



Low Dropout Voltage Regulators

The LM2931 series consists of positive fixed and adjustable output voltage regulators that are specifically designed to maintain proper regulation with an extremely low input-to-output voltage differential. These devices are capable of supplying output currents in excess of 100 mA and feature a low bias current of 0.4 mA at 10 mA output.

Designed primarily to survive in the harsh automotive environment, these devices will protect all external load circuitry from input fault conditions caused by reverse battery connection, two battery jump starts, and excessive line transients during load dump. This series also includes internal current limiting, thermal shutdown, and additionally, is able to withstand temporary power-up with mirror-image insertion.

Due to the low dropout voltage and bias current specifications, the LM2931 series is ideally suited for battery powered industrial and consumer equipment where an extension of useful battery life is desirable. The 'C' suffix adjustable output regulators feature an output inhibit pin which is extremely useful in microprocessor-based systems.

- Input-to-Output Voltage Differential of $< 0.6\text{ V @ }100\text{ mA}$
- Output Current in Excess of 100 mA
- Low Bias Current
- 60 V Load Dump Protection
- -50 V Reverse Transient Protection
- Internal Current Limiting with Thermal Shutdown
- Temporary Mirror-Image Protection
- Ideally Suited for Battery Powered Equipment
- Economical 5-Lead TO-220 Package with Two Optional Leadforms
- Available in Surface Mount SOP-8, D²PAK and DPAK Packages

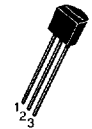
(See Following Page for Ordering Information.)

LM2931 Series

LOW DROPOUT VOLTAGE REGULATORS

FIXED OUTPUT VOLTAGE

Z SUFFIX
PLASTIC PACKAGE
CASE 29



Pin 1. Output
2. Ground
3. Input

T SUFFIX
PLASTIC PACKAGE
CASE 221A

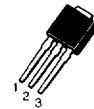


Pin 1. Input
2. Ground
3. Output

Heatsink surface connected to Pin 2.



DT SUFFIX
PLASTIC PACKAGE
CASE 369A
(DPAK)

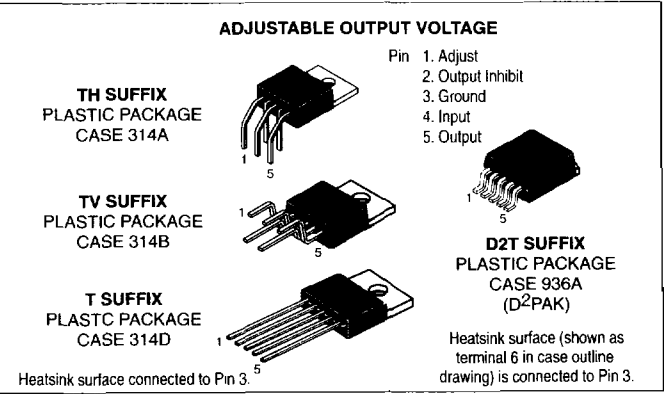
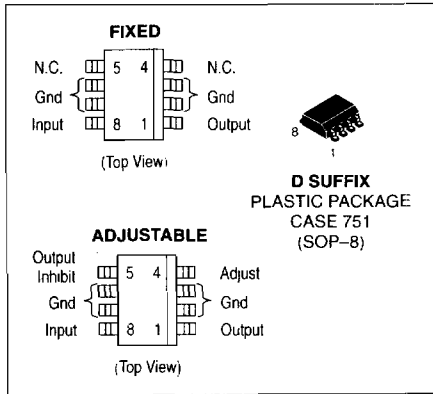


DT-1 SUFFIX
PLASTIC PACKAGE
CASE 369
(DPAK)

D2T SUFFIX
PLASTIC PACKAGE
CASE 936
(D²PAK)



Heatsink surface (shown as terminal 4 in case outline drawing) is connected to Pin 2.



LM2931 Series

ORDERING INFORMATION

Device	Output		Case	Package	
	Voltage	Tolerance			
LM2931AD-5.0	5.0 V	± 3.8%	751	SOP-8 Surface Mount	
LM2931ADT-5.0			369A	Surface Mount DPAK	
LM2931ADT-1-5.0			369	DPAK	
LM2931AD2T-5.0			936	Surface Mount D ² PAK	
LM2931AT-5.0			221A	TO-220 Type	
LM2931AZ-5.0			29	TO-92 Type	
LM2931D-5.0		± 5.0%	751	SOP-8 Surface Mount	
LM2931D2T-5.0			936	Surface Mount D ² PAK	
LM2931DT-5.0			369A	Surface Mount DPAK	
LM2931DT-1-5.0			369	DPAK	
LM2931T-5.0			221A	TO-220 Type	
LM2931Z-5.0			29	TO-92 Type	
LM2931CD			Adjustable	751	SOP-8 Surface Mount
LM2931CD2T				936A	Surface Mount D ² PAK
LM2931CT	314D			5-Pin TO-220 Type	
LM2931CTH	314A			5-Pin Horizontal Leadform	
LM2931CTV	314B	5-Pin Vertical Leadform			

3

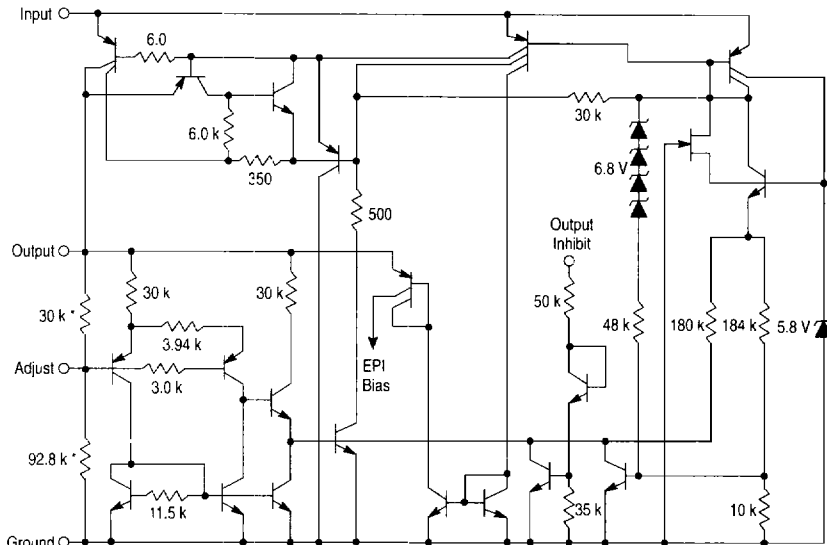
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Input Voltage Continuous	V_I	40	Vdc
Transient Input Voltage ($\tau \leq 100$ ms)	$V_I(\tau)$	60	Vpk
Transient Reverse Polarity Input Voltage 1.0% Duty Cycle, $\tau \leq 100$ ms	$-V_I(\tau)$	-50	Vpk
Power Dissipation Case 29 (TO-92 Type) $T_A = 25^\circ\text{C}$ Thermal Resistance, Junction-to-Ambient Thermal Resistance, Junction-to-Case	P_D $R_{\theta JA}$ $R_{\theta JC}$	Internally Limited 178 83	W °C/W °C/W
Case 221A, 314A, 314B and 314D (TO-220 Type) $T_A = 25^\circ\text{C}$ Thermal Resistance, Junction-to-Ambient Thermal Resistance, Junction-to-Case	P_D $R_{\theta JA}$ $R_{\theta JC}$	Internally Limited 65 5.0	W °C/W °C/W
Case 369 and 369A (DPAK) [Note 1] $T_A = 25^\circ\text{C}$ Thermal Resistance, Junction-to-Ambient Thermal Resistance, Junction-to-Case	P_D $R_{\theta JA}$ $R_{\theta JC}$	Internally Limited 92 6.0	W °C/W °C/W
Case 751 (SOP-8) [Note 2] $T_A = 25^\circ\text{C}$ Thermal Resistance, Junction-to-Ambient Thermal Resistance, Junction-to-Case	P_D $R_{\theta JA}$ $R_{\theta JC}$	Internally Limited 160 25	W °C/W °C/W
Case 936 and 936A (D ² PAK) [Note 3] $T_A = 25^\circ\text{C}$ Thermal Resistance, Junction-to-Ambient Thermal Resistance, Junction-to-Case	P_D $R_{\theta JA}$ $R_{\theta JC}$	Internally Limited 70 5.0	W °C/W °C/W
Tested Operating Junction Temperature Range	T_J	-40 to +125	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C

- NOTES:** 1. DPAK Junction-to-Ambient Thermal Resistance is for vertical mounting. Refer to Figure 23 for board mounted Thermal Resistance.
 2. SOP-8 Junction-to-Ambient Thermal Resistance is for minimum recommended pad size. Refer to Figure 23 for Thermal Resistance variation versus pad size.
 3. D²PAK Junction-to-Ambient Thermal Resistance is for vertical mounting. Refer to Figure 25 for board mounted Thermal Resistance.

LM2931 Series

Representative Schematic Diagram



*Deleted on Adjustable Regulators

This device contains 26 active transistors.

ELECTRICAL CHARACTERISTICS ($V_{in} = 14\text{ V}$, $I_O = 10\text{ mA}$, $C_O = 100\text{ }\mu\text{F}$, $C_{O(ESR)} = 0.3\text{ }\Omega$, $T_J = 25^\circ\text{C}$ [Note 4].)

Characteristic	Symbol	LM2931-5.0			LM2931A-5.0			Unit
		Min	Typ	Max	Min	Typ	Max	
FIXED OUTPUT								
Output Voltage $V_{in} = 14\text{ V}$, $I_O = 10\text{ mA}$, $T_J = 25^\circ\text{C}$ $V_{in} = 6.0\text{ V to } 26\text{ V}$, $I_O \leq 100\text{ mA}$, $T_J = -40^\circ\text{ to } +125^\circ\text{C}$	V_O	4.75 4.50	5.0 -	5.25 5.50	4.81 4.75	5.0 -	5.19 5.25	V
Line Regulation $V_{in} = 9.0\text{ V to } 16\text{ V}$ $V_{in} = 6.0\text{ V to } 26\text{ V}$	Reg_{line}	- -	2.0 4.0	10 30	- -	2.0 4.0	10 30	mV
Load Regulation ($I_O = 5.0\text{ mA to } 100\text{ mA}$)	Reg_{load}	-	14	50	-	14	50	mV
Output Impedance $I_O = 10\text{ mA}$, $\Delta I_O = 1.0\text{ mA}$, $f = 100\text{ Hz to } 10\text{ kHz}$	Z_O	-	200	-	-	200	-	$\text{m}\Omega$
Bias Current $V_{in} = 14\text{ V}$, $I_O = 100\text{ mA}$, $T_J = 25^\circ\text{C}$ $V_{in} = 6.0\text{ V to } 26\text{ V}$, $I_O = 10\text{ mA}$, $T_J = -40^\circ\text{ to } +125^\circ\text{C}$	I_B	- -	5.8 0.4	30 1.0	- -	5.8 0.4	30 1.0	mA
Output Noise Voltage ($f = 10\text{ Hz to } 100\text{ kHz}$)	V_n	-	700	-	-	700	-	μV_{rms}
Long Term Stability	S	-	20	-	-	20	-	mV/kHR
Ripple Rejection ($f = 120\text{ Hz}$)	RR	60	90	-	60	90	-	dB
Dropout Voltage $I_O = 10\text{ mA}$ $I_O = 100\text{ mA}$	V_{I-V_O}	- -	0.015 0.16	0.2 0.6	- -	0.015 0.16	0.2 0.6	V
Over-Voltage Shutdown Threshold	$V_{th(OV)}$	26	29.5	40	26	29.5	40	V
Output Voltage with Reverse Polarity Input ($V_{in} = -15\text{ V}$)	$-V_O$	-0.3	0	-	-0.3	0	-	V

NOTE: 4 Low duty cycle pulse techniques are used during test to maintain junction temperature as close to ambient as possible.

LM2931 Series

ELECTRICAL CHARACTERISTICS ($V_{in} = 14\text{ V}$, $V_O = 3.0\text{ V}$, $I_O = 10\text{ mA}$, $R_1 = 27\text{ k}$, $C_O = 100\text{ }\mu\text{F}$, $C_{O(ESR)} = 0.3\text{ }\Omega$, $T_J = 25^\circ\text{C}$ [Note 4].)

Characteristic	Symbol	LM2931C			Unit
		Min	Typ	Max	
ADJUSTABLE OUTPUT					
Reference Voltage (Note 5, Figure 18) $I_O = 10\text{ mA}$, $T_J = 25^\circ\text{C}$ $I_O \leq 100\text{ mA}$, $T_J = -40\text{ to }+125^\circ\text{C}$	V_{ref}	1.14 1.08	1.20 –	1.26 1.32	V
Output Voltage Range	V_O range	3.0 to 24	2.7 to 29.5	–	V
Line Regulation ($V_{in} = V_O + 0.6\text{ V}$ to 26 V)	Reg _{line}	–	0.2	1.5	mV/V
Load Regulation ($I_O = 5.0\text{ mA}$ to 100 mA)	Reg _{load}	–	0.3	1.0	%/V
Output Impedance $I_O = 10\text{ mA}$, $\Delta I_O = 1.0\text{ mA}$, $f = 10\text{ Hz}$ to 10 kHz	Z_O	–	40	–	m Ω /V
Bias Current $I_O = 100\text{ mA}$ $I_O = 10\text{ mA}$ Output Inhibited ($V_{th(OI)} = 2.5\text{ V}$)	I_B	– – –	6.0 0.4 0.2	– 1.0 1.0	mA
Adjustment Pin Current	I_{Adj}	–	0.2	–	μA
Output Noise Voltage ($f = 10\text{ Hz}$ to 100 kHz)	V_n	–	140	–	$\mu\text{V}_{rms}/\text{V}$
Long-Term Stability	S	–	0.4	–	%/kHR
Ripple Rejection ($f = 120\text{ Hz}$)	RR	0.10	0.003	–	%/V
Dropout Voltage $I_O = 10\text{ mA}$ $I_O = 100\text{ mA}$	$V_I - V_O$	– –	0.015 0.16	0.2 0.6	V
Over-Voltage Shutdown Threshold	$V_{th(OV)}$	26	29.5	40	V
Output Voltage with Reverse Polarity Input ($V_{in} = -15\text{ V}$)	$-V_O$	-0.3	0	–	V
Output Inhibit Threshold Voltages Output "On": $T_J = 25^\circ\text{C}$ $T_J = -40^\circ\text{ to }+125^\circ\text{C}$ Output "Off": $T_J = 25^\circ\text{C}$ $T_J = -40^\circ\text{ to }+125^\circ\text{C}$	$V_{th(OI)}$	– – 2.50 3.25	2.15 – 2.26 –	1.90 1.20 – –	V
Output Inhibit Threshold Current ($V_{th(OI)} = 2.5\text{ V}$)	$I_{th(OI)}$	–	30	50	μA

NOTES: 4. Low duty cycle pulse techniques are used during test to maintain junction temperature as close to ambient as possible.

5. The reference voltage on the adjustable device is measured from the output to the adjust pin across R_1 .

Figure 1. Dropout Voltage versus Output Current

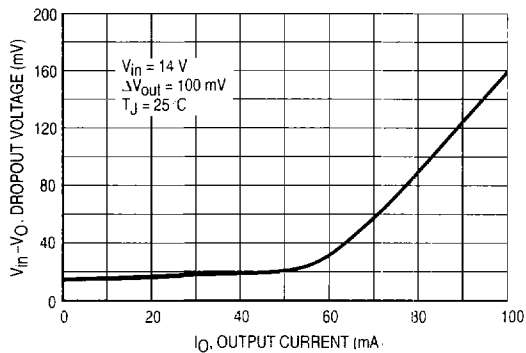


Figure 2. Dropout Voltage versus Junction Temperature

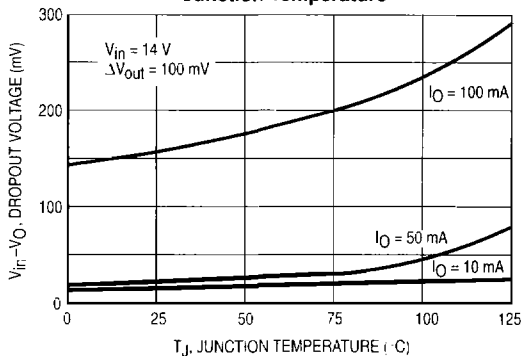


Figure 3. Peak Output Current versus Input Voltage

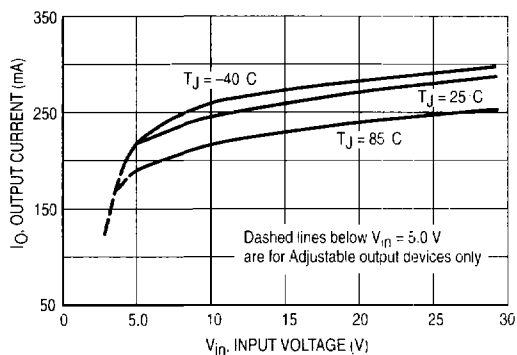


Figure 4. Output Voltage versus Input Voltage

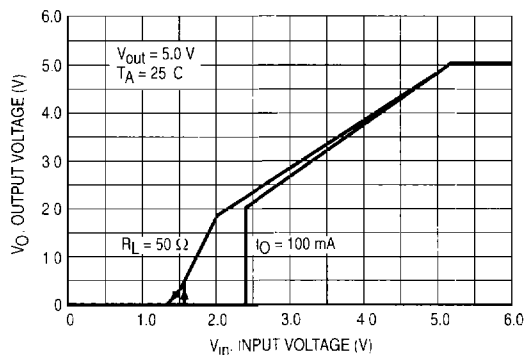


Figure 5. Output Voltage versus Input Voltage

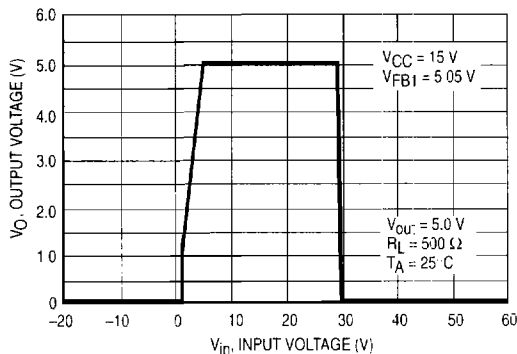
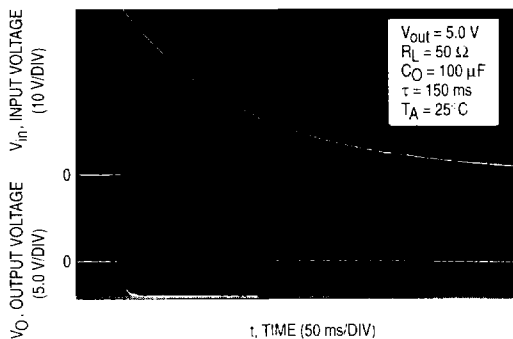


Figure 6. Load Dump Characteristics



LM2931 Series

Figure 7. Bias Current versus Input Voltage

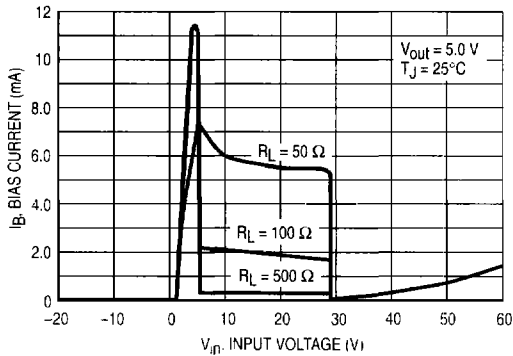


Figure 8. Bias Current versus Output Current

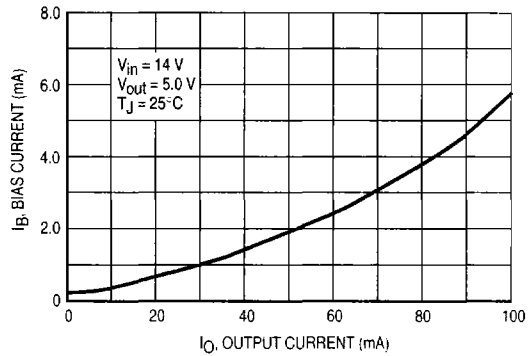


Figure 9. Bias Current versus Junction Temperature

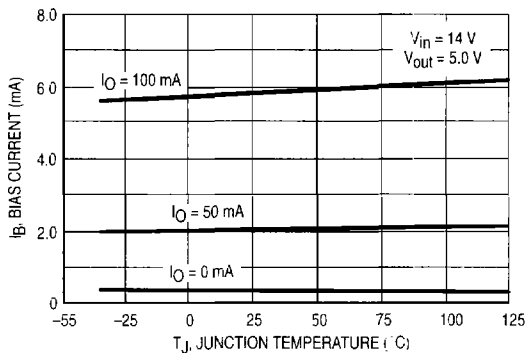


Figure 10. Output Impedance versus Frequency

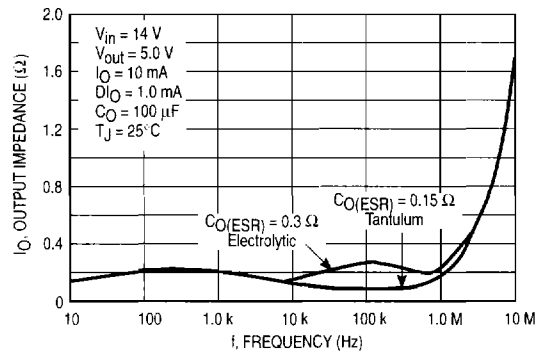


Figure 11. Ripple Rejection versus Frequency

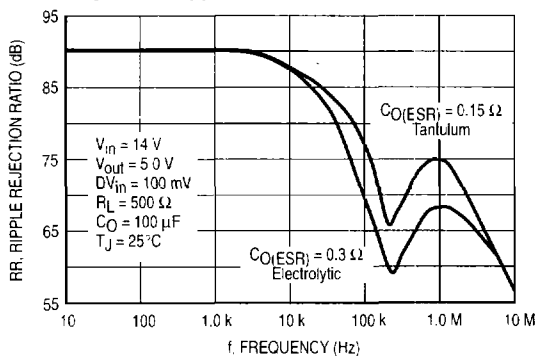
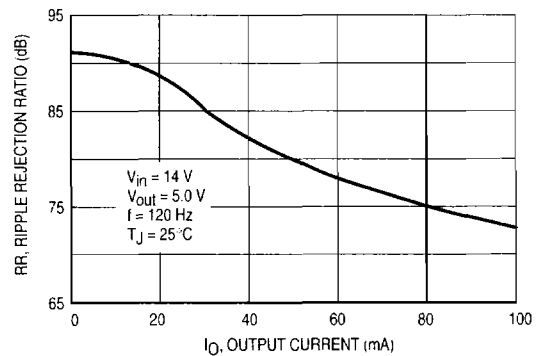


Figure 12. Ripple Rejection versus Output Current



LM2931 Series

Figure 13. Line Regulation

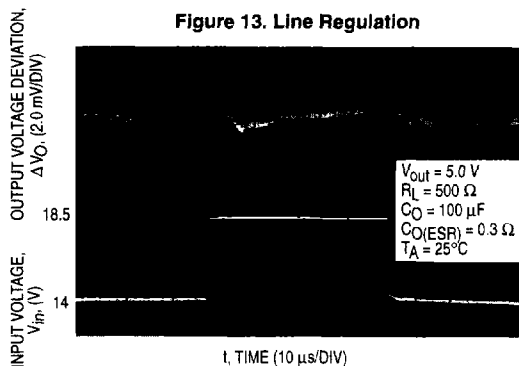


Figure 14. Load Regulation

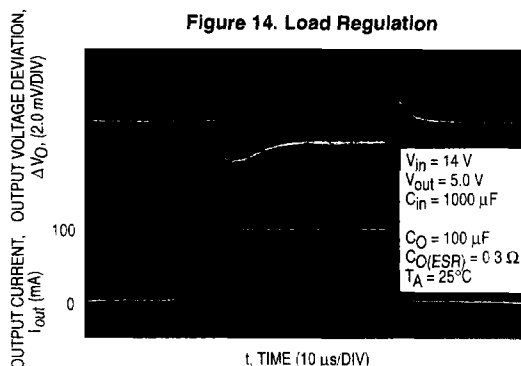


Figure 15. Reference Voltage versus Output Voltage

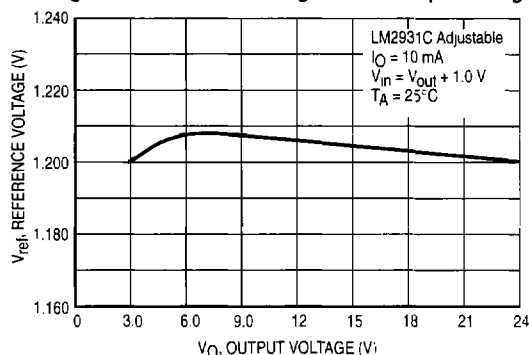
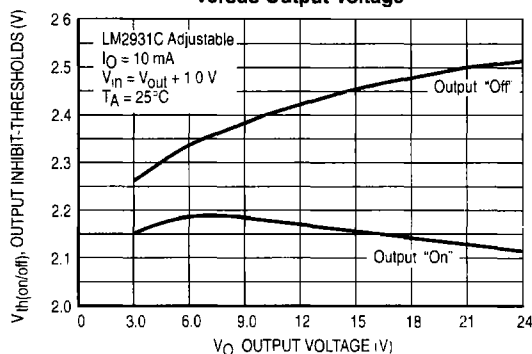


Figure 16. Output Inhibit-Thresholds versus Output Voltage



APPLICATIONS INFORMATION

The LM2931 series regulators are designed with many protection features making them essentially blow-out proof. These features include internal current limiting, thermal shutdown, overvoltage and reverse polarity input protection, and the capability to withstand temporary power-up with mirror-image insertion. Typical application circuits for the fixed and adjustable output device are shown in Figures 17 and 18.

The input bypass capacitor C_{in} is recommended if the regulator is located an appreciable distance ($\geq 4"$) from the supply input filter. This will reduce the circuit's sensitivity to the input line impedance at high frequencies.

This regulator series is not internally compensated and thus requires an external output capacitor for stability. The capacitance value required is dependent upon the load current, output voltage for the adjustable regulator, and the type of capacitor selected. The least stable condition is encountered at maximum load current and minimum output voltage. Figure 22 shows that for operation in the "Stable" region, under the conditions specified, the magnitude of the output capacitor impedance $|Z_O|$ must not exceed $0.4 \ \Omega$. This limit must be observed over the entire operating temperature range of the regulator circuit.

With economical electrolytic capacitors, cold temperature operation can pose a serious stability problem. As the electrolyte freezes, around -30°C , the capacitance will decrease and the equivalent series resistance (ESR) will increase drastically, causing the circuit to oscillate. Quality electrolytic capacitors with extended temperature ranges of -40° to $+85^\circ\text{C}$ and -55° to $+105^\circ\text{C}$ are readily available. Solid tantalum capacitors may be a better choice if small size is a requirement, however, the maximum $|Z_O|$ limit over temperature must be observed.

Note that in the stable region, the output noise voltage is linearly proportional to $|Z_O|$. In effect, C_O dictates the high frequency roll-off point of the circuit. Operation in the area titled "Marginally Stable" will cause the output of the regulator to exhibit random bursts of oscillation that decay in an under-damped fashion. Continuous oscillation occurs when operating in the area titled "Unstable". It is suggested that oven testing of the entire circuit be performed with maximum load, minimum input voltage, and minimum ambient temperature.

Figure 17. Fixed Output Regulator

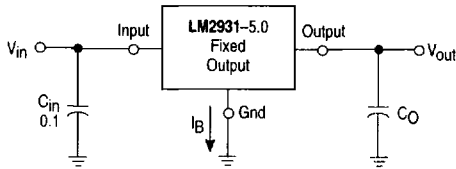
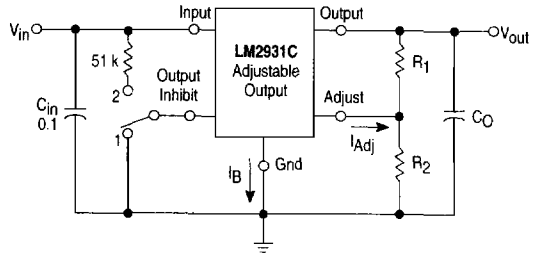


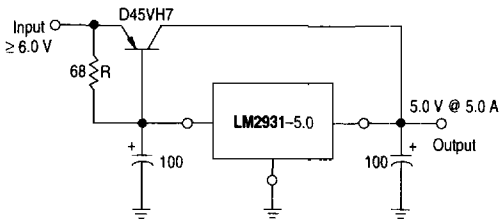
Figure 18. Adjustable Output Regulator



Switch Position 1 = Output "On", 2 = Output "Off"

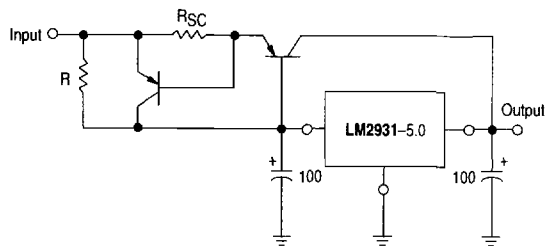
$$V_{out} = V_{ref} \left(1 + \frac{R_2}{R_1} \right) + I_{Adj} R_2 \quad 22.5 \text{ k} \geq \frac{R_1 R_2}{R_1 + R_2}$$

Figure 19. (5.0 A) Low Differential Voltage Regulator



The LM2931 series can be current boosted with a PNP transistor. The D45VH7, on a heatsink, will provide an output current of 5.0 A with an input to output voltage differential of approximately 1.0 V. Resistor R in conjunction with the V_{BE} of the PNP determines when the pass transistor begins conducting. This circuit is not short circuit proof.

Figure 20. Current Boost Regulator with Short Circuit Projection



The circuit of Figure 19 can be modified to provide supply protection against short circuits by adding the current sense resistor R_{SC} and an additional PNP transistor. The current sensing PNP must be capable of handling the short circuit current of the LM2931. Safe operating area of both transistors must be considered under worst case conditions.

Figure 21. Constant Intensity Lamp Flasher

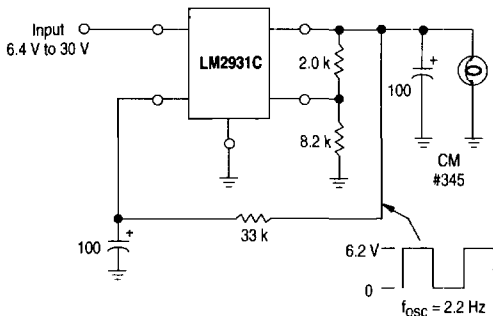
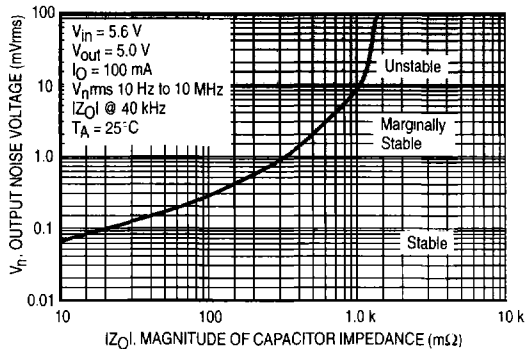


Figure 22. Output Noise Voltage versus Output Capacitor Impedance



LM2931 Series

Figure 23. SOP-8 Thermal Resistance and Maximum Power Dissipation versus P.C.B. Copper Length

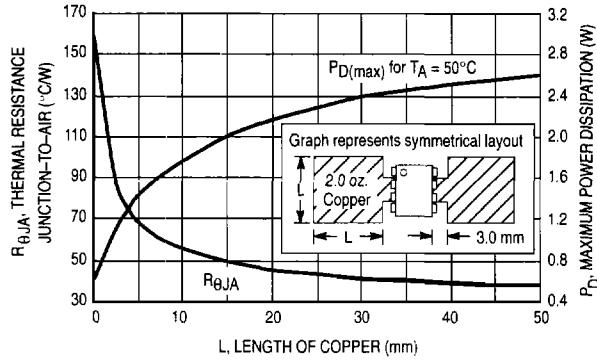


Figure 24. DPAK Thermal Resistance and Maximum Power Dissipation versus P.C.B. Copper Length

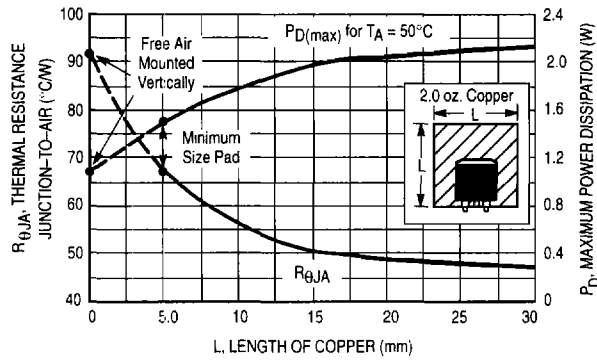
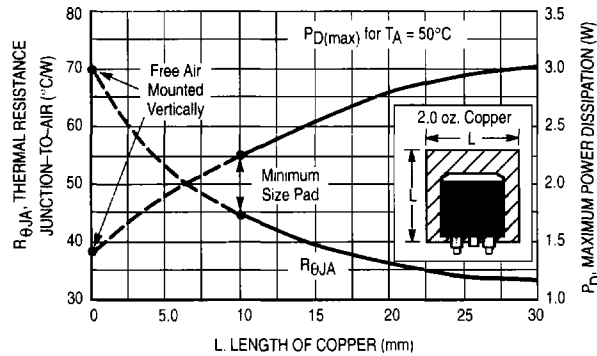


Figure 25. 3-Pin and 5-Pin D²PAK Thermal Resistance and Maximum Power Dissipation versus P.C.B. Copper Length



LM2931 Series

DEFINITIONS

Dropout Voltage – The input/output voltage differential at which the regulator output no longer maintains regulation against further reductions in input voltage. Measured when the output decreases 100 mV from nominal value at 14 V input, dropout voltage is affected by junction temperature and load current.

Line Regulation – The change in output voltage for a change in the input voltage. The measurement is made under conditions of low dissipation or by using pulse techniques such that the average chip temperature is not significantly affected.

Load Regulation – The change in output voltage for a change in load current at constant chip temperature.

Maximum Power Dissipation – The maximum total device dissipation for which the regulator will operate within specifications.

Bias Current – That part of the input current that is not delivered to the load.

Output Noise Voltage – The rms AC voltage at the output, with constant load and no input ripple, measured over a specified frequency range.

Long-Term Stability – Output voltage stability under accelerated life test conditions with the maximum rated voltage listed in the devices electrical characteristics and maximum power dissipation.