Nanopower Comparator with Reference

FEATURES

- **Ultralow Quiescent Current: 0.3μA Typ**
- **Reference Output Drives 0.01μF Capacitor**
- **Adjustable Hysteresis**
- **Available in 3mm x 3mm x 0.8mm DFN Package**
- Wide Supply Range: 2V to 11V
- Input Voltage Range Includes the Negative Supply
- Reference Output Sources Up to 1mA
- TTL/CMOS Compatible Outputs
- 60μs Propagation Delay with 10mV Overdrive
- No Crowbar Current
- 40mA Continuous Source Current
- Pin Compatible with LTC1440, MAX921, MAX931

APPLICATIONS

- Battery-Powered System Monitoring
- Threshold Detectors
- Window Comparators
- Oscillator Circuits

LT, LTC and LT are registered trademarks of Linear Technology Corporation.

DESCRIPTION

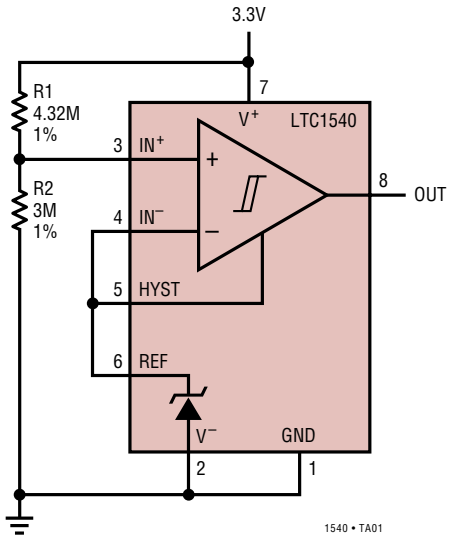
The LTC®1540 is an ultralow power, single comparator with built-in reference. The comparator's features include less than 0.6μA supply current over the commercial temperature range, a 1.182V ±2% reference, programmable hysteresis and TTL/CMOS outputs that sink and source current. The reference output can drive a bypass capacitor of up to 0.01μF without oscillation.

The comparator operates from a single 2V to 11V supply or a dual ±1V to ±5.5V supply. Comparator hysteresis is easily programmed by using two resistors and the HYST pin. Each comparator's input operates from the negative supply to within 1.3V of the positive supply. The comparator output stage can continuously source up to 40mA. By eliminating the cross-conducting current that normally occur when the comparator changes logic states, power supply glitches are eliminated.

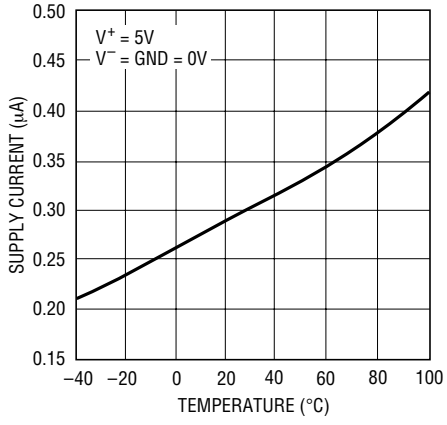
The LTC1540 is available in the 8-pin MSOP and SO packages. For space limited applications, the LTC1540 is available in a 3mm x 3mm low profile (0.8mm) dual fine-pitch leadless package (DFN).

TYPICAL APPLICATION

Nanopower 2.9V V_{CC} Threshold Detector



LTC1540 Supply Current vs Temperature



ABSOLUTE MAXIMUM RATINGS

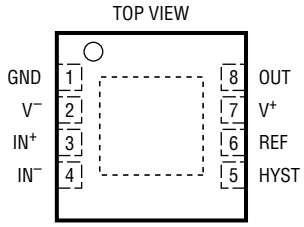
Voltage
- V^+ to V^-, V^+ to GND, GND to V^- ..... 12V to –0.3V
- IN^+, IN^-, HYST ..... (V^+ + 0.3V) to (V^- – 0.3V)
- REF ..... (V^+ + 0.3V) to (V^- – 0.3V)
- OUT ..... (V^+ + 0.3V) to (GND – 0.3V)

Current
- IN^+, IN^-, HYST 20mA
- REF 20mA
- OUT 50mA

OUT Short-Circuit Duration ($V^+ \leq 5.5V$) ..... Continuous
Power Dissipation 500mW
Operating Temperature Range
- LTC1540C ..... 0°C to 70°C
- LTC1540I ..... –40°C to 85°C

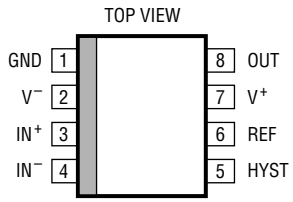
Storage Temperature Range ..... –65°C to 150°C
(DD Package) ..... –65°C to 125°C
Lead Temperature (Soldering, 10 sec) ..... 300°C

PACKAGE/ORDER INFORMATION



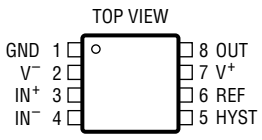
DD PACKAGE
8-LEAD (3mm × 3mm) PLASTIC DFN

T_{JMAX} = 125°C, θ_{JA} = 160°C/W (NOTE 2) UNDERSIDE METAL CONNECTED TO V^- (PCB CONNECTION OPTIONAL)



S8 PACKAGE
8-LEAD PLASTIC SO

T_{JMAX} = 150°C, θ_{JA} = 175°C/W



MS8 PACKAGE
8-LEAD PLASTIC MSOP

T_{JMAX} = 150°C, θ_{JA} = 250°C/W

ORDER PART NUMBER	DD PART MARKING*	ORDER PART NUMBER	S8 PART MARKING	ORDER PART NUMBER	MS8 PART MARKING
LTC1540CDD LTC1540IDD	LAAS	LTC1540CS8 LTC1540IS8	1540 1540I	LTC1540CMS8 LTC1540IMS8	LTCE LTADV

Consult LTC Marketing for parts specified with wider operating temperature ranges. *Temperature grades are identified by a label on the shipping container.

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V^+ = 5V, V^- = GND = 0V, T_A = 25°C unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Power Supply							
V^+	Supply Voltage Range		●	2.0		11.0	V
I_{CC}	Supply Current	$IN^+ = IN^- = 80mV$, HYST = REF, C-Grade	●		0.3	0.68	µA
		$IN^+ = IN^- = 80mV$, HYST = REF, I-Grade	●			0.71	µA
Comparator							
V_{OS}	Comparator Input Offset Voltage	V_{CM} = 2.5V				±12	mV
			●			±15	mV
		LTC1540CMS8/IMS8	●			±16	mV
I_{IN}	Input Leakage Current (IN^+, IN^-)	$V_{IN^+} = V_{IN^-}$ = 2.5V	●		±0.01	±1.0	nA
	Input Leakage Current (HYST)		●		±0.02	±1.0	nA
V_{CM}	Comparator Input Common Mode Range		●	V^-		V^+ – 1.3V	V
CMRR	Common Mode Rejection Ratio	V^- to V^+ – 1.3V			0.1	1	mV/V
PSRR	Power Supply Rejection Ratio	V^+ = 2V to 11V			0.1	1	mV/V

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V^+ = 5V, V^- = GND = 0V, T_A = 25°C unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS			MIN	TYP	MAX	UNITS
V_{HYST}	Hysteresis Input Voltage Range			●	REF – 50mV		REF	V
t_{PD}	Propagation Delay	C_{OUT} = 100pF	Overdrive = 10mV			60		µs
			Overdrive = 100mV			50		µs
V_{OH}	Output High Voltage	I_O = –13mA		●	V^+ – 0.4V			V
V_{OL}	Output Low Voltage	I_O = 1.8mA		●			GND + 0.4V	V
Reference								
V_{REF}	Reference Voltage	No Load	(SO-8)/(DFN) Commercial	●	1.158	1.182	1.206	V
			MS8 Commercial	●	1.156	1.182	1.208	V
			(SO-8)/(MS8)/(DFN) Industrial	●	1.152	1.182	1.212	V
ΔV_{REF}	Load Regulation	0 ≤ I_{SOURCE} ≤ 100µA		●		0.5	2.5	mV
		0 ≤ I_{SINK} ≤ 10µA				0.5	1.5	mV
				●			5	mV

V^+ = 3V, V^- = GND = 0V, T_A = 25°C unless otherwise noted.

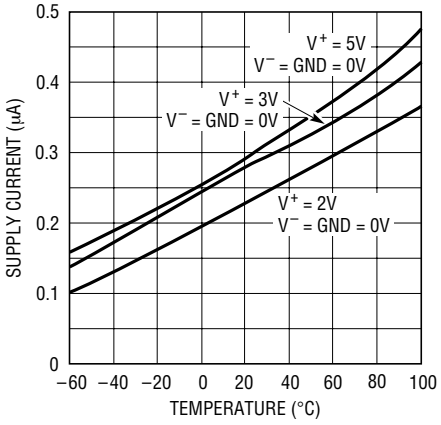
SYMBOL	PARAMETER	CONDITIONS			MIN	TYP	MAX	UNITS
Power Supply								
V^+	Supply Voltage Range			●	2		11	V
I_{CC}	Supply Current	$IN^+ = IN^-$ = 80mV, HYST = REF, C-Grade		●		0.28	0.61	µA
		$IN^+ = IN^-$ = 80mV, HYST = REF, I-Grade		●			0.64	µA
Comparator								
V_{OS}	Comparator Input Offset Voltage	V_{CM} = 2.5V					±12	mV
				●			±15	mV
		LTC1540CMS8/IMS8		●			±16	mV
I_{IN}	Input Leakage Current (IN^+, IN^-)	$V_{IN}^+ = V_{IN}^-$ = 1.5V		●		±0.01	±1	nA
	Input Leakage Current (HYST)			●		±0.02	±1	nA
V_{CM}	Comparator Input Common Mode Range			●	V^-		V^+ – 1.3V	V
CMRR	Common Mode Rejection Ratio	V^- to V^+ – 1.3V				0.1	1	mV/V
PSRR	Power Supply Rejection Ratio	V^+ = 2V to 11V				0.1	1	mV/V
V_{HYST}	Hysteresis Input Voltage Range			●	REF – 50mV		REF	V
t_{PD}	Propagation Delay	C_{OUT} = 100pF	Overdrive = 10mV			70		µs
			Overdrive = 100mV			60		µs
V_{OH}	Output High Voltage	I_O = –8mA		●	V^+ – 0.4V			V
V_{OL}	Output Low Voltage	I_O = 0.8mA		●			GND + 0.4V	V
Reference								
V_{REF}	Reference Voltage	No Load	(SO-8)/(DFN) Commercial	●	1.158	1.182	1.206	V
			MS8 Commercial	●	1.156	1.182	1.208	V
			(SO-8)/(MS8)/(DFN) Industrial	●	1.152	1.182	1.212	V
ΔV_{REF}	Load Regulation	0 ≤ I_{SOURCE} ≤ 100µA		●		0.75	3.5	mV
		0 ≤ I_{SINK} ≤ 10µA				0.5	1.5	mV
				●			5	mV

Note 1: Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

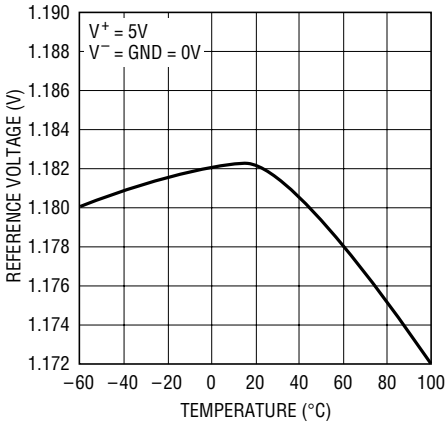
Note 2: The θ_{JA} specified for the DD package is with minimal PCB heat spreading metal. Using expanded metal area on all layers of a board reduces this value.

TYPICAL PERFORMANCE CHARACTERISTICS

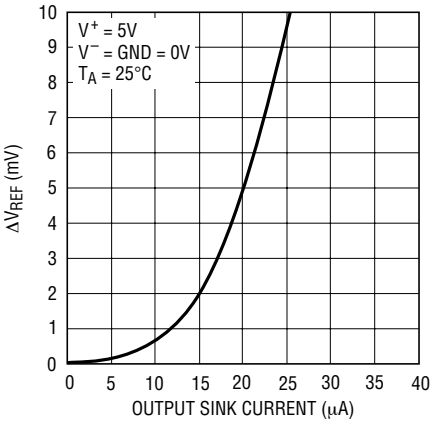
Supply Current vs Temperature



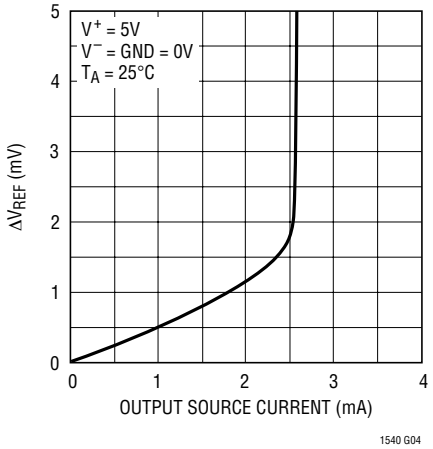
Reference Voltage vs Temperature



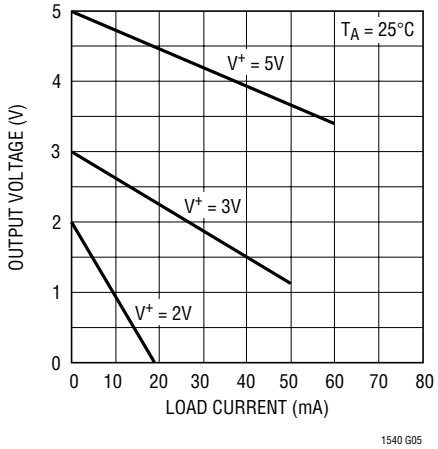
Reference Voltage Load Regulation (Sink)



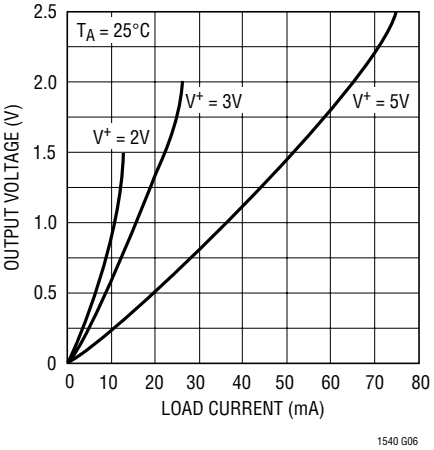
Reference Voltage Load Regulation (Source)



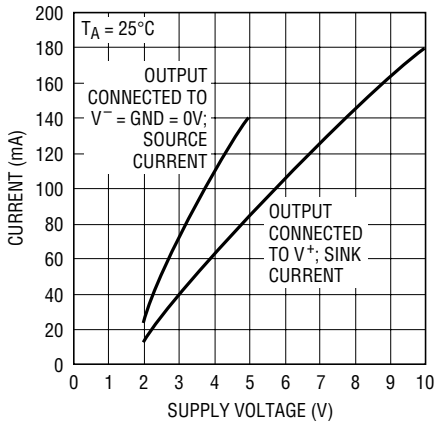
Comparator Output Voltage (High) vs Load Current



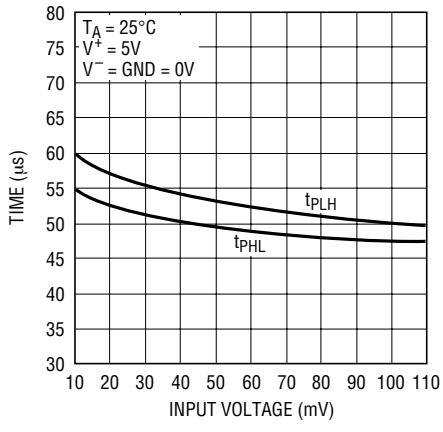
Comparator Output Voltage (Low) vs Load Current



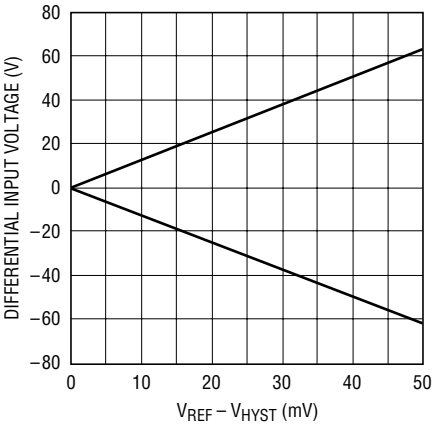
Comparator Short-Circuit Current vs Supply Voltage



Comparator Response Time vs Input Overdrive



Hysteresis Control



PIN FUNCTIONS

GND (Pin 1): Ground. Connect to V^- for single supply operation.

V^- (Pin 2): Negative Supply. Potential should be more negative than GND. Connect to ground for single supply operation.

IN^+ (Pin 3): Noninverting Comparator Input. Input common mode range from V^- to $V^+ – 1.3V$. Input current typically 10pA at 25°C.

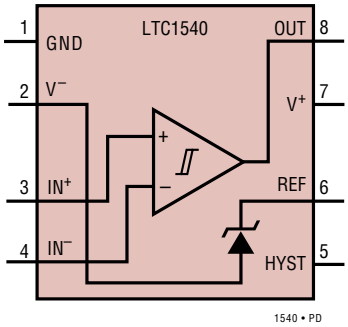
IN^- (Pin 4): Inverting Comparator Input. Input common mode range from V^- to $V^+ – 1.3V$. Input current typically 10pA at 25°C.

HYST (Pin 5): Hysteresis Input. Connect to REF if not used. Input voltage range is from V_{REF} to $V_{REF} – 50mV$.

REF (Pin 6): Reference Output. 1.182V with respect to V^-. Can source up to 1mA and sink 10μA at 25°C. Drive 0.01μF bypass capacitor without oscillation.

V^+ (Pin 7): Positive Supply operating voltage is from 2V to 11V.

OUT (Pin 8): Comparator CMOS Output. Swings from GND to V^+. Output can source up to 40mA and sink 5mA.



APPLICATIONS INFORMATION

The LTC1540 is a nanopower comparator with a built-in 1.182V reference. Features include programmable hysteresis, wide supply voltage range (2V to 11V) and the ability of the reference to drive up to a 0.01μF capacitor without oscillation. The comparator's CMOS outputs can source up to 40mA while supply current glitches that normally occur when switching logic states, have been eliminated.

Power Supplies

The comparator operates from a single 2V to 11V supply. The LTC1540 includes a separate ground for the comparator output stage, allowing a split supply ranging from ±1V to ±5.5V. Connecting V^- to GND will allow single supply operation. If the comparator output is required to source more than 1mA, or the supply source impedance is high, V^+ should be bypassed with a 0.1μF capacitor.

Comparator Inputs

The comparator inputs can swing from the negative supply, V^-, to within 1.3V (max) of the positive supply V^+. The inputs can be forced 300mV below V^- or above V^+ without damage and the typical input leakage current is only ±10pA.

Comparator Output

The comparator output swings between GND and V^+ to assure TTL compatibility with a split supply. The output is capable of sourcing up to 40mA and sinking up to 5mA while still maintaining nanoampere quiescent currents. The output stage does not generate crowbar switching currents during transitions which helps minimize parasitic feedback through the supply pins.

Voltage Reference

The internal bandgap reference has a voltage of 1.182V referenced to V^-. The reference accuracy is ±2.0% from 0°C to 70°C. It can source up to 1mA and sink up to 10μA with a 5V supply. The reference can drive a bypass capacitor of up to 0.01μF without oscillation and by inserting a series resistor, capacitance values up to 10μF can be used (Figure 1).

Figure 2 shows the resistor value required for different capacitor values to achieve critical damping. Bypassing the reference can help prevent false tripping of the comparators by preventing glitches on V^+ or reference load transients from disturbing the reference output voltage.

APPLICATIONS INFORMATION

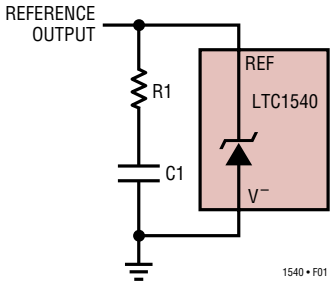


Figure 1. Damping the Reference Output

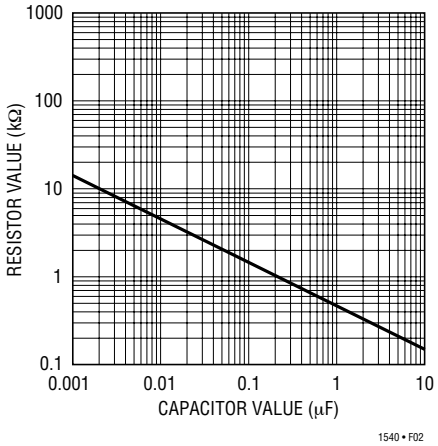


Figure 2. Damping Resistance vs Bypass Capacitor Value

Figure 3 shows the bypassed reference output with a square wave applied to the V^+ pin. Resistors R2 and R3 set 10mV of hysteresis voltage band while R1 damps the reference response. Note that the comparator output doesn't trip.

Low Voltage Operation: $V^+ = 1.6V$

The guaranteed minimum operating voltage is 2V (or ±1V). As the total supply voltage is reduced below 2V, the performance degrades and the supply current falls. At low supply voltages, the comparator's output drive is reduced and the propagation delay increases. The V_{REF} and V_{OS} are also slightly worse. The useful input voltage range extends from the negative supply to 0.9V below the positive supply. Test your prototype over the full temperature and supply voltage range if operation below 2V is anticipated. Because of the increase in supply current, operation below 1.5V is not recommended (Figure 4).

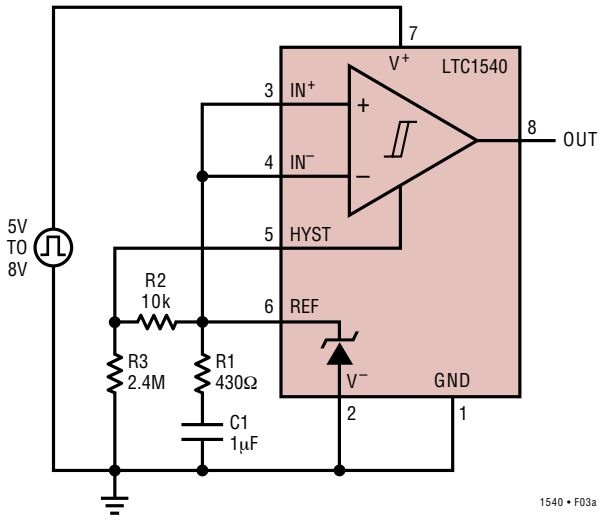


Figure 3a. Power Supply Transient Test Circuit

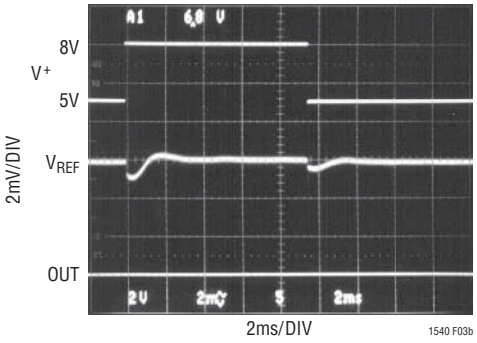


Figure 3b. Power Supply Transient Rejection

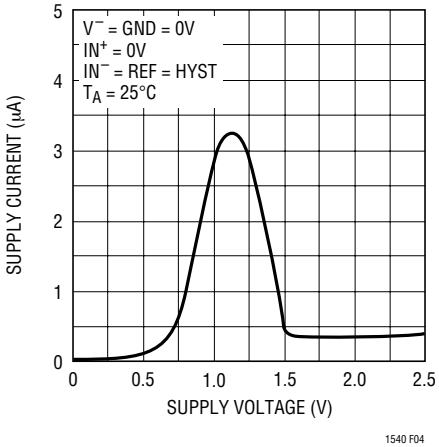


Figure 4. Supply Current vs Supply Voltage

APPLICATIONS INFORMATION

Hysteresis

Hysteresis can be added to the LTC1540 by connecting a resistor (R1) between the REF and HYST pins and a second resistor (R2) from HYST to V^- (Figure 5).

The difference between the upper and lower threshold voltages, or hysteresis voltage band (V_{HB}), is equal to twice the voltage difference between the REF and HYST pins.

When more hysteresis is added, the upper threshold increases the same amount as the low threshold decreases. The maximum voltage allowed between REF and HYST pins is 50mV, producing a maximum hysteresis voltage band of 100mV. The hysteresis band may vary by up to 15%. If hysteresis is not wanted, the HYST pin should be shorted to REF. Acceptable values for I_{REF} range from 0.1μA to 5μA. If 2.4M is chosen for R2, then the value of R1 (kΩ) is equal to the value of V_{HB} (mV).

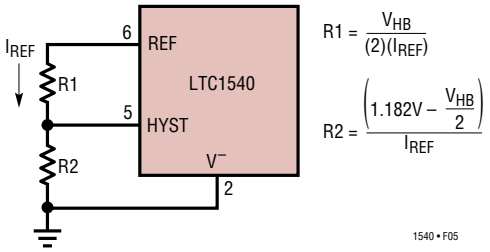


Figure 5. Programmable Hysteresis

TYPICAL APPLICATIONS

Level Detector

The LTC1540 is ideal for use as a nanopower level detector as shown in Figure 6. R1 and R2 form a voltage divider from V_{IN} to the noninverting comparator input. R3 and R4 set the hysteresis voltage, and R5 and C1 bypass the reference output. The following design procedure can be used to select the component values:

1. Choose the V_{IN} voltage trip level, in this example 4.65V.
2. Calculate the required resistive divider ratio.

   Ratio = V_{REF}/V_{IN}

   Ratio = 1.182V/4.65V = 0.254
3. Choose the required hysteresis voltage band at the input V_{HBIN}, in this example 60mV. Calculate the hysteresis voltage band referred to the comparator input V_{HB}.

   $V_{HB} = (V_{HBIN})(Ratio)$

   $V_{HB} = (60mV)(0.254)$

   $V_{HB} = 15.24mV$
4. Choose the values for R3 and R4 to set the hysteresis.

   R4 = 2.4M

   R3 (kΩ) = 15k, V_{HB} (mV) = 15mV
5. Choose the values for R1 and R2 to set the trip point.

$$R1 = \frac{V_{REF}}{I_{BIAS}} = \frac{1.182V}{1\mu A} = 1.18M$$

$$R2 = R1\left[\frac{V_{IN}}{V_{REF} + \frac{V_{HB}}{2}} - 1\right]$$

$$R2 = 1.18M\left[\frac{4.65V}{1.182V + \frac{15mV}{2}} - 1\right]$$

$$R2 = 3.40M$$

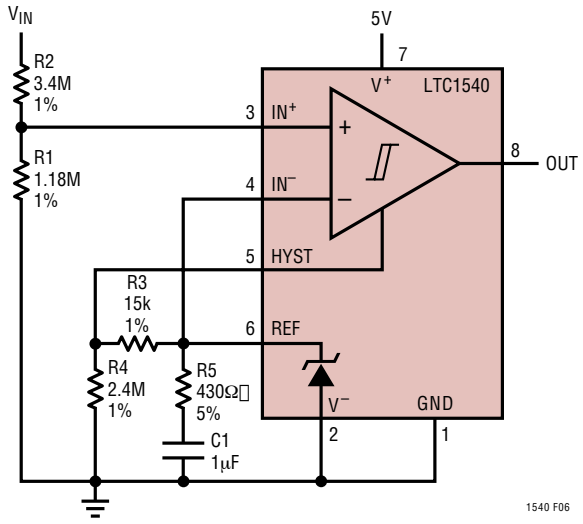


Figure 6. Glitch-Free Level Detector with Hysteresis

TYPICAL APPLICATIONS

3.3V Output Low Dropout Linear Regulator

The LTC1540 can be connected as a micropower (I_Q = 5.5μA at V_{IN} = 5V) low dropout linear regulator (Figure 7). When the output is low, Q1 turns on, allowing current to charge output capacitor C1. Local feedback formed by R4, Q1 and Q2 creates a constant-current source from the 5V input to C1. R4, R1 and Q2's V_{BE} also provide current limiting in the case of an output short-circuit to ground. C2 reduces output ripple, while the R2-R3 feedback voltage divider establishes the output voltage.

Auto Power-Off Source

Figure 8 shows the circuit for a 30mA power supply that has a timed auto power-off function. The comparator output is the switched power supply output. With a 10mA load, it typically provides a voltage of (V_{BAT} – 0.17V). The whole circuit draws a mere 0.8μA of quiescent current with V_{BAT} = 5V. The three resistor voltage divider programs 50mV of hysteresis for the comparator, and sets the IN^- voltage at 200mV. This gives an IN^+ trip threshold of approximately 150mV

The RC time constant determines the maximum power-on time of the OUT pin before power down occurs. This period can be approximated by:

$t = 4.6RC$ (seconds)

The actual time will vary with both the leakage current of the capacitor and the input current at the IN^+ pin.

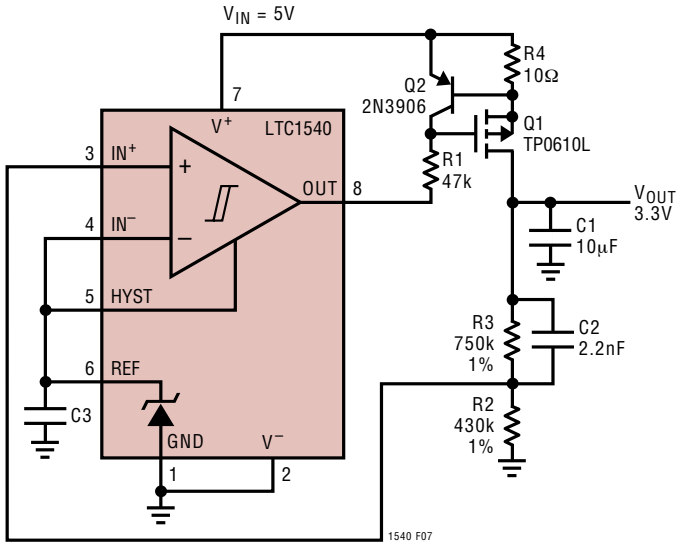


Figure 7. 3.3V Output Low Dropout Linear Regulator

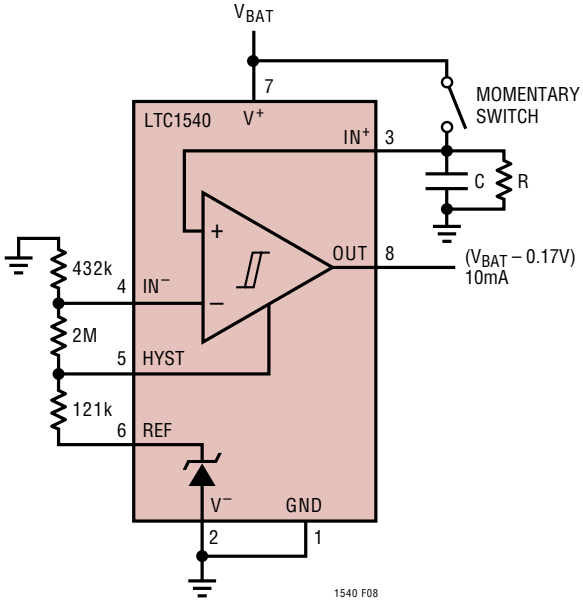


Figure 8. Auto Power-Off Switch Operates on 0.8μA Quiescent Current

TYPICAL APPLICATIONS

Low-Battery Detect

Figure 9 shows how to use the LTC1540 for a low-battery detect, drawing only 1.4μA at V_{BAT} = 2V. The circuit is powered by a 2-cell NiCd battery. The V_{BAT} pin could be as low as 1.6V when the batteries are completely depleted. The electrical specifications of the LTC1540 guarantee operation down to a supply voltage of 2V, but it is still functional with the supply as low as 1.6V. Some parameters, such as V_{REF} and V_{OS}, will be degraded on lower supply voltages. The input voltage range extends from 0.9V below the positive supply to the negative supply.

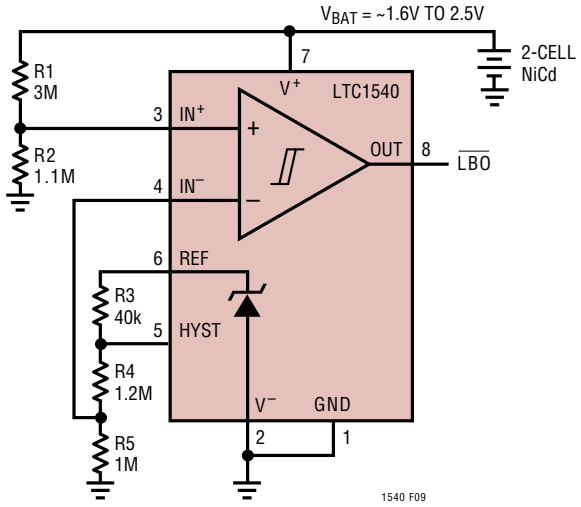
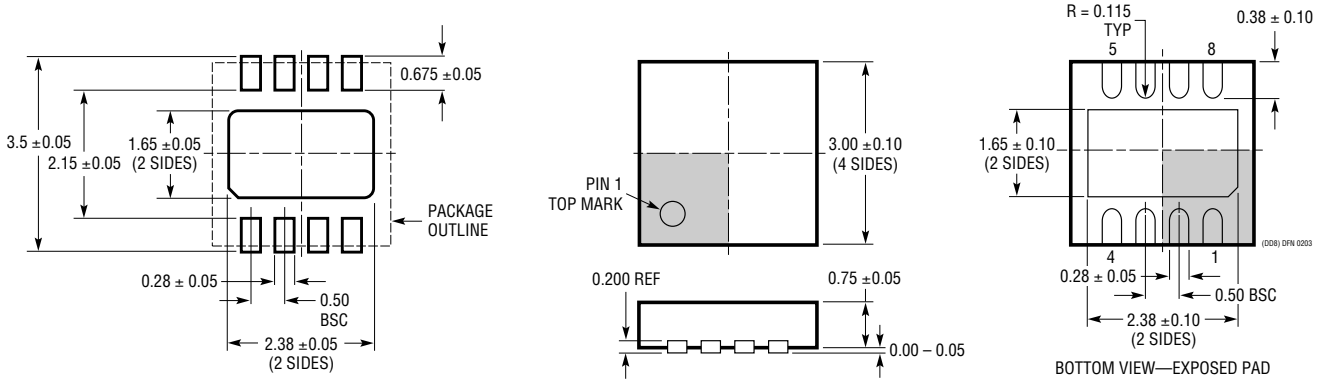


Figure 9. Low-Battery Detect Works Down to 1.6V

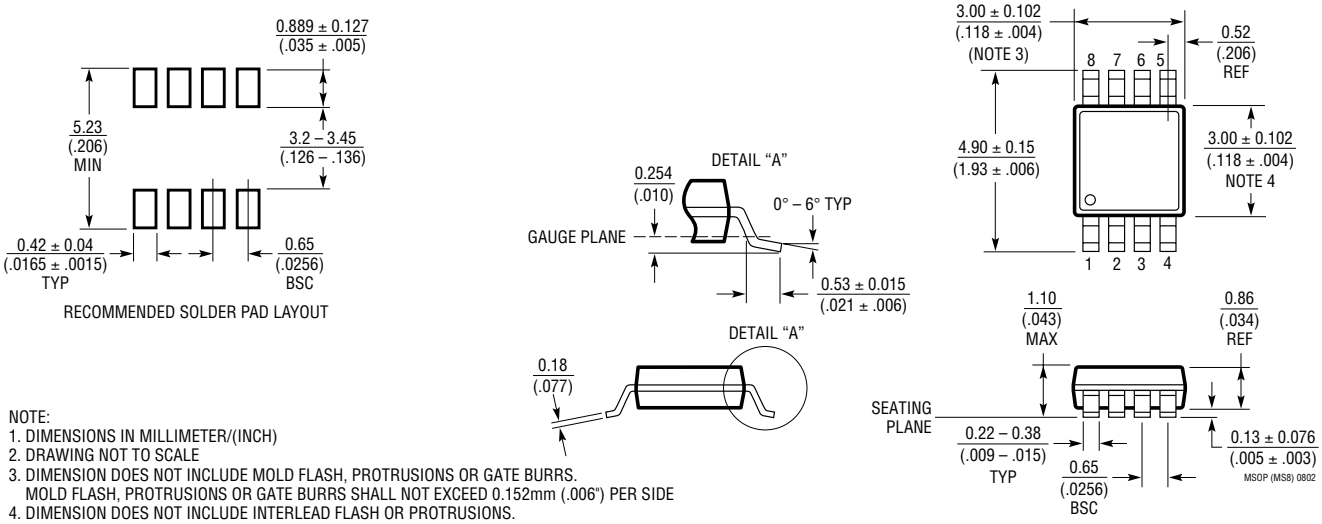
PACKAGE DESCRIPTION

DD Package
8-Lead Plastic DFN (3mm × 3mm)
(Reference LTC DWG # 05-08-1698)



NOTE:
1. DRAWING TO BE MADE A JEDEC PACKAGE OUTLINE M0-229 VARIATION OF (WEED-1)
2. ALL DIMENSIONS ARE IN MILLIMETERS
3. DIMENSIONS OF EXPOSED PAD ON BOTTOM OF PACKAGE DO NOT INCLUDE MOLD FLASH. MOLD FLASH, IF PRESENT, SHALL NOT EXCEED 0.15mm ON ANY SIDE
4. EXPOSED PAD SHALL BE SOLDER PLATED

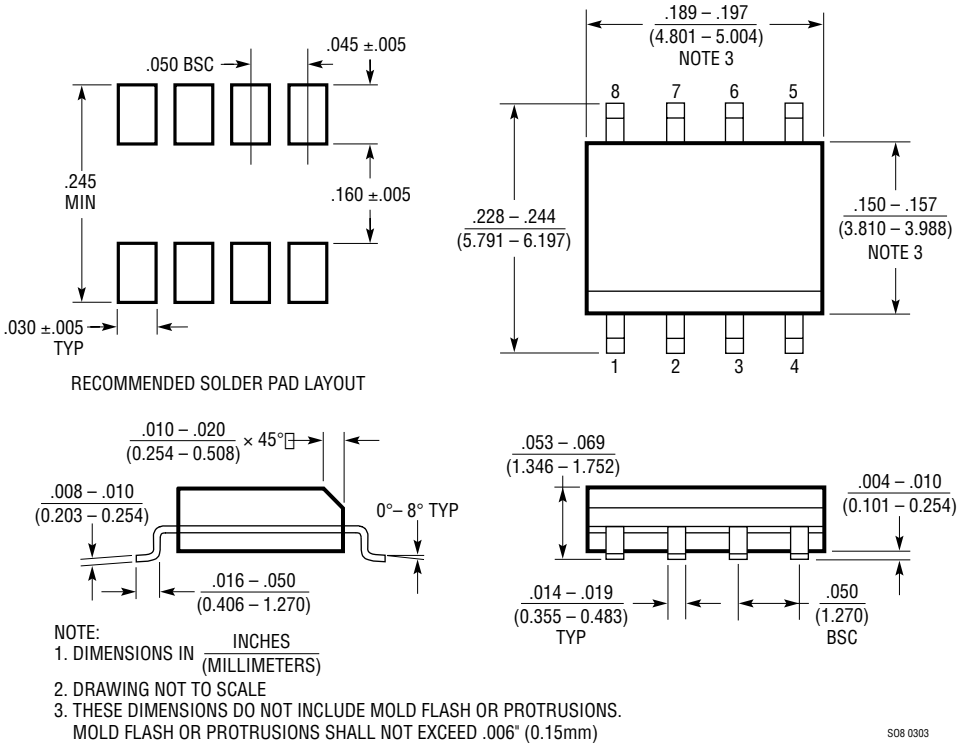
MS8 Package
8-Lead Plastic MSOP
(Reference LTC DWG # 05-08-1660)



NOTE:
1. DIMENSIONS IN MILLIMETER/(INCH)
2. DRAWING NOT TO SCALE
3. DIMENSION DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS. MOLD FLASH, PROTRUSIONS OR GATE BURRS SHALL NOT EXCEED 0.152mm (.006") PER SIDE
4. DIMENSION DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSIONS. INTERLEAD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.152mm (.006") PER SIDE
5. LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE 0.102mm (.004") MAX

PACKAGE DESCRIPTION

S8 Package
8-Lead Plastic Small Outline (Narrow .150 Inch)
(Reference LTC DWG # 05-08-1610)



NOTE:
1. DIMENSIONS IN $\frac{\text{INCHES}}{(\text{MILLIMETERS})}$
2. DRAWING NOT TO SCALE
3. THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
   MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .006" (0.15mm)

SO8 0303

Information furnished by Linear Technology Corporation is believed to be accurate and reliable. However, no responsibility is assumed for its use. Linear Technology Corporation makes no representation that the interconnection of its circuits as described herein will not infringe on existing patent rights.

TYPICAL APPLICATION

RF Field Detector

Figure 10 shows the complete circuit for a field detector which was tested at 445MHz. A transmission line is used to match the detector diode (1N5712) to a quarter-wave whip antenna. The 0.23λ wavelength transmission line section transforms the 1pF (350Ω) diode junction capacitance to a virtual short at the base of the antenna. At the same time it converts the received antenna current to a voltage loop at the diode, giving excellent sensitivity.

The rectified output is monitored by the LTC1540 comparator. The internal reference is used to set up a threshold of about 18mV at the inverting input. A rising edge at the comparator output triggers a one shot that temporarily enables answer back and any other pulsed functions.

The total supply current is 400nA. Among other monolithic one shots, the CD4047 draws the least amount of transient current.

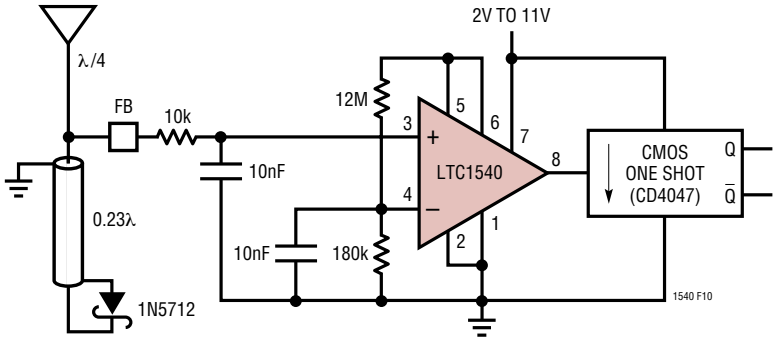


Figure 10. Nanopower Field Detector

RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT®1178/LT1179	Dual/Quad 17μA Precision Single Supply Op Amps	70μV Max V_{OS}, 5nA Max I_{BIAS}
LT1351	Single 250μA, 3MHz, 200V/μs Op Amp with Shutdown	C-Load™ Op Amp Stable Driving Any Capacitive Load
LT1352/LT1353	Dual/Quad 250μA, 3MHz, 200V/μs Op Amps	C-Load Op Amps Stable Driving Any Capacitive Load
LTC1440	Micropower Comparator with 1% Reference	1.182V ±1% Reference, ±10mV (Max) Input Offset
LTC1443/LTC1444/LTC1445	Micropower Quad Comparators with 1% Reference	LTC1443 Has 1.182V Reference, LTC1444/LTC1445 Have 1.221V Reference and Adjustable Hysteresis
LTC1474	Low Quiescent Current High Efficiency Step-Down Converter	10μA Standby Current, 92% Efficiency, Space Saving 8-Pin MSOP Package
LT1495	1.5μA Max, Dual Precision Rail-to-Rail Input and Output Op Amp	375μV Max V_{OS}, 250pA I_{BIAS}, 25pA I_{OS}
LT1521	300mA Low Dropout Regulator with Micropower Quiescent Current and Shutdown	0.5V Dropout Voltage, 12μA Quiescent Current, Adjustable Output 3V, 3.3V and 5V Fixed
LT1634	Micropower Precision Shunt Voltage Reference	1.25V, 2.5V, 4.096V, 5V Outputs, 10μA Operating Current, 0.05% Initial Accuracy 25ppm/°C Max Drift, SO-8, MSOP and TO-92 Packages

C-Load is a trademark of Linear Technology Corporation.

Linear Technology Corporation
1630 McCarthy Blvd., Milpitas, CA 95035-7417
(408) 432-1900 • FAX: (408) 434-0507 • www.linear.com

LT/TP 0403 1K REV A • PRINTED IN USA

© LINEAR TECHNOLOGY CORPORATION 1997