

General Description

The MAX4073 low-cost, high-side current-sense amplifier features a voltage output that eliminates the need for gain-setting resistors making it ideal for cell phones, notebook computers, PDAs, and other systems where current monitoring is crucial. High-side current monitoring does not interfere with the ground path of the battery charger making the MAX4073 particularly useful in battery-powered systems. The input common-mode range of +2V to +28V is independent of the supply voltage. The MAX4073's wide 1.8MHz bandwidth makes it suitable for use inside battery-charger control loops.

The combination of three gain versions and a selectable external-sense resistor sets the full-scale current reading. The MAX4073 offers a high level of integration, resulting in a simple and compact current-sense solution.

The MAX4073 operates from a +3V to +28V single supply and draws only 0.5mA of supply current. This device is specified over the automotive operating temperature range (-40°C to +125°C) and is available in a space-saving 5-pin SC70 package (half the size of the SOT23).

For a similar device in a 6-pin SOT23 with a wider common-mode voltage range (0 to +28V), see the MAX4173 data sheet.

Applications

Cell Phones

Notebook Computers

Portable/Battery-Powered Systems

Smart Battery Packs/Chargers

PDAs

Power Management Systems

PA Bias Control

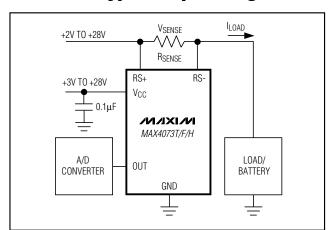
General System/Board-Level Current Monitoring

Precision Current Sources

Features

- **♦ Low-Cost, Compact, Current-Sense Solution**
- ♦ Three Gain Versions Available
 - +20V/V (MAX4073T)
 - +50V/V (MAX4073F)
 - +100V/V (MAX4073H)
- **♦** ±1.0% Full-Scale Accuracy
- ♦ 500µA Supply Current
- ♦ Wide 1.8MHz Bandwidth
- ♦ +3V to +28V Operating Supply
- ♦ Wide +2V to +28V Common-Mode Range Independent of Supply Voltage
- **♦** Automotive Temperature Range (-40°C to +125°C)
- ♦ Available in Space-Saving 5-Pin SC70 Package

Typical Operating Circuit



Pin Configurations appear at end of data sheet.

Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE	GAIN (V/V)	TOP MARK
MAX4073TAXK-T	-40°C to +125°C	5 SC70-5	20	ACM
MAX4073TAUT-T	-40°C to +125°C	6 SOT23-6	20	AAUE
MAX4073FAXK-T	-40°C to +125°C	5 SC70-5	50	ACN
MAX4073FAUT-T	-40°C to +125°C	6 SOT23-6	50	AAUF
MAX4073HAXK-T	-40°C to +125°C	5 SC70-5	100	ACO
MAX4073HAUT-T	-40°C to +125°C	6 SOT23-6	100	AAUG

ABSOLUTE MAXIMUM RATINGS

V _{CC} to GND	
RS+, RS- to GND	0.3V to +30V
OUT to GND	
Output Short-Circuit to GND	Continuous
Differential Input Voltage (V _{RS+} - V _{RS-})	±5V
Current Into Any Pin	
Continuous Power Dissipation ($T_A = +70$	°C)
5-pin SC70 (derate 2.27mW/°C above	+70°C)200mW
6-pin SOT23 (derate 8.7mW/°C above	+70°C)696mW

Operating Temperature Range	40°C to +125°C
Junction Temperature	+150°C
Storage Temperature Range	65°C to +150°C
Lead Temperature (soldering, 10s)	+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

 $(V_{RS+} = +2V \text{ to } +28V, V_{SENSE} = (V_{RS+} - V_{RS-}) = 0, V_{CC} = +3V \text{ to } +28V, T_A = T_{MIN} \text{ to } T_{MAX}, \text{ unless otherwise noted. Typical values are at } T_A = +25^{\circ}C.)$ (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Operating Voltage Range	Vcc	(Note 2)	3		28	V	
Common-Mode Input Range	V _{CMR}	(Note 3)	2		28	V	
Common-Mode Rejection	CMR	V _{SENSE} = 100m\	V, V _{CC} = 12V		90		dB
Supply Current	Icc	$V_{CC} = 28V$			0.5	1.2	mA
Leakage Current	I _{RS+} /I _{RS-}	$V_{CC} = 0$, $V_{RS+} =$: 28V		0.05	1	μΑ
Input Bias Current	I _{RS+}				20	60	
Input bias Current	I _{RS-}			40	120	μΑ	
Full-Scale Sense Voltage	V _{SENSE}	V _{SENSE} = (V _{RS+}	- V _{RS-})		150		mV
Total OUT Voltage Error (Note 4)		V _{SENSE} = 100m\	$V, V_{CC} = 12V, V_{RS+} = 2V$		±1.0		
		Vsense = 100mV, Vcc = 12V, Vrs+ = 12V, TA = +25°C Vsense = 100mV, Vcc = 12V, Vrs+ = 12V, TA = Tmin to Tmax Vsense = 100mV, Vcc = 28V, Vrs+ = 28V, TA = +25°C			±1.0	±5.0	%
						±7.0	
					±1.0	±5.0	%
	Vsense = 100mV, Vcc = 28V, V _{RS+} = 28V, T _A = T _{MIN} to T _{MAX}				±8.5		
		V _{SENSE} = 6.25mV (Note 5); V _{CC} = 12V, V _{RS+} = 12V			±7.5		
Extrapolated Input Offset Voltage	Vos	$V_{CC} = V_{RS+} = 12$		1.0		mV	
		Vsense = 150mV	MAX4073T, V _{CC} = 3V				
OUT High Voltage	(VCC - VOH)		MAX4073F, V _{CC} = 7.5V		0.8 1.2		V
		100111	MAX4073H, V _{CC} = 15V				

ELECTRICAL CHARACTERISTICS (continued)

 $(V_{RS+} = +2V \text{ to } +28V, V_{SENSE} = (V_{RS+} - V_{RS-}) = 0, V_{CC} = +3V \text{ to } +28V, T_A = T_{MIN} \text{ to } T_{MAX}, \text{ unless otherwise noted. Typical values are at } T_A = +25^{\circ}C.)$ (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS	
Bandwidth	BW		MAX4073T, V _{SENSE} = 100mV		1.8		MHz	
		V _{CC} = 12V, V _{RS+} = 12V, C _{LOAD} = 5pF	MAX4073F, V _{SENSE} = 100mV		1.7			
Danuwium			MAX4073H, VSENSE = 100mV		1.6			
			MAX4073T/F/H VSENSE = 6.25mV (Note 5)		600		kHz	
		MAX4073T			20			
Gain	AV	MAX4073F			50		V/V	
		MAX4073H			100			
	ΔΑV	VCC = 12V, VRS+ = 12V, VSENSE = 10mV to 150mV, MAX4073T/F	T _A = +25°C		±1.0	±4.5	%	
Gain Accuracy			TA = TMIN to TMAX			±6.5		
		VCC = 12V, VRS+ = 12V, VSENSE = 10mV to 100mV, MAX4073H	TA = +25°C		±1.0	±4.5		
			TA = TMIN to TMAX			±6.5		
OUT Settling Time to 1% of Final Value		VCC = 12V VRS+ = 12V CLOAD = 5pF	VSENSE = 6.25mV to 100mV		400		_ ns	
			V _{SENSE} = 100mV to 6.25mV		800			
Output Resistance	Rout				12		kΩ	
		Vcc = 3V to 28V	V _{SENSE} = 60mV, MAX4073T	70	78		_	
Power-Supply Rejection Ratio	PSRR		V _{SENSE} = 24mV, MAX4073F	70	85		dB	
			V _{SENSE} = 12mV, MAX4073H	70	90			
Power-Up Time (Note 6)		CLOAD = 5pF, VSENSE = 100mV			5		μs	
Saturation Recovery Time (Note 7)		V _{CC} = 12V, V _{RS+} = 12V, C _{LOAD} = 5pF			5		μs	

Note 1: All devices are 100% production tested at T_A = +25°C. All temperature limits are guaranteed by design.

Note 2: Inferred from PSRR test.

Note 3: Inferred from OUT Voltage Error test.

Note 4: Total OUT Voltage Error is the sum of the gain and offset errors.

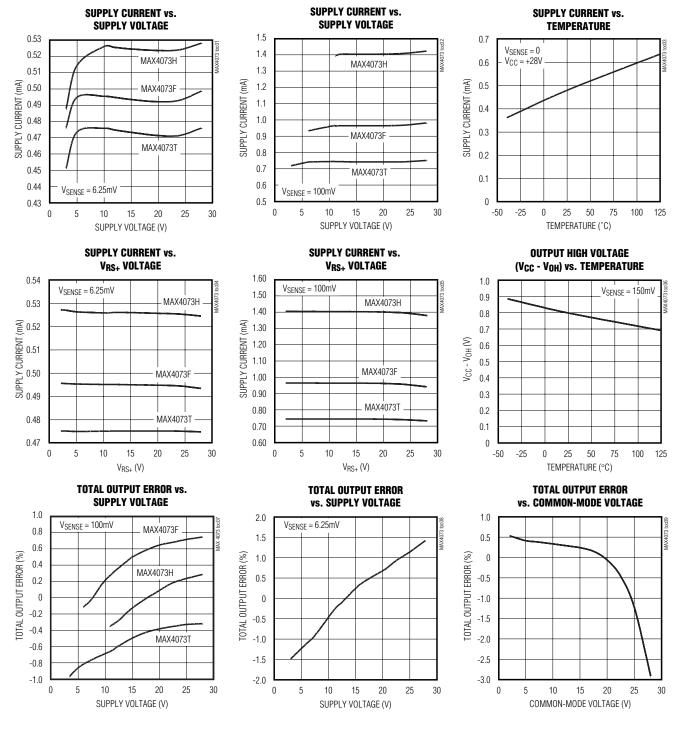
Note 5: 6.25mV = 1/16 of 100mV full-scale sense voltage.

Note 6: Output settles to within 1% of final value.

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

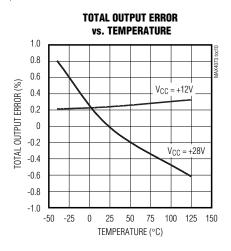
Typical Operating Characteristics

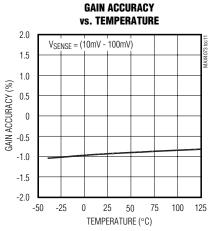
 $(V_{CC} = +12V, V_{RS+} = +12V, V_{SENSE} = 100 \text{mV}, C_L = 5 \text{pF}, T_A = +25 ^{\circ}\text{C}, unless otherwise noted.})$

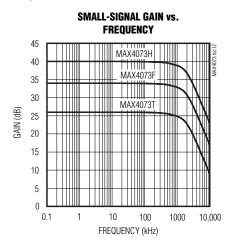


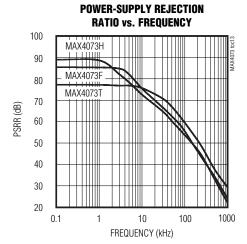
Typical Operating Characteristics (continued)

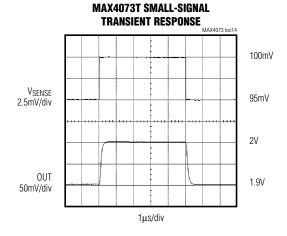
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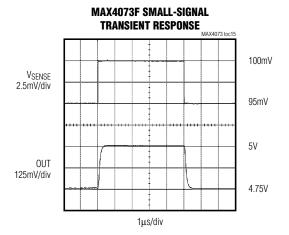


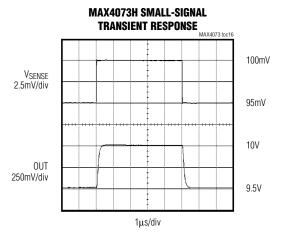






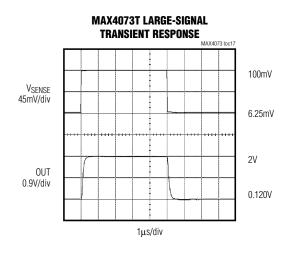


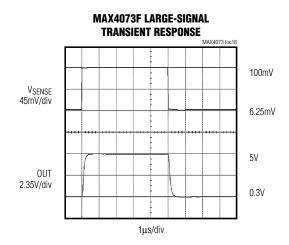


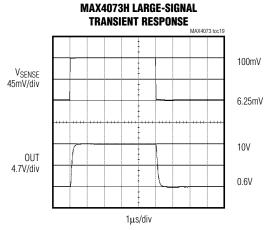


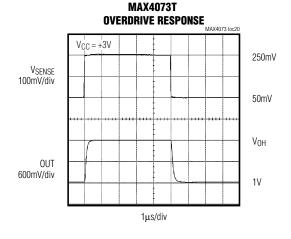
Typical Operating Characteristics (continued)

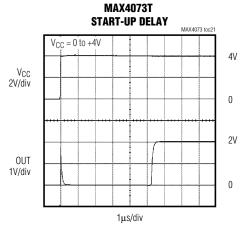
 $(V_{CC} = +12V, V_{RS+} = +12V, V_{SENSE} = 100 \text{mV}, C_L = 5 \text{pF}, T_A = +25 ^{\circ}\text{C}, unless otherwise noted.})$











Pin Description

PIN		NAME	FUNCTION	
SOT23-6	SC70-5			
1, 2	2	GND	Ground	
3	3	Vcc	Supply Voltage Input. Bypass to GND with a 0.1μF capacitor.	
4	4	RS+	Power-Side Connection to the External Sense Resistor	
5	5	RS-	Load-Side Connection to the External Sense Resistor	
6	1	OUT	Voltage Output. V_{OUT} is proportional to V_{SENSE} . Output impedance is approximately $12k\Omega$.	

Detailed Description

The MAX4073 high-side current-sense amplifier features a +2V to +28V input common-mode range that is independent of supply voltage. This feature allows the monitoring of current out of a battery as low as +2V and also enables high-side current sensing at voltages greater than the supply voltage (VCC).

The MAX4073 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 $IRGD = \beta \times IRG1$. Solving $IRGD = \beta \times (ILOAD)(RSENSE) /$ RG1. Assuming infinite output impedance, Vout = (IRGD) (RGD). Substituting in for IRGD and rearranging, Vout = $\beta \times (RGD / RG1)(RSENSE \times ILOAD)$. The parts gain equals $\beta \times RGD / RG1$. Therefore, VOUT = (GAIN) (RSENSE)(ILOAD), where GAIN = 20V/V for MAX4073T, GAIN = 50V/V for MAX4073F, and GAIN = 100V/V for MAX4073H.

Set the full-scale output range by selecting RSENSE and the appropriate gain version of the MAX4073.

_Applications Information

Recommended Component Values

The MAX4073 senses a wide variety of currents with different sense resistor values. Table 1 lists common resistor values for typical operation of the MAX4073.

Choosing RSENSE

To measure lower currents more accurately, use a large value for RSENSE. The larger value develops a

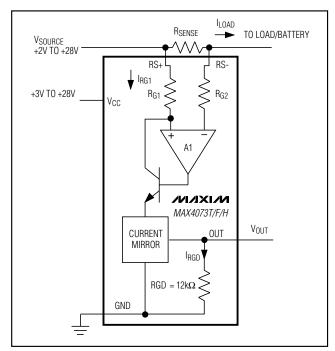


Figure 1. Functional Diagram

higher-sense voltage that reduces offset voltage errors of the internal op amp. Typical sense voltages range between 10mV and 150mV.

In applications monitoring very high currents, RSENSE must be able to dissipate the I²R 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 (±5V).

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.

For VSENSE = 100mV, full-scale output voltage can be 2V, 5V, or 10V depending on the gain. For proper operation, ensure V_{CC} exceeds the full-scale output voltage by 1.2V (see Output High Voltage (V_{CC} - V_{OH}) vs. Temperature in the *Typical Operating Characteristics*).

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 MAX4073T (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 MAX4073 is a current source driving a $12k\Omega$ resistance. Resistive loading added to OUT reduces the output gain of the MAX4073. 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 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.

Current Source Circuit

Figure 3 shows a block diagram using the MAX4073 with a switching regulator to make a current source.

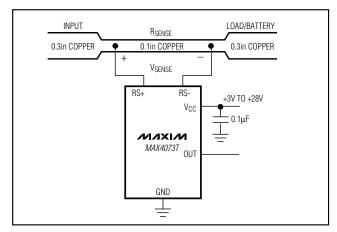


Figure 2. MAX4073T Connections Showing Use of PC Board

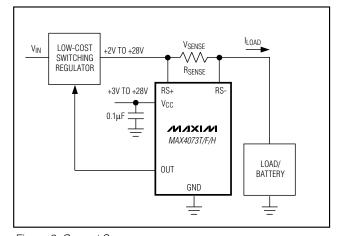
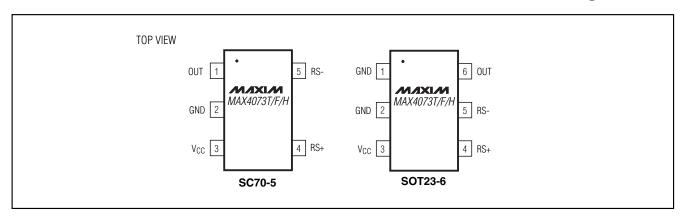


Figure 3. Current Source

Table 1. Recommended Component Values

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

Pin Configurations

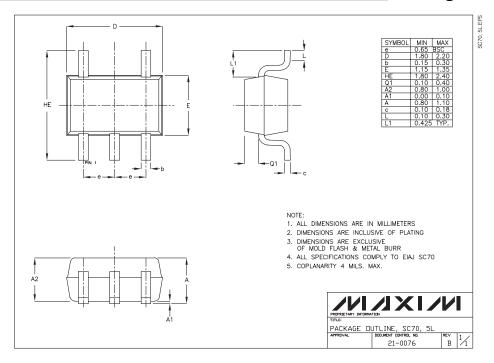


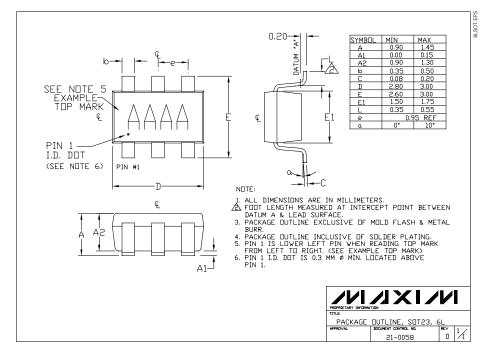
Chip Information

TRANSISTOR COUNT: 187

PROCESS: Bipolar

Package Information





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.

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