19-0335; Rev 2; 12/96

MAXIM

Precision, High-Side Current-Sense Amplifiers

General Description

The MAX471/MAX472 are complete, bidirectional, high-side current-sense amplifiers for portable PCs, telephones, and other systems where battery/DC power-line monitoring is critical. High-side power-line monitoring is especially useful in battery-powered systems, since it does not interfere with the ground paths of the battery chargers or monitors often found in "smart" batteries.

The MAX471 has an internal 35mΩ current-sense resistor and measures battery currents up to ±3A. For applications requiring higher current or increased flexibility, the MAX472 functions with external sense and gain-setting resistors. Both devices have a current output that can be converted to a ground-referred voltage with a single resistor, allowing a wide range of battery voltages and currents.

An open-collector SIGN output indicates current-flow direction, so the user can monitor whether a battery is being charged or discharged. Both devices operate from 3V to 36V, draw less than 100µA over temperature, and include a 18µA max shutdown mode.

Applications

- Portable PCs:
  - Notebooks/Subnotebooks/Palmtops
- Smart Battery Packs
- Cellular Phones
- Portable Phones
- Portable Test/Measurement Systems
- Battery-Operated Systems
- Energy Management Systems

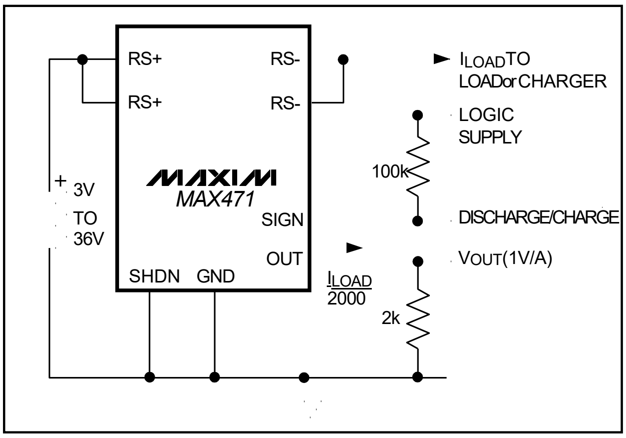
Features

- ♦ Complete High-Side Current Sensing
- ♦ Precision Internal Sense Resistor (MAX471)
- ♦ 2% Accuracy Over Temperature
- ♦ Monitors Both Charge and Discharge
- ♦ 3A Sense Capability with Internal Sense Resistor (MAX471)
- ♦ Higher Current-Sense Capability with External Sense Resistor (MAX472)
- ♦ 100µA Max Supply Current
- ♦ 18µA Max Shutdown Mode
- ♦ 3V to 36V Supply Operation
- ♦ 8-Pin DIP/SO Packages

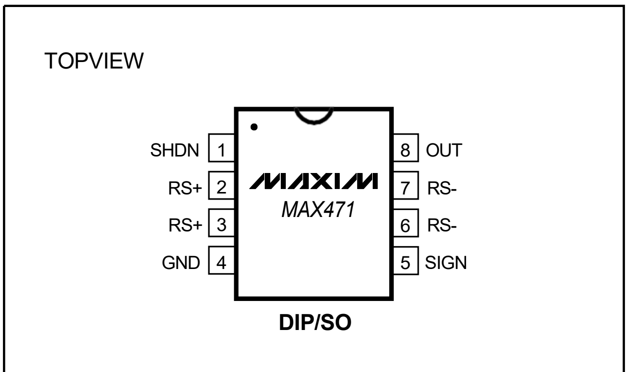
Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE
MAX471CPA	0°C to +70°C	8 Plastic DIP
MAX471CSA	0°C to +70°C	8 SO
MAX471EPA	-40°C to +85°C	8 Plastic DIP
MAX471ESA	-40°C to +85°C	8 SO
MAX472CPA	0°C to +70°C	8 Plastic DIP
MAX472CSA	0°C to +70°C	8 SO
MAX472EPA	-40°C to +85°C	8 Plastic DIP
MAX472ESA	-40°C to +85°C	8 SO

Typical Operating Circuit



Pin Configurations



MAX472 Pin Configuration continued on last page.

Precision, High-Side Current-Sense Amplifiers

ABSOLUTE MAXIMUM RATINGS

Supply Voltage, RS+, RS-, V_{CC} to GND ....V, +40V
RMS Current, RS+ to RS- (MAX471 only).......................... ±3.3A
Peak Current, (RS+ to RS-)....................................... see Figure 5
Differential Input Voltage, RG1 to RG2 (MAX472 only) .... ±0.3V
Voltage at Any Pin Except SIGN
  MAX471 only..-0.3V to (RS+ - 0.3V)
  MAX472 only.. 0.3V to (V_{CC} + 0.3V)
Voltage at SIGN..V to +40V
Current into SHDN, GND, OUT, RG1, RG2, V_{CC}...................±50mA
Current into SIGN..+10mA, -50mA

Continuous Power Dissipation (T_A = +70°C)
  MAX471 (Note 1):
  Plastic DIP (derate 17.5mW/°C above +70°C).................. 1.4W
  SO (derate 9.9mW/°C above +70°C)............................ 791mW
  MAX472 :
  Plastic DIP (derate 9.09mW/°C above +70°C).............. 727mW
  SO (derate 5.88mW/°C above +70°C).......................... 471mW
Operating Temperature Ranges
  MAX47_C_A...0°C to +70°C
  MAX47_E_A ....-40°C to +85°C
Junction Temperature Range ....-60°C to +150°C
Storage Temperature Range ....-60°C to +160°C
Lead Temperature (soldering, 10sec) .... +300°C

Note 1: Due to special packaging considerations, MAX471 (DIP, SO) has a higher power dissipation rating than the MAX472. RS+ and RS- must be soldered to large copper traces to achieve this dissipation rating.

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—MAX471

(RS+ = +3V to +36V, T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A = +25°C.)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Supply Voltage	V_{RS+}			3		36	V
Supply Current	I_{RS+}	I_{LOAD} = 0A, excludes I_{SIGN}			50	113	µA
Sense Current	I_{LOAD}					±3	A_{RMS}
Sense Resistor	R_{SENSE}				35	70	mW
Current-Sense Ratio	I_{OUT}/ I_{LOAD}	I_{LOAD} = 1A, RS+ = 10V	MAX471C	0.490	0.500	0.510	mA/A
			MAX471E	0.4875	0.500	0.5125	
No-Load OUT Error		I_{LOAD} = 0A, RS+ = 10V	MAX471C			2.5	µA
			MAX471E			3.0	
Low-Level OUT Error		I_{LOAD} = 30mA, RS+ = 10V	MAX471C			±2.5	µA
			MAX471E			±3.0	
Power-Supply Rejection Ratio	PSRR	3V £ RS+ £ 36V, I_{LOAD} = 1A				0.1	%/V
SIGN Threshold (I_{LOAD} required to switch SIGN)		MAX471C			±4.0	±6.0	mA
		MAX471E				±7.0	
SIGN Output Leakage Current		V_{SIGN} = 36V				1.0	µA
SIGN Sink Current	I_{OL}	V_{SIGN} = 0.3V		0.1			mA
Shutdown Supply Current	$I_{RS+(SHDN)}$	V_{SHDN} = 2.4V; V_{CC} = 3V to 20V			1.5	18.0	µA
SHDN Input Low Voltage	V_{IL}					0.3	V
SHDN Input Low Current	I_{IL}	V_{SHDN} = 0V				1.0	µA
SHDN Input High Voltage	V_{IH}			2.4			V
SHDN Input High Current	I_{IH}	V_{SHDN} = 2.4V				1.0	µA
OUT Output Voltage Range	V_{OUT}			0		V_{RS+} - 1.5	V
OUT Output Resistance	R_{OUT}	I_{LOAD} = 3.0A, V_{OUT} = 0V to (V_{RS+} - 1.5V)		1	3		MW
OUT Rise, Fall Time	t_R, t_F	I_{LOAD} = 50mA to 3.0A, R_{OUT} = 2kW, C_{OUT} = 50pF, 10% to 90%			4		µs
OUT Settling Time to 1% of Final Value	t_s	I_{LOAD} = 100mA to 3.0A, R_{OUT} = 2kW, C_{OUT} = 50pF			15		µs

ELECTRICAL CHARACTERISTICS—MAX472

(V_{CC} = +3V to +36V, RG1 = RG2 = 200Ω, T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A = +25°C.)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Supply Voltage	V_{CC}			3		36	V
Supply Current	I_{CC}	I_{LOAD} = 0A, excludes I_{SIGN}; V_{CC} = 3V to 20V			20	48	µA
Input Offset Voltage (Note 2)	V_{OS}	MAX472C				120	µV
		MAX472E				140	
Input Bias Current	I_{RG1}, I_{RG2}				20	35	µA
Input Bias-Current Matching	I_{OS}	I_{RG1} - I_{RG2}			±0.4	±3.0	µA
OUT Current Accuracy	I_{RG}/I_{OUT}	V_{SENSE} = 100mV, V_{CC} = 10V (Note 3)	MAX472C			±2	%
			MAX472E			±2.5	
No-Load OUT Error		V_{CC} = 10V, V_{SENSE} = 0V	MAX472C			2.5	µA
			MAX472E			3	
Low-Level OUT Error		V_{CC} = 10V, V_{SENSE} = 3mV	MAX472C			±2.5	µA
			MAX472E			±3.0	
Power-Supply Rejection Ratio	PSRR	3V ≤ V_{CC} ≤ 36V, V_{SENSE} = 100mV				0.1	%/V
SIGN Threshold (V_{SENSE} required to switch SIGN)		V_{CC} = 10V	MAX472C		60	120	µV
			MAX472E		60	140	
SIGN Output Leakage Current		V_{SIGN} = 36V				1.0	µA
SIGN Output Sink Current		V_{SIGN} = 0.3V		0.1			mA
Shutdown Supply Current	$I_{CC(SHDN)}$	V_{SHDN} = 2.4V; V_{CC} = 3V to 20V			1.5	18.0	µA
SHDN Input Low Voltage	V_{IL}					0.3	V
SHDN Input Low Current	I_{IL}	V_{SHDN} = 0V				1.0	µA
SHDN Input High Voltage	V_{IH}			2.4			V
SHDN Input High Current	I_{IH}	V_{SHDN} = 2.4V				1.0	µA
OUT Output Voltage Range	V_{OUT}			0		V_{CC} - 1.5	V
OUT Output Resistance	R_{OUT}	I_{OUT} = 1.5mA		1	3		MΩ
OUT Rise, Fall Time	t_R, t_F	V_{SENSE} = 5mV to 150mV, R_{OUT} = 2kΩ, C_{OUT} = 50pF, 10% to 90%			4		µs
OUT Settling Time to 1% of Final Value	t_S	V_{SENSE} = 5mV to 150mV, R_{OUT} = 2kΩ, C_{OUT} = 50pF			15		µs
Maximum Output Current	I_{OUT}			1.5			mA

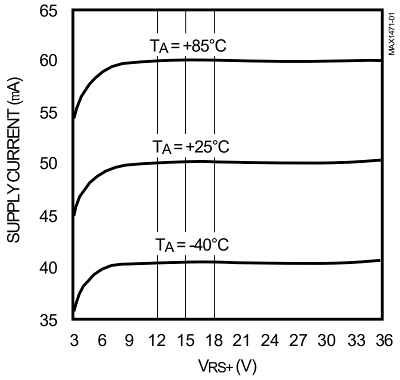
Note 2: V_{OS} is defined as the input voltage (V_{SENSE}) required to give minimum I_{OUT}.
Note 3: V_{SENSE} is the voltage across the sense resistor.

Precision, High-Side Current-Sense Amplifiers

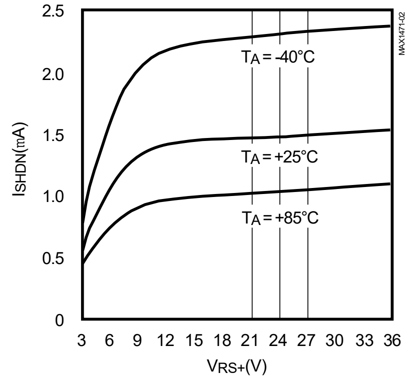
Typical Operating Characteristics

(Typical Operating Circuit (MAX471) or circuit of Figure 4, RG1 = RG2 = 200Ω, ROUT = 2kΩ (MAX472), TA = +25°C, unless otherwise noted.)

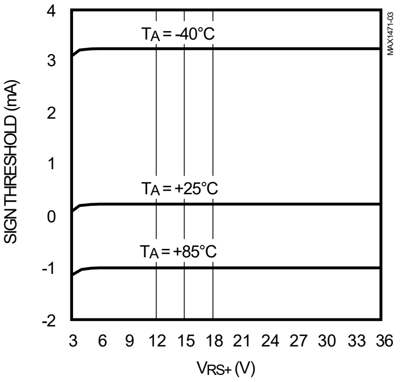
SUPPLY CURRENT vs. SUPPLY VOLTAGE



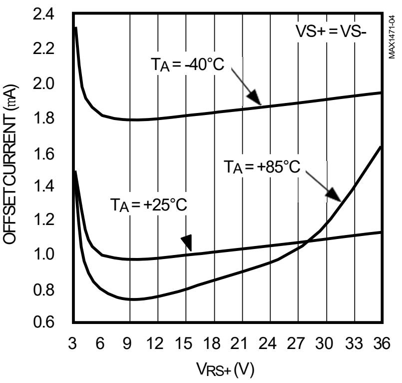
SHUTDOWN CURRENT vs. SUPPLY VOLTAGE



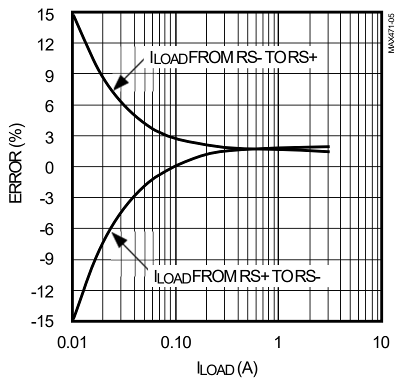
SIGN THRESHOLD vs. SUPPLY VOLTAGE



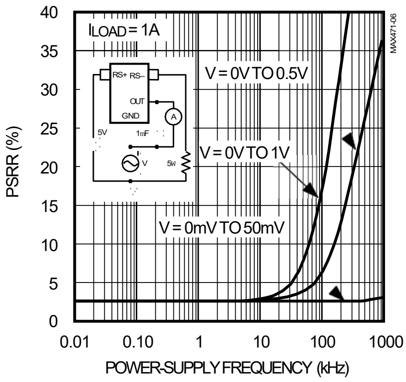
MAX471 NO-LOAD OFFSET CURRENT vs. SUPPLY VOLTAGE



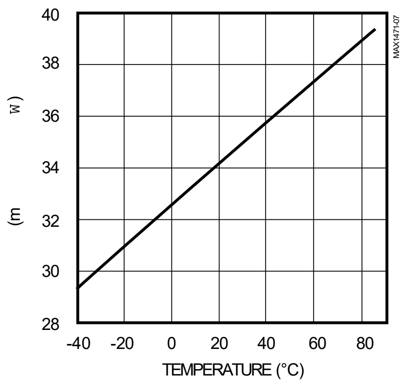
MAX471 ERROR vs. LOAD CURRENT



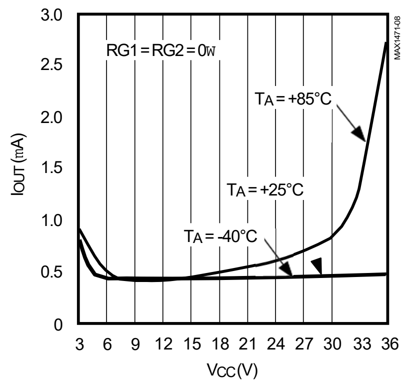
MAX471 POWER-SUPPLY REJECTION RATIO vs. FREQUENCY



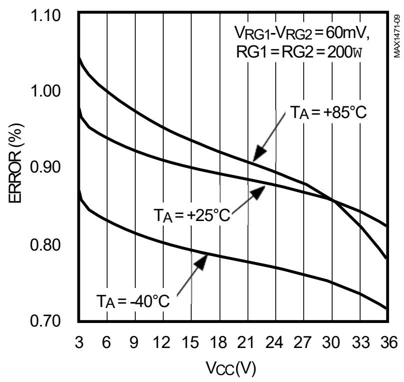
MAX471 RS+ TO RS- RESISTANCE vs. TEMPERATURE



MAX472 NO-LOAD OUTPUT ERROR vs. SUPPLY VOLTAGE



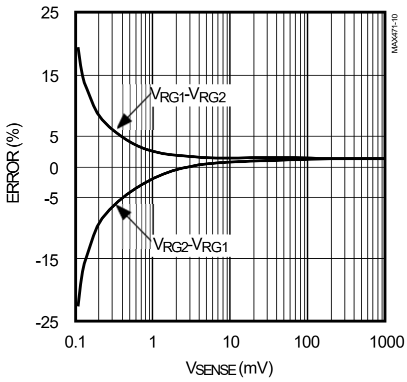
MAX472 ERROR vs. SUPPLY VOLTAGE



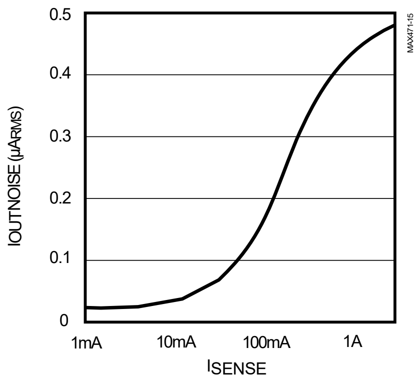
Typical Operating Characteristics (continued)

(Typical Operating Circuit (MAX471) or circuit of Figure 4, RG1 = RG2 = 200Ω, R_{OUT} = 2kΩ (MAX472), T_A = +25°C, unless otherwise noted.)

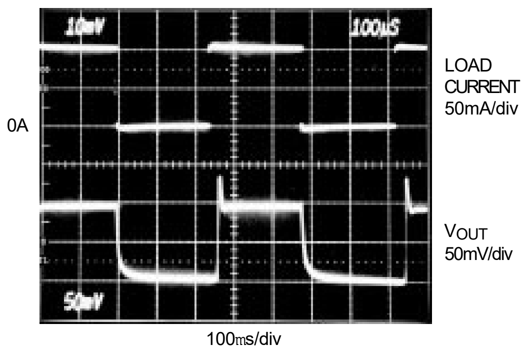
MAX472
ERROR vs. SENSE VOLTAGE



MAX471
NOISE vs. LOAD CURRENT

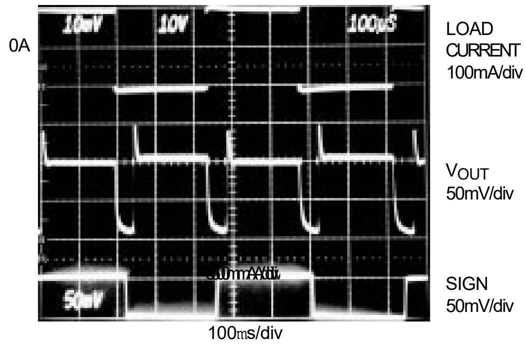


MAX471
0mA to 100mA TRANSIENT RESPONSE



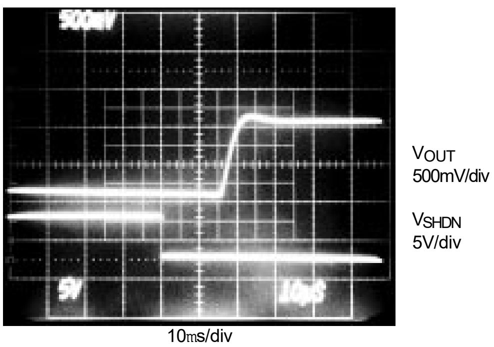
V_{CC}=10V, R_{OUT}=2kΩ 1%, SIGN PULL-UP=50kΩ 1%

MAX471
-100mA to +100mA TRANSIENT RESPONSE



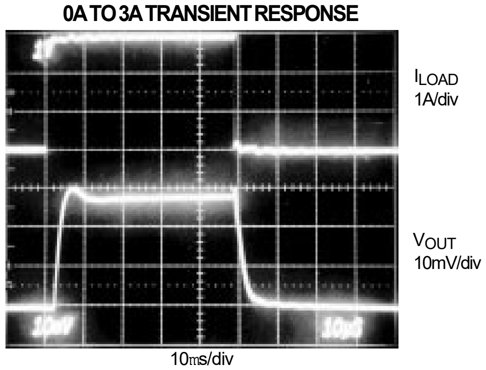
V_{CC}=10V, R_{OUT}=2kΩ 1%, SIGN PULL-UP=50kΩ 1%

MAX471
START-UP DELAY



I_{LOAD}=1A, R_{OUT}=2kΩ 1%

MAX471
0A TO 3A TRANSIENT RESPONSE



R_{OUT}=2kΩ 1%