Application Report

SNVA747B–October 2015–Revised March 2017

Active OR-ing Solution with LM74610-Q1 Smart Diode Controller

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ABSTRACT

This application note demonstrates the use of TI's Zero Iq Reverse Polarity Protection Smart Diode Controllers- LM74610-Q1 as a highly effective solution in redundant N+1 power supply arrangements. It also highlights higher solution efficiency, ease of use and the unique scheme of the LM74610-Q1 as a replacement of Schottky diodes and P-channel MOSFET solutions.

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1 Introduction

The LM74610-Q1 is a controller device, used in conjunction with an external N-Channel MOSFET in a reverse polarity protection circuitry. The LM74610 is designed to drive an external MOSFET and emulate an ideal diode rectifier when connected in series with a power supply. This revolutionary device has a unique floating scheme and the design architecture is not referenced to ground. This mimics an ideal diode solution and makes LM74610-Q1 essentially a zero Iq device.

The LM74610-Q1 provides a charge pump gate drive for an external N-Channel MOSFET and a fast pull-down to turn the FET OFF in the event of reverse polarity. It can be combined with a verity of MOSFETs and has no positive input voltage or output current limitation. It can protect the circuit from negative voltage including ISO spikes down to -45V. The forward voltage losses mainly depend on the R_{DSON} of the selected MOSFET. This is because the MOSFET conducts 98% and the body diode conducts only 2% of the time with 0.6V of typical diode forward bias drop.

2 OR-ing Controller Requirements

Basic redundant power architecture comprises of two or more voltage or power supply sources driving a single load. The redundant supply architectures are commonly used in high-end systems including many automotive and communication hardware designs. Some systems require high availability to choose between more than one available power sources and often use multiple parallel-connected power supplies to improve reliability. Active OR-ing solutions are used in redundant power architectures of various bus voltages, depending on the end system requirement. The voltage range can vary between low (2.5V, 3.3V, 5V) and medium voltage up to 48V.

The power supplies in redundant power architecture typically have low output impedance. They are all active simultaneously and typical system requirement is unidirectional current path. This prevents the smaller voltage supplies from following voltage of the higher voltage source.

3 OR-ing Solution Approaches

In it's simplest form, the OR-ing solution for redundant power supplies consists of Schottky OR-ing diodes that protect the system against an input power supply fault condition. A diode OR-ing device has unidirectional current flow, thus it isolates the fault from the redundant bus. The system keeps running off the remaining power sources if one or more sources become faulty. A diode OR-ing device provides effective and low cost solution with few components. Nevertheless, the diodes forward voltage drops affects the efficiency of the system permanently, since each diode in an OR-ing application spends most of its time in forward conduction mode. These power losses become significant at higher current and increase the requirements for thermal management and allocated board space. In today’s high-end systems, the lossy diodes can cause more complications and affect the performance of the surrounding components.

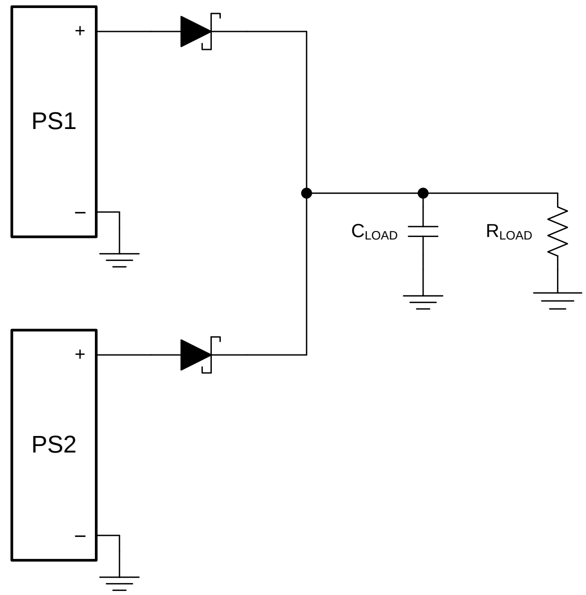

Figure 1. Schottky Diodes Used for OR-ing

Using the example of the 12V, 8A supply, and assuming a forward voltage drop of 0.4 V, a total of 3.2W is dissipated in the Schottky diode. This results in an unnecessary reduction in the efficiency of the system. In addition, proper thermal management must be implemented to handle the power dissipation due to diode's forward drop.

4 Active OR-ing Solution with LM74610-Q1 Smart Diode Controller

One solution to the lossy schottky diode is to replace them with MOSFETs and controller ICs. The ON state forward voltage loss in a MOSFET is insignificant and depends upon the RDSON of the MOSFET. The power losses become substantially lower than the schottky diode for equivalent current. This solution has a small increase in complexity; however it eliminates the need for diode heatsinks or a large thermal copper area in PCB layout for high power applications. This scheme of active OR-ing typically shows 10x reduction in power losses versus a diode OR-ing device.

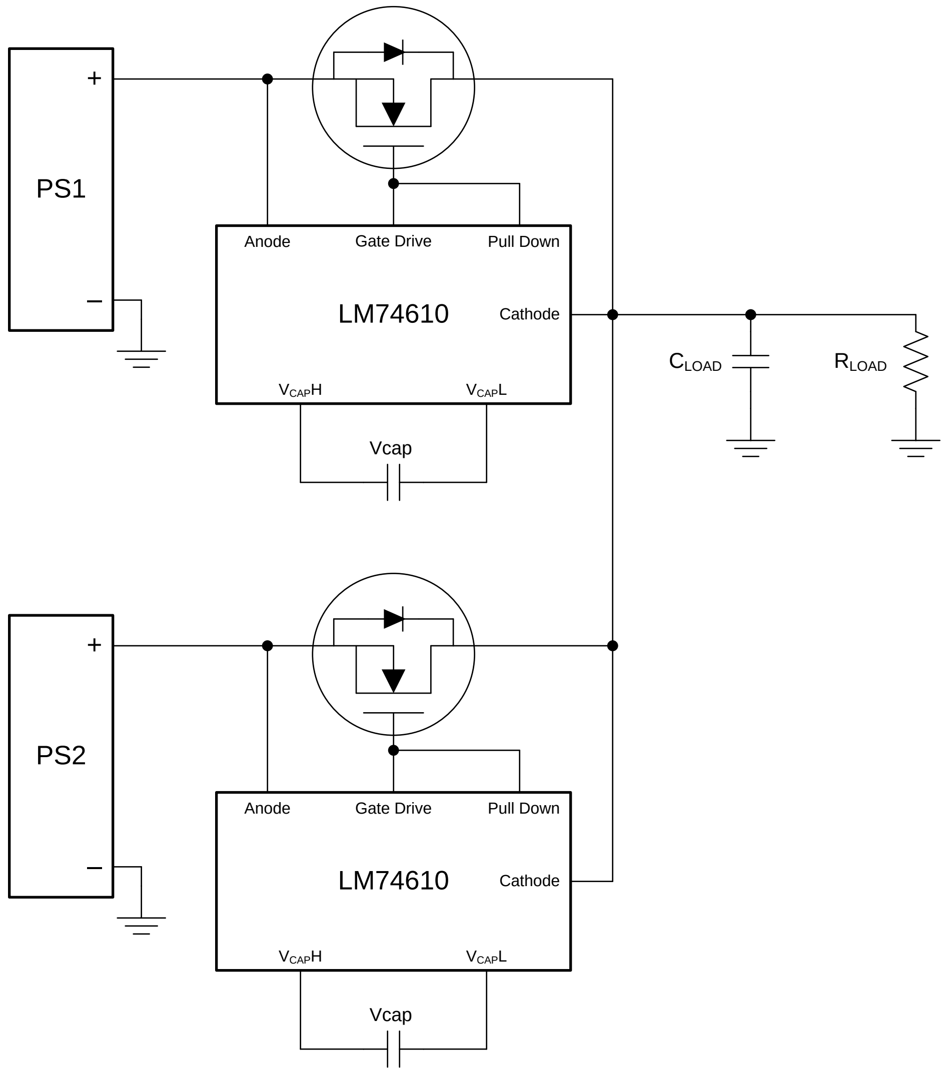

Figure 2. Active OR-ing Application Circuit with LM74610-Q1

The LM74610-Q1 ICs combined with N-Channel MOSFETs behave as ideal diode rectifiers in an OR-ing device. The source to drain voltage (V_{DS}) for each FET is monitors by the ANODE and CATHODE pins of the LM74610-Q1. An internal charge pump is used to provide the GATE drive for the each MOSFET. Therefore, the forward conduction is through MOSFET 98% of the time which avoids the diode forward voltage drop. The body diode of the MOSFET only conducts the remaining 2% of the time to allow the charge pump capacitor to be fully charged.

When power is initially applied, the load current ($_{ld}$) will flow through the body diodes of both MOSFETs. This will produce a voltage drop (V_f) across the body diodes of the MOSFETs. If the detected V_f is positive, it is used to charge up the charge pump capacitor Vcap. When Vcap charge reaches a high voltage threshold, 6.1V (typical), the MOSFET gate is turned ON for a much longer period of time. The gate will remain ON and the drain current will flow though the MOSFET until the charge pump capacitor reaches its lower threshold, ~5.1V.

In any OR-ing controller device, if the input supplies operate at slightly different voltages, the common load follows the higher voltage supply. This situation causes a reverse current flow from the common load point to the lower voltage supply rail. Schottky diodes are very effective in blocking this current immediately. However, active OR-ing with MOSFET has trade-offs. When a MOSFET is turned ON, it allows current to flow in either direction through its channel. If one of the power sources operate at higher voltage or fail due to a short circuit, a large current can be allowed to flow in the reverse direction as long as the MOSFET gate is enhanced. If this situation sustains for long period of time, the bus voltage will discharge and bring down the end system.

5 Active OR-ing Fast Pull-Down Solution with LM74610-Q1

This is essential for an OR-ing device to fast detect the reverse current and instantly pull-down the MOSFET gate to block the reverse current flow. An effective OR-ing solution needs to be extremely fast to limit the reverse current amount and duration, similar to the conventional diode OR-ing device. The LM74610-Q1 devices in Active OR-ing configuration constantly sense the voltage difference between ANODE and CATHODE pins, which are the voltage levels at the power sources (PS1, PS2) and the common load point respectively. When either of the power sources operates at lower voltage, it makes the common load point voltage of the OR-ing device higher than the supply voltage. Alternatively, the CATHODE pin detects higher voltage than the ANODE pin of the LM74610-Q1. Once a negative polarity is sensed, the Pull-Down pin (connected to the Gate), shuts down the FET gate within 2μsec by sinking and discharging gate capacitance. This fast pull-down function limits the amount and duration of reverse current flow. The reverse leakage current for the LM74610-Q1 doesn't exceed 110μA which is much smaller than the reverse leakage current of a Schottky Diode (15mA). Figure 3 shows the LM74610-Q1 fast pull-down response to a negative voltage across Anode and Cathode pins.

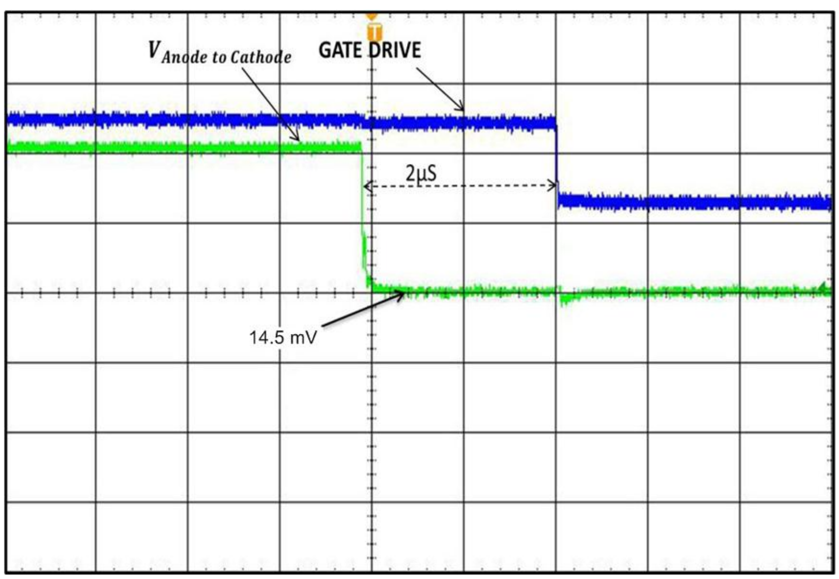

Figure 3. LM74610-Q1 Pull-Down Operation when Negative Polarity is Detected

The scope plot in Figure 3 shows the high speed turn off of the external MOSFET gate during an input power supply fault condition that causes reverse current flow through the MOSFET.

6 Advantages of LM74610-Q1 OR-ing Device

The LM74610-Q1 offers the following advantages when used in an OR-ing device:

1. The forward voltage drop is very low compared to the Schottky diodes. The forward voltage drop depends on the RDSON of the external MOSFET used in scheme.
2. The low forward voltage drop translates to very low power dissipation as compared to simple schottky diodes.
3. The LM74610-Q1 OR-ing device is highly efficient and has lack of dependencies on thermal management overhead.
4. It has more accuracy with respect to reverse current threshold across the MOSFET.
5. Fast GATE pull-down function to limit the amount and duration of reverse current through the MOSFET during an input power source fault condition
6. Smaller package size VSSOP 8-pin, combined with an external MOSFET and charge pump capacitor makes the solution size comparable to D2PAK schottky diodes.

7 Schematic

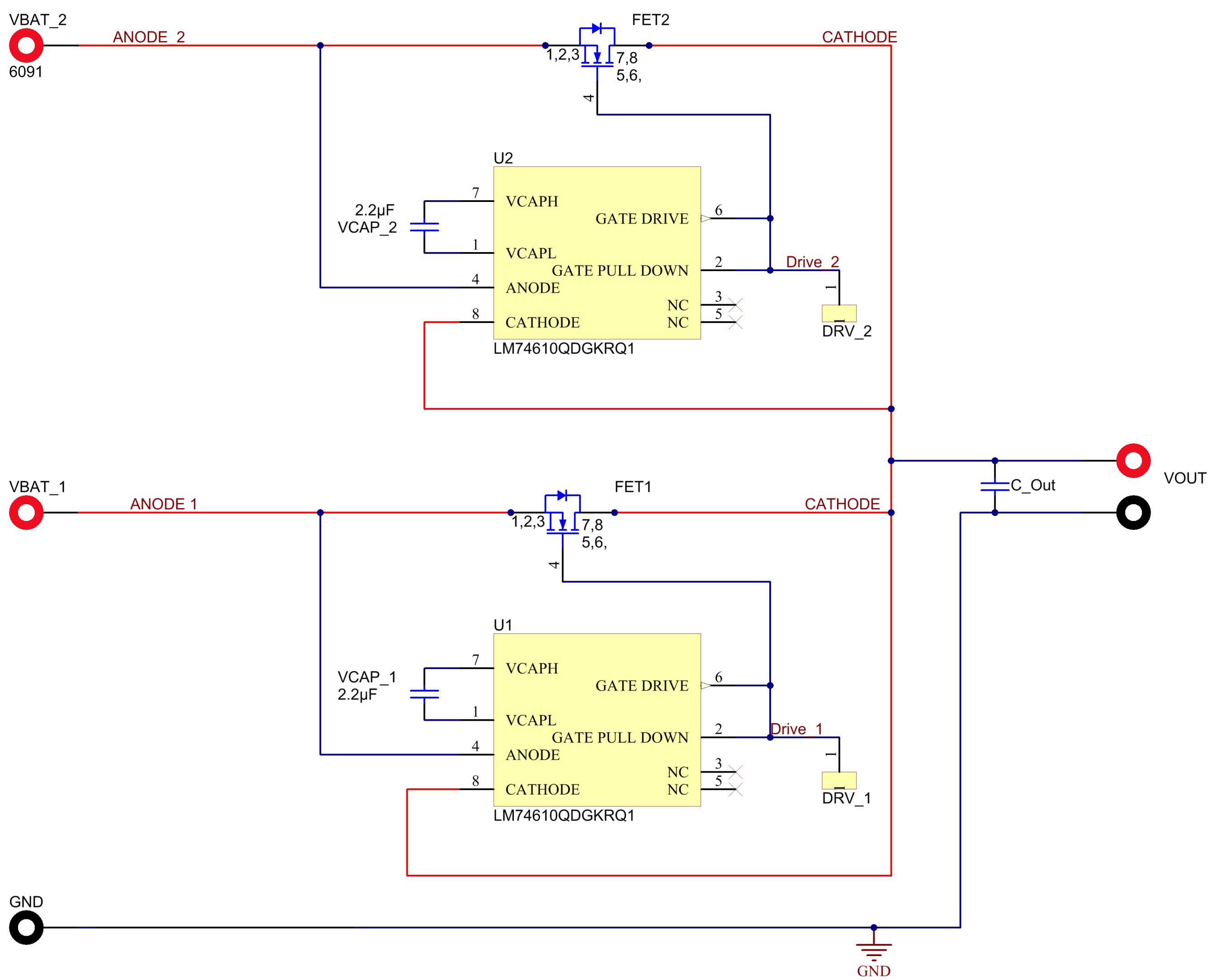

Figure 4. Schematic of LM74610-Q1 OR-ing Device

8 Test Results

8.1 Power Supply Failure

LM74610-Q1 OR-ing device with 5A Load and 12V supply

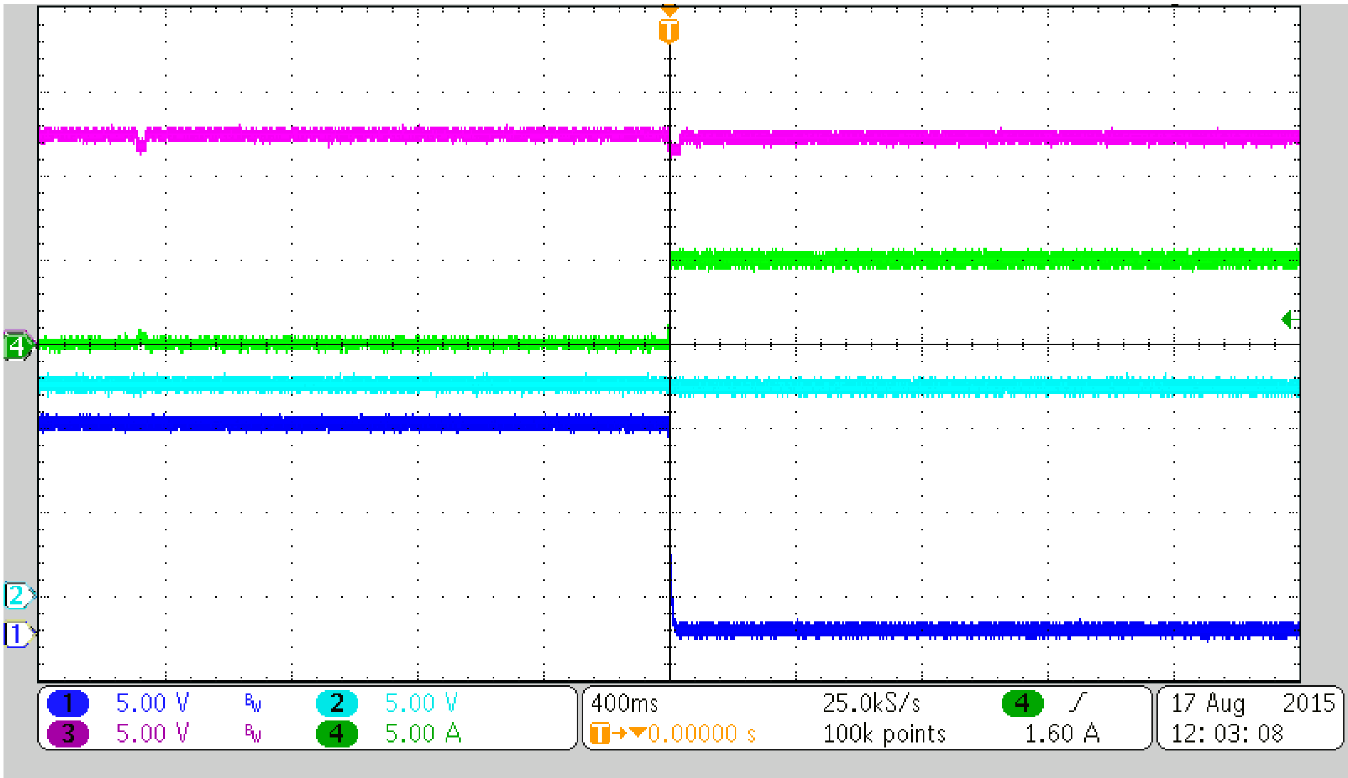

Figure 5. LM74610-Q1 OR-ing Device when PS1 Fails

Ch1 : Input voltage source 1 (12V to 0V)

Ch2 : Input voltage source 2 (12V)

Ch3 : Output Voltage of OR-ing device at common load point

Ch4: Input Current of voltage source 2

8.2 Power Supply Failure

LM74610-Q1 OR-ing device with 5A Load and 12V supply.

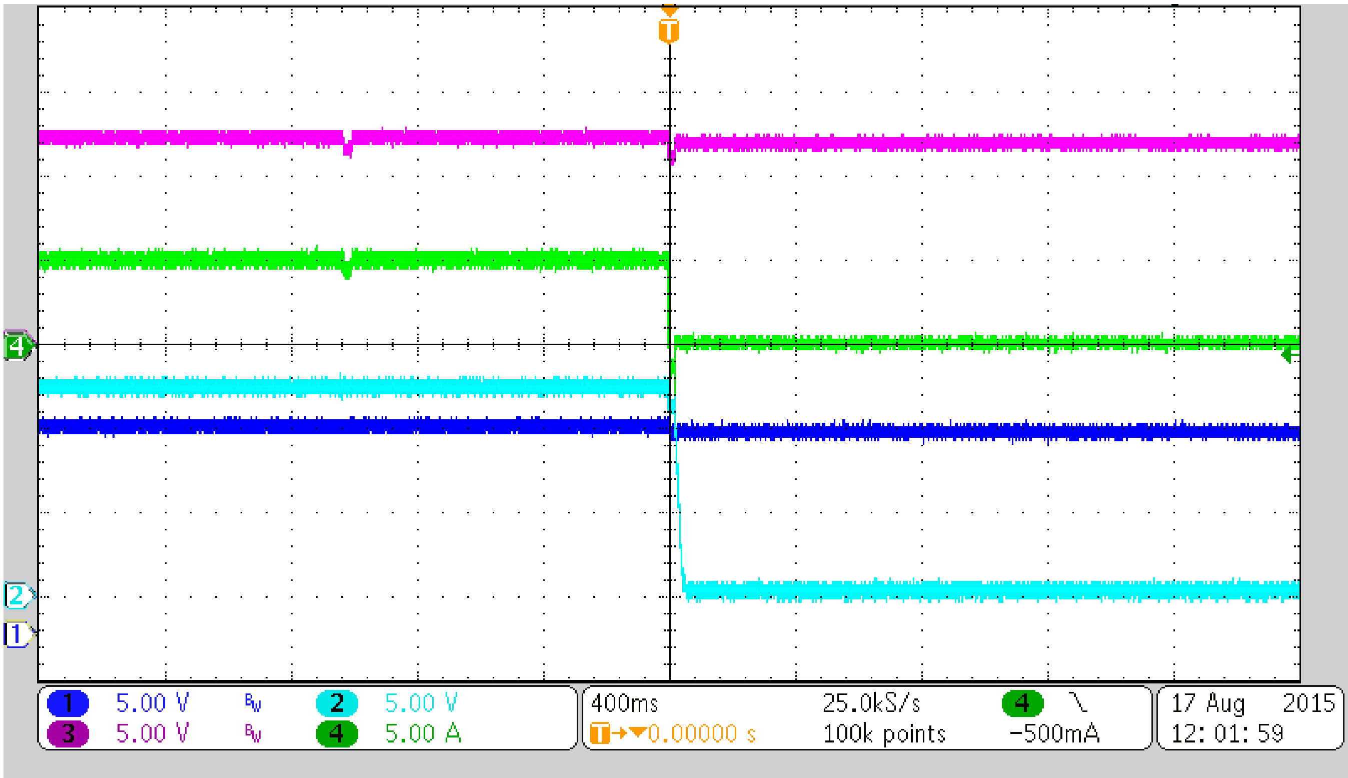

Figure 6. LM74610-Q1 OR-ing Device when P2 Fails

Ch1: Input voltage source 1 (12V)

Ch2: Input voltage source 2 (12V to 0V)

Ch3: Output Voltage or OR-ing device at common load point

Ch4: Input Current of voltage source 2

8.3 Power Supply Disruption

LM74610-Q1 OR-ing device with 5A Load and 12V supply.

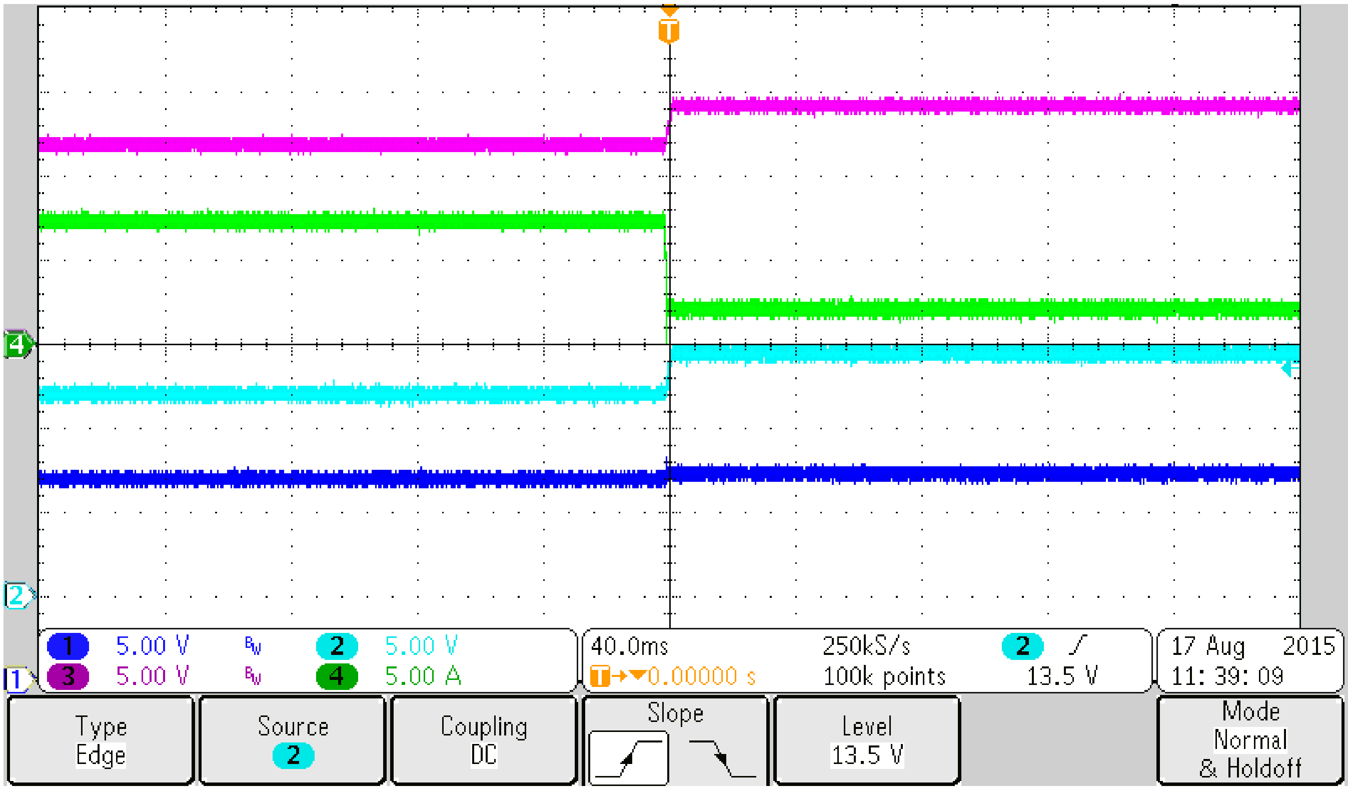

Figure 7. LM74610-Q1 OR-ing Device with PS2 Increase

Ch1: Input voltage source 1 (12V)

Ch2: Input voltage source 2 (12V to 14V)

Ch3: Output Voltage or OR-ing device at common load point

Ch4: Input Current of voltage source 1

8.4 Power Supply Disruption

LM74610-Q1 OR-ing device with 5A Load and 12V supply

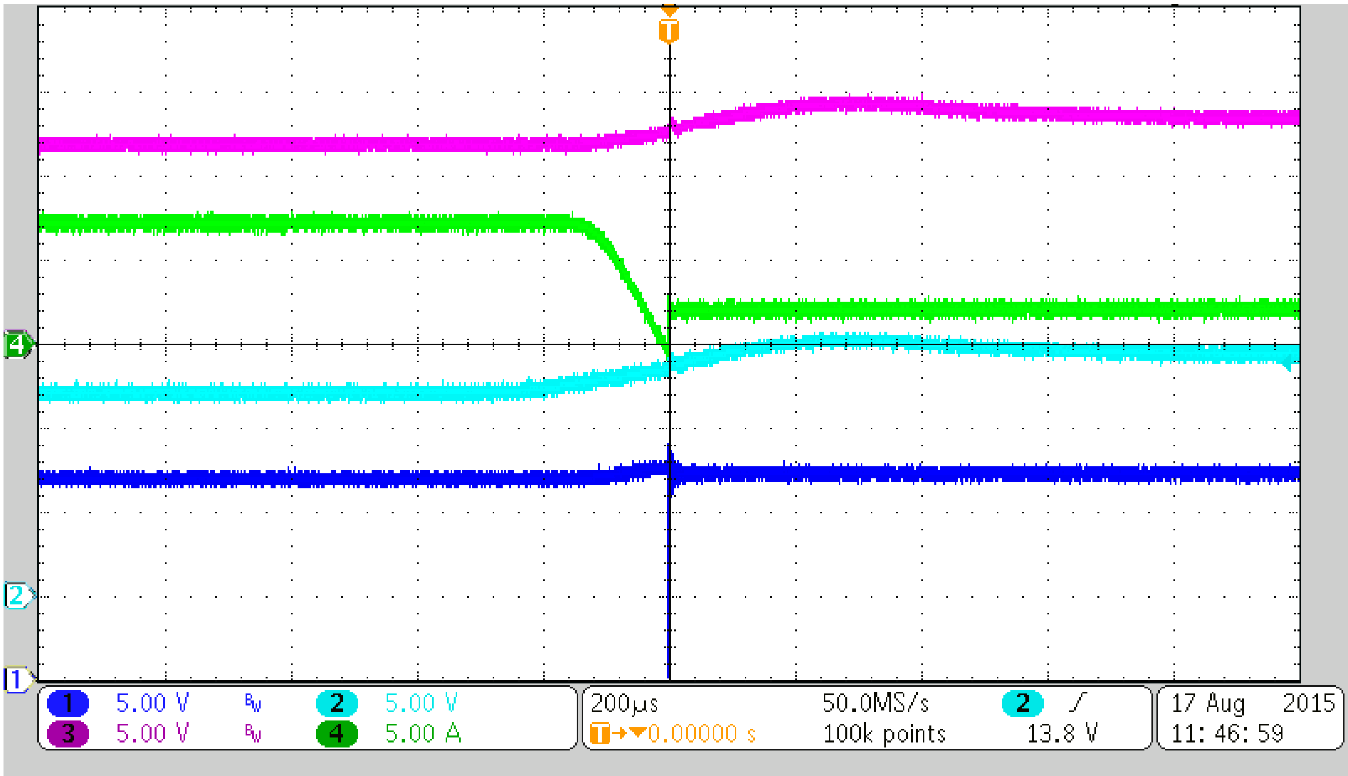

Figure 8. LM74610-Q1 OR-ing Device when PS2 Increases

Ch1: Input voltage source 1 (12V)

Ch2: Input voltage source 2 (12V to 14V)

Ch3: Output Voltage or OR-ing Device at common load point

Ch4: Input Current of voltage source 1

8.5 Response to a Power Supply Interruption

In the following example, one of the power supplies (PS2) voltage is changing constantly (Ch3). As a result, the input current shifts to the higher voltage rail. This is an important characteristic of a conventional diode OR-ing device. The LM74610-Q1 based OR-ing device demonstrates similar behavior.

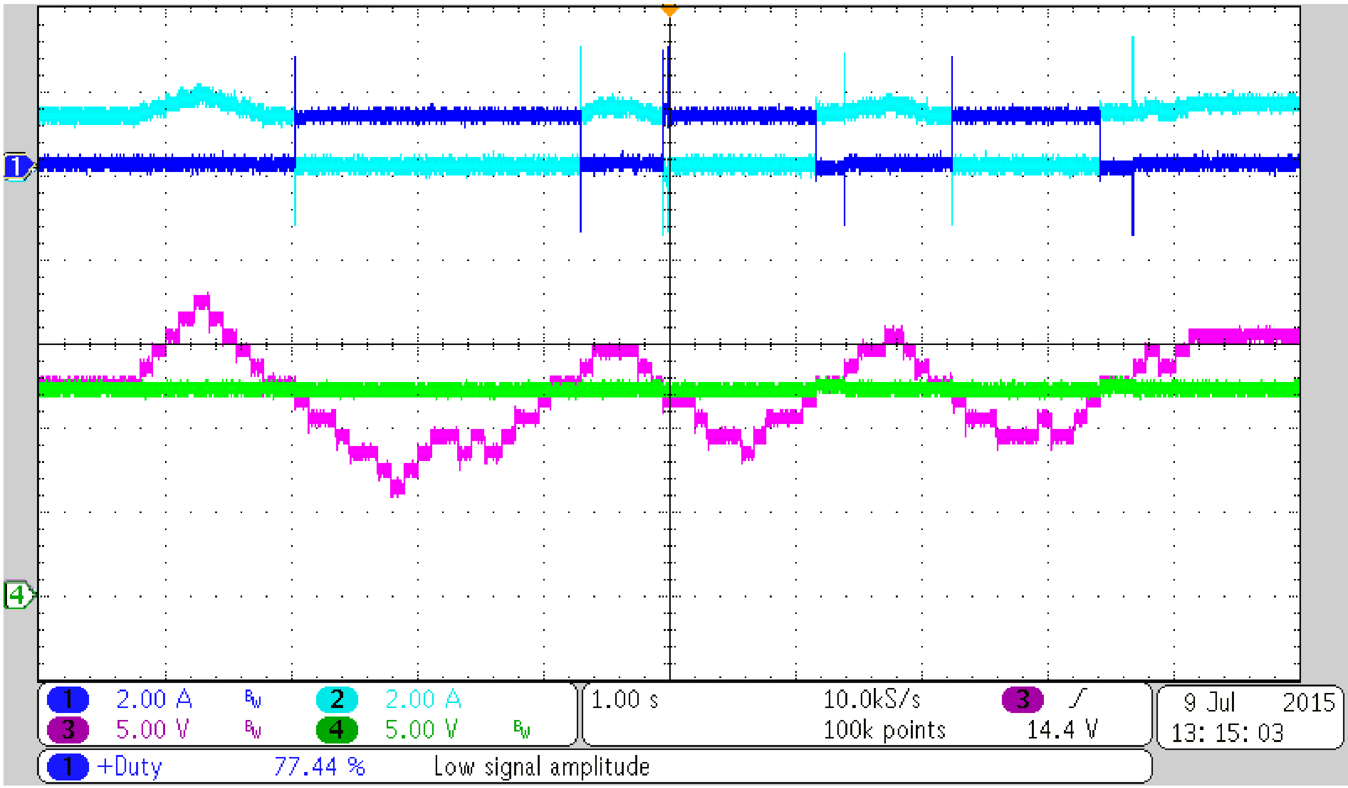

Figure 9. LM74610-Q1 OR-ing Device

Ch1: Input current of supply 1

Ch2: Input current of supply 2

Ch3: Input voltage source 2 (constantly changing)

Ch4: Input voltage source 1

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from A Revision (March 2016) to B Revision **Page**

- Added this sentence. Active OR-ing solutions are used in redundant power architectures of various bus voltages, depending on the end system requirement. The voltage range can vary between low (2.5V, 3.3V, 5V) and medium voltage up to 48V. 2
- Added clarification in last paragraph. 5
- Changed Ch4: Input Current of voltage source 2 8
- Changed Ch4: Input Current of voltage source 1 9
- Changed Ch4: Input voltage source 1 11

Changes from Original (October 2015) to A Revision **Page**

- Changed revision history was incorrect for this version A. Updating to correct revision history in SNVA747B 11

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