SILICON GENERAL

LINEAR INTEGRATED CIRCUITS

SG138A/SG238A/SG338A
SG138/SG238/SG338

5 AMP POSITIVE ADJUSTABLE VOLTAGE REGLATOR

DESCRIPTION

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

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

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

FEATURES

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

HIGH RELIABILITY FEATURES -SG138A/SG138

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

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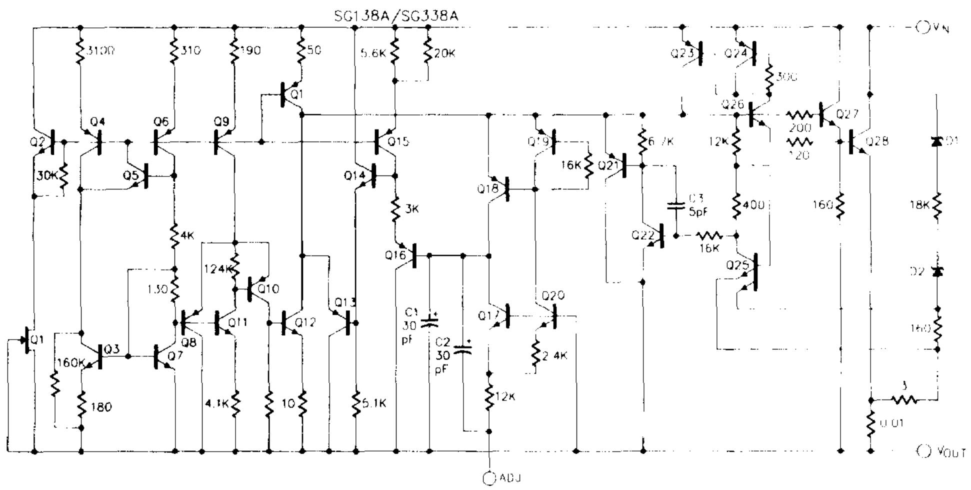
SCHEMATIC



April 1990

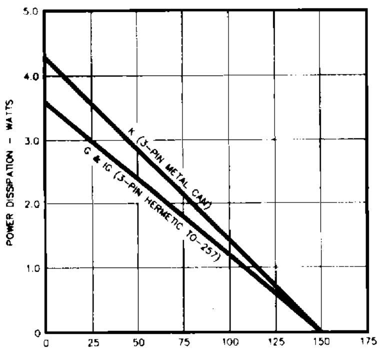
ABSOLUTE MAXIMUM RATINGS (Note 1)

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

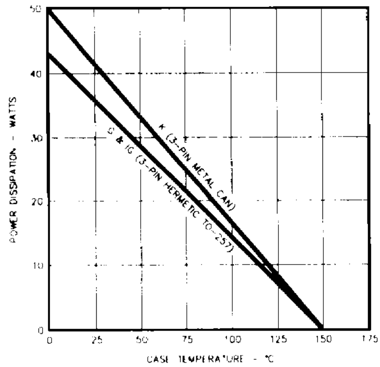
Operating Junction Temperature
Hermetic (K, G, IG-Packages) .... 150°C
Lead Temperature (Soldering, 10 Seconds) .... 300°C

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

THERMAL DERATING CURVES



MAXIMUM POWER DISSIPATION vs AMBIENT TEMPERATURE



MAXIMUM POWER DISSIPATION vs CASE TEMPERATURE

RECOMMENDED OPERATING CONDITIONS (Note 2)

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

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

Note 2: Range over which the device is functional.

ELECTRICAL SPECIFICATIONS

(Unless otherwise specified, these specifications apply over full operating ambient temperatures for SG138A/SG138 with -55°C ≤ T_A ≤ 150°C, SG238A/SG238 with -25°C ≤ T_A ≤ 150°C, SG338A/SG338 with 0°C ≤ T_A ≤ 125°C, V_{IN} - V_{OUT} = 5.0V, I_{OUT} =2.5mA. Low duty cycle pulse testing techniques are used which maintains junction and case temperatures equal to the ambient temperature.)

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

ELECTRICAL SPECIFICATIONS (continued)

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

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

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

4

CHARACTERISTIC CURVES

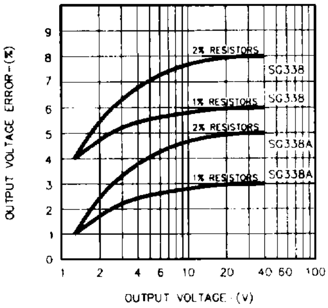


FIGURE 1.
OUTPUT VOLTAGE ERROR VS. OUTPUT VOLTAGE

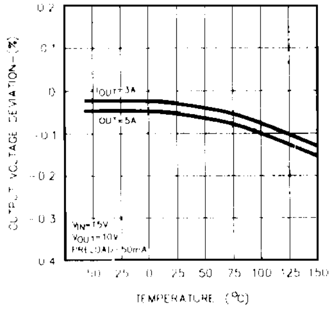


FIGURE 2.
LOAD REGULATION VS. TEMPERATURE

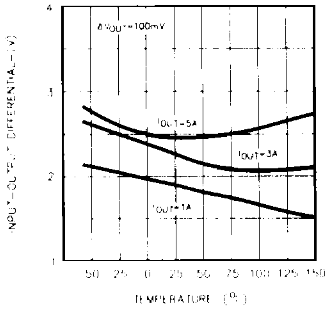


FIGURE 3.
DROPOUT VOLTAGE VS. TEMPERATURE

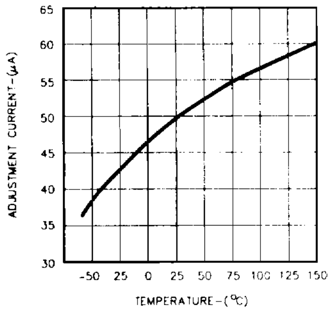


FIGURE 4.
ADJUSTMENT CURRENT VS. TEMPERATURE

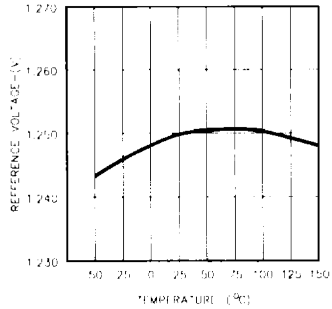


FIGURE 5.
TEMPERATURE STABILITY

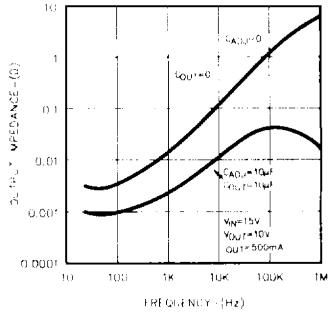


FIGURE 6.
OUTPUT IMPEDANCE VS. FREQUENCY

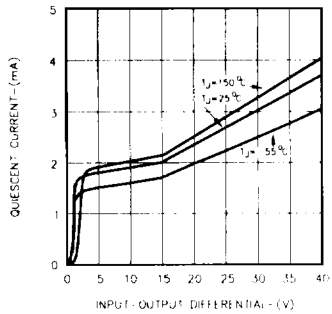


FIGURE 7.
MINIMUM OPERATING CURRENT VS. INPUT - OUTPUT DIFFERENTIAL

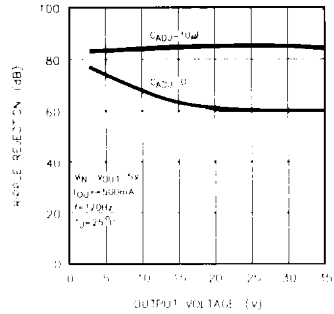


FIGURE 8.
RIPPLE REJECTION VS. OUTPUT VOLTAGE

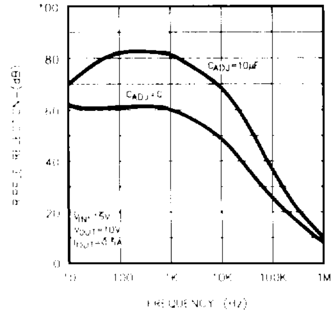


FIGURE 9.
RIPPLE REJECTION VS. FREQUENCY

CHARACTERISTIC CURVES (continued)

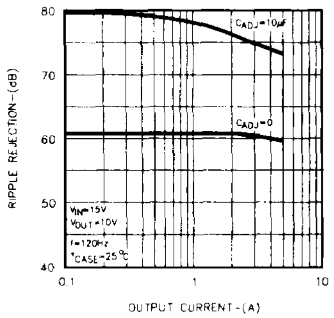


FIGURE 10.
RIPPLE REJECTION

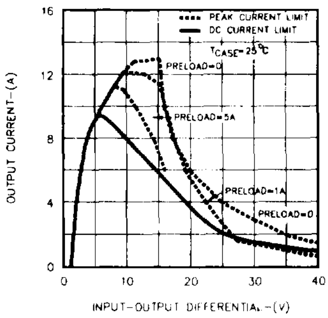


FIGURE 11.
CURRENT LIMIT VS. INPUT - OUTPUT DIFFERENTIAL

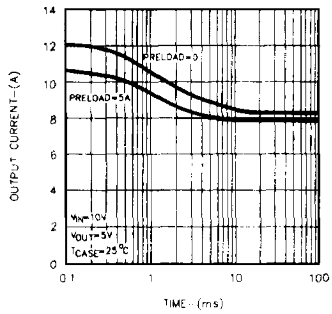


FIGURE 12.
CURRENT LIMIT VS. PERIOD

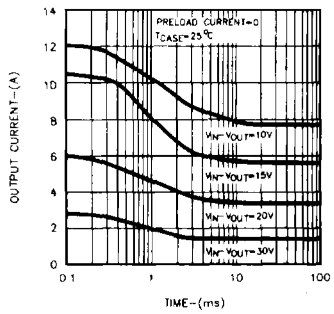


FIGURE 13.
CURRENT LIMIT VS. PERIOD

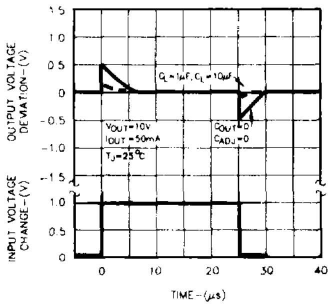


FIGURE 14.
LINE TRANSIENT RESPONSE VS. PERIOD

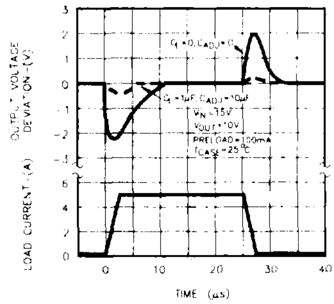


FIGURE 15.
LOAD TRANSIENT RESPONSE VS. PERIOD

APPLICATION INFORMATION

GENERAL

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

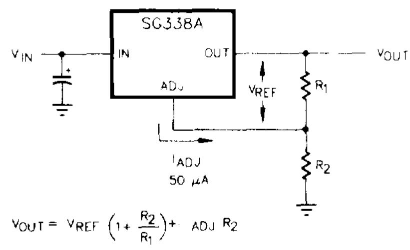


FIGURE 16 - BASIC ADJUSTABLE REGULATOR

APPLICATION INFORMATION (continued)

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

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

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

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

Table of ½% and 1% Standard Resistance Values

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

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

BYPASS CAPACITORS

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

PROTECTION DIODES

The SG138A/338A do not require a protection diode from the adjustment terminal to the output (see Figure17). Improved internal circuitry eliminates the need for this diode when the adjustment pin is bypassed with a capacitor to improve ripple rejection.If a very large output capacitor is used, such as a 100μF shown in Figure 2, the regulator could be damaged or destroyed if the input is accidentally shorted to ground or crowbarred, due to the output capacitor discharging into the output terminal of the regulator. To prevent this, a diode D1 as shown, is recommended to safely discharge the capacitor.

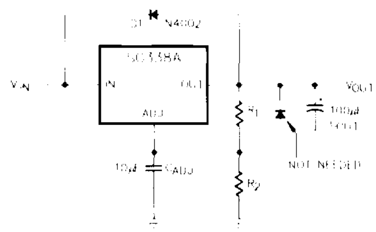


FIGURE 17 - REMOVING PROTECTION DIODE

LOAD REGULATION

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

$$R_p \times \left(\frac{R2 + R1}{R1}\right), R_p = \text{Parasitic Line Resistance.}$$

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

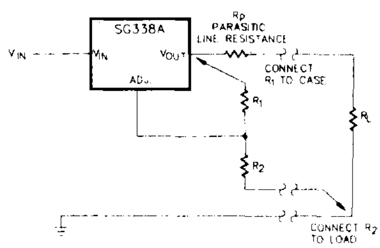
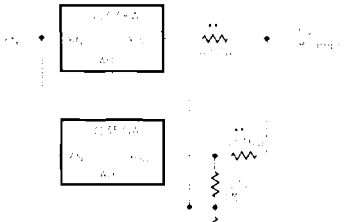


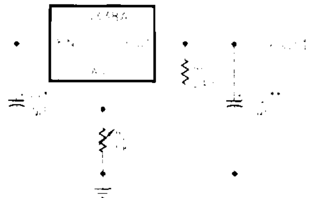
FIGURE 18 - CONNECTIONS FOR BEST LOAD REGULATION

TYPICAL APPLICATIONS



* This circuit will not work with LM version devices.
** Current sharing resistors degrade regulation to 1%

FIGURE 19 - PARALLEL REGULATORS FOR HIGHER CURRENT



* Needed if device is far from filter capacitor
** Optional - improves transient response

FIGURE 20 - 1.2V - 25V ADJUSTABLE REGULATOR

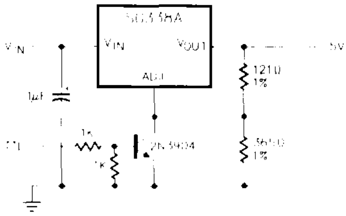
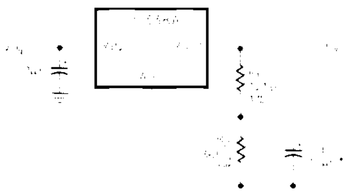


FIGURE 21 - 5V REGULATOR WITH SHUT DOWN



* C_1 improves ripple rejection. X_C should be small compared to R_1

FIGURE 22 - IMPROVING RIPPLE REJECTION

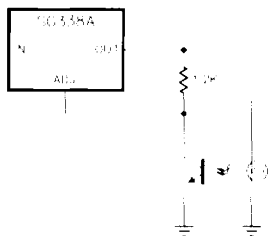


FIGURE 23 - AUTOMATIC LIGHT CONTROL

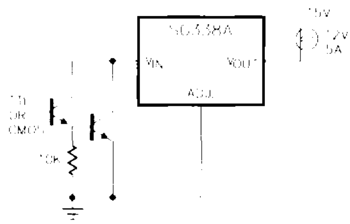


FIGURE 24 - PROTECTED HIGH CURRENT LAMP DRIVER

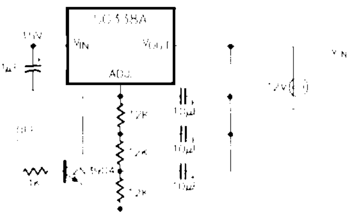


FIGURE 25 - LAMP FLASHER

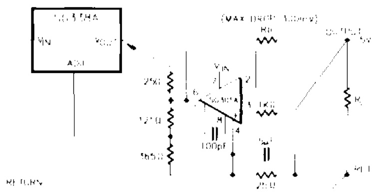


FIGURE 26 - REMOTE SENSING

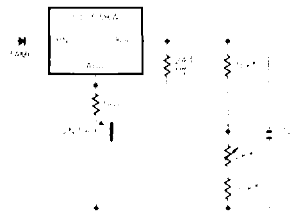
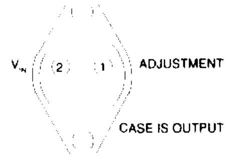


FIGURE 27 - TEMPERATURE COMPENSATED LEAD ACID BATTERY CHARGER

CONNECTION DIAGRAMS & ORDERING INFORMATION (See Notes Below)

Package	Part No.	Ambient Temperature Range	Connection Diagram
3-PIN METAL CAN K-PACKAGE	SG138AK/883B	-55°C to 150°C	
	SG138AK	-55°C to 150°C	
	SG238AK	-25°C to 150°C	
	SG338AK	0°C to 125°C	
	SG138K/883B	-55°C to 150°C	
	SG138K	-55°C to 150°C	
	SG238K	-25°C to 150°C	
	SG338K	0°C to 125°C	
3-PIN HERMETIC TO-257 G-PACKAGE (non-Isolated)	SG138AG/883B	-55°C to 150°C	
	SG138AG	-55°C to 150°C	
	SG138G/883B	-55°C to 150°C	
	SG138G	-55°C to 150°C	
3-PIN HERMETIC TO-257 IG-PACKAGE (Isolated)	SG138AIG/883B	-55°C to 150°C	
	SG138AIG	-55°C to 150°C	
	SG138IG/883B	-55°C to 150°C	
	SG138IG	-55°C to 150°C	

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