

LT1084C 5-A, LOW-DROPOUT, ADJUSTABLE POSITIVE REGULATOR

D3118, JULY 1988 – REVISED JANUARY 1992

- Adjustable Output . . . 1 V to 35 V
- 5-A Output Capability
- Dropout Voltage
1.5 V at Maximum Current
1 V at Minimum Current
- Input Regulation . . . 0.015% Typ
- Output Regulation . . . 0.01% Typ
- 100% Thermal Limit Burn-In

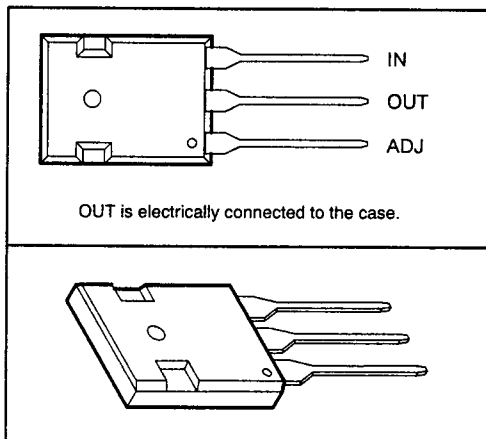
description

The LT1084C is a 3-terminal low-dropout adjustable positive regulator that operates with higher efficiency than currently available devices with output loads up to 5 A. Internal circuitry is designed to operate with a small input-to-output differential voltage of 1.3 V (typical) and all dropout voltages are specified as a function of output current. Dropout voltage reaches a maximum of 1.5 V at maximum output current. On-chip circuitry holds the reference voltage constant to within 1%. Current limiting is used to minimize the stress on both the regulator and power source circuits under overload conditions.

The LT1084C is terminal compatible with older 3-terminal regulators. A 10- μ F output capacitor is required, as in most regulator designs. In P-N-P regulators, up to 10% of the output current is lost as bias (quiescent) current, but the LT1084C bias current flows into the load, which improves power efficiency.

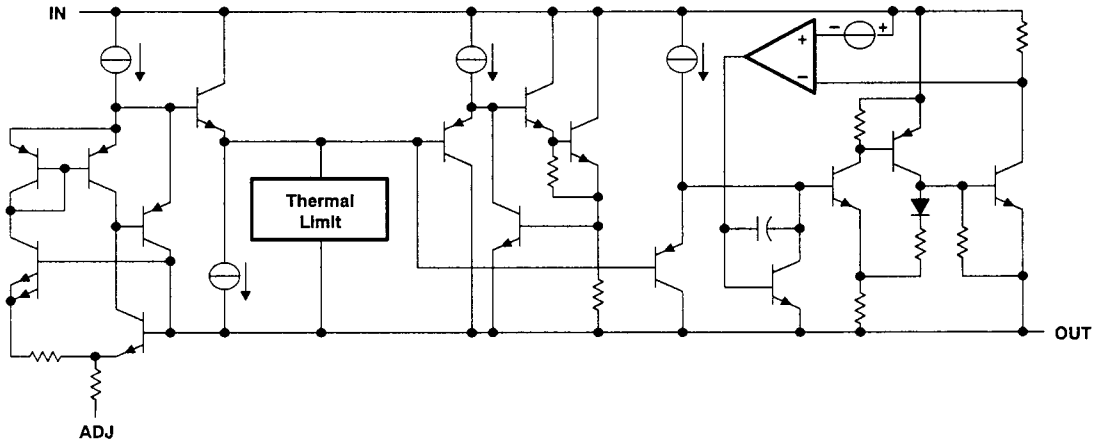
Typical applications include high-efficiency linear regulators, post regulators for switching power supplies, constant-current regulators, and battery chargers.

KK PACKAGE
(TOP VIEW)



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functional block diagram



absolute maximum ratings over operating temperature range (unless otherwise noted)

Input-to-output differential voltage	30 V
Output current, I_O	8 A
Power dissipation	Internally self-limited
Operating virtual-junction temperature range: Control section	0°C to 125°C
Power transistor	0°C to 150°C
Storage temperature range	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

recommended operating conditions

		MIN	MAX	UNIT
Output current, I_O			5	A
Operating virtual-junction temperature, T_J	Control section	0	125	°C
	Power transistor	0	150	

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electrical characteristics at specified virtual-junction temperature (unless otherwise noted)

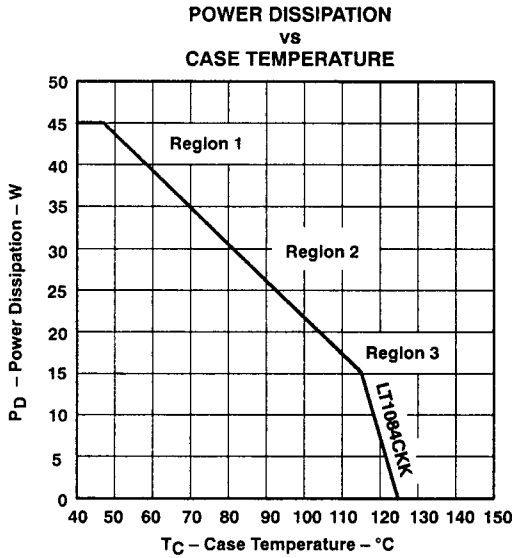
PARAMETER	TEST CONDITIONS	T _J [†]	MIN	TYP	MAX	UNIT
Input regulation	V _I – V _O = 1.5 V to 15 V, I _O = 10 mA	25°C		0.015%	0.2%	
		Full range		0.035%	0.2%	
	V _I – V _O = 15 V to 30 V, See Notes 1 and 2	Full range		0.05%	0.5%	
Ripple rejection	V _I – V _O = 3 V, f = 120 Hz, I _O = 5 A (full load), See Notes 3 and 4	Full range	60	75		dB
Output regulation	V _I – V _O = 3 V, I _O = 10 mA to 5 A (full load), See Notes 1, 2, and 3	25°C		0.1%	0.3%	
		Full range		0.2%	0.4%	
Output voltage change with temperature		Full range		0.5%		
Thermal regulation	t _w = 30 ms	T _A = 25°C		0.003	0.015	%/W
Output voltage long-term drift	After 1000 hours at T _J = 125°C	25°C		0.3%	1%	
Output noise voltage (% of V _O)	f = 10 Hz to 10 kHz	25°C		0.003%		
Minimum output operating current	V _I – V _O = 25 V	Full range		5	10	mA
Current limit	V _I – V _O = 5 V	Full range		5.5	6.5	A
	V _I – V _O = 25 V			0.3	0.6	
Dropout voltage	ΔV _{ref} = 1%, I _O = full load	Full range		1.3	1.5	V
ADJ current		25°C		55		μA
		Full range			120	
Change in ADJ current	V _I – V _O = 1.5 V to 25 V, I _O = 10 mA to 5 A (full load), See Note 3	Full range		0.2	5	μA
Reference voltage, V _O – V _{ADJ}	V _I – V _O = 1.5 V to 25 V, I _O = 10 mA to 5 A (full load), See Note 3	Full range	1.225	1.250	1.270	V

[†] Full range is 0°C to 125°C.

- NOTES: 1. Input regulation is expressed as the percentage change in output voltage per 1-V change at the input. See thermal regulation specifications for changes in output voltage due to heating effects. Input and output regulation are measured at a constant junction temperature by low-duty-cycle pulse testing. Use pulses (t_w ≤ 10 μs, duty cycle ≤ 5%) to limit changes in average internal dissipation. Output voltage changes due to large changes in internal dissipation must be taken into account separately.
2. Input and output regulation are specified up to the maximum power dissipation of 45 W. Power dissipation is determined by the product of input-to-output differential voltage and output current. Maximum power dissipation is not available over the full input-to-output voltage range. See Figure 2.
3. I_O (full load) is defined on the current-limit graph (Figure 2) as the minimum value of current limiting as a function of input-to-output differential voltage. Note that 45-W power dissipation is achievable, but only over a limited range of input-to-output differential voltage.
4. Ripple rejection is measured with a 25-μF capacitor between ADJ and ground and a 25-μF tantalum capacitor between OUT and ground.

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TYPICAL CHARACTERISTICS



Region 1 is limited by the full load current, see Figure 2 and Notes 2 and 3.

Region 2 is limited by the maximum junction temperature of the power transistor. The slope is based on the thermal resistance $R_{\theta JC}$, which is $2.3^{\circ}\text{C}/\text{W}$.

Region 3 is limited by the maximum junction temperature of the control section. The slope is based on the thermal resistance $R_{\theta JC}$, which is $0.65^{\circ}\text{C}/\text{W}$.

Figure 1

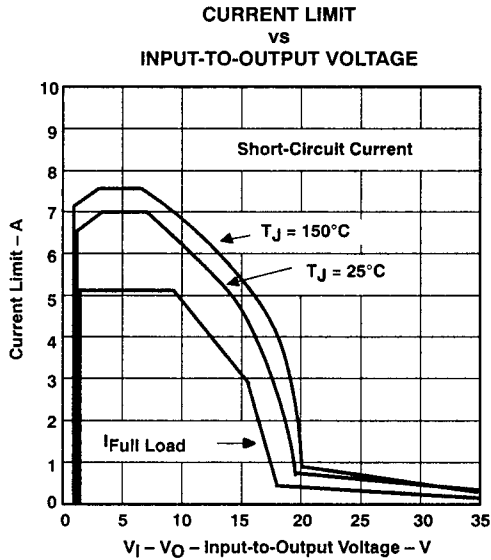


Figure 2

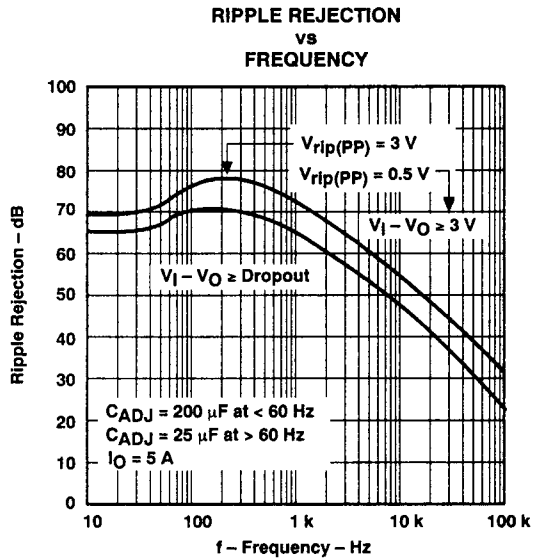
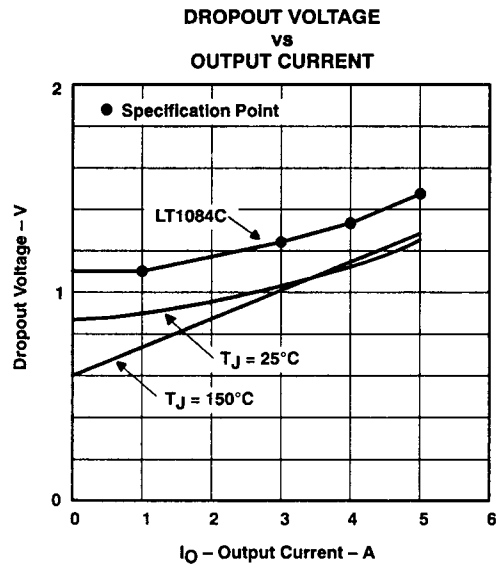
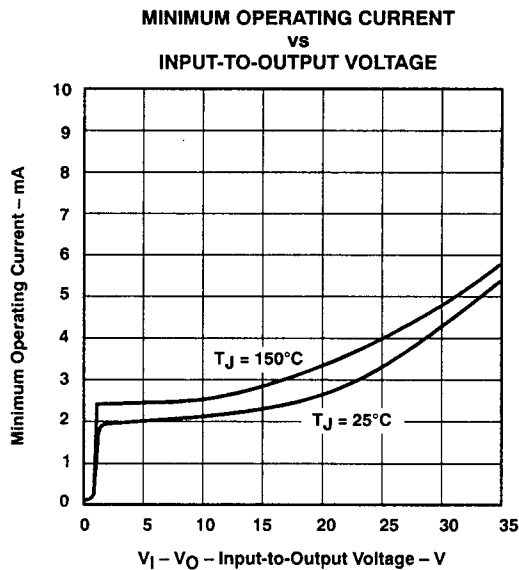
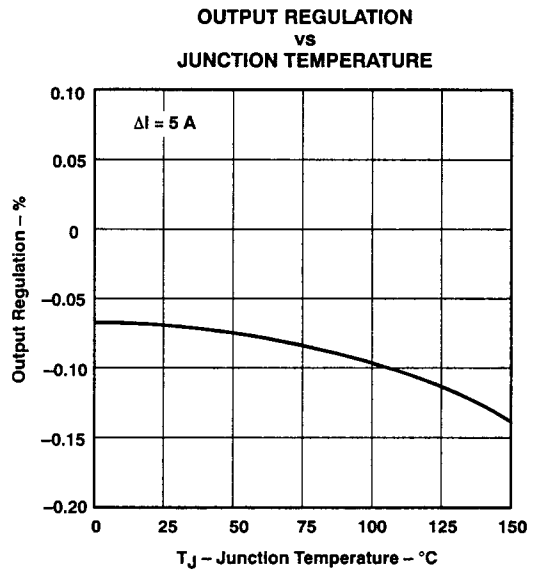
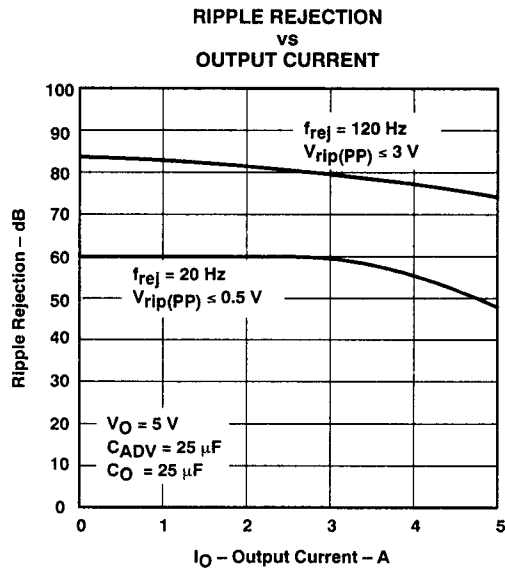


Figure 3



TYPICAL CHARACTERISTICS



TYPICAL CHARACTERISTICS

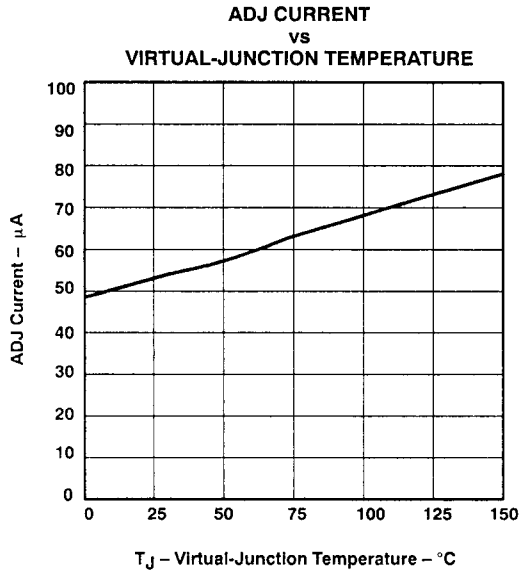


Figure 8

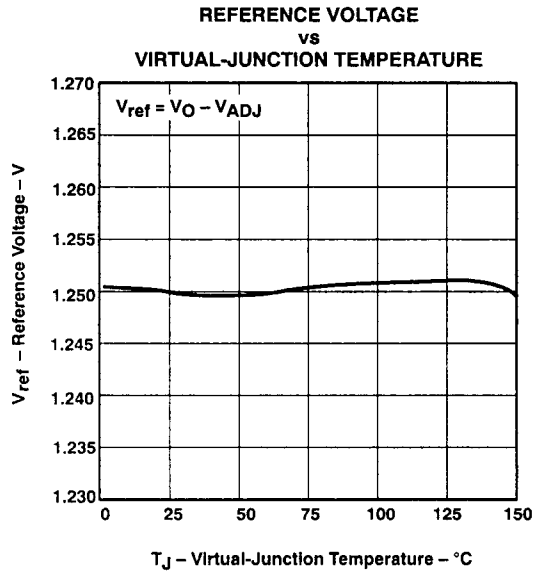


Figure 9

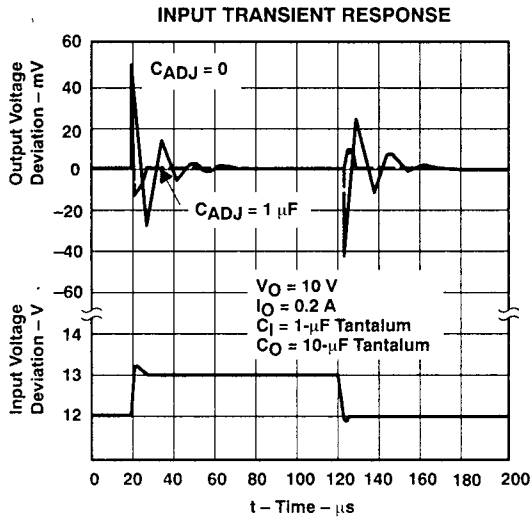


Figure 10

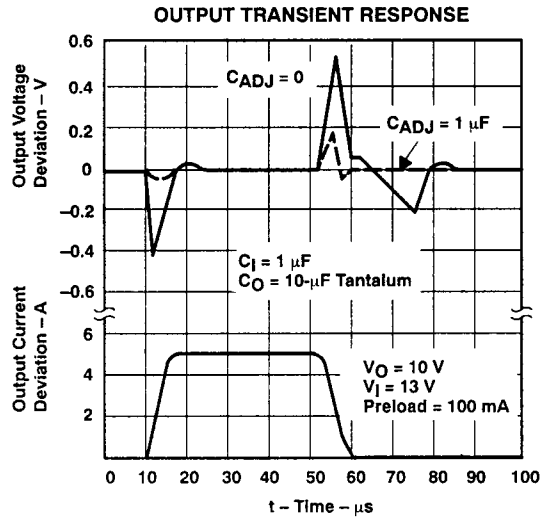


Figure 11

APPLICATION INFORMATION

The LT1084C 3-terminal adjustable regulator is easy to use and has all the protection features that are expected in high-performance voltage regulators. It is short-circuit protected. Safe-area protection and thermal shutdown turn off the regulator when the junction temperature exceeds approximately 165°C.

The regulator is terminal compatible with older 3-terminal adjustable devices and offers lower dropout voltage and voltage reference tolerance. The reference voltage-versus-temperature stability is improved. The only circuit difference between using the LT1084C and older regulators is the need for an output capacitor for more stability.

stability

The circuit design used in the LT1084C requires the use of an output capacitor as part of the device frequency compensation. For all operating conditions, the addition of 150- μ F aluminum electrolytic or a 22- μ F solid tantalum capacitor on the output ensures stability. Typically, capacitors that are much smaller in value can be used with the LT1084C. Many different types of capacitors, with widely varying characteristics, are available that differ in capacitor tolerance (up to plus or minus 100%), equivalent series resistance, and capacitor temperature coefficient. The 150- μ F or 22- μ F values will ensure stability.

When ADJ bypassed to improve ripple rejection, the requirement for an output capacitor increases. The 22- μ F tantalum or 150- μ F electrolytic capacitor values cover all cases of bypassing ADJ. Without bypassing ADJ, smaller capacitors can be used with good results. The recommended capacitors needed to ensure stability are listed in the following table:

RECOMMENDED OUTPUT CAPACITOR VALUES

IN	OUT	ADJ
10 μ F	10- μ F Tantalum or 50- μ F Aluminum	None
10 μ F	22- μ F Tantalum or 150- μ F Aluminum	20 μ F

Typically, capacitor values of 100 μ F are used on the output of many regulators to ensure good transient response with large load-current changes. Output capacitance can be increased without limit to improve the stability and transient response of the LT1084C regulator.

Another stability problem that can occur in monolithic regulators is current-limit oscillations. This problem occurs during current limiting when the safe-area protection exhibits a negative impedance. The safe-area protection decreases the current limit as the input-to-output voltage increases. This acts as a negative resistance since increasing voltage causes current to decrease. Negative resistance during current limiting is not unique to the LT1084C and is present on all power IC regulators. The value of 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 be unstable. This system problem 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 LT1084C does not need any protection diodes. Older adjustable regulators required protection diodes between ADJ and OUT and from OUT to IN to prevent overstressing the IC. The internal current paths on the LT1084C ADJ are limited by the internal resistors. Therefore, no protection diode is needed to ensure device safety under short-circuit conditions even with capacitors on ADJ. See Figure 12.

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Diodes between IN and OUT are usually not needed. The internal diode between IN and OUT of the LT1084C can handle microsecond surge currents of 50 A to 100 A. Even with large output capacitances, it is difficult to obtain those values of surge currents in normal operations. Damage can occur only when using high values of output capacitance (1000 μF to 5000 μF) with IN instantaneously shorted to ground. A crowbar circuit at IN can generate those kinds of currents, and a diode from output-to-input is then recommended. Normal power supply on-off cycling or even connecting and disconnecting in the system will not generate a large enough current to cause damage. ADJ can be driven, on a transient basis, plus or minus 25 V with respect to OUT without device degradation. As with any IC regulator, exceeding the maximum input-to-output differential voltage causes the internal transistors to break down, and the protection circuitry does not prevent this.

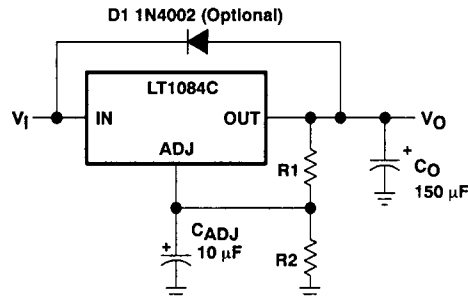


Figure 12

overload recovery

The LT1084C regulator has safe-area protection that decreases the current limit as input-to-output voltage increases, so the power transistor operates inside a safe region for all values of input-to-output voltage. This protection is designed to provide some output current at all values of input-to-output voltage up to the device breakdown.

When power is turned on and IN voltage rises, the OUT follows IN and the input-to-output differential voltage remains small to allow a large current demand on the regulator to be supplied. With high input voltage and low output voltage, a problem occurs that is common to older regulators (such as the 7800 series) as well as the LT1084C. OUT voltage will not recover after removal of an output short. The load line for such a large load may intersect the OUT current curve at two points. If this happens, there are two stable OUT operating points for the regulator. With a double intersection, the power supply may need to be cycled to zero and brought up again to make OUT recover.

ripple rejection

The typical curves for ripple rejection reflect values for a bypassed ADJ. This curve will be true for all values of output voltage. For proper bypassing and ripple rejection near the values shown, the impedance of the ADJ capacitor at the ripple frequency should equal the value of resistor R1 (normally 100 Ω to 120 Ω). The capacitance of the required ADJ capacitor is a function of the input ripple frequency. The ADJ capacitor should be 13 μF with R1 equal to 100 Ω at a frequency of 120 Hz. Only 0.16 μF is needed at 10 kHz. See Figure 16.

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

output voltage

The LT1084C develops a 1.25-V reference voltage between OUT and ADJ (see Figure 13). When resistor R1 is placed between these two terminals, a constant current flows through R1 and through R2 to set the overall OUT voltage. Normally this current is the specified minimum output current of 10 mA. Since I_{ADJ} is very small and constant when compared with the current through R1, I_{ADJ} can usually be ignored and represents a small error.

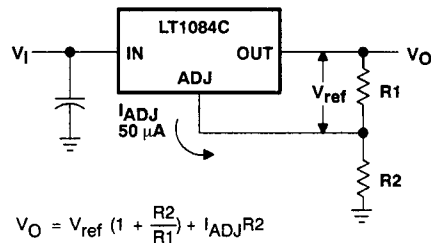


Figure 13

output regulation

The LT1084C is not able to provide true remote-load sensing with only three terminals. Output regulation will be limited by the resistance of the wire connecting the regulator to the load. The data-sheet specification for output regulation is measured at the bottom of the package. Negative-side sensing is a true Kelvin connection that has the bottom of the output divider returned to the negative side of the load. The best output regulation is obtained when the top of the resistor divider R1 is connected directly to the case or OUT, not to the load. This is illustrated in Figure 14. If resistor R1 were connected to the load, the effective resistance between the regulator and the load would be as shown:

$$R_{eff} = R_P \times (R_2 + R_1)/R_1$$

Assuming $R_P = 0.004 \Omega$ per foot (16-gauge wire), this calculation gives 4 mV per foot at a load current of 1 A. It is important to keep the positive lead between regulator and load as short as possible and use large wire or circuit-board traces to minimize this problem. Connected as shown in Figure 14, R_P is not multiplied by the divider ratio.

thermal considerations

The LT1084C regulator has internal power and thermal-limiting circuitry designed to protect the device under overload conditions. For continuous normal-load conditions, maximum junction temperature ratings must not be exceeded. It is important to give careful consideration to all sources of thermal resistance from device junction to ambient. This includes junction-to-case, case-to-heat-sink interface, and heat-sink resistance. New

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thermal-resistance specifications have been developed to more accurately reflect device temperature and ensure safe operating temperatures. The maximum ratings table and the explanation with Figure 1 provide maximum junction temperature and thermal resistance for the control section and separately for the power transistor. Previous regulators used a single junction-to-case thermal resistance specification that was an average of the two values. This method 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 of the device 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, but the added contribution to thermal resistance must be considered. The KK package is electrically connected to OUT.

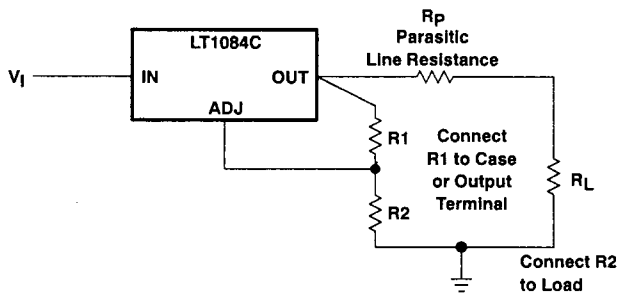


Figure 14

thermal example

Using an LT1084CCKK regulator (KK plastic package and commercial temperature) and assuming:

$$V_I = 9 \text{ V (maximum continuous)}, V_O = 5 \text{ V}, I_O = 5 \text{ A}, \\ T_A = 75^\circ\text{C}, R_{\theta\text{HSA}} = 1^\circ\text{C/W}, R_{\theta\text{CHS}} = 0.2^\circ\text{C/W}$$

Maximum thermal resistances: (see Figure 1)

$$\text{Control section } R_{\theta\text{JC}} = 0.65^\circ\text{C/W}, \\ \text{Power transistor } R_{\theta\text{JC}} = 2.3^\circ\text{C/W}$$

Power dissipation under these conditions is equal to:

$$P_D = (V_I - V_O) (I_O) = (9 - 5) (5) = 20 \text{ W}$$

Junction temperature is calculated using:

$$T_J = T_A + P_D(R_{\theta\text{HSA}} + R_{\theta\text{CHS}} + R_{\theta\text{JC}})$$

Junction temperature for control section:

$$T_J = 75 + 20(1 + 0.2 + 0.65) = 112^\circ\text{C}$$

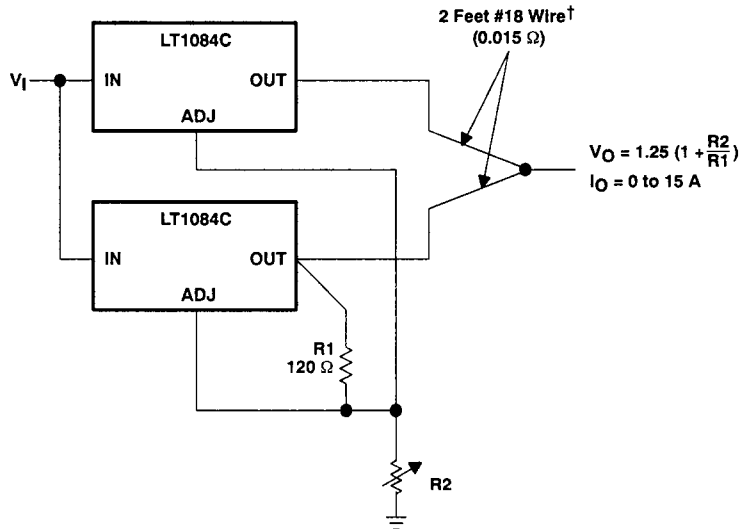
Junction temperature for power transistor:

$$T_J = 75 + 20(1 + 0.2 + 2.3) = 145^\circ\text{C}$$

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

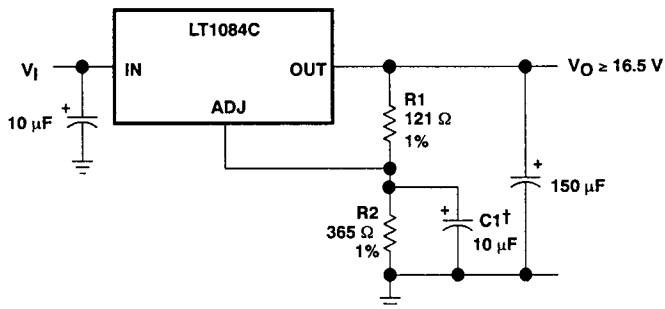


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† The # 18 wire acts as ballast resistance, insuring current sharing between both devices.

Figure 15. Paralleling Regulators



† C1 improves ripple rejection. X_C should be equal to R_1 at ripple frequency.

Figure 16. Improving Ripple Rejection

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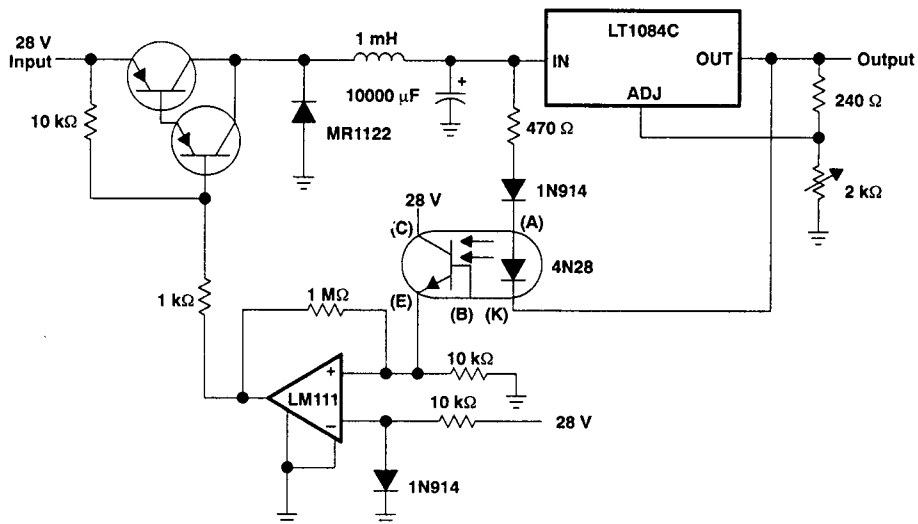


Figure 17. High-Efficiency Regulator

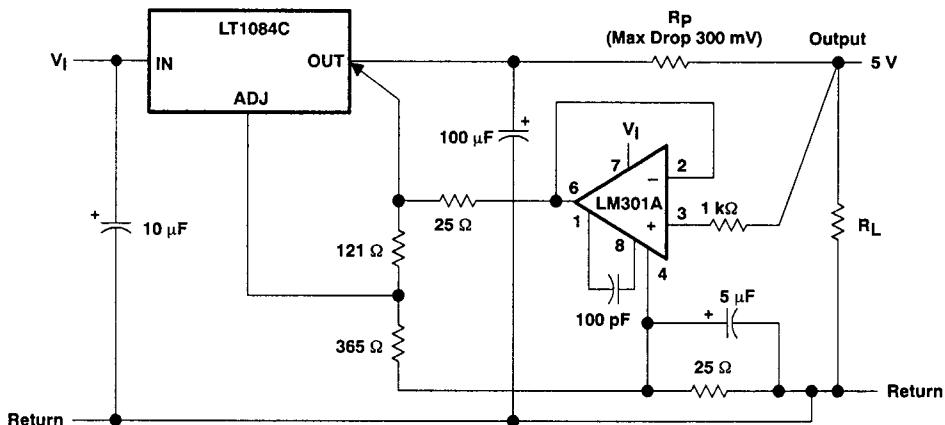
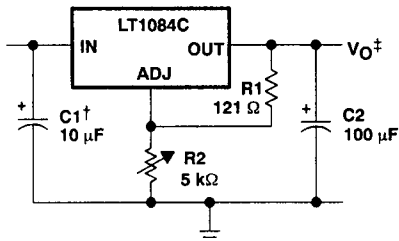


Figure 18. Remote Sensing

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† Needed if device is far from filter capacitors.

$$\ddagger V_O = 1.25 \left(1 + \frac{R_2}{R_1} \right) V$$

Figure 19. 1.2-V to 15-V Adjustable Regulator

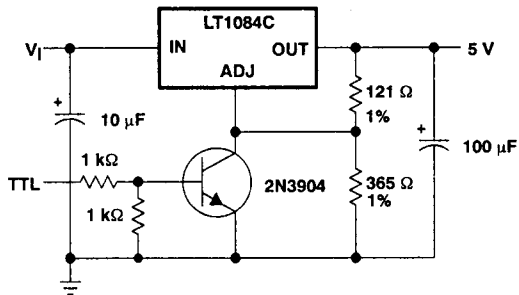


Figure 20. 5-V Regulator With Shutdown

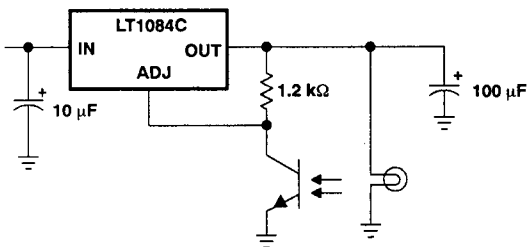


Figure 21. Automatic Light Control

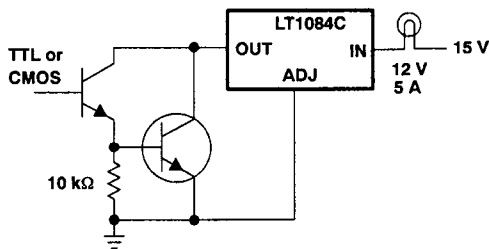


Figure 22. Protected High-Current Lamp Driver