19-1434; Rev 1; 5/99

Low-Cost, SOT23, Voltage-Output, High-Side Current-Sense Amplifier

General Description

The MAX4173 low-cost, precision, high-side current-sense amplifier is available in a tiny SOT23-6 package. It features a voltage output that eliminates the need for gain-setting resistors and it is ideal for today's notebook computers, cell phones, and other systems where current monitoring is critical. High-side current monitoring is especially useful in battery-powered systems, since it does not interfere with the ground path of the battery charger. The input common-mode range of 0 to +28V is independent of the supply voltage and ensures that the current-sense feedback remains viable even when connected to a battery in deep discharge. The MAX4173's wide 1.7MHz bandwidth makes it suitable for use inside battery charger control loops.

The combination of three gain versions and a user-selectable external sense resistor sets the full-scale current reading. This feature offers a high level of integration, resulting in a simple and compact current-sense solution.

The MAX4173 operates from a single +3V to +28V supply, typically draws only 420µA of supply current over the extended operating temperature range (-40°C to +85°C), and is offered in the space-saving SOT23-6 package.

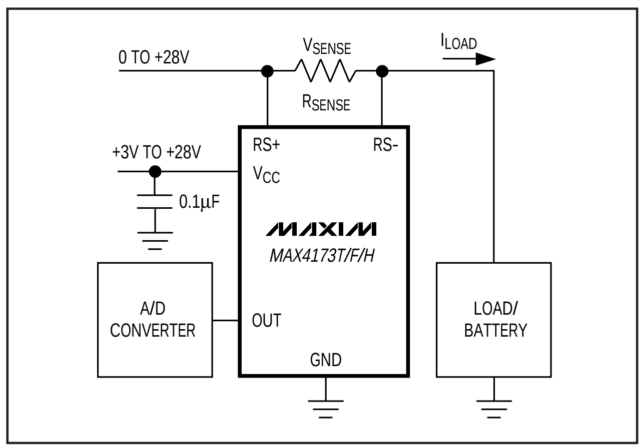
Applications

Notebook Computers
Portable/Battery-Powered Systems
Smart Battery Packs/Chargers
Cell Phones
Power-Management Systems
General System/Board-Level Current Monitoring
PA Bias Control
Precision Current Sources

Features

- **Low-Cost, Compact Current-Sense Solution**
- **Wide 0 to +28V Common-Mode Range Independent of Supply Voltage**
- **Three Gain Versions Available**
  - **+20V/V (MAX4173T)**
  - **+50V/V (MAX4173F)**
  - **+100V/V (MAX4173H)**
- **±0.5% Full-Scale Accuracy**
- **420µA Supply Current**
- **Wide 1.7MHz Bandwidth (MAX4173T)**
- **+3V to +28V Operating Supply**
- **Available in Space-Saving SOT23-6 Package**

Typical Operating Circuit



Ordering Information

PART	GAIN (V/V)	TEMP. RANGE	PIN-PACKAGE	SOT TOP MARK
MAX4173TEUT-T	20	-40°C to +85°C	6 SOT23-6	AABN
MAX4173TESA	20	-40°C to +85°C	8 SO	–
MAX4173FEUT-T	50	-40°C to +85°C	6 SOT23-6	AABD
MAX4173FESA	50	-40°C to +85°C	8 SO	–
MAX4173HEUT-T	100	-40°C to +85°C	6 SOT23-6	AABP
MAX4173HESA	100	-40°C to +85°C	8 SO	–

Pin Configurations appear at end of data sheet.

ABSOLUTE MAXIMUM RATINGS

V_{CC}, RS+, RS- to GND .... -0.3V to +30V
OUT to GND .... -0.3V to (V_{CC} + 0.3V)
Output Short-Circuit to V_{CC} or GND .... Continuous
Differential Input Voltage (V_{RS+} - V_{RS-}) .... ±0.3V
Current into Any Pin... ±20mA

Continuous Power Dissipation (T_A = +70°C)
8-Pin SO (derate 5.88mW/°C above +70°C)............... 471mW
SOT23-6 (derate 8.7mW/°C above +70°C)................. 696mW
Operating Temperature Range .... -40°C to +85°C
Storage Temperature Range .... -65°C to +150°C
Lead Temperature (soldering, 10sec) .... +300°C

Stresses beyond those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

(V_{RS+} = 0 to +28V, V_{CC} = +3V to +28V, V_{SENSE} = 0, T_A = T_{MIN} to T_{MAX}, R_{LOAD} = ∞ unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Operating Voltage Range	V_{CC}	Guaranteed by PSR test	3		28	V
Common-Mode Input Range	V_{CMR}	(Note 2)	0		28	V
Common-Mode Rejection	CMR	V_{RS+} > +2.0V		90		dB
Supply Current	I_{CC}	V_{RS+} > +2.0V, V_{CC} = 12V		0.42	1.0	mA
Leakage Current	I_{RS+}, I_{RS-}	V_{CC} = 0		0.3	3	µA
Input Bias Current	I_{RS+}	V_{RS+} > +2.0V	0		50	µA
		V_{RS+} ≤ +2.0V	-350		50	
	I_{RS-}	V_{RS+} > +2.0V	0		100	
		V_{RS+} ≤ +2.0V	-700		100	
Full-Scale Sense Voltage	V_{SENSE}	V_{SENSE} = V_{RS+} - V_{RS-}		150		mV
Total OUT Voltage Error (Note 3)		V_{SENSE} = +100mV, V_{CC} = +12V, V_{RS+} = +12V		±0.5	5.75	%
		V_{SENSE} = +100mV, V_{CC} = +12V, V_{RS+} = +12V, T_A = +25°C		0.5	3.25	
		V_{SENSE} = +100mV, V_{CC} = +28V, V_{RS+} = +28V		0.5	5.75	
		V_{SENSE} = +100mV, V_{CC} = +12V, V_{RS+} = +0.1V		-9	±24	
		V_{CC} = +12V, V_{RS+} =+12V, V_{SENSE} = +6.25mV (Note 4)		±7.5		
OUT High Voltage (Note 5)	(V_{CC} - V_{OH})	MAX4173T, V_{CC} = +3.0V		0.8	1.2	V
		MAX4173F, V_{CC} = +7.5V		0.8	1.2	
		MAX4173H, V_{CC} = +15V		0.8	1.2	

ELECTRICAL CHARACTERISTICS (continued)

(V_{RS+} = 0 to +28V, V_{CC} = +3V to +28V, V_{SENSE} = 0, T_A = T_{MIN} to T_{MAX}, R_{LOAD} = ∞ unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

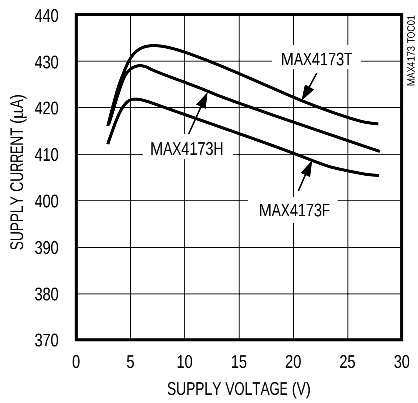
PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Bandwidth	BW	V_{RS+} = +12V, V_{CC} = +12V, C_{LOAD} = 5pF	MAX4173T, V_{SENSE} = +100mV,		1.7		MHz
			MAX4173F, V_{SENSE} = +100mV,		1.4		
			MAX4173H, V_{SENSE} = +100mV,		1.2		
			V_{SENSE} = +6.25mV, (Note 4)		0.6		
Gain	A_V	MAX4173T			20		V/V
		MAX4173F			50		
		MAX4173H			100		
Gain Accuracy	ΔA_V	MAX4173T/F V_{SENSE} = +10mV to +150mV	T_A = -40°C to +85°C			4.0	%
			T_A = +25°C		0.5	±2.5	
		MAX4173H V_{SENSE} = +10mV to +100mV	T_A = -40°C to +85°C			4.0	
			T_A = +25°C		0.5	±2.5	
OUT Settling Time to 1% of Final Value		V_{CC} = +12V, V_{RS+} = +12V, C_{LOAD} = 5pF	V_{SENSE} = +6.25mV to +100mV		400		ns
			V_{SENSE} = +100mV to +6.25mV		800		
OUT Output Resistance	R_{OUT}				12		kΩ
Power-Supply Rejection	PSR	MAX4173T, V_{SENSE} = 80mV, V_{RS+} ≥ +2V		60	84		dB
		MAX4173F, V_{SENSE} = 32mV, V_{RS+} ≥ +2V		60	91		
		MAX4173H, V_{SENSE} = 16mV, V_{RS+} ≥ +2V		60	95		
Power-Up Time to 1% of Final Value		V_{SENSE} = +100mV, C_{LOAD} = 5pF			10		µs
Saturation Recovery Time		V_{CC} = +12V, V_{RS+} = +12V (Note 6)			10		µs

Note 1: All devices are 100% production tested at T_A = +25°C. All temperature limits are guaranteed by design.
Note 2: Guaranteed by Total Output Voltage Error Test.
Note 3: Total OUT Voltage Error is the sum of gain and offset voltage errors.
Note 4: +6.25mV = 1/16 of +100mV full-scale voltage.
Note 5: V_{SENSE} such that output stage is in saturation.
Note 6: The device does not experience phase reversal when overdriven.

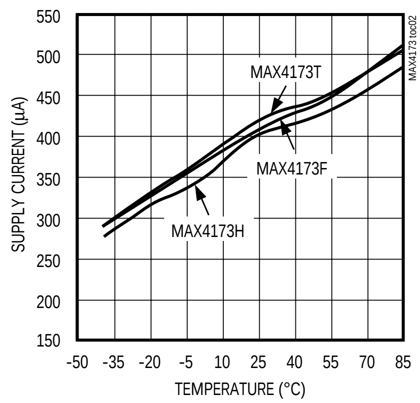
Typical Operating Characteristics

(V_{CC} = +12V, V_{RS+} = +12V, V_{SENSE} = +100mV, T_A = +25°C, unless otherwise noted.)

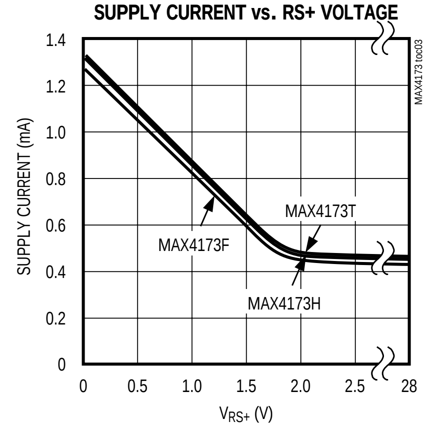
SUPPLY CURRENT vs. SUPPLY VOLTAGE



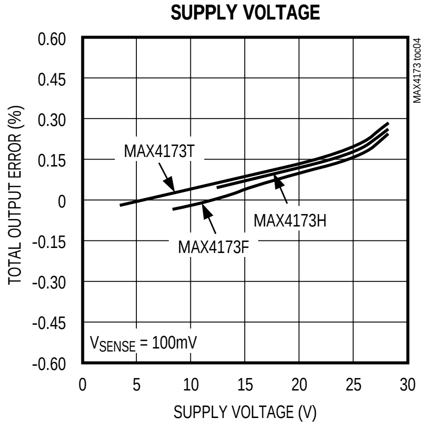
SUPPLY CURRENT vs. TEMPERATURE



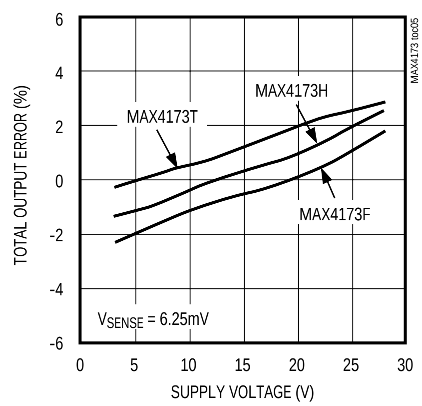
SUPPLY CURRENT vs. RS+ VOLTAGE



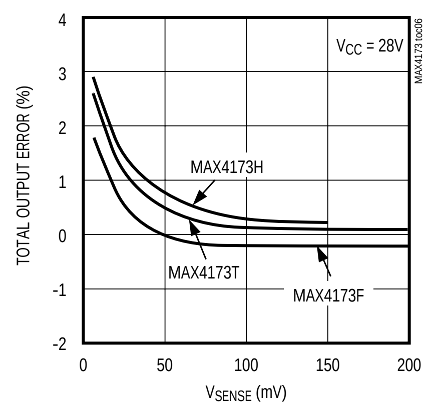
TOTAL OUTPUT ERROR vs. SUPPLY VOLTAGE



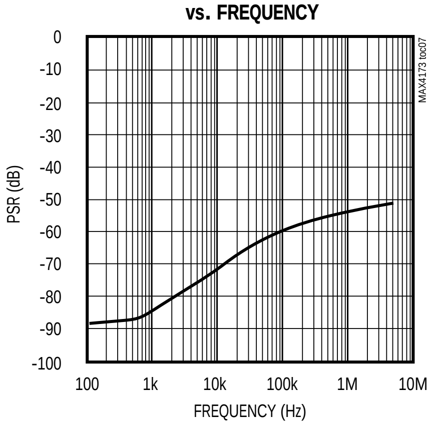
TOTAL OUTPUT ERROR vs. SUPPLY VOLTAGE



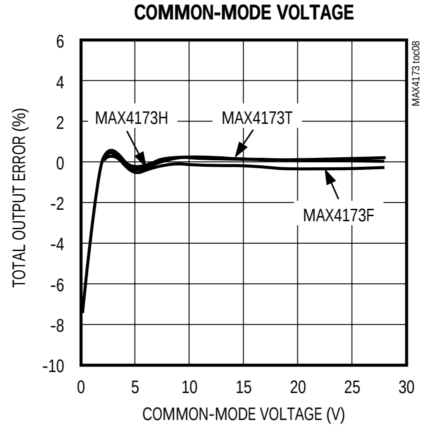
TOTAL OUTPUT ERROR vs. FULL-SCALE SENSE VOLTAGE



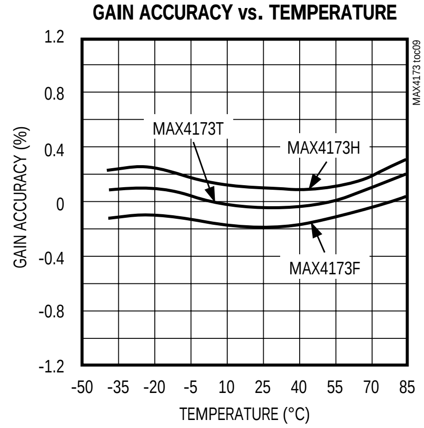
POWER-SUPPLY REJECTION vs. FREQUENCY



TOTAL OUTPUT ERROR vs. COMMON-MODE VOLTAGE



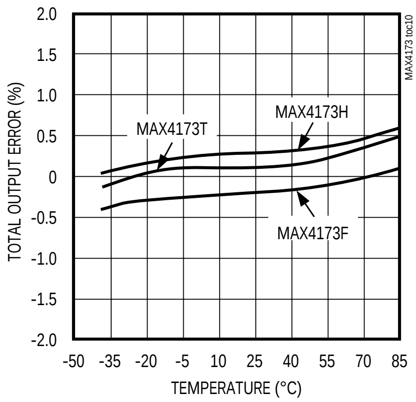
GAIN ACCURACY vs. TEMPERATURE



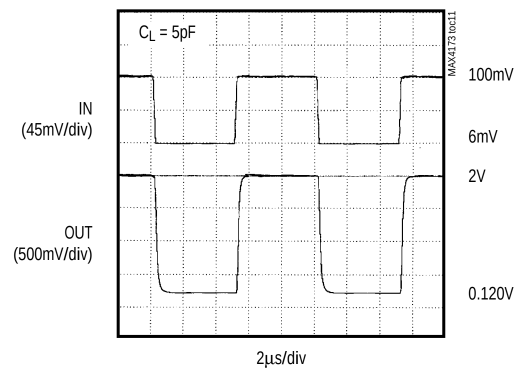
Typical Operating Characteristics (continued)

(V_{CC} = +12V, V_{RS+} = +12V, V_{SENSE} = +100mV, T_A = +25°C, unless otherwise noted.)

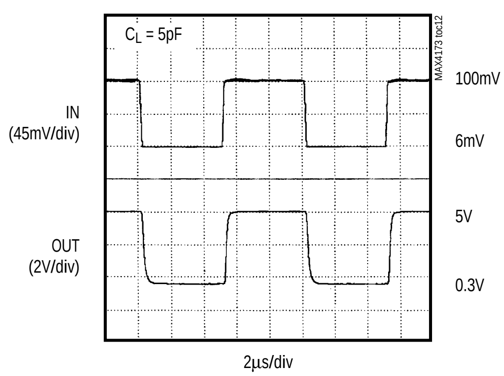
TOTAL OUTPUT ERROR vs. TEMPERATURE



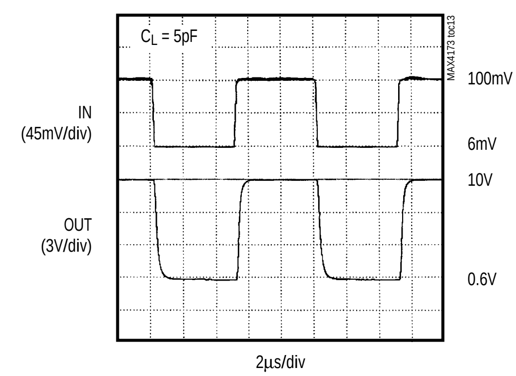
MAX4173T LARGE-SIGNAL TRANSIENT RESPONSE (V_{SENSE} = 6mV to 100mV)



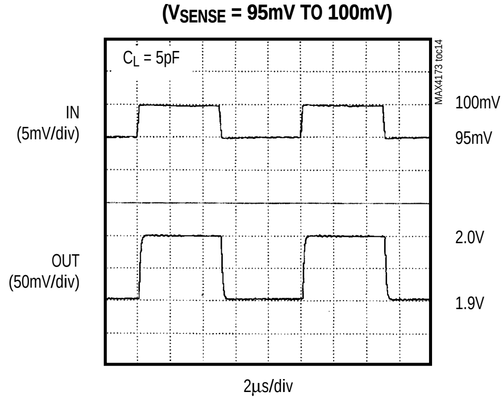
MAX4173F LARGE-SIGNAL TRANSIENT RESPONSE (V_{SENSE} = 6mV to 100mV)



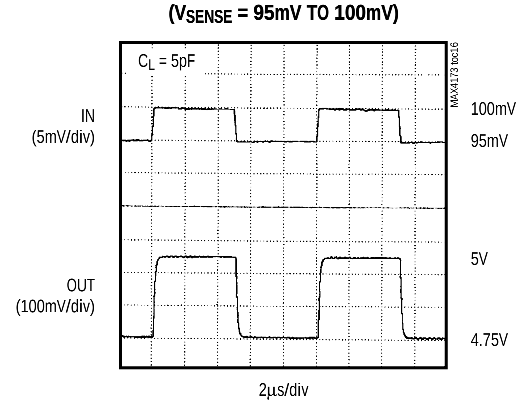
MAX4173H LARGE-SIGNAL TRANSIENT RESPONSE (V_{SENSE} = 6mV to 100mV)



MAX4173T SMALL-SIGNAL TRANSIENT RESPONSE (V_{SENSE} = 95mV TO 100mV)



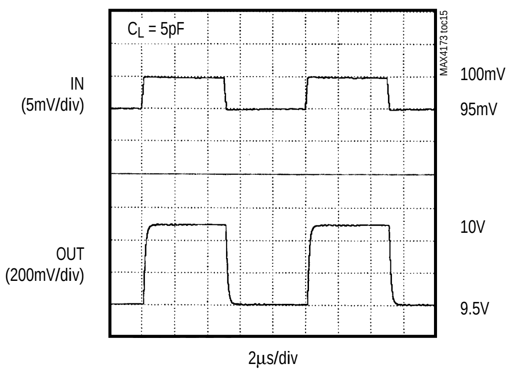
MAX4173F SMALL-SIGNAL TRANSIENT RESPONSE (V_{SENSE} = 95mV TO 100mV)



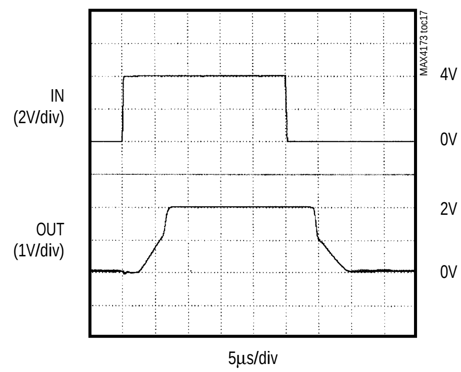
Typical Operating Characteristics (continued)

(V_{CC} = +12V, V_{RS+} = +12V, V_{SENSE} = +100mV, T_A = +25°C, unless otherwise noted.)

MAX4173H
SMALL-SIGNAL TRANSIENT RESPONSE
(V_{SENSE} = 95mV to 100mV)



START-UP DELAY (V_{CC} = 0 to 4V)
(V_{SENSE} = 100mV)



Pin Description

PIN		NAME	FUNCTION
SOT23-6	SO		
1, 2	3	GND	Ground
3	1	V_{CC}	Supply Voltage Input. Bypass to GND with a 0.1µF capacitor.
4	8	RS+	Power-Side Connection to the External Sense Resistor
5	6	RS-	Load-Side Connection for the External Sense Resistor
6	4	OUT	Voltage Output. V_{OUT} is proportional to V_{SENSE} (V_{RS+} - V_{RS-}). Output impedance is approximately 12kΩ.
–	2, 5, 7	N.C.	No Connection. Not internally connected.

Detailed Description

The MAX4173 high-side current-sense amplifier features a 0 to +28V input common-mode range that is independent of supply voltage. This feature allows the monitoring of current out of a battery in deep discharge and also enables high-side current sensing at voltages greater than the supply voltage (V_{CC}).

The MAX4173 operates as follows: Current from the source flows through R_{SENSE} to the load (Figure 1). Since the internal-sense amplifier's inverting input has high impedance, negligible current flows through RG2 (neglecting the input bias current). Therefore, the sense amplifier's inverting-input voltage equals V_{SOURCE} - (I_{LOAD})(R_{SENSE}). The amplifier's open-loop gain forces its noninverting input to the same voltage as the inverting input. Therefore, the drop across RG1 equals (I_{LOAD})(R_{SENSE}). Since I_{RG1} flows through RG1, I_{RG1} = (I_{LOAD})(R_{SENSE}) / RG1. The internal current mirror multiplies I_{RG1} by a current gain factor, β, to give $I_{RGD} = \beta \cdot I_{RG1}$. Solving $I_{RGD} = \beta \cdot (I_{LOAD})(R_{SENSE})$ / RG1. Assuming infinite output impedance, V_{OUT} = (I_{RGD})(RGD). Substituting in for I_{RGD} and rearranging, $V_{OUT} = \beta \cdot$ (RGD / RG1)($R_{SENSE} \cdot I_{LOAD}$). The parts gain equals $\beta \cdot$ RGD / RG1. Therefore, V_{OUT} = (GAIN) (R_{SENSE}) (I_{LOAD}), where GAIN = 20 for MAX4173T, GAIN = 50 for MAX4173F, and GAIN = 100 for MAX4173H.

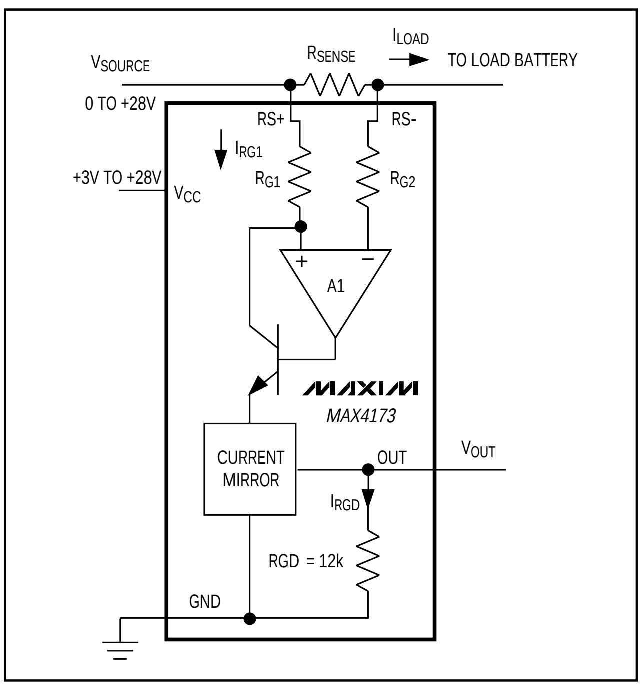


Figure 1. Functional Diagram

Set the full-scale output range by selecting R_{SENSE} and the appropriate gain version of the MAX4173.

Applications Information

Recommended Component Values

The MAX4173 senses a wide variety of currents with different sense resistor values. Table 1 lists common resistor values for typical operation of the MAX4173.

Choosing R_{SENSE}

To measure lower currents more accurately, use a high value for R_{SENSE}. The high value develops a higher sense voltage that reduces offset voltage errors of the internal op amp.

In applications monitoring very high currents, R_{SENSE} must be able to dissipate the I^2R losses. If the resistor's rated power dissipation is exceeded, its value may drift or it may fail altogether, causing a differential voltage across the terminals in excess of the absolute maximum ratings.

If I_{SENSE} has a large high-frequency component, minimize the inductance of R_{SENSE}. Wire-wound resistors have the highest inductance, metal-film resistors are somewhat better, and low-inductance metal-film resistors are best suited for these applications.

Using a PCB Trace as R_{SENSE}

If the cost of R_{SENSE} is an issue and accuracy is not critical, use the alternative solution shown in Figure 2. This solution uses copper PC board traces to create a sense resistor. The resistivity of a 0.1-inch-wide trace of 2-ounce copper is approximately 30mΩ/ft. The resistance-temperature coefficient of copper is fairly high (approximately 0.4%/°C), so systems that experience a wide temperature variance must compensate for this effect. In addition, do not exceed the maximum power dissipation of the copper trace.

For example, the MAX4173T (with a maximum load current of 10A and an R_{SENSE} of 5mΩ) creates a full-scale V_{SENSE} of 50mV that yields a maximum V_{OUT} of 1V. R_{SENSE} in this case requires about 2 inches of 0.1 inch-wide copper trace.

Output Impedance

The output of the MAX4173 is a current source driving a 12kΩ resistance. Resistive loading added to OUT reduces the output gain of the MAX4173. To minimize output errors for most applications, connect OUT to a high-impedance input stage. When output buffering is required, choose an op amp with a common-mode input range and an output voltage swing that includes ground when operating with a single supply. The op

Table 1. Recommended Component Values

FULL-SCALE LOAD CURRENT I_{LOAD} (A)	CURRENT-SENSE RESISTOR R_{SENSE} (mΩ)	GAIN	FULL-SCALE OUTPUT VOLTAGE (FULL-SCALE V_{SENSE} = 100mV) V_{OUT} (V)
0.1	1000	20	2.0
		50	5.0
		100	10.0
1	100	20	2.0
		50	5.0
		100	10.0
5	20	20	2.0
		50	5.0
		100	10.0
10	10	20	2.0
		50	5.0
		100	10.0

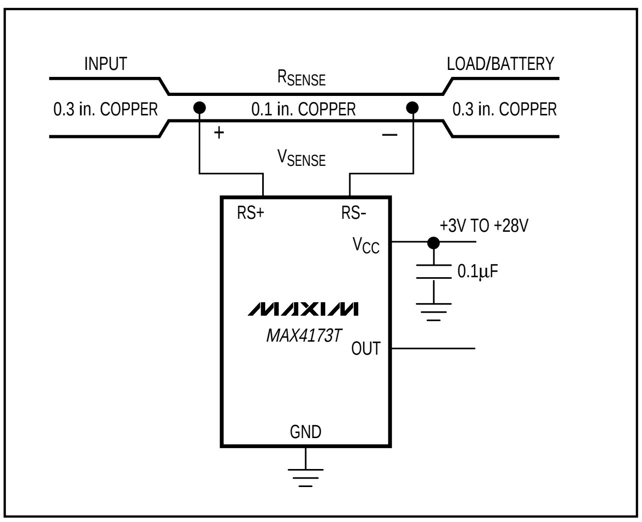


Figure 2. MAX4173 Connections Showing Use of PC Board

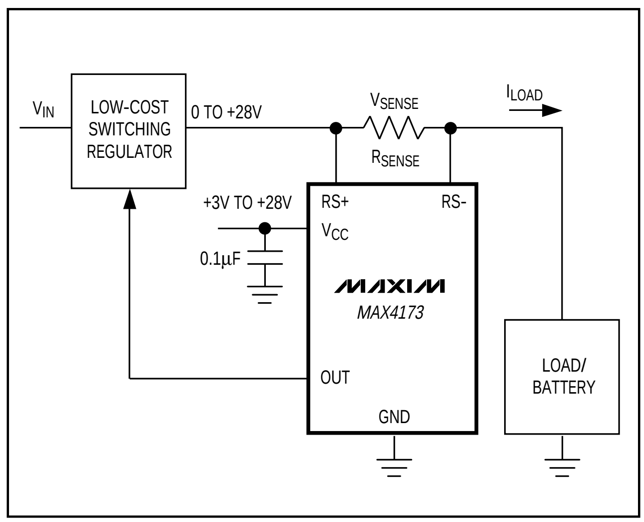


Figure 3. Current Source

amp's supply voltage range should be at least as high as any voltage the system may encounter.

The percent error introduced by output loading is determined with the following formula:

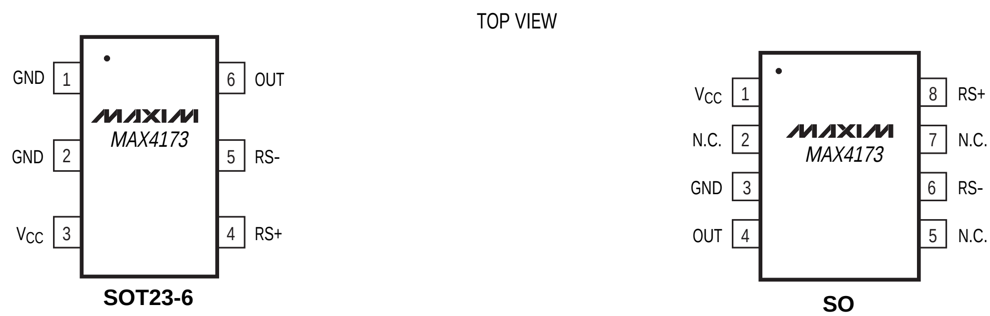
$$\%_{ERROR} = 100\left(\frac{R_{LOAD}}{12k\Omega + R_{LOAD}} - 1\right)$$

where R_{LOAD} is the external load applied to OUT.

Current Source Circuit

Figure 3 shows a block diagram using the MAX4173 with a switching regulator to make a current source.

Pin Configurations

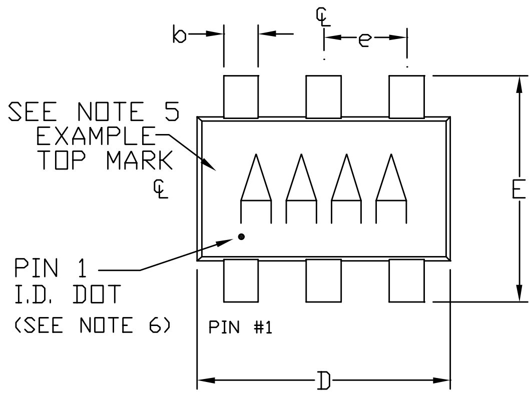


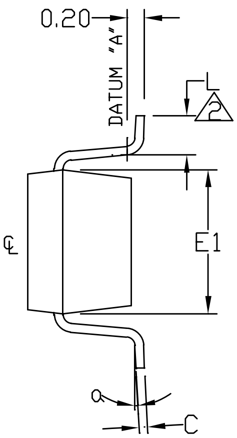
Chip Information

TRANSISTOR COUNT: 187

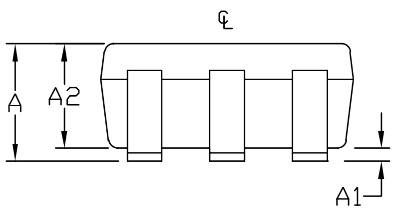
Package Information

6LSOT.EPS





SYMBOL	MIN	MAX
A	0.90	1.45
A1	0.00	0.15
A2	0.90	1.30
b	0.35	0.50
C	0.08	0.20
D	2.80	3.00
E	2.60	3.00
E1	1.50	1.75
L	0.35	0.55
e	0.95 REF	
α	0°	10°



NOTE:

1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. FOOT LENGTH MEASURED AT INTERCEPT POINT BETWEEN DATUM A & LEAD SURFACE.
3. PACKAGE OUTLINE EXCLUSIVE OF MOLD FLASH & METAL BURR.
4. PACKAGE OUTLINE INCLUSIVE OF SOLDER PLATING.
5. PIN 1 IS LOWER LEFT PIN WHEN READING TOP MARK FROM LEFT TO RIGHT. (SEE EXAMPLE TOP MARK)
6. PIN 1 I.D. DOT IS 0.3 MM ø MIN. LOCATED ABOVE PIN 1.

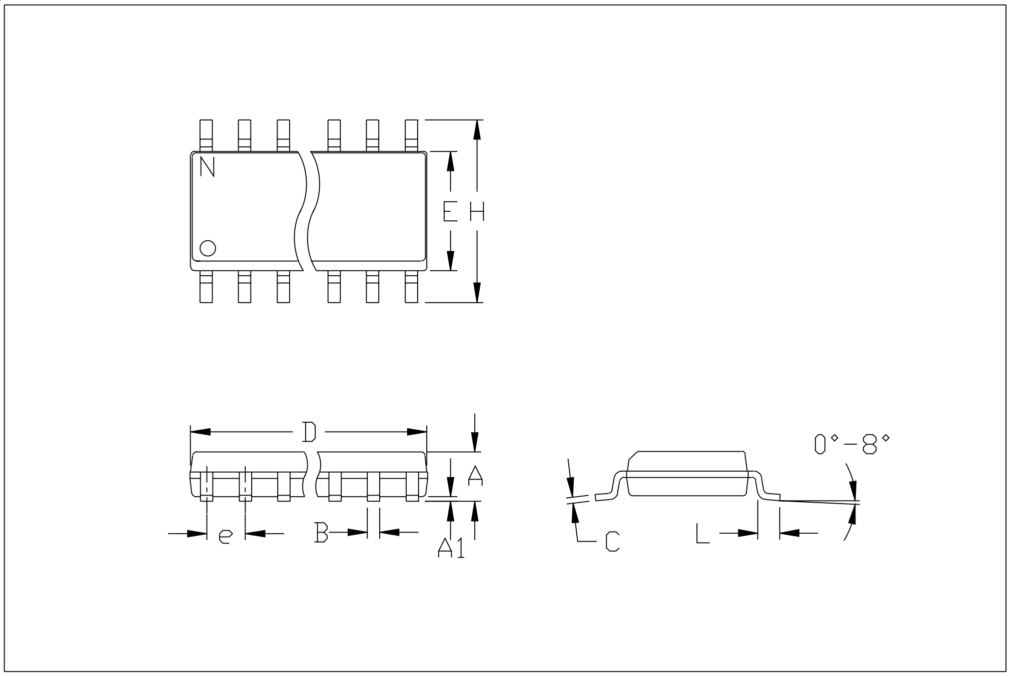
MAXIM

PROPRIETARY INFORMATION

TITLE: PACKAGE OUTLINE, SOT23, 6L

APPROVAL	DOCUMENT CONTROL NO.	REV	
	21-0058	D	1/1

Package Information (continued)



	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.053	0.069	1.35	1.75
A1	0.004	0.010	0.10	0.25
B	0.014	0.019	0.35	0.49
C	0.007	0.010	0.19	0.25
e	0.050		1.27	
E	0.150	0.157	3.80	4.00
H	0.228	0.244	5.80	6.20
h	0.010	0.020	0.25	0.50
L	0.016	0.050	0.40	1.27

	INCHES		MILLIMETERS			
	MIN	MAX	MIN	MAX	N	MS012
D	0.189	0.197	4.80	5.00	8	A
D	0.337	0.344	8.55	8.75	14	B
D	0.386	0.394	9.80	10.00	16	C

NOTES:
1. D&E DO NOT INCLUDE MOLD FLASH
2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED .15mm (.006")
3. LEADS TO BE COPLANAR WITHIN .102mm (.004")
4. CONTROLLING DIMENSION: MILLIMETER
5. MEETS JEDEC MS012-XX AS SHOWN IN ABOVE TABLE
6. N = NUMBER OF PINS

MAXIM
120 SAN GABRIEL DR. SUNNYVALE CA 94086 FAX (408) 737 7194

TITLE: PACKAGE FAMILY OUTLINE: SOIC .150" | 1/1 | DOCUMENT CONTROL NUMBER: 21-0041 | REV: A

Low-Cost, SOT23, Voltage-Output, High-Side Current-Sense Amplifier

NOTES