National Semiconductor

April 9, 2008

LM317L
3-Terminal Adjustable Regulator

General Description

The LM317L is an adjustable 3-terminal positive voltage regulator capable of supplying 100mA over a 1.2V to 37V output range. It is exceptionally easy to use and requires only two external resistors to set the output voltage. Further, both line and load regulation are better than standard fixed regulators. Also, the LM317L is available packaged in a standard TO-92 transistor package which is easy to use.

In addition to higher performance than fixed regulators, the LM317L offers full overload protection. 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 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, the LM317L 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.

Also, it makes an especially simple adjustable switching regulator, a programmable output regulator, or by connecting a fixed resistor between the adjustment and output, the LM317L 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.

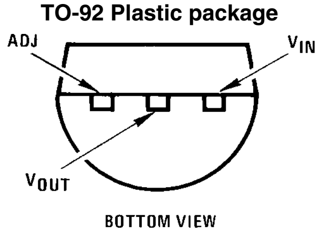
The LM317L is available in a standard TO-92 transistor package, the SO-8 package, and 6-Bump micro SMD package. The LM317L is rated for operation over a –25°C to 125°C range.

Features

- Adjustable output down to 1.2V
- Guaranteed 100mA output current
- Line regulation typically 0.01%V
- Load regulation typically 0.1%
- Current limit constant with temperature
- Eliminates the need to stock many voltages
- Standard 3-lead transistor package
- 80dB ripple rejection
- Available in TO-92, SO-8, or 6-Bump micro SMD package
- Output is short circuit protected
- See AN-1112 for micro SMD considerations

Connection Diagrams

TO-92 Plastic package



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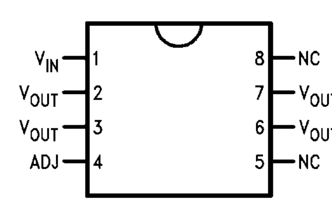
8-Pin SOIC



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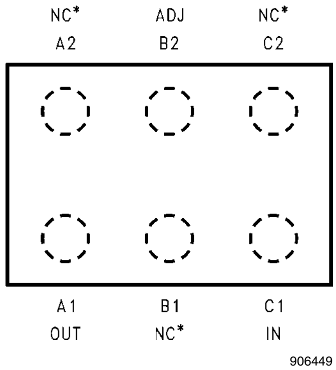
Top View

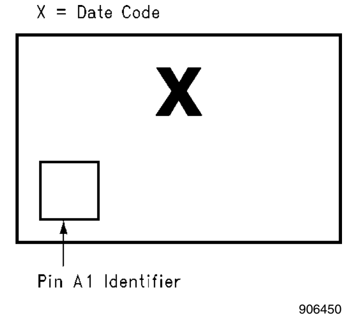
6-Bump micro SMD



*NC = Not Internally connected.

Top View
(Bump Side Down)

micro SMD Laser Mark



Ordering Information

Package	Part Number	Package Marking	Media Transport	NSC Drawing
TO-92	LM317LZ	LM317LZ	1.8k Units per Box	Z03A
8-Pin SOIC	LM317LM	LM317LM	Rails	M08A
6-Bump micro SMD	* LM317LIBP	–	250 Units Tape and Reel	BPA06HPB
	* LM317LIBPX	–	3k Units Tape and Reel	
	* LM317LITP	–	250 Units Tape and Reel	TPA06HPA
	* LM317LITPX	–	3k Units Tape and Reel	

Note: The micro SMD package marking is a single digit manufacturing Date Code only.

Absolute Maximum Ratings (Note 1)

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

Power Dissipation	Internally Limited
Input-Output Voltage Differential	40V
Operating Junction Temperature Range	−40°C to +125°C
Storage Temperature	−55°C to +150°C
Lead Temperature (Soldering, 4 seconds)	260°C
Output is Short Circuit Protected	
ESD Susceptibility	
Human Body Model (Note 5)	2kV

Electrical Characteristics (Note 2)

Parameter	Conditions	Min	Typ	Max	Units
Line Regulation	T_J = 25°C, 3V ≤ (V_{IN} − V_{OUT}) ≤ 40V, I_L ≤ 20mA (Note 3)		0.01	0.04	%/V
Load Regulation	T_J = 25°C, 5mA ≤ I_{OUT} ≤ I_{MAX}, (Note 3)		0.1	0.5	%
Thermal Regulation	T_J = 25°C, 10ms Pulse		0.04	0.2	%/W
Adjustment Pin Current			50	100	µA
Adjustment Pin Current Change	5mA ≤ I_L ≤ 100mA 3V ≤ (V_{IN} − V_{OUT}) ≤ 40V, P ≤ 625mW		0.2	5	µA
Reference Voltage	3V ≤ (V_{IN} − V_{OUT}) ≤ 40V, (Note 4) 5mA ≤ I_{OUT} ≤ 100mA, P ≤ 625mW	1.20	1.25	1.30	V
Line Regulation	3V ≤ (V_{IN} − V_{OUT}) ≤ 40V, I_L ≤ 20mA (Note 3)		0.02	0.07	%/V
Load Regulation	5mA ≤ I_{OUT} ≤ 100mA, (Note 3)		0.3	1.5	%
Temperature Stability	T_{MIN} ≤ T_J ≤ T_{Max}		0.65		%
Minimum Load Current	(V_{IN} − V_{OUT}) ≤ 40V 3V ≤ (V_{IN} − V_{OUT}) ≤ 15V		3.5 1.5	5 2.5	mA
Current Limit	3V ≤ (V_{IN} − V_{OUT}) ≤ 13V (V_{IN} − V_{OUT}) = 40V	100 25	200 50	300 150	mA mA
Rms Output Noise, % of V_{OUT}	T_J = 25°C, 10Hz ≤ f ≤ 10kHz		0.003		%
Ripple Rejection Ratio	V_{OUT} = 10V, f = 120Hz, C_{ADJ} = 0 C_{ADJ} = 10µF	 66	65 80		dB dB
Long-Term Stability	T_J = 125°C, 1000 Hours		0.3	1	%
Thermal Resistance Junction to Ambient	Z Package 0.4″ Leads Z Package 0.125 Leads SO-8 Package 6-Bump micro SMD		180 160 165 290		°C/W °C/W °C/W °C/W

Note 1: "Absolute Maximum Ratings" indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits.

Note 2: Unless otherwise noted, these specifications apply: −25°C ≤ T_j ≤ 125°C for the LM317L; V_{IN} − V_{OUT} = 5V and I_{OUT} = 40mA. Although power dissipation is internally limited, these specifications are applicable for power dissipations up to 625mW. I_{MAX} is 100mA.

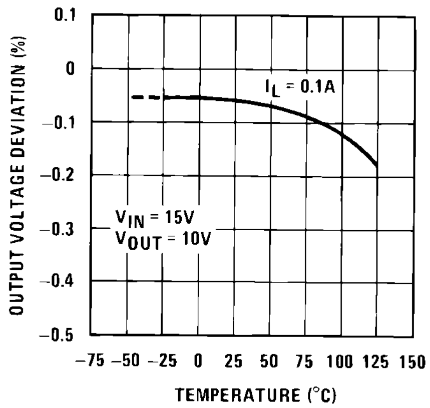
Note 3: Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output voltage due to heating effects are covered under the specification for thermal regulation.

Note 4: Thermal resistance of the TO-92 package is 180°C/W junction to ambient with 0.4″ leads from a PC board and 160°C/W junction to ambient with 0.125″ lead length to PC board.

Note 5: The human body model is a 100pF capacitor discharged through a 1.5kΩ resistor into each pin.

Typical Performance Characteristics (Output capacitor = 0µF unless otherwise noted.)

Load Regulation



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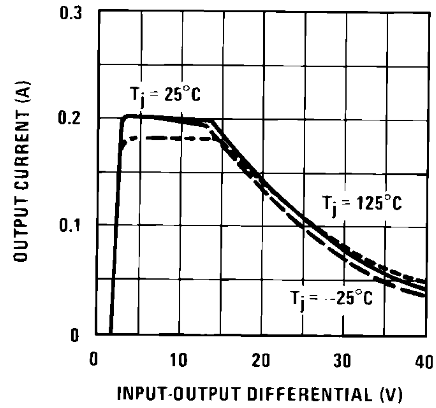
Current Limit



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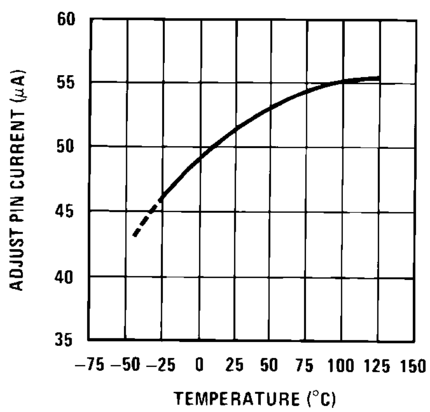
Adjustment Current



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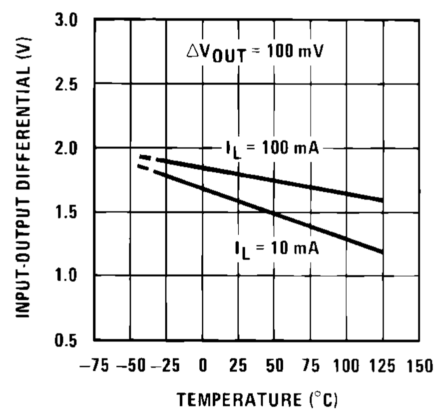
Dropout Voltage



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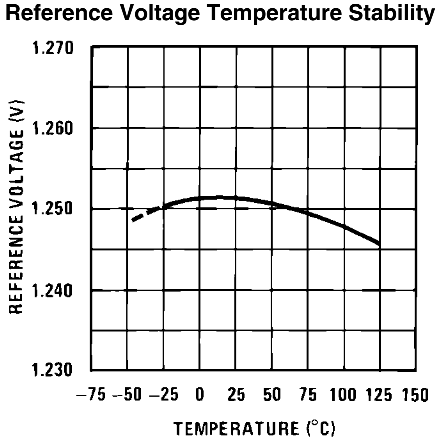
Reference Voltage Temperature Stability



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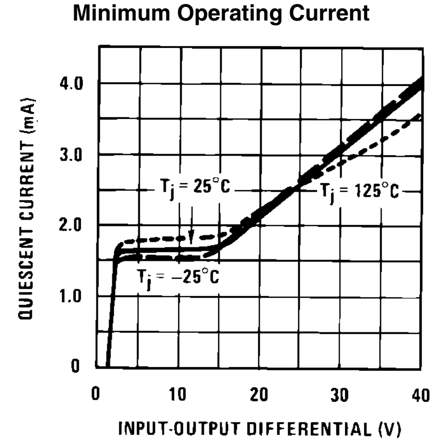
Minimum Operating Current



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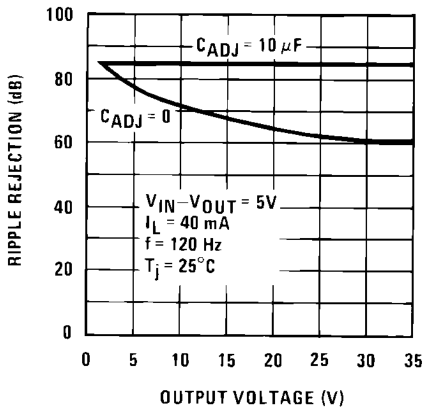
Ripple Rejection



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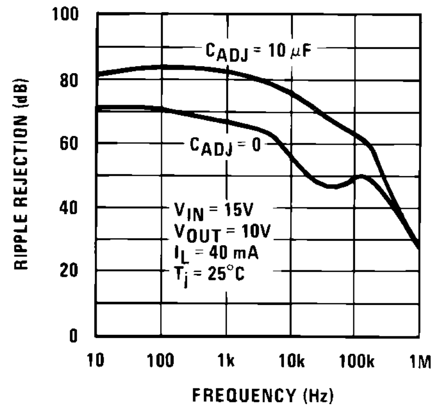
Ripple Rejection



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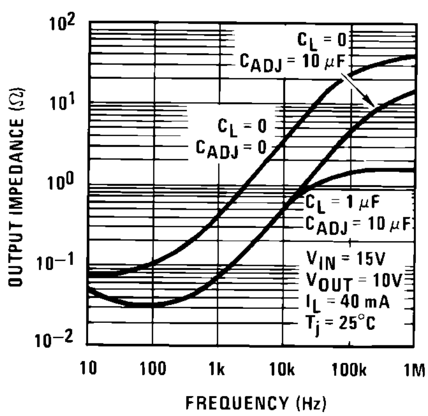
Output Impedance



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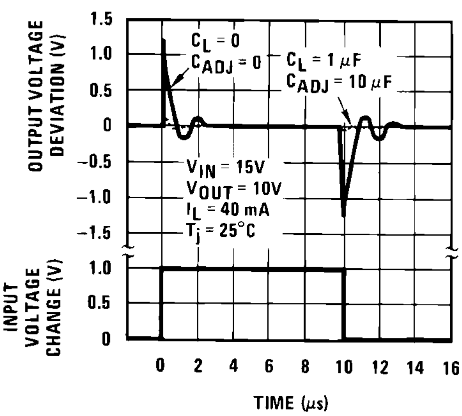
Line Transient Response



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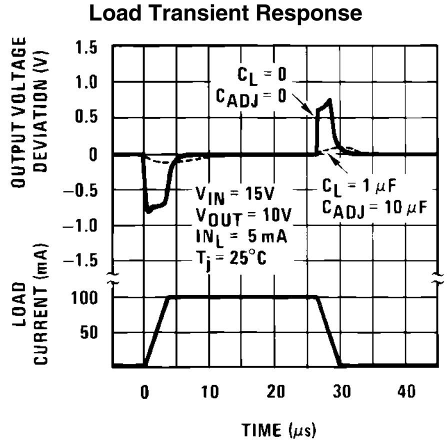
Load Transient Response



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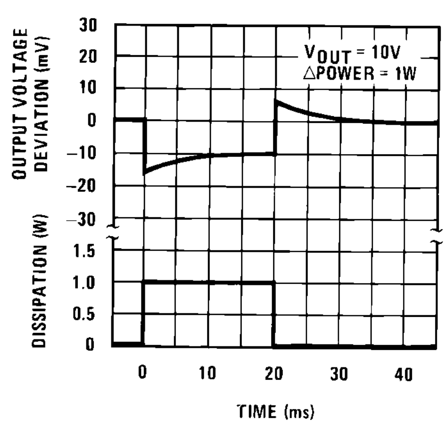
Thermal Regulation



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Application Hints

In operation, the LM317L 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

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

Since the 100µA current from the adjustment terminal represents an error term, the LM317L 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.

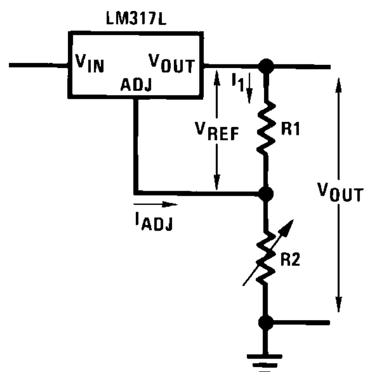

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FIGURE 1.

EXTERNAL CAPACITORS

An input bypass capacitor is recommended in case the regulator is more than 6 inches away from the usual large filter capacitor. A 0.1µF disc or 1µF 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 LM317L to improve ripple rejection and noise. This bypass capacitor prevents ripple and noise from being amplified as the output voltage is increased. With a 10µF bypass capacitor 80dB ripple rejection is obtainable at any output level. Increases over 10µF do not appreciably improve the ripple rejection at frequencies above 120Hz. 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 25µF in aluminum electrolytic to equal 1µF 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 0.5MHz. For this reason, a 0.01µF disc may seem to work better than a 0.1µF disc as a bypass.

Although the LM317L is stable with no output capacitors, like any feedback circuit, certain values of external capacitance can cause excessive ringing. This occurs with values between 500pF and 5000pF. A 1µF solid tantalum (or 25µF aluminum electrolytic) on the output swamps this effect and insures stability.

LOAD REGULATION

The LM317L 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 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 $0.05\Omega \times I_L$. 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.

With the TO-92 package, it is easy to minimize the resistance from the case to the set resistor, by using two separate leads to the output pin. The ground of R2 can be returned near the ground of the load to provide remote ground sensing and improve load regulation.

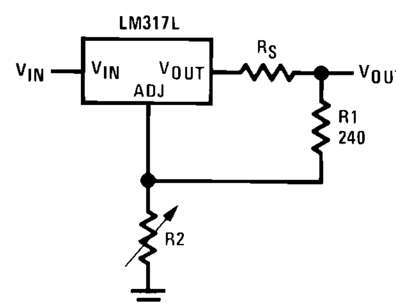

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FIGURE 2. Regulator with Line Resistance in Output Lead

THERMAL REGULATION

When power is dissipated in an IC, a temperature gradient occurs across the IC chip affecting the individual IC circuit components. With an IC regulator, this gradient can be especially severe since power dissipation is large. Thermal regulation is the effect of these temperature gradients on output voltage (in percentage output change) per watt of power change in a specified time. Thermal regulation error is independent of electrical regulation or temperature coefficient, and occurs within 5ms to 50ms after a change in power dissipation. Thermal regulation depends on IC layout as well as electrical design. The thermal regulation of a voltage regulator is defined as the percentage change of V_{OUT}, per watt, within the first 10ms after a step of power is applied. The LM317L specification is 0.2%/W, maximum.

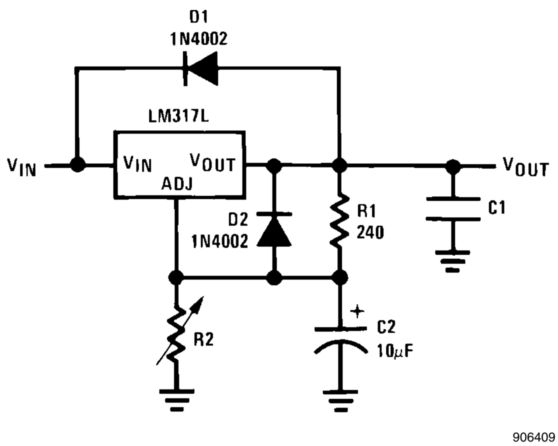
In the Thermal Regulation curve at the bottom of the Typical Performance Characteristics page, a typical LM317L's output changes only 7mV (or 0.07% of $V_{OUT} = -10V$) when a 1W pulse is applied for 10ms. This performance is thus well inside the specification limit of 0.2%/W × 1W = 0.2% maximum. When the 1W pulse is ended, the thermal regulation again shows a 7mV change as the gradients across the LM317L chip die out. Note that the load regulation error of about 14mV (0.14%) is additional to the thermal regulation error.

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 10µF 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 LM317L, this discharge path is through a large junction that is able to sustain a 2A surge with no problem. This is not true of other types of positive regulators. For output capacitors of 25 µF or less, the LM317L's ballast resistors and output structure limit the peak current to a low enough level so that there is no need to use a protection diode.

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 LM317L is a 50Ω resistor which limits the peak discharge current. No protection is needed for output voltages of 25V or less and 10µF capacitance. *Figure 3* shows an LM317L with protection diodes included for use with outputs greater than 25V and high values of output capacitance.



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

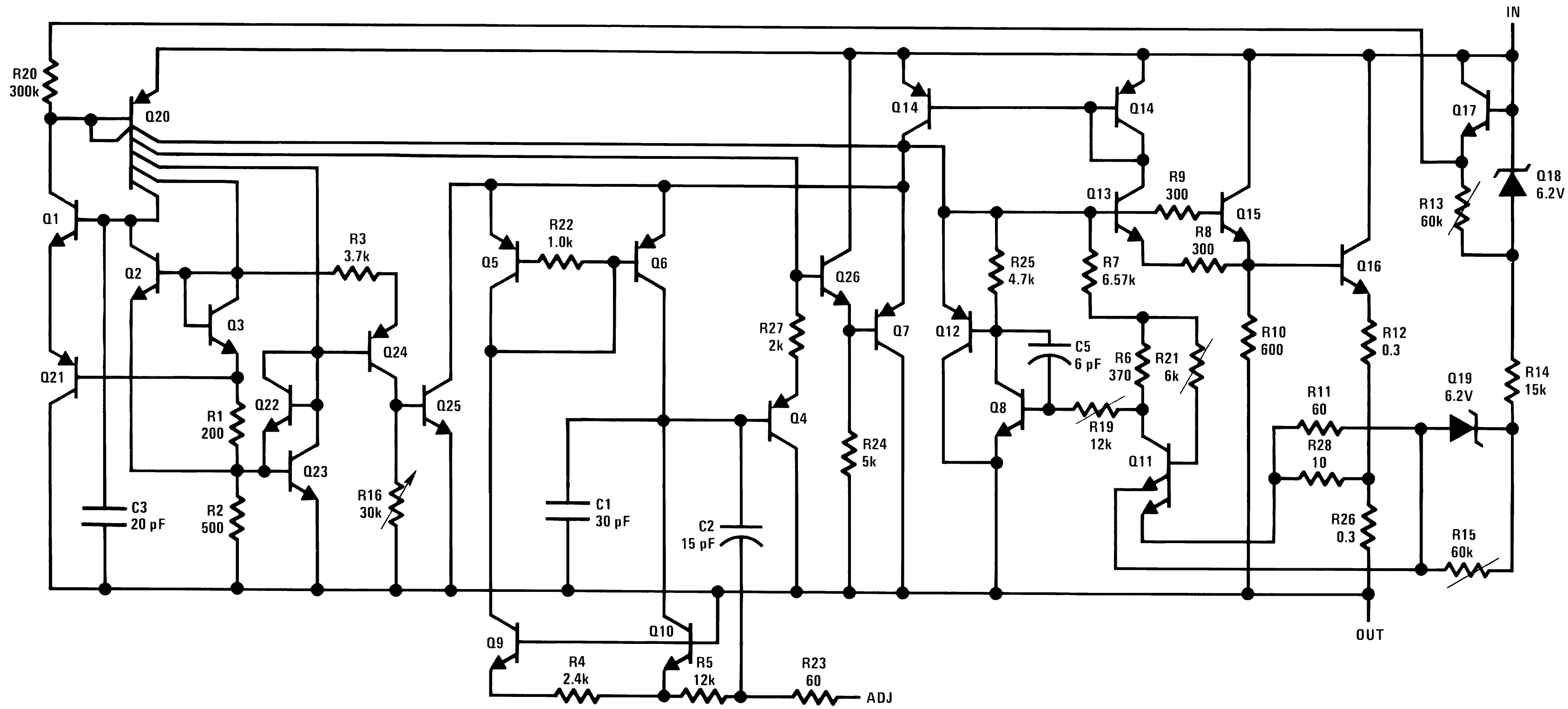
D1 protects against C1
D2 protects against C2

FIGURE 3. Regulator with Protection Diodes

LM317L micro SMD Light Sensitivity

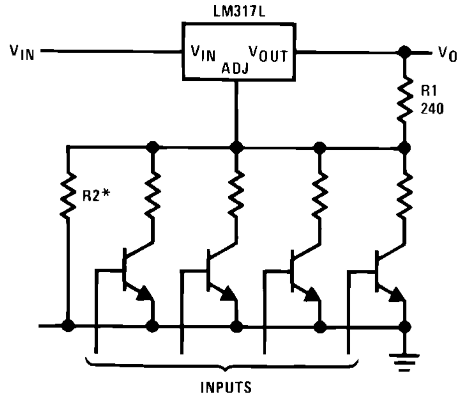
Exposing the LM317L micro SMD package to bright sunlight may cause the V_{REF} to drop. In a normal office environment of fluorescent lighting the output is not affected. The LM317 micro SMD does not sustain permanent damage from light exposure. Removing the light source will cause LM317L's V_{REF} to recover to the proper value.

Schematic Diagram



Typical Applications

Digitally Selected Outputs



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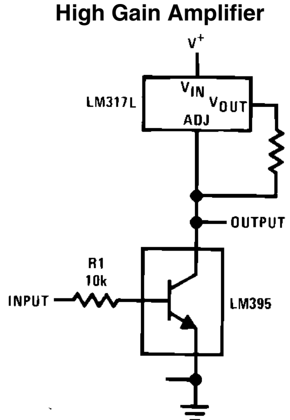
*Sets maximum V_{OUT}

High Gain Amplifier



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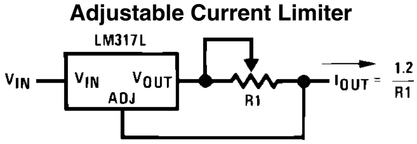
Adjustable Current Limiter



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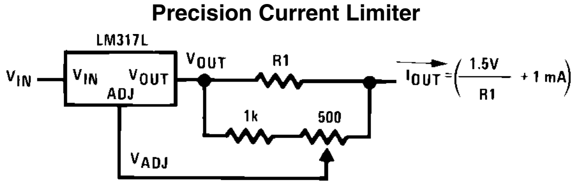
12 ≤ R1 ≤ 240

Precision Current Limiter



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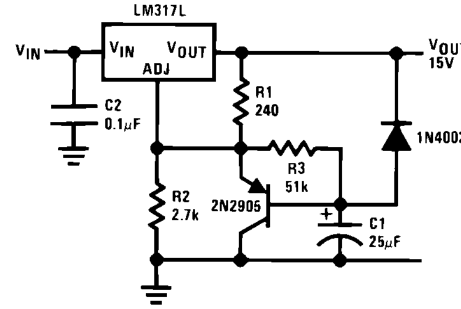
Slow Turn-On 15V Regulator



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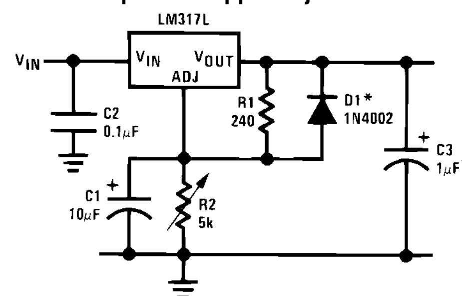
Adjustable Regulator with Improved Ripple Rejection



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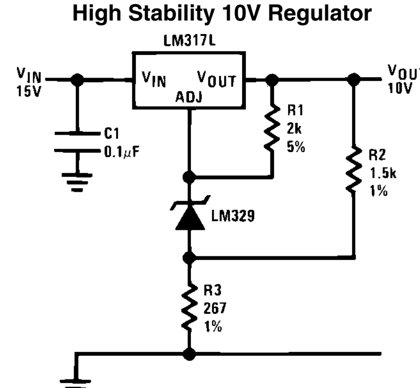
†Solid tantalum

*Discharges C1 if output is shorted to ground

High Stability 10V Regulator



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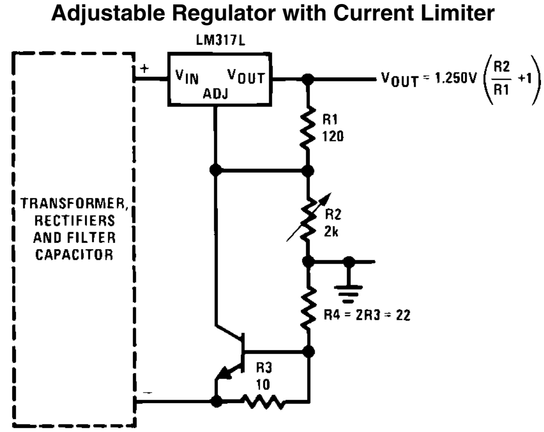
Adjustable Regulator with Current Limiter



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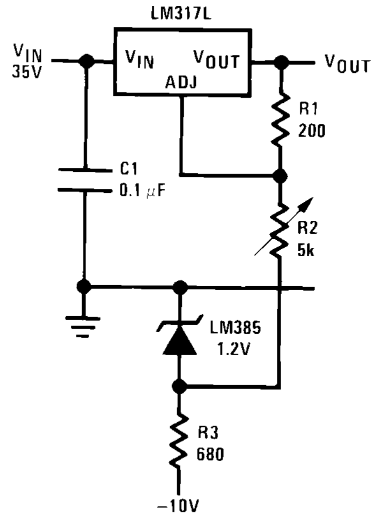
Short circuit current is approximately 600 mV/R3, or 60mA (compared to LM317LZ's 200mA current limit).

At 25mA output only 3/4V of drop occurs in R3 and R4.

0V–30V Regulator



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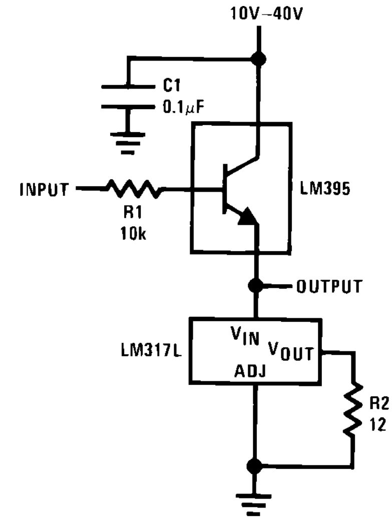
Full output current not available at high input-output voltages

Power Follower



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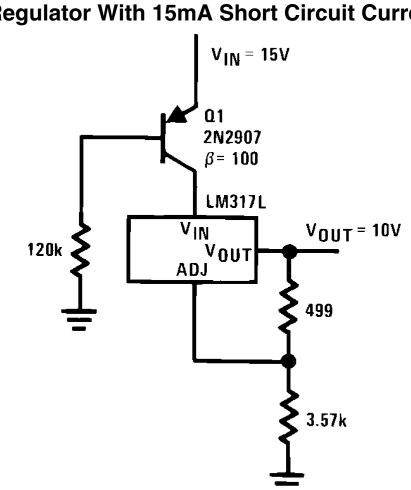
Regulator With 15mA Short Circuit Current



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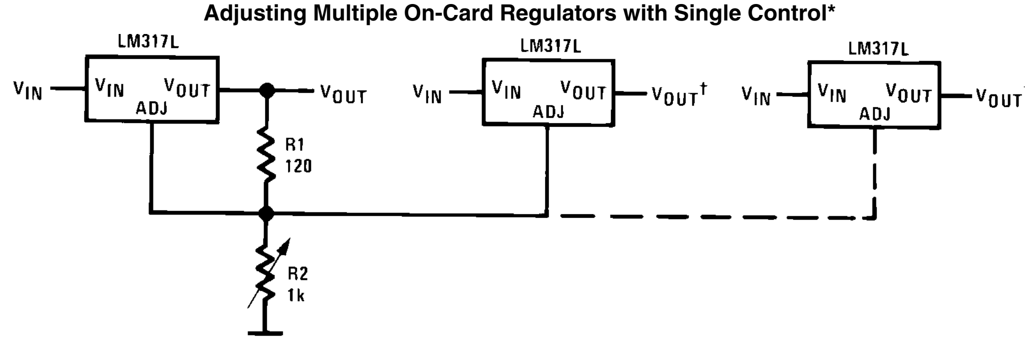
Adjusting Multiple On-Card Regulators with Single Control*



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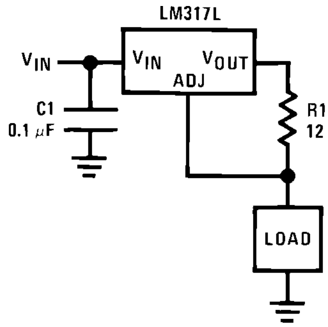
*All outputs within ± 100mV

†Minimum load −5mA

100mA Current Regulator



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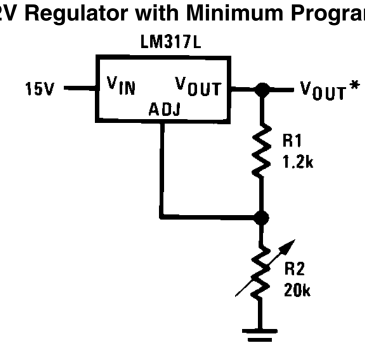
1.2V–12V Regulator with Minimum Program Current



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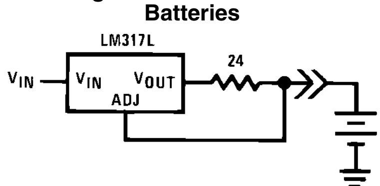
*Minimum load current ≈ 2 mA

50mA Constant Current Battery Charger for Nickel-Cadmium Batteries



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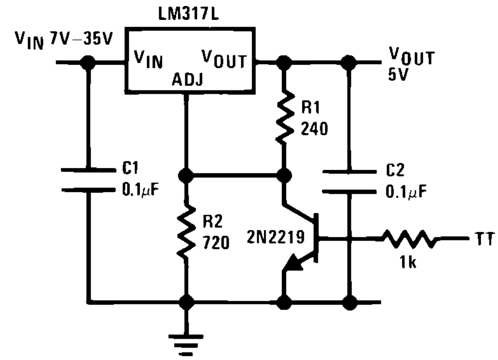
5V Logic Regulator with Electronic Shutdown*



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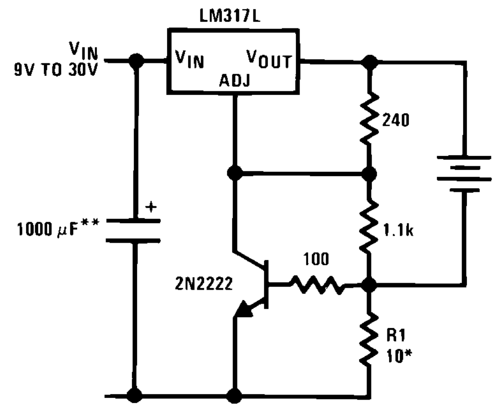
*Minimum output ≈ 1.2V

Current Limited 6V Charger



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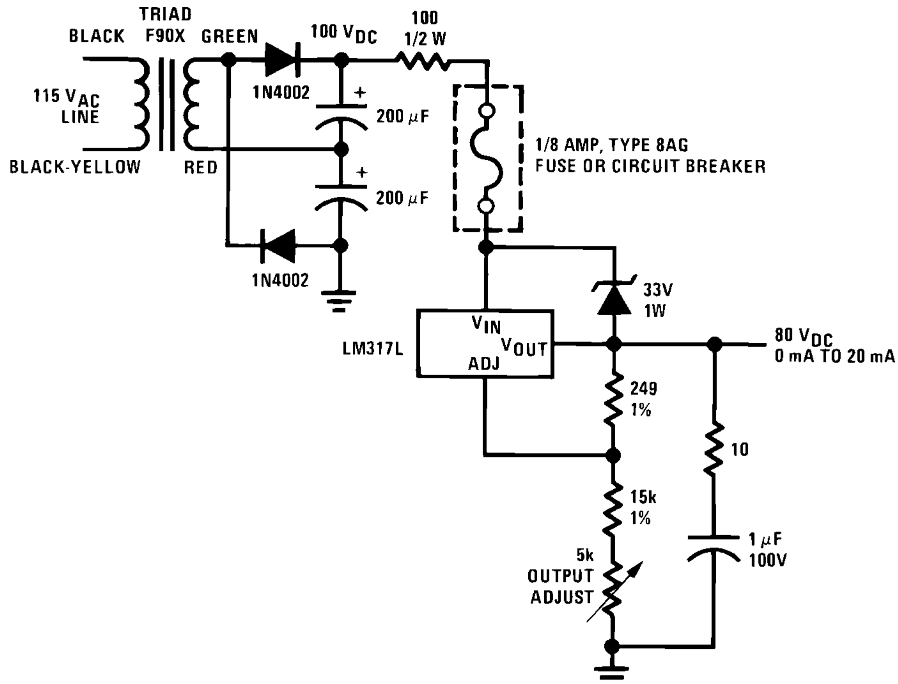
*Sets peak current, I_{PEAK} = 0.6V/R1

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

Short Circuit Protected 80V Supply



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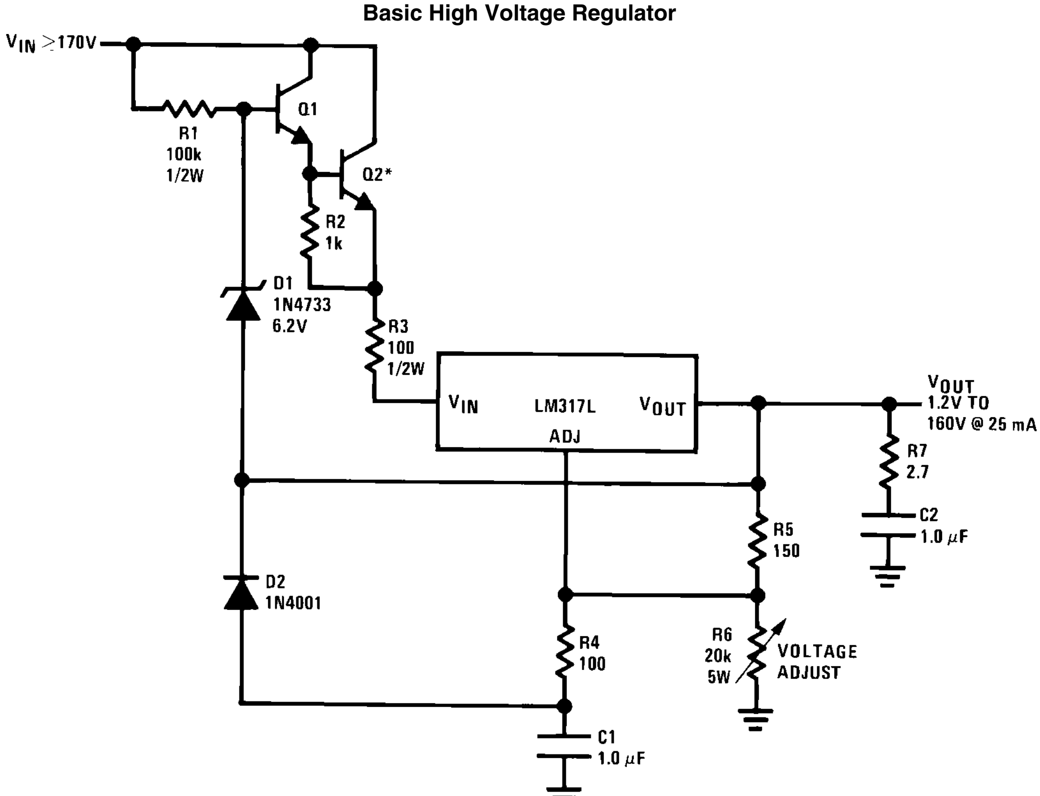
Basic High Voltage Regulator



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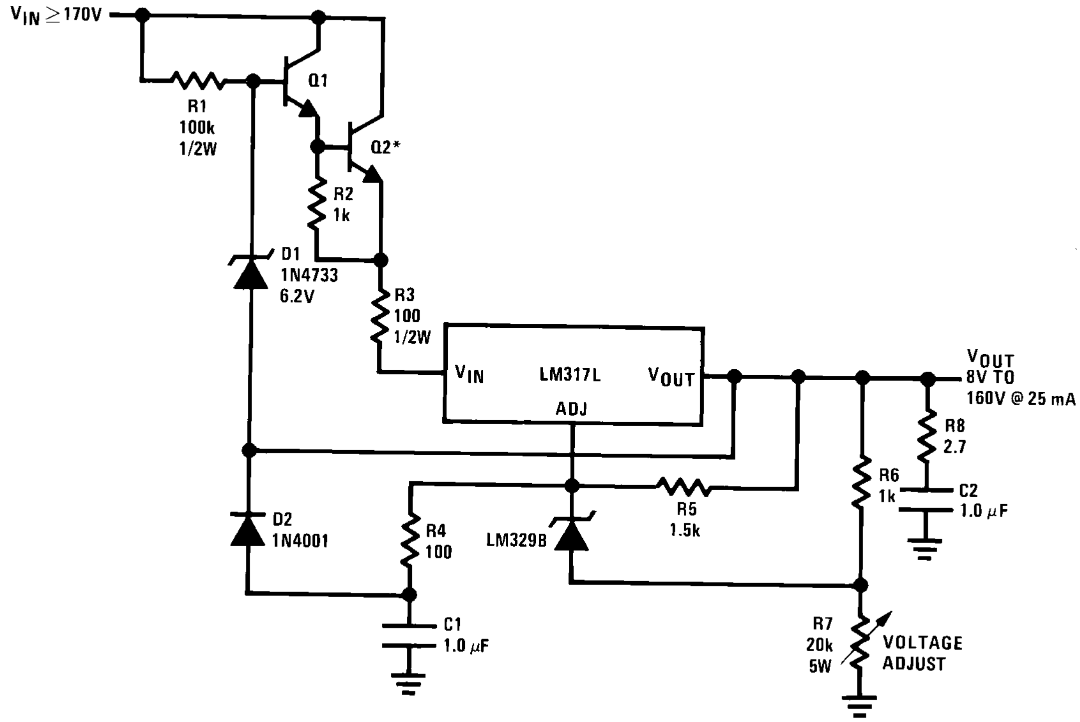
Q1, Q2: NSD134 or similar
C1, C2: 1μF, 200V mylar**
*Heat sink

Precision High Voltage Regulator



906430

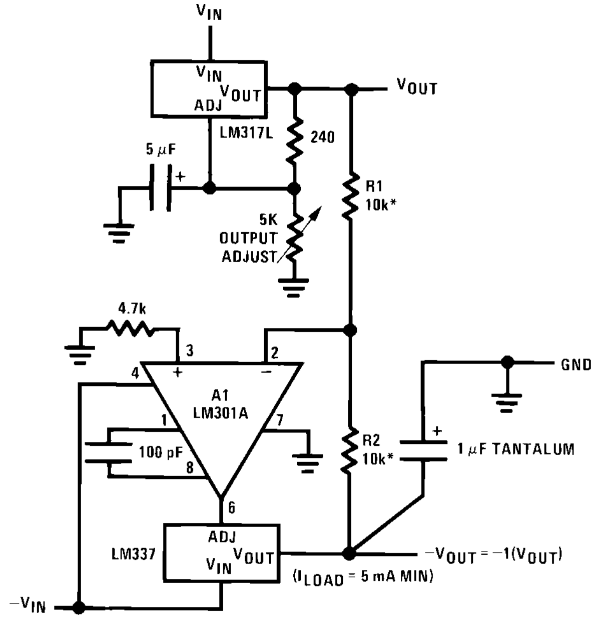
Q1, Q2: NSD134 or similar

C1, C2: 1μF, 200V mylar**

*Heat sink

**Mylar is a registered trademark of DuPont Co.

Tracking Regulator

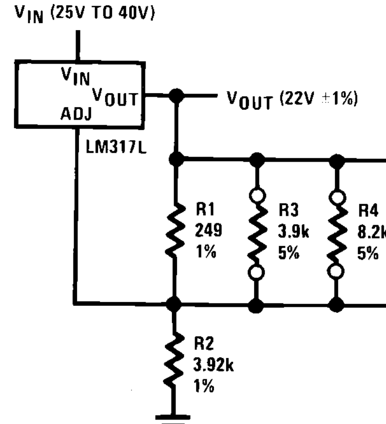


906431

A1 = LM301A, LM307, or LF13741 only

R1, R2 = matched resistors with good TC tracking

Regulator With Trimmable Output Voltage



906432

Trim Procedure:

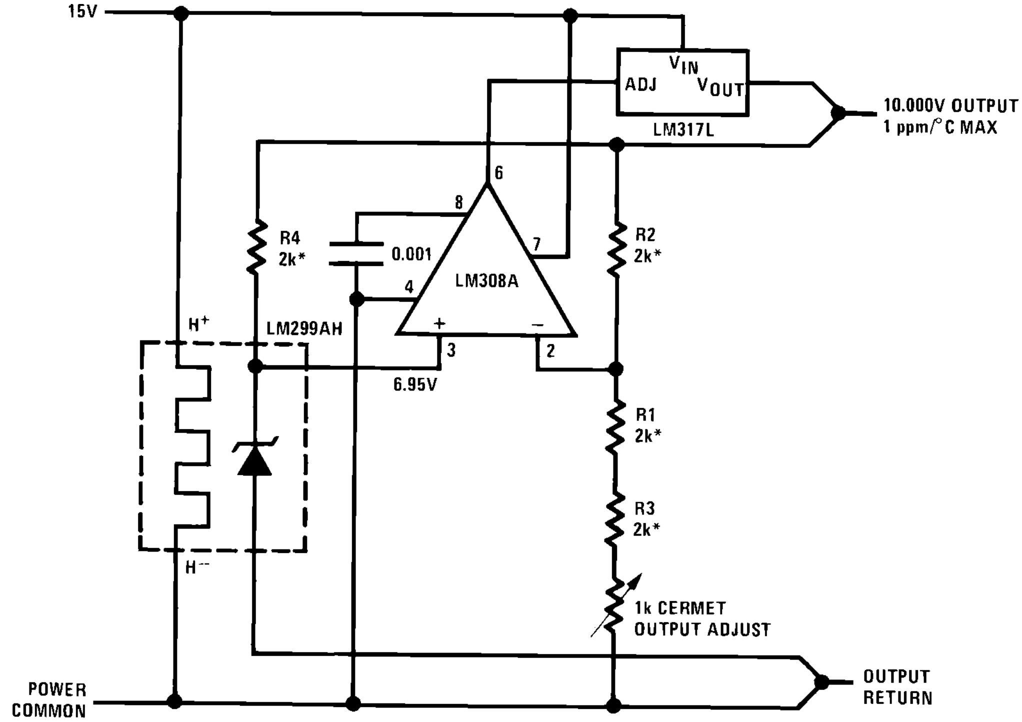
—If V_{OUT} is 23.08V or higher, cut out R3 (if lower, don't cut it out).

—Then if V_{OUT} is 22.47V or higher, cut out R4 (if lower, don't).

—Then if V_{OUT} is 22.16V or higher, cut out R5 (if lower, don't).

This will trim the output to well within ±1% of 22.00 V_{DC}, without any of the expense or uncertainty of a trim pot (see LB-46). Of course, this technique can be used at any output voltage level.

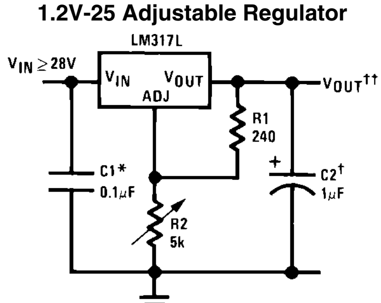
Precision Reference with Short-Circuit Proof Output



906433

*R1–R4 from thin-film network,
Beckman 694-3-R2K-D or similar

1.2V-25 Adjustable Regulator

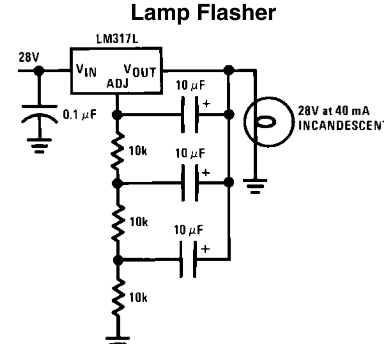


906401

Full output current not available at high input-output voltages
†Optional—improves transient response
*Needed if device is more than 6 inches from filter capacitors

$$\dagger\dagger V_{OUT} = 1.25V\left(1 + \frac{R2}{R1}\right) + I_{ADJ}\,(R_2)$$

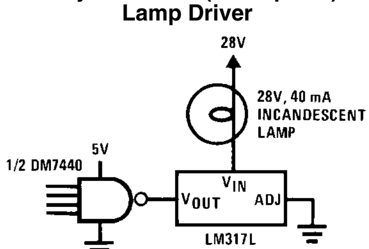
Lamp Flasher



906403

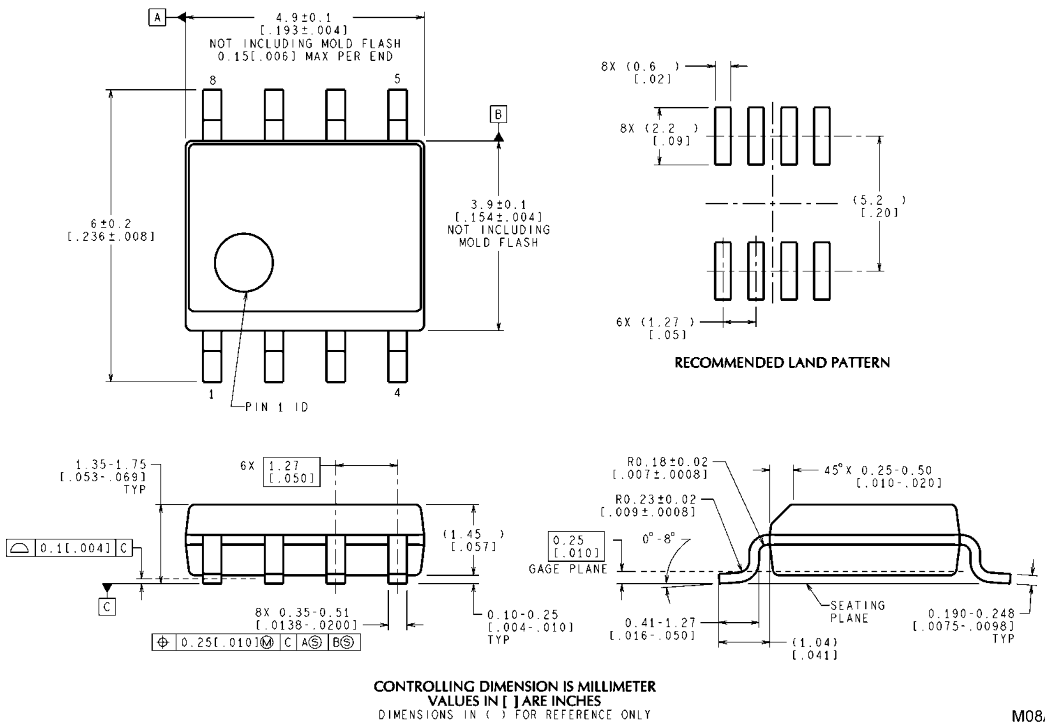
Output rate—4 flashes per second at 10% duty cycle

Fully Protected (Bulletproof) Lamp Driver



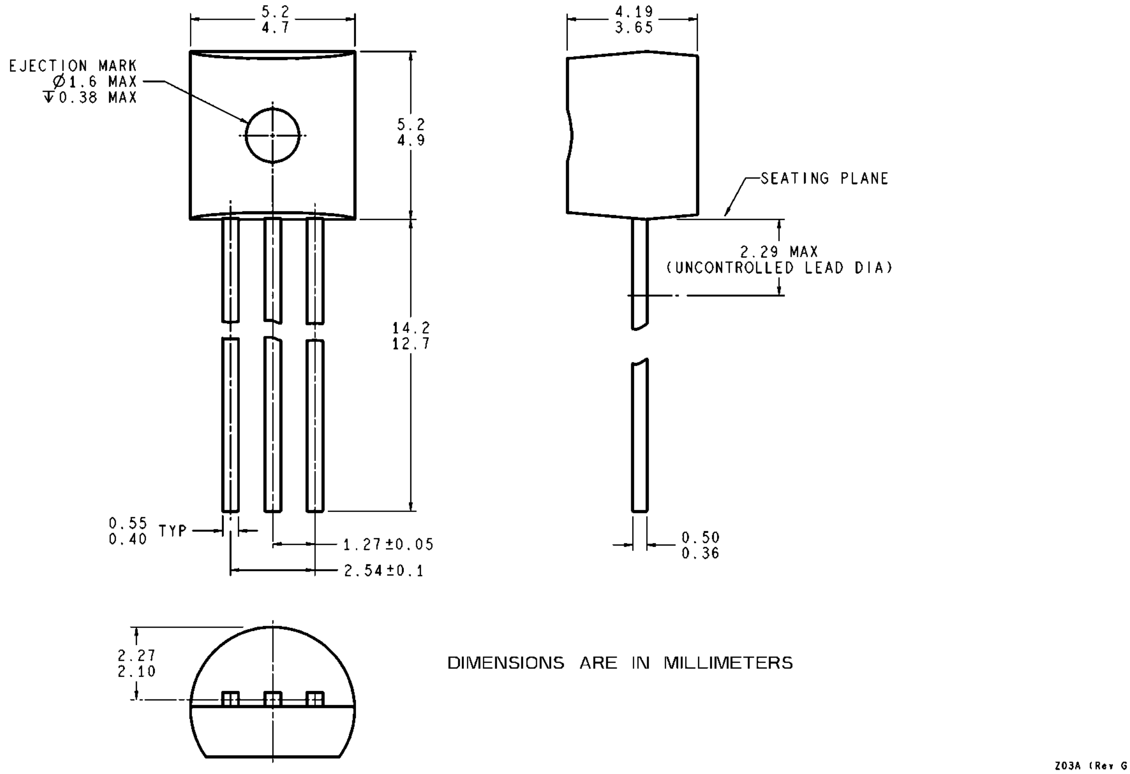
906402

Physical Dimensions inches (millimeters) unless otherwise noted

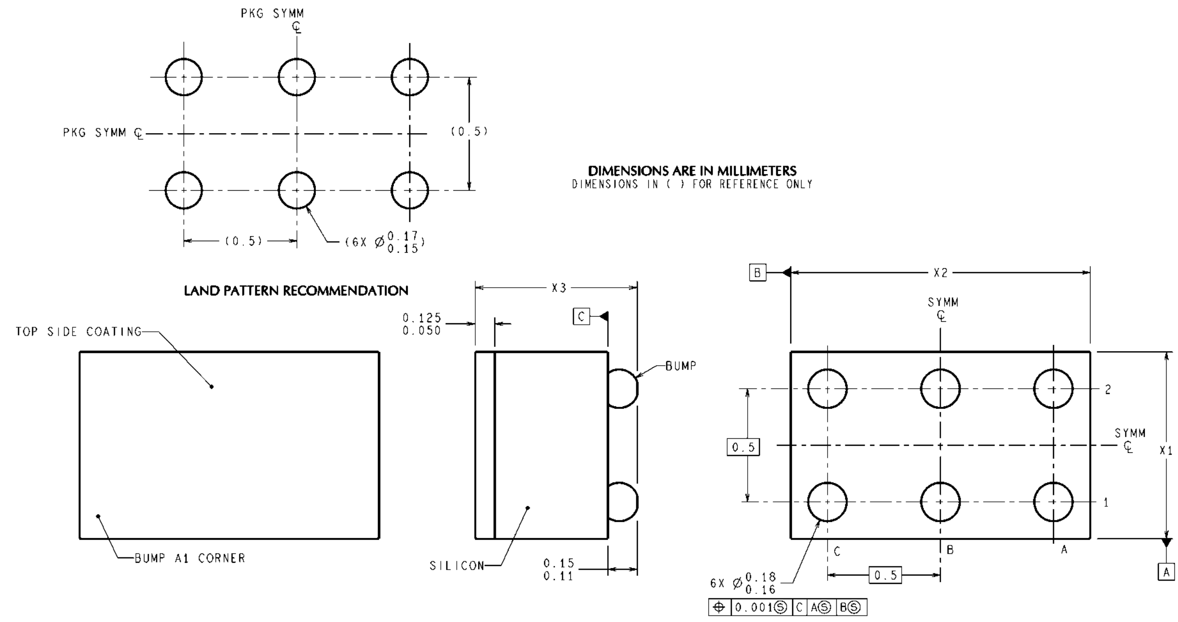


M08A (Rev L)

SO-8 Molded Package
NS Package Number M08A



TO-92 Plastic Package (Z)
NS Package Number Z03A

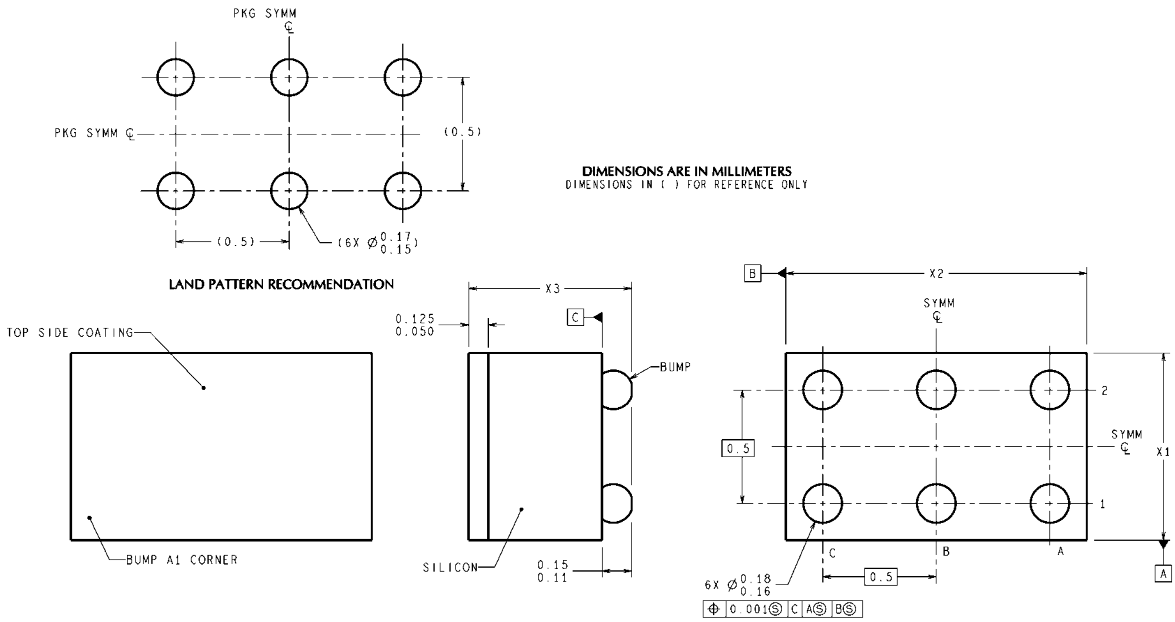


BPA06XXX (Rev D)

NOTE: UNLESS OTHERWISE SPECIFIED.

1. EPOXY COATING
2. 63Sn/37Pb EUTECTIC BUMP.
3. RECOMMEND NON-SOLDER MASK DEFINED LANDING PAD.
4. PIN A1 IS ESTABLISHED BY LOWER LEFT CORNER WITH RESPECT TO TEXT ORIENTATION PINS ARE NUMBERED COUNTERCLOCKWISE.
5. XXX IN DRAWING NUMBER REPRESENTS PACKAGE SIZE VARIATION WHERE X_1 IS PACKAGE WIDTH, X_2 IS PACKAGE LENGTH AND X_3 IS PACKAGE HEIGHT.
6. REFERENCE JEDEC REGISTRATION MO-211, VARIATION BC.

6-Bump micro SMD
NS Package Number BPA06HPB
X_1 = 0.955 X_2 = 1.615 X_3 =0.850



TPA06XXX (Rev B)

NOTE: UNLESS OTHERWISE SPECIFIED.

1. EPOXY COATING
2. 63Sn/37Pb EUTECTIC BUMP.
3. RECOMMEND NON-SOLDER MASK DEFINED LANDING PAD.
4. PIN A1 IS ESTABLISHED BY LOWER LEFT CORNER WITH RESPECT TO TEXT ORIENTATION PINS ARE NUMBERED COUNTERCLOCKWISE.
5. XXX IN DRAWING NUMBER REPRESENTS PACKAGE SIZE VARIATION WHERE X_1 IS PACKAGE WIDTH, X_2 IS PACKAGE LENGTH AND X_3 IS PACKAGE HEIGHT.
6. REFERENCE JEDEC REGISTRATION MO-211, VARIATION BC.

6-Bump micro SMD
NS Package Number TPA06HPA
X_1 = 0.955 X_2 = 1.615 X_3 =0.500

Notes

Notes

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National Semiconductor

September 2001

LM117/LM317A/LM317 3-Terminal Adjustable Regulator

General Description

The LM117 series of adjustable 3-terminal positive voltage regulators is capable of supplying in excess of 1.5A over a 1.2V to 37V output range. They are exceptionally easy to use and require only two external resistors to set the output voltage. Further, both line and load regulation are better than standard fixed regulators. Also, the LM117 is packaged in standard transistor packages which are easily mounted and handled.

In addition to higher performance than fixed regulators, the LM117 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 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, the LM117 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 LM117 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.

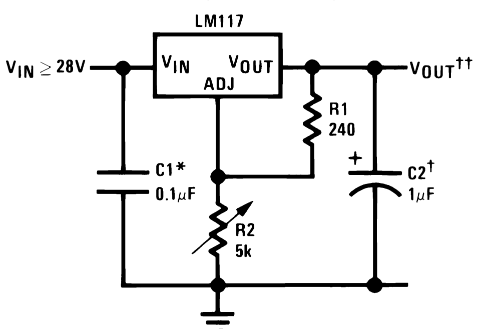
For applications requiring greater output current, see LM150 series (3A) and LM138 series (5A) data sheets. For the negative complement, see LM137 series data sheet.

Features

- Guaranteed 1% output voltage tolerance (LM317A)
- Guaranteed max. 0.01%/V line regulation (LM317A)
- Guaranteed max. 0.3% load regulation (LM117)
- Guaranteed 1.5A output current
- Adjustable output down to 1.2V
- Current limit constant with temperature
- P^+ Product Enhancement tested
- 80 dB ripple rejection
- Output is short-circuit protected

Typical Applications

1.2V–25V Adjustable Regulator



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Full output current not available at high input-output voltages

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

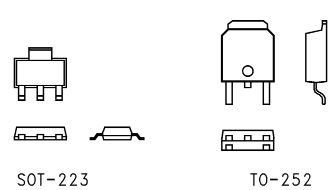
†Optional — improves transient response. Output capacitors in the range of 1 μF to 1000 μF of aluminum or tantalum electrolytic are commonly used to provide improved output impedance and rejection of transients.

$$††V_{OUT} = 1.25V \left(1 + \frac{R2}{R1}\right) + I_{ADJ}(R_2)$$

LM117 Series Packages

Part Number Suffix	Package	Design Load Current
K	TO-3	1.5A
H	**TO-39**	**0.5A**
T	TO-220	1.5A
E	**LCC**	**0.5A**
S	TO-263	1.5A
EMP	SOT-223	1A
MDT	**TO-252**	**0.5A**

SOT-223 vs D-Pak (TO-252) Packages



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Scale 1:1

 DS009063

Absolute Maximum Ratings (Note 1)

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

Power Dissipation	Internally Limited
Input-Output Voltage Differential	+40V, −0.3V
Storage Temperature	−65˚C to +150˚C
Lead Temperature	
Metal Package (Soldering, 10 seconds)	300˚C
Plastic Package (Soldering, 4 seconds)	260˚C
ESD Tolerance (Note 5)	3 kV

Operating Temperature Range

LM117	$-55˚C \leq T_J \leq +150˚C$
LM317A	$-40˚C \leq T_J \leq +125˚C$
LM317	$0˚C \leq T_J \leq +125˚C$

Preconditioning

Thermal Limit Burn-In	All Devices 100%

Electrical Characteristics (Note 3)

Specifications with standard type face are for T_J = 25˚C, and those with **boldface type** apply over **full Operating Temperature Range**. Unless otherwise specified, $V_{IN} - V_{OUT}$ = 5V, and I_{OUT} = 10 mA.

Parameter	Conditions	**LM117** (Note 2)			Units
		Min	**Typ**	**Max**	
Reference Voltage					V
	$3V \leq (V_{IN} - V_{OUT}) \leq 40V$, $10\ mA \leq I_{OUT} \leq I_{MAX}$, $P \leq P_{MAX}$	**1.20**	**1.25**	**1.30**	V
Line Regulation	$3V \leq (V_{IN} - V_{OUT}) \leq 40V$ (Note 4)		0.01	0.02	%/V
			0.02	**0.05**	%/V
Load Regulation	$10\ mA \leq I_{OUT} \leq I_{MAX}$ (Note 4)		0.1	0.3	%
			0.3	**1**	%
Thermal Regulation	20 ms Pulse		0.03	0.07	%/W
Adjustment Pin Current			**50**	**100**	μA
Adjustment Pin Current Change	$10\ mA \leq I_{OUT} \leq I_{MAX}$ $3V \leq (V_{IN} - V_{OUT}) \leq 40V$		**0.2**	**5**	μA
Temperature Stability	$T_{MIN} \leq T_J \leq T_{MAX}$		**1**		%
Minimum Load Current	$(V_{IN} - V_{OUT})$ = 40V		**3.5**	**5**	mA
Current Limit	$(V_{IN} - V_{OUT}) \leq 15V$ K Package H Packages	 **1.5** **0.5**	 **2.2** **0.8**	 **3.4** **1.8**	 A A
	$(V_{IN} - V_{OUT})$ = 40V K Package H Package	 0.3 0.15	 0.4 0.2		 A A
RMS Output Noise, % of V_{OUT}	$10\ Hz \leq f \leq 10\ kHz$		0.003		%
Ripple Rejection Ratio	V_{OUT} = 10V, f = 120 Hz, C_{ADJ} = 0 μF		**65**		dB
	V_{OUT} = 10V, f = 120 Hz, C_{ADJ} = 10 μF	**66**	**80**		dB
Long-Term Stability	T_J = 125˚C, 1000 hrs		0.3	1	%
Thermal Resistance, Junction-to-Case	K Package H Package E Package		2.3 12	3 15	˚C/W ˚C/W ˚C/W
Thermal Resistance, Junction-to-Ambient (No Heat Sink)	K Package H Package E Package		35 140		˚C/W ˚C/W ˚C/W

Electrical Characteristics (Note 3)

Specifications with standard type face are for $T_J = 25°C$, and those with **boldface type** apply over **full Operating Temperature Range**. Unless otherwise specified, $V_{IN} - V_{OUT} = 5V$, and $I_{OUT} = 10$ mA.

Parameter	Conditions	LM317A			LM317			Units
		Min	Typ	Max	Min	Typ	Max	
Reference Voltage		1.238	1.250	1.262				V
	$3V \le (V_{IN} - V_{OUT}) \le 40V$, $10\text{ mA} \le I_{OUT} \le I_{MAX}$, $P \le P_{MAX}$	**1.225**	**1.250**	**1.270**	**1.20**	**1.25**	**1.30**	V
Line Regulation	$3V \le (V_{IN} - V_{OUT}) \le 40V$ (Note 4)		0.005	0.01		0.01	0.04	%/V
			0.01	**0.02**		**0.02**	**0.07**	%/V
Load Regulation	$10\text{ mA} \le I_{OUT} \le I_{MAX}$ (Note 4)		0.1	0.5		0.1	0.5	%
			0.3	**1**		**0.3**	**1.5**	%
Thermal Regulation	20 ms Pulse		0.04	0.07		0.04	0.07	%/W
Adjustment Pin Current			**50**	**100**		**50**	**100**	µA
Adjustment Pin Current Change	$10\text{ mA} \le I_{OUT} \le I_{MAX}$ $3V \le (V_{IN} - V_{OUT}) \le 40V$		**0.2**	**5**		**0.2**	**5**	µA
Temperature Stability	$T_{MIN} \le T_J \le T_{MAX}$		**1**			**1**		%
Minimum Load Current	$(V_{IN} - V_{OUT}) = 40V$		**3.5**	**10**		**3.5**	**10**	mA
Current Limit	$(V_{IN} - V_{OUT}) \le 15V$							
	K, T, S Packages	**1.5**	**2.2**	**3.4**	**1.5**	**2.2**	**3.4**	A
	H Package	**0.5**	**0.8**	**1.8**	**0.5**	**0.8**	**1.8**	A
	MP Package	**1.5**	**2.2**	**3.4**	**1.5**	**2.2**	**3.4**	A
	$(V_{IN} - V_{OUT}) = 40V$							
	K, T, S Packages	0.15	0.4		0.15	0.4		A
	H Package	0.075	0.2		0.075	0.2		A
	MP Package	0.55	0.4		0.15	0.4		A
RMS Output Noise, % of V_{OUT}	$10\text{ Hz} \le f \le 10\text{ kHz}$		0.003			0.003		%
Ripple Rejection Ratio	$V_{OUT} = 10V$, f = 120 Hz, $C_{ADJ} = 0$ µF		**65**			**65**		dB
	$V_{OUT} = 10V$, f = 120 Hz, $C_{ADJ} = 10$ µF	**66**	**80**		**66**	**80**		dB
Long-Term Stability	$T_J = 125°C$, 1000 hrs		0.3	1		0.3	1	%
Thermal Resistance, Junction-to-Case	K Package					2.3	3	°C/W
	MDT Package					5		°C/W
	H Package		12	15		12	15	°C/W
	T Package		4	5		4		°C/W
	MP Package		23.5			23.5		°C/W
Thermal Resistance, Junction-to-Ambient (No Heat Sink)	K Package		35			35		°C/W
	MDT Package(Note 6)					92		°C/W
	H Package		140			140		°C/W
	T Package		50			50		°C/W
	S Package (Note 6)		50			50		°C/W

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed.

Note 2: Refer to RETS117H drawing for the LM117H, or the RETS117K for the LM117K military specifications.

Note 3: Although power dissipation is internally limited, these specifications are applicable for maximum power dissipations of 2W for the TO-39 and SOT-223 and 20W for the TO-3, TO-220, and TO-263. I_{MAX} is 1.5A for the TO-3, TO-220, and TO-263 packages, 0.5A for the TO-39 package and 1A for the SOT-223 Package. All limits (i.e., the numbers in the Min. and Max. columns) are guaranteed to National's AOQL (Average Outgoing Quality Level).

Note 4: Regulation is measured at a constant junction temperature, using pulse testing with a low duty cycle. Changes in output voltage due to heating effects are covered under the specifications for thermal regulation.

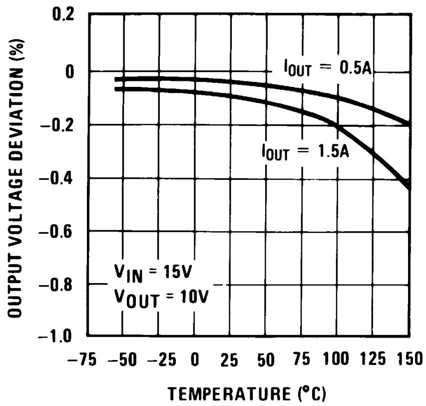
Note 5: Human body model, 100 pF discharged through a 1.5 kΩ resistor.

Note 6: If the TO-263 or TO-252 packages are used, the thermal resistance can be reduced by increasing the PC board copper area thermally connected to the package. Using 0.5 square inches of copper area. θ_{JA} is 50°C/W; with 1 square inch of copper area, θ_{JA} is 37°C/W; and with 1.6 or more square inches of copper area, θ_{JA} is 32°C/W. If the SOT-223 package is used, the thermal resistance can be reduced by increasing the PC board copper area (see applications hints for heatsinking).

Output Capacitor = 0 µF unless otherwise noted

Typical Performance Characteristics

Load Regulation



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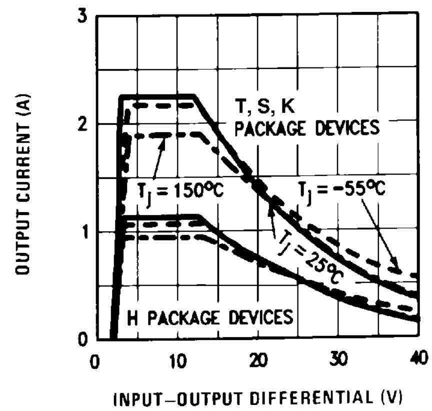
Current Limit



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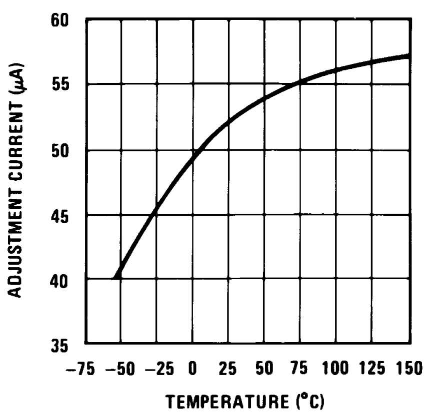
Adjustment Current



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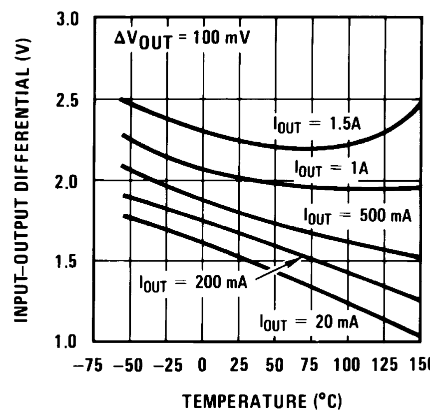
Dropout Voltage



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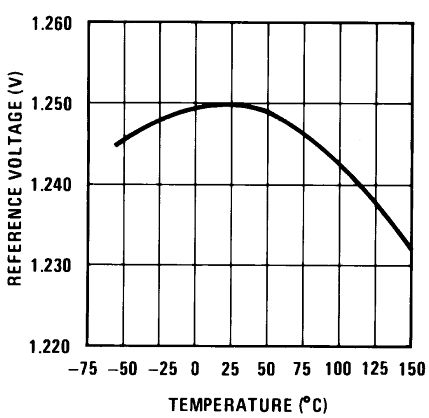
Temperature Stability



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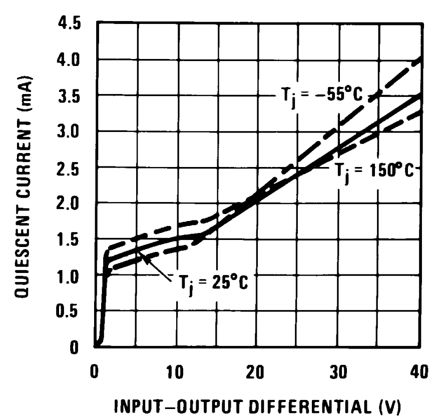
Minimum Operating Current



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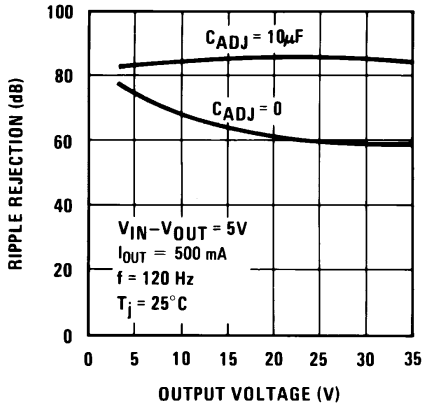
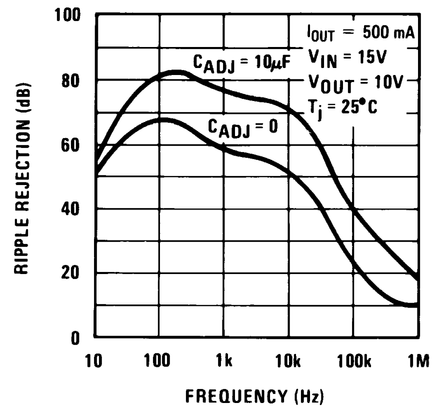
Typical Performance Characteristics (Continued)

Ripple Rejection



00906343

Ripple Rejection



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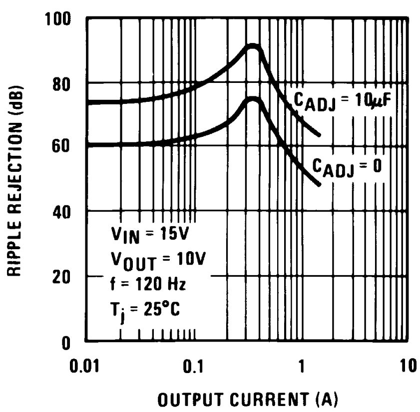
Ripple Rejection



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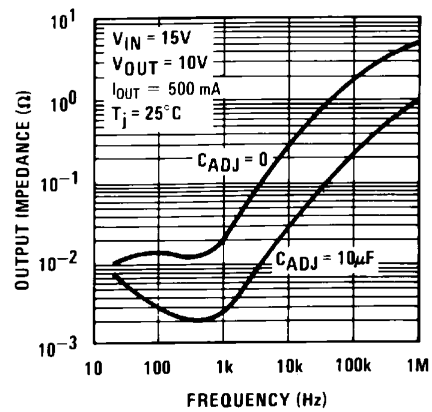
Output Impedance



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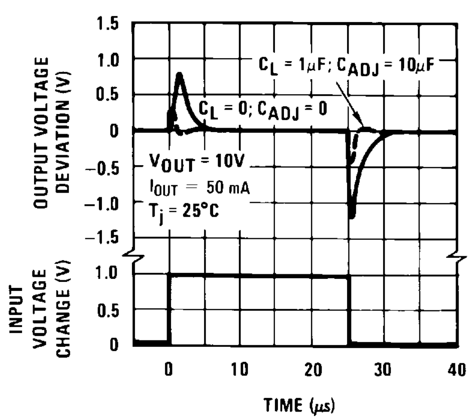
Line Transient Response



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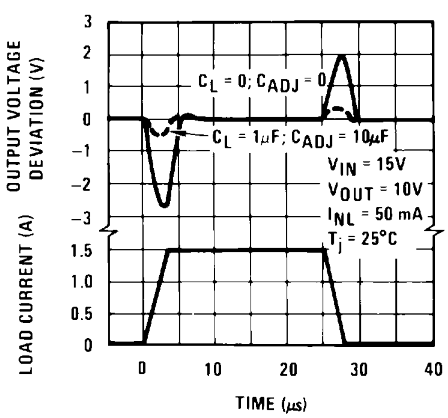
Load Transient Response



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Application Hints

In operation, the LM117 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

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

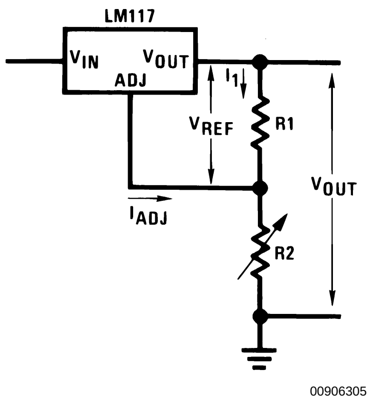


FIGURE 1.

Since the 100 µA current from the adjustment terminal represents an error term, the LM117 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 LM117 to improve ripple rejection. This bypass capacitor prevents ripple from being amplified as the output voltage is increased. With a 10 µF bypass capacitor 80 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 LM117 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. Any increase of the load capacitance larger than 10 µF will merely improve the loop stability and output impedance.

Load Regulation

The LM117 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 x 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.

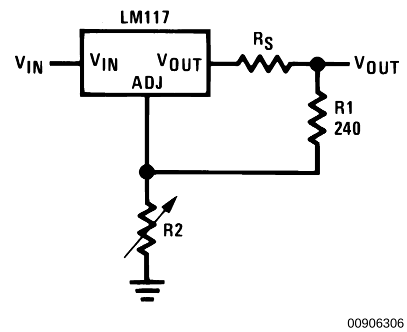


FIGURE 2. Regulator with Line Resistance in Output Lead

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. However, with the TO-39 package, care should be taken to minimize the wire length of the output lead. The ground of R2 can be returned near the ground of the load to provide remote ground sensing and improve load regulation.

Protection Diodes

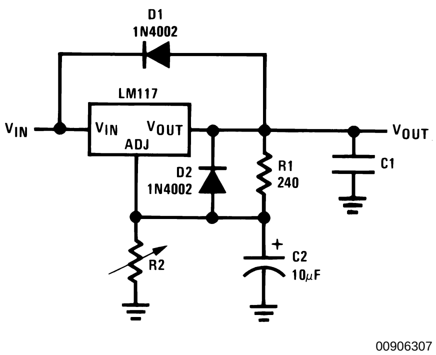
When external capacitors are used with *any* IC regulator it is sometimes necessary to add protection diodes to prevent the capacitors from discharging through low current points into the regulator. Most 10 µF capacitors have low enough internal series resistance to deliver 20A spikes when shorted. Although 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 LM117, this discharge path is through a large junction that is able to sustain 15A 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

Application Hints (Continued)

when *either* the input or output is shorted. Internal to the LM117 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 LM117 with protection diodes included for use with outputs greater than 25V and high values of output capacitance.



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

D1 protects against C1

D2 protects against C2

FIGURE 3. Regulator with Protection Diodes

When a value for $\theta_{(H-A)}$ is found using the equation shown, *a heatsink must be selected that has a value that is less than or equal to this number.*

$\theta_{(H-A)}$ is specified numerically by the heatsink manufacturer in the catalog, or shown in a curve that plots temperature rise vs power dissipation for the heatsink.

HEATSINKING TO-263, SOT-223 AND TO-252 PACKAGE PARTS

The TO-263 (“S”), SOT-223 (“MP”) and TO-252 (”DT”) packages use a copper plane on the PCB and the PCB itself as a heatsink. To optimize the heat sinking ability of the plane and PCB, solder the tab of the package to the plane.

Figure 4 shows for the TO-263 the measured values of $\theta_{(J-A)}$ for different copper area sizes using a typical PCB with 1 ounce copper *and no solder mask over the copper area used for heatsinking.*

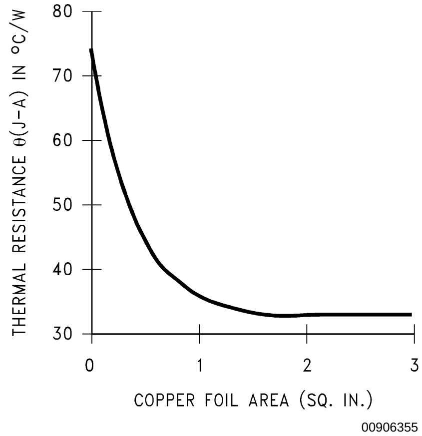


FIGURE 4. $\theta_{(J-A)}$ vs Copper (1 ounce) Area for the TO-263 Package

As shown in the figure, increasing the copper area beyond 1 square inch produces very little improvement. It should also be observed that the minimum value of $\theta_{(J-A)}$ for the TO-263 package mounted to a PCB is 32˚C/W.

As a design aid, *Figure 5* shows the maximum allowable power dissipation compared to ambient temperature for the TO-263 device (assuming $\theta_{(J-A)}$ is 35˚C/W and the maximum junction temperature is 125˚C).

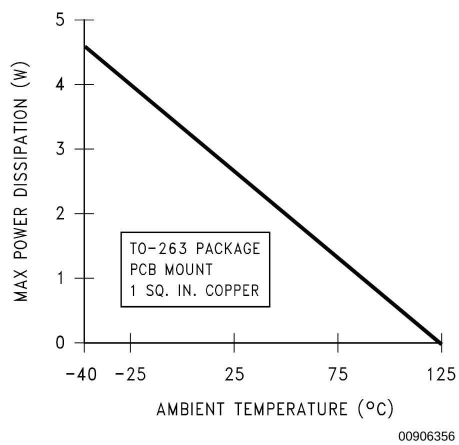


FIGURE 5. Maximum Power Dissipation vs T_{AMB} for the TO-263 Package

Figure 6 and *Figure 7* show the information for the SOT-223 package. *Figure 7* assumes a $\theta_{(J-A)}$ of 74˚C/W for 1 ounce copper and 51˚C/W for 2 ounce copper and a maximum junction temperature of 125˚C.

Application Hints (Continued)

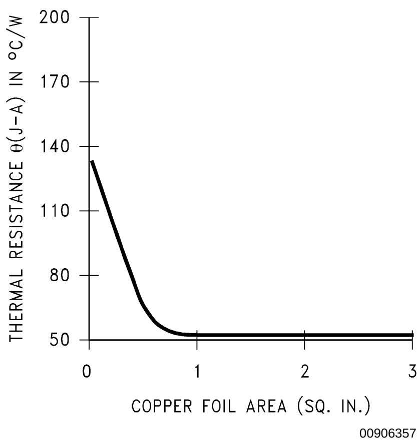


FIGURE 6. $\theta_{(J-A)}$ vs Copper (2 ounce) Area for the SOT-223 Package

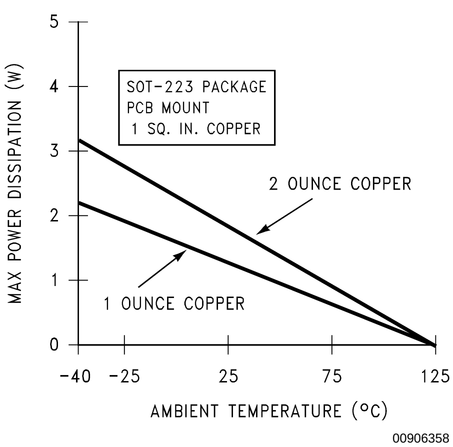


FIGURE 7. Maximum Power Dissipation vs T_{AMB} for the SOT-223 Package

The LM317 regulators have internal thermal shutdown to protect the device from over-heating. Under all possible operating conditions, the junction temperature of the LM317 must be within the range of 0˚C to 125˚C. A heatsink may be required depending on the maximum power dissipation and maximum ambient temperature of the application. To determine if a heatsink is needed, the power dissipated by the regulator, P_D, must be calculated:

$I_{IN} = I_L + I_G$

$P_D = (V_{IN} - V_{OUT}) I_L + V_{IN} I_G$

Figure 8 shows the voltage and currents which are present in the circuit.

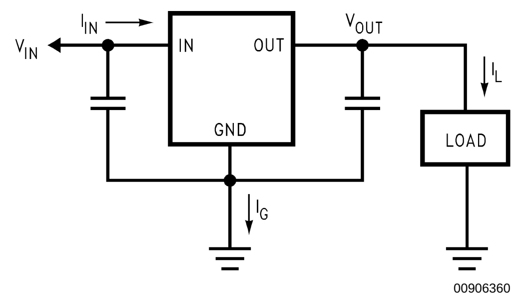


FIGURE 8. Power Dissipation Diagram

The next parameter which must be calculated is the maximum allowable temperature rise, T_R(max):

$T_R(\text{max}) = T_J(\text{max}) - T_A(\text{max})$

where T_J(max) is the maximum allowable junction temperature (125˚C), and T_A(max) is the maximum ambient temperature which will be encountered in the application.

Using the calculated values for T_R(max) and P_D, the maximum allowable value for the junction-to-ambient thermal resistance (θ_{JA}) can be calculated:

$\theta_{JA} = T_R(\text{max})/P_D$

If the maximum allowable value for θ_{JA} is found to be ≥92˚C/W (Typical Rated Value) for TO-252 package, no heatsink is needed since the package alone will dissipate enough heat to satisfy these requirements. If the calculated value for θ_{JA} falls below these limits, a heatsink is required.

As a design aid, *Table 1* shows the value of the θ_{JA} of TO-252 for different heatsink area. The copper patterns that we used to measure these θ_{JA}s are shown at the end of the Application Notes Section. *Figure 9* reflects the same test results as what are in the *Table 1*

Figure 10 shows the maximum allowable power dissipation vs. ambient temperature for the TO-252 device. *Figure 11* shows the maximum allowable power dissipation vs. copper area (in^2) for the TO-252 device. Please see AN1028 for power enhancement techniques to be used with SOT-223 and TO-252 packages.

TABLE 1. θ_{JA} Different Heatsink Area

Layout	Copper Area		Thermal Resistance
	Top Side (in^2)*	Bottom Side (in^2)	(θ_{JA}˚C/W) TO-252
1	0.0123	0	103
2	0.066	0	87
3	0.3	0	60
4	0.53	0	54
5	0.76	0	52
6	1	0	47
7	0	0.2	84
8	0	0.4	70
9	0	0.6	63

Application Hints (Continued)

TABLE 1. θ_{JA} Different Heatsink Area (Continued)

Layout	Copper Area		Thermal Resistance
10	0	0.8	57
11	0	1	57
12	0.066	0.066	89
13	0.175	0.175	72
14	0.284	0.284	61
15	0.392	0.392	55
16	0.5	0.5	53

Note: * Tab of device attached to topside of copper.

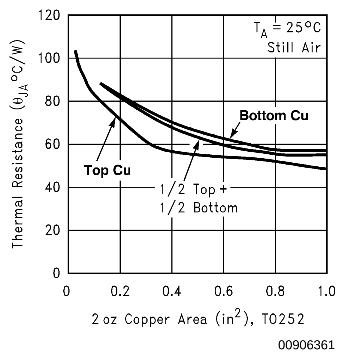


FIGURE 9. θ_{JA} vs 2oz Copper Area for TO-252

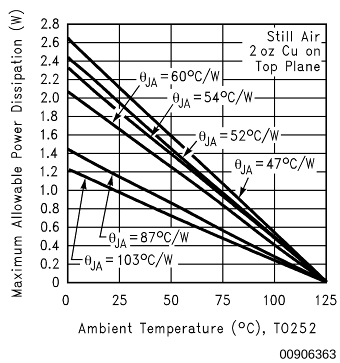


FIGURE 10. Maximum Allowable Power Dissipation vs. Ambient Temperature for TO-252

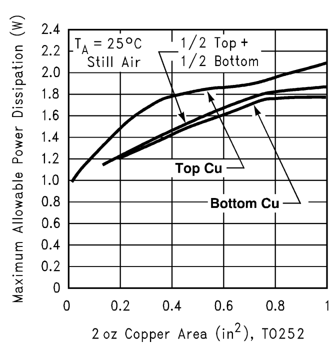


FIGURE 11. Maximum Allowable Power Dissipation vs. 2oz Copper Area for TO-252

Application Hints (Continued)

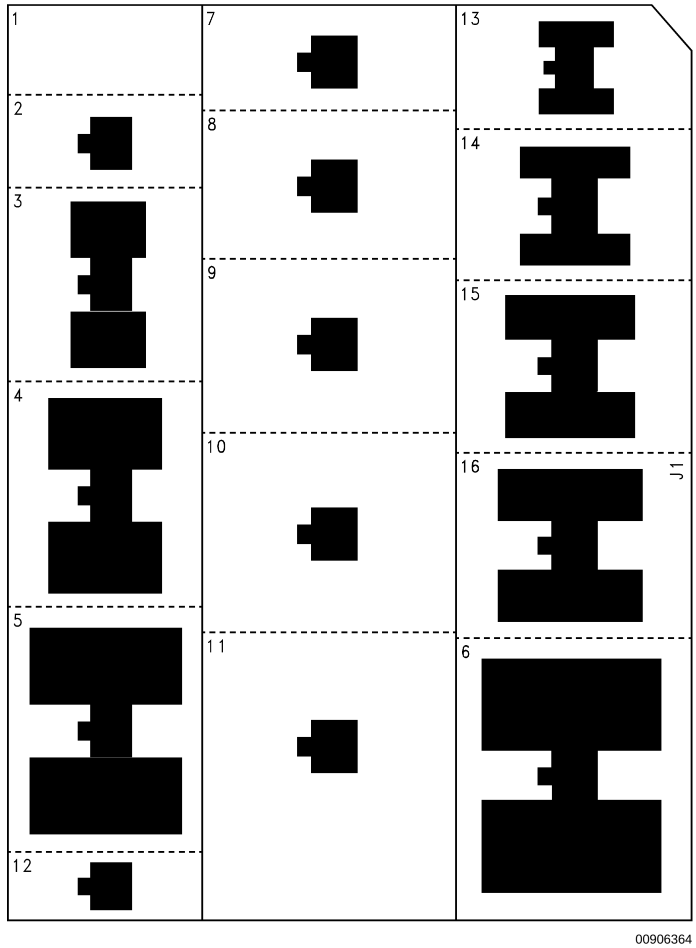


FIGURE 12. Top View of the Thermal Test Pattern in Actual Scale

Application Hints (Continued)

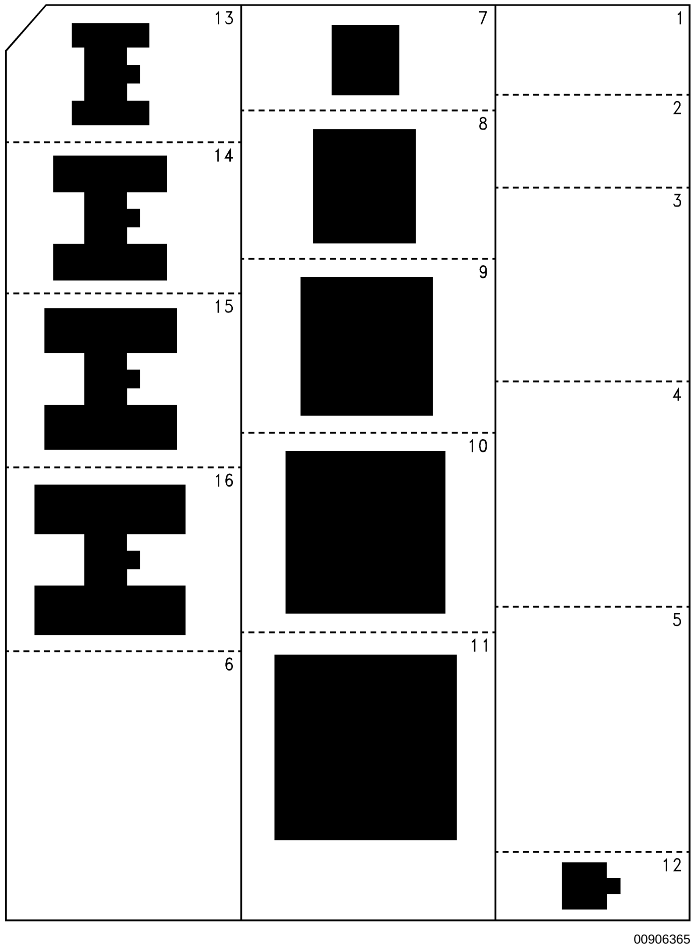
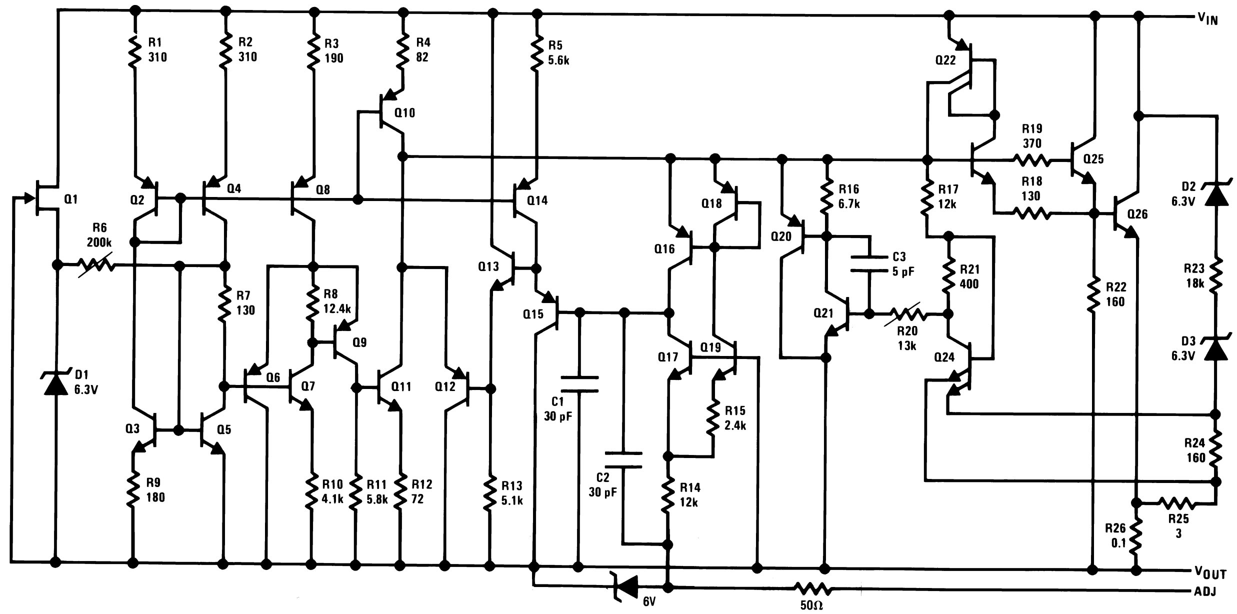


FIGURE 13. Bottom View of the Thermal Test Pattern in Actual Scale

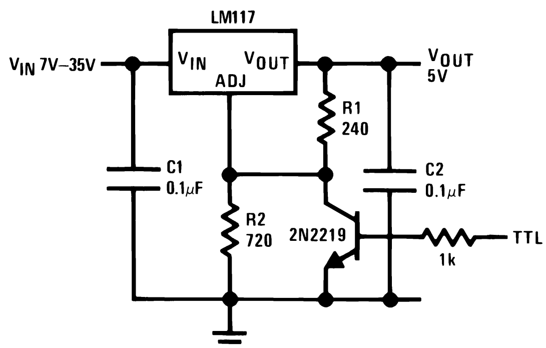
Schematic Diagram



00906308

Typical Applications

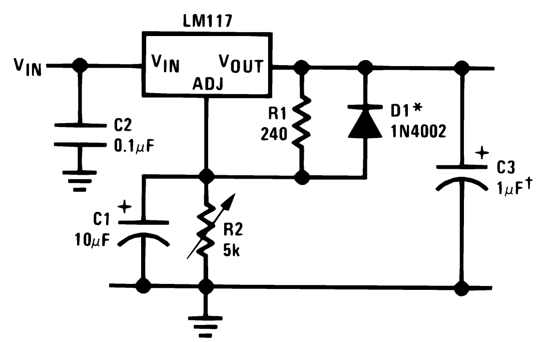
5V Logic Regulator with Electronic Shutdown*



00906303

*Min. output ≅ 1.2V

Adjustable Regulator with Improved Ripple Rejection

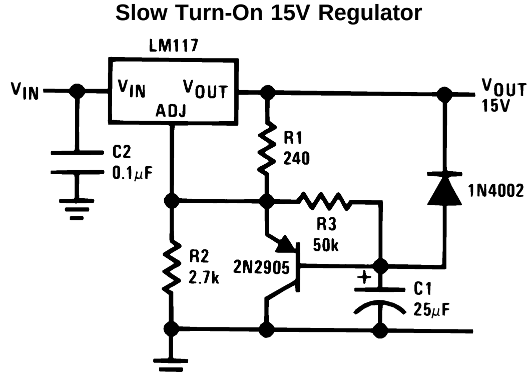


00906310

†Solid tantalum

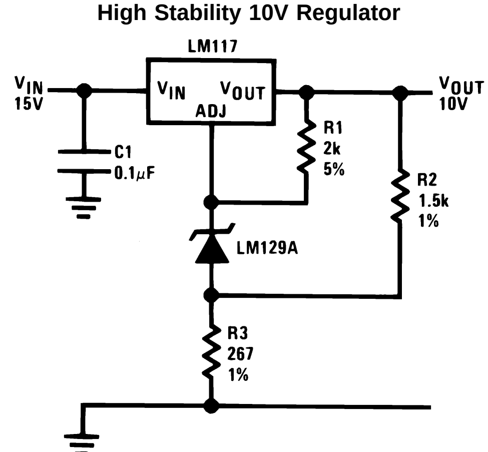
*Discharges C1 if output is shorted to ground

Slow Turn-On 15V Regulator



00906309

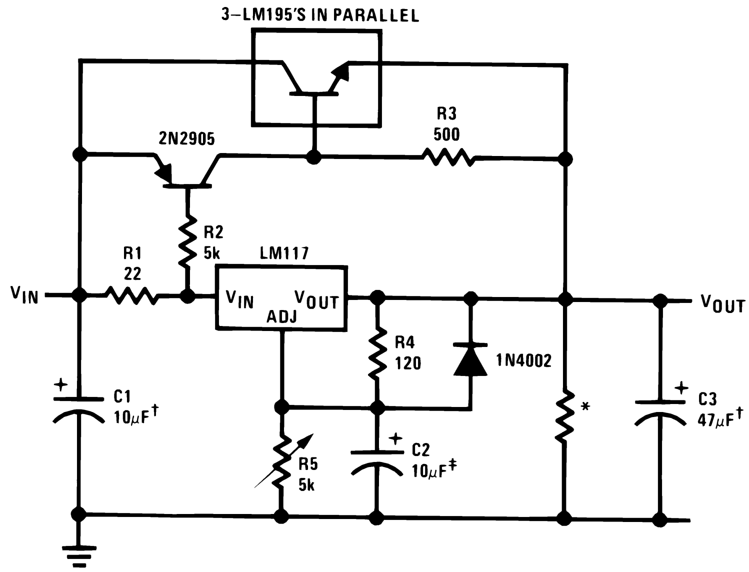
High Stability 10V Regulator



00906311

Typical Applications (Continued)

High Current Adjustable Regulator



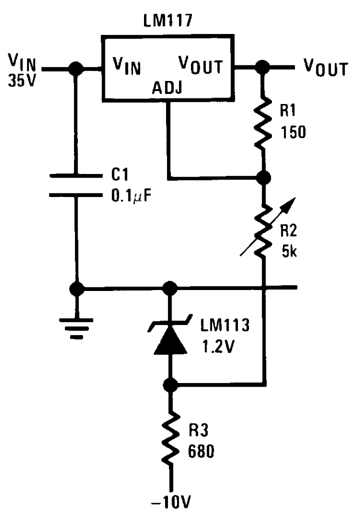
00906312

‡Optional — improves ripple rejection

†Solid tantalum

*Minimum load current = 30 mA

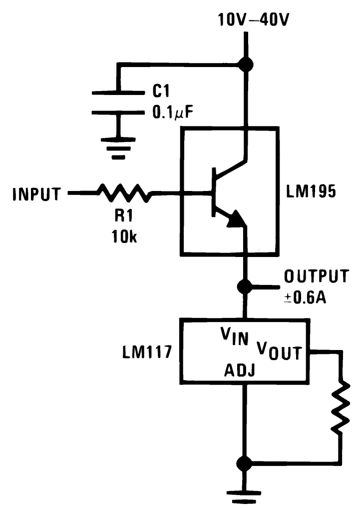
0 to 30V Regulator



00906313

Full output current not available at high input-output voltages

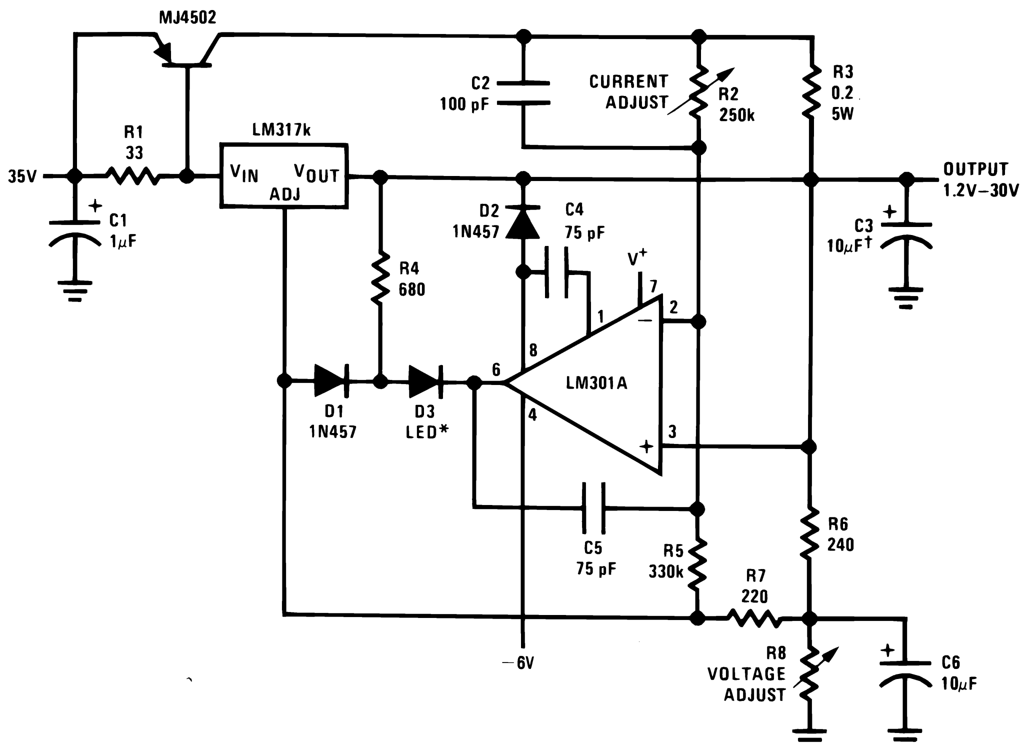
Power Follower



00906314

Typical Applications (Continued)

5A Constant Voltage/Constant Current Regulator

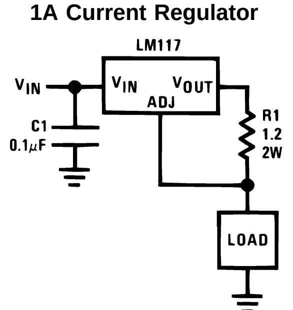


00906315

†Solid tantalum

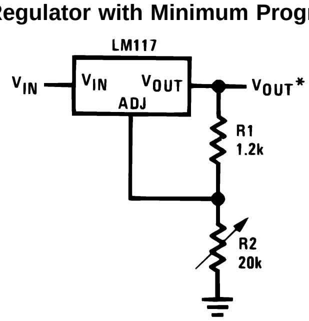
*Lights in constant current mode

1A Current Regulator



00906316

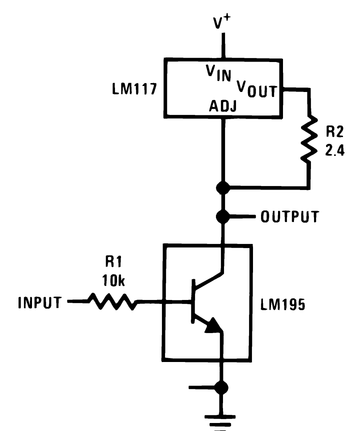
1.2V−20V Regulator with Minimum Program Current



00906317

*Minimum load current ≈ 4 mA

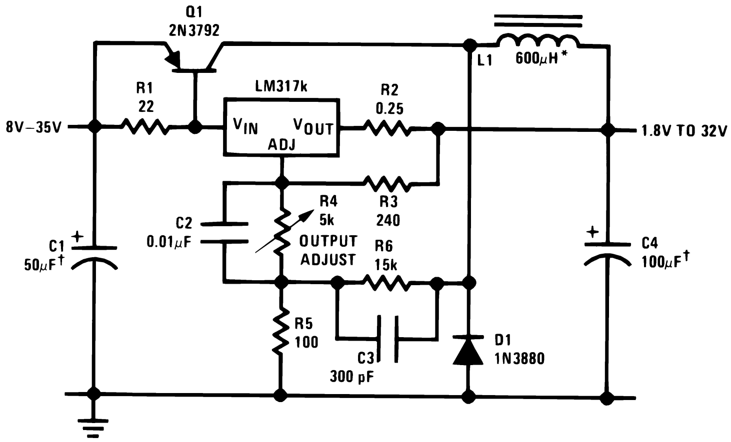
High Gain Amplifier



00906318

Typical Applications (Continued)

Low Cost 3A Switching Regulator

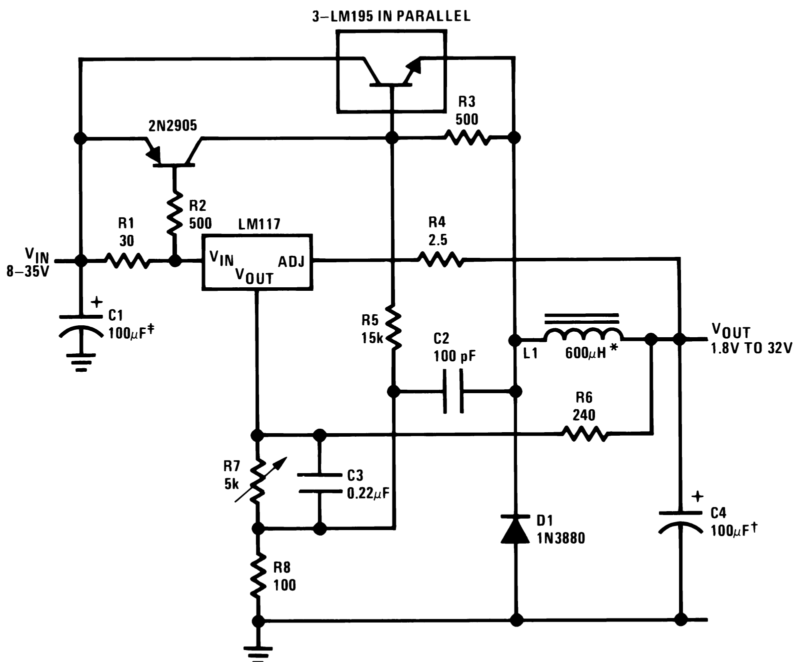


00906319

†Solid tantalum

*Core — Arnold A-254168-2 60 turns

4A Switching Regulator with Overload Protection

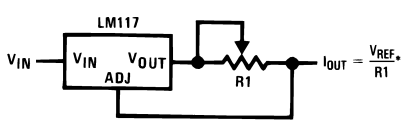


00906320

†Solid tantalum

*Core — Arnold A-254168-2 60 turns

Precision Current Limiter

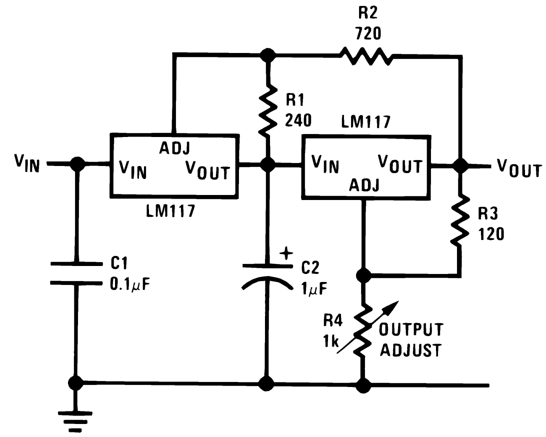


$^*0.8\Omega \leq R1 \leq 120\Omega$

00906321

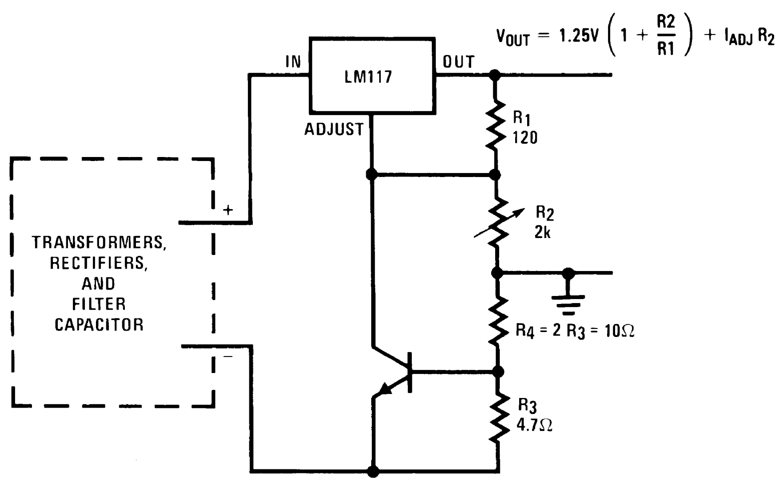
Typical Applications (Continued)

Tracking Preregulator



00906322

Current Limited Voltage Regulator



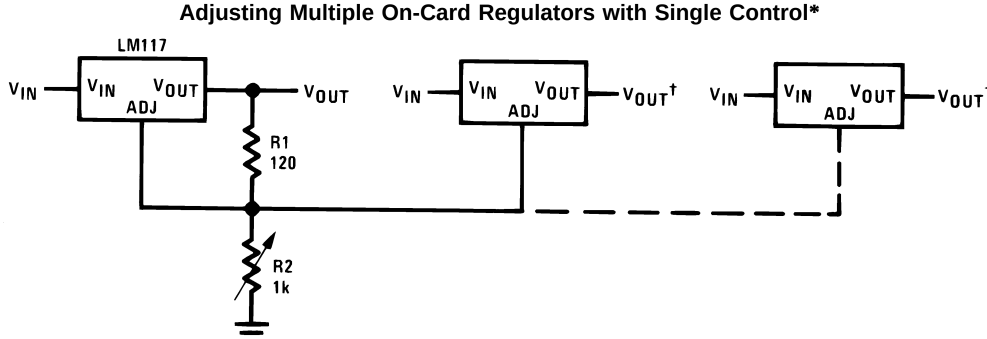
00906323

– Short circuit current is approximately $\frac{600\text{ mV}}{R3}$, or 120 mA

(Compared to LM117's higher current limit)

— At 50 mA output only ¾ volt of drop occurs in R_3 and R_4

Adjusting Multiple On-Card Regulators with Single Control*



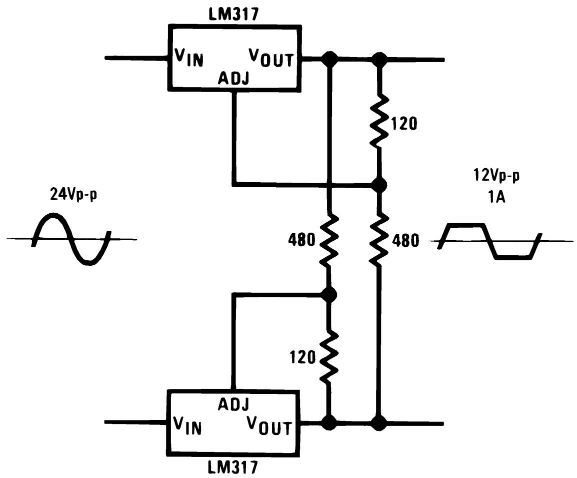
00906324

*All outputs within ±100 mV

†Minimum load — 10 mA

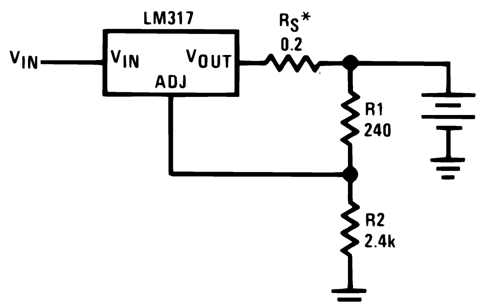
Typical Applications (Continued)

AC Voltage Regulator



00906325

12V Battery Charger

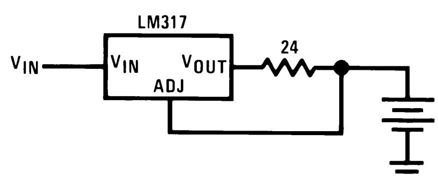


00906326

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

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

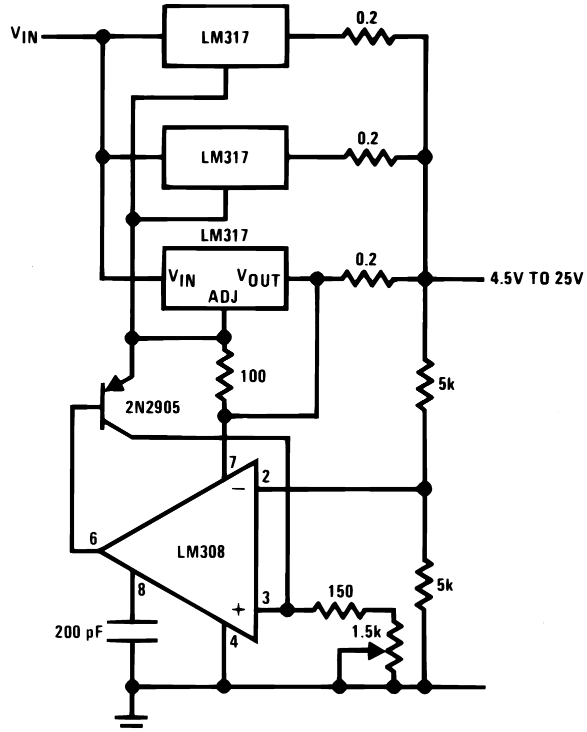
50 mA Constant Current Battery Charger



00906327

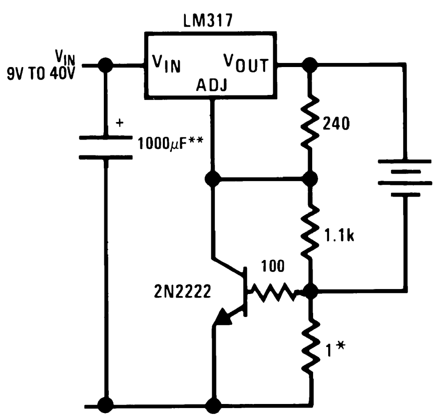
Typical Applications (Continued)

Adjustable 4A Regulator



00906328

Current Limited 6V Charger

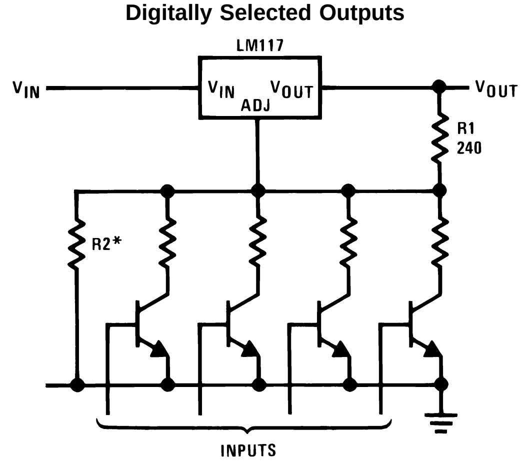


00906329

*Sets peak current (0.6A for 1Ω)

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

Digitally Selected Outputs

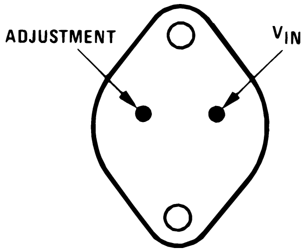


00906302

*Sets maximum V_{OUT}

Connection Diagrams

(TO-3)
Metal Can Package

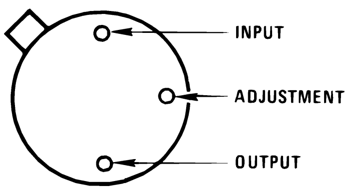


00906330

Bottom View
Steel Package
Order Number LM117K STEEL
or LM317K STEEL
See NS Package Number K02A
Order Number LM117K/883
See NS Package Number K02C

CASE IS OUTPUT

(TO-39)
Metal Can Package

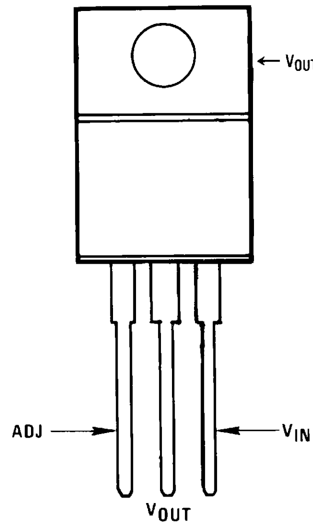


00906331

Bottom View
Order Number LM117H, LM117H/883,
LM317AH or LM317H
See NS Package Number H03A

CASE IS OUTPUT

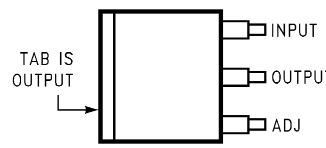
(TO-220)
Plastic Package



00906332

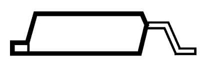
Front View
Order Number LM317AT or LM317T
See NS Package Number T03B

(TO-263) Surface-Mount Package



00906335

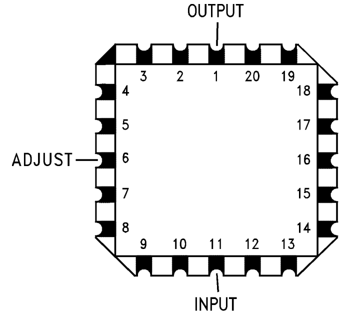
Top View



00906336

Side View
Order Number LM317S
See NS Package Number TS3B

Ceramic Leadless
Chip Carrier

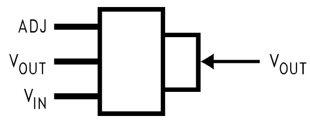


00906334

Top View
Order Number LM117E/883
See NS Package Number E20A

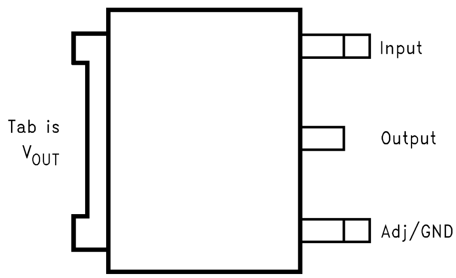
Connection Diagrams (Continued)

4-Lead SOT-223



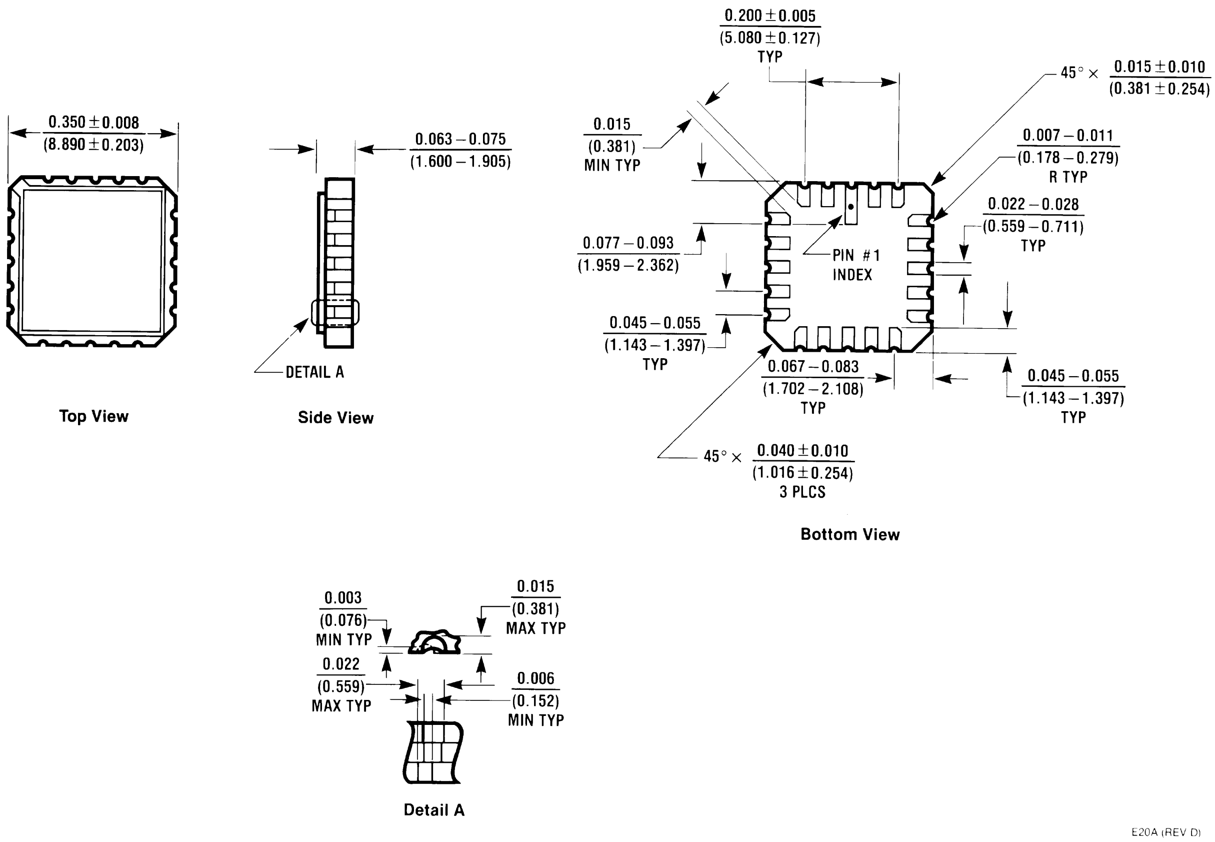
Front View
Order Part Number LM317EMP or LM317AEMP
See NSC Package Number MA04A

TO-252 (D-Pak)



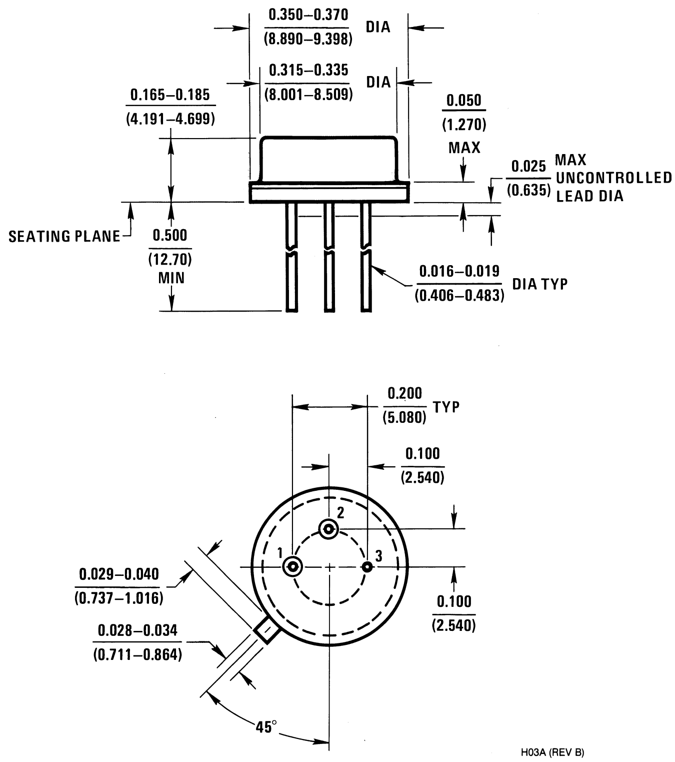
Front View
Order Part Number LM317MDT
See NSC Package Number TD03B

Physical Dimensions inches (millimeters) unless otherwise noted

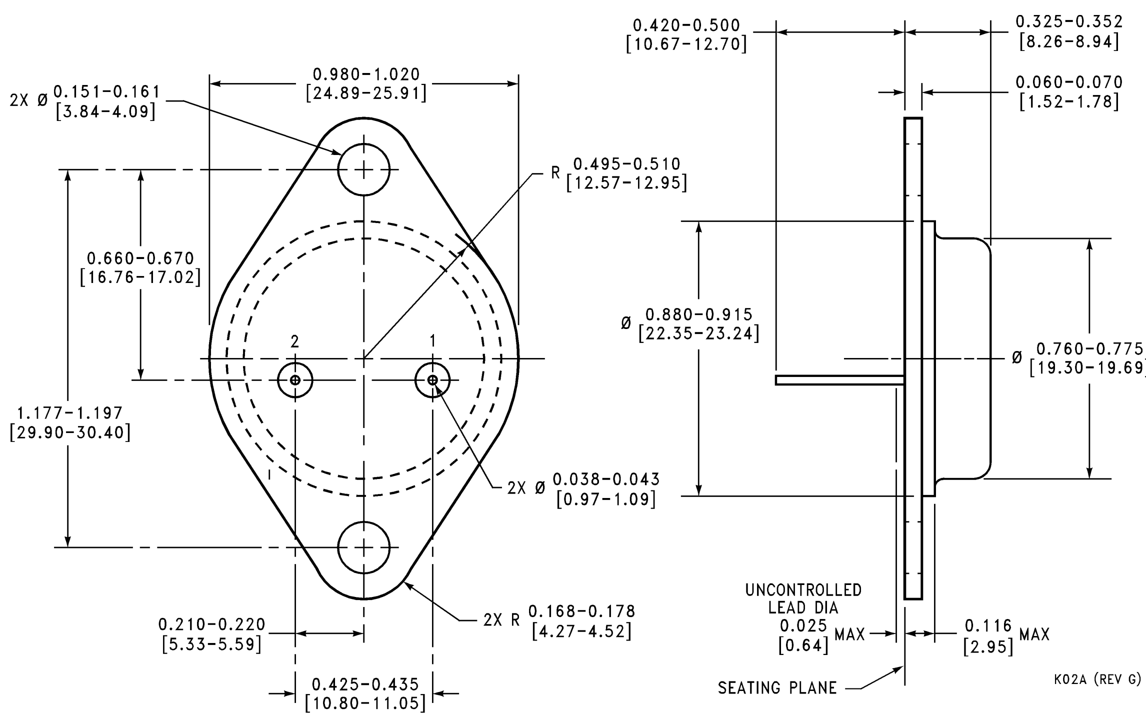


Ceramic Leadless Chip Carrier
Order Number LM117E/883
NS Package Number E20A

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)

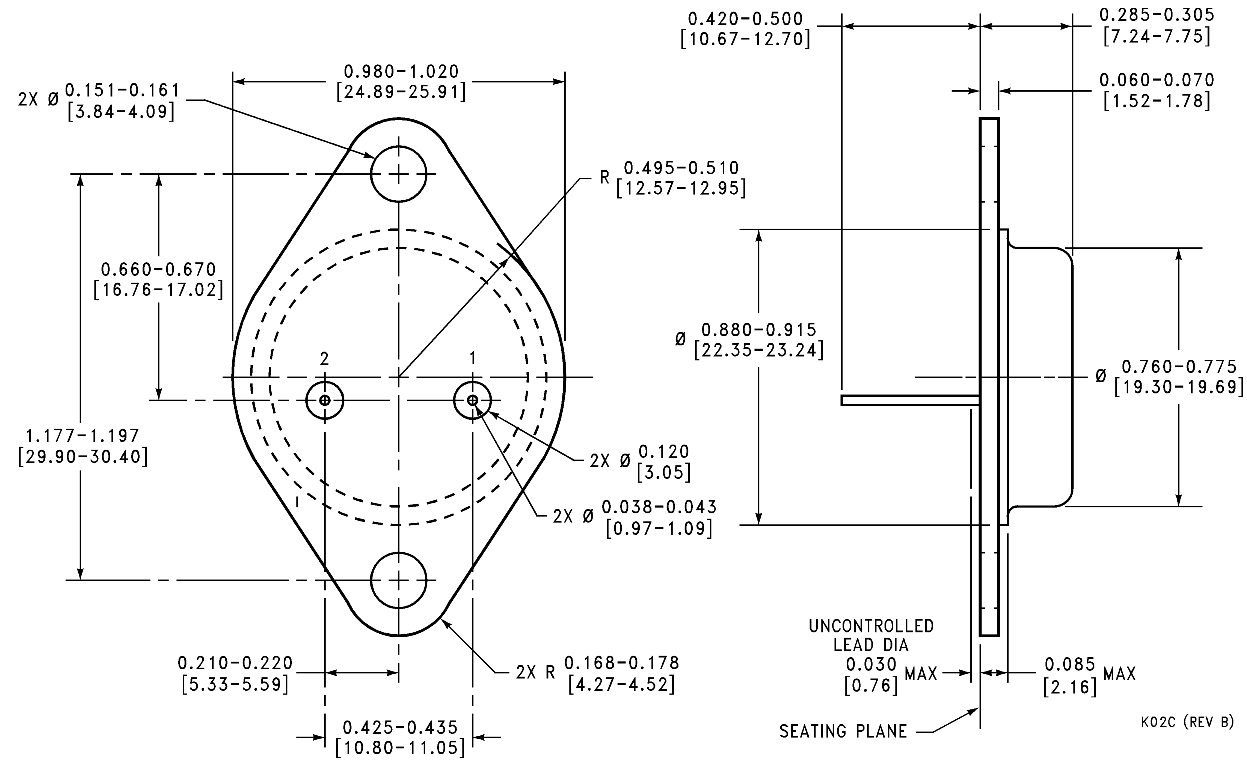


(TO-39) Metal Can Package
Order Number LM117H, LM117H/883, LM317AH or LM317H
NS Package Number H03A



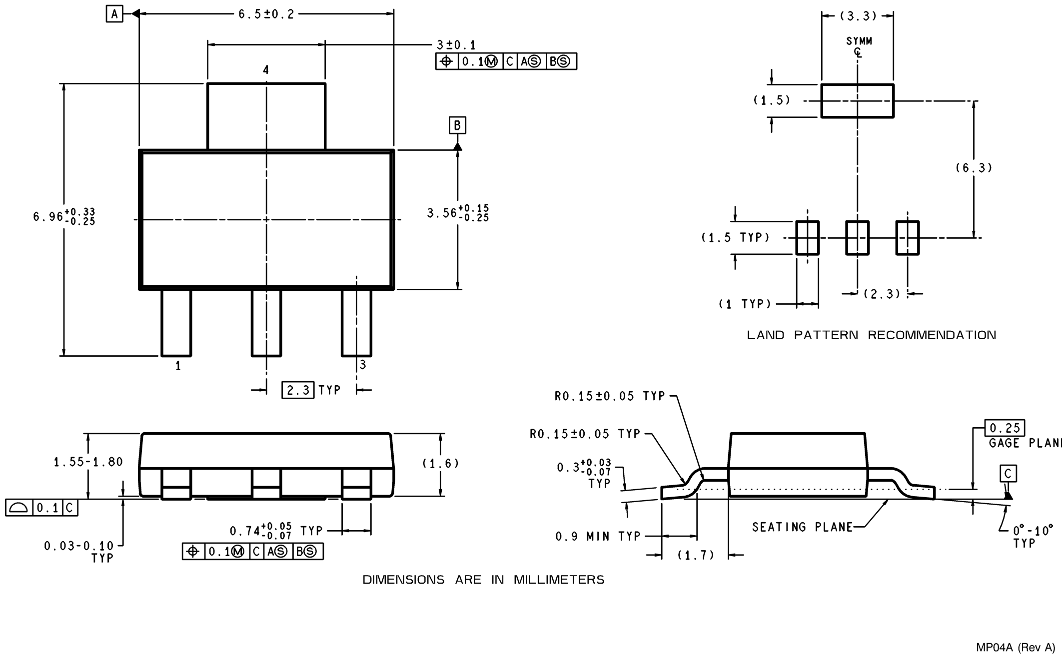
TO-3 Metal Can Package (K)
Order Number LM117K STEEL,
LM117K STEEL/883, or LM317K STEEL
NS Package Number K02A

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)

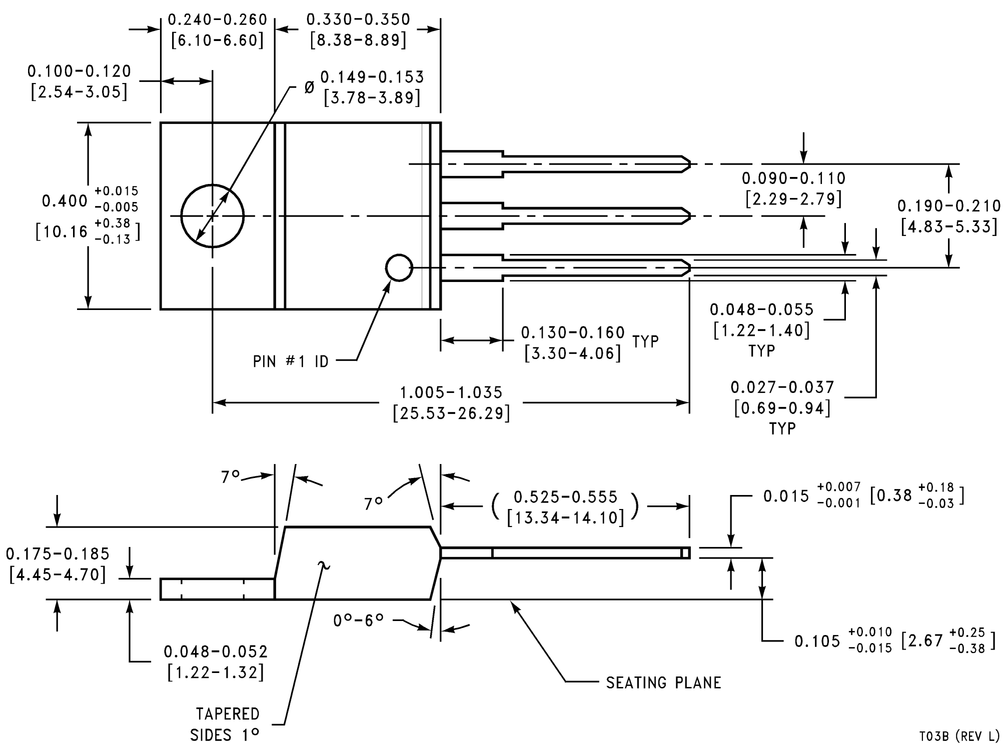


TO-3 Metal Can Package (K)
Mil-Aero Product
Order Number LM117K/883
NS Package Number K02C

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)

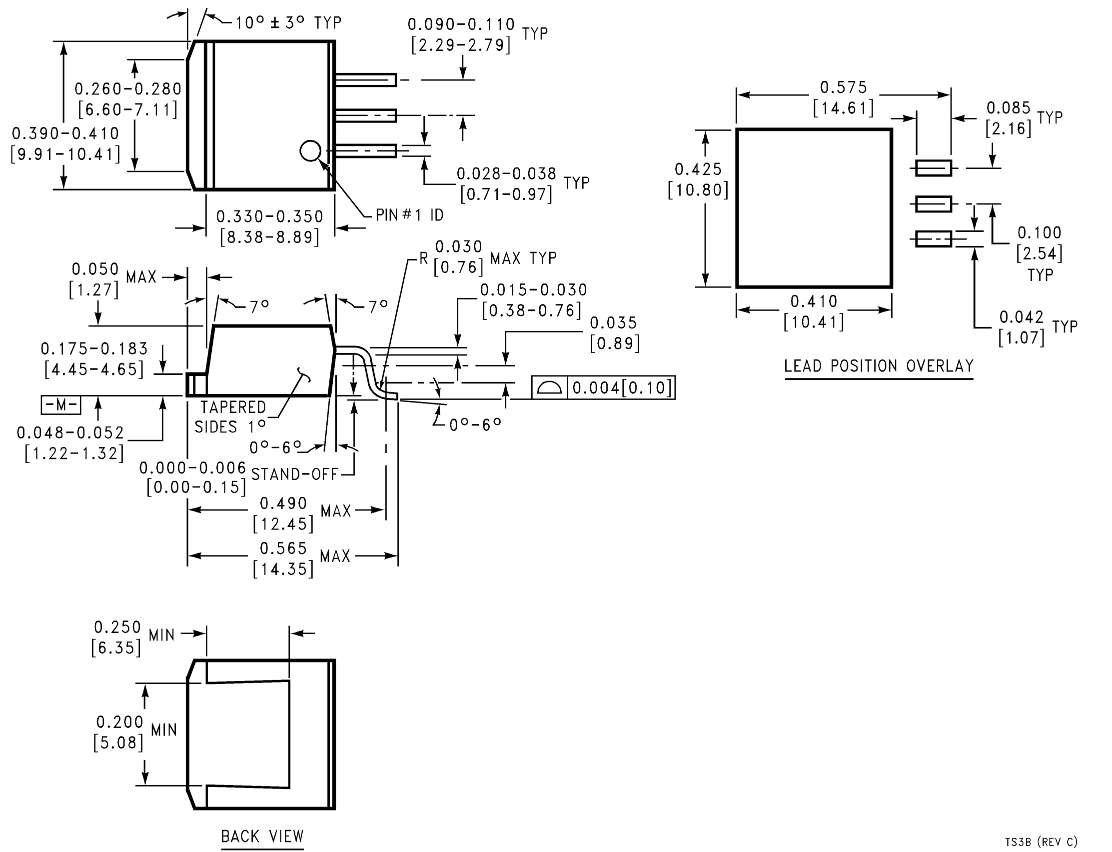


4-Lead SOT-223 Package
Order Number LM317AEMP or LM317EMP
NS Package Number MP04A

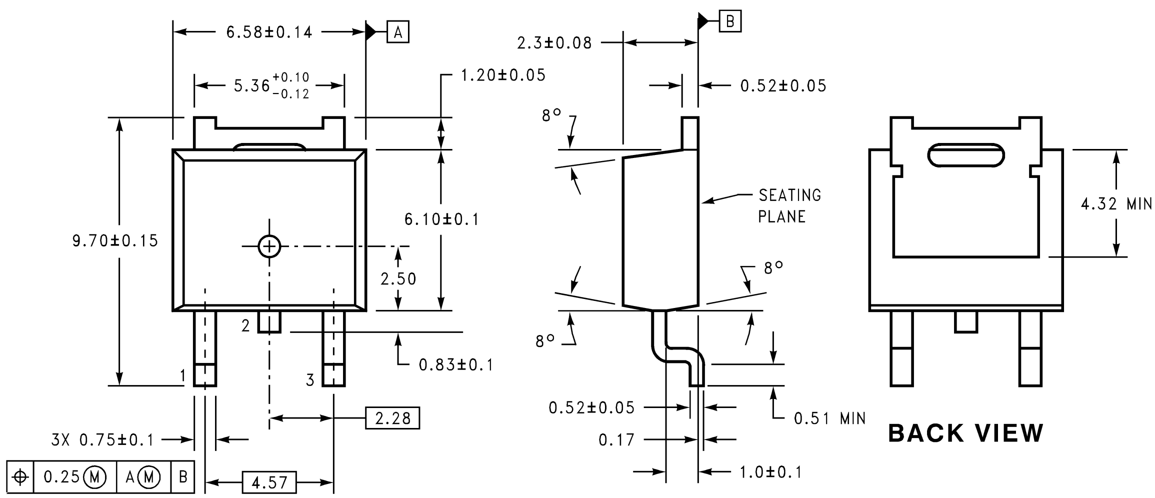


(TO-220) Outline Drawing
Order Number LM317AT or LM317T
NS Package Number T03B

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



Order Number LM317S
NS Package Number TS3B



DIMENSIONS ARE IN MILLIMETERS

TD03B (REV A)

Order Number LM317MDT
NS Package Number TD03B

Notes

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