Application Note

Controlling Inrush Current with Slew Rate Control using Renesas Load Switches

AN-CM-226

Abstract

This application note describes the benefits of controlling inrush current with slew rate control using Renesas load switches.

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Terms and Definitions

MOSFET	metal-oxide-semiconductor field-effect transistor
RF	radio frequency

1 References

[1] SLG59M1717V, Datasheet, Renesas Electronics

2 Introduction

Electronic products often utilize high side P-channel MOSFET's to manage power usage by turning on and off power to sections of circuitry. For example, in a battery powered RF device, an RF power amplifier and associated circuitry would be energized only when transmitting RF energy. As a result of controlling power to sections of circuitry, inrush currents will occur when the circuitry is energized. Left unchecked, inrush current can detrimentally affect the quality, reliability and performance of electronic products by causing voltage transients at the output of battery systems, switching and linear regulators. Low power products such as battery powered devices typically have low quiescent current linear voltage regulators that can be negatively affected by inrush currents due to their low regulation bandwidth. The output voltage of lithium battery systems can also be negatively affected by inrush currents due to their varying output resistance and possible passivation. Lower temperatures can exacerbate this effect even more due to the increased output resistance. These unwanted effects can cause erratic product behaviors such as micro-controller resets, perturbation of oscillators, and negative effects on analog and digital circuitry. The use of Renesas load switches will control the inrush currents by design thus avoiding the negative effects associated with these inrush currents.

3 Inrush Currents

Inrush currents are caused when capacitors are charged during initial application of voltage. The slew rate of the voltage being applied to the capacitance and the value of the capacitance will determine the inrush current as follows:

The inrush current can be expressed as $I_{INRUSH} = C_{LOAD} \times \frac{dv}{dt}$ where C_{LOAD} is the circuit capacitance being charged, and $\frac{dv}{dt}$ is the rate of change of the voltage being applied. Thus as an example, if the capacitance value equals 10 µF and the rise time of the voltage being applied is 5 V/µs, then the inrush current equals $10 \times 10^{-6} \times \frac{5}{10^{-6}}$ = 50 amps.

4 Enhanced Product Quality due to Inrush Current Control

Unchecked large inrush currents can negatively affect the quality of electronic products. Inrush currents will vary from product to product due to varying component characteristics, aging, and temperature variations. If inrush currents are not controlled by design, then it is possible a percentage of shipped products will be problematic, resulting in field returns and unwanted associated costs. The steps necessary to control inrush current involve circuitry that controls the slew rate of the voltage being applied to sections of circuitry being energized. Renesas load switch parts incorporate circuitry that provide a programmable slew rate. For example, if the slew rate is programmed to a value of 1 V/ms, then the resulting inrush current for a capacitor with a value of 10 µF would be $10 \times 10^{-6} \times \frac{\mathbf{1}}{\mathbf{10^{-3}}}$ = 0.01 amps or 10 mA.

Below is an oscilloscope image showing the transient inrush current (yellow trace-2 A/div) without the use of slew rate control. Note the resulting 0.7 V voltage dip (blue trace1 V/div) at the power source which in this case is a lithium battery system (3.6 V). The peak inrush current is 9.2 amps. The high side switch was implemented with a P-channel MOSFET as the series pass element. This is a very common method used for implementation of a high side load switch that controls the power of sections of circuitry. The white trace-2 V/div is the voltage being applied to the load which consists of a 15 µF capacitor.

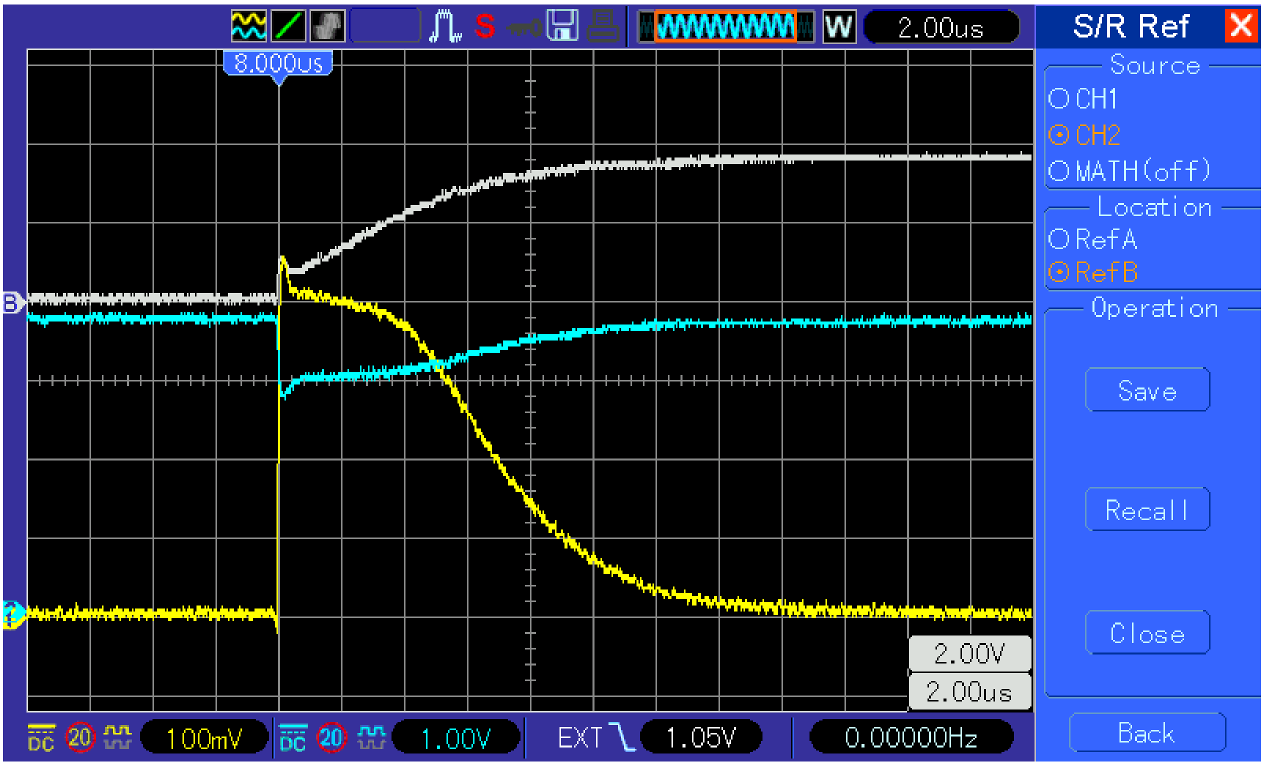

Figure 1: No Slew Rate Control

C_{LOAD} =15 µF, V_{IN} = 3.6 V, R_{LOAD}= no load

5 Control Inrush Current with Renesas Load Switch Parts

Renesas high side load switch solutions utilize a programmable controlled slew rate when the switch is enabled. The use of a controlled slew rate on a high side switch will substantially reduce the inrush currents that are a result of energizing sections of circuitry that utilize bulk and decoupling capacitors. Controlling these inrush currents by design will eliminate the negative effects of these large unwanted transient currents.

Below is an oscilloscope image showing the transient inrush current with the use of slew rate control. The peak current (blue trace-5 mA/div) is a constant 10 mA. The high side switch is a SLG59M1717V GreenFET load switch. As compared to the above example which shows a peak inrush current of 9.2 A, the 10 mA achieved with the use of the SLG59M1717V part will cause far less perturbation to the power system. Note the voltage ramp (yellow trace-1 V/div) being generated by the RenesasSLG59M1717V GreenFET load switch. The white trace is the battery voltage (AC coupled-10 mv/div) showing only a 5 mV dip.

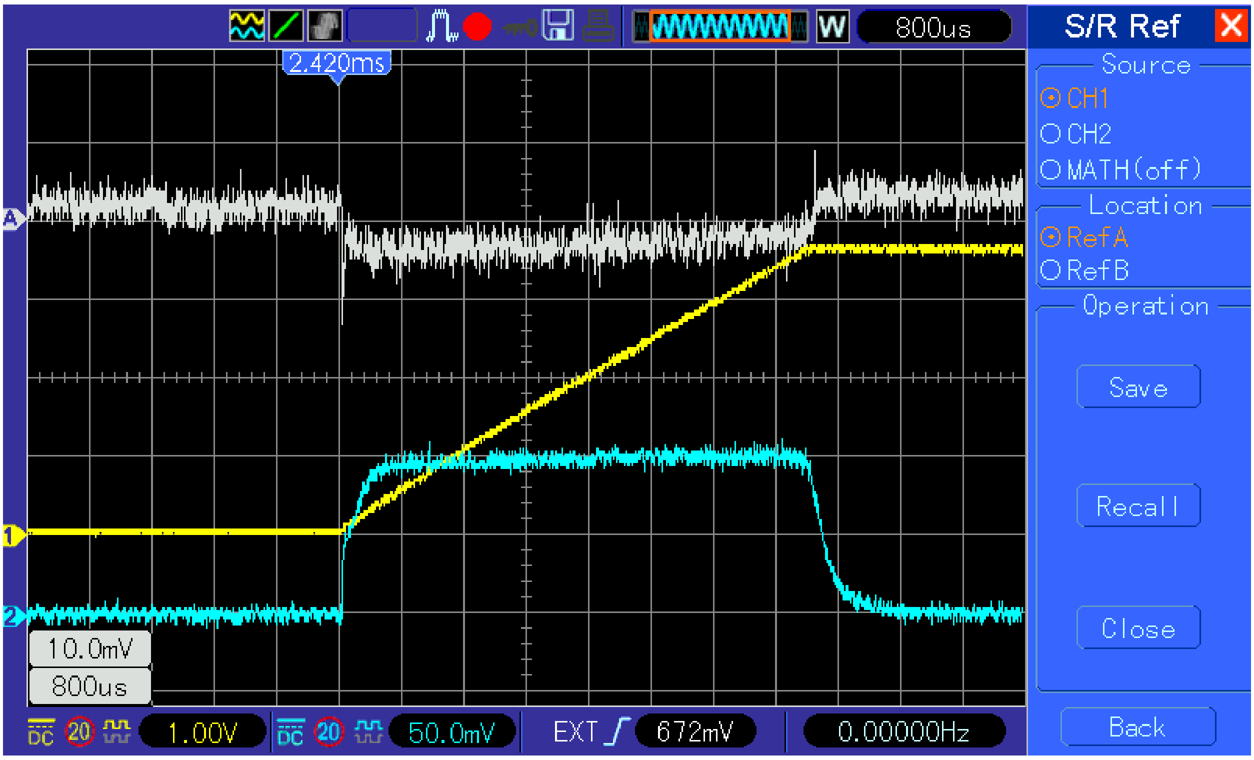

Figure 2: Slew Rate Control Implemented

SLG59M1717V evaluation board, C_{SLEW} = 22 nF, C_{LOAD}=15 µF, V_{DD} = V_{IN} = 3.6 V, R_{LOAD} = no load

6 Test and Measurement Setup and Schematic

The following is the schematic of the two test setups utilized to obtain data. Circuit A was used to measure inrush current without slew rate control. Circuit B was used to measure inrush current with slew rate control using the Renesas SLG59M1717V evaluation board.

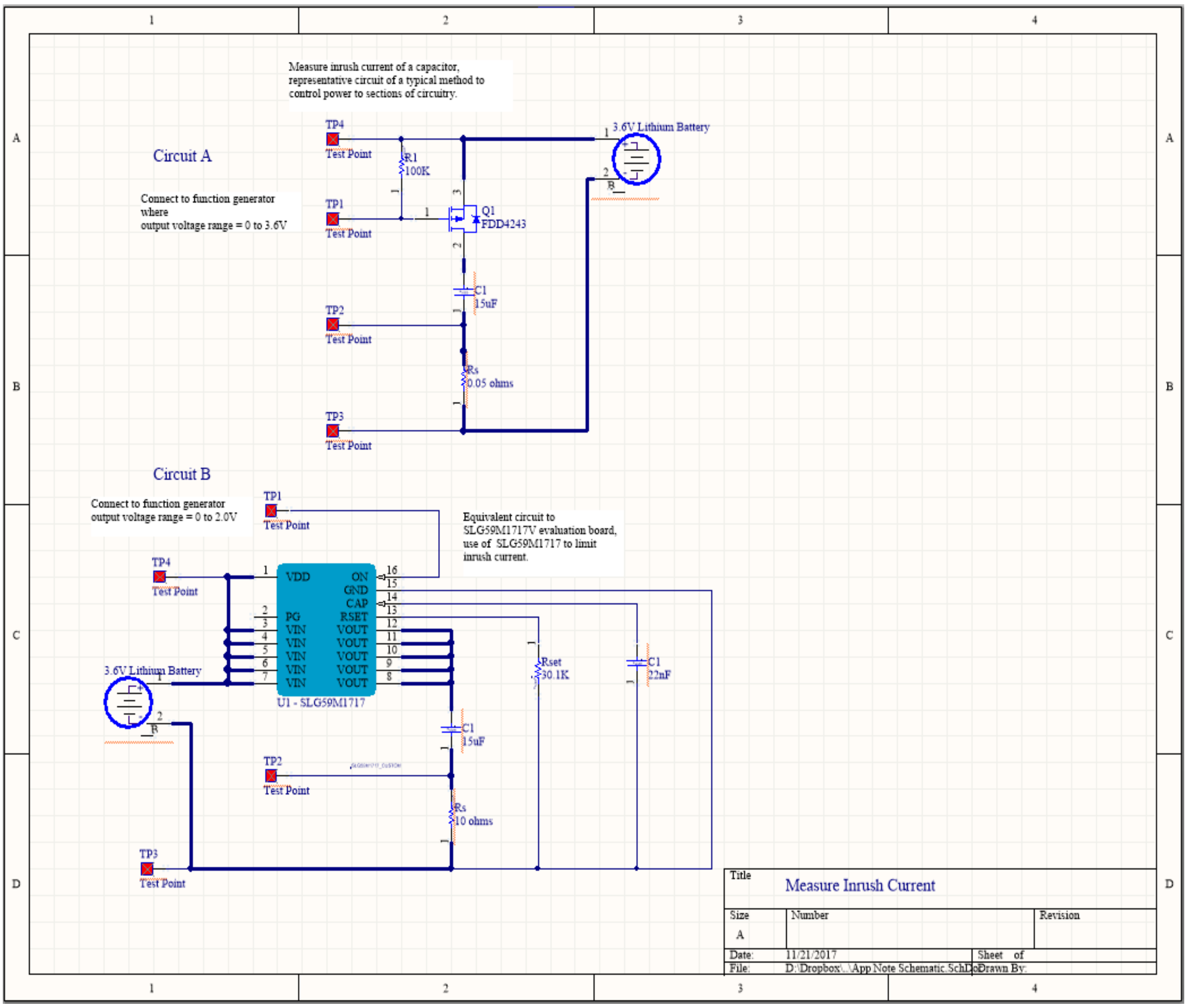

Figure 3: The Schematic of The Two Test Setups Utilized To Obtain Data

6.1 Theory of Operation (Circuit A)

The function of Circuit A is to measure inrush current into C1. The value of C1 was chosen to be 15 µF. The use of a P-Channel MOSFET is typical for controlling the power to sections of circuitry. Rs is utilized to convert the inrush current to a voltage that can be measured with an oscilloscope. The inrush current is expected to be in the 10 A and more range, thus the reason for choosing a resistor value of 50 mΩ. The voltage value will be 50 mV per amp. There are considerations when measuring large inrush currents. A low side measurement technique was used so both inrush current and battery voltage can be measured simultaneously with a common ground and displayed on a 2-channel oscilloscope. To minimize wire resistance and resulting voltage drop errors caused by the large inrush current, large diameter wires and component leads were used as shown in bold on the schematic.

TP2 and TP3 are used to connect the voltage across Rs to the channel of an oscilloscope. Use a 10X probe. TP3 is the common ground. The battery voltage is measured at TP4 with a 10X probe.

TP1 is the connection point for the output of a function generator. The function generator waveform should be set to pulse, with the amplitude high voltage set to 3.6 V and the low voltage set to 0 V.

6.2 Theory of Operation (Circuit B)

Circuit B was used to measure inrush current into C1 with slew rate control using the Renesas SLG59M1717V evaluation board. The value of C1 was chosen to be 15 µF. Rs is utilized to convert the inrush current to a voltage that can be measured with an oscilloscope. The inrush current is expected to be in the 10 mA range, thus the reason for choosing a resistor value of 10 ohms. The voltage value will be 10 mV / mA.

TP2 and TP3 are used to connect the voltage across Rs to the channel of an oscilloscope. Use a 10X probe. TP3 is the common ground. Set the probe BW to 20 MHz. The battery voltage is measured with a 10X probe by placing the probe directly on TP4.

TP1 is the connection point for the output of a function generator. The function generator mode should be pulse, with the amplitude set to 2 V.

7 Results

Renesas high side load switch solutions utilize a programmable controlled slew rate when the switch is enabled. The use of a controlled slew rate on a high side switch will substantially reduce the inrush currents that are a result of energizing sections of circuitry that utilize bulk and decoupling capacitors. Controlling these inrush currents by design will eliminate the negative effects of these large unwanted transient currents.

8 Conclusion

Inrush currents can potentially degrade the quality and performance of electronic products. Without inrush current control by design, unwanted voltage dips, transients and perturbations can occur on the output of battery systems and linear and switching power supplies. The use of Renesas load switches with slew rate control will improve the quality, performance and reliability of electronic products

Revision History

Revision	Date	Description
1.0	05-Mar-2018	Initial version

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