μA78L02/5/6/8/12/15-DB,S

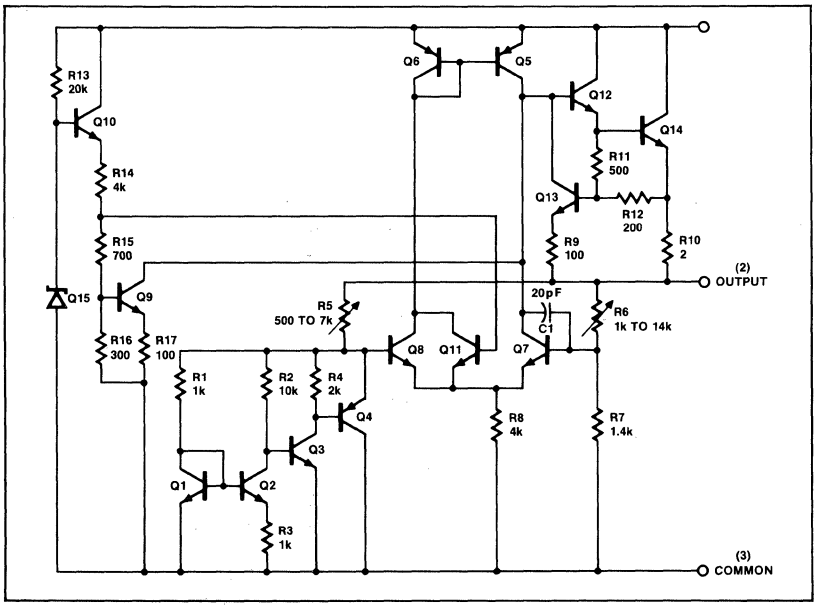
DESCRIPTION

The μA78L00 series of 3-Terminal Positive Voltage Regulators employ internal current limiting and thermal shutdown, making them essentially indestructible. If adequate heat sinking is provided, they can deliver up to 100mA output current. They are intended as fixed voltage regulators in a wide range of applications including local or on card regulation for elimination of noise and distribution problems associated with single point regulation. In addition, they can be used with power pass elements to make high current voltage regulators. The μA78L00 used as a Zener diode/resistor combination replacement, offers an effective output impedance improvement of typically two orders of magnitude, along with lower quiescent current and lower noise.

FEATURES

- **Output curent up to 100mA**
- **No external components**
- **Internal thermal overload protection**
- **Internal short circuit current limiting**
- **Available in JEDEC TO-92 and low profile TO-39 packages**
- **Output voltages of 2.6V, 5V, 6.2V, 8.2V, 12V and 15V**
- **Output voltage tolerances or ±5% (78L00-A) and ±10% (78L00) over the temperature range**

EQUIVALENT CIRCUIT

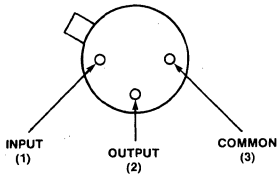


ABSOLUTE MAXIMUM RATINGS

PARAMETER	RATING	UNIT
Input voltage		
2.6V, 5V, 6.2V and 8.2V	30	V
12V and 15V	35	V
Internal power dissipation	Internally limited	
Storage temperature range		
Metal can (TO-39 type)	-65 to +150	°C
Molded TO-92	-55 to +150	°C
Operating junction temperature range	0 to +150	°C
Lead temperatures		
Metal can (soldering, 60s time limit)	300	°C
Molded TO-92 (soldering, 10s time limit)	260	°C

CONNECTION DIAGRAMS

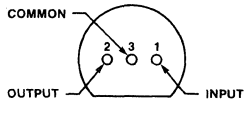
DB PACKAGE (TO-39)



ORDER INFORMATION

OUTPUT VOLTAGE	PART NO.
2.6V	78L02CDB
2.6V	78L02ACDB
5V	78L05CDB
5V	78L05ACDB
6V	78L06CDB
6V	78L06ACDB
8.2V	78L08CDB
8.2V	78L08ACDB
12V	78L12CDB
12V	78L12ACDB
15V	78L15CDB
15V	78L15ACDB

S PACKAGE (JEDEC TO-92)



ORDER INFORMATION

OUTPUT VOLTAGE	PART NO.
2.6V	78L02CS
2.6V	78L02ACS
5V	78L05CS
5V	78L05ACS
6V	78L06CS
6V	78L06ACS
8.2V	78L08CS
8.2V	78L08ACS
12V	78L12CS
12V	78L12ACS
15V	78L15CS
15V	78L15ACS

DC ELECTRICAL CHARACTERISTICS

I_{OUT} = 40mA, 0°C ≤ T_J ≤ +125°C, C_{IN} = 0.33μF, C_{OUT} = 0.1μF unless otherwise specified.

PARAMETER		TEST CONDITIONS	78L02AC			78L02C			UNIT
			Min	Typ	Max	Min	Typ	Max	
V_{OUT}	Output voltage	T_J = 25°C		V_{IN} = 9.0V 2.6			V_{IN} = 9.0V 2.6		V
			2.5	4.75V ≤ V_{IN} ≤ 20V	2.7	2.4	4.75V ≤ V_{IN} ≤ 20V	2.8	
		1mA ≤ I_{OUT} ≤ 70mA	2.45		2.75	2.35		2.85	V
		1mA ≤ I_{OUT} ≤ 40mA	2.45		2.75	2.35		2.85	V
	Line regulation	T_J = 25°C		4.75 ≤ V_{IN} ≤ 20V 40	100		4.75V ≤ V_{IN} ≤ 20V 40	125	mV
				5V ≤ V_{IN} ≤ 20V 30	75		5V ≤ V_{IN} ≤ 20V 30	100	mV
	Load regulation	1mA ≤ I_{OUT} ≤ 100mA, T_J = 25°C		10	50		10	50	mV
		1mA ≤ I_{OUT} ≤ 40mA, T_J = 25°C		4.0	25		4.0	25	mW
I_{CC}		T_J = 25°C		3.6	6.0		3.6	6.0	mA
		T_J = 125°C			5.5			5.5	mA
ΔI_{CC}				5V ≤ V_{IN} ≤ 20V			5V ≤ V_{IN} ≤ 20V		
		With line			2.5			2.5	mA
		With load, 1mA ≤ I_{OUT} ≤ 40mA			0.1			0.2	mA
	Output noise voltage	T_J = 25°C, 10Hz ≤ f ≤ 100kHz		30			30		μV
	Long term stability			10			10		mV
	Ripple rejection	T_J = 25°C, f = 120Hz	43	6V ≤ V_{IN} ≤ 16V 51		42	6V ≤ V_{IN} ≤ 16V 51		dB
	Dropout voltage	T_A = 25°C		1.7			1.7		V
V_{OUT}	Output temperature drift	I_{OUT} = 5mA		-0.4			-0.4		mV/°C
I_{SC}		T_J = 25°C		140			140		mA

DC ELECTRICAL CHARACTERISTICS (Cont'd)

PARAMETER		TEST CONDITIONS	78L05AC			78L05C			UNIT
			Min	Typ	Max	Min	Typ	Max	
V_{OUT}	Output voltage	T_J = 25°C		V_{IN} = 10V 5.0			V_{IN} = 10V 5.0		V
			4.8	7V ≤ V_{IN} ≤ 20V	5.2	4.6	7V ≤ V_{IN} ≤ 20V	5.4	
		1mA ≤ I_{OUT} ≤ 70mA	4.75		5.25	4.50		5.50	V
		1mA ≤ I_{OUT} ≤ 40mA	4.75		5.25	4.50		5.50	V
	Line regulation	T_J = 25°C		7V ≤ V_{IN} ≤ 20V 55	150		7V ≤ V_{IN} ≤ 20V 55	200	mV
				8V ≤ V_{IN} ≤ 20V 45	100		8V ≤ V_{IN} ≤ 20V 45	150	mV
	Load regulation	1mA ≤ I_{OUT} ≤ 100mA, T_J = 25°C		11	60		11	60	mV
		1mA ≤ I_{OUT} ≤ 40mA, T_J = 25°C		5.0	30		5.0	30	mW
I_{CC}		T_J = 25°C		3.8	6.0		3.8	6.0	mA
		T_J = 125°C			5.5			5.5	mA
ΔI_{CC}				8V ≤ V_{IN} ≤ 20V			8V ≤ V_{IN} ≤ 20V		
		With line			1.5			1.5	mA
		With load, 1mA ≤ I_{OUT} ≤ 40mA			0.1			0.2	mA
	Output noise voltage	T_J = 25°C, 10Hz ≤ f ≤ 100kHz		40			40		μV
	Long term stability			12			12		mV
	Ripple rejection	T_J = 25°C, f = 120Hz	41	8V ≤ V_{IN} ≤ 18V 49		40	8V ≤ V_{IN} ≤ 18V 49		dB
	Dropout voltage	T_A = 25°C		1.7			1.7		V
V_{OUT}	Output temperature drift	I_{OUT} = 5mA		-0.65			-0.65		mV/°C
I_{SC}		T_J = 25°C		140			140		mA

DC ELECTRICAL CHARACTERISTICS

(Cont'd) I_{OUT} = 40mA, 0°C ≤ T_J ≤ +125°C, C_{IN} = 0.33μF, C_{OUT} = 0.1μF unless otherwise specified.

PARAMETER	TEST CONDITIONS	78L06AC			78L06C			UNIT
		Min	Typ	Max	Min	Typ	Max	
V_{OUT} Output voltage			V_{IN} = 12V			V_{IN} = 12V		
	T_J = 25°C	5.95	6.2	6.45	5.7	6.2	6.7	V
			8.5V ≤ V_{IN} ≤ 20V			8.5V ≤ V_{IN} ≤ 20V		
	1mA ≤ I_{OUT} ≤ 70mA	5.90		6.50	5.60		6.80	V
	1mA ≤ I_{OUT} ≤ 40mA	5.90		6.50	5.6		6.8	V
Line regulation	T_J = 25°C		8.5V ≤ V_{IN} ≤ 20V			8.5V ≤ V_{IN} ≤ 20V		
			65	175		65	200	mV
			9V ≤ V_{IN} ≤ 20V			9V ≤ V_{IN} ≤ 20V		
			55	125		55	150	mV
Load regulation	1mA ≤ I_{OUT} ≤ 100mA, T_J = 25°C		13	80		13	80	mV
	1mA ≤ I_{OUT} ≤ 40mA, T_J = 25°C		6.0	40		6.0	40	mV
I_{CC}	T_J = 25°C		3.9	6.0		3.9	6.0	mV
	T_J = 125°C			5.5			5.5	mA
ΔI_{CC}			9.0V ≤ V_{IN} ≤ 20V			9.0V ≤ V_{IN} ≤ 20V		
	With line			1.5			1.5	mA
	With load, 1mA ≤ I_{OUT} ≤ 40mA			0.1			0.2	mA
Output noise voltage	T_J = 25°C, 10Hz ≤ f ≤ 100kHz		50			50		μA
Long term stability			14			14		mV
Ripple rejection	T_J = 25°C, f = 120Hz		10V ≤ V_{IN} ≤ 20V			10V ≤ V_{IN} ≤ 20V		
		40	46		39	46		dB
Dropout voltage	T_A = 25°C		1.7			1.7		V
V_{OUT} Output temperature drift	I_{OUT} = 5mA		-0.75			-0.75		mV/°C
I_{SC}	T_J = 25°C		140			140		mA

DC ELECTRICAL CHARACTERISTICS

(Cont'd)

PARAMETER	TEST CONDITIONS	78L08AC			78L08C			UNIT
		Min	Typ	Max	Min	Typ	Max	
V_{OUT} Output voltage			V_{IN} = 14V			V_{IN} = 14V		
	T_J = 25°C	7.87	8.2	8.53	7.54	8.20	8.86	V
			11V ≤ V_{IN} ≤ 23V			11V ≤ V_{IN} ≤ 23V		
	1mA ≤ I_{OUT} ≤ 70mA	7.8		8.60	7.40		9.0	V
	1mA ≤ I_{OUT} ≤ 40mA	7.8		8.6	7.40		9.0	V
Line regulation	T_J = 25°C		11V ≤ V_{IN} ≤ 23V			11V ≤ V_{IN} ≤ 23V		
			80	175		80	200	mV
			12V ≤ V_{IN} ≤ 23V			12V ≤ V_{IN} ≤ 23V		
			70	125		70	150	mV
Load regulation	1mA ≤ I_{OUT} ≤ 100mA, T_J = 25°C		15	80		20	90	mV
	1mA ≤ I_{OUT} ≤ 40mA, T_J = 25°C		8.0	40		10	45	mV
I_{CC}	T_J = 25°C		3.9	6.0		4.2	6.5	mV
	T_J = 125°C			5.5			6.0	mA
ΔI_{CC}			12V ≤ V_{IN} ≤ 23V			12V ≤ V_{IN} ≤ 23V		
	With line			1.5			1.5	mA
	With load, 1mA ≤ I_{OUT} ≤ 40mA			0.1			0.2	mA
Output noise voltage	T_J = 25°C, 10Hz ≤ f ≤ 100kHz		60			60		μA
Long term stability			19			19		mV
Ripple rejection	T_J = 25°C, f = 120Hz		12V ≤ V_{IN} ≤ 22V			12V ≤ V_{IN} ≤ 22V		
		39	45		38	49		dB
Dropout voltage	T_A = 25°C		1.7			1.7		V
V_{OUT} Output temperature drift	I_{OUT} = 5mA		-0.8			-0.8		mV/°C
I_{SC}	T_J = 25°C		140			140		mA

DC ELECTRICAL CHARACTERISTICS (Cont'd) I_{OUT} = 40mA, 0°C ≤ T_J ≤ +125°C, C_{IN} = 0.33μF, C_{OUT} = 0.1μF unless otherwise specified.

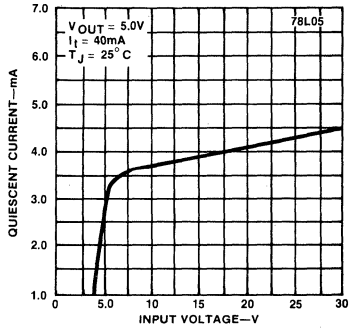
PARAMETER		TEST CONDITIONS	78L12AC			78L12C			UNIT
			Min	Typ	Max	Min	Typ	Max	
V_{OUT}	Output voltage	T_J = 25°C		V_{IN} = 19V 12			V_{IN} = 19V 12		
			11.5		12.5	11.1		12.9	V
				14.5V ≤ V_{IN} ≤ 27V			14.5V ≤ V_{IN} ≤ 27V		
		1mA ≤ I_{OUT} ≤ 70mA	11.4		12.6	10.8		13.2	V
		1mA ≤ I_{OUT} ≤ 40mA	11.4		12.6	10.8		13.2	V
	Line regulation	T_J = 25°C		14.5V ≤ V_{IN} ≤ 27V 120	250		14.5V ≤ V_{IN} ≤ 27V 120	250	mV
				16V ≤ V_{IN} ≤ 27V			16V ≤ V_{IN} ≤ 27V		
				100	200		100	200	mV
	Load regulation	1mA ≤ I_{OUT} ≤ 100mA, T_J = 25°C		20	100		20	100	mV
		1mA ≤ I_{OUT} ≤ 40mA, T_J = 25°C		10	50		10	50	mV
I_{CC}		T_J = 25°C		4.2	6.5		4.2	6.5	mA
		T_J = 125°C			6.0			6.0	mA
ΔI_{CC}				16V ≤ V_{IN} ≤ 27V			16V ≤ V_{IN} ≤ 27V		
		With line			1.5			1.5	mA
		With load, 1mA ≤ I_{OUT} ≤ 40mA			0.1			0.2	mA
	Output noise voltage	T_J = 25°C, 10Hz ≤ f ≤ 100kHz		80			80		μA
	Long term stability			24			24		mV
				15V ≤ V_{IN} ≤ 25V			15V ≤ V_{IN} ≤ 25V		
	Ripple rejection	T_J = 25°C, f = 120Hz	37	42		36	42		dB
	Dropout voltage	T_A = 25°C		1.7			1.7		V
V_{OUT}	Output temperature drift	I_{OUT} = 5mA		-1.0			-1.0		mV/°C
I_{SC}		T_J = 25°C		140			140		mA

DC ELECTRICAL CHARACTERISTICS (Cont'd)

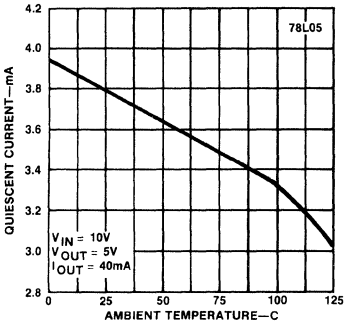
PARAMETER		TEST CONDITIONS	78L15AC			78L15C			UNIT
			Min	Typ	Max	Min	Typ	Max	
V_{OUT}	Output voltage	T_J = 25°C		V_{IN} = 23V 15			V_{IN} = 23V 15		
			14.4		15.6	13.8		16.2	V
				17.5V ≤ V_{IN} ≤ 30V			17.5V ≤ V_{IN} ≤ 30V		
		1mA ≤ I_{OUT} ≤ 70mA	14.25		15.75	13.5		16.5	V
		1mA ≤ I_{OUT} ≤ 40mA	14.25		15.75	13.5		16.5	V
	Line regulation	T_J = 25°C		17.5V ≤ V_{IN} ≤ 30V 130	300		17.5V ≤ V_{IN} ≤ 30V 130	300	mV
				20V ≤ V_{IN} ≤ 30V			20V ≤ V_{IN} ≤ 30V		
				110	250		110	250	mV
	Load regulation	1mA ≤ I_{OUT} ≤ 100mA, T_J = 25°C		25	150		25	150	mV
		1mA ≤ I_{OUT} ≤ 40mA, T_J = 25°C		12	75		12	75	mV
I_{CC}		T_J = 25°C		4.4	6.5		4.4	6.5	mA
		T_J = 125°C			6.0			6.0	mA
ΔI_{CC}				20V ≤ V_{IN} ≤ 30V			20V ≤ V_{IN} ≤ 30V		
		With line			1.5			1.5	mA
		With load, 1mA ≤ I_{OUT} ≤ 40mA			0.1			0.2	mA
	Output noise voltage	T_J = 25°C, 10Hz ≤ f ≤ 100kHz		90			90		μV
	Long term stability			30			30		mV
				18.5V ≤ V_{IN} ≤ 28.5V			18.5V ≤ V_{IN} ≤ 28.5V		
	Ripple rejection	T_J = 25°C, f = 120Hz	34	39		33	39		dB
	Dropout voltage	T_A = 25°C		1.7			1.7		V
V_{OUT}	Output temperature drift	I_{OUT} = 5mA		-1.3			-1.3		mV/°C
I_{SC}		T_J = 25°C		140			140		mA

TYPICAL PERFORMANCE CHARACTERISTICS

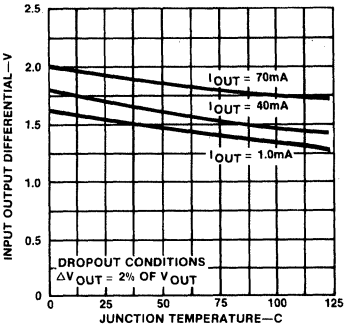
QUIESCENT CURRENT AS A FUNCTION OF INPUT VOLTAGE



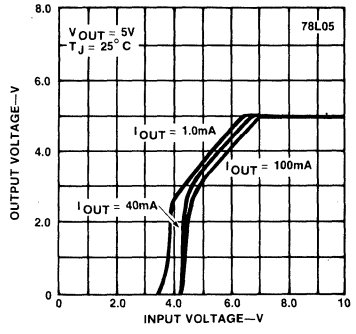
QUIESCENT CURRENT AS A FUNCTION OF TEMPERATURE



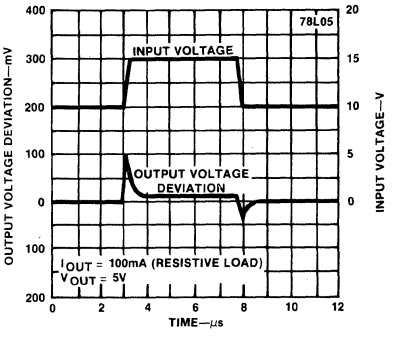
DROPOUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



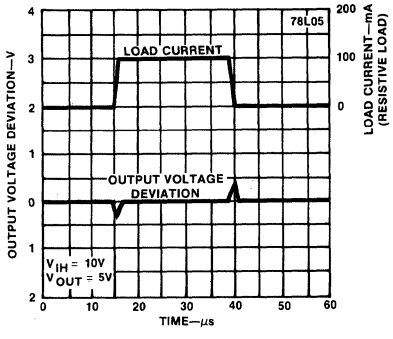
DROPOUT CHARACTERISTICS



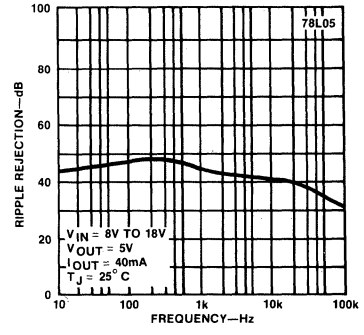
LINE TRANSIENT RESPONSE



LOAD TRANSIENT RESPONSE



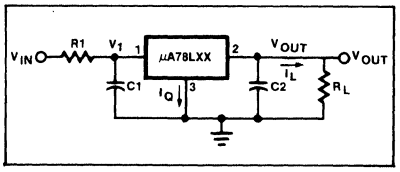
RIPPLE REJECTION AS A FUNCTION OF FREQUENCY



NOTE

Other μA78L00 Series Devices have similar curves.

HIGH DISSIPATION APPLICATION



When it is necessary to operate a μA78L00 regulator with a large input-output differential voltage, the addition of series resistor R1 will extend the output current range of the device by sharing the total dissipation between R1 and the regulator.

R1 may be calculated from

$$R1 = \frac{V_{IN(MIN)} - V_{OUT} - 2.0V}{I_{L(MAX)} + I_Q}$$

where IQ is the regulator quiescent current.

Regulator power dissipation at maximum input voltage and maximum load current is now

$$P_{D(MAX)} = (V_1 - V_{OUT})\, I_{L(MAX)} + V_1\, I_Q$$

where

$$V_1 = V_{IN(MAX)} - (I_{L(MAX)} + I_Q)\, R1$$

The presence of R1 will affect load regulation according to the equation:

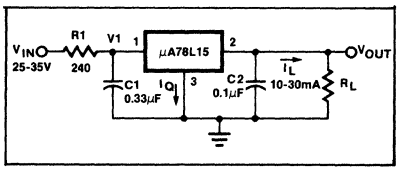
load regulation (at constant V_{IN}) = load regulation (at constant V_1) + (line regulation, mV per V) X (R1) X (ΔI_L).

As an example, consider a 15V regulator with a supply voltage of 30 ± 5V, required to supply a maximum load current of 30mA. IQ is 4.3mA, and minimum load current is to be 10mA.

$$R1 = \frac{25 - 15 - 2}{30 + 4.3} \quad \frac{8}{34.3} = 240\Omega$$

$$V_1 = 35 - (30 + 4.3)\ .24 = 35 - 8.2 = 26.8V$$

$$P_{D(MAX)} = (26.8 - 15)\ 30 + 26.8\ (4.3)$$
$$= 354 + 115$$
$$= 470mW,$$ which will permit operation up to 70°C in most applications.



Line regulation of this circuit is typically 110mV for an input range of 25-35V at a constant load current, i.e. 11mV/V.

Load regulation = constant V_1 load regulation (typically 10mV, 10-30mA I_L) + (11mV/V) X 0.24 X 20mA (typically 53mV)
= 63mV for a load current change of 20mA at a constant V_{IN} of 30V.

THERMAL CONSIDERATIONS

The TO-92 molded package is capable of unusually high power dissipation due to the lead frame design. However, its thermal capabilities are generally overlooked because of a lack of understanding of the thermal paths from the semiconductor junction to ambient temperature. While thermal resistance is normally specified for the device mounted 1cm above an infinite heat sink, very little has been mentioned of the options available to improve on the conservatively rated thermal capability.

An explanation of the thermal paths of the TO-92 and comparison of the thermal equivalent circuit of the TO-39 metal package with that of the TO-92 will allow the designer to determine the thermal stress he is applying in any give application.

THE METAL CAN THERMAL MODEL

In the TO-39 case, where the die is attached directly to the base of a metal package, the thermal equivalent circuit is often represented simply as a series connection of the junction-to-case thermal resistance, θ_{JC}, and the case-to-ambient thermal resistance, θ_{CA}, as shown in Figure 1.

In this model, the current source represents the thermal energy source; TJ is the junction temperature, assuming a constant surface temperature across the die; θ_{JC} is the junction-to-case thermal resistance, measured at a point on the case directly beneath the die location; θ_{CA} is the thermal resistance from the case to the ultimate heat sink, ambient temperature, as represented by the battery. The heat flow is analogous to electrical current, and temperature to voltage. The total thermal resistance from junction to ambient is then:

$$\theta_{JA} = \theta_{JC} + \theta_{CA}$$

The maximum power dissipation is a function of the maximum permissible junction temperature (which is a function of the package materials and construction) and the total thermal resistance from the junction to ambient temperature. Junction temperature is assumed to the limiting factor.

Thus: maximum power dissipation

$$P_D = \frac{T_{J(MAX)} - T_A}{\theta_{JC} + \theta_{CA}}$$

Since $\theta_{JA} = \theta_{JC} + \theta_{CA}$

then $$\theta_{JA} = \frac{T_{J(MAX)} - T_A}{P_D}$$

or $$\theta_{JA}\, P_D = T_J - T_A$$

$$P_D = \frac{T_J - T_A}{\theta_{JA}}$$

Therefore, using the V_{BE} method of junction temperature sensing, and attaching a thermocouple to the case at the location specified, the relative values of θ_{JC}, and θ_{CA} can readily be determined.

The thermal ratings of the metal can package are normally presented with the case attached to an infinite heat sink at still air ambient temperature. This causes θ_{CA} to go to zero resulting in θ_{JC} representing the total θ_{JA}. The infinite heat sink is an unrealizable condition in the practical world, but serves to project a goal.

THE TO-92 PACKAGE

The TO-92 package thermal paths are considerably more complex than those of the TO-39 metal can package. In addition to the path through the molding compound to ambient temperature, there is another path through the leads in parallel with the case path, to ambient temperature, as shown in Figure 2.

The total thermal resistance in this model is then:

$$\theta_{JA} = \frac{(\theta_{JC} + \theta_{CA})\ (\theta_{JL} + \theta_{LA})}{\theta_{JC} + \theta_{CA} + \theta_{JL}\ \theta_{LA}}$$

Where:
- θ_{JC} = thermal resistance of the case between the regulator die and a point on the case directly above the die location.
- θ_{CA} = thermal resistance between the case and air at ambient temperature.
- θ_{JL} = thermal resistance from transistor die through the collector lead to a point $1/16$" below the regulator case.
- θ_{LA} = total thermal resistance of the collector-base-emitter leads to ambient temperature.

As one can see from Figure 1, the metal can package generally does not have the lead cooling path because of the high thermal resistances resulting from the construction of the header, case and leads. Normally, this material is kovar. Now, θ_{JC} and θ_{JL} are within the package and not variable by the user. However, θ_{CA} and θ_{LA} are outside the package and can be effectively used to control the total thermal resistance and, therefore, junction temperature.

Replacing θ_{JA} of equation (1) with θ_{JA} equation (3) gives:

$$\theta_{JA} = \frac{(\theta_{JC} + \theta_{CA})(\theta_{JL} \alpha \theta_{LA})}{\theta_{JC} + \theta_{CA} + \theta_{JL} + \theta_{LA}} = \frac{T_J - T_A}{P_D}$$

The maximum T_J allowed in equation (4) is 150°C. The maximum power dissipation is determined by the net total thermal resistance θ_{JA}, the parallel equivalent networks of the case series path and lead series path, divided into the difference of the maximum junction temperature, 150°C, and ambient temperature generally specified as 25°C. In the case of the 78LXX, the maximum dissipation of a .4 inch condition is:

$$P_D = \frac{150 - 25}{\theta_{JA}}, \theta_{JA} = 180°C/W$$

$$P_D = 0.7W$$

If lead length is reduced to .125 inch θ_{JA} becomes 160°C, and $P_D(MAX) = 0.78W$.

METHODS OF HEAT SINKING

With two external thermal resistances in each leg of a parallel network available to the circuit designer as variables, he can choose the method of heat sinking most applicable to his particular situation. To demonstrate, consider the effect of placing a small 72°C/W flag type heat sink, such as the Staver F1-7D-2, on the 78LXX molded case. The heat sink effectively replaces the θ_{CA} (Figure 2) and the new thermal resistance, θ_{JA}, is:

θ_{JA} = 145°C/W (assuming .125 inch lead length)

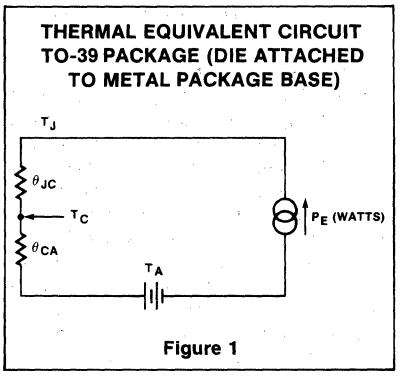


Figure 1

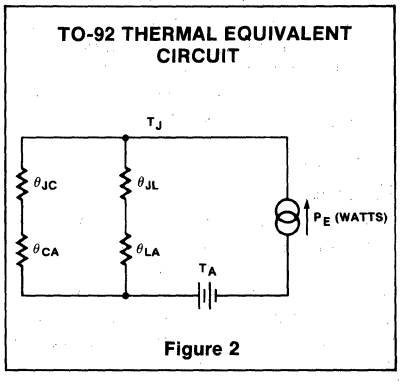


Figure 2

The net change of 15°C/W increases the allowable power dissipation to 0.86W with an inserted cost of 1-2 cents. A still further decrease in θ_{JA} could be achieved by using a sink rated at 46°C/W, such as the Staver FS-7A. Also, if the case sinking does not provide an adequate reduction in total θ_{JA}, the other external thermal resistance, θ_{LA}, may be reduced by shortening the lead length from package base to mounting medium. However, one point must be kept in mind. The lead thermal path includes a thermal resistance, θ_{SA}, from the leads at the mounting point to ambient, that is, the mounting medium, θ_{LA} is then equal to $\theta_{LS} + \theta_{SA}$. The new model is shown in Figure 3.

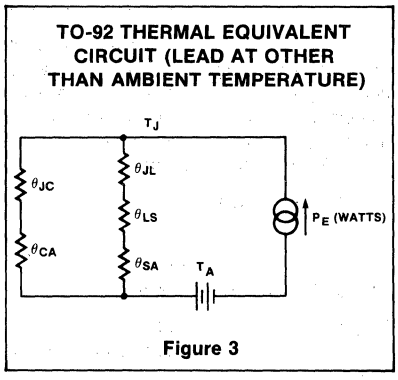


Figure 3

In the case of a socket, θ_{SA} could be as high as 270°C/W, thus causing a net increase in θ_{JA} and a consequent decrease in the maximum dissipation capability. Shortening the lead length may return the net θ_{JA} to the original value, but lead sinking would not be accomplished.

In those cases where the regulator is inserted into a copper clad printed circuit board, it is advantageous to have a maximum area of copper at the entry points of the leads. While it would be desirable to rigorously define the effect of PC board copper, the real world variables are too great to allow anything more than a few general observations.

The best analogy for PC board copper is to compare it with parallel resistors. Beyond some point, additonal resistors are not significantly effective; beyond some point, additional copper area is not effective.