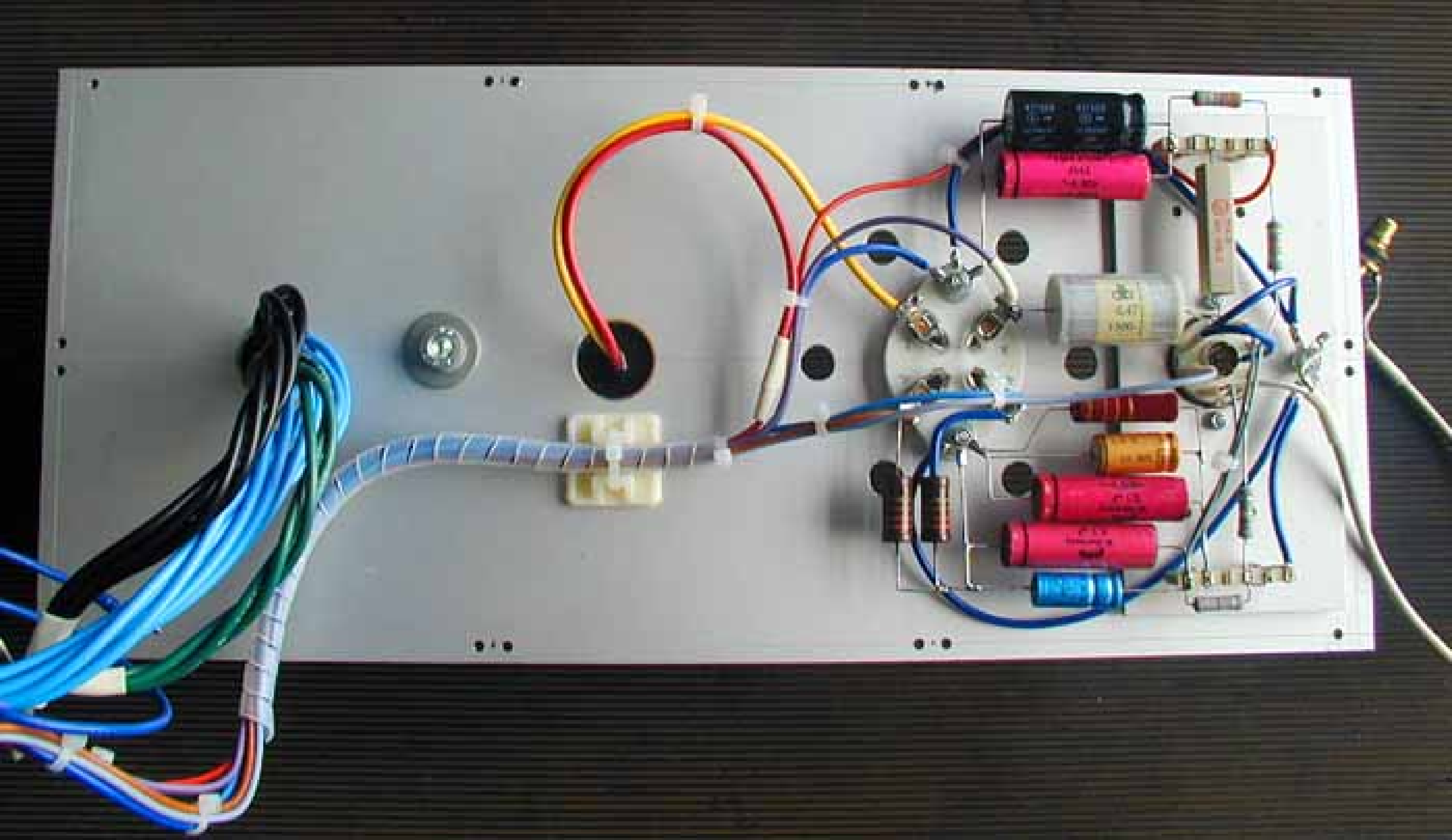
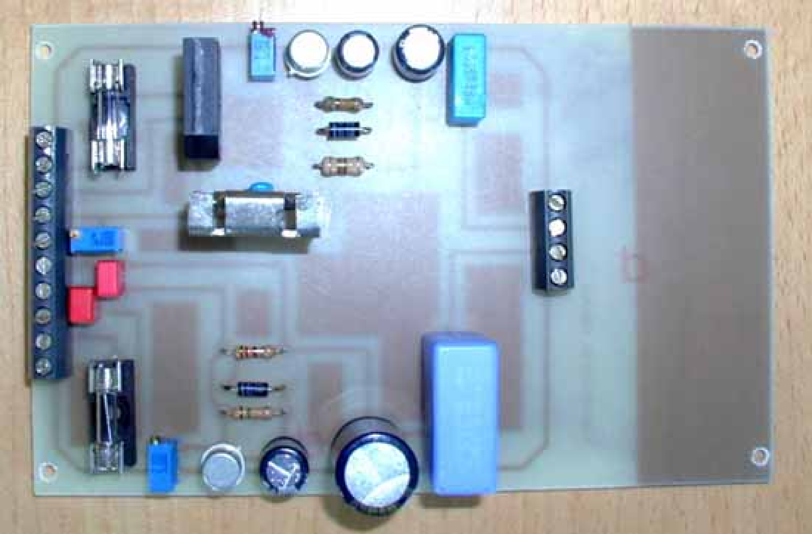
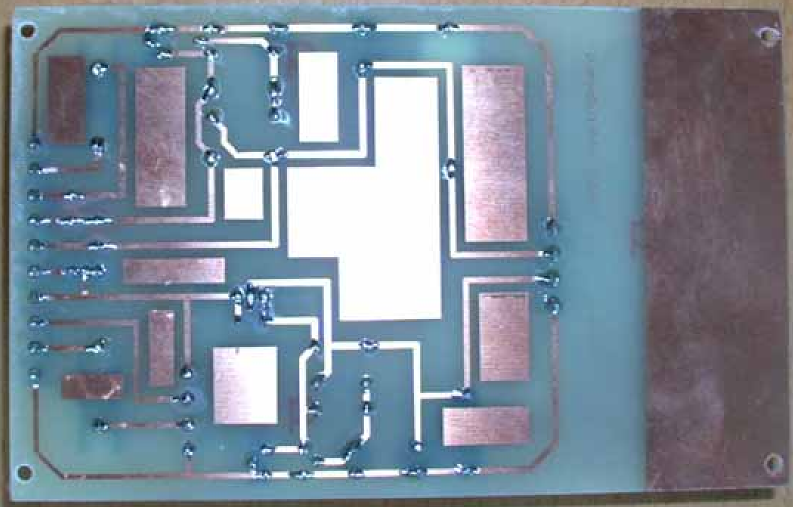

SHM 002 SE
Mono Tube Power Amplifier
Power on
Ready


SHM 002 SE
Mono Tube Power Amplifier
Power on
Input
Ready

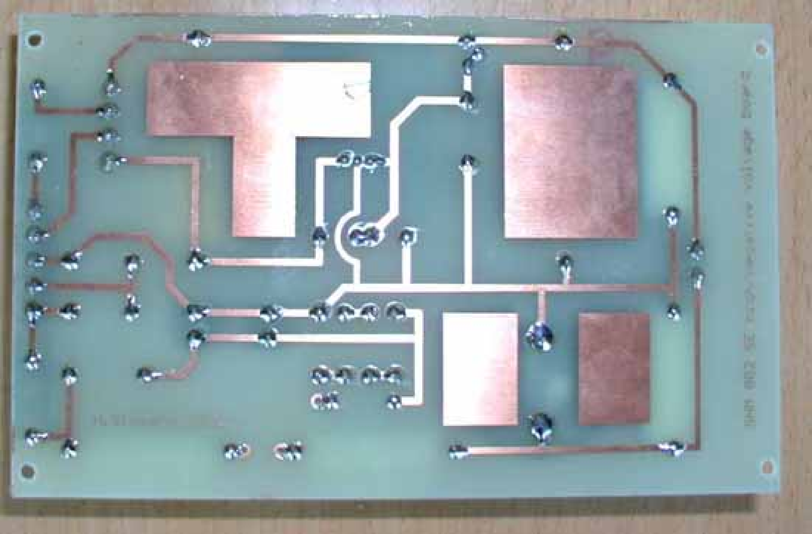

8 Ohm
4 Ohm
Ground
AC/230V



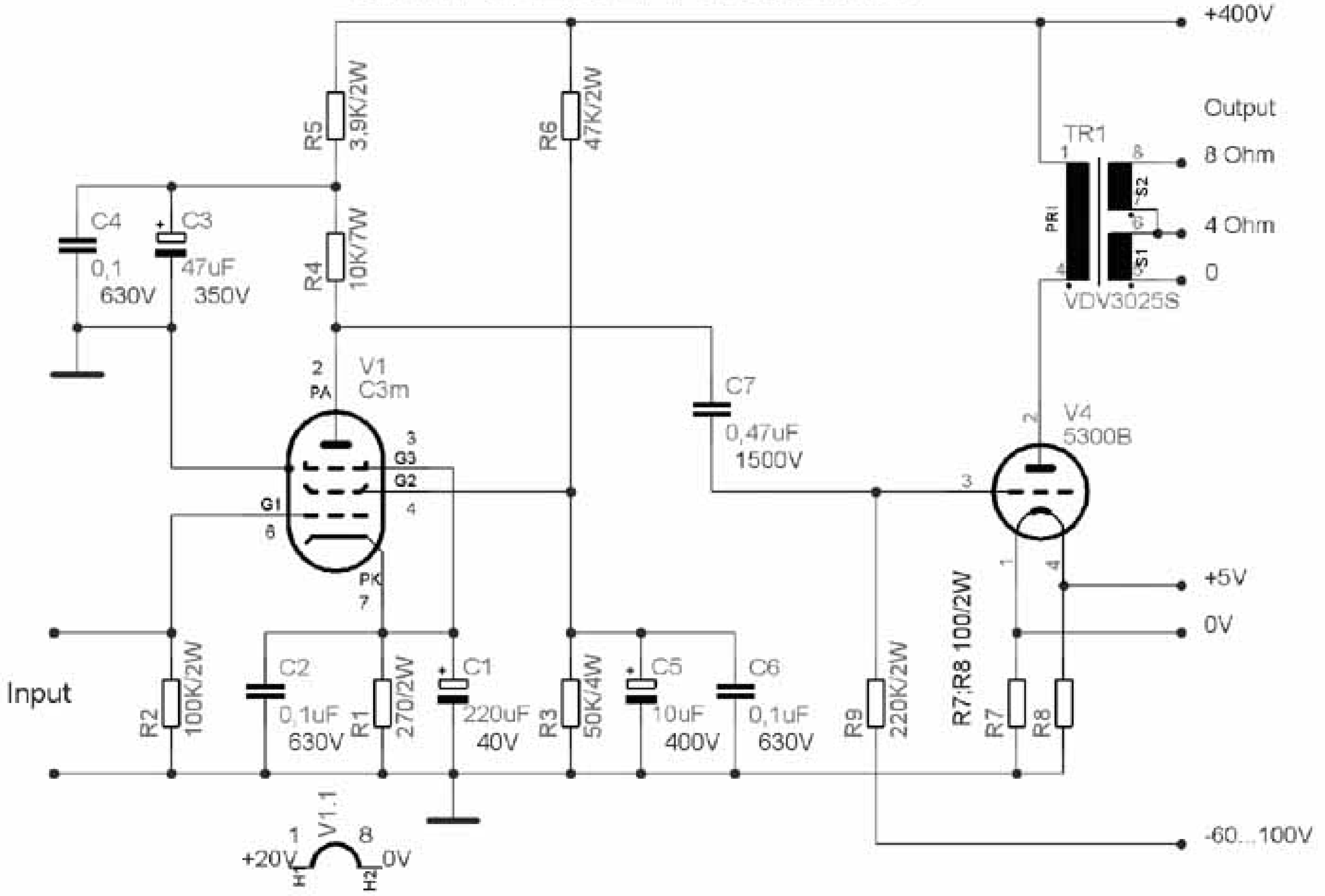




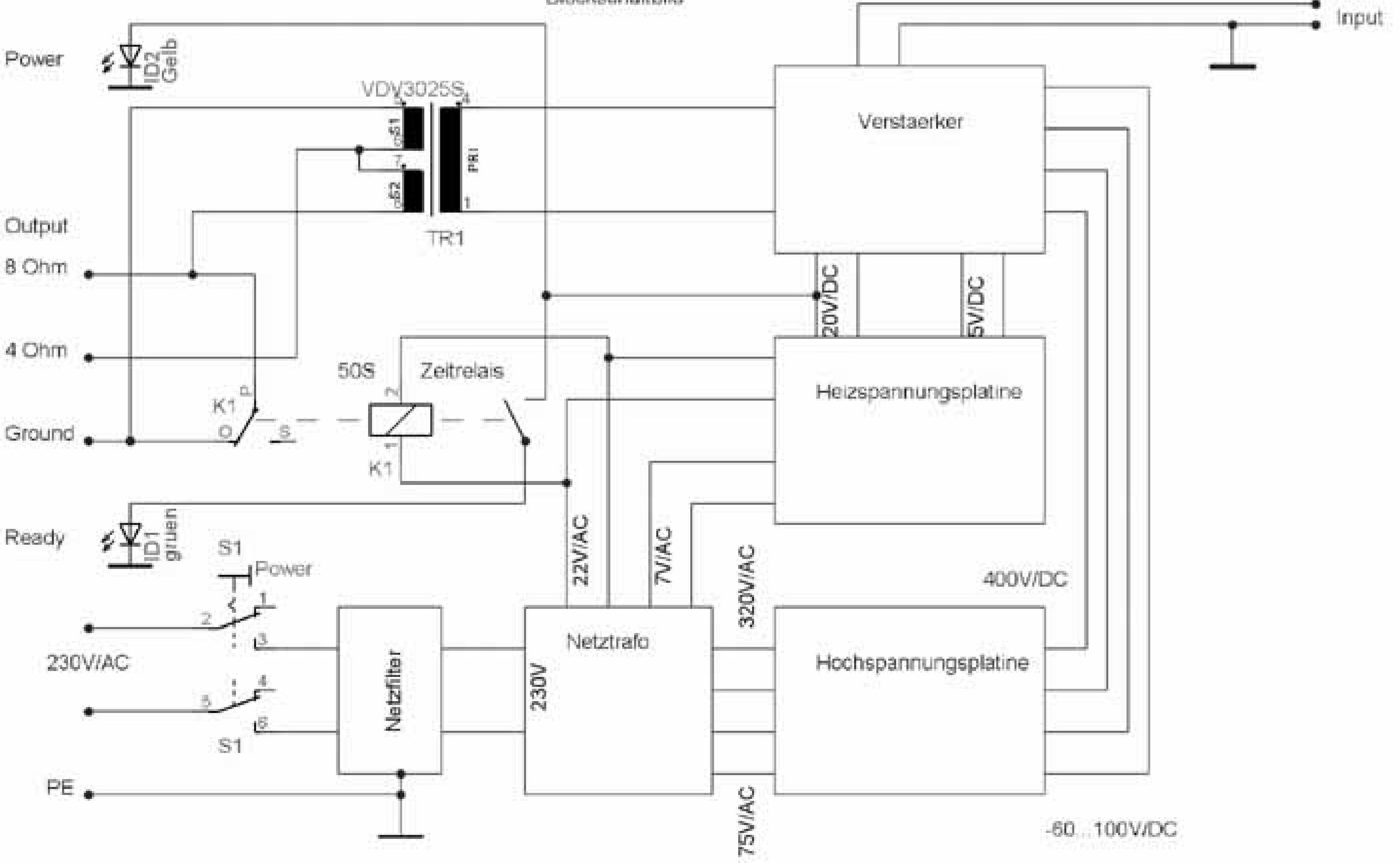

220MFD 250V
6R8 10%
100R 10%



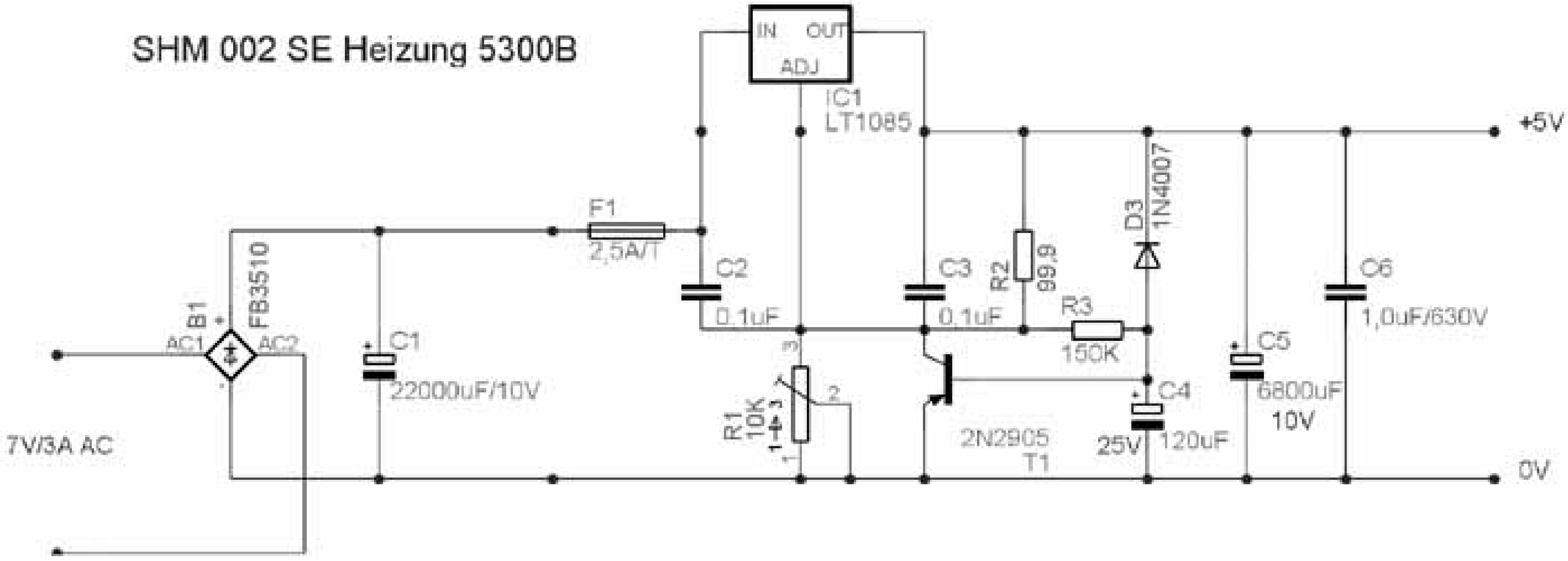
SHM 002 SE Verstaerker

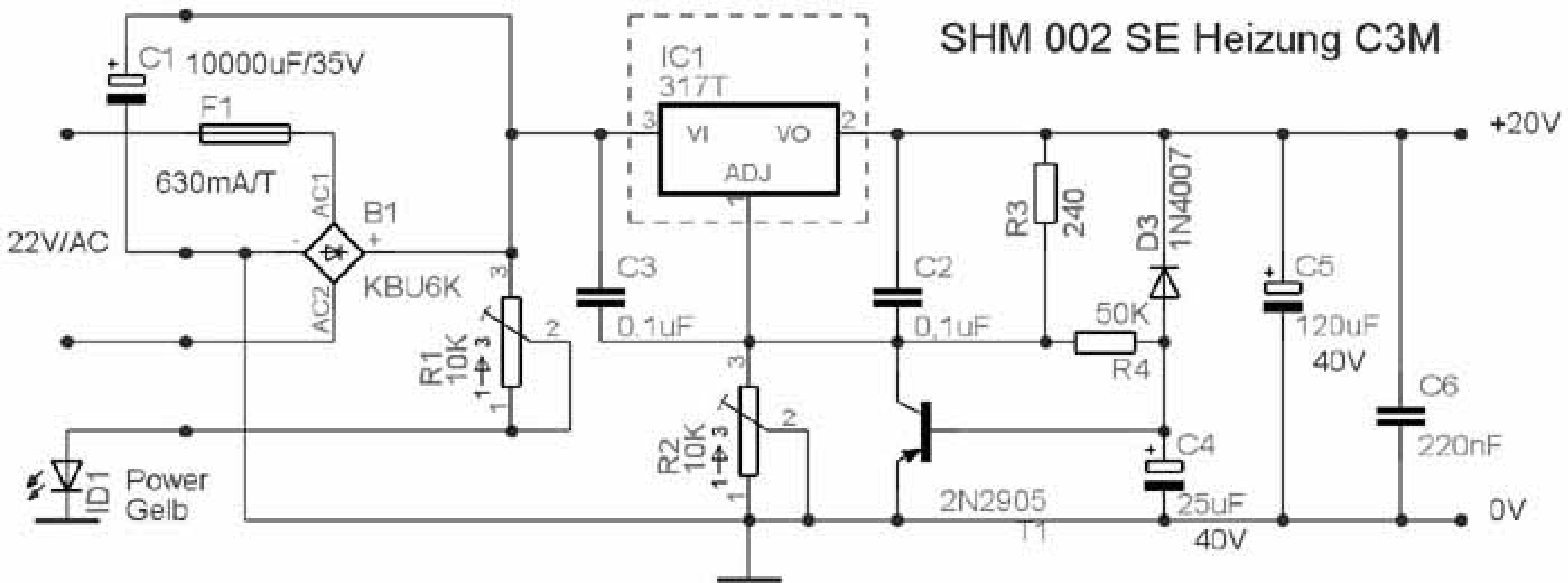


Blockschaltbild

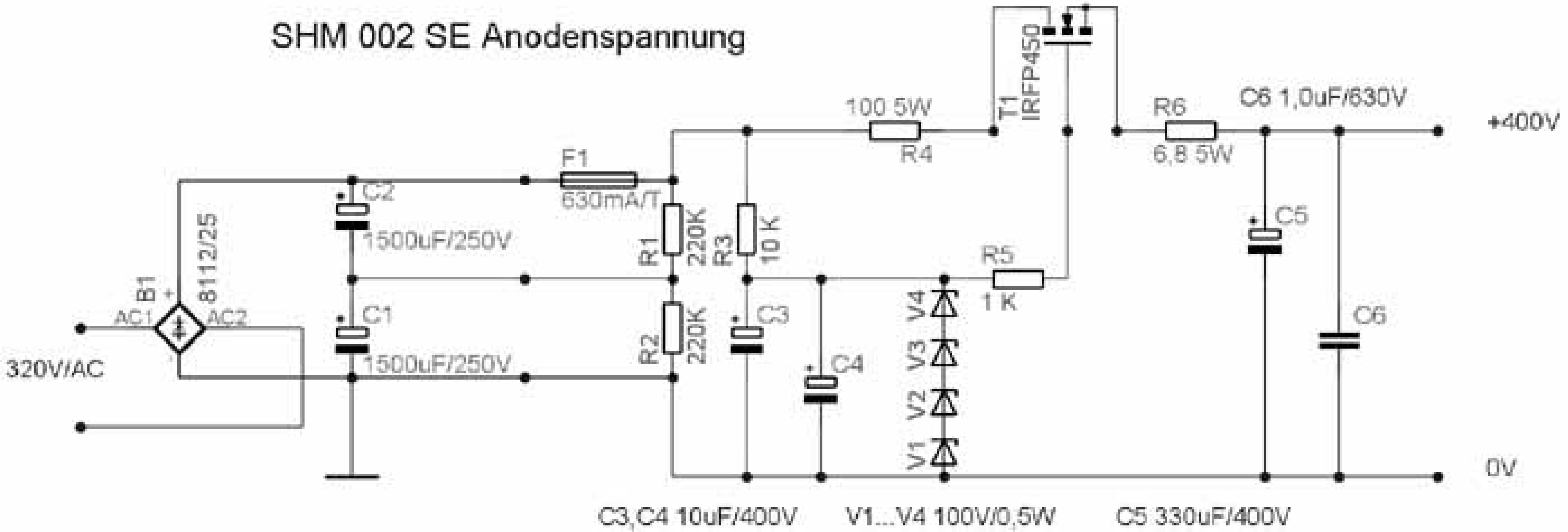


SHM 002 SE Heizung 5300B

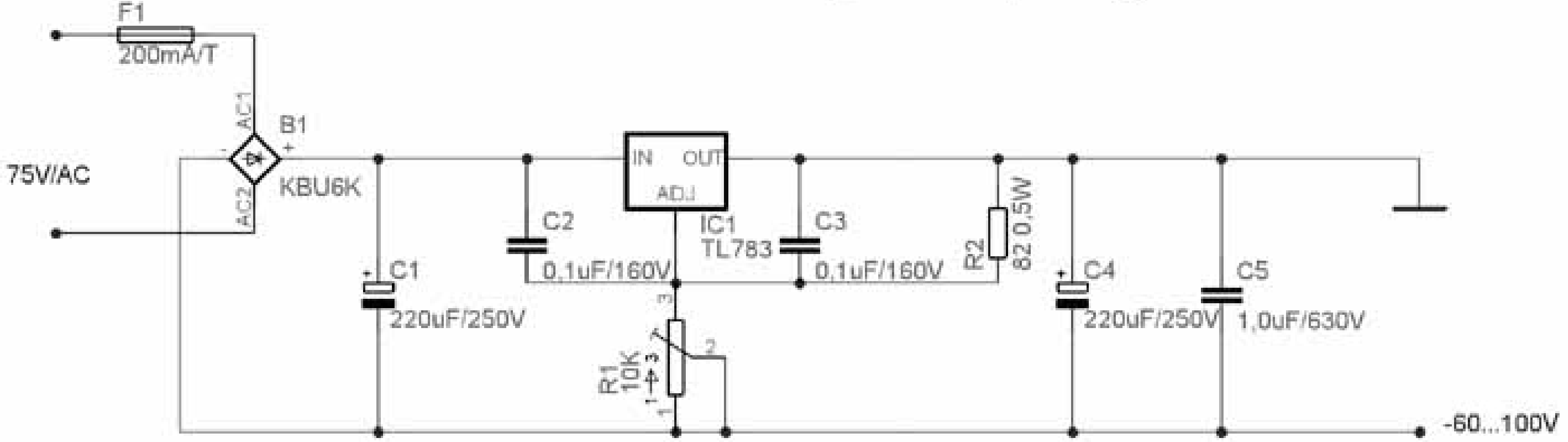


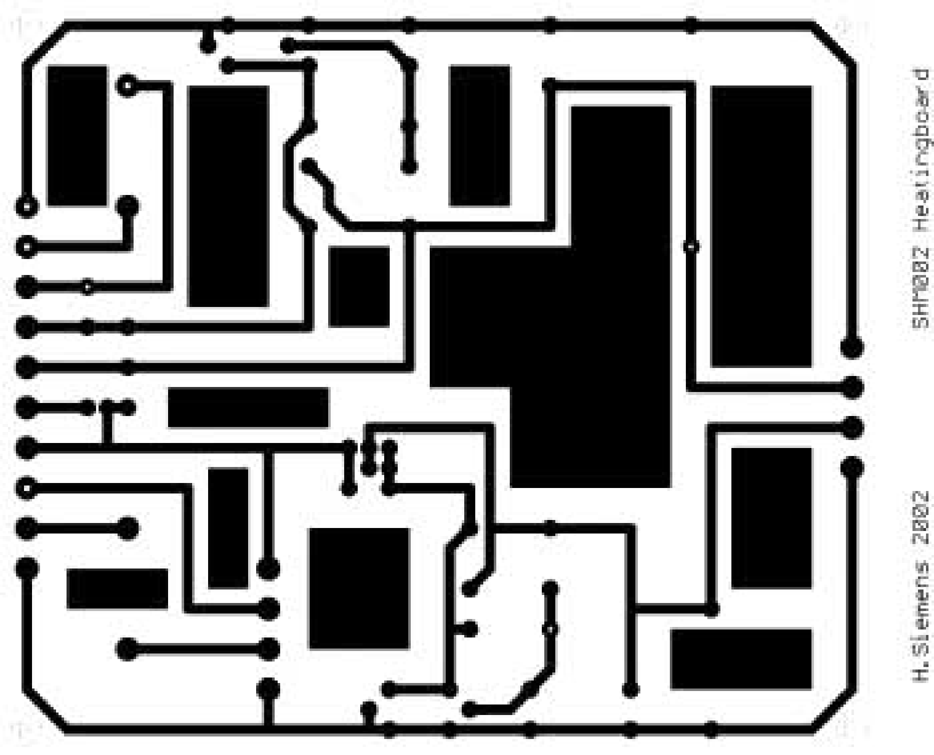

SHM 002 SE Heizung C3M
C1 10000uF/35V
F1
630mA/T
22V/AC
AC1
B1
KBU6K
AC2
R1 10K
IC1 317T
VI
VO
ADJ
C3 0.1uF
R2 10K
C2 0.1uF
2N2905
T1
R3 240
D3 1N4007
50K
R4
C4 25uF 40V
C5 120uF 40V
C6 220nF
+20V
0V
ID1 Power Gelb

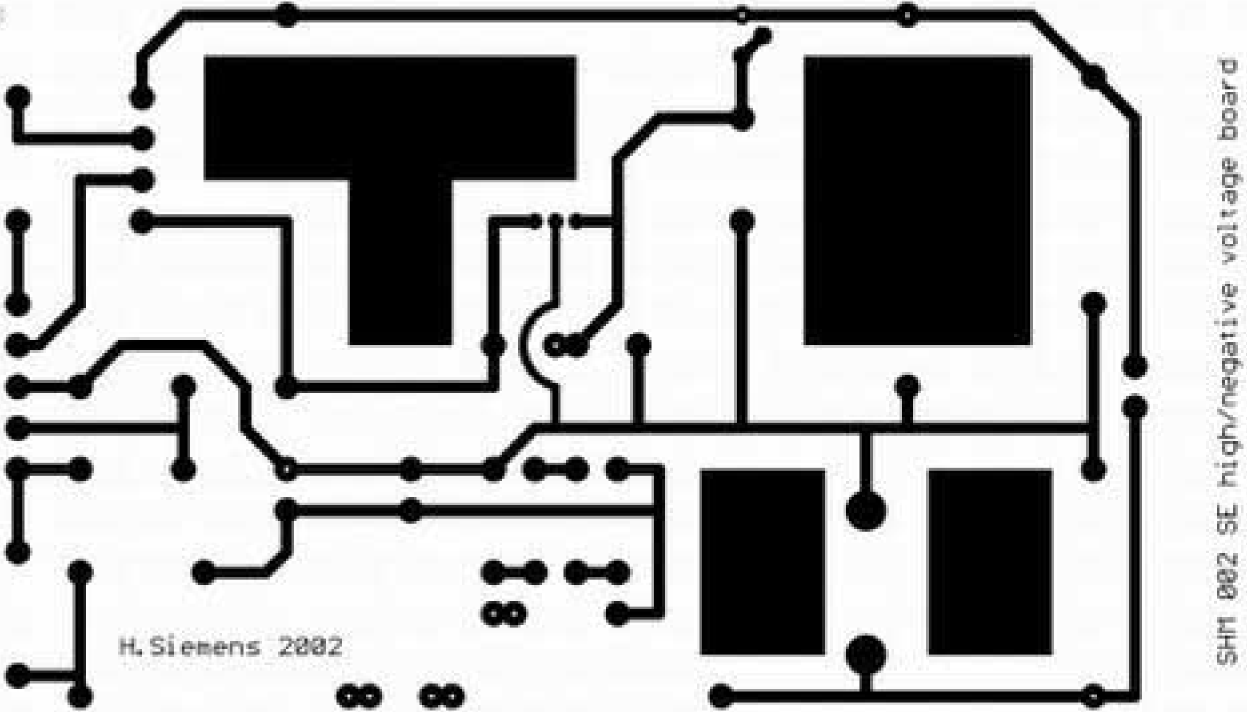
SHM 002 SE Anodenspannung



SHM 002 SE Negative Vorspannung




SHR002 Heatingboard
H. Siemens 2002


H.Siemens 2002
SHM 002 SE high/negative voltage board

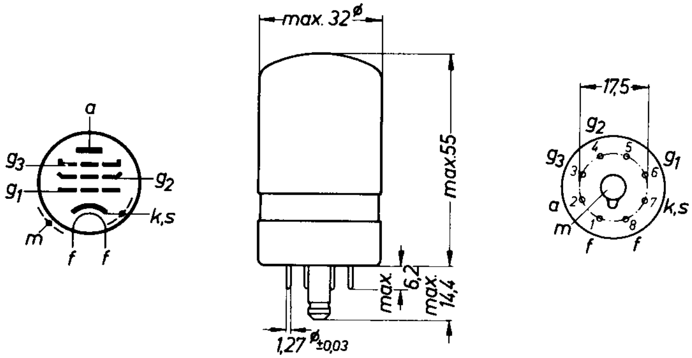
PENTODE

Art und Verwendung

Universal - Pentode hoher Konstanz und Lebensdauer für den Nachrichtenweitverkehr. Besonders geeignet für NF-, ZF- und HF- Verstärker in Vor- und Endstufen, Oszillatoren, Mischstufen und Regelverstärker.

Qualitätsmerkmale

Lange Lebensdauer (> 10 000 Std.)
Große Zuverlässigkeit
Enge Toleranzen
Zwischenschichtfreie Spezialkathode



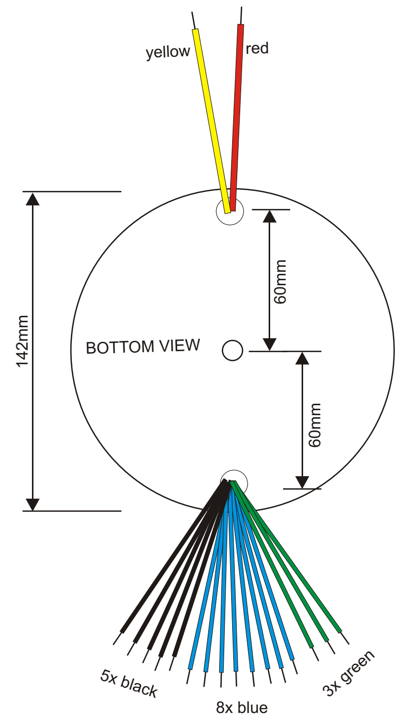
Maße in mm

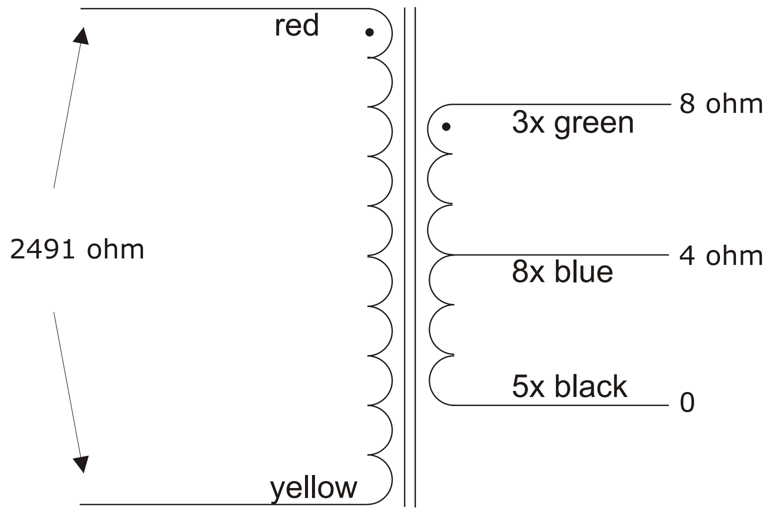
Sockel	: Kontinentaler Schlüsselsockel	Gewicht:	ca. 30 g
Fassungen:	Preßstoff 9 Rel lp 12	Einbau :	beliebig
	Keramik Rel stv 149		

WIDE BANDWIDTH LOW LOSS TOROIDAL SINGLE ENDED OUTPUT TRANSFORMER

TYPE & APPLICATION	:	VDV-3025-SE; 300B & equivalents	
Primary Impedance	:	Raa 2.491	[k]
Secondary Impedance	:	Rls 4	[ ]
Turns Ratio Np/Ns	:	Ratio 24.957	[ ]
-.1 dB Frequency Range [Hz] - [kHz]	:	flf 23.371	fhf 21.98
-1 dB Frequency Range [Hz] - [kHz]	:	fl1 9.968	fh1 49.057
-3 dB Frequency Range [Hz] - [kHz]	:	fl3 5.073	fh3 91.218
Nominal Power (1)	:	Pn 13	[W]
Full Power Bandwidth Starting at	:	fPnom 20	[Hz]
Total Primary Inductance (2)	:	Lp 18	[H]
Primary Leakage Inductance to sec.	:	lsp 5.5	[mH]
Effective Primary Capacitance	:	Cip 1	[nF]
Saturation Primary Current	:	2 Idc 204.312	[mA]
Total Primary DC Resistance	:	Rip 40	[ ]
Total Secondary DC Resistance	:	Ris 0.1	[ ]
Tubes Plate Resistance	:	rp 0.7	[k]
Insertion Loss	:	Iloss 0.175	[dB]
Q-factor 2-nd order HF roll-of (5)	:	Q 0.487	[ ]
HF roll-off Specific Frequency (5)	:	Fo 147.208	[kHz]
Quality Factor = Lp/Lsp (5)	:	QF $3.273 \cdot 10^3$	[ ]
Quality Decade Factor (5)	:	QDF 3.515	[ ]
Tuning Factor (5)	:	TF 5.494	[ ]
Tuning Decade Factor (5)	:	TDF 0.74	[ ]
Frequency Decade Factor (4,5)	:	FDF 4.255	[ ]

(1): calculated and measured under the conditions of applying 0.5*Idc-sat.
(2): 230 Volt 50 Hz measurement over the total primary winding
(3): calculated and measured at 1 mWatt in Rls; ri and Rls are pure Ohmic
(4): defined as FDF = log(fh3/fl3) = number of frequency decades transfered
(5): ir. Menno van der Veen; Theory and Practise of Wide Bandwidth Toroidal Output Transformers, 97-th AES Convention San Francisco, preprint





13 Watt single ended power
Primary impedance 2491 ohm
Power bandwith 20Hz - 91kHz (-3dB)

Height 72 mm
Diameter 142 mm
Weight 4.6kg
All leads solid and approx 200mm long
Fully potted in aluminium black textured shell

Amendments:
March 2009: Size of potting shell reduced to 142 x 72mm.

Industrieweg 14
NL-7161BX NEEDE
The Netherlands

PO-Box 27
NL-7160AA NEEDE
The Netherlands
Tel.+31 (0)545 28 3456
Fax+31 (0)545 28 3457

info@amplimo.nl
http://www.amplimo.nl

HB 02-03-2003

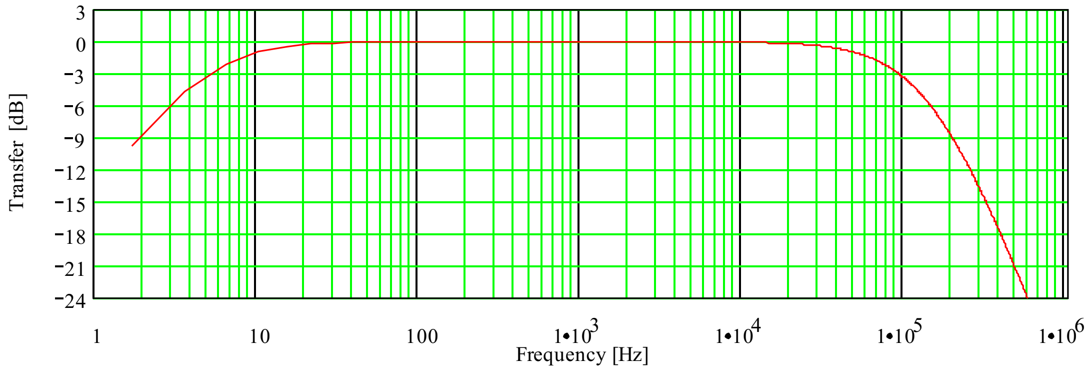
VDV3025SE

WIDE BANDWITH TOROIDAL
SINGLE_ENDED
TUBE OUTPUT TRANSFORMER

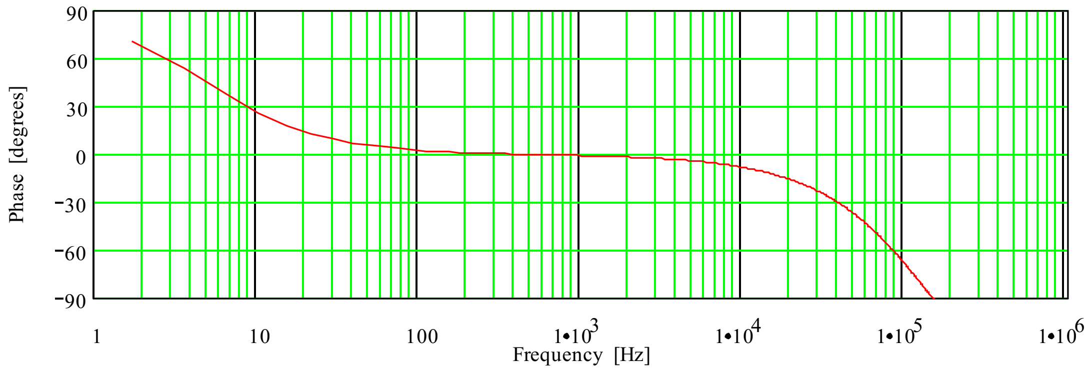
WIDE BANDWIDTH LOW LOSS TOROIDAL SINGLE ENDED OUTPUT TRANSFORMER

VDV - 3025 - SE

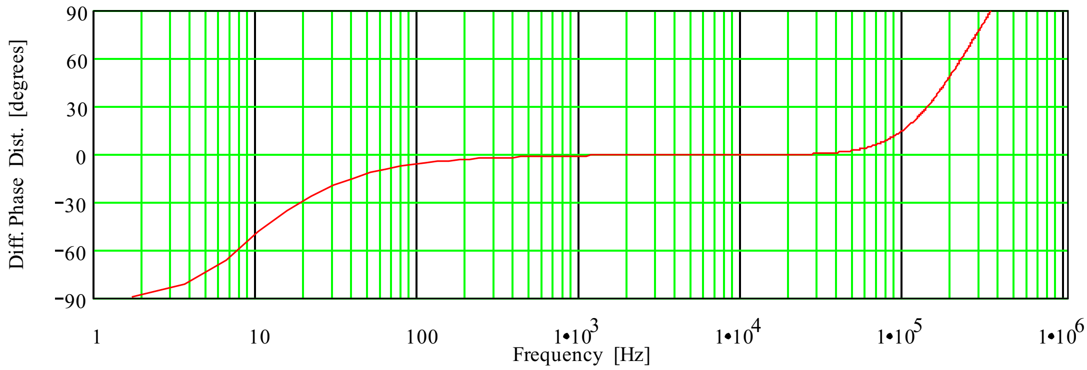
[dB] Frequency Response; Vertical: 3 dB/div; Horizontal: 1 Hz to 1 MHz (3)



[degrees] Phase Response; Vertical: 30 deg./div; Horizontal: 1 Hz to 1 MHz



[degrees] Differential Phase Response; vert. 30 deg./div; hor. 1 Hz to 1 MHz
See: W.M.Leach, Differential Time Delay..; JAES sept.89 pp.709-715



Heizung

U_f	=	20	V 1)
I_f	=	125 ± 5	mA

Heizart: indirekt durch Wechsel- oder Gleichstrom, Parallel- oder Serienspeisung

Kapazitäten

C_e	=	8,5 ± 1,0	pF
$C_e'(I_k=19mA)$	≈	10,5	pF
C_a	=	6,0 ± 1,5	pF
C_{ag1}	<	18	mpF
C_{ag3}	=	1,2	pF
C_{af}	<	150	mpF
C_{g3g2}	=	2,2	pF
C_{g2g1}	=	3	pF
C_{g1k}	=	4,5	pF
C_{g1f}	<	60	mpF 2)
C_{kf}	=	7	pF

Triodenschaltung (g_2 und g_3 an a)

C_e	=	5	pF
C_a	=	7,5	pF
C_{ag1}	=	4	pF

1) Die Lebensdauergarantie setzt voraus, daß die Heizspannung bei Parallelspeisung nicht mehr als ± 5 % (absolute Grenzen) und der Heizstrom bei Serienspeisung nicht mehr als ± 1,5 % (absolute Grenzen) um den Sollwert schwanken.

2) Mittelwert 40 mpF

Kenndaten

		min.	nom.	max.		
U_a	=		220		60	V
U_{g3}	=		0		0	V
U_{g2}	=		150		60	V
R_k	=		250		300	Ω
I_a	=	13,5	16	19	5	mA
I_{g2}	=	2,0	3,0	4,0	1	mA
S	=	5,5	6,5	7,8	4,7	mA/V
μ_{g2g1}	=		19			
R_i	=	200	250	-	150	kΩ
R_{iL}	=		1,2		2	kΩ
$R_{äq}$	≦		1,2		0,65	kΩ
$-U_g$ ($+I_g = 0,3\,\mu A$)	≦		1,3			V
$-U_g$ ($I_a = 0,1\,mA$)	≦		14			V

Triodenschaltung (g_2 und g_3 an a)

U_a	=	220	V
R_k	=	500	Ω
I_a	=	18,5	mA
S	=	7,2	mA/V
μ	=	18	
R_i	=	2,5	kΩ
$R_{äq}$	=	650	Ω

GRENZDATEN
BESONDERE ANGABEN

Grenzdaten

U_{ao}	max.	550	V
U_a	max.	300	V
Q_a	max.	4,0	W
U_{g3o}	max.	550	V
U_{g3}	max.	300	V
Q_{g3}	max.	1,0	W
U_{g2o}	max.	550	V
U_{g2}	max.	300	V
Q_{g2}	max.	1,0	W
$-U_{g1}$	max.	100	V
Q_{g1}	max.	50	mW
R_{g1} (Q_a>1,5W)	max.	0,5	MΩ
R_{g1} (Q_a≦1,5W)	max.	3,0	MΩ
I_k	max.	30	mA
U_{fk}	max.	120	V
R_{fk}	max.	20	kΩ
$t_{hülse}$	max.	120	°C

Besondere Angaben

Negativer Gitterstrom

$-I_{g1}$	≦	0,5	µA

Meßeinstellung: siehe Kenndaten mit U_a = 220 V

Besondere Angaben

Isolationswiderstände

R_{is} (a/alle übrigen Elektroden bei U_{is}=300V)	$\geq$	1000	MΩ
R_{is} (g/alle übrigen Elektroden bei U_{is}=100V)	$\geq$	1000	MΩ
R_{is} (fk bei U_{is}=100V)	$\geq$	100	MΩ

gemessen bei U_f = 20 V

Mikrophonie

Die Röhre darf ohne besondere Maßnahmen gegen Mikrophonie in Schaltungen verwendet werden, die für eine Eingangsspannung $U_{g1\sim} > 10$ mV eine Leistung der Endröhre von 50 mW ergeben.

Brumm

U_{br}	$\leq$	10	µA

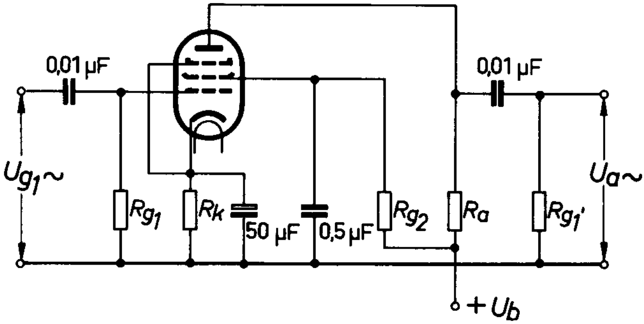
Meßeinstellung: U_b = 200 V, R_a = 200 kΩ, R_{g2} = 1,2 MΩ, R_{g1} = 0,5 MΩ, R_k = 1,5 kΩ, C_k = 1000 µF völlig geschirmte Röhrenfassung und geerdete Mittelzapfung des Heiztransformators.

Ende der Lebensdauer

I_a	$\leq$	11,5	mA
S	$\leq$	4,5	mA/V
$-I_{g1}$	$\geq$	1,0	µA

Meßeinstellung: siehe Kenndaten mit U_a = 220 V

Betriebsdaten als NF-Vorverstärker



R_a = 200 kΩ, R_{g1} = 1 MΩ, R_{g1}' = 0,5 MΩ					
U_b	100	200	250	300	V
R_{g2}	1	1,2	1,2	1,2	MΩ
R_k	3	1,5	1,2	1	kΩ
I_a	0,35	0,7	0,9	1,1	mA
I_{g2}	0,08	0,15	0,18	0,22	mA
V	130	215	250	270	
$U_a\sim$ (k=0,5%)	3	3,5	4	6	V
$U_a\sim$ (k=1%)	5	6	8	12	V
$U_a\sim$ (k=2%)	8	12	17	22	V

Betriebsdaten als Leistungsverstärker

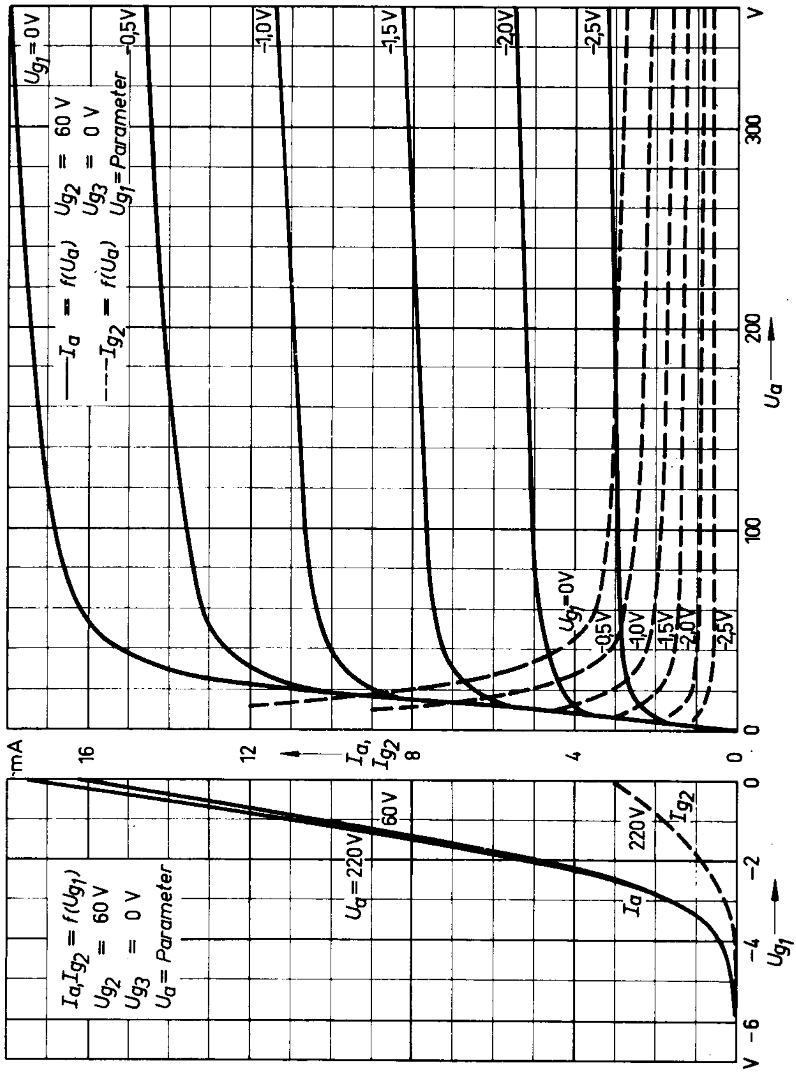
Eintakt A-Betrieb

U_a	=	220		V
U_{g3}	=	0		V
U_{g2}	=	150		V
R_a	=	10		kΩ
R_k	=	250		Ω
$U_{g1}\sim$	=	0	3,8	V
Ia	=	16	17,4	mA
I_{g2}	=	3,2	5	mA
$N_a\sim$	=	-	1,5	W
k	=	-	10	%

KENNLINIENFELDER

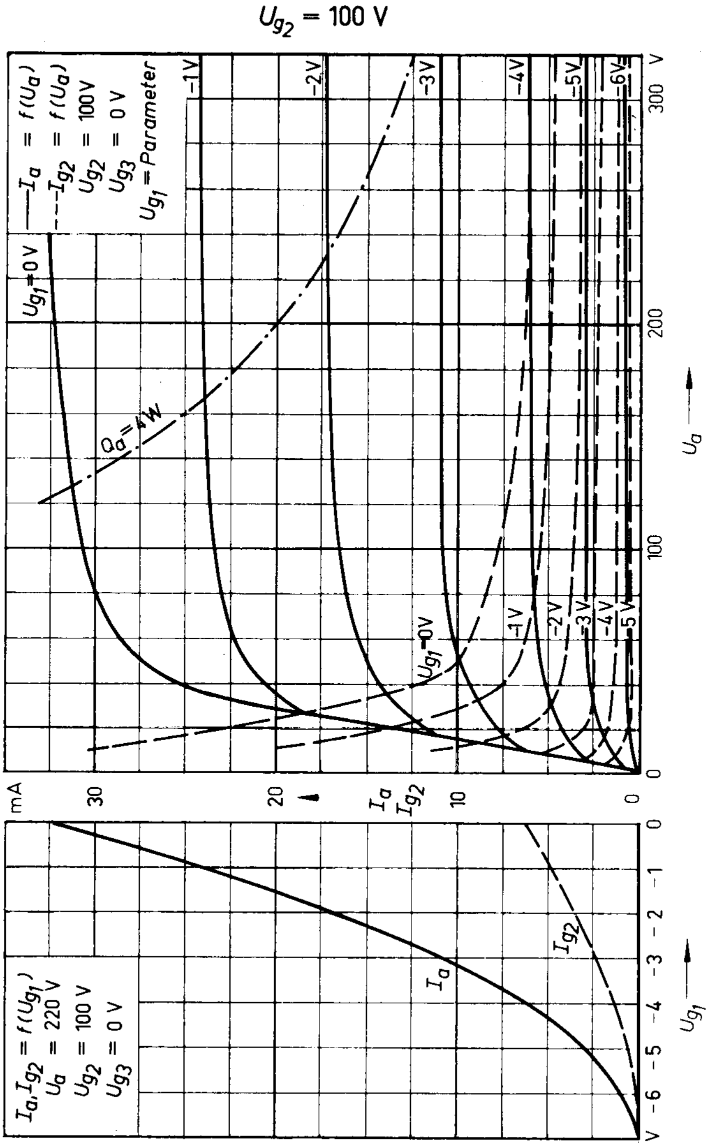
$I_a, I_{g_2} = f(U_{g_1}) \qquad I_a, I_{g_2} = f(U_a)$

$U_{g_2} = 60\,V$



KENNLINIENFELDER

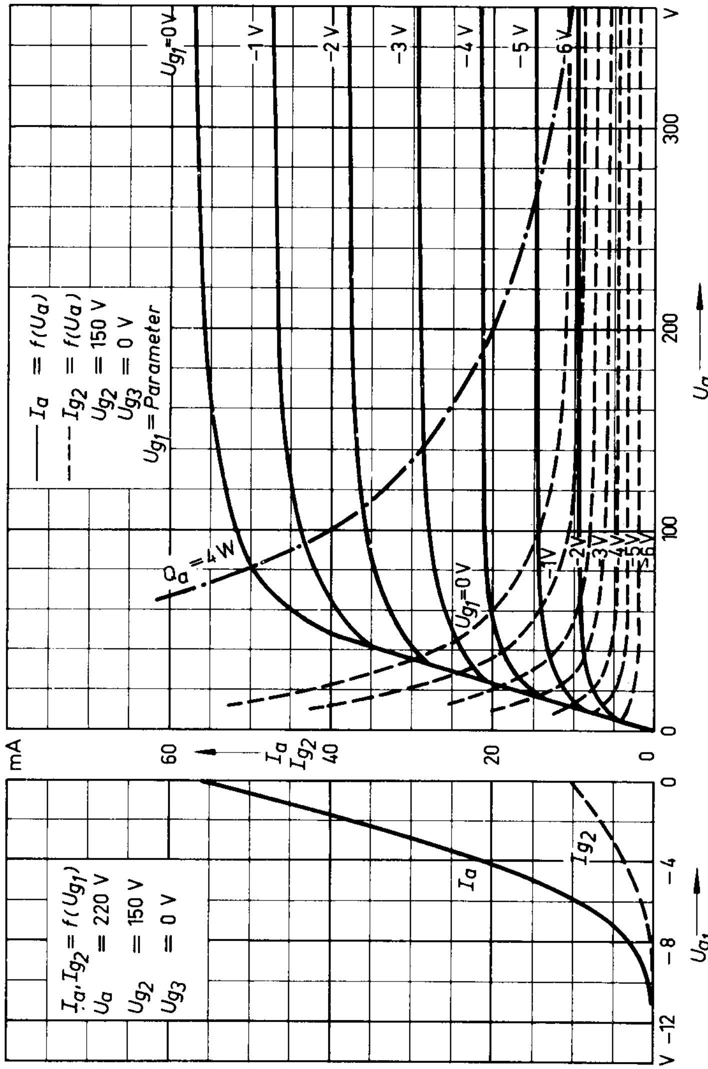
$I_a, I_{g_2} = f(U_{g_1})$ $I_a, I_{g_2} = f(U_a)$



KENNLINIENFELDER

$I_a, I_{g_2} = f(U_{g_1}) \qquad I_a, I_{g_2} = f(U_a)$

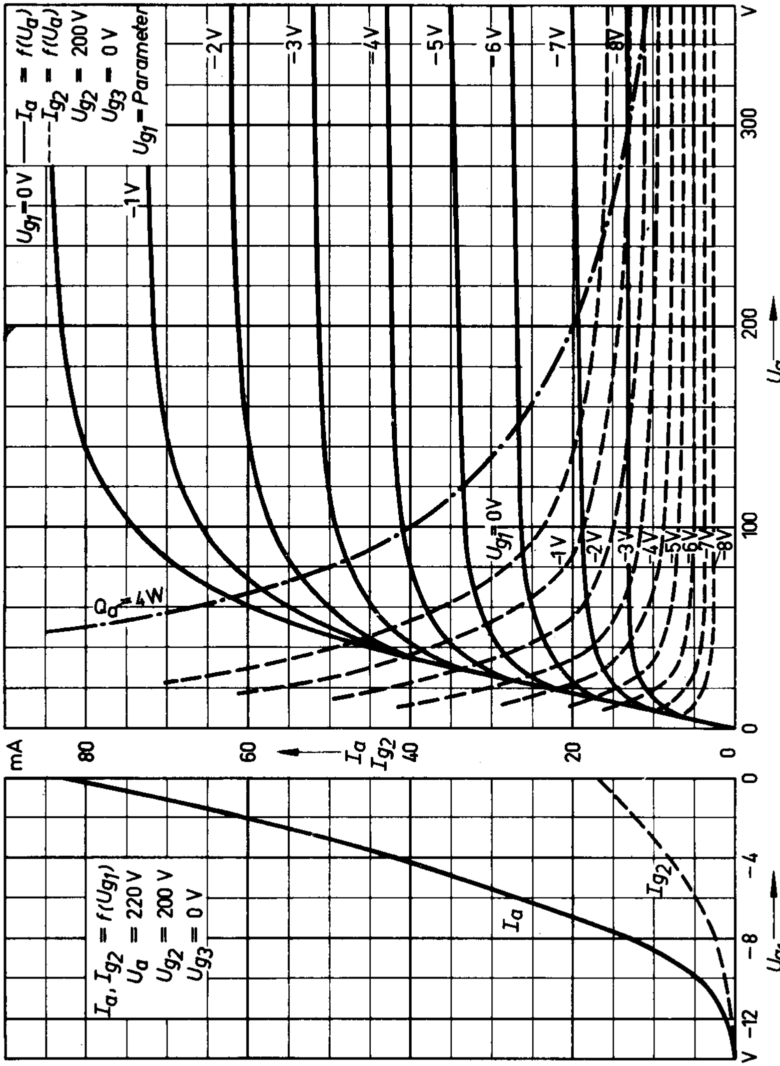
$U_{g_2} = 150$ V



KENNLINIENFELDER

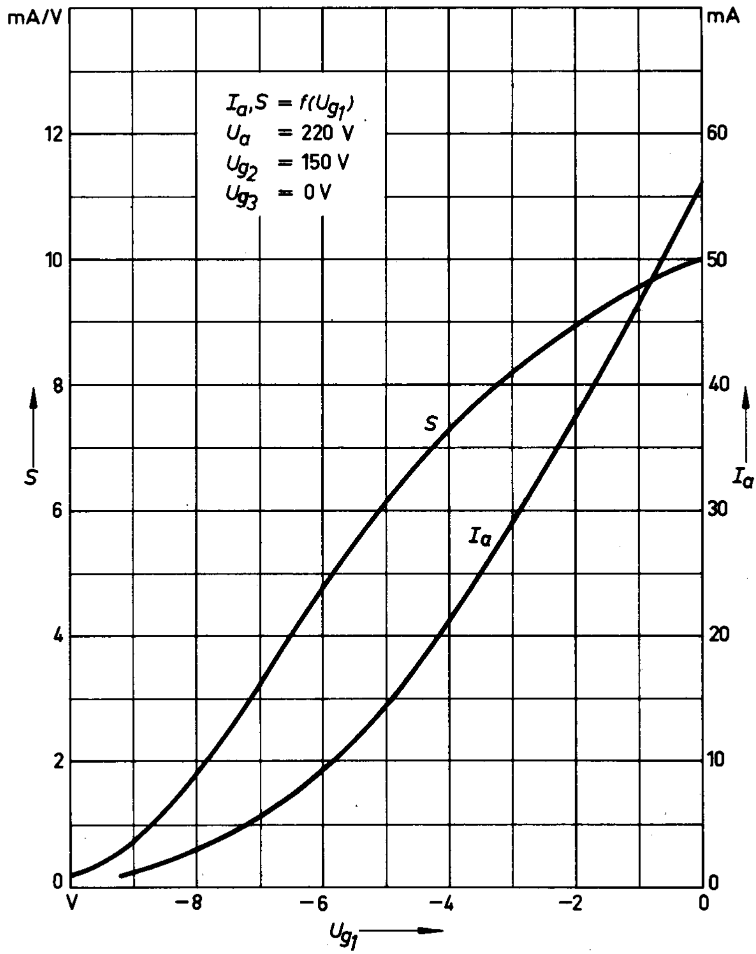
$I_a, I_{g_2} = f(U_{g_1}) \qquad I_a, I_{g_2} = f(U_a)$

$U_{g_2} = 200\ V$



KENNLINIEN

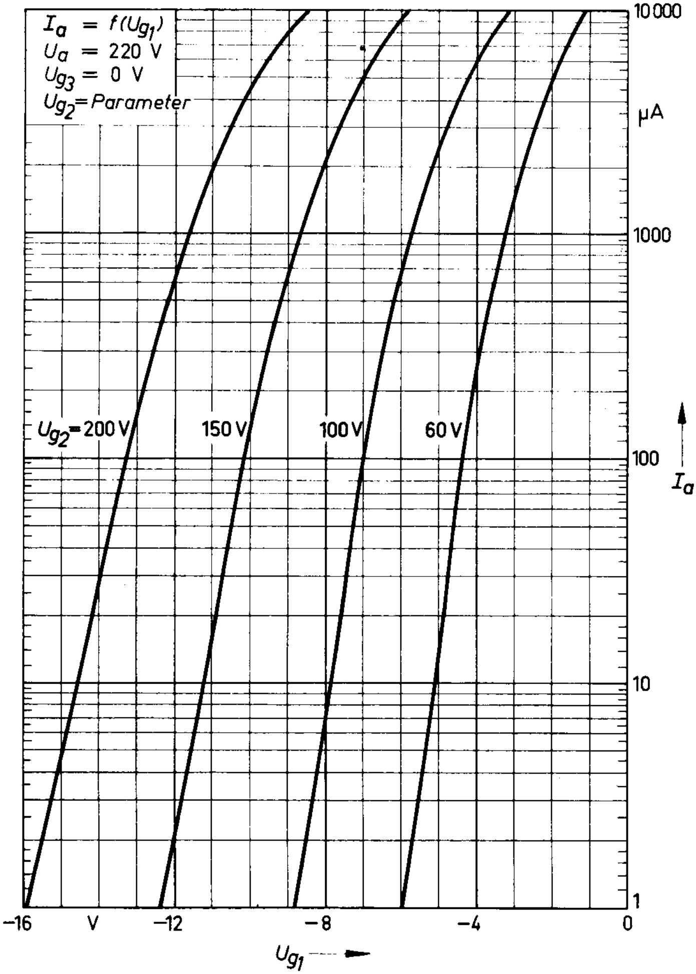
$I_a, S = f(U_{g_1})$



KENNLINIENFELD

$I_a = f\,(U_{g_1})$

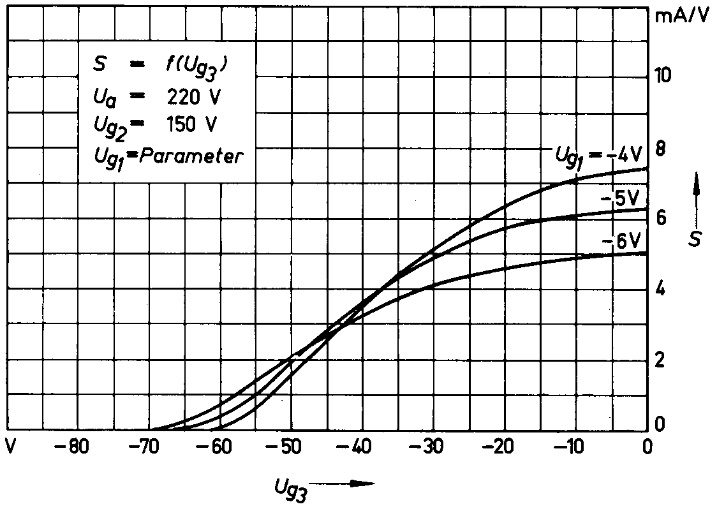
SIEMENS RÖHREN

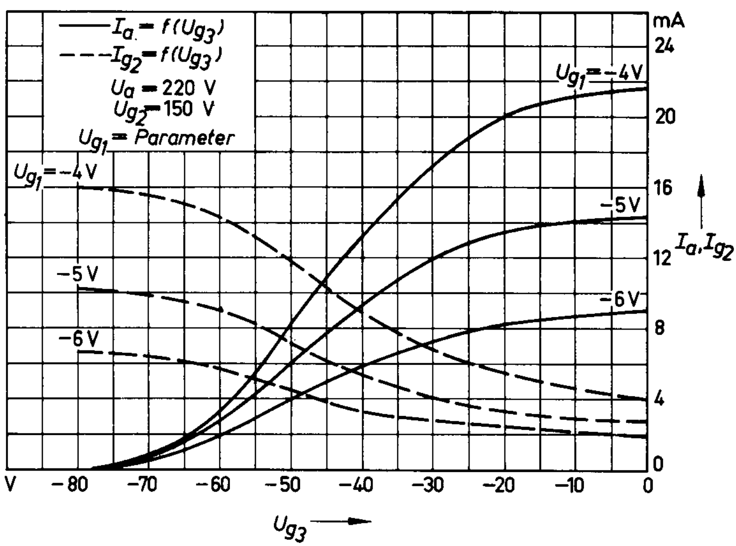


SIEMENS RÖHREN

BREMSGITTERKENNLINIENFELDER

$S = f(U_{g_3})$ $\quad I_a, I_{g_2} = f(U_{g_3})$

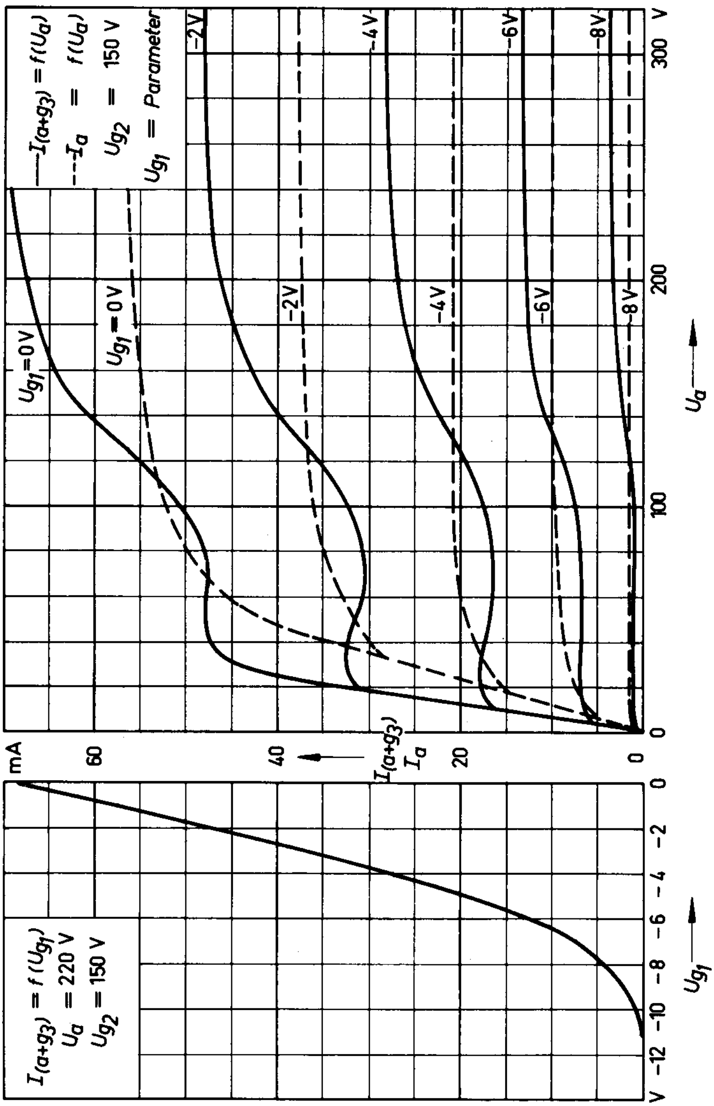




KENNLINIENFELDER

$I_{(a+g_3)} = f(U_{g_1})$ $\quad$ $I_{(a+g_3)} = f(U_a)$

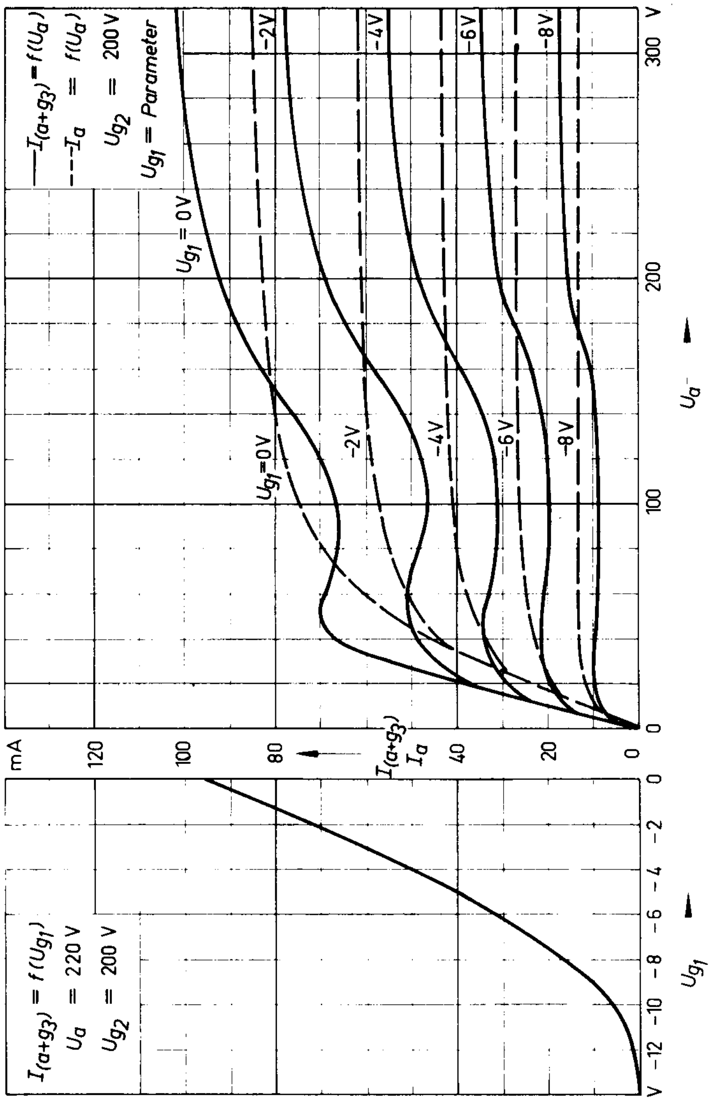
Tetrodenschaltung



KENNLINIENFELDER

$I_{(a+g_3)} = f(U_{g_1})$ $\quad$ $I_{(a+g_3)} = f(U_a)$

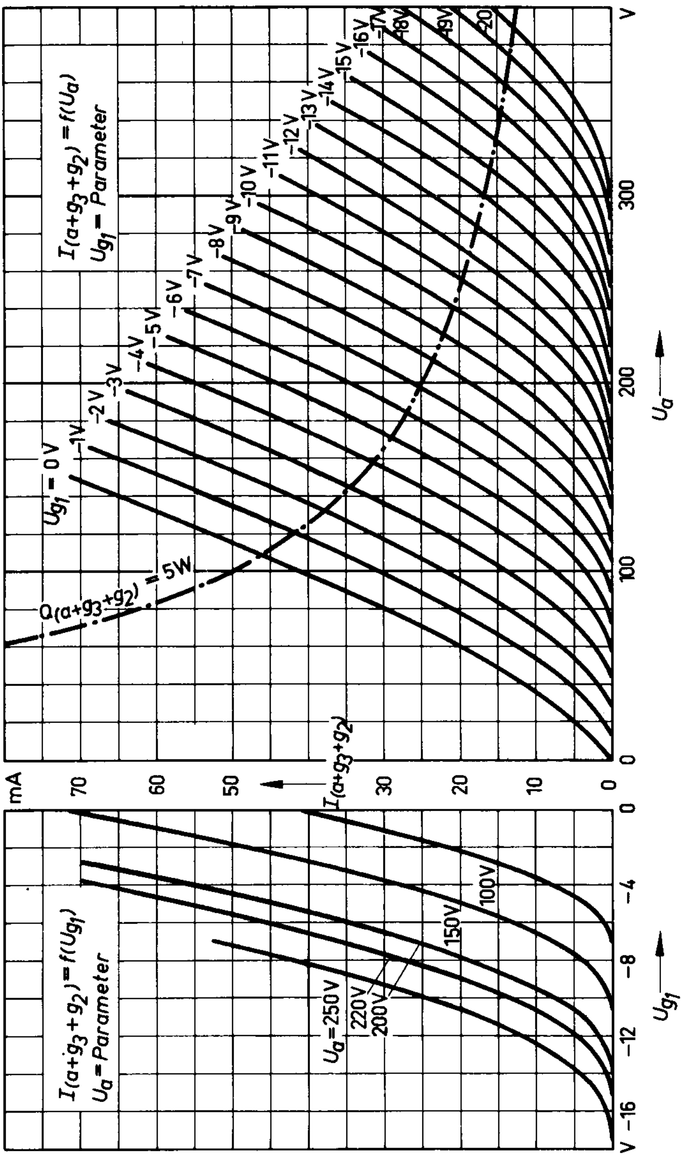
Tetrodenschaltung



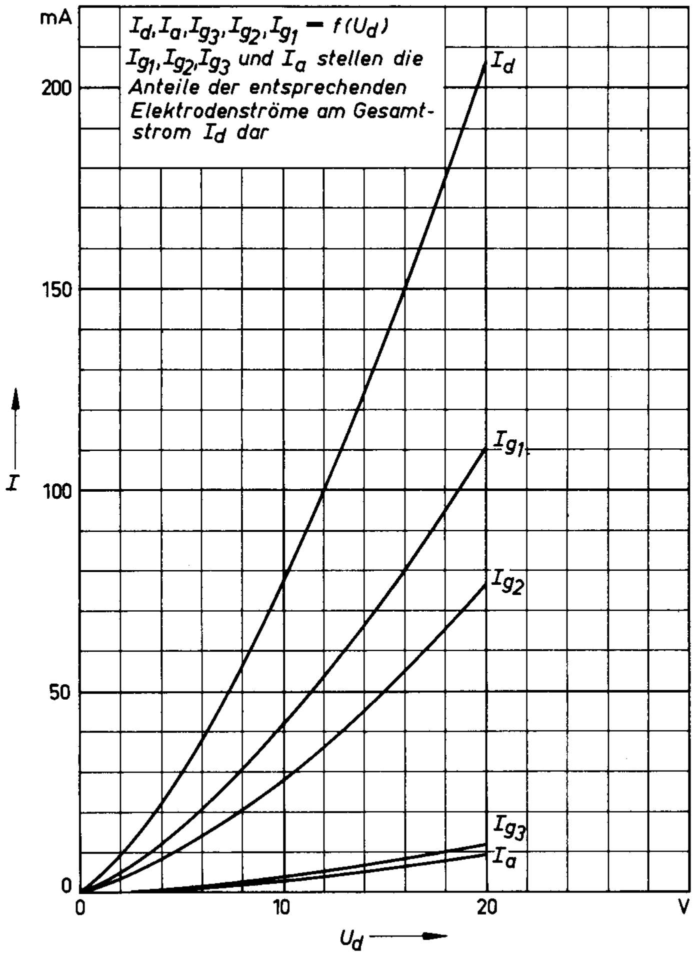
KENNLINIENFELDER

$I_{(a+g_3+g_2)} = f(U_{g1})$ $\quad$ $I_{(a+g_3+g_2)} = f(U_a)$

Triodenschaltung

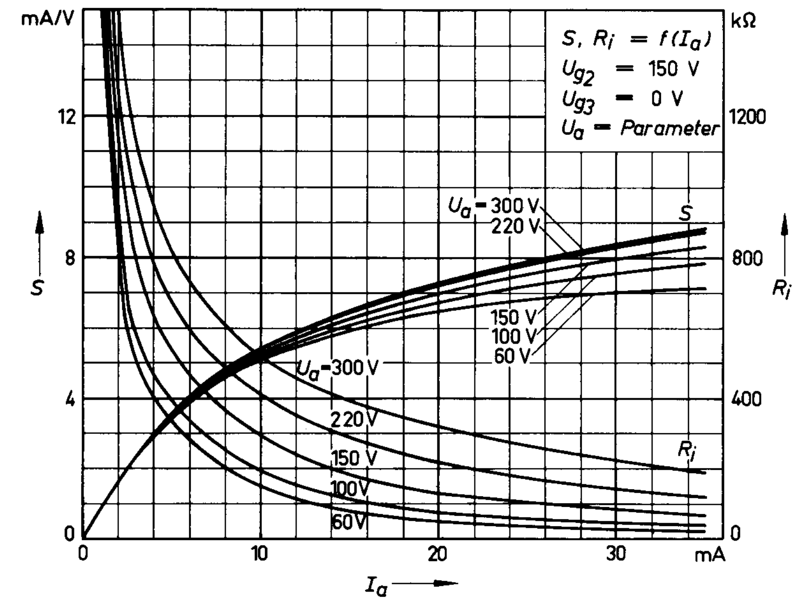


Diodenschaltung

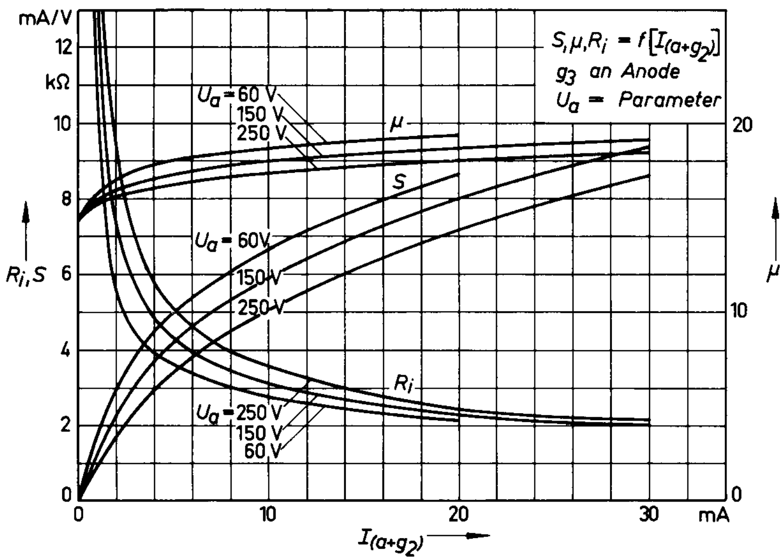


KENNLINIENFELDER

$S, R_i = f(I_a) \qquad S, \mu, R_i = f(I_{(a+g_2)})$

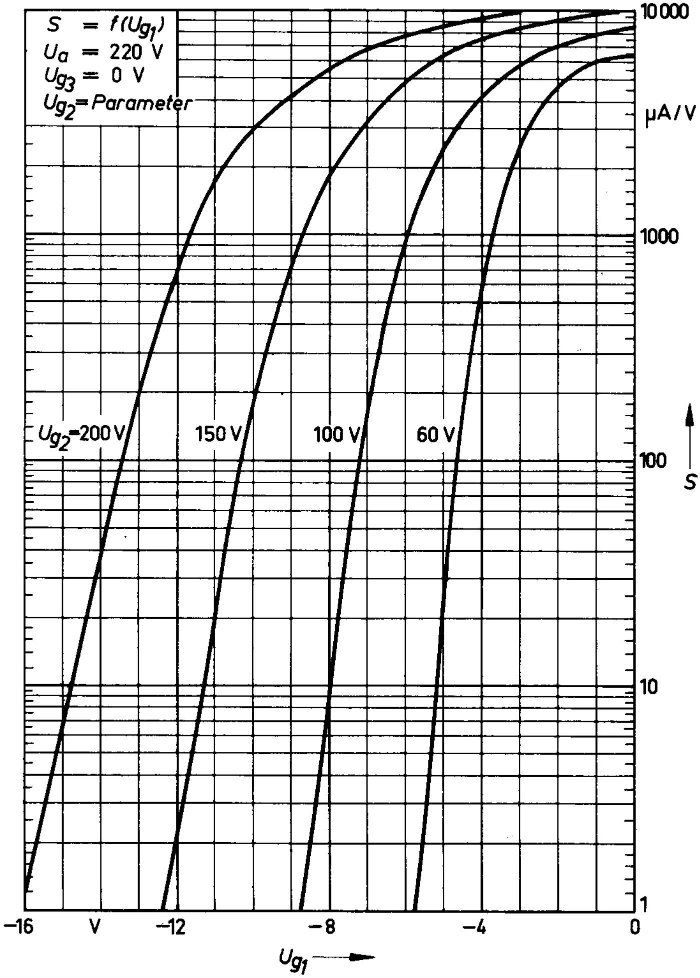


Triodenschaltung



STEILHEITSKENNLINIENFELD

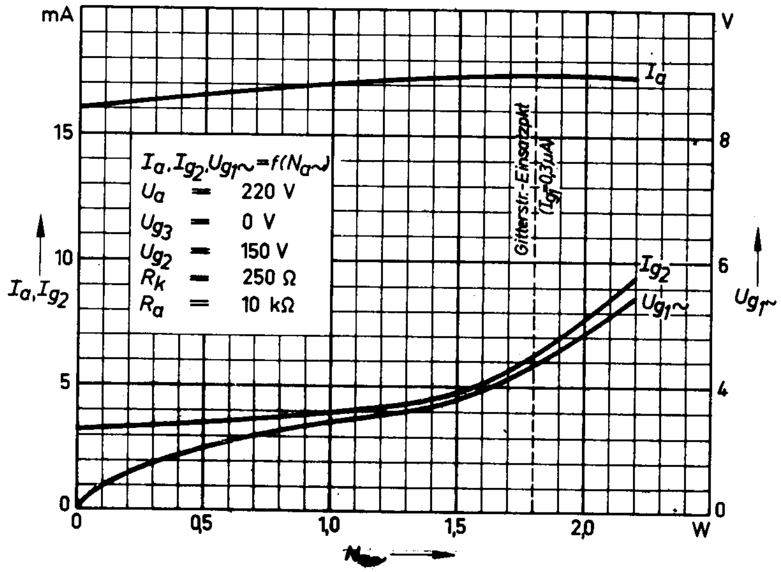
$S = f(U_{g_1})$

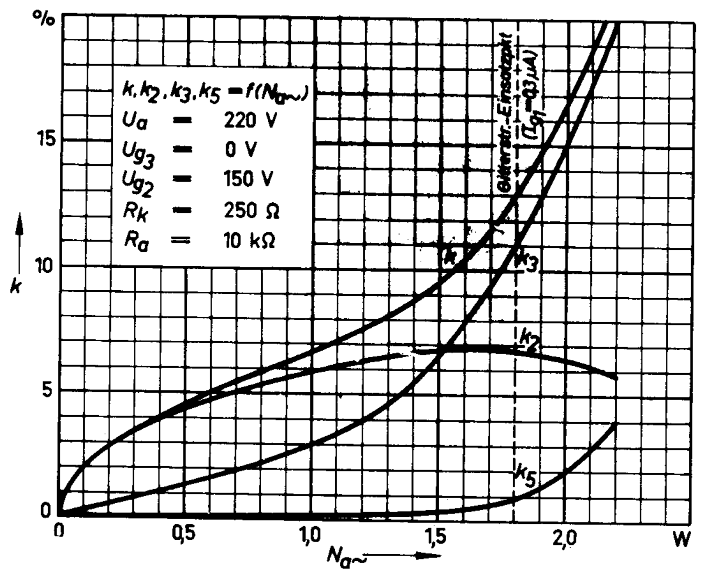


LEISTUNGSKENNLINIEN

$I_a, I_{g_2}, U_{g_1\sim}, k = f(N_{a\sim})$

$K, K_2, K_3, K_5 = f(N_{a\sim})$





SIEMENS & HALSKE AKTIENGESELLSCHAFT

WERNERWERK FÜR BAUELEMENTE

(Reprinted from the Italian magazine Audion. *Translation by Valeriano Tora)*

DUAL SINGLE 300B STEREO AMPLIFIER

BY FABRIZIO CAPPELLETI

This article describes a single-ended 300B, Class A output-stage stereo power amplifier, with no feedback and a rectifier tube and choke-type filter power supply. It features high-quality low-stray flux power and output transformers, the power one being tuned to the filter stage, and it includes traditional "in air" wiring and selected quality components. The balanced output stage allows bridging of the two channels for a double output power single-stage amp.

This 300B stereo amplifier (*Fig. 1*) is easy to build and is available as a kit at the extremely reasonable cost of 2,450,000 liras (approximately $1,500). The design of this amp is relatively simple (and inexpensive), since it uses only one driving pentode, chosen after careful consideration of both electrical and sonic properties.

It includes a "telephone" type tube, the TS49/PT49, which easily drives the 300B well over the high end of the audio range. Its good transconductance and rather low internal impedance allowed a circuit design with a sensitivity of only 800mV for 8W output, which

PHOTO 1: The finished amplifier.

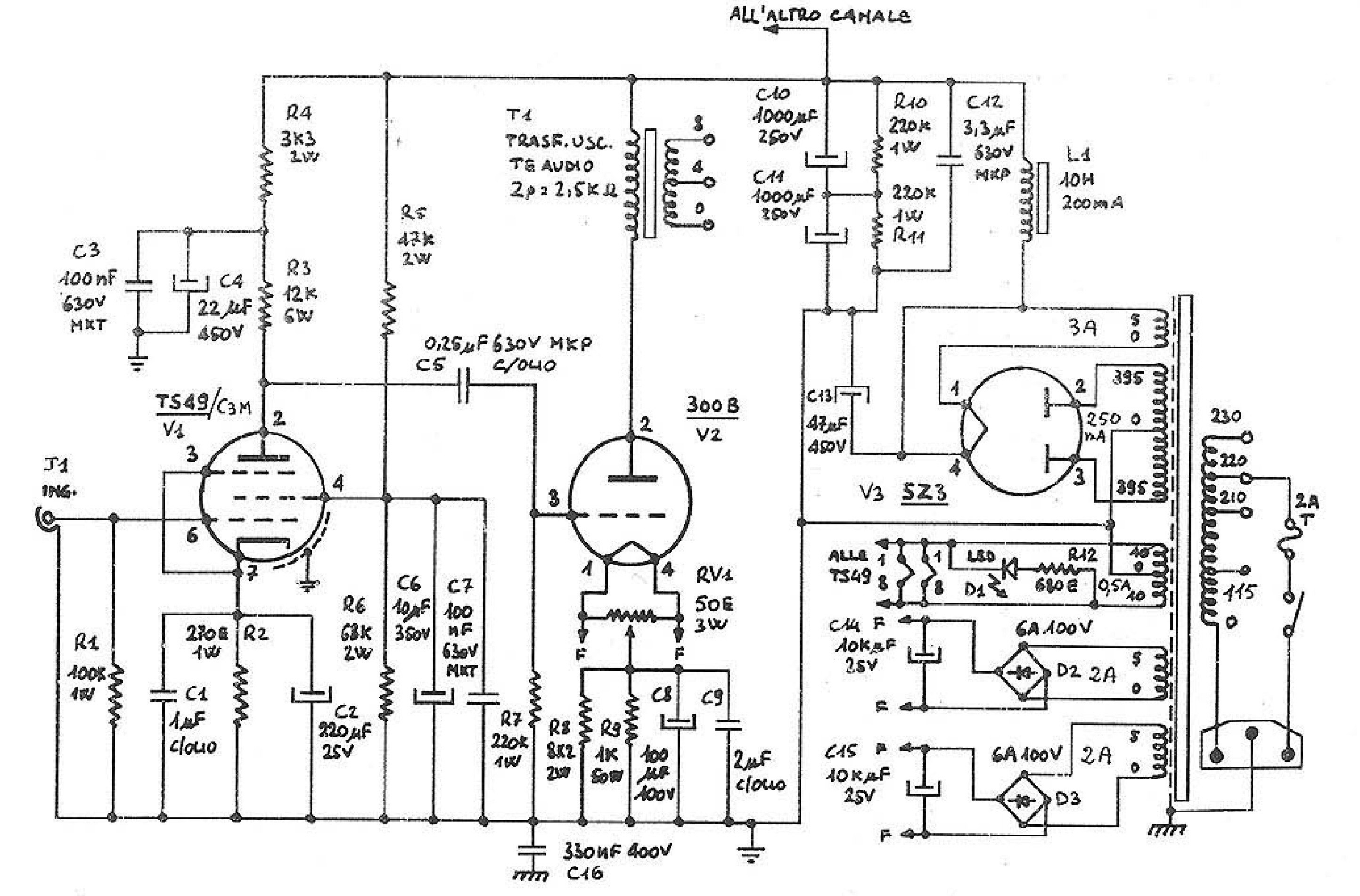


FIGURE 1: Schematic of the dual single 300B amp.

makes it suitable for direct connection to a CD player.

For all practical purposes, the TS49 turned out to be quite an exceptional tube, with very good electrical characteristics and excellent musicality in spite of its somewhat odd physical shape. Unfortunately, you will not have the pleasure of looking at a glowing glass tube, since this TS49 is enclosed in a black metal can for shielding purposes, but you will surely be rewarded by what this tube brings to your ears.

Electrical Circuit

The power-supply stage (*Fig. 2*) is common to both channels, which makes it both economical and easy to assemble–yet it is by no means of poor quality, being well oversized for the task. We are well aware of the influence this stage has on the performance of any amplifier, and particularly on that of an SE triode amp.

A single transformer supplies all voltages. A somewhat forgotten but still glorious old tube, the 5Z3, rectifies the plate voltage, while C13, L1, and the C10–C11 series form a classic pi filter to provide adequate leveling. C10 and C11 act like a single 500μF capacitor, and, together with C12, are largely responsible for the wide dynamic range. To eliminate hum problems, the 300B's filament is DC fed.

Power output is set at 8W, which does not overstress the output triode, but it is better not to pull the Chinese 300B "by the neck" if you don't want to replace them too often. We chose autopolarization essentially for two reasons: first, it's easily achieved and doesn't require any adjustment, and second, it ensures a wider stability margin against output-tube grid current than negative grid polarization. Although the 300B filament is DC fed, we still provided RV1 to further balance any residual hum, and actually found it quite useful.

Polarization of 300B is provided by R8/R9 parallel, bypassed by the parallel C8/C9. R9 is a 50W power resistor.

The driver stage, as already mentioned, makes use of a TS49/PT49 in a standard Class-A pentode configuration, optimized both electrically and musically. The same single driver stage is used to drive a single ended with 211 and 6C33 Class A.

TABLE 1	
AMP SPECIFICATIONS	
Stereo output power:	8W RMS per channel
Mono output power:	16W RMS
Frequency response:	16Hz–60kHz @ –2dB
Total gain:	10dB
Input sensitivity:	770mV
Output noise:	<0.5 mV

Transformers

Output and power-supply transformer quality, together with the choke-type filter, are mostly responsible for the character of this project. We thoroughly verified the winding specifications of these components for their electrical properties and sonic transparency, and we assembled many prototypes before arriving at the definitive choice. For the output, we wanted a low-resistance, electrically transparent component to achieve optimum interfacing of the output tube with the load; in fact, the total primary internal resistance is not more than 0.5Ω.

The secondaries are wound with a special technique that keeps their DC resistance below 0.2Ω. This results in a high

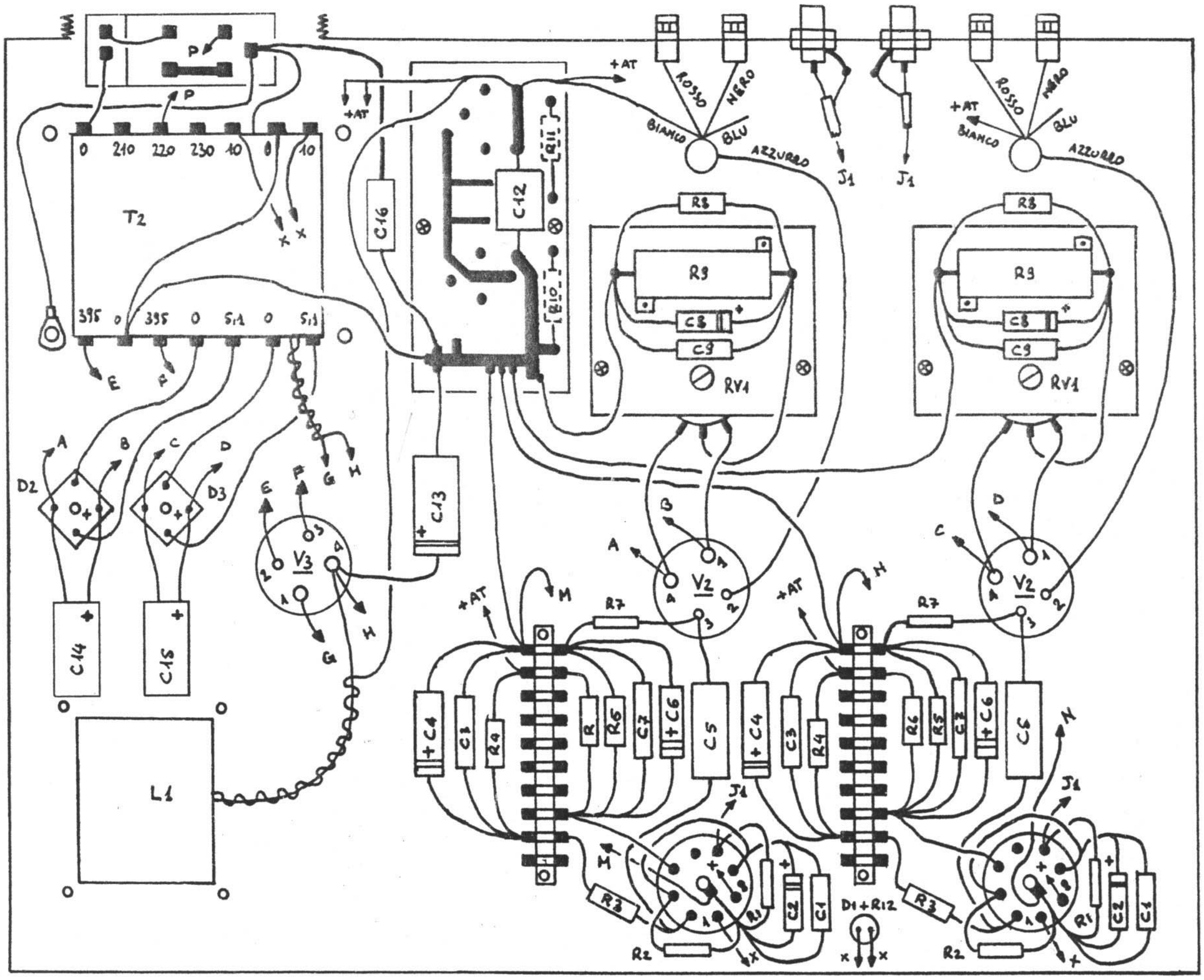


FIGURE 2: Component placement.

damping factor, which, being completely without negative feedback, relies heavily on the output transformer's specs for the load-damping characteristics.

Of course, for optimum low-frequency response, the output transformer is provided with an air gap in its iron core to prevent saturation due to DC flowing through the primary windings. The size of this gap isn't just the result of mathematical calculations; each transformer is optimized through observation of the sine wave at maximum output power and nominal polarization current.

Winding Geometry

Primary inductance was determined to reconcile the need for good high-frequency-response linearity with the number of turns used. The winding geometry and type of insulation used determine the component's capacitance value and resonance frequency.

The winding technique is complex, since it avoids use of modern digital-controlled automatic machines, relying instead on experienced winders who work on manual machines to optimize wire tension and turn spacing, filling each space with an even layer of wire without overlapping turns and with maximum precision.

Most of the winding concepts used for the output transformer also apply to construction of the power-supply transformer, with the addition of safety requirements according to standard European and international rules and regulations. For instance, due to the high voltages here, the requirements include a copper electrostatic shield between primary and secondary windings and proper separation between windings and terminal leads.

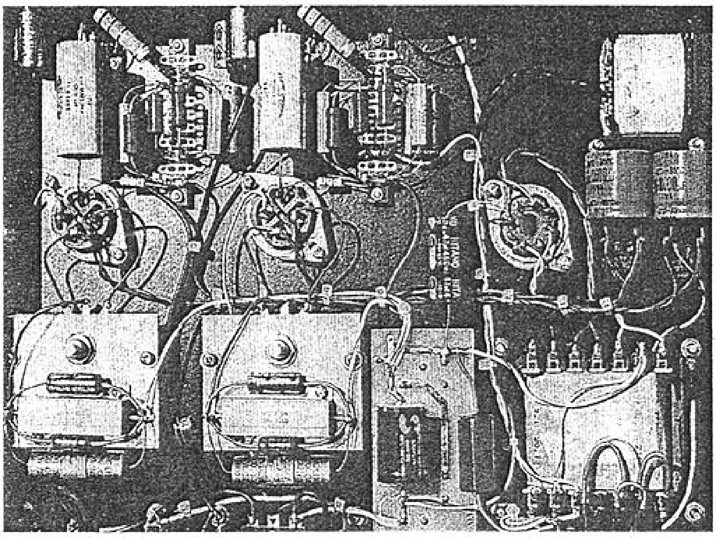


PHOTO 2: View of the amp's interior.

Testing is done on each unit, not on a sampling basis. The most significant tests are nondestructive insulation testing and measuring accurate voltage and no-load current. Inductance value must not resonate with the filter capacitor and the type of choke used. Transformers are the most critical and costly part of a tube amplifier because they greatly influence the good results of the finished product.

Building the Unit

This easy-to-assemble kit comes with a manual, complete with component layout. Also included is a black steel cabinet with all cut-outs and screw holes, as well as solid olive-wood side panels. The kit includes output transformers, power-supply transformer, filter choke, tubes, and all passive components (*Photos 1* and *2* show the finished product).

Performance and Conclusions

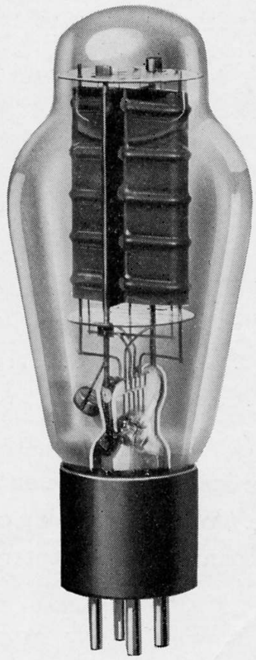
The unit achieves very good performance figures, validated through extensive listening tests, which we conducted to eliminate all those little sonic blemishes that come with every prototype. You can hear and appreciate the 8W of this amp even with somewhat inefficient speakers. All those we tested highlighted the remarkable transparency that, together with excellent musicality, make this a very high-level kit.

In conclusion, we must point out that building a high-level amplifier doesn't mean just jotting down a circuit and throwing a few good-quality components together. Rather, it involves thoroughly studying the project, then testing, listening, and trying again so as to avoid ending up with doubtful results. ❖

This kit is available from Audion, Giampiero Pagini, Casella postale 6599 Centro Settoriale Novoli, 50127 Florence, Italy, voice/FAX +39 55 293267. Price is 2,450,000 liras (about $1,500) plus shipping. A manual (in English) is also available. Contact Audion for more information.

Western Electric

300A and 300B Vacuum Tubes



Classification—Moderate power, filamentary triodes for Class A service

These tubes are identical except for the location of the bayonet pin in the base.

Application—Audio-frequency amplifier in positions where power outputs of approximately ten watts or less are required at relatively low plate voltages.

Dimensions—Dimensions, outline diagrams of the tubes and bases, and the arrangement of electrode connections to the base terminals are shown in Figures 1 and 2.

Base and Mounting—These vacuum tubes employ medium, four-pin thrust type bases suitable for use in Western Electric 143B or similar sockets. The 300B tube has the bayonet pin so located that it may also be mounted in a Western Electric 100M, 115B or similar socket.

The tubes may be mounted in either a vertical or horizontal position. If mounted in a horizontal position, the plane of the filament, which is indicated in Figure 2, should be vertical.

Average Direct Interelectrode Capacitances

Grid to plate	15 $\mu\mu$f.
Grid to filament	9 $\mu\mu$f.
Plate to filament	4.3$\mu\mu$f.

Filament Rating

Filament voltage	5.0 volts, a.c. or d.c.
Nominal filament current	1.2 amperes

The filaments of these tubes are designed to operate on a voltage basis and should be operated at as near the rated voltage as possible. When alternating current is used for heating the filament, the grid and plate returns should be connected to a center tap on the secondary of the filament transformer.

Characteristics—Average characteristics—($E_f = 5.0$ volts, a.c., $E_b = 300$ volts and $E_c = -61$ volts).

Plate current	60 milliamperes
Amplification factor	3.85
Plate resistance	700 ohms
Grid to plate transconductance	5500 micromhos

Plate-current characteristics for a typical tube are shown in Figure 3 as functions of grid bias, for alternating-current filament supply. The corresponding amplification-factor, plate-resistance, and transconductance characteristics are given in Figures 4, 5 and 6, respectively. When direct-current filament supply is used, and the grid and plate returns are connected to the negative end of the filament, the same characteristics are applicable if 3.5 is subtracted from the numerical value of each grid bias.

Limiting Operating Conditions for Safe Operation—not simultaneous ratings

Maximum plate voltage	450 volts
Maximum plate dissipation	40 watts
Maximum plate current of average tube for fixed grid bias	70 milliamperes
Maximum plate current for manually adjusted grid bias or self-biasing circuit	100 milliamperes

Recommended Operating Conditions

Recommended and maximum conditions for alternating-current filament supply are given in the table. Recommended conditions or others of no greater severity should be selected in preference to maximum conditions wherever possible. The life of the tube at maximum operating conditions will be shorter than at the recommended conditions.

Where it is necessary to operate the tube at or near the maximum plate current of 100 milliamperes, provision should be made for adjusting the grid bias of each tube independently, so that the maximum safe plate current will not be exceeded in any tube. Alternatively, a self-biasing circuit may be used, in which the grid bias for the tube is obtained from the voltage drop produced by the plate current of that tube flowing through a resistance.

Where it is necessary to use a fixed grid bias, the plate current of the average tube should be limited to a maximum value of 70 milliamperes, so that tubes having plate currents higher than the average will not exceed the maximum safe plate current.

Power Output and Distortion

Performance data including power output, second and third harmonic levels for a number of operating conditions are given in the table.

The variation of power output and harmonic levels with load resistance for several values of operating plate current are shown in Figures 7, 8 and 9, for a plate voltage of 350 volts.

The peak value of the sinusoidal input voltage, E_{gm}, which gives the indicated power output, P_m, and harmonic levels, F_{2m} and F_{3m}, for each point in both the curves and the table, is numerically equal to the grid biasing voltage at that point. For a smaller input voltage E_g, the approximate levels may be computed from the following relations.

$$P = P_m \left(\frac{E_g}{E_{gm}}\right)^2$$

$$F_2 = F_{2m} + 20 \log_{10} \frac{E_{gm}}{E_g}$$

$$F_3 = F_{3m} + 40 \log_{10} \frac{E_{gm}}{E_g}$$

TABLE

	Plate Voltage Volts	Grid Bias Volts	Plate Current Milliamperes	Load Resistance Ohms	Power Output Watts	Second Harmonic db	Third Harmonic db
Recommended	200	— 42	30	2000	3.0	20	31
Operating	200	— 39	40	2500	2.6	26	38
Conditions	200	— 37	50	2500	2.5	30	45
	250	— 55	30	2000	4.9	18	27
	250	— 55	30	4500	3.2	27	40
	250	— 52	40	3000	4.0	26	36
	250	— 50	50	2500	4.4	26	39
	250	— 48	60	2000	4.7	26	38
	250	— 48	60	2700	4.1	30	45
	250	— 45	80	1500	5.0	26	41
	300	— 65	40	2500	6.7	20	30
	300	— 63	50	2000	7.2	21	29
	300	— 63	50	3000	6.1	26	37
	300	— 61	60	2400	6.6	26	37
	300	— 61	60	3400	5.6	30	44
	300	— 58	80	1700	7.5	26	37
	350	— 76	50	3600	7.8	26	38
	350	— 76	50	5000	6.2	30	45
	350	— 74	60	2000	10.2	21	30
	350	— 74	60	3000	8.3	26	38
	350	— 74	60	4000	7.0	30	44
	350	— 71	80	2200	9.6	26	39
	400	— 91	40	5000	8.4	26	37
	400	— 89	50	3000	11.5	21	31
	400	— 89	50	4000	9.4	25	38
	400	— 87	60	3500	10.5	26	38
	400	— 87	60	5000	8.3	30	46
	400	— 84	80	2500	12.5	25	37
Maximum	450	—104	40	6000	9.5	26	38
Operating	450	—102	50	5000	10.7	27	39
Conditions	450	—102	50	6500	9.0	30	45
	450	—100	60	4000	12.5	26	38
	450	—100	60	5500	10.1	30	44
	450	— 97	80	2000	17.8	21	30
	450	— 97	80	3000	14.6	26	37
	450	— 97	80	4500	11.5	31	45

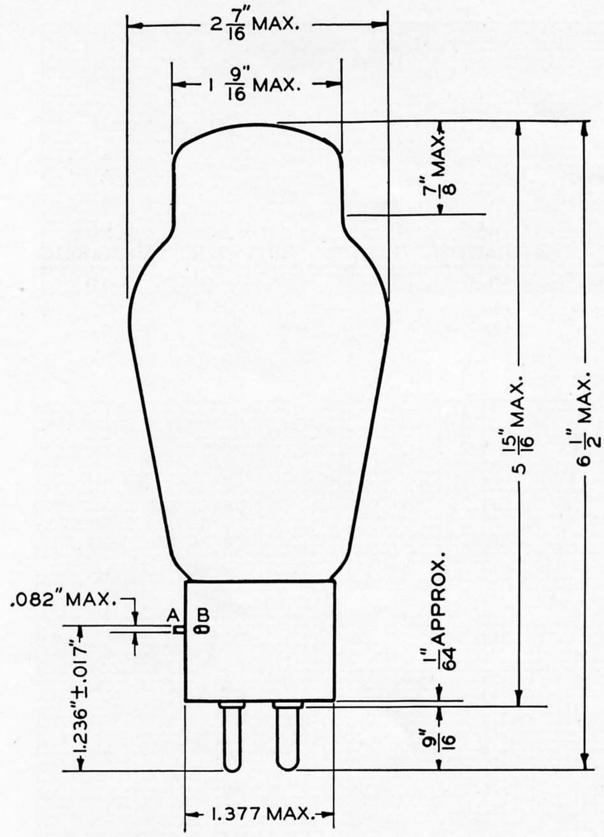


FIG. 1

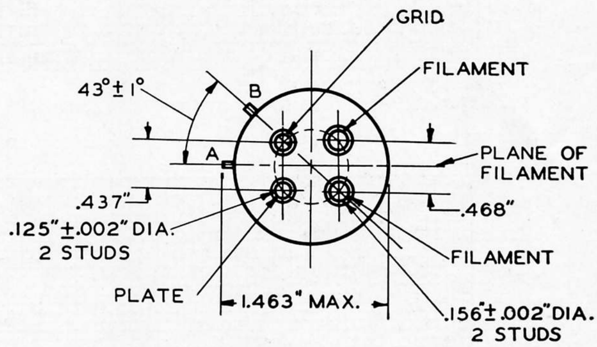


FIG. 2

A—LOCATION OF BAYONET PIN FOR 300A TUBE
B—LOCATION OF BAYONET PIN FOR 300B TUBE

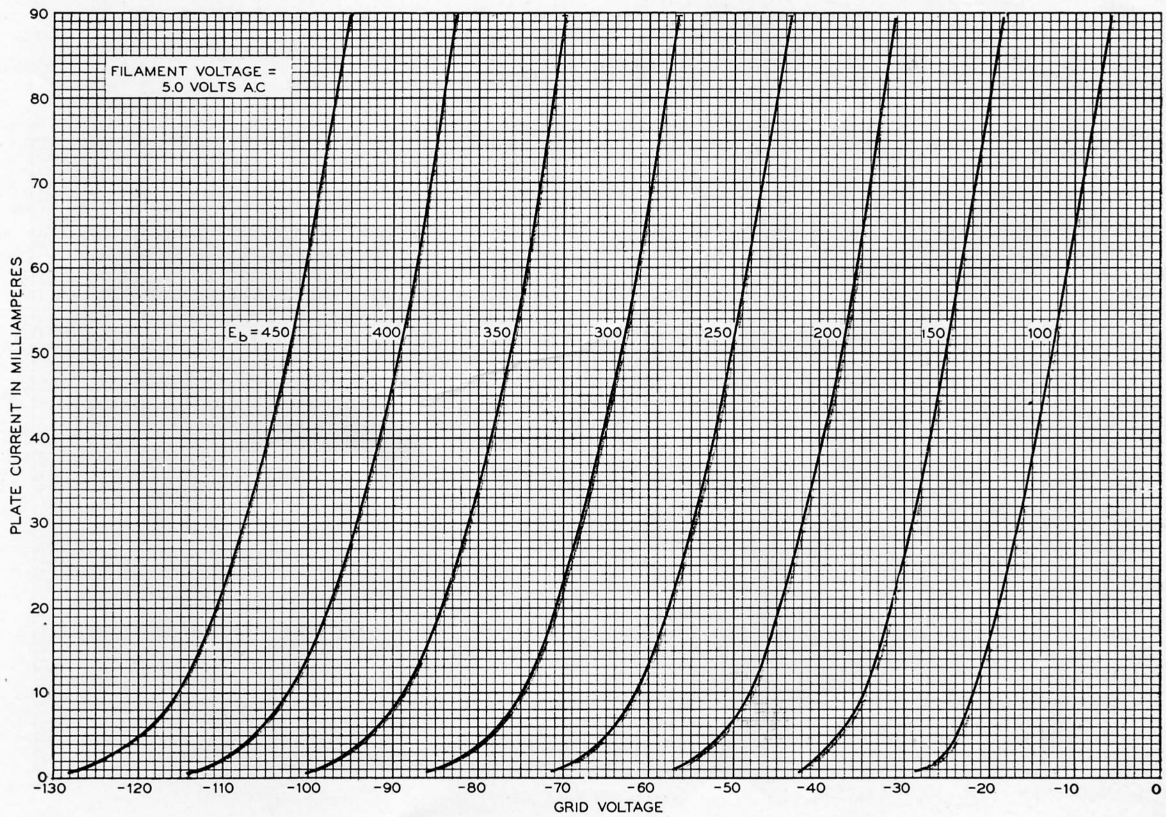


FIG. 3

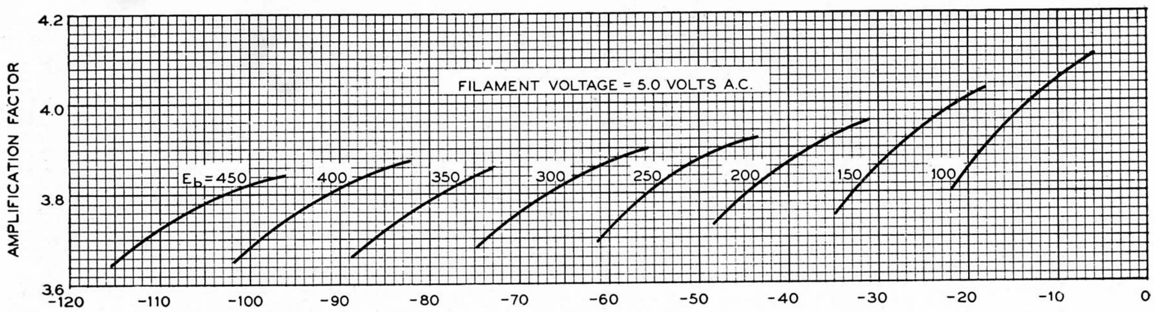


FIG. 4

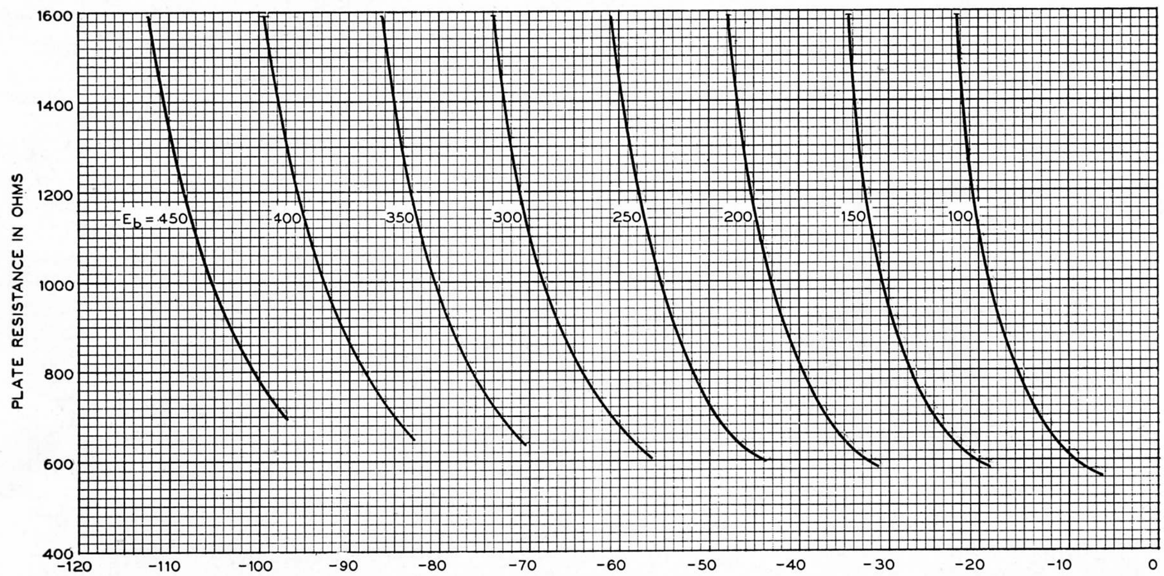


FIG. 5

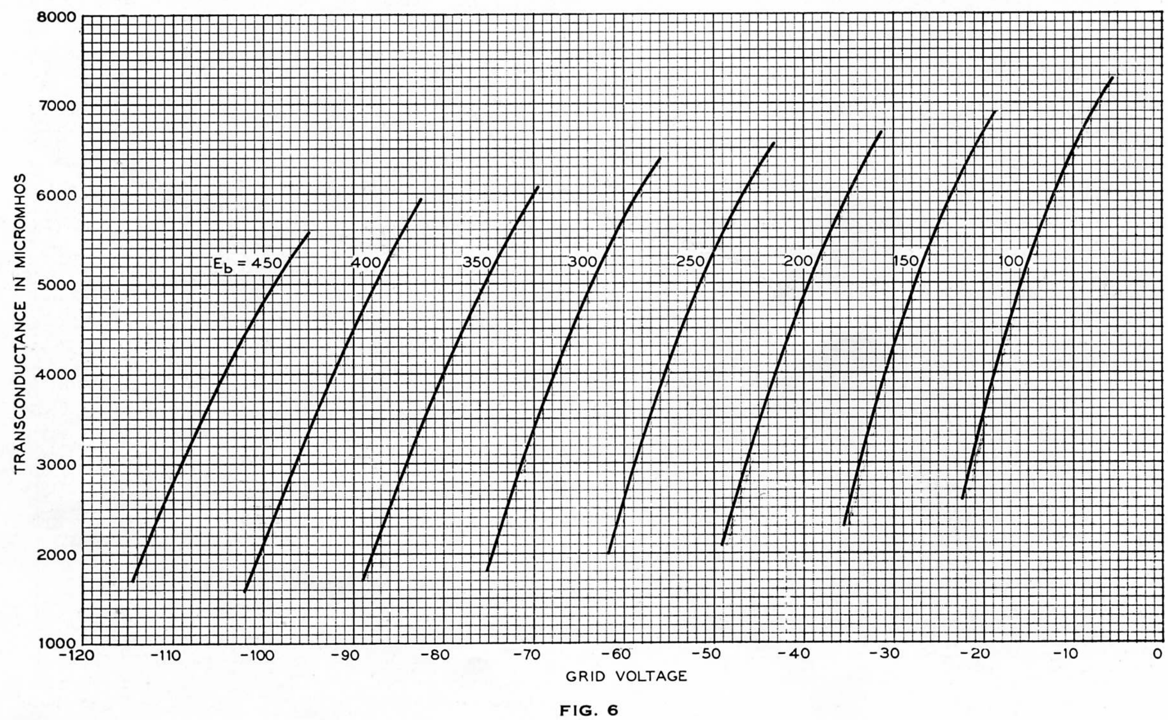


FIG. 6

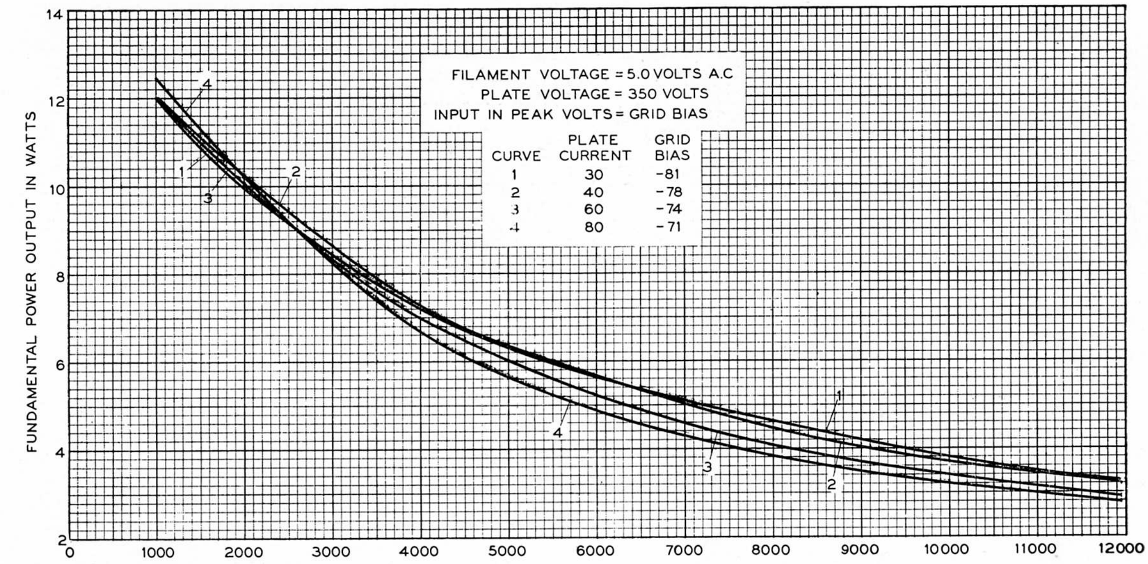


FIG. 7

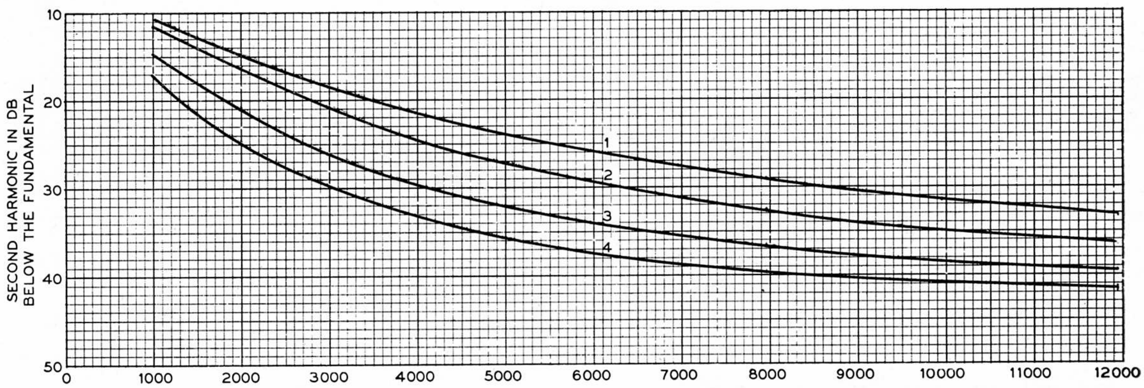


FIG. 8

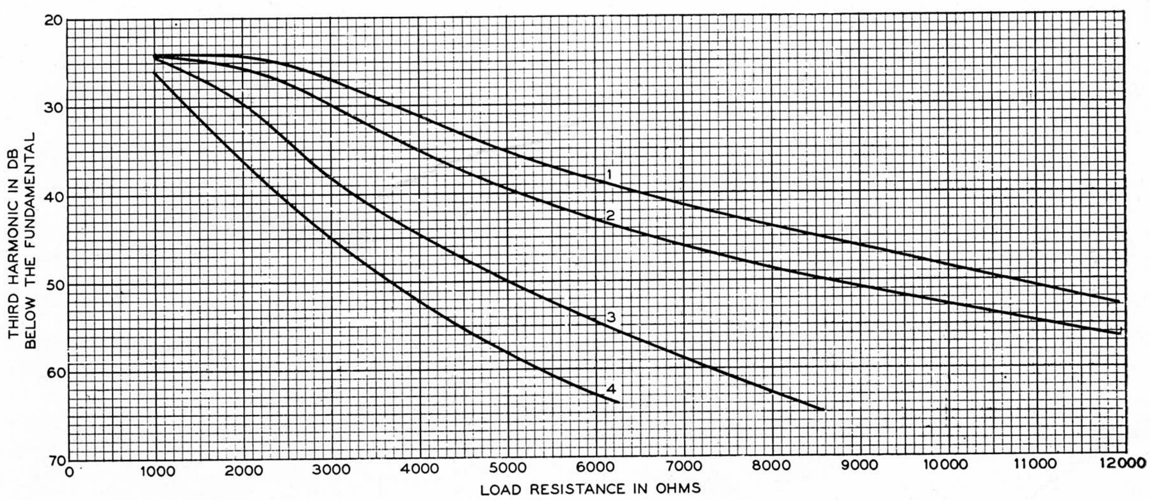
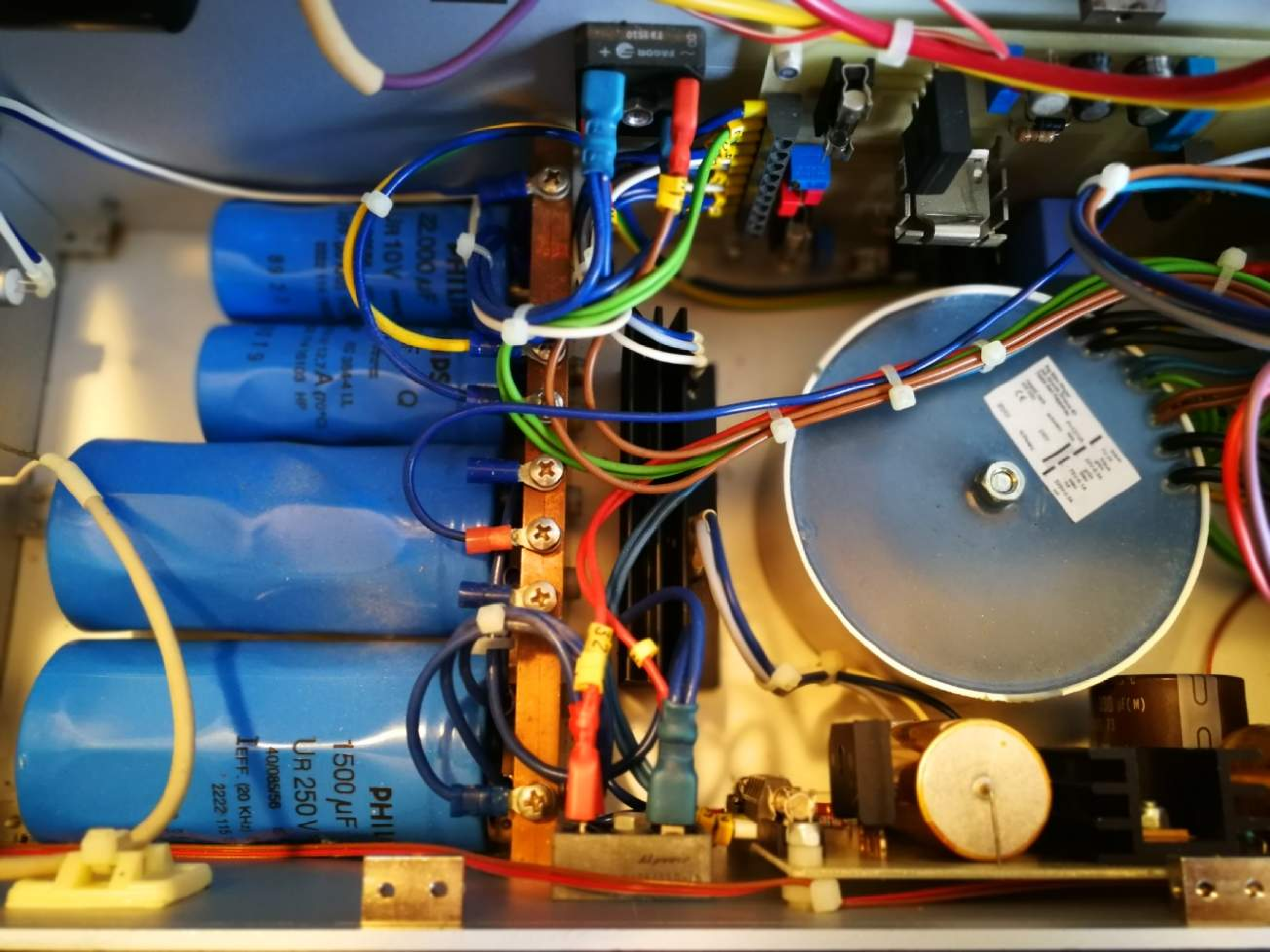


FIG. 9

1-H-39-6M
PRINTED IN U.S.A.

Developments of Bell Telephone Laboratories, Incorporated, research laboratories of the American Telephone and Telegraph Company and the Western Electric Company


1500 µF
UR 250 V


Ing.Büro Ringler
Joh.Strauss Strasse 40
74906 Bad Rappenau
P=131VA
50Hz
Hergest. nach
VDE 0551
CE
schwarz
230V
schwarz
20/01
braun
7V-3A
braun
grün
22V-0.3A
grün
blau
75V-0.1A
blau
rot
320V-0.3A
rot


JOY-iT
DMSO2D72
Handheld Oscillosco
CH1 = 2.00V
CH2 = 100V
T→ 0.000ns
Time 20.00us
F1
F2
F3
F4
Scope
DMM
AWG
Menu
Trig
Enter
Auto
Channel
Time
A
mA
COM
V/Ω/C/
10A MAX
UNFUSED
FUSED
CAT II 600V
COAXIAL

7.5A, 5A, 3A Low Dropout Positive Adjustable Regulators

FEATURES

- Three-Terminal Adjustable
- Output Current of 3A, 5A or 7.5A
- Operates Down to 1V Dropout
- Guaranteed Dropout Voltage at Multiple Current Levels
- Line Regulation: 0.015%
- Load Regulation: 0.01%
- 100% Thermal Limit Functional Test
- Fixed Versions Available

APPLICATIONS

- High Efficiency Linear Regulators
- Post Regulators for Switching Supplies
- Constant Current Regulators
- Battery Chargers

DEVICE	OUTPUT CURRENT*
LT1083	7.5A
LT1084	5.0A
LT1085	3.0A

*For a 1.5A low dropout regulator see the LT1086 data sheet.

DESCRIPTION

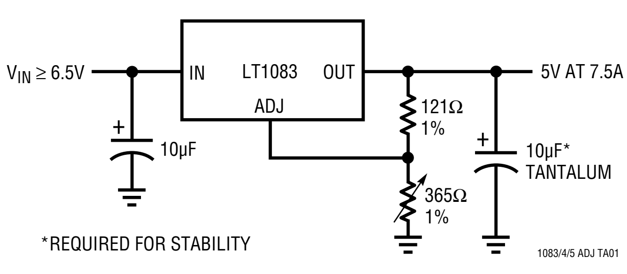
The LT1083 series of positive adjustable regulators are designed to provide 7.5A, 5A and 3A with higher efficiency than currently available devices. All internal circuitry is designed to operate down to 1V input-to-output differential and the dropout voltage is fully specified as a function of load current. Dropout is guaranteed at a maximum of 1.5V at maximum output current, decreasing at lower load currents. On-chip trimming adjusts the reference voltage to 1%. Current limit is also trimmed, minimizing the stress on both the regulator and power source circuitry under overload conditions.

The LT1083/LT1084/LT1085 devices are pin compatible with older three-terminal regulators. A 10µF output capacitor is required on these new devices. However, this is included in most regulator designs.

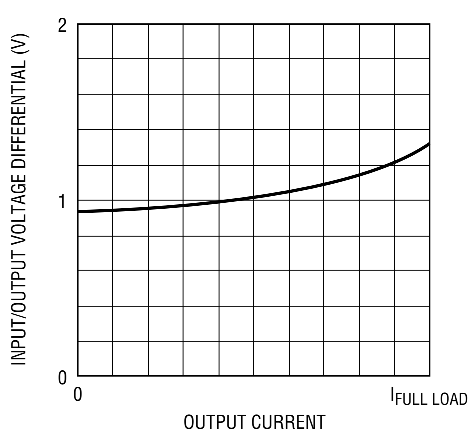
Unlike PNP regulators, where up to 10% of the output current is wasted as quiescent current, the LT1083 quiescent current flows into the load, increasing efficiency.

TYPICAL APPLICATION

5V, 7.5A Regulator



Dropout Voltage vs Output Current



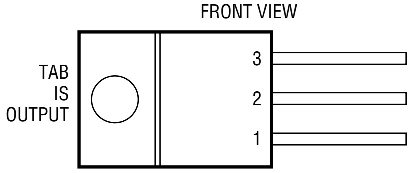
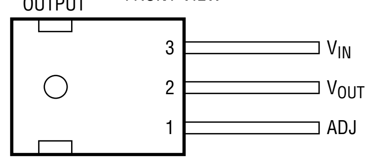
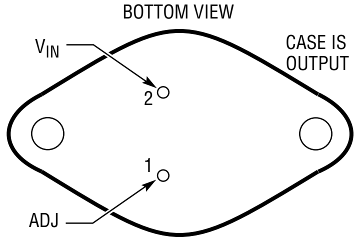
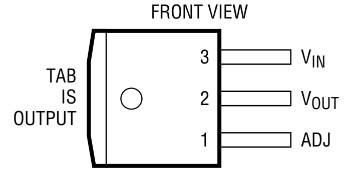
ABSOLUTE MAXIMUM RATINGS

Power Dissipation .... Internally Limited
Input-to-Output Voltage Differential
"C" Grades 30V
"I" Grades 30V
"M" Grades 35V
Operating Junction Temperature Range
"C" Grades: Control Section .... 0°C to 125°C
Power Transistor .... 0°C to 150°C
"I" Grades: Control Section .... –40°C to 125°C
Power Transistor .... –40°C to 150°C
"M" Grades: Control Section .... –55°C to 150°C
Power Transistor .... –55°C to 200°C
Storage Temperature Range .... –65°C to 150°C
Lead Temperature (Soldering, 10 sec) .... 300°C

PRECONDITIONING

100% thermal shutdown functional test.

PACKAGE/ORDER INFORMATION

	ORDER PART NUMBER		ORDER PART NUMBER
 T PACKAGE 3-LEAD PLASTIC TO-220 θ_{JA} = 50°C/W	LT1084CT LT1084IT LT1085CT LT1085IT	 P PACKAGE 3-LEAD PLASTIC TO-3P θ_{JA} = 35°C/W	LT1083CP LT1084CP
 K PACKAGE 2-LEAD TO-3 METAL CAN θ_{JA} = 35°C/W	LT1083CK LT1083MK LT1084CK LT1084MK LT1085CK LT1085MK	 M PACKAGE 3-LEAD PLASTIC DD θ_{JA} = 30°C/W* *WITH PACKAGE SOLDERED TO 0.5IN² COPPER AREA OVER BACKSIDE GROUND PLANE OR INTERNAL POWER PLANE. θ_{JA} CAN VARY FROM 20°C/W TO > 40°C/W DEPENDING ON MOUNTING TECHNIQUE.	LT1084CM LT1085CM

ELECTRICAL CHARACTERISTICS

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Reference Voltage	I_{OUT} = 10mA, T_J = 25°C, (V_{IN} – V_{OUT}) = 3V		1.238	1.250	1.262	V
	10mA ≤ I_{OUT} ≤ $I_{FULL\ LOAD}$ 1.5V ≤ (V_{IN} – V_{OUT}) ≤ 25V (Notes 3, 5, 6)	●	1.225	1.250	1.270	V
Line Regulation	I_{LOAD} = 10mA, 1.5V ≤ (V_{IN} – V_{OUT}) ≤ 15V, T_J = 25°C (Notes 1, 2)			0.015	0.2	%
		●		0.035	0.2	%
	M Grade: 15V ≤ (V_{IN} – V_{OUT}) ≤ 35V (Notes 1, 2)	●		0.05	0.5	%
	C, I Grades: 15V ≤ (V_{IN} – V_{OUT}) ≤ 30V (Notes 1, 2)	●		0.05	0.5	%

ELECTRICAL CHARACTERISTICS

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Load Regulation	$(V_{IN} - V_{OUT}) = 3V$ $10mA \le I_{OUT} \le I_{FULL\ LOAD}$ $T_J = 25°C$ (Notes 1, 2, 3, 5)			0.1	0.3	%
		●		0.2	0.4	%
Dropout Voltage	$\Delta V_{REF} = 1\%$, $I_{OUT} = I_{FULLLOAD}$ (Notes 4, 5, 7)	●		1.3	1.5	V
Current Limit						
LT1083	$(V_{IN} - V_{OUT}) = 5V$	●	8.0	9.5		A
	$(V_{IN} - V_{OUT}) = 25V$	●	0.4	1.0		A
LT1084	$(V_{IN} - V_{OUT}) = 5V$	●	5.5	6.5		A
	$(V_{IN} - V_{OUT}) = 25V$	●	0.3	0.6		A
LT1085	$(V_{IN} - V_{OUT}) = 5V$	●	3.2	4.0		A
	$(V_{IN} - V_{OUT}) = 25V$	●	0.2	0.5		A
Minimum Load Current	$(V_{IN} - V_{OUT}) = 25V$	●		5	10	mA
Thermal Regulation	$T_A = 25°C$, 30ms Pulse					
LT1083				0.002	0.010	%/W
LT1084				0.003	0.015	%/W
LT1085				0.004	0.020	%/W
Ripple Rejection	f = 120Hz, $C_{ADJ} = 25\mu F$, $C_{OUT} = 25\mu F$ Tantalum $I_{OUT} = I_{FULL\ LOAD}$, $(V_{IN} - V_{OUT}) = 3V$ (Notes 5, 6, 7)	●	60	75		dB
Adjust Pin Current	$T_J = 25°C$			55		μA
		●			120	μA
Adjust Pin Current Change	$10mA \le I_{OUT} \le I_{FULL\ LOAD}$ $1.5V \le (V_{IN} - V_{OUT}) \le 25V$ (Note 5)	●		0.2	5	μA
Temperature Stability		●		0.5		%
Long Term Stability	$T_A = 125°C$, 1000 Hrs			0.3	1	%
RMS Output Noise (% of V_{OUT})	$T_A = 25°C$ $10Hz = \le f \le 10kHz$			0.003		%
Thermal Resistance Junction-to-Case	Control Circuitry/Power Transistor					
LT1083	K Package				0.6/1.6	°C/W
	P Package				0.5/1.6	°C/W
LT1084	K Package				0.75/2.3	°C/W
	P Package				0.65/2.3	°C/W
	M, T Packages				0.65/2.7	°C/W
LT1085	K Package				0.9/3.0	°C/W
	M, T Packages				0.7/3.0	°C/W

The ● denotes the specifications which apply over the full operating temperature range.

Note 1: See thermal regulation specifications for changes in output voltage due to heating effects. Load and line regulation are measured at a constant junction temperature by low duty cycle pulse testing.

Note 2: Line and load regulation are guaranteed up to the maximum power dissapation (60W for the LT1083, 45W for the LT1084 (K, P), 30W for the LT1084 (T) and 30W for the LT1085). Power dissipation is determined by the input/output differential and the output current. Guaranteed maximum power dissipation will not be available over the full input/output voltage range.

Note 3: $I_{FULL\ LOAD}$ is defined in the current limit curves. The $I_{FULLLOAD}$ curve is defined as the minimum value of current limit as a function of input-to-output voltage. Note that the 60W power dissipation for the LT1083 (45W for the LT1084 (K, P), 30W for the LT1084 (T), 30W for the LT1085) is only achievable over a limited range of input-to-output voltage.

Note 4: Dropout voltage is specified over the full output current range of the device. Test points and limits are shown on the Dropout Voltage curve.

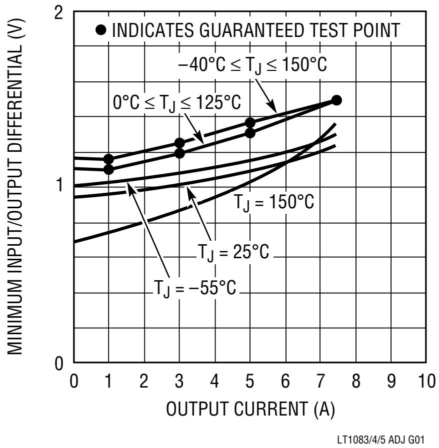
Note 5: For LT1083 $I_{FULL\ LOAD}$ is 5A for $-55°C \le T_J < -40°C$ and 7.5A for $T_J \ge -40°C$.

Note 6: $1.7V \le (V_{IN} - V_{OUT}) \le 25V$ for LT1084 at $-55°C \le T_J \le -40°C$.

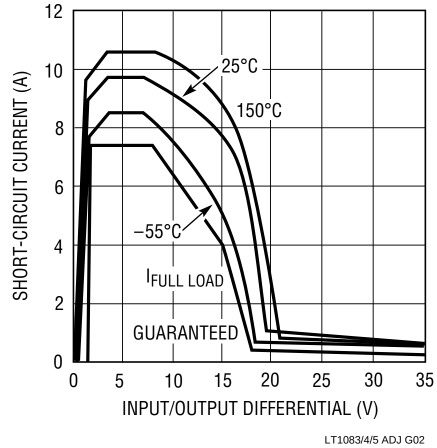
Note 7: Dropout is 1.7V maximum for LT1084 at $-55°C \le T_J \le -40°C$.

TYPICAL PERFORMANCE CHARACTERISTICS

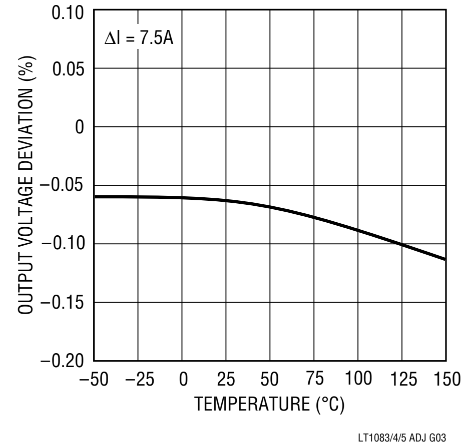
LT1083
Dropout Voltage



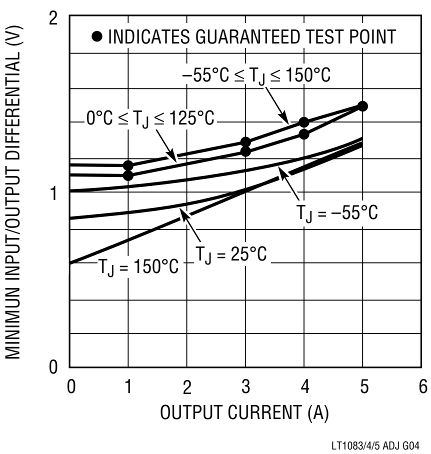
LT1083
Short-Circut Current



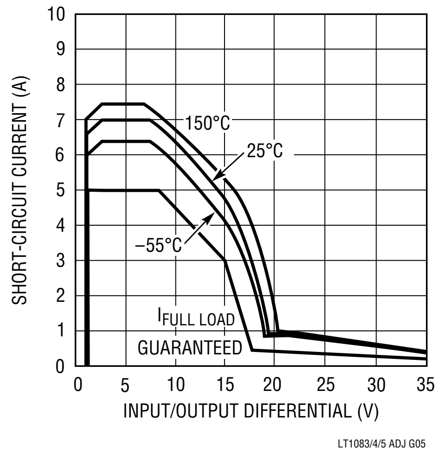
LT1083
Load Regulation



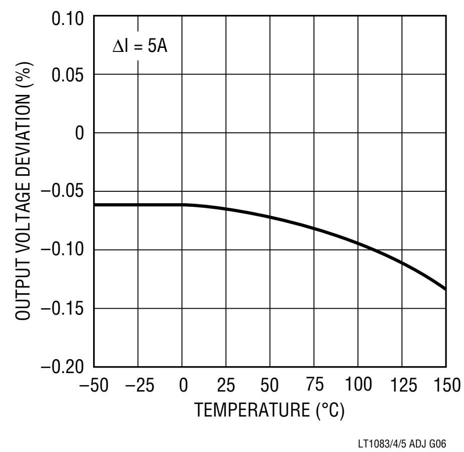
LT1084
Dropout Voltage



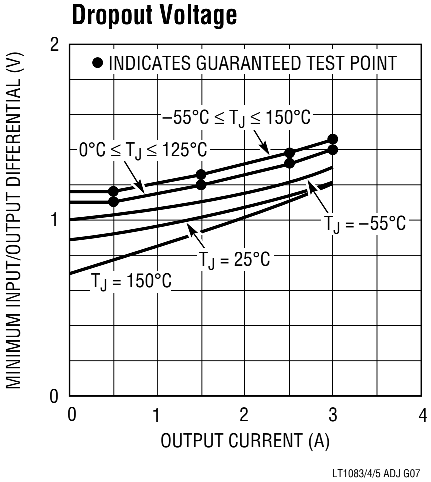
LT11084
Short-Circut Current



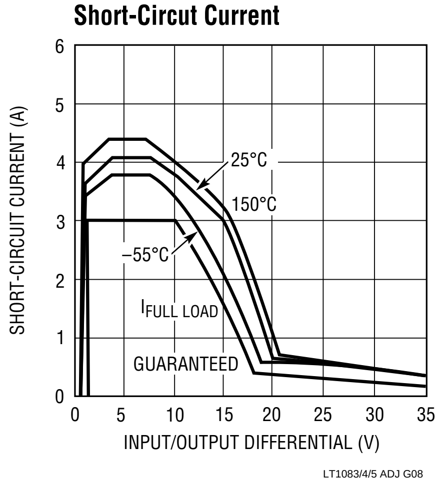
LT1084
Load Regulation



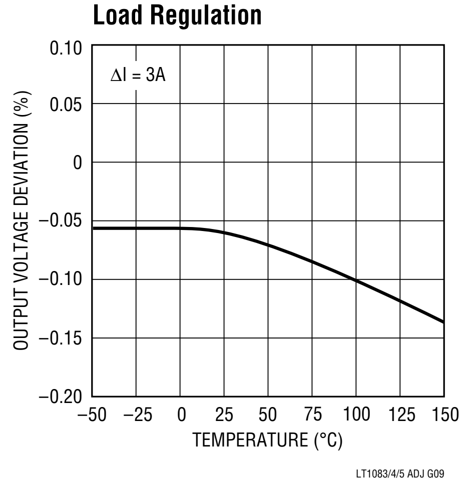
LT1085
Dropout Voltage



LT1085
Short-Circut Current

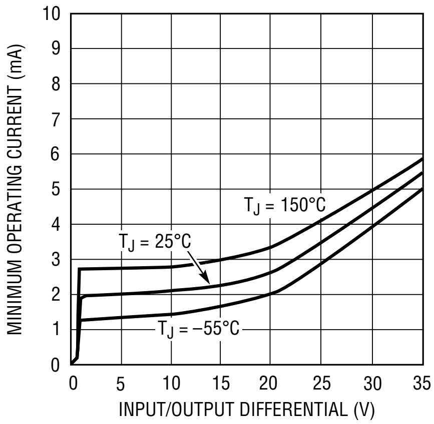


LT1085
Load Regulation



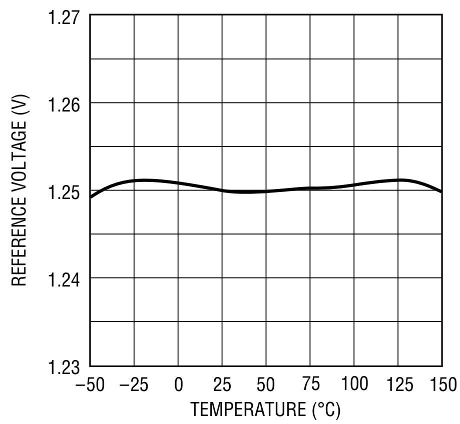
TYPICAL PERFORMANCE CHARACTERISTICS

Minimum Operating Current



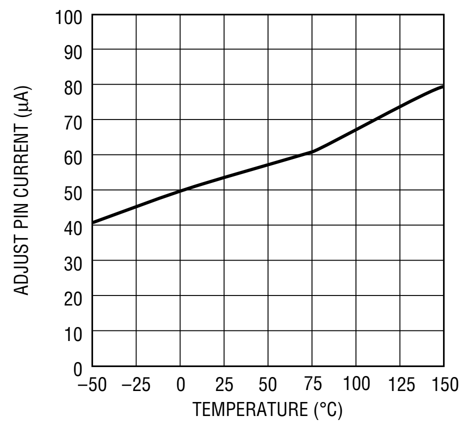
LT1083/4/5 ADJ G10

Temperature Stability



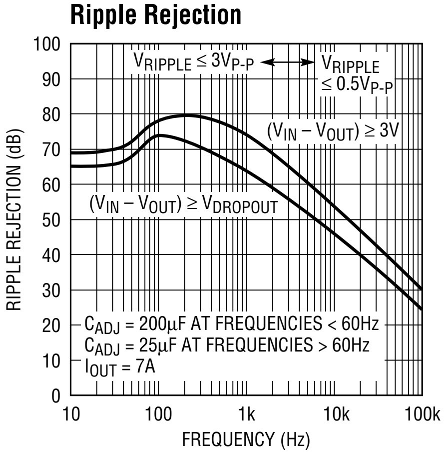
LT1083/4/5 ADJ G11

Adjust Pin Current



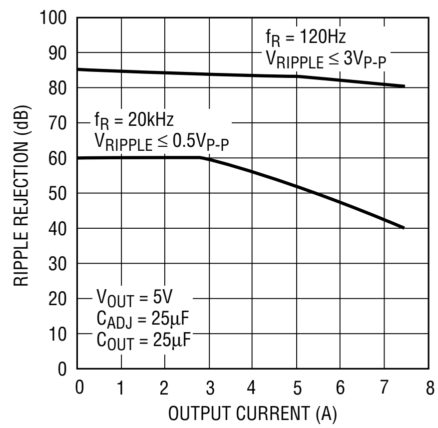
LT1083/4/5 ADJ G12

LT1083
Ripple Rejection



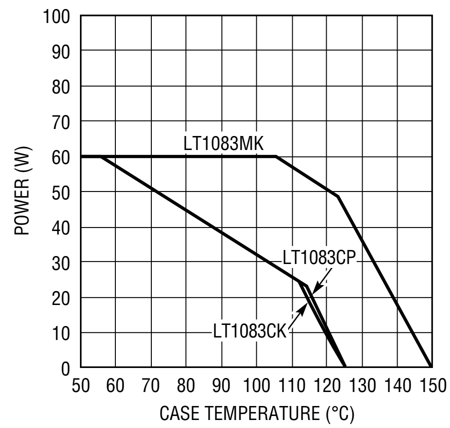
1083/4/5 ADJ G13

LT1083
Ripple Rejection vs Current



1083/4/5 ADJ G14

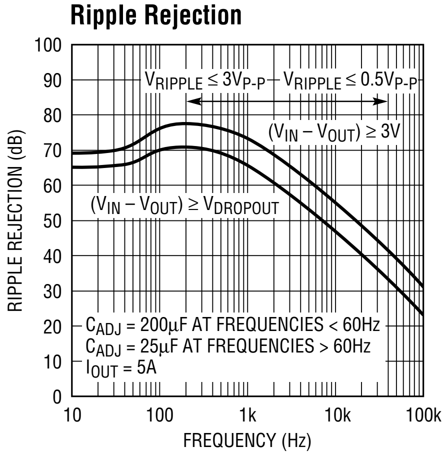
LT1083
Maximum Power Dissipation*



* AS LIMITED BY MAXIMUM JUNCTION TEMPERATURE

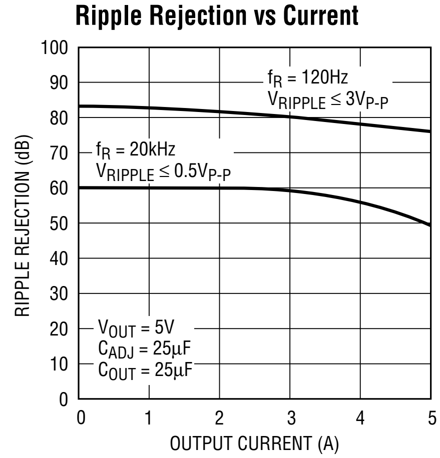
LT1083/4/5 ADJ G15

LT1084
Ripple Rejection



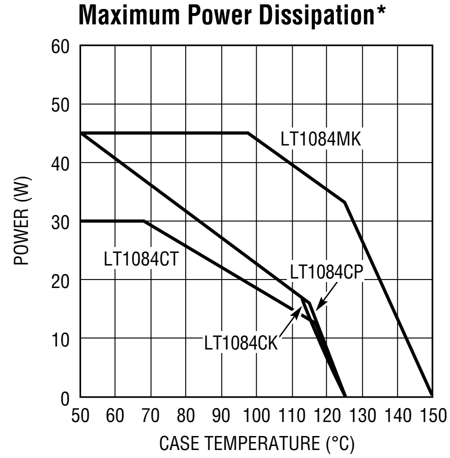
1083/4/5 ADJ G16

LT1084
Ripple Rejection vs Current



1083/4/5 ADJ G17

LT1084
Maximum Power Dissipation*

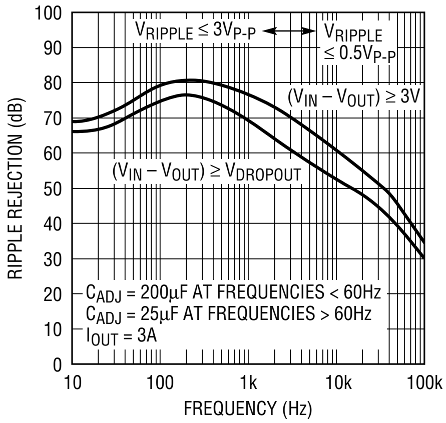


* AS LIMITED BY MAXIMUM JUNCTION TEMPERATURE

LT1083/4/5 ADJ G18

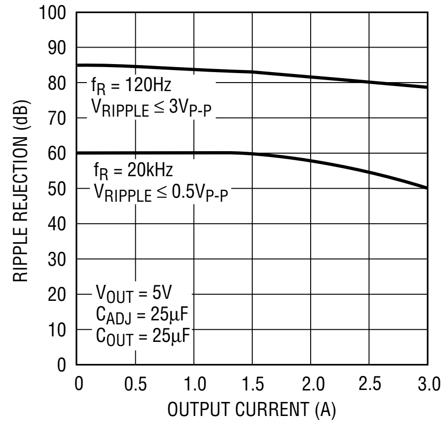
TYPICAL PERFORMANCE CHARACTERISTICS

LT1085 Ripple Rejection



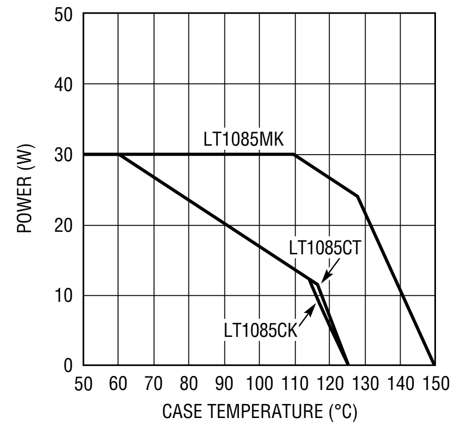
1083/4/5 ADJ G19

LT1085 Ripple Rejection vs Current



1083/4/5 ADJ G20

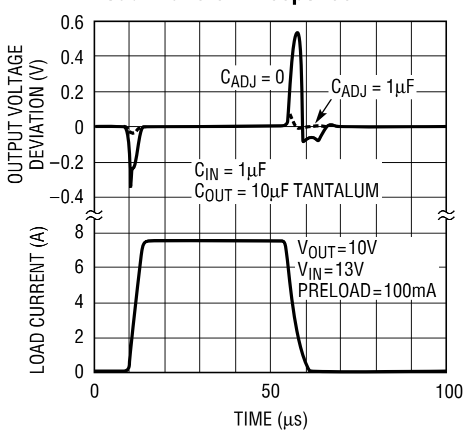
LT1085 Maximum Power Dissipation*



* AS LIMITED BY MAXIMUM JUNCTION TEMPERATURE

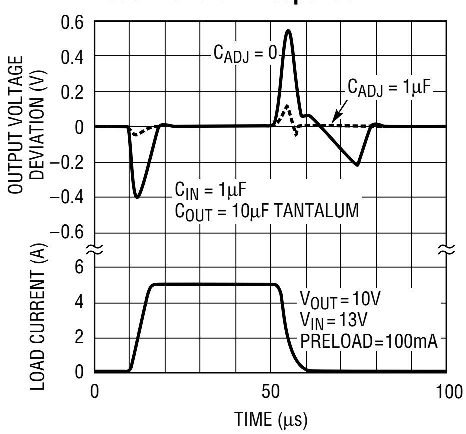
LT1083/4/5 ADJ G21

LT1083 Load Transient Response



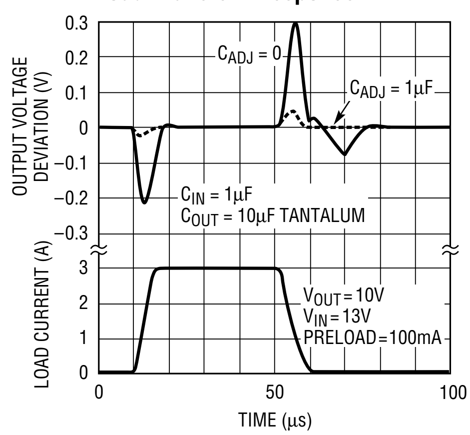
1083/4/5 ADJ G22

LT1084 Load Transient Response



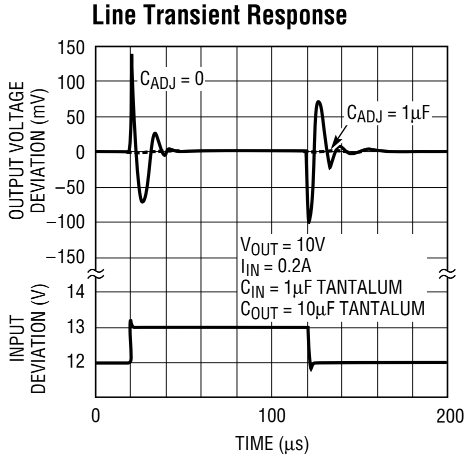
1083/4/5 ADJ G23

LT1085 Load Transient Response



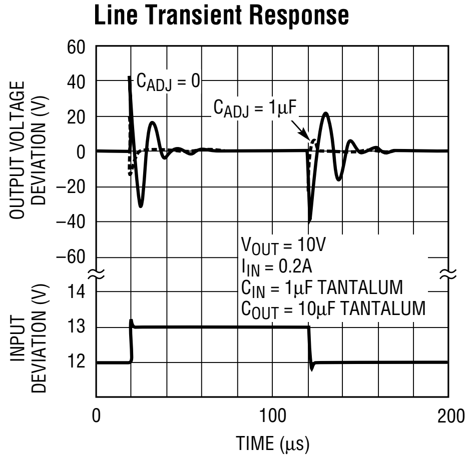
1083/4/5 ADJ G24

LT1083 Line Transient Response



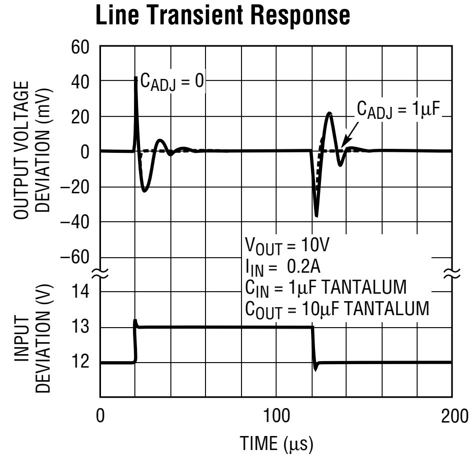
1083/4/5 ADJ G25

LT1084 Line Transient Response



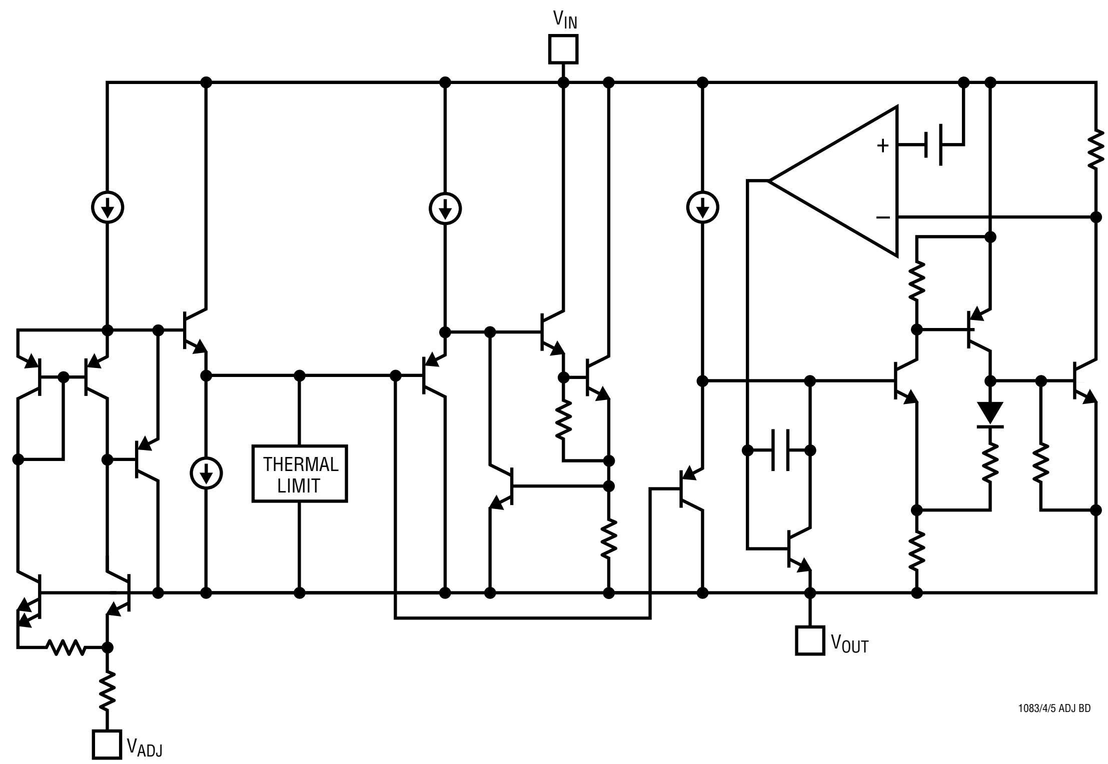
1083/4/5 ADJ G26

LT1085 Line Transient Response



1083/4/5 ADJ G27

BLOCK DIAGRAM



APPLICATIONS INFORMATION

The LT1083 family of three-terminal adjustable regulators is easy to use and has all the protection features that are expected in high performance voltage regulators. They are short-circuit protected, and have safe area protection as well as thermal shutdown to turn off the regulator should the junction temperature exceed about 165°C.

These regulators are pin compatible with older three-terminal adjustable devices, offer lower dropout voltage and more precise reference tolerance. Further, the reference stability with temperature is improved over older types of regulators. The only circuit difference between using the LT1083 family and older regulators is that this new family requires an output capacitor for stability.

Stability

The circuit design used in the LT1083 family requires the use of an output capacitor as part of the device frequency compensation. For all operating conditions, the addition of 150µF aluminium electrolytic or a 22µF solid tantalum on the output will ensure stability. Normally, capacitors much smaller than this can be used with the LT1083. Many different types of capacitors with widely varying characteristics are available. These capacitors differ in capacitor tolerance (sometimes ranging up to ±100%), equivalent series resistance, and capacitance temperature coefficient. The 150µF or 22µF values given will ensure stability.

When the adjustment terminal is bypassed to improve the ripple rejection, the requirement for an output capacitor increases. The value of 22µF tantalum or 150µF aluminum covers all cases of bypassing the adjustment terminal. Without bypassing the adjustment terminal, smaller capacitors can be used with equally good results and the table below shows approximately what size capacitors are needed to ensure stability.

Recommended Capacitor Values

INPUT	OUTPUT	ADJUSTMENT
10µF	10µF Tantalum, 50µF Aluminum	None
10µF	22µF Tantalum, 150µF Aluminum	20µF

APPLICATIONS INFORMATION

Normally, capacitor values on the order of 100µF are used in the output of many regulators to ensure good transient response with heavy load current changes. Output capacitance can be increased without limit and larger values of output capacitor further improve stability and transient response of the LT1083 regulators.

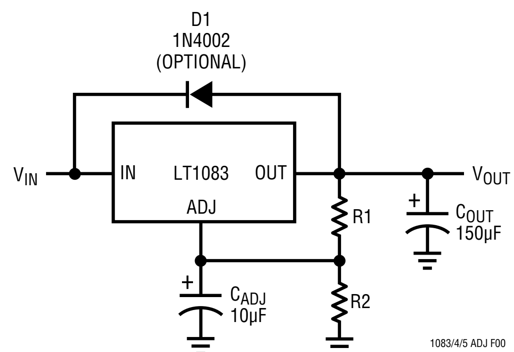
Another possible stability problem that can occur in monolithic IC regulators is current limit oscillations. These can occur because, in current limit, the safe area protection exhibits a negative impedance. The safe area protection decreases the current limit as the input-to-output voltage increases. That is the equivalent of having a negative resistance since increasing voltage causes current to decrease. Negative resistance during current limit is not unique to the LT1083 series and has been present on all power IC regulators. The value of the negative resistance is a function of how fast the current limit is folded back as input-to-output voltage increases. This negative resistance can react with capacitors or inductors on the input to cause oscillation during current limiting. Depending on the value of series resistance, the overall circuitry may end up unstable. Since this is a system problem, it is not necessarily easy to solve; however, it does not cause any problems with the IC regulator and can usually be ignored.

Protection Diodes

In normal operation, the LT1083 family does not need any protection diodes. Older adjustable regulators required protection diodes between the adjustment pin and the output and from the output to the input to prevent overstressing the die. The internal current paths on the LT1083 adjustment pin are limited by internal resistors. Therefore, even with capacitors on the adjustment pin, no protection diode is needed to ensure device safety under short-circuit conditions.

Diodes between input and output are usually not needed. The internal diode between the input and the output pins of the LT1083 family can handle microsecond surge currents of 50A to 100A. Even with large output capacitances, it is very difficult to get those values of surge currents in normal operations. Only with a high value of output capacitors, such as 1000µF to 5000µF and with the input pin instantaneously shorted to ground, can damage occur. A crowbar circuit at the input of the LT1083 can generate those kinds of currents, and a diode from output to input is then recommended. Normal power supply cycling or even plugging and unplugging in the system will not generate current large enough to do any damage.

The adjustment pin can be driven on a transient basis ±25V, with respect to the output without any device degradation. Of course, as with any IC regulator, exceeding the maximum input to output voltage differential causes the internal transistors to break down and none of the protection circuitry is functional.



Overload Recovery

Like any of the IC power regulators, the LT1083 has safe area protection. The safe area protection decreases the current limit as input-to-output voltage increases and keeps the power transistor inside a safe operating region for all values of input-to-output voltage. The LT1083 protection is designed to provide some output current at all values of input-to-output voltage up to the device breakdown.

When power is first turned on, as the input voltage rises, the output follows the input, allowing the regulator to start up into very heavy loads. During the start-up, as the input voltage is rising, the input-to-output voltage differential remains small, allowing the regulator to supply large output currents. With high input voltage, a problem can occur wherein removal of an output short will not allow the output voltage to recover. Older regulators, such as the 7800 series, also exhibited this phenomenon, so it is not unique to the LT1083.

APPLICATIONS INFORMATION

The problem occurs with a heavy output load when the input voltage is high and the output voltage is low, such as immediately after removal of a short. The load line for such a load may intersect the output current curve at two points. If this happens, there are two stable output operating points for the regulator. With this double intersection, the power supply may need to be cycled down to zero and brought up again to make the output recover.

Ripple Rejection

The typical curves for ripple rejection reflect values for a bypassed adjustment pin. This curve will be true for all values of output voltage. For proper bypassing and ripple rejection approaching the values shown, the impedance of the adjust pin capacitor at the ripple frequency should be less than the value of R1, (normally 100Ω to 120Ω). The size of the required adjust pin capacitor is a function of the input ripple frequency. At 120Hz the adjust pin capacitor should be 25µF if R1 = 100Ω. At 10kHz only 0.22µF is needed.

For circuits without an adjust pin bypass capacitor, the ripple rejection will be a function of output voltage. The output ripple will increase directly as a ratio of the output voltage to the reference voltage (V_{OUT}/V_{REF}). For example, with the output voltage equal to 5V and no adjust pin capacitor, the output ripple will be higher by the ratio of 5V/1.25V or four times larger. Ripple rejection will be degraded by 12dB from the value shown on the typical curve.

Output Voltage

The LT1083 develops a 1.25V reference voltage between the output and the adjust terminal (see Figure 1). By placing a resistor R1 between these two terminals, a constant current is caused to flow through R1 and down through R2 to set the overall output voltage. Normally this current is the specified minimum load current of 10mA. Because I_{ADJ} is very small and constant when compared with the current through R1, it represents a small error and can usually be ignored.

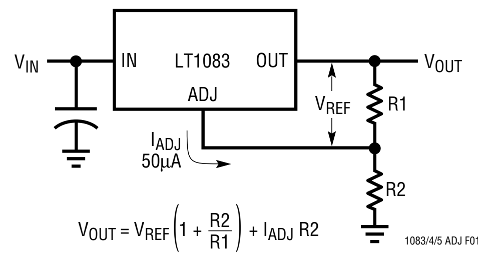


Figure 1. Basic Adjustable Regulator

Load Regulation

Because the LT1083 is a three-terminal device, it is not possible to provide true remote load sensing. Load regulation will be limited by the resistance of the wire connecting the regulator to the load. The data sheet specification for load regulation is measured at the bottom of the package. Negative side sensing is a true Kelvin connection, with the bottom of the output divider returned to the negative side of the load. Although it may not be immediately obvious, best load regulation is obtained when the top of the resistor divider R1 is connected *directly* to the case *not to the load*. This is illustrated in Figure 2. If R1 were connected to the load, the effective resistance between the regulator and the load would be:

$$R_P \times \left(\frac{R2+R1}{R1}\right),\ R_P = \text{Parasitic Line Resistance}$$

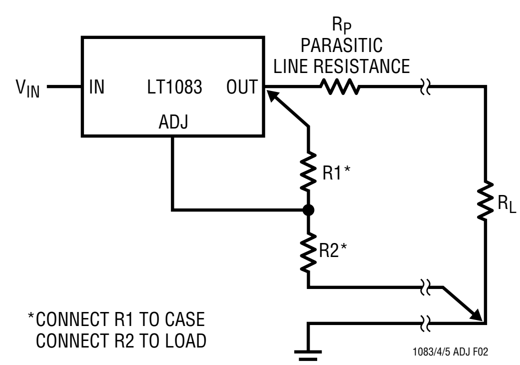


Figure 2. Connections for Best Load Regulation

APPLICATIONS INFORMATION

Connected as shown, R_P is not multiplied by the divider ratio. R_P is about 0.004Ω per foot using 16-gauge wire. This translates to 4mV/ft at 1A load current, so it is important to keep the positive lead between regulator and load as short as possible and use large wire or PC board traces.

Thermal Considerations

The LT1083 series of regulators have internal power and thermal limiting circuitry designed to protect the device under overload conditions. For continuous normal load conditions however, maximum junction temperature ratings must not be exceeded. It is important to give careful consideration to all sources of thermal resistance from junction to ambient. This includes junction-to-case, case-to-heat sink interface, and heat sink resistance itself. New thermal resistance specifications have been developed to more accurately reflect device temperature and ensure safe operating temperatures. The data section for these new regulators provides a separate thermal resistance and maximum junction temperature for both the *Control Section* and the *Power Transistor*. Previous regulators, with a single junction-to-case thermal resistance specification, used an average of the two values provided here and therefore could allow excessive junction temperatures under certain conditions of ambient temperature and heat sink resistance. To avoid this possibility, calculations should be made for both sections to ensure that both thermal limits are met.

Junction-to-case thermal resistance is specified from the IC junction to the bottom of the case directly below the die. This is the lowest resistance path for heat flow. Proper mounting is required to ensure the best possible thermal flow from this area of the package to the heat sink. Thermal compound at the case-to-heat sink interface is strongly recommended. If the case of the device must be electrically isolated, a thermally conductive spacer can be used, as long as its added contribution to thermal resistance is considered. Note that the case of all devices in this series is electrically connected to the output.

For example, using an LT1083CK (TO-3, Commercial) and assuming:

V_{IN} (max continuous) = 9V, V_{OUT} = 5V, I_{OUT} = 6A,

T_A = 75°C, $\theta_{HEAT\ SINK}$ = 1°C/W,

$\theta_{CASE\text{-}TO\text{-}HEAT\ SINK}$ = 0.2°C/W for K package with thermal compound.

Power dissipation under these conditions is equal to:

$$P_D = (V_{IN} - V_{OUT})(I_{OUT}) = 24W$$

Junction temperature will be equal to:

$$T_J = T_A + P_D(\theta_{HEAT\ SINK} + \theta_{CASE\text{-}TO\text{-}HEAT\ SINK} + \theta_{JC})$$

For the Control Section:

$$T_J = 75°C + 24W(1°C/W + 0.2°C/W + 0.6°C/W) = 118°C$$

118°C < 125°C = T_{JMAX} (Control Section Commercial Range)

For the Power Transistor:

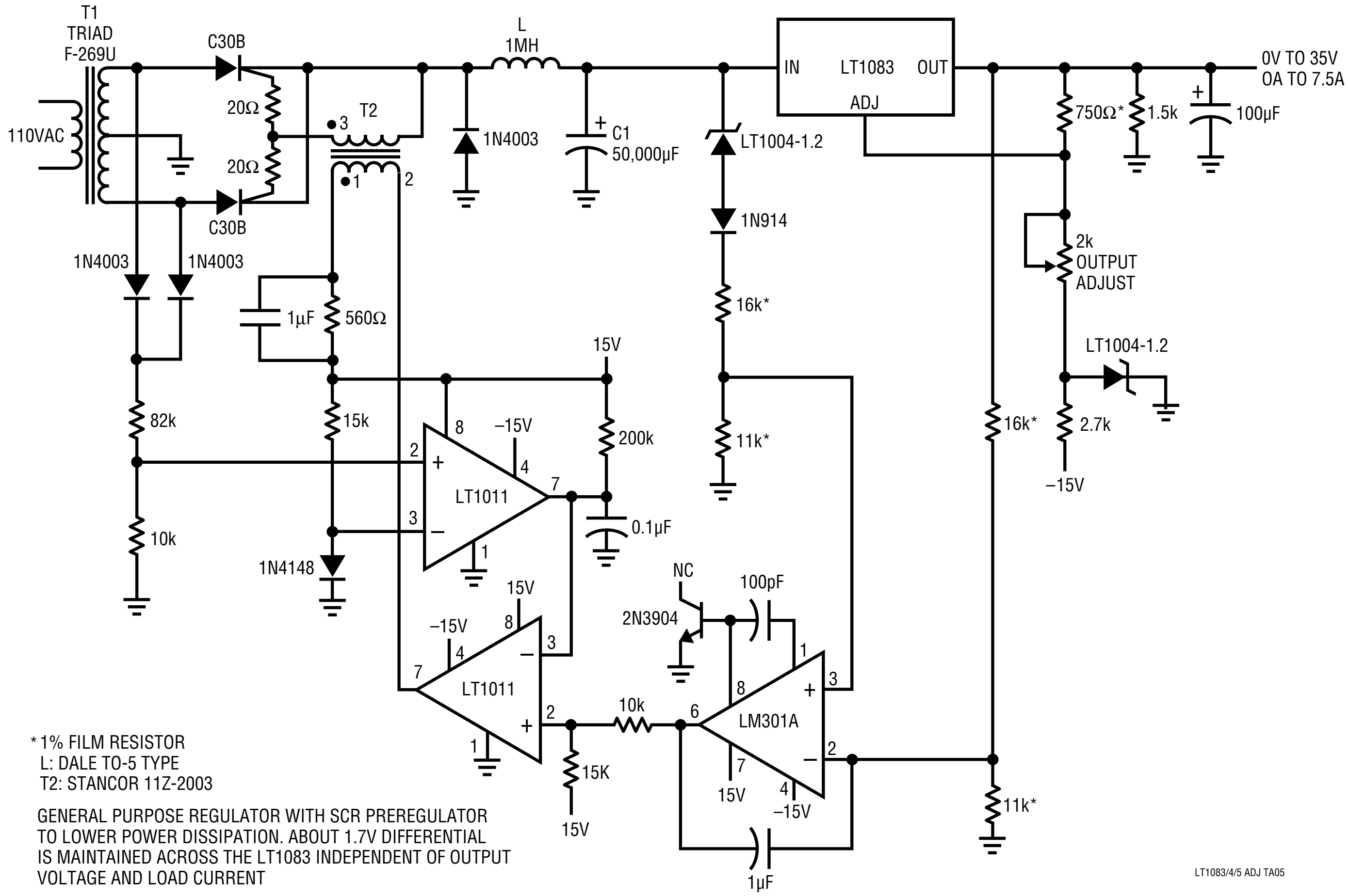
$$T_J = 75°C + 24W(1°C/W + 0.2°C/W + 1.6°C/W) = 142°C$$

142°C < 150°C = T_{JMAX} (Power Transistor Commercial Range)

In both cases the junction temperature is below the maximum rating for the respective sections, ensuring reliable operation.

TYPICAL APPLICATIONS

7.5A Variable Regulator

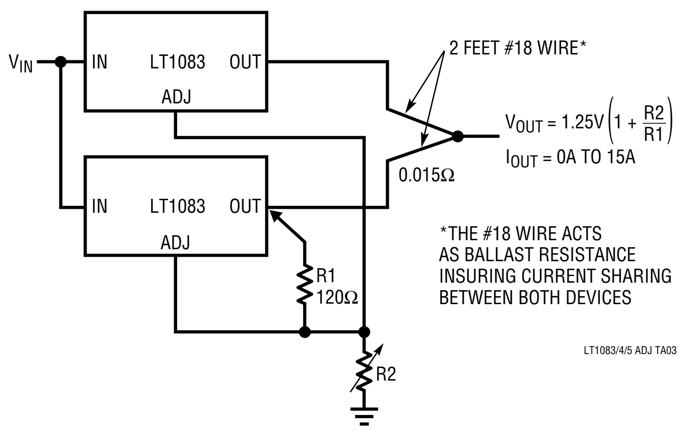


* 1% FILM RESISTOR
L: DALE TO-5 TYPE
T2: STANCOR 11Z-2003

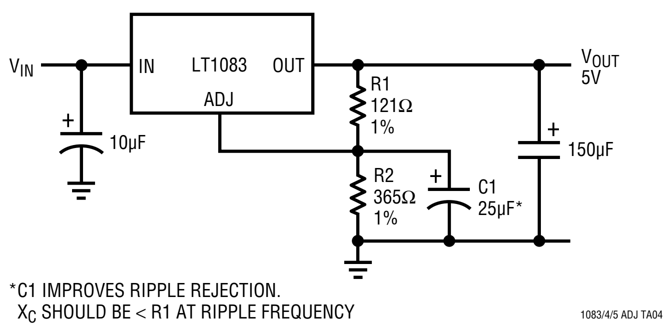
GENERAL PURPOSE REGULATOR WITH SCR PREREGULATOR TO LOWER POWER DISSIPATION. ABOUT 1.7V DIFFERENTIAL IS MAINTAINED ACROSS THE LT1083 INDEPENDENT OF OUTPUT VOLTAGE AND LOAD CURRENT

TYPICAL APPLICATIONS

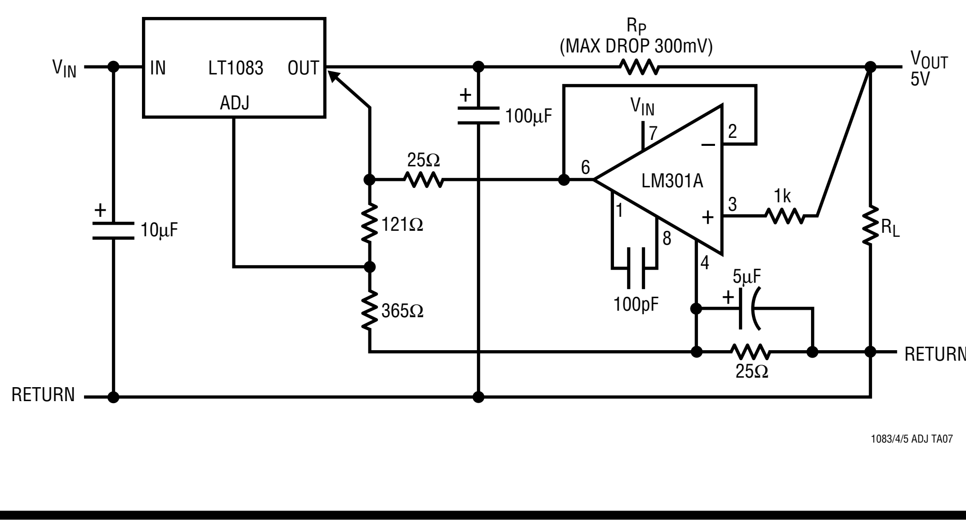
Paralleling Regulators



Improving Ripple Rejection

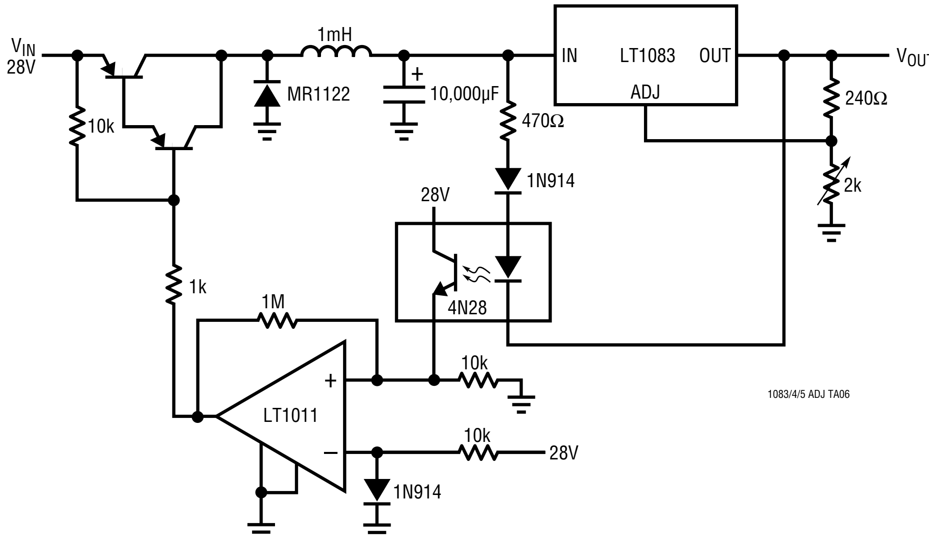


Remote Sensing

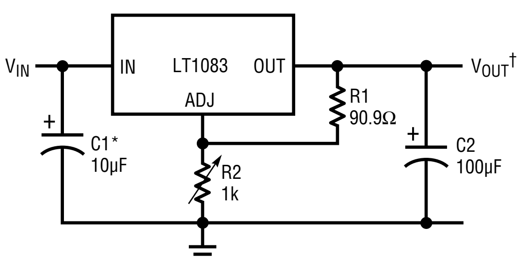


TYPICAL APPLICATIONS

High Efficiency Regulator with Switching Preregulator



1.2V to 15V Adjustable Regulator

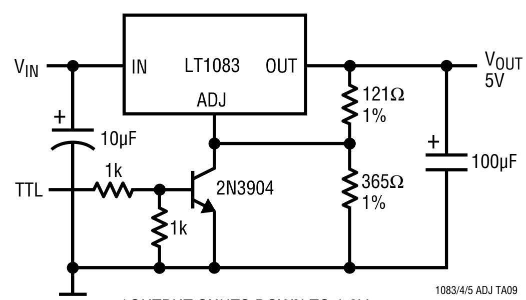


*NEEDED IF DEVICE IS FAR FROM FILTER CAPACITORS

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

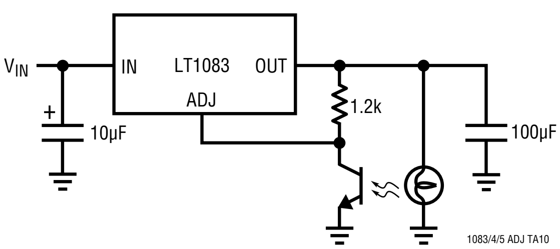
1083/4/5 ADJ TA08

5V Regulator with Shutdown*

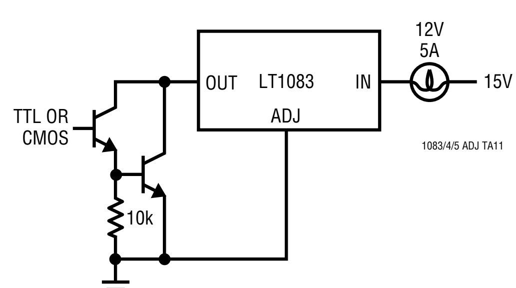


*OUTPUT SHUTS DOWN TO 1.3V

Automatic Light Control



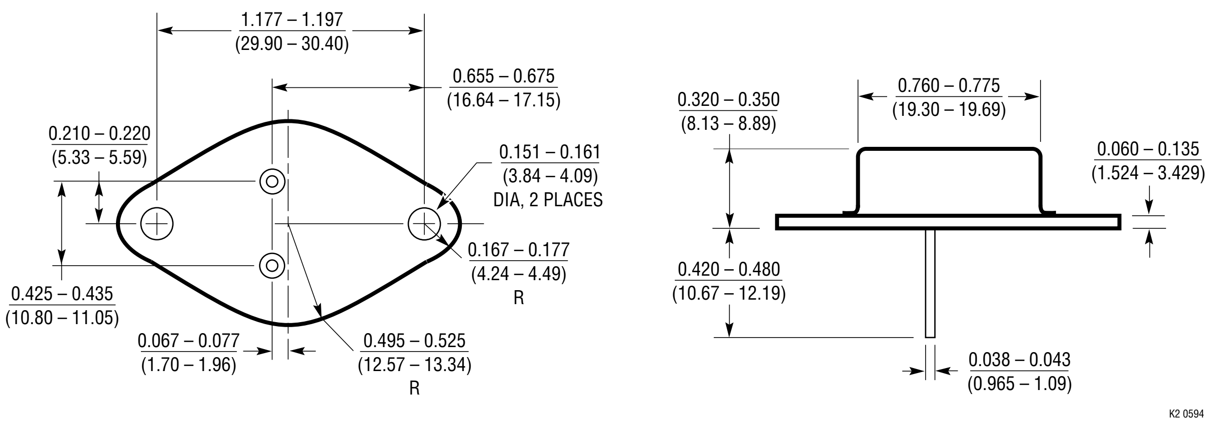
Protected High Current Lamp Driver



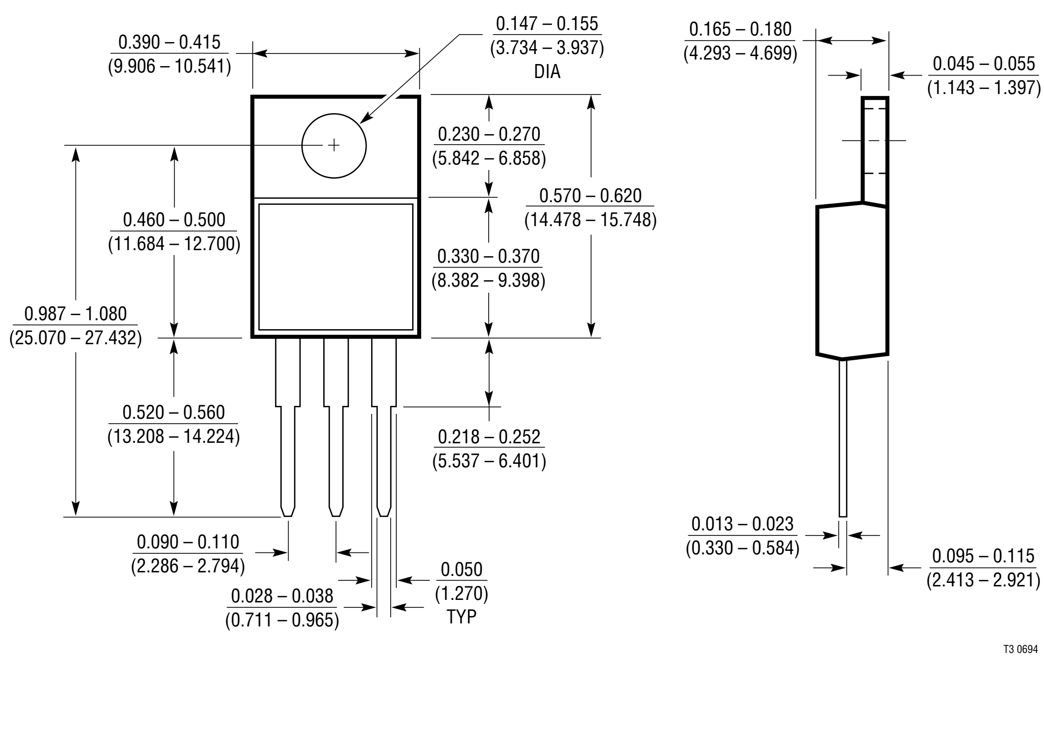
PACKAGE DESCRIPTION

Dimension in inches (millimeters) unless otherwise noted.

K Package
2-Lead TO-3 Metal Can



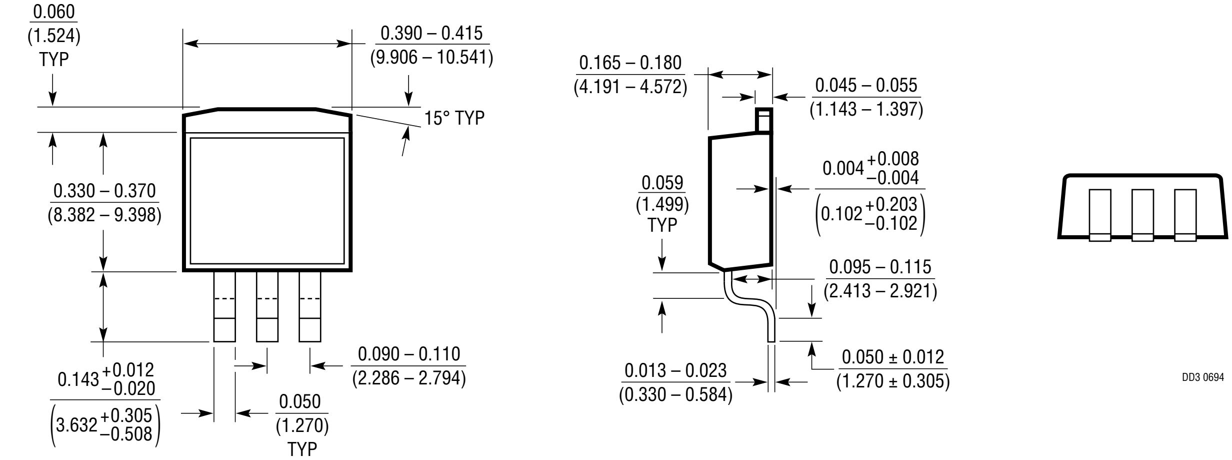
T Package
3-Lead Plastic TO-220



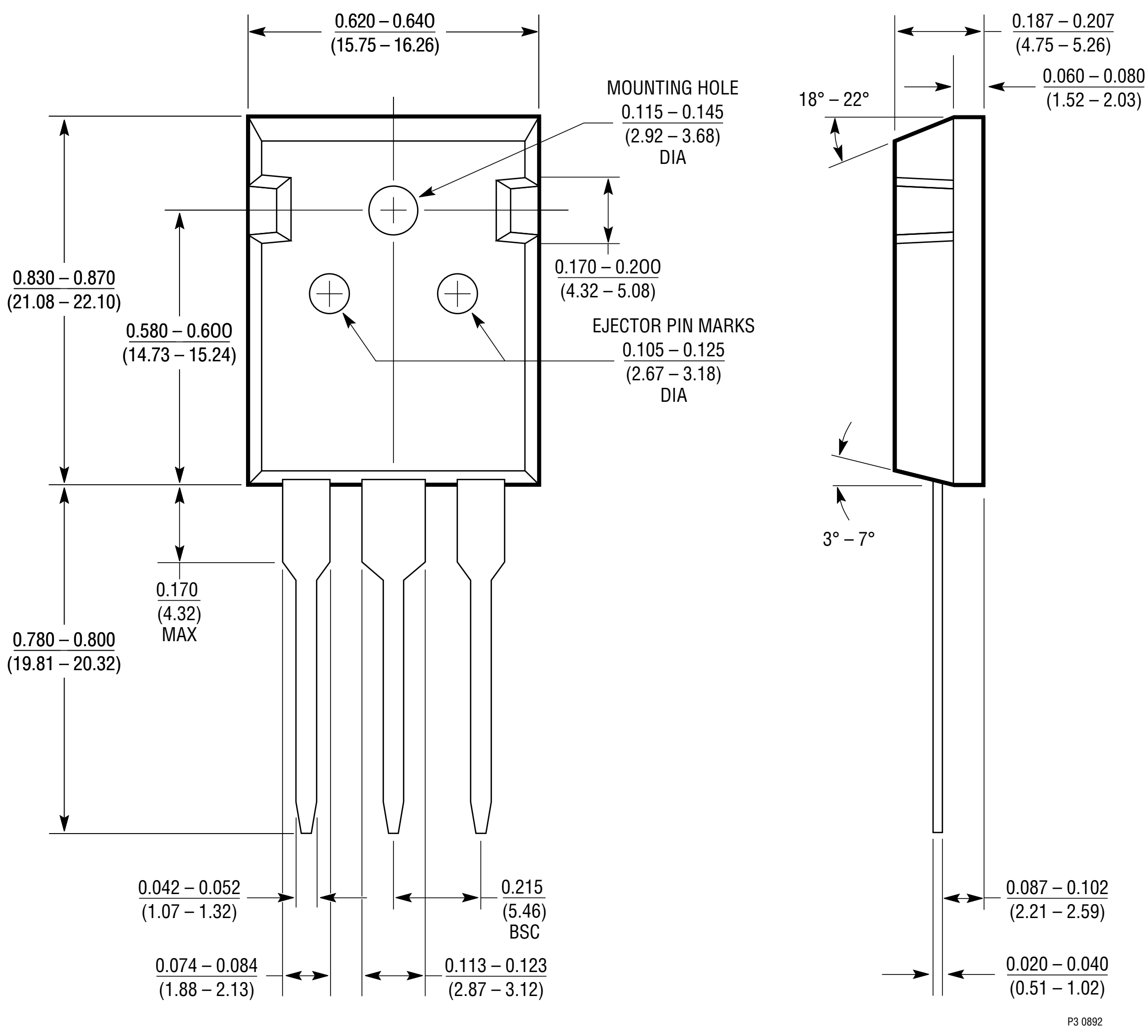
PACKAGE DESCRIPTION

Dimension in inches (millimeters) unless otherwise noted.

M Package
3-Lead DD



P Package
3-Lead TO-3P Plastic



U.S. Area Sales Offices

NORTHEAST REGION
Linear Technology Corporation
One Oxford Valley
2300 E. Lincoln Hwy.,Suite 306
Langhorne, PA 19047
Phone: (215) 757-8578
FAX: (215) 757-5631

Linear Technology Corporation
266 Lowell St., Suite B-8
Wilmington, MA 01887
Phone: (508) 658-3881
FAX: (508) 658-2701

SOUTHEAST REGION
Linear Technology Corporation
17060 Dallas Parkway
Suite 208
Dallas, TX 75248
Phone: (214) 733-3071
FAX: (214) 380-5138

CENTRAL REGION
Linear Technology Corporation
Chesapeake Square
229 Mitchell Court, Suite A-25
Addison, IL 60101
Phone: (708) 620-6910
FAX: (708) 620-6977

SOUTHWEST REGION
Linear Technology Corporation
22141 Ventura Blvd.
Suite 206
Woodland Hills, CA 91364
Phone: (818) 703-0835
FAX: (818) 703-0517

NORTHWEST REGION
Linear Technology Corporation
782 Sycamore Dr.
Milpitas, CA 95035
Phone: (408) 428-2050
FAX: (408) 432-6331

International Sales Offices

FRANCE
Linear Technology S.A.R.L.
Immeuble "Le Quartz"
58 Chemin de la Justice
92290 Chatenay Malabry
France
Phone: 33-1-41079555
FAX: 33-1-46314613

GERMANY
Linear Techonolgy GmbH
Untere Hauptstr. 9
D-85386 Eching
Germany
Phone: 49-89-3197410
FAX: 49-89-3194821

JAPAN
Linear Technology KK
5F YZ Bldg.
4-4-12 Iidabashi, Chiyoda-Ku
Tokyo, 102 Japan
Phone: 81-3-3237-7891
FAX: 81-3-3237-8010

KOREA
Linear Technology Korea Branch
Namsong Building, #505
Itaewon-Dong 260-199
Yongsan-Ku, Seoul
Korea
Phone: 82-2-792-1617
FAX: 82-2-792-1619

SINGAPORE
Linear Technology Pte. Ltd.
101 Boon Keng Road
#02-15 Kallang Ind. Estates
Singapore 1233
Phone: 65-293-5322
FAX: 65-292-0398

TAIWAN
Linear Technology Corporation
Rm. 801, No. 46, Sec. 2
Chung Shan N. Rd.
Taipei, Taiwan, R.O.C.
Phone: 886-2-521-7575
FAX: 886-2-562-2285

UNITED KINGDOM
Linear Technology (UK) Ltd.
The Coliseum, Riverside Way
Camberley, Surrey GU15 3YL
United Kingdom
Phone: 44-276-677676
FAX: 44-276-64851

World Headquarters

Linear Technology Corporation
1630 McCarthy Blvd.
Milpitas, CA 95035-7487
Phone: (408) 432-1900
FAX: (408) 434-0507

Linear Technology Corporation
1630 McCarthy Blvd., Milpitas, CA 95035-7487
(408) 432-1900 • FAX: (408) 434-0507 • TELEX: 499-3977
LT/GP 0694 REV C 5K • PRINTED IN USA
LINEAR TECHNOLOGY

TL783 High-voltage Adjustable Regulator

1 Features

- Output Adjustable From 1.25 V to 125 V when Used with an External Resistor Divider
- 700-mA Output Current
- Full Short-Circuit, Safe-Operating-Area, and Thermal-Shutdown Protection
- 0.001%/V Typical Input Voltage Regulation
- 0.15% Typical Output Voltage Regulation
- 76-dB Typical Ripple Rejection

2 Applications

- Electronic Point of Sale
- Medical, Health, and Fitness Applications
- Printers
- Applications and White Goods

3 Description

The TL783 device is an adjustable three-terminal high-voltage regulator with an output range of 1.25 V to 125 V and a DMOS output transistor capable of sourcing more than 700 mA. It is designed for use in high-voltage applications where standard bipolar regulators cannot be used. Excellent performance specifications, superior to those of most bipolar regulators, are achieved through circuit design and advanced layout techniques.

Device Information(1)

PART NUMBER	PACKAGE (PIN)	BODY SIZE (NOM)
TL783	TO-220 (3)	10.17 mm × 9.02 mm
		10.16 mm × 8.70 mm
	PFM (3)	9.40 mm × 8.00 mm
	TO-263 (3)	10.18 mm × 8.41 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

4 Simplified Schematic

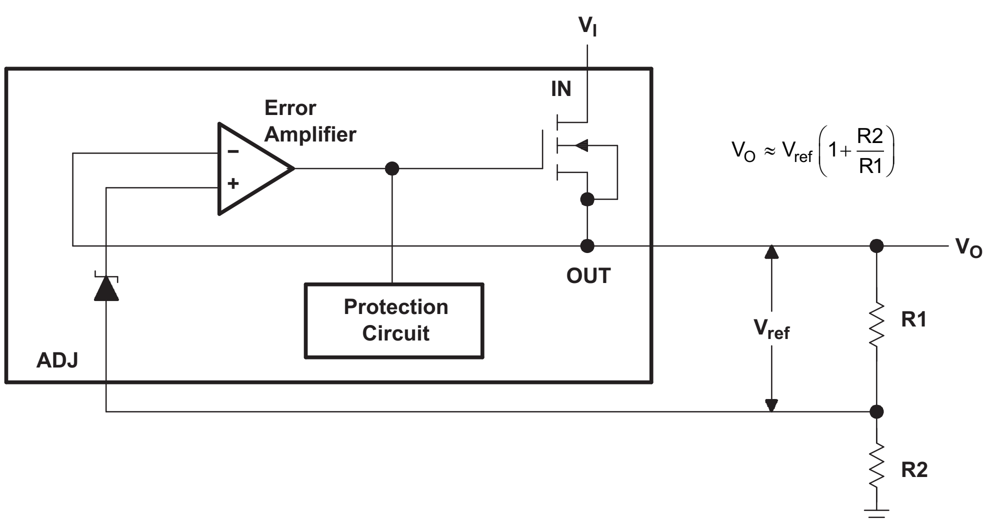


Table of Contents

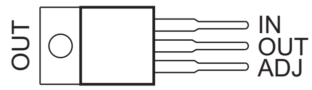
5 Revision History

Changes from Revision M (April 2008) to Revision N **Page**

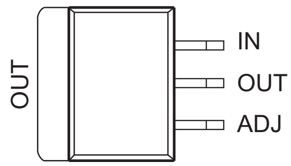
- Added *Applications*, *Device Information* table, *Pin Functions* table, *ESD Ratings* table, *Thermal Information* table, *Typical Characteristics*, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section. 1
- Deleted *Ordering Information* table. 1

6 Pin Configuration and Functions

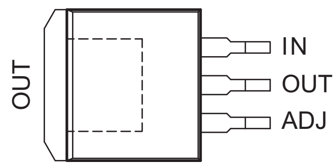
KC (TO-220) PACKAGE
(TOP VIEW)



KTE (PowerFLEX™) PACKAGE
(TOP VIEW)



KTT (TO-263) PACKAGE
(TOP VIEW)



Pin Functions

PIN				TYPE	DESCRIPTION
NAME	KC TO-220	KTE PowerFLEX™	KTT TO-263		
ADJ	1	1	1	I/O	Voltage adjustment pin. Connect a resistor divider to determine the output voltage.
IN	3	3	3	I	Supply Input
OUT	2	2	2	O	Voltage Output

7 Specifications

7.1 Absolute Maximum Ratings

over operating temperature range (unless otherwise noted)(1)

		MIN	MAX	UNIT
$V_I - V_O$	Input-to-output differential voltage		125	V
T_J	Operating virtual junction temperature		150	°C
T_{stg}	Storage temperature range	–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

7.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins(1)	2500	V
		Charged device model (CDM), per JEDEC specification JESD22-C101, all pins(2)	1000	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

7.3 Recommended Operating Conditions

		MIN	MAX	UNIT
$V_I - V_O$	Input-to-output differential voltage		125	V
I_O	Output current	15	700	mA
T_J	Operating virtual junction temperature	0	125	°C

7.4 Thermal Information

THERMAL METRIC(1)		TL783			UNIT
		KTE	KTT	KC	
		3 PINS			
$R_{\theta JA}$	Junction-to-ambient thermal resistance	23	25.3	19	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	N/A	18	17	
$R_{\theta JP}$	Junction-to-exposed-pad thermal resistance	2.7	1.94	3	

(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, SPRA953.

7.5 Electrical Characteristics

$V_I - V_O$ = 25 V, I_O = 0.5 A, T_J = 0°C to 125°C (unless otherwise noted)

PARAMETER	TEST CONDITIONS(1)		MIN	TYP	MAX	UNIT
Input voltage regulation(2)	$V_I - V_O$ = 20 V to 125 V, P ≤ rated dissipation	T_J = 25°C		0.001	0.01	%/V
		T_J = 0°C to 125°C		0.004	0.02	
Ripple rejection	$\Delta V_{I(PP)}$ = 10 V, V_O = 10 V, f = 120 Hz		66	76		dB
Output voltage regulation	I_O = 15 mA to 700 mA, T_J = 25°C	V_O ≤ 5 V		7.5	25	mV
		V_O ≥ 5 V		0.15%	0.5%	—
	I_O = 15 mA to 700 mA, P ≤ rated dissipation	V_O ≤ 5 V		20	70	mV
		V_O ≥ 5 V		0.3%	1.5%	—
Output voltage change with temperature				0.4%		
Output voltage long-term drift	1000 hours at T_J = 125°C, $V_I - V_O$ = 125 V			0.2%		
Output noise voltage	f = 10 Hz to 10 kHz, T_J = 25°C			0.003%		
Minimum output current to maintain regulation	$V_I - V_O$ = 125 V				15	mA
Peak output current	$V_I - V_O$ = 25 V, t = 1 ms			1100		mA
	$V_I - V_O$ = 15 V, t = 30 ms			715		
	$V_I - V_O$ = 25 V, t = 30 ms		700	900		
	$V_I - V_O$ = 125 V, t = 30 ms		100	250		
ADJ input current				83	110	μA
Change in ADJ input current	$V_I - V_O$ = 15 V to 125 V, I_O = 15 mA to 700 mA, P ≤ rated dissipation			0.5	5	μA
Reference voltage (OUT to ADJ)(3)	$V_I - V_O$ = 10 V to 125 V, I_O = 15 mA to 700 mA, P ≤ rated dissipation		1.2	1.27	1.3	V

(1) Pulse-testing techniques maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.
(2) Input voltage regulation is expressed here as the percentage change in output voltage per 1-V change at the input
(3) Due to the dropout voltage and output current-limiting characteristics of this device, output current is limited to less than 700 mA at input-to-output voltage differentials of less than 25 V.

7.6 Typical Characteristics

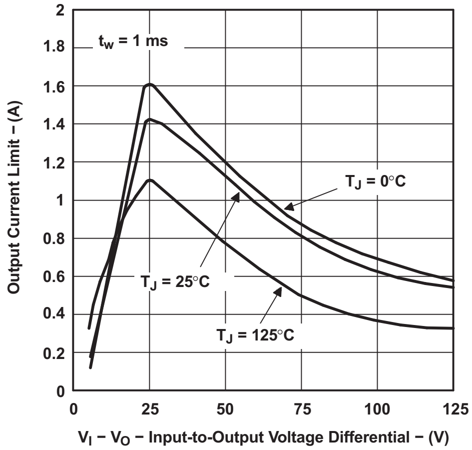


Figure 1. Output Current Limit vs Input-to-Output Voltage Differential

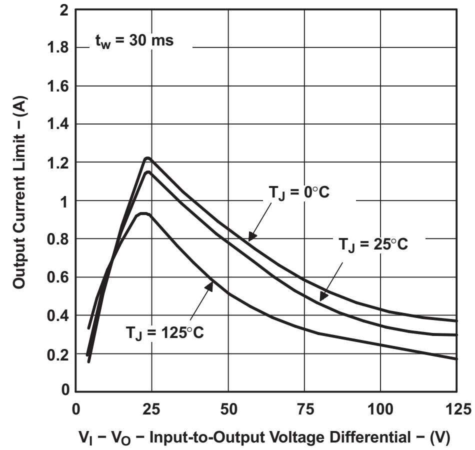


Figure 2. Output Current Limit vs Input-to-Output Voltage Differential

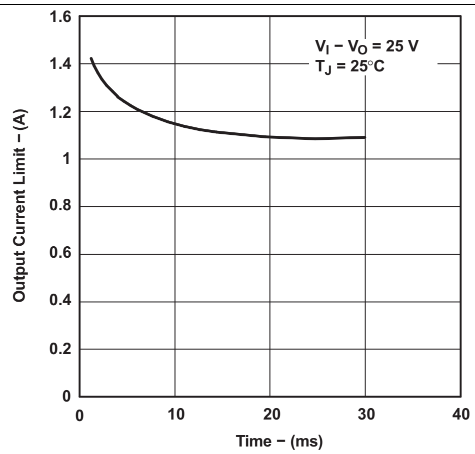


Figure 3. Output Current Limit vs Time

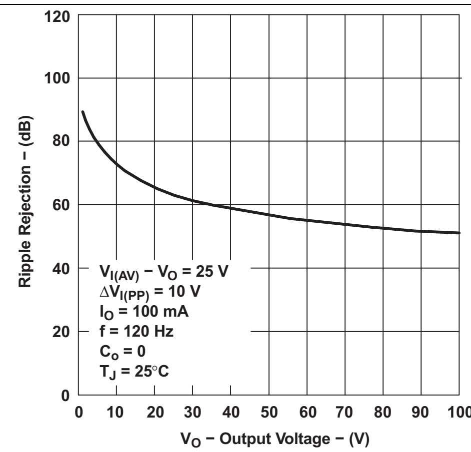


Figure 4. Ripple Rejection vs Output Voltage

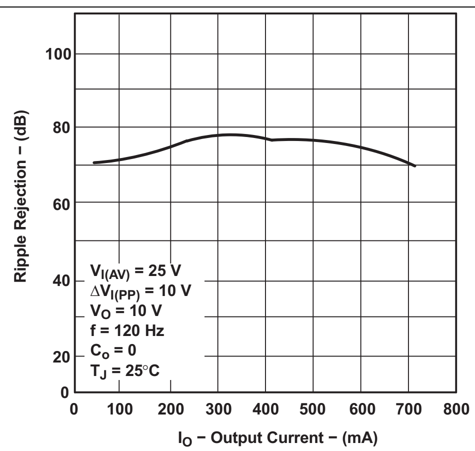


Figure 5. Ripple Rejection vs Output Current

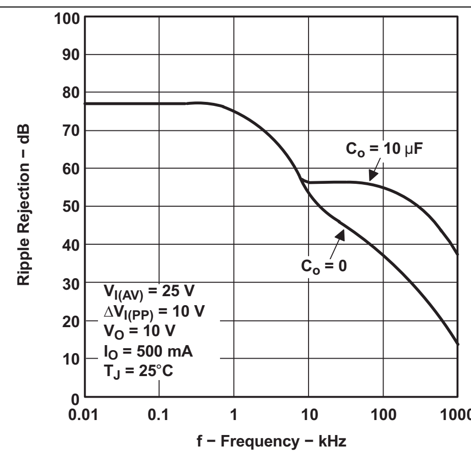


Figure 6. Ripple Rejection vs Frequency

Typical Characteristics (continued)

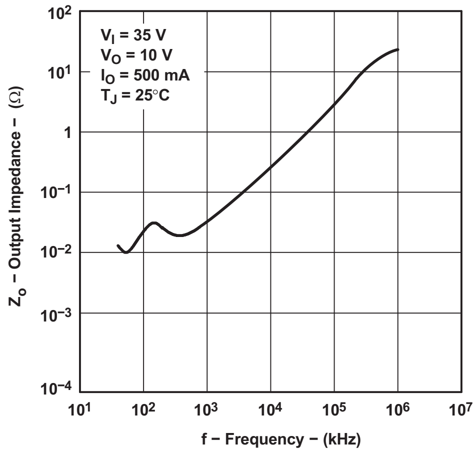


Figure 7. Output Impedance vs Frequency

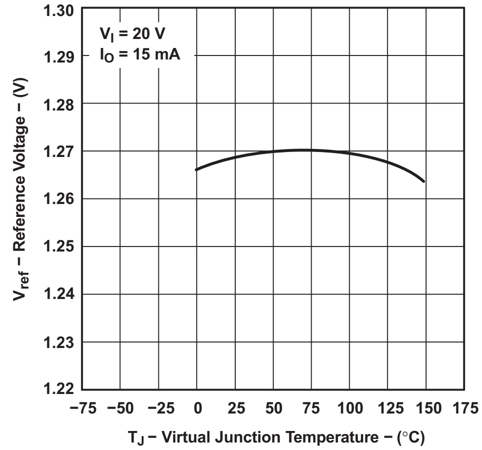


Figure 8. Reference Voltage vs Virtual Junction Temperature

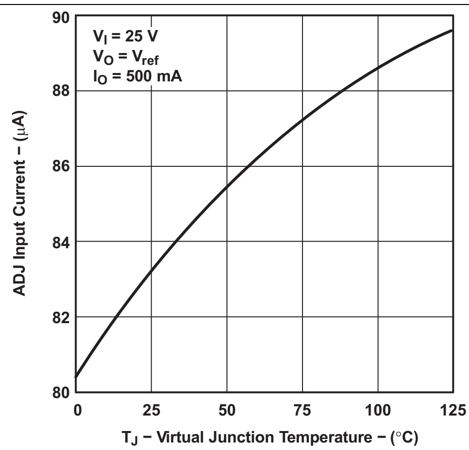


Figure 9. Input Current at ADJ vs Virtual Junction Temperature

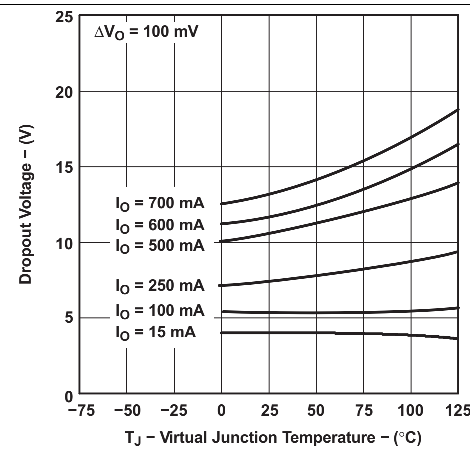


Figure 10. Dropout Voltage vs Virtual Junction Temperature

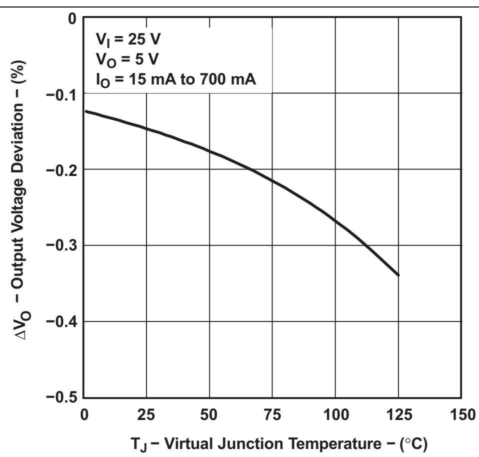
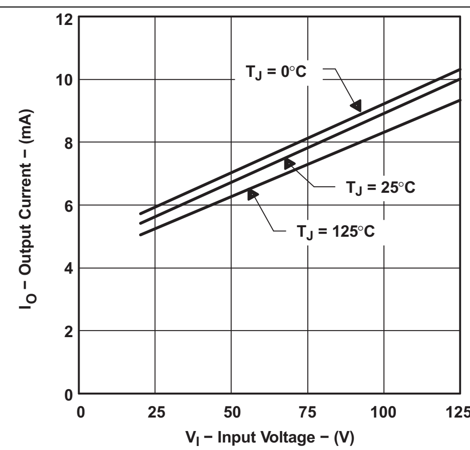


Figure 11. Output Voltage Deviation vs Virtual Junction Temperature



(1) This is the minimum current required to maintain voltage regulation.

Figure 12. Output Current vs Input Voltage

8 Detailed Description

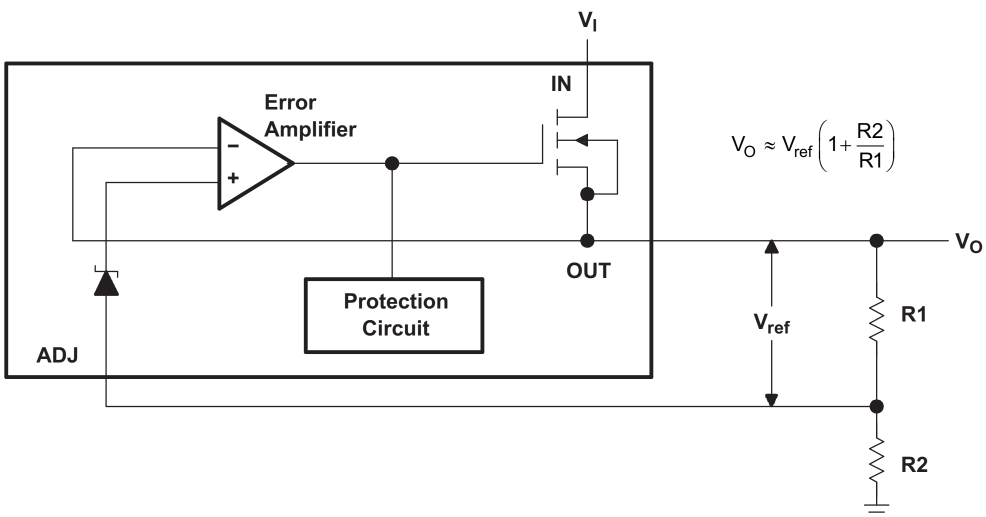
8.1 Overview

The TL783 device is an adjustable three-terminal high-voltage regulator with an output range of 1.25 V to 125 V and a DMOS output transistor capable of sourcing more than 700 mA. It is designed for use in high-voltage applications where standard bipolar regulators cannot be used. Excellent performance specifications, superior to those of most bipolar regulators, are achieved through circuit design and advanced layout techniques.

As a state-of-the-art regulator, the TL783 device combines standard bipolar circuitry with high-voltage double-diffused MOS transistors on one chip, to yield a device capable of withstanding voltages far higher than standard bipolar integrated circuits. Because of its lack of secondary-breakdown and thermal-runaway characteristics usually associated with bipolar outputs, the TL783 maintains full overload protection while operating at up to 125 V from input to output. Other features of the device include current limiting, safe-operating-area (SOA) protection, and thermal shutdown. Even if ADJ is disconnected inadvertently, the protection circuitry remains functional.

Only two external resistors are required to program the output voltage. An input bypass capacitor is necessary only when the regulator is situated far from the input filter. An output capacitor, although not required, improves transient response and protection from instantaneous output short circuits. Excellent ripple rejection can be achieved without a bypass capacitor at the adjustment terminal.

8.2 Functional Block Diagram



8.3 Feature Description

- Output Adjustable From 1.25 V to 125 V when Used with an External Resistor Divider
- 700-mA Output Current
- Full Short-Circuit, Safe-Operating-Area, and Thermal-Shutdown Protection
- 0.001%/V Typical Input Voltage Regulation
- 0.15% Typical Output Voltage Regulation
- 76-dB Typical Ripple Rejection

8.4 Device Functional Modes

8.4.1 Active Mode

The TL783 acts as a high-voltage adjustable regulator. The device works to keep the voltage at the OUT pin 1.25 V higher than the voltage at the ADJ pin. Therefore, a resistor divider can be used to set the output voltage.

9 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

9.1 Application Information

9.1.1 General Configurations

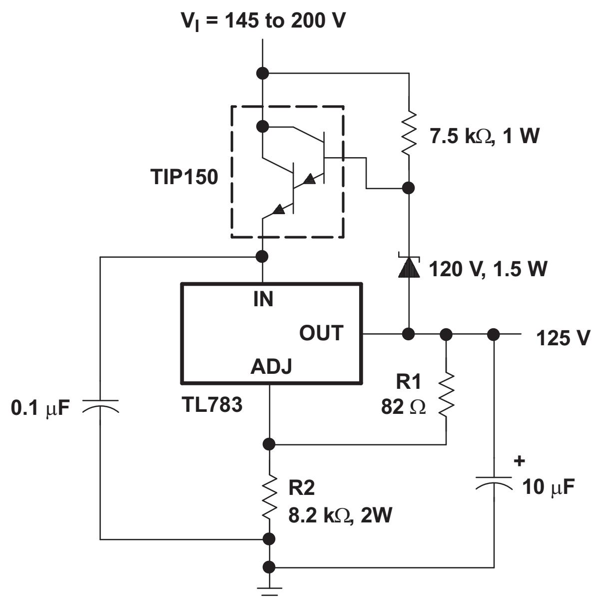


Figure 13. 125-V Short-Circuit-Protected Off-Line Regulator

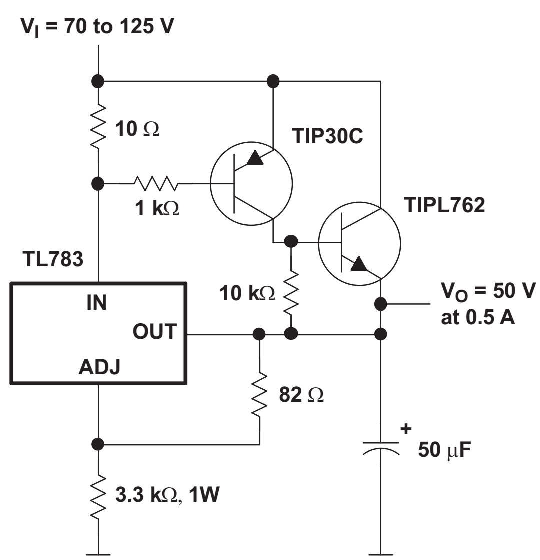


Figure 14. 50-V Regulator With Current Boost

Application Information (continued)

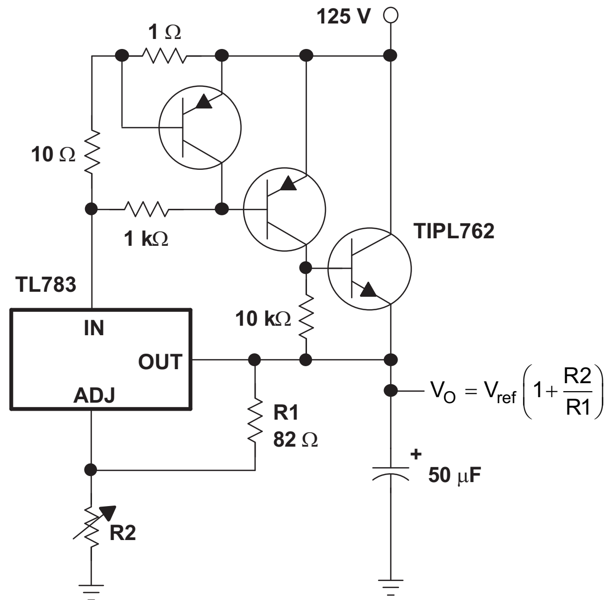


Figure 15. Adjustable Regulator With Current Boost and Current Limit

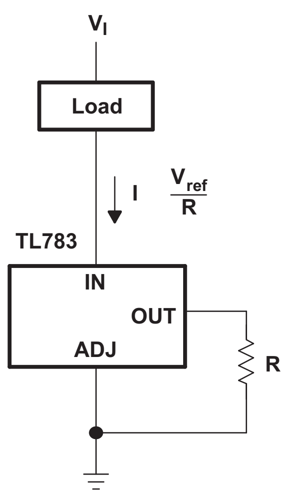


Figure 16. Current-Sinking Regulator

Application Information (continued)

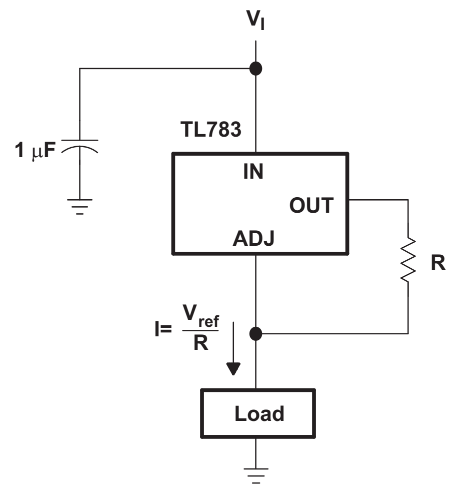


Figure 17. Current-Sourcing Regulator

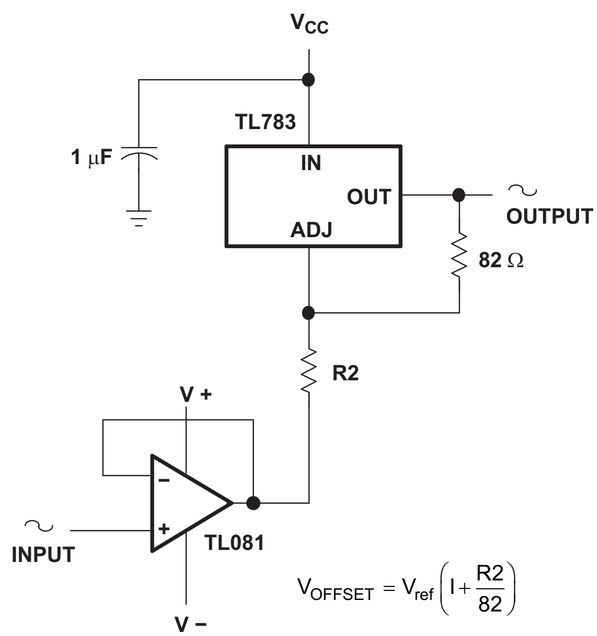


Figure 18. High-Voltage Unity-Gain Offset Amplifier

Application Information (continued)

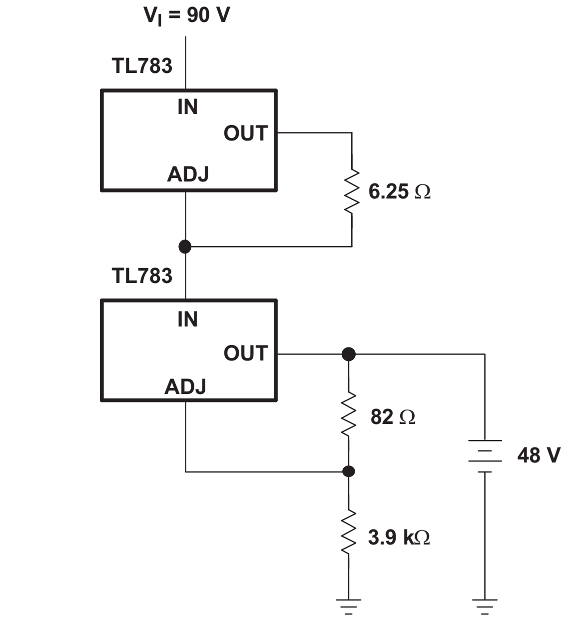
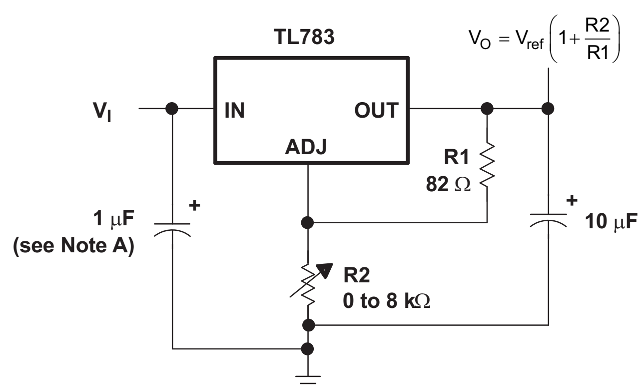


Figure 19. 48-V 200-mA Float Charger

9.2 Typical Application

The TL783 is typically used as an adjustable regulator.



A. Needed if device is more than 4 inches from filter capacitor

Figure 20. 1.25-V to 115-V Adjustable Regulator

9.2.1 Design Requirements

- Input and output decoupling capacitors for noise filtering.
- Resistor divider consisting of R1 and R2 to set the output voltage.

Typical Application (continued)

9.2.2 Detailed Design Procedure

The internal reference (see *Simplified Schematic*) generates 1.25 V nominal (V_{ref}) between OUT and ADJ. This voltage is developed across R1 and causes a constant current to flow through R1 and the programming resistor R2, giving an output voltage of:

$$V_O = V_{ref} (1 + R2 / R1) + I_{I(ADJ)} (R2)$$

or

$$V_O \approx V_{ref} (1 + R2 / R1)$$

The TL783 was designed to minimize the input current at ADJ and maintain consistency over line and load variations, thereby minimizing the associated (R2) error term.

To maintain $I_{I(ADJ)}$ at a low level, all quiescent operating current is returned to the output terminal. This quiescent current must be sunk by the external load and is the minimum load current necessary to prevent the output from rising. The recommended R1 value of 82 Ω provides a minimum load current of 15 mA. Larger values can be used when the input-to-output differential voltage is less than 125 V (see the output-current curve in Figure 12) or when the load sinks some portion of the minimum current.

9.2.2.1 Bypass Capacitors

The TL783 regulator is stable without bypass capacitors; however, any regulator becomes unstable with certain values of output capacitance if an input capacitor is not used. Therefore, the use of input bypassing is recommended whenever the regulator is located more than four inches from the power-supply filter capacitor. A 1-µF tantalum or aluminum electrolytic capacitor usually is sufficient.

Adjustment-terminal capacitors are not recommended for use on the TL783 because they can seriously degrade load transient response, as well as create a need for extra protection circuitry. Excellent ripple rejection presently is achieved without this added capacitor.

Due to the relatively low gain of the MOS output stage, output voltage dropout may occur under large-load transient conditions. The addition of an output bypass capacitor greatly enhances load transient response and prevents dropout. For most applications, it is recommended that an output bypass capacitor be used, with a minimum value of:

$$C_o (\mu F) = 15 / V_O$$

Larger values provide proportionally better transient-response characteristics.

Typical Application (continued)

9.2.2.2 Protection Circuitry

The TL783 regulator includes built-in protection circuits capable of guarding the device against most overload conditions encountered in normal operation. These protective features are current limiting, safe-operating-area protection, and thermal shutdown. These circuits protect the device under occasional fault conditions only. Continuous operation in the current limit or thermal shutdown mode is not recommended.

The internal protection circuits of the TL783 protect the device up to maximum-rated V_I as long as certain precautions are taken. If V_I is switched on instantaneously, transients exceeding maximum input ratings may occur, which can destroy the regulator. Usually, these are caused by lead inductance and bypass capacitors causing a ringing voltage on the input. In addition, when rise times in excess of 10 V/ns are applied to the input, a parasitic npn transistor in parallel with the DMOS output can be turned on, causing the device to fail. If the device is operated over 50 V and the input is switched on, rather than ramped on, a low-Q capacitor, such as tantalum or aluminum electrolytic, should be used, rather than ceramic, paper, or plastic bypass capacitors. A Q factor of 0.015, or greater, usually provides adequate damping to suppress ringing. Normally, no problems occur if the input voltage is allowed to ramp upward through the action of an ac line rectifier and filter network.

Similarly, when an instantaneous short circuit is applied to the output, both ringing and excessive fall times can result. A tantalum or aluminum electrolytic bypass capacitor is recommended to eliminate this problem. However, if a large output capacitor is used, and the input is shorted, addition of a protection diode may be necessary to prevent capacitor discharge through the regulator. The amount of discharge current delivered is dependent on output voltage, size of capacitor, and fall time of V_I. A protective diode (see Figure 21) is required only for capacitance values greater than:

$$C_o\ (\mu F) = 3 \times 10^4 / (V_O)^2$$

Care always should be taken to prevent insertion of regulators into a socket with power on. Power should be turned off before removing or inserting regulators.

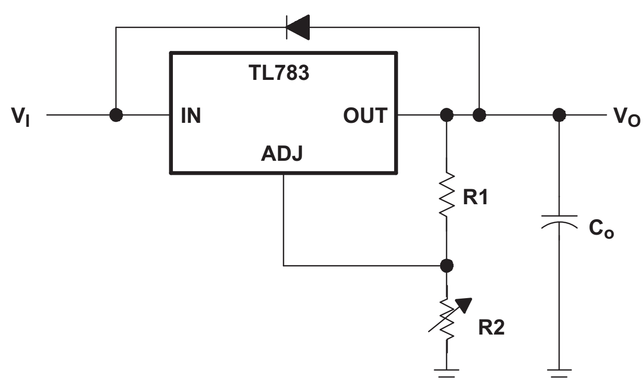


Figure 21. Regulator With Protective Diode

Typical Application (continued)

9.2.2.3 Load Regulation

The current-set resistor (R1) should be located close to the regulator output terminal, rather than near the load. This eliminates long line drops from being amplified, through the action of R1 and R2, to degrade load regulation. To provide remote ground sensing, R2 should be near the load ground.

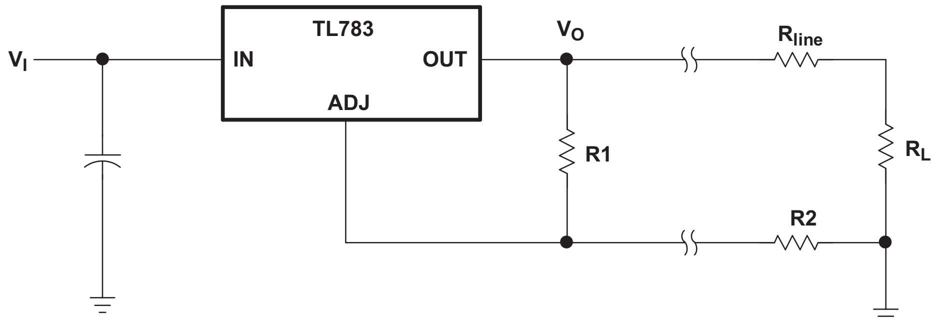


Figure 22. Regulator With Current-Set Resistor

9.2.3 Application Curves

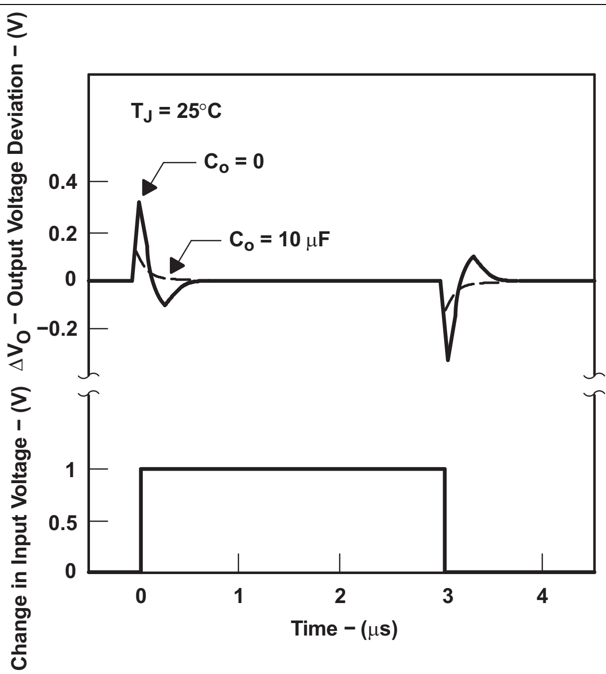


Figure 23. Line Transient Response

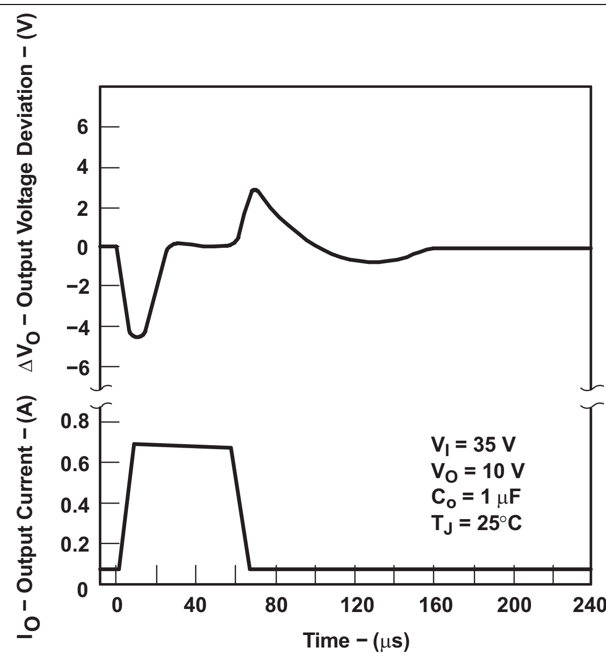


Figure 24. Load Transient Response

10 Power Supply Recommendations

A decoupling capacitor is needed on the IN pin of the TL783 if the TL783 is more than 4 inches from its power supply's filter capacitor. The differential input and output voltage levels are detailed in *Recommended Operating Conditions*.

11 Layout

11.1 Layout Guidelines

Input and output traces should be thick enough to handle desired currents, which can reach up to 700 mA on the output. ADJ pin traces can be smaller because the adjustment current is negligible.

11.2 Layout Example

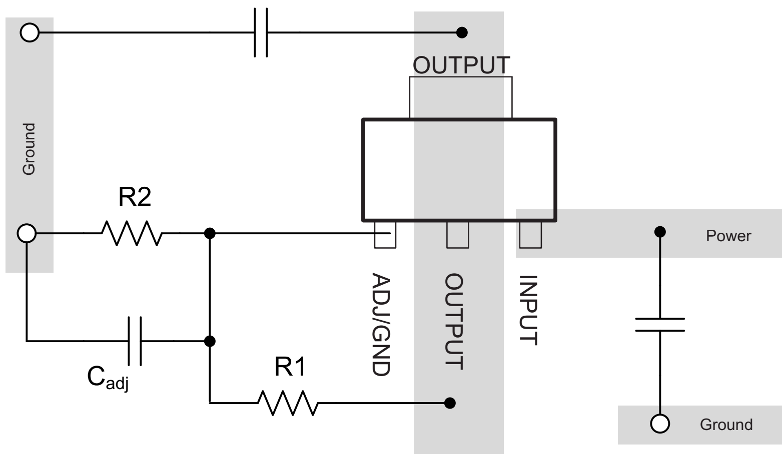


Figure 25. Layout Example

12 Device and Documentation Support

12.1 Trademarks

All trademarks are the property of their respective owners.

12.2 Electrostatic Discharge Caution

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.

12.3 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

13 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TL783CKCSE3	ACTIVE	TO-220	KCS	3	50	RoHS & Green	SN	N / A for Pkg Type	0 to 125	TL783C	Samples
TL783CKTTR	ACTIVE	DDPAK/ TO-263	KTT	3	500	RoHS & Green	SN	Level-3-245C-168 HR	0 to 125	TL783C	Samples
TL783CKTTRG3	ACTIVE	DDPAK/ TO-263	KTT	3	500	RoHS & Green	SN	Level-3-245C-168 HR	0 to 125	TL783C	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) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(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.

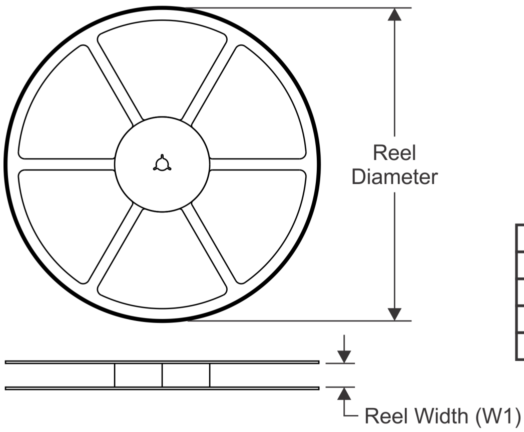
(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

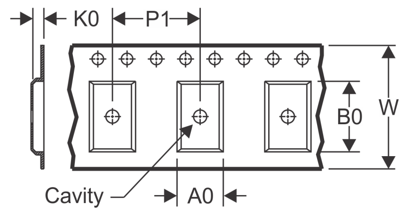
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

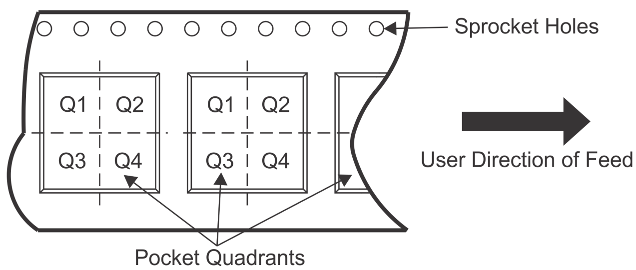


TAPE DIMENSIONS



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

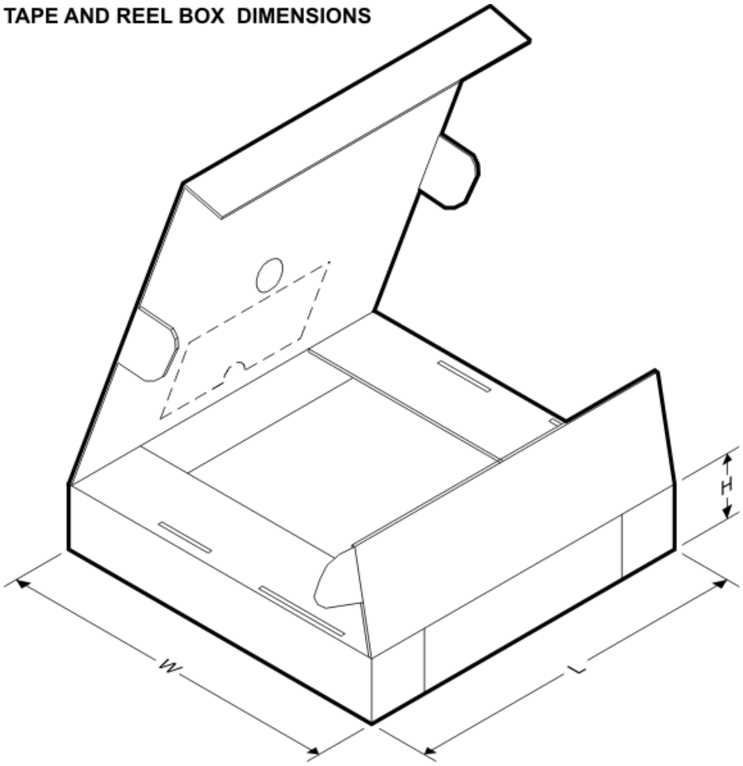
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
TL783CKTTR	DDPAK/ TO-263	KTT	3	500	330.0	24.4	10.8	16.1	4.9	16.0	24.0	Q2
TL783CKTTR	DDPAK/ TO-263	KTT	3	500	330.0	24.4	10.8	16.3	5.11	16.0	24.0	Q2

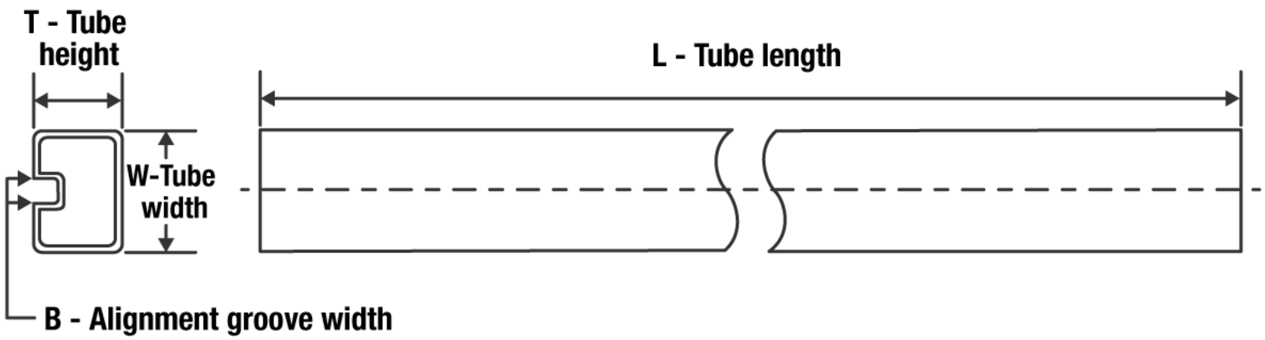
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TL783CKTTR	DDPAK/TO-263	KTT	3	500	350.0	334.0	47.0
TL783CKTTR	DDPAK/TO-263	KTT	3	500	340.0	340.0	38.0

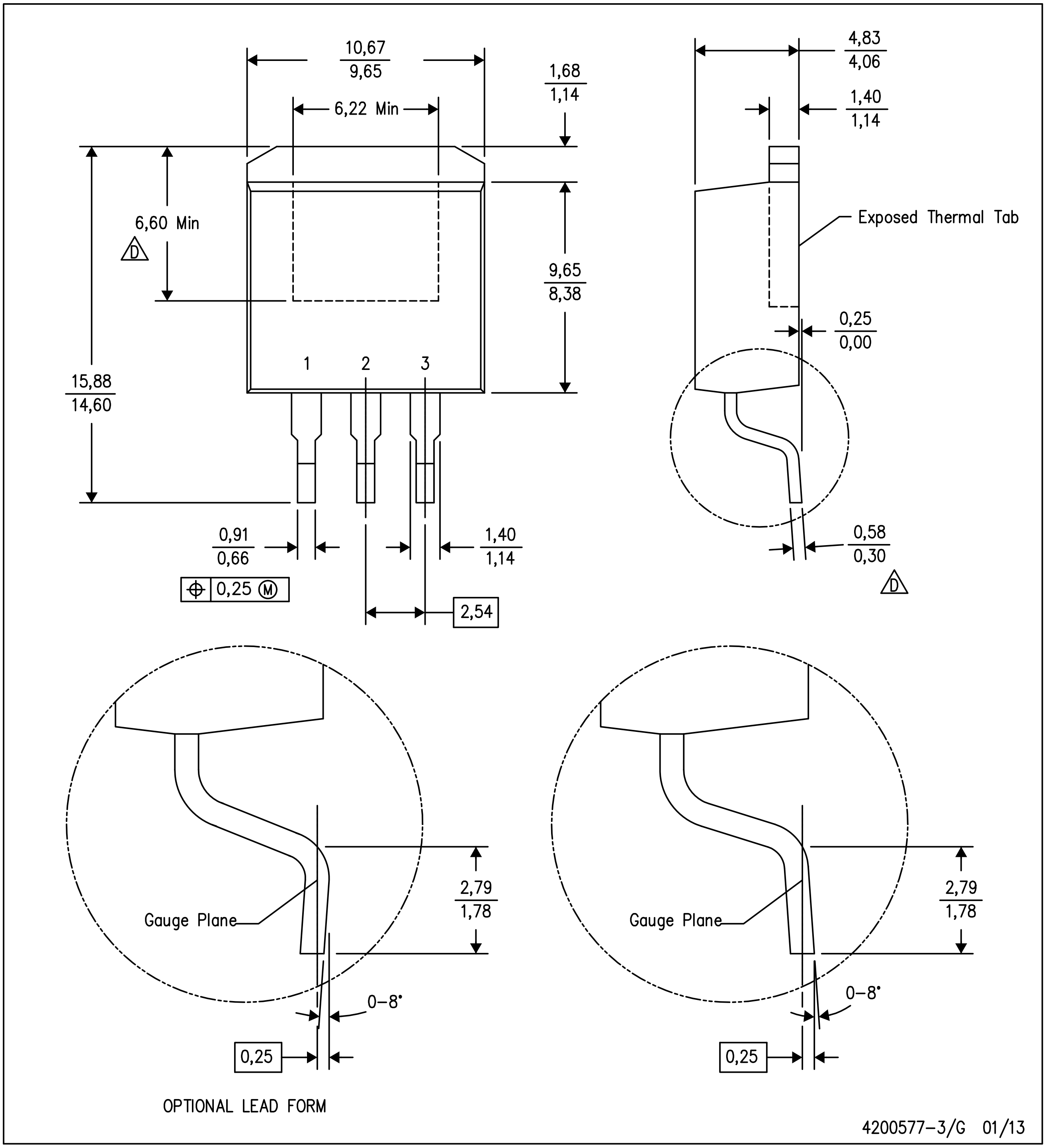
TUBE



*All dimensions are nominal

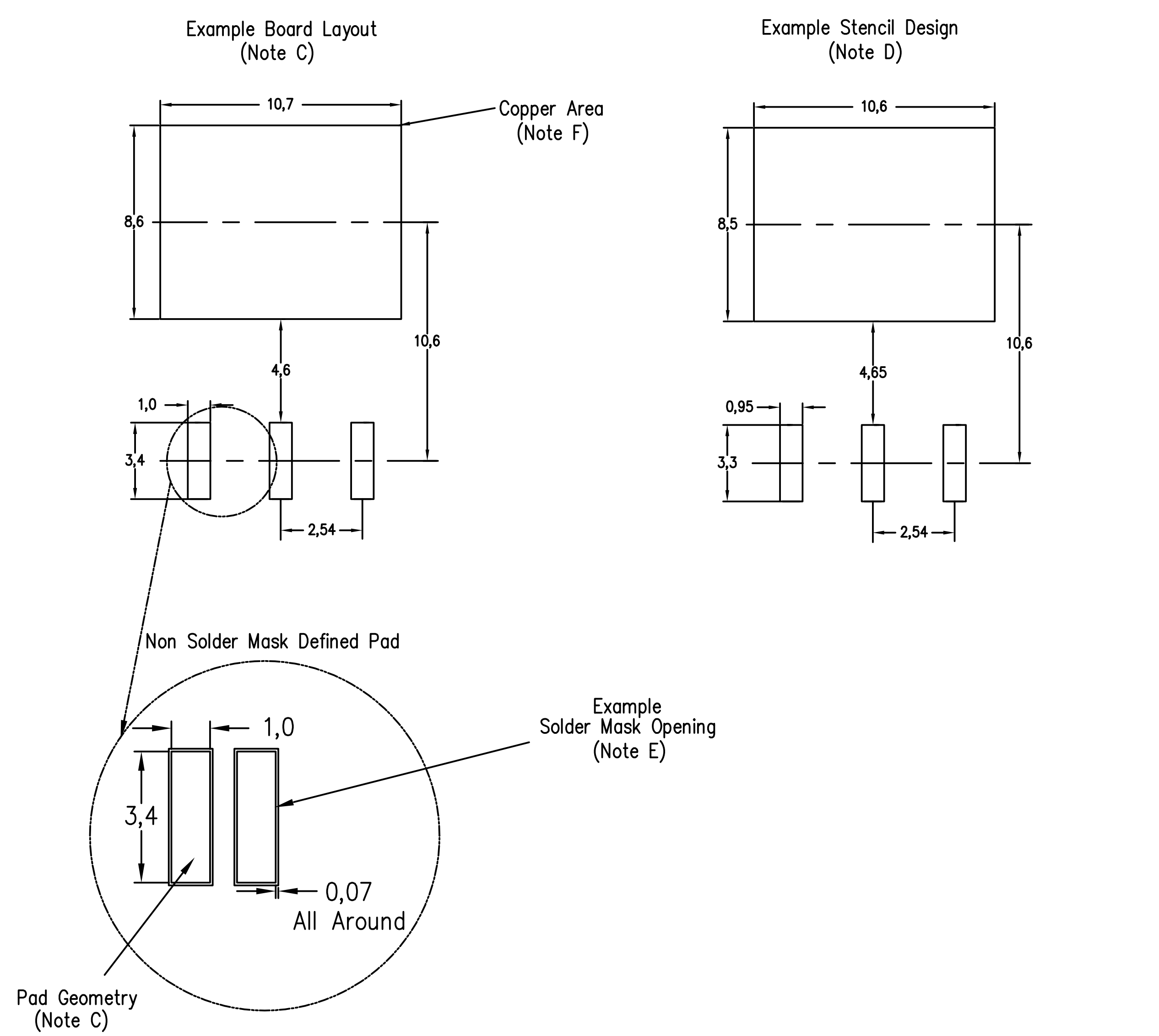
Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (µm)	B (mm)
TL783CKCSE3	KCS	TO-220	3	50	532	34.1	700	9.6

KTT (R–PSFM–G3) PLASTIC FLANGE–MOUNT PACKAGE



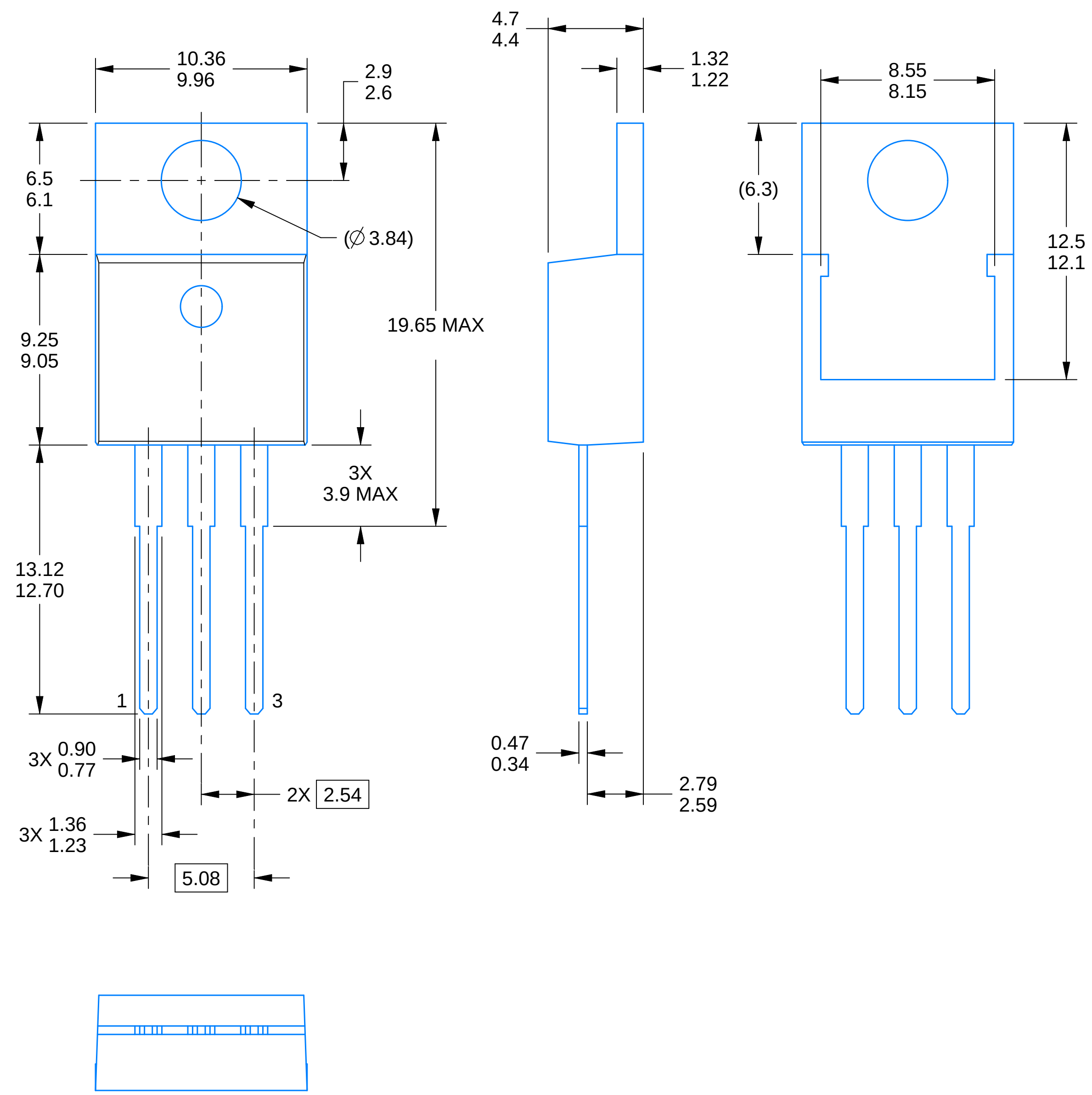
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion. Mold flash or protrusion not to exceed 0.005 (0,13) per side.
D. Falls within JEDEC TO–263 variation AA, except minimum lead thickness and minimum exposed pad length.

KTT (R–PSFM–G3) PLASTIC FLANGE–MOUNT PACKAGE



4208208–2/C 08/12

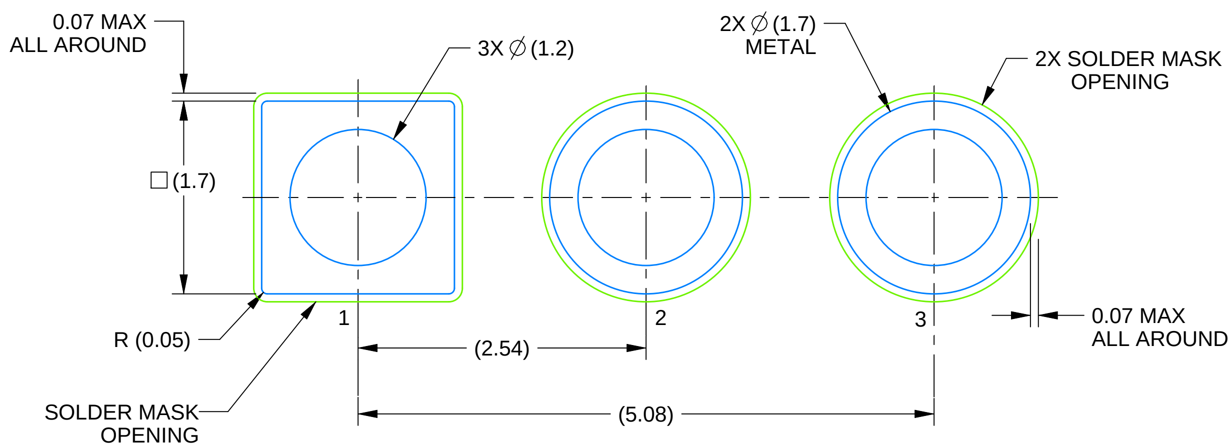
NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–SM–782 is recommended for alternate designs.
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC–7525.
E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.
F. This package is designed to be soldered to a thermal pad on the board. Refer to the Product Datasheet for specific thermal information, via requirements, and recommended thermal pad size. For thermal pad sizes larger than shown a solder mask defined pad is recommended in order to maintain the solderable pad geometry while increasing copper area.



4222214/B 08/2018

NOTES:

1. Dimensions are in millimeters. Any dimension in brackets or parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Reference JEDEC registration TO-220.



LAND PATTERN EXAMPLE
NON-SOLDER MASK DEFINED
SCALE:15X

LM117, LM317-N Wide Temperature Three-Pin Adjustable Regulator

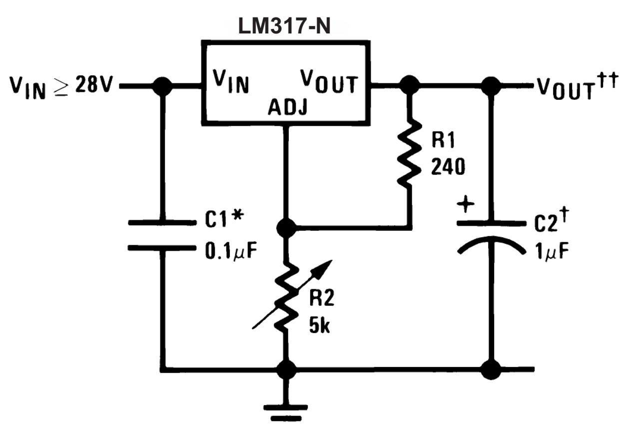
1 Features

- For a newer drop-in alternative, see the LM317
- Typ. 0.1% load regulation
- Typ. 0.01%/V line regulation
- 1.5-A output current
- Adjustable output down to 1.25 V
- Current limit constant with temperature
- 80-dB ripple rejection
- Short-circuit protected output
- −55°C to 150°C operating temperature range (LM117)

2 Applications

- Multifunction printers
- AC drive power stage modules
- Electricity meters
- Servo drive control modules
- Merchant network and server PSU

Typical Application



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

†Optional—improves transient response

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

3 Description

The LM117 and LM317-N series of adjustable 3-pin positive voltage regulators are capable of supplying in excess of 1.5 A over a 1.25-V to 37-V output range and a wide temperature 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.

The LM117 and LM317-N offer full overload protection such as current limit, thermal overload protection and safe area protection. All overload protection circuitry remains fully functional even if the adjustment terminal is disconnected.

Typically, 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 that are difficult to achieve with standard 3-terminal regulators.

Because the regulator is *floating* and detects 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. That is, avoid short-circuiting the output.

By connecting a fixed resistor between the adjustment pin and output, the LM117 and LM317-N can be also 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 1.25 V where most loads draw little current.

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

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LM117	TO-3 (2)	38.94 mm x 25.40 mm
	TO (3)	8.255 mm × 8.255 mm
LM317-N	TO-3 (2)	38.94 mm x 25.40 mm
	TO-220 (3)	14.986 mm × 10.16 mm
	TO-263 (3)	10.18 mm × 8.41 mm
	SOT-223 (4)	6.50 mm × 3.50 mm
	TO (3)	8.255 mm × 8.255 mm
	TO-252 (3)	6.58 mm × 6.10 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Table of Contents

4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision P (October 2015) to Revision Q	Page
• Added alternative device *Features* bullet	1
• Changed *Applications* section	1
• Changed *Device Comparison Table*	3
• Changed *Related Documentation* section	36

Changes from Revision O (January 2014) to Revision P	Page
• Added, updated, or renamed the following sections: *Description*; *Pin Configuration and Functions*; *Specifications*; *ESD Ratings* table; *Application and Implementation*; *Power Supply Recommendations*; *Layout*; *Mechanical, Packaging, and Ordering Information*	1
• Removed information regarding LM317A, formerly part of this data sheet. LM317A can now be found in the TI catalog under literature number SNVSAC2	1

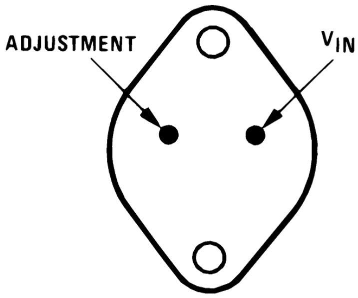
Changes from Revision N (August 2013) to Revision O	Page
• Deleted MDT Package (over Full Operating Temperature Range)	8
• Changed Current Limit MIN from 0.112 to 0.15 and TYP from 0.3 to 0.4 for (VIN – VOUT) = 40 V in the LM317A and LM317-N Electrical Characteristics Section	8
• Deleted MDT Package	8

5 Device Comparison Table

I_{OUT}	PARAMETER	LM317	LM317-N	LM317A	LM317HV	UNIT
1.5 A	Input voltage range	4.25 - 40	4.25 - 40	4.25 - 40	4.25 - 60	V
	Load regulation accuracy	1.5	1.5	1	1.5	%
	PSRR (120 Hz)	64	80	80	65	dB
	Recommended operating temperature	0 to 125	0 to 125	–40 to 125	0 to 125	°C
	TO-220 (NDE) T_{JA}	23.5	23.2	23.3	23	°C/W
	TO-200 (KCT) T_{JA}	37.9	N/A	N/A	N/A	°C/W
	TO-252 T_{JA}	N/A	54	54	N/A	°C/W
	TO-263 T_{JA}	38	41	N/A	N/A	°C/W
	SOT-223 T_{JA}	66.8	59.6	59.6	N/A	°C/W
	TO-92 T_{JA}	N/A	186	186	N/A	°C/W
0.5 A		LM317M				
	Input voltage range	3.75 - 40				V
	Load regulation accuracy	1.5				%
	PSRR (120 Hz)	80				dB
	Recommended operating temperature	-40 - 125				°C
	SOT-223 T_{JA}	60.2				°C/W
	TO-252 T_{JA}	56.9				°C/W
0.1 A		LM317L	LM317L-N			
	Input voltage range	3.75 - 40	4.25 - 40			V
	Load regulation accuracy	1	1.5			%
	PSRR (120 Hz)	62	80			dB
	Recommended operating temperature	–40 to 125	–40 to 125			°C
	SOT-23 T_{JA}	167.8	N/A			°C/W
	SO-8 T_{JA}	N/A	165			°C/W
	DSBGA T_{JA}	N/A	290			°C/W
	TO-92 T_{JA}	N/A	180			°C/W

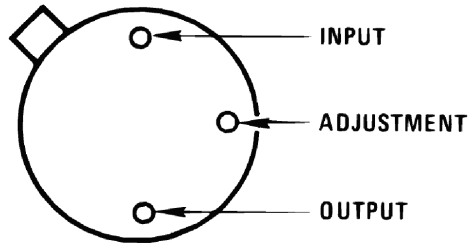
6 Pin Configuration and Functions

NDS Metal Can Package
2-Pin TO-3
Bottom View



Case is Output

NDT Metal Can Package
3-Pin TO
Bottom View

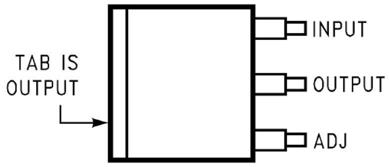


Case is Output

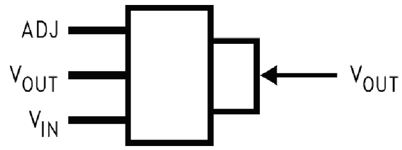
Pin Functions, Metal Can Packages

PIN			I/O	DESCRIPTION
NAME	TO-3	TO		
ADJ	1	2	—	Adjust pin
V_{OUT}	CASE	3, CASE	O	Output voltage pin for the regulator
V_{IN}	2	1	I	Input voltage pin for the regulator

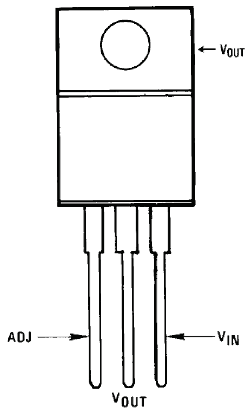
KTT Surface-Mount Package
3-Pin DDPAK/TO-263
Top View



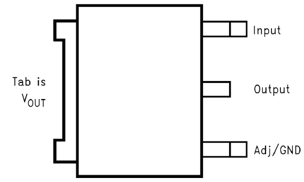
DCY Surface-Mount Package
4-Pin SOT-223
Top View



NDE Plastic Package
3-Pin TO-220
Front View



NDP Surface-Mount Package
3-Pin TO-252
Front View



Pin Functions

PIN					I/O	DESCRIPTION
NAME	TO-263	TO-220	SOT-223	TO-252		
ADJ	1	1	1	1	—	Adjust pin
V_{OUT}	2, TAB	2, TAB	2, 4	2, TAB	O	Output voltage pin for the regulator
V_{IN}	3	3	3	3	I	Input voltage pin for the regulator

7 Specifications

7.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1) (2)

	MIN	MAX	UNIT
Power dissipation	Internally Limited		
Input-output voltage differential	−0.3	40	V
Storage temperature, T_{stg}	−65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/Distributors for availability and specifications.

7.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM)(1)	±3000	V

(1) Manufacturing with less than 500-V HBM is possible with the necessary precautions. Pins listed as ±3000 V may actually have higher performance.

7.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

	MIN	MAX	UNIT
Operating temperature (LM117)	−55	150	°C
Operating temperature (LM317-N)	0	125	°C

7.4 Thermal Information, LM117

THERMAL METRIC(1)		LM117		UNIT
		NDS (TO-3)	NDT (TO)	
		2 PINS	3 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance(2)	39	186	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	2	21	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC package thermal metrics* application report.
(2) No heatsink.

7.5 Thermal Information, LM317-N

THERMAL METRIC[1][2]		LM317-N					UNIT
		KTT (TO-263)	NDE (TO-220)	DCY (SOT-223)	NDT (TO)	NDP (TO-252)	
		3 PINS	3 PINS	4 PINS	3 PINS	3 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	41.0	23.3	59.6	186[3]	54	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	43.6	16.2	39.3	21	51.3	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	23.6	4.9	8.4	—	28.6	°C/W
ψ_{JT}	Junction-to-top characterization parameter	10.4	2.7	1.8	—	3.9	°C/W
ψ_{JB}	Junction-to-board characterization parameter	22.6	4.9	8.3	—	28.1	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	0.9	1.1	—	—	0.9	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC package thermal metrics* application report.
(2) When surface mount packages are used (SOT-223, TO-252), the junction to ambient thermal resistance can be reduced by increasing the PCB copper area that is thermally connected to the package. See *Heatsink Requirements* for heatsink techniques.
(3) No heatsink.

7.6 LM117 Electrical Characteristics

Some specifications apply over full Operating Temperature Range as noted. Unless otherwise specified, T_J = 25°C, $V_{IN} - V_{OUT}$ = 5 V, and I_{OUT} = 10 mA.[1][2]

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Reference voltage	$3\text{ V} \le (V_{IN} - V_{OUT}) \le 40\text{ V}$, $10\text{ mA} \le I_{OUT} \le I_{MAX}$[1] (over full operating temperature range)		1.2	1.25	1.3	V
Line regulation	$3\text{ V} \le (V_{IN} - V_{OUT}) \le 40\text{ V}$[3]	T_J = 25°C		0.01	0.02	%/V
		over full operating temperature range		0.02	0.05	
Load regulation	$10\text{ mA} \le I_{OUT} \le I_{MAX}$[1][3]	T_J = 25°C		0.1%	0.3%	
		over full operating temperature range		0.3%	1%	
Thermal regulation	20-ms pulse			0.03	0.07	%/W
Adjustment pin current	over full operating temperature range			50	100	µA
Adjustment pin current change	$10\text{ mA} \le I_{OUT} \le I_{MAX}$[1] $3\text{ V} \le (V_{IN} - V_{OUT}) \le 40\text{ V}$ (over full operating temperature range)			0.2	5	µA
Temperature stability	$T_{MIN} \le T_J \le$ TMAX (over full operating temperature range)			1%		
Minimum load current	$(V_{IN} - V_{OUT})$ = 40 V (over full operating temperature range)			3.5	5	mA
Current limit	$(V_{IN} - V_{OUT}) \le 15\text{ V}$	TO-3 Package (over full operating temperature range)	1.5	2.2	3.4	A
		TO-39 Package (over full operating temperature range)	0.5	0.8	1.8	
	$(V_{IN} - V_{OUT})$ = 40 V	TO-3 package	0.3	0.4		A
		TO-39 package	0.15	0.2		
RMS output noise, % of V_{OUT}	10 Hz ≤ f ≤ 10 kHz			0.003%		
Ripple rejection ratio	V_{OUT} = 10 V, f = 120 Hz, C_{ADJ} = 0 µF (over full operating temperature range)			65		dB
	V_{OUT} = 10 V, f = 120 Hz, C_{ADJ} = 10 µF (over full operating temperature range)		66	80		dB
Long-term stability	T_J = 125°C, 1000 hrs			0.3%	1%	

(1) I_{MAX} = 1.5 A for the NDS (TO-3), NDE (TO-220), and KTT (TO-263) packages. I_{MAX} = 1.0 A for the DCY (SOT-223) package. I_{MAX} = 0.5 A for the NDT (TO) and NDP (TO-252) packages. Device power dissipation (P_D) is limited by ambient temperature (T_A), device maximum junction temperature (T_J), and package thermal resistance ($R_{\theta JA}$). The maximum allowable power dissipation at any temperature is : $P_{D(MAX)} = ((T_{J(MAX)} - T_A) / R_{\theta JA})$. All Min. and Max. limits are ensured to TI's Average Outgoing Quality Level (AOQL).
(2) Specifications and availability for military and space grades of LM117/883 can be found in the LM117QML data sheet. Specifications and availability for military and space grades of LM117 can be found in the LM117JAN data sheet.
(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.

7.7 LM317-N Electrical Characteristics[1]

Some specifications apply over full Operating Temperature Range as noted. Unless otherwise specified, T_J = 25°C, $V_{IN} - V_{OUT}$ = 5 V, and I_{OUT} = 10 mA.

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Reference voltage	T_J = 25°C			1.25		V
Reference voltage	3 V ≤ ($V_{IN} - V_{OUT}$) ≤ 40 V, 10 mA ≤ I_{OUT} ≤ I_{MAX}[1] (over Full Operating Temperature Range)		1.2	1.25	1.3	V
Line regulation	3V ≤ ($V_{IN} - V_{OUT}$) ≤ 40 V[2]	T_J = 25°C		0.01	0.04	%/V
Line regulation	3V ≤ ($V_{IN} - V_{OUT}$) ≤ 40 V[2]	(over full operating temperature range)		0.02	0.07	%/V
Load regulation	10 mA ≤ I_{OUT} ≤ I_{MAX}[1][2]	T_J = 25°C		0.1%	0.5%	
Load regulation	10 mA ≤ I_{OUT} ≤ I_{MAX}[1][2]	(over full operating temperature range)		0.3%	1.5%	
Thermal regulation	20-ms pulse			0.04	0.07	%/W
Adjustment pin current	(over full operating temperature range)			50	100	µA
Adjustment pin current change	10 mA ≤ I_{OUT} ≤ I_{MAX}[1] 3V ≤ ($V_{IN} - V_{OUT}$) ≤ 40V	(over full operating temperature range)		0.2	5	µA
Temperature stability	$T_{MIN} \leq T_J \leq T_{MAX}$	(over full operating temperature range)		1%		
Minimum load current	($V_{IN} - V_{OUT}$) = 40 V	(over full operating temperature range)		3.5	10	mA
Current limit	($V_{IN} - V_{OUT}$) ≤ 15 V	TO-3, TO-263 Packages (over full operating temperature range)	1.5	2.2	3.4	A
Current limit	($V_{IN} - V_{OUT}$) ≤ 15 V	SOT-223, TO-220 Packages (over full operating temperature range)	1.5	2.2	3.4	A
Current limit	($V_{IN} - V_{OUT}$) ≤ 15 V	TO, TO-252 Package (over full operating temperature range)	0.5	0.8	1.8	A
Current limit	($V_{IN} - V_{OUT}$) = 40 V	TO-3, TO-263 packages	0.15	0.4		A
Current limit	($V_{IN} - V_{OUT}$) = 40 V	SOT-223, TO-220 packages	0.15	0.4		A
Current limit	($V_{IN} - V_{OUT}$) = 40 V	TO, TO-252 package	0.075	0.2		A
RMS output noise, % of V_{OUT}	10 Hz ≤ f ≤ 10 kHz			0.003%		
Ripple rejection ratio	V_{OUT} = 10 V, f = 120 Hz, C_{ADJ} = 0 µF (over full operating temperature range)			65		dB
Ripple rejection ratio	V_{OUT} = 10V, f = 120 Hz, C_{ADJ} = 10 µF (over full operating temperature range)		66	80		dB
Long-term stability	T_J = 125°C, 1000 hrs			0.3%	1%	

(1) I_{MAX} = 1.5 A for the NDS (TO-3), NDE (TO-220), and KTT (TO-263) packages. I_{MAX} = 1.0 A for the DCY (SOT-223) package. I_{MAX} = 0.5 A for the NDT (TO) and NDP (TO-252) packages. Device power dissipation (P_D) is limited by ambient temperature (T_A), device maximum junction temperature (T_J), and package thermal resistance ($R_{\theta JA}$). The maximum allowable power dissipation at any temperature is : $P_{D(MAX)} = ((T_{J(MAX)} - T_A) / R_{\theta JA})$. 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.

7.8 Typical Characteristics

output Capacitor = 0 μF (unless otherwise noted)

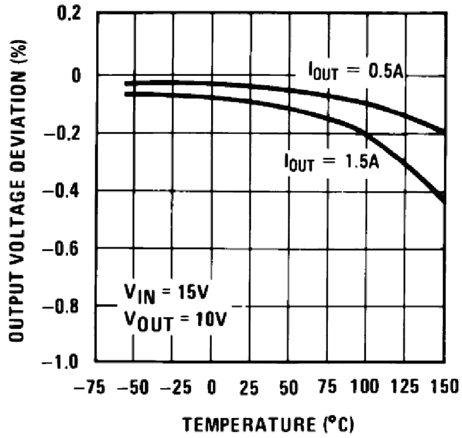


Figure 1. Load Regulation

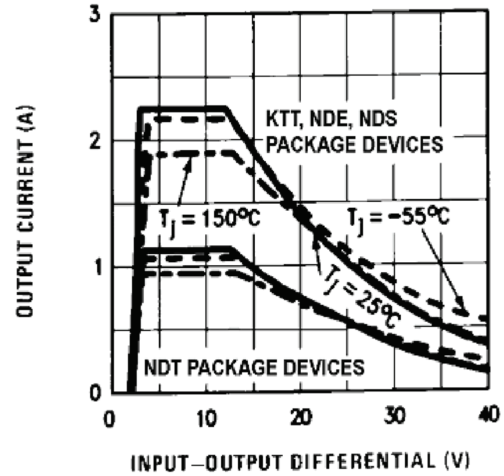


Figure 2. Current Limit

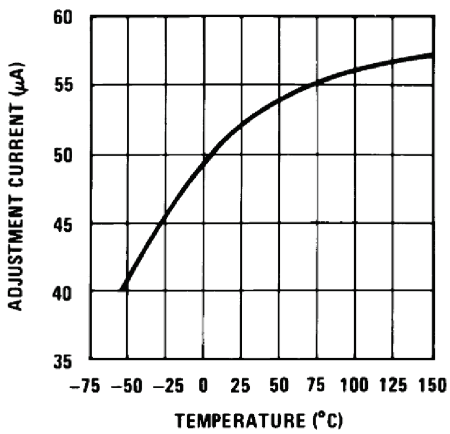


Figure 3. Adjustment Current

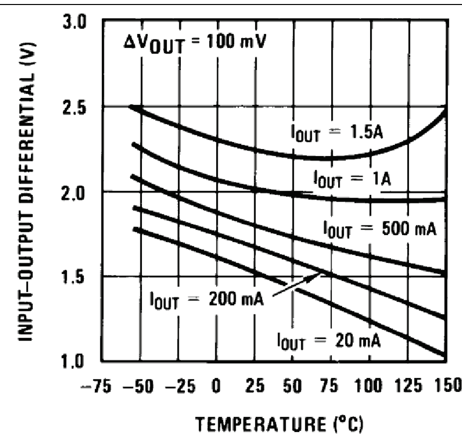


Figure 4. Dropout Voltage

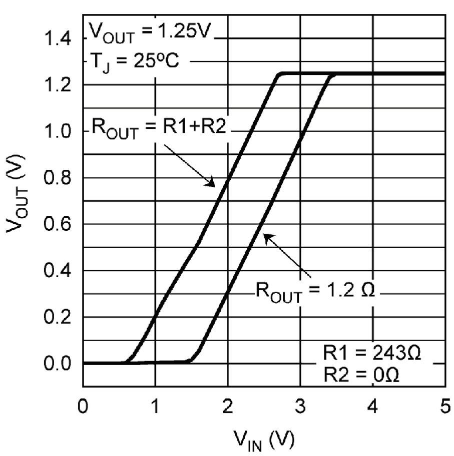


Figure 5. V_{OUT} vs V_{IN}, $V_{OUT} = V_{REF}$

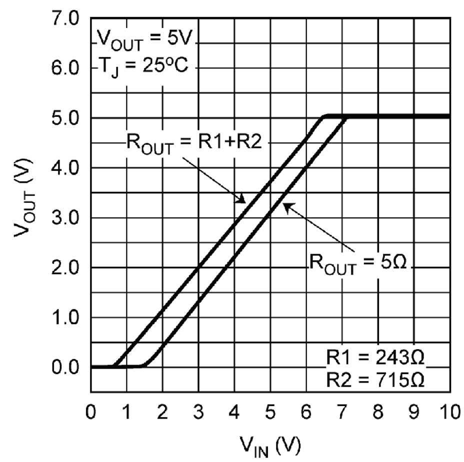


Figure 6. V_{OUT} vs V_{IN}, V_{OUT} = 5 V

Typical Characteristics (continued)

output Capacitor = 0 μF (unless otherwise noted)

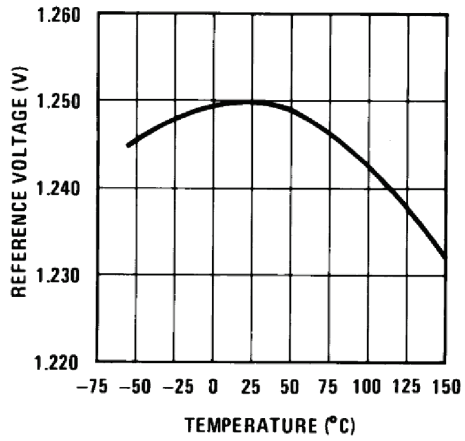


Figure 7. Temperature Stability

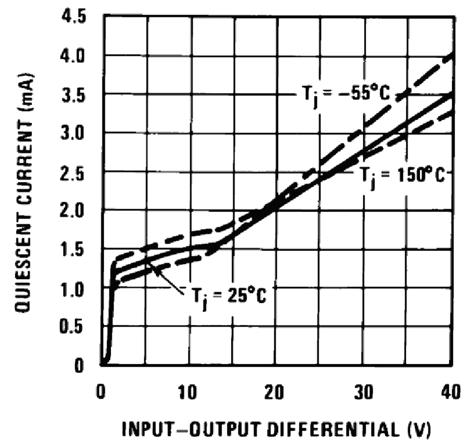


Figure 8. Minimum Operating Current

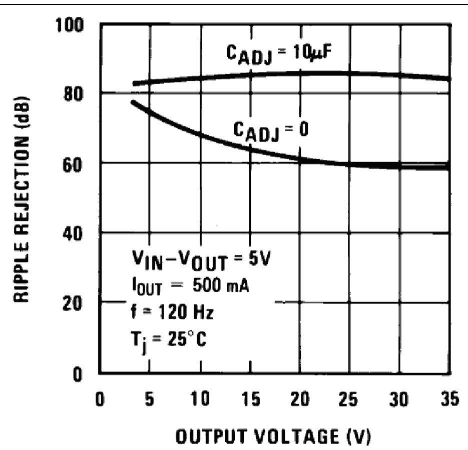


Figure 9. Ripple Rejection

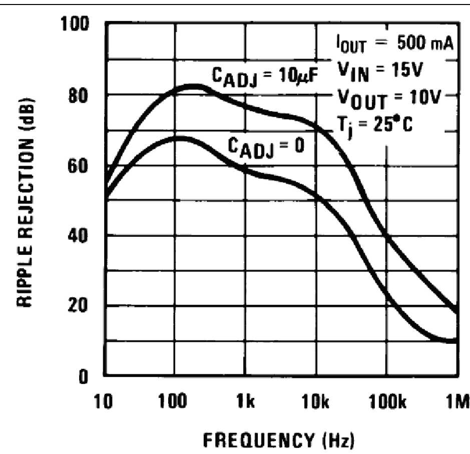


Figure 10. Ripple Rejection

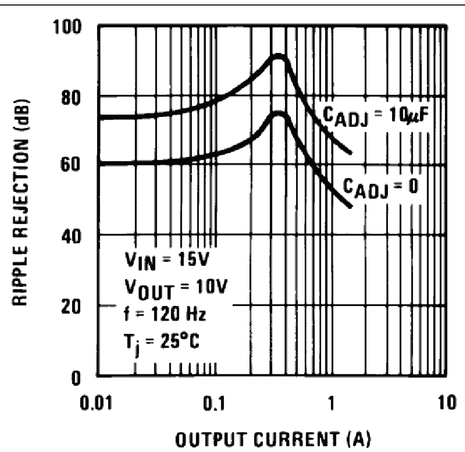


Figure 11. Ripple Rejection

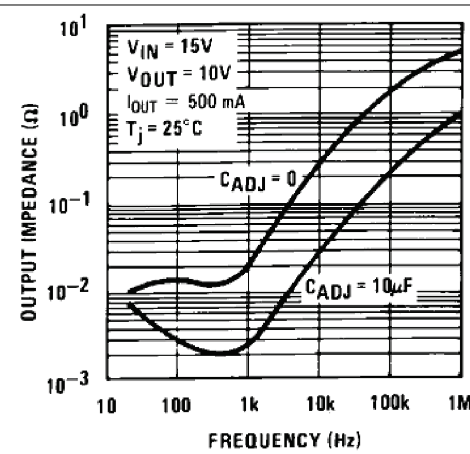


Figure 12. Output Impedance

Typical Characteristics (continued)

output Capacitor = 0 μF (unless otherwise noted)

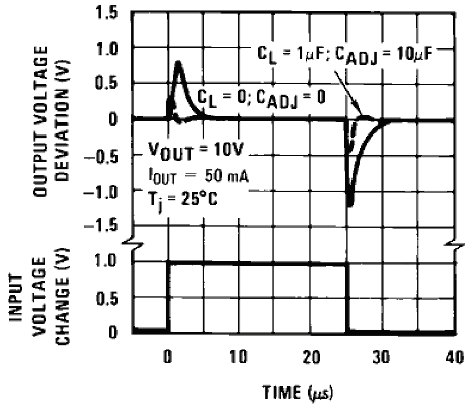


Figure 13. Line Transient Response

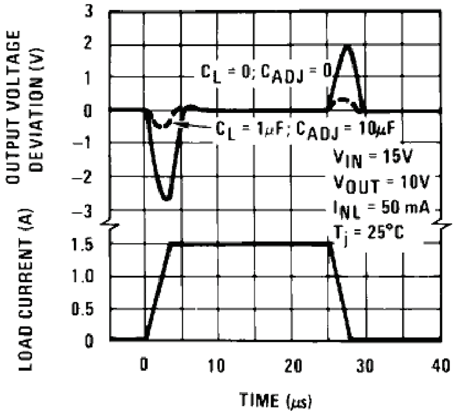


Figure 14. Load Transient Response

8 Detailed Description

8.1 Overview

In operation, the LM317-N develops a nominal 1.25-V reference voltage, V_{REF}, between the output and adjustment terminal. The reference voltage is impressed across program resistor R1 and, because the voltage is constant, a constant current I_1 then flows through the output set resistor R2, giving an output voltage calculated by Equation 1:

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

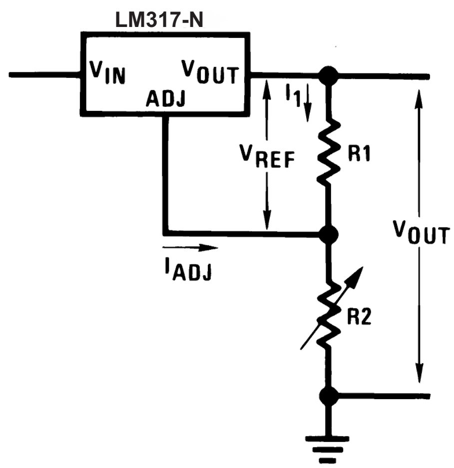
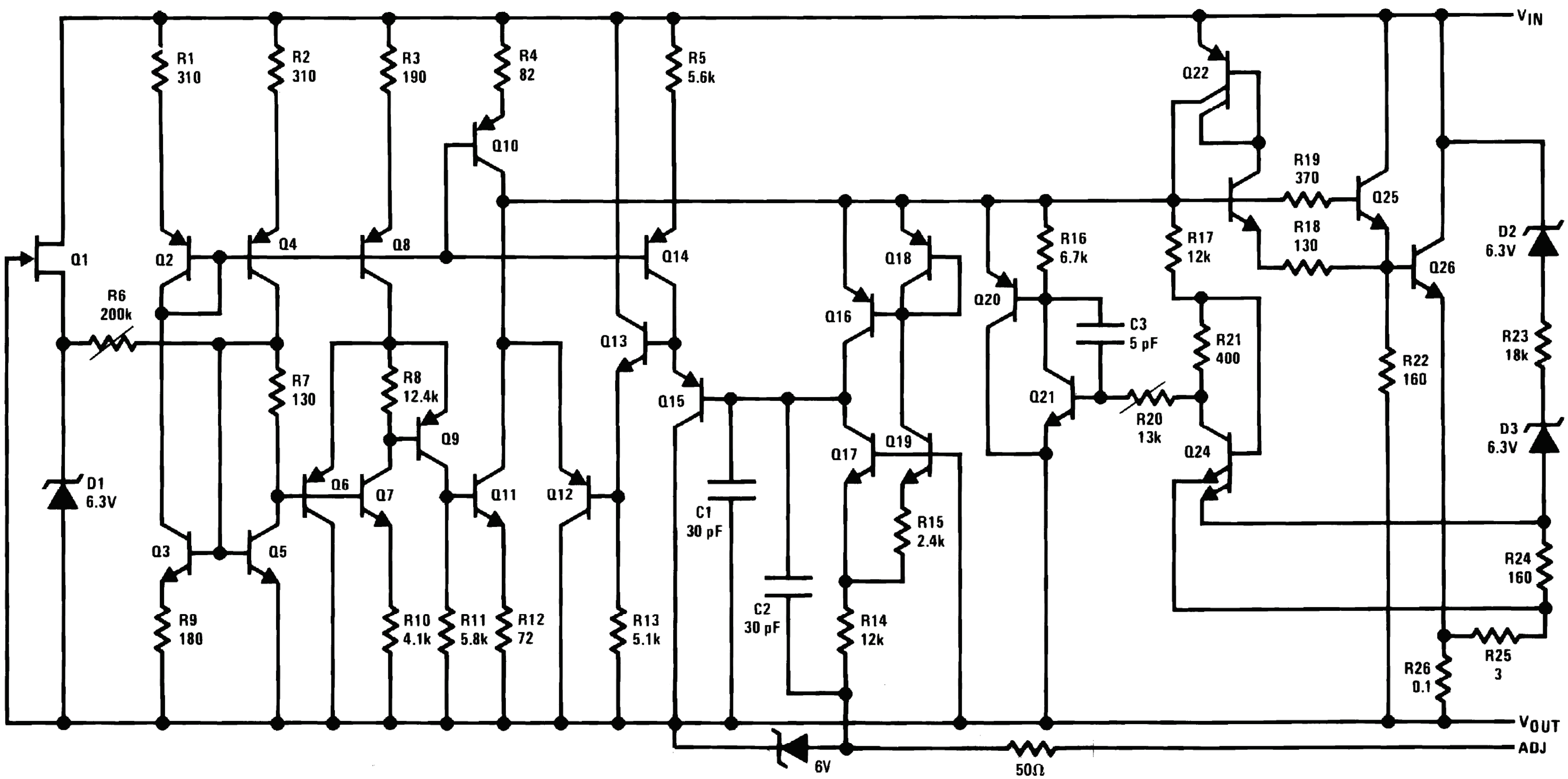


Figure 15. Setting the V_{OUT} Voltage

Because the 100-µA current from the adjustment terminal represents an error term, the LM317-N 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.

8.2 Functional Block Diagram



8.3 Feature Description

8.3.1 Load Regulation

The LM317-N is capable of providing extremely good load regulation but a few precautions are needed to obtain maximum performance. The current set resistor, R1, must be connected near the output terminal of the regulator rather than near the load. If R1 is placed too far from the output terminal, then the increased trace resistance, R_S, will cause an error voltage drop in the adjustment loop and degrade load regulation performance. Therefore, R1 must be placed as close as possible to the output terminal to minimize R_S and maximize load regulation performance.

Figure 16 shows the effect of the trace resistance, R_S, when R1 is placed far from the output terminal of the regulator. It is clear that R_S will cause an error voltage drop especially during higher current loads, so it is important to minimize the R_S trace resistance by keeping R1 close to the regulator output terminal.

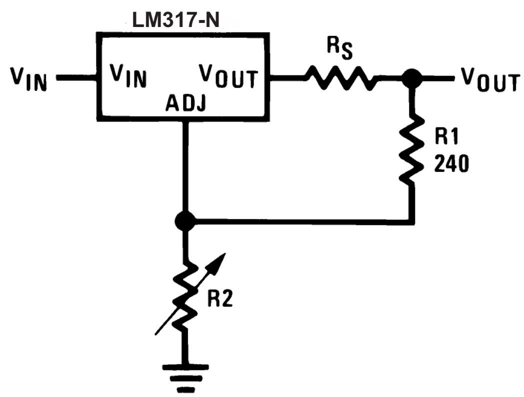


Figure 16. Regulator With Line Resistance in Output Lead

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 must 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.

8.4 Device Functional Modes

8.4.1 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 LM317-N 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. However, 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 LM317-N 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.

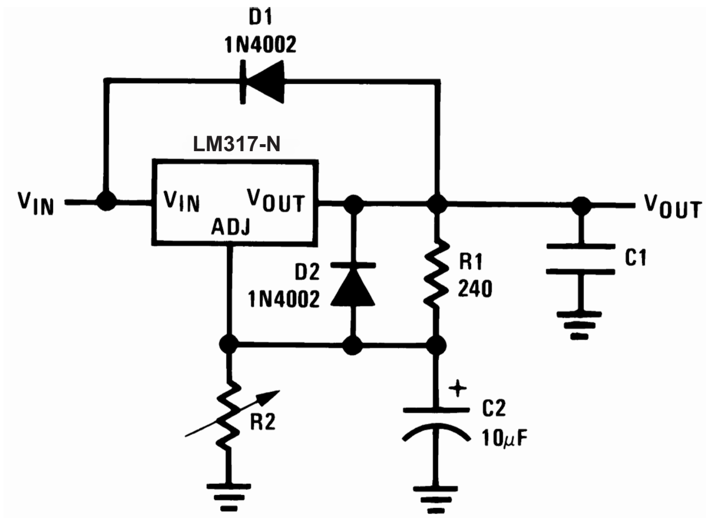
Device Functional Modes (continued)

8.4.2 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 20-A 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 LM317-N, this discharge path is through a large junction that is able to sustain 15-A 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 LM317-N is a 50-Ω resistor which limits the peak discharge current. No protection is needed for output voltages of 25 V or less and 10-µF capacitance. Figure 17 shows an LM317-N with protection diodes included for use with outputs greater than 25 V and high values of output capacitance.



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

D1 protects against C1

D2 protects against C2

Figure 17. Regulator With Protection Diodes

9 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers must validate and test their design implementation to confirm system functionality.

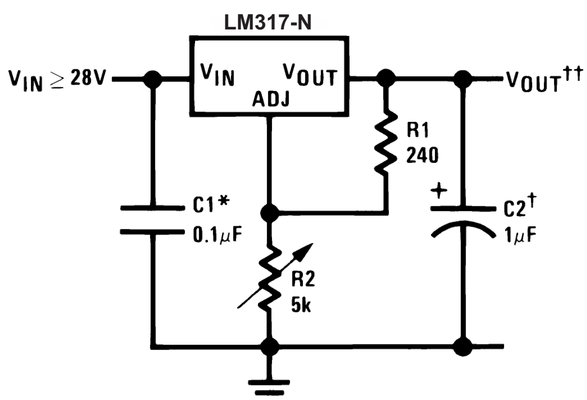
9.1 Application Information

The LM117 and LM317-N are versatile, high performance, linear regulators with high accuracy and a wide temperature range. An output capacitor can be added to further improve transient response, and the ADJ pin can be bypassed to achieve very high ripple-rejection ratios. Its functionality can be utilized in many different applications that require high performance regulation, such as battery chargers, constant current regulators, and microprocessor supplies.

9.2 Typical Applications

9.2.1 1.25-V to 25-V Adjustable Regulator

The LM117 can be used as a simple, low-dropout regulator to enable a variety of output voltages needed for demanding applications. By using an adjustable R2 resistor, a variety of output voltages can be made possible as shown in Figure 18.



NOTE: Full output current not available at high input-output voltages
*Needed if device is more than 6 inches from filter capacitors.
†Optional—improves transient response. Output capacitors in the range of 1 µF to 1000 µF of aluminum or tantalum electrolytic are commonly used to provide improved output impedance and rejection of transients.

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

Figure 18. 1.25-V to 25-V Adjustable Regulator

9.2.1.1 Design Requirements

The device component count is very minimal, employing two resistors as part of a voltage divider circuit and an output capacitor for load regulation. An input capacitor is needed if the device is more than 6 inches from filter capacitors. An optional bypass capacitor across R2 can also be used to improve PSRR.

9.2.1.2 Detailed Design Procedure

The output voltage is set based on the selection of the two resistors, R1 and R2, as shown in Figure 18. For details on capacitor selection, refer to *External Capacitors*.

Typical Applications (continued)

9.2.1.3 Application Curve

As shown in Figure 19, V_{OUT} will rise with V_{IN} minus some dropout voltage. This dropout voltage during startup will vary with R_{OUT}.

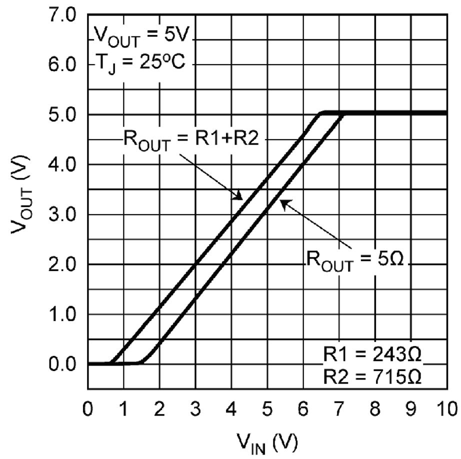
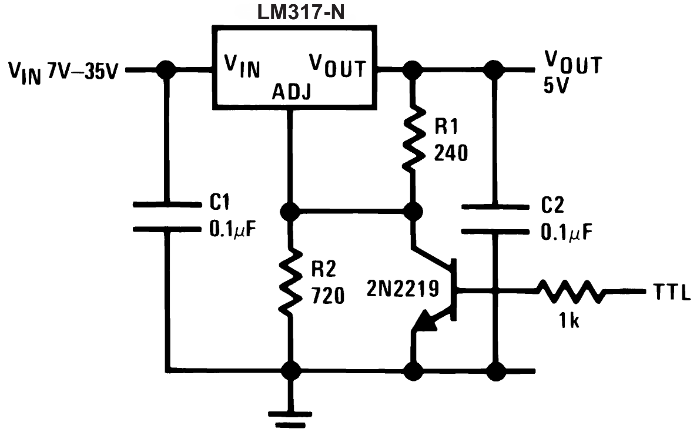


Figure 19. V_{OUT} vs V_{IN}, V_{OUT} = 5V

9.2.2 5-V Logic Regulator With Electronic Shutdown

Figure 20 shows a variation of the 5-V output regulator application uses the L117 along with an NPN transistor to provide shutdown control. The NPN will either block or sink the current from the ADJ pin by responding to the TTL pin logic. When TTL is pulled high, the NPN is on and pulls the ADJ pin to GND, and the LM117 outputs about 1.25 V. When TTL is pulled low, the NPN is off and the regulator outputs according to the programmed adjustable voltage.



NOTE: Min. output ≅ 1.2 V

Figure 20. 5-V Logic Regulator With Electronic Shutdown

Typical Applications (continued)

9.2.3 Slow Turnon 15-V Regulator

An application of LM117 includes a PNP transistor with a capacitor to implement slow turnon functionality (see Figure 21). As V_{IN} rises, the PNP sinks current from the ADJ rail. The output voltage at start up is the addition of the 1.25-V reference plus the drop across the base to emitter. While this is happening, the capacitor begins to charge and eventually opens the PNP. At this point, the device functions normally, regulating the output at 15 V. A diode is placed between C1 and V_{OUT} to provide a path for the capacitor to discharge. Such controlled turnon is useful for limiting the in-rush current.

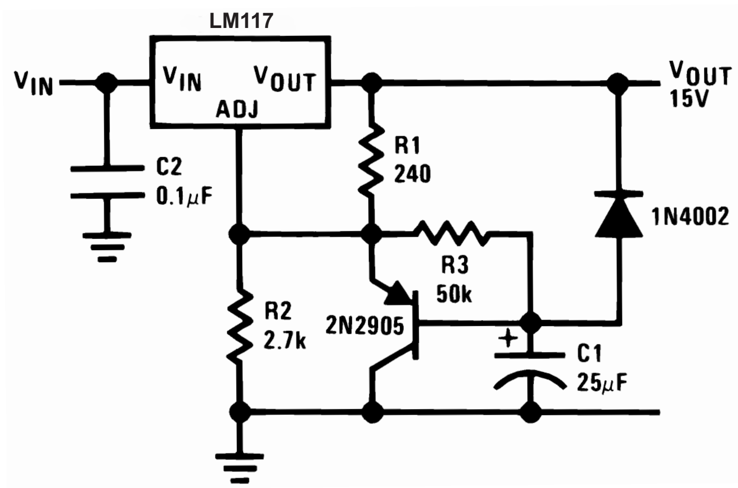
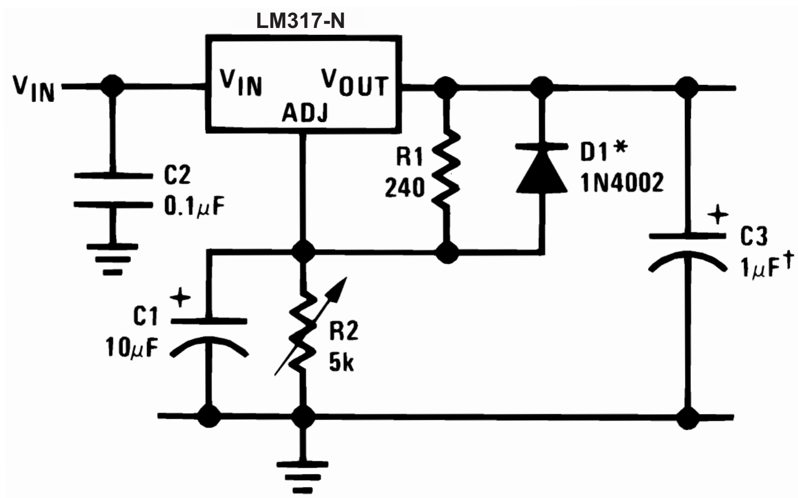


Figure 21. Slow Turnon 15-V Regulator

Typical Applications (continued)

9.2.4 Adjustable Regulator With Improved Ripple Rejection

To improve ripple rejection, a capacitor is used to bypass the ADJ pin to GND (see Figure 22). This is used to smooth output ripple by cleaning the feedback path and stopping unnecessary noise from being fed back into the device, propagating the noise.



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

Figure 22. Adjustable Regulator With Improved Ripple Rejection

9.2.5 High Stability 10-V Regulator

Using a high stability shunt voltage reference in the feedback path, such as the LM329, provides damping necessary for a stable, low noise output (see Figure 23).

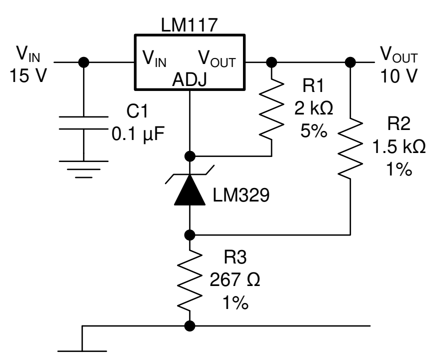


Figure 23. High Stability 10-V Regulator

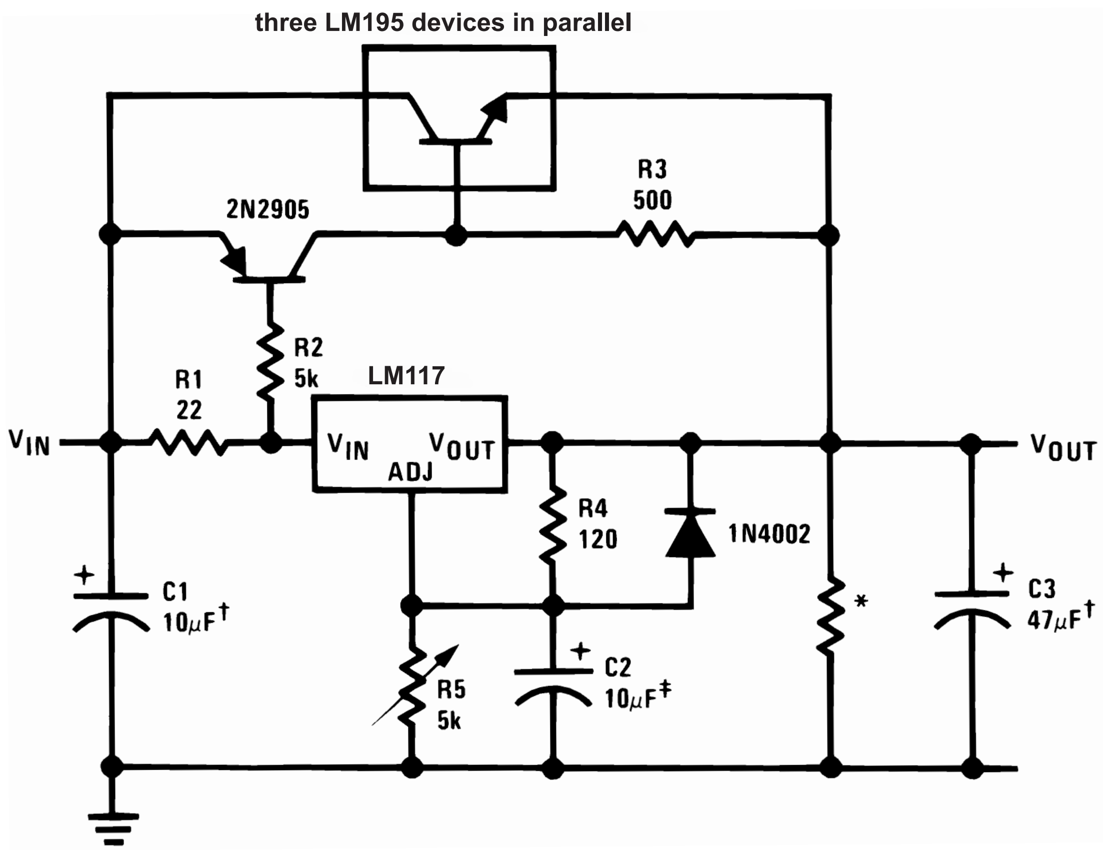
Typical Applications (continued)

9.2.6 High-Current Adjustable Regulator

Using the LM195 power transistor in parallel with the LM117 can increase the maximum possible output load current (see Figure 24). Sense resistor R1 provides the 0.6 V across base to emitter to turn on the PNP. This on switch allows current to flow, and the voltage drop across R3 drives three LM195 power transistors designed to carry an excess of 1 A each.

NOTE

The selection of R1 determines a minimum load current for the PNP to turn on. The higher the resistor value, the lower the load current must be before the transistors turn on.



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

Figure 24. High-Current Adjustable Regulator

Typical Applications (continued)

9.2.7 Emitter-Follower Current Amplifier

The LM117 is used as a constant current source in the emitter follower circuit (see Figure 25). The LM195 power transistor is being used as a current gain amplifier, boosting the INPUT current. The LM117 provides a stable current bias than just using a resistor.

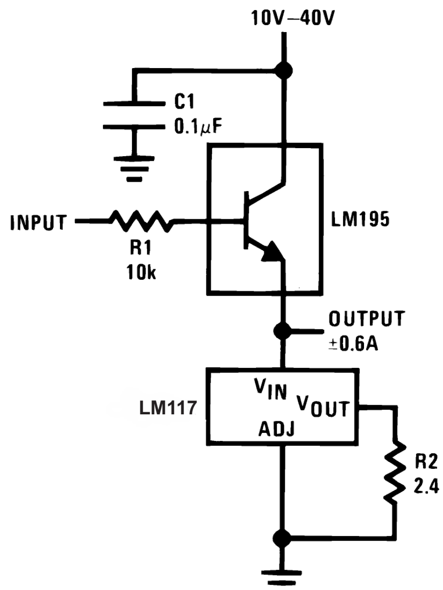


Figure 25. Emitter-Follower Current Amplifier

9.2.8 1-A Current Regulator

A simple, fixed current regulator can be made by placing a resistor between the V_{OUT} and ADJ pins of the LM117 (see Figure 26). By regulating a constant 1.25 V between these two terminals, a constant current is delivered to the load.

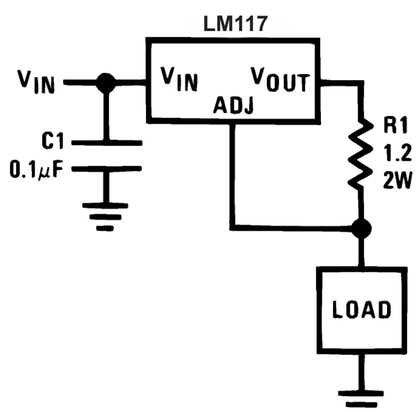


Figure 26. 1-A Current Regulator

Typical Applications (continued)

9.2.9 Common-Emitter Amplifier

Sometimes it is necessary to use a power transistor for high current gain. In this case, the LM117 provides constant current at the collector of the LM195 in this common emitter application (see Figure 27). The 1.25-V reference between V_{OUT} and ADJ is maintained across the 2.4-Ω resistor, providing about 500-mA constant bias current into the collector of the LM195.

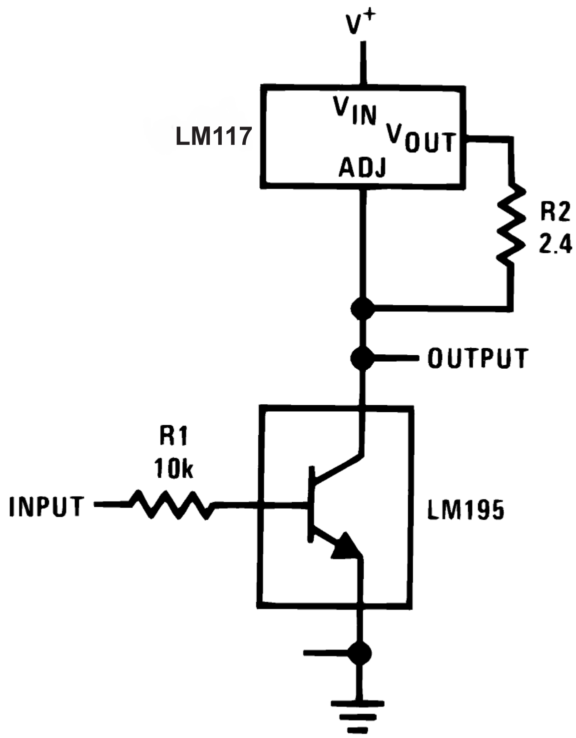
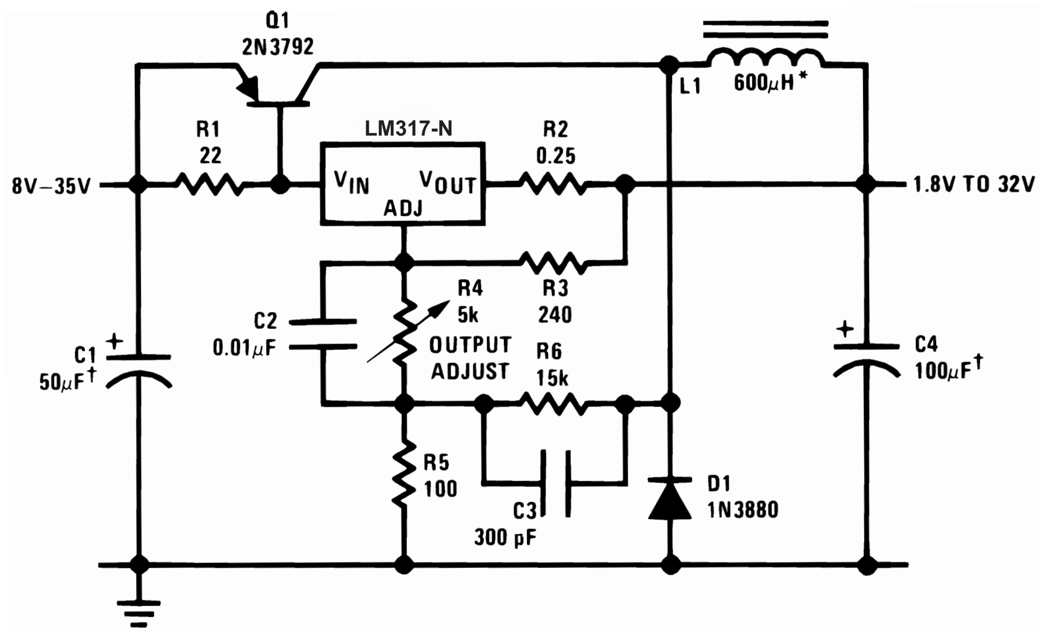


Figure 27. Common-Emitter Amplifier

Typical Applications (continued)

9.2.10 Low-Cost 3-A Switching Regulator

The LM317-N can be used in a switching buck regulator application in cost sensitive applications that require high efficiency. The switch node above D1 oscillates between ground and VIN, as the voltage across sense resistor R1 drives the power transistor on and off. Figure 28 exhibits self-oscillating behavior by negative feedback through R6 and C3 to the ADJ pin of the LM317-N.



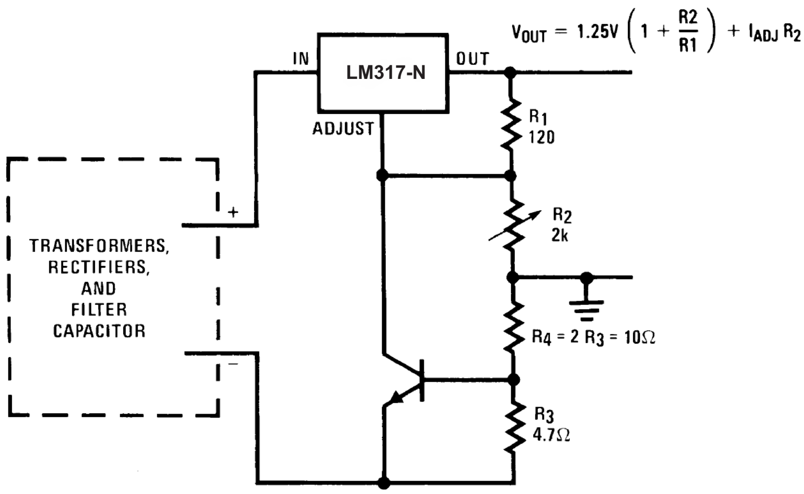
NOTE: †Solid tantalum
*Core—Arnold A-254168-2 60 turns

Figure 28. Low-Cost 3-A Switching Regulator

Typical Applications (continued)

9.2.11 Current-Limited Voltage Regulator

A maximum limit on output current can be set using the circuit shown in Figure 29. The load current travels through R3 and R4. As the load current increases, the voltage drop across R3 increases until the NPN transistor is driven, during which the ADJ pin is pulled down to ground and the output voltage is pulled down to the reference voltage of 1.25 V.



–*Short circuit current is approximately* $\frac{600\ mV}{R3}$, *or 210 mA*

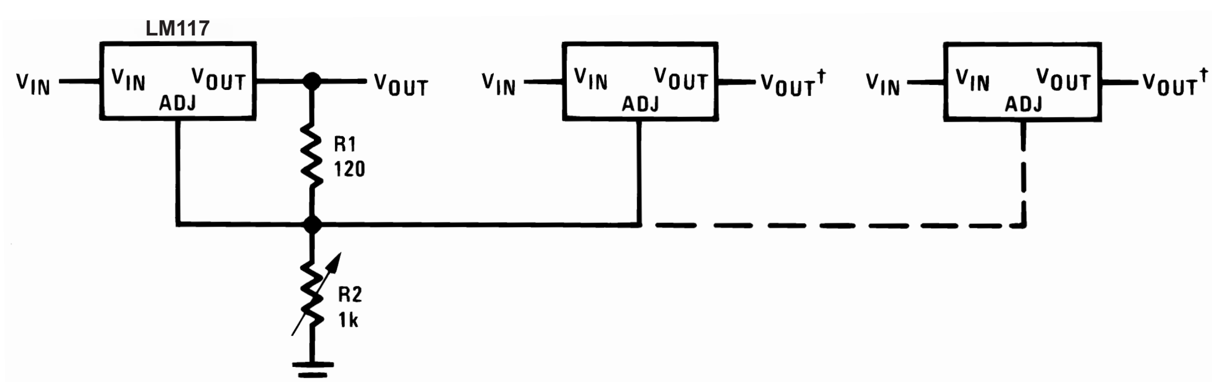
(Compared to LM117's higher current limit)

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

Figure 29. Current-Limited Voltage Regulator

9.2.12 Adjusting Multiple On-Card Regulators With Single Control

Figure 30 shows how multiple LM117 regulators can be controlled by setting one resistor. Because each device maintains the reference voltage of about 1.25 V between its V_{OUT} and ADJ pins, we can connect each ADJ rail to a single resistor, setting the same output voltage across all devices. This allows for independent outputs, each responding to its corresponding input only. Designers must also consider that by the nature of the circuit, changes to R1 and R2 will affect all regulators.



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

Figure 30. Adjusting Multiple On-Card Regulators With Single Control

Typical Applications (continued)

9.2.13 AC Voltage Regulator

In Figure 31, the top regulator is +6 V above the bottom regulator. It is clear that when the input rises above +6 V plus the dropout voltage, only the top LM317-N regulates +6 V at the output. When the input falls below –6 V minus the dropout voltage, only the bottom LM317-N regulates –6 V at the output. For regions where the output is not clipped, there is no regulation taking place, so the output follows the input.

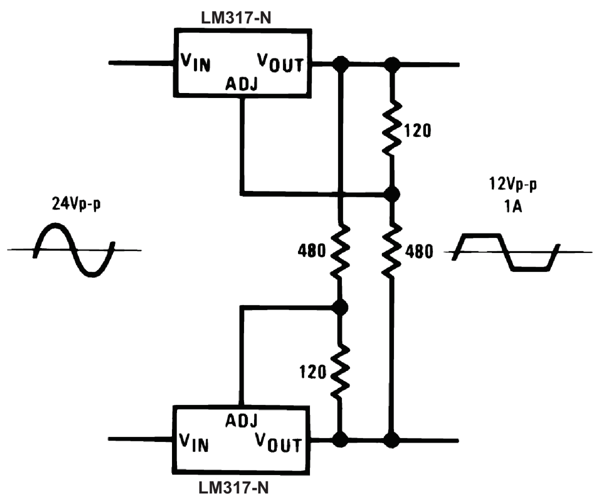
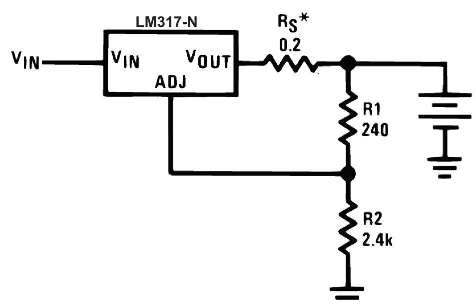


Figure 31. AC Voltage Regulator

9.2.14 12-V Battery Charger

The LM317-N can be used in a battery charger application shown in Figure 32, where the device maintains either constant voltage or constant current mode depending on the current charge of the battery. To do this, the part senses the voltage drop across the battery and delivers the maximum charging current necessary to charge the battery. When the battery charge is low, there exists a voltage drop across the sense resistor R_S, providing constant current to the battery at that instant. As the battery approaches full charge, the potential drop across R_S approaches zero, reducing the current and maintaining the fixed voltage of the battery.



*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 32. 12-V Battery Charger

Typical Applications (continued)

9.2.15 Adjustable 4-A Regulator

Using three LM317-N devices in parallel increases load current capability (Figure 33). Output voltage is set by the variable resistor tied to the non-inverting terminal of the operational amplifier, and reference current to the transistor is developed across the 100 Ω resistor. When output voltage rises, the operational amplifier corrects by drawing current from the base, closing the transistor. This effectively pulls ADJ down and lowers the output voltage through negative feedback.

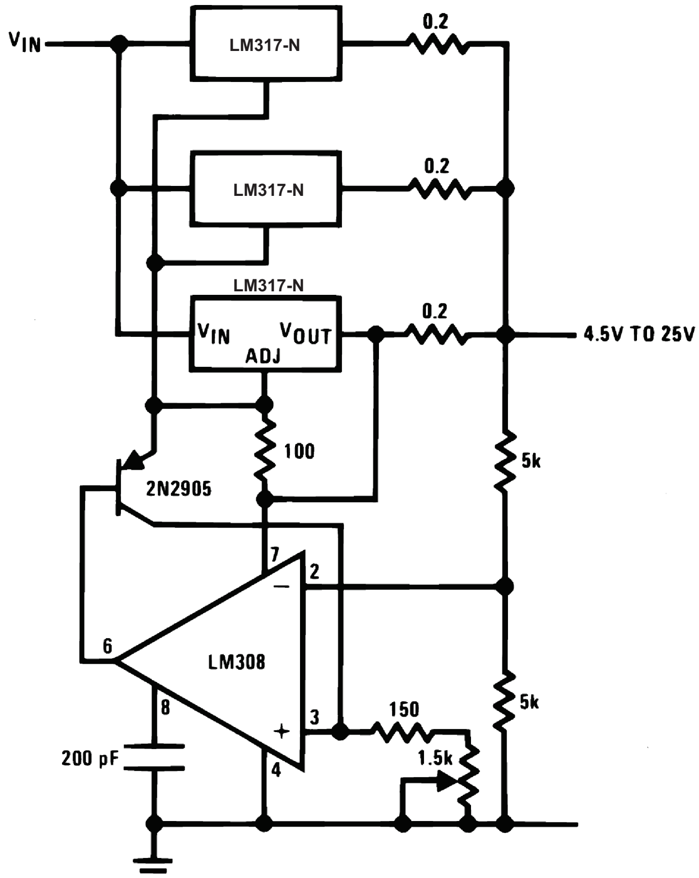
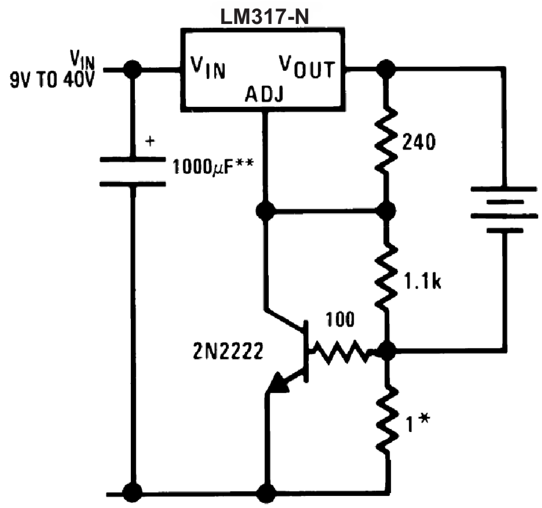


Figure 33. Adjustable 4-A Regulator

Typical Applications (continued)

9.2.16 Current-Limited 6-V Charger

The current in a battery charger application is limited by switching between constant current and constant voltage states (see Figure 34). When the battery pulls low current, the drop across the 1 Ω resistor is not substantial and the NPN remains off. A constant voltage is seen across the battery, as regulated by the resistor divider. When current through the battery rises past peak current, the 1 Ω provides enough voltage to turn the transistor on, pulling ADJ close to ground. This results in limiting the maximum current to the battery.

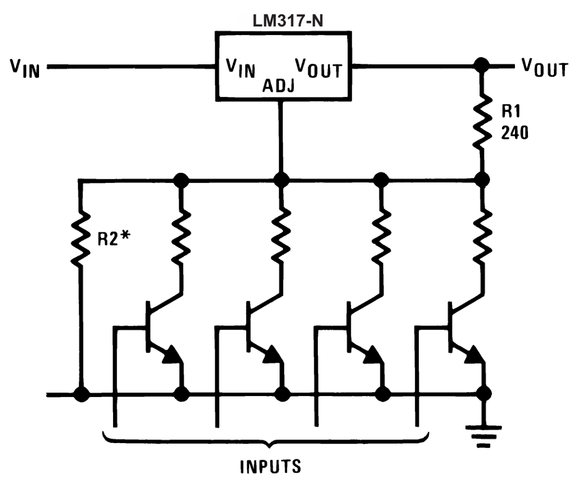


*Sets peak current (0.6A for 1Ω)
**The 1000-µF is recommended to filter out input transients

Figure 34. Current-Limited 6-V Charger

9.2.17 Digitally Selected Outputs

Figure 35 demonstrates a digitally selectable output voltage. In its default state, all transistors are off and the output voltage is set based on R1 and R2. By driving certain transistors, the associated resistor is connected in parallel to R2, modifying the output voltage of the regulator.



*Sets maximum V_{OUT}

Figure 35. Digitally Selected Outputs

$$V_{OUT} = V_{REF}\left(1 + \frac{R2}{R1}\right) + I_{ADJ}R2 \tag{2}$$

10 Power Supply Recommendations

The input supply to the LM117 and LM317-N must be kept at a voltage level such that its maximum input to output differential voltage is not exceeded. The minimum dropout voltage must also be met with extra headroom when possible to keep the LM117 and LM317-N in regulation. An input capacitor is recommended, especially when the input pin is located more than 6 inches away from the power supply source. For more information regarding capacitor selection, refer to *External Capacitors*.

11 Layout

11.1 Layout Guidelines

Some layout guidelines must be followed to ensure proper regulation of the output voltage with minimum noise. Traces carrying the load current must be wide to reduce the amount of parasitic trace inductance and the feedback loop from V_{OUT} to ADJ must be kept as short as possible. To improve PSRR, a bypass capacitor can be placed at the ADJ pin and must be located as close as possible to the IC. In cases when V_{IN} shorts to ground, an external diode must be placed from V_{OUT} to V_{IN} to divert the surge current from the output capacitor and protect the IC. Similarly, in cases when a large bypass capacitor is placed at the ADJ pin and V_{OUT} shorts to ground, an external diode must be placed from ADJ to V_{OUT} to provide a path for the bypass capacitor to discharge. These diodes must be placed close to the corresponding IC pins to increase their effectiveness.

11.1.1 Thermal Considerations

11.1.1.1 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 must not exceed the rated maximum junction temperature (T_J) of 150°C for the LM117, or 125°C for the 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 calculate with Equation 3:

$$P_D = ((V_{IN} - V_{OUT}) \times I_L) + (V_{IN} \times I_G) \quad (3)$$

Figure 36 shows the voltage and currents which are present in the circuit.

The next parameter which must be calculated is the maximum allowable temperature rise, $T_{R(MAX)}$ in Equation 4:

$$T_{R(MAX)} = T_{J(MAX)} - T_{A(MAX)} \quad (4)$$

where $T_{J(MAX)}$ is the maximum allowable junction temperature (150°C for the LM117, or 125°C for the LM317-N), and $T_{A(MAX)}$ is the maximum ambient temperature that 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 ($R_{\theta JA}$) can be calculated with Equation 5:

$$R_{\theta JA} = (T_{R(MAX)} / P_D) \quad (5)$$

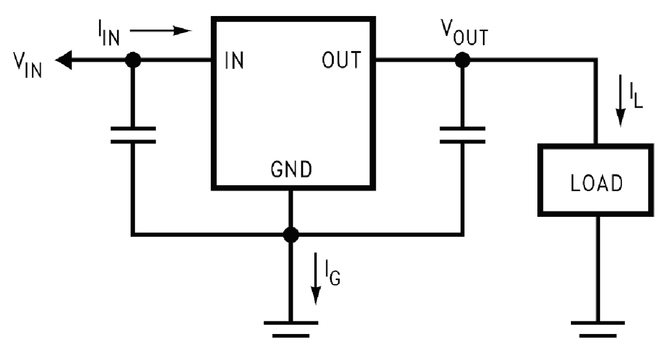


Figure 36. Power Dissipation Diagram

Layout Guidelines (continued)

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 ($R_{\theta JA}$) must be lowered by adding a heatsink, or some combination of these.

If a heatsink is needed, the value can be calculated from Equation 6:

$$\theta_{HA} \leq (R_{\theta JA} - (\theta_{CH} + R_{\theta JC}))$$

where

- θ_{CH} is the thermal resistance of the contact area between the device case and the heatsink surface
- $R_{\theta JC}$ is thermal resistance from the junction of the die to surface of the package case (6)

When a value for θ_{HA} 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 θ_{HA} 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.

11.1.1.2 Heatsinking Surface Mount Packages

The TO-263 (KTT), SOT-223 (DCY) and TO-252 (NDP) 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.

11.1.1.2.1 Heatsinking the SOT-223 (DCY) Package

Figure 37 and Figure 38 show the information for the SOT-223 package. Figure 38 assumes a $R_{\theta JA}$ of 74°C/W for 1-oz. copper and 59.6°C/W for 2-oz. copper and a maximum junction temperature of 125°C. See the *AN-1028 Maximum Power Enhancement Techniques for Power Packages* application note for thermal enhancement techniques to be used with SOT-223 and TO-252 packages.

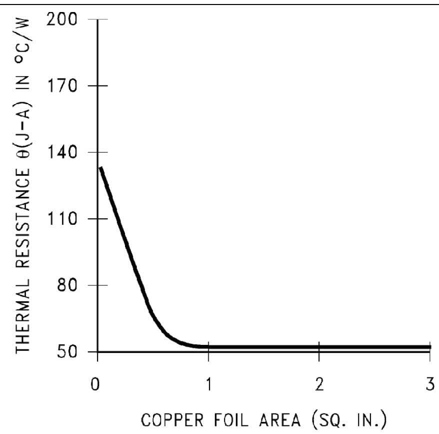


Figure 37. $R_{\theta JA}$ vs Copper (2-oz.) Area for the SOT-223 Package

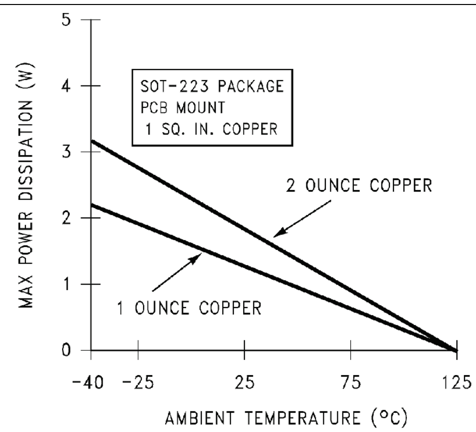


Figure 38. Maximum Power Dissipation vs T_{AMB} for the SOT-223 Package

Layout Guidelines (continued)

11.1.1.2.2 Heatsinking the TO-263 (KTT) Package

Figure 39 shows for the TO-263 the measured values of $R_{\theta JA}$ for different copper area sizes using a typical PCB with 1-oz. copper and no solder mask over the copper area used for heatsinking.

As shown in Figure 39, increasing the copper area beyond 1 square inch produces very little improvement. It must also be observed that the minimum value of $R_{\theta JA}$ for the TO-263 package mounted to a PCB is 32°C/W.

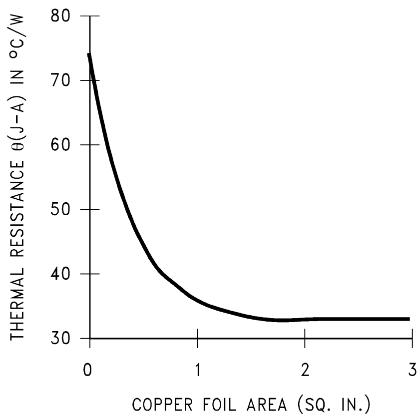


Figure 39. $R_{\theta JA}$ vs Copper (1-oz.) Area for the TO-263 Package

As a design aid, Figure 40 shows the maximum allowable power dissipation compared to ambient temperature for the TO-263 device (assuming $R_{\theta JA}$ is 35°C/W and the maximum junction temperature is 125°C).

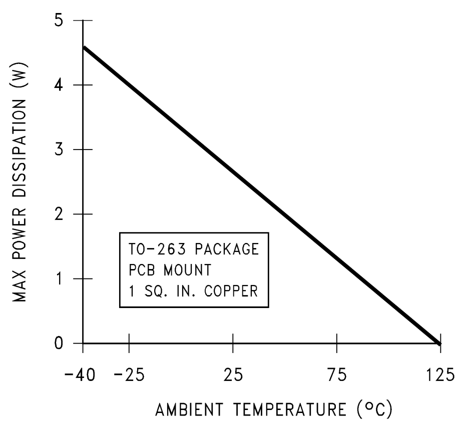


Figure 40. Maximum Power Dissipation vs T_{AMB} for the TO-263 Package

11.1.1.2.3 Heatsinking the TO-252 (NDP) Package

If the maximum allowable value for $R_{\theta JA}$ is found to be ≥ 54°C/W (typical rated value) for the TO-252 package, no heatsink is needed because the package alone will dissipate enough heat to satisfy these requirements. If the calculated value for $R_{\theta JA}$ falls below these limits, a heatsink is required.

As a design aid, Table 1 shows the value of the $R_{\theta JA}$ of NDP the package for different heatsink area. The copper patterns that we used to measure these $R_{\theta JA}$s are shown in Figure 45. Figure 41 reflects the same test results as what are in Table 1.

Figure 42 shows the maximum allowable power dissipation versus ambient temperature for the TO-252 device. Figure 43 shows the maximum allowable power dissipation versus copper area (in^2) for the TO-252 device. See the *AN-1028 Maximum Power Enhancement Techniques for Power Packages* application note for thermal enhancement techniques to be used with SOT-223 and TO-252 packages.

Layout Guidelines (continued)

Table 1. $R_{\theta JA}$ Different Heatsink Area

LAYOUT	COPPER AREA		THERMAL RESISTANCE
	Top Side (in²)(1)	Bottom Side (in²)	($R_{\theta JA}$°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	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.

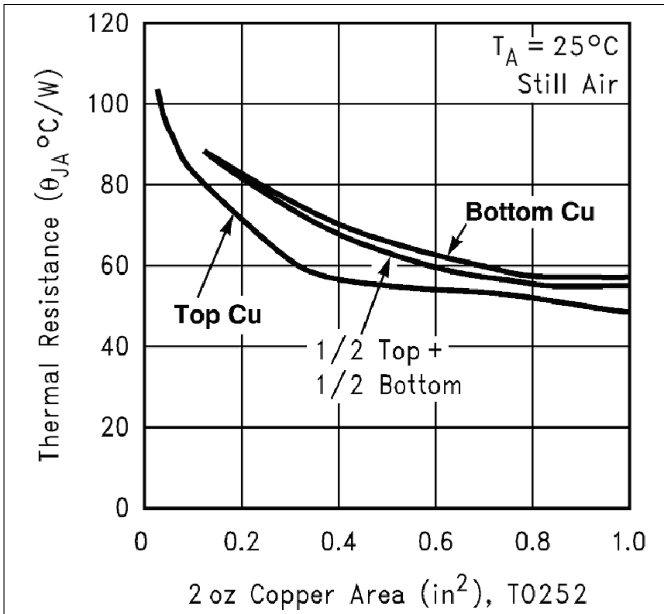


Figure 41. $R_{\theta JA}$ vs 2-oz. Copper Area for TO-252

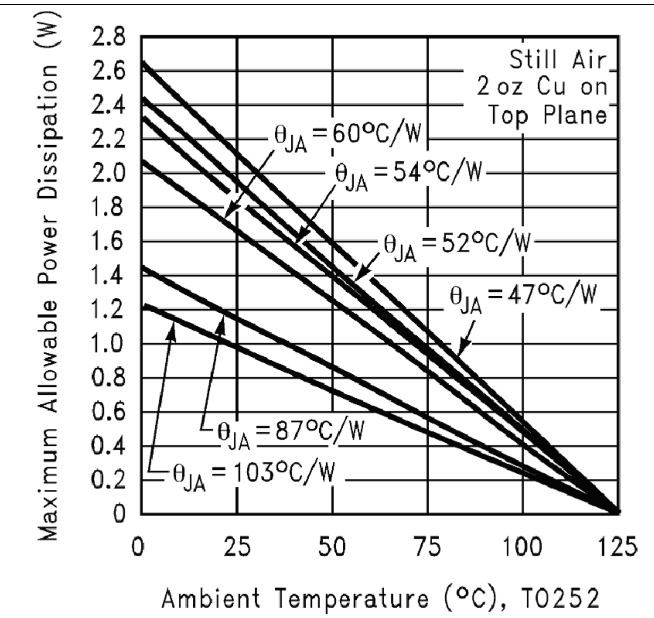


Figure 42. Maximum Allowable Power Dissipation vs Ambient Temperature for TO-252

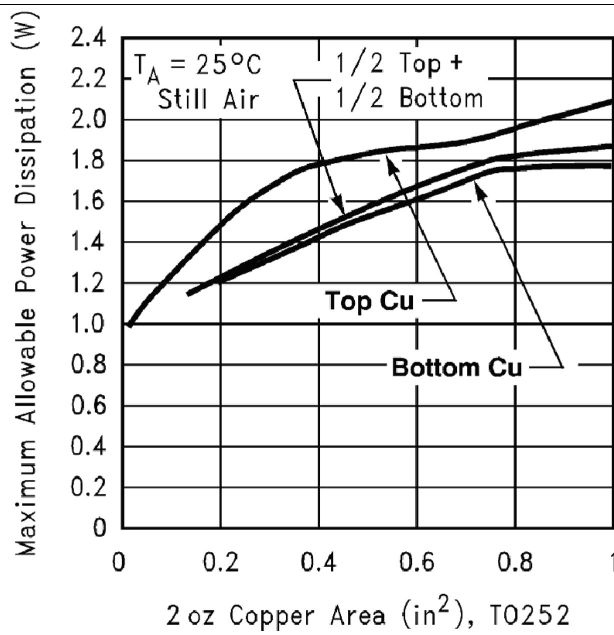


Figure 43. Maximum Allowable Power Dissipation vs 2-oz. Copper Area for TO-252

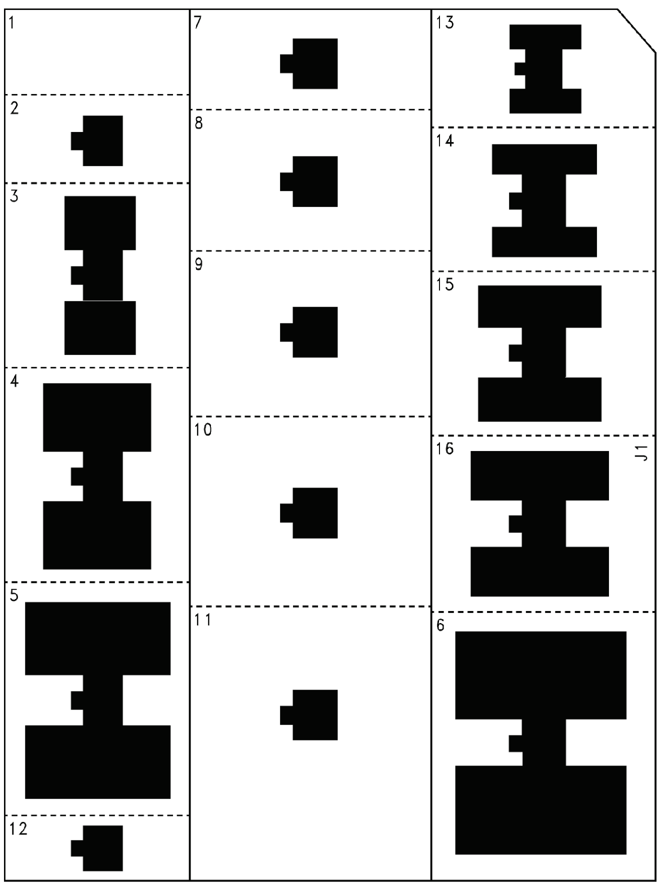


Figure 44. Top View of the Thermal Test Pattern in Actual Scale

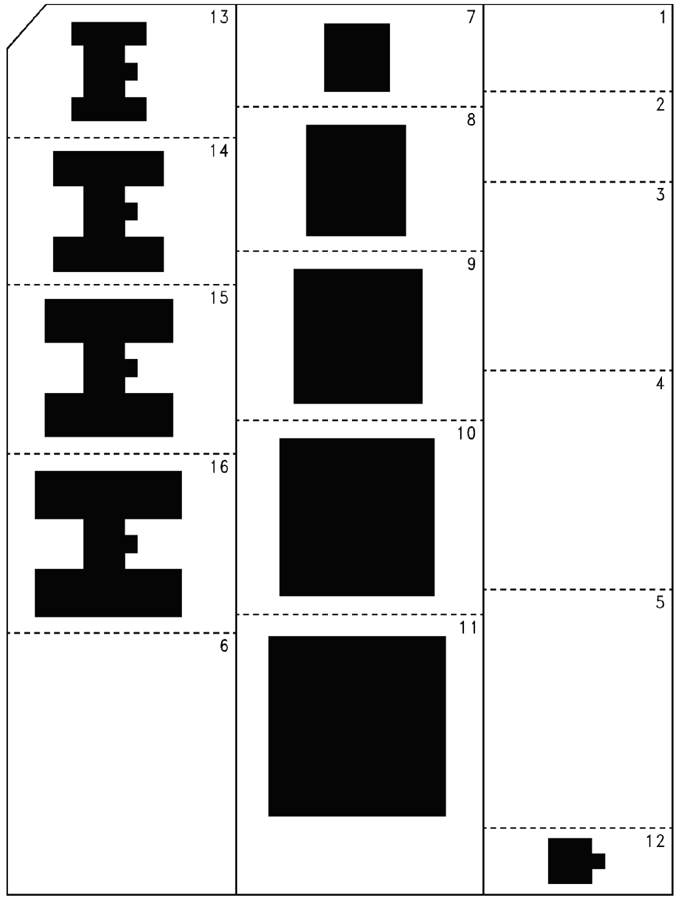


Figure 45. Bottom View of the Thermal Test Pattern in Actual Scale

11.2 Layout Examples

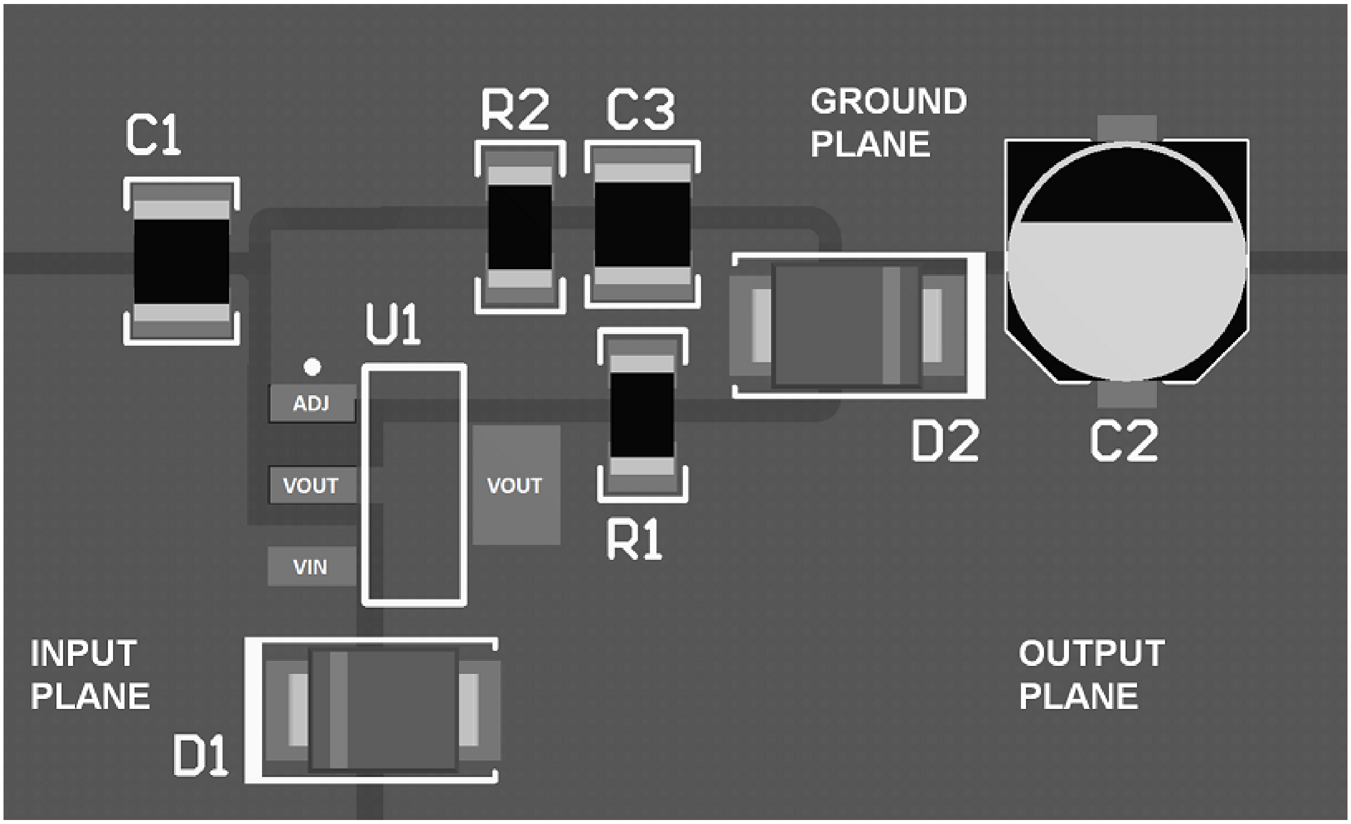


Figure 46. Layout Example (SOT-223)

Layout Examples (continued)

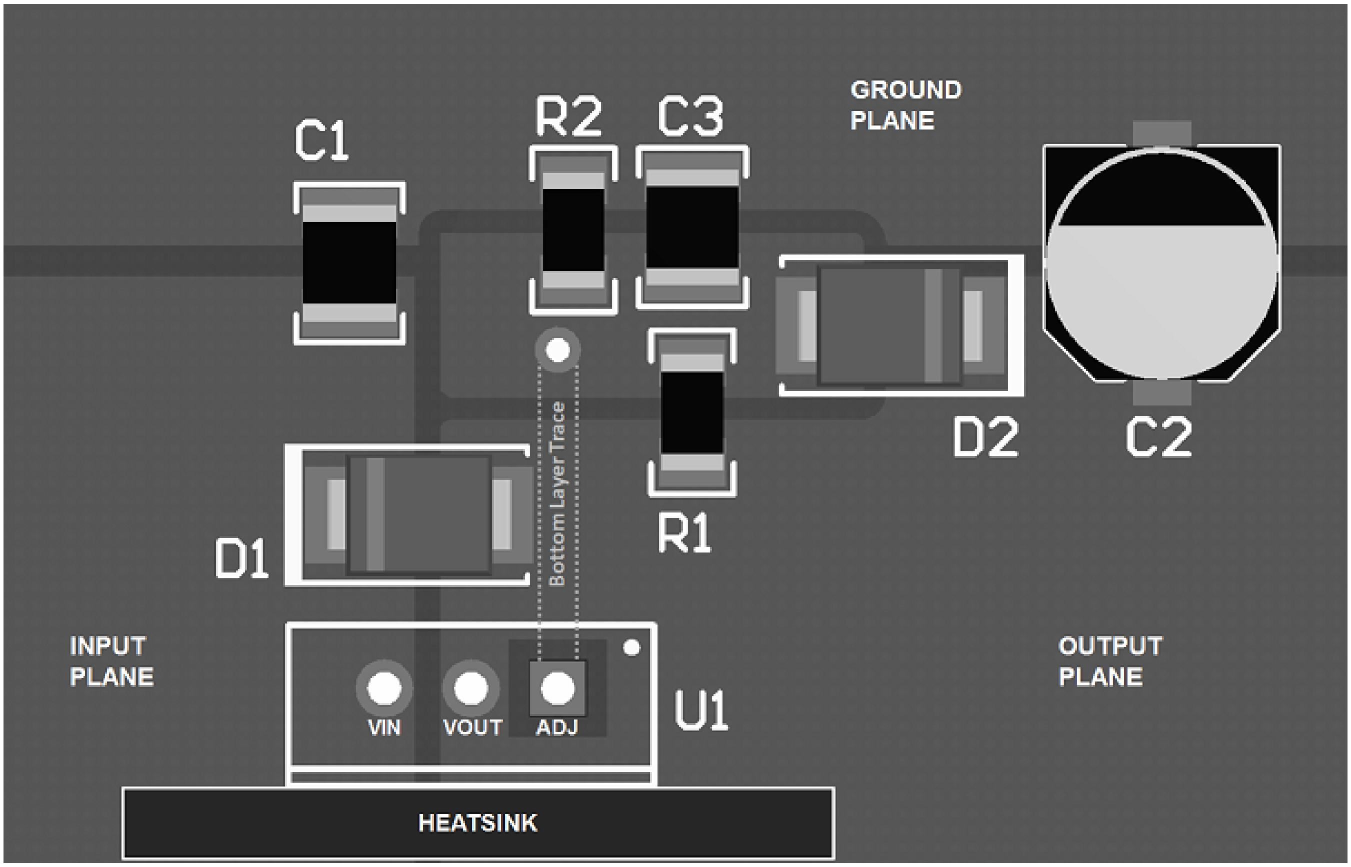


Figure 47. Layout Example (TO-220)

12 Device and Documentation Support

12.1 Documentation Support

12.1.1 Related Documentation

For related documentation see the following:

- Texas Instruments, *LM150/LM350A/LM350 3-Amp Adjustable Regulators* data sheet
- Texas Instruments, *LM138 and LM338 5-Amp Adjustable Regulators* data sheet
- Texas Instruments, *LM137, LM337-N 3-Terminal Adjustable Negative Regulators* data sheet
- Texas Instruments, *LM117QML 3-Terminal Adjustable Regulator* data sheet
- Texas Instruments, *LM117JAN 3-Terminal Adjustable Regulator* data sheet
- Texas Instruments, *AN-1028 Maximum Power Enhancement Techniques for Power Packages* application note

12.2 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to order now.

Table 2. Related Links

PARTS	PRODUCT FOLDER	ORDER NOW	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
LM117	Click here	Click here	Click here	Click here	Click here
LM317-N	Click here	Click here	Click here	Click here	Click here

12.3 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

12.4 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

12.5 Trademarks

E2E is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

12.6 Electrostatic Discharge Caution

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

12.7 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

13 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LM117H	ACTIVE	TO	NDT	3	500	RoHS & Green	AU	Level-1-NA-UNLIM	-55 to 150	(LM117HP+, LM117H P+)	Samples
LM117H/NOPB	ACTIVE	TO	NDT	3	500	RoHS & Green	AU	Level-1-NA-UNLIM	-55 to 150	(LM117HP+, LM117H P+)	Samples
LM117K	ACTIVE	TO-3	NDS	2	50	Non-RoHS & Non-Green	Call TI	Call TI	-55 to 125	LM117K STEELP+	Samples
LM117K STEEL	ACTIVE	TO-3	NDS	2	50	Non-RoHS & Non-Green	Call TI	Call TI	-55 to 150	LM117K STEELP+	Samples
LM117K STEEL/NOPB	ACTIVE	TO-3	NDS	2	50	RoHS & Green	Call TI	Level-1-NA-UNLIM	-55 to 150	LM117K STEELP+	Samples
LM317EMP	NRND	SOT-223	DCY	4	1000	Non-RoHS & Green	Call TI	Level-1-260C-UNLIM	0 to 125	N01A	
LM317EMP/NOPB	ACTIVE	SOT-223	DCY	4	1000	RoHS & Green	SN	Level-1-260C-UNLIM	0 to 125	N01A	Samples
LM317EMPX/NOPB	ACTIVE	SOT-223	DCY	4	2000	RoHS & Green	SN	Level-1-260C-UNLIM	0 to 125	N01A	Samples
LM317H	ACTIVE	TO	NDT	3	500	RoHS & Green	AU	Level-1-NA-UNLIM	0 to 0	(LM317HP+, LM317H P+)	Samples
LM317H/NOPB	ACTIVE	TO	NDT	3	500	RoHS & Green	AU	Level-1-NA-UNLIM	0 to 0	(LM317HP+, LM317H P+)	Samples
LM317MDT/NOPB	ACTIVE	TO-252	NDP	3	75	RoHS & Green	SN	Level-2-260C-1 YEAR	0 to 125	LM317 MDT	Samples
LM317MDTX/NOPB	ACTIVE	TO-252	NDP	3	2500	RoHS & Green	SN	Level-2-260C-1 YEAR	0 to 125	LM317 MDT	Samples
LM317S/NOPB	ACTIVE	DDPAK/ TO-263	KTT	3	45	RoHS-Exempt & Green	SN	Level-3-245C-168 HR	0 to 125	LM317S P+	Samples
LM317SX/NOPB	ACTIVE	DDPAK/ TO-263	KTT	3	500	RoHS-Exempt & Green	SN	Level-3-245C-168 HR	0 to 125	LM317S P+	Samples
LM317T	NRND	TO-220	NDE	3	45	Non-RoHS & Green	Call TI	Level-1-NA-UNLIM		LM317T P+	
LM317T/LF01	ACTIVE	TO-220	NDG	3	45	RoHS-Exempt & Green	SN	Level-4-260C-72 HR		LM317T P+	Samples
LM317T/NOPB	ACTIVE	TO-220	NDE	3	45	RoHS & Green	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] **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

[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.

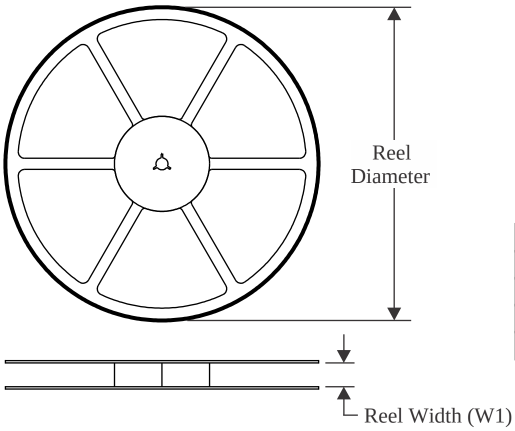
[6] Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

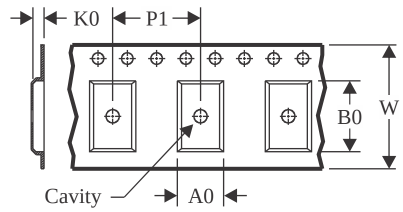
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

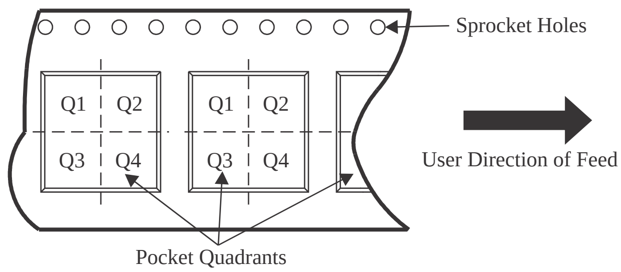


TAPE DIMENSIONS



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

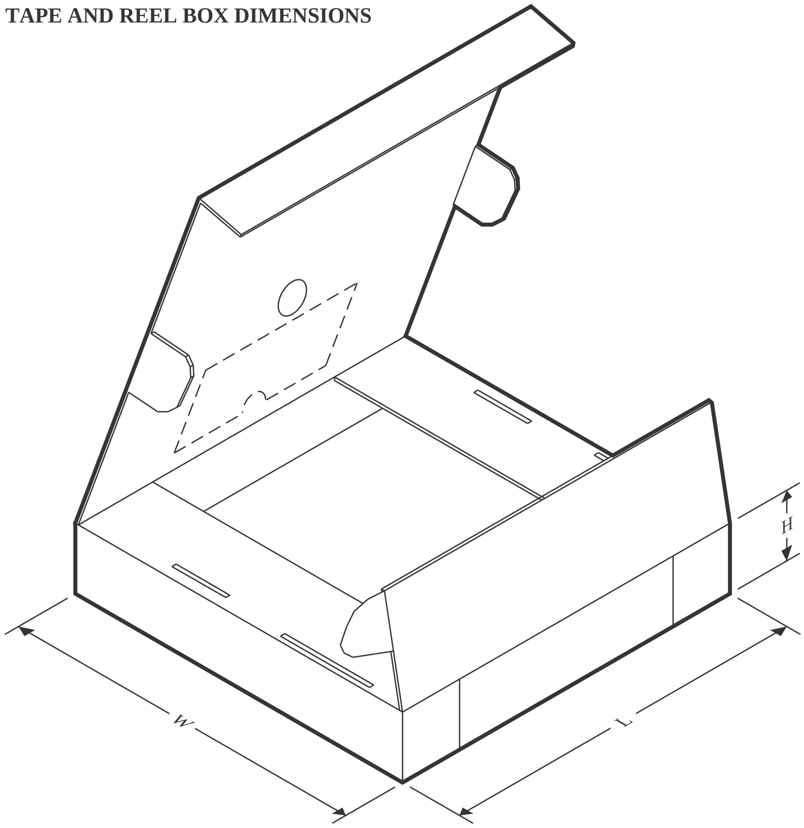
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
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

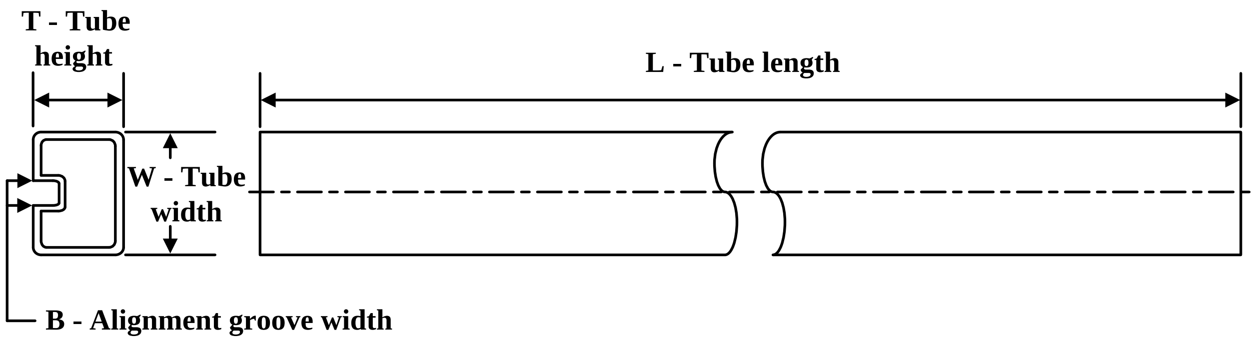
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
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	356.0	356.0	35.0
LM317SX/NOPB	DDPAK/TO-263	KTT	3	500	367.0	367.0	45.0

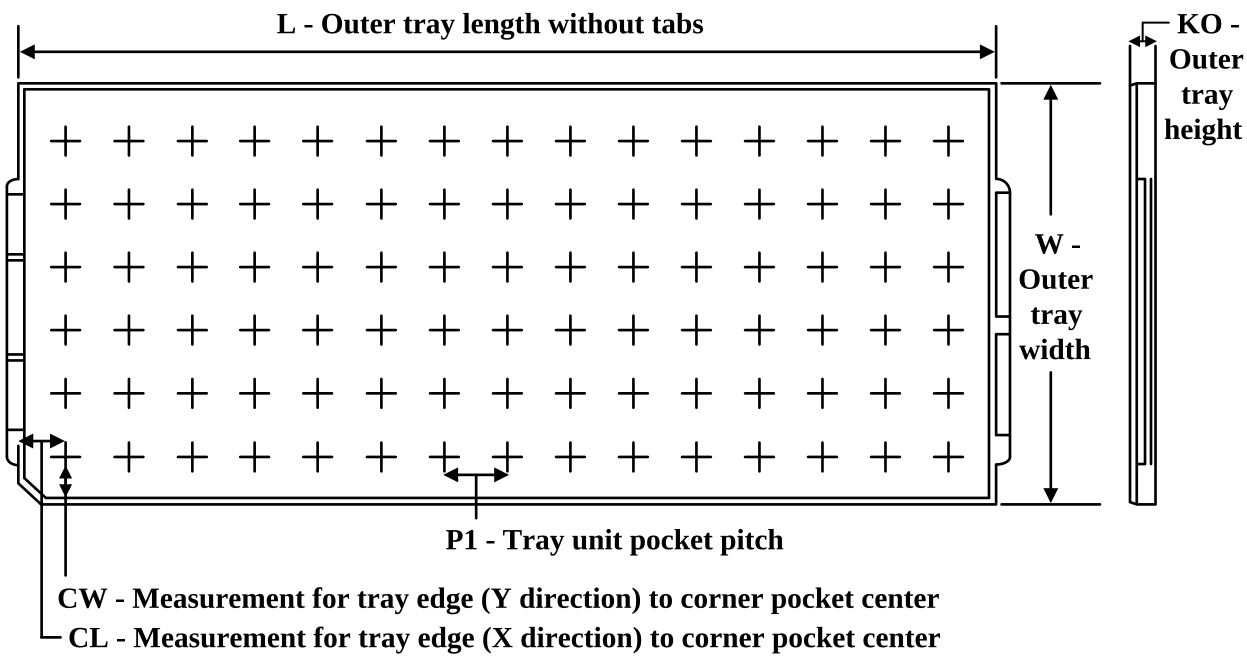
TUBE



*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (µm)	B (mm)
LM317MDT/NOPB	NDP	TO-252	3	75	508	20	4165.6	3.1
LM317S/NOPB	KTT	TO-263	3	45	502	25	8204.2	9.19
LM317T	NDE	TO-220	3	45	502	33	6985	4.06
LM317T	NDE	TO-220	3	45	502	33	6985	4.06
LM317T/LF01	NDG	TO-220	3	45	502	25	8204.2	9.19
LM317T/NOPB	NDE	TO-220	3	45	502	33	6985	4.06

TRAY

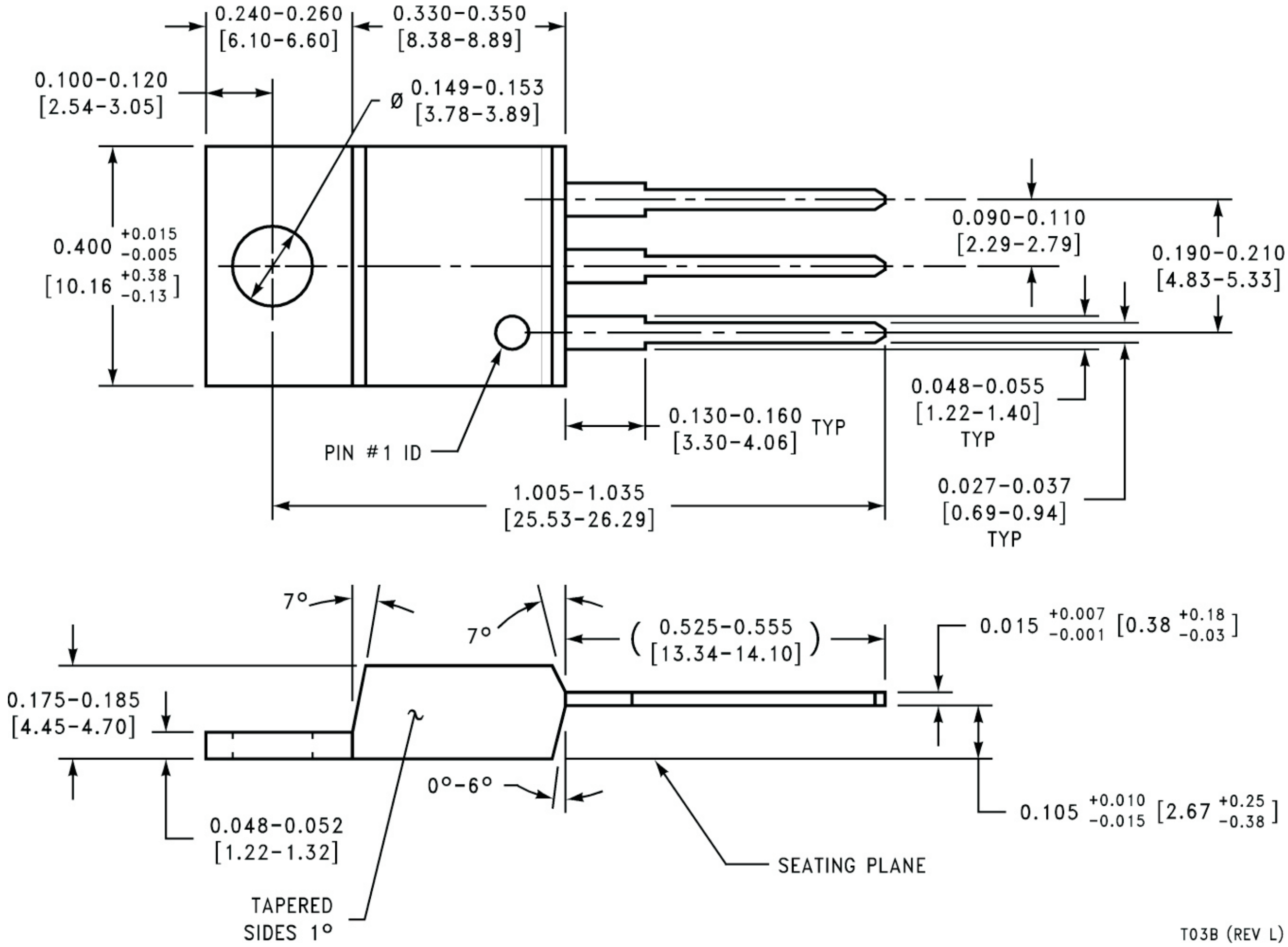


Chamfer on Tray corner indicates Pin 1 orientation of packed units.

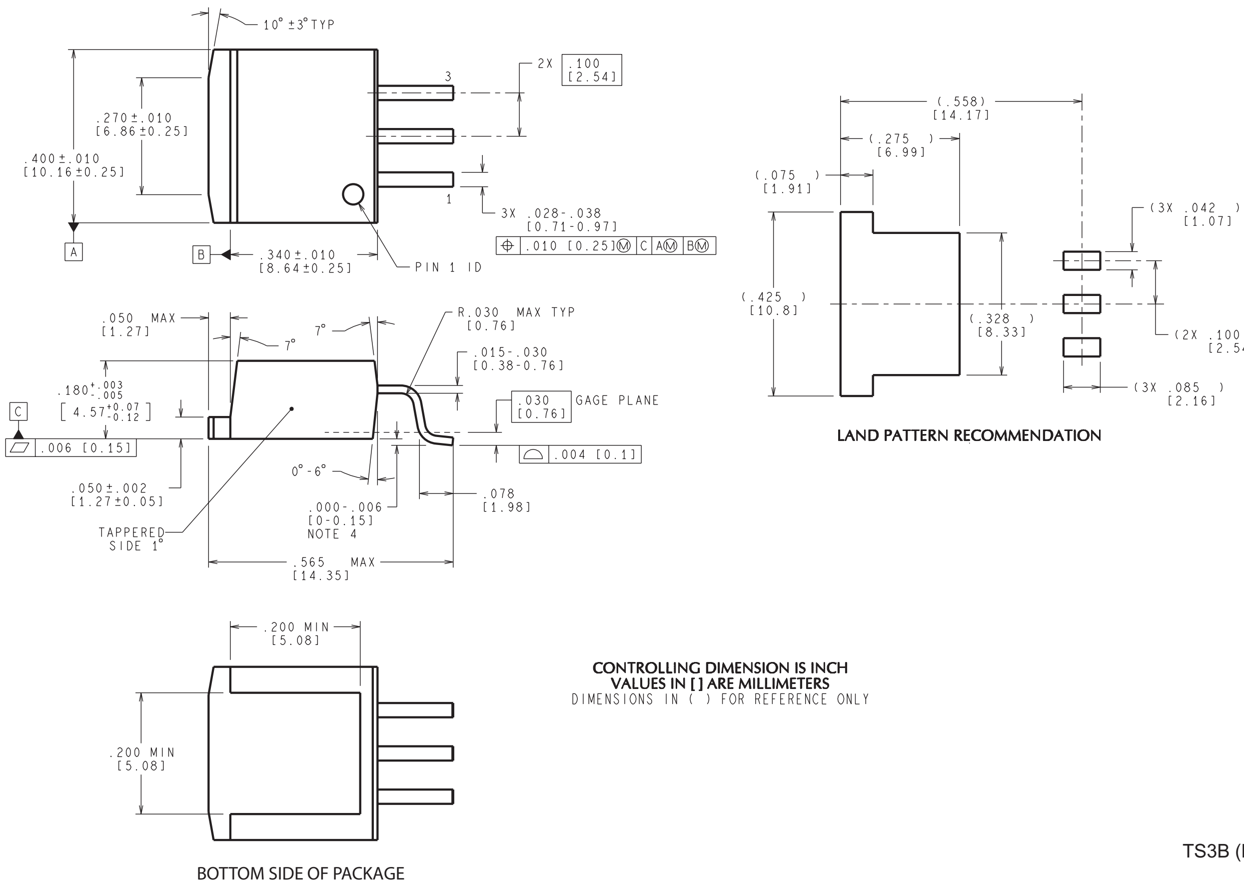
*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	Unit array matrix	Max temperature (°C)	L (mm)	W (mm)	K0 (µm)	P1 (mm)	CL (mm)	CW (mm)
LM117K	NDS	TO-CAN	2	50	9 X 6	NA	292.1	215.9	25654	3.87	22.3	25.4
LM117K STEEL	NDS	TO-CAN	2	50	9 X 6	NA	292.1	215.9	25654	3.87	22.3	25.4
LM117K STEEL/NOPB	NDS	TO-CAN	2	50	9 X 6	NA	292.1	215.9	25654	3.87	22.3	25.4

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)

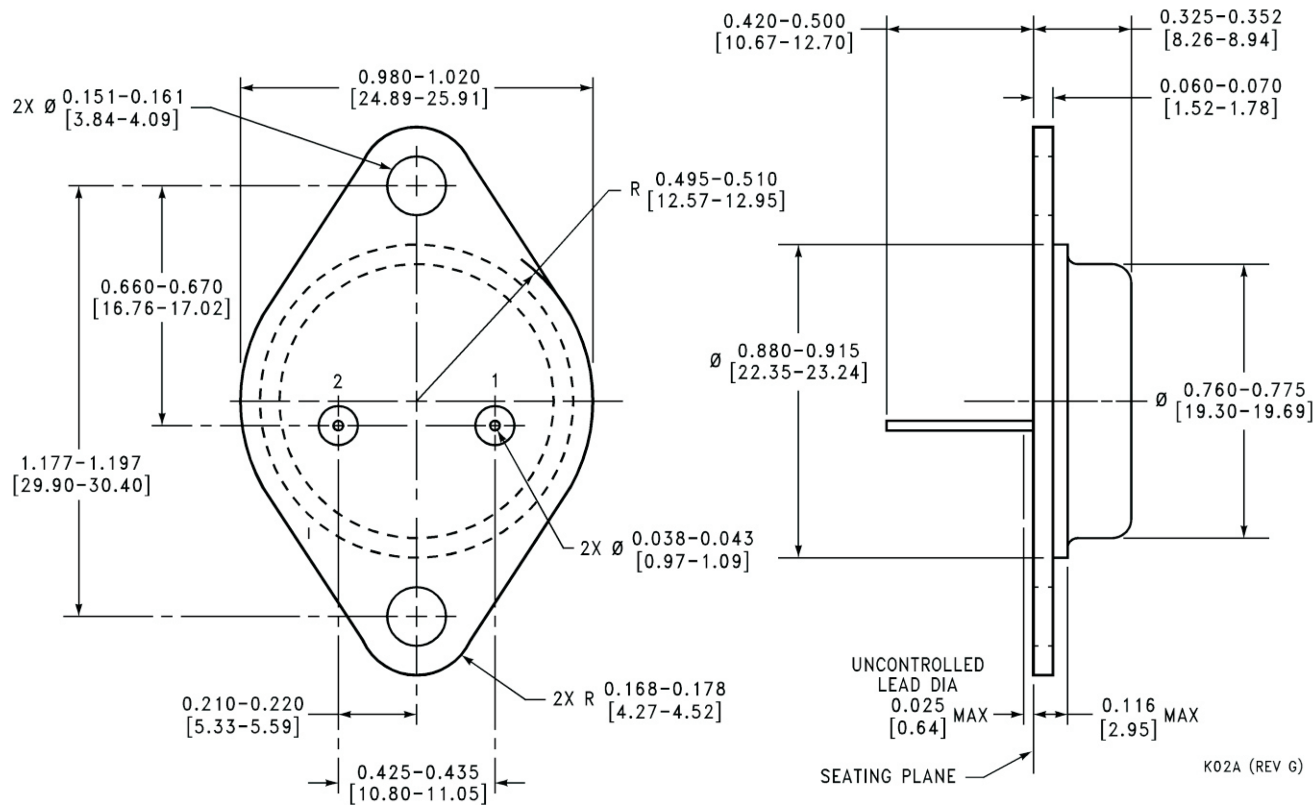
KTT0003B



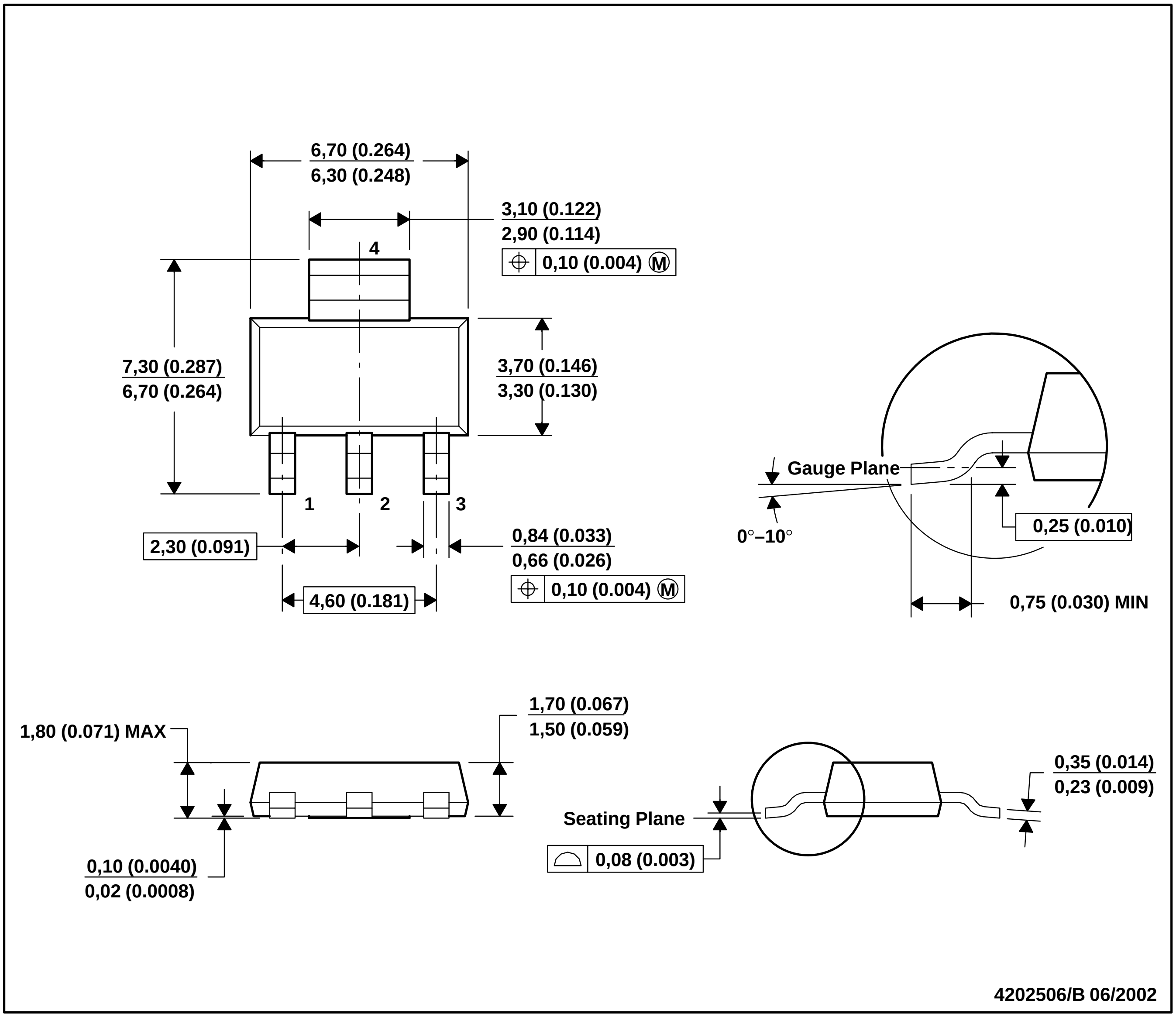
CONTROLLING DIMENSION IS INCH
VALUES IN [ ] ARE MILLIMETERS
DIMENSIONS IN ( ) FOR REFERENCE ONLY

TS3B (Rev F)

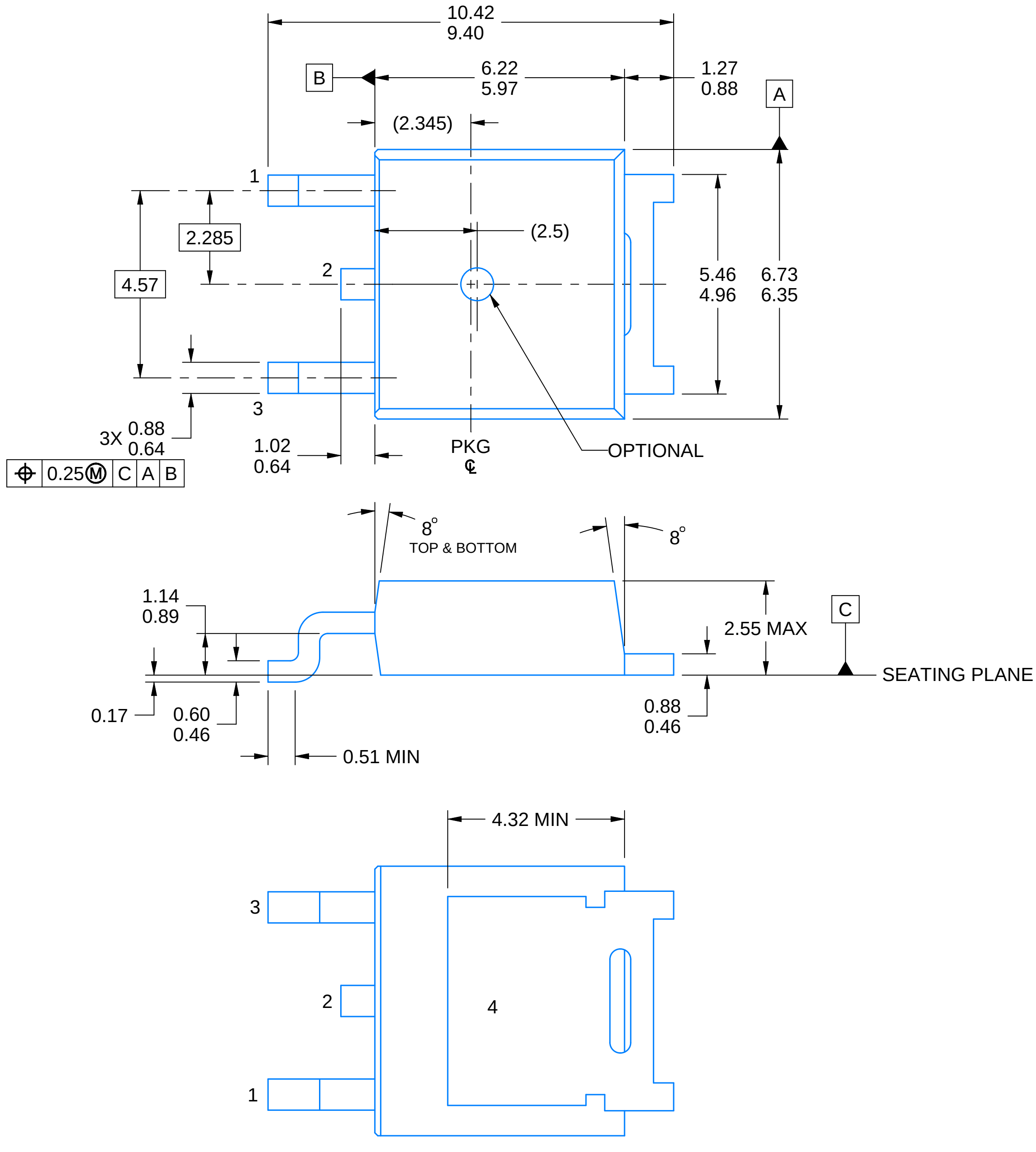
NDS0002A


2X Ø 0.151–0.161
[3.84–4.09]
0.980–1.020
[24.89–25.91]
R 0.495–0.510
[12.57–12.95]
0.660–0.670
[16.76–17.02]
2
1
1.177–1.197
[29.90–30.40]
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)

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



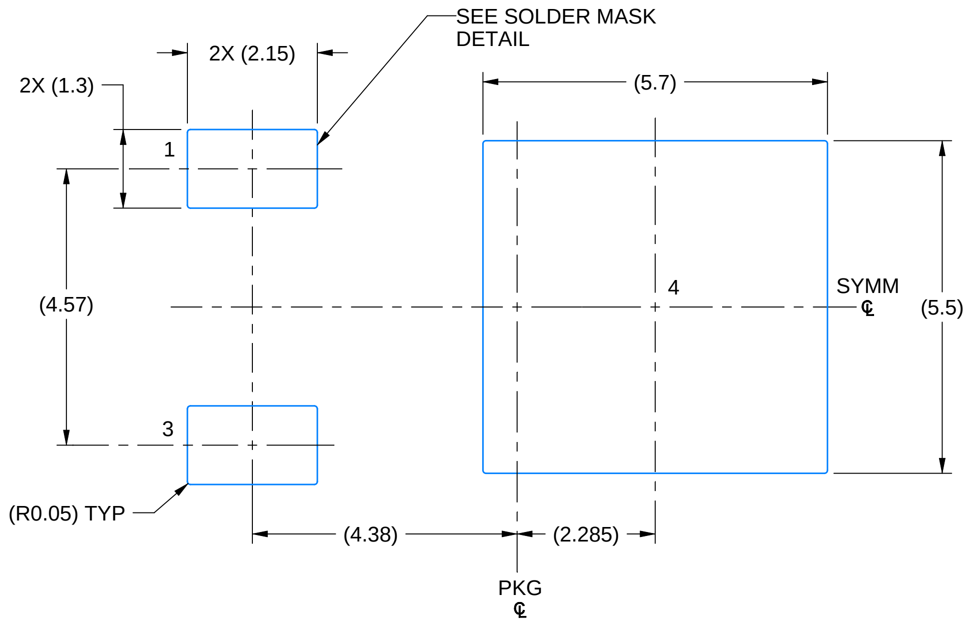
NOTES: A. All linear dimensions are in millimeters (inches).
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion.
D. Falls within JEDEC TO-261 Variation AA.



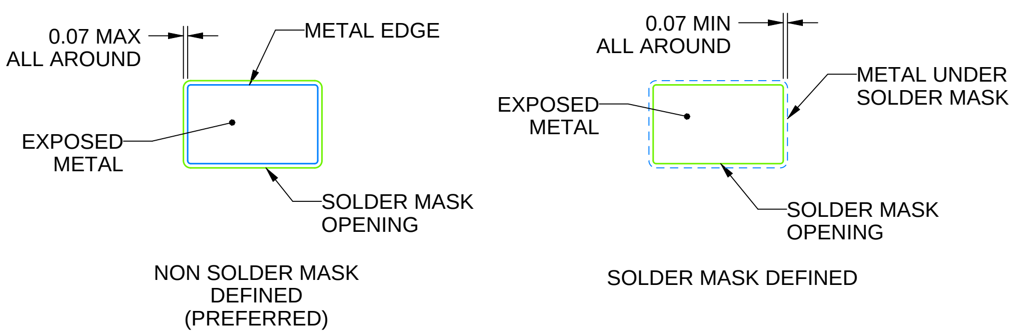
4219870/A 03/2018

NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Reference JEDEC registration TO-252.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 8X

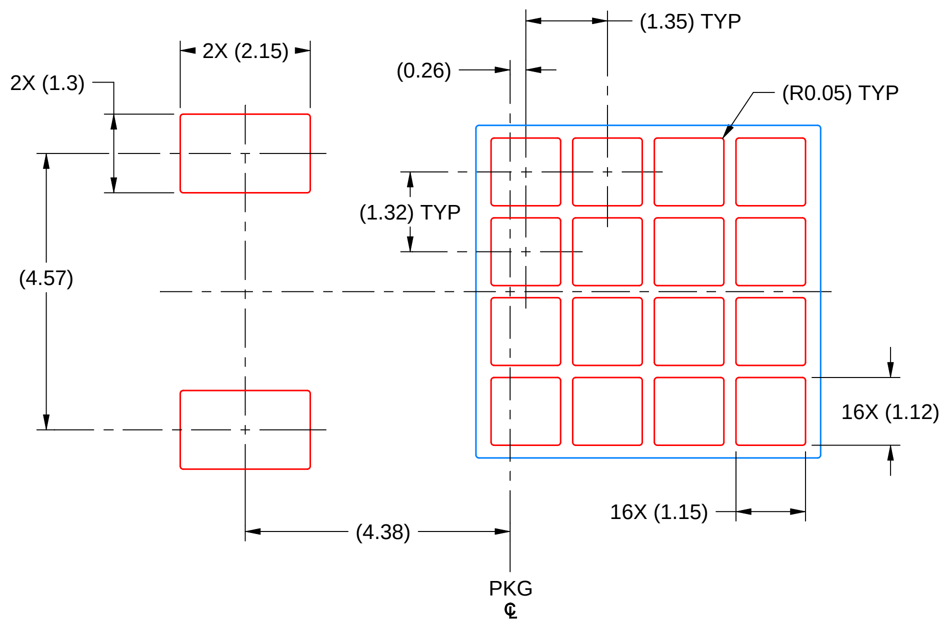


SOLDER MASK DETAIL

4219870/A 03/2018

NOTES: (continued)

4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature numbers SLMA002(www.ti.com/lit/slm002) and SLMA004 (www.ti.com/lit/slma004).
5. Vias are optional depending on application, refer to device data sheet. It is recommended that vias under paste be filled, plugged or tented.



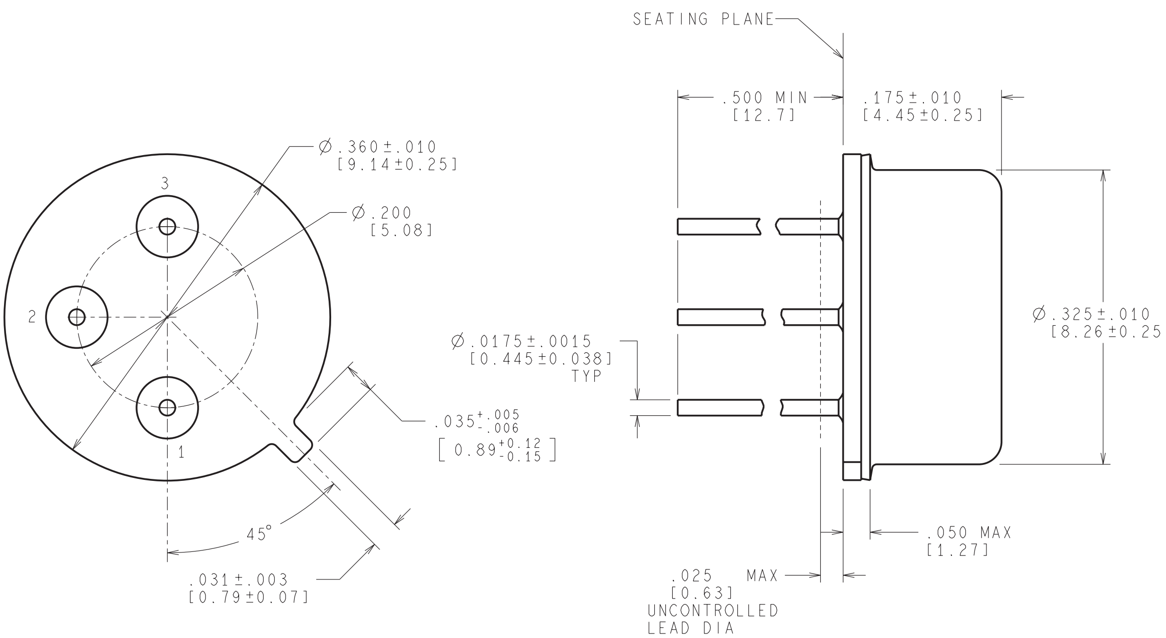
SOLDER PASTE EXAMPLE
BASED ON 0.125 MM THICK STENCIL
SCALE: 8X

4219870/A 03/2018

NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
7. Board assembly site may have different recommendations for stencil design.

NDT0003A



CONTROLLING DIMENSION IS INCH
VALUES IN [ ] ARE MILLIMETERS

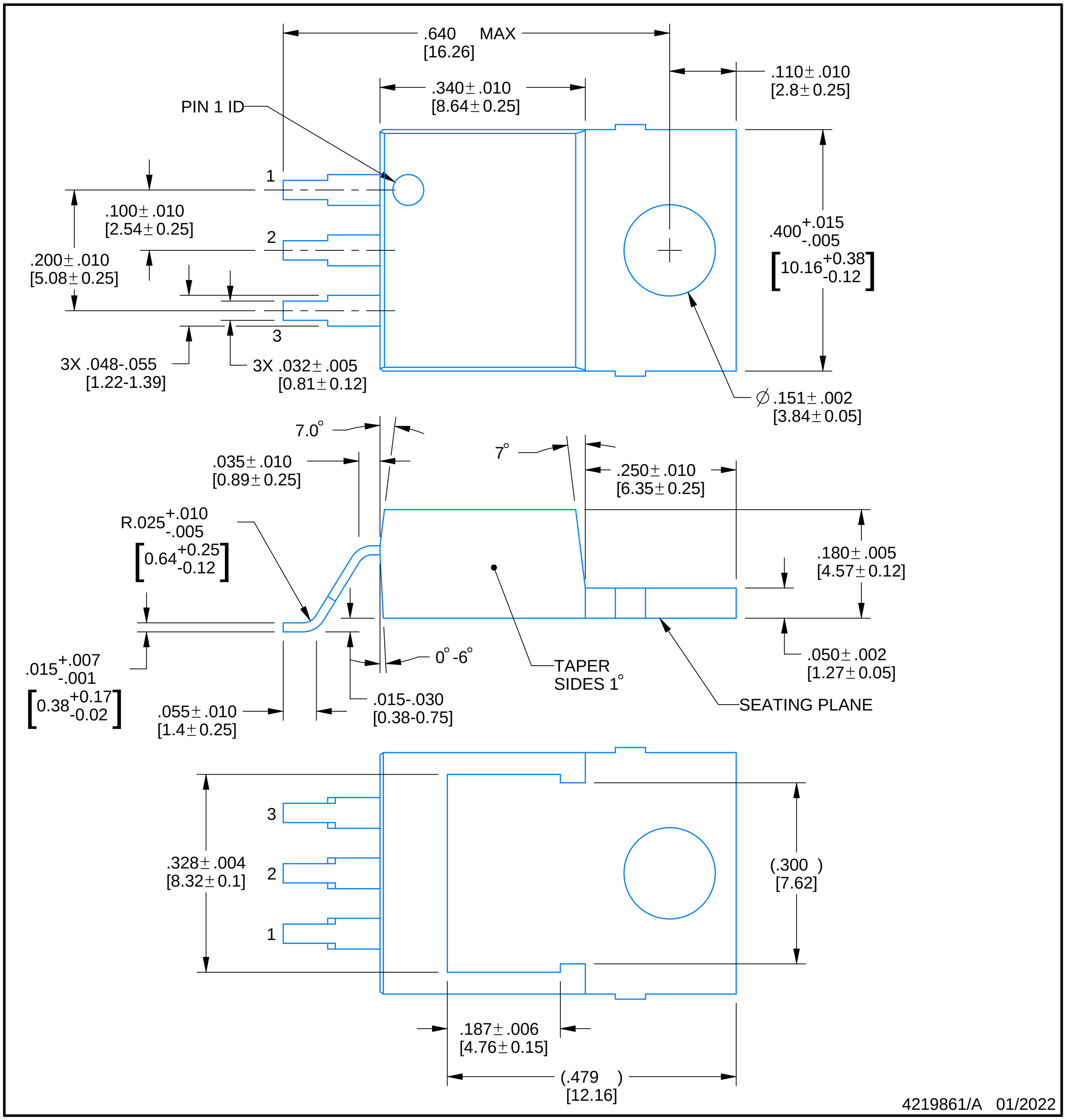
MIL-PRF-38535
CONFIGURATION CONTROL

H03A (Rev D)

PACKAGE OUTLINE

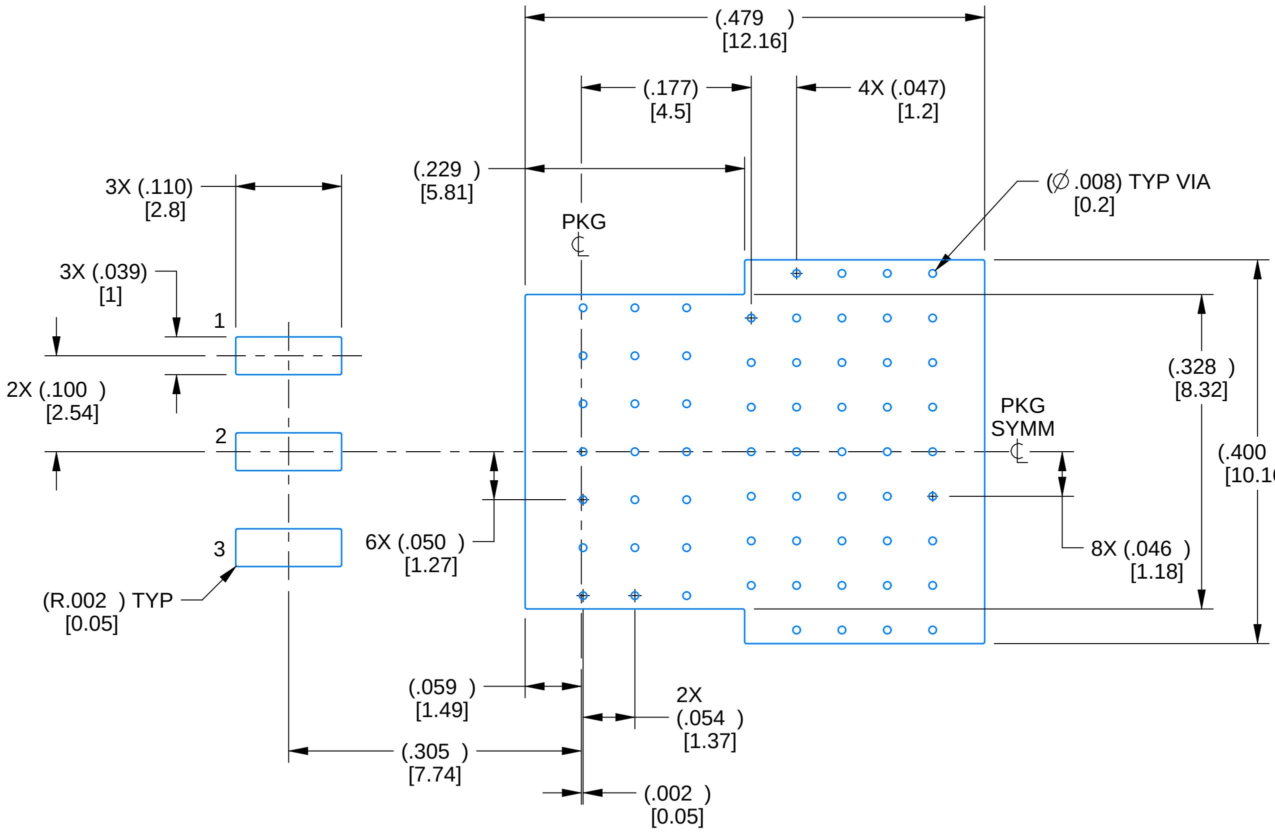
TO-220 - 4.69 mm max height

TRANSISTOR OUTLINE

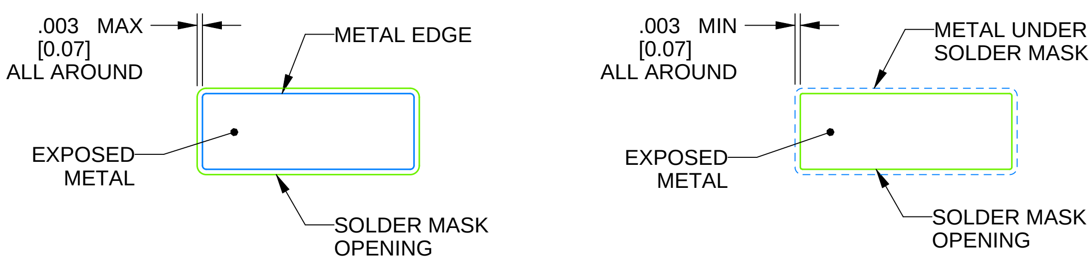


NOTES:

1. All controlling linear dimensions are in inches. Dimensions in brackets are in millimeters. Any dimension in brackets or parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 5X



NON SOLDER MASK
DEFINED

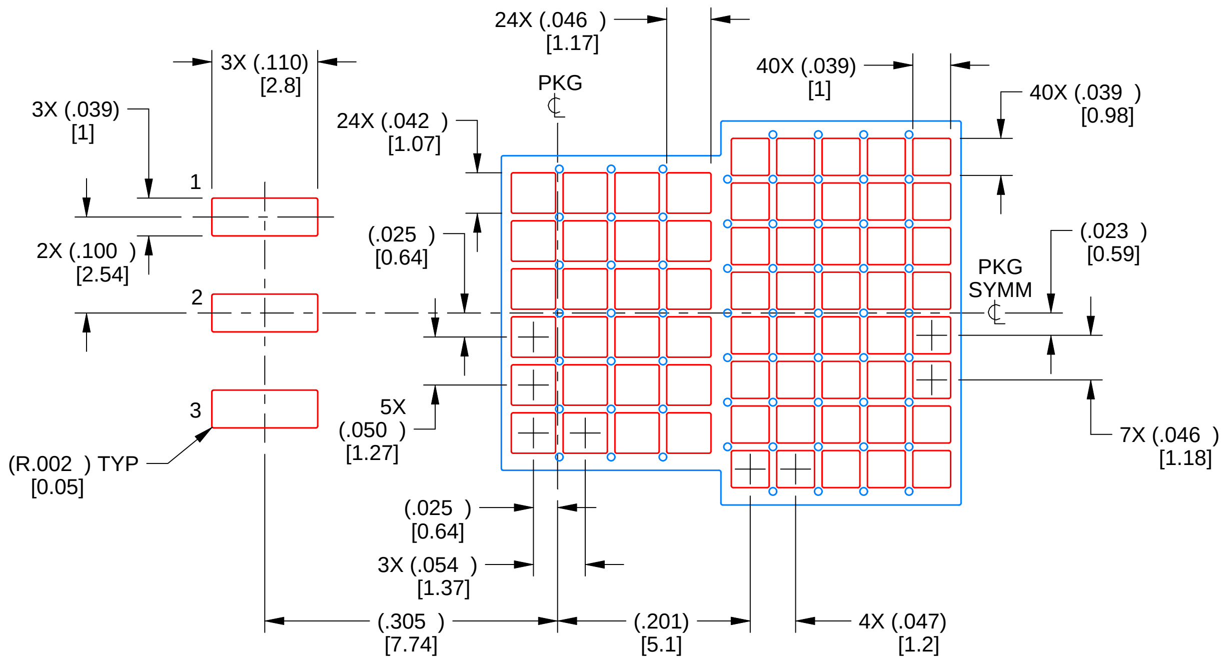
SOLDER MASK
DEFINED

SOLDER MASK DETAILS

4219861/A 01/2022

NOTES: (continued)

3. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature numbers SLMA002(www.ti.com/lit/slm002) and SLMA004 (www.ti.com/lit/slma004).
4. Vias are optional depending on application, refer to device data sheet. It is recommended that vias under paste be filled, plugged or tented.



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD
61% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE
SCALE: 5X

4219861/A 01/2022

NOTES: (continued)

5. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
6. Board assembly site may have different recommendations for stencil design.

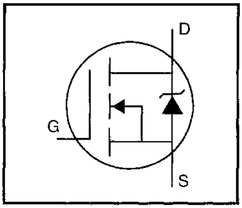
International Rectifier

PD-9.458C

IRFP450

HEXFET® Power MOSFET

- Dynamic dv/dt Rating
- Repetitive Avalanche Rated
- Isolated Central Mounting Hole
- Fast Switching
- Ease of Paralleling
- Simple Drive Requirements



$V_{DSS} = 500V$

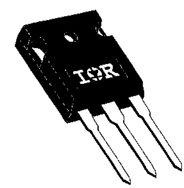
$R_{DS(on)} = 0.40\Omega$

$I_D = 14A$

Description

Third Generation HEXFETs from International Rectifier provide the designer with the best combination of fast switching, ruggedized device design, low on-resistance and cost-effectiveness.

The TO-247 package is preferred for commercial–industrial applications where higher power levels preclude the use of TO-220 devices. The TO-247 is similar but superior to the earlier TO-218 package because of its isolated mounting hole. It also provides greater creepage distance between pins to meet the requirements of most safety specifications.



TO-247AC

DATA SHEETS

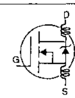
Absolute Maximum Ratings

	Parameter	Max.	Units
I_D @ $T_C = 25°C$	Continuous Drain Current, V_{GS} @ 10 V	14	A
I_D @ $T_C = 100°C$	Continuous Drain Current, V_{GS} @ 10 V	8.7	
I_{DM}	Pulsed Drain Current ①	56	
P_D @ $T_C = 25°C$	Power Dissipation	190	W
	Linear Derating Factor	1.5	W/°C
V_{GS}	Gate-to-Source Voltage	±20	V
E_{AS}	Single Pulse Avalanche Energy ②	760	mJ
I_{AR}	Avalanche Current ①	8.7	A
E_{AR}	Repetitive Avalanche Energy ①	19	mJ
dv/dt	Peak Diode Recovery dv/dt ③	3.5	V/ns
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to +150	°C
	Soldering Temperature, for 10 seconds	300 (1.6mm from case)	
	Mounting Torque, 6-32 or M3 screw	10 lbf•in (1.1 N•m)	

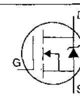
Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	—	—	0.65	°C/W
$R_{\theta CS}$	Case-to-Sink, Flat, Greased Surface	—	0.24	—	
$R_{\theta JA}$	Junction-to-Ambient	—	—	40	

Electrical Characteristics @ $T_J = 25°C$ (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
$V_{(BR)DSS}$	Drain-to-Source Breakdown Voltage	500	—	—	V	V_{GS}=0V, I_D= 250µA
$\Delta V_{(BR)DSS}/\Delta T_J$	Breakdown Voltage Temp. Coefficient	—	0.63	—	V/°C	Reference to 25°C, I_D= 1mA
$R_{DS(on)}$	Static Drain-to-Source On-Resistance	—	—	0.40	Ω	V_{GS}=10V, I_D=8.4A ④
$V_{GS(th)}$	Gate Threshold Voltage	2.0	—	4.0	V	$V_{DS}=V_{GS}$, I_D= 250µA
g_{fs}	Forward Transconductance	9.3	—	—	S	V_{DS}=50V, I_D=8.4A ④
I_{DSS}	Drain-to-Source Leakage Current	—	—	25	µA	V_{DS}=500V, V_{GS}=0V
		—	—	250		V_{DS}=400V, V_{GS}=0V, T_J=125°C
I_{GSS}	Gate-to-Source Forward Leakage	—	—	100	nA	V_{GS}=20V
	Gate-to-Source Reverse Leakage	—	—	-100		V_{GS}=-20V
Q_g	Total Gate Charge	—	—	150	nC	I_D=14A
Q_{gs}	Gate-to-Source Charge	—	—	20		V_{DS}=400V
Q_{gd}	Gate-to-Drain ("Miller") Charge	—	—	80		V_{GS}=10V See Fig. 6 and 13 ④
$t_{d(on)}$	Turn-On Delay Time	—	17	—	ns	V_{DD}=250V
t_r	Rise Time	—	47	—		I_D=14A
$t_{d(off)}$	Turn-Off Delay Time	—	92	—		R_G=6.2Ω
t_f	Fall Time	—	44	—		R_D=17Ω See Figure 10 ④
L_D	Internal Drain Inductance	—	5.0	—	nH	Between lead, 6 mm (0.25in.) from package and center of die contact 
L_S	Internal Source Inductance	—	13	—		
C_{iss}	Input Capacitance	—	2600	—	pF	V_{GS}=0V
C_{oss}	Output Capacitance	—	720	—		V_{DS}= 25V
C_{rss}	Reverse Transfer Capacitance	—	340	—		f=1.0MHz See Figure 5

Source-Drain Ratings and Characteristics

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
I_S	Continuous Source Current (Body Diode)	—	—	14	A	MOSFET symbol showing the integral reverse p-n junction diode. 
I_{SM}	Pulsed Source Current (Body Diode) ①	—	—	56		
V_{SD}	Diode Forward Voltage	—	—	1.4	V	T_J=25°C, I_S=14A, V_{GS}=0V ④
t_{rr}	Reverse Recovery Time	—	540	810	ns	T_J=25°C, I_F=14A
Q_{rr}	Reverse Recovery Charge	—	4.8	7.2	µC	di/dt=100A/µs ④
t_{on}	Forward Turn-On Time	Intrinsic turn-on time is neglegible (turn-on is dominated by L_S+L_D)				

Notes:

① Repetitive rating; pulse width limited by max. junction temperature (See Figure 11)

② V_{DD}=50V, starting T_J=25°C, L=7.0mH R_G=25Ω, I_{AS}=14A (See Figure 12)

③ I_{SD}≤14A, di/dt≤130A/µs, $V_{DD}≤V_{(BR)DSS}$, T_J≤150°C

④ Pulse width ≤ 300 µs; duty cycle ≤2%.

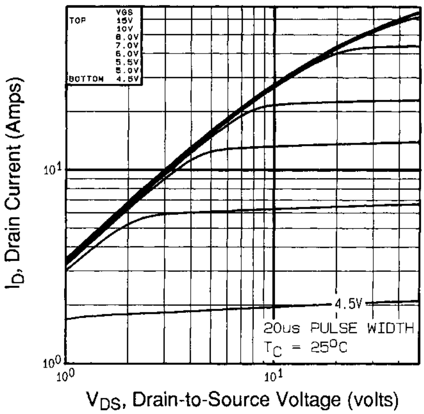


Fig 1. Typical Output Characteristics, T_C=25°C

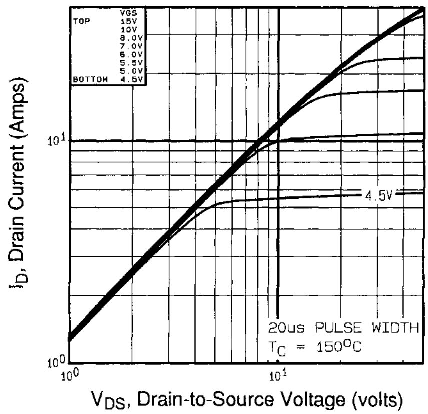


Fig 2. Typical Output Characteristics, T_C=150°C

DATA SHEETS

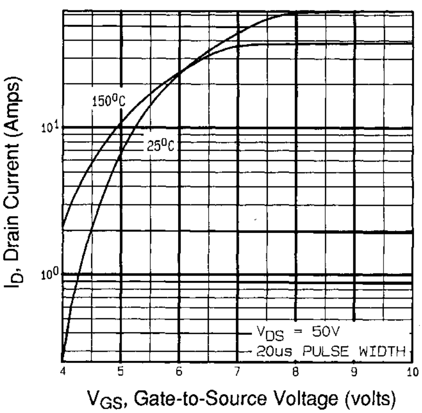


Fig 3. Typical Transfer Characteristics

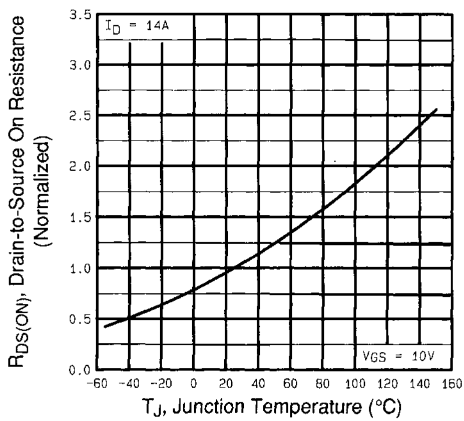


Fig 4. Normalized On-Resistance Vs. Temperature

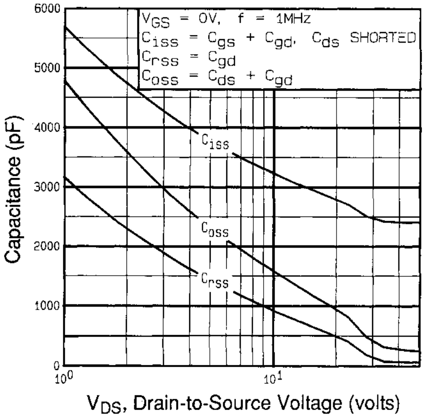


Fig 5. Typical Capacitance Vs. Drain-to-Source Voltage

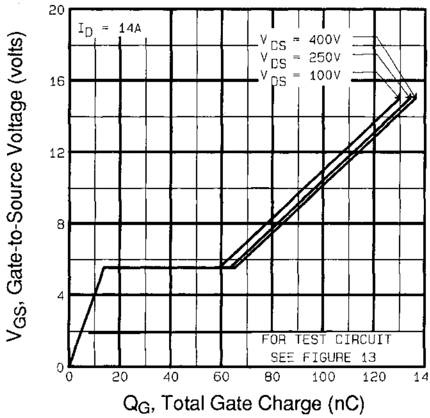


Fig 6. Typical Gate Charge Vs. Gate-to-Source Voltage

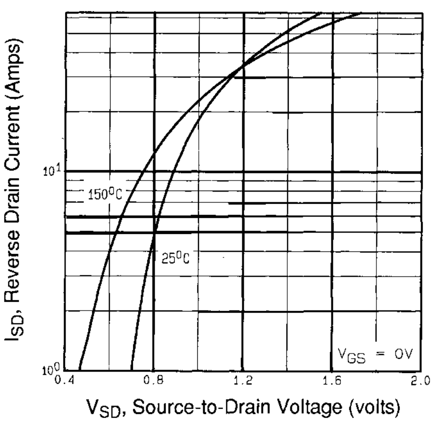


Fig 7. Typical Source-Drain Diode Forward Voltage

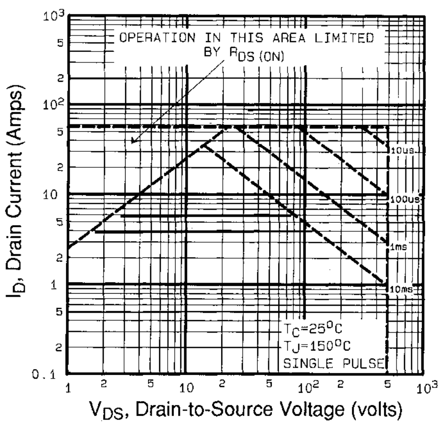


Fig 8. Maximum Safe Operating Area

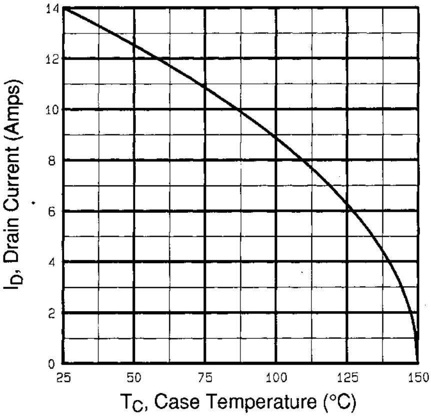


Fig 9. Maximum Drain Current Vs. Case Temperature

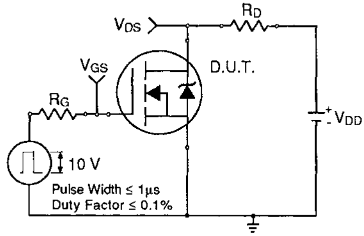


Fig 10a. Switching Time Test Circuit

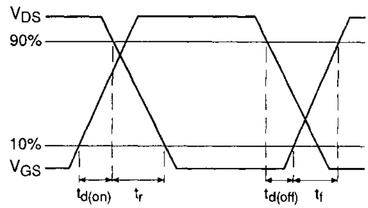


Fig 10b. Switching Time Waveforms

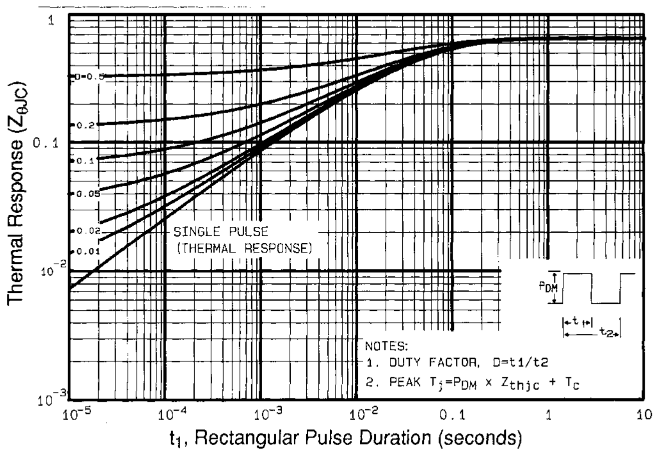


Fig 11. Maximum Effective Transient Thermal Impedance, Junction-to-Case

DATA SHEETS

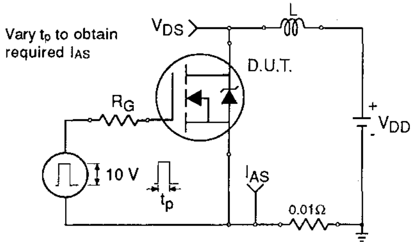


Fig 12a. Unclamped Inductive Test Circuit

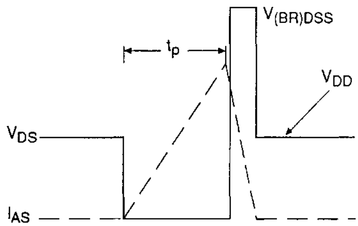


Fig 12b. Unclamped Inductive Waveforms

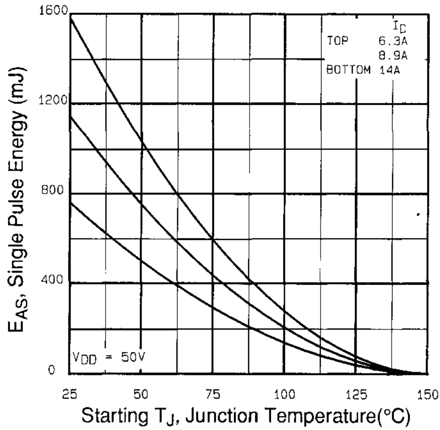


Fig 12c. Maximum Avalanche Energy Vs. Drain Current

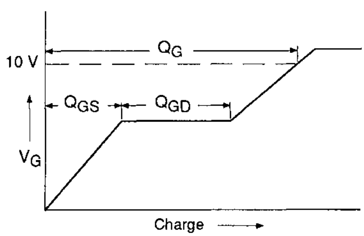


Fig 13a. Basic Gate Charge Waveform

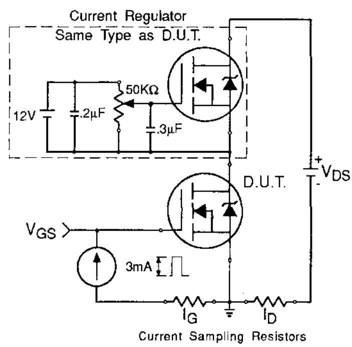


Fig 13b. Gate Charge Test Circuit

Appendix A: Figure 14, Peak Diode Recovery dv/dt Test Circuit – See page 1505

Appendix B: Package Outline Mechanical Drawing – See page 1511

Appendix C: Part Marking Information – See page 1517

International IOR Rectifier

Universal Metall-Brückengleichrichter