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AND9685/D

eFuse Load Current Measurement

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APPLICATION NOTE

Introduction

The On Semiconductor eFuse protection devices are primarily used for limiting the system load current in the event of overload or short circuit conditions. Almost all of those eFuse protection devices provide additional features such as soft start, output voltage clamp, reverse current protection, adjustable load current limit with external resistor and so on. Some of the eFuses provide additional feature of load current monitoring which is implemented as a voltage output through an IMON pin. The user can measure the voltage at the IMON pin which would be proportional to the load current.

This application note describes the load current measurement solution for the eFuses which do not provide load current monitoring feature. Since almost all of the eFuses provide adjustable current limit functionality by utilizing an external current limiting resistor between I_{LIMIT} and Source pins, it is possible to connect a current sense amplifier across that resistor and measure the voltage drop across it which would be proportional to the load current. This method mainly requires a current sense amplifier and allows user to measure the system load current without introducing any additional resistance in series with the load path.

Schematics

A typical schematics of an eFuse configuration together with the 20 Ω RLIMIT resistor used for load current limit programming is shown in Figure 1. The load current measurement circuit implementation is shown within a dashed rectangle. Only current sense amplifier with a decoupling capacitor is required.

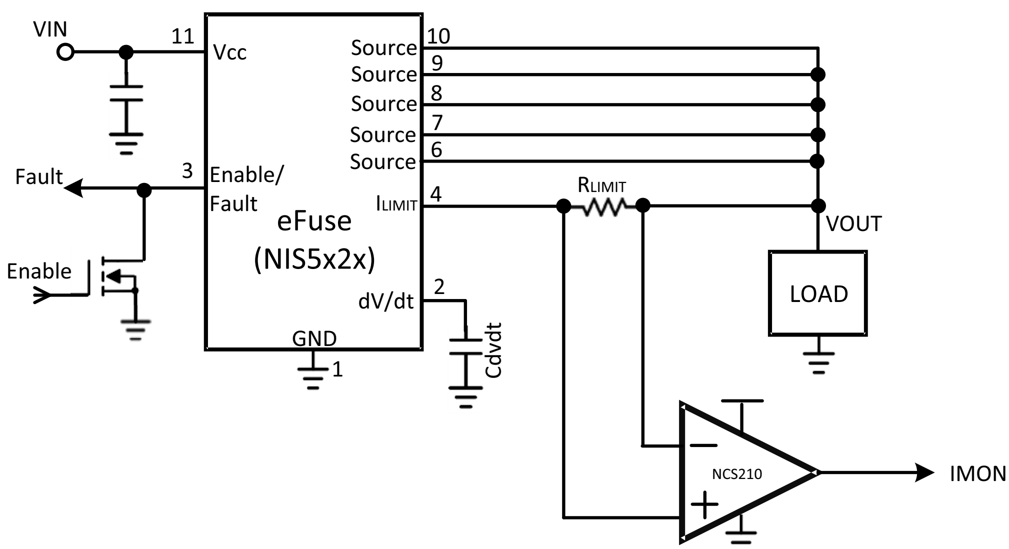

Figure 1. 12 V eFuse Configuration with Load Current Measurement Circuit

One of the most important parameters to consider when selecting a current sense amplifier are: wide common mode range, low offset voltage, low gain error, rail−to−rail input and output and a wide input supply range which exceeds the supply range of the eFuse input and output voltage.

Typical current sense or current shunt amplifiers also have integrated gain and feedback resistors. It is important to utilize such a current sense amplifier where those integrated resistors have much higher resistance than the resistance of the external RLIMIT current programming resistor. The schematics in Figure. 1 shows a 12 V eFuse together with the NCS210 rail−to−rail current sense amplifier with a gain of 200, ±60 μV offset voltage, 1% gain error and supply range up to 26 V.

The Source output pin of the eFuse will be at a lower voltage potential than the VCC input pin due to a small voltage drop across the eFuse input and output pins. The I_{LIMIT} pin also has a lower voltage potential than the VCC pin, but slightly higher voltage potential than Source pins. The higher the load current, the higher the voltage drop across the RLIMIT resistor. This voltage drop will be amplified by a current sense amplifier and used as a measure of load current. It is important to connect the positive input of the current sense amplifier to the I_{LIMIT} pin and negative input to Source pins of the eFuse. The Reference pin of the current sense amplifier should be connected to ground. It is also recommended to use a 1% accuracy RLIMIT resistor.

The output of the current sense amplifier can easily drive high impedance, low capacitance load such as an ADC or measurement equipment. If a low impedance or high capacitance load needs to be driven it is recommended to use additional buffer amplifier with a high slew rate after the current sense amplifier. If the output of current sense amplifier is fed to ADC for digitizing, it would be reasonable to connect a shunt Zener diode at the output of the current sense amplifier in order to limit its output voltage during the eFuse current overload events in order to protect ADC input.

Layout

Typical current sense amplifiers usually come in a small packages such as SOT−363 or UQFN10. It is important to place a current sense amplifier close to the RLIMIT resistor and decoupling capacitor close to the supply rail of current sense amplifier. Use value of 0.1 μF and thick traces for decoupling capacitor. The traces connecting current sense amplifier with RLIMIT resistor should not be close to any traces carrying fast switching signals.

Refer to Figure 2 for an example layout configuration when using current sense amplifier to measure the eFuse load current. The decoupling capacitor is connected close to the current sense amplifier supply pins. The input positive and negative terminals of current sense amplifier are connected to the R_{LIMIT} resistor with minimal routing. The R_{LIMIT} resistor is also connected to output node and I_{LIMIT} pin of eFuse with minimal routing. Overall solution is no larger than a 4x4 mm footprint of NIS5021.

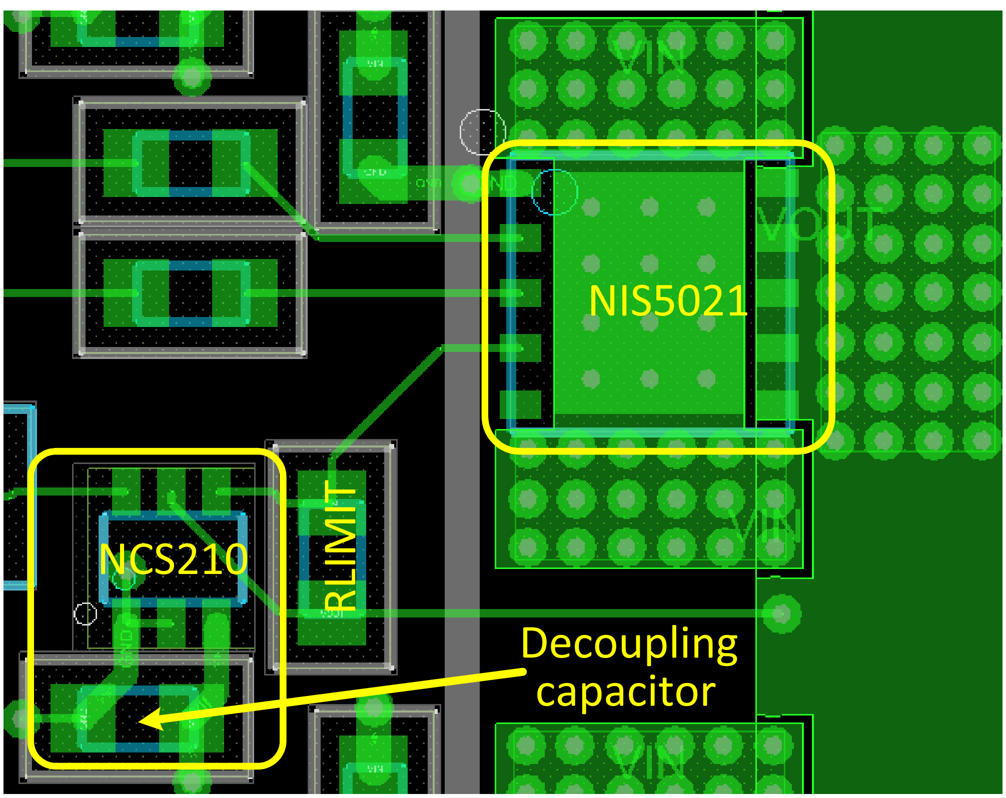

Figure 2. Example PCB Layout for the Load Current Sense Solution

Performance

The typical voltage drop across RLIMIT resistor versus load current for one of the ON Semiconductor 12V NIS5x2x eFuses is shown in Figure 3. For every 1 Amp of load current there is approximately 7.5 mV voltage drop across 20 Ω RLIMIT resistor, this voltage drop will depend on the value of the resistor and eFuse type, since every family of eFuse has its own proportion between the main load current and the current flowing across the RLIMIT resistor.

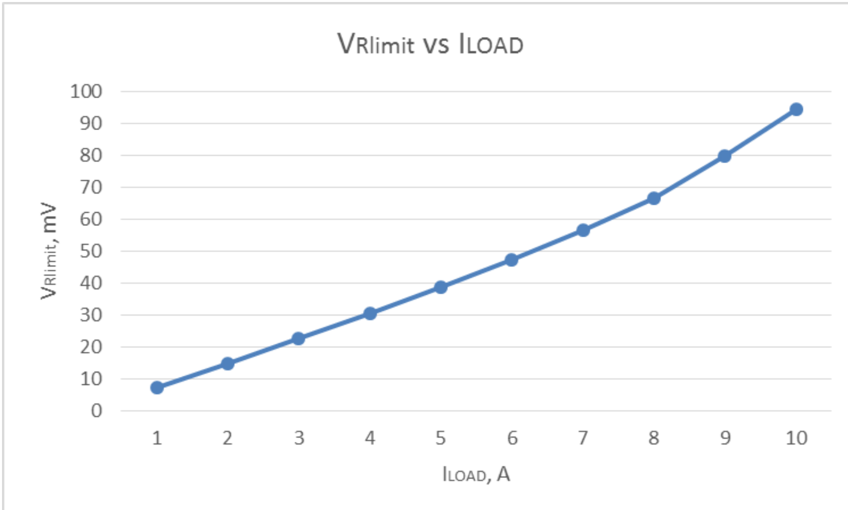

Figure 3. Voltage drop across R_{LIMIT} versus the load current

The Figure 4 shows a schematics of two NIS5x2x eFuses connected in parallel.

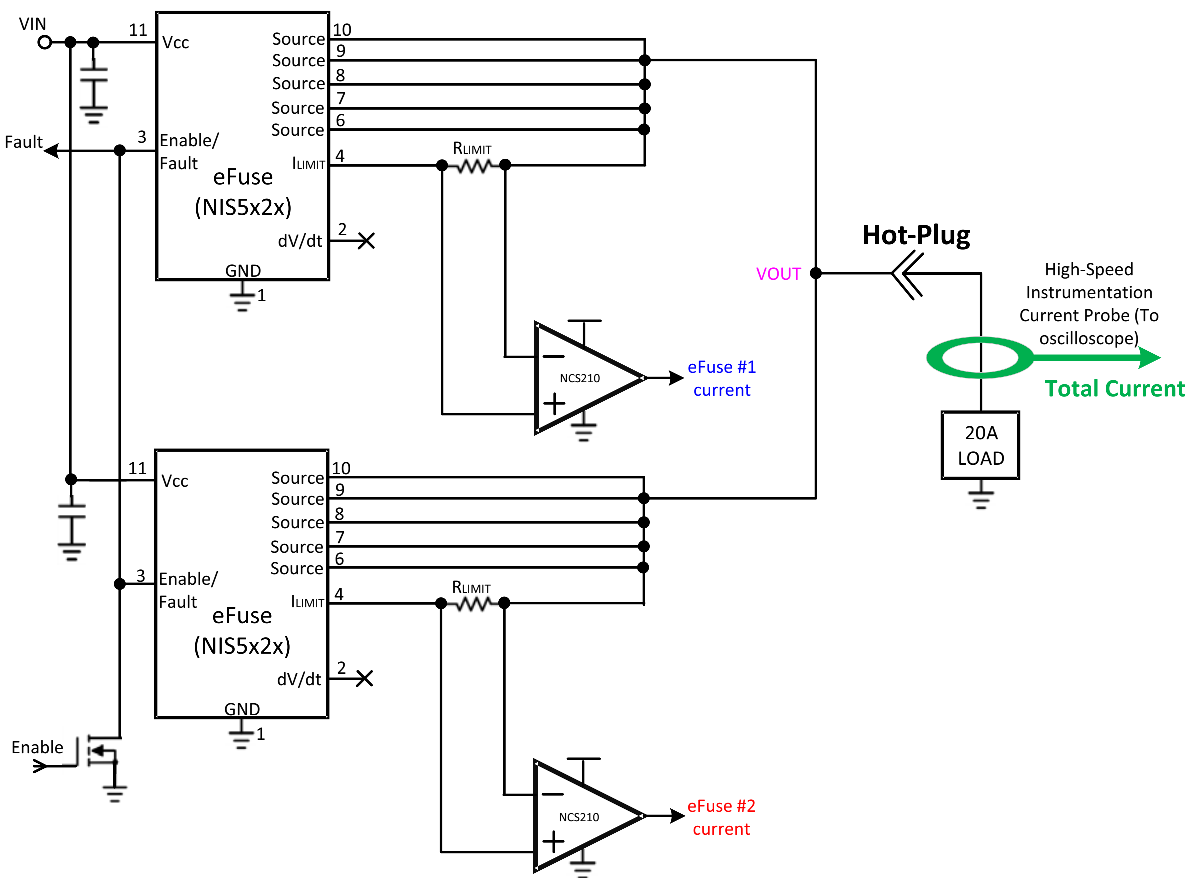

Figure 4. Parallel configuration of two NIS5x2x eFuses with individual load current monitoring

The Figure 5 shows the measurement error versus load current for the 12 V NIS5x2x eFuse. In this case one can achieve around 90% accuracy for most of the eFuse continuous current capability. The measurement accuracy would drop another 10−12% if the eFuse is operated at the maximum current rating.

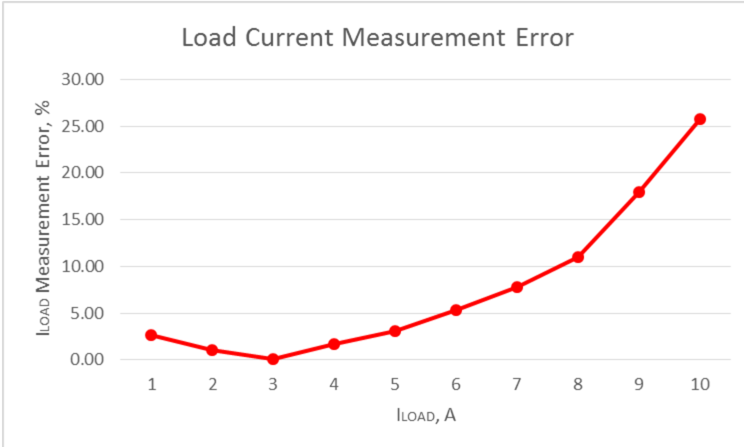

Figure 5. Load current measurement error vs Load Current

The Figure 6 shows a scope screenshot of a 20 A load hot plugged to the outputs of two NIS5x2x 12 V eFuses connected in parallel. Each eFuse in that configuration utilized a current sense amplifier across the RLIMIT resistor, the output of each current sense amplifier is connected to a scope and plotted as a red and blue traces. The purple trace shows the common connected VOUT voltage of two eFuses and the green trace shows the overall total current measured with instrumentation grade high−speed current probe. In this configuration a current sense amplifier similar to NCS210 but with a gain of 50 was used.

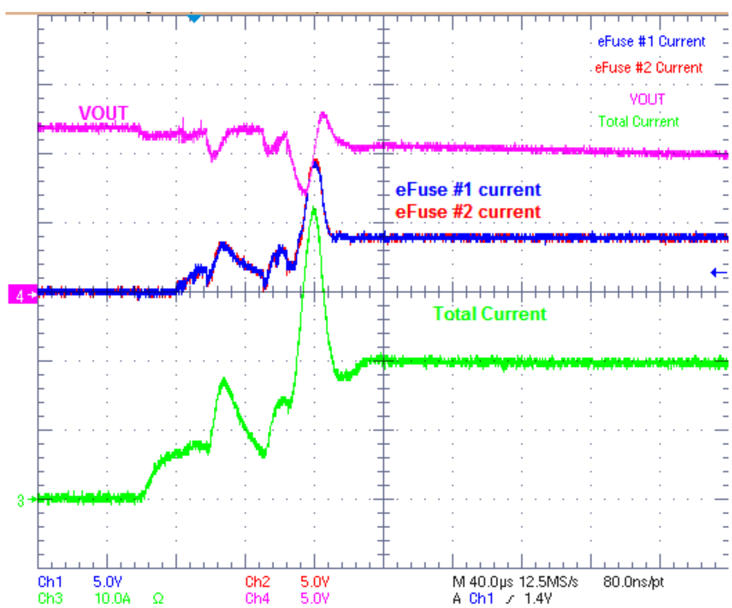

Figure 6. Hot plug to 20 A load and eFuse load current measurement

Once the hot plug event is gone the total current measured by an instrumentation current probe is settled to 20 A. Since the current is equally shared by eFuses connected in parallel, each eFuse in this case carries around 10 A current. From Figure 3, the voltage drop across 20 Ω RLIMIT resistor for this eFuse at 10 A load is around 94.3 mV, since we are using a current sense amplifier with a gain of 50, we see a voltage of around 94.3 mV x 50 = 4.7 V at the outputs of both current sense amplifiers as shown in red and blue traces in Figure 6.

The current is also perfectly shared among eFuses during a fast output load hot−plug event and properly measured by current sense amplifiers as seen from the scope shot in Figure 6, this can be achieved if current sense amplifiers are fast enough and provide 25−40 kHz 3dB bandwidth.

Conclusion

This application note demonstrated a cheap and effective way of adding a load current measurement solution to current limiting electronic fuses. The solution requires only one active device in a compact SOT−363 or UQFN10 package and minimum supporting passive components for it, such as decoupling capacitor. This solution provides measured load current not only in a static configuration but also during dynamic events.

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