DESIGN NOTES

Sense Milliamps to Kiloamps and Digitize to 12 Bits – Design Note 227

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Introduction

The LT®1787 high side current sense amplifier provides a precision measurement of current into or out of a power source. The part generates an output voltage that is directly proportional to the current flowing through an external current sense resistor. With a miniscule 40μV (typical) input offset voltage, the LT1787 has a better than 12-bit, zero-cross accurate dynamic range at 250mV full-scale input. A hefty 60V maximum supply voltage specification allows the part to be used not only in low voltage battery applications but also in higher voltage telecom and industrial applications. Independent V_{EE} and V_{BIAS} pins make the application of the LT1787 extremely versatile.

The device is self-powered from the supply that it is monitoring and requires only 60μA of supply current. The power supply rejection ratio of the LT1787 is in excess of 120dB. The part has a fixed voltage gain of 8 from input to output.

Additional LT1787 features include provisions for input noise filtering (both differential and common mode) and the ability to operate over a very wide supply range of 2.5V to 60V. A functional diagram of the part and its theory of operation is detailed in the side bar. The part is available in both 8-lead SO and MSOP packages.

Operation with an A/D Converter

Figure 1 shows a detailed schematic of a high resolution (12-bit), bidirectional current-to-bits converter using an LT1787, the LT1783 SOT-23 1.2MHz micropower, rail-to-rail op amp and the LTC1404 SO-8 packaged, 12-bit analog-to-digital converter with shutdown. The circuit, as shown, allows digitization of input current from approximately –3A to approximately 2A with 12-bit resolution.

The LT1787's output voltage is buffered by the LT1783, filtered and applied to the LTC1404's A_{IN} pin. The precision bias voltage applied to the V_{BIAS} pin of the LT1787 is obtained from the LTC1404's reference output and is typically 2.43V. This bias voltage sets the zero-current output of the LT1787 to 2.43V, or approximately mid-range for the A-to-D converter, allowing measurement of current in both the positive and negative directions. Note that the LTC1404's internal reference voltage is 4.096V; thus the output of the converter is 1 count per millivolt of input voltage from the LT1787's output, or 8 counts/mV of input voltage across R_{SENSE}. Zero sense-current translates to 2.43V or 2430 counts from the converter. Full-scale positive current is 4096 counts and full-scale negative current is 0 counts.

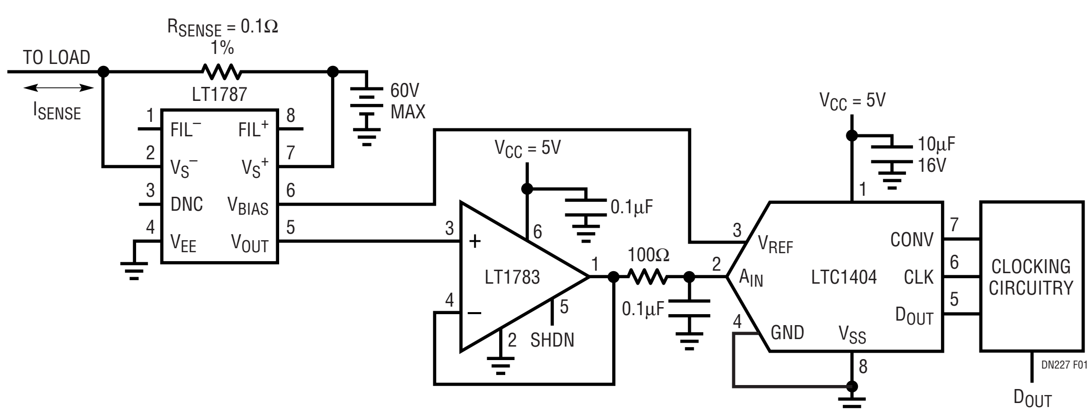

Figure 1. LT1787 Connected to LTC1404 ADC: Bidirectional Current-to-Bits Converter

Figure 2 shows current versus output code for the complete system. The LTC1404 has a digital interface consisting of the CLK and CONV input and the D_{OUT} serial digital output. The signals provide wide flexibility in allowing the part to be interfaced to most microprocessors and DSPs.

The output voltage, V_{OUT}, of the LT1787 is related to the input sense voltage by the following relationships:

$$V_{SENSE} = I_{SENSE} \bullet R_{SENSE}$$

$$V_{OUT} = 8(V_{SENSE}) + V_{BIAS}$$

Although a –3A to 2A range was selected for this illustration, other current ranges can be accommodated by a simple change in value of the sense resistor. The correct R_{SENSE} value is derived so that the product of the maximum sense current and the sense resistor value is equal to the desired maximum sense voltage (250mV for 12-bit resolution). For instance, the value of the sense resistor to sense a maximum current of 10A is 250mV/10A = 0.025Ω. The smallest measurable current is then 10A/4096 counts = 2.44mA/count. If only 10-bit resolution is desired, then the full-scale voltage can be reduced to 60mV and R_{SENSE} reduced to 0.006Ω. Ensure that the power dissipated in the sense resistor, $I_{MAX}^2 \bullet R_{SENSE}$, does not exceed the maximum power rating of the resistor.

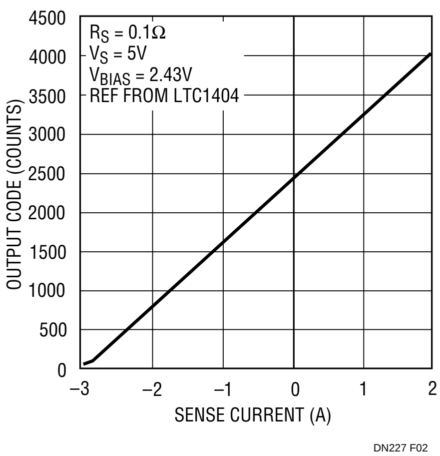

Figure 2. Current vs Output Code

Conclusion

The LT1787 high side current sense amplifier provides an easy-to-use method of sensing current with 12-bit resolution for a multiplicity of application areas. The part can operate to 60V, making it ideal for higher voltage systems in telecom or industrial applications. Additionally, the part can find application in battery-powered, handheld equipment and computers, where the need for gauging the amount of current consumed and/or the amount of charge remaining in the battery is critical.

Theory of Operation (See Figure 3)

Inputs V_S^+ and V_S^- apply the sense voltage to matched resistors R_{G1} and R_{G2}. The opposite ends of resistors R_{G1} and R_{G2} are forced to be at equal potentials by the voltage gain of amplifier A1. The currents through R_{G1} and R_{G2} are forced to flow through transistors Q1 and Q2 and are summed at node V_{OUT} by the 1:1 current mirror. The net current from R_{G1} and R_{G2} flowing through resistor R_{OUT} gives a voltage gain of eight. Positive sense voltages result in V_{OUT} being positive with respect to pin V_{BIAS}.

Pins V_{EE}, V_{BIAS} and V_{OUT} may be connected in a variety of ways to interface with subsequent circuitry. Split supply and single supply output configurations are easily supported.

Supply current for amplifier A1 is drawn from the V_S^- pin. The user may choose to include this current in the monitored current (through R_{SENSE}) by careful choice of connection polarity.

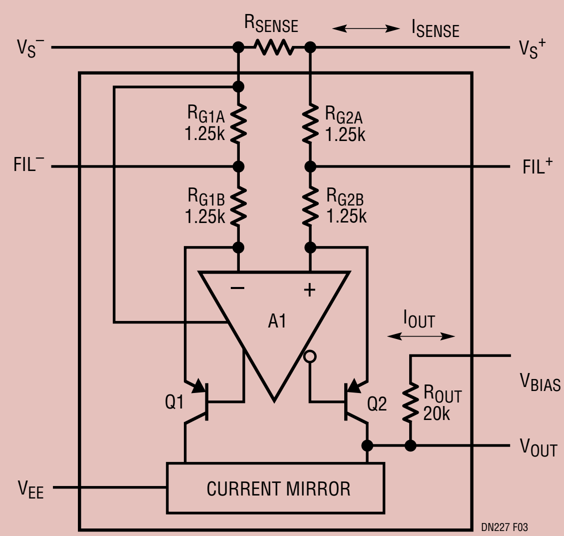

Figure 3. LT1787 Functional Diagram

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