LM117/LM317A/LM317-N 3-Terminal Adjustable Regulator

Check for Samples: LM117, LM317-N

FEATURES

- **Specified 1% Output Voltage Tolerance (LM317A)**
- **Specified Max. 0.01%/V Line Regulation (LM317A)**
- **Specified Max. 0.3% Load Regulation (LM117)**
- **Specified 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**

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.

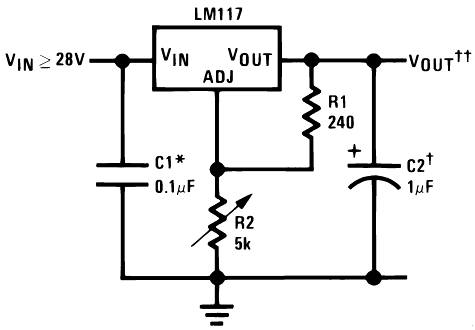
Besides replacing fixed regulators, the LM117 is useful in a wide variety of other applications. Since the regulator is “floating” and sees only the input-to-output differential voltage, supplies of several hundred volts can be regulated as long as the maximum input to output differential is not exceeded, 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.

Typical Applications

Figure 1. 1.2V–25V Adjustable Regulator



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 1μF to 1000μF 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/LM317A/LM317-N Package Options

Part Number	Suffix	Package	Output Current
LM117, LM317-N	NDS	TO-3	1.5A
LM317A, LM317-N	NDE	TO-220	1.5A
LM317-N	KTT	TO-263	1.5A
LM317A, LM317-N	DCY	SOT-223	1.0A
LM117, LM317A, LM317-N	NDT	TO	0.5A
LM117	NAJ	LCCC	0.5A
LM317A, LM317-N	NDP	PFM	0.5A

SOT-223 vs. PFM Packages

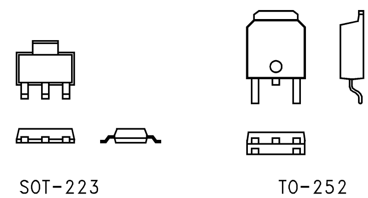
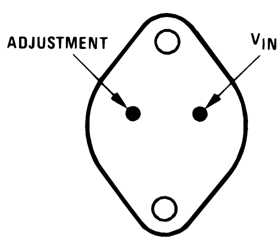


Figure 2. Scale 1:1

Connection Diagrams

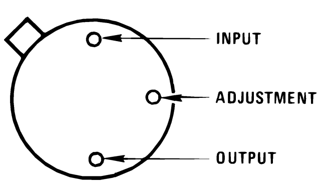
TO-3 (NDS)
Metal Can Package



CASE IS OUTPUT

Figure 3. Bottom View
Bottom View
Package Number NDS or K

TO (NDT)
Metal Can Package



CASE IS OUTPUT

Figure 4. Bottom View
Package Number NDT

Figure 5. TO-263 (KTT)
Surface-Mount Package

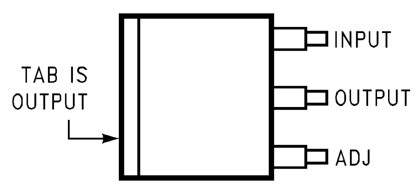


Figure 6. Top View

TO-263 (KTT)
Surface-Mount Package

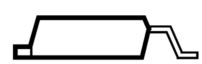


Figure 7. Side View
Package Number KTT

**TO-220 (NDE)
Plastic Package**

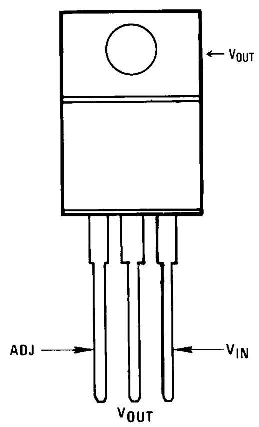


**Figure 8. Front View
Package Number NDE**

Ceramic Leadless Chip Carrier (NAJ)

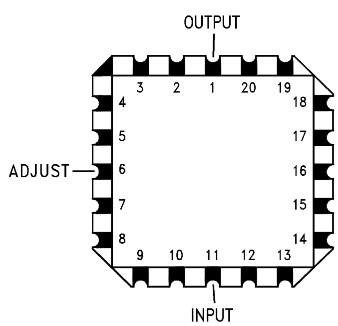


**Figure 9. Top View
Package Number NAJ**

4-Lead SOT-223 (DCY)

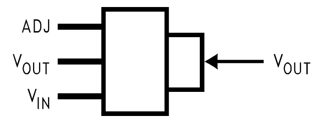


**Figure 10. Front View
Package Number DCY**

PFM (NDP)

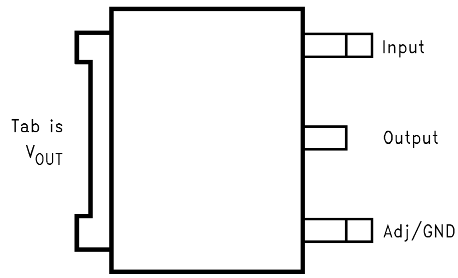


**Figure 11. Front View
Package Number NDP**

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

Absolute Maximum Ratings[(1)(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 [(3)]		3 kV

(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 ensure specific performance limits. For ensured specifications and test conditions, see the Electrical Characteristics. The ensured specifications apply only for the test conditions listed.
(2) If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/Distributors for availability and specifications.
(3) Human body model, 100 pF discharged through a 1.5 kΩ resistor.

Operating Temperature Range

LM117	$-55°C \le T_J \le +150°C$
LM317A	$-40°C \le T_J \le +125°C$
LM317-N	$0°C \le T_J \le +125°C$
Preconditioning	
Thermal Limit Burn-In	All Devices 100%

LM117 Electrical Characteristics[(1)]

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 [(2)] Min	Typ	Max	Units
Reference Voltage	$3V \le (V_{IN} - V_{OUT}) \le 40V$, $10\ mA \le I_{OUT} \le I_{MAX}$ [(1)]		**1.20**	**1.25**	**1.30**	V
Line Regulation	$3V \le (V_{IN} - V_{OUT}) \le 40V$ [(3)]			0.01 **0.02**	0.02 **0.05**	%/V
Load Regulation	$10\ mA \le I_{OUT} \le I_{MAX}$ [(1)] [(3)]			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	$10\ mA \le I_{OUT} \le I_{MAX}$ [(1)] $3V \le (V_{IN} - V_{OUT}) \le 40V$			**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	$(V_{IN} - V_{OUT}) \le 15V$	NDS Package	**1.5**	**2.2**	**3.4**	A
		NDT, NAJ Package	**0.5**	**0.8**	**1.8**	
	$(V_{IN} - V_{OUT}) = 40V$	NDS Package	0.3	0.4		A
		NDT, NAJ Package	0.15	0.20		
RMS Output Noise, % of V_{OUT}	$10\ Hz \le f \le 10\ kHz$			0.003		%

(1) I_{MAX} = 1.5A for the NDS (TO-3), NDE (TO-220), and KTT (TO-263) packages. I_{MAX} = 1.0A for the DCY (SOT-223) package. I_{MAX} = 0.5A for the NDT (TO), MDT (PFM), and NAJ (LCCC) packages. Device power dissipation (P_D) is limited by ambient temperature (T_A), device maximum junction temperature (T_J), and package thermal resistance (θ_{JA}). The maximum allowable power dissipation at any temperature is : $P_{D(MAX)} = ((T_{J(MAX)} - T_A)/\theta_{JA})$. All Min. and Max. limits are ensured to TI's Average Outgoing Quality Level (AOQL).
(2) Refer to RETS117H drawing for the LM117H, or the RETS117K for the LM117K military specifications.
(3) 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.

LM117 Electrical Characteristics[1] (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.

Parameter	Conditions	LM117 [2]			
		Min	Typ	Max	Units
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, θ_{JC} Junction-to-Case	NDS (TO-3) Package		2		°C/W
	NDT (TO) Package		21		
	NAJ (LCCC) Package		12		
Thermal Resistance, θ_{JA} Junction-to-Ambient (No Heat Sink)	NDS (TO-3) Package		39		°C/W
	NDT (TO) Package		186		
	NAJ (LCCC) Package		88		

LM317A and LM317-N Electrical Characteristics[1]

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-N			
			Min	Typ	Max	Min	Typ	Max	Units
Reference Voltage			1.238	1.250	1.262	-	1.25	-	V
	3V ≤ ($V_{IN} - V_{OUT}$) ≤ 40V, 10 mA ≤ I_{OUT} ≤ I_{MAX} [1]		**1.225**	**1.250**	**1.270**	**1.20**	**1.25**	**1.30**	V
Line Regulation	3V ≤ ($V_{IN} - V_{OUT}$) ≤ 40V [2]			0.005 **0.01**	0.01 **0.02**		0.01 **0.02**	0.04 **0.07**	%/V
Load Regulation	10 mA ≤ I_{OUT} ≤ I_{MAX} [1] [2]			0.1 **0.3**	0.5 **1**		0.1 **0.3**	0.5 **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} [1] 3V ≤ ($V_{IN} - V_{OUT}$) ≤ 40V			**0.2**	**5**		**0.2**	**5**	µA
Temperature Stability	T_{MIN} ≤ T_J ≤ 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	NDS, KTT Packages	-	-	-	**1.5**	**2.2**	**3.4**	A
		DCY, NDE Packages	**1.5**	**2.2**	**3.4**	**1.5**	**2.2**	**3.4**	
		NDT, MDT Packages	**0.5**	**0.8**	**1.8**	**0.5**	**0.8**	**1.8**	
	($V_{IN} - V_{OUT}$) = 40V	NDS, KTT Packages	-	-		0.15	0.40		A
		DCY, NDE Packages	0.112	0.30		0.112	0.30		
		NDT, MDT Packages	0.075	0.20		0.075	0.20		
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	%

(1) I_{MAX} = 1.5A for the NDS (TO-3), NDE (TO-220), and KTT (TO-263) packages. I_{MAX} = 1.0A for the DCY (SOT-223) package. I_{MAX} = 0.5A for the NDT (TO), MDT (PFM), and NAJ (LCCC) packages. Device power dissipation (P_D) is limited by ambient temperature (T_A), device maximum junction temperature (T_J), and package thermal resistance (θ_{JA}). The maximum allowable power dissipation at any temperature is : $P_{D(MAX)} = ((T_{J(MAX)} - T_A)/\theta_{JA})$. All Min. and Max. limits are ensured to TI's Average Outgoing Quality Level (AOQL).

(2) 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.

LM317A and LM317-N Electrical Characteristics[(1)] (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.

Parameter	Conditions	LM317A			LM317-N			
		Min	Typ	Max	Min	Typ	Max	Units
Thermal Resistance, θ_{JC} Junction-to-Case	NDS (TO-3) Package		-			2		°C/W
	NDE (TO-220) Package		4			4		
	KTT (TO-263) Package		-			4		
	DCY (SOT-223) Package		23.5			23.5		
	NDT (TO) Package		21			21		
	MDT (PFM) Package		12			12		
Thermal Resistance, θ_{JA} Junction-to-Ambient (No Heat Sink)	NDS (TO-3) Package		-			39		°C/W
	NDE (TO-220) Package		50			50		
	KTT (TO-263) Package [(3)]		-			50		
	DCY (SOT-223) Package [(3)]		140			140		
	NDT (TO) Package		186			186		
	MDT (PFM) Package [(3)]		103			103		

(3) When surface mount packages are used (TO-263, SOT-223, PFM), the junction to ambient thermal resistance can be reduced by increasing the PC board copper area that is thermally connected to the package. See the Applications Hints section for heatsink techniques.

Typical Performance Characteristics

Output Capacitor = 0 μF unless otherwise noted

Load Regulation

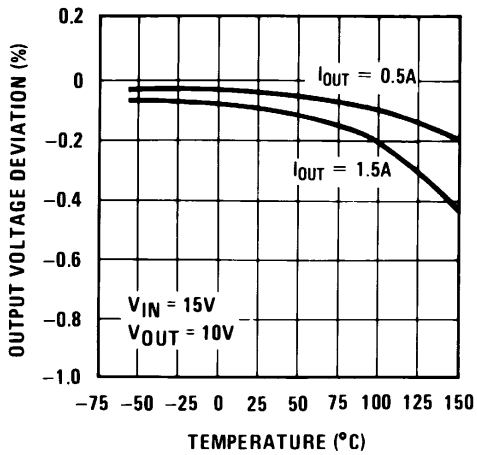


Figure 12.

Current Limit

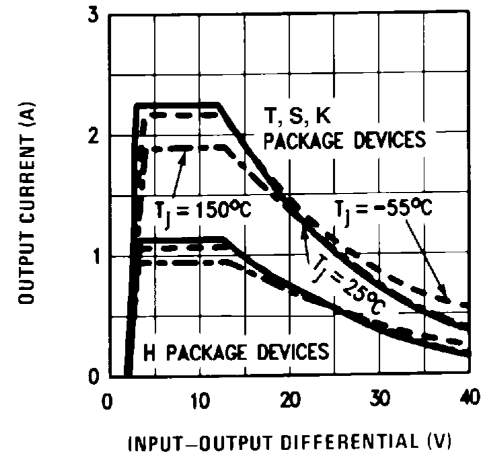


Figure 13.

Adjustment Current

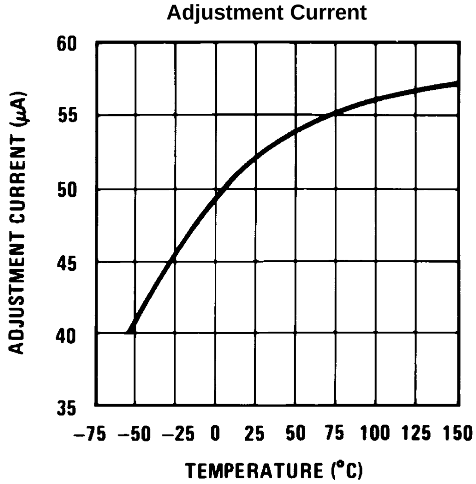


Figure 14.

Dropout Voltage

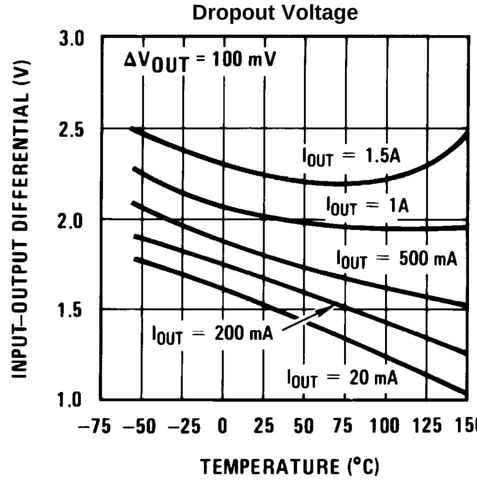


Figure 15.

V_{OUT} vs V_{IN}, V_{OUT} = V_{REF}

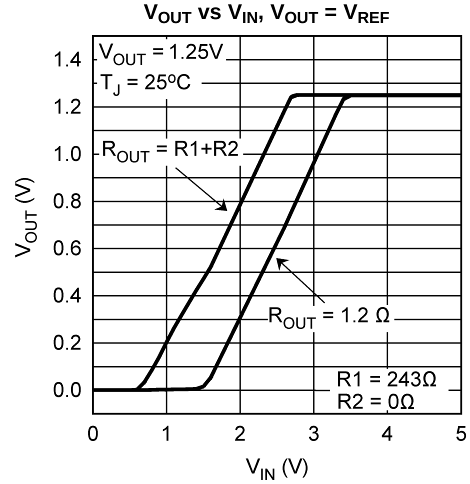


Figure 16.

V_{OUT} vs V_{IN}, V_{OUT} = 5V

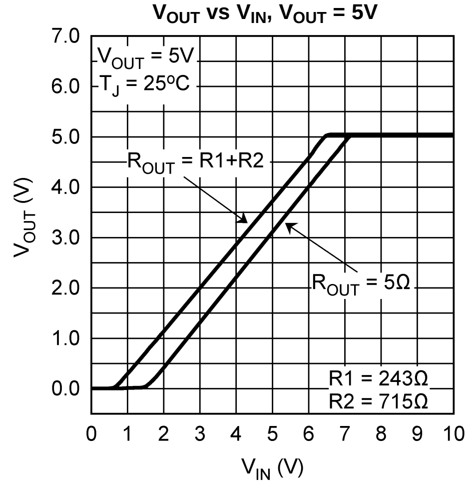


Figure 17.

Typical Performance Characteristics (continued)

Output Capacitor = 0 μF unless otherwise noted

Temperature Stability

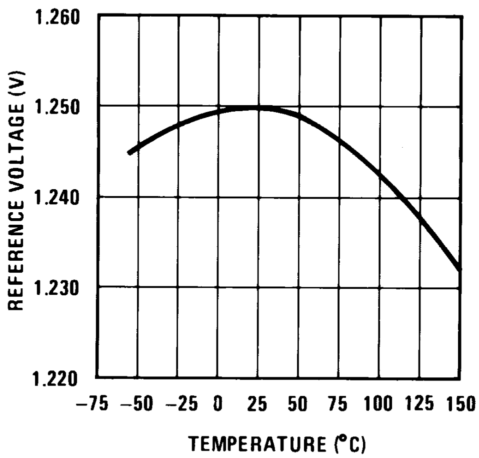


Figure 18.

Minimum Operating Current

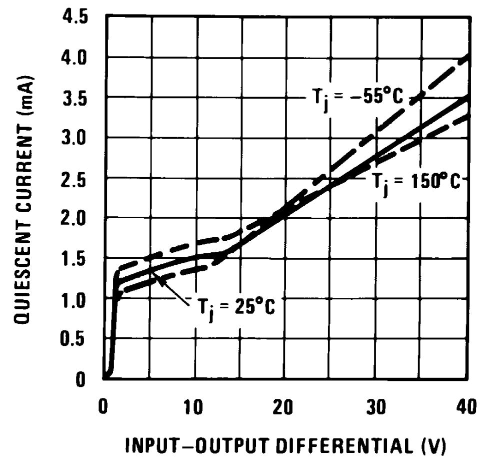


Figure 19.

Ripple Rejection

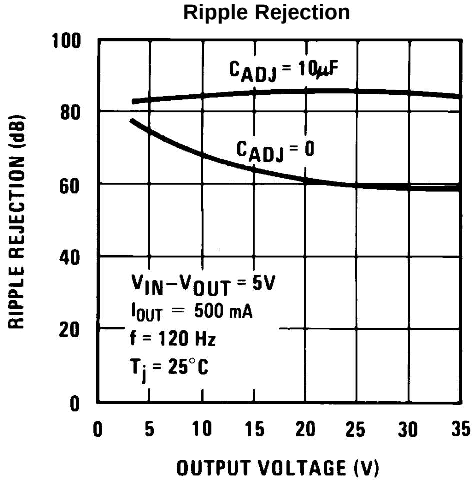


Figure 20.

Ripple Rejection

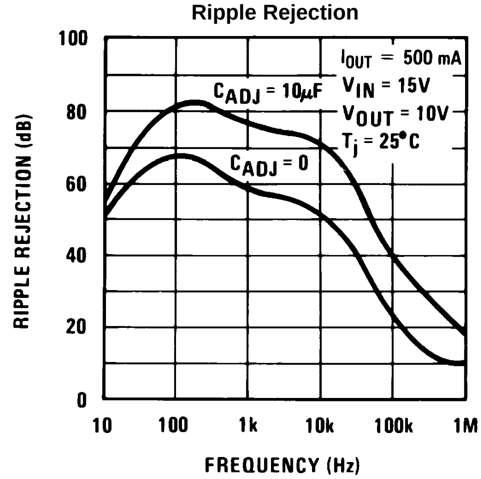


Figure 21.

Ripple Rejection

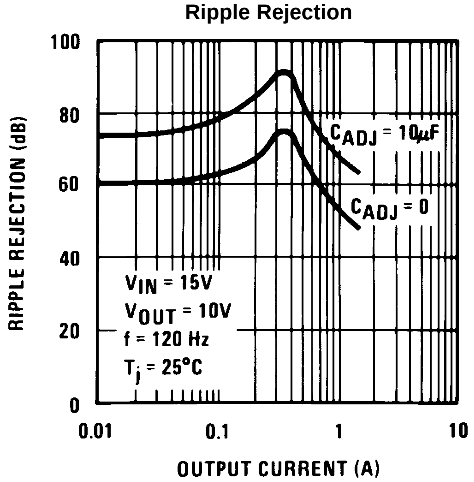


Figure 22.

Output Impedance

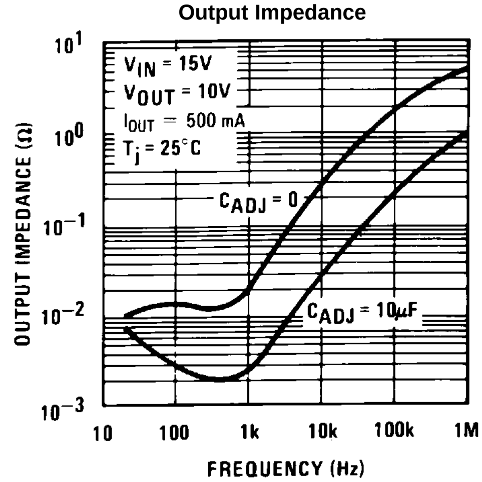


Figure 23.

Typical Performance Characteristics (continued)

Output Capacitor = 0 μF unless otherwise noted

Line Transient Response

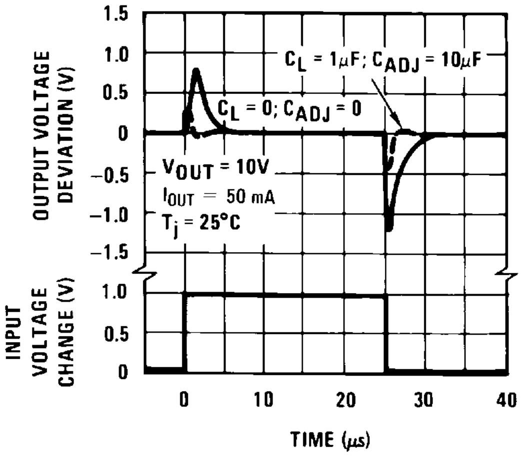


Figure 24.

Load Transient Response

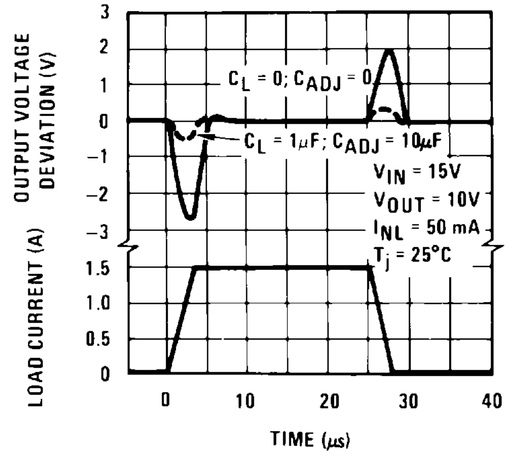
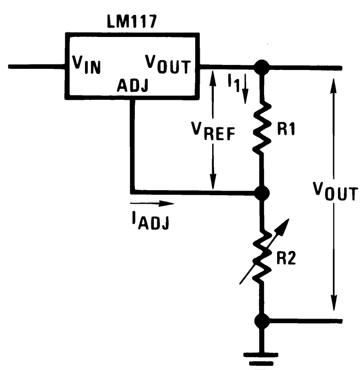


Figure 25.

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

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



Since the 100μA 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 0.1μF 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 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 80dB ripple rejection is obtainable at any output level. Increases over 10 μF 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 25 μF 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 0.5 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 × 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 26 shows the effect of resistance between the regulator and 240Ω set resistor.

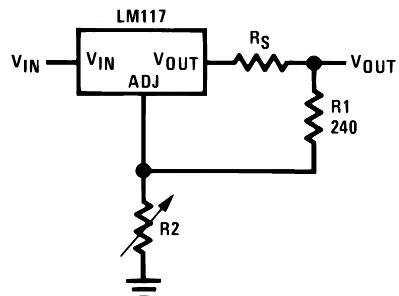


Figure 26. Regulator with Line Resistance in Output Lead

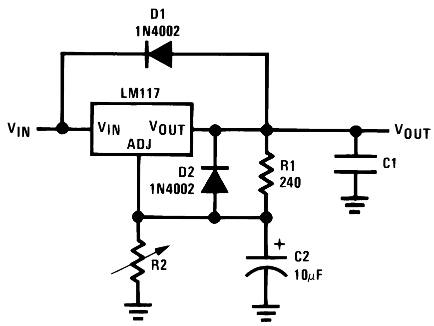
With the TO-3 package, it is easy to minimize the resistance from the case to the set resistor, by using two separate leads to the case. However, with the TO package, care should be taken to minimize the wire length of the output lead. The ground of R2 can be returned near the ground of the load to provide 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 the 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 27* 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 27. Regulator with Protection Diodes

Heatsink Requirements

The LM317-N regulators have internal thermal shutdown to protect the device from over-heating. Under all operating conditions, the junction temperature of the LM317-N should not exceed the rated maximum junction temperature (T_J) of 150°C for the LM117, or 125°C for the LM317A and LM317-N. A heatsink may be required depending on the maximum device power dissipation and the maximum ambient temperature of the application. To determine if a heatsink is needed, the power dissipated by the regulator, P_D, must be calculated:

$$P_D = ((V_{IN} - V_{OUT}) \times I_L) + (V_{IN} \times I_G) \quad (2)$$

Figure 28 shows the voltage and currents which are present in the circuit.

The next parameter which must be calculated is the maximum allowable temperature rise, $T_{R(MAX)}$:

$$T_{R(MAX)} = T_{J(MAX)} - T_{A(MAX)} \quad (3)$$

where $T_{J(MAX)}$ is the maximum allowable junction temperature (150°C for the LM117, or 125°C for the LM317A/LM317-N), 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:

$$\theta_{JA} = (T_{R(MAX)} / P_D) \quad (4)$$

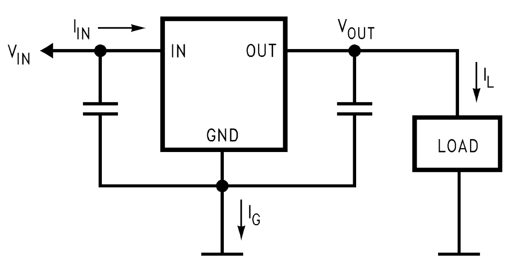


Figure 28. Power Dissipation Diagram

If the calculated maximum allowable thermal resistance is higher than the actual package rating, then no additional work is needed. If the calculated maximum allowable thermal resistance is lower than the actual package rating either the power dissipation (P_D) needs to be reduced, the maximum ambient temperature $T_{A(MAX)}$ needs to be reduced, the thermal resistance (θ_{JA}) must be lowered by adding a heatsink, or some combination of these.

If a heatsink is needed, the value can be calculated from the formula:

$$\theta_{HA} \le (\theta_{JA} - (\theta_{CH} + \theta_{JC})) \quad (5)$$

where (θ_{CH} is the thermal resistance of the contact area between the device case and the heatsink surface, and θ_{JC} is thermal resistance from the junction of the die to surface of the package case.

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.

The $\theta_{(H-A)}$ rating 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 Surface Mount Packages

The TO-263 (KTT), SOT-223 (DCY) and PFM (MDT) 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.

Heatsinking the SOT-223 Package

Figure 29 and Figure 30 show the information for the SOT-223 package. Figure 30 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. Please see AN-1028 (literature number SNVA036) for thermal enhancement techniques to be used with SOT-223 and PFM packages.

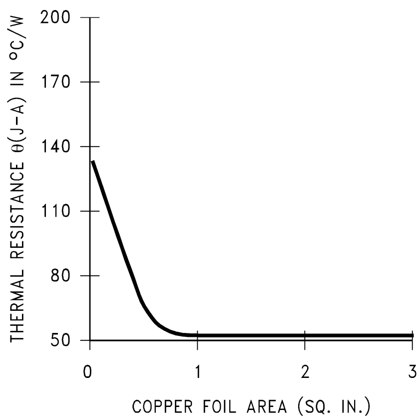


Figure 29. $\theta_{(J-A)}$ vs Copper (2 ounce) Area for the SOT-223 Package

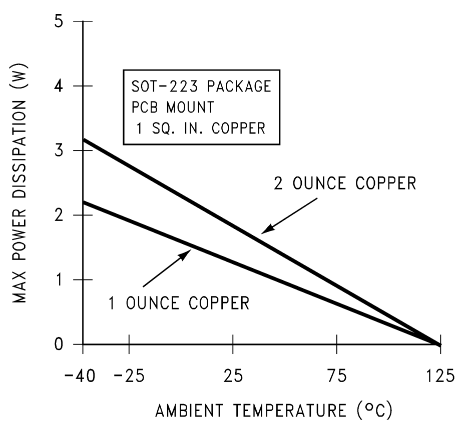


Figure 30. Maximum Power Dissipation vs T_{AMB} for the SOT-223 Package

Heatsinking the TO-263 Package

Figure 31 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.

As shown in Figure 31, 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.

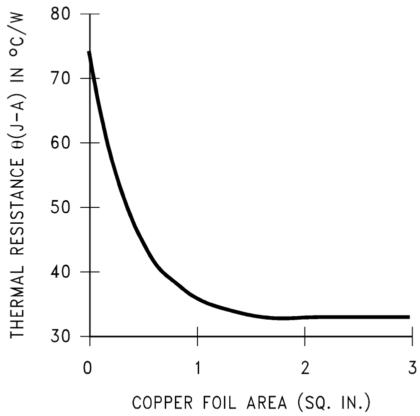


Figure 31. $\theta_{(J-A)}$ vs Copper (1 ounce) Area for the TO-263 Package

As a design aid, Figure 32 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).

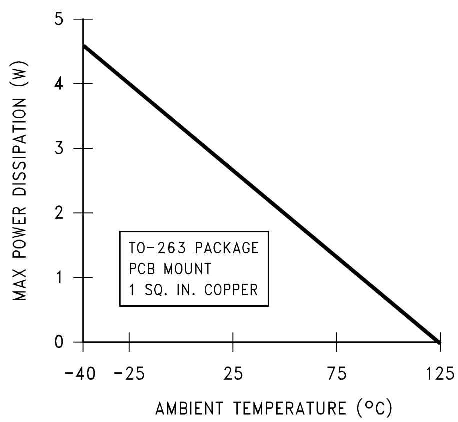


Figure 32. Maximum Power Dissipation vs T_{AMB} for the TO-263 Package

Heatsinking the PFM Package

If the maximum allowable value for θ_{JA} is found to be ≥103°C/W (Typical Rated Value) for PFM 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 PFM for different heatsink area. The copper patterns that we used to measure these θ_{JA}s are shown in Figure 37. Figure 33 reflects the same test results as what are in Table 1.

Figure 34 shows the maximum allowable power dissipation vs. ambient temperature for the PFM device. Figure 35 shows the maximum allowable power dissipation vs. copper area (in^2) for the PFM device. Please see AN-1028 (literature number SNVA036) for thermal enhancement techniques to be used with SOT-223 and PFM packages.

Table 1. θ_{JA} Different Heatsink Area

Layout	Copper Area		Thermal Resistance (θ_{JA}°C/W) PFM
	Top Side (in^2)(1)	Bottom Side (in^2)	
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	0	47
7	0.066	0.2	84
8	0.066	0.4	70
9	0.066	0.6	63
10	0.066	0.8	57
11	0.066	1.0	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

(1) Tab of device attached to topside of copper.

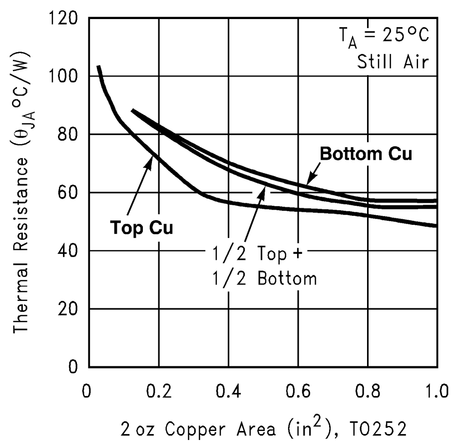


Figure 33. θ_{JA} vs 2oz Copper Area for PFM

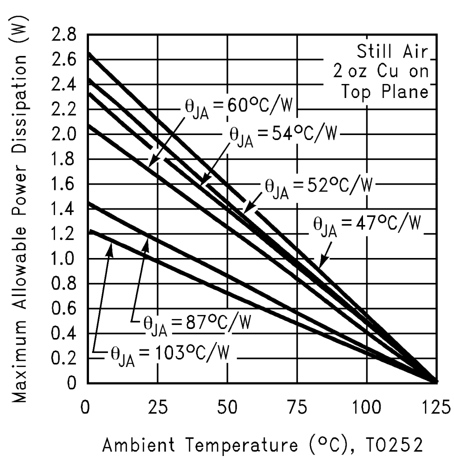


Figure 34. Maximum Allowable Power Dissipation vs. Ambient Temperature for PFM

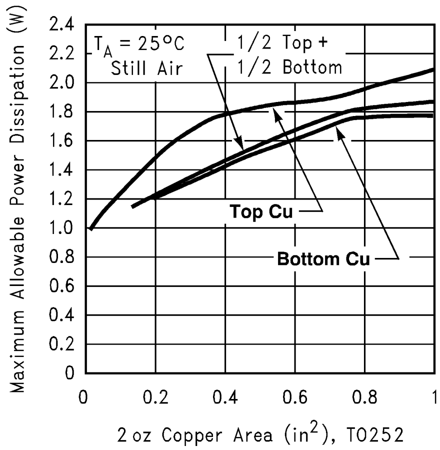


Figure 35. Maximum Allowable Power Dissipation vs. 2oz Copper Area for PFM

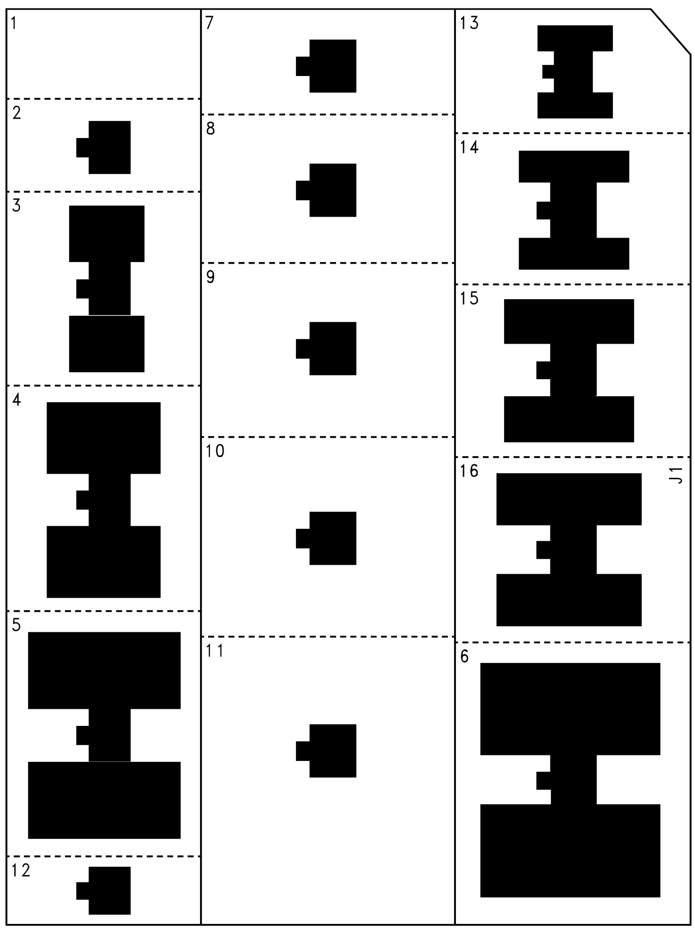


Figure 36. Top View of the Thermal Test Pattern in Actual Scale

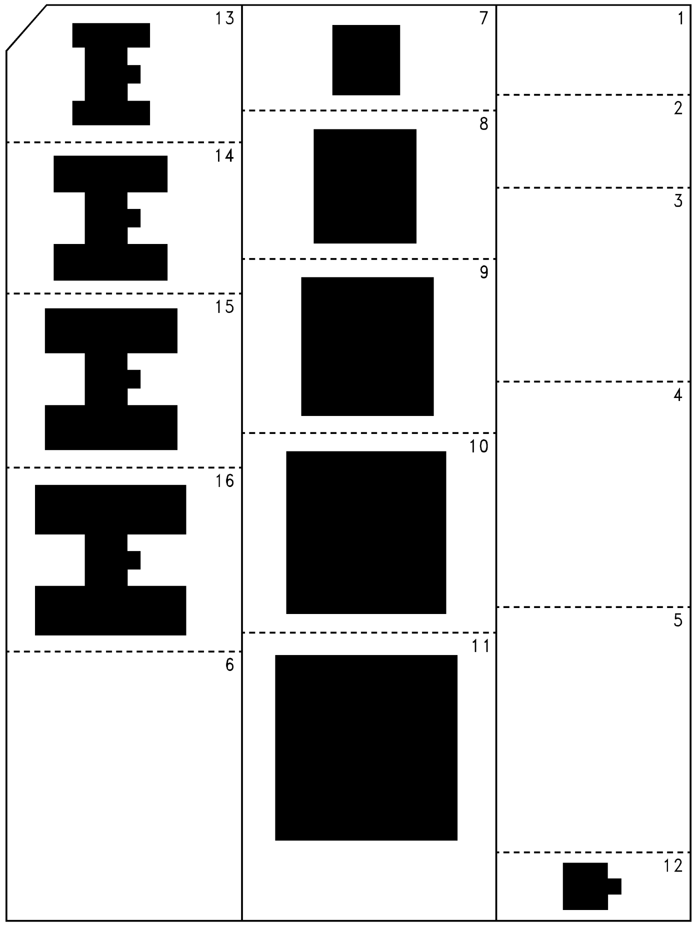
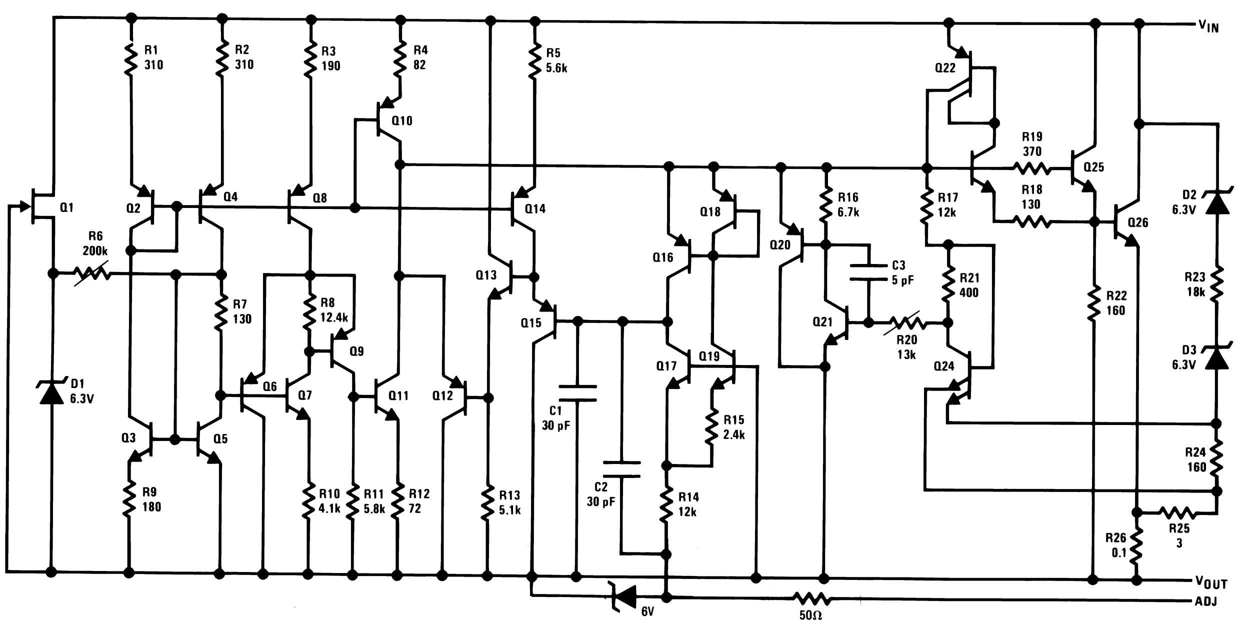
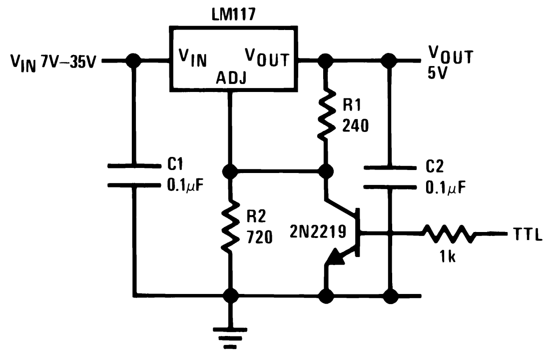


Figure 37. Bottom View of the Thermal Test Pattern in Actual Scale

Schematic Diagram



Typical Applications



Note: Min. output ≅ 1.2V

Figure 38. 5V Logic Regulator with Electronic Shutdown

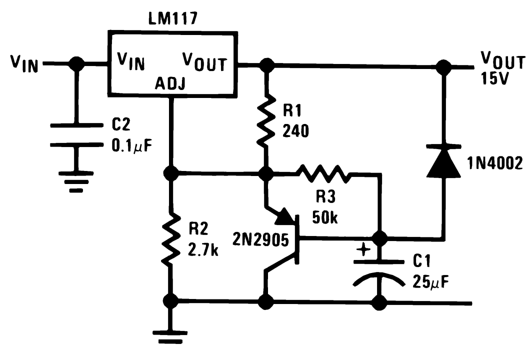
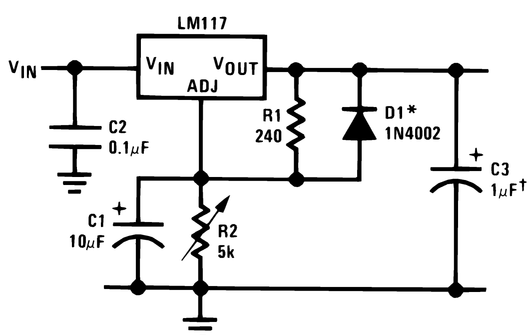


Figure 39. Slow Turn-On 15V Regulator

Figure 40.



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

Figure 41. Adjustable Regulator with Improved Ripple Rejection

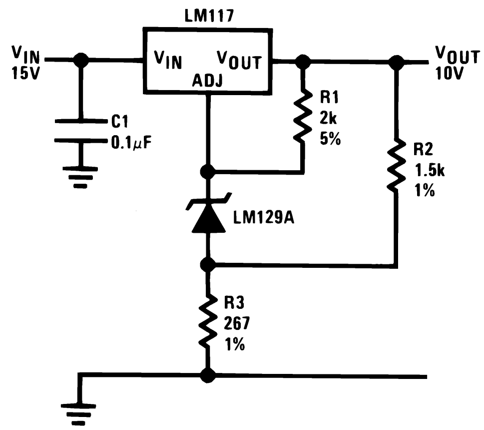
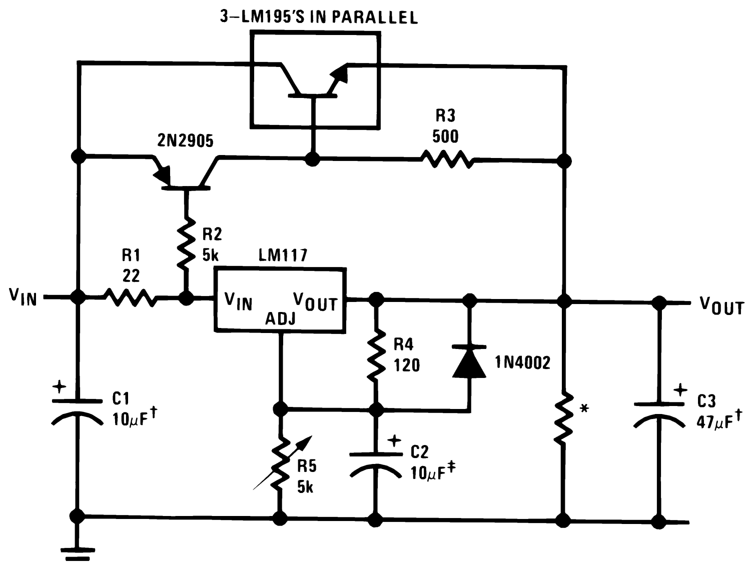
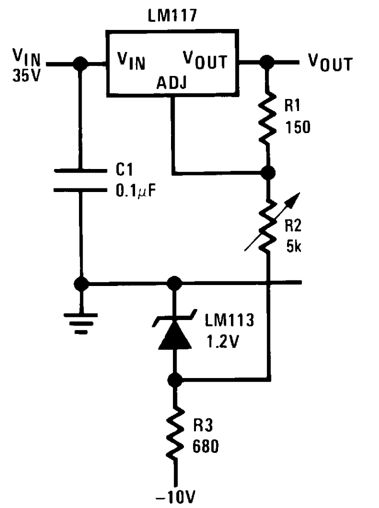


Figure 42. High Stability 10V Regulator



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

Figure 43. High Current Adjustable Regulator



Full output current not available at high input-output voltages

Figure 44. 0 to 30V Regulator

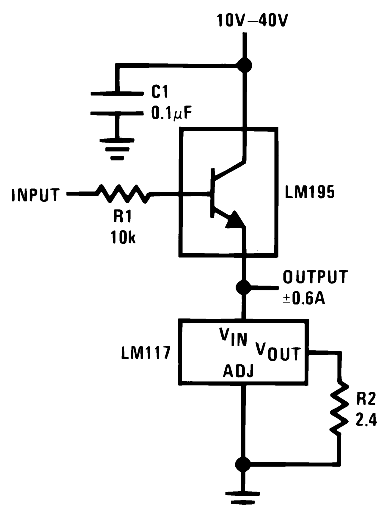
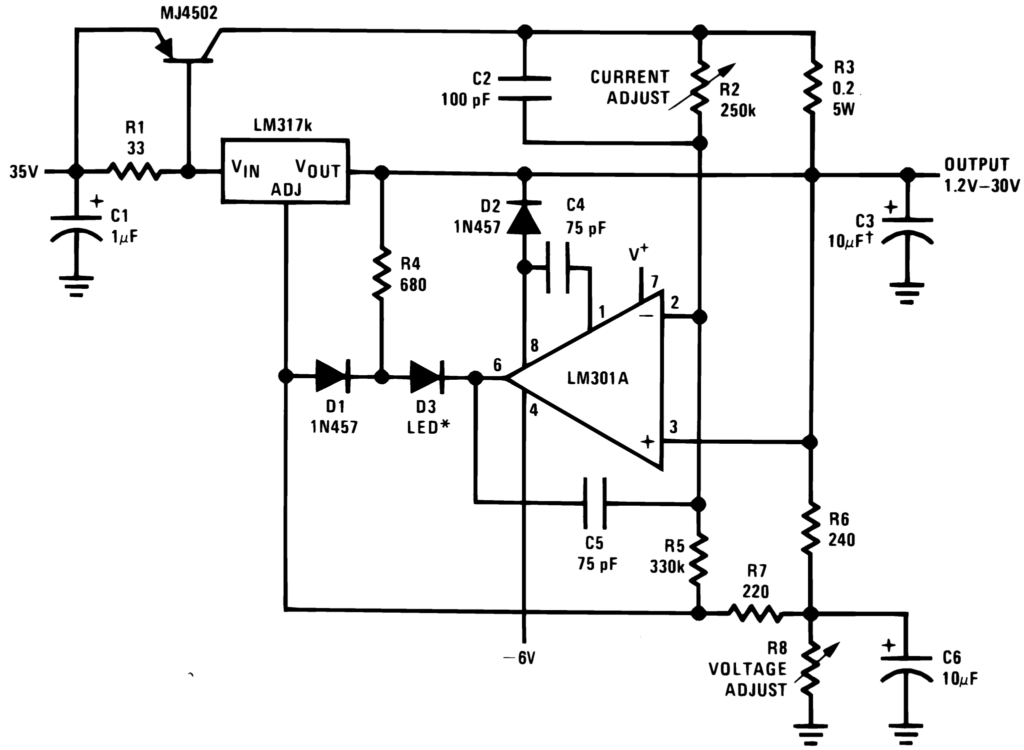


Figure 45. Power Follower



†Solid tantalum
*Lights in constant current mode

Figure 46. 5A Constant Voltage/Constant Current Regulator

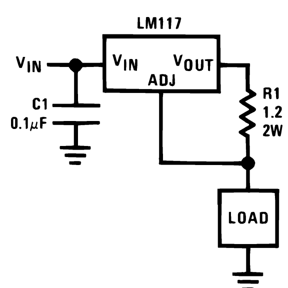
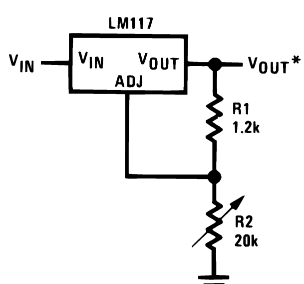


Figure 47. 1A Current Regulator



*Minimum load current ≅ 4 mA

Figure 48. 1.2V–20V Regulator with Minimum Program Current

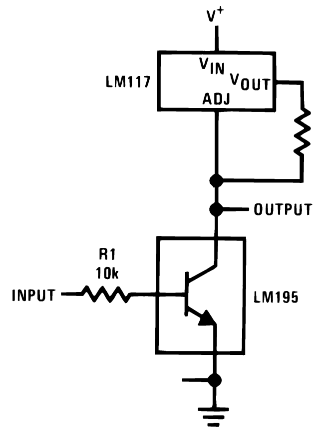
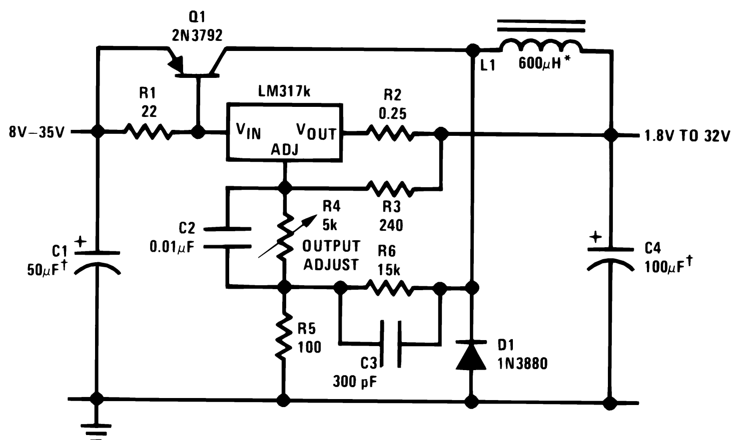
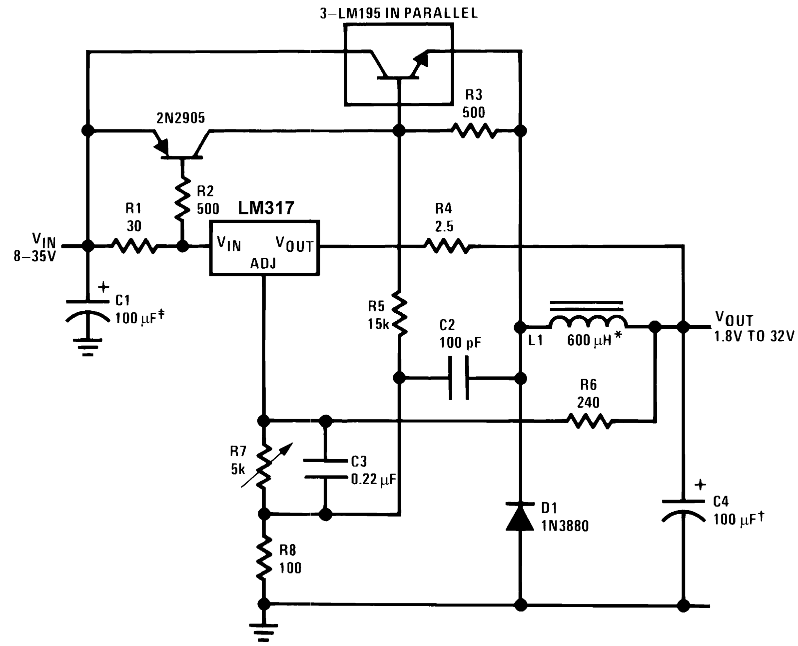


Figure 49. High Gain Amplifier



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

Figure 50. Low Cost 3A Switching Regulator



†Solid tantalum

*Core—Arnold A-254168-2 60 turns

Figure 51. 4A Switching Regulator with Overload Protection

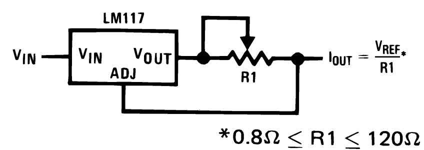


Figure 52. Precision Current Limiter

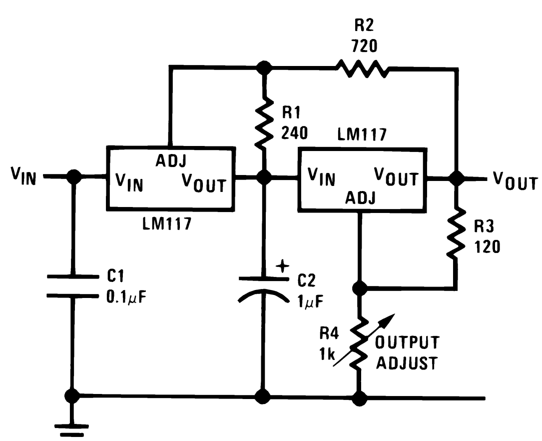
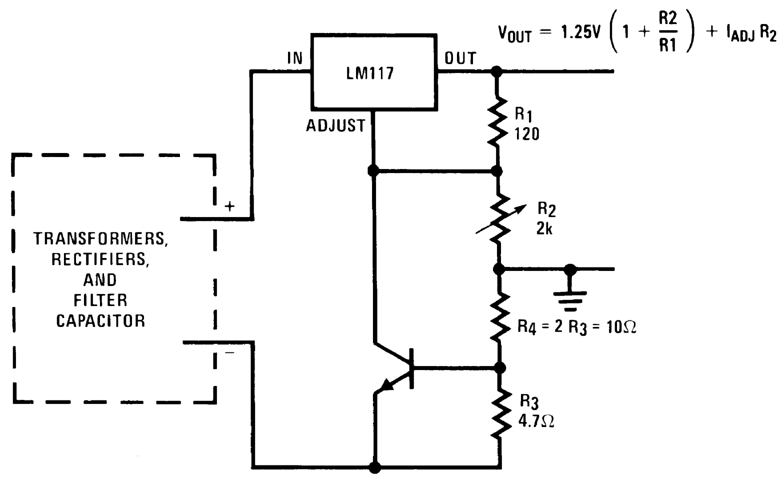


Figure 53. Tracking Preregulator

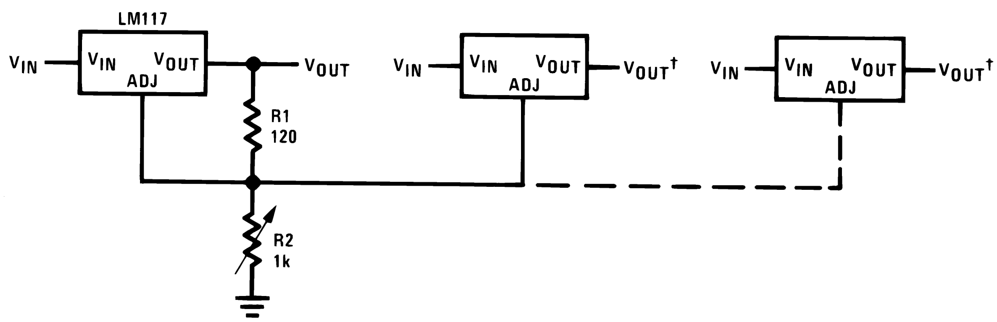


– Short circuit current is approximately $\frac{600\text{ mV}}{R3}$, or 120 mA

(Compared to LM117's higher current limit)

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

Figure 54. Current Limited Voltage Regulator



Note: All outputs within ±100 mV

†Minimum load—10 mA

Figure 55. Adjusting Multiple On-Card Regulators with Single Control

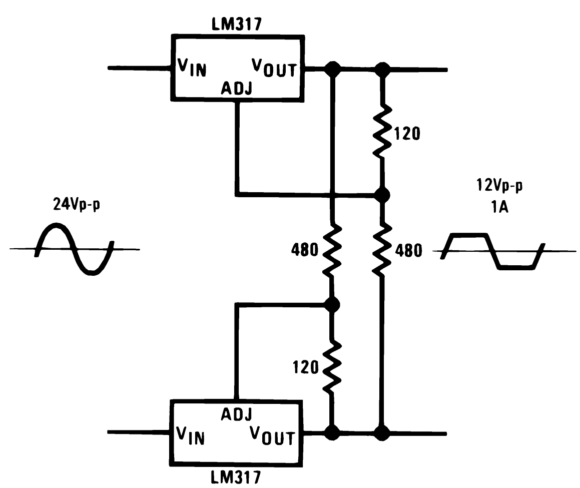
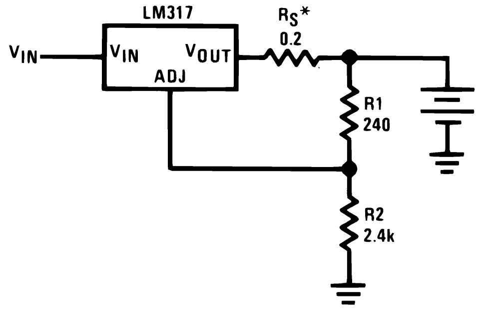


Figure 56. AC Voltage Regulator



*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.

Figure 57. 12V Battery Charger

Figure 58.

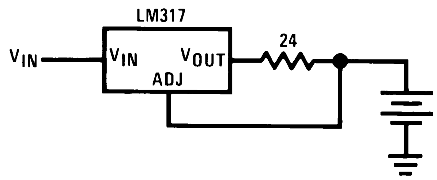


Figure 59. 50mA Constant Current Battery Charger

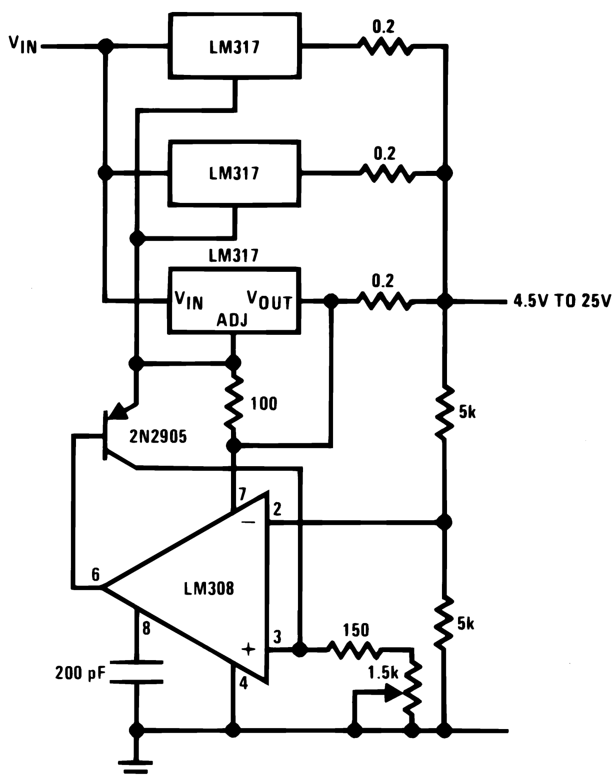
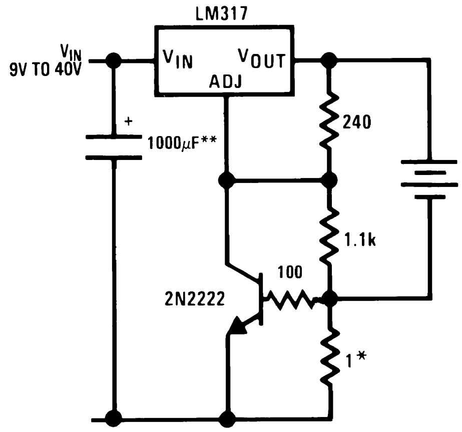


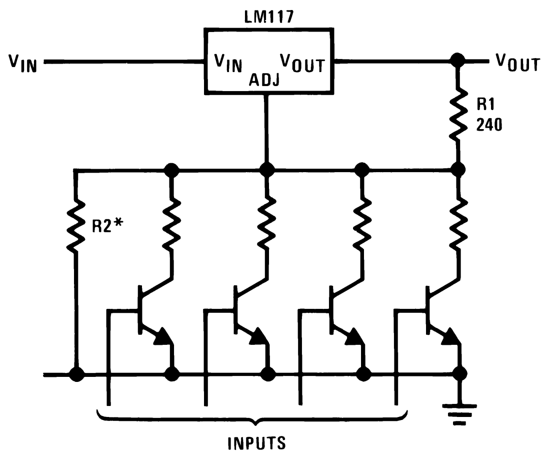
Figure 60. Adjustable 4A Regulator



*Sets peak current (0.6A for 1Ω)

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

Figure 61. Current Limited 6V Charger



*Sets maximum V_{OUT}

Figure 62. Digitally Selected Outputs

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LM117H	ACTIVE	TO	NDT	3	500	Green (RoHS & no Sb/Br)	POST-PLATE	Level-1-NA-UNLIM	-55 to 125	LM117HP+	Samples
LM117H/NOPB	ACTIVE	TO	NDT	3	500	Green (RoHS & no Sb/Br)	POST-PLATE	Level-1-NA-UNLIM	-55 to 125	LM117HP+	Samples
LM117K	ACTIVE	TO-3	NDS	2	50	TBD	Call TI	Call TI	-55 to 125	LM117K STEELP+	Samples
LM117K STEEL	ACTIVE	TO-3	NDS	2	50	TBD	Call TI	Call TI	-55 to 125	LM117K STEELP+	Samples
LM117K STEEL/NOPB	ACTIVE	TO-3	NDS	2	50	Green (RoHS & no Sb/Br)	POST-PLATE	Level-1-NA-UNLIM	-55 to 125	LM117K STEELP+	Samples
LM317AEMP	ACTIVE	SOT-223	DCY	4	1000	TBD	Call TI	Call TI	-40 to 125	N07A	Samples
LM317AEMP/NOPB	ACTIVE	SOT-223	DCY	4	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	N07A	Samples
LM317AEMPX	ACTIVE	SOT-223	DCY	4	2000	TBD	Call TI	Call TI		N07A	Samples
LM317AEMPX/NOPB	ACTIVE	SOT-223	DCY	4	2000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	N07A	Samples
LM317AH	ACTIVE	TO	NDT	3	500	Green (RoHS & no Sb/Br)	POST-PLATE	Level-1-NA-UNLIM	-40 to 125	LM317AHP+	Samples
LM317AH/NOPB	ACTIVE	TO	NDT	3	500	Green (RoHS & no Sb/Br)	POST-PLATE	Level-1-NA-UNLIM	-40 to 125	LM317AHP+	Samples
LM317AMDT	ACTIVE	TO-252	NDP	3	75	TBD	Call TI	Call TI	-40 to 125	LM317 AMDT	Samples
LM317AMDT/NOPB	ACTIVE	TO-252	NDP	3	75	Green (RoHS & no Sb/Br)	CU SN	Level-2-260C-1 YEAR	-40 to 125	LM317 AMDT	Samples
LM317AMDTX	ACTIVE	TO-252	NDP	3	2500	TBD	Call TI	Call TI	-40 to 125	LM317 AMDT	Samples
LM317AMDTX/NOPB	ACTIVE	TO-252	NDP	3	2500	Green (RoHS & no Sb/Br)	CU SN	Level-2-260C-1 YEAR	-40 to 125	LM317 AMDT	Samples
LM317AT	ACTIVE	TO-220	NDE	3	45	TBD	Call TI	Call TI	-40 to 125	LM317AT P+	Samples
LM317AT/NOPB	ACTIVE	TO-220	NDE	3	45	Pb-Free (RoHS Exempt)	CU SN	Level-1-NA-UNLIM	-40 to 125	LM317AT P+	Samples
LM317EMP	ACTIVE	SOT-223	DCY	4	1000	TBD	Call TI	Call TI	0 to 125	N01A	Samples

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LM317EMP/NOPB	ACTIVE	SOT-223	DCY	4	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	0 to 125	N01A	Samples
LM317EMPX/NOPB	ACTIVE	SOT-223	DCY	4	2000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	0 to 125	N01A	Samples
LM317H	ACTIVE	TO	NDT	3	500	Green (RoHS & no Sb/Br)	POST-PLATE	Level-1-NA-UNLIM	0 to 125	LM317HP+	Samples
LM317H/NOPB	ACTIVE	TO	NDT	3	500	Green (RoHS & no Sb/Br)	POST-PLATE	Level-1-NA-UNLIM	0 to 125	LM317HP+	Samples
LM317K STEEL	ACTIVE	TO-3	NDS	2	50	TBD	Call TI	Call TI	0 to 125	LM317K STEELP+	Samples
LM317K STEEL/NOPB	ACTIVE	TO-3	NDS	2	50	Green (RoHS & no Sb/Br)	POST-PLATE	Level-1-NA-UNLIM	0 to 125	LM317K STEELP+	Samples
LM317MDT/NOPB	ACTIVE	TO-252	NDP	3	75	Green (RoHS & no Sb/Br)	CU SN	Level-2-260C-1 YEAR	0 to 125	LM317 MDT	Samples
LM317MDTX/NOPB	ACTIVE	TO-252	NDP	3	2500	Green (RoHS & no Sb/Br)	CU SN	Level-2-260C-1 YEAR	0 to 125	LM317 MDT	Samples
LM317S/NOPB	ACTIVE	DDPAK/ TO-263	KTT	3	45	Pb-Free (RoHS Exempt)	CU SN	Level-3-245C-168 HR	0 to 125	LM317S P+	Samples
LM317SX/NOPB	ACTIVE	DDPAK/ TO-263	KTT	3	500	Pb-Free (RoHS Exempt)	CU SN	Level-3-245C-168 HR	0 to 125	LM317S P+	Samples
LM317T	ACTIVE	TO-220	NDE	3	45	TBD	Call TI	Call TI		LM317T P+	Samples
LM317T/LF01	ACTIVE	TO-220	NDG	3	45	Pb-Free (RoHS Exempt)	CU SN	Level-4-260C-72 HR		LM317T P+	Samples
LM317T/NOPB	ACTIVE	TO-220	NDE	3	45	Green (RoHS & no Sb/Br)	CU SN	Level-1-NA-UNLIM	0 to 125	LM317T P+	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.

Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

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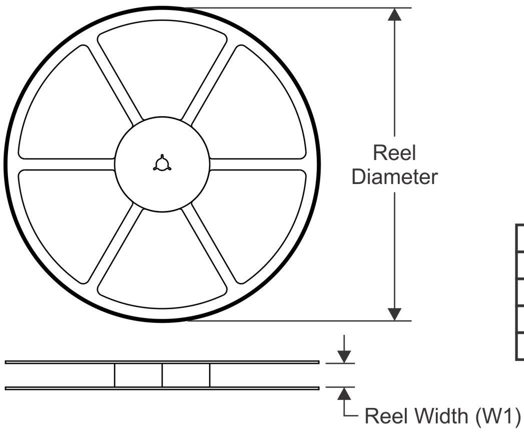
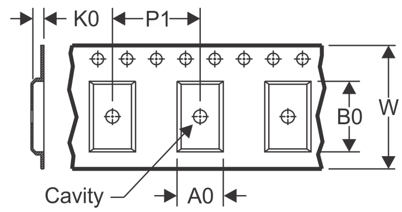
TAPE AND REEL INFORMATION

REEL DIMENSIONS

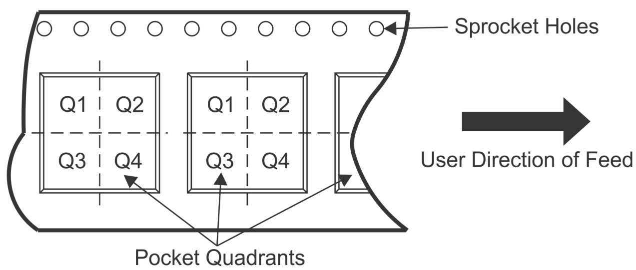


TAPE DIMENSIONS



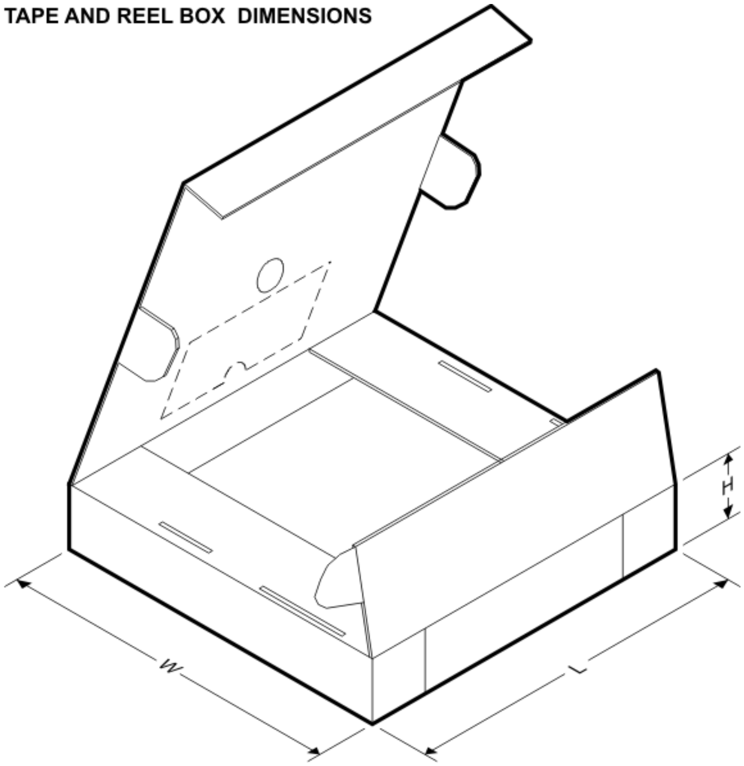
A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

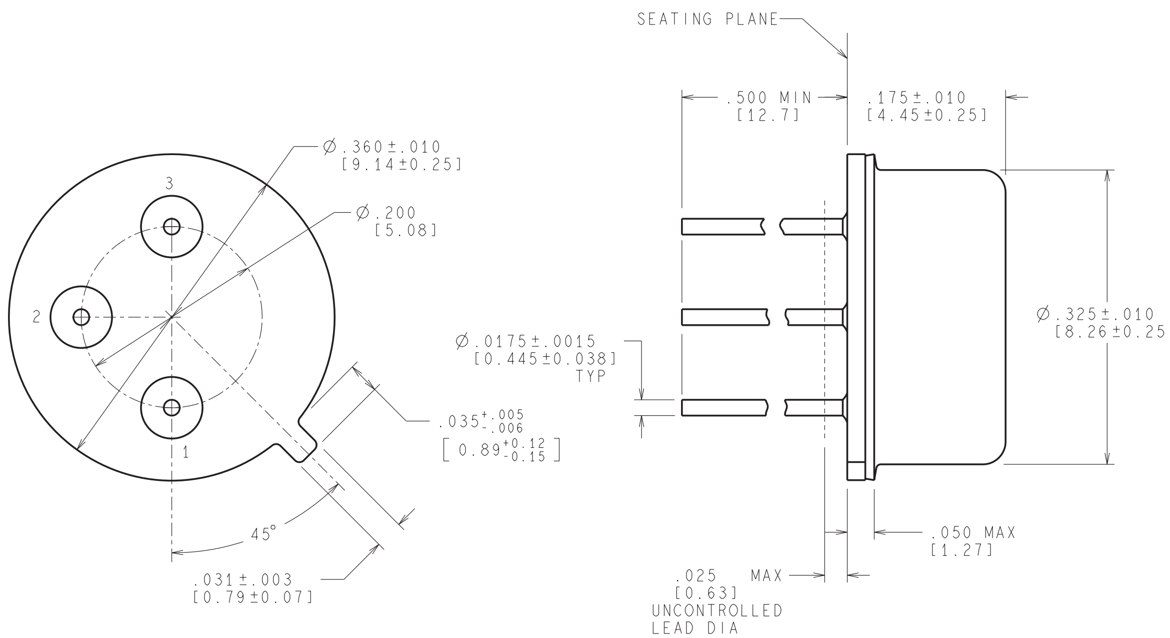
Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LM317AEMP	SOT-223	DCY	4	1000	330.0	16.4	7.0	7.5	2.2	12.0	16.0	Q3
LM317AEMP/NOPB	SOT-223	DCY	4	1000	330.0	16.4	7.0	7.5	2.2	12.0	16.0	Q3
LM317AEMPX	SOT-223	DCY	4	2000	330.0	16.4	7.0	7.5	2.2	12.0	16.0	Q3
LM317AEMPX/NOPB	SOT-223	DCY	4	2000	330.0	16.4	7.0	7.5	2.2	12.0	16.0	Q3
LM317AMDTX	TO-252	NDP	3	2500	330.0	16.4	6.9	10.5	2.7	8.0	16.0	Q2
LM317AMDTX/NOPB	TO-252	NDP	3	2500	330.0	16.4	6.9	10.5	2.7	8.0	16.0	Q2
LM317EMP	SOT-223	DCY	4	1000	330.0	16.4	7.0	7.5	2.2	12.0	16.0	Q3
LM317EMP/NOPB	SOT-223	DCY	4	1000	330.0	16.4	7.0	7.5	2.2	12.0	16.0	Q3
LM317EMPX/NOPB	SOT-223	DCY	4	2000	330.0	16.4	7.0	7.5	2.2	12.0	16.0	Q3
LM317MDTX/NOPB	TO-252	NDP	3	2500	330.0	16.4	6.9	10.5	2.7	8.0	16.0	Q2
LM317SX/NOPB	DDPAK/ TO-263	KTT	3	500	330.0	24.4	10.75	14.85	5.0	16.0	24.0	Q2



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM317AEMP	SOT-223	DCY	4	1000	367.0	367.0	35.0
LM317AEMP/NOPB	SOT-223	DCY	4	1000	367.0	367.0	35.0
LM317AEMPX	SOT-223	DCY	4	2000	367.0	367.0	35.0
LM317AEMPX/NOPB	SOT-223	DCY	4	2000	367.0	367.0	35.0
LM317AMDTX	TO-252	NDP	3	2500	367.0	367.0	35.0
LM317AMDTX/NOPB	TO-252	NDP	3	2500	367.0	367.0	38.0
LM317EMP	SOT-223	DCY	4	1000	367.0	367.0	35.0
LM317EMP/NOPB	SOT-223	DCY	4	1000	367.0	367.0	35.0
LM317EMPX/NOPB	SOT-223	DCY	4	2000	367.0	367.0	35.0
LM317MDTX/NOPB	TO-252	NDP	3	2500	367.0	367.0	38.0
LM317SX/NOPB	DDPAK/TO-263	KTT	3	500	367.0	367.0	45.0

NDT0003A

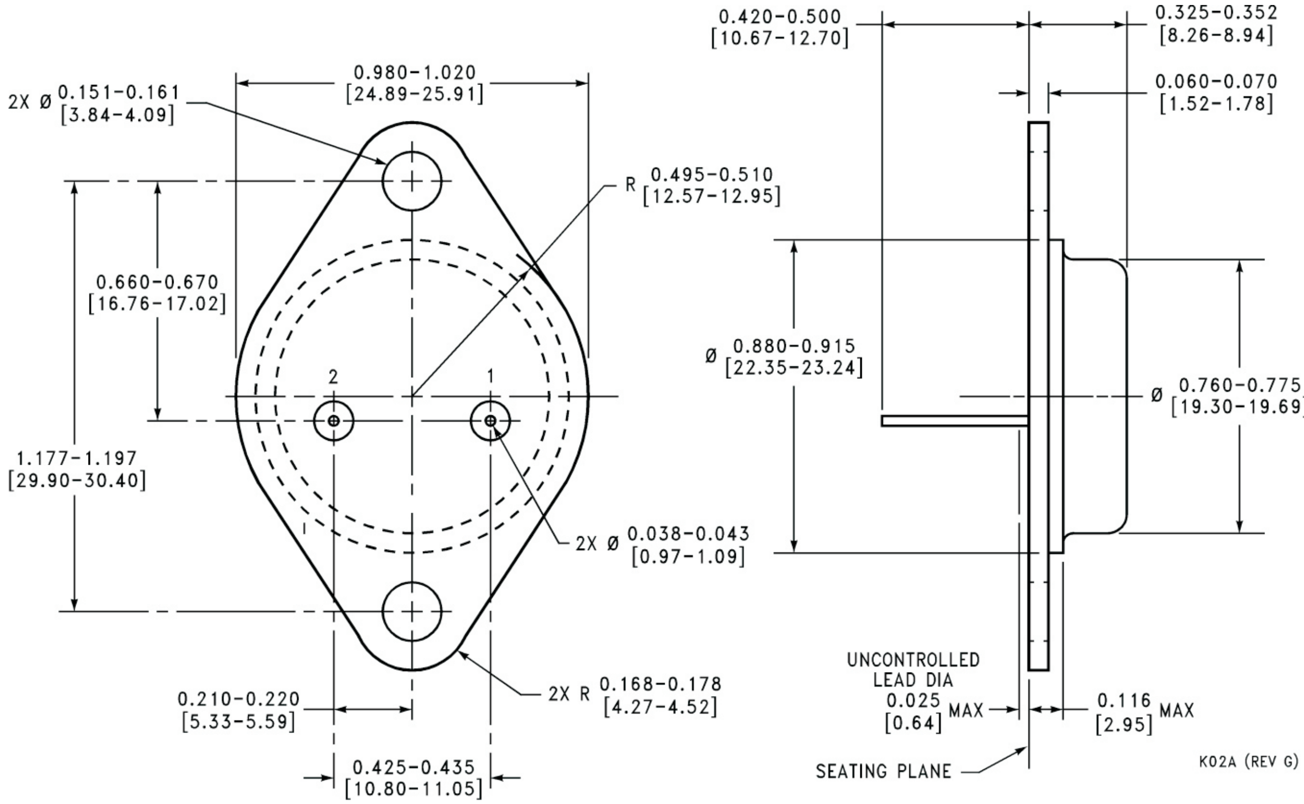


CONTROLLING DIMENSION IS INCH
VALUES IN [ ] ARE MILLIMETERS

MIL-PRF-38535
CONFIGURATION CONTROL

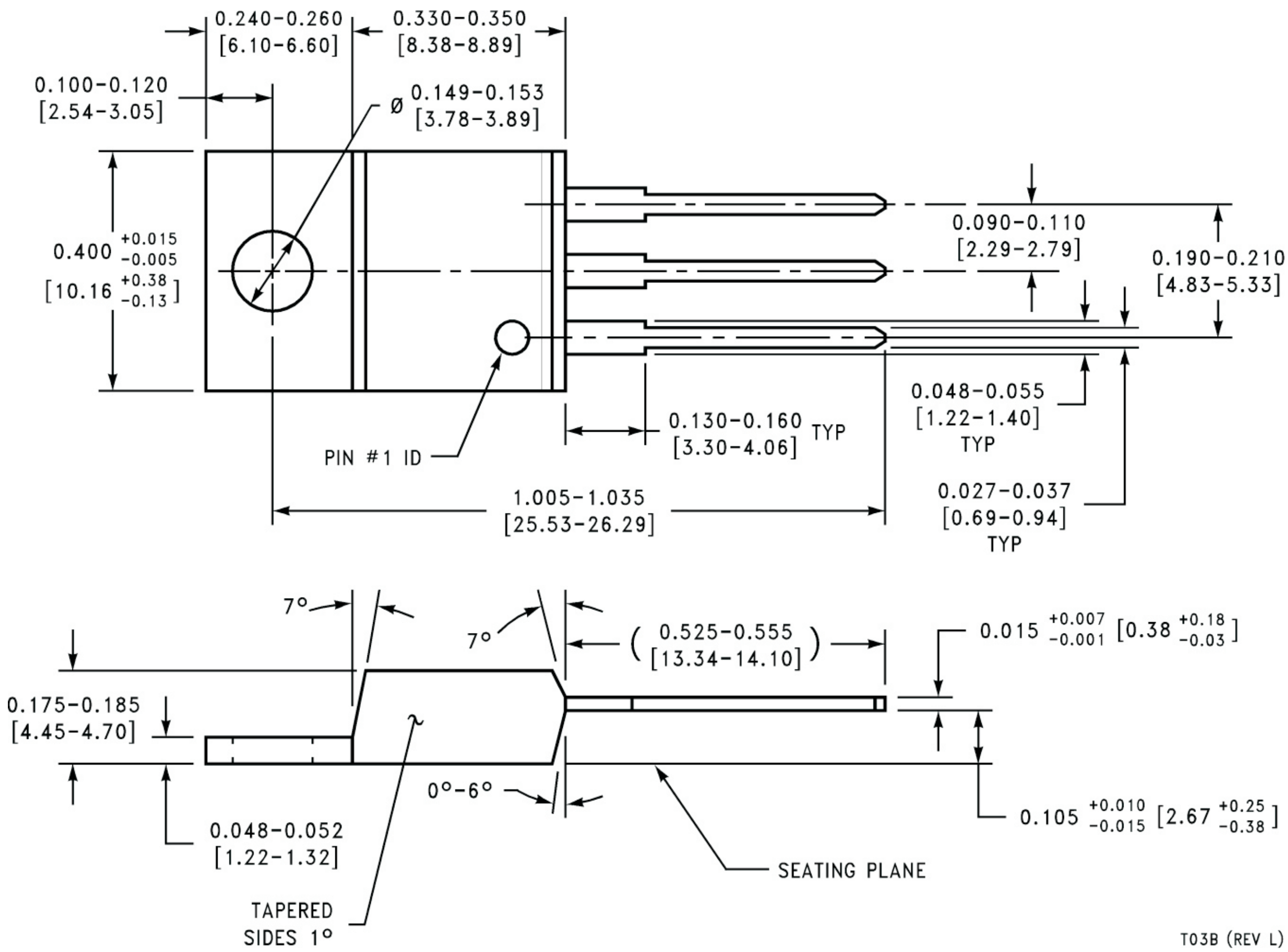
H03A (Rev D)

NDS0002A



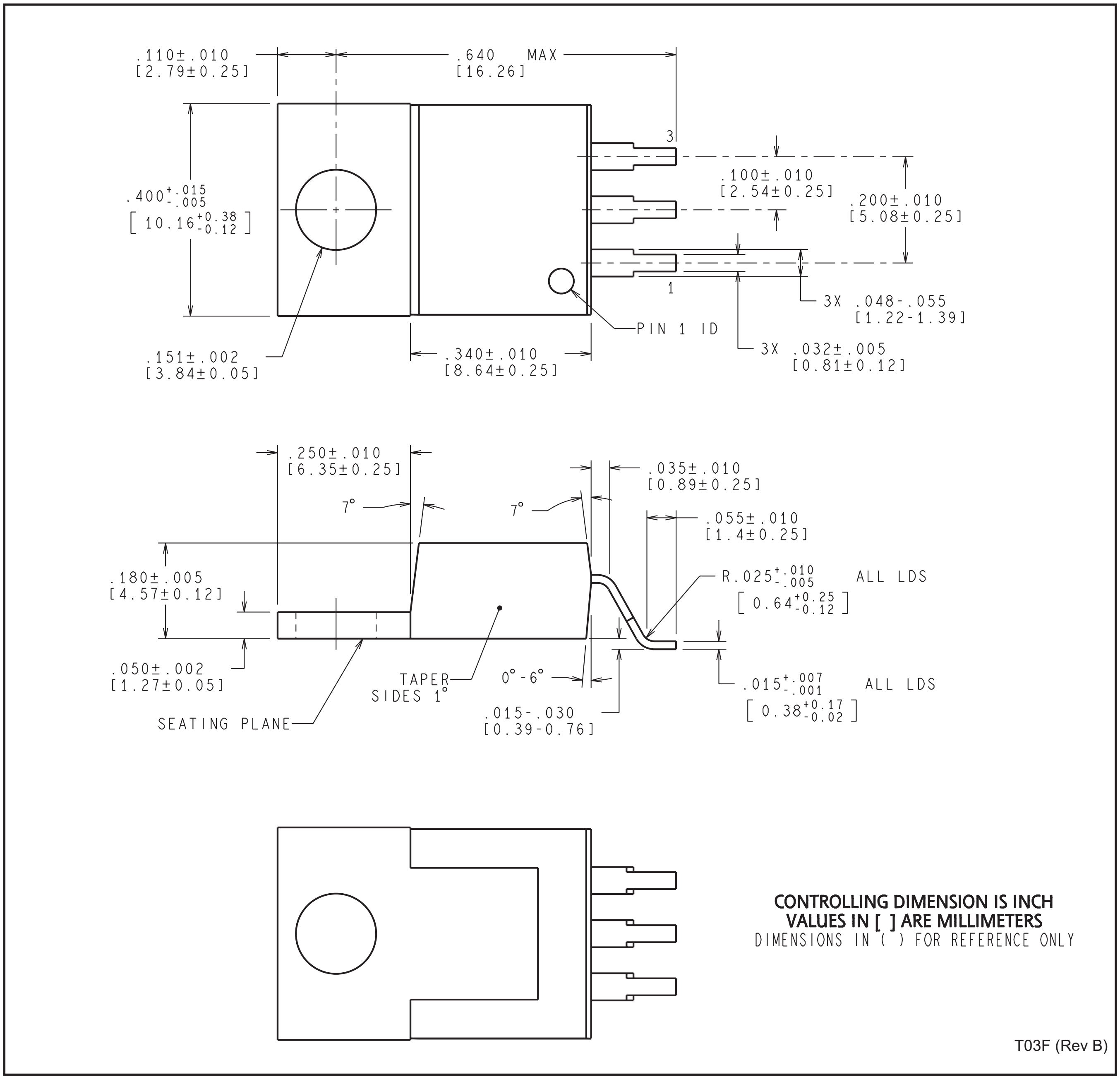
0.980-1.020
[24.89-25.91]
2X Ø 0.151-0.161
[3.84-4.09]
R 0.495-0.510
[12.57-12.95]
0.660-0.670
[16.76-17.02]
1.177-1.197
[29.90-30.40]
2
1
2X Ø 0.038-0.043
[0.97-1.09]
2X R 0.168-0.178
[4.27-4.52]
0.210-0.220
[5.33-5.59]
0.425-0.435
[10.80-11.05]
0.420-0.500
[10.67-12.70]
0.325-0.352
[8.26-8.94]
0.060-0.070
[1.52-1.78]
Ø 0.880-0.915
[22.35-23.24]
Ø 0.760-0.775
[19.30-19.69]
UNCONTROLLED
LEAD DIA
0.025
[0.64] MAX
0.116
[2.95] MAX
SEATING PLANE
K02A (REV G)

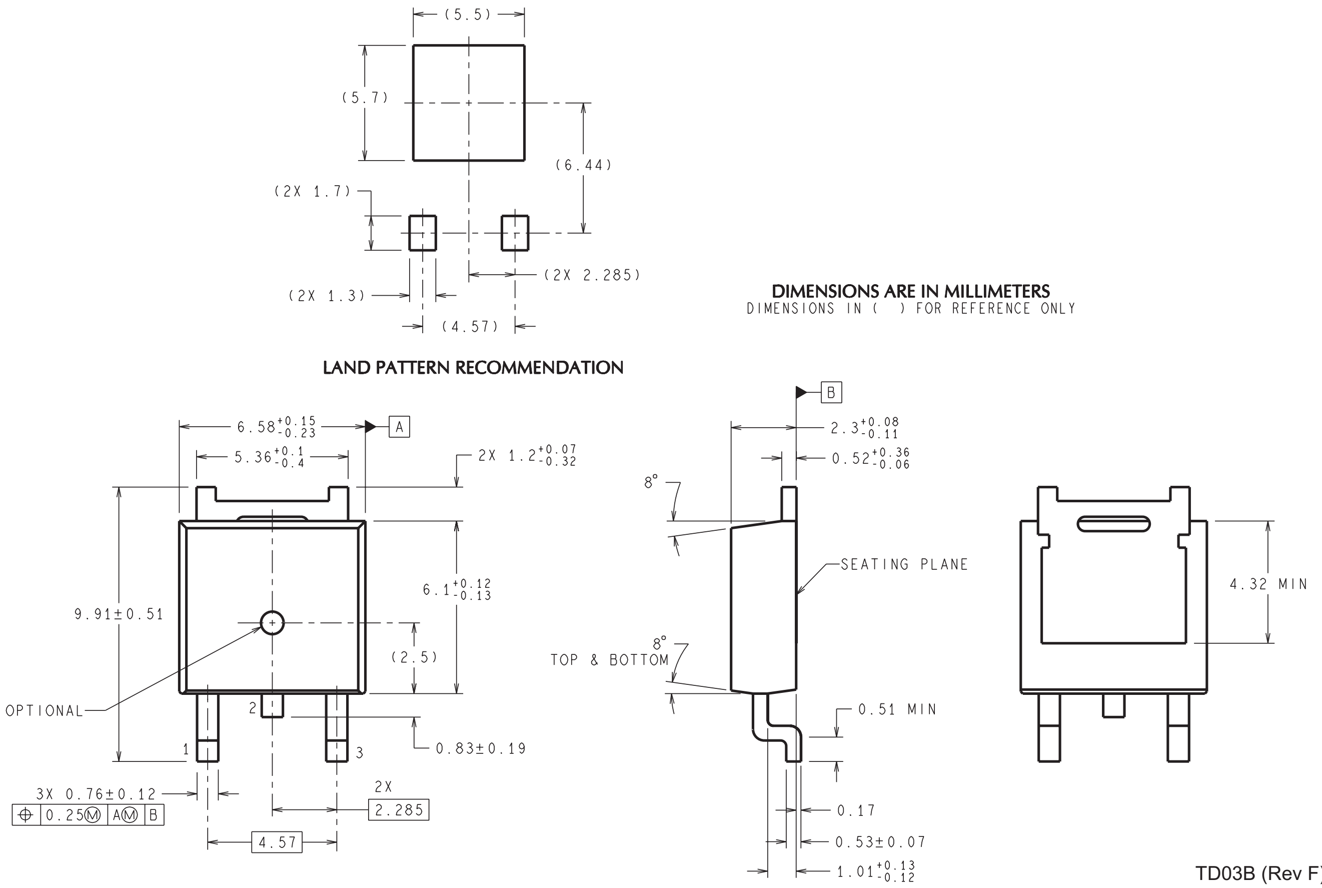
NDE0003B



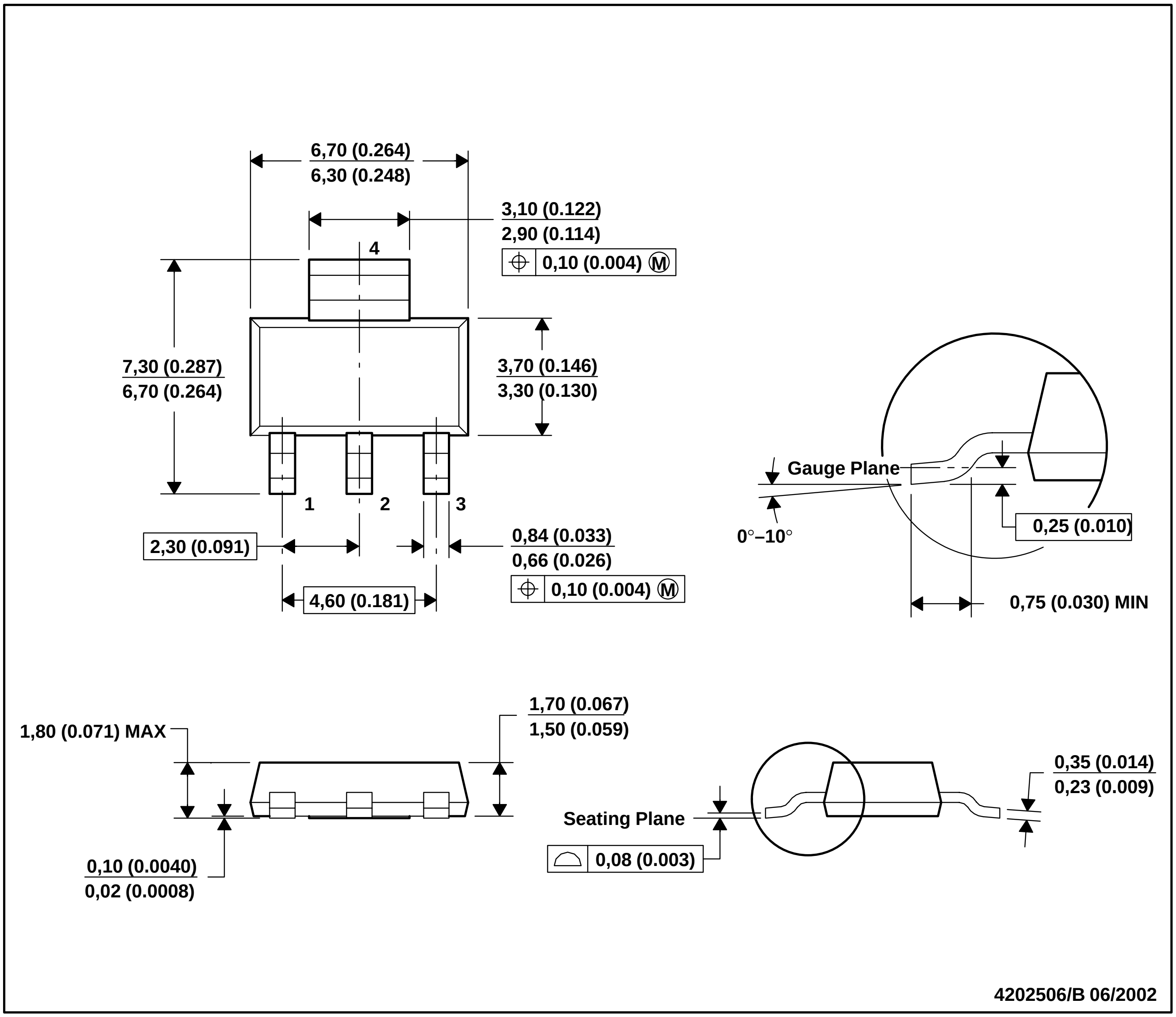
0.240–0.260
[6.10–6.60]
0.330–0.350
[8.38–8.89]
0.100–0.120
[2.54–3.05]
Ø 0.149–0.153
[3.78–3.89]
0.400 +0.015 −0.005
[10.16 +0.38 −0.13]
0.090–0.110
[2.29–2.79]
0.190–0.210
[4.83–5.33]
0.048–0.055
[1.22–1.40]
TYP
0.130–0.160 TYP
[3.30–4.06]
PIN #1 ID
1.005–1.035
[25.53–26.29]
0.027–0.037
[0.69–0.94]
TYP
7°
7°
(0.525–0.555
[13.34–14.10])
0.015 +0.007 −0.001 [0.38 +0.18 −0.03]
0.175–0.185
[4.45–4.70]
0°–6°
0.105 +0.010 −0.015 [2.67 +0.25 −0.38]
0.048–0.052
[1.22–1.32]
SEATING PLANE
TAPERED
SIDES 1°
T03B (REV L)

NDG0003F


.110±.010
[2.79±0.25]
.640 MAX
[16.26]
3
.400+.015 -.005
[10.16+0.38 -0.12]
.100±.010
[2.54±0.25]
.200±.010
[5.08±0.25]
1
3X .048-.055
[1.22-1.39]
PIN 1 ID
.151±.002
[3.84±0.05]
.340±.010
[8.64±0.25]
3X .032±.005
[0.81±0.12]
.250±.010
[6.35±0.25]
.035±.010
[0.89±0.25]
7°
7°
.055±.010
[1.4±0.25]
.180±.005
[4.57±0.12]
R.025+.010 -.005 ALL LDS
[0.64+0.25 -0.12]
.050±.002
[1.27±0.05]
TAPER
SIDES 1°
0°-6°
.015-.030
[0.39-0.76]
.015+.007 -.001 ALL LDS
[0.38+0.17 -0.02]
SEATING PLANE
CONTROLLING DIMENSION IS INCH
VALUES IN [ ] ARE MILLIMETERS
DIMENSIONS IN ( ) FOR REFERENCE ONLY
T03F (Rev B)

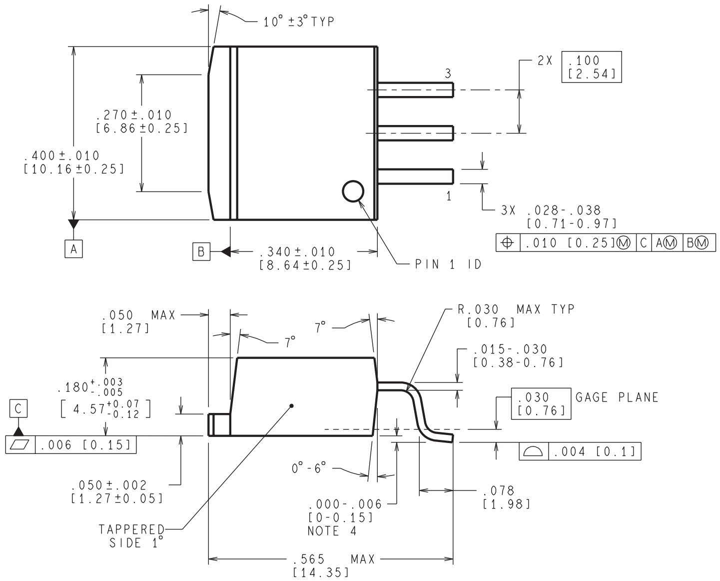

(5.5)
(5.7)
(6.44)
(2X 1.7)
(2X 2.285)
(2X 1.3)
(4.57)
LAND PATTERN RECOMMENDATION
DIMENSIONS ARE IN MILLIMETERS
DIMENSIONS IN ( ) FOR REFERENCE ONLY
6.58 +0.15 -0.23
A
5.36 +0.1 -0.4
2X 1.2 +0.07 -0.32
9.91±0.51
6.1 +0.12 -0.13
(2.5)
OPTIONAL
0.83±0.19
1
2
3
3X 0.76±0.12
0.25 M A M B
2X
2.285
4.57
B
2.3 +0.08 -0.11
0.52 +0.36 -0.06
8°
SEATING PLANE
8°
TOP & BOTTOM
0.51 MIN
0.17
0.53±0.07
1.01 +0.13 -0.12
4.32 MIN
TD03B (Rev F)

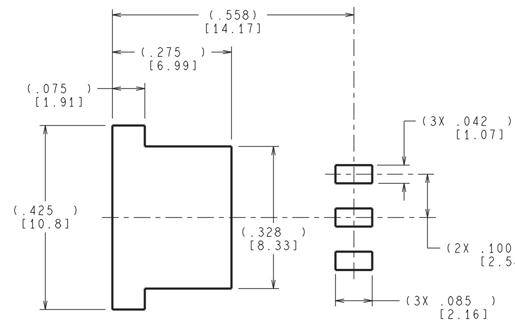
DCY (R-PDSO-G4) **PLASTIC SMALL-OUTLINE**



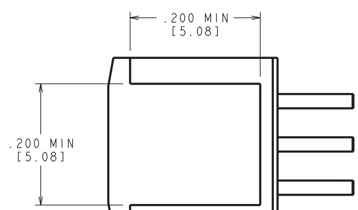
NOTES: A. All linear dimensions are in millimeters (inches).
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion.
D. Falls within JEDEC TO-261 Variation AA.

KTT0003B





LAND PATTERN RECOMMENDATION



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BOTTOM SIDE OF PACKAGE

TS3B (Rev F)

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