Test Report: PMP31236

Gate Driver Reference Design for HybridPACK™ Drive IGBT Module

Description

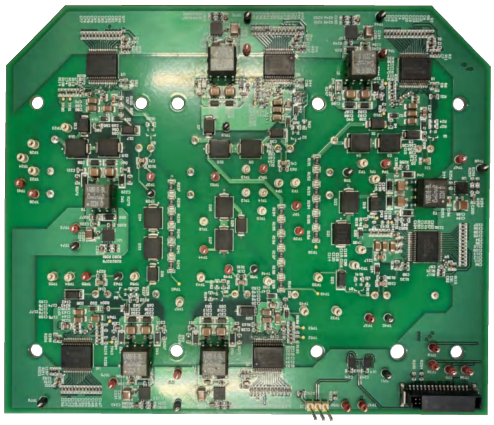
This reference uses six UCC5880-Q1 gate-drive integrated circuits (ICs) and six LM5180-Q1 isolated bias supplies to interface with and drive Infineon® HybridPACK™ insulated-gate bipolar transistor (IGBT) modules. The isolated output voltage is +15.0 V and −8.0 V with 100-mA maximum output current each. The input voltage range on the primary side is from 8.0 V to 16.0 V.

Features

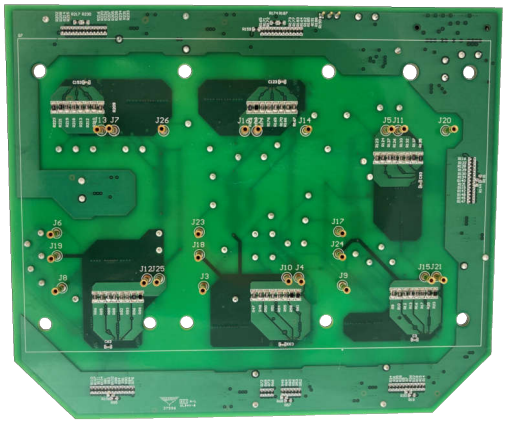
- Tested design that provides isolated bias and isolated drive for high-power IGBTs
- Complete isolated conversion for +15-V and −8-V rails from KL30
- Gate drive strength adjustable on the fly through analog signals or serial peripheral interface (SPI)
- Configurable through SPI daisy chain
- Advanced protection features in driver ease functional safety qualification

Applications

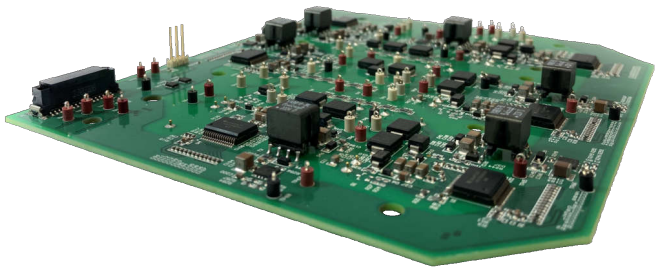
- Traction inverter-high voltage



Top Board Photo



Bottom Board Photo



Angled Board Photo

1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1-1. Voltage and Current Requirements

Parameter	Specifications
Input Voltage Isolated Bias Supply	8.0 V to 16.0 V, 36 V_{peak}
Output Voltage Isolated Bias Supply 1	+15.0 V
Output Voltage Isolated Bias Supply 2	−8.0 V
Output Current Isolated Bias Supply (MAX)	100 mA
Isolation	1500 V
Input Voltage Gate Driver and Logic	3.3 V

1.2 Considerations

- One lab power supply needs to provide the KL30 input voltage.
- One more lab power supply needs to provide 3.3 V for the primary gate driver supply and logic circuits.
- A jumper is needed on J2 to choose between manual gate-drive strength selection via I/O or through SPI.
- For the tests, no IGBT module was connected to the PCB.

1.3 Dimensions

The outline of the board is 163.2 mm × 135.2 mm.

2 Testing and Results

2.1 Thermal Images

2.1.1 10-kHz Switching With 50% Duty Cycle Using the 15-A Gate Drive Output

2.1.1.1 PCB Top Side

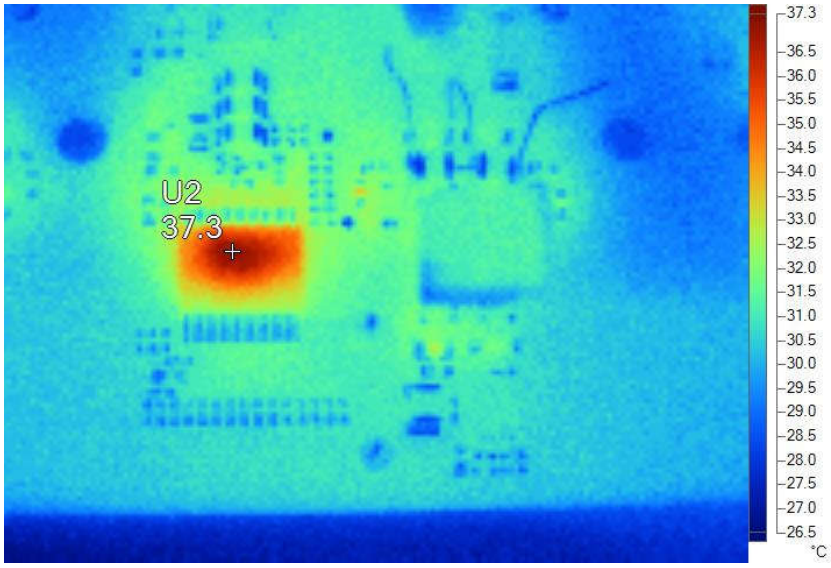


Figure 2-1. PCB Top Infrared (IR) Photo for 50% Duty Cycle Switching

Name	Temperature
U2	37.3°C

2.1.1.2 PCB Bottom Side

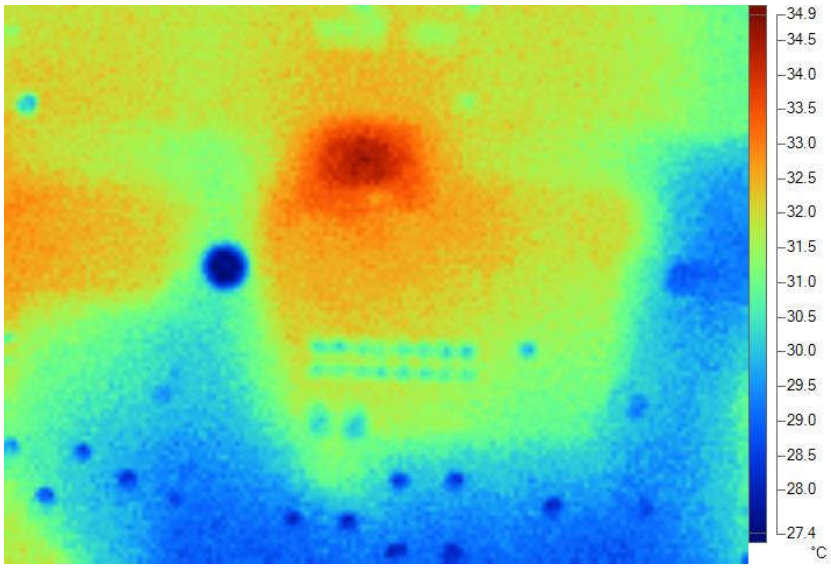


Figure 2-2. PCB Bottom IR Photo for 50% Duty Cycle Switching

On the bottom side of the PCB the area with the largest temperature rise is underneath the IC (U2), where the gate drive signals connect to their respective polygons.

2.1.2 10-kHz Switching With 80% Duty Cycle Using the 15-A Gate Drive Output

2.1.2.1 PCB Top Side

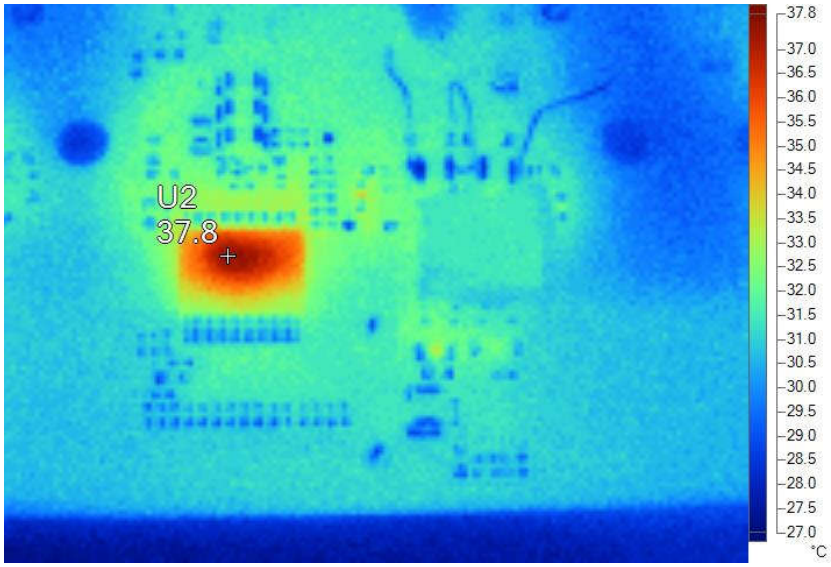


Figure 2-3. PCB Top IR Photo for 80% Duty Cycle Switching

Name	Temperature
U2	37.8°C

2.1.2.2 PCB Bottom Side

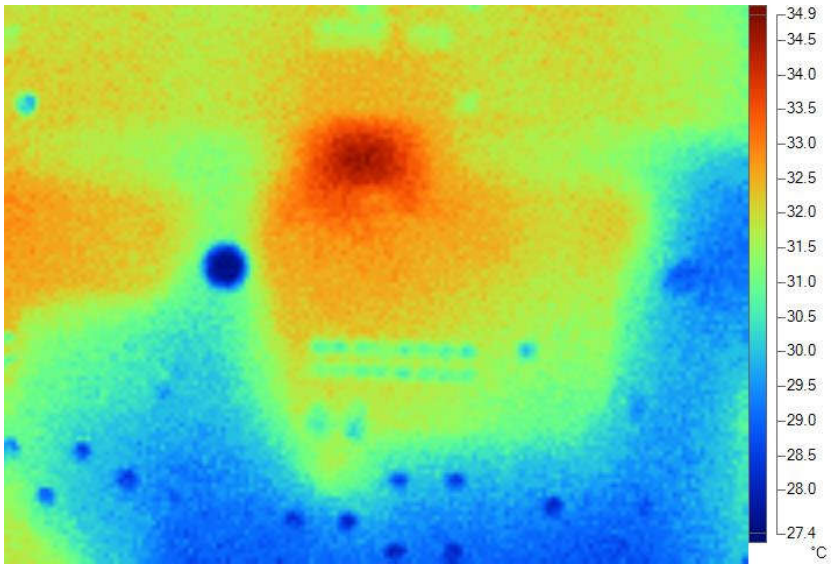


Figure 2-4. PCB Bottom IR Photo for 80% Duty Cycle Switching

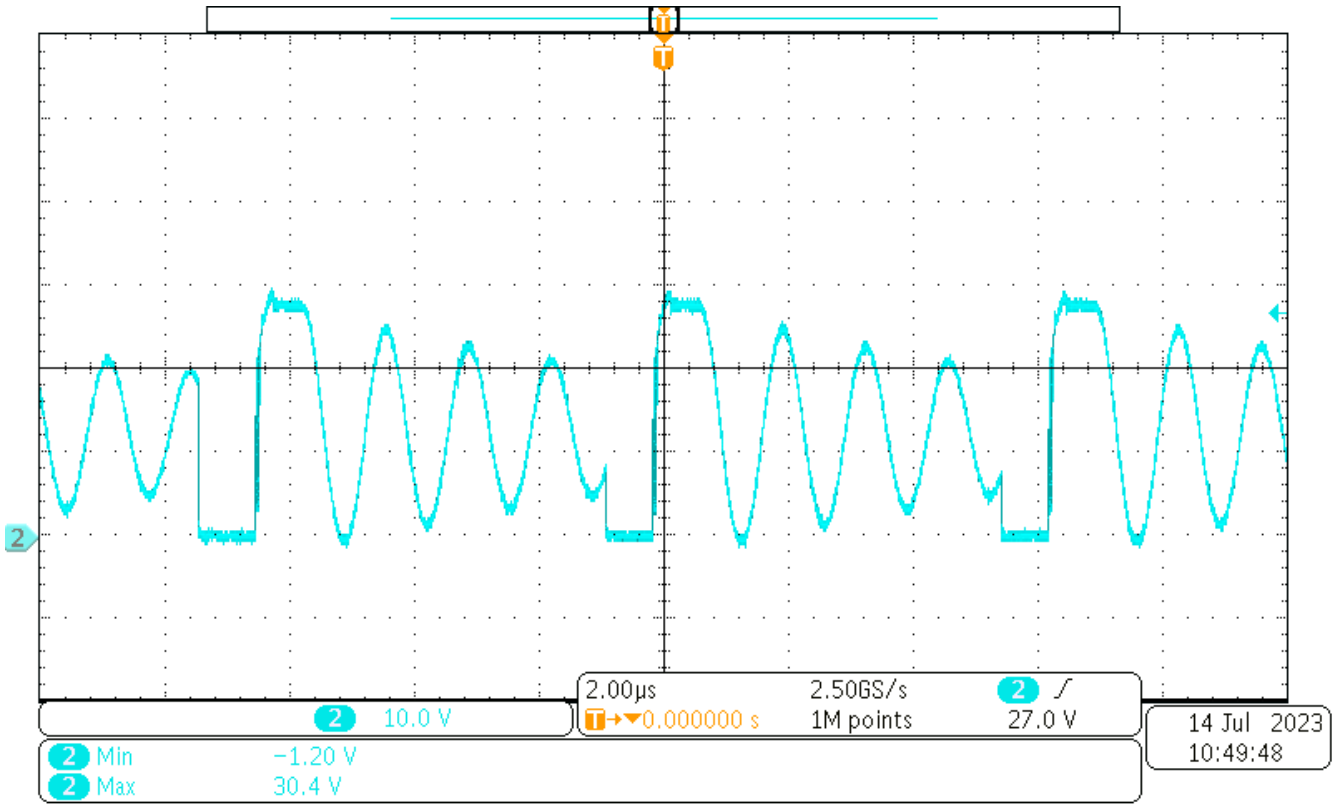
On the bottom side of the PCB the area with the largest temperature rise is underneath the IC (U2), where the gate drive signals connect to their respective polygons.

3 Waveforms

3.1 Switching

3.1.1 LM5180-Q1 Bias Supply

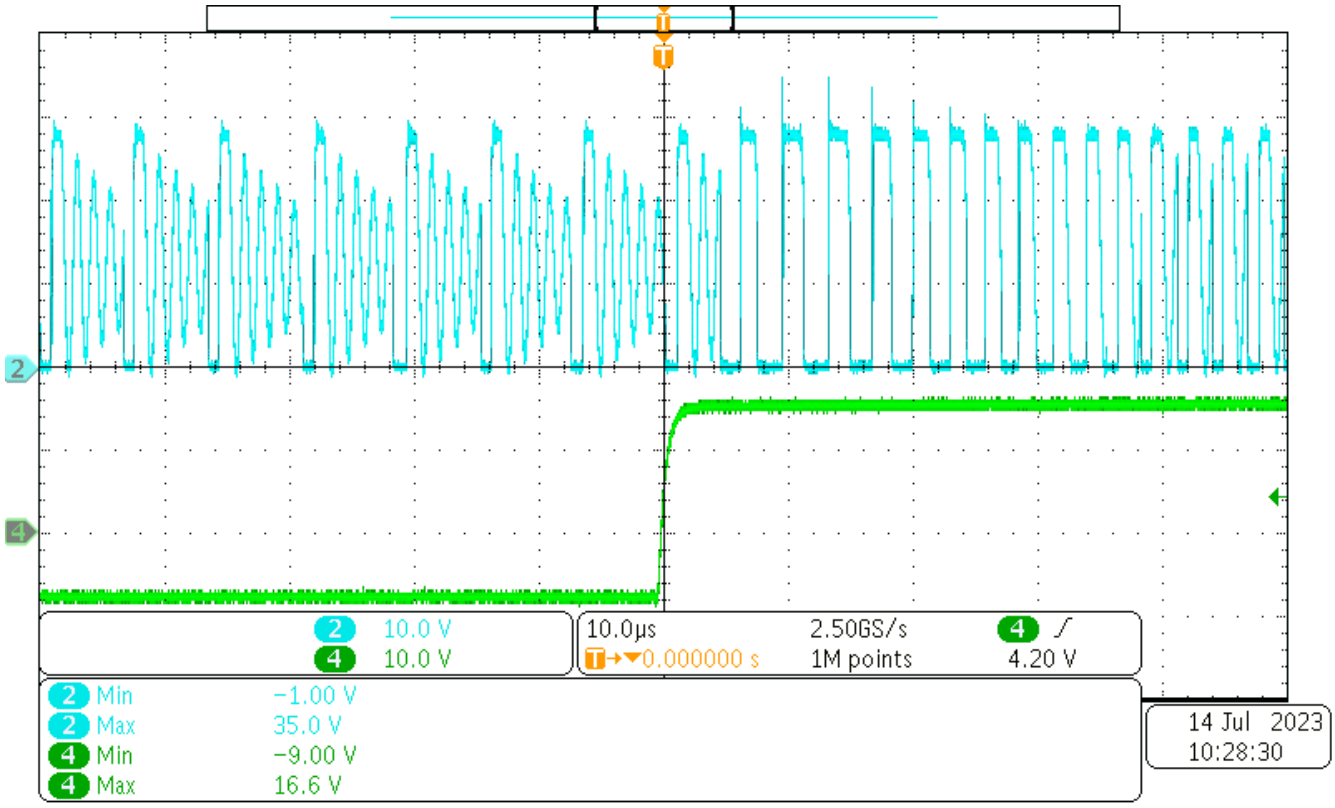
3.1.1.1 12.4-V Input Voltage – Steady State



Ch2: LM5180-Q1 switching node at 12.4 V_{IN} [scale: 10.0 V / div, 2.0 µs / div]

Figure 3-1. Switching Node of LM5180-Q1 at 12.0-V Input Voltage

3.1.1.2 12.4-V Input Voltage – Gate Drive Transient



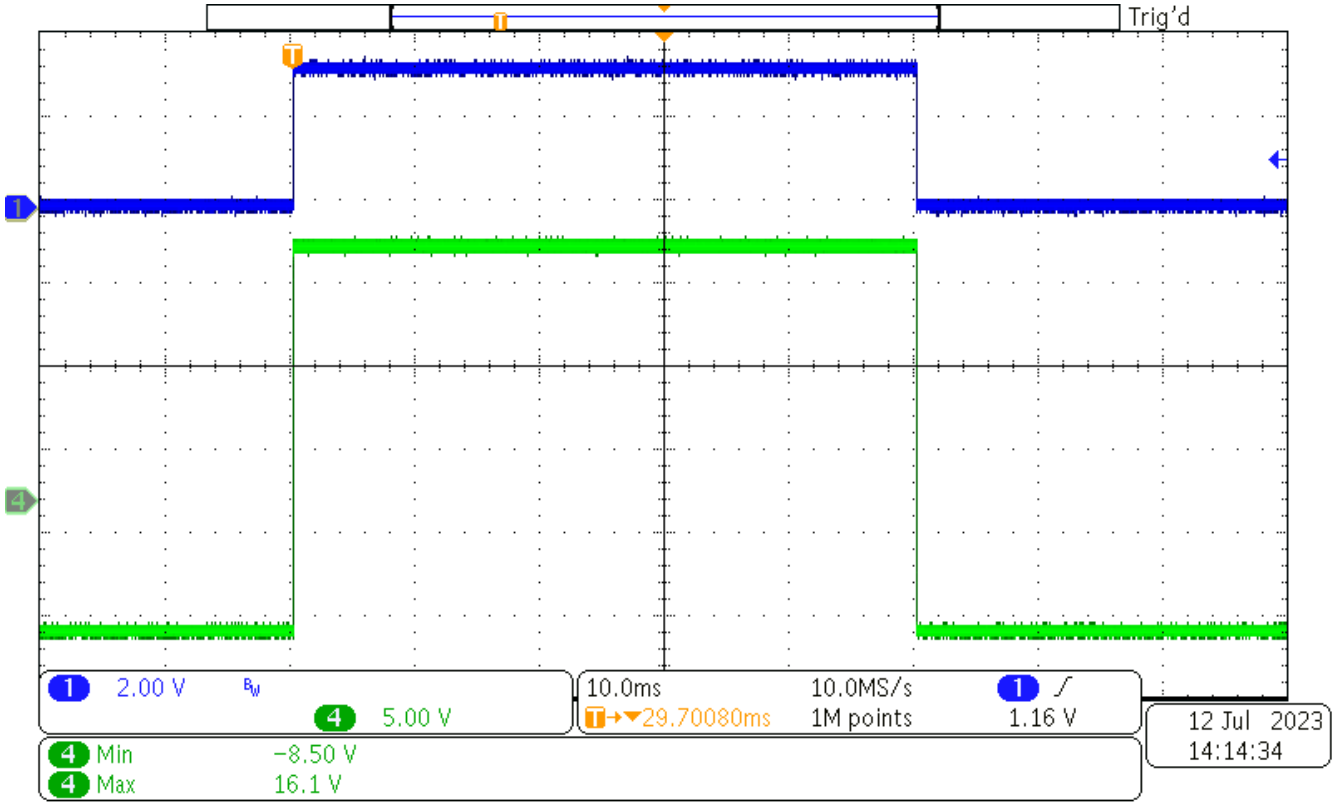
Ch2: LM5180-Q1 switching node at 12.4-V_{IN} [scale: 10.0 V / div, 10.0 µs / div]

Ch4: Gate drive switching transition from low to high state using the 15-A gate drive output [scale: 10.0 V / div, 10.0 µs / div]

Figure 3-2. Switching Node of LM5180-Q1 at 12.0-V Input Voltage During Gate Drive Transient

3.1.2 UCC5880-Q1 Gate Driver

3.1.2.1 PWM Signal and Gate Drive Signal

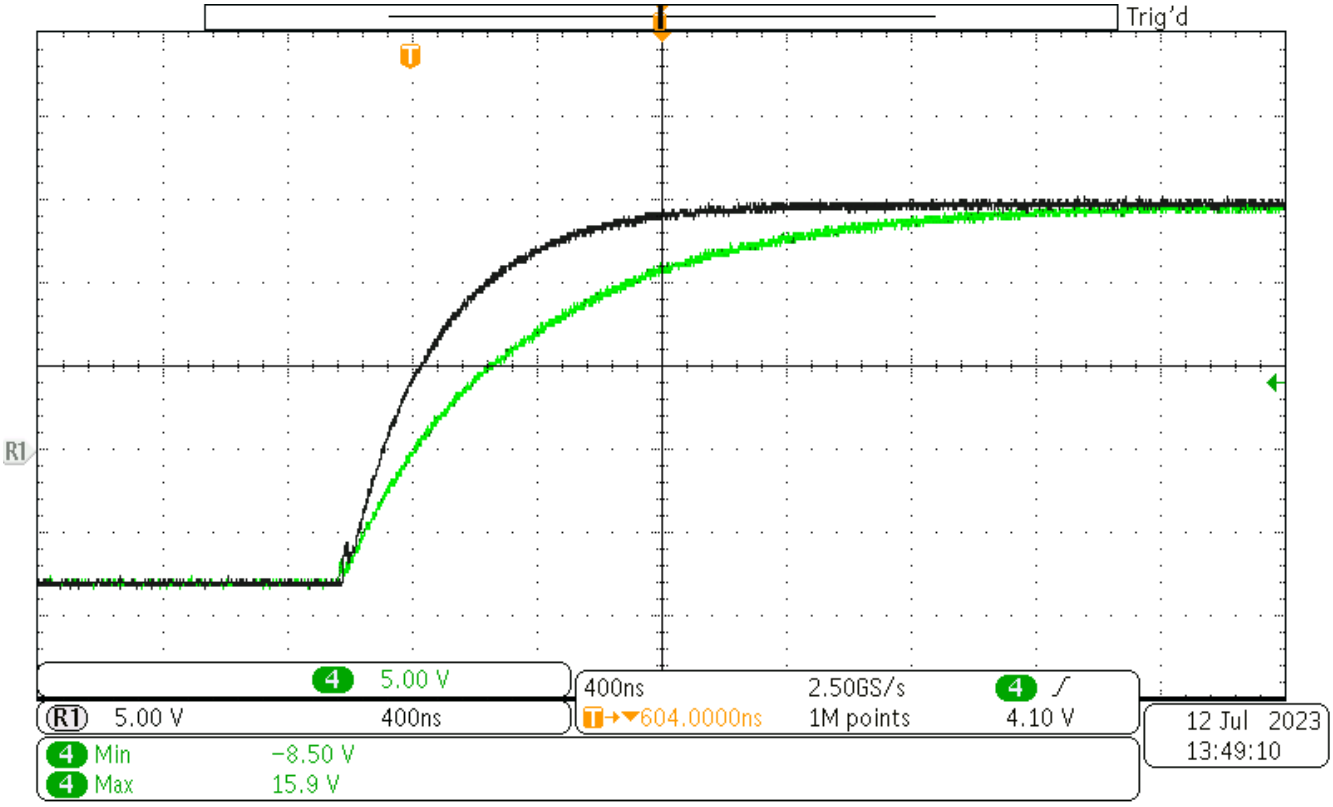


Ch1: Gate drive input PWM signal [scale: 2.0 V / div, 10.0 ms / div]
Ch4: 10-kHz Gate drive switching waveform using the 15-A gate drive output [scale: 5.0 V / div, 10.0 ms / div]

Figure 3-3. Switching Node of LM5180-Q1 at 12.0-V Input Voltage during Gate Drive Transient

3.1.2.2 Gate Drive Turn on

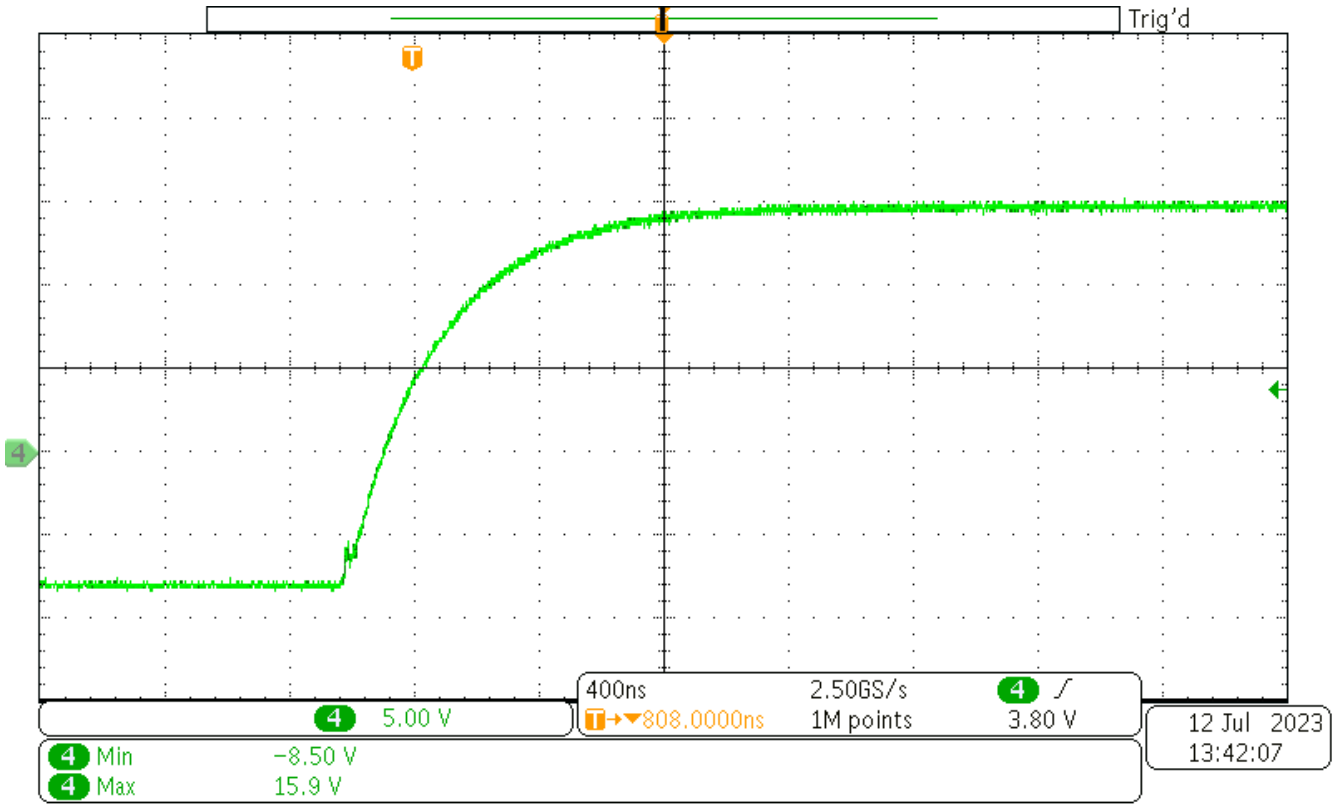
3.1.2.2.1 Comparison (Configurable With External Logic or Through SPI)



R1: Gate drive switching transition from low to high state using the 15-A gate drive output [scale: 5.0 V / div, 400 ns / div]
Ch4: Gate drive switching transition from low to high state using the 5-A gate drive output [scale: 5.0 V / div, 400 ns / div]

Figure 3-4. Gate Drive Turn-on Event of the UCC5880-Q1 With Different Drive Outputs

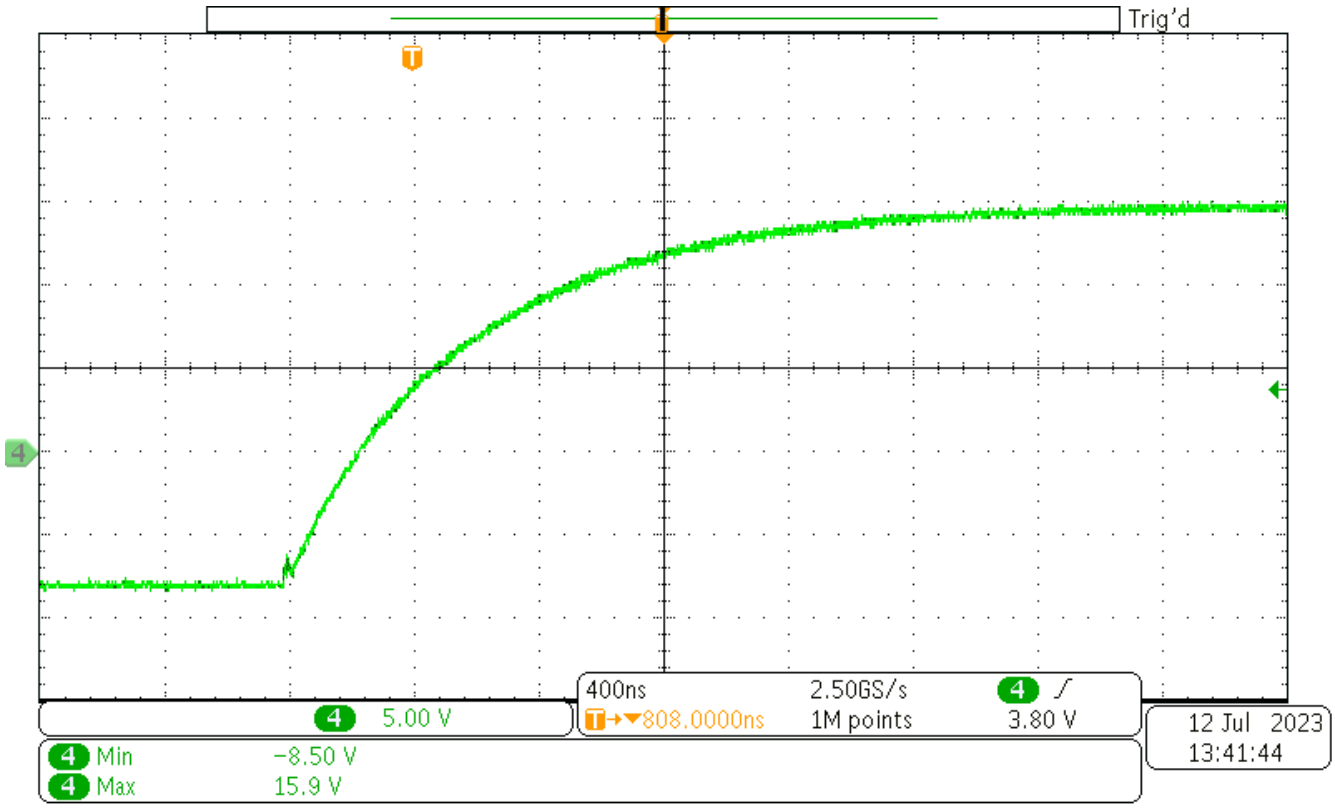
3.1.2.2.2 15-A Driver Output



Ch4: Gate drive switching transition from low to high state using the 15-A gate drive output [scale: 5.0 V / div, 400 ns / div]

Figure 3-5. Gate Drive Turn-on Event of the UCC5880-Q1 With 15-A Drive Output

3.1.2.2.3 5-A Driver Output

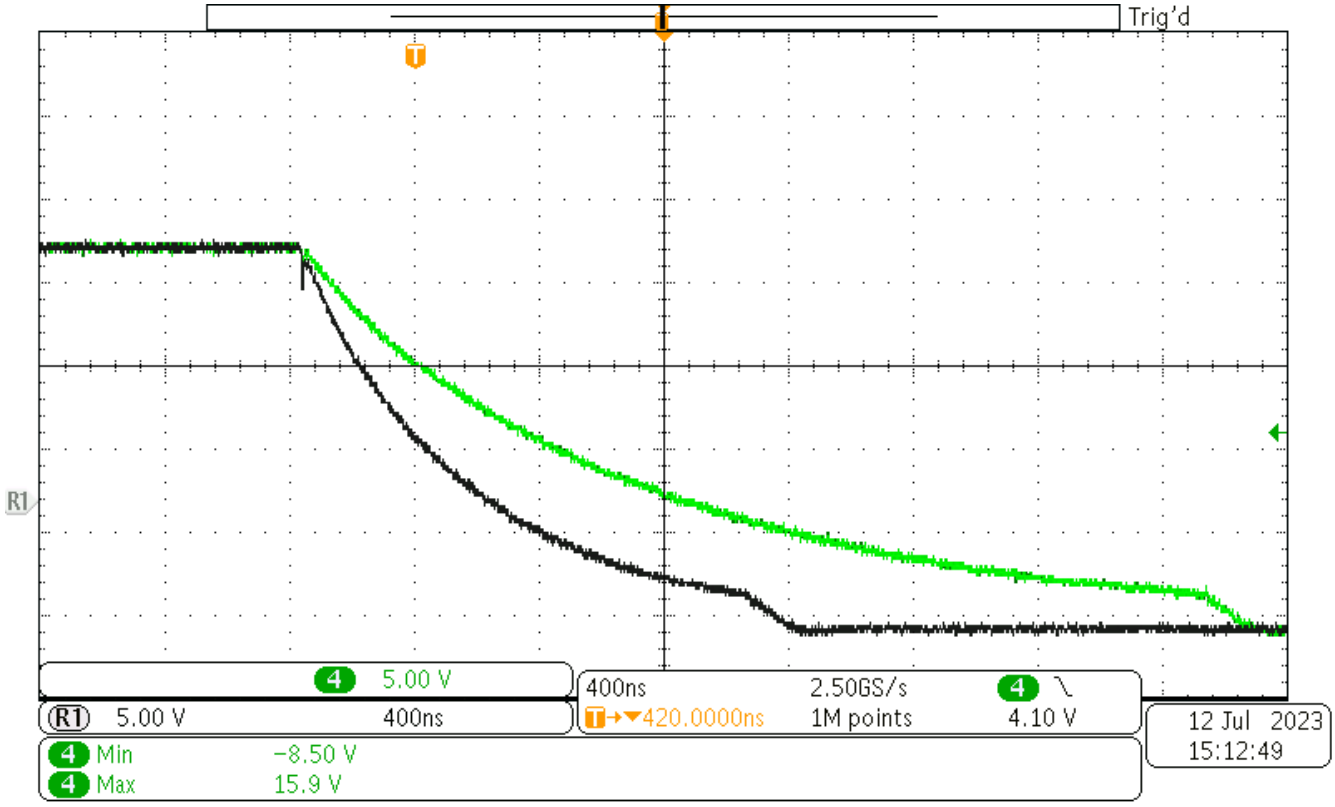


Ch4: Gate drive switching transition from low to high state using the 5-A gate drive output [scale: 5.0V / div, 400 ns / div]

Figure 3-6. Gate Drive Turn-on Event of the UCC5880-Q1 With 5-A Drive Output

3.1.2.3 Gate Drive Turn off

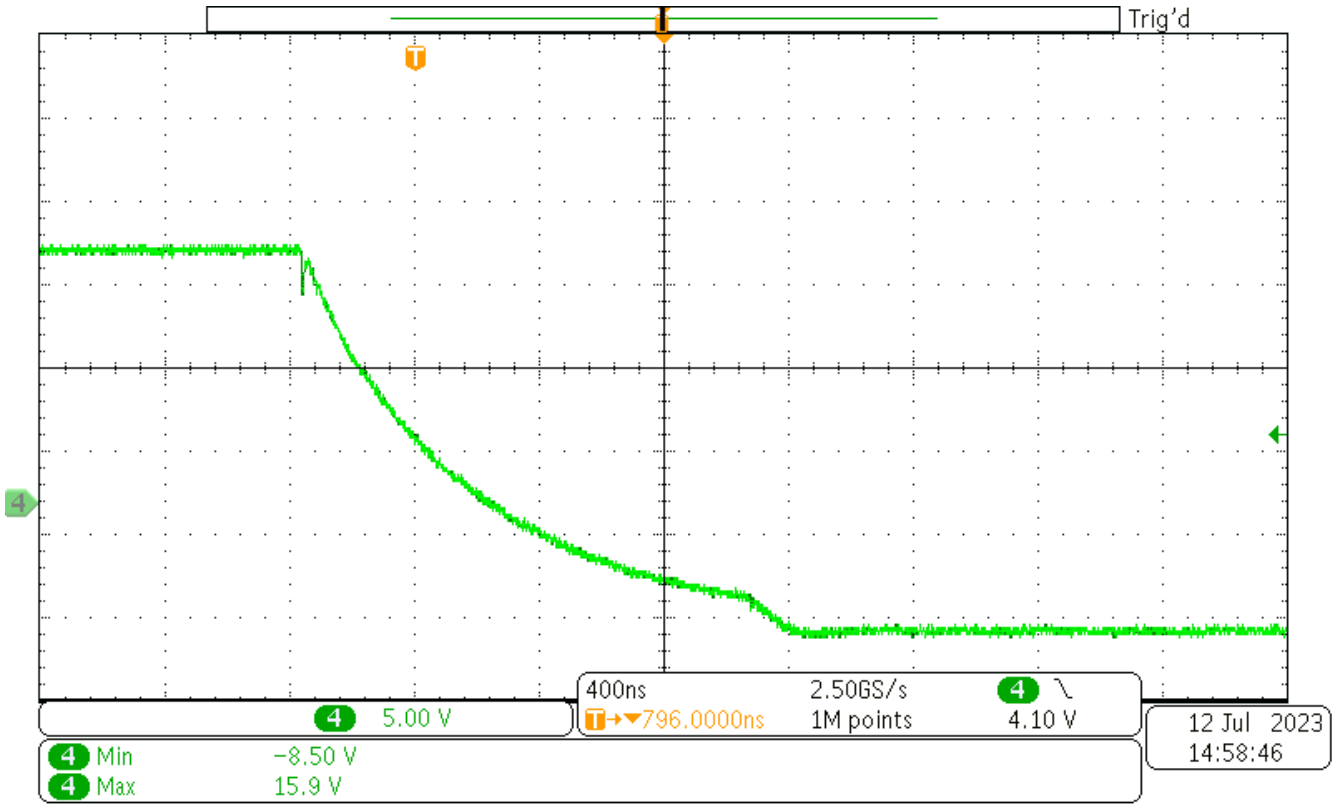
3.1.2.3.1 Comparison (configurable with external logic or through SPI)



R1: Gate drive switching transition from high to low state using the 15-A gate drive output [scale: 5.0 V/ div, 400 ns / div]
Ch4: Gate drive switching transition from high to low state using the 5-A gate drive output [scale: 5.0 V / div, 400 ns / div]

Figure 3-7. Gate Drive Turn-off Event of the UCC5880-Q1 with Different Drive Outputs

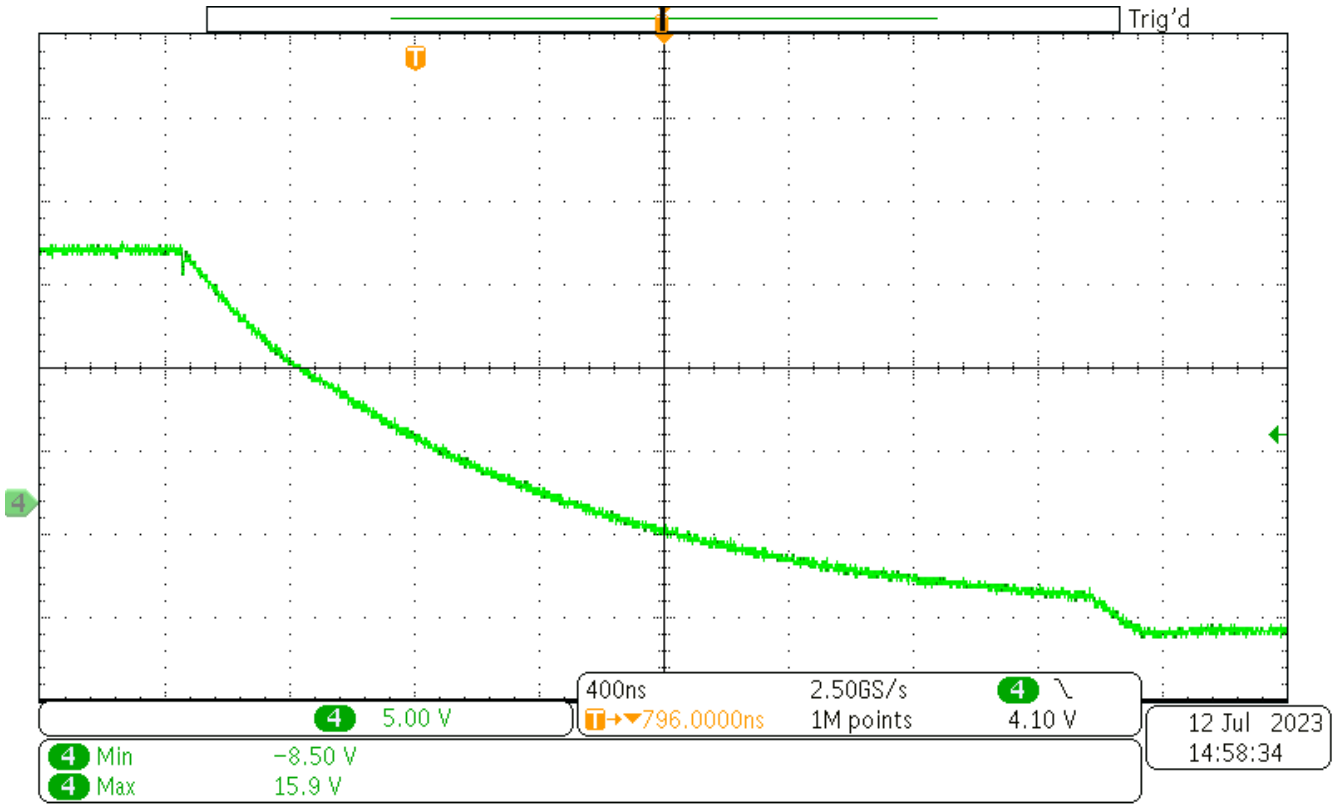
3.1.2.3.2 15 A Driver Output



Ch4: Gate drive switching transition from high to low state using the 15-A gate drive output [scale: 5.0 V / div, 400 ns / div]

Figure 3-8. Gate Drive Turn-off Event of the UCC5880-Q1 with 15-A Drive Output

3.1.2.3.3 5-A Driver Output



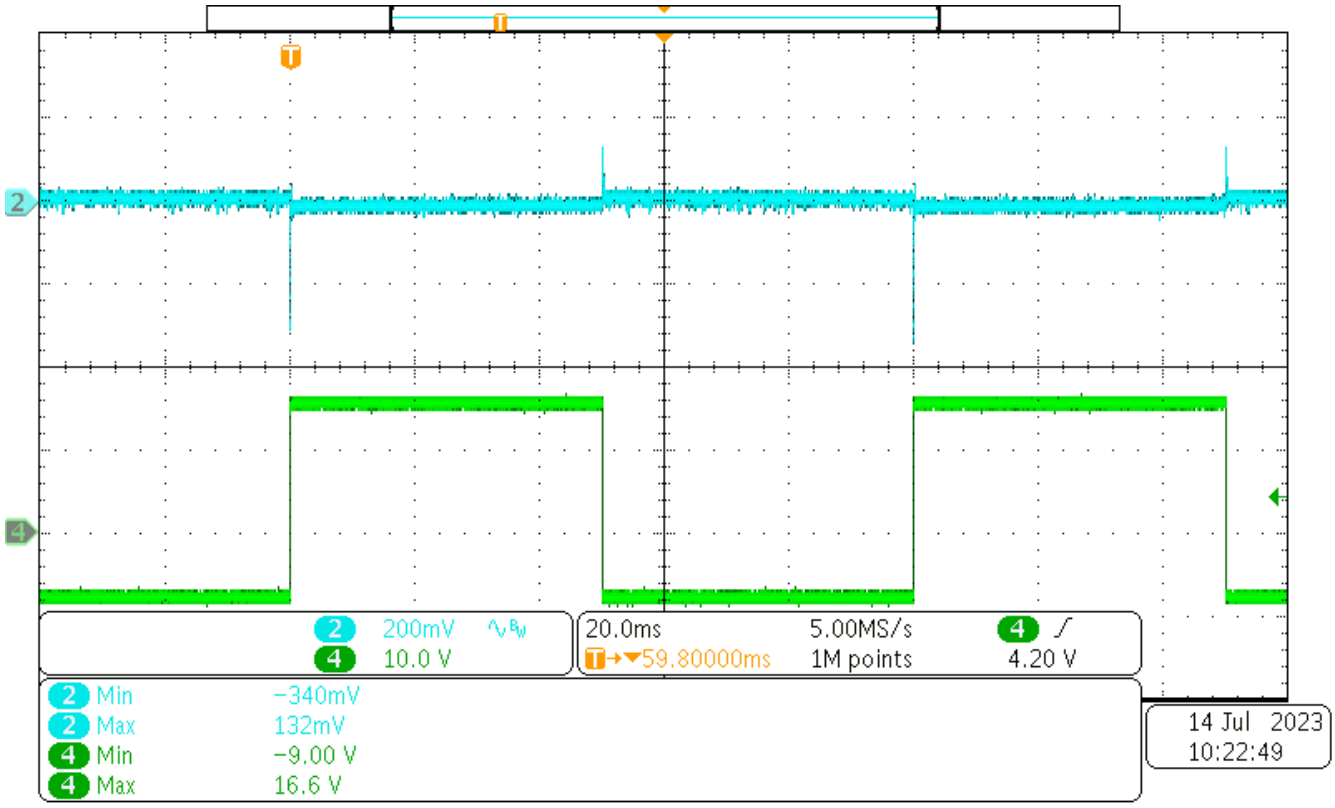
Ch4: Gate drive switching transition from high to low state using the 5-A gate drive output [scale: 5.0 V / div, 400 ns / div]

Figure 3-9. Gate Drive Turn-on Event of the UCC5880-Q1 With 5-A Drive Output

3.2 Load Transients

The UCC5880-Q1 gate driver and a 100-nF capacitor at the combined gate driver output (C41) have been used to create the load transients for the LM5180-Q1.

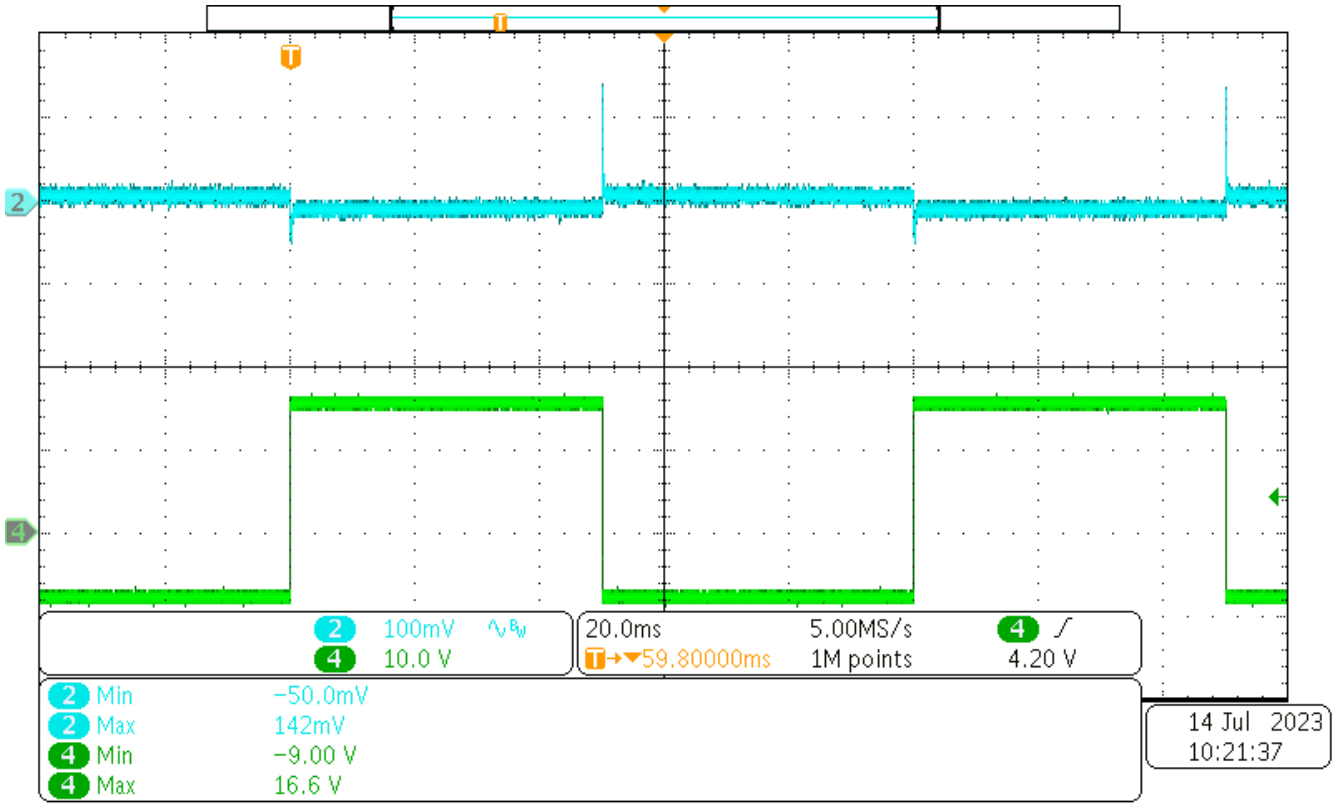
3.2.1 15-V Output at 12.4-V Input Voltage and 50% Duty Cycle Switching



Ch2: AC-coupled 15-V output voltage, bandwidth limited (20 MHz) [scale: 200 mV / div, 20.0 ms / div]
Ch4: 10-kHz Gate drive switching waveform using the 15-A gate drive output [scale: 10.0 V / div, 20.0 ms / div]

Figure 3-10. Load Transient Behavior of the 15-V Output at 12.4-V Input Voltage and 80% Duty Cycle Switching

3.2.2 −8-V Output at 12.4-V Input Voltage and 50% Duty Cycle Switching

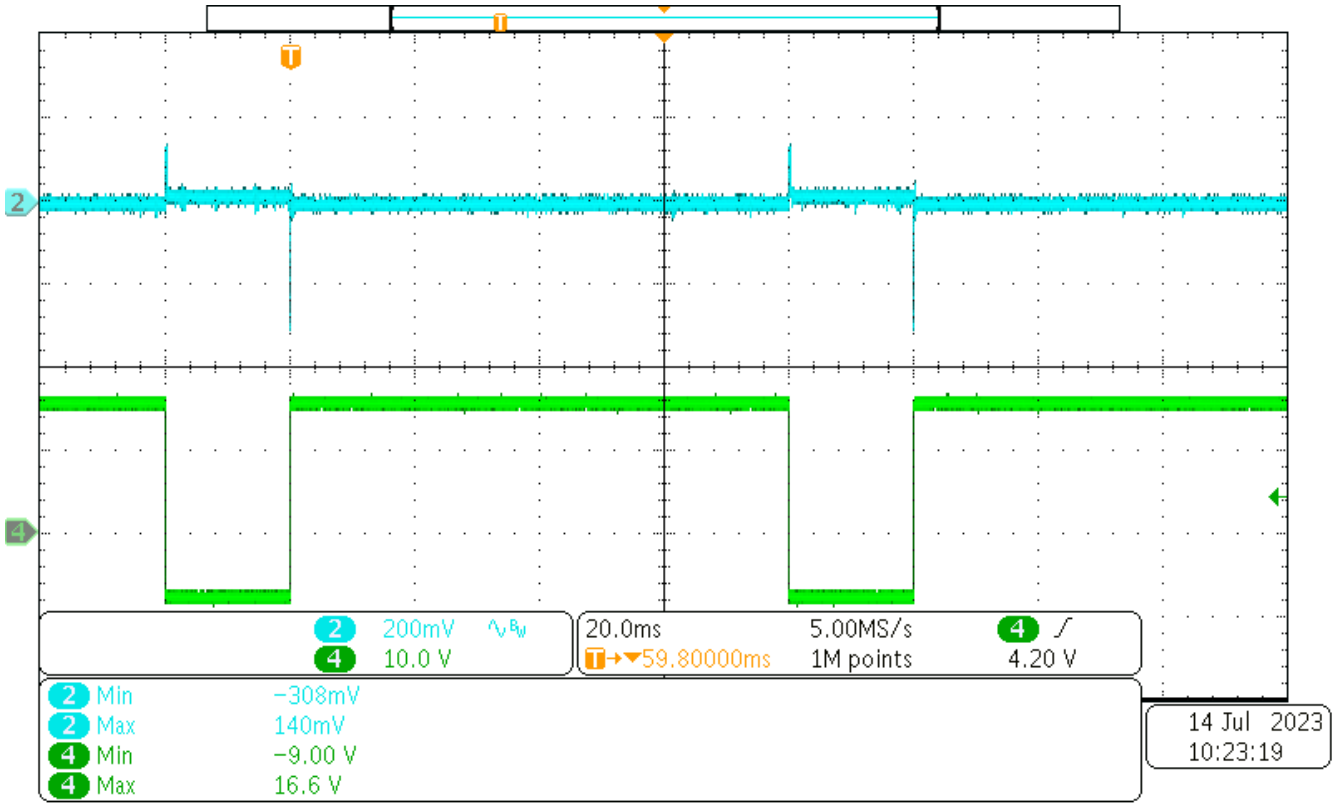


Ch2: AC-coupled −8-V output voltage, bandwidth limited (20 MHz) [scale: 100 mV / div, 20.0 ms / div]

Ch4: 10-kHz Gate drive switching waveform using the 15-A gate drive output [scale: 10.0 V / div, 20.0 ms / div]

Figure 3-11. Load Transient Behavior of the −8-V Output at 12.4-V Input Voltage and 50% Duty Cycle Switching

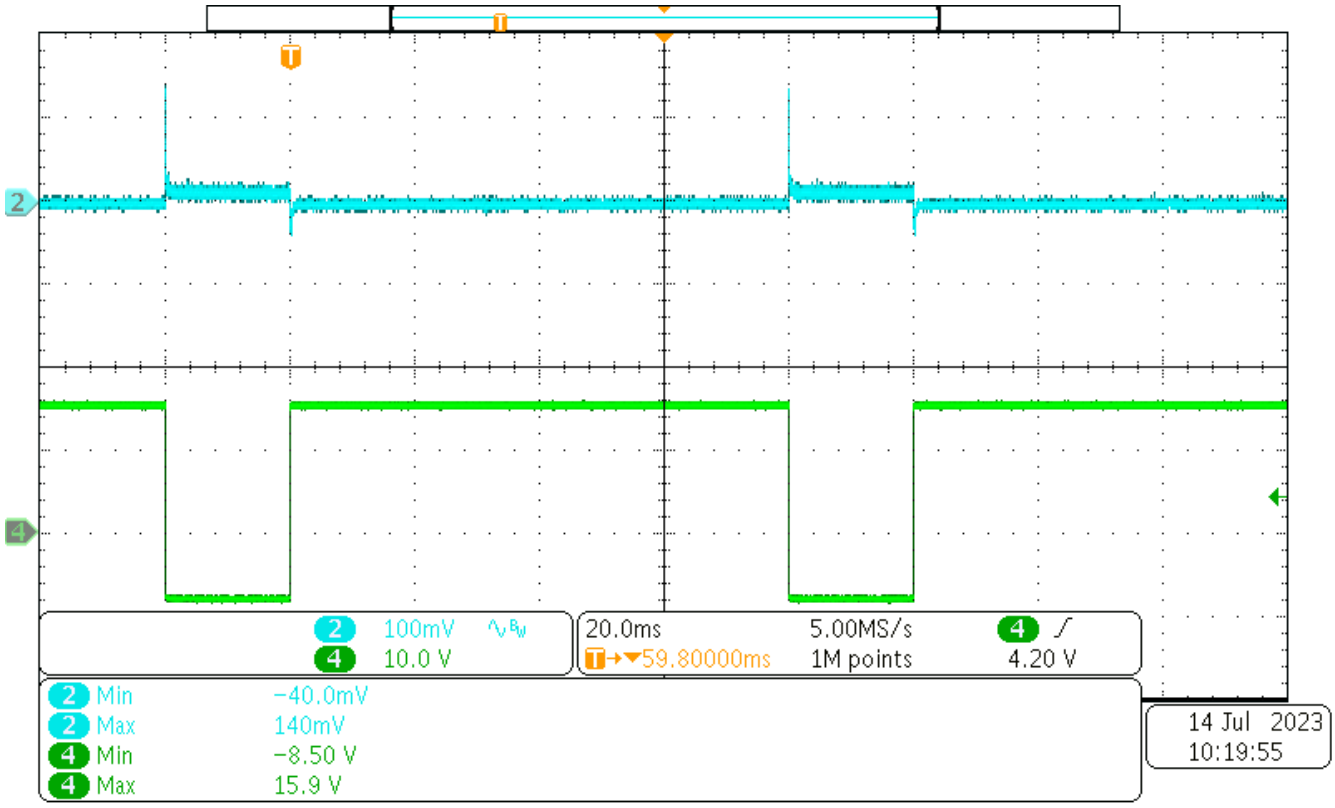
3.2.3 15-V Output at 12.4-V Input Voltage and 80% Duty Cycle Switching



Ch2: AC-coupled 15-V output voltage, bandwidth limited (20 MHz) [scale: 100 mV / div, 20.0 ms / div]

Figure 3-12. Load Transient Behavior of the 15-V Output at 12.4-V Input Voltage and 80% Duty Cycle Switching

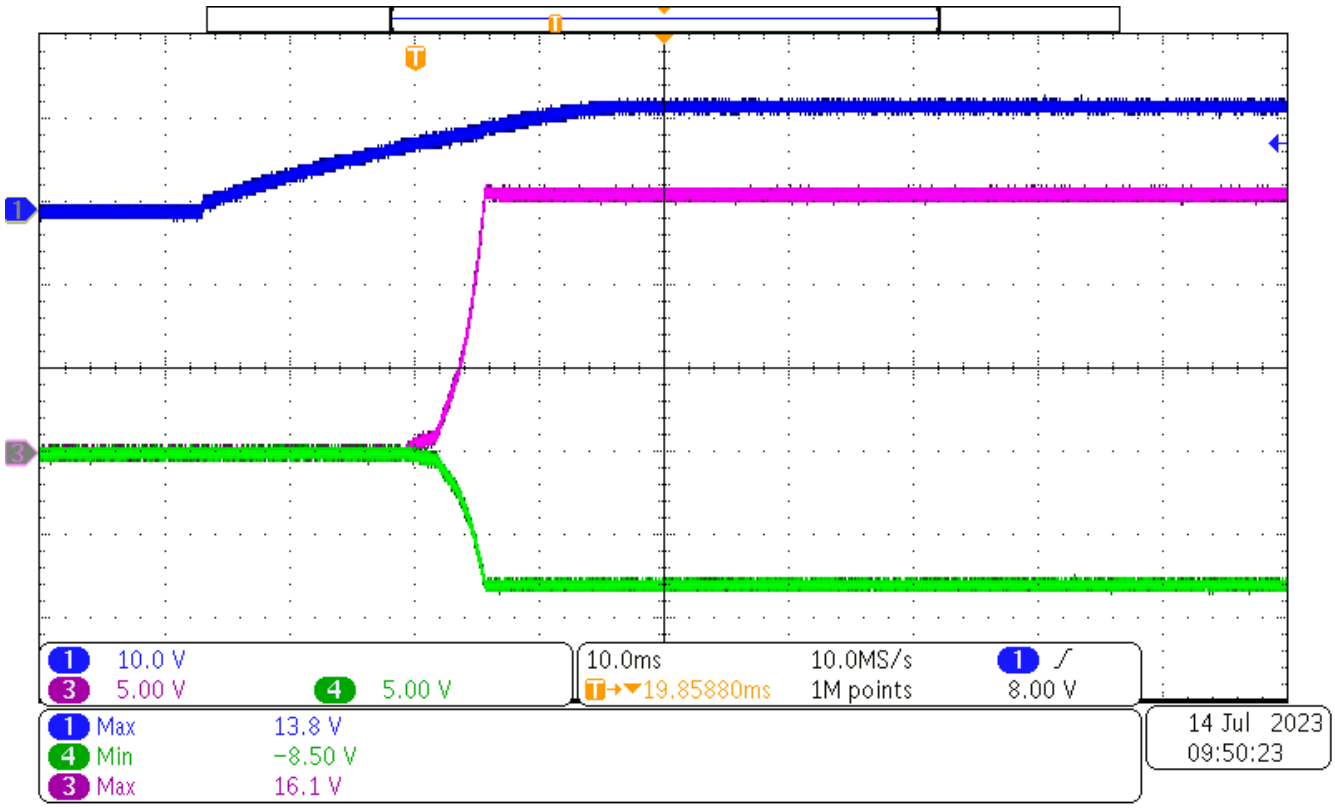
3.2.4 −8-V Output at 12.4-V Input Voltage and 80% Duty Cycle Switching



Ch2: AC-coupled −8-V output voltage, bandwidth limited (20 MHz) [scale: 100 mV / div, 20.0 ms / div]

Figure 3-13. Load Transient Behavior of the −8-V Output at 12.4-V Input Voltage and 80% Duty Cycle Switching

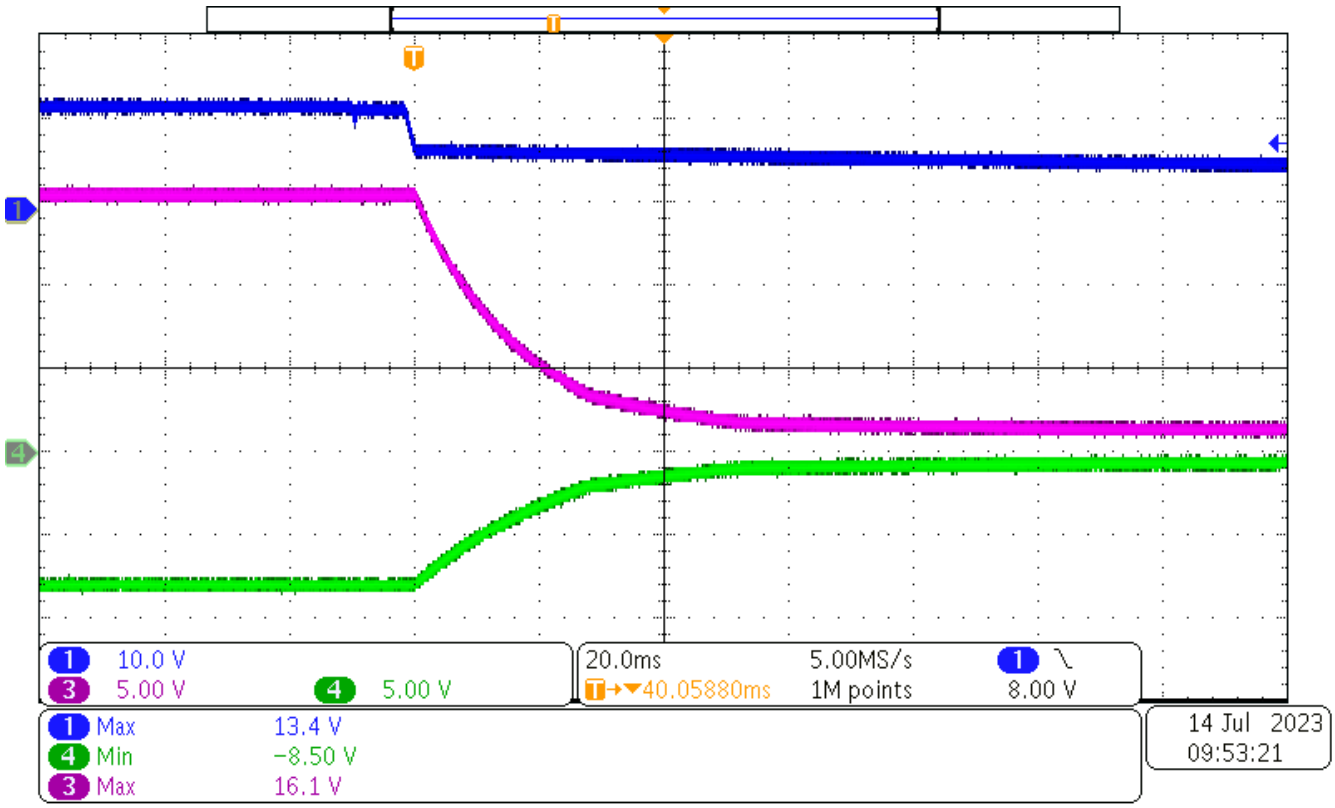
3.3 Start-Up Sequence Isolated Bias Supply LM5180-Q1



Ch1: Input voltage at 12.4 V, [scale: 10.0 V / div, 10.0 ms / div]
Ch3: 15-V output voltage [scale: 5.0 V / div, 10.0 ms / div]
Ch4: −8-V output voltage [scale: 5.0 V / div, 10.0 ms / div]

Figure 3-14. Start-Up Behavior of the LM5180-Q1 Isolated Bias Supply

3.4 Shutdown Sequence Isolated Bias Supply LM5180-Q1



Ch1: Input voltage at 12.4 V [scale: 10.0 V / div, 10.0 ms / div]
Ch3: 15-V output voltage [scale: 5.0 V / div, 10.0 ms / div]
Ch4: −8-V output voltage [scale: 5.0 V / div, 10.0 ms / div]

Figure 3-15. Shutdown Behavior of the LM5180-Q1 Isolated Bias Supply

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