

# Automatic Voltage Switch using SLG59H1008V

## SLG59H1008V

This application note describes the use of Renesas SLG59H1008V in Automatic Voltage Switch applications

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## 1. References

For related documents please visit:

[Load Switches | Renesas](#)

- [1] [SLG59H1008V Datasheet, Renesas Electronics](#)
- [2] [SLG55021 Datasheet, Renesas Electronics](#)
- [3] [LM321 Datasheet](#)
- [4] [LM317L Datasheet](#)
- [5] [Atmega328 Datasheet](#)
- [6] [L78L05 Datasheet](#)

## 2. Terms and Definitions

AVS	Automatic Voltage Switch
MCU	Microcontroller Unit
IC	Integrated Circuit
UPS	Uninterruptable Power Supply
DC	Direct Current
PCB	Printed Circuit Board

## 3. Introduction

Portable electronic device or cordless devices are becoming ubiquitous in recent years thanks to the advantages they bring to the table in terms of size mobility and flexibility in their deployment. For starters, the numerous problems arise with the need to manage different voltage rating switched power supplies in order to maintain charge all devices. Practically it's possible to connect a wrong power supply and eventually damage the device, sometimes beyond repair. There is a solution to solve this kind of problems which can enable multiple devices operating at different voltage levels to share the same power supply without a problem as long the voltage range is supported and if not, it will prevent the wrong voltage from passing through. To achieve this, a High Voltage GreenFET technology device is required to perform within the selected voltage range, over voltage and under voltage protection, and MCU to automate the process.

## 4. Automatic Voltage Switch Concept

Automatic Voltage Switches are devices that provide protection to a connected load. AVS respond to input voltage to activate or deactivate a load when the supply voltage exceeds or underlines the programmed limits. They are typically used in applications like UPS and Monophasic smart switches. It may also be used in power management unit of electronic devices.

In general, AVS device have a single undervoltage and overvoltage reference voltages that serve as the system operation limits. A simplified block diagram of AVS is illustrated in [Figure 1](#).

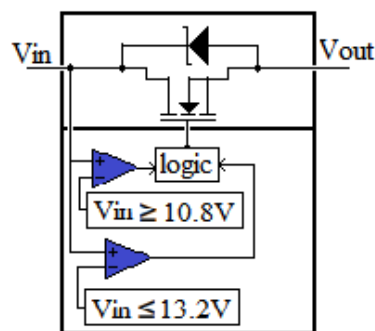


Figure 1: Automatic Voltage Switch Analogue Equivalent

## Automatic Voltage Switch using SLG59H1008V

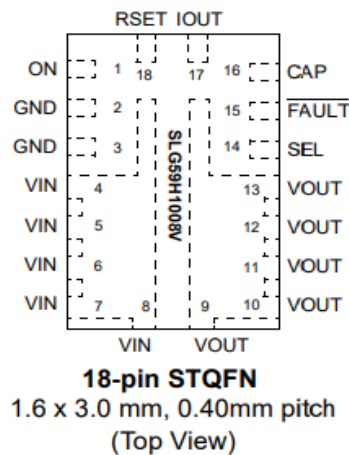
From technical standpoint, the implementation of a high voltage DC AVS require a MOSFETs, because of its low ON resistance and high drain current.

For flexibility purpose, the system requires a GreenFET with two selectable voltage limits.

From controlling standpoint, the voltage limits can only be controlled by MCU that can decide under what conditions to set the configurations for the specified voltage limits and maintain the protection features of the system.

### 4.1 SLG59H1008V Resume

The SLG59H1008V is a load switch designed to control 12 V or 24 V power rails up to a current of 4 A. It contains all the necessary logic blocks for protection against Short-circuit, Overcurrent, Undervoltage and Overvoltage lockout windows, overheating protection and current monitoring.



**Figure 2: Pin Configuration for SLG59H1008V**

The following list provides more details on the functions of each pin:

- **ON** pin: Initiates the operation of the SLG59H1008V's state machine when asserted HIGH. To disable the IC, the pin must be connected to GND because there is no internal pull-down resistor.
- **GND** pin: Is a Ground connection. Connect this pin to system analog or power ground plane.
- **VIN** pin: Supply the power for the operation of the SLG59H1008V, its internal control circuitry, and the drain terminal of the nFET load switch.
- **VOUT** pin: Source terminal pin of the nFET load switch.
- **SEL** pin: Selects one of the two undervoltage/overvoltage lockout window. When SEL = LOW, the  $V_{IN}$  undervoltage/overvoltage lockout window is set for  $12\text{ V} \pm 10\%$  applications (mode 0). When SEL = HIGH, the  $V_{IN}$  undervoltage/overvoltage lockout window is set for  $24\text{ V} \pm 5\%$  applications (mode1).
- **FAULT** pin: Open drain output. FAULT is asserted within  $T_{FAULT\_LOW}$  when a  $V_{IN}$  undervoltage,  $V_{IN}$  overvoltage, a current-limit, or an over-temperature condition is detected.
- **CAP** pin: Sets the  $V_{OUT}$  slew rate and overall turn-on time.
- **IOUT** pin: Is the SLG59H1008V's power MOSFET load current monitor output.

- **RSET** pin: Sets the active current limit threshold. A 91 k $\Omega$  resistor sets the SLG59H1008V's active current limit to 1 A and a 20 k $\Omega$  resistor sets the active current limit to 4.5 A.

### 4.2 Using SLG59H1008V in Automatic Voltage Switching Applications

The SLG59H1008V is designed from the ground up to be suitable for voltage switching applications. The part comes with a 4 A rated load switch that is well suited for variety of systems that can handle two voltage extremes. The part is based on a N-Channel MOSFET, suitable for low and high power loads, what makes the part shines it's the presence of voltage select, analog current monitoring and fault detection modules allowing an external MCU to control the part and read operation parameters.

When using SLG59H1008V in AVS applications, an external grounding resistor  $R_{SET} = 20 \text{ k}\Omega$  is connected to set the load switch current limit to 4.5 A. A grounding capacitor  $C_{SLEW} = 10 \text{ nF}$  is connected to set  $V_{OUT}$  slew rate and overall turn-on time while a grounding resistor  $R_{IOUT} = 84 \text{ k}\Omega$  and capacitor  $C_{IOUT} = 180 \text{ pF}$  are connected to generate  $V_{IOUT}$  with optimal linearity.

### 4.3 System Architecture

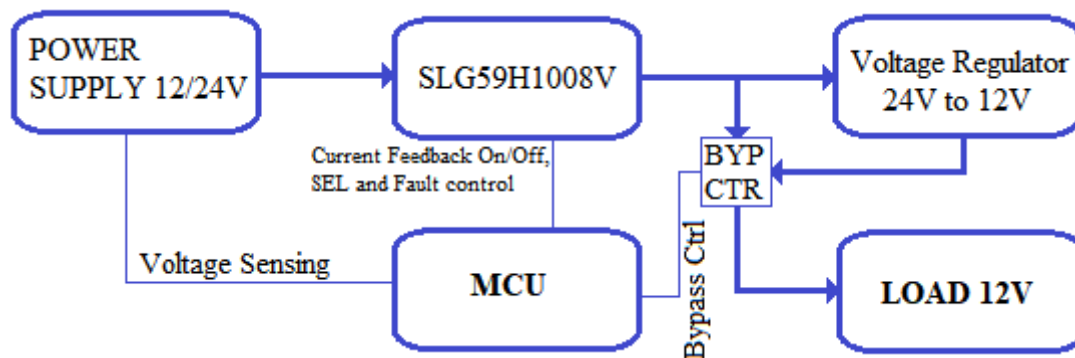


Figure 3: System Architecture

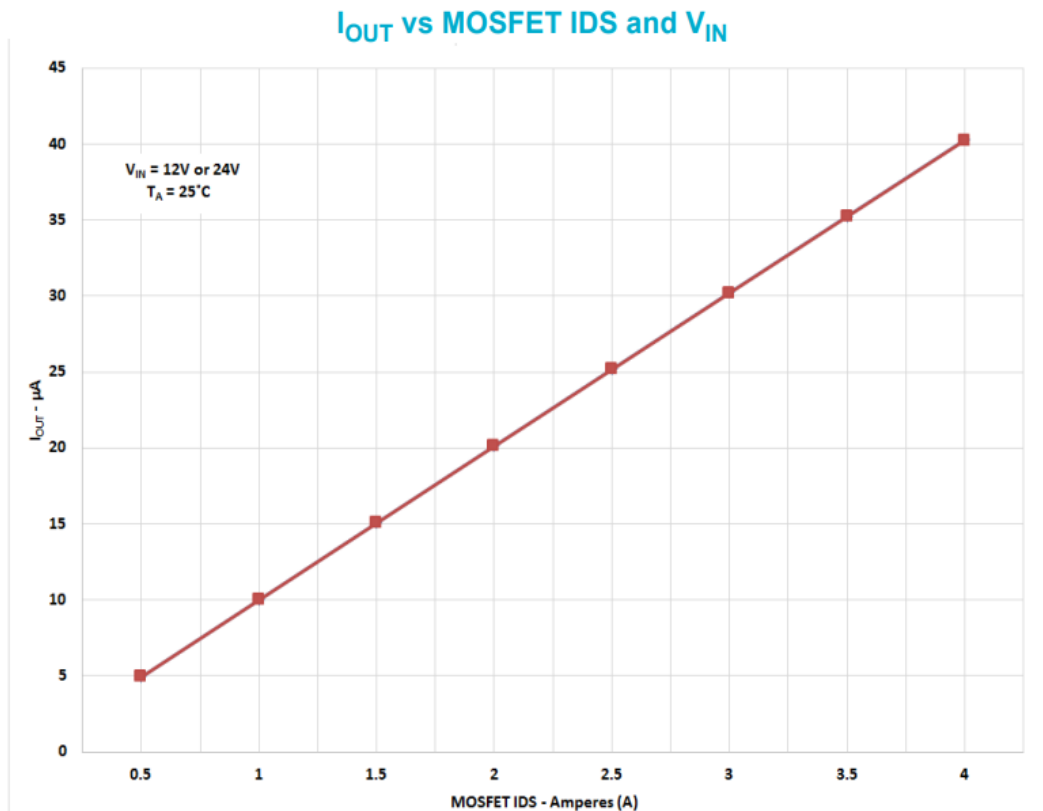
The system is composed of four main blocks with different functions:

- The SLG59H1008V block is the heart of the system. This block handles the power input and has all the features required to perform load switch, current sensing, fault detection and pin selectable 12 V/24 V input overvoltage and undervoltage lockout.
- Voltage Regulator block is the final check point of the system. Since the system is designed to allow 12 V/24 V input, this stage is responsible for regulating the 24 V input down to 12 V.
- Bypass control block is responsible for selecting the source of output voltage. Bypass control is implemented on two SLG55021 MOSFET drivers and a pair of N-channel-MOSFETs. The bypass control selects one of the two voltage sources for the load – 12 V directly from the High Voltage GreenFET or 12 V from the regulator. Only one of the MOSFET should be active at a time. The cases are  $V_{IN} = 12V - V_{MVLin} = \text{HIGH}$  and  $V_{Vreg} = \text{LOW}$  and if  $V_{IN} = 24V - V_{Vreg} = \text{HIGH}$  and  $V_{MVLin} = \text{LOW}$ .

- Microcontroller block is the brains of the system. It controls all the operations of the systems from current monitoring input voltage to input voltage range selection. The MCU works as a voltmeter and ammeter to verify if voltage and current parameters are within nominal values. In case of overcurrent or overvoltage events, the MCU shutdowns the whole system and prevents any damage.

In voltmeter mode the MCU reads  $V_{IN}$  to decide what  $V_{SEL}$  logic to apply. In case  $V_{IN} = 12\text{ V} - V_{SEL} = \text{LOW}$  and if  $V_{IN} = 24\text{ V} - V_{SEL} = \text{HIGH}$ .

In ammeter mode the MCU reads and calculates the MOSFET load current to determine the power drawn. The output current signal is proportional to the current through the n-channel MOSFET, please see [Figure 4](#) for reference.



**Figure 4:  $I_{OUT}$  vs MOSFET  $I_{DS}$**

Since the  $I_{OUT}$  pin is a current output there is a need for grounding resistor and capacitor to convert the current into voltage and then the MCU can measure it. The resultant voltage is proportional to the  $I_{OUT}$  output current. The voltage is a product of:  $V_{IOUT} = R_{IOUT} \times I_{OUT}$ .

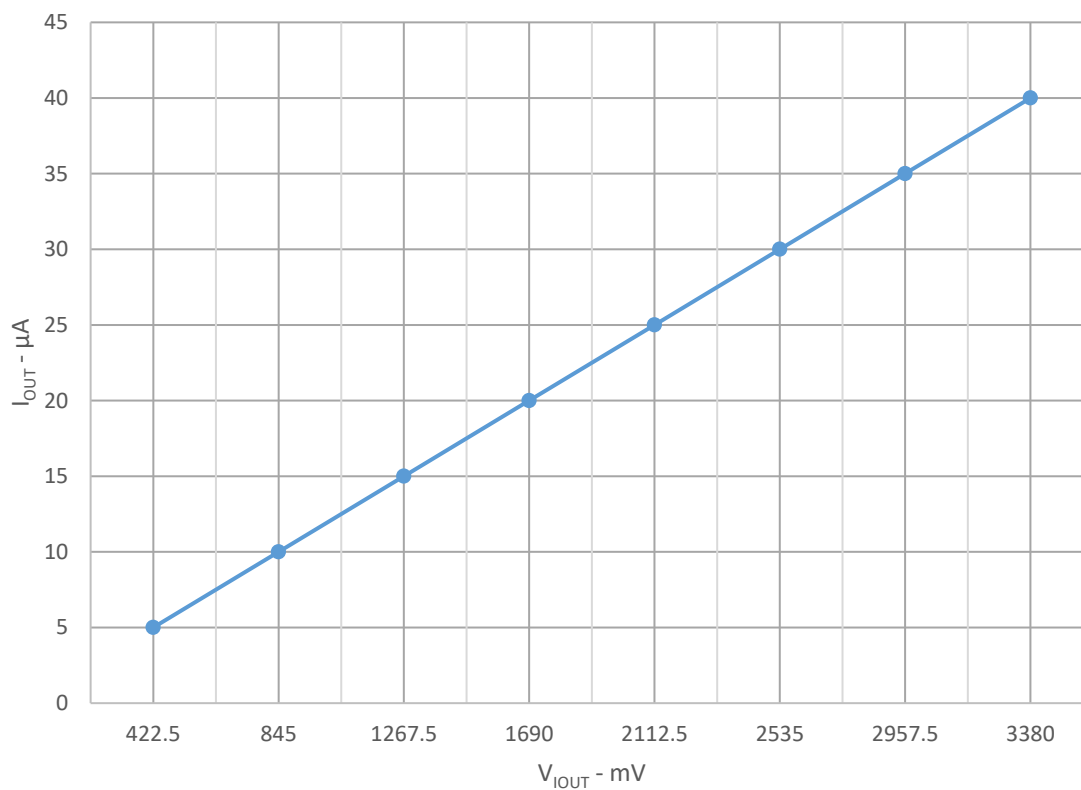


Figure 5: MOSFET  $I_{OUT}$  vs  $V_{IOUT}$  with Grounding Resistor = 84 k $\Omega$

## 4.5 Application Circuit

The internal circuit has seven integral parts. U1 is the Atmega328 system MCU. The IRF7403 is a generic n-MOS transistor. The SLG55021 is a high-side MOSFET driver. U3 is the L78L05\_5V voltage regulator. J1 is the system I<sup>2</sup>C slave communication port. J2 is the input voltage terminal. J3 is the circuit output voltage terminal.

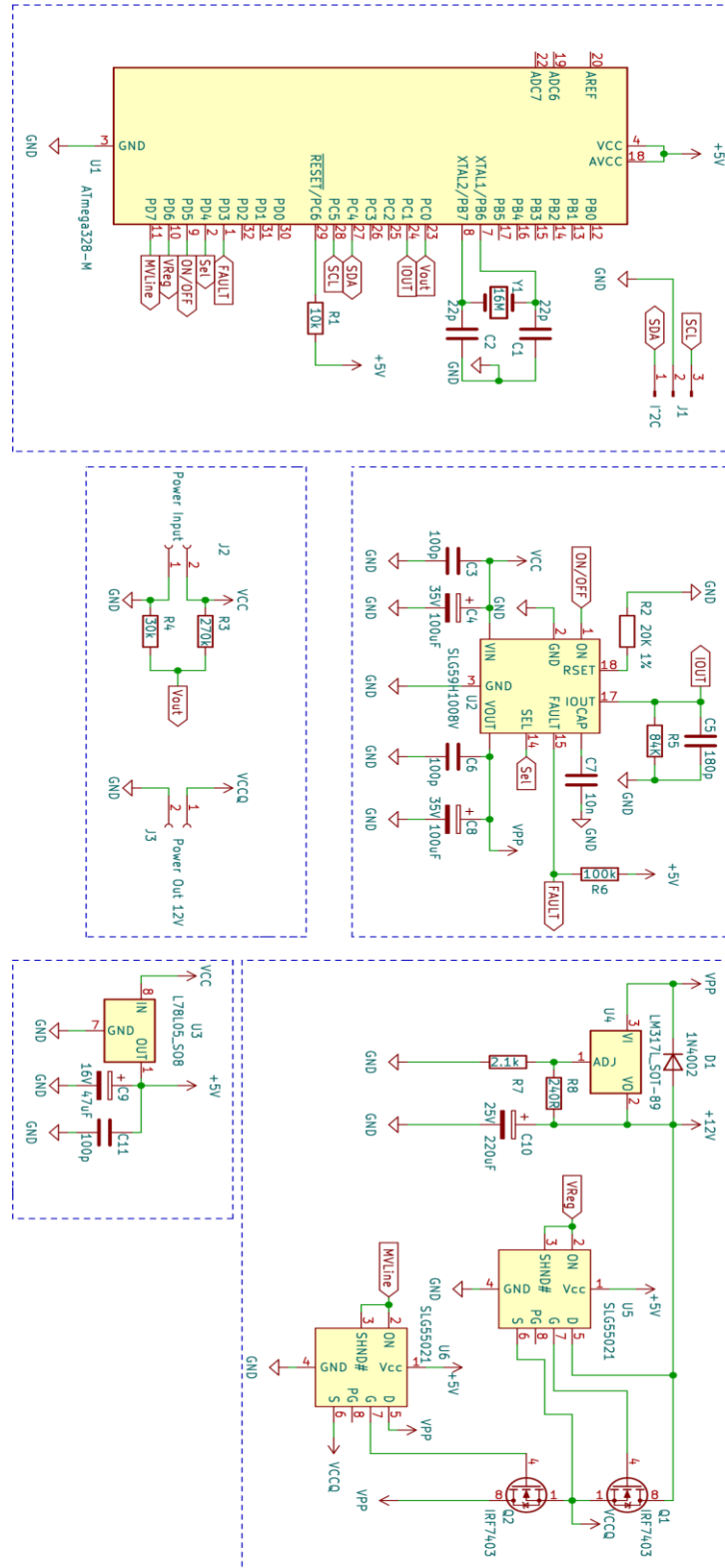


Figure 6: Schematic of an AVS

## 5. Test Setup

For testing the circuit in the application, host system was simulated and debugged using Proteus, which was used for the circuit design, programming of the MCU and performance analysis of the circuit. The circuit is not designed with tight timings because of the low voltage and current sample rate at 10 samples/second.

### 5.1 Test Software Algorithm

The test software algorithm is shown in Figure 7. Operation starts with applying voltage to the circuit. By default, the MCU sets the GreenFET and MOSFET drivers in OFF state and waits for 250 ms before passing to the next step. After power up completion of the first step, the MCU begins to read the  $V_{IN}$  (at rate of 10Hz) to verify if  $V_{IN}$  meets operating ranges. In case  $V_{IN} = 12$  V, the MCU sets system at mode 0 and in case of  $V_{IN} = 24$  V, the MCU sets the system to enter mode 1. In case  $V_{IN} > 25.5$  V or  $V_{IN} < 10.7$  V, the MCU will return to step 1 and repeat the process. The High Voltage GreenFET current verification is done to ensure the load current draw doesn't exceed the operating limit of the SLG59H1008V and prevents it from an overcurrent/short-circuit event. The current verification is implemented by reading the voltage at  $I_{OUT}$  ( $V_{I_{OUT}}$ ) pin, see Figure 5 for reference. If  $V_{I_{OUT}} < 3379$  mV the system will go to the previous step (current sensor verification) to retry the process. If  $V_{I_{OUT}} > 3380$  mV the system will disable all outputs and power OFF the High Voltage GreenFET and wait for 2000 ms before retrying the whole process.

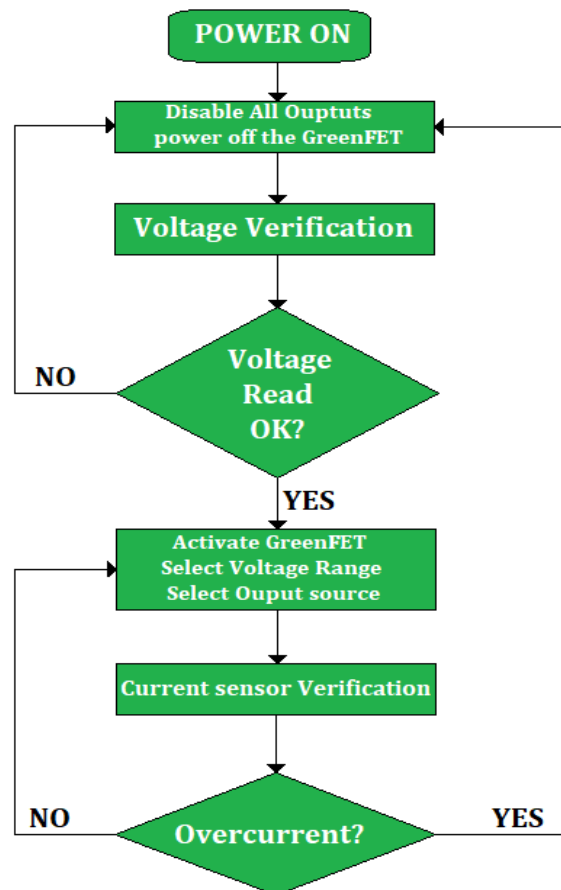


Figure 7: System Algorithm



## 6. Tests

### 6.1 Test Procedures

To ensure functionality of the circuit below procedures were performed:

- Power ON Procedure
- Voltage Verification
- Current Sensor Verification

### 6.2 Test Results

#### 6.2.1 Turn ON Procedure

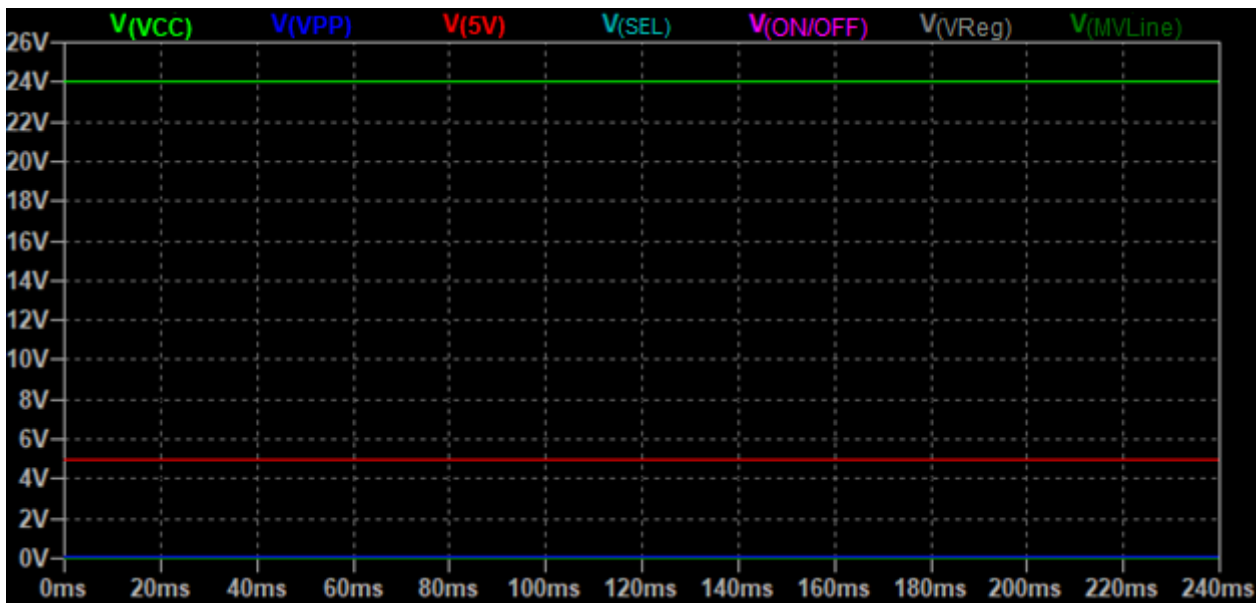
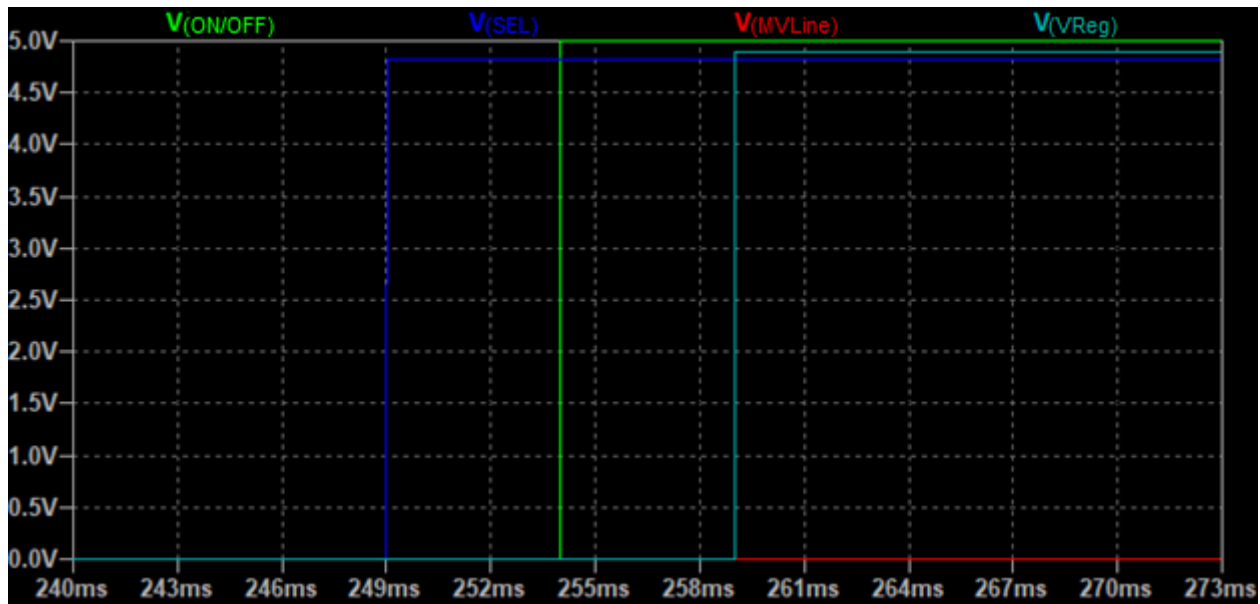
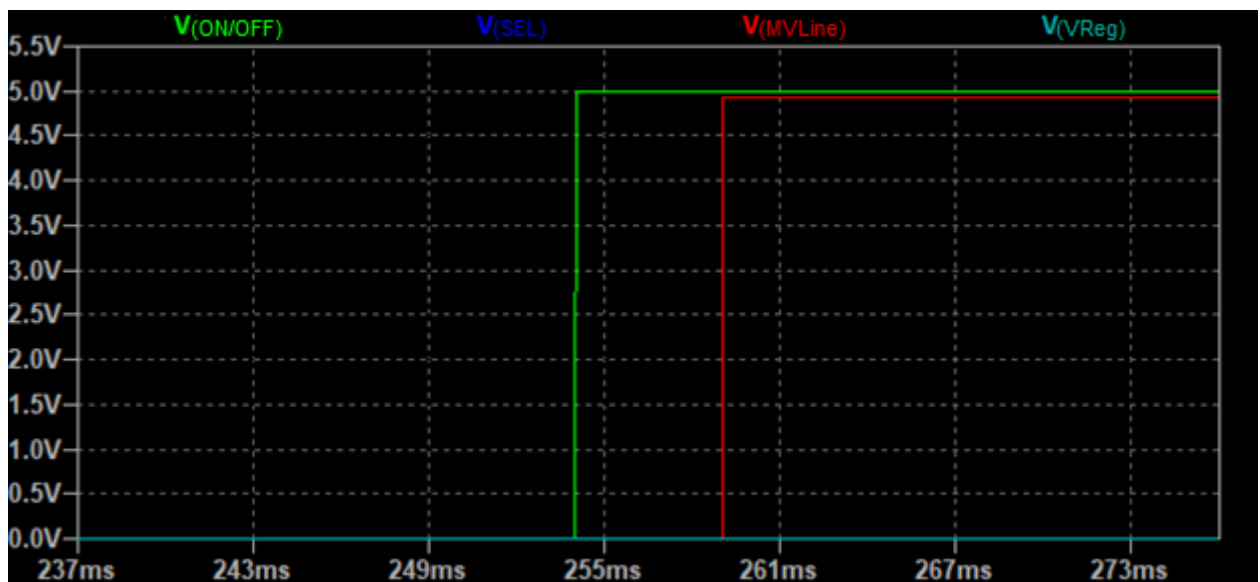


Figure 8: Power ON Sequence

It's possible to verify that control pins  $V_{ON}$ ,  $V_{SEL}$ ,  $V_{VREG}$  and  $V_{MVLine}$  are LOW for the first 250ms after power is established.

#### 6.2.2 Voltage Range Selection

After power ON, MCU begins to read the input voltage  $V_{IN}$  to determinate correct SLG59H1008V configurations. The first pin to be toggled is the SEL ( $V_{SEL}$ ) to set the voltage lockout at 12 V or 24 V. For 24 V operation  $V_{SEL}$  must be set HIGH and for 12 V operation  $V_{SEL}$  must be set LOW. Then ON ( $V_{ON}$ ) pin set  $V_{ON} = \text{HIGH}$  to turn on the SLG59H1008V and  $V_{ON} = \text{LOW}$  to turn it OFF. At last, the voltage bypass control MVLine ( $V_{MVLine}$ ) will be set HIGH if input voltage is 12 V or VReg ( $V_{VReg}$ ) will be set HIGH if input voltage is 24 V.

Figure 9: Timing Sequence for Input Voltage  $V_{IN} = 24\text{ V}$ Figure 10: Timing Sequence for Input Voltage  $V_{IN} = 12\text{ V}$ 

### 6.2.1. Current Verification

Current sensor verification is implemented by reading the current coming from the SLG59H1008V's current sense output ( $I_{OUT}$ ) and comparing it to a pre-programmed max value in the MCU. Proper calibration of the MCU analog reference supply voltage is important to prevent erratic behavior at high current. The overcurrent state is maintained for about 100 ms since some loads have high start-up current.

The load current can be obtained by the following formula  $I = \frac{V_{IOUT}}{R_{IOUT} \times 0.01}$  where  $V_{IOUT}$  is the voltage generated at the SLG59H1008V  $I_{OUT}$  pin and  $R_{IOUT}$  is the grounding resistor at  $I_{OUT}$  pin.

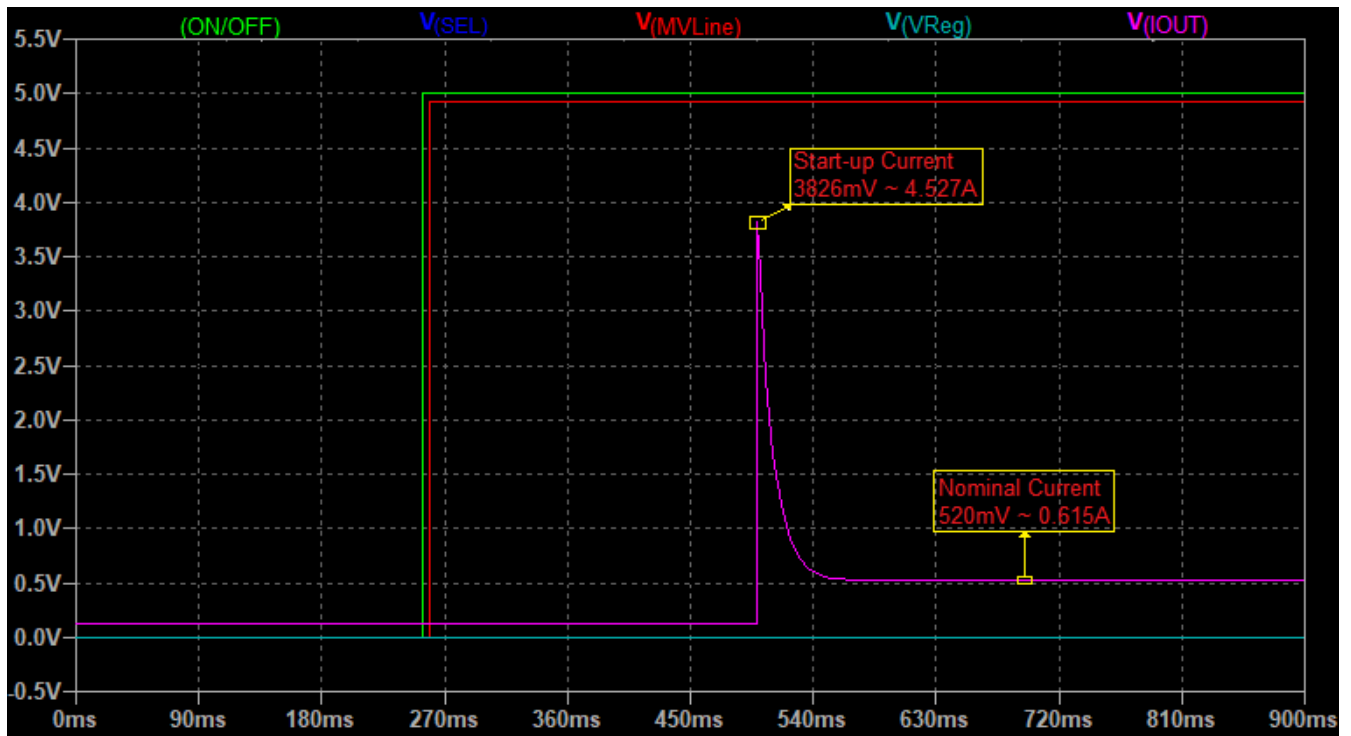


Figure 10: Signal Diagram of High Start-up Current

In Figure 10 an example of a high start-up current spike is shown and it exceeds the SLG59H1008V max limit of 4.5A. While such current spike can be dangerous, in this case isn't harmful since it only lasted for few milliseconds before stabilizing at nominal value. This kind of high current burst is caused by a load that contain high capacitance or decoupling capacitors.

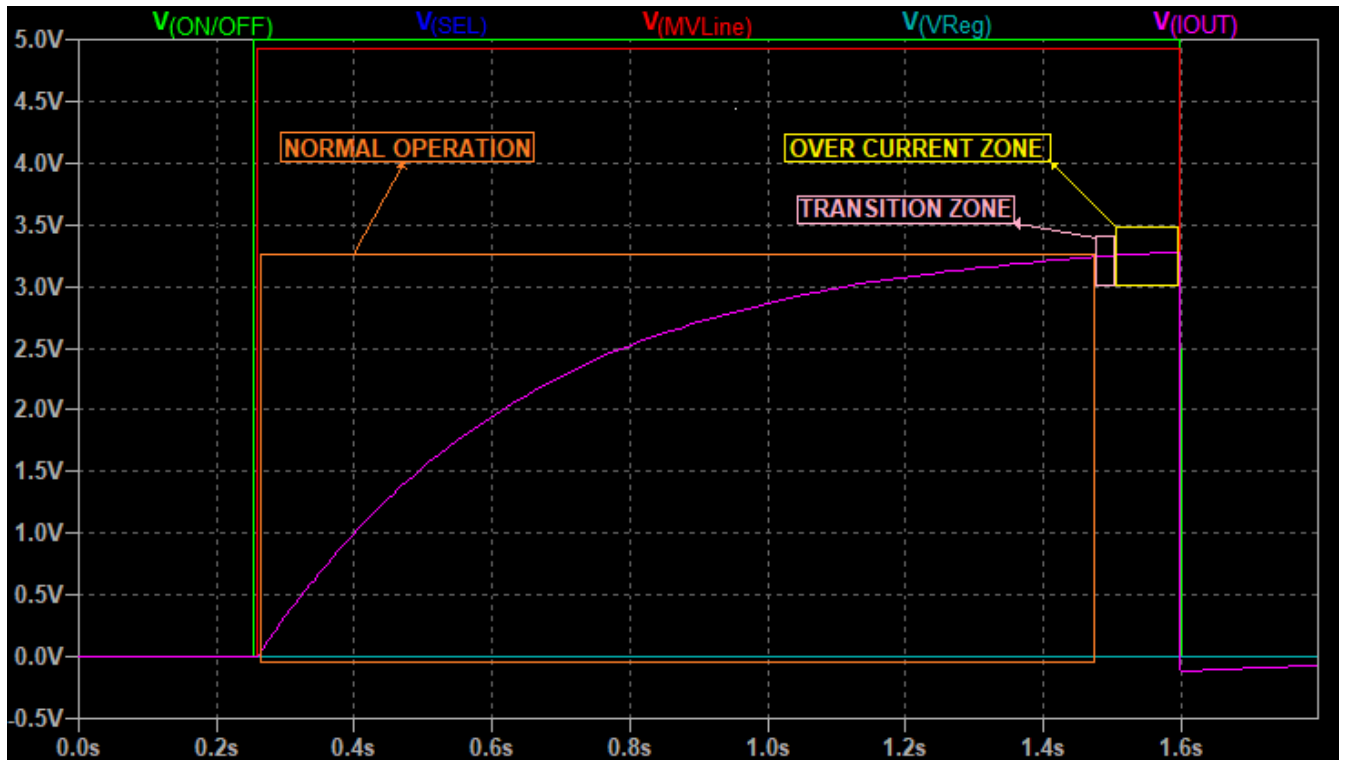


Figure 11: Signal Diagram of an Overcurrent Event with Control Signals Deactivation

Figure 11 shows an example of a current curve. This current curve shows the various current zones. When the load current is between 0 A and 3.99 A the system is at normal operation. Once the load current is at 4 A the system is at a transition state, but operation is allowed since it's at the 4 A maximum continuous operating current level. When the load current is greater than 4 A the system is at overcurrent state. This state is only allowed for a pre-programmed 100 ms duration and allows current to reach 4.5 A, see Figure 10 for reference. If overcurrent state is maintained for more than 100 ms the system will power OFF the High Voltage GreenFET.

## 7. Conclusion

In this application note, the SLG59H1008V GreenFET load switch is implemented in AVS application intended for use in systems that can work with different input voltage ranges. The benefits of Renesas High Voltage GreenFET products is that total application cost is reduced due to all required functions for the system which are already integrated into a single small IC, especially operating voltage range switch, current sensing and fault detection. When designing a circuit to implement this solution, attention is required to maximize PCB passive cooling efficiency.

## 8. Revision History

Revision	Date	Description
1.00	May 15, 2023	Initial release.

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