Keywords: current-sense amplifiers, stepup converter, boost converter, instrumentation amplifiers, IAs, high common mode, telecom

APPLICATION NOTE 4495

Current-Sense Amplifier Doubles as a High-Common Mode Instrumentation Amplifier

By: Ahmad Ayar
Dec 03, 2012

Abstract: This application note discusses differences between current-sense and instrumentation amplifiers. The article also shows how a standard boost converter (MAX668) and a current-sense amplifier (MAX4080) can form a regulator that derives +5V from -48V, without isolation, and why this matters for the telecom industry.

A similar version of this article appeared in the November 1, 2008 issue of *Power Electronics Technology* magazine.

Introduction

Instrumentation amplifiers (IAs) are used where gain accuracy and dc precision are important, such as in measurement and test equipment. The downside of IAs is the cost. However, inexpensive current-sense amplifiers handle high common-mode voltages and share some traits with IAs. As a result, in some applications, such as a ground-referenced -48V to +5V power converter, current-sense amplifiers can replace IAs, thereby reducing cost.

Current-Sense Amplifiers vs. Instrumentation Amplifiers

A current-sense amplifier senses the voltage developed by a precision "sense resistor" connected across its differential inputs. The resistor sits at a voltage level higher than that of other supplies in the system. The output, a scaled-up precision single-ended replica of the differential input voltage, is referred to the system equipotential (ground).

The precision gain of the current-sense amplifier reduces, for a given current value, the voltage burden imposed by the sense resistor on the line in which current is measured, since less drop in the sense resistor is required for the output voltage needed to measure it. A current-sense amplifier therefore complies with the basic description of a voltage instrumentation amplifier (IA): it is a precision-gain differential amplifier.

The main difference between current-sense amplifiers and IAs is that IAs generally operate in the four quadrants defined by an input-voltage axis and the orthogonal common-mode voltage axis (±input voltage, ±CMV). In contrast, standard current-sense amplifiers operate only in one quadrant (usually +input voltage, +CMV), and some in two quadrants (±input voltage, +CMV). For current-sense amplifiers, the sign of the input voltage is determined by the polarity of the measured current. Also, CMV ranges are wider for current-sense amplifiers.

In Power Converter Applications

Current sensing is not the only application that benefits from an ability to amplify signals with precision and deliver them at levels separated by a large voltage difference. The standard application of **Figure 1** (a ground-referenced -48V to +5V power converter) shows the capability of today's current-sense amplifiers.

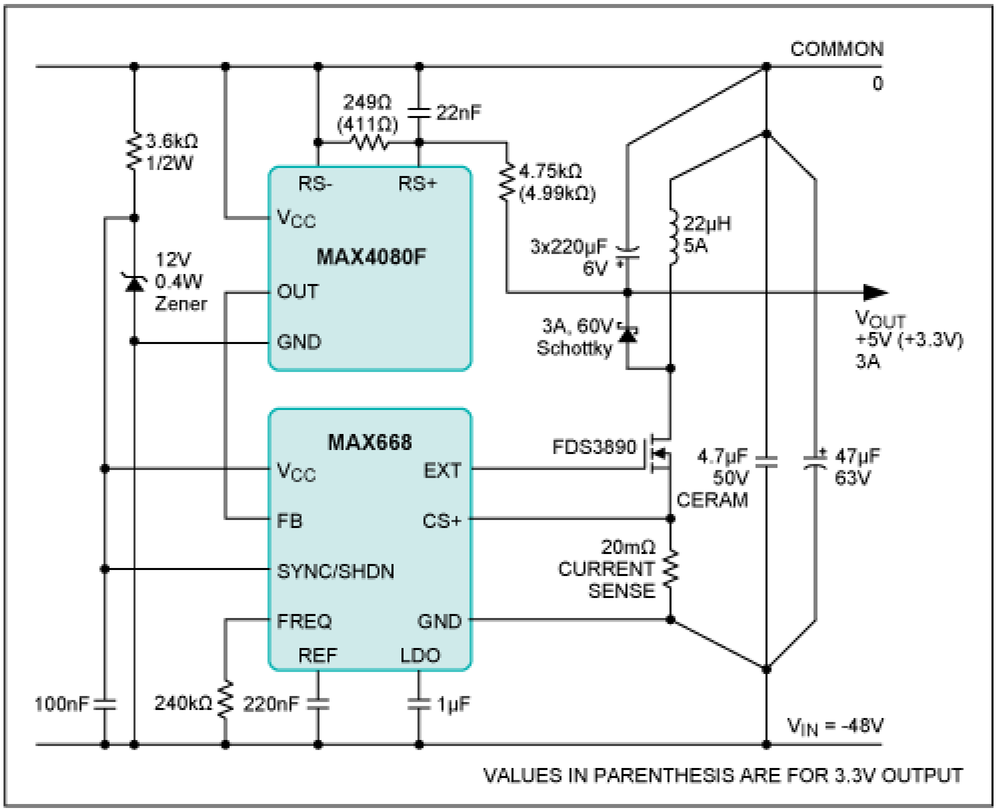

Figure 1. This simple power converter derives +5V (or +3.3V) from -48V.

It is easy (in concept) to design a switching converter whose input source and output voltage are of opposite polarity. When you get to the engineering details, however, the choice of circuit topology is more difficult. For converters that operate with a standard positive energy source, the reference levels for output voltage and regulator feedback voltage are the same: the negative side of the energy source. In this case the level is -48V, as defined by the converter's positive-source topology.

This -48V reference contradicts the intent of the application, which assumes that the low-voltage positive output must be regulated with respect to the common (ground) point. Isolated topologies (flyback, forward) that operate with different reference points for the input voltage and regulated output are preferred for this type of application, despite their higher costs and more complicated circuitry.

For the simpler solution of Figure 1, a standard switching converter operates in a non-isolated topology. In place of the conventional transformer/optocoupler design that isolates, separates, and shifts the output-sense level to the converter's regulation point, it employs for that purpose a current-sense amplifier (MAX4080F). The converter IC in this example is a MAX668, but the circuit can be implemented with other step-up converters.

The MAX668 step-up converter has a regulation set-point of 1.25V at the FB terminal, and the MAX4080F has a gain of 5 between the voltage at its differential input and the voltage between its OUT and GND terminals. The differential-input voltage necessary to produce 1.25V at the converter's FB terminal is 0.250V. When the system is in regulation, a voltage divider connected between the +5V output and system ground (common) produces 0.250V as required at the MAX4080F differential input.

Figure 2 illustrates the circuit regulation at a constant load of 1A for both the +5V and +3.3V versions, and **Figure 3** graphs efficiency vs. load current for both versions. The maximum allowed voltage difference between the MAX4080F inputs and its GND terminal is 75V, and its CMRR (common mode rejection ratio) is 120dB.

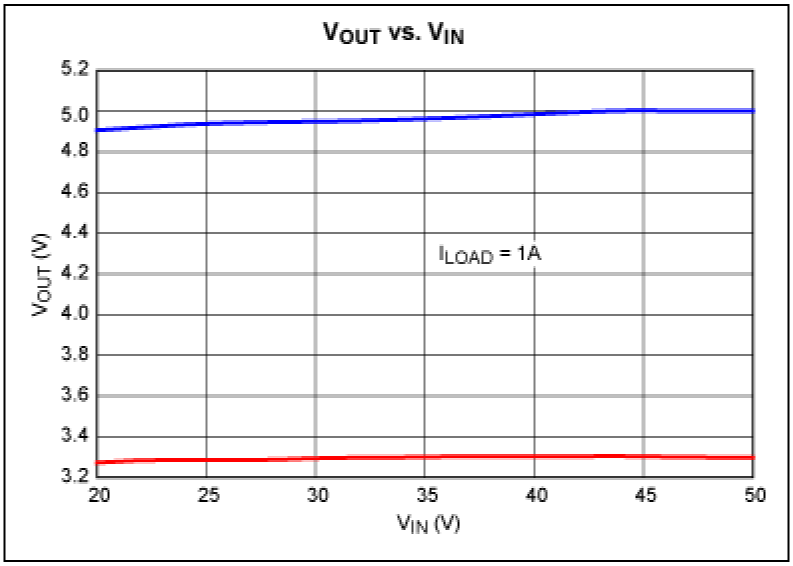

Figure 2. V_{OUT} vs. V_{IN} for the circuit in Figure 1. Graph shows that circuit regulation at a constant load of 1A improves somewhat for the higher input voltages for both the +5V and +3.3V versions.

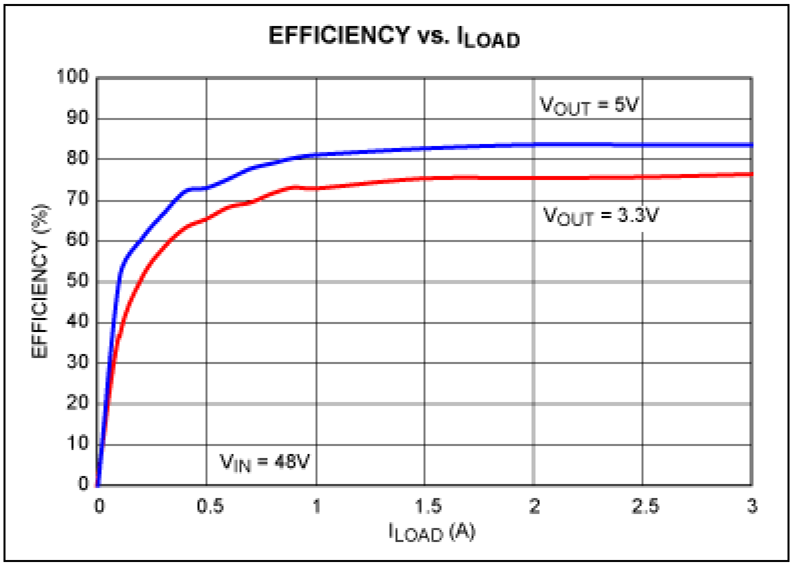

Figure 3. Efficiency vs. load current for the circuit in Figure 1.

Why Low-Voltage from -48V Systems Matters

To protect telephone wires from electrolytic corrosion, the first telephone-system exchanges employed a "central-battery" power supply whose polarity was negative with respect to ground (earth). And, to ensure good low-noise contacts in the relays used in those systems, the supply voltage (-48V) was made higher than that of most other battery-powered systems.

Since the early sixties, however, electronics systems have evolved in another direction. Driven by the dominance of npn bipolar transistors as the reigning active devices, almost all power supplies for today's analog and digital systems generate voltages that are positive with respect to the reference equipotential (ground).

Because the bulk of today's telecom power is distributed and used much as it was in the early days, the main power source is still -48V with a large battery backup. Telecom systems, on the other hand, are now totally electronic and require low-voltage positive power-supply lines. Thus, the generation of low-voltage positive power from -48V systems is a common requirement.

Conclusion

As we have seen, current-sense amplifiers and instrumentation amplifiers share some core traits, which can allow more inexpensive current-sense amplifiers to be used in place of expensive instrumentation amplifiers. We have described an alternative example circuit, comprised of a current-sense amplifier (MAX4080F) and a boost converter IC (MAX668). Amplifying signals with precision and delivering them at levels separated by a large voltage difference is not just of benefit to current sensing but also for a ground-referenced -48V to +5V power converter, such that is used in telecom systems.

Related Parts

MAX4080	76V, High-Side, Current-Sense Amplifiers with Voltage Output	Free Samples
MAX668	1.8V to 28V Input, PWM Step-Up Controllers in µMAX	Free Samples

More Information
For Technical Support: http://www.maximintegrated.com/support
For Samples: http://www.maximintegrated.com/samples
Other Questions and Comments: http://www.maximintegrated.com/contact

Application Note 4495: http://www.maximintegrated.com/an4495
APPLICATION NOTE 4495, AN4495, AN 4495, APP4495, Appnote4495, Appnote 4495