N

LM317MDT D-Pak Qualification Package

Fall 1999

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Introduction

Introduction

General Product Description

The LM317MDT is a 3-terminal positive voltage regulator capable of supplying 500mA over a 1.2V to 37V output range in the D-Pak (TO-252) package. It is exceptionally easy to use and requires only two external resistors to set the output voltage. Included on the chip are current limit, thermal overload protection, and safe area protection.

Reliability/Qualification Overview

The TO-252 package underwent a variety of tests to qualify this new package at National Semiconductor. The package successfully passed autoclave, high temperature storage, static operating life, temperature humidity bias, temperature cycle, and power cycle testing and has been qualified as a level one moisture sensitive package. Refer to the reliability report included in this booklet for further information about the qualification.

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Datasheet

National Semiconductor

August 1999

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.

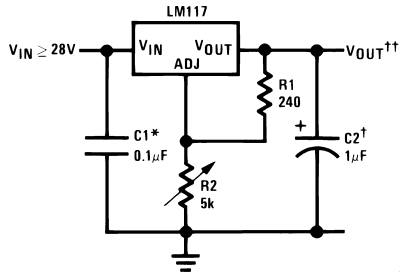
For applications requiring greater output current, see LM150 series (3A) and LM138 series (5A) data sheets. For the negative complement, see LM137 series data sheet.

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.

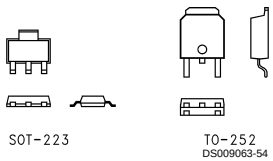
†Optional — improves transient response. Output capacitors in the range of 1 μF to 1000 μF of aluminum or tantalum electrolytic are commonly used to provide improved output impedance and rejection of transients.

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

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

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	$-55^{\circ}C \le T_J \le +150^{\circ}C$
LM317A	$-40^{\circ}C \le T_J \le +125^{\circ}C$
LM317	$0^{\circ}C \le T_J \le +125^{\circ}C$

Preconditioning

Thermal Limit Burn-In	All Devices 100%

Electrical Characteristics (Note 3)

Specifications with standard type face are for $T_J = 25^{\circ}C$, 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
	$3V \le (V_{IN} - V_{OUT}) \le 40V$, $10\text{ mA} \le I_{OUT} \le I_{MAX}$, $P \le P_{MAX}$	**1.20**	**1.25**	**1.30**	V
Line Regulation	$3V \le (V_{IN} - V_{OUT}) \le 40V$ (Note 4)		0.01	0.02	%/V
			0.02	**0.05**	%/V
Load Regulation	$10\text{ mA} \le I_{OUT} \le I_{MAX}$ (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	$10\text{ mA} \le I_{OUT} \le I_{MAX}$, $3V \le (V_{IN} - V_{OUT}) \le 40V$		**0.2**	**5**	µA
Temperature Stability	$T_{MIN} \le T_J \le T_{MAX}$		**1**		%
Minimum Load Current	$(V_{IN} - V_{OUT}) = 40V$		**3.5**	**5**	mA
Current Limit	$(V_{IN} - V_{OUT}) \le 15V$				
	K Package	**1.5**	**2.2**	**3.4**	A
	H Packages	**0.5**	**0.8**	**1.8**	A
	$(V_{IN} - V_{OUT}) = 40V$				
	K Package	0.3	0.4		A
	H Package	0.15	0.2		A
RMS Output Noise, % of V_{OUT}	10 Hz ≤ f ≤ 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	$T_J = 125^{\circ}C$, 1000 hrs		0.3	1	%
Thermal Resistance, Junction-to-Case	K Package		2.3	3	˚C/W
	H Package		12	15	˚C/W
	E Package				˚C/W
Thermal Resistance, Junction-to-Ambient (No Heat Sink)	K Package		35		˚C/W
	H Package		140		˚C/W
	E Package				˚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 ≤ ($V_{IN} - V_{OUT}$) ≤ 40V, 10 mA ≤ I_{OUT} ≤ I_{MAX}, P ≤ P_{MAX}	**1.225**	**1.250**	**1.270**	**1.20**	**1.25**	**1.30**	V
Line Regulation	3V ≤ ($V_{IN} - V_{OUT}$) ≤ 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 ≤ I_{OUT} ≤ 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 ≤ I_{OUT} ≤ I_{MAX} 3V ≤ ($V_{IN} - V_{OUT}$) ≤ 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	($V_{IN} - V_{OUT}$) ≤ 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 Hz ≤ f ≤ 10 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.

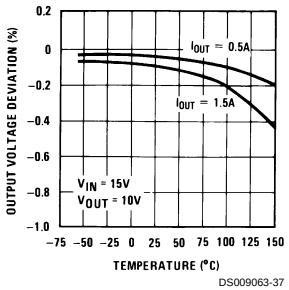
Note 5: Human body model, 100 pF discharged through a 1.5 kΩ resistor.

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. 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).

Typical Performance Characteristics

Output Capacitor = 0 µF unless otherwise noted

Load Regulation



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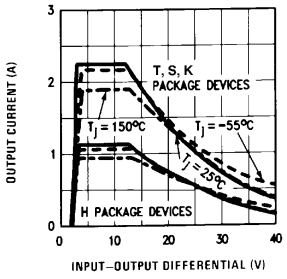
Current Limit



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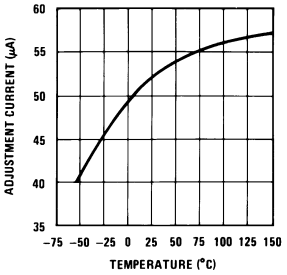
Adjustment Current



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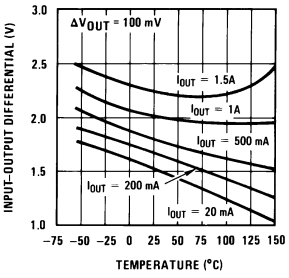
Dropout Voltage



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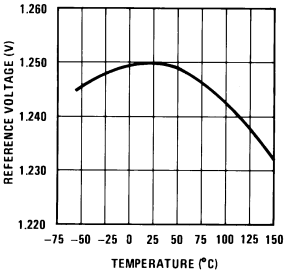
Temperature Stability



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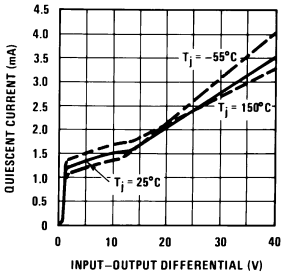
Minimum Operating Current



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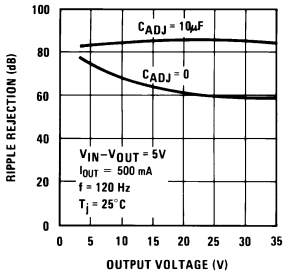
Ripple Rejection



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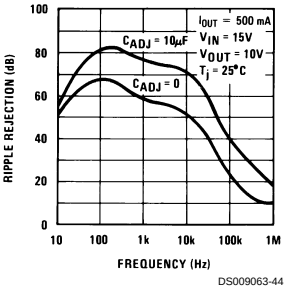
Ripple Rejection



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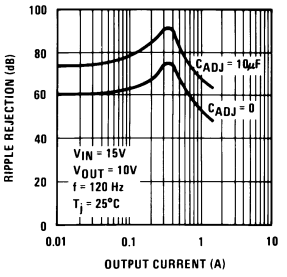
Ripple Rejection



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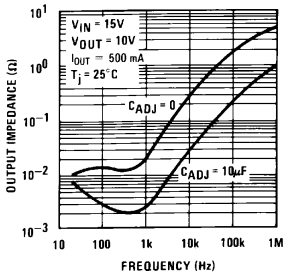
Output Impedance



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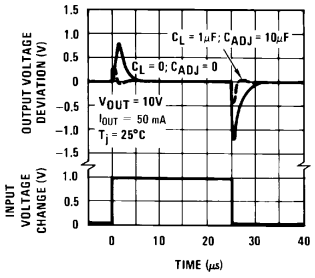
Line Transient Response



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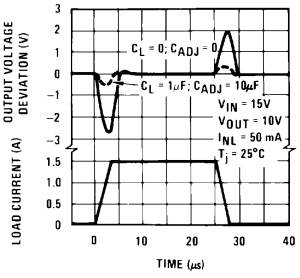
Load Transient Response



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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

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

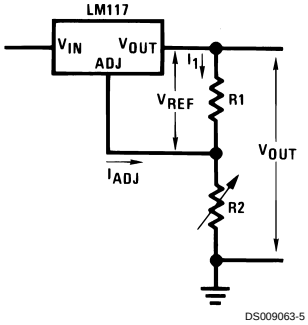


FIGURE 1.

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.

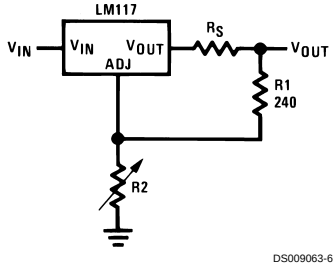


FIGURE 2. Regulator with Line Resistance in Output Lead

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

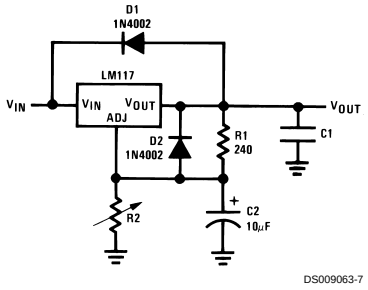
When external capacitors are used with *any* IC regulator it is sometimes necessary to add protection diodes to prevent the capacitors from discharging through low current points into the regulator. Most 10 µF capacitors have low enough internal series resistance to deliver 20A spikes when shorted. Although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

Application Hints (Continued)

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.*

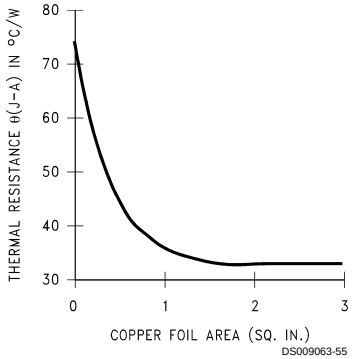


FIGURE 4. $\theta_{(J-A)}$ vs Copper (1 ounce) Area for the TO-263 Package

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).

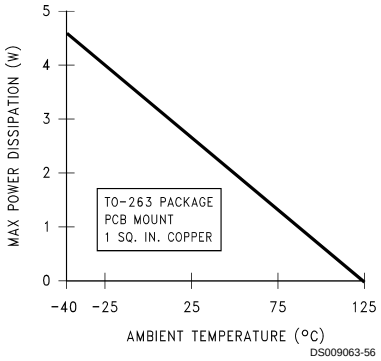


FIGURE 5. Maximum Power Dissipation vs T_{AMB} for the TO-263 Package

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.

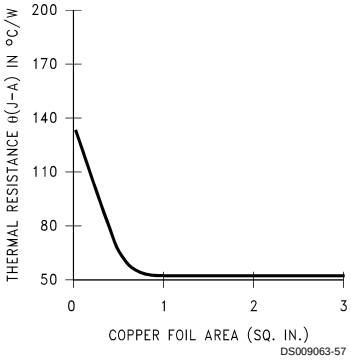


FIGURE 6. $\theta_{(J-A)}$ vs Copper (2 ounce) Area for the SOT-223 Package

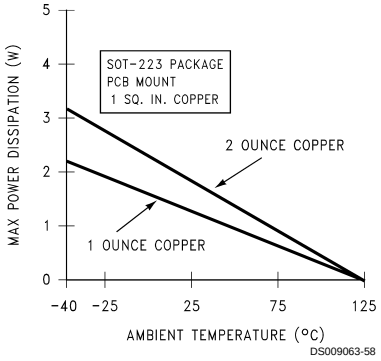


FIGURE 7. Maximum Power Dissipation vs T_{AMB} for the SOT-223 Package

Application Hints (Continued)

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.

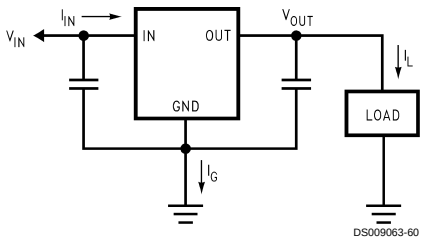


FIGURE 8. Power Dissipation Diagram

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

$T_R(max) = T_J(max) - T_A(max)$

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:

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

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
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.

Application Hints (Continued)

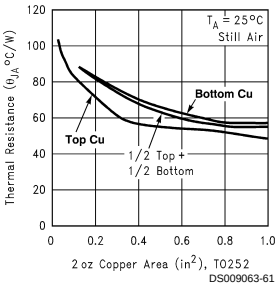


FIGURE 9. θ_{JA} vs 2oz Copper Area for TO-252

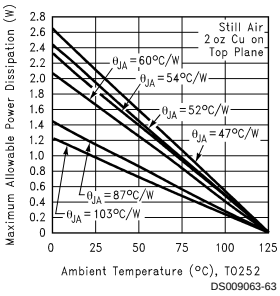


FIGURE 10. Maximum Allowable Power Dissipation vs. Ambient Temperature for TO-252

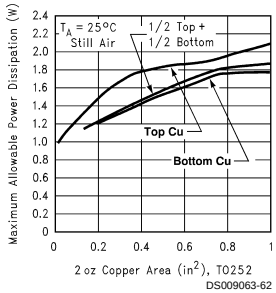


FIGURE 11. Maximum Allowable Power Dissipation vs. 2oz Copper Area for TO-252

Application Hints (Continued)

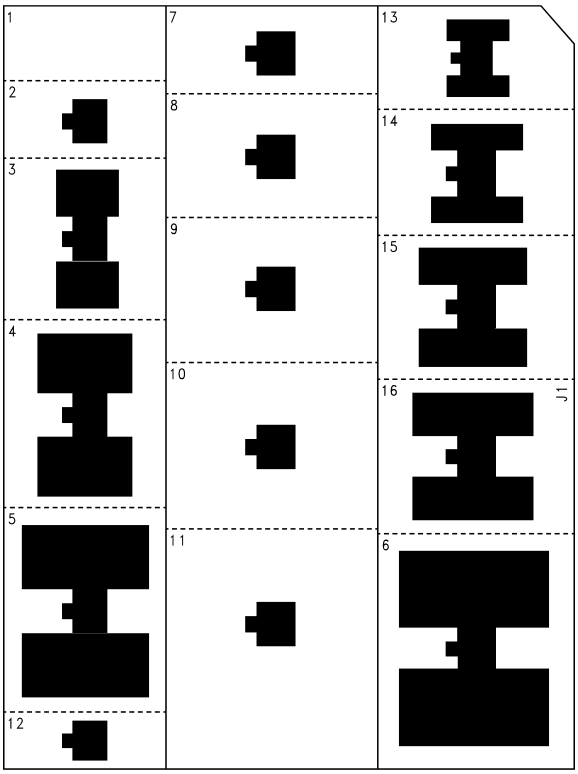


FIGURE 12. Top View of the Thermal Test Pattern in Actual Scale

Application Hints (Continued)

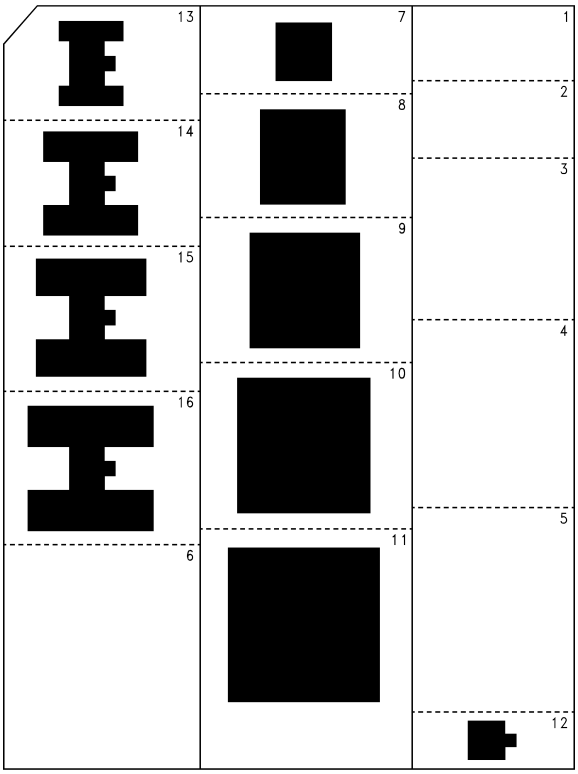
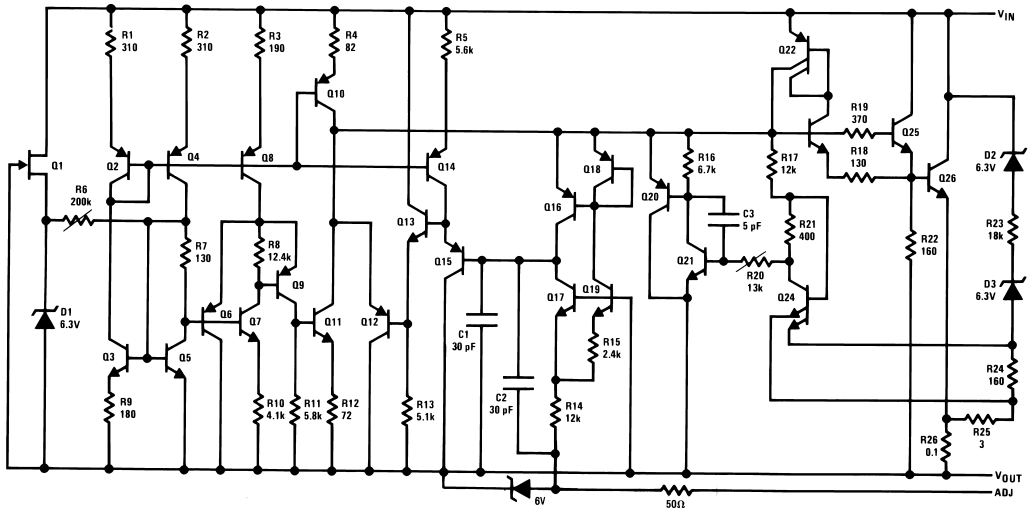


FIGURE 13. Bottom View of the Thermal Test Pattern in Actual Scale

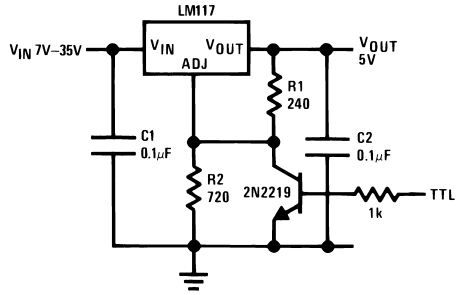
Schematic Diagram



DS009063-8

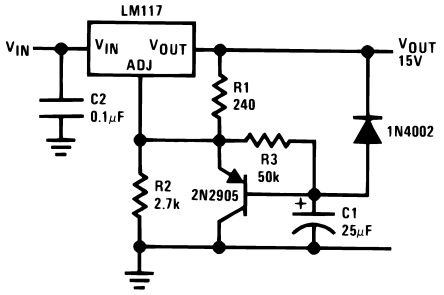
Typical Applications

5V Logic Regulator with Electronic Shutdown*



DS009063-3

Slow Turn-On 15V Regulator

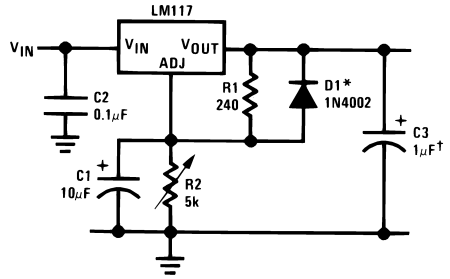


DS009063-9

*Min. output ≈ 1.2V

Typical Applications (Continued)

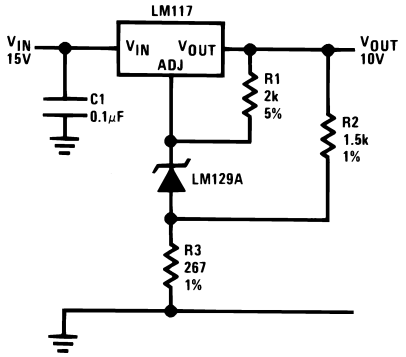
Adjustable Regulator with Improved Ripple Rejection



DS009063-10

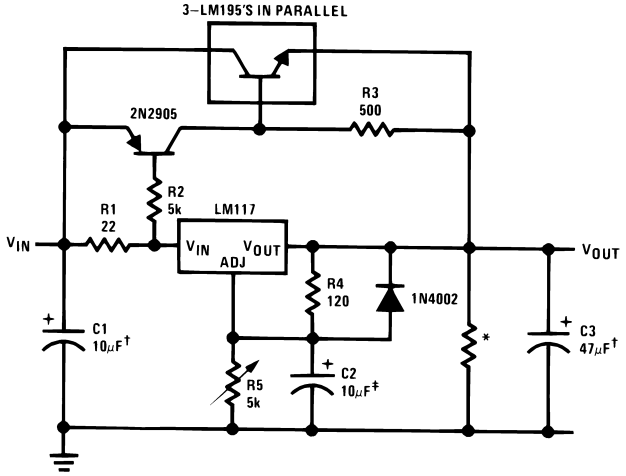
†Solid tantalum
*Discharges C1 if output is shorted to ground

High Stability 10V Regulator



DS009063-11

High Current Adjustable Regulator

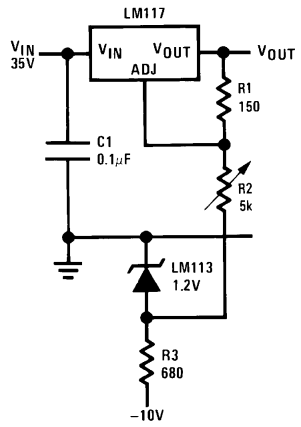


DS009063-12

‡Optional — improves ripple rejection
†Solid tantalum
*Minimum load current = 30 mA

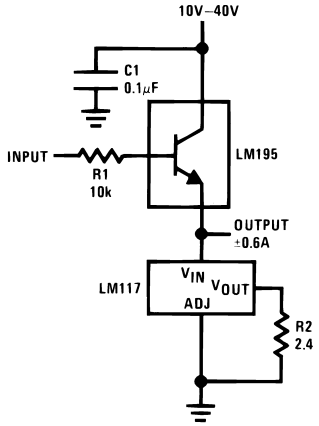
Typical Applications (Continued)

0 to 30V Regulator



DS009063-13

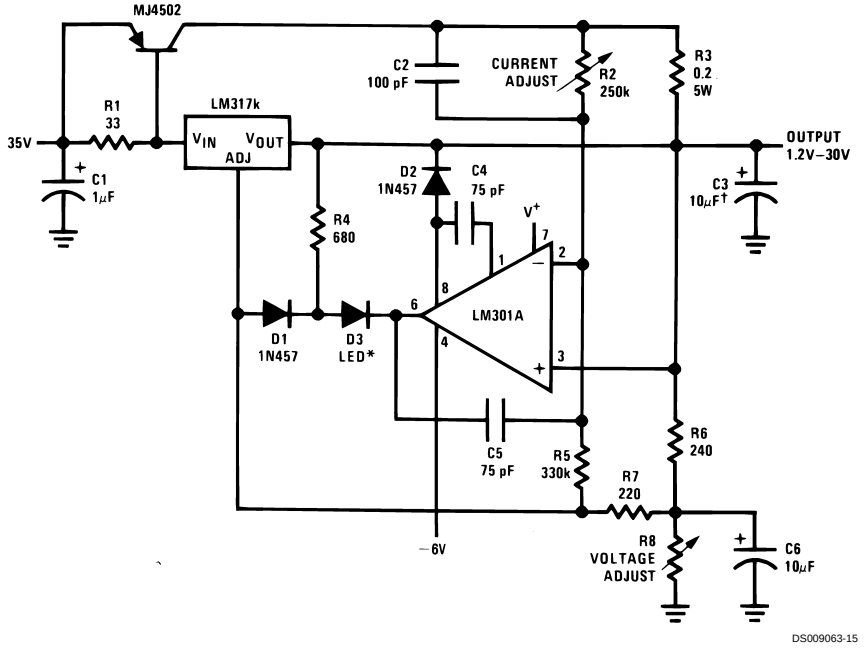
Power Follower



DS009063-14

Full output current not available at high input-output voltages

5A Constant Voltage/Constant Current Regulator

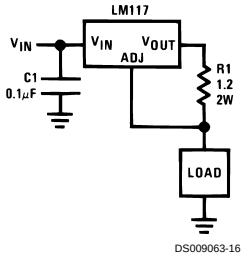


DS009063-15

†Solid tantalum
*Lights in constant current mode

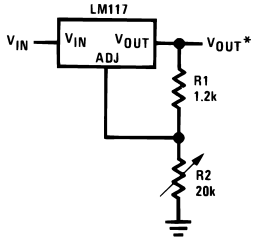
Typical Applications (Continued)

1A Current Regulator



DS009063-16

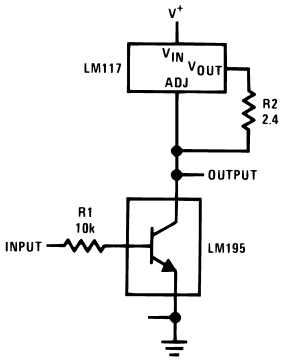
1.2V–20V Regulator with Minimum Program Current



DS009063-17

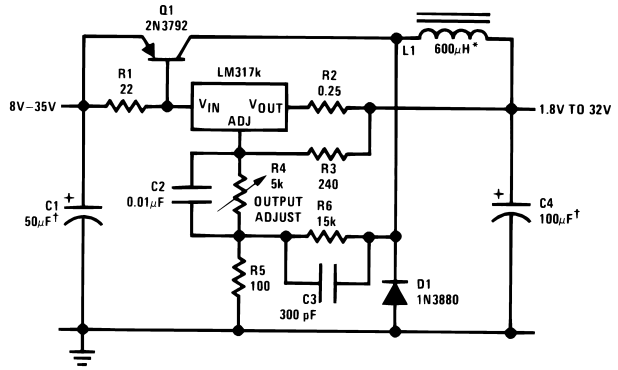
*Minimum load current ≅ 4 mA

High Gain Amplifier



DS009063-18

Low Cost 3A Switching Regulator

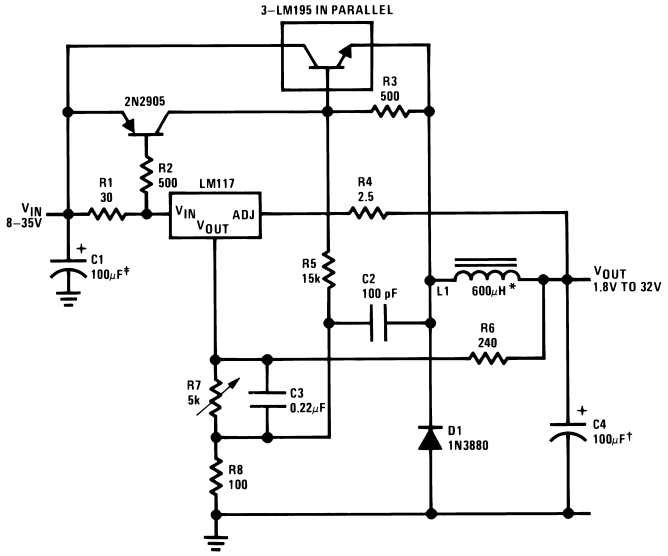


DS009063-19

†Solid tantalum
*Core — Arnold A-254168-2 60 turns

Typical Applications (Continued)

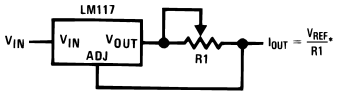
4A Switching Regulator with Overload Protection



DS009063-20

†Solid tantalum
*Core — Arnold A-254168-2 60 turns

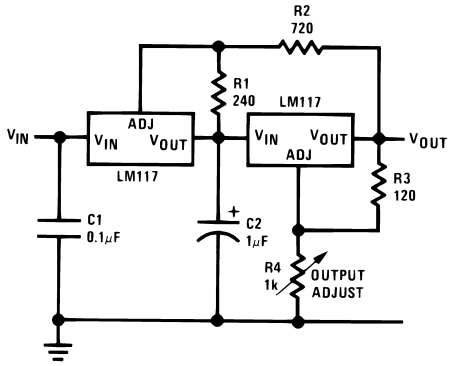
Precision Current Limiter



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

DS009063-21

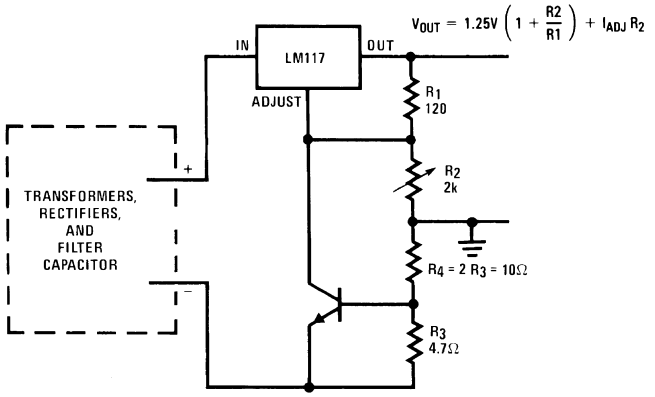
Tracking Preregulator



DS009063-22

Typical Applications (Continued)

Current Limited Voltage Regulator

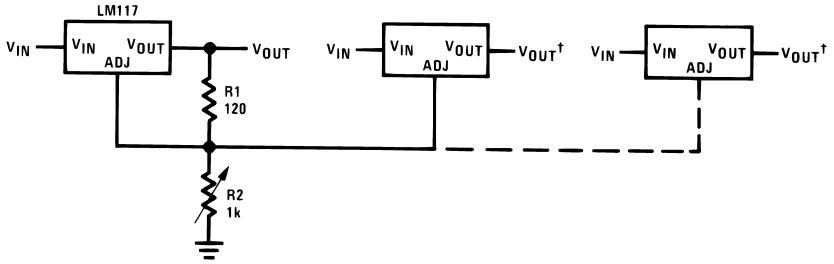


DS009063-23

— Short circuit current is approximately $\frac{600\ mV}{R3}$, 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

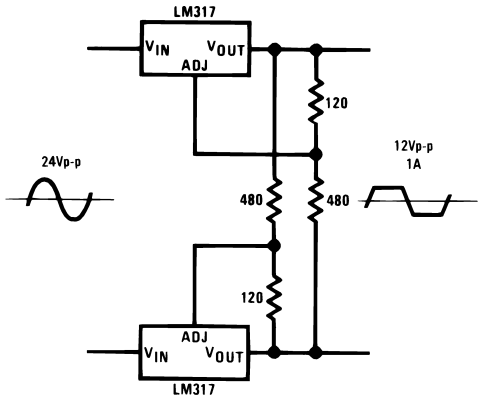
Adjusting Multiple On-Card Regulators with Single Control*



DS009063-24

*All outputs within ±100 mV
†Minimum load — 10 mA

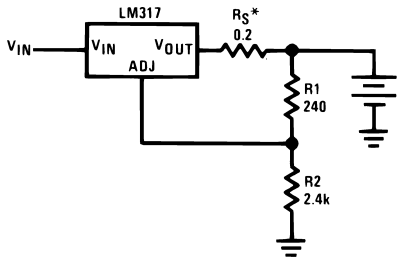
AC Voltage Regulator



DS009063-25

Typical Applications (Continued)

12V Battery Charger

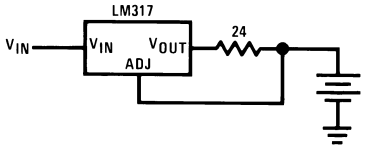


DS009063-26

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

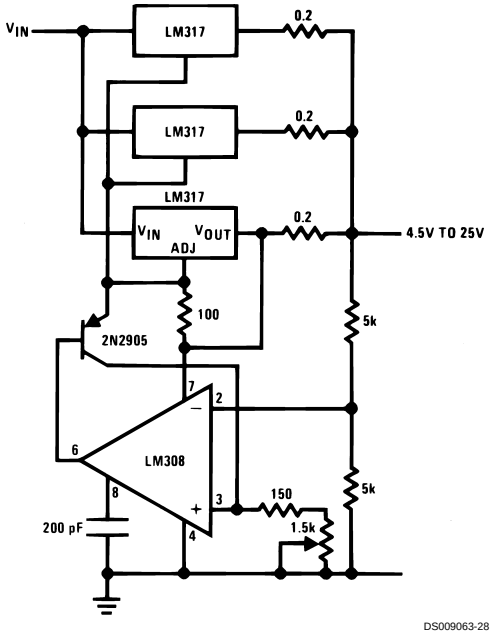
Use of R_S allows low charging rates with fully charged battery.

50 mA Constant Current Battery Charger



DS009063-27

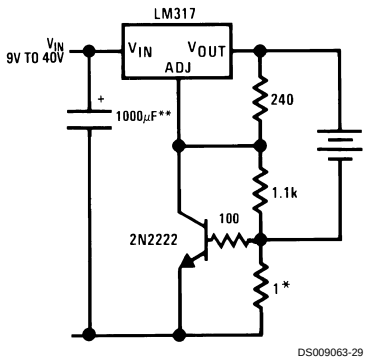
Adjustable 4A Regulator



DS009063-28

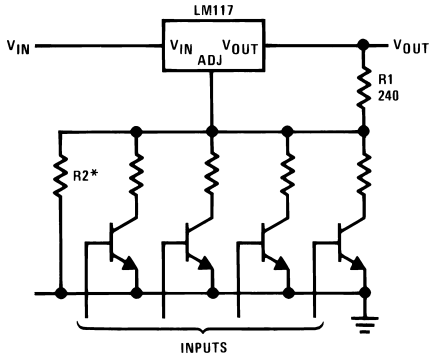
Typical Applications (Continued)

Current Limited 6V Charger



*Sets peak current (0.6A for 1Ω)
**The 1000 µF is recommended to filter out input transients

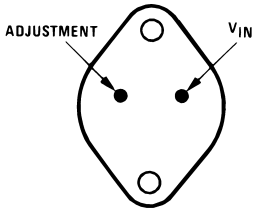
Digitally Selected Outputs



*Sets maximum V_{OUT}

Connection Diagrams

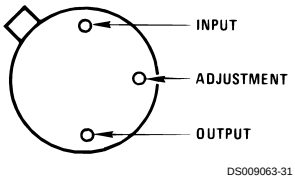
(TO-3)
Metal Can Package



CASE IS OUTPUT

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

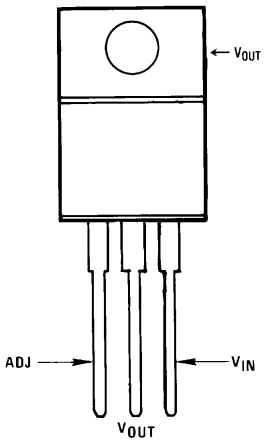
(TO-39)
Metal Can Package



CASE IS OUTPUT

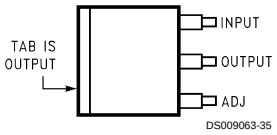
Bottom View
Order Number LM117H,
LM117H/883,
LM317AH or LM317H
See NS Package Number H03A

(TO-220)
Plastic Package



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

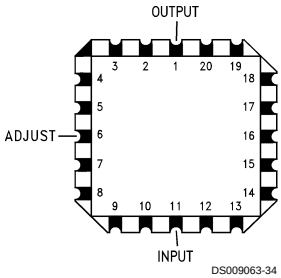
(TO-263) Surface-Mount Package



Top View

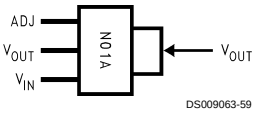
Side View
Order Number LM317S
See NS Package Number TS3B

Ceramic Leadless
Chip Carrier



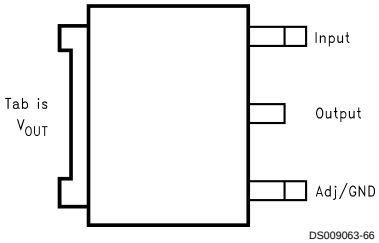
Top View
Order Number LM117E/883
See NS Package Number E20A

3-Lead SOT-223



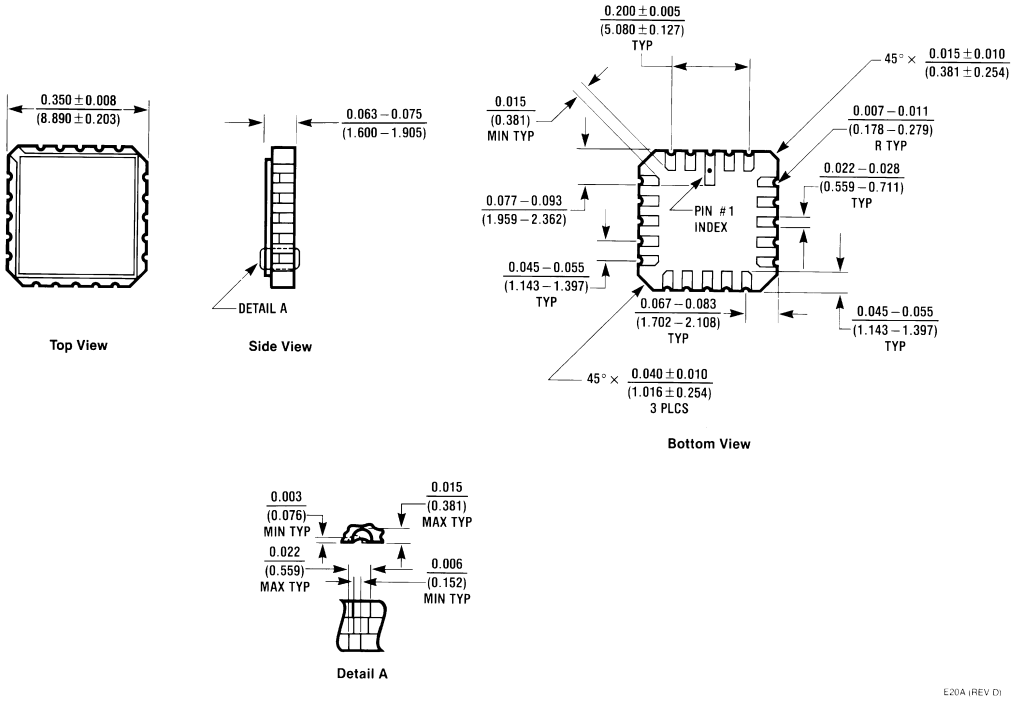
Front View
Order Part Number LM317EMP or
LM317AEMP
Package Marked N01A
See NSC Package Number MA04A

TO-252 (D-Pak)



Front View
Order Part Number LM317DT
See NSC Package Number TD03B

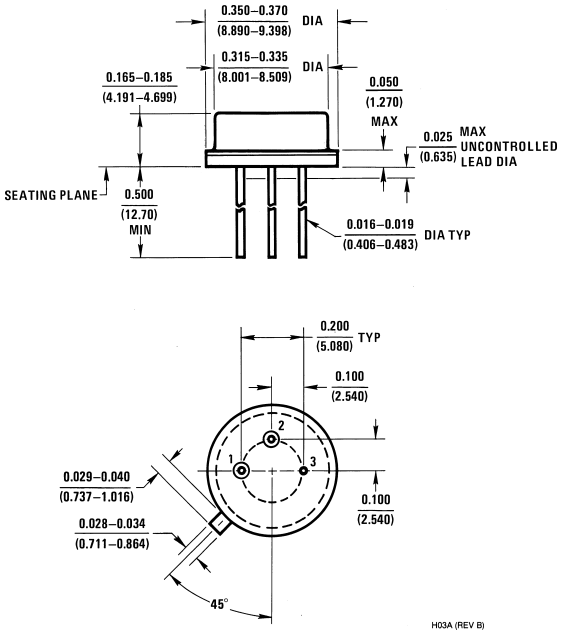
Physical Dimensions inches (millimeters) unless otherwise noted



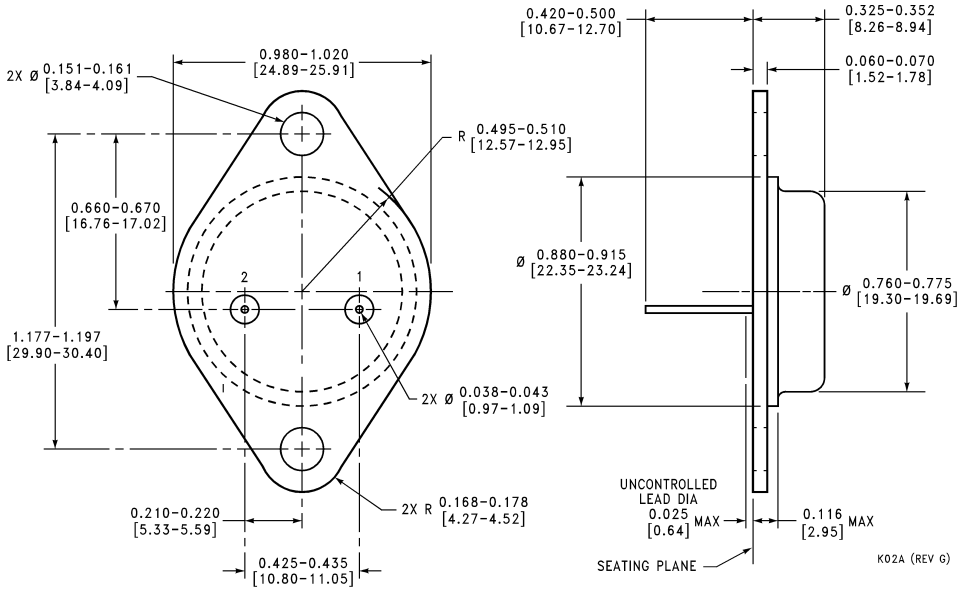
E20A (REV D)

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

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

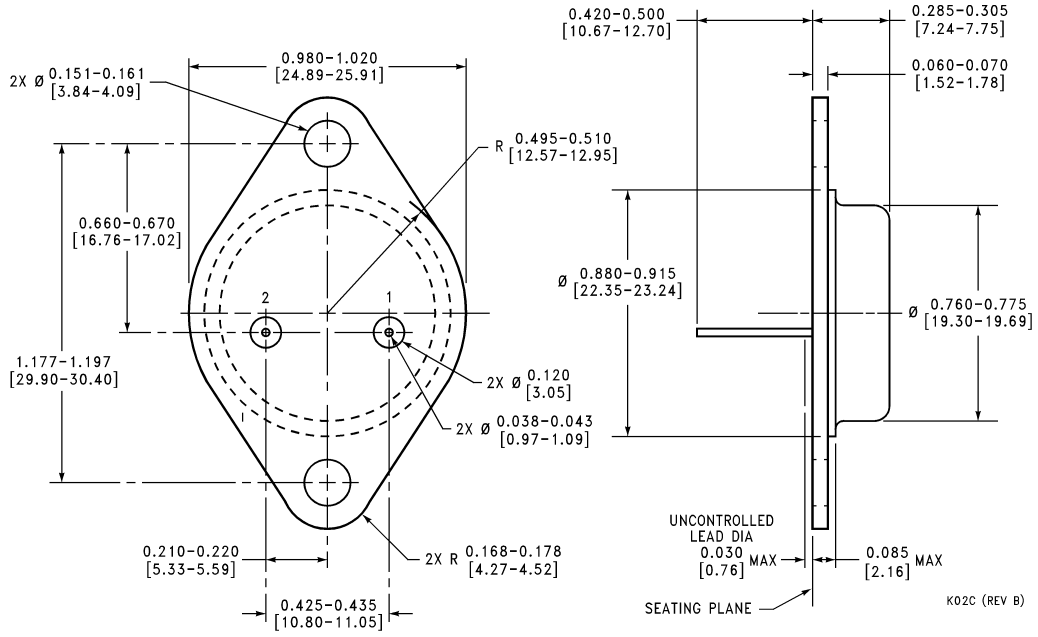


(TO-39) Metal Can Package
Order Number LM117H, LM117H/883, LM317AH or LM317H
NS Package Number H03A



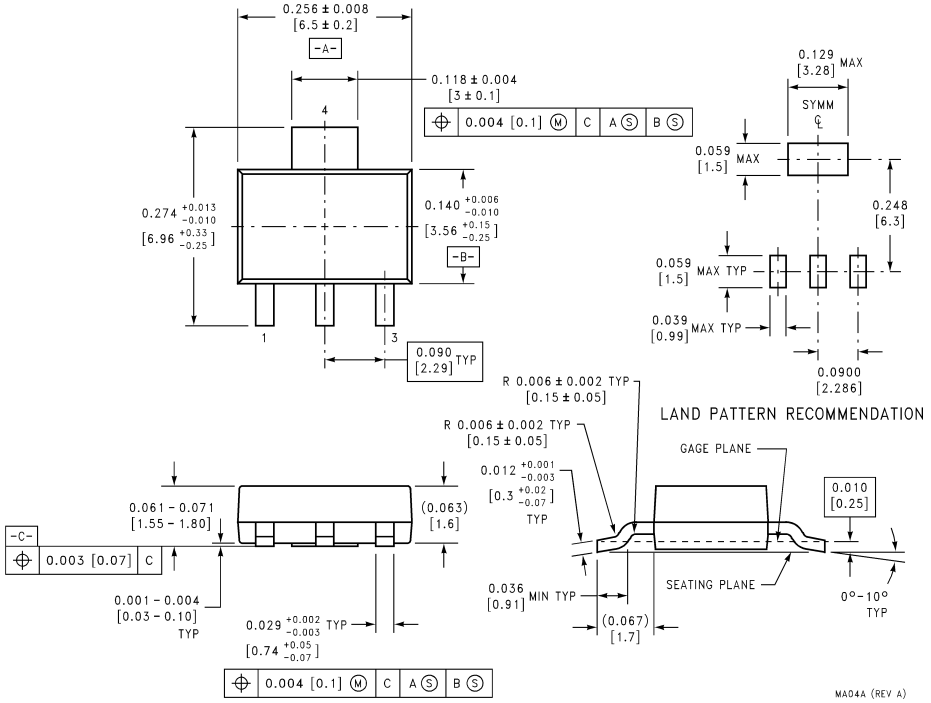
TO-3 Metal Can Package (K)
Order Number LM117K STEEL,
LM117K STEEL/883, or LM317K STEEL
NS Package Number K02A

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



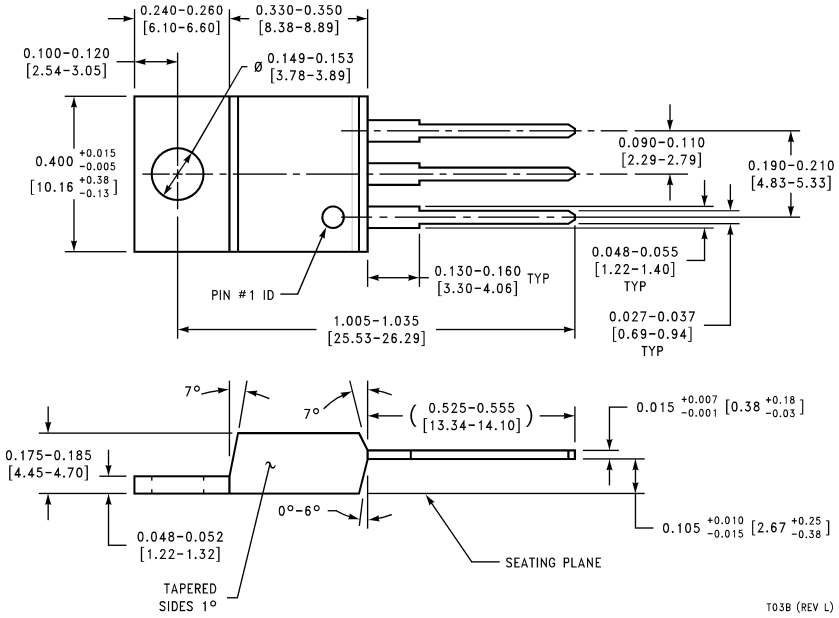
TO-3 Metal Can Package (K)
Mil-Aero Product
Order Number LM117K/883
NS Package Number K02C

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



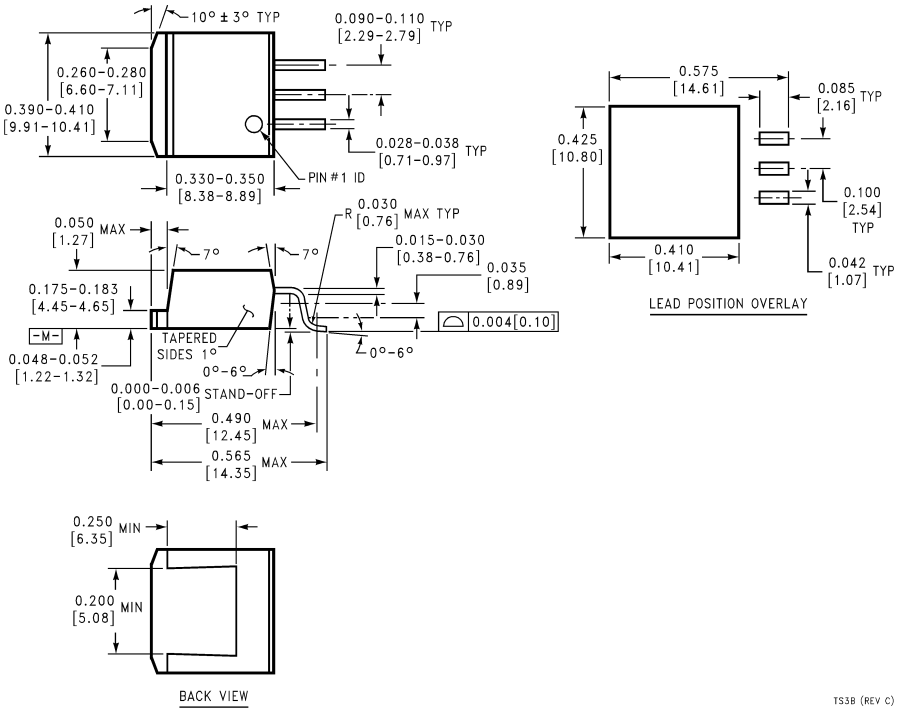
3-Lead SOT-223 Package
Order Number LM317AEMP or LM317EMP
NS Package Number MA04A

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



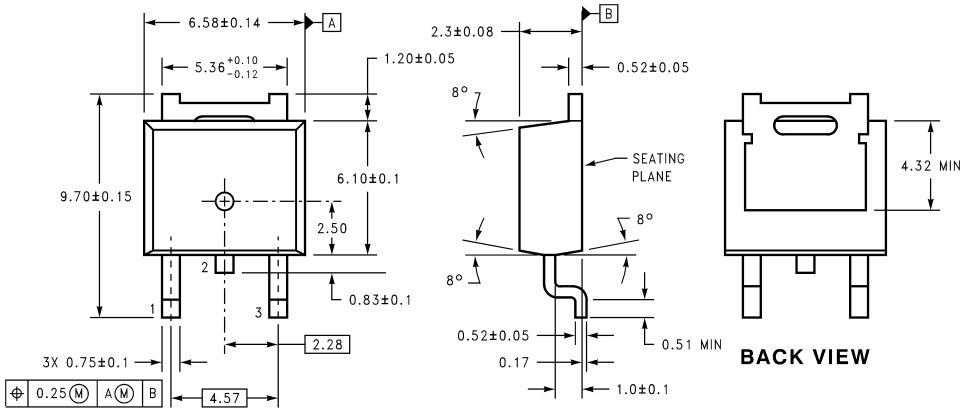
(TO-220) Outline Drawing
Order Number LM317AT or LM317T
NS Package Number T03B

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



Order Number LM317S
NS Package Number TS3B

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



DIMENSIONS ARE IN MILLIMETERS

TD03B (REV A)

Order Number LM317MDT
NS Package Number TD03B

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 AND GENERAL COUNSEL 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.

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Process Information

Process Information

Process Details

Fabrication Site:	Fab 1, Greenock, NSUK
Process Technology:	SLM
Wafer Diameter:	4 inches
Number of Masks:	7
Metalization:	0.5% Copper / Aluminum
Passivation:	VOM & Nitride

Process Mask Steps

Name	Mask #
COLLECTOR	10
ISOLATION	20
BASE	30
EMITTER	40
CONTACT	50
METAL	60
PAD	70

Process Flow

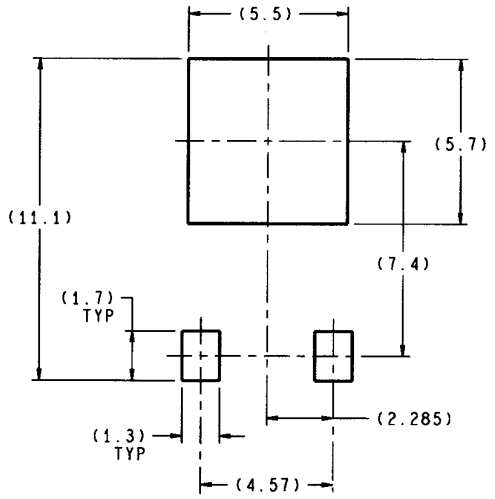
1. Initial Oxidation
2. Laserscribe
3. Collector Mask
4. Collector Implant
5. Collector Drive
6. Epi Strip
7. Epi Growth
8. Epi Reoxidation
9. Iso Mask
10. Iso Pre-Deposition
11. Iso Drive
12. Strip Oxide
13. FTA Implant
14. FTA Re-Oxidation
15. Base Mask
16. Pre-Base Implant Oxidation
17. Base Implant
18. Base Drive
19. Emitter Mask
20. Emitter Pre-Deposition
21. Vapox Over Emitter
22. Getter
23. Post Getter dip
24. LIC Anneal
25. Contact Mask
26. Metal Deposition
27. Metal Mask
28. VOM
29. Nitride Deposition
30. Pad Mask
31. Anneal

Packaging Information

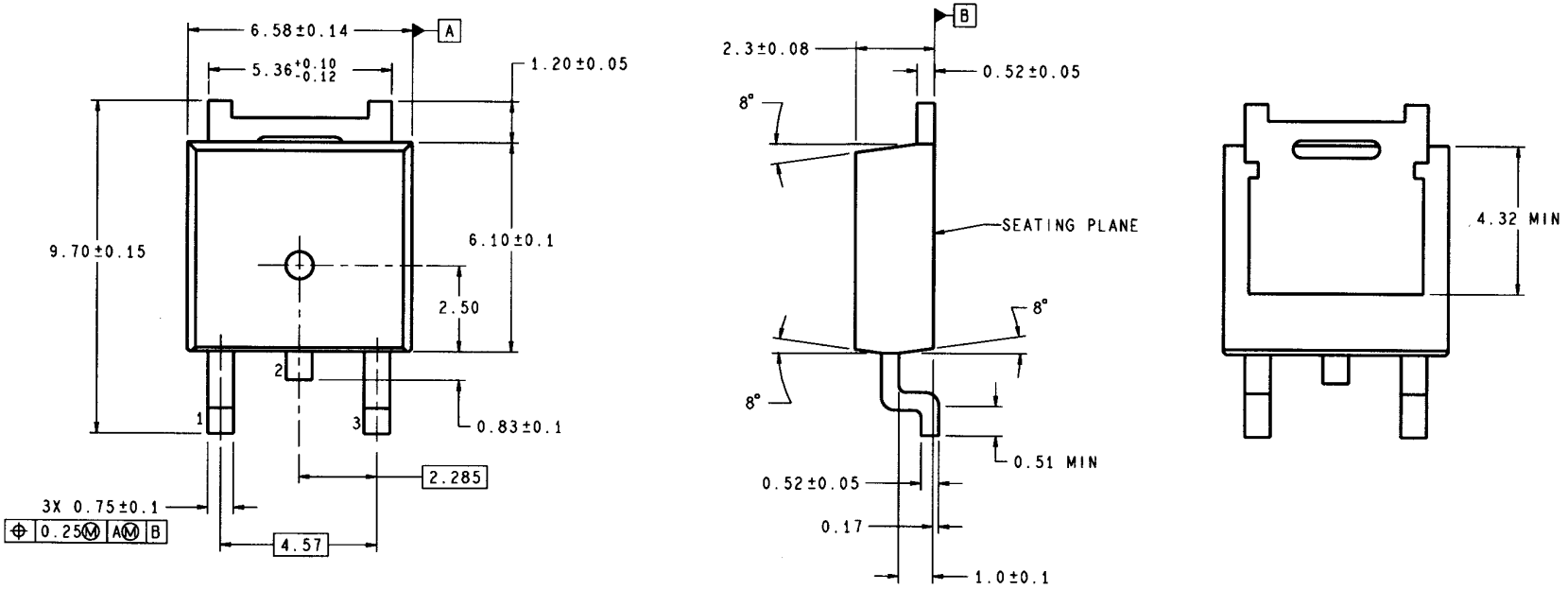
Package Material

Generic Package Type	**3 Lead TO-252 (D-Pak)**
NS Package Number	TD03B
Mold Compound Type **Manufacturer, Designation**	EME-7200 Sumitomo
Lead Frame Material **Manufacturer**	TAMAC4
External Lead **Frame Coating**	Solder Plate Sn/Pb
Pins	3 Pins
Die Attach Material	Hi Lead Solder
Bond Wire	Gold, 1.5mils
Bond Type	Thermosonic Ball
Package Thermal	110^{o}C/W

REVISIONS				
LTR	DESCRIPTION	E.C.N.	DATE	BY/APP'D
A	RELEASE TO DOCUMENT CONTROL	12120	10/23/1998	NOR/MS/SH
B	ADD LAND PATTERN RECOMMENDATION VIEW; DIM 2.285 WAS 2.28	12261	06/30/1999	MS/PS



LAND PATTERN RECOMMENDATION



DIMENSIONS ARE IN MILLIMETERS

NOTES: UNLESS OTHERWISE SPECIFIED

1. STANDARD LEAD FINISH:
   5.08 MICROMETERS MINIMUM
   LEAD/TIN 15/85 ON TAMAC 4.

2. REFERENCE JEDEC REGISTRATION TO-252.
   VARIATION AA, ISSUE C, DATED SEPT 1988.

APPROVALS	DATE
DRAWN NOR A.P	10/23/1998
DFTG. CHK. THANH LEQUANG	06/30/1999
ENGR. CHK. PETER SPALDING	06/30/1999

PROJECTION

INCH [MM]

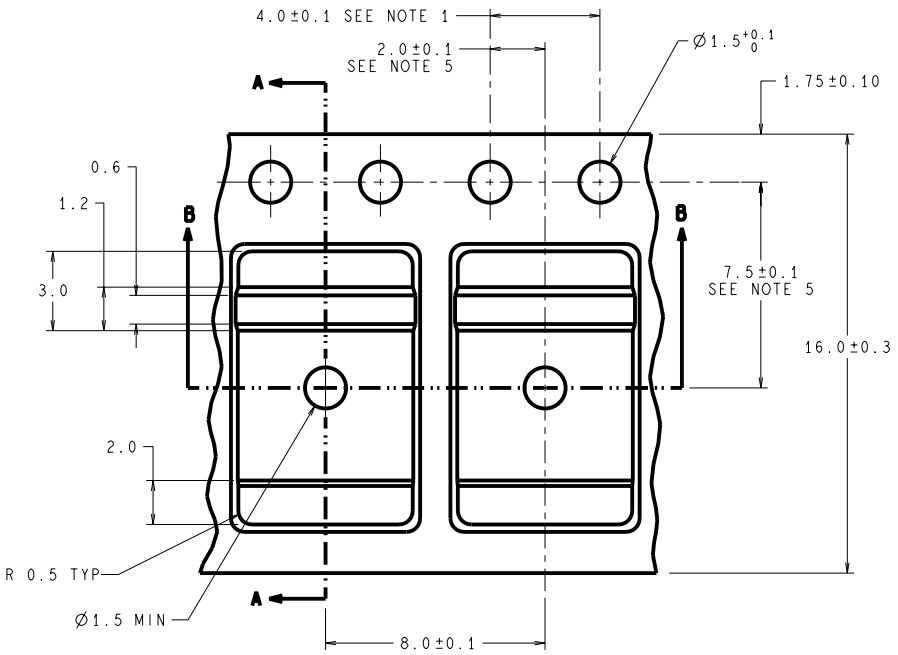
National Semiconductor
2900 Semiconductor dr. Santa Clara, CA 95052-8090

TO-252, MOLDED, JEDEC,
6.58 X 6.10 X 2.30mm BODY,
3 LD, 2.28mm PITCH, S/M

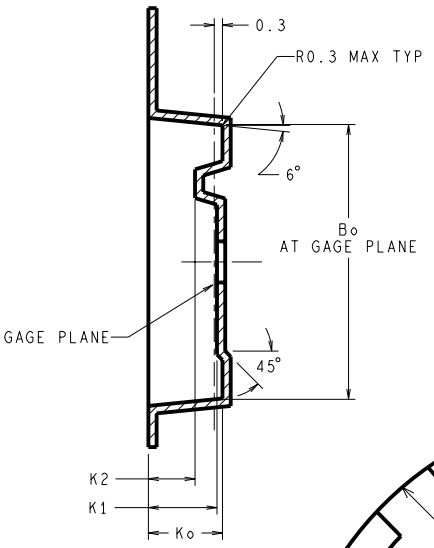
SCALE	SIZE	DRAWING NUMBER	REV
N/A	C	(SC)MKT-TD03B	B

DO NOT SCALE DRAWING | SHEET 1 of 1

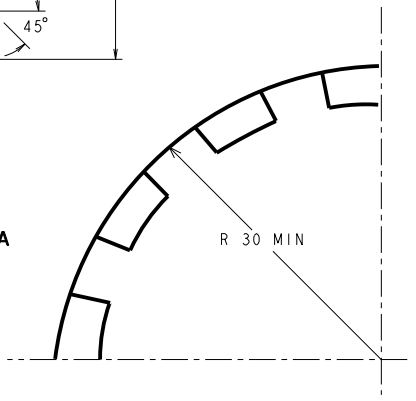
REVISIONS				
LTR	DESCRIPTION	E.C.N.	DATE	BY/APP'D
A	RELEASE TO DOCUMENT CONTROL	12123	11/16/1998	NOR/MS/TG



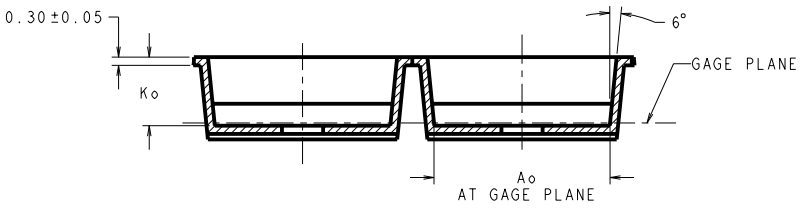
SECTION B-B



SECTION A-A



ALLOWABLE BEND RADIUS
NOT TO SCALE



NOTES:

1. CUMMULATIVE PITCH TOLERANCE FOR FEEDING HOLES AND CAVITIES (CHIP POCKETS) NOT TO EXCEED .008 [0.20] OVER 10 PITCH SPAN.
2. THRU HOLE INSIDE CAVITY IS CENTERED WITHIN CAVITY.
3. CAMBER NOT TO EXCEED 1mm IN 100mm.
4. Ko MEASURED FROM THE PLAN ON THE INSIDE BOTTOM OF THE POCKET TO THE TOP SURFACE OF THE CARRIER.
5. POCKET POSITION RELATIVE TO SPROCKET HOLE MEASURED AS TRUE POSITION OF POCKET,NOT POCKET HOLE.

QUALITY ASSURANCE PROVISIONS
Requirements shall be in accordance with NSC Mat'l Procurement Specification #8081 and as specified herein. The procuring activity reserves the right to perform inspection in accordance with this specification and to return shipments that fail.

01	068785	3/5	6.9	10.5	2.7	2.5	1.7
OPT	STOCK #	LD COUNT	DIM Ao	DIM Bo	DIM Ko	DIM K1	DIM K2

DIMENSIONS ARE IN MILLIMETERS

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ARE:
DECIMALS: ANGLES:
.XX ± 0.10 ± 1°
.XXX ± N/A
.XXXX ± N/A
MATERIAL N/A
FINISH N/A
DO NOT SCALE DRAWING

APPROVALS	DATE
DRAWN NOR A. R	09/24/1998
DFTG. CHK.	
ENGR. CHK. T. O. GOH	11/16/1998

PROJECTION INCH [MM]

National Semiconductor
2900 Semiconductor dr, Santa Clara, CA 95052-8090

TAPE, EMBOSSED, 16MM, TO-251/252

SCALE	SIZE	DRAWING NUMBER	REV
8X	C	(SC)39-2259	A

FORMERLY: N/A SHEET 1 of 1

SCALE 8.000

Reliability Data

National Semiconductor

Reliability Test Report

File Number:
FEM19990001
Originator:
Suresh Kumar
Date:January 4, 1999

Purpose

Qualification of T0252 (DPAK) package assembled in IDS

Approvals

Reliability Engineer	**Date**
Mgr. Rel. Engineering	**Date**

Reference File Numbers

REM199803515
REM199804014
Q19980613

Distribution List

Sharon Ko, KP Kok, CS Teoh

Abstract

This qualification is to qualify a new package T0252 (DPAK) which will be assembled in IDS. T0252 is a very new package to NSC. IDS is also a new subcontractor. Thus this qual plan will qualify T0252 package and IDS subcontractor at the same time.

Description

Test Request	Device Name	Sbgp	Wafer Die Run	Fab Loc	Fab Line	Pkg Code	# Leads	Assy Loc	Date Cd	Mold Cmpnd
REM199803515	LM317TS	A	HM094456	UK	Bip Linear	T0252	003	IDS	9836	EME7200
REM199803515	LM317TS	B	HM094448	UK	Bip Linear	T0252	003	IDS	9836	EME7200
REM199803515	LM317TS	C	HM094495	UK	Bip Linear	T0252	003	IDS	9836	EME7200
REM199804014	LM2940TS-5.0	A	XXXXXXXXXX	UK	Bip Linear	T0252	003	IDS	9848	EME7200
REM199804014	LM2940TS-5.0	B	XXXXXXXXXX	UK	Bip Linear	T0252	003	IDS	9848	EME7200

Tests Performed

Preconditioning Flow
TMCL (-40/60C) 5cyc → Bake (125C) 24 hrs → THST (85C/85%) 168hrs → Reflow (235C) 3 passes → Flux Immersion → Rinse → Dry → ATE

Test: Autoclave Test (ACLV)

Test Request	Device	Sbgrp	Rel Humidity	Pressure	High Temp	LowTemp
REM199803515	LM317TS	A	100	15	121	
REM199803515	LM317TS	B	100	15	121	
REM199803515	LM317TS	C	100	15	121	

Timepoints:	Test Request	TP	Duration
	REM199803515	1	168

Test: High Temperature Storage test (bake) (HTSL)

Test Request	Device	Sbgrp	Rel Humidity	Pressure	High Temp	LowTemp
REM199803515	LM317TS	A			150	
REM199803515	LM317TS	B			150	
REM199803515	LM317TS	C			150	

Timepoints:	Test Request	TP	Duration
	REM199803515	1	168
	REM199803515	2	500
	REM199803515	3	1000

Test: Operating Life Test (Static) (SOPL)

Test Request	Device	Sbgrp	Rel Humidity	Pressure	High Temp	LowTemp
REM199803515	LM317TS	A			125	
REM199803515	LM317TS	B			125	
REM199803515	LM317TS	C			125	

Timepoints:	Test Request	TP	Duration
	REM199803515	1	168
	REM199803515	2	500
	REM199803515	3	1000

Test: Power Cycle (PRCL)

Test Request	Device	Sbgrp	Rel Humidity	Pressure	High Temp	LowTemp
REM199804014	LM2940TS-5.0	A			125	25
REM199804014	LM2940TS-5.0	B			125	25

Timepoints:	Test Request	TP	Duration
	REM199804014	1	15000
	REM199804014	2	30000

Test: Temperature Cycle (TMCL)

Test Request	Device	Sbgrp	Rel Humidity	Pressure	High Temp	LowTemp
REM199803515	LM317TS	A			150	-65
REM199803515	LM317TS	B			150	-65
REM199803515	LM317TS	C			150	-65

Timepoints:	Test Request	TP	Duration
	REM199803515	1	500
	REM199803515	2	1000

Test: Temperature Humidity Bias Test (THBT)

Test Request	Device	Sbgrp	Rel Humidity	Pressure	High Temp	LowTemp
REM199803515	LM317TS	A	85		85	
REM199803515	LM317TS	B	85		85	
REM199803515	LM317TS	C	85		85	

Timepoints:	Test Request	TP	Duration
	REM199803515	1	168
	REM199803515	2	500
	REM199803515	3	1000

Results/Discussion

Test: Autoclave Test (ACLV)

Test Request	Device	Sbgrp	TP	Duration	Sample Size	Rejects
REM199803515	LM317TS	A	0	Precond	50	0
REM199803515	LM317TS	A	1	168	50	0
REM199803515	LM317TS	B	2	Precond	50	0
REM199803515	LM317TS	B	1	168	50	0
REM199803515	LM317TS	C	2	Precond	50	0
REM199803515	LM317TS	C	1	168	50	0

Test: High Temperature Storage test (bake) (HTSL)

Test Request	Device	Sbgrp	TP	Duration	Sample Size	Rejects
REM199803515	LM317TS	A	1	168	100	0
REM199803515	LM317TS	A	2	500	100	0
REM199803515	LM317TS	A	3	1000	100	0
REM199803515	LM317TS	B	1	168	100	0
REM199803515	LM317TS	B	2	500	100	0
REM199803515	LM317TS	B	3	1000	100	0

REM199803515	LM317TS	C	1	168	100	0
REM199803515	LM317TS	C	2	500	100	0
REM199803515	LM317TS	C	3	1000	100	0

Test: Operating Life Test (Static) (SOPL)

Test Request	Device	Sbgrp	TP	Duration	Sample Size	Rejects
REM199803515	LM317TS	A	1	168	100	0
REM199803515	LM317TS	A	2	500	100	0
REM199803515	LM317TS	A	3	1000	100	0
REM199803515	LM317TS	B	1	168	100	0
REM199803515	LM317TS	B	2	500	100	0
REM199803515	LM317TS	B	3	1000	100	0
REM199803515	LM317TS	C	1	168	100	0
REM199803515	LM317TS	C	2	500	100	0
REM199803515	LM317TS	C	3	1000	100	0

Test: Temperature Humidity Bias Test (THBT)

Test Request	Device	Sbgrp	TP	Duration	Sample Size	Rejects
REM199803515	LM317TS	A	1	168	100	0
REM199803515	LM317TS	A	2	500	100	0
REM199803515	LM317TS	B	1	168	100	0
REM199803515	LM317TS	B	2	500	100	0
REM199803515	LM317TS	C	1	168	100	0
REM199803515	LM317TS	C	2	500	100	0

Test: Temperature Cycle (TMCL)

Test Request	Device	Sbgrp	TP	Duration	Sample Size	Rejects
REM199803515	LM317TS	A	1	500	100	0
REM199803515	LM317TS	A	2	1000	100	0
REM199803515	LM317TS	B	1	500	100	0
REM199803515	LM317TS	B	2	1000	100	0
REM199803515	LM317TS	C	1	500	100	0
REM199803515	LM317TS	C	2	1000	100	0

Test: Power Cycle (PRCL)

Test Request	Device	Sbgrp	TP	Duration	Sample Size	Rejects
REM199804014	LM2940TS-5.0	A	1	15000	77	0
REM199804014	LM2940TS-5.0	B	1	15000	77	0

Conclusion

Based on the qualification results, the TO252 (DPAK) package is qualified to be assembled. IDS being the subcontractor is also qualified to assemble this package. Based on the moisture sensitivity test done, this package is qualified as a level 1 moisture sensitive package.