and PW packages are only available left-end taped and reeled.

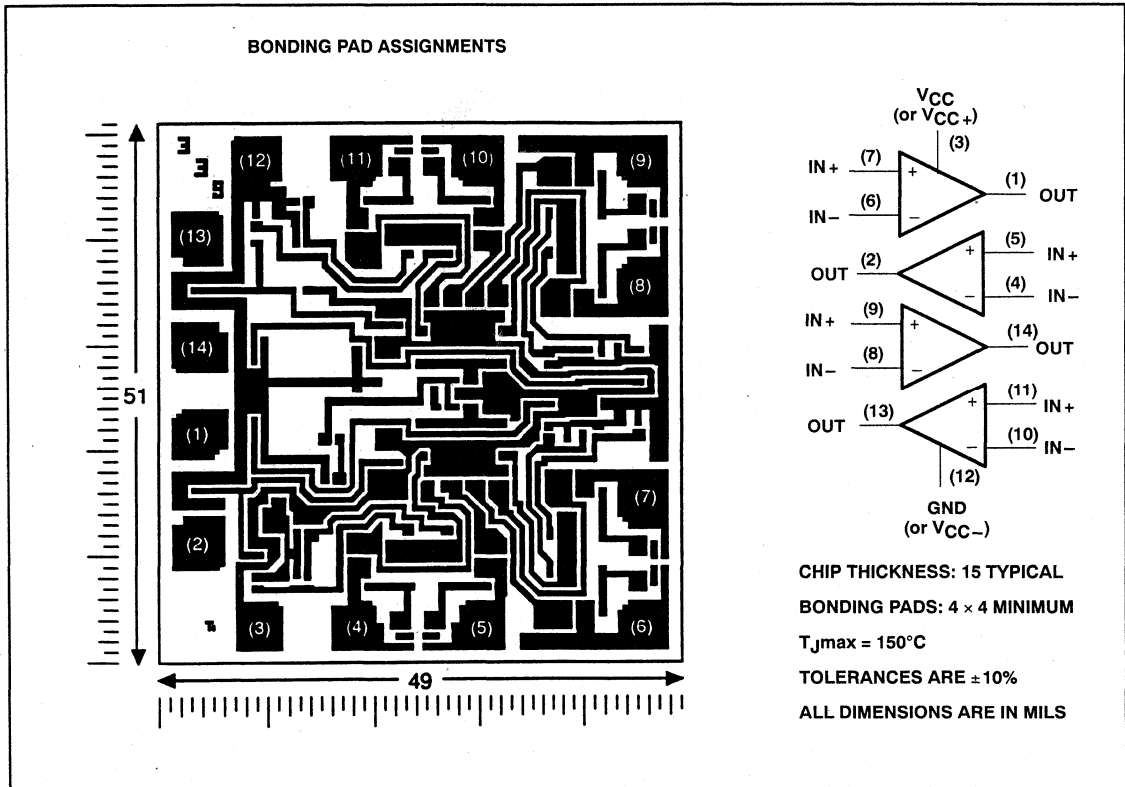
[§] Chips are tested at 25°C. See electrical characteristics.



LM339Y QUADRUPLE DIFFERENTIAL COMPARATORS

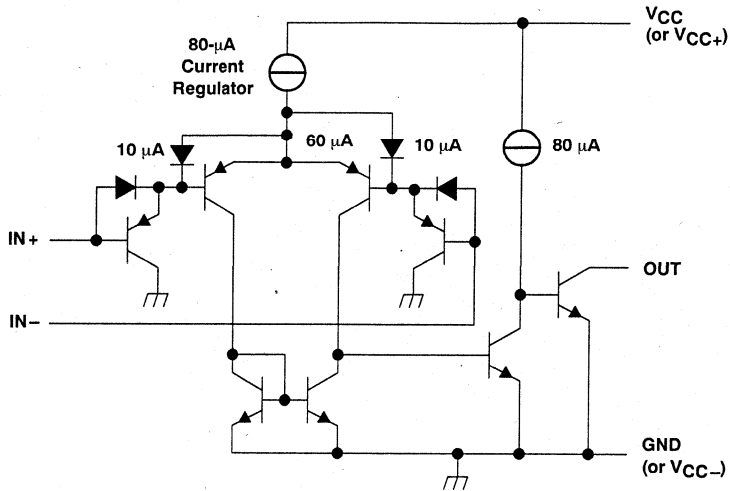
chip information

These chips, properly assembled, display characteristics similar to the LM339 (see electrical table on the LM339Y). Thermal compression or ultrasonic bonding may be used on the doped aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



**LM139, LM239, LM339, LM139A
LM239A, LM339A, LM339Y, LM2901, LM2901Q
QUADRUPLE DIFFERENTIAL COMPARATORS**

schematic (each comparator)



All current values shown are nominal.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|------------------------------|
| Supply voltage, V_{CC} (see Note 1) | 36 V |
| Differential input voltage (see Note 2) | ± 36 V |
| Input voltage range (either input) | -0.3 V to 36 V |
| Output voltage | 36 V |
| Output current | 20 mA |
| Duration of output short circuit to ground (see Note 3) | unlimited |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range: | |
| LM139, LM139A | -55°C to 125°C |
| LM239, LM239A | -25°C to 85°C |
| LM339, LM339A | 0°C to 70°C |
| LM2901, LM2901Q | -40°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D, DB, N, or PW package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package | 300°C |

- NOTES: 1. All voltage values, except differential voltages, are with respect to network ground terminal.
2. Differential voltages are at the noninverting input terminal with respect to the inverting input.
3. Short circuits from outputs to V_{CC} can cause excessive heating and eventual destruction.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR | DERATE ABOVE T_A | $T_A = 70^\circ\text{C}$ POWER RATING | $T_A = 85^\circ\text{C}$ POWER RATING | $T_A = 125^\circ\text{C}$ POWER RATING |
|---------|---|--------------------|-----------------------|--|--|---|
| D | 900 mW | 7.6 mW/°C | 31°C | 608 mW | 494 mW | — |
| DB | 775 mW | 6.2 mW/°C | 25°C | 496 mW | 403 mW | 155 mW |
| FK | 900 mW | 11.0 mW/°C | 68°C | 880 mW | 715 mW | 275 mW |
| J | 900 mW | 11.0 mW/°C | 68°C | 880 mW | 715 mW | 275 mW |
| N | 900 mW | 9.2 mW/°C | 52°C | 736 mW | 598 mW | — |
| PW | 700 mW | 5.6 mW/°C | 25°C | 448 mW | 364 mW | 140 mW |



electrical characteristics at specified free-air temperature, $V_{CC} = 5\text{ V}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS† | LM139 | | LM139A | | UNIT |
|---|--|-------------------|------|-------------------|------|------|
| | | MIN | TYP‡ | MAX | MIN | |
| V_{IO} Input offset voltage | $V_{CC} = 5\text{ V}$ to 30 V , $V_{IC} = V_{ICRmin}$, $V_O = 1.4\text{ V}$ | | | | | |
| | 25°C | 2 | 5 | 1 | 2 | mV |
| I_{IO} Input offset current | $V_O = 1.4\text{ V}$ | | | | | |
| | 25°C to 125°C | 3 | 25 | 3 | 25 | nA |
| I_{IB} Input bias current | $V_O = 1.4\text{ V}$ | | | | | |
| | 25°C to 125°C | -25 | -100 | -25 | -100 | nA |
| V_{ICR} Common-mode input voltage range | | | | | | |
| | 25°C | 0 to $V_{CC}-1.5$ | | 0 to $V_{CC}-1.5$ | | V |
| V_{AVD} Large-signal differential voltage amplification | $V_{CC} \pm 7.5\text{ V}$, $V_O = -5\text{ V}$ to 5 V | | | | | |
| | 25°C | 200 | 200 | 50 | 200 | V/mV |
| I_{OH} High-level output current | $V_{OH} = 5\text{ V}$ | | | | | |
| | 25°C | 0.1 | 0.1 | 0.1 | 0.1 | nA |
| V_{OL} Low-level output voltage | $V_{ID} = 1\text{ V}$ | | | | | |
| | 25°C to 125°C | 150 | 400 | 150 | 400 | mV |
| I_{OL} Low-level output current | $V_{ID} = -1\text{ V}$, $I_{OL} = 4\text{ mA}$ | | | | | |
| | 25°C to 125°C | 6 | 700 | 6 | 700 | mA |
| I_{CC} Supply current (four comparators) | $V_{ID} = -1\text{ V}$, $V_{OL} = 1.5\text{ V}$ | | | | | |
| | 25°C | 6 | 16 | 6 | 16 | mA |
| | $V_O = 2.5\text{ V}$, No load | | | | | |
| | 25°C | 0.8 | 2 | 0.8 | 2 | mA |

† All characteristics are measured with zero common-mode input voltage unless otherwise specified.

‡ All typical values measured at $T_A = 25^\circ\text{C}$.

switching characteristics, $V_{CC} = 5\text{ V}$, $T_A = 25^\circ\text{C}$

| PARAMETER | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---------------|---|---|-----|-----|-----|---------------|
| | R_L connected to 5 V through 5.1 k Ω , $C_L = 15\text{ pF}$, See Note 4 | 100-mV input step with 5-mV overdrive TTL-level input step | | | | |
| Response time | | | | 1.3 | | μs |

§ C_L includes probe and jig capacitance.

NOTE 4: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.

LM239, LM339, LM239A, LM339A, LM2901, LM2901Q QUADRUPLE DIFFERENTIAL COMPARATORS

electrical characteristics at specified free-air temperature, $V_{CC} = 5\text{ V}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS† | LM239, LM339 | | | LM239A, LM339A | | | LM2901, LM2901Q | | | UNIT |
|-----------|---|----------------------|------|------|----------------------|------|----------------------|-----------------|------|-----|---------------|
| | | MIN | TYP‡ | MAX | MIN | TYP‡ | MAX | MIN | TYP‡ | MAX | |
| V_{IO} | $V_{CC} = 5\text{ V to }30\text{ V}$, $V_{IC} = V_{ICRmin}$, $V_O = 1.4\text{ V}$ | 2 | 5 | 2 | 1 | 2 | 2 | 7 | | | |
| I_{IO} | $V_O = 1.4\text{ V}$ | 5 | 50 | 9 | 5 | 50 | 5 | 50 | 15 | | mV |
| I_{IB} | $V_O = 1.4\text{ V}$ | -25 | -250 | -400 | -25 | -250 | -25 | -250 | -250 | | nA |
| V_{ICR} | Common-mode input voltage range | 0 to $V_{CC}-1.5$ | | | 0 to $V_{CC}-1.5$ | | 0 to $V_{CC}-1.5$ | | | | V |
| A_{VD} | Large-signal differential voltage amplification | 50 | 200 | | 50 | 200 | 25 | 100 | | | V/mV |
| I_{OH} | High-level output current | 0.1 | 50 | 1 | 0.1 | 50 | 0.1 | 50 | 50 | | nA |
| I_{OL} | Low-level output current | 150 | 400 | 700 | 150 | 400 | 150 | 400 | 150 | 500 | μA |
| I_{CC} | Supply current (four comparators) | 6 | 16 | 2 | 6 | 16 | 6 | 16 | 6 | 16 | mA |

† Full range (MIN to MAX) for LM239 and LM239A is -25°C to 85°C , for LM339 and LM339A is 0°C to 70°C , and for LM2901 is -40°C to 125°C . All characteristics are measured with zero common-mode input voltage unless otherwise specified.

‡ All typical values measured at $T_A = 25^\circ\text{C}$.

switching characteristics, $V_{CC} = 5\text{ V}$, $T_A = 25^\circ\text{C}$

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-----------|-----------------|-----|-----|-----|------|
| | | | | | |

§ C_L includes probe and jig capacitance.

NOTE 4: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.

LM339Y QUADRUPLE DIFFERENTIAL COMPARATOR

electrical characteristics at $V_{CC} = 5\text{ V}$, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS† | MIN | TYP | MAX | UNIT |
|--|--|----------------------|-----|------|------|
| V_{IO} Input offset voltage | $V_{CC} = 5\text{ V to } 30\text{ V}$, $V_O = 1.4\text{ V}$, $V_{IC} = V_{ICRmin}$, | | 2 | 5 | mV |
| I_{IO} Input offset current | $V_O = 1.4\text{ V}$ | | 5 | 50 | nA |
| I_{IB} Input bias current | $V_O = 1.4\text{ V}$ | | -25 | -250 | nA |
| V_{ICR} Common-mode input voltage range | | 0 to $V_{CC}-1.5$ | | | V |
| A_{VD} Large-signal differential voltage amplification | $V_{CC} = 15\text{ V}$, $R_L \geq 15\text{ k}\Omega$ to V_{CC} , $V_O = 1.4\text{ V to } 11.4\text{ V}$, | 25 | 100 | | V/mV |
| I_{OH} High-level output current | $V_{ID} = 1\text{ V}$, $V_{OH} = 5\text{ V}$ | | 0.1 | 50 | nA |
| V_{OL} Low-level output voltage | $V_{ID} = -1\text{ V}$, $I_{OL} = 4\text{ mA}$ | | 150 | 400 | mV |
| I_{OL} Low-level output current | $V_{ID} = -1\text{ V}$, $V_{OL} = 1.5\text{ V}$ | 6 | 16 | | mA |
| I_{CC} Supply current (four comparators) | $V_O = 2.5\text{ V}$, No load | | 0.8 | 2 | mA |
| | $V_O = 30\text{ V}$, No load | | 1 | 2.5 | mA |

† All characteristics are measured with zero common-mode input voltage unless otherwise specified.

switching characteristics, $V_{CC} = 5\text{ V}$, $T_A = 25^\circ\text{C}$

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---------------|---|---------------------------------------|-----|-----|------|
| Response time | R_L connected to 5 V through 5.1 k Ω , $C_L = 15\text{ pF}$ †, See Note 4 | 100-mV input step with 5-mV overdrive | | 1.3 | ns |
| | TTL1-level input step | | 0.3 | | |

† C_L includes probe and jig capacitance.

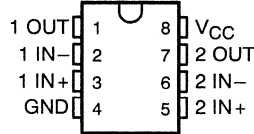
NOTE 4: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.

LM193, LM293, LM393, LM293A LM393A, LM393Y, LM2903, LM2903Q DUAL DIFFERENTIAL COMPARATORS

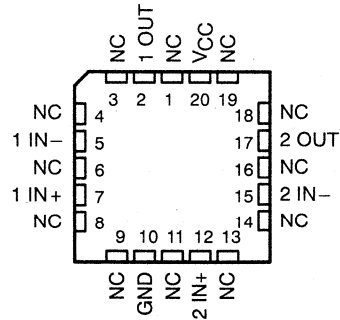
D2232, JUNE 1976—REVISED NOVEMBER 1991

- Single Supply or Dual Supplies
- Wide Range of Supply Voltage . . . 2 to 36 V
- Low Supply Current Drain Independent of Supply Voltage . . . 0.5 mA Typ
- Low Input Bias Current . . . 25 nA Typ
- Low Input Offset Current . . . 3 nA Typ (LM193)
- Low Input Offset Voltage . . . 2 mV Typ
- Common-Mode Input Voltage Range Includes Ground
- Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage . . . ± 36 V
- Low Output Saturation Voltage
- Output Compatible With TTL, MOS, and CMOS

D, DB, JG, P, OR PW PACKAGE
(TOP VIEW)



FK PACKAGE
(TOP VIEW)



NC—No internal connection

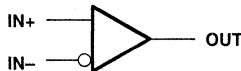
description

These devices consist of two independent voltage comparators that are designed to operate from a single power supply over a wide range of voltages. Operation from dual supplies is also possible as long as the difference between the two supplies is 2 V to 36 V and V_{CC} is at least 1.5 V more positive than the input common-mode voltage. Current drain is independent of the supply voltage. The outputs can be connected to other open-collector outputs to achieve wired-AND relationships.

The LM2903Q is manufactured to demanding automotive requirements.

The LM193 is characterized for operation from -55°C to 125°C. The LM293 and LM293A are characterized for operation from -25°C to 85°C. The LM393 and LM393A are characterized for operation from 0°C to 70°C. The LM2903 and LM2903Q are characterized for operation from -40°C to 125°C.

symbol (each comparator)



**LM193, LM293, LM393, LM293A
LM393A, LM393Y, LM2903, LM2903Q
DUAL DIFFERENTIAL COMPARATORS**

AVAILABLE OPTIONS

| T _A | V _{IO} max at 25°C | PACKAGE | | | | | | CHIP FORM (Y) [§] |
|----------------------|--------------------------------|--------------------------------------|---------------------------|-------------------------|------------------------|-------------------------|----------------------------|----------------------------------|
| | | SMALL OUTLINE (D) [†] | SSOP (DB) [‡] | CHIP CARRIER (FK) | CERAMIC DIP (JG) | PLASTIC DIP (P) | TSSOP (PW) [‡] | |
| 0°C to 70°C | 5 mV 2 mV | LM393D LM393AD | LM393DB | | | LM393P LM393AP | LM393PW | LM393Y |
| -25°C to 85°C | 5 mV 2 mV | LM293D LM293AD | | | | LM293P LM293AP | | |
| -40°C to 125°C | 7 mV 7 mV | LM2903D LM2903QD | LM2903DB | | | LM2903P LM2903QP | LM2903PW | |
| -55°C to 125°C | 5 mV | LM193D | | LM193FK | LM193JG | LM193P | | |

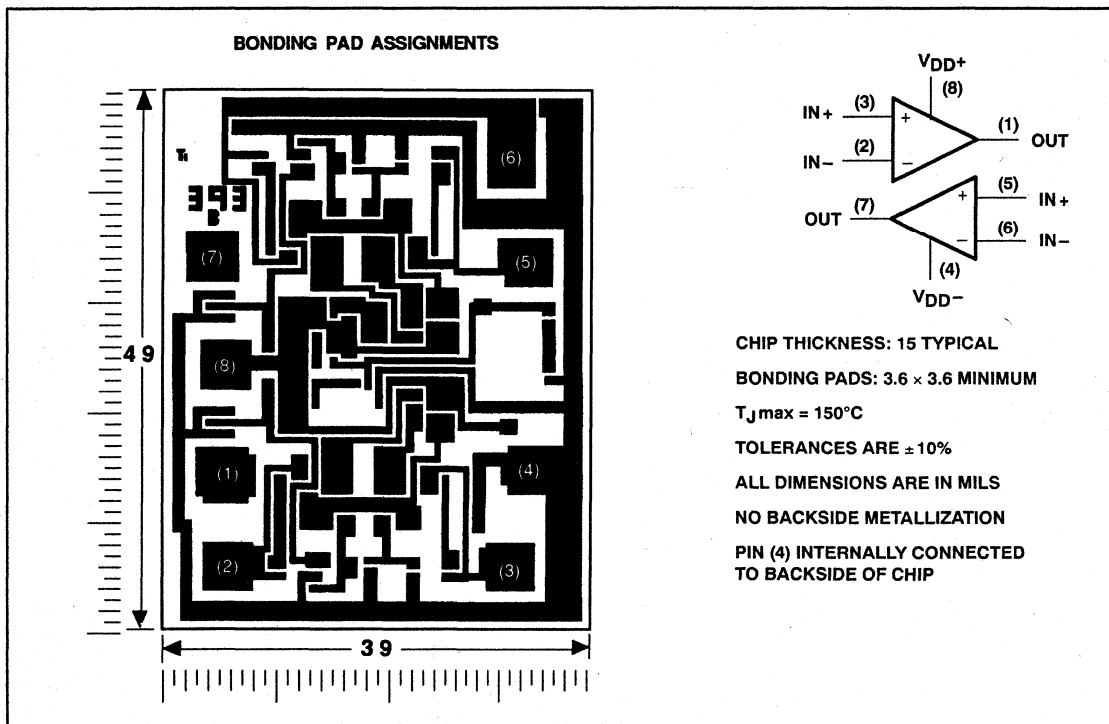
[†] The D package is available taped and reeled. Add the suffix R (e.g., LM393DR).

[‡] The DB and PW packages are only available left-end taped and reeled. Add suffix LE (e.g., LM393DBLE).

[§] Chips are tested at 25°C. See LM393Y for electrical characteristics.

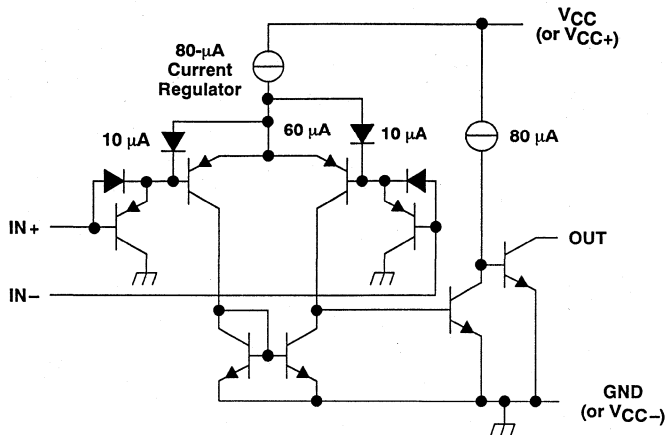
LM393Y chip information

These chips, properly assembled, display characteristics similar to the LM393 (see electrical table on LM393Y). Thermal compression or ultrasonic bonding may be used on the doped aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



LM193, LM293, LM393, LM293A LM393A, LM2903, LM2903Q DUAL DIFFERENTIAL COMPARATORS

schematic (each comparator)



| Component Count: | |
|------------------|----|
| Epi-SET | 1 |
| Diodes | 2 |
| Resistors | 2 |
| Transistors | 30 |

Current values shown are nominal.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|------------------------------|
| Supply voltage, V_{CC} (see Note 1) | 36 V |
| Differential input voltage (see Note 2) | ± 36 V |
| Input voltage range (either input) | -0.3 V to 36 V |
| Output voltage | 36 V |
| Output current | 20 mA |
| Duration of output short-circuit to ground (see Note 3) | unlimited |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range: | |
| LM193 | -55°C to 125°C |
| LM293, LM293A | -25°C to 85°C |
| LM393, LM393A | 0°C to 70°C |
| LM2903, LM2903Q | -40°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D, DB, P, or PW package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package | 300°C |

NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.

2. Differential voltages are at the noninverting input terminal with respect to the inverting input.

3. Short circuits from outputs to V_{CC} can cause excessive heating and eventual destruction.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR | DERATE ABOVE T_A | $T_A = 70^\circ\text{C}$ POWER RATING | $T_A = 85^\circ\text{C}$ POWER RATING | $T_A = 125^\circ\text{C}$ POWER RATING |
|---------|---|--------------------|-----------------------|--|--|---|
| D | 725 mW | 5.8 mW/°C | 25°C | 464 mW | 377 mW | 145 mW |
| DB | 525 mW | 4.2 mW/°C | 25°C | 336 mW | 273 mW | N/A |
| FK | 900 mW | 11.0 mW/°C | 68°C | 880 mW | 715 mW | 275 mW |
| JG | 900 mW | 8.4 mW/°C | 43°C | 672 mW | 546 mW | 210 mW |
| P | 900 mW | 8.0 mW/°C | 37°C | 640 mW | 520 mW | 200 mW |
| PW | 525 mW | 4.2 mW/°C | 25°C | 336 mW | 273 mW | N/A |


**TEXAS
INSTRUMENTS**

POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

LM193, LM293, LM393, LM293A LM393A, LM2903, LM2903Q DUAL DIFFERENTIAL COMPARATORS

electrical characteristics at specified free-air temperature, $V_{CC} = 5\text{ V}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS† | LM193 | | | LM293, LM393 | | | LM293A, LM393A | | | LM2903, LM2903Q | | | UNIT |
|--|---|-------------------|------|-------------------|--------------|-------------------|------|-------------------|------|-------------------|-----------------|-------------------|---------------|------|
| | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| V_{IO} Input offset voltage | $V_{CC} = 5\text{ V}$ to 30 V , | 2 | 5 | 2 | 5 | 1 | 2 | 2 | 7 | | | | | |
| | $V_{IC} = V_{IC\text{ min}}$, $V_O = 1.4\text{ V}$ Full range | | 9 | | 9 | | 4 | | 15 | | | | | mV |
| I_{IO} Input offset current | $V_O = 1.4\text{ V}$ Full range | 3 | 25 | 5 | 50 | 5 | 50 | 5 | 50 | 5 | 50 | 200 | nA | |
| | $V_O = 1.4\text{ V}$ Full range | -25 | -100 | -25 | -250 | -25 | -250 | -25 | -250 | -25 | -250 | -500 | nA | |
| V_{ICR} Common-mode input voltage range‡ | 25°C | 0 to $V_{CC}-1.5$ | | 0 to $V_{CC}-1.5$ | | 0 to $V_{CC}-1.5$ | | 0 to $V_{CC}-1.5$ | | 0 to $V_{CC}-1.5$ | | 0 to $V_{CC}-1.5$ | V | |
| | Full range | 0 to $V_{CC}-2$ | | 0 to $V_{CC}-2$ | | 0 to $V_{CC}-2$ | | 0 to $V_{CC}-2$ | | 0 to $V_{CC}-2$ | | 0 to $V_{CC}-2$ | V | |
| A_{VD} Large-signal differential voltage amplification | $V_{CC} = 15\text{ V}$, | 50 | 200 | 50 | 200 | 50 | 200 | 50 | 200 | 50 | 200 | 25 | V/mV | |
| | $V_O = 1.4\text{ V}$ to 11.4 V , $R_L \geq 15\text{ k}\Omega$ to V_{CC} | | | | | | | | | | | | | |
| I_{OH} High-level output current | $V_{OH} = 5\text{ V}$, $V_{ID} = 1\text{ V}$ $V_{OH} = 30\text{ V}$, $V_{ID} = 1\text{ V}$ | 0.1 | | 0.1 | 50 | 0.1 | 50 | 0.1 | 50 | 0.1 | 50 | 0.1 | 50 | nA |
| | Full range | 1 | | 1 | | 1 | | 1 | | 1 | | 1 | μA | |
| V_{OL} Low-level output voltage | $I_{OL} = 4\text{ mA}$, $V_{ID} = -1\text{ V}$ | 150 | 400 | 150 | 400 | 150 | 400 | 150 | 400 | 150 | 400 | 150 | 400 | mV |
| | Full range | 700 | | 700 | | 700 | | 700 | | 700 | | 700 | mV | |
| I_{OL} Low-level output current | $V_{OL} = 1.5\text{ V}$, $V_{ID} = 1\text{ V}$ | 6 | | 6 | | 6 | | 6 | | 6 | | 6 | mA | |
| | Full range | 2.5 | | 2.5 | | 2.5 | | 2.5 | | 2.5 | | 2.5 | mA | |
| I_{CC} Supply current | $R_L = \infty$ | 0.8 | 1 | 0.8 | 1 | 0.8 | 1 | 0.8 | 1 | 0.8 | 1 | 0.8 | 1 | mA |
| | $V_{CC} = 5\text{ V}$ $V_{CC} = 30\text{ V}$ | | | | | | | | | | | | | 2.5 |

† Full range (MIN or MAX) for LM193 is -55°C to 125°C ; for LM293 and LM293A is 25°C to 85°C ; for the LM393 and LM393A is 0°C to 70°C ; and for LM2903 and LM2903Q is -40°C to 125°C . All characteristics are measured with zero common-mode input voltage unless otherwise specified.
‡ The voltage at either input or common-mode should not be allowed to go negative by more than 0.3 V . The upper end of the common-mode voltage range is $V_{CC} + 1.5\text{ V}$, but either or both inputs can go to 30 V without damage.

switching characteristics, $V_{CC} = 5\text{ V}$, $T_A = 25^\circ\text{C}$

| PARAMETER | TEST CONDITIONS | MIN | | | TYP | | | MAX | | | UNIT | |
|---------------|--|---------------------------------------|--|--|-----|--|--|-----|--|--|------|---------------|
| | | | | | | | | | | | | |
| Response time | R_L connected to 5 V through $5.1\text{ k}\Omega$, $C_L = 15\text{ pF}$, See Note 4 | 100-mV input step with 5-mV overdrive | | | | | | | | | 1.3 | μs |
| | | TTL-level input step | | | | | | | | | 0.3 | |

§ C_L includes probe and jig capacitance.

NOTE 4: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V .

LM393Y DUAL DIFFERENTIAL COMPARATOR

electrical characteristics at $V_{CC} = 5\text{ V}$, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

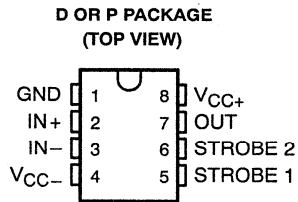
| PARAMETER | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|--|--|-----|----------------------|------|------|
| V_{IO} Input offset voltage | $V_{CC} = 5\text{ V to }30\text{ V}$, $V_{IC} = V_{ICRmin}$, $V_O = 1.4\text{ V}$ | | 2 | 5 | mV |
| I_{IO} Input offset current | | | 5 | 50 | nA |
| I_{IB} Input bias current | | | -25 | -250 | nA |
| V_{ICR} Common-mode input voltage range | $V_{CC} = 5\text{ V to }30\text{ V}$ | | 0 to $V_{CC}-1.5$ | | V |
| A_{VD} Large-signal differential voltage amplification | $V_{CC} = 15\text{ V}$, $R_L \geq 15\text{ k}\Omega\text{ to }V_{CC}$ | | 25 | 200 | V/mV |
| I_{OH} High-level output current | $V_{OH} = 5\text{ V}$, $V_{ID} = 1\text{ V}$ | | 0.1 | 50 | nA |
| V_{OL} Low-level output voltage | $I_{OL} = 4\text{ mA}$, $V_{ID} = -1\text{ V}$ | | 150 | 400 | mV |
| I_{OL} Low-level output current | $V_{OL} = 1.5\text{ V}$, $V_{ID} = -1\text{ V}$ | 6 | | | mA |
| I_{CC} Supply current | $R_L = \infty$, $V_{CC} = 5\text{ V}$ | | 0.8 | 1 | mA |

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified.

LM306 DIFFERENTIAL COMPARATOR WITH STROBES

D1108, OCTOBER 1979—REVISED OCTOBER 1991

- **Fast Response Times**
- **Improved Gain and Accuracy**
- **Fanout to 10 Series 54/74 TTL Loads**
- **Strobe Capability**
- **Short-Circuit and Surge Protection**
- **Designed to Be Interchangeable With National Semiconductor LM306**



description

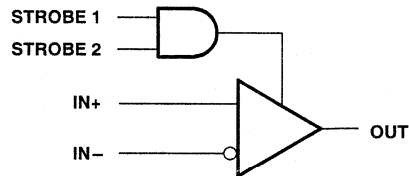
The LM306 is a high-speed voltage comparator with differential inputs, a low-impedance high-sink-current (100 mA) output, and two strobe inputs. This device detects low-level analog or digital signals and can drive digital logic or lamps and relays directly. Short-circuit protection and surge-current limiting is provided.

A low-level input at either strobe causes the output to remain high regardless of the differential input.

When both strobe inputs are either open or at a high logic level, the output voltage is controlled by the differential input voltage. The circuit will operate with any negative supply voltage between -3 V and -12 V with little difference in performance.

The LM306 is characterized for operation from 0°C to 70°C .

functional block diagram

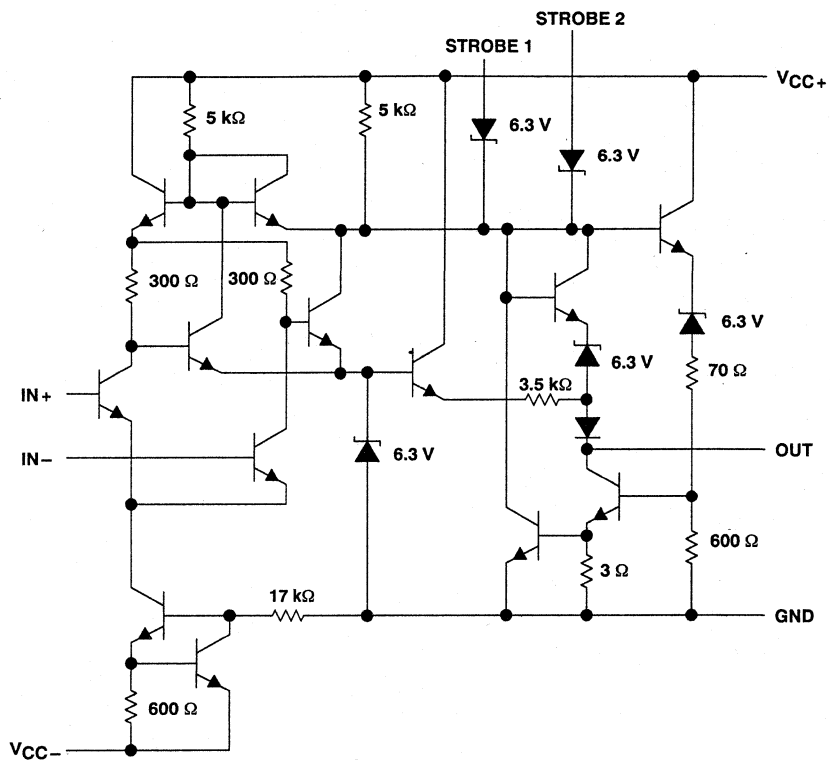


AVAILABLE OPTIONS

| T_A | $V_{IO\text{ max}}$ at 25°C | PACKAGE | |
|---|--|----------------------|--------------------|
| | | SMALL OUTLINE (D) | PLASTIC DIP (P) |
| 0°C to 70°C | 5 MV | LM306D | LM306P |

LM306 DIFFERENTIAL COMPARATOR WITH STROBES

schematic



Resistor values are nominal.

LM306 DIFFERENTIAL COMPARATOR WITH STROBES

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|--|
| Supply voltage, V_{CC+} (see Note 1) | 15 V |
| Supply voltage, V_{CC-} (see Note 1) | -15 V |
| Differential input voltage (see Note 2) | ± 5 V |
| Input voltage (either input, see Notes 1 and 3) | ± 7 V |
| Strobe voltage range (see Note 1) | 0 V to V_{CC+} |
| Output voltage (see Note 1) | 24 V |
| Voltage from output to V_{CC-} | 30 V |
| Duration of output short-circuit to ground (see Note 4) | 10 s |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range | 0°C to 70°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

- NOTES: 1. All voltage values, except differential voltages and the voltage from the output to V_{CC-} , are with respect to the network ground terminal.
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input.
 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 7 V, whichever is less.
 4. The output may be shorted to ground or either power supply.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^{\circ}\text{C}$ POWER RATING | DERATING FACTOR | DERATE ABOVE T_A | $T_A = 70^{\circ}\text{C}$ POWER RATING |
|---------|---|----------------------------|-----------------------|--|
| D | 600 mW | 5.8 mW/ $^{\circ}\text{C}$ | 46°C | 464 mW |
| P | 600 mW | 8.0 mW/ $^{\circ}\text{C}$ | 75°C | 600 mW |

LM306 DIFFERENTIAL COMPARATOR WITH STROBES

electrical characteristics at specified free-air temperature, $V_{CC+} = 12\text{ V}$, $V_{CC-} = -3\text{ V to } -12\text{ V}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS† | | T_A ‡ | MIN | TYP | MAX | UNIT |
|----------------|---|---|-------------------------|-------------|-----|---------|------|------------------------------|
| V_{IO} | Input offset voltage | $R_S \leq 200\ \Omega$, | See Note 5 | 25°C | | 1.6§ | 5 | mV |
| | | | | Full range | | | 6.5 | |
| α_{VIO} | Average temperature coefficient of input offset voltage | $R_S = 50\ \Omega$, | See Note 5 | Full range | | 5 | 20 | $\mu\text{V}/^\circ\text{C}$ |
| I_{IO} | Input offset current | | See Note 5 | 25°C | | 1.8 | 5 | μA |
| | | | | MIN | | 1 | 7.5 | |
| | | | | MAX | | 0.5 | 5 | |
| α_{IIO} | Average temperature coefficient of input offset current | | See Note 5 | MIN to 25°C | | 24 | 100 | nA/°C |
| | | | | 25°C to MAX | | 15 | 50 | |
| I_{IB} | Input bias current | $V_O = 0.5\text{ V to } 5\text{ V}$ | | MIN to 25°C | | | 40 | μA |
| | | | | 25°C to MAX | | 16 | 25 | |
| $I_{IL(S)}$ | Low-level strobe current | $V_{(\text{strobe})} = 0.4\text{ V}$ | | Full range | | -1.7 | -3.2 | mA |
| $V_{IH(S)}$ | High-level strobe voltage | | | Full range | | 2.2 | | V |
| $V_{IL(S)}$ | Low-level strobe voltage | | | Full range | | | 0.9 | V |
| V_{ICR} | Common-mode input voltage range | $V_{CC-} = -7\text{ V to } -12\text{ V}$ | | Full range | | ± 5 | | V |
| V_{ID} | Differential input voltage range | | | Full range | | ± 5 | | V |
| AVD | Large-signal differential voltage amplification | No load, $V_O = 0.5\text{ V to } 5\text{ V}$ | | 25°C | | 40 | | V/mV |
| V_{OH} | High-level output voltage | $I_{OH} = -400\ \mu\text{A}$ | $V_{ID} = 8\text{ mV}$ | Full range | | 2.5 | 5.5 | V |
| V_{OL} | Low-level output voltage | $I_{OL} = 100\text{ mA}$ | $V_{ID} = -7\text{ mV}$ | 25°C | | 0.8 | 2 | V |
| | | $I_{OL} = 50\text{ mA}$ | $V_{ID} = -7\text{ mV}$ | Full range | | | 1 | |
| | | $I_{OL} = 16\text{ mA}$ | $V_{ID} = -8\text{ mV}$ | Full range | | | | |
| I_{OH} | High-level output current | $V_{OH} = 8\text{ V to } 24\text{ V}$ | $V_{ID} = 7\text{ mV}$ | MIN to 25°C | | 0.02 | 2 | μA |
| | | | $V_{ID} = 8\text{ mV}$ | 25°C to MAX | | | | |
| I_{CC+} | Supply current from V_{CC+} | $V_{ID} = -5\text{ mV}$, | No load | Full range | | 6.6 | 10 | mA |
| I_{CC-} | Supply current from V_{CC-} | No load | | Full range | | -1.9 | -3.6 | mA |

† Unless otherwise noted, all characteristics are measured with both strobes open.

‡ Full range is 0°C to 70°C.

§ This typical value is at $V_{CC+} = 12\text{ V}$, $V_{CC-} = -6\text{ V}$.

NOTE 5: The offset voltages and offset currents given are the maximum values required to drive the output down to the low range (V_{OL}) or up to the high range (V_{OH}). Thus these parameters actually define an error band and take into account the worst-case effects of voltage gain and input impedance.

switching characteristics, $V_{CC+} = 12\text{ V}$, $V_{CC-} = -6\text{ V}$, $T_A = 25^\circ\text{C}$

| PARAMETER | TEST CONDITIONS† | MIN | TYP | MAX | UNIT |
|---|---|-----|-----|-----|------|
| Response time, low-to-high-level output | $R_L = 390\ \Omega$ to 5 V, $C_L = 15\text{ pF}$, See Note 6 | | 28 | 40 | ns |

† Unless otherwise noted, all characteristics are measured with both strobes open.

NOTE 6: The response time specified is for a 100-mV input step with 5-mV overdrive and is the interval between the input step function and the instant when the output crosses 1.4 V.



TYPICAL CHARACTERISTICS

INPUT OFFSET CURRENT
vs
FREE-AIR TEMPERATURE

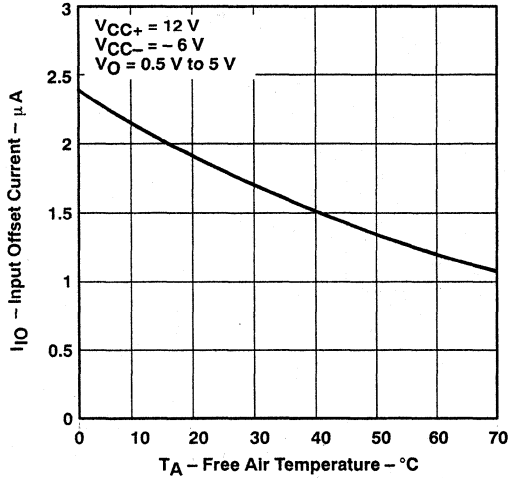


Figure 1

INPUT BIAS CURRENT
vs
FREE-AIR TEMPERATURE

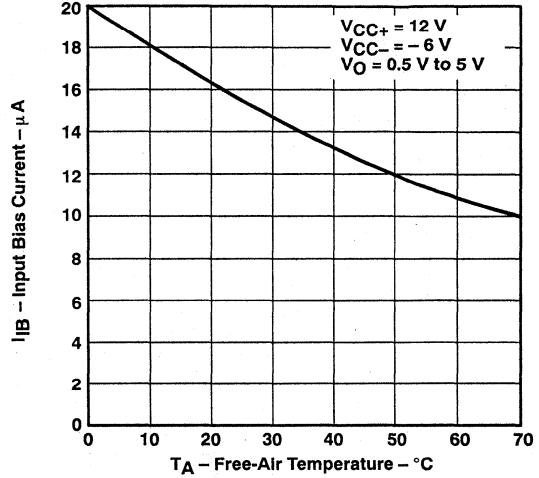


Figure 2

HIGH-LEVEL OUTPUT VOLTAGE
vs
FREE-AIR TEMPERATURE

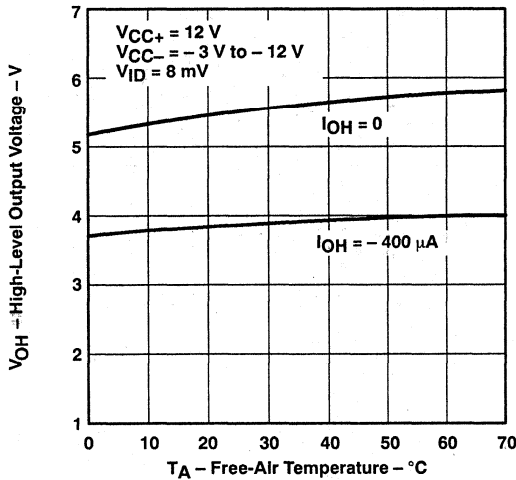


Figure 3

LOW-LEVEL OUTPUT VOLTAGE
vs
FREE-AIR TEMPERATURE

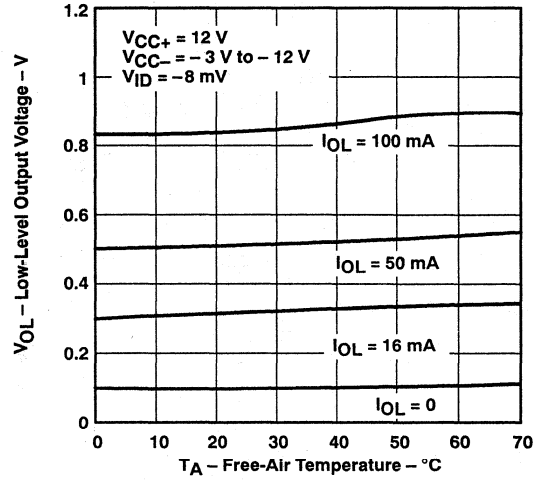


Figure 4

LM306 DIFFERENTIAL COMPARATOR WITH STROBES

TYPICAL CHARACTERISTICS

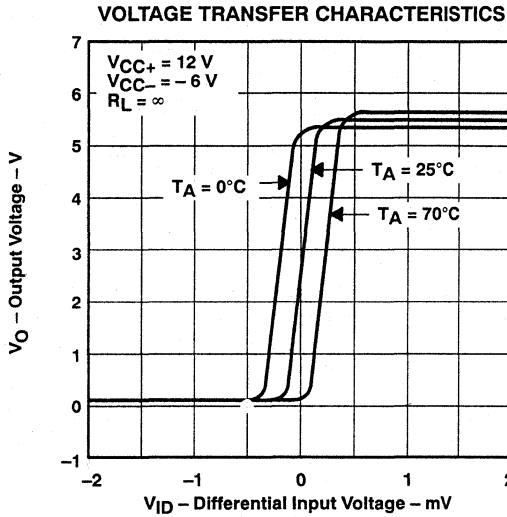


Figure 5

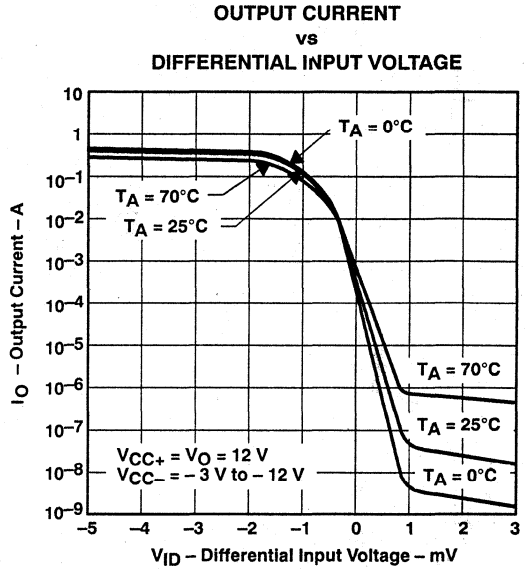


Figure 6

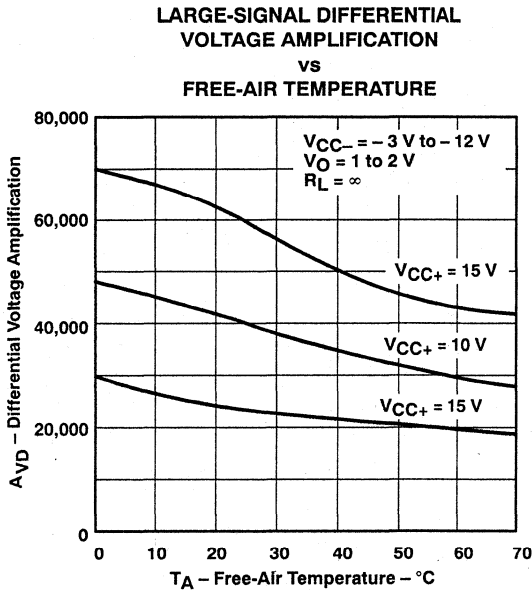


Figure 7

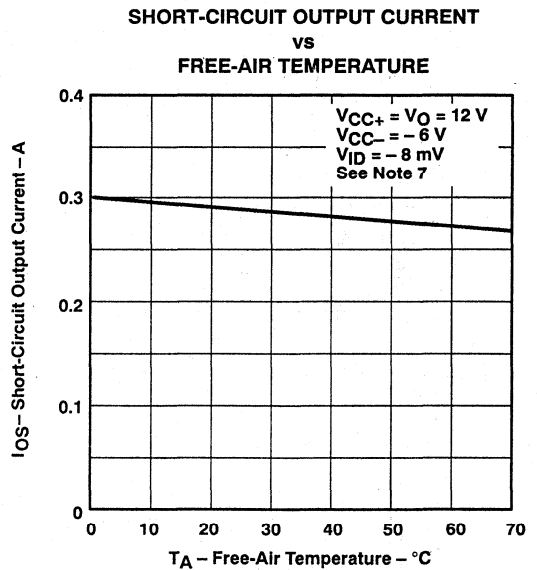


Figure 8

NOTE 7: This parameter was measured using a single 5-ms pulse.

TYPICAL CHARACTERISTICS

**OUTPUT RESPONSE FOR
VARIOUS INPUT OVERDRIVES**

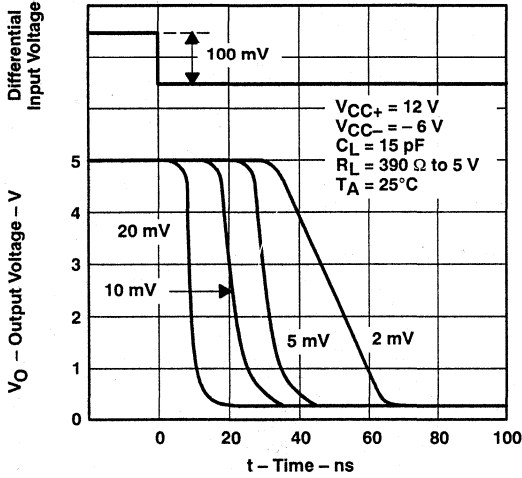


Figure 9

**OUTPUT RESPONSE FOR
VARIOUS INPUT OVERDRIVES**

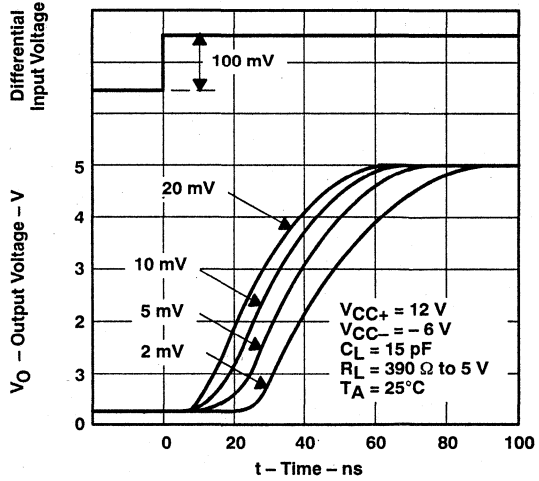


Figure 10

**SUPPLY CURRENT FROM V_{CC+}
vs
SUPPLY VOLTAGE V_{CC+}**

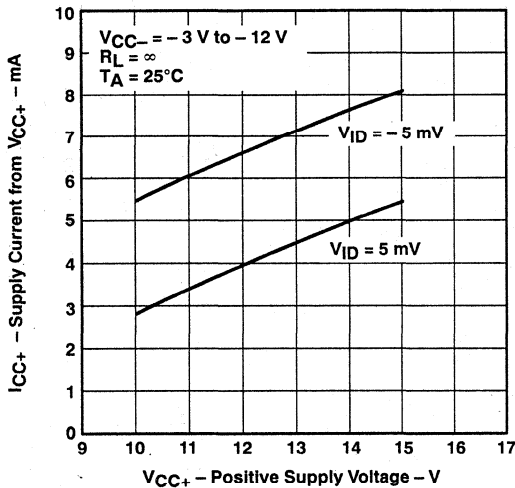


Figure 11

**SUPPLY CURRENT FROM V_{CC-}
vs
SUPPLY VOLTAGE V_{CC-}**

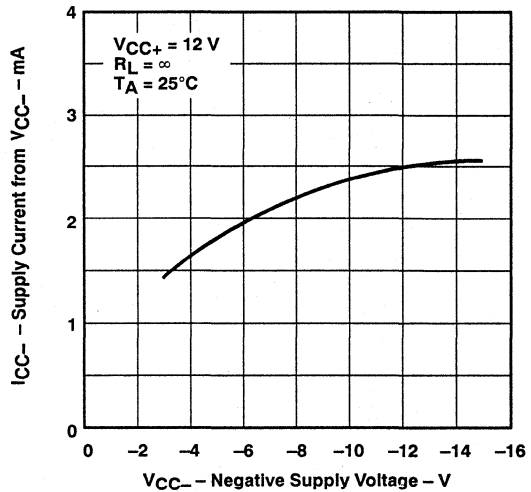


Figure 12

LM306
DIFFERENTIAL COMPARATOR WITH STROBES

TYPICAL CHARACTERISTICS

**TOTAL POWER DISSIPATION
vs
FREE-AIR TEMPERATURE**

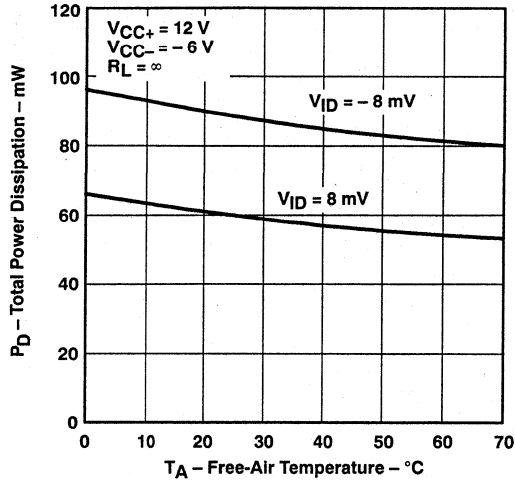


Figure 13

LM3302 QUADRUPLE DIFFERENTIAL COMPARATOR

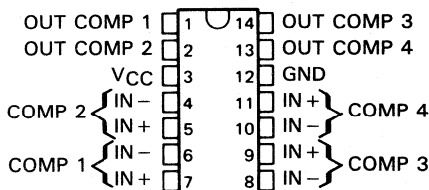
D2402, OCTOBER 1977—REVISED APRIL 1988

- Single Supply or Dual Supplies
- Wide Range of Supply Voltage . . . 2 to 28 Volts
- Low Supply Current Drain Independent of Supply Voltage . . . 0.8 mA Typ
- Low Input Bias Current . . . 25 nA Typ
- Low Input Offset Current . . . 3 nA Typ
- Low Input Offset Voltage . . . 3 mV Typ
- Common-Mode Input Voltage Range Includes Ground
- Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage . . . ± 28 V
- Low Output Saturation Voltage
- Output Compatible with TTL, MOS, and CMOS

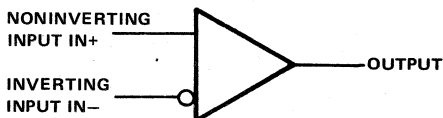
description

This device consists of four independent voltage comparators that are designed to operate from a single power supply over a wide range of voltages. Operation from dual supplies is also possible so long as the difference between the two supplies is 2 V to 28 V and pin 3 is at least 1.5 V more positive than the input common-mode voltage. Current drain is independent of the supply voltage. The outputs can be connected to other open-collector outputs to achieve wired-AND relationships.

D, J, OR N PACKAGE
(TOP VIEW)



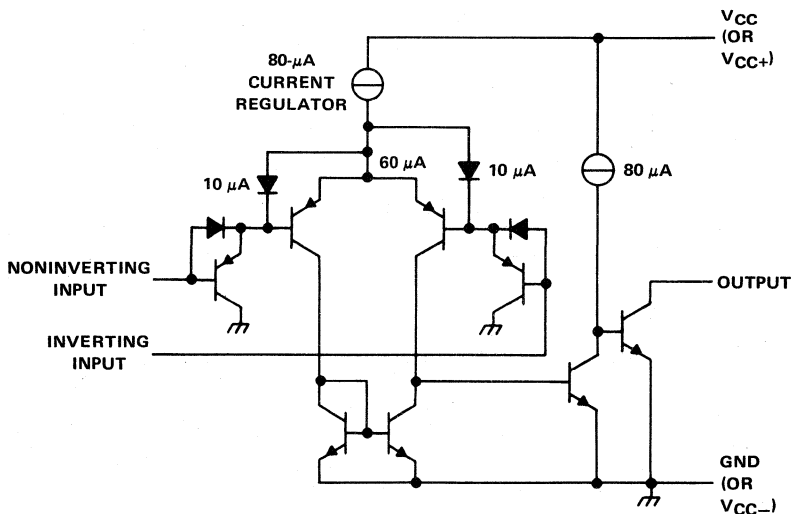
symbol (each comparator)



AVAILABLE OPTIONS

| SYMBOLIZATION | | OPERATING TEMPERATURE RANGE | V_{IO} MAX at 25°C |
|---------------|----------------|-----------------------------|----------------------|
| DEVICE | PACKAGE SUFFIX | | |
| LM3302 | D, J, N | -40°C to 85°C | 20 mV |

The D packages are available taped and reeled. Add the suffix R to the device type, when ordering. (i.e., LM3302DR)



Current values shown are nominal.

PRODUCTION DATA documents contain information current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.



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LM3302 QUADRUPLE DIFFERENTIAL COMPARATOR

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Supply voltage, V_{CC} (see Note 1) | 28 V |
| Differential input voltage (see Note 2) | ± 28 V |
| Input voltage range (either input) | -0.3 V to 28 V |
| Output voltage | 28 V |
| Output current | 20 mA |
| Duration of output short-circuit to ground (see Note 3) | unlimited |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range | -40°C to 85°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package | 300°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or N package | 260°C |

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
 3. Short circuits from the output to V_{CC} can cause excessive heating and eventual destruction.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ | DERATING FACTOR | $T_A = 70^\circ\text{C}$ | $T_A = 85^\circ\text{C}$ |
|---------|-----------------------------|--------------------------------|--------------------------|--------------------------|
| | POWER RATING | ABOVE $T_A = 25^\circ\text{C}$ | POWER RATING | POWER RATING |
| D | 950 mW | 7.6 mW/°C | 608 mW | 494 mW |
| J | 1025 mW | 8.2 mW/°C | 656 mW | 533 mW |
| N | 1150 mW | 9.2 mW/°C | 736 mW | 598 mW |

electrical characteristics at specified free-air temperature, $V_{CC} = 5$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS† | | MIN | TYP | MAX | UNIT |
|-----------|---|---|---------------|-------------------|-------|------|---------|
| V_{IO} | Input offset voltage | $V_{CC} = 5$ V to 28 V, $V_{IC} = V_{ICR}$ min, $V_O = 1.4$ V | 25°C | 3 | 20 | mV | |
| | | | -40°C to 85°C | | 40 | | |
| I_{IO} | Input offset current | $V_O = 1.4$ V | 25°C | 3 | 100 | nA | |
| | | | -40°C to 85°C | | 300 | | |
| I_{IB} | Input bias current | | 25°C | -25 | -500 | nA | |
| | | | -40°C to 85°C | | -1000 | | |
| V_{ICR} | Common-mode input voltage range | | 25°C | 0 to $V_{CC}-1.5$ | V | | |
| | | | -40°C to 85°C | 0 to $V_{CC}-2$ | | | |
| AVD | Large-signal differential voltage amplification | $V_{CC} = 15$ V, $V_O = 1.4$ V to 11.4 V, $R_L = 15$ k Ω to V_{CC} | 25°C | 2 | 30 | V/mV | |
| I_{OH} | High-level output current | $V_{ID} = 1$ V, $V_{OH} = 5$ V | 25°C | 0.1 | | nA | |
| | | | -40°C to 85°C | | | 1 | μ A |
| V_{OL} | Low-level output voltage | $V_{ID} = 1$ V, $I_{OL} = 4$ mA | 25°C | 150 | 500 | mV | |
| | | | 40°C to 85°C | | 700 | | |
| I_{OL} | Low-level output current | $V_{ID} = 1$ V, $V_{OL} = 1.5$ V | 25°C | 6 | 16 | mA | |
| I_{CC} | Supply current (four comparators) | $V_O = 2.5$ V, No load | 25°C | 0.8 | 2 | mA | |

† All characteristics are measured with zero common-mode input voltage unless otherwise specified.



LM3302
QUADRUPLE DIFFERENTIAL COMPARATOR

switching characteristics, $V_{CC} = 5\text{ V}$, $T_A = 25^\circ\text{C}$

| PARAMETER | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---------------|--|---------------------------------------|-----|-----|-----|---------------|
| Response time | $R_L = 5.1\text{ k}\Omega$ to 5 V, $C_L = 15\text{ pF}$ †, See Note 4 | 100-mV input step with 5-mV overdrive | | 1.3 | | μs |
| | | TTL-level input step | | 0.3 | | |

† C_L includes probe and jig capacitance.

NOTE 4: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.

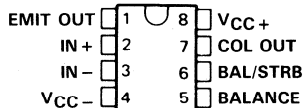
LP111, LP211, LP311

LOW-POWER DIFFERENTIAL COMPARATORS WITH STROBES

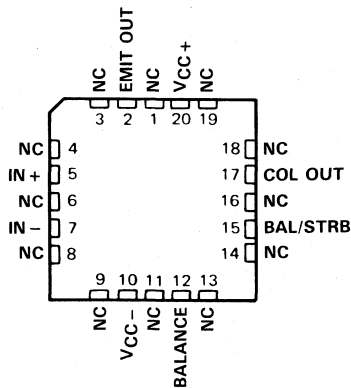
D3019, JUNE 1987—REVISED MAY 1988

- Low Power Drain — 900 μ W Typical with 5-V Supply
- Operates from ± 15 V or from a Single Supply as Low as 3 V
- Output Drive Capability of 25 mA
- Emitter Output Can Swing Below Negative Supply
- Response Time — 1.2 μ s Typ
- Low Input Currents:
 - Offset Current . . . 2 nA Typ
 - Bias Current . . . 15 nA Typ
- Wide Common-Mode Input Range:
 - 14.5 V to 13.5 V with ± 15 -V Supply
- Same Pinout as LM111, LM211, LM311
- Designed to be Interchangeable with National Semiconductor LP311

LP111 . . . JG DUAL-IN-LINE PACKAGE
LP211, LP311 . . . D, JG, OR P PACKAGE
(TOP VIEW)



LP111 . . . FK CHIP CARRIER PACKAGE
(TOP VIEW)

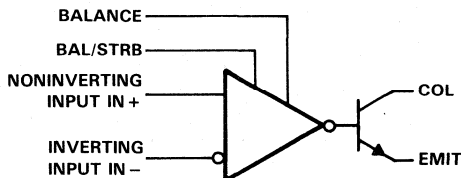


NC—No internal connection

description

The LP111, LP211, and LP311 are a low-power versions of the industry-standard LM111, LM211, and LM311. They take advantage of stable, high-value, ion-implanted resistors to perform the same function as the LM311 series, with a 30:1 reduction in power consumption but only a 6:1 slowdown in response time. Thus, they are well-suited for battery-powered applications and all other applications where fast response times are not needed. They operate over a wide range of supply voltages, from ± 18 V down to a single 3-V supply with less than 300 μ A current drain, but are still capable

functional block diagram



AVAILABLE OPTIONS

| T _A | V _{IO} MAX AT 25°C | PACKAGE | | | |
|----------------|-----------------------------|-------------------|--------------|------------------|-----------------|
| | | SMALL OUTLINE (D) | CERAMIC (FK) | CERAMIC DIP (JG) | PLASTIC DIP (P) |
| 0°C to 70°C | 7.5 mV | LP311D | — | LP311JG | LP311P |
| -25°C to 85°C | 7.5 mV | LP211D | — | LP211JG | LP211P |
| -55°C to 125°C | 7.5 mV | — | LP111FK | LP111JG | — |

The D package is available taped and reeled. Add the suffix R to the device type when ordering, (e.g., LP311DR)

PRODUCTION DATA documents contain information current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.



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LP111, LP211, LP311 LOW-POWER DIFFERENTIAL COMPARATORS WITH STROBES

description (continued)

of driving a 25-mA load. The LP111, LP211, and LP311 are quite easy to apply free of oscillation if ordinary precautions are taken to minimize stray coupling from the output to either input or to the trim pins.

The LP111 is characterized for operation over the full military temperature range of -55°C to 125°C . The LP211 is characterized for operation from -25°C to 85°C , and the LP311 is characterized for operation from 0°C to 70°C .

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|--|
| Supply voltage, V_{CC+} (see Note 1) | 18 V |
| Supply voltage, V_{CC-} (see Note 1) | -18 V |
| Differential input voltage (see Note 2) | ± 30 V |
| Input voltage (either input, see Notes 1 and 3) | ± 15 V |
| Voltage from emitter output to V_{CC-} | 30 V |
| Voltage from collector output to V_{CC-} | 40 V |
| Voltage from collector output to emitter output | 40 V |
| Duration of output short-circuit (see Note 4) | 40 V |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range: LP111 | -55°C to 125°C |
| LP211 | -25°C to 85°C |
| LP311 | 0°C to 70°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package | 260°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package | 300°C |

- NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between V_{CC+} and V_{CC-} .
 2. Differential input voltages are at the noninverting input terminal with respect to the inverting terminal.
 3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage of ± 15 V, whichever is less.
 4. The output may be shorted to ground or to either power supply.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^{\circ}\text{C}$ POWER RATING | DERATING FACTOR | DERATE ABOVE T_A | $T_A = 70^{\circ}\text{C}$ POWER RATING | $T_A = 85^{\circ}\text{C}$ POWER RATING | $T_A = 125^{\circ}\text{C}$ POWER RATING |
|------------|---|-----------------------------|-----------------------|--|--|---|
| D | 500 mW | 5.8 mW/ $^{\circ}\text{C}$ | 64°C | 464 mW | 377 mW | — |
| FK | 1375 mW | 11.0 mW/ $^{\circ}\text{C}$ | 25°C | 880 mW | 715 mW | 275 mW |
| JG (LP111) | 1050 mW | 8.4 mW/ $^{\circ}\text{C}$ | 25°C | 672 mW | 546 mW | 210 mW |
| JG (LP_11) | 825 mW | 6.6 mW/ $^{\circ}\text{C}$ | 25°C | 528 mW | 429 mW | — |
| P | 500 mW | 8.0 mW/ $^{\circ}\text{C}$ | 88°C | 500 mW | 500 mW | — |

recommended operating conditions

| | MIN | NOM | MAX | UNITS |
|--|-----------------|-----|-----------------|-------|
| Input voltage ($ V_{CC\pm} \leq 15$ V) | $V_{CC-} + 0.5$ | | $V_{CC+} - 1.5$ | V |
| Supply voltage, $V_{CC+} - V_{CC-}$ | 3.5 | | 30 | V |

LP111, LP211, LP311
LOW-POWER DIFFERENTIAL COMPARATORS WITH STROBES

electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15\text{ V}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | MIN | TYP [†] | MAX | UNIT |
|--------------|---|---|------------|----------------|------------------|---------------|------|
| V_{ID} | Input offset voltage | RS < 100 k Ω , See Note 5 | 25 °C | 2 | 7.5 | mV | |
| | | | Full Range | | 10 | | |
| I_{IO} | Input offset current | See Note 5 | 25 °C | 2 | 25 | nA | |
| | | | Full Range | | 35 | | |
| I_{IB} | Input bias current | | 25 °C | 15 | 100 | nA | |
| | | | Full Range | | 150 | | |
| V_{OL} | Low-level output voltage | $V_{ID} > 10\text{ mV}$, See Note 6 $V_{CC} = 4.5\text{ V}$, $V_{CC-} = 0$, $V_{ID} < -10\text{ mV}$, $I_{OL} = 1.6\text{ mA}$, See Note 6 | 25 °C | 0.4 | 1.5 | V | |
| | | | Full Range | LP111 | 0.1 | | 0.7 |
| | | | | LP211 LP311 | 0.1 | | 0.4 |
| | Low-level strobe current | $V_{(strobe)} = 0.3\text{ V}$, $V_{ID} < -10\text{ mV}$, See Note 7 | 25 °C | 100 | 300 | μA | |
| $I_{O(off)}$ | Output off-state current | $V_{ID} > 10\text{ mV}$, $V_{CE} = 35\text{ V}$ | 25 °C | 0.2 | 100 | nA | |
| A_{VD} | Large signal differential voltage amplification | $R_L = 5\text{ k}\Omega$ | 25 °C | 40 | 100 | V/mV | |
| I_{CC+} | Supply current from V_{CC+} | $V_{ID} = -50\text{ mV}$, $R_L = \infty$ | Full Range | 150 | 300 | μA | |
| I_{CC-} | Supply current from V_{CC-} | $V_{ID} = 50\text{ mV}$, $R_L = \infty$ | Full Range | -80 | -180 | μA | |

[†]All typical values are at $V_{CC\pm} = \pm 15\text{ V}$, $T_A = 25\text{ }^\circ\text{C}$.

NOTES: 5. The offset voltages and offset currents given are the maximum values required to drive the output within 1 V of either supply with a 1-mA load. Thus, these parameters define an error band and take into account the worst-case effects of voltage gain and input impedance.

6. Voltages are with respect to EMIT OUT and V_{CC-} tied together.

7. The strobe should not be shorted to ground; it should be current driven at 100 μA to 300 μA .

switching characteristics at $V_{CC\pm} = \pm 15\text{ V}$, $T_A = 25\text{ }^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---------------|-----------------|-----|-----|-----|---------------|
| Response time | See Note 8 | | 1.2 | | μs |

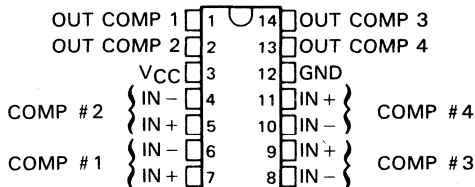
NOTE 8: The response time is specified for a 100-mV input step with 5-mV overdrive.

LP239, LP339, LP2901 LOW-POWER QUAD DIFFERENTIAL COMPARATORS

D3044, OCTOBER 1987—REVISED MAY 1988

- **Ultralow Power Supply Current**
Drain . . . Typically 60 μ A
- **Low Input Biasing Current** . . . 3 nA
- **Low Input Offset Current** . . . ± 0.5 nA
- **Low Input Offset Voltage** . . . ± 2 mV
- **Common-Mode Input Voltage Includes Ground**
- **Output Voltage Compatible with MOS and CMOS Logic**
- **High Output Sink-Current Capability**
(30 mA at $V_O = 2$ V)
- **Power Supply Input Reverse-Voltage Protected**
- **Single-Power-Supply Operation**
- **Pin-for-Pin Compatible with LM239, LM339, LM2901**

D, J, OR N PACKAGE
(TOP VIEW)



description

The LP239, LP339, and LP2901 are low-power quadruple differential comparators. Each device consists of four independent voltage comparators designed specifically to operate from a single power supply and typically to draw 60- μ A drain current over a wide range of voltages. Operation from split power supplies is also possible and the ultralow power supply drain current is independent of the power supply voltage.

Applications include limit comparators, simple analog-to-digital converters, pulse generators, squarewave generators, time delay generators, voltage controlled oscillators, multivibrators, and high-voltage logic gates. The LP239, LP339, and LP2901 were specifically designed to interface with the CMOS logic family. The ultralow power supply current makes these products desirable in battery-powered applications.

The LP239 is characterized for operation from -25°C to 85°C . The LP339 is characterized for operation from 0°C to 70°C . The LP2901 is characterized for operation from -40°C to 85°C .

AVAILABLE OPTIONS

| T _A | V _{IO} MAX AT 25°C | PACKAGE | | |
|---------------------|--------------------------------|----------------------|--------------------|--------------------|
| | | SMALL-OUTLINE (D) | PLASTIC DIP (N) | CERAMIC DIP (J) |
| 0°C to 70°C | ± 5 mV | LP339D | LP339N | LP339J |
| -25°C to 85°C | ± 5 mV | LP239D | LP239N | LP239J |
| -40°C to 85°C | ± 5 mV | LP2901D | LP2901N | LP2901J |

D packages are available taped-and-reeled. Add "R" suffix to device type when ordering (e.g., LP339DR).

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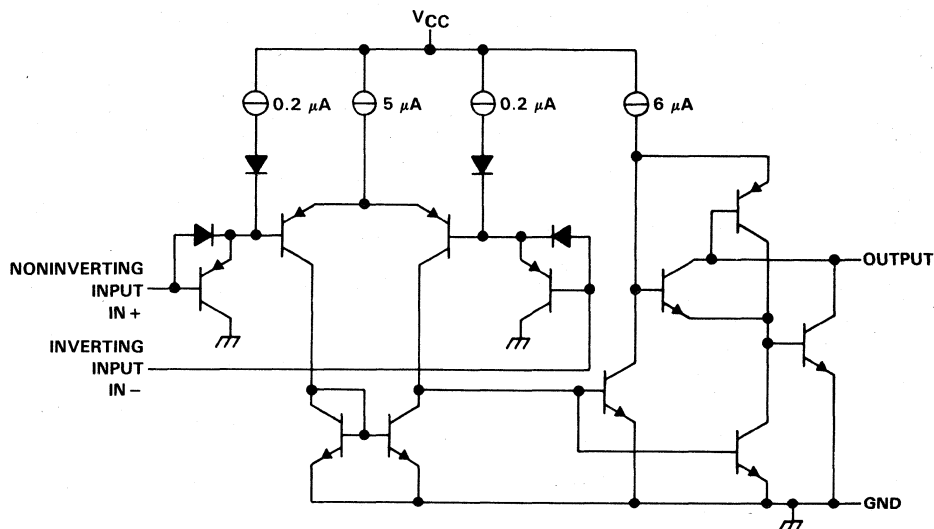


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LP239, LP339, LP2901 LOW-POWER QUAD DIFFERENTIAL COMPARATORS

schematic diagram (each comparator)



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Supply voltage, V_{CC} (see Note 1) | 36 V |
| Differential input voltage, V_{ID} (see Note 2) | ± 36 V |
| Input voltage range (either input) | -0.3 V to 36 V |
| Input current, $V_I \leq -0.3$ V (see Note 3) | -50 mA |
| Duration of output short-circuit to ground (see Note 4) | unlimited |
| Continuous total dissipation (see Note 5) | See Dissipation Rating Table |
| Operating free-air temperature range: LP239 | -25°C to 85°C |
| LP339 | 0°C to 70°C |
| LP2901 | -40°C to 85°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or N package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package | 300°C |

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
 3. This input current only exists when the voltage at any of the inputs is driven negative. The current flows through the collector-base junction of the input clamping device. In addition to the clamping device action, there is lateral n-p-n parasitic transistor action. This action is not destructive and normal output states are re-established when the input voltage returns to a value more positive than -0.3 V at $T_A = 25^\circ\text{C}$.
 4. Short circuits between outputs to V_{CC} can cause excessive heating and eventual destruction.
 5. If the output transistors are allowed to saturate, the low bias dissipation and the on-off characteristics of the outputs keep the dissipation very small (usually less than 100 mW).

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ | DERATING FACTOR | $T_A = 70^\circ\text{C}$ | $T_A = 85^\circ\text{C}$ |
|---------|-----------------------------|--------------------------------|--------------------------|--------------------------|
| | POWER RATING | ABOVE $T_A = 25^\circ\text{C}$ | POWER RATING | POWER RATING |
| D | 950 mW | 7.6 mW/°C | 608 mW | 494 mW |
| J | 1025 mW | 8.2 mW/°C | 656 mW | 533 mW |
| N | 1150 mW | 9.2 mW/°C | 736 mW | 598 mW |

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LP239, LP339, LP2901 LOW-POWER QUAD DIFFERENTIAL COMPARATORS

recommended operating conditions

| | | LP2901 | | | LP239 | | | LP339 | | | UNIT |
|---------------------------------------|------------------------|--------|-----|-----|-------|-----|-----|-------|-----|-----|------|
| | | MIN | NOM | MAX | MIN | NOM | MAX | MIN | NOM | MAX | |
| Supply voltage, V_{CC} | | 5 | | 30 | 5 | | 30 | 5 | | 30 | V |
| Common-mode input voltage, V_{IC} | $V_{CC} = 5\text{ V}$ | 0 | | 3 | 0 | | 3 | 0 | | 3 | V |
| | $V_{CC} = 30\text{ V}$ | 0 | | 28 | 0 | | 28 | 0 | | 28 | V |
| Input voltage, V_I | $V_{CC} = 5\text{ V}$ | 0 | | 3 | 0 | | 3 | 0 | | 3 | V |
| | $V_{CC} = 30\text{ V}$ | 0 | | 28 | 0 | | 28 | 0 | | 28 | V |
| Operating free-air temperature, T_A | | -40 | | 85 | -25 | | 85 | 0 | | 70 | °C |

electrical characteristics, $V_{CC} = 5\text{ V}$, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | | | MIN | TYP | MAX | UNIT |
|---|--|------------------------------------|------------|-----|---------------------|-------------------|---------------|
| V_{IO} Input offset voltage | $V_{CC} = 5\text{ V to } 30\text{ V}$, $R_S = 0$, | $V_O = 2\text{ V}$, See Note 6 | 25 °C | | ± 2 | ± 5 | mV |
| | | | Full range | | | ± 9 | |
| I_{IO} Input offset current | | | 25 °C | | ± 0.5 | ± 5 | nA |
| | | | Full range | | | ± 15 | |
| I_{IB} Input bias current | See Note 7 | | 25 °C | | - 2.5 | - 25 | nA |
| | | | Full range | | | - 4 | |
| V_{ICR} Common-mode input voltage range | Single supply | | 25 °C | | 0 to $V_{CC} - 1.5$ | | V |
| | | | Full range | | | 0 to $V_{CC} - 2$ | |
| AVD Large-signal differential voltage amplification | $V_{CC} = 15\text{ V}$, | $R_L = 15\text{ k}\Omega$ | | | 500 | | V/mV |
| Output sink current | $V_{I-} = 1\text{ V}$, $V_{I+} = 0$ | $V_O = 2\text{ V}$ (see Note 8) | 25 °C | | 20 | 30 | mA |
| | | | Full range | | | 15 | |
| Output leakage current | $V_{I+} = 1\text{ V}$, $V_{I-} = 0$ | $V_O = 0.4\text{ V}$ | 25 °C | | 0.2 | 0.7 | nA |
| | | $V_O = 5\text{ V}$ | 25 °C | | | 0.1 | |
| V_{ID} Differential input voltage | $V_I \leq 0$ (or V_{CC-} on split supplies) | | Full range | | | 1 | μA |
| | | | | | | 36 | |
| I_{CC} Supply current | $R_L = \infty$ all comparators | | | | 60 | 100 | μA |

NOTES: 6. V_{IO} is measured over the full common-mode input voltage range.

7. Because of the p-n-p input stage, the direction of the current is out of the device. This current is essentially constant (i.e., independent of the output state). Therefore, no loading change exists on the reference or input lines as long as the common-mode input voltage range is not exceeded.

8. The output sink current is a function of the output voltage. These devices have a bimodal output section that allows them to sink (via a Darlington connection) large currents at output voltages greater than 1.5 V, and smaller currents at output voltages less than 1.5 V.

switching characteristics, $V_{CC} = 5\text{ V}$, $T_A = 25^\circ\text{C}$, R_L connected to 5 V through 5.1 k Ω

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|----------------------------|---|-----|-----|-----|---------------|
| Large-signal response time | TTL logic swing, $V_{ref} = 1.4\text{ V}$ | | 1.3 | | μs |
| Response time | | | 8 | | μs |

LP239, LP339, LP2901 LOW-POWER QUAD DIFFERENTIAL COMPARATORS

TYPICAL APPLICATION DATA

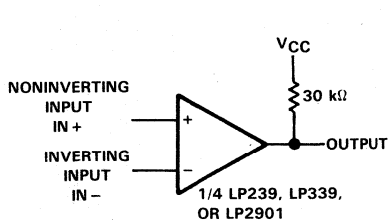


FIGURE 1. BASIC COMPARATOR

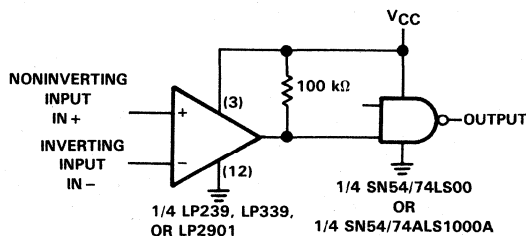


FIGURE 2. CMOS DRIVER

All pins of any unused comparators should be grounded. The bias network of the LP239, LP339, and LP2901 establishes a drain current that is independent of the magnitude of the power supply voltage over the range of 2 V to 30 V. It is usually necessary to use a bypass capacitor across the power supply line.

The differential input voltage may be larger than V_{CC} without damaging the device. Protection should be provided to prevent the input voltages from going negative by more than -0.3 V. The output section has two distinct modes of operation: a Darlington mode and a grounded-emitter mode. This unique drive circuit permits the device to sink 30 mA at $V_O = 2$ V in the Darlington mode and $700 \mu\text{A}$ at $V_O = 0.4$ V in the ground-emitter mode. Figure 3 is a simplified schematic diagram of the output section. The output section is configured in a Darlington connection (ignoring Q3). Therefore, if the output voltage is held high enough (above 1 V), Q1 is not saturated and the output current is limited only by the product of the h_{FE} of Q1, the h_{FE} of Q2, and I1 and by the $60\text{-}\Omega$ saturation resistance of Q2. The devices are capable of driving LEDs, relays, etc., in this mode while maintaining an ultralow power supply current of $60 \mu\text{A}$ typically.

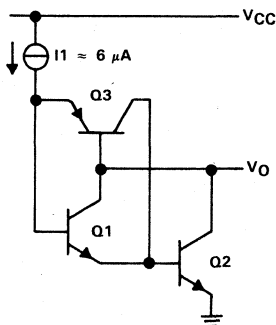


FIGURE 3. OUTPUT SECTION SCHEMATIC DIAGRAM

Without transistor Q3, if the output voltage were allowed to drop below 0.8 V, transistor Q1 would saturate and the output current would drop to zero. The circuit would be unable to pull low current loads down to ground or the negative supply, if used. Transistor Q3 has been included to bypass transistor Q1 under these conditions and apply the current I1 directly to the base of Q2. The output sink current is now approximately I1 times the h_{FE} of Q2 ($700 \mu\text{A}$ at $V_O = 0.4$ V). The output of the devices exhibit a bimodal characteristic with a smooth transition between modes.

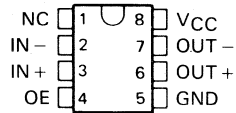
In both cases, the output is an uncommitted collector. Therefore several outputs can be tied together to provide a dot logic function. An output pull-up resistor can be connected to any available power supply voltage within the permitted power supply voltage range, and there is no restriction on this voltage based on the magnitude of the voltage that is applied to the V_{CC} terminal of the package.

TL712 DIFFERENTIAL COMPARATOR

D2741, JUNE 1983—REVISED JULY 1989

- Operates from a 5-V Supply
- 0 to 5 V Common-Mode Input Voltage Range
- Self-Biased Inputs
- Complementary 3-State Outputs
- Enable Capability
- Hysteresis . . . 5 mV Typ
- Response Times . . . 25 ns Typ

D, JG, OR P PACKAGE
(TOP VIEW)



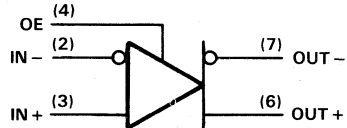
NC—No internal connection

description

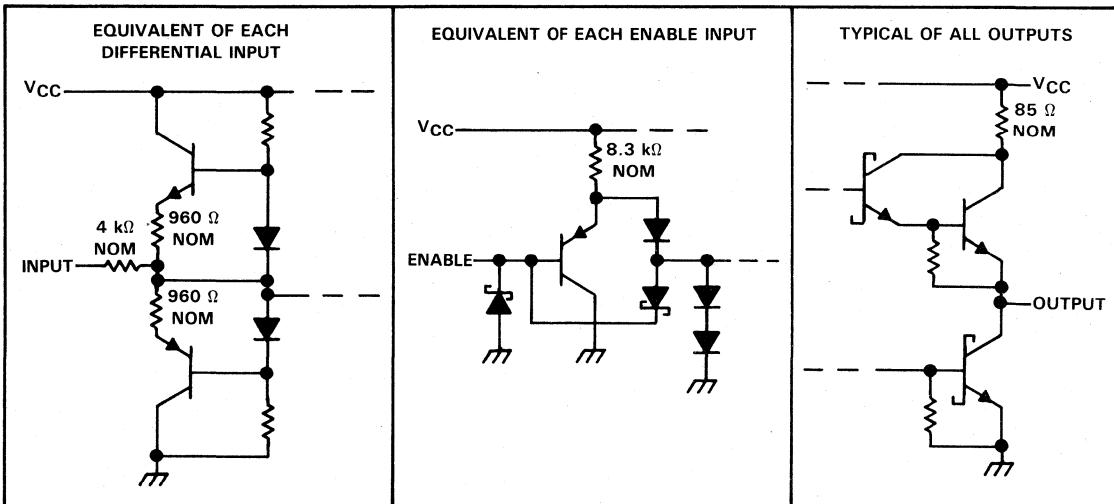
The TL712 is a high-speed comparator fabricated with bipolar Schottky process technology. The circuit has differential analog inputs and complementary 3-state TTL-compatible logic outputs with symmetrical switching characteristics. When the output enable, OE, is low, both outputs are in the high-impedance state. This device operates from a single 5-V supply and is useful as a disk memory read-chain data comparator.

The TL712 is characterized for operation from 0°C to 70°C.

symbol (positive logic)



schematics of inputs and outputs



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TL712

DIFFERENTIAL COMPARATOR

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|----------------|
| Supply voltage, V_{CC} (see Note 1) | 7 V |
| Input voltage, any differential input | ± 25 V |
| Differential input voltage (see Note 2) | ± 25 V |
| Enable input voltage | 7 V |
| Low-level output current | 50 mA |
| Operating free-air temperature range | 0°C to 70°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package | 300°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package | 260°C |

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.
2. Differential voltage values are at the noninverting terminal with respect to the inverting terminal.

recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|---------------------------------------|------|-----|------|------|
| Supply voltage, V_{CC} | 4.75 | 5 | 5.25 | V |
| Common-mode input voltage, V_{IC} | 0 | | 5 | V |
| High-level output current, I_{OH} | | | -1 | mA |
| Low-level output current, I_{OL} | | | 16 | mA |
| Operating free-air temperature, T_A | 0 | | 70 | °C |

electrical characteristics at $V_{CC} = 5$ V, $T_A = 25$ °C

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|--------------------------------------|-------------------|-----|------|------|
| V_T Threshold voltage (V_{T+} and V_{T-}) | $V_{ICR} = 0$ to 5 V | -100 [†] | | 100 | mV |
| V_{hys} Hysteresis ($V_{T+} - V_{T-}$) | | | 5 | | mV |
| V_{OH} High-level output voltage | $V_{ID} = 100$ mV, $I_{OH} = -1$ mA | 2.7 | 3.5 | | V |
| V_{OL} Low-level output voltage | $V_{ID} = -100$ mV, $I_{OL} = 16$ mA | | 0.4 | 0.5 | V |
| I_{OZ} Off-state output current | $V_O = 2.4$ V | | | -20 | μA |
| I_I Enable current | $V_I = 5.5$ V | | | 100 | μA |
| I_{IH} High-level enable current | $V_{IH} = 2.7$ V | | | 20 | μA |
| I_{IL} Low-level enable current | $V_{IL} = 0.4$ V | | | -360 | μA |
| r_i Differential input resistance | | 4 | | | kΩ |
| r_o Output resistance | | | | 100 | Ω |
| I_{OS} Short-circuit output current | | -15 | | -85 | mA |
| I_{CC} Supply current | $V_{ID} = 0$, No load | | 17 | 20 | mA |

[†]The algebraic convention, where the more negative limit is designated as minimum, is used in this data sheet for input threshold voltage levels only.

switching characteristics, $V_{CC} = 5$ V, $T_A = 25$ °C

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|--------------------------|-----|-----|-----|------|
| t_{PLH} Propagation delay time, low-to-high-level output | TTL load (see Figure 1), | | 25 | | ns |
| t_{PHL} Propagation delay time, high-to-low-level output | See Note 3 | | 25 | | ns |

NOTE 3: The response time specified is for a 100-mV input step with 5-mV overdrive (105 mV total), and is the interval between the input step function and the instant when the output crosses 2.5 V.

PARAMETER MEASUREMENT INFORMATION

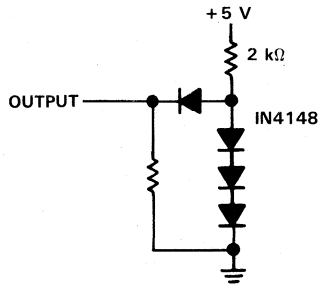


FIGURE 1. TTL OUTPUT LOAD CIRCUIT

TYPICAL CHARACTERISTICS

OUTPUT RESPONSE FOR VARIOUS
INPUT OVERDRIVES

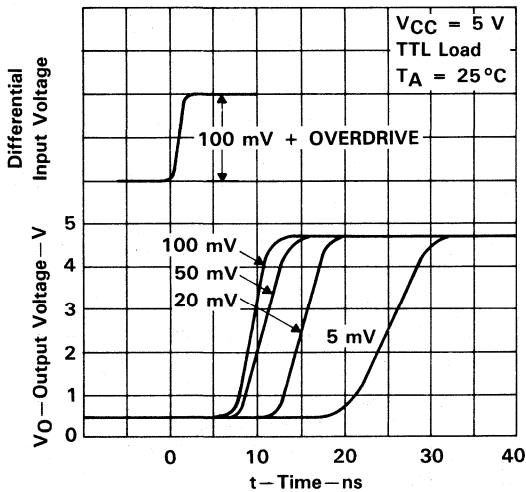


FIGURE 2

OUTPUT RESPONSE FOR VARIOUS
INPUT OVERDRIVES

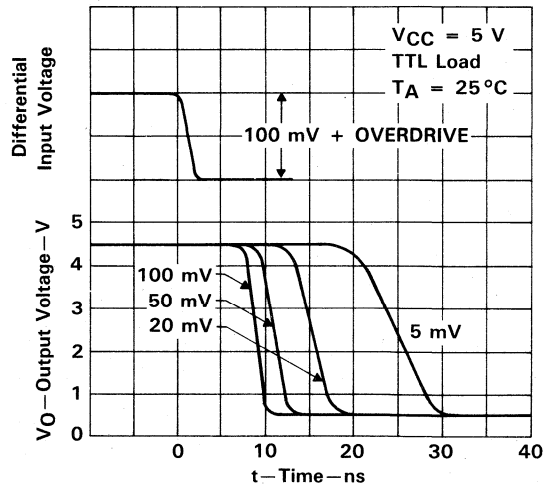


FIGURE 3

TYPICAL CHARACTERISTICS

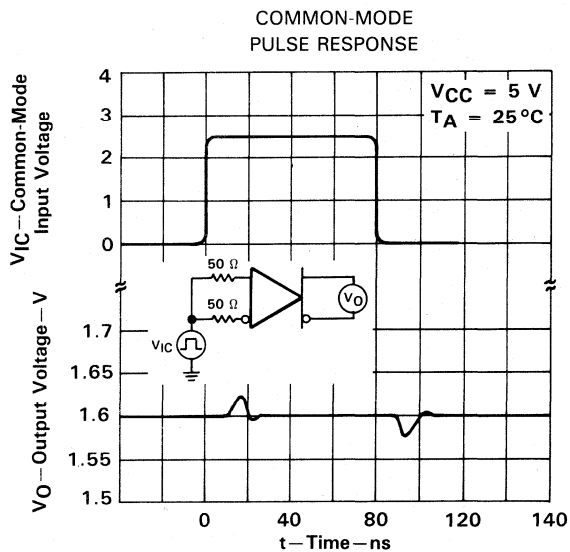


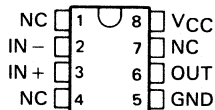
FIGURE 4

TL714C HIGH-SPEED DIFFERENTIAL COMPARATOR

D3131, DECEMBER 1988—REVISED JUNE 1989

- Operates from a 5-V Supply
- Self-Biasing Inputs
- Hysteresis . . . 10 mV Typical
- Response Time . . . 6 ns Typical
- Maximum Operating Frequency . . . 50 MHz Typical

D OR P PACKAGE
(TOP VIEW)



NC—No internal connection

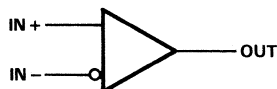
description

The TL714C is a high-speed differential comparator fabricated with bipolar Schottky process technology. The circuit has differential inputs and a TTL-compatible logic output with symmetrical switching characteristics.

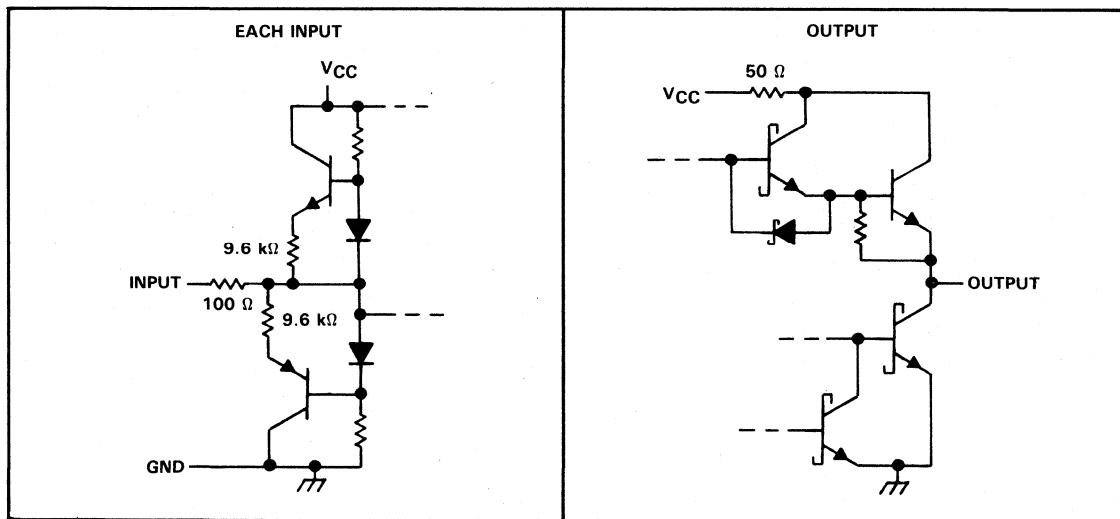
The device operates from a single 5-V supply and is useful as a disk-memory read-chain data comparator.

The TL714C is characterized for operation from 0°C to 70°C.

symbol



schematic of inputs and output



All resistor values shown are nominal.

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TL714C

HIGH-SPEED DIFFERENTIAL COMPARATOR

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Supply voltage, V_{CC} (see Note 1) | 7 V |
| Differential input voltage, V_{ID} (see Note 2) | ± 5 V |
| Input voltage range | V_{CC} to GND |
| Low-level output current, I_{OL} | 40 mA |
| Continuous total power dissipation | See Dissipation Rating Table |
| Operating free-air temperature range | 0°C to 70°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

- NOTES: 1. All voltage values, except for differential voltage, are with respect to the network ground.
 2. Differential voltage values are at the noninverting terminal with respect to the inverting terminal.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR | DERATE ABOVE T_A | $T_A = 70^\circ\text{C}$ POWER RATING |
|---------|---|--------------------|-----------------------|--|
| D | 500 mW | 5.8 mW/°C | 64°C | 464 mW |
| P | 500 mW | N/A | N/A | 500 mW |

recommended operating conditions

| PARAMETER | MIN | MAX | UNIT |
|---------------------------------------|-----------------------------|------|------|
| Supply voltage, V_{CC} | 4.75 | 5.25 | V |
| Common-mode input voltage, V_{IC} | 1.4 to $V_{CC} - 1.4$ | | V |
| High-level output current, I_{OH} | | -1 | mA |
| Low-level output current, I_{OL} | | 16 | mA |
| Operating free-air temperature, T_A | 0 | 70 | °C |

electrical characteristics over free-air operating temperature range, $V_{CC} = 5$ V (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP [†] | MAX | UNIT |
|--|--------------------------------------|-----|------------------|----------|------------|
| V_T Threshold voltage | $V_{IC} = 1.4$ V to 3.6 V | | | ± 75 | mV |
| V_{hys} Hysteresis ($V_{T+} - V_{T-}$) | | 2 | 10 | 30 | mV |
| V_{OH} High-level output voltage | $V_{ID} = 100$ mV, $I_{OH} = -1$ mA | 2.7 | 3.4 | | V |
| V_{OL} Low-level output voltage | $V_{ID} = -100$ mV, $I_{OL} = 16$ mA | | 0.4 | 0.5 | V |
| I_{OS} Short-circuit output current | | -30 | | -110 | mA |
| r_i Differential input resistance | | 2.9 | | | k Ω |
| I_{CC} Supply current | $V_{ID} = -100$ mV, $I_O = 0$ | | 7 | 12 | mA |

[†]All typical values are at $T_A = 25^\circ\text{C}$.

switching characteristics, $V_{CC} = 5$ V, $T_A = 25^\circ\text{C}$

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|---|-----|-----|-----|------|
| f_{max} Maximum operating frequency | $V_{ID} = \pm 250$ mV, $t_r = t_f = 4$ ns, $C_L = 25$ pF, Input duty cycle = 50% | | 50 | | MHz |
| t_{PLH} Propagation delay time, low-to-high-level output | $V_{ID} = \pm 100$ mV, $C_L = 25$ pF, | | 6 | 12 | ns |
| t_{PHL} Propagation delay time, high-to-low-level output | See Figures 1 and 2 | | 6 | 12 | ns |
| t_r Rise time | $V_{ID} = \pm 100$ mV, $C_L = 25$ pF, | | 4 | 8 | ns |
| t_f Fall time | See Figure 3 | | 4 | 8 | ns |



PARAMETER MEASUREMENT INFORMATION

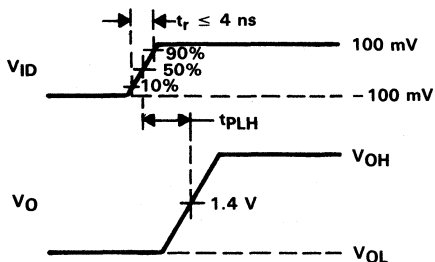


FIGURE 1. PROPAGATION DELAY TIME, LOW TO HIGH (t_{PLH})

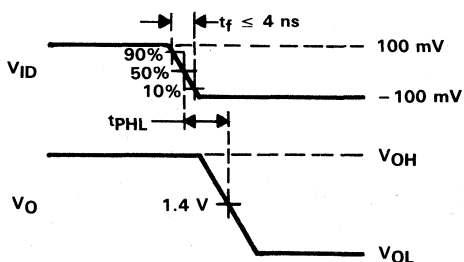


FIGURE 2. PROPAGATION DELAY TIME, HIGH TO LOW (t_{PHL})

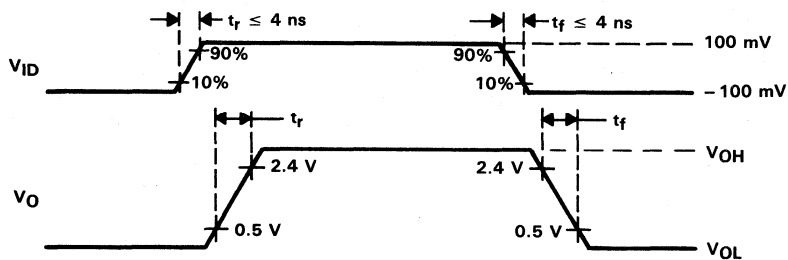


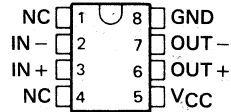
FIGURE 3. RISE AND FALL TIMES (t_r , t_f)

TL721 DIFFERENTIAL COMPARATOR

D2781, FEBRUARY 1984—REVISED OCTOBER 1988

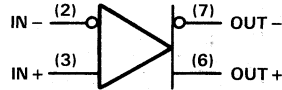
- Operates from a -5.2-V Power Supply
- Self-Biased Inputs
- Common-Mode Input Voltage Range
 $0\text{ V to }-5.2\text{ V}$
- MECL III and MECL 10 000 Compatible
- Complementary ECL-Compatible Outputs
- Hysteresis . . . 5 mV Typ
- Response Times . . . 10 ns Typ

D, JG, OR P PACKAGE
(TOP VIEW)



NC—No internal connection

symbol



description

The TL721 is a high-speed voltage comparator fabricated with bipolar Schottky[†] process technology. The circuit has differential analog inputs and complementary ECL-compatible logic outputs with symmetrical switching characteristics. The device operates from a single -5.2-volt supply and is useful as a disk memory read-chain data comparator.

The TL721 is characterized for operation from 0°C to 70°C .

[†]Integrated Schottky-Barrier diode-clamped transistor is patented by Texas Instruments. U.S. Patent Number 3,463,975.

PRODUCTION DATA documents contain information current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

**TEXAS
INSTRUMENTS**

POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

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TL721 DIFFERENTIAL COMPARATOR

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|----------------|
| Supply voltage, V_{CC} (see Note 1) | -7 V |
| Input voltage, any differential input | ± 25 V |
| Differential input voltage (see Note 2) | ± 25 V |
| Low-level output current | 50 mA |
| Operating free-air temperature range | 0°C to 70°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package | 300°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package | 260°C |

- NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.
2. Differential voltage values are at the noninverting terminal with respect to the inverting terminal.

recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|---------------------------------------|-----|------|---------|------|
| Supply voltage, V_{CC} | | -5.2 | | V |
| Common-mode input voltage, V_{IC} | | | ± 7 | V |
| High-level output current, I_{OH} | | | -1 | mA |
| Low-level output current, I_{OL} | | | 16 | mA |
| Operating free-air temperature, T_A | 0 | | 70 | °C |

electrical characteristics at $T_A = 25^\circ\text{C}$, $V_{CC} = -5.2$ V

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|--------------------|-----|-------|------------|
| V_T Threshold voltage (V_{T+} and V_{T-}) | $V_{IC} = V_{ICR}$ min | -100 [†] | | 100 | mV |
| V_{hys} Hysteresis ($V_{T+} - V_{T-}$) | | | 5 | | mV |
| V_{OH} High-level output voltage | $V_{ID} = 100$ mV, $R_L = 50 \Omega$ to -2 V | -0.96 [†] | | -0.81 | V |
| V_{OL} Low-level output voltage | $V_{ID} = -100$ mV, $R_L = 50 \Omega$ to -2 V | -1.85 [†] | | -1.65 | V |
| V_{ICR} Common-mode input voltage range | | 0 to -5.2 | | | V |
| r_{in} Input resistance | | | 4 | | k Ω |
| I_{CC} Supply current | $V_{ID} = 0$, No load | | -13 | -17 | mA |

[†]The algebraic convention, in which the more negative limit is designated as minimum, is used in this data sheet for input threshold and output voltage levels only.

switching characteristics at $T_A = 25^\circ\text{C}$, $V_{CC} = -5.2$ V

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|--|-----|-----|-----|------|
| t_{PLH} Propagation delay time, low-to-high-level output | $\Delta V_{ID} = +200$ mV to -200 mV or -200 mV to +200 mV, | | 18 | | ns |
| t_{PHL} Propagation delay time, high-to-low-level output | $R_L = 50 \Omega$ to -2 V | | 18 | | ns |



TYPICAL CHARACTERISTICS

OUTPUT RESPONSES FOR VARIOUS
INPUT OVERDRIVES

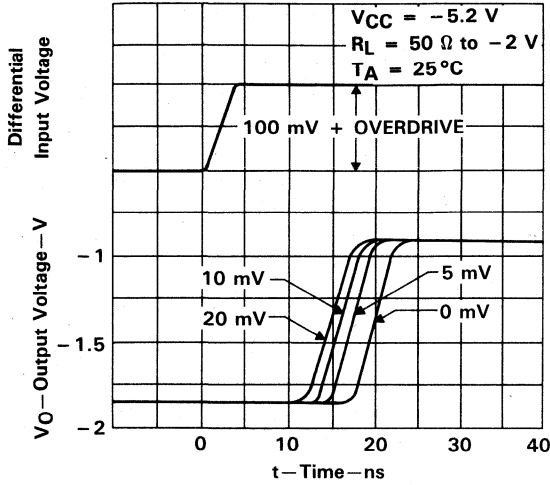


FIGURE 1

OUTPUT RESPONSES FOR VARIOUS
INPUT OVERDRIVES

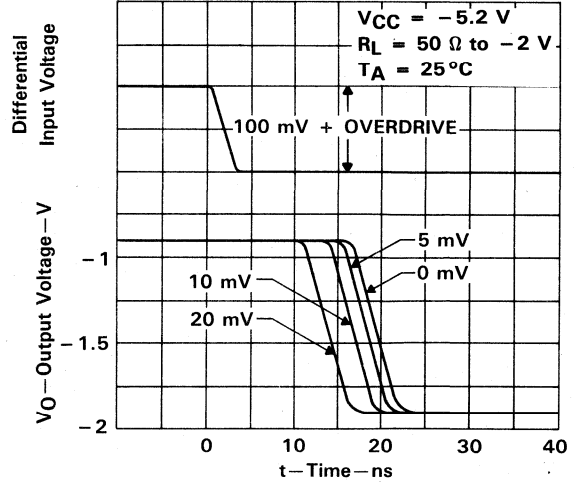


FIGURE 2

COMMON-MODE
PULSE RESPONSE

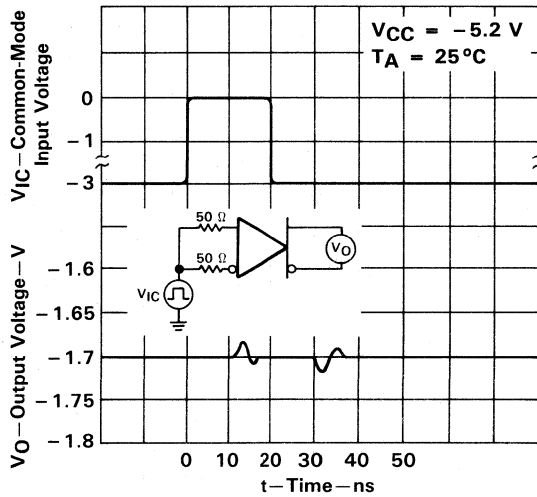


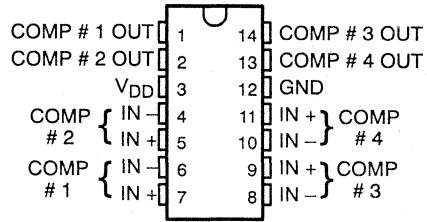
FIGURE 3

TLC139M, TLC339C, TLC339I, TLC339M, TLC339Q QUADRUPLE MICROPOWER LinCMOS™ COMPARATORS

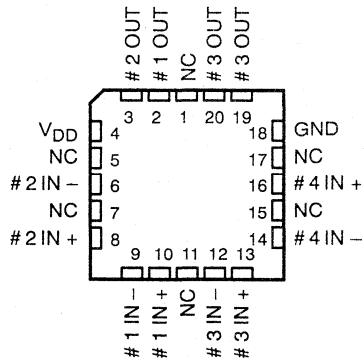
D3135, DECEMBER 1986 – REVISED JANUARY 1991

- Very Low Power . . . 200 μ W Typ at 5 V
- Fast Response Time . . . 2.5 μ s Typ With 5-mV Overdrive
- Single Supply Operation:
 - TLC139M . . . 4 V to 16 V
 - TLC339M . . . 4 V to 16 V
 - TLC339C . . . 3 V to 16 V
 - TLC339I . . . 3 V to 16 V
- High Input Impedance . . . $10^{12} \Omega$ Typ
- Input Offset Voltage Change at Worst Case Input Condition Typically 0.23 μ V/Month Including the First 30 Days
- On-Chip ESD Protection

D, J, OR N PACKAGE
(TOP VIEW)



FK PACKAGE
(TOP VIEW)



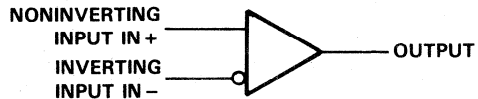
NC – No internal connection

description

The TLC139/TLC339 consists of four independent differential-voltage comparators designed to operate from a single supply. It is functionally similar to the LM139/LM339 family but uses 1/20th the power for similar response times. The open-drain MOS output stage interfaces to a variety of loads and supplies, as well as "wired" logic functions. For a similar device with a push-pull output configuration, see the TLC3704 data sheet.

Texas Instruments LinCMOS™ process offers superior analog performance to standard CMOS processes. Along with the standard CMOS advantages of low power without sacrificing speed, high input impedance, and low bias currents, the LinCMOS™ process offers extremely stable input offset voltages, even with differential input stresses of several volts. This characteristic makes it possible to build reliable CMOS comparators.

symbol (each comparator)



AVAILABLE OPTIONS

| T _A | V _{IO} max at 25°C | PACKAGE | | | |
|-----------------|-----------------------------|-------------------|-------------------|-----------------|-----------------|
| | | SMALL OUTLINE (D) | CHIP CARRIER (FK) | CERAMIC DIP (J) | PLASTIC DIP (N) |
| 0°C to 70°C | 5 mV | TLC339CD | – | – | TLC339CN |
| – 40°C to 85°C | 5 mV | TLC339ID | – | – | TLC339IN |
| – 40°C to 125°C | 5 mV | TLC339QD | – | – | TLC339QN |
| – 55°C to 125°C | 5 mV | TLC339MD | TLC139MFK | TLC139MJ | TLC339MN |

The D package is available taped and reeled. Add the suffix R to the device type, (e.g., TLC339CDR).

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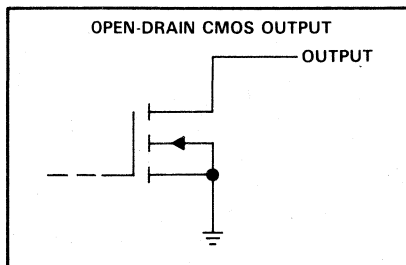
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TLC139M, TLC339C, TLC339I, TLC339M, TLC339Q QUADRUPLE MICROPPOWER LinCMOS™ COMPARATORS

description (continued)

The TLC139M and TLC339M are characterized for operation over the full military temperature range of -55°C to 125°C . The TLC339C is characterized for operation over the commercial temperature range of 0°C to 70°C . The TLC339I is characterized for operation over the industrial temperature range of -40°C to 85°C . The TLC339Q is characterized for operation over the extended industrial temperature range of -40°C to 125°C .

output schematic



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|--|
| Supply voltage range, V_{DD} (see Note 1) | $-0.3\text{ V to }18\text{ V}$ |
| Differential input voltage (see Note 2) | $\pm 18\text{ V}$ |
| Input voltage range, V_I | $-0.3\text{ V to }V_{DD}$ |
| Output voltage range, V_O | $-0.3\text{ V to }V_{DD}$ |
| Input current, I_I | $\pm 5\text{ mA}$ |
| Output current, I_O (each output) | 20 mA |
| Total supply current into V_{DD} terminal | 40 mA |
| Total current out of ground terminal | 60 mA |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range: TLC139M | $-55^{\circ}\text{C to }125^{\circ}\text{C}$ |
| TLC339C | $0^{\circ}\text{C to }70^{\circ}\text{C}$ |
| TLC339I | $-40^{\circ}\text{C to }85^{\circ}\text{C}$ |
| TLC339M | $-55^{\circ}\text{C to }125^{\circ}\text{C}$ |
| TLC339Q | $-40^{\circ}\text{C to }125^{\circ}\text{C}$ |
| Storage temperature range | $-65^{\circ}\text{C to }150^{\circ}\text{C}$ |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or N package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package | 300°C |

- NOTES: 1. All voltage values, except differential voltages, are with respect to network ground.
2. Differential voltages are at the noninverting input with respect to the inverting input.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^{\circ}\text{C}$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25^{\circ}\text{C}$ | $T_A = 70^{\circ}\text{C}$ POWER RATING | $T_A = 85^{\circ}\text{C}$ POWER RATING | $T_A = 125^{\circ}\text{C}$ POWER RATING |
|---------|---|---|--|--|---|
| D | 950 mW | 7.6 mW/ $^{\circ}\text{C}$ | 608 mW | 494 mW | 190 mW |
| FK | 1375 mW | 11.0 mW/ $^{\circ}\text{C}$ | 880 mW | 715 mW | 275 mW |
| J | 1375 mW | 11.0 mW/ $^{\circ}\text{C}$ | 880 mW | 715 mW | 275 mW |
| N | 1150 mW | 9.2 mW/ $^{\circ}\text{C}$ | 736 mW | 598 mW | 230 mW |

TLC139M, TLC339M
QUADRUPLE MICROPOWER LinCMOS™ COMPARATORS

recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|---------------------------------------|-----|-----|--------------|------|
| Supply voltage, V_{DD} | 4 | 5 | 16 | V |
| Common-mode input voltage, V_{IC} | 0 | | $V_{DD}-1.5$ | V |
| Low-level output current, I_{OL} | | | 20 | mA |
| Operating free-air temperature, T_A | -55 | | 125 | °C |

electrical characteristics at specified operating free-air temperature, $V_{DD} = 5$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS† | MIN | TYP | MAX | UNIT |
|-----------|-----------------------------------|--|----------------|-------------------|-----|------|
| V_{IO} | Input offset voltage | $V_{IC} = V_{ICRmin}$, $V_{DD} = 5$ V to 10 V, See Note 3 | 25°C | 1.4 | 5 | mV |
| | | | -55°C to 125°C | | 10 | |
| I_{IO} | Input offset current | $V_{IC} = 2.5$ V | 25°C | 1 | | pA |
| | | | 125°C | | 15 | nA |
| I_{IB} | Input bias current | $V_{IC} = 2.5$ V | 25°C | 5 | | pA |
| | | | 125°C | | 30 | nA |
| V_{ICR} | Common-mode input voltage range | | 25°C | 0 to $V_{DD}-1$ | | V |
| | | | -55°C to 125°C | 0 to $V_{DD}-1.5$ | | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICRmin}$ | 25°C | 84 | | dB |
| | | | 125°C | 84 | | |
| | | | -55°C | 84 | | |
| k_{SVR} | Supply voltage rejection ratio | $V_{DD} = 5$ V to 10 V | 25°C | 85 | | dB |
| | | | 125°C | 84 | | |
| | | | -55°C | 84 | | |
| V_{OL} | Low-level output voltage | $V_{ID} = -1$ V, $I_{OL} = 6$ mA | 25°C | 300 | 400 | mV |
| | | | 125°C | | 800 | |
| I_{OH} | High-level output current | $V_{ID} = 1$ V, $V_O = 5$ V | 25°C | 0.8 | 40 | nA |
| | | | 125°C | | 1 | μA |
| I_{DD} | Supply current (four comparators) | No load, Outputs low | 25°C | 44 | 80 | μA |
| | | | -55°C to 125°C | | 175 | |

† All characteristics are measured with zero common-mode voltage unless otherwise noted.

NOTE 3: The offset voltage limits given are the maximum values required to drive the output up to 4.5 V or down to 0.3 V with a 2.5-kΩ load to V_{DD} .

TLC339C

QUADRUPLE MICROPOWER LINCMOS™ COMPARATOR

recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|---------------------------------------|------|-----|----------------|------|
| Supply voltage, V_{DD} | 3 | 5 | 16 | V |
| Common-mode input voltage, V_{IC} | -0.2 | | $V_{DD} - 1.5$ | V |
| Low-level output current, I_{OL} | | 8 | 20 | mA |
| Operating free-air temperature, T_A | 0 | | 70 | °C |

electrical characteristics at specified operating free-air temperature, $V_{DD} = 5$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS† | T_A | MIN | TYP | MAX | UNIT |
|-----------|-----------------------------------|--|-------------|------|-----|----------------|------|
| V_{IO} | Input offset voltage | $V_{IC} = V_{ICRmin}$, $V_{DD} = 5$ V to 10 V, See Note 3 | 25°C | | 1.4 | 5 | mV |
| | | | 0°C to 70°C | | | 6.5 | |
| I_{IO} | Input offset current | $V_{IC} = 2.5$ V | 25°C | | 1 | | pA |
| | | | 70°C | | | 0.3 | nA |
| I_{IB} | Input bias current | $V_{IC} = 2.5$ V | 25°C | | 5 | | pA |
| | | | 70°C | | | 0.6 | nA |
| V_{ICR} | Common-mode input voltage range | | 25°C | 0 to | | $V_{DD} - 1$ | V |
| | | | 0°C to 70°C | 0 to | | $V_{DD} - 1.5$ | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICRmin}$ | 25°C | | 84 | | dB |
| | | | 70°C | | 84 | | |
| | | | 0°C | | 84 | | |
| k_{SVR} | Supply voltage rejection ratio | $V_{DD} = 5$ V to 10 V | 25°C | | 85 | | dB |
| | | | 70°C | | 85 | | |
| | | | 0°C | | 85 | | |
| V_{OL} | Low-level output voltage | $V_{ID} = -1$ V, $I_{OL} = 6$ mA | 25°C | | 300 | 400 | mV |
| | | | 70°C | | | 650 | |
| I_{OH} | High-level output current | $V_{ID} = 1$ V, $V_O = 5$ V | 25°C | | 0.8 | 40 | nA |
| | | | 70°C | | | 1 | μA |
| I_{DD} | Supply current (four comparators) | No load, Outputs low | 25°C | | 44 | 80 | μA |
| | | | 0°C to 70°C | | | 100 | |

† All characteristics are measured with zero common-mode voltage unless otherwise noted.

NOTE 3: The offset voltage limits given are the maximum values required to drive the output up to 4.5 V or down to 0.3 V with a 2.5-kΩ load to V_{DD} .

TLC3391
QUADRUPLE MICROPOWER LinCMOS™ COMPARATOR

recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|---------------------------------------|------|----------------|-----|------|
| Supply voltage, V_{DD} | 3 | 5 | 16 | V |
| Common-mode input voltage, V_{IC} | -0.2 | $V_{DD} - 1.5$ | | V |
| Low-level output current, I_{OL} | | 8 | 20 | mA |
| Operating free-air temperature, T_A | -40 | | 85 | °C |

electrical characteristics at specified operating free-air temperature, $V_{DD} = 5\text{ V}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS† | T_A | MIN | TYP | MAX | UNIT |
|-----------|-----------------------------------|---|---------------|---------------------|-----|-----|------|
| V_{IO} | Input offset voltage | $V_{IC} = V_{ICRmin}$, $V_{DD} = 5\text{ V to }10\text{ V}$, See Note 3 | 25°C | | 1.4 | 5 | mV |
| | | | -40°C to 85°C | | | 7 | |
| I_{IO} | Input offset current | $V_{IC} = 2.5\text{ V}$ | 25°C | | 1 | | pA |
| | | | 85°C | | | 1 | nA |
| I_{IB} | Input bias current | $V_{IC} = 2.5\text{ V}$ | 25°C | | 5 | | pA |
| | | | 85°C | | | 2 | nA |
| V_{ICR} | Common-mode input voltage range | | 25°C | 0 to $V_{DD} - 1$ | | | V |
| | | | -40°C to 85°C | 0 to $V_{DD} - 1.5$ | | | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICRmin}$ | 25°C | 84 | | | dB |
| | | | 85°C | 84 | | | |
| | | | -40°C | 84 | | | |
| k_{SVR} | Supply voltage rejection ratio | $V_{DD} = 5\text{ V to }10\text{ V}$ | 25°C | 85 | | | dB |
| | | | 85°C | 85 | | | |
| | | | -40°C | 84 | | | |
| V_{OL} | Low-level output voltage | $V_{ID} = -1\text{ V}$, $I_{OH} = 6\text{ mA}$ | 25°C | 300 | 400 | | mV |
| | | | 85°C | | 700 | | |
| I_{OH} | High-level output current | $V_{ID} = 1\text{ V}$, $V_O = 5\text{ VmA}$ | 25°C | 0.8 | 40 | | nA |
| | | | 85°C | | 1 | | μA |
| I_{DD} | Supply current (four comparators) | No load, Outputs low | 25°C | 44 | 80 | | μA |
| | | | -40°C to 85°C | | 125 | | |

† All characteristics are measured with zero common-mode voltage unless otherwise noted.

NOTE 3: The offset voltage limits given are the maximum values required to drive the output up to 4.5 V or down to 0.3 V with a 2.5-kΩ load to V_{DD} .

TLC339Q

QUADRUPLE MICROPOWER LinCMOS™ COMPARATORS

recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|---------------------------------------|-----|--------------|-----|------|
| Supply voltage, V_{DD} | 4 | 5 | 16 | V |
| Common-mode input voltage, V_{IC} | 0 | $V_{DD}-1.5$ | | V |
| Low-level output current, I_{OL} | | | 20 | mA |
| Operating free-air temperature, T_A | -40 | | 125 | °C |

electrical characteristics at specified operating free-air temperature, $V_{DD} = 5\text{ V}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS† | MIN | TYP | MAX | UNIT |
|-----------|-----------------------------------|---|----------------|-------------------|-----|------|
| V_{IO} | Input offset voltage | $V_{IC} = V_{ICRmin}$, $V_{DD} = 5\text{ V to }10\text{ V}$, See Note 3 | 25°C | 1.4 | 5 | mV |
| | | | -40°C to 125°C | | 10 | |
| I_{IO} | Input offset current | $V_{IC} = 2.5\text{ V}$ | 25°C | 1 | | pA |
| | | | 125°C | | 15 | nA |
| I_{IB} | Input bias current | $V_{IC} = 2.5\text{ V}$ | 25°C | 5 | | pA |
| | | | 125°C | | 30 | nA |
| V_{ICR} | Common-mode input voltage range | | 25°C | 0 to $V_{DD}-1$ | | V |
| | | | -40°C to 125°C | 0 to $V_{DD}-1.5$ | | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICRmin}$ | 25°C | 84 | | dB |
| | | | 125°C | 84 | | |
| | | | -40°C | 84 | | |
| k_{SVR} | Supply voltage rejection ratio | $V_{DD} = 5\text{ V to }10\text{ V}$ | 25°C | 85 | | dB |
| | | | 125°C | 84 | | |
| | | | -40°C | 84 | | |
| V_{OL} | Low-level output voltage | $V_{ID} = -1\text{ V}$, $I_{OL} = 6\text{ mA}$ | 25°C | 300 | 400 | mV |
| | | | 125°C | | 800 | |
| I_{OH} | High-level output current | $V_{ID} = 1\text{ V}$, $V_O = 5\text{ V}$ | 25°C | 0.8 | 40 | nA |
| | | | 125°C | | 1 | μA |
| I_{DD} | Supply current (four comparators) | No load, Outputs low | 25°C | 44 | 80 | μA |
| | | | -40°C to 125°C | | 125 | |

† All characteristics are measured with zero common-mode voltage unless otherwise noted.

NOTE 3: The offset voltage limits given are the maximum values required to drive the output up to 4.5 V or down to 0.3 V with a 2.5-kΩ load to V_{DD} .

TLC139M, TLC339C, TLC339I, TLC339M, TLC339Q QUADRUPLE MICROPOWER LinCMOS™ COMPARATORS

switching characteristics, $V_{DD} = 5\text{ V}$, $T_A = 25^\circ\text{C}$ (see Figure 3)

| PARAMETER | | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|------------------|--|---------------------------------------|--|-----|------|-----|------|
| t _{PLH} | Propagation delay time, low-to-high level output | f = 10 kHz, C _L = 15 pF | Overdrive = 2 mV | | 4.5 | | μs |
| | | | Overdrive = 5 mV | | 2.5 | | |
| | | | Overdrive = 10 mV | | 1.7 | | |
| | | | Overdrive = 20 mV | | 1.2 | | |
| | | | Overdrive = 40 mV | | 1.0 | | |
| | | | V _I = 1.4 V step at IN+ pin | | 1.1 | | |
| t _{PHL} | Propagation delay time, high-to-low level output | f = 10 kHz, C _L = 15 pF | Overdrive = 2 mV | | 3.6 | | μs |
| | | | Overdrive = 5 mV | | 2.1 | | |
| | | | Overdrive = 10 mV | | 1.3 | | |
| | | | Overdrive = 20 mV | | 0.85 | | |
| | | | Overdrive = 40 mV | | 0.55 | | |
| | | | V _I = 1.4 V step at IN+ pin | | 0.10 | | |
| t _{THL} | Transition time, high-to-low level output | f = 10 kHz, C _L = 15 pF | Overdrive = 50 mV | | 20 | | ns |

PARAMETER MEASUREMENT INFORMATION

The TLC139 and TLC339 contain a digital output stage that, if held in the linear region of the transfer curve, can cause damage to the device. Conventional operational amplifier/comparator testing incorporates the use of a servo-loop that is designed to force the device output to a level within this linear region. Since the servo-loop method of testing cannot be used, the following alternatives for testing parameters such as input offset voltage, common-mode rejection, etc., are suggested.

To verify that the input offset voltage falls within the limits specified, the limit value is applied to the input as shown in Figure 1(a). With the noninverting input positive with respect to the inverting input, the output should be high. With the input polarity reversed, the output should be low.

A similar test can be made to verify the input offset voltage at the common-mode extremes. The supply voltages can be slewed as shown in Figure 1(b) for the V_{ICR} test, rather than changing the input voltages, to provide greater accuracy.

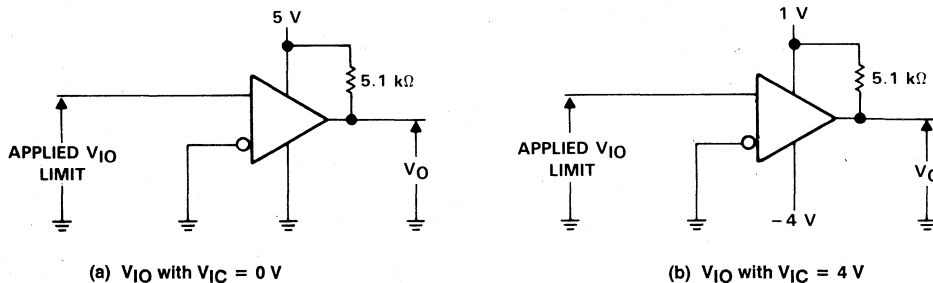


FIGURE 1. METHOD FOR VERIFYING THAT INPUT OFFSET VOLTAGE IS WITHIN SPECIFIED LIMITS

A close approximation of the input offset voltage can be obtained by using a binary search method to vary the differential input voltage while monitoring the output state. When the applied input voltage differential is equal but opposite in polarity to the input offset voltage, the output will change state.

PARAMETER MEASUREMENT INFORMATION

Figure 2 illustrates a practical circuit for direct dc measurement of input offset voltage that does not bias the comparator into the linear region. The circuit consists of a switching mode servo loop in which U1A generates a triangular waveform of approximately 20-mV amplitude. U1B acts as a buffer, with C2 and R4 removing any residual dc offset. The signal is then applied to the inverting input of the comparator under test, while the noninverting input is driven by the output of the integrator formed by U1C through the voltage divider formed by R9 and R10. The loop reaches a stable operating point when the output of the comparator under test has a duty cycle of exactly 50%, which can only occur when the incoming triangle wave is "sliced" symmetrically or when the voltage at the noninverting input exactly equals the input offset voltage.

Voltage divider R9 and R10 provides a step-up of the input offset voltage by a factor of 100 to make measurement easier. The values of R5, R8, R9, and R10 can significantly influence the accuracy of the reading; therefore, it is suggested that their tolerance level be 1% or lower.

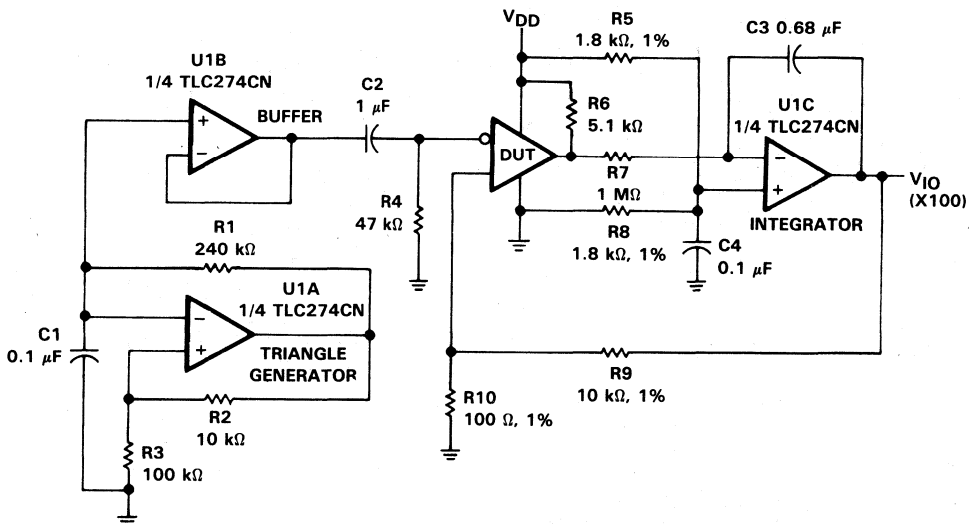


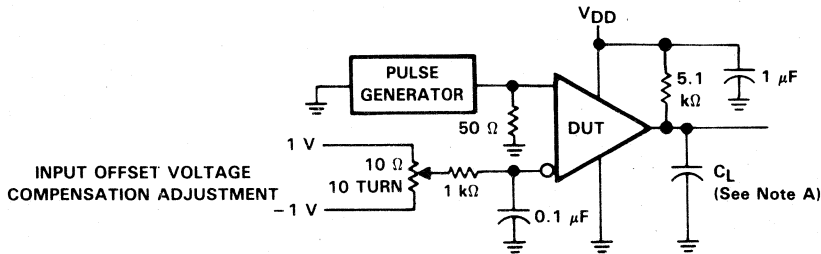
FIGURE 2. CIRCUIT FOR INPUT OFFSET VOLTAGE MEASUREMENT

Measuring the extremely low values of input current requires isolation from all other sources of leakage current and compensation for the leakage of the test socket and board. With a good picoammeter, the socket and board leakage can be measured with no device in the socket. Subsequently, this open socket leakage value can be subtracted from the measurement obtained with a device in the socket to obtain the actual input current of the device.

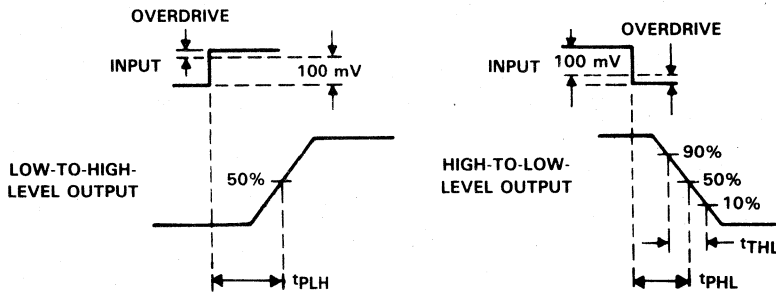
TLC139M, TLC339C, TLC339I, TLC339M, TLC339Q QUADRUPLE MICROPOWER LinCMOS™ COMPARATORS

PARAMETER MEASUREMENT INFORMATION

Propagation delay time is defined as the interval between the application of an input step function and the instant when the output reaches 50% of its maximum value. Propagation delay time, low-to-high-level output, is measured from the leading edge of the input pulse, while propagation delay time, high-to-low-level output, is measured from the trailing edge of the input pulse. Propagation delay time measurement at low input signal levels can be greatly affected by the input offset voltage. The offset voltage should be balanced by the adjustment at the inverting input (as shown in Figure 3) so that the circuit is just at the transition point. Then a low signal, for example 105-mV or 5-mV overdrive, will cause the output to change state.



TEST CIRCUIT



VOLTAGE WAVEFORMS

NOTE A: C_L includes probe and jig capacitance.

FIGURE 3. PROPAGATION DELAY, RISE, AND FALL TIMES
CIRCUIT AND VOLTAGE WAVEFORMS

TLC139M, TLC339C, TLC339I, TLC339M, TLC339Q
 QUADRUPLE MICROPOWER LinCMOS™ COMPARATORS

TYPICAL CHARACTERISTICS†

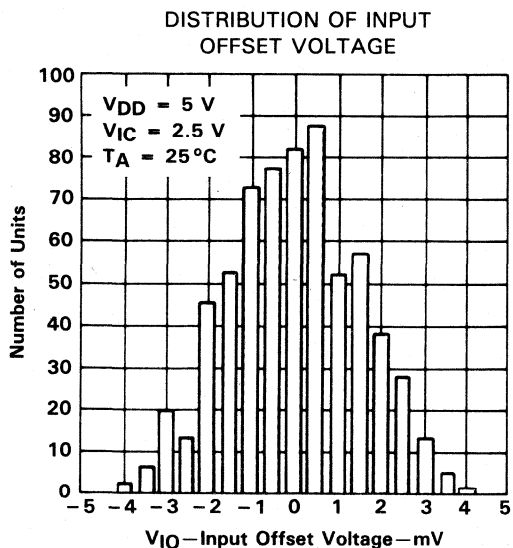


FIGURE 4

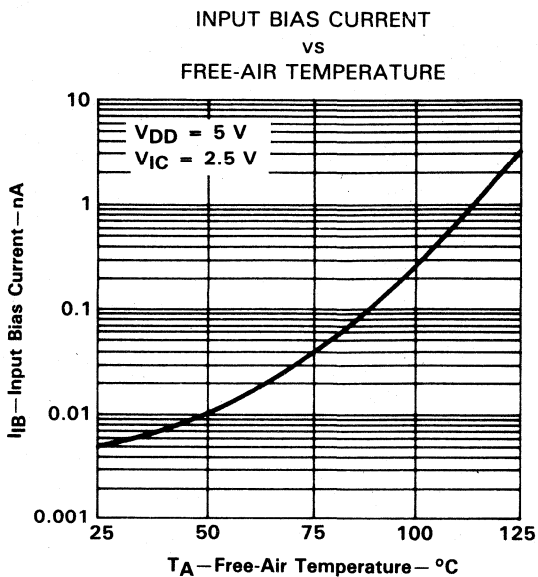


FIGURE 5

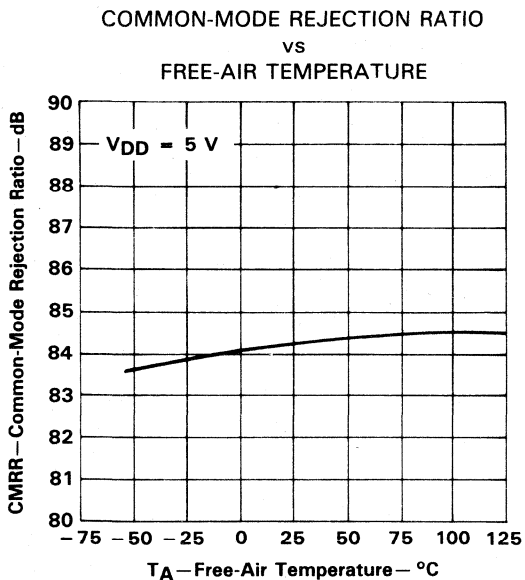


FIGURE 6

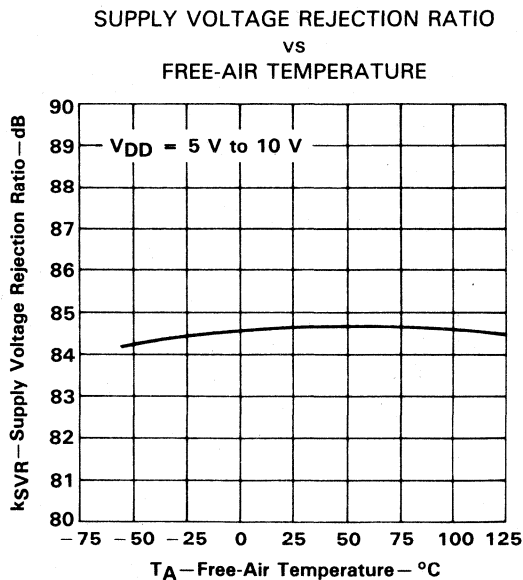


FIGURE 7

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TLC139M, TLC339C, TLC339I, TLC339M, TLC339Q QUADRUPLE MICROPOWER LinCMOS™ COMPARATORS

TYPICAL CHARACTERISTICS†

HIGH-LEVEL OUTPUT CURRENT
vs
HIGH-LEVEL OUTPUT VOLTAGE

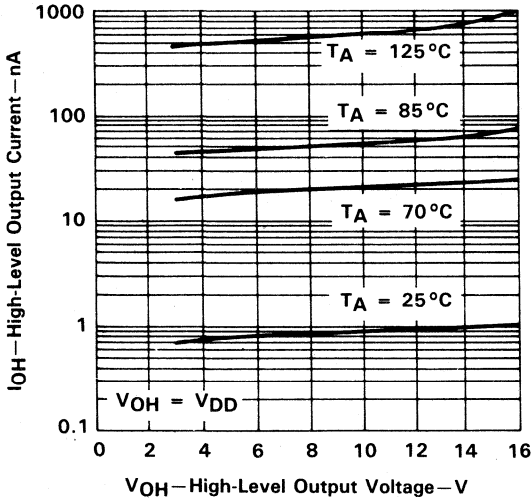


FIGURE 8

HIGH-LEVEL OUTPUT CURRENT
vs
FREE-AIR TEMPERATURE

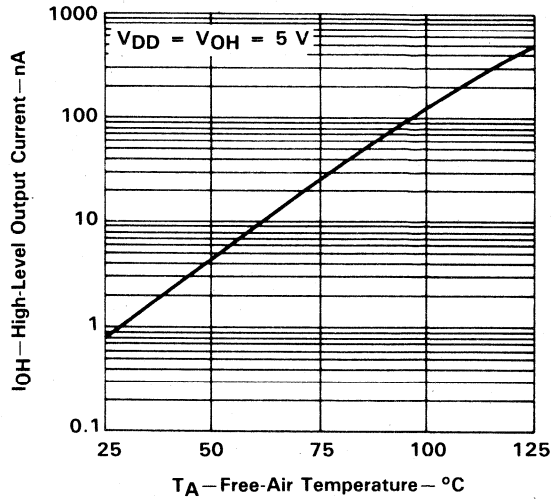


FIGURE 9

LOW-LEVEL OUTPUT VOLTAGE
vs
LOW-LEVEL OUTPUT CURRENT

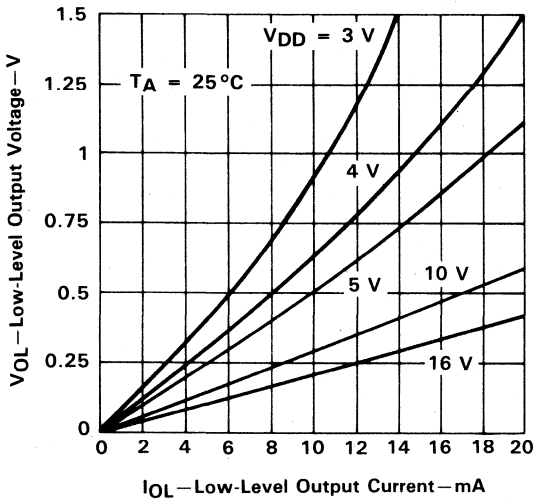


FIGURE 10

LOW-LEVEL OUTPUT VOLTAGE
vs
FREE-AIR TEMPERATURE

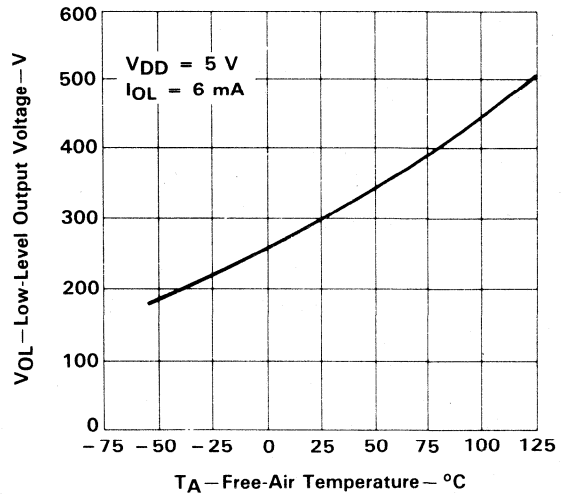


FIGURE 11

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TLC139M, TLC339C, TLC339I, TLC339M, TLC339Q
QUADRUPLE MICROPOWER LinCMOS™ COMPARATORS

TYPICAL CHARACTERISTICS†

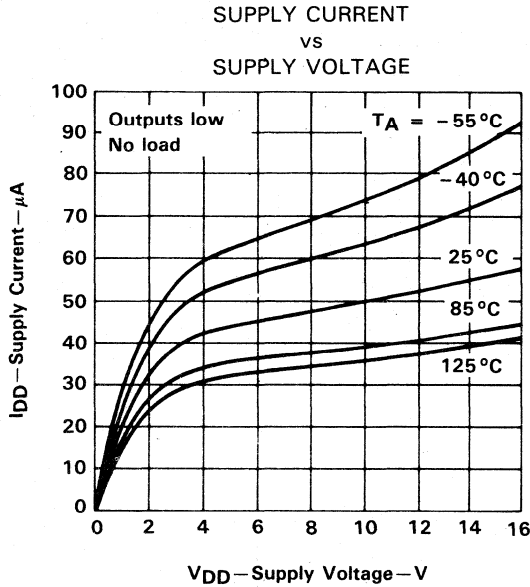


FIGURE 12

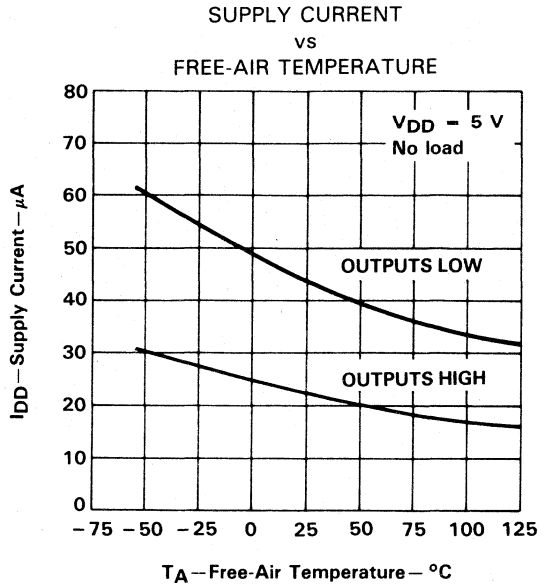


FIGURE 13

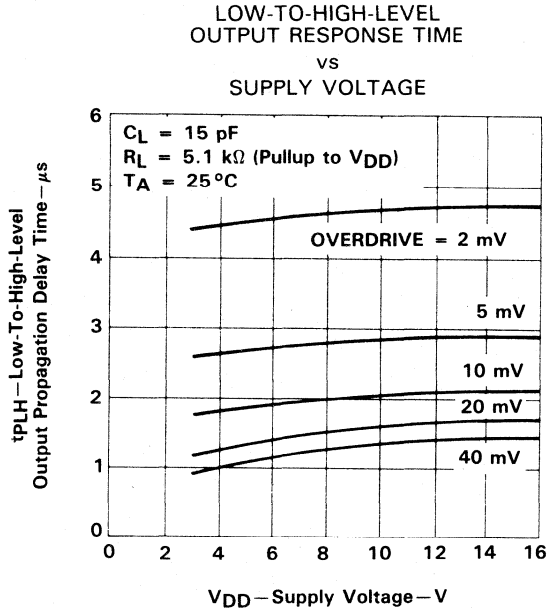


FIGURE 14

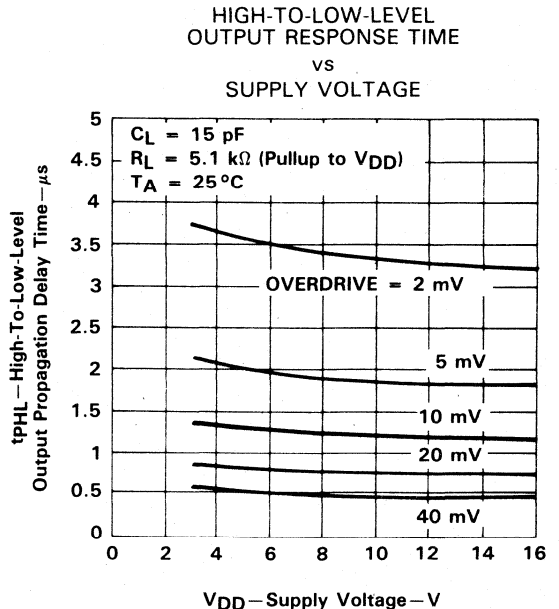


FIGURE 15

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TLC139M, TLC339C, TLC339I, TLC339M, TLC339Q
 QUADRUPLE MICROPOWER LinCMOS™ COMPARATORS

TYPICAL CHARACTERISTICS

LOW-TO-HIGH-LEVEL OUTPUT
 PROPAGATION DELAY
 FOR VARIOUS OVERDRIVE VOLTAGES

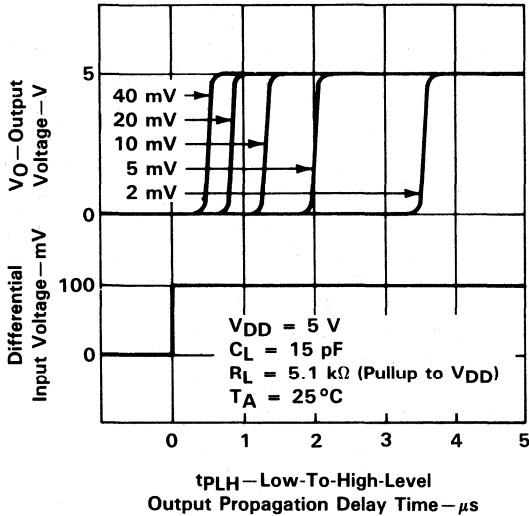


FIGURE 16

OUTPUT FALL TIME
 vs
 SUPPLY VOLTAGE

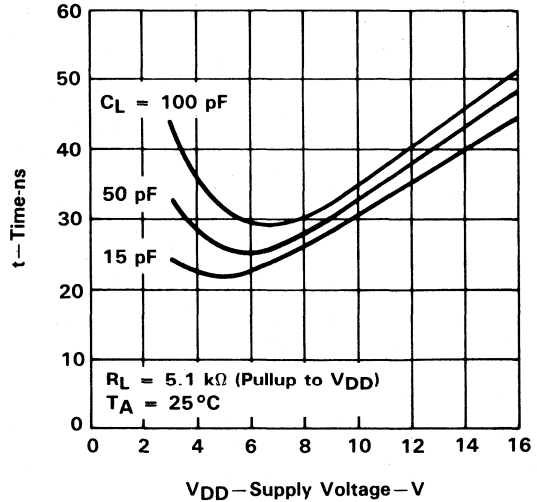


FIGURE 17

HIGH-TO-LOW-LEVEL OUTPUT
 PROPAGATION DELAY
 FOR VARIOUS OVERDRIVE VOLTAGES

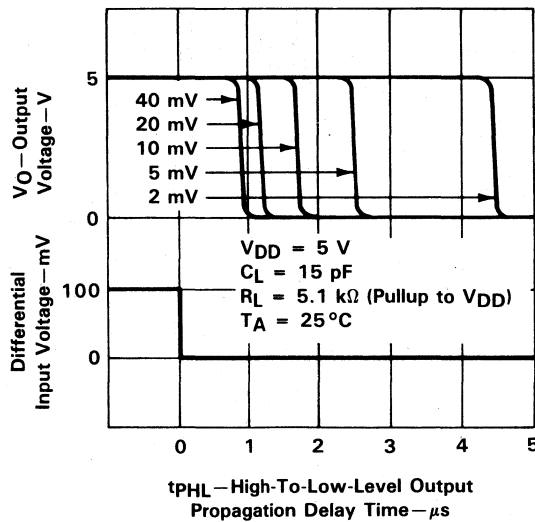


FIGURE 18

TLC139M, TLC339C, TLC339I, TLC339M, TLC339Q QUADRUPLE MICROPOWER LinCMOS™ COMPARATORS

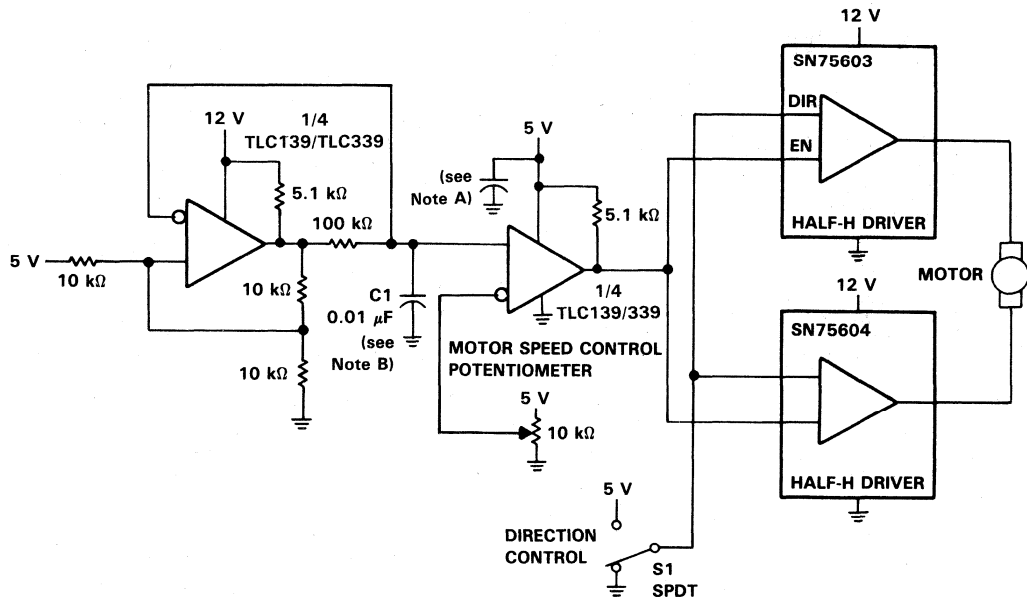
APPLICATION INFORMATION

The inputs should always remain within the supply rails in order to avoid forward biasing the diodes in the electrostatic discharge (ESD) protection structure. If either input exceeds this range, the device will not be damaged as long as the input current is limited to less than 5 mA. To maintain the expected output state, the inputs must remain within the common-mode range. For example, at 25°C with $V_{DD} = 5\text{ V}$, both inputs must remain between -0.2 V and 4 V to assure proper device operation.

To assure reliable operation, the supply should be decoupled with a capacitor ($0.1\text{ }\mu\text{F}$) positioned as close to the device as possible.

Be careful to note the output and supply current limitations since the TLC139/TLC339 does not provide current protection. For example, each output can source or sink a maximum of 20 mA; however, the total current to ground can only be an absolute maximum of 60 mA. This prohibits sinking 20 mA from each of the four outputs simultaneously since the total current to ground would be 80 mA.

The TLC139 and TLC339 have internal ESD protection circuits that will prevent functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2; however, care should be exercised in handling these devices as exposure to ESD may result in the degradation of the device parametric performance.

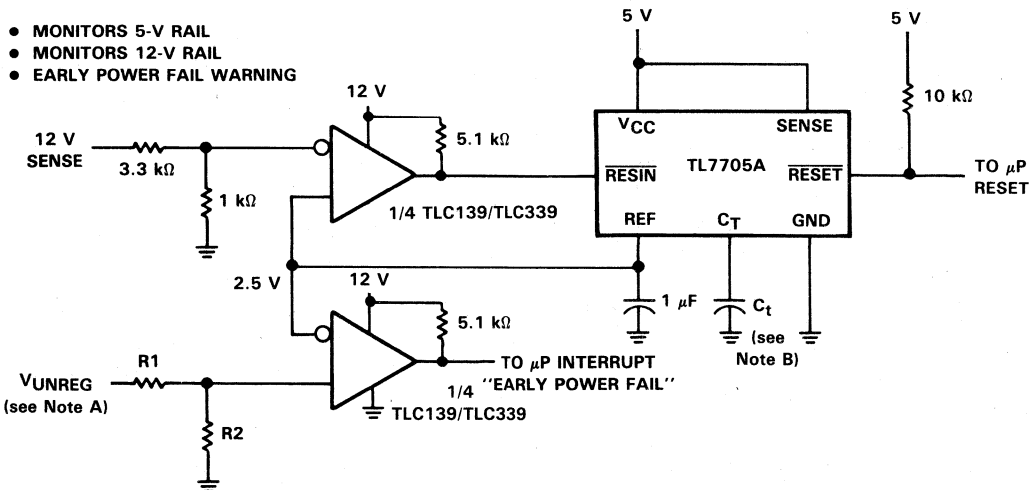


- NOTES: A. The recommended minimum capacitance is $10\text{ }\mu\text{F}$ to eliminate common ground switching noise.
B. Select C1 for change in oscillator frequency.

FIGURE 19. PULSE-WIDTH-MODULATED MOTOR SPEED CONTROLLER

TLC139M, TLC339C, TLC339I, TLC339M, TLC339Q QUADRUPLE MICROPOWER LinCMOS™ COMPARATORS

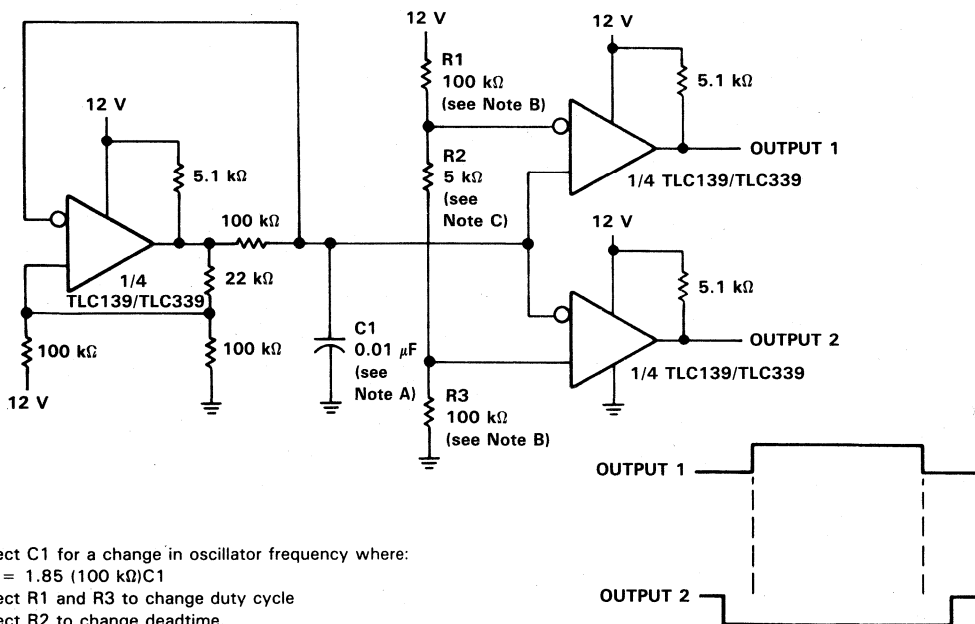
TYPICAL APPLICATION DATA



NOTES: A. $V_{UNREG} = 2.5 \left(\frac{R1 + R2}{R2} \right)$

B. The value of C_t determines the time delay of reset.

FIGURE 20. ENHANCED SUPPLY SUPERVISOR



NOTES: A. Select C_1 for a change in oscillator frequency where:

$1/f = 1.85 (100 \text{ k}\Omega) C_1$

B. Select R_1 and R_3 to change duty cycle

C. Select R_2 to change deadtime.

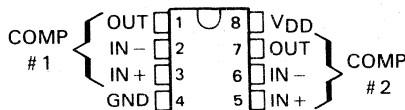
FIGURE 21. TWO-PHASE NONOVERLAPPING CLOCK GENERATOR

TLC352C, TLC352I, TLC352M LinCMOS™ DUAL DIFFERENTIAL COMPARATORS

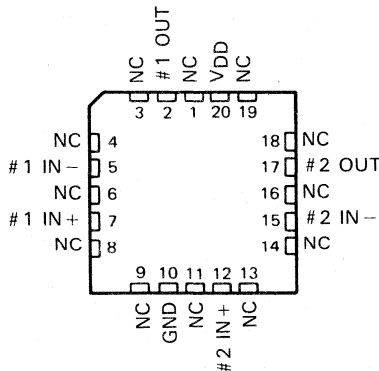
D2901, SEPTEMBER 1985—REVISED OCTOBER 1990

- Single- or Dual-Supply Operation
- Wide Range of Supply Voltages . . . 1.4 V to 18 V
- Very Low Supply Current Drain
150 μ A Typ at 5 V
65 μ A Typ at 1.4 V
- Built-In ESD Protection
- High Input Impedance . . . $10^{12} \Omega$ Typ
- Extremely Low Input Bias Current 5 pA Typ
- Ultrastable Low Input Offset Voltage
- Input Offset Voltage Change at Worst-Case Input Conditions Typically 0.23 μ V/Month, Including the First 30 Days
- Common-Mode Input Voltage Range Includes Ground
- Outputs Compatible with TTL, MOS, and CMOS
- Pin-Compatible with LM393

TLC352C, TLC352I . . . D OR P PACKAGE
TLC352M . . . JG PACKAGE
(TOP VIEW)



TLC352M . . . FK PACKAGE
(TOP VIEW)



NC—No internal connection

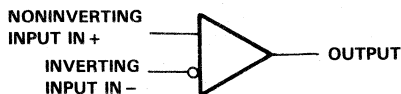
description

This device is fabricated using LinCMOS™ technology and consists of two independent voltage comparators, each designed to operate from a single power supply. Operation from dual supplies is also possible so long as the difference between the two supplies is 1.4 V to 18 V. Each device features extremely high input impedance (typically greater than $10^{12} \Omega$), which allows direct interface to high-impedance sources. The outputs are n-channel open-drain configurations and can be connected to achieve positive-logic wired-AND relationships. The capability of the TLC352 to operate from a 1.4-V supply makes this device ideal for low-voltage battery applications.

The TLC352 has internal electrostatic discharge (ESD) protection circuits and has been classified with a 2000-V ESD rating tested under MIL-STD-883C, Method 3015. However, care should be exercised in handling this device as exposure to ESD may result in degradation of the device parametric performance.

The TLC352C is characterized for operation from 0°C to 70°C. The TLC352I is characterized for operation over the industrial temperature range of -40°C to 85°C. The TLC352M is characterized for operation over the full military temperature range of -55°C to 125°C.

symbol (each comparator)



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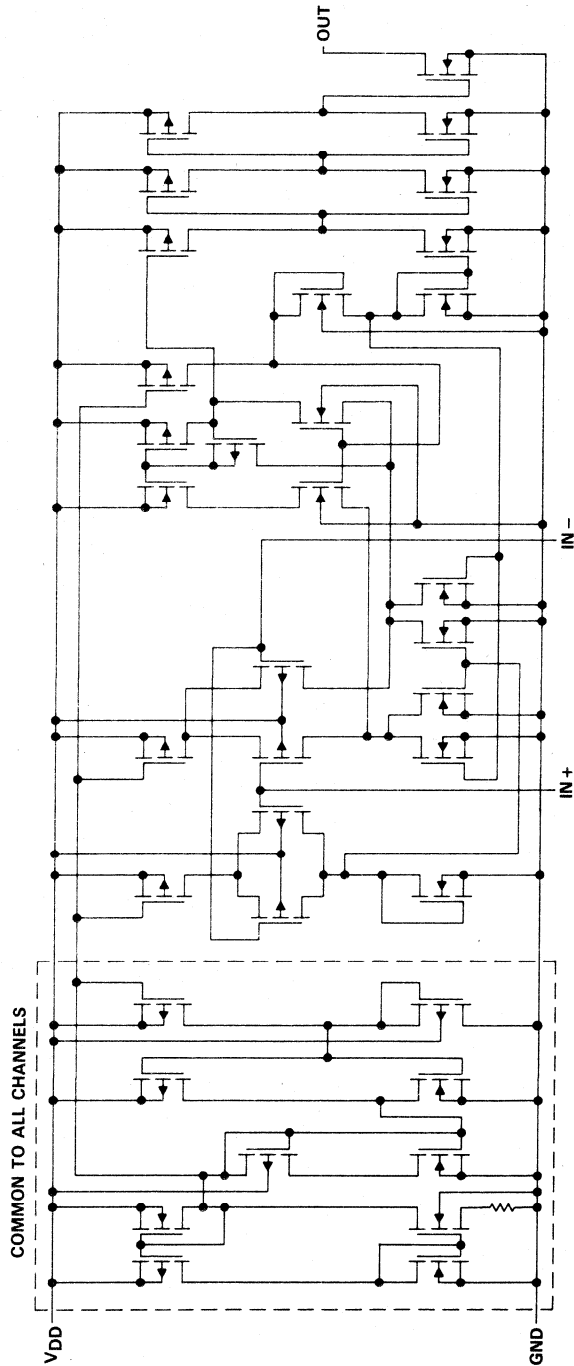
TEXAS
INSTRUMENTS

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TLC352C, TLC352I, TLC352M LinCMOS™ DUAL DIFFERENTIAL COMPARATORS

equivalent schematic (each comparator)



TLC352C, TLC352I, TLC352M LinCMOS™ DUAL DIFFERENTIAL COMPARATORS

AVAILABLE OPTIONS

| T _A | V _{IO} MAX AT 25°C | PACKAGE | | | |
|----------------------|--------------------------------|----------------------|----------------------|---------------------|--------------------|
| | | SMALL-OUTLINE (D) | CHIP-CARRIER (FK) | CERAMIC DIP (JG) | PLASTIC DIP (P) |
| 0°C to 70°C | 5 mV | TLC352CD | — | — | TLC352CP |
| -40°C to 85°C | 5 mV | TLC352ID | — | — | TLC352IP |
| -55°C to 125°C | 5 mV | — | TLC352MFK | TLC352MJG | — |

D packages are available taped and reeled. Add "R" suffix to device type, (e.g., TLC352CDR).

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Supply voltage, V _{DD} (see Note 1) | 18 V |
| Differential input voltage, V _{ID} (see Note 2) | ±18 V |
| Input voltage, V _I | V _{DD} |
| Input voltage range | -0.3 V to 18 V |
| Output voltage, V _O | 18 V |
| Input current, I _I | ±5 mA |
| Output current, I _O | 20 mA |
| Duration of output short-circuit to ground (see Note 3) | unlimited |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range: TLC352C | 0°C to 70°C |
| TLC352I | -40°C to 85°C |
| TLC352M | -55°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package | 300°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package | 260°C |

- NOTES: 1. All voltage values except differential voltages are with respect to network ground.
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
 3. Short circuits from outputs to V_{DD} can cause excessive heating and eventual device destruction.

DISSIPATION RATING TABLE

| PACKAGE | T _A ≤ 25°C POWER RATING | DERATING FACTOR | DERATE ABOVE T _A | T _A = 70°C POWER RATING | T _A = 85°C POWER RATING | T _A = 125°C POWER RATING |
|---------|---------------------------------------|--------------------|--------------------------------|---------------------------------------|---------------------------------------|--|
| D | 500 mW | 5.8 mW/°C | 64°C | 464 mW | 377 mW | N/A |
| FK | 500 mW | 11.0 mW/°C | 104°C | 500 mW | 500 mW | 275 mW |
| JG | 500 mW | 8.4 mW/°C | 90°C | 500 mW | 500 mW | 210 mW |
| P | 500 mW | N/A | N/A | 500 mW | 500 mW | N/A |

TLC352C, TLC352I, TLC352M

LiCMOS™ DUAL DIFFERENTIAL COMPARATORS

recommended operating conditions

| | C-SUFFIX | | | I-SUFFIX | | | M-SUFFIX | | | UNIT |
|--|------------------------|-----|-----|----------|-----|-----|----------|-----|-----|------|
| | MIN | NOM | MAX | MIN | NOM | MAX | MIN | NOM | MAX | |
| Supply voltage, V _{DD} | 1.4 | 16 | 16 | 1.4 | 16 | 16 | 1.4 | 16 | 16 | V |
| Common-mode input voltage, V _{IC} | V _{DD} = 5 V | | | | | | | | | |
| | 0 | 3.5 | 0 | 0 | 3.5 | 0 | 0 | 3.5 | 0 | 3.5 |
| Operating free-air temperature, T _A | V _{DD} = 10 V | | | | | | | | | |
| | 0 | 8.5 | 0 | 0 | 8.5 | 0 | 0 | 8.5 | 0 | 8.5 |
| | 0 | 70 | -40 | 85 | -55 | 125 | 125 | 125 | 125 | °C |

electrical characteristics at specified free-air temperature, V_{DD} = 1.4 V (unless otherwise noted)

| PARAMETER | TEST CONDITIONS† | TLC352C | | | TLC352I | | | TLC352M | | | UNIT |
|--|--|--------------------|-----|-----|---------|-----|-----|---------|-----|-----|------|
| | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| V _{IO} Input offset voltage | V _{IC} = V _{ICR} min, See Note 4 | 25°C | | | | | | | | | mV |
| | | Full range | | | | | | | | | |
| I _{IO} Input offset current | | 25°C | | | | | | | | | pA |
| | | MAX T _A | | | | | | | | | |
| I _{IB} Input bias current | | 25°C | | | | | | | | | pA |
| | | MAX T _A | | | | | | | | | |
| V _{ICR} Common-mode input voltage range | | 0 to 0.2 | | | | | | | | | V |
| | | Full range | | | | | | | | | |
| V _{OL} Low-level output voltage | V _{ID} = -0.5 V, I _{OL} = 0.6 mA | 25°C | | | | | | | | | mV |
| | | Full range | | | | | | | | | |
| I _{OL} Low-level output current | V _{ID} = -0.5 V, V _{OL} = 0.3 V | 25°C | | | | | | | | | mA |
| | | Full range | | | | | | | | | |
| I _{DD} Supply current (two comparators) | V _{ID} = 0.5 V, No load | 25°C | | | | | | | | | μA |
| | | Full range | | | | | | | | | |

† All characteristics are measured with zero common-mode input voltage unless otherwise noted. Full range is 0°C to 70°C for TLC352C, -40°C to 85°C for TLC352I, and -55°C to 125°C for TLC352M. IMPORTANT: See Parameter Measurement Information.

NOTE 4: The offset voltage limits given are the maximum values required to drive the output above 1.25 V or below 150 mV with a 10-kΩ resistor between the output and V_{DD}. They can be verified by applying the limit value to the input and checking for the appropriate output state.

electrical characteristics at specified free-air temperature, VDD = 5 V (unless otherwise noted)

| PARAMETER | TEST CONDITIONS† | TLC352C | | | TLC352I | | | TLC352M | | | UNIT |
|--|--|------------|--------------------------|------|--------------------------|-----|--------------------------|---------|--------------------------|-----|------|
| | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| V _{IO} Input offset voltage | V _{IC} = V _{ICR} min, See Note 5 | 25°C | 1 | 5 | 1 | 5 | 1 | 5 | 1 | 5 | mV |
| | | Full range | | 6.5 | | 7 | | 10 | | 10 | |
| I _{IO} Input offset current | 25°C MAX T _A | | 1 | 0.3 | | 1 | | 1 | | 1 | pA |
| | | 25°C | | 5 | | 5 | | 5 | | 5 | |
| I _{IB} Input bias current | 25°C MAX T _A | | | 0.6 | | 2 | | 20 | | 20 | nA |
| | | 25°C | 0 to V _{DD-1} | | 0 to V _{DD-1} | | 0 to V _{DD-1} | | 0 to V _{DD-1} | | |
| V _{ICR} Common-mode input voltage range | Full range | | 0 to V _{DD-1.5} | | 0 to V _{DD-1.5} | | 0 to V _{DD-1.5} | | 0 to V _{DD-1.5} | | V |
| | | 25°C | | 0.1 | | 0.1 | | 0.1 | | 0.1 | |
| I _{OH} High-level output current | V _{ID} = 1 V V _{OH} = 5 V V _{OH} = 15 V | 25°C | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | μA |
| | | Full range | | 150 | | 400 | | 150 | | 400 | |
| V _{OL} Low-level output voltage | V _{ID} = -1 V, I _{OL} = 4 mA | 25°C | 700 | 700 | 700 | 700 | 700 | 700 | 700 | 700 | mV |
| | | Full range | | 6 | | 16 | | 6 | | 16 | |
| I _{OL} Low-level output current | V _{ID} = -1 V, V _{OL} = 1.5 V | 25°C | 6 | 16 | 6 | 16 | 6 | 16 | 6 | 16 | mA |
| | | Full range | | 0.15 | | 0.3 | | 0.15 | | 0.3 | |
| I _{DD} Supply current (two comparators) | V _{ID} = 1 V, No load | 25°C | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | mA |
| | | Full range | | 0.4 | | 0.4 | | 0.4 | | 0.4 | |

† All characteristics are measured with zero common-mode input voltage unless otherwise noted. Full range is 0°C to 70°C for TLC352C, -40°C to 85°C for TLC352I, and -55°C to 125°C for TLC352M. IMPORTANT: See Parameter Measurement Information.

NOTE 5: The offset voltage limits given are the maximum values required to drive the output above 4 V or below 400 mV with a 10-kΩ resistor between the output and V_{DD}. They can be verified by applying the limit value to the input and checking for the appropriate output state.

switching characteristics, VDD = 5 V, T_A = 25°C

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---------------|---|-----|-----|-----|------|
| Response time | R _L connected to 5 V through 5.1 kΩ, | | 650 | | ns |
| | C _L = 15 pF†, See Note 6 TTL-level input step | | 200 | | |

† C_L includes probe and jig capacitance.

NOTE 6: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.

PARAMETER MEASUREMENT INFORMATION

The digital output stage of the TLC352 can be damaged if it is held in the linear region of the transfer curve. Conventional operational amplifier/comparator testing incorporates the use of a servo-loop that is designed to force the device output to a level within this linear region. Since the servo-loop method of testing cannot be used, the following alternative for measuring parameters such as input offset voltage, common-mode rejection, etc., are offered.

To verify that the input offset voltage falls within the limits specified, the limit value is applied to the input as shown in Figure 1 (a). With the noninverting input positive with respect to the inverting input, the output should be high. With the input polarity reversed, the output should be low.

A similar test can be made to verify the input offset voltage at the common-mode extremes. The supply voltages can be slewed as shown in Figure 1 (b) for the V_{ICR} test, rather than changing the input voltages, to provide greater accuracy.

A close approximation of the input offset voltage can be obtained by using a binary search method to vary the differential input voltage while monitoring the output state. When the applied input voltage differential is equal, but opposite in polarity, to the input offset voltage, the output will change states.

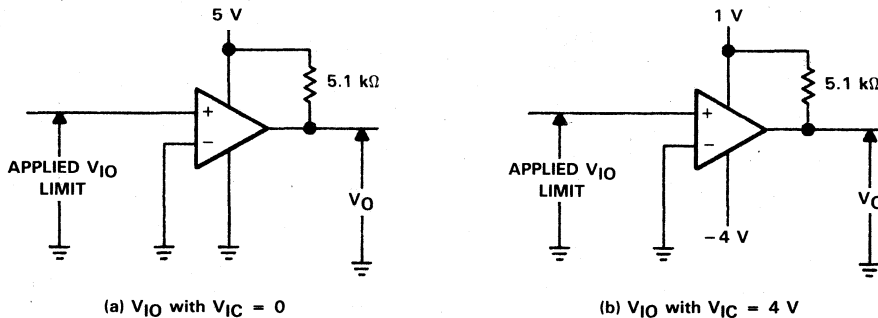


FIGURE 1. METHOD FOR VERIFYING THAT INPUT OFFSET VOLTAGE IS WITHIN SPECIFIED LIMITS

PARAMETER MEASUREMENT INFORMATION

Figure 2 illustrates a practical circuit for direct dc measurement of input offset voltage that does not bias the comparator into the linear region. The circuit consists of a switching-mode servo loop in which U1a generates a triangular waveform of approximately 20-mV amplitude. U1b acts as a buffer, with C2 and R4 removing any residual dc offset. The signal is then applied to the inverting input of the comparator under test, while the noninverting input is driven by the output of the integrator formed by U1c through the voltage divider formed by R9 and R10. The loop reaches a stable operating point when the output of the comparator under test has a duty cycle of exactly 50%, which can only occur when the incoming triangle wave is "sliced" symmetrically or when the voltage at the noninverting input exactly equals the input offset voltage.

Voltage divider R9 and R10 provides a step-up of the input offset voltage by a factor of 100 to make measurement easier. The values of R5, R8, R9, and R10 can significantly influence the accuracy of the reading; therefore, it is suggested that their tolerance level be 1% or lower.

Measuring the extremely low values of input current requires isolation from all other sources of leakage current and compensation for the leakage of the test socket and board. With a good picoammeter, the socket and board leakage can be measured with no device in the socket. Subsequently, this open-socket leakage value can be subtracted from the measurement obtained with a device in the socket to obtain the actual input current of the device.

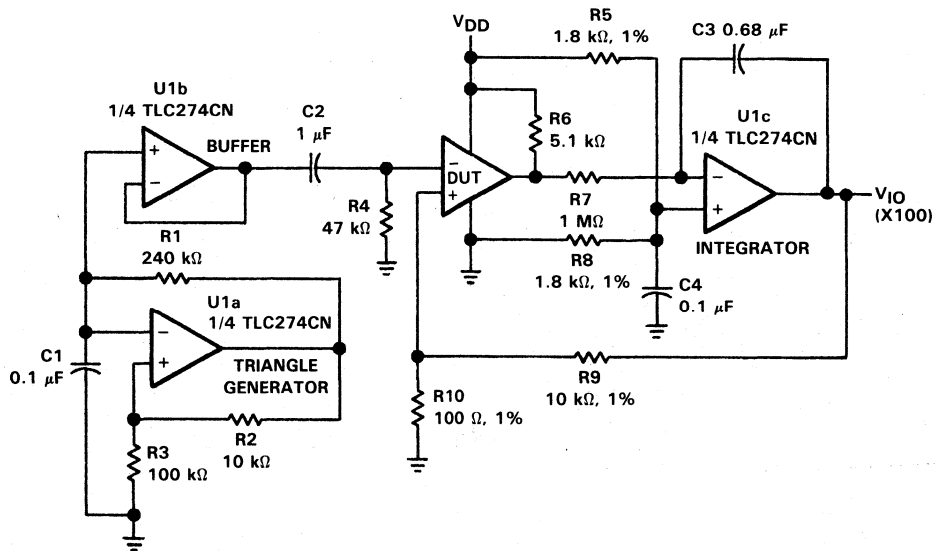
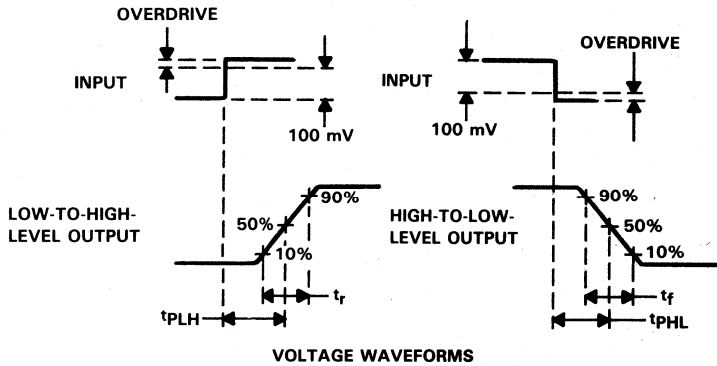
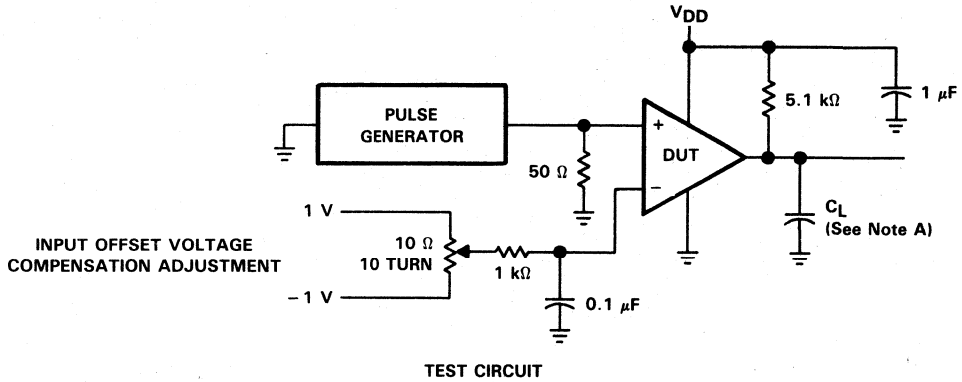


FIGURE 2. CIRCUIT FOR INPUT OFFSET VOLTAGE MEASUREMENT

PARAMETER MEASUREMENT INFORMATION

Response time is defined as the interval between the application of an input step function and the instant when the output reaches 50% of its maximum value. Response time, low-to-high-level output, is measured from the leading edge of the input pulse, while response time, high-to-low-level output, is measured from the trailing edge of the input pulse. Response-time measurement at low input signal levels can be greatly affected by the input offset voltage. The offset voltage should be balanced by the adjustment at the inverting input (as shown in Figure 3) so that the circuit is just at the transition point. Then a low signal, for example 105-mV or 5-mV overdrive, will cause the output to change state.



NOTE A: C_L includes probe and jig capacitance.

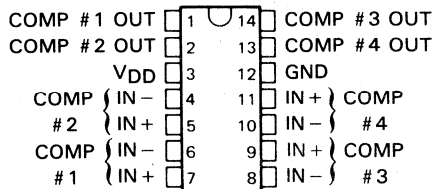
FIGURE 3. RESPONSE, RISE, AND FALL TIMES CIRCUIT AND VOLTAGE WAVEFORMS

TLC354C, TLC354I, TLC354M LinCMOS™ QUADRUPLE DIFFERENTIAL COMPARATORS

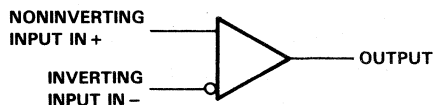
D2901, SEPTEMBER 1985—REVISED NOVEMBER 1990

- Single- or Dual-Supply Operation
- Wide Range of Supply Voltages . . . 1.4 V to 18 V
- Very Low Supply Current Drain
300 μA Typ at 5 V
130 μA Typ at 1.4 V
- Built-In ESD Protection
- High Input Impedance . . . 10^{12} Typ
- Extremely Low Input Bias Current 5 pA Typ
- Ultrastable Low Input Offset Voltage
- Input Offset Voltage Change at Worst-Case Input Conditions Typically 0.23 $\mu\text{V}/\text{Month}$, Including the First 30 Days
- Common-Mode Input Voltage Range Includes Ground
- Outputs Compatible with TTL, MOS, and CMOS
- Pin-Compatible with LM339

D OR N PACKAGE
(TOP VIEW)



symbol (each comparator)



description

This device is fabricated using LinCMOS™ technology and consists of four independent voltage comparators; each is designed to operate from a single power supply. Operation from dual supplies is also possible if the difference between the two supplies is 1.4 V to 18 V. Each device features extremely high input impedance (typically greater than $10^{12} \Omega$), which allows direct interface to high-impedance sources. The outputs are n-channel open-drain configurations and can be connected to achieve positive-logic wired-AND relationships. The capability of the TLC354 to operate from a 1.4-V supply makes this device ideal for low-voltage battery applications.

The TLC354 has internal electrostatic discharge (ESD) protection circuits and has been classified with a 2000-V ESD rating tested under MIL-STD-883C, Method 3015. However, care should be exercised in handling this device as exposure to ESD may result in degradation of the device parametric performance.

The TLC354C is characterized for operation from 0°C to 70°C. The TLC354I is characterized for operation over the industrial temperature range of -40°C to 85°C. The TLC354M is characterized for operation over the full military temperature range of -55°C to 125°C.

LinCMOS is a trademark of Texas Instruments Incorporated.

PRODUCTION DATA documents contain information current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

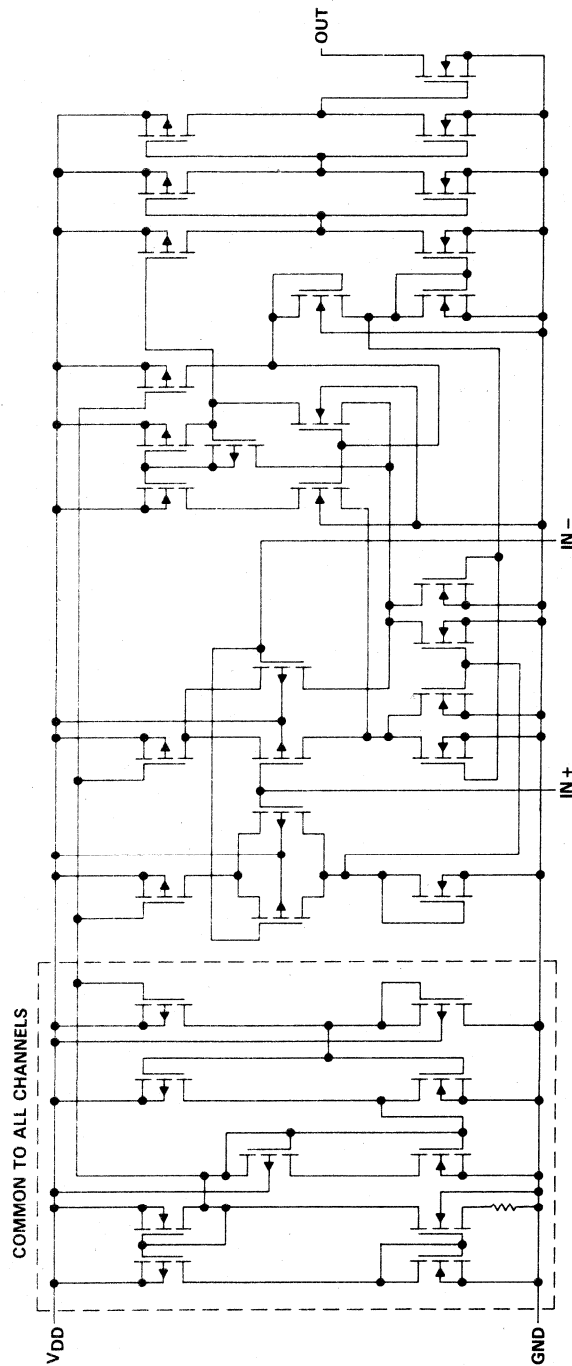


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TLC354C, TLC354I, TLC354M
LinCMOS™ QUADRUPLE DIFFERENTIAL COMPARATORS

equivalent schematic (each comparator)



TLC354C, TLC354I, TLC354M LinCMOS™ QUADRUPLE DIFFERENTIAL COMPARATORS

AVAILABLE OPTIONS

| T _A | V _{IO} MAX AT 25°C | PACKAGE | |
|----------------------|--------------------------------|----------------------|--------------------|
| | | SMALL-OUTLINE (D) | PLASTIC DIP (N) |
| 0°C to 70°C | 5 mV | TLC354CD | TLC354CN |
| -40°C to 85°C | 5 mV | TLC354ID | TLC354IN |
| -55°C to 125°C | 5 mV | TLC354MD | TLC354MN |

D packages are available taped and reeled. Add "R" suffix to device type, (e.g., TLC354CDR).

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Supply voltage, V _{DD} (see Note 1) | 18 V |
| Differential input voltage, V _{ID} (see Note 2) | ±18 V |
| Input voltage, V _I | V _{DD} |
| Input voltage range | -0.3 V to 18 V |
| Output voltage, V _O | 18 V |
| Input current, I _I | ±5 mA |
| Output current, I _O | 20 mA |
| Duration of output short circuit to ground (see Note 3) | unlimited |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range: TLC354C | 0°C to 70°C |
| TLC354I | -40°C to 85°C |
| TLC354M | -55°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

- NOTES: 1. All voltage values except differential voltages are with respect to network ground.
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
 3. Short circuits from outputs to V_{DD} can cause excessive heating and eventual device destruction.

DISSIPATION RATING TABLE

| PACKAGE | T _A ≤ 25°C POWER RATING | DERATING FACTOR | DERATE ABOVE T _A | T _A = 70°C POWER RATING | T _A = 85°C POWER RATING | T _A = 125°C POWER RATING |
|---------|---------------------------------------|--------------------|--------------------------------|---------------------------------------|---------------------------------------|--|
| D | 500 mW | 7.6 mW/°C | 84°C | 500 mW | 494 mW | 190 mW |
| N | 500 mW | 9.2 mW/°C | 96°C | 500 mW | 500 mW | 230 mW |

TLC354C, TLC354I, TLC354M LinCMOS™ QUADRUPLE DIFFERENTIAL COMPARATORS

recommended operating conditions

| | C-SUFFIX | | | I-SUFFIX | | | M-SUFFIX | | | UNIT |
|--|-------------------------|-----|-----|----------|-----|-----|----------|-----|-----|------|
| | MIN | NOM | MAX | MIN | NOM | MAX | MIN | NOM | MAX | |
| Supply voltage, V _{DD} | 1.4 | | 16 | 1.4 | | 16 | 1.4 | | 16 | V |
| Common-mode input voltage, V _{IC} | V _{DD} = 1.4 V | | | | | | | | | |
| | V _{DD} = 5 V | | | | | | | | | |
| | V _{DD} = 10 V | | | | | | | | | |
| Operating free-air temperature, T _A | 0 | | 70 | -40 | | 85 | -55 | | 125 | °C |

electrical characteristics at specified free-air temperature, V_{DD} = 1.4 V (unless otherwise noted)

| PARAMETER | TEST CONDITIONS† | TLC354C | | | TLC354I | | | TLC354M | | | UNIT |
|---|--|--------------------|-----|-----|---------|-----|-----|---------|-----|-----|------|
| | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| V _{IO} Input offset voltage | V _{IC} = V _{ICR} min, See Note 4 | 25°C | | | | | | | | | mV |
| | | Full range | | | | | | | | | |
| I _{IO} Input offset current | | 25°C | | | | | | | | | pA |
| | | MAX T _A | | | | | | | | | |
| I _{IB} Input bias current | | 25°C | | | | | | | | | pA |
| | | MAX T _A | | | | | | | | | |
| V _{ICR} Common-mode input voltage range | | 0 to 0.2 | | | | | | | | | V |
| | | 25°C | | | | | | | | | |
| I _{OH} High-level output current | V _{ID} = 1 V V _{OH} = 5 V V _{OH} = 15 V | 0.1 | | | | | | | | | nA |
| | | Full range | | | | | | | | | |
| V _{OL} Low-level output voltage | V _{ID} = -0.5 V, I _{OL} = 0.6 mA | 100 | | | | | | | | | mV |
| | | Full range | | | | | | | | | |
| I _{OL} Low-level output current | V _{ID} = -0.5 V, V _{OL} = 300 mV | 1 | | | | | | | | | mA |
| | | 25°C | | | | | | | | | |
| I _{DD} Supply current (four comparators) | V _{ID} = 0.5 V, No load | 130 | | | | | | | | | μA |
| | | Full range | | | | | | | | | |

† All characteristics are measured with zero common-mode input voltage unless otherwise noted. Full range is 0°C to 70°C for the TLC354C, -40°C to 85°C for the TLC354I, and -55°C to 125°C for the TLC354M. IMPORTANT: See Parameter Measurement Information.

NOTE 4: The offset voltage limits given are the maximum values required to drive the output above 1.25 V or below 150 mV with a 10-kΩ resistor between the output and V_{DD}. They can be verified by applying the limit value to the input and checking for the appropriate output state.

electrical characteristics at specified free-air temperature, VDD = 5 V (unless otherwise noted)

| PARAMETER | TEST CONDITIONS† | TLC354C | | | TLC354I | | | TLC354M | | | UNIT |
|---|--|---------------------------|-----|---------------------------|---------|---------------------------|-----|---------------------------|-----|---------------------------|------|
| | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| V _{IO} Input offset voltage | V _{IC} = V _{ICR} min, See Note 4 | 25°C | 2 | 5 | 2 | 5 | 2 | 5 | 2 | 5 | mV |
| | | Full range | | 6.5 | | 7 | | 10 | | 10 | |
| I _{IO} Input offset current | 25°C | 1 | | 1 | | 1 | | 1 | | 1 | pA |
| | | MAX TA | | 0.3 | | 1 | | 10 | | 10 | |
| I _{IB} Input bias current | 25°C | 5 | | 5 | | 5 | | 5 | | 5 | pA |
| | | MAX TA | | 0.6 | | 2 | | 20 | | 20 | |
| V _{ICR} Common-mode input voltage range | 25°C | 0 to V _{DD} -1 | | 0 to V _{DD} -1 | | 0 to V _{DD} -1 | | 0 to V _{DD} -1 | | 0 to V _{DD} -1 | V |
| | | 0 to V _{DD} -1.5 | | 0 to V _{DD} -1.5 | | 0 to V _{DD} -1.5 | | 0 to V _{DD} -1.5 | | 0 to V _{DD} -1.5 | |
| | | Full range | | 0 to V _{DD} -1.5 | | 0 to V _{DD} -1.5 | | 0 to V _{DD} -1.5 | | 0 to V _{DD} -1.5 | |
| I _{OH} High-level output current | V _{ID} = 1 V, V _{OH} = 5 V, V _{OH} = 15 V | 25°C | 0.1 | 1 | 0.1 | 1 | 0.1 | 1 | 0.1 | 1 | nA |
| | | Full range | | 1 | | 1 | | 1 | | 1 | |
| V _{OL} Low-level output voltage | V _{ID} = -1 V, I _{OL} = 4 mA | 25°C | 150 | 400 | 150 | 400 | 150 | 400 | 150 | 400 | mV |
| | | Full range | | 700 | | 700 | | 700 | | 700 | |
| I _{OL} Low-level output current | V _{ID} = -1 V, V _{OL} = 1.5 V | 25°C | 6 | 16 | 6 | 16 | 6 | 16 | 6 | 16 | mA |
| | | Full range | | 0.3 | 0.6 | | 0.3 | 0.6 | | 0.3 | |
| I _{DD} Supply current (four comparators) | V _{ID} = 1 V, No load | 25°C | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 | mA |
| | | Full range | | 0.8 | | 0.8 | | 0.8 | | 0.8 | |

† All characteristics are measured with zero common-mode input voltage unless otherwise noted. Full range is 0°C to 70°C for the TLC354C, -40°C to 85°C for the TLC354I, and -55°C to 125°C for the TLC354M. IMPORTANT: See Parameter Measurement Information.

NOTE 4: The offset voltage limits given are the maximum values required to drive the output above 4 V or below 400 mV with a 10-kΩ resistor between the output and V_{DD}. They can be verified by applying the limit value to the input and checking for the appropriate output state.

switching characteristics, VDD = 5 V, TA = 25 °C

| PARAMETER | TEST CONDITIONS | | | | UNIT |
|---------------|---|-----|-----|------|------|
| | MIN | TYP | MAX | UNIT | |
| Response time | R _L connected to 5 V through 5.1 kΩ, 100-mV input step with 5-mV overdrive | | | | ns |
| | C _L = 15 pF†, See Note 5 | | | | |
| | TTL-level input step | | | | |

† C_L includes probe and jig capacitance.

NOTE 5: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.

PARAMETER MEASUREMENT INFORMATION

The digital output stage of the TLC354 can be damaged if it is held in the linear region of the transfer curve. Conventional operational amplifier/comparator testing incorporates the use of a servo-loop that is designed to force the device output to a level within this linear region. Since the servo-loop method of testing cannot be used, the following alternative for measuring parameters such as input offset voltage, common-mode rejection, etc., are offered.

To verify that the input offset voltage falls within the limits specified, the limit value is applied to the input as shown in Figure 1(a). With the noninverting input positive with respect to the inverting input, the output should be high. With the input polarity reversed, the output should be low.

A similar test can be made to verify the input offset voltage at the common-mode extremes. The supply voltages can be slewed as shown in Figure 1(b) for the V_{ICR} test, rather than changing the input voltages, to provide greater accuracy.

A close approximation of the input offset voltage can be obtained by using a binary search method to vary the differential input voltage while monitoring the output state. When the applied input voltage differential is equal, but opposite in polarity to the input offset voltage, the output will change state.

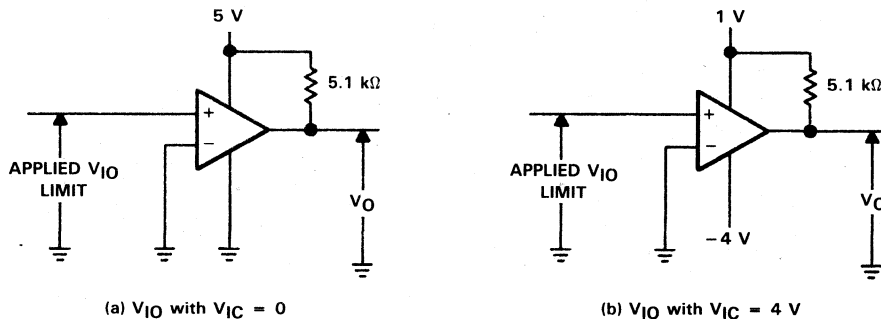


FIGURE 1. METHOD FOR VERIFYING THAT INPUT OFFSET VOLTAGE IS WITHIN SPECIFIED LIMITS

PARAMETER MEASUREMENT INFORMATION

Figure 2 illustrates a practical circuit for direct dc measurement of input offset voltage that does not bias the comparator into the linear region. The circuit consists of a switching-mode servo loop in which U1a generates a triangular waveform of approximately 20-mV amplitude. U1b acts as a buffer, with C2 and R4 removing any residual dc offset. The signal is then applied to the inverting input of the comparator under test, while the noninverting input is driven by the output of the integrator formed by U1c through the voltage divider formed by R9 and R10. The loop reaches a stable operating point when the output of the comparator under test has a duty cycle of exactly 50%, which can only occur when the incoming triangle wave is "sliced" symmetrically or when the voltage at the noninverting input exactly equals the input offset voltage.

Voltage divider R9 and R10 provides a step-up of the input offset voltage by a factor of 100 to make measurement easier. The values of R5, R8, R9, and R10 can significantly influence the accuracy of the reading; therefore, it is suggested that their tolerance level be 1% or lower.

Measuring the extremely low values of input current requires isolation from all other sources of leakage current and compensation for the leakage of the test socket and board. With a good picoammeter, the socket and board leakage can be measured with no device in the socket. Subsequently, this open-socket leakage value can be subtracted from the measurement obtained with a device in the socket to obtain the actual input current of the device.

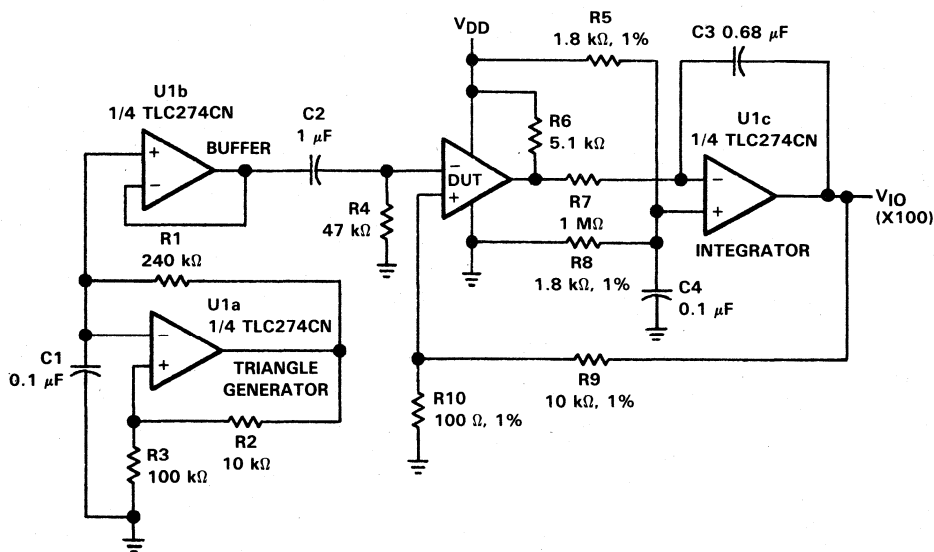
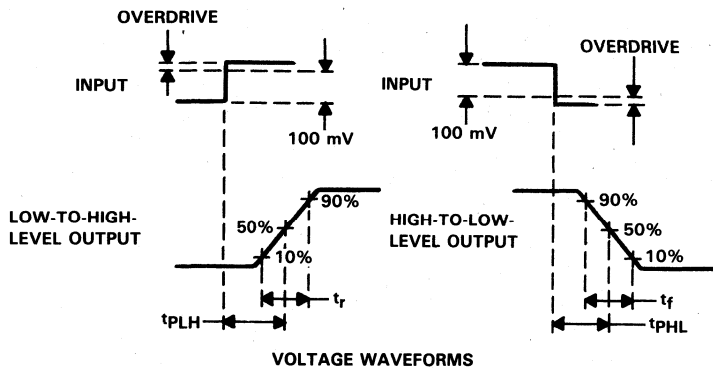
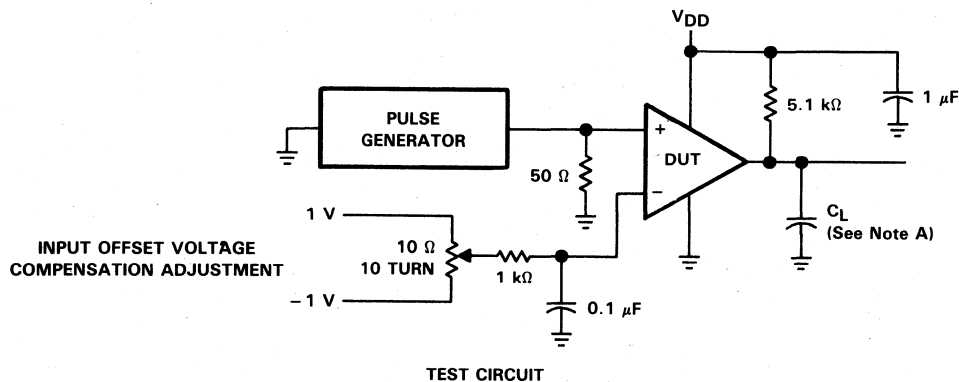


FIGURE 2. CIRCUIT FOR INPUT OFFSET VOLTAGE MEASUREMENT

PARAMETER MEASUREMENT INFORMATION

Response time is defined as the interval between the application of an input step function and the instant when the output reaches 50% of its maximum value. Response time, low-to-high-level output, is measured from the leading edge of the input pulse, while response time, high-to-low-level output, is measured from the trailing edge of the input pulse. Response-time measurement at low input signal levels can be greatly affected by the input offset voltage. The offset voltage should be balanced by the adjustment at the inverting input (as shown in Figure 3) so that the circuit is at the transition point. Then a low signal, for example 105-mV or 5-mV overdrive, will cause the output to change state.



NOTE A: C_L includes probe and jig capacitance.

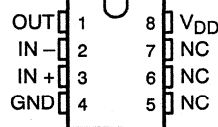
FIGURE 3. RESPONSE, RISE, AND FALL TIMES CIRCUIT AND VOLTAGE WAVEFORMS

TLC371C, TLC371I, TLC371M, TLC371Y LinCMOS™ DIFFERENTIAL COMPARATORS

D3865, JULY 1991—REVISED FEBRUARY 1992

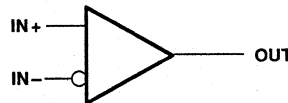
- Single or Dual-Supply Operation
- Wide Range of Supply Voltages
3 V to 16 V
- Very Low Supply Current Drain
75 μ A Typ at 5 V
- Fast Response Time . . . 200 ns Typ for
TTL-Level Input Step
- Built-In ESD Protection
- Extremely Low Input Bias Current
5 pA Typ
- Ultrastable Low Input Offset Voltage
- Common-Mode Input Voltage Range
Includes Ground
- Output Compatible with TTL, MOS, and
CMOS

D OR P PACKAGE
(TOP VIEW)



NC — No internal connection

symbol



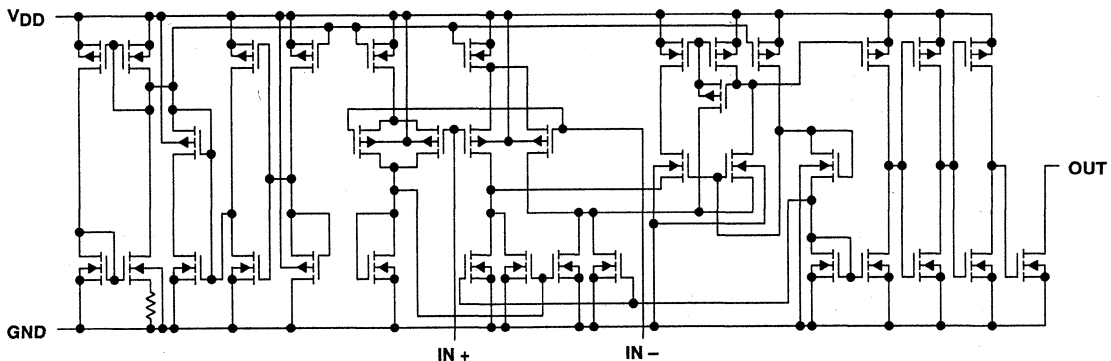
description

The TLC371 is a voltage comparator fabricated using LinCMOS™ technology and designed to operate from a single power supply. Operation from dual supplies is also possible if the difference between the two supplies is 2 V to 18 V. The TLC371 features extremely high input impedance, allowing direct interfacing with high-impedance sources. The output is in n-channel open-drain configuration.

The TLC371 has internal electrostatic discharge (ESD) protection circuits and has been classified with a 2000-V ESD rating tested under MIL-STD-883, Method 3015.1. However, care should be exercised in handling this device as exposure to ESD may result in a degradation of the device parametric performance.

The TLC371C is characterized for operation from 0°C to 70°C. The TLC371I is characterized for operation from -40°C to 85°C. The TLC371M is characterized for operation over the full military temperature range of -55°C to 125°C.

equivalent schematic (each comparator)



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PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

**TEXAS
INSTRUMENTS**

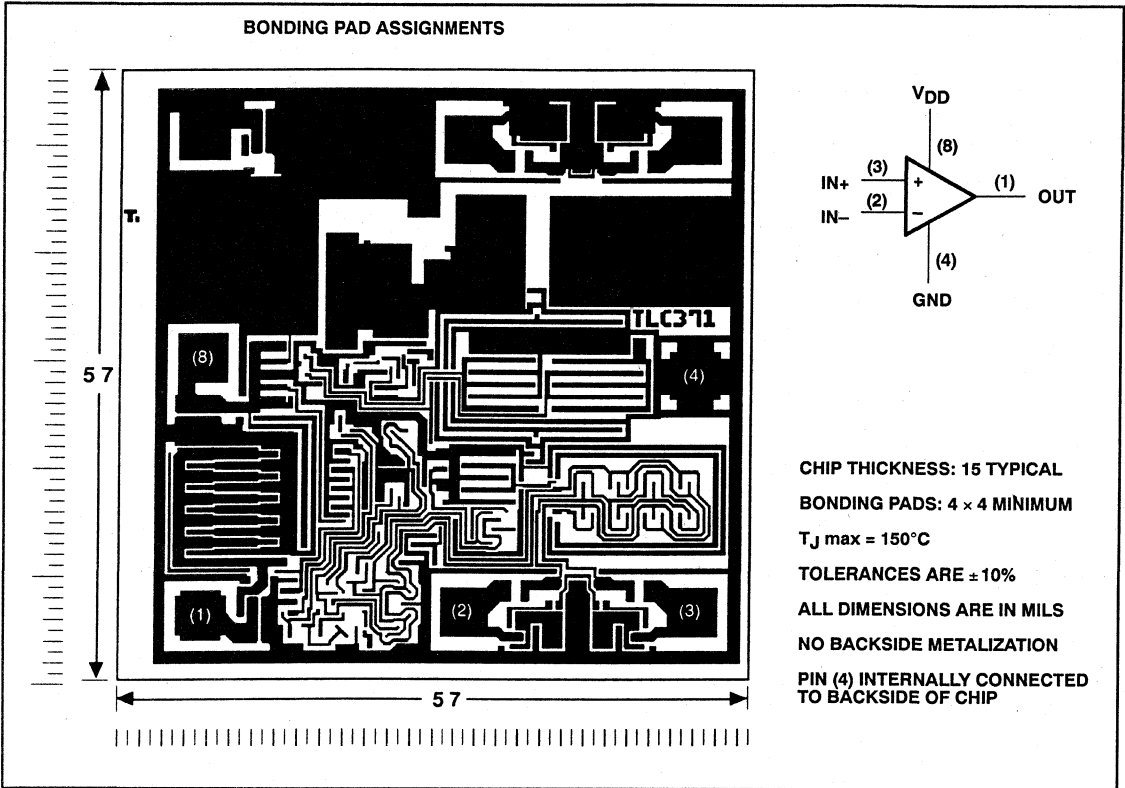
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TLC371Y LinCMOS™ DIFFERENTIAL COMPARATORS

chip information

These chips, properly assembled, display characteristics similar to the TLC371 (see electrical table on TLC371Y). Thermal compression or ultrasonic bonding may be used on the doped aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



TLC371C, TLC371I, TLC371M, TLC371Y LinCMOS™ DIFFERENTIAL COMPARATOR

AVAILABLE OPTIONS

| T _A | V _{IO} max at 25°C | PACKAGE | | CHIP FORM (Y) |
|----------------|--------------------------------|----------------------|--------------------|------------------|
| | | SMALL OUTLINE (D) | PLASTIC DIP (P) | |
| 0°C to 70°C | 5 mV | TLC371CD | TLC371CP | TLC371Y† |
| -40°C to 85°C | 5 mV | TLC371ID | TLC371IP | |
| -55°C to 125°C | 5 mV | TLC371MD | TLC371MP | |

† Chips are tested at T_A = 25°C. See TLC371Y for electrical characteristics.
The D package is available taped and reeled. Add the suffix "R" to the device type (e.g., TLC371CDR).

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Supply voltage, V _{DD} (see Note 1) | 18 V |
| Differential input voltage, V _{ID} (see Note 2) | ± 18 V |
| Input voltage range, V _I | -0.3 to 18 V |
| Output voltage, V _O | 18 V |
| Input current, I _I | ± 5 mA |
| Output current, I _O | 20 mA |
| Duration of output short circuit to ground (see Note 3) | unlimited |
| Continuous total power dissipation | See Dissipation Rating Table |
| Operating free-air temperature range: TLC371C | 0 to 70°C |
| TLC371I | -40°C to 85°C |
| TLC371M | -55°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

- NOTES: 1. All voltage values, except differential voltages, are with respect to network ground.
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. Short circuits from outputs to V_{DD} can cause excessive heating and eventual device destruction.

DISSIPATION RATING TABLE

| PACKAGE | T _A ≤ 25°C POWER RATING | DERATING FACTOR | DERATE ABOVE T _A | T _A = 70°C POWER RATING | T _A = 85°C POWER RATING | T _A = 125°C POWER RATING |
|---------|---------------------------------------|--------------------|--------------------------------|---------------------------------------|---------------------------------------|--|
| D | 500 mW | 5.8 mW/°C | 64°C | 464 mW | 377 mW | 145 mW |
| P | 500 mW | 8.0 mW/°C | 87°C | 500 mW | 500 mW | 200 mW |

recommended operating conditions

| | | C-SUFFIX | | | I-SUFFIX | | | M-SUFFIX | | | UNIT |
|--|------------------------|----------|-----|-----|----------|-----|-----|----------|-----|-----|------|
| | | MIN | NOM | MAX | MIN | NOM | MAX | MIN | NOM | MAX | |
| Supply voltage, V _{DD} | | 3 | | 16 | 3 | | 16 | 4 | | 16 | V |
| Common-mode input voltage, V _{IC} | V _{DD} = 5 V | 0 | | 3.5 | 0 | | 3.5 | 0 | | 3.5 | V |
| | V _{DD} = 10 V | 0 | | 8.5 | 0 | | 8.5 | 0 | | 8.5 | |
| Operating free-air temperature, T _A | | 0 | | 70 | -40 | | 85 | -55 | | 125 | °C |

TLC371C, TLC371I, TLC371M

LinCMOS™ DIFFERENTIAL COMPARATORS

electrical characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T_A † | TLC371C | | | TLC371I | | | TLC371M | | | UNIT |
|---|--|------------|-----------------|--------------|-----|-----------------|--------------|-----------------|--------------|-----------------|---------------|------|
| | | | MIN | TYP‡ | MAX | MIN | TYP‡ | MAX | MIN | TYP‡ | MAX | |
| V_{IO} Input offset voltage | $V_{IC} = V_{ICR\text{ min}}$, See Note 4 | 25°C | 1 | 5 | 5 | 1 | 5 | 1 | 5 | 5 | mV | |
| | | Full range | | 6.5 | 7 | | 7 | | 10 | | | |
| I_{IO} Input offset current | | 25°C | 1 | | | 1 | | 1 | | 1 | pA | |
| | | MAX | | 0.3 | | | 1 | | 10 | | | |
| I_{IB} Input bias current | | 25°C | 5 | | | 5 | | 5 | | 5 | pA | |
| | | MAX | | 0.6 | | | 2 | | 20 | | | |
| V_{ICR} Common-mode input voltage range | | 25°C | 0 to $V_{DD}-1$ | | | 0 to $V_{DD}-1$ | | 0 to $V_{DD}-1$ | | 0 to $V_{DD}-1$ | V | |
| | | Full range | | $V_{DD}-1.5$ | | | $V_{DD}-1.5$ | | $V_{DD}-1.5$ | | | |
| I_{OH} High-level output current | $V_{ID} = 1\text{ V}$ $V_{OH} = 5\text{ V}$ $V_{OH} = 15\text{ V}$ | 25°C | 0.1 | | | 0.1 | | 0.1 | | 0.1 | mA | |
| | | Full range | | 1 | | | 1 | | 3 | | | |
| V_{OL} Low-level output voltage | $V_{ID} = -1\text{ V}$, $I_{OL} = 4\text{ mA}$ | 25°C | 150 | 400 | 400 | 150 | 400 | 150 | 400 | 150 | mV | |
| | | Full range | | 700 | 700 | | 700 | | 700 | | | |
| I_{OL} Low-level output current | $V_{ID} = -1\text{ V}$, $V_{OL} = 1.5\text{ V}$ | 25°C | 6 | 16 | 16 | 6 | 16 | 6 | 16 | 16 | mA | |
| | | Full range | | 75 | 150 | | 75 | | 150 | | | |
| I_{DD} Supply current | $V_{ID} = 1\text{ V}$, No load | 25°C | | 200 | 200 | | 200 | | 200 | | μA | |
| | | Full range | | | | | | | | | | |

† All characteristics are measured with zero common-mode input voltage unless otherwise noted. Full range is 0°C to 70°C for TLC371C, -40°C to 85°C for TLC371I, and -55°C to 125°C for TLC371M. IMPORTANT: See Parameter Measurement Information.

‡ All typical values are at $T_A = 25^\circ\text{C}$.

NOTE 4: The offset voltage limits given are the maximum values required to drive the output above 4 V or below 400 mV with a 10-k Ω resistor between the output and V_{DD} . They can be verified by applying the limit value to the input and checking for the appropriate output state.

switching characteristics, $V_{DD} = 5\text{ V}$, $T_A = 25^\circ\text{C}$

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-----------|----------------------|-----|-----|-----|------|
| | | | | | |
| | TTL-level input step | | 200 | | |

§ C_L includes probe and jig capacitance.

NOTE 5: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.

TLC371Y
LinCMOS™ DIFFERENTIAL COMPARATOR

electrical characteristics at $V_{DD} = 5\text{ V}$, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-----------|---------------------------------|-----------------------|-------------------|-----|-----|---------------|
| V_{IO} | Input offset voltage | $V_{IC} = V_{ICRmin}$ | | 1 | 5 | mV |
| I_{IO} | Input offset current | | | 1 | 100 | pA |
| I_{IB} | Input bias current | | | 5 | 100 | pA |
| V_{ICR} | Common-mode input voltage range | | 0 to $V_{DD} - 1$ | | | V |
| I_{OH} | High-level output current | | | 0.1 | | nA |
| V_{OL} | Low-level output voltage | | | 150 | 400 | mV |
| I_{OL} | Low-level output current | | 6 | 16 | | mA |
| I_{DD} | Supply current | | | 75 | 150 | μA |

PARAMETER MEASUREMENT INFORMATION

The digital output stage of the TLC371 can be damaged if it is held in the linear region of the transfer curve. Conventional operational amplifier/comparator testing incorporates the use of a servo-loop that is designed to force the device output to a level within this linear region. Since the servo-loop method of testing cannot be used, the following alternatives for measuring parameters such as input offset voltage, common-mode rejection, etc., are offered.

To verify that the input offset voltage falls within the limits specified, the limit value is applied to the input as shown in Figure 1(a). With the noninverting input positive with respect to the inverting input, the output should be high. With the input polarity reversed, the output should be low.

A similar test can be made to verify the input offset voltage at the common-mode extremes. The supply voltages can be slewed as shown in Figure 1(b) for the V_{ICR} test, rather than changing the input voltages, to provide greater accuracy.

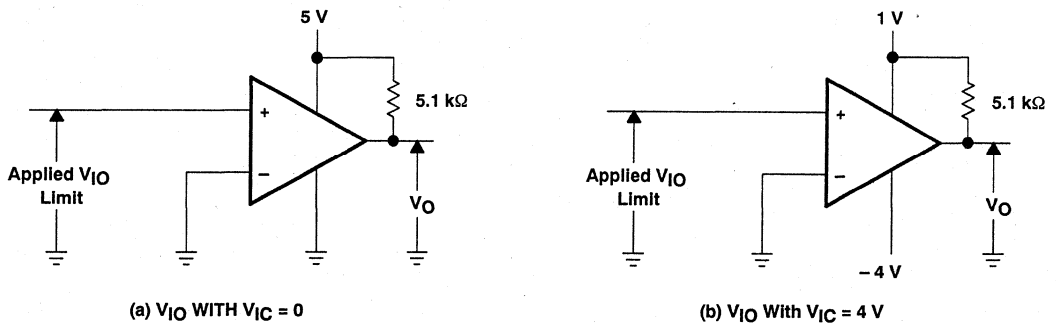


Figure 1. Method for Verifying That Input Offset Voltage Is Within Specified Limits

A close approximation of the input offset voltage can be obtained by using a binary search method to vary the differential input voltage while monitoring the output state. When the applied input voltage differential is equal, but opposite in polarity, to the input offset voltage, the output will change states.

PARAMETER MEASUREMENT INFORMATION

Figure 2 illustrates a practical circuit for direct dc measurement of input offset voltage that does not bias the comparator in the linear region. The circuit consists of a switching-mode servo-loop in which U1a generates a triangular waveform of approximately 20-mV amplitude. U1b acts as a buffer, with C2 and R4 removing any residual dc offset. The signal is then applied to the inverting input of the comparator under test, while the noninverting input is driven by the output of the integrator formed by U1c through the voltage divider formed by R9 and R10. The loop reaches a stable operating point when the output of the comparator under test has a duty cycle of exactly 50%, which can only occur when the incoming triangle wave is "sliced" symmetrically or when the voltage at the noninverting input exactly equals the input offset voltage.

Voltage divider R9 and R10 provides a step-up of the input offset voltage by a factor of 100 to make measurement easier. The values of R5, R8, R9, and R10 can significantly influence the accuracy of the reading; therefore, it is suggested that their tolerance level be 1% or lower.

Measuring the extremely low values of input current requires isolation from all other sources of leakage current and compensation for the leakage of the test socket and board. With a good picoammeter, the socket and board leakage can be measured with no device in the socket. Subsequently, this open-socket leakage value can be subtracted from the measurement obtained with a device in the socket to obtain the actual input current of the device.

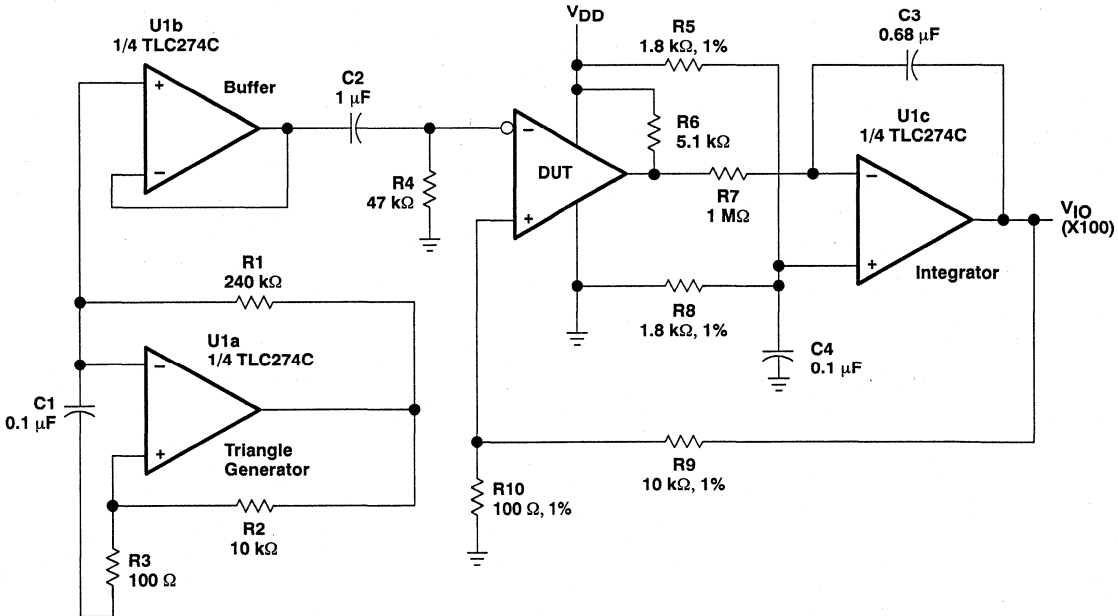
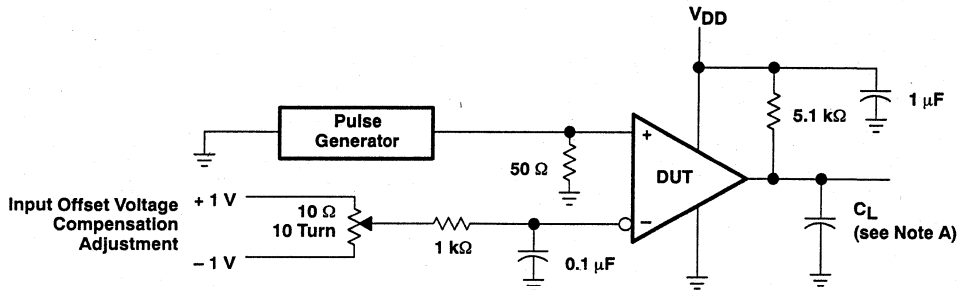


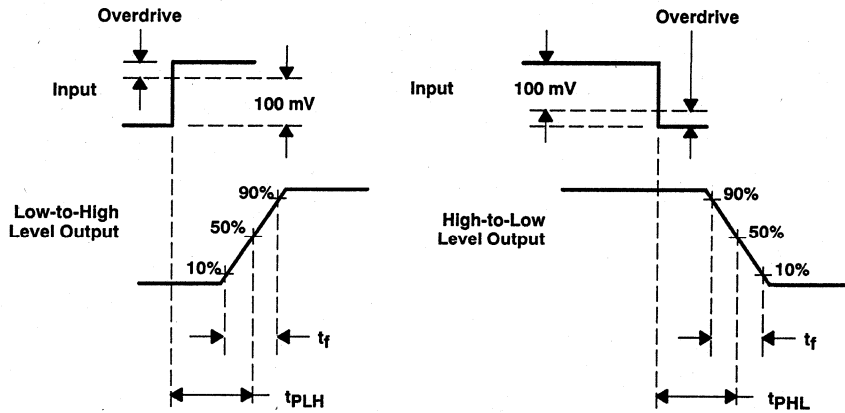
Figure 2. Circuit for Input Offset Voltage Measurement

PARAMETER MEASUREMENT INFORMATION

Propagation delay time is defined as the interval between the application of an input step function and the instant when the output reaches 50% of its maximum value. Propagation delay time, low-to-high-level output, is measured from the leading edge of the input pulse, while propagation delay time, high-to-low-level output, is measured from the trailing edge of the input pulse. Propagation delay time measurement at low input signal levels can be greatly affected by the input offset voltage. The offset voltage should be balanced by the adjustment at the inverting input (as shown in Figure 3) so that the circuit is just at the transition point. Then a low signal, for example 105 mV or 5 mV overdrive, will cause the output to change state.



TEST CIRCUIT



VOLTAGE WAVEFORMS

NOTE A: C_L includes probe and jig capacitance.

Figure 3. Propagation Delay, Rise, and Fall Times Circuit and Voltage Waveforms

PRINCIPLES OF OPERATION

LinCMOS™ process

The LinCMOS™ process is a linear polysilicon-gate CMOS process. Primarily designed for single-supply applications, LinCMOS™ products facilitate the design of a wide range of high-performance analog functions from operational amplifiers to complex mixed-mode converters.

While digital designers are experienced with CMOS, MOS technologies are relatively new for analog designers. This short guide is intended to answer the most frequently asked questions related to the quality and reliability of LinCMOS™ products. If you have any further questions, please contact your local TI sales office.

electrostatic discharge

CMOS circuits are prone to gate oxide breakdown when exposed to high voltages even if the exposure is only for very short periods of time. Electrostatic discharge (ESD) is one of the most common causes of damage to CMOS devices. It can occur when a device is handled without proper consideration for environmental electrostatic charges, e.g., during board assembly. If a circuit in which one amplifier from a dual op amp is being used and the unused pins are left open, high voltages will tend to develop. If there is no provision for ESD protection, these voltages may eventually punch through the gate oxide and cause the device to fail. To prevent voltage build-up, each pin is protected by internal circuitry.

Standard ESD protection circuits safely shunt the ESD current by providing a mechanism whereby one or more transistors break down at voltages higher than the normal operating voltages but lower than the breakdown voltage of the input gate. This type of protection scheme is limited by leakage currents which flow through the shunting transistors during normal operation after an ESD voltage has occurred. Although these currents are small, on the order of tens of nanoamps, CMOS amplifiers are often specified to draw input currents as low as tens of picoamps.

To overcome this limitation, TI design engineers developed the patented ESD protection circuit shown in Figure 4. This circuit can withstand several successive 2-kV ESD pulses, while reducing or eliminating leakage currents that may be drawn through the input pins. A more detailed discussion of the operation of TI's ESD protection circuit is presented on the next page.

All input and output pins on LinCMOS™ and Advanced LinCMOS™ products have associated ESD protection circuitry that undergoes qualification testing to withstand 2000 V discharged from a 100-pF capacitor through a 1500-Ω resistor (human body model) and 200 V from a 100-pF capacitor with no current-limiting resistor (charged device model). These tests simulate both operator and machine handling of devices during normal test and assembly operations.

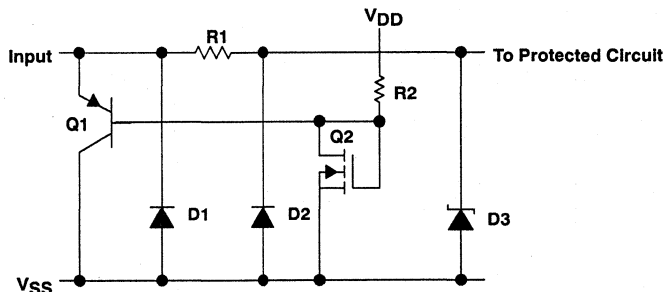


Figure 4. LinCMOS™ ESD Protection Schematic

Advanced LinCMOS is a trademark of Texas Instruments Incorporated.



input protection circuit operation

Texas Instruments patented protection circuitry allows for both positive- and negative-going ESD transients. These transients are characterized by extremely fast rise times and usually low energies, and can occur both when the device has all pins open and when it is installed in a circuit.

positive ESD transients

Initial positive charged energy is shunted through Q1 to V_{SS} . Q1 will turn on when the voltage at the input rises above the voltage on the V_{DD} pin by a value equal to the V_{BE} of Q1. The base current increases through R2 with input current as Q1 saturates. The base current through R2 will force the voltage at the drain and gate of Q2 to exceed its threshold level ($V_T \sim 22$ to 26 V) and turn Q2 on. The shunted input current through Q1 to V_{SS} is now shunted through the n-channel enhancement-type MOSFET Q2 to V_{SS} . If the voltage on the input pin continues to rise, the breakdown voltage of the zener diode D3 is exceeded and all remaining energy is dissipated in R1 and D3. The breakdown voltage of D3 is designed to be 24 to 27 V, which is well below the gate oxide voltage of the circuit to be protected.

negative ESD transients

The negative charged ESD transients are shunted directly through D1. Additional energy is dissipated in R1 and D2 as D2 becomes forward biased. The voltage seen by the protected circuit is -0.3 V to -1 V (the forward voltage of D1 and D2).

circuit design considerations

LinCMOS™ products are being used in actual circuit environments that have input voltages that exceed the recommended common-mode input voltage range and activate the input protection circuit. Even under normal operation, these conditions occur during circuit power-up or power-down, and in many cases, when the device is being used for a signal conditioning function. The input voltages can exceed V_{ICR} and not damage the device only if the inputs are current limited. The recommended current limit shown on most product data sheets is ± 5 mA. Figures 5 and 6 show typical characteristics for input voltage vs input current.

Normal operation and correct output state can be expected even when the input voltage exceeds the positive supply voltage. Again, the input current should be externally limited even though internal positive current limiting is achieved in the input protection circuit by the action of Q1. When Q1 is on, it will saturate and limit the current to approximately 5-mA collector current by design. When saturated, Q1 base current increases with input current. This base current is forced into the V_{DD} pin and into the device I_{DD} or the V_{DD} supply through R2 producing the current limiting effects shown in Figure 5. This internal limiting lasts only as long as the input voltage is below the V_T of Q2.

When the input voltage exceeds the negative supply voltage, normal operation is affected and output voltage states may not be correct. Also, the isolation between channels of multiple devices (duals and quads) can be severely affected. External current limiting must be used since this current will be directly shunted by D1 and D2 and no internal limiting is achieved. If normal output voltage states are required, an external input voltage clamp is required (see Figure 7).

INPUT CURRENT
 vs
 INPUT VOLTAGE

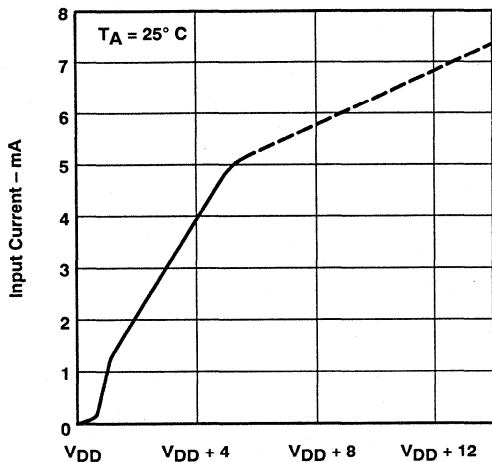


Figure 5

INPUT CURRENT
 vs
 INPUT VOLTAGE

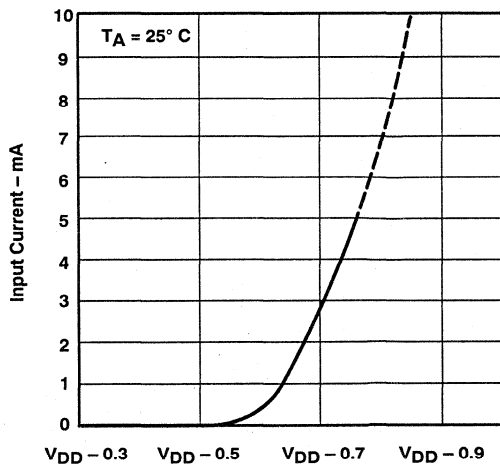
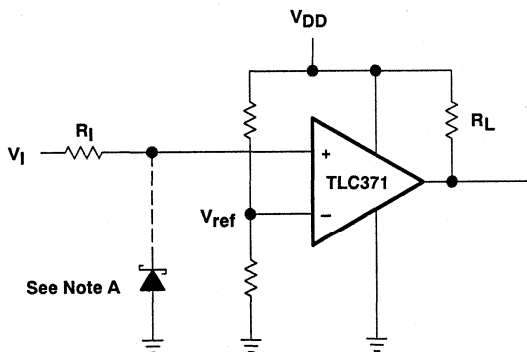


Figure 6



Positive Voltage Input Current Limit :

$$R_I = \frac{V_I - V_{DD} - 0.3 \text{ V}}{5 \text{ mA}}$$

Negative Voltage Input Current Limit :

$$R_I = \frac{-V_I - V_{DD} - (-0.3 \text{ V})}{5 \text{ mA}}$$

NOTE A: If the correct input state is required when the negative input exceeds V_{SS}, a Schottky clamp is required.

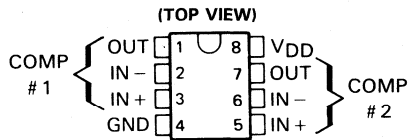
Figure 7. Typical Input Current-Limiting Configuration for a LinCMOS™ Comparator

TLC372C, TLC372I, TLC372M, TLC372Q LinCMOS™ DUAL DIFFERENTIAL COMPARATORS

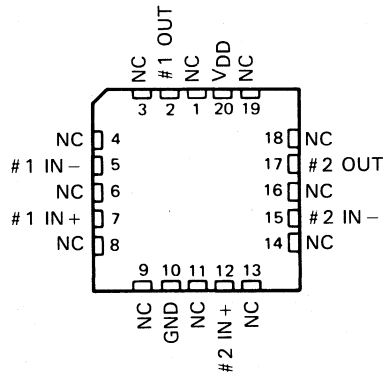
D2821, NOVEMBER 1983—REVISED OCTOBER 1990

- Single or Dual-Supply Operation
- Wide Range of Supply Voltages . . . 2 V to 18 V
- Very Low Supply Current Drain 150 μ A Typ at 5 V
- Fast Response Time . . . 200 ns Typ for TTL-Level Input Step
- Built-In ESD Protection
- High Input Impedance . . . 10¹² Ω Typ
- Extremely Low Input Bias Current 5 pA Typ
- Ultrastable Low Input Offset Voltage
- Input Offset Voltage Change at Worst-Case Input Conditions Typically 0.23 μ V/Month, Including the First 30 Days
- Common-Mode Input Voltage Range Includes Ground
- Outputs Compatible with TTL, MOS, and CMOS
- Pin-Compatible with LM393

TLC372C, TLC372I, TLC372M, TLC372Q
D OR P PACKAGE
TLC372M . . . JG PACKAGE

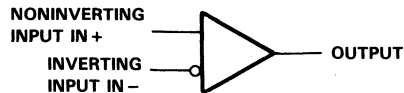


TLC372M . . . FK PACKAGE
(TOP VIEW)



NC—No internal connection

symbol (each comparator)



description

This device is fabricated using LinCMOS™ technology and consists of two independent voltage comparators, each designed to operate from a single power supply. Operation from dual supplies is also possible if the difference between the two supplies is 2 V to 18 V. Each device features extremely high input impedance (typically greater than 10¹² Ω), allowing direct interfacing with high-impedance sources. The outputs are n-channel open-drain configurations and can be connected to achieve positive-logic wired-AND relationships.

The TLC372 has internal electrostatic discharge (ESD) protection circuits and has been classified with a 2000-V ESD rating tested under MIL-STD-883C, Method 3015.1. However, care should be exercised in handling this device as exposure to ESD may result in a degradation of the device parametric performance.

The TLC372C is characterized for operation from 0°C to 70°C. The TLC372I is characterized for operation from -40°C to 85°C. The TLC372M is characterized for operation over the full military temperature range of -55°C to 125°C. The TLC372Q is characterized for operation from -40°C to 125°C.

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PRODUCTION DATA documents contain information current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

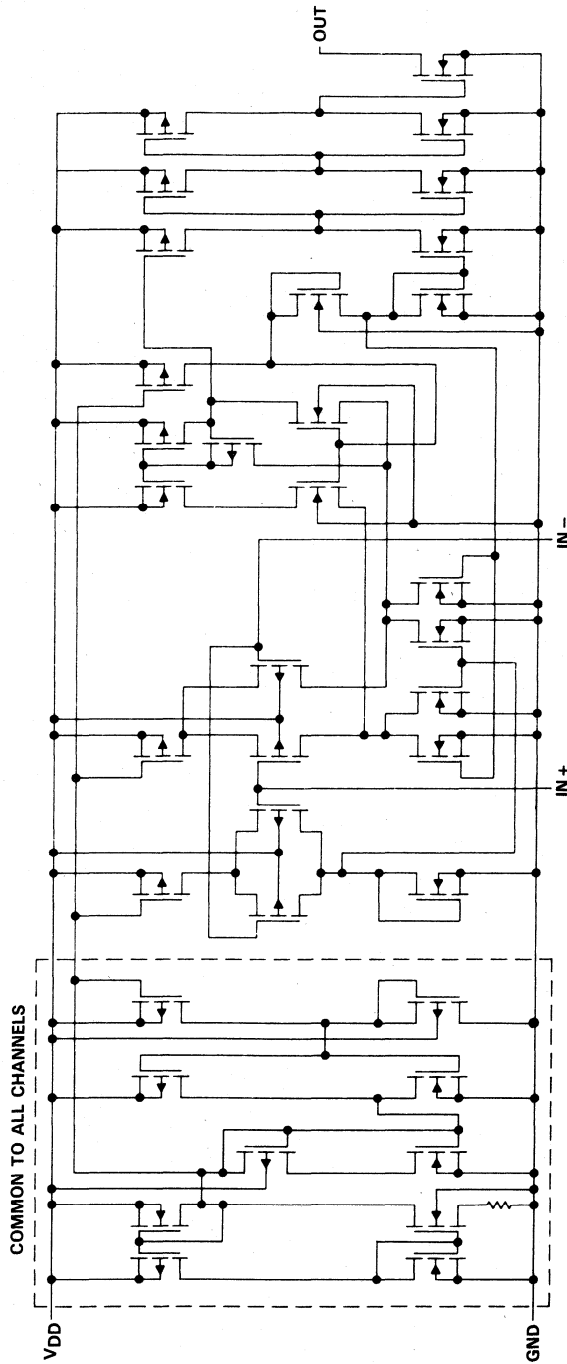
TEXAS
INSTRUMENTS

POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

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TLC372C, TLC372I, TLC372M, TLC372Q
LinCMOS™ DUAL DIFFERENTIAL COMPARATORS

equivalent schematic (each comparator)



TEXAS
INSTRUMENTS

POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

TLC372C, TLC372I, TLC372M, TLC372Q LinCMOS™ DUAL DIFFERENTIAL COMPARATORS

AVAILABLE OPTIONS

| T _A | V _{IO} MAX AT 25°C | PACKAGE | | | |
|----------------------|--------------------------------|----------------------|----------------------|---------------------|--------------------|
| | | SMALL-OUTLINE (D) | CHIP-CARRIER (FK) | CERAMIC DIP (JG) | PLASTIC DIP (P) |
| 0°C to 70°C | 5 mV | TLC372CD | — | — | TLC372CP |
| -40°C to 85°C | 5 mV | TLC372ID | — | — | TLC372IP |
| -55°C to 125°C | 5 mV | TLC372MD | TLC372MFK | TLC372MJG | TLC372MP |
| -40°C to 125°C | 5 mV | TLC372QD | — | — | TLC372QP |

D packages are available taped and reeled. Add "R" suffix to device type, (e.g., TLC372CDR).

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Supply voltage, V _{DD} (see Note 1) | 18 V |
| Differential input voltage, V _{ID} (see Note 2) | ±18 V |
| Input voltage range, V _I | -0.3 V to 18 V |
| Output voltage, V _O | 18 V |
| Input current, I _I | ±5 mA |
| Output current, I _O | 20 mA |
| Duration of output short-circuit to ground (see Note 3) | unlimited |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range: TLC372C | 0°C to 70°C |
| TLC372I | -40°C to 85°C |
| TLC372M | -55°C to 125°C |
| TLC372Q | -40°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds, D or P package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package | 300°C |

- NOTES: 1. All voltage values except differential voltages are with respect to network ground.
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
 3. Short circuits from outputs to V_{DD} can cause excessive heating and eventual device destruction.

DISSIPATION RATING TABLE

| PACKAGE | T _A ≤ 25°C POWER RATING | DERATING FACTOR | DERATE ABOVE T _A | T _A = 70°C POWER RATING | T _A = 85°C POWER RATING | T _A = 125°C POWER RATING |
|---------|---------------------------------------|--------------------|--------------------------------|---------------------------------------|---------------------------------------|--|
| D | 500 mW | 5.8 mW/°C | 64°C | 464 mW | 377 mW | 145 mW |
| FK | 500 mW | 11.0 mW/°C | 104°C | 500 mW | 500 mW | 275 mW |
| JG | 500 mW | 8.4 mW/°C | 90°C | 500 mW | 500 mW | 210 mW |
| P | 500 mW | 8.0 mW/°C | 87°C | 500 mW | 500 mW | 200 mW |

TLC372C, TLC372I, TLC372M, TLC372O

LinCMOS™ DUAL DIFFERENTIAL COMPARATORS

recommended operating conditions

| | C-SUFFIX | | | I-SUFFIX | | | M-SUFFIX | | | O-SUFFIX | | | UNIT |
|--|------------------------|-----|-----|----------|-----|-----|----------|-----|-----|----------|-----|-----|------|
| | MIN | NOM | MAX | MIN | NOM | MAX | MIN | NOM | MAX | MIN | NOM | MAX | |
| Supply voltage, V _{DD} | 3 | 16 | 16 | 3 | 16 | 16 | 4 | 16 | 16 | 3 | 16 | 16 | V |
| Common-mode input voltage, V _{IC} | V _{DD} = 5 V | | | 0 | 3.5 | 3.5 | 0 | 3.5 | 3.5 | 0 | 3.5 | 3.5 | V |
| | V _{DD} = 10 V | | | 0 | 8.5 | 8.5 | 0 | 8.5 | 8.5 | 0 | 8.5 | 8.5 | V |
| Operating free-air temperature, T _A | 0 | 70 | 85 | -40 | 85 | 85 | -55 | 125 | 125 | -40 | 125 | 125 | °C |

electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | T _A † | TLC372C | | | TLC372I | | | TLC372M/O | | | UNIT |
|--|--|--------------------|---------------------------|-----|-----|---------------------------|-----|-----|---------------------------|-----|-----|------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| V _{IO} Input offset voltage | V _{IC} = V _{ICR} min. See Note 4 | 25°C Full range | 1 | 5 | 5 | 1 | 5 | 5 | 1 | 5 | 5 | mV |
| I _{IO} Input offset current | | 25°C MAX | 1 | 0.3 | 0.3 | 1 | 1 | 1 | 1 | 1 | 1 | pA |
| I _{IB} Input bias current | | 25°C MAX | 5 | 0.6 | 0.6 | 5 | 5 | 5 | 5 | 5 | 5 | nA |
| Common-mode input voltage range | | 25°C | 0 to V _{DD} -1 | | | 0 to V _{DD} -1 | | | 0 to V _{DD} -1 | | | V |
| | | Full range | 0 to V _{DD} -1.5 | | | 0 to V _{DD} -1.5 | | | 0 to V _{DD} -1.5 | | | V |
| I _{OH} High-level output current | V _{OH} = 5 V | 25°C | 0.1 | | | 0.1 | | | 0.1 | | | nA |
| | V _{OH} = 1.5 V | Full range | 1 | | | 1 | | | 3 | | | μA |
| V _{OL} Low-level output voltage | I _{OL} = 4 mA | 25°C | 150 | 400 | 400 | 150 | 400 | 400 | 150 | 400 | 400 | mV |
| | | Full range | 700 | | | 700 | | | 700 | | | mV |
| I _{OL} Low-level output current | V _{OL} = 1.5 V | 25°C | 6 | 16 | 16 | 6 | 16 | 16 | 6 | 16 | 16 | mA |
| I _{DD} Supply current (two comparators) | V _{IO} = 1 V, No load | 25°C | 150 | 300 | 300 | 150 | 300 | 300 | 150 | 300 | 300 | μA |
| | | Full range | 400 | | | 400 | | | 400 | | | μA |

† All characteristics are measured with zero common-mode input voltage unless otherwise noted. Full range is 0°C to 70°C for TLC372C, -40°C to 85°C for TLC372I, -55°C to 125°C for TLC372M, and -40°C to 125°C for TLC372O. IMPORTANT: See Parameter Measurement Information.

NOTE 4: The offset voltage limits given are the maximum values required to drive the output above 4 V or below 400 mV with a 10-kΩ resistor between the output and V_{DD}. They can be verified by applying the limit value to the input and checking for the appropriate output state.

switching characteristics, V_{DD} = 5 V, T_A = 25°C

| PARAMETER | TEST CONDITIONS | | | |
|---------------|---|-----|-----|------|
| | MIN | TYP | MAX | UNIT |
| Response time | R _L connected to 5 V through 5.1 kΩ, 100-mV input step with 5-mV overdrive | | | |
| | 650 | | | ns |
| | C _L = 15 pF. See Note 5 | | | |
| | 200 | | | ns |

† C_L includes probe and jig capacitance.

NOTE 5: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.



PARAMETER MEASUREMENT INFORMATION

The digital output stage of the TLC372 can be damaged if it is held in the linear region of the transfer curve. Conventional operational amplifier/comparator testing incorporates the use of a servo-loop that is designed to force the device output to a level within this linear region. Since the servo-loop method of testing cannot be used, the following alternative for measuring parameters such as input offset voltage, common-mode rejection, etc., are offered.

To verify that the input offset voltage falls within the limits specified, the limit value is applied to the input as shown in Figure 1(a). With the noninverting input positive with respect to the inverting input, the output should be high. With the input polarity reversed, the output should be low.

A similar test can be made to verify the input offset voltage at the common-mode extremes. The supply voltages can be slewed as shown in Figure 1(b) for the V_{ICR} test, rather than changing the input voltages, to provide greater accuracy.

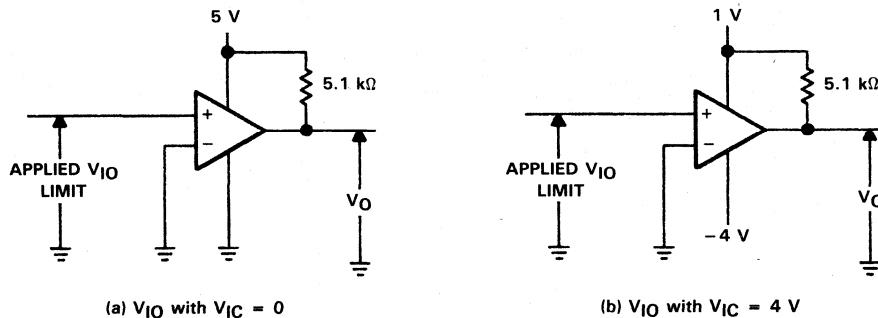


FIGURE 1. METHOD FOR VERIFYING THAT INPUT OFFSET VOLTAGE IS WITHIN SPECIFIED LIMITS

A close approximation of the input offset voltage can be obtained by using a binary search method to vary the differential input voltage while monitoring the output state. When the applied input voltage differential is equal, but opposite in polarity, to the input offset voltage, the output will change states.

PARAMETER MEASUREMENT INFORMATION

Figure 2 illustrates a practical circuit for direct dc measurement of input offset voltage that does not bias the comparator into the linear region. The circuit consists of a switching-mode servo loop in which U1a generates a triangular waveform of approximately 20-mV amplitude. U1b acts as a buffer, with C2 and R4 removing any residual dc offset. The signal is then applied to the inverting input of the comparator under test, while the noninverting input is driven by the output of the integrator formed by U1c through the voltage divider formed by R9 and R10. The loop reaches a stable operating point when the output of the comparator under test has a duty cycle of exactly 50%, which can only occur when the incoming triangle wave is "sliced" symmetrically or when the voltage at the noninverting input exactly equals the input offset voltage.

Voltage divider R9 and R10 provides a step-up of the input offset voltage by a factor of 100 to make measurement easier. The values of R5, R8, R9, and R10 can significantly influence the accuracy of the reading; therefore, it is suggested that their tolerance level be 1% or lower.

Measuring the extremely low values of input current requires isolation from all other sources of leakage current and compensation for the leakage of the test socket and board. With a good picoammeter, the socket and board leakage can be measured with no device in the socket. Subsequently, this open-socket leakage value can be subtracted from the measurement obtained with a device in the socket to obtain the actual input current of the device.

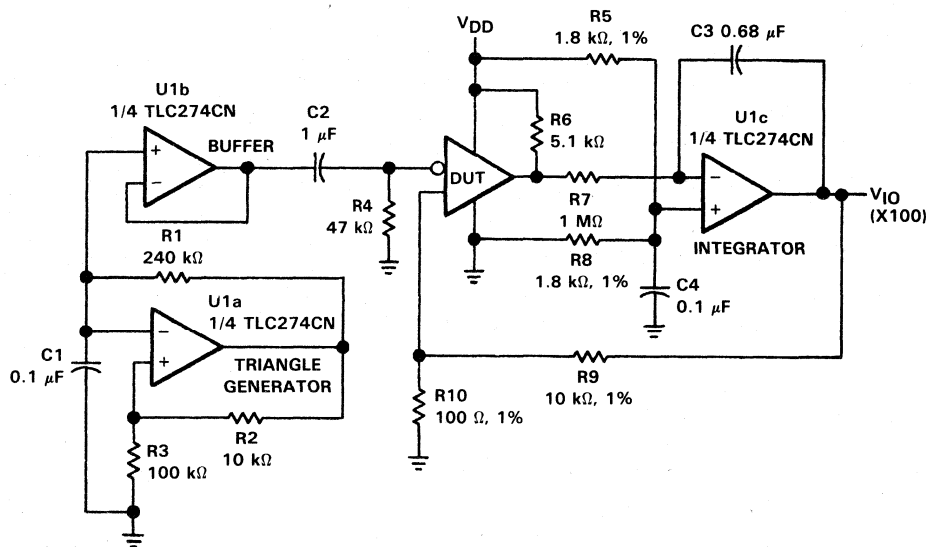
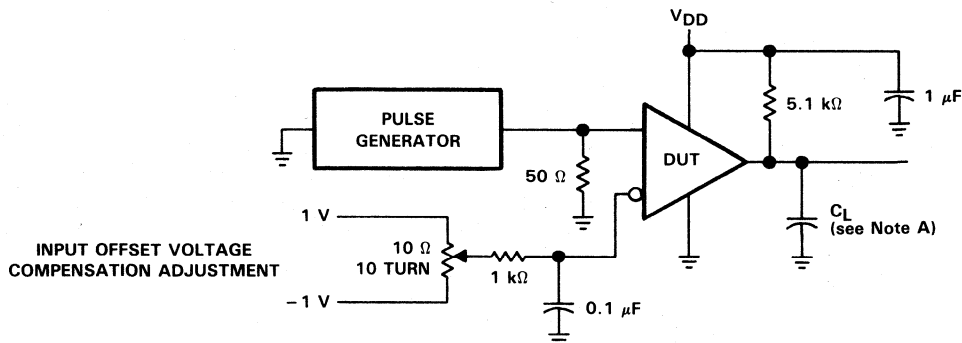


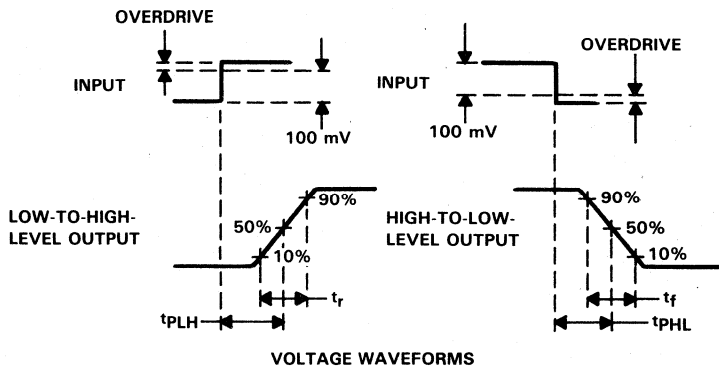
FIGURE 2. CIRCUIT FOR INPUT OFFSET VOLTAGE MEASUREMENT

PARAMETER MEASUREMENT INFORMATION

Response time is defined as the interval between the application of an input step function and the instant when the output reaches 50% of its maximum value. Response time, low-to-high-level output, is measured from the leading edge of the input pulse, while response time, high-to-low-level output, is measured from the trailing edge of the input pulse. Response-time measurement at low input signal levels can be greatly affected by the input offset voltage. The offset voltage should be balanced by the adjustment at the inverting input (as shown in Figure 3) so that the circuit is just at the transition point. Then a low signal, for example 105-mV or 5-mV overdrive, will cause the output to change state.



TEST CIRCUIT



VOLTAGE WAVEFORMS

NOTE A: C_L includes probe and jig capacitance.

FIGURE 3. RESPONSE, RISE, AND FALL TIMES CIRCUIT AND VOLTAGE WAVEFORMS

PRINCIPLES OF OPERATION

LinCMOS™ process

LinCMOS™ process is a Linear polysilicon-gate Complementary-MOS process. Primarily designed for single-supply applications, LinCMOS™ products facilitate the design of a wide range of high-performance analog functions, from operational amplifiers to complex mixed-mode converters.

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electrostatic discharge

CMOS circuits are prone to gate oxide breakdown when exposed to high voltages even if the exposure is only for very short periods of time. Electrostatic discharge (ESD) is one of the most common causes of damage to CMOS devices. It can occur when a device is handled without proper consideration for environmental electrostatic charges, e.g. during board assembly. If a circuit in which one amplifier from a dual op amp is being used and the unused pins are left open, high voltages will tend to develop. If there is no provision for ESD protection, these voltages may eventually punch through the gate oxide and cause the device to fail. To prevent voltage build-up, each pin is protected by internal circuitry.

Standard ESD protection circuits safely shunt the ESD current by providing a mechanism whereby one or more transistors break down at voltages higher than the normal operating voltages but lower than the breakdown voltage of the input gate. This type of protection scheme is limited by leakage currents which flow through the shunting transistors during normal operation after an ESD voltage has occurred. Although these currents are small, on the order of tens of nanoamps, CMOS amplifiers are often specified to draw input currents as low as tens of picoamps.

To overcome this limitation, TI design engineers developed the patented ESD protection circuit shown in Figure 4. This circuit can withstand several successive 2-kV ESD pulses, while reducing or eliminating leakage currents that may be drawn through the input pins. A more detailed discussion of the operation of TI's ESD protection circuit is presented on the next page.

All input and output pins on LinCMOS™ and Advanced LinCMOS™ products have associated ESD protection circuitry that undergoes qualification testing to withstand 2000 V discharged from a 100-pF capacitor through a 1500-Ω resistor (human body model) and 200 V from a 100-pF capacitor with no current-limiting resistor (charged device model). These tests simulate both operator and machine handling of devices during normal test and assembly operations.

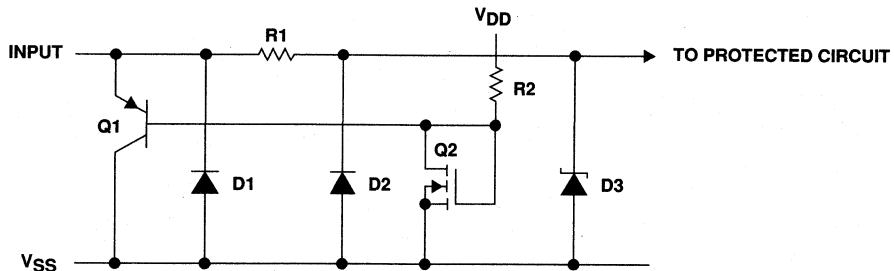


FIGURE 4. LinCMOS™ ESD PROTECTION SCHEMATIC

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input protection circuit operation

Texas Instruments patented protection circuitry allows for both positive- and negative-going ESD transients. These transients are characterized by extremely fast rise times and usually low energies, and can occur both when the device has all pins open and when it is installed in a circuit.

positive ESD transients

Initial positive charged energy is shunted through Q1 to V_{SS}. Q1 will turn on when the voltage at the input rises above the voltage on the V_{DD} pin by a value equal to the V_{BE} of Q1. The base current increases through R2 with input current as Q1 saturates. The base current through R2 will force the voltage at the drain and gate of Q2 to exceed its threshold level ($V_T \sim 22$ to 26 V) and turn Q2 on. The shunted input current through Q1 to V_{SS} is now shunted through the n-channel enhancement-type MOSFET Q2 to V_{SS}. If the voltage on the input pin continues to rise, the breakdown voltage of the zener diode D3 is exceeded, and all remaining energy is dissipated in R1 and D3. The breakdown voltage of D3 is designed to be 24 to 27 V, which is well below the gate oxide voltage of the circuit to be protected.

negative ESD transients

The negative charged ESD transients are shunted directly through D1. Additional energy is dissipated in R1 and D2 as D2 becomes forward biased. The voltage seen by the protected circuit is -0.3 V to -1 V, (the forward voltage of D1 and D2).

circuit-design considerations

LinCMOS™ products are being used in actual circuit environments that have input voltages that exceed the recommended common-mode input voltage range and activate the input protection circuit. Even under "normal" operation, these conditions occur during circuit power-up or power-down, and in many cases, when the device is being used for a signal conditioning function. The input voltages can exceed V_{ICR} and not damage the device only if the inputs are current limited. The recommended current limit shown on most product data sheets is ± 5 mA. Figures 5 and 6 show typical characteristics for input voltage vs input current.

Normal operation and correct output state can be expected even when the input voltage exceeds the positive supply voltage. Again, the input current should be externally limited even though internal positive current limiting is achieved in the input protection circuit by the action of Q1. When Q1 is on, it will saturate and limit the current to approximately 5-mA collector current by design. When saturated, Q1 base current increases with input current. This base current is forced into the V_{DD} pin and into the device I_{DD} or the V_{DD} supply through R2 producing the current limiting effects shown in Figure 5. This internal limiting lasts only as long as the input voltage is below the V_T of Q2.

When the input voltage exceeds the negative supply voltage, normal operation is affected and output voltage states may not be correct. Also, the isolation between channels of multiple devices (duals and quads) can be severely affected. External current limiting must be used since this current will be directly shunted by D1 and D2 and no internal limiting is achieved. If normal output voltage states are required, an external input voltage clamp is required (see Figure 7).

TLC372C, TLC372I, TLC372M, TLC372Q
LinCMOS™ DUAL DIFFERENTIAL COMPARATORS

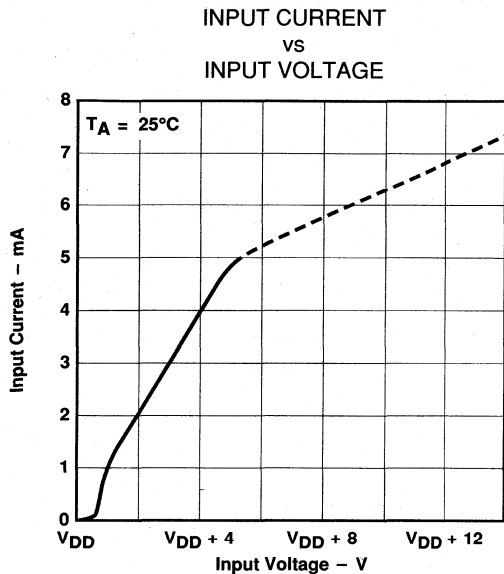


FIGURE 5

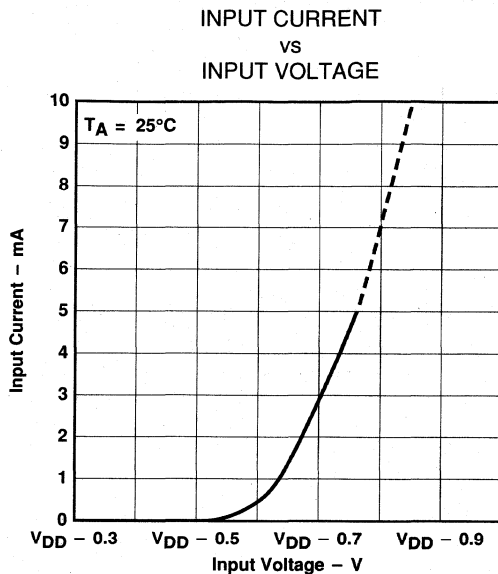
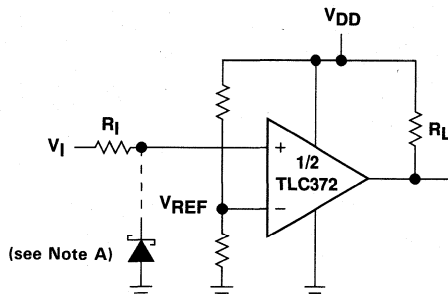


FIGURE 6



Positive Voltage Input Current Limit:

$$R_I = \frac{+V_I - V_{DD} - 0.3 \text{ V}}{5 \text{ mA}}$$

Negative Voltage Input Current Limit:

$$R_I = \frac{-V_I - V_{DD} - (-0.3 \text{ V})}{5 \text{ mA}}$$

Note A: If the correct output state is required when the negative input exceeds V_{SS} , a schottky clamp is required.

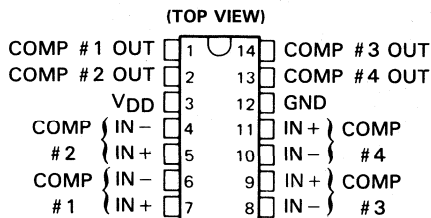
FIGURE 7. TYPICAL INPUT CURRENT-LIMITING CONFIGURATION FOR A LinCMOS™ COMPARATOR

TLC374C, TLC374I, TLC374M, TLC374Q LinCMOS™ QUADRUPLE DIFFERENTIAL COMPARATORS

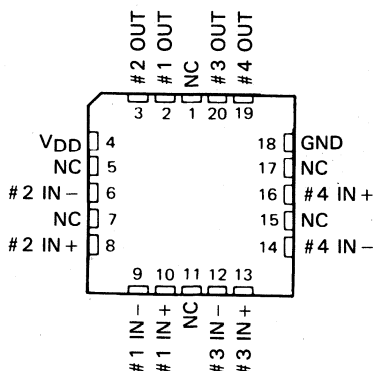
D2783, NOVEMBER 1983—REVISED MAY 1990

- Single or Dual-Supply Operation
- Wide Range of Supply Voltages . . . 2 V to 18 V
- Very Low Supply Current Drain 0.3 mA Typ at 5 V
- Fast Response Time . . . 200 ns Typ for TTL-Level Input Step
- Built-In ESD Protection
- High Input Impedance . . . 10^{12} Typ
- Extremely Low Input Bias Current 5 pA Typ
- Ultrastable Low Input Offset Voltage
- Input Offset Voltage Change at Worst-Case Input Conditions Typically $0.23 \mu\text{V}/\text{Month}$, Including the First 30 Days
- Common-Mode Input Voltage Range Includes Ground
- Outputs Compatible with TTL, MOS, and CMOS
- Pin-Compatible with LM339

TLC374C, TLC374I, TLC374Q . . . D OR N PACKAGE
TLC374M . . . J PACKAGE



TLC374M . . . FK PACKAGE
(TOP VIEW)



NC—No internal connection

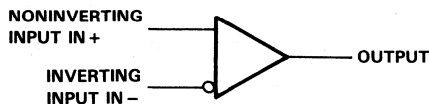
description

This device is fabricated using LinCMOS™ technology and consists of four independent voltage comparators designed to operate from a single power supply. Operation from dual supplies is also possible if the difference between the two supplies is 2 V to 18 V. Each device features extremely high input impedance (typically greater than $10^{12} \Omega$) allowing direct interfacing with high-impedance sources. The outputs are n-channel open-drain configurations and can be connected to achieve positive-logic wired-AND relationships.

The TLC374 has internal electrostatic discharge (ESD) protection circuits and has been classified with a 2000-V ESD rating tested under MIL-STD-883C, Method 3015.1. However, care should be exercised in handling this device as exposure to ESD may result in a degradation of the device parametric performance.

The TLC374C is characterized for operation from 0°C to 70°C . The TLC374I is characterized for operation from -40°C to 85°C . The TLC374M is characterized for operation over the full military temperature range of -55°C to 125°C . The TLC374Q is characterized for operation from -40°C to 125°C .

symbol (each comparator)



LinCMOS is a trademark of Texas Instruments Incorporated.

PRODUCTION DATA documents contain information current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

TEXAS
INSTRUMENTS

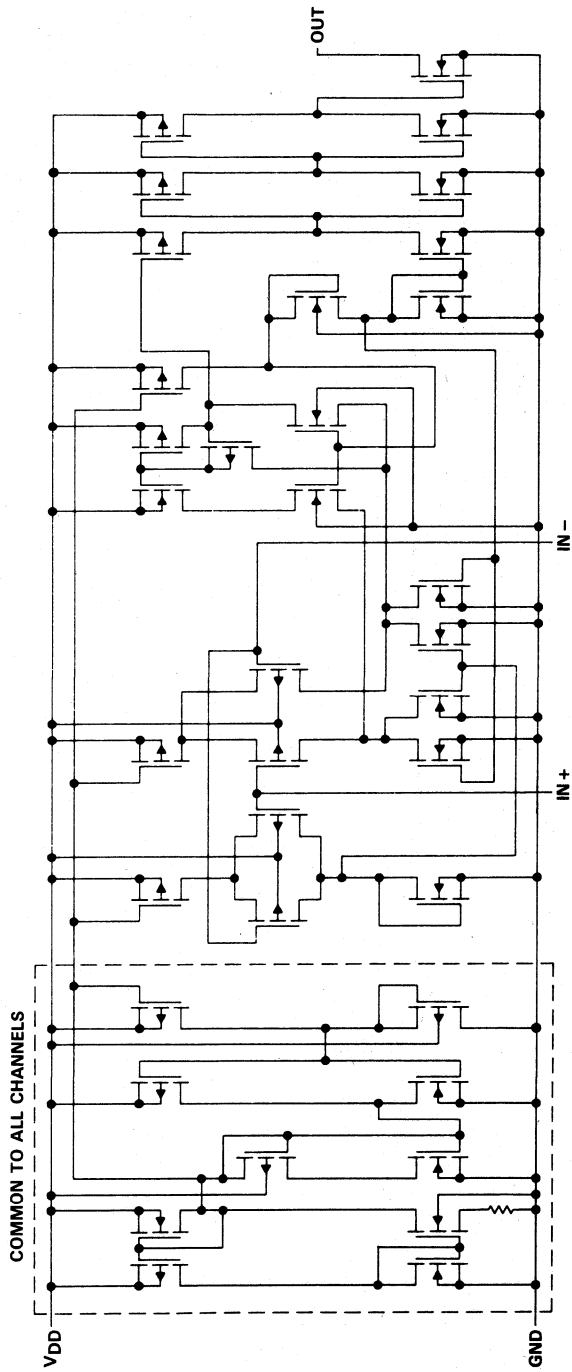
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3-119

TLC374C, TLC374I, TLC374M, TLC374Q
LinCMOS™ QUADRUPLE DIFFERENTIAL COMPARATORS

equivalent schematic (each comparator)



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TLC374C, TLC374I, TLC374M, TLC374Q LinCMOS™ QUADRUPLE DIFFERENTIAL COMPARATORS

AVAILABLE OPTIONS

| T _A | V _{IO} MAX AT 25°C | PACKAGE | | | |
|----------------------|--------------------------------|----------------------|----------------------|--------------------|--------------------|
| | | SMALL-OUTLINE (D) | CHIP-CARRIER (FK) | CERAMIC DIP (J) | PLASTIC DIP (N) |
| 0°C to 70°C | 5 mV | TLC374CD | — | — | TLC374CN |
| -40°C to 85°C | 5 mV | TLC374ID | — | — | TLC374IN |
| -55°C to 125°C | 5 mV | TLC374MD | TLC374MFK | TLC374MJ | TLC374MN |
| -40°C to 125°C | 5 mV | TLC374QD | — | — | TLC374QN |

D packages are available taped and reeled. Add "R" suffix to device type (e.g., TLC374CDR).

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Supply voltage, V _{DD} (see Note 1) | 18 V |
| Differential input voltage, V _{ID} (see Note 2) | ±18 V |
| Input voltage, V _I | V _{DD} |
| Input voltage range | -0.3 V to 18 V |
| Output voltage, V _O | 18 V |
| Input current, I _I | ±5 mA |
| Output current, I _O | 20 mA |
| Duration of output short-circuit to ground (see Note 3) | unlimited |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range: TLC374C | 0°C to 70°C |
| TLC374I | -40°C to 85°C |
| TLC374M | -55°C to 125°C |
| TLC374Q | -40°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds, D or N package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package | 300°C |

- NOTES: 1. All voltage values except differential voltages are with respect to network ground.
 2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
 3. Short circuits from outputs to V_{DD} can cause excessive heating and eventual device destruction.

DISSIPATION RATING TABLE

| PACKAGE | T _A ≤ 25°C POWER RATING | DERATING FACTOR | DERATE ABOVE T _A | T _A = 70°C POWER RATING | T _A = 85°C POWER RATING | T _A = 125°C POWER RATING |
|---------|---------------------------------------|--------------------|--------------------------------|---------------------------------------|---------------------------------------|--|
| D | 500 mW | 7.6 mW/°C | 84°C | 500 mW | 494 mW | 190 mW |
| FK | 500 mW | 11.0 mW/°C | 104°C | 500 mW | 500 mW | 275 mW |
| J | 500 mW | 11.0 mW/°C | 104°C | 500 mW | 500 mW | 275 mW |
| N | 500 mW | 9.2 mW/°C | 95°C | 500 mW | 500 mW | 230 mW |

TLC374C, TLC374I, TLC374M, TLC374O LinCMOS™ QUADRUPLE DIFFERENTIAL COMPARATORS

recommended operating conditions

| | C-SUFFIX | | I-SUFFIX | | M-SUFFIX | | Q-SUFFIX | | UNIT |
|---------------------------------------|------------------------|-----|----------|-----|----------|-----|----------|-----|------|
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | |
| Supply voltage, V_{DD} | 3 | 16 | 3 | 16 | 4 | 16 | 4 | 16 | V |
| Common-mode input voltage, V_{IC} | $V_{DD} = 5\text{ V}$ | | 0 | 3.5 | 0 | 3.5 | 0 | 3.5 | V |
| | $V_{DD} = 10\text{ V}$ | | 0 | 8.5 | 0 | 8.5 | 0 | 8.5 | V |
| Operating free-air temperature, T_A | 0 | 70 | -40 | 85 | -55 | 125 | -40 | 125 | °C |

electrical characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | TLC374C | | TLC374I | | TLC374M/Q | | UNIT | |
|--|--|------------|-------------------|-------------------|-------------------|-------------------|-------------------|------|---------------|
| | | MIN | MAX | MIN | MAX | MIN | MAX | | |
| V_{IO} Input offset voltage | $V_{IC} = V_{ICR\text{ min}}$, See Note 4 | 25°C | 1 | 5 | 1 | 5 | 1 | 5 | mV |
| | | Full range | | 6.5 | | 7 | | 10 | |
| I_{IO} Input offset current | | 25°C | 1 | | 1 | | 1 | pA | |
| I_{IB} Input bias current | | MAX | 5 | 0.3 | 5 | 1 | 10 | nA | |
| | | MAX | | 0.6 | | 2 | | 20 | nA |
| V_{ICR} Common-mode input voltage range | | 25°C | 0 to $V_{DD}-1$ | 0 to $V_{DD}-1$ | 0 to $V_{DD}-1$ | 0 to $V_{DD}-1$ | 0 to $V_{DD}-1$ | V | |
| | | Full range | 0 to $V_{DD}-1.5$ | 0 to $V_{DD}-1.5$ | 0 to $V_{DD}-1.5$ | 0 to $V_{DD}-1.5$ | 0 to $V_{DD}-1.5$ | | |
| I_{OH} High-level output current | $V_{ID} = 1\text{ V}$, $V_{OH} = 5\text{ V}$, $V_{OH} = 15\text{ V}$ | 25°C | 0.1 | 1 | 0.1 | 1 | 0.1 | nA | |
| | | Full range | | 1 | | 1 | | 1 | |
| V_{OL} Low-level output voltage | $V_{ID} = -1\text{ V}$, $I_{OL} = 4\text{ mA}$ | 25°C | 150 | 400 | 150 | 400 | 150 | 400 | mV |
| | | Full range | | 700 | | 700 | | 700 | |
| I_{OL} Low-level output current | $V_{ID} = -1\text{ V}$, $V_{OL} = 1.5\text{ V}$ | 25°C | 6 | 16 | 6 | 16 | 6 | 16 | mA |
| I_{DD} Supply current (four comparators) | $V_{ID} = 1\text{ V}$, No load | 25°C | 300 | 600 | 300 | 600 | 300 | 600 | μA |
| | | Full range | | 800 | | 800 | | 800 | |

† All characteristics are measured with zero common-mode input voltage unless otherwise noted. Full range is 0°C to 70°C for TLC374C, -40°C to 85°C for TLC374I, -55°C to 125°C for TLC374M, and -40°C to 125°C for TLC374O. IMPORTANT: See Parameter Measurement Information.

NOTE 4: The offset voltage limits given are the maximum values required to drive the output above 4 V or below 400 mV with a 10-k Ω resistor between the output and V_{DD} . They can be verified by applying the limit value to the input and checking for the appropriate output state.

switching characteristics, $V_{DD} = 5\text{ V}$, $T_A = 25\text{ }^\circ\text{C}$

| PARAMETER | TEST CONDITIONS | | | UNIT |
|---------------|---|-----|-----|------|
| | MIN | TYP | MAX | |
| Response time | R_L connected to 5 V through 5.1 k Ω , 100-mV input step with 5-mV overdrive | 650 | | ns |
| | $C_L = 15\text{ pF}^\ddagger$, See Note 5 | 200 | | |

† C_L includes probe and jig capacitance.

NOTE 5: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.

PARAMETER MEASUREMENT INFORMATION

The digital output stage of the TLC374 can be damaged if it is held in the linear region of the transfer curve. Conventional operational amplifier/comparator testing incorporates the use of a servo-loop that is designed to force the device output to a level within this linear region. Since the servo-loop method of testing cannot be used, the following alternative for measuring parameters such as input offset voltage, common-mode rejection, etc., are offered.

To verify that the input offset voltage falls within the limits specified, the limit value is applied to the input as shown in Figure 1(a). With the noninverting input positive with respect to the inverting input, the output should be high. With the input polarity reversed, the output should be low.

A similar test can be made to verify the input offset voltage at the common-mode extremes. The supply voltages can be slewed as shown in Figure 1(b) for the V_{ICR} test, rather than changing the input voltages to provide greater accuracy.

A close approximation of the input offset voltage can be obtained by using a binary search method to vary the differential input voltage while monitoring the output state. When the applied input voltage differential is equal, but opposite in polarity to the input offset voltage, the output will change state.

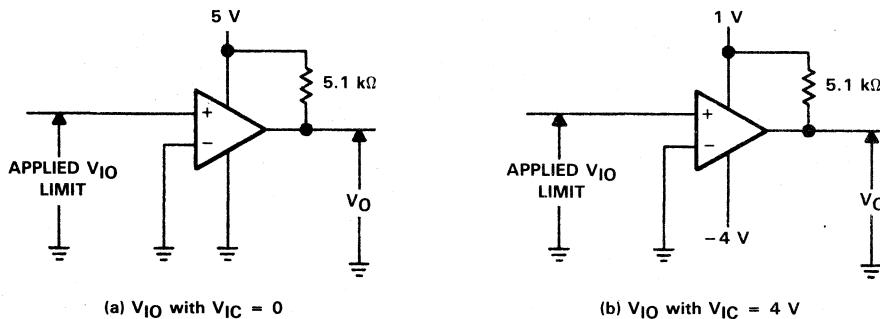


FIGURE 1. METHOD FOR VERIFYING THAT INPUT OFFSET VOLTAGE IS WITHIN SPECIFIED LIMITS

PARAMETER MEASUREMENT INFORMATION

Figure 2 illustrates a practical circuit for direct dc measurement of input offset voltage that does not bias the comparator into the linear region. The circuit consists of a switching-mode servo loop in which U1a generates a triangular waveform of approximately 20-mV amplitude. U1b acts as a buffer, with C2 and R4 removing any residual dc offset. The signal is then applied to the inverting input of the comparator under test, while the noninverting input is driven by the output of the integrator formed by U1c through the voltage divider formed by R9 and R10. The loop reaches a stable operating point when the output of the comparator under test has a duty cycle of exactly 50%, which can only occur when the incoming triangle wave is "sliced" symmetrically or when the voltage at the noninverting input exactly equals the input offset voltage.

Voltage divider R9 and R10 provides a step-up of the input offset voltage by a factor of 100 to make measurement easier. The values of R5, R8, R9, and R10 can significantly influence the accuracy of the reading; therefore, it is suggested that their tolerance level be 1% or lower.

Measuring the extremely low values of input current requires isolation from all other sources of leakage current and compensation for the leakage of the test socket and board. With a good picoammeter, the socket and board leakage can be measured with no device in the socket. Subsequently, this open-socket leakage value can be subtracted from the measurement obtained with a device in the socket to obtain the actual input current of the device.

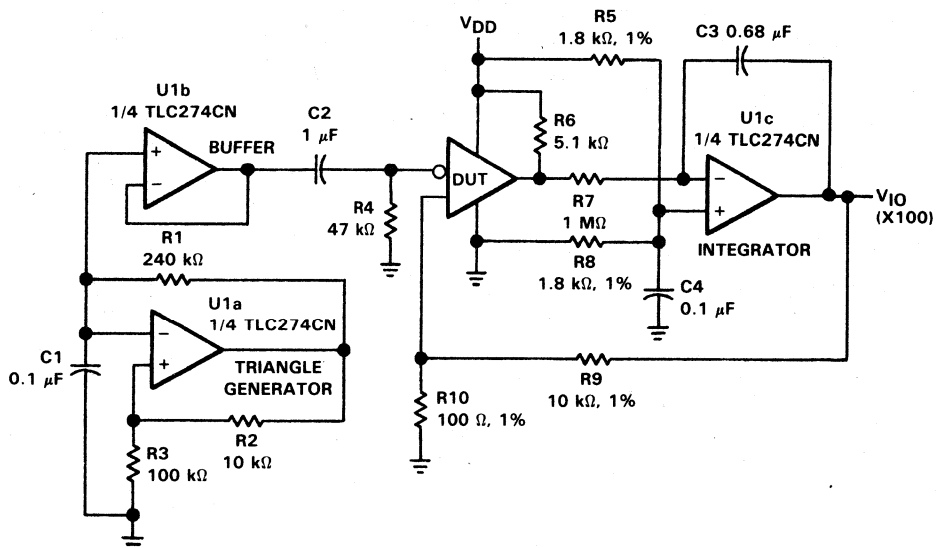
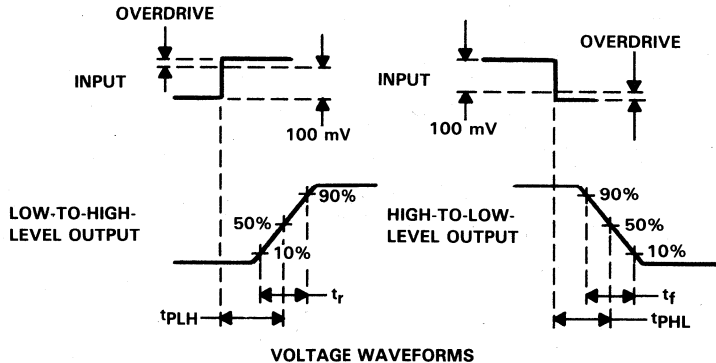
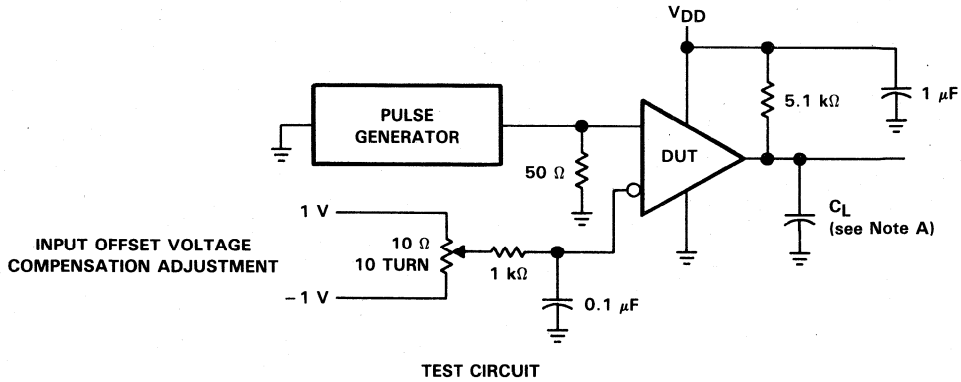


FIGURE 2. CIRCUIT FOR INPUT OFFSET VOLTAGE MEASUREMENT

PARAMETER MEASUREMENT INFORMATION

Response time is defined as the interval between the application of an input step function and the instant when the output reaches 50% of its maximum value. Response time, low-to-high-level output, is measured from the leading edge of the input pulse, while response time, high-to-low-level output, is measured from the trailing edge of the input pulse. Response-time measurement at low input signal levels can be greatly affected by the input offset voltage. The offset voltage should be balanced by the adjustment at the inverting input (as shown in Figure 3) so that the circuit is just at the transition point. Then a low signal, for example 105-mV or 5-mV overdrive, will cause the output to change state.



NOTE A: C_L includes probe and jig capacitance.

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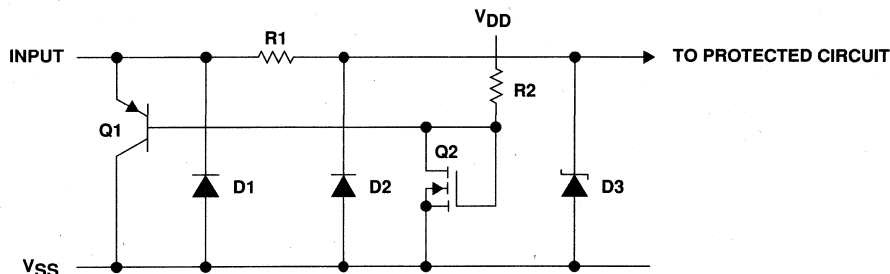


FIGURE 4. LinCMOS™ ESD PROTECTION SCHEMATIC

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Initial positive charged energy is shunted through Q1 to V_{SS}. Q1 will turn on when the voltage at the input rises above the voltage on the V_{DD} pin by a value equal to the V_{BE} of Q1. The base current increases through R2 with input current as Q1 saturates. The base current through R2 as Q1 saturates forces the voltage at the drain and gate of Q2 to exceed its threshold level ($V_T \sim 22$ to 26 V) and turn on Q2. The shunted input current through Q1 to V_{SS} is now shunted through the n-channel enhancement-type MOSFET Q2 to V_{SS}. If the voltage on the input pin continues to rise, the breakdown voltage of the zener diode D3 is exceeded and all remaining energy is dissipated in R1 and D3. The breakdown voltage of D3 is designed to be 24 V to 27 V, which is well below the gate oxide voltage of the circuit to be protected.

negative ESD transients

The negative charged ESD transients are shunted directly through D1. Additional energy is dissipated in R1 and D2 as D2 becomes forward-biased. The voltage seen by the protected circuit is -0.3 V to -1.0 V, (the forward voltage of D1 and D2).

circuit-design considerations

LinCMOS™ products are being used in actual circuit environments that have input voltages that exceed the recommended common-mode input voltage range and activate the input protection circuit. Even under "normal" operation, these conditions occur during circuit power-up or power-down, and in many cases, when the device is being used for a signal conditioning function. The input voltages can exceed V_{ICR} and not damage the device only if the inputs are current limited. The recommended current limit shown on most product data sheets is ± 5 mA. Figures 5 and 6 show typical characteristics for input voltage vs input current.

Normal operation and correct output state can be expected even when the input voltage exceeds the positive supply voltage. The input current should be externally limited even though internal positive current limiting is achieved in the input protection circuit by the action of Q1. When Q1 is on, it will saturate and limit the current to approximately 5-mA collector current by design. When saturated, Q1 base current increases with input current. This base current is forced into the V_{DD} pin and into the device I_{DD} or the V_{DD} supply through R2 producing the current limiting effects shown in Figure 5. This internal limiting lasts only as long as the input voltage is below the V_T of Q2.

When the input voltage exceeds the negative supply voltage, normal operation is affected and output voltage states may not be correct. Also, the isolation between channels of multiple devices (duals and quads) can be severely affected. External current limiting must be used since this current will be directly shunted by D1 and D2, and no internal limiting is achieved. If normal output voltage states are required, an external input voltage clamp is required (see Figure 7).

TYPICAL CHARACTERISTICS

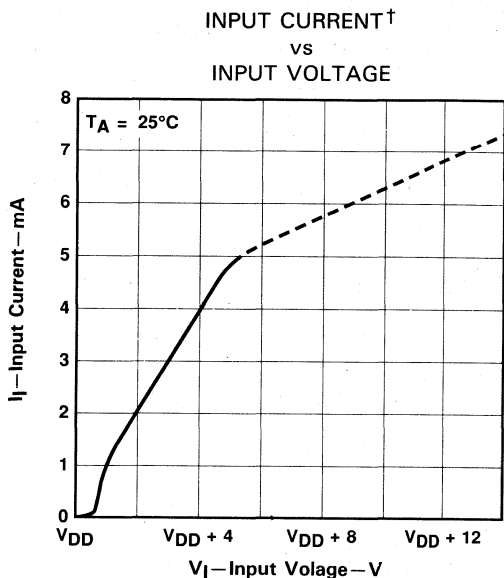


FIGURE 5

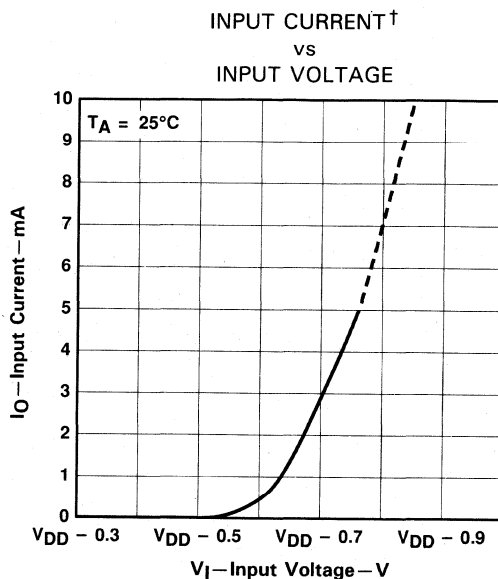
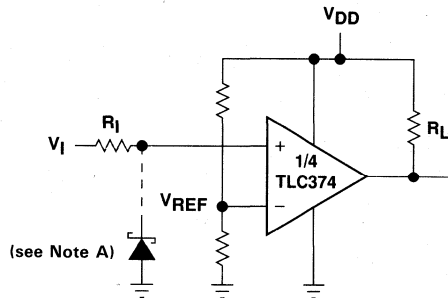


FIGURE 6

†The dashed line identifies an area of operation where some degradation of parametric performance may be experienced.



Positive Voltage Input Current Limit:

$$R_I = \frac{+V_I - V_{DD} - 0.3 \text{ V}}{5 \text{ mA}}$$

Negative Voltage Input Current Limit:

$$R_I = \frac{-V_I - V_{DD} - (-0.3 \text{ V})}{5 \text{ mA}}$$

Note A: If the correct output state is required when the negative input exceeds V_{SS} , a schottky clamp is required.

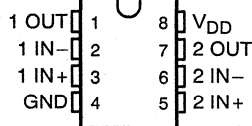
FIGURE 7. TYPICAL INPUT CURRENT-LIMITING CONFIGURATION FOR A LinCMOS™ COMPARATOR

TLC393C, TLC393I, TLC393M DUAL MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

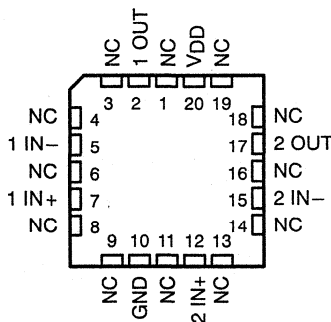
D3241, DECEMBER 1986—REVISED JANUARY 1992

- **Very Low Power . . . 110 μ W Typ at 5 V**
- **Fast Response Time . . . $t_{PLH} = 2.5 \mu$ s Typ With 5-mV Overdrive**
- **Single Supply Operation:**
 TLC393C . . . 3 V to 16 V
 TLC393I . . . 3 V to 16 V
 TLC393M . . . 4 V to 16 V
- **On-Chip ESD Protection**

**D, JG, OR P PACKAGE
(TOP VIEW)**



**FK PACKAGE
(TOP VIEW)**



NC — No internal connection

description

The TLC393 consists of dual independent micropower voltage comparators designed to operate from a single supply. It is functionally similar to the LM393 but uses 1/20th the power for similar response times. The open-drain MOS output stage will interface to a variety of loads and supplies. For a similar device with a push-pull output configuration, see the TLC3702 data sheet.

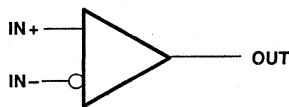
Texas Instruments LinCMOS™ process offers superior analog performance to standard CMOS processes. Along with the standard CMOS advantages of low power without sacrificing speed, high input impedance, and low bias currents, the LinCMOS™ process offers extremely stable input offset voltages, even with differential input stresses of several volts. This characteristic makes it possible to build reliable CMOS comparators.

The TLC393C is characterized for operation over the commercial temperature range of 0°C to 70°C.

The TLC393I is characterized for operation over the extended industrial temperature range of -40°C to 85°C.

The TLC393M is characterized for operation over the full military temperature range of -55°C to 125°C.

symbol (each comparator)



AVAILABLE OPTIONS

| T _A | V _{IO} max at 25°C | PACKAGE | | | |
|----------------|-----------------------------|-------------------|-------------------|------------------|-----------------|
| | | SMALL OUTLINE (D) | CHIP CARRIER (FK) | CERAMIC DIP (JG) | PLASTIC DIP (P) |
| 0°C to 70°C | 5 mV | TLC393CD | — | — | TLC393CP |
| -40°C to 85°C | 5 mV | TLC393ID | — | — | TLC393IP |
| -55°C to 125°C | 5 mV | TLC393MD | TLC393MFK | TLC393MJG | TLC393MP |

The D package is available taped and reeled. Add the suffix "R" to the device type (e.g., TLC393CDR).

LinCMOS is a trademark of Texas Instruments Incorporated.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

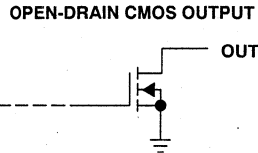


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TLC393C, TLC393I, TLC393M DUAL MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

schematic



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Supply voltage range, V_{DD} (see Note 1) | − 0.3 V to 18 V |
| Differential input voltage, V_{ID} (see Note 2) | ± 18 V |
| Input voltage range, V_I | − 0.3 V to V_{DD} |
| Output voltage range, V_O | − 0.3 V to V_{DD} |
| Input current, I_I | ± 5 mA |
| Output current, I_O (each output) | 20 mA |
| Total supply current into V_{DD} terminal | 40 mA |
| Total current out of ground terminal | 40 mA |
| Continuous total power dissipation | See Dissipation Rating Table |
| Operating free-air temperature range: TLC393C | 0°C to 70°C |
| TLC393I | − 40°C to 85°C |
| TLC393M | − 55°C to 125°C |
| Storage temperature range | − 65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package | 300°C |

- NOTES: 1. All voltage values, except differential voltages, are with respect to network ground.
2. Differential voltages are at the noninverting input with respect to the inverting input.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$ | $T_A = 70^\circ\text{C}$ POWER RATING | $T_A = 85^\circ\text{C}$ POWER RATING | $T_A = 125^\circ\text{C}$ POWER RATING |
|---------|---|---|--|--|---|
| D | 725 mW | 5.8 mW/°C | 464 mW | 377 mW | — |
| FK | 1375 mW | 11.0 mW/°C | 880 mW | 715 mW | 275 mW |
| JG | 1050 mW | 8.4 mW/°C | 672 mW | 546 mW | 210 mW |
| P | 1000 mW | 8.0 mW/°C | 640 mW | 520 mW | — |

TLC393C

DUAL MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|---------------------------------------|------|-----|----------------|------|
| Supply voltage, V_{DD} | 3 | 5 | 16 | V |
| Common-mode input voltage, V_{IC} | -0.2 | | $V_{DD} - 1.5$ | V |
| Low-level output current, I_{OL} | | | 20 | mA |
| Operating free-air temperature, T_A | 0 | | 70 | °C |

electrical characteristics at specified operating free-air temperature, $V_{DD} = 5\text{ V}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS† | T_A | MIN | TYP | MAX | UNIT |
|-----------|-----------------------------------|---|-------------|---------------------|-----|-----|------|
| V_{IO} | Input offset voltage | $V_{IC} = V_{ICRmin}$, $V_{DD} = 5\text{ V to }10\text{ V}$, See Note 3 | 25°C | 1.4 | 5 | | mV |
| | | | 0°C to 70°C | | | 6.5 | |
| I_{IO} | Input offset current | $V_{IC} = 2.5\text{ V}$ | 25°C | 1 | | | pA |
| | | | 70°C | | | 0.3 | nA |
| I_{IB} | Input bias current | $V_{IC} = 2.5\text{ V}$ | 25°C | 5 | | | pA |
| | | | 70°C | | | 0.6 | nA |
| V_{ICR} | Common-mode input voltage range | | 25°C | 0 to $V_{DD} - 1$ | | | V |
| | | | 0°C to 70°C | 0 to $V_{DD} - 1.5$ | | | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICRmin}$ | 25°C | 84 | | | dB |
| | | | 70°C | 84 | | | |
| | | | 0°C | 84 | | | |
| k_{SVR} | Supply voltage rejection ratio | $V_{DD} = 5\text{ V to }10\text{ V}$ | 25°C | 85 | | | dB |
| | | | 70°C | 85 | | | |
| | | | 0°C | 85 | | | |
| V_{OL} | Low-level output voltage | $V_{ID} = -1\text{ V}$, $I_{OL} = 6\text{ mA}$ | 25°C | 300 | 400 | | mV |
| | | | 70°C | | | 650 | |
| I_{OH} | High-level output current | $V_{ID} = 1\text{ V}$, $V_O = 5\text{ V}$ | 25°C | 0.8 | 40 | | nA |
| | | | 70°C | | | 1 | μA |
| I_{DD} | Supply current (both comparators) | No load, Outputs low | 25°C | 22 | 40 | | μA |
| | | | 0°C to 70°C | | | 50 | |

† All characteristics are measured with zero common-mode voltage unless otherwise noted.

NOTE 3: The offset voltage limits given are the maximum values required to drive the output up to 4.5 V or down to 0.3 V.

TLC3931

DUAL MICROWPOWER LinCMOS™ VOLTAGE COMPARATORS

recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|---------------------------------------|------|----------------|-----|------|
| Supply voltage, V_{DD} | 3 | 5 | 16 | V |
| Common-mode input voltage, V_{IC} | -0.2 | $V_{DD} - 1.5$ | | V |
| Low-level output current, I_{OL} | | | 20 | mA |
| Operating free-air temperature, T_A | -40 | | 85 | °C |

electrical characteristics at specified operating free-air temperature, $V_{DD} = 5$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS† | T_A | MIN | TYP | MAX | UNIT |
|-----------|-----------------------------------|--|---------------|------|----------------|-----|------|
| V_{IO} | Input offset voltage | $V_{IC} = V_{ICRmin}$, $V_{DD} = 5$ V to 10 V, See Note 3 | 25°C | | 1.4 | 5 | mV |
| | | | -40°C to 85°C | | | 7 | |
| I_{IO} | Input offset current | $V_{IC} = 2.5$ V | 25°C | | 1 | | pA |
| | | | 85°C | | | 1 | nA |
| I_{IB} | Input bias current | $V_{IC} = 2.5$ V | 25°C | | 5 | | pA |
| | | | 85°C | | | 2 | nA |
| V_{ICR} | Common-mode input voltage range | | 25°C | 0 to | $V_{DD} - 1$ | | V |
| | | | -40°C to 85°C | 0 to | $V_{DD} - 1.5$ | | |
| $CMRR$ | Common-mode rejection ratio | $V_{IC} = V_{ICRmin}$ | 25°C | | 84 | | dB |
| | | | 85°C | | 84 | | |
| | | | -40°C | | 84 | | |
| k_{SVR} | Supply voltage rejection ratio | $V_{DD} = 5$ V to 10 V | 25°C | | 85 | | dB |
| | | | 85°C | | 85 | | |
| | | | -40°C | | 84 | | |
| V_{OL} | Low-level output voltage | $V_{ID} = -1$ V, $I_{OH} = 6$ mA | 25°C | | 300 | 400 | mV |
| | | | 85°C | | | 700 | |
| I_{OH} | High-level output current | $V_{ID} = 1$ V, $V_O = 5$ VmA | 25°C | | 0.8 | 40 | nA |
| | | | 85°C | | | 1 | μA |
| I_{DD} | Supply current (both comparators) | No load, Outputs low | 25°C | | 22 | 40 | μA |
| | | | -40°C to 85°C | | | 65 | |

† All characteristics are measured with zero common-mode voltage unless otherwise noted.

NOTE 4: The offset voltage limits given are the maximum values required to drive the output up to 4.5 V or down to 0.3 V.



TLC393M

DUAL MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|---------------------------------------|-----|----------------|-----|-----------|
| Supply voltage, V_{DD} | 4 | 5 | 16 | V |
| Common-mode input voltage, V_{IC} | 0 | $V_{DD} - 1.5$ | | V |
| Low-level output current, I_{OL} | | | | 20 mA |
| Operating free-air temperature, T_A | -55 | | | 125 °C |

electrical characteristics at specified operating free-air temperature, $V_{DD} = 5$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS† | T_A | MIN | TYP | MAX | UNIT |
|-----------|-----------------------------------|--|----------------|---------------------|-----|-----|------|
| V_{IO} | Input offset voltage | $V_{IC} = V_{ICRmin}$, $V_{DD} = 5$ V to 10 V, See Note 4 | 25°C | 1.4 | | 5 | mV |
| | | | -55°C to 125°C | | | 10 | |
| I_{IO} | Input offset current | $V_{IC} = 2.5$ V | 25°C | 1 | | | pA |
| | | | 125°C | | | 15 | nA |
| I_{IB} | Input bias current | $V_{IC} = 2.5$ V | 25°C | 5 | | | pA |
| | | | 125°C | | | 30 | nA |
| V_{ICR} | Common-mode input voltage range | | 25°C | 0 to $V_{DD} - 1$ | | | V |
| | | | -55°C to 125°C | 0 to $V_{DD} - 1.5$ | | | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICRmin}$ | 25°C | 84 | | | dB |
| | | | 125°C | 84 | | | |
| | | | -55°C | 84 | | | |
| kSVR | Supply voltage rejection ratio | $V_{DD} = 5$ V to 10 V | 25°C | 85 | | | dB |
| | | | 125°C | 84 | | | |
| | | | -55°C | 84 | | | |
| V_{OL} | Low-level output voltage | $V_{ID} = -1$ V, $I_{OL} = 6$ mA | 25°C | 300 | 400 | | mV |
| | | | 125°C | 800 | | | |
| I_{OH} | High-level output current | $V_{ID} = 1$ V, $V_O = 5$ V | 25°C | 0.8 | 40 | | nA |
| | | | 125°C | 1 | | | μA |
| I_{DD} | Supply current (both comparators) | No load, Outputs low | 25°C | 22 | 40 | | μA |
| | | | -55°C to 125°C | 90 | | | |

† All characteristics are measured with zero common-mode voltage unless otherwise noted.

NOTE 4: The offset voltage limits given are the maximum values required to drive the output up to 4.5 V or down to 0.3 V with a 2.5-kΩ load to V_{DD} .

TLC393C, TLC393I, TLC393M
DUAL MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

switching characteristics, $V_{DD} = 5\text{ V}$, $T_A = 25^\circ\text{C}$ (see Figure 3)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|--|--|-------------------|-----|-----|------|
| t _{PLH} | Propagation delay time, low-to-high-level output | f = 10 kHz, C _L = 15 pF | Overdrive = 2 mV | | 4.5 | μs |
| | | | Overdrive = 5 mV | | 2.5 | |
| | | | Overdrive = 10 mV | | 1.7 | |
| | | | Overdrive = 20 mV | | 1.2 | |
| | | | Overdrive = 40 mV | | 1.1 | |
| t _{PHL} | Propagation delay time, high-to-low-level output | V _I = 1.4-V step at IN+ pin | | 1.1 | μs | |
| | | f = 10 kHz, C _L = 15 pF | Overdrive = 2 mV | | | 3.6 |
| | | | Overdrive = 5 mV | | | 2.1 |
| | | | Overdrive = 10 mV | | | 1.3 |
| | | | Overdrive = 20 mV | | | 0.85 |
| | | | Overdrive = 40 mV | | | 0.55 |
| V _I = 1.4-V step at IN+ pin | | 0.10 | | | | |
| t _f | Fall time, output | f = 10 kHz, C _L = 15 pF | Overdrive = 50 mV | | 22 | ns |

PARAMETER MEASUREMENT INFORMATION

The TLC393 contains a digital output stage which, if held in the linear region of the transfer curve, can cause damage to the device. Conventional operational amplifier/comparator testing incorporates the use of a servo loop that is designed to force the device output to a level within this linear region. Since the servo-loop method of testing cannot be used, the following alternatives for testing parameters such as input offset voltage, common-mode rejection ratio, etc., are suggested.

To verify that the input offset voltage falls within the limits specified, the limit value is applied to the input as shown in Figure 1 (a). With the noninverting input positive with respect to the inverting input, the output should be high. With the input polarity reversed, the output should be low.

A similar test can be made to verify the input offset voltage at the common-mode extremes. The supply voltages can be slewed as shown in Figure 1 (b) for the V_{ICR} test, rather than changing the input voltages, to provide greater accuracy.

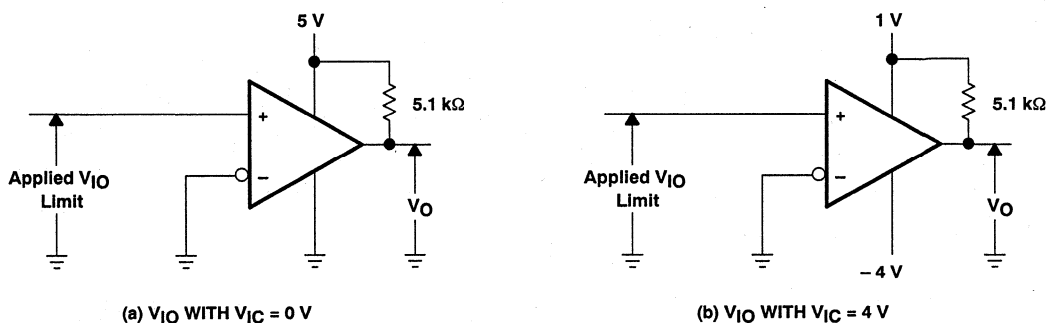


Figure 1. Method for Verifying That Input Offset Voltage Is Within Specified Limits

A close approximation of the input offset voltage can be obtained by using a binary search method to vary the differential input voltage while monitoring the output state. When the applied input voltage differential is equal, but opposite in polarity, to the input offset voltage, the output will change states.

Figure 2 illustrates a practical circuit for direct dc measurement of input offset voltage that does not bias the comparator in the linear region. The circuit consists of a switching-mode servo loop in which U1A generates a triangular waveform of approximately 20-mV amplitude. U1B acts as a buffer, with C2 and R4 removing any residual dc offset. The signal is then applied to the inverting input of the comparator under test, while the noninverting input is driven by the output of the integrator formed by U1C through the voltage divider formed by R9 and R10. The loop reaches a stable operating point when the output of the comparator under test has a duty cycle of exactly 50%, which can only occur when the incoming triangle wave is "sliced" symmetrically or when the voltage at the noninverting input exactly equals the input offset voltage.

The voltage divider formed by R9 and R10 provides an increase in input offset voltage by a factor of 100 to make measurement easier. The values of R5, R8, R9, and R10 can significantly influence the accuracy of the reading; therefore, it is suggested that their tolerance level be 1% or lower.

Measuring the extremely low values of input current requires isolation from all other sources of leakage current and compensation for the leakage of the test socket and board. With a good picoammeter, the socket and board leakage can be measured with no device in the socket. Subsequently, this open-socket leakage value can be subtracted from the measurement obtained with a device in the socket to obtain the actual input current of the device.

PARAMETER MEASUREMENT INFORMATION

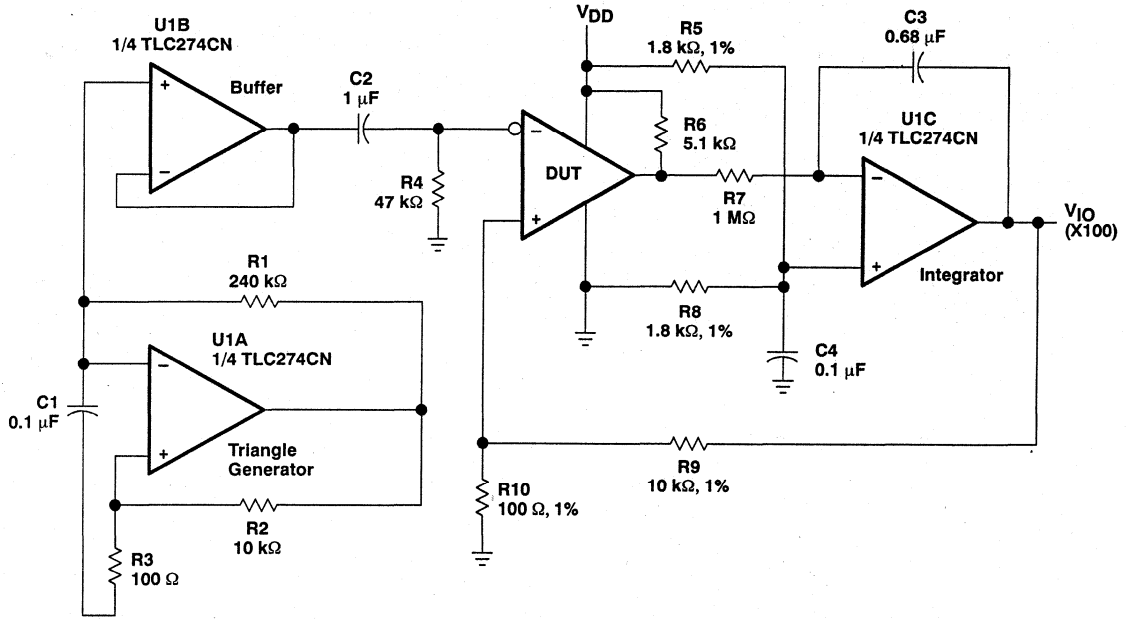
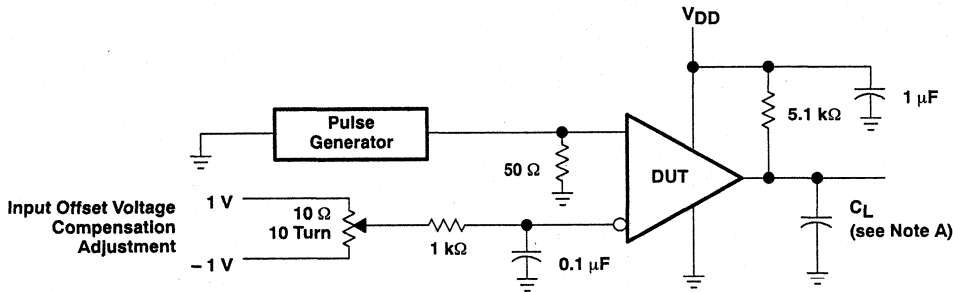


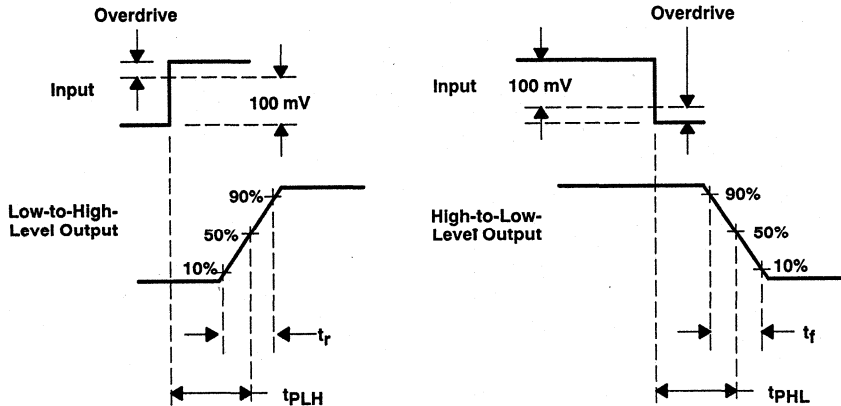
Figure 2. Circuit for Input Offset Voltage Measurement

PARAMETER MEASUREMENT INFORMATION

Propagation delay time is defined as the interval between the application of an input step function and the instant when the output reaches 50% of its maximum value. Propagation delay time, low-to-high-level output is measured from the leading edge of the input pulse, while propagation delay time, high-to-low-level output, is measured from the trailing edge of the input pulse. Propagation delay time measurement at low input signal levels can be greatly affected by the input offset voltage. The offset voltage should be balanced by the adjustment at the inverting input (as shown in Figure 3) so that the circuit is just at the transition point. Then a low signal, for example, 105 mV or 5 mV overdrive, will cause the output to change state.



TEST CIRCUIT



VOLTAGE WAVEFORMS

NOTE A: C_L includes probe and jig capacitance.

Figure 3. Propagation Delay, Rise Time, and Fall Time Circuit and Voltage Waveforms

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DUAL MICROWPOWER LinCMOS™ VOLTAGE COMPARATORS

TYPICAL CHARACTERISTICS†

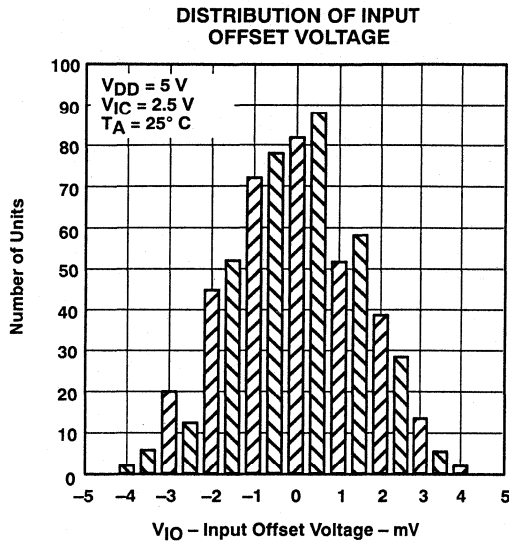


Figure 4

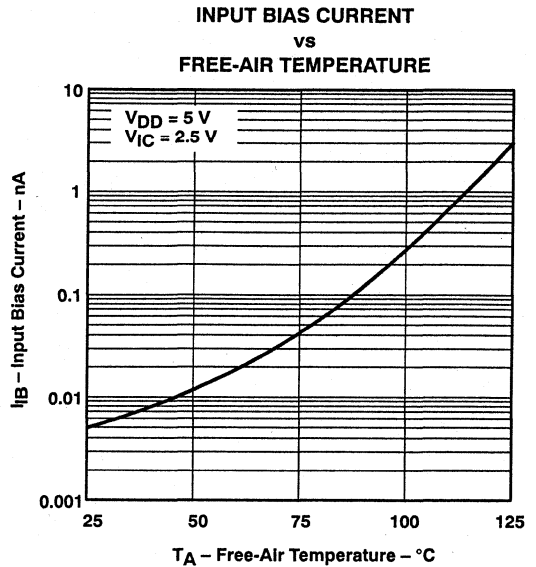


Figure 5

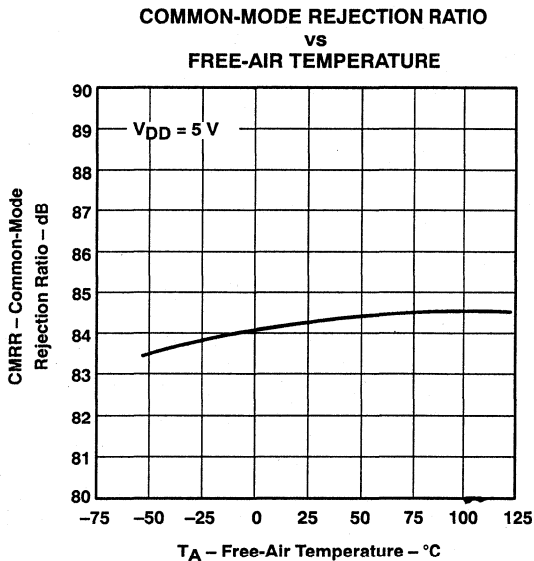


Figure 6

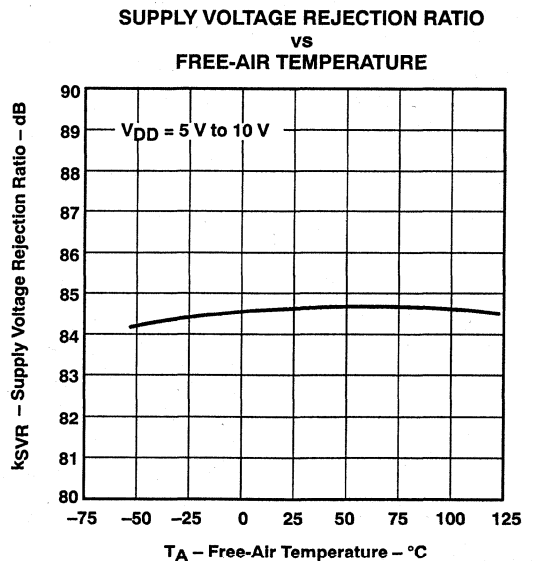


Figure 7

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS†

LOW-LEVEL OUTPUT VOLTAGE
 vs
 LOW-LEVEL OUTPUT CURRENT

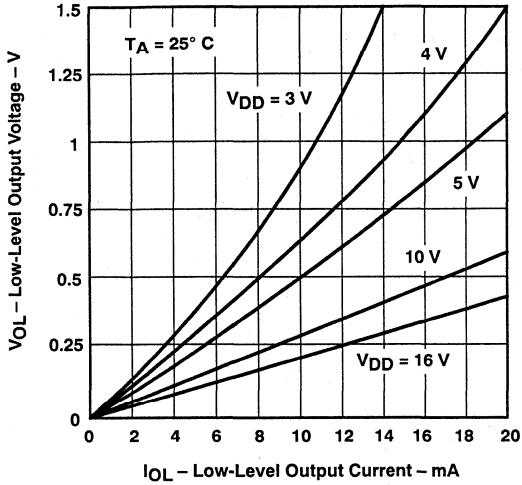


Figure 8

LOW-LEVEL OUTPUT VOLTAGE
 vs
 FREE-AIR TEMPERATURE

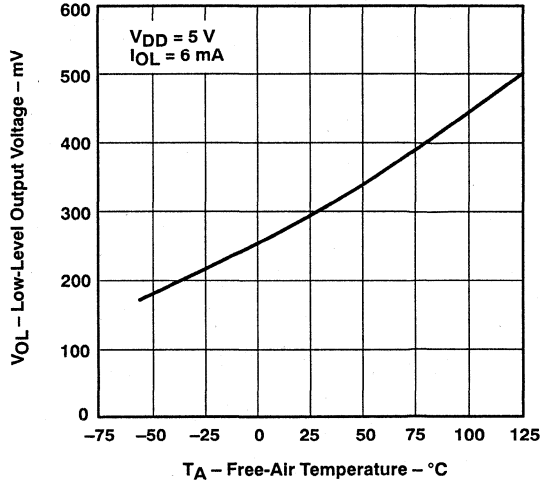


Figure 9

HIGH-LEVEL OUTPUT CURRENT
 vs
 HIGH-LEVEL OUTPUT VOLTAGE

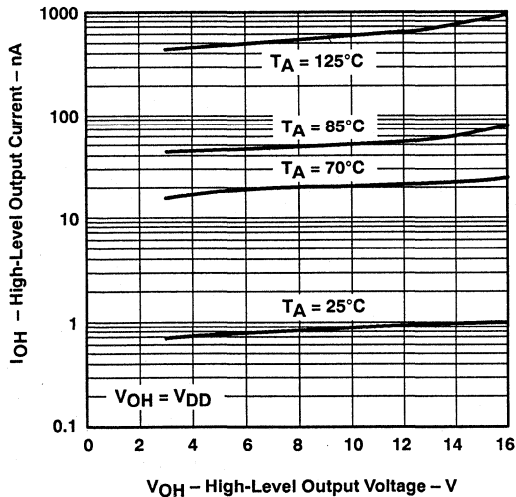


Figure 10

HIGH-LEVEL OUTPUT CURRENT
 vs
 FREE-AIR TEMPERATURE

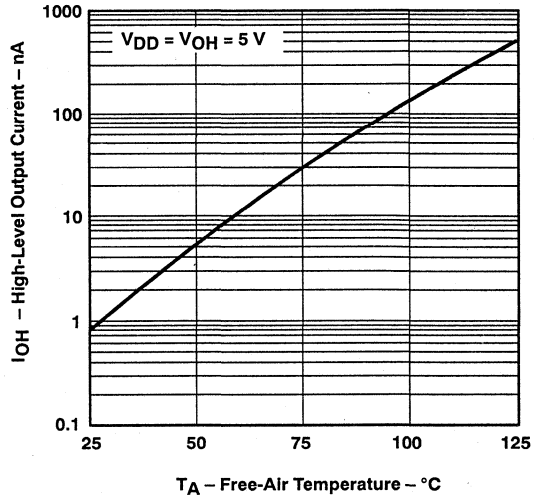


Figure 11

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

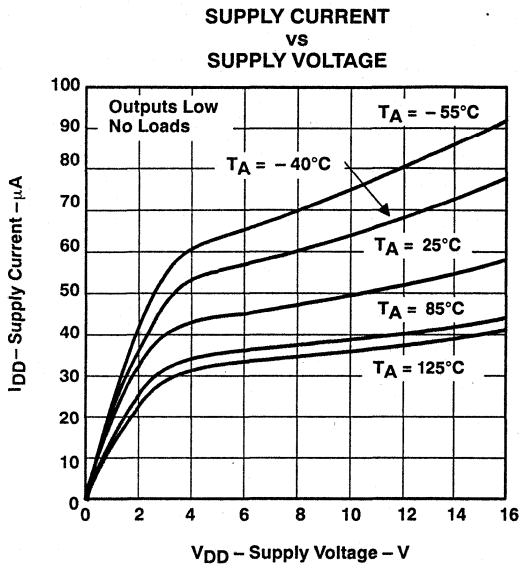


Figure 12

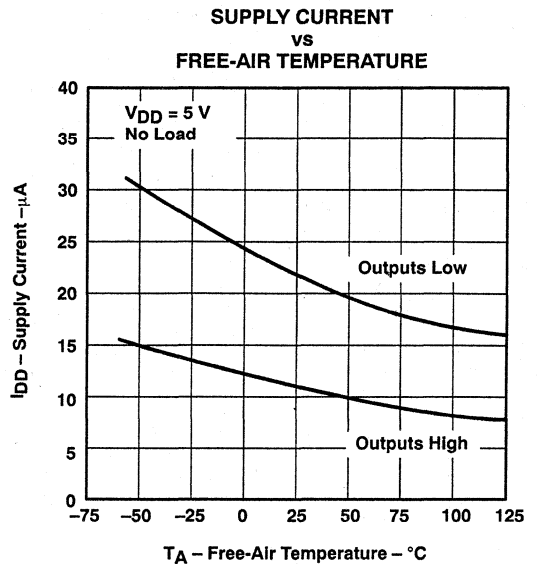


Figure 13

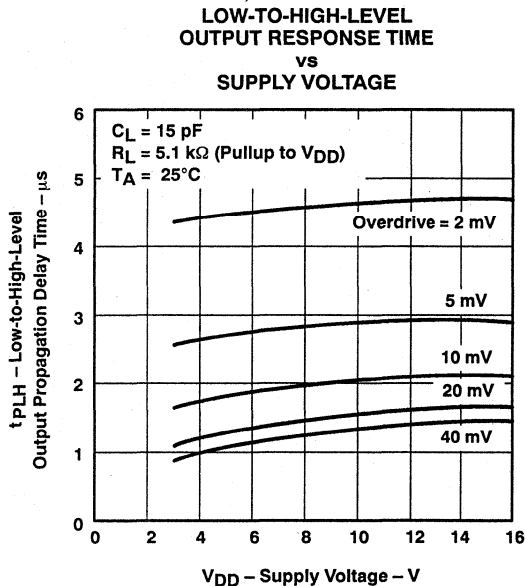


Figure 14

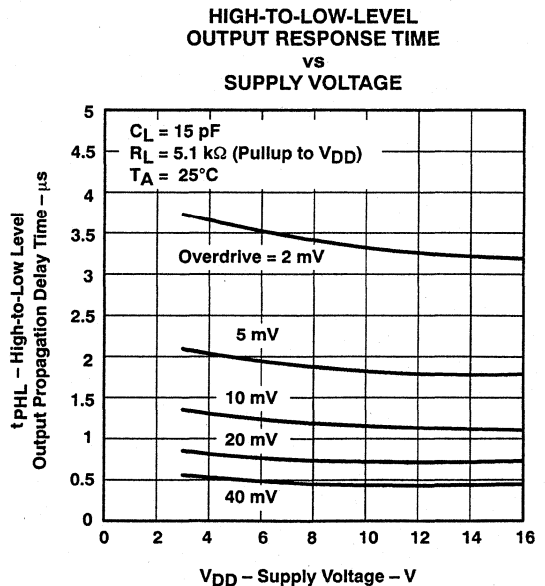


Figure 15

TYPICAL CHARACTERISTICS

LOW-TO-HIGH-LEVEL OUTPUT
 PROPAGATION DELAY
 FOR VARIOUS INPUT OVERDRIVES

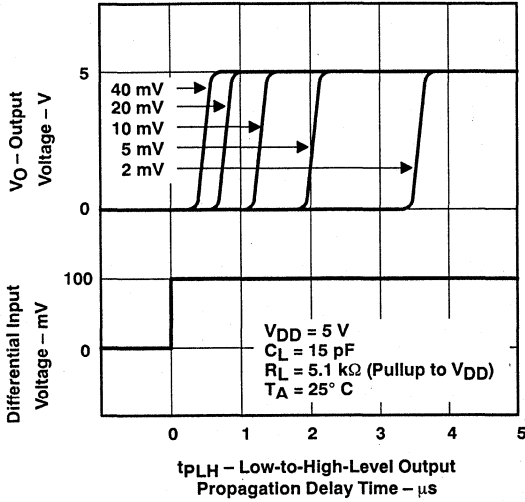


Figure 16

HIGH-TO-LOW-LEVEL OUTPUT
 PROPAGATION DELAY
 FOR VARIOUS INPUT OVERDRIVES

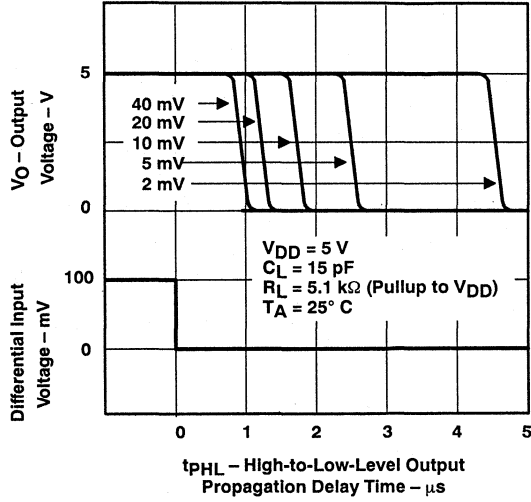


Figure 17

OUTPUT FALL TIME
 vs
 SUPPLY VOLTAGE

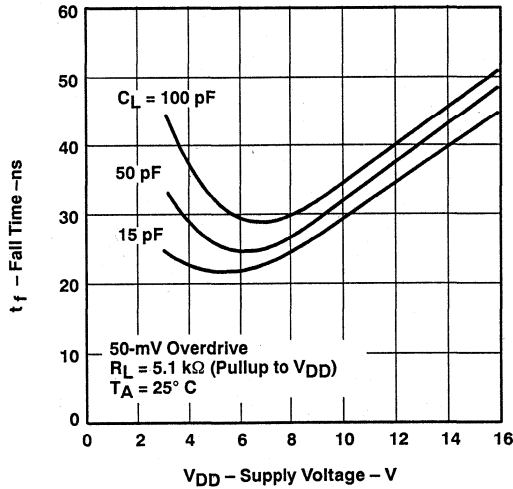


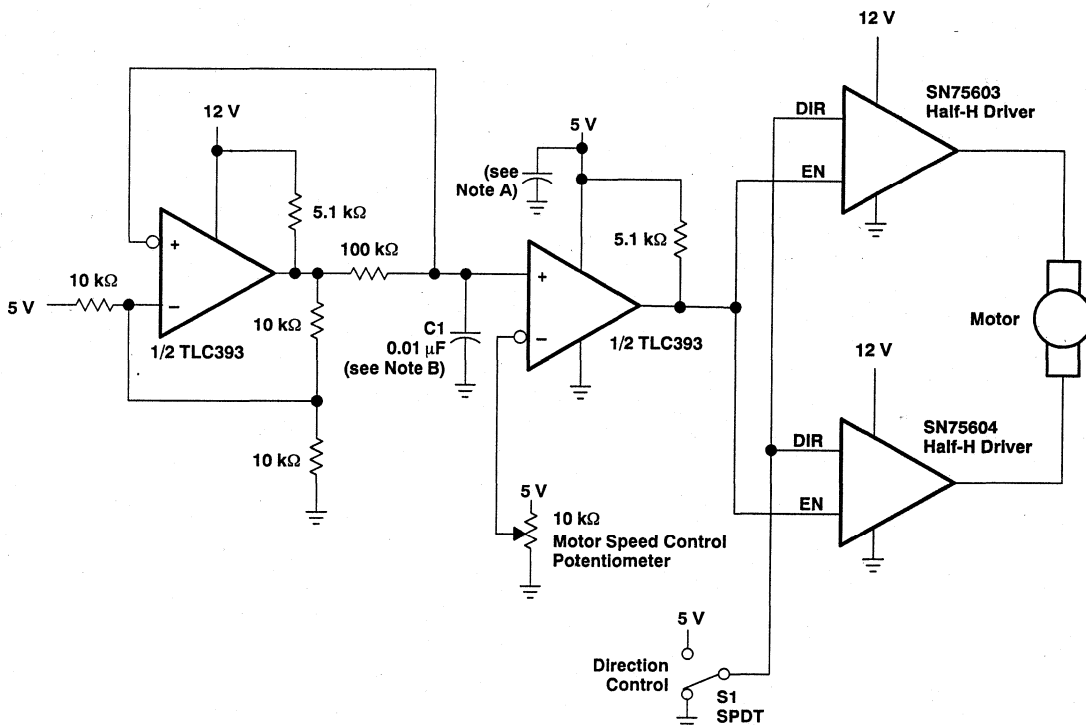
Figure 18.

APPLICATION INFORMATION

The input should always remain within the supply rails in order to avoid forward biasing the diodes in the electrostatic discharge (ESD) protection structure. If either input exceeds this range, the device will not be damaged as long as the input current is limited to less than 5 mA. To maintain the expected output state, the inputs must remain within the common-mode range. For example, at 25°C with $V_{DD} = 5\text{ V}$, both inputs must remain between -0.2 V and 4 V to assure proper device operation.

To assure reliable operation, the supply should be decoupled with a capacitor ($0.1\text{-}\mu\text{F}$) positioned as close to the device as possible.

The TLC393 has internal ESD-protection circuits that will prevent functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2; however, care should be exercised in handling these devices, as exposure to ESD may result in the degradation of the device parametric performance.

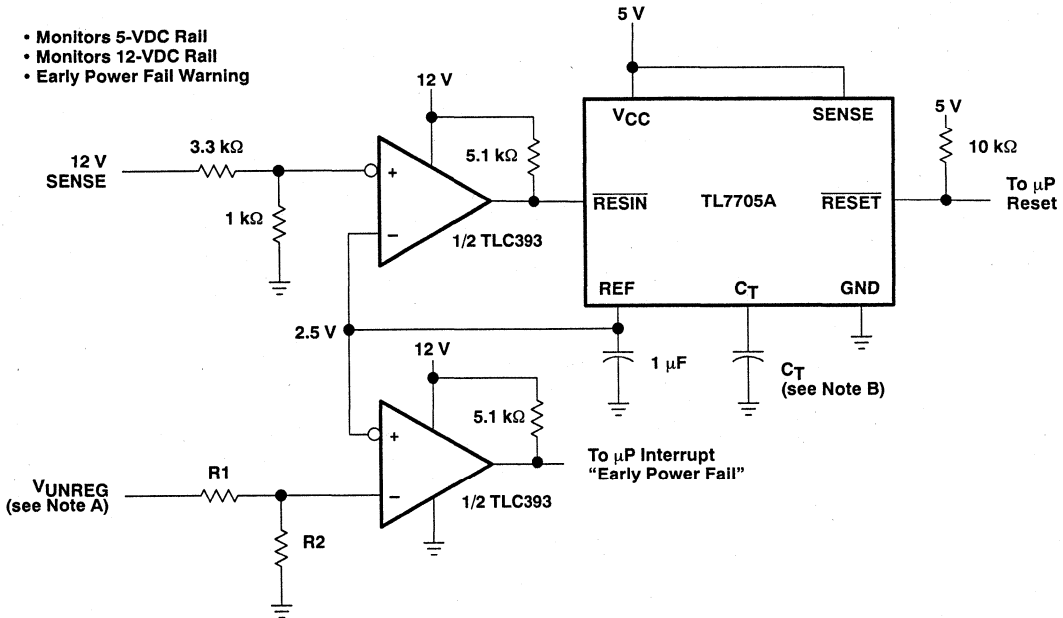


NOTES: A. The recommended minimum capacitance is $10\text{ }\mu\text{F}$ to eliminate common ground switching noise.
 B. Adjust C1 for change in oscillator frequency.

Figure 19. Pulse-Width-Modulated Motor Speed Controller

APPLICATION INFORMATION

- Monitors 5-VDC Rail
- Monitors 12-VDC Rail
- Early Power Fail Warning

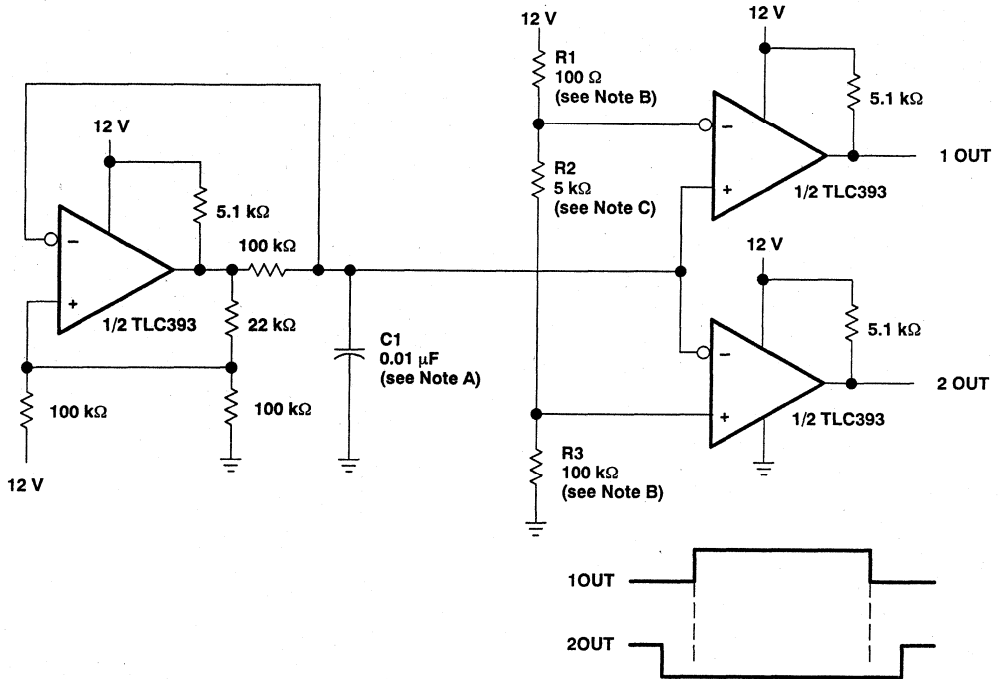


NOTES: A. $V_{UNREG} = 2.5 \frac{(R1 + R2)}{R2}$

B. The value of C_T determines the time delay of reset.

Figure 20. Enhanced Supply Supervisor

APPLICATION INFORMATION



- NOTES: A. Adjust C1 for a change in oscillator frequency where:
 $1/f = 1.85(100 \text{ k}\Omega)C1$
 B. Adjust R1 and R3 to change duty cycle.
 C. Adjust R2 to change deadtime.

Figure 21. Two-Phase Nonoverlapping Clock Generator

TLC3702C, TLC3702I, TLC3702M, TLC3702Q DUAL MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

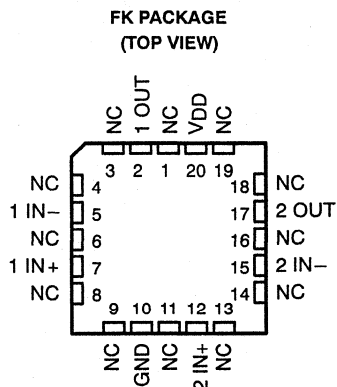
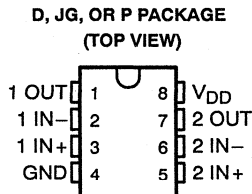
D3209, NOVEMBER 1986 — REVISED NOVEMBER 1991

- **Push-Pull CMOS Output Drives Capacitive Loads Without Pullup Resistor,**
 $I_O = \pm 8 \text{ mA}$
- **Very Low Power . . . 100 μW Typ at 5 V**
- **Fast Response Time . . . $t_{PLH} = 2.7 \mu\text{s}$ Typ**
With 5-mV Overdrive
- **Single-Supply Operation . . . 3 V to 16 V**
TLC3702M . . . 4 V to 16 V
- **On-Chip ESD Protection**

description

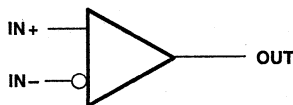
The TLC3702 consists of two independent micropower voltage comparators designed to operate from a single supply and be compatible with modern HCMOS logic systems. They are functionally similar to the LM339 but use 1/20th the power for similar response times. The push-pull CMOS output stage will drive capacitive loads directly without a power-consuming pullup resistor to achieve the stated response time. Eliminating the pullup resistor not only reduces power dissipation, but also saves board space and component cost. The output stage is also fully compatible with TTL requirements.

Texas Instruments LinCMOS™ process offers superior analog performance to standard CMOS processes. Along with the standard CMOS advantages of low power without sacrificing speed, high input impedance, and low bias currents, the LinCMOS™ process offers extremely stable input offset voltages with large differential input voltages. This characteristic makes it possible to build reliable CMOS comparators.



NC—No internal connection

symbol (each comparator)



AVAILABLE OPTIONS

| T_A | V_{IO} max at 25°C | PACKAGE | | | |
|----------------|-------------------------|----------------------|-----------------|---------------------|--------------------|
| | | SMALL OUTLINE (D) | CERAMIC (FK) | CERAMIC DIP (JG) | PLASTIC DIP (P) |
| 0°C to 70°C | 5 mV | TLC3702CD | — | — | TLC3702CP |
| -40°C to 85°C | 5 mV | TLC3702ID | — | — | TLC3702IP |
| -55°C to 125°C | 5 mV | — | TLC3702MFK | TLC3702MJG | — |
| -40°C to 125°C | 5 mV | — | — | TLC3702QJG | — |

The D package is available taped and reeled. Add "R" suffix to the device type (e.g., TLC3702CDR).

LinCMOS is a trademark of Texas Instruments Incorporated.

PRODUCTION DATA information is current as of publication date.
Products conform to specifications per the terms of Texas
Instruments standard warranty. Production processing does not
necessarily include testing of all parameters.

**TEXAS
INSTRUMENTS**

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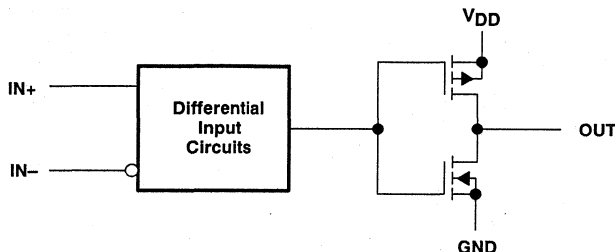
TLC3702C, TLC3702I, TLC3702M, TLC3702Q

DUAL MICROWPOWER LinCMOS™ VOLTAGE COMPARATORS

description (continued)

The TLC3702C is characterized for operation over the commercial temperature range of 0°C to 70°C. The TLC3702I is characterized for operation over the extended industrial temperature range of -40°C to 85°C. The TLC3702M is characterized for operation over the full military temperature range of -55°C to 125°C. The TLC3702Q is characterized for operation from -40°C to 125°C.

functional block diagram (each comparator)



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Supply voltage range, V_{DD} (see Note 1) | -0.3 V to 18 V |
| Differential input voltage (see Note 2) | ± 18 V |
| Input voltage range, V_I | -0.3 to V_{DD} |
| Output voltage range, V_O | -0.3 to V_{DD} |
| Input current, I_I | ± 5 mA |
| Output current, I_O (each output) | ± 20 mA |
| Total supply current into V_{DD} terminal | 40 mA |
| Total current out of ground terminal | 40 mA |
| Continuous total power dissipation | See Dissipation Rating Table |
| Operating free-air temperature range: | |
| TLC3702C | 0 to 70°C |
| TLC3702I | -40°C to 85°C |
| TLC3702M | -55°C to 125°C |
| TLC3702Q | -40°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package | 300°C |

- NOTES: 1. All voltage values, except differential voltages, are with respect to network ground.
 2. Differential voltages are at the noninverting input with respect to the inverting input.

DISSIPATION RATING TABLE

| PACKAGE | $T_A = 25^\circ\text{C}$ | DERATING FACTOR | $T_A = 70^\circ\text{C}$ | $T_A = 85^\circ\text{C}$ | $T_A = 125^\circ\text{C}$ |
|---------|--------------------------|--------------------------------|--------------------------|--------------------------|---------------------------|
| | POWER RATING | ABOVE $T_A = 25^\circ\text{C}$ | POWER RATING | POWER RATING | POWER RATING |
| D | 725 mW | 5.8 mW/°C | 464 mW | 377 mW | N/A |
| FK | 1375 mW | 11.0 mW/°C | 880 mW | 715 mW | 275 mW |
| JG | 1050 mW | 8.4 mW/°C | 672 mW | 546 mW | 210 mW |
| P | 1000 mW | 8.0 mW/°C | 640 mW | 520 mW | N/A |



TLC3702C

DUAL MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|---------------------------------------|------|-----|----------------|------|
| Supply voltage, V_{DD} | 3 | 5 | 16 | V |
| Common-mode input voltage, V_{IC} | -0.2 | | $V_{DD} - 1.5$ | V |
| High-level output current, I_{OH} | | | -20 | mA |
| Low-level output current, I_{OL} | | | 20 | mA |
| Operating free-air temperature, T_A | 0 | | 70 | °C |

electrical characteristics at specified operating free-air temperature, $V_{DD} = 5\text{ V}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS† | T_A | MIN | TYP | MAX | UNIT |
|-----------|-----------------------------------|--|-------------|------------------------|-----|-----|------|
| V_{IO} | Input offset voltage | $V_{IC} = V_{ICRmin}$, $V_{DD} = 5\text{ V to }10\text{ V}$, See Note 3 | 25°C | 1.2 | | 5 | mV |
| | | | 0°C to 70°C | | | | |
| I_{IO} | Input offset current | $V_{IC} = 2.5\text{ V}$ | 25°C | | 1 | | pA |
| | | | 70°C | | | 0.3 | nA |
| I_{IB} | Input bias current | $V_{IC} = 2.5\text{ V}$ | 25°C | | 5 | | pA |
| | | | 70°C | | | 0.6 | nA |
| V_{ICR} | Common-mode input voltage range | | 25°C | 0 to $V_{DD} - 1$ | | | V |
| | | | 0°C to 70°C | 0 to $V_{DD} - 1.5$ | | | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICRmin}$ | 25°C | | 84 | | dB |
| | | | 70°C | | 84 | | |
| | | | 0°C | | 84 | | |
| kSVR | Supply voltage rejection ratio | $V_{DD} = 5\text{ V to }10\text{ V}$ | 25°C | | 85 | | dB |
| | | | 70°C | | 85 | | |
| | | | 0°C | | 85 | | |
| V_{OH} | High-level output voltage | $V_{ID} = 1\text{ V}$, $I_{OH} = -4\text{ mA}$ | 25°C | 4.5 | 4.7 | | V |
| | | | 70°C | 4.3 | | | |
| V_{OL} | Low-level output voltage | $V_{ID} = -1\text{ V}$, $I_{OL} = 4\text{ mA}$ | 25°C | | 210 | 300 | mV |
| | | | 70°C | | | 375 | |
| I_{DD} | Supply current (both comparators) | No load, Outputs low | 25°C | | 18 | 40 | µA |
| | | | 0°C to 70°C | | | 50 | |

† All characteristics are measured with zero common-mode voltage unless otherwise noted.

NOTE 3: The offset voltage limits given are the maximum values required to drive the output up to 4.5 V or down to 0.3 V.

TLC3702I

DUAL MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|---------------------------------------|------|-----|----------------|------|
| Supply voltage, V_{DD} | 3 | 5 | 16 | V |
| Common-mode input voltage, V_{IC} | -0.2 | | $V_{DD} - 1.5$ | V |
| High-level output current, I_{OH} | | | -20 | mA |
| Low-level output current, I_{OL} | | | 20 | mA |
| Operating free-air temperature, T_A | -40 | | 85 | °C |

electrical characteristics at specified operating free-air temperature, $V_{DD} = 5$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS† | T_A | MIN | TYP | MAX | UNIT |
|-----------|-----------------------------------|---|---------------|------------------------|-----|-----|------|
| V_{IO} | Input offset voltage | $V_{IC} = V_{ICRmin}$, $V_{DD} = 5$ V to 10 V, See Note 3 | 25°C | | 1.2 | 5 | mV |
| | | | -40°C to 85°C | | | 7 | |
| I_{IO} | Input offset current | $V_{IC} = 2.5$ V | 25°C | | 1 | | pA |
| | | | 85°C | | | 1 | nA |
| I_{IB} | Input bias current | $V_{IC} = 2.5$ V | 25°C | | 5 | | pA |
| | | | 85°C | | | 2 | nA |
| V_{ICR} | Common-mode input voltage range | | 25°C | 0 to $V_{DD} - 1$ | | | V |
| | | | -40°C to 85°C | 0 to $V_{DD} - 1.5$ | | | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICRmin}$ | 25°C | | 84 | | dB |
| | | | 85°C | | 84 | | |
| | | | -40°C | | 83 | | |
| k_{SVR} | Supply voltage rejection ratio | $V_{DD} = 5$ V to 10 V | 25°C | | 85 | | dB |
| | | | 85°C | | 85 | | |
| | | | -40°C | | 83 | | |
| V_{OH} | High-level output voltage | $V_{ID} = 1$ V, $I_{OH} = -4$ mA | 25°C | 4.5 | 4.7 | | V |
| | | | 85°C | 4.3 | | | |
| V_{OL} | Low-level output voltage | $V_{ID} = -1$ V, $I_{OL} = 4$ mA | 25°C | | 210 | 300 | mV |
| | | | 85°C | | | 400 | |
| I_{DD} | Supply current (both comparators) | No load, Outputs low | 25°C | | 18 | 40 | μA |
| | | | -40°C to 85°C | | | 65 | |

† All characteristics are measured with zero common-mode voltage unless otherwise noted.

NOTE 3: The offset voltage limits given are the maximum values required to drive the output up to 4.5 V or down to 0.3 V.

TLC3702M

DUAL MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|---------------------------------------|-----|----------------|-----|--------|
| Supply voltage, V_{DD} | 4 | 5 | 16 | V |
| Common-mode input voltage, V_{IC} | 0 | $V_{DD} - 1.5$ | | V |
| High-level output current, I_{OH} | | | | -20 mA |
| Low-level output current, I_{OL} | | | | 20 mA |
| Operating free-air temperature, T_A | -55 | 125 | | °C |

electrical characteristics at specified operating free-air temperature, $V_{DD} = 5\text{ V}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS† | T_A | MIN | TYP | MAX | UNIT |
|--|--|----------------|---------------------|-----|-----|-------|
| V_{IO} Input offset voltage | $V_{IC} = V_{ICRmin}$, $V_{DD} = 5\text{ V to }10\text{ V}$, See Note 3 | 25°C | | 1.2 | 5 | mV |
| | | -55°C to 125°C | | | | |
| I_{IO} Input offset current | $V_{IC} = 2.5\text{ V}$ | 25°C | 1 | | | pA |
| | | 125°C | | | | 15 nA |
| I_{IB} Input bias current | $V_{IC} = 2.5\text{ V}$ | 25°C | 5 | | | pA |
| | | 125°C | | | | 30 nA |
| V_{ICR} Common-mode input voltage range | | 25°C | 0 to $V_{DD} - 1$ | | | V |
| | | -55°C to 125°C | 0 to $V_{DD} - 1.5$ | | | |
| CMRR Common-mode rejection ratio | $V_{IC} = V_{ICRmin}$ | 25°C | 84 | | | dB |
| | | 125°C | 83 | | | |
| | | -55°C | 82 | | | |
| kSVR Supply voltage rejection ratio | $V_{DD} = 5\text{ V to }10\text{ V}$ | 25°C | 85 | | | dB |
| | | 125°C | 85 | | | |
| | | -55°C | 82 | | | |
| V_{OH} High-level output voltage | $V_{ID} = 1\text{ V}$, $I_{OH} = -4\text{ mA}$ | 25°C | 4.5 | 4.7 | | V |
| | | 125°C | 4.2 | | | |
| V_{OL} Low-level output voltage | $V_{ID} = -1\text{ V}$, $I_{OL} = 4\text{ mA}$ | 25°C | 210 | | 300 | mV |
| | | 125°C | 500 | | | |
| I_{DD} Supply current (both comparators) | No load, Outputs low | 25°C | 18 | | 40 | μA |
| | | -55°C to 125°C | 90 | | | |

† All characteristics are measured with zero common-mode voltage unless otherwise noted.

NOTE 3: The offset voltage limits given are the maximum values required to drive the output up to 4.5 V or down to 0.3 V.

TLC3702Q

DUAL MICROWPOWER LinCMOS™ VOLTAGE COMPARATORS

recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|---------------------------------------|------|-----|----------------|------|
| Supply voltage, V_{DD} | 3 | 5 | 16 | V |
| Common-mode input voltage, V_{IC} | -0.2 | | $V_{DD} - 1.5$ | V |
| High-level output current, I_{OH} | | | -20 | mA |
| Low-level output current, I_{OL} | | | 20 | mA |
| Operating free-air temperature, T_A | -40 | | 125 | °C |

electrical characteristics at specified operating free-air temperature, $V_{DD} = 5$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS† | T_A | MIN | TYP | MAX | UNIT |
|-----------|-----------------------------------|---|----------------|------|----------------|-----|------|
| V_{IO} | Input offset voltage | $V_{IC} = V_{ICRmin}$, $V_{DD} = 5$ V to 10 V, See Note 3 | 25°C | | 1.2 | 5 | mV |
| | | | -40°C to 125°C | | | | |
| I_{IO} | Input offset current | $V_{IC} = 2.5$ V | 25°C | | 1 | | pA |
| | | | 125°C | | | 15 | nA |
| I_{IB} | Input bias current | $V_{IC} = 2.5$ V | 25°C | | 5 | | pA |
| | | | 125°C | | | 30 | nA |
| V_{ICR} | Common-mode input voltage range | | 25°C | 0 to | $V_{DD} - 1$ | | V |
| | | | -40°C to 125°C | 0 to | $V_{DD} - 1.5$ | | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICRmin}$ | 25°C | | 84 | | dB |
| | | | 125°C | | 83 | | |
| | | | -40°C | | 83 | | |
| k_{SVR} | Supply voltage rejection ratio | $V_{DD} = 5$ V to 10 V | 25°C | | 85 | | dB |
| | | | 125°C | | 85 | | |
| | | | -40°C | | 83 | | |
| V_{OH} | High-level output voltage | $V_{ID} = 1$ V, $I_{OH} = -4$ mA | 25°C | 4.5 | 4.7 | | V |
| | | | 125°C | 4.2 | | | |
| V_{OL} | Low-level output voltage | $V_{ID} = -1$ V, $I_{OL} = 4$ mA | 25°C | | 210 | 300 | mV |
| | | | 125°C | | | 500 | |
| I_{DD} | Supply current (both comparators) | No load, Outputs low | 25°C | | 18 | 40 | μA |
| | | | -40°C to 125°C | | | 90 | |

† All characteristics are measured with zero common-mode voltage unless otherwise noted.

NOTE 3: The offset voltage limits given are the maximum values required to drive the output up to 4.5 V or down to 0.3 V.



TLC3702C, TLC3702I, TLC3702M, TLC3702Q
DUAL MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

switching characteristics, $V_{DD} = 5\text{ V}$, $T_A = 25^\circ\text{C}$

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|------------------|---|---------------------------------------|---|------|-----|------|
| t _{PLH} | Propagation delay time, low-to-high-level output† | f = 10 kHz, C _L = 50 pF | Overdrive = 2 mV | 4.5 | | μs |
| | | | Overdrive = 5 mV | 2.7 | | |
| | | | Overdrive = 10 mV | 1.9 | | |
| | | | Overdrive = 20 mV | 1.4 | | |
| | | | Overdrive = 40 mV | 1.1 | | |
| t _{PHL} | Propagation delay time, high-to-low-level output† | f = 10 kHz, C _L = 50 pF | V _I = 1.4 V step at IN + pin | 1.1 | | μs |
| | | | Overdrive = 2 mV | 4 | | |
| | | | Overdrive = 5 mV | 2.3 | | |
| | | | Overdrive = 10 mV | 1.5 | | |
| | | | Overdrive = 20 mV | 0.95 | | |
| | | | Overdrive = 40 mV | 0.65 | | |
| t _f | Fall time | f = 10 kHz, C _L = 50 pF | Overdrive = 50 mV | 50 | | ns |
| t _r | Rise time | f = 10 kHz, C _L = 50 pF | Overdrive = 50 mV | 125 | | ns |

† Simultaneous switching of inputs will cause degradation in output response.

PRINCIPLES OF OPERATION

LinCMOS™ process

The LinCMOS™ process is a linear polysilicon-gate CMOS process. Primarily designed for single-supply applications, LinCMOS™ products facilitate the design of a wide range of high-performance analog functions from operational amplifiers to complex mixed-mode converters.

While digital designers are experienced with CMOS, MOS technologies are relatively new for analog designers. This short guide is intended to answer the most frequently asked questions related to the quality and reliability of LinCMOS™ products. If you have any further questions, please contact your local TI sales office.

electrostatic discharge

CMOS circuits are prone to gate oxide breakdown when exposed to high voltages even if the exposure is only for very short periods of time. Electrostatic discharge (ESD) is one of the most common causes of damage to CMOS devices. It can occur when a device is handled without proper consideration for environmental electrostatic charges, e.g., during board assembly. If a circuit in which one amplifier from a dual op amp is being used and the unused pins are left open, high voltages will tend to develop. If there is no provision for ESD protection, these voltages may eventually punch through the gate oxide and cause the device to fail. To prevent voltage buildup, each pin is protected by internal circuitry.

Standard ESD-protection circuits safely shunt the ESD current by providing a mechanism whereby one or more transistors break down at voltages higher than the normal operating voltages but lower than the breakdown voltage of the input gate. This type of protection scheme is limited by leakage currents which flow through the shunting transistors during normal operation after an ESD voltage has occurred. Although these currents are small, on the order of tens of nanoamps, CMOS amplifiers are often specified to draw input currents as low as tens of picoamps.

To overcome this limitation, TI design engineers developed the patented ESD-protection circuit shown in Figure 1. This circuit can withstand several successive 2-kV ESD pulses, while reducing or eliminating leakage currents that may be drawn through the input pins. A more detailed discussion of the operation of the TI ESD protection circuit is presented on the next page.

All input and output pins on LinCMOS™ and Advanced LinCMOS™ products have associated ESD-protection circuitry that undergoes qualification testing to withstand 2000 V discharged from a 100-pF capacitor through a 1500-Ω resistor (human body model) and 200 V from a 100-pF capacitor with no current-limiting resistor (charged device model). These tests simulate both operator and machine handling of devices during normal test and assembly operations.

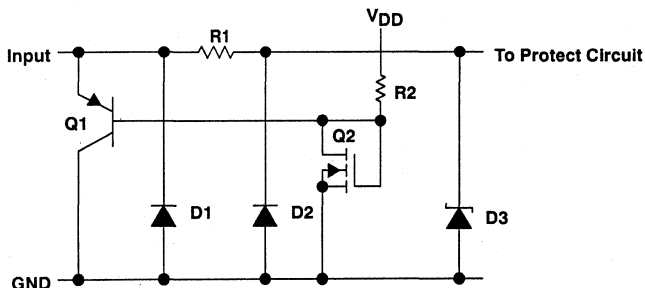


Figure 1. LinCMOS™ ESD-Protection Schematic

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input protection circuit operation

Texas Instruments patented protection circuitry allows for both positive- and negative-going ESD transients. These transients are characterized by extremely fast rise times and usually low energies, and can occur both when the device has all pins open and when it is installed in a circuit.

positive ESD transients

Initial positive charged energy is shunted through Q1 to V_{SS} . Q1 will turn on when the voltage at the input rises above the voltage on the V_{DD} pin by a value equal to the V_{BE} of Q1. The base current increases through R2 with input current as Q1 saturates. The base current through R2 will force the voltage at the drain and gate of Q2 to exceed its threshold level ($V_T \sim 22$ to 26 V) and turn Q2 on. The shunted input current through Q1 to V_{SS} is now shunted through the n-channel enhancement-type MOSFET Q2 to V_{SS} . If the voltage on the input pin continues to rise, the breakdown voltage of the zener diode D3 is exceeded and all remaining energy is dissipated in R1 and D3. The breakdown voltage of D3 is designed to be 24 to 27 V, which is well below the gate-oxide voltage of the circuit to be protected.

negative ESD transients

The negative charged ESD transients are shunted directly through D1. Additional energy is dissipated in R1 and D2 as D2 becomes forward biased. The voltage seen by the protected circuit is -0.3 V to -1 V (the forward voltage of D1 and D2).

circuit-design considerations

LinCMOS™ products are being used in actual circuit environments that have input voltages that exceed the recommended common-mode input voltage range and activate the input protection circuit. Even under normal operation, these conditions occur during circuit power up or power down, and in many cases, when the device is being used for a signal conditioning function. The input voltages can exceed V_{ICR} and not damage the device only if the inputs are current limited. The recommended current limit shown on most product data sheets is ± 5 mA. Figure 2 and 3 show typical characteristics for input voltage versus input current.

Normal operation and correct output state can be expected even when the input voltage exceeds the positive supply voltage. Again, the input current should be externally limited even though internal positive current limiting is achieved in the input protection circuit by the action of Q1. When Q1 is on, it will saturate and limit the current to approximately 5-mA collector current by design. When saturated, Q1 base current increases with input current. This base current is forced into the V_{DD} pin and into the device I_{DD} or the V_{DD} supply through R2 producing the current limiting effects shown in Figure 2. This internal limiting lasts only as long as the input voltage is below the V_T of Q2.

When the input voltage exceeds the negative supply voltage, normal operation is affected and output voltage states may not be correct. Also, the isolation between channels of multiple devices (duals and quads) can be severely affected. External current limiting must be used since this current will be directly shunted by D1 and D2 and no internal limiting is achieved. If normal output voltage states are required, an external input voltage clamp is required (see Figure 4).

TLC3702C, TLC3702I, TLC3702M, TLC3702Q
 DUAL MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

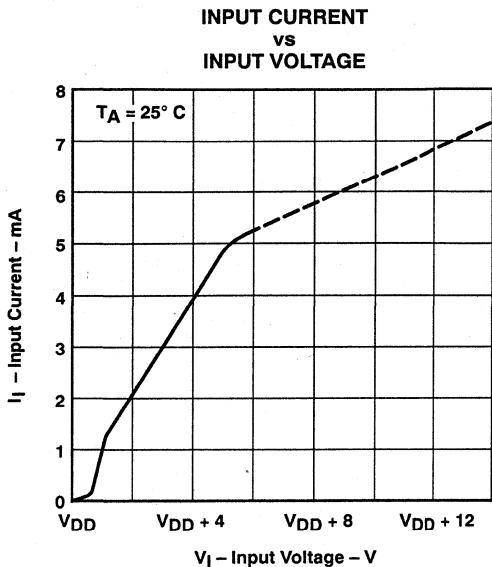


Figure 2

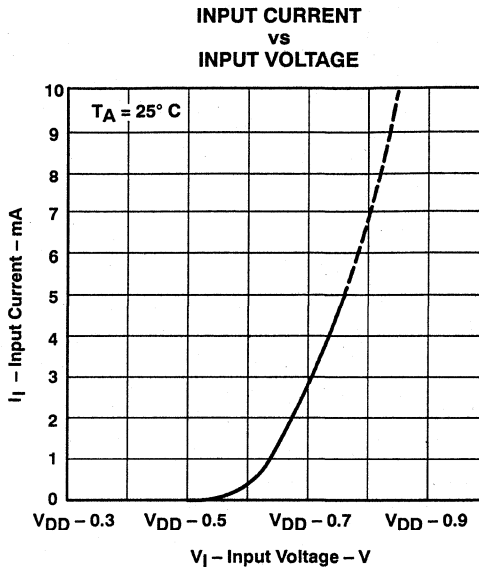
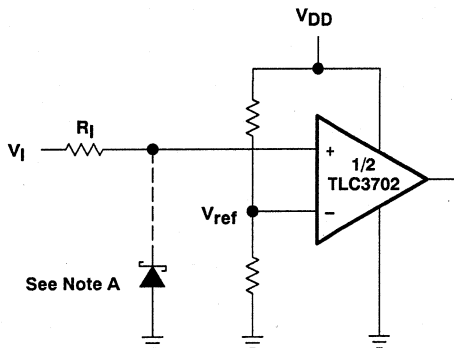


Figure 3



Positive Voltage Input Current Limit :

$$R_I = \frac{V_I - V_{DD} - 0.3\text{ V}}{5\text{ mA}}$$

Negative Voltage Input Current Limit :

$$R_I = \frac{-V_I - V_{DD} - (-0.3\text{ V})}{5\text{ mA}}$$

NOTE A: If the correct input state is required when the negative input exceeds GND, a Schottky clamp is required.

Figure 4. Typical Input Current-Limiting Configuration for a LinCMOS™ Comparator

TLC3702C, TLC3702I, TLC3702M, TLC3702Q DUAL MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

PARAMETER MEASUREMENT INFORMATION

The TLC3702 contains a digital output stage which, if held in the linear region of the transfer curve, can cause damage to the device. Conventional operational amplifier/comparator testing incorporates the use of a servo loop which is designed to force the device output to a level within this linear region. Since the servo-loop method of testing cannot be used, we offer the following alternatives for measuring parameters such as input offset voltage, common-mode rejection, etc.

To verify that the input offset voltage falls within the limits specified, the limit value is applied to the input as shown in Figure 5(a). With the noninverting input positive with respect to the inverting input, the output should be high. With the input polarity reversed, the output should be low.

A similar test can be made to verify the input offset voltage at the common-mode extremes. The supply voltages can be slewed as shown in Figure 5(b) for the V_{ICR} test, rather than changing the input voltages, to provide greater accuracy.

A close approximation of the input offset voltage can be obtained by using a binary search method to vary the differential input voltage while monitoring the output state. When the applied input voltage differential is equal, but opposite in polarity, to the input offset voltage, the output will change states.

Figure 6 illustrates a practical circuit for direct dc measurement of input offset voltage that does not bias the comparator in the linear region. The circuit consists of a switching mode servo loop in which IC1a generates a triangular waveform of approximately 20-mV amplitude. IC1b acts as a buffer, with C2 and R4 removing any residual dc offset. The signal is then applied to the inverting input of the comparator under test, while the noninverting input is driven by the output of the integrator formed by IC1c through the voltage divider formed by R8 and R9. The loop reaches a stable operating point when the output of the comparator under test has a duty cycle of exactly 50%, which can only occur when the incoming triangle wave is sliced symmetrically or when the voltage at the noninverting input exactly equals the input offset voltage.

Voltage divider R8 and R9 provides an increase in input offset voltage by a factor of 100 to make measurement easier. The values of R5, R7, R8, and R9 can significantly influence the accuracy of the reading; therefore, it is suggested that their tolerance level be one percent or lower.

Measuring the extremely low values of input current requires isolation from all other sources of leakage current and compensation for the leakage of the test socket and board. With a good picoammeter, the socket and board leakage can be measured with no device in the socket. Subsequently, this open socket leakage value can be subtracted from the measurement obtained with a device in the socket to obtain the actual input current of the device.

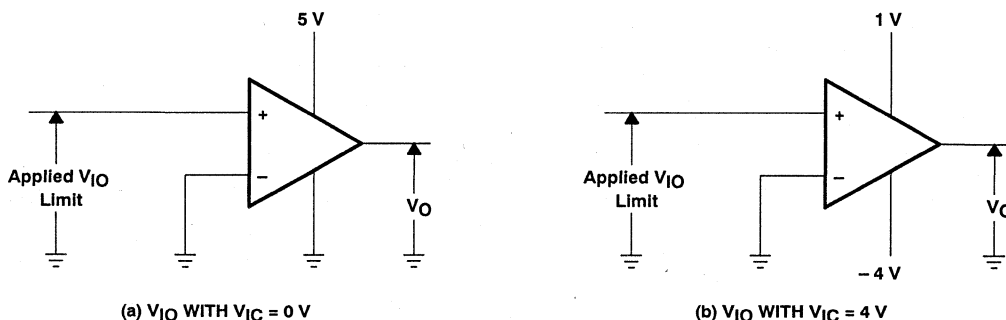


Figure 5. Method for Verifying That Input Offset Voltage Is Within Specified Limits

PARAMETER MEASUREMENT INFORMATION

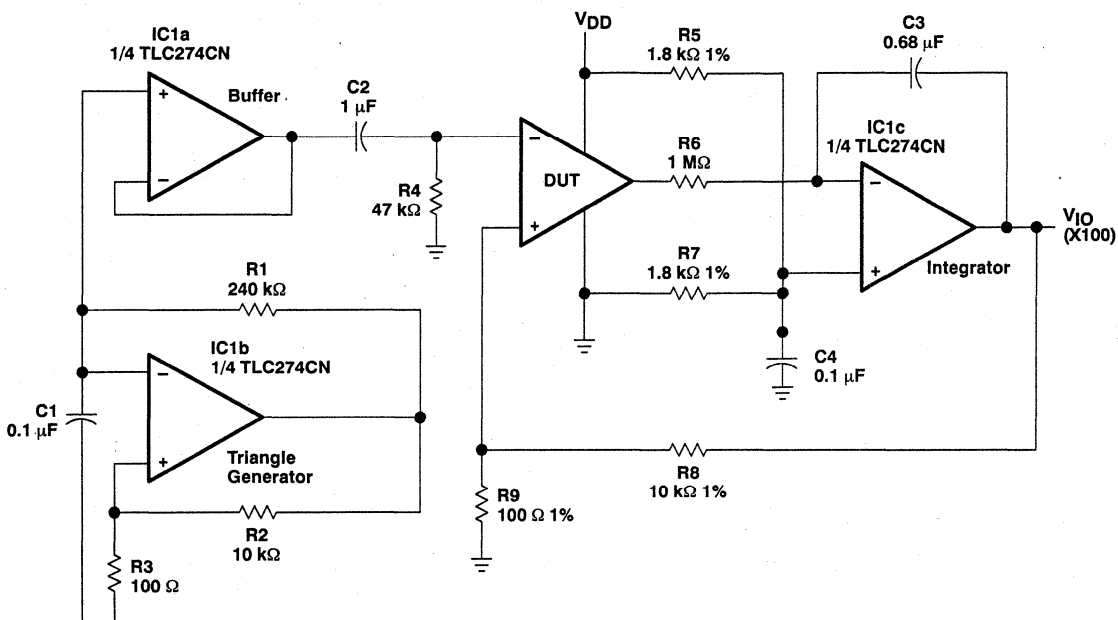
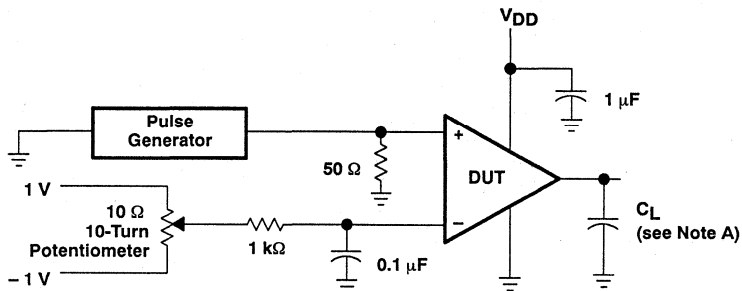


Figure 6. Circuit for Input Offset Voltage Measurement

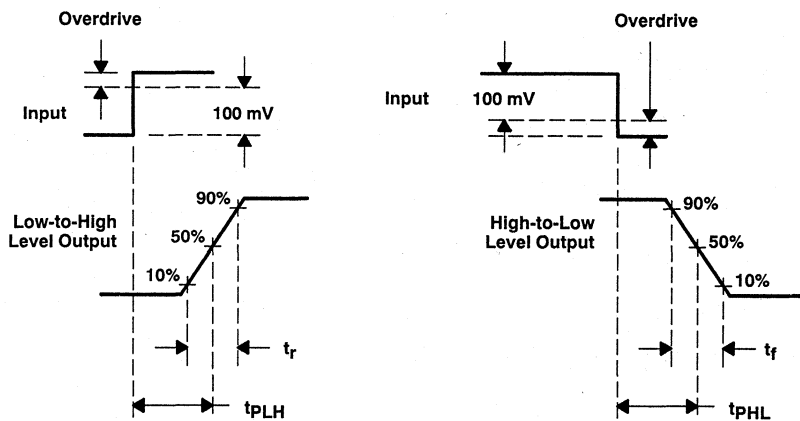
Response time is defined as the interval between the application of an input step function and the instant when the output reaches 50% of its maximum value. Response time for the low-to-high-level output is measured from the leading edge of the input pulse, while response time for the high-to-low-level output is measured from the trailing edge of the input pulse. Response time measurement at low input signal levels can be greatly affected by the input offset voltage. The offset voltage should be balanced by the adjustment at the inverting input (as shown in Figure 7) so that the circuit is just at the transition point. Then a low signal, for example 105-mV or 5-mV overdrive, will cause the output to change state.

TLC3702C, TLC3702I, TLC3702M, TLC3702Q DUAL MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

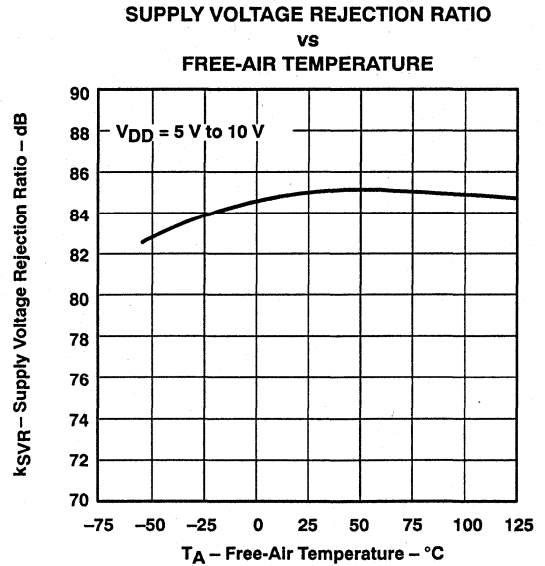
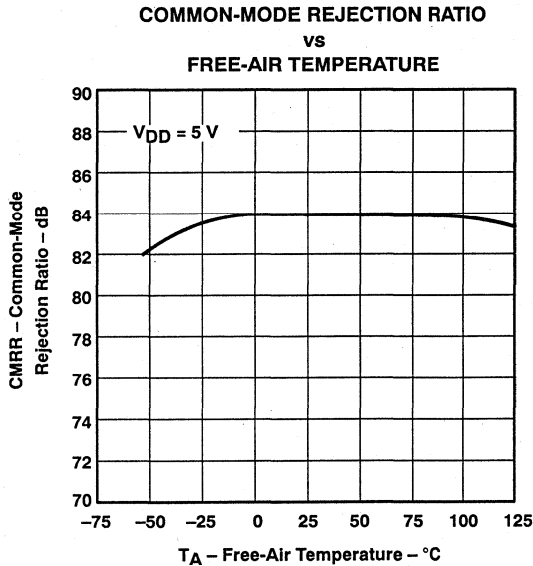
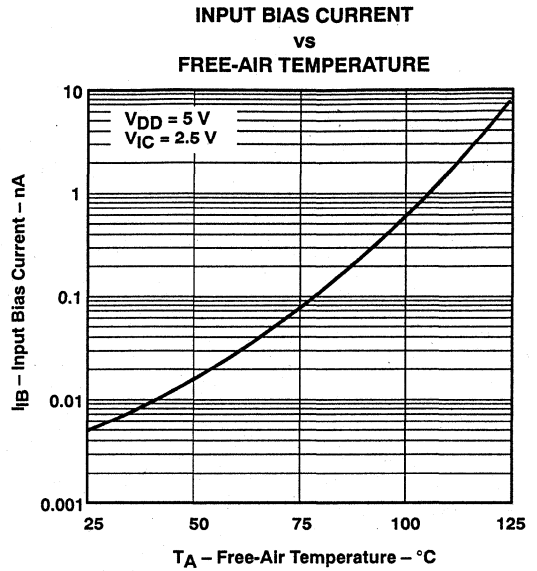
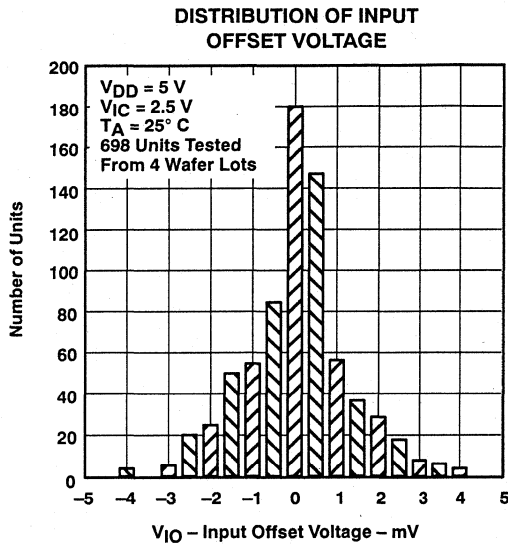


VOLTAGE WAVEFORMS

NOTE A: C_L includes probe and jig capacitance.

Figure 7. Response, Rise, and Fall Times Circuit and Voltage Waveforms

TYPICAL CHARACTERISTICS†



† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



TYPICAL CHARACTERISTICS†

HIGH-LEVEL OUTPUT VOLTAGE
 vs
 FREE-AIR TEMPERATURE

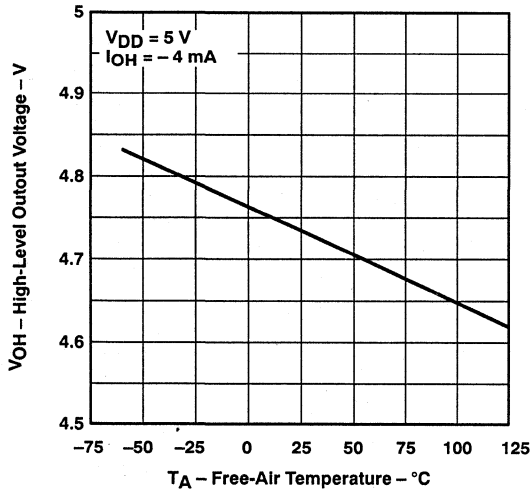


Figure 12

HIGH-LEVEL OUTPUT VOLTAGE
 vs
 HIGH-LEVEL OUTPUT CURRENT

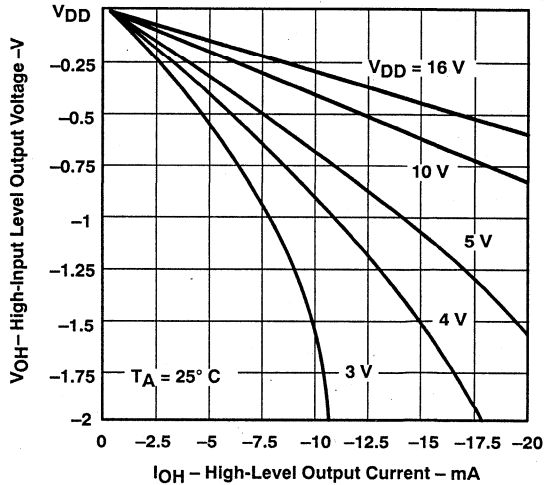


Figure 13

LOW-LEVEL OUTPUT VOLTAGE
 vs
 LOW-LEVEL OUTPUT CURRENT

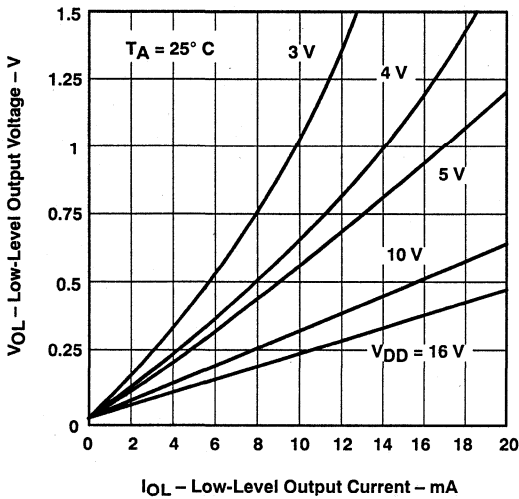


Figure 14

LOW-LEVEL OUTPUT VOLTAGE
 vs
 FREE-AIR TEMPERATURE

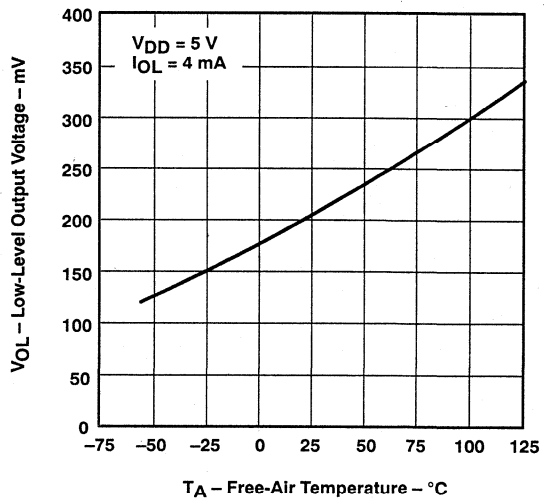


Figure 15

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

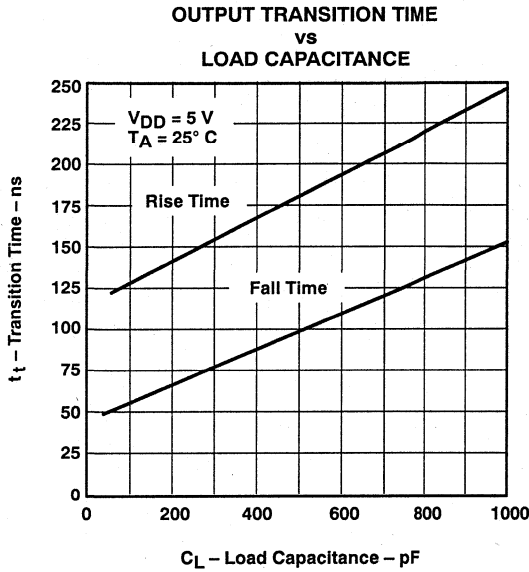


Figure 16

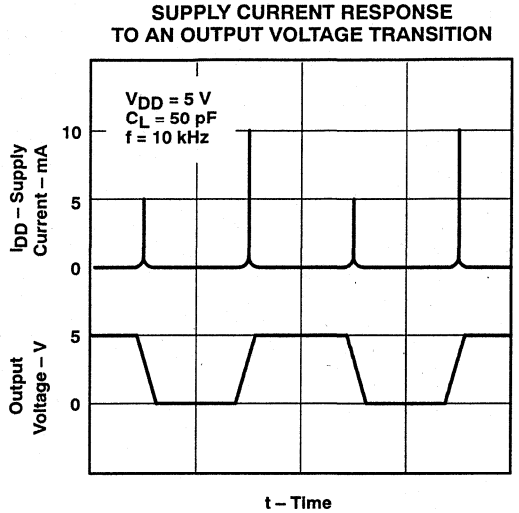


Figure 17

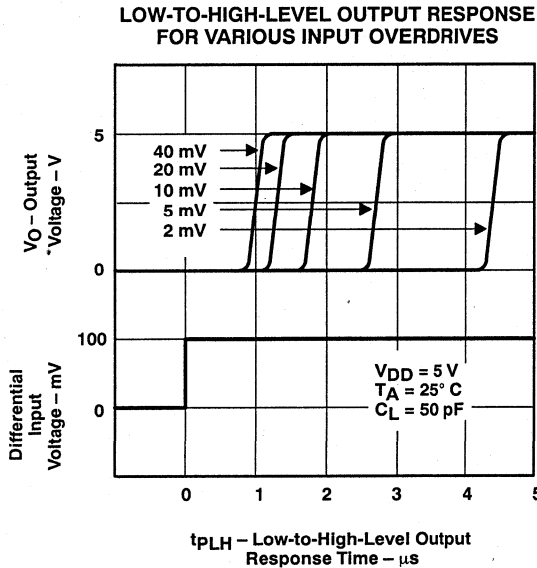


Figure 18

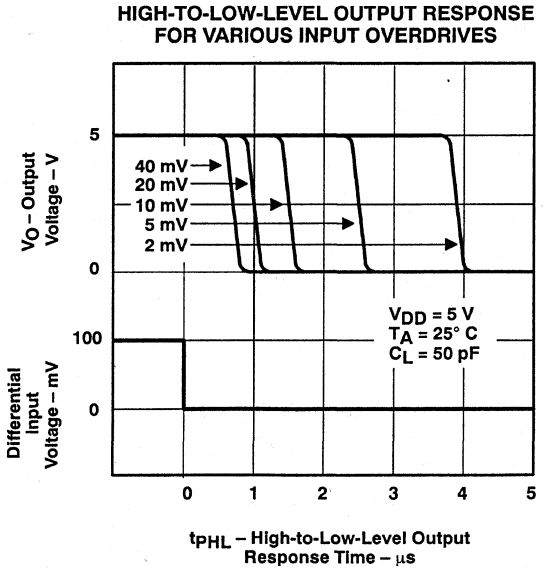


Figure 19

TYPICAL CHARACTERISTICS

LOW-TO-HIGH-LEVEL
 OUTPUT RESPONSE TIME
 vs
 SUPPLY VOLTAGE

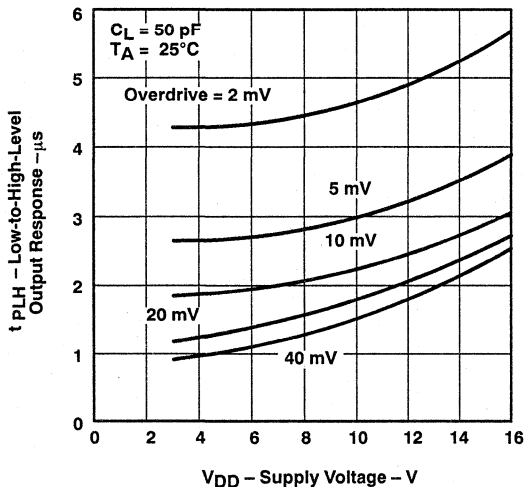


Figure 20

HIGH-TO-LOW-LEVEL
 OUTPUT RESPONSE TIME
 vs
 SUPPLY VOLTAGE

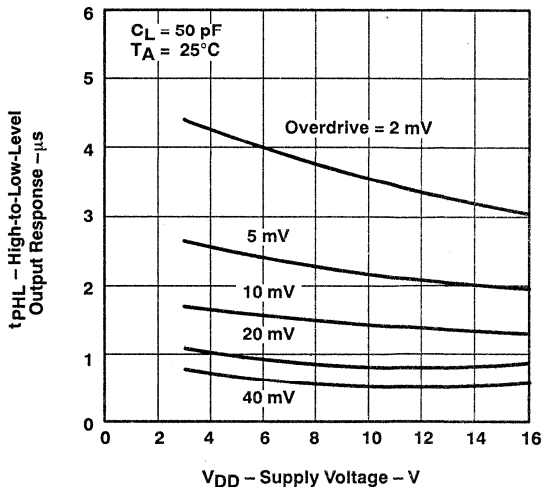


Figure 21

AVERAGE SUPPLY CURRENT
 (PER COMPARATOR)
 vs
 FREQUENCY

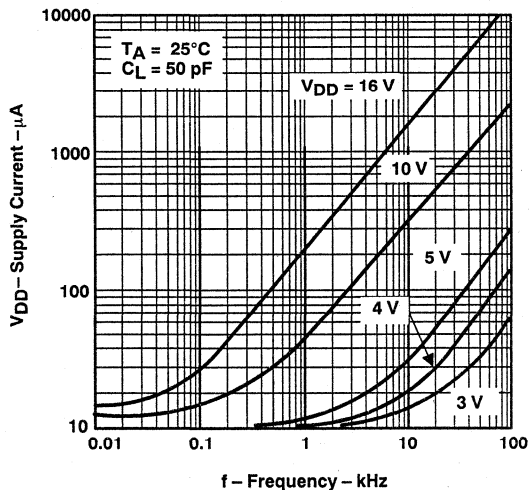


Figure 22

SUPPLY CURRENT
 vs
 SUPPLY VOLTAGE

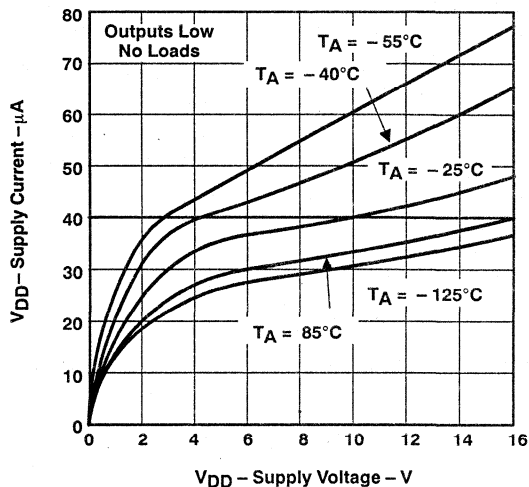


Figure 23

TYPICAL CHARACTERISTICS†

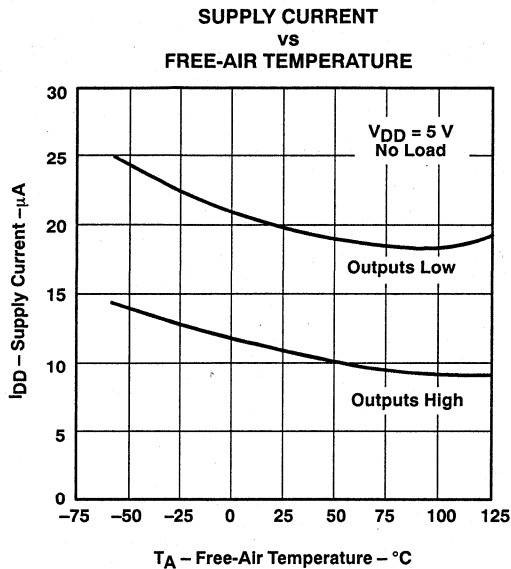


Figure 24

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

APPLICATION INFORMATION

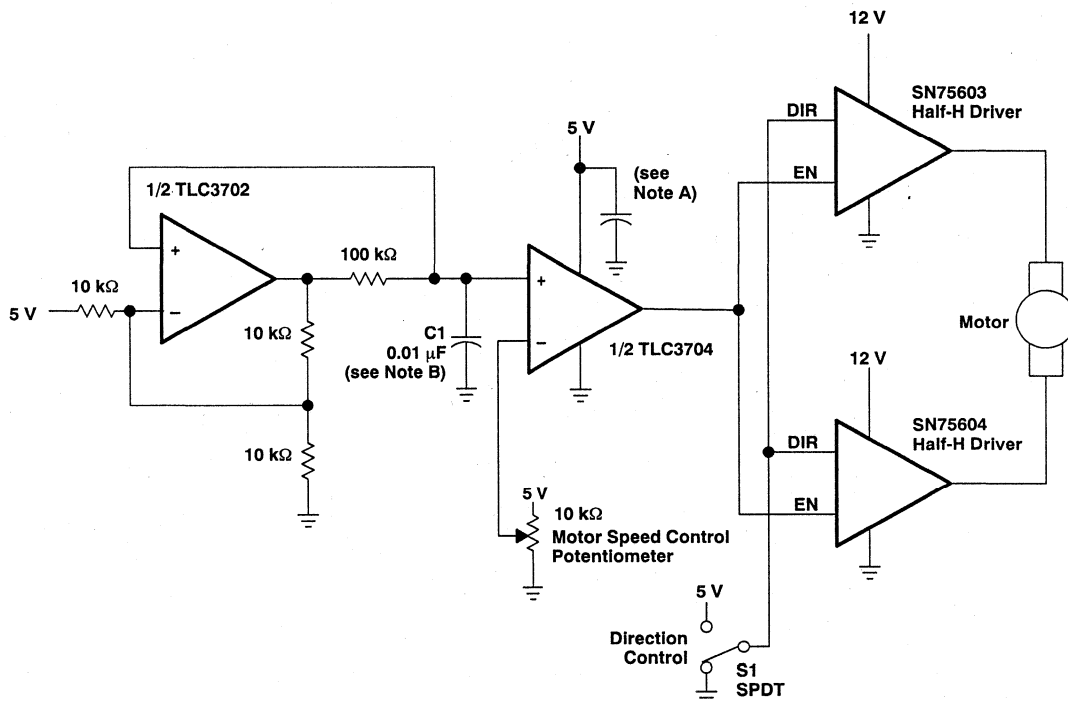
The inputs should always remain within the supply rails in order to avoid forward biasing the diodes in the electrostatic discharge (ESD) protection structure. If either Input exceeds this range, the device will not be damaged as long as the input is limited to less than 5 mA. To maintain the expected output state, the inputs must remain within the common-mode range. For example, at 25°C with $V_{DD} = 5$ V, both inputs must remain between -0.2 V and 4 V to ensure proper device operation.

To ensure reliable operation, the supply should be decoupled with a capacitor (0.1 μ F) that is positioned as close to the device as possible.

The TLC3702 has internal ESD protection circuits that will prevent functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2; however, care should be exercised in handling these devices as exposure to ESD may result in the degradation of the device parametric performance.

TLC3702C, TLC3702I, TLC3702M, TLC3702Q DUAL MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

APPLICATION INFORMATION



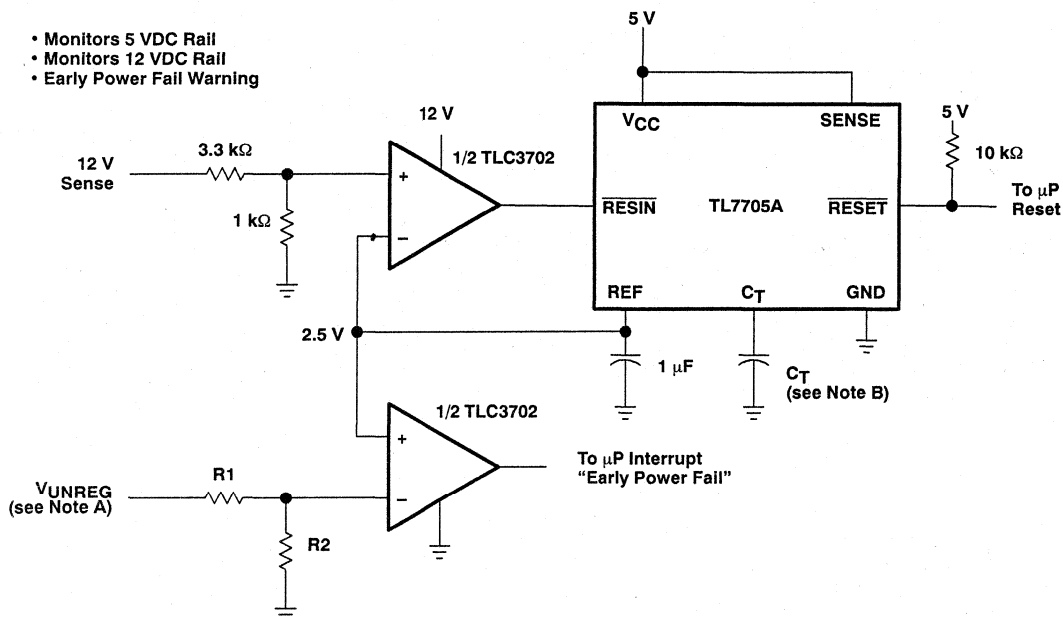
NOTES: A. The recommended minimum capacitance is 10 μ F to eliminate common ground switching noise.
B. Adjust C1 for change in oscillator frequency.

Figure 25. Pulse-Width-Modulated Motor Speed Controller

TLC3702C, TLC3702I, TLC3702M, TLC3702Q
DUAL MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

APPLICATION INFORMATION

- Monitors 5 VDC Rail
- Monitors 12 VDC Rail
- Early Power Fail Warning

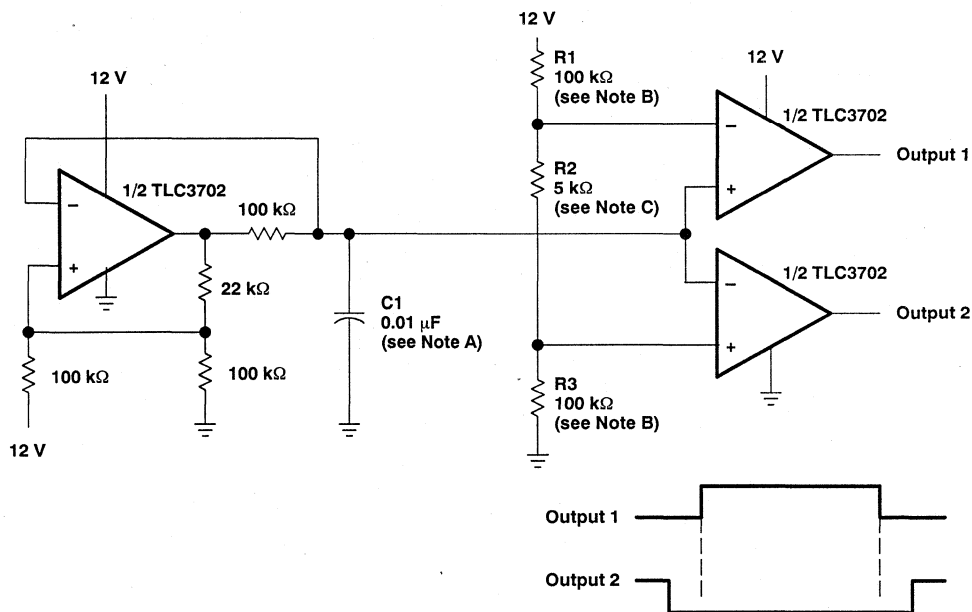


NOTES: A. $V_{UNREG} = 2.5 \frac{(R1 + R2)}{R2}$

B. The value of C_T determines the time delay of reset.

Figure 26. Enhanced Supply Supervisor

APPLICATION INFORMATION



- NOTES: A. Adjust C1 for a change in oscillator frequency where:
 $1/f = 1.85(100 \text{ k}\Omega)C1$
 B. Adjust R1 and R3 to change duty cycle
 C. Adjust R2 to change deadtime

Figure 27. Two-Phase Nonoverlapping Clock Generator

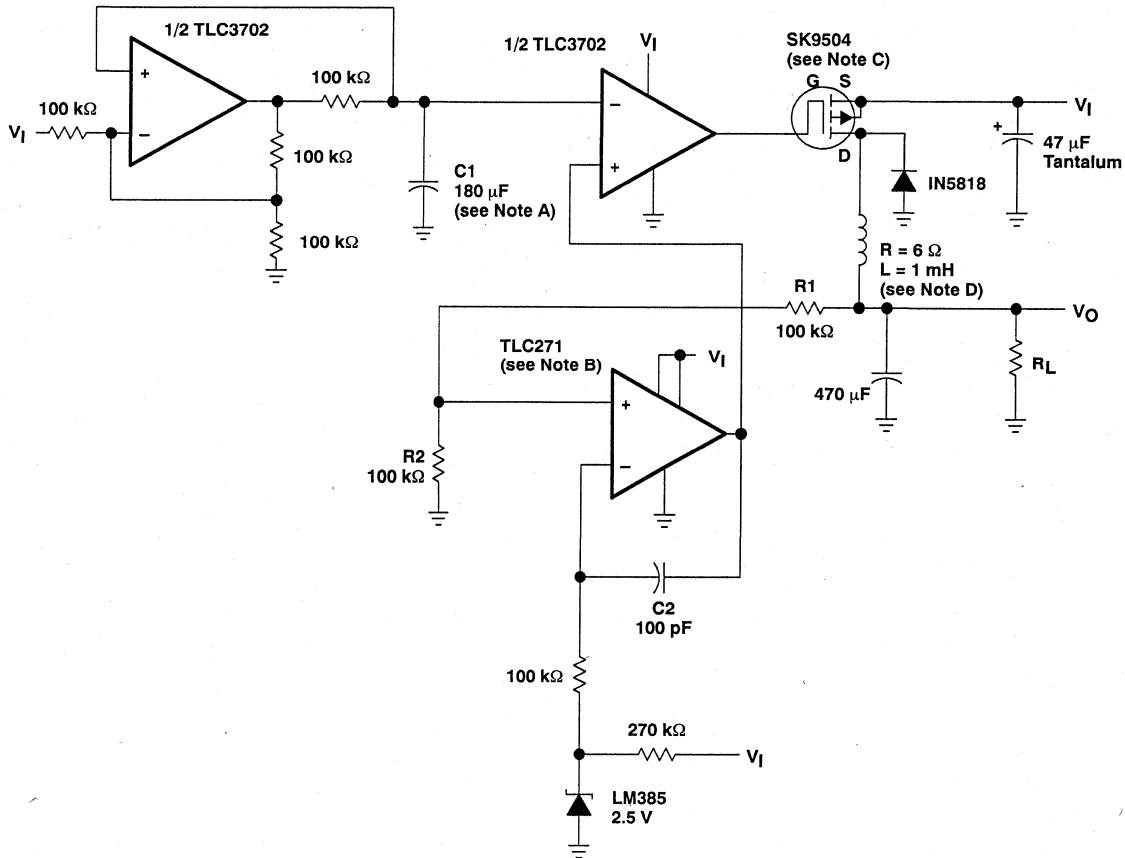
TLC3702C, TLC3702I, TLC3702M, TLC3702Q
 DUAL MICROWPOWER LinCMOS™ VOLTAGE COMPARATORS

APPLICATION INFORMATION

$$V_I = 6 \text{ V to } 16 \text{ V}$$

$$I_L = 0.01 \text{ mA to } 0.25 \text{ mA}$$

$$V_O = 2.5 \frac{(R_1 + R_2)}{R_2}$$



- NOTES: A. Adjust C1 for a change in oscillator frequency
 B. TLC271 – Tie pin 8 to pin 7 for low bias operation
 C. SK9504 – V_{DS} = 40 V
 I_{DS} = 1 A
 D. To achieve microampere current drive, the inductance of the circuit must be increased.

Figure 28. Micropower Switching Regulator

TLC3704C, TLC3704I, TLC3704M, TLC3704Q QUADRUPLE MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

D3240, NOVEMBER 1986—REVISED NOVEMBER 1991

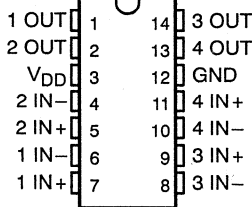
- **Push-Pull CMOS Output Drives Capacitive Loads Without Pullup Resistor,**
 $I_O = \pm 8 \text{ mA}$
- **Very Low Power . . . 200 μW Typ at 5 V**
- **Fast Response Time . . . $t_{PLH} = 2.7 \mu\text{s}$ Typ With 5-mV Overdrive**
- **Single Supply Operation . . . 3 V to 16 V**
TLC3704M . . . 4 V to 16 V
- **On-Chip ESD Protection**

description

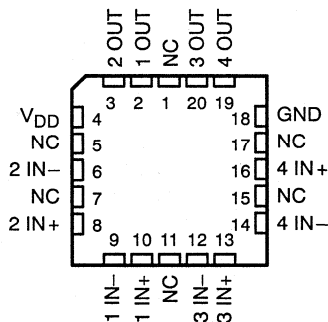
The TLC3704 consists of four independent micropower voltage comparators designed to operate from a single supply and be compatible with modern HCMOS logic systems. They are functionally similar to the LM339 but use 1/20th the power for similar response times. The push-pull CMOS output stage will drive capacitive loads directly without a power-consuming pullup resistor to achieve the stated response time. Eliminating the pullup resistor not only reduces power dissipation, but also saves board space and component cost. The output stage is also fully compatible with TTL requirements.

Texas Instruments LinCMOS™ process offers superior analog performance to standard CMOS processes. Along with the standard CMOS advantages of low power without sacrificing speed, high input impedance, and low bias currents, the LinCMOS™ process offers extremely stable input offset voltages with large differential input voltages. This characteristic makes it possible to build reliable CMOS comparators.

D, J, OR N PACKAGE
(TOP VIEW)

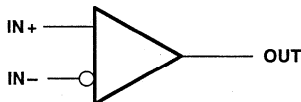


FK PACKAGE
(TOP VIEW)



NC — No internal connection

symbol (each comparator)



AVAILABLE OPTIONS

| T _A | V _{IO} max at 25°C | PACKAGE | | | |
|----------------|--------------------------------|----------------------|-----------------|--------------------|--------------------|
| | | SMALL OUTLINE (D) | CERAMIC (FK) | CERAMIC DIP (J) | PLASTIC DIP (N) |
| 0°C to 70°C | 5 mV | TLC3704CD | — | — | TLC3704CN |
| –40°C to 85°C | 5 mV | TLC3704ID | — | — | TLC3704IN |
| –55°C to 125°C | 5 mV | — | TLC3704MFK | TLC3704MJ | — |
| –40°C to 125°C | 5 mV | — | — | TLC3704QJ | — |

The D package is available taped and reeled. Add "R" suffix to the device type (e.g., TLC3704CDR).

LinCMOS is a trademark of Texas Instruments Incorporated.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

**TEXAS
INSTRUMENTS**

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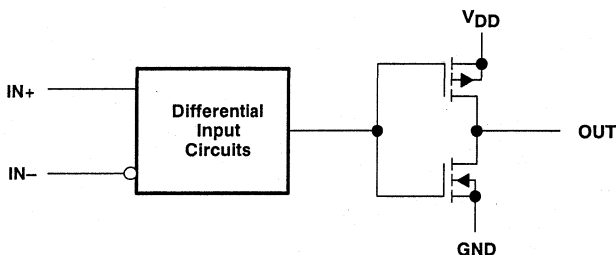
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TLC3704C, TLC3704I, TLC3704M, TLC3704Q QUADRUPLE MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

description (continued)

The TLC3704C is characterized for operation over the commercial temperature range of 0°C to 70°C. The TLC3704I is characterized for operation over the extended industrial temperature range of -40°C to 85°C. The TLC3704M is characterized for operation over the full military temperature range of -55°C to 125°C. The TLC3704Q is characterized for operation from -40°C to 125°C.

functional block diagram (each comparator)



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Supply voltage range, V_{DD} (see Note 1) | -0.3 V to 18 V |
| Differential input voltage (see Note 2) | ± 18 V |
| Input voltage range, V_I | -0.3 to V_{DD} |
| Output voltage range, V_O | -0.3 to V_{DD} |
| Input current, I_I | ± 5 mA |
| Output current, I_O (each output) | ± 20 mA |
| Total supply current into V_{DD} terminal | 40 mA |
| Total current out of ground terminal | 60 mA |
| Continuous total power dissipation | See Dissipation Rating Table |
| Operating free-air temperature range: TLC3704C | 0 to 70°C |
| TLC3704I | -40°C to 85°C |
| TLC3704M | -55°C to 125°C |
| TLC3704Q | -40°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or N package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package | 300°C |

- NOTES: 1. All voltage values, except differential voltages, are with respect to network ground.
2. Differential voltages are at the noninverting input with respect to the inverting input.

DISSIPATION RATING TABLE

| PACKAGE | $T_A = 25^\circ\text{C}$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$ | $T_A = 70^\circ\text{C}$ POWER RATING | $T_A = 85^\circ\text{C}$ POWER RATING | $T_A = 125^\circ\text{C}$ POWER RATING |
|---------|--|---|--|--|---|
| D | 950 mW | 7.6 mW/°C | 608 mW | 494 mW | N/A |
| FK | 1375 mW | 11.0 mW/°C | 880 mW | 715 mW | 275 mW |
| J | 1375 mW | 11.0 mW/°C | 880 mW | 715 mW | 275 mW |
| N | 1150 mW | 9.2 mW/°C | 736 mW | 598 mW | N/A |

TLC3704C

QUADRUPLE MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|---------------------------------------|------|-----|----------------|------|
| Supply voltage, V_{DD} | 3 | 5 | 16 | V |
| Common-mode input voltage, V_{IC} | -0.2 | | $V_{DD} - 1.5$ | V |
| High-level output current, I_{OH} | | | -20 | mA |
| Low-level output current, I_{OL} | | | 20 | mA |
| Operating free-air temperature, T_A | 0 | | 70 | °C |

electrical characteristics at specified operating free-air temperature, $V_{DD} = 5$ V (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS† | T_A | MIN | TYP | MAX | UNIT |
|-----------|-----------------------------------|---|-------------|---------------------|-----|---------|------|
| V_{IO} | Input offset voltage | $V_{IC} = V_{ICRmin}$, $V_{DD} = 5$ V to 10 V, See Note 3 | 25°C | 1.2 | | 5 | mV |
| | | | 0°C to 70°C | | | 6.5 | |
| I_{IO} | Input offset current | $V_{IC} = 2.5$ V | 25°C | | 1 | | pA |
| | | | 70°C | | | 0.3 | nA |
| I_{IB} | Input bias current | $V_{IC} = 2.5$ V | 25°C | | 5 | | pA |
| | | | 70°C | | | 0.6 | nA |
| V_{ICR} | Common-mode input voltage range | | 25°C | 0 to $V_{DD} - 1$ | | | V |
| | | | 0°C to 70°C | 0 to $V_{DD} - 1.5$ | | | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICRmin}$ | 25°C | 84 | | dB | |
| | | | 70°C | 84 | | | |
| | | | 0°C | 84 | | | |
| k_{SVR} | Supply voltage rejection ratio | $V_{DD} = 5$ V to 10 V | 25°C | 85 | | dB | |
| | | | 70°C | 85 | | | |
| | | | 0°C | 85 | | | |
| V_{OH} | High-level output voltage | $V_{ID} = 1$ V, $I_{OH} = -4$ mA | 25°C | 4.5 | 4.7 | V | |
| | | | 70°C | 4.3 | | | |
| V_{OL} | Low-level output voltage | $V_{ID} = -1$ V, $I_{OL} = 4$ mA | 25°C | 210 | 300 | mV | |
| | | | 70°C | 375 | | | |
| I_{DD} | Supply current (four comparators) | No load, Outputs low | 25°C | 35 | 80 | μ A | |
| | | | 0°C to 70°C | 100 | | | |

† All characteristics are measured with zero common-mode voltage unless otherwise noted.

NOTE 3: The offset voltage limits given are the maximum values required to drive the output up to 4.5 V or down to 0.3 V.

TLC3704I
QUADRUPLE MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|---------------------------------------|------|----------------|-----|--------|
| Supply voltage, V_{DD} | 3 | 5 | 16 | V |
| Common-mode input voltage, V_{IC} | -0.2 | $V_{DD} - 1.5$ | | V |
| High-level output current, I_{OH} | | | | -20 mA |
| Low-level output current, I_{OL} | | | | 20 mA |
| Operating free-air temperature, T_A | -40 | 85 | | °C |

electrical characteristics at specified operating free-air temperature, $V_{DD} = 5$ V, $V_{IC} = 0$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | T_A | MIN | TYP | MAX | UNIT |
|-----------|-----------------------------------|---|---------------|---------------------|-----|-----|------|
| V_{IO} | Input offset voltage | $V_{IC} = V_{ICRmin}$, $V_{DD} = 5$ V to 10 V, See Note 3 | 25°C | 1.2 | 5 | | mV |
| | | | -40°C to 85°C | | | 7 | |
| I_{IO} | Input offset current | $V_{IC} = 2.5$ V | 25°C | 1 | | | pA |
| | | | 85°C | | | 1 | |
| I_{IB} | Input bias current | $V_{IC} = 2.5$ V | 25°C | 5 | | | pA |
| | | | 85°C | | | 2 | |
| V_{ICR} | Common-mode input voltage range | | 25°C | 0 to $V_{DD} - 1$ | | | V |
| | | | -40°C to 85°C | 0 to $V_{DD} - 1.5$ | | | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICRmin}$ | 25°C | 84 | | | dB |
| | | | 85°C | 84 | | | |
| | | | -40°C | 83 | | | |
| kSVR | Supply voltage rejection ratio | $V_{DD} = 5$ V to 10 V | 25°C | 85 | | | dB |
| | | | 85°C | 85 | | | |
| | | | -40°C | 83 | | | |
| V_{OH} | High-level output voltage | $V_{ID} = 1$ V, $I_{OH} = -4$ mA | 25°C | 4.5 | 4.7 | | V |
| | | | 85°C | 4.3 | | | |
| V_{OL} | Low-level output voltage | $V_{ID} = -1$ V, $I_{OL} = 4$ mA | 25°C | 210 | 300 | | mV |
| | | | 85°C | 400 | | | |
| I_{DD} | Supply current (four comparators) | No load, Outputs low | 25°C | 35 | 80 | | μA |
| | | | -40°C to 85°C | 125 | | | |

NOTE 3: The offset voltage limits given are the maximum values required to drive the output up to 4.5 V or down to 0.3 V.



TLC3704M

QUADRUPLE MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|---------------------------------------|-----|----------------|-----|--------|
| Supply voltage, V_{DD} | 4 | 5 | 16 | V |
| Common-mode input voltage, V_{IC} | 0 | $V_{DD} - 1.5$ | | V |
| High-level output current, I_{OH} | | | | -20 mA |
| Low-level output current, I_{OL} | | | | 20 mA |
| Operating free-air temperature, T_A | -55 | | | 125 °C |

electrical characteristics at specified operating free-air temperature, $V_{DD} = 5\text{ V}$, $V_{IC} = 0$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | T_A | MIN | TYP | MAX | UNIT |
|-----------|-----------------------------------|---|----------------|---------------------|-----|-----|------|
| V_{IO} | Input offset voltage | $V_{IC} = V_{ICRmin}$, $V_{DD} = 5\text{ V to } 10\text{ V}$, See Note 3 | 25°C | 1.2 | | 5 | mV |
| | | | -55°C to 125°C | | | 10 | |
| I_{IO} | Input offset current | $V_{IC} = 2.5\text{ V}$ | 25°C | 1 | | | pA |
| | | | 125°C | | | 15 | nA |
| I_{IB} | Input bias current | $V_{IC} = 2.5\text{ V}$ | 25°C | 5 | | | pA |
| | | | 125°C | | | 30 | nA |
| V_{ICR} | Common-mode input voltage range | | 25°C | 0 to $V_{DD} - 1$ | | | V |
| | | | -55°C to 125°C | 0 to $V_{DD} - 1.5$ | | | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICRmin}$ | 25°C | 84 | | | dB |
| | | | 125°C | 83 | | | |
| | | | -55°C | 82 | | | |
| kSVR | Supply voltage rejection ratio | $V_{DD} = 5\text{ V to } 10\text{ V}$ | 25°C | 85 | | | dB |
| | | | 125°C | 85 | | | |
| | | | -55°C | 82 | | | |
| V_{OH} | High-level output voltage | $V_{ID} = 1\text{ V}$, $I_{OH} = -4\text{ mA}$ | 25°C | 4.5 | 4.7 | | V |
| | | | 125°C | 4.2 | | | |
| V_{OL} | Low-level output voltage | $V_{ID} = -1\text{ V}$, $I_{OL} = 4\text{ mA}$ | 25°C | 210 | | 300 | mV |
| | | | 125°C | 500 | | | |
| I_{DD} | Supply current (four comparators) | No load, Outputs low | 25°C | 35 | | 80 | µA |
| | | | -55°C to 125°C | 175 | | | |

NOTE 3: The offset voltage limits given are the maximum values required to drive the output up to 4.5 V or down to 0.3 V.



TLC3704Q

QUADRUPLE MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|---------------------------------------|------|-----|----------------|------|
| Supply voltage, V_{DD} | 3 | 5 | 16 | V |
| Common-mode input voltage, V_{IC} | -0.2 | | $V_{DD} - 1.5$ | V |
| High-level output current, I_{OH} | | | -20 | mA |
| Low-level output current, I_{OL} | | | 20 | mA |
| Operating free-air temperature, T_A | -40 | | 125 | °C |

electrical characteristics at specified operating free-air temperature, $V_{DD} = 5$ V, $V_{IC} = 0$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | T_A | MIN | TYP | MAX | UNIT |
|-----------|-----------------------------------|---|----------------|------|-----|----------------|------|
| V_{IO} | Input offset voltage | $V_{IC} = V_{ICRmin}$, $V_{DD} = 5$ V to 10 V, See Note 3 | 25°C | | 1.2 | 5 | mV |
| | | | -40°C to 125°C | | | 7 | |
| I_{IO} | Input offset current | $V_{IC} = 2.5$ V | 25°C | | 1 | | pA |
| | | | 125°C | | | 15 | nA |
| I_{IB} | Input bias current | $V_{IC} = 2.5$ V | 25°C | | 5 | | pA |
| | | | 125°C | | | 30 | nA |
| V_{ICR} | Common-mode input voltage range | | 25°C | 0 to | | $V_{DD} - 1$ | V |
| | | | -40°C to 125°C | 0 to | | $V_{DD} - 1.5$ | |
| CMRR | Common-mode rejection ratio | $V_{IC} = V_{ICRmin}$ | 25°C | | 84 | | dB |
| | | | 125°C | | 83 | | |
| | | | -40°C | | 83 | | |
| kSVR | Supply voltage rejection ratio | $V_{DD} = 5$ V to 10 V | 25°C | | 85 | | dB |
| | | | 125°C | | 85 | | |
| | | | -40°C | | 83 | | |
| V_{OH} | High-level output voltage | $V_{ID} = 1$ V, $I_{OH} = -4$ mA | 25°C | 4.5 | 4.7 | | V |
| | | | 125°C | 4.2 | | | |
| V_{OL} | Low-level output voltage | $V_{ID} = -1$ V, $I_{OL} = 4$ mA | 25°C | | 210 | 300 | mV |
| | | | 125°C | | | 500 | |
| I_{DD} | Supply current (four comparators) | No load, Outputs low | 25°C | | 35 | 80 | μA |
| | | | -40°C to 125°C | | | 175 | |

NOTE 3: The offset voltage limits given are the maximum values required to drive the output up to 4.5 V or down to 0.3 V.



TLC3704C, TLC3804I, TLC3704M, TLC3704Q
QUADRUPLE MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

switching characteristics, $V_{DD} = 5\text{ V}$, $T_A = 25^\circ\text{C}$

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-----------|---|---------------------------------------|-------------------|------|------|---------------|
| t_{PLH} | Propagation delay time, low-to-high-level output† | f = 10 kHz, $C_L = 50\text{ pF}$ | Overdrive = 2 mV | | 4.5 | μs |
| | | | Overdrive = 5 mV | | 2.7 | |
| | | | Overdrive = 10 mV | | 1.9 | |
| | | | Overdrive = 20 mV | | 1.4 | |
| | | | Overdrive = 40 mV | | 1.1 | |
| | | $V_I = 1.4\text{-V}$ step at IN + pin | | 1.1 | | |
| t_{PHL} | Propagation delay time, high-to-low-level output† | f = 10 kHz, $C_L = 50\text{ pF}$ | Overdrive = 2 mV | | 4 | μs |
| | | | Overdrive = 5 mV | | 2.3 | |
| | | | Overdrive = 10 mV | | 1.5 | |
| | | | Overdrive = 20 mV | | 0.95 | |
| | | | Overdrive = 40 mV | | 0.65 | |
| | | $V_I = 1.4\text{-V}$ step at IN + pin | | 0.15 | | |
| t_f | Fall time | f = 10 kHz, $C_L = 50\text{ pF}$ | Overdrive = 50 mV | | 50 | ns |
| t_r | Rise time | f = 10 kHz, $C_L = 50\text{ pF}$ | Overdrive = 50 mV | | 125 | ns |

† Simultaneous switching of inputs will cause degradation in output response.

TLC3704C, TLC3704I, TLC3704M, TLC3704Q QUADRUPLE MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

PRINCIPLES OF OPERATION

LinCMOS™ process

The LinCMOS™ process is a linear polysilicon-gate CMOS process. Primarily designed for single-supply applications, LinCMOS™ products facilitate the design of a wide range of high-performance analog functions from operational amplifiers to complex mixed-mode converters.

While digital designers are experienced with CMOS, MOS technologies are relatively new for analog designers. This short guide is intended to answer the most frequently asked questions related to the quality and reliability of LinCMOS™ products. If you have any further questions, please contact your local TI sales office.

electrostatic discharge

CMOS circuits are prone to gate oxide breakdown when exposed to high voltages even if the exposure is only for very short periods of time. Electrostatic discharge (ESD) is one of the most common causes of damage to CMOS devices. It can occur when a device is handled without proper consideration for environmental electrostatic charges, e.g., during board assembly. If a circuit in which one amplifier from a dual op amp is being used and the unused pins are left open, high voltages will tend to develop. If there is no provision for ESD protection, these voltages may eventually punch through the gate oxide and cause the device to fail. To prevent voltage buildup, each pin is protected by internal circuitry.

Standard ESD-protection circuits safely shunt the ESD current by providing a mechanism whereby one or more transistors break down at voltages higher than the normal operating voltages but lower than the breakdown voltage of the input gate. This type of protection scheme is limited by leakage currents which flow through the shunting transistors during normal operation after an ESD voltage has occurred. Although these currents are small, on the order of tens of nanoamps, CMOS amplifiers are often specified to draw input currents as low as tens of picoamps.

To overcome this limitation, TI design engineers developed the patented ESD-protection circuit shown in Figure 1. This circuit can withstand several successive 2-kV ESD pulses, while reducing or eliminating leakage currents that may be drawn through the input pins. A more detailed discussion of the operation of the TI ESD protection circuit is presented on the next page.

All input and output pins on LinCMOS™ and Advanced LinCMOS™ products have associated ESD-protection circuitry that undergoes qualification testing to withstand 2000 V discharged from a 100-pF capacitor through a 1500-Ω resistor (human body model) and 200 V from a 100-pF capacitor with no current-limiting resistor (charged device model). These tests simulate both operator and machine handling of devices during normal test and assembly operations.

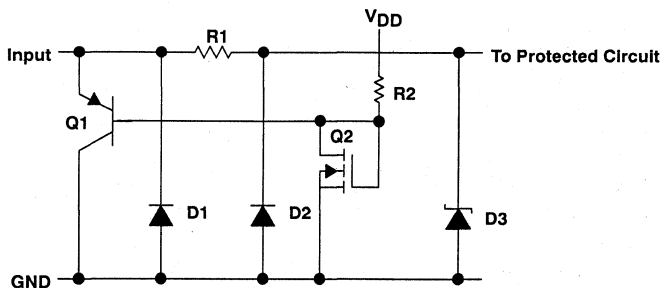


Figure 1. LinCMOS™ ESD-Protection Schematic

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TLC3704C, TLC3704I, TLC3704M, TLC3704Q

QUADRUPLE MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

input protection circuit operation

Texas Instruments patented protection circuitry allows for both positive- and negative-going ESD transients. These transients are characterized by extremely fast rise times and usually low energies, and can occur both when the device has all pins open and when it is installed in a circuit.

positive ESD transients

Initial positive charged energy is shunted through Q1 to V_{SS} . Q1 will turn on when the voltage at the input rises above the voltage on the V_{DD} pin by a value equal to the V_{BE} of Q1. The base current increases through R2 with input current as Q1 saturates. The base current through R2 will force the voltage at the drain and gate of Q2 to exceed its threshold level ($V_T \sim 22$ to 26 V) and turn Q2 on. The shunted input current through Q1 to V_{SS} is now shunted through the n-channel enhancement-type MOSFET Q2 to V_{SS} . If the voltage on the input pin continues to rise, the breakdown voltage of the zener diode D3 is exceeded and all remaining energy is dissipated in R1 and D3. The breakdown voltage of D3 is designed to be 24 to 27 V, which is well below the gate-oxide voltage of the circuit to be protected.

negative ESD transients

The negative charged ESD transients are shunted directly through D1. Additional energy is dissipated in R1 and D2 as D2 becomes forward biased. The voltage seen by the protected circuit is -0.3 V to -1 V (the forward voltage of D1 and D2).

circuit-design considerations

LinCMOS™ products are being used in actual circuit environments that have input voltages that exceed the recommended common-mode input voltage range and activate the input protection circuit. Even under normal operation, these conditions occur during circuit power up or power down, and in many cases, when the device is being used for a signal conditioning function. The input voltages can exceed V_{ICR} and not damage the device only if the inputs are current limited. The recommended current limit shown on most product data sheets is ± 5 mA. Figures 2 and 3 show typical characteristics for input voltage versus input current.

Normal operation and correct output state can be expected even when the input voltage exceeds the positive supply voltage. Again, the input current should be externally limited even though internal positive current limiting is achieved in the input protection circuit by the action of Q1. When Q1 is on, it will saturate and limit the current to approximately 5-mA collector current by design. When saturated, Q1 base current increases with input current. This base current is forced into the V_{DD} pin and into the device I_{DD} or the V_{DD} supply through R2 producing the current limiting effects shown in Figure 2. This internal limiting lasts only as long as the input voltage is below the V_T of Q2.

When the input voltage exceeds the negative supply voltage, normal operation is affected and output voltage states may not be correct. Also, the isolation between channels of multiple devices (duals and quads) can be severely affected. External current limiting must be used since this current will be directly shunted by D1 and D2 and no internal limiting is achieved. If normal output voltage states are required, an external input voltage clamp is required (see Figure 4).

TLC3704C, TLC3704I, TLC3704M, TLC3704Q
 QUADRUPLE MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

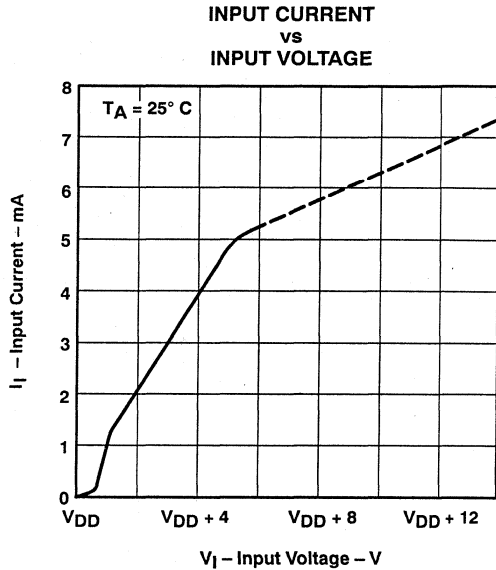


Figure 2

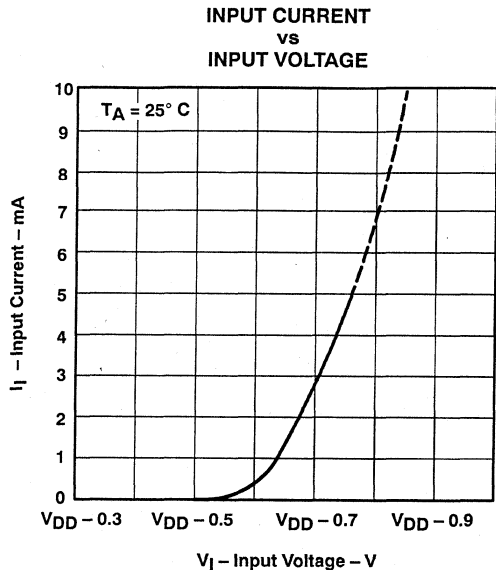
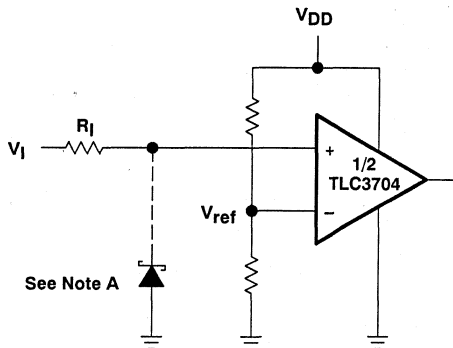


Figure 3



Positive Voltage Input Current Limit :

$$R_I = \frac{V_I - V_{DD} - 0.3\text{ V}}{5\text{ mA}}$$

Negative Voltage Input Current Limit :

$$R_I = \frac{-V_I - V_{DD} - (-0.3\text{ V})}{5\text{ mA}}$$

NOTE A: If the correct input state is required when the negative input exceeds GND, a Schottky clamp is required.

Figure 4. Typical Input Current-Limiting Configuration for a LinCMOS™ Comparator

TLC3704C, TLC3704I, TLC3704M, TLC3704Q QUADRUPLE MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

PARAMETER MEASUREMENT INFORMATION

The TLC3704 contains a digital output stage which, if held in the linear region of the transfer curve, can cause damage to the device. Conventional operational amplifier/comparator testing incorporates the use of a servo loop which is designed to force the device output to a level within this linear region. Since the servo-loop method of testing cannot be used, we offer the following alternatives for measuring parameters such as input offset voltage, common-mode rejection, etc.

To verify that the input offset voltage falls within the limits specified, the limit value is applied to the input as shown in Figure 5(a). With the noninverting input positive with respect to the inverting input, the output should be high. With the input polarity reversed, the output should be low.

A similar test can be made to verify the input offset voltage at the common-mode extremes. The supply voltages can be slewed as shown in Figure 5(b) for the V_{ICR} test, rather than changing the input voltages, to provide greater accuracy.

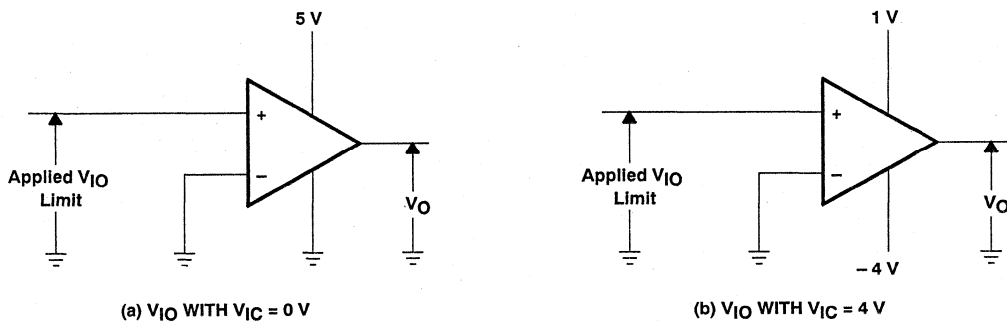


Figure 5. Method for Verifying That Input Offset Voltage Is Within Specified Limits

A close approximation of the input offset voltage can be obtained by using a binary search method to vary the differential input voltage while monitoring the output state. When the applied input voltage differential is equal, but opposite in polarity, to the input offset voltage, the output will change states.

Figure 6 illustrates a practical circuit for direct dc measurement of input offset voltage that does not bias the comparator in the linear region. The circuit consists of a switching mode servo loop in which IC1a generates a triangular waveform of approximately 20-mV amplitude. IC1b acts as a buffer, with C2 and R4 removing any residual d.c. offset. The signal is then applied to the inverting input of the comparator under test, while the noninverting input is driven by the output of the integrator formed by IC1c through the voltage divider formed by R8 and R9. The loop reaches a stable operating point when the output of the comparator under test has a duty cycle of exactly 50%, which can only occur when the incoming triangle wave is "sliced" symmetrically or when the voltage at the noninverting input exactly equals the input offset voltage.

Voltage divider R8 and R9 provides an increase in the input offset voltage by a factor of 100 to make measurement easier. The values of R5, R7, R8, and R9 can significantly influence the accuracy of the reading; therefore, it is suggested that their tolerance level be one percent or lower.

Measuring the extremely low values of input current requires isolation from all other sources of leakage current and compensation for the leakage of the test socket and board. With a good picoammeter, the socket and board leakage can be measured with no device in the socket. Subsequently, this open socket leakage value can be subtracted from the measurement obtained with a device in the socket to obtain the actual input current of the device.

PARAMETER MEASUREMENT INFORMATION

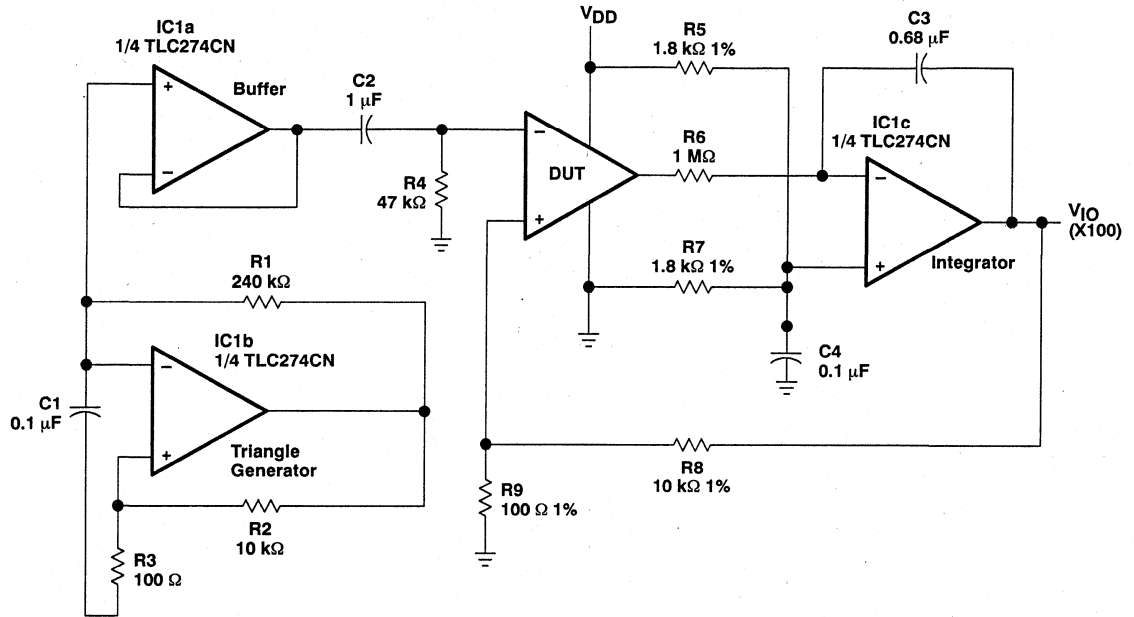
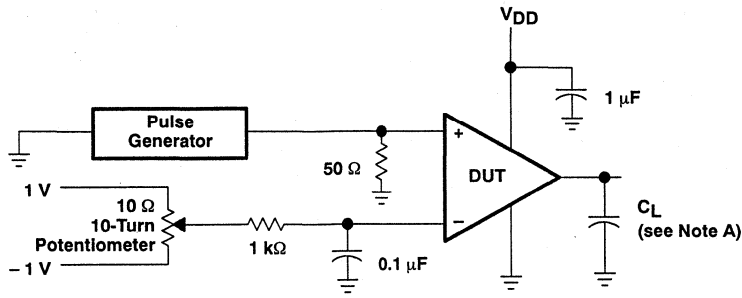


Figure 6. Circuit for Input Offset Voltage Measurement

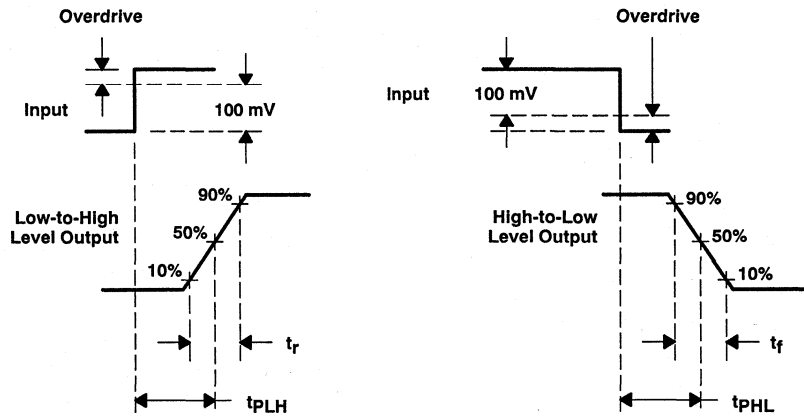
Response time is defined as the interval between the application of an input step function and the instant when the output reaches 50% of its maximum value. Response time for the low-to-high-level output is measured from the leading edge of the input pulse, while response time for the high-to-low-level output is measured from the trailing edge of the input pulse. Response time measurement at low input signal levels can be greatly affected by the input offset voltage. The offset voltage should be balanced by the adjustment at the inverting input (as shown in Figure 7) so that the circuit is just at the transition point. Then a low signal, for example 105-mV or 5-mV overdrive, will cause the output to change state.

TLC3704C, TLC3704I, TLC3704M, TLC3704Q
 QUADRUPLE MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



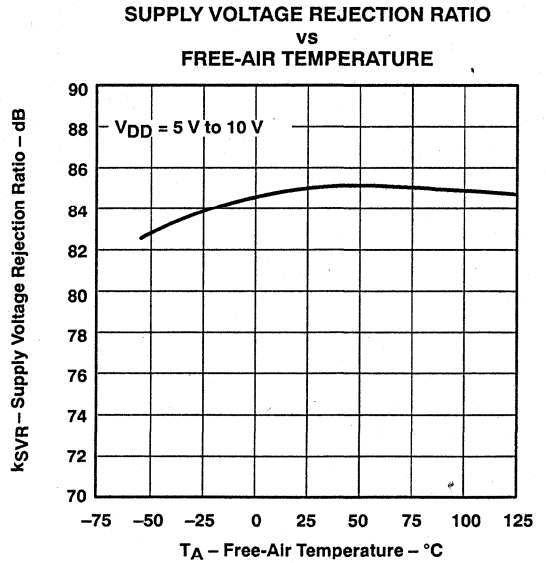
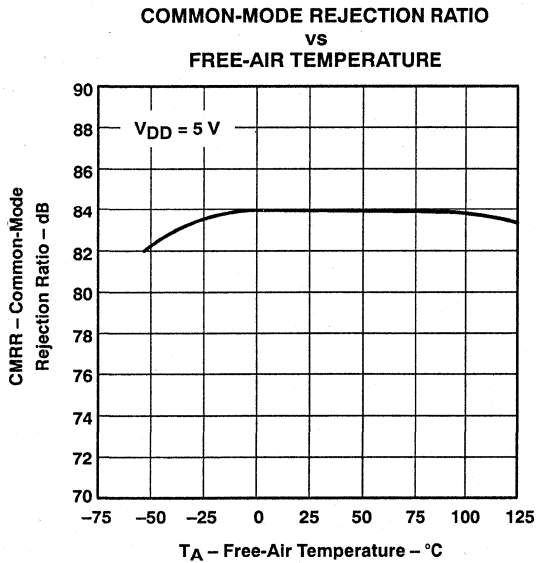
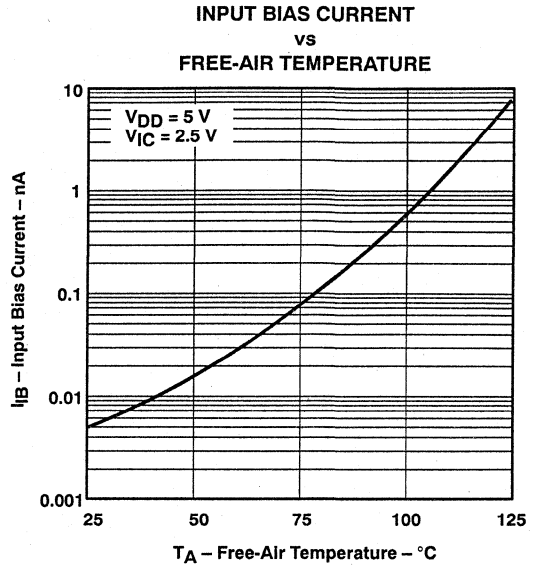
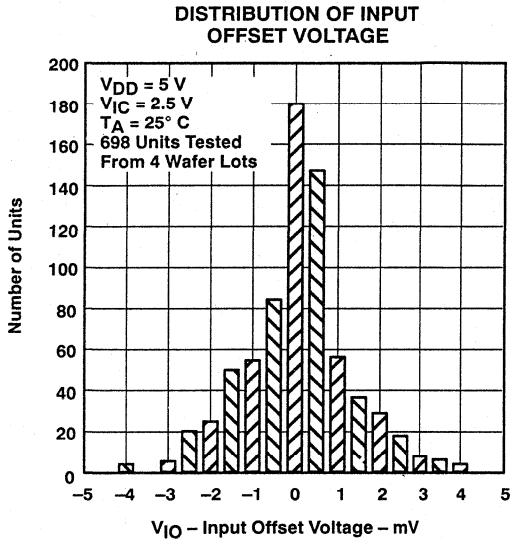
VOLTAGE WAVEFORMS

NOTE A: C_L includes probe and jig capacitance.

Figure 7. Response, Rise, and Fall Times Circuit and Voltage Waveforms

TLC3704C, TLC3704I, TLC3704M, TLC3704Q
QUADRUPLE MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

TYPICAL CHARACTERISTICS†

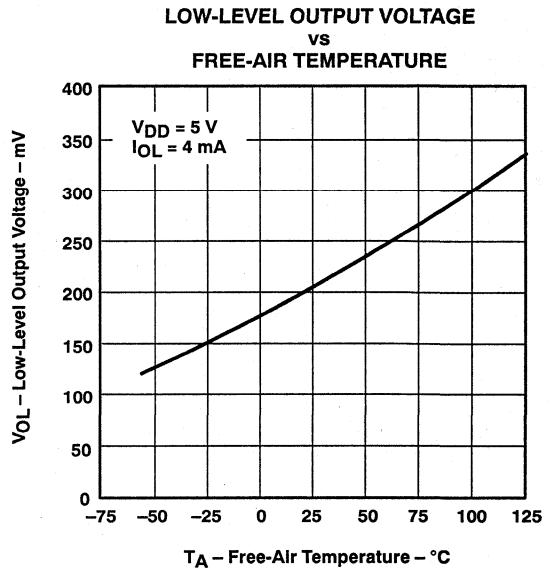
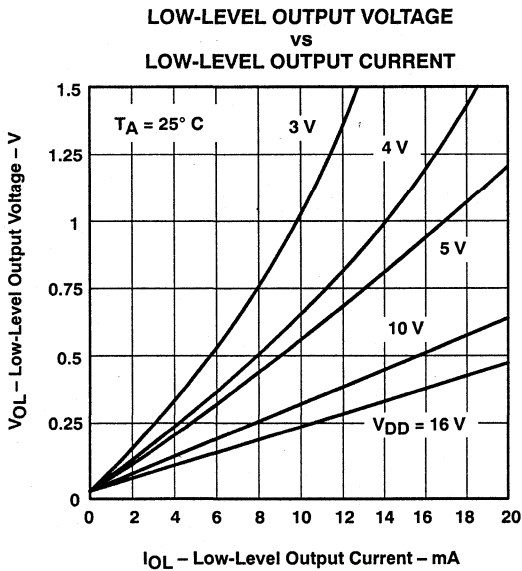
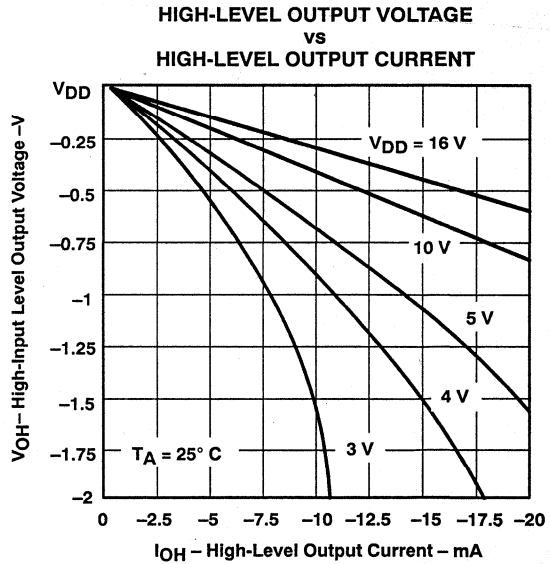
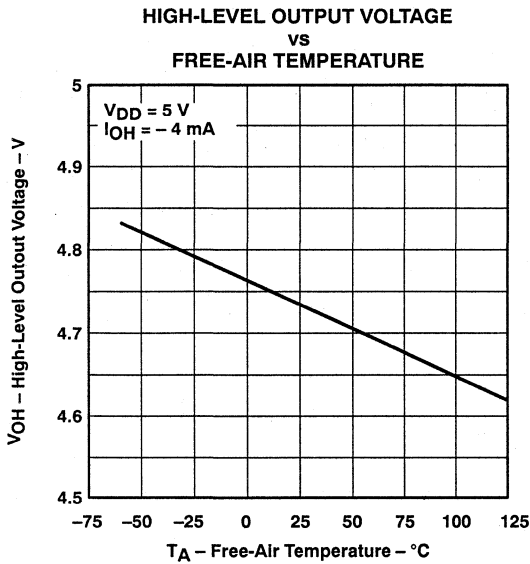


† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.



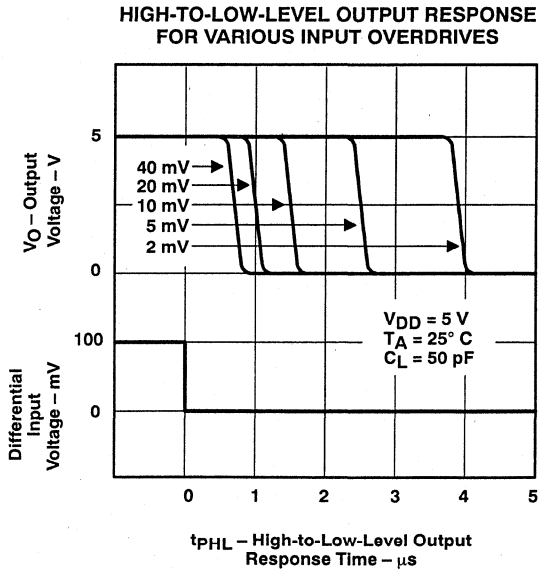
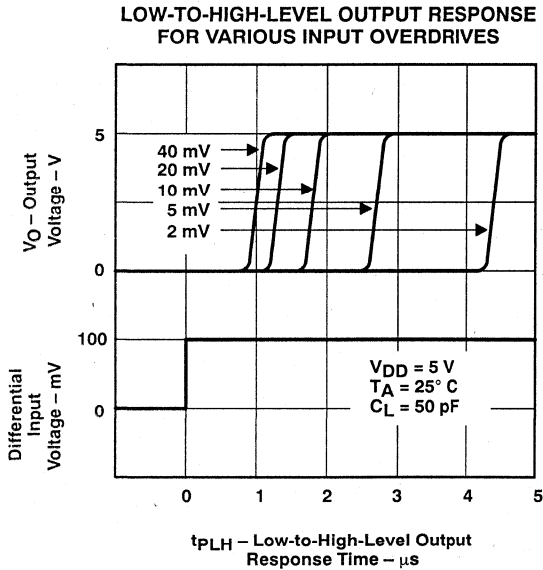
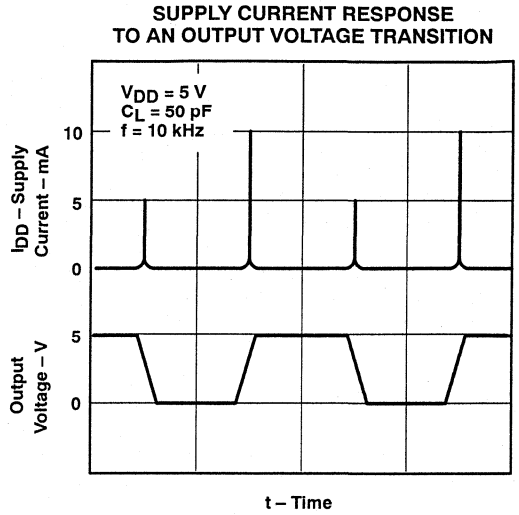
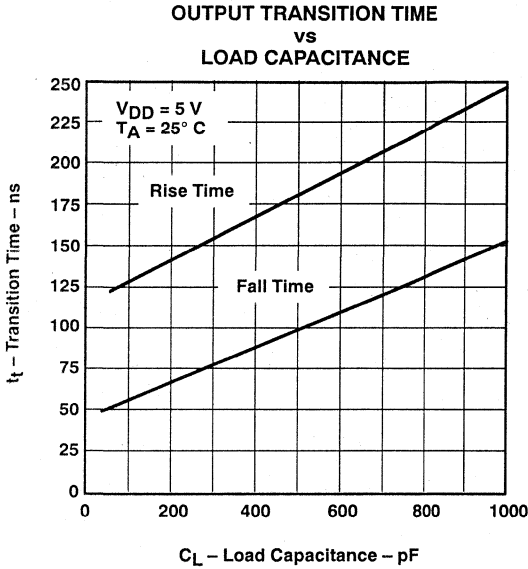
TLC3704C, TLC3704I, TLC3704M, TLC3704Q QUADRUPLE MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

TYPICAL CHARACTERISTICS†



† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS



TLC3704C, TLC3704I, TLC3704M, TLC3704Q QUADRUPLE MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

TYPICAL CHARACTERISTICS

**LOW-TO-HIGH-LEVEL
OUTPUT RESPONSE TIME
vs
SUPPLY VOLTAGE**

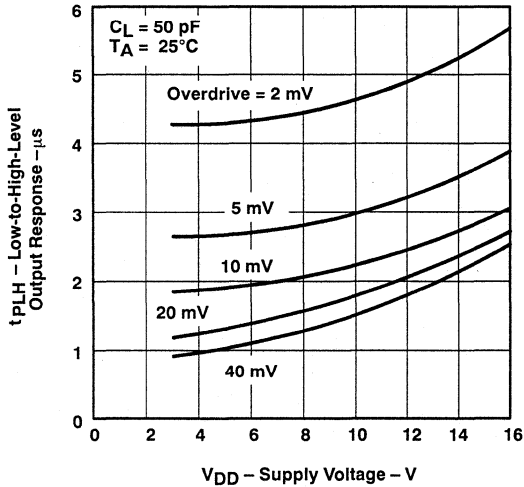


Figure 20

**HIGH-TO-LOW-LEVEL
OUTPUT RESPONSE TIME
vs
SUPPLY VOLTAGE**

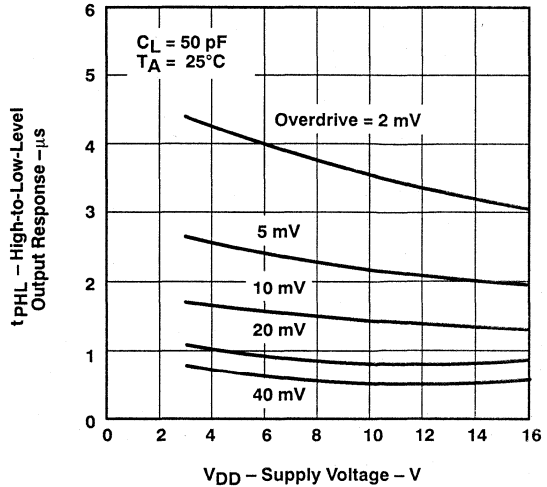


Figure 21

**AVERAGE SUPPLY CURRENT
(PER COMPARATOR)
vs
FREQUENCY**

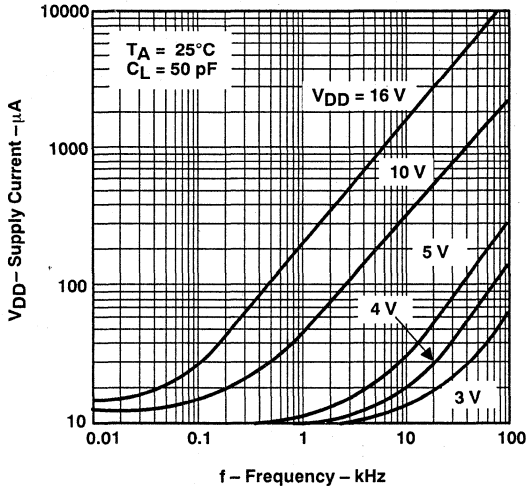


Figure 22

**SUPPLY CURRENT
vs
SUPPLY VOLTAGE**

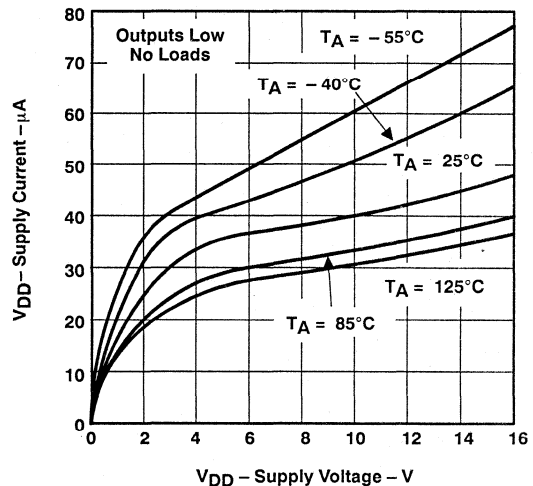


Figure 23

TLC3704C, TLC3704I, TLC3704M, TLC3704Q QUADRUPLE MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

TYPICAL CHARACTERISTICS†

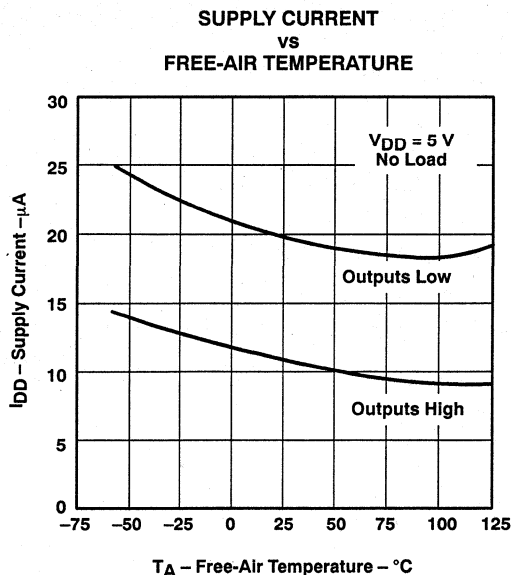


Figure 24

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

APPLICATION INFORMATION

The inputs should always remain within the supply rails in order to avoid forward biasing the diodes in the electrostatic discharge (ESD) protection structure. If either input exceeds this range, the device will not be damaged as long as the input is limited to less than 5 mA. To maintain the expected output state, the inputs must remain within the common-mode range. For example, at 25°C with $V_{DD} = 5$ V, both inputs must remain between -0.2 V and 4 V to ensure proper device operation.

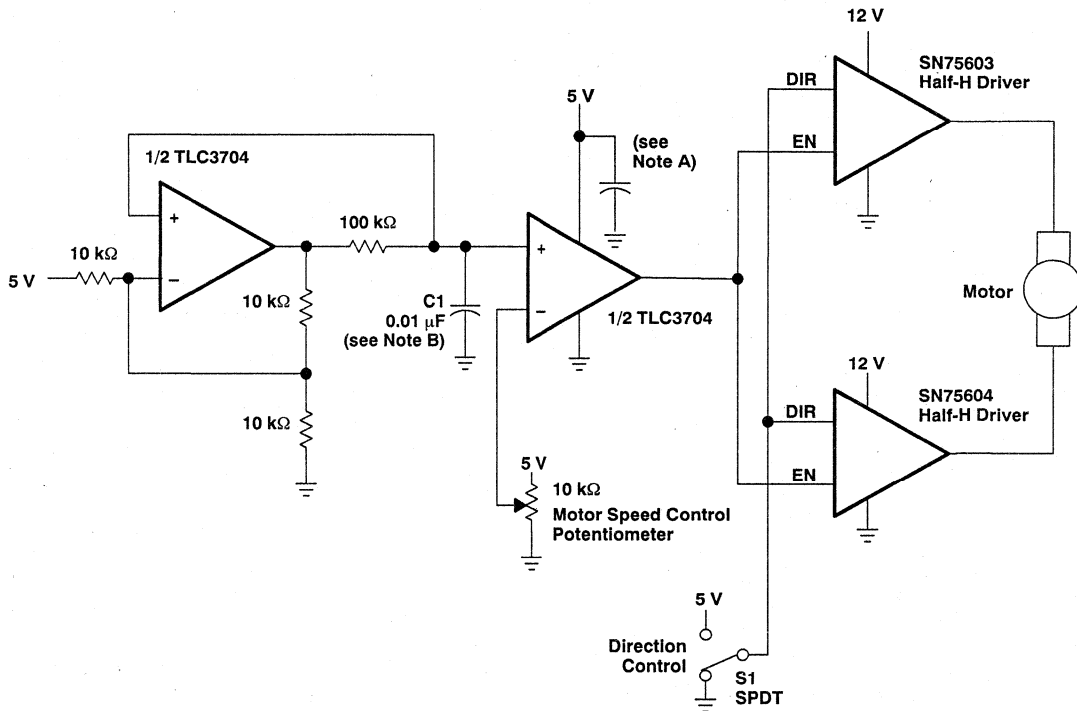
To ensure reliable operation, the supply should be decoupled with a capacitor (0.1 μ F) that is positioned as close to the device as possible.

Be careful to note the output and supply current limitations since the TLC3704 does not provide current protection. For example, each output can source or sink a maximum of 20 mA; however, the total current to ground can only be an absolute maximum of 60 mA. This prohibits sinking 20 mA from each of the four outputs simultaneously since the total current to ground would be 80 mA.

The TLC3704 has internal ESD protection circuits that will prevent functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2; however, care should be exercised in handling these devices as exposure to ESD may result in the degradation of the device parametric performance.

TLC3704C, TLC3704I, TLC3704M, TLC3704Q
QUADRUPLE MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

APPLICATION INFORMATION

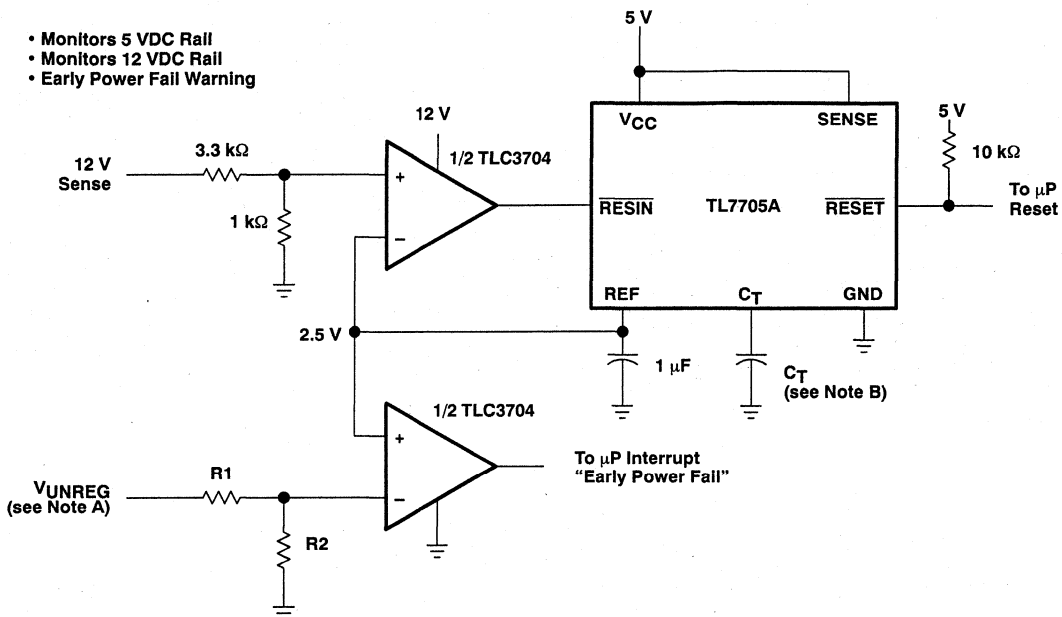


NOTES: A. The recommended minimum capacitance is 10 μ F to eliminate common ground switching noise.
 B. Adjust C1 for change in oscillator frequency

Figure 25. Pulse-Width-Modulated Motor Speed Controller

TLC3704C, TLC3704I, TLC3704M, TLC3704Q
QUADRUPLE MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

APPLICATION INFORMATION

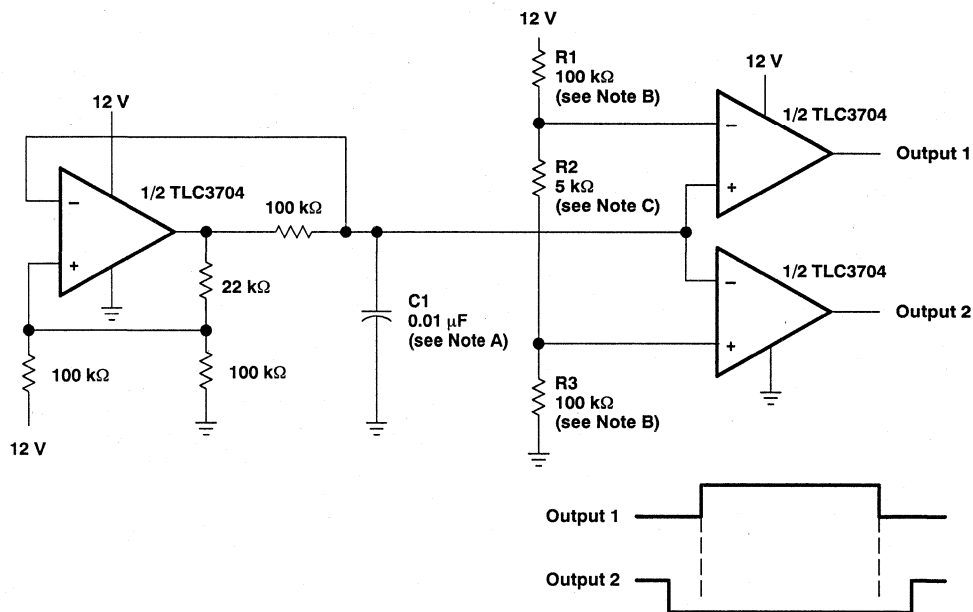


NOTES: A. $V_{UNREG} = 2.5 \frac{(R1 + R2)}{R2}$

B. The value of C_T determines the time delay of reset.

Figure 26. Enhanced Supply Supervisor

APPLICATION INFORMATION



- NOTES: A. Adjust C1 for a change in oscillator frequency where:
 $1/f = 1.85(100 \text{ k}\Omega)C1$
 B. Adjust R1 and R3 to change duty cycle
 C. Adjust R2 to change deadtime

Figure 27. Two-Phase Nonoverlapping Clock Generator

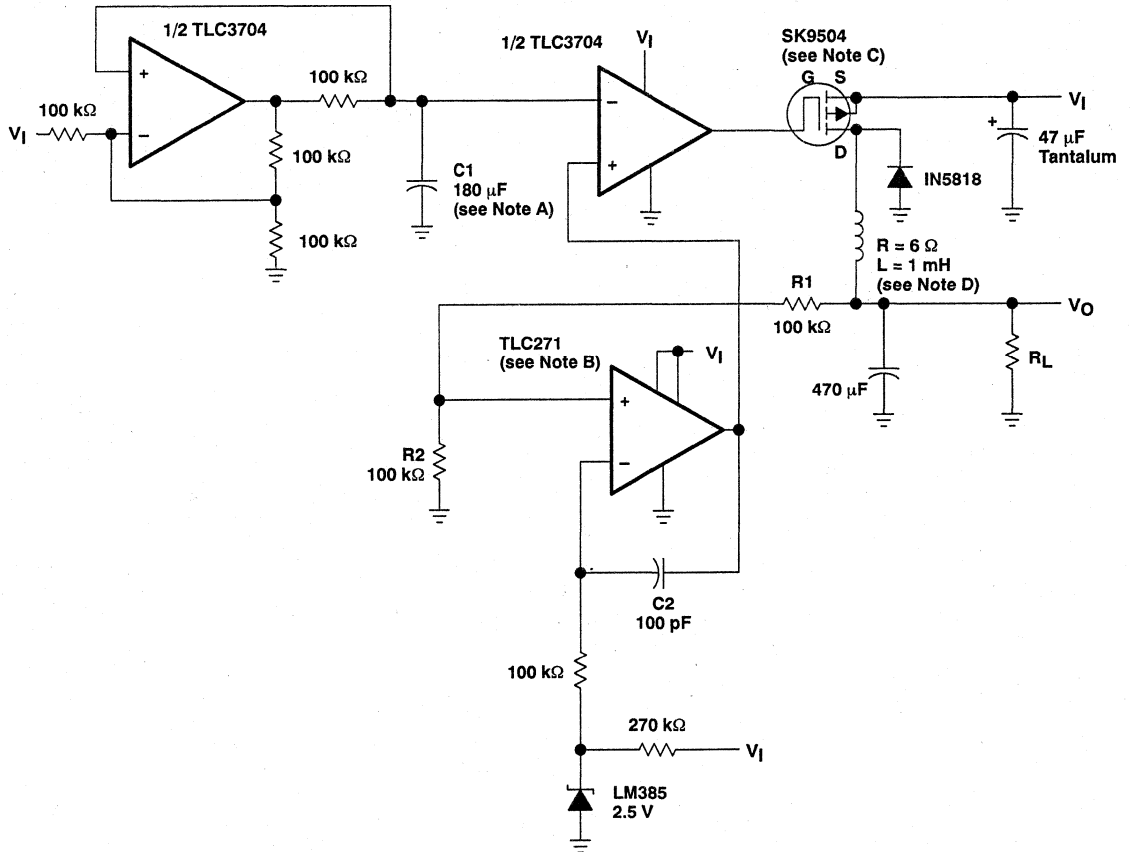
TLC3704C, TLC3704I, TLC3704M, TLC3704Q
QUADRUPLE MICROPOWER LinCMOS™ VOLTAGE COMPARATORS

APPLICATION INFORMATION

$$V_I = 6 \text{ V to } 16 \text{ V}$$

$$I_L = 0.01 \text{ mA to } 0.25 \text{ mA}$$

$$V_O = 2.5 \frac{(R_1 + R_2)}{R_2}$$



- NOTES: A. Adjust C1 for a change in oscillator frequency
 B. TLC271 – Tie pin 8 to pin 7 for low bias operation
 C. SK9504 – V_{DS} = 40 V
 I_{DS} = 1 A
 D. To achieve microampere current drive, the inductance of the circuit must be increased.

Figure 28. Micropower Switching Regulator

| | |
|--|----------|
| General Information | 1 |
| VRegs/Supervisors and Bldg Blocks | 2 |
| Comparators | 3 |
| Special Functions | 4 |
| Thermal Design Considerations | 5 |
| Mechanical Data | 6 |

4

Special Functions

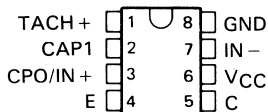
LM2907, LM2917 FREQUENCY-TO-VOLTAGE CONVERTERS

D3003, MARCH 1986—REVISED OCTOBER 1988

- Output Swings to Ground for Zero-Frequency Input
- Only One RC Network Provides Frequency Doubling for Low Ripple
- 8-Pin Versions Interface Directly to Variable-Reluctance Magnetic Pickups
- Uncommitted Collector and Emitter Outputs Provide 40-mA Sink or Source Current to Operate Relays, Solenoids, Meters, or LEDs
- Built-In Hysteresis for Noise Immunity
- Linearity Typically $\pm 0.3\%$
- 8-Pin Versions are Fully Protected from Damage Due to TACH Input Swing Above VCC and Below Ground

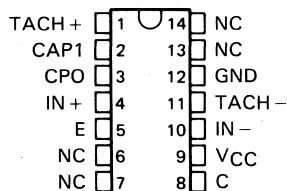
LM2907, LM2917 . . . D OR P PACKAGE

(TOP VIEW)



LM2907, LM2917 . . . D OR N PACKAGE

(TOP VIEW)



NC—No internal connection

applications

Over/under speed sensing
 Frequency-to-voltage conversion
 Speedometers
 Breaker-point dwell meters
 Hand-held tachometers
 Speed governors
 Cruise control
 Automotive door-lock control
 Clutch control
 Horn control
 Touch or sound switches

description

The LM2907 and LM2917 are monolithic frequency-to-voltage converters with an output circuit designed to operate a relay, lamp, or other load when the input frequency reaches or exceeds a selected rate. The converter (tachometer) section consists of a comparator driving a charge pump and offers frequency doubling for low ripple, full input protection in 8-pin versions, and an output swing to ground for a zero-frequency input. The output section consists of an operational amplifier, normally operating as a comparator, that drives an output transistor with both the collector and emitter floating. The circuit can either sink or source 40 mA of load current.

Two basic configurations of the devices are offered; an 8-pin version and a 14-pin version. The 8-pin versions have a ground-referenced tachometer input and an internal connection between the tachometer output and the operational amplifier input. The 8-pin version is well suited to single-speed or single-frequency switching or fully buffered frequency-to-voltage conversion applications. The more versatile 14-pin versions provide differential tachometer inputs and uncommitted operational amplifier inputs. In the 14-pin versions, the tachometer input can be floated and the operational amplifier becomes suitable for active filter conditioning of the tachometer output.

The LM2917 has an active shunt regulator connected across the power leads. The regulator clamps the supply voltage so that stable frequency-to-voltage and frequency-to-current conversions are possible with any supply voltage and a suitable resistor.

The LM2907 and LM2917 are designed for operation from -40°C to 85°C .

PRODUCTION DATA documents contain information current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

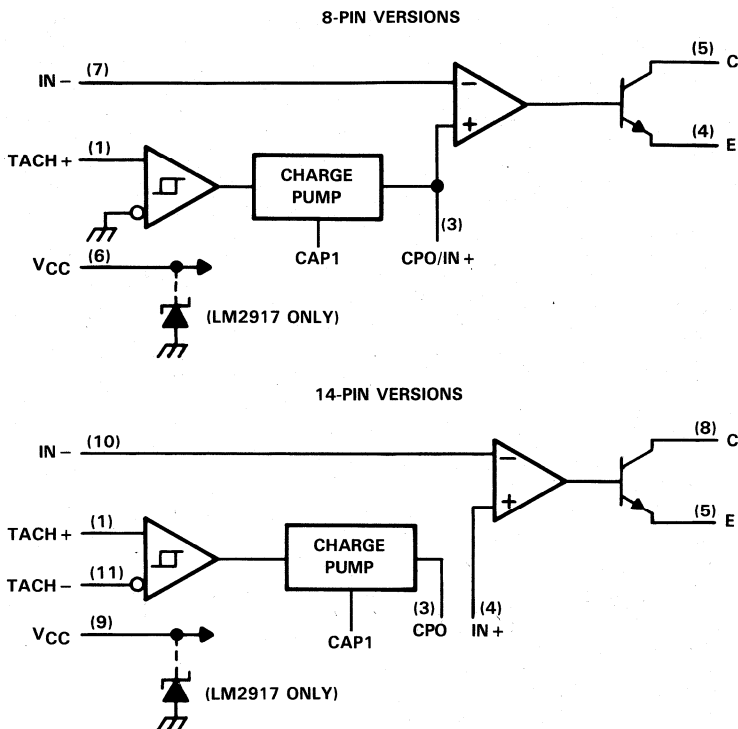


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LM2907, LM2917 FREQUENCY-TO-VOLTAGE CONVERTERS

functional block diagrams



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Supply voltage, V_{CC} : LM2907 | 28 V |
| Supply current, I_{CC} : LM2917 | 25 mA |
| Collector-to-emitter voltage | 28 V |
| Operational amplifier input voltage, $IN+$ and $IN-$ | 0 V to V_{CC} |
| Tachometer input voltage: 8-pin version TACH+ | 0 V to 28 V |
| 14-pin version TACH+ and TACH- | 0 V to V_{CC} |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range | -40°C to 85°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature range 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ | DERATING FACTOR | $T_A = 85^\circ\text{C}$ |
|-------------|-----------------------------|--------------------------------|--------------------------|
| | POWER RATING | ABOVE $T_A = 25^\circ\text{C}$ | POWER RATING |
| D (8 pins) | 725 mW | 5.8 mW/°C | 377 mW |
| D (14 pins) | 900 mW | 7.2 mW/°C | 468 mW |
| N | 1000 mW | 7.7 mW/°C | 500 mW |
| P | 900 mW | 7.2 mW/°C | 468 mW |

LM2907, LM2917 FREQUENCY-TO-VOLTAGE CONVERTERS

electrical characteristics, $V_{CC} = 12\text{ V}$ (LM2907), $V_+ = 12\text{ V}$ through $470\ \Omega$ (LM2917), $T_A = 25\ ^\circ\text{C}$
converter (tachometer) section

| PARAMETER | | TEST CONDITIONS | LM2907 | | | LM2917 | | | UNIT |
|-----------|-----------------------------------|--|---|----------|----------|-------------|----------|----------|---------------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| V_T | Input threshold voltage | $V_I = 250\text{ mV}$, $f = 1\text{ kHz}$ | ± 10 | ± 15 | ± 40 | ± 10 | ± 15 | ± 40 | mV |
| V_{hys} | Input hysteresis (see Note 1) | $V_I = 250\text{ mV}$, $f = 1\text{ kHz}$ | 30 | | | 30 | | | mV |
| V_{IO} | Input offset voltage (see Note 1) | 8-pin versions | $V_I = 250\text{ mV}$, $f = 1\text{ kHz}$ | | | 5 15 | | | mV |
| | | 14-pin versions | $V_{ID} = 250\text{ mV}$, $f = 1\text{ kHz}$ | | | 3.5 10 | | | |
| I_B | Input bias current | $V_I = \pm 50\text{ mV}$ | 0.1 1 | | | 0.1 1 | | | μA |
| V_{OH} | High-level output voltage, CAP1 | V_I or $V_{ID} = 125\text{ mV}$ | 8.3 | | | 5.0 | | | V |
| V_{OL} | Low-level output voltage, CAP1 | V_I or $V_{ID} = -125\text{ mV}$ | 2.3 | | | 1.2 | | | V |
| I_O | Output current, CAP1, CPO | CAP1 and CPO at 6 V | 140 | 180 | 240 | | | | μA |
| | | CAP1 and CPO at 3.8 V | | | | 140 | 180 | 240 | |
| | Leakage current, CPO | CAP1 open, CPO at 0 V, See Note 3 | 0.1 | | | 0.1 | | | μA |
| | Gain constant | | 0.9 | 1 | 1.1 | 0.9 | 1 | 1.1 | |
| | Nonlinearity (see Note 2) | $f = 1\text{ kHz}$, 5 kHz , or 10 kHz | 0.3 ± 1 | | | 0.3 ± 1 | | | % |

output section

| PARAMETER | | TEST CONDITIONS | LM2907 | | | LM2917 | | | UNIT |
|---------------|--------------------------------------|-------------------------------------|---------|-----|-----|---------|-----|-----|------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| V_{IO} | Input offset voltage | $V_I = 6\text{ V}$, See Note 3 | 3 10 | | | | | | mV |
| | | $V_I = 3.8\text{ V}$, See Note 3 | | | | 3 10 | | | |
| I_B | Bias current | $V_I = 6\text{ V}$ | 50 500 | | | | | | nA |
| | | $V_I = 3.8\text{ V}$ | | | | 50 500 | | | |
| A_V | Voltage amplification | | 200 | | | 200 | | | V/mV |
| I_C | Collector output (sink) current | $V_C = 1\text{ V}$, $V_E = 0$ | 40 | 50 | | 40 | 50 | | mA |
| I_E | Emitter output (source) current | $V_C = V_{CC}$, $V_E = V_{CC} - 2$ | -10 | | | -10 | | | mA |
| $V_{CE(sat)}$ | Collector-emitter saturation voltage | $I_C = 5\text{ mA}$ | 0.1 0.5 | | | 0.1 0.5 | | | V |
| | | $I_C = 20\text{ mA}$ | 1 | | | 1 | | | |
| | | $I_C = 50\text{ mA}$ | 1 1.5 | | | 1 1.5 | | | |

- NOTES: 1. Hysteresis is the algebraic difference $V_{T+} - V_{T-}$; offset voltage is the difference in magnitudes $|V_{T+}| - |V_{T-}|$. See parameter measurement information test circuits.
 2. Nonlinearity is defined as the deviation of V_O at CPO for $f = 5\text{ kHz}$ from a straight line defined by the V_O at 1 kHz and V_O at 10 kHz, with $C1 = 1000\ \mu\text{F}$, $R1 = 68\text{ k}\Omega$, $C2 = 0.22\ \mu\text{F}$.
 3. Pin 2 must be bypassed with a $0.001\text{-}\mu\text{F}$ capacitor to prevent oscillation for these tests.

LM2907, LM2917 FREQUENCY-TO-VOLTAGE CONVERTERS

electrical characteristics

zener regulator (LM2917 only) $V_+ = 12\text{ V}$ through $470\ \Omega$, $T_A = 25^\circ\text{C}$

| PARAMETER | | MIN | TYP | MAX | UNIT |
|-----------------|---|-----|------|-----|----------------------|
| V_{CC} | Regulated supply voltage | | 7.56 | | V |
| r_s | Series resistance | | 10.5 | 15 | Ω |
| αV_{CC} | Temperature coefficient of regulated supply voltage | | 1 | | mV/ $^\circ\text{C}$ |

total device (LM2907 only) $V_{CC} = 12\text{ V}$, $T_A = 25^\circ\text{C}$

| PARAMETER | | MIN | TYP | MAX | UNIT |
|-----------|----------------|-----|-----|-----|------|
| I_{CC} | Supply current | | 3.8 | 6 | mA |

PARAMETER MEASUREMENT INFORMATION

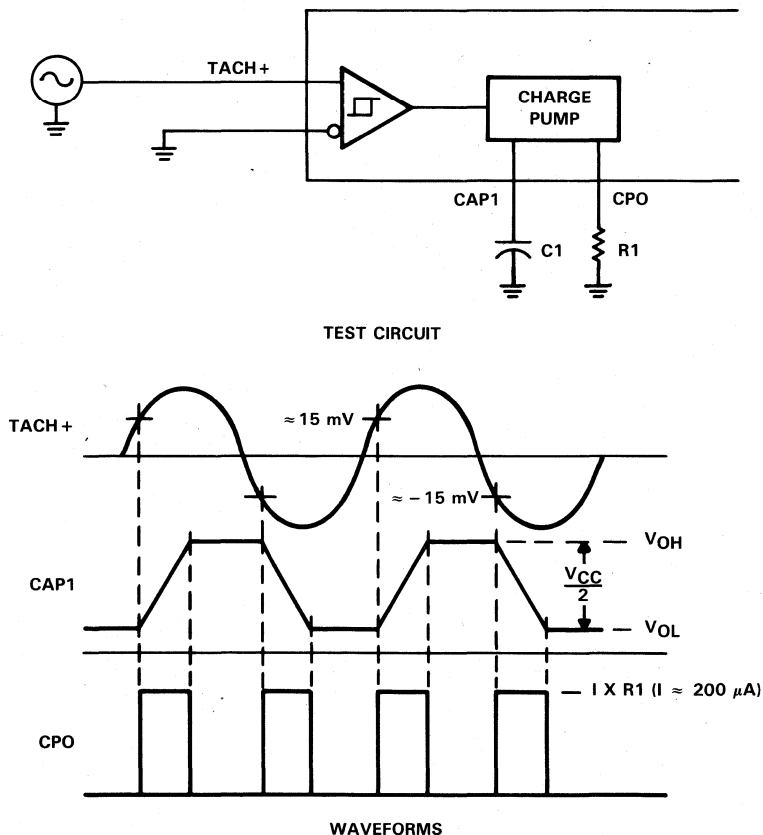


FIGURE 1. TEST CIRCUIT AND WAVEFORMS

TYPICAL APPLICATION DATA

The LM2907 and LM2917 frequency-to-voltage converter circuits are designed for maximum versatility with a minimum of external parts. The first stage of these devices is a differential comparator. The single-input 8-pin versions have one input grounded so that an input signal must swing above and below ground and exceed the input thresholds to produce an output. This version is specifically for magnetic variable-reluctance pickups, which typically provide a single-ended ac output. These single-ended inputs are fully protected against voltage swings to ± 28 V, which are easily attained by these types of pickups.

The differential-input 14-pin versions provide the option of setting the input reference level and still having hysteresis around that level to provide excellent noise rejection in any application. The input protection is removed in the 14-pin versions. Therefore, neither of the differential inputs should exceed the limits of the supply voltage. An input must not go below ground without a resistance in the lead to limit the current that will flow in the epi-substrate diode. The charge pump circuit that follows the input stage produces a dc output voltage proportional to the input frequency. The charge pump circuit (see Figure 2) consists of a timing capacitor (C1), an output resistor (R1), and an integrating or filter capacitor (C2). When the input changes state (due to a suitable zero crossing or differential voltage on the input), the timing capacitor is either charged or discharged linearly with a constant current of $200 \mu\text{A}$ through CAP1 between two voltages whose difference is $V_{CC}/2$. Within one-half cycle of the input frequency or a time equal to $1/2f$, the change in charge on C1 is equal to $(V_{CC}/2)C1$. The average amount of current pumped into or out of the capacitor is:

$$\text{CAP1 current (average)} = \frac{Q}{T} = C1 \cdot \frac{V_{CC}}{2} \cdot 2f = V_{CC} \cdot f \cdot C1$$

The output of the charge pump accurately mirrors the CAP1 current into the load resistor (R1) connected to CPO. If the pulses of current are integrated with a filter capacitor, the output voltage is the average CAP1 current times R1, and the total equation becomes:

$$V_O = V_{CC} \cdot f \cdot C1 \cdot R1 \cdot K$$

where K is the gain factor, which is typically 1.

The size of C2 is dependent only on the amount of ripple allowable and the required response time.

selection of R1, C1, and C2

To achieve optimum performance, there are some limitations to be considered in the selection of R1 and C1. The timing capacitor controls the RC time and provides internal compensation for the charge pump circuit. For very accurate operation it should be 100 pF or greater. Smaller values, especially at lower temperatures, can cause an error current through R1. $V_O/R1$ must be less than or equal to the output current at CPO, which is fixed typically at $180 \mu\text{A}$. If R1 is too large it becomes a significant fraction of the output impedance at CPO, which degrades the linearity. In addition, ripple voltage must be considered when selecting R1. The size of C2 is directly affected by the size of R1. An expression that describes the ripple content at CPO is:

$$V_{\text{ripple}} = \frac{V_{CC}}{2} \cdot \frac{C1}{C2} \cdot (1 - V_{CC} \cdot f \cdot \frac{C1}{200}) \quad \text{volts peak-to-peak}$$

where

- C1 and C2 are in farads
- V_{CC} is in volts
- f is in hertz.

TYPICAL APPLICATION DATA

R1 cannot be chosen independently of ripple because response time or the time it takes V_O to stabilize at a new level increases as the size of C2 increases. A compromise between ripple, response time, and linearity must be chosen carefully. As a final consideration, the maximum attainable input frequency is determined by V_{CC} , C1, and I_{cap} (current through CAP1).

$$f_{max} = \frac{I_{cap}}{C1 \cdot V_{CC}} \quad \text{hertz}$$

where

I_{cap} is typically 200 μA
 C1 is in farads
 V_{CC} is in volts.

zener regulator options (LM2917)

For those applications in which an output voltage or current must be obtained independently of supply voltage variations, the LM2917 can be used. The most important factor in selecting a dropping resistor for the unregulated supply is that the frequency-to-voltage converter circuit and the operational amplifier alone require approximately 3 mA at the voltage level set by the zener diode. At low supply voltages there must be some current flowing in the resistor above the 3 mA circuit current to operate the regulator. As an example, if the supply voltage varies between 9 and 16 V, a resistance of 470 Ω will minimize the zener voltage variation to typically 160 mV. If the resistance goes under 400 Ω or above 600 Ω , the zener variation quickly rises above 200 mV for the same input variation.

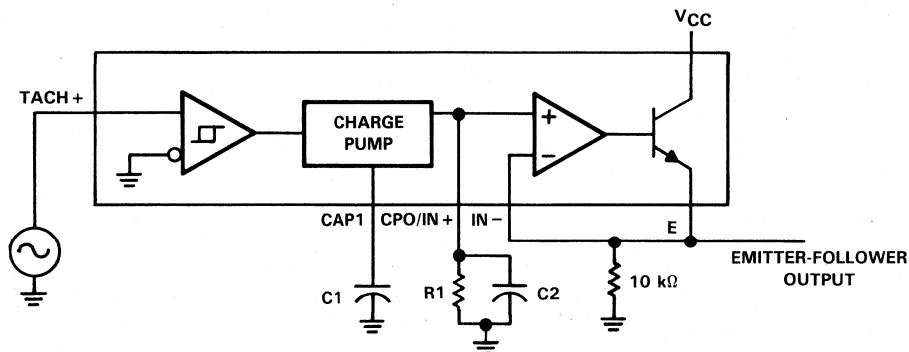


FIGURE 2. MINIMUM-COMPONENT TACHOMETER

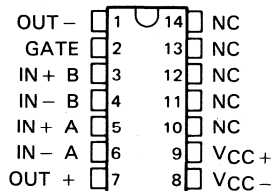
MC1445

GATE-CONTROLLED 2-CHANNEL-INPUT VIDEO AMPLIFIER

D2572, JANUARY 1980—REVISED APRIL 1988

- Differential Inputs and Outputs
- Channel Select Time . . . 20 ns Typ
- Bandwidth Typically 50 MHz
- 16-dB Minimum Gain
- Common-Mode Rejection Typically 85 dB
- Broadband Noise Typically 25 μ V

J OR N DUAL-IN-LINE PACKAGE
(TOP VIEW)



NC—No internal connection

FUNCTION TABLE

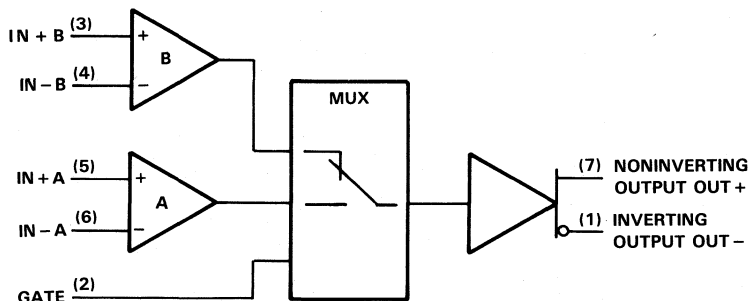
| GATE INPUT | SELECT |
|------------|-----------|
| H | Channel A |
| L | Channel B |

description

The MC1445 is a general-purpose, gated, dual-channel wideband amplifier designed for use in video-signal mixing and switching. Channel selection is accomplished by control of the voltage level at the gate. A high logic level selects channel A; a low logic level selects channel B. The unselected channel will have a gain of one or less.

The MC1445 is characterized for operation from 0°C to 75°C.

block diagram



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|------------------------------|
| Supply voltage, V_{CC+} (see Note 1) | 12 V |
| Supply voltage, V_{CC-} (see Note 1) | -12 V |
| Differential input voltage, V_{ID} (see Note 2) | ± 5 V |
| Output current, I_O | ± 25 mA |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature | 0°C to 75°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package | 300°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: N package | 260°C |

- NOTES: 1. Voltage values, except differential input voltage, are with respect to the midpoint of V_{CC+} and V_{CC-} .
 2. Differential input voltages are measured at a noninverting input terminal with respect to the appropriate inverting input terminal.

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MC1445 GATE-CONTROLLED 2-CHANNEL-INPUT VIDEO AMPLIFIER

DISSIPATION RATING TABLE

| PACKAGE | T _A ≤ 25°C POWER RATING | DERATING FACTOR | DERATE ABOVE T _A | T _A = 75°C POWER RATING |
|---------|---------------------------------------|--------------------|--------------------------------|---------------------------------------|
| J | 626 mW | 8.2 mW/°C | 74°C | 615 mW |
| N | 625 mW | N/A | N/A | 625 mW |

recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|--|-----|-----|-----|------|
| Supply voltage, V _{CC+} | | 5 | 8 | V |
| Supply voltage, V _{CC-} | | -5 | -8 | V |
| Operating free-air temperature range, T _A | 0 | | 75 | °C |

electrical characteristics at V_{CC+} = 5 V, V_{CC-} = -5 V, T_A = 25°C

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|------------------|--|-----|-------|-----|------|
| A _{VS} | Large-signal single-ended voltage amplification f = 125 kHz, V _i = 20 mV | 16 | 19.5 | 23 | dB |
| BW | Bandwidth V _i = 20 mV | | 50 | | MHz |
| V _{IO} | Input offset voltage | | | 7.5 | mV |
| I _{IO} | Input offset current | | 2 | | μA |
| I _{IB} | Input bias current | | 15 | 30 | μA |
| V _{ICR} | Common-mode voltage range | | ± 2.5 | | V |
| V _{OQ} | Quiescent output voltage | | 0.1 | | V |
| ΔV _{OQ} | Change in quiescent output voltage Gate input change from 5 V to 0 V | | ± 15 | | mV |
| V _{OPP} | Maximum peak-to-peak output voltage swing f = 125 kHz, R _L = 1 kΩ | 1.5 | 2.5 | | V |
| z _i | Input impedance f = 125 kHz | 3 | 10 | | kΩ |
| z _o | Output impedance f = 50 kHz | | 25 | | Ω |
| CMRR | Common-mode rejection ratio f = 50 kHz | | 85 | | dB |
| V _n | Broadband equivalent input noise voltage BW = 5 Hz to 10 MHz, R _S = 50 Ω | | 25 | | μV |
| V _{TH} | High-level gate threshold voltage A _{VS(A)} ≥ 16 dB, A _{VS(B)} ≤ 0 dB | | 1.3 | 3 | V |
| V _{TL} | Low-level gate threshold voltage A _{VS(B)} ≥ 16 dB, A _{VS(A)} ≤ 0 dB | 0.2 | 0.4 | | V |
| I _{IH} | High-level gate current V _I = 5 V | | | 4 | μA |
| I _{IL} | Low-level gate current V _I = 0 | | | 4 | mA |
| t _{PLH} | Propagation delay time, low-to-high-level output ΔV _I = 20 mV, 50% to 50% | | 6.5 | | ns |
| t _{PHL} | Propagation delay time, high-to-low-level output ΔV _I = 20 mV, 50% to 50% | | 6.3 | | ns |
| t _{TLH} | Transition time, low-to-high-level output ΔV _I = 20 mV, 10% to 90% | | 6.5 | | ns |
| t _{THL} | Transition time, high-to-low-level output ΔV _I = 20 mV, 10% to 90% | | 7 | | ns |
| I _{CC+} | Supply current from V _{CC+} No load, No signal | | 7 | 15 | mA |
| I _{CC-} | Supply current from V _{CC-} No load, No signal | | -7 | -15 | mA |
| P _D | Power dissipation No load, No signal | | 70 | 150 | mW |

NE555, NE555Y, SA555, SE555, SE555C PRECISION TIMERS

D1669, SEPTEMBER 1973—REVISED FEBRUARY 1992

- Timing From Microseconds to Hours
- Astable or Monostable Operation
- Adjustable Duty Cycle
- TTL-Compatible Output Can Sink or Source up to 200 mA
- Functionally Interchangeable With the Signetics NE555, SA555, SE555, SE555C; Have Same Pinout

SE555C FROM TI IS NOT RECOMMENDED FOR NEW DESIGNS

description

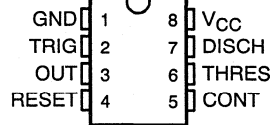
These devices are precision monolithic timing circuits capable of producing accurate time delays or oscillation. In the time-delay or monostable mode of operation, the timed interval is controlled by a single external resistor and capacitor network. In the astable mode of operation, the frequency and duty cycle may be independently controlled with two external resistors and a single external capacitor.

The threshold and trigger levels are normally two-thirds and one-third, respectively, of V_{CC} . These levels can be altered by use of the control voltage terminal. When the trigger input falls below the trigger level, the flip-flop is set and the output goes high. If the trigger input is above the trigger level and the threshold input is above the threshold level, the flip-flop is reset and the output is low. RESET can override all other inputs and can be used to initiate a new timing cycle. When RESET goes low, the flip-flop is reset and the output goes low. Whenever the output is low, a low-impedance path is provided between DISCH and ground.

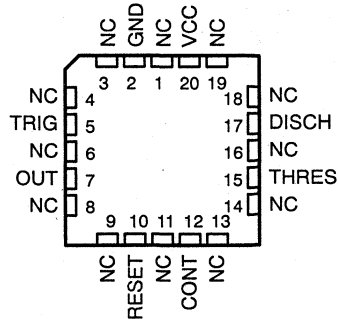
The output circuit is capable of sinking or sourcing current up to 200 mA. Operation is specified for supplies of 5 V to 15 V. With a 5-V supply, output levels are compatible with TTL inputs.

The NE555 is characterized for operation from 0°C to 70°C. The SA555 is characterized for operation from -40°C to 85°C. The SE555 and SE555C are characterized for operation over the full military range of -55°C to 125°C.

D, JG, OR P PACKAGE
(TOP VIEW)



FK PACKAGE
(TOP VIEW)



NC—No internal connection

AVAILABLE OPTIONS

| T _A | PACKAGE | | | | | CHIP FORM (Y) |
|----------------|--|-------------------|-------------------|-----------------|-----------------|---------------|
| | V _{THRES} max V _{CC} = 15 V | SMALL OUTLINE (D) | CHIP CARRIER (FK) | CERAMIC DIP (J) | PLASTIC DIP (P) | |
| 0°C to 70°C | 11.2 V | NE555D | | | NE555P | NE555Y |
| -40°C to 85°C | 11.2 V | SA555D | | | SA555P | |
| -55°C to 125°C | 10.6 V | SE555D | SE555FK | SE555JG | SE555P | |
| | 11.2 V | SE555CD | SE555CFK | SE555CJG | SE555CP | |

The D package is available taped and reeled. Add the suffix R to the device type (e.g., NE555DR).

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.



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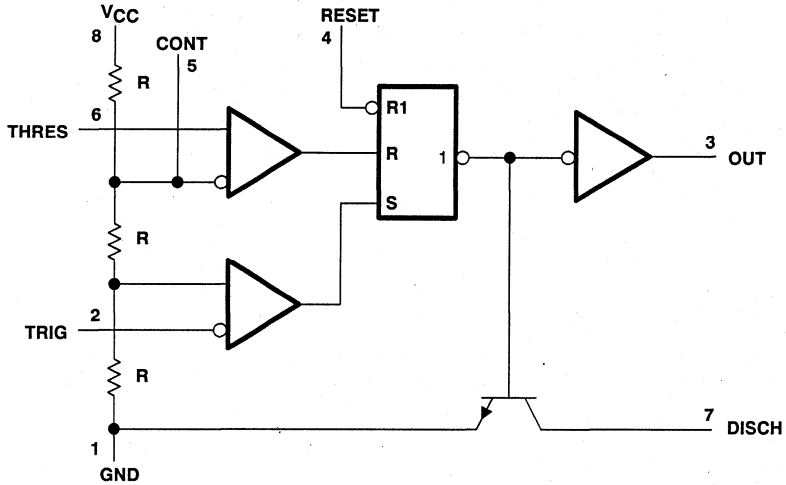
NE555, NE555Y, SA555, SE555, SE555C PRECISION TIMERS

FUNCTION TABLE

| RESET | TRIGGER VOLTAGE† | THRESHOLD VOLTAGE† | OUTPUT | DISCHARGE SWITCH |
|-------|------------------|--------------------|---------------------------|------------------|
| Low | Irrelevant | Irrelevant | Low | On |
| High | $< 1/3 V_{DD}$ | Irrelevant | High | Off |
| High | $> 1/3 V_{DD}$ | $> 2/3 V_{DD}$ | Low | On |
| High | $> 1/3 V_{DD}$ | $< 2/3 V_{DD}$ | As previously established | |

† Voltage levels shown are nominal.

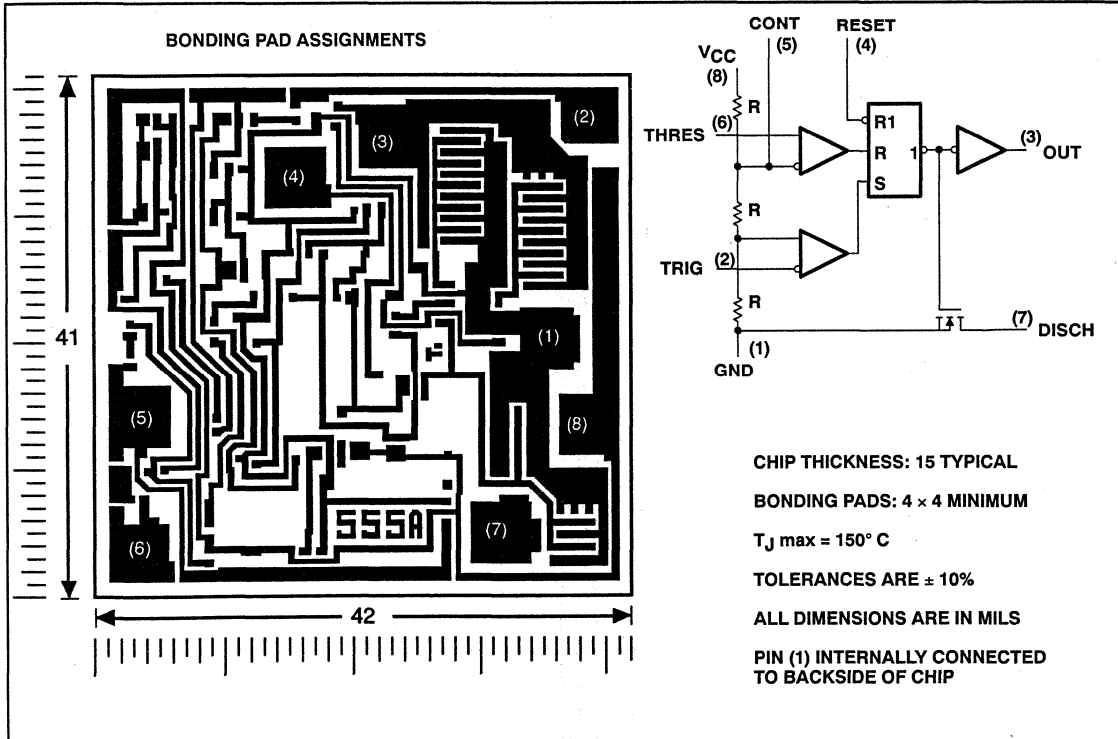
functional block diagram



RESET can override TRIG, which can override THRES.
Pin numbers shown are for the D, JG, and P packages only.

chip information

These chips, properly assembled, display characteristics similar to the NE555 (see electrical table for NE555Y). Thermal compression or ultrasonic bonding may be used on the doped aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



NE555, SA555, SE555, SE555C PRECISION TIMERS

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Supply voltage, V_{CC} (See Note 1) | 18 V |
| Input voltage (CONT, RESET, THRES, and TRIG) | V_{CC} |
| Output current | ± 225 mA |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range: NE555 | 0°C to 70°C |
| SA555 | -40°C to 85°C |
| SE555, SE555C | -55°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package | 300°C |

NOTE 1: All voltage values are with respect to network ground terminal.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$ | $T_A = 70^\circ\text{C}$ POWER RATING | $T_A = 85^\circ\text{C}$ POWER RATING | $T_A = 125^\circ\text{C}$ POWER RATING |
|--------------------|---|---|--|--|---|
| D | 725 mW | 5.8 mW/°C | 464 mW | 377 mW | N/A |
| FK | 1375 mW | 11.0 mW/°C | 880 mW | 715 mW | 275 mW |
| JG (SE555, SE555C) | 1050 mW | 8.4 mW/°C | 672 mW | 546 mW | 210 mW |
| JG (SA555, NE555C) | 825 mW | 6.6 mW/°C | 528 mW | 429 mW | N/A |
| P | 1000 mW | 8.0 mW/°C | 640 mW | 520 mW | N/A |

recommended operating conditions

| | NE555 | | SA555 | | SE555 | | SE555C | | UNIT |
|--|-----------|-----|-----------|-----|-----------|-----|-----------|-----|------|
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | |
| Supply voltage, V_{CC} | 4.5 | 16 | 4.5 | 16 | 4.5 | 18 | 4.5 | 16 | V |
| Input voltage (CONT, RESET, THRES, and TRIG) | V_{CC} | | V_{CC} | | V_{CC} | | V_{CC} | | V |
| Output current | ± 200 | | ± 200 | | ± 200 | | ± 200 | | mA |
| Operating free-air temperature, T_A | 0 | 70 | -40 | 85 | -55 | 125 | -55 | 125 | °C |

NE555, SA555, SE555, SE555C PRECISION TIMERS

electrical characteristics, $V_{CC} = 5\text{ V to }15\text{ V}$, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | | SE555 | | | NE555, SA555, SE555C | | | UNIT |
|--------------------------------|------------------------|---------------------------|-------|------|------|----------------------|------|------|---------------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| THRES voltage level | $V_{CC} = 15\text{ V}$ | | 9.4 | 10 | 10.6 | 8.8 | 10 | 11.2 | V |
| | $V_{CC} = 5\text{ V}$ | | 2.7 | 3.3 | 4 | 2.4 | 3.3 | 4.2 | |
| THRES current (see Note 2) | | | | 30 | 250 | | 30 | 250 | nA |
| TRIG voltage level | $V_{CC} = 15\text{ V}$ | | 4.8 | 5 | 5.2 | 4.5 | 5 | 5.6 | V |
| | $V_{CC} = 5\text{ V}$ | | 1.45 | 1.67 | 1.9 | 1.1 | 1.67 | 2.2 | |
| TRIG current | TRIG at 0 V | | | 0.5 | 0.9 | | 0.5 | 2 | μA |
| RESET voltage level | | | 0.3 | 0.7 | 1 | 0.3 | 0.7 | 1 | V |
| RESET current | RESET at V_{CC} | | | 0.1 | 0.4 | | 0.1 | 0.4 | mA |
| | RESET at 0 V | | | -0.4 | -1 | | -0.4 | -1.5 | |
| DISCH switch off-state current | | | | 20 | 100 | | 20 | 100 | nA |
| CONT voltage (open circuit) | $V_{CC} = 15\text{ V}$ | | 9.6 | 10 | 10.4 | 9 | 10 | 11 | V |
| | $V_{CC} = 5\text{ V}$ | | 2.9 | 3.3 | 3.8 | 2.6 | 3.3 | 4 | |
| Low-level output voltage | $V_{CC} = 15\text{ V}$ | $I_{OL} = 10\text{ mA}$ | | 0.1 | 0.15 | | 0.1 | 0.25 | V |
| | | $I_{OL} = 50\text{ mA}$ | | 0.4 | 0.5 | | 0.4 | 0.75 | |
| | | $I_{OL} = 100\text{ mA}$ | | 2 | 2.2 | | 2 | 2.5 | |
| | | $I_{OL} = 200\text{ mA}$ | | 2.5 | | | 2.5 | | |
| | $V_{CC} = 5\text{ V}$ | $I_{OL} = 5\text{ mA}$ | | 0.1 | 0.2 | | 0.1 | 0.35 | |
| | | $I_{OL} = 8\text{ mA}$ | | 0.15 | 0.25 | | 0.15 | 0.4 | |
| High-level output voltage | $V_{CC} = 15\text{ V}$ | $I_{OH} = -100\text{ mA}$ | 13 | 13.3 | | 12.75 | 13.3 | V | |
| | | $I_{OH} = -200\text{ mA}$ | | 12.5 | | 12.5 | | | |
| | $V_{CC} = 5\text{ V}$ | $I_{OH} = -100\text{ mA}$ | 3 | 3.3 | | 2.75 | 3.3 | | |
| Supply current | Output low, No load | $V_{CC} = 15\text{ V}$ | | 10 | 12 | | 10 | 15 | mA |
| | | $V_{CC} = 5\text{ V}$ | | 3 | 5 | | 3 | 6 | |
| | Output high, No load | $V_{CC} = 15\text{ V}$ | | 9 | 10 | | 9 | 13 | |
| | | $V_{CC} = 5\text{ V}$ | | 2 | 4 | | 2 | 5 | |

NOTE 2: This parameter influences the maximum value of the timing resistors R_A and R_B in the circuit of Figure 12. For example, when $V_{CC} = 5\text{ V}$, the maximum value is $R = R_A + R_B = 3.4\text{ M}\Omega$, and for $V_{CC} = 15\text{ V}$, the maximum value is $10\text{ M}\Omega$.

operating characteristics, $V_{CC} = 5\text{ V}$ and 15 V

| PARAMETER | | TEST CONDITIONS† | SE555 | | | NE555, SA555, SE555C | | | UNIT |
|---|-------------------------|--|-------|------|-------|----------------------|-----|--------|------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| Initial error of timing interval‡ | Each timer, monostable§ | $T_A = 25^\circ\text{C}$ | 0.5% | 1.5% | | 1% | 3% | | |
| | Each timer, astable¶ | | 1.5% | | 2.25% | | | | |
| Temperature coefficient of timing interval | Each timer, monostable§ | $T_A = \text{MIN to MAX}$ | 30 | 100 | | 50 | | ppm/°C | |
| | Each timer, astable¶ | | 90 | | 150 | | | | |
| Supply voltage sensitivity of timing interval | Each timer, monostable§ | $T_A = 25^\circ\text{C}$ | 0.05 | 0.2 | | 0.1 | 0.5 | %V | |
| | Each timer, astable¶ | | 0.15 | | 0.3 | | | | |
| Output pulse rise time | | $C_L = 15\text{ pF}$, $T_A = 25^\circ\text{C}$ | 100 | 200 | | 100 | 300 | ns | |
| Output pulse fall time | | | 100 | 200 | | 100 | 300 | | |

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

‡ Timing interval error is defined as the difference between the measured value and the average value of a random sample from each process run.

§ Values specified are for a device in a monostable circuit similar to Figure 9, with component values as follow: $R_A = 2\text{ k}\Omega$ to $100\text{ k}\Omega$, $C = 0.1\text{ }\mu\text{F}$.

¶ Values specified are for a device in an astable circuit similar to Figure 12, with component values as follow: $R_A = 1\text{ k}\Omega$ to $100\text{ k}\Omega$, $C = 0.1\text{ }\mu\text{F}$.



NE555Y PRECISION TIMERS

electrical characteristics, $V_{CC} = 5\text{ V to }15\text{ V}$, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|--------------------------------|------------------------|---------------------------|-------|------|------|---------------|
| THRES voltage level | $V_{CC} = 15\text{ V}$ | | 8.8 | 10 | 11.2 | V |
| | $V_{CC} = 5\text{ V}$ | | 2.4 | 3.3 | 4.2 | |
| THRES current (see Note 2) | | | | 30 | 250 | nA |
| TRIG voltage level | $V_{CC} = 15\text{ V}$ | | 4.5 | 5 | 5.6 | V |
| | $V_{CC} = 5\text{ V}$ | | 1.1 | 1.67 | 2.2 | |
| TRIG current | TRIG at 0 V | | | 0.5 | 2 | μA |
| RESET voltage level | | | 0.3 | 0.7 | 1 | V |
| RESET current | RESET at V_{CC} | | | 0.1 | 0.4 | mA |
| | RESET at 0 V | | | -0.4 | -1.5 | |
| DISCH switch off-state current | | | | 20 | 100 | nA |
| CONT voltage (open circuit) | $V_{CC} = 15\text{ V}$ | | 9 | 10 | 11 | V |
| | $V_{CC} = 5\text{ V}$ | | 2.6 | 3.3 | 4 | |
| Low-level output voltage | $V_{CC} = 15\text{ V}$ | $I_{OL} = 10\text{ mA}$ | | 0.1 | 0.25 | V |
| | | $I_{OL} = 50\text{ mA}$ | | 0.4 | 0.75 | |
| | | $I_{OL} = 100\text{ mA}$ | | 2 | 2.5 | |
| | | $I_{OL} = 200\text{ mA}$ | | 2.5 | | |
| | $V_{CC} = 5\text{ V}$ | $I_{OL} = 5\text{ mA}$ | | 0.1 | 0.35 | |
| | | $I_{OL} = 8\text{ mA}$ | | 0.15 | 0.4 | |
| High-level output voltage | $V_{CC} = 15\text{ V}$ | $I_{OH} = -100\text{ mA}$ | 12.75 | 13.3 | V | |
| | | $I_{OH} = -200\text{ mA}$ | | 12.5 | | |
| | $V_{CC} = 5\text{ V}$ | $I_{OH} = -100\text{ mA}$ | 2.75 | 3.3 | | |
| | | | | | | |
| Supply current | Output low, No load | $V_{CC} = 15\text{ V}$ | | 10 | 15 | mA |
| | | $V_{CC} = 5\text{ V}$ | | 3 | 6 | |
| | Output high, No load | $V_{CC} = 15\text{ V}$ | | 9 | 13 | |
| | | $V_{CC} = 5\text{ V}$ | | 2 | 5 | |

NOTE 2: This parameter influences the maximum value of the timing resistors R_A and R_B in the circuit of Figure 12. For example, when $V_{CC} = 5\text{ V}$, the maximum value is $R = R_A + R_B = 3.4\text{ M}\Omega$, and for $V_{CC} = 15\text{ V}$, the maximum value is $10\text{ M}\Omega$.

operating characteristics, $V_{CC} = 5\text{ V and }15\text{ V}$, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|-------------------------|-----|-------|-----|------|
| Initial error of timing interval† | Each timer, monostable‡ | | 1% | 3% | |
| | Each timer, astable§ | | 2.25% | | |
| Supply voltage sensitivity of timing interval | Each timer, monostable‡ | | 0.1 | 0.5 | %V |
| | Each timer, astable§ | | 0.3 | | |
| Output pulse rise time | $C_L = 15\text{ pF}$ | | 100 | 300 | ns |
| Output pulse fall time | | | 100 | 300 | |

† Timing interval error is defined as the difference between the measured value and the average value of a random sample from each process run.

‡ Values specified are for a device in a monostable circuit similar to Figure 9, with component values as follow: $R_A = 2\text{ k}\Omega$ to $100\text{ k}\Omega$, $C = 0.1\text{ }\mu\text{F}$.

§ Values specified are for a device in an astable circuit similar to Figure 12, with component values as follow: $R_A = 1\text{ k}\Omega$ to $100\text{ k}\Omega$, $C = 0.1\text{ }\mu\text{F}$.

TYPICAL CHARACTERISTICS†

LOW-LEVEL OUTPUT VOLTAGE
vs
LOW-LEVEL OUTPUT CURRENT

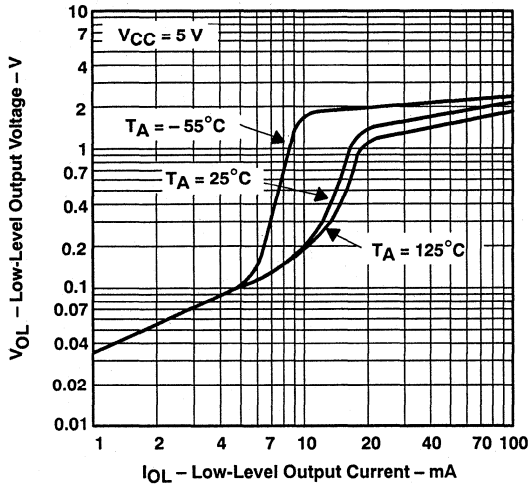


Figure 1

LOW-LEVEL OUTPUT VOLTAGE
vs
LOW-LEVEL OUTPUT CURRENT

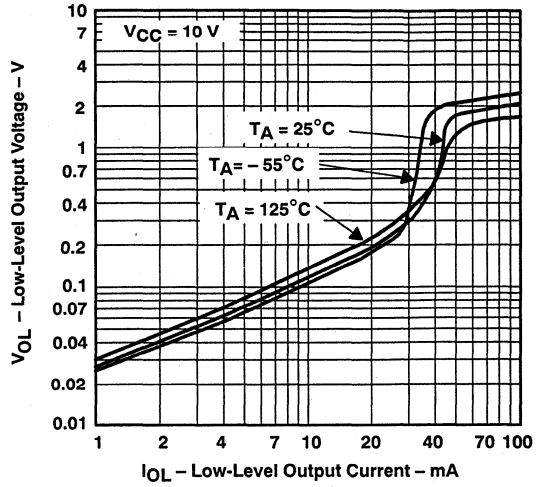


Figure 2

LOW-LEVEL OUTPUT VOLTAGE
vs
LOW-LEVEL OUTPUT CURRENT

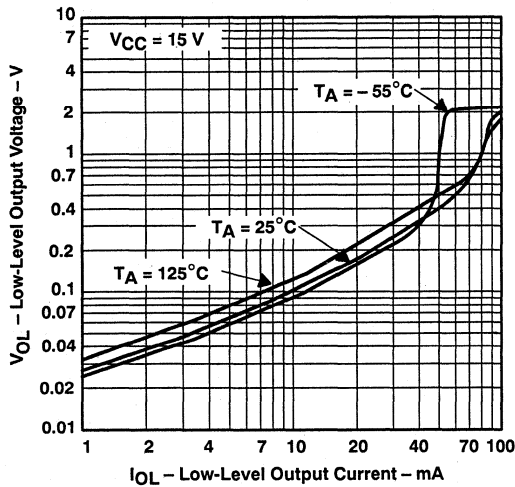


Figure 3

DROP BETWEEN SUPPLY VOLTAGE AND OUTPUT
vs
HIGH-LEVEL OUTPUT CURRENT

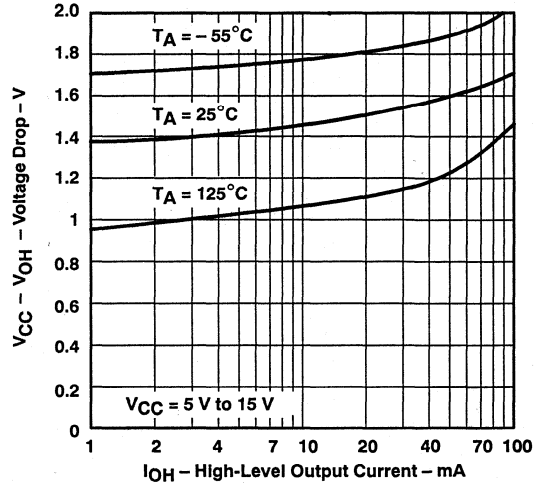


Figure 4

† Data for temperatures below 0°C and above 70°C are applicable for SE555 circuits only.

TYPICAL CHARACTERISTICS†

SUPPLY CURRENT
vs
SUPPLY VOLTAGE

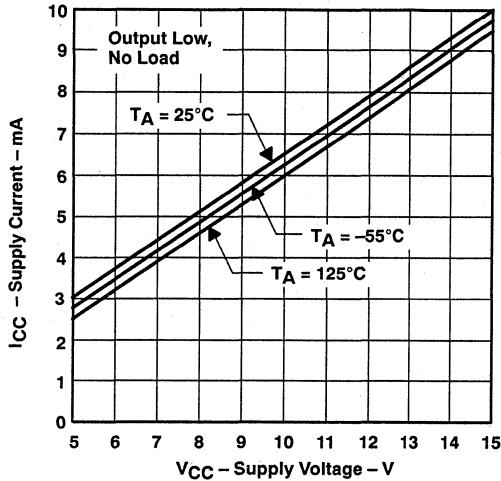


Figure 5

NORMALIZED OUTPUT PULSE DURATION
(MONOSTABLE OPERATION)
vs
SUPPLY VOLTAGE

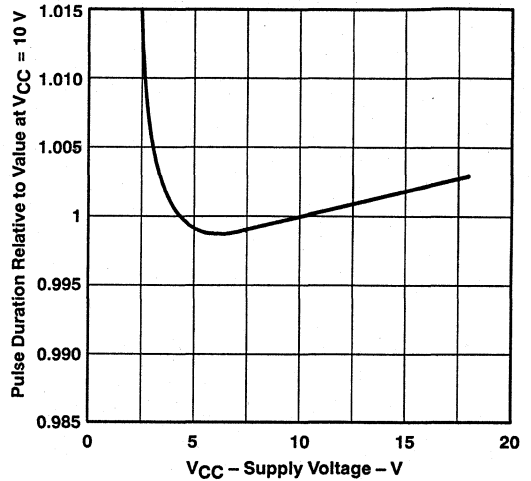


Figure 6

NORMALIZED OUTPUT PULSE DURATION
(MONOSTABLE OPERATION)
vs
FREE-AIR TEMPERATURE

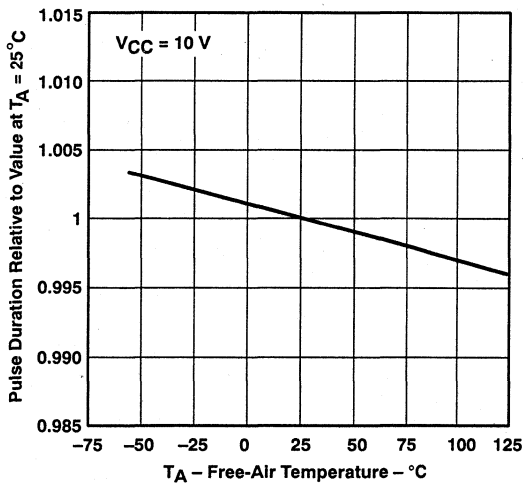


Figure 7

PROPAGATION DELAY TIME
vs
LOWEST VOLTAGE LEVEL
OF TRIGGER PULSE

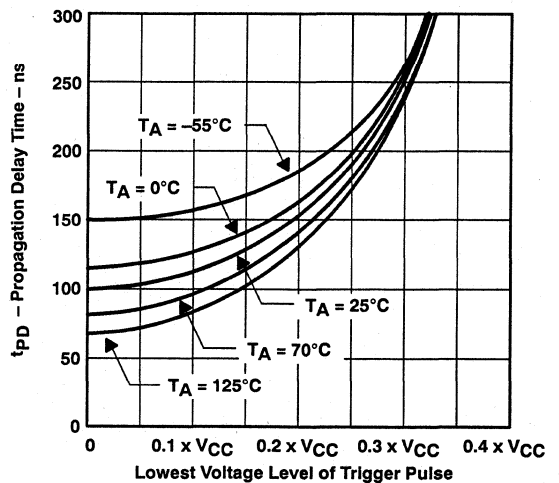


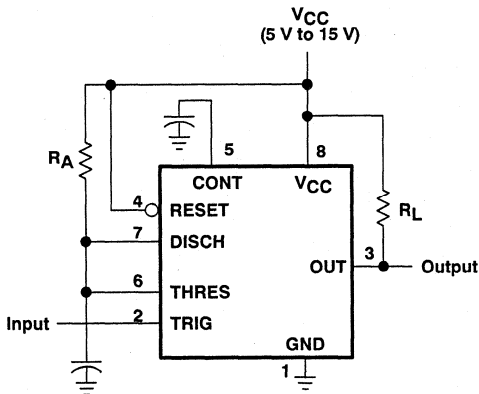
Figure 8

† Data for temperatures below 0°C and above 70°C are applicable for SE555 circuits only.

APPLICATION INFORMATION

monostable operation

For monostable operation, any of these timers may be connected as shown in Figure 9. If the output is low, application of a negative-going pulse to TRIG sets the flip-flop (\bar{Q} goes low), drives the output high, and turns off Q1. Capacitor C is then charged through R_A until the voltage across the capacitor reaches the threshold voltage of THRES input. If TRIG has returned to a high level, the output of the threshold comparator will reset the flip-flop (\bar{Q} goes high), drive the output low, and discharge C through Q1.



Pin numbers shown are for the D, JG, and P packages.

Figure 9. Circuit for Monostable Operation

Monostable operation is initiated when TRIG voltage falls below the trigger threshold. Once initiated, the sequence ends only if TRIG is high at the end of the timing interval. Because of the threshold level and saturation voltage of Q1, the output pulse duration is approximately $t_w = 1.1R_A C$. Figure 11 is a plot of the time constant for various values of R_A and C. The threshold levels and charge rates are both directly proportional to the supply voltage, V_{CC} . The timing interval is therefore independent of the supply voltage, so long as the supply voltage is constant during the time interval.

Applying a negative-going trigger pulse simultaneously to RESET and TRIG during the timing interval discharges C and re-initiates the cycle, commencing on the positive edge of the reset pulse. The output is held low as long as the reset pulse is low. To prevent false triggering, when RESET is not used, it should be connected to V_{CC} .

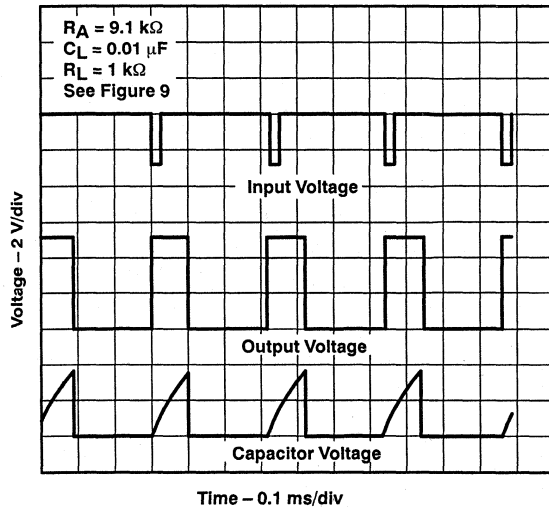


Figure 10. Typical Monostable Waveforms

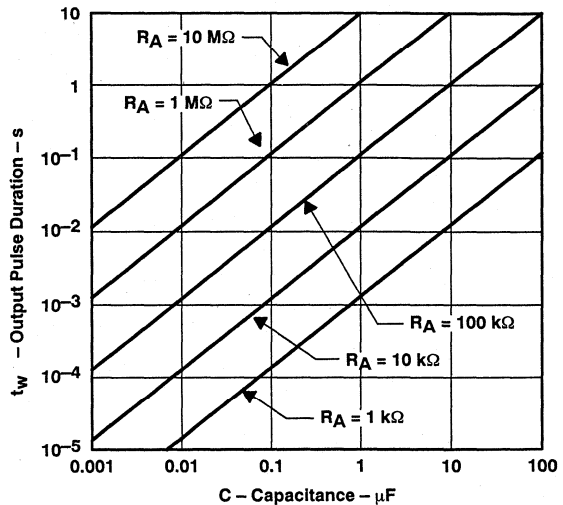


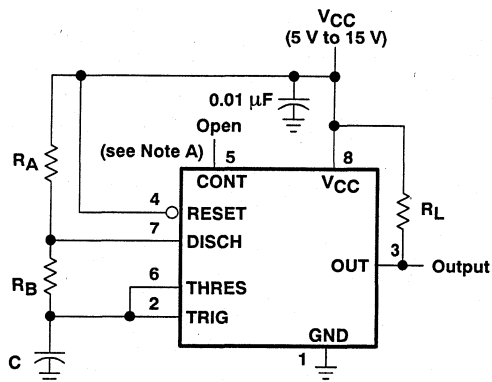
Figure 11. Output Pulse Duration vs Capacitance

APPLICATION INFORMATION

astable operation

As shown in Figure 12, adding a second resistor, R_B , to the circuit of Figure 9 and connecting the trigger input to the threshold input causes the timer to self-trigger and run as a multivibrator. The capacitor C will charge through R_A and R_B and then discharge through R_B only. The duty cycle may be controlled, therefore, by the values of R_A and R_B .

This astable connection results in capacitor C charging and discharging between the threshold-voltage level ($\approx 0.67 \cdot V_{CC}$) and the trigger-voltage level ($\approx 0.33 \cdot V_{CC}$). As in the monostable circuit, charge and discharge times (and therefore the frequency and duty cycle) are independent of the supply voltage.



Pin numbrs shown are for the D, JG, and P packages.
NOTE A: Decoupling CONT voltage to ground with a capacitor may improve operation. This should be evaluated for individual applications.

Figure 12. Circuit for Astable Operation

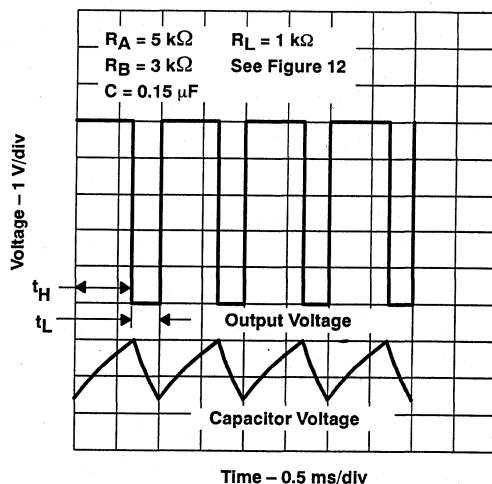


Figure 13. Typical Astable Waveforms

APPLICATION INFORMATION

Figure 13 shows typical waveforms generated during astable operation. The output high-level duration t_H and low-level duration t_L may be calculated as follows:

$$t_H = 0.693 (R_A + R_B) C$$

$$t_L = 0.693 (R_B) C$$

Other useful relationships are shown below.

$$\text{period} = t_H + t_L = 0.693 (R_A + 2R_B) C$$

$$\text{frequency} \approx \frac{1.44}{(R_A + 2R_B) C}$$

$$\text{Output driver duty cycle} = \frac{t_L}{t_H + t_L} = \frac{R_B}{R_A + 2R_B}$$

$$\text{Output waveform duty cycle} = \frac{t_H}{t_H + t_L} = 1 - \frac{R_B}{R_A + 2R_B}$$

$$\text{Low-to-high ratio} = \frac{t_L}{t_H} = \frac{R_B}{R_A + R_B}$$

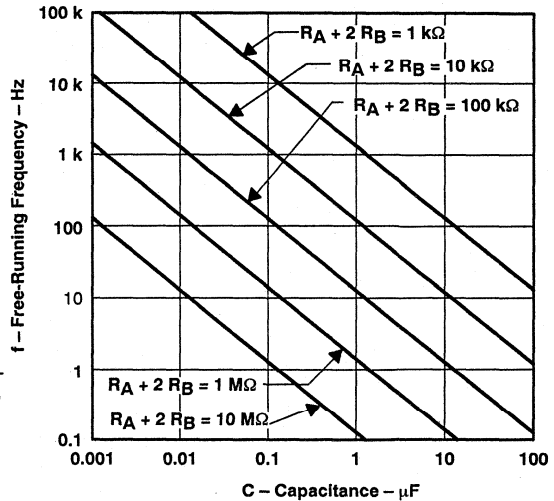
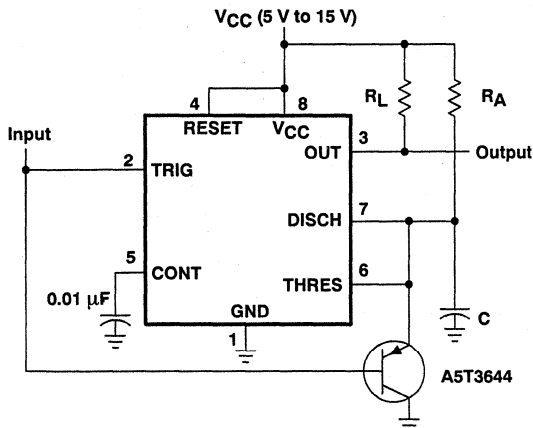


Figure 14. Free-Running Frequency

missing-pulse detector

The circuit shown in Figure 15 may be used to detect a missing pulse or abnormally long spacing between consecutive pulses in a train of pulses. The timing interval of the monostable circuit is continuously retriggered by the input pulse train as long as the pulse spacing is less than the timing interval. A longer pulse spacing, missing pulse, or terminated pulse train permits the timing interval to be completed, thereby generating an output pulse as illustrated in Figure 16.



Pin numbers shown are shown for the D, JG, and P packages.

Figure 15. Circuit for Missing-Pulse Detector

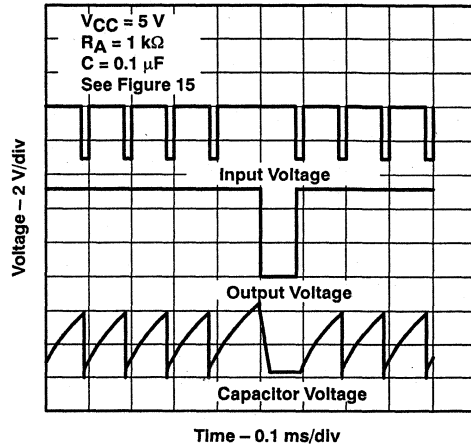


Figure 16. Missing-Pulse Detector Waveform

APPLICATION INFORMATION

frequency divider

By adjusting the length of the timing cycle, the basic circuit of Figure 9 can be made to operate as a frequency divider. Figure 17 illustrates a divide-by-three circuit that makes use of the fact that retriggering cannot occur during the timing cycle.

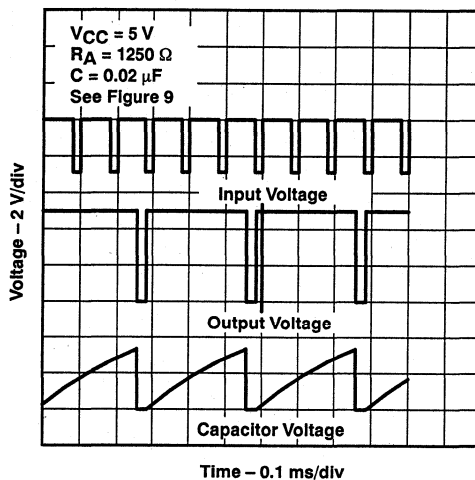
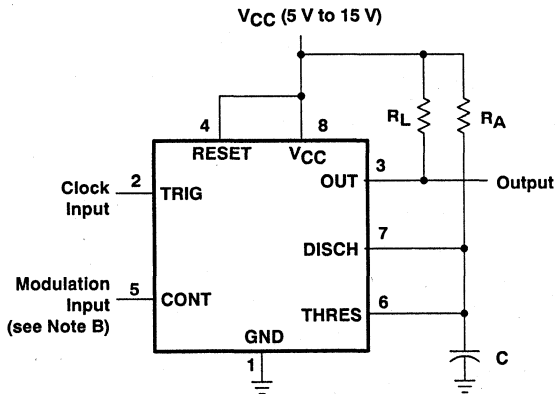


Figure 17. Divide-By-Three Circuit Waveforms

pulse-width modulation

The operation of the timer may be modified by modulating the internal threshold and trigger voltages, which is accomplished by applying an external voltage (or current) to CONT. Figure 18 shows a circuit for pulse-width modulation. A continuous input pulse train triggers the monostable circuit, and a control signal modulates the threshold voltage. Figure 19 illustrates the resulting output pulse-width modulation. While a sine-wave modulation signal is illustrated, any wave shape could be used.

APPLICATION INFORMATION



Pin numbers shown are for the D, JG, and P packages only.

NOTE B: The modulating signal may be direct or capacitively coupled to CONT. For direct coupling, the effects of modulation source voltage and impedance on the bias of the timer should be considered.

Figure 18. Circuit For Pulse-Width Modulation

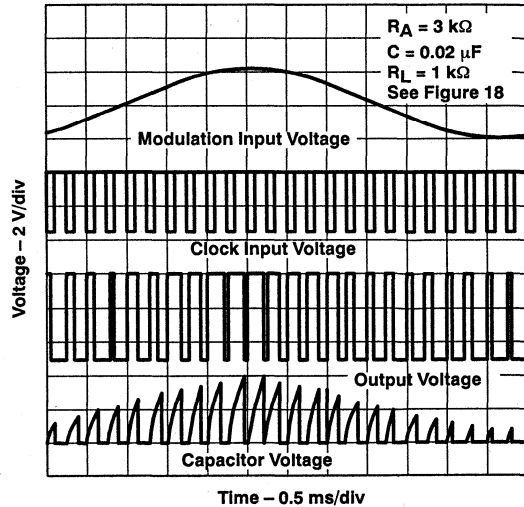
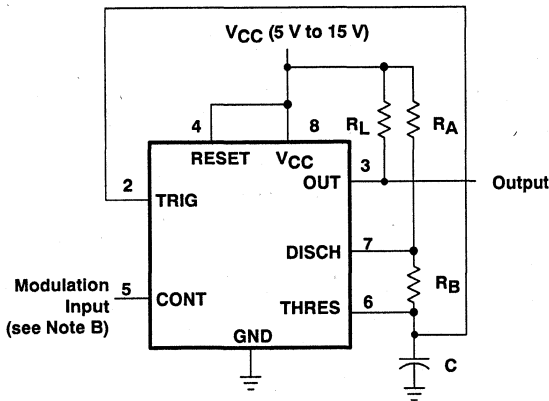


Figure 19. Pulse-Width Modulation Waveforms

pulse-position modulation

As shown in Figure 20, any of these timers may be used as a pulse-position modulator. This application modulates the threshold voltage, and thereby the time delay, of a free-running oscillator. Figure 21 illustrates a triangular-wave modulation signal for such a circuit; however, any wave shape could be used.



Pin numbers shown are for the D, JG, and P packages only.

NOTE B: The modulating signal may be direct or capacitively coupled to CONT. For direct coupling, the effects of modulation source voltage and impedance on the bias of the timer should be considered.

Figure 20. Circuit for Pulse-Position Modulation

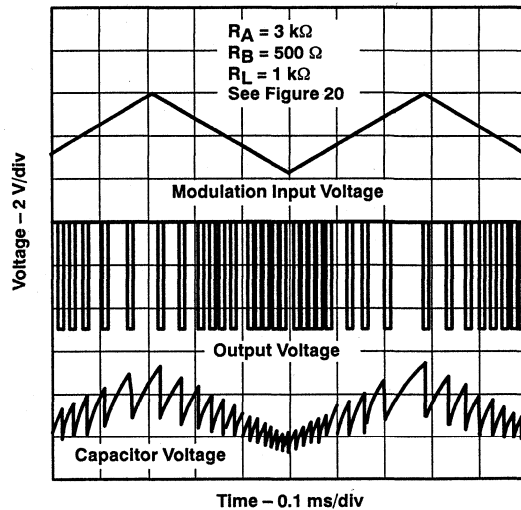
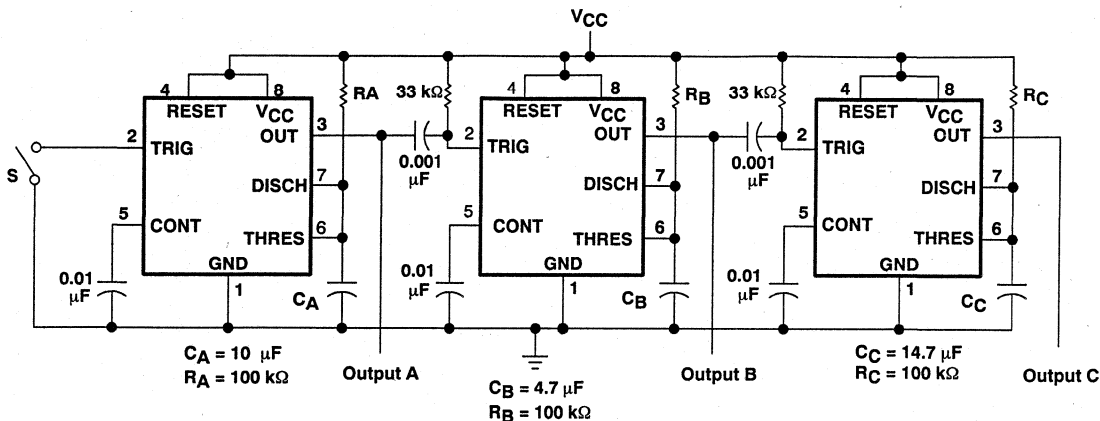


Figure 21. Pulse Position-Modulation Waveforms

APPLICATION INFORMATION

sequential timer



S closes momentarily at $t = 0$.
Pin numbers shown are for the D, JG, and P packages only.

Figure 22. Sequential Timer Circuit

Many applications, such as computers, require signals for initializing conditions during start-up. Other applications, such as test equipment, require activation of test signals in sequence. These timing circuits may be connected to provide such sequential control. The timers may be used in various combinations of astable or monostable circuit connections, with or without modulation, for extremely flexible waveform control. Figure 22 illustrates a sequencer circuit with possible applications in many systems, and Figure 23 shows the output waveforms.

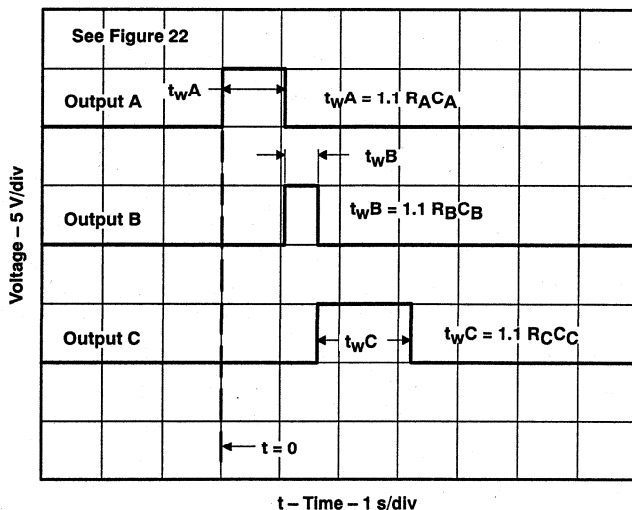


Figure 23. Sequential Timer Waveforms

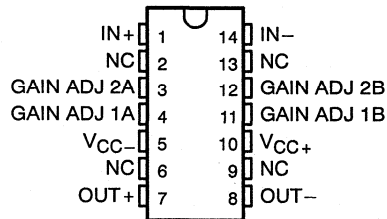
NE592, SE592 DIFFERENTIAL VIDEO AMPLIFIERS

D2667, FEBRUARY 1984—REVISED NOVEMBER 1991

- 90-MHz Bandwidth
- Adjustable Gain to 400
- No Frequency Compensation Required
- Adjustable Pass Band
- Designed to Be Interchangeable With Signetics SE592 and NE592

| DEVICE TYPE | TEMPERATURE RANGE | A _{VD} RANGE (GAIN OPTION 1) |
|-------------|-------------------|---------------------------------------|
| NE592 | 0°C to 70°C | 250–600 |
| SE592 | –55°C to 125°C | 300–500 |

NE592 . . . D OR N PACKAGE
SE592 . . . J PACKAGE
(TOP VIEW)



NC—No internal connection

description

These devices are monolithic two-stage video amplifiers with differential inputs and differential outputs.

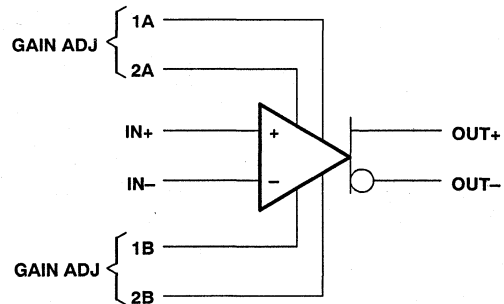
Internal series-shunt feedback provides wide bandwidth, low phase distortion, and excellent gain stability. Emitter-follower outputs enable the device to drive capacitive loads, and all stages are current-source biased to obtain high common-mode and supply-voltage rejection ratios.

Fixed differential amplification of nominally 100 or 400 may be selected without external components, or amplification may be adjusted from 0 to 400 by the use of a single external resistor connected between the gain-adjustment pins 1A and 1B. External frequency-compensating components are required for any gain option.

The devices are particularly useful in magnetic-tape or disk-file systems using phase or NRZ encoding and in high-speed thin-film or plated-wire memories. Other applications include general-purpose video and pulse amplifiers where wide bandwidth, low phase shift, and excellent gain stability are required.

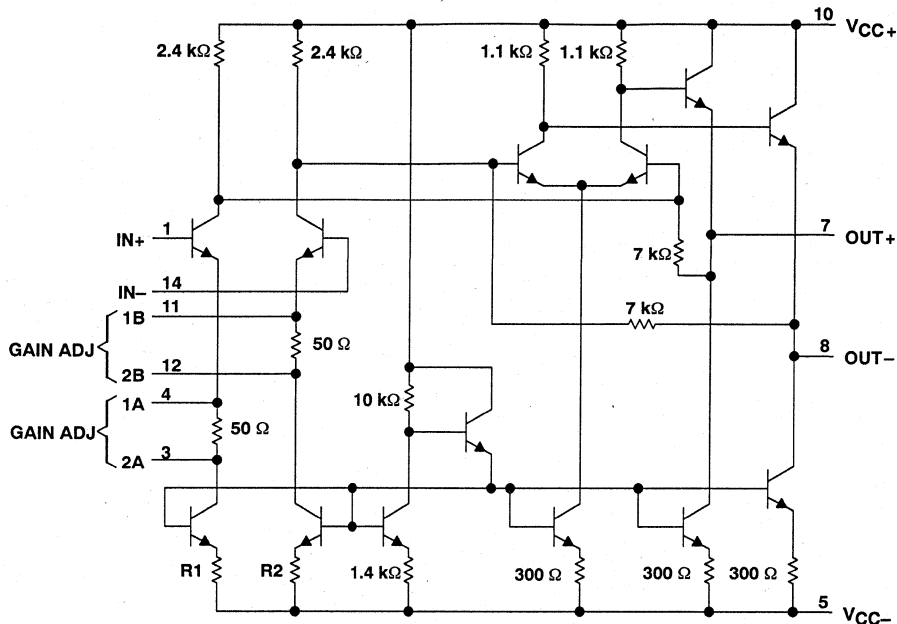
The NE592 is characterized for operation from 0°C to 70°C. The SE592 is characterized for operation over the full military temperature range of –55°C to 125°C.

symbol



NE592, SE592 DIFFERENTIAL VIDEO AMPLIFIERS

schematic



All resistor values shown are in ohms and nominal.
In NE592 or SE592, R1 = 500 Ω, R2 = 500 Ω.

absolute maximum ratings over operating free-air temperature (unless otherwise noted)

| | |
|--|------------------------------|
| Supply voltage, V_{CC+} (see Note 1) | 8 V |
| Supply voltage, V_{CC-} (see Note 1) | -8 V |
| Differential input voltage | ± 5 V |
| Common-mode input voltage | ± 6 V |
| Output current | 10 mA |
| Continuous total power dissipation | See Dissipation Rating Table |
| Operating free-air temperature range: NE592 | 0°C to 70°C |
| SE592 | -55°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or N package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package | 300°C |

NOTE 1: All voltage values except differential input voltages are with respect to the midpoint between V_{CC+} and V_{CC-} .

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR | DERATE ABOVE T_A | $T_A = 70^\circ\text{C}$ POWER RATING | $T_A = 125^\circ\text{C}$ POWER RATING |
|---------|---|--------------------|-----------------------|--|---|
| D | 500 mW | N/A | N/A | 500 mW | |
| J | 500 mW | 11 mW/°C | 105°C | 500 mW | 275 mW |
| N | 500 mW | N/A | N/A | 500 mW | |

NE592, SE592 DIFFERENTIAL VIDEO AMPLIFIERS

recommended operating conditions

| | NE592 | | | SE592 | | | UNIT |
|---------------------------------------|-------|-----|-----|-------|-----|-----|------|
| | MIN | NOM | MAX | MIN | NOM | MAX | |
| Supply voltage, V_{CC+} | 3 | 6 | 8 | 3 | 6 | 8 | V |
| Supply voltage, V_{CC-} | -3 | -6 | -8 | -3 | -6 | -8 | V |
| Operating free-air temperature, T_A | 0 | | 70 | -55 | | 125 | °C |

electrical characteristics, $V_{CC\pm} = \pm 6\text{ V}$, $T_A = 25^\circ\text{C}$

| PARAMETER | | TEST FIGURE | TEST CONDITIONS | GAIN OPTION† | MIN | TYP | MAX | UNIT |
|------------------------|---|-------------|--|--------------|---------|------|------------------|------|
| AVD | Large-signal differential voltage amplification | 1 | $V_{O(PP)} = 3\text{ V}$, $R_L = 2\text{ k}\Omega$ | 1 | 300 | 400 | 500 | V/V |
| | | | | 2 | 90 | 100 | 110 | |
| BW | Bandwidth (-3 dB) | 2 | $V_{O(PP)} = 1\text{ V}$ | 1 | 40 | | MHz | |
| | | | | 2 | 90 | | | |
| I_{IO} | Input offset current | | | 1, 2, or 3 | 0.4 | 3 | μA | |
| I_{IB} | Input bias current | | | 1, 2, or 3 | 9 | 20 | μA | |
| V_{ICR} | Common-mode input voltage range | 3 | | 1, 2, or 3 | ± 1 | | V | |
| V_{OC} | Common-mode output voltage | 1 | $R_L = \infty$ | 1, 2, or 3 | 2.4 | 2.9 | 3.4 | V |
| V_{OO} | Output offset voltage | 1 | $V_{IO} = 0$, $R_L = \infty$ | 1 | 1.5 | | V | |
| | | | | 2 | 1 | | | |
| | | | | 3 | 0.35 | 0.75 | | |
| $V_{O(PP)}$ | Maximum peak-to-peak output voltage swing | 1 | $R_L = 2\text{ k}\Omega$ | 1, 2, or 3 | 3 | 4 | V | |
| r_i | Input resistance | | | 1 | 4 | | $\text{k}\Omega$ | |
| | | | | 2 | 20 | 30 | | |
| r_o | Output resistance | | | | 20 | | Ω | |
| C_i | Input capacitance | | | | 2 | | pF | |
| CMRR | Common-mode rejection ratio | 3 | $V_{IC} = \pm 1\text{ V}$, $f = 100\text{ kHz}$ | 2 | 60 | 86 | dB | |
| | | 3 | $V_{IC} = \pm 1\text{ V}$, $f = 5\text{ MHz}$ | 2 | 60 | | | |
| k_{SVR} | Supply-voltage rejection ratio ($\Delta V_{CC+}/\Delta V_{IO}$) | 4 | $\Delta V_{CC+} = \pm 0.5\text{ V}$, $\Delta V_{CC-} = \pm 0.5\text{ V}$ | 2 | 50 | 70 | dB | |
| V_n | Broadband equivalent input noise voltage | 4 | $BW = 1\text{ kHz to } 10\text{ MHz}$ | 1, 2, or 3 | 12 | | μV | |
| t_{pd} | Propagation delay time | 2 | $\Delta V_O = 1\text{ V}$ | 1 | 7.5 | | ns | |
| | | | | 2 | 6 | 10 | | |
| t_r | Rise time | 2 | $\Delta V_O = 1\text{ V}$ | 1 | 10.5 | | ns | |
| | | | | 2 | 4.5 | 10 | | |
| $I_{\text{sink(max)}}$ | Maximum output sink current | | | 1, 2, or 3 | 3 | 4 | mA | |
| I_{CC} | Supply current | | No load, No signal | 1, 2, or 3 | 18 | 24 | mA | |

† The gain option is selected as follows:

Gain Option 1 . . . Gain Adjust pin 1A is connected to pin 1B, pins 2A and 2B are open.

Gain Option 2 . . . Gain Adjust pin 2A is connected to pin 2B, pins 1A and 1B are open.

Gain Option 3 . . . All Gain Adjust pins are open.

NE592 DIFFERENTIAL VIDEO AMPLIFIER

electrical characteristics, $V_{CC\pm} = \pm 6\text{ V}$, $T_A = 25^\circ\text{C}$

| PARAMETER | TEST FIGURE | TEST CONDITIONS | GAIN OPTION† | MIN | TYP | MAX | UNIT |
|------------------------|-------------|--|--------------|---------|-----|------|---------------|
| A _{VD} | 1 | $V_{O(PP)} = 3\text{ V}$, $R_L = 2\text{ k}\Omega$ | 1 | 250 | 400 | 600 | V/V |
| | | | 2 | 80 | 100 | 120 | |
| BW | 2 | $V_{O(PP)} = 1\text{ V}$ | 1 | 40 | | | MHz |
| | | | 2 | 90 | | | |
| I _{IO} | | $V_{IC} = 0$ | 1, 2, or 3 | 0.4 | | 5 | μA |
| I _{IB} | | $V_{IC} = 0$ | 1, 2, or 3 | 9 | | 30 | μA |
| V _{ICR} | 3 | | 1, 2, or 3 | ± 1 | | | V |
| V _{OC} | 1 | $R_L = \infty$ | | 2.4 | 2.9 | 3.4 | V |
| V _{OO} | 1 | $V_{IO} = 0$, $R_L = \infty$ | 1 or 2 | | | 1.5 | V |
| | | | 3 | 0.35 | | 0.75 | |
| V _{O(PP)} | 1 | $R_L = 2\text{ k}\Omega$ | 1, 2, or 3 | 3 | 4 | | V |
| r _i | | | 1 | 4 | | | k Ω |
| | | | 2 | 10 | 30 | | |
| r _o | | | | 20 | | | Ω |
| C _i | | | | 2 | | | pF |
| CMRR | 3 | $V_{IC} = \pm 1\text{ V}$, $f = 100\text{ kHz}$ | 2 | 60 | 86 | | dB |
| | 3 | $V_{IC} = \pm 1\text{ V}$, $f = 5\text{ MHz}$ | 2 | 60 | | | |
| k _{SVR} | 4 | $\Delta V_{CC+} = \pm 0.5\text{ V}$, $\Delta V_{CC-} = \pm 0.5\text{ V}$ | 2 | 50 | 70 | | dB |
| V _n | 4 | BW = 1 kHz to 10 MHz | 1, 2, or 3 | 12 | | | μV |
| t _{pd} | 2 | $\Delta V_O = 1\text{ V}$ | 1 | 7.5 | | | ns |
| | | | 2 | 6 | 10 | | |
| t _r | 2 | $\Delta V_O = 1\text{ V}$ | 1 | 10.5 | | | ns |
| | | | 2 | 4.5 | 12 | | |
| I _{sink(max)} | | | 1, 2, or 3 | 3 | 4 | | mA |
| I _{CC} | | No load, No signal | 1, 2, or 3 | 18 | | 24 | mA |

† The gain option is selected as follows:

- Gain Option 1 . . . Gain Adjust pin 1A is connected to pin 1B, pins 2A and 2B are open.
- Gain Option 2 . . . Gain Adjust pin 2A is connected to pin 2B, pins 1A and 1B are open.
- Gain Option 3 . . . All Gain Adjust pins are open.

NE592
DIFFERENTIAL VIDEO AMPLIFIER

electrical characteristics over recommended operating free-air temperature range, $V_{CC\pm} = \pm 6\text{ V}$

| PARAMETER | TEST FIGURE | TEST CONDITIONS | GAIN OPTION† | MIN | TYP | MAX | UNIT |
|------------------------|--|--|--------------|---------|-----|-----|------------------|
| A_{VD} | Large-signal differential voltage amplification | $V_{O(PP)} = 3\text{ V}$ | 1 | 250 | | 600 | V/V |
| | | | 2 | 80 | | 120 | |
| I_{IO} | Input offset current | | 1 or 2 | | | 6 | μA |
| I_{IB} | Input bias current | | 1 or 2 | | | 40 | μA |
| V_{ICR} | Common-mode input voltage range | | 1 or 2 | ± 1 | | | V |
| V_{OO} | Output offset voltage | $V_{IO} = 0, R_L = \infty$ | 1 or 2 | | | 1.5 | V |
| | | | 3 | | | 1 | |
| $V_{O(PP)}$ | Maximum output voltage peak-to-peak swing | $R_L = 2\text{ k}\Omega$ | 1 or 2 | 2.8 | | | V |
| r_i | Input resistance | | 2 | 8 | | | $\text{k}\Omega$ |
| CMRR | Common-mode rejection ratio | $V_{IC} = \pm 1\text{ V}, f = 100\text{ kHz}$ | 2 | 50 | | | dB |
| k_{SVR} | Supply-voltage rejection ratio ($\Delta V_{CC}/\Delta V_{IO}$) | $\Delta V_{CC+} = \pm 0.5\text{ V}, \Delta V_{CC-} = \pm 0.5\text{ V}$ | 2 | 50 | | | dB |
| $I_{\text{sink(max)}}$ | Maximum output sink current | | 1, 2, or 3 | | | | mA |
| I_{CC} | Supply current | No load, No signal | 1, 2, or 3 | | | 27 | mA |

† The gain option is selected as follows:

Gain Option 1 . . . Gain Adjust pin 1A is connected to pin 1B, pins 2A and 2B are open.

Gain Option 2 . . . Gain Adjust pin 2A is connected to pin 2B, pins 1A and 1B are open.

Gain Option 3 . . . All Gain Adjust pins are open.

SE592 DIFFERENTIAL VIDEO AMPLIFIER

electrical characteristics over recommended operating free-air temperature range, $V_{CC\pm} = \pm 6\text{ V}$

| PARAMETER | | TEST FIGURE | TEST CONDITIONS | GAIN OPTION† | MIN | TYP | MAX | UNIT |
|------------------------|--|-------------|--|--------------|-----|-----|-----|------|
| A _{VD} | Large-signal differential voltage amplification | 1 | V _{O(PP)} = 3 V | 1 | 250 | | 600 | V/V |
| | | | | 2 | 80 | | 120 | |
| I _{IO} | Input offset current | | | 1 or 2 | | | 5 | μA |
| I _{IB} | Input bias current | | | 1 or 2 | | | 40 | μA |
| V _{ICR} | Common-mode input voltage range | 3 | | 1 or 2 | ±1 | | | V |
| V _{OO} | Output offset voltage | 1 | V _{ID} = 0, R _L = ∞ | 1 | | | 1.5 | V |
| | | | | 2 | | | 1.2 | |
| | | | | 3 | | | 1 | |
| V _{O(PP)} | Maximum output voltage peak-to-peak swing | 1 | R _L = 2 kΩ | 1 or 2 | 2.5 | | | V |
| r _i | Input resistance | | | 2 | 8 | | | kΩ |
| CMRR | Common-mode rejection ratio | 3 | V _{IC} = ±1 V, f = 100 kHz | 2 | 50 | | | dB |
| k _{SVR} | Supply-voltage rejection ratio (ΔV _{CC} /ΔV _{IO}) | 4 | ΔV _{CC+} = ±0.5 V, ΔV _{CC-} = ±0.5 V | 2 | 50 | | | dB |
| I _{sink(max)} | Maximum output sink current | | | 1, 2, or 3 | 2.5 | | | mA |
| I _{CC} | Supply current | 1 | No load, No signal | 1, 2, or 3 | | | 27 | mA |

† The gain option is selected as follows:

Gain Option 1 . . . Gain Adjust pin 1A is connected to pin 1B, pins 2A and 2B are open.

Gain Option 2 . . . Gain Adjust pin 2A is connected to pin 2B, pins 1A and 1B are open.

Gain Option 3 . . . All Gain Adjust pins are open.

PARAMETER MEASUREMENT INFORMATION

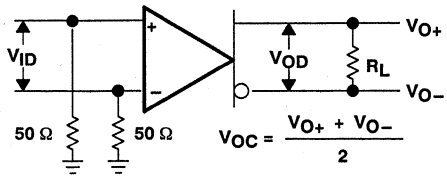


Figure 1

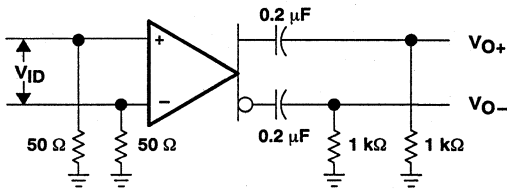


Figure 2

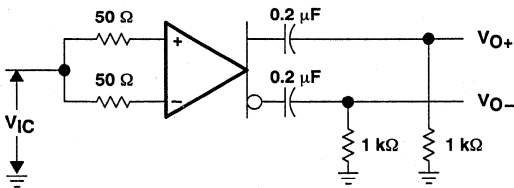


Figure 3

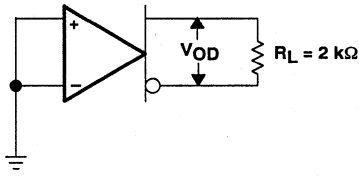


Figure 4

SE556, SE556C, SA556, NE556 DUAL PRECISION TIMERS

D2440, APRIL 1978—REVISED OCTOBER 1988

- Two Precision Timing Circuits per Package
- Astable or Monostable Operation
- TTL-Compatible Output Can Sink or Source Up to 150 mA
- Active Pull-Up or Pull-Down
- Designed to be Interchangeable with Signetics SE556, SE556C, SA556, NE556

APPLICATIONS

| | |
|---|-------------------------------------|
| Precision Timer from Microseconds to Hours | Sequential Timer Pulse Generator |
| Pulse-Shaping Circuit | Time-Delay Circuit |
| Missing-Pulse Detector | Frequency Divider |
| Tone-Burst Generator | Appliance Timer |
| Pulse-Width Modulator | Industrial Controls |
| Pulse-Position Modulator | Touch-Tone Encoder |

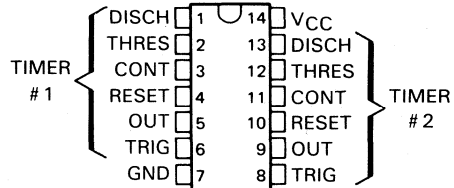
**SE556C FROM TI IS NOT
RECOMMENDED FOR NEW DESIGNS**

description

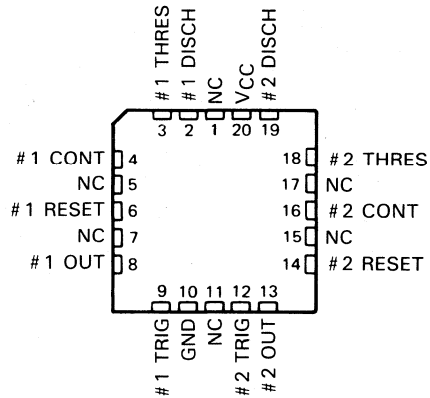
These devices provide two monolithic, independent timing circuits of the SE555, SE555C, SA555, or NE555 type in each package. These circuits can be operated in the astable or the monostable mode with external resistor-capacitor timing control. The basic timing provided by the RC time constant may be actively controlled by modulating the bias of the control voltage input.

The threshold and trigger levels are normally two-thirds and one-third respectively of V_{CC} . These levels can be altered by use of the control voltage terminal. When the trigger input falls below trigger level, the flip-flop is set and the output goes high. If the trigger input is above the threshold level and the threshold input is above the threshold level, the flip-flop is reset and the output is low. The reset input can override all other inputs and can be used to initiate a new timing cycle. When the reset input goes low, the flip-flop is reset and the output goes low. Whenever the output is low, a low impedance path is provided between the discharge terminal and ground.

SE556, SE556C . . . J PACKAGE
SA556, NE556 . . . D, J, OR N PACKAGE
(TOP VIEW)

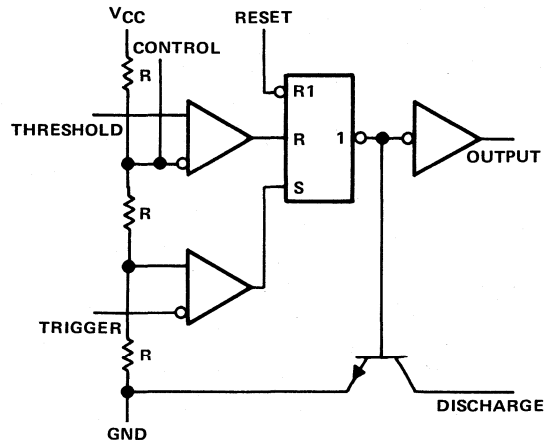


SE556, SE556C . . . FK PACKAGE
(TOP VIEW)



NC—No internal connection

functional block diagram (each timer)



Reset can override Trigger, which can override Threshold.

PRODUCTION DATA documents contain information current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

**TEXAS
INSTRUMENTS**

POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

Copyright © 1983, Texas Instruments Incorporated

SE556, SE556C, SA556, NE556 DUAL PRECISION TIMERS

The SE556 and SE556C are characterized for operation over the full military range of -55°C to 125°C . The SA556 is characterized for operation from -40°C to 85°C , and the NE556 is characterized for operation from 0°C to 70°C .

AVAILABLE OPTIONS

| T _A RANGE | V _{thres} MAX V _{CC} = 15 V | PACKAGE | | | |
|-------------------------|--|-------------------------|-------------------------|-----------------------|-----------------------|
| | | SMALL OUTLINE (D) | CHIP CARRIER (FK) | CERAMIC DIP (J) | PLASTIC DIP (N) |
| 0°C to 70°C | 11.2 V | NE556D | | NE556J | NE556N |
| -40°C to 85°C | 11.2 V | SA556D | | SA556J | SA556N |
| -55°C to 125°C | 10.6 V 11.2 V | | SE556FK SE556CFK | SE556J SE556CJ | |

The D package is available taped and reeled. Add the suffix R to the device type (e.g., NE556DR).

FUNCTION TABLE

| RESET | TRIGGER VOLTAGE† | THRESHOLD VOLTAGE† | OUTPUT | DISCHARGE SWITCH |
|-------|-----------------------|-----------------------|---------------------------|---------------------|
| Low | Irrelevant | Irrelevant | Low | On |
| High | < 1/3 V _{DD} | Irrelevant | High | Off |
| High | > 1/3 V _{DD} | > 2/3 V _{DD} | Low | On |
| High | > 1/3 V _{DD} | < 2/3 V _{DD} | As previously established | |

†Voltage levels shown are nominal.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Supply voltage, V _{CC} (See Note 1) | 18 V |
| Input voltage (control, reset, threshold, and trigger) | V _{CC} |
| Output current | ±225 mA |
| Continuous total dissipation | see Dissipation Rating Table |
| Operating free-air temperature range: SE556, SE556C | -55°C to 125°C |
| SA556 | -40°C to 85°C |
| NE556 | 0°C to 70°C |
| Storage temperature range | -65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package | 300°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or N package | 260°C |

NOTE 1: All voltage values are with respect to network ground terminal.

DISSIPATION RATING TABLE

| PACKAGE | T _A ≤ 25°C | DERATING FACTOR | T _A = 70°C | T _A = 85°C | T _A = 125°C |
|-------------------|-----------------------|-----------------------------|-----------------------|-----------------------|------------------------|
| | POWER RATING | ABOVE T _A = 25°C | POWER RATING | POWER RATING | POWER RATING |
| D | 950 mW | 7.6 mW/°C | 608 mW | 494 mW | N/A |
| FK | 1375 mW | 11.0 mW/°C | 880 mW | 715 mW | 275 mW |
| J (SE556, SE556C) | 1375 mW | 11.0 mW/°C | 880 mW | 715 mW | 275 mW |
| J (SA556, NE556) | 1025 mW | 8.2 mW/°C | 656 mW | 533 mW | N/A |
| N | 1575 mW | 12.6 mW/°C | 1008 mW | 819 mW | N/A |

TEXAS
INSTRUMENTS

POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

SE556, SE556C, SA556, NE556 DUAL PRECISION TIMERS

recommended operating conditions

| | SE556 | | SE556C | | SA556 | | NE556 | | UNIT |
|--|-----------|-----|-----------|-----|-----------|-----|-----------|-----|------|
| | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | |
| Supply voltage, V_{CC} | 4.5 | 18 | 4.5 | 16 | 4.5 | 16 | 4.5 | 16 | V |
| Input voltage (control, reset, threshold, and trigger) | V_{CC} | | V_{CC} | | V_{CC} | | V_{CC} | | V |
| Output current | ± 200 | | ± 200 | | ± 200 | | ± 200 | | mA |
| Operating free-air temperature, T_A | -55 | 125 | -55 | 125 | -40 | 85 | 0 | 70 | °C |

electrical characteristics at 25°C free-air temperature, $V_{CC} = 5\text{ V to }15\text{ V}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | SE556 | | | SE556C, SA556, NE556 | | | UNIT |
|------------------------------------|------------------------|---------------------------|------|------|----------------------|-------|------|---------------|
| | | MIN | TYP | MAX | MIN | TYP | MAX | |
| Threshold voltage level | $V_{CC} = 15\text{ V}$ | 9.4 | 10 | 10.6 | 8.8 | 10 | 11.2 | V |
| | $V_{CC} = 5\text{ V}$ | 2.7 | 3.3 | 4 | 2.4 | 3.3 | 4.2 | |
| Threshold current (see Note 2) | | 30 | 250 | | 30 | 250 | nA | |
| Trigger voltage level | $V_{CC} = 15\text{ V}$ | 4.8 | 5 | 5.2 | 4.5 | 5 | 5.6 | V |
| | $V_{CC} = 5\text{ V}$ | 1.45 | 1.67 | 1.9 | 1.1 | 1.67 | 2.2 | |
| Trigger current | Trigger at 0 V | | 0.5 | 0.9 | | 0.5 | 2 | μA |
| Reset voltage level | | 0.3 | 0.7 | 1 | 0.3 | 0.7 | 1 | V |
| Reset current | Reset at V_{CC} | | 0.1 | 0.4 | | 0.1 | 0.4 | mA |
| | Reset at 0 V | | -0.4 | -1 | | -0.4 | -1.5 | |
| Discharge switch off-state current | | 20 | 100 | | 20 | 100 | nA | |
| Control voltage (open circuit) | $V_{CC} = 15\text{ V}$ | 9.6 | 10 | 10.4 | 9 | 10 | 11 | V |
| | $V_{CC} = 5\text{ V}$ | 2.9 | 3.3 | 3.8 | 2.6 | 3.3 | 4 | |
| Low-level output voltage | $V_{CC} = 15\text{ V}$ | $I_{OL} = 10\text{ mA}$ | 0.1 | 0.15 | | 0.1 | 0.25 | V |
| | | $I_{OL} = 50\text{ mA}$ | 0.4 | 0.5 | | 0.4 | 0.75 | |
| | | $I_{OL} = 100\text{ mA}$ | 2 | 2.2 | | 2 | 2.5 | |
| | | $I_{OL} = 200\text{ mA}$ | 2.5 | | | 2.5 | | |
| | $V_{CC} = 5\text{ V}$ | $I_{OL} = 5\text{ mA}$ | 0.1 | 0.15 | | 0.1 | 0.25 | |
| | | $I_{OL} = 8\text{ mA}$ | 0.15 | 0.25 | | 0.15 | 0.3 | |
| High-level output voltage | $V_{CC} = 15\text{ V}$ | $I_{OH} = -100\text{ mA}$ | 13 | 13.3 | | 12.75 | 13.3 | V |
| | | $I_{OH} = -200\text{ mA}$ | | 12.5 | | | 12.5 | |
| | $V_{CC} = 5\text{ V}$ | $I_{OH} = -100\text{ mA}$ | 3 | 3.3 | | 2.75 | 3.3 | |
| Supply current | Output low, No load | $V_{CC} = 15\text{ V}$ | 20 | 24 | | 20 | 30 | mA |
| | | $V_{CC} = 5\text{ V}$ | 6 | 10 | | 6 | 12 | |
| | Output high, No load | $V_{CC} = 15\text{ V}$ | 18 | 20 | | 18 | 26 | |
| | | $V_{CC} = 5\text{ V}$ | 4 | 8 | | 4 | 10 | |

NOTE 2: This parameter influences the maximum value of the timing resistors R_A and R_B in the circuit of Figure 1. For example, when $V_{CC} = 5\text{ V}$, the maximum value is $R = R_A + R_B \approx 3.4\text{ M}\Omega$, and for $V_{CC} = 15\text{ V}$, the maximum value is $\approx 10\text{ M}\Omega$.

SE556, SE556C, SA556, NE556 DUAL PRECISION TIMERS

operating characteristics, $V_{CC} = 5\text{ V}$ and 15 V

| PARAMETER | | TEST CONDITIONS† | SE556 | | | SE556C, SA556, NE556 | | | UNIT |
|---|-------------------------|---------------------------|-----------|-----|-----------|----------------------|-----|--------|------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| Initial error of timing interval‡ | Each timer, monostable§ | $T_A = 25^\circ\text{C}$ | 0.5 | | 1.5 | 1 | | 3 | % |
| | Each timer, astable¶ | | 1.5 | | 2.25 | | | | |
| | Timer 1 – Timer 2 | | ± 0.5 | | ± 1 | | | | |
| Temperature coefficient of timing interval | Each timer, monostable§ | $T_A = \text{MIN to MAX}$ | 30 | 100 | 50 | | | ppm/°C | |
| | Each timer, astable¶ | | 90 | | 150 | | | | |
| | Timer 1 – Timer 2 | | ± 10 | | ± 10 | | | | |
| Supply voltage sensitivity of timing interval | Each timer, monostable§ | $T_A = 25^\circ\text{C}$ | 0.05 | | 0.2 | 0.1 | | 0.5 | %/V |
| | Each timer, astable¶ | | 0.15 | | 0.3 | | | | |
| | Timer 1 – Timer 2 | | ± 0.1 | | ± 0.2 | | | | |
| Output pulse rise time | | $C_L = 15\text{ pF}$ | 100 | 200 | 100 | | 300 | ns | |
| Output pulse fall time | | $T_A = 25^\circ\text{C}$ | 100 | 200 | 100 | | 300 | | |

†For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

‡Timing interval error is defined as the difference between the measured value and the average value of a random sample from each process run.

§Values specified are for a device in a monostable circuit similar to Figure 2, with component values as follow: $R_A = 2\text{ k}\Omega$ to $100\text{ k}\Omega$, $C = 0.1\text{ }\mu\text{F}$.

¶Values specified are for a device in an astable circuit similar to Figure 1, with component values as follow: $R_A = 1\text{ k}\Omega$ to $100\text{ k}\Omega$, $C = 0.1\text{ }\mu\text{F}$.

TYPICAL APPLICATION DATA

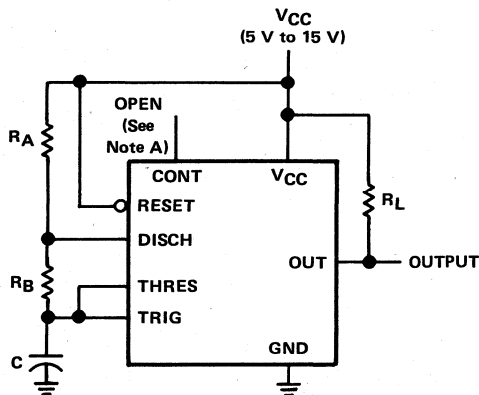


FIGURE 1. CIRCUIT FOR ASTABLE OPERATION

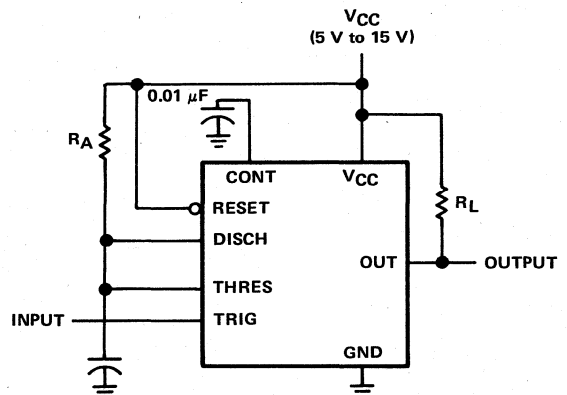


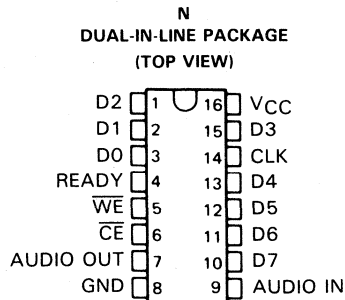
FIGURE 2. CIRCUIT FOR MONOSTABLE OPERATION

NOTE A: Bypassing the control voltage input to ground with a capacitor may improve operation. This should be evaluated for individual applications.

SN76494, SN76494A, SN76496, SN76496A PROGRAMMABLE TONE/NOISE GENERATOR

D2801, JUNE 1984—REVISED JANUARY 1989

- Each Circuit Contains 3 Programmable Tone Generators
- Programmable White-Noise Generator
- Programmable Attenuation
- Simultaneous Sounds
- Up to 500 kHz Clock Input for SN76494 and 4 MHz for SN76496
- External Audio Input for SN76496 May Be Summed with Internally Generated Tones
- The SN76494A and SN76496A are Interchangeable with the SN76494 and SN76496, Respectively



description

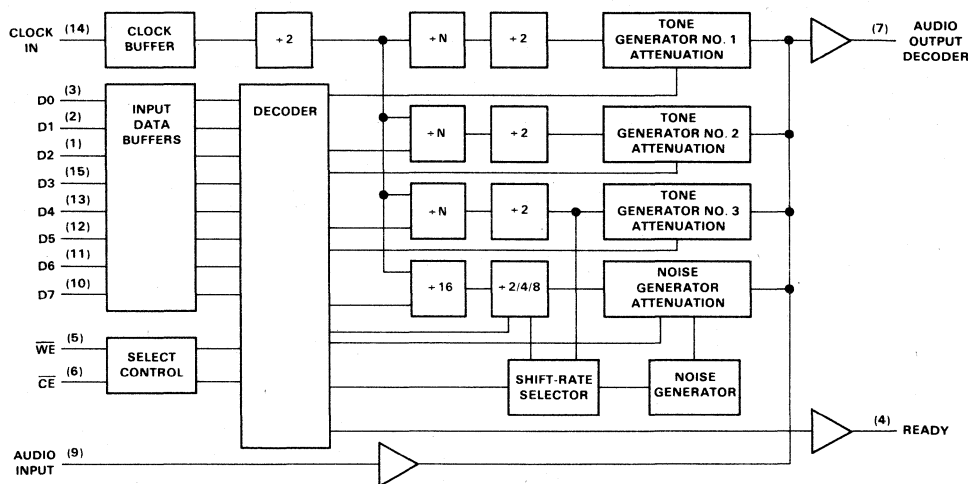
The SN76494 and SN76494A digital complex sound generators are integrated injection logic (I²L) tone generators designed to provide low-cost tone or noise generation capability in microprocessor systems. The SN76494 and SN76494A are data-bus-based input-output peripheral devices that interface the microprocessor through 8 data lines and 3 control lines.

The SN76494 and SN76494A are identical to the SN76496 and SN76496A except that the maximum clock input frequency for SN76494 and SN76494A is 500 kHz and for SN76496 and SN76496A, it is 4 MHz. A "divide-by-eight" stage is deleted from the SN76496 and SN76496A circuitry so that only 4 clock pulses are required to load the data into the SN76494 and SN76494A, compared to 32 pulses for the SN76496 and SN76496A.

Either of these devices may also be used as a replacement for the SN76489A in all applications if pin 9 is left open or grounded. The output load must be limited to 10 mA.

When audio input is not desired in the SN76494, SN76494A, SN76496 or SN76496A, the audio input pin should be grounded.

functional block diagram



PRODUCTION DATA documents contain information current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

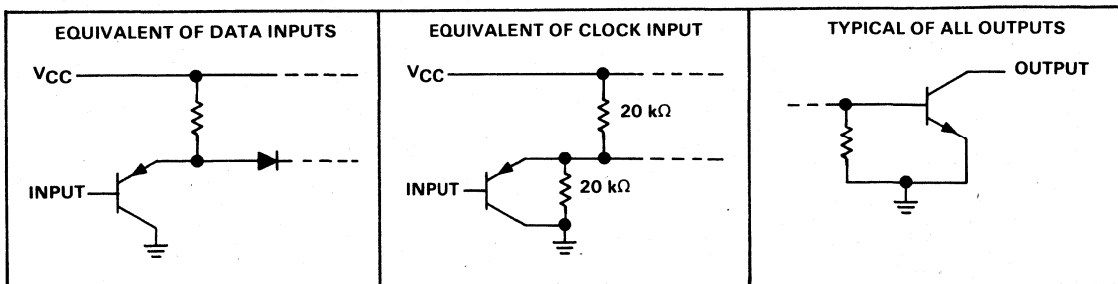

**TEXAS
INSTRUMENTS**

POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

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SN76494, SN76494A, SN76496, SN76496A PROGRAMMABLE TONE/NOISE GENERATOR

schematics of inputs and outputs



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|----------------|
| Supply voltage, V_{CC} (see Note 1) | 7 V |
| Input voltage, V_I : Audio input | 0.9 V |
| All other inputs | 7 V |
| Output current at pin 7 | 10 mA |
| Continuous total power dissipation at (or below) 25°C free-air temperature (see Note 2) | 1150 mW |
| Operating free-air temperature range | 0°C to 70°C |
| Storage temperature range | -55°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTES: 1. All voltage values are with respect to network ground terminal.

2. For operation above 25°C free-air temperature, derate linearly to 736 mW at 70°C at the rate of 9.2 mW/°C.

recommended operating conditions

| | | SN76494, SN76494A | | | SN76496, SN76496A | | | UNIT |
|-------------|--|-------------------|-----|-----|-------------------|-----|-----|------|
| | | MIN | NOM | MAX | MIN | NOM | MAX | |
| V_{CC} | Supply voltage | 4.5 | 5 | 5.5 | 4.5 | 5 | 5.5 | V |
| V_{IH} | High-level input voltage | 2 | | | 2 | | | V |
| V_{IL} | Low-level input voltage | | | 0.8 | | | 0.8 | V |
| I_I | Audio input current | 0 | | 1.8 | 0 | | 1.8 | mA |
| V_{OH} | High-level output voltage (pin 4) | | | 5.5 | | | 5.5 | V |
| I_{OL} | Low-level output current (pin 4) | | | 2 | | | 2 | mA |
| f_{clock} | Input clock frequency | | | 0.5 | | | 4 | MHz |
| $t_{d(WE)}$ | Delay time, \overline{CE} low to \overline{WE} low | 0 | | | 0 | | | ns |
| t_{su} | Setup time, data before $\overline{WE}\downarrow$ or $\overline{CE}\downarrow$ | 0 | | | 0 | | | ns |
| t_h | Hold time, data after $READY\uparrow$ | 0 | | | 0 | | | ns |
| T_A | Operating free-air temperature | 0 | | 70 | 0 | | 70 | °C |

SN76494, SN76494A, SN76496, SN76496A PROGRAMMABLE TONE/NOISE GENERATOR

electrical characteristics over recommended ranges of supply voltage and operating free-air temperature range (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|------------------|---|---|--------------------|------|------|------|
| I _{OH} | High-level output current (pin 4) | V _O = 5.5 V | | | 10 | μA |
| I _{IH} | High-level input current (All digital inputs) | V _I = V _{CC} | | | 10 | μA |
| I _{IL} | Low-level input current | CE input | V _I = 0 | -25 | -175 | μA |
| | | All other digital inputs | | -10 | -70 | |
| V _{IB} | Input bias voltage, audio (pin 9) | R = 4.7 kΩ to V _{CC} | 0.5 | 0.7 | 0.9 | V |
| V _{OH} | High-level output voltage (pin 7) | | | | 5.5 | V |
| V _{OL} | Low-level output voltage (pin 4) | I _{OL} = 2 mA | | 0.25 | 0.4 | V |
| V _{OPP} | Peak-to-peak output voltage (pin 7) | V _{CC} = 5 V, Attenuation: Generator under test = 0 dB All other generators = 30 dB | 260 | | | mV |
| I _{CC} | Supply current | | | 30 | 50 | mA |
| Attenuation | 2 dB NOM | See Table 1 | 1 | 2 | 3 | dB |
| | 4 dB NOM | | 3 | 4 | 5 | |
| | 8 dB NOM | | 7 | 8 | 9 | |
| | 16 dB NOM | | 15 | 16 | 17 | |
| C _i | Input capacitance | | | | 15 | pF |

† Typical values are at V_{CC} = 5 V, T_A = 25°C.

switching characteristics, V_{CC} = 5 V, T_A = 25°C

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|------------------|---|---|-----|-----|-----|------|
| t _{PHL} | Propagation delay time, high-to-low level RDY output from CE | C _L = 225 pF, R _L = 2 kΩ to V _{CC} | | 90 | 150 | ns |
| t _{PHL} | Propagation delay time high-to-low level, RDY output from WE | | | 90 | | ns |
| t _{PLH} | Propagation delay time low-to-high level, RDY output from CLK | | | 90 | | ns |

PARAMETER MEASUREMENT INFORMATION

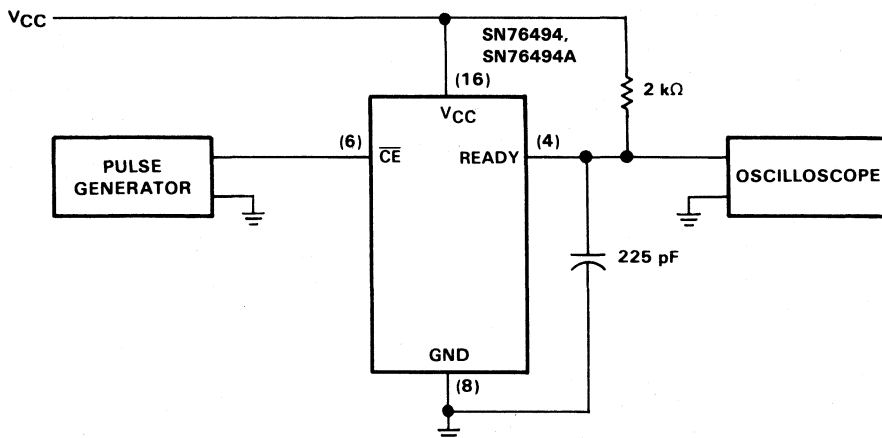


FIGURE 1. t_{PHL} TEST CIRCUIT

SN76494, SN76494A, SN76496, SN76496A PROGRAMMABLE TONE/NOISE GENERATOR

pin assignments and functions

| SIGNATURE | PIN | I/O | DESCRIPTION |
|-----------------|-----|-----|---|
| \overline{CE} | 6 | I | Chip Enable. When chip enable is low, the device is operational, input terminals are enabled, and data may be entered. |
| D0 (MSB) | 3 | I | D0 through D7 -- Input data bus |
| D1 | 2 | I | |
| D2 | 1 | I | |
| D3 | 15 | I | |
| D4 | 13 | I | |
| D5 | 12 | I | |
| D6 | 11 | I | |
| D7 (LSB) | 10 | I | |
| VCC | 16 | I | Supply voltage (5 V nom) |
| GND | 8 | O | Ground reference |
| CLOCK | 14 | I | Input Clock |
| \overline{WE} | 5 | I | Write Enable. When \overline{CE} is enabled and \overline{WE} is active (low), input on the data bus is accepted. \overline{CE} and \overline{WE} must be held low until READY returns high (four clock cycles for the SN76494 and SN76494A or 32 clock cycles for the SN76496 and SN76496A). If \overline{WE} remains low throughout four additional clock cycles for the SN76494 and SN76494A (32 clock cycles for the SN76496 and SN76496A) a new write cycle will be initiated. |
| READY | 4 | O | When low, READY indicates that a write cycle is in progress; data on the input bus must remain valid until READY returns high. |
| AUDIO IN | 9 | I | Audio input from external source |
| AUDIO OUT | 7 | O | Audio Drive Out |

PRINCIPLES OF OPERATION

tone generators

Each tone generator consists of a frequency synthesis section and an attenuation section. The frequency synthesis section requires 10 bits of information (F0-F9) to define half the period of the desired frequency (f). F0 is the most significant bit and F9 is the least significant bit. This information is loaded into a 10-stage tone counter, which counts down at an N/2 rate where N is the input clock frequency. When the tone counter counts down to zero, a borrow signal is produced. This borrow signal toggles the frequency flip-flop and also reloads the tone counter. Thus, the period of the desired frequency is twice the value of the period register.

The frequency can be calculated by the following:

$$f = \frac{N}{4n} \text{ for SN76494 and SN76494A, or } f = \frac{N}{32n} \text{ for SN76496 and SN76496A}$$

where N = clock in Hz
n = 10-bit binary number

The output level of each tone/noise generator may be selected by programming a four stage attenuator. The attenuator values, along with their bit position in the data word, are shown in Table 1. Multiple attenuation control bits may be true simultaneously. Thus, the maximum attenuation is 30 dB.

SN76494, SN76494A, SN76496, SN76496A PROGRAMMABLE TONE/NOISE GENERATOR

TABLE 1. ATTENUATION CONTROL

| BIT POSITION | | | | WEIGHT (In dB) |
|--------------|----|----|----|-------------------|
| A0 | A1 | A2 | A3 | |
| 0 | 0 | 0 | 1 | 2 |
| 0 | 0 | 1 | 0 | 4 |
| 0 | 1 | 0 | 0 | 8 |
| 1 | 0 | 0 | 0 | 16 |
| 1 | 1 | 1 | 1 | OFF |

noise generator

The noise generator consists of a noise source and an attenuator. The noise source is a shift register with an exclusive OR-feedback network. The feedback network has provisions to protect the shift register from being locked in the zero state.

TABLE 2. NOISE FEEDBACK CONTROL

| FEEDBACK | CONFIGURATION |
|----------|------------------|
| 0 | "Periodic" noise |
| 1 | "White" noise |

Whenever the noise control register is changed, the shift register is cleared. The shift register will shift at one of four rates as determined by the two NF bits. The fixed shift rates are derived from the input clock.

TABLE 3. NOISE GENERATOR FREQUENCY CONTROL

| BITS | | SHIFT RATE |
|------|-----|--------------------------|
| NF0 | NF1 | |
| 0 | 0 | N/64 |
| 0 | 1 | N/128 |
| 1 | 0 | N/256 |
| 1 | 1 | Tone generator #3 output |

The output of the noise source is connected to a programmable attenuator as shown in Figure 4.

output buffer/amplifier

The output buffer is a conventional operational amplifier summing circuit. It sums the three tone generator outputs, the noise generator output, and any audio input through pin 9. The output buffer will generate up to 10 mA.

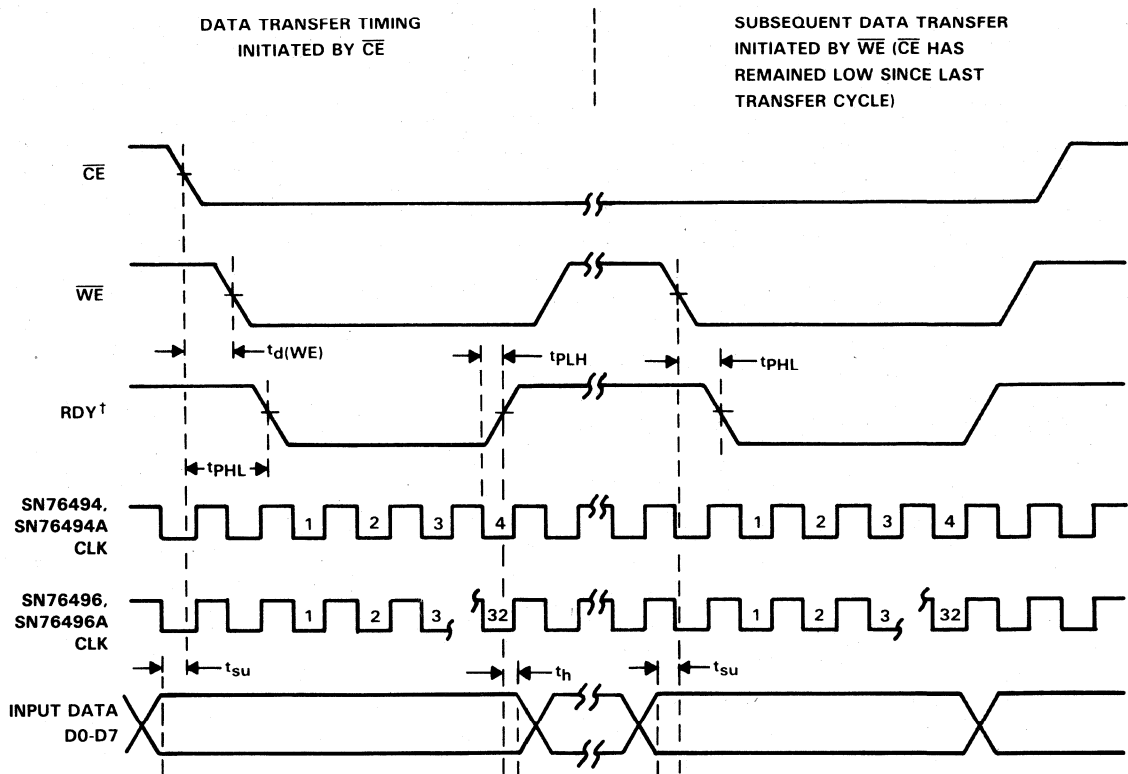
To prevent oscillations in the output buffer, the output (pin 7) should be decoupled. This is done by putting 10 ohms in series with 0.1 μ F from pin 7 to ground (see Figure 3).

data transfer

The microprocessor selects the SN76494, SN76494A, SN76496, or SN76496A by taking \overline{CE} low (low voltage). Unless \overline{CE} is low, no data transfer can occur. When \overline{CE} is low, the \overline{WE} signal strobes the contents of the data bus to the appropriate control register. The data bus contents must be valid at this time.

SN76494, SN76494A, SN76496, SN76496A PROGRAMMABLE TONE/NOISE GENERATOR

The SN76494 and SN76494A require approximately 4 clock cycles to load the data into the control register. The SN76496 and SN76496A require approximately 32 clock cycles. The open-collector READY output is used to synchronize the microprocessor to this transfer and is pulled to the false state (low) immediately following the falling edge of \overline{CE} (or \overline{WE} when data transfer is initiated by \overline{WE}). READY will go high upon completion of the data transfer cycle. The data transfer timing is shown below.



[†] \overline{WE} must be returned high (inactive) within 4 clock pulses for the SN76494 and SN76494A (32 clock pulses for the SN76496 and SN76496A) after RDY returns high. Otherwise, a new data transfer cycle will be initiated.

FIGURE 2. DATA TRANSFER TIMING

TABLE 4. FUNCTION TABLE

| INPUTS | | OUTPUT |
|-----------------|-----------------|--------|
| \overline{CE} | \overline{WE} | READY |
| L | L | L |
| L | H | L |
| H | L | H |
| H | H | H |

This table is valid when the device is:

- (1) not being clocked, and
- (2) is initialized by pulling \overline{WE} and \overline{CE} high.

SN76494, SN76494A, SN76496, SN76496A PROGRAMMABLE TONE/NOISE GENERATOR

CPU interface to SN76494, SN76494A, SN76496 or SN76496A

The microprocessor interfaces with the SN76494, SN76494A, SN76496, or SN76496A by means of the 8 data lines and 3 control lines (\overline{WE} , \overline{CE} and READY). Each tone generator requires 10 bits of information to select the frequency and four bits of information to select the attenuation. A frequency selection requires a double-byte transfer, while an attenuator selection requires a single-byte transfer.

If no other control registers on the chip are accessed, a tone generator may be rapidly updated by initially sending both bytes of frequency and register data, followed by just the second byte of data for succeeding values. The register address is latched on the chip, so the data will continue going into the same register. This allows the six most significant bits to be quickly modified for frequency sweeps.

control registers

The devices have 8 internal registers that are used to control the 3 tone generators and the noise source. During all data transfers to the devices, the first byte contains a 3-bit field that determines the destination control register. The register address codes are shown in Table 5.

TABLE 5. REGISTER ADDRESS FIELD

| R0 | R1 | R2 | DESTINATION CONTROL REGISTER |
|----|----|----|------------------------------|
| 0 | 0 | 0 | Tone 1 Frequency |
| 0 | 0 | 1 | Tone 1 Attenuation |
| 0 | 1 | 0 | Tone 2 Frequency |
| 0 | 1 | 1 | Tone 2 Attenuation |
| 1 | 0 | 0 | Tone 3 Frequency |
| 1 | 0 | 1 | Tone 3 Attenuation |
| 1 | 1 | 0 | Noise Control |
| 1 | 1 | 1 | Noise Attenuation |

data formats

The formats required to transfer data are shown below.

| REG ADDR | | | | DATA | | | |
|----------|----|----|----|-------|----|----|----|
| 1 | R0 | R1 | R2 | F6 | F7 | F8 | F9 |
| BIT 0 | | | | BIT 7 | | | |

FIRST BYTE

UPDATE NOISE SOURCE

(SINGLE BYTE TRANSFER)

| DATA | | | | | | | |
|-------|---|-------------|----|----|----|----|-------|
| 0 | x | F0 | F1 | F2 | F3 | F4 | F5 |
| BIT 0 | | SECOND BYTE | | | | | BIT 7 |

BIT 0

SECOND BYTE

BIT 7

| REG ADDR | | | | SHIFT | | | |
|----------|----|----|----|-------|----|-----|-----|
| 1 | R0 | R1 | R2 | x | FB | NF0 | NF1 |
| BIT 0 | | | | BIT 7 | | | |

BIT 0

BIT 7

UPDATE ATTENUATOR (SINGLE BYTE TRANSFER)

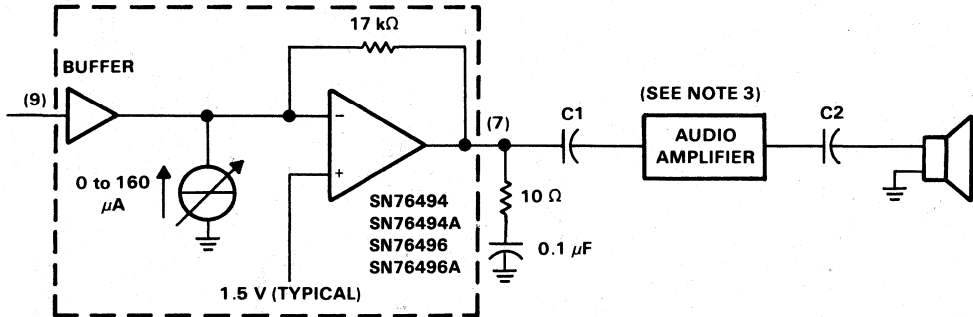
| REG ADDR | | | | DATA | | | |
|----------|----|----|----|-------|----|----|----|
| 1 | R0 | R1 | R2 | A0 | A1 | A2 | A3 |
| BIT 0 | | | | BIT 7 | | | |

BIT 0

BIT 7

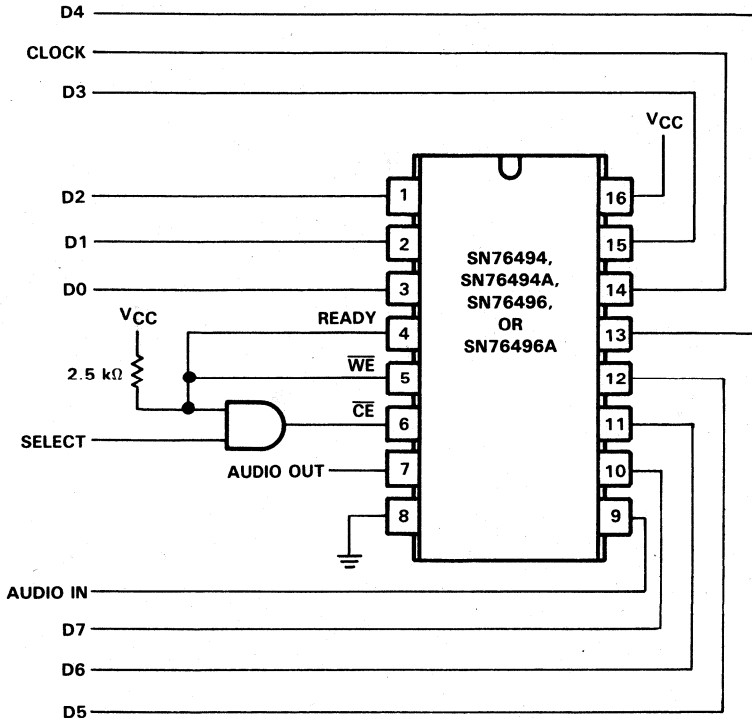
SN76494, SN76494A, SN76496, SN76496A PROGRAMMABLE TONE/NOISE GENERATOR

TYPICAL APPLICATION DATA



NOTE 3: The capacitance values of C1 and C2 are determined by the frequency response desired and the audio amplifier used.

FIGURE 3. EXTERNAL AUDIO OUTPUT INTERFACE



- NOTES: 4. The data lines must be latched so that the data remains on them at least 32 clock cycles for the SN76496 and SN76496A or (4 clock cycles for the SN76494 and SN76494A) after the select line goes low.
5. The select pulse should be a negative-going pulse with minimum duration of 150 ns.

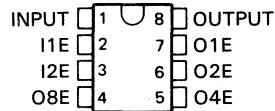
FIGURE 4. MICROCOMPUTER PARALLEL PORT INTERFACE

TL010I, TL010C ADJUSTABLE-RATIO CURRENT MIRRORS

D2738, SEPTEMBER 1983—REVISED APRIL 1988

- 33 Distinct Input-to-Output Emitter Ratios from 3:1 to 1:15
- Wide Input current Range: 1 μ A to 3 mA
- 35-Volt Output Capability
- High Output Impedance

P DUAL-IN-LINE PACKAGE
(TOP VIEW)



description

The TL010 is a Wilson current mirror that provides output current in a selectable fixed ratio to the input current. The ratio is substantially independent of changes in load, voltages, and temperature. Selecting the ratio consists of connecting appropriate input-emitter pins and output-emitter pins to ground as shown in Figure 1.

The TL010 is designed to operate with up to 3 mA input current if all three input-emitter pins are used. It will also operate at voltages up to 35 V.

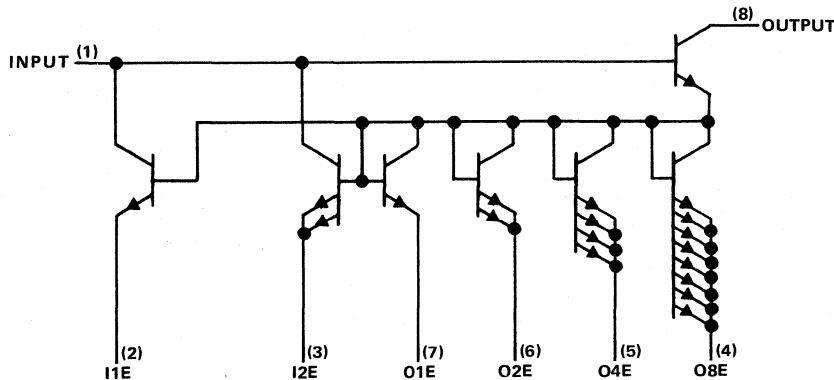
The TL010I is characterized for operation from -40°C to 85°C . The TL010C is characterized for operation from 0°C to 70°C .

typical values of current ratio at $T_A = 25^{\circ}\text{C}^{\dagger}$

| EMITTER RATIO m:n [†] | CURRENT RATIO $h_F = I_O/I_I$ | EMITTER RATIO m:n [†] | CURRENT RATIO $h_F = I_O/I_I$ | EMITTER RATIO m:n [†] | CURRENT RATIO $h_F = I_O/I_I$ |
|-----------------------------------|----------------------------------|-----------------------------------|----------------------------------|-----------------------------------|----------------------------------|
| 1:15 | 14.1 | 1:6 | 5.78 | 3:8 | 2.61 |
| 1:14 | 13.2 | 2:11 | 5.34 | 2:5 | 2.43 |
| 1:13 | 12.3 | 1:5 | 4.82 | 3:7 | 2.26 |
| 1:12 | 11.4 | 3:14 | 4.53 | 1:2 | 1.98 |
| 1:11 | 10.5 | 2:9 | 4.38 | 3:5 | 1.64 |
| 1:10 | 9.55 | 3:13 | 4.21 | 2:3 | 1.45 |
| 1:9 | 8.62 | 1:4 | 3.89 | 3:4 | 1.32 |
| 1:8 | 7.72 | 3:11 | 3.57 | 1:1 | 0.99 |
| 2:15 | 7.23 | 2:7 | 3.40 | 3:2 | 0.663 |
| 1:7 | 6.71 | 3:10 | 3.25 | 2:1 | 0.50 |
| 2:13 | 6.29 | 1:3 | 2.90 | 3:1 | 0.332 |

[†]m is the number of input emitters used, n is the number of output emitters used.

schematic



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TL010I, TL010C ADJUSTABLE-RATIO CURRENT MIRRORS

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|----------------|
| Output voltage (see Note 1) | 45 V |
| Input current | 5 mA |
| Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2) | 725 mW |
| Operating free-air temperature range: TL010I | -40°C to 85°C |
| TL010C | 0°C to 70°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTES: 1. Input and output voltages are with respect to the common terminal. Neither voltage should be more negative than -0.3 V.
2. For operation above 25°C free-air temperature, derate linearly at the rate of 8.0 mW/°C.

recommended operating conditions

| | TL010I | | TL010C | | UNIT |
|--|--------|-----|--------|-----|------|
| | MIN | MAX | MIN | MAX | |
| Output voltage, V_O | 5 | 35 | 5 | 35 | V |
| Input voltage, V_I | 0.6 | 1.7 | 0.65 | 1.6 | V |
| Input current per input emitter, I_I | 0.001 | 1 | 0.001 | 1 | mA |
| Operating free-air temperature, T_A | -40 | 85 | 0 | 70 | °C |

electrical characteristics over recommended ranges of operating free-air temperature and output voltage (unless otherwise noted)

| PARAMETER | TEST CONDITIONS† | TL010I | | | TL010C | | | UNIT | |
|--|---|----------------------------------|---------|------|--------|---------|------|--------|----|
| | | MIN | TYP‡ | MAX | MIN | TYP‡ | MAX | | |
| V_I Input voltage | $I_I = m \times 1 \mu\text{A}$ | 1 | | | 1 | | | V | |
| | $I_I = m \times 10 \mu\text{A}$ | 1.1 | | | 1.1 | | | | |
| | $I_I = m \times 100 \mu\text{A}$ | 1.25 | | | 1.25 | | | | |
| | $I_I = m \times 1 \text{mA}$ | 1.4 | | | 1.4 | | | | |
| h_F Current ratio (I_O/I_I) | $I_I = \text{MIN to MAX}$ | $m:n = 1:8$ | 6.97 | 7.72 | 8.13 | 7.05 | 7.72 | 8.13 | |
| | | $m:n = 1:4$ | 3.61 | 3.89 | 4.05 | 3.64 | 3.89 | 4.05 | |
| | | $m:n = 1:2$ | 1.84 | 1.98 | 2.07 | 1.88 | 1.98 | 2.07 | |
| | | $m:n = 1:1$ | 0.89 | 0.99 | 1.08 | 0.94 | 0.99 | 1.04 | |
| | | $m:n = 2:1$ | 0.46 | 0.50 | 0.56 | 0.475 | 0.50 | 0.525 | |
| α_{hF} Temperature coefficient of current ratio | $I_I = \text{MIN to MAX}$ | 300 | | | 300 | | | ppm/°C | |
| Output-to-input isolation | $I_I = \text{MIN to MAX}$, $f = 1 \text{ kHz}$ | 60 | | | 60 | | | dB | |
| $V_{O(th)}$ Output threshold voltage§ | $I_I = \text{MIN to MAX}$ | $T_A = \text{MIN}$ | 1.1 | | | 1.05 | | | V |
| | | $T_A = 25^\circ\text{C}$ | 1 | | | 1 | | | |
| r_o Output resistance¶ | $F = 1 \text{ kHz}$ | $I_I = m \times 10 \mu\text{A}$ | 200 m/n | | | 200 m/n | | | MΩ |
| | | $I_I = m \times 100 \mu\text{A}$ | 20 m/n | | | 20 m/n | | | |
| | | $I_I = m \times 1 \text{mA}$ | 2 m/n | | | 2 m/n | | | |
| f_{max} Maximum operating frequency# | $I_I = m \times 1 \text{mA}$, $R_L = 500 \Omega$ | 10 | | | 10 | | | MHz | |

† m is the number of input emitters, n is the number of output emitters. For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

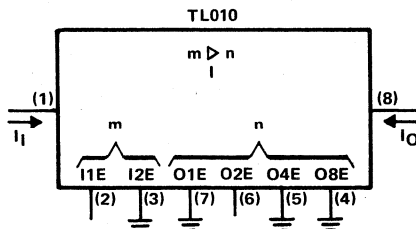
‡ All typical values are at $T_A = 25^\circ\text{C}$.

§ Output threshold voltage is the voltage at which the current ratio is equal to 90% of its value at $V_O = 15 \text{V}$.

¶ The output resistance is directly proportional to the number of input emitters divided by the number of output emitters (m/n).

Maximum operating frequency is the frequency at which the output current is down 3 dB from its low-frequency value.

TYPICAL APPLICATION INFORMATION



See Notes 3 and 4

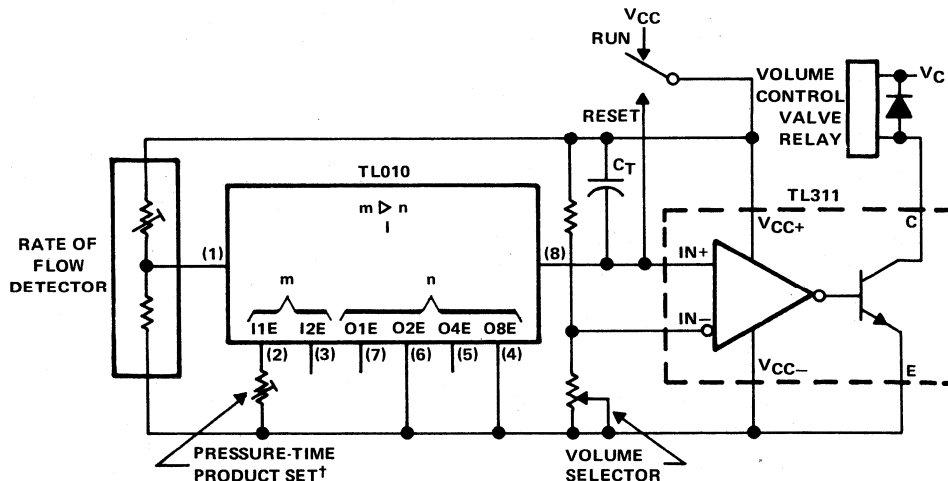
- NOTES: 3. Selected emitters must be grounded as close as possible to the package to avoid unstable device behavior. Using the fixed-Beta model, the current ratio for a current mirror of m input emitters and n output emitters may be calculated as

$$\frac{I_O}{I_i} = \frac{\beta^2 n + \beta(n + m)}{\beta^2 m + (\beta + 1)(m + n)}$$

Second-order effects, such as on-chip self-heating, may slightly perturb the observed ratio from the calculated value.

4. At high current levels, a small capacitor (270 pF) may be required between the input and output terminals to improve stability.

FIGURE 1. CURRENT MIRROR SET FOR A CURRENT RATIO OF 2:13



†Adjust for a mirror of 11.9

FIGURE 2. TYPICAL APPLICATION CIRCUIT

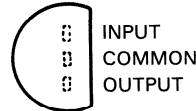
In the application shown in Figure 2, the problem is to measure a precise volume of liquid flowing through a line and shut off the flow with a relay when limit is reached. For the particular volume to be measured and the pressure detector used, a current gain of 11.9 is required. By setting the TLO10 for a gain of 10 with the emitter selection, the exact gain of 11.9 may be obtained by adjusting the pressure-time product control.

SERIES TL011, TL012, TL014A, TL021 FIXED-RATIO N-P-N CURRENT MIRRORS

D2614, FEBRUARY 1984—REVISED OCTOBER 1988

- **Wide Input Current Range:**
1 μ A to 1 mA
- **35-Volt Output Capability**
- **High Output Impedance**
- **Current-Ratio Tolerances Over Full Temperature Range;**
± 8% for I Suffix
± 7% for C Suffix
- **Typically Less Than ± 1% Error at 25°C**

LP PACKAGE
(TOP VIEW)



| TEMPERATURE RANGE | INPUT-TO-OUTPUT CURRENT RATIO | | | |
|-------------------|-------------------------------|--------|---------|--------|
| | 1:1 | 1:2 | 1:4 | 2:1 |
| -40°C to 85°C | TL011I | TL012I | | TL021I |
| 0°C to 70°C | TL011C | TL012C | TL014AC | TL021C |

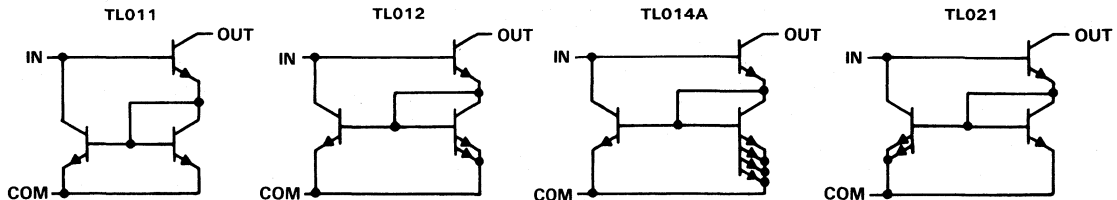
description

The TL011, TL012, TL014A, and TL021 are Wilson current mirrors with output currents in fixed proportion to the input currents and substantially independent of changes in voltage, load, and temperature. These devices make use of the tight matching properties of identical bipolar transistors on a monolithic integrated circuit chip to achieve current-ratio accuracy typically better than 98%.

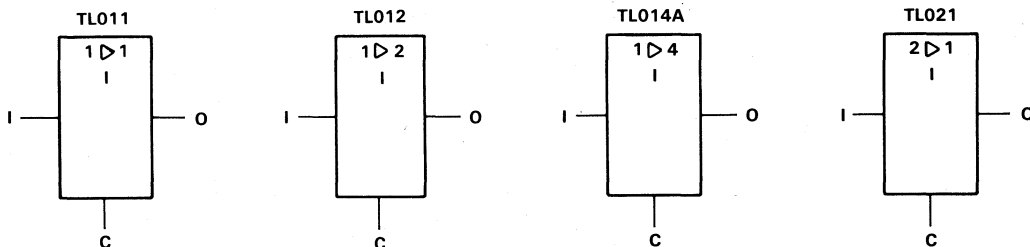
Current mirrors are used extensively in linear integrated circuit designs as active loads for operational-amplifier stages and as current sources for other stages. The TL011 family gives the designer this same capability with no sacrifice in accuracy or stability.

The TL011, TL012, and TL014A are designed to operate with input currents up to 1 mA and output voltage up to 35 V. The TL021 is designed for 2 mA and 35 V.

schematics



symbols



PRODUCTION DATA documents contain information current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.


TEXAS INSTRUMENTS
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SERIES TL011, TL012, TL014A, TL021 FIXED-RATIO N-P-N CURRENT MIRRORS

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|----------------|
| Output voltage (see Note 1) | 45 V |
| Input current | 5 mA |
| Continuous total dissipation at (or below) 25°C free-air temperature (see Note 2) | 775 mW |
| Operating free-air temperature range: TL011I, TL012I, TL021I | -40°C to 85°C |
| TL011C, TL012C, TL014AC, TL021C | 0°C to 70°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

- NOTES: 1. Input and output voltages are with respect to the common terminal. Neither voltage should be more negative than -0.3 V.
 2. For operation above 25°C free-air temperature, derate linearly at the rate of 6.2 mW/°C. The LP package dissipation rating was based on thermal resistance, $R_{\theta JA}$, measured in still air with the device mounted in an Augat socket. The bottom of the package was 10 mm (0.375 in.) above the socket.

recommended operating conditions

| | | TL0__I | | TL0__C, AC | | UNIT |
|---------------------------------------|------------|--------|-----|------------|-----|------|
| | | MIN | MAX | MIN | MAX | |
| Output voltage, V_O | | 5 | 35 | 5 | 35 | V |
| Input current, I_O | TL021 | 0.002 | 2 | 0.002 | 2 | mA |
| | All others | 0.001 | 1 | 0.001 | 1 | |
| Operating free-air temperature, T_A | | -40 | 85 | 0 | 70 | °C |

**SERIES TL011, TL012, TL014A, TL021
FIXED-RATIO N-P-N CURRENT MIRRORS**

electrical characteristics over recommended ranges of operating free-air temperature and output voltage (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | TL011 | | TL012 | | TL014A | | TL021 | | UNIT | | | |
|---|--|-------|------|-------|------|--------|------|-------|------|------|-------|-----|---------|
| | | MIN | TYP† | MAX | MIN | TYP† | MAX | MIN | TYP† | | MAX | | |
| V _I Input voltage | I _I = 1 μA | | 1 | | 1 | | 1 | | | | | | |
| | I _I = 2 μA | | | | | | | | 1 | | | | |
| | I _I = 10 μA | | 1.1 | | 1.1 | | 1.1 | | | | | | |
| | I _I = 20 μA | | | | | | | | 1.1 | V | | | |
| | I _I = 100 μA | | 1.25 | | 1.25 | | 1.25 | | | | | | |
| | I _I = 200 μA | | | | | | | | 1.25 | | | | |
| | I _I = 1 mA | | 1.4 | | 1.4 | | 1.4 | | | | | | |
| h _F Current ratio I _O /I _I | TLO ₋ J | | | | | | | | | | | | |
| | TLO ₋ C, AC | | | | | | | | | | | | |
| α _{IF} Temperature coefficient of current ratio | I _I = MIN to MAX† | 0.92 | 1 | 1.08 | 1.84 | 2 | 2.16 | 3.68 | 4 | 4.32 | 0.46 | 0.5 | 0.54 |
| | I _I = MIN to MAX | 0.93 | 1 | 1.07 | 1.86 | 2 | 2.14 | 3.72 | 4 | 4.28 | 0.465 | 0.5 | 0.535 |
| Output-to-input isolation | I _I = MIN to MAX, f = 1 kHz | | 50 | | 100 | | 200 | | 200 | | | | .ppm/°C |
| | I _I = MIN to MAX, f = 1 kHz | 80 | | 80 | | 80 | | 80 | | 80 | | | dB |
| V _{O(th)} Output threshold voltage‡ | TLO ₋ J | | | 1.35 | | 1.35 | | 1.35 | | 1.35 | | | |
| | TLO ₋ C, AC | | | 1.25 | | 1.25 | | 1.25 | | 1.25 | | | V |
| | All | | | 1.2 | | 1.2 | | 1.2 | | 1.2 | | | |
| r _o Output resistance | I _I = 10 μA | | 200 | | 100 | | 50 | | 200 | | | | MΩ |
| | I _I = 20 μA | | | | | | | | | | | | |
| | I _I = 100 μA | | 20 | | 10 | | 5 | | 20 | | | | |
| | I _I = 200 μA | | | | | | | | | | | | |
| | I _I = 1 mA | | 2 | | 1 | | 0.5 | | 2 | | | | |
| f _{max} Maximum operating frequency†† | I _I = MAX | | 10 | | 10 | | 10 | | 10 | | | | MHz |

† All typical values are at T_A = 25°C.

‡ For test conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

§ Output threshold voltage is the voltage at which the current ratio is equal to 90% of its value at V_O = 15 V.

¶ Maximum operating frequency is the frequency at which the output current is down 3 dB from its low frequency value.



**SERIES TL011, TL012, TL014A, TL021
FIXED-RATIO N-P-N CURRENT MIRRORS**

TYPICAL CHARACTERISTICS

**TL011
CURRENT RATIO
vs
FREE-AIR TEMPERATURE**

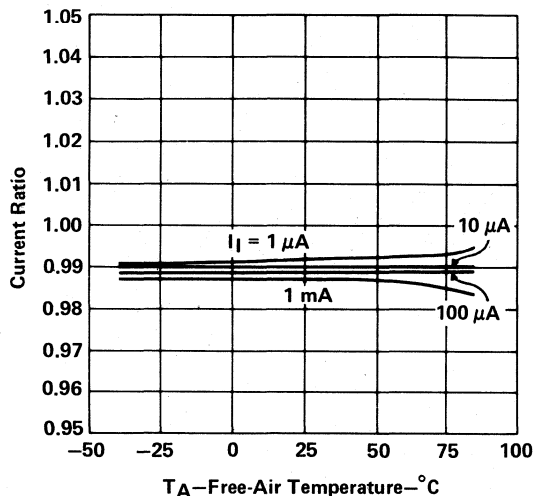


FIGURE 1

**TL012
CURRENT RATIO
vs
FREE-AIR TEMPERATURE**

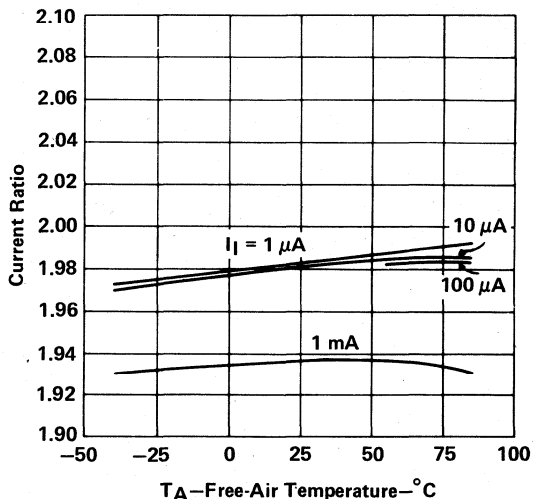


FIGURE 2

**TL014A
CURRENT RATIO
vs
FREE-AIR TEMPERATURE**

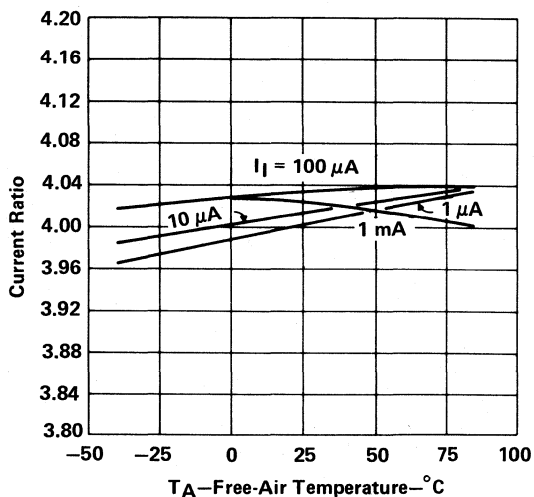


FIGURE 3

**TL021
CURRENT RATIO
vs
FREE-AIR TEMPERATURE**

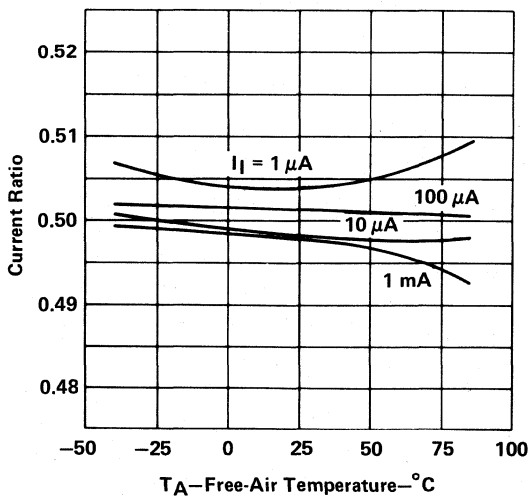


FIGURE 4



TYPICAL APPLICATIONS INFORMATION

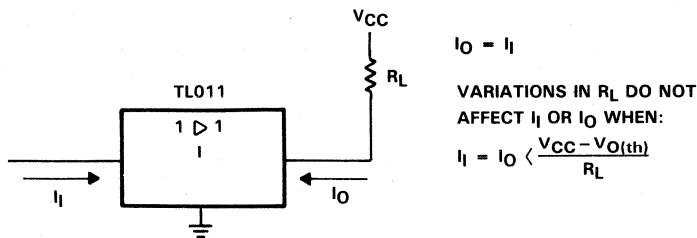
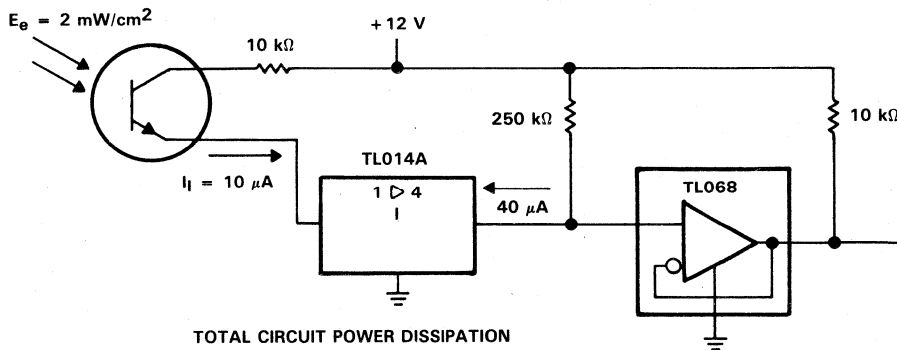


FIGURE 5. BASIC CURRENT BUFFER



Idle condition: $P_D = 1.5$ mW typical
 On condition: $P_D = 12.5$ mW typical
 10 μ A from phototransistor provides a V_O swing of 10 V at 1 mA.

FIGURE 6. PHOTOTRANSISTOR PREAMPLIFIER

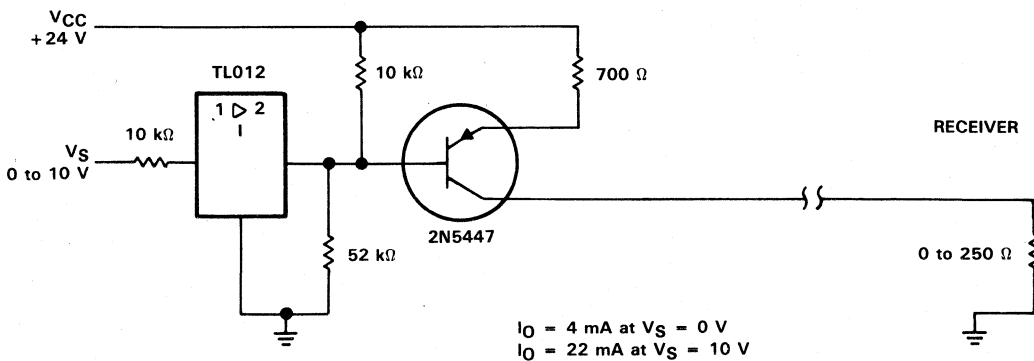


FIGURE 7. TWO-WIRE LINEAR CURRENT-MODE TRANSMITTER

TL026C

DIFFERENTIAL HIGH-FREQUENCY AMPLIFIER WITH AGC

D2790, JUNE 1985—REVISED JULY 1990

- Low Output Common-Mode Sensitivity to AGC Voltages
- Input and Output Impedances Independent of AGC Voltage
- Peak Gain . . . 38 dB Typ
- Wide AGC Range . . . 50 dB Typ
- 3-dB Bandwidth . . . 50 MHz
- Other Characteristics Similar to NE592 and uA733

description

This device is a monolithic two-stage high-frequency amplifier with differential inputs and outputs.

Internal feedback provides wide bandwidth, low phase distortion, and excellent gain stability. Variable gain based on signal summation provides large AGC control over a wide bandwidth with low harmonic distortion. Emitter-follower outputs enable the device to drive capacitive loads. All stages are current-source biased to obtain high common-mode and supply-voltage rejection ratios. The gain may be electronically attenuated by applying a control voltage to the AGC pin. No external frequency compensation components are required.

This device is particularly useful in TV and radio IF and RF AGC circuits, as well as magnetic-tape and disk-file systems where AGC is needed. Other applications include video and pulse amplifiers where a large AGC range, wide bandwidth, low phase shift, and excellent gain stability are required.

The TL026C is characterized for operation from 0°C to 70°C.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

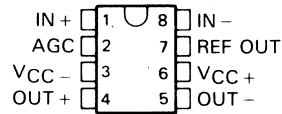
| | |
|--|------------------------------|
| Supply voltage, V_{CC+} (see Note 1) | 8 V |
| Supply voltage, V_{CC-} (see Note 1) | -8 V |
| Differential input voltage | ±5 V |
| Common-mode input voltage | ±6 V |
| Output current | 10 mA |
| Continuous total power dissipation | See Dissipation Rating Table |
| Operating free-air temperature | 0°C to 70°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 1: All voltages are with respect to the midpoint between V_{CC+} and V_{CC-} except differential input and output voltages.

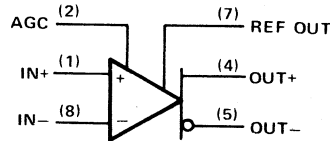
DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ | DERATING FACTOR | $T_A = 70^\circ\text{C}$ |
|---------|-----------------------------|--------------------------------|--------------------------|
| | POWER RATING | ABOVE $T_A = 25^\circ\text{C}$ | POWER RATING |
| D | 725 mW | 5.8 mW/°C | 464 mW |
| P | 1000 mW | 8.0 mW/°C | 640 mW |

**D OR P PACKAGE
(TOP VIEW)**



symbol



TL026C

DIFFERENTIAL HIGH-FREQUENCY AMPLIFIER WITH AGC

recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|---------------------------------------|-----|-----|-----|------|
| Supply voltage, V_{CC+} | 3 | 6 | 8 | V |
| Supply voltage, V_{CC-} | -3 | -6 | -8 | V |
| Operating free-air temperature, T_A | 0 | | 70 | °C |

electrical characteristics at 25 °C operating free-air temperature, $V_{CC\pm} = \pm 6$ V, $V_{AGC} = 0$, REF OUT pin open (unless otherwise specified)

| PARAMETER | TEST FIGURE | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|-------------|---|---------|----------|------|------------|
| A_{VD} Large-signal differential voltage amplification | 1 | $V_{O(PP)} = 3$ V, $R_L = 2$ k Ω | 65 | 85 | 105 | V/V |
| ΔA_{VD} Change in voltage amplification | 1 | $V_{I(PP)} = 28.5$ mV, $R_L = 2$ k Ω , $V_{AGC} - V_{ref} = \pm 180$ mV | | -50 | | dB |
| V_{ref} Voltage at REF OUT | | $I_{ref} = -1$ mA to 100 μ A | 1.3 | | 1.5 | V |
| BW Bandwidth (-3 dB) | 2 | $V_{O(PP)} = 1$ V, $V_{AGC} - V_{ref} = \pm 180$ mV | | 50 | | MHz |
| I_{IO} Input offset current | | | | 0.4 | 5 | μ A |
| I_{IB} Input bias current | | | | 10 | 30 | μ A |
| V_{ICR} Common-mode input voltage range | 3 | | ± 1 | | | V |
| V_{OC} Common-mode output voltage | 1 | $R_L = \infty$ | 3.25 | 3.75 | 4.25 | V |
| ΔV_{OC} Change in common-mode output voltage | 1 | $V_{AGC} = 0$ to 2 V, $R_L = \infty$ | | | 300 | mV |
| V_{OO} Output offset voltage | 1 | $V_{ID} = 0$, $R_L = \infty$ | | | 0.75 | V |
| $V_{O(PP)}$ Maximum peak-to-peak output voltage swing | 1 | $R_L = 2$ k Ω | 3 | 4 | | V |
| r_i Input resistance at AGC, IN+, or IN- | | | 10 | 30 | | k Ω |
| r_o Output resistance | | | | 20 | | Ω |
| CMRR Common-mode rejection ratio | 3 3 | $V_{IC} = \pm 1$ V, $f = 100$ kHz $V_{IC} = \pm 1$ V, $f = 5$ mHz | 60 | 86 60 | | dB |
| k_{SVR} Supply voltage rejection ratio ($\Delta V_{CC}/\Delta V_{IO}$) | 4 | $\Delta V_{CC+} = \pm 0.5$ V, $\Delta V_{CC-} = \pm 0.5$ V | 50 | 70 | | dB |
| V_n Broadband equivalent noise voltage | 4 | BW = 1 kHz to 10 MHz | | 12 | | μ V |
| t_{pd} Propagation delay time | 2 | $\Delta V_O = 1$ V | | 6 | 10 | ns |
| t_r Rise time | 2 | $\Delta V_O = 1$ V | | 4.5 | 12 | ns |
| $I_{sink(max)}$ Maximum output sink current | | $V_{ID} = 1$ V, $V_O = 3$ V | 3 | 4 | | mA |
| I_{CC} Supply current | | No load, No signal | | 22 | 27 | mA |

TL026C

DIFFERENTIAL HIGH-FREQUENCY AMPLIFIER WITH AGC

electrical characteristics over recommended operating free-air temperature range, $V_{CC\pm} = \pm 6\text{ V}$, $V_{AGC} = 0$, REF OUT pin open (unless otherwise specified)

| PARAMETER | TEST FIGURE | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-----------------|-------------|--|---------|-----|-----|------------------|
| A_{VD} | 1 | $V_{O(PP)} = 3\text{ V}$, $R_L = 2\text{ k}\Omega$ | 55 | 115 | | V/V |
| I_{IO} | | | | 6 | | μA |
| I_{IB} | | | | 40 | | μA |
| V_{ICR} | 3 | | ± 1 | | | V |
| V_{OD} | 1 | $V_{ID} = 0$, $R_L = \infty$ | | 1.5 | | V |
| $V_{O(PP)}$ | 1 | $R_L = 2\text{ k}\Omega$ | 2.8 | | | V |
| r_i | | | 8 | | | $\text{k}\Omega$ |
| CMRR | 3 | $V_{IC} = \pm 1\text{ V}$, $f = 100\text{ kHz}$ | 50 | | | dB |
| k_{SVR} | 4 | $\Delta V_{CC+} = \pm 0.5\text{ V}$, $\Delta V_{CC-} = \pm 0.5\text{ V}$ | 50 | | | dB |
| $I_{sink(max)}$ | | $V_{ID} = 1\text{ V}$, $V_O = 3\text{ V}$ | 2.8 | 4 | | mA |
| I_{CC} | 1 | No load, No signal | | 30 | | mA |

PARAMETER MEASUREMENT INFORMATION

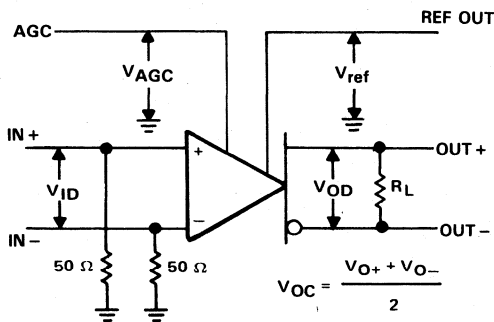


FIGURE 1

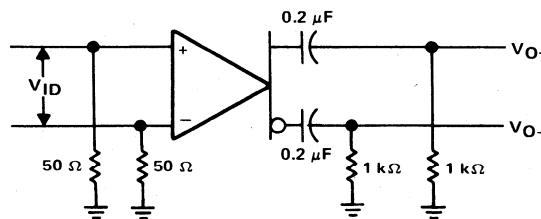


FIGURE 2

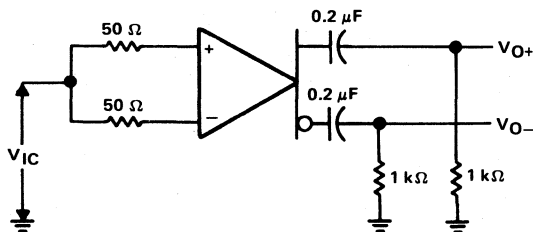


FIGURE 3

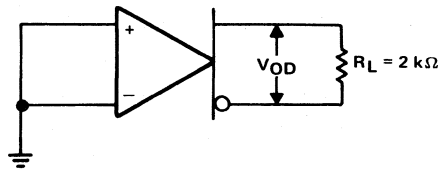


FIGURE 4

TL026C

DIFFERENTIAL HIGH-FREQUENCY AMPLIFIER WITH AGC

TYPICAL CHARACTERISTICS

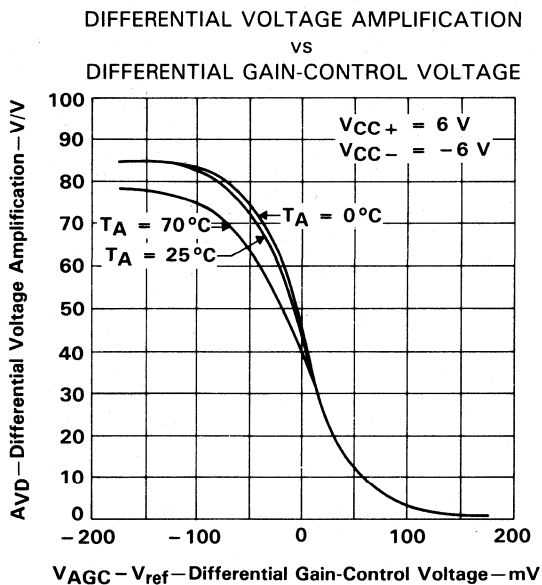


FIGURE 5

TYPICAL APPLICATION INFORMATION

gain characteristics

Figure 5 shows the differential voltage amplification versus the differential gain-control voltage ($V_{AGC} - V_{ref}$). V_{AGC} is the absolute voltage applied to the AGC input and V_{ref} is the dc voltage at the REF OUT output. As V_{AGC} increases with respect to V_{ref} , the TL026C gain changes from maximum to minimum. As shown in Figure 5 for example, V_{AGC} would have to vary from approximately 180 mV less than V_{ref} to approximately 180 mV greater than V_{ref} to change the gain from maximum to minimum. The total signal change in V_{AGC} is defined by the following equation.

$$\Delta V_{AGC} = V_{ref} + 180 \text{ mV} - (V_{ref} - 180 \text{ mV}) \quad (1)$$

$$\Delta V_{AGC} = 360 \text{ mV}$$

However, because V_{AGC} varies as the ac AGC signal varies and also differentially around V_{ref} , then V_{AGC} should have an ac signal component and a dc component. To preserve the dc and thermal tracking of the device, this dc voltage must be generated from V_{ref} . To apply proper bias to the AGC input, the external circuit used to generate V_{AGC} must combine these two voltages. Figures 6 and 7 show two circuits that will perform this operation and are easy to implement. The circuits use a standard dual operational amplifier for AGC feedback. By providing rectification and the required feedback gain, these circuits are also complete AGC systems.

circuit operation

Amplifier A1 amplifies and inverts the rectified and filtered AGC signal voltage V_C producing output voltage V_1 . Amplifier A2 is a differential amplifier that inverts V_1 again and adds the scaled V_{ref} voltage. This conditioning makes V_{AGC} the sum of the signal plus the scaled V_{ref} . As the signal voltage increases, V_{AGC} increases and the gain of the TLC026C is reduced. This maintains a constant output level.

feedback circuit equations

Following the AGC input signal (Figures 6 and 7) from the OUT output through the feedback amplifiers to the AGC input produces the following equation:

1. AC output to diode D1, assuming sinusoidal signals

$$V_o = V_{OP} (\sin (wt)) \quad (2)$$

where:

$$V_{OP} = \text{peak voltage of } V_o$$

2. Diode D1 and capacitor C1 output

$$V_c = V_{OP} - V_F \quad (3)$$

where:

$$V_F = \text{forward voltage drop of D1}$$

$$V_c = \text{voltage across capacitor C1}$$

3. A1 output

$$V_1 = - \frac{R_2}{R_1} V_c \quad (4)$$

TYPICAL APPLICATION INFORMATION

4. A2 output (R3 = R4)

$$V_{AGC} = \frac{R2}{R1} V_C + 2 \frac{R6}{R5 + R6} V_{ref} \quad (5)$$

Amplifier A2 inverts V1 producing a positive AGC signal voltage. Therefore, the input voltage to the TL026C AGC pin consists of an AGC signal equal to:

$$\frac{R2}{R1} V_C \quad (6)$$

and a dc voltage derived from V_{ref} , defined as the quiescent value of V_{AGC} .

$$V_{AGC}(q) = 2 \frac{R6}{R5 + R6} V_{ref} \quad (7)$$

For the initial resistor calculations, V_{ref} is assumed to be typically 1.4 V making quiescent V_{AGC} approximately 1.22 V ($V_{AGC}(q) = V_{ref} - 180$ mV). This voltage allows the TL026C to operate at maximum gain under no-signal and low-signal conditions. In addition, with V_{ref} used as both internal and external reference, its variation from device to device automatically adjusts the overall bias and makes AGC operation essentially independent of the absolute value of V_{ref} . The resistor divider needs to be calculated only once and is valid for the full tolerance of V_{ref} .

output voltage limits (see Figures 6 and 7)

The output voltage level desired must fall within the following limits.

1. Because the data sheet minimum output swing is 3 V peak-to-peak using a 2-k Ω load resistor, the user-selected design limit for the peak output swing should not exceed 1.5 V.
2. The voltage drop of the rectifying diode determines the lower voltage limit. When a silicon diode is used, this voltage is approximately 0.7 V. The output voltage V_O must have sufficient amplitude to exceed the rectifying diode drop. A schottky diode can be used to reduce the V_O level required.

gain calculations for a peak output voltage of 1 V

A peak output voltage of 1 V was chosen for gain calculations because it is approximately midway between the limits of conditions 1 and 2 in the preceding paragraph.

Using equation 3 ($V_C = V_{OP} - V_d$), V_C is calculated as follows:

$$V_C = 1 \text{ V} - 0.7 \text{ V}$$

$$V_C = 0.3 \text{ V}$$

Therefore, the gain of A1 must produce a voltage V1 that is equal to or greater than the total change in V_{AGC} for maximum TL026C gain change.

With a total change in V_{AGC} of 360 mV and using equation 4, the calculation is as follows:

$$-\frac{V1}{V_C} = \frac{\Delta V_{AGC}}{V_C} = \frac{R2}{R1} = \frac{0.36}{0.3} = 1.2$$

If R1 is 10 k Ω , R2 is 1.2 times R1 or 12 k Ω .

TYPICAL APPLICATION INFORMATION

Since the output voltage for this circuit must be between 0.85 V and 1.3 V, the component values in Figures 6 and 7 provide a nominal 1-V peak output limit. This limit is the best choice to allow for temperature variations of the diode and minimum output voltage specification.

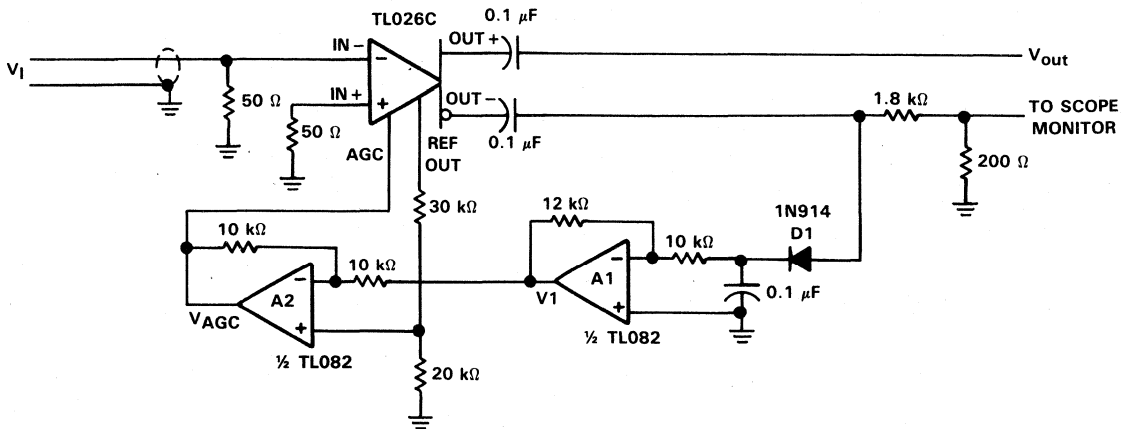
The circuit values in Figures 6 and 7 will produce the best results in this general application. Because of rectification and device input constraints, the circuit in Figure 6 will not provide attenuation and has about 32 dB of control range. The circuit shown in Figure 7 will have approximately 25% variation in the peak output voltage limit due to the variation in gain of the TL592 device to device. In addition, if a lower output voltage is desired, the output of the TL026C can be used for approximately 40 mV of controlled signal.

considerations for the use of the TL026C

To obtain the most reliable results, RF breadboarding techniques must be used. A groundplane board should be used and power supplies should be bypassed with 0.1- μ F capacitors. Input leads and output leads should be as short as possible and separated from each other.

A peak input voltage greater than 200 mV will begin to saturate the input stages of the TL026C and, while the circuit is in the AGC mode, the output signal may become distorted.

To observe the output signal of TL026C or TL592, low-capacitance FET probes or the output voltage divider technique shown in Figure 6 should be used.



NOTE: $V_{CC+} = 6\text{ V}$ and $V_{CC-} = -6\text{ V}$ for TL026C and amplifiers A1 and A2.

FIGURE 6. TYPICAL APPLICATION CIRCUIT WITH NO ATTENUATION

TL027C, TL027M DIFFERENTIAL HIGH-FREQUENCY AMPLIFIERS WITH AGC

D2888, JUNE 1985—REVISED JULY 1990

- Low Output Common-Mode Sensitivity to AGC Voltages
- Input and Output Impedances Independent of AGC Voltage
- Wide AGC Range . . . 50 dB Typ
- 3-dB Bandwidth . . . 50 MHz
- Other Characteristics Similar to NE592 and μ A733

DEVICE FEATURES

| | GAIN | AGC |
|---------------|-------|-------|
| Gain Option 1 | 50 dB | 50 dB |
| Gain Option 2 | 38 dB | 50 dB |

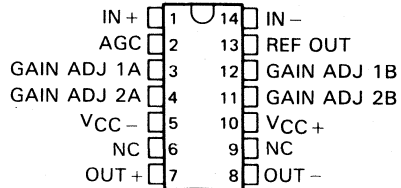
description

This device is a monolithic two-stage high-frequency amplifier with differential inputs and outputs. Internal feedback provides wide bandwidth, low phase distortion, and excellent gain stability. Variable gain based on signal summation provides large AGC control over a wide bandwidth with low harmonic distortion. Emitter-follower outputs enable the device to drive capacitive loads. All stages are current-source biased to obtain high common-mode and supply-voltage rejection ratios. The gain may be electronically attenuated by applying a control voltage to the AGC pins. No external frequency compensation components are required.

This device is particularly useful in TV and radio IF and RF AGC circuits, as well as magnetic-tape and disk-file systems where AGC is needed. Other applications include video and pulse amplifiers for which a large AGC range, wide bandwidth, low phase shift, and excellent gain stability are required.

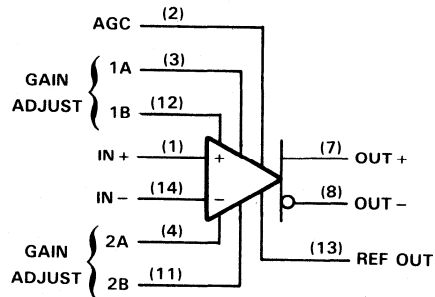
The TL027C is characterized for operation from 0°C to 70°C. The TL027M is characterized for operation over the full military temperature range of -55°C to 125°C.

D, J, OR N PACKAGE (TOP VIEW)



NC — No internal connection

symbol



TL027C, TL027M

DIFFERENTIAL HIGH-FREQUENCY AMPLIFIERS WITH AGC

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Supply voltage, V_{CC+} (see Note 1) | 8 V |
| Supply voltage, V_{CC-} (see Note 1) | -8 V |
| Differential input voltage | ± 5 V |
| Common-mode input voltage | ± 6 V |
| Output current | 10 mA |
| Continuous total power dissipation | See Dissipation Rating Table |
| Operating free-air temperature: TL027C | 0°C to 70°C |
| TL027M | -55°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or N package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package | 300°C |

NOTE 1: All voltage values are with respect to the midpoint between V_{CC+} and V_{CC-} except differential input and output voltages.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ | DERATING FACTOR | DERATE ABOVE T_A | $T_A = 70^\circ\text{C}$ | $T_A = 125^\circ\text{C}$ |
|--------------|-----------------------------|-----------------|--------------------|--------------------------|---------------------------|
| | POWER RATING | | | POWER RATING | POWER RATING |
| D | 500 mW | 7.6 mW/°C | 84°C | 500 mW | 190 mW |
| J (C-SUFFIX) | 500 mW | 8.2 mW/°C | 89°C | 500 mW | 205 mW |
| J (M-SUFFIX) | 500 mW | 11.0 mW/°C | 104°C | 500 mW | 275 mW |
| N | 500 mW | 9.2 mW/°C | 95°C | 500 mW | 230 mW |

recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|---------------------------------------|--------|-----|-----|------|
| Supply voltage, V_{CC+} | 3 | 6 | 8 | V |
| Supply voltage, V_{CC-} | -3 | -6 | -8 | V |
| Operating free-air temperature, T_A | TL027C | 0 | 70 | °C |
| | TL027M | -55 | 125 | |

electrical characteristics over recommended operating free-air temperature range, $V_{CC\pm} = \pm 6$ V, $V_{AGC} = 0$, REF OUT pin open (unless otherwise noted)

| PARAMETER | TEST FIGURE | TEST CONDITIONS | GAIN OPTION† | MIN | TYP | MAX | UNIT |
|------------------------|-------------|--|--------------|---------|-----|-----|------------|
| A _{VD} | 1 | $V_{O(PP)} = 3$ V, $R_L = 2$ k Ω | 1 | 150 | 450 | | V/V |
| | | | 2 | 55 | 115 | | |
| I _{IQ} | | | 1 or 2 | | | 6 | μ A |
| I _{IB} | | | 1 or 2 | | | 40 | μ A |
| V _{ICR} | 3 | | 2 | ± 1 | | | V |
| V _{OO} | 1 | $V_{ID} = 0$, $R_L = \infty$ | 1 or 2 | | | 1.5 | V |
| V _{O(PP)} | 1 | $R_L = 2$ k Ω | 1 or 2 | 2.8 | | | V |
| r _i | | | 2 | 8 | | | k Ω |
| CMRR | 3 | $V_{IC} = \pm 1$ V, $f < 100$ kHz | 2 | 50 | | | dB |
| k _{SVR} | 4 | $\Delta V_{CC+} = \pm 0.5$ V, $\Delta V_{CC-} = \pm 0.5$ V | 2 | 50 | | | dB |
| I _{sink(max)} | | $V_{ID} = 1$ V, $V_O = 3$ V | 1 or 2 | 2.8 | 4 | | mA |
| I _{CC} | 1 | No load, No signal | 1 or 2 | | | 30 | mA |

† The gain option is selected as follows:

Gain Option 1... Gain Adjust pin 1A is connected to pin 1B, pins 2A and 2B are open.

Gain Option 2... Gain Adjust pin 2A is connected to pin 2B, pins 1A and 1B are open.



TL027C, TL027M

DIFFERENTIAL HIGH-FREQUENCY AMPLIFIERS WITH AGC

electrical characteristics, $V_{CC\pm} = \pm 6\text{ V}$, $V_{AGC} = 0$, $T_A = 25^\circ\text{C}$, REF OUT pin open (unless otherwise noted)

| PARAMETER | TEST FIGURE | TEST CONDITIONS | GAIN OPTION† | MIN | TYP | MAX | UNIT |
|------------------|-------------|--|--------------|---------|------|------|---------------|
| | | | | | | | |
| A _{VD} | 1 | $V_{O(PP)} = 3\text{ V}$, $R_L = 2\text{ k}\Omega$ | 1 | 200 | 300 | 400 | V/V |
| | | | 2 | 65 | 85 | 105 | |
| ΔA_{VD1} | 1 | $V_{I(PP)} = 7.5\text{ mV}$, $R_L = 2\text{ k}\Omega$, $V_{AGC} - V_{ref} = \pm 180\text{ mV}$ | 1 | -50 | | | dB |
| ΔA_{VD2} | 1 | $V_{I(PP)} = 28.5\text{ mV}$, $R_L = 2\text{ k}\Omega$, $V_{AGC} - V_{ref} = \pm 180\text{ mV}$ | 2 | -50 | | | dB |
| V_{ref} | | $I_{ref} = 1\text{ mA}$ to $100\ \mu\text{A}$ | 1 | 1.3 | | 1.5 | V |
| BW | 2 | $V_{O(PP)} = 1\text{ V}$, $V_{AGC} - V_{ref} = \pm 180\text{ mV}$ | 1 | 20 | | | MHz |
| | | | 2 | 50 | | | |
| I_{IO} | | | 1 or 2 | 0.4 | | 5 | μA |
| I_{IB} | | | 1 or 2 | 10 | | 30 | μA |
| V_{ICR} | 3 | | 2 | ± 1 | | | V |
| V_{OC} | 1 | $R_L = \infty$ | 1 or 2 | 3.25 | 3.75 | 4.25 | V |
| ΔV_{OC} | 1 | $V_{AGC} = 0$ to 2 V , $R_L = \infty$ | 1 or 2 | | | 300 | mV |
| V_{OO} | 1 | $V_{ID} = 0$, $R_L = \infty$ | 1 or 2 | | | 0.75 | V |
| $V_{O(PP)}$ | 1 | $R_L = 2\text{ k}\Omega$ | 1 or 2 | 3 | 4 | | V |
| r_i | | | 1 | 4 | | | k Ω |
| | | | 2 | 10 | 30 | | |
| r_o | | | | 20 | | | Ω |
| C_i | | | | 2 | | | pF |
| CMRR | 3 | $V_{IC} = \pm 1\text{ V}$, $f < 100\text{ kHz}$ | 2 | 60 | 86 | | dB |
| | 3 | $V_{IC} = \pm 1\text{ V}$, $f = 5\text{ MHz}$ | 2 | 60 | | | |
| k _{SVR} | 4 | $\Delta V_{CC+} = \pm 0.5\text{ V}$, $\Delta V_{CC-} = \pm 0.5\text{ V}$ | 2 | 50 | 70 | | dB |
| V_n | 4 | BW = 1 kHz to 10 MHz | 1 or 2 | 12 | | | μV |
| t_{pd} | 2 | $\Delta V_O = \pm 1\text{ V}$ | 1 | 7.5 | | | ns |
| | | | 2 | 6 | 10 | | |
| t_r | 2 | $\Delta V_O = \pm 1\text{ V}$ | 1 | 10.5 | | | ns |
| | | | 2 | 4.5 | 12 | | |
| $I_{sink(max)}$ | | $V_{ID} = 1\text{ V}$, $V_O = 3\text{ V}$ | 1 or 2 | 3 | 4 | | mA |
| I_{CC} | | No load, No signal | 1 or 2 | 22 | 27 | | mA |

† The gain option is selected as follows:

Gain Option 1. . . Gain Adjust pin 1A is connected to pin 1B, pins 2A and 2B are open.

Gain Option 2. . . Gain Adjust pin 2A is connected to pin 2B, pins 1A and 1B are open.

TL027C, TL027M

DIFFERENTIAL HIGH-FREQUENCY AMPLIFIERS WITH AGC

PARAMETER MEASUREMENT INFORMATION

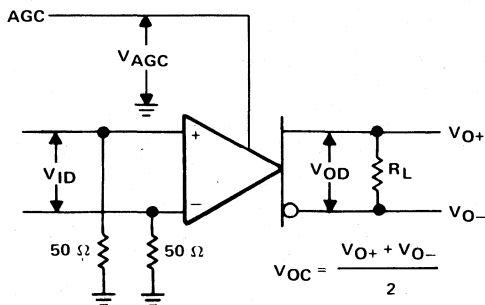


FIGURE 1

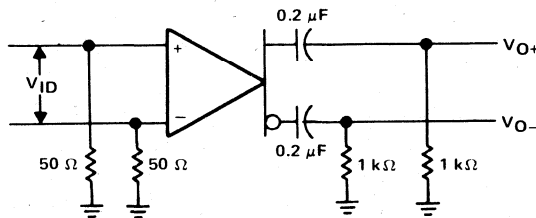


FIGURE 2

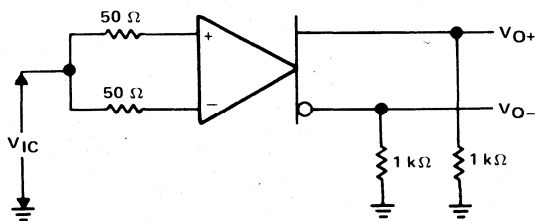


FIGURE 3

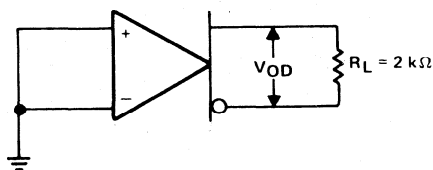


FIGURE 4

TYPICAL CHARACTERISTICS

DIFFERENTIAL VOLTAGE AMPLIFICATION
vs
DIFFERENTIAL GAIN-CONTROL VOLTAGE

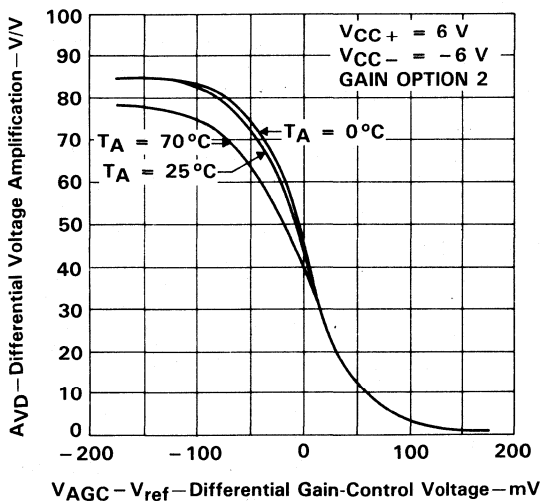


FIGURE 5

DIFFERENTIAL VOLTAGE AMPLIFICATION
vs
DIFFERENTIAL GAIN-CONTROL VOLTAGE

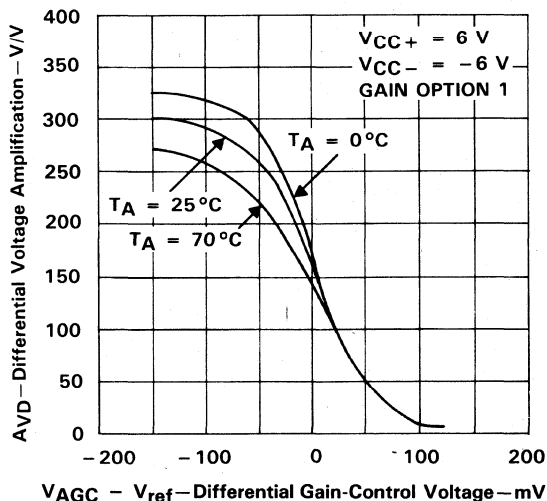


FIGURE 6

TYPICAL APPLICATION INFORMATION

gain characteristics

Figure 5 and 6 show the differential voltage amplification versus the differential gain-control voltage ($V_{AGC} - V_{ref}$). V_{AGC} is the absolute voltage applied to the AGC input and V_{ref} is the dc voltage at the REF OUT output. As V_{AGC} increases with respect to V_{ref} , the TL027C gain changes from maximum to minimum. As shown in Figure 5 for example, V_{AGC} would have to vary from approximately 180 mV less than V_{ref} to approximately 180 mV greater than V_{ref} to change the gain from maximum to minimum. The total signal change in V_{AGC} is defined by the following equation.

$$\begin{aligned} \Delta V_{AGC} &= V_{ref} + 180 \text{ mV} - (V_{ref} - 180 \text{ mV}) & (1) \\ \Delta V_{AGC} &= 360 \text{ mV} \end{aligned}$$

However, because V_{AGC} varies as the ac AGC signal varies and also differentially around V_{ref} , then V_{AGC} should have an ac signal component and a dc component. To preserve the dc and thermal tracking of the device, this dc voltage must be generated from V_{ref} . To apply proper bias to the AGC input, the external circuit used to generate V_{AGC} must combine these two voltages. Figures 7 and 8 show two circuits that will perform this operation and are easy to implement. The circuits use a standard dual operational amplifier for AGC feedback. By providing rectification and the required feedback gain, these circuits are also complete AGC systems.

circuit operation

Amplifier A1 amplifies and inverts the rectified and filtered AGC signal voltage V_C producing output voltage V1. Amplifier A2 is a differential amplifier that inverts V1 again and adds the scaled V_{ref} voltage. This conditioning makes V_{AGC} the sum of the signal plus the scaled V_{ref} . As the signal voltage increases, V_{AGC} increases and the gain of the TL027C is reduced. This maintains a constant output level.

feedback circuit equations

Following the AGC input signal (Figures 7 and 8) from the OUT – through the feedback amplifiers to the AGC input produces the following equations.

1. AC output to diode D1, assuming sinusoidal signals

$$V_o = V_{OP} (\sin(\omega t)) \quad (2)$$

where:

$$V_{OP} = \text{peak voltage of } V_o$$

2. Diode D1 and capacitor C1 output

$$V_C = V_{OP} - V_F \quad (3)$$

where:

$$\begin{aligned} V_F &= \text{forward voltage drop of D1} \\ V_C &= \text{voltage across capacitor C1} \end{aligned}$$

3. A1 output

$$V1 = - \frac{R2}{R1} V_C \quad (4)$$

TYPICAL APPLICATION INFORMATION

4. A2 output ($R3 = R4$)

$$V_{AGC} = \frac{R2}{R1} V_C + 2 \frac{R1}{R5 + R6} V_{ref} \quad (5)$$

Amplifier A2 inverts V1 producing a positive AGC signal voltage. Therefore, the input voltage to the TL027C AGC pin consists of an AGC signal equal to:

$$\frac{R2}{R1} V_C \quad (6)$$

and a dc voltage derived from V_{ref} , defined as the quiescent value of V_{AGC} .

$$V_{AGC(q)} = 2 \frac{R6}{R5 + R6} V_{ref} \quad (7)$$

For the initial resistor calculations, V_{ref} is assumed to be typically 1.4 V making quiescent V_{AGC} approximately 1.22 V ($V_{AGC(q)} = V_{ref} - 180$ mV). This voltage allows the TL027C to operate at maximum gain under no-signal and low-signal conditions. In addition, with V_{ref} used as both internal and external reference, its variation from device to device automatically adjusts the overall bias and makes AGC operation essentially independent of the absolute value of V_{ref} . The resistor divider needs to be calculated only once and is valid for the full tolerance of V_{ref} .

output voltage limits (see Figures 7 and 8)

The output voltage level desired must fall within the following limits:

1. Because the data sheet minimum output swing is 3 V peak-to-peak using a 2-k Ω load resistor, the user-selected design limit for the peak output swing should not exceed 1.5 V.
2. The voltage drop of the rectifying diode determines the lower voltage limit. When a silicon diode is used, this voltage is approximately 0.7 V. The output voltage V_O must have sufficient amplitude to exceed the rectifying diode drop. A schottky diode can be used to reduce the V_O level required.

gain calculations for a peak output voltage of 1 V

A peak output voltage of 1 V was chosen for gain calculations because it is approximately midway between the limits of conditions 1 and 2 in the preceding paragraph.

Using equation 3 ($V_C = V_{OP} - V_d$), V_C is calculated as follows:

$$V_C = 1 \text{ V} - 0.7 \text{ V}$$

$$V_C = 0.3 \text{ V}$$

Therefore, the gain of A1 must produce a voltage V1 that is equal to or greater than the total change in V_{AGC} for maximum TL027C gain change.

With a total change in V_{AGC} of 360 mV and using equation 4, the calculation is as follows:

$$-\frac{V1}{V_C} = \frac{\Delta V_{AGC}}{V_C} = \frac{R2}{R1} = \frac{0.36}{0.3} = 1.2$$

If R1 is 10 k Ω , R2 is 1.2 times R1 or 12 k Ω .

TL027C, TL027M

DIFFERENTIAL HIGH-FREQUENCY AMPLIFIERS WITH AGC

TYPICAL APPLICATION INFORMATION

Since the output voltage for this circuit must be between 0.85 V and 1.3 V, the component values in Figures 7 and 8 provide a nominal 1-V peak output limit. This limit is the best choice to allow for temperature variations of the diode and minimum output voltage specification.

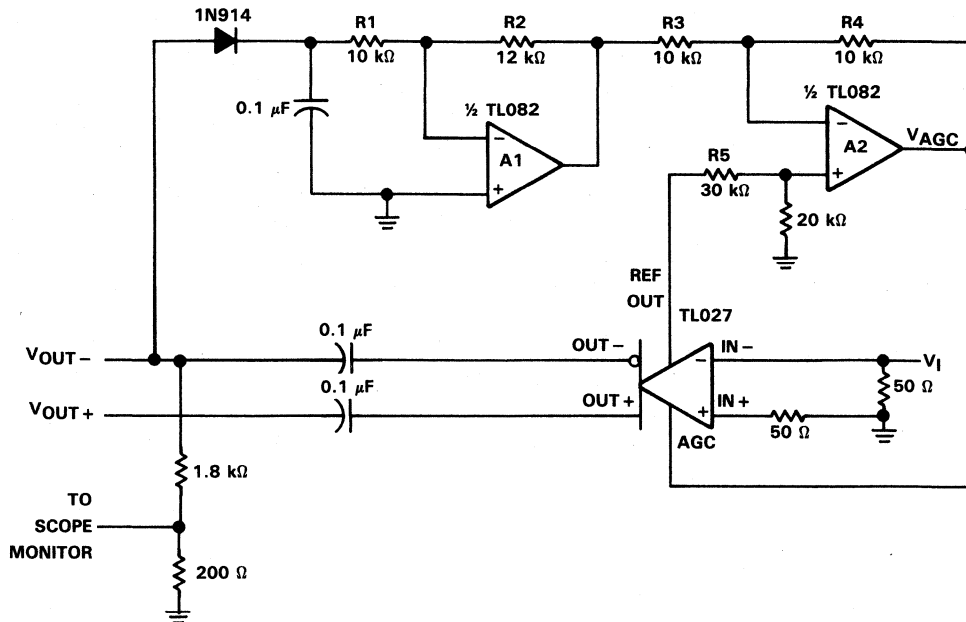
The circuit values in Figures 7 and 8 will produce the best results in this general application. Because of rectification and device input constraints, the circuit in Figure 7 will not provide attenuation and has about 32 dB of control range. The circuit shown in Figure 8 will have approximately 25% variation in the peak output voltage limit due to the variation in gain of the TL592 device to device. In addition, if a lower output voltage is desired, the output of the TL027C can be used for approximately 40 mV of controlled signal.

considerations for the use of the TL027C

To obtain the most reliable results, RF breadboarding techniques must be used. A groundplane board should be used and power supplies should be bypassed with 0.1- μ F capacitors. Input leads and output leads should be as short as possible and separated from each other.

A peak input voltage greater than 200 mV will begin to saturate the input stages of the TL027C and, while the circuit is in the AGC mode, the output signal may become distorted.

To observe the output signal of TL027C or TL592, low-capacitance FET probes or the output voltage divider technique shown in Figure 7 should be used.



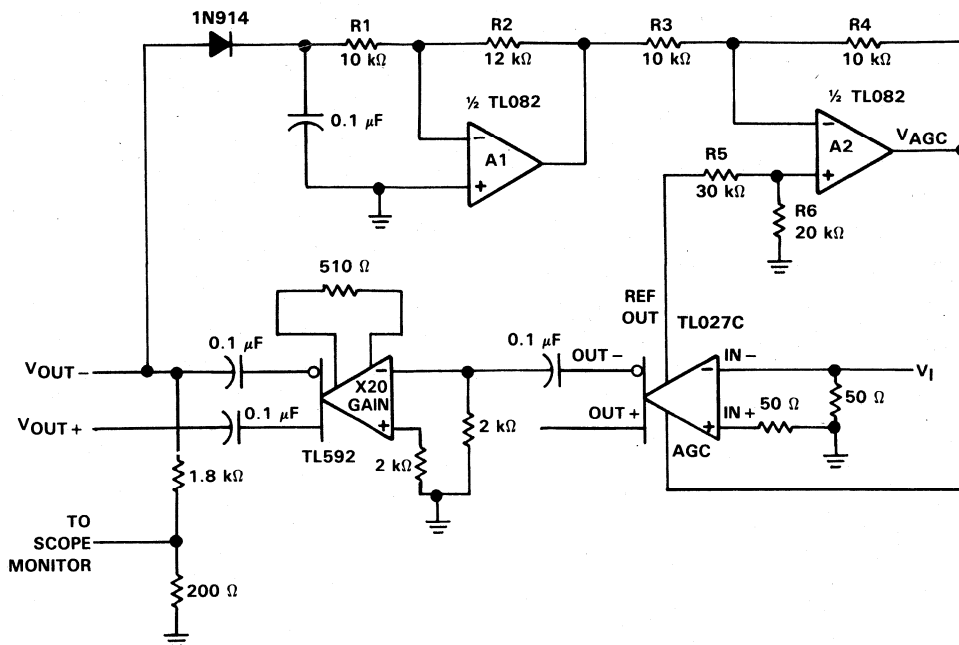
NOTES: A. $V_{CC+} = 6$ V and $V_{CC-} = -6$ V for TL027C and amplifiers A1 and A2.

B. On the TL027, short pin 3 to pin 12 and pin 4 to pin 11. Connect pins 6 and 9 to ground.

FIGURE 7. TYPICAL APPLICATION CIRCUIT WITH NO ATTENUATION

TL027C, TL027M DIFFERENTIAL HIGH-FREQUENCY AMPLIFIERS WITH AGC

TYPICAL APPLICATION INFORMATION



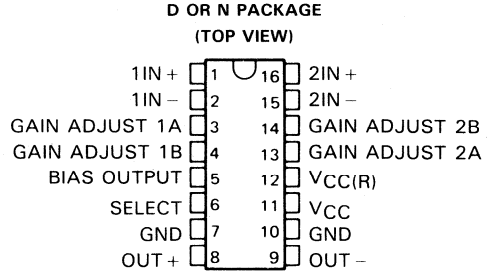
- NOTES: A. $V_{CC+} = 6\text{ V}$ and $V_{CC-} = -6\text{ V}$ for TL027C and amplifiers A1 and A2.
 B. On TL027, short pin 3 to pin 12 and pin 4 to pin 11. Connect pins 6 and 9 to ground.

FIGURE 8. TYPICAL APPLICATION CIRCUIT WITH ATTENUATION

TL040C 2-CHANNEL MULTIPLEXED VIDEO AMPLIFIER

D3002, MARCH 1986—REVISED DECEMBER 1988

- Designed for Use with the TL041 Magnetic Field Pulse Detector
- Wide Bandwidth . . . 20 MHz Typ
- Low Noise . . . Less than 8 μ V Typ
- Independently Adjustable Channel Gains . . . Up to 450 Typ
- No Frequency Compensation Required
- Internal Voltage Source Eliminates External Components
- Input Channel Select Pin is Compatible with TTL and CMOS
- Low Power Dissipation . . . 150 mW Typ



CHANNEL SELECT TABLE

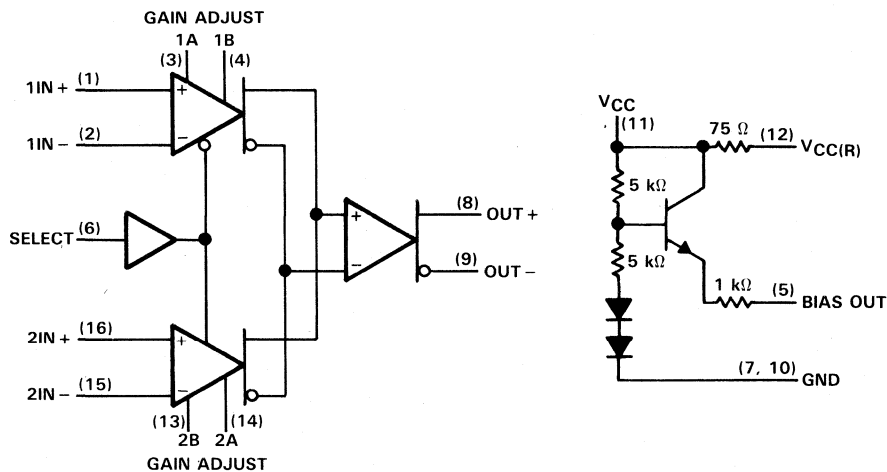
| SELECT | CHANNEL |
|--------|---------|
| L | 1 |
| H | 2 |

description

The TL040 is a two-channel multiplexed video amplifier designed for use with magnetic pulse detectors in streaming tape drives. The circuit design eliminates many external components, and the D package allows substantial reduction in circuit board area. The gain of each channel is a function of the resistance across its gain-adjust pins (A-B) with maximum gain occurring when the terminals are shorted.

The VCC(R) pin provides supply voltage decoupling required by some designs. The BIAS OUT pin provides a voltage source for other circuits that is approximately equal to 1/2 VCC.

functional block diagram



PRODUCTION DATA documents contain information current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.



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TLO40C

2-CHANNEL MULTIPLEXED VIDEO AMPLIFIER

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|-----------------------|
| Supply voltage, VCC (see Note 1) | 14 V |
| Input voltage range | -0.2 V to VCC + 0.2 V |
| Continuous total power dissipation | 600 mW |
| Operating free-air temperature range | 0°C to 70°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 1: All voltages except differential voltages are with respect to the ground terminals.

recommended operating conditions

| | MIN | TYP | MAX | UNIT |
|--|------|-----|------|------|
| Supply voltage, VCC | 10.8 | 12 | 13.2 | V |
| Common-mode input voltage (diff inputs), V _{IC} | 5 | 6 | 7 | V |
| High-level input voltage, SELECT input, V _{IH} | 2 | | | V |
| Low-level input voltage, SELECT input, V _{IL} | | | 0.8 | V |
| Output sink current (diff outputs), I _{sink} | | | 1.5 | mA |
| Operating free-air temperature, T _A | 0 | | 70 | °C |

electrical characteristics of selected channel at T_A = 25°C, VCC = 12 V, R_{AB} = 0, R_L = 2 kΩ (unless otherwise noted)

| PARAMETER | TEST FIGURE | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|-------------|---|-----|-----|------|------|
| A _{VD} Large-signal differential voltage amplification | 1 | | 300 | 530 | 600 | V/V |
| Channel amplification mismatch | 1 | | | 1% | | |
| Large-signal differential voltage attenuation | 1 | ΔV _I = 50 mV on unselected input | | 60 | | dB |
| V _{OC} Common-mode output voltage | 1 | R _L = ∞ | | 8.5 | | V |
| V _{OPP} Maximum peak-to-peak output voltage swing | 1 | | | 4 | | V |
| BW Bandwidth (-3 dB) | 2 | | | 20 | | MHz |
| I _{IQ} Input offset current | 1 | | | 0.1 | 3 | μA |
| I _{IB} Input bias current | 1 | | | 6 | 17 | μA |
| V _{OD} Differential output voltage | 1 | R _L = ∞, V _{ID} = 0 | | 0.2 | | V |
| r _i Input resistance (differential inputs) | | | | 4 | | kΩ |
| CMRR Common-mode rejection ratio | 3 | V _{IC} = 5 V to 7 V | 60 | 100 | | dB |
| k _{SVR} Supply-voltage rejection ratio (ΔV _{CC} /ΔV _{IO}) | 4 | VCC = 10.8 V to 13.2 V | 50 | 70 | | dB |
| V _n Broadband equivalent input noise voltage | 4 | | | <5 | | μV |
| I _{IH} High-level input current, Select input | | V _{IH} = 2.7 V | | | -0.4 | mA |
| I _{IL} Low-level input current, Select input | | V _{IL} = 0.4 V | | | 20 | μA |
| t _{pd} Propagation delay time (differential inputs) | 2 | ΔV _O = 1 V | | 15 | | ns |
| t _r Output rise time | 2 | ΔV _O = 1 V | | 20 | | ns |
| I _{CC} Supply current | 1 | | | 12 | 15 | mA |
| Bias output voltage | 1 | | 5 | 6 | 7 | V |

PARAMETER MEASUREMENT INFORMATION

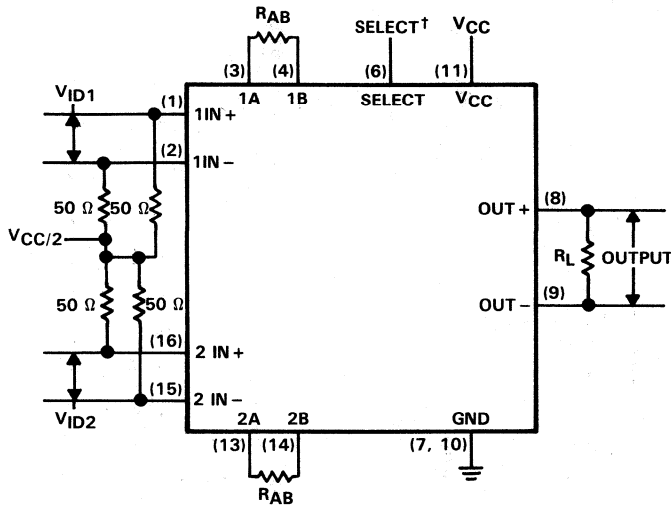


FIGURE 1

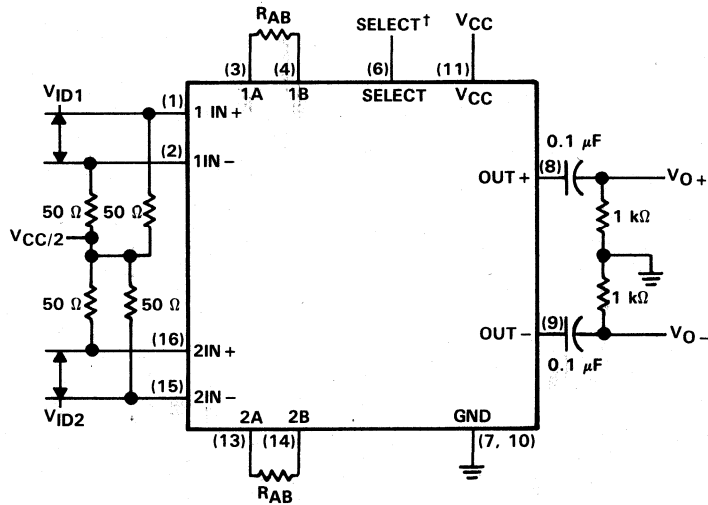


FIGURE 2

†Select input must be at proper logic level to select desired input channel.

TL040C
2-CHANNEL MULTIPLEXED VIDEO AMPLIFIER

PARAMETER MEASUREMENT INFORMATION (continued)

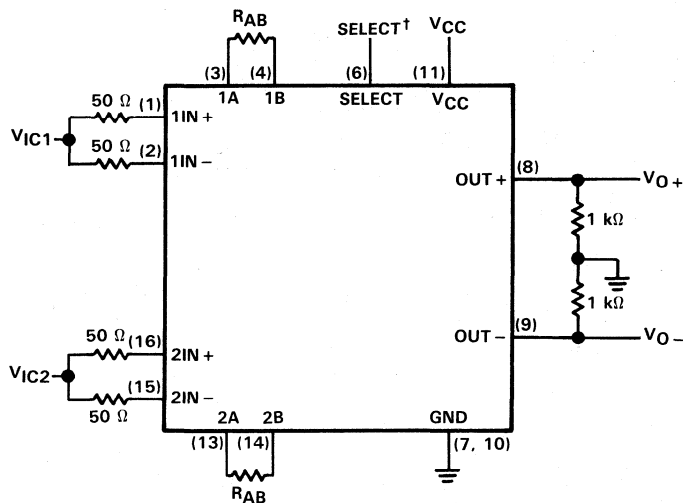


FIGURE 3

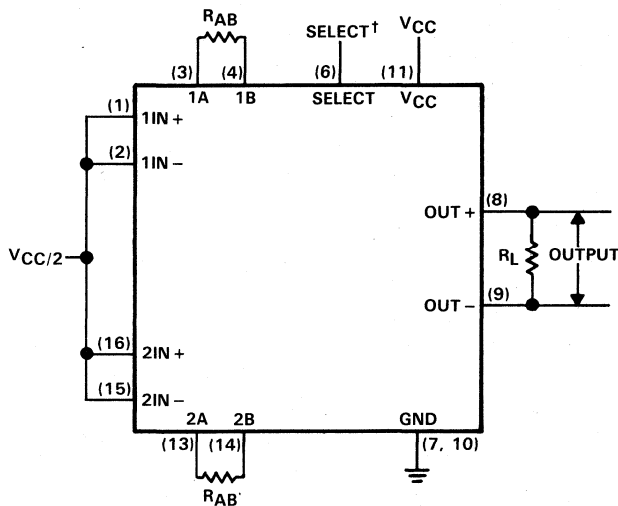


FIGURE 4

†Select input must be at proper logic level to select desired input channel.

TYPICAL CHARACTERISTICS

LARGE-SIGNAL DIFFERENTIAL
VOLTAGE AMPLIFICATION
vs
GAIN-ADJUST RESISTANCE

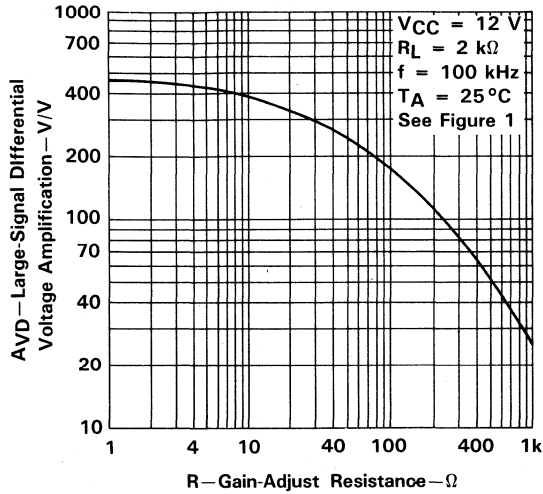


FIGURE 5

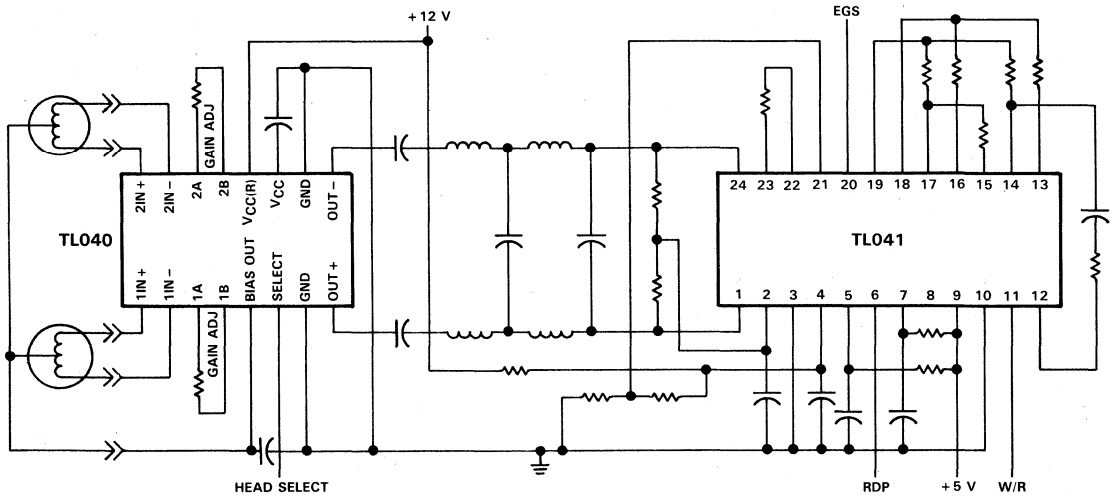
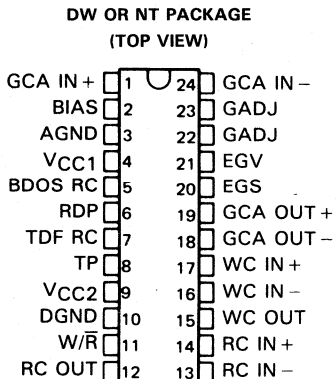


FIGURE 6. READ SIGNAL CIRCUIT FOR A STREAMING TAPE DRIVE

TL041AC TAPE READ SIGNAL CONDITIONER

D3024, AUGUST 1987—REVISED SEPTEMBER 1989

- **Designed for Signal Processing in Streaming-Tape Memory Units in Combination with TL040 Two-Channel Video Amplifier**
- **Space-Saving LSI Circuits Include:**
 - Two High-Speed Differential Comparators**
 - Time-Domain Filter**
 - Bidirectional One-Shot Multivibrator**
 - Gain-Controlled Video Amplifier with Differential Inputs and Outputs**
- **Amplifier and Comparator**
Bandwidth . . . 20 MHz Typical
- **Maximum Data Rate at Read Data Pulse (RDP) . . . 1.4 Mb/s Typical**
- **Available in 300-mil Dual-In-Line and "Small Outline" Plastic Packages**



description

The TL041AC is a magnetic tape read signal conditioner designed for use with the TL040 video amplifier. When combined, these devices amplify the low-signal output from a streaming-tape playback head and reconstruct the data as originally written on the tape. The TL041AC includes a gain-controlled amplifier, two comparators, read/write select logic, a time-domain filter, and a bidirectional one-shot multivibrator.

The amplifier has differential inputs, differential outputs, and electronic gain control. A special feature of the electronic gain control is the Electronic Gain Select (EGS). When the EGS input is high, the Electronic Gain Voltage (EGV) input is driven low and amplifier gain is determined by the value of the resistor connected between the Gain Adjust (GADJ) pins. When the EGS input is low, the gain set by the resistor is increased by an amount determined by the voltage applied to the EGV pin.

To accommodate different magnetic tape output signal levels, the amplifier gain may be switched by logic at the EGS input, controlled manually with an adjustable voltage at the EGV input, or automatically adjusted with an automatic gain control (AGC) circuit applying a control voltage to the EGV input.

The comparator functions are controlled by a logic input to the Write/Read (W/\bar{R}) select input. With the W/\bar{R} input low, the read comparator output (usually connected as a zero-crossing detector) is sent to the time-domain filter. When W/\bar{R} is high, the write comparator output is used to provide write amplitude verification in a typical read-after-write function.

The time-domain filter helps to ensure the input data is valid. A capacitor in series with a resistor, connected to the time-domain filter pin (TDF RC), begins charging at the leading edge of an input pulse from the read comparator. If the input pulse does not remain high for one RC time constant, the pulse is considered invalid and no signal is passed to the bidirectional one-shot multivibrator (BDOS). However, if the input pulse remains high for longer than one RC time constant, the pulse is considered valid and the signal is passed through the time-domain filter to trigger the BDOS. When triggered, the BDOS provides a pulse to the Read Data Pulse (RDP) output. The RDP output pulse duration is determined by a resistor-capacitor network connected to the BDOS RC pin.

The TL041AC is characterized for operation from 0°C to 70°C.

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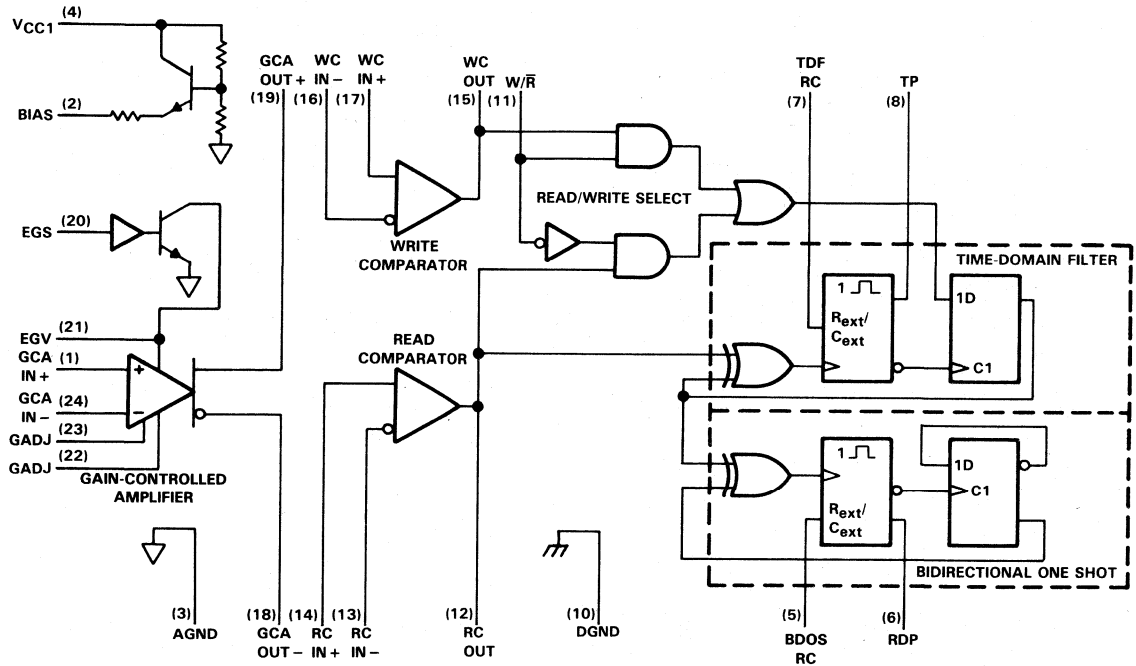

**TEXAS
INSTRUMENTS**

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TL041AC TAPE READ SIGNAL CONDITIONER

functional block diagram



FUNCTION TABLE

| EGS | W/R | INPUT CONDITIONS | | I/O NAME | I/O CONDITION |
|-----|-----|---|--|----------|-----------------------------|
| | | DIFFERENTIAL INPUTS WRITE OR READ COMPARATOR | | | |
| | X | RC IN+ > RC IN- | | RC OUT | H |
| | X | RC IN- > RC IN+ | | RC OUT | L |
| | L | X | | RC OUT | Input to time-domain filter |
| | X | WC IN+ > WC IN- | | WC OUT | H |
| | X | WC IN- > WC IN+ | | WC OUT | L |
| | H | X | | WC OUT | Input to time-domain filter |
| H | | X | | EGV | L |
| L | | X | | EGV | Input |

TL041AC
TAPE READ SIGNAL CONDITIONER

| PIN | | DESCRIPTION |
|-----------|-----|--|
| NAME | NO. | |
| AGND | 3 | Analog ground |
| BDOS RC | 5 | Bidirectional one-shot resistor and capacitor |
| BIAS | 2 | Output bias voltage |
| DGND | 10 | Digital ground |
| EGS | 20 | Electronic gain select |
| EGV | 21 | Electronic gain voltage |
| GCA IN - | 24 | Gain-controlled amplifier, inverting input |
| GCA IN + | 1 | Gain-controlled amplifier, noninverting input |
| GADJ | 22 | Gain adjust |
| GADJ | 23 | Gain adjust |
| GCA OUT - | 18 | Gain-controlled amplifier, inverting output |
| GCA OUT + | 19 | Gain-controlled amplifier, noninverting output |
| RC IN - | 13 | Read comparator, inverting input |
| RC IN + | 14 | Read comparator, noninverting input |
| RC OUT | 12 | Read comparator out |
| RDP | 6 | Read data pulse |
| TDF RC | 7 | Time-domain filter resistor and capacitor |
| TP | 8 | Test point |
| VCC1 | 4 | Analog collector supply voltage |
| VCC2 | 9 | Digital collector supply voltage |
| WC IN - | 16 | Write comparator, inverting input |
| WC IN + | 17 | Write comparator, noninverting input |
| WC OUT | 15 | Write comparator out |
| W/R | 11 | Write/read |

TLO41AC

TAPE READ SIGNAL CONDITIONER

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|-----------------------------------|
| Supply voltage: V_{CC1} (see Note 1) | 14 V |
| V_{CC2} | 7 V |
| Input voltage range: Amplifier and comparators | AGND - 0.2 V to $V_{CC1} + 0.2$ V |
| Multivibrators and logic | AGND - 0.2 V to $V_{CC2} + 0.2$ V |
| Input current: EGV (see Note 2) | ± 2 mA |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range | 0°C to 70°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from the case for 10 seconds | 260°C |

- NOTES: 1. All voltages except differential voltages are with respect to network ground terminals (AGND and DGND tied together).
 2. Driving EGV high from a low-impedance source ($> \pm 2$ mA capability) with EGS high can result in damage to the device.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$ | $T_A = 70^\circ\text{C}$ POWER RATING |
|---------|---|---|--|
| DW | 1350 mW | 10.8 mW/°C | 864 mW/°C |
| NT | 1700 mW | 13.6 mW/°C | 1088 mW/°C |

recommended operating conditions

| | | MIN | NOM | MAX | UNIT |
|---|-------------------------------|------|-----|--------------|---------------|
| Supply voltage, V_{CC1} | | 10.8 | 12 | 13.2 | V |
| Supply voltage, V_{CC2} | | 4.5 | 5 | 5.5 | V |
| High-level input voltage, V_{IH} | EGS or W/R | 2 | | | V |
| Low-level input voltage, V_{IL} | EGS or W/R | | | 0.8 | V |
| Input voltage, V_I | EGS | 0 | | 10 | V |
| | EGV | 0 | | $0.8V_{CC1}$ | |
| Common-mode input voltage to gain-control amplifier, V_{IC} | | | 4 | | V |
| High-level output current, I_{OH} | WC OUT, RC OUT, TP, or RDP | | | -400 | μA |
| Low-level output current, I_{OL} | WC OUT, RC OUT, TP, or RDP | | | 8 | mA |
| Pulse duration, t_w | TP or RDP | 40 | | | ns |
| External timing resistance, (see Note 3) | TDF or BDOS RC | 5 | | 25 | k Ω |
| External timing capacitance | TDF or BDOS RC) | 0.01 | 0.1 | 1000 | nF |
| Operating free-air temperature, T_A | | 0 | | 70 | °C |

NOTE 3: Some high resistance and capacitance combinations may produce abnormal output waveforms.

electrical characteristics at $V_{CC1} = 12\text{ V}$, $V_{CC2} = 5\text{ V}$, $V_{IC}(GIC) = V_{bias}$, $R_{ADJ} = 5\text{ k}\Omega$, EGS at high level, EGV at 0 V , $r_i = 50\ \Omega$, $R_L = 2\text{ k}\Omega$, $T_A = 25\text{ }^\circ\text{C}$ (unless otherwise noted)

gain-controlled amplifier

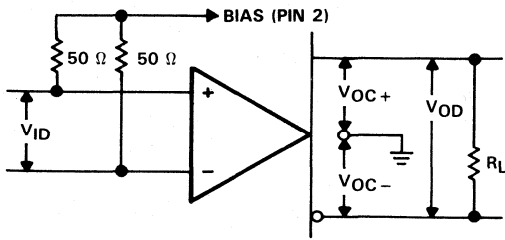
| PARAMETER | | TEST FIGURE | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---------------|---|-------------|---|-----|------|------|------------------|
| V_{OO} | Output offset voltage | 1 | $V_{ID} = 0$, $V_{OD} = V_O$ | | 0.35 | 0.75 | V |
| V_{OPP} | Maximum differential output voltage | 1 | $V_{ID} = 1\text{ V}$, $V_{OPP} = V_O$ | 3 | 6 | | V |
| A_{VD} | Large-signal differential voltage amplification | 1 | $V_{ID} = 20\text{ mV}$, EGS high | 8 | 14 | 20 | V/V |
| | | | $V_{id} = 20\text{ mV}$, EGS low, $f = 455\text{ kHz}$ | | 19 | | V/V |
| | | | | | 90 | | |
| CMRR | Common-mode rejection ratio | 2 | $V_{IC} = 2\text{ V to } 5\text{ V}$ | 60 | 80 | | dB |
| V_{IC} | Common-mode input voltage | 2 | | 2 | | 5 | V |
| V_{OC} | Common-mode output voltage | 1 | $V_{ID} = 0$ | 4 | 5.8 | 6.4 | V |
| I_{IO} | Input offset current | 1 | $I_{IB+} - I_{IB-}$ | | 0.2 | 3 | μA |
| I_O | Output current, sink | | | 1.5 | 2 | | mA |
| I_{IB} | Input bias current | 1 | $(I_{IB+} + I_{IB-})/2$ | | 5 | 17 | μA |
| $V_{O(BIAS)}$ | Bias output voltage | 1 | | 3 | 4 | 5 | V |
| $z_{O(BIAS)}$ | Bias output impedance | | | | 1 | | $\text{k}\Omega$ |
| z_i | Input impedance | | | | 30 | | $\text{k}\Omega$ |
| BW | Bandwidth (-3 dB) | 3 | | | 20 | | MHz |
| kSVR | Supply voltage rejection ratio | 4 | $V_{CC1} = 10.8\text{ V to } 13.2\text{ V}$ | 50 | 70 | | dB |
| I_{CC1} | Supply current from V_{CC1} | | $V_{CC1} = 13.2\text{ V}$, No signal | | 32 | 45 | mA |

logic section

| PARAMETER | | TEST FIGURE | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-----------|--|-------------|---|-----|-----|------|---------------|
| V_{OH} | High-level output voltage | | $V_{CC2} = 4.5\text{ V}$, $V_{ID} = 0.1\text{ V}$, $I_{OH} = -400\ \mu\text{A}$ | 2.7 | 3.5 | | V |
| V_{OL} | Low-level output voltage | | $V_{CC2} = 4.5\text{ V}$, $V_{ID} = 0.1\text{ V}$, $I_{OL} = 8\text{ mA}$ | | 260 | 500 | mV |
| V_{ICR} | Common-mode input voltage, comparators | | | 2 | | 7 | V |
| I_{IH} | High-level input current | EGS | $V_{I(EGS)} = 2.7\text{ V}$ | | 120 | 200 | μA |
| | | W/R | $V_{I(W/R)} = 2.7\text{ V}$ | | | 20 | |
| I_{IL} | Low-level input current | EGS | $V_{I(EGS)} = 0.4\text{ V}$ | | | -20 | μA |
| | | W/R | $V_{I(W/R)} = 0.4\text{ V}$ | | | -400 | |
| I_{CC2} | Supply current from V_{CC2} | | $V_{CC2} = 5.5\text{ V}$, No signal | | 22 | 31 | mA |
| | Response time | | 100-mV step, 5-mV overdrive | | 50 | | ns |
| t_w | Pulse duration of one-shots (TP, RDP) | | $R_{ext} = 5\text{ k}\Omega$, $C_{ext} = 100\text{ pF}$ | | 360 | | ns |
| | | | $R_{ext} = 20\text{ k}\Omega$, $C_{ext} = 33\text{ pF}$ | | 460 | | |

TL041AC
TAPE READ SIGNAL CONDITIONER

PARAMETER MEASUREMENT INFORMATION



$V_{OO} = V_{OD}$ with $V_{ID} = 0$
 $V_{OPP} = V_{OD}$ with $V_{ID} = 1\text{ V}$
 $A_{VD} = \frac{V_{OD}}{V_{ID}}$ with $V_{ID} = 20\text{ mV}$
 $V_{OC} = \frac{V_{OC+} + V_{OC-}}{2}$ with $V_{ID} = 0$

FIGURE 1

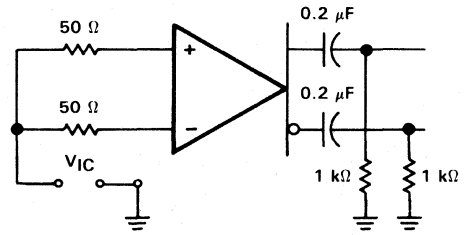


FIGURE 2

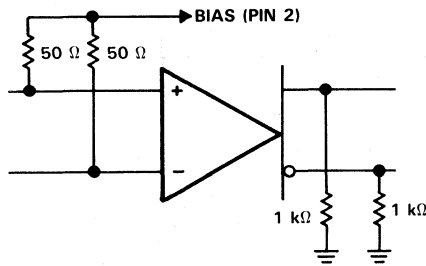


FIGURE 3

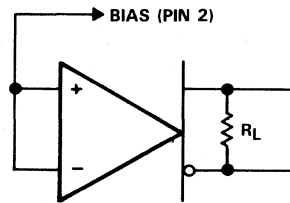


FIGURE 4

TYPICAL CHARACTERISTICS

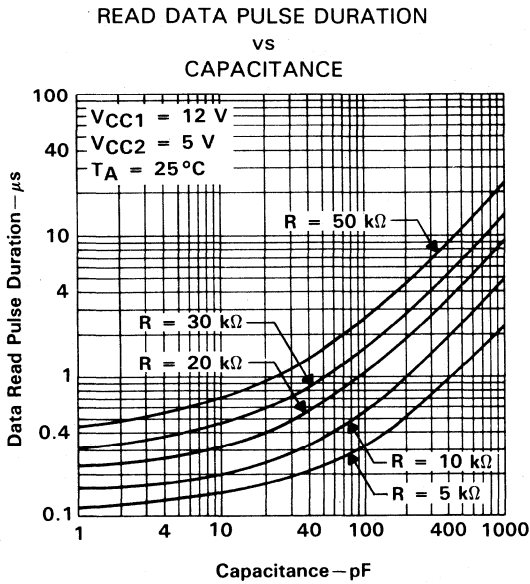


FIGURE 5

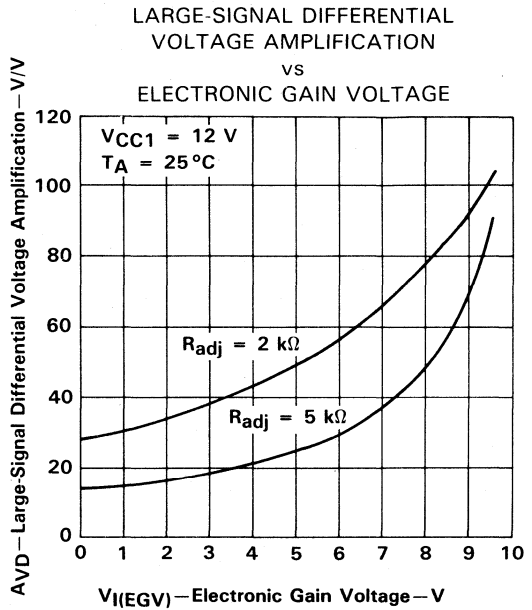


FIGURE 6

TYPICAL APPLICATION DATA

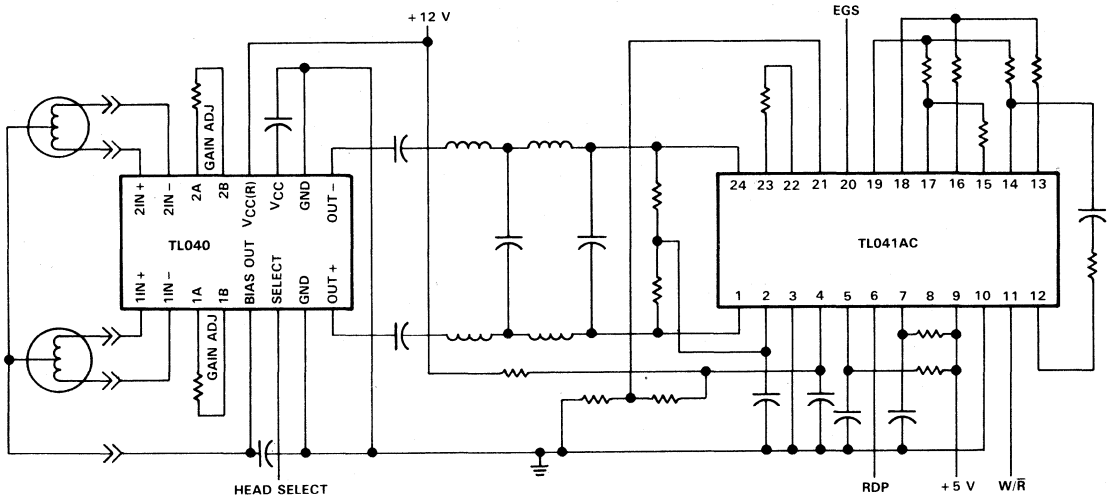


FIGURE 7. READ SIGNAL CIRCUIT FOR A STREAMING TAPE DRIVE

TL441AM LOGARITHMIC AMPLIFIER

D956, JUNE 1976—REVISED FEBRUARY 1989

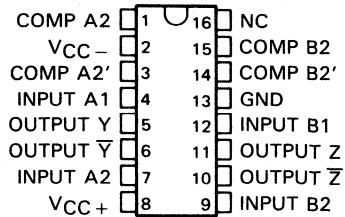
- Excellent Dynamic Range
- Wide Bandwidth
- Built-In Temperature Compensation
- Log Linearity (30 dB Sections) . . . 1 dB Typ
- Wide Input Voltage Range

description

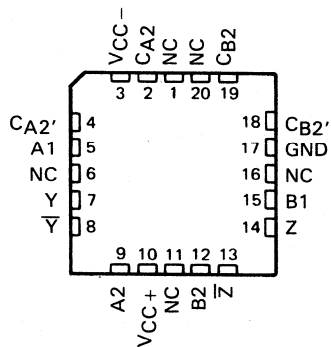
This monolithic amplifier circuit contains four 30-dB logarithmic stages. Gain in each stage is such that the output of each stage is proportional to the logarithm of the input voltage over the 30-dB input voltage range. Each half of the circuit contains two of these 30-dB stages summed together in one differential output that is proportional to the sum of the logarithms of the input voltages of the two stages. The four stages may be interconnected to obtain a theoretical input voltage range of 120 dB. In practice, this permits the input voltage range to be typically greater than 80 dB with log linearity of ± 0.5 dB (see application data). Bandwidth is from dc to 40 MHz.

This circuit is useful in military weapons systems, broadband radar, and infrared reconnaissance systems. It serves for data compression and analog compensation. This logarithmic amplifier is used in log IF circuitry as well as video and log amplifiers. The TL441AM is characterized for operation over the full military temperature range of -55°C to 125°C .

J PACKAGE
(TOP VIEW)

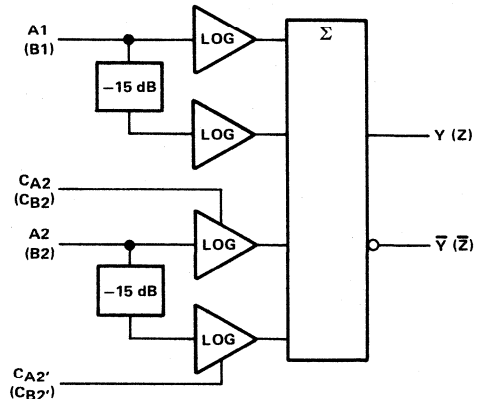


FK PACKAGE
(TOP VIEW)



NC—No internal connection

functional block diagram (one half)



$Y \propto \log A1 + \log A2$; $Z \propto \log B1 + \log B2$
 where: A1, A2, B1, and B2 are in dBV, 0 dBV = 1 V.
 CA2, CA2', CB2, and CB2' are detector compensation inputs.

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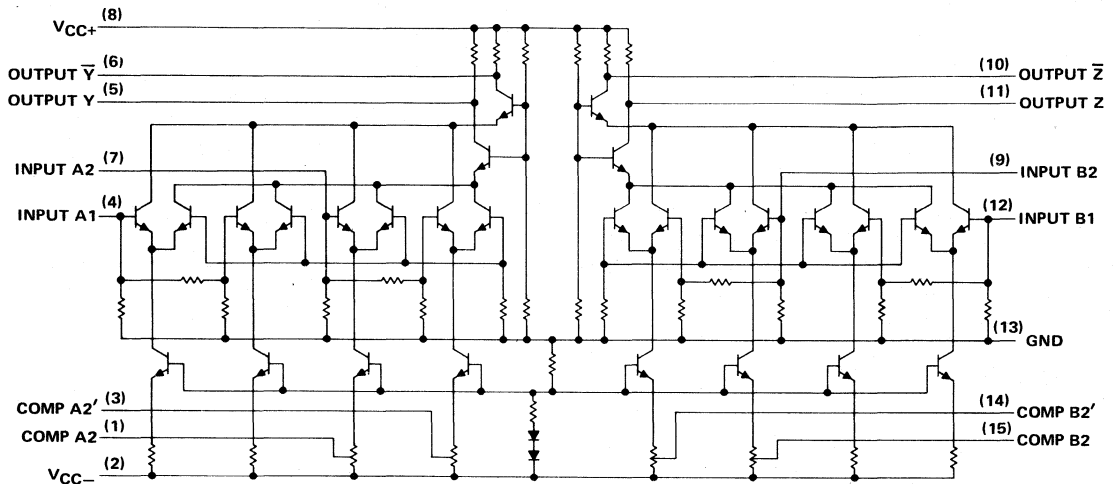
TEXAS
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TL441AM LOGARITHMIC AMPLIFIER

schematic



Pin numbers shown are for the J package.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|------------------------------|
| Supply voltages (see Note 1): V_{CC+} | 8 V |
| V_{CC-} | -8 V |
| Input voltage (see Note 1) | 6 V |
| Output sink current (any one output) | 30 mA |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range | -55°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package | 300°C |

NOTE: 1. All voltages, except differential output voltages, are with respect to network ground terminal.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR | DERATE ABOVE T_A | $T_A = 70^\circ\text{C}$ POWER RATING | $T_A = 125^\circ\text{C}$ POWER RATING |
|---------|---|--------------------|-----------------------|--|---|
| FK | 500 mW | 11.0 mW/°C | 104°C | 500 mW | 275 mW |
| J | 500 mW | 11.0 mW/°C | 104°C | 500 mW | 275 mW |

recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|---|------|-----|-----|------|
| Peak-to-peak input voltage for each 30-dB stage | 0.01 | | 1 | V |
| Operating free-air temperature, T_A | -55 | | 125 | °C |

electrical characteristics, $V_{CC+} = 6\text{ V}$, $V_{CC-} = -6\text{ V}$, $T_A = 25^\circ\text{C}$

| PARAMETER | TEST FIGURE | MIN | TYP | MAX | UNIT |
|---|-------------|------|----------|----------|----------|
| Differential output offset voltage | 1 | | ± 25 | ± 70 | mV |
| Quiescent output voltage | 2 | 5.45 | 5.6 | 5.85 | V |
| DC scale factor (differential output), each 3-dB stage, -35 dBV to -5 dBV | 3 | 7 | 8 | 11 | mV/dB |
| AC scale factor (differential output) | | | 8 | | mV/dB |
| DC error at -20 dBV (midpoint of -35 dBV to -5 dBV range) | 3 | | 1 | 2.6 | dB |
| Input impedance | | | 500 | | Ω |
| Output impedance | | | 200 | | Ω |
| Rise time, 10% to 90% points, $C_L = 24\text{ pF}$ | 4 | | 20 | 35 | ns |
| Supply current from V_{CC+} | 2 | 14.5 | 18.5 | 23 | mA |
| Supply current from V_{CC-} | 2 | -6 | -8.5 | -10.5 | mA |
| Power dissipation | 2 | 123 | 162 | 201 | mW |

electrical characteristics over operating free-air temperature range, $V_{CC+} = 6\text{ V}$, $V_{CC-} = -6\text{ V}$ (unless otherwise noted)

| PARAMETER | TEST FIGURE | MIN | TYP | MAX | UNIT |
|---|-------------|------|---------------------------|-----------|-------|
| Differential output offset voltage | 1 | | | ± 100 | mV |
| Quiescent output voltage | 2 | 5.3 | | 5.85 | V |
| DC scale factor (differential output) each 30-dB stage, -35 dBV to -5 dBV | 3 | 7 | | 11 | mV/dB |
| DC error at -20 dBV (midpoint of -35 dBV to -5 dBV range) | 3 | | $T_A = -55^\circ\text{C}$ | 4 | dB |
| | | | $T_A = 125^\circ\text{C}$ | 3 | |
| Supply current from V_{CC+} | 2 | 10 | | 31 | mA |
| Supply current from V_{CC-} | 2 | -4.5 | | -15 | mA |
| Power dissipation | 2 | 87 | | 276 | mW |

PARAMETER MEASUREMENT INFORMATION

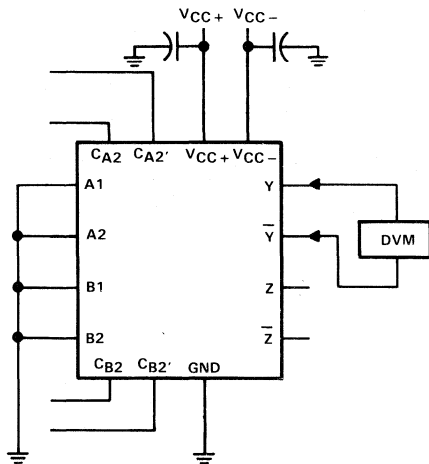


FIGURE 1

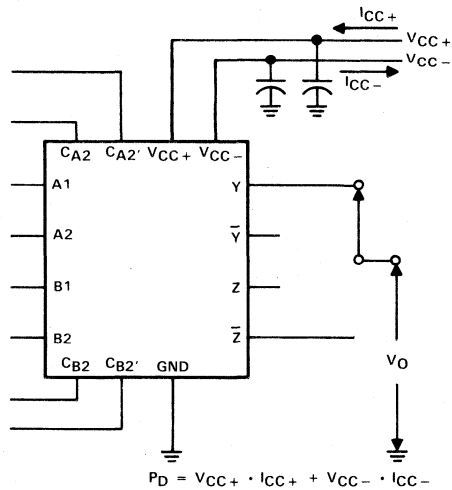
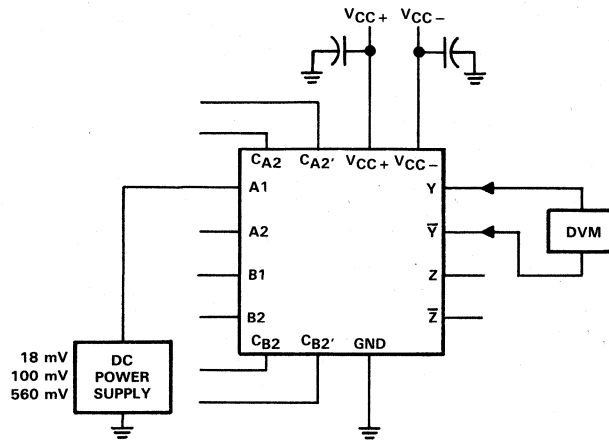


FIGURE 2

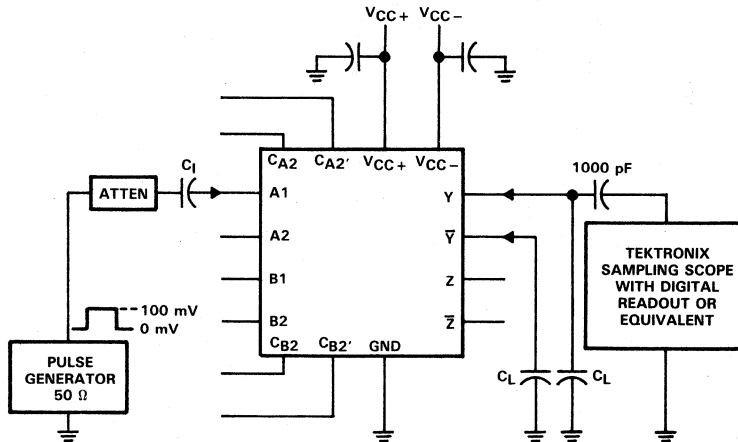
PARAMETER MEASUREMENT INFORMATION



$$\text{Scale Factor} = \frac{[V_{\text{out}}(560 \text{ mV}) - V_{\text{out}}(18 \text{ mV})] \text{ mV}}{30 \text{ dB}}$$

$$\text{Error} = \frac{|V_{\text{out}}(100 \text{ mV}) - 0.5 V_{\text{out}}(560 \text{ mV}) - 0.5 V_{\text{out}}(18 \text{ mV})|}{\text{Scale Factor}}$$

FIGURE 3



- NOTES:
- A. The input pulse has the following characteristics:
 $t_w = 200 \text{ ns}$, $t_r \leq 2 \text{ ns}$, $t_f \leq 2 \text{ ns}$, $\text{PRR} \leq 10 \text{ MHz}$.
 - B. Capacitor C_1 consists of three capacitors in parallel: $1 \mu\text{F}$, $0.1 \mu\text{F}$, and $0.01 \mu\text{F}$.
 - C. C_L includes probe and jig capacitance.

FIGURE 4

TYPICAL CHARACTERISTICS

**DIFFERENTIAL OUTPUT OFFSET VOLTAGE
vs
FREE-AIR TEMPERATURE**

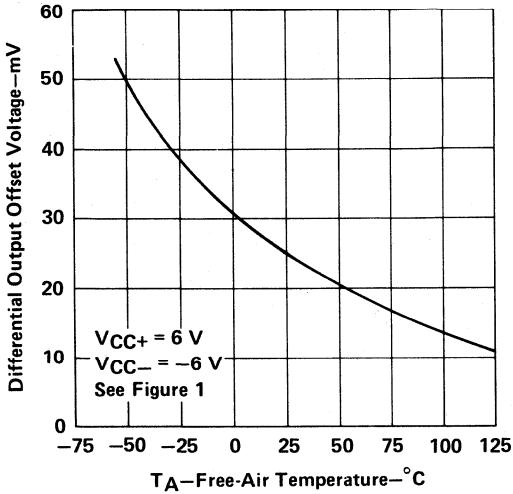


FIGURE 5

**QUIESCENT OUTPUT VOLTAGE
vs
FREE-AIR TEMPERATURE**

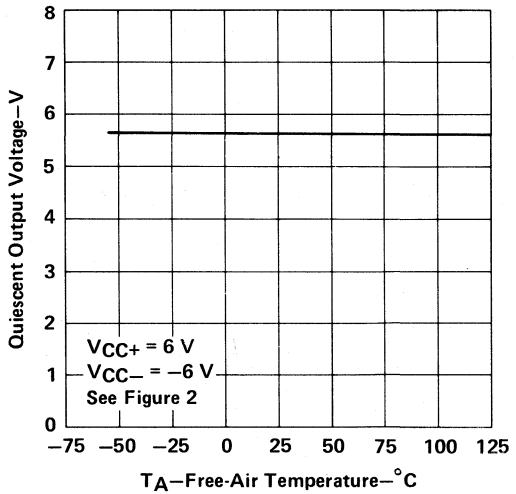


FIGURE 6

**DC SCALE FACTOR
vs
FREE-AIR TEMPERATURE**

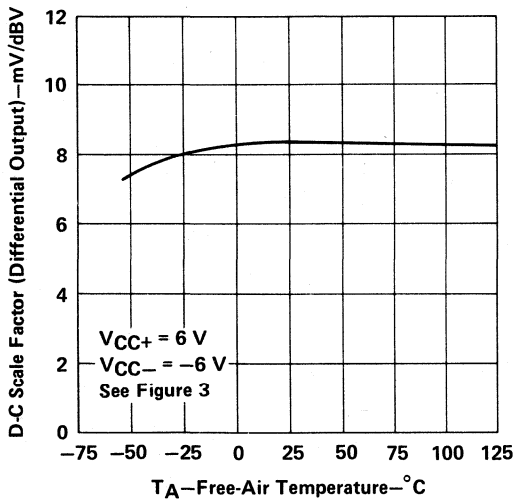


FIGURE 7

**DC ERROR
vs
FREE-AIR TEMPERATURE**

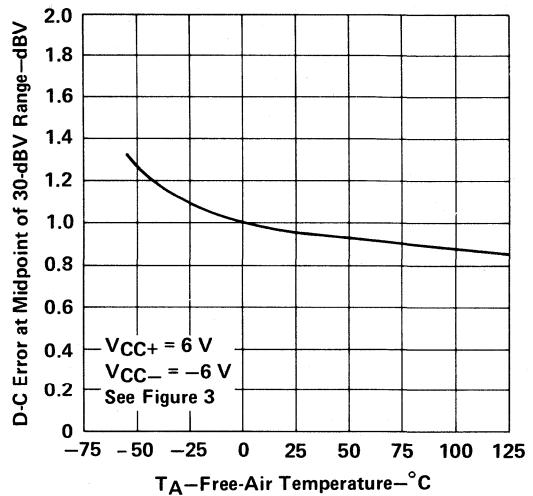


FIGURE 8

TYPICAL CHARACTERISTICS

OUTPUT RISE TIME
vs
LOAD CAPACITANCE

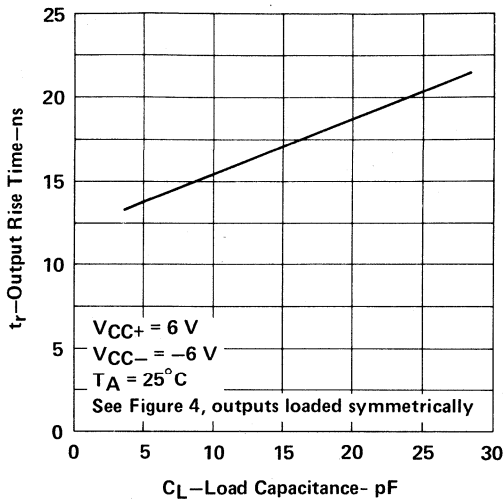


FIGURE 9

POWER DISSIPATION
vs
FREE-AIR TEMPERATURE

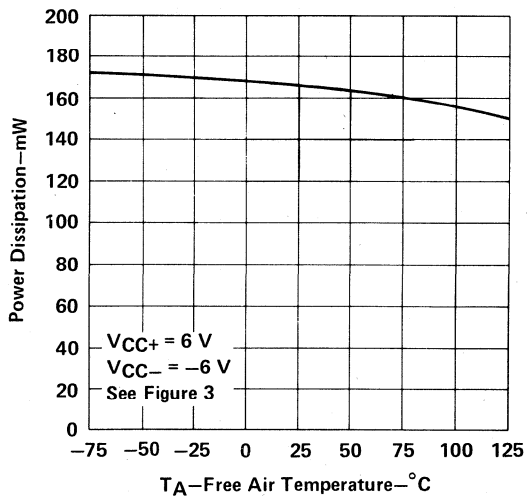


FIGURE 10

TYPICAL APPLICATION DATA

Although designed for high-performance applications such as broadband radar infrared detection and weapons systems, this device has a wide range of applications in data compression and analog computation.

basic logarithmic function

The basic logarithmic response is derived from the exponential current-voltage relationship of collector current and base-emitter voltage. This relationship is given in the equation:

$$m \cdot V_{BE} = \ln [(I_C + I_{CES})/I_{CES}]$$

where:

- I_C = collector current
- I_{CES} = collector current at $V_{BE} = 0$
- $m = q/kT$ (in V^{-1})
- V_{BE} = base-emitter voltage

The differential input amplifier allows dual-polarity inputs, is self-compensating for temperature variations, and is relatively insensitive to common-mode noise.

Four compensation points are made available to allow slight variations in the gain (slope) of the two individual 15-dB stages of input A2 and B2. By slightly changing the voltage on any of the compensation pins from its quiescent value, the gain of that particular 15-dB stage can be adjusted to match the other 15-dB stage in the pair. The compensation pins may also be used to match the transfer characteristics of input A2 to A1 or B2 to B1.

The log stages in each half of the circuit are summed by directly connecting their collectors together and summing through a common-base output stage. The two sets of output collectors are used to give two log outputs, Y and \bar{Y} (or Z and \bar{Z}) which are equal in amplitude but opposite in polarity. This increases the versatility of the device.

By proper choice of external connections, linear amplification, linear attenuation, and many different applications requiring logarithmic signal processing are possible.

functional block diagram

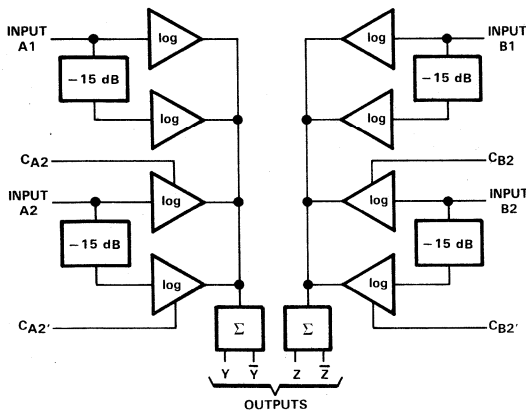


FIGURE 11

logarithmic sections

As can be seen from the schematic, there are eight differential pairs. Each pair is a 15-dB log subsection, and each input feeds two pairs for a range of 30-dB per stage.

input levels

The recommended input voltage range of any one stage is given as 0.01 V to 1 V. Input levels in excess of 1 V may result in a distorted output. When several log sections are summed together, the distorted area of one section overlaps with the next section and the resulting distortion is insignificant. However, there is a limit to the amount of overdrive that may be applied. As the input drive reaches ± 3.5 V, saturation occurs, clamping the collector-summing line and severely distorting the output. Therefore, the signal to any input must be limited to approximately ± 3 V to ensure a clean output.

output levels

Differential-output-voltage levels are low, generally less than 0.6 V. As demonstrated in Figure 12, the output swing and the slope of the output response can be adjusted by varying the gain by means of the slope control. The coordinate origin may also be adjusted by positioning the offset of the output buffer.

TL441AM LOGARITHMIC AMPLIFIER

TYPICAL APPLICATION DATA

circuits

Figures 12 through 19 show typical circuits using this logarithmic amplifier. Operational amplifiers not otherwise designated are TLC271. For operation at higher frequencies, the TL592 is recommended instead of the TLC271.

TYPICAL TRANSFER CHARACTERISTICS

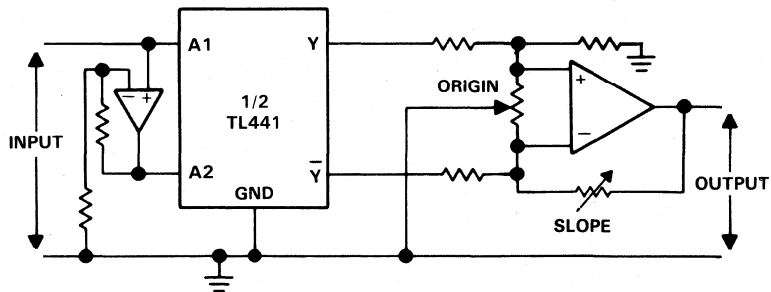
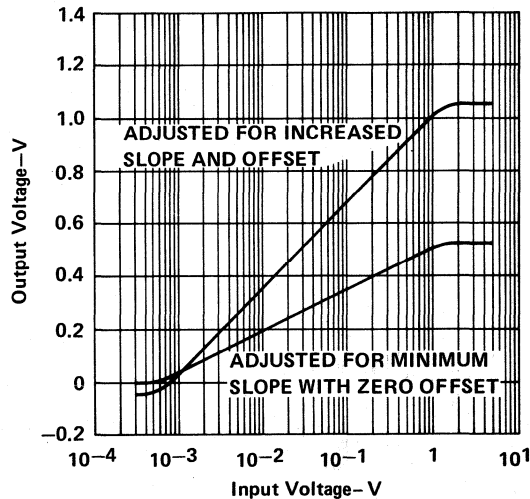


FIGURE 12. OUTPUT SLOPE AND ORIGIN ADJUSTMENT

TYPICAL APPLICATION DATA

TRANSFER CHARACTERISTICS
OF TWO TYPICAL INPUT STAGES

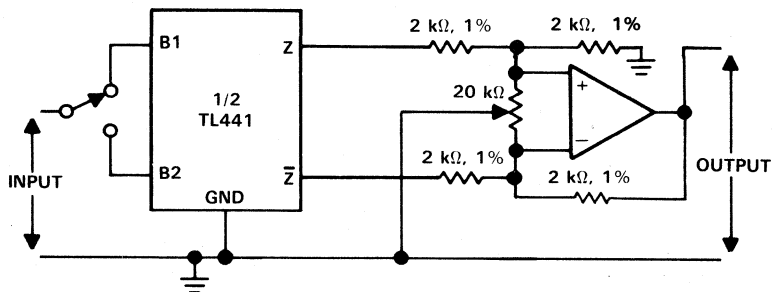
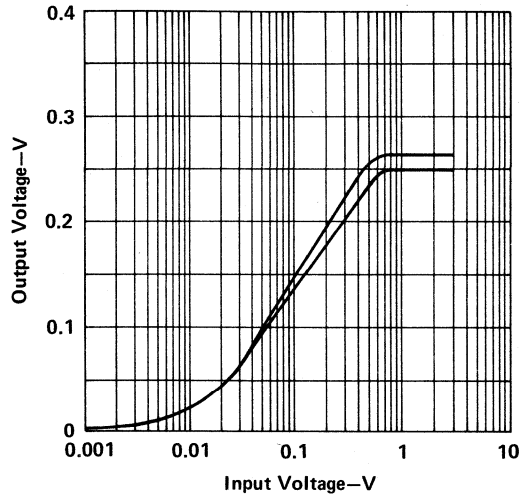


FIGURE 13. UTILIZATION OF SEPARATE STAGES

TYPICAL APPLICATION DATA

**TRANSFER CHARACTERISTICS
WITH BOTH SIDES PARALLELED**

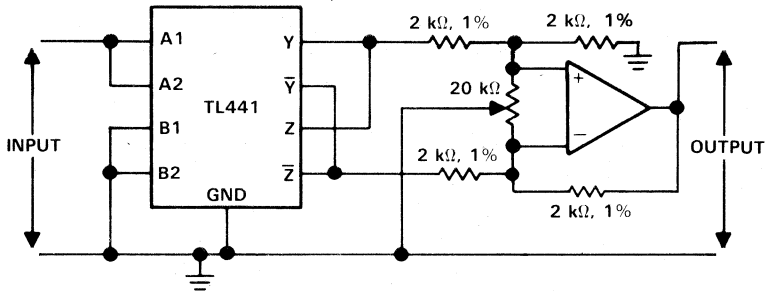
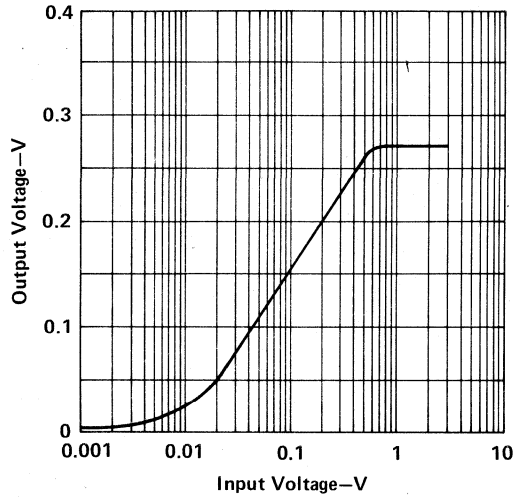
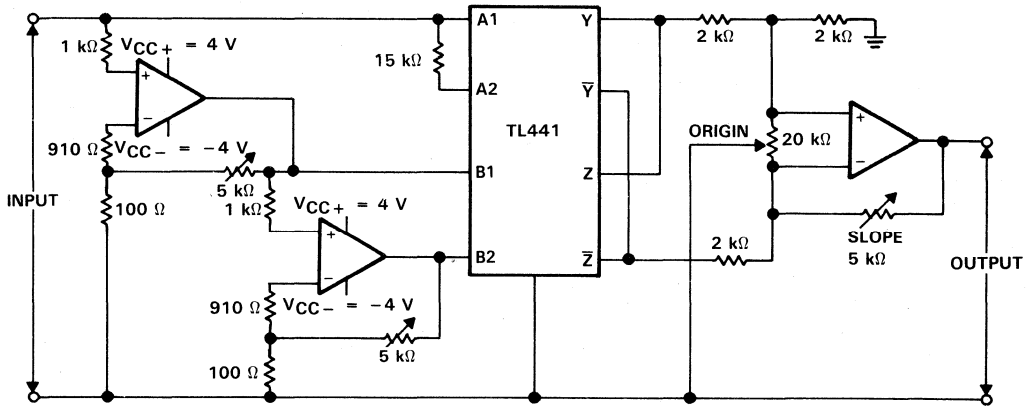
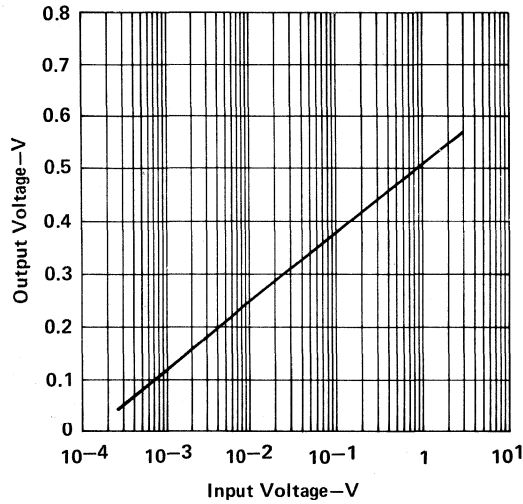


FIGURE 14. UTILIZATION OF PARALLELED INPUTS

TYPICAL APPLICATION DATA

TRANSFER CHARACTERISTICS

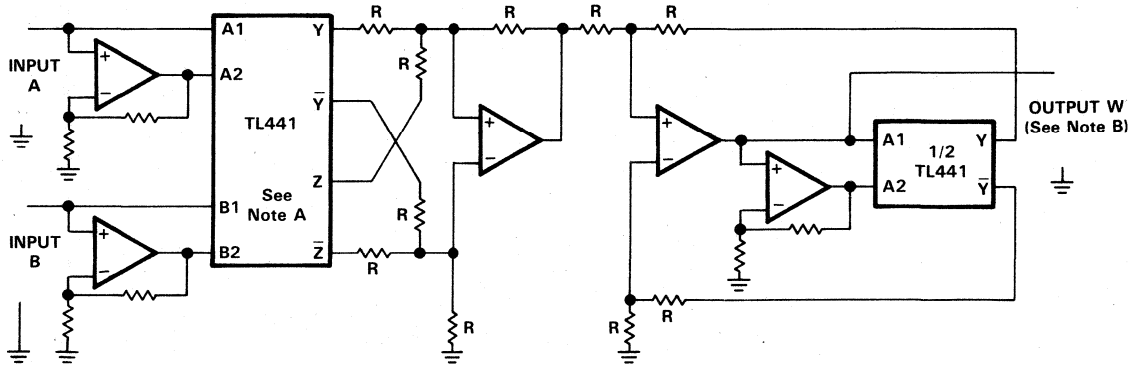


- NOTES: A. Inputs are limited by reducing the supply voltages for the input amplifiers to ± 4 V.
B. The gains of the input amplifiers are adjusted to achieve smooth transitions.

Figure 15. LOGARITHMIC AMPLIFIER WITH INPUT VOLTAGE RANGE GREATER THAN 80 dB

TL441AM LOGARITHMIC AMPLIFIER

TYPICAL APPLICATION DATA



NOTES: A. Connections shown are for multiplication. For division, Z and \bar{Z} connections are reversed.

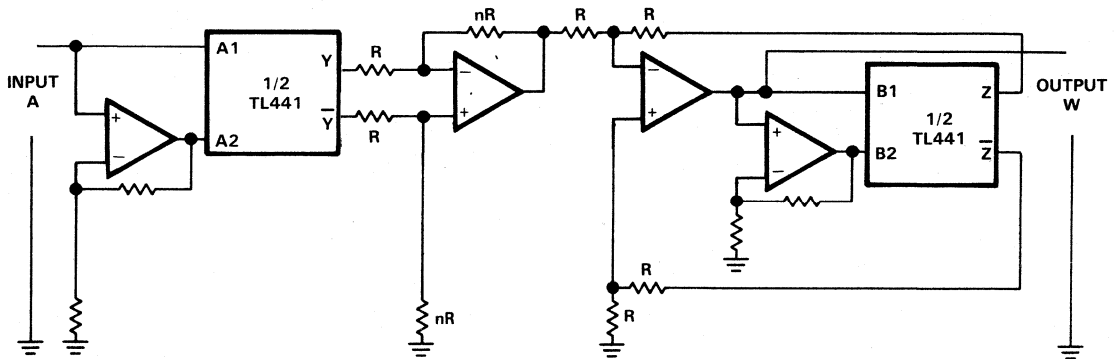
B. Output W may need to be amplified to give actual product or quotient of A and B.

C. R designates resistors of equal value, typically 2 k Ω to 10 k Ω .

Multiplication: $W = A \cdot B \Rightarrow \log W = \log A + \log B$, or $W = a^{(\log_a A + \log_a B)}$

Division: $W = A/B \Rightarrow \log W = \log A - \log B$, or $W = a^{(\log_a A - \log_a B)}$

FIGURE 16. MULTIPLICATION OR DIVISION

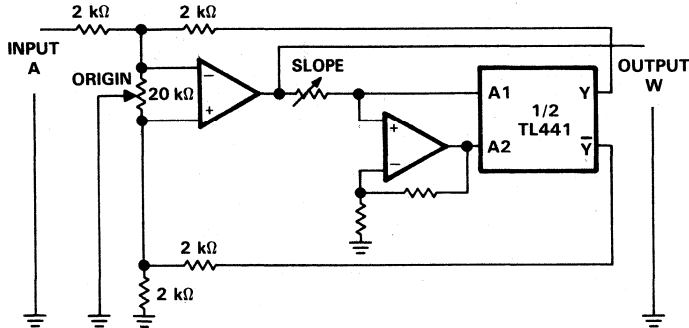


NOTE: R designates resistors of equal value, typically 2 k Ω to 10 k Ω . The power to which the input variable is raised is fixed by setting nR. Output W may need to be amplified to give the correct value.

Exponential: $W = A^n \Rightarrow \log W = n \log A$, or $W = a^{(n \log_a A)}$

FIGURE 17. RAISING A VARIABLE TO A FIXED POWER

TYPICAL APPLICATION DATA



NOTE: Adjust the slope to correspond to the base "a".
Exponential to any base: $W = a$

FIGURE 18. RAISING A FIXED NUMBER TO A VARIABLE POWER

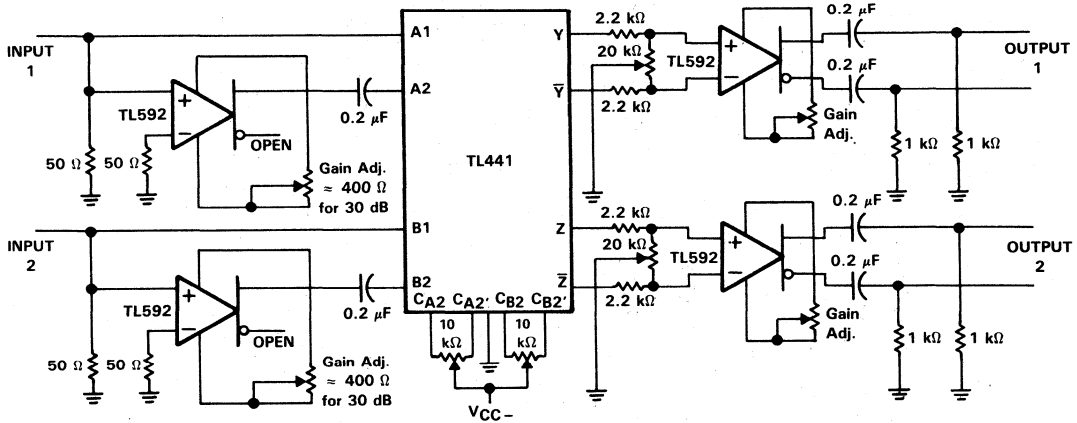


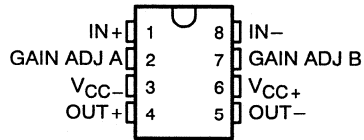
FIGURE 19. DUAL-CHANNEL RF LOGARITHMIC AMPLIFIER WITH 50-dB INPUT RANGE PER CHANNEL AT 10 MHz

TL592 DIFFERENTIAL VIDEO AMPLIFIER

D2668, NOVEMBER 1983—REVISED NOVEMBER 1991

- 8-Pin Version of NE592 . . . Saves Printed Circuit Board Space
- Adjustable Gain to Typically 400 V/V
- No Frequency Compensation Required
- Adjustable Pass Band
- A_{VD} Range . . . 250–600 V/V

D OR P PACKAGE
(TOP VIEW)



description

This device is a monolithic two-stage video amplifier with differential inputs and differential outputs.

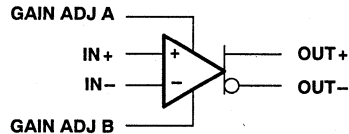
Internal series-shunt feedback provides wide bandwidth, low phase distortion, and excellent gain stability. Emitter-follower outputs enable the device to drive capacitive loads. All stages are current-source biased to obtain high common-mode and supply-voltage rejection ratios.

Fixed differential amplification of nominally 400 V/V can be selected without external components, or amplification may be adjusted from 0 to approximately 400 V/V by the use of a single external resistor connected between the gain adjustment pins A and B. No external frequency-compensating components are required for any gain option.

The device is particularly useful in magnetic-tape or disk-file systems using phase or NRZ encoding and in high-speed thin-film or plated-wire memories. Other applications include general-purpose video and pulse amplifiers where wide bandwidth, low phase shift, and excellent gain stability are required.

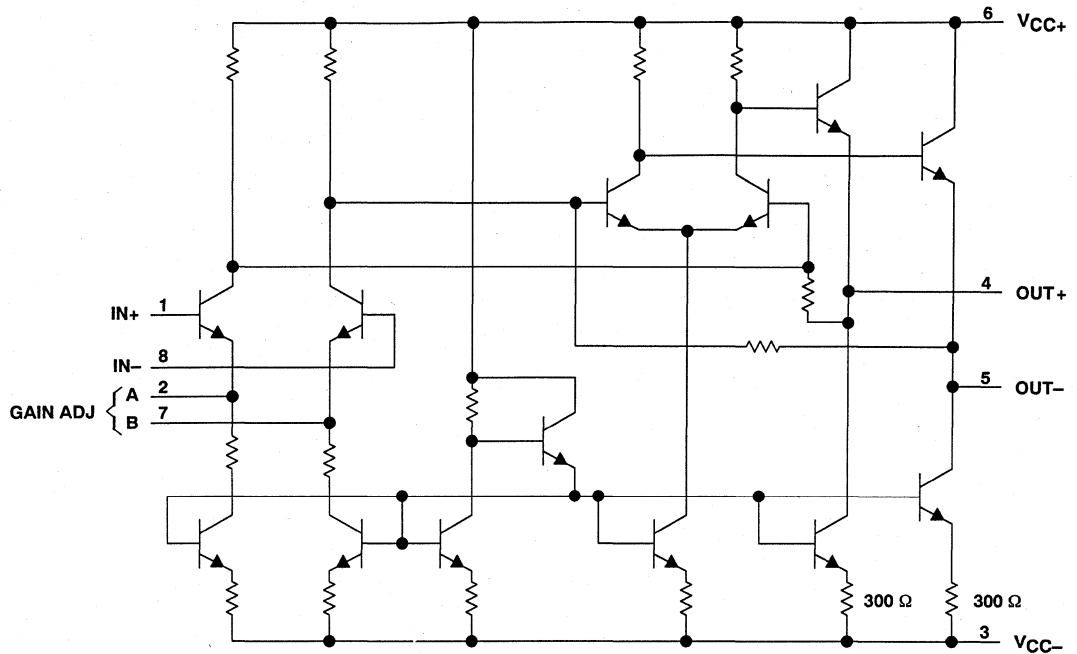
The TL592 is characterized for operation from 0°C to 70°C.

symbol



TL592 DIFFERENTIAL VIDEO AMPLIFIER

schematic



Resistor values shown are nominal.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|------------------------|
| Supply voltage, V_{CC+} (see Note 1) | 8 V |
| Supply voltage, V_{CC-} (see Note 1) | -8 V |
| Differential input voltage | ± 5 V |
| Voltage range, any input | V_{CC+} to V_{CC-} |
| Output current | 10 mA |
| Continuous total power dissipation at 70°C | 500 mW |
| Operating free-air temperature range | 0°C to 70°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 1: All voltage values except differential input voltages are with respect to the midpoint between V_{CC+} and V_{CC-} .

recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|---------------------------------------|-----|-----|-----|------|
| Supply voltage, V_{CC+} | 3 | 6 | 8 | V |
| Supply voltage, V_{CC-} | -3 | -6 | -8 | V |
| Operating free-air temperature, T_A | 0 | | 70 | °C |

electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 6\text{ V}$, $R_L = 2\text{ k}\Omega$ (unless otherwise noted)

| PARAMETER | TEST FIGURE | TEST CONDITIONS | T_A † | GAIN OPTION‡ | MIN TYP MAX | | | UNIT |
|-----------------|-------------|--|-------------|--------------|-------------|------|------|------------------|
| | | | | | | | | |
| AVD | 1 | $V_{O(PP)} = 3\text{ V}$, $R_L = 2\text{ k}\Omega$ | 25°C | 1 | 250 | 400 | 600 | V/V |
| | | | Full range | | | | 600 | |
| BW | 2 | $V_{O(PP)} = 1\text{ V}$ | 25°C | 1 | | 50 | | MHz |
| I_{IO} | | $V_{IC} = 0$ | 25°C | 1 or 2 | | 0.4 | 5 | μA |
| | | | Full range | | | | 6 | |
| I_{IB} | | $V_{IC} = 0$ | 25°C | 1 or 2 | | 9 | 30 | μA |
| | | | Full range | | | | 40 | |
| V_{ICR} | 3 | | 25°C | 1 or 2 | ± 1 | | | V |
| | | | Full range | | ± 1 | | | |
| V_{OC} | 1 | $R_L = \infty$ | 25°C | 2 | 2.4 | 2.9 | 3.4 | V |
| V_{OO} | 1 | $V_{ID} = 0$, $R_L = \infty$ | 25°C | 2 | | 0.35 | 0.75 | V |
| | | | Full range | | | | 1.5 | |
| $V_{O(PP)}$ | 1 | $R_L = 2\text{ k}\Omega$ | 25°C | 1 | 3 | 4 | | V |
| | | | Full range | | | 2.8 | | |
| z_i | | $V_{OD} = 1\text{ V}$, $f = 1\text{ kHz to } 10\text{ MHz}$ | 25°C | 1 | | 4 | | $\text{k}\Omega$ |
| | | | Full range | | | 3.6 | | |
| CMRR | 3 | $V_{IC} = \pm 1\text{ V}$ | f = 100 kHz | 1 | 60 | 86 | dB | |
| | | | f = 5 MHz | | | | | 60 |
| | | | f = 100 kHz | | Full range | 50 | | |
| | | | f = 5 MHz | | | 60 | | |
| k_{SVR} | 4 | $\Delta V_{CC+} = \pm 0.5\text{ V}$, $\Delta V_{CC-} = \pm 0.5\text{ V}$ | 25°C | 1 | 50 | 70 | dB | |
| | | | Full range | | 50 | | | |
| V_n | 4 | $BW = 1\text{ kHz to } 10\text{ MHz}$ | 25°C | 1 or 2 | | 12 | | μV |
| t_{pd} | 2 | $\Delta V_O = 1\text{ V}$ | 25°C | 2 | | 7.5 | | ns |
| t_r | 2 | $\Delta V_O = 1\text{ V}$ | 25°C | 2 | | 10.5 | | ns |
| $I_{sink(max)}$ | | | | 1, 2, or 3 | 3 | 4 | | mA |
| I_{CC} | | No load, No signal | 25°C | 1 or 2 | | 18 | 24 | mA |
| | | | Full range | | | | 27 | |

† Full range is 0°C to 70°C.

‡ The gain option is selected as follows:

Gain Option 1 . . . Gain adjust pin A is connected to pin B.

Gain Option 2 . . . Gain adjust pins A and B are open.

PARAMETER MEASUREMENT INFORMATION

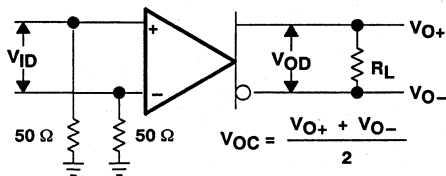


Figure 1

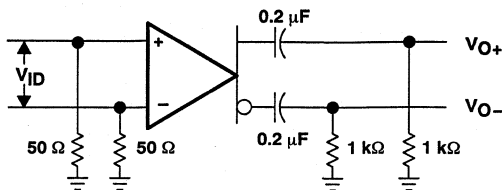


Figure 2

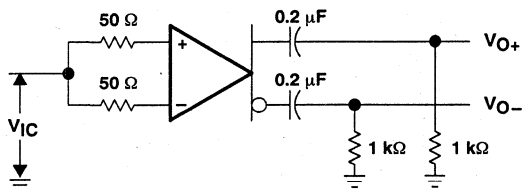


Figure 3

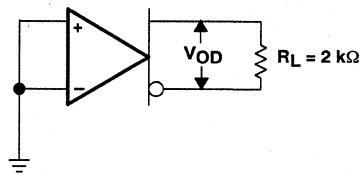


Figure 4

TL592B DIFFERENTIAL VIDEO AMPLIFIER

D2668, JUNE 1985—REVISED APRIL 1988

- Adjustable Gain to 400 Typ
- No Frequency Compensation Required
- Low Noise . . . $3 \mu\text{V}$ Typ V_N

description

This device is a monolithic two-stage video amplifier with differential inputs and differential outputs. It features internal series-shunt feedback that provides wide bandwidth, low phase distortion, and excellent gain stability. Emitter-follower outputs enable the device to drive capacitive loads. All stages are current-source biased to obtain high common-mode and supply-voltage rejection ratios.

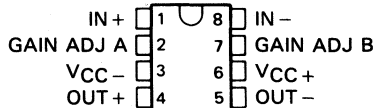
The differential gain is typically 400 when the gain adjust pins are connected together, or amplification may be adjusted from near 0 to 400 by the use of a single external resistor connected between the gain adjustment pins A and B. No external frequency-compensating components are required for any gain option.

The device is particularly useful in magnetic-tape or disk-file systems using phase or NRZ encoding and in high-speed thin-film or plated-wire memories. Other applications include general-purpose video and pulse amplifiers.

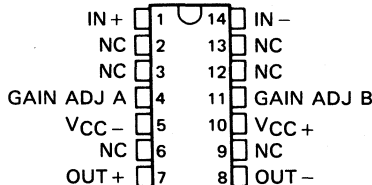
The device achieves low equivalent noise voltage through special processing and a new circuit layout incorporating input transistors with low base resistance.

The TL592B is characterized for operation from 0°C to 70°C .

D8† OR P PACKAGE (TOP VIEW)



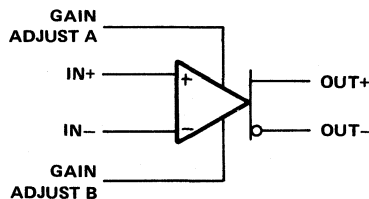
D14† OR N PACKAGE (TOP VIEW)



NC—No internal connection

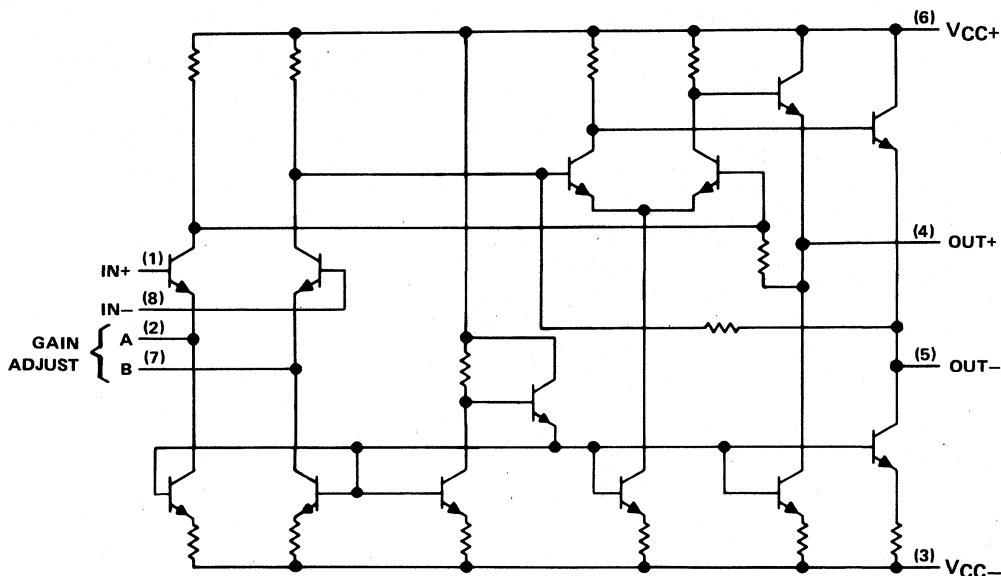
†D8 and D14 are the codes used to differentiate the 8-pin and 14-pin versions, respectively.

symbol



TL592B DIFFERENTIAL VIDEO AMPLIFIER

schematic



absolute maximum ratings over operating free-air temperature (unless otherwise noted)

| | |
|--|------------------------------|
| Supply voltage, V_{CC+} (see Note 1) | 8 V |
| Supply voltage, V_{CC-} | -8 V |
| Differential input voltage | ± 5 V |
| Voltage range, any input | V_{CC+} to V_{CC-} |
| Output current | 10 mA |
| Continuous total power dissipation | See Dissipation Rating Table |
| Operating free-air temperature range | 0°C to 70°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTES: 1. All voltage values except differential input voltages are with respect to the midpoint between V_{CC+} and V_{CC-} .

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR | DERATE ABOVE T_A | $T_A = 70^\circ\text{C}$ POWER RATING |
|---------|---|--------------------|-----------------------|--|
| D8 | 530 mW | 5.8 mW/°C | 59°C | 464 mW |
| D14 | 530 mW | N/A | N/A | 530 mW |
| N | 530 mW | N/A | N/A | 530 mW |
| P | 530 mW | N/A | N/A | 530 mW |

recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|---------------------------------------|-----|-----|-----|------|
| Supply voltage, V_{CC+} | 3 | 6 | 8 | V |
| Supply voltage, V_{CC-} | -3 | -6 | -8 | V |
| Operating free-air temperature, T_A | 0 | | 70 | °C |



TL592B
DIFFERENTIAL VIDEO AMPLIFIER

electrical characteristics at specified free-air temperature, $V_{CC+} = 6\text{ V}$, $V_{CC-} = -6\text{ V}$, $R_L = 2\text{ k}\Omega$ (unless otherwise noted)

| PARAMETER | | TEST FIGURE | TEST CONDITIONS† | | MIN | TYP | MAX | UNIT | | |
|-----------------|--|-------------|---|---|-------------|-----|----------------------|---------|------------------|-----|
| AVD | Large-signal differential voltage amplification | 1 | $V_{OPP} = 3\text{ V}$, $R_{AB} = 0$ | $R_L = 2\text{ k}\Omega$ | 25°C | 300 | 400 | 500 | V/V | |
| | | | | | 0°C to 70°C | 250 | | 600 | | |
| AVD2 | Large-signal differential voltage amplification | 1 | $V_{OPP} = 3\text{ V}$, $R_{AB} = 1\text{ k}\Omega$ | $R_L = 2\text{ k}\Omega$ | 25°C | | 13 | V/V | | |
| BW | Bandwidth (-3 dB) | 2 | $V_{OPP} = 1\text{ V}$, $R_{AB} = 0$ | | 25°C | | 50 | MHz | | |
| I_{IO} | Input offset current | | | | 25°C | | 0.4 | 5 | μA | |
| | | | | | 0°C to 70°C | | | 6 | | |
| I_{IB} | Input bias current | | | | 25°C | | 9 | 30 | μA | |
| | | | | | 0°C to 70°C | | | 40 | | |
| V_{ICR} | Common-mode input voltage range | 3 | | | 25°C | | ± 1 | | V | |
| | | | | | 0°C to 70°C | | | ± 1 | | |
| V_{OC} | Common-mode output voltage | 1 | $R_L = \infty$ | | 25°C | 2.4 | 2.9 | 3.4 | V | |
| V_{OO} | Output offset voltage | 1 | $V_{ID} = 0$, $R_{AB} = \infty$, $R_L = \infty$ | | 25°C | | 0.35 | 0.75 | V | |
| | | | | | 0°C to 70°C | | | | | 1.5 |
| V_{OPP} | Peak-to-peak output voltage swing | 1 | $R_L = 2\text{ k}\Omega$ | $R_{AB} = 0$ | 25°C | | 3 | 4 | V | |
| | | | | | 0°C to 70°C | | | 2.8 | | |
| r_i | Input resistance | | $V_{OD} = 1\text{ V}$, $R_{AB} = 0$ | | 25°C | | | 4 | $\text{k}\Omega$ | |
| | | | | | 0°C to 70°C | | | 3.6 | | |
| r_o | Output resistance | | | | 0°C to 70°C | | | 30 | Ω | |
| C_i | Input capacitance | | | | 25°C | | | 5 | pF | |
| CMRR | Common-mode rejection ratio | 3 | $V_{IC} = \pm 1\text{ V}$, $R_{AB} = 0$ | | 25°C | | $f = 100\text{ kHz}$ | 60 | 86 | dB |
| | | | | | | | $f = 5\text{ MHz}$ | | 60 | |
| | | | | | 0°C to 70°C | | $f = 100\text{ kHz}$ | 50 | | |
| | | | | | | | $f = 5\text{ MHz}$ | | 60 | |
| k_{SVR} | Supply voltage rejection ratio ($\Delta V_{CC}/\Delta V_{IO}$) | 4 | $\Delta V_{CC+} = \pm 0.5\text{ V}$, $\Delta V_{CC-} = \pm 0.5\text{ V}$, $R_{AB} = 0$ | | 25°C | | 50 | 70 | dB | |
| | | | | | 0°C to 70°C | | | 50 | | |
| V_n | Broadband equivalent input noise voltage | 4 | | $\text{BW} = 1\text{ kHz to } 10\text{ MHz}$ | 25°C | | | 3 | μV | |
| t_{pd} | Propagation delay time | 2 | | $\Delta V_O = 1\text{ V}$ | 25°C | | | 7.5 | ns | |
| t_r | Rise time | 2 | | $\Delta V_O = 1\text{ V}$ | 25°C | | | 10.5 | ns | |
| $I_{sink(max)}$ | Maximum output sink current | | | $V_{ID} = 1\text{ V}$, $V_O = 3\text{ V}$ | | | | 3 | 4 | mA |
| I_{CC} | Supply current | | No load, | No signal | 25°C | | | 18 | 24 | mA |
| | | | | | 0°C to 70°C | | | | 27 | |

† R_{AB} is the gain-adjustment resistor connected between gain-adjust pins A and B. If not specified for a particular parameter, its value is irrelevant to that parameter.

PARAMETER MEASUREMENT INFORMATION

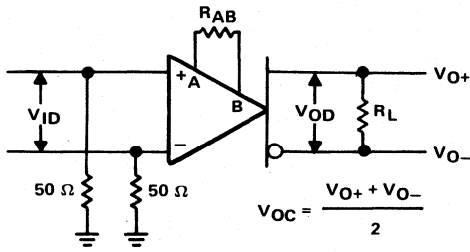


FIGURE 1

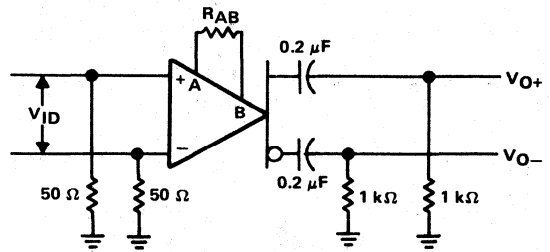


FIGURE 2

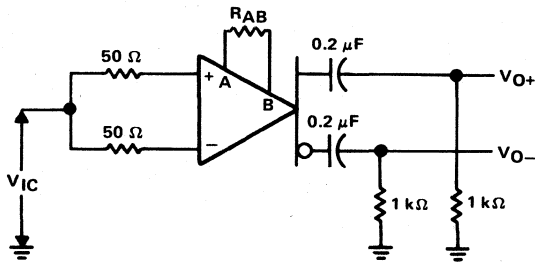


FIGURE 3

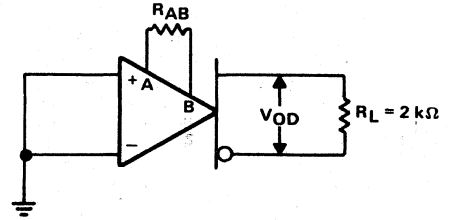


FIGURE 4

TYPICAL CHARACTERISTICS

LARGE-SIGNAL DIFFERENTIAL
VOLTAGE AMPLIFICATION

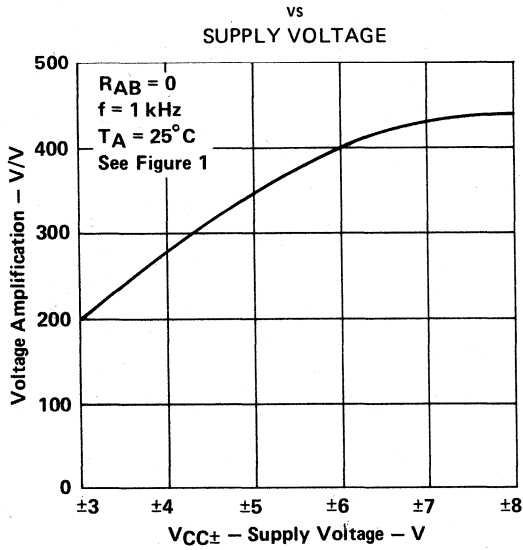


FIGURE 5

LARGE-SIGNAL DIFFERENTIAL
VOLTAGE AMPLIFICATION

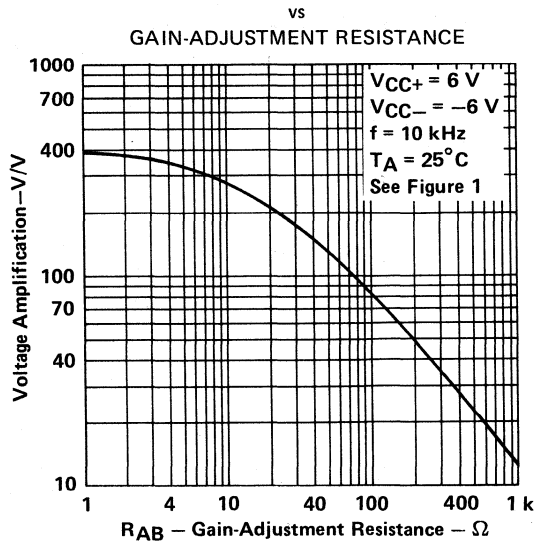


FIGURE 6

SUPPLY CURRENT
vs
SUPPLY VOLTAGE

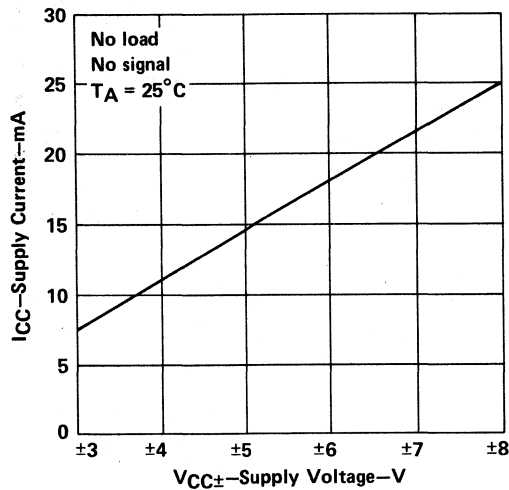


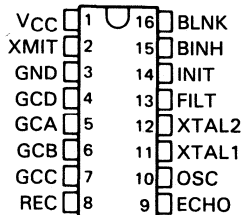
FIGURE 7

TL851 SONAR RANGING CONTROL

D2760, SEPTEMBER 1983—REVISED MARCH 1988

- Designed for Use with the TL852 in Sonar Ranging Modules Like the SN28827
- Operates with Single Supply
- Accurate Clock Output for External Use
- Synchronous 4-Bit Gain Control Output
- Internal 1.2-V Level Detector for Receive
- TTL-Compatible
- Interfaces to Electrostatic or Piezoelectric Transducers

N DUAL-IN-LINE PACKAGE (TOP VIEW)



description

The TL851 is an economical digital I²L ranging control integrated circuit designed for use with the Texas Instruments TL852 Sonar ranging receiver integrated circuit.

The TL851 is designed for distance measurement from six inches to 35 feet. The device has an internal oscillator that uses a low-cost external ceramic resonator. With a simple interface and a 420-kHz ceramic resonator, the device will drive a 50-kHz electrostatic transducer.

The device cycle begins when Initiate (INIT) is taken to the high logic level. There must be at least 5 ms from initial power up (V_{CC}) to the first initiate signal in order for all the device internal latches to reset and for the ceramic-resonator-controlled oscillator to stabilize. The device will transmit a burst of 16 pulses each time INIT is taken high.

The oscillator output (OSC) is enabled by INIT. The oscillator frequency is the ceramic resonator frequency divided by 8.5 for the first 16 cycles (during transmit) and then the oscillator frequency changes to the ceramic resonator frequency divided by 4.5 for the remainder of the device cycle.

When used with an external 420 kilohertz ceramic resonator, the device internal blanking disables the receive input (REC) for 3.8 ms after initiate to exclude false receive inputs that may be caused by transducer ringing. The internal blanking feature also eliminates echos from objects closer than 1.3 feet from the transducer. If it is necessary to detect objects closer than 1.3 feet, then the internal blanking may be shortened by taking the blanking inhibit (BINH) high, enabling the receive input. The blanking input (BLNK) may be used to disable the receive input and reset ECHO to a low logic level at any time during the device cycle for selective echo exclusion or for a multiple-echo mode of operation.

The device provides a synchronous 4-bit gain control output (12 steps) designed to control the gain of the TL852 sonar ranging receiver integrated circuit. The digital gain control waveforms are shown in Figure 2 with the nominal transition times from INIT listed in the Gain Control Output Table.

The threshold of the internal receive level detector is 1.2 volts. The TL851 operates over a supply voltage range of 4.5 volts to 6.8 volts and is characterized for operation from 0°C to 40°C.

PRODUCTION DATA documents contain information current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.



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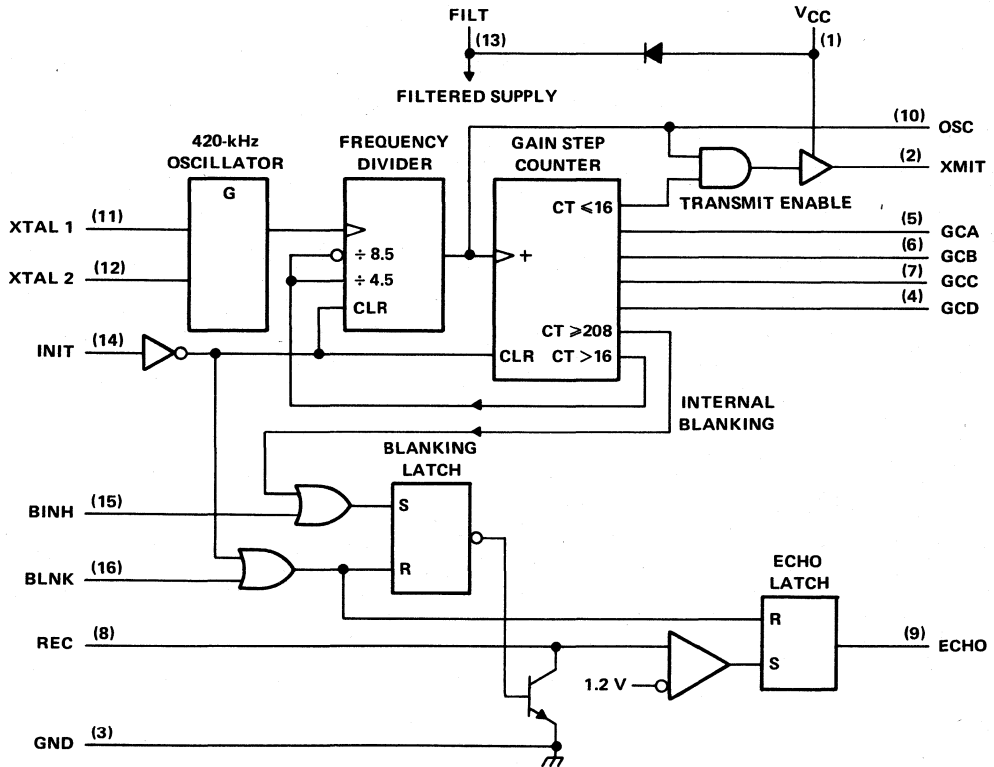
TL851 SONAR RANGING CONTROL

GAIN CONTROL OUTPUT TABLE

| STEP NUMBER | GCD | GCC | GCB | GCA | TIME (ms) FROM INITIATE † |
|-------------|-----|-----|-----|-----|---------------------------|
| 0 | L | L | L | L | 2.38 ms |
| 1 | L | L | L | H | 5.12 ms |
| 2 | L | L | L | L | 7.87 ms |
| 3 | L | L | H | H | 10.61 ms |
| 4 | L | H | L | L | 13.35 ms |
| 5 | L | H | L | H | 16.09 ms |
| 6 | L | H | H | L | 18.84 ms |
| 7 | L | H | H | H | 21.58 ms |
| 8 | H | L | L | L | 27.07 ms |
| 9 | H | L | L | H | 32.55 ms |
| 10 | H | L | H | L | 38.04 ms |
| 11 | H | L | H | H | INIT ↓ |

† This is the time to the end of the indicated step and assumes a nominal 420-kHz ceramic resonator.

functional block diagram



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|----------------|
| Voltage at any pin with respect to GND | -0.5 V to 7 V |
| Voltage at any pin with respect to V _{CC} | -7 V to 0.5 V |
| Continuous power dissipation at (or below) 25°C free-air temperature (see Note 1) | 1150 mW |
| Operating free-air temperature range | 0°C to 70°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 1: For operation above 25°C, derate linearly at the rate of 9.2 mW/°C.

recommended operating conditions

| | | MIN | MAX | UNIT |
|--|------------------|-----|-----|------|
| Supply voltage, V _{CC} | | 4.5 | 6.8 | V |
| High-level input voltage, V _{IH} | BLNK, BINH, INIT | 2.1 | | V |
| Low-level input voltage, V _{IL} | BLNK, BINH, INIT | | 0.6 | V |
| Delay time, power up to INIT high | | 5 | | ms |
| Operating free-air temperature, T _A | | 0 | 40 | °C |

electrical characteristics over recommended ranges of supply voltage and operating free-air temperature

| PARAMETER | | TEST CONDITIONS | MIN | TYP [†] | MAX | UNIT |
|--|-------------------------------|--------------------------|-----|-------------------|-----|------|
| Input current | BLNK, BINH, INIT | V _I = 2.1 V | | | 1 | mA |
| High-level output current, I _{OH} | ECHO, OSC, GCA, GCB, GCC, GCD | V _{OH} = 5.5 V | | | 100 | μA |
| Low-level output voltage, V _{OL} | ECHO, OSC, GCA, GCB, GCC, GCD | I _{OL} = 1.6 mA | | | 0.4 | V |
| On-state output current | SMIT output | V _O = 1 V | | -140 | | mA |
| Internal blanking interval | REC input | | | 2.38 [‡] | | ms |
| Frequency during 16-pulse transmit period | OSC output | | | 49.4 [‡] | | kHz |
| | XMIT output | | | 49.4 [‡] | | |
| Frequency after 16-pulse transmit period | OSC output | | | 93.3 [‡] | | kHz |
| | XMIT output | | | 0 | | |
| Supply current, I _{CC} | During transmit period | | | | 260 | mA |
| | After transmit period | | | | 55 | |

[†]Typical values are at V_{CC} = 5 V and T_A = 25°C.

[‡]These typical values apply for a 420-kHz ceramic resonator.

TL851 SONAR RANGING CONTROL

schematics of inputs and outputs

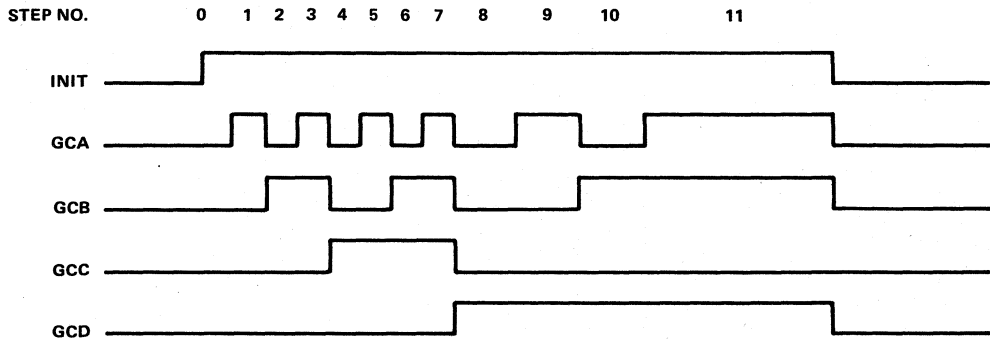
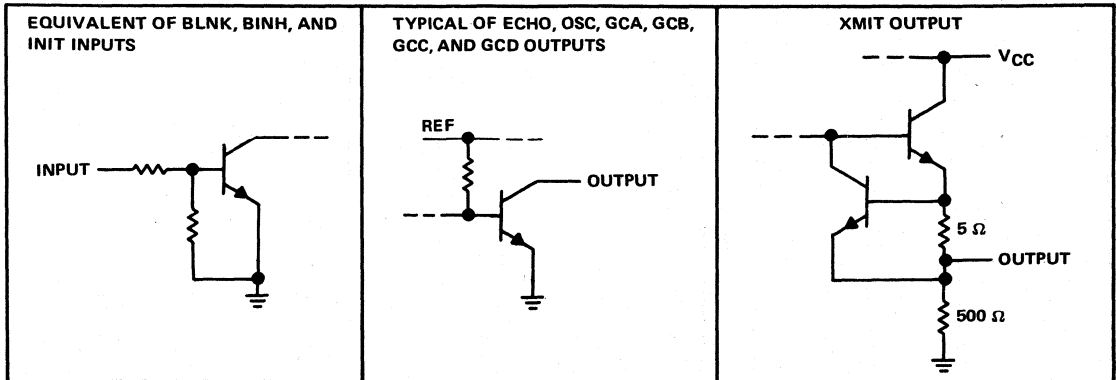


FIGURE 1. DIGITAL GAIN CONTROL WAVEFORMS

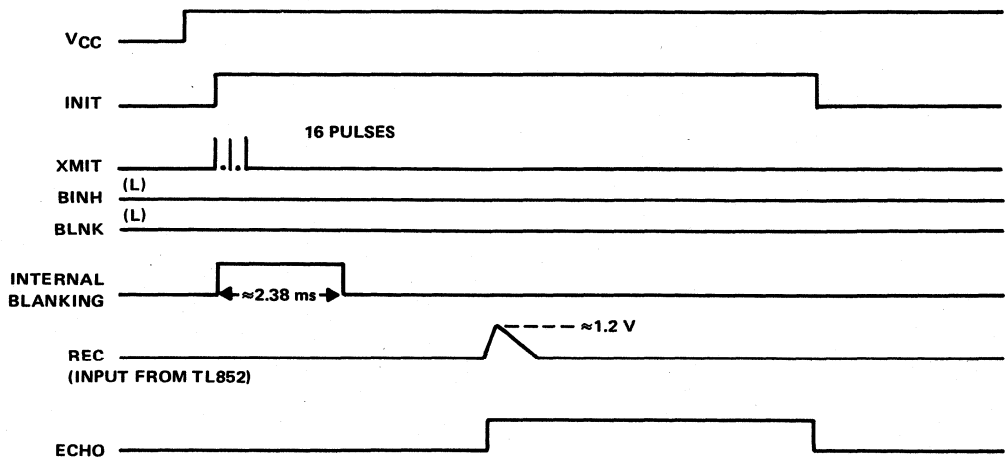


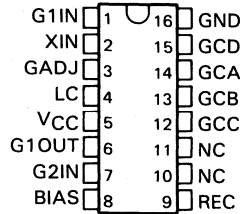
FIGURE 2. EXAMPLE OF SINGLE-ECHO-MODE CYCLE WHEN USED WITH THE TL852 RECEIVER AND 420-KHz CERAMIC RESONATOR

TL852 SONAR RANGING RECEIVER

D2779, SEPTEMBER 1983—REVISED MARCH 1988

- Designed for Use with the TL851 in Sonar Ranging Modules Like the SN28827
- Digitally Controlled Variable-Gain Variable-Bandwidth Amplifier
- Operational Frequency Range of 20 kHz to 90 kHz
- TTL-Compatible
- Operates from Power Sources of 4.5 V to 6.8 V
- Interfaces to Electrostatic or Piezoelectric Transducers
- Overall Gain Adjustable with One External Resistor

N DUAL-IN-LINE PACKAGE (TOP VIEW)



NC—No internal connection

description

The TL852 is an economical sonar ranging receiver integrated circuit for use with the TL851 control integrated circuit. A minimum of external components is required for operation, and this amplifier easily interfaces to Polaroid's 50-kilohertz electrostatic transducer. An external 68-kilohm $\pm 5\%$ resistor from pin 8 (Bias) to pin 16 (GND) provides the internal biasing reference. Amplifier gain can be set with a resistor from pin 1 (G1IN) to pin 3 (GADJ). Required amplifier gain will vary for different applications. Using the detect-level measurement circuit of Figure 1, a nominal peak-to-peak value of 230 millivolts input during gain step 2 is recommended for most applications. For reliable operation, a level no lower than 50 millivolts should be used. The recommended detect level of 230 millivolts can be obtained for most amplifiers with an R1 value between 5 kilohms and 20 kilohms.

Digital control of amplifier gain is provided with gain control inputs on pins 12 through 15. These inputs must be driven synchronously (all inputs stable within 0.1 microsecond) to avoid false receive output signals due to invalid logic counts. This can be done easily with the TL851 control IC. A plot showing relative gain for the various gain steps versus time can be seen in Figure 2. To dampen ringing of the 50-kilohertz electrostatic transducer, a 5-kilohm resistor from pin 1 (GAIN) to pin 2 (XIN) is recommended.

An external parallel combination of inductance and capacitance between pin 4 (LC) and pin 5 (VCC) provides an amplifier with an externally controlled gain and Q. This not only allows control of gain to compensate for attenuation of signal with distance, but also maximizes noise and sidelobe rejection. Care must be taken to accurately tune the L-C combination at operating frequency or gain and Q will be greatly reduced at higher gain steps.

AC coupling between stages of the amplifier is accomplished with a 0.01-microfarad capacitor for proper biasing.

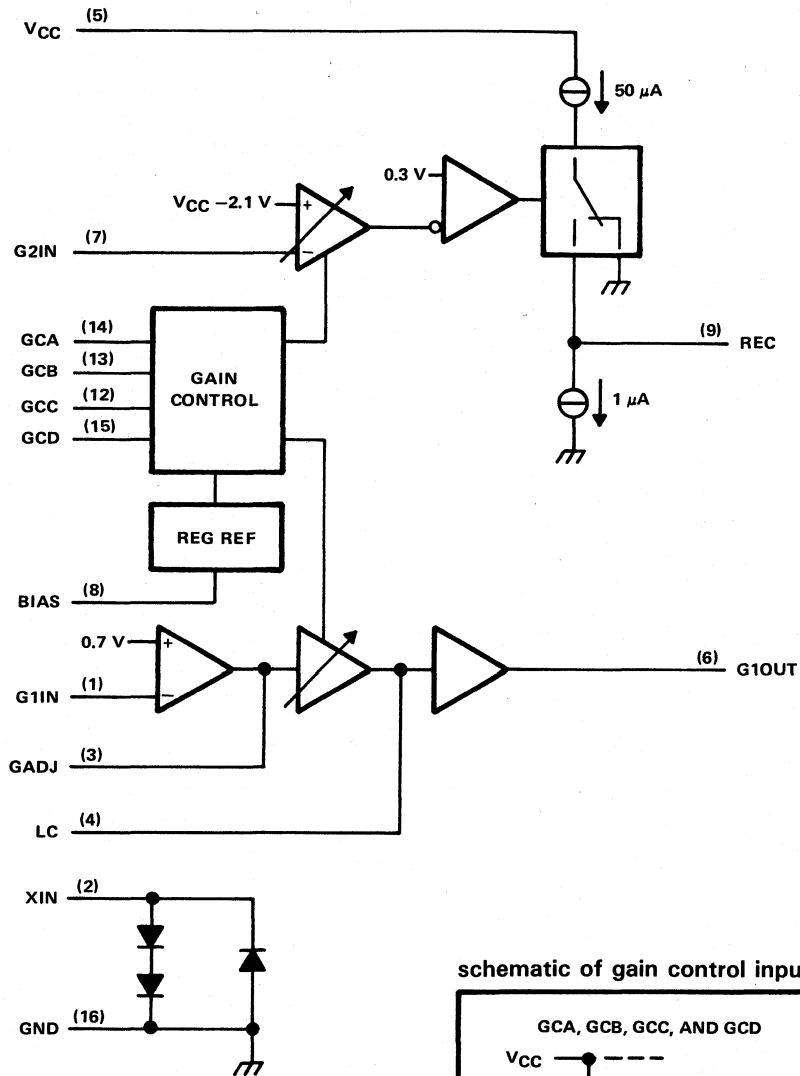
The receive output is normally held at a low level by an internal 1-microampere current source. When an input of sufficient amplitude is received, the output is driven alternately by the 1-microampere discharge current and a 50-microampere charging current. A 1000-picofarad capacitor is required from the receive output (pin 9) to ground (pin 16) to integrate the received signal so that one or two noise pulses will not be recognized.

Pin 2 (XIN) provides clamping for the transformer secondary when used for transducer transmit drive as shown in Figure 4 of the SN28827 data sheet.

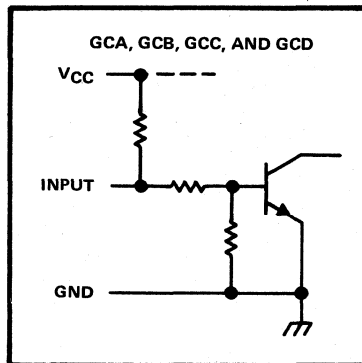
The TL852 is characterized for operation from 0°C to 40°C

TL852 SONAR RANGING RECEIVER

functional block diagram



schematic of gain control inputs



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|----------------|
| Voltage at any pin with respect to GND | -0.5 V to 7 V |
| Voltage at any pin with respect to V_{CC} | -7 V to 0.5 V |
| XIN input current (50% duty cycle) | ± 60 mA |
| Continuous power dissipation at (or below) 25°C free-air temperature (see Note 1) | 1150 mW |
| Operating free-air temperature range | -40°C to 85°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 1: For operation above 25°C, derate linearly at the rate of 9.2 mW/°C.

recommended operating conditions

| | MIN | MAX | UNIT |
|---------------------------------------|-----|-----|------------|
| Supply voltage, V_{CC} | 4.5 | 6.8 | V |
| High-level input voltage, V_{IH} | 2.1 | 0.6 | V |
| Low-level input voltage, V_{IL} | | | V |
| Bias resistor between pins 8 and 16 | 64 | 72 | k Ω |
| Operating free-air temperature, T_A | 0 | 40 | °C |

electrical characteristics over recommended ranges of supply voltage and operating free-air temperature

| PARAMETER | TEST CONDITIONS | MIN | TYP [†] | MAX | UNIT |
|--|--|-----|------------------|------|---------|
| Input clamp voltage at XIN | $I_I = 40$ mA | | | 2.5 | V |
| | $I_I = -40$ mA | | | -1.5 | |
| Open-circuit input voltage at GCA, GCB, GCC, GCD | $V_{CC} = 5$ V, $I_I = 0$ | | 2.5 | | V |
| High-level input current, I_{IH} , into GCA, GCB, GCC, GCD | $V_{CC} = 5$ V, $V_{IH} = 2$ V | | -0.5 | | mA |
| Low-level input current, I_{IL} , into GCA, GCB, GCC, GCD | $V_{CC} = 5$ V, $V_{IL} = 0$ | | | -3 | mA |
| Receive output current | $I_{G2IN} = -100$ μ A, $V_O = 0.3$ V | | 1 | | μ A |
| | $I_{G2IN} = 100$ μ A, $V_O = 0.1$ V | | | -50 | |
| Supply current, I_{CC} | | | | 45 | mA |

[†]Typical values are at $V_{CC} = 5$ V and $T_A = 25^\circ\text{C}$.

TYPICAL APPLICATION INFORMATION

GAIN STEP TABLE

| GCD | GCC | GCB | GCA | STEP NUMBER |
|-----|-----|-----|-----|-------------|
| L | L | L | L | 0 |
| L | L | L | H | 1 |
| L | L | H | L | 2 |
| L | L | H | H | 3 |
| L | H | L | L | 4 |
| L | H | L | H | 5 |
| L | H | H | L | 6 |
| L | H | H | H | 7 |
| H | L | L | L | 8 |
| H | L | L | H | 9 |
| H | L | H | L | 10 |
| H | L | H | H | 11 |

RECEIVER GAIN
vs
GAIN STEP NUMBERS

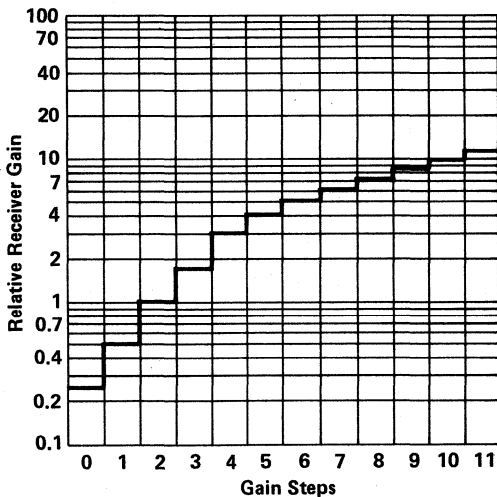


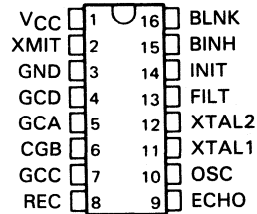
FIGURE 2

TL853 SONAR RANGING CONTROL

D2843, DECEMBER 1984—REVISED MARCH 1988

- Designed for Use with the TL852 in Sonar Ranging Modules Like the SN28828
- Operates with Single Supply
- Accurate Clock Output for External Use
- Synchronous 4-Bit Gain Control Output
- Internal 1.2-V Level Detector for Receive
- TTL-Compatible
- Interface to 40-kHz Piezoelectric or Electrostatic Transducers

N DUAL-IN-LINE PACKAGE (TOP VIEW)



description

The TL853 is an economical digital I²L ranging control integrated circuit designed for use with the Texas Instruments TL852 Sonar ranging receiver integrated circuit.

The TL853 is designed for distance measurement ranging from six inches to 35 feet. The device has an internal oscillator that uses a low-cost external ceramic resonator. With a simple interface and a 420-kHz ceramic resonator, the device will drive a 40-kHz piezoelectric transducer.

The device cycle begins when Initiate (INIT) is taken to the high logic level. There must be at least 5 ms from initial power up (VCC) to the first initiate signal in order for all the device internal latches to reset and for the ceramic-resonator-controlled oscillator to stabilize. The device will transmit a burst of 16 pulses each time INIT is taken high.

The oscillator output (OSC) is enabled by INIT. The oscillator frequency is the ceramic resonator frequency divided by 10.5 for the first 16 cycles (during transmit) and then the oscillator frequency changes to the ceramic resonator frequency divided by 4.5 for the remainder of the device cycle.

When used with an external 420-kilohertz ceramic resonator, the device internal blanking disables the receive input (REC) for 2.46 ms after initiate to exclude false receive inputs that may be caused by transducer ringing. The internal blanking feature also eliminates echos from objects closer than 1.37 feet from the transducer. If it is necessary to detect objects closer than 1.37 feet, then the internal blanking may be shortened by taking the blanking inhibit (BINH) high, enabling the receive input. The blanking input (BLNK) may be used to disable the receive input and reset ECHO to a low logic level at any time during the device cycle for selective echo exclusion or for a multiple-echo mode of operation.

The device provides a synchronous 4-bit gain control output (12 steps) designed to control the gain of the TL852 sonar ranging receiver integrated circuit. The digital gain control waveforms are shown in Figure 2 with the nominal transition times from INIT listed in the Gain Control Output Table.

The threshold of the internal receive level detector is 1.2 volts. The TL853 operates over a supply voltage range of 4.5 volts to 6.8 volts and is characterized for operation from 0°C to 40°C.

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4-119

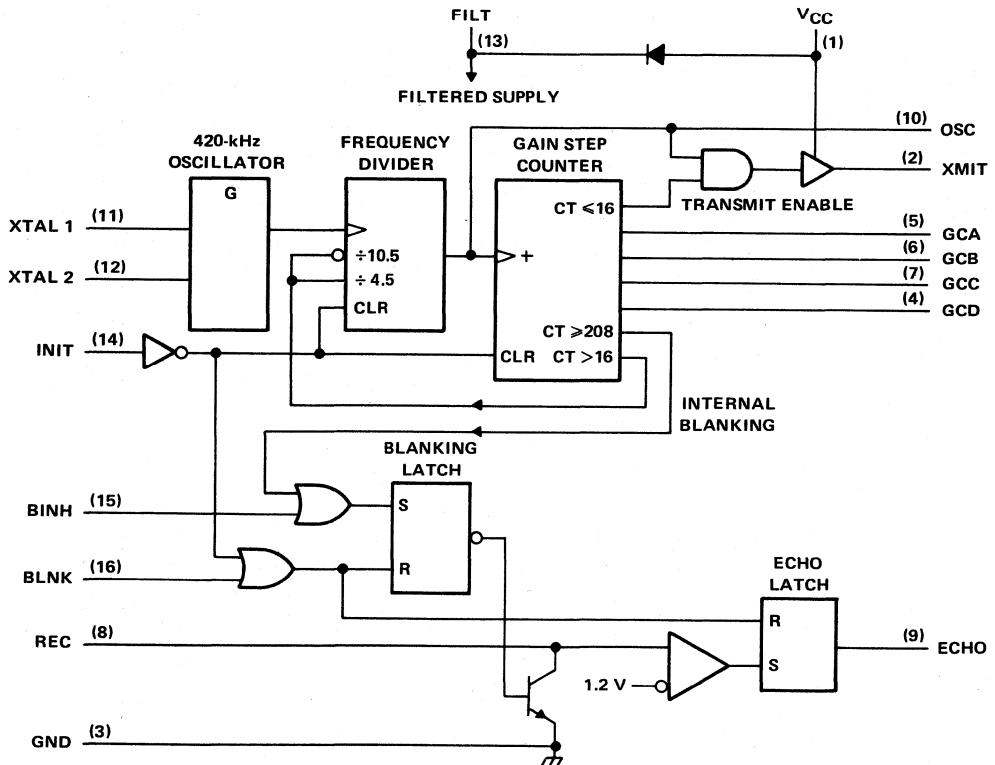
TL853 SONAR RANGING CONTROL

GAIN CONTROL OUTPUT TABLE

| STEP NUMBER | CGD | GCC | GCB | GCA | TIME (ms) FROM INITIATE† |
|-------------|-----|-----|-----|-----|--------------------------|
| 0 | L | L | L | L | 2.46 ms |
| 1 | L | L | L | H | 5.2 ms |
| 2 | L | L | H | L | 7.94 ms |
| 3 | L | L | H | H | 10.69 ms |
| 4 | L | H | L | L | 13.43 ms |
| 5 | L | H | L | H | 16.17 ms |
| 6 | L | H | H | L | 18.91 ms |
| 7 | L | H | H | H | 21.66 ms |
| 8 | H | L | L | L | 27.14 ms |
| 9 | H | L | L | H | 32.63 ms |
| 10 | H | L | H | L | 38.11 ms |
| 11 | H | L | H | H | INIT ↓ |

†This is the time to the end of the indicated step and assumes a nominal 420-kHz ceramic resonator.

functional block diagram



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|----------------|
| Voltage at any pin with respect to GND | -0.5 V to 7 V |
| Voltage at any pin with respect to V _{CC} | -7 V to 0.5 V |
| Continuous power dissipation at (or below) 25°C free-air temperature (see Note 1) | 1150 mW |
| Operating free-air temperature range | 0°C to 70°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 1: For operation above 25°C, derate linearly at the rate of 9.2 mW/°C.

recommended operating conditions

| | | MIN | MAX | UNIT |
|--|------------------|-----|-----|------|
| Supply voltage, V _{CC} | | 4.5 | 6.8 | V |
| High-level input voltage, V _{IH} | BLNK, BINH, INIT | 2.1 | | V |
| Low-level input voltage, V _{IL} | BLNK, BINH, INIT | | 0.6 | V |
| Delay time, power up to INIT high | | 5 | | ms |
| Operating free-air temperature, T _A | | 0 | 40 | °C |

electrical characteristics over recommended ranges of supply voltage and operating free-air temperature

| PARAMETER | | TEST CONDITIONS | MIN | TYP [†] | MAX | UNIT |
|--|----------------------------------|--------------------------|-------------------|------------------|-----|------|
| Input current | BLNK, BINH, INIT | V _I = 2.1 V | | | 1 | mA |
| High-level output current, I _{OH} | ECHO, OSC, GCA, GCB, GCC, GCD | V _{OH} = 5.5 mA | | | 100 | μA |
| Low-level output voltage, V _{OL} | ECHO, OSC, GCA, GCB, GCC, GCD | I _{OL} = 1.6 mA | | | 0.4 | V |
| On-state output current | XMIT output | V _O = 1 V | -140 | | | mA |
| Internal blanking interval | REC input | | 2.46 [‡] | | | ms |
| Frequency during 16-pulse transmit period | OSC output | | 40 [‡] | | | kHz |
| | XMIT output | | 40 [‡] | | | |
| Frequency after 16-pulse transmit period | OSC output | | 93.3 [‡] | | | kHz |
| | XMIT output | | 0 | | | |
| Supply current, I _{CC} | During transmit period | | | | 260 | mA |
| | After transmit period | | | | 55 | |

[†]Typical values are at V_{CC} = 5 V and T_A = 25°C.

[‡]These typical values apply for a 420-kHz ceramic resonator.

TL853 SONAR RANGING CONTROL

schematics of inputs and outputs

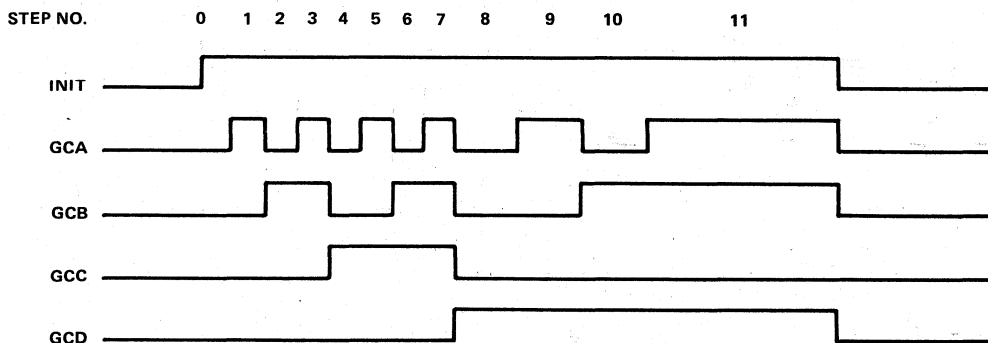
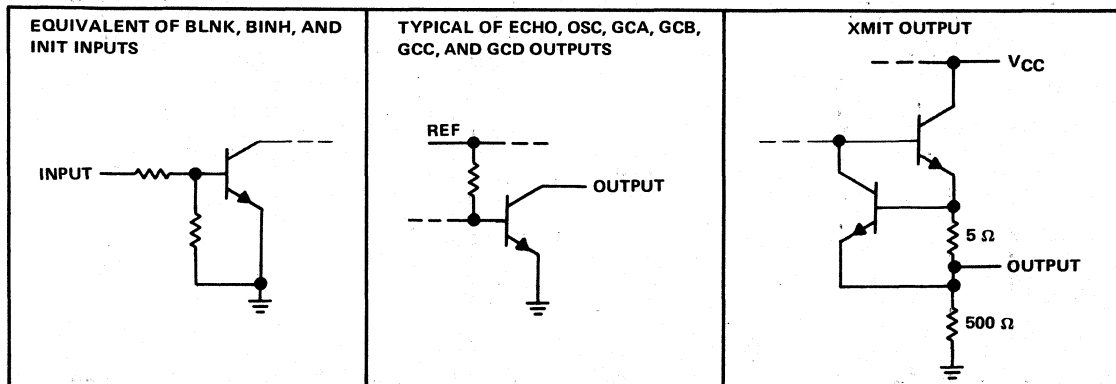


FIGURE 1. DIGITAL GAIN CONTROL WAVEFORMS

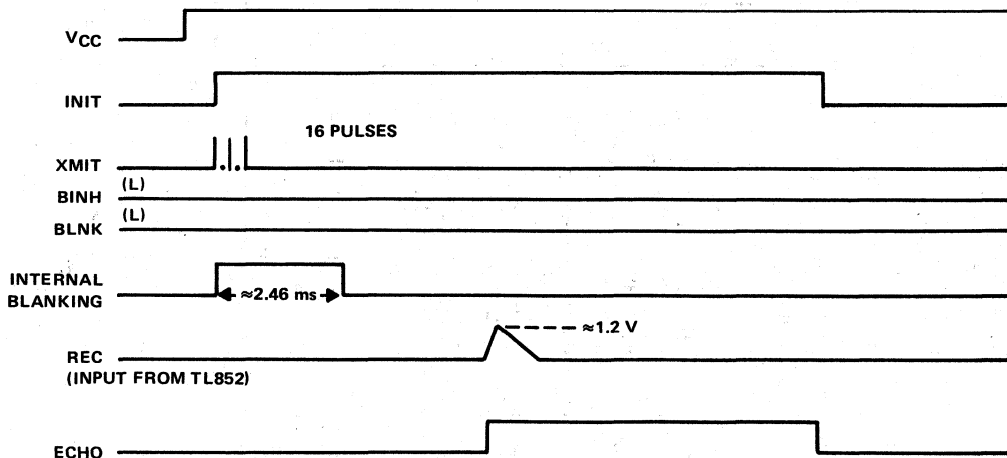


FIGURE 2. EXAMPLE OF SINGLE-ECHO-MODE CYCLE WHEN USED WITH THE TL852 RECEIVER AND 420-KHZ CERAMIC RESONATOR

TEXAS
INSTRUMENTS

POST OFFICE BOX 655303 • DALLAS, TEXAS 75265

TLC551C, TLC551Y LinCMOS™ TIMERS

DD2791, FEBRUARY 1984—REVISED NOVEMBER 1991

- **Very Low Power Consumption . . . 1 mW**
Typ at $V_{DD} = 5\text{ V}$
- **Capable of Operation in Astable Mode**
- **CMOS Output Capable of Swinging Rail to Rail**
- **High Output-Current Capability**
Sink 100 mA Typ
Source 10 mA Typ
- **Output Fully Compatible With CMOS, TTL, and MOS**
- **Low Supply Current Reduces Spikes During Output Transitions**
- **Single-Supply Operation From 1 V to 15 V**
- **Functionally Interchangeable With the NE555; Has Same Pinout**
- **ESD Protection Exceeds 2000 V Per MIL-STD-883C, Method 3015.2**

description

The TLC551 is a monolithic timing circuit that is fabricated using TI's LinCMOS™ process. The timer is fully compatible with CMOS, TTL, and MOS logic and operates at frequencies up to 2 MHz. Compared to the NE555 timer, this device uses smaller timing capacitors because of its high input impedance. As a result, more accurate time delays and oscillations are possible. Power consumption is low across the full range of power supply voltage.

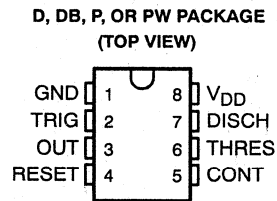
Like the NE555, the TLC551 has a trigger level equal to approximately one-third of the supply voltage and a threshold level equal to approximately two-thirds of the supply voltage. These levels can be altered by use of the control voltage terminal. When the trigger input falls below the trigger level, the flip-flop is set and the output goes high. If the trigger input is above the trigger level and the threshold input is above the threshold level, the flip-flop is reset and the output is low. The reset input can override all other inputs and can be used to initiate a new timing cycle. If the reset input is low, the flip-flop is reset and the output is low. Whenever the output is low, a low-impedance path is provided between the discharge terminal and ground.

While the CMOS output is capable of sinking over 100 mA and sourcing over 10 mA, the TLC551 exhibits greatly reduced supply-current spikes during output transitions. This minimizes the need for the large decoupling capacitors required by the NE555.

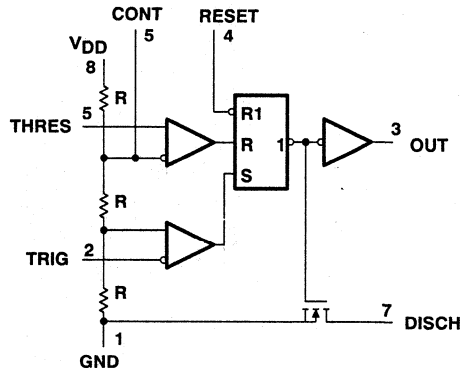
These devices have internal electrostatic discharge (ESD) protection circuits that will prevent catastrophic failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2. However, care should be exercised in handling these devices, as exposure to ESD may result in degradation of parametric performance.

All unused inputs should be tied to an appropriate logic level to prevent false triggering.

The TLC551C is characterized for operation from 0°C to 70°C.



functional block diagram



Reset can override Trigger, which can override Threshold.

LinCMOS is a trademark of Texas Instruments Incorporated.

PRODUCTION DATA Information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

**TEXAS
INSTRUMENTS**

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4-123

TLC551C, TLC551Y
LinCMOS™ TIMERS

AVAILABLE OPTIONS

| T _A | V _{DD} RANGE | PACKAGE | | | | |
|----------------|--------------------------|-------------------------|--------------|--------------------|---------------|------------------|
| | | SMALL OUTLINE (D) | SSOP (DB) | PLASTIC DIP (P) | TSSOP (PW) | CHIP FORM (Y) |
| 0°C to 70°C | 1 V to 18 V | TLC551CD | TLC551CDBLE | TLC551CP | TLC551CPWLE | TLC551Y |

The D package is available taped and reeled. Add the suffix R (e.g., TLC551CDR).
 The DB and PW packages are only available left-end taped and reeled.
 Chips are tested at 25°C.

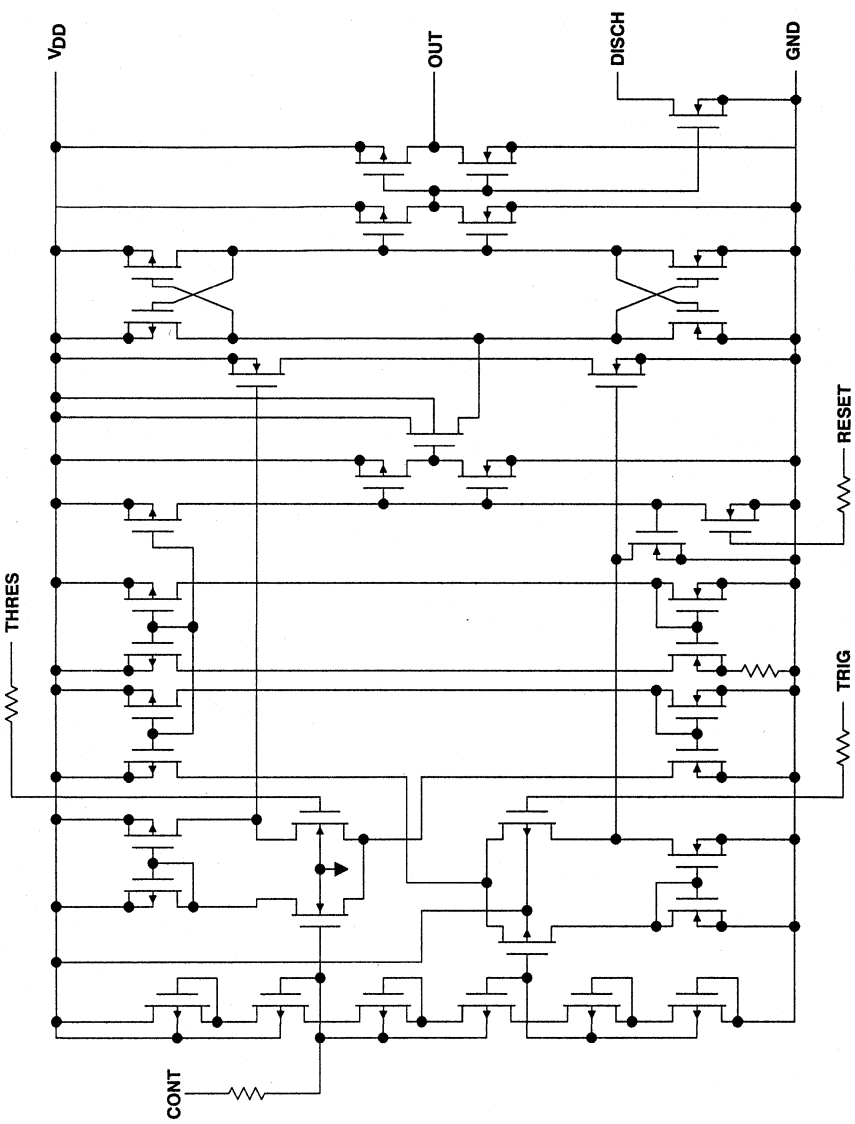
FUNCTION TABLE

| RESET VOLTAGE† | TRIGGER VOLTAGE† | THRESHOLD VOLTAGE† | OUTPUT | DISCHARGE SWITCH |
|-------------------|---------------------|-----------------------|---------------------------|---------------------|
| <MIN | Irrelevant | Irrelevant | Low | On |
| >MAX | <MIN | Irrelevant | High | Off |
| >MAX | >MAX | >MAX | Low | On |
| >MAX | >MAX | <MIN | As previously established | |

† For conditions shown as MIN or MAX, use the appropriate value specified under electrical characteristics.

equivalent schematic (each channel)

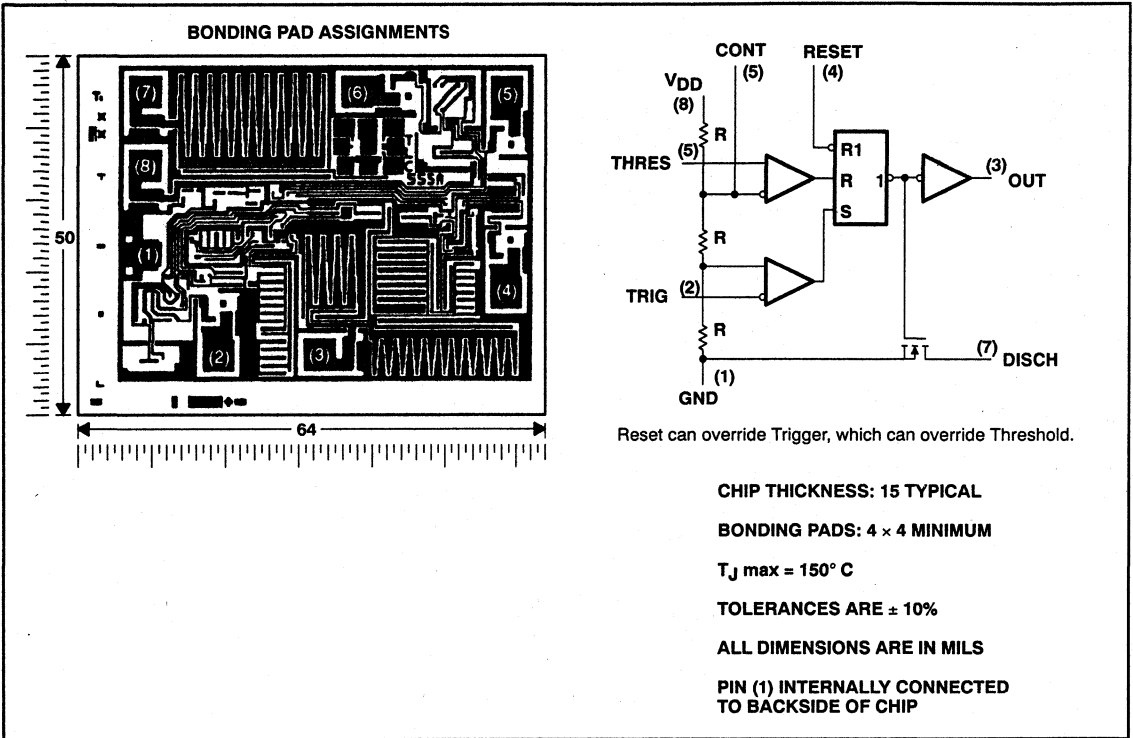
| |
|-------------------------------|
| ACTUAL DEVICE COMPONENT COUNT |
| Transistors 39 |
| Resistors 5 |



TLC551Y
LinCMOS™ TIMER

chip information

These chips, properly assembled, display characteristics similar to the TLC551. Thermal compression or ultrasonic bonding may be used on the doped aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Supply voltage, V_{DD} (see Note 1) | 18 V |
| Input voltage range (any input) | -0.3 to V_{DD} |
| Sink current, discharge or output | 150 mA |
| Source current, output | 15 mA |
| Continuous total power dissipation | See Dissipation Rating Table |
| Operating free-air temperature range | 0°C to 70°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 1: All voltage values are with respect to network ground terminal.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$ | $T_A = 70^\circ\text{C}$ POWER RATING |
|----------|---|---|--|
| D | 725 mW | 5.8 mW/°C | 464 mW |
| DB or PW | 525 mW | 4.2 mW/°C | 336 mW |
| P | 1000 mW | 8.0 mW/°C | 640 mW |

recommended operating conditions

| | MIN | MAX | UNIT |
|---|-----|-----|------|
| Supply voltage, V_{DD} | 1 | 15 | V |
| Operating free-air temperature range, T_A | 0 | 70 | °C |

TLC551C
LinCMOS™ TIMER

electrical characteristics at specified free-air temperature, $V_{DD} = 1\text{ V}$

| PARAMETER | | TEST CONDITIONS | T_A^\dagger | MIN | TYP | MAX | UNIT |
|--|---------------------------|-----------------------------|---------------|-------|------|-------|---------------|
| V_T | Threshold voltage | | 25°C | 0.475 | 0.67 | 0.85 | V |
| | | | Full range | 0.45 | | 0.875 | |
| I_T | Threshold current | | 25°C | | 10 | | pA |
| | | | MAX | | 75 | | |
| V_{trigger} | Trigger voltage | | 25°C | 0.15 | 0.33 | 0.425 | V |
| | | | Full range | 0.1 | | 0.45 | |
| I_{trigger} | Trigger current | | 25°C | | 10 | | pA |
| | | | MAX | | 75 | | |
| V_{reset} | Reset voltage | | 25°C | 0.4 | 0.7 | 1 | V |
| | | | Full range | 0.3 | | 1 | |
| I_{reset} | Reset current | | 25°C | | 10 | | pA |
| | | | MAX | | 75 | | |
| Control voltage (open circuit) as a percentage of supply voltage | | | MAX | 66.7% | | | |
| Discharge switch on-stage voltage | | $I_{OL} = 100\ \mu\text{A}$ | 25°C | | 0.02 | 0.15 | V |
| | | | Full range | | | 0.2 | |
| Discharge switch off-stage current | | | 25°C | | 0.1 | | nA |
| | | | MAX | | 0.5 | | |
| V_{OH} | High-level output voltage | $I_{OH} = -10\ \mu\text{A}$ | 25°C | 0.6 | 0.98 | | V |
| | | | Full range | 0.6 | | | |
| V_{OL} | Low-level output voltage | $I_{OL} = 100\ \mu\text{A}$ | 25°C | | 0.03 | 0.2 | V |
| | | | Full range | | | 0.25 | |
| I_{DD} | Supply current | See Note 2 | 25°C | | 15 | 100 | μA |
| | | | Full range | | | 150 | |

† Full range is 0°C to 70°C.

NOTE 2: These values apply for the expected operating configurations in which the THRES terminal is connected directly to the DISCH terminal or to the TRIG terminal.

electrical characteristics at specified free-air temperature, $V_{DD} = 2\text{ V}$

| PARAMETER | | TEST CONDITIONS | T_A^\dagger | MIN | TYP | MAX | UNIT |
|--|------------------------------------|------------------------------|---------------|-------|------|------|---------------|
| V_T | Threshold voltage | | 25°C | 0.95 | 1.33 | 1.65 | V |
| | | | Full range | 0.85 | | 1.75 | |
| I_T | Threshold current | | 25°C | | 10 | | pA |
| | | | MAX | | 75 | | |
| V_{trigger} | Trigger voltage | | 25°C | 0.4 | 0.67 | 0.95 | V |
| | | | Full range | 0.3 | | 1.05 | |
| I_{trigger} | Trigger current | | 25°C | | 10 | | pA |
| | | | MAX | | 75 | | |
| V_{reset} | Reset voltage | | 25°C | 0.4 | 1.1 | 1.5 | V |
| | | | Full range | 0.3 | | 1.8 | |
| I_{reset} | Reset current | | 25°C | | 10 | | pA |
| | | | MAX | | 75 | | |
| Control voltage (open circuit) as a percentage of supply voltage | | | MAX | 66.7% | | | |
| | Discharge switch on-stage voltage | $I_{OL} = 1\text{ mA}$ | 25°C | | 0.03 | 0.2 | V |
| | | | Full range | | | 0.25 | |
| | Discharge switch off-stage current | | 25°C | | 0.1 | | nA |
| | | | MAX | | 0.5 | | |
| V_{OH} | High-level output voltage | $I_{OH} = -300\ \mu\text{A}$ | 25°C | 1.5 | 1.9 | | V |
| | | | Full range | 1.5 | | | |
| V_{OL} | Low-level output voltage | $I_{OL} = 1\text{ mA}$ | 25°C | | 0.07 | 0.3 | V |
| | | | Full range | | | 0.35 | |
| I_{DD} | Supply current | See Note 2 | 25°C | | 65 | 250 | μA |
| | | | Full range | | | 400 | |

† Full range is 0°C to 70°C.

NOTE 2: These values apply for the expected operating configurations in which the THRES terminal is connected directly to the DISCH terminal or to the TRIG terminal.

TLC551C
LinCMOS™ TIMER

electrical characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$

| PARAMETER | | TEST CONDITIONS | T_A † | MIN | TYP | MAX | UNIT | |
|--|------------------------------------|--------------------------|------------|-------|------|------|------|------|
| V_T | Threshold voltage | | 25°C | 2.8 | 3.3 | 3.8 | V | |
| | | | Full range | 2.7 | | 3.9 | | |
| I_T | Threshold current | | 25°C | 10 | | | pA | |
| | | | MAX | 75 | | | | |
| V_{trigger} | Trigger voltage | | 25°C | 1.36 | 1.66 | 1.96 | V | |
| | | | Full range | 1.26 | | 2.06 | | |
| I_{trigger} | Trigger current | | 25°C | 10 | | | pA | |
| | | | MAX | 75 | | | | |
| V_{reset} | Reset voltage | | 25°C | 0.4 | 1.1 | 1.5 | V | |
| | | | Full range | 0.3 | | 1.8 | | |
| I_{reset} | Reset current | | 25°C | 10 | | | pA | |
| | | | MAX | 75 | | | | |
| Control voltage (open circuit) as a percentage of supply voltage | | | MAX | 66.7% | | | | |
| | Discharge switch on-state voltage | $I_{OL} = 10\text{ mA}$ | 25°C | 0.14 | 0.5 | | V | |
| | | | Full range | | 0.6 | | | |
| | Discharge switch off-state current | | 25°C | 0.1 | | | nA | |
| | | | MAX | 0.5 | | | | |
| V_{OH} | High-level output voltage | $I_{OH} = -1\text{ mA}$ | 25°C | 4.1 | 4.8 | | V | |
| | | | Full range | 4.1 | | | | |
| V_{OL} | Low-level output voltage | $I_{OL} = 8\text{ mA}$ | 25°C | 0.21 | 0.4 | | V | |
| | | | Full range | | 0.5 | | | |
| | | $I_{OL} = 5\text{ mA}$ | 25°C | 0.13 | | 0.3 | | |
| | | | Full range | | | 0.4 | | |
| | | $I_{OL} = 3.2\text{ mA}$ | 25°C | 0.08 | 0.3 | | | |
| | | | Full range | | | | | 0.35 |
| I_{DD} | Supply current | See Note 2 | 25°C | 170 | 350 | | μA | |
| | | | Full range | | | | | 500 |

† Full range is 0°C to 70°C.

NOTE 2: These values apply for the expected operating configurations in which the THRES terminal is connected directly to the DISCH terminal or to the TRIG terminal.



electrical characteristics at specified free-air temperature, $V_{DD} = 15\text{ V}$

| PARAMETER | | TEST CONDITIONS | T_A^\dagger | MIN | TYP | MAX | UNIT |
|--|---------------------------|--------------------------|---------------|-------|------|-------|---------------|
| V_T | Threshold voltage | | 25°C | 9.45 | | 10.55 | V |
| | | | Full range | 9.35 | | 10.65 | |
| I_T | Threshold current | | 25°C | | 10 | | pA |
| | | | MAX | | 75 | | |
| V_{trigger} | Trigger voltage | | 25°C | 4.65 | 5 | 5.35 | V |
| | | | Full range | 4.55 | | 5.45 | |
| I_{trigger} | Trigger current | | 25°C | | 10 | | pA |
| | | | MAX | | 75 | | |
| V_{reset} | Reset voltage | | 25°C | 0.4 | 1.1 | 1.5 | V |
| | | | Full range | 0.3 | | 1.8 | |
| I_{reset} | Reset current | | 25°C | | 10 | | pA |
| | | | MAX | | 75 | | |
| Control voltage (open circuit) as a percentage of supply voltage | | | MAX | 66.7% | | | |
| Discharge switch on-state voltage | | $I_{OL} = 100\text{ mA}$ | 25°C | 0.77 | | 1.7 | V |
| | | | Full range | | | 1.8 | |
| Discharge switch off-state current | | | 25°C | | 0.1 | | nA |
| | | | MAX | | 0.5 | | |
| V_{OH} | High-level output voltage | $I_{OH} = -10\text{ mA}$ | 25°C | 12.5 | 14.2 | | V |
| | | | Full range | | 12.5 | | |
| | | $I_{OH} = -5\text{ mA}$ | 25°C | 13.5 | 14.6 | | |
| | | | Full range | | 13.5 | | |
| | | $I_{OH} = -1\text{ mA}$ | 25°C | 14.2 | 14.9 | | |
| | | | Full range | | 14.2 | | |
| V_{OL} | Low-level output voltage | $I_{OL} = 100\text{ mA}$ | 25°C | 1.28 | 3.2 | | V |
| | | | Full range | | | 3.6 | |
| | | $I_{OL} = 50\text{ mA}$ | 25°C | 0.63 | 1 | | |
| | | | Full range | | | 1.3 | |
| | | $I_{OL} = 10\text{ mA}$ | 25°C | 0.12 | 0.3 | | |
| | | | Full range | | | 0.4 | |
| I_{DD} | Supply current | See Note 2 | 25°C | 360 | 600 | | μA |
| | | | Full range | | | 800 | |

† Full range is 0°C to 70°C.

NOTE 2: These values apply for the expected operating configurations in which the THRES terminal is connected directly to the DISCH terminal or to the TRIG terminal.

operating characteristics, $V_{DD} = 5\text{ V}$, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|---|-----|-----|-----|------|
| Initial error of timing interval ‡ | $V_{DD} = 5\text{ V to }15\text{ V}$, $R_A = R_B = 1\text{ k}\Omega$ to $100\text{ k}\Omega$, | | 1% | 3% | |
| Supply voltage sensitivity of timing interval | $C_T = 0.1\text{ }\mu\text{F}$, See Note 3 | | 0.1 | 0.5 | %/V |
| t_r Output pulse rise time | $R_L = 10\text{ M}\Omega$, $C_L = 10\text{ pF}$ | | 20 | 75 | ns |
| t_f Output pulse fall time | | | 15 | 60 | |
| f_{max} Maximum frequency in astable mode | $R_A = 470\text{ }\Omega$, $R_B = 200\text{ }\Omega$, $C_T = 200\text{ pF}$, See Note 3 | 1.2 | 1.8 | | MHz |

‡ Timing interval error is defined as the difference between the measured value and the average value of a random sample from each process run.

NOTE 3: R_A , R_B , and C_T are as defined in Figure 1.

TLC551Y
LinCMOS™ TIMER

electrical characteristics at $V_{DD} = 5\text{ V}$, $T_A = 25^\circ\text{C}$

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|----------------------|--|--------------------------|------|-------|------|---------------|
| V_T | Threshold voltage | | 2.8 | 3.3 | 3.8 | V |
| I_T | Threshold current | | | 10 | | pA |
| V_{trigger} | Trigger voltage | | 1.36 | 1.66 | 1.96 | V |
| I_{trigger} | Trigger current | | | 10 | | pA |
| V_{reset} | Reset voltage | | 0.4 | 1.1 | 1.5 | V |
| I_{reset} | Reset current | | | 10 | | pA |
| | Control voltage (open circuit) as a percentage of supply voltage | | | 66.7% | | |
| | Discharge switch on-state voltage | $I_{OL} = 10\text{ mA}$ | | 0.14 | 0.5 | V |
| | Discharge switch off-state current | | | 0.1 | | nA |
| V_{OH} | High-level output voltage | $I_{OH} = -1\text{ mA}$ | 4.1 | 4.8 | | V |
| V_{OL} | Low-level output voltage | $I_{OL} = 8\text{ mA}$ | | 0.21 | 0.4 | V |
| | | $I_{OL} = 5\text{ mA}$ | | 0.13 | 0.3 | |
| | | $I_{OL} = 3.2\text{ mA}$ | | 0.08 | 0.3 | |
| I_{DD} | Supply current | See Note 2 | | 170 | 350 | μA |

NOTE 2: These values apply for the expected operating configurations in which the THRES terminal is connected directly to the DISCH terminal or to the TRIG terminal.

APPLICATION INFORMATION

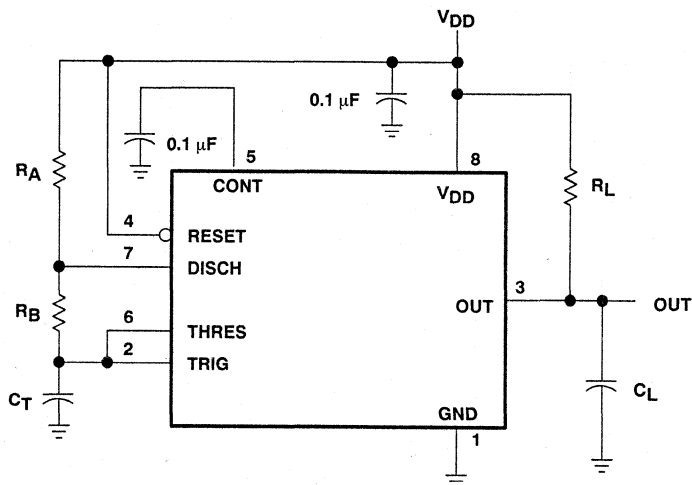


Figure 1. Circuit for Astable Operation

TLC552C DUAL LinCMOS™ TIMER

D2796, FEBRUARY 1984—REVISED MAY 1988

- Very Low Power Consumption . . . 2 mW
Typ at $V_{DD} = 5\text{ V}$
- Capable of Operation in Astable Mode
- CMOS Output Capable of Swinging Rail to Rail
- High Output-Current Capability
. . . Sink 100 mA Typ
. . . Source 10 mA Typ
- Output Fully Compatible with CMOS, TTL, and MOS
- Low Supply Current Reduces Spikes During Output Transitions
- High-Impedance Inputs . . . $10^{12}\ \Omega$ Typ
- Single-Supply Operation from 1 V to 18 V
- Functionally Interchangeable with the NE555; Has Same Pinout

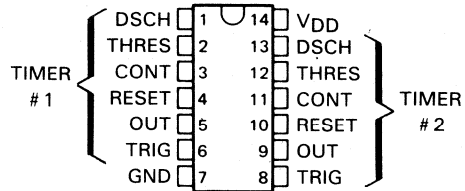
description

The TLC552 is a monolithic timing circuit fabricated using TI's LinCMOS™ process, which provides full compatibility with CMOS, TTL, and MOS logic and operation at frequencies up to 2 MHz. Accurate time delays and oscillations are possible with smaller, less-expensive timing capacitors than the NE555 because of the high input impedance. Power consumption is low across the full range of power supply voltages.

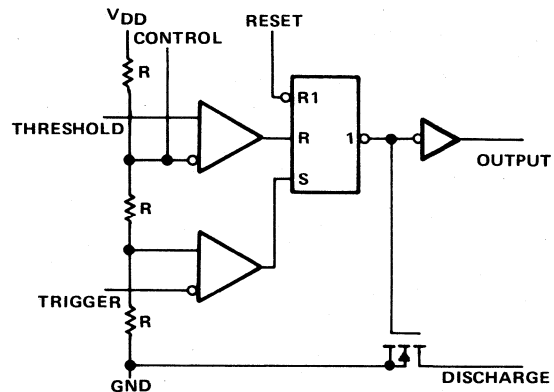
Like the NE555, the TLC552 has a trigger level approximately one-third of the supply voltage and a threshold level approximately two-thirds of the supply voltage. These levels can be altered by use of the control voltage terminal. When the trigger input falls below the trigger level, the flip-flop is set and the output goes high. If the trigger input is above the trigger level and the threshold input is above the threshold level, the flip-flop is reset and the output is low. The reset input can override all other inputs and can be used to initiate a new timing cycle. If the reset input is low, the flip-flop is reset and the output is low. Whenever the output is low, a low-impedance path is provided between the discharge terminal and ground.

While the CMOS output is capable of sinking over 100 milliamperes and sourcing over 10 milliamperes, the TLC552 exhibits greatly reduced supply-current spikes during output transitions. This minimizes the need for the large decoupling capacitors required by the NE555.

D OR N PACKAGE
(TOP VIEW)



functional block diagram (each timer)



Reset can override Trigger and Threshold.
Trigger can override Threshold.

AVAILABLE OPTIONS

| SYMBOLIZATION | | OPERATING TEMPERATURE RANGE | V_T MAX at 25°C |
|---------------|----------------|-----------------------------|-------------------|
| DEVICE | PACKAGE SUFFIX | | |
| TLC552C | D,N | 0°C to 70°C | 3.8 mV |

The D packages are available taped and reeled. Add the suffix R to the device type when ordering. (i.e. TLC552CDR)

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PRODUCTION DATA documents contain information current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

TEXAS
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TLC552C

DUAL LinCMOS™ TIMER

description (continued)

These devices have internal electrostatic discharge (ESD) protection circuits that will prevent catastrophic failures at voltages up to 2000 volts as tested under MIL-STD-883C, Method 3015.2. However, care should be exercised in handling these devices as exposure to ESD may result in a degradation of the device parametric performance.

All unused inputs should be tied to an appropriate logic level to prevent false triggering.

The TLC552C is characterized for operation from 0°C to 70°C.

FUNCTION TABLE

| RESET VOLTAGE† | TRIGGER VOLTAGE† | THRESHOLD VOLTAGE† | OUTPUT | DISCHARGE SWITCH |
|----------------|------------------|--------------------|---------------------------|------------------|
| <MIN | Irrelevant | Irrelevant | Low | On |
| >MAX | <MIN | Irrelevant | High | Off |
| >MAX | >MAX | >MAX | Low | On |
| >MAX | >MAX | <MIN | As previously established | |

†For conditions shown as MIN or MAX, use the appropriate value specified under electrical characteristics.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|------------------------------|
| Supply voltage, V_{DD} (see Note 1) | 18 V |
| Input voltage range (any input) | -0.3 V to V_{DD} |
| Sink current, discharge or output | 150 mA |
| Source current, output | 15 mA |
| Continuous total dissipation | See Dissipation Rating Table |
| Operating free-air temperature range | 0°C to 70°C |
| Storage temperature range | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or N package | 260°C |

NOTE 1: All voltage values are with respect to network ground terminal.

DISSIPATION RATING TABLE

| PACKAGE | POWER RATING | DERATING FACTOR | ABOVE T_A |
|---------|--------------|-----------------|-------------|
| D | 950 mW | 7.6 mW/°C | 25°C |
| N | 1150 mW | 9.2 mW/°C | 25°C |

recommended operating conditions

| | MIN | MAX | UNIT |
|---------------------------------------|-----|-----|------|
| Supply voltage, V_{DD} | 1 | 18 | V |
| Operating free-air temperature, T_A | 0 | 70 | °C |

electrical characteristics at specified free-air temperature, V_{DD} = 1 V

| PARAMETER | TEST CONDITIONS† | MIN | TYP | MAX | UNIT |
|--|--------------------------|-------|-------|-------|------|
| | | | | | |
| Threshold voltage level | 25 °C | 0.475 | 0.67 | 0.85 | V |
| | Full range | 0.45 | | 0.875 | |
| Threshold current | 25 °C | | 10 | | pA |
| | MAX | | 75 | | |
| Trigger voltage level | 25 °C | 0.15 | 0.33 | 0.425 | V |
| | Full range | 0.1 | | 1.45 | |
| Trigger current | 25 °C | | 10 | | pA |
| | MAX | | 75 | | |
| Reset voltage level | 25 °C | 0.4 | 0.7 | 1 | V |
| | Full range | 0.3 | | 1 | |
| Reset current | 25 °C | | 10 | | pA |
| | MAX | | 75 | | |
| Control voltage (open-circuit) as a percentage of supply voltage | MAX | | 66.7% | | |
| Discharge switch on-state voltage | I _{OL} = 100 μA | | 0.02 | 0.15 | V |
| | Full range | | | 0.2 | |
| Discharge switch off-state current | 25 °C | | 0.1 | | nA |
| | MAX | | 0.5 | | |
| Low-level output voltage | I _{OL} = 100 μA | | 0.03 | 0.2 | V |
| | Full range | | | 0.25 | |
| High-level output voltage | I _{OH} = -10 μA | | 0.6 | 0.98 | V |
| | Full range | | 0.6 | | |
| Supply current | 25 °C | | 30 | 200 | μA |
| | Full range | | | 300 | |

† Full range (MIN to MAX) is 0 °C to 70 °C.

TLC552C
DUAL LinCMOS™ TIMER

electrical characteristics at specified free-air temperature, $V_{DD} = 2\text{ V}$

| PARAMETER | TEST CONDITIONS† | MIN | TYP | MAX | UNIT |
|--|------------------|-------|------|------|------|
| Threshold voltage level | 25°C | 0.95 | 1.33 | 1.65 | V |
| | Full range | 0.85 | | 1.75 | |
| Threshold current | 25°C | 10 | | | pA |
| | MAX | 75 | | | |
| Trigger voltage level | 25°C | 0.4 | 0.67 | 0.95 | V |
| | Full range | 0.3 | | 1.05 | |
| Trigger current | 25°C | 10 | | | pA |
| | MAX | 75 | | | |
| Reset voltage level | 25°C | 0.4 | 1.1 | 1.5 | V |
| | Full range | 0.3 | | 1.8 | |
| Reset current | 25°C | 10 | | | pA |
| | MAX | 75 | | | |
| Control voltage (open-circuit) as a percentage of supply voltage | MAX | 66.7% | | | |
| Discharge switch on-state voltage | 25°C | 0.03 | | | V |
| | Full range | 0.25 | | | |
| Discharge switch off-state current | 25°C | 0.1 | | | nA |
| | MAX | 0.5 | | | |
| Low-level output voltage | 25°C | 0.07 | 0.3 | | V |
| | Full range | 0.35 | | | |
| High-level output voltage | 25°C | 1.5 | 1.9 | | V |
| | Full range | 1.5 | | | |
| Supply current | 25°C | 130 | | 500 | μA |
| | Full range | 800 | | | |

† Full range (MIN to MAX) is 0°C to 70°C.



electrical characteristics at specified free-air temperature, V_{DD} = 5 V

| PARAMETER | TEST CONDITIONS† | MIN | TYP | MAX | UNIT |
|--|--------------------------|------------|------|------|------|
| | | | | | |
| Threshold voltage level | 25°C | 2.8 | 3.3 | 3.8 | V |
| | Full range | 2.7 | | 3.9 | |
| Threshold current | 25°C | 10 | | | pA |
| | MAX | 75 | | | |
| Trigger voltage level | 25°C | 1.36 | 1.66 | 1.96 | V |
| | Full range | 1.26 | | 2.06 | |
| Trigger current | 25°C | 10 | | | pA |
| | MAX | 75 | | | |
| Reset voltage level | 25°C | 0.4 | 1.1 | 1.5 | V |
| | Full range | 0.3 | | 1.8 | |
| Reset current | 25°C | 10 | | | pA |
| | MAX | 75 | | | |
| Control voltage (open-circuit) as a percentage of supply voltage | MAX | 66.7% | | | |
| Discharge switch on-state voltage | I _{OL} = 10 mA | 25°C | 0.14 | 0.5 | V |
| | | Full range | | 0.6 | |
| Discharge switch off-state current | | 25°C | 0.1 | | nA |
| | | MAX | 0.5 | | |
| Low-level output voltage | I _{OL} = 8 mA | 25°C | 0.21 | 0.4 | V |
| | | Full range | | 0.5 | |
| | I _{OL} = 5 mA | 25°C | 0.13 | 0.3 | |
| | | Full range | | 0.4 | |
| | I _{OL} = 3.2 mA | 25°C | 0.08 | 0.3 | |
| | | Full range | | 0.35 | |
| High-level output voltage | I _{OH} = -1 mA | 25°C | 4.1 | 4.8 | V |
| | | Full range | 4.1 | | |
| Supply current | | 25°C | 340 | 700 | μA |
| | | Full range | | 1000 | |

† Full range (MIN to MAX) is 0°C to 70°C.

TLC552C
DUAL LinCMOS™ TIMER

electrical characteristics at specified free-air temperature, $V_{DD} = 15\text{ V}$

| PARAMETER | TEST CONDITIONS† | MIN | TYP | MAX | UNIT |
|--|--------------------------|------------|------|-------|------|
| | | | | | |
| Threshold voltage level | 25°C | 9.45 | 10 | 10.55 | V |
| | Full range | 9.35 | | 10.65 | |
| Threshold current | 25°C | | 10 | | pA |
| | MAX | | 75 | | |
| Trigger voltage level | 25°C | 4.65 | 5 | 5.35 | V |
| | Full range | 4.55 | | 5.45 | |
| Trigger current | 25°C | | 10 | | pA |
| | MAX | | 75 | | |
| Reset voltage level | 25°C | 0.4 | 1.1 | 1.5 | V |
| | Full range | 0.3 | | 1.8 | |
| Reset current | 25°C | | 10 | | pA |
| | MAX | | 75 | | |
| Control voltage (open-circuit) as a percentage of supply voltage | MAX | 66.7% | | | |
| Discharge switch on-state voltage | $I_{OL} = 100\text{ mA}$ | 25°C | 0.77 | 1.7 | V |
| | | Full range | | 1.8 | |
| Discharge switch off-state current | | 25°C | 0.1 | | nA |
| | | MAX | 0.5 | | |
| Low-level output voltage | $I_{OL} = 100\text{ mA}$ | 25°C | 1.28 | 3.2 | V |
| | | Full range | | 3.6 | |
| | $I_{OL} = 50\text{ mA}$ | 25°C | 0.63 | 1 | |
| | | Full range | | 1.3 | |
| | $I_{OL} = 10\text{ mA}$ | 25°C | 0.12 | 0.3 | |
| | | Full range | | 0.4 | |
| High-level output voltage | $I_{OH} = -10\text{ mA}$ | 25°C | 12.5 | 14.2 | V |
| | | Full range | 12.5 | | |
| | $I_{OH} = -5\text{ mA}$ | 25°C | 13.5 | 14.6 | |
| | | Full range | 13.5 | | |
| | $I_{OH} = -1\text{ mA}$ | 25°C | 14.2 | 14.9 | |
| | | Full range | 14.2 | | |
| Supply current | | 25°C | 0.72 | 1.2 | mA |
| | | Full range | | 1.6 | |

† Full range (MIN to MAX) is 0°C to 70°C.



electrical characteristics at specified free-air temperature, V_{DD} = 18 V

| PARAMETER | TEST CONDITIONS† | MIN | TYP | MAX | UNIT |
|--|--------------------------|------------|------|------|------|
| Threshold voltage level | 25 °C | 11.4 | 12 | 12.6 | V |
| | Full range | 10.9 | | 12.7 | |
| Threshold current | 25 °C | | 10 | | pA |
| | MAX | | 75 | | |
| Trigger voltage level | 25 °C | 5.6 | 6 | 6.4 | V |
| | Full range | 5.5 | | 6.5 | |
| Trigger current | 25 °C | | 10 | | pA |
| | MAX | | 75 | | |
| Reset voltage level | 25 °C | 0.4 | 1.1 | 1.5 | V |
| | Full range | 0.3 | | 1.8 | |
| Reset current | 25 °C | | 10 | | pA |
| | MAX | | 75 | | |
| Control voltage (open-circuit) as a percentage of supply voltage | MAX | 66.7% | | | |
| Discharge switch on-state voltage | I _{OL} = 100 mA | 25 °C | 0.72 | 1.5 | V |
| | | Full range | | 1.6 | |
| Discharge switch off-state current | | 25 °C | 0.1 | | nA |
| | | MAX | 0.5 | | |
| Low-level output voltage | I _{OL} = 3.2 mA | 25 °C | 0.04 | 0.3 | V |
| | | Full range | | 0.35 | |
| High-level output voltage | I _{OH} = -1 mA | 25 °C | 17.3 | 17.9 | V |
| | | Full range | 17.3 | | |
| Supply current | | 25 °C | 0.84 | 1.2 | mA |
| | | Full range | | 1.6 | |

† Full range (MIN to MAX) is 0 °C to 70 °C.

operating characteristics, V_{DD} = 5 V, T_A = 25 °C (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|--|-----|-----|-----|------|
| Initial error of timing interval‡ | V _{DD} = 5 V to 15 V, R _A = R _B = 1 kΩ to 100 kΩ, C _T = 0.1 μF, See Note 2 | | 1% | 3% | |
| Supply voltage sensitivity of timing interval | | | 0.1 | 0.5 | %/V |
| Output pulse rise time | R _L = 10 MΩ, C _L = 10 pF | | 20 | 75 | ns |
| Output pulse fall time | | | 15 | 60 | |
| Maximum frequency in astable mode | R _A = 470 Ω, R _B = 200 Ω, C _T = 200 pF, See Note 2 | 1.2 | 2.8 | | MHz |

NOTE 2: R_A, R_B, and C_T are as defined in Figure 1.

‡ Timing interval error is defined as the difference between the measured value and the nominal value of a random sample.

TYPICAL APPLICATION DATA

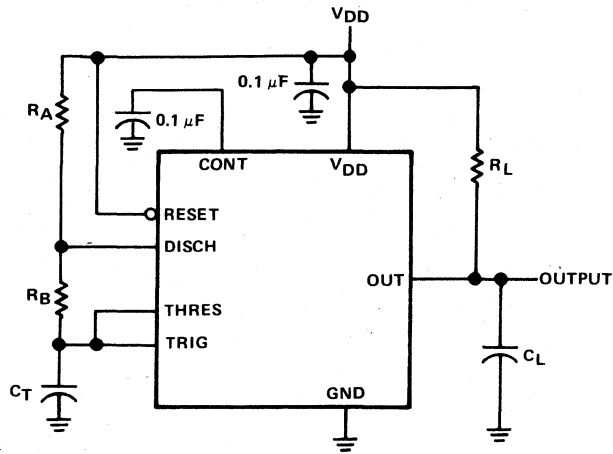


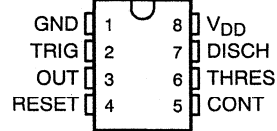
FIGURE 1. CIRCUIT FOR ASTABLE OPERATION

TLC555C, TLC555I, TLC555M, TLC555Y LinCMOS™ TIMERS

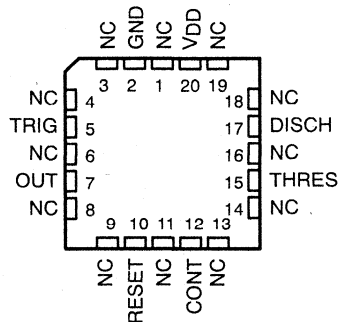
D2784, SEPTEMBER 1983 — REVISED NOVEMBER 1991

- **Very Low Power Consumption . . . 1 mW**
Typ at $V_{DD} = 5\text{ V}$
- **Capable of Operation in Astable Mode**
- **CMOS Output Capable of Swinging Rail to Rail**
- **High Output-Current Capability**
Sink 100 mA Typ
Source 10 mA Typ
- **Output Fully Compatible With CMOS, TTL, and MOS**
- **Low Supply Current Reduces Spikes During Output Transitions**
- **Single-Supply Operation From 2 V to 15 V**
- **Functionally Interchangeable With the NE555; Has Same Pinout**
- **ESD Protection Exceeds 2000 V Per MIL-STD-883C, Method 3015.2**

D, DB, JG, P, OR PW PACKAGE
(TOP VIEW)



FK PACKAGE
(TOP VIEW)



NC – No internal connection

description

The TLC555 is a monolithic timing circuit that is fabricated using TI's LinCMOS™ process. The timer is fully compatible with CMOS, TTL, and MOS logic and operates at frequencies up to 2 MHz. Compared to the NE555 timer, this device uses smaller timing capacitors because of its high input impedance. As a result, more accurate time delays and oscillations are possible. Power consumption is low across the full range of power supply voltage.

Like the NE555, the TLC555 has a trigger level equal to approximately one-third of the supply voltage and a threshold level equal to approximately two-thirds of the supply voltage. These levels can be altered by use of the control voltage terminal. When the trigger input falls below the trigger level, the flip-flop is set and the output goes high. If the trigger input is above the trigger level and the threshold input is above the threshold level, the flip-flop is reset and the output is low. The reset input can override all other inputs and can be used to initiate a new timing cycle. If the reset input is low, the flip-flop is reset and the output is low. Whenever the output is low, a low-impedance path is provided between the discharge terminal and ground.

While the CMOS output is capable of sinking over 100 mA and sourcing over 10 mA, the TLC555 exhibits greatly reduced supply-current spikes during output transitions. This minimizes the need for the large decoupling capacitors required by the NE555.

These devices have internal electrostatic discharge (ESD) protection circuits that will prevent catastrophic failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2. However, care should be exercised in handling these devices, as exposure to ESD may result in degradation of parametric performance.

All unused inputs should be tied to an appropriate logic level to prevent false triggering.

The TLC555C is characterized for operation from 0°C to 70°C. The TLC555I is characterized for operation from -40°C to 85°C. The TLC555M is characterized for operation over the full military temperature range of -55°C to 125°C.

LinCMOS is a trademark of Texas Instruments Incorporated.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

**TEXAS
INSTRUMENTS**

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TLC555C, TLC555I, TLC555M, TLC555Y LinCMOS™ TIMERS

AVAILABLE OPTIONS

| T _A | V _{DD} RANGE | PACKAGE | | | | | | |
|----------------|-----------------------|-------------------|-------------|-------------------|------------------|-----------------|-------------|---------------|
| | | SMALL OUTLINE (D) | SSOP (DB) | CHIP CARRIER (FK) | CERAMIC DIP (JG) | PLASTIC DIP (P) | TSSOP (PW) | CHIP FORM (Y) |
| 0°C to 70°C | 2 V to 15 V | TLC555CD | TLC555CDBLE | | | TLC555CP | TLC555CPWLE | TLC555Y |
| -40°C to 85°C | 3 V to 15 V | TLC555ID | | | | TLC555IP | | |
| -55°C to 125°C | 5 V to 15 V | TLC555MD | | TLC555MFK | TLC555MJG | TLC555MP | | |

The D package is available taped and reeled. Add the suffix R (e.g., TLC555CDR).

The DB and PW packages are only available left-end taped and reeled.

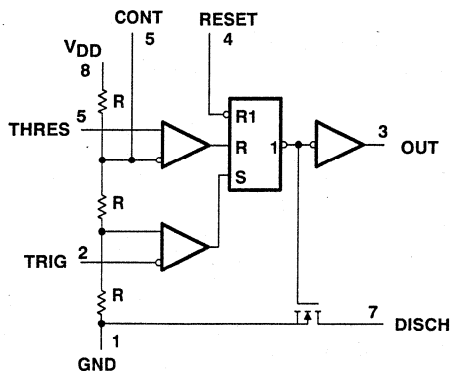
Chips are tested at 25°C.

FUNCTION TABLE

| RESET VOLTAGE† | TRIGGER VOLTAGE† | THRESHOLD VOLTAGE† | OUTPUT | DISCHARGE SWITCH |
|----------------|------------------|--------------------|---------------------------|------------------|
| <MIN | Irrelevant | Irrelevant | L | On |
| >MAX | <MIN | Irrelevant | H | Off |
| >MAX | >MAX | >MAX | L | On |
| >MAX | >MAX | <MIN | As previously established | |

† For conditions shown as MIN or MAX, use the appropriate value specified under electrical characteristics.

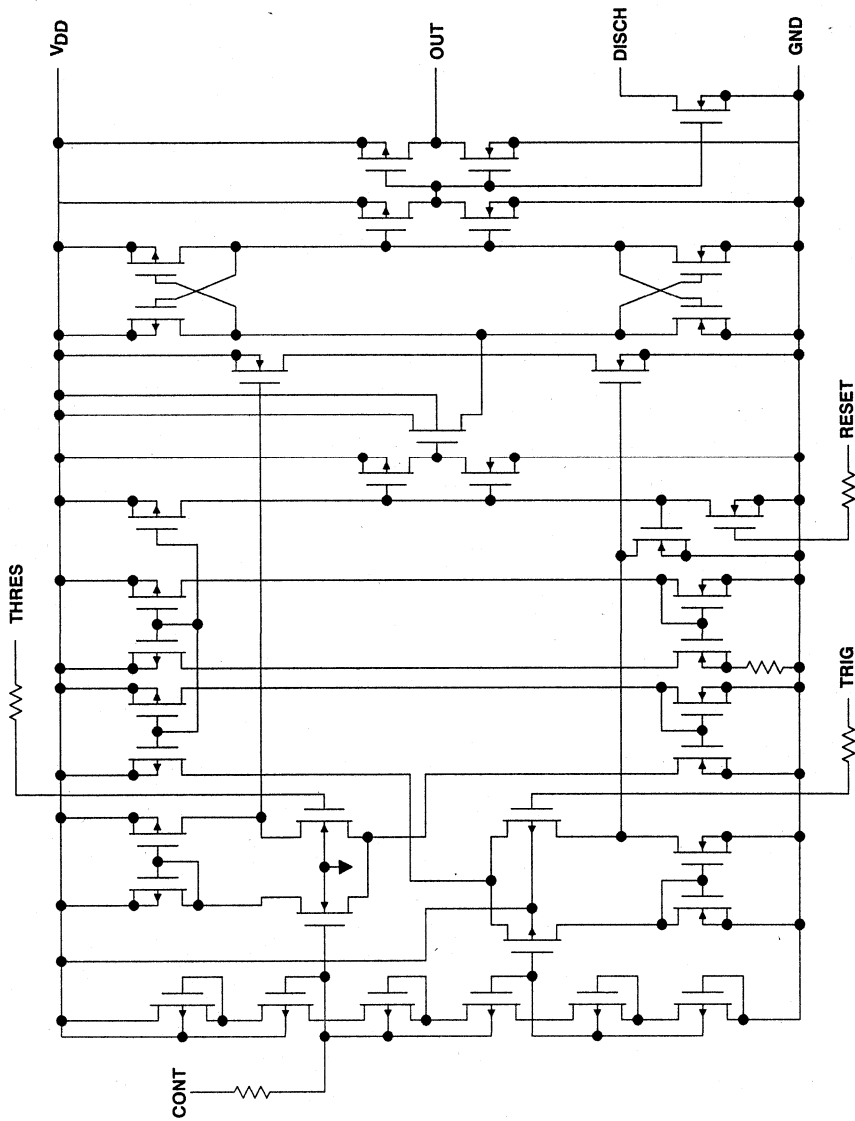
functional block diagram



Pin numbers are for all packages except FK.
Reset can override TRIG, which can override THRES.

equivalent schematic (each channel)

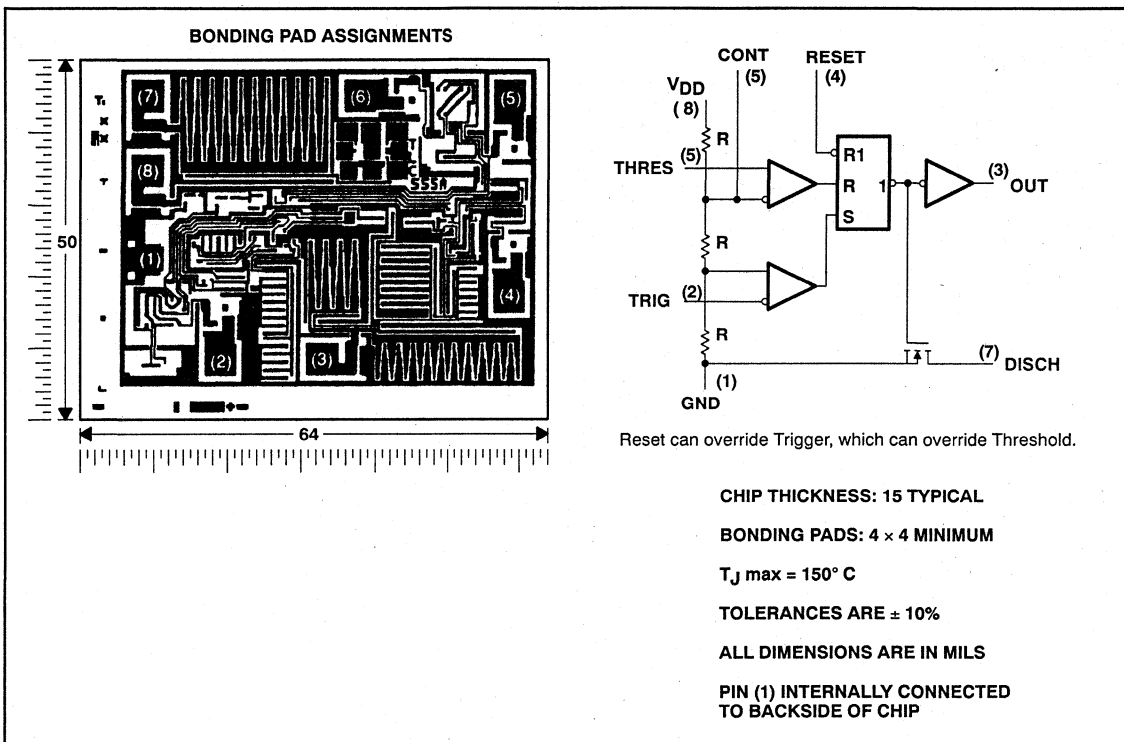
| ACTUAL DEVICE COMPONENT COUNT | COMPONENT COUNT |
|-------------------------------|-----------------|
| Transistors | 39 |
| Resistors | 5 |



TLC555Y LinCMOS™ TIMER

chip information

These chips, properly assembled, display characteristics similar to the TLC555. Thermal compression or ultrasonic bonding may be used on the doped aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.



TLC555C, TLC555I, TLC555M, TLC555V
LinCMOS™ TIMERS

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|---|------------------------------|
| Supply voltage, V_{DD} (see Note 1) | 18 V |
| Input voltage range (any input) | -0.3 to V_{DD} |
| Sink current, discharge or output | 150 mA |
| Source current, output | 15 mA |
| Continuous total power dissipation | See Dissipation Rating Table |
| Operating free-air temperature range, T_A : C-suffix | 0°C to 70°C |
| I-suffix | -40°C to 85°C |
| M-suffix | -55°C to 125°C |
| Storage temperature range | -65°C to 150°C |
| Case temperature for 60 seconds: FK package | 260°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package | 300°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D, DB, P, or PW package | 260°C |

NOTE 1: All voltage values are with respect to network ground terminal.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ POWER RATING | DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$ | $T_A = 70^\circ\text{C}$ POWER RATING | $T_A = 85^\circ\text{C}$ POWER RATING | $T_A = 125^\circ\text{C}$ POWER RATING |
|----------|---|---|--|--|---|
| D | 725 mW | 5.8 mW/°C | 464 mW | 377 mW | N/A |
| DB or PW | 525 mW | 4.2 mW/°C | 336 mW | — | — |
| FK | 1375 mW | 11.0 mW/°C | 880 mW | 715 mW | 275 mW |
| JG | 1050 mW | 8.4 mW/°C | 672 mW | 546 mW | 210 mW |
| P | 1000 mW | 8.0 mW/°C | 640 mW | 520 mW | N/A |

recommended operating conditions

| | | MIN | MAX | UNIT |
|---|---------|-----|-----|------|
| Supply voltage, V_{DD} | | 2 | 15 | V |
| Operating free-air temperature range, T_A | TLC555C | 0 | 70 | °C |
| | TLC555I | -40 | 85 | |
| | TLC555M | -55 | 125 | |

TLC555C, TLC555I LinCMOS™ TIMERS

electrical characteristics at specified free-air temperature, $V_{DD} = 3\text{ V}$ for TLC555I, $V_{DD} = 2\text{ V}$ for TLC555C

| PARAMETER | TEST CONDITIONS | T_A^\dagger | TLC555C | | | TLC555I | | | UNIT |
|--|------------------------------|---------------|---------|------|------|---------|-----|-------|---------------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| V_T Threshold voltage | | 25°C | 0.95 | 1.33 | 1.65 | 1.6 | 2.4 | V | |
| | | Full range | 0.85 | | 1.75 | 1.5 | 2.5 | | |
| I_T Threshold current | | 25°C | 10 | | | 10 | | | pA |
| | | MAX | 75 | | | 150 | | | |
| V_{trigger} Trigger voltage | | 25°C | 0.4 | 0.67 | 0.95 | 0.71 | 1 | 1.29 | V |
| | | Full range | 0.3 | | 1.05 | 0.61 | | 1.39 | |
| I_{trigger} Trigger current | | 25°C | 10 | | | 10 | | | pA |
| | | MAX | 75 | | | 150 | | | |
| V_{reset} Reset voltage | | 25°C | 0.4 | 1.1 | 1.5 | 0.4 | 1.1 | 1.5 | V |
| | | Full range | 0.3 | | 2 | 0.3 | | 1.8 | |
| I_{reset} Reset current | | 25°C | 10 | | | 10 | | | pA |
| | | MAX | 75 | | | 150 | | | |
| Control voltage (open circuit) as a percentage of supply voltage | | MAX | 66.7% | | | 66.7% | | | |
| Discharge switch on-stage voltage | $I_{OL} = 1\text{ mA}$ | 25°C | 0.03 | | 0.2 | 0.03 | | 0.2 | V |
| | | Full range | | | 0.25 | | | 0.375 | |
| Discharge switch off-stage current | | 25°C | 0.1 | | | 0.1 | | | nA |
| | | MAX | 0.5 | | | 120 | | | |
| V_{OH} High-level output voltage | $I_{OH} = -300\ \mu\text{A}$ | 25°C | 1.5 | 1.9 | | 1.5 | 1.9 | | V |
| | | Full range | 1.5 | | | 2.5 | | | |
| V_{OL} Low-level output voltage | $I_{OL} = 1\text{ mA}$ | 25°C | 0.07 | | 0.3 | 0.07 | | 0.3 | V |
| | | Full range | | | 0.35 | | | 0.4 | |
| I_{DD} Supply current | See Note 2 | 25°C | 250 | | | 250 | | | μA |
| | | Full range | 400 | | | 500 | | | |

† Full range is 0°C to 70°C for TLC555C and -40°C to 85°C for TLC555I.

NOTE 2: These values apply for the expected operating configurations in which the THRES terminal is connected directly to the DISCH terminal or to the TRIG terminal.

electrical characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$

| PARAMETER | TEST CONDITIONS | T _A † | TLC555C | | | TLC555I | | | TLC555M | | | UNIT | |
|--|---------------------------|--------------------------|------------|------|------|---------|------|------|---------|------|------|------|---|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | | |
| V _T | Threshold voltage | 25°C | 2.8 | 3.3 | 3.8 | 2.8 | 3.3 | 3.8 | 2.8 | 3.3 | 3.8 | V | |
| | | Full range | 2.7 | | 3.9 | 2.7 | | 3.9 | 2.7 | | 3.9 | | |
| I _T | Threshold current | 25°C | 10 | | | 10 | | | 10 | | | pA | |
| | | MAX | 75 | | | 150 | | | 5000 | | | | |
| V _{trigger} | Trigger voltage | 25°C | 1.36 | 1.66 | 1.96 | 1.36 | 1.66 | 1.96 | 1.36 | 1.66 | 1.96 | V | |
| | | Full range | 1.26 | | 2.06 | 1.26 | | 2.06 | 1.26 | | 2.06 | | |
| I _{trigger} | Trigger current | 25°C | 10 | | | 10 | | | 10 | | | pA | |
| | | MAX | 75 | | | 150 | | | 5000 | | | | |
| V _{reset} | Reset voltage | 25°C | 0.4 | 1.1 | 1.5 | 0.4 | 1.1 | 1.5 | 0.4 | 1.1 | 1.5 | V | |
| | | Full range | 0.3 | | 1.8 | 0.3 | | 1.8 | 0.3 | | 1.8 | | |
| I _{reset} | Reset current | 25°C | 10 | | | 10 | | | 10 | | | pA | |
| | | MAX | 75 | | | 150 | | | 5000 | | | | |
| Control voltage (open circuit) as a percentage of supply voltage | | MAX | 66.7% | | | 66.7% | | | 66.7% | | | | |
| Discharge switch on-state voltage | I _{OL} = 10 mA | 25°C | 0.14 | | 0.5 | 0.14 | | 0.5 | 0.14 | | 0.5 | V | |
| | | Full range | | | 0.6 | | | 0.6 | | | 0.6 | | |
| Discharge switch off-state current | | 25°C | 0.1 | | | 0.1 | | | 0.1 | | | nA | |
| | | MAX | 0.5 | | | 120 | | | 120 | | | | |
| V _{OH} | High-level output voltage | 25°C | 4.1 | 4.8 | | 4.1 | 4.8 | | 4.1 | 4.8 | | V | |
| | | Full range | 4.1 | | | 4.1 | | | 4.1 | | | | |
| V _{OL} | Low-level output voltage | I _{OL} = 8 mA | 25°C | 0.21 | | 0.4 | 0.21 | | 0.4 | 0.21 | | 0.4 | V |
| | | | Full range | | | 0.5 | | | 0.5 | | | 0.6 | |
| | | I _{OL} = 5 mA | 25°C | 0.13 | | 0.3 | 0.13 | | 0.3 | 0.13 | | 0.3 | |
| | | | Full range | | | 0.4 | | | 0.4 | | | 0.45 | |
| | | I _{OH} = 3.2 mA | 25°C | 0.08 | | 0.3 | 0.08 | | 0.3 | 0.08 | | 0.3 | |
| | | | Full range | | | 0.35 | | | 0.35 | | | 0.4 | |
| I _{DD} | Supply current | 25°C | 170 | | 350 | 170 | | 350 | 170 | | 350 | μA | |
| | | Full range | | | 500 | | | 600 | | | 700 | | |

† Full range is 0°C to 70°C for TLC555C, -40°C to 85°C for TLC555I, and -55°C to 125°C for TLC555M.

NOTE 2: These values apply for the expected operating configurations in which the THRES terminal is connected directly to the DISCH terminal or to the TRIG terminal.

TLC555C, TLC555I, TLC555M LinCMOS™ TIMERS

electrical characteristics at specified free-air temperature, $V_{DD} = 15\text{ V}$

| PARAMETER | TEST CONDITIONS | T_A † | TLC555C | | | TLC555I | | | TLC555M | | | UNIT |
|--|--------------------------|------------|---------|------|-------|---------|------|-------|---------|------|-------|---------------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| V_T Threshold voltage | | 25°C | 9.45 | 10 | 10.55 | 9.45 | 10 | 10.55 | 9.45 | 10 | 10.55 | V |
| | | Full range | 9.35 | | 10.65 | 9.35 | | 10.65 | 9.35 | | 10.65 | |
| I_T Threshold current | | 25°C | 10 | | | 10 | | | 10 | | | pA |
| | | MAX | 75 | | | 150 | | | 5000 | | | |
| $V_{trigger}$ Trigger voltage | | 25°C | 4.65 | 5 | 5.35 | 4.65 | 5 | 5.35 | 4.65 | 5 | 5.35 | V |
| | | Full range | 4.55 | | 5.45 | 4.55 | | 5.45 | 4.55 | | 5.45 | |
| $I_{trigger}$ Trigger current | | 25°C | 10 | | | 10 | | | 10 | | | pA |
| | | MAX | 75 | | | 150 | | | 5000 | | | |
| V_{reset} Reset voltage | | 25°C | 0.4 | 1.1 | 1.5 | 0.4 | 1.1 | 1.5 | 0.4 | 1.1 | 1.5 | V |
| | | Full range | 0.3 | | 1.8 | 0.3 | | 1.8 | 0.3 | | 1.8 | |
| I_{reset} Reset current | | 25°C | 10 | | | 10 | | | 10 | | | pA |
| | | MAX | 75 | | | 150 | | | 5000 | | | |
| Control voltage (open circuit) as a percentage of supply voltage | | MAX | 66.7% | | | 66.7% | | | 66.7% | | | |
| Discharge switch on-state voltage | $I_{OL} = 100\text{ mA}$ | 25°C | 0.77 | 1.7 | | 0.77 | 1.7 | | 0.77 | 1.7 | | V |
| | | Full range | | 1.8 | | | 1.8 | | | 1.8 | | |
| Discharge switch off-state current | | 25°C | 0.1 | | | 0.1 | | | 0.1 | | | nA |
| | | MAX | 0.5 | | | 120 | | | 120 | | | |
| V_{OH} High-level output voltage | $I_{OH} = -10\text{ mA}$ | 25°C | 12.5 | 14.2 | | 12.5 | 14.2 | | 12.5 | 14.2 | | V |
| | | Full range | 12.5 | | | 12.5 | | | 12.5 | | | |
| | $I_{OH} = -5\text{ mA}$ | 25°C | 13.5 | 14.6 | | 13.5 | 14.6 | | 13.5 | 14.6 | | |
| | | Full range | 13.5 | | | 13.5 | | | 13.5 | | | |
| | $I_{OH} = -1\text{ mA}$ | 25°C | 14.2 | 14.9 | | 14.2 | 14.9 | | 14.2 | 14.9 | | |
| | | Full range | 14.2 | | | 14.2 | | | 14.2 | | | |
| V_{OL} Low-level output voltage | $I_{OL} = 100\text{ mA}$ | 25°C | 1.28 | 3.2 | | 1.28 | 3.2 | | 1.28 | 3.2 | | V |
| | | Full range | | 3.6 | | | 3.7 | | | 3.8 | | |
| | $I_{OL} = 50\text{ mA}$ | 25°C | 0.63 | 1 | | 0.63 | 1 | | 0.63 | 1 | | |
| | | Full range | | 1.3 | | | 1.4 | | | 1.5 | | |
| | $I_{OL} = 10\text{ mA}$ | 25°C | 0.12 | 0.3 | | 0.12 | 0.3 | | 0.12 | 0.3 | | |
| | | Full range | | 0.4 | | | 0.4 | | | 0.45 | | |
| I_{DD} Supply current | See Note 2 | 25°C | 360 | 600 | | 360 | 600 | | 360 | 600 | | μA |
| | | Full range | | 800 | | | 900 | | | 1000 | | |

† Full range is 0°C to 70°C for TLC555C, -40°C to 85°C for TLC555I, and -55°C to 125°C for TLC555M.

NOTE 2 These values apply for the expected operating configurations in which the THRES terminal is connected directly to the DISCH terminal or to the TRIG terminal.

operating characteristics, $V_{DD} = 5\text{ V}$, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|--|-----|-----|-----|------|
| Initial error of timing interval‡ | $V_{DD} = 5\text{ V to }15\text{ V}$, $R_A = R_B = 1\text{ k}\Omega$ to $100\text{ k}\Omega$, $C_T = 0.1\text{ }\mu\text{F}$, See Note 3 | | 1% | 3% | |
| Supply voltage sensitivity of timing interval | | | | | |
| t_r Output pulse rise time | $R_L = 10\text{ M}\Omega$, $C_L = 10\text{ pF}$ | | 20 | 75 | ns |
| t_f Output pulse fall time | | | 15 | 60 | |
| f_{max} Maximum frequency in astable mode | $R_A = 470\text{ }\Omega$, $R_B = 200\text{ }\Omega$, $C_T = 200\text{ pF}$, See Note 3 | 1.2 | 2.1 | | MHz |

‡ Timing interval error is defined as the difference between the measured value and the average value of a random sample from each process run.

NOTE 3: R_A , R_B , and C_T are as defined in Figure 1.

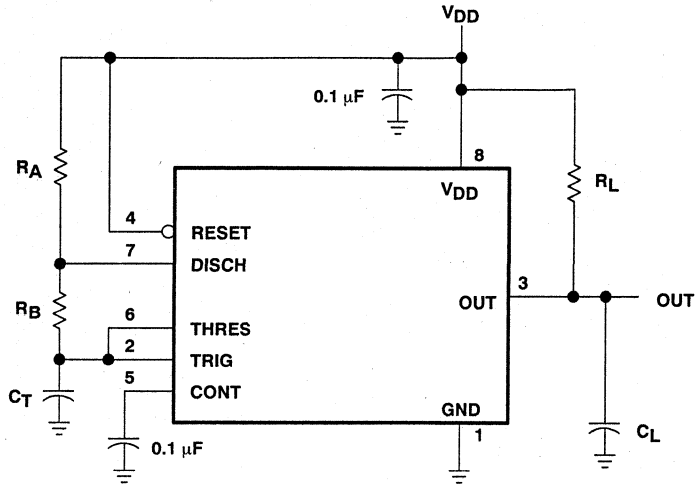


electrical characteristics at $V_{DD} = 5\text{ V}$, $T_A = 25^\circ\text{C}$

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|----------------------|--|--------------------------|------|-------|------|---------------|
| V_T | Threshold voltage | | 2.8 | 3.3 | 3.8 | V |
| I_T | Threshold current | | | 10 | | pA |
| V_{trigger} | Trigger voltage | | 1.36 | 1.66 | 1.96 | V |
| I_{trigger} | Trigger current | | | 10 | | pA |
| V_{reset} | Reset voltage | | 0.4 | 1.1 | 1.5 | V |
| I_{reset} | Reset current | | | 10 | | pA |
| | Control voltage (open circuit) as a percentage of supply voltage | | | 66.7% | | |
| | Discharge switch on-state voltage | $I_{OL} = 10\text{ mA}$ | | 0.14 | 0.5 | V |
| | Discharge switch off-state current | | | 0.1 | | nA |
| V_{OH} | High-level output voltage | $I_{OH} = -1\text{ mA}$ | 4.1 | 4.8 | | V |
| V_{OL} | Low-level output voltage | $I_{OL} = 8\text{ mA}$ | | 0.21 | 0.4 | V |
| | | $I_{OL} = 5\text{ mA}$ | | 0.13 | 0.3 | |
| | | $I_{OL} = 3.2\text{ mA}$ | - | 0.08 | 0.3 | |
| I_{DD} | Supply current | See Note 2 | | 170 | 350 | μA |

NOTE 2: These values apply for the expected operating configurations in which the THRES terminal is connected directly to the DISCH terminal or to the TRIG terminal.

APPLICATION INFORMATION



Pin numbers are for all packages except FK.

Figure 1. Circuit for Astable Operation

TLC556C, TLC556I, TLC556M, TLC556Y DUAL LinCMOS™ TIMERS

D2796, FEBRUARY 1984 –REVISED FEBRUARY 1992

- **Very Low Power Consumption . . . 2 mW**
Typ at $V_{DD} = 5\text{ V}$
- **Capable of Operation in Astable Mode**
- **CMOS Output Capable of Swinging Rail to Rail**
- **High Output-Current Capability**
Sink 100 mA Typ
Source 10 mA Typ
- **Output Fully Compatible With CMOS, TTL, and MOS**
- **Low Supply Current Reduces Spikes During Output Transitions**
- **Single-Supply Operation From 2 V to 15 V**
- **Functionally interchangeable With the NE556; Has Same Pinout**

description

The TLC556 series are monolithic timing circuits fabricated using the TI LinCMOS™ process, which provides full compatibility with CMOS, TTL, and MOS logic and operates at frequencies up to 2 MHz. Accurate time delays and oscillations are possible with smaller, less-expensive timing capacitors than the NE556 because of the high input impedance. Power consumption is low across the full range of power supply voltages.

Like the NE556, the TLC556 has a trigger level approximately one-third of the supply voltage and a threshold level approximately two-thirds of the supply voltage. These levels can be altered by use of the control voltage terminal. When the trigger input falls below the trigger level, the flip-flop is set and the output goes high. If the trigger input is above the trigger level and the threshold input is above the threshold level, the flip-flop is reset and the output is low. The reset input can override all other inputs and can be used to initiate a new timing cycle. If the reset input is low, the flip-flop is reset and the output is low. Whenever the output is low, a low-impedance path is provided between the discharge terminal and ground.

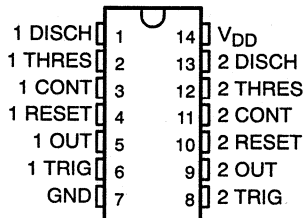
While the CMOS output is capable of sinking over 100 mA and sourcing over 10 mA, the TLC556 exhibits greatly reduced supply-current spikes during output transitions. This minimizes the need for the large decoupling capacitors required by the NE556.

These devices have internal electrostatic-discharge (ESD) protection circuits that prevent catastrophic failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015. However, care should be exercised in handling these devices, as exposure to ESD may result in degradation of the device parametric performance.

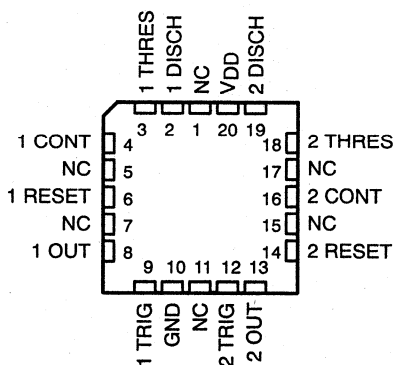
All unused inputs should be tied to an appropriate logic level to prevent false triggering.

The TLC556C is characterized for operation from 0°C to 70°C. The TLC556I is characterized for operation from -40°C to 85°C. The TLC556M is characterized for operation over the full military temperature range of -55°C to 125°C.

D, J, OR N PACKAGE
(TOP VIEW)



FK PACKAGE
(TOP VIEW)



NC—No internal connection

LinCMOS is a trademark of Texas Instruments Incorporated.

PRODUCTION DATA Information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.



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TLC556C, TLC556I, TLC556M, TLC556Y DUAL LinCMOS™ TIMERS

AVAILABLE OPTIONS

| TA RANGE | VDD RANGE | PACKAGE | | | | CHIP FORM (Y) |
|----------------|-------------|-------------------|-------------------|-----------------|-----------------|---------------|
| | | SMALL OUTLINE (D) | CHIP CARRIER (FK) | CERAMIC DIP (J) | PLASTIC DIP (N) | |
| 0°C to 70°C | 2 V to 18 V | TLC556CD | | | TLC556CN | TLC556Y |
| -40°C to 85°C | 3 V to 18 V | TLC556ID | | | TLC556IN | |
| -55°C to 125°C | 5 V to 18 V | TLC556MD | TLC556MFK | TLC556MJ | TLC556MN | |

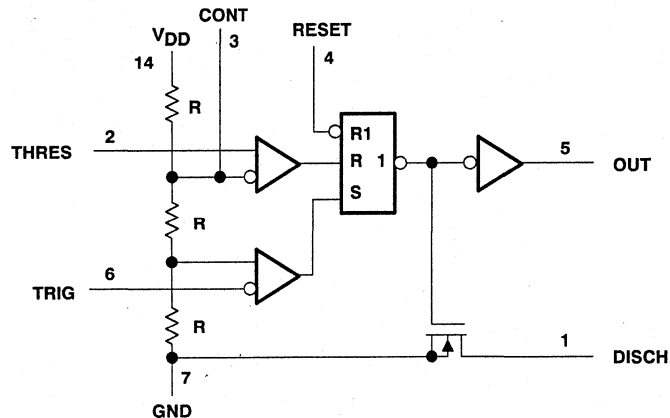
The D package is available taped and reeled. Add the suffix R to the device type (e.g., TLC556CDR).

FUNCTION TABLE

| RESET VOLTAGE† | TRIGGER VOLTAGE† | THRESHOLD VOLTAGE† | OUTPUT | DISCHARGE SWITCH |
|----------------|------------------|--------------------|---------------------------|------------------|
| < MIN | Irrelevant | Irrelevant | L | On |
| > MAX | < MIN | Irrelevant | H | Off |
| >MAX | >MAX | >MAX | L | On |
| > MAX | > MAX | < MIN | As previously established | |

† For conditions shown as MIN or MAX, use the appropriate value specified under electrical characteristics.

functional block diagram (each timer)



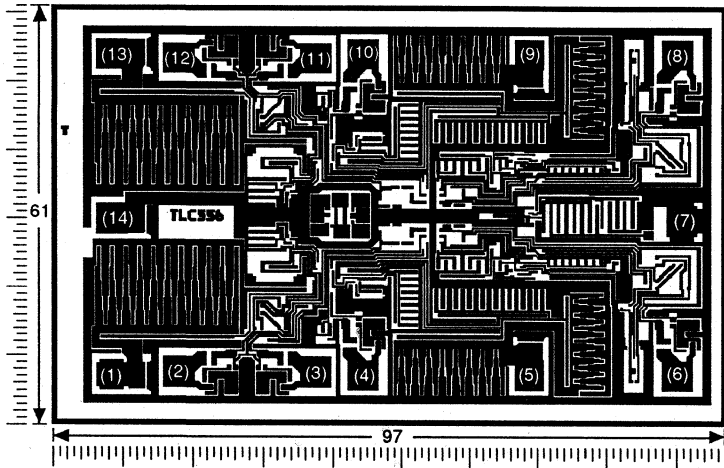
RESET can override TRIG and THRES.
TRIG can override THRES.

Pin numbers shown are for the D, J, or N packages.

chip information

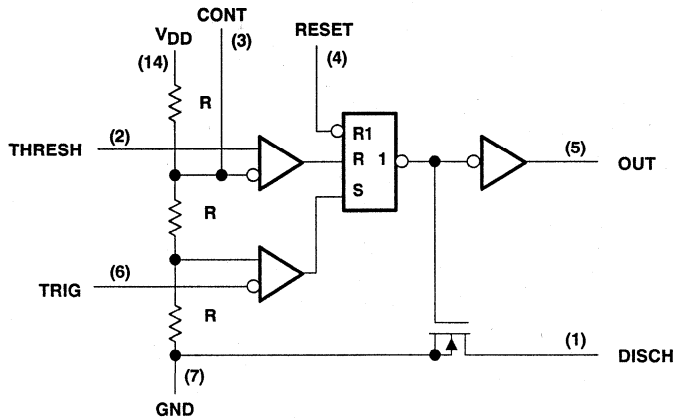
These chips, properly assembled, display characteristics similar to the TLC556 (see electrical table). Thermal compression or ultrasonic bonding may be used on the doped aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.

BONDING PAD ASSIGNMENTS



CHIP THICKNESS: 15 TYPICAL
 BONDING PADS: 4 x 4 MINIMUM
 $T_J \text{ max} = 150^\circ\text{C}$
 TOLERANCES ARE $\pm 10\%$
 ALL DIMENSIONS ARE IN MILS
 NO BACKSIDE METALLIZATION
 PIN (7) INTERNALLY CONNECTED
 TO BACKSIDE OF CHIP

FUNCTIONAL BLOCK DIAGRAM (EACH TIMER)



TLC556C, TLC556I, TLC556M

DUAL LinCMOS™ TIMERS

absolute maximum ratings over operating free-air temperature (unless otherwise noted)

| | TLC556C | TLC556I | TLC556M | UNIT |
|--|------------------------------|------------------|------------------|------|
| Supply voltage, V_{DD} (see Note 1) | 18 | 18 | 18 | V |
| Input voltage range, V_I | -0.3 to V_{DD} | -0.3 to V_{DD} | -0.3 to V_{DD} | V |
| Sink current, discharge or output | 150 | 150 | 150 | mA |
| Source current, output | 15 | 15 | 15 | mA |
| Continuous total power dissipation | See Dissipation Rating Table | | | |
| Operating free-air temperature range | 0 to 70 | -40 to 85 | -55 to 125 | °C |
| Storage temperature range | -65 to 150 | -65 to 150 | -65 to 150 | °C |
| Case temperature for 60 seconds | FK package | | 260 | °C |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds | J package | | 300 | |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | D or N package | 260 | 260 | |

NOTE 1: All voltage values are with respect to network ground terminal.

DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$ | DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$ | $T_A = 70^\circ\text{C}$ | $T_A = 85^\circ\text{C}$ | $T_A = 125^\circ\text{C}$ |
|---------|-----------------------------|---|--------------------------|--------------------------|---------------------------|
| | POWER RATING | | POWER RATING | POWER RATING | POWER RATING |
| D | 950 mW | 7.6 mW/°C | 608 mW | 494 mW | N/A |
| FK | 1375 mW | 11.0 mW/°C | 880 mW | 715 mW | 275 mW |
| J | 1375 mW | 11.0 mW/°C | 880 mW | 715 mW | 275 mW |
| N | 1150 mW | 9.2 mW/°C | 736 mW | 598 mW | N/A |

recommended operating conditions

| | | MIN | MAX | UNIT |
|---|---------|-----|-----|------|
| Supply voltage, V_{DD} | | 2 | 15 | V |
| Operating free-air temperature range, T_A | TLC556C | 0 | 70 | °C |
| | TLC556I | -40 | 85 | |
| | TLC556M | -55 | 125 | |

TLC556C, TLC556I
DUAL LinCMOS™ TIMERS

electrical characteristics at specified free-air temperature, $V_{DD} = 2\text{ V}$ for TLC556C, $V_{DD} = 3\text{ V}$ for TLC556I

| PARAMETER | TEST CONDITIONS | T_A^\dagger | TLC556C | | | TLC556I | | | UNIT |
|--|------------------------------------|---------------|---------|------|------|---------|-----|-------|---------------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| V_T Threshold voltage | | 25°C | 0.95 | 1.33 | 1.65 | 1.6 | 2 | 2.4 | V |
| | | Full range | 0.85 | | 1.75 | 1.5 | | 2.5 | |
| I_T Threshold current | | 25°C | 10 | | | 10 | | | pA |
| | | MAX | 75 | | | 150 | | | |
| $V_{trigger}$ Trigger voltage | | 25°C | 0.4 | 0.67 | 0.95 | 0.71 | 1 | 1.29 | V |
| | | Full range | 0.3 | | 1.05 | 0.61 | | 1.39 | |
| $I_{trigger}$ Trigger current | | 25°C | 10 | | | 10 | | | pA |
| | | MAX | 75 | | | 150 | | | |
| V_{reset} Reset voltage | | 25°C | 0.4 | 1.1 | 1.5 | 0.4 | 1.1 | 1.5 | V |
| | | Full range | 0.3 | | 1.8 | 0.3 | | 1.8 | |
| I_{reset} Reset current | | 25°C | 10 | | | 10 | | | pA |
| | | MAX | 75 | | | 150 | | | |
| Control voltage (open circuit) as a percentage of supply voltage | | MAX | 66.7% | | | 66.7% | | | |
| Discharge switch on-state voltage | $I_{OL} = 1\text{ mA}$ | 25°C | 0.04 | 0.2 | | 0.03 | 0.2 | | V |
| | | Full range | | | 0.25 | | | 0.375 | |
| Discharge switch off-state current | | 25°C | 0.1 | | | 0.1 | | | nA |
| | | MAX | 0.5 | | | 120 | | | |
| V_{OH} High-level output voltage | $I_{OH} = -300\text{ }\mu\text{A}$ | 25°C | 1.5 | 1.9 | | 1.5 | 1.9 | | V |
| | | Full range | 1.5 | | | 2.5 | | | |
| V_{OL} Low-level output voltage | $I_{OL} = 1\text{ mA}$ | 25°C | 0.07 | 0.3 | | 0.07 | 0.3 | | V |
| | | Full range | | | 0.35 | | | 0.4 | |
| I_{DD} Supply current | See Note 2 | 25°C | 130 | 500 | | 130 | 500 | | μA |
| | | Full range | | | 800 | | | 1000 | |

† Full range is 0°C to 70°C for TLC556C and -40°C to 85°C for TLC556I.

NOTE 2: These values apply for the expected operating configurations in which THRES is connected directly to DISCH or TRIG.

TLC556C, TLC556I, TLC556M DUAL LinCMOS™ TIMERS

electrical characteristics at specified free-air temperature, $V_{DD} = 5\text{ V}$

| PARAMETER | TEST CONDITIONS | T_A^\dagger | TLC556C | | | TLC556I | | | TLC556M | | | UNIT |
|--|--------------------------|---------------|---------|------|------|---------|------|------|---------|------|------|---------------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| V_T Threshold voltage | | 25°C | 2.8 | 3.3 | 3.8 | 2.8 | 3.3 | 3.8 | 2.8 | 3.3 | 3.8 | V |
| | | Full range | 2.7 | | 3.9 | 2.7 | | 3.9 | 2.7 | | 3.9 | |
| I_T Threshold current | | 25°C | 10 | | | 10 | | | 10 | | | pA |
| | | MAX | 75 | | | 150 | | | 5000 | | | |
| $V_{trigger}$ Trigger voltage | | 25°C | 1.36 | 1.66 | 1.96 | 1.36 | 1.66 | 1.96 | 1.36 | 1.66 | 1.96 | V |
| | | Full range | 1.26 | | 2.06 | 1.26 | | 2.06 | 1.26 | | 2.06 | |
| $I_{trigger}$ Trigger current | | 25°C | 10 | | | 10 | | | 10 | | | pA |
| | | MAX | 75 | | | 150 | | | 5000 | | | |
| V_{reset} Reset voltage | | 25°C | 0.4 | 1.1 | 1.5 | 0.4 | 1.1 | 1.5 | 0.4 | 1.1 | 1.5 | V |
| | | Full range | 0.3 | | 1.8 | 0.3 | | 1.8 | 0.3 | | 1.8 | |
| I_{reset} Reset current | | 25°C | 10 | | | 10 | | | 10 | | | pA |
| | | MAX | 75 | | | 150 | | | 5000 | | | |
| Control voltage (open circuit) as a percentage of supply voltage | | MAX | 66.7% | | | 66.7% | | | 66.7% | | | |
| Discharge switch on-state voltage | $I_{OL} = 10\text{ mA}$ | 25°C | 0.15 | | 0.5 | 0.15 | | 0.5 | 0.15 | | 0.5 | V |
| | | Full range | | | 0.6 | | | 0.6 | | | 0.6 | |
| Discharge switch off-state current | | 25°C | 0.1 | | | 0.1 | | | 0.1 | | | nA |
| | | MAX | 0.5 | | | 2 | | | 120 | | | |
| V_{OH} High-level output voltage | $I_{OH} = -1\text{ mA}$ | 25°C | 4.1 | 4.8 | | 4.1 | 4.8 | | 4.1 | 4.8 | | V |
| | | Full range | 4.1 | | | 4.1 | | | 4.1 | | | |
| V_{OL} Low-level output voltage | $I_{OL} = 8\text{ mA}$ | 25°C | 0.21 | | 0.4 | 0.21 | | 0.4 | 0.21 | | 0.4 | V |
| | | Full range | | | 0.5 | | | 0.5 | | | 0.6 | |
| | $I_{OL} = 5\text{ mA}$ | 25°C | 0.13 | | 0.3 | 0.13 | | 0.3 | 0.13 | | 0.3 | |
| | | Full range | | | 0.4 | | | 0.4 | | | 0.45 | |
| | $I_{OL} = 3.2\text{ mA}$ | 25°C | 0.08 | | 0.3 | 0.08 | | 0.3 | 0.08 | | 0.3 | |
| | | Full range | | | 0.35 | | | 0.35 | | | 0.4 | |
| I_{DD} Supply current | See Note 2 | 25°C | 340 | | 700 | 340 | | 700 | 340 | | 700 | μA |
| | | Full range | | | 1000 | | | 1200 | | | 1400 | |

† Full range is 0°C to 70°C for TLC556C, -40°C to 85°C for TLC556I, and -55°C to 125°C for TLC556M.

NOTE 2: These values apply for the expected operating configurations in which THRES is connected directly to DISCH or to TRIG.

electrical characteristics at specified free-air temperature, $V_{DD} = 15\text{ V}$

| PARAMETER | TEST CONDITIONS | T_A † | TLC556C | | | TLC556I | | | TLC556M | | | UNIT |
|--|--------------------------|------------|---------|------|-------|---------|------|-------|---------|------|-------|------|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | MIN | TYP | MAX | |
| V_T Threshold voltage | | 25°C | 9.45 | 10 | 10.55 | 9.45 | 10 | 10.55 | 9.45 | 10 | 10.55 | V |
| | | Full range | 9.35 | | 10.65 | 9.35 | | 10.65 | 9.35 | | 10.65 | |
| I_T Threshold current | | 25°C | | 10 | | | 10 | | | 10 | | pA |
| | | MAX | | 75 | | | 150 | | | 5000 | | |
| $V_{trigger}$ Trigger voltage | | 25°C | 4.65 | 5 | 5.35 | 4.65 | 5 | 5.35 | 4.65 | 5 | 5.35 | V |
| | | Full range | 4.55 | | 5.45 | 4.55 | | 5.45 | 4.55 | | 5.45 | |
| $I_{trigger}$ Trigger current | | 25°C | | 10 | | | 10 | | | 10 | | pA |
| | | MAX | | 75 | | | 150 | | | 5000 | | |
| V_{reset} Reset voltage | | 25°C | 0.4 | 1.1 | 1.5 | 0.4 | 1.1 | 1.5 | 0.4 | 1.1 | 1.5 | V |
| | | Full range | 0.3 | | 1.8 | 0.3 | | 1.8 | 0.3 | | 1.8 | |
| I_{reset} Reset current | | 25°C | | 10 | | | 10 | | | 10 | | pA |
| | | MAX | | 75 | | | 150 | | | 5000 | | |
| Control voltage (open circuit) as a percentage of supply voltage | | MAX | 66.7% | | | 66.7% | | | 66.7% | | | |
| Discharge switch on-state voltage | $I_{OL} = 100\text{ mA}$ | 25°C | | 0.8 | 1.7 | | 0.8 | 1.7 | | 0.8 | 1.7 | V |
| | | Full range | | | 1.8 | | | 1.8 | | | 1.8 | |
| Discharge switch off-state current | | 25°C | | 0.1 | | | 0.1 | | | 0.1 | | nA |
| | | MAX | | 0.5 | | | 2 | | | 120 | | |
| V_{OH} High-level output voltage | $I_{OH} = -10\text{ mA}$ | 25°C | 12.5 | 14.2 | | 12.5 | 14.2 | | 12.5 | 14.2 | | V |
| | | Full range | 12.5 | | | 12.5 | | | 12.5 | | | |
| | $I_{OH} = -5\text{ mA}$ | 25°C | 13.5 | 14.6 | | 13.5 | 14.6 | | 13.5 | 14.6 | | |
| | | Full range | 13.5 | | | 13.5 | | | 13.5 | | | |
| $I_{OH} = -1\text{ mA}$ | 25°C | 14.2 | 14.9 | | 14.2 | 14.9 | | 14.2 | 14.9 | | | |
| | Full range | 14.2 | | | 14.2 | | | 14.2 | | | | |
| V_{OL} Low-level output voltage | $I_{OL} = 100\text{ mA}$ | 25°C | | 1.28 | 3.2 | | 1.28 | 3.2 | | 1.28 | 3.2 | V |
| | | Full range | | | 3.6 | | | 3.7 | | | 3.8 | |
| | $I_{OL} = 50\text{ mA}$ | 25°C | | 0.63 | 1 | | 0.63 | 1 | | 0.63 | 1 | |
| | | Full range | | | 1.3 | | | 1.4 | | | 1.5 | |
| | $I_{OL} = 10\text{ mA}$ | 25°C | | 0.12 | 0.3 | | 0.12 | 0.3 | | 0.12 | 0.3 | |
| | | Full range | | | 0.4 | | | 0.4 | | | 0.45 | |
| I_{DD} Supply current | See Note 2 | 25°C | | 0.72 | 1.2 | | 0.72 | 1.2 | | 0.72 | 1.2 | mA |
| | | Full range | | | 1.6 | | | 1.8 | | | 2 | |

† Full range is 0°C to 70°C for TLC556C, -40°C to 85°C for TLC556I, and -55°C to 125°C for TLC556M.

NOTE 2: These values apply for the expected operating configurations in which THRES is connected directly to DISCH or TRIG.

TLC556Y
DUAL LinCMOS™ TIMER

electrical characteristics, $V_{DD} = 5\text{ V}$, $T_A = 25^\circ\text{C}$

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|----------------------|------------------------------------|--------------------------|------|------|------|---------------|
| V_T | Threshold voltage | | 2.8 | 3.3 | 3.8 | V |
| I_T | Threshold current | | | 10 | | pA |
| V_{trigger} | Trigger voltage | | 1.36 | 1.66 | 1.96 | V |
| I_{trigger} | Trigger current | | | 10 | | pA |
| V_{reset} | Reset voltage | | 0.4 | 1.1 | 1.5 | V |
| I_{reset} | Reset current | | | 10 | | pA |
| | Discharge switch on-state voltage | $I_{OL} = 10\text{ mA}$ | | 0.15 | 0.5 | V |
| | Discharge switch off-state current | | | 0.1 | | nA |
| V_{OH} | High-level output voltage | $I_{OH} = -1\text{ mA}$ | 4.1 | 4.8 | | V |
| V_{OL} | Low-level output voltage | $I_{OL} = 8\text{ mA}$ | | 0.21 | 0.4 | V |
| | | $I_{OL} = 5\text{ mA}$ | | 0.13 | 0.3 | |
| | | $I_{OL} = 2.1\text{ mA}$ | | 0.08 | 0.3 | |
| I_{DD} | Supply current | See Note 2 | | 3.40 | 700 | μA |

NOTE 2: These values apply for the expected operating configurations in which THRES is connected directly to DISCH or TRIG.



operating characteristics, $V_{DD} = 5\text{ V}$, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|-----|-----|-----|------|
| Initial error of timing interval † | $V_{DD} = 5\text{ V to }15\text{ V}$, $R_A = R_B = 1\text{ k}\Omega\text{ to }100\text{ k}\Omega$ | | 1% | 3% | |
| Supply voltage sensitivity of timing interval | $C_T = 0.1\text{ }\mu\text{F}$, See Note 3 | | 0.1 | 0.5 | %/V |
| t_r Output pulse rise time | $R_L = 10\text{ M}\Omega$, $C_L = 10\text{ pF}$ | | 20 | 75 | ns |
| t_f Output pulse fall time | | | 15 | 60 | |
| f_{max} Maximum frequency in astable mode | $R_A = 470\text{ }\Omega$, $C_T = 200\text{ pF}$, $R_B = 200\text{ }\Omega$, See Note 3 | 1.2 | 2.1 | | MHz |

† Timing interval error is defined as the difference between the measured value and the average value of a random sample from each process run.
NOTE 3: R_A , R_B , and C_T are as defined in Figure 3.

TYPICAL CHARACTERISTICS

DISCHARGE SWITCH ON-STATE RESISTANCE
vs
FREE-AIR TEMPERATURE

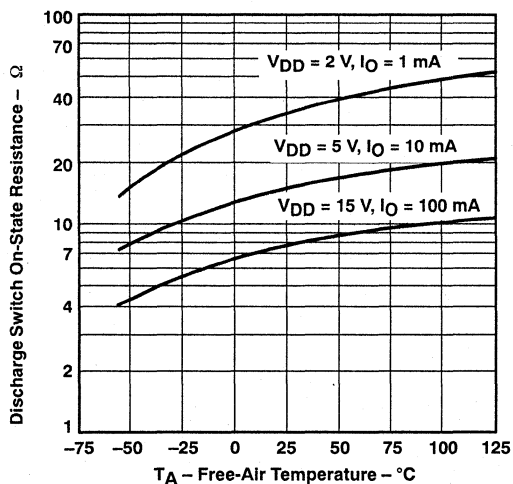
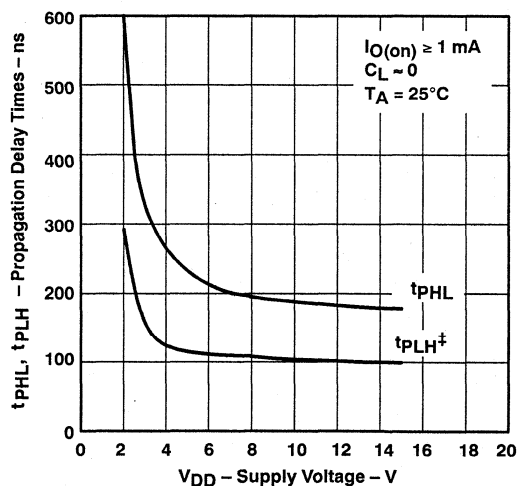


Figure 1

PROPAGATION DELAY TIMES
TO DISCHARGE OUTPUT
FROM TRIGGER AND THRESHOLD
SHORTED TOGETHER
vs
SUPPLY VOLTAGE



‡ The effects of the load resistance on these values must be taken into account separately.

Figure 2

APPLICATION INFORMATION

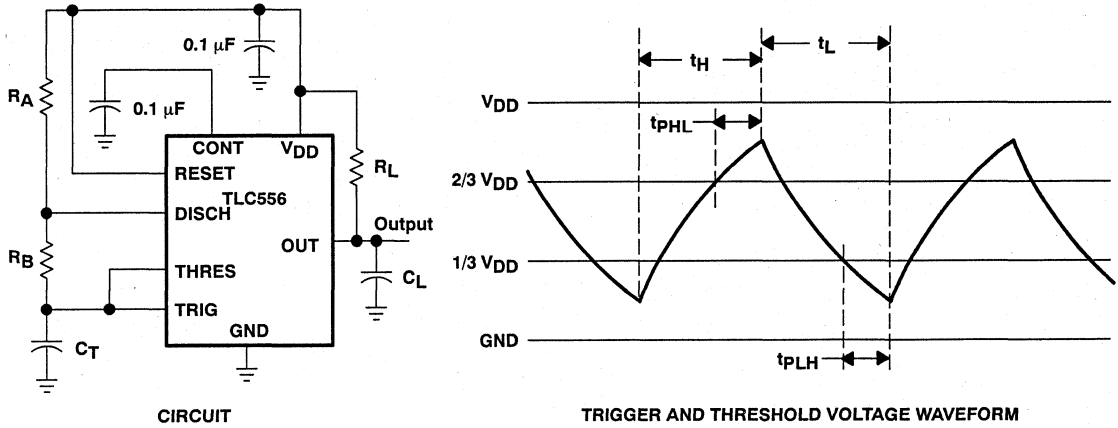


Figure 3. Astable Operation

Connecting the trigger input to the threshold input, as shown in Figure 3, causes the timer to run as a multivibrator. The capacitor C_T charges through R_A and R_B to the trigger voltage level (approximately $0.67 V_{DD}$) and then discharges through R_B only to the value of the threshold voltage level (approximately $0.33 V_{DD}$). The output is high during the charging cycle (t_H) and low during the discharge cycle (t_L). The duty cycle is controlled by the values of R_A , and R_B , and C_T , as shown in the equations below.

$$t_H \approx C_T (R_A + R_B) \ln 2 \quad (\ln 2 = 0.693)$$

$$t_L \approx C_T R_B \ln 2$$

$$\text{Period} = t_H + t_L \approx C_T (R_A + 2R_B) \ln 2$$

$$\text{Output driver duty cycle} = \frac{t_L}{t_H + t_L} \approx 1 - \frac{R_B}{R_A + 2R_B}$$

$$\text{Output waveform duty cycle} = \frac{t_H}{t_H + t_L} \approx \frac{R_B}{R_A + 2R_B}$$

The $0.1\text{-}\mu\text{F}$ capacitor at CONT in Figure 3 decreases the period by about 10%.

The formulas shown above do not allow for any propagation delay from the trigger and threshold inputs to the discharge output. These delay times add directly to the period and create differences between calculated and actual values that increase with frequency. In addition, the discharge output resistance r_{on} adds to R_B to provide another source of error in the calculation when R_B is very low or r_{on} is very high.

The equations below provide better agreement with measured values.

$$t_H = C_T (R_A + R_B) \ln \left[3 - \exp \left(\frac{-t_{PLH}}{C_T (R_B + r_{on})} \right) \right] + t_{PHL}$$

$$t_L = C_T (R_B + r_{on}) \ln \left[3 - \exp \left(\frac{-t_{PHL}}{C_T (R_A + R_B)} \right) \right] + t_{PLH}$$

APPLICATION INFORMATION

The preceding equations and those given earlier are similar in that a time constant is multiplied by the logarithm of a number or function. The limit values of the logarithmic terms must be between $\ln 2$ at low frequencies and $\ln 3$ at extremely high frequencies. For a duty cycle close to 50%, an appropriate constant for the logarithmic

terms can be substituted with good results. Duty cycles less than 50% $\frac{t_H}{t_H + t_L}$ will require that $\frac{t_H}{t_L} < 1$ and possibly $R_A \leq r_{ON}$. These conditions can be difficult to obtain.

In monostable applications, the trip point of the trigger input can be set by a voltage applied to CONT. An input voltage between 10% and 80% of the supply voltage from a resistor divider with at least 500- μ A bias provides good results.

μA733M, μA733C DIFFERENTIAL VIDEO AMPLIFIERS

D922, NOVEMBER 1970—REVISED APRIL 1988

- 200-MHz Bandwidth
- 250-kΩ Input Resistance
- Selectable Nominal Amplification of 10, 100, or 400
- No Frequency Compensation Required
- Designed to be Interchangeable with Fairchild μA733M and μA733C

description

The μA733 is a monolithic two-stage video amplifier with differential inputs and differential outputs.

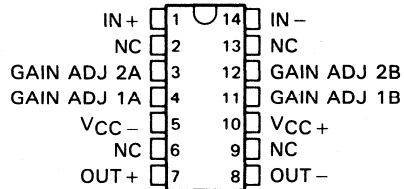
Internal series-shunt feedback provides wide bandwidth, low phase distortion, and excellent gain stability. Emitter-follower outputs enable the device to drive capacitive loads and all stages are current-source biased to obtain high common-mode and supply-voltage rejection ratios.

Fixed differential amplification of 10, 100, or 400 may be selected without external components, or amplification may be adjusted from 10 to 400 by the use of a single external resistor connected between 1A and 1B. No external frequency-compensating components are required for any gain option.

The device is particularly useful in magnetic-tape or disc-file systems using phase or NRZ encoding and in high-speed thin-film or plated-wire memories. Other applications include general purpose video and pulse amplifiers where wide bandwidth, low phase shift, and excellent gain stability are required.

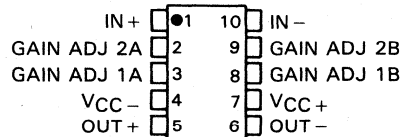
The μA733M is characterized for operation over the full military temperature range of -55°C to 125°C ; the μA733C is characterized for operation from 0°C to 70°C .

μA733M . . . J DUAL-IN-LINE PACKAGE
μA733C . . . D OR N PACKAGE
(TOP VIEW)

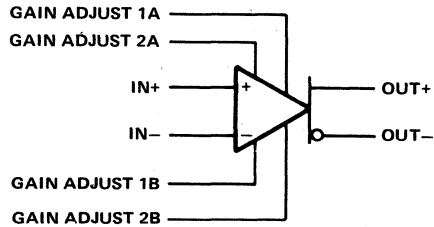


NC—No internal connection

UA733M . . . U FLAT PACKAGE
(TOP VIEW)



symbol



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | μA733M | UA733C | UNIT |
|--|------------------------------|------------|--------------------|
| Supply voltage V_{CC+} (See Note 1) | 8 | 8 | V |
| Supply voltage V_{CC-} (See Note 1) | -8 | -8 | V |
| Differential input voltage | ± 5 | ± 5 | V |
| Common-mode input voltage | ± 6 | ± 6 | V |
| Output current | 10 | 10 | mA |
| Continuous total power dissipation | See Dissipation Rating Table | | |
| Operating free-air temperature range | -55 to 125 | 0 to 70 | $^{\circ}\text{C}$ |
| Storage temperature range | -65 to 150 | -65 to 150 | $^{\circ}\text{C}$ |
| Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds | J or U package | 300 | $^{\circ}\text{C}$ |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | D or N package | 260 | $^{\circ}\text{C}$ |

NOTE 1. All voltage values, except differential input voltages, are with respect to the midpoint between V_{CC+} and V_{CC-} .

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uA733M, uA733C DIFFERENTIAL VIDEO AMPLIFIERS

DISSIPATION RATING TABLE

| PACKAGE | T _A ≤ 25°C POWER RATING | DERATING FACTOR | DERATE ABOVE T _A | T _A = 70°C POWER RATING | T _A = 125°C POWER RATING |
|------------|---------------------------------------|--------------------|--------------------------------|---------------------------------------|--|
| D | 500 mW | N/A | N/A | 500 mW | N/A |
| J (uA733M) | 500 mW | 11.0 mW/°C | 104°C | 500 mW | 275 mW |
| N | 500 mW | N/A | N/A | 500 mW | N/A |
| U | 500 mW | 5.4 mW/°C | 57°C | 432 mW | 135 mW |

electrical characteristics, V_{CC+} = 6 V, V_{CC-} = -6 V, T_A = 25°C

| PARAMETER | TEST FIGURE | TEST CONDITIONS | GAIN OPTION† | uA733M | | | uA733C | | | UNIT |
|------------------------|--|--|-----------------|--------|-----|-----|--------|-----|-----|------|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| A _{VD} | Large-signal differential voltage amplification | V _{OD} = 1 V | 1 | 300 | 400 | 500 | 250 | 400 | 600 | V/V |
| | | | 2 | 90 | 100 | 110 | 80 | 100 | 120 | |
| | | | 3 | 9 | 10 | 11 | 8 | 10 | 12 | |
| BW | Bandwidth | R _S = 50 Ω | 1 | 50 | | | 50 | | | MHz |
| | | | 2 | 90 | | | 90 | | | |
| | | | 3 | 200 | | | 200 | | | |
| I _{IO} | Input offset current | | Any | 0.4 | | | 0.4 | | | μA |
| I _{IB} | Input bias current | | Any | 9 | | | 9 | | | μA |
| V _{ICR} | Common-mode input voltage range | | Any | ±1 | | | ±1 | | | V |
| V _{OC} | Common-mode output voltage | | Any | 2.4 | 2.9 | 3.4 | 2.4 | 2.9 | 3.4 | V |
| V _{OO} | Output offset voltage | | 1 | 0.6 | | | 0.6 | | | V |
| | | | 2 & 3 | 0.35 | | | 0.35 | | | |
| V _{OPP} | Maximum peak-to-peak output voltage swing | | Any | 3 | 4.7 | | 3 | 4.7 | | V |
| r _i | Input resistance | V _{OD} ≤ 1 V | 1 | 4 | | | 4 | | | kΩ |
| | | | 2 | 20 | 24 | | 10 | 24 | | |
| | | | 3 | 250 | | | 250 | | | |
| r _o | Output resistance | | | 20 | | | 20 | | | Ω |
| C _i | Input capacitance | V _{OD} ≤ 1 V | 2 | 2 | | | 2 | | | pF |
| CMRR | Common-mode rejection ratio | V _{IC} = ±1 V, f ≤ 100 kHz | 2 | 60 | 86 | | 60 | 86 | | dB |
| | | V _{IC} = ±1 V, f = 5 MHz | 2 | 70 | | | 70 | | | |
| k _{SVR} | Supply voltage rejection ratio (ΔV _{CC} /ΔV _{IO}) | ΔV _{CC+} = ±0.5 V, ΔV _{CC-} = ±0.5 V | 2 | 50 | 70 | | 50 | 70 | | dB |
| V _n | Broadband equivalent input noise voltage | BW = 1 kHz to 10 MHz | Any | 12 | | | 12 | | | μV |
| t _{pd} | Propagation delay time | R _S = 50 Ω, Output voltage step = 1 V | 1 | 7.5 | | | 7.5 | | | ns |
| | | | 2 | 6.0 | 10 | | 6.0 | 10 | | |
| | | | 3 | 3.6 | | | 3.6 | | | |
| t _r | Rise time | R _S = 50 Ω, Output voltage step = 1 V | 1 | 10.5 | | | 10.5 | | | ns |
| | | | 2 | 4.5 | 10 | | 4.5 | 12 | | |
| | | | 3 | 2.5 | | | 2.5 | | | |
| I _{sink(max)} | Maximum output sink current | | Any | 2.5 | 3.6 | | 2.5 | 3.6 | | mA |
| I _{CC} | Supply current | No load, No signal | Any | 16 | 24 | | 16 | 24 | | mA |

† The gain option is selected as follows:

Gain Option 1 . . . Gain-adjust pin 1A is connected to pin 1B, and pins 2A and 2B are open.

Gain Option 2 . . . Gain-adjust pin 1A and pin 1B are open, pin 2A is connected to pin 2B.

Gain Option 3 . . . All four gain-adjust pins are open.



uA733M, uA733C DIFFERENTIAL VIDEO AMPLIFIERS

electrical characteristics, $V_{CC+} = 6\text{ V}$, $V_{CC-} = -6\text{ V}$, $T_A = -55^\circ\text{C}$ to 125°C for uA733M, 0°C to 70°C for uA733C

| PARAMETER | TEST FIGURE | TEST CONDITIONS | GAIN OPTION† | uA733M | | uA733C | | UNIT |
|------------------------|-------------|---|--------------|--------|-----|--------|-----|------|
| | | | | MIN | MAX | MIN | MAX | |
| A _{VD} | 1 | V _{OD} = 1 V | 1 | 200 | 600 | 250 | 600 | V/V |
| | | | 2 | 80 | 120 | 80 | 120 | |
| | | | 3 | 8 | 12 | 8 | 12 | |
| I _{IO} | | | Any | | 5 | | 6 | μA |
| I _{IB} | | | Any | | 40 | | 40 | μA |
| V _{ICR} | 1 | | Any | ±1 | | ±1 | | V |
| V _{OO} | 1 | | 1 | | 1.5 | | 1.5 | V |
| | | | 2 & 3 | | 1.2 | | 1.5 | |
| V _{OPP} | 1 | | Any | 2.5 | | 2.8 | | V |
| r _i | 3 | V _{OD} ≤ 1 V | 2 | 8 | | 8 | | kΩ |
| CMRR | 4 | V _{IC} = ±1 V, f ≤ 100 kHz | 2 | 50 | | 50 | | dB |
| | | V _{IC} = ±1 V, f = 5 MHz | 2 | | | | | |
| k _{SVR} | 1 | ΔV _{CC+} = ±0.5 V, ΔV _{CC-} = ±0.5 V | 2 | 50 | | 50 | | dB |
| I _{sink(max)} | | | Any | 2.2 | | 2.5 | | mA |
| I _{CC} | | No load, No signal | Any | | 27 | | 27 | mA |

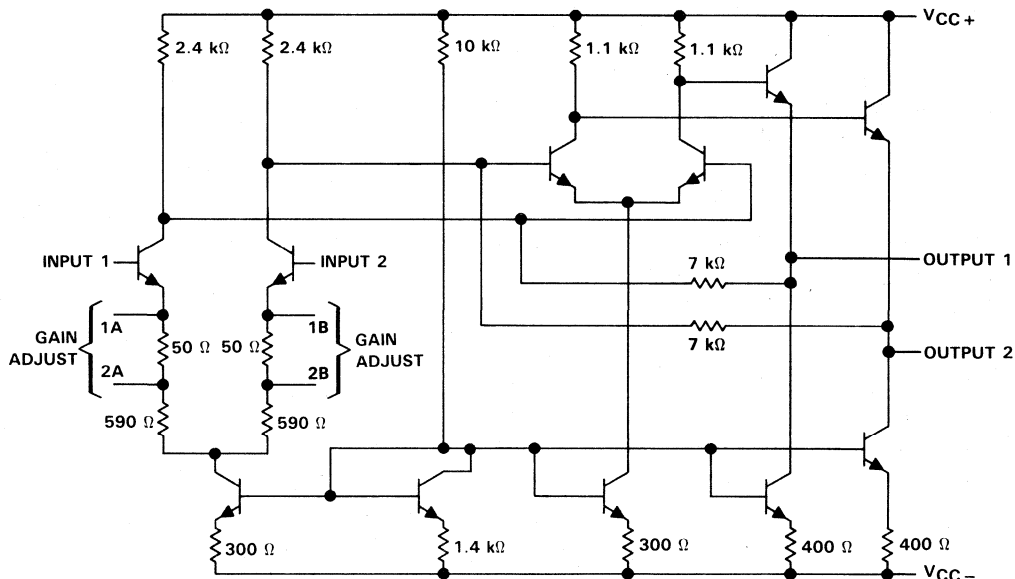
†The gain option is selected as follows:

Gain Option 1 . . . Gain-adjust pin 1A is connected to pin 1B, and pins 2A and 2B are open.

Gain Option 2 . . . Gain-adjust pin 1A and pin 1B are open, pin 2A is connected to pin 2B.

Gain Option 3 . . . All four gain-adjust pins are open.

schematic



Component values shown are nominal.

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DEFINITION OF TERMS

Large-Signal Differential Voltage Amplification (A_{VD}) The ratio of the change in voltage between the output terminals to the change in voltage between the input terminals producing it.

Bandwidth (BW) The range of frequencies within which the differential gain of the amplifier is not more than 3 dB below its low-frequency value.

Input Offset Current (I_{IO}) The difference between the currents into the two input terminals with the inputs grounded.

Input Bias Current (I_{IB}) The average of the currents into the two input terminals with the inputs grounded.

Input Voltage Range (V_I) The range of voltage that if exceeded at either input terminal will cause the amplifier to cease functioning properly.

Common-Mode Output Voltage (V_{OC}) The average of the d-c voltages at the two output terminals.

Output Offset Voltage (V_{OO}) The difference between the d-c voltages at the two output terminals when the input terminals are grounded.

Maximum Peak-to-Peak Output Voltage Swing (V_{OPP}) The maximum peak-to-peak output voltage swing that can be obtained without clipping. This includes the unbalance caused by output offset voltage.

Input Resistance (r_i) The resistance between the input terminals with either input grounded.

Output Resistance (r_o) The resistance between either output terminal and ground.

Input Capacitance (C_i) The capacitance between the input terminals with either input grounded.

Common-Mode Rejection Ratio (CMRR) The ratio of differential voltage amplification to common-mode voltage amplification. This is measured by determining the ratio of a change in input common-mode voltage to the resulting change in input offset voltage.

Supply Voltage Rejection Ratio (k_{SVR}) The absolute value of the ratio of the change in power supply voltages to the change in input offset voltage. For these devices, both supply voltages are varied symmetrically.

Equivalent Input Noise Voltage (V_n) The voltage of an ideal voltage source (having an internal impedance equal to zero) in series with the input terminals of the device that represents the part of the internally generated noise that can properly be represented by a voltage source.

Propagation Delay Time (t_{pd}) The interval between the application of an input voltage step and its arrival at either output, measured at 50% of the final value.

Rise Time (t_r) The time required for an output voltage step to change from 10% to 90% of its final value.

Maximum Output Sink Current ($I_{sink(max)}$) The maximum available current into either output terminal when that output is at its most negative potential.

Supply Current (I_{CC}) The average of the magnitudes of the two supply currents I_{CC1} and I_{CC2} .

PARAMETER MEASUREMENT INFORMATION

test circuits

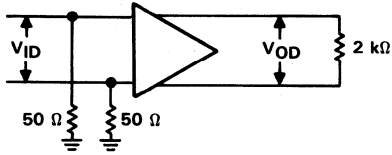


FIGURE 1

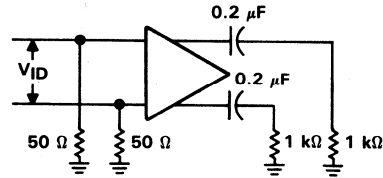


FIGURE 2

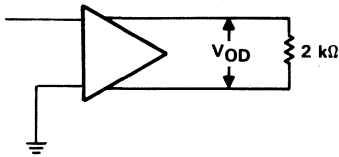


FIGURE 3

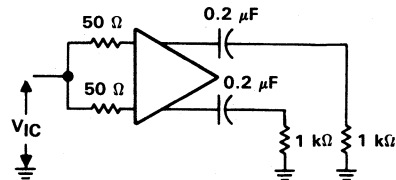


FIGURE 4

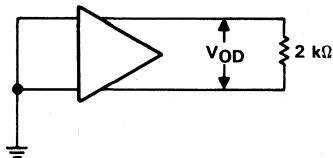
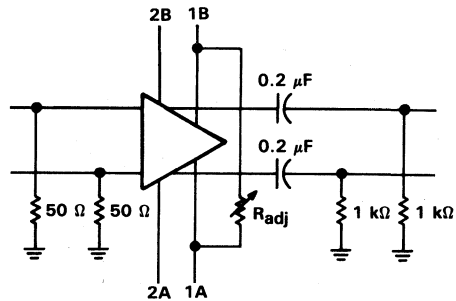


FIGURE 5



VOLTAGE AMPLIFICATION ADJUSTMENT

FIGURE 6

uA733M, uA733C
DIFFERENTIAL VIDEO AMPLIFIERS

TYPICAL CHARACTERISTICS

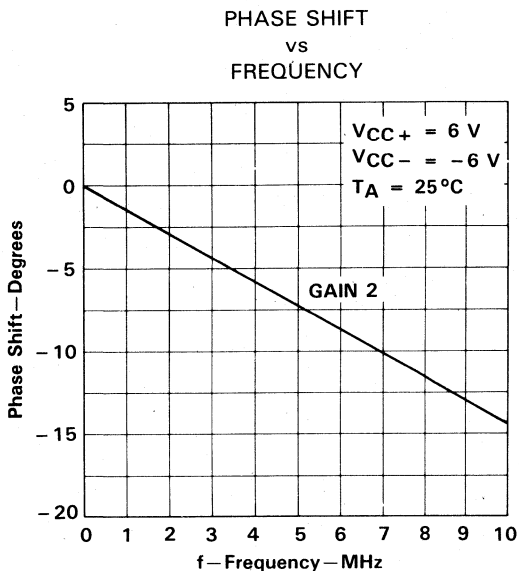


FIGURE 7

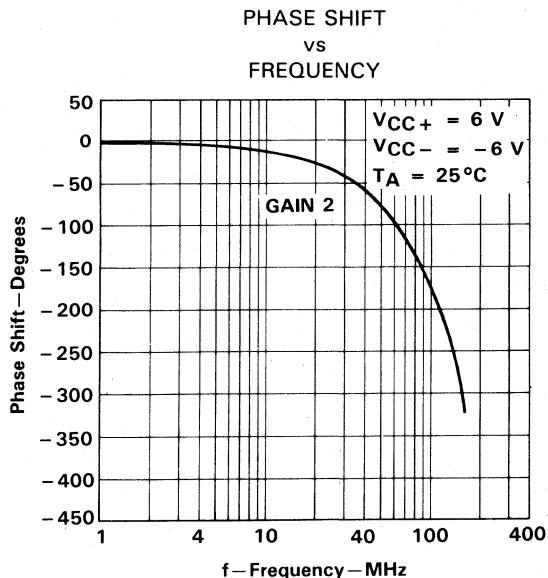


FIGURE 8

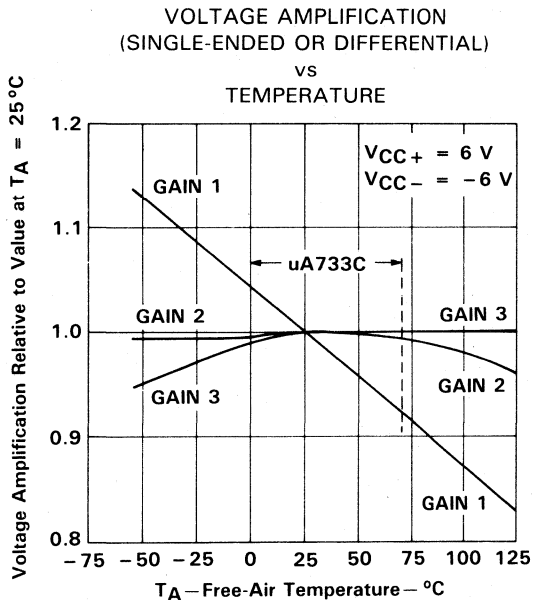


FIGURE 9

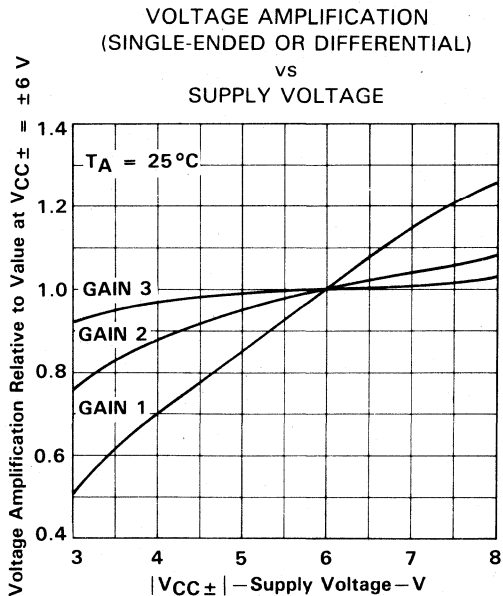


FIGURE 10



TYPICAL CHARACTERISTICS

DIFFERENTIAL VOLTAGE AMPLIFICATION
 vs
RESISTANCE BETWEEN G1A AND G1B

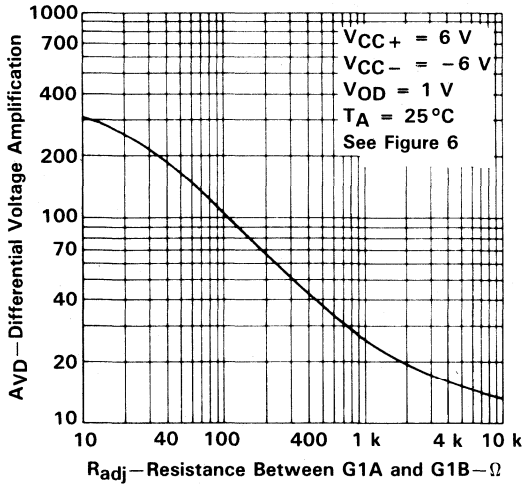


FIGURE 11

SINGLE-ENDED VOLTAGE AMPLIFICATION
 vs
FREQUENCY

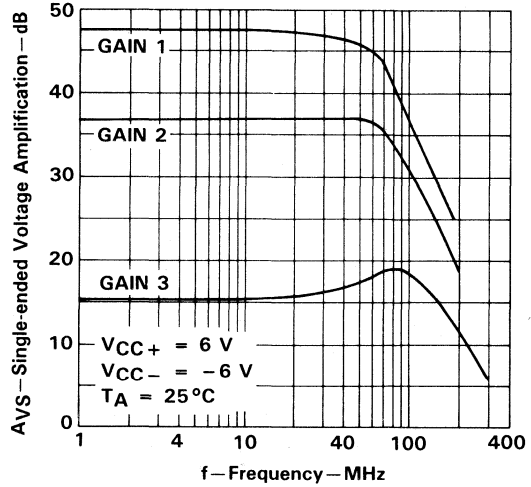


FIGURE 12

SUPPLY CURRENT
 vs
FREE-AIR TEMPERATURE

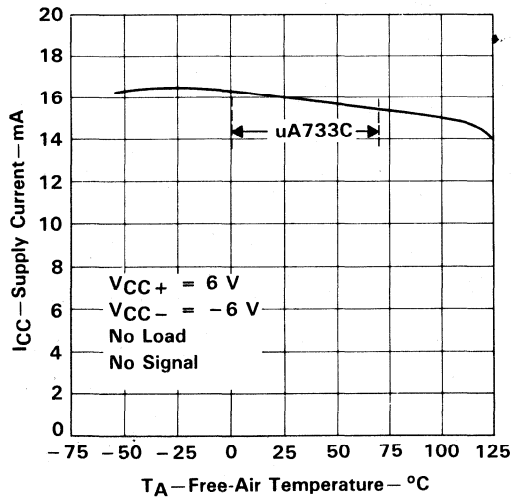


FIGURE 13

SUPPLY CURRENT
 vs
SUPPLY VOLTAGE

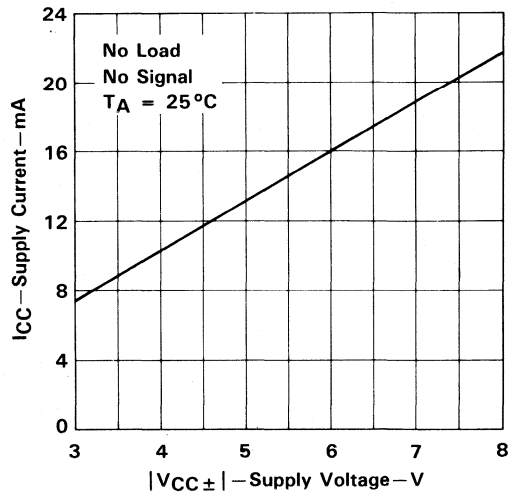


FIGURE 14

TYPICAL CHARACTERISTICS

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE
 vs
 LOAD RESISTANCE

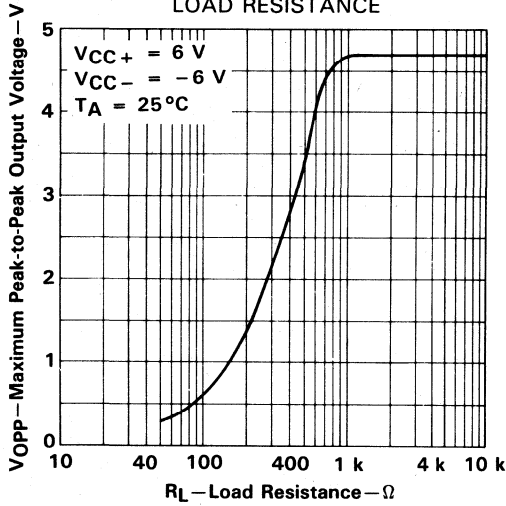


FIGURE 15

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE
 vs
 SUPPLY VOLTAGE

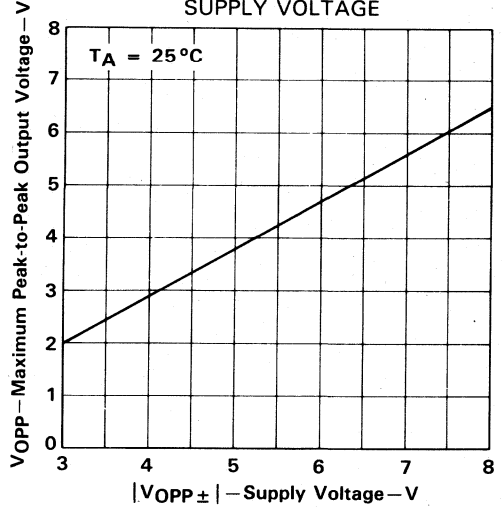


FIGURE 16

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE
 vs
 FREQUENCY

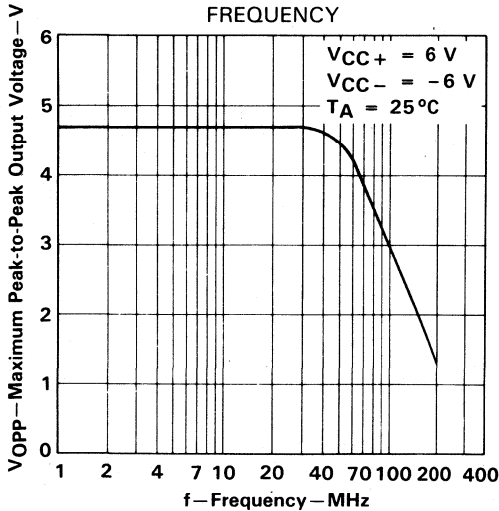


FIGURE 17

INPUT RESISTANCE
 vs
 FREE-AIR TEMPERATURE

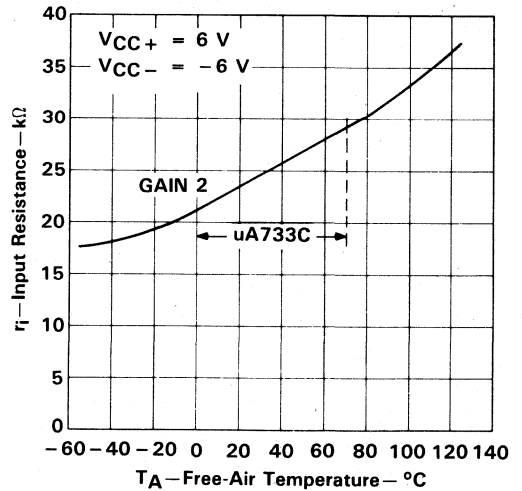


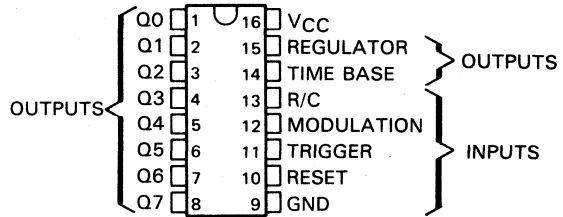
FIGURE 18

uA2240C PROGRAMMABLE TIMER/COUNTER

D2442, JUNE 1978 — REVISED MAY 1988

- Accurate Timing from Microseconds to Days
- Programmable Delays from 1 Time Constant to 255 Time Constants
- Outputs Compatible with TTL and CMOS
- Wide Supply-Voltage Range
- External Sync and Modulation Capability

N DUAL-IN-LINE PACKAGE
(TOP VIEW)



description

These circuits consist of a time-base oscillator, and eight-bit counter, a control flip-flop, and a voltage regulator. The frequency of the time-base oscillator is set by the time constant of an external resistor and capacitor at pin 13 and can be synchronized or modulated by signals applied to the modulation input. The output of the time-base section is applied directly to the input of the counter section and also appears at pin 14 (time base). The time-base pin may be used to monitor the frequency of the oscillator, to provide an output pulse to other circuitry, or (with the time-base section disabled) to drive the counter input from an external source. The counter input is activated on a negative-going transition. The reset input stops the time-base oscillator and sets each binary output, Q0 through Q7, and the time-base output to a TTL high level. After resetting, the trigger input starts the oscillator and all Q outputs go low. Once triggered, the uA2240C will ignore any signals at the trigger input until it is reset.

The uA2240C timer/counter may be operated in the free-running mode or with output-signal feedback to the reset input for automatic reset. Two or more binary outputs may be connected together to generate complex pulse patterns, or each output may be used separately to provide eight output frequencies. Using two circuits in cascade can provide precise time delays of up to three years.

The uA2240C is characterized for operation from 0°C to 70°C.

AVAILABLE OPTIONS

| SYMBOLIZATION | | OPERATING TEMPERATURE RANGE | V _T MAX at 25°C |
|---------------|----------------|-----------------------------|----------------------------|
| DEVICE | PACKAGE SUFFIX | | |
| uA2240C | N | 0°C to 70°C | 2 V |

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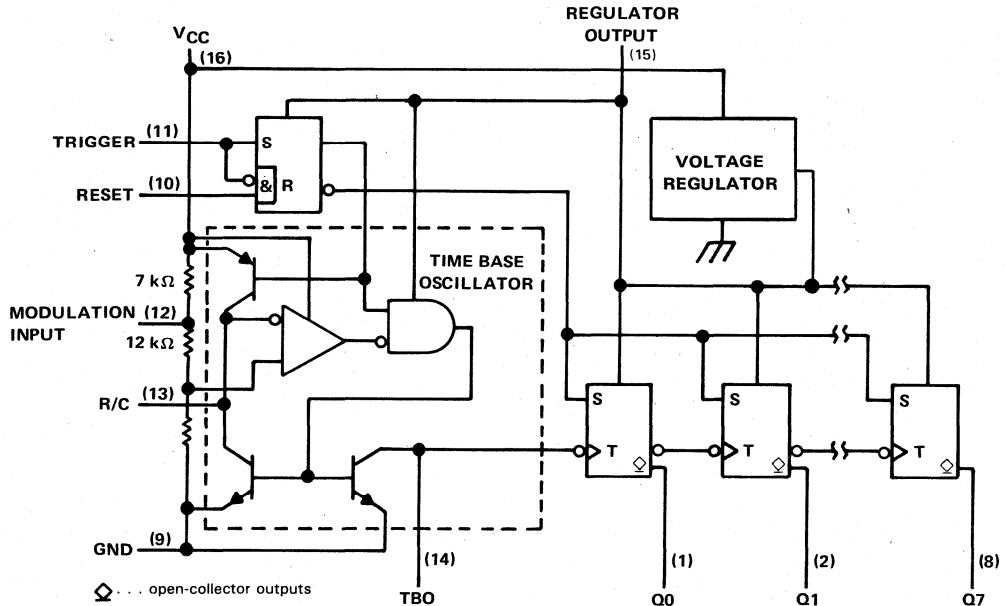
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uA2240C PROGRAMMABLE TIMER/COUNTER

functional block diagram



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

| | |
|--|-------------|
| Supply voltage, V_{CC} (see Note 1) | 18 V |
| Output voltage: Q0 thru Q7 | 18 V |
| Output current: Q0 thru Q7 | 10 mA |
| Regulator output current | -5 mA |
| Continuous dissipation at (or below) 25°C free-air temperature | 650 mW |
| Operating free-air temperature range | 0°C to 70°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°C |

NOTE 1: Voltage values are with respect to the network ground terminal.

recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|--|-------|-----|------|------|
| Supply voltage, V_{CC} (see Note 2) | 4 | | 14 | V |
| Timing resistor | 0.001 | | 10 | MΩ |
| Timing capacitor | 0.01 | | 1000 | μF |
| Counter input frequency (Pin 14) | | 1.5 | | MHz |
| Pull-up resistor, time-base output | | 20 | | kΩ |
| Trigger and reset input pulse voltage | 2 | 3 | | V |
| Trigger and reset input pulse duration | 2 | | | μs |
| External clock input pulse voltage | 3 | | | V |
| External clock input pulse duration | 1 | | | μs |

NOTE 2: For operation with $V_{CC} \leq 4.5$ V, short regulator output to V_{CC} .



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electrical characteristics at 25°C free-air temperature

| PARAMETER | TEST CIRCUIT | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|--------------|--|-----|------|-----|------|
| Regulator output voltage | 1 | V _{CC} = 5 V, Trigger and reset open or grounded | 3.9 | 4.4 | | V |
| | 2 | V _{CC} = 15 V, Trigger and reset open or grounded | 5.8 | 6.3 | 6.8 | |
| Modulation input open circuit voltage | 1 | V _{CC} = 5 V, Trigger and reset open or grounded | 2.8 | 3.5 | 4.2 | V |
| | | V _{CC} = 15 V, Trigger and reset open or grounded | | 10.5 | | |
| Trigger threshold voltage | 1 | V _{CC} = 5 V, Reset at 0 V | | 1.4 | 2 | V |
| High-level trigger current | 1 | V _{CC} = 5 V, Trigger at 2 V, Reset at 0 V | | 10 | | μA |
| Reset threshold voltage | 1 | V _{CC} = 5 V, Trigger at 0 V | | 1.4 | 2 | V |
| High-level reset current | 1 | V _{CC} = 5 V, Trigger at 0 V | | 10 | | μA |
| Counter input (time base) threshold voltage | 2 | V _{CC} = 5 V, Trigger and reset open or grounded | 1 | 1.4 | | V |
| Low-level output current, Q0 thru Q7 | 2 | V _{CC} = 5 V, Trigger at 2 V, Reset at 0 V, V _{OL} < 0.4 V | 2 | 4 | | mA |
| High-level output current, Q0 thru Q7 | 2 | V _{OH} = 15 V, Reset at 2 V, Trigger at 0 V | | 0.01 | 15 | μA |
| Supply current | 1 | V _{CC} = 5 V, Trigger at 0 V, Reset at 5 V | | 4 | 7 | mA |
| | 1 | V _{CC} = 15 V, Trigger at 0 V, Reset at 5 V | | 13 | 18 | |
| | 3 | V ₊ = 4 V | | 1.5 | | |

operating characteristics at 25°C free-air temperature (unless otherwise noted)

| PARAMETER | TEST CIRCUIT | TEST CONDITIONS† | MIN | TYP | MAX | UNIT |
|--|--------------|---|------------------------|-------|------|--------|
| Initial error of time base‡ | 1 | V _{CC} = 5 V, Trigger at 5 V, Reset at 0 V | | ±0.5 | ±5 | % |
| Temperature coefficient of time-base period | 1 | T _A = 0°C to 70°C | V _{CC} = 5 V | -200 | | ppm/°C |
| | | | V _{CC} = 15 V | -80 | | |
| Supply voltage sensitivity of time-base period | 1 | V _{CC} ≥ 8 V | | -0.08 | -0.3 | %/V |
| Time-base output frequency | 1 | V _{CC} = 5 V, R = MIN, C = MIN | | 130 | | kHz |
| Propagation delay time | | see Note 3 | From trigger input | 1 | | μs |
| | | | From reset input | 0.8 | | |
| Output rise time | 2 | R _L = 3 kΩ, C _L = 10 pF | Q0 thru Q7 | 180 | | ns |
| Output fall time | | | | 180 | | |

†For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

‡This is the time-base period error due only to the uA2240C and expressed as a percentage of nominal (1.00 RC).

NOTE 3: Propagation delay time is measured from the 50% point on the leading edge of an input pulse to the 50% point on the leading edge of the resulting change of state at Q0.

PARAMETER MEASUREMENT INFORMATION

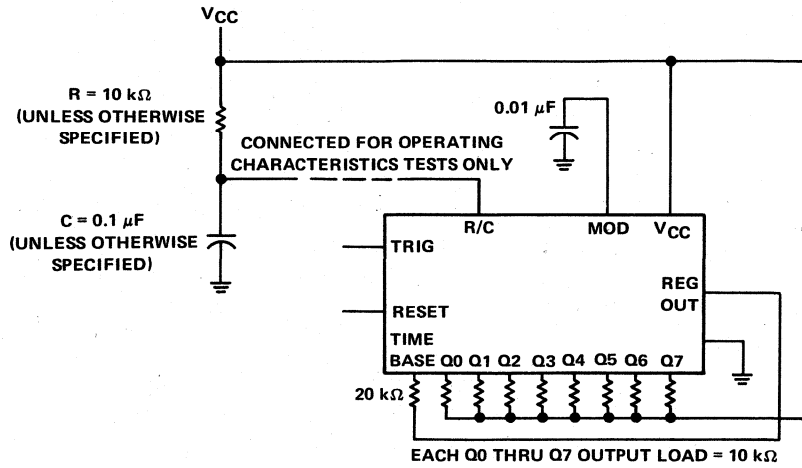


FIGURE 1. GENERAL TEST CIRCUIT

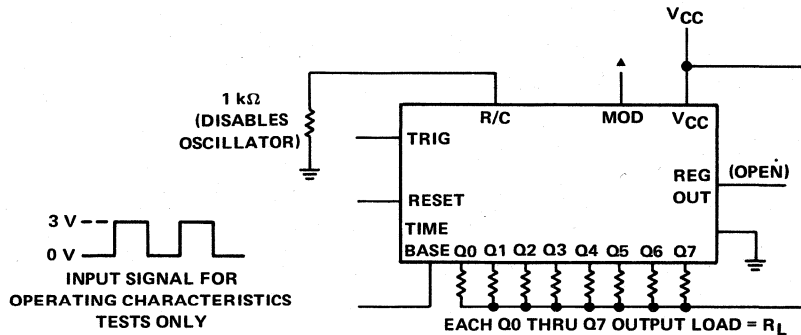


FIGURE 2. COUNTER TEST CIRCUIT

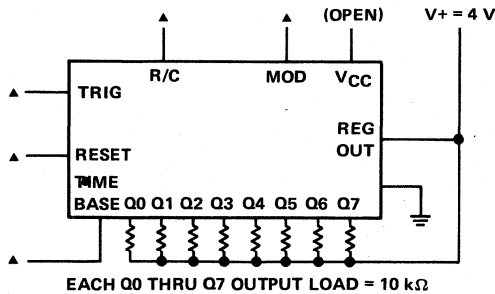


FIGURE 3. REDUCED-POWER TEST CIRCUIT (TIME BASE DISABLED)

▲ These connections may be open or grounded for this test.

TYPICAL CHARACTERISTICS

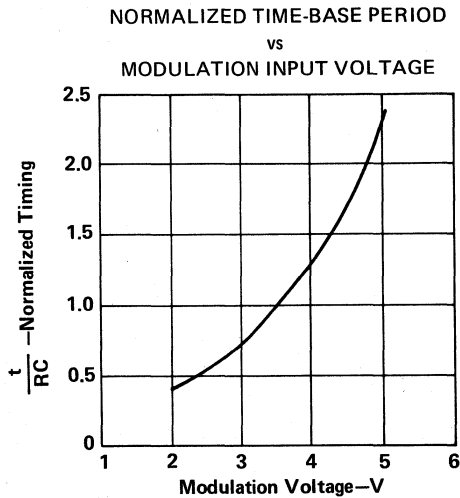
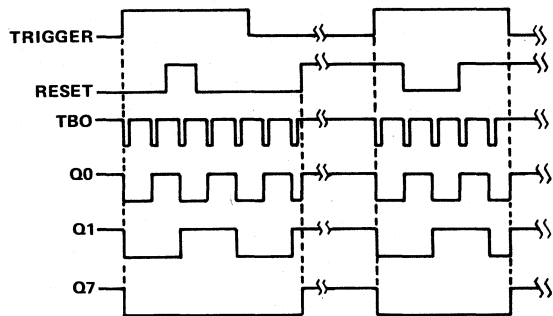


FIGURE 4

TYPICAL APPLICATION INFORMATION

Figure 5 shows voltage waveforms for typical operation of the uA2240C. If both reset and trigger inputs are low during power-up, the timer/counter will be in a reset state with all binary (Q) outputs high and the oscillator stopped. In this state, a high level on the trigger input starts the time-base oscillator. The initial negative-going pulse from the oscillator sets the Q outputs to low logic levels at the beginning of the first time-base period. The uA2240C will ignore any further signals at the trigger input until after a reset signal is applied to the reset input. With the trigger input low, a high level at the reset input will set Q outputs high and stop the time-base oscillator. If the reset signal occurs while the trigger input is high, the reset is ignored. If the reset input remains high when the trigger input goes low, the uA2240C will reset.



**FIGURE 5. TIMING DIAGRAM OF
 OUTPUT WAVEFORMS**

uA2240C PROGRAMMABLE TIMER/COUNTER

TYPICAL APPLICATION INFORMATION

In monostable applications of the uA2240C, one or more of the binary outputs will be connected to the reset terminal as shown in Figure 6. The binary outputs are open-collector stages that can be connected together to a common pull-up resistor to provide a "wired-OR" function. The combined output will be low as long as any one of the outputs is low. This type of arrangement can be used for time delays that are integer multiples of the time-base period. For example, if Q5 ($2^5 = 32$) only is connected to the reset input, every trigger pulse will generate a 32-period active-low output. Similarly, if Q0, Q4, and Q5 are connected to reset, each trigger pulse creates a 49-period delay.

In astable operation, the uA2240C will free-run from the time it is triggered until it receives an external reset signal.

The period of the time-base oscillator is equal to the RC time constant of an external resistor and capacitor connected as shown in Figure 6 when the modulation input is open (approximately 3.5 V internal, see Figure 4). Under conditions of high supply voltage ($V_{CC} > 7$ V) and low value of timing capacitor ($C < 0.1 \mu\text{F}$), the pulse duration of the time-base oscillator may be too short to properly trigger the counters. This situation can be corrected by adding a 300-pF capacitor between the time-base output and ground. The time-base output (TBO) is an open-collector output that requires a 20-k Ω pull-up resistor to Pin 15 for proper operation. The time-base pin may also be used as an input to the counters for an external time-base or as an active-low inhibit input to interrupt counting without resetting.

The modulation input varies the ratio of the time-base period to the RC time constant as a function of the dc bias voltage (see Figure 4). It can also be used to synchronize the timer/counter to an external clock or sync signal.

The regulator output is used internally to drive the binary counters and the control logic. This terminal can also be used to supply voltage to additional uA2240C devices to minimize power dissipation when several timer circuits are cascaded. For circuit operation with an external clock, the regulator output can be used as the V_{CC} input terminal to power down the internal time base and reduce power dissipation. When supply voltages less than 4.5 V are used with the internal time base, Pin 15 should be shorted to Pin 16.

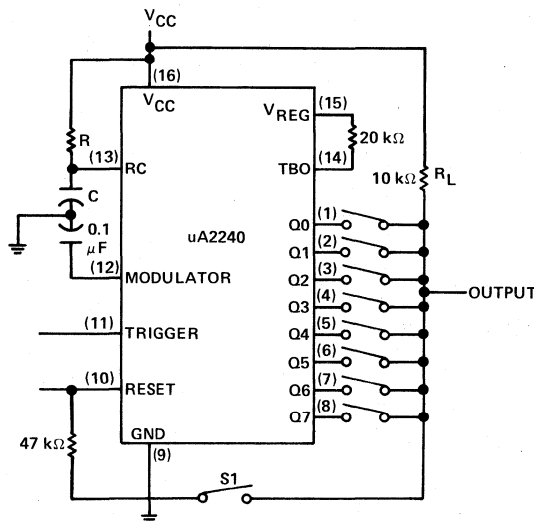


FIGURE 6. BASIC CONNECTIONS FOR TIMING APPLICATIONS



| | |
|--|----------|
| General Information | 1 |
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| Comparators | 3 |
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| Thermal Design Considerations | 5 |
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5 Thermal Design Considerations

***Thermal Considerations in
Design of Power Supplies
Application Report***



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Thermal Considerations in Design of Power Supplies

Introduction

Power supply circuit designers place emphasis on suppressing transients, improving regulation, and increasing efficiency, yet minimum effort is concentrated toward thermal considerations and packaging of the power supply. Serious efforts must be given to thermal design and packaging to minimize power supply failures in the field. If sufficient attention is given to the important parameters supplied by the semiconductor manufacturers (e.g., maximum junction temperature, junction-to-case, and junction-to-ambient thermal resistance), proper heat removal can be achieved. Thermal resistance is the temperature difference between two points divided by the power dissipation, normally stated in °C/W. The reference temperature can be the ambient temperature or the temperature of a heat sink that is attached to the integrated circuit (IC) package.

Heat can be transferred from the transistor or integrated circuit package by three methods: conduction, convection, and radiation.

Conduction is the transmission of energy by a medium not involving movement of the medium itself. This method is predominant in junction to the case or from the case to a heat sink heat transfer from the semiconductor. Length, cross-section, and temperature differential of the medium are key parameters that determine conduction.

Convection is the transmission of energy or mass by a medium involving movement of the medium itself. This method is predominant in the transfer of heat from the case to ambient or a heat sink to ambient. Surface conditions, convecting fluids, velocity, and temperature difference are dominant factors in convection.

Radiation is the emission and propagation of waves transmitting energy through space or some medium. This method is important in heat transfer from the cooling-fin surface of a heat sink. Thermal emissivity, surface area, and temperature difference between radiating and adjacent mediums are key factors that determine radiation.

Basic Thermal Circuit and Symbols

Figure 1 illustrates the various heat flow paths, temperatures, and thermal resistances of a steady-state thermal model using a KC package with formed leads. A popular concept is to display this thermal model as a network of series resistors as shown in Figure 2, comparing the thermal circuit analogy to an electric circuit. Extending this Ohm's-law concept of this thermal circuit, temperature is analogous to voltage and thermal resistance to ohmic resistance. Figure 2 provides an expression for:

$$T_J = T_A + P_D(R_{\theta JC} + R_{\theta CS} + R_{\theta SA}) \quad (1)$$

or $T_J = T_A + P_D(R_{\theta JA})$ for a regulator without external heat sink

where

- T_J = junction temperature in °C
- T_A = ambient air temperature in °C
- $R_{\theta JC}$ = thermal resistance, junction-to-case in °C/W
- $R_{\theta CS}$ = thermal resistance, case-to-heat sink °C/W
- $R_{\theta SA}$ = thermal resistance, heat sink-to-ambient in °C/W
- $R_{\theta JA}$ = thermal resistance, junction to ambient °C/W
- P_D = power dissipated by semiconductor device in W

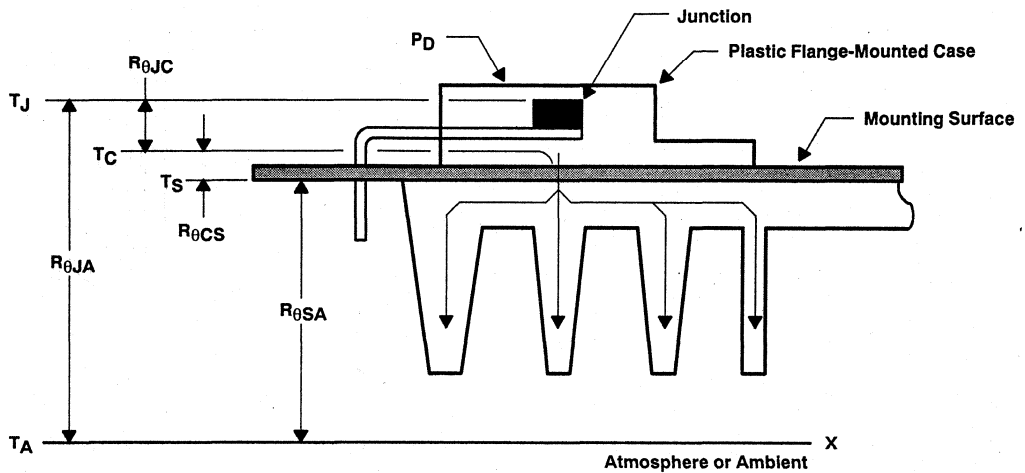


Figure 1. Semiconductor Thermal Model

The junction-to-ambient thermal resistance, $R_{\theta JA}$, can be expressed as a sum of thermal resistances listed below:

$$R_{\theta JA} = R_{\theta JC} + R_{\theta CS} + R_{\theta SA} \quad (2)$$

Equation 2 is applicable only when an external heat sink is used. If only a mounting (internal) heat sink is used, or the device does not have a heat sink, the $R_{\theta JA}$ is equal to the $R_{\theta JA}$ specified on the product data sheet. $R_{\theta JC}$ normally is given on the data sheet also, and the junction-to-case thermal resistance is a function of the material, size of the package, die area and thickness, and integrity of the die bond to the case, lead frame, or chip carrier. $R_{\theta CS}$ depends on the package, heat-sink-interface (mounting of the regulator to the heat sink) area, and integrity of the contact surface. Typical values for $R_{\theta CS}$ for different packages are shown in Table 1.

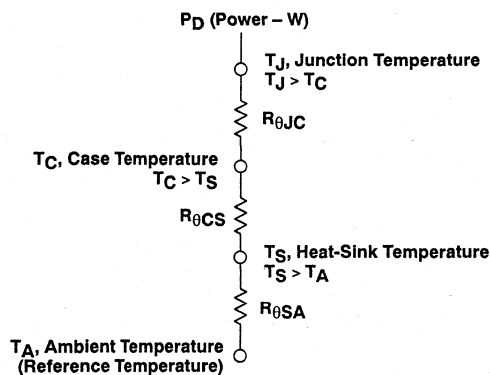


Figure 2. Basic Semiconductor Heat Sink Steady State Thermal Circuit

Table 1. $R_{\theta CS}$ for Different Types of Packages and Mounting Conditions

| PACKAGE | METAL-TO-METAL | METAL-TO-METAL WITH THERMAL COMPOUND | CONTACT WITH MICA WASHER AND THERMAL COMPOUND† |
|-------------|----------------|--------------------------------------|--|
| TO-3 | 0.52°C/W | 0.14°C/W | 0.36°C/W |
| KC (TO-220) | 1.1°C/W | 1°C/W | 1.7°C/W |

† Typical values extracted from heat-sink manufacturers curves.

The $R_{\theta SA}$ found on the heat sink data sheets depends on the attributes of the heat sink and the ambient conditions. Convection and radiation are heat flow methods affecting the heat sink to ambient thermal resistance.

Typically, the ambient temperature (T_A), maximum junction temperature (T_J), power dissipation (P_D), and thermal resistance from junction-to-case ($R_{\theta JC}$) are known. To ensure safe operations of any semiconductor, the device junction temperature must be maintained below the maximum value given on the product data sheet. As with any semiconductor component, these devices have thermal and electrical limitations that must be adhered to if desired performance and service time are to be achieved. In addition, improved reliability can be obtained by selecting conservative operating procedures and thermal ranges. Normally, the electrical and thermal characteristics are interrelated with the actual operating ranges that are heavily dependent on the component application.

Thermal Design Examples

The following examples are given to illustrate the design procedure in:

1. Ascertaining the maximum allowable power dissipation of a semiconductor device
2. Determining the maximum junction-to-ambient air temperature (T_{Amax}) using a mounting (internal) heat sink, or regulator without internal heat sink
3. Selecting an external heat sink by calculating the heat sink-to-ambient thermal resistance ($R_{\theta SA}$).

To ascertain the maximum allowable power dissipation of a semiconductor device, use equation 3:

$$P_D = \frac{T_{Jmax} - T_A}{R_{\theta JA}} \quad (3)$$

$$P_D = \frac{150^\circ\text{C} - 75^\circ\text{C}}{121.95^\circ\text{C/W}} = 0.62 \text{ W}$$

where

$$T_{Jmax} = 150^\circ\text{C} \text{ (design limit)}$$

$$T_A = 75^\circ\text{C}$$

$$R_{\theta JA} = 1/\text{derating value} = 1/8.2 \text{ mW/}^\circ\text{C (DW package)} = 121.95^\circ\text{C/W}$$

$$T_{Jmax} = T_A + P_D(R_{\theta JC} + R_{\theta CS} + R_{\theta SA})$$

To ascertain the maximum T_A for an uA78M12C regulator with an internal heat sink, use equation 4:

$$T_J = T_A + P_D(R_{\theta JA}) \quad (4)$$

$$T_A = T_J - P_D(R_{\theta JA})$$

$$T_A = 125 - (0.8 \times 62.5)$$

$$T_A = 75^\circ\text{C}$$

where

$$P_D = 0.8 \text{ W}$$

$$T_J = 125^\circ\text{C}$$

$$R_{\theta JA} = 1/\text{derating factor} = 1/0.016 = 62.5^\circ\text{C/W}$$

Derating factor of KC (TO-220) package is 16 mW/°C (from uA78M12C data sheet)

To ascertain the heat sink-to-ambient thermal resistance ($R_{\theta SA}$) for selection of an external heat sink using the uA7915C regulator, the heat sink should be mounted metal-to-metal using a thermal compound.

$$R_{\theta SA} = \frac{T_J - T_A}{P_D} - R_{\theta JC} - R_{\theta CS} \quad (5)$$

$$R_{\theta SA} = \frac{125 - 75}{3} - 4 - 1 = 11.7^\circ\text{C/W}$$

where

$$P_D = 3 \text{ W}$$

$$T_J = 125^\circ\text{C}$$

$$T_A = 75^\circ\text{C}$$

$$R_{\theta JC} = 4^\circ\text{C/W (from the uA7915C data sheet)}$$

$$R_{\theta CS} = 1^\circ\text{C/W from Table 1 (KC or TO-220 case)}$$

$$R_{\theta JA} = \frac{T_J - T_A}{P_D} = R_{\theta JC} + R_{\theta CS} + R_{\theta SA}$$

A Thermalloy 7019 or Staver V3-5 heat sink meets the desired requirements (see Table 3).

Table 2. Available Heat Sinks for TO-3 Packages

| $R_{\theta SA}$ RANGE† °C/W | MANUFACTURER‡ | |
|--------------------------------|---------------------------------|---|
| | STAVER | THERMALLOY |
| 3 to 5 | V3-5-2 | 6004, 6053, 6054, 6214, 6216 |
| 5 to 8 | V3-3-2 | 6002, 6003, 6015, 6016, 6052, 6060, 6061, 6213 |
| 8 to 13 | V1-3, V1-5, V3-3, V3-5, V3-7-96 | 6001, 6013, 6014, 6051 |

Table 3. Available Heat Sinks for KC (TO-220) Packages

| $R_{\theta SA}$ RANGE† °C/W | MANUFACTURER‡ | |
|--------------------------------|---------------|------------------------------|
| | STAVER | THERMALLOY |
| 3 to 5 | V3-5-2 | 6072/6071 |
| 5 to 8 | V3-3-2 | 6072, 7021, 7025 |
| 8 to 13 | V3-3, V3-5 | 6021, 6030, 6032, 7019, 7020 |

† All values are typical as determined from characteristic curves received from manufacturers.

‡ This table is representative of two heat sink manufacturers; many others are available.

General Suggestions for Efficient Thermal Management

Suggestions are as follows:

1. Place regulator components away from heat-dissipating components and mount hardware in an area that provides a good heat-dissipation path for the regulator.
2. For applications requiring electrical insulation of the heat sink from the regulator, use a thin (0.003-inch) mica washer. A thermal lubricant must be placed on both sides of the washer.
3. If a heat sink with fins is used with the regulator, align the fins in a vertical plane for a more efficient transfer of heat.
4. Select a heat sink with a mounting surface that has a finish and flatness comparable to the regulator package. Use thermal compounds to minimize voids, scratches, and imperfections between the mating surfaces. Use of thermal compounds with an insulating washer is more significant than with a metal-to-metal contact.
5. Attach a regulator heat sink to the regulator before soldering and mounting on the PC board. Maximum lead temperatures are 260°C for ten seconds with plastic packages or 300°C for sixty seconds for ceramic packages at a distance of 1/16th inch from case.

Conclusion

Thermal considerations in the design of power supplies are straight-forward, and with emphasis on heat reduction and conservative operating techniques, more efficient and reliable designs will be realized. The design parameters are normally under the control of the circuit designer and, with compromises, the variables can be controlled to achieve a product that will experience fewer failures in the field. On the other hand, if the thermal design considerations are overlooked or minimized, many of the power supply failures in the field may result from an inadequate thermal design approach.

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6

Mechanical Data

ORDERING INSTRUCTIONS

Electrical characteristics presented in this data book, unless otherwise noted, apply for the circuit type(s) listed in the page heading regardless of package. The availability of a circuit function in a particular package is denoted by an alphabetical reference above the pin-connection diagram(s). These alphabetical references refer to mechanical outline drawings shown in this section.

Factory orders for circuits described in this data book should include a four-part type number as shown in the following example.

Example: **TL** **598M** **J** **/883B**

Prefix _____

MUST CONTAIN TWO OR THREE LETTERS

- SN TI Special Functions or Interface Products
- TL, TLE TI Linear Products
- TLC TI Linear Silicon-Gate CMOS Products

STANDARD SECOND-SOURCE PREFIXES

- AD Analog Devices
- ADC, LF, LM, LP, or MP National
- LT or LTC Linear Technology
- MC Motorola
- NE, SA, or SE Signetics
- OP PMI
- RC, RM, or RV Raytheon
- uA Fairchild/National
- UC Unitrode

Unique Circuit Description Including Temperature Range _____

MUST CONTAIN TWO OR MORE CHARACTERS

(From Individual Data Sheets)

- Examples: 10 34070
 592 1451AC
 7757 2217-285

Package _____

MUST CONTAIN ONE OR TWO LETTERS

- D, DB, DW, FK, FN, J, JD, JG, KC, KK, KV, LP, N, NS, NT, NW, P, PK, PW, U
- (From Pin-Connection Diagrams on Individual Data Sheet)

MIL-STD-883B, Method 5004, Class B _____

Omit /883B When Not Applicable



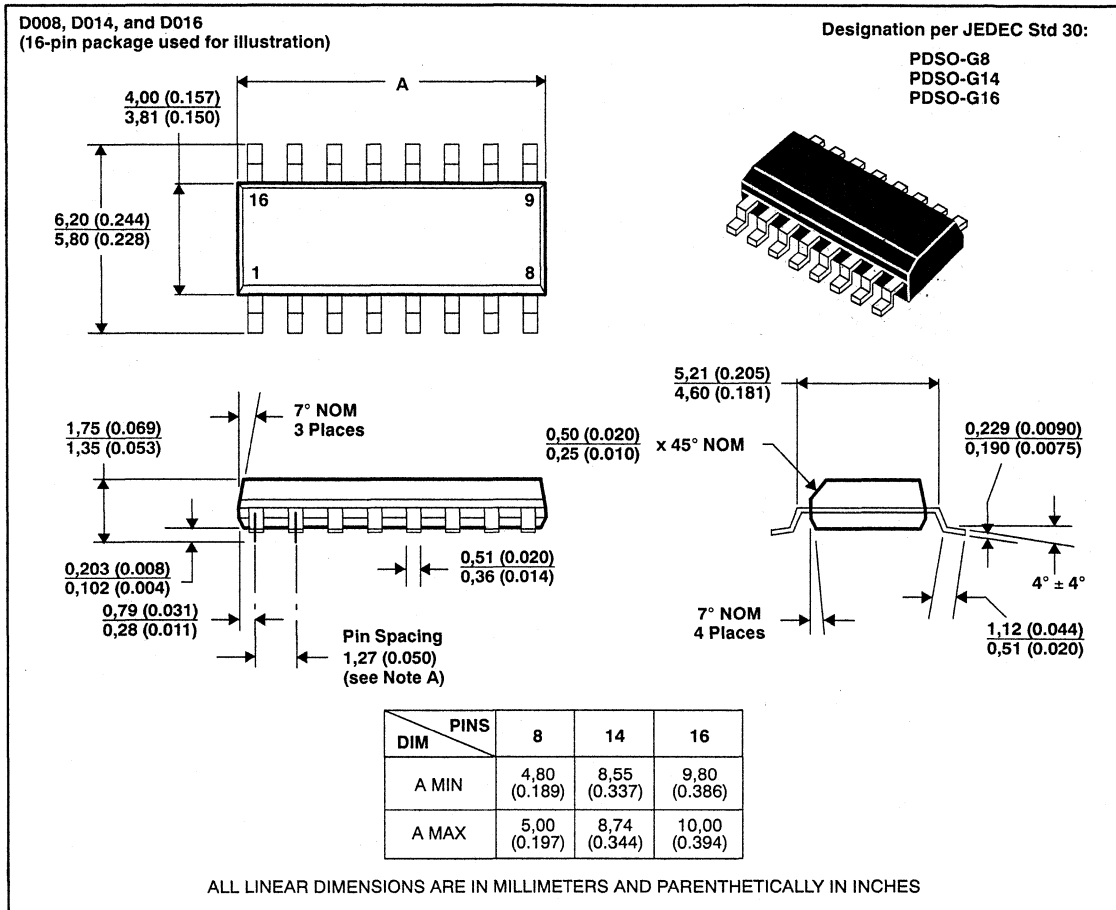
ORDERING INSTRUCTIONS

Circuits are shipped in one of the carriers below. Unless a specific method of shipment is specified by the customer (with possible additional costs), circuits will be shipped via the most practical carrier.

- | | | |
|---|---|--|
| Dual-In-Line (J, JD, JG, N, NT, NS, NW, P) – A-Channel Antistatic or Conductive Plastic Tubing | Shrink Small Outline (DB) – Tape and Reel Thin Shrink Small Outline (PW) – Tape and Reel | Plug-In (LP) – Plastic Bag – Tape and Reel |
| Small Outline (D, DW) – Tape and Reel – Antistatic or Conductive Plastic Tubing | Chip Carriers (FK, FN) – Antistatic or Conductive Plastic Tubing | Power Tab (KC, KK, KV) – A-Channel Antistatic or Conductive Plastic Tubing |
| | Flat (U) – Milton Ross Carriers | |

D008, D014, and D016
plastic small-outline packages

Each of these small-outline packages consists of a circuit mounted on a lead frame and encapsulated within a plastic compound. The compound will withstand soldering temperature with no deformation, and circuit performance characteristics will remain stable when operated in high-humidity conditions. Leads require no additional cleaning or processing when used in soldered assembly.

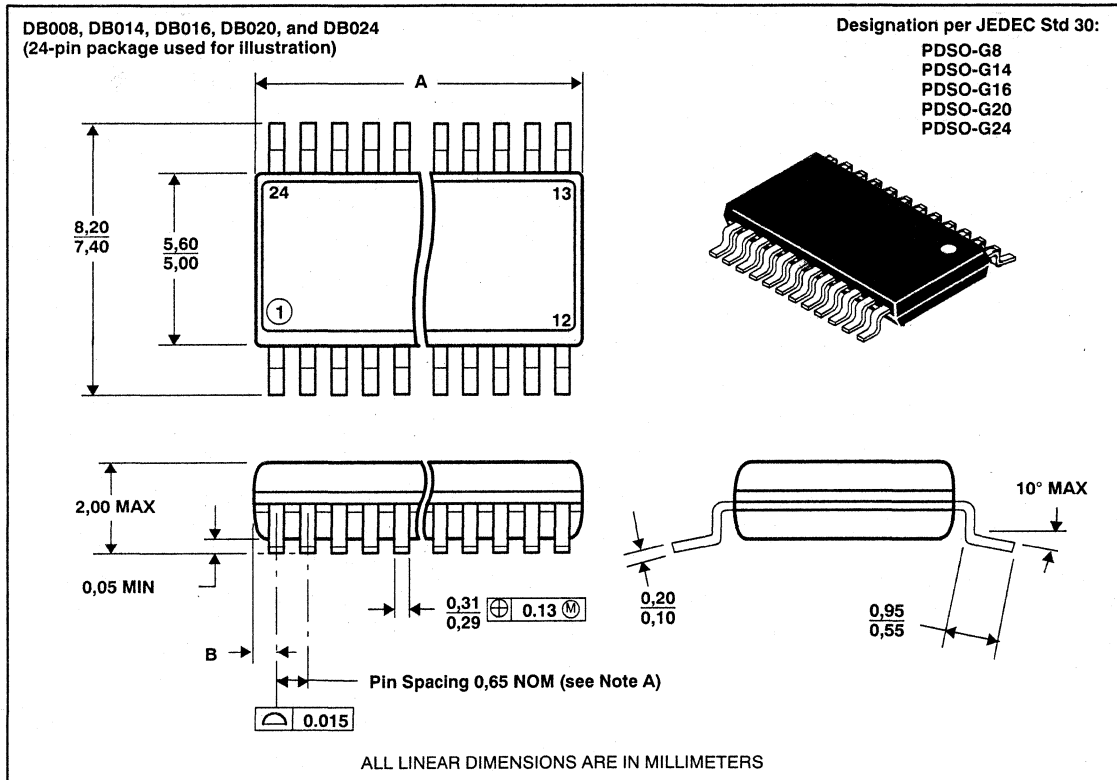


- NOTES: A. Leads are within 0,25 (0.010) radius of true position at maximum material condition.
 B. Body dimensions do not include mold flash or protrusion.
 C. Mold flash or protrusion shall not exceed 0,15 (0.006).
 D. Lead tips to be planar within ±0,051 (0.002) exclusive of solder.

MECHANICAL DATA

DB008, DB014, DB016, DB020, and DB024 shrink small-outline packages

These shrink small-outline packages consist of a circuit mounted on a lead frame and encapsulated within a plastic compound. The compound will withstand soldering temperature with no deformation, and circuit performance characteristics will remain stable when operated in high-humidity conditions. Leads require no additional cleaning or processing when used in soldered assembly.



- NOTES: A. Leads are within 0,25 mm radius of true position at maximum material condition.
B. Body dimensions do not include mold flash or protrusion.
C. Mold or flash end protrusion shall not exceed 0,15 mm.
D. Interlead flash shall be controlled by TI statistical process control (additional information available through TI field office).
E. Lead tips to be planar within $\pm 0,05$ mm exclusive of solder.

| DIM \ PINS | 8 | 14 | 16 | 20 | 24 |
|------------|------|------|------|------|------|
| A MIN | 2,70 | 5,90 | 5,90 | 6,90 | 7,90 |
| A MAX | 3,30 | 6,50 | 6,50 | 7,50 | 8,50 |
| B MAX | 0,68 | 1,30 | 0,98 | 0,83 | 0,68 |

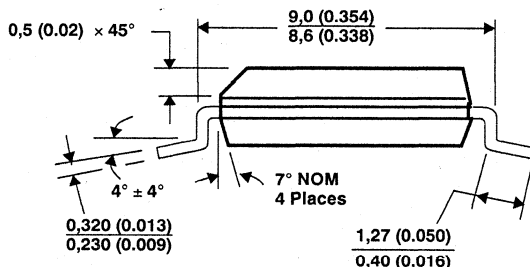
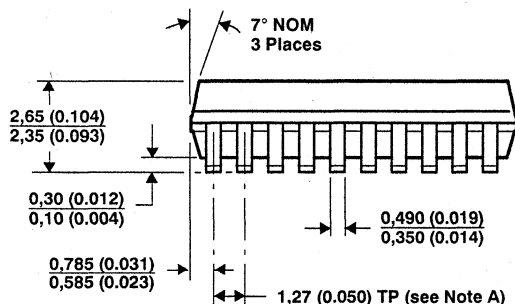
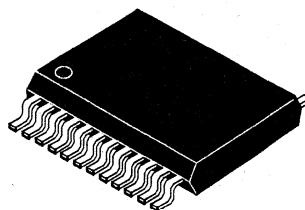
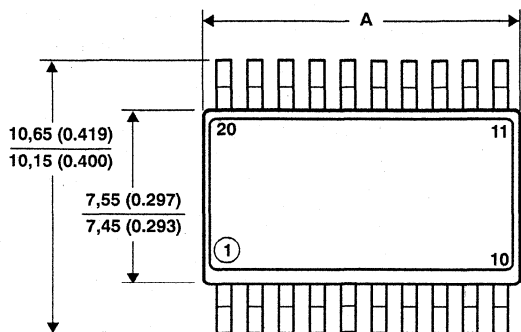
DW016, DW020, DW024, and DW028
plastic small-outline packages

Each of these small-outline packages consists of a circuit mounted on a lead frame and encapsulated within a plastic compound. The compound will withstand soldering temperature with no deformation, and circuit performance characteristics will remain stable when operated in high-humidity conditions. Leads require no additional cleaning or processing when used in soldered assembly.

DW016, DW020, DW024, and DW028
(20-pin package used for illustration)

Designation per JEDEC Std 30:

- PDSO-G16
- PDSO-G20
- PDSO-G24
- PDSO-G28



| DIM \ PINS | PINS | | | |
|------------|------------------|------------------|------------------|------------------|
| | 16 | 20 | 24 | 28 |
| A MIN | 10,16 (0.400) | 12,70 (0.500) | 15,29 (0.602) | 17,68 (0.696) |
| A MAX | 10,36 (0.408) | 12,90 (0.508) | 15,49 (0.610) | 17,88 (0.704) |

ALL LINEAR DIMENSIONS ARE IN MILLIMETERS AND PARENTHETICALLY IN INCHES

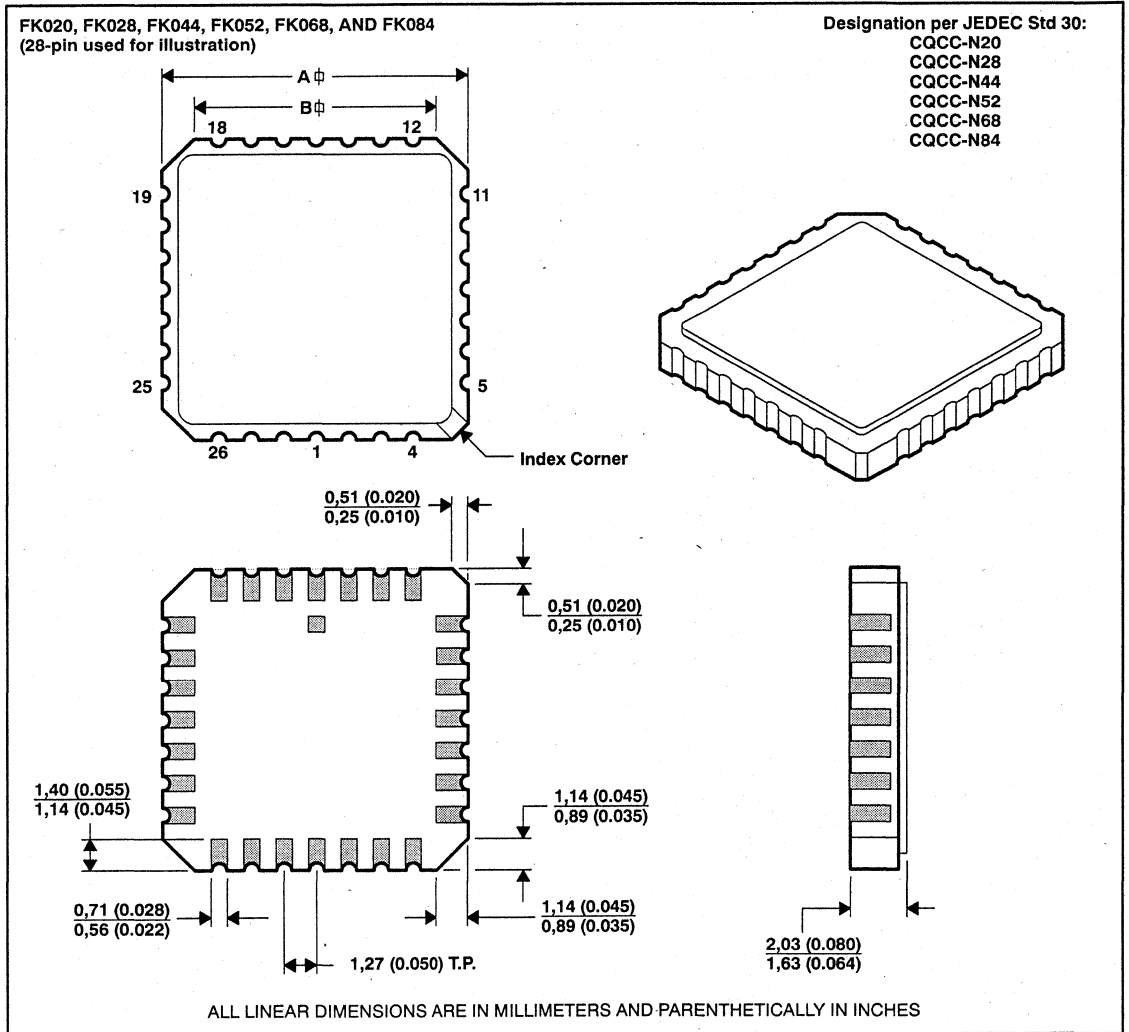
- NOTES: A. Leads are within 0,25 (0.010) radius of true position at maximum material condition.
 B. Body dimensions do not include mold flash or protrusion.
 C. Mold flash or protrusion shall not exceed, 0,15 (0.006).
 D. Lead tips to be planar within ±0,051 (0.002) exclusive of solder.

MECHANICAL DATA

FK020, FK028, FK044, FK052, FK068, and FK084 ceramic chip carrier

Each of these hermetically sealed chip carrier packages has a three-layer ceramic base with a metal lid and braze seal. These packages are intended for surface mounting on solder leads on 1,27 (0.050) centers. Terminals require no additional cleaning or processing when used in soldered assembly.

FK package terminal assignments conform to JEDEC Standards 1 and 2.



NOTES: A. See next page for A and B dimensions.

FK020, FK028, FK044, FK052, FK068, and FK084
ceramic chip carrier (continued)

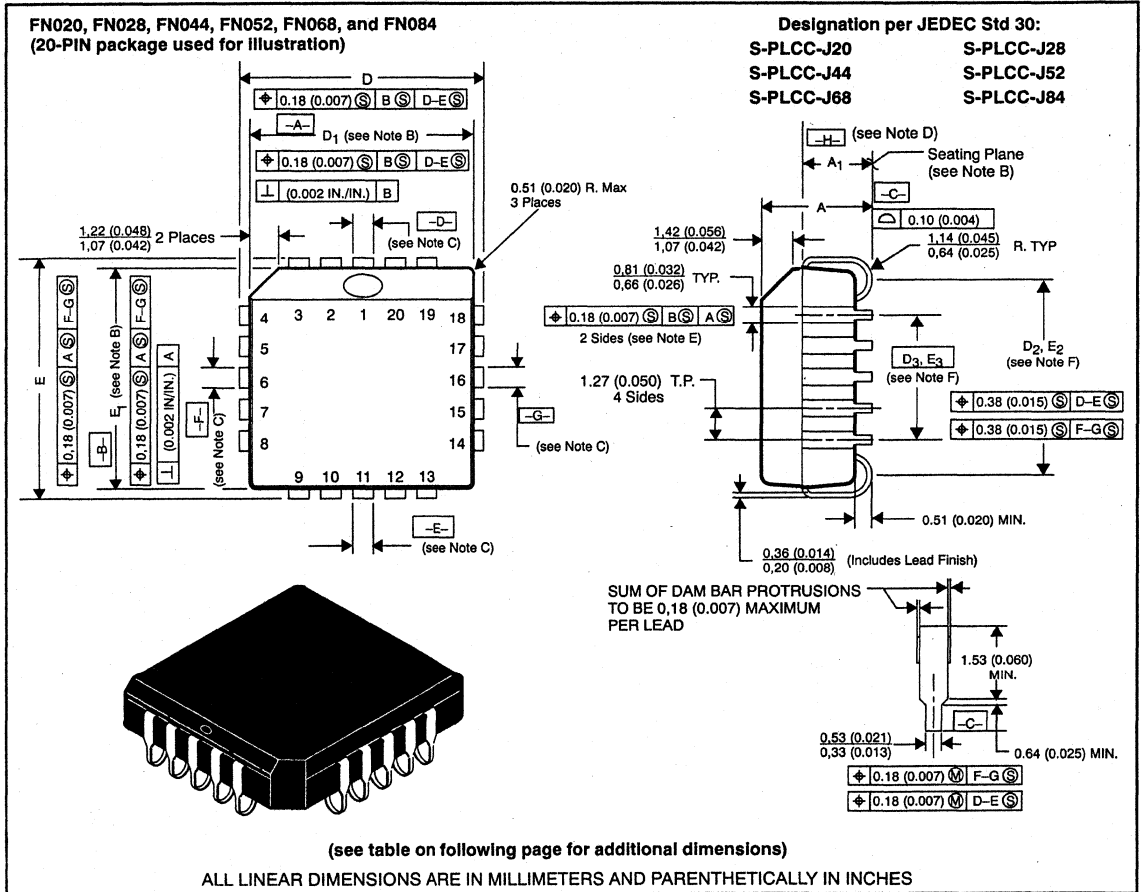
| JEDEC OUTLINE DESIGNATION† | NUMBER OF TERMINALS | A | | B | |
|-------------------------------|------------------------|---------------|---------------|---------------|---------------|
| | | MIN | MAX | MIN | MAX |
| MS-004-CB | 20 | 8,69 (0.342) | 9,09 (0.358) | 7,80 (0.307) | 9,09 (0.358) |
| MS-004-CC | 28 | 11,23 (0.442) | 11,63 (0.458) | 10,31 (0.406) | 11,63 (0.458) |
| MS-004-CD | 44 | 16,26 (0.640) | 16,76 (0.660) | 12,58 (0.495) | 14,22 (0.560) |
| MS-004-CE | 52 | 18,78 (0.740) | 19,32 (0.760) | 12,58 (0.495) | 14,22 (0.560) |
| MS-004-CF | 68 | 23,83 (0.938) | 24,43 (0.962) | 21,60 (0.850) | 21,80 (0.858) |
| MS-004-CG | 84 | 28,99 (1,141) | 29,59 (1,164) | 26,60 (1,047) | 27,00 (1,063) |

† All dimensions and notes for the specified JEDEC outline apply.

MECHANICAL DATA

FN020, FN028, FN044, FN052, FN068, and FN084 plastic J-leaded chip carrier

Each of these chip carrier packages consists of a circuit mounted on a lead frame and encapsulated within an electrically nonconductive plastic compound. The compound withstands soldering temperatures with no deformation, and circuit performance characteristics remain stable when the devices are operated in high-humidity conditions. The package is intended for surface mounting on 1,27 (0.050) centers. Leads require no additional cleaning or processing when used in soldered assembly.



- NOTES: B. All dimensions conform to JEDEC Specification MO-047AA/AF. Dimensions and tolerancing are per ANSI Y14.5M - 1982.
 C. Dimensions D₁ and E₁ do not include mold flash protrusion. Protrusion shall not exceed 0,25 (0.010) on any side. Centerline of center pin each side is within 0,10 (0.004) of package centerline by dimension B. The lead contact points are planar within 0,10 (0.004).
 D. Datums $\boxed{D-E}$ and $\boxed{F-G}$ for center leads are determined at datum $\boxed{-H-}$.
 E. Datum $\boxed{-H-}$ is located at top of leads where they exit plastic body.
 F. Location of datums $\boxed{-A-}$ and $\boxed{-B-}$ to be determined at datum $\boxed{-H-}$.
 G. Determined at seating plane $\boxed{-C-}$.

**FN020, FN028, FN044, FN052, FN068, and FN084
plastic J-leaded chip carrier (continued)**

| JEDEC OUTLINE | NO. OF PINS | A | | A ₁ | | D, E | | D ₁ , E ₁ | | D ₂ , E ₂ | | D ₃ , E ₃ |
|------------------|----------------|-----------------|-----------------|-----------------|-----------------|------------------|------------------|---------------------------------|------------------|---------------------------------|------------------|---------------------------------|
| | | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | MIN | MAX | BASIC |
| MO-047AA | 20 | 4,19 (0.165) | 4,57 (0.180) | 2,29 (0.090) | 3,05 (0.120) | 9,78 (0.385) | 10,03 (0.395) | 8,89 (0.350) | 9,04 (0.356) | 7,37 (0.290) | 8,38 (0.330) | 5,08 (0.200) |
| MO-047AB | 28 | 4,19 (0.165) | 4,57 (0.180) | 2,29 (0.090) | 3,05 (0.120) | 12,32 (0.485) | 12,57 (0.495) | 11,43 (0.450) | 11,58 (0.456) | 9,91 (0.390) | 10,92 (0.430) | 7,62 (0.300) |
| MO-047AC | 44 | 4,19 (0.165) | 4,57 (0.180) | 2,29 (0.090) | 3,05 (0.120) | 17,40 (0.685) | 17,65 (0.695) | 16,51 (0.650) | 16,66 (0.656) | 14,99 (0.590) | 16,00 (0.630) | 12,70 (0.500) |
| MO-047AD | 52 | 4,19 (0.165) | 5,08 (0.200) | 2,29 (0.090) | 3,30 (0.130) | 19,94 (0.785) | 20,19 (0.795) | 19,05 (0.750) | 19,20 (0.756) | 17,53 (0.690) | 18,54 (0.730) | 15,24 (0.600) |
| MO-047AE | 68 | 4,19 (0.165) | 5,08 (0.200) | 2,29 (0.090) | 3,30 (0.130) | 25,02 (0.985) | 25,27 (0.995) | 24,13 (0.950) | 24,33 (0.958) | 22,61 (0.890) | 23,62 (0.930) | 20,32 (0.800) |
| MO-047AF | 84 | 4,19 (0.165) | 5,08 (0.200) | 2,29 (0.090) | 3,30 (0.130) | 30,10 (1.185) | 30,35 (1.195) | 29,21 (1.150) | 29,41 (1.141) | 27,69 (1.090) | 28,70 (1.130) | 25,40 (1.000) |

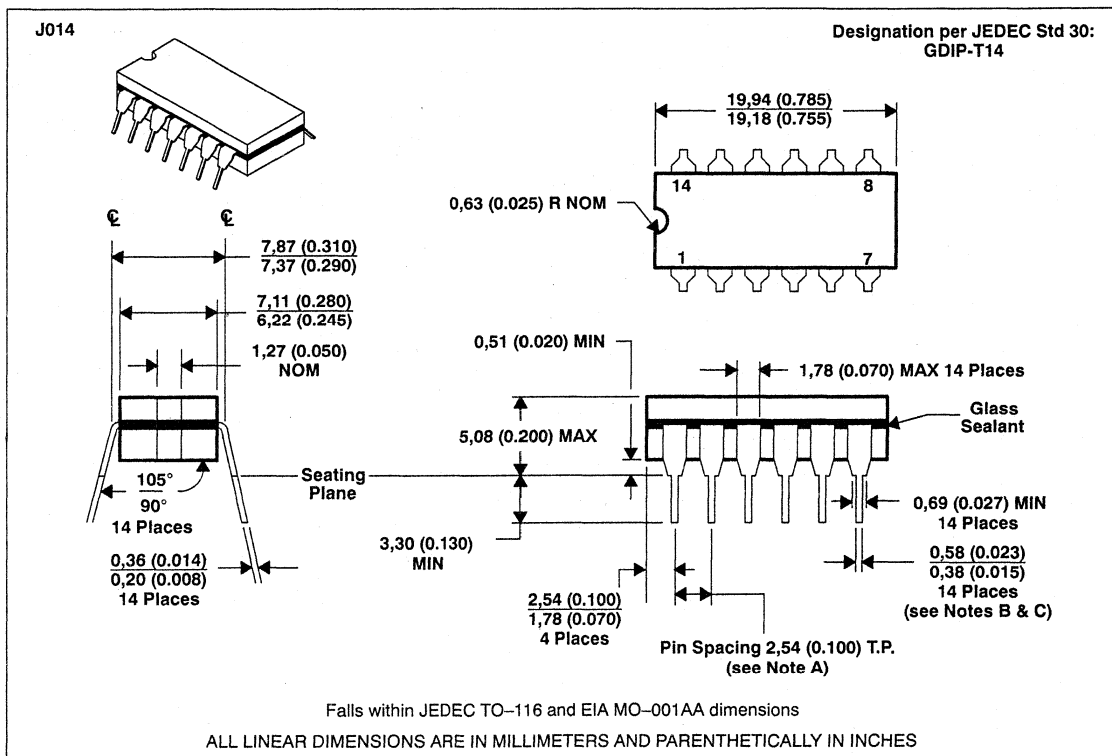
NOTES A: All dimensions conform to JEDEC Specification MO-047AA/AF. Dimensions and tolerancing are per ANSI Y14.5M – 1982.

F: Determined at seating plane - C -.

MECHANICAL DATA

J014 ceramic dual-in-line package

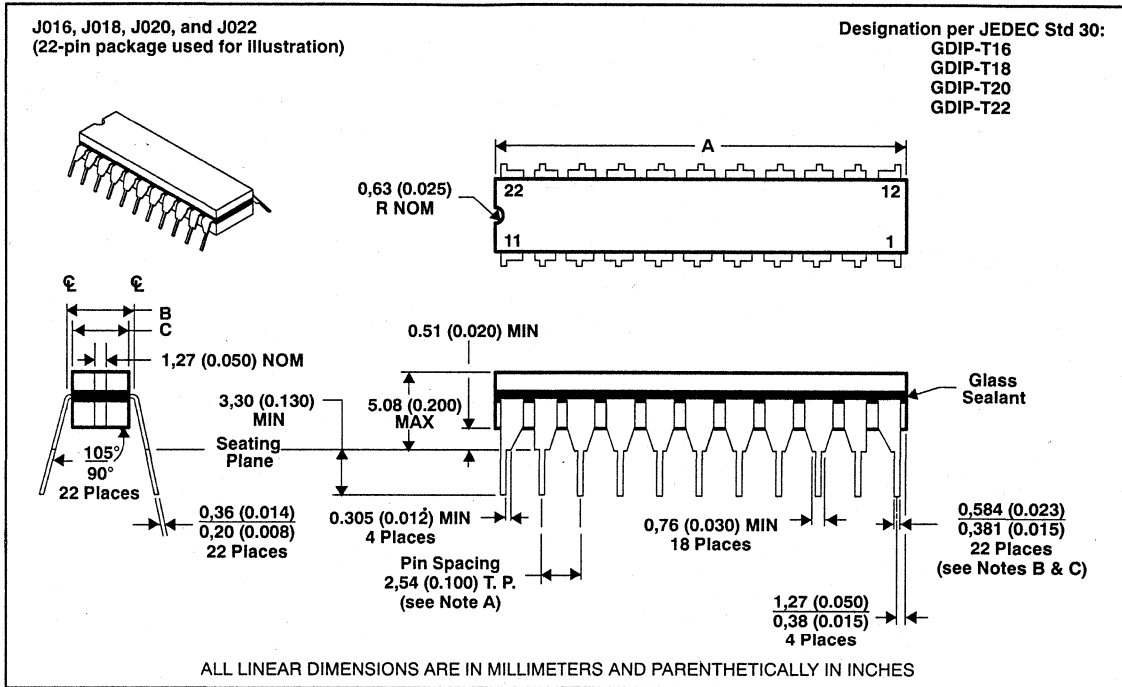
This hermetically sealed dual-in-line package consists of a ceramic base, ceramic cap, and lead frame. Hermetic sealing is accomplished with glass. The package is intended for insertion in mounting hole rows on 7,62 (0.300) centers. Once the leads are compressed and inserted, sufficient tension is provided to secure the package in the board during soldering. Tin-plated ("bright-dipped") leads require no additional cleaning or processing when used in soldered assembly.



- NOTES: A. Each pin centerline is located within 0,25 (0.010) of its true longitudinal position.
 B. This dimension does not apply for solder-dipped leads.
 C. When solder-dipped leads are specified, dipped area of the lead extends from the lead tip to at least 0,51 (0.020) above seating plane.

J016, J018, J020, and J022
ceramic dual-in-line

These hermetically sealed dual-in-line packages consist of a ceramic base, ceramic cap, and a lead frame. Hermetic sealing is accomplished with glass. These packages are intended for insertion in mounting-hole rows of 7,62 (0.300) centers for the J016, J018, J020, and 10,16 (0.400) centers for the J022, respectively. Once the leads are compressed and inserted, sufficient tension is provided to secure the package in the board during soldering. Tin-plated (bright-dipped) leads require no additional cleaning or processing when used in solder assembly.



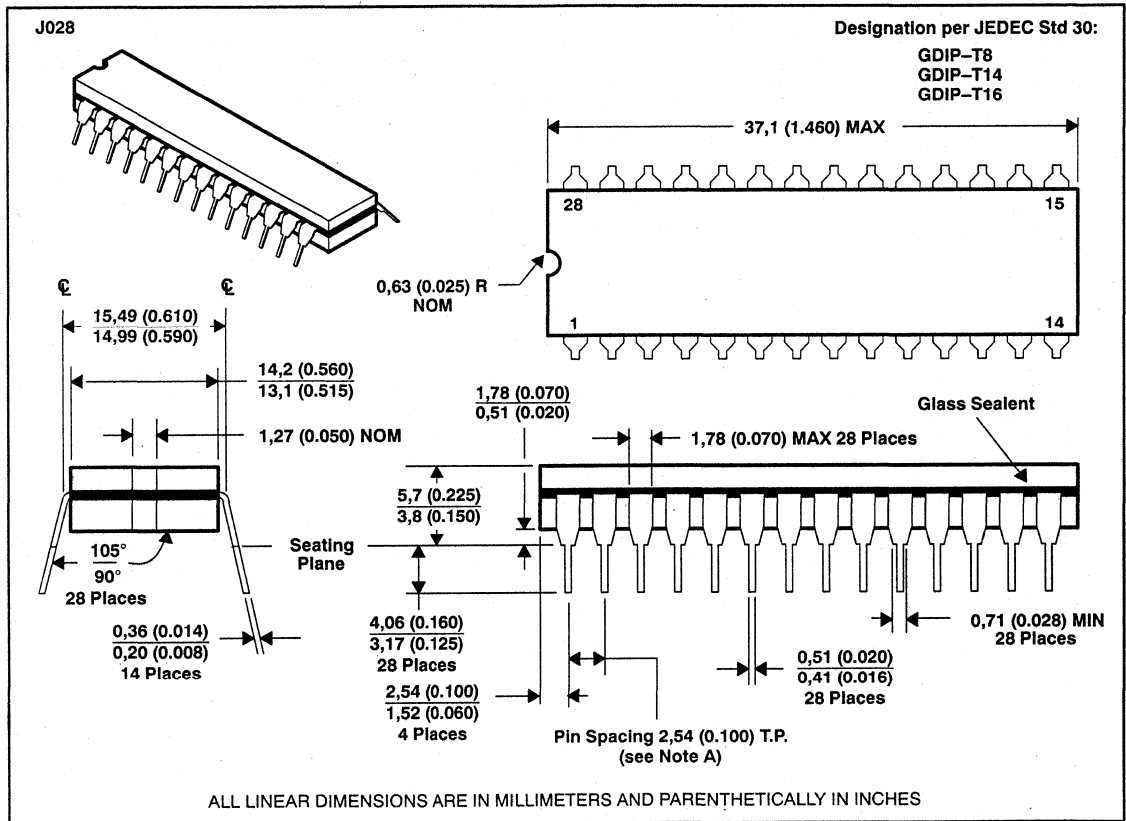
| PINS | DIM | A | | B | | C | |
|------|-----|---------------|---------------|--------------|---------------|--------------|--------------|
| | | MIN | MAX | MIN | MAX | MIN | MAX |
| 16 | | 19,18 (0.755) | 19,94 (0.785) | 7,37 (0.290) | 7,87 (0.310) | 6,22 (0.245) | 7,62 (0.300) |
| 18 | | | 23,1 (0.910) | 7,37 (0.290) | 7,87 (0.310) | 6,22 (0.245) | 7,62 (0.300) |
| 20 | | 23,62 (0.930) | 24,76 (0.975) | 7,37 (0.290) | 7,87 (0.310) | 6,22 (0.245) | 7,62 (0.300) |
| 22 | | | 28,0 (1.100) | 9,91 (0.390) | 10,41 (0.410) | | 9,65 (0.388) |

- NOTES: A. Each pin centerline is located within 0,25 (0.010) of its true longitudinal position.
 B. This dimension does not apply for solder-dipped leads.
 C. When solder-dipped leads are specified, dipped area of the lead extends from the lead tip to at least 0,51 (0.020) above the seating plane.

MECHANICAL DATA

J028 ceramic dual-in-line package

This hermetically sealed dual-in-line package consists of a ceramic base, ceramic cap, and lead frame. Hermetic sealing is accomplished with glass. The package is intended for insertion in mounting hole rows on 15,24 (0.600) centers. Once the leads are compressed and inserted, sufficient tension is provided to secure the package in the board during soldering. Tin-plated ("bright-dipped") leads require no additional cleaning or processing when used in soldered assembly.



NOTES: D. Each pin centerline is located within 0,25 (0.010) of its true longitudinal position.

E. This dimension does not apply for solder-dipped leads.

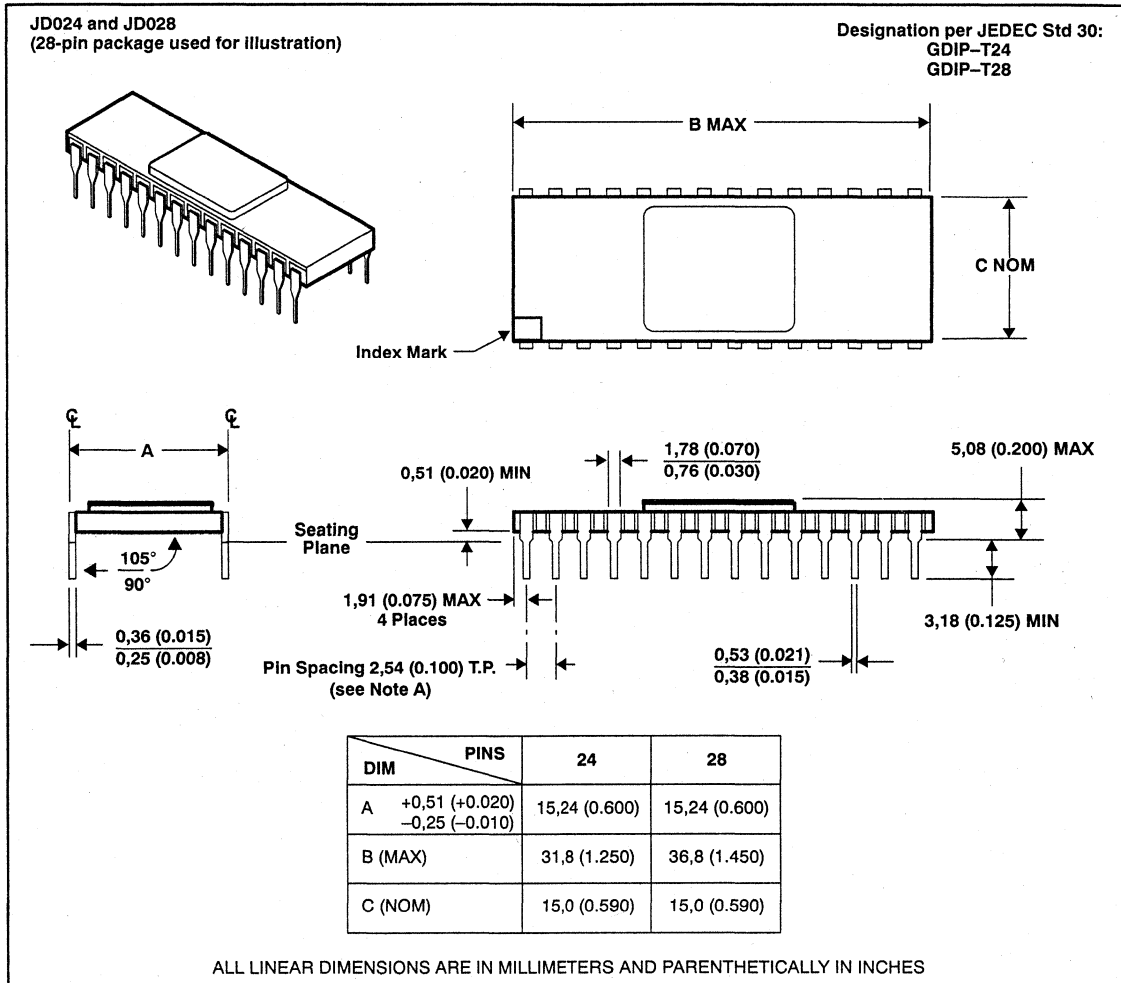
F. When solder-dipped leads are specified, dipped area of the lead extends from the lead tip to at least 0,51 (0.020) above seating plane.

TEXAS
INSTRUMENTS

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JD024 and JD028
ceramic side-braze dual-in-line packages

These hermetically sealed dual-in-line packages consist of a ceramic base, metal cap, and side-brazed tin-plated leads. These packages are intended for insertion in mounting-hole rows of 15,24 (0.600) centers. Leads require no additional cleaning or processing when used in solder assembly.

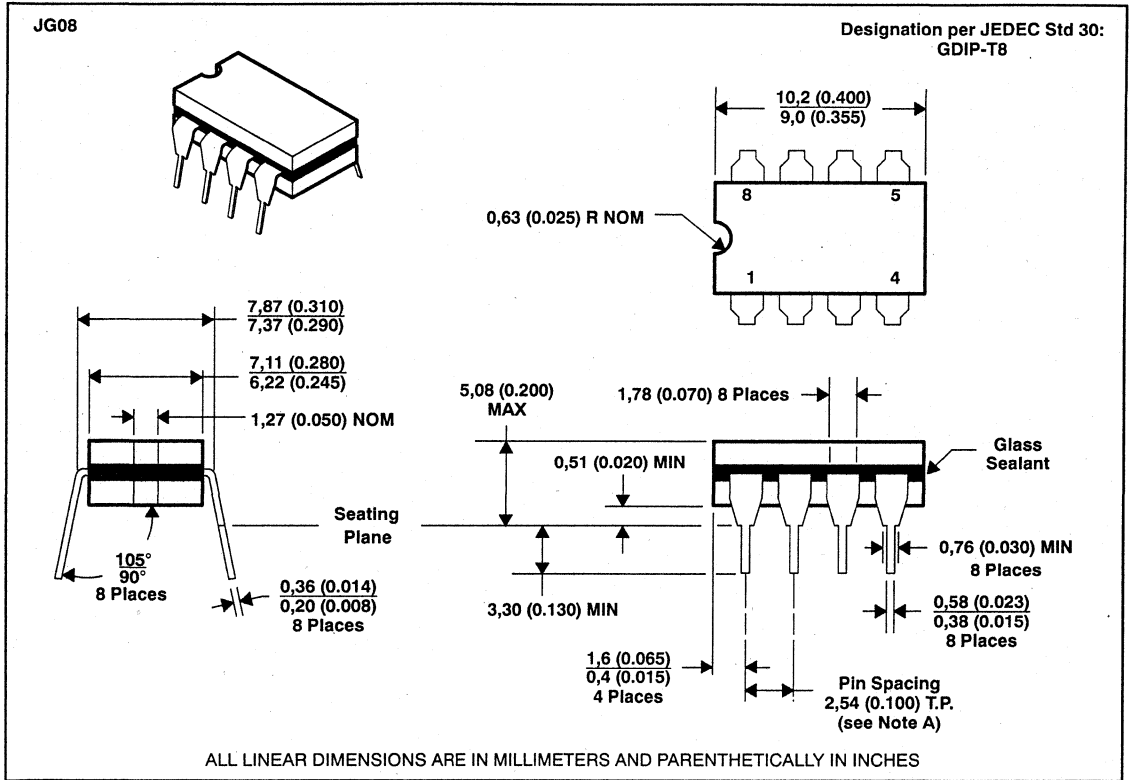


NOTE A: Each pin centerline is located within 0,25 (0.010) of its true longitudinal position.

MECHANICAL DATA

JG008 ceramic dual-in-line package

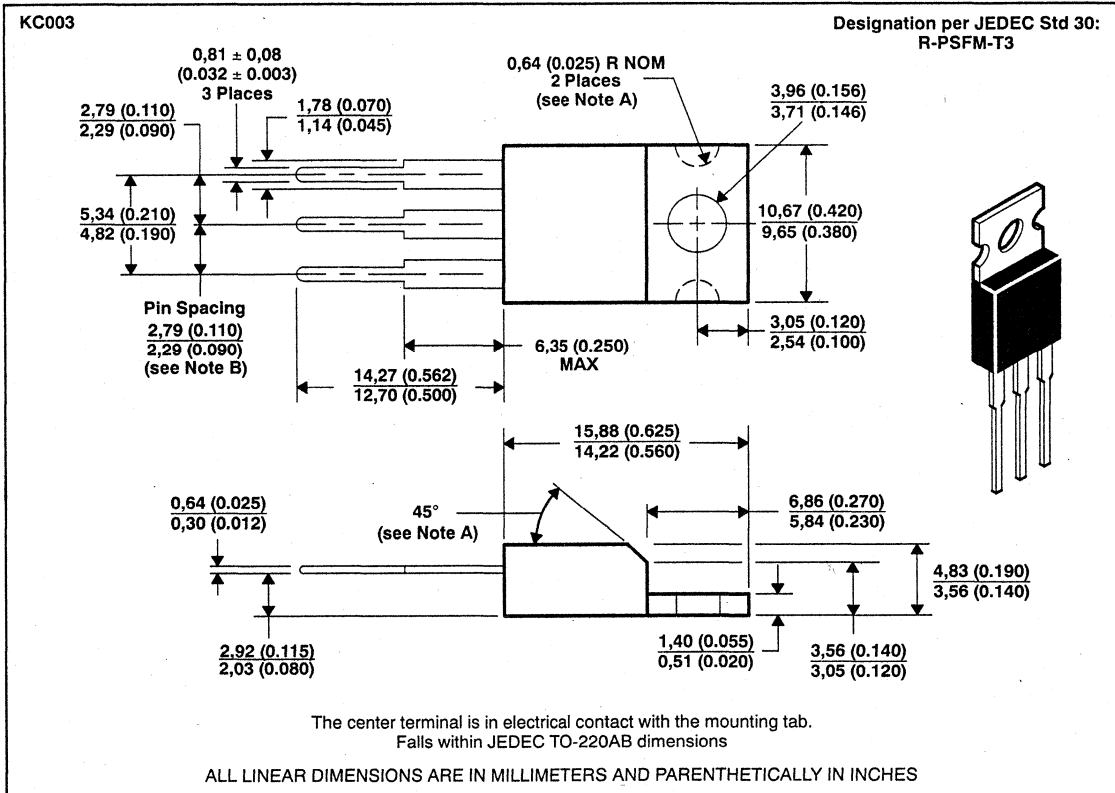
This hermetically sealed dual-in-line package consists of a ceramic base, ceramic cap, and lead frame. Hermetic sealing is accomplished with glass. The package is intended for insertion in mounting hole rows on 7,62 (0.300) centers. Once the leads are compressed and inserted, sufficient tension is provided to secure the package in the board during soldering. Tin-plated ("bright-dipped") leads require no additional cleaning or processing when used in soldered assembly.



NOTE A: Each pin centerline is located within 0,25 (0.010) of its true longitudinal position.

KC003
plastic flange-mount package

This package consists of a circuit mounted on a lead frame and encapsulated within a plastic compound. The compound will withstand soldering temperature with no deformation, and circuit performance characteristics will remain stable when the package is operated under high-humidity conditions.

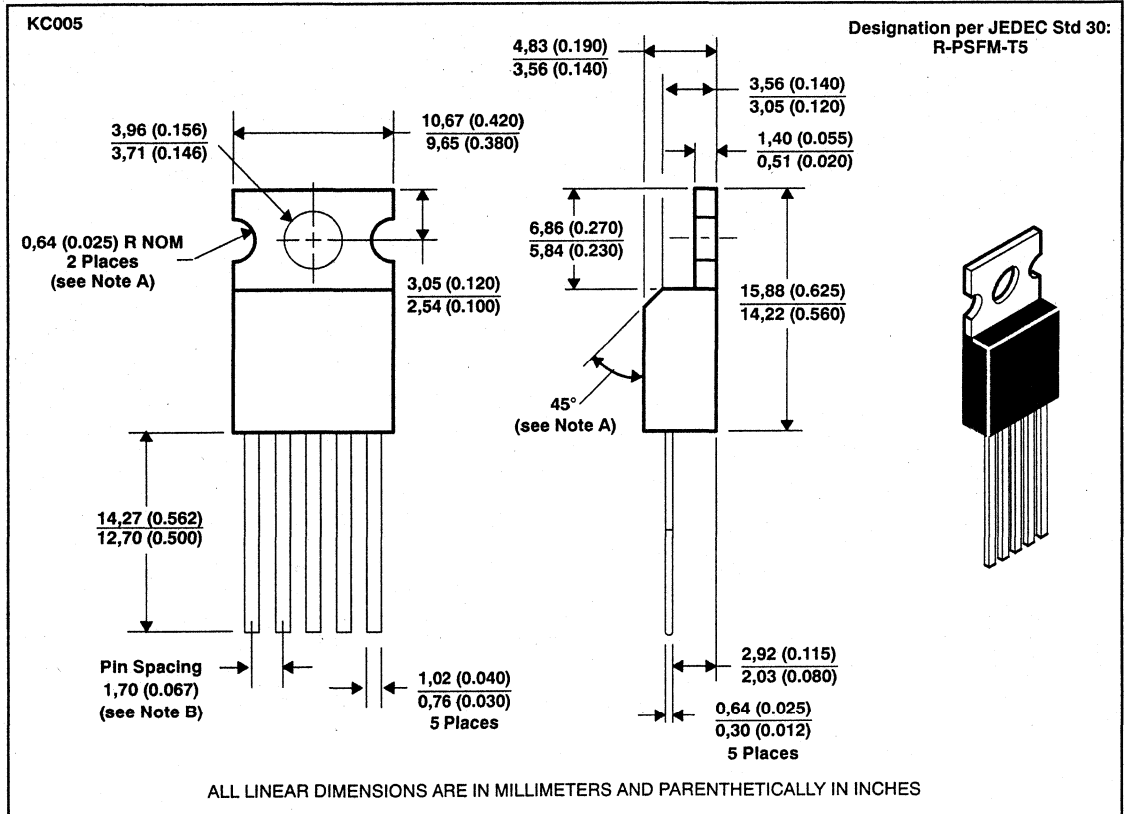


- NOTES: A. Notches and/or mold chamfer may or may not be present.
 B. Leads are within 0,13 (0,005) radius of true position (T.P.) at maximum material conditions.

MECHANICAL DATA

KC005 plastic flange-mount package

This package consists of a circuit mounted on a lead frame and encapsulated within a plastic compound. The compound will withstand soldering temperature with no deformation, and circuit performance characteristics will remain stable when the package is operated under high-humidity conditions.

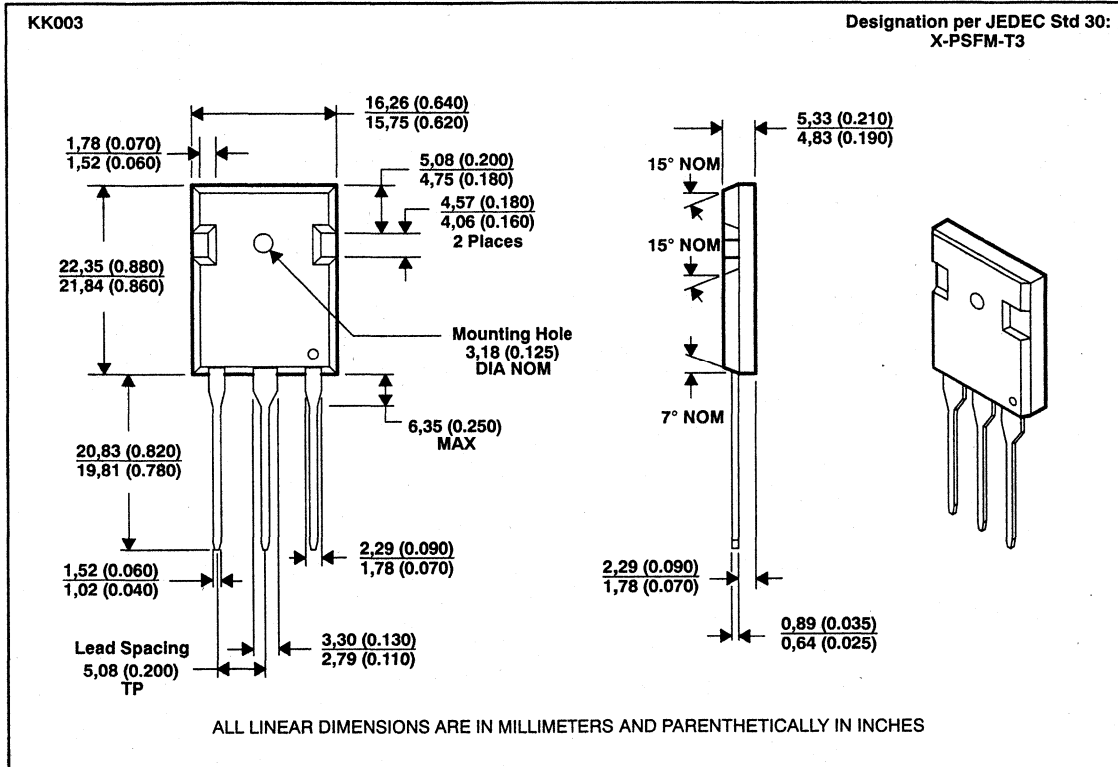


NOTES: A. Notches and chamfer may or may not be present.

B. Leads are with 0,13 (0.005) radius of true position (T.P.) at maximum material conditions.

KK003
plastic flange-mount package

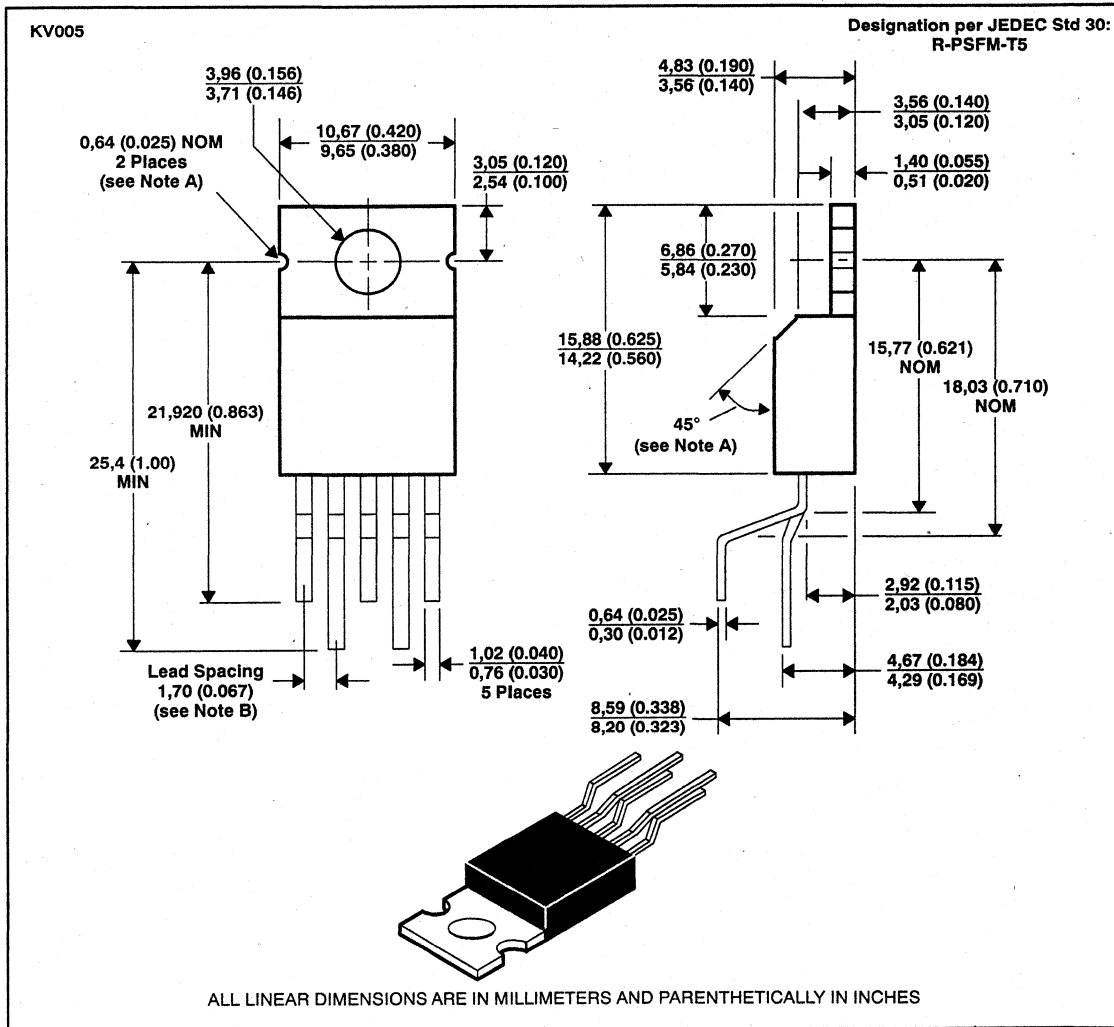
This package consists of a circuit mounted on a lead frame and encapsulated within a plastic compound. The compound will withstand soldering temperature with no deformation, and circuit performance characteristics will remain stable when the package is operated under high-humidity conditions.



MECHANICAL DATA

KV005 plastic flange-mount package

This package consists of a circuit mounted on a lead frame and encapsulated within a plastic compound. The compound will withstand soldering temperature with no deformation, and circuit performance characteristics will remain stable when the package is operated under high-humidity conditions.



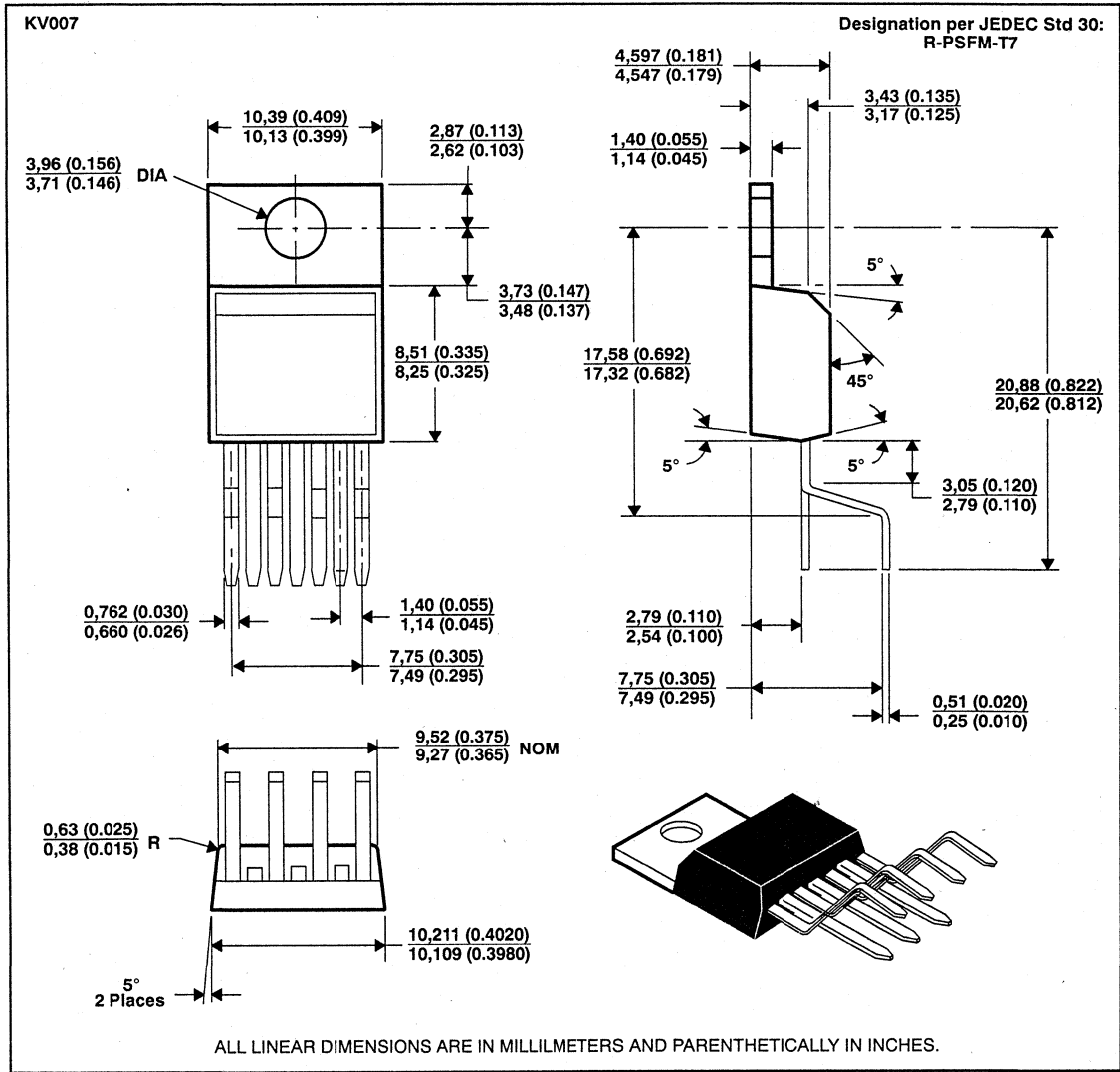
NOTES: A. Notches and chamfer may or may not be present.

B. Leads are with 0,13 (0.005) radius of true position (T.P.) at maximum material conditions.

TEXAS
INSTRUMENTS

KV007 plastic flange-mount package

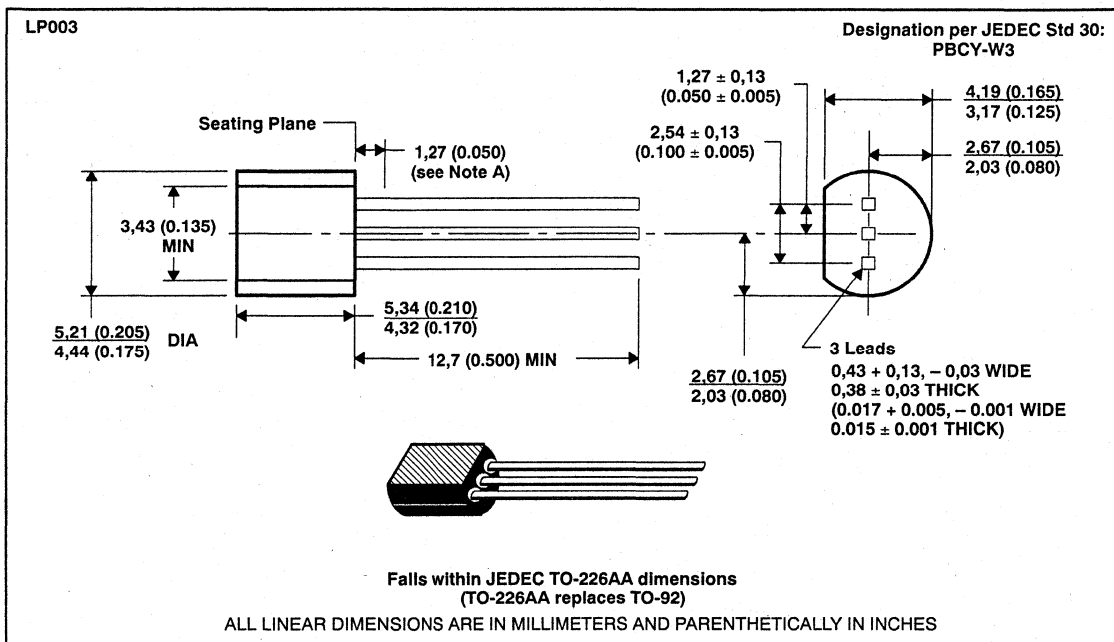
This package consists of a circuit mounted on a lead frame and encapsulated within a plastic compound. The compound will withstand soldering temperature with no deformation, and circuit performance characteristics will remain stable when the package is operated under high-humidity conditions.



MECHANICAL DATA

LP003 plastic cylindrical package

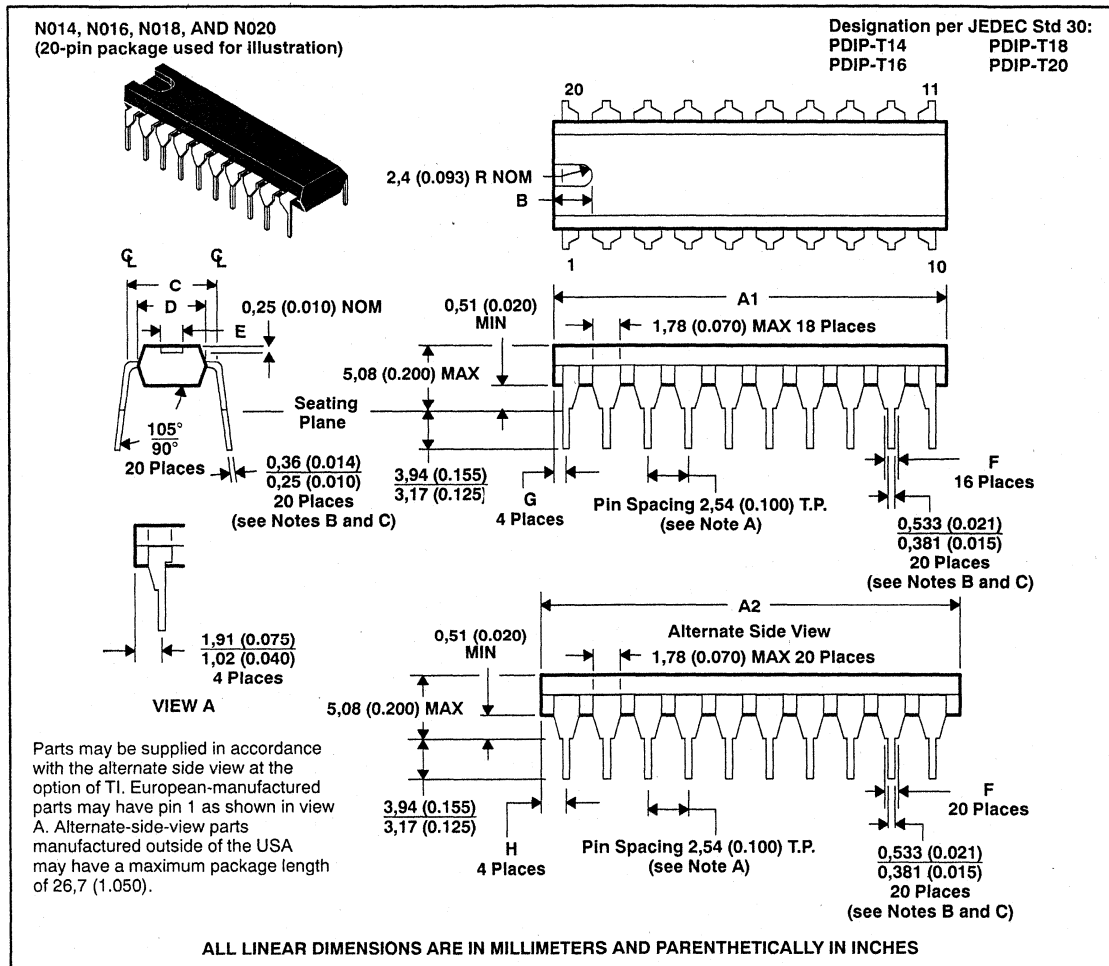
This package consists of a circuit mounted on a lead frame and encapsulated within a plastic compound. The compound will withstand soldering temperature with no deformation and circuit performance characteristics remain stable when operated in high-humidity conditions. Leads require no additional cleaning or processing when used in soldered assembly.



NOTE A: Lead dimensions are not controlled within this area.

N014, N016, N018, and N020
300-mil plastic dual-in-line packages

These dual-in-line packages consist of a circuit mounted on a lead frame and encapsulated within a plastic compound. The compound will withstand soldering temperature with no deformation and circuit performance characteristics will remain stable when operated in high-humidity conditions. These packages are intended for insertion in mounting-hole rows on 7,62 (0.300) centers. Once the leads are compressed and inserted, sufficient tension is provided to secure the package in the board during soldering. Leads require no additional cleaning or processing when used in soldered assembly.



- NOTES: A. Each pin centerline is located within 0,25 (0.010) of its true longitudinal position.
 B. This dimension does not apply for solder-dipped leads.
 C. When solder-dipped leads are specified, dipped area of the lead extends from the lead tip to at least 0,51 (0.020) above seating plane.

MECHANICAL DATA

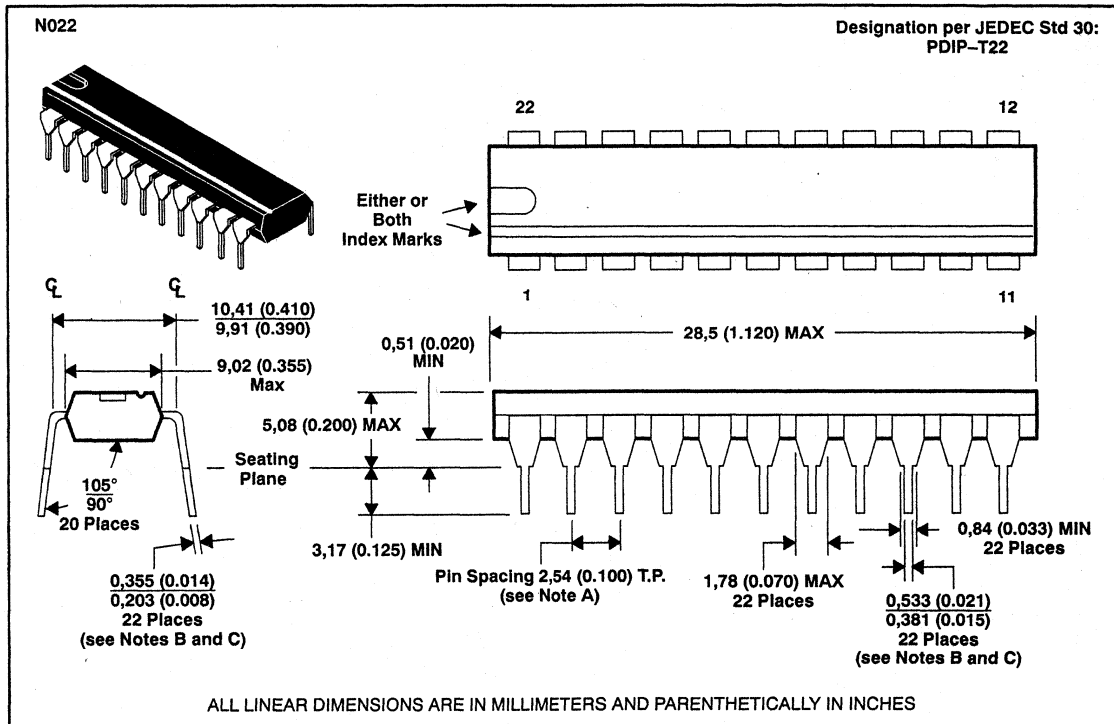
N014, N016, N018, and N020 300-mil plastic dual-in-line package (continued)

| DIM \ PIN | | PIN | | | |
|-----------|-----|--------------|--------------|--------------|---------------|
| | | 14 | 16 | 18 | 20 |
| A1 | MIN | 18,0 (0.710) | | | 23,22 (0.914) |
| | MAX | 19,8 (0.780) | 19,8 (0.780) | 23,4 (0.920) | 24,77 (0.975) |
| A2 | MIN | 18,0 (0.710) | | | 23,62 (0.930) |
| | MAX | 19,8 (0.780) | | | 25,4 (1.000) |
| B | NOM | 2,8 (0.110) | 2,8 (0.110) | 4,06 (0.160) | 2,80 (0.110) |
| C | MIN | 7,37 (0.290) | 7,37 (0.290) | 7,37 (0.290) | 7,37 (0.290) |
| | MAX | 7,87 (0.310) | 7,87 (0.310) | 7,87 (0.310) | 7,87 (0.310) |
| D | MIN | 6,10 (0.240) | 6,10 (0.240) | | 6,60 (0.240) |
| | MAX | 6,60 (0.260) | 6,60 (0.260) | 6,99 (0.275) | 7,11 (0.280) |
| E | NOM | 2,0 (0.080) | 2,0 (0.080) | 2,03 (0.080) | 2,0 (0.080) |
| F | MIN | 0,84 (0.033) | 0,84 (0.033) | 0,89 (0.035) | 0,84 (0.033) |
| G | MIN | (see Note A) | 0,38 (0.015) | (See Note A) | 1,68 (0.066) |
| | MAX | (see Note A) | 1,65 (0.065) | (see Note A) | 0,22 (0.009) |
| H | MIN | 2,54 (0.100) | 1,02 (0.040) | 0,23 (0.009) | 0,38 (0.015) |
| | MAX | 1,52 (0.060) | 2,41 (0.095) | 1,91 (0.075) | 1,27 (0.050) |

NOTES: A. The 14-pin and 18-pin plastic dual-in-line package is only offered with the external pins shaped in their entirety, and do not have alternate side view dimensions.

N022
400-mil plastic dual-in-line package

This dual-in-line package consist of a circuit mounted on a lead frame and encapsulated within a plastic compound. The compound will withstand soldering temperature with no deformation and circuit performance characteristics will remain stable when operated in high-humidity conditions. This package is intended for insertion in mounting-hole rows on 10,16 (0.400) centers . Once the leads are compressed and inserted, sufficient tension is provided to secure the package in the board during soldering. Leads require no additional cleaning or processing when used in soldered assembly.

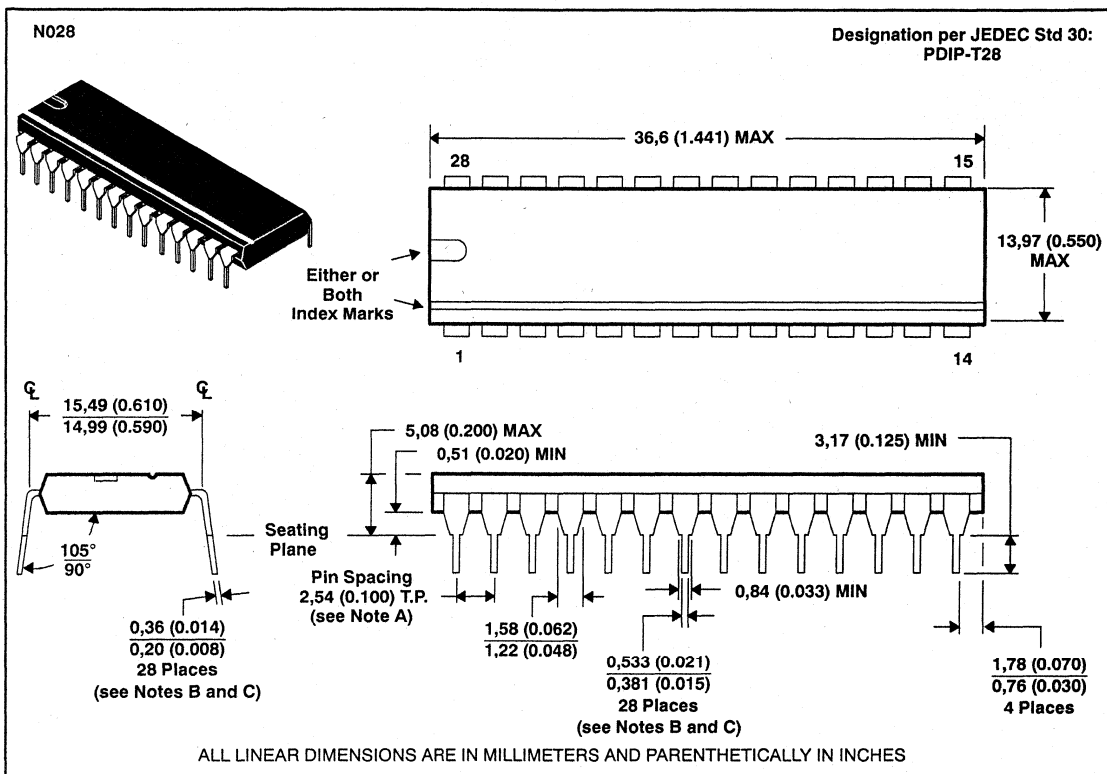


- NOTES: B. Each pin centerline is located within 0,25 (0.010) of its true longitudinal position.
 C. This dimension does not apply for solder-dipped leads.
 D. When solder-dipped leads are specified, dipped area of the lead extends from the lead tip to at least 0,51 (0.020) above seating plane.

MECHANICAL DATA

N028 600-mil plastic dual-in-line package

This dual-in-line package consists of a circuit mounted on a lead frame and encapsulated within a plastic compound. The compound will withstand soldering temperature with no deformation and circuit performance characteristics will remain stable when operated in high-humidity conditions. This package is intended for insertion in mounting-hole rows on 15,24 (0.600) centers (see Note A). Once the leads are compressed and inserted, sufficient tension is provided to secure the package in the board during soldering. Leads require no additional cleaning or processing when used in soldered assembly.



NOTES: A. Each pin centerline is located within 0,25 (0.010) of its true longitudinal position.

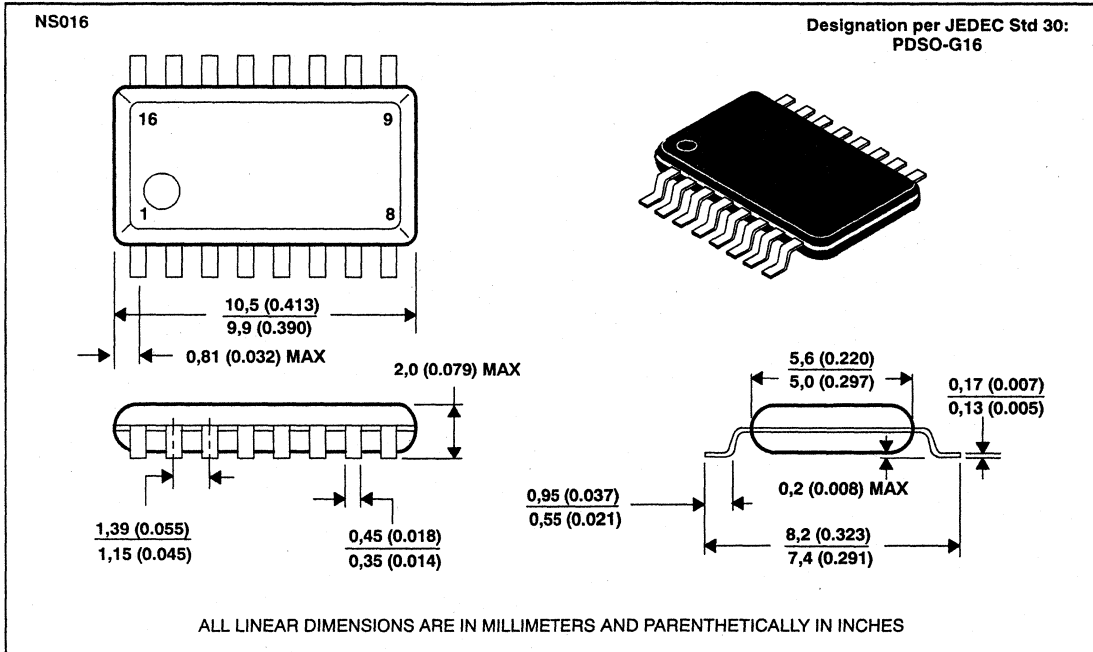
B. This dimension does not apply for solder-dipped leads.

C. When solder-dipped leads are specified, dipped area of the lead extends from the lead tip to at least 0,51 (0.020) above seating plane.

TEXAS
INSTRUMENTS

NS016
plastic package

This package consists of a circuit mounted on a lead frame and encapsulated within a plastic compound. The compound withstands soldering temperature with no deformation, and circuit performance characteristics remain stable when operated in high-humidity conditions. Leads require no additional cleaning or processing when used in soldered assembly.



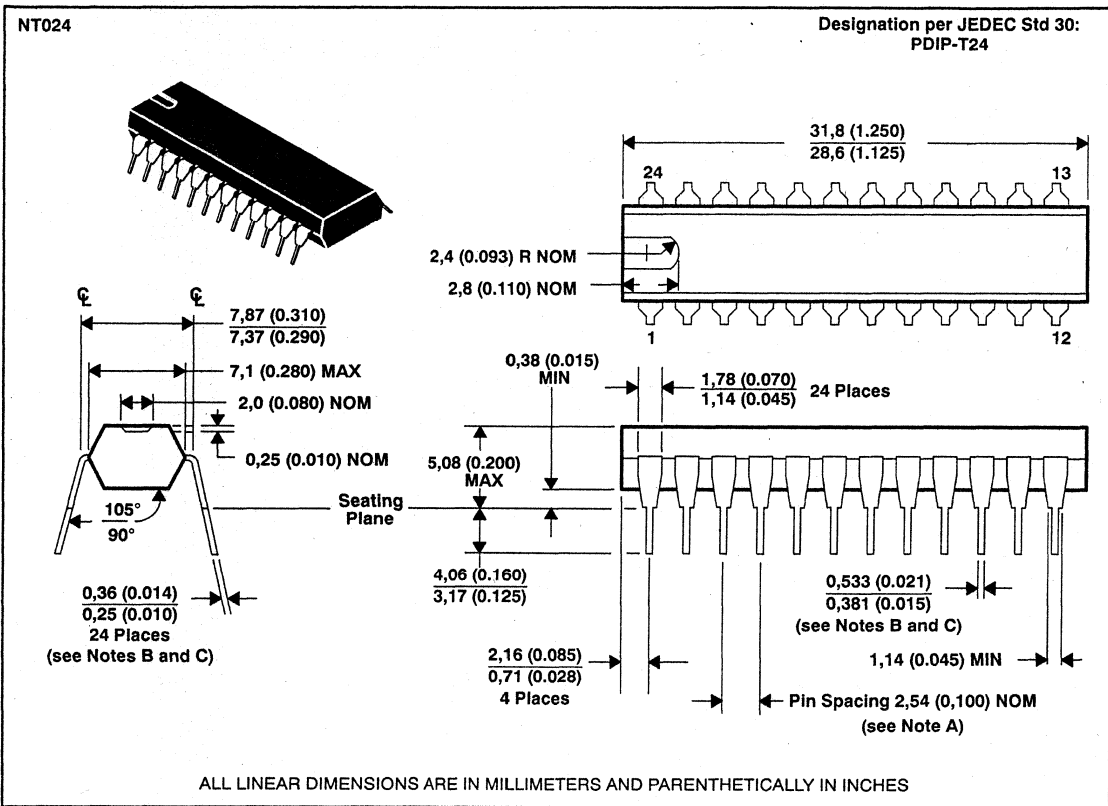
MECHANICAL DATA

NT024

300-mil plastic dual-in-line packages

This package consists of a circuit mounted on a lead frame and encapsulated within a plastic compound. The compound will withstand soldering temperature with no deformation and circuit performance characteristics will remain stable when operated in high-humidity conditions. This package is intended for insertion in mounting-hole rows on 7,62 (0.300) centers. Once the leads are compressed and inserted, sufficient tension is provided to secure the package in the board during soldering. Leads require no additional cleaning or processing when used in soldered assembly.

NOTE: For all except 24-pin package, the letter N is used by itself since the 24-pin package may be available in more than one row-spacing. For the 24-pin package, the 7,62 (0.300) version is designated NT; the 15,24 (0.600) version is designated NW. If no second letter or row-spacing is specified, the package is assumed to have 15,24 (0.600) row-spacing.



NOTES: A. Each pin centerline is located within 0,25 (0.010) of its true longitudinal position.

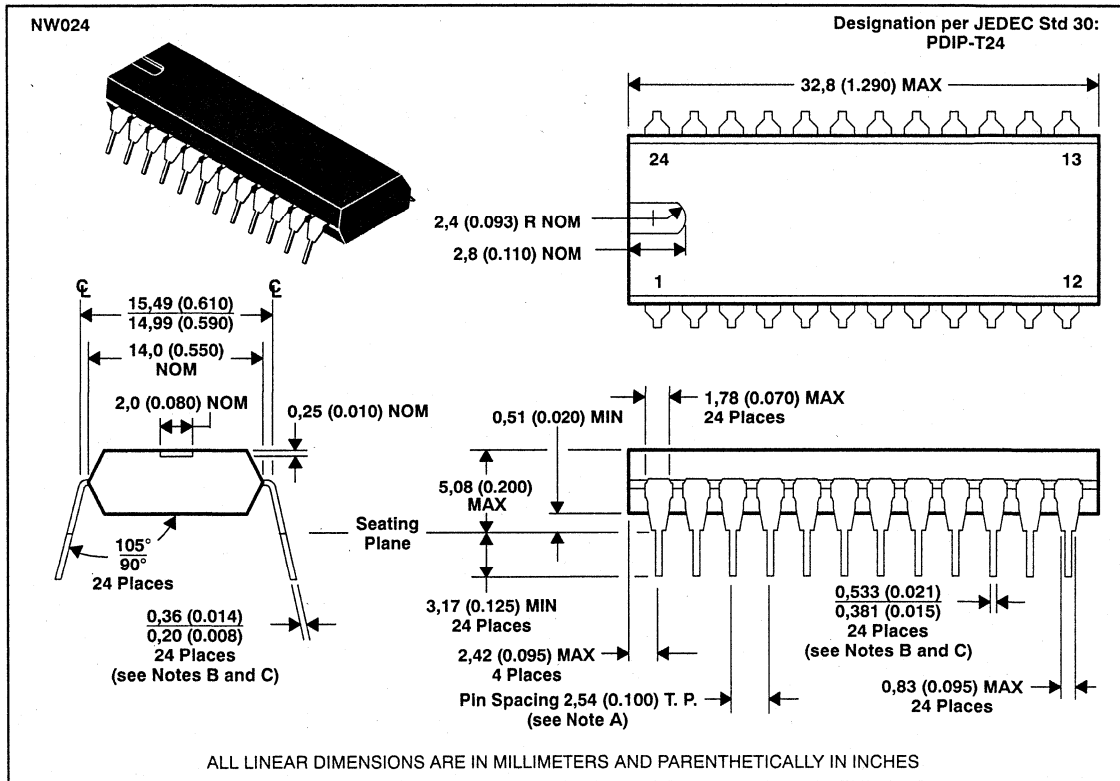
B. This dimension does not apply for solder-dipped leads.

C. When solder-dipped leads are specified, dipped area of the lead extends from the lead tip to at least 0,51 (0.020) above seating plane.

NW024
600-mil plastic dual-in-line package

This dual-in-line package consist of a circuit mounted on a lead frame and encapsulated within a plastic compound. The compound will withstand soldering temperature with no deformation and circuit performance characteristics will remain stable when operated in high-humidity conditions. This package is intended for insertion in mounting-hole rows on 15,24 (0.600) centers. Once the leads are compressed and inserted, sufficient tension is provided to secure the package in the board during soldering. Leads require no additional cleaning or processing when used in soldered assembly.

NOTE: For all except 24-pin packages, the letter N is used by itself since only the 24-pin package is available in more than one row-spacing. For the 24-pin package, the 7,62 (0.300) version is designated NT; the 15,24 (0.600) version is designated NW. If no second letter or row-spacing is specified, the package is assumed to have 15,24 (0.600) row-spacing.

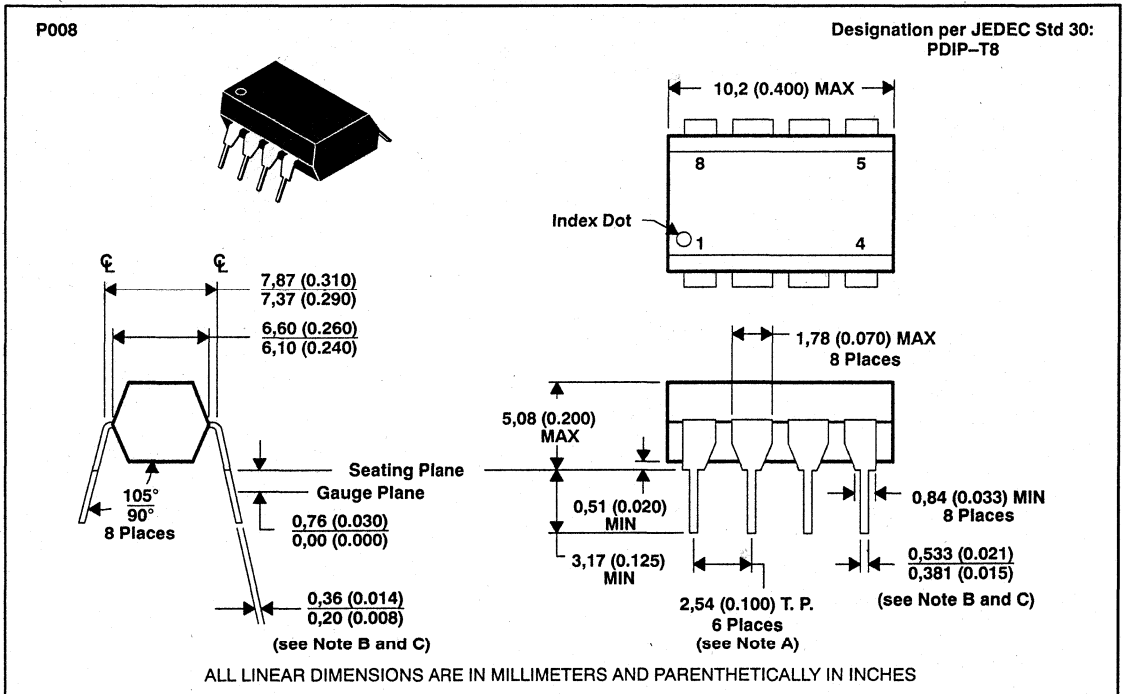


- NOTES: A. Each pin centerline is located within 0,25 (0.010) of its true longitudinal position.
 B. This dimension does not apply for solder-dipped leads.
 C. When solder-dipped leads are specified, dipped area of the lead extends from the lead tip to at least 0,51 (0.020) above seating plane.

MECHANICAL DATA

P008 plastic dual-in-line package

This package consists of a circuit mounted on an 8-pin lead frame and encapsulated within a plastic compound. The compound will withstand soldering temperature with no deformation, and circuit performance characteristics will remain stable when operated in high-humidity conditions. The package is intended for insertion in mounting-hole rows on 7,62 (0.300) centers. Once the leads are compressed and inserted, sufficient tension is provided to secure the package in the board during soldering. Solder-plated lead require no additional cleaning or processing when used in soldered assembly.



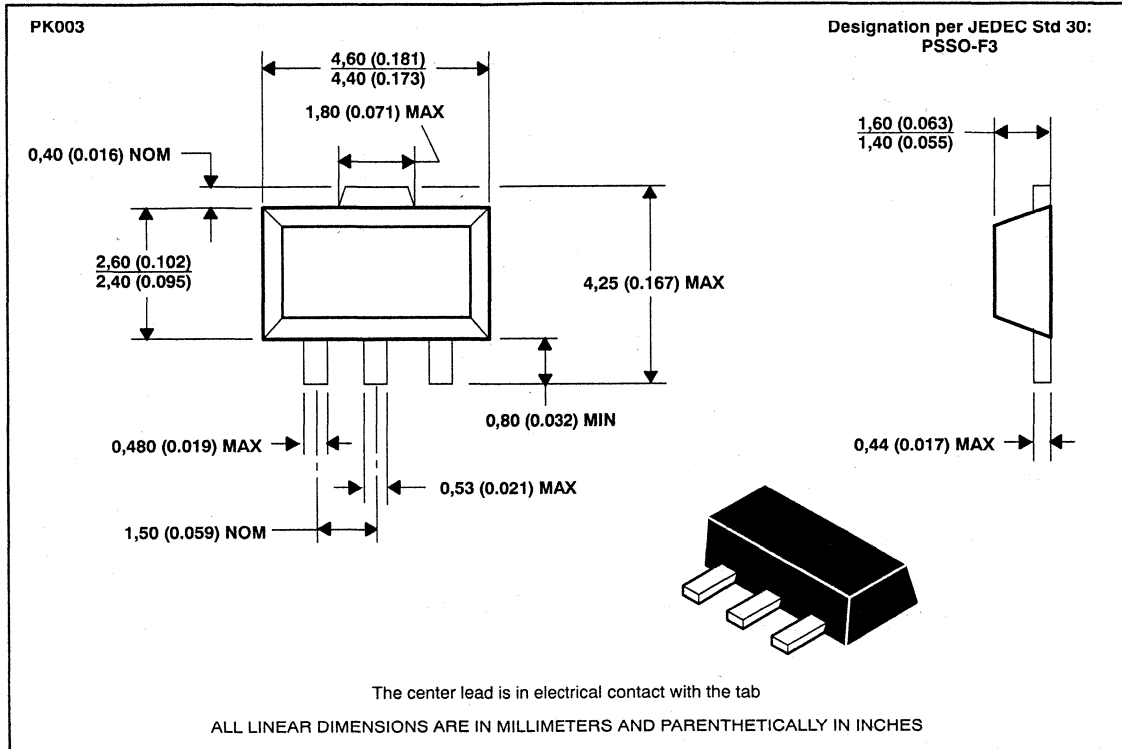
NOTES: A. Each pin centerline is located within 0,25 (0.010) of its true longitudinal position.

B. This dimension does not apply for solder-dipped leads.

C. When solder-dipped leads are specified, dipped area of the lead extends from the lead tip to at least 0,51 (0.020) above seating plane.

PK003
plastic lead-mount package

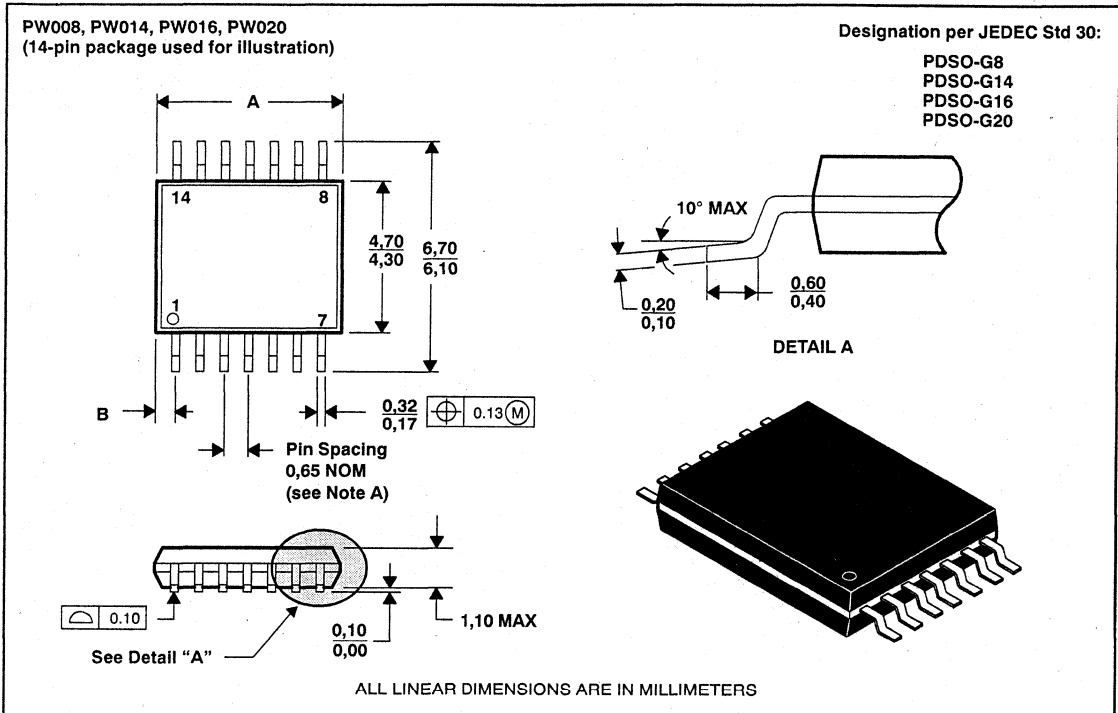
This package consists of a circuit mounted on a lead frame and encapsulated within a plastic compound. The compound will withstand soldering temperature with no deformation, and circuit performance characteristics will remain stable when operated in high-humidity conditions.



MECHANICAL DATA

PW008, PW014, PW016, PW020 shrink small-outline packages

These shrink small-outline packages consist of a circuit mounted on a lead frame and encapsulated within a plastic compound. The compound will withstand soldering temperature with no deformation, and circuit performance characteristics will remain stable when operated in high-humidity conditions. Leads require no additional cleaning or processing when used in soldered assembly.

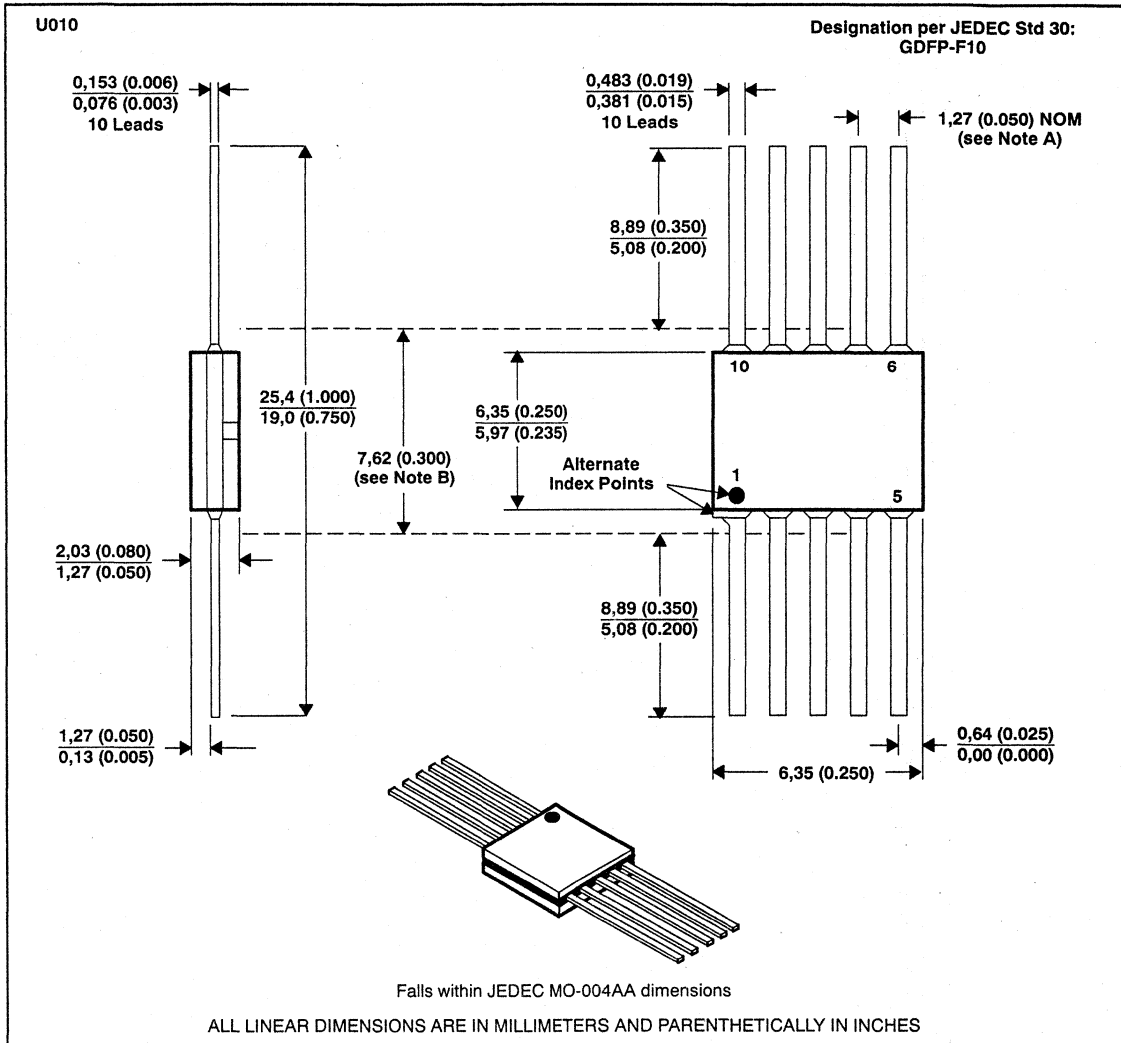


- NOTES: A. Leads are within 0,25 mm radius of true position at maximum material condition.
B. Body dimensions include mold flash or protrusion.
C. Mold flash or protrusion shall not exceed 0,15 mm.
D. Lead tips to be planar within $\pm 0,051$ mm exclusive of of solder.

| DIM | PINS | 8 | 14 | 16 | 20 |
|-------|-------|------|------|------|------|
| | A MIN | | 2,99 | 4,99 | 4,99 |
| A MAX | | 3,03 | 5,30 | 5,30 | 6,80 |
| B MAX | | 0,65 | 0,70 | 0,38 | 0,48 |

U010
ceramic flat package

This flat package consists of a ceramic base, ceramic cap, and lead frame. Circuit bars are alloy mounted. Hermetic sealing is accomplished with glass. Leads require no additional cleaning or processing when used in soldered assembly.

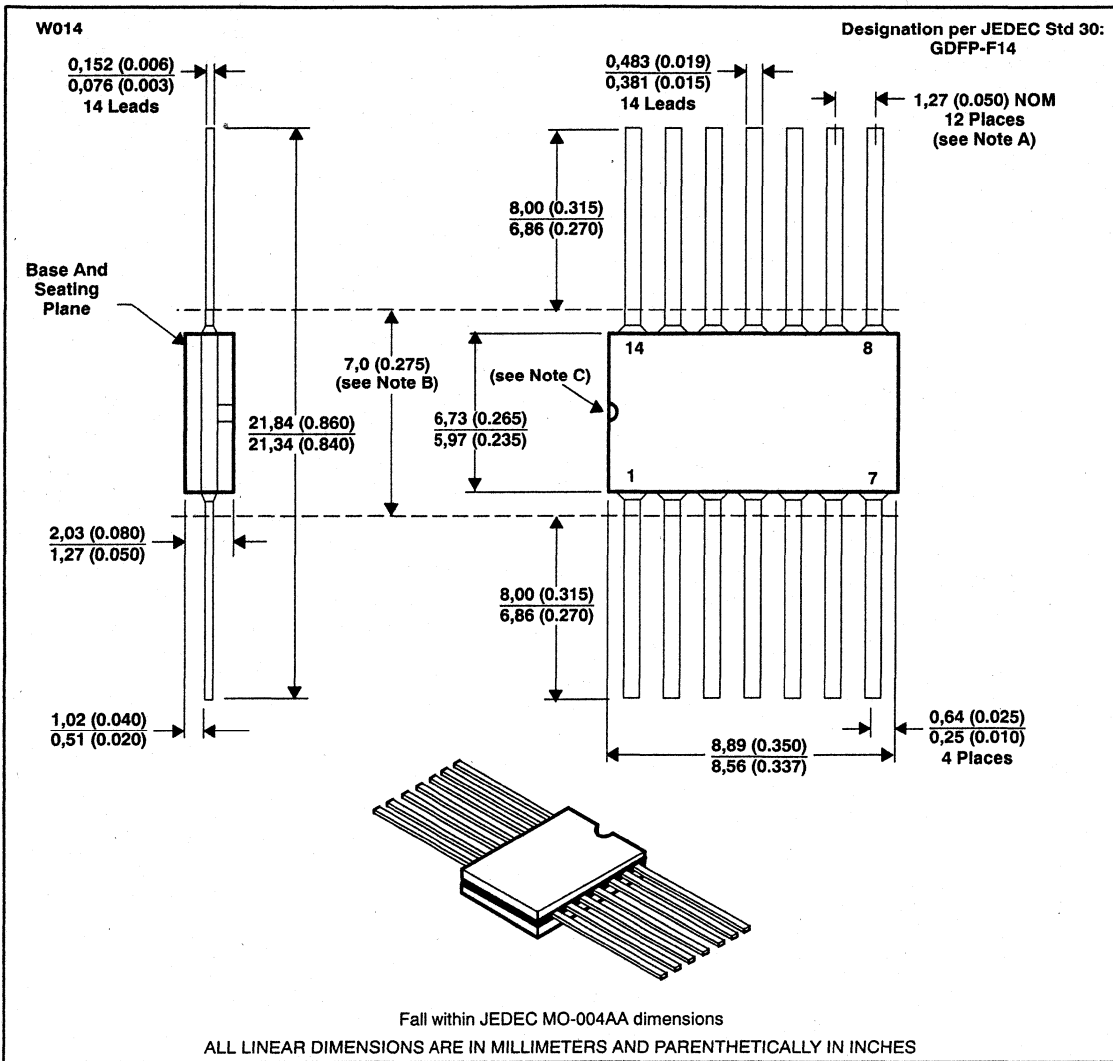


NOTES: A. Leads are within 0,13 (0.005) radius of true position (T.P.) at maximum material conditions.
B. This dimension determines a zone within which all body and lead irregularities lie.

MECHANICAL DATA

W014 ceramic flat package

This hermetically sealed flat package consists of an electrically nonconductive ceramic base and cap and a lead frame. Hermetic sealing is accomplished with glass. Leads require no additional cleaning or processing when used in soldered assembly.



NOTES: A. Leads are within 0,13 (0.005) radius of true position (T.P.) at maximum material condition.

B. This dimension determines a zone within which all body and lead irregularities lie.

C. Index point is provided on cap for terminal identification only.

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