

## FEATURES

- 40 $\mu$ A Supply Current
- 125mA Output Current
- 2.5V Reference Voltage
- Reference Output Sources 1mA and Sinks 0.5mA
- Dual Output Comparator
- Comparator Sinks 10mA
- Dropout Detector
- 0.2V Dropout Voltage
- Thermal Limiting
- Available in SO Package

## APPLICATIONS

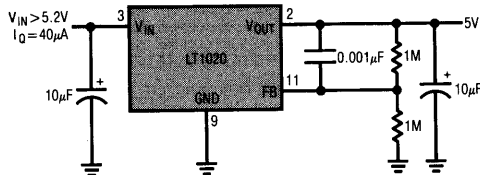
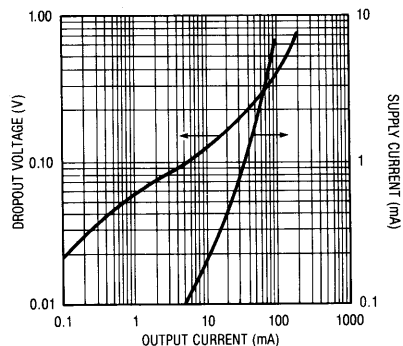
- Battery Systems
- Battery Backup System
- Portable Terminals
- Portable Instruments

## DESCRIPTION

The LT1020 is a combination micropower positive regulator and free collector comparator on a single monolithic chip. With only 40 $\mu$ A supply current, the LT1020 can supply over 125mA of output current. Input voltage range is from 4.5V to 36V and dropout voltage is 0.6V at 125mA. Dropout voltage decreases with lower load currents. Also included on the chip is a class B output 2.5V reference that can either source or sink current. A dropout detector provides an output current to indicate when the regulator is about to drop out of regulation.

The dual output comparator can be used as a comparator for system or battery monitoring. For example, the comparator can be used to warn of low system voltage while the dropout detector shuts down the system to prevent abnormal operation. Frequency compensation of the comparator for amplifier applications can be obtained by adding external output capacitance. Dual output or positive and negative regulators can also be made.

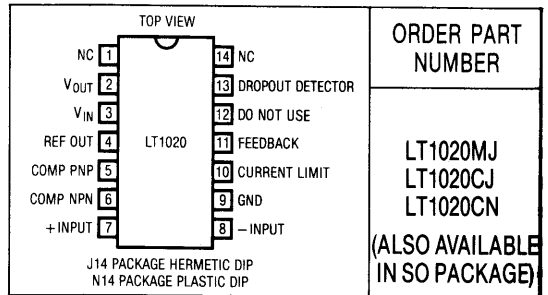
The 2.5V reference will source or sink current. This allows it to be used as a supply splitter or auxiliary output.

**4**
**5V Regulator**

**Dropout Voltage and Supply Current**


**ABSOLUTE MAXIMUM RATINGS**

Input Voltage .....	36V
NPN Collector Voltage .....	36V
PNP Collector Voltage .....	Supply - 36V
Output Short Circuit Duration .....	Indefinite
Power Dissipation .....	Internally Limited
Operating Temperature Range	
LT1020C .....	0°C to 100°C
LT1020M .....	-55°C to 125°C
Storage Temperature Range	
LT1020C,M .....	-65°C to 150°C

**PACKAGE/ORDER INFORMATION**



**ELECTRICAL CHARACTERISTICS**  $T_j = 25^\circ\text{C}$

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
<b>Reference</b>					
Reference Voltage	$4.5\text{V} \leq V_{IN} \leq 36\text{V}$	2.46	2.50	2.54	V
Line Regulation	$4.5\text{V} \leq V_{IN} \leq 36\text{V}$		0.01	0.015	%/V
Load Regulation	$-0.5\text{mA} \leq I_{REF} \leq 1\text{mA}, V_{IN} = 12\text{V}$		0.2	0.3	%
Output Source Current	$V_{IN} = 5\text{V}$	1	4		mA
Output Sink Current	$V_{IN} = 5\text{V}$	0.5	2		mA
Temperature Stability			1		%
<b>Regulator</b>					
Supply Current	$V_{IN} = 6\text{V}, I_{OUT} \leq 100\mu\text{A}$ $V_{IN} = 36\text{V}, I_{OUT} \leq 100\mu\text{A}$ $V_{IN} = 12\text{V}, I_{OUT} = 125\text{mA}$		45 75 11	80 120 20	$\mu\text{A}$ $\mu\text{A}$ mA
Output Current	$(V_{IN} - V_{OUT}) \geq 1\text{V}, V_{IN} \geq 6\text{V}$	125			mA
Load Regulation	$(V_{IN} - V_{OUT}) \geq 1\text{V}, V_{IN} \geq 6\text{V}$		0.2	0.5	%
Line Regulation	$6\text{V} \leq V_{IN} \leq 36\text{V}$		0.01	0.015	%/V
Dropout Voltage	$I_{OUT} = 100\mu\text{A}$ $I_{OUT} = 125\text{mA}$		0.02 0.4	0.05 0.65	V V
Feedback Sense Voltage	$V_{IN} = 12\text{V}$	2.44	2.5	2.56	V
Dropout Detector Current	$\Delta V_{OUT} = -0.05\text{V}$	3	20		$\mu\text{A}$
Feedback Bias Current			15	40	nA
Minimum Load Current	$V_{IN} = 36\text{V}$		1	5	$\mu\text{A}$
Short Circuit Current	$V_{IN} = 36\text{V}$ Pin 9 and Pin 10 shorted, $V_{IN} = 4.5\text{V}$	3	250 30	360	mA mA
<b>Comparator</b>					
Offset Voltage	$0\text{V} \leq V_{CM} \leq 35\text{V}, V_{IN} = 36\text{V}$		3	7	mV
Bias Current	$0\text{V} \leq V_{CM} \leq 35\text{V}, V_{IN} = 36\text{V}$		15	40	nA
Offset Current	$0\text{V} \leq V_{CM} \leq 35\text{V}, V_{IN} = 36\text{V}$		4	15	nA
Gain-NPN Pulldown	$\Delta V_{OUT} = 29\text{V}, R_L = 20\text{k}$	2000	10000		V/V
Common Mode Rejection	$0\text{V} \leq V_{CM} \leq 35\text{V}, V_{IN} = 36\text{V}$	80	94		dB

## ELECTRICAL CHARACTERISTICS

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
<b>Comparator</b>					
Power Supply Rejection	$4.5V \leq V_S \leq 36V$	80	96		dB
Output Sink Current	$V_{IN} = 4.5V$	10	18		mA
NPN Saturation Voltage	$I_{OUT} = 1mA$		0.4	0.6	V
Output Source Current		60	200		$\mu A$
Input Voltage Range		0		$V_{IN} - 1$	V
Response Time			5		$\mu S$
Leakage Current (NPN)				2	$\mu A$

## ELECTRICAL CHARACTERISTICS

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS	
<b>Reference</b>						
Reference Voltage	$4.5V \leq V_{IN} \leq 36V$	●	2.40	2.50	2.55	V
Line Regulation	$4.5V \leq V_{IN} \leq 36V$	●		0.01	0.02	%/V
Load Regulation	$-0.5mA \leq I_{REF} \leq 1mA, V_{IN} = 12V$	●		0.3	0.4	%
Output Source Current	$V_{IN} = 5V$	●	1			mA
Output Sink Current	$V_{IN} = 5V$	●	0.5			mA
<b>Regulator</b>						
Supply Current	$V_{IN} = 6V, I_{OUT} \leq 100\mu A$ $V_{IN} = 36V, I_{OUT} \leq 100\mu A$ $V_{IN} = 12V, I_{OUT} = 125mA$	●		65 85 11	95 120 20	$\mu A$ $\mu A$ mA
Output Current	$(V_{IN} - V_{OUT}) \geq 1V, V_{IN} \geq 6V$	●	125			mA
Load Regulation	$(V_{IN} - V_{OUT}) \geq 1V, V_{IN} \geq 6V$	●			1	%
Line Regulation	$6V \leq V_{IN} \leq 36V$	●			0.02	%/V
Dropout Voltage	$I_{OUT} = 100\mu A$ $I_{OUT} = 125mA$	●			0.06 0.85	V V
Feedback Sense Voltage	$V_{IN} = 12V$	●	2.38	2.5	2.57	V
Dropout Detector Current	$\Delta V_{OUT} = -0.05V$	●	3			$\mu A$
Feedback Bias Current		●			50	nA
Minimum Load Current	$V_{IN} = 36V$	●			50	$\mu A$
Short Circuit Current	$V_{IN} = 36V$ Pin 9 and Pin 10 shorted, $V_{IN} = 4.5V$	●	2.5	240	360	mA mA
<b>Comparator</b>						
Offset Voltage	$0V \leq V_{CM} \leq 35V, V_{IN} = 36V$	●			10	mV
Bias Current	$0V \leq V_{CM} \leq 35V, V_{IN} = 36V$ (Note 1)	●		15	60	nA
Offset Current	$0V \leq V_{CM} \leq 35V, V_{IN} = 36V$	●			20	nA
Gain-NPN Pulldown	$\Delta V_{OUT} = 29V, R_L = 20k$	●	1000			V/V
Common Mode Rejection	$0V \leq V_{CM} \leq 35V, V_{IN} = 36V$	●	80			dB
Power Supply Rejection	$4.5V \leq V_S \leq 36V$	●	80			dB
Output Sink Current	$V_{IN} = 4.5V$ (Note 2)	●	5	10		mA
Output Source Current		●	40	120		$\mu A$
Input Voltage Range		●	0		$V_{IN} - 1$	V
Leakage Current (NPN)	$V_{IN} = 36V$	●			8	$\mu A$

The ● denotes the specifications which apply over full operating temperature range.

**Note 1:** For  $0V \leq V_{CM} \leq 0.1V$  and  $T > 85^\circ C$  I bias max is 100nA.

**Note 2:** For  $T_A \leq -40^\circ C$  output sink current min is 2.5mA.

## PIN FUNCTIONS

Pins 1, 12, 14—No internal connection.

Pin 2—**Regulator Output.** Main output, requires 10 $\mu$ F output capacitor. Can be shorted to  $V_{IN}$  or ground without damaging device.

Pin 3—**Input Supply.** Bypass with 10 $\mu$ F cap. Must always be more positive than ground.

Pin 4—**Reference.** 2.5V can source or sink current. May be shorted to ground or up to 5V. Voltages in excess of 5V can damage the device.

Pin 5—**Comparator PNP Output.** Pull up current source for the comparator. May be connected to any voltage from  $V_{IN}$  to 36V more negative than  $V_{IN}$  (operates below ground). Short circuit protected. For example, if  $V_{IN}$  is 6V then pin 5 will operate to -30V.

Pin 6—**Comparator NPN Output.** May be connected to any voltage from ground to 36V more positive than ground (operates above  $V_{IN}$ ). Short circuit protected.

Pins 7, 8—**Comparator Inputs.** Operates from ground to  $V_{IN} - 1V$ . Comparator inputs will withstand 36V even with  $V_{IN}$  of 0V.

Pin 9—**Ground.**

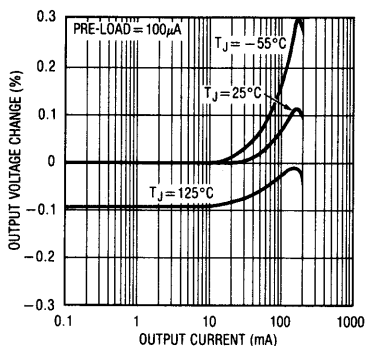
Pin 10—**Current Limit.** Connecting this pin to ground decreases the regulator current limit to 3mA min. Leave open when not used.

Pin 11—**Feedback.** This is the feedback point of the regulator. When operating, it is nominally at 2.5V. Optimum source resistance is 200k to 500k. The feedback pin should not be driven below ground or more positive than 5V.

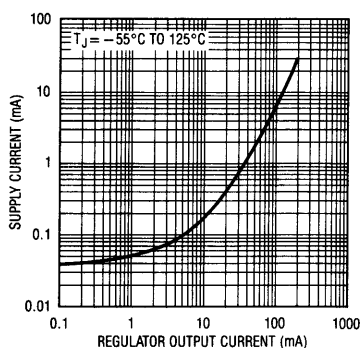
Pin 13—**Dropout Detector.** This pin acts like a current source from  $V_{IN}$  which turns on when the output transistor goes into saturation. The magnitude of the current depends on the magnitude of the output current and the input-output voltage differential. Pin current ranges from 5 $\mu$ A to about 300 $\mu$ A.

## TYPICAL PERFORMANCE CHARACTERISTICS

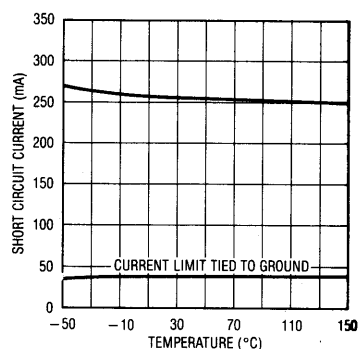
Regulator Load Regulation



Supply Current



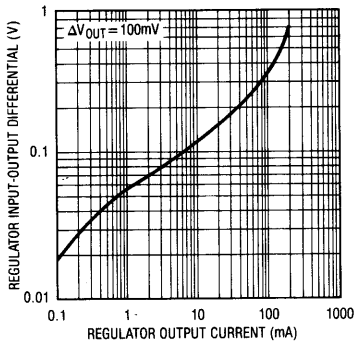
Regulator Short Circuit Current



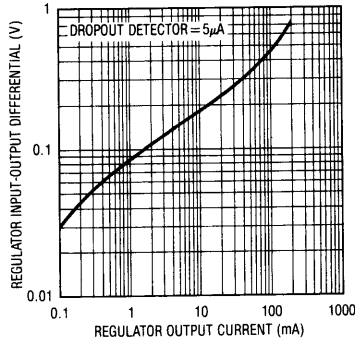
# TYPICAL PERFORMANCE CHARACTERISTICS

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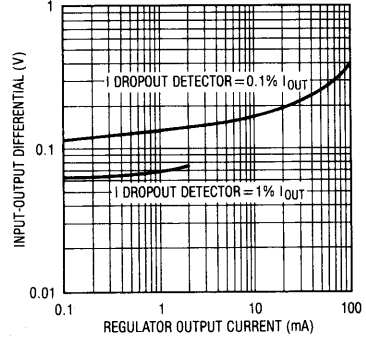
Dropout Voltage



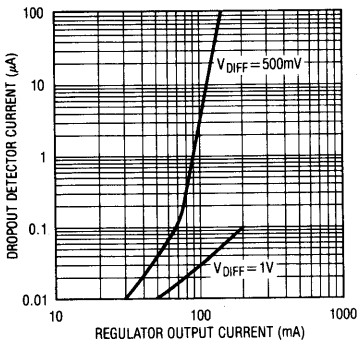
Dropout Voltage



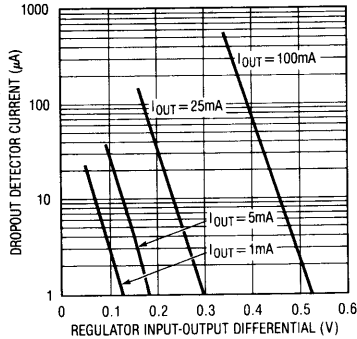
Dropout Voltage



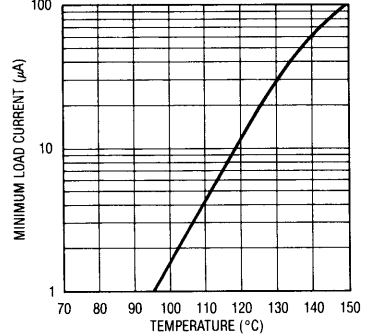
Dropout Detector Current



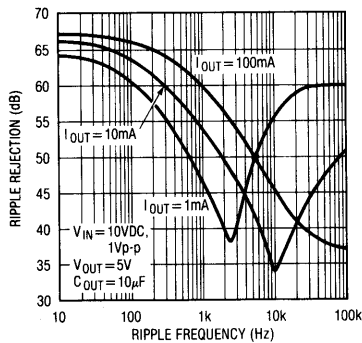
Dropout Detector Current



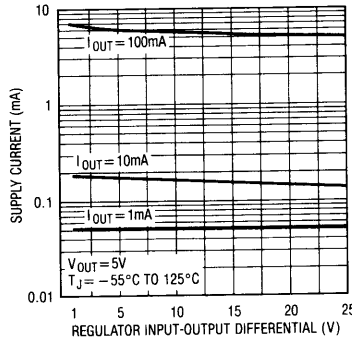
Regulator Minimum Load Current



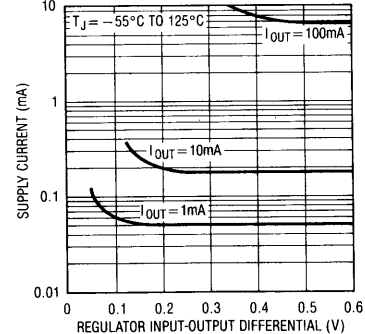
Regulator Ripple Rejection



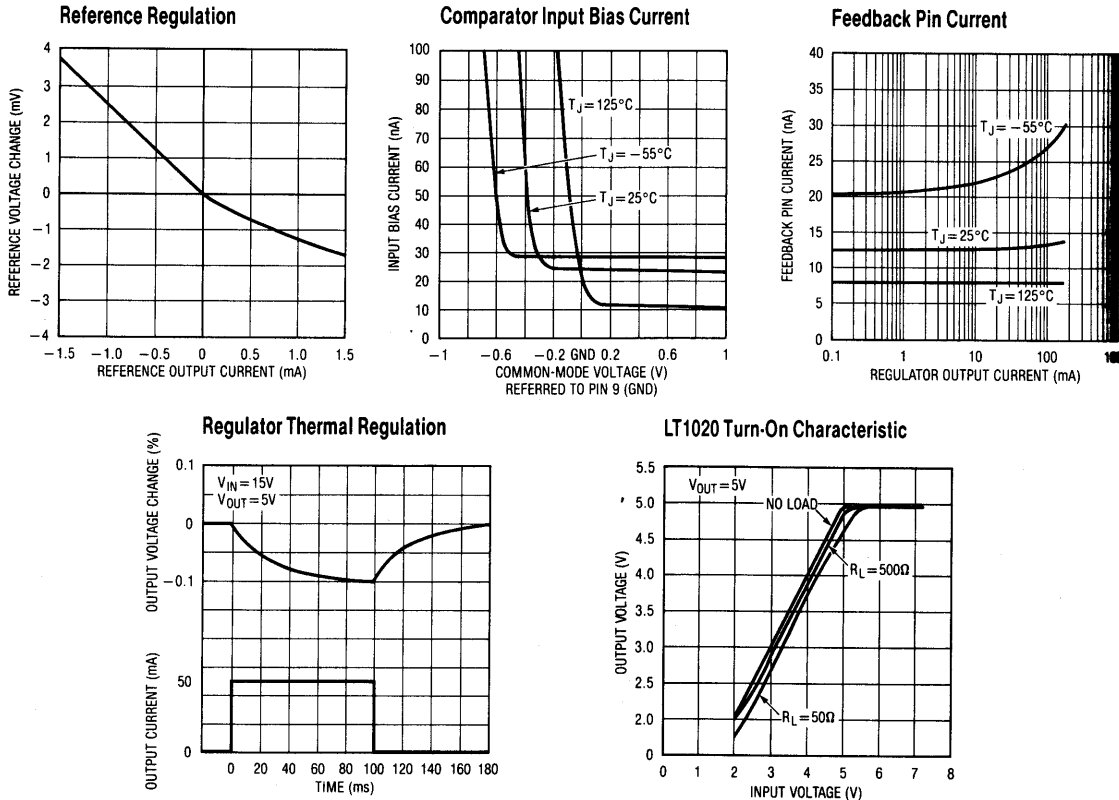
Supply Current



Supply Current at Dropout



## TYPICAL PERFORMANCE CHARACTERISTICS



## APPLICATION HINTS

The LT1020 is especially suited for micropower system applications. For example, the comparator section of the LT1020 may be used as a battery checker to provide an indication of low battery. The dropout detector can shut-down the system when the battery voltage becomes too low to regulate. Another type of system application for the LT1020 would be to generate the equivalent of split supplies off of a single power input. The regulator section provides regulated output voltage and the reference, which can both source and sink current is then an artificial system ground providing a split supply for the system.

For many applications the comparator can be frequency compensated to operate as an amplifier. Compensation

values for various gains are given in the datasheet. The comparator gain is purposely low to make it easier to frequency compensate as an amplifier. Two outputs are available on the comparator, the NPN output is capable of sinking 10mA and can drive loads connected to voltages in excess of the positive power supply. This is useful for driving switches or linear regulators off of a higher input voltage. The PNP output, which is capable of sourcing 100 $\mu\text{A}$  can drive loads below ground. It can be used to make negative regulators with the addition of an external pass transistor. Both outputs can be tied together to provide an output that swings from rail-to-rail for comparator or amplifier applications. Although it is not specified, the gain for the PNP output is about 500-1000.

## APPLICATION HINTS

If the PNP output is being used, to maximize the gain, a 1-5mA load should be placed upon the NPN output collector. This is easily done by connecting a resistor between the NPN collector and the reference output. (Providing this operating current to the NPN side increases the internal emitter base voltages and maximizes the gain of the PNP stage.) Without this loading on the NPN collector, at temperatures in excess of 75°C, the gain of the PNP collector can decrease by a factor of 2 or 3.

### Reference

Internal to the LT1020 is a 2.5V trimmed class B output reference. The reference was designed to be able to source or sink current so it could be used in supply splitting applications as well as a general purpose reference for external circuitry. The design of the reference allows it to source typically 4 or 5mA and sink 2mA. The available source and sink current decreases as temperature increases. It is sometimes desirable to decrease the AC output impedance by placing an output capacitor on them. The reference in the LT1020 becomes unstable with large capacitive loads placed directly on it. When using an output capacitor, about 20Ω should be used to isolate the capacitor from the reference pin. This 20Ω resistor can be placed directly in series with the capacitor or alternatively the reference line can have 20Ω placed in series with it and then a capacitor to ground. This is shown in Figure 1. Other than placing large capacitive loads on the reference, no other precautions are necessary and the reference is stable with nominal stray capacitances.

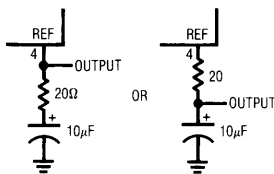


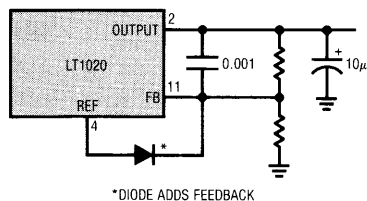
Figure 1. Bypassing Reference

### Overload Protection

The main regulator in the LT1020 is current limited at approximately 250mA. The current limit is stable with both input voltage and temperature. A current limit pin, when strapped to ground, decreases the output current. This allows the output current to be set to a lower value than 250mA. The output current available with the current limit pin strapped to ground is not well controlled so if precise current limiting is desired it should be provided externally as is shown in some of the application circuits.

If the device is overloaded for long periods of time, thermal shutdown turns the output off. In thermal shutdown, there may be some oscillations which can disturb external circuitry. A diode connected between the reference and feedback terminal provides hysteresis under thermal shutdown, so that the device turns on and off with about a 5 second period and there are no higher frequency oscillations. This is shown in Figure 2. This diode is recommended for most applications. Thermal shutdown temperature is set at approximately 145°.

Like most other IC regulators, a minimum load is required on the output of the LT1020 to maintain regulation. For most standard regulators this is normally specified at 5mA. Of course, for a micropower regulator this would be a tremendously large current. The output current must be large enough to absorb all the leakage current of the pass transistor at the maximum operating temperature. It also affects the transient response; low output currents have long recovery times from load transients. At high operating temperatures the minimum load current increases and



\*DIODE ADDS FEEDBACK

Figure 2. Minimizing Oscillation In Thermal Shutdown

## APPLICATION HINTS

having too low of a load current may cause the output to go unregulated. Devices are tested for minimum load current at high temperature. The output voltage setting resistors to the feedback terminal can usually be used to provide the minimum load current.

### Frequency Compensation

The LT1020 is frequency compensated by a dominant pole on the output. An output capacitor of  $10\mu\text{F}$  is usually large enough to provide good stability. Increasing the output capacitor above  $10\mu\text{F}$  further improves stability. In order to insure stability, a feedback capacitor is needed between the output pin and the feedback pin. This is because stray capacitance can form another pole with the large value of feedback resistors used with the LT1020. Also, a feedback capacitor minimizes noise pickup and improves ripple rejection.

With the large dynamic operating range of the output current, 10000:1, frequency response changes widely. Low AC impedance capacitors are needed to insure stability. While solid tantalum are best, aluminum electrolytics can be used but larger capacitor values may be needed.

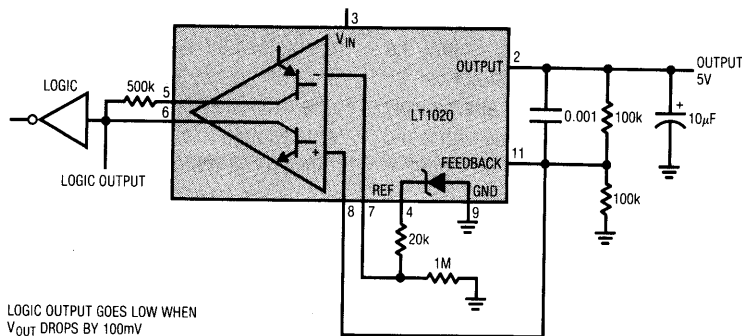
The CURRENT LIMIT pin allows one of the internal nodes to be rolled off with a  $0.05\mu\text{F}$  capacitor to ground. With this capacitor, lower values of regulator output capacitance can be used (down to  $1\mu\text{F}$ ) for low ( $<20\text{mA}$ ) output currents. Values of capacitance greater than  $0.05\mu\text{F}$  degrade the transient response, so are not recommended.

If the CURRENT LIMIT pin is connected to GND, the current limit is decreased and only a  $1\mu\text{F}$  output capacitor is needed.

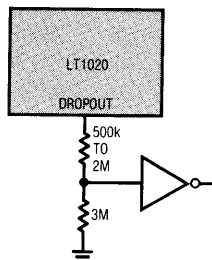
When bypassing the reference, a  $20\Omega$  resistor must be connected in series with the capacitor.

## TYPICAL APPLICATIONS

Regulator With Output Voltage Monitor



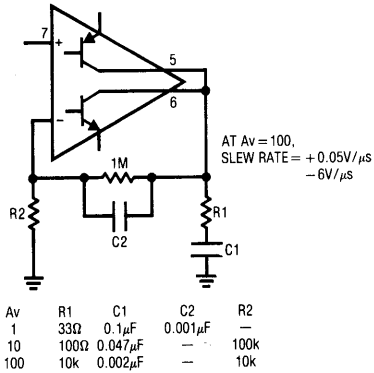
Driving Logic With Dropout Detector



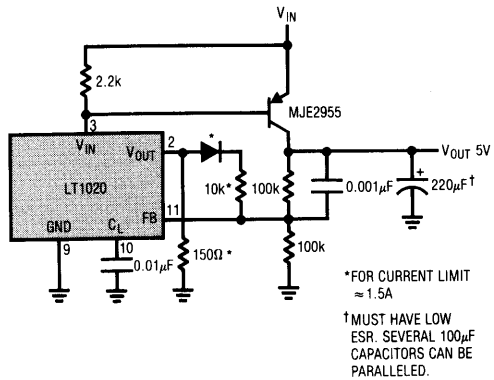


# TYPICAL APPLICATIONS

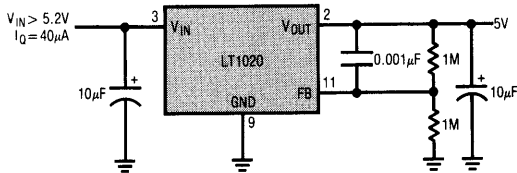
Compensating the Comparator as an Op Amp



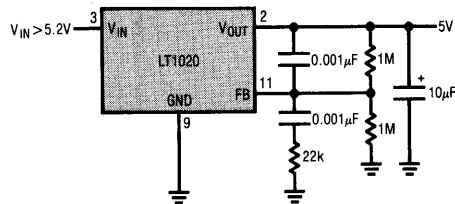
1 Amp Low Dropout Regulator



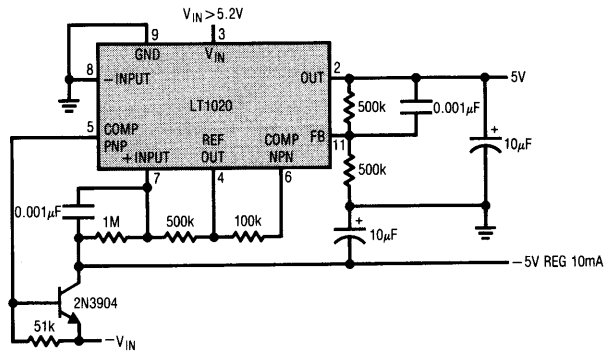
5V Regulator



Regulator with Improved Transient Response

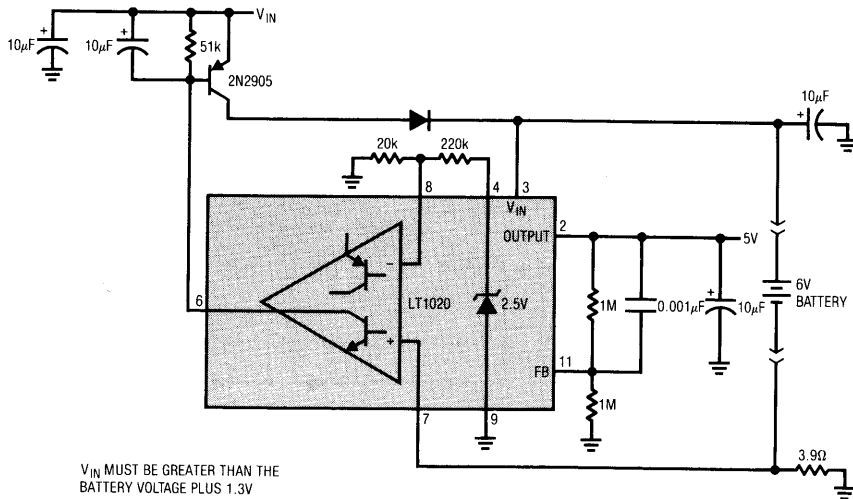


Dual Output Regulator

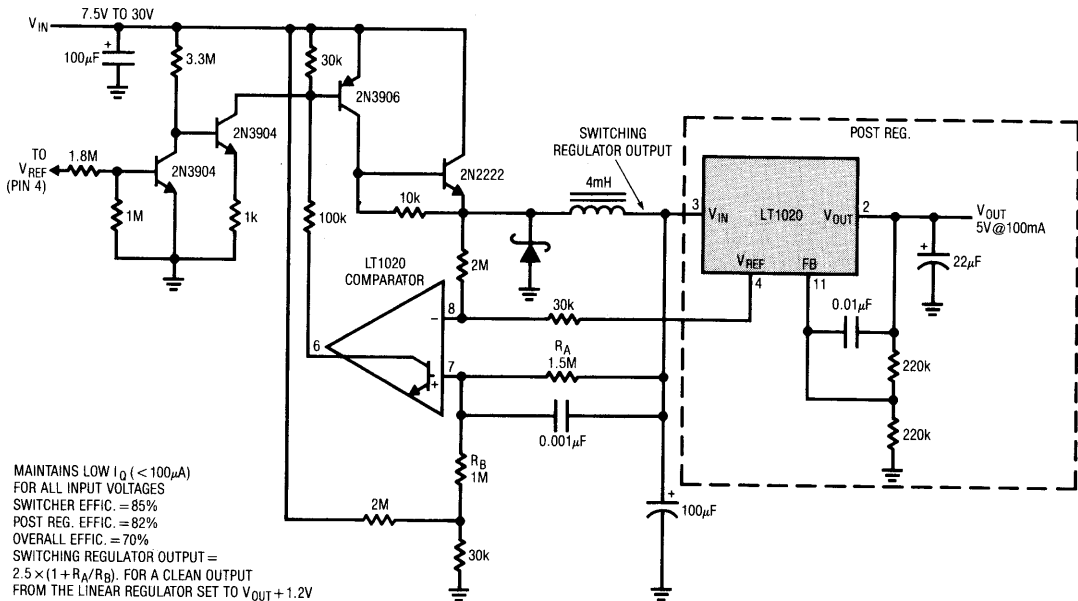


TYPICAL APPLICATIONS

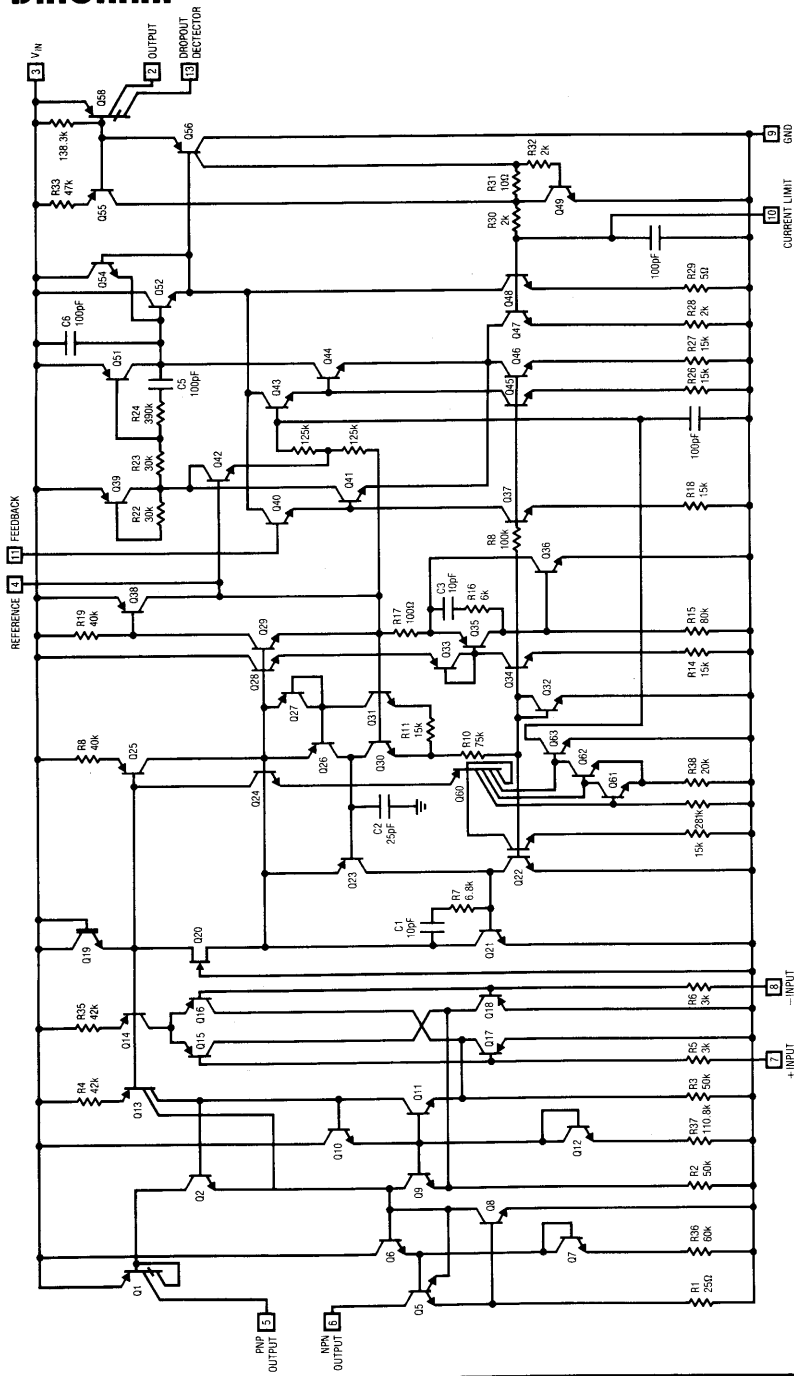
50mA Battery Charger and Regulator



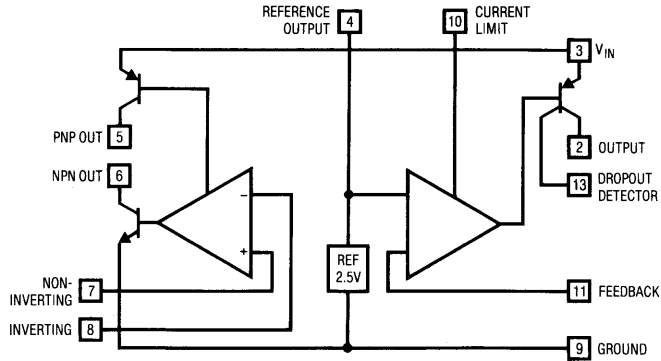
Switching Preregulator for Wide Input Voltage Range



# SCHEMATIC DIAGRAM



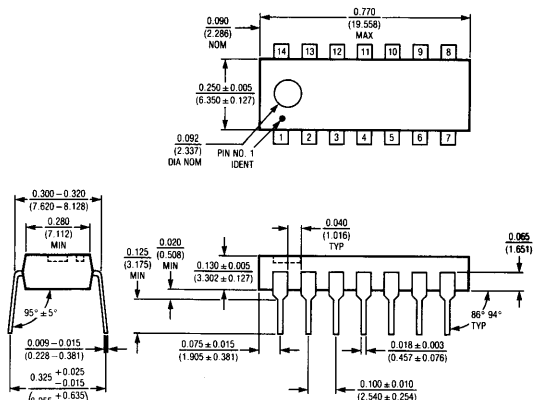
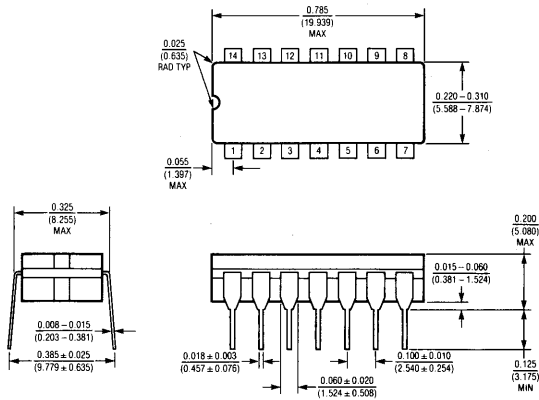
**BLOCK DIAGRAM**



**PACKAGE DESCRIPTION** Dimensions in inches (millimeters) unless otherwise noted.

**J14 Package  
Hermetic DIP**

**N14 Package  
Plastic DIP**



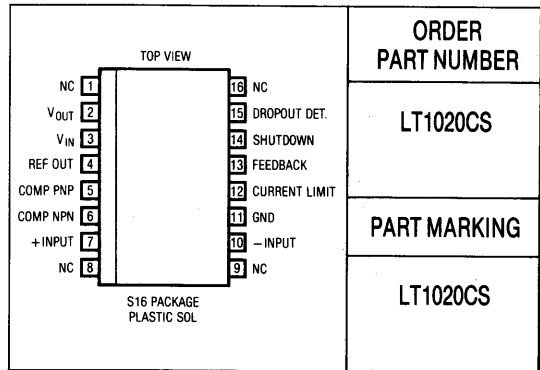
$T_{jmax}$ 150°C	$\Theta_{JA}$ 80°C/W
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$T_{jmax}$ 110°C	$\Theta_{JA}$ 130°C/W
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**ABSOLUTE MAXIMUM RATINGS**

Input Voltage .....	36V
NPN Collector Voltage .....	36V
PNP Collector Voltage .....	Supply - 36V
Output Short Circuit Duration .....	Indefinite
Power Dissipation .....	Internally Limited
Operating Temperature Range .....	0°C to 100°C
Storage Temperature Range .....	- 65°C to 150°C

**PACKAGE/ORDER INFORMATION**



**ELECTRICAL CHARACTERISTICS**  $T_j = 25^\circ\text{C}$

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
<b>Reference</b>					
Reference Voltage	$4.5\text{V} \leq V_{IN} \leq 36\text{V}$	2.46	2.50	2.54	V
Line Regulation	$4.5\text{V} \leq V_{IN} \leq 36\text{V}$		0.01	0.015	%/V
Load Regulation	$-0.5\text{mA} \leq I_{REF} \leq 1\text{mA}, V_{IN} = 12\text{V}$		0.2	0.3	%
Output Source Current	$V_{IN} = 5\text{V}$	1	4		mA
Output Sink Current	$V_{IN} = 5\text{V}$	0.5	2		mA
Temperature Stability			1		%
<b>Regulator</b>					
Supply Current	$V_{IN} = 6\text{V}, I_{OUT} \leq 100\mu\text{A}$ $V_{IN} = 36\text{V}, I_{OUT} \leq 100\mu\text{A}$ $V_{IN} = 12\text{V}, I_{OUT} = 125\text{mA}$ $V_{IN} \leq 36\text{V}$ Shutdown		45 75 11 50	80 120 20	$\mu\text{A}$ $\mu\text{A}$ mA $\mu\text{A}$
Output Current	$(V_{IN} - V_{OUT}) \geq 1\text{V}, V_{IN} \geq 6\text{V}$	125			mA
Load Regulation	$(V_{IN} - V_{OUT}) \geq 1\text{V}, V_{IN} \geq 6\text{V}$		0.2	0.5	%
Line Regulation	$6\text{V} \leq V_{IN} \leq 36\text{V}$		0.01	0.015	%/V
Dropout Voltage	$I_{OUT} = 100\mu\text{A}$ $I_{OUT} = 125\text{mA}$		0.02 0.4	0.05 0.65	V V
Feedback Sense Voltage	$V_{IN} = 12\text{V}$	2.44	2.5	2.56	V
Dropout Detector Current	$\Delta V_{OUT} = -0.05\text{V}$	3	20		$\mu\text{A}$
Feedback Bias Current			15	40	nA
Minimum Load Current	$V_{IN} = 36\text{V}$		1	5	$\mu\text{A}$
Short Circuit Current	$V_{IN} = 36\text{V}$ Pin 11 and Pin 12 shorted, $V_{IN} = 4.5\text{V}$	3	250 30	360	mA mA
<b>Comparator</b>					
Offset Voltage	$0\text{V} \leq V_{CM} \leq 35\text{V}, V_{IN} = 36\text{V}$		3	7	mV
Bias Current	$0\text{V} \leq V_{CM} \leq 35\text{V}, V_{IN} = 36\text{V}$		15	40	nA
Offset Current	$0\text{V} \leq V_{CM} \leq 35\text{V}, V_{IN} = 36\text{V}$		4	15	nA
Gain-NPN Pulldown	$\Delta V_{OUT} = 29\text{V}, R_L = 20\text{k}$	2000	10000		V/V
Common Mode Rejection	$0\text{V} \leq V_{CM} \leq 35\text{V}, V_{IN} = 36\text{V}$	80	94		dB