Micropower Regulator and Comparator

FEATURES

- 40μA 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 Systems
- Portable Terminals
- Portable Instruments

DESCRIPTION

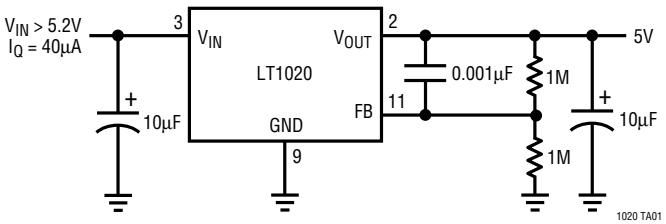
The LT1020 is a combination micropower positive regulator and free collector comparator on a single monolithic chip. With only 40μA supply current, the LT1020 can supply over 125mA of output current. Input voltage range is from 4.5V to 36V and dropout voltage is 0.6V at 125mA. Dropout voltage decreases 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.

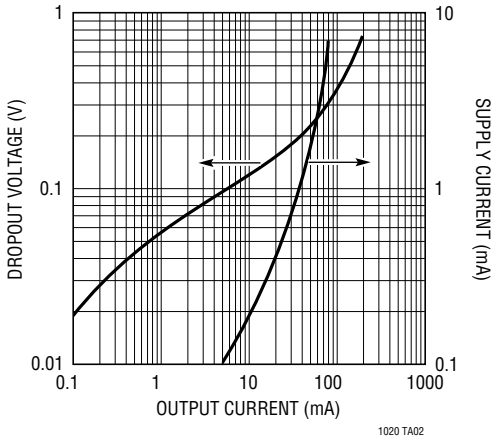
The 2.5V reference will source or sink current. This allows it to be used as a supply splitter or auxiliary output.

TYPICAL APPLICATION

5V Regulator



Dropout Voltage and Supply Current

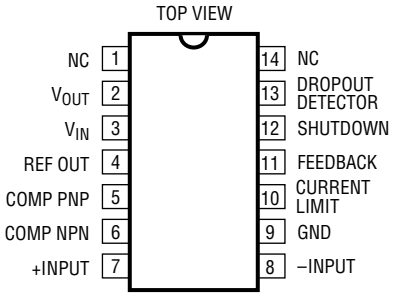


ABSOLUTE MAXIMUM RATINGS

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

Operating Temperature Range
LT1020C..... 0°C to 100°C
LT1020I ..... –40°C to 100 °C
LT1020M ..... –55°C to 125°C
Lead Temperature (Soldering, 10 sec)..... 300°C

PACKAGE/ORDER INFORMATION



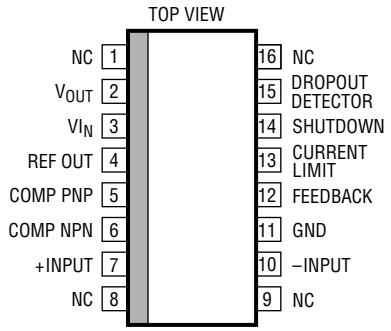
J PACKAGE
14-LEAD CERAMIC DIP

N PACKAGE
14-LEAD PLASTIC DIP

T_{JMAX} = 150°C, θ_{JA} = 80°C/W (J)
T_{JMAX} = 110°C, θ_{JA} = 130°C/W (N)

ORDER PART NUMBER

LT1020CJ
LT1020CN
LT1020IJ
LT1020IN
LT1020MJ



S PACKAGE
16-LEAD PLASTIC SOIC

T_{JMAX} = 110°C, θ_{JA} = 150°C/W

ORDER PART NUMBER

LT1020CS
LT1020IS

ELECTRICAL CHARACTERISTICS T_J = 25°C

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Reference					
Reference Voltage	$4.5V \le V_{IN} \le 36V$	2.46	2.50	2.54	V
Line Regulation	$4.5V \le V_{IN} \le 36V$		0.01	0.015	%/V
Load Regulation	$-0.5mA \le I_{REF} \le 1mA$, V_{IN} = 12V		0.2	0.3	%
Output Source Current	V_{IN} = 5V	1	4		mA
Output Sink Current	V_{IN} = 5V	0.5	2		mA
Temperature Stability			1		%
Regulator					
Supply Current	V_{IN} = 6V, $I_{OUT} \le 100\mu A$		45	80	µA
	V_{IN} = 36V, $I_{OUT} \le 100\mu A$		75	120	µA
	V_{IN} = 12V, I_{OUT} = 125mA		11	20	mA
Output Current	$(V_{IN} - V_{OUT}) \ge 1V$, $V_{IN} \ge 6V$	125			mA
Load Regulation	$(V_{IN} - V_{OUT}) \ge 1V$, $V_{IN} \ge 6V$		0.2	0.5	%
Line Regulation	$6V \le V_{IN} \le 36V$		0.01	0.015	%/V
Dropout Voltage	$I_{OUT} = 100\mu A$		0.02	0.05	V
	I_{OUT} = 125mA		0.4	0.65	V
Feedback Sense Voltage	V_{IN} = 12V	2.44	2.5	2.56	V
Dropout Detector Current	$\Delta V_{OUT} = -0.05V$, $I_{OUT} = 500\mu A$	3	20		µA

ELECTRICAL CHARACTERISTICS $T_J = 25°C$

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Regulator					
Feedback Bias Current			15	40	nA
Minimum Load Current	V_{IN} = 36V		1	5	µA
Short-Circuit Current	V_{IN} = 36V		300	400	mA
	Pins 9 and 10 Shorted, V_{IN} = 4.5V	3	30		mA
Comparator					
Offset Voltage	0V ≤ V_{CM} ≤ 35V, V_{IN} = 36V		3	7	mV
Bias Current	0V ≤ V_{CM} ≤ 35V, V_{IN} = 36V		15	40	nA
Offset Current	0V ≤ V_{CM} ≤ 35V, V_{IN} = 36V		4	15	nA
Gain-NPN Pull-Down	ΔV_{OUT} = 29V, R_L = 20k	2000	10000		V/V
Common-Mode Rejection	0V ≤ V_{CM} ≤ 35V, V_{IN} = 36V	80	94		dB
Power Supply Rejection	4.5V ≤ V_S ≤ 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		µA
Input Voltage Range		0		V_{IN} – 1	V
Response Time			5		µs
Leakage Current (NPN)				2	µA

ELECTRICAL CHARACTERISTICS

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Reference						
Reference Voltage	4.5V ≤ V_{IN} ≤ 36V	●	2.40	2.50	2.55	V
Line Regulation	4.5V ≤ V_{IN} ≤ 36V	●		0.01	0.02	%/V
Load Regulation	–0.5mA ≤ I_{REF} ≤ 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
Regulator						
Supply Current	V_{IN} = 6V, I_{OUT} ≤ 100µA	●		65	95	µA
	V_{IN} = 36V, I_{OUT} ≤ 100µA	●		85	120	µA
	V_{IN} = 12V, I_{OUT} = 125mA	●		11	20	mA
Output Current	(V_{IN} – V_{OUT}) ≥ 1V, V_{IN} ≥ 6V	●	125			mA
Load Regulation	(V_{IN} – V_{OUT}) ≥ 1V, V_{IN} ≥ 6V	●			1	%
Line Regulation	6V ≤ V_{IN} ≤ 36V	●			0.02	%/V
Dropout Voltage	I_{OUT} = 100µA	●			0.06	V
	I_{OUT} = 125mA	●			0.85	V
Feedback Sense Voltage	V_{IN} = 12V	●	2.38	2.5	2.57	V
Dropout Detector Current	ΔV_{OUT} = –0.05V, I_{OUT} = 500µA	●	3			µA
Feedback Bias Current		●			50	nA
Minimum Load Current	V_{IN} = 36V	●			50	µA
Short-Circuit Current	V_{IN} = 36V	●		300	400	mA
	Pins 9 and 10 Shorted, V_{IN} = 4.5V	●	2.5	30		mA
Comparator						
Offset Voltage	0V ≤ V_{CM} ≤ 35V, V_{IN} = 36V	●			10	mV
Bias Current	0V ≤ V_{CM} ≤ 35V, V_{IN} = 36V (Note 1)	●		15	60	nA
Offset Current	0V ≤ V_{CM} ≤ 35V, V_{IN} = 36V	●			20	nA
Gain-NPN Pull-Down	ΔV_{OUT} = 29V, R_L = 20k	●	1000			V/V

ELECTRICAL CHARACTERISTICS

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Comparator						
Common-Mode Rejection	$0V \le V_{CM} \le 35V$, $V_{IN} = 36V$	●	80			dB
Power Supply Rejection	$4.5V \le V_{IN} \le 36V$	●	80			dB
Output Sink Current	$V_{IN} = 4.5V$ (Note 2)	●	5	10		mA
Output Source Current		●	40	120		µA
Input Voltage Range		●	0		$V_{IN} - 1$	V
Leakage Current (NPN)	$V_{IN} = 36V$	●			8	µA

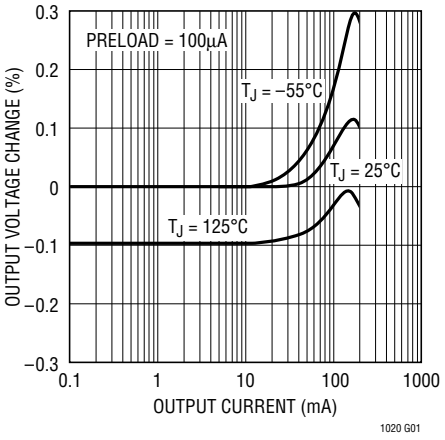
The ● denotes specifications which apply over the full operating temperature range.

Note 1: For $0V \le V_{CM} \le 0.1V$ and $T > 85°C$ $I_{BIAS(MAX)}$ is 100nA.

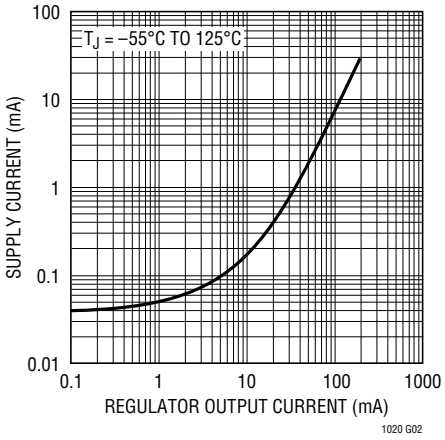
Note 2: For $T_A \le -40°C$ output $I_{SINK(MIN)}$ is 2.5mA.

TYPICAL PERFORMANCE CHARACTERISTICS

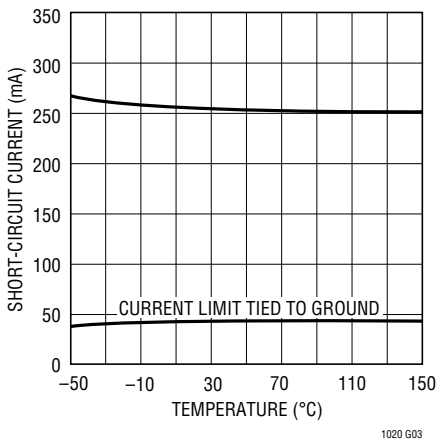
Regulator Load Regulation



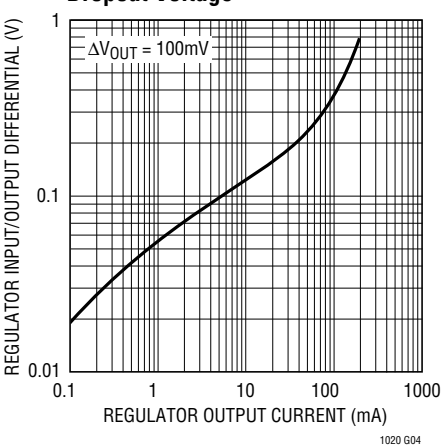
Supply Current



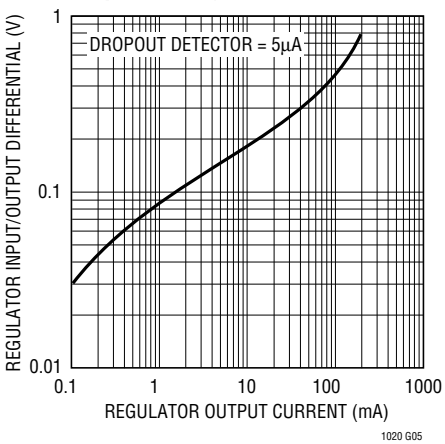
Regulator Short-Circuit Current



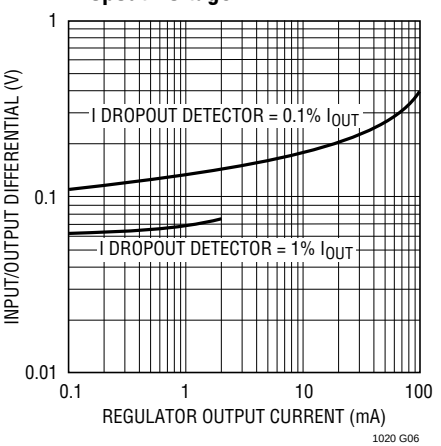
Dropout Voltage



Dropout Voltage

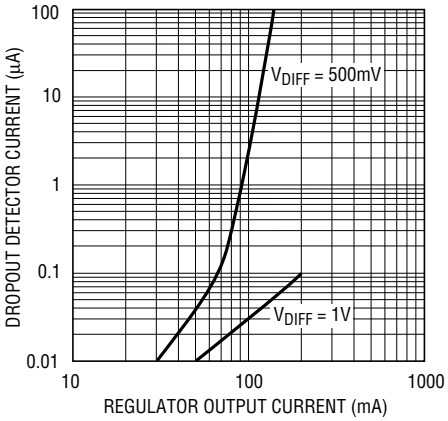


Dropout Voltage

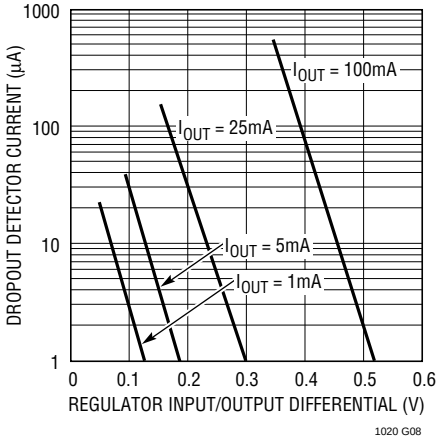


TYPICAL PERFORMANCE CHARACTERISTICS

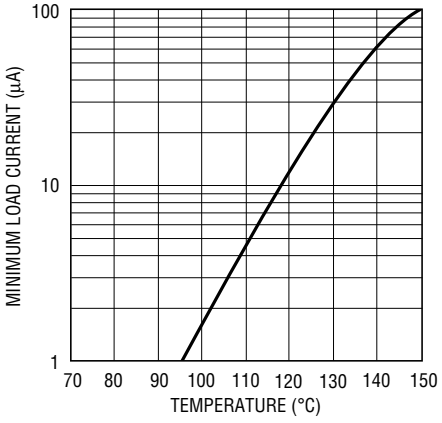
Dropout Detector Current



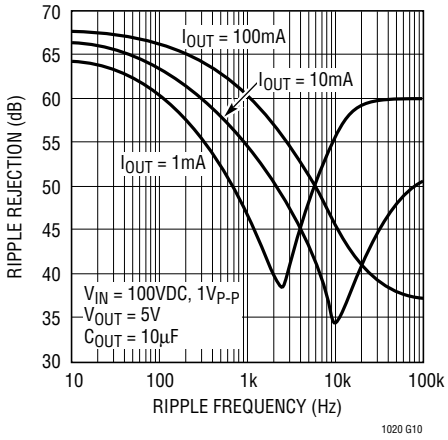
Dropout Detector Current



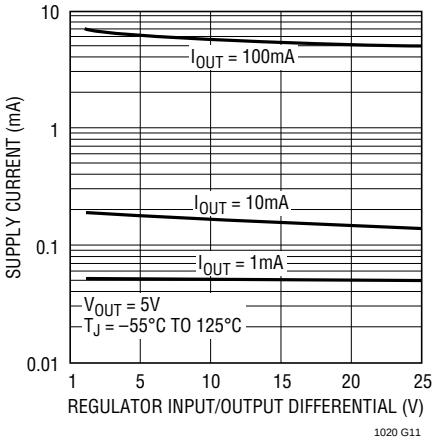
Regulator Minimum Load Current



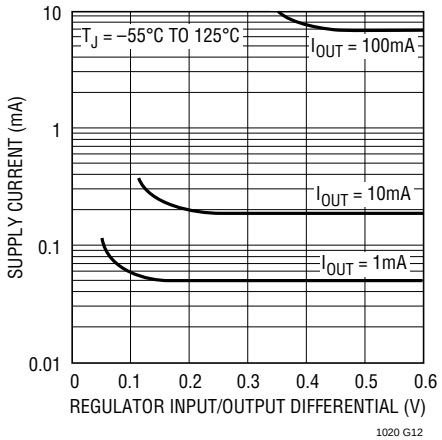
Regulator Ripple Rejection



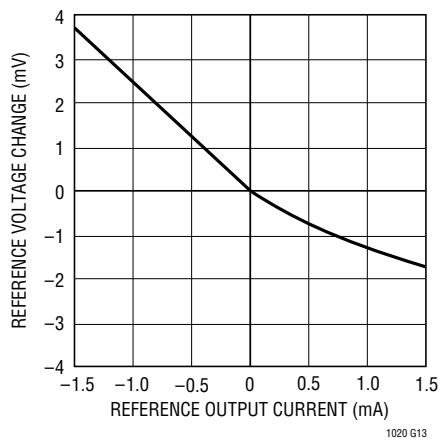
Supply Current



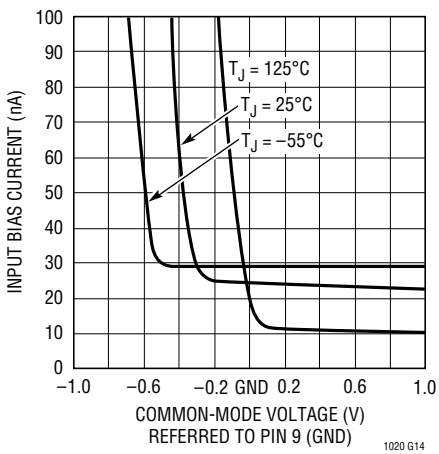
Supply Current at Dropout



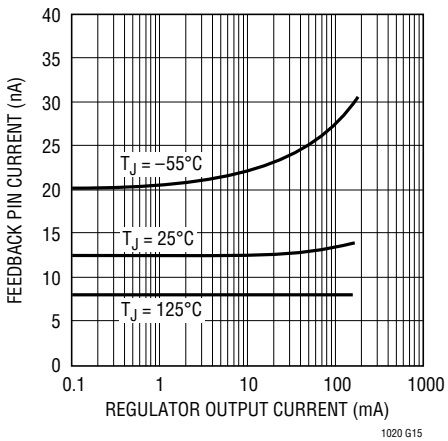
Reference Regulation



Comparator Input Bias Current

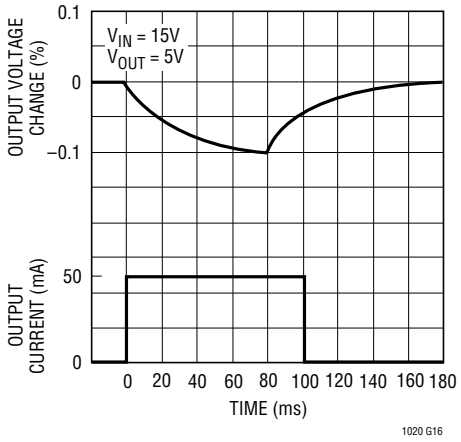


Feedback Pin Current

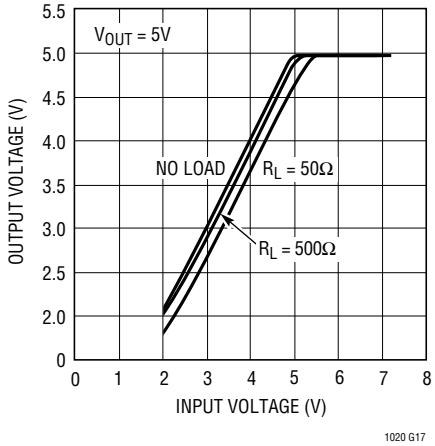


TYPICAL PERFORMANCE CHARACTERISTICS

Regulator Thermal Regulation



LT1020 Turn-On Characteristic



PIN FUNCTIONS

Pins 1, 14: No internal connection.

Pin 2: Regulator Output. Main output, requires 10µF output capacitor. Can be shorted to V_{IN} or ground without damaging the device.

Pin 3: Input Supply. Bypass with 10µF capacitor. 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.

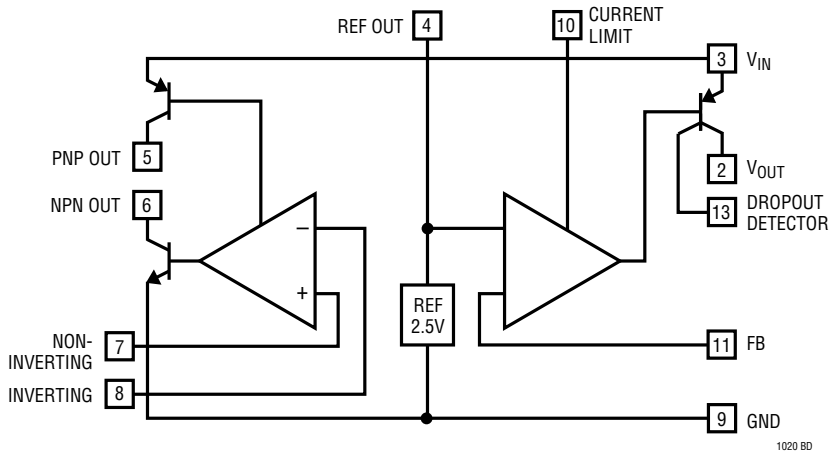
Pin 10: Current Limit. Connecting this pin to ground decreases the regulator current limit to 3mA minimum. Leave open when not used.

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 12: Shutdown. Turns output off.

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 5µA to about 300µA.

BLOCK DIAGRAM



APPLICATIONS INFORMATION

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 from 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 data sheet. 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 from a higher input voltage. The PNP output, which is capable of sourcing 100μA 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 to 1000.

If the PNP output is being used, to maximize the gain a 1μA to 5μA 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 4mA 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

APPLICATIONS INFORMATION

other precautions are necessary and the reference is stable with nominal stray capacitances.

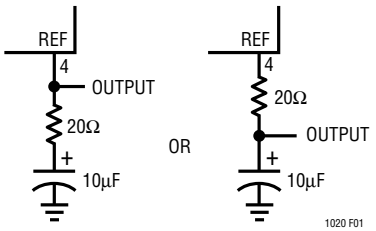


Figure 1. Bypassing Reference

Overload Protection

The main regulator in the LT1020 is current limited at approximately 350mA. 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°C.

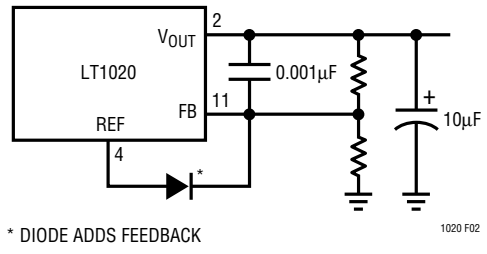


Figure 2. Minimizing Oscillation in Thermal Shutdown

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 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 10µF is usually large enough to provide good stability. Increasing the output capacitor above 10µF 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.

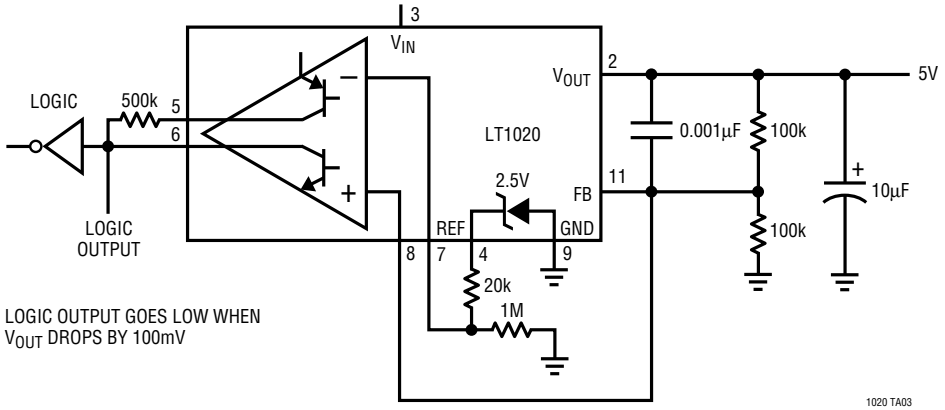
The CURRENT LIMIT pin allows one of the internal nodes to be rolled off with a 0.05µF capacitor to ground. With this capacitor, lower values of regulator output capacitance can be used (down to 1µF) for low (<20mA) output currents. Values of capacitance greater than 0.05µF degrade the transient response,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

If the CURRENT LIMIT pin is connected to GND, the current limit is decreased and only a 1µF output capacitor is needed.

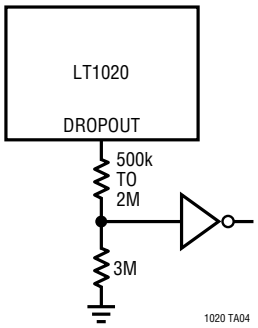
When bypassing the reference, a 20Ω resistor must be connected in series with the capacitor.

TYPICAL APPLICATIONS

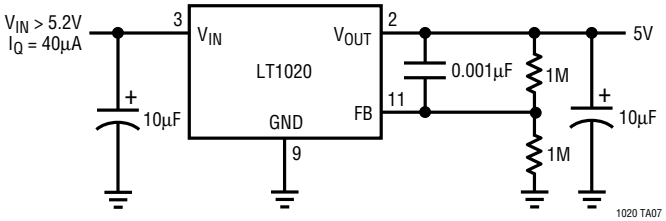
Regulator with Output Voltage Monitor



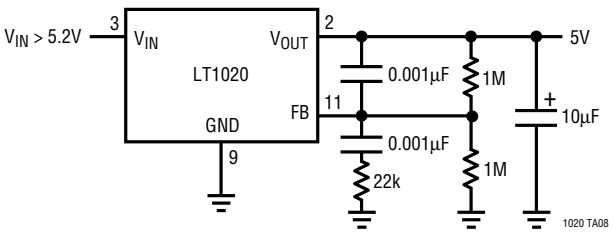
Driving Logic with Dropout Detector



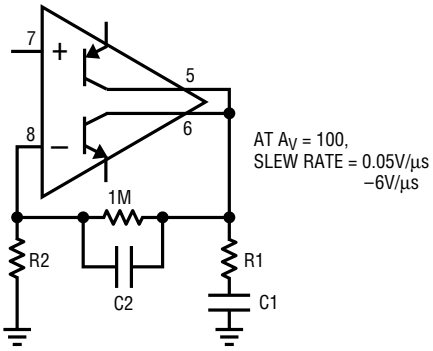
5V Regulator



Regulator with Improved Transient Response



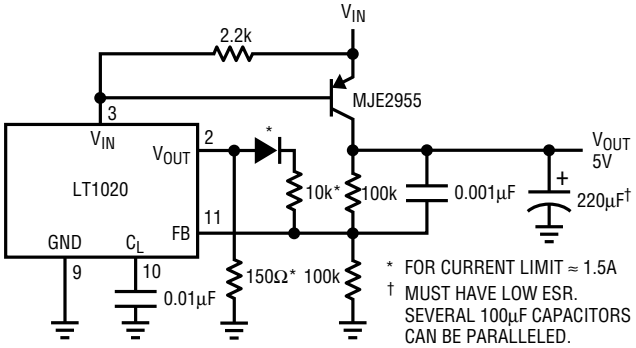
Compensating the Comparator As an Op Amp



A_V	R1	C1	C2	R2
1	33Ω	0.1µF	0.001µF	–
10	100Ω	0.047µF	–	100k
100	10k	0.002µF	–	10k

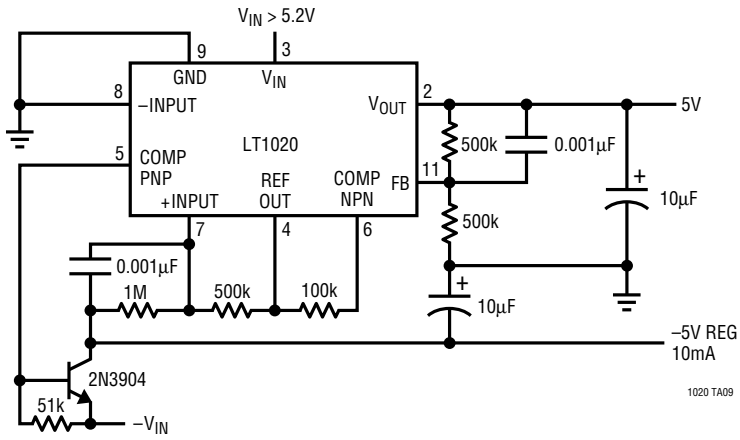
TYPICAL APPLICATIONS

1 Amp Low Dropout Regulator

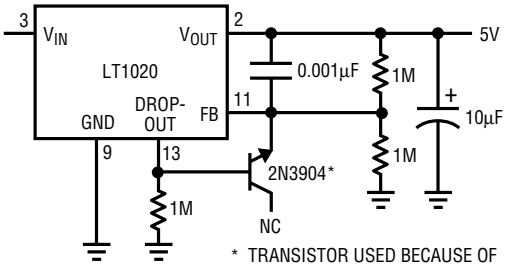


SEE LT1129 DATA SHEET FOR 700mA OUTPUT

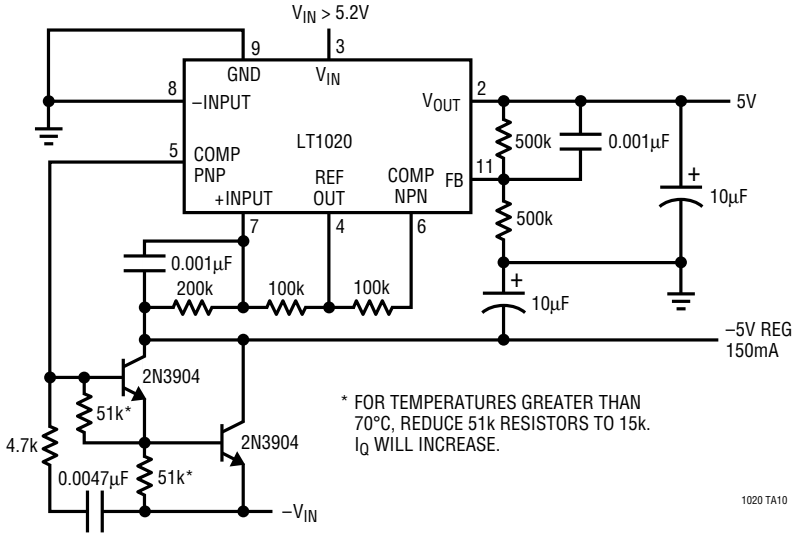
Dual Output Regulator



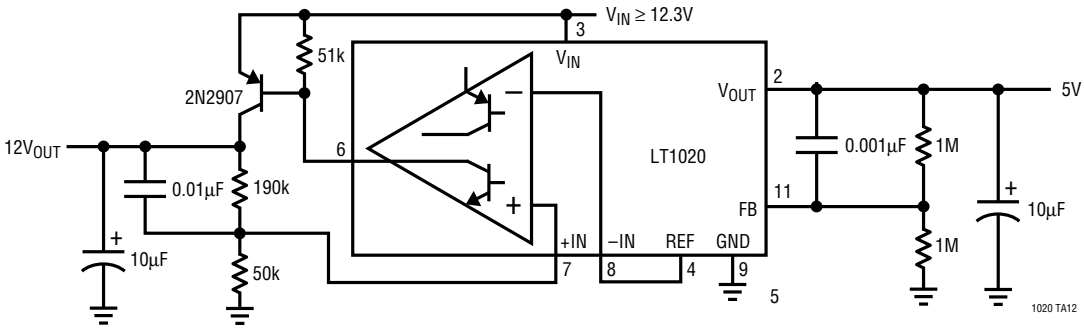
Maintaining Lowest I_Q at Dropout



Dual Output 150mA Regulator

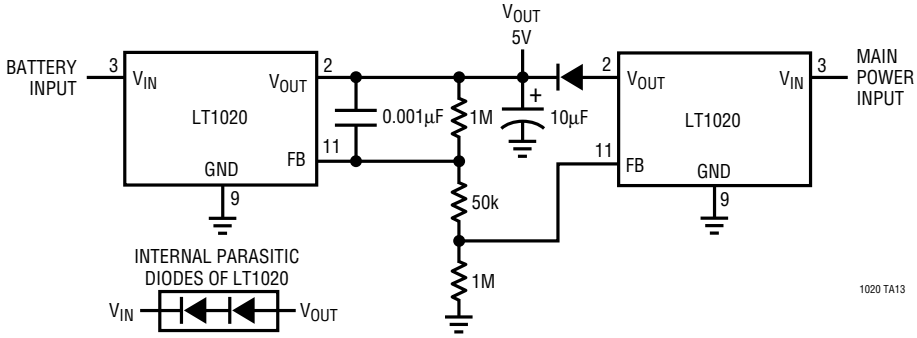


Dual Output Positive Regulator

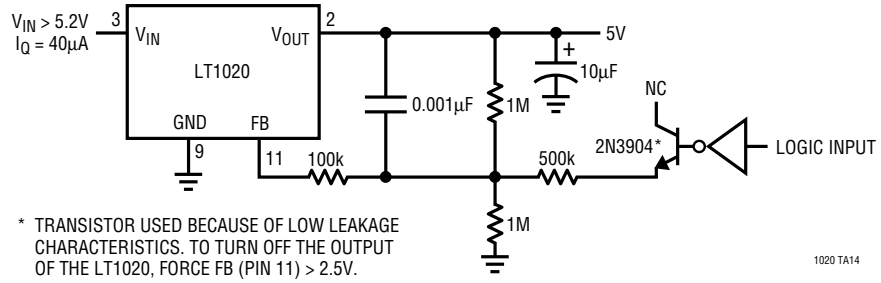


TYPICAL APPLICATIONS

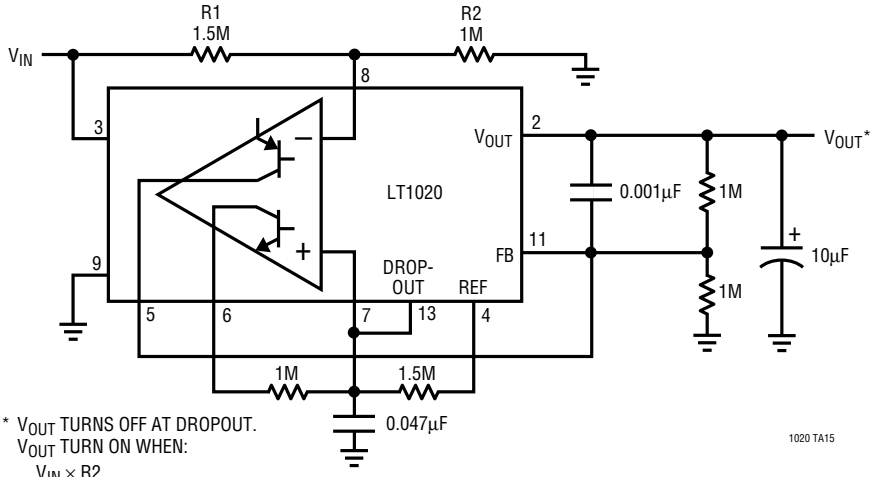
Battery Backup Regulator



5V Regulator with Shutdown

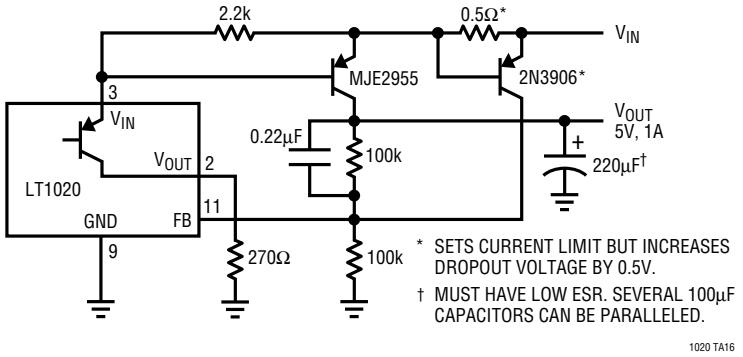


Turn-Off at Dropout

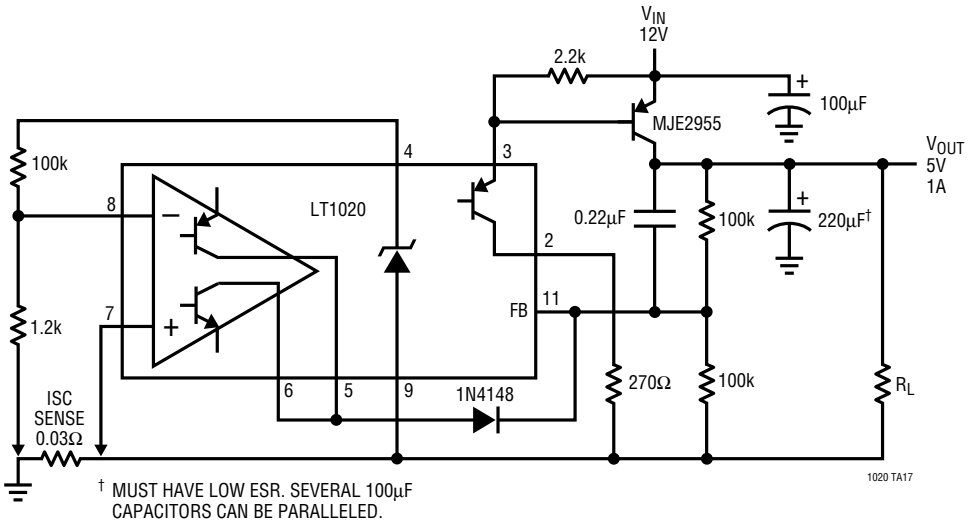


TYPICAL APPLICATIONS

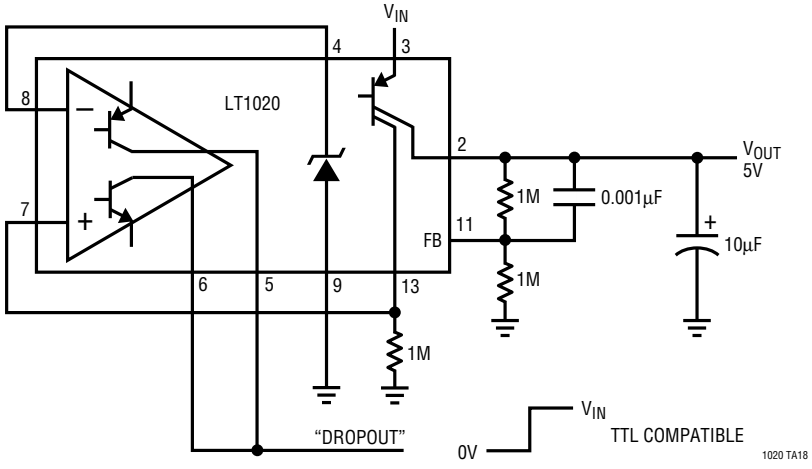
Current Limited 1 Amp Regulator



1 Amp Regulator with Precision Current Limit

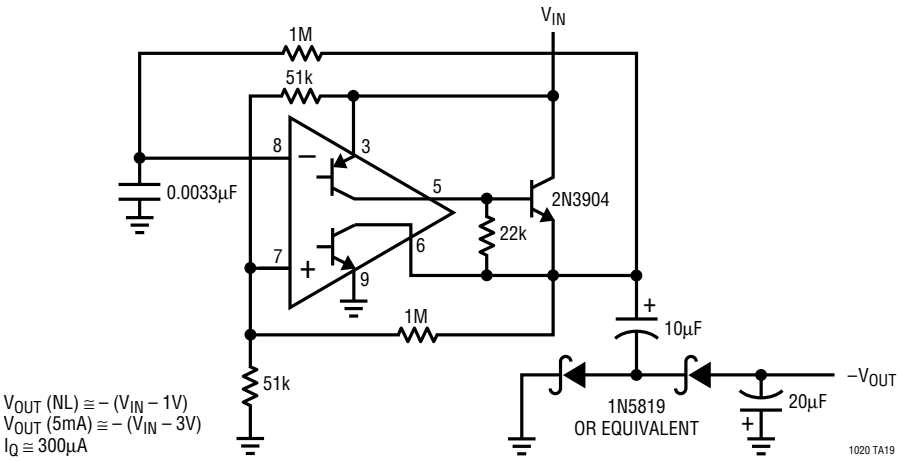


Logic Output on Dropout

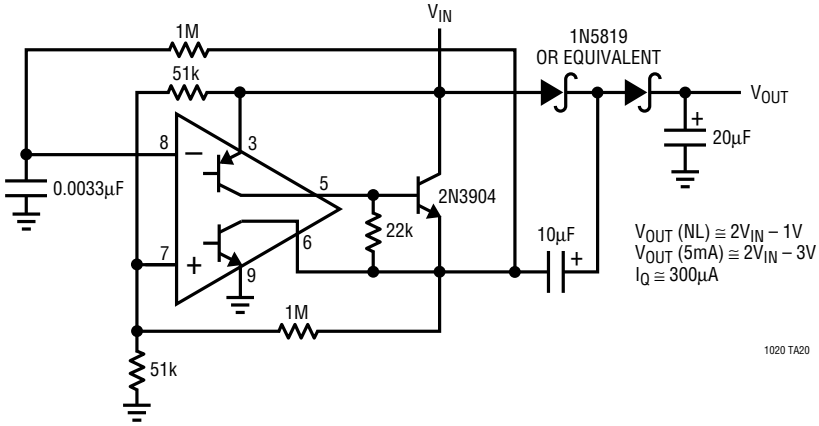


TYPICAL APPLICATIONS

Charge Pump Negative Voltage Generator

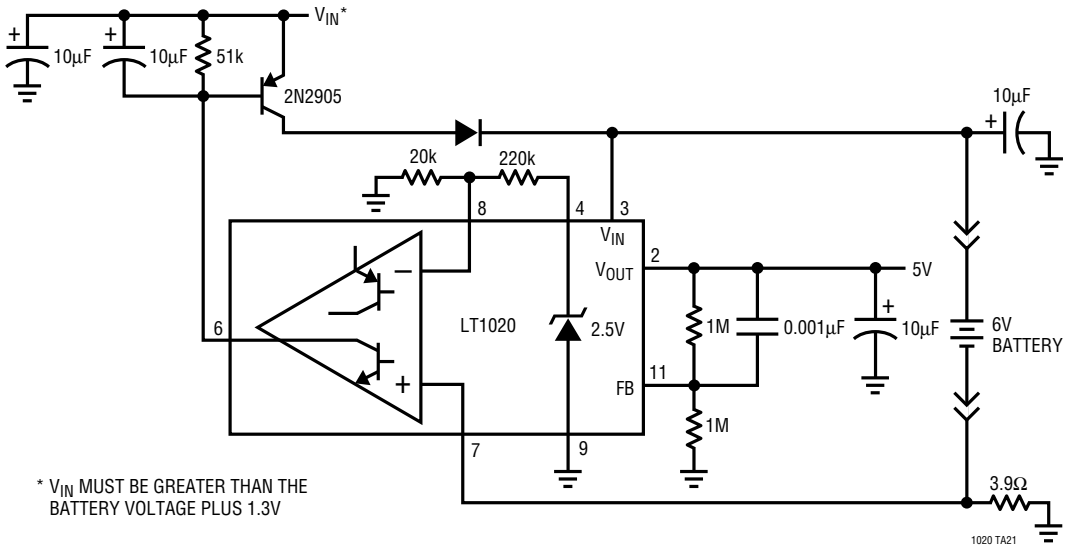


Charge Pump Voltage Doubler

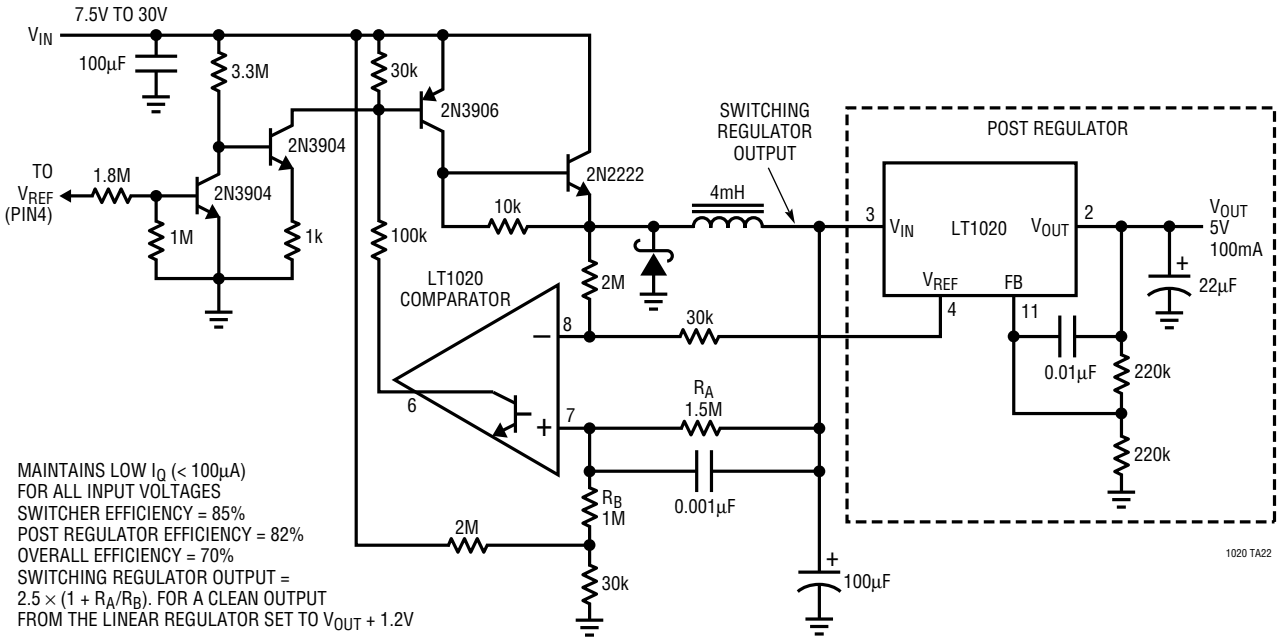


TYPICAL APPLICATIONS

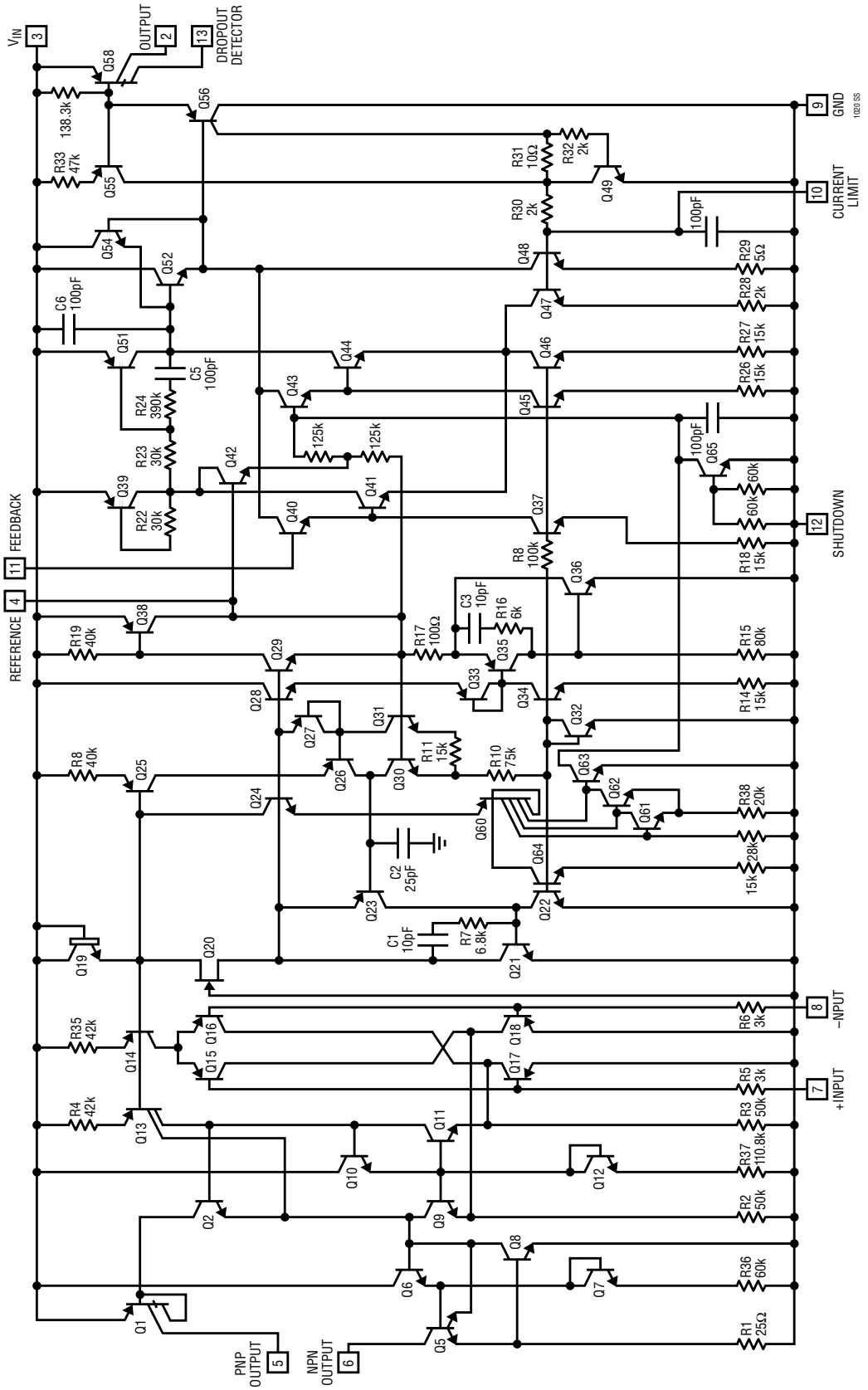
50mA Battery Charger and Regulator



Switching Preregulator for Wide Input Voltage Range



SCHEMATIC DIAGRAM

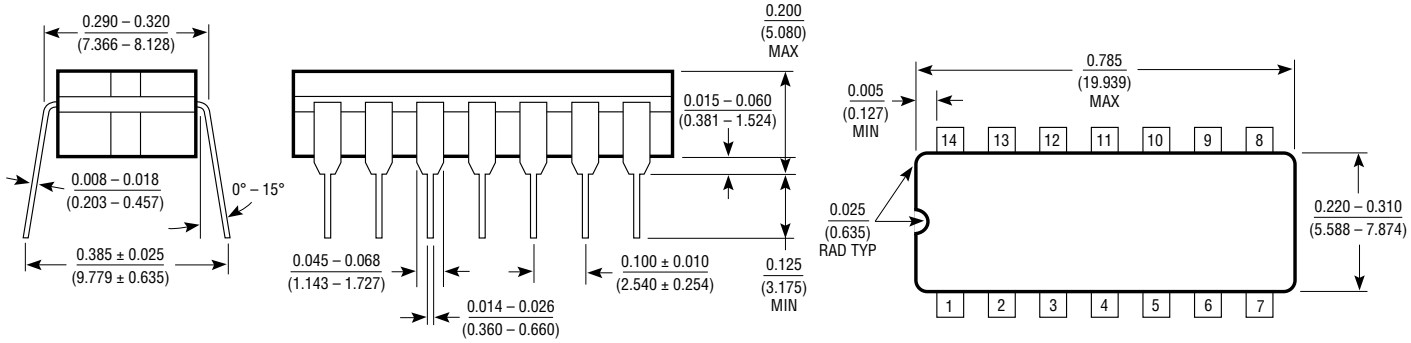


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PACKAGE DESCRIPTION

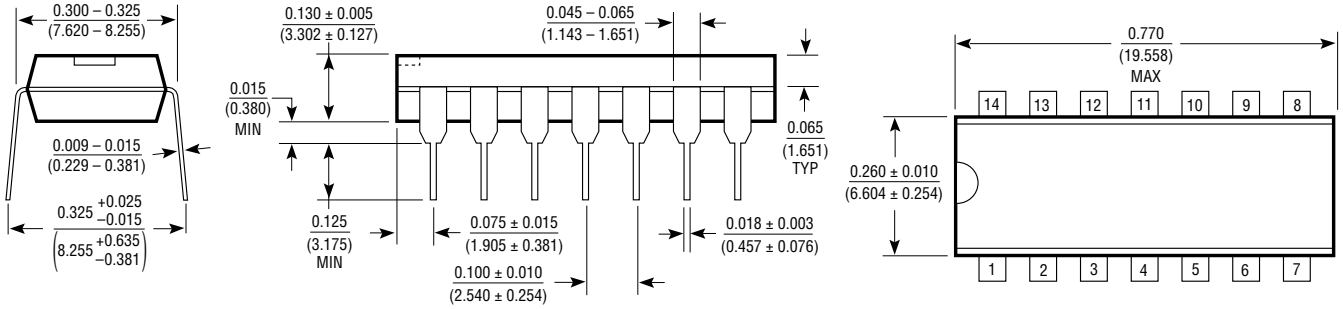
Dimensions in inches (millimeters) unless otherwise noted.

J Package
14-Lead Ceramic DIP

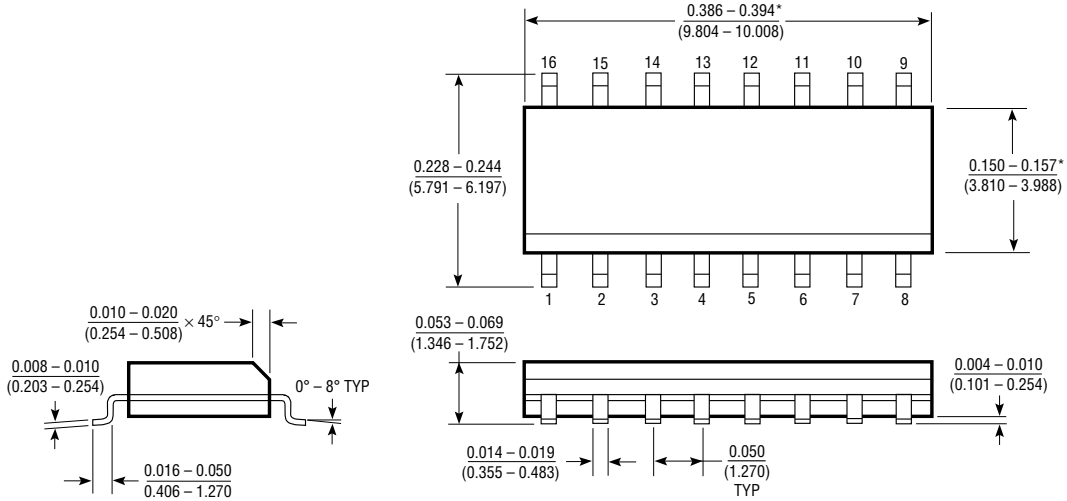


NOTE: LEAD DIMENSIONS APPLY TO SOLDER DIP OR TIN PLATE LEADS.

N Package
14-Lead Plastic DIP



S Package
16-Lead Plastic SOIC



*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 INCH (0.15mm).

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