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

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 VCC or GND	Continuous
Differential Input Voltage (V _{RS+} - V _{RS-})	±0.3V
Current into Any Pin	±20mA

Continuous Power Dissipation ($T_A = +70^{\circ}C$)	
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, 10s)	+300°C
Soldering Temperature (reflow)	+260°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

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

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS	
Operating Voltage Range	Vcc	Guaranteed by PSR test		3		28	V	
Common-Mode Input Range	VCMR	(Note 2)		0		28	V	
Common-Mode Rejection	CMR	V _{RS+} > +2.0V			90		dB	
Supply Current	Icc	$V_{RS+} > +2.0V, V_{CC} > 12V$			0.42	1.0	mA	
Leakage Current	I _{RS+} , I _{RS-}	$V_{CC} = 0V, V_{RS+} = 28V$			0.3	3	μΑ	
	Inc	V _{RS+} > +2.0V		0		50		
Input Dies Current	I _{RS+}	V _{RS+} ≤ +2.0V		-350		50	1 .	
Input Bias Current	lee	V _{RS+} > +2.0V		0		100	0 μA	
	I _{RS} -	V _{RS+} ≤ +2.0V		-700	700 100			
Full-Scale Sense Voltage	VSENSE	VSENSE = VRS+ - VRS-			150		mV	
		V _{SENSE} = +100mV, V _{CC} = -	$+12V$, $V_{RS+} = +12V$	±0.5 5.75		5.75		
		$V_{SENSE} = +100$ mV, $V_{CC} = +12$ V, $V_{RS+} = +12$ V, $T_{A} = +25$ °C			0.5	3.25		
Total OUT Voltage Error (Note 3)		V _{SENSE} = +100mV, V _{CC} = +28V, V _{RS+} = +28V			0.5	5.75	%	
(Note 3)		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			
		MAX4173T, V _{CC} = +3.0V, V V _{SENSE} = 250mV	/ _{RS+} = 28V,		0.8	1.2		
Out High Voltage (Note 5)	(VCC - VOH)	MAX4173F, $V_{CC} = +7.5V$, $V_{RS+} = 28V$, $V_{SENSE} = 250 \text{mV}$			0.8	1.2	V	
		MAX4173H, $V_{CC} = +15V$, $V_{RS+} = 28V$, $V_{SENSE} = 250mV$			0.8	1.2		
OUT Low Voltage	Vol	MAX4173TEUT, VCC = +5V, V _{RS+} = 0.89V,	T _A = +25°C		1.2	5	mV	
OUT LOW VOILage	VoL	VCC = +5V, VRS+ = 0.89V, VSENSE = 0mV			40	IIIV		

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

ELECTRICAL CHARACTERISTICS (continued)

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

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS	
	BW	V _{RS+} = +12V, V _{CC} = +12V, C _{LOAD} = 5pF	MAX4173T, VSENSE = +100mV		1.7		- MHz	
			MAX4173F, VSENSE = +100mV		1.4			
Bandwidth			MAX4173H, V _{SENSE} = +100mV		1.2			
			V _{SENSE} = +6.25mV (Note 4)		0.6			
		MAX4173T			20			
Gain	Av	MAX4173F			50		V/V	
		MAX4173H			100			
	ΔΑγ	MAX4173T/F V _{SENSE} = +10mV to +150mV, VCC = V _{RS+} = 12V	T _A = +25°C		0.5	±2.5	- %	
Gain Accuracy	ΔΑΨ		$T_A = -40^{\circ}C \text{ to } +85^{\circ}C$			4.0		
	ΔΑγ	MAX4173H VSENSE = +10mV to +100mV, VCC = V _{RS+} = 12V	T _A = +25°C		0.5	±2.5		
			$T_A = -40^{\circ}C \text{ to } +85^{\circ}C$			4.0		
Input Offset Voltage	Vos ,	MAX4173TEUT, V _{RS+} = 12V	$T_A = +25^{\circ}C$		0.3	±3	mV	
(Note 6)	VUS		$T_A = -40^{\circ}C \text{ to } +85^{\circ}C$			±5		
OUT Settling Time to 1% of		V _{CC} = +12V, V _{RS+} = 12V,	VSENSE = +6.25mV to +100mV		400			
Final Value		C _{LOAD} = 5pF	V _{SENSE} = +100mV to +6.25mV		800		ns	
OUT Output Resistance	Rout				12		kΩ	
		MAX4173T, V _{SENSE} = 80mV, V _{RS+} ≥ +2V		60	84			
Power-Supply Rejection	PSR	MAX4173F, V _{SENSE} = 32mV, V _{RS+} ≥ +2V		60	91		dB	
		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 7)			10		μs	

Note 1: All devices are 100% production tested at $T_A = +25^{\circ}C$. 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.

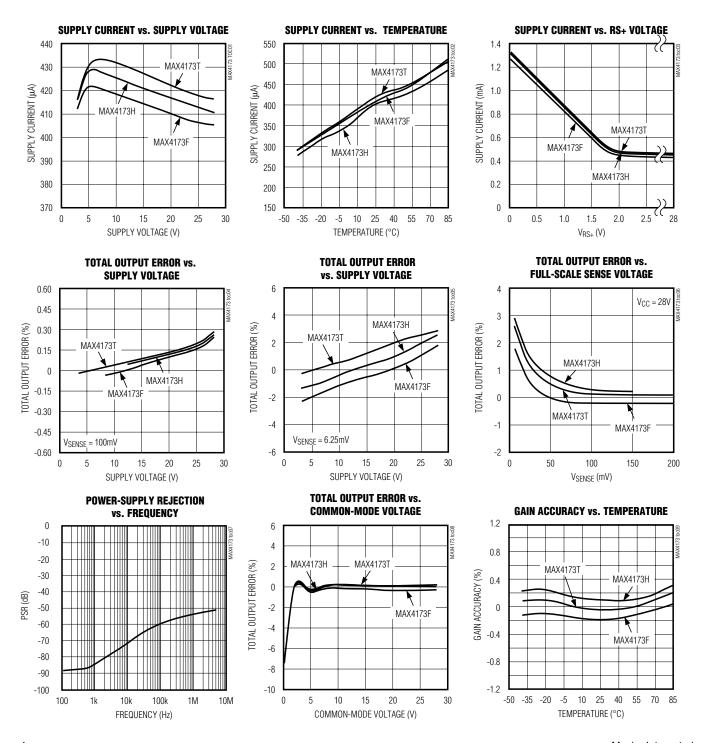
Note 6: V_{OS} is extrapolated from the Gain Accuracy tests.

Note 7: The device does not experience phase reversal when overdriven.

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

Typical Operating Characteristics

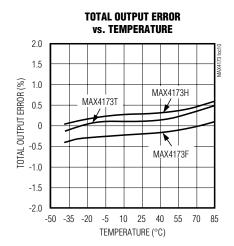
(VCC = +12V, VRS+ = +12V, VSENSE = +100mV, TA = +25°C, unless otherwise noted.)



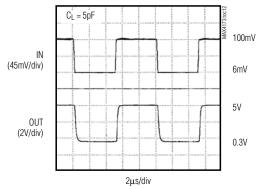
Low-Cost, SOT23, Voltage-Output, High-Side Current-Sense Amplifier

Typical Operating Characteristics (continued)

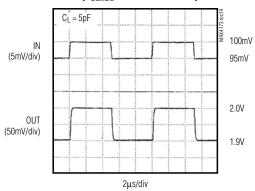
 $(V_{CC} = +12V, V_{RS+} = +12V, V_{SENSE} = +100mV, T_A = +25^{\circ}C, unless otherwise noted.)$



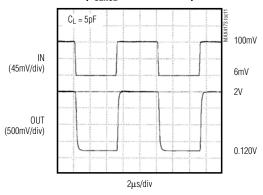
MAX4173F LARGE-SIGNAL TRANSIENT RESPONSE (V_{SENSE} = 6mV to 100mV)



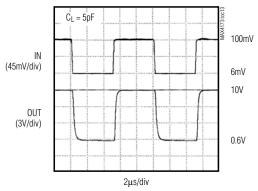
MAX4173T SMALL-SIGNAL TRANSIENT RESPONSE (VSENSE = 95mV TO 100mV)



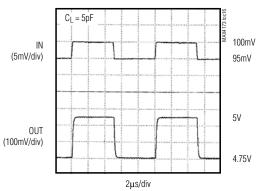
MAX4173T LARGE-SIGNAL TRANSIENT RESPONSE (VSENSE = 6mV to 100mV)



MAX4173H LARGE-SIGNAL TRANSIENT RESPONSE (VSENSE = 6mV to 100mV)



MAX4173F SMALL-SIGNAL TRANSIENT RESPONSE (VSENSE = 95mV TO 100mV)

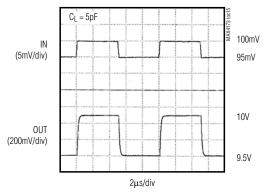


Low-Cost, SOT23, Voltage-Output, High-Side Current-Sense Amplifier

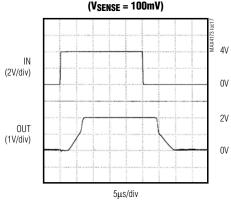
Typical Operating Characteristics (continued)

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

MAX4173H SMALL-SIGNAL TRANSIENT RESPONSE (VSENSE = 95mV to 100mV)



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



Pin Description

PIN		NAME	FUNCTION		
SOT23	so	INAIVIE	FUNCTION		
1, 2	3	GND	Ground		
3	1	Vcc	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. Vout is proportional to Vsense (Vrs+ - Vrs-). Output impedance is approximately $12k\Omega$.		
_	2, 5, 7	N.C.	No Connection. Not internally connected.		

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

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 (VCC).

The MAX4173 operates as follows: Current from the source flows through RSENSE 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 VSOURCE - (ILOAD)(RSENSE). The amplifier's open-loop gain forces its noninverting input to the same voltage as the inverting input. Therefore, the drop across RG1 equals (ILOAD)(RSENSE). Since IRG1 flows through RG1, IRG1 = (ILOAD)(RSENSE) / RG1. The internal current mirror multiplies IRG1 by a current gain factor, β , to give $IRGD = \beta \cdot IRG1$. Solving $IRGD = \beta \cdot (ILOAD)(RSENSE) /$ RG1. Assuming infinite output impedance, Vout = (IRGD) (RGD). Substituting in for IRGD and rearranging, Vout = $\beta \cdot (RGD / RG1)(RSENSE \cdot ILOAD)$. The parts gain equals $\beta \cdot RGD / RG1$. Therefore, $V_{OUT} = (GAIN) (R_{SENSE})$ (ILOAD), where GAIN = 20 for MAX4173T, GAIN = 50 for MAX4173F. and GAIN = 100 for MAX4173H.

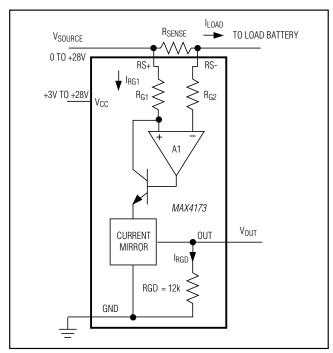


Figure 1. Functional Diagram

Set the full-scale output range by selecting RSENSE 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 RSENSE

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

In applications monitoring very high currents, RSENSE must be able to dissipate the $\rm I^2R$ 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 ISENSE has a large high-frequency component, minimize the inductance of RSENSE. 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 RSENSE

If the cost of RSENSE 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 $30m\Omega/\text{ft}$. 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 RSENSE of $5m\Omega$) creates a full-scale VSENSE of 50mV that yields a maximum VOUT of 1V. RSENSE in this case requires about 2 inches of 0.1 inchwide copper trace.

Output Impedance

The output of the MAX4173 is a current source driving a $12k\Omega$ 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

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

Table 1. Recommended Component Values

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

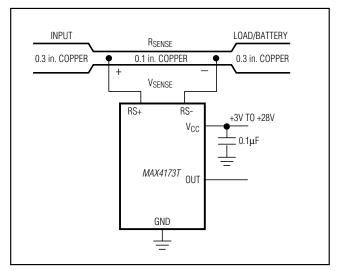


Figure 2. MAX4173 Connections Showing Use of PC Board

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 RLOAD is the external load applied to OUT.

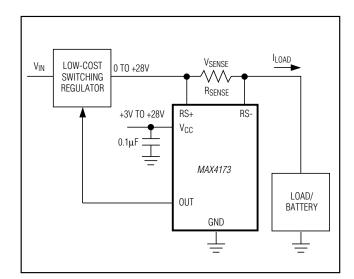


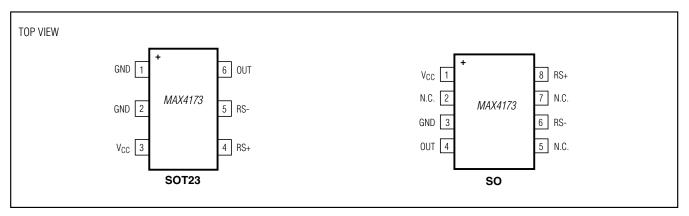
Figure 3. Current Source

Current Source Circuit

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

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

Pin Configurations



Package Information

For the latest package outline information and land patterns (footprints), go to www.maxim-ic.com/packages. Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

PACKAGE TYPE	PACKAGE CODE	OUTLINE NO.	LAND PATTERN NO.
8 SO	S8+4	21-0041	<u>90-0096</u>
6 SOT23	U6+2	21-0058	<u>90-0175</u>

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

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
4	6/10	Clarified 0V to 2V is not a high-accuracy range for the device, added lead-free options and soldering temperature	1, 2
5	4/11	Updated V _{RS+} conditions to synchronize with tested material	2, 3



Maxim cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in a Maxim product. No circuit patent licenses are implied. Maxim reserves the right to change the circuitry and specifications without notice at any time. The parametric values (min and max limits) shown in the Electrical Characteristics table are guaranteed. Other parametric values quoted in this data sheet are provided for guidance.