MOTOROLA

LM350

Three-Terminal Adjustable Output Positive Voltage Regulator

THREE–TERMINAL ADJUSTABLE POSITIVE VOLTAGE REGULATOR

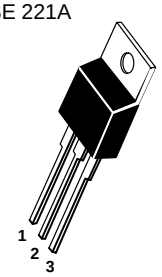
SEMICONDUCTOR TECHNICAL DATA

The LM350 is an adjustable three–terminal positive voltage regulator capable of supplying in excess of 3.0 A over an output voltage range of 1.2 V to 33 V. This voltage regulator is exceptionally easy to use and requires only two external resistors to set the output voltage. Further, it employs internal current limiting, thermal shutdown and safe area compensation, making it essentially blow–out proof.

The LM350 serves a wide variety of applications including local, on card regulation. This device also makes an especially simple adjustable switching regulator, a programmable output regulator, or by connecting a fixed resistor between the adjustment and output, the LM350 can be used as a precision current regulator.

- Guaranteed 3.0 A Output Current
- Output Adjustable between 1.2 V and 33 V
- Load Regulation Typically 0.1%
- Line Regulation Typically 0.005%/V
- Internal Thermal Overload Protection
- Internal Short Circuit Current Limiting Constant with Temperature
- Output Transistor Safe Area Compensation
- Floating Operation for High Voltage Applications
- Standard 3–lead Transistor Package
- Eliminates Stocking Many Fixed Voltages

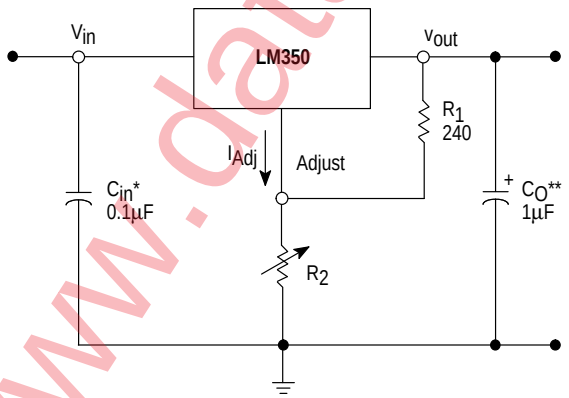
T SUFFIX
PLASTIC PACKAGE
CASE 221A



Pin 1. Adjust
2. V_{out}
3. V_{in}

Heatsink surface is connected to Pin 2.

Simplified Application



* = C_{in} is required if regulator is located an appreciable distance from power supply filter.
** = C_O is not needed for stability, however, it does improve transient response.

$$V_{out} = 1.25\ V\left(1 + \frac{R_2}{R_1}\right) + I_{Adj}\,R_2$$

Since I_{Adj} is controlled to less than 100 µA, the error associated with this term is negligible in most applications.

ORDERING INFORMATION

Device	Operating Temperature Range	Package
LM350T	T_J = 0° to +125°C	Plastic Power
LM350BT#	T_J = –40° to +125°C	Plastic Power

Automotive temperature range selections are available with special test conditions and additional tests. Contact your local Motorola sales office for information.

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MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Input–Output Voltage Differential	$V_I–V_O$	35	Vdc
Power Dissipation	P_D	Internally Limited	W
Operating Junction Temperature Range	T_J	–40 to +125	°C
Storage Temperature Range	T_{stg}	–65 to +150	°C
Soldering Lead Temperature (10 seconds)	T_{solder}	300	°C

ELECTRICAL CHARACTERISTICS ($V_I–V_O$ = 5.0 V; I_L = 1.5 A; $T_J = T_{low}$ to T_{high}; P_{max} [Note 1], unless otherwise noted.)

Characteristics	Figure	Symbol	Min	Typ	Max	Unit
Line Regulation (Note 2) T_A = 25°C, 3.0 V ≤ $V_I–V_O$ ≤ 35 V	1	Reg_{line}	–	0.0005	0.03	%/V
Load Regulation (Note 2) T_A = 25°C, 10 mA ≤ I_I ≤ 3.0 A V_O ≤ 5.0 V V_O ≥ 5.0 V	2	Reg_{load}	 –	 5.0	 25	 mV
			–	0.1	0.5	% V_O
Thermal Regulation, Pulse = 20 ms, (T_A = +25°C)		Reg_{therm}	–	0.002	–	% V_O/W
Adjustment Pin Current	3	I_{Adj}	–	50	100	μA
Adjustment Pin Current Change 3.0 V ≤ $V_I–V_O$ ≤ 35 V 10 mA ≤ I_L ≤ 3.0 A, P_D ≤ P_{max}	1,2	ΔI_{Adj}	–	0.2	5.0	μA
Reference Voltage 3.0 V ≤ $V_I–V_O$ ≤ 35 V 10 mA ≤ I_O ≤ 3.0 A, P_D ≤ P_{max}	3	V_{ref}	1.20	1.25	1.30	V
Line Regulation (Note 2) 3.0 V ≤ $V_I–V_O$ ≤ 35 V	1	Reg_{line}	–	0.02	0.07	%/V
Load Regulation (Note 2) 10 mA ≤ I_L ≤ 3.0 A V_O ≤ 5.0 V V_O ≥ 5.0 V	2	Reg_{load}	 –	 20	 70	 mV
			–	0.3	1.5	% V_O
Temperature Stability ($T_{low} ≤ T_J ≤ T_{high}$)	3	T_S	–	1.0	–	% V_O
Minimum Load Current to Maintain Regulation ($V_I–V_O$ = 35 V)	3	I_{Lmin}	–	3.5	10	mA
Maximum Output Current $V_I–V_O$ ≤ 10 V, P_D ≤ P_{max} $V_I–V_O$ = 30 V, P_D ≤ P_{max}, T_A = 25°C	3	I_{max}	 3.0 0.25	 4.5 1.0	 – –	A
RMS Noise, % of V_O T_A= 25°C, 10 Hz ≤ f ≤ 10 kHz		N	–	0.003	–	% V_O
Ripple Rejection, V_O = 10 V, f = 120 Hz (Note 3) Without C_{Adj} C_{Adj} = 10 μF	4	RR	 – 66	 65 80	 – –	dB
Long Term Stability, $T_J = T_{high}$ (Note 4) T_A= 25°C for Endpoint Measurements	3	S	–	0.3	1.0	%/1.0 k Hrs.
Thermal Resistance, Junction–to–Case Peak (Note 5) Average (Note 6)		$R_{\theta JC}$	 – –	 2.3 –	 – 1.5	°C/W

NOTES: 1. T_{low} to T_{high} = 0° to +125°C; P_{max} = 25 W for LM350T; T_{low} to T_{high} = –40° to +125°C; P_{max} = 25 W for LM350BT
2. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.
3. C_{Adj}, when used, is connected between the adjustment pin and ground.
4. Since Long–Term Stability cannot be measured on each device before shipment, this specification is an engineering estimate of average stability from lot to lot.
5. Thermal Resistance evaluated measuring the hottest temperature on the die using an infrared scanner. This method of evaluation yields very accurate thermal resistance values which are conservative when compared to the other measurement techniques.
6. The average die temperature is used to derive the value of thermal resistance junction to case (average).

Representative Schematic Diagram

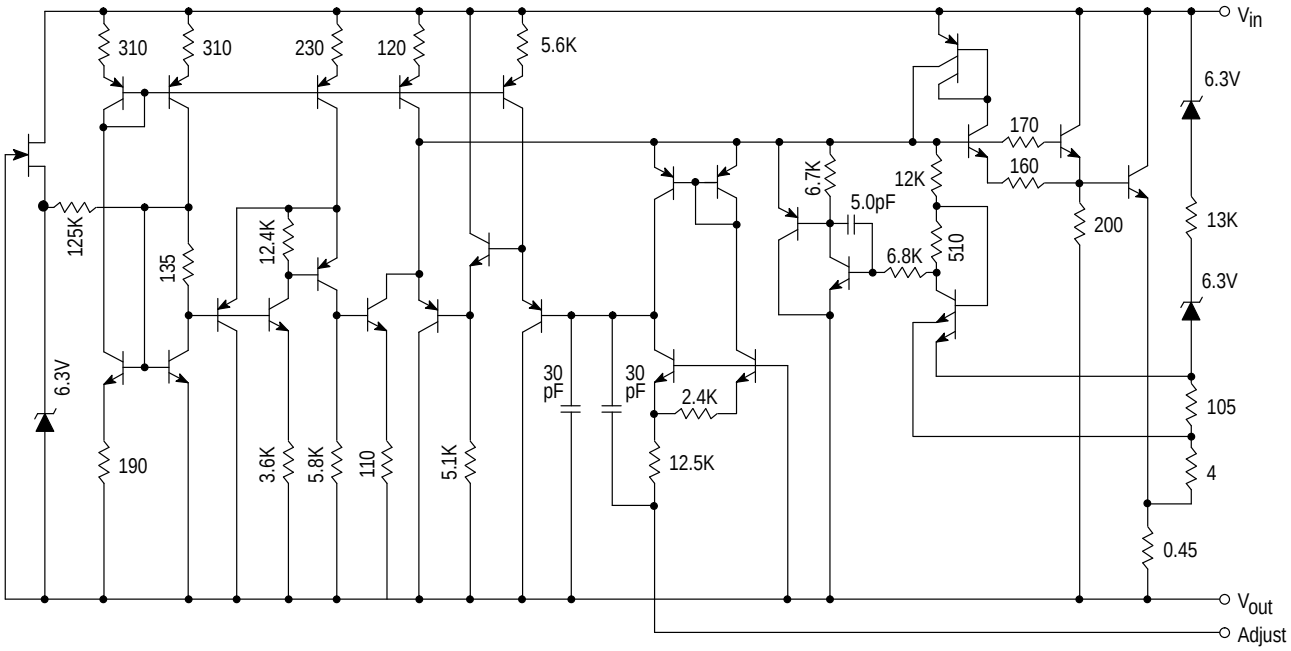


Figure 1. Line Regulation and ΔI_{Adj}/Line Test Circuit

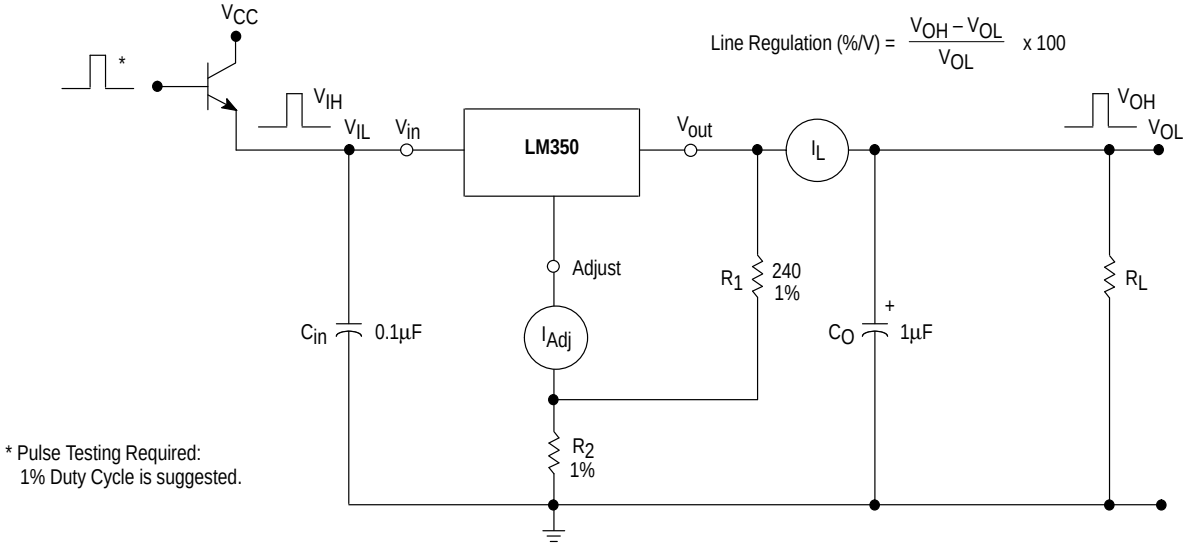


Figure 2. Load Regulation and ΔI_{Adj}/Load Test Circuit

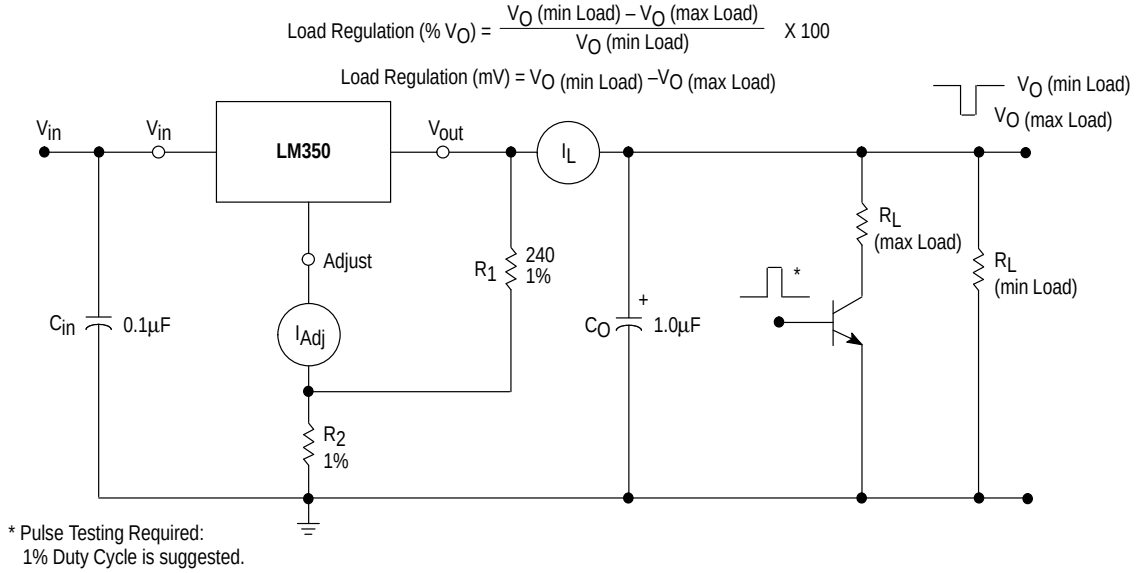


Figure 3. Standard Test Circuit

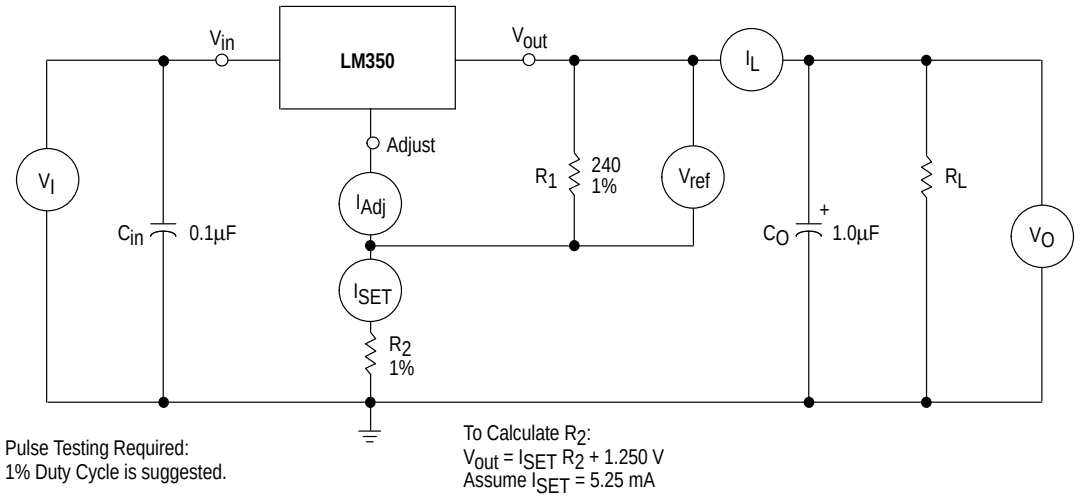


Figure 4. Ripple Rejection Test Circuit

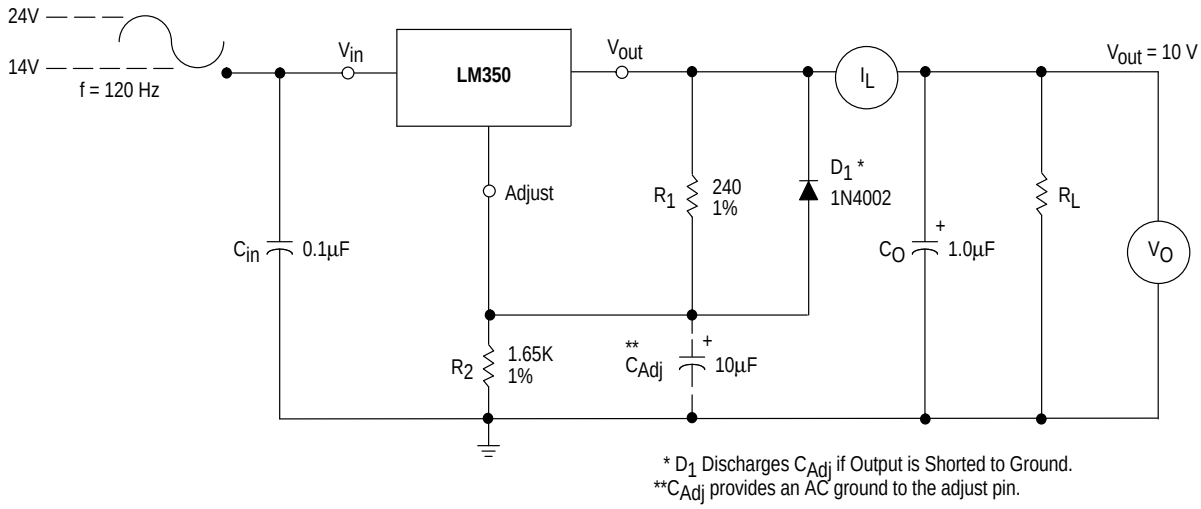


Figure 5. Load Regulation

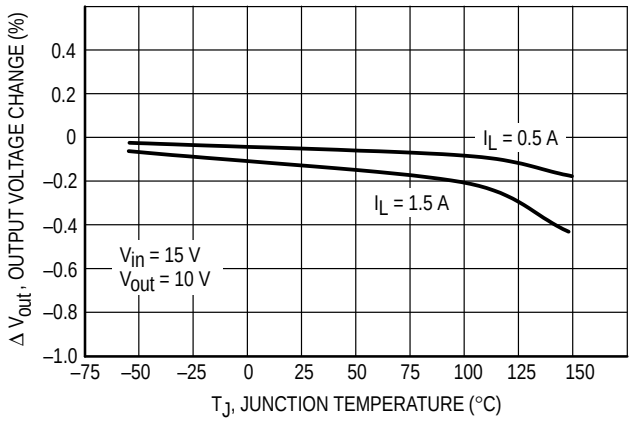


Figure 6. Current Limit

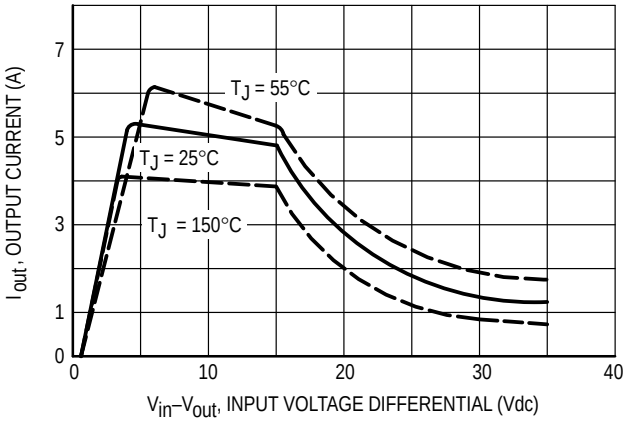


Figure 7. Adjustment Pin Current

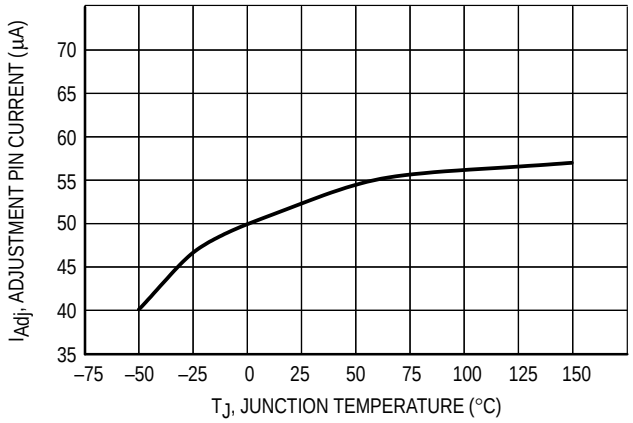


Figure 8. Dropout Voltage

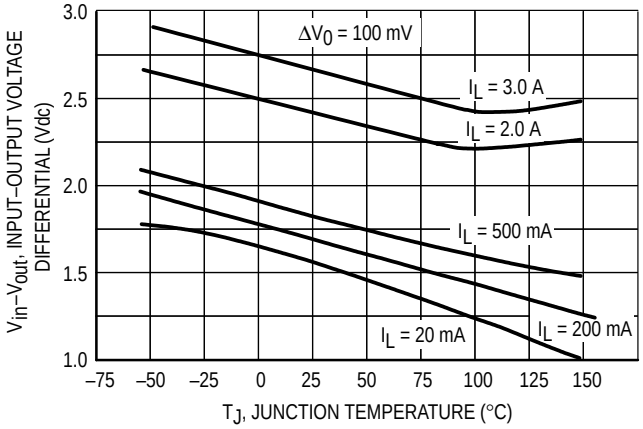


Figure 9. Temperature Stability

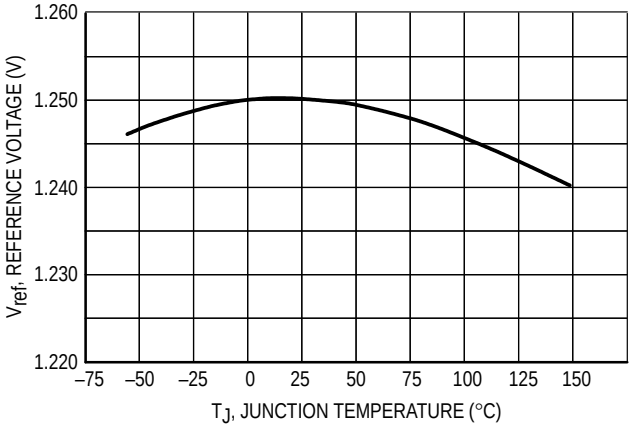


Figure 10. Minimum Operating Current

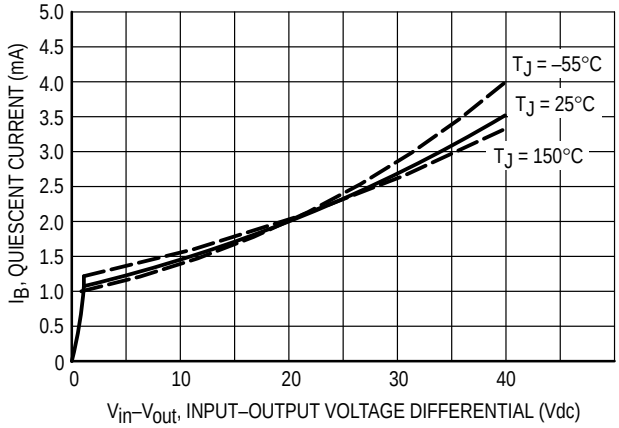


Figure 11. Ripple Rejection versus Output Voltage

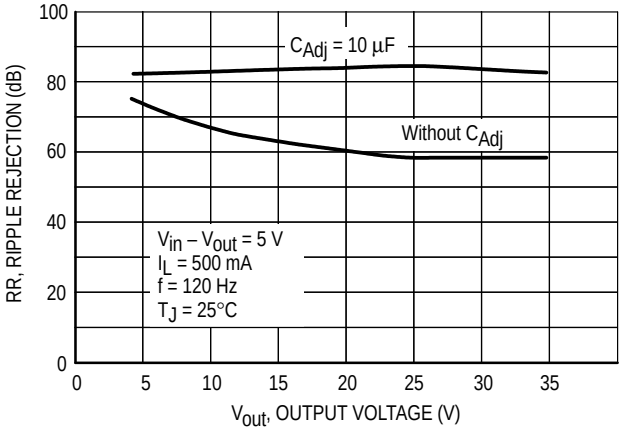


Figure 12. Ripple Rejection versus Output Current

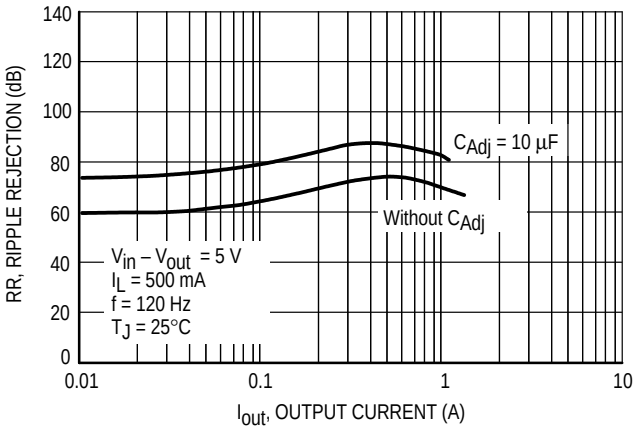


Figure 13. Ripple Rejection versus Frequency

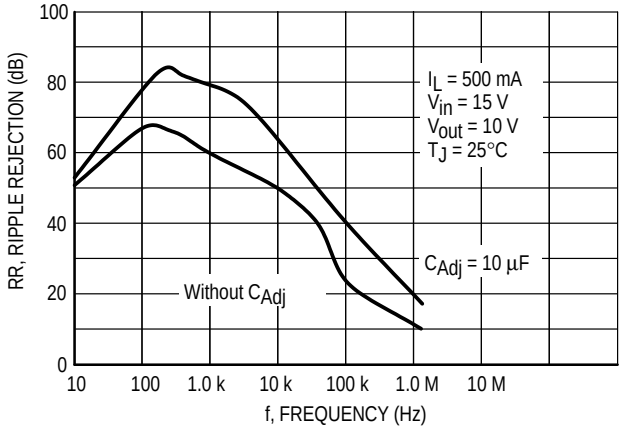


Figure 14. Output Impedance

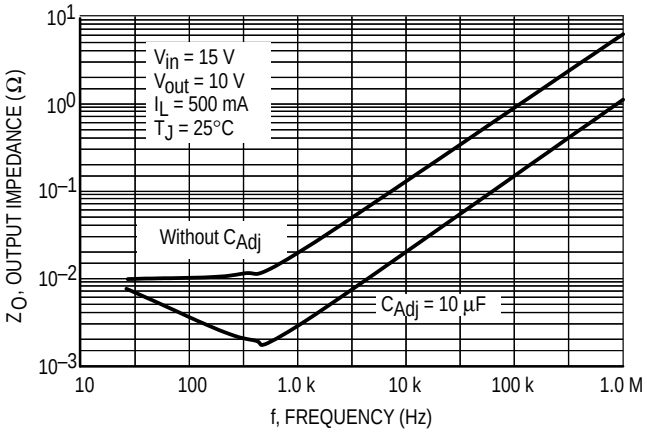


Figure 15. Line Transient Response

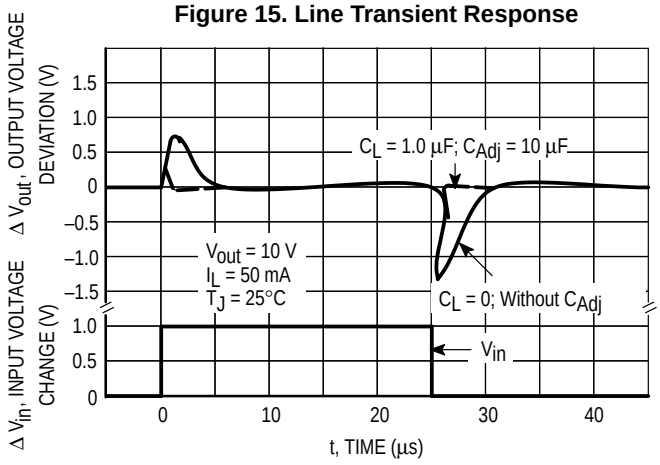
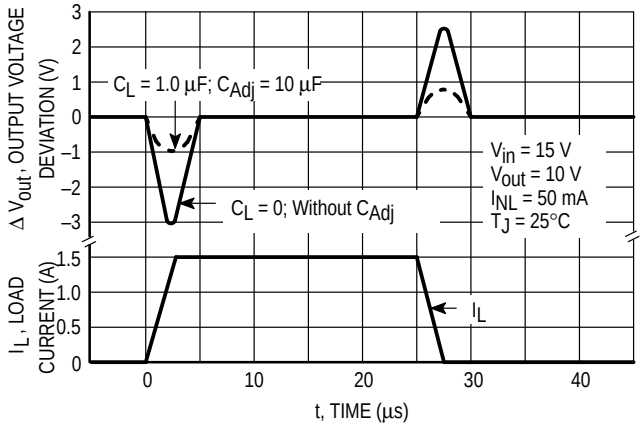


Figure 16. Load Transient Response



APPLICATIONS INFORMATION

Basic Circuit Operation

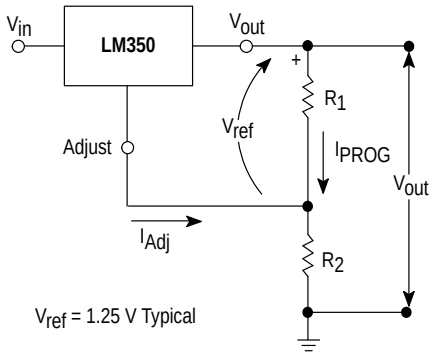
The LM350 is a three–terminal floating regulator. In operation, the LM350 develops and maintains a nominal 1.25 V reference (V_{ref}) between its output and adjustment terminals. This reference voltage is converted to a programming current (I_{PROG}) by R_1 (see Figure 17), and this constant current flows through R_2 to ground. The regulated output voltage is given by:

$$V_{out} = V_{ref} (1 + \frac{R_2}{R_1}) + I_{Adj} R_2$$

Since the current from the terminal (I_{Adj}) represents an error term in the equation, the LM350 was designed to control I_{Adj} to less than 100 μA and keep it constant. To do this, all quiescent operating current is returned to the output terminal. This imposes the requirement for a minimum load current. If the load current is less than this minimum, the output voltage will rise.

Since the LM350 is a floating regulator, it is only the voltage differential across the circuit which is important to performance, and operation at high voltages with respect to ground is possible.

Figure 17. Basic Circuit Configuration



Load Regulation

The LM350 is capable of providing extremely good load regulation, but a few precautions are needed to obtain maximum performance. For best performance, the programming resistor (R_1) should be connected as close to the regulator as possible to minimize line drops which effectively appear in series with the reference, thereby degrading regulation. The ground end of R_2 can be returned near the load ground to provide remote ground sensing and improve load regulation.

External Capacitors

A 0.1 μF disc or 1 μF tantalum input bypass capacitor (C_{in}) is recommended to reduce the sensitivity to input line impedance.

The adjustment terminal may be bypassed to ground to improve ripple rejection. This capacitor (C_{Adj}) prevents ripple from being amplified as the output voltage is increased. A 10 μF capacitor should improve ripple rejection about 15 dB at 120 Hz in a 10 V application.

Although the LM350 is stable with no output capacitance, like any feedback circuit, certain values of external capacitance can cause excessive ringing. An output capacitance (C_O) in the form of a 1 μF tantalum or 25 μF aluminum electrolytic capacitor on the output swamps this effect and insures stability.

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.

Figure 18 shows the LM350 with the recommended protection diodes for output voltages in excess of 25 V or high capacitance values (C_O > 25 μF, C_{Adj} > 10 μF). Diode D_1 prevents C_O from discharging thru the IC during an input short circuit. Diode D_2 protects against capacitor C_{Adj} discharging through the IC during an output short circuit. The combination of diodes D_1 and D_2 prevents C_{Adj} from discharging through the IC during an input short circuit.

Figure 18. Voltage Regulator with Protection Diodes

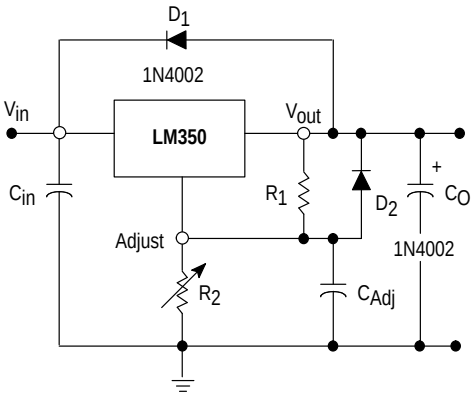
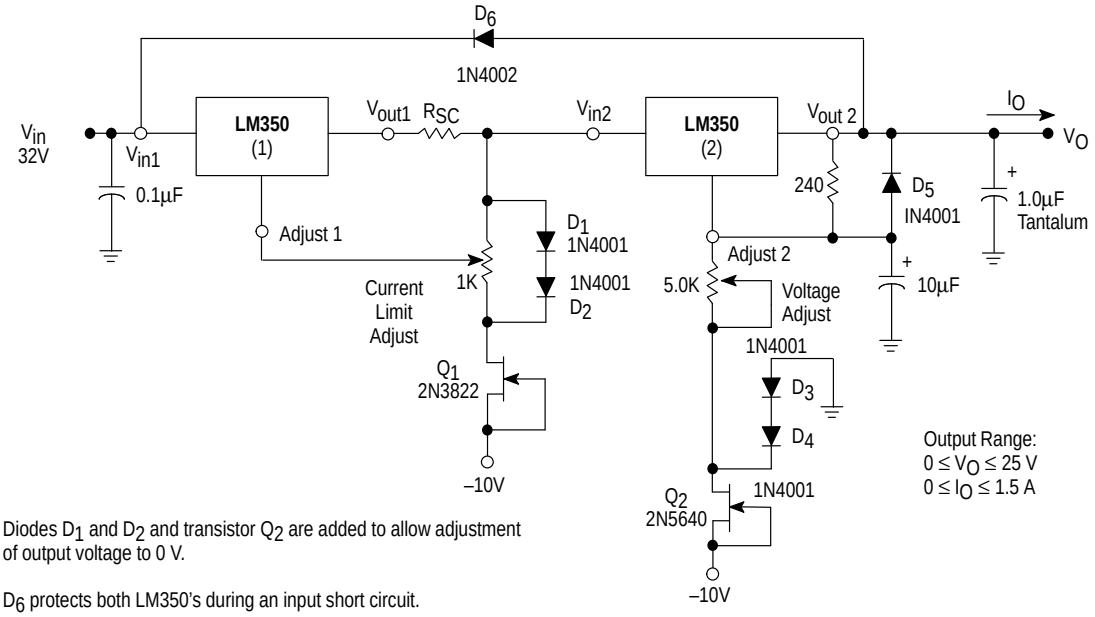


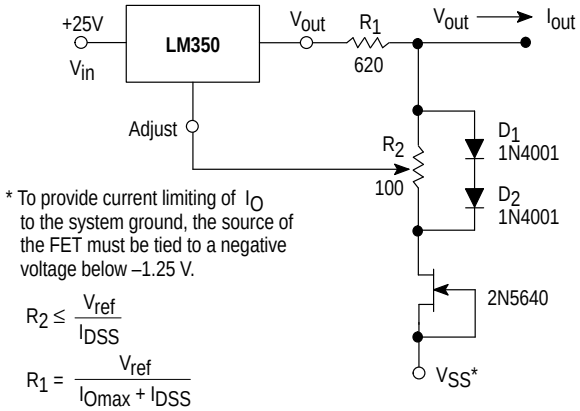
Figure 19. “Laboratory” Power Supply with Adjustable Current Limit and Output Voltage



Diodes D_1 and D_2 and transistor Q_2 are added to allow adjustment of output voltage to 0 V.

D_6 protects both LM350’s during an input short circuit.

Figure 20. Adjustable Current Limiter



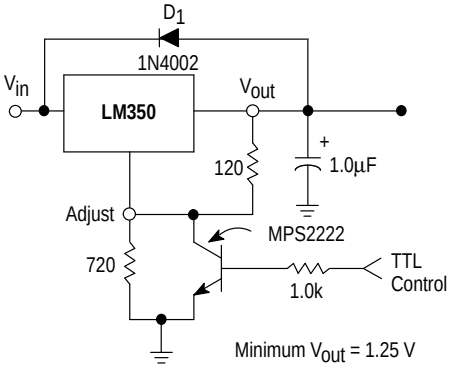
* To provide current limiting of I_O to the system ground, the source of the FET must be tied to a negative voltage below –1.25 V.

$$R_2 \leq \frac{V_{ref}}{I_{DSS}}$$

$$R_1 = \frac{V_{ref}}{I_{Omax} + I_{DSS}}$$

$V_O < V_{(BR)DSS} + 1.25\ V + V_{SS}$
$I_{Lmin} - I_{DSS} < I_O < 3.0\ A$
As shown $O < I_O < 1.0\ A$

Figure 21. 5.0 V Electronic Shutdown Regulator



D_1 protects the device during an input short circuit.

Figure 22. Slow Turn–On Regulator

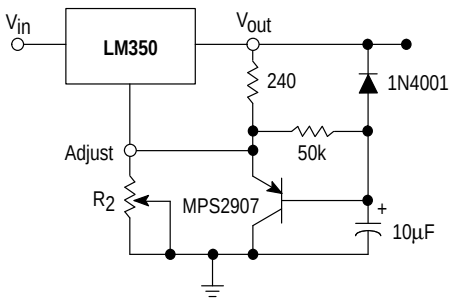
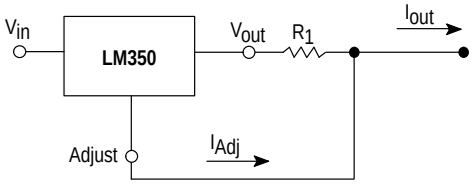


Figure 23. Current Regulator



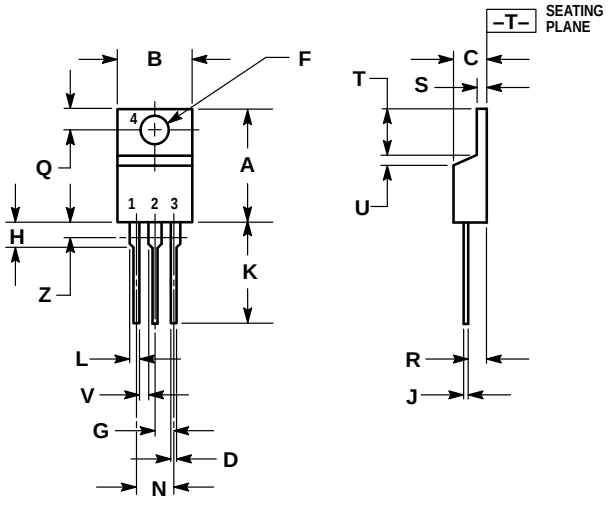
$$I_{out} = \left(\frac{V_{ref}}{R_1}\right) + I_{Adj}$$

$$\cong \frac{1.25\ V}{R_1}$$

$10\ mA \leq I_{out} \leq 3.0\ A$

OUTLINE DIMENSIONS

T SUFFIX
PLASTIC PACKAGE
CASE 221A–06
ISSUE Y



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. DIMENSION Z DEFINES A ZONE WHERE ALL BODY AND LEAD IRREGULARITIES ARE ALLOWED.

	INCHES		MILLIMETERS	
DIM	MIN	MAX	MIN	MAX
A	0.570	0.620	14.48	15.75
B	0.380	0.405	9.66	10.28
C	0.160	0.190	4.07	4.82
D	0.025	0.035	0.64	0.88
F	0.142	0.147	3.61	3.73
G	0.095	0.105	2.42	2.66
H	0.110	0.155	2.80	3.93
J	0.018	0.025	0.46	0.64
K	0.500	0.562	12.70	14.27
L	0.045	0.060	1.15	1.52
N	0.190	0.210	4.83	5.33
Q	0.100	0.120	2.54	3.04
R	0.080	0.110	2.04	2.79
S	0.045	0.055	1.15	1.39
T	0.235	0.255	5.97	6.47
U	0.000	0.050	0.00	1.27
V	0.045	—	1.15	—
Z	—	0.080	—	2.04

NOTES

NOTES

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