

## User Manual

<b>Title</b>	<b>RDHP-2256Q</b>
<b>Application</b>	2-Channel Bitstream Error Emulator for Automotive ISO 26262 Software Designs (DSPACE Compatible)
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<b>Revision</b>	1.5



**Figure 1.** Bitstream error emulator hardware

### **Feature Set**

- Automatic and manual emulation of gate driver errors, warnings, and temperature signals
- SCALE-EV gate driver ASICs (SIC2192FQ) used for emulation accuracy
- Microcontroller for input and output signal handling
- DSPACE system input terminals and standard SCALE-EV family interface connector
- Powered from single external 5 V, 3 A power supply (USB-C connector or input terminals)
- 25 V gate supply voltage generated internally

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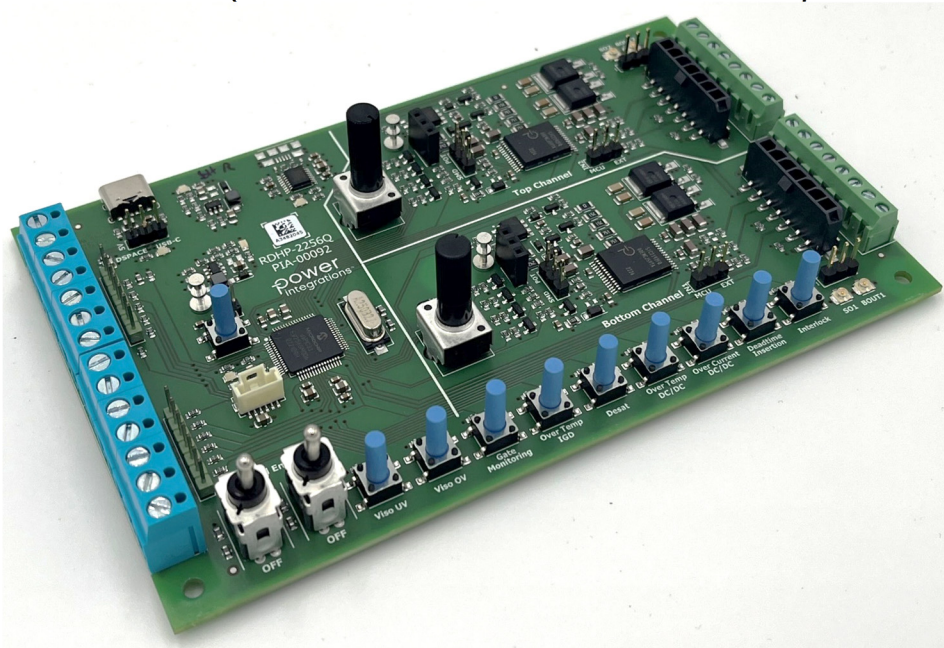
## 1 Description

The RDHP-2256Q simulates and emulate the SCALE-EV IGBT and SiC MOSFET plug and play automotive gate drivers to support system software development according to ISO 262632. The RDHP-2256Q hardware allows the software designer to test all gate driver functions under "low voltage" conditions. One (1) RDHP-2256Q simulates one half bridge, three (3) RDHP-2256Qs would simulate a three-phase two-level inverter.

The RDHP-2256Q is operated with standard PWM signals. The following errors or warnings can be simulated by request, per channel:

- 1) DESAT failure
- 2) Dead time failure
- 3) Interlock failure
- 4) DC/DC overcurrent failure
- 5) Over temperature DC/DC
- 6) Over temperature IGD (Gate driver booster stage)
- 7) Gate monitoring failure
- 8) Gate driver supply over voltage
- 9) Gate driver supply under voltage
- 10) NTC temperature value simulation

Failures and warnings can be activated by using the onboard push buttons or by digital signals from the DSPACE input interface or other electrical control systems.



**Figure 2.** RDHP-2256Q hardware with push button, switches, and potentiometers for temperature simulations

## 2 Design Specifications

### 2.1 Electrical Specifications

Description	Symbol	Min	Typ	Max	Units
<b>Primary Side Supply Voltage</b>					
Supply voltage referenced to GND	<b>V<sub>5V</sub></b>	4.75	5	5.25	V
Reference ground	<b>GND</b>		0		V
<b>Integrated Secondary Side Supply Voltage</b>					
Positive supply voltage referenced to V <sub>VEEX</sub>	<b>V<sub>VISOx</sub></b>		15		V
Secondary side reference potential per channel	<b>V<sub>VEEX</sub></b>		0		V
Negative supply voltage referenced to V <sub>VEEX</sub>	<b>V<sub>COM</sub></b>		-10		V
<b>Input and Output Signals</b>					
PWM input signals (0V = LOW, 5V = HIGH)	<b>V<sub>INx</sub></b>	0		5	V
PWM input signal frequency	<b>f<sub>INx</sub></b>		20		kHz
DSPACE input signals (0V = LOW, 5V = HIGH)	<b>V<sub>DSPACE</sub></b>	0		5	V
Status feedback signal (0V = FAULT, 5V = NO FAULT)	<b>V<sub>SOx</sub></b>	0	5		V

### 2.2 Environmental Specifications

Description	Symbol	Min	Typ	Max	Units
Ambient temperature	<b>T<sub>a</sub></b>		25		°C
Altitude of operation	<b>h<sub>a</sub></b>		2000		m

### 3 Functional Sections

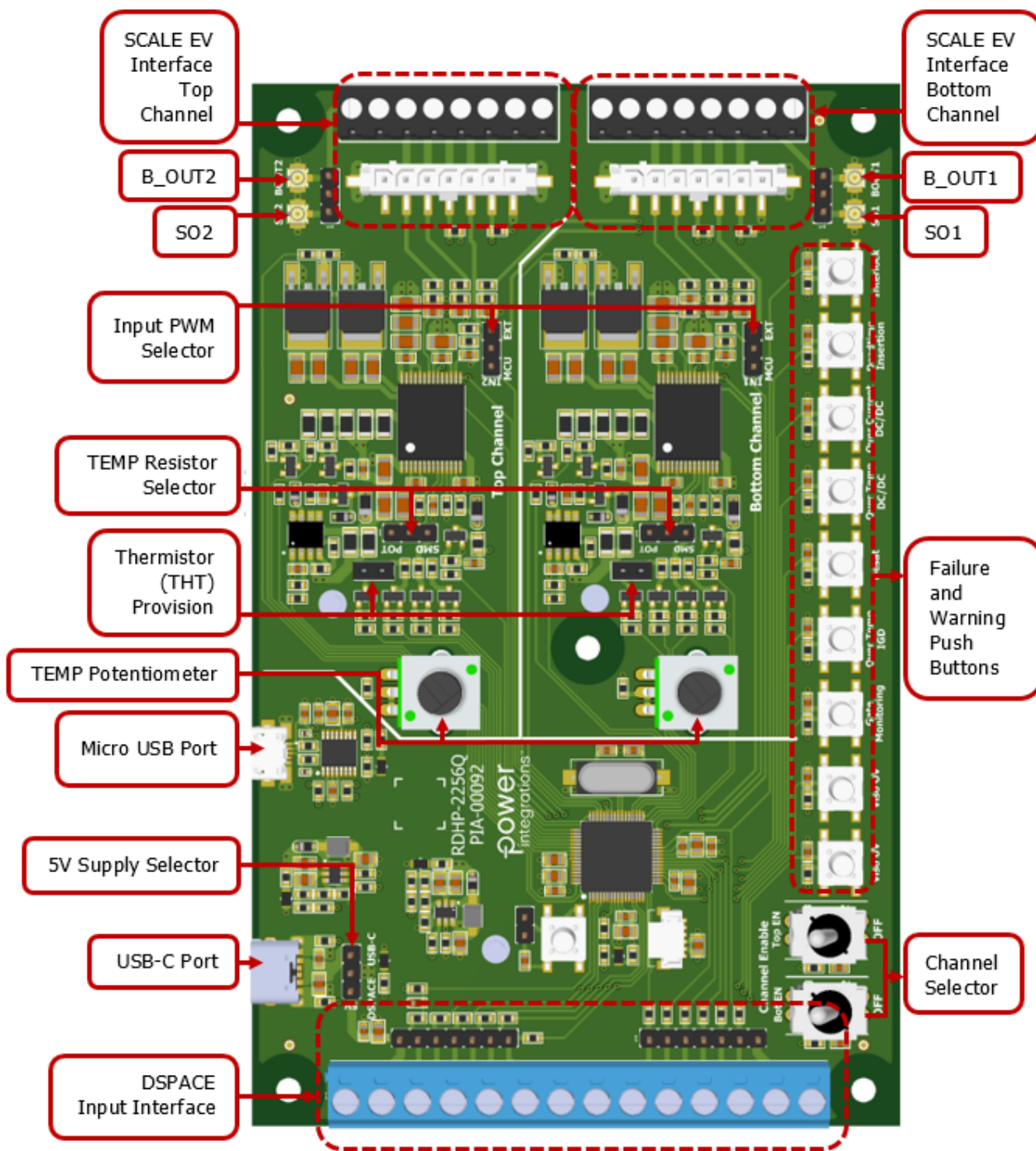


Figure 3. Unit 3D render (Portrait)



## 4 User Interface

### 4.1 DSPACE Input Interface

Pin No.	Label on Enclosure	I/O	Function
1	5V VCC	Supply	Primary-side supply voltage
2	TEMP	Input	Cycle discrete resistance values at TEMP pin
3	Bot EN	Input	Enable bottom channel bitstream error emulation
4	Top EN	Input	Enable top channel bitstream error emulation
5	Viso UV	Input	Trigger VISO under voltage warning
6	Viso OV	Input	Trigger VISO over voltage warning
7	Gate M	Input	Trigger gate monitoring warning
8	OT IGD	Input	Trigger gate driver over temperature warning
9	DESAT	Input	Trigger DESAT detection
10	OT DC/DC	Input	Trigger DC/DC over temperature warning
11	OC DC/DC	Input	Trigger primary-side DC/DC controller overcurrent warning
12	DT INSRT	Input	Trigger dead time insertion warning
13	Interlock	Input	Trigger interlock warning
14	GND	Supply	Common ground potential

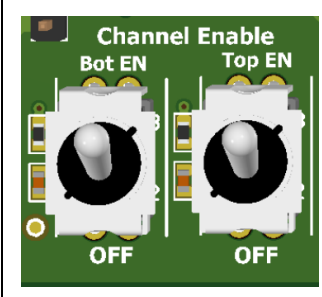
**Table 1.** DSPACE input interface pin assignment and functions

### 4.2 Failure and Warning Push Buttons

Label on Enclosure	I/O	Function
Interlock	Input	Trigger interlock warning
Deadtime Insertion	Input	Trigger dead time insertion warning
Over Curr DC/DC	Input	Trigger primary-side DC/DC controller overcurrent warning
Over Temp DC/DC	Input	Trigger DC/DC over temperature warning
DESAT	Input	Trigger DESAT detection
Over Temp IGD	Input	Trigger gate driver over temperature warning
Gate Monitoring	Input	Trigger gate monitoring warning
Viso OV	Input	Trigger VISO over voltage warning
Viso UV	Input	Trigger VISO under voltage warning

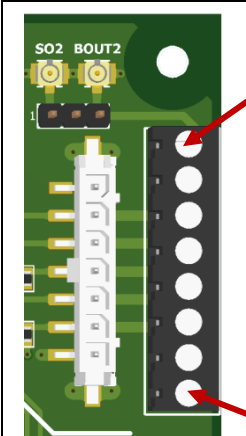
**Table 2.** Failure and warning push button functions

### 4.3 Channel Selector Toggle Switches

	Label on Enclosure	I/O	Function
Bot EN	Input	Enable error emulation on the bottom channel (Toggle up)	
Top EN	Input	Enable error emulation on the top channel (Toggle up)	
OFF	Input	Disable error emulation on top and/or bottom channel (Toggle down)	

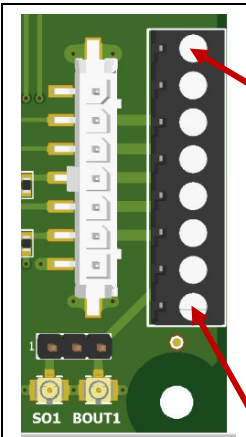
**Table 3.** Channel selector toggle switch selections and functions

### 4.4 Top Channel Gate Driver ASIC Interface

	Pin No.	Label on Enclosure	I/O	Function
8	GATE2	Output	Top channel gate signal	
7	VEE2	Supply	Top channel negative supply voltage reference	
6	ASC_AD2	Input	Primary-side ASC_AD pin signal	
5	_AD_EN	Input	Primary-side ASC_AD_EN pin signal	
4	SO2	Output	Logic fault signal	
3	IN2	Input	Logic command signal	
2	BOUT2	Output	Digital bitstream output	
1	GND	Supply	Common ground potential	

**Table 4.** Top channel SCALE EV interface pin assignment and functions

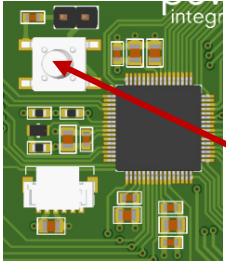
### 4.5 Bottom Channel Gate Driver ASIC Interface

	Pin No.	Label on Enclosure	I/O	Function
8	GATE1	Output	Bottom channel gate signal	
7	VEE1	Supply	Bottom channel negative supply voltage reference	
6	ASC_AD1	Input	Primary-side ASC_AD pin signal	
5	_AD_EN1	Input	Primary-side ASC_AD_EN pin signal	
4	SO1	Output	Logic fault signal	
3	IN1	Input	Logic command signal	
2	BOUT1	Output	Digital bitstream output	
1	GND	Supply	Common ground potential	

**Table 5.** Bottom channel SCALE EV interface pin assignment and functions



## 4.6 Microcontroller Reset Button

	Label on Enclosure	I/O	Function
	MCU Reset	Input	Reset onboard microcontroller  Note: Errors/warnings may be flagged by the bitstream reader GUI when the onboard microcontroller is reset due to the microcontroller's initialization process.

**Table 6.** Microcontroller reset button function

## 5 Operation Guide

### 5.1 Bitstream Error Emulation Available

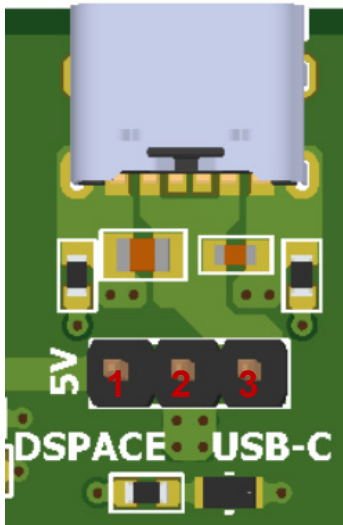
1. Temperature Sensor
2.  $V_{VISO}$  Under Voltage
3.  $V_{VISO}$  Over Voltage
4. Gate Monitor
5. Over Temperature ( $OT_{1GD}$  and  $OT_{2GD}$ )
6. DESAT Detection
7. Over Temperature ( $OT_{1DCDC}$  and  $OT_{2DCDC}$ )
8. Primary-side DC/DC Controller Overcurrent Warning
9. Dead Time Insertion
10. Interlock

### 5.2 Limitations

1. Minimum power supply rating of 15 W (5 V, 3 A).
2. All errors can be triggered on both top and bottom channels simultaneously, except for Over Temperature ( $OT_{1DCDC}$  and  $OT_{2DCDC}$ ).
3. Dead Time Insertion and Interlock will always be triggered on both top and bottom channels simultaneously.
4. Error emulation is only executed once the push button is released or the rising edge of a digital signal from the DSPACE input interface is detected.
5. Only one error emulation can be triggered at a time.
6. Channel switching is prohibited while an error emulation is currently executing.

## 5.3 Board Setup

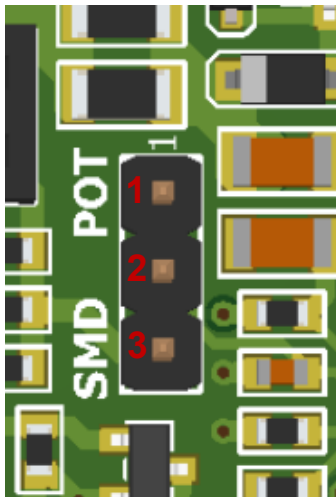
### 5.3.1 5 V Power Supply Selection



A power adapter/power supply with a minimum rating of **15 W (5 V, 3 A)** is required for powering up the board.

1. To supply the board through the USB-C port
  - Short pin 2 and pin 3 of the "5V Supply Selector" using a jumper.
  - Connect the USB-C end of a power cable to the USB-C port of the board.
  - Connect the other end of the power cable to a power adapter.
2. To supply the board through the DSPACE input interface
  - Short pin 2 and pin 1 of the "5V Supply Selector" using a jumper.
  - Connect the negative wire of the power supply to the "GND" pin (Pin 14) of the DSPACE input interface.
  - Connect the positive wire of the power supply to the "5V VCC" pin (Pin 1) of the DSPACE input interface.

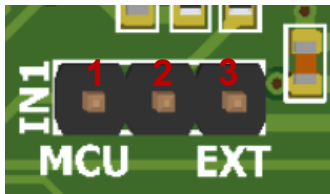
### 5.3.2 TEMP Resistor Selection (Top and Bottom Channel)



1. To connect the potentiometer to the TEMP pin of SIC2192FQ
  - Short pin 2 and pin 1 of the "TEMP Resistor Selector" using a jumper.
2. To connect the discrete SMD resistors and THT thermistor provision to the TEMP pin of SIC2192FQ
  - Short pin 2 and pin 3 of the "TEMP Resistor Selector" using a jumper.

No manual button is available for cycling SMD resistors to the TEMP pin of SIC2192FQ. Control for cycling the SMD resistors to the TEMP pin of SIC2192FQ can only be done using a digital signal through "TEMP" pin (Pin 2) of the DSPACE input interface.

### 5.3.3 Input PWM Selection (Top and Bottom Channel)



1. To use the input signal generated from the microcontroller during bitstream error emulation
  - Short pin 2 and pin 1 of the "Input PWM Selector" using a jumper.
2. To use an external PWM signal during bitstream error emulation
  - Short pin 2 and pin 3 of the "Input PWM Selector" using a jumper.
  - Connect the negative wire of the signal cable to the "GND" pin (Pin 1) of the SCALE EV interface.
  - Connect the positive wire of the signal cable to the "INx" pin (Pin 3) of the SCALE EV interface.
  - OR*
  - Insert a Molex connector to the Molex socket with its pin 3 connected to the external PWM signal line

Frequency for the external IN PWM signal can be set to 20 kHz.

### 5.3.4 SO and B\_OUT Connection (Top and Bottom Channel)



1. Using coaxial connectors
  - Connect the SOx coaxial port from the emulator board to the SO coaxial port of an adapter board using an ultra-fine coaxial cable (Part Number: UFL-2HF6-068N1T-AC-200).
  - Connect the B\_OUTx coaxial port from the emulator board to the B\_OUT coaxial port of an adapter board using an ultra-fine coaxial cable (Part Number: UFL-2HF6-068N1T-AC-200).
  - Connect the adapter board to a computer using a USB cable.
2. Using the SCALE EV interface
  - Insert a Molex connector to the Molex socket with its pin 4 corresponding to the SOx signal line and pin 2 to the B\_OUTx signal line.

Probing the SOx and B\_OUTx signal is possible through pin 1 and pin 3 of the pin connectors shown in the image on the left (Pin 2 is GND) or through the "SOx" pin (Pin 4) and "B\_OUTx" pin (Pin 2) of the SCALE EV interface.

### 5.3.5 *Error Triggering Mode*

The DSPACE input interface is connected in parallel to the push buttons for manual triggering. Since the signal to trigger bitstream errors are set to “active low”, it is important to ensure that the terminals of the controls for the triggering method not being used be pulled high or open to avoid false triggering of bitstream errors.

1. To emulate errors manually (Manual Triggering)
  - Ensure pins/terminals of the DSPACE input interface corresponding to the input triggers for the errors are open or pulled “high”.
2. To emulate errors using the DSPACE system (Automated Triggering)
  - Ensure both channel selector switches are toggled off.
  - Configure digital signals going into the DSPACE input interface to “active low” (Typical pulse width  $\approx$  1ms).

## 5.4 **Sequence for Operation**

1. Set up selectors and connections on the board based on preferred testing cases.
2. Toggle both channel selector switches off.
3. Plug power brick to outlet OR turn on power supply.
  - Four (4) green LEDs should light up upon successful power up;
    - o one (1) LED to indicate presence of a 5 V supply;
    - o two (2) LEDs to indicate presence of voltage output from the low-power step up converters;
    - o and one (1) blinking LED to indicate successful power up and initialization of the microcontroller.
4. Reset bitstream reader GUI.
  - Errors from the bitstream reader GUI upon board start-up are expected since the microcontroller still needs to initialize control signals for the error emulation circuits on the board.
5. Toggle the channel selector switches OR input a “low” signal on the “Bot EN” pin (Pin 3) and/or “Top EN” pin (Pin 4) of the DSPACE input interface to select the channel/s to emulate errors on.
6. Press push buttons (Manual Triggering) OR input 1-ms active-low pulses on the DSPACE input interface (Automated Triggering) to trigger bitstream errors.
  - Faster blinking of the LED near the microcontroller indicates an error emulation program currently being executed.
7. Repeat (4.) or (5.) if necessary.
8. Repeat (6.).

## 5.5 **Sequence for Power Down**

1. Ensure no error emulation program is still being executed.
  - LED near the microcontroller must not be blinking fast.
2. Toggle both channel selector switches off.
3. Unplug power adapter from outlet OR turn off power supply.

4. Disconnect wires from the interfaces, connectors, and USB ports.

## 5.6 Error Emulation

1. The channel/s selected to emulate errors on should be enabled using the channel selector switches or by inputting a "low" signal on the "Bot EN" pin (Pin 3) and/or "Top EN" pin (Pin 4) of the DSPACE input interface before triggering any errors. If no channel is enabled, no errors will be emulated on the board.
2. The LED located near the microcontroller blinks faster when an error emulator program is currently being executed.

### 5.6.1 *Temperature Sensor*

1. If the potentiometer is connected to the TEMP pin of SIC2192FQ:
  - Turn the potentiometer knob to see the change in resistance values at the TEMP pin of SIC2192FQ
2. If the discrete SMD resistors and THT thermistor provision is connected to the TEMP pin of SIC2192FQ:
  - Initially, the header socket for the THT thermistor provision is already connected to the TEMP pin of SIC2192FQ
  - Input a 1-ms active-low pulse on the "TEMP" pin (Pin 2) of the DSPACE input interface.
  - 1<sup>st</sup> input connects the 15 k $\Omega$  resistor only at the TEMP pin of SIC2192FQ.
  - 2<sup>nd</sup> input connects the 5.1 k $\Omega$  resistor only at the TEMP pin of SIC2192FQ.
  - 3<sup>rd</sup> input connects the 150  $\Omega$  resistor only at the TEMP pin of SIC2192FQ.
  - 4<sup>th</sup> input connects the header socket for the THT thermistor provision only to the TEMP pin of SIC2192FQ again.
  - Succeeding inputs repeats the cycle.

### 5.6.2 *V<sub>VISO</sub> Under Voltage*

1. Press the "Viso UV" push button OR input a 1-ms active-low pulse on the "Viso UV" pin (Pin 5) of the DSPACE input interface.

### 5.6.3 *V<sub>VISO</sub> Over Voltage*

1. Press the "Viso OV" push button OR input a 1-ms active-low pulse on the "Viso OV" pin (Pin 6) of the DSPACE input interface.

### 5.6.4 *Gate Monitoring*

1. If an external PWM signal will be used during the bitstream error emulation, enable the PWM signal.
2. Press the "Gate Monitoring" push button OR input a 1-ms active-low pulse on the "Gate M" pin (Pin 7) of the DSPACE input interface.

### 5.6.5 *Over Temperature (OT1<sub>GD</sub> and OT2<sub>GD</sub>)*

1. Press the "Over Temp IGD" push button OR input a 1-ms active-low pulse on the "OT IGD" pin (Pin 8) of the DSPACE input interface.
2. Successful error triggering should speed up the blinking of the LED near the microcontroller.
3. Wait for the LED to return to its normal blinking speed (trigger duration  $\approx$  5 to 6 s)

### 5.6.6 *DESAT*

1. If an external PWM signal will be used during the bitstream error emulation, enable the PWM signal.
2. Press the "DESAT" push button OR input a 1-ms active-low pulse on the "DESAT" pin (Pin 9) of the DSPACE input interface.

Note:

- DESAT error emulation reports multiple error on the bitstream reader GUI. Errors that may be reported on the bitstream GUI along with the DESAT error are as follows:
  - V<sub>VISO</sub> Under Voltage
  - V<sub>VISO</sub> Over Voltage
  - Gate Monitor
  - Over Temperature (OT1GD and OT2GD)
  - Secondary Side Fluxlink Out Of Service 10  $\mu$ s
  - Secondary Side Fluxlink Out Of Service  $\geq$  20  $\mu$ s
  - CRC
  - Primary Side Fluxlink Out Of Service 10  $\mu$ s
  - Primary Side Fluxlink Out Of Service  $\geq$  20  $\mu$ s

### 5.6.7 *Over Temperature (OT1<sub>DCDC</sub> and OT2<sub>DCDC</sub>)*

1. Press the "Over Temp DC/DC" push button OR input a 1-ms active-low pulse on the "OT DC/DC" pin (Pin 10) of the DSPACE input interface.
2. Successful error triggering should speed up the blinking of the LED near the microcontroller.
3. Wait for the LED to return to its normal blinking speed (trigger duration  $\approx$  60 to 80 s) or manually reset the emulation by pressing the "Over Temp DC/DC" push button again or by inputting another 1-ms active-low pulse on the "OT DC/DC" pin (Pin 10) of the DSPACE input interface. Successful reset returns the LED to its normal blinking speed.

Note:

- Only one (1) channel can be enabled during an Over Temperature (OT1<sub>DCDC</sub> and OT2<sub>DCDC</sub>). No Over Temperature (OT1<sub>DCDC</sub> and OT2<sub>DCDC</sub>) error will be emulated if both channels are enabled.
- Primary Side DC/DC Controller Overcurrent will also be flagged on the bitstream reader GUI when triggering Over Temperature (OT1<sub>DCDC</sub> and OT2<sub>DCDC</sub>) error. This



behavior always occurs **ONLY** on the RDHP-2256Q board due to the nature of how the Over Temperature (OT1<sub>DCDC</sub> and OT2<sub>DCDC</sub>) is emulated on the board. In actual system-level applications, Primary Side DC/DC Controller Overcurrent may not always be present when there is an Over Temperature (OT1<sub>DCDC</sub> and OT2<sub>DCDC</sub>) error.

#### 5.6.8 Primary-side DC/DC Controller Overcurrent Warning

1. Press the "Over Curr DC/DC" push button OR input a 1-ms active-low pulse on the "OC DC/DC" pin (Pin 11) of the DSPACE input interface.

#### 5.6.9 Dead Time Insertion

1. Press the "Deadtime Insertion" push button OR input a 1-ms active-low pulse on the "DT INSRT" pin (Pin 12) of the DSPACE input interface.
2. If an external PWM signal will be used during the bitstream error emulation, manually remove the dead time of the external input PWM signals.

#### 5.6.10 Interlock

1. Press the "Interlock" push button OR input a 1-ms active-low pulse on the "Interlock" pin (Pin 13) of the DSPACE input interface.
2. If an external PWM signal will be used during the bitstream error emulation, it is recommended to set one of the external input signals to a 0 – 5 V, 75  $\mu$ s single pulse and the other external input signal to a 0 – 5 V, 25  $\mu$ s single pulse. Set the two signals as center aligned similar to the image below.

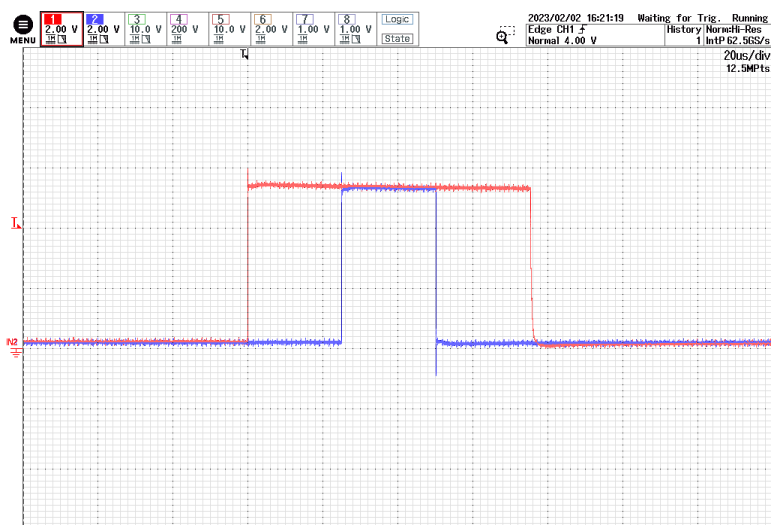


Figure 4. Recommended external input signal waveforms for triggering "Interlock"

## 6 Revision History

Revision	Date	Change(s)	Author	Reviewer	Approver
1.5	08-Feb-23	Initial Release.	JS	CC, MCR	MH

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