

LOW DROPOUT REGULATORS

FEATURES

- Low Quiescent Bias Current of 75 μ A
- Low Input-to-Output Voltage Differential of 50mV at 100 μ A and 380mV at 100mA
- 5.0V, 3.3V or 3.0V \pm 0.5% Allows Use as a Regulator or Reference
- Extremely Tight Line and Load Regulation
- Requires Only a 1.0 μ F Output Capacitor for Stability
- Internal Current and Thermal Limiting TC2951
- $\overline{\text{ERROR}}$ Output Signals an Out of Regulation Condition
- Output Programmable from 1.25V to 29V
- Logic Level Shutdown Input

ORDERING INFORMATION

Part Number	Package	Temperature Range
TC2950-3.0VVB	3-Pin DPAK	-40° to +125°C
TC2950-3.3VVB	3-Pin DPAK	-40° to +125°C
TC2950-5.0VVB	3-Pin DPAK	-40° to +125°C
TC2951-3.0VOA	8-Pin SOIC (Narrow)	-40° to +125°C
TC2951-3.3VOA	8-Pin SOIC (Narrow)	-40° to +125°C
TC2951-VOA*	8-Pin SOIC (Narrow)	-40° to +125°C
TC2951A-VOA*	8-Pin SOIC (Narrow)	-40° to +125°C

*Note: Contact company about other voltage and package options. This indicates adjustable version.

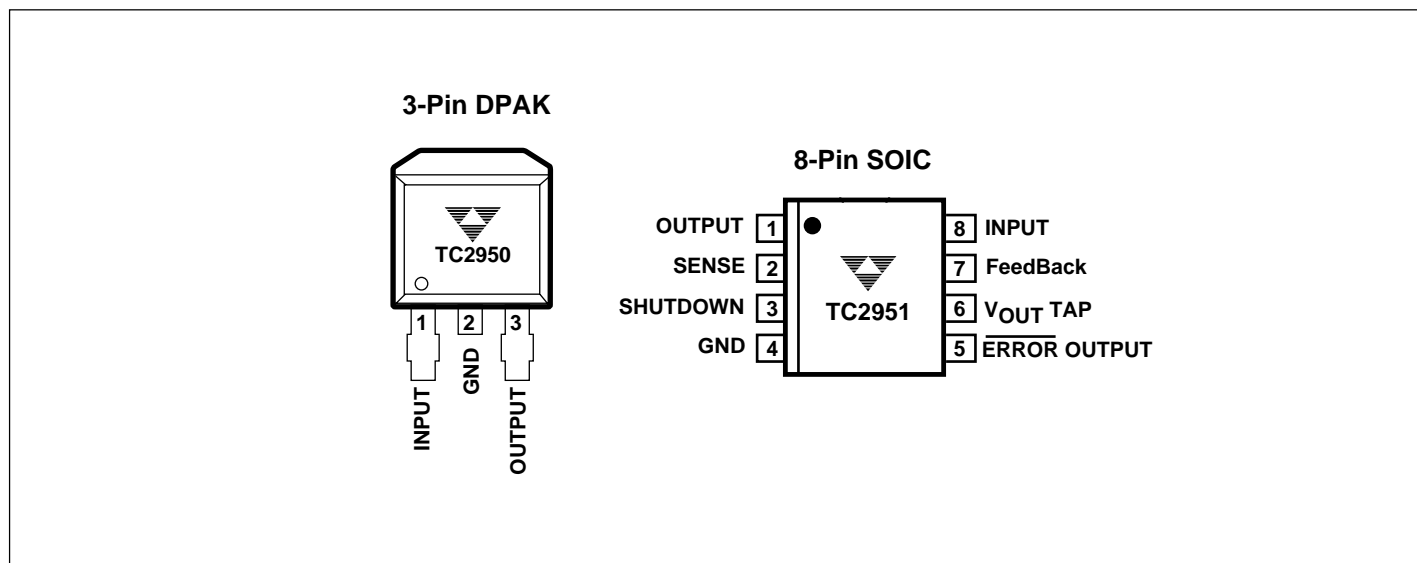
GENERAL DESCRIPTION

The TC2950 and TC2951 are micropower voltage regulators that are specifically designed to maintain proper regulation with an extremely low input-to-output voltage differential. These devices feature a very low quiescent bias current of 75 μ A and are capable of supplying output currents in excess of 100mA. Internal current and thermal limiting protection is provided.

The TC2951 has three additional features. The first is the $\overline{\text{ERROR}}$ Output that can be used to signal external circuitry of an out of regulation condition, or as a microprocessor power-on reset. The second feature allows the output voltage to be preset to 5.0V, 3.3V or 3.0V output (depending on the version) or programmed from 1.25V to 29V. It consists of a pinned out resistor divider along with direct access to the $\overline{\text{ERROR}}$ Amplifier feedback input. The third feature is a Shutdown input that allows a logic level signal to turn-off or turn-on the regulator output.

Due to the low input-to-output voltage differential and bias current specifications, these devices are ideally suited for battery powered computer, consumer, and industrial equipment where an extension of useful battery life is desirable. The TC2950 is available in a 3-Pin DPAK, and the TC2951 is available in a 8-Pin SOIC package.

PIN CONFIGURATIONS



TC2950 TC2951

ABSOLUTE MAXIMUM RATINGS*

Input Voltage	$V_{CC} = 30$
Max Power Dissipation.....	(Internally Limited)
	(8-Pin SOIC)
Thermal Resistance, Junction-to-Ambient ...	180°C/W
Thermal Resistance, Junction-to-Case	45°C/W
	(3-Pin DPAK)
Thermal Resistance, Junction-to-Ambient	92°C/W
Thermal Resistance, Junction-to-Case	6.0°C/W

Feedback Input Voltage	-1.5 to +30V
Shutdown Input Voltage	-0.3 to +30V
Error Comparator Output Voltage	-0.3 to +30V
Operating Junction Temperature	-40° to +125°C
Storage Temperature Range	-65°C to +150°C

*This is a stress rating only, and functional operation of the device at these or any other conditions beyond those indicated in the operation section of the specifications is not implied. Exposure to absolute maximum ratings conditions for extended periods of time may affect device reliability.

- NOTE: 1. The Junction-to-Ambient Thermal Resistance is determined by
PC board copper area per Figure 26.
2. ESD data available upon request.

ELECTRICAL CHARACTERISTICS ($V_{IN} = V_{OUT} + 1.0V$, $I_O = 100\mu A$, $C_O = 1.0\mu F$, $T_J = 25^\circ C$ [Note 1], unless otherwise noted.)

Symbol	Parameter	Device	Test Conditions	Min	Typ	Max	Units
V_{OUT}	Output Voltage, 5.0V Versions	TC2950	$V_{IN} = 6.0V$, $I_{OUT} = 100\mu A$, $T_J = 25^\circ C$	4.950	5.000	5.050	V
		TC2950	$T_J = -40$ to $+125^\circ C$	4.900	—	5.100	V
		TC2950	$V_{IN} = 6.0$ to $30V$, $I_O = 100\mu A$ to $100mA$, $T_J = -40$ to $+125^\circ C$	4.880	—	5.120	V
	Output Voltage, 3.3V Versions	TC2950/51	$V_{IN} = 4.3V$, $I_O = 100\mu A$, $T_J = 25^\circ C$	3.267	3.300	3.333	V
		TC2950/51	$T_J = -40$ to $+125^\circ C$	3.234	—	3.366	V
		TC2950/51	$V_{IN} = 4.3V$ to $30V$, $I_{OUT} = 100\mu A$ to $100mA$, $T_J = -40$ to $+125^\circ C$	3.221	—	3.379	V
	Output Voltage, 3.0V Versions	TC2950/51	$V_{IN} = 4.0V$, $I_O = 100\mu A$, $T_J = 25^\circ C$	2.970	3.000	3.030	V
		TC2950/51	$T_J = -40$ to $+125^\circ C$	2.940	—	3.060	V
		TC2950/51	$V_{IN} = 4.0$ to $30V$, $I_{OUT} = 100\mu A$ to $100mA$, $T_J = -40$ to $+125^\circ C$	2.928	—	3.072	V
REG_{LINE}	Line Regulation	TC2950/51	$V_{IN} = V_{OUT(nom)} + 1.0V$ to $30V$ [Note 2]	—	0.08	0.20	%
REG_{LOAD}	Line Regulation	TC2950/51	($I_{OUT} = 100\mu A$ to $100mA$)	—	0.13	0.20	%
$V_I - V_O$	Dropout Voltage		$I_{OUT} = 100\mu A$ $I_{OUT} = 100mA$	— —	30 350	80 450	mV
I_{CC}	Supply Bias Current		$I_{OUT} = 100\mu A$ $I_{OUT} = 100mA$	— —	93 4.0	120 12	μA mA
$I_{CC(dropout)}$	Dropout Supply Bias Current		$V_{IN} = V_{OUT(nom)} - 0.5V$, $I_{OUT} = 100\mu A$ [Note 2]	—	110	170	mA
I_{Limit}	Current Limit		V_{OUT} Shorted to Ground	—	220	300	mA
$REG_{thermal}$	Thermal Regulation			—	0.05	0.20	%/W
V_N	Output Noise Voltage		10Hz to 100kHz [Note 3]				μV_{rms}
			$C_L = 1.0\mu F$	—	126	—	
			$C_L = 100\mu F$	—	56	—	

- NOTES: 1. Low duty pulse techniques are used during test to maintain junction temperature as close to ambient as possible.
2. $V_{OUT(nom)}$ is the part number voltage option.
3. Noise tests on the TC2951 are made with a 0.01 μF capacitor connected across Pins 7 and 1.

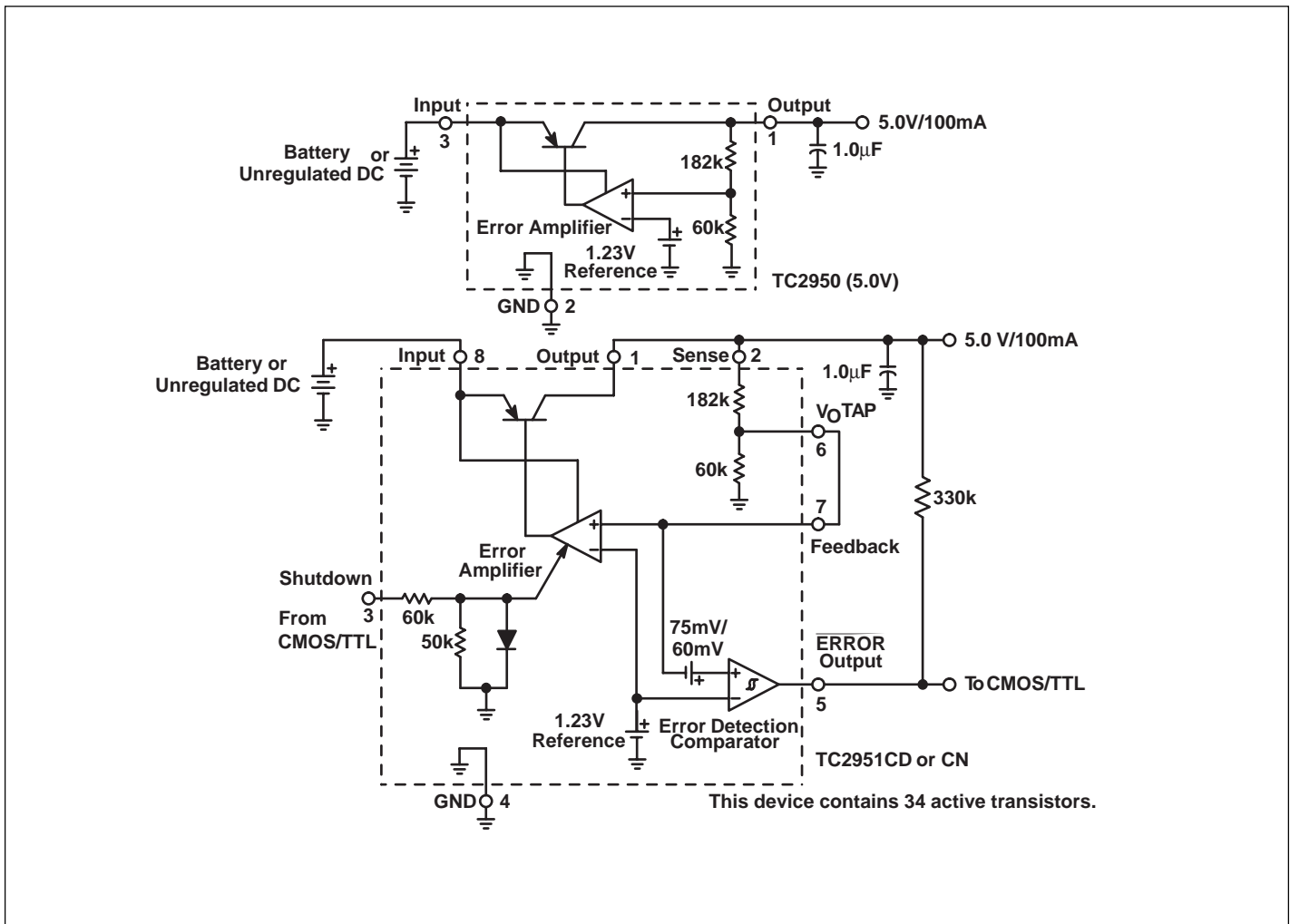
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ELECTRICAL CHARACTERISTICS (Cont.) ($V_{IN} = V_{OUT} + 1.0V$, $I_O = 100\mu A$, $C_O = 1.0\mu F$, $T_J = 25^\circ C$ [Note 1], unless otherwise noted.)

Symbol	Parameter	Device	Test Conditions	Min	Typ	Max	Units
ERROR COMPARATOR							
I_{LKG}	Output Leakage Current		$V_{OH} = 30V$	—	0.01	1.0	μA
V_{OL}	Output Low Voltage		$V_{IN} = 4.5V$, $I_{OL} = 400\mu A$	—	150	250	mV
V_{THU}	Upper Threshold Voltage		$V_{IN} = 6.0V$	40	45	—	mV
V_{THL}	Lower Threshold Voltage		$V_{IN} = 6.0V$	—	60	95	mV
V_{HY}	Hysteresis		$V_{IN} = 6.0V$	—	15	—	mV
SHUTDOWN INPUT							
V_{SHTDN}	Input Logic Voltage		Logic "0" (Regulator "On") Logic "1" (Regulator "Off")	0 2.0	— —	0.7 30	V
I_{SHTDN}	Shutdown Pin Input Current		$V_{SHTDN} = 2.4V$ $V_{SHTDN} = 30V$	— —	35 450	50 600	μA
I_{OFF}	Regulator Output Current in Shutdown Mode		$V_{IN} = 30V$, $V_{SHTDN} = 2.0V$, $V_O = 0$, Pin 6 Connected to Pin 7)	—	3.0	10	μA

REPRESENTATIVE BLOCK DIAGRAMS



TC2950 TC2951

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 drops 100mV below its nominal value (which is measured at 1.0V differential), dropout voltage is affected by junction temperature, load current and minimum input supply requirements.

Line Regulation

The change in output voltage for a change in input voltage. The measurement is made under conditions of low dissipation or by using pulse techniques such that 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

Current which is used to operate the regulator chip and 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.

Leakage Current

Current drawn through a bipolar transistor collector-base junction, under a specified collector voltage, when the transistor is "off".

Upper Threshold Voltage

Voltage applied to the comparator input terminal, below the reference voltage which is applied to the other comparator input terminal, which causes the comparator output to change state from a logic "0" to "1".

Lower Threshold Voltage

Voltage applied to the comparator input terminal, below the reference voltage which is applied to the other comparator input terminal, which causes the comparator output to change state from a logic "1" to "0".

Hysteresis

The difference between Lower Threshold voltage and Upper Threshold voltage.

Figure 1. Quiescent Current

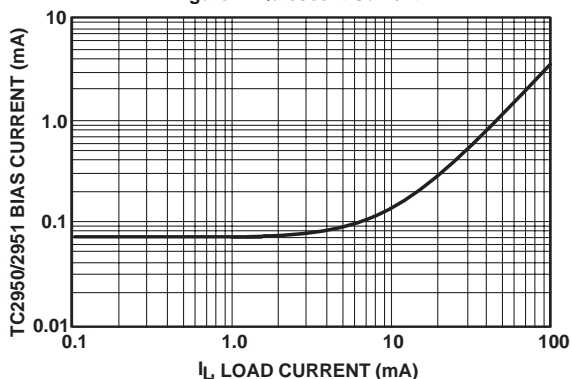


Figure 2. Dropout Characteristics

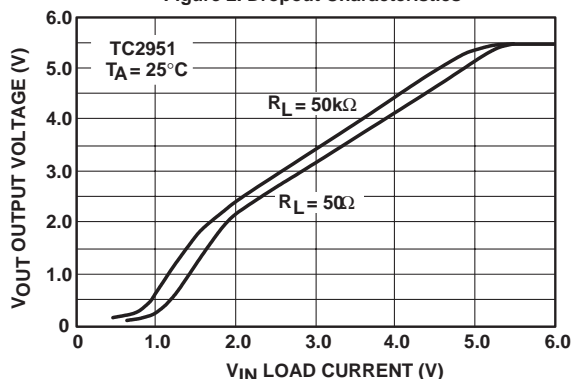


Figure 3. Input Current

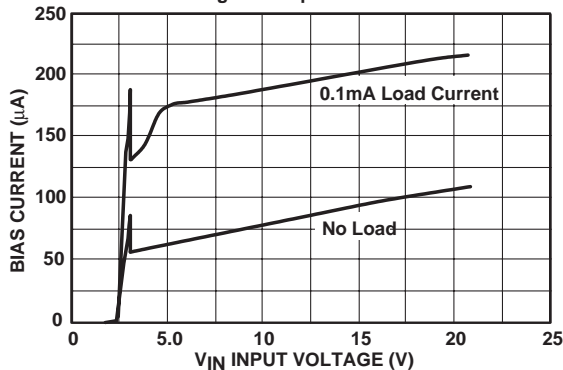
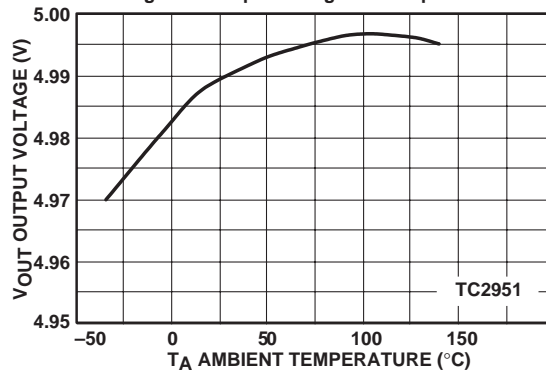


Figure 4. Output Voltage vs. Temperature



TYPICAL CHARACTERISTICS

Figure 5. Dropout Voltage vs. Output Current

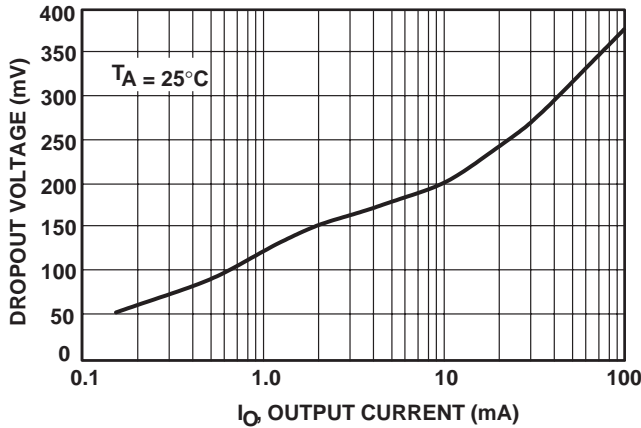


Figure 6. Dropout Voltage vs. Temperature

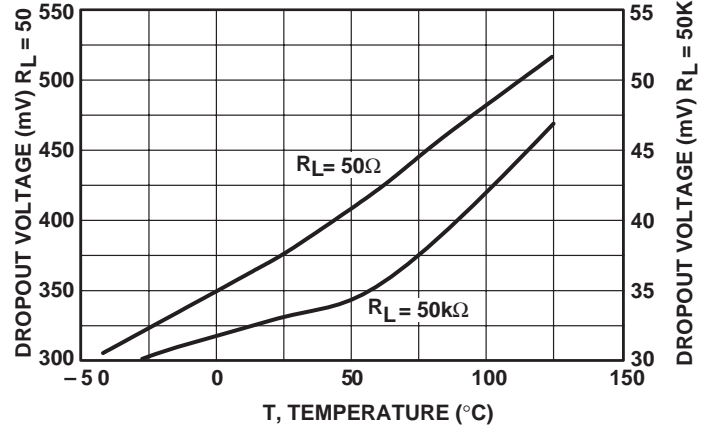


Figure 7. Error Comparator Output

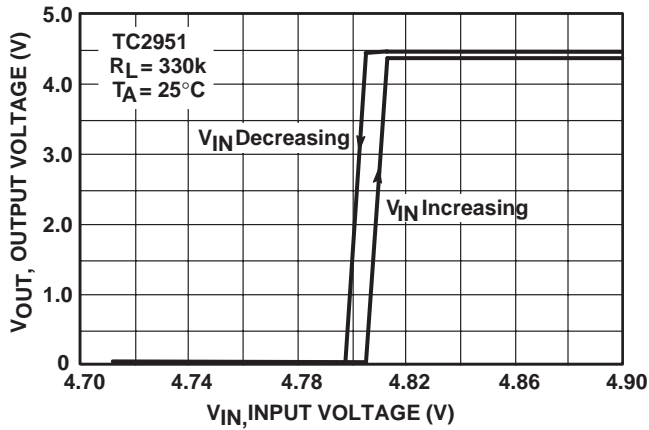


Figure 8. Line Transient Response

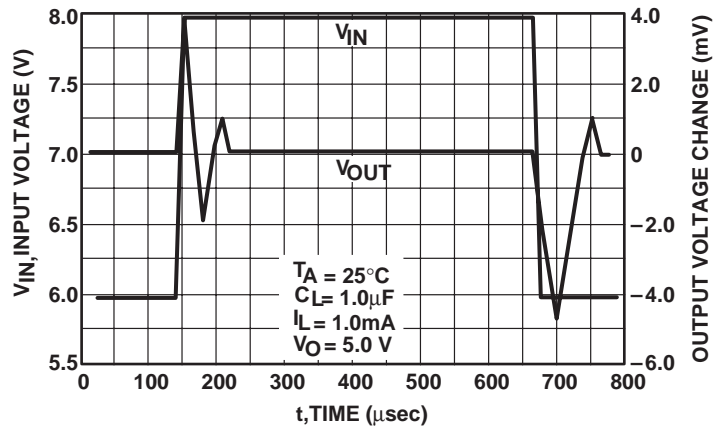


Figure 9. TC2951 Enable Transient

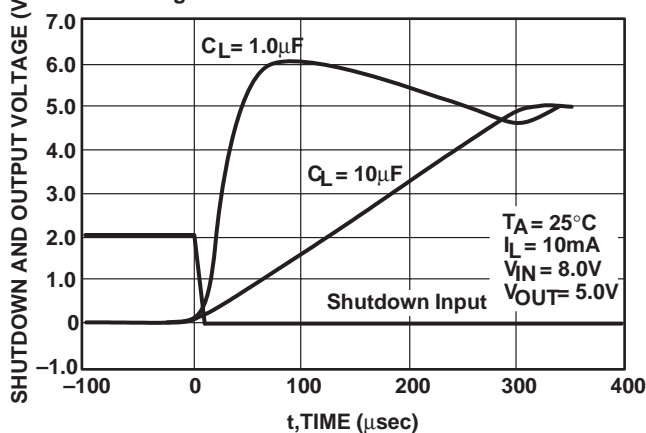
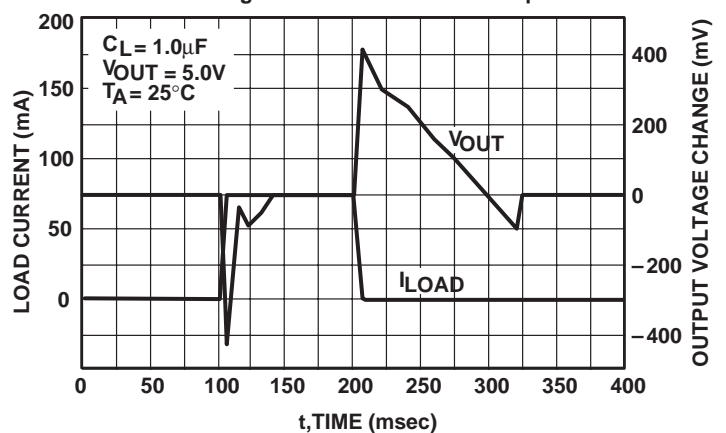


Figure 10. Load Transient Response



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TYPICAL CHARACTERISTICS

Figure 11. Ripple Rejection

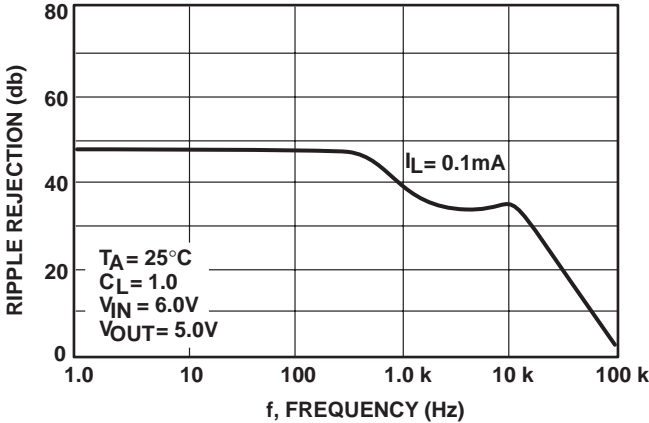


Figure 12. Output Noise

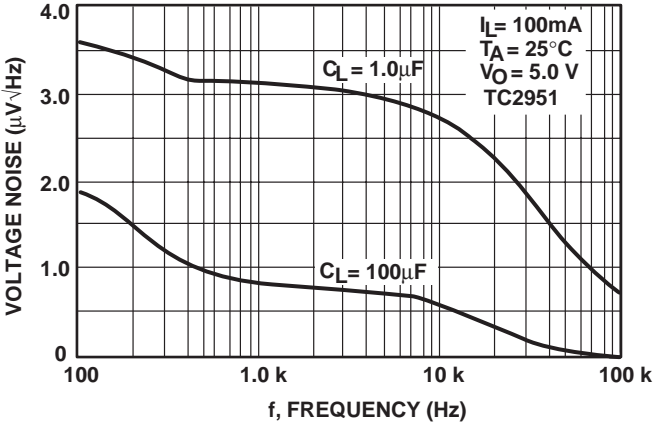


Figure 13. Shutdown Threshold Voltage vs. Temperature

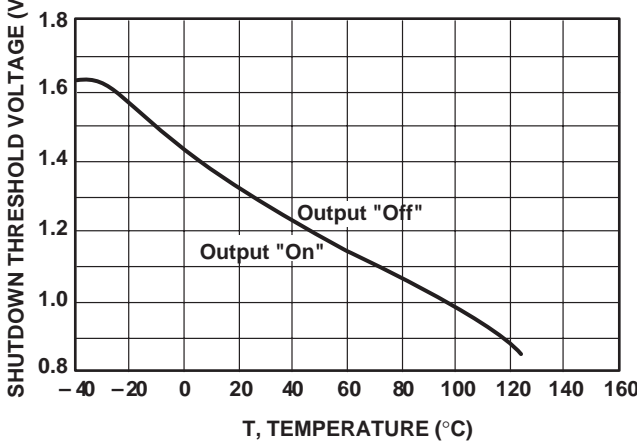
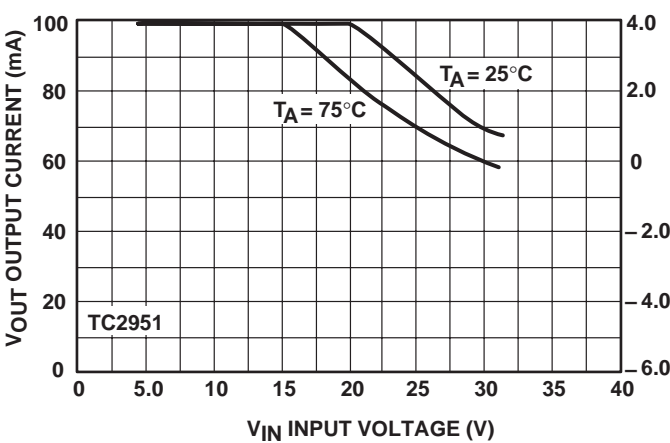


Figure 14. Maximum Rated Output Current



APPLICATIONS INFORMATION

INTRODUCTION

The TC2950/TC2951 regulators are designed with internal current limiting and thermal shutdown making them user-friendly. Typical application circuits for the TC2950 and TC2951 are shown in Figures 17 through 25.

These regulators are not internally compensated and thus require a 1.0 μ F (or greater) capacitance between the TC2950/TC2951 output terminal and ground for stability.

Most types of aluminum, tantalum or multilayer ceramic will perform adequately. Solid tantalums or appropriate multilayer ceramic capacitors are recommended for operation below 25°C.

At lower values of output current, less output capacitance is required for output stability. The capacitor can be reduced to 0.33 μ F for currents less than 10mA, or 0.1 μ F for currents/below 1.0 mA. Using the 8-pin versions at voltages less than 5.0 V operates the error amplifier at lower values of gain, so that more output capacitance is needed for stability. For the worst case operating condition of a 100 mA load at 1.23V output (Output Pin 1 connected to the feedback Pin 7) a minimum capacitance of 3.3 μ F is recommended.

The TC2950 will remain stable and in regulation when operated with no output load. When setting the output voltage of the TC2951 with external resistors, the resistance values should be chosen to draw a minimum of 1.0 μ A.

A bypass capacitor is recommended across the TC2950/TC2951 input to ground if more than 4 inches of wire connects the input to either a battery or power supply filter capacitor.

Input capacitance at the TC2951 Feedback Pin 7 can create a pole, causing instability if high value external resistors are used to set the output voltage. Adding a 100pF capacitor between the Output Pin 1 and the Feedback Pin 7 and increasing the output filter capacitor to at least 3.3 μ F will stabilize the feedback loop.

$\overline{\text{ERROR}}$ Detection Comparator

The comparator switches to a positive logic low whenever the TC2951 output voltage falls more than approximately 5.0% out of regulation. This value is the comparator's designed-in offset voltage of 60mV divided by the 1.235V internal reference. As shown in the representative block diagram. This trip level remains 5.0% below normal regardless of the value of regulated output voltage. For example, the error flag trip level is 4.75V for a normal 5.0V regulated output, or 9.50V for a 10V output voltage.

Figure 1 is a timing diagram which shows the $\overline{\text{ERROR}}$ signal and the regulated output voltage as the input voltage to the TC2951 is ramped up and down. The $\overline{\text{ERROR}}$ signal becomes valid (low) at about 1.3V input. It goes high when

the input reaches about 5.0V (V_{OUT} exceeds about 4.75 V). Since the TC2951's dropout voltage is dependent upon the load current (refer to the curve in the Typical Performance Characteristics), the input voltage trip point will vary with load current. The output voltage trip point does not vary with load.

The error comparator output is an open collector which requires an external pull-up resistor. This resistor may be returned to the output or some other voltage within the system. The resistance value should be chosen to be consistent with the 400 μ A sink capability of the error comparator. A value between 100k and 1.0M Ω is suggested. No pull-up resistance is required if this output is unused.

When operated in the shutdown mode, the error comparator output will go high if it has been pulled up to an external supply. To avoid this invalid response, the error comparator output should be pulled up to V_{OUT} (see Figure 15).

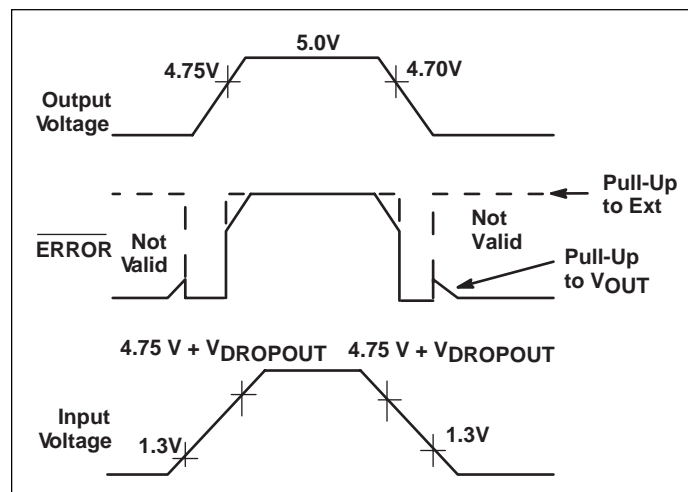


Figure 15. $\overline{\text{ERROR}}$ Output Timing

Programming the Output Voltage (TC2951)

The TC2951 may be pin-strapped for 5.0V using its internal voltage divider by tying Pin 1 (output) to Pin 2 (sense) and Pin 7 (feedback) to Pin 6 (5.0V tap). Alternatively, it may be programmed for any output voltage between its 1.235 reference voltage and its 30 V maximum rating. An external pair of resistors is required, as shown in Figure 16.

The complete equation for the output voltage is:

$$V_{\text{OUT}} = V_{\text{REF}} (1 + R1/R2) + I_{\text{FB}} R1$$

where V_{REF} is the nominal 1.235V reference voltage and I_{FB} is the feedback pin bias current, nominally -20nA. The minimum recommended load current of 1.0 μ A forces an upper limit of 1.2 M Ω on the value of R2, if the regulator must work with no load. I_{FB} will produce a 2% typical error in V_{OUT}

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which may be eliminated at room temperature by adjusting R1. For better accuracy, choosing R2 = 100k reduces this error to 0.17% while increasing the resistor program current to 12 μA. Since the TC2951 typically draws 75 μA at no load with Pin 2 open circuited, the extra 12 μA of current drawn is often a worthwhile tradeoff for eliminating the need to set output voltage in test.

Output Noise

In many applications it is desirable to reduce the noise present at the output. Reducing the regulator bandwidth by increasing the size of the output capacitor is the only method for reducing noise on the 3-Pin TC2950. However, increasing the capacitor from 1.0 μF to 220 μF only decreases the noise from 430 μV to 160 mV_{RMS} for a 100 kHz bandwidth at the 5.0V output. Noise can be reduced fourfold by a bypass capacitor across R1, since it reduces the high frequency gain from 4 to unity. Pick

$$C_{\text{Bypass}} \approx \frac{1}{2\pi R1 \times 200\text{Hz}}$$

or about 0.01 μF. When doing this, the output capacitor must be increased to 3.3 μF to maintain stability. These changes reduce the output noise from 430 μV to 126 μV_{RMS} for a 100 kHz bandwidth at 5.0V output. With bypass capacitor added, noise no longer scales with output voltage so that improvements are more dramatic at higher output voltages.

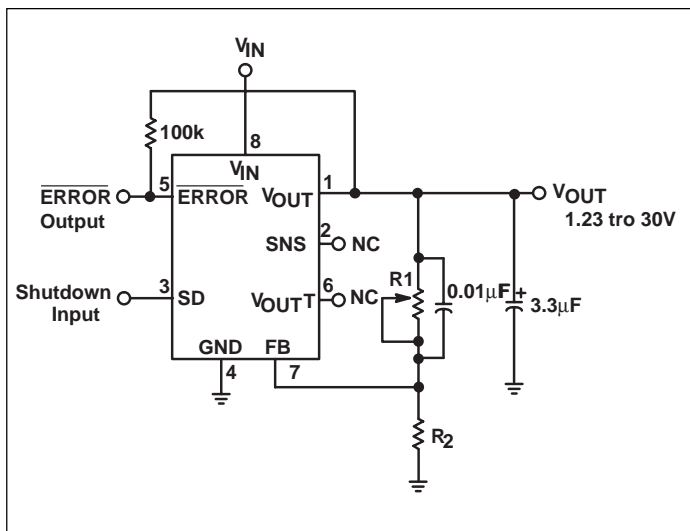


Figure 16. Adjustable Regulator

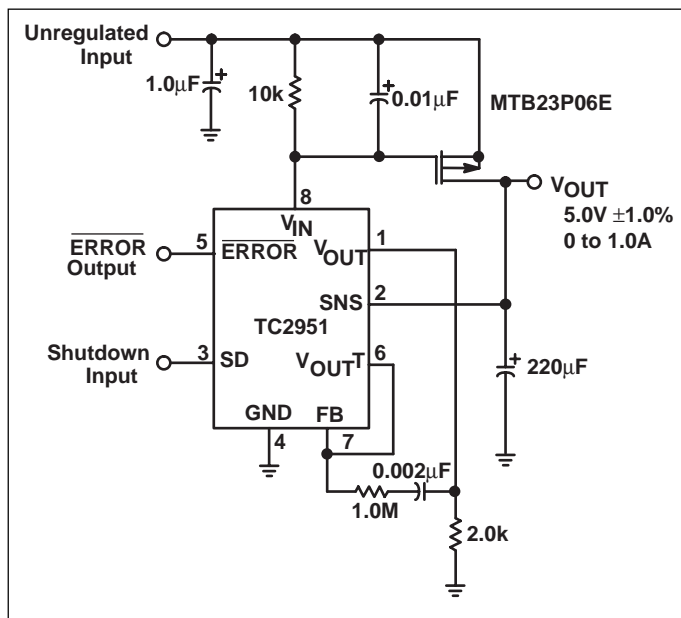


Figure 17. 1.0A Regulator with 1.2V Dropout

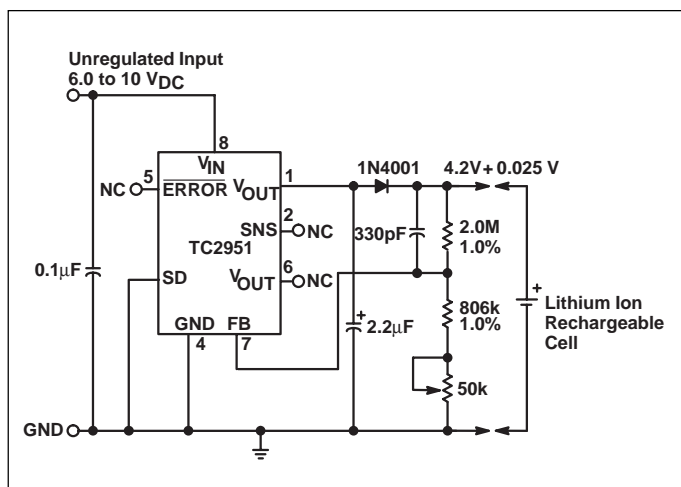


Figure 18. Lithium Ion Battery Cell Charger

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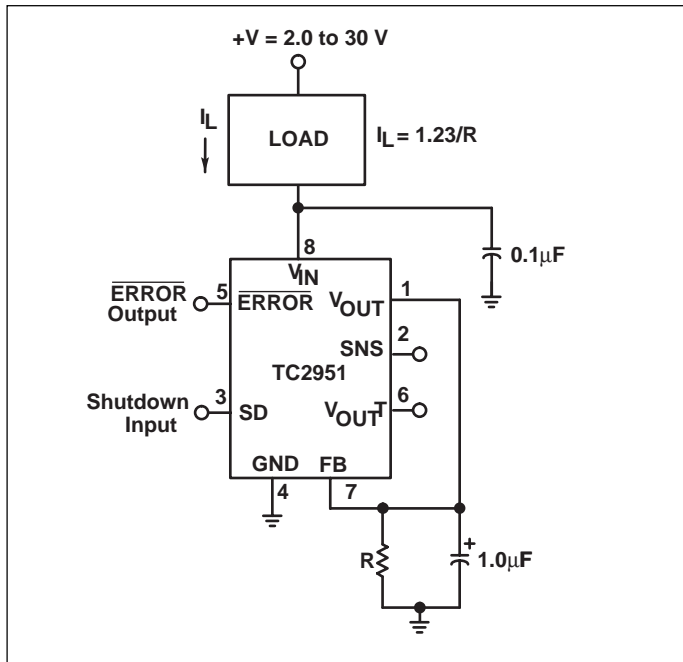


Figure 19. Low Drift Current Sink

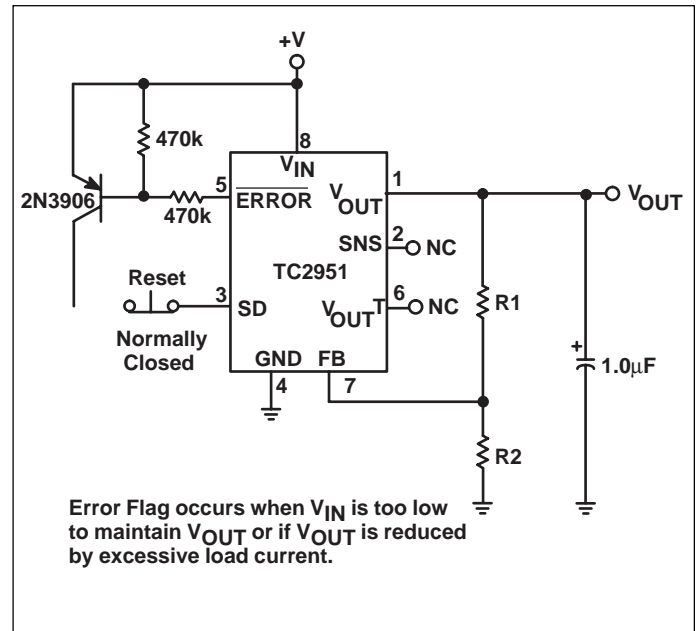


Figure 20. Latch Off When ERROR Flag Occurs

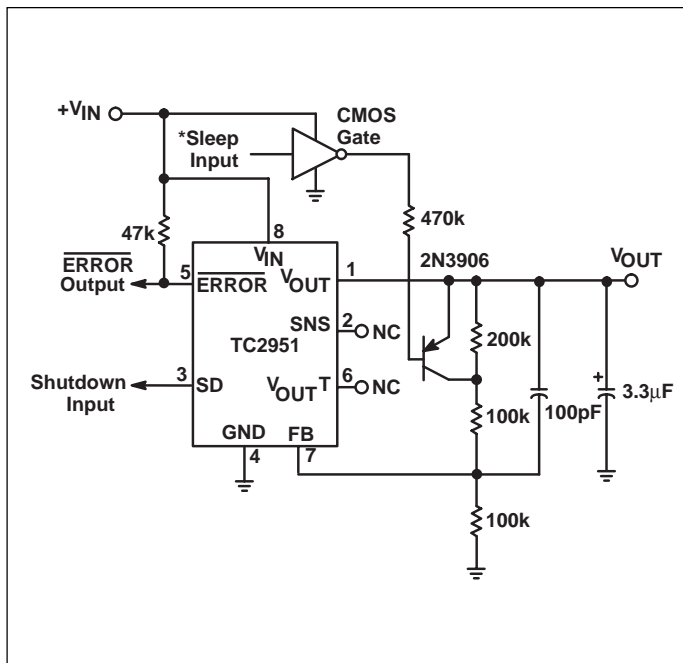


Figure 21. 5.0V Regulator with 2.5V Sleep Function

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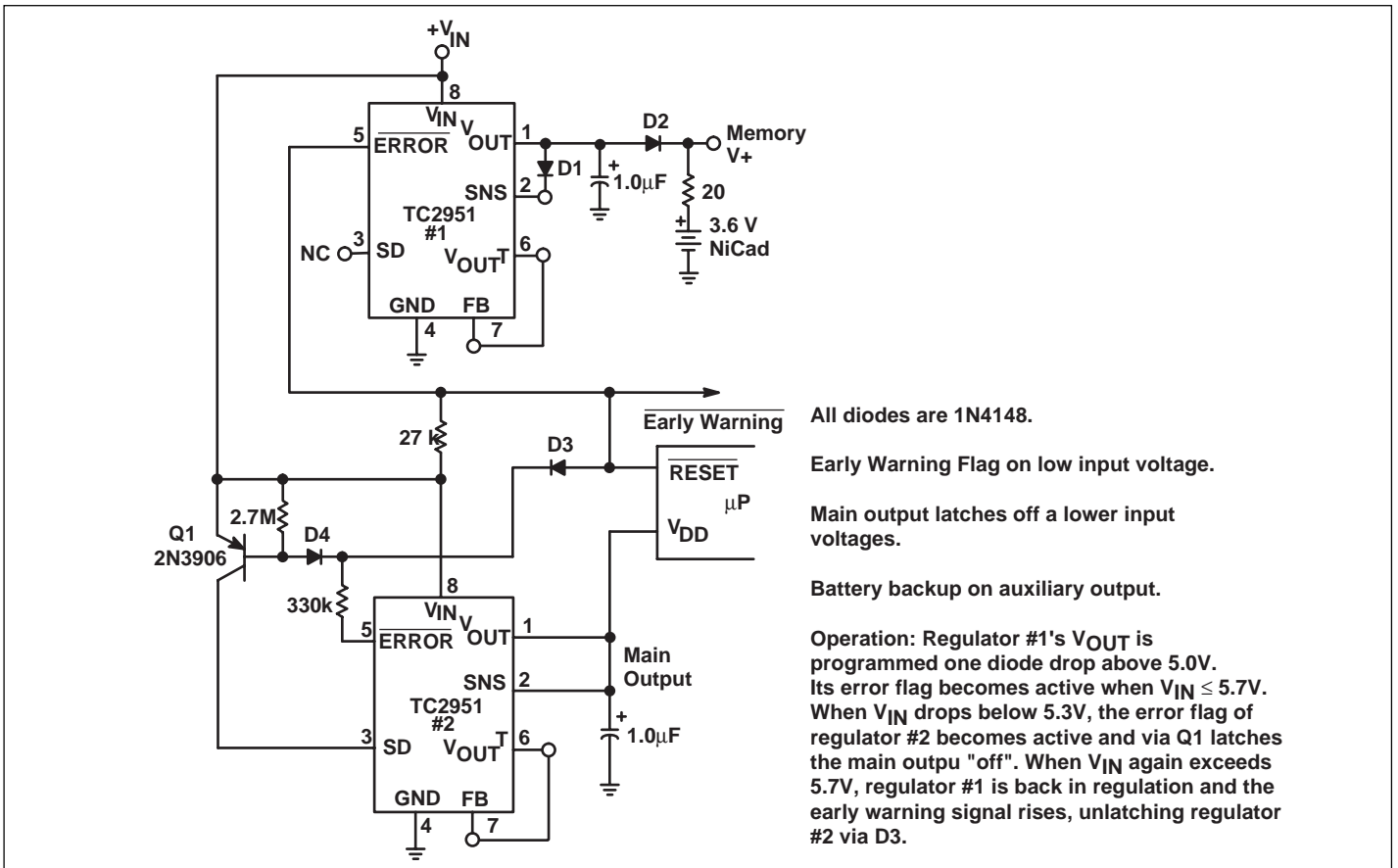


Figure 22. 5.0V Regulator with Early Warning and Auxiliary Output

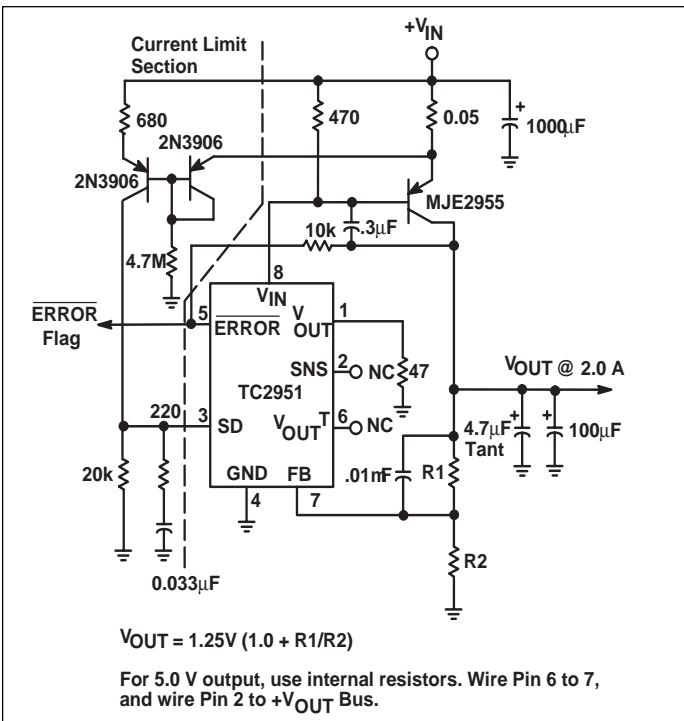


Figure 23. 2.0A Low Dropout Regulator

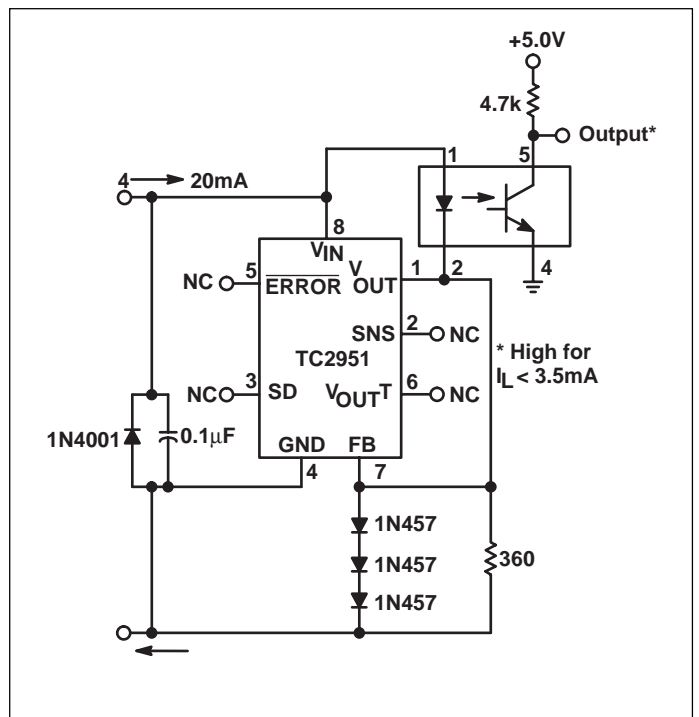


Figure 24. Open Circuit Detector for 4.0 to 20mA Current Loop

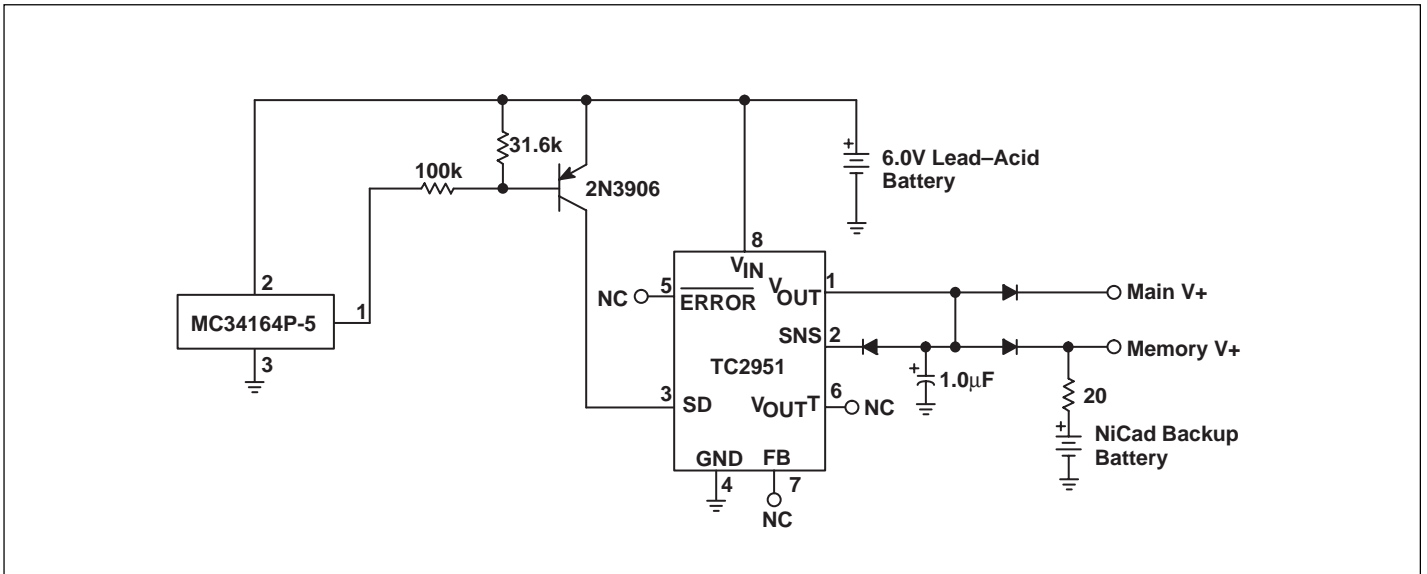


Figure 25. Low Battery Disconnect

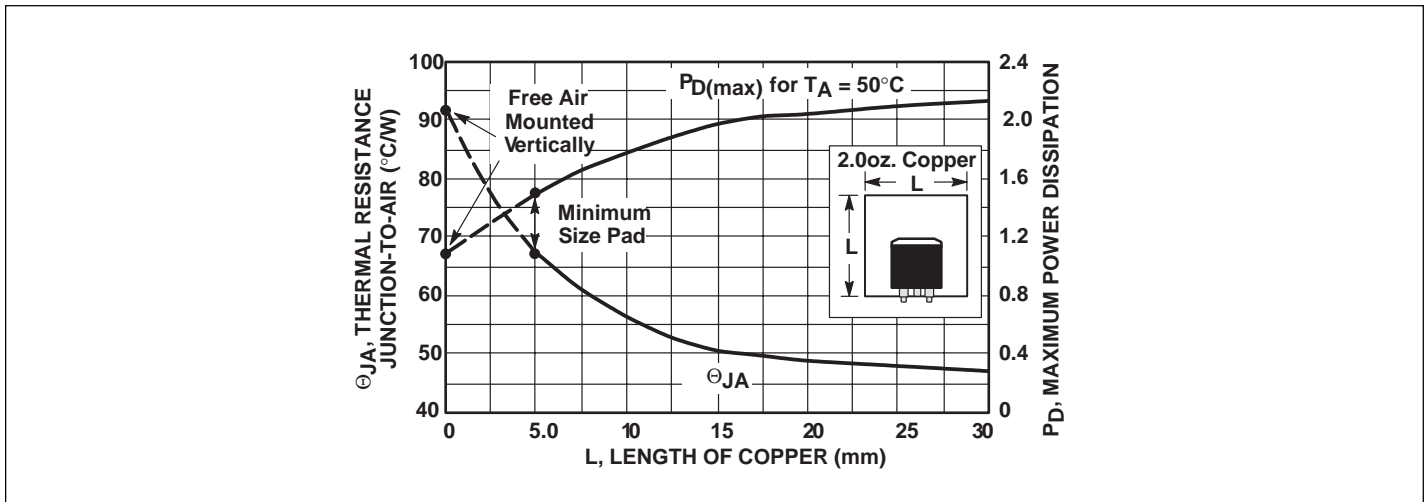
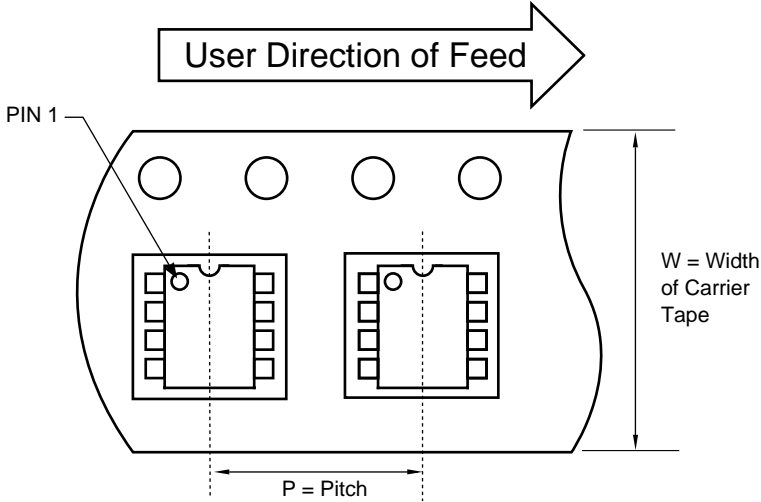


Figure 26. DPAK Thermal Resistance and Maximum Power Dissipation versus P.C.B. Copper Length

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TAPE AND REEL COMPONENTS

Component Taping Orientation for SOIC Devices

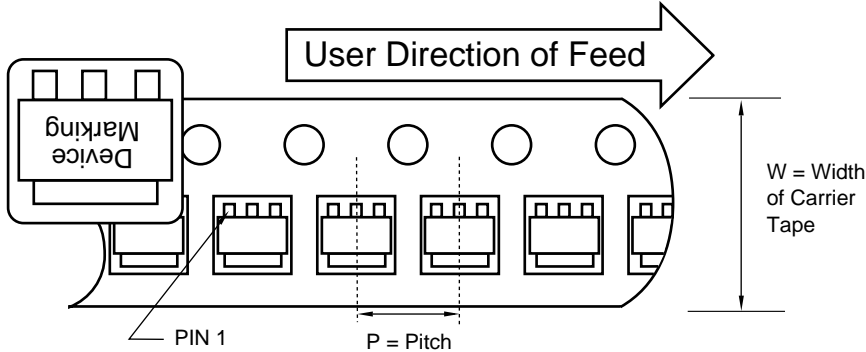


Standard Reel Component Orientation for 713 or TR Suffix Device

Carrier Tape, Reel Size, and Number of Components Per Reel

Package	Carrier Width (W)	Pitch (P)	Part Per Full Reel	Reel Size
8-Pin SOIC (N)	12 mm	8 mm	2500	13 in

Component Taping Orientation for 3-Pin DPAK Devices



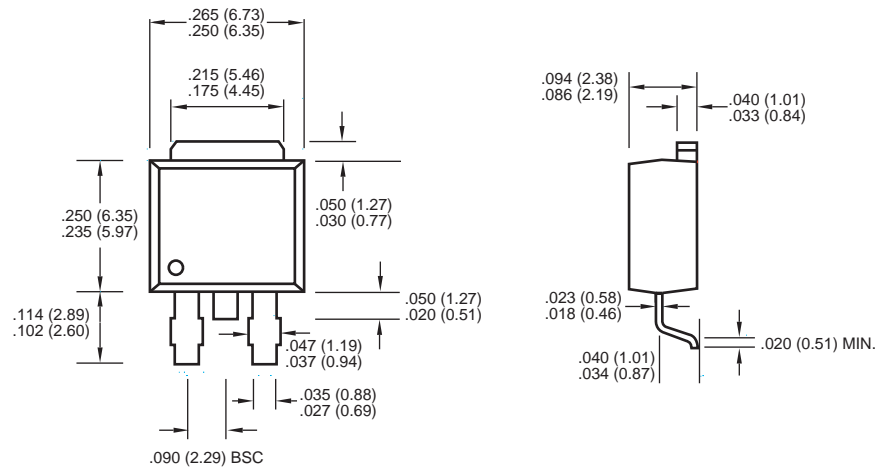
Standard Reel Component Orientation for TR Suffix Device (Mark Right Side Up)

Carrier Tape, Reel Size, and Number of Components Per Reel

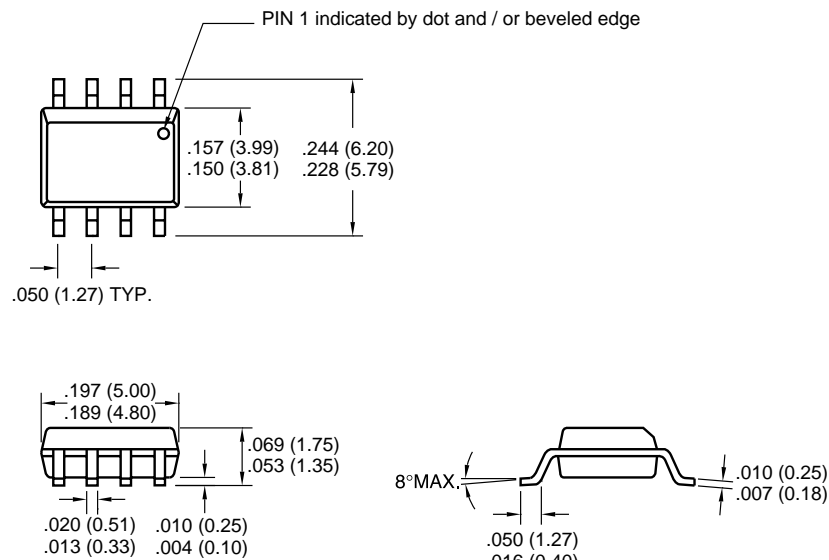
Package	Carrier Width (W)	Pitch (P)	Part Per Full Reel	Reel Size
3-Pin DPAK	16mm	8mm	2500	13

PACKAGE DIMENSIONS

3-Pin DPAK



8-Pin SOIC (Narrow)



Dimensions: inches (mm)

Sales Offices

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