Application Note

Extending the GreenFET Load Switch Maximum Operating Current

AN-CM-272

Abstract

This application note describes how to extend the maximum operating current range of the GreenFET load switches while preserving all protection features. Corresponding oscilloscope captures of operational behavior are included.

Contents

Figures

1 Terms and Definitions

ACL Active Current Limit
SOA Safe Operation Area
PCB Printed Circuit Board

2 References

[1] SLG59H1006V, Datasheet
[2] SLG59M1714V, Datasheet
[3] SLG59M1568V, Datasheet
[4] AN-1068, GreenFET and High Voltage GreenFET Load Switch Basics, Application Note

3 Introduction

Some applications require a load switch to control high drive currents. One way to address this application requirement is to select a load switch with a higher current handling capability at least 20% higher than the usage scenario's maximum steady-state requirement. However, if such a product exists, the solution may very well occupy a larger PCB area, may consume more power, and may be quite expensive. Another option is to use two, lower-IDS-rated, lower-priced GreenFET load switches in parallel. An immediate benefit in using two GreenFET load switches in parallel is a smaller overall RDS_{ON} while maintaining low supply current consumption when both GreenFET load switches are ON. Renesas's proprietary MOSFET design and driver IP has the distinct advantage of very low part-to-part RDS_{ON} variation and thus current sharing between two GreenFET load switches in parallel is very well balanced.

4 Using a Pair of SLG59H1006Vs in Parallel

One of the GreenFET load switches that can be connected in parallel is the HFET1 line of 13.2- and 25.2-V GreenFET load switches. As an example, a pair of SLG59H1006Vs will be illustrated with its corresponding application circuit shown in Figure 1. The SLG59H1006V is a high-performance, self-powered 13.1 mΩ NMOS load switch designed for all 4.5 V to 22 V power rails up to 5 A. Using a proprietary MOSFET design, the SLG59H1006V achieves a stable 13.1 mΩ RDS_{ON} across a wide input voltage range. In combining novel FET design and copper pillar interconnects, the SLG59H1006V package also exhibits a low thermal resistance for high-current operation.

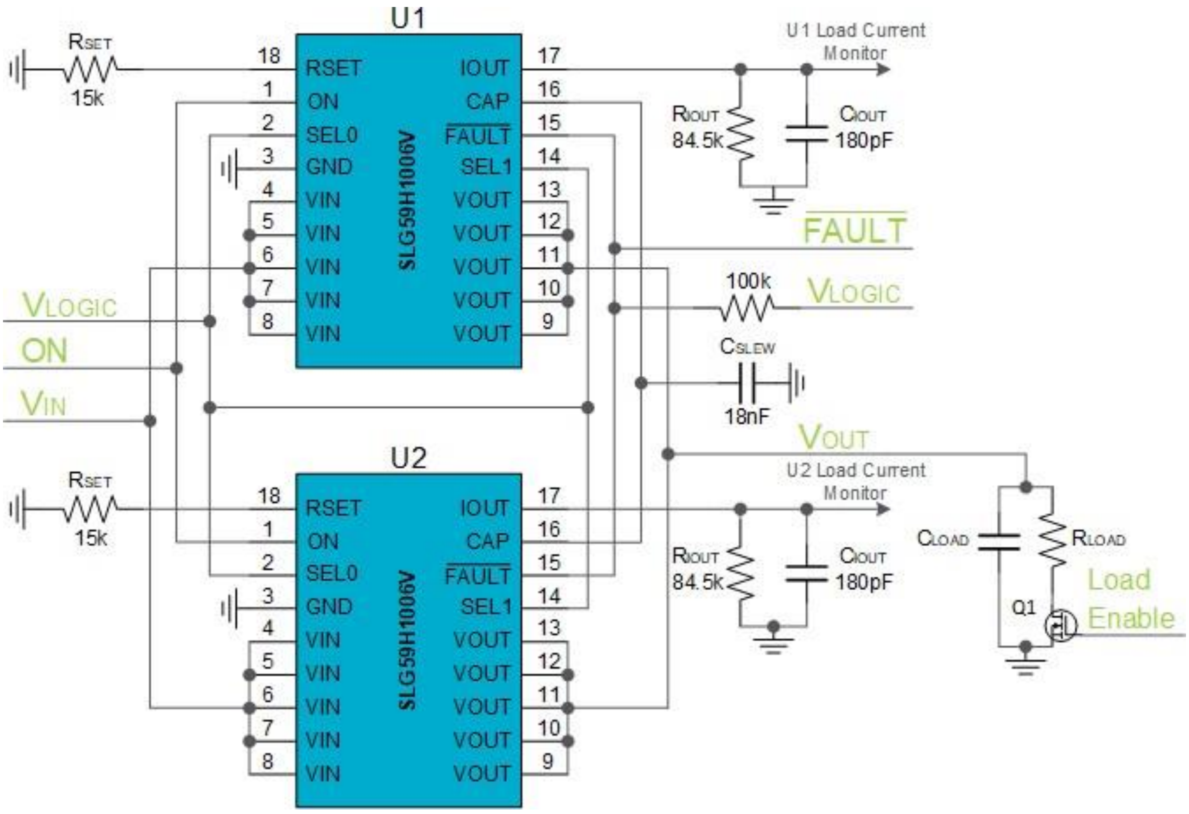

Figure 1: Application Diagram of using a pair of SLG59H1006Vs in parallel

Typical operational waveforms of this parallel GreenFET load switch solution are illustrated in Figure 2 through Figure 7.

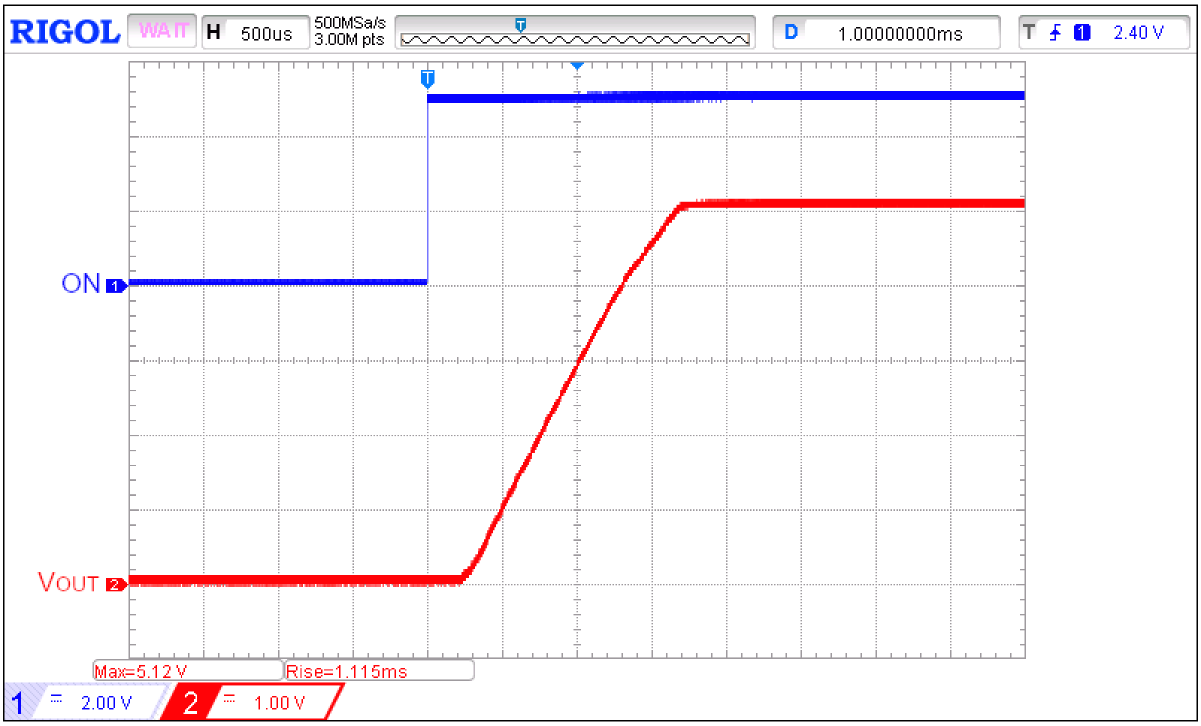

Figure 2: Two SLG59H1006Vs Operating in Parallel: Turn ON Operation; V_{LOGIC} = 5 V, V_{IN} = 5 V, C_{SLEW} = 18 nF, R_{LOAD} = 100 Ω, C_{LOAD} = 10 µF, Load Enable = HIGH

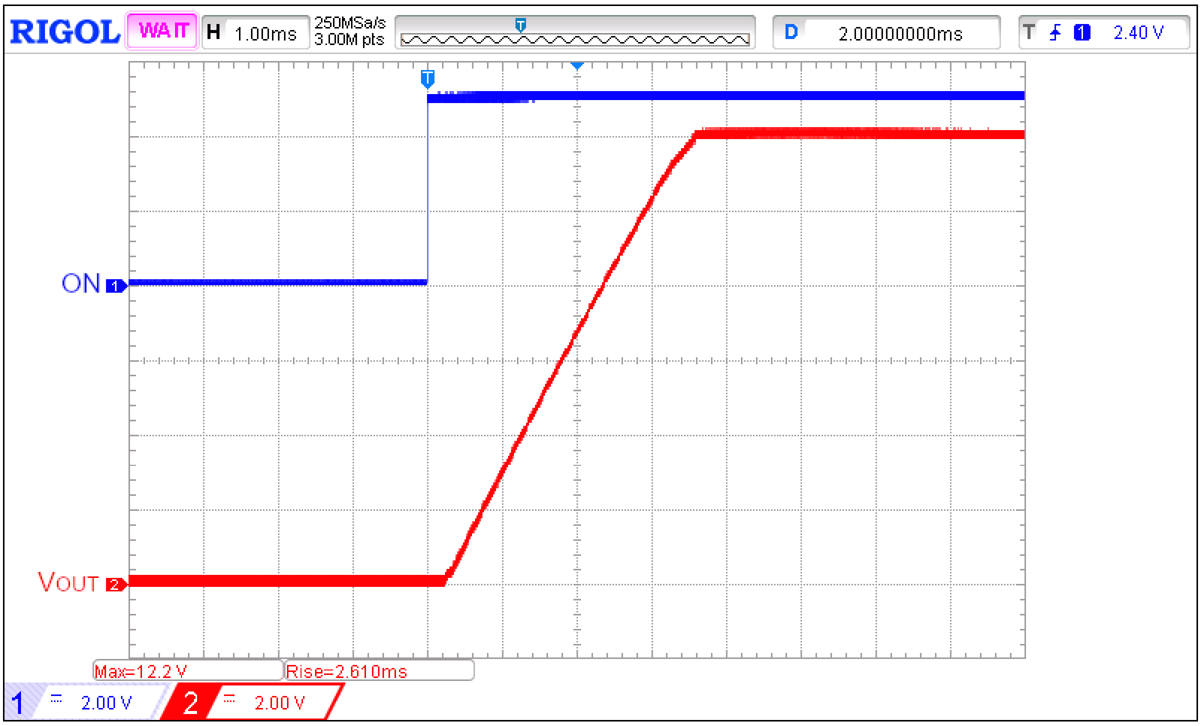

Figure 3: Two SLG59H1006Vs Operating in Parallel: Turn ON Operation; V_{LOGIC} = 5 V, V_{IN} = 12 V, C_{SLEW} = 18 nF, R_{LOAD} = 100 Ω, C_{LOAD} = 10 µF, Load Enable = HIGH

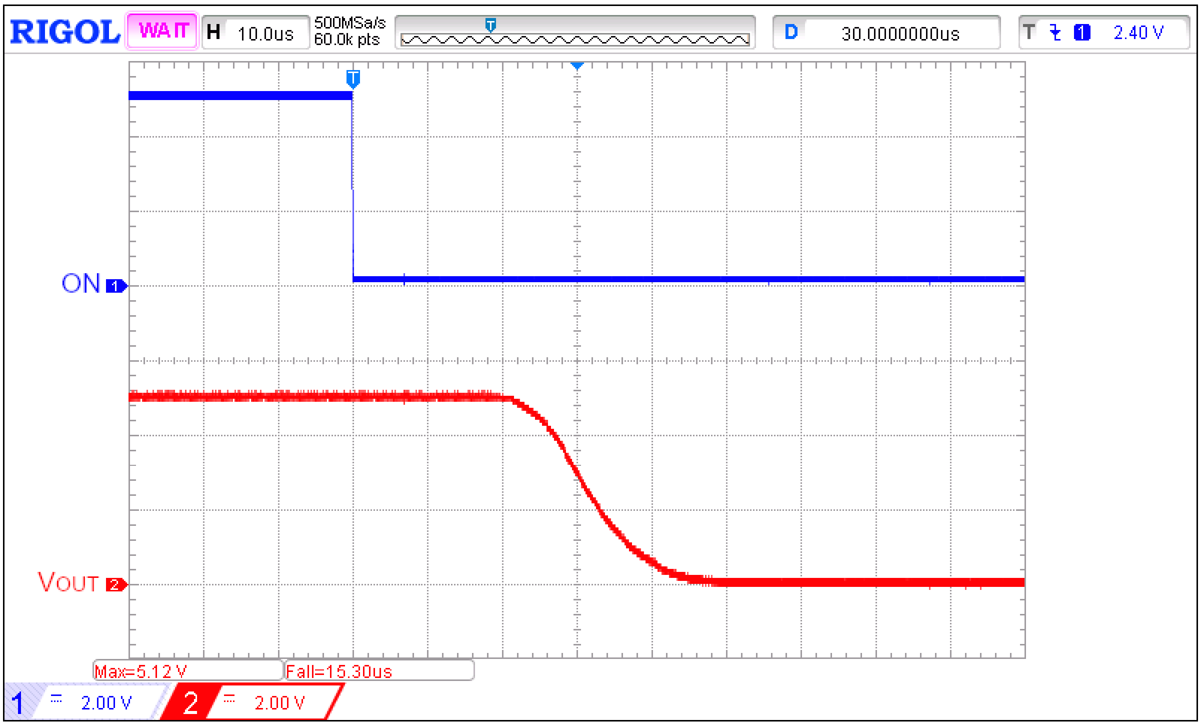

Figure 4: Two SLG59H1006Vs Operating in Parallel: Turn OFF operation; V_{LOGIC} = 5 V, V_{IN} = 5 V, C_{SLEW} = 18 nF, R_{LOAD} = 100 Ω, no C_{LOAD}, Load Enable = HIGH

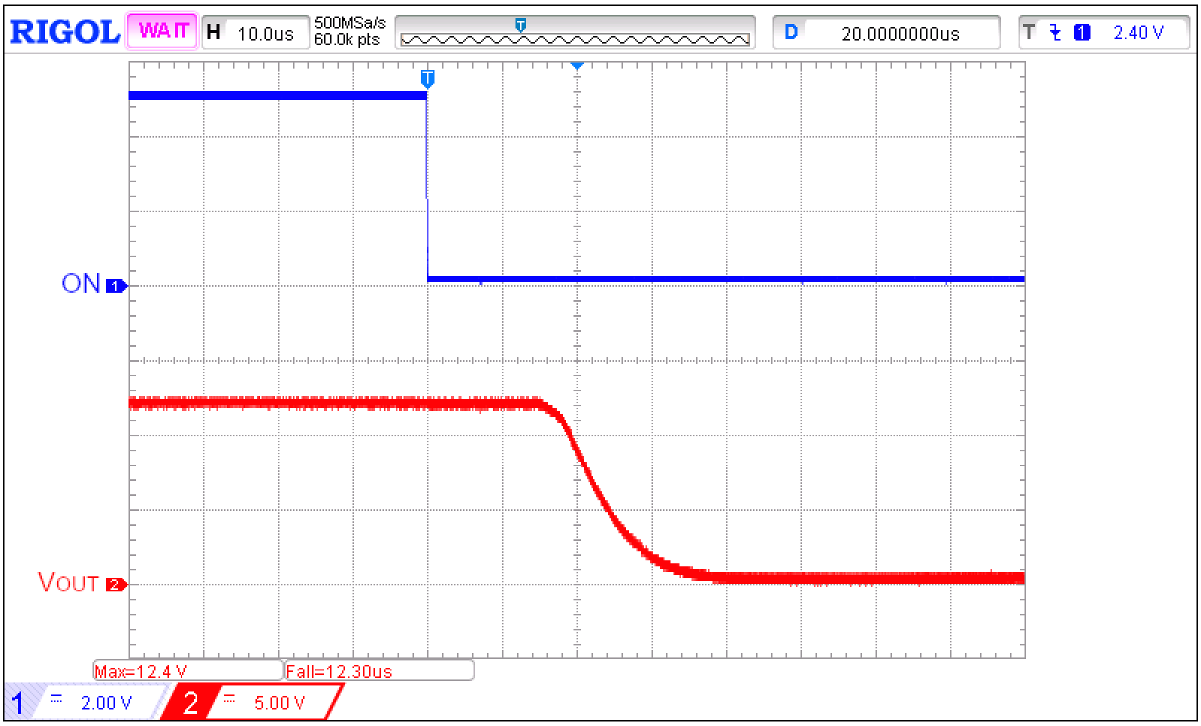

Figure 5: Two SLG59H1006Vs Operating in Parallel: Turn OFF operation; V_{LOGIC} = 5 V, V_{IN} = 12 V, C_{SLEW} = 18 nF, R_{LOAD} = 100 Ω, no C_{LOAD}, Load Enable = HIGH

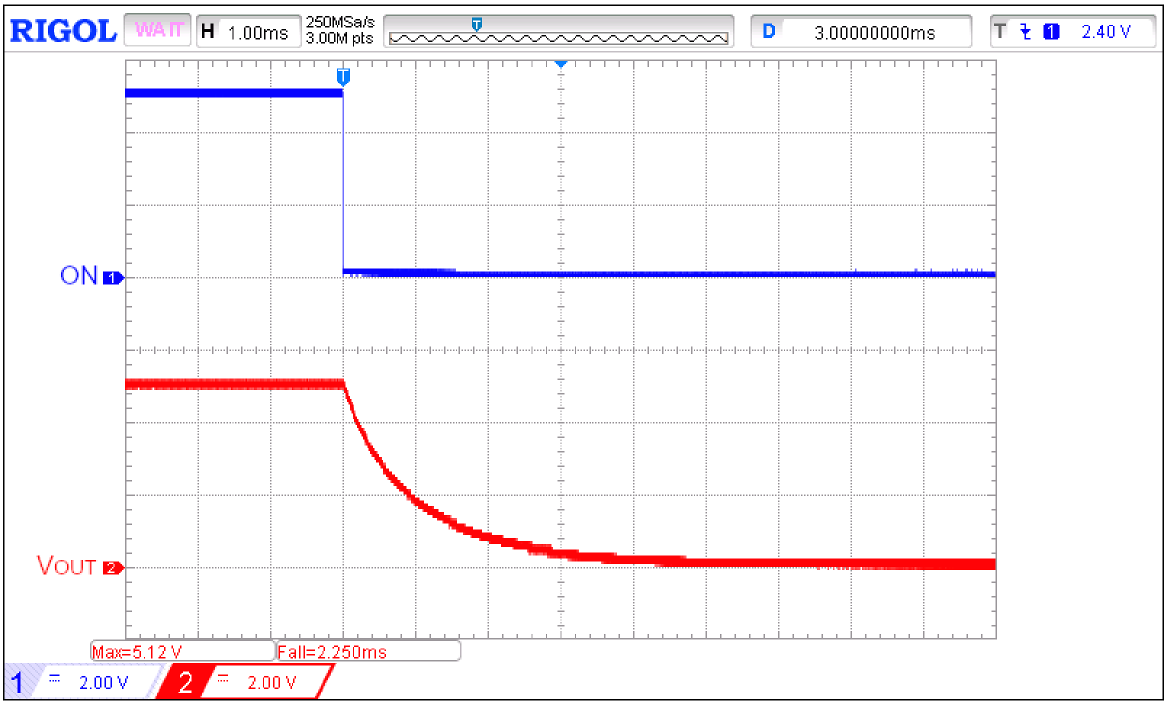

Figure 6: Two SLG59H1006Vs Operating in Parallel: Turn OFF operation; V_{LOGIC} = 5 V, V_{IN} = 5 V, C_{SLEW} = 18 nF, R_{LOAD} = 100 Ω, C_{LOAD} = 10 μF, Load Enable = HIGH

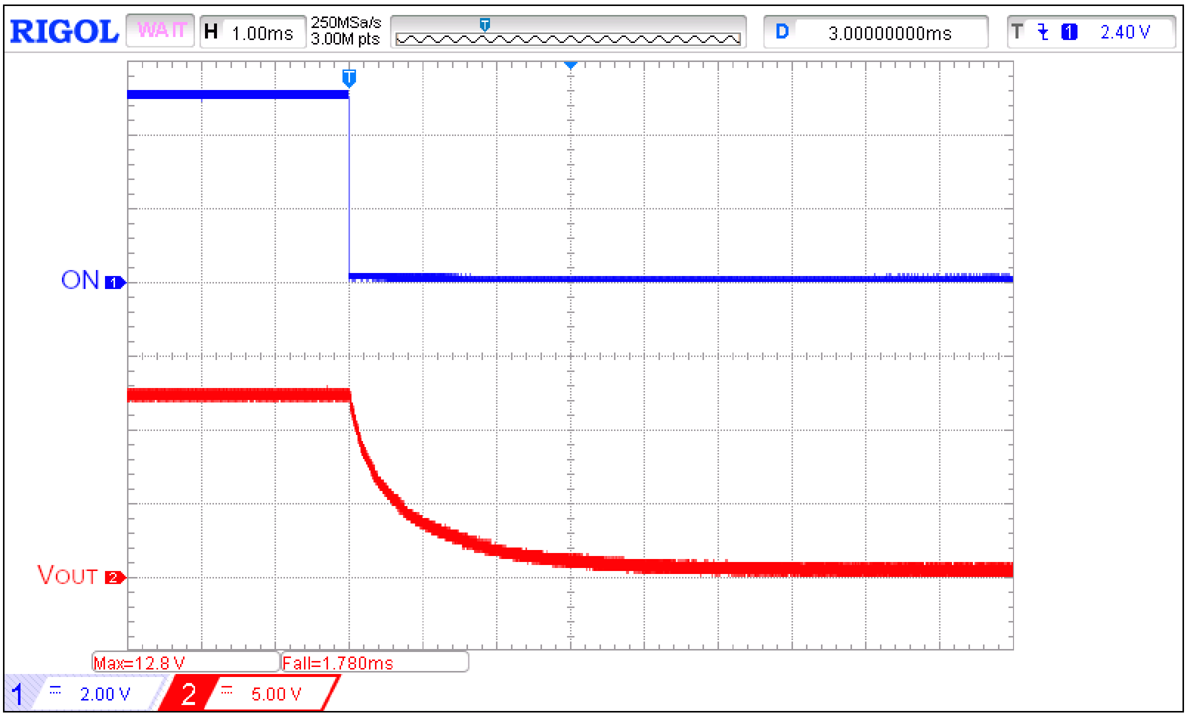

Figure 7: Two SLG59H1006Vs Operating in Parallel: Turn OFF operation; V_{LOGIC} = 5 V, V_{IN} = 12 V, C_{SLEW} = 18 nF, R_{LOAD} = 100 Ω, C_{LOAD} = 10 μF, Load Enable = HIGH

A circuit configuration like this one retains all the SLG59H1006V's protection features: active current limit (ACL), short circuit protection (SCL), inrush current control, thermal shutdown, and FET safe operation area (SOA). For inrush current control, separate capacitors at each CAP pin of U1 and U2, as well as a common capacitor for both CAP pins can be used. It should be noted that in the case of a common capacitor at CAP pins, VOUT ramp time will be twice as fast when compared to the case for same CSLEW value at each CAP pin. This is caused by the fact that the slew capacitor is being charged by two GreenFET load switches simultaneously. This common CSLEW configuration is preferred as both GreenFET load switches will power up simultaneously. Since the ACL for both GreenFET load switches is set to 6 A with external resistors to the RSET pins, the ACL of the overall circuit is 12 A. Corresponding operating waveforms for different input voltages are presented in Figure 8 and Figure 9.

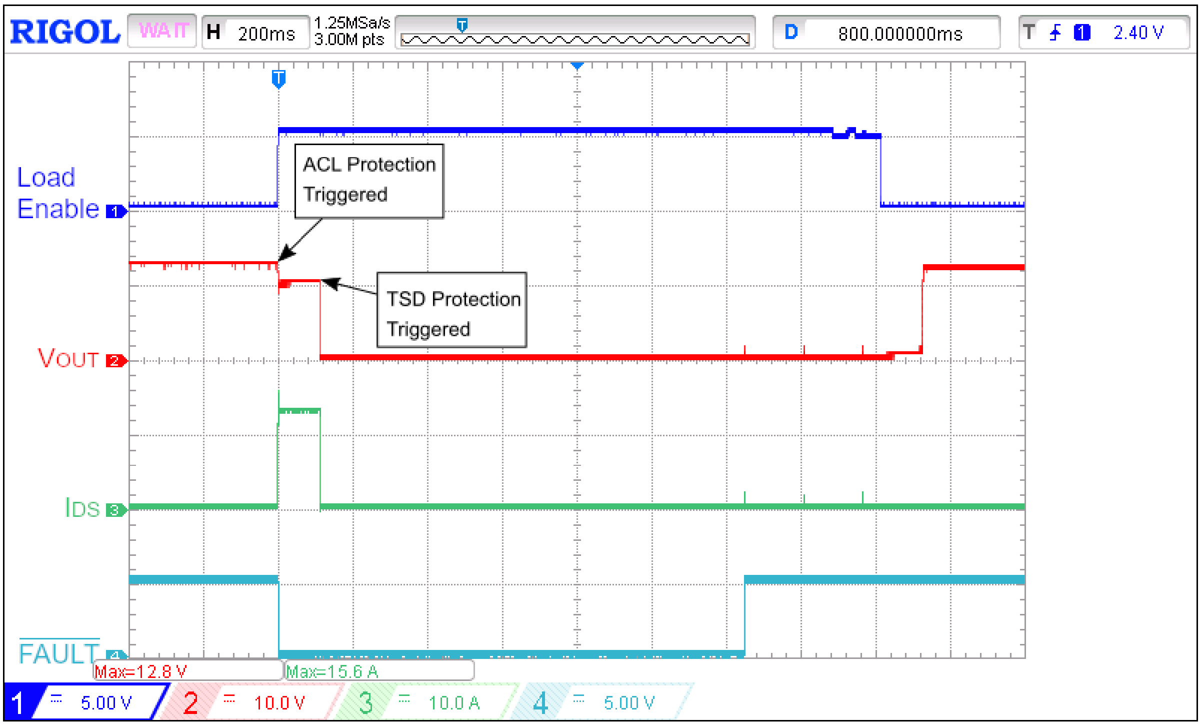

Figure 8: Two SLG59H1006Vs Operating in Parallel: ACL with SOA operation; V_{LOGIC} = 5 V, V_{IN} = 12 V, C_{SLEW} = 18 nF, I_{ACL} = 12 A, R_{SET_U1} = 15 kΩ, R_{SET_U2} = 15 kΩ, R_{LOAD} = 0.8 Ω, C_{LOAD} = 10 µF, ON = HIGH

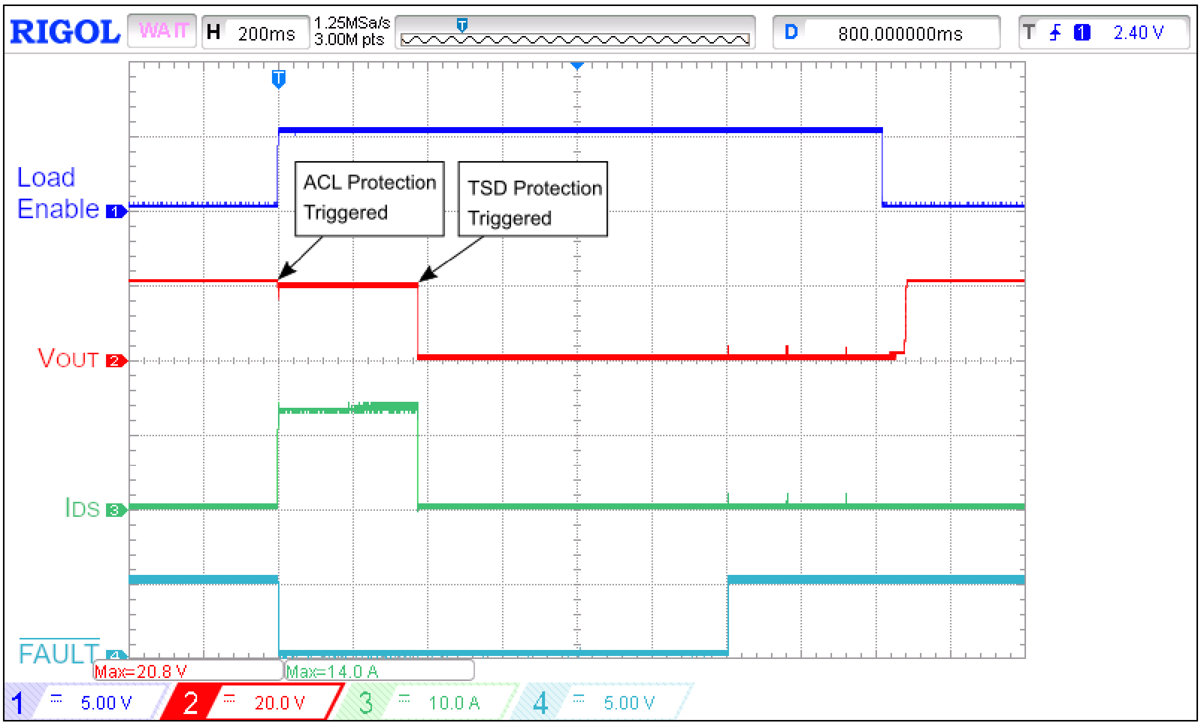

Figure 9: Two SLG59H1006Vs Operating in Parallel: ACL with SOA operation; V_{LOGIC} = 5 V, V_{IN} = 20 V, C_{SLEW} = 18 nF, I_{ACL} = 12 A, R_{SET_U1} = 15 kΩ, R_{SET_U2} = 15 kΩ, R_{LOAD} = 1.4 Ω, C_{LOAD} = 10 µF, ON = HIGH

There are two implementations for current monitoring of such a system. The first one is to monitor currents through each GreenFET load switch using their component IOUT pins as was shown in Figure 1. In this case, each IOUT will generate a 10 µA/A transfer characteristic. The corresponding waveform is presented in Figure 10.

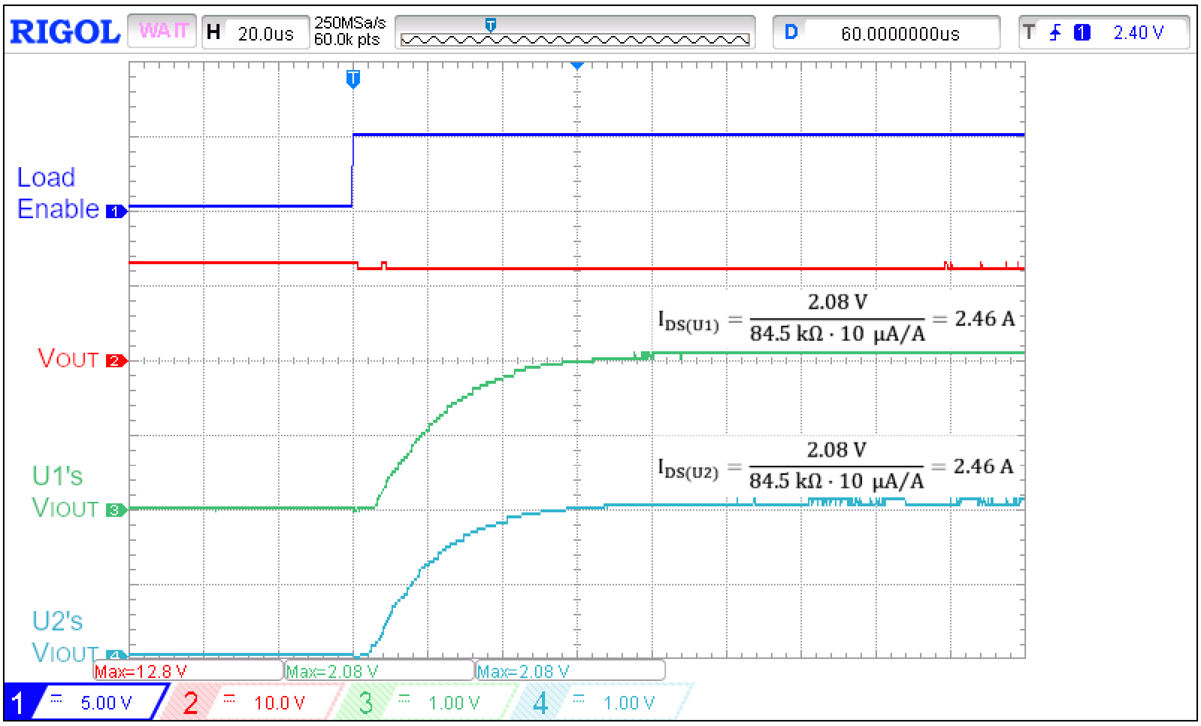

Figure 10: Two SLG59H1006Vs Operating in Parallel: IOUT operation; V_{LOGIC} = 5 V, V_{IN} = 12 V, I_{DS} = 5 A R_{IOUT_U1} = 84.5 kΩ, C_{IOUT_U1} = 180 pF, R_{IOUT_U2} = 84.5 kΩ, C_{IOUT_U2} = 180 pF, ON = HIGH

A second way is to monitor the load current of the whole circuit by connecting component IOUT pins together. Such a connection is illustrated in Figure 11. In this case, the combination circuit will also generate a 10 µA/A transfer characteristic; however, the IOUT resistor should be changed to extend current measurement range and this should be taken into consideration. The operating waveform is shown in Figure 12.

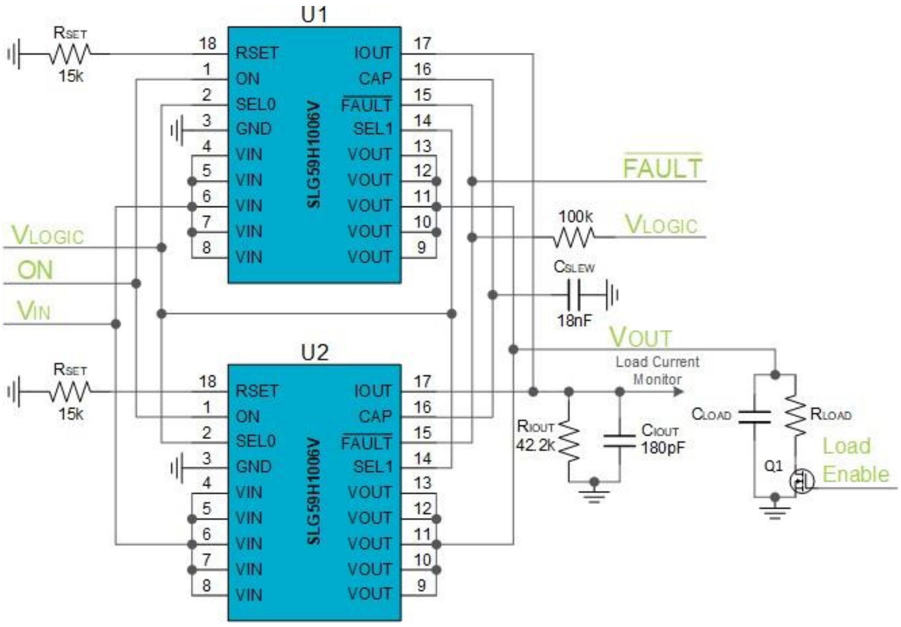

Figure 11: Application Diagram of using two SLG59H1006Vs in parallel with common IOUT pins

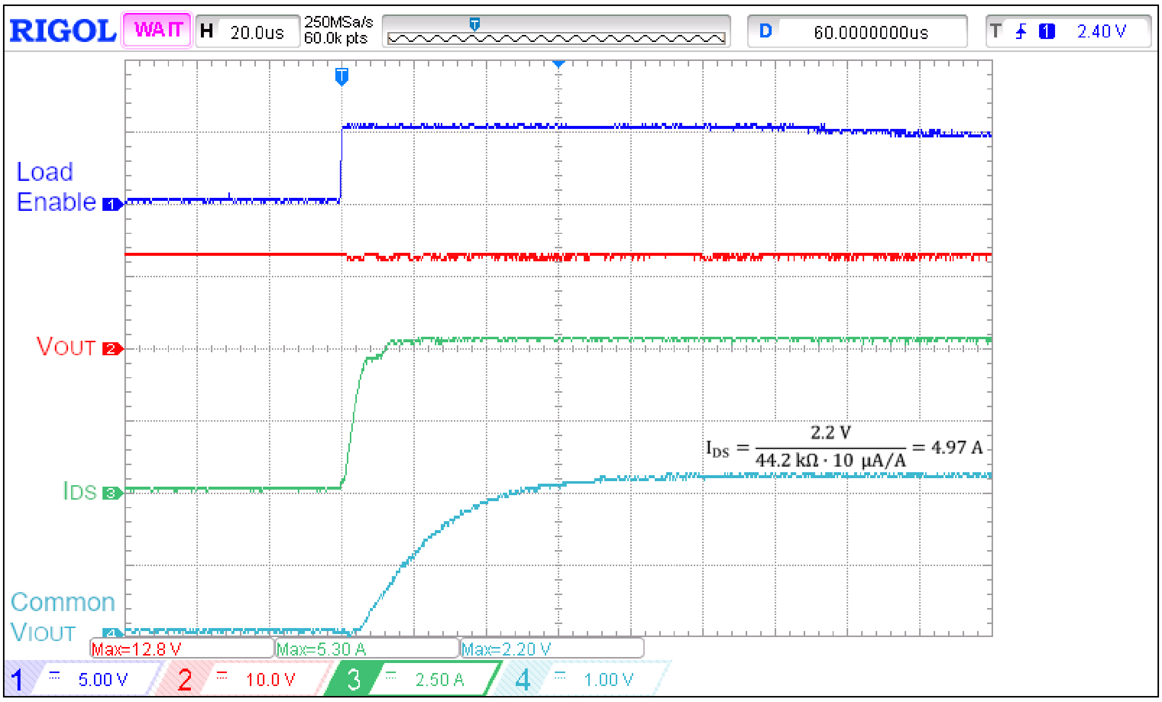

Figure 12: Two SLG59H1006Vs Operating in Parallel: Common IOUT operation; V_{LOGIC} = 5 V, V_{IN} = 12 V, I_{DS} = 5 A, R_{IOUT} = 44.2 kΩ, C_{IOUT} = 180 pF, ON = HIGH

5 Using a Pair of SLG59M1714Vs in Parallel

For V_{IN} voltages up to 5.5 V and load current higher than 4 A, a SLG59M1714V GreenFET load switch can be configured in a similar fashion to that of the SLG59H1006V. Operating from 2.5 V to 5.5 V supply voltage, the SLG59M1714V is a 15 mΩ, 4 A single channel GreenFET load switch with back-to-back reverse-current blocking when OFF. Incorporating two-stage current protection as well as thermal protection and fault signaling, the SLG59M1714V is designed for all 0.8 V to 5.5 V power rail applications. Typical application connection using two SLG59M1714V in parallel is illustrated in Figure 13.

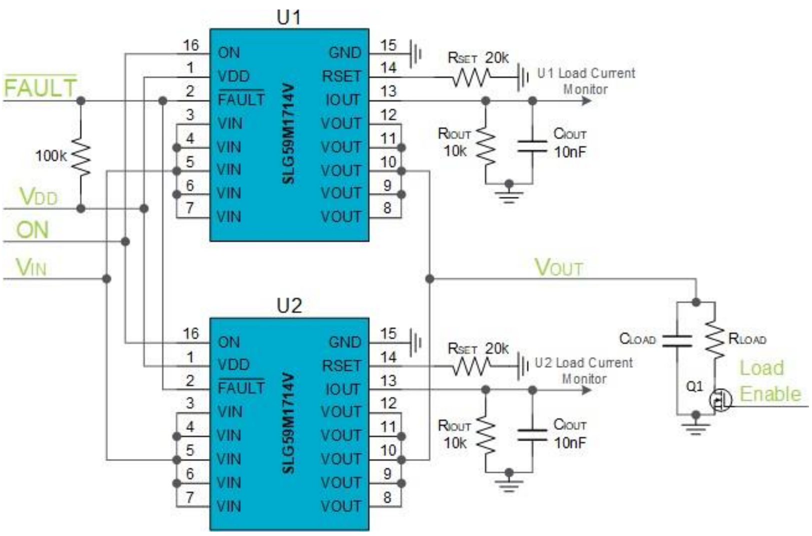

Figure 13: Application Diagram of using a pair of SLG59M1714Vs in parallel

As shown in Figure 13, the component IOUT pins are separated to independently monitor current through each power MOSFET. The SLG59M1714V's IOUT transfer characteristic is 100 □A/A and this should be considered when choosing resistor on IOUT pin. Typical operational waveforms of this GreenFET load switch solution are illustrated from Figure 14 through Figure 18.

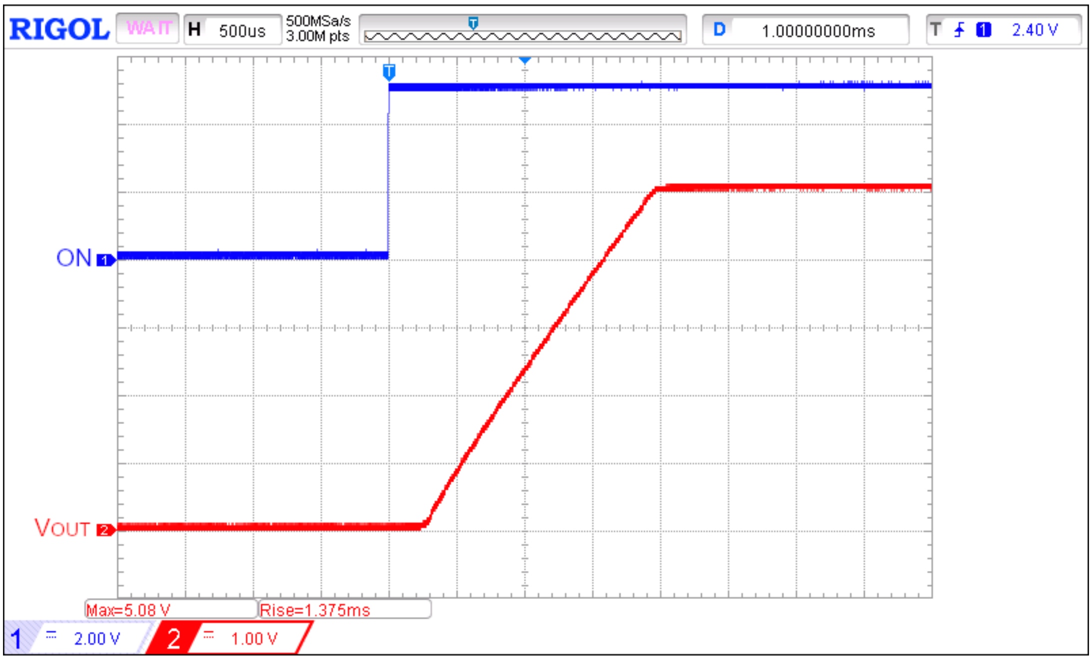

Figure 14: Two SLG59M1714Vs Operating in Parallel: Turn ON Operation; V_{DD} = 5 V, V_{IN} = 5 V, R_{LOAD} = 100 Ω, C_{LOAD} = 10 µF, Load Enable = HIGH

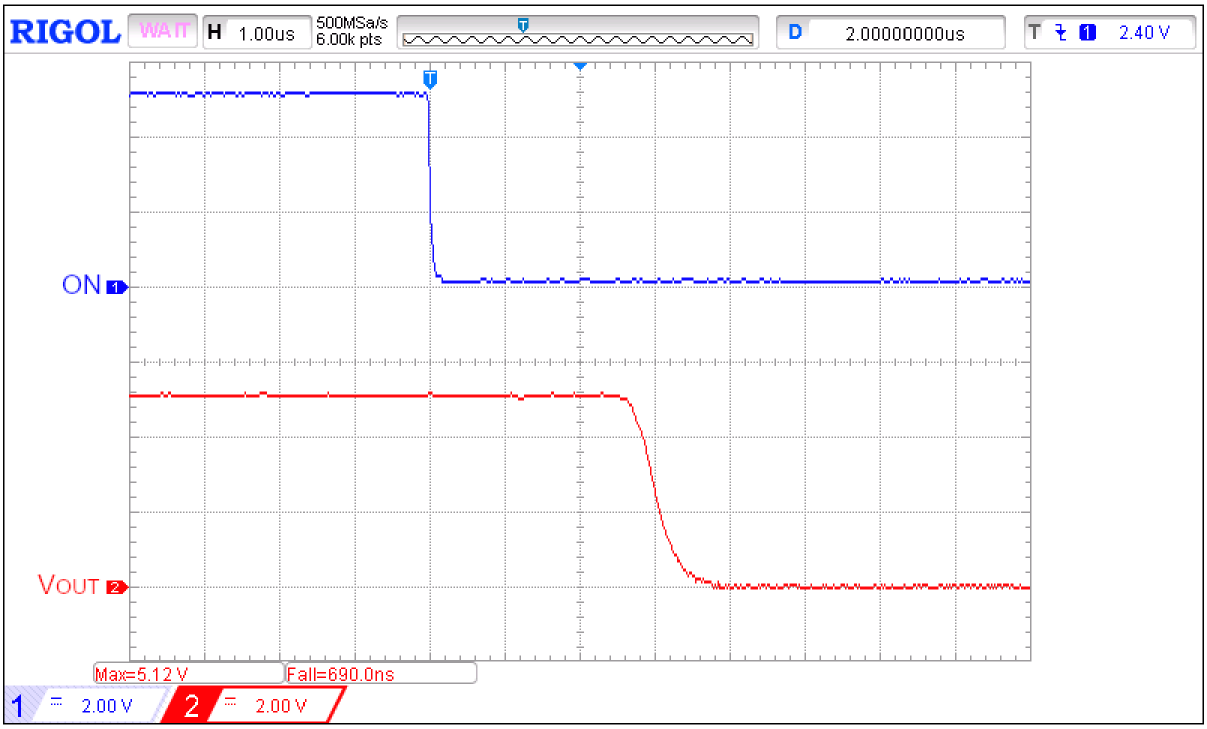

Figure 15: Two SLG59M1714Vs Operating in Parallel: Turn OFF Operation; V_{DD} = 5 V, V_{IN} = 5 V, R_{LOAD} = 100 Ω, no C_{LOAD}, Load Enable = HIGH

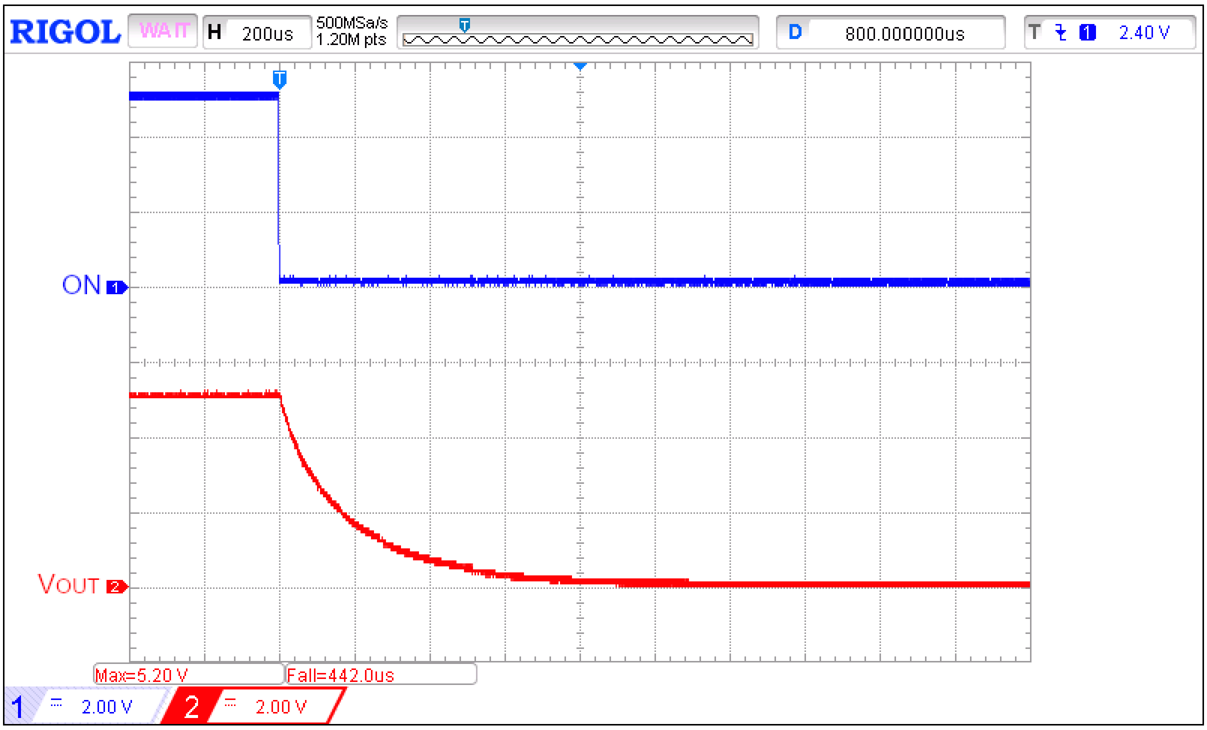

Figure 16: Two SLG59M1714Vs Operating in Parallel: Turn OFF Operation; V_{DD} = 5 V, V_{IN} = 5 V, R_{LOAD} = 100 Ω, C_{LOAD} = 10 µF, Load Enable = HIGH

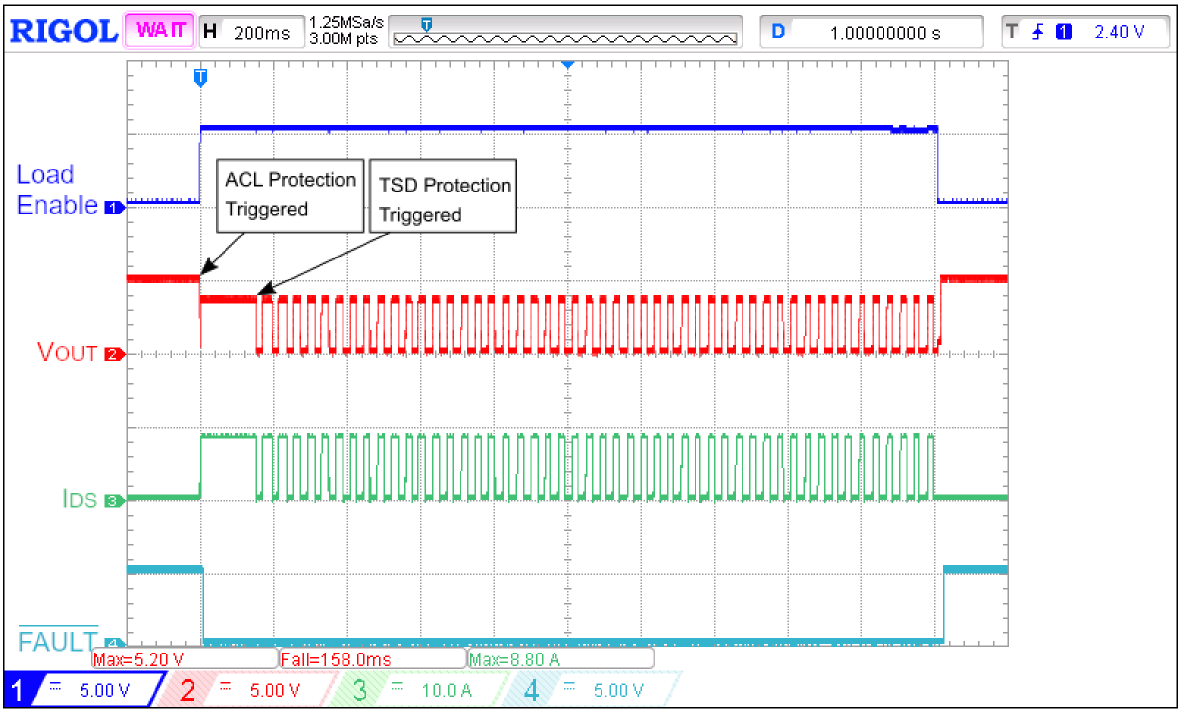

Figure 17: Two SLG59M1714Vs Operating in Parallel: ACL with thermal protection operation; V_{DD} = 5 V, V_{IN} = 5 V, I_{ACL} = 8 A, R_{SET_U1} = 20 kΩ, R_{SET_U2} = 20 kΩ, R_{LOAD} = 0.6 Ω, C_{LOAD} = 10 µF, ON = HIGH

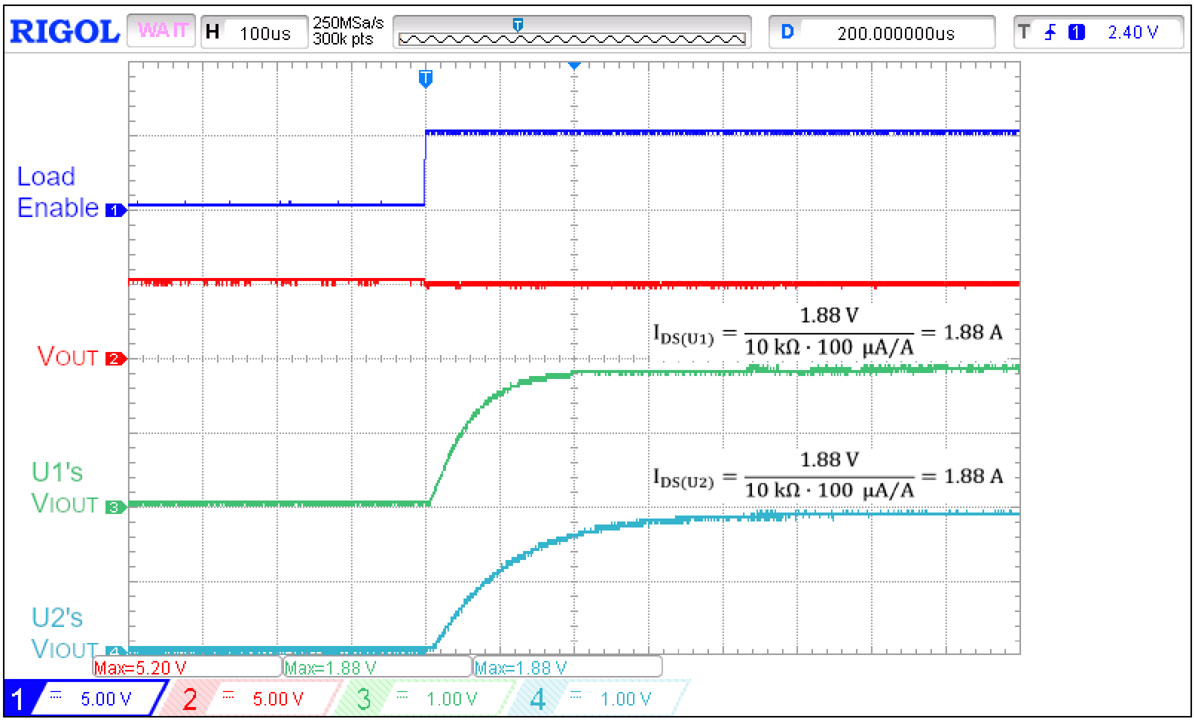

Figure 18: Two SLG59M1714Vs Operating in Parallel: Independent I_{OUT} operation; V_{DD} = 5 V, V_{IN} = 5 V, I_{DS} = 4 A, R_{IOUT}_U1 = 10 kΩ, C_{IOUT_U1} = 10 nF, R_{IOUT}_U2 = 10 kΩ, C_{IOUT}_U2 = 10 nF, ON = HIGH

Also, as was the case with the SLG59H1006V, it is possible to combine the component IOUT pins to monitor total load current from one pin. The corresponding SLG59M1714V application configuration and its IOUT signal are illustrated in Figure 19 and Figure 20 respectively. Please note that the system will also generate a 100 µA/A transfer characteristic and the IOUT resistor (RIOUT) should be changed to extend measurement current range.

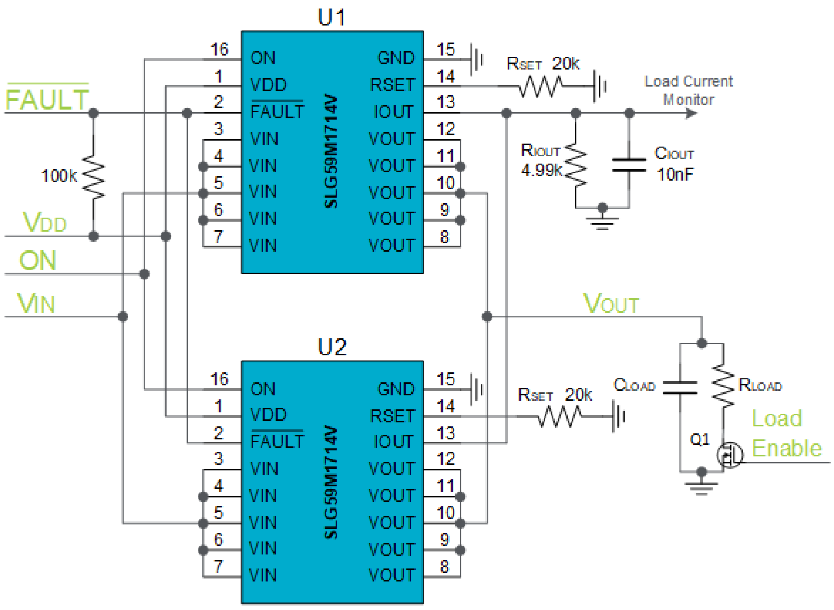

Figure 19: Application Diagram of using two SLG59M1714Vs in parallel with common IOUT pins

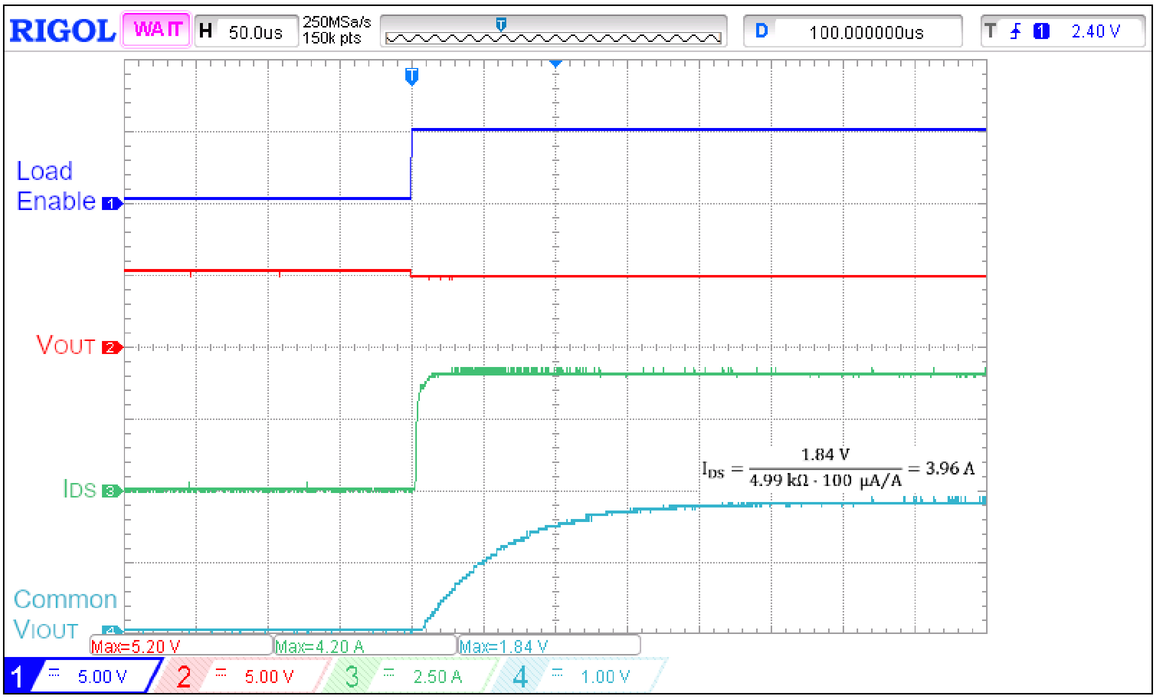

Figure 20: Two SLG59M1714Vs Operating in Parallel: Common IOUT operation; V_{DD} = 5 V, V_{IN} = 5 V, I_{DS} = 4 A, R_{IOUT} = 4.99 kΩ, C_{IOUT} = 10 nF, ON = HIGH

6 Using a Single, High-current GreenFET Load Switches SLG59M1568V

If a load-current monitor feature is not required, it is possible to use single SLG59M1568V GreenFET load switch. Operating from 2.5 V to 5.5 V supply voltage, the SLG59M1568 is a 7.3 mΩ, 9 A single channel GreenFET load switch that can switch power rails from 1 V to 5.5 V. An application diagram of using SLG59M1568V is illustrated in Figure 21

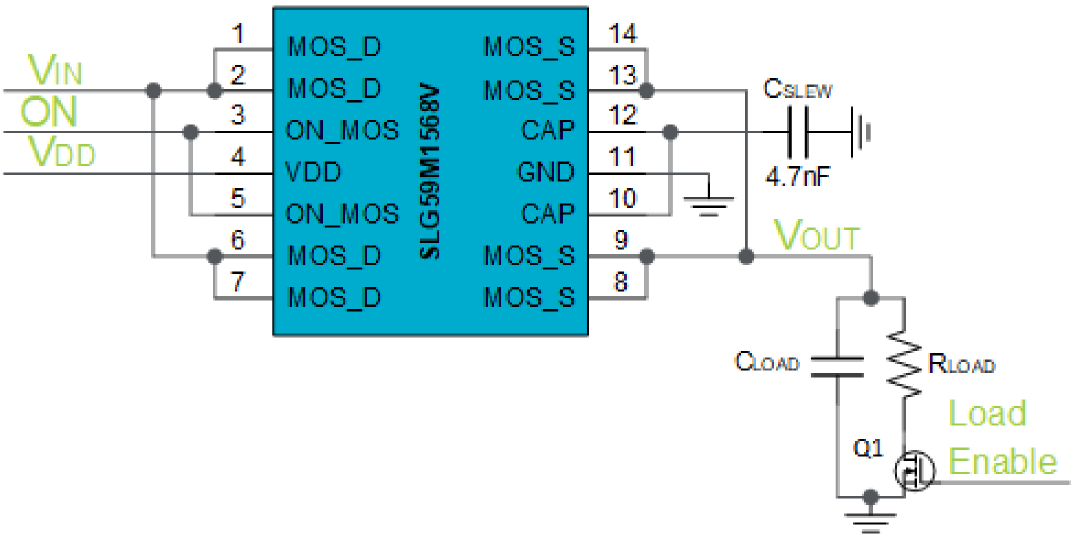

Figure 21: Application Diagram of using SLG59M1568V

Typical operational waveforms of this GreenFET load switch solution are illustrated from Figure 22 through Figure 25.

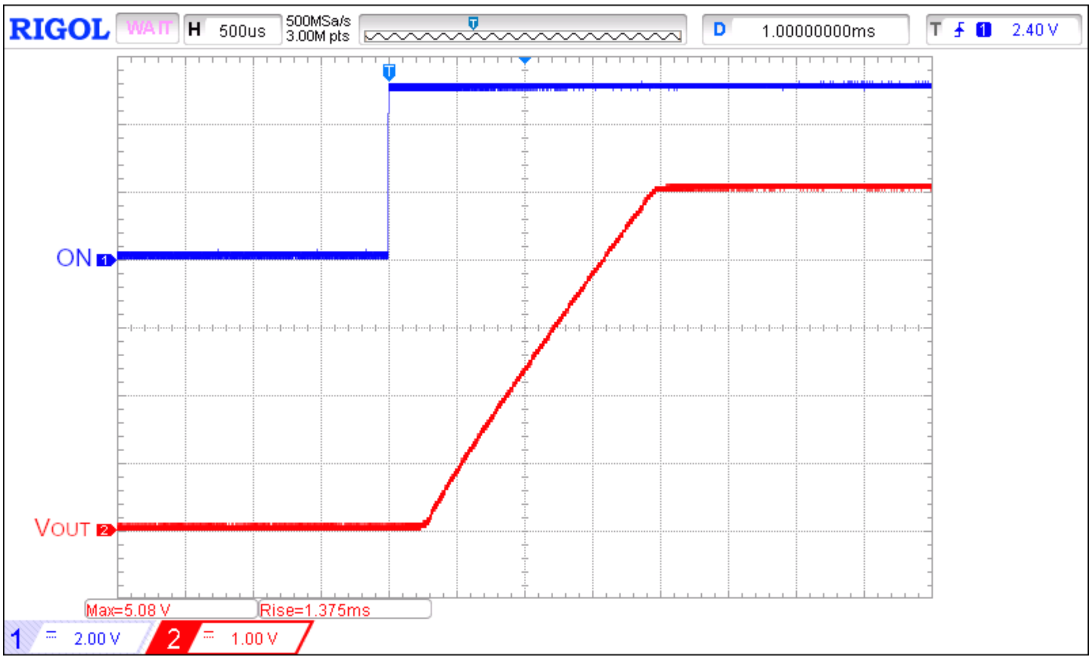

Figure 22: SLG59M1568V Turn ON Operation; V_{DD} = 5 V, V_{IN} = 5 V, C_{SLEW} = 4.7 nF, R_{LOAD} = 20 Ω, C_{LOAD} = 10 μF, Load Enable = HIGH

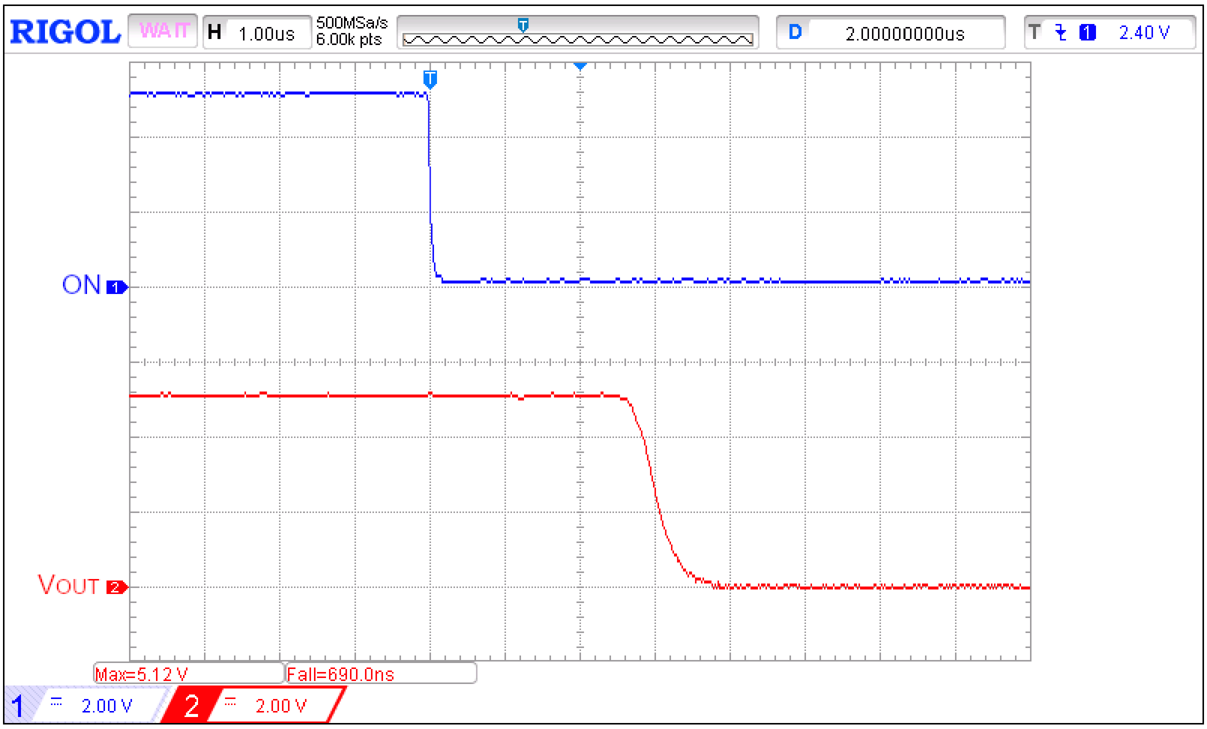

Figure 23: SLG59M1568V Turn OFF Operation; V_{DD} = 5 V, V_{IN} = 5 V, C_{SLEW} = 4.7 nF, R_{LOAD} = 20 Ω, no C_{LOAD}, Load Enable = HIGH

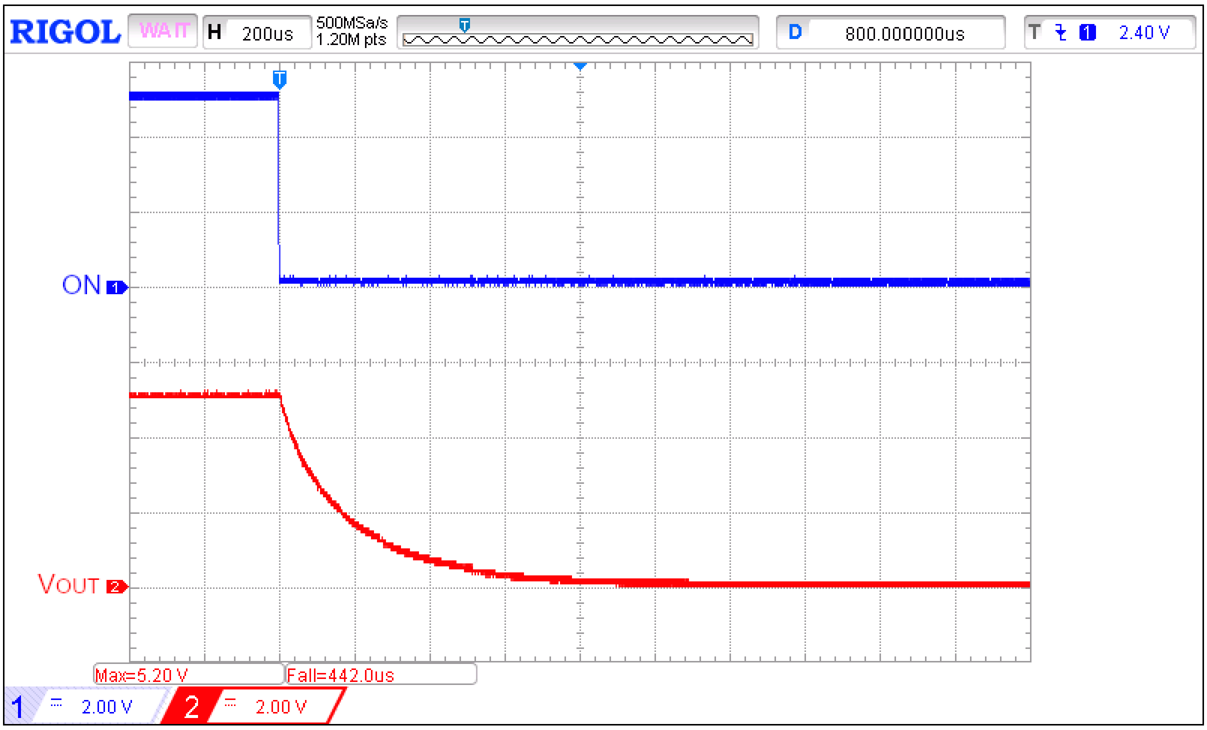

Figure 24: SLG59M1568V Turn OFF Operation; V_{DD} = 5 V, V_{IN} = 5 V, C_{SLEW} = 4.7 nF, R_{LOAD} = 20 Ω, C_{LOAD} = 10 µF, Load Enable = HIGH

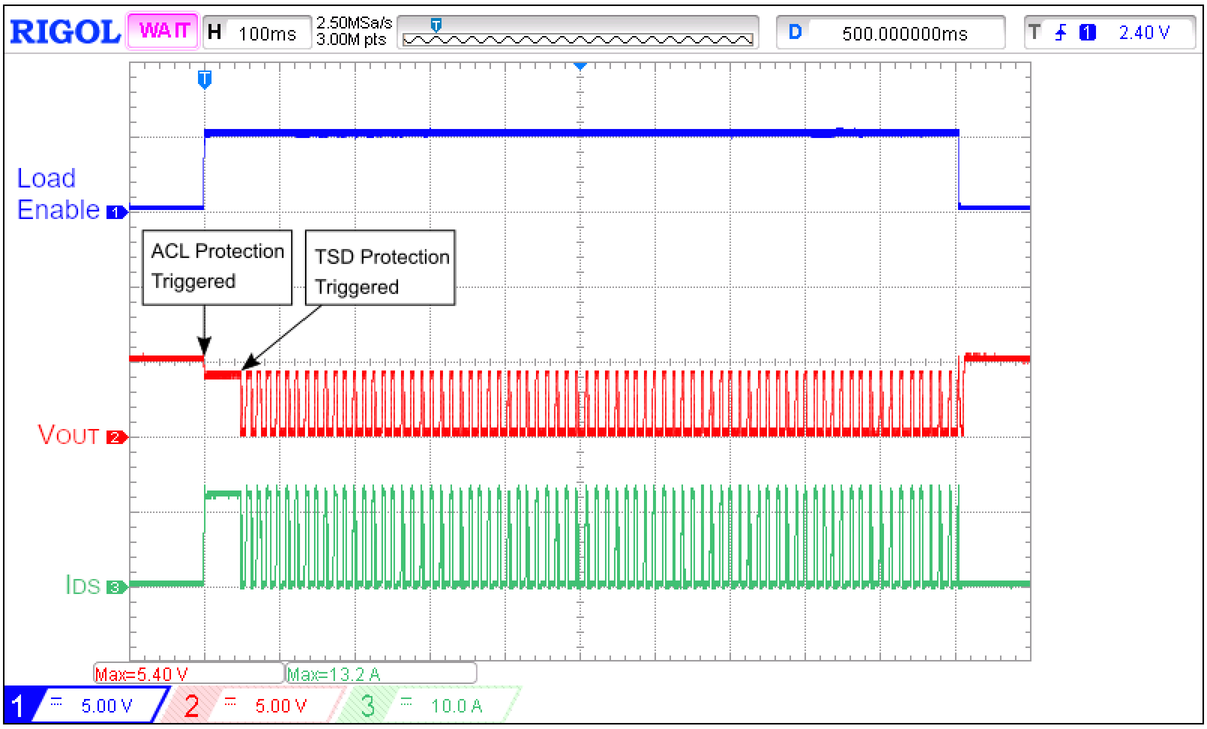

Figure 25: SLG59M1568V ACL with thermal protection operation; V_{DD} = 5 V, V_{IN} = 5 V, I_{ACL} = 12 A, R_{LOAD} = 0.4 Ω, C_{LOAD} = 10 µF, ON = HIGH

7 Recommended PCB Layouts

All PCB traces have parasitic resistance, capacitance, and inductance. If there were a difference in path length from the input power source to the GreenFET load switches' VIN, VOUT pads, this delta trace length would create a current imbalance. In this case, the PCB layout should be designed properly to minimize parasitic impedance and, especially parasitic inductance, on both sets of VIN and VOUT pins.

Excess trace inductance may cause a delay effect during on/off operation. Figure 26, Figure 27 and Figure 28 show the recommended PCB layouts for applications using SLG59H1006Vs, SLG59M1714Vs and SLG59M1568V, respectively.

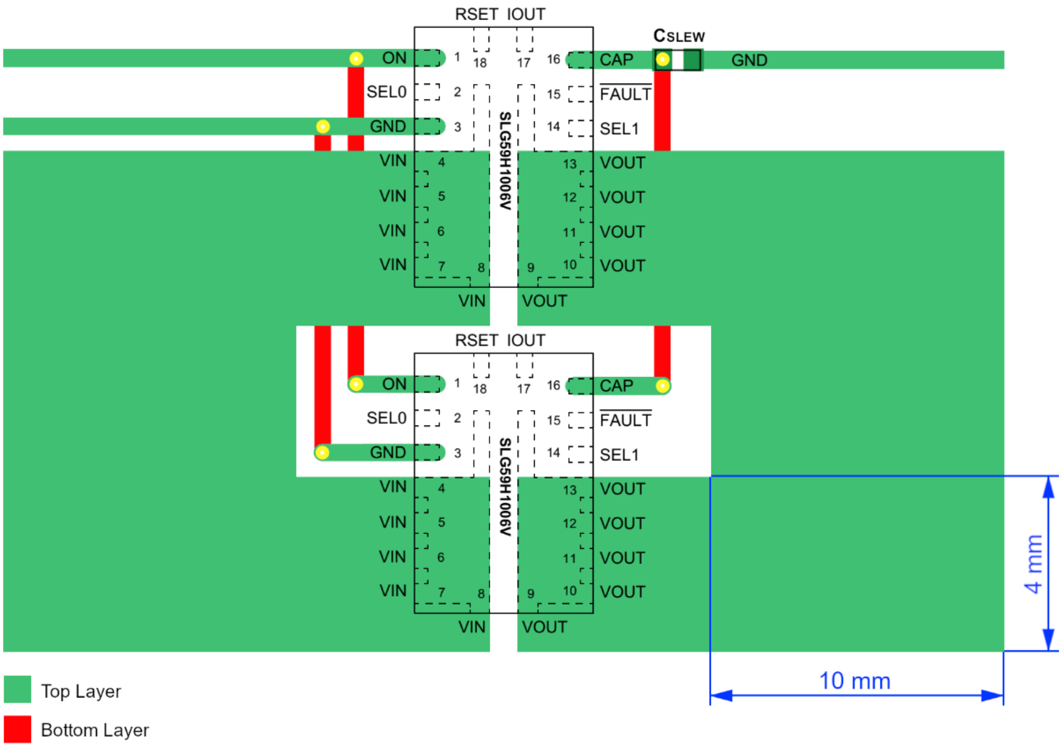

Figure 26: Recommended PCB layout for two SLG59H1006Vs operating in parallel

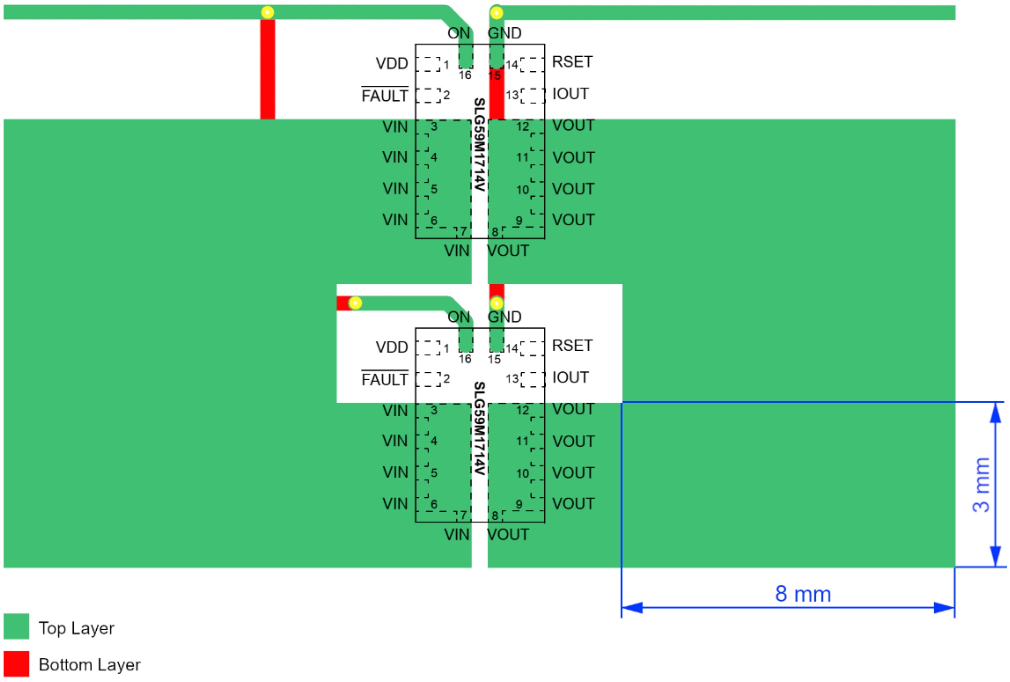

Figure 27: Recommended PCB layout for two SLG59M1714Vs operating in parallel

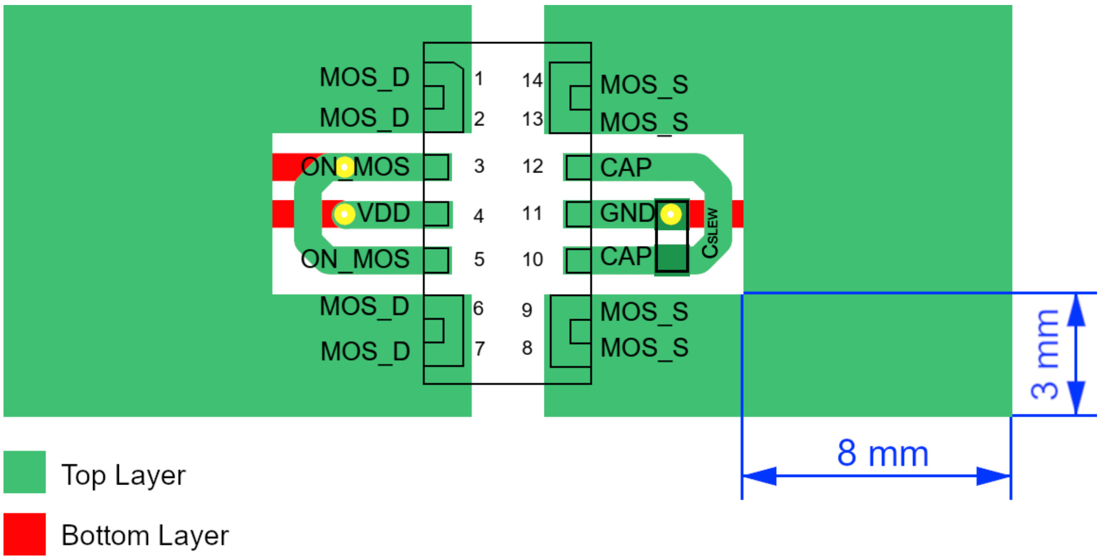

Figure 28: Recommended PCB layout for using a SLG59M1568V

8 Conclusions

Renesas provides a number of highly differentiated, low system cost load switches for various load current applications. To extend maximum operating current, the GreenFET load switches are an excellent choice for their very low, high-performance RDS_{ONs} and can be used in parallel with minimal risk of current-hogging or imbalance. The GreenFET load switches used in parallel retain all their circuit protection features and a select number of the GreenFET load switches offer analog load-current monitor outputs.

Revision History

Revision	Date	Description
1.0	22-Feb-2019	Initial Version

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