National Semiconductor

LM78MG
4-Terminal Adjustable Voltage Regulator

General Description

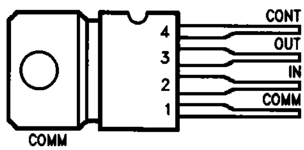
The LM78MG is a 4-terminal adjustable positive voltage regulator that has an output voltage range between 5V and 30V. It is designed to operate with a maximum input voltage of 40V and to deliver up to 500 mA of load current. Output current capability can be increased to greater than 10A through use of one or more external transistors.

Features

- Output current in excess of 0.5A
- Output voltage adjustable from 5V to 30V
- Internal thermal overload protection
- Internal short circuit current protection
- Output transistor safe-area protection

Connection Diagram and Ordering Information

(TO-202)
Plastic Package



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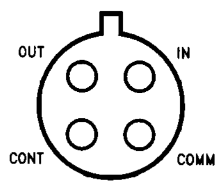
Top View

Heat sink tabs connected to comm through device substrate. Not recommended for direct electrical connection.

Order Number LM78MGCP
See NS Package Number P04A

(TO-39)
Metal Can



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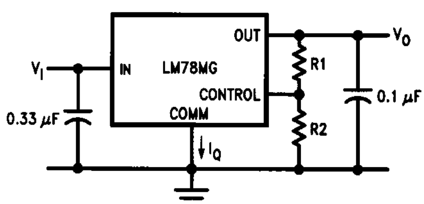
Bottom View

Order Number LM78MGH/883
See NS Package Number HA04E

LM78MG Test Circuit 1

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

V_{CONT} Nominally = 5V
Recommended R2 current ≈ 1 mA
R2 = 5 kΩ



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Absolute Maximum Ratings

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Storage Temperature Range	−65°C to +150°C
Junction Temperature Range	
LM78MGC	0°C to +150°C
LM78MG	−55°C to +150°C
Lead Temperature (Soldering, 10 sec.)	265°C
Internal Power Dissipation	Internally Limited
Input Voltage	+40V
Control Lead Voltage	$0V \le V_C \le V_O$

LM78MGC

Electrical Characteristics

$0°C \le T_A \le 125°C$ for LM78MGC, $V_I = 10V$, $I_O = 350$ mA, $C_I = 0.33\ \mu F$, $C_O = 0.1\ \mu F$, Test Circuit 1, unless otherwise specified

Symbol	Parameter	Conditions (Notes 1, 2)		Min	Typ	Max	Units
V_{IN}	Input Voltage Range	$T_J = 25°C$		7.5		40	V
V_{OUT}	Output Voltage Range	$V_I = V_O + 5.0V$		5.0		30	V
V_O	Output Voltage Tolerance	$(V_O + 3.0V) \le V_I \le (V_O + 15V)$, $5.0\ mA \le I_O \le 350\ mA$, $P_D \le 5.0W$, $V_{I\ Max} = 38V$	$T_J = 25°C$			4.0	% (V_O)
						5.0	
$\Delta V_O/\Delta V_{IN}$	Line Regulation	$T_J = 25°C$, $I_O = 200$ mA, $V_O \le 10V$, $(V_O + 2.5V) \le V_I \le (V_O + 20V)$,				1.0	%(V_O)
$\Delta V_O/\Delta I_{LOAD}$	Load Regulation	$T_J = 25°C$, $5.0\ mA \le I_O \le 500\ mA$, $V_I = V_O + 7.0V$				1.0	%(V_O)
I_C	Control Lead Current	$T_J = 25°C$			1.0	6.0	μA
						7.0	
I_Q	Quiescent Current	$T_J = 25°C$			2.8	5.0	mA
						6.0	
$\Delta V_{IN}/\Delta V_{OUT}$	Ripple Rejection	$I_O = 125$ mA, $8.0V \le V_I \le 18V$, $V_O = 5.0V$, $f = 2400$ Hz		62	80		dB
e_n	Output Noise Voltage	$10\ Hz \le f \le 100\ kHz$, $V_O = 5.0V$			8	40	$\mu V/V_O$
$V_{IN}-V_{OUT}$	Dropout Voltage (Note 3)				2	2.5	V
I_{SC}	Short Circuit Current	$V_I = 35V$, $T_J = 25°C$				600	mA
I_{pk}	Peak Output Current	$T_J = 25°C$		0.4	0.8	1.4	A
$\Delta V_O/\Delta T$	Average Temperature Coefficient of Output Voltage	$V_O = 5.0V$, $I_O = 5.0$ mA	$T_A = 0°C$ to $+25°C$			0.4	mV/°C/ V_O
			$T_A = 25°C$ to $125°C$			0.3	
V_C	Control Lead Voltage (Reference)	$T_J = 25°C$		4.8	5.0	5.2	V
				4.75		5.25	

LM78MG

Electrical Characteristics

$-55°C \le T_A \le 125°C$ for LM78MG, $V_I = 10V$, $I_O = 350$ mA, $C_I = 0.33$ µF, $C_O = 0.1$ µF, Test Circuit 1, unless otherwise specified (Note 6).

Symbol	Parameter	Conditions (Notes 1, 2)		Min	Typ	Max	Units
V_{IN}	Input Voltage Range	$T_J = 25°C$		7.5		40	V
V_{OUT}	Output Voltage Range	$V_I = V_O + 5.0V$		5.0		30	V
V_O	Output Voltage Tolerance	$(V_O + 3.0V) \le V_I \le (V_O + 15V)$, 5.0 mA $\le I_O \le$ 350 mA, $P_D \le 5.0W$, $V_{I\,Max} = 38V$	$T_J = 25°C$			4.0	% (V_O)
						5.0	
$\Delta V_O/\Delta V_{IN}$	Line Regulation	$T_J = 25°C$, $I_O = 200$ mA, $V_O \le 10V$, $(V_O + 2.5V) \le V_I \le (V_O + 20V)$,				1.0	%(V_O)
$\Delta V_O/\Delta I_{LOAD}$	Load Regulation	$T_J = 25°C$, 5.0 mA $\le I_O \le$ 500 mA, $V_I = V_O + 7.0V$				1.0	%(V_O)
I_C	Control Lead Current	$T_J = 25°C$			1.0	6.0	µA
						7.0	
I_Q	Quiescent Current (Note 5)	$T_J = 25°C$			2.8	7.0	mA
						8.0	
$\Delta V_{IN}/\Delta V_{OUT}$	Ripple Rejection	$I_O = 125$ mA, $V_I = 10V$, $V_O = 5.0V$, f = 2400 Hz		60	80		dB
e_n	Output Noise Voltage	10 Hz $\le$ f $\le$ 100 kHz, $V_O = 5.0V$			8	40	µV/V_O
$V_{IN}-V_{OUT}$	Dropout Voltage (Note 3)				2	2.5	V
I_{SC}	Short Circuit Current	$V_I = 35V$, $T_J = 25°C$				600	mA
I_{pk}	Peak Output Current	$T_J = 25°C$, $V_I = 12V$ (Note 4)		0.4	0.8	1.4	A
$\Delta V_O/\Delta T$	Average Temperature Coefficient of Output Voltage	$V_O = 5.0V$, $I_O = 5.0$ mA	$T_A = 0°C$ to $+25°C$			0.4	mV/°C/V_O
			$T_A = 25°C$ to $125°C$			0.3	
V_C	Control Lead Voltage (Reference)	$T_J = 25°C$		4.8	5.0	5.2	V
				4.75		5.25	

Note 1: V_O is defined as $V_O = \frac{R1 + R2}{R2}(5.0)$.

Note 2: All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ($t_W \le 10$ ms, duty cycle $\le 5\%$). Output voltage changes due to changes in internal temperature must be taken into account separately.

Note 3: Dropout voltage is defined as that input/output voltage differential which causes the output voltage to decrease by 5% of its initial value.

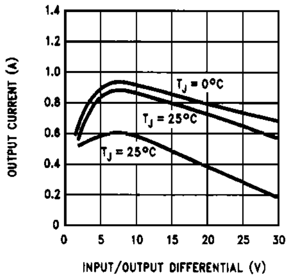
Note 4: The peak output current is defined as the output current when V_{OUT} is equal to 90% of its nominal value.

Note 5: This measurement includes 1 mA provided to the output resistors.

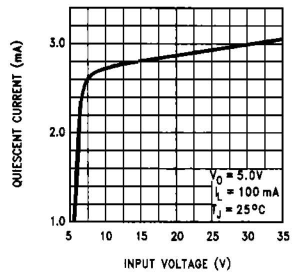
Note 6: A military RETS electrical test specification is available on request. At the time of printing, the LM78MGH RETS specification complied fully with the limits in the table on this page.

Typical Performance Characteristic

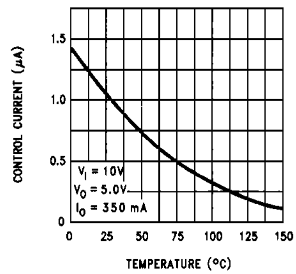
Peak Output Current vs Input/Output Differential Voltage



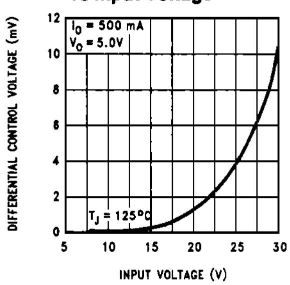
Quiescent Current vs Input Voltage



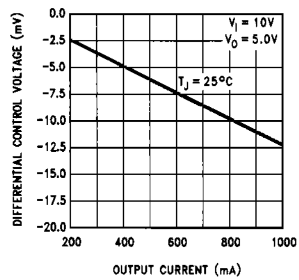
Control Current vs Temperature



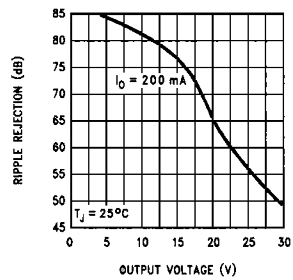
Differential Control Voltage vs Input Voltage



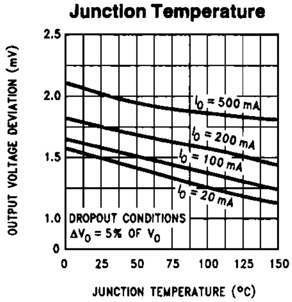
Differential Control Voltage vs Output Current



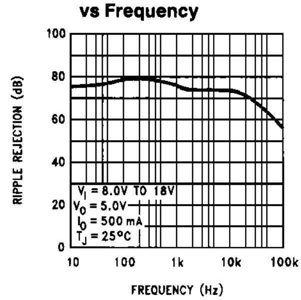
Ripple Rejection vs Output Voltage



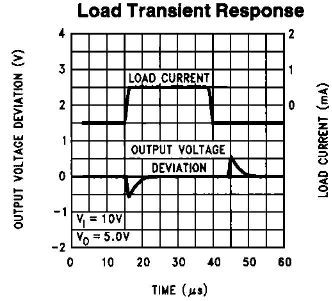
Dropout Voltage vs Junction Temperature



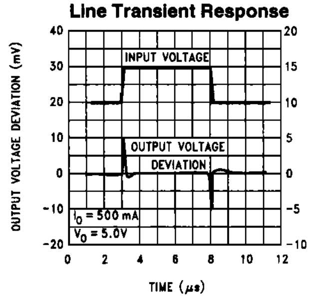
Ripple Rejection vs Frequency



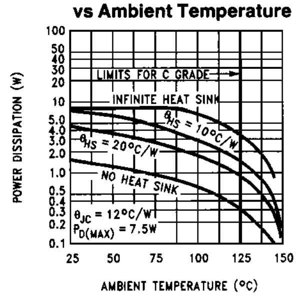
Load Transient Response



Line Transient Response



Worst Case Power Dissipation vs Ambient Temperature



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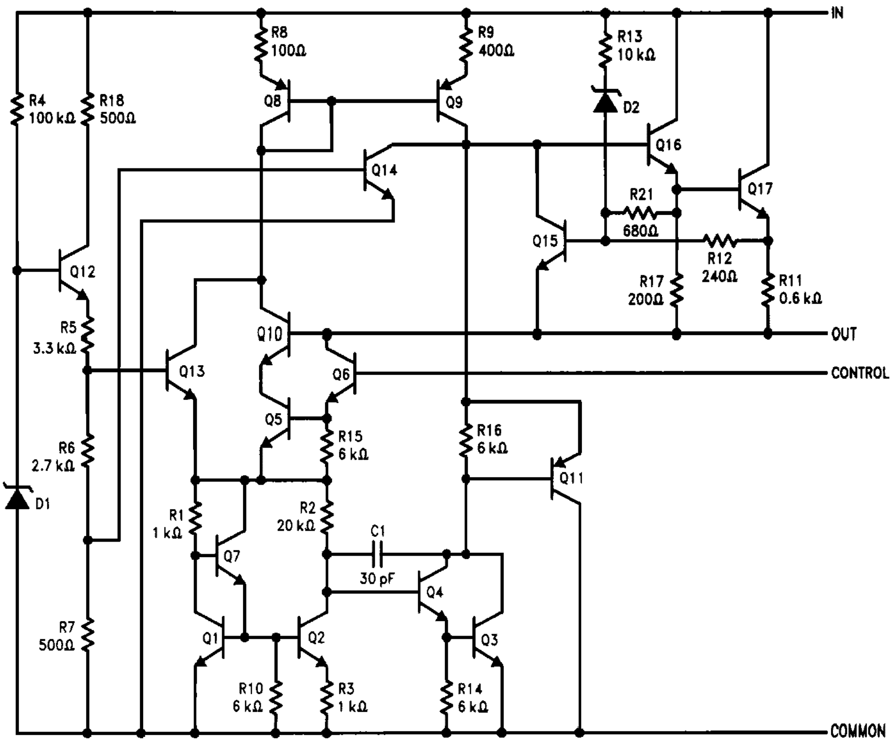
LM78MG Equivalent Circuit



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Design Considerations

The LM78MGC variable voltage regulator has an output voltage which varies from V_{CONT} to typically

$$V_I - 2.0V \text{ by } V_O = V_{CONT} \frac{(R1 + R2)}{R2}$$

The nominal reference voltage of the LM78MG is 5.0V. If we allow 1.0 mA to flow in the control swing to eliminate bias current effects, we can make R2 = 5 kΩ in the LM78MG. The output voltage is then: V_O = (R1 + R2) Volts, where R1 and R2 are in kΩs.

Example: If R2 = 5.0 kΩ and R1 = 10 kΩ then
V_O = 15V nominal, for the LM78MGC.

By proper wiring of the feedback resistors, load regulation of the device can be improved significantly.

The LM78MGC regulator has thermal overload protection from excessive power, internal short circuit protection which limits the circuit's maximum current, and output transistor safe-area protection for reducing the output current as the voltage across the pass transistor is increased.

Although the internal power dissipation is limited, the junction temperature must be kept below the maximum specified temperature in order to meet data sheet specifications.

To calculate the maximum junction temperature or heat sink required, the following thermal resistance values should be used:

Package	Typ θ_{JC}	Max θ_{JC}	Typ θ_{JA}	Max θ_{JA}
Power Watt	8.0	12.0	70	75

$$P_{D\,Max} = \frac{T_{J\,Max} - T_A}{\theta_{JC} + \theta_{CA}} \text{ or}$$

$$\frac{T_{J\,Max} - T_A}{\theta_{JA}} \text{ (without a heat sink)}$$

$$\theta_{CA} = \theta_{CS} + \theta_{SA}$$

Solving for T_J:

$$T_J = T_A + P_D(\theta_{JC} + \theta_{CA}) \text{ or}$$

$$T_A + P_D\theta_{JA} \text{ (without heat sink)}$$

Where

T_J = Junction Temperature

T_A = Ambient Temperature

P_D = Power Dissipation

θ_{JC} = Junction-to-Case Thermal Resistance

θ_{CA} = Case-to-Ambient Thermal Resistance

θ_{CS} = Case-to-Heat Sink Thermal Resistance

θ_{SA} = Heat Sink-to-Ambient Thermal Resistance

θ_{JA} = Junction-to-Ambient Thermal Resistance

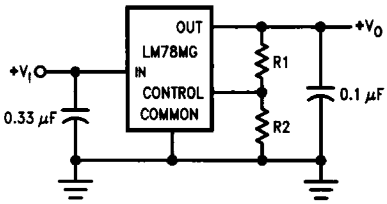
Typical Applications

Bypass capacitors are recommended for stable operation of the LM78MG over the input voltage and output current ranges. Output bypass capacitors will improve the transient response of the regulator.

The bypass capacitors, (0.33 μF on the input, 0.1 μF on the output) should be ceramic or solid tantalum which have good high frequency characteristics. The bypass capacitors should be mounted with the shortest leads, and if possible, directly across the regulator terminals.

Note 1: All resistor values in ohms.

Basic Positive Regulator



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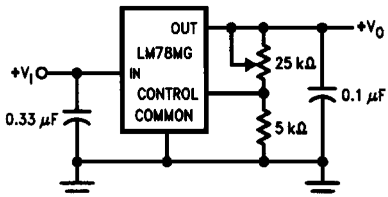
$$V_O = V_{CONT}\left(\frac{R1 + R2}{R2}\right)$$

Positive 5.0V to 30V Adjustable Regulator



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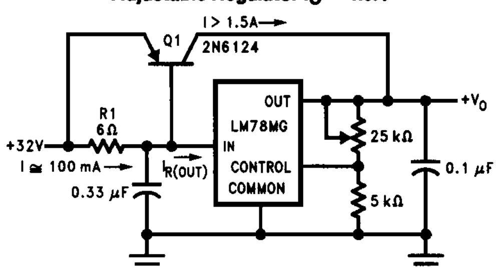
Positive 5.0V to 30V Adjustable Regulator $I_O > 1.5A$



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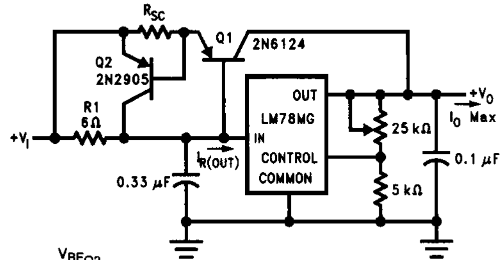
$$R1 = \frac{\beta V_{BE(Q1)}}{\beta I_{R\,Max} - I_{O\,Max}}$$

Note: External series pass device is not short circuit protected.

Positive High Current Short Circuit Protected Regulator



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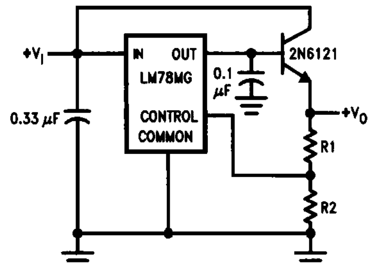
$$R_{SC} = \frac{V_{BE_{Q2}}}{I_{O\,Max}}$$

$$R1 = \frac{\beta V_{BE\,Q1} + \beta I_{O\,Max} R_{SC}}{\beta I_{R\,Max} - I_{O\,Max}}$$

Positive High-Current Voltage Regulators



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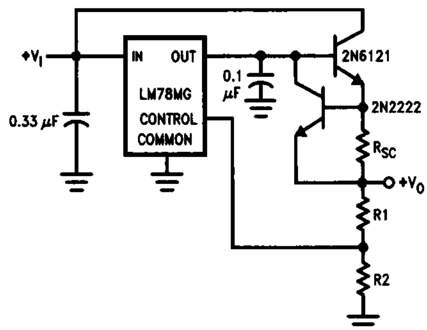
External Series Pass (a)



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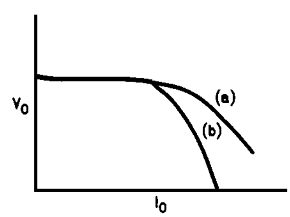
External Series Pass with Short-Circuit Limit (b)



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Current Limit Graph