Compensate for Wire Drop to a Remote Load

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A common problem in power distribution systems is degradation of regulation due to the wire voltage drop between the regulator and the load. Any increase in wire resistance, cable length or load current increases the voltage drop over the distribution wire, increasing the difference between voltage at the load and the voltage programmed by the regulator. Remote sensing requires routing additional wires to the load. No extra wiring is required with the LT6110 cable/wire drop compensator. This article shows how the LT6110 can improve regulation by compensating for a wide range of regulator-to-load voltage drops.

THE LT6110 CABLE/WIRE COMPENSATOR

Figure 1 shows a 1-wire compensation block diagram. If the remote load circuit does not share the regulator's ground, two wires are required, one to the load and one ground return wire. The LT6110 high side amplifier senses the load current by measuring the voltage, V_{SENSE}, across the sense resistor, R_{SENSE}, and sinks a current, I_{IOUT}, proportional to the load current, I_{LOAD}. I_{IOUT} scale factor is programmable with the R_{IN} resistor from 10µA to 1mA. Wire voltage drop, V_{DROP}, compensation is accomplished by sinking I_{IOUT} through the R_{FA} feedback resistor to increase the regulator's output by an amount equal to V_{DROP}. An LT6110 cable/wire voltage drop compensation design is simple: set the $I_{IOUT} \bullet R_{FA}$ product equal to the maximum cable/wire voltage drop.

The LT6110 includes an internal 20mΩ R_{SENSE} suitable for load currents up to 3A; an external R_{SENSE} is required for I_{LOAD} greater than 3A. The external R_{SENSE} can be a sense resistor, the DC resistance of an inductor or a PCB trace resistor. In addition to the I_{IOUT} sink current, the LT6110 IMON pin provides a sourcing current, IMON, to compensate current-referenced linear regulators such as the LT3080.

COMPENSATING CABLE VOLTAGE DROPS FOR A BUCK REGULATOR

Figure 2 shows a complete cable/wire voltage drop compensation system consisting of a 3.3V, 5A buck regulator and an LT6110, which regulates the voltage of a remote load connected through 20 feet of 18 AWG copper wire. The buck regulator's 5A output requires the use of an external R_{SENSE}.

The maximum 5A I_{LOAD} through the 140mΩ wire resistance and 25mΩ R_{SENSE} creates an 825mV voltage drop. To regulate the load voltage, V_{LOAD}, for 0A ≤ I_{LOAD} ≤ 5A, $I_{IOUT} \bullet R_{FA}$ must equal 825mV. There are two design options: select I_{IOUT} and calculate the R_{FA} resistor,

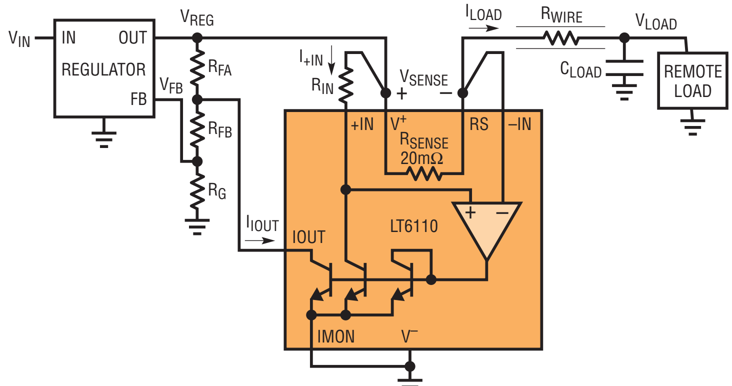

Figure 1. No extra wires are required to compensate for wire voltage drop to a remote load

For precise load regulation, an accurate estimate of the resistance between the power source and load is required. If R_{WIRE}, R_{SENSE} and the resistance of the cable connectors and PCB traces in series with the wire are accurately estimated, the LT6110 can compensate for a wide range of voltage drops to a high degree of precision.

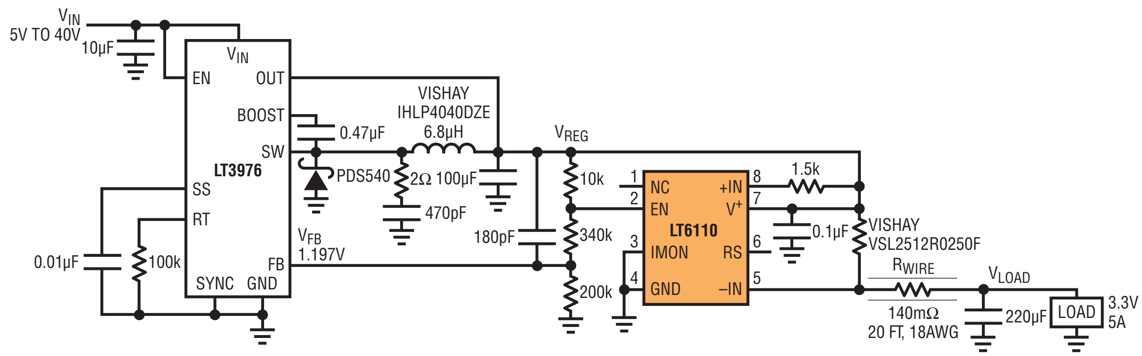

Figure 2. Example of a high current remote load regulation: a 3.3V, 5A buck regulator with LT6110 cable/wire voltage drop compensation

or design the regulator's feedback resistors for very low current and calculate the R_{IN} resistor to set I_{IOUT}. Typically I_{IOUT} is set to 100µA (the I_{IOUT} error is ±1% from 30µA to 300µA). In the Figure 2 circuit the feedback path current is 6µA (V_{FB}/200k), the R_{FA} resistor is 10k and the R_{IN} resistor must be calculated to set $I_{IOUT} \bullet R_{FA}$ = 825mV.

$$I_{IOUT} = V_{SENSE}/R_{IN}$$
$$I_{IOUT} \bullet R_{FA} = V_{DROP}$$

and

$$R_{IN} = R_{FA} \bullet \frac{R_{SENSE}}{R_{SENSE} \bullet R_{WIRE}}$$

so for R_{FA} = 10k, R_{SENSE} = 25mΩ and R_{WIRE} = 140mΩ, R_{IN} = 1.5k.

Without cable/wire drop compensation the maximum change in load voltage, ΔV_{LOAD}, is 700mV (5 • 140mΩ), or an error of 21.2% for a 3.3V output. The LT6110 reduces ΔV_{LOAD} to only 50mV at 25°C, or an error of 1.5%. This is an order of magnitude improvement in load regulation.

PRECISION LOAD REGULATION

A modest improvement in load regulation with the LT6110 only requires a moderately accurate R_{WIRE} estimation. The load regulation error is the product of two errors: error due to the wire/cable resistance and error due to the LT6110 compensation circuit. For example, using the Figure 2 circuit, even if the R_{SENSE} and R_{WIRE} calculation error is 25%, the LT6110 still reduces V_{LOAD} error to 6.25%.

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Using the LT6110, an accurate R_{WIRE} estimation and a precision R_{SENSE}, the ΔV_{LOAD} compensation error can be reduced to match the regulator's voltage error over any length of wire.

CONCLUSION

The LT6110 cable/wire voltage drop compensator improves the voltage regulation of remote loads, where high current, long cable runs and resistance would otherwise significantly affect regulation. Accurate regulation can be achieved without adding sense wires, buying Kelvin resistors, using more copper or implementing point-of-load regulators—common drawbacks of other solutions. In contrast, compensator solutions require little space while minimizing design complexity and component costs. ■