GS-R MODULES
Application Manual

2nd EDITION

MARCH 1987

SGS® Systems Division

SGS IN THE WORLD

SGS Systems Division

IDENTITY

Late in 1957, SGS was founded around a team of researchers who were already carrying out pioneer work in the field of semiconductors. From that small nucleus, the company has evolved into a Group of Companies, operating on a worldwide basis as a broad range semiconductor producer, with billings over 300 million dollars and employing over 9500 people.

The SGS Group of Companies has now reached a total of 11 subsidiaries, located in Brazil, France, Germany, Italy, Malta, Malaysia, Singapore, Sweden, Switzerland, United Kingdom and the USA.

To go with its logo, the company takes the motto "Technology and Service", underlining the accent given to the development of state-of-the-art technologies and the corporate commitment to offer customers the best quality and service in the industry.

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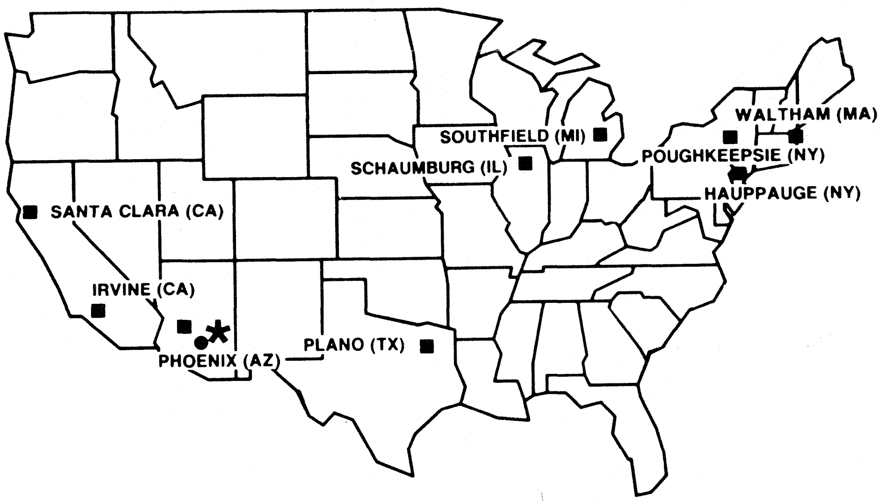

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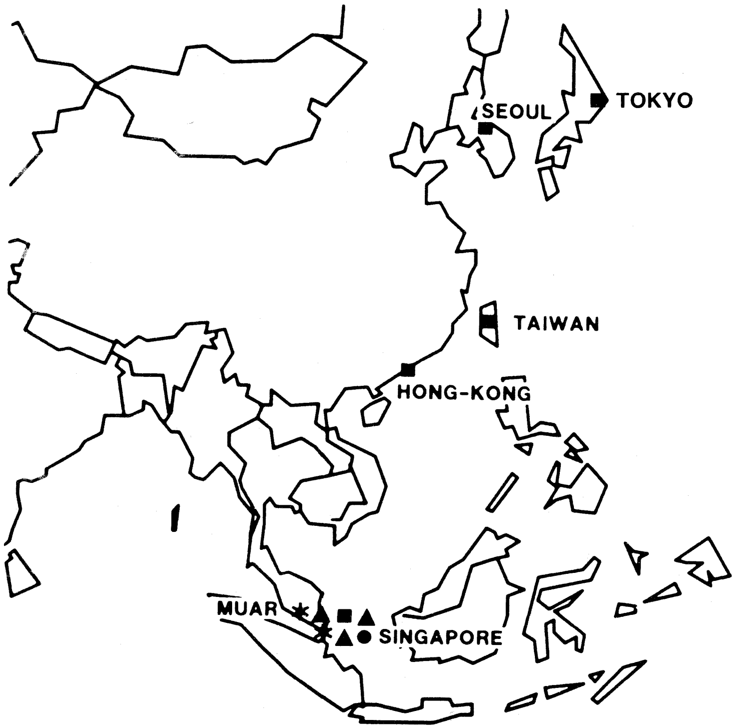

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GS-R MODULES APPLICATIONS

by
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SGS Systems Division

THE APPLICATIONS OF THE GS-R MODULES

The GS-R modules are switch mode voltage regulators designed and manufactured by the SGS-Systems Division.
Electrical characteristics of these modules are fully described on the relevant data sheet.
Even if voltage regulators are designed for a very specific function i.e. voltage regulation, they can be used for many other applications such as:

- ON-OFF temperature controller
- Proportional temperature controller
- DC Motor control
- DC Motor control with tachofeedback
- Battery charger
  etc.

In the following pages, 18 applications based on GS-R family are shortly described.

GS-R APPLICATIONS LIST

1. Design of 50/60 Hz input transformer, rectifying bridge and capacitor
2. How to choose a protecting fuse
3. Heat-sink calculations and examples
4. Additional output filtering
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6. Preregulator for distributed power supply
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12. Power supply with adjustable output voltage, adjustable output current
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14. On-off temperature controller
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16. DC motor control
17. DC motor control with tachofeedback
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1. DESIGN OF 50/60 HZ INPUT TRANSFORMER, RECTIFYING BRIDGE AND FILTER CAPACITOR

One of the most common applications of GS-R modules is the power supply driven by the mains through a 50/60 Hz transformer, followed by a rectifying bridge of diodes and the filter capacitor as shown in fig. 1.

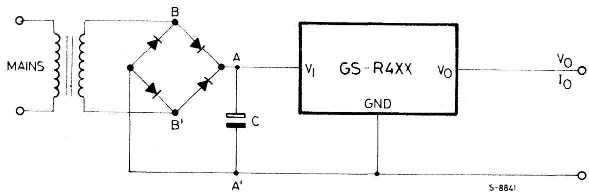


Fig. 1 - Mains Derived Power Supply

The design of this application is described, step by step in the following.

DEFINITIONS

C	= Filter capacitor value
f	= Input AC voltage frequency : 50/60 Hz
I_O	= Output current
$I_{F(AV)}$	= Rectifying diodes average forward current
$I_{F(pk)}$	= Rectifying diodes peak current
$I_{F(RMS)}$	= Rectifying diodes RMS current
$I_{i(DC)}$	= Regulator average input current
I_{SEC}	= RMS value of current on B-B'
I_{SURGE}	= Surge current through diodes at switch on
P_O	= Output power
r_f	= Ratio of RMS ripple voltage to DC average voltage on point A
R_L	= Equivalent load across points A-A'
R_S	= Equivalent series resistance of transformer + rectifying bridge
VA	= Product of RMS value of voltage and current on point B-B'
$V_{i(DC)}$	= Nominal average voltage on point A-A'
$V_{i(pk)max}$	= Maximum voltage on point A-A'
$V_{i(pk)min}$	= Minimum voltage on point A-A'
V_{ripple}	= Peak to peak value of ripple voltage on A-A'
V_{SEC}	= RMS value of AC voltage on B-B'
η	= Efficiency of the switching mode voltage regulator

As an example, we will consider a GS-R51212 application and the relative design conditions:

5V / 3,5A
+12V / 0,1A
−12V / 0,1A

Maximum output ripple voltage: 30mVpp at 50/60 Hz. Total output power Po = 20W.

The design of this application is described, step by step in the following.

1. Fix the maximum and minimum voltage across A-A'. From GS-R51212 data sheet we choose:

$$V_{ipk\ max} = 40V \qquad V_{ipk\ min} = 20V.$$

This guarantees wide input voltage variations, safe operations ($V_{ipk\ max} = 40V$) and optimum efficiency ($V_{ipk\ min} = 20V$).

2. Calculate the nominal average DC voltage $V_{i(DC)}$ on A-A' that will correspond to the nominal value of the AC main. To allow simmetrical variation (above and below the nominal value), $V_{i(DC)}$ must be at the middle of the input voltage range:

$$V_{i(DC)} = \frac{V_{ipkmax} - V_{ipkmin}}{2} + V_{ipkmin} = \frac{40\text{-}20}{2} + 20 = 30V$$

3. By assuming a mains variation of +/−15% of nominal AC value, let's calculate the maximum allowed input voltage acceptable under nominal conditions:

$$V_{i(pk)nom} = V_{i(pk)max} - 15\% = 40 - 15\% = 34V.$$

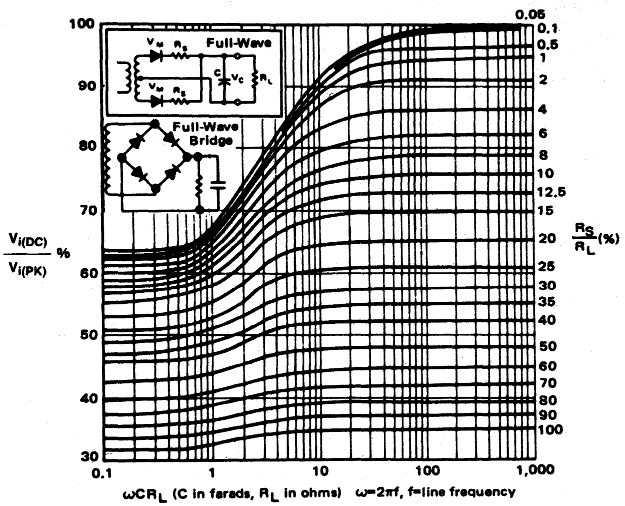


Fig. 2 - Input Voltage (DC/pk) Ratio for Full Wave Rectifier

4. Let's calculate:

$$\frac{V_{i(DC)}}{V_{i(pk)nom}} = \frac{30}{34} = 0,88.$$

5. From the graph of fig. 2 for $\frac{V_{i(DC)}}{V_{i(pk)}} = 0,88$ you get:

$$\omega CR_L = 10 \qquad \frac{R_S}{R_L} = 2\%$$

6. Let's calculate R_L. The equivalent load resistance as seen from point A-A' is:

$$R_L = \frac{\eta \bullet V^2_{i(DC)}}{P_o} = \frac{0,75 \bullet 30^2}{20} = 33,75$$

$\eta = 0,75$ is derived from GS-R51212 data sheet.

7. Let's calculate C and R_S

$$C = \frac{10}{2\pi f\ R_L} = \frac{10}{2\pi \bullet 50 \bullet 33,75} = 943\ \mu F$$

$$R_S = 0,02\ R_L = 0,02 \bullet 33,75 = 0,67\ \Omega.$$

To take into account the spread of commercially available capacitors, the value of C is increased i.e. 1500 μF/50V.

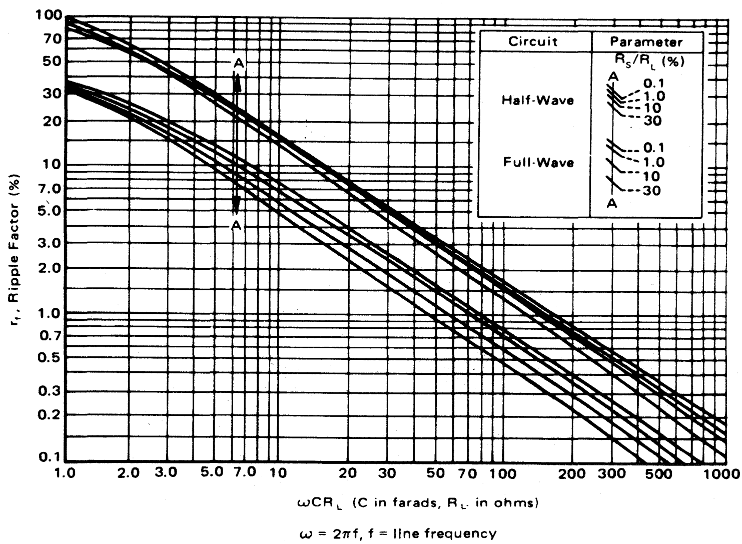


Fig. 3 - Ripple Voltage Vs. Input Capacitance and R_S/R_L

8. Let's calculate the ripple voltage obtained with $\omega CR_L = 10$ and $\frac{R_s}{R_L} = 0,02$ from graph of fig. 3

$$r_f = \frac{V_{ripple\ RMS}}{V_{i(DC)}} = 7\%$$

Therefore

$$V_{ripple} = 2\sqrt{2} \cdot V_{i(DC)} \cdot 0,07 = 5,94\ V_{pp}.$$

9. Let's calculate the output ripple voltage at 5V. From GS-R51212 data sheet, SVR (Supply Voltage Rejection) = 50 dB = 316.

$$V_{ripple\ out} = \frac{5,94}{316} = 18,8\ mVpp.$$

This value is lower than the design data (30mVpp).

10. Let's verify maximum and minimum voltage on A-A' for various AC line conditions. The maximum and minimum values are given by:

$$V_{i(pk)max} = \left(V_{i(DC)} + \frac{1}{2} V_{ripple} \right) \cdot 1,15 = 38V$$

$$V_{i(pk)min} = \left(V_{i(DC)} - \frac{1}{2} V_{ripple} \right) \cdot 0,85 = 23V$$

The extreme values (38V and 23V) are within the design limits (40V and 20V).

11. Let's calculate the secondary nominal RMS voltage on B-B'

$$V_{SEC} = \frac{V_{i(pk)nom} + 1,5}{\sqrt{2}} = \frac{33,0 + 1,5}{\sqrt{2}} = 24,4V.$$

1,5V takes into account the voltage drop on rectifying diodes.

12. Let's calculate the transformer ratio:

$$n = \frac{V_{AC}}{V_{SEC}}$$

For a European mains

$$n = \frac{220}{24,4} = 9,1$$

13. Let's calculate the average DC input current to the regulator

$$I_{i(DC)} = \frac{P_O}{\eta \cdot V_{i(DC)}} = \frac{20}{0,75 \cdot 30} = 0,88A$$

14. Let's calculate the average, peak, RMS surge values of the current through rectifiers.

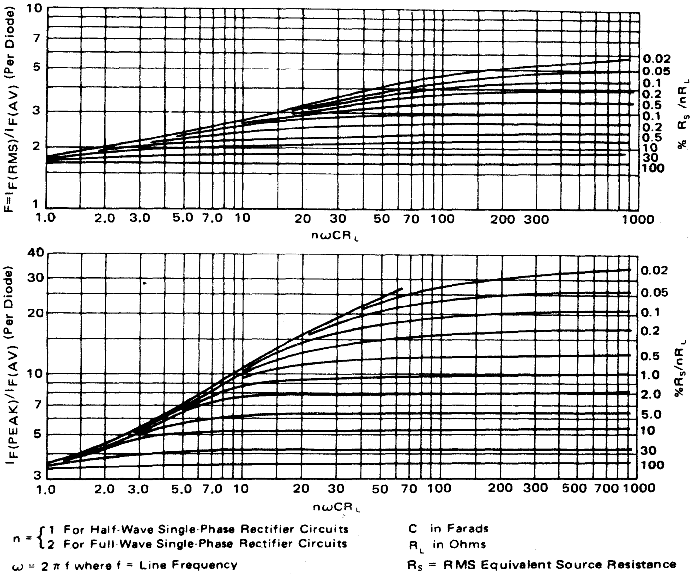


Fig. 4 - RMS/Average and Peak/Average Diode Current Relation

In a rectifying bridge, the current is 50% shared between each couple of diodes. Therefore, for each couple of diodes, the equivalent load is $2R_L$. From the graphs of fig. 4, for

$$2\omega CR_L = 20 \qquad \frac{R_S}{2R_L} = 1\%$$

we obtain:

$$\frac{I_{F(RMS)}}{I_{F(AV)}} = 2 \qquad \frac{I_{F(pk)}}{I_{F(AV)}} = 9,5$$

where:

$$I_{F(AV)} = \frac{1}{2} \cdot I_{i(DC)} = \frac{1}{2} \cdot 0,88 = 0,44A$$

$$I_{F(RMS)} = 2 \cdot I_{F(AV)} = 2 \cdot 0,44 = 0,88A$$

$$I_{F(pk)} = 9{,}5 \cdot I_{F(AV)} = 9{,}5 \cdot 0{,}44 = 4{,}2A.$$

$$I_{surge} = \frac{V_{i(pk)max}}{R_S + ESR} = \frac{38}{0{,}67 + 0{,}094} = 50A$$

ESR is the Equivalent Series Resistance of filter capacitor. For example, SPRAGUE 53D192G050HJ6 is a 1900 μF/50V capacitor with ESR = 94mΩ at 120 Hz.

15. Let's calculate I_{SEC} and VA from point 14.

$$I_{F(RMS)} = 2\ I_{F(AV)}$$

$$I_{SEC} = \frac{I_{i(DC)}}{\sqrt{2}} \cdot 2 = \frac{0{,}88}{\sqrt{2}} \cdot 2 = 1{,}25A$$

$$VA = V_{SEC} \cdot I_{SEC} = 25{,}3 \cdot 1{,}25 = 32VA$$

In the worst case, VA + 15% = 37VA.

2. HOW TO CHOOSE THE PROTECTING FUSE

The GS-R400 family protects the load against overvoltage by an internal crow-bar that continuously senses the output voltage and fires a thyristor when the voltage is higher than the nominal +20%. Thyristor current capability is 150A.

The crowbar can be activated either by an overvoltage generated by an external injected voltage, or by a failure of the module itself.

In the first case the module limits the input current to a safe value, and, to recover the normal operations, it is sufficient to switch off the input voltage for a time greater than the discharge time of the input filter capacitor.

In the second case, the failure is pratically a module input-output short circuit. The input current is no more limited by the module, and it is necessary to provide a method for disconnecting the module from the input voltage in a very short time to avoid board failures where the module is mounted.

The simplest method foresees the use of a fuse in the input path to limit the fault current to a safe value.

The proper fuse should be selected with some criteria:

- the fuse must handle the steady state current
- the fuse must handle the inrush current that occurs at turn-on
- the fuse must blow if the module has an input to output short circuit.

To this purpose, a fuse is normally selected with rated current between 150 and 250% of the rated full-load input current.

This usually provides enough overload capability to prevent fuse blowing from aging and fatigue due to repeated turn-on overload.

It is also necessary to examine the opening time versus the fuse overload characteristics, and the best choice is the high reliability, low cost, standard commercial units like 3AG, 3AB or DIN41661.

All the units must be of the fast type with fusing characteristics as depicted in the dashed area of fig. 5.

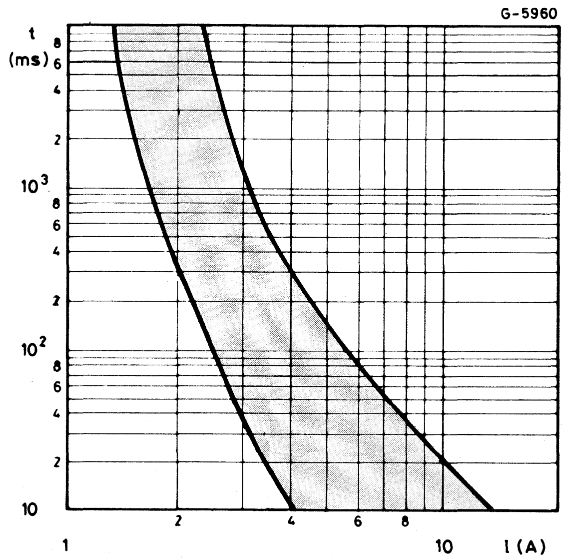


Fig. 5 - Fast Fusing Intervention Curve

As an example, for a GS-R405 unit supplied by a 24V minimum input voltage, the fuse rating can be calculated as follows.

At a maximum delivered power of 20W, assuming a 70% efficiency, the input power will be 28,5W and the input current 1,2A.

The fuse rating will be 2A that guarantees a maximum fusing time of 20 ms (typical 2 ms) for a current of 20A that can be generally accepted without board problem.

3. HEAT-SINK CALCULATIONS AND EXAMPLES

In many cases, the GS-R modules don't require any additional cooling methods because the dimensions and the shape of the metal boxes were studied to offer the minimum possible thermal resistance case to ambient for a given volume.

It should be remembered, that GS-R modules are **power devices** i.e. products that deliver power and dissipate power and, depending on ambient temperature, an additional heat-sink or forced ventilation or both may be required to keep the unit within safe temperature range.

We would like here to eliminate a wrong parameter that has been plaguing technical literature of power devices for 30 years: **the operating ambient temperature specified among ABSOLUTE MAXIMUM RATING.**

The concept of operating ambient temperature is totally meaningless when we deal with power components, because the operating ambient temperature depends on how a power device is used.

What can be unambiguously defined is the maximum junction temperature of a power semiconductor device or the case temperature of a GS-R module.

To prove this, let's consider the following example:

GS-R 405/2	at $V_{IN} = 24V$	$I_o = 3A$	$P_o = 15W$	$Tcase_{max} = 85°C$
GS-R 424	at $V_{IN} = 36V$	$I_o = 4A$	$P_o = 96W$	$Tcase_{max} = 85°C$

From data sheets we can get the respective efficiencies η and power dissipations

$$P_d = P_o\left(\frac{1}{\eta} - 1\right).$$

GS-R405/2	$\eta = 0{,}75$	$P_d = 5W$
GS-R424	$\eta = 0{,}87$	$P_d = 14{,}4W$

In case of natural convection (no heat-sink or forced ventilation) the thermal resistance case to ambient and the maximum ambient temperature ($Tamb_{max} = T_{c\ max} - R_{TH} \cdot P_d$) will be

GS-R405/2	$R_{TH} = 8°C/W$	$Tamb_{max} = 85 - 8 \cdot 5 = 45°C$
GS-R424	$R_{TH} = 4{,}5°C/W$	$Tamb_{max} = 85 - 4{,}5 \cdot 14{,}4 = 20{,}2°C$

As you can see, the maximum operating ambient temperatures are quite different in the two cases.

In practice a designer must fix four preliminary values such as:

V_{IN} = input voltage
V_{OUT} = output voltage
I_{OUT} = output current
Tamb = maximum ambient temperature at which the system must operate.

From these data, it is easy to determine whether an additional heat-sink is required or not and the relevant size i.e. the thermal resistance.

The step by step calculation is as follows:

1. Calculate output power:

$$P_O = V_O \cdot I_O.$$

2. On data sheet, from V_O, V_{IN}, I_O, the efficiency is obtained:

$$\eta = \frac{P_O}{P_i}$$

3. The actual power dissipation is given by:

$$P_d = P_O \left(\frac{1}{\eta} - 1\right).$$

4. The case temperature is calculated:

$$T_{case} = Tamb_{max} + R_{TH} \cdot P_d$$

(R_{TH} is shown on data sheet).

5. If Tcase < 85°C no external heat-sink is required.

   If Tcase > 85°C then proceed as follows.

6. Let's calculate what thermal resistance case to ambient is needed:

$$R_{TH\ (TOT)} = \frac{85°C - Tamb_{max}}{P_d}$$

This is the total thermal resistance i.e. the parallel of the GS-R and external heat-sink thermal resistances.

7. The thermal resistance of additional heat-sink is calculated:

$$R_{TH\ (HS)} = \frac{R_{TH\ module} \cdot R_{TOT.}}{R_{TH\ module} - R_{TOT.}}$$

   As an example the following case is discussed.

   For a particular application two modules must be used, the GS-R405/2 and GS-R400V.

Conditions:

$V_{IN} = 36V$

$V_{01} = 5V$

$V_{02} = 30V$

$I_{01} = 1A$

$I_{02} = 4A$

$Tamb_{max} = 55°C$

1. Output powers:

$$P_{01} = 5 \bullet 1 = 5W \qquad P_{02} = 30 \bullet 4 = 120W$$

2. From data sheet:

$$\eta_1 = 0,65 \qquad \eta_2 = 0,9$$

3. Power dissipations:

$$P_{d1} = 5\left(\frac{1}{0,65} - 1\right) = 2,7W \qquad P_{d2} = 120\left(\frac{1}{0.9} - 1\right) = 13,3W.$$

4. Case temperatures:

$$T_{C1} = 55 + 8 \bullet 2,7 = 76,6°C \qquad T_{c2} = 55 + 4,5 \bullet 13,3 = 115°C.$$

5. The GS-R405/2 does not require heat-sink that is on the contrary required for GS-R400V.

6. Total thermal resistance for GS-R400V

$$R_{TH\ (TOT)} = \frac{85\text{-}55}{13,3} = 2,25°C/W.$$

7. Thermal resistance of external heat-sink

$$R_{TH\ HS} = \frac{4,5 \bullet 2,25}{4,5 - 2,25} = 4,5°C/W.$$

The following table gives the thermal resistance of commercially available heat-sinks.

Manufacturer	Part number	R_{TH}(°C/W)	Mounting	Fastening
Thermalloy	6177	3	Horiz.	Screw
	6152	4	Vert.	Screw
	6111	10	Vert.	Adhesive
Fischer	SK18	3	Vert.	Screw
	SK48	3	Vert.	Screw
	SK07	4	Vert.	Adhesive
SGE Bosari	SR50	6	Vert.	Adhesive
Assman	V5440	4	Vert.	Adhesive
	V5382	4	Horiz.	Screw
	V5460	3	Vert.	Screw
	V5510	3	Vert.	Screw

To help designers to calculate the heat-sink, a special program has been developed by G. Fusaroli for IBM PC. This program is on a 5 1/4" floppy disk and can be ordered using the code GS-R400 DISK.

The mask displayed on the screen is:

SGS - SYSTEMS DIVISION	
GS-R400 CALCULATOR	
OPERATING CONDITIONS	
D.C. Input Voltage	(xx.x V) =
D.C. Output Voltage	(xx.x V) =
D.C. Output Current	(x.x A) =
Max. Ambient Temperature	(°C) =
Output Power	(W) =
Dissipated Power	(W) =
Efficiency	(η) =
Case Temperature no H-S	(°C) =

Fig. 6 - Video Mask for Heat-sink Calculation

By entering the relevant data asked by the mask, the thermal resistance of external heat-sink, if required, is immediately displayed.

4. ADDITIONAL OUTPUT FILTERING

The GS-R400s are switch mode voltage regulators; therefore the output voltage always contains a certain amount of voltage ripple at the switching frequency i.e. 100 KHz. (Refer to data sheet to evaluate the amount of ripple and noise). In some applications, a cleaner output voltage may be required.

To drastically reduce the output ripple and noise, an external LC filter can be added as shown in Fig. 7.

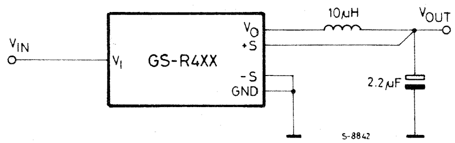


Fig. 7 - GS-R400 Output Filtering

The sensing S+ compensates automatically the DC voltage drop caused by additional LC filter.

As a practical example with L = 10 µH and C = 2,2 µF the following values of output ripple have been measured

		GS-R405 Vi = 35V Io = 4A	GS-R424 Vi = 35V Io = 4A
Without	LC filter	60 mVpp	60 mVpp
With	LC filter	<10 mVpp	<10 mVpp

The ripple reduction is widely dependent on the high frequency characteristics of the output capacitor and on the P.C.B. layout.

To minimize the noise, the P.C.B. must be double side and one side must be used as a ground plane.

In such a condition, we have an effective six side shield and the noise value will be in the range of 30/60 mVpp. Because of the high frequency of the noise, special measurement techniques must be used so that correct measurements are obtained, i.e. the conventional ground clip of the probe should never be used because it acts as an antenna creating an extaneous voltage which is not part of the module output voltage.

5. VOLTAGE SENSE FOR REMOTE LOADS

This functions is automatically provided by the GS-R400 family by using the two S+ and S− pins that sense the actual voltage across the remote load.

This voltage sense forces the direct output voltage to be as high as to compensate the voltage drop in connecting wires and to assure the nominal output voltage across the load.

It is possible to compensate the voltage drop on the connecting wires also when a couple of sensing wires is not available, by using the circuit of fig. 8.

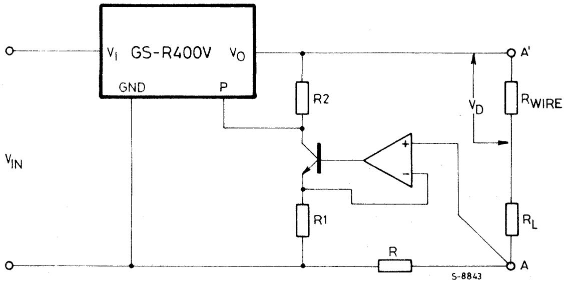


Fig. 8 - Two Wire Remote Voltage Senses

The value of R must be equal to the total connecting wires resistance so that the voltage across R is exactly equal to the total voltage drop on wires, and it is repeated on R1 and doubled on R2.

Output voltage on A-A' will be V + VD and the voltage across the remote load will be V + VD − VD = V.

Practically R2 will be chosen to given a no-load output voltage on A-A' equal to the remote load needed voltage. Then the value of R1 is calculated

$$R1 = \frac{1}{2} \cdot R2$$

The ability of the circuit to compensate connecting wires resistance has been tested by using:

$$R_{CONNECTING\ WIRES} = R = 0{,}1\ \Omega$$

The results are shown below.

V_{IN} (V)	I_{OUT} (A)	V_{OUT} (V)
30	0,5	5,030
30	1.0	5,026
30	2.0	5,018
30	3.0	5,001
30	4.0	4,985

6. PREREGULATOR FOR DISTRIBUTED POWER SUPPLY

Local on card regulation is the best choice for very complex systems where many logic boards have to be supplied under tight voltage tolerance.

To keep the power dissipation low, voltage regulators with very low drop voltage must be used: they must be supplied at the minimum input voltage. In the following application, a GS-R400V supplies an array of up to 10 low drop voltage regulators.

One of them is used to generate the overall system RESET.

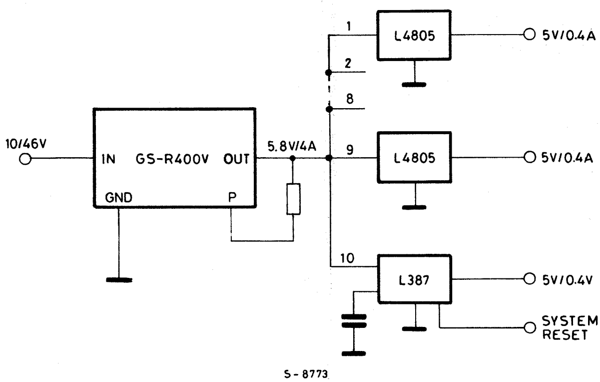
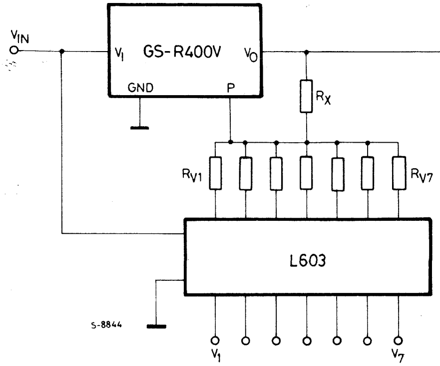


Fig. 9 - Preregulation for Distributed Power Supply

7. DIGITALLY SELECTED OUTPUT VOLTAGES

The GS-R400V output voltage can be digitally programmed by a TTL signal applied to an array of transistors such as L603 as shown in fig. 10.



$$V_{OUT} = 5,1 \cdot \left(\frac{Rx}{2,670 \ // \ RV} + 1 \right)$$

Rx, Rv in KΩ

Fig. 10 - Digitally Programmed Power Supply

During the definition of the resistors value, care must be taken against the voltage drop across the transistors.

8. HIGH INPUT VOLTAGE

When a GS-R400 module must be supplied by an input voltage higher than the maximum acceptable (46V), the circuit of fig. 11 may be used.

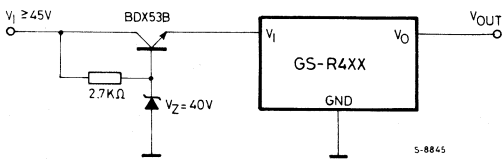


Fig. 11 - How to Use GS-R400 Modules with an Input Voltage Greater than 46V.

This solution allows good efficiency even in the worst case ($V_O = 5V$), as reported in the following table:

Vin	Iin	Vout	Iout	Effic.	Vin(min)
60V	0,18A	5.1V	1A	48%	10V
60V	0.35A	5.1V	2A	49%	10V
60V	0.4 A	15.1V	1A	63%	20V
60V	0.8 A	15.1V	2A	63%	20V
60V	0.6 A	24.0V	1A	67%	30V
60V	1.2 A	24.0V	2A	67%	30V
60V	1.0 A	40.0V	1A	67%	48V
60V	2.0 A	40.0V	2A	67%	48V

The series pass darlington requires a heat-sink that must be selected according to the power dissipation, i.e. (Vin-Vzener). Iin and the Zener diode is a 40V/1W unit.

9. PARALLEL CONNECTION OF GS-R400 MODULES

The maximum output current of GS-R400 series is 4A.

When higher output current is required, two (or more) modules can be parallel connected as shown in fig. 12.

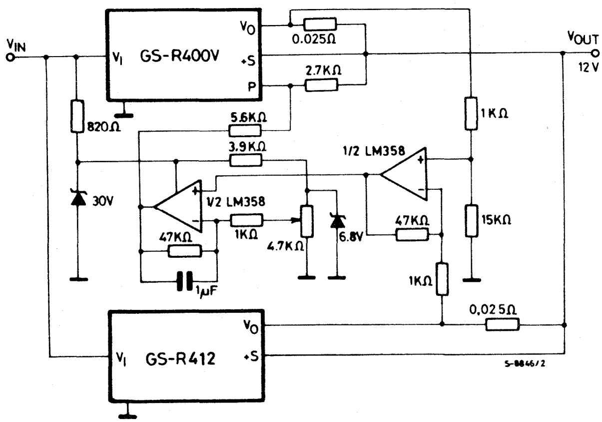


Fig. 12 - GS-R400 Parallel Connection

In a parallel connection, equal current share between the two modules is mandatory. This is assured by the presence of two current sensing resistors (0,1Ω) and a differential amplifier.

In this application one module acts as MASTER, while the other is forced to be a SLAVE. The SLAVE must be a GS-R400V type in order that its output voltage is adjusted by the differential amplifier to have the same voltage drop (i.e. the same output current) in the two sensing resistors.

The 30V Zener diode keeps supply voltage to the differential amplifiers within safe limits. The sensing pins S+ compensate the voltage drop on current sensing resistors.

10. DUAL OUTPUT TRACKING POWER SUPPLY

The two solutions presented in the following are useful whenever a split supply voltage is required.

The first, reported in fig. 13, can be used when a high power is required on both the outputs, such as in industrial applications. It uses a high power operational amplifier able to deliver output current over 2 Amps, provided that it is mounted on a proper heat-sink.

A constraint of this circuit is the maximum voltage on the main output, Vo that cannot be higher than 38V. The minimum voltage Vo necessary to guarantee proper operation of the power amplifier is 6V.

This circuit is suitable to supply both the control logic and the power output stage, in a typical microprocessor industrial controller.

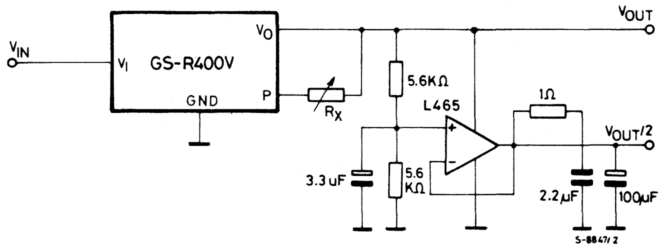


Fig. 13 - High Power Dual Output Tracking Power Supply

The second solution, reported in fig. 14 is the most advisable when small power is required from higher voltage i.e. the supply voltage required by some operational amplifiers.

The approach is completely different because of the small output current requirements, and it consists of a series regulator able to deliver a current of 100/200mA, whose reference voltage is derived from the main output.

Also this circuit is subject to one limitation imposed by the maximum supply voltage of the operational amplifier, that cannot be normally higher than 36V.

No heat-sinking of the T1 pass transistor is required in typical conditions, but it is mandatory to guarantee the survival in a short circuit environment.

The output current of this auxiliary output is limited to about 250mA by the action of T2 that sinks current from the base of T1 when the voltage drop across R1 is greater than 600mV.

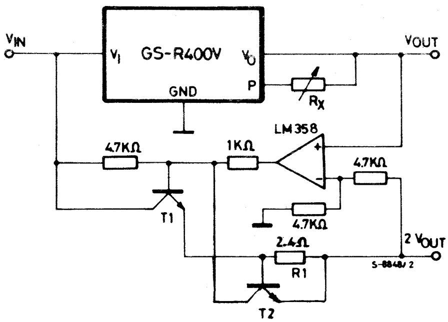
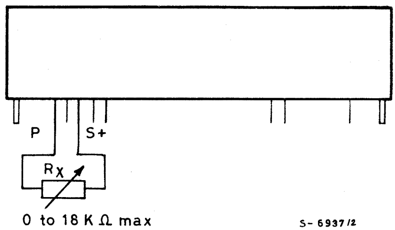


Fig. 14 - Tracking Power Supply with Low Power Secondary Output.

11. OUTPUT VOLTAGE LOWER THAN 5V

On the GS-R400V the output voltage can be modified by setting the value of an external resistor connected between pins P and S+



$$Rx = 2{,}67 \left(\frac{Vo}{5{,}1} - 1 \right) k\Omega$$

Fig. 15 - GS-R400V Output Voltage Programming (5 ÷ 40V)

When an output voltage lower than 5V is required, the following circuit may be used.

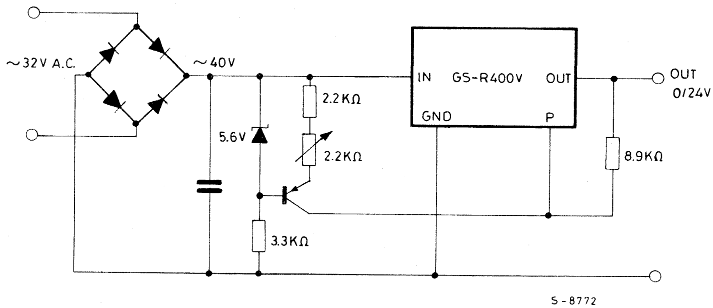


Fig. 16 - GS-R400V Output Voltage Programming (0 ÷ 24V)

12. VOLTAGE AND CURRENT LIMITED POWER SUPPLY

The GS-R400 modules offer an overcurrent limitation whose value is internally set at about 5/6 Amps, but sometimes a lower value is required for lower loads.

The circuit presented in fig. 17 allows the regulation of both the output voltage and the current, and can be used as a laboratory power supply.

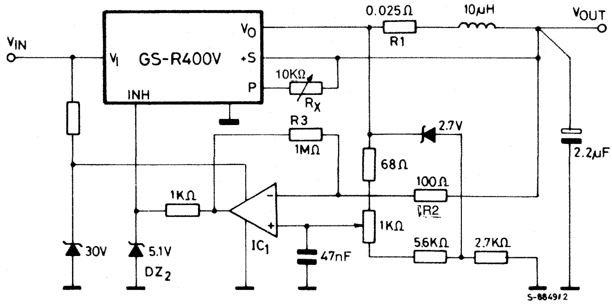


Fig. 17 - Variable Voltage and Current Limited Power Supply

The circuit requires an external comparator that is supplied by the input voltage, and requires a Zener diode if this voltage is higher than 36V. The inverting input is connected to the power supply output while the non-inverting input is driven by a variable voltage.

This voltage is compared to the voltage developed on the current sensing resistor R1 and, whenever the value is greater than the preset one, the inhibit pin is activated and the output voltage is shut off. The normal operation is restarted as soon as the overload conditions are removed.

The output comparator swing has been limited to 5V by using the Zener diode DZ2, to comply with the GS-R400 data sheet limit.

The 10K Ohm variable resistor provides the output voltage regulation between 5 and 24V, while the current limit is set by 1K Ohm variable resistor that defines the trip level of the comparator IC1.

The reference voltage is stabilized so that the current limit trip point is constant despite of the output voltage variation. The two resistors R2 and R3 guarantee that at zero output current, the comparator output is active otherwise the circuit is unable to start up.

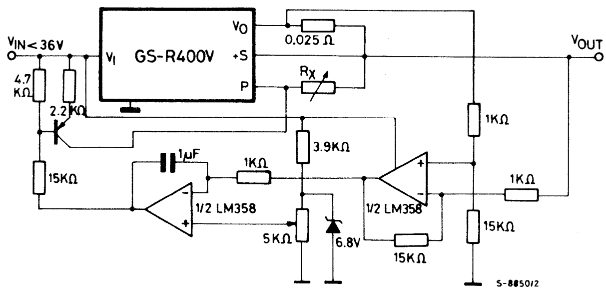


Fig. 18 0 ÷ 24V Variable Power Supply

The figure 18 shows another application where it is possible to adjust the output voltage from 0V to 24V and the output current from 0,25A to 4A.

13. AC VOLTAGE ON ADJUSTABLE DC LEVEL

The output DC voltage of the GS-R400V can be modulated by an external frequency so that it can be used for metering/measurement purposes such as the PSRR of an audio amplifier, or as a lamp driver in an optical link, etc.

The schematic diagram of this audio frequency application, reported in fig. 19, shows that the generator is connected to the summing point P through a series connected R-C filter that will be selected according to the following rules:

a) the A.C. low frequency generator must be coupled to the summing node using a capacitor.

b) the RC time constant will be at least 10 times the minimum frequency to be used.

c) the resistor must be greater than 470 Ohm to guarantee the correct circuit start-up.

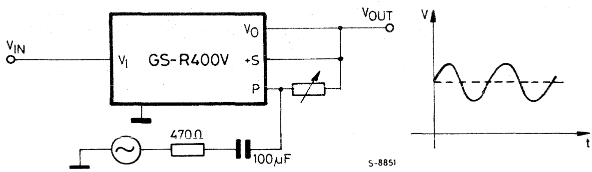


Fig. 19 - Output Voltage Modulation

The typical band width of this circuit is about 2 KHz, and the modulation depth depends on the output voltage and on the output current as reported in fig. 20.

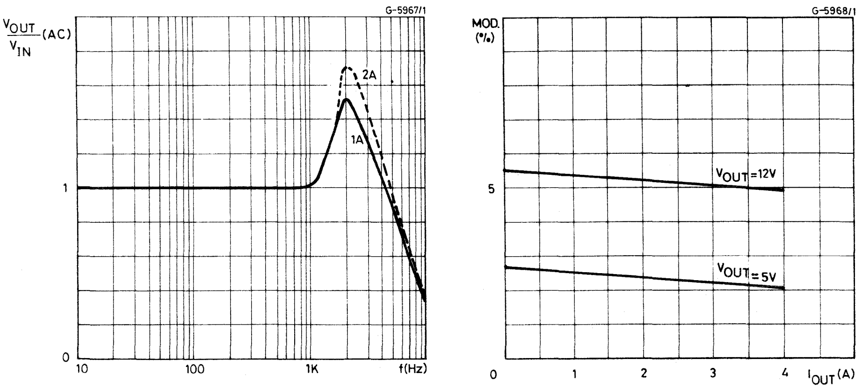


Fig. 20 - Band Width and Modulation Depth Vs. Load

14. ON-OFF TEMPERATURE CONTROLLER

The GS-R400 can be used as a simple and inexpensive high precision temperature controller, useful for driving small or medium loads, such as a quarz crystal oven or a thermostated high frequency free-running oscillator.

The schematic of the application is shown in fig. 21, and the operation is based on the thermal characteristics of a constant current driven diode that shows a −2 mV/°C thermal characteristic.

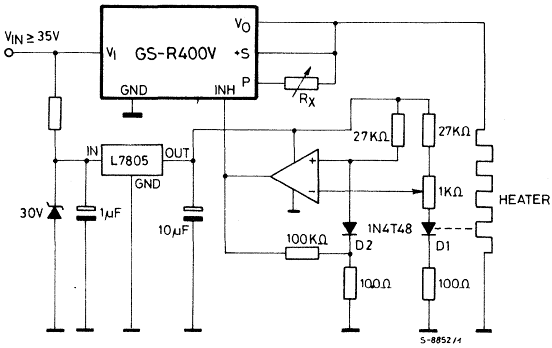


Fig. 21 - On-Off Temperature Controller

The two comparator inputs are connected to the arms of a bridge, each containing a diode. The diode D1 is used to perform the temperature sensing and it is thermally connected with the heater or with the target object, and the heater is driven by the GS-R400V output voltage till a bridge balance condition is reached.

A relative temperature range of 25/110°C is covered using the reported component values i.e. the heater temperature is constant with respect to the external reference diode temperature D2.

It is possible to obtain an absolute temperature set by replacing the diode D2 with a 4,3K Ohm resistor.

The GS-R400V output voltage trimming capability can be used to set the output voltage to a value that minimizes the temperature ripple, for a particular thermal time constant. To avoid oscillation, a small hysteresys value has been added (about 2,5°C).

The comparator supply voltage has been stabilized to avoid level interface problems with the inhibit input, and because the bridge requires a stable supply voltage to guarantee a constant diode current.

15. PROPORTIONAL TEMPERATURE CONTROLLER

An ON-OFF temperature controller always exhibits a certain amount of temperature ripple caused by the ON-OFF switching of the driver. A proportional temperature controller adjusts continuously the power delivered to the heater and a very tight temperature control may be achieved.

The application is shown in fig. 22. The temperature sensing element D1 may be substituted by an NTC resistor of proper value. The temperature is set by proper adjustment of the bridge.

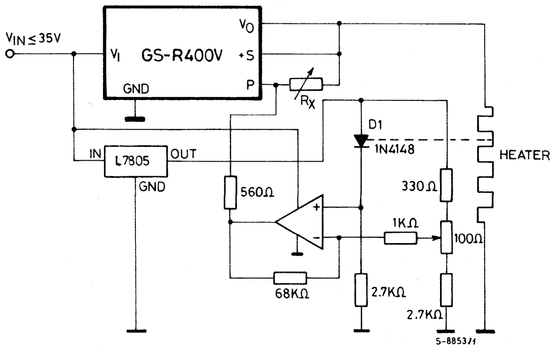


Fig. 22 - Proportional Temperature Controller.

16. DC MOTOR CONTROL

The GS-R400V can be used as a motor speed controller as shown in fig. 23.

The speed is regulated by sensing the motor current, and by changing the supply voltage to compensate the internal voltage drops on RM.

If we assume a motor with the following characteristics

$$I_M = 1A \qquad R_M = 10\Omega \qquad BEMF = 5V$$

and we refer to fig. 23, we can see that a voltage proportional to the current flowing through the motor is developed on resistor R_1.

This voltage is used to adjust the output through a current mirror.

The value of the resistor R_1 can be selected by using pratical considerations like power dissipation and minimum voltage drop.

In the following example, we choose:

$$R_1 = 1\Omega$$

this states the ratio $\frac{R_M}{R1}$

$$n = \frac{R_M}{R1} = 10$$

and now we can calculate R_2:

$$R_2 = \frac{R_T}{n+1} = \frac{1000}{10+1} = 90.9\ \Omega$$

In these conditions we have:

$$V_o = 1\Omega \cdot I_M + B_{EMF} + R_M \cdot I_M = 1v + 5v + 10v = 16v$$

If now we assume that I_M raises to 1.5A due to a torque variation, the output voltage will change to:

$$V_o = 1\Omega \cdot I_M + B_{EMF} + R_M \cdot I_M = 1.5 + 5V + 15V = 21.5V$$

Depending on the motor characteristics, some compensation to prevent system oscillation can be required.

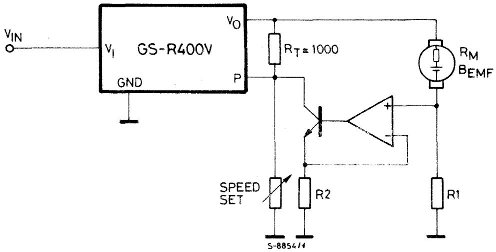


Fig. 23 - Current Sensing DC Motor Control

17. DC MOTOR CONTROL WITH TACHOFEEDBACK

The speed control of a DC motor can be performed with a low cost solution like that reported in the previous paragraph; or by using a tachometric feedback able to guarantee a tight control almost independent on motor torque like that reported in fig. 24.

The GS-R400V output voltage is regulated by comparing the output voltage of the tacho generator with a DC reference Voltage and generating an error signal used for trimming the output voltage in such a way to reduce the error signal to zero.

Also this circuit may require some compensation to minimize overshoots and to guarantee the stability in every operating condition.

The supply voltage for the operational amplifier can be derived from the input voltage by using a Zener diode that is used as reference.

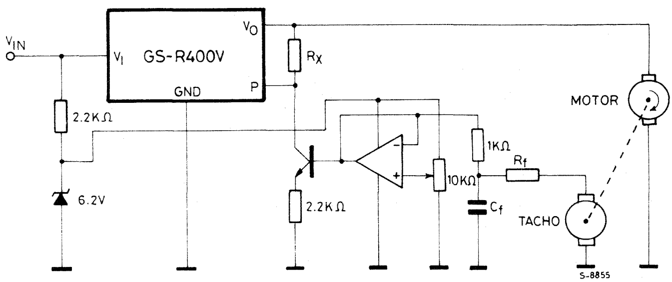


Fig. 24 - Tachofeedback DC Motor Control

18. SIMPLE UNINTERRUPTABLE POWER SUPPLY

The GS-R400 family of modules is particularly suited for application in electronic equipments that require a continuous supply even if the AC input fails.

In these applications, high efficiency and circuit simplicity are mandatory to minimize the overall cost.

The electrical circuit is reported in fig. 25 and two diodes are required to switch from AC to DC operations.

The L200 is used for battery charging. To this purpose, its output current is limited to a value of about 1/8 of the battery current rating in Amp/hour while the output voltage is set to Vbat•1.1.

The rating of the battery is chosen according to the following formula:

$$A/h = \frac{Pout}{Vbatt \cdot Eff} \cdot t$$

where t is expressed in hours.

For the reported example, by assuming 1/2 hour of AC power interruption the resulting rating is:

$$A/h = \frac{39}{24 \cdot 0.7} \cdot 0.5 = 1.16\ A/h$$

The power supply can be easily manufactured to meet the VDE specs for EMI by using a transformer with shield between the primary and the secondary winding, and an input filter.

To minimize RFI it is necessary to use a double side PCB with one side used as a ground plane, and the other side for connections.

$$R_L = \frac{0{,}45V}{\frac{1}{8} \cdot \frac{Pout}{V_{batt} \cdot Eff} \cdot t} \qquad R_p = \frac{820}{2{,}77}\,(1{,}1 \cdot V_{batt} - 2{,}77)\Omega.$$

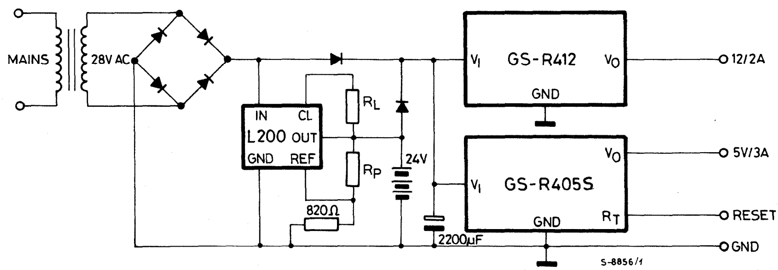


Fig. 25 - Uninterruptable Power Supply

GS-R MODULES RELIABILITY

SGS Systems Division

INTRODUCTION

Following our tradition of publishing official and detailed Quality and Reliability guarantees for customers, SGS Systems Division presents the first edition of the Reliability program for Modules and Subassemblies.

The document outlines the major tests executed by SGS Systems Division to guarantee Modules and Subassemblies quality.

It contains a description of the acceptable quality levels, describes the execution of the qualification and periodical reliability tests carried out as production monitor, plus a summary of the main quality controls and quality assurance operations and procedures performed during the manufacturing process.

Two calculation examples of predicted MTBF according to the MIL-HDBK-217D method, both for different operating and environmental conditions, are also provided for the GS-R400 module. This method can also be used for boards and subassemblies.

CHAPTER 1 - SGS PRODUCTS QUALITY ASSURANCE

1.1 SGS QUALITY AND RELIABILITY POLICY

The product Quality and Reliability proceed from the design and development process of each new product, through the production and shipment up to the service supplied to the customer.

It is well known that Reliability is part of the product itself. SGS has a Total Quality Control policy to manufacture consistently reliable high quality products. Everyone in the company must recognize the importance of mantaining and improving Quality and Reliability levels.

SGS policy allows the problem solving as they arise. Total Quality Control prevents quality problems rather than simply eliminating defective finished products.

This policy gives to the customer many advantages because it guarantees a better Quality and Reliability and cost reduction.

1.2 SGS ORGANIZATION AND MANAGEMENT

SGS is organized into product divisions, geographical sales areas and corporate departments.

Quality and Reliability activities are managed and performed by the Corporate Q & R dept directly reporting to the top management and Quality and Reliability departments at the division and plant levels.

This organization allows SGS to guarantee Quality and Reliability for a wide product range effectively and efficiently.

The Corporate Q & R defines quality strategies, targets and Quality and Reliability programs for all SGS products, defines procedures and the specification system, auditing their implementation. Another function of this group is to perform advanced reliability studies and to evaluate the reliability predictions for new products and systems.

Corporate Q & R also collects, analyses and distributes Quality and Reliability data from every quality control department, summarizing the results for the top management and emphasizing the main corrective actions in progress or required.

Division Q & R departments perform incoming material inspection, process control, finished product inspection, reliability testing, failure analysis and require and coordinate all corrective actions necessary to improve Quality and Reliability.

These departments evaluate the new processes and products reliability and issue reports to the customers.

Division Q & R departments interface directly the customers from the design phase to the product release.

Plant Q & R departments perform Quality and Reliability testing for their manufacturing processes.

They keep close contact with Corporate and Divisional Q & R departments to ensure that Quality and Reliability targets are reached and provide periodical Quality and Reliability reports showing the process trend.
Plant Q & R departments can propose quality specifications changes.

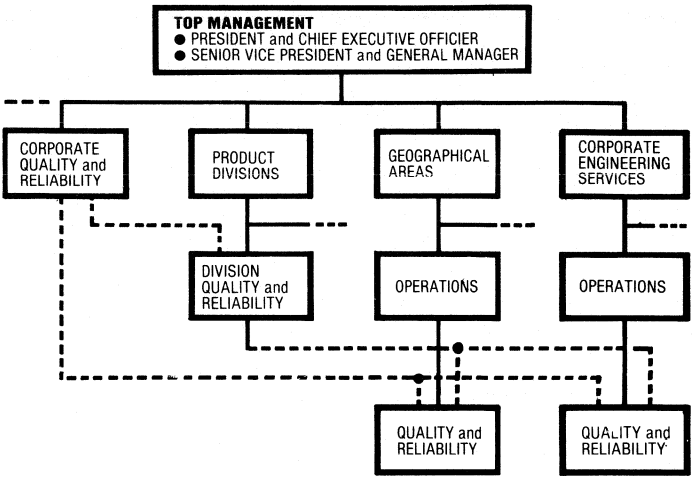


Fig. 1 - SGS Quality Organization Diagram

1.3 DESIGN-IN FOR QUALITY AND RELIABILITY

Since the Quality and Reliability depend on a large extent on the basic structure, SGS pays much attention to Quality and Reliability features just from the design phase. The most important points are the user reliability requirements, the operating conditions and the reliability checkpoints for components, materials and process.

The design review consists of a study of design documents, the choice of reliability tests and methods, a check on the process compatibility to achieve the design goals, and the review of past failures in similar products.

New products and processes qualification consist of four activities:

1 - New production process technical qualification

2 - New production process production qualification

3 - New materials qualification

4 - New product qualification

Technical qualification is performed on a small product sample at the pre-production phase. Production qualification is performed on the large-scale production process.

CHAPTER 2 - QUALITY AND RELIABILITY ACTIVITIES

2.1 QUALITY CONTROL

SGS issues a product specification for every raw material and inspects all incoming lots according to MIL STD 105D sampling plans.

Material is furnished only by SGS qualified suppliers, and trace is mantained from incoming lots through finished products to ensure that corrective actions can be executed promptly and effectively.

The quality control system for purchased materials is shown in Fig. 2.

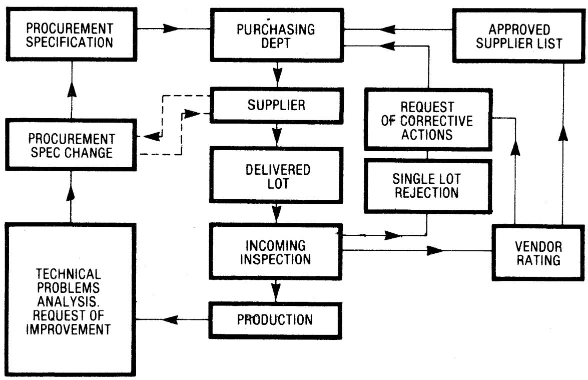


Fig. 2 - Purchased Material Quality Control Organization

2.2 THE RELIABILITY APPROACH

SGS pays particular attention during the design and manufacturing stages and it studies the various factors that affect the products Reliability both in operational and environmental conditions.

Subsystems reliability is described in quantitative terms by measuring the failure rate as a function of time. The failure rate distribution of a product follows the familiar bathtub curve shown in Fig. 3.

This curve is divided into three time zones, as shown in the figure. The lenght of each zone depends on the various components used in the product and operating stresses.

Zone A covers the infant mortality period where failure modes are usually open and short circuits that causes complete functional failures and seriously degraded performances.

Zone B represents the random failure part of the distribution curve related to the useful life. This period, generally very long, depends on the stress (temperature, applied voltage, applied power, circuit complexity etc).

Failures in zone C are wear out failures consisting of catastrophic failures and degraded parameters.

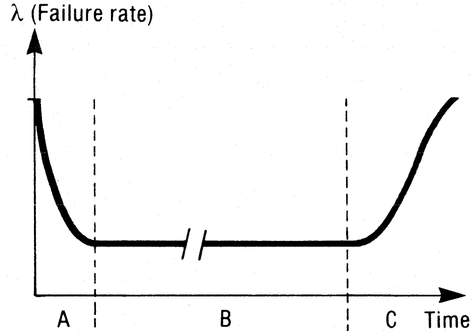


Fig. 3 - Failure rate distribution curve

2.3 THE RELIABILITY TESTS

There are two types of reliability tests:

— tests executed during the product design and development
— tests executed during the production phase.

The first type is usually executed on a small sample but for a long time, or under very accelerated conditions to investigate worn out failures and to determine tolerances and limits of the design.

The second type is executed periodically during the production to check, mantain and improve the assured Quality and Reliability levels.

All reliability tests performed by SGS are under more severe conditions than those met in the field. These conditions, although accelerated, are chosen to simulate stress conditions of the current operation, and care is taken to ensure that the failure modes and mechanism are unchanged.

2.4 THE FAILURE ANALYSIS

The failure analysis is the investigation made on products that fail during laboratory testing or in field, to determine the failure cause. Failures may be caused by production defects or by using the product outside the absolute maximum rating limits. In the first case, failure analysis helps SGS to improve the production process, in the second, it helps the customer to eliminate design errors that overstress the product.

Failure analysis involves more than simply opening the package or remove some screw and looking inside. The failure mechanisms are complex and varied so it is necessary to perform a logical sequence of operations and examinations to discover the origin of the problem. To identify the failure mechanism requires an understanding of manufacturing process, a sound knowledge of the technology plus the knowledge of the working conditions during applications.

SGS sophisticated failure analysis facilities allow to identify rapidly the corrective actions to improve the production quality and to gauge the performance of manufacturing processes so that they can be better adapted to the new products development.

2.5 THE RELIABILITY PREVISION

The reliability prevision is essential in the development and maintenance of electronic equipments, but to actually prove reliability figures is so expensive and time spending that it is normally unused. Fortunately, data obtained from accelerated simulated conditions give the relationship between applied stress and failure rate that is supported by data collected in the field.

To predict reliability, data collected from accelerated tests and operating life tests performed at high temperature are related to normal operating conditions, and the failure rate estimated with sufficient accuracy.

Reliability prevision is very interesting during the design phase to give an early estimation of equipment reliability and to provide data for design analysis and reliability growth monitoring.

Fig. 4 shows the temperature derating curves and the multiplying factors for temperature reduction. The various lines correspond to the activation energies associated with the different involved failure mechanisms.

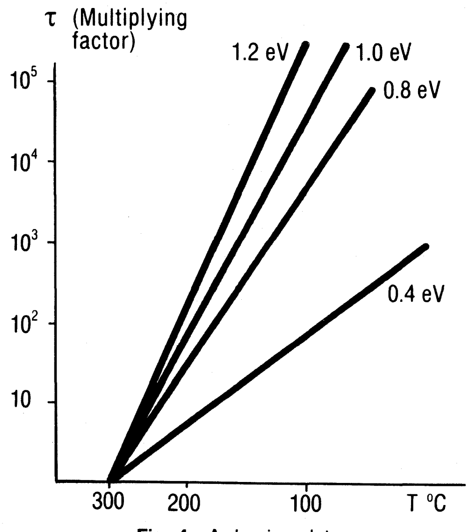


Fig. 4 - Arrhenius plot

Current reliability prediction models, such as MIL HDBK 217D, give useful predictions for a wide range of components.

These models are derived from accelerated life tests, screening, burn-in, reliability tests, field experience, product characterization and failure data.

In the following table the values of FITs (failure in time or (failure/hour) x 10E-9) extracted from the MIL HDBK 217D are reported.

The MIL HDBK 217D predicted failure rates are conservative values. They result from historical data and cannot take into consideration the continuous technological improvements in the semiconductor field.

In the following table an example of the failure rate prediction for various active and passive components is reported for different operating temperatures.

Table 1 - Failure rate prevision example

Component Family	Failure rate (FITs) prediction			
	25°C	50°C	75°C	100°C
Signal Diode	24	38	66	160
Signal Diode	35	54	94	228
Power Diode	31	50	80	123
Power Diode	104	161	280	685
Zener Diode	35	42	52	70
Zener Diode	50	64	94	181
Sign. Trans.	<1	<1	2	10
Sign. Trans.	<1	2	20	100
Power Trans.	<1	<1	1	6
Power Trans.	<1	5	50	500
Power LIC	<1	3	25	200
Signal LIC	<1	2	15	120
MOS Logic	2	15	130	650
MOS Memory	10	55	230	2100
CMOS	1	10	120	1200
CMOS	<1	2	20	200
Res. Composition	18	47	120	311
Res. Composition	45	124	325	—
Res. Metallic	44	55	67	91
Res. Metallic	75	95	130	—
Res. WireWound	265	297	362	500
Res. WireWound	540	702	918	1405
Res. Network	5	14	34	73
Alumin. Cap.	68	120	272	800
Alumin. Cap.	300	560	1240	3800
Alumin. Cap.	480	1104	3840	18000
Alumin. Cap.	1870	4320	14880	75000
Ceram. Cap.	75	79	83	89
Ceram. Cap.	500	540	562	603
Mylar Cap.	20	20	24	41
Mylar Cap.	468	487	580	1030
Tantal. Cap.	405	500	749	1467
Tantal. Cap.	2370	2900	4370	—
Transformer	308	376	513	890
Inductor	62	75	103	178
Printed boards	.015	.015	.015	.015
Connectors	7	16	29	48

Note: For semiconductors, the temperature is to be intended as junction temperature.

Table 2 - Conditions for failure rate prevision

Component or Family	Operating conditions for failure rate prediction
Signal Diode	Glass device - 50% rated voltage
Signal Diode	Glass device - 100% rated voltage
Power Diode	Plastic device - 50% rated power
Power Diode	Plastic device - 100% rated power
Zener Diode	Glass device - 50% rated current
Zener Diode	Glass device - 100% rated current
Sign. Trans.	Hermetic device - 100% rated voltage *
Sign. Trans.	Plastic device - 100% rated voltage *
Power Trans.	Hermetic device - 100% rated voltage *
Power Trans.	Plastic device - 100% rated voltage *
Power LIC	Multiwatt - 100% rated voltage *
Signal LIC	Plastic minidip - 100% rated voltage *
MOS Logic	Plastic microprocessor *
MOS Memory	Ceramic EPROM 64k *
CMOS	Plastic gate/MSI - 100% rated voltage *
CMOS	Ceramic gate/MSI - 100% rated voltage *
Res. Composition	< =1Mohm - 50% rated power
Res. Composition	< =1Mohm - 100% rated power
Res. Metallic	< =1Mohm - 50% rated power
Res. Metallic	< =1Mohm - 100% rated power
Res. WireWound	< =100Kohm - 50% rated power
Res. WireWound	< =100Kohm - 100% rated power
Res. Network	For any internal resistor
Alumin. Cap.	<47μF low leak. - 50% rated voltage
Alumin. Cap.	<47μF low leak. - 100% rated voltage
Alumin. Cap	<1500μF - 50% rated voltage
Alumin. Cap	<1500μF - 100% rated voltage
Ceram. Cap	<100nF - 50% rated voltage
Ceram. Cap.	<100nF - 100% rated voltage
Mylar Cap.	<200nF - 50% rated voltage
Mylar Cap.	<200nF - 100% rated voltage
Tantal. Cap.	< =10μF - TAG 50% rated voltage
Tantal. Cap.	< =10μF - TAG 100% rated voltage
Transformer	130°C max operating temperature
Inductor	130°C max operating temperature
Printed boards	Dual side wave soldered - any hole
Connectors	For boards Diallyphtalate - any pin

Note: For the asterisk marked components, the reported figures are historical data measured and collected by SGS.

2.6 RELIABILITY AND USER APPLICATION

The Reliability heavily depends on the electrical and mechanical stresses encountered in the user application. Designers must therefore pay much attention to electrical circuit design, mounting techniques and environmental conditions to exploit the inherent reliability of the components.

2.6.1 Maximum ratings

The "Absolute Maximum Ratings" found on SGS data sheets are limit values of the operating and environmental conditions that must never be exceeded, even temporarily, otherwise the component may be degraded or destroyed.

Even if the device works correctly outside these limits, its lifetime can be greatly reduced.

2.6.2 Derating

Temperature is one of the main factors affecting the reliability of almost every component.

I.e. for semiconductor devices, the failure rate increases rapidly with the junction temperature following the Arrhenius law:

$$\lambda = A \cdot e^{-Ea/KTj}$$

where

A = constant	K = Boltzmann's constant
Ea = activation energy	Tj = junction temperature

Taking the typical activation energy for random failure as leV this gives a six fold increase in failure rate for a temperature rise of 20°C.

Activation energies are in the range of 0.3 to 0.6eV (typically 0.44eV) for infant mortality failures and 0.6 to 1.4eV for random failures.

These considerations can be extended, using different coefficients, to the majority of the components and then to maximize reliability, designers should keep the temperature as low as possible.

2.6.3 Electrical loading

During normal operation, voltage, current and power dissipation all affect the useful component life. Excessive power dissipation raises the temperature with a consequent increase of failure rate; voltages and currents outside the recommended working conditions may cause degradation or premature failure.

2.6.4 Performance limits relaxation

During the component life some degradation of the performance characteristics is possible. Circuit designers can therefore increase the electronic equipment reliability at very little cost by relaxing the performance limits specified. Therefore adding an extra safety margin allows the equipment to keep on working even if the component performance shows little shifts.

2.6.5 Mechanical stresses

SGS performs a variety of reliability tests to check the resistance to mechanical stresses, vibration, shocks, etc during the transport and the use.

Care should still be taken by user to avoid excessive mechanical stress on the product.

2.6.6 Mounting on heatsinks

External heatsinks are often required to prevent excessive temperature rises. The user must be careful to avoid mechanical damage during mounting and to ensure adequate heat flow.

The heatsink should be flat, the screws (of a suitable type) tightened to the correct torque and silicon grease used when necessary.

2.6.7 Soldering

Soldering must be done at controlled temperature and for the possible shortest time.

After soldering operations, residual flux must be removed to ensure good reliability. If ultrasonic cleaning is used, take care to avoid resonance effects.

Do not use trichloroethilene solvent.

To avoid deterioration of the solderability, parts should be stored in an environment free from dust and reactive gas with temperature in the range 5-30°C and humidity from 40 to 60%.
Rapid temperature changes should be avoided because they may cause condensation.

2.7 THE SPECIFICATION SYSTEM

Quality and reliability are measurable parameters. The measurements to be meaningful, must be carried out in strict accordance with written procedures and test methods.

Similarly, production processes must be managed repeatedly. This means that detailed instructions and descriptions of every process step must be prepared and updated.

This information is formalized in the company specifications that cover all the Quality and Reliability procedures and the process instructions.

Table 3 - The Specification System

SGS Internal Specifications	Purchasing Materials	Production	Testing & Finishing
Material Specifications	X		
Process Specifications		X	
Quality in Process Specifications		X	
Quality Acceptance Specifications		X	
Reliability Specifications			X
Reliability Methods Specifications			X

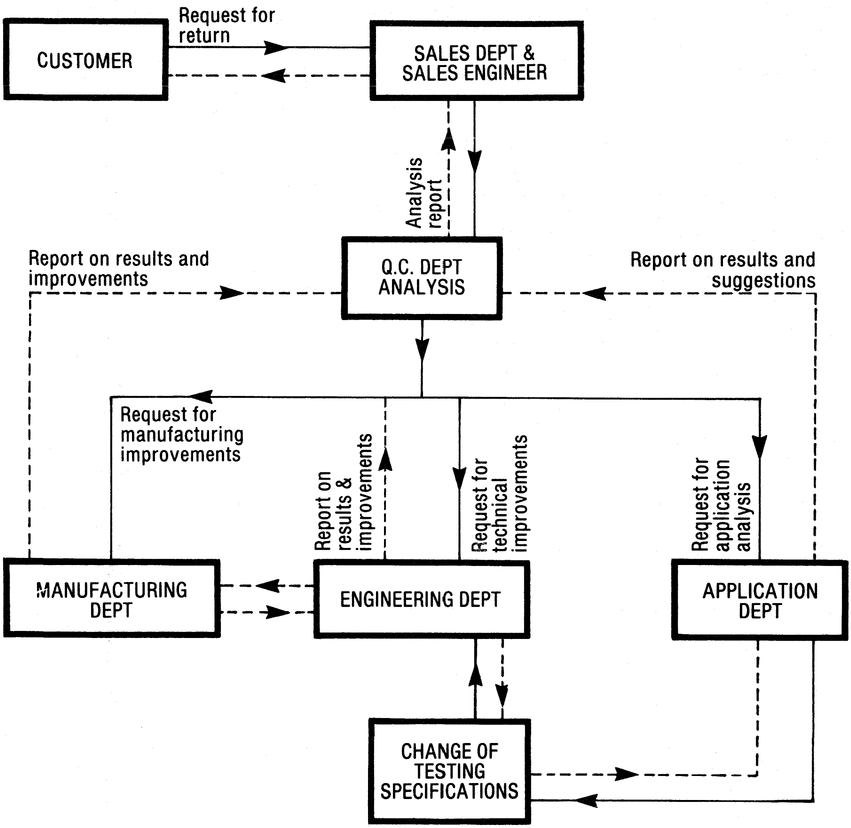


Fig. 5 - Example of customer return process

CHAPTER 3 — THE SGS STANDARD PRODUCT ASSURANCE PROGRAM

3. GENERAL INFORMATION

The following informations are valid for all products ordered from SGS without any special agreement.

3.1.1 Marking

Each part will be marked using a contrasting ink with the following standard informations:

1 - SGS logo
2 - Device type (as detailed in the specification)
3 - Serial number (where applicable)
4 - Lot code (production lot, where applicable)

3.1.2 Packaging

Devices will be packed in the SGS standard package. The following informations will be marked on the first package:

1 - SGS logo
2 - Device type as shown on the order confirmation
3 - Quantity in the package
4 - SGS order confirmation
5 - Optional warning label

3.1.3 Testing and finishing

All the parts will be submitted to a 100% electrical testing according to SGS data sheet.

3.1.4 External visual and mechanical inspection criteria definitions

Inoperative Mechanical Defects (critical) i.e. wrong pin indication, broken or weakened leads and connectors, missing or broken cover, mixed package, etc.

Visuals Defects (significant mechanical defects but not functional defects) i.e. deformed pin, unmarked packages or with illegible marking, cosmetic defects, package dimensions.

3.1.5 Certification

Certificate of Conformance will be enclosed when requested and agreed.

3.1.6 Reference specification

Basic sampling procedure and tables for inspection by attributes are the same foreseen by MIL-STD-105D.
In general the single sampling plan will be used but the customer may use other sampling plans (with, of course the same AQLs and inspection levels).

3.1.7 Precedence of documents

For the purpose of contractual interpretation, in case of conflict, documents shall take the following priority:

1 - Purchase order or contract. The text of the order or contract prevails over any other specification.

2 - Detail specification. The detail specification agreed between customer and vendor prevails over this present specification and any other reference specification.

3 - Generic specification. The generic specification (including this programme) prevails over all reference specification.

4 - Relevant specification. All reference documents apply only to the extent defined herein.

3.1.8 Essential terms and definitions

To interpret this general specification, the following terms and definitions are applied:

- Detailed Specification

  A specification which covers a particular component or range of components, and which describes that component including rated and/or limiting values and characteristics.

  The detailed specification will also provide the inspection requirements or appropriate reference to this general specification.

- Inspection Lot

  A lot of parts presented together for inspection from which a sample is to be drawn and inspected to determine conformance with the acceptance criteria of the specification.

- Production Lot

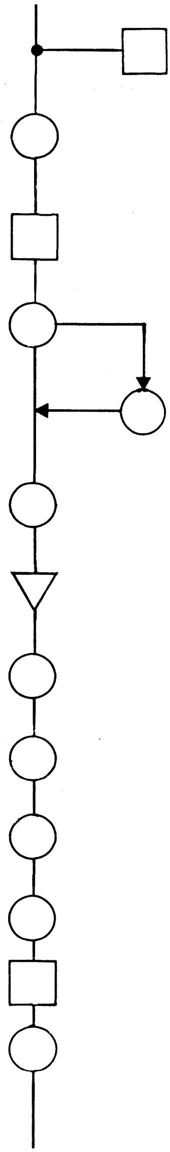
  A quantity of components manufactured within a period not exceeding four weeks.

- Delivery Lot

  A quantity of parts delivered to an order at one time. One delivery lot may consist of one or more inspection lots or parts thereof.

- Certificate of conformance

  A document issued with a delivery lot stating that the parts have been taken from one or more inspection lots accepted under specification requirements.



1 - Material inspection - Raw materials are inspected following written specs and records are mantained for traceability

2 - Board assembling - mounting, soldering, etc. to produce semifinished parts

3 - Visual inspection - Parts are inspected and corrected if necessary

4 - Electrical test - Each part is electrically tested and identified if it doesn't meet electrical requirements

5 - Failure analysis/repair - Each failed part is tested and repaired, and records are maintained

6 - Final assembly - The parts are assembled to metal case (if applicable)

7 - Visual inspection - Assembled but unsealed units are individually inspected

8 - Sealing - The parts are sealed (if possible)

9 - Final electrical test - Parts are tested for operational characteristics and limits

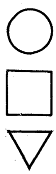
10 - Lead finish - The leads are tested for mechanical dimensions and solderability

11 - Marking - The parts are marked as for specification

12 - Group A Inspection - A sample is tested to verify AQL

13 - Packaging and shipping

Legend:

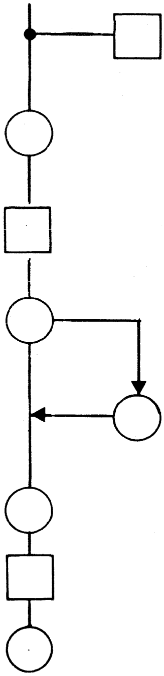


= 100% Manufacturing activity

= 100% in process control

= Gate inspection (sample acceptance)

Fig. 6 - Standard modules manufacturing process flow chart



1 - Material inspection - Raw materials are inspected following written specs and records are mantained for traceability

2 - Board assembling - mounting, soldering, etc. to produce semifinished parts

3 - Visual inspection - Parts are inspected and corrected, if necessary

9 - Final electrical test - Parts are tested for operational characteristics and limits

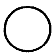
5 - Failure analysis/repair - Each failed part is tested and repaired, and records are mantained

11 - Marking - The parts are marked as for specification

12 - Group A Inspection - A sample is tested to verify AQL

13 - Packaging and shipping

Legend:

 = 100% Manufacturing activity

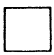
 100% in process control

Fig. 7 - Subassembly and boards manufacturing process flow chart

3.2 QUALITY TEST DURING MANUFACTURING

Process steps	Tests	Description
3	Visual	Check for short between adiacent pins and for right components orientation.
4	Electrical	Test right operational characteristics and limits/test
7	Visual	Check right final assembly, I.C. orientation etc.
9	Electrical	Test exaustive operational characteristics and limits
10	Mechanical	Test for pin size and alignement and absence of potting material
	Solderability	Verify pins solderability at 230°C +/− 5°C for 5 +/− 0.5 sec with preconditioning
11	Visual	Marking orientation and readability
12	Various	See paragraph 3.3
13	Various	Verify quantity, type, boxing labelling, documentation etc.

3.3 GROUP A INSPECTION

The quality guarantees specified here are the minimum quality leves defined for SGS modules starting from January 1st 1985.

Subgroup	Parameter	Insp. Level	AQL
A1	Visual and mechanical inspection	I	0.15
A2	Inoperative failures electrical/mechanical	II	0.15
A3	DC parameters	II	0.25
A4	AC parameters	S4	0.40

The Subgroup A4 applies only to boards.

The sample size per lot to be tested can be chosen using the following table:

Lot size range	General Inspection Levels		
	I	II	S4
16 — 25	3	5	3
26 — 50	5	8	5
51 — 90	5	13	5
91 — 150	8	20	8
151 — 280	13	32	13
281 — 500	20	50	13
501 — 1200	32	80	20
1201 — 3200	50	125	32
3201 — 10000	80	200	32
10001 — 35000	125	315	50
35001 — 150000	200	500	80

The acceptance criteria to be used are reported in the following table where:

Acc = Acceptance number
Re = Rejection number

Sample size	Acceptance Quality Level					
	0.15		0.25		0.40	
	Acc	Re	Acc	Re	Acc	Re
3	0	1	0	1	0	1
5	0	1	0	1	0	1
8	0	1	0	1	0	1
13	0	1	0	1	0	1
20	0	1	0	1	0	1
32	0	1	0	1	0	1
50	0	1	0	1	0	1
80	0	1	0	1	0	2
125	0	1	1	2	1	2
200	1	2	1	2	2	3
315	1	2	2	3	3	4
500	2	3	3	4	5	6

APPENDIX 1 - MTBF CALCULATION EXAMPLES

This appendix contains two examples of MTBF calculation, made according to MIL-HDBK-217D.

For this exercise, performed on GS-R405 and GS-R412 modules, the following load and environmental operating condition have been chosen:

Cond.1	Vin = 20V	Vout = 5V	Iout = 3A	Ta = 40°C	GS-R405
Cond.2	Vin = 20V	Vout = 5V	Iout = 3A	Ta = 55°C	GS-R405
Cond.3	Vin = 30V	Vout = 12V	Iout = 3A	Ta = 55°C	GS-R412

The class of environmental operating conditions, chosen to correctly evaluate the components stresses, as foreseen by MIL-HDBK-217D, is the following:

Ground-Fixed like installation in permanent racks with adequate cooling air and installation in unheated buildings; includes permanent installation of air traffic control, radar and communication facilities, and missile silo ground support equipment.

Ground-Benign Non mobile, laboratory environment readily accessible to maintenance; it includes laboratory instruments and test equipment, medical electronic equipment, business and scientific computer complexes.

First of all the power dissipated on the module and on the various components is calculated obtaining the following results:

Operating Condition	**1**	**2**	**3**
Output Power (W)	15.0	15.0	36.0
Efficiency (%)	74.0	74.0	80.0
Diss. Power (W)	5.3	5.3	9.0
Diode Power (W)	3.0	3.0	5.0
LIC Power (W)	2.0	2.0	3.6
Comp. Power (W)	0.3	0.3	0.4

Then the case temperature is calculated by knowing that the module to ambient thermal resistance is 5°C/W:

Cond. 1 $40 + (5.3 \cdot 5) = 66.5°C$

Cond. 2 $55 + (5.3 \cdot 5) = 81.5°C$

Codn. 3 $55 + (9 \cdot 5) = 100.0°C$

As shown above, condition 2 is out of the spec limits and it is necessary to add an external heath-sink to lower the case temperature. The standard available parts show a thermal resistance in the range 3-10°C/W and selecting a 6°C/W unit, for cond. 2 and 3 a module to ambient thermal resistance of 2.8°C/W is obtained and the new values of case temperature are:

Cond. 2 $55 + (5.3 \cdot 2.8) = 70°C$

Cond. 3 $55 + (9 \cdot 2.8) = 80°C$

Now it is possible to extimate the junction temperature by knowing that the junction to case thermal resistance, for the two power devices, are respectively 3°C/W for the LIC and 4°C/W for the Diode.

Operating condition	1	2	3
Case Temperature (°C)	66.5	70.0	80.0
Component Temper. (°C)	70.0	74.0	86.0
Diode Junct. Temp. (°C)	81.5	78.5	95.0
LIC Junct. Temp. (°C)	73.0	77.0	91.0

The next step foresees the definition of the number, by type, the operating conditions in terms of percentage of the rated power/voltage of the various components and materials used in the module.

Component description	GS-R405	GS-R412
Resistor carbon film	6	6
Resistor metal film	—	2
Capacitor ceramic	3	3
Cap. Al. Elect. low-leakage	1	1
Cap. Al. Electrolitic	2	2
Power plastic LIC	1	1
Power plastic Diode	1	1
Power plastic SCR	1	1
Toroidal inductor	1	1
PCB dual side (holes)	60	64

Component description	Operating conditions
Resistor carbon film	< =10% rated power
Resistor metal film	< =10% rated power
Capacitor ceramic	< =36nF < =10% rated voltage
Cap. Al. Elect. low-leakage	< =2.5μF < =20% rated voltage
Cap. Al. Electrolitic	< =100μF < =50% rated voltage
Power plastic LIC	Multiwatt 50% rated voltage
Power plastic Diode	< =10A < =60% rated voltage
Power plastic SCR	< =10A < =10% rated voltage
Toroidal inductor	130°C max operating temperature
PCB dual side	not applicable

By using the tables and the appropriate coefficients reported in the MIL-HDBK-217D, it is possible to define the FIT for the Ground-Fixed environmental operating condition:

Ground-Fixed	**Cond.1**	**Cond.2**	**Cond.3**
Resistor carbon film	72	72	86
Resistor metal film	24	24	29
Capacitor ceramic	15	15	18
Cap. Al. Elect. low-leakage	280	335	490
Cap. Al. Electrolitic	2735	3265	4800
Power plastic LIC	70	90	200
Power plastic Diode	65	60	86
Power plastic SCR	25	33	45
Toroidal inductor	80	85	103
PCB dual side	1	1	1
Total FIT ($\cdot 10^{-9}$)	3367	3980	5858

The same calculation is now repeated for the Ground-Benign operating environment:

Ground-Benign	**Cond.1**	**Cond.2**	**Cond.3**
Resistor carbon film	25	25	30
Resistor metal film	8	8	10
Capacitor ceramic	9	9	11
Cap. Al. Elect. low-leakage	117	140	205
Cap. Al. Electrolitic	1140	1360	2000
Power plastic LIC	18	23	51
Power plastic Diode	17	15	22
Power plastic SCR	7	8	12
Toroidal inductor	14	15	18
PCB dual side	1	1	1
Total FIT ($\cdot 10^{-9}$)	1356	1604	2360

It is possible now to calculate the MTBF both for continuous operations and for a well defined mission profile that foresees a 30% operative time against a 70% in-operative time, and the Reject Rate percentage (x 1000 hours x 1000 pcs) by using the formula:

$$MTBF = \frac{1}{FIT} \qquad \text{Reject rate} = FIT \times 10^6$$

MTBF and Rejects for continuous operations Ground-Fixed environment

	MTBF(hours)	**Rej.Rate** (‰$\cdot$1000 hours)
Condition 1	297.000	3.3
Condition 2	251.000	4.0
Condition 3	170.000	5.9

MTBF and Rejects for a 30% on - 70% off mission Ground-Fixed environment

	MTBF(hours)	**Rej.Rate** (⁰/oo•1000 hours)
Condition 1	999.000	1.0
Condition 2	836.000	1.2
Condition 3	566.000	1.8

In the same way it is possible to calculate the MTBF and the Rejects percentage for the Ground-Benign condition.

MTBF and Rejects for continuous operations Ground-Benign environment

	MTBF(hours)	**Rej.Rate** (⁰/oo•1000 hours)
Condition 1	737.000	1.4
Condition 2	623.000	1.6
Condition 3	423.000	2.4

MTBF and Rejects for a 30% on - 70% off mission Ground-Benign environment

	MTBF(hours)	**Rej.Rate** (⁰/oo•1000 hours)
Condition 1	2.456.000	0.4
Condition 2	2.076.000	0.5
Condition 3	1.410.000	0.7

The same exercise has been performed on the GS-R405/2 for a Ground-Fixed 100% operating environment using the following selected operating conditions:

Cond.1	Vin = 24V	Iout = 1A	Ta = 25°C	Eff = 74%
Cond.2	Vin = 24V	Iout = 2A	Ta = 25°C	Eff = 78%
Cond.3	Vin = 24V	Iout = 3A	Ta = 25°C	Eff = 80%
Cond.4	Vin = 24V	Iout = 1A	Ta = 55°C	Eff = 74%
Cond.5	Vin = 24V	Iout = 2A	Ta = 55°C	Eff = 78%
Cond.6	Vin = 24V	Iout = 3A	Ta = 55°C	Eff = 80%

By knowing that in these operating conditions the percentage of conduction of the power switch is about 20%, the dissipated power on the main components can be estimated obtaining the following figures:

Operating condition	**1**	**2**	**3**	**4**	**5**	**6**
Output Power (W)	5	10	15	5	10	15
Efficiency (%)	74	78	80	74	78	80
Diss. Power (W)	1.75	2.82	3.75	1.75	2.82	3.75
Diode Power (W)	0.72	1.45	2.16	0.72	1.45	2.16
LIC Power (W)	0.93	1.22	1.39	0.93	1.22	1.39
Comp. Power (W)	0.10	0.15	0.20	0.10	0.15	0.20

It is possible now to define the main components temperature:

Operating condition	1	2	3	4	5	6
Case Temperature (°C)	39	47.5	55	69	77.5	85
Diode Junct. Temp. (°C)	47	63.5	78.7	77	93.5	108.7
LIC Junct. Temp. (°C)	41.5	51.2	59.2	71.5	81.2	89.2
Components Temp. (°C)	41	50.5	59	71	80.5	89

Condition "6" shows a case temperature at the limit stated as "Absolute Maximum Rating" so it is not applicable unless an external eathsink is added.
The components used in the module and the relative operating conditions are:

Quant.	Component description	Operating conditions
2	Resistor Metal-film	$<10\%$ rated power
3	Capacitor ceramic	$<=36nF$ $<=10\%$ rated voltage
1	Elect. Cap. Tantalum	$<=2.5\mu F$ $<=30\%$ rated voltage
1	Elect. Cap. Tantalum	$<=500\mu F$ $<=40\%$ rated voltage
1	Elect. Cap. Aluminum	$<=50\mu F$ $<=50\%$ rated voltage
1	Power plastic LIC	Multiwatt 60% rated voltage
1	Power plastic Diode	$<=10A$ $<=50\%$ rated voltage
1	Power Hermetic SCR	$<=10A$ $<=10\%$ rated voltage
1	Toroidal inductor	130°C max operating temp.
1	PCB dual side	50 holes

It is possible now to find the FITs for any component and for the selected operating conditions:

Operating condition	1	2	3	4	5
Resistor metal film	19	20	23	24	26
Capacitor ceramic	13	13	14	14	15
Elect. Cap. Tantalum $<2.5\mu F$	225	247	328	345	405
Elect. Cap. Tantalum $<500\mu F$	528	580	765	792	950
Elect. Cap. Aluminum $<50\mu F$	386	504	924	957	1394
Power plastic LIC	30	40	70	70	100
Power plastic Diode	45	56	80	86	116
Power hermetic SCR	11	14	20	21	24
Toroidal inductor	57	63	78	80	94
PCB dual side	1	1	1	1	1
Total FIT ($\cdot 10^{-9}$)	1315	1538	2303	2390	3125

It is possible now to calculate both MTBF and Reject percentage and the results are the following:

Cond.1 Vin = 24V Iout = 1A Ta = 25°C Eff = 74%

MTBF = 760,400 hours
Rejects Rate = 1.28‰•1000 hours

Cond.2 Vin = 24V Iout = 2A Ta = 25°C Eff = 78%

MTBF = 650,100 hours
Rejects Rate = 1.51‰•1000 hours

Cond.3 Vin = 24V Iout = 3A Ta = 25°C Eff = 80%

MTBF = 434,200 hours
Rejects Rate = 2.28‰•1000 hours

Cond.4 Vin = 24V Iout = 1A Ta = 55°C Eff = 74%

MTBF = 418,400 hours
Rejects Rate = 2.37‰•1000 hours

Cond.5 Vin = 24V Iout = 2A Ta = 55°C Eff = 78%

MTBF = 320,000 hours
Rejects Rate = 3.12‰•1000 hours

By using this method, it is possible to calculate the MTBF and the Reject for any other more complex module, subassembly or board by simply choosing the right figures for the various components or active devices.

APPENDIX 2 - WARRANTY POLICY

Modules and subassembly and board, because of their different manufacturing methods, need different warranty policy.

The module, as a completely sealed and unreparable unit (such as GS-R400), follows the same rules of the standard semiconductor.

The modules are accepted or rejected through the incoming inspection accordingly to the various test results and the AQL levels described herein (Par. 3.3).

The subassemblies and the boards are normally warranted 6 months, during which the repair of defective parts (not caused by bad use) is free of charge.

GS-R MODULES DATASHEETS

SGS Systems Division

Systems Division

GS-R400 Family

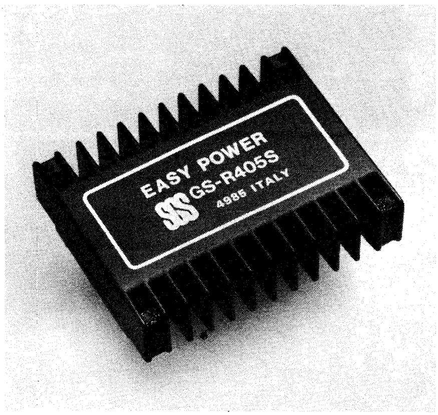
140W SWITCHING VOLTAGE REGULATOR MODULES

The GS-R400 series is a complete family of HIGH CURRENT HIGH VOLTAGE SWITCHING VOLTAGE REGULATORS available in several output voltages from 5,1 to 40 V.

These step down regulators shielded for EMI, can provide local on-card regulation, or be used in central power supply systems, in both professional and industrial applications.

FEATURES

- MTBF in excess of 200.000 hours
- No external components required
- PC card or chassis mountable
- High output current (4 A)
- High input voltage (48 V)
- Fixed or adjustable output voltage
- High efficiency (up to 90%)
- Soft start
- Remote inhibit/enable
- Remote output voltage sense
- Reset output (GS-R405S only)
- Non-latching short circuit protection
- Thermal protection
- Crow bar protection for the load



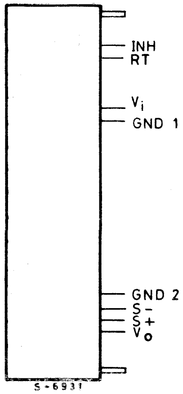
PRODUCTS FAMILY

Order Number	Output Voltage	Reset Output
GS-R405S	5.1 V	Yes
GS-R405	5.1 V	—
GS-R412	12 V	—
GS-R415	15 V	—
GS-R424	24 V	—
GS-R400V	Adjustable 5.1 to 40 V	—

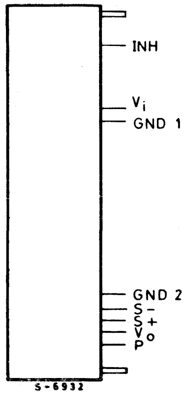
GS-R400 Family

CONNECTION DIAGRAM (side view)

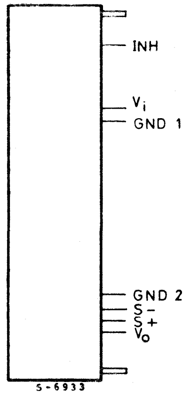
GS-R405S



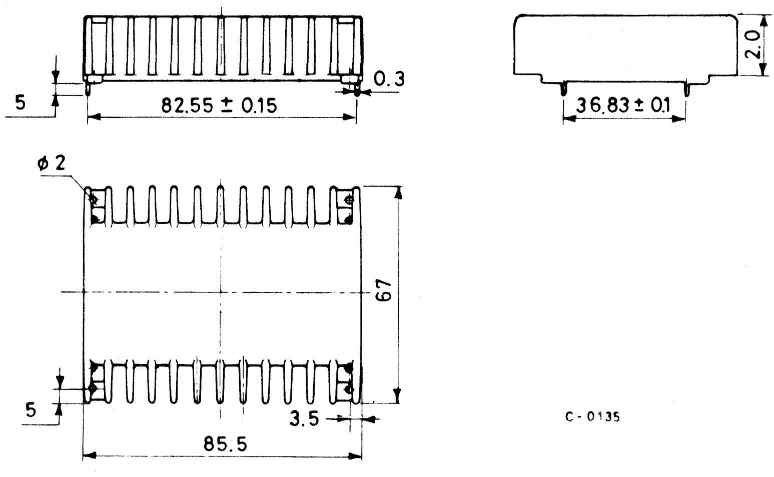
GS-R400V



GS-R405/412/415/424



MECHANICAL DATA (dimensions in mm)



PIN FUNCTIONS

PIN	FUNCTION
INH - Inhibit	TTL compatible input. A logic high level signal applied to this pin disables the module. To be connected to GND_2 when not used.
RT - Reset Output	Available on GS-R405S only. Reset voltage is high (5.1 V) when output voltage reaches nominal value (5.1 V) and it is generated with a fixed 100 ms delay.
V_i - Input Voltage	Unregulated DC voltage input. Maximum voltage must not exceed 48 V. Recommended maximum operating voltage is 46 V.
GND_1 - Ground	Common ground for input voltage.
GND_2 - Ground	Common ground of high current path.
S− - Sensing Negative	For connection to remote load, this pin senses the actual ground of the load itself. To be connected to GND_2 when not used. The module case can be connected to this pin when remote sensing is not used.
S+ - Sensing Positive	For connection to remote loads this pin allows voltage sensing on the load itself. To be connected to V_O when not used. [illegible]
V_O - Output Voltage	Regulated and stabilized DC voltage is available on this pin. Max output current is 4 A. The device is protected against short circuit of this pin to ground or to supply.
P - Output Voltage Programming	Available on GS-R400V only. A variable resistor (18 KΩ max) connected between this pin and S+ adjusts the output voltage.

ABSOLUTE MAXIMUM RATINGS

V_i	DC input voltage	48 V
I_{RT}	Reset output sink current	20 mA
V_{INH}	Inhibit voltage	15 V
T_{stg}	Storage temperature range	−40 to + 105°C
T_{cop}	Operating case temperature range	−20 to + 85°C

Recommended maximum operating input voltage is 46V

ELECTRICAL CHARACTERISTICS (T_{amb} = 25°C unless otherwise specified)

TYPE			GS-R 405S			GS-R 405			GS-R 412			UNIT
	PARAMETER	Test Condit.	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
V_0	Output Voltage	$V_i=V_0+8V, I_0=1A$	5	5.1	5.2	5	5.1	5.2	11.5	12	12.5	V
V_0	Temperature Stability	$V_i=V_0+8V, I_0=1A$		0.2			0.2			0.5		mv/°C
V_i	Input Voltage	$I_0=1$ A	9		46	9		46	16		46	V
I_0	Output Current	$V_i=V_0+8V$	0.2		4	0.2		4	0.2		4	A
I_{OL}	Current Limit	$V_i=V_0+8V$		5	8		5	8		5	8	A
I_{isc}	Average Input Current	$V_i=46V$ Output shorted		0.1	0.2		0.1	0.2		0.1	0.2	A
f_s	Switching Frequency	$I_0=1$ A		100			100			100		KHz
η	Efficiency	$V_i=V_0+8V$ $I_0=1A$		75			75			85		%
ΔV_0	Line Regulation	$I_0=1A$ $V_i=V_0+4V$ to 46V		2			2			2		mV/V
SVR	Supply voltage rejection	f=100 Hz $I_0=1A$		4			4			6		mV/V
ΔV_0	Load Regulation	$\Delta I_0=2$ A (1 to 3 A)		20			20			40		mV/A
V_r	Ripple Voltage	$I_{out}=2A$		25			25			50		mV
t_{ss}	Soft start time	$V_{in}=V_{out}+10V$		15			15			25		ms
V_{INHL}	Low Inhibit Voltage				0.8			0.8			0.8	V
V_{INHH}	High Inhibit Voltage		2.0		5.5	2.0		5.5	2.0		5.5	V
I_{INH}	Input Current High	$V_{INH}=5V$			500			500			500	μA
t_{CB}	Crow bar Delay Time			5			5			5		μs
V_{RH}	Reset High Level			5			—			—		V
V_{RL}	Reset Low Level	$I_{RL}=5mA$ $I_{RL}=15mA$			0.2 0.4			— —			— —	V V
t_R	Reset Delay Time			100			—			—		ms
V_{SD}	Max Differential Sense Voltage	S− to GND_2 V_0 to S+			200			200			200	mV

ELECTRICAL CHARACTERISTICS (T_{amb} = 25°C unless otherwise specified)

TYPE			GS-R 415			GS-R 424			GS-R 400V			UNIT
PARAMETER		Test Condit.	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
V_o	Output Voltage	$V_i = V_o + 8V$	14.3	15	15.6	23	24	25	5.1	—	40*	V
V_o	Temperature Stability	$V_i = V_o + 8V, I_o = 1A$		0,2			0.6			0.2/1.6		mV/°C
V_i	Input Voltage	$I_o = 1$ A	19		46	28		46	9		46	V
I_o	Output Current	$V_i = V_o + 8V$	0.2		4	0.2		4	0.2		4*	A
I_{OL}	Current Limit	$V_i = V_o + 8V$		5	8		5	8		5	8	A
I_{isc}	Average Input Current	$V_i = 46V$ Output shorted		0.1	0.2		0.1	0.2		0.1	0.2	A
f_s	Switching Frequency	$I_o = 1$ A		100			100			100		KHz
η	Efficiency	$V_i = V_o + 8V$ $I_o = 1A$		90			90			75/90		%
ΔV_o	Line Regulation	$I_o = 1A$ $V_i = V_o + 4V$ to 46V		5			6			6		mV/V
SVR	Supply voltage rejection	f = 100 Hz $I_o = 1A$		8			12			12		mV/V
ΔV_o	Load Regulation	$\Delta I_o = 2$ A (1 to 3 A)		60			90			20/90		mV/A
V_r	Ripple Voltage	$I_{out} = 2A$		60			100			25/150		mV
t_{ss}	Soft start time	$V_{in} = V_{out} + 10V$		25			35			15/35		ms
V_{INHL}	Low Inhibit Voltage				0.8			0.8			0.8	V
V_{INHH}	High Inhibit Voltage		2.0		5.5	2.0		5.5	2.0		5.5	V
I_{INH}	Input Current High	$V_{INH} = 5V$			500			500			500	μA
t_{CB}	Crow bar Delay Time			5			5			5		μs
V_{RH}	Reset High Level			—			—			—		V
V_{RL}	Reset Low Level	$I_{RL} = 5mA$ $I_{RL} = 15mA$			— —			— —			— —	V V
t_R	Reset Delay Time			—			—			—		ms
V_{SD}	Max Differential Sense Voltage	S− to GND_2 V_o to S+			200			200			200	mV

* Maximum Output Current is guaranteed up to $V_o = 36V$ and derated linearly to 3A at $V_o = 40V$.

MODULE OPERATION

The GS-R400 series is a family of step down switching mode voltage regulators.

Unregulated DC input voltage must be higher than nominal output voltage by, at least, 4 V. Minimum input voltage is therefore 9 V for GS-R405S and GS-R405; maximum input voltage is 48 V for all the types.

Output voltage is fixed or adjustable (GS-R400V). The maximum current delivered by the output pin is 4 A. A minimum output current of 200 mA is required for proper module operation. In no-load condition, the module still works, but the electrical characteristics are slightly modified vs. specifications.

To prevent excessive over current at switch on, a soft start function is provided. Nominal output voltage is approached gradually in about 15 ms.

The module can be inhibited by a TTL, NMOS or CMOS compatible voltage applied to the INH pin. When this voltage is at high level, the module is switched off: if the inhibit signal goes from high to low level, the module restarts softly.
Maximum DC voltage applicable to this pin is 15 V. When remote control (inhibit) of the module is not used, the INH pin must be connected to GND_2.

The remote load sensing is another feature provided in all the models.

This function is performed by two pins (S^+, S^-) that can monitor the voltage directly across the load when this load is connected to the module by long wires: voltage drop on these wires is automatically compensated. Maximum drop compensation must not exceed 100 mV. The case of the module is internally connected to S^-. Therefore, the case must be always isolated from ground if the sensing function is used. The switching frequency of the module is about 100 KHz. To prevent EMI, the module is contained in a metal box that provides shielding and heatsink.

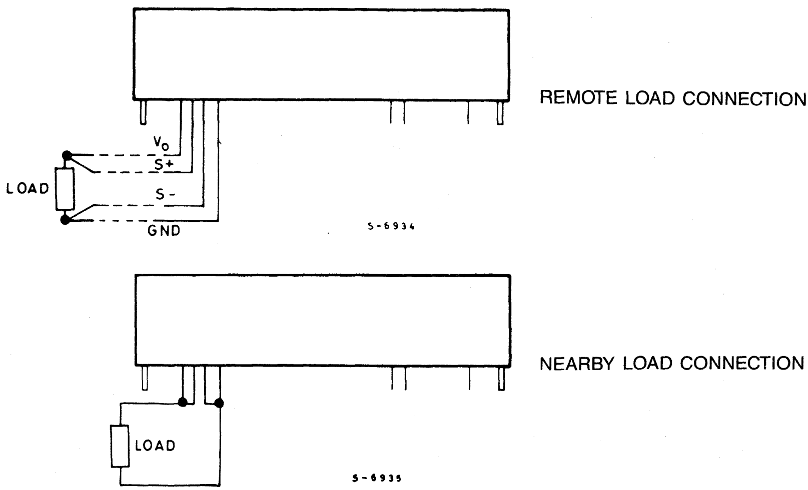


Fig. 1 - Module connection to remote or nearby loads

GS-R405S

The RESET output is provided on GS-R405S only as an auxiliary function to reset or inhibit microprocessors when the output voltage, at switch on and off, reaches a prefixed value of 4.9 to 5.1 V or when the output voltage, for any reason, drops below nominal value by more than 100 mV. In any case the minimum falling threshold value is 4.75 V or higher and the reset output voltage is generated with a fixed delay of 100 ms.

Time delay of the reset function also rejects wrong information caused by occasional spikes generated during switch on and off.

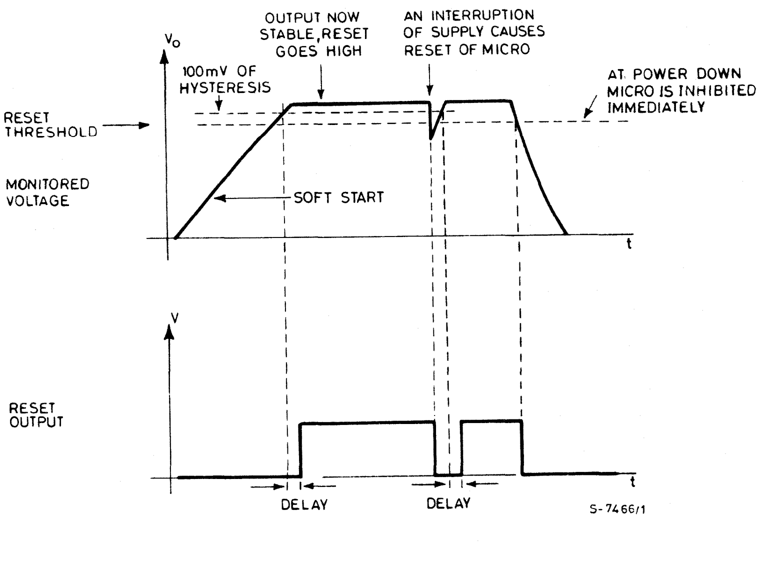


Fig. 2 - Output voltages reset as a function of output voltage and time

GS-R400V

The output voltage of this model can be adjusted in a range from 5.1 to 40 V by use of an external variable resistor as shown in Fig. 3.

The variable resistor can be substituted by a fixed value Rx to obtain a fixed output voltage V_O according to the formula:

$$Rx = 2.67 \cdot \left(\frac{V_o}{5.1} - 1 \right) K\Omega$$

where V_O can vary from 5.1 to 40 V.

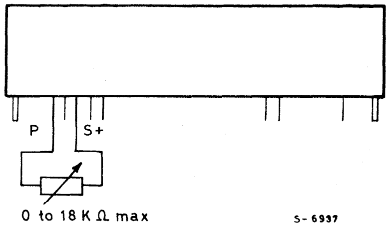


Fig. 3 - Output voltage adjustment on GS-R400V

MODULE PROTECTIONS

THERMAL PROTECTION

The module has inside a thermal protection. When ambient temperature reaches prohibitive values, so that internal junction temperature of active components reaches 150°C, the module is switched off. Normal operation is restored when internal junction temperature falls below 130°C: this large hysteresis allows an extremely low frequency intermittent operation (ON - OFF) caused by thermal overload.

SHORT CIRCUIT PROTECTION

The module is protected against occasional and permanent short circuits of the output pin to ground or against output current overloads.

When output current exceeds the maximum allowed value for safe operation, the output is automatically disabled. After a fixed time, the module starts again in a soft mode: if the overload is still present, the module switches off and the cycle is repeated until the overload condition is removed. The average overload current is limited to a safe value for the module itself. Input current during output short circuit is always lower than in regular operation.

LOAD PROTECTION

The module protects, by a crow bar circuit, the load connected to its output against overvoltages.

This circuit senses continuously the output voltage: if, for any reason, the output voltage of the module exceeds by +20% the nominal value (fixed or adjustable), the crow bar protection is activated and it short circuits the output pin to ground. This protection prevents also damages to module if output pin is wrongly connected to supply voltage.

THERMAL DATA

The thermal resistance module to ambient is about 5°C/W. This means that if the internal power dissipation is 10 W, the temperature on the surface of the module is about 50°C over ambient temperature.

According to ambient temperature and/or to power dissipation, an additional heat-sink may be required. Four holes are provided on the metal box of the module to allow the mounting of this optional external heatsink.

It is recommended to keep the metal box temperature below 85°C.

TYPICAL APPLICATIONS

The high input voltage range allows both cost saving on 50/60 Hz transformer when the module is supplied from the main and the possibility to supply the module with batteries that, according to their charge status, can show large spread on voltage.

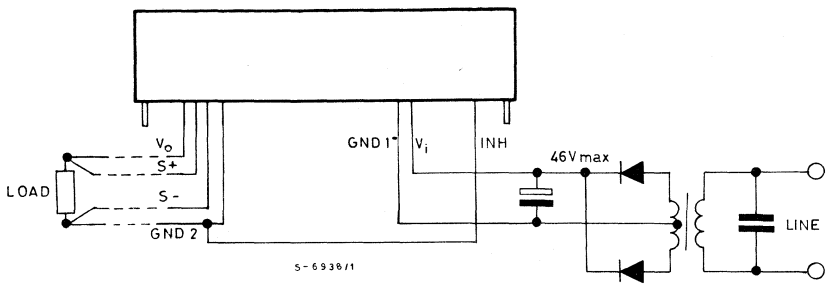


Fig. 4 - A typical application of GS-R400 family

The module has, internally, an input filtering capacitor between pin V_I and GND_1. At the switching frequency therefore the equivalent input circuit is as shown in Fig. 5.

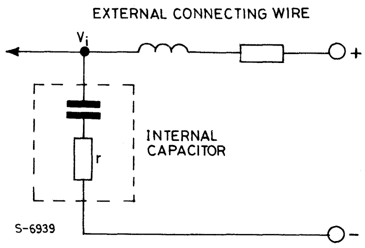


Fig. 5 - Equivalent input circuit of GS-R400 voltage regulator

Since I_I is a high frequency alternating current, the inductance associated to long input connecting wire can cause a voltage ripple on point V_I that produces a ripple current across internal capacitor and a power dissipation on r.
When long connecting wires are used, the input capacitor may be damaged by this power dissipation. For this reason it is suggested to keep input connecting wires as short as possible and to use a low E.S.R. capacitor as input line filter.

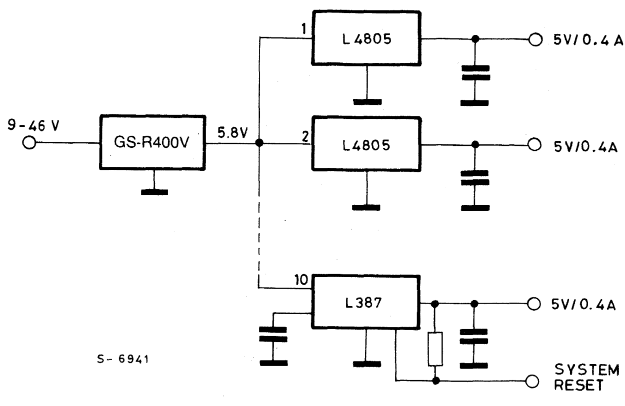


Fig. 6 - Preregulators for Distributed Supplies

The fixed voltage regulators shown on Fig. 6 are available from SGS. An overall low power dissipation is achieved due to the high efficiency of the GS-R400V and inherent low voltage drop of fixed regulators. Up to 10 different points can be supplied, using L4805 or L387.

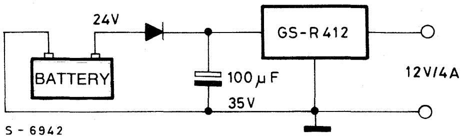


Fig. 7 - 24 V to 12 V Power Conversion for Trucks

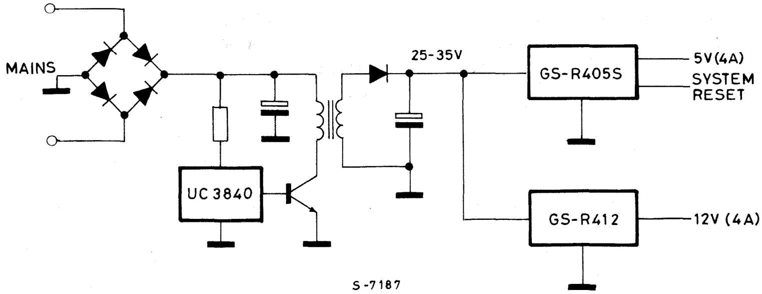


Fig. 8 - Multiple output supply using preregulator

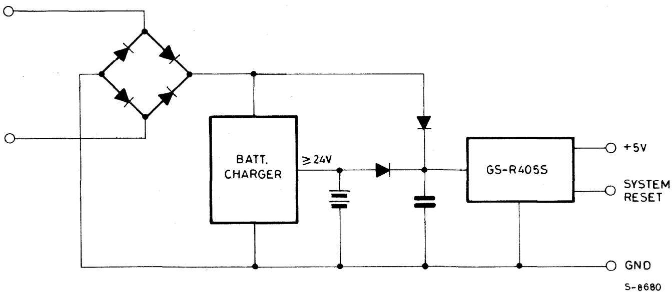
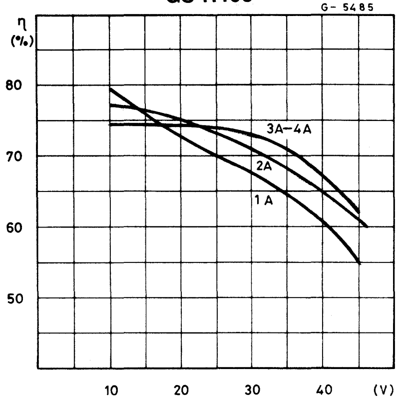


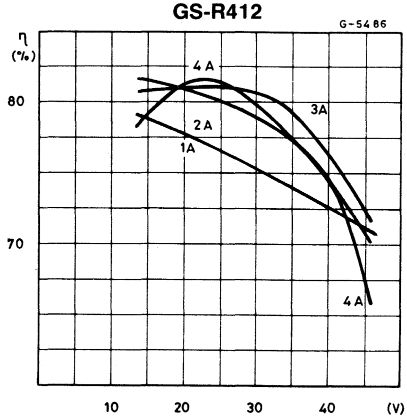
Fig. 9 - Uninterruptable power supply

EFFICIENCY VS. INPUT VOLTAGE & OUTPUT CURRENT

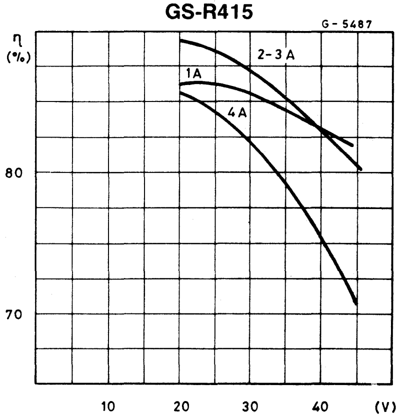
GS-R405



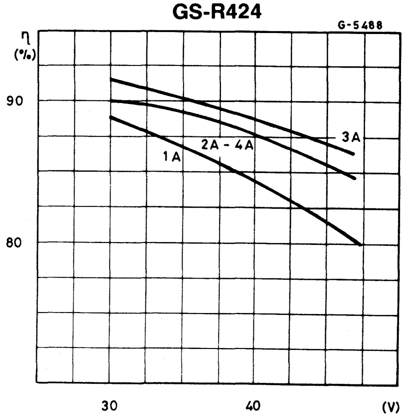
GS-R412



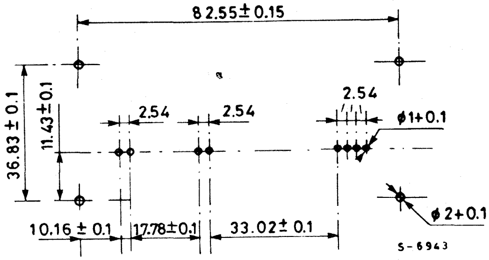
GS-R415



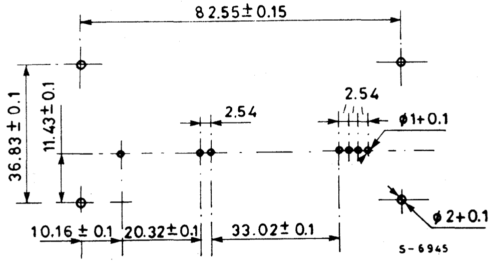
GS-R424



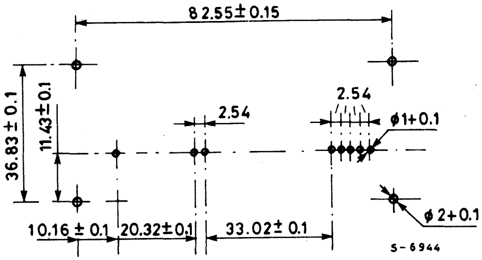
MOTHER BOARD LAYOUT



GS-R405S



GS-R405
GS-R412
GS-R415
GS-R424



GS-R400V

Printed Circuit Drilling (Components Side)

Required holes pattern to be drilled on the mother boards to allow correct mounting

SGS Systems Division

GS-R400/2 Family

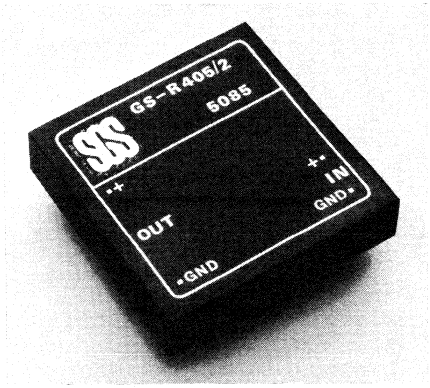
SWITCHING VOLTAGE REGULATOR MODULES

The GS-R400/2 is a family of SMALL SIZE HIGH CURRENT HIGH VOLTAGE SWITCHING VOLTAGE REGULATORS.

These step down regulators, shielded for EMI, can provide local on-card regulation, or be used in central power supply systems, in both professional and industrial applications.

FEATURES

- MTBF in excess of 500.000 hours
- No external components required
- PC card or chassis mountable
- High output current (4 A)
- High input voltage (40 V)
- Fixed output voltage (5.1 V; 12 V)
- High efficiency (up to 85%)
- Soft start
- Non-latching short circuit protection
- Thermal protection
- Crow bar protection for the load
- High power/volume ratio (24 Watt/cubic inch)



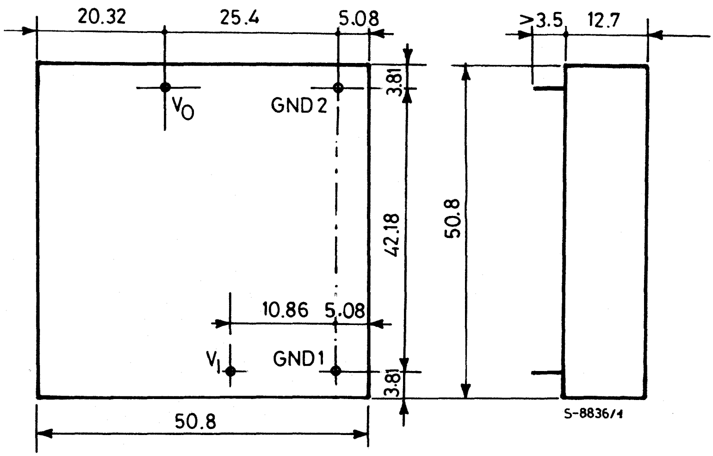
PRODUCTS FAMILY

Order Number	Output Voltage
GS-R405/2	5.1 V
GS-R412/2	12 V

ABSOLUTE MAXIMUM RATINGS

V_i	DC input voltage	40 V
I_o	Output Current	4 A
T_{stg}	Storage temperature range	−40 to + 105°C
T_{cop}	Operating case temperature range	−20 to + 85°C

MECHANICAL DIMENSIONS AND CONNECTION DIAGRAM (Bottom view)



PIN FUNCTIONS

PIN	FUNCTION
V_i - Input Voltage	Unregulated DC voltage input. Maximum voltage must not exceed 40 V.
GND_1 - Ground	Common ground for input voltage.
GND_2 - Ground	Common ground of high current path.
V_O - Output Voltage	Regulated and stabilized DC voltage is available on this pin. Max output current is 4 A. The device is protected against short circuit of this pin to ground or to supply.

The case is electrically connected to GND.

ELECTRICAL CHARACTERISTICS (T_{amb} = 25°C unless otherwise specified)

TYPE		GS-R 405/2			GS-R 412/2			UNIT
PARAMETER	Test Condit.	Min	Typ	Max	Min	Typ	Max	
V_0 Output Voltage	V_i=24V I_0=1A	5	5.1	5.2	11.5	12	12.5	V
V_0 Temperature Stability	V_i=24V I_0=1A		0.2			0.5		mv/°C
V_i Input Voltage	I_0=1A	9		40	16		40	V
I_0 Output Current*	V_i=24V	0.1		4	0.1		4	A
I_{OL} Current Limit	V_i=V_0+8V		5	8		5	8	A
I_{isc} Average Input Current	V_i=40V Output shorted		0.1	0.2		0.1	0.2	A
f_s Switching Frequency			100			100		KHz
η Efficiency	V_i=24V I_0=2A		80			85		%
ΔV_0 Line Regulation	I_0=1A V_i=16 to 26V		2			2		mV/V
SVR Supply voltage rejection	f=100 Hz I_0=1A		4			6		mV/V
ΔV_0 Load Regulation	V_i=24V I_0=0.5 to 1.5A		20			40		mV/A
V_r Ripple Voltage	I_{out}=2A		25			50		mV
V_n Noise Voltage	I_{out}=2A		25			35		mV
I_r Reflected I_{in}	V_i=24V I_0=1A		60			120		mA
T_{r1} Line Transient recovery time	I_0=1A V_i=16 to 26V		500			500		μs
T_{r2} Load Transient recovery time	V_i=24V V_i=0.5 to 1.5A		100			100		μs
Rth Thermal resistance			8			8		°C/W
t_{ss} Soft start time	V_{in}=V_{out}+10V		15			25		ms
t_{CB} Crow bar Delay Time			5			5		μs
V_{CB} Crow bar Threshold			6			14.5		V

* The maximum current can be delivered when t_{case}<85°C. Forced ventilation or additional heat-sink may be required to keep T_{case}<85°C

MODULE OPERATION

The GSR400/2 series is a family of step down switching mode voltage regulators.

Unregulated DC input voltage must be higher than nominal output voltage by, at least, 4 V.

Minimum input voltage is therefore 9 V for GS-R405/2 and maximum input voltage is 40 V for all the types.

The output voltage is fixed and the maximum current delivered by the output pin is 4 A. A minimum output current of 100 mA is required for proper module operation. In no-load condition, the module still works, but the electrical characteristics are slightly modified vs. specifications.

To prevent excessive over current at switch on, a soft start function is provided. Nominal output voltage is approached gradually in about 15 to 25 ms.

The switching frequency of the module is 100 KHz. To prevent EMI, the module is contained in a metal box that provides shielding and heat-sink.

MODULE PROTECTIONS

THERMAL PROTECTION

The module is provided with a thermal protection. When ambient temperature reaches prohibitive values, so that internal junction temperature of active components reaches 150°C, the module is switched off. Normal operation is restored when internal junction temperature falls below 130°C: this large hysteresis allows an extremely low frequency intermittent operation (ON - OFF) caused by thermal overload.

SHORT CIRCUIT PROTECTION

The module is protected against occasional and permanent short circuits of the output pin to ground or against output current overloads.

When the output current exceeds the maximum allowed value for safe operation, the output is automatically disabled. After a fixed time, the module starts again in a soft mode: if the overload is still present, the module switches off and the cycle is repeated until the overload condition is removed. The average overload current is limited to a safe value for the module itself. Input current during output short circuit is always lower than in regular operation.

LOAD PROTECTION

The module protects, by a crow bar circuit, the load connected to its output against overvoltages.

This circuit senses continuously the output voltage: if, for any reason, the output voltage of the module exceeds by +20% the nominal value, the crow bar protection is activated and it short circuits the output pin to ground. This protection prevents also damages to the module if the output pin is wrongly connected to the supply voltage.

OPERATING AMBIENT TEMPERATURE RANGE

The GS-R400/2 modules are power devices, i.e. devices that deliver and dissipate power. The power dissipation is related to the delivered ouput power by

$$P_d = P_o\left(\frac{1}{\eta} - 1\right)$$

where $$\eta = \text{efficiency} = \frac{P_o}{P_{IN}}$$

The operating ambient temperature range cannot be simply defined by numbers because it depends on many conditions that must be previously defined.

On the contrary, the operating case temperature is well defined and it ranges from −20 to +85°C.

The two extremes are imposed by reliable operation of aluminium electrolytic capacitors that are housed inside the modules.

From these data, the maximum ambient temperature range can be easily calculated, as show in the following example:

$V_{IN} = 24V$ $V_{OUT} = 5V;\ 12V$ $I_{OUT} = 3A.$

The dissipated powers of GS-R405/2 and GS-R412/2 are respectively:

$P_{d\ 5V} = 3.75W$ $P_{d\ 12V} = 6.4W$

By knowing the thermal resistance case to ambient $R_{TH} = 8°C/W$ for natural convection condition, the maximum ambient temperature for a case maximum temperature of 85°C will be

$$T_{amb_{max}} = T_{case_{max}} - P_d \cdot R_{TH}$$

i.e.

$T_{amb\ 5V} = 85 - 3.75 \cdot 8 = 55°C$ max $T_{amb\ 12V} = 85 - 8 \cdot 6.4 = 34°C$ max

This ambient temperature can be increased by lowering the thermal resistance case to ambient. Various methods can be adopted such as addition of external heatsink on forced ventilation or both.

If an external heat-sink with $R_{TH} = 10°C/W$ is used, the values are modified as follows.

The total thermal resistance case to ambient is the parallel of the two thermal resistances

$$R_{TH\ TOT} = \frac{R_{TH\ CASE} \cdot R_{TH\ HEAT\text{-}SINK}}{R_{TH\ CASE} + R_{TH\ HEAT\text{-}SINK}} = 4.5°C/W$$

$T_{amb\ 5V} = 68°C$ max $T_{amb\ 12V} = 56°C$ max.

TYPICAL APPLICATIONS

The high input voltage range allows both cost saving on 50/60 Hz transformer when the module is supplied from the mains, and the possibility to supply the module with batteries that, according to their charge status, can show large spread on voltage.

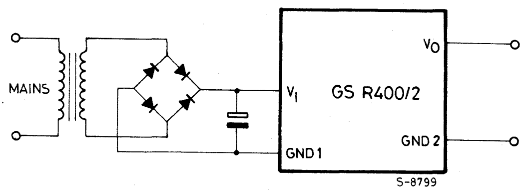


Fig. 1 - A Typical Application of GS-R400/2 Voltage Regulator

The module has, internally, an input filtering capacitor between pin V_I and GND_1. Therefore, at the switching frequency the equivalent input circuit is as shown in fig. 2.

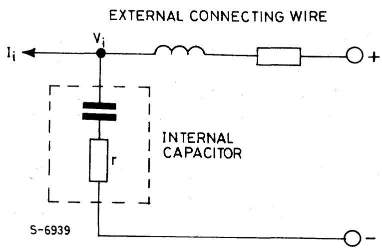
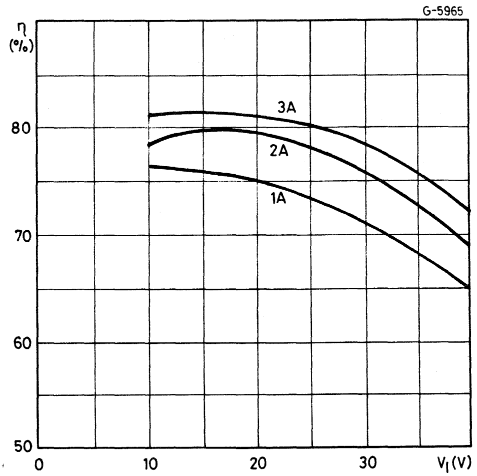


Fig. 2 - Equivalent Input Circuit of GS-R400/2 Voltage Regulator

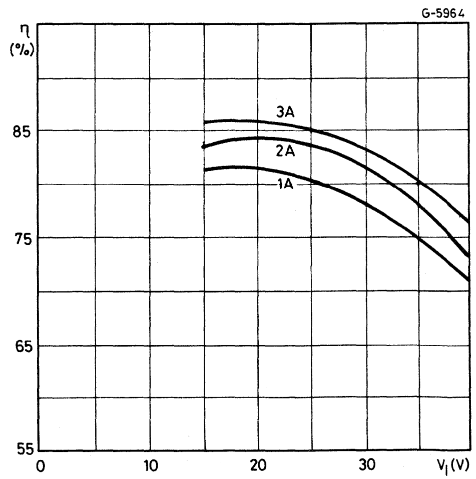
Since I_I is a high frequency alternating current, the inductance associated to long input connecting wire can cause a voltage ripple on point V_I that produces a ripple current across internal capacitor and a power dissipation on r.

When long connecting wires are used, the input capacitor may be damaged by this power dissipation. For this reason it is suggested to keep input connecting wires as short as possible and to use a low E.S.R. capacitor as input line filter.

EFFICIENCY VS. INPUT VOLTAGE & OUTPUT CURRENT



GS-R405/2



GS-R412/2

SGS Systems Division

GS-R400VB

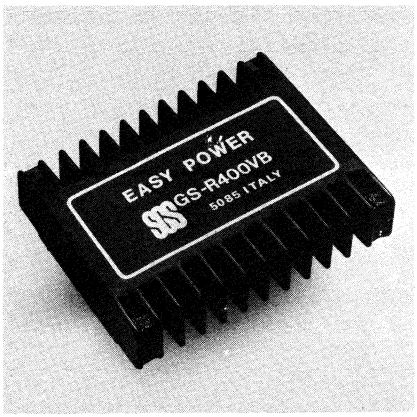
140W SWITCHING VOLTAGE REGULATOR MODULE

The GS-R400VB is a HIGH CURRENT HIGH VOLTAGE SWITCHING VOLTAGE REGULATOR particularly suited for designing multiple outputs power supplies.

This step down regulator shielded for EMI, can provide local on-card regulation, or be used in central power supply systems, in both professional and industrial applications.

FEATURES

- MTBF in excess of 200.000 hours
- PC card or chassis mountable
- High output current (4 A)
- High input voltage (48 V)
- Adjustable output voltage (5.1 to 40 V)
- High efficiency (up to 90%)
- Soft start
- External syncronization
- Remote inhibit/enable
- Remote output voltage sense
- Non-latching short circuit protection
- Thermal protection
- Crow bar protection for the load
- Maximum current limiting



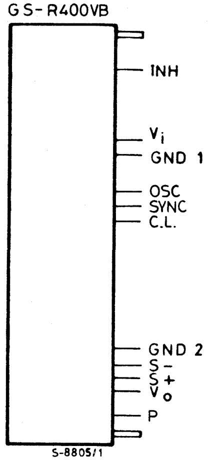
Order Number: GS-R400VB

ABSOLUTE MAXIMUM RATINGS

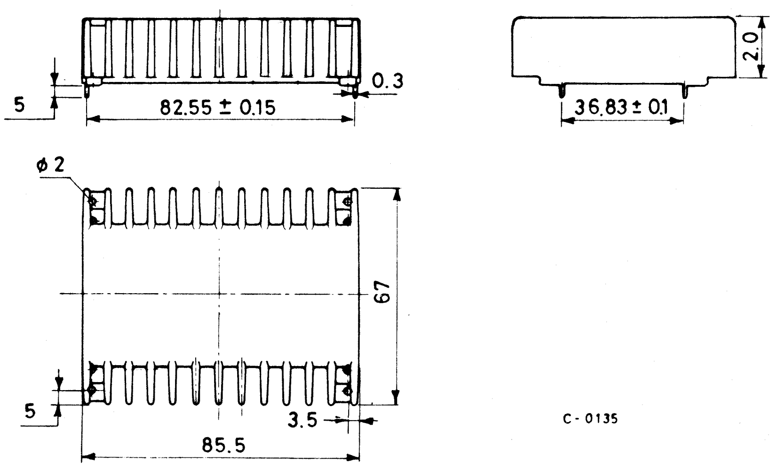
V_i	DC input voltage	48 V
I	Output current	4 A
V_{INH}	Inhibit voltage	15 V
T_{stg}	Storage temperature range	−40 to + 105°C
T_{cop}	Operating case temperature range	−20 to + 85°C

Recommended maximum operating input voltage is 46 V.

CONNECTION DIAGRAM (side view)



MECHANICAL DATA (dimension in mm)



PIN FUNCTIONS

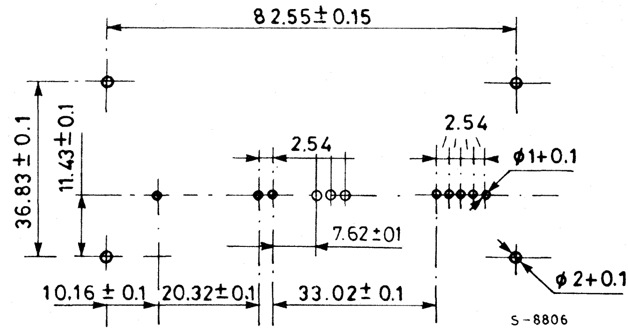
PIN	FUNCTION
INH - Inhibit	TTL compatible input. A logic high level signal applied to this pin disables the module. To be connected to GND_2 when not used.
V_i - Input Voltage	Unregulated DC voltage input. Maximum voltage must not exceed 48 V. Recommended maximum operating voltage is 46 V.
GND_1 - Ground	Common ground for input voltage.
OSC - Oscillator Output Pin	An internal RC network determines the 100 KHz PWM switching frequency. This pin must be connected SYNC if the unit is a Master.
SYNC - Syncronization Input Pin	This pin must be connected to SYNC pin of the Master unit.
C.L. - Current Limit	An external resistor connected between this pin and S− fixes the maximum output current (2,2 KΩ min). To be left open when current set is not used.
GND_2 - Ground	Common ground of high current path.
S− - Sensing Negative	For connection to remote load, this pin senses the actual ground of the load itself. To be connected to GND_2 when not used. This pin is connected to case.
S+ - Sensing Positive	For connection to remote loads this pin allows voltage sensing on the load itself. To be connected to V_O when not used.
V_o - Output Voltage	Regulated and stabilized DC voltage is available on this pin. Max output current is 4 A. The device is protected against short circuit of this pin to ground or to supply.
P - Output Voltage Programming	A variable resistor (18 KΩ max) connected between this pin and S+ sets the output voltage.

ELECTRICAL CHARACTERISTICS (T_{amb} = 25°C unless otherwise specified)

	PARAMETER	Test Conditions	Min	Typ	Max	Unit
V_0	Output Voltage	$V_i=V_0+8V$	5.1	—	40*	V
V_0	Temperature Stability	$I_0=1A$ $V_i=V_0+8V$		0.2/1.6		mV/°C
V_i	Input Voltage	$I_0=1A$	9		46	V
I_0	Output Current	$V_i=V_0+8V$	0.2		4*	A
I_{OL}	Current Limit	$V_i=V_0+8V$	0.5	5	8	A
I_{isc}	Average Input Current	$V_i=46V$ Output shorted		0.2	0.4	A
f_s	Switching Frequency	$I_0=1A$		100		KHz
η	Efficiency	$V_i=V_0+8V$ $I_0=1A$		75/90		%
ΔV_0	Line Regulation	$I_0=1A$ $V_i=V_0+4V$ to 48V		2/6		mV/V
SVR	Supply Voltage Rejection	$f_0=100$ Hz $I_0=1A$		4/12	—	mV/V
ΔV_0	Load Regulation	$\Delta I_0=2A$ (1 to 3A)		20/90	—	mV/A
V_r	Ripple Voltage	$I_{OUT}=2A$		25/150		mV
t_{ss}	Soft Start Time	$V_{in}=V_{OUT}+10V$		15	—	ms
V_{INHL}	Low Inhibit Voltage				0.8	V
V_{INHH}	High Inhibit Voltage		2.0		5.5	V
I_{INH}	Input Current High	$V_{INH}=5V$			500	μA
t_{CB}	Crow bar Delay Time			5		μs
R_{CL}	Current Limit Resistor		2,2		∞	KΩ
R_{SET}	Voltage Setting Resistor		0		18	KΩ
V_{SD}	Max Differential Sense Voltage	V_0 to S+ S– to GND_2			200	mV

* Maximum Output Current is guaranteed up to $V_0=36V$ and derated linearly to 3A at $V_0=40V$.

MOTHER BOARD LAYOUT



MODULE OPERATION

The GS-R400VB is a step down switching mode voltage regulator.

Unregulated DC input voltage must be higher than nominal output voltage by, at least, 4 V. Minimum input voltage is therefore 9 V for 5.1 V output, while maximum input voltage is 48 V.

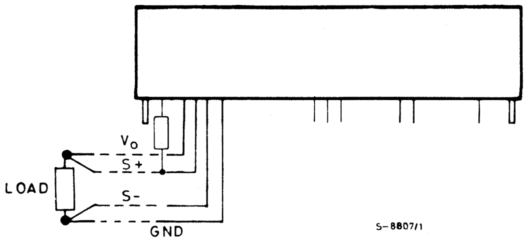
Output voltage is adjustable. The maximum current delivered by the output pin is 4 A and this value can be programmed by using an external resistor connected between C.L. pin and the S− pin. A minimum output current of 100 mA is required for proper module operation. In no-load condition, the module still works, but electrical characteristics are slightly modified vs. specifications. When external current limiting is not used, C.L. pin must be left open.

To prevent excessive over current at switch on, a soft start function is provided. Nominal output voltage is approached gradually in about 15 ms.

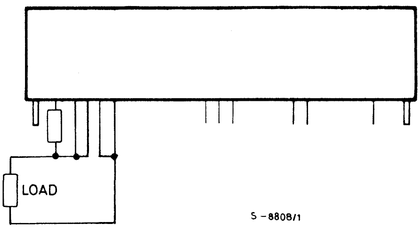
The module can be inhibited by a TTL, N MOS or C MOS compatible voltage applied to the INH pin. When this voltage is at high level, the module is switched off: if the inhibit signal goes from high to low level, the module restarts softly.
Maximum DC voltage applicable to this pin is 15 V. When remote control (inhibit) of the module is not used, the INH pin must be connected to GND_2.

The remote load sensing is another feature provided by the GS-R400VB.

This function is performed by two pins (S+, S−) that can monitor the voltage directly across the load when this load is connected to the module by long wires: voltage drop on these wires is automatically compensated.
The case of the module is internally connected to S−. Therefore, the case must be always isolated from ground if S− is used.
The switching frequency of the module is 100 KHz. To prevent EMI, the module is contained in a metal box that provides shielding and heat-sink.



REMOTE LOAD CONNECTION



NEARBY LOAD CONNECTION

Fig. 1 - Module connection to remote or nearby loads

The output voltage can be adjusted in a range from 5.1 to 40 V by use of an external variable resistor as shown in Fig. 2.

The variable resistor can be substituted by a fixed resistor; the value of Rx to obtain a fixed output voltage V_O is calculated according to the formula:

$$Rx = 2.67 \cdot \left(\frac{V_o}{5.1} - 1 \right) K\,\Omega$$

where V_O can vary from 5.1 to 40 V.

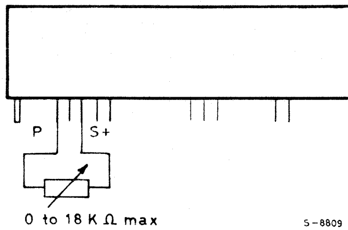


Fig. 2 - Output voltage adjustment on GS-R400VB

The output overcurrent protection limit can be programmed by using an external resistor R_L connected between to current limit C.L. pin and S−.

The value can be selected according to the curve shown in fig. 3

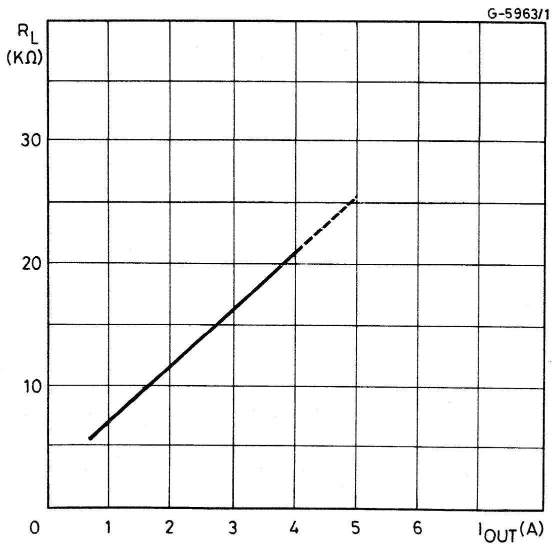


Fig. 3 - Current Limit vs programming resistor value

TYPICAL APPLICATION

The GS-R400VB is designed for multiple outputs power supplies and to this purpose two pins, named OSCILLATOR and SYNCHRONIZATION are available.

When used in a stand alone application or as a master of a multiple outputs unit, these two pins must be tied together.

If the unit is a slave, the SYNC input must be connected to the OSC output of the master unit, and the OSC pin of the slave must be left open as shown in fig. 4.

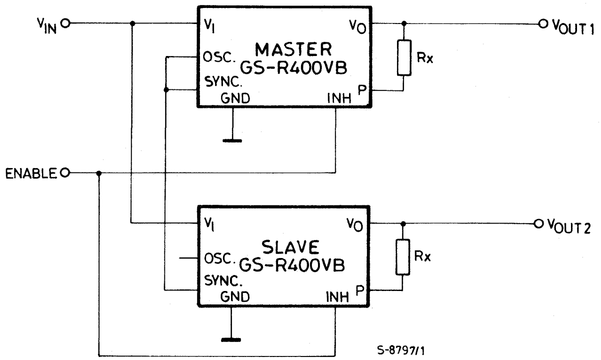


Fig. 4 - GS-R400VB multiple outputs connection

The module has, internally, an input filtering capacitor between pin V_I and GND_1. At the switching frequency therefore the equivalent input circuit is as shown in Fig. 5.

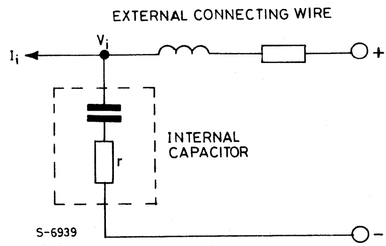


Fig. 5 - Equivalent input circuit of GS-R400 voltage regulator

Since I_I is a high frequency alternating current, the inductance associated to long input connecting wire can cause a voltage ripple on point V_I that produces a ripple current across internal capacitor and a power dissipation on r.
When long connecting wires are used, the input capacitor may be damaged by this power dissipation. For this reason it is suggested to keep input connecting wires as short as possible and to use a low E.S.R. capacitor as input line filter.

The Oscillator output can drive up to four Synchronous inputs. The layout of the PCB must be accurately checked to avoid noise injection on the Oscillator output line, otherwise the overall power supply characteristics will be heavily impaired.

MODULE PROTECTIONS

THERMAL PROTECTION

The module has inside a thermal protection. When ambient temperature reaches prohibitive values, so that internal junction temperature of active components reaches 150°C, the module is switched off. Normal operation is restored when internal junction temperature falls below 130°C: this large hysteresis allows an extremely low frequency intermittent operation (ON - OFF) caused by thermal overload.

SHORT CIRCUIT PROTECTION

The module is protected against occasional and permanent short circuits of the output pin to ground or against output current overloads.

When output current exceeds the maximum programmed value the output is automatically disabled. After a fixed time, the module starts again in a soft mode: if the overload is still present, the module switches off and the cycle is repeated until the overload condition is removed. The average overload current is limited to a safe value for the module itself. Input current during output short circuit is always lower than in regular operation.

LOAD PROTECTION

The module protects, by a crow bar circuit, the load connected to its output against overvoltages.

This circuit senses continuously the output voltage: if, for any reason, the output voltage of the module exceeds by +20% the nominal value (fixed or adjustable), the crow bar protection is activated and it short circuits the output pin to ground. This protection prevents also damages to module if output pin is wrongly connected to supply voltage.

THERMAL DATA

The thermal resistance module to ambient is about 5°C/W. This means that if the internal power dissipation is 10 W, the temperature on the module surface is about 50°C over ambient temperature.

According to ambient temperature and/or to power dissipation, an additional heat-sink may be required. Four holes are provided on the metal box of the module to allow the mounting of this optional external heat-sink.

SGS Systems Division

GS-R51212

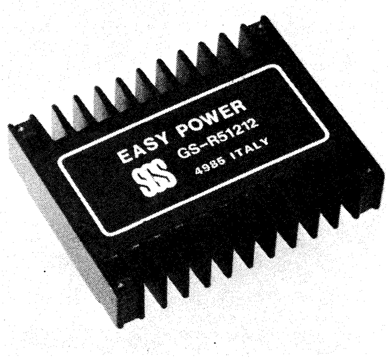
TRIPLE OUTPUT SWITCHING VOLTAGE REGULATOR MODULE

The GS-R51212 is a triple output HIGH CURRENT HIGH VOLTAGE SWITCHING VOLTAGE REGULATOR that provides +5 V and 12 V outputs.

This step down regulator shielded for EMI, provides local on-card regulation. The very large input voltage range allows flexibility in both professional and industrial applications.

FEATURES

- MTBF in excess of 200.000 hours
- No external components required
- PC card or chassis mountable
- High output current (3.5 A on 5 V output)
- High input voltage (40 V)
- Two 12 V; 0.15 A isolated outputs
- High efficiency (up to 90%)
- Soft start
- Reset output
- Non-latching short circuit protection
- Thermal protection
- Crow bar protection for the load

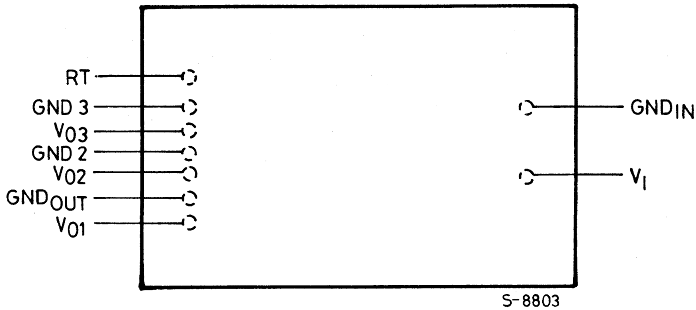


Order Number: GS-R51212

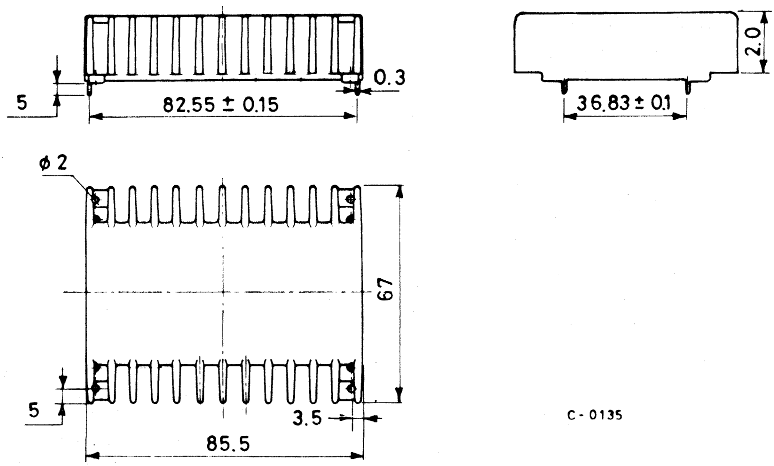
ABSOLUTE MAXIMUM RATINGS

V_i	DC input voltage	40 V
I_{RT}	Reset output sink current	20 mA
T_{stg}	Storage temperature range	−40 to + 105°C
T_{cop}	Operating case temperature range	−20 to + 85°C

CONNECTION DIAGRAM (top view)



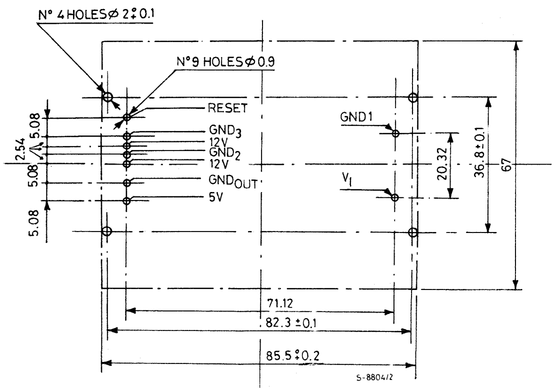
MECHANICAL DATA (dimensions in mm)



PIN FUNCTIONS

PIN		FUNCTION
RT	Reset Output	Reset output is high when output voltage reaches nominal value (5.1 V) and it is generated with a fixed 100 ms delay. A proper resistor (270 Ω min) must be connected between this pin and V_{O1}
V_i	Input Voltage	Unregulated DC voltage input. Maximum voltage must not exceed 40 V.
GND_{IN}	Ground	Common ground for input voltage.
GND_{OUT}	Ground	Common ground of high current path. The case of the module is connected to this pin.
V_{O1}	5 V Output Voltage	Regulated and stabilized DC voltage is available on this pin. Max output current is 3.5 A. The device is protected against short circuit of this pin to ground or to supply.
V_{O2}	12 V Output Voltage	Regulated and stabilized 12 V DC output at 150 mA max. current referred to GND_2. This output can float ±50 V in respect to GND_{OUT} and GND_3.
GND_2	Ground	Reference ground for V_{O2} output.
V_{O3}	12 V Output Voltage	Regulated and stabilized 12 V DC output at 150 mA max. current referred to GND_3. This output can float ±50 V in respect to GND_{OUT} and GND_2.
GND_3	Ground	Reference ground for V_{O3} output.

MOTHER BOARD LAYOUT



Printed Circuit Drilling (components side)

ELECTRICAL CHARACTERISTICS (T_{amb} = 25°C unless otherwise specified)

PARAMETER		Test Conditions	Min	Typ	Max	Unit
V_{o1}	Output Voltage	V_i=24V I_{o1}=2.5A	4.9	5.1	5.2	V
V_{o2}	Output Voltage	V_i=24V I_{o2}=0.1A	11.5		12.5	V
V_{o3}	Output Voltage	V_i=24V I_{o3}=0.1A	11.5		12.5	V
V_o	Temperature Stability	All Outputs		0.2		mV/°C
V_i	Input Voltage	I_{o1}=2.5A $I_{o2/3}$=.1A	9.0		40	V
I_{o1}	Output Current	V_i=24V	0.5		3.5	A
I_{o2}	Output Current	V_i=24V			.15	A
I_{o3}	Output Current	V_i=24V			.15	A
I_{sc}	Average Input Current	V_i=40V V_{out1}=0V		0.2		A
I_{sc}	Average Input Current	V_i=40V $V_{out1/2/3}$=0V		0.4		A
I_r	Reflected Iin	V_i=24V I_{o1}=2.5A I_{o2}=0.1A I_{o3}=0.1A		160		mA
f_s	Switching Frequency			100		KHz
η	Efficiency	V_i=24V I_{o1}=2.5A I_{o2}=0.1A I_{o3}=0.1A		75		%
ΔV_o	Line Regulation	I_{o1}=2.5A V_i=15 to 25V I_{o2}=0.1A I_{o3}=0.1A		2		mV/V
ΔV_o	Load Regulation	V_i=24V I_{o1}=.5 to 2.5A V_i=24V I_{o2}=.05 to .1A V_i=24V I_{o3}=.05 to .1A		20 1 1		mV/A mV/A mV/A
SVR	Supply Rejection	50/60Hz		4		mV/V
V_r	Ripple Voltage	V_i=24V I_{o1}=2.5A		30		mV
V_n	Noise Voltage	V_i=24V I_{o1}=2.5A		40		mV
I_{rh}	Reset Leakage Current				100	µA
V_{rl}	Reset Low Level	I_{reset}=5mA		0.2		V
T_{rd}	Reset Delay Time			100		ms
T_{r1}	Line Transient Recovery Time	I_{o1}=2.5A V_i=15 to 35V		500		µs
T_{r2}	Load Transient Recovery Time	V_i=24V I_o=.5 to 2.5A		200		µs
R_{th}	Thermal Resistance			5		°C/W

MODULE OPERATION

The GSR51212 is a triple output switching mode voltage regulator.

Unregulated DC input voltage must be higher than nominal output voltage by, at least, 4 V. Minimum input voltage is therefore 9 V while maximum input voltage is 40 V.

The main output voltage is 5 V and the maximum current delivered is 3.5 A. A minimum output current of 500 mA is required for proper module operation.

The current available on the 12 Volt outputs depends on the current delivered by the main output and the value of the input voltage.

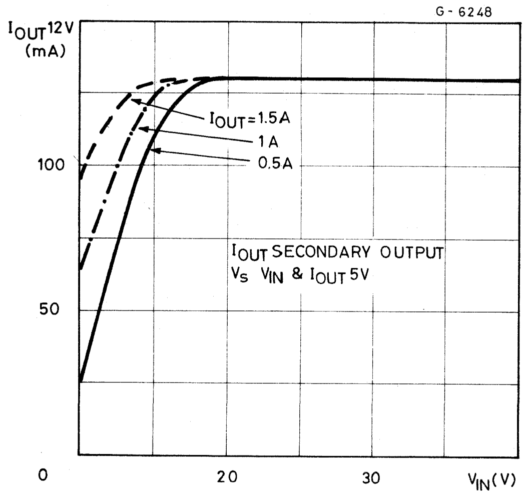


Fig. 1 - Current available from 12V ouput vs. input voltage and 5V output current

To prevent excessive over current at switch on, a soft start function is provided. Nominal output voltage is approached gradually in about 15 ms.

The switching frequency of the module is 100 KHz. To prevent EMI, the module is contained in a metal box that provides shielding and heat-sink.

The RESET output is an auxiliary function useful to reset or inhibit microprocessors when the output voltage, at switch on and off, reaches a prefixed value of 4.9 to 5.1 V or when the output voltage, for any reason, drops below nominal value by more than 100 mV. In any case the minimum falling threshold value is 4.75 V or higher and the reset output voltage is generated with a fixed delay of 100 ms.

This is an open collector output to guarantee maximum flexibility.

Time delay of the reset function also rejects wrong information caused by occasional spikes generated during switch on and off.

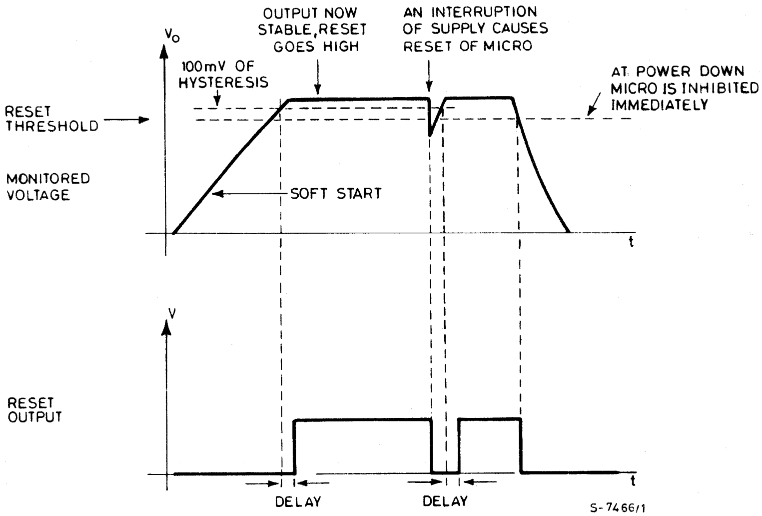


Fig. 2 - Reset as a function of output voltage and time

MODULE PROTECTIONS

THERMAL PROTECTION

The module has inside a thermal protection. When ambient temperature reaches prohibitive values, so that internal junction temperature of active components reaches 150°C, the module is switched off. Normal operation is restored when internal junction temperature falls below 130°C: this large hysteresis allows an extremely low frequency intermittent operation (ON - OFF) caused by thermal overload.

SHORT CIRCUIT PROTECTION

The module is protected against occasional and permanent short circuits of the output pins to their respective grounds or against output current overloads.

When the 5 V output current exceeds the maximum allowed value for safe operation, the output is automatically disabled. After a fixed time, the module starts again in a soft mode: if the overload is still present, the module switches off and the cycle is repeated until the overload condition is removed. The average overload current is limited to a safe value for the module itself. Input current during output short circuit is always lower than in regular operation.

LOAD PROTECTION

The module protects, by a crow bar circuit, the load connected to the 5 V output against overvoltages.

This circuit senses continuously the output voltage: if, for any reason, the output voltage of the module exceeds 6 V, the crow bar protection is activated and it short circuits the output pin to ground.

THERMAL DATA

The thermal resistance module to ambient is about 5°C/W. This means that if the internal power dissipation is 10 W, the temperature of the module surface is about 50°C over ambient temperature.

According to ambient temperature and/or to power dissipation, an additional heat-sink may be required. Four holes are provided on the metal box of the module to allow the mounting of this optional external heat-sink.

TYPICAL APPLICATIONS

The high input voltage range allows both cost saving on 50/60 Hz transformer when the module is supplied from the main and the possibility to supply the module with batteries that, according to their charge status, can show large spread on voltage.

The module has, internally, an input filtering capacitor between pin V_I and GND_1. At a high switching frequency the equivalent input circuit is as shown in Fig. 2. Since I_I is a high frequency alternating current, the inductance associated to long input connecting wire can cause a voltage ripple on point V_I that produces a ripple current across internal capacitor and a power dissipation on r.
When long connecting wires are used, the input capacitor may be damaged by this power dissipation. For this reason it is suggested to keep input connecting wires as short as possible and to use a low ESR capacitor as input line filter.

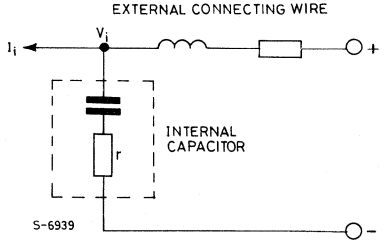
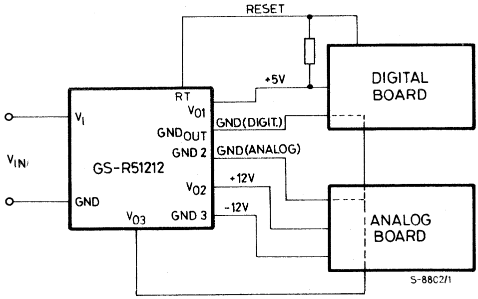


Fig. 3 - Equivalent input circuit of GS-R51212 voltage regulator



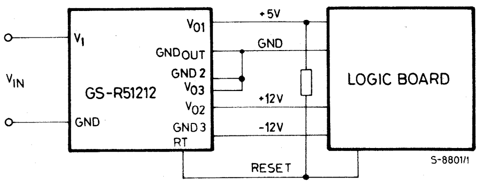


Fig. 4 - GS-R51212 typical applications

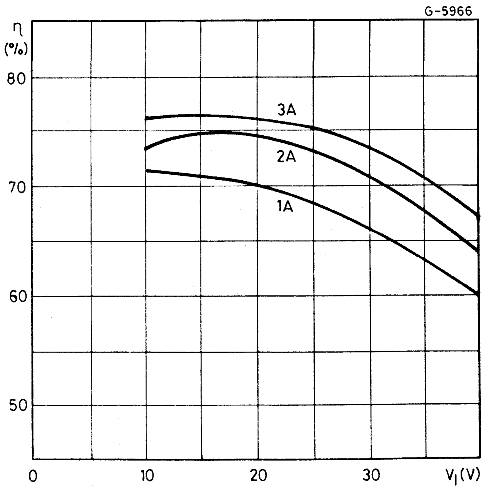


Fig. 5 - Efficiency vs. input voltage

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