National Semiconductor

May 1996

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.

LM117 Series Packages and Power Capability

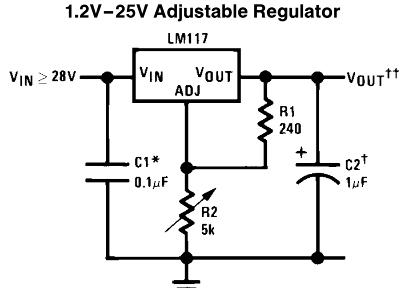
Part Number Suffix	Package	Rated Power Dissipation	Design Load Current
K	TO-3	20W	1.5A
H	TO-39	2W	0.5A
T	TO-220	20W	1.5A
E	LCC	2W	0.5A
S	TO-263	4W	1.5A

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



TL/H/9063–1

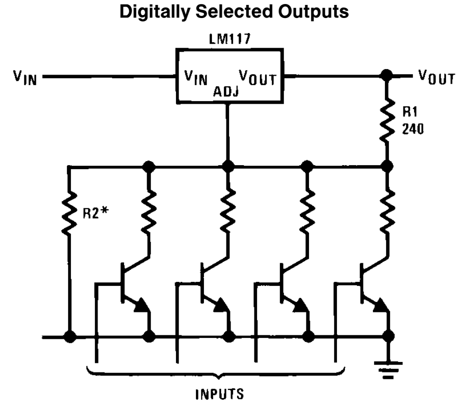
Full output current not available at high input-output voltages

*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.

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

Digitally Selected Outputs



TL/H/9063–2

*Sets maximum V_{OUT}

Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications. (Note 2)

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

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. (Note 3)

Parameter	Conditions	LM117 (Note 2)			Units
		Min	Typ	Max	
Reference Voltage					V
	$3V \leq (V_{IN} - V_{OUT}) \leq 40V$, $10\text{ mA} \leq I_{OUT} \leq I_{MAX}$, $P \leq P_{MAX}$	**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	$10\text{ mA} \leq I_{OUT} \leq I_{MAX}$ (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	$10\text{ mA} \leq I_{OUT} \leq I_{MAX}$ $3V \leq (V_{IN} - V_{OUT}) \leq 40V$		**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, K Packages	 **1.5** **0.5**	 **2.2** **0.8**	 **3.4** **1.8**	 A A
	$(V_{IN} - V_{OUT}) = 40V$ K Package H, K Packages	 0.3 0.15	 0.4 0.2		 A A
RMS Output Noise, % of V_{OUT}	$10\text{ Hz} \leq f \leq 10\text{ kHz}$		0.003		%
Ripple Rejection Ratio	$V_{OUT} = 10V$, $f = 120$ Hz, $C_{ADJ} = 0\ \mu F$		**65**		dB
	$V_{OUT} = 10V$, $f = 120$ Hz, $C_{ADJ} = 10\ \mu F$	**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 (Continued)

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. (Note 3)

Parameter	Conditions	LM317A			LM317			Units
		Min	Typ	Max	Min	Typ	Max	
Reference Voltage		1.238	1.250	1.262				V
	$3V \le (V_{IN} - V_{OUT}) \le 40V$, $10\ mA \le I_{OUT} \le I_{MAX}$, $P \le P_{MAX}$	**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	$10\ mA \le I_{OUT} \le I_{MAX}$ (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	$10\ mA \le I_{OUT} \le I_{MAX}$ $3V \le (V_{IN} - V_{OUT}) \le 40V$		**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 Packages H, P Packages	 **1.5** **0.5**	 **2.2** **0.8**	 **3.4** **1.8**	 **1.5** **0.5**	 **2.2** **0.8**	 **3.4** **1.8**	 A A
	$(V_{IN} - V_{OUT}) = 40V$ K, T Packages H, P Packages	 0.15 0.075	 0.4 0.2		 0.15 0.075	 0.4 0.2		 A A
RMS Output Noise, % of V_{OUT}	$10\ Hz \le f \le 10\ kHz$		0.003			0.003		%
Ripple Rejection Ratio	$V_{OUT} = 10V$, f = 120 Hz, $C_{ADJ} = 0\ \mu F$		**65**			**65**		dB
	$V_{OUT} = 10V$, f = 120 Hz, $C_{ADJ} = 10\ \mu F$	**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 H Package T Package P Package		 12 4 	 15 5 		2.3 12 4 	3 15 	°C/W °C/W °C/W °C/W
Thermal Resistance, Junction-to-Ambient (No Heat Sink)	K Package H Package T Package P Package (Note 6)		35 140 50 			35 140 50 50		°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 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 20W for the TO-3 and TO-220. I_{MAX} is 1.5A for the TO-3 and TO-220 packages and 0.5A for the TO-39 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.

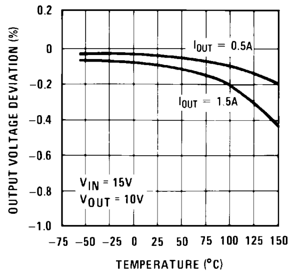
Note 5: Human body model, 100 pF discharged through a 1.5 kΩ resistor.

Note 6: If the TO-263 package is 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.

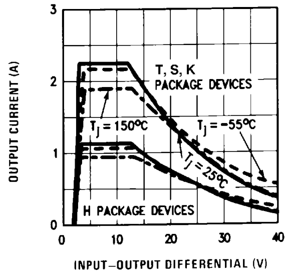
Typical Performance Characteristics

Output Capacitor = 0 μF unless otherwise noted

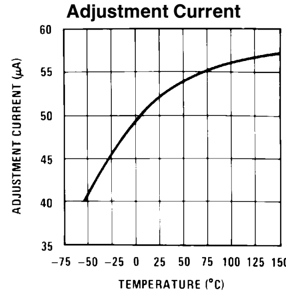
Load Regulation



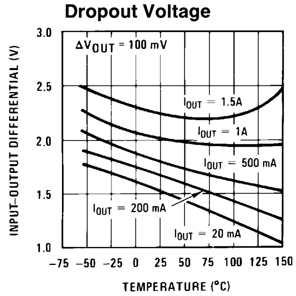
Current Limit



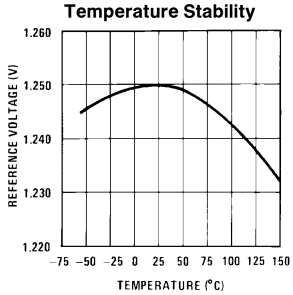
Adjustment Current



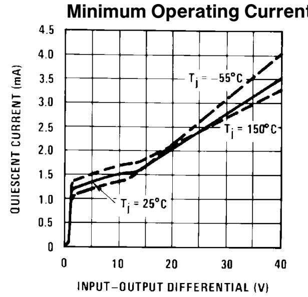
Dropout Voltage



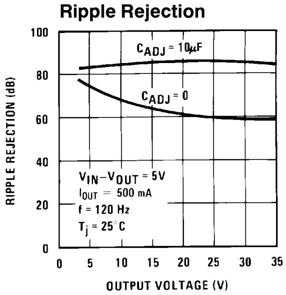
Temperature Stability



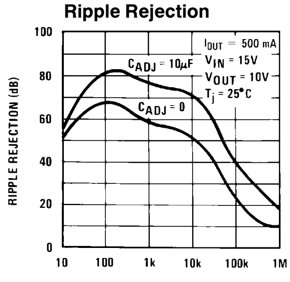
Minimum Operating Current



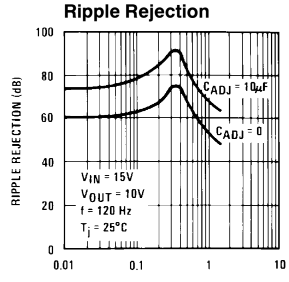
Ripple Rejection



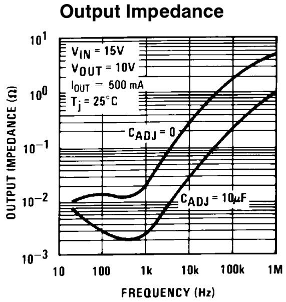
Ripple Rejection



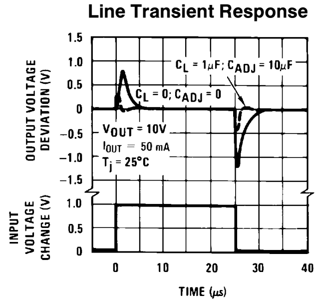
Ripple Rejection



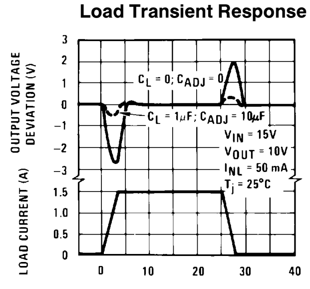
Output Impedance



Line Transient Response



Load Transient Response

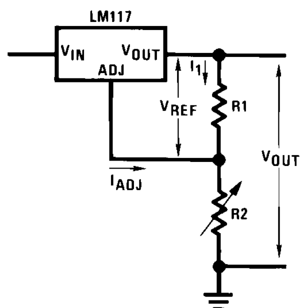


TL/H/9063–4

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

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



TL/H/9063–5

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.

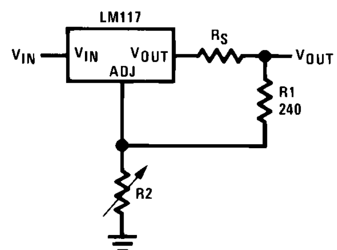
In general, the best type of capacitors to use is solid tantalum. Solid tantalum capacitors have low impedance even at high frequencies. Depending upon capacitor construction, it takes about 25 μF in aluminum electrolytic to equal 1 μF solid tantalum at high frequencies. Ceramic capacitors are also good 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 $\times$ 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.



TL/H/9063–6

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-5 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.

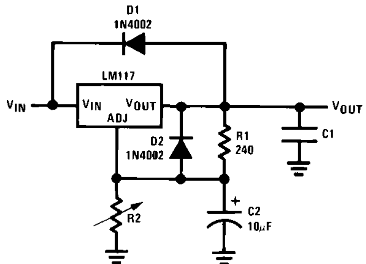
Protection Diodes

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.

Application Hints (Continued)

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 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.



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

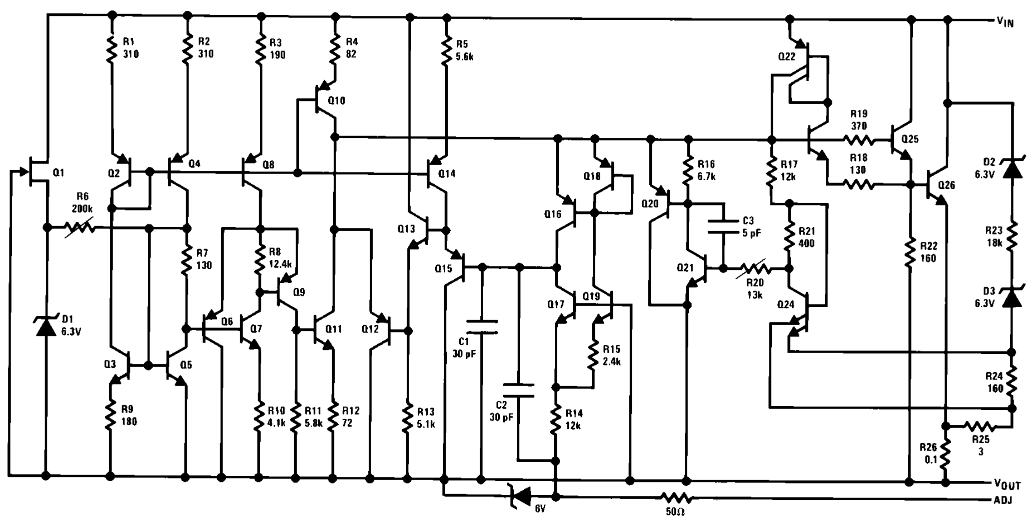
D1 protects against C1

D2 protects against C2

TL/H/9063–7

FIGURE 3. Regulator with Protection Diodes

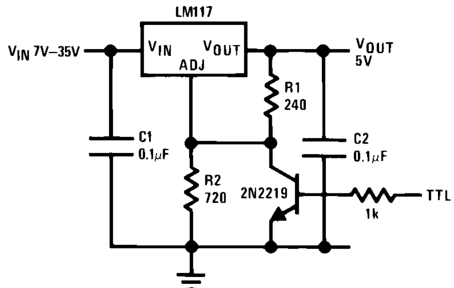
Schematic Diagram



TL/H/9063–8

Typical Applications (Continued)

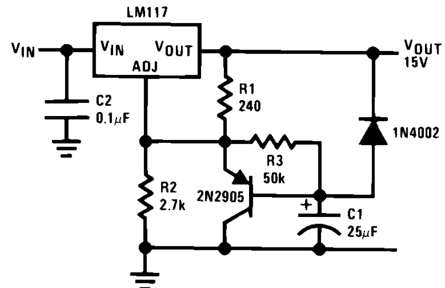
5V Logic Regulator with Electronic Shutdown*



*Min. output ≈ 1.2V

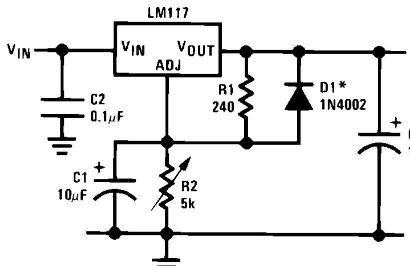
TL/H/9063–3

Slow Turn-On 15V Regulator



TL/H/9063–9

Adjustable Regulator with Improved Ripple Rejection

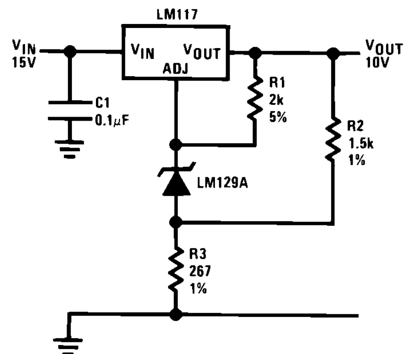


†Solid tantalum

*Discharges C1 if output is shorted to ground

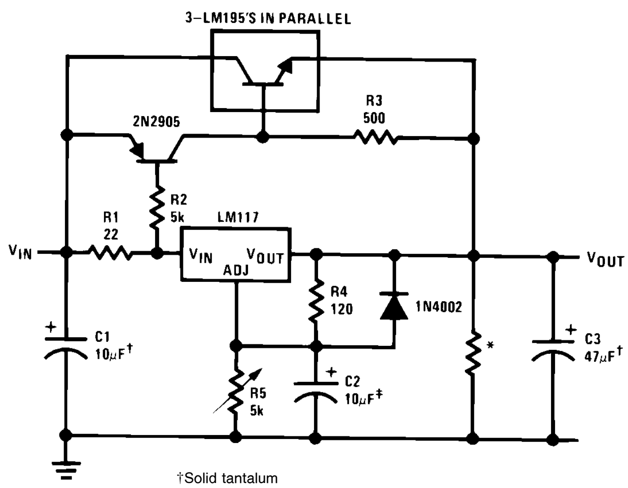
TL/H/9063–10

High Stability 10V Regulator



TL/H/9063–11

High Current Adjustable Regulator



†Solid tantalum

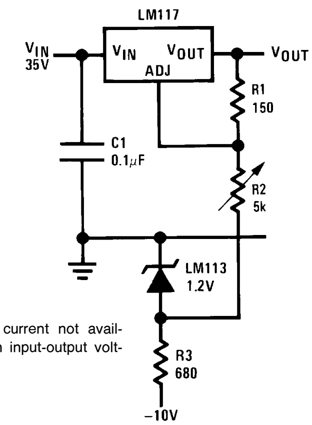
*Minimum load current = 30 mA

‡Optional—improves ripple rejection

TL/H/9063–12

Typical Applications (Continued)

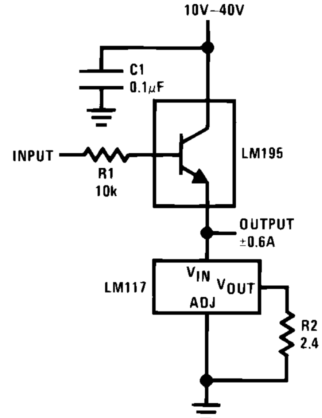
0 to 30V Regulator



Full output current not available at high input-output voltages

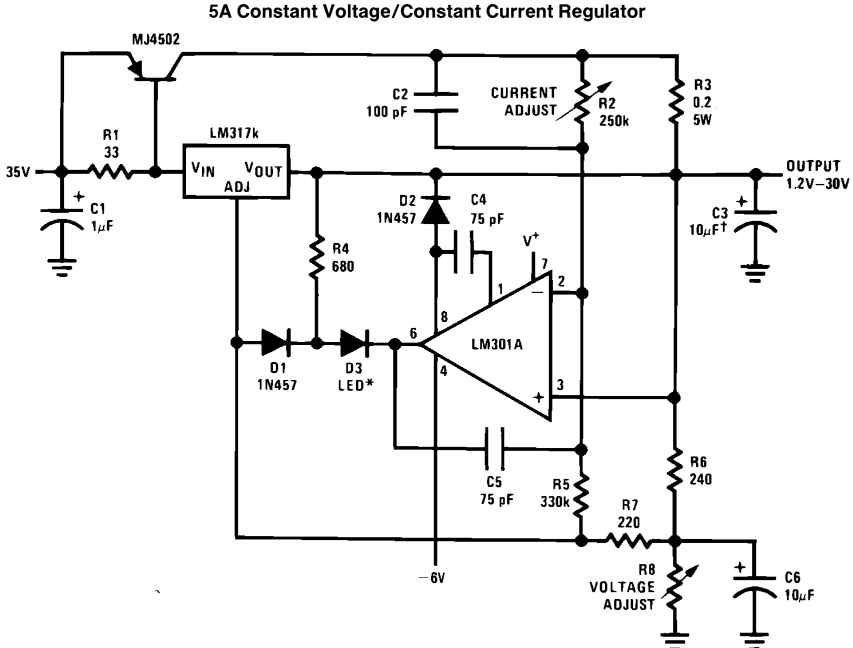
TL/H/9063–13

Power Follower



TL/H/9063–14

5A Constant Voltage/Constant Current Regulator



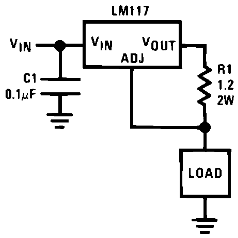
†Solid tantalum

*Lights in constant current mode

TL/H/9063–15

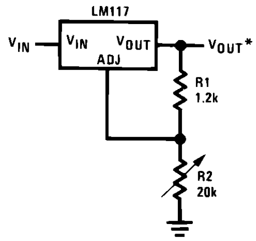
Typical Applications (Continued)

1A Current Regulator



TL/H/9063–16

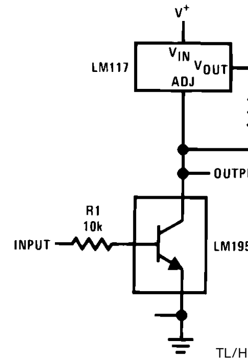
1.2V–20V Regulator with Minimum Program Current



TL/H/9063–17

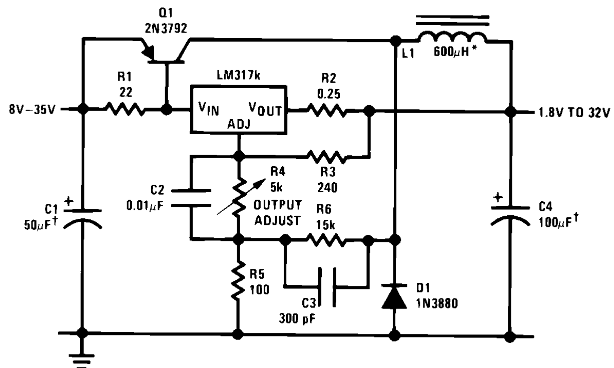
*Minimum load current ≈ 4 mA

High Gain Amplifier



TL/H/9063–18

Low Cost 3A Switching Regulator

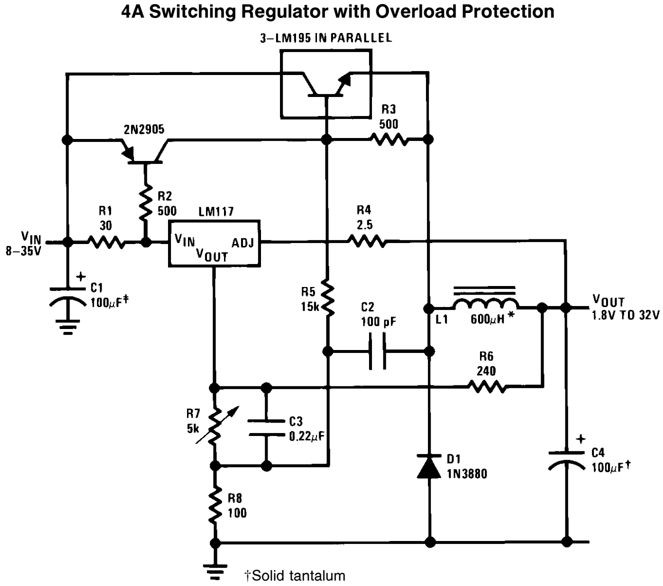


†Solid tantalum

*Core—Arnold A-254168-2 60 turns

TL/H/9063–19

4A Switching Regulator with Overload Protection

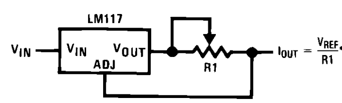


†Solid tantalum

*Core—Arnold A-254168-2 60 turns

TL/H/9063–20

Precision Current Limiter

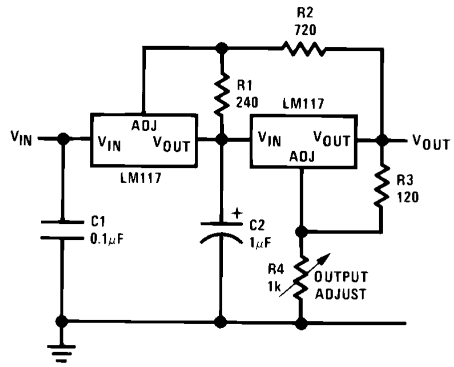


*0.8Ω ≤ R1 ≤ 120Ω

TL/H/9063–21

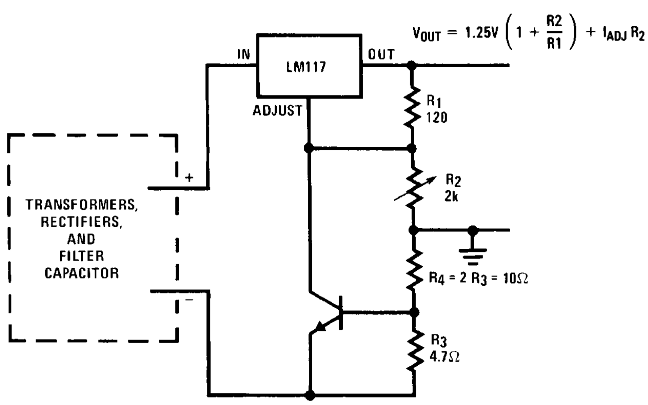
Typical Applications (Continued)

Tracking Preregulator



TL/H/9063–22

Current Limited Voltage Regulator



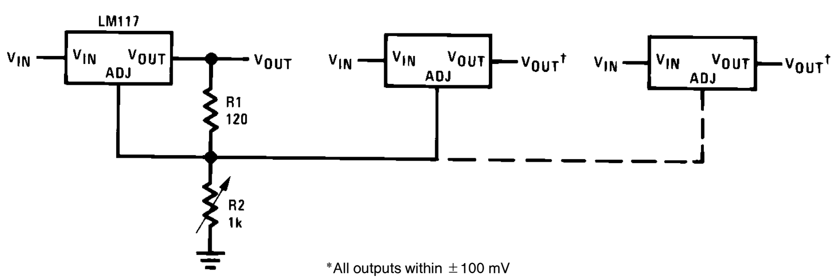
TL/H/9063–23

– 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*



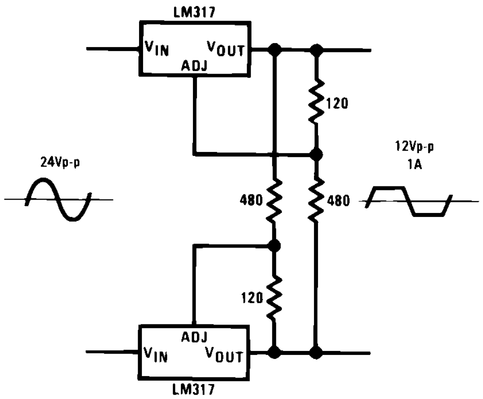
*All outputs within ±100 mV

†Minimum load—10 mA

TL/H/9063–24

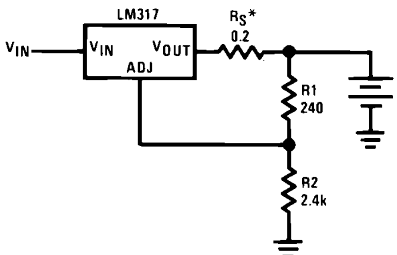
Typical Applications (Continued)

AC Voltage Regulator



TL/H/9063–25

12V Battery Charger

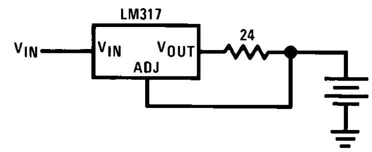


TL/H/9063–26

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

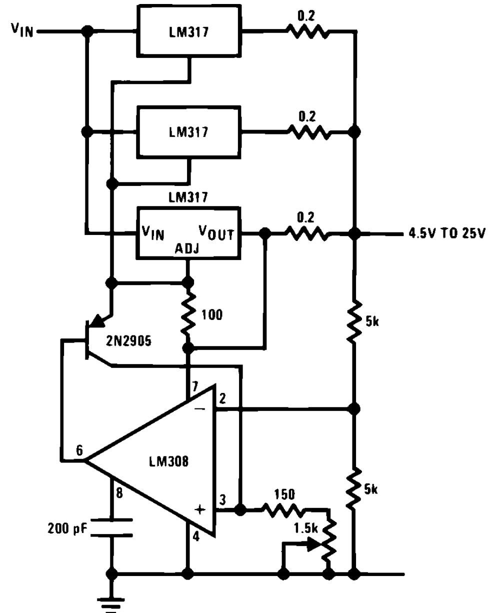
Use of R_S allows low charging rates with fully charged battery.

50 mA Constant Current Battery Charger



TL/H/9063–27

Adjustable 4A Regulator

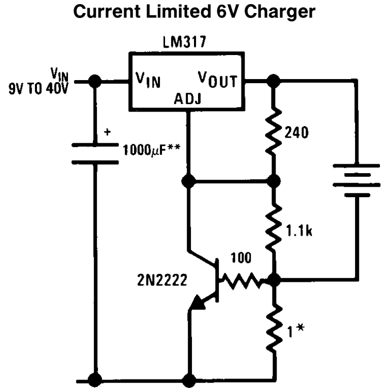


TL/H/9063–28

Current Limited 6V Charger

*Sets peak current (0.6A for 1Ω)

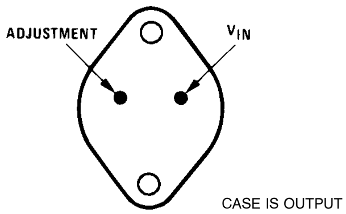
**The 1000 μF is recommended to filter out input transients



TL/H/9063–29

Connection Diagrams

(TO-3)
Metal Can Package

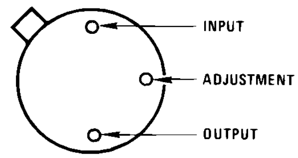


TL/H/9063–30

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

(TO-39)
Metal Can Package

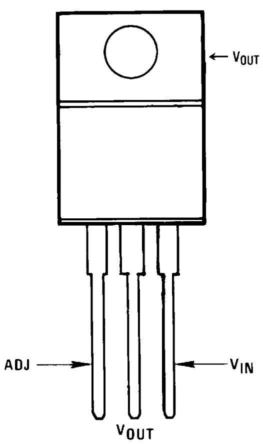


TL/H/9063–31

Bottom View

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

(TO-220)
Plastic Package

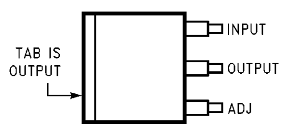


TL/H/9063–32

Front View

Order Number LM317AT or LM317T
See NS Package Number T03B

(TO-263) Surface-Mount Package



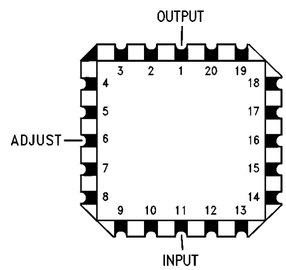
TL/H/9063–35

Top View

TL/H/9063–36

Side View

Order Number LM317S
See NS Package Number TS3B

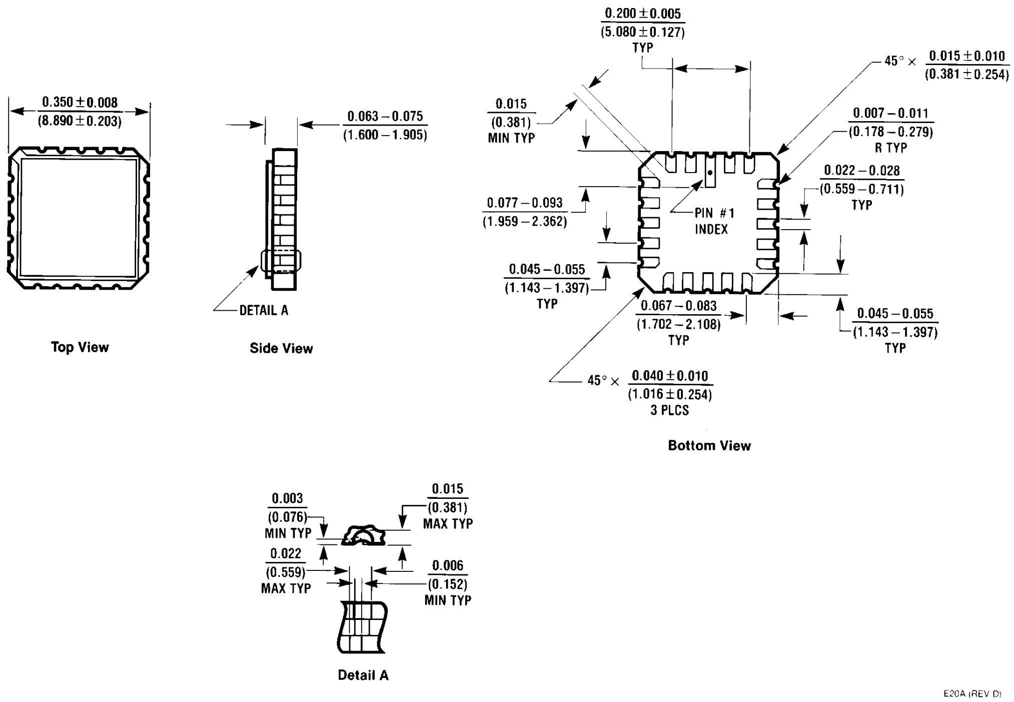


TL/H/9063–34

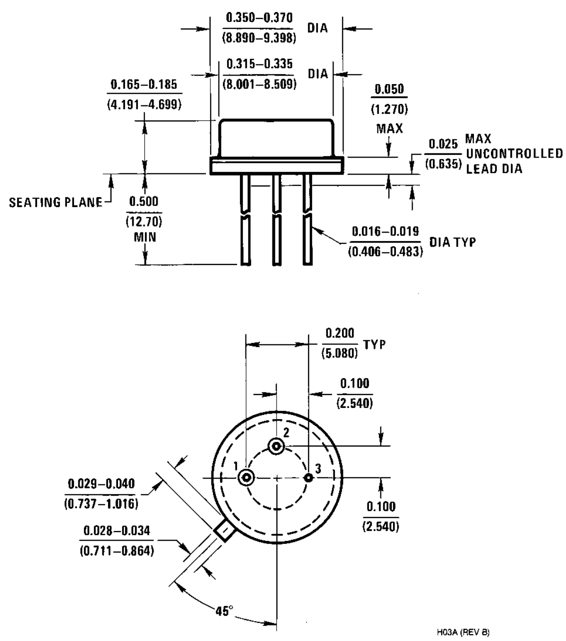
Top View

Order Number LM117E/883
See NS Package Number E20A

Physical Dimensions inches (millimeters) unless otherwise noted

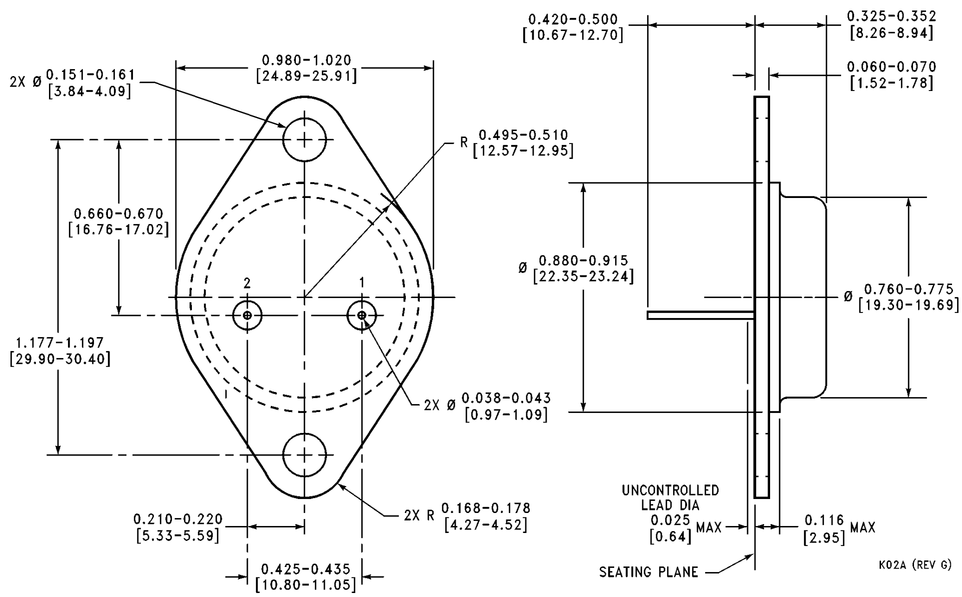


Order Number LM117E/883
NS Package Number E20A

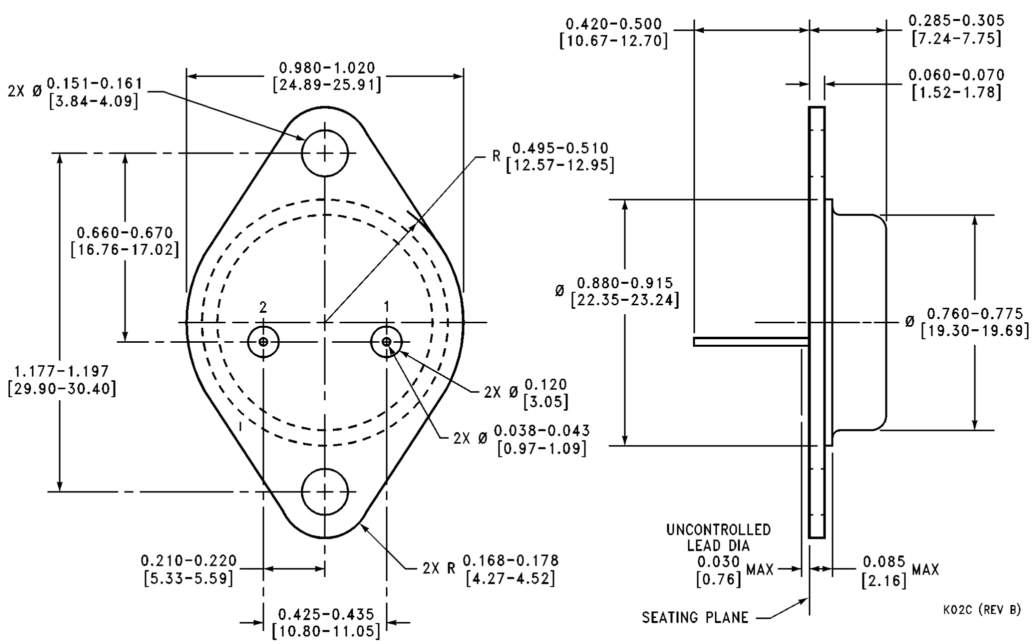


(TO-39) Metal Can Package
Order Number LM117H, LM117H/883, LM317AH or LM317H
NS Package Number H03A

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

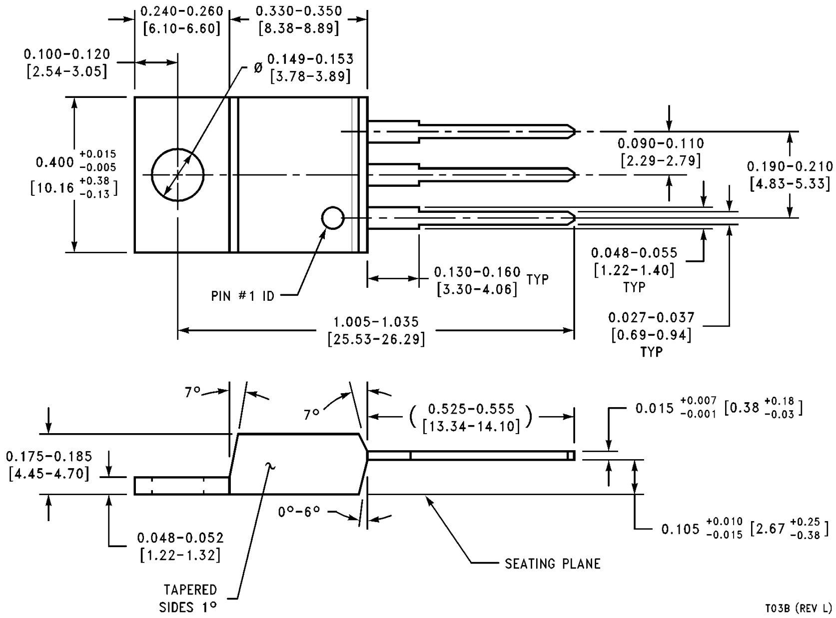


TO-3 Metal Can Package (K)
Order Number LM117K STEEL,
LM117K STEEL/883, or LM317K STEEL
NS Package Number K02A



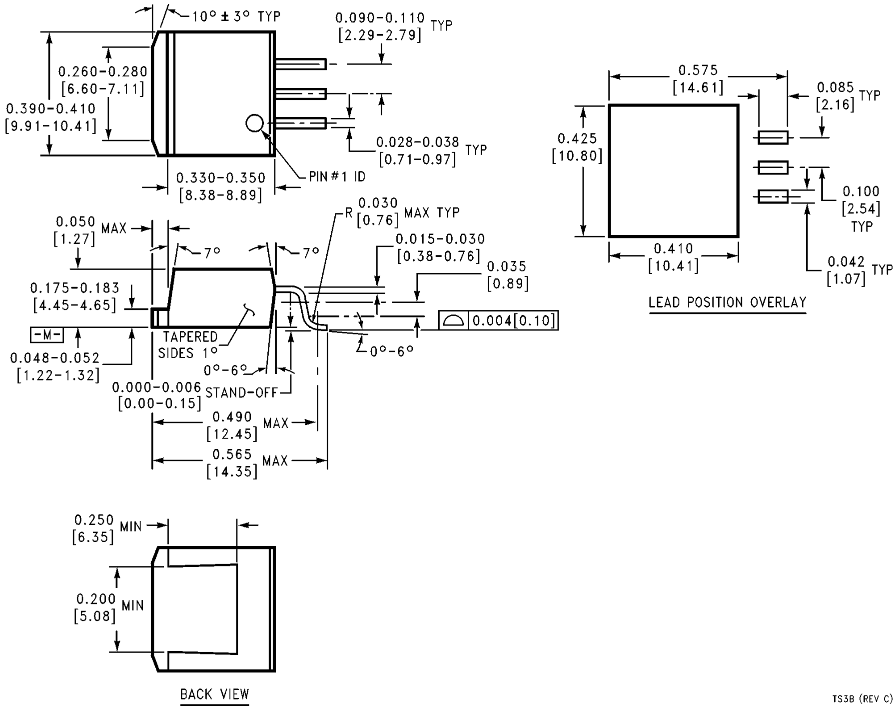
TO-3 Metal Can Package (K)
Mil-Aero Product
Order Number LM117K/883
NS Package Number K02C

Physical Dimensions inches, (millimeters) (Continued)



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

Physical Dimensions inches, (millimeters) (Continued)



Order Number LM317S
NS Package Number TS3B

LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform, when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

National Semiconductor Corporation
1111 West Bardin Road
Arlington, TX 76017
Tel: 1(800) 272-9959
Fax: 1(800) 737-7018

National Semiconductor Europe
Fax: +49 (0) 180-530 85 86
Email: europe.support@nsc.com
Deutsch Tel: +49 (0) 180-530 85 85
English Tel: +49 (0) 180-532 78 32
Français Tel: +49 (0) 180-532 93 58
Italiano Tel: +49 (0) 180-534 16 80

National Semiconductor Hong Kong Ltd.
13th Floor, Straight Block,
Ocean Centre, 5 Canton Rd.
Tsimshatsui, Kowloon
Hong Kong
Tel: (852) 2737-1600
Fax: (852) 2736-9960

National Semiconductor Japan Ltd.
Tel: 81-043-299-2308
Fax: 81-043-299-2408

http://www.national.com