

Intel® Enpirion® Power Solutions

Implementing Current Sense Using Intel® Enpirion® Power Solutions

Application Note

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1. Introduction

In many applications, the desire to conserve power and optimize performance has driven the necessity to accurately monitor voltage and current. The amount of power consumed can be calculated from these measurements.

Voltage monitoring is typically straightforward since the voltage can be measured at the output of the regulator or directly at the load. A sense resistor is typically used to measure the current which must be placed in series with the output, changing the circuit and possibly affecting performance.

This application note discusses the correct placement of the sense resistor, design trade-offs, and an implementation for the best performance and flexibility of the design.

2. Typical Circuit Implementation

Figure 1 shows a simplified Intel® Enpirion® PowerSoC. The typical circuit consists of more parts but only the critical components will be considered here. The critical components noted are feedback resistors, (R_A , R_B) input (C_{IN}) output, output capacitor (C_{OUT}), and the compensation components (C_A and R_{CA}).

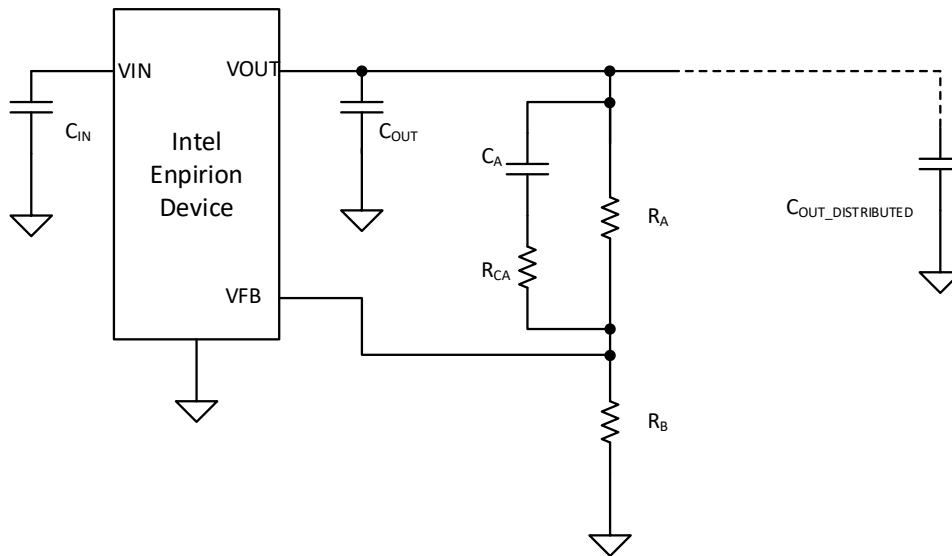


Figure 1: Typical Implementation of the Intel Enpirion PowerSoC

3. Current Sense Circuit Implementation

To measure current, a known low value resistor needs to be connected in series with output terminal of a regulator. This way a current is converted to voltage and then the value of current can be calculated by dividing this measured voltage by the sense resistor value. To minimize the voltage drop and heat dissipation, a low value (1-10 mΩ) resistor should be used (R_{sense}). It is also important to use a precise resistor with low temperature coefficients to make sure the measurement error is minimized. A low voltage is created across the resistor, which may then be amplified¹ before it is measured by an analog-to-digital converter (ADC) or system monitor, such as Intel MAX® 10 FPGAs (with internal ADC). A typical current sense circuit is represented in Figure 2.

¹ A commonly available part is the INA210. Consult the datasheet for specific application information.

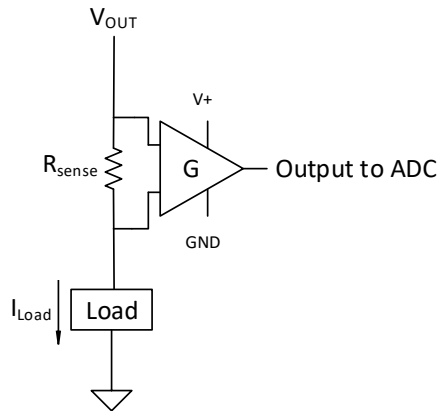


Figure 2: A Typical Current Sense Circuit with Amplification.

$$I_{\text{Load}} = 6 \text{ A}$$

$$R_{\text{sense}} = 10 \text{ m}\Omega$$

$$V_{\text{drop}} = I_{\text{Load}} \times R_{\text{sense}}$$

$$= 6 \text{ A} \times 10 \text{ m}\Omega = 0.06 \text{ V}$$

$$= 60 \text{ mV}$$

$$P_D = I^2 R$$

$$= (6)^2 \times 10 \text{ m}\Omega = 0.36 \text{ W}$$

For the 10 mΩ resistor chosen, it will provide 10 mV / A conversion and dissipate 0.36 W, requiring a 0.5 W or 1 W rated part. At full load of 6 A the maximum sensed voltage will be only 60 mV, may require amplification to be measured accurately by an ADC. A gain (G) of approximately 30 would amplify the signal to 1.8 V, suitable for measurement with an ADC.

It should also be noted that the addition of the series resistor will also introduce a voltage drop of 60 mV. This means that the voltage measured at output will be 60 mV lower than expected. For a 0.90 V core supply of an FPGA, this introduces an error of 6.7%. Typical maximum allowable error is 5% or less. Furthermore, this error depends on the amount of current passing through the resistor. This is a

significant error that needs to be compensated for; the following sections describe a method to compensate for this error while maintaining the performance of the PowerSoC.

4. PowerSoC Current Measurement

As previously discussed, the insertion of the sense resistor, R_{sense} into the current path causes a voltage drop affecting the accuracy of the output voltage. Figure 3 shows two possible options, “A” and “B” for the placement of the sense resistor. Only one of the resistors needs to be placed and there are advantages of choosing one over the other.

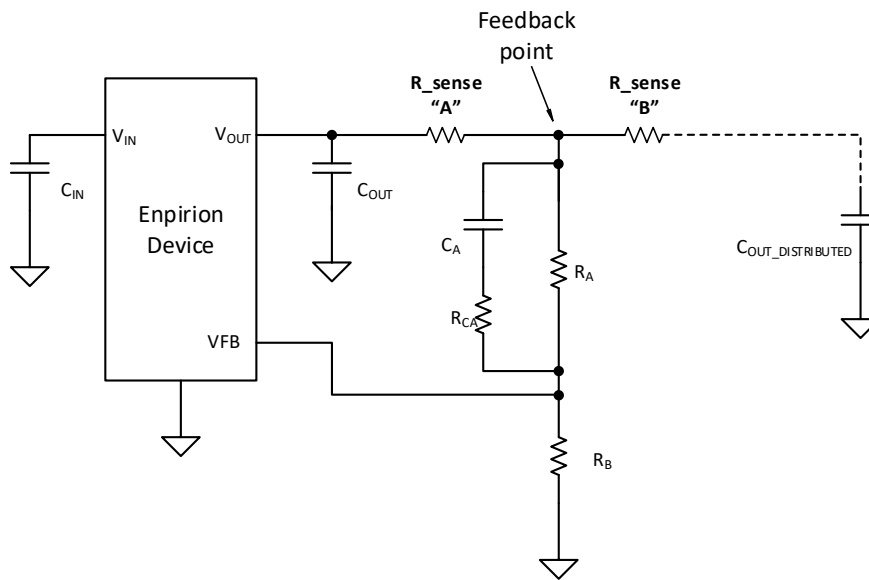


Figure 3: Inserting the Current Sense Resistor into the Circuit.

By placing R_{sense} in position “B” in Figure 3, the load will always see a voltage less than the power supply, introducing an error. To compensate for this error, R_{sense} is placed *inside* the control loop, close to C_{OUT} —the feedback point is taken after the resistor. In this configuration, the voltage drop is compensated for by the feedback path. Talking in general the feedback sense point should be closer to V_{OUT} of the point of load voltage regulators that does not have differential sense capability.



The sense resistor should be placed in the output path, *after* the output capacitance (C_{OUT}) of the power supply, close to the voltage regulator. The kelvin sense technique for the sense resistor connection should be used while routing the sense traces on a PCB.

5. Practical Implementation

Introducing the sense resistor R_{sense} can impact the performance of the PowerSoC, affecting the stability. For this reason, the stability should be measured using appropriate techniques and equipment. To account for measuring the stability in-circuit, the schematic shown in Figure 4 is recommended.

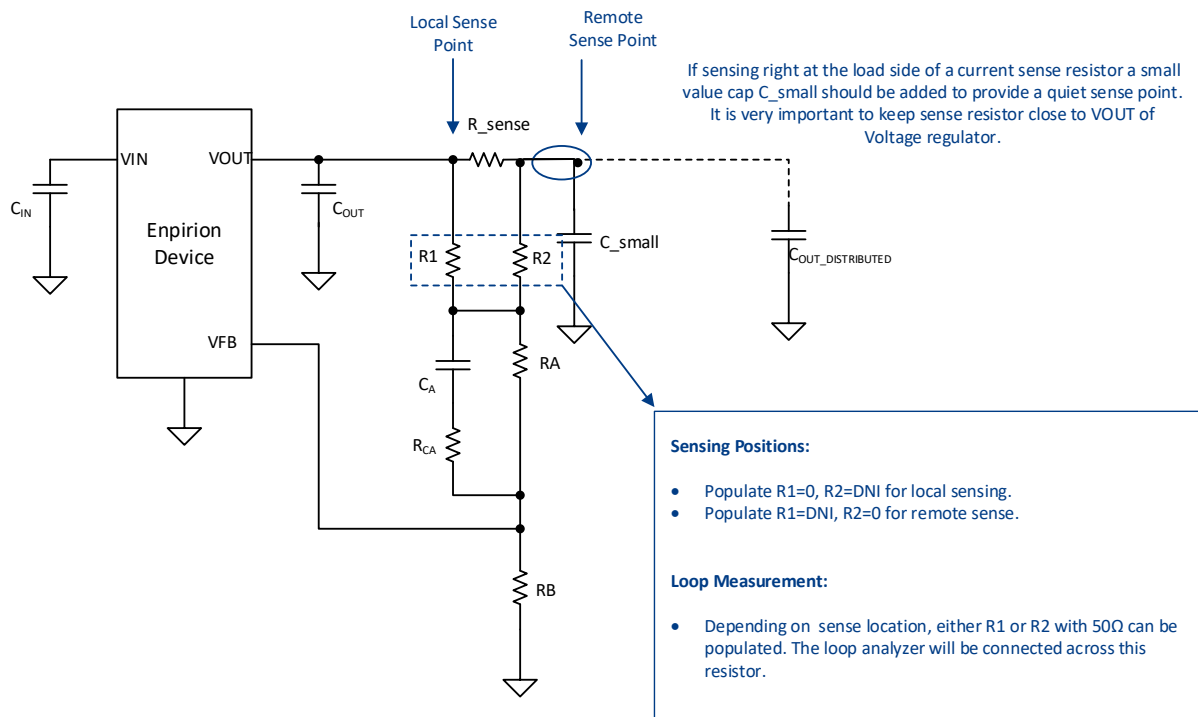


Figure 4: A Practical Implementation of Current Measurement.

In Figure 4, additional considerations are made to ensure that measurements can be made, and the circuit can be adjusted. For normal operation, populate $R1$ (0Ω) and leave $R2$ open (unpopulated). For a compensated output, leave $R1$ open (unpopulated) and insert $R2$ (0Ω).

The addition of the small filter capacitor (100 pF – 0.1 μ F), C_small helps to get rid of any measurement noise.

At a minimum, it is recommended to include R1 and R2 to assist with testing and characterization of the power supply.

For performing a loop stability measurement, the 0 Ω resistor should be replaced with a 50 Ω resistor as shown in Figure 5. To perform the actual loop stability measurements, refer to the manufacturer's gain-phase analyzer equipment documentation details on how to perform the loop stability measurements. Figure 5 outlines the basic setup to do the loop stability measurement.

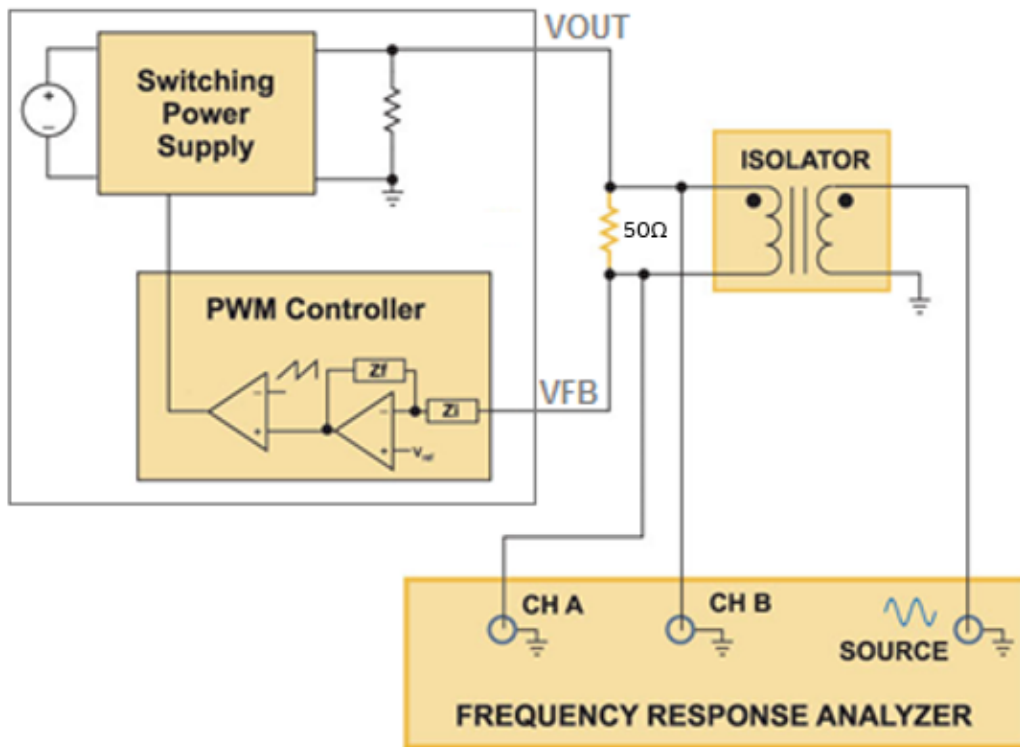


Figure 5: Loop Measurement Connection Details.



6. Conclusion

Intel Enpirion-integrated PowerSoC modules provide a fast and easy means to power devices over a wide varying range of output currents. Using the standard schematic and layout guidelines, minor modifications can be made to allow for accurate current measurements while maintaining accuracy, dynamic response, and EMI performance.



7.Revision History

Revision Number	Description	Revision Date
001	Initial release.	December 2018