19-1548; Rev 0; 10/99

MAXIM

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

General Description

The MAX4372 low-cost, precision, high-side current-sense amplifier is available in a tiny, space-saving SOT23-5 package. Offered in three gain versions (T = +20V/V, F = +50V/V, and H = +100V/V), this device operates from a single +2.7V to +28V supply and consumes only 30µA. It features a voltage output that eliminates the need for gain-setting resistors and is ideal for today's notebook computers, cell phones, and other systems where battery/DC 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 2-cell battery pack in deep discharge.

The user can set the full-scale current reading by choosing the device (T, F, or H) with the desired voltage gain and selecting the appropriate external sense resistor. This capability offers a high level of integration and flexibility, resulting in a simple and compact current-sense solution. For higher bandwidth applications, refer to the MAX4173T/F/H data sheet.

Applications

Power-Management Systems

General-System/Board-Level Current Monitoring

Notebook Computers

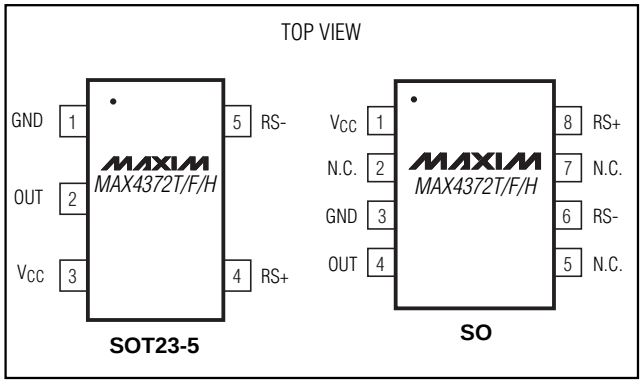
Portable/Battery-Powered Systems

Smart-Battery Packs/Chargers

Cell Phones

Precision-Current Sources

Pin Configurations



Features

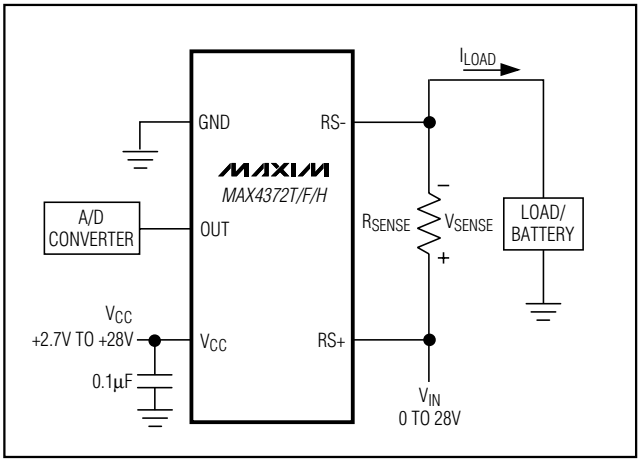
- Low-Cost, Compact Current-Sense Solution
- 30µA Supply Current
- +2.7V to +28V Operating Supply
- 0.18% Full-Scale Accuracy
- Low 1.5Ω Output Impedance
- Three Gain Versions Available
  - +20V/V (MAX4372T)
  - +50V/V (MAX4372F)
  - +100V/V (MAX4372H)
- Wide 0 to +28V Common-Mode Range, Independent of Supply Voltage
- Available in Space-Saving SOT23-5 Package

Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE	TOP MARK
MAX4372TEUK-T	-40°C to +85°C	5 SOT23-5	ADIU
MAX4372TESA	-40°C to +85°C	8 SO	—
MAX4372FEUK-T	-40°C to +85°C	5 SOT23-5	ADIV
MAX4372FESA	-40°C to +85°C	8 SO	—
MAX4372HEUK-T	-40°C to +85°C	5 SOT23-5	ADIW
MAX4372HESA	-40°C to +85°C	8 SO	—

Note: *Gain values are as follows: +20V/V for the T version, +50V/V for the F version, and +100V/V for the H version.*

Typical Operating Circuit



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

ABSOLUTE MAXIMUM RATINGS

V_{CC}, RS+, RS- to GND .....-0.3V to +30V
OUT to GND .....-0.3V to +15V
Differential Input Voltage (V_{RS+} - V_{RS-}) .....±0.3V
Current into Any Pin.....±10mA

Continuous Power Dissipation (T_A = +70°C)
5-Pin SOT23 (derate 7.1mW/°C above +70°C).....571mW
8-Pin SO (derate 5.88mW/°C above +70°C).....471mW
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} = +2.7V to +28V, V_{SENSE} = 0, R_{LOAD} = 1MΩ, T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Operating Voltage Range (Note 2)	V_{CC}		2.7		28	V
Common-Mode Input Range (Note 3)	V_{CMR}		0		28	V
Common-Mode Rejection	CMR	V_{RS+} > 2V		85		dB
Supply Current	I_{CC}	V_{RS+} > 2V, V_{SENSE} = 5mV		30	60	µA
Leakage Current	I_{RS+}, I_{RS-}	V_{CC} = 0		0.05	1.2	µA
Input Bias Current	I_{RS+}	V_{RS+} > 2V	0		1	µA
		V_{RS+} ≤ 2V	-25		2	
	I_{RS-}	V_{RS+} > 2V	0		2	
		V_{RS+} ≤ 2V	-50		2	
Full-Scale Sense Voltage (Note 4)	V_{SENSE}	Gain = +20V/V or +50V/V		150		mV
		Gain = +100V/V		100		
Full-Scale Accuracy (Note 5)		V_{SENSE} = 100mV, V_{CC} = 12V, V_{RS+} = 12V, T_A = +25°C (Note 6)		±0.18	±3	%
Total OUT Voltage Error (Note 5)		V_{SENSE} = 100mV, V_{CC} = 12V, V_{RS+} = 12V (Note 6)			±6	%
		V_{SENSE} = 100mV, V_{CC} = 28V, V_{RS+} = 28V (Note 6)		±0.15	±7	
		V_{SENSE} = 100mV, V_{CC} = 12V, V_{RS+} = 0.1V (Note 6)		±1	±28	
		V_{SENSE} = 6.25mV, V_{CC} = 12V, V_{RS+} = 12V (Note 7)		±0.15		
OUT Low Voltage		V_{CC} = 2.7V, I_{OUT} = 10µA		2.6		mV
		V_{CC} = 2.7V, I_{OUT} = 100µA		9	65	
OUT High Voltage	V_{CC} - V_{OH}	V_{CC} = 2.7V, I_{OUT} = -500µA		0.1	0.25	V

ELECTRICAL CHARACTERISTICS (continued)

(V_{RS+} = 0 to +28V, V_{CC} = +2.7V to +28V, V_{SENSE} = 0, R_{LOAD} = 1MΩ, T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
-3dB Bandwidth	BW	V_{RS+} = 12V, V_{CC} = 12V, C_{LOAD} = 10pF	V_{SENSE} = 100mV, gain = +20V/V		275		kHz
			V_{SENSE} = 100mV, gain = +50V/V		200		
			V_{SENSE} = 100mV, gain = +100V/V		110		
			V_{SENSE} = 6.25mV		50		
Gain		MAX4372T			20		V/V
		MAX4372F			50		
		MAX4372H			100		
Gain Accuracy		V_{SENSE} = 20mV to 100mV	T_A = +25°C		±0.25	±2.5	%
			T_A = -40°C to +85°C			±5.5	
OUT Settling Time to 1% of Final Value		Gain = +20V/V, V_{CC} = 12V, V_{RS+} = 12V, C_{LOAD} = 10pF	V_{SENSE} = 6.25mV to 100mV		20		µs
			V_{SENSE} = 100mV to 6.25mV		20		
Capacitive Load Stability		No sustained oscillations			1000		pF
OUT Output Resistance	ROUT	V_{SENSE} = 100mV			1.5		Ω
Power-Supply Rejection	PSR	V_{OUT} = 2V, V_{RS+} > 2V		75	85		dB
Power-Up Time to 1% of Final Value		V_{CC} = 12V, V_{RS+} = 12V, V_{SENSE} = 100mV, C_{LOAD} = 10pF			0.5		ms
Saturation Recovery Time (Note 8)		V_{CC} = 12V, V_{RS+} = 12V, C_{LOAD} = 10pF			0.1		ms

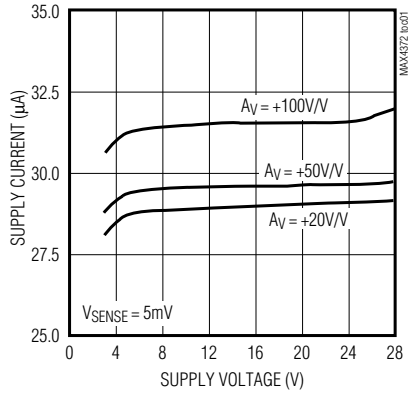
Note 1: All devices are 100% production tested at T_A = +25°C. All temperature limits are guaranteed by design.
Note 2: Guaranteed by PSR test.
Note 3: Guaranteed by OUT Voltage Error test.
Note 4: Output voltage is internally clamped not to exceed 12V.
Note 5: Total OUT voltage error is the sum of gain and offset voltage errors.
Note 6: Measured at I_{OUT} = -500µA (R_{LOAD} = 4kΩ for gain = +20V/V, R_{LOAD} = 10kΩ for gain = +50V/V, R_{LOAD} = 20kΩ for gain = +100V/V).
Note 7: +6.25mV = 1/16 of +100mV full-scale voltage (C/16).
Note 8: The device will not reverse phase when overdriven.

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

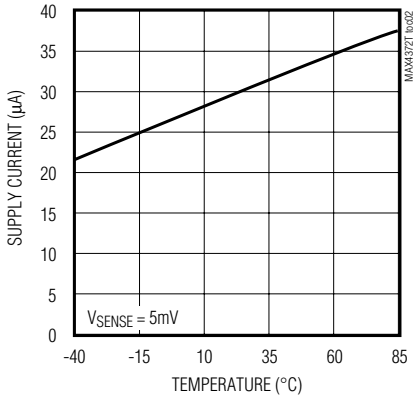
Typical Operating Characteristics

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

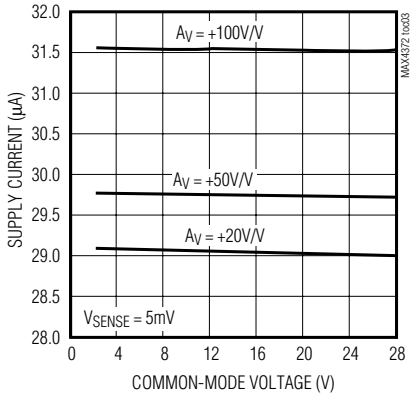
SUPPLY CURRENT vs. SUPPLY VOLTAGE



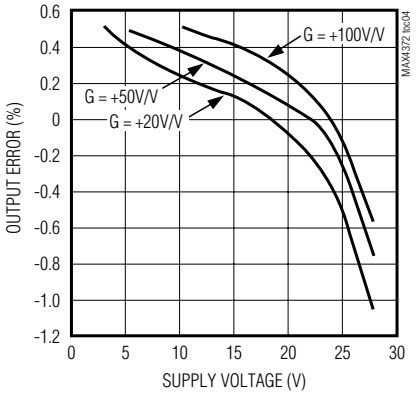
SUPPLY CURRENT vs. TEMPERATURE



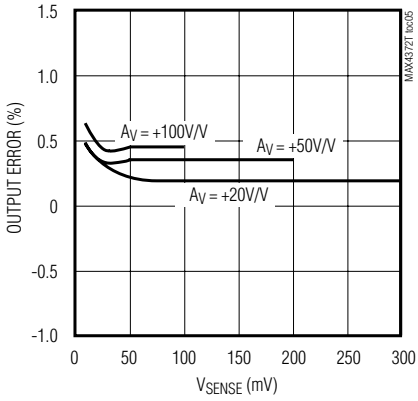
SUPPLY CURRENT vs. COMMON-MODE VOLTAGE



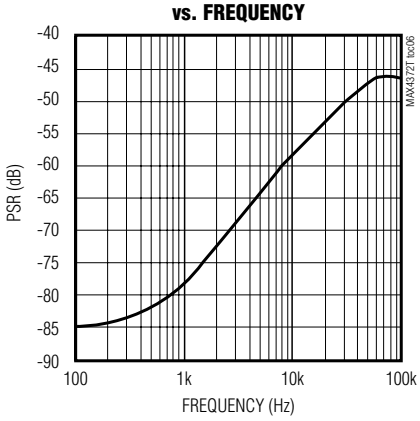
TOTAL OUTPUT ERROR vs. SUPPLY VOLTAGE



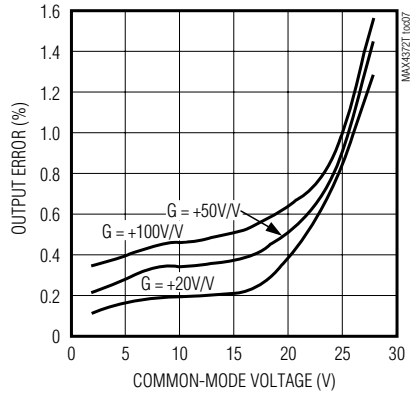
TOTAL OUTPUT ERROR vs. V_{SENSE}



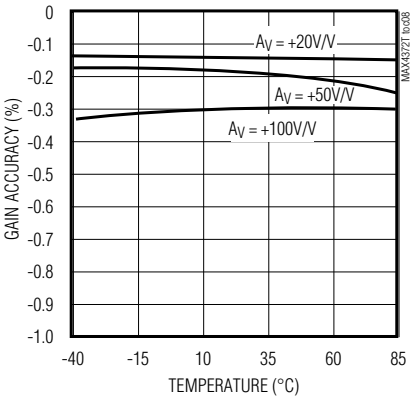
POWER-SUPPLY REJECTION vs. FREQUENCY



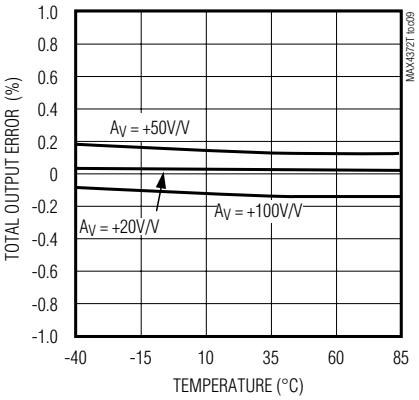
TOTAL OUTPUT ERROR vs. COMMON-MODE VOLTAGE



GAIN ACCURACY vs. TEMPERATURE



TOTAL OUTPUT ERROR vs. TEMPERATURE

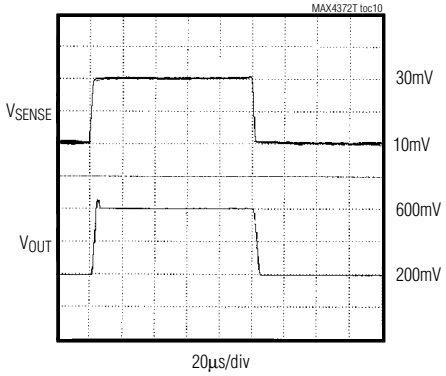


Low-Cost, SOT23, Micropower, High-Side Current-Sense Amplifier with Voltage Output

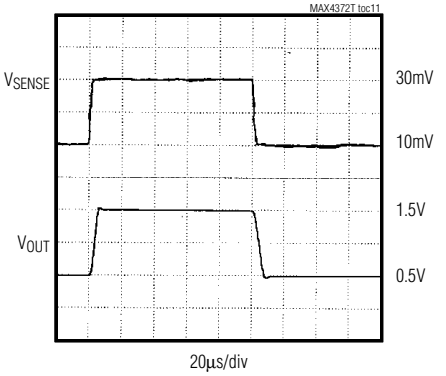
Typical Operating Characteristics (continued)

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

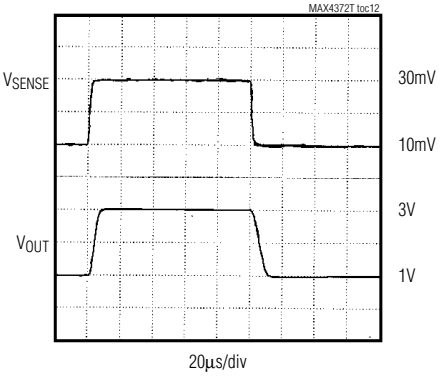
MAX4372T SMALL-SIGNAL TRANSIENT RESPONSE



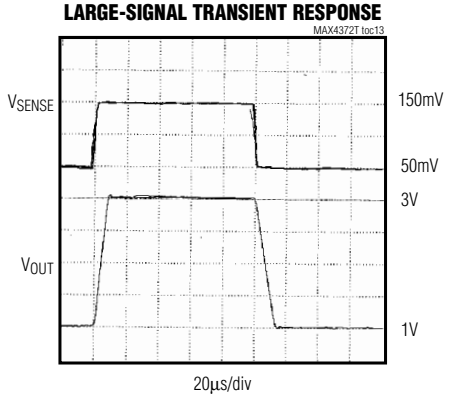
MAX4372F SMALL-SIGNAL TRANSIENT RESPONSE



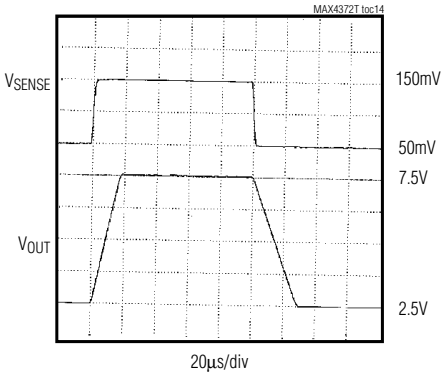
MAX4372H SMALL-SIGNAL TRANSIENT RESPONSE



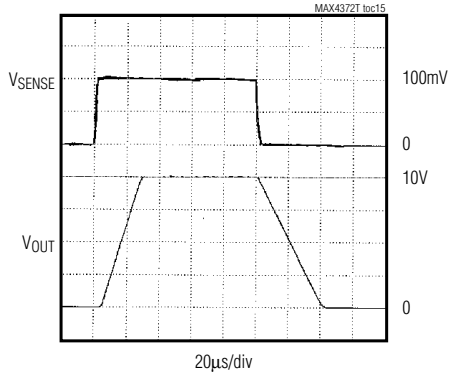
MAX4372T LARGE-SIGNAL TRANSIENT RESPONSE



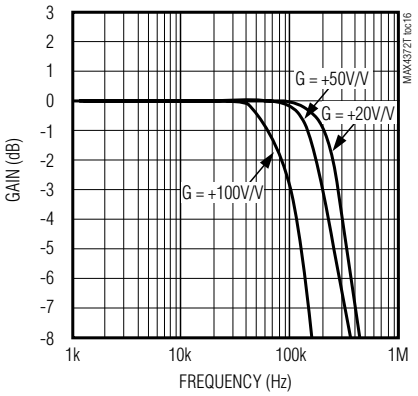
MAX4372F LARGE-SIGNAL TRANSIENT RESPONSE



MAX4372H LARGE-SIGNAL TRANSIENT RESPONSE



SMALL-SIGNAL GAIN vs. FREQUENCY



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

Pin Description

PIN		NAME	FUNCTION
SOT23-5	SO		
1	3	GND	Ground
2	4	OUT	Output Voltage. V_{OUT} is proportional to the magnitude of V_{SENSE} (V_{RS+} - V_{RS-}).
3	1	V_{CC}	Supply Voltage
4	8	RS+	Power Connection to the External Sense Resistor
5	6	RS-	Load-Side Connection to the External Sense Resistor
—	2, 5, 7	N.C.	No Connection. Not internally connected.

Detailed Description

The MAX4372 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 flow out of a battery in deep discharge, and also enables high-side current sensing at voltages far in excess of the supply voltage (V_{CC}).

Current flows through the sense resistor, generating a sense voltage (Figure 1). Since A1's inverting input is high impedance, the voltage on the negative terminal equals V_{IN} - V_{SENSE}. A1 forces its positive terminal to match its negative terminal; therefore, the voltage across R_{G1} (V_{IN} - V1-) equals V_{SENSE}. This creates a current to flow through R_{G1} equal to V_{SENSE} / R_{G1}. The transistor and current mirror amplify the current by a factor of β. This makes the current flowing out of the current mirror equal to:

$$I_M = \beta V_{SENSE} / R_{G1}$$

A2's positive terminal presents high impedance, so this current flows through R_{GD}, with the following result:

$$V_{2+} = R_{GD} \beta \cdot V_{SENSE} / R_{G1}$$

R1 and R2 set the closed-loop gain for A2, which amplifies V_{2+}, yielding:

$$V_{OUT} = R_{GD} \cdot \beta \cdot V_{SENSE} / R_{G1} (1 + R2 / R1)$$

The gain of the device equals:

$$\frac{V_{OUT}}{V_{SENSE}} = R_{GD} \cdot \beta (1 + R2 / R1) / R_{G1}$$

Applications Information

Recommended Component Values

The MAX4372 operates over a wide variety of current ranges with different sense resistors. Table 1 lists common resistor values for typical operation of the MAX4372.

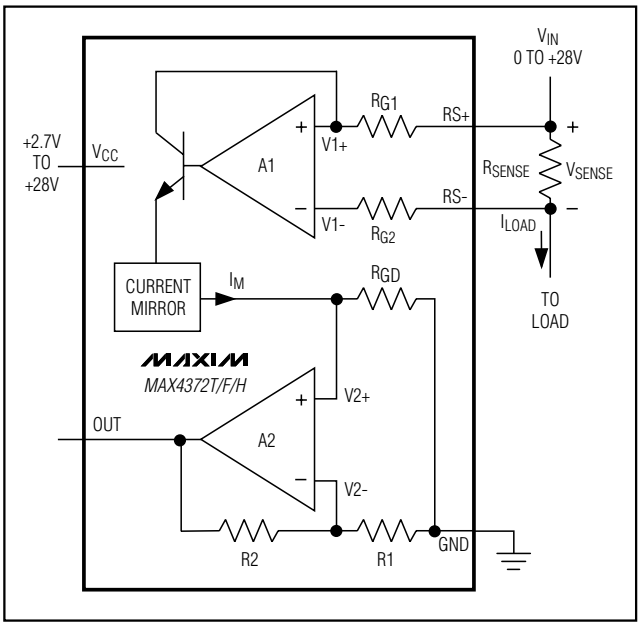


Figure 1. Functional Diagram

Choosing R_{SENSE}

Given the gain and maximum load current, select R_{SENSE} such that V_{CC} - V_{OUT} does not exceed +0.25V and V_{OUT} does not exceed +10V. To measure lower currents more accurately, use a high value for R_{SENSE}. A higher value develops a higher sense voltage, which overcomes offset voltage errors of the internal current amplifier.

In applications monitoring very high current, ensure R_{SENSE} is able to dissipate its own 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.

Table 1. Recommended Component Values

FULL-SCALE LOAD CURRENT, I_{LOAD} (A)	CURRENT-SENSE RESISTOR, R_{SENSE} (mΩ)	GAIN (V/V)	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

Using a PC Board 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 about 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, self-heating will introduce a nonlinearity error. Do not exceed the maximum power dissipation of the copper trace.

For example, the MAX4372T (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.

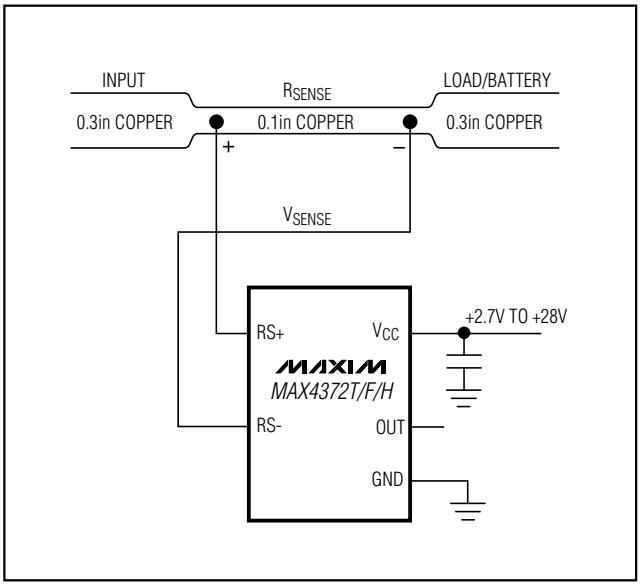


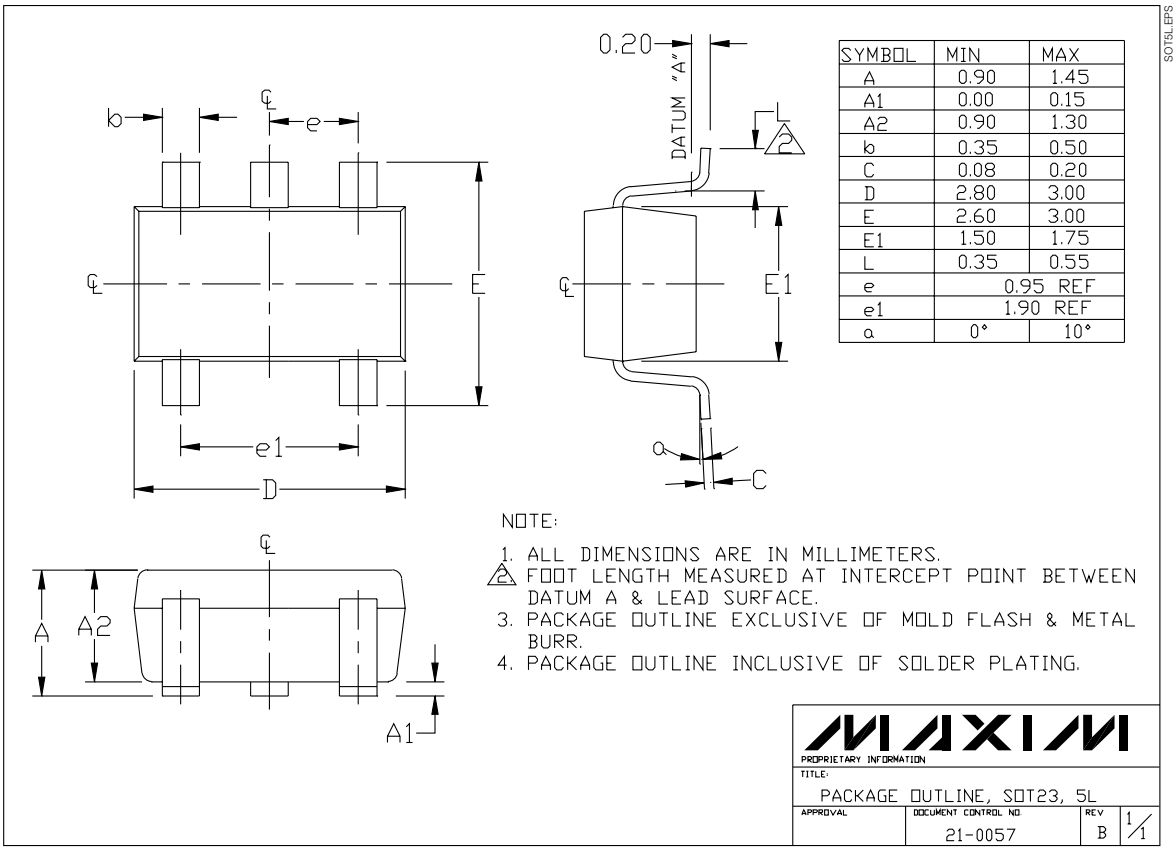
Figure 2. Connections Showing Use of PC Board

Chip Information

TRANSISTOR COUNT: 225

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

Package Information



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	
e1	1.90 REF	
α	0°	10°

SUNSTAR商斯达实业集团是集研发、生产、工程、销售、代理经销 、技术咨询、信息服务等为一体的高科技企业，是专业高科技电子产品生产厂家，是具有 10 多年历史的专业电子元器件供应商，是中国最早和最大的仓储式连锁规模经营大型综合电子零部件代理分销商之一,是一家专业代理和分銷世界各大品牌IC芯片和電子元器件的连锁经营綜合性国际公司。在香港、北京、深圳、上海、西安、成都等全国主要电子市场设有直属分公司和产品展示展销窗口门市部专卖店及代理分销商，已在全国范围内建成强大统一的供货和代理分销网络。 我们专业代理经销、开发生产电子元器件、集成电路、传感器、微波光电元器件、工控机/DOC/DOM电子盘、专用电路、单片机开发、MCU/DSP/ARM/FPGA软件硬件、二极管、三极管、模块等，是您可靠的一站式现货配套供应商、方案提供商、部件功能模块开发配套商。**专业以现代信息产业（计算机、通讯及传感器）三大支柱之一的传感器为主营业务，专业经营各类传感器的代理、销售生产、网络信息、科技图书资料及配套产品设计、工程开发。我们的专业网站——中国传感器科技信息网（全球传感器数据库） www.SENSOR-IC.COM 服务于全球高科技生产商及贸易商，为企业科技产品开发提供技术交流平台。欢迎各厂商互通有无、交换信息、交换链接、发布寻求代理信息。欢迎国外高科技传感器、变送器、执行器、自动控制产品厂商介绍产品到 中国，共同开拓市场。**本网站是关于各种传感器-变送器-仪器仪表及工业自动化大型专业网站,深入到工业控制、系统工程计 测计量、自动化、安防报警、消费电子等众多领域，把最新的传感器-变送器-仪器仪表买卖信息,最新技术供求,最新采购商,行业动态，发展方向，最新的技术应用和市场资讯及时的传递给广大科技开发、科学研究、产品设计人员。本网站已成功为石油、化工、电力、医药、生物、航空、航天、国防、能源、冶金、电子、工业、农业、交通、汽车、矿山、煤炭、纺织、信息、通信、IT、安防、环保、印刷、科研、气象、仪器仪表等领域从事科学研究、产品设计、开发、生产制造的科技人员、管理人员 、和采购人员提供满意服务。 **我公司专业开发生产、代理、经销、**销售各种传感器、变送器、敏感元器件、开关、执行器、仪器仪表、自动化控制系统： 专门从事设计、生产、销售各种传感器、变送器、各种测控仪表、热工仪表、现场控制器、计算机控制系统、数据采集系统、各类环境监控系统、专用控制系统应用软件以及嵌入式系统开发及应用等工作。如热敏电阻、压敏电阻、温度传感器、温度变送器、湿度传感器、 湿度变送器、气体传感器、 气体变送器、压力传感器、 压力变送、称重传感器、物（液）位传感器、物（液）位变送器、流量传感器、 流量变送器、电流（压）传感器、溶氧传感器、霍尔传感器 、图像传感器、超声波传感器、位移传感器、速度传感器、加速度传感器、扭距传感器、红外传感器、紫外传感器、 火焰传感器、激光传感器、振动传感器、轴角传感器、光电传感器、接近传感器、干簧管传感器、继电器传感器、微型电泵、磁敏（阻）传感器 、压力开关、接近开关、光电开关、色标传感器、光纤传感器、齿轮测速传感器、 时间继电器、计数器、计米器、温控仪、固态继电器、调压模块、电磁铁、电压表、电流表等特殊传感器 。 同时承接传感器应用电路、产品设计和自动化工程项目。

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