LM2931 Series

100 mA, Adjustable Output, LDO Voltage Regulator with 60 V Load Dump Protection

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.

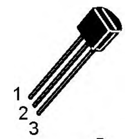
- Input–to–Output Voltage Differential of < 0.6 V @ 100 mA
- Output Current in Excess of 100 mA
- Low Bias Current
- 60 V Load Dump Protection
- –50 V Reverse Transient Protection
- Internal Current Limiting with Thermal Shutdown
- Temporary Mirror–Image Protection
- Ideally Suited for Battery Powered Equipment
- Economical 5–Lead TO–220 Package with Two Optional Leadforms
- Available in Surface Mount SOP–8, D²PAK and DPAK Packages
- High Accuracy (±2%) Reference (LM2931AC) Available

ON Semiconductor™

http://onsemi.com

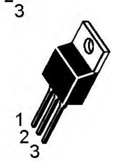
FIXED OUTPUT VOLTAGE

TO–92
Z SUFFIX
CASE 29

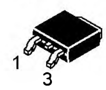


Pin 1. Output
2. Ground
3. Input

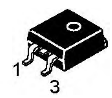
TO–220
T SUFFIX
CASE 221A



DPAK
DT SUFFIX
CASE 369A



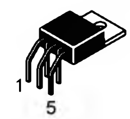
D²PAK
D2T SUFFIX
CASE 936



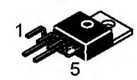
Pin 1. Input
2. Ground
3. Output

ADJUSTABLE OUTPUT VOLTAGE

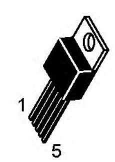
TO–220
TH SUFFIX
CASE 314A



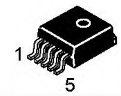
TO–220
TV SUFFIX
CASE 314B



TO–220
T SUFFIX
CASE 314D

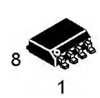


D²PAK
D2T SUFFIX
CASE 936A

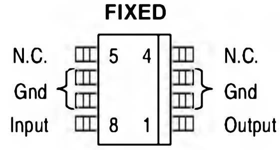


Pin 1. Adjust
2. Output Inhibit
3. Ground
4. Input
5. Output

SOIC–8
D SUFFIX
CASE 751

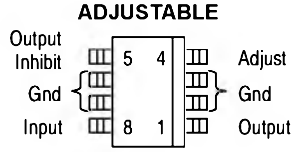


FIXED



(Top View)

ADJUSTABLE



(Top View)

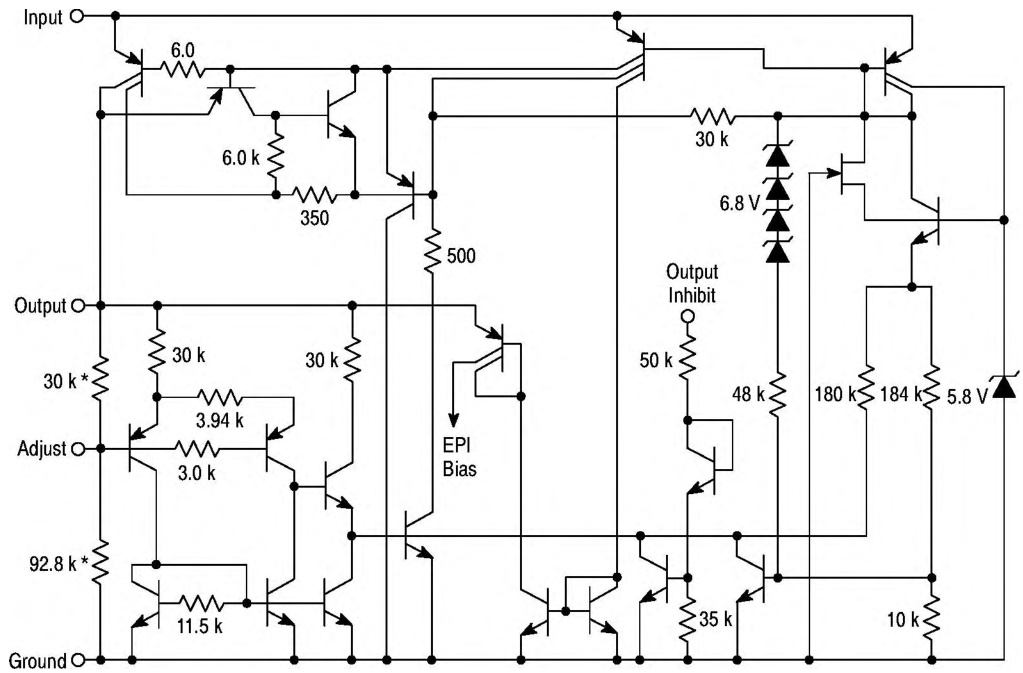
ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section on page 340 of this data sheet.

DEVICE MARKING INFORMATION

See general marking and heatsink information in the device marking section on page 341 of this data sheet.

Representative Schematic Diagram



*Deleted on Adjustable Regulators

This device contains 26 active transistors.

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°C	P_D	Internally Limited	W
Thermal Resistance, Junction–to–Ambient	$R_{\theta JA}$	178	°C/W
Thermal Resistance, Junction–to–Case	$R_{\theta JC}$	83	°C/W
Case 221A, 314A, 314B and 314D (TO–220 Type)			
T_A = 25°C	P_D	Internally Limited	W
Thermal Resistance, Junction–to–Ambient	$R_{\theta JA}$	65	°C/W
Thermal Resistance, Junction–to–Case	$R_{\theta JC}$	5.0	°C/W
Case 369A (DPAK) (Note 1)			
T_A = 25°C	P_D	Internally Limited	W
Thermal Resistance, Junction–to–Ambient	$R_{\theta JA}$	92	°C/W
Thermal Resistance, Junction–to–Case	$R_{\theta JC}$	6.0	°C/W
Case 751 (SOP–8) (Note 2)			
T_A = 25°C	P_D	Internally Limited	W
Thermal Resistance, Junction–to–Ambient	$R_{\theta JA}$	160	°C/W
Thermal Resistance, Junction–to–Case	$R_{\theta JC}$	25	°C/W
Case 936 and 936A (D^2PAK) (Note 3)			
T_A = 25°C	P_D	Internally Limited	W
Thermal Resistance, Junction–to–Ambient	$R_{\theta JA}$	70	°C/W
Thermal Resistance, Junction–to–Case	$R_{\theta JC}$	5.0	°C/W
Tested Operating Junction Temperature Range	T_J	–40 to +125	°C
Storage Temperature Range	T_{stg}	–65 to +150	°C

1. DPAK Junction–to–Ambient Thermal Resistance is for vertical mounting. Refer to Figure 24 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. D^2PAK Junction–to–Ambient Thermal Resistance is for vertical mounting. Refer to Figure 25 for board mounted Thermal Resistance.
4. ESD data available upon request.

ELECTRICAL CHARACTERISTICS (V_{in} = 14 V, I_O = 10 mA, C_O = 100 μF, $C_{O(ESR)}$ = 0.3 Ω, T_J = 25°C [Note 5])

Characteristic	Symbol	LM2931–5.0			LM2931A–5.0			Unit
		Min	Typ	Max	Min	Typ	Max	
FIXED OUTPUT								
Output Voltage	V_O							V
V_{in} = 14 V, I_O = 10 mA, T_J = 25°C		4.75	5.0	5.25	4.81	5.0	5.19	
V_{in} = 6.0 V to 26 V, $I_O \leq$ 100 mA, T_J = –40° to +125°C		4.50	–	5.50	4.75	–	5.25	
Line Regulation	Reg_{line}							mV
V_{in} = 9.0 V to 16 V		–	2.0	10	–	2.0	10	
V_{in} = 6.0 V to 26 V		–	4.0	30	–	4.0	30	
Load Regulation (I_O = 5.0 mA to 100 mA)	Reg_{load}	–	14	50	–	14	50	mV
Output Impedance	Z_O							mΩ
I_O = 10 mA, ΔI_O = 1.0 mA, f = 100 Hz to 10 kHz		–	200	–	–	200	–	
Bias Current	I_B							mA
V_{in} = 14 V, I_O = 100 mA, T_J = 25°C		–	5.8	30	–	5.8	30	
V_{in} = 6.0 V to 26 V, I_O = 10 mA, T_J = –40° to +125°C		–	0.4	1.0	–	0.4	1.0	
Output Noise Voltage (f = 10 Hz to 100 kHz)	V_n	–	700	–	–	700	–	μVrms
Long Term Stability	S	–	20	–	–	20	–	mV/kHR
Ripple Rejection (f = 120 Hz)	RR	60	90	–	60	90	–	dB
Dropout Voltage	V_I–V_O							V
I_O = 10 mA		–	0.015	0.2	–	0.015	0.2	
I_O = 100 mA		–	0.16	0.6	–	0.16	0.6	
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 V)	$–V_O$	–0.3	0	–	–0.3	0	–	V

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

ELECTRICAL CHARACTERISTICS (V_{in} = 14 V, I_O = 10 mA, C_O = 100 µF, $C_{O(ESR)}$ = 0.3 Ω, T_J = 25°C [Note 5])

Characteristic	Symbol	LM2931C Min	LM2931C Typ	LM2931C Max	LM2931AC Min	LM2931AC Typ	LM2931AC Typ	Unit
ADJUSTABLE OUTPUT								
Reference Voltage (Note 6., Figure 18)	V_{ref}							V
I_O = 10 mA, T_J = 25°C		1.14	1.20	1.26	1.17	1.20	1.23	
I_O ≤ 100 mA, T_J = –40 to +125°C		1.08	–	1.32	1.15	–	1.25	
Output Voltage Range	$V_{O\ range}$	3.0 to 24	2.7 to 29.5	–	3.0 to 24	2.7 to 29.5	–	V
Line Regulation (V_{in} = V_O + 0.6 V to 26 V)	Reg_{line}	–	0.2	1.5	–	0.2	1.5	mV/V
Load Regulation (I_O = 5.0 mA to 100 mA)	Reg_{load}	–	0.3	1.0	–	0.3	1.0	%/V
Output Impedance	Z_O							mΩ/V
I_O = 10 mA, ΔI_O = 1.0 mA, f = 10 Hz to 10 kHz		–	40	–	–	40	–	
Bias Current	I_B							mA
I_O = 100 mA		–	6.0	–	–	6.0	–	
I_O = 10 mA		–	0.4	1.0	–	0.4	1.0	
Output Inhibited ($V_{th(OI)}$ = 2.5 V)		–	0.2	1.0	–	0.2	1.0	
Adjustment Pin Current	I_{Adj}	–	0.2	–	–	0.2	–	µA
Output Noise Voltage (f = 10 Hz to 100 kHz)	V_n	–	140	–	–	140	–	µVrms/V
Long–Term Stability	S	–	0.4	–	–	0.4	–	%/kHR
Ripple Rejection (f = 120 Hz)	RR	0.10	0.003	–	0.10	0.003	–	%/V
Dropout Voltage	V_I–V_O							V
I_O = 10 mA		–	0.015	0.2	–	0.015	0.2	
I_O = 100 mA		–	0.16	0.6	–	0.16	0.6	
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 V)	$-V_O$	–0.3	0	–	–0.3	0	–	V
Output Inhibit Threshold Voltages	$V_{th(OI)}$							V
Output "On": T_J = 25°C		–	2.15	1.90	–	2.15	1.90	
T_J = –40° to +125°C		–	–	1.20	–	–	1.20	
Output "Off": T_J = 25°C		2.50	2.26	–	2.50	2.26	–	
T_J = –40° to +125°C		3.25	–	–	3.25	–	–	
Output Inhibit Threshold Current ($V_{th(OI)}$ = 2.5 V)	$I_{th(OI)}$	–	30	50	–	30	50	µA

5. Low duty cycle pulse techniques are used during test to maintain junction temperature as close to ambient as possible.
6. The reference voltage on the adjustable device is measured from the output to the adjust pin across R_1.

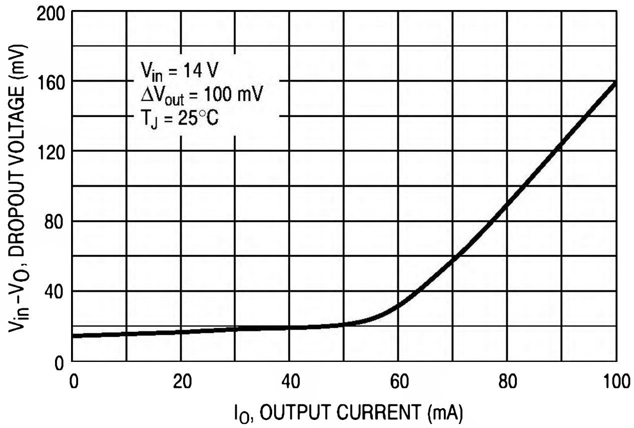


Figure 1. Dropout Voltage versus Output Current

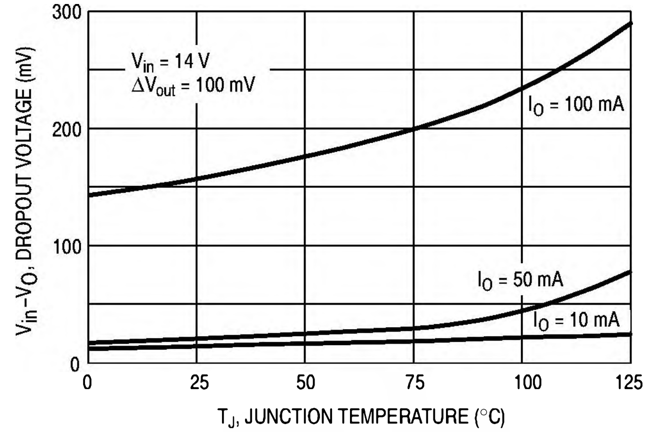


Figure 2. Dropout Voltage versus Junction Temperature

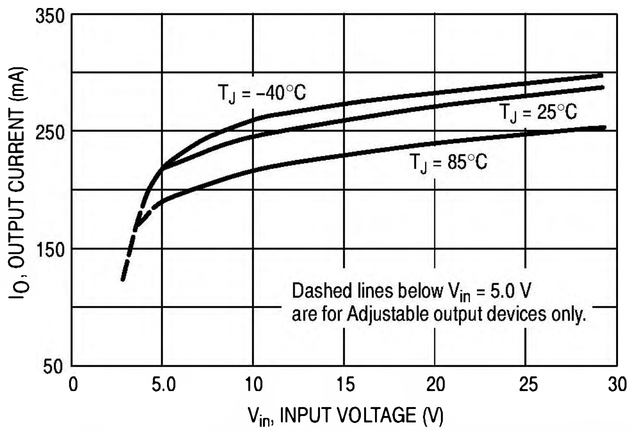


Figure 3. Peak Output Current versus Input Voltage

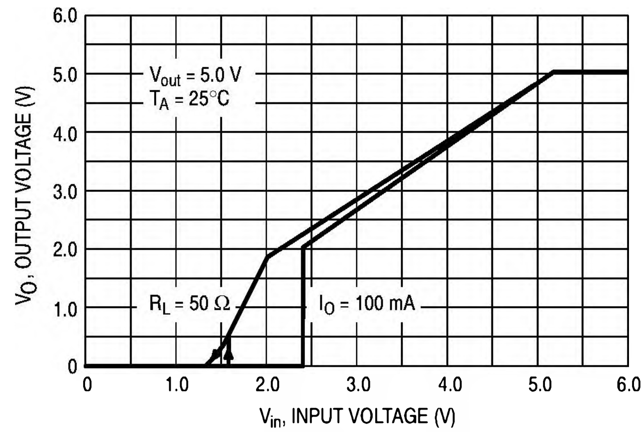


Figure 4. Output Voltage versus Input Voltage

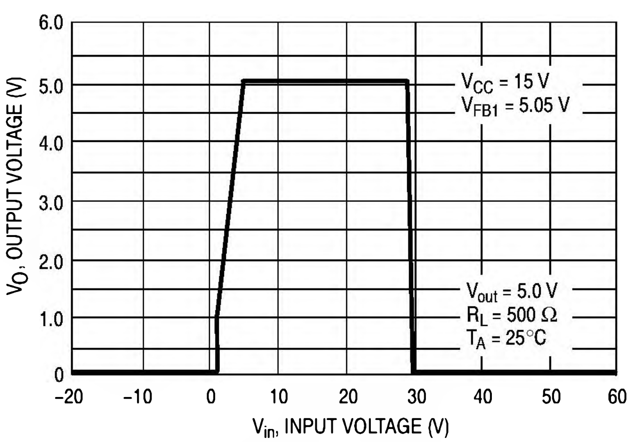


Figure 5. Output Voltage versus Input Voltage

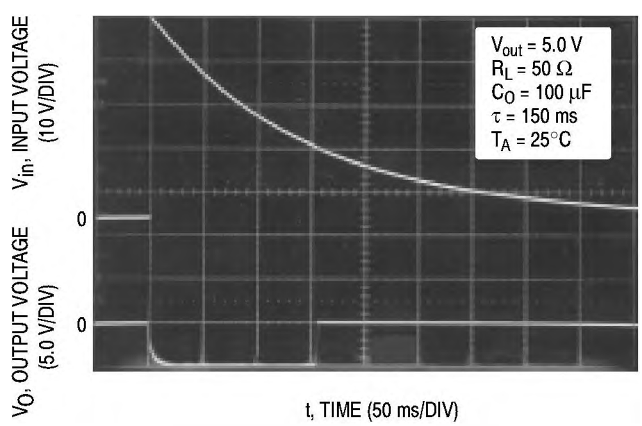


Figure 6. Load Dump Characteristics

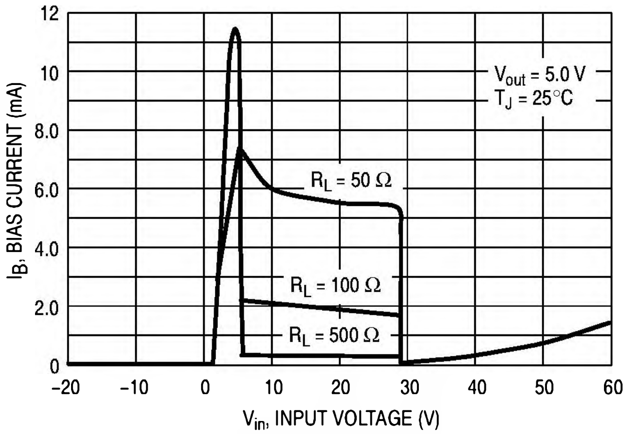


Figure 7. Bias Current versus Input Voltage

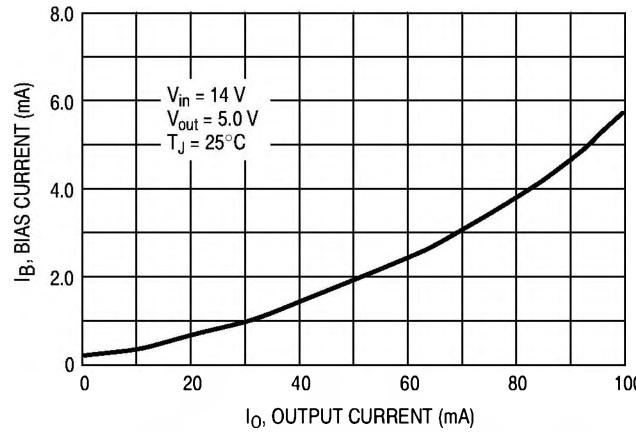


Figure 8. Bias Current versus Output Current

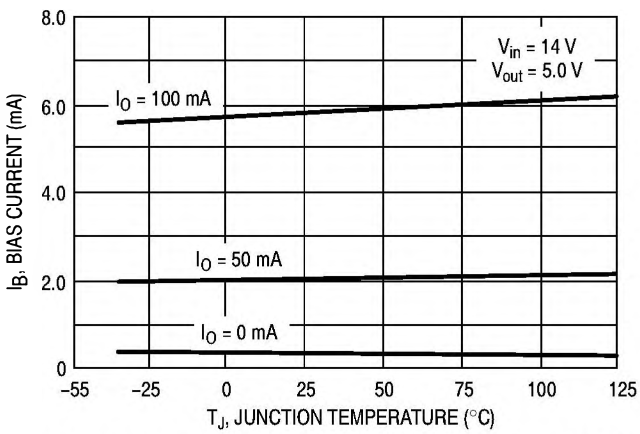


Figure 9. Bias Current versus Junction Temperature

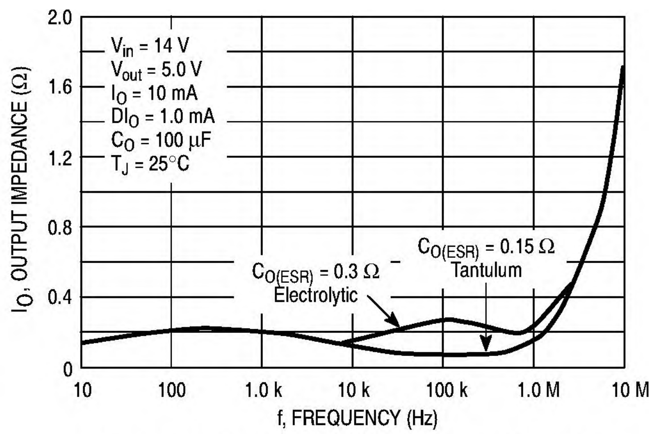


Figure 10. Output Impedance versus Frequency

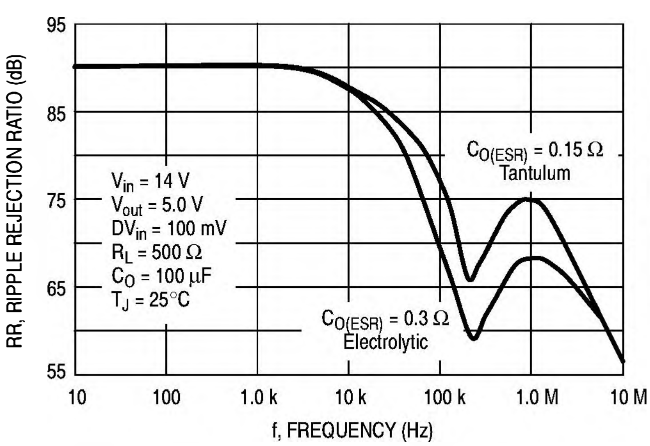


Figure 11. Ripple Rejection versus Frequency

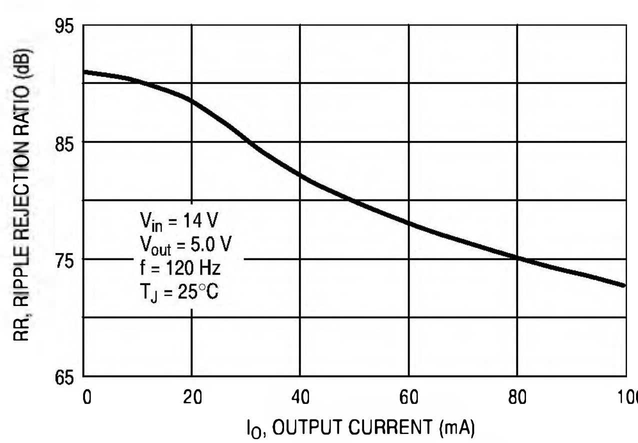


Figure 12. Ripple Rejection versus Output Current

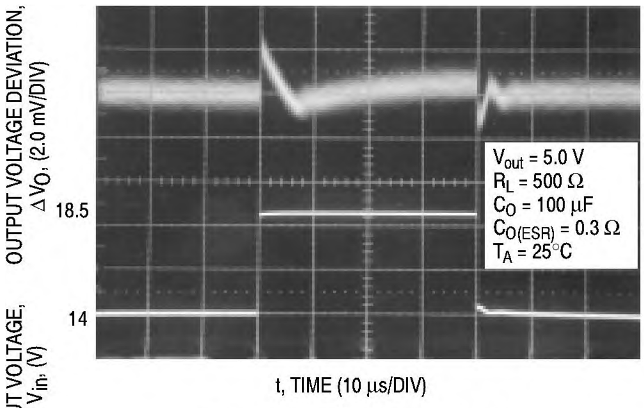


Figure 13. Line Regulation

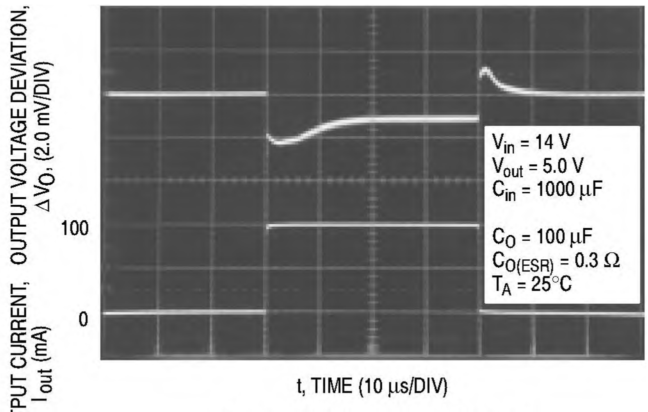


Figure 14. Load Regulation

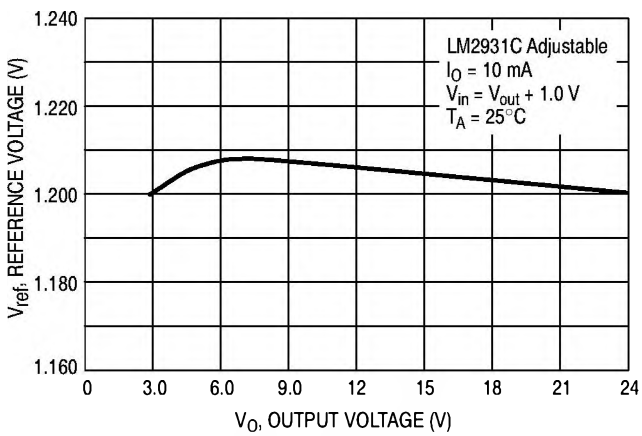


Figure 15. Reference Voltage versus Output Voltage

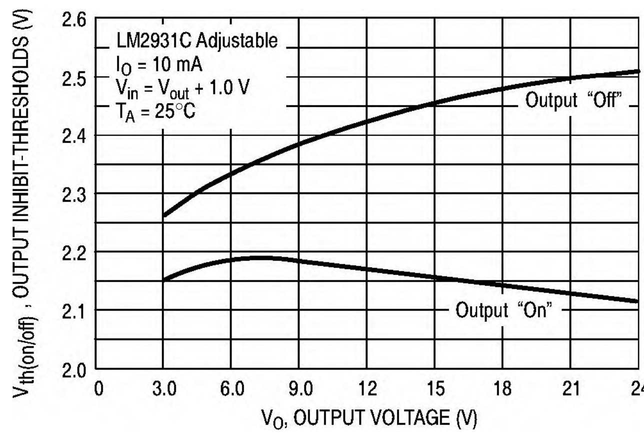


Figure 16. Output Inhibit–Thresholds versus Output Voltage

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 (≥ 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 Ω. 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°C and –55° to +105°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.

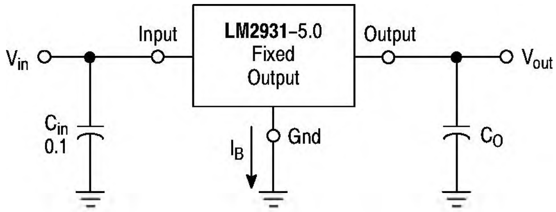
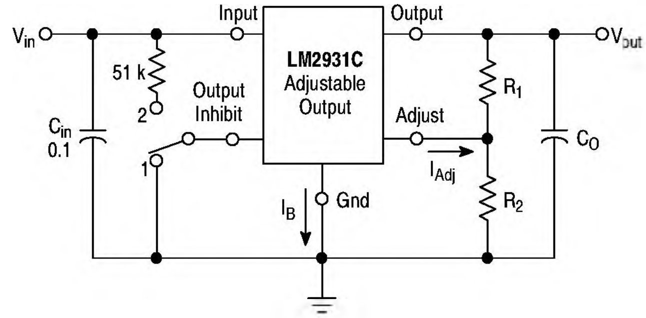


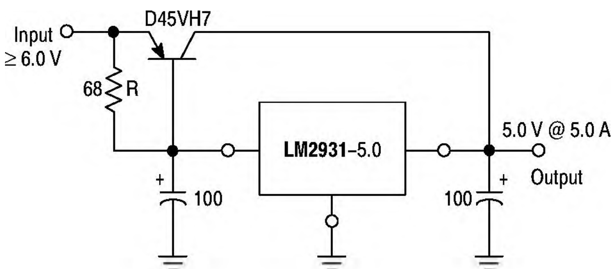
Figure 17. Fixed Output Regulator



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

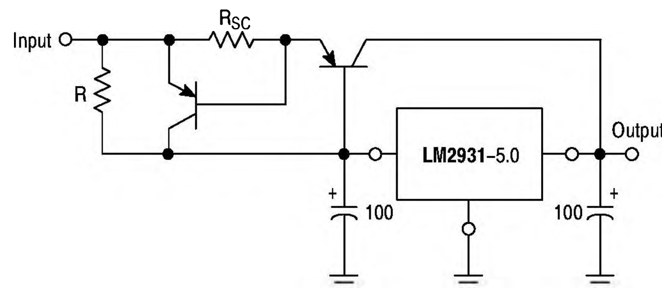
$$V_{out} = V_{ref}\left(1 + \frac{R_2}{R_1}\right) + I_{Adj} R_2 \qquad 22.5\text{ k} \geq \frac{R_1 R_2}{R_1 + R_2}$$

Figure 18. Adjustable Output 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 19. (5.0 A) Low Differential Voltage Regulator



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 20. Current Boost Regulator with Short Circuit Projection

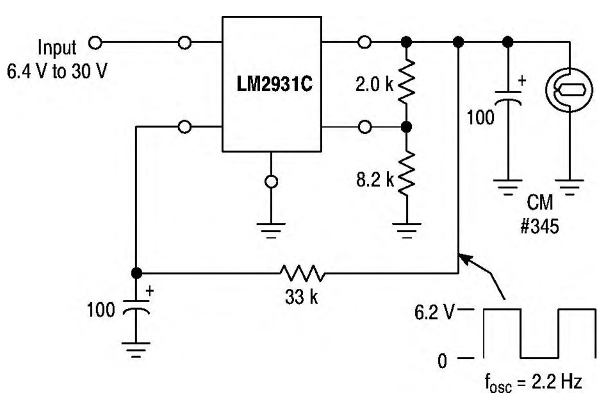


Figure 21. Constant Intensity Lamp Flasher

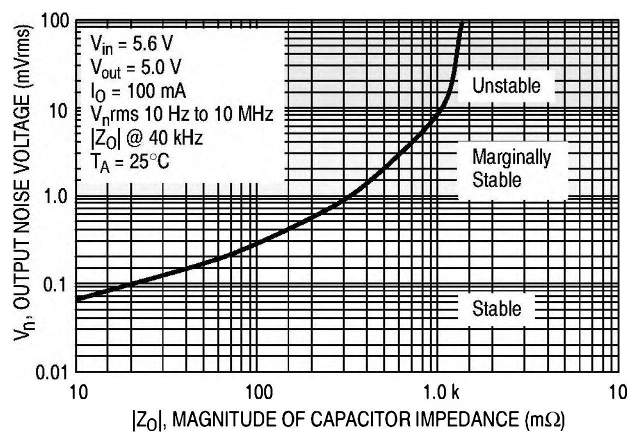


Figure 22. Output Noise Voltage versus Output Capacitor Impedance

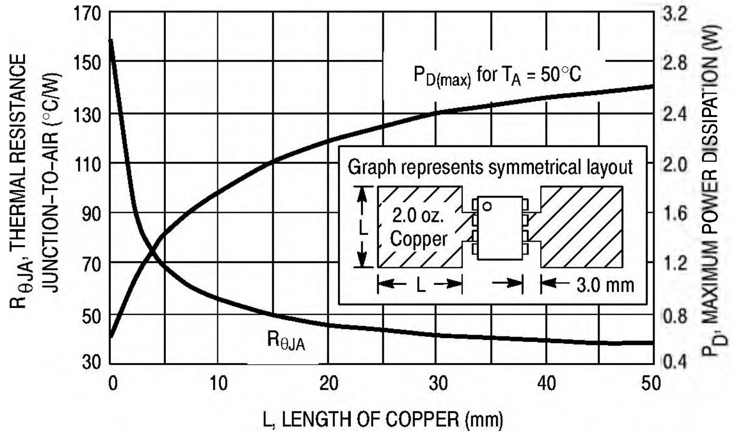


Figure 23. SOP−8 Thermal Resistance and Maximum Power Dissipation versus P.C.B. Copper Length

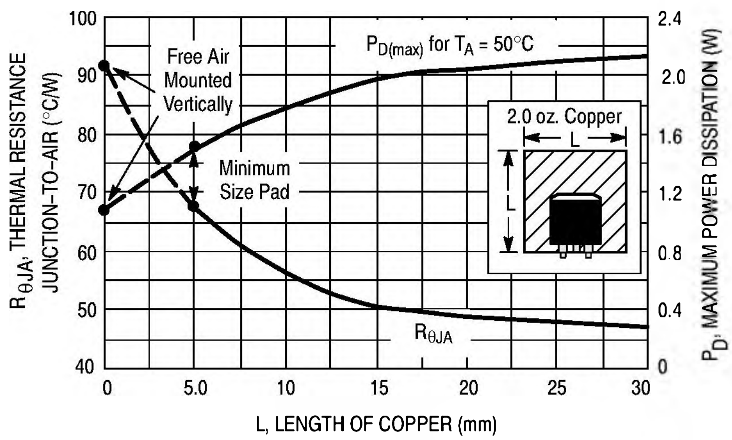


Figure 24. DPAK Thermal Resistance and Maximum Power Dissipation versus P.C.B. Copper Length

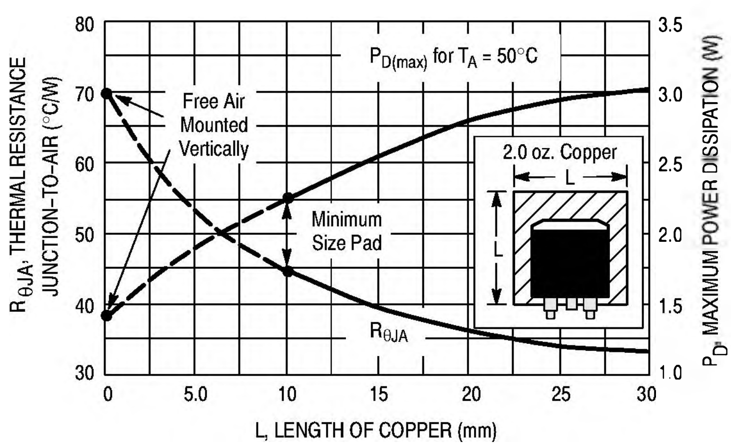


Figure 25. 3−Pin and 5−Pin D^{2}PAK Thermal Resistance and Maximum Power Dissipation versus P.C.B. Copper Length

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.

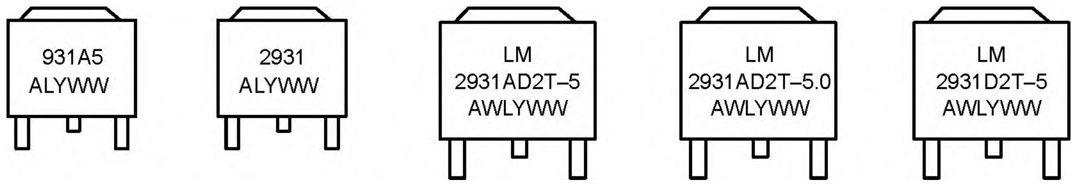
Long–Term Stability – Output voltage stability under accelerated life test conditions with the maximum rated voltage listed in the devices electrical characteristics and maximum power dissipation.

ORDERING INFORMATION

Device	Output Voltage	Output Tolerance	Package	Shipping
LM2931AD–5.0	5.0 V	±3.8%	SOIC–8	98 Units/Rail
LM2931AD–5.0R2			SOIC–8	2500 Tape & Reel
LM2931ADT–5.0			DPAK	75 Units/Rail
LM2931ADT–5.0RK			DPAK	2500 VacPk Reel
LM2931AD2T–5.0			D^2PAK	50 Units/Rail
LM2931AD2T–5.0R4			D^2PAK	800 VacPk Reel
LM2931AT–5.0			TO–220	50 Units/Rail
LM2931AZ–5.0			TO–92	2000/Inner Bag
LM2931AZ–5.0RA			TO–92	2000 Tape & Reel
LM2931AZ–5.0RP			TO–92	2000/Ammo Pack
LM2931D–5.0		±5.0%	SOIC–8	98 Units/Rail
LM2931D–5.0R2			SOIC–8	2500 Tape & Reel
LM2931D2T–5.0			D^2PAK	50 Units/Rail
LM2931D2T–5.0R4			D^2PAK	800 VacPk Reel
LM2931DT–5.0			DPAK	75 Units/Rail
LM2931T–5.0			TO–220	50 Units/Rail
LM2931Z–5.0			TO–92	2000/Inner Bag
LM2931Z–5.0RA			TO–92	2000 Tape & Reel
LM2931Z–5.0RP			TO–92	2000/Ammo Pack
LM2931CD	Adjustable		SOIC–8	98 Units/Rail
LM2931CDR2			SOIC–8	2500 Tape & Reel
LM2931CD2T			D^2PAK	50 Units/Rail
LM2931CD2TR4			D^2PAK	800 VacPk Reel
LM2931CT			TO–220	50 Units/Rail
LM2931ACD		±2.0%	SOIC–8	98 Units/Rail
LM2931ACDR2			SOIC–8	2500 Tape & Reel
LM2931ACD2TR4			D^2PAK	800 VacPk Reel
LM2931ACTV			TO–220	50 Units/Rail

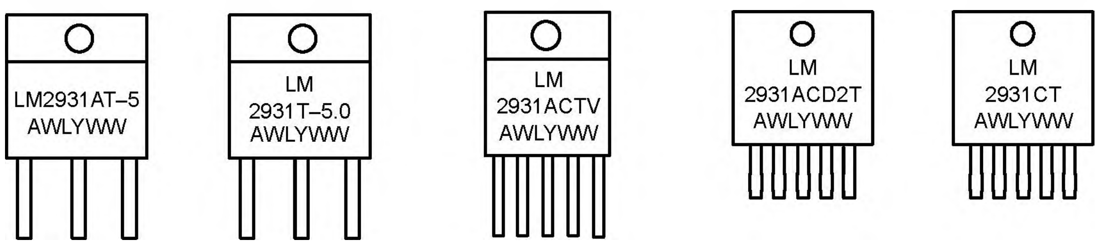
MARKING DIAGRAMS

DPAK DT SUFFIX CASE 369A | **DPAK DT SUFFIX CASE 369A** | **D2PAK D2T SUFFIX CASE 936** | **D2PAK D2T SUFFIX CASE 936** | **D2PAK D2T SUFFIX CASE 936**



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

TO–220 T SUFFIX CASE 221A | **TO–220 T SUFFIX CASE 221A** | **TO–220 T SUFFIX CASE 314D** | **D2PAK D2T SUFFIX CASE 936A** | **D2PAK D2T SUFFIX CASE 936A**

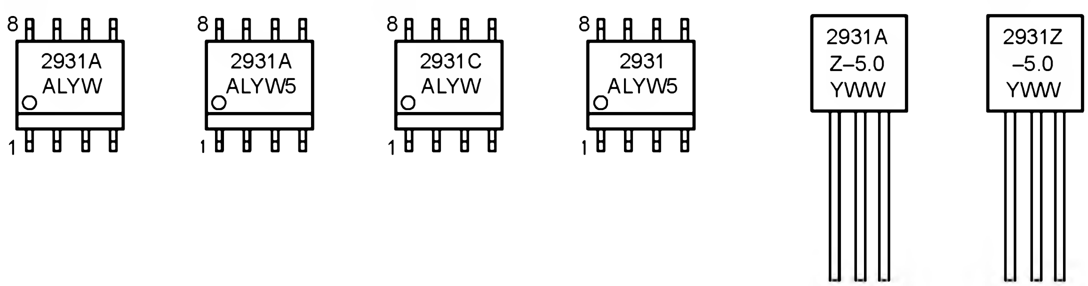


Heatsink surface connected to Pin 2.

Heatsink surface connected to Pin 3.

Heatsink surface (shown as terminal 6 in case outline drawing) is connected to Pin 3.

SO–8 D SUFFIX CASE 751 | **SO–8 D SUFFIX CASE 751** | **SO–8 D SUFFIX CASE 751** | **SO–8 D SUFFIX CASE 751** | **TO–92 Z SUFFIX CASE 029** | **TO–92 Z SUFFIX CASE 029**



A = Assembly Location
WL, L = Wafer Lot
YY, Y = Year
WW, W = Work Week