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APPLICATION NOTE 4507

Load-Power Monitor Improves High-Side Current Measurements

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Abstract: Combining a high-side current-sense amplifier with an analog voltage multiplier, MAX4211 shown can easily measure the power dissipated in a load. One multiplier input connects to the load voltage, and the other to an internal analog of the load current—that is, a proportional voltage produced by the internal current-sense amplifier. The multiplier output ($V_L I_L$) is then a voltage proportional to load power.

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An IC that combines a high-side current-sense amplifier with an analog voltage multiplier (MAX4211) can easily measure the power dissipated in a load. One multiplier input connects to the load voltage, and the other to an internal analog of the load current—i.e., a proportional voltage produced by the internal current-sense amplifier. The multiplier output ($V_L I_L$) is then a voltage proportional to load power.

The internal multiplier can also enable extra precision in high-side current measurements, for applications in which the current signal is digitized by an A-D converter. Whether the ADC's voltage reference is internal or external to the ADC, the accuracy of the digitized load-current measurement depends strongly on the accuracy and stability of that reference.

To minimize this dependency on voltage-reference accuracy, connect the multiplier's external input to the reference voltage via a resistive divider (**Figure 1**). The current measurement is then ratiometric: any error or drift in the reference voltage has a proportional effect on the ADC's input, and thereby achieves a first-order cancellation of full-scale error caused by the reference voltage. The circuit shown can measure battery charge and discharge currents in a wide range of applications, and it works equally well with a voltage reference internal to the ADC, driving the R1-R2 divider.

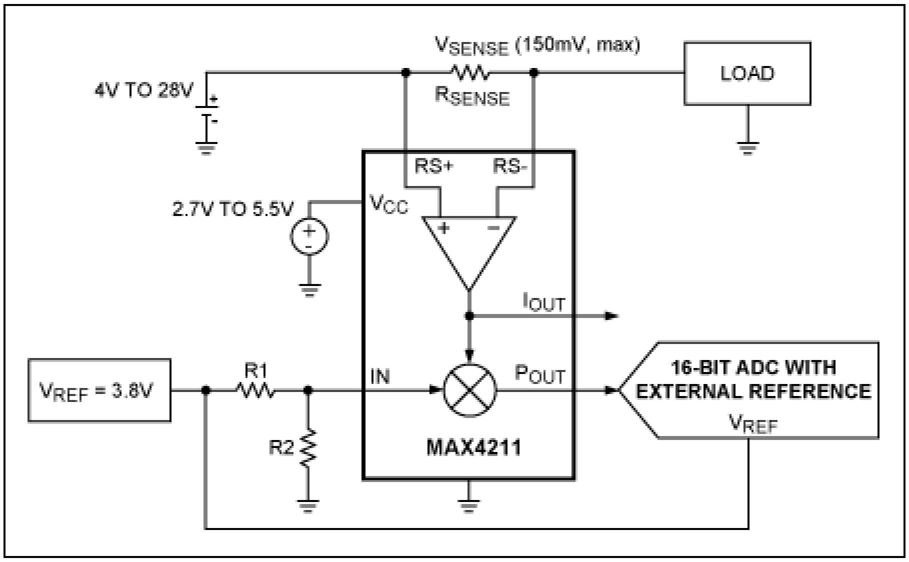

Figure 1. This circuit uses a high-side power/current monitor (MAX4211) plus an ADC with external reference voltage to measure battery charge currents.

The IC's multiplier output (P_{OUT}) feeds a 16-bit ADC whose input voltage range is 0V to V_{REF}. V_{REF}, provided here by an external voltage regulator, should be between 1.2V and 3.8V (3.8V in this case). The multiplier input must be limited to a range of 0V to 1V, which is accomplished by dividing the 3.8V reference voltage with the R1/R2 resistor divider. Assuming R2 = 1kΩ and R1 = 2.8kΩ, then V_{IN} = 1V. The IC has a gain of 25 between V_{SENSE} and I_{OUT}, and a sense-voltage range (V_{SENSE}) of 0V to 150mV, which produces (at both P_{OUT} and I_{OUT}) an output in the range 0V to 3.75V.

Thus, the use of P_{OUT} (instead of I_{OUT}) confers an advantage: the signal fed to the ADC, which is proportional to current in the load, is scaled by V_{REF}. The following equation relates the P_{OUT}/V_{REF} ratio to I_{LOAD}, R_{SENSE}, and the values of R1 and R2:

$$P_{OUT}/V_{REF} = I_{LOAD} \times R_{SENSE} \times 25 \times V_{REF} \times R2/(R1 + R2)/V_{REF} = I_{LOAD} \times R_{SENSE} \times 25 \times R2/(R1 + R2)$$

Note that the ratio of ADC input to ADC full-scale (P_{OUT}/V_{REF}) does not depend on the accuracy of V_{REF}.

Overall accuracy of the current measurement depends on many factors: resistor tolerance, amplifier gain error, voltage offset and bias current, reference voltage accuracy, ADC errors, and drift versus temperature for all the above. This circuit improves accuracy by eliminating only one of these causes—the reference voltage inaccuracy. V_{REF} is affected by at least three sources of error:

- Initial dc error as a percentage of the nominal value
- V_{REF} changes with load
- V_{REF} changes with temperature

A graph of the multiplier input (IN) vs. temperature, with V_{CC} = 5V and V_{SENSE} constant at 100mV, shows the effect of temperature on the reference voltage (**Figure 2**). To see the advantage of the ratiometric output at P_{OUT}, compare the P_{OUT}/V_{IN} ratio and its linear ideal with the I_{OUT}/V_{IN} ratio and its linear ideal, as they vary with temperature (Figure 3). Note that the ratiometric P_{OUT} output (top) does not deviate from the ideal.

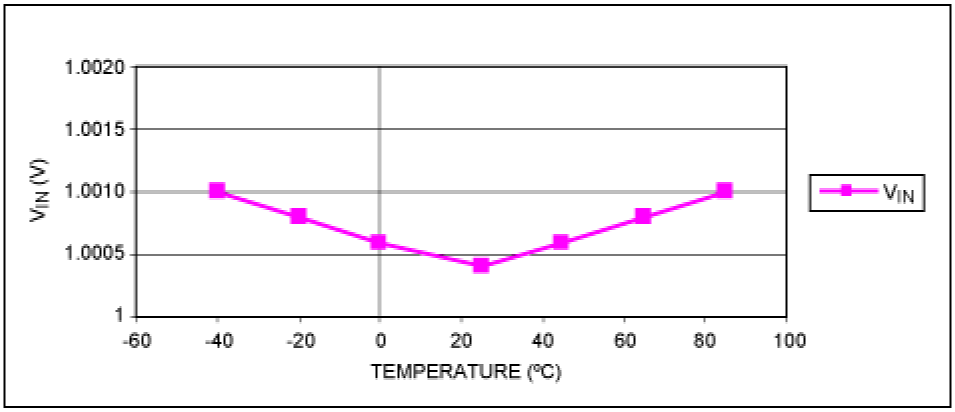

Figure 2. V_{IN} vs. temperature for the Figure 1 circuit.

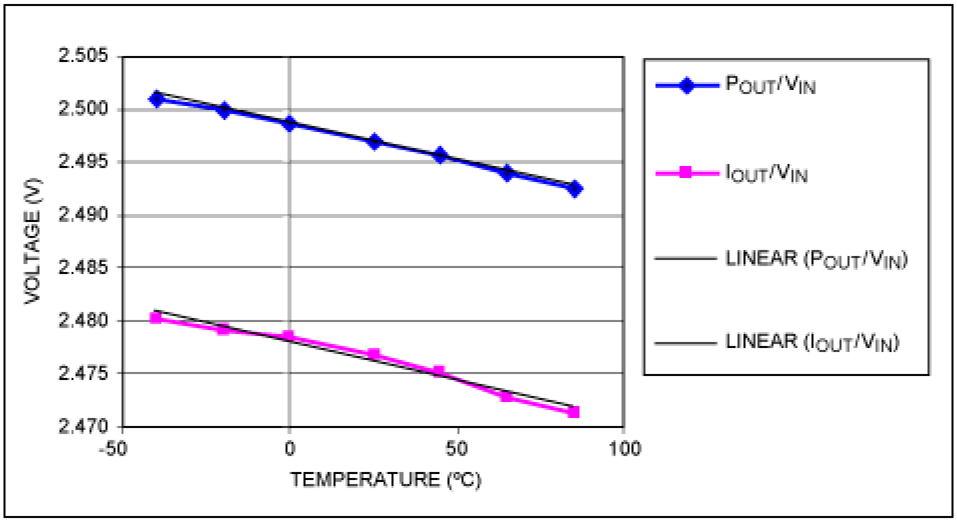

Figure 3. P_{OUT}/V_{IN} and I_{OUT}/V_{IN} vs. temperature for the Figure 1 circuit, with V_{SENSE} = 100mV.

Related Parts		
MAX4211	High-Side Power and Current Monitors	Free Samples

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