National Semiconductor Corporation

LM150/LM350 3 Amp Adjustable Power Regulators

General Description

The LM150/LM350 are adjustable 3-terminal positive voltage regulators capable of supplying in excess of 3A over a 1.2V to 33V output range. They are exceptionally easy to use and require only 2 external resistors to set the output voltage. Further, both line and load regulation are comparable to discrete designs. Also, the LM150 is packaged in standard transistor packages which are easily mounted and handled.

In addition to higher performance than fixed regulators, the LM150 series offers full overload protection available only in IC's. Included on the chip are current limit, thermal overload protection and safe area protection. All overload protection circuitry remains fully functional even if the adjustment terminal is accidentally disconnected.

Normally, no capacitors are needed unless the device is situated more than 6 inches from the input filter capacitors in which case an input bypass is needed. An optional output capacitor can be added to improve transient response. The adjustment terminal can be bypassed to achieve very high ripple rejection ratios which are difficult to achieve with standard 3-terminal regulators.

Besides replacing fixed regulators or discrete designs, the LM150 is useful in a wide variety of other applications. Since the regulator is "floating" and sees only the input-to-output differential voltage, supplies of several hundred volts can be regulated as long as the maximum input to output differential is not exceeded, i.e., avoid short-circuiting the output.

Also, it makes an especially simple adjustable switching regulator, a programmable output regulator, or by connecting a fixed resistor between the adjustment pin and output, the LM150 can be used as a precision current regulator. Supplies with electronic shutdown can be achieved by clamping the adjustment terminal to ground which programs the output to 1.2V where most loads draw little current.

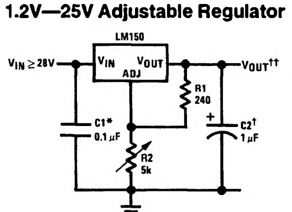
The LM150K/LM350K are packaged in standard steel TO-3 transistor packages. The LM350T is packaged in a TO-220 plastic package. The LM150 is rated for operation from −55°C to +150°C, and the LM350 from 0°C to +125°C.

Features

- Adjustable output down to 1.2V
- Guaranteed 3A output current
- Line regulation typically 0.005%/V
- Load regulation typically 0.1%
- Guaranteed thermal regulation
- Output is short circuit protected
- Current limit constant with temperature
- 100% electrical burn-in in thermal limit
- Eliminates the need to stock many voltages
- Standard 3-lead transistor package
- 86 dB ripple rejection

Typical Applications

1.2V—25V Adjustable Regulator



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Full output current not available at high input-output voltages.

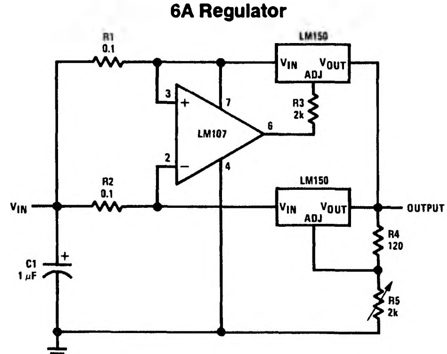
†Optional—improves transient response. Output capacitors in the range of 1 µF to 1000 µF of aluminum or tantalum electrolytic are commonly used to provide improved output impedance and rejection of transients.

*Needed if device is more than 6 inches from filter capacitors.

$$††V_{OUT} = 1.25V\left(1 + \frac{R2}{R1}\right) + I_{ADJ}(R2)$$

Note: Usually R1 = 240Ω for LM150 and R1 = 120Ω for LM350.

6A Regulator



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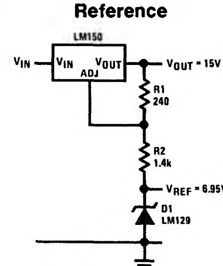
Regulator and Voltage Reference



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Absolute Maximum Ratings

If Military/Aerospace specified devices are required, contact the National Semiconductor Sales Office/ Distributors for availability and specifications.
(Note 3)

Power Dissipation	Internally limited
Input–Output Voltage Differential	35V
Operating Junction Temperature Range	
LM150	−55°C to +150°C
LM350	0°C to +125°C
Storage Temperature	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C
Plastic Package (Soldering, 4 seconds)	260°C

Preconditioning

Burn-In in Thermal Limit — All Devices 100%

ESD Rating to be determined.

Electrical Characteristics (Note 1)

Parameter	Conditions	LM150			LM350			Units
		Min	Typ	Max	Min	Typ	Max	
Line Regulation	$T_A = 25°C$, $3V \le (V_{IN} - V_{OUT}) \le 35V$, $I_L = 0.010A$ (Note 2)		0.005	0.01		0.005	0.03	%/V
Load Regulation	$T_A = 25°C$, $10mA \le I_{OUT} \le 3A$		0.1	0.3		0.1	0.5	%
Thermal Regulation	Pulse = 20 ms, $T_j = 25°C$		0.002	0.01		0.002	0.03	%/W
Adjustment Pin Current			50	100		50	100	μA
Adjustment Pin Current Change	$10 mA \le I_L \le 3A$ $3V \le (V_{IN} - V_{OUT}) \le 35V$		0.2	5		0.2	5	μA
Reference Voltage	$3V \le (V_{IN} - V_{OUT}) \le 35V$, (Note 3) $10 mA \le I_{OUT} \le 3A$, $P \le 30W$	1.20	1.25	1.30	1.20	1.25	1.30	V
Line Regulation	$3V \le (V_{IN} - V_{OUT}) \le 35V$, (Note 2) $I_L = 0.010A$		0.02	0.05		0.02	0.07	%/V
Load Regulation	$10 mA \le I_{OUT} \le 3A$, (Note 2)		0.3	1		0.3	1.5	%
Temperature Stability	$T_{MIN} \le T_j \le T_{MAX}$		1			1		%
Minimum Load Current	$V_{IN} - V_{OUT} = 35V$		3.5	5		3.5	10	mA
Current Limit	$(V_{IN} - V_{OUT}) \le 10V$ $(V_{IN} - V_{OUT}) = 30V$, $T_j = +25°C$	3.0 0.3	4.5 1		3.0 0.25	4.5 1		A A
RMS Output Noise, % of V_{OUT}	$T_j = 25°C$, $10 Hz \le f \le 10 kHz$		0.001			0.001		%
Ripple Rejection Ratio	$V_{OUT} = 10V$, f = 120 Hz $C_{ADJ} = 10 \mu F$	 66	65 86		 66	65 86		dB dB
Long Term Stability	$T_j = 125°C$, 1000 hours		0.3	1		0.3	1	%
Thermal Resistance, Junction to Case	K Package T Package		 3	1.5 4		 3	1.5 4	°C/W °C/W
Thermal Resistance, Junction to Ambient (No Heat Sink)	K Package T Package		35 50			35 50		°C/W °C/W

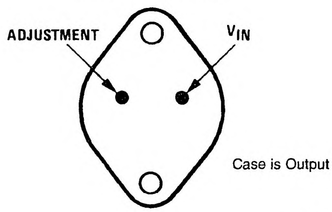
Note 1: Unless otherwise specified, these specifications apply $-55°C \le T_j \le +150°C$ for the LM150, $0°C \le T_j \le 125°C$ for the LM350. $V_{IN} - V_{OUT} = 5V$, and $I_{OUT} = 10$ mA. These specifications are applicable for power dissipations up to 30W for the K package and 25W for the T package. Power dissipation is guaranteed at these values up to 15 volts input-output differential. Above 15 volts differential, power dissipation will be limited by internal protection circuitry.

Note 2: Regulation is measured at constant junction temperature. Changes in output voltage due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

Note 3: Refer to RETS150K drawing for military specifications of the LM150K.

Connection Diagrams (See Physical Dimensions section for further information)

(TO-3 STEEL)
Metal Can Package



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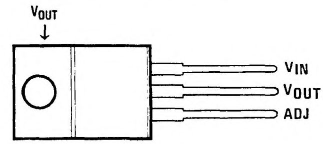
Bottom View

Order Number LM150K STEEL or LM350K STEEL
See NS Package Number K02A

(TO-220)
Plastic Package



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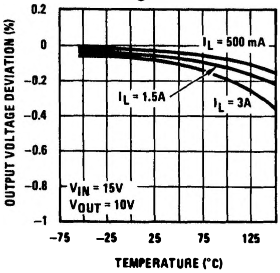
Front View

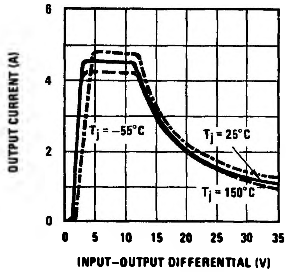
Order Number LM350T
See NS Package Number T03B

Typical Performance Characteristics

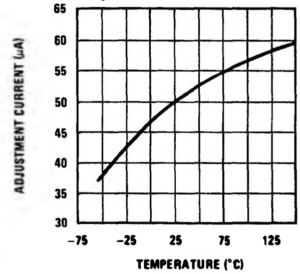
Load Regulation



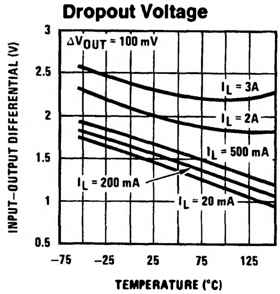
Current Limit



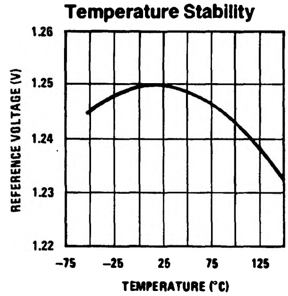
Adjustment Current



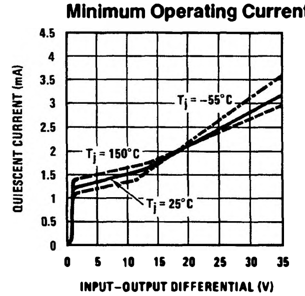
Dropout Voltage



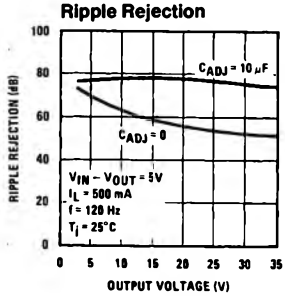
Temperature Stability



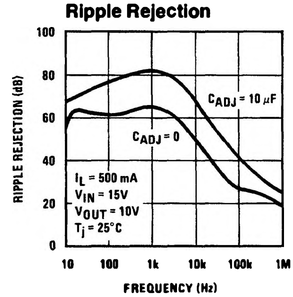
Minimum Operating Current



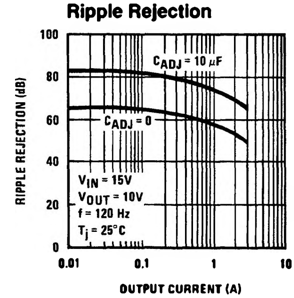
Ripple Rejection



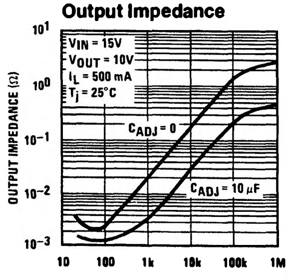
Ripple Rejection



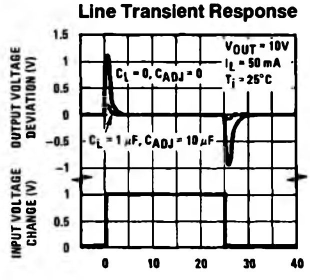
Ripple Rejection



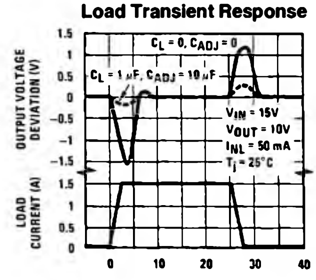
Output Impedance



Line Transient Response



Load Transient Response



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Application Hints

In operation, the LM150 develops a nominal 1.25V reference voltage, V_{REF}, between the output and adjustment terminal. The reference voltage is impressed across program resistor R1 and, since the voltage is constant, a constant current I_1 then flows through the output set resistor R2, giving an output voltage of

$$V_{OUT} = V_{REF}\left(1 + \frac{R2}{R1}\right) + I_{ADJ}\,R2.$$

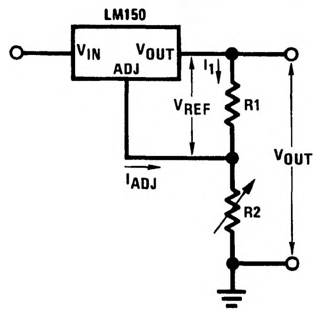

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FIGURE 1

Since the 50 μA current from the adjustment terminal represents an error term, the LM150 was designed to minimize I_{ADJ} and make it very constant with line and load changes. To do this, all quiescent operating current is returned to the output establishing a minimum load current requirement. If there is insufficient load on the output, the output will rise.

EXTERNAL CAPACITORS

An input bypass capacitor is recommended. A 0.1 μF disc or 1 μF solid tantalum on the input is suitable input bypassing for almost all applications. The device is more sensitive to the absence of input bypassing when adjustment or output capacitors are used but the above values will eliminate the possibility of problems.

The adjustment terminal can be bypassed to ground on the LM150 to improve ripple rejection. This bypass capacitor prevents ripple from being amplified as the output voltage is increased. With a 10 μF bypass capacitor 86 dB ripple rejection is obtainable at any output level. Increases over 10 μF do not appreciably improve the ripple rejection at frequencies above 120 Hz. If the bypass capacitor is used, it is sometimes necessary to include protection diodes to prevent the capacitor from discharging through internal low current paths and damaging the device.

In general, the best type of capacitors to use is solid tantalum. Solid tantalum capacitors have low impedance even at high frequencies. Depending upon capacitor construction, it takes about 25 μF in aluminum electrolytic to equal 1 μF solid tantalum at high frequencies. Ceramic capacitors are also good at high frequencies, but some types have a large decrease in capacitance at frequencies around 0.5 MHz. For this reason, 0.01 μF disc may seem to work better than a 0.1 μF disc as a bypass.

Although the LM150 is stable with no output capacitors, like any feedback circuit, certain values of external capacitance can cause excessive ringing. This occurs with values between 500 pF and 5000 pF. A 1 μF solid tantalum (or 25 μF aluminum electrolytic) on the output swamps this effect and insures stability.

LOAD REGULATION

The LM150 is capable of providing extremely good load regulation but a few precautions are needed to obtain maximum performance. The current set resistor connected between the adjustment terminal and the output terminal (usually 240Ω) should be tied directly to the output (case) of the regulator rather than near the load. This eliminates line drops from appearing effectively in series with the reference and degrading regulation. For example, a 15V regulator with 0.05Ω resistance between the regulator and load will have a load regulation due to line resistance of 0.05Ω × I_L. If the set resistor is connected near the load the effective line resistance will be 0.05Ω (1 + R2/R1) or in this case, 11.5 times worse.

Figure 2 shows the effect of resistance between the regulator and 240Ω set resistor.

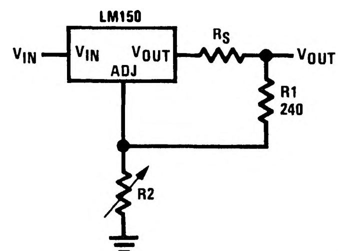

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FIGURE 2. Regulator with Line Resistance in Output Lead

With the TO-3 package, it is easy to minimize the resistance from the case to the set resistor, by using two separate leads to the case. The ground of R2 can be returned near the ground of the load to provide remote ground sensing and improve load regulation.

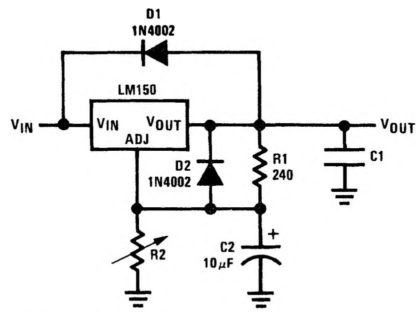
PROTECTION DIODES

When external capacitors are used with *any* IC regulator it is sometimes necessary to add protection diodes to prevent the capacitors from discharging through low current points into the regulator. Most 10 μF capacitors have low enough internal series resistance to deliver 20A spikes when shorted. Although the surge is short, there is enough energy to damage parts of the IC.

When an output capacitor is connected to a regulator and the input is shorted, the output capacitor will discharge into the output of the regulator. The discharge current depends on the value of the capacitor, the output voltage of the regulator, and the rate of decrease of V_{IN}. In the LM150, this discharge path is through a large junction that is able to sustain 25A surge with no problem. This is not true of other types of positive regulators. For output capacitors of 25 μF or less, there is no need to use diodes.

The bypass capacitor on the adjustment terminal can discharge through a low current junction. Discharge occurs when *either* the input or output is shorted. Internal to the LM150 is a 50Ω resistor which limits the peak discharge current. No protection is needed for output voltages of 25V or less and 10 μF capacitance. *Figure 3* shows an LM150 with protection diodes included for use with outputs greater than 25V and high values of output capacitance.

Application Hints (Continued)



D1 protects against C1

D2 protects against C2

$$V_{OUT} = 1.25V\left(1 + \frac{R2}{R1}\right) + I_{ADJ}R2$$

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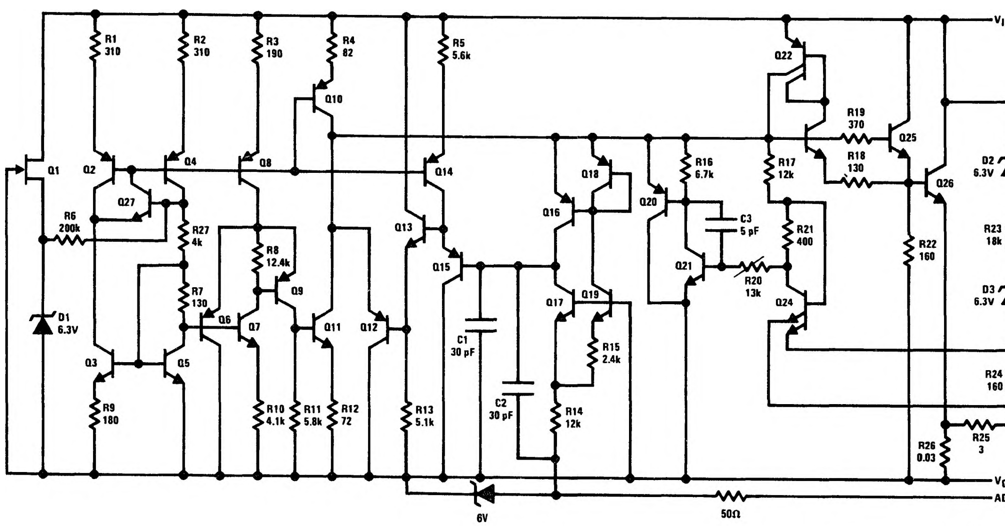
FIGURE 3. Regulator with Protection Diodes

Schematic Diagram



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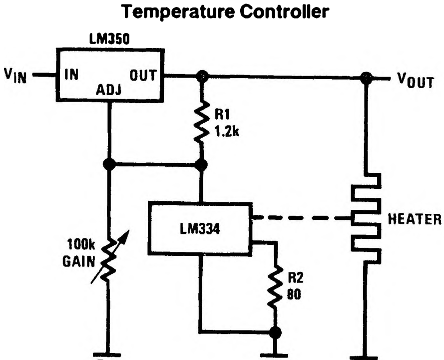
Typical Applications (Continued)

Temperature Controller



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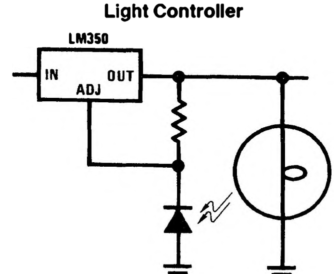
Light Controller



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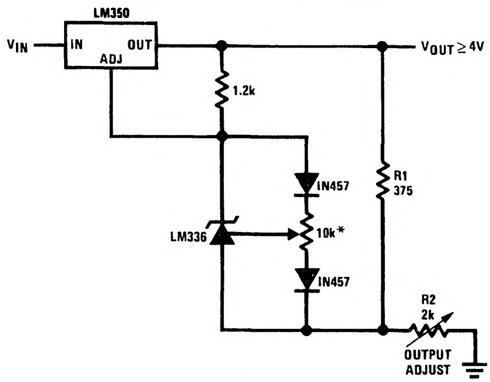
Typical Applications (Continued)

Precision Power Regulator with Low Temperature Coefficient



*Adjust for 3.75V across R1

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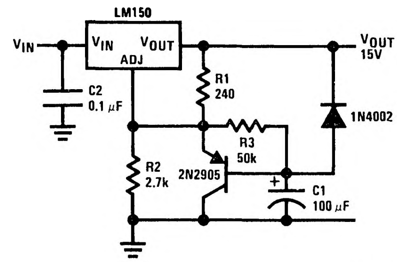
Slow Turn-ON 15V Regulator



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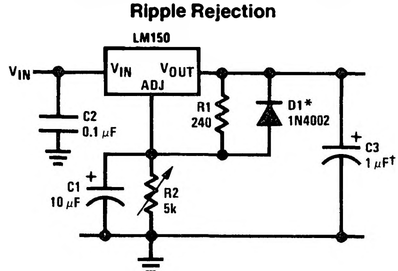
Adjustable Regulator with Improved Ripple Rejection



†Solid tantalum

*Discharges C1 if output is shorted to ground

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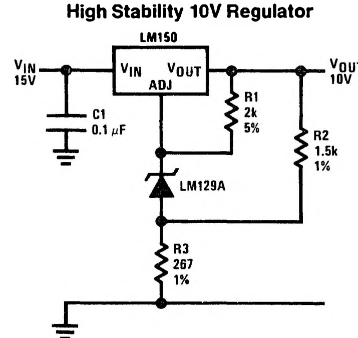
High Stability 10V Regulator



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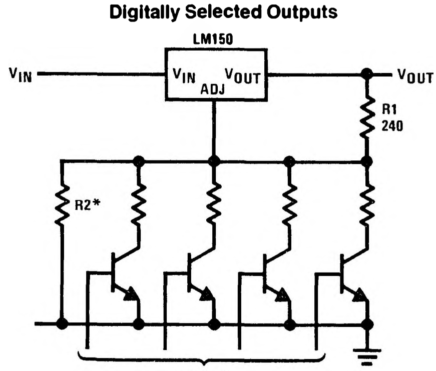
Digitally Selected Outputs



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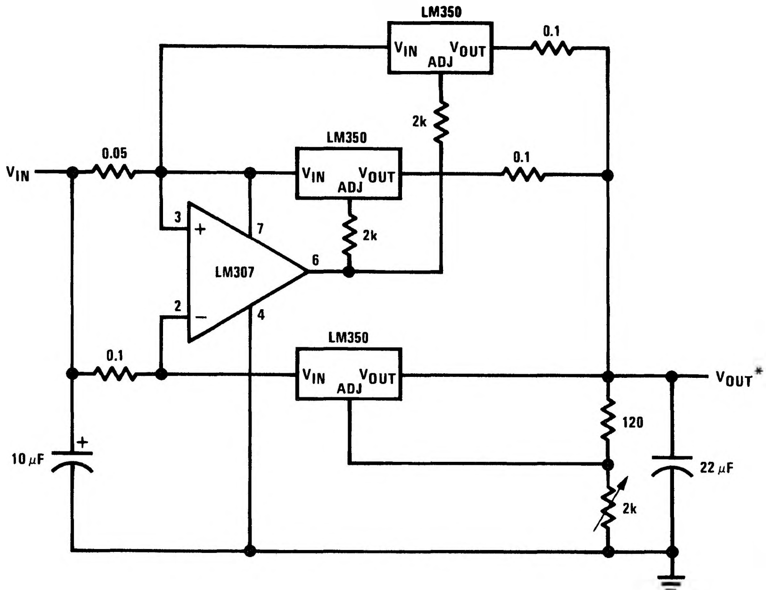
*Sets maximum V_{OUT}

Typical Applications (Continued)

10A Regulator



*Minimum load current 50 mA

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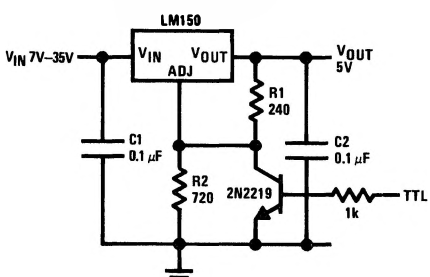
5V Logic Regulator with Electronic Shutdown*



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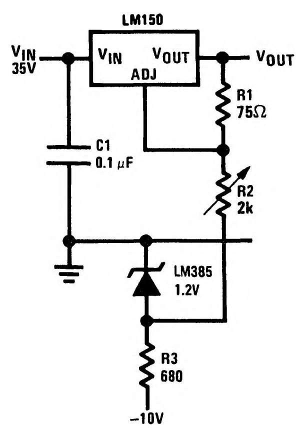
*Min output ≈ 1.2V

0 to 30V Regulator



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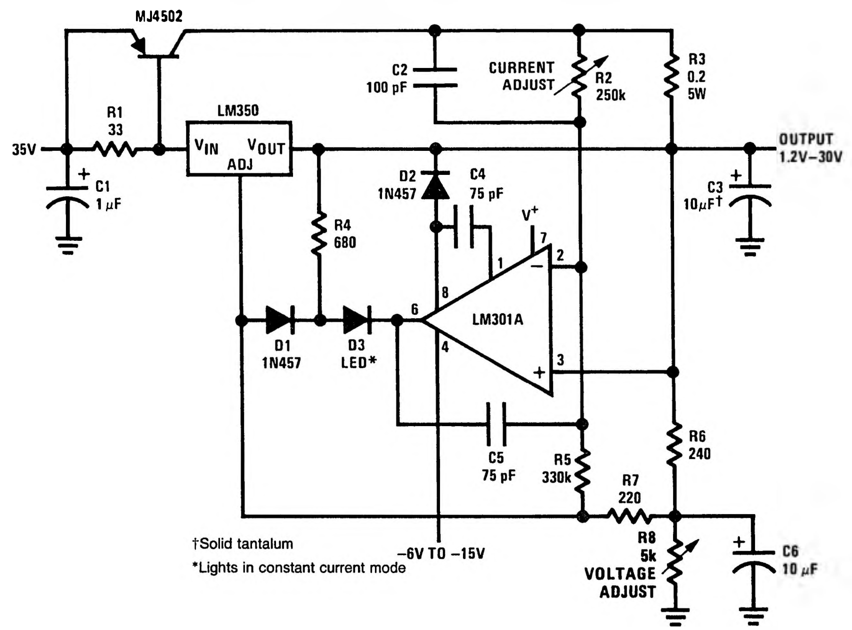
Full output current not available at high input-output voltages

Typical Applications (Continued)

5A Constant Voltage/Constant Current Regulator



†Solid tantalum

*Lights in constant current mode

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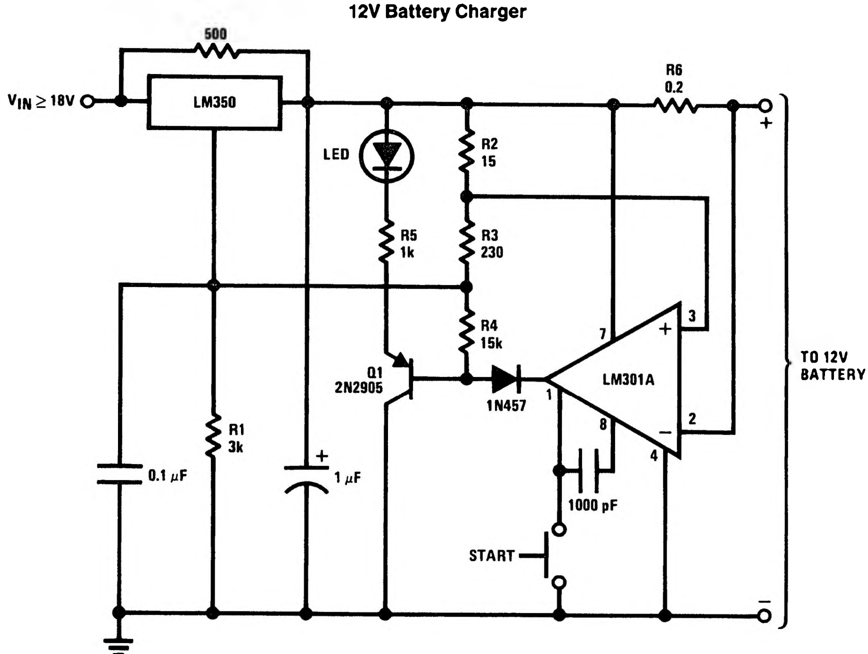
12V Battery Charger



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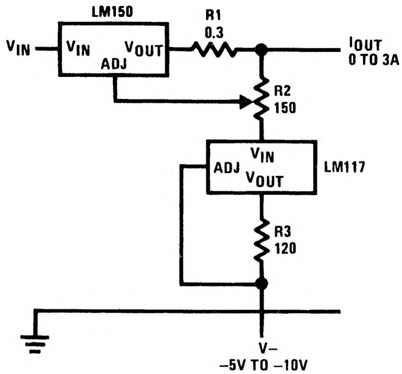
Typical Applications (Continued)

Adjustable Current Regulator



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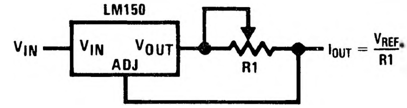
Precision Current Limiter



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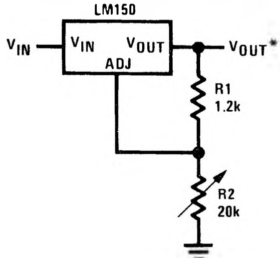
*$0.4 \le R_1 \le 120\Omega$

1.2V–20V Regulator with Minimum Program Current



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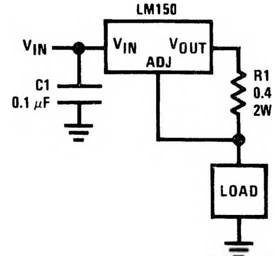
*Minimum load current ≈ 4 mA

3A Current Regulator



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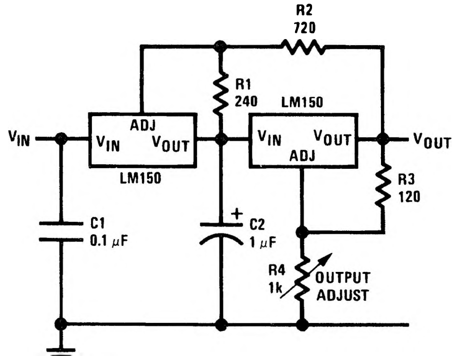
Tracking Preregulator



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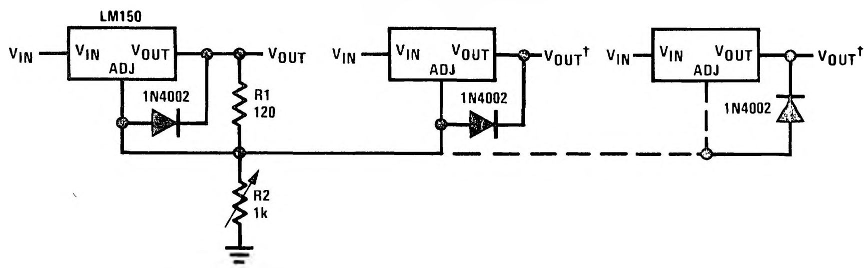
Typical Applications (Continued)

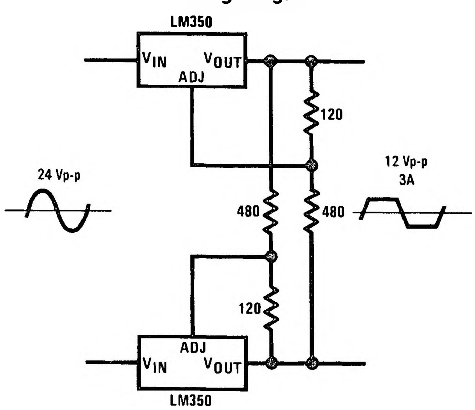
Adjusting Multiple On-Card Regulators with Single Control*



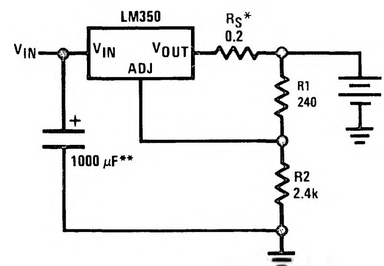
†Minimum load—10 mA

*All outputs within ±100 mV

AC Voltage Regulator



Simple 12V Battery Charger



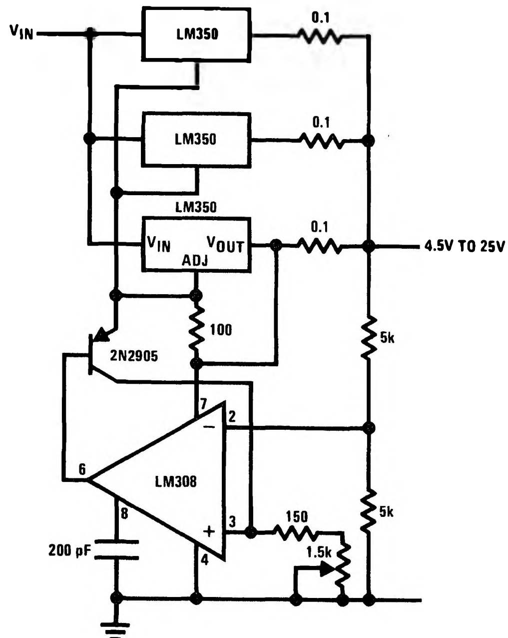
*R_S—sets output impedance of charger: $Z_{OUT} = R_S \left(1 + \frac{R2}{R1}\right)$

Use of R_S allows low charging rates with fully charged battery.

**1000 μF is recommended to filter out any input transients

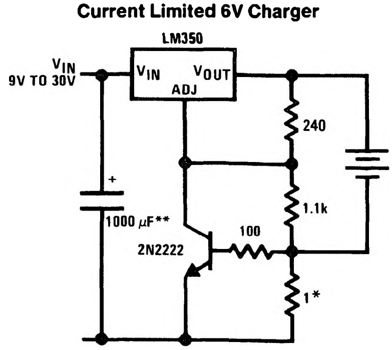
Typical Applications (Continued)

Adjustable 10A Regulator



TL/H/9061-31

Current Limited 6V Charger



TL/H/9061-32

*Sets peak current (2A for 0.3Ω)

**1000 µF is recommended to filter out any input transients.