# Application Note

## Applying Dialog Integrated Power Switches in Bidirectional Applications

### AN-CM-268


## Abstract

*This application note describes how to use Dialog unidirectional integrated power switches in bidirectional applications while keep operating all protection features including Current Limiting, Short Circuit Protection, Thermal Shutdown Protection and Inrush Current Control. Corresponding oscilloscope captures of operational behavior are included.*

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# 1 Terms and Definitions

| | |
|---|---|
| BPS | Bidirectional Power Switch |
| IPS | Integrated Power Switch |
| ACL | Active Current Limit |

# 2 References

[1] SLG59M1558V, Datasheet, Dialog Semiconductor.

[2] SLG59M1709V, Datasheet, Dialog Semiconductor.

[3] AN-1068, GFET3 and HFET1 Integrated Power Switch Basics, Application Note, Dialog Semiconductor.

Author: Andrii Hrypa

 

# 3 Introduction

Portable devices constitute the fastest growing segment of modern electronics in number and type. When portable devices are charging, current flows INTO the battery. When the charging adapter is removed and the portable device is powered up, current flows FROM the battery to power the device. It follows that such a system needs an active component which can conduct current in both directions. Furthermore, this component should have an ability to block positive and negative voltages to prevent battery discharge when the device is turned off. There are, in general, two ways to deal with this system-level issue. The first one is to use dedicated bidirectional power switches available on the market, but at a hefty price. Another way is to construct such an active component using discrete or integrated MOSFETs, at lower cost. This is the approach we will describe.

MOSFETs have a body diode, so it blocks voltage only in one direction. To block voltages in both directions, an additional series diode of opposite polarity can be used, but in this case, current flow is unidirectional. To achieve bidirectional current flow with ability to block voltages in both directions, a second MOSFET is needed. Thus, a bidirectional power switch (BPS) is a four-quadrant switch that can block positive and negative voltages in the OFF state and allows load currents in either direction in the ON state.

Figure 1 shows common configurations which can be used for BPS realization using MOSFETs: a) - common drain N-channel MOSFETs; b) - common source N-channel MOSFETs; c) - common drain P-channel MOSFETs and d) - common source P-channel MOSFETs.

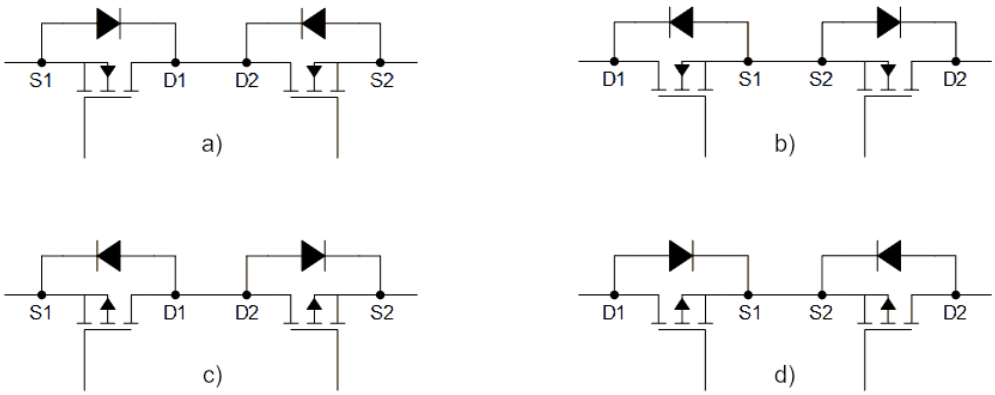


**Figure 1. Common Configurations for BPS Realization**

This application note will describe BPSs constructed with common-drain connected pairs of Dialog unidirectional integrated power switches (IPS), both P and N-channel. In these circuits, the IPSs' source terminals are respectively connected to power supply and load.

# 4 A Very Low-power, Bidirectional Power Switch using Two SLG59M1558Vs

The SLG59M1558V is a 28.5 mΩ, 1.0 A rated P-channel MOSFET controlled by a single ON pin and is packaged in an ultra-small 1.0 x 1.0 mm package. Serially connecting these two IPSs in the way shown in Figure 2, a simple and very small bidirectional power switch can be obtained.

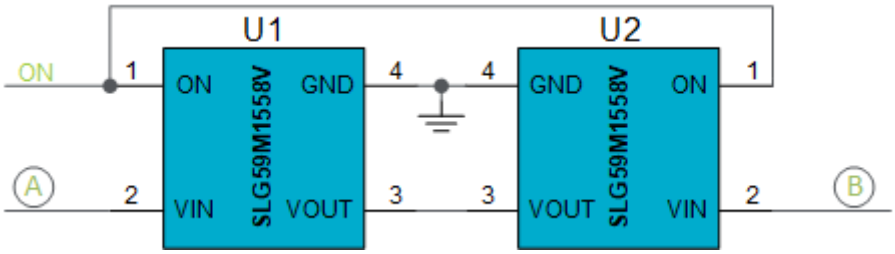


**Figure 2. A Very Small and Very Low Power Bidirectional Power Switch Realization using a Pair of Dialog SLG59M1558V IPSs**

Let's assume that terminal "A" is the input terminal of the BPS and the ON pin is asserted LOW. The "B" terminal has a 20 Ω load resistor and 10 µF load capacitor. When 5 V is applied at terminal "A" this voltage is blocked from U2-3 because the ON pin is asserted LOW. When the ON pin becomes asserted HIGH, U1 and U2 close simultaneously and the voltage appears at terminal "B". This power-up operation is illustrated in Figure 3.

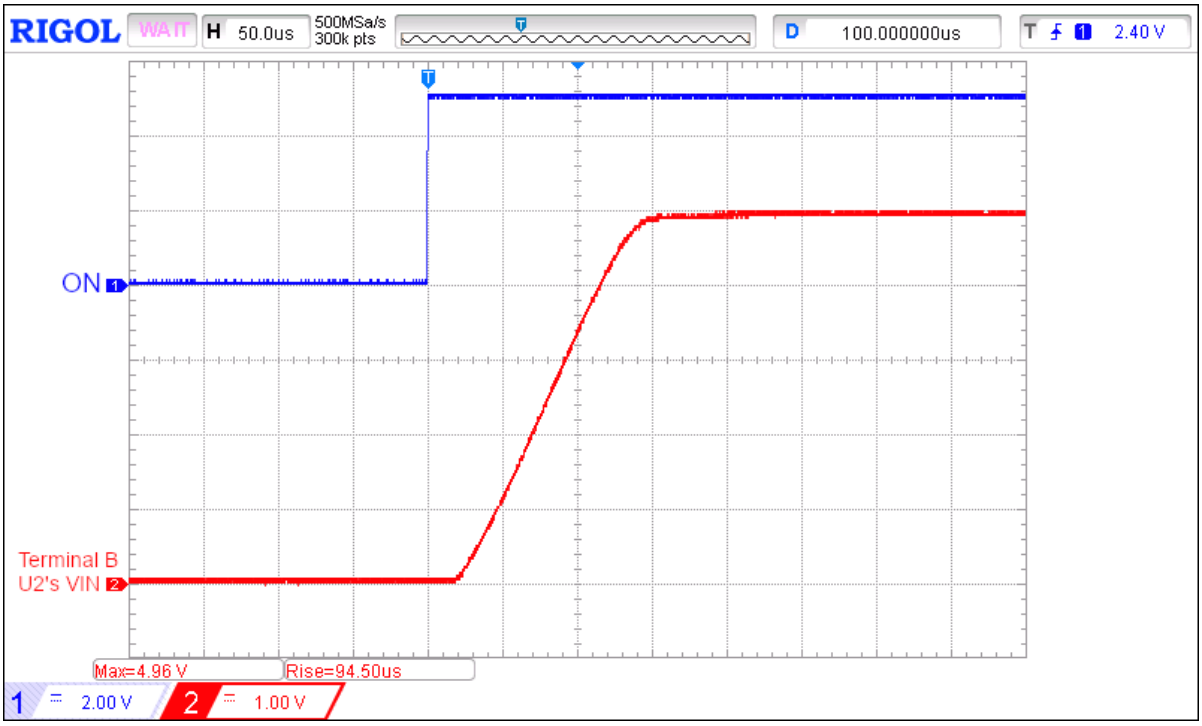


**Figure 3. BPS turn-ON Operation for Two, Series-connected SLG59M1558V IPSs for $V_{IN(A)}$ = 5 V, $R_{LOAD}$ = 20 Ω, $C_{LOAD}$ = 10 µF**

BPS turn off operation waveforms with and without capacitive loads are presented in Figure 4 and Figure 5, respectively.

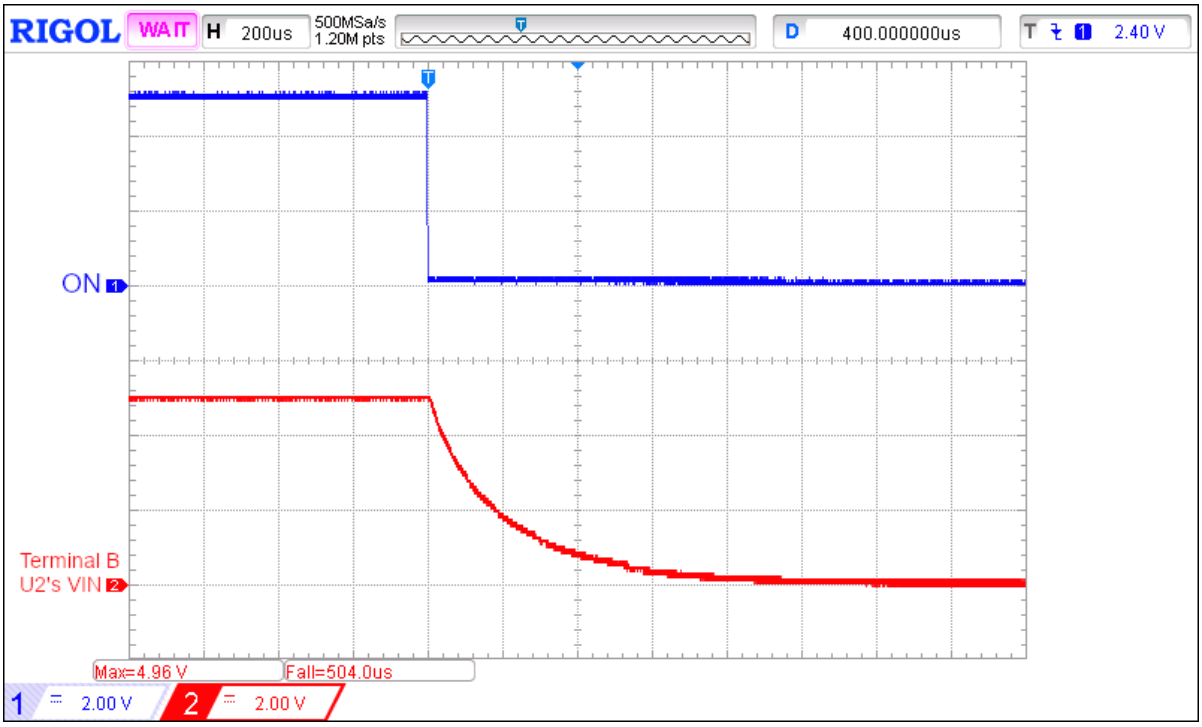


**Figure 4. BPS Turn-OFF Operation for Two, Series-connected SLG59M1558V IPSs for $V_{IN(A)}$ = 5 V, $R_{LOAD}$ = 20 Ω, $C_{LOAD}$ = 10 µF**

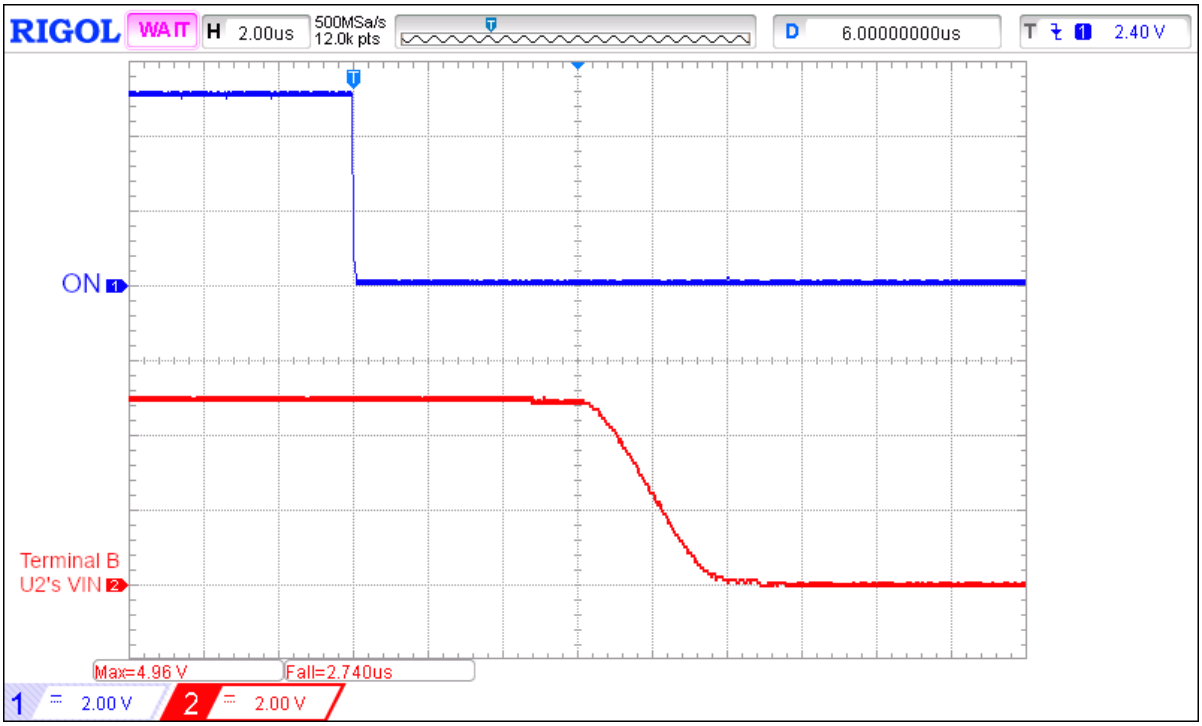


**Figure 5. BPS Turn-OFF Operation for Two, Series-connected SLG59M1558V IPSs for $V_{IN(A)}$ = 5 V, $R_{LOAD}$ = 20 Ω, no $C_{LOAD}$**

BPS behavior for reverse load-current operation is the same.

 

# 5 A Feature-rich, High-performance Bidirectional Power Switch using Two SLG59M1709Vs

Operating from a 2.5 V to 5.5 V power supply and fully specified over the -40 °C to 85 °C temperature range, the SLG59M1709V is a high-performance 4 mΩ, 4 A single-channel nFET integrated power switch with adjustable inrush current control which is achieved by adjusting the $V_{OUT}$ slew rate with an external capacitor. Using a proprietary MOSFET design, the SLG59M1709V achieves a stable 4 mΩ $RDS_{ON}$ across a wide input/supply voltage range. Incorporating two-stage current protection as well as thermal protection, the SLG59M1709V is designed for all 0.8 V to 5.5 V power rail applications.

For this type of Dialog IPS, a common drain connection is selected as was shown in Figure 1a. The resulting design of this BPS is shown in Figure 6.

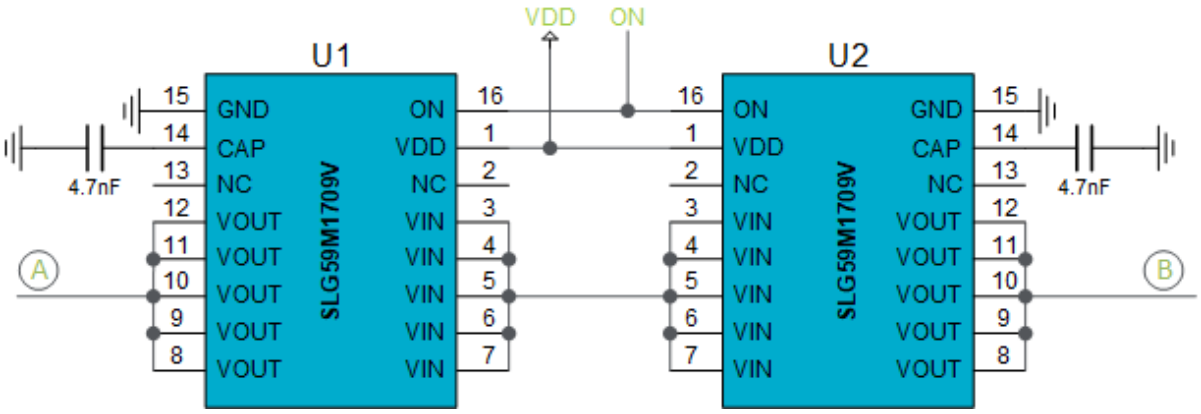


**Figure 6: A High-performance, Bidirectional Power Switch using a Pair of Dialog SLG59M1709V IPSs.**

ON and VDD pins of U1 and U2 are connected in parallel, respectively, so both ICs can be turned on and off simultaneously. The BPS's output voltage follows a linear ramp set by a capacitor connected to each CAP pin. A larger capacitor value at the CAP pin produces a slower ramp, reducing inrush current from capacitive loads.

By applying 5 V at terminal "A", which corresponds to the U1's VOUT pins (U1-[8:12]), imparts a voltage at the node common to U1 and U2. This takes place because of the U1's body diode, which in this case is forward biased. Since there is a voltage drop across this diode, the voltage at the node common to both ICs (U1-[3:7] and U2-[3:7]) is approximately 4.4 V. This voltage is blocked by U2 because its ON pin asserted LOW. When the ON pin is asserted HIGH, both IPSs power up and the voltage now appears at terminal "B". During power up, a small transition, illustrated in Figure 7, can be observed. It is caused by internal linear ramp control circuit operation.

Turn-off operation waveforms with and without capacitive loads are presented in Figure 8 and Figure 9, respectively.

The reverse operational behavior of the BPS from terminal "B" to terminal "A" remains the same as in the forward direction.

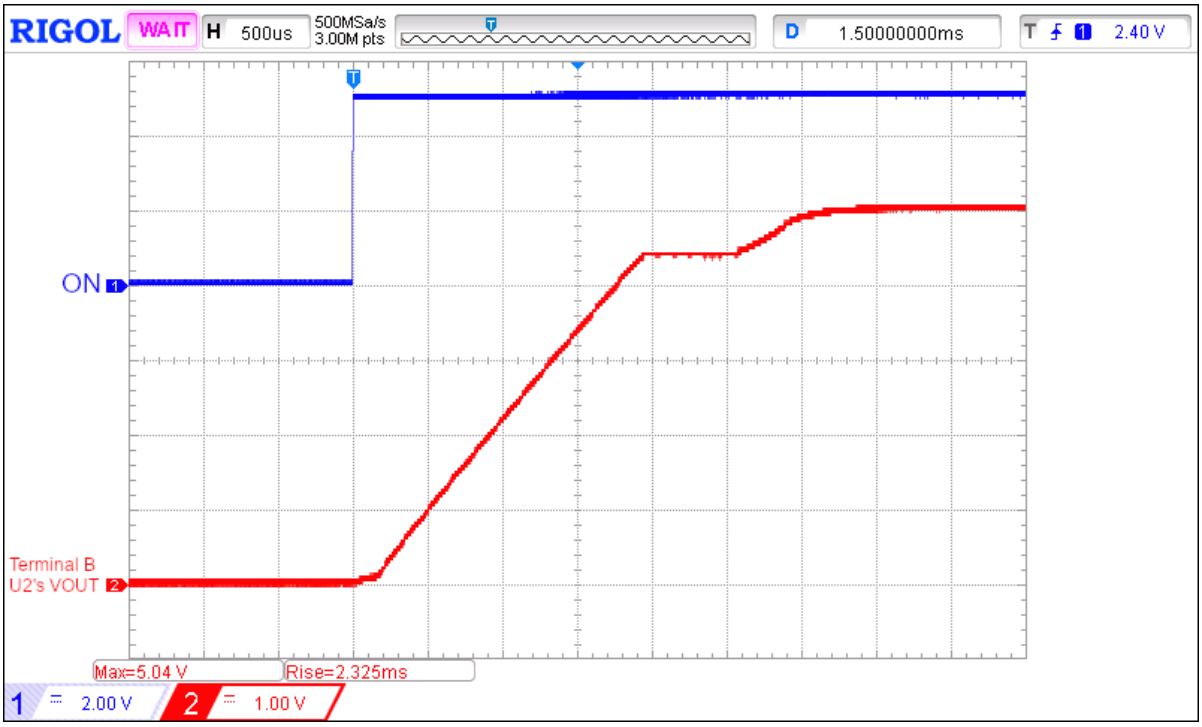


**Figure 7. BPS Turn-ON Operation using a Pair of Series-connected SLG59M1709V IPSs for $V_{OUT(A)}$ = 5 V, $R_{LOAD}$ = 20 Ω, $C_{LOAD}$ = 10 µF**

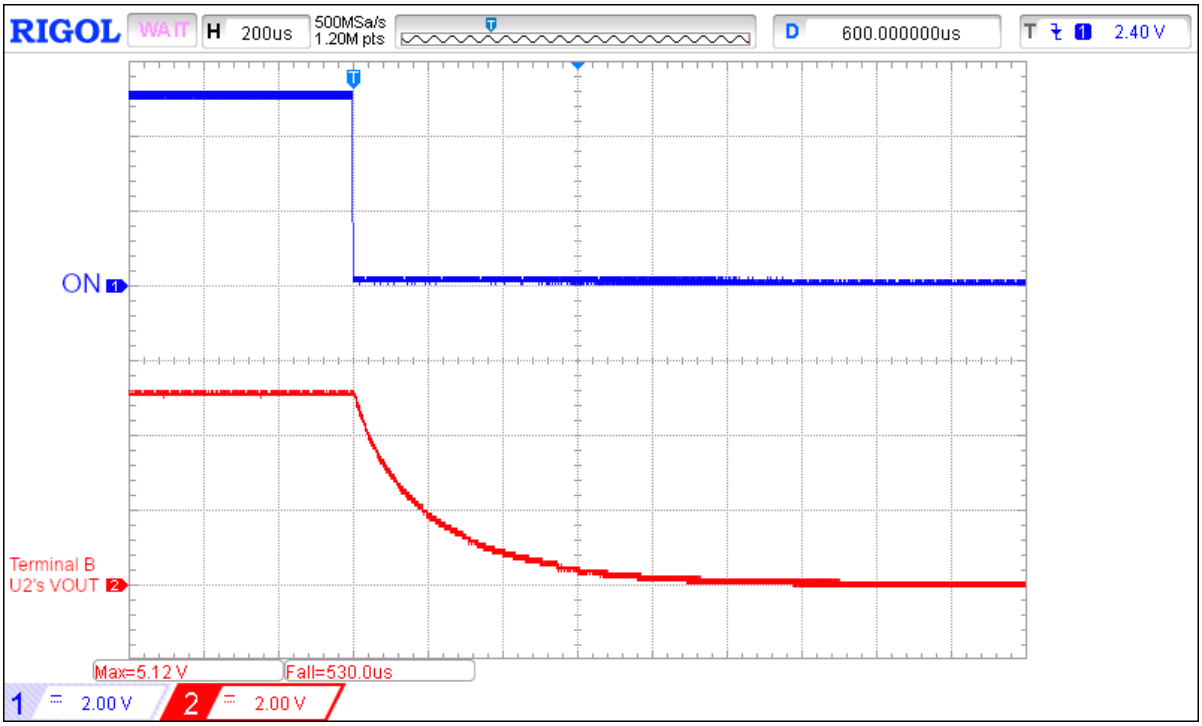


**Figure 8. BPS Turn-OFF Operation using a Pair of Series-connected SLG59M1709V IPSs for $V_{OUT(A)}$ = 5 V, $R_{LOAD}$ = 20 Ω, $C_{LOAD}$ = 10 µF**

 

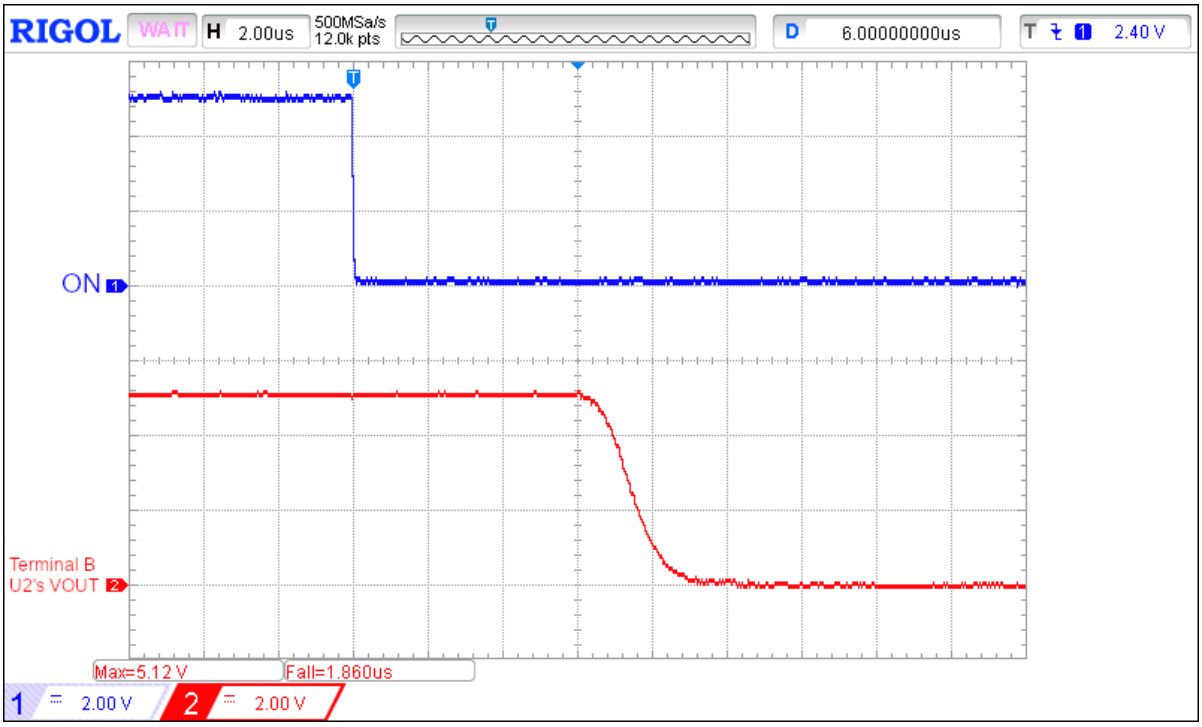


**Figure 9. BPS Turn-OFF Operation using a Pair of Series-connected SLG59M1709V IPSs for $V_{OUT(A)}$ = 5 V, $R_{LOAD}$ = 20 Ω, no $C_{LOAD}$**

Constructing a bidirectional power switch using the SLG59M1709V and similar IPSs retains all protection features. Thus, an IPS's Active Current Limit, Short Circuit Protection, Thermal Shutdown Protection, and Inrush Current Control can easily protect important components upstream and downstream of the IPS as well as the IPS itself.

For example, when the BPS's output voltage is greater than 300 mV, output current is initially limited to U2's Active Current Limit ($I_{ACL}$) threshold which is 8 A (from the SLG59M1709V's spec sheet). When a load current overload is detected, U2's ACL monitor increases U2's FET resistance to keep the current from exceeding the U2's $I_{ACL}$ threshold. During active current-limit operation, the output voltage is also reduced by $I_{ACL}$ x $RDS_{ON(ACL)}$. However, if the load-current overload condition persists where the die temperature rises because of the increased FET resistance, the U2's internal Thermal Shutdown Protection circuit will be activated. If the die temperature exceeds 125 °C, U2's FET is shut OFF completely, thereby allowing the die to cool. When U2's die cools to 100 °C, U2's FET is turned back on. This process may repeat while the output current overload condition persists. Operation of both Active Current Limit protection as well as Thermal Shutdown Protection is illustrated in Figure 10.

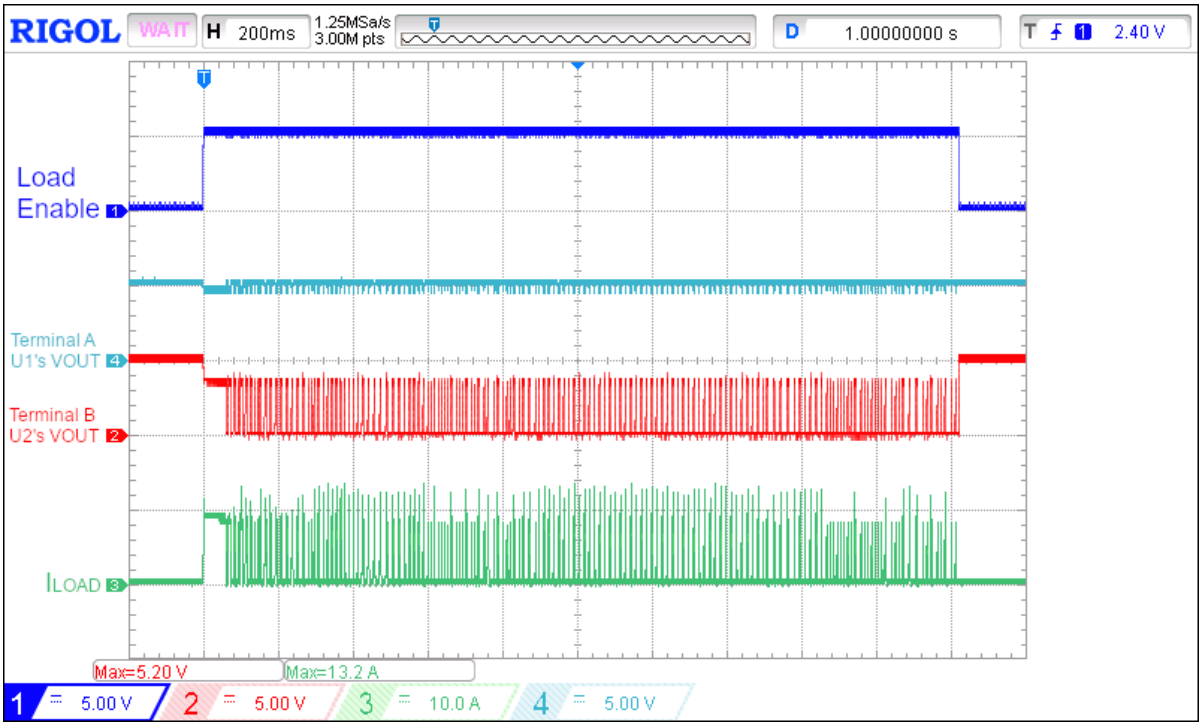


**Figure 10. BPS ACL and Thermal Shutdown Protection Operation Waveform using a Pair of Series-connected SLG59M1709V IPSs**

When the BPS's output voltage is less than 300 mV (a short circuit condition), the U2's internal Short-circuit Current Limit (SCL) monitor limits the FET current to approximately 500 mA (the $I_{SCL}$ threshold). Observed BPS behavior is shown in Figure 11.

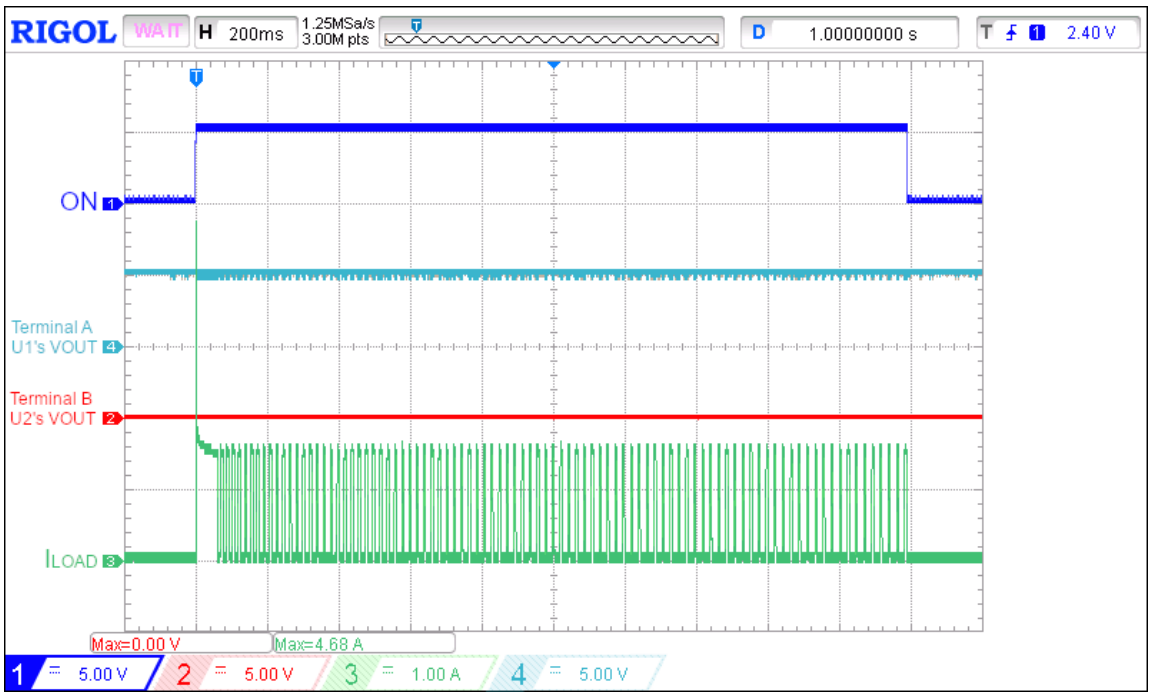


**Figure 11. BPS Short Circuit Protection with Thermal Shutdown Protection Operation using a Pair of Series-connected SLG59M1709V IPSs**

# 6 Conclusions

In this application note, the SLG59M1558V and SLG59M1709V Dialog IPSs were configured for bidirectional applications. Additionally, it is also possible to use other P- and N-channel Dialog IPSs provided that those IPSs do not include Reverse-Current Blocking, Reverse-Voltage Blocking, and VOUT Discharge features. Dialog IPSs featuring Active Current Limiting and Short Circuit Current Limiting Modes with Thermal Shutdown Protection, and Inrush Current Control are all excellent candidates for constructing high-performance, pcb space-efficient bidirectional power switches.

The list of GFET3 Dialog IPSs which can be used for bidirectional power switching applications (at time of this writing) are listed below:

- SLG59M1442V
- SLG59M1545V
- SLG59M1556V
- SLG59M1599V
- SLG59M1657V
- SLG59M1710V
- SLG59M1721V
- SLG59M1735C

More detailed information can be found on www.dialog-semiconductor.com/power-switching

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| Status | Definition |
|---|---|
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# Contacting Dialog Semiconductor

United Kingdom (Headquarters)
*Dialog Semiconductor (UK) LTD*
Phone: +44 1793 757700

Germany
*Dialog Semiconductor GmbH*
Phone: +49 7021 805-0

The Netherlands
*Dialog Semiconductor B.V.*
Phone: +31 73 640 8822

Email:
enquiry@diasemi.com

North America
*Dialog Semiconductor Inc.*
Phone: +1 408 845 8500

Japan
*Dialog Semiconductor K. K.*
Phone: +81 3 5769 5100

Taiwan
*Dialog Semiconductor Taiwan*
Phone: +886 281 786 222

Web site:
www.dialog-semiconductor.com

Hong Kong
*Dialog Semiconductor Hong Kong*
Phone: +852 2607 4271

Korea
*Dialog Semiconductor Korea*
Phone: +82 2 3469 8200

China (Shenzhen)
*Dialog Semiconductor China*
Phone: +86 755 2981 3669

China (Shanghai)
*Dialog Semiconductor China*
Phone: +86 21 5424 9058