ASD2-EVAL-001

TO-247 SiC MOSFET and ASD2-EVAL-001 Evaluation Board User Guide

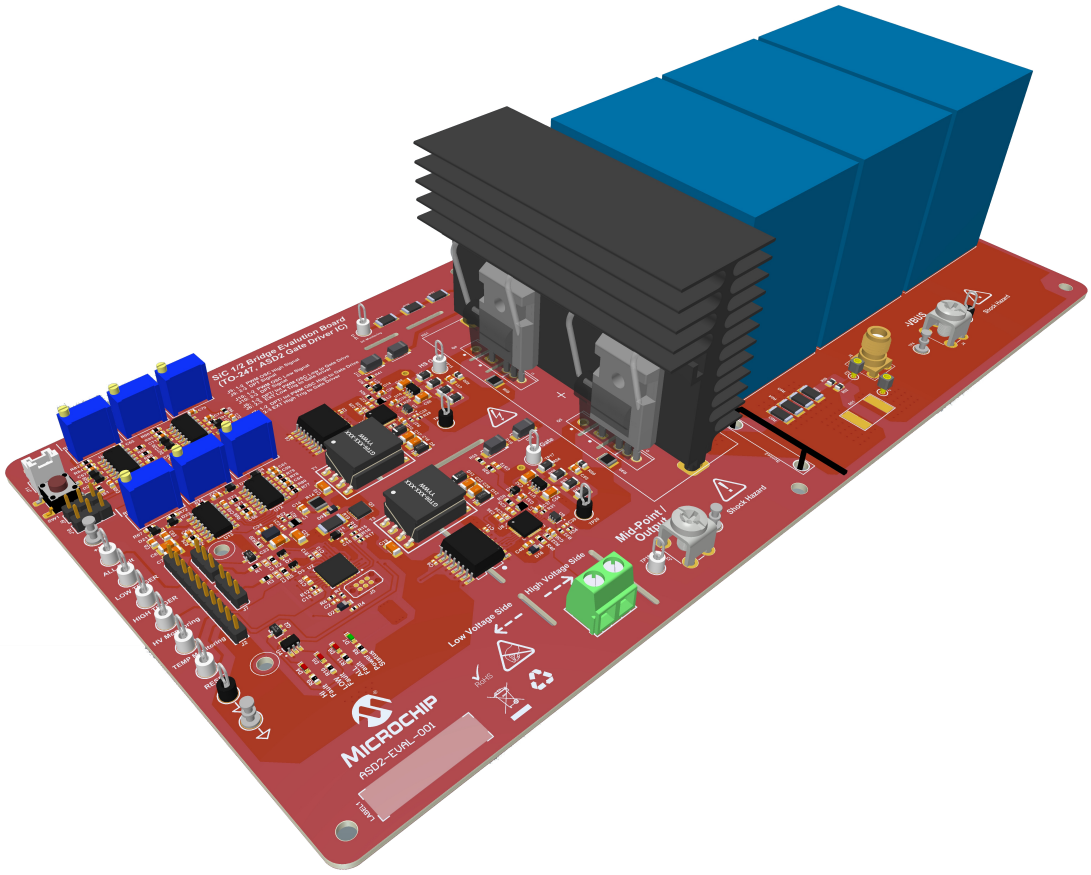
Introduction

The ASD2-EVAL-001 Evaluation Board incorporates Microchip's Silicon Carbide (SiC) Digital Gate Driver IC (ASD2), enabling better control and protection of SiC MOSFET-based power systems. The ASD2 IC drives Microchip's SiC MOSFETs in discrete TO-247 packages, including 3-pin and 4-pin versions. This board features an optimized layout that minimizes the commutation loop inductance and is equipped with Rogowski Coil and shunt-based current measurement options.

This board is developed to support Microchip's customers during the initial stage of designing power converter applications and characterize high voltage devices (MOSFETs) with ASD2 Digital Gate Drivers. The board is a cost-effective development platform for ASD2 Digital Gate Drivers and SiC discrete devices.

The following figure shows the 3D view of the ASD2-EVAL-001 Evaluation Board (this figure is for illustration purposes only, the actual product may vary due to product enhancement).

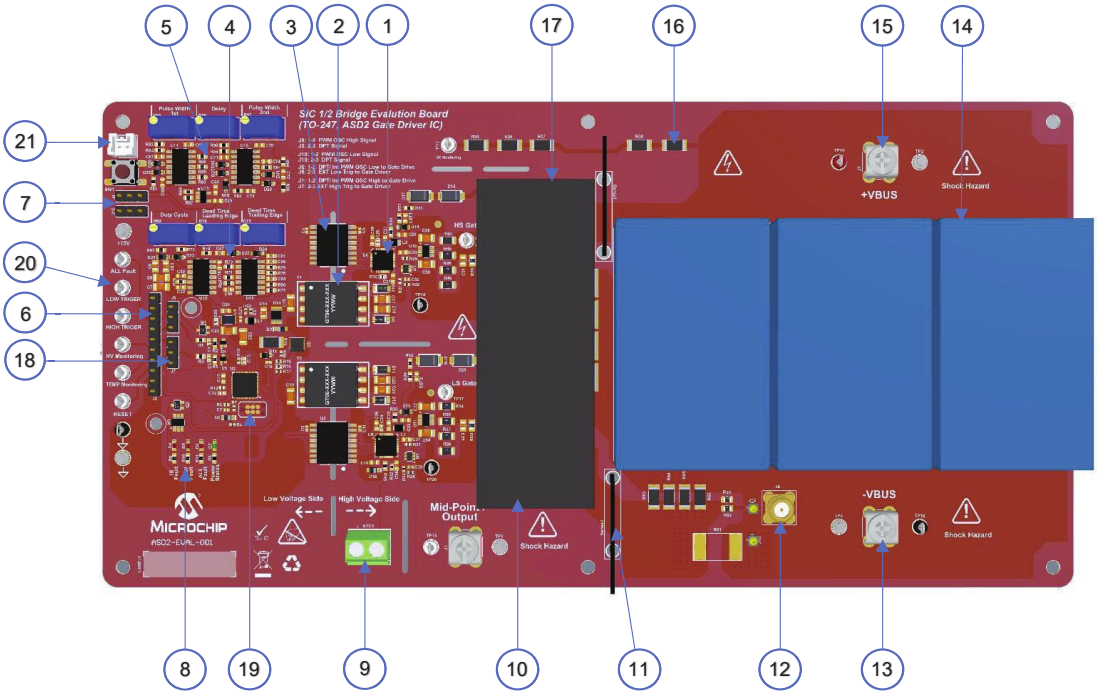
Figure 1. ASD2-EVAL-001 Evaluation Board—3D Board Model



Features

The following figure shows the key hardware features of the ASD2-EVAL-001 Evaluation Board.

Figure 2. ASD2-EVAL-001 Evaluation Board—Hardware Features

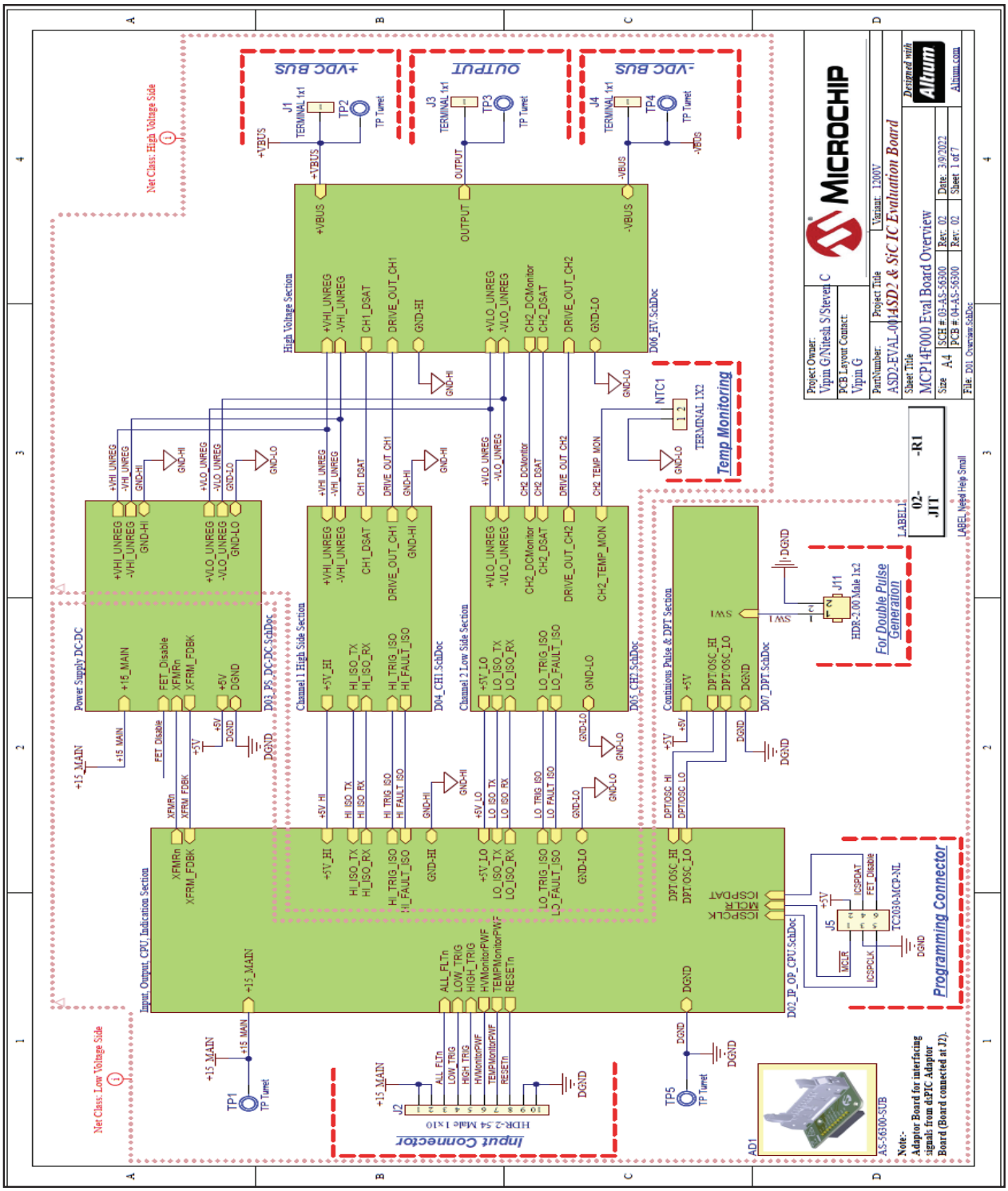


1. Microchip ASD2 IC with configurable augmented switching, DSAT protection, and power supply protection.
2. Isolated power supply for high side and low side secondary section.
3. Isolators are provided to isolate gate signals which are transmitted from primary side to secondary side, with a minimum CMTI of 100 kV/µs.
4. On board continuous pulse train generator circuit, where the pulse width/duty cycle of the waveform can be changed.
5. On board circuit which can generate two pulses for double pulse testing. The pulse width of the two pulses and the delay time in between can be modified.
6. Provision for interfacing dsPIC Adapter Board at connector J2 with help of a Sub-Adapter Interfacing Board (AS-56300-SUB).
7. Provision for selecting signals source—Double Pulse Test (DPT) section or continuous pulse generator.
8. LED indications provide various fault and power ON status.
9. Provision to interface external NTC and characterize temperature related feature of ASD2.
10. Power Device (SiC MOSFET) mounted on the Heatsink.
11. Provision for measuring current at high side and low side devices using a Rogowski Coil.
12. Provision for measuring current by using a shunt resistor with help of BNC connector.
13. Provision of connecting Negative Voltage Bus Terminal (–VBUS).
14. High Voltage bulk capacitors (66 µf\F).
15. Provision for connecting to the Positive High Voltage Bus Terminal (+VBUS), accepts up to 1200V with respect to Negative Bus terminal (–VBUS).
16. Provision for Monitoring High Voltage.
17. Heatsink for power device (SiC MOSFET).
18. Provision for selecting PWM signal coming from dsPIC Adapter or on board generated PWM signal.
19. Programming header for primary side controller.
20. Test-point for monitoring various signal (monitoring connector J2 signals).
21. Provision for interfacing external push-button for generating double pulse signal.

Block Diagram

The following drawing shows the block diagram of the ASD2-EVAL-001 Evaluation Board.

Figure 3. ASD2-EVAL-001 Evaluation Board—Block Diagram



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1. Safety Information

Read this document before operating ASD2-EVAL-001 Evaluation Board. It is not necessary to touch the board while it is energized. All test and measurement probes or attachments must be attached before the board is energized. Never leave this board unattended or handle it when energized, and always ensure that all bulk capacitors have completely discharged prior to handling the board. Do not change the devices to be tested until the board is disconnected from the electrical source and the bulk capacitors have fully discharged.

Do not touch the board when it is energized; allow the bulk capacitors to discharge completely before handling it. There can be very high voltages on this evaluation board when connected to an electrical source, and some components on this board can reach temperatures above 50°C. Further, these conditions will continue for a short time after the electrical source is disconnected until the bulk capacitors are fully discharged.

Ensure that appropriate safety procedures are followed when operating this board, as any of the following can occur if you handle or use this board without following proper safety precautions:

- Death
- Serious injury
- Electrocution
- Electrical shock
- Electrical burns
- Severe heat burns

2. Hardware

This chapter describes the design and test results of the ASD2-EVAL-001 Evaluation Board.

2.1 Power Supply

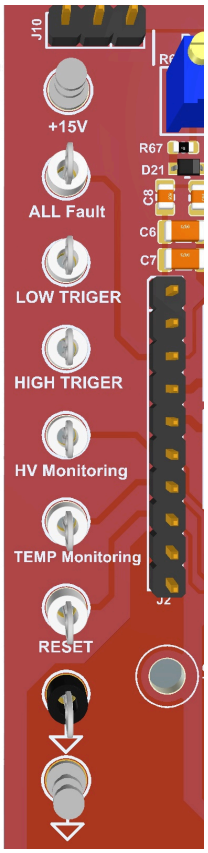
This section describes the electrical specifications of the ASD2-EVAL-001 Evaluation Board.

2.1.1 External Power Supply

The ASD2-EVAL-001 Evaluation Board operates on +15 V_{DC}. An external power supply of +15 V_{DC} is provided at connector J2 on pin 1 and pin 2 with respect to pin 9 and pin 10 (GND). The current consumption in the quiescent stage without applying any pulses is approximately 60 mA, 65 mA in double pulse mode, and 80 mA in OSC mode. A supply of +15 V_{DC} can be provided at the test point (terminal). Further, +5 V_{DC} is generated on-board using a regulator U5 IC. See the following figure.

The external power supply of +15 V_{DC} is sourced from a low-voltage variable DC power supply (for example, Dual Channel DC Power Supply Adjustable, Part Number 72-10500, Make TENMA).

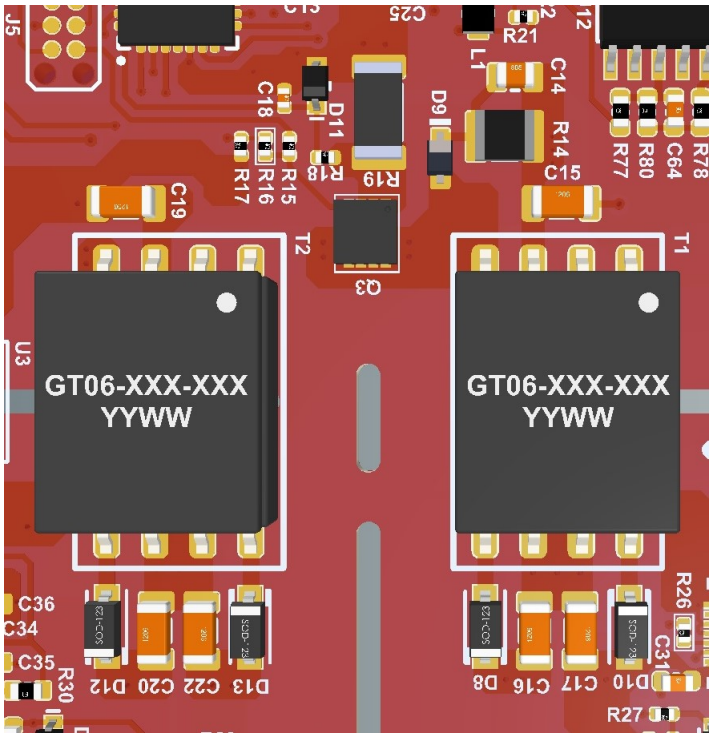
Figure 2-1. J2 Connector



2.1.2 Power Supply for Gate Driver

The ASD2-EVAL-001 Evaluation Board consists of an isolated gate driver power supply, where +23.5 V_{DC} and –8 V_{DC} are generated from +15 V_{DC} input voltage for High-Side and Low-Side sections, and the power rating for each channel is 3W. See the following figure for more information.

Figure 2-2. Power Supply for Gate Driver



2.1.3 Power from Programming Header

An external +5 V_{DC} power supply is provided through the connector J5 while the primary side controller is programmed. Supplying an external +15 V_{DC} power supply is mandatory during the programming of the primary side controller. At this time, the gate driver power supply is disabled.

2.2 Use of Double Pulse Generation Circuit

The ASD2-EVAL-001 Evaluation Board is provided with a double pulse generation circuit, as shown in the following figure. It consists of a switch (SW1) and three preset multi-turn potentiometers. By pressing switch SW1 once, a double pulse waveform is generated. Connect an external switch at connector J11 to generate a double-pulse waveform. POT R85 is used to set/change the pulse width of the first pulse, POT R96 is used to set/change the delay between the first and second pulse, and POT R97 is used to set/change the pulse width of the second pulse.

Verify the pulse widths before further high voltage characterization of SiC devices (MOSFET). This can be verified by examining the signal generated on pin 3 of the connectors J9 and J10 using the oscilloscope.

Figure 2-3. Double Pulse Generation Circuit

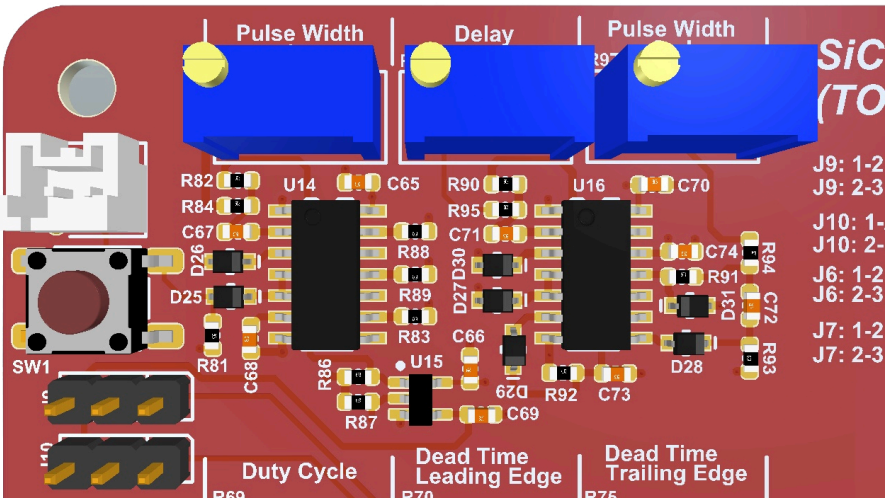
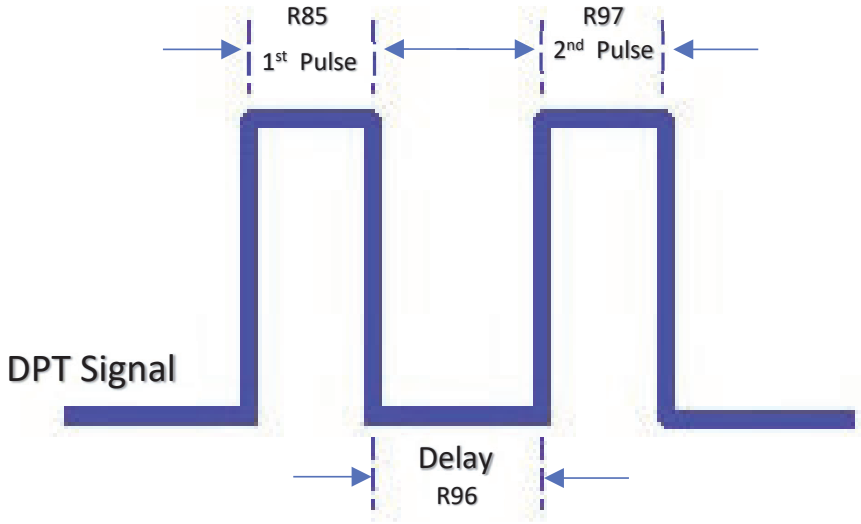


Figure 2-4. Double Pulse Waveform



To characterize the High-Side device, place the jumper on pin 2 and pin 3 of the connector J9, and to characterize the Low-Side device, place the jumper on pin 2 and pin 3 of the connector J10. In double pulse mode, only one device must be characterized at a time.

The minimum adjustable pulse width for the first and second pulse is 1 µs, and the minimum adjustable delay set between both the pulses is approximately 4 µs. See the following figure for more information.

Figure 2-5. Minimum Double Pulse Waveform

The maximum pulse width for the first and second pulse is 24 us, and the minimum delay set between both the pulses is approximately 6.5 µs. See the following figure for more information.

Figure 2-6. Maximum Double Pulse Waveform

2.3 Use of Continuous Pulse Train Generation Circuit

The ASD2-EVAL-001 Evaluation Board is equipped with a continuous pulse train generation circuit. This circuit generates a fixed frequency signal. The board consists of three preset multi-turn potentiometers, as shown in the following figure.

Figure 2-7. Continuous Pulse Generation Circuit

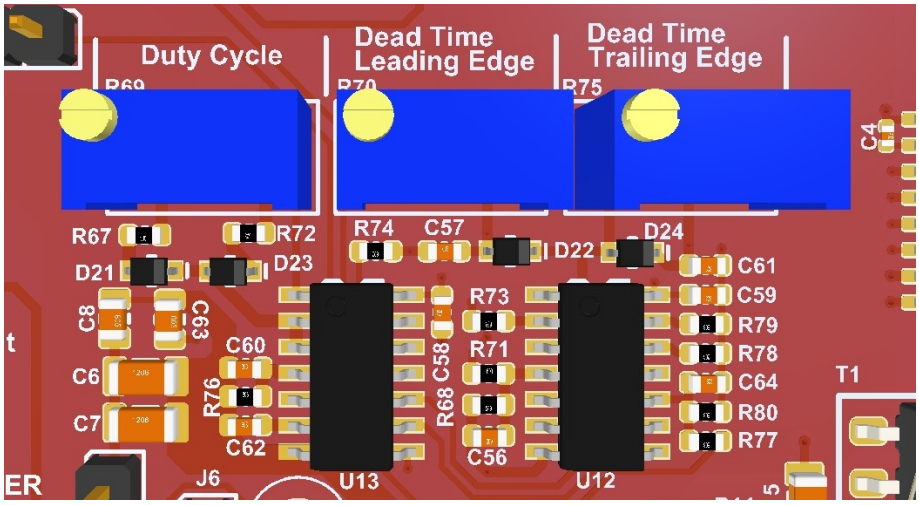
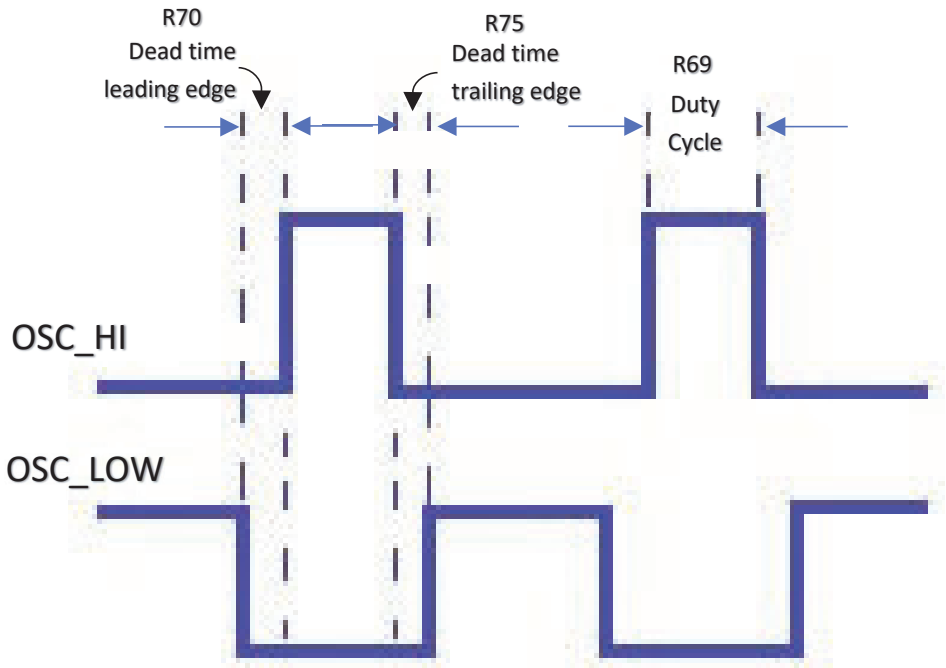


Figure 2-8. Continuous Pulse Waveform



POT R69 is used to set/change Duty Cycle of pulse from 5% to 95%.

⚠ CAUTION Microchip does not recommend setting POT at below 5% and above 95%.

POT R70 is used to set/change the hardware Dead-time at leading edge of the pulse by minimum 9 ns and maximum 24 ns. POT R75 is used set/change the hardware Dead-time at trailing edge of the pulse by minimum 9 ns and maximum 44 ns.

Prior to applying these signals to devices, check these signals at the respected connectors. A High-Side continuous pulse (OSC_HI) must be observed at pin 1 of the connector J9, whereas a Low-Side continuous pulse (OSC_LO) must be observed at pin 1 of the connector J10. These signals can be transferred further by placing a 2-pin jumper at pin 1 and pin 2 of the connectors J9 and J10.

Note: Signals can be routed from either the double pulse section or the continuous pulse train section.

⚠ CAUTION Microchip recommends modifying the jumpers and POTs only when the high-voltage side is not powered and discharged.

The following figures show the waveform for POT R69 set at 10%, 50%, and 90%.

Figure 2-9. Low-Side Trigger Set at 10% and High-Side Set at 90% with Frequency 10 kHz

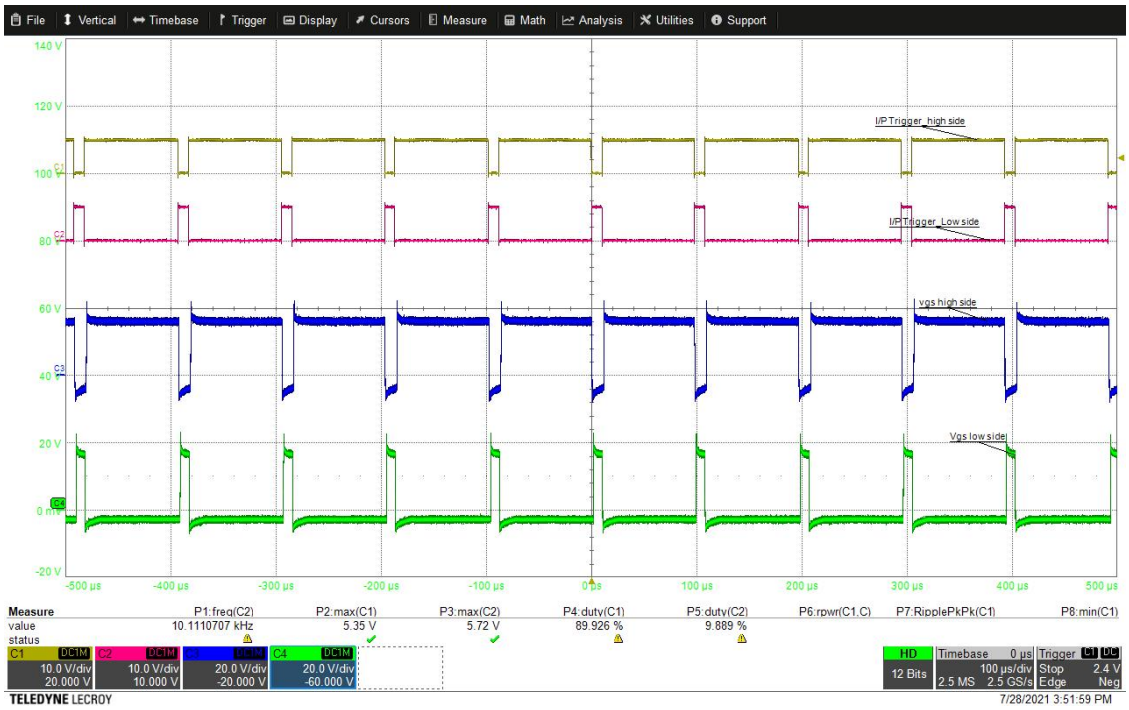


Figure 2-10. Low-Side Trigger Set at 50% and High-Side Set at 50% with Frequency 14.5 kHz

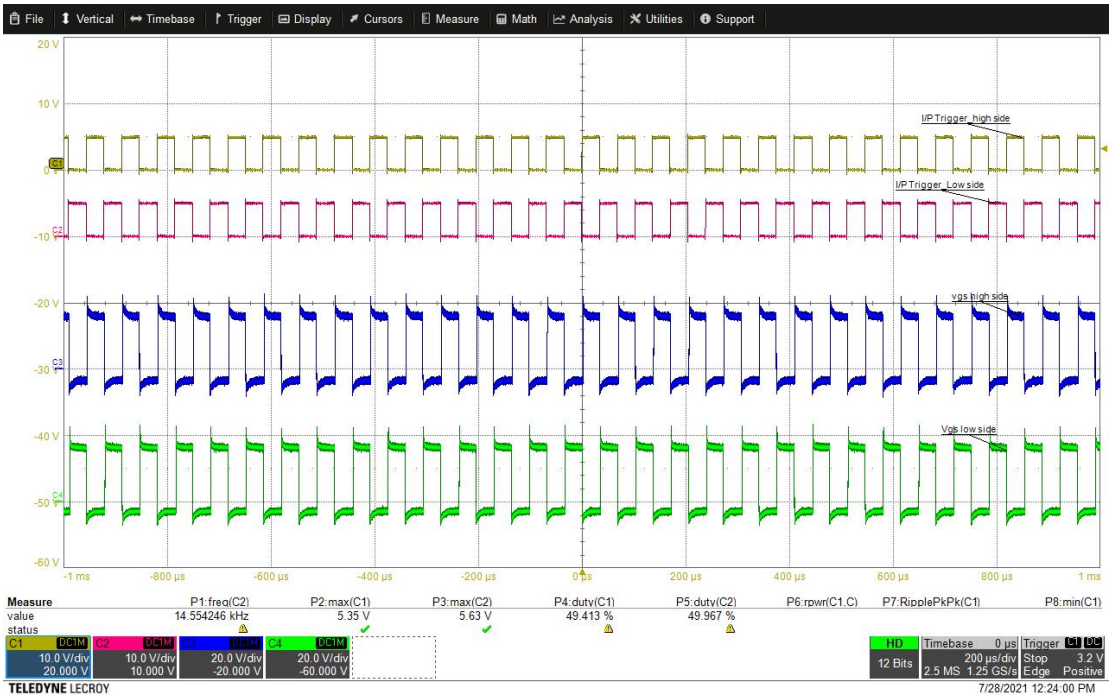
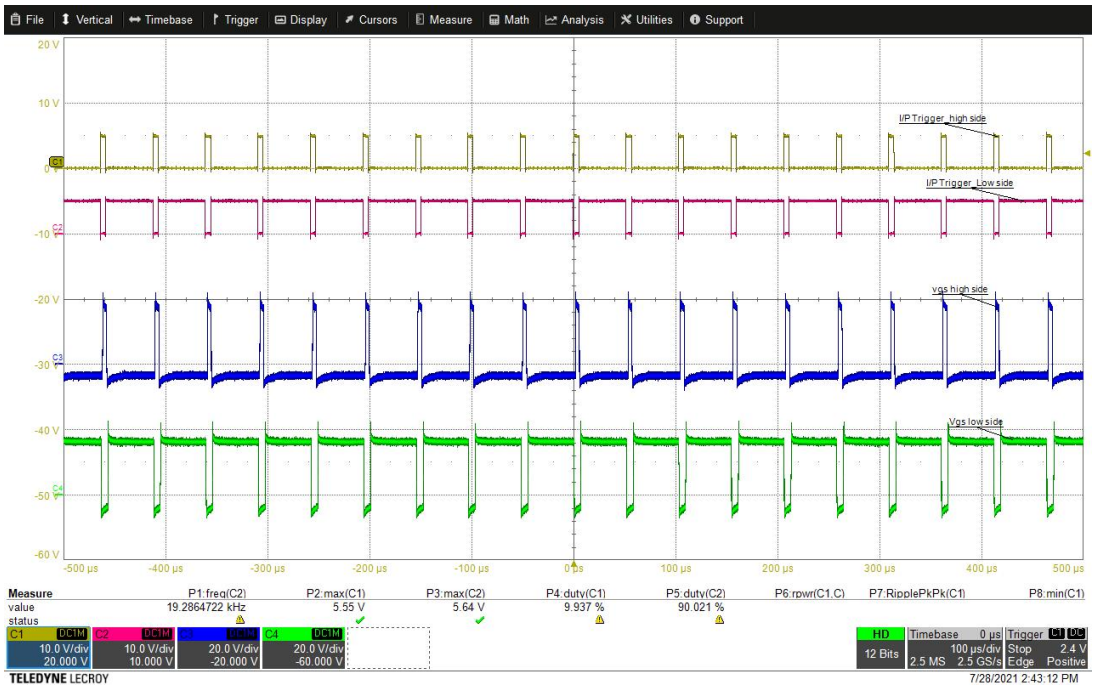


Figure 2-11. Low-Side Trigger Set at 90% and High-Side Set at 10% with Frequency 20 kHz

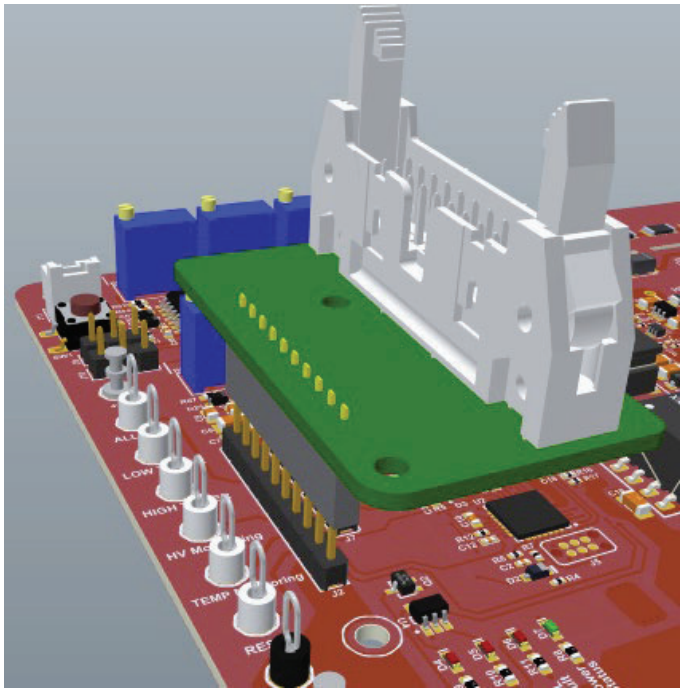


2.4 Use of Sub Adapter Board for dsPIC33CK Curiosity Board

The dsPIC Adapter can be connected through a Sub-Adapter Board (AS-56300-SUB), which is placed at the connector J2.

The following figure shows the placement of the Sub-Adapter Board (AS-56300-SUB) on the connector J2.

Figure 2-12. Placement of Sub-Adapter Board (AS-56300-SUB)



Note: The ASD2-EVAL-001 Evaluation Board is configured for a 5V input trigger pulse for the high and low trigger inputs. If supplying 15V trigger inputs, the board must be modified by changing resistor values of R2 and R5 from 10 kΩ to 1 kΩ.

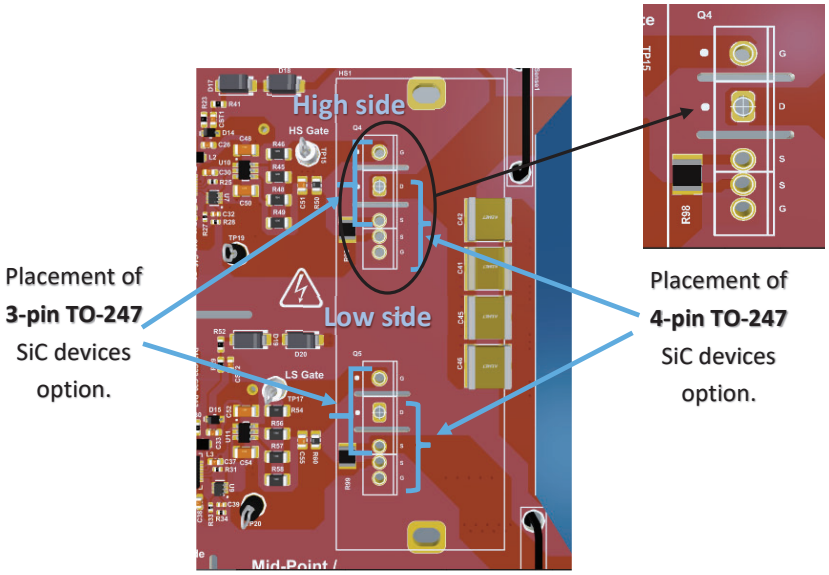
2.5 Testing of SiC Discrete MOSFET

The ASD2-EVAL-001 Evaluation Board is used to test and characterize 650V, 700V, 900V, and 1200V TO-247 packages with 3-pin and 4-pin SiC MOSFETs. Microchip SiC devices are available at: Microchip SiC Devices.

The following figure shows the mounting of 3-pin and 4-pin devices at the High-Side and Low-Side of the evaluation board. When testing devices in a TO-247 3-pin package, the board must be modified by mounting R98 and R99 resistors (0Ω).

Note: Microchip recommends mounting the same package on the High-Side and Low-Side (3-pin/4-pin) during the characterization.

Figure 2-13. Placement of SiC Discrete MOSFET



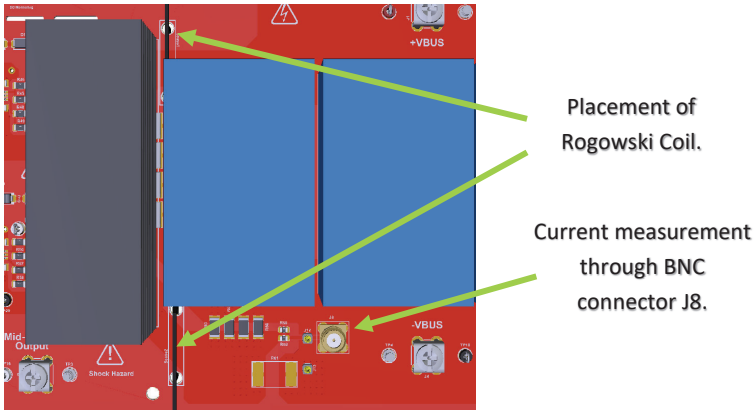
The ASD2-EVAL-001 Evaluation Board offers two options for current monitoring:

1. Rogowski Coil
2. Shunt Resistor

Measurement with the Shunt Resister is possible through the BNC connector J8. However, this is not isolated on the board and it is recommended to isolate the oscilloscope channel.

The following figure shows the placement of the Rogowski Coil and BNC connector J8. The Rogowski Coil option can be used to measure the current flowing through the Drain of the High-Side device and the Source of the Low-Side device.

Figure 2-14. Current Sensing Options



2.6 Programming of Primary Side Controller and ASD2 IC

The primary side controller communicates and configures the ASD2 Gate Driver IC. With the help of the Intelligent Configuration Tool, a configuration file is generated in the form of a hex file and loaded onto the primary controller through the PicKit3/4. This configuration is done through the connector J5, see Figure 2-16. Figure 2-15 shows the peripheral circuitry around ASD2 IC U8 (Low-Side is shown in Figure 2-15).

Instructions for the Intelligent Configuration Tool, and ASD2 Gate Driver IC and programming of primary side controller are available at:

- Intelligent Configuration Tool User Guide
- Device Programming Instructions and Quick Start Guide

Figure 2-15. ASD2 IC Peripheral

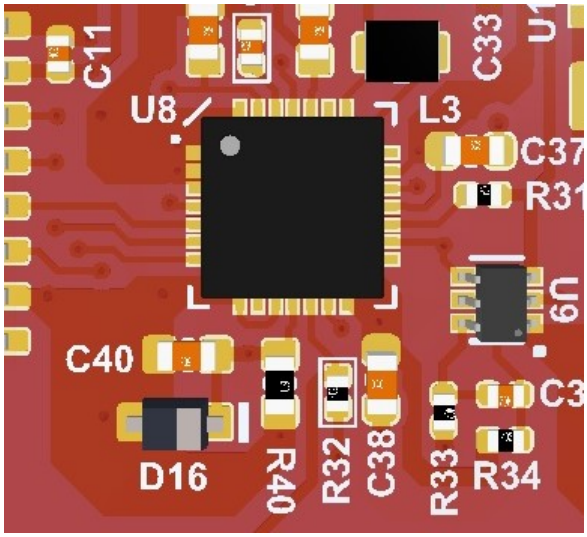
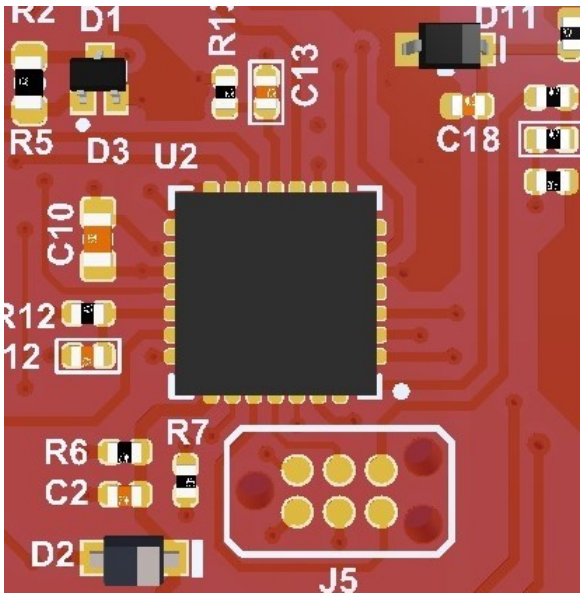


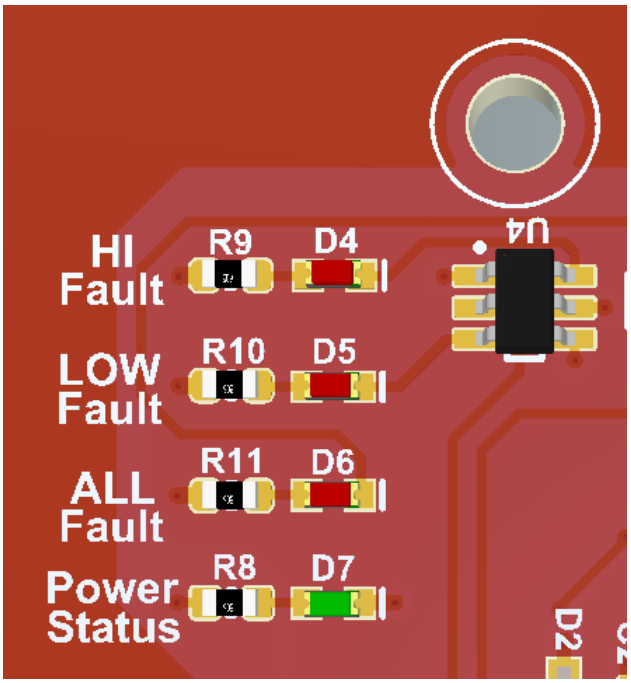
Figure 2-16. Programming of Primary Side Controller



2.7 Fault Indication

The evaluation board is provided with the status LEDs for faults and power indication, as shown in the following figure.

Figure 2-17. LED Indications



The following table lists the evaluation board status indication LEDs.

Table 2-1. Faults and Power Indication LEDs

Designation	Function
HI Fault	Indicates fault at the secondary High-Side
Low Fault	Indicates fault at the secondary Low-Side
All Fault	Indicates fault at the secondary High-Side or Low-Side
Power Status	Indicates a healthy power supply to the board

2.8 Test Results

The following table shows the test conditions considered when performing a test on Microchip's MSC060SMA070B4 SiC discrete MOSFET.

Table 2-2. Test Conditions

Parameters	Values
DUT Half-Bridge Placement	Low-Side
Voltage	470V
Current	20A
Load for DPT Test	Inductor of 320 µH
Load for DSAT Test	Resistor of 5Ω
Scope Filter	None
Gate Resistors	Varied (see Table 2-3 for RG_{on} and RG_{off} values)

2.8.1 Turn-On Measurements

The following table shows the Augmented setting for Turn-On measurements.

Table 2-3. Parameters Set in Software for Turn-On Measurements

	Voltage Level	Time	RG_{on}	RG_{off}
Turn-On Step	3.5V	110 ns	0.55Ω	4Ω

The following results were obtained during the testing:

- Less cross conduction observed on the VGS signal than the waveform without the Augmented setting.
- The current overshoot is reduced from 34.4A to 19.7A. E_{on} losses are increased from 149 µJ to 391 µJ.
- With an increase in RG_{on} value, E_{on} losses are more, and cross conduction is observed on VGS.

The following figures show the effect and oscilloscope waveform for with and without the Turn-On Augmented measurement settings, with the RG_{on} value set to 0.55Ω.

Figure 2-18. Without Turn-On Augmented Setting

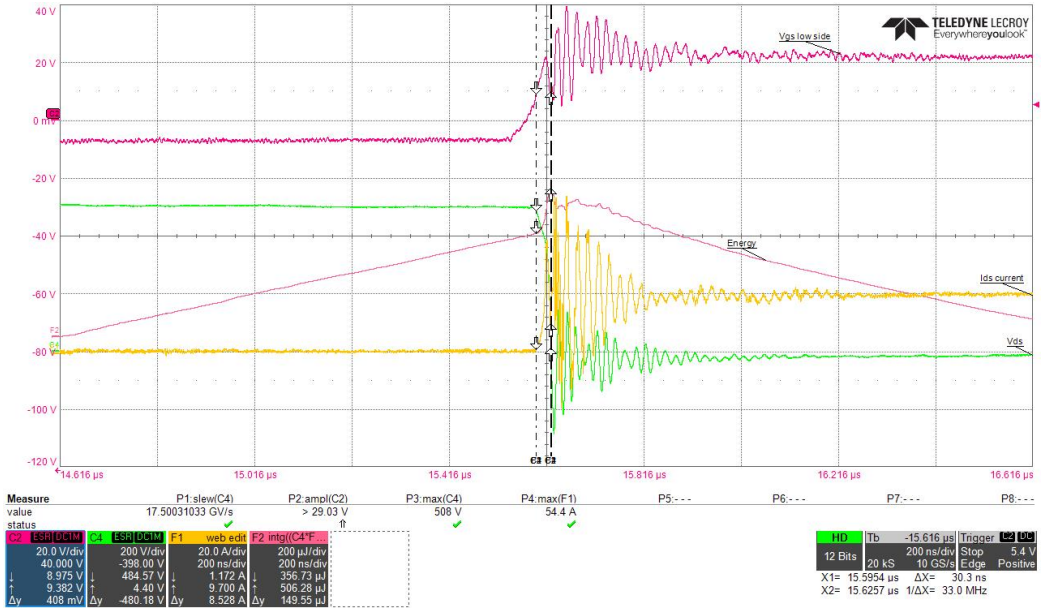
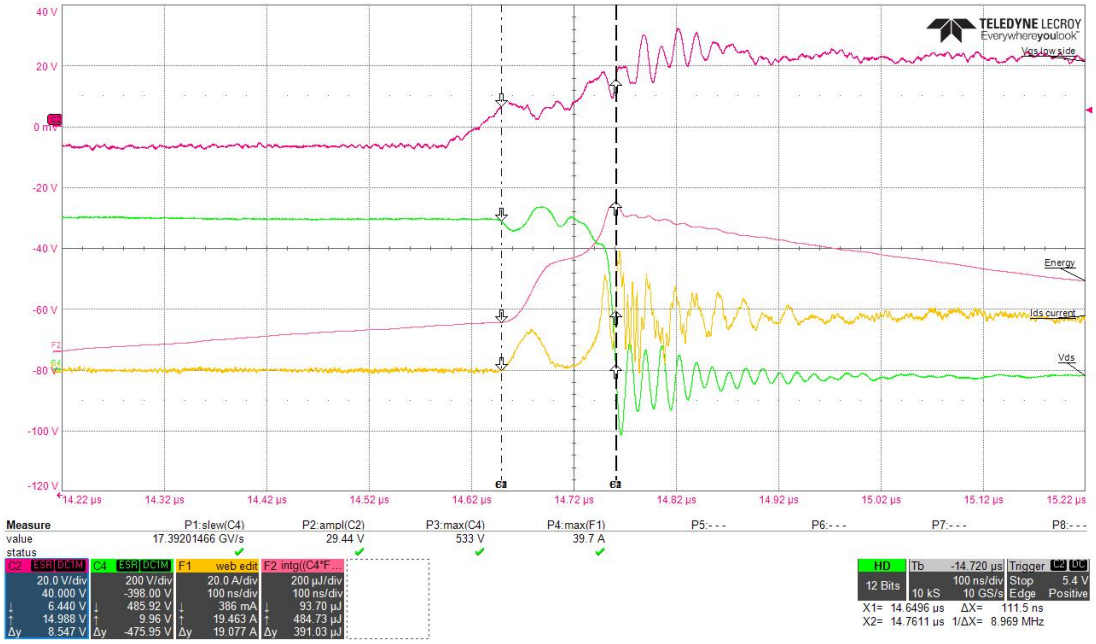


Figure 2-19. With Turn-On Augmented Setting



2.8.2 Turn-Off Measurements

The following table shows the Augmented settings for Turn-Off measurements.

Table 2-4. Parameters Set in Software for Turn-Off Measurements

	Voltage Level	Time	RG_{on}	RG_{off}
Turn-Off Step 1	3.5V	200 ns	4Ω	4Ω
Turn-Off Step 2	2.0V	100 ns		

The following results were obtained during the testing:

- No cross conduction observed on VGS Signal as compared to the waveform of without Augmented setting.
- The voltage overshoot is reduced from 249V to 107V.
- The E_{off} losses are increased from 128 µJ to 328 µJ.

The following figures show the effect and the oscilloscope waveform for with and without three-level Turn-Off Augment measurement settings, with the Rg_{off} value set to 4Ω.

Figure 2-20. Without Turn-Off Augmented Setting

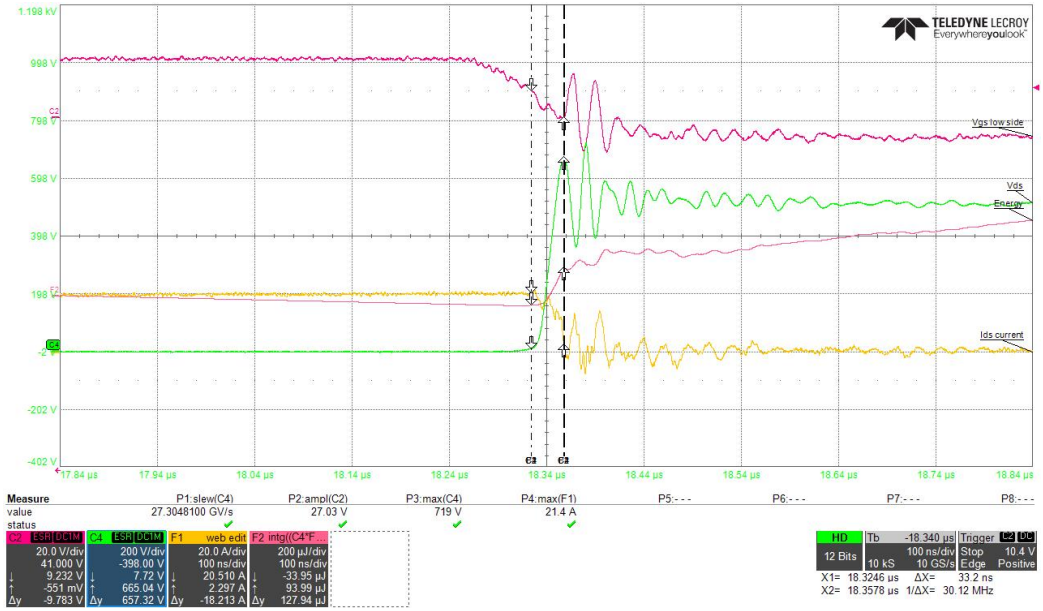
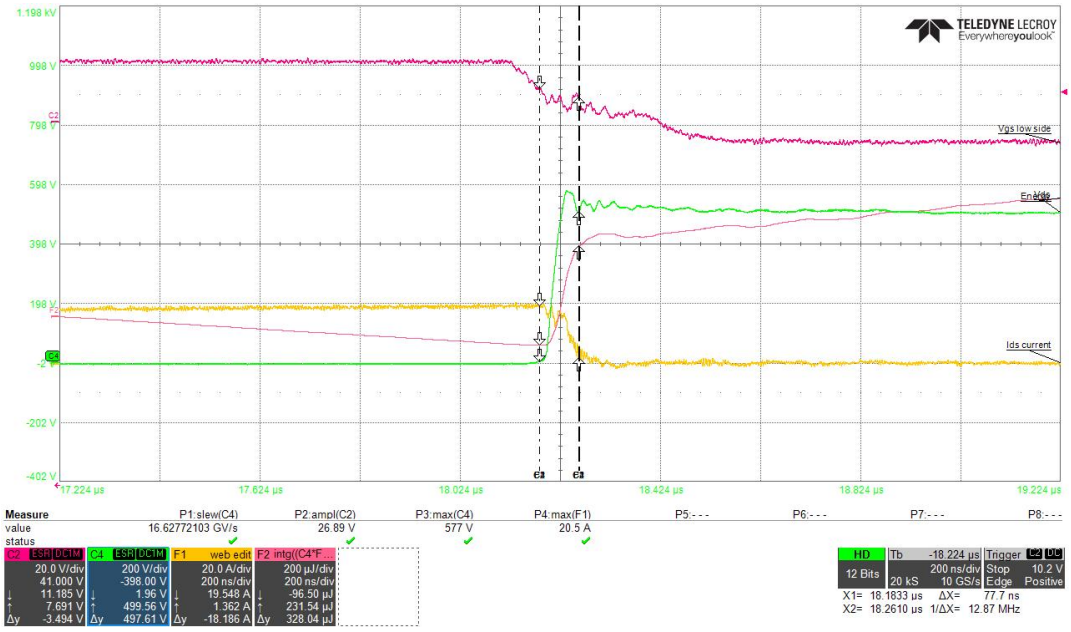


Figure 2-21. With Turn-Off Augmented Setting



2.8.3 DSAT Operation

The following tables show the DSAT operation parameters set in the software.

Table 2-5. DSAT Detection Parameters

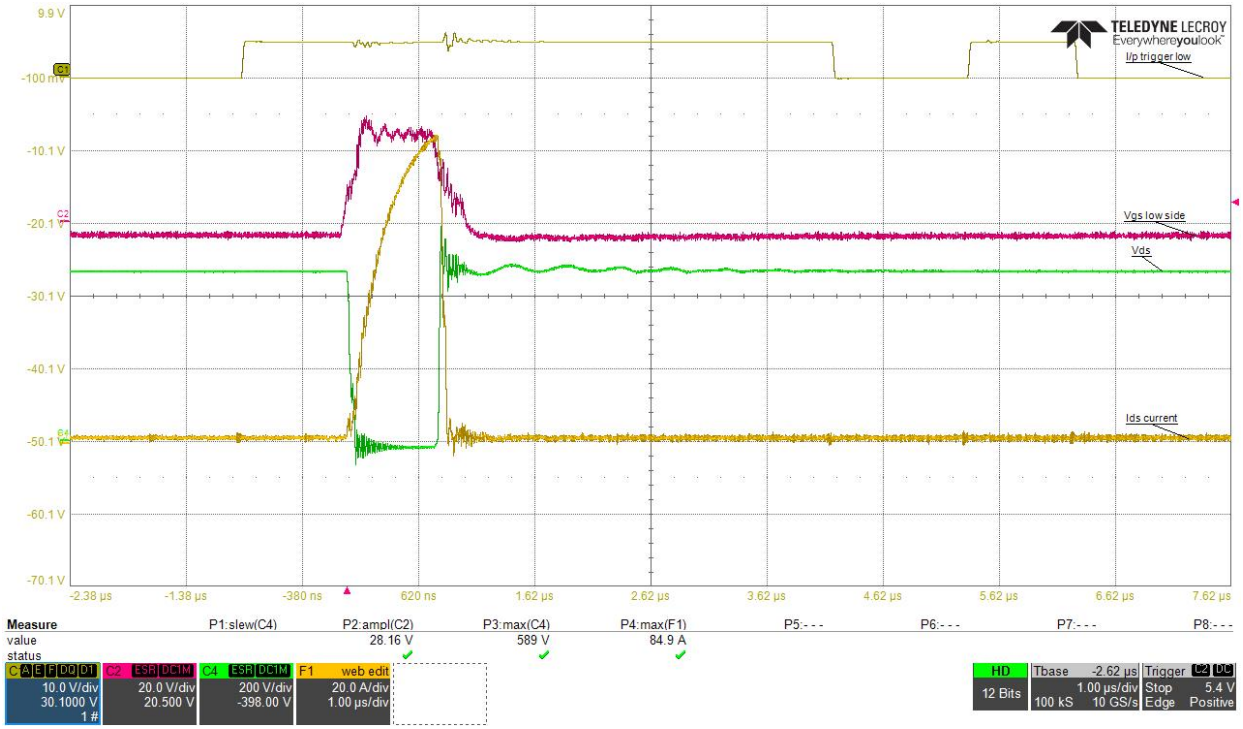
Parameter	Value
DSAT Voltage Level	3.0V
Blanking Time	200 ns
Input De-glitch Time	200 ns

Table 2-6. DSAT Turn-Off Parameters

Parameter	Voltage level	Time	RG_{off}
DSAT Off Step 1	6V	100 ns	4Ω
DSAT Off Step 2	4V	100 ns	
DSAT Off Step 3	2V	100 ns	

The following figure shows the DSAT operation (Short-Circuit Protection).

Figure 2-22. DSAT Operation



3. Auxiliary Equipment

Following are the auxiliary equipment that are required to test the ASD2-EVAL-001 Evaluation Board.

- Lower voltage variable DC power supply (0V–30V/2A)
- DC unregulated high voltage power supply (0V–2500V/1.5A)
- Oscilloscope (LeCroy—Model HDO6104A)
- Rogowski Current Waveform Transducer (1.0 mV/A)—For current measurement.
- GW Instek GOP-050 High Voltage Differential Probes—For high voltage measurement.
- PICkit 3/PICkit 4 In-circuit Debugger—For programming primary side controller.

4. Appendix A: Schematics and Board Layout

This chapter contains the pinout, schematics, and the board layout information for the ASD2-EVAL-001 Evaluation Board.

4.1 Pinout

The following tables show the pinout and the electrical parameters for connectors J1, J2, J3, J4, J5, J6, J7, J9, J10, and NTC respectively.

Table 4-1. Pinout and Electrical Parameters—J1 Connector

Name	J1	Function/Description	Remark
+VBUS	1	Positive High Voltage Bus	—

Table 4-2. Pinout and Electrical Parameters—J2 Connector

Name	J2	Function/Description	Remark
+15_MAIN	1	Supply Voltage	—
+15_MAIN	2	Supply Voltage	—
ALL_FLTn	3	Single Fault for High and Low-Side	—
LOW_TRIG	4	PWM Input Trigger Signal for Low-Side	5V Input Signal
HIGH_TRIG	5	PWM Input Trigger Signal for High-Side	5V Input Signal
HVMonitorPWF	6	High Voltage Monitoring PWF Signal	—
TEMPMonitorPWF	7	Temperature Monitoring PWF Signal	—
RESETn	8	Signal to Reset Fault	—
DGND	9	Primary-Side Ground	—
DGND	10	Primary-Side Ground	—

Table 4-3. Pinout and Electrical Parameters—J3 Connector

Name	J3	Function/Description	Remark
OUTPUT	1	Half Bridge High Voltage Output Signal	—

Table 4-4. Pinout and Electrical Parameters—J4 Connector

Name	J4	Function/Description	Remark
-VBUS	1	Negative Voltage Bus	—

Table 4-5. Pinout and Electrical Parameters—J5 Connector

Name	J5	Function/Description	Remark
MCLR	1	Master Clear Pin	—
+5V	2	5V VDD Supply	—

.....continued

Name	J5	Function/Description	Remark
DGND	3	Primary-Side Ground	—
ICSPDAT	4	Serial Data Line	—
ICSPCLK	5	Serial Clock Line	—
FET_Disable	6	Signal to Disable DC-DC converter Power Switch	—

Table 4-6. Pinout and Electrical Parameters—J6 Connector

Name	J6	Function/Description	Remark
DPT/OSC_LO	1	Double Pulse Signal or Internal Generated PWM Signal for Low-Side	This connector is used for transferring signal.
No Net Name	2	—	
LOW_TRIG	3	PWM Input Trigger Signal for Low-Side	

Table 4-7. Pinout and Electrical Parameters—J7 Connector

Name	J7	Function/Description	Remark
DPT/OSC_HI	1	Double Pulse Signal or Internal Generated PWM Signal for High-Side	This connector is used for transferring signal.
No Net Name	2	—	
HIGH_TRIG	3	PWM Input Trigger Signal for High-Side	

Table 4-8. Pinout and Electrical Parameters—J9 Connector

Name	J9	Function/Description	Remark
OSC_HI	1	Internal Generated PWM Signal for High-Side	—
DPT/OSC_HI	2	Double Pulse Signal or Internal Generated PWM Signal for High-Side	—
DPT_SIGNAL	3	Double Pulse Signal	—

Table 4-9. Pinout and Electrical Parameters—J10 Connector

Name	J10	Function/Description	Remark
OSC_LO	1	Internal Generated PWM Signal for Low-Side	—
DPT/OSC_LO	2	Double Pulse Signal or Internal Generated PWM Signal for Low-Side	—
DPT_SIGNAL	3	Double Pulse Signal	—

Table 4-10. Pinout and Electrical Parameters—J11 Connector

Name	J11	Function/Description	Remark
SW1	1	Connect External Switch with respect to Ground (GND)	—
GND	2		

Table 4-11. Pinout and Electrical Parameters—NTC Connector

Name	NTC	Function/Description	Remark
GND_LO	1	Secondary Side Ground Low-Side	—
CH2_TEMP_MON	2	Temperature Monitoring NTC Signal	—

4.2 ASD2-EVAL-001 Evaluation Board Schematics

The following figures show the board schematic of the ASD2-EVAL-001 Evaluation Board.

Figure 4-1. ASD2-EVAL-001 Evaluation Board—Schematic 1 of 6

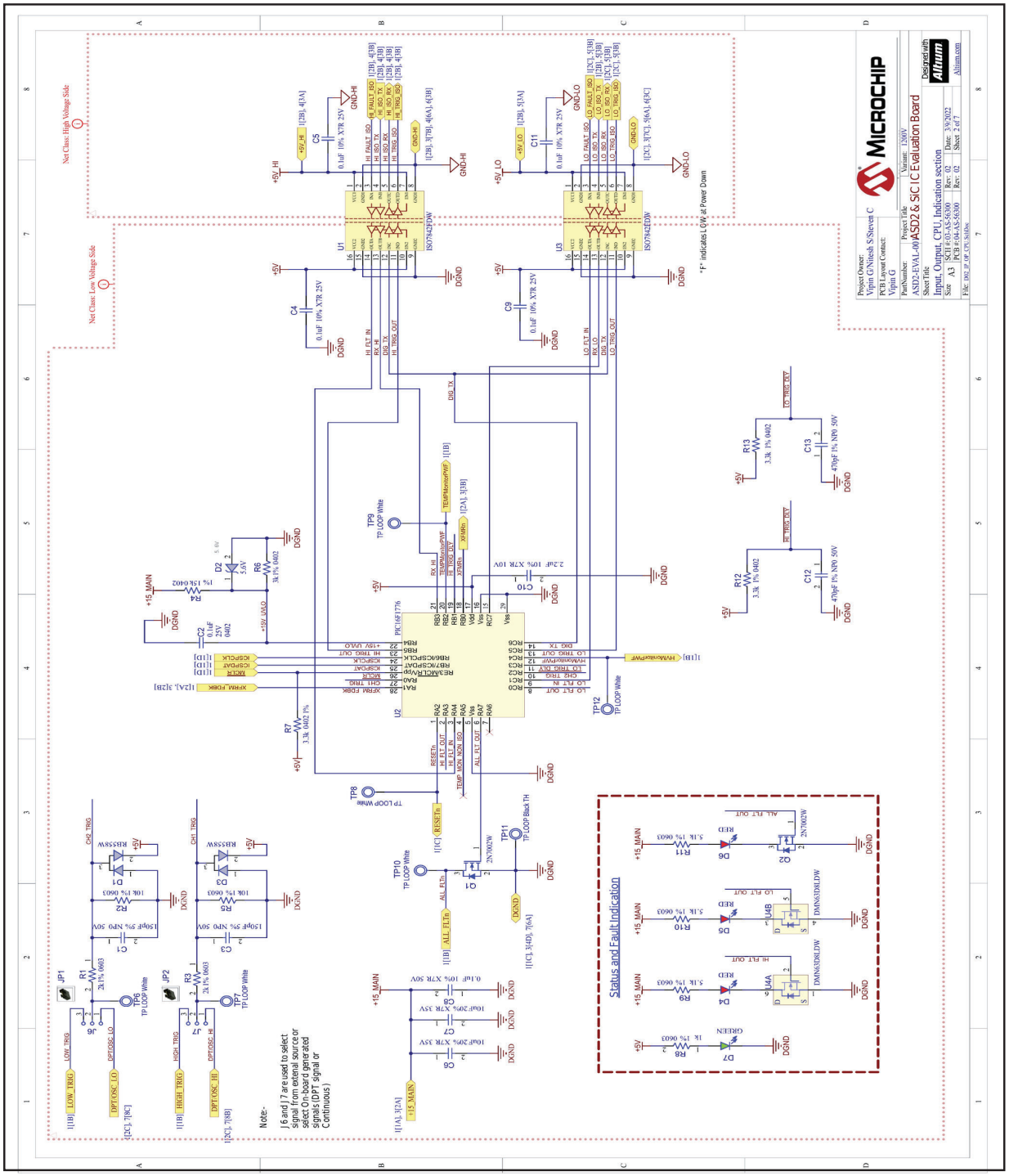


Figure 4-2. ASD2-EVAL-001 Evaluation Board—Schematic 2 of 6

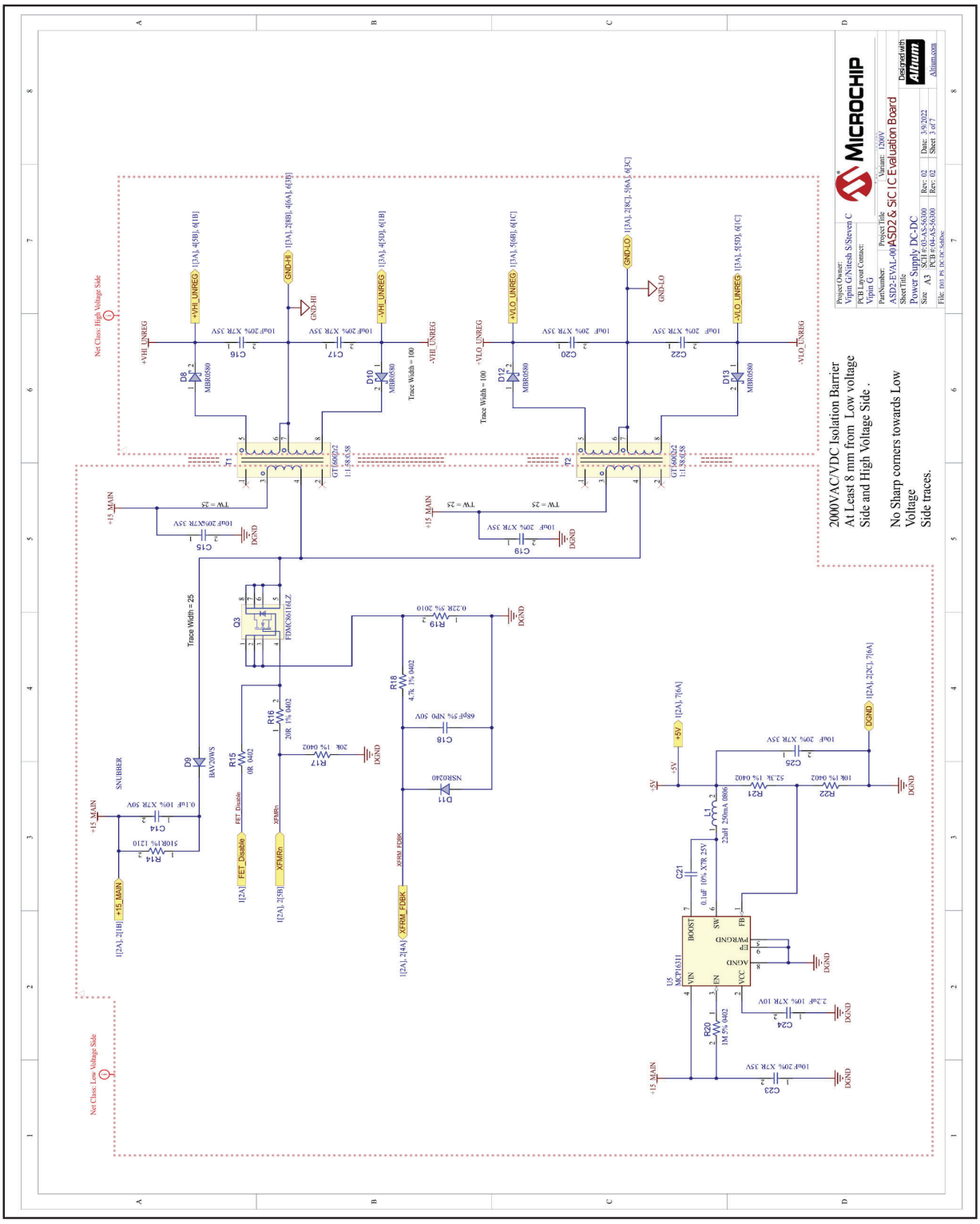


Figure 4-3. ASD2-EVAL-001 Evaluation Board—Schematic 3 of 6

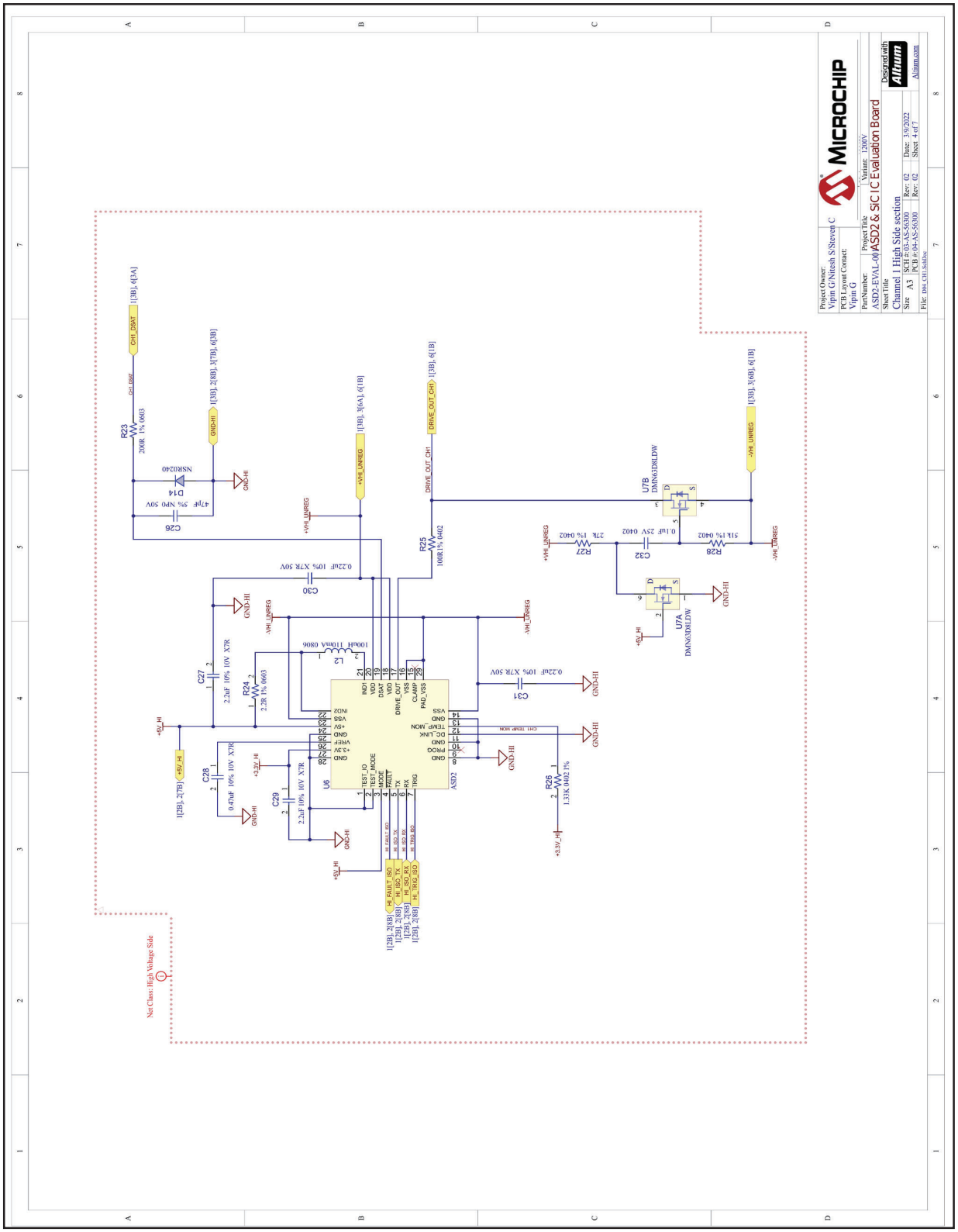


Figure 4-4. ASD2-EVAL-001 Evaluation Board—Schematic 4 of 6

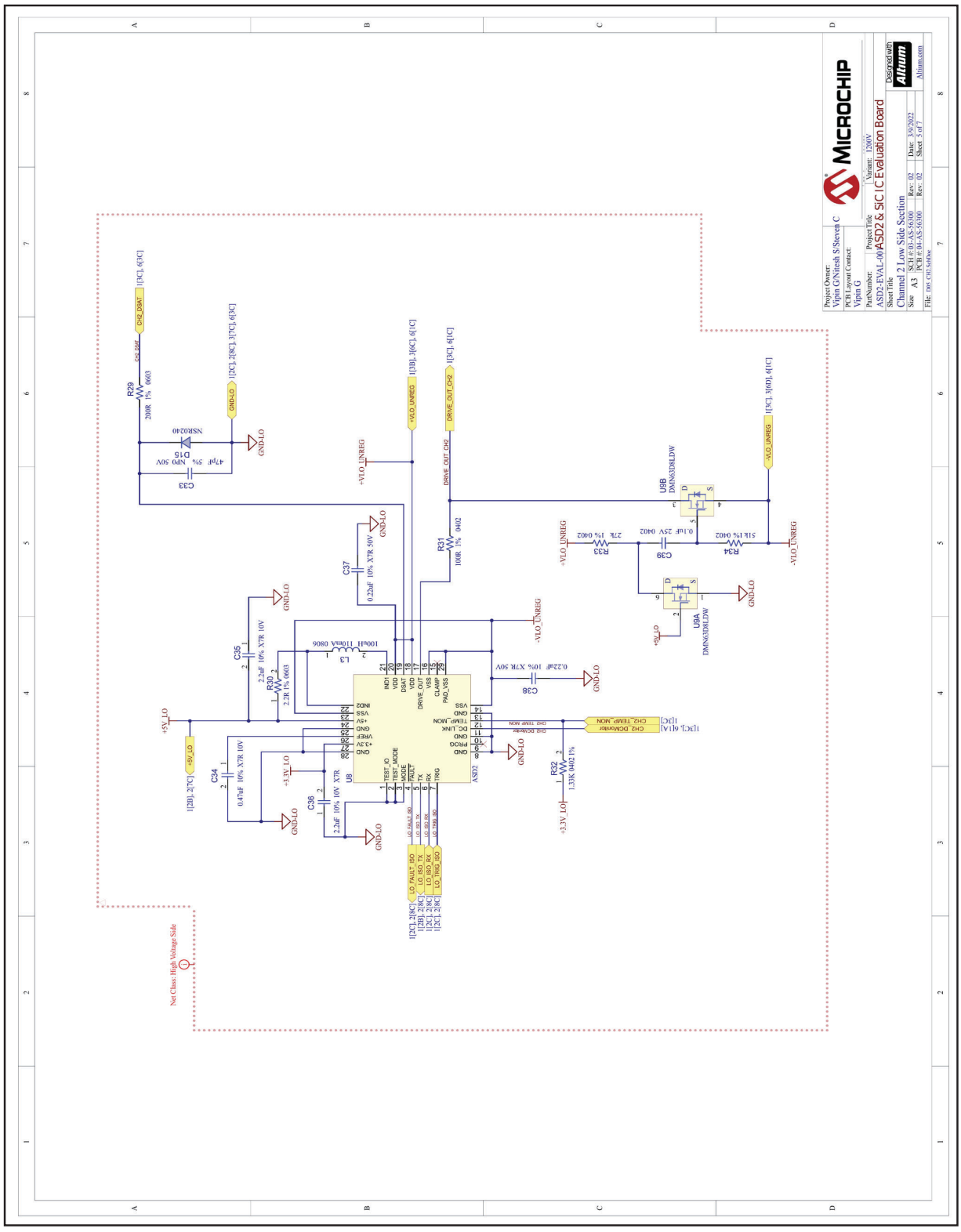


Figure 4-5. ASD2-EVAL-001 Evaluation Board—Schematic 5 of 6

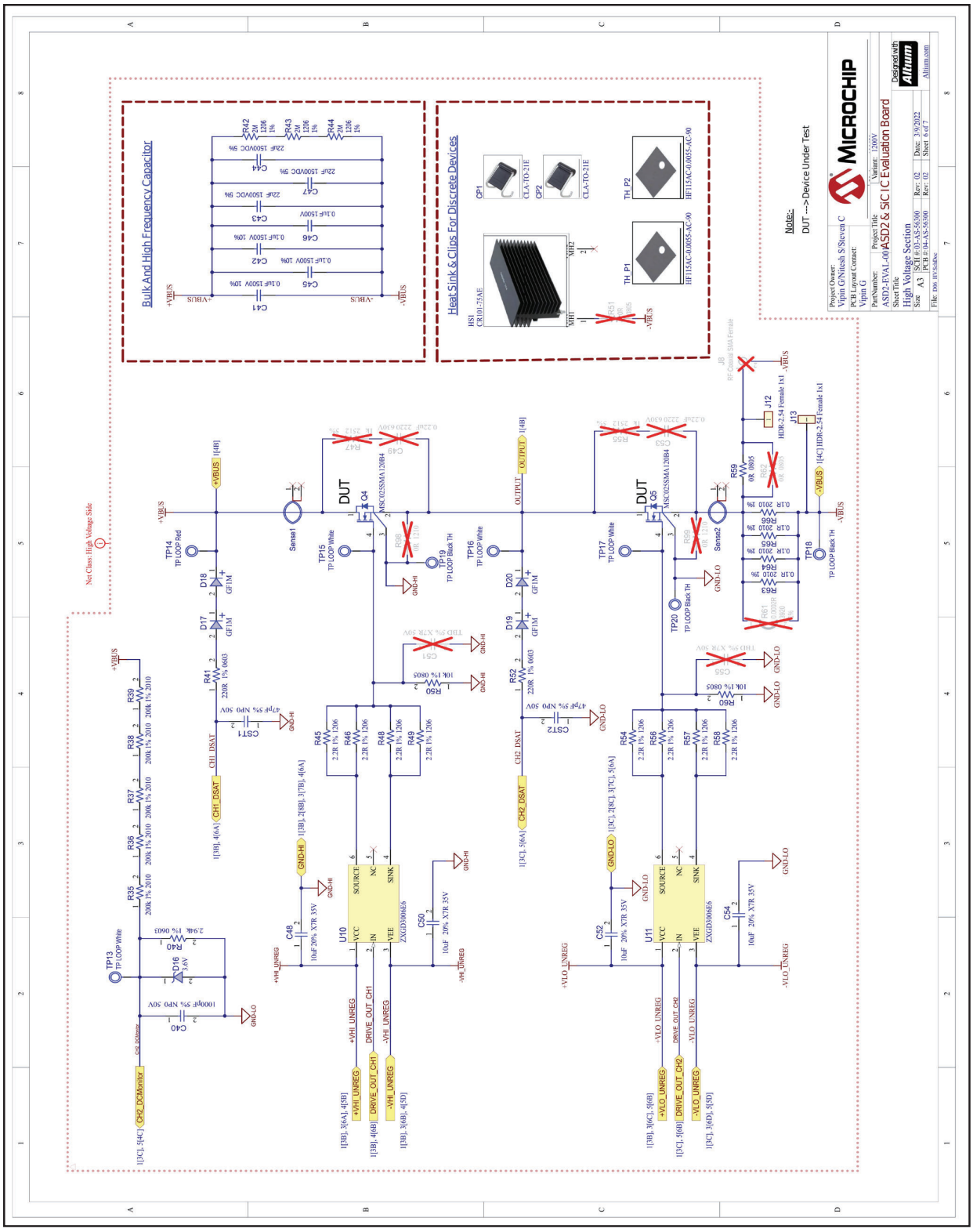
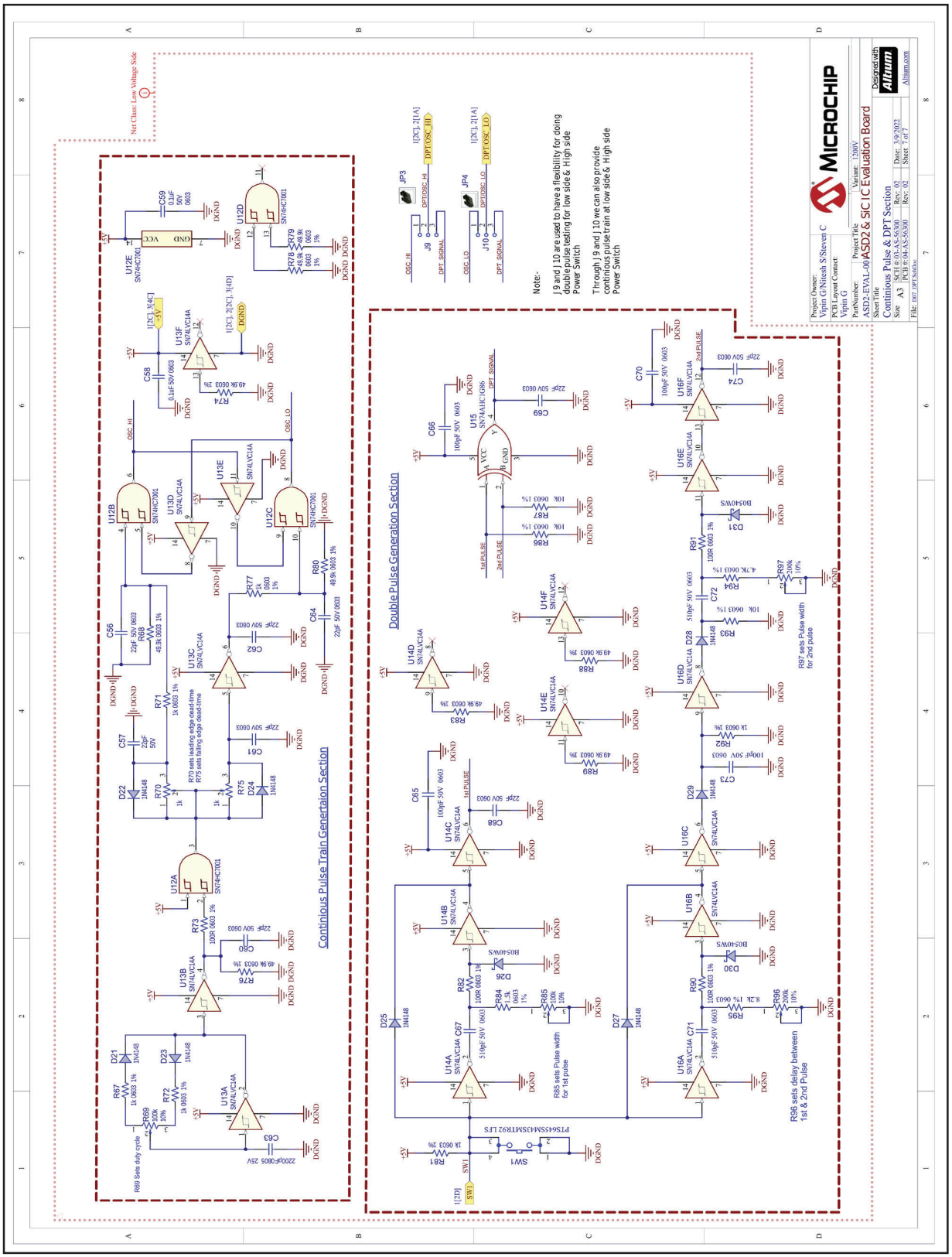


Figure 4-6. ASD2-EVAL-001 Evaluation Board—Schematic 6 of 6



4.3 ASD2-EVAL-001 Evaluation Board PCB Layout

The ASD2-EVAL-001 Evaluation Board is a four-layer FR4, 1.6 mm, Plated-Through-Hole (PTH) PCB construction.

The following figures show the PCB layers of the ASD2-EVAL-001 Evaluation Board.

Figure 4-7. ASD2-EVAL-001 Evaluation Board—Top Silk Layer

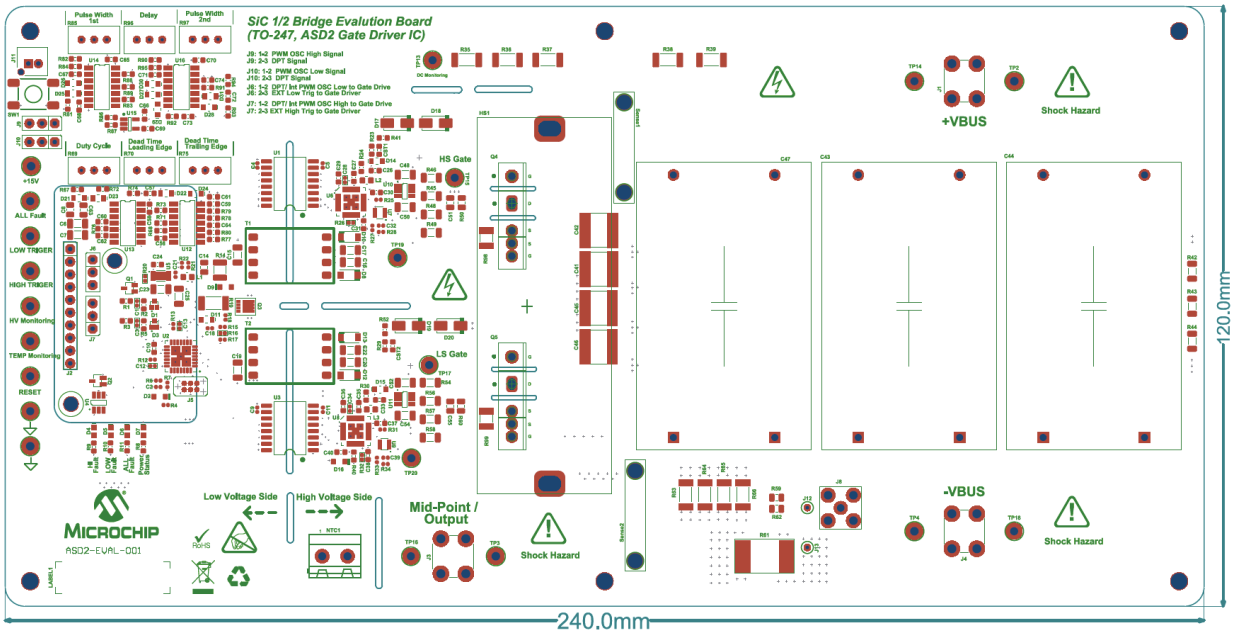


Figure 4-8. ASD2-EVAL-001 Evaluation Board—Top Copper Layer

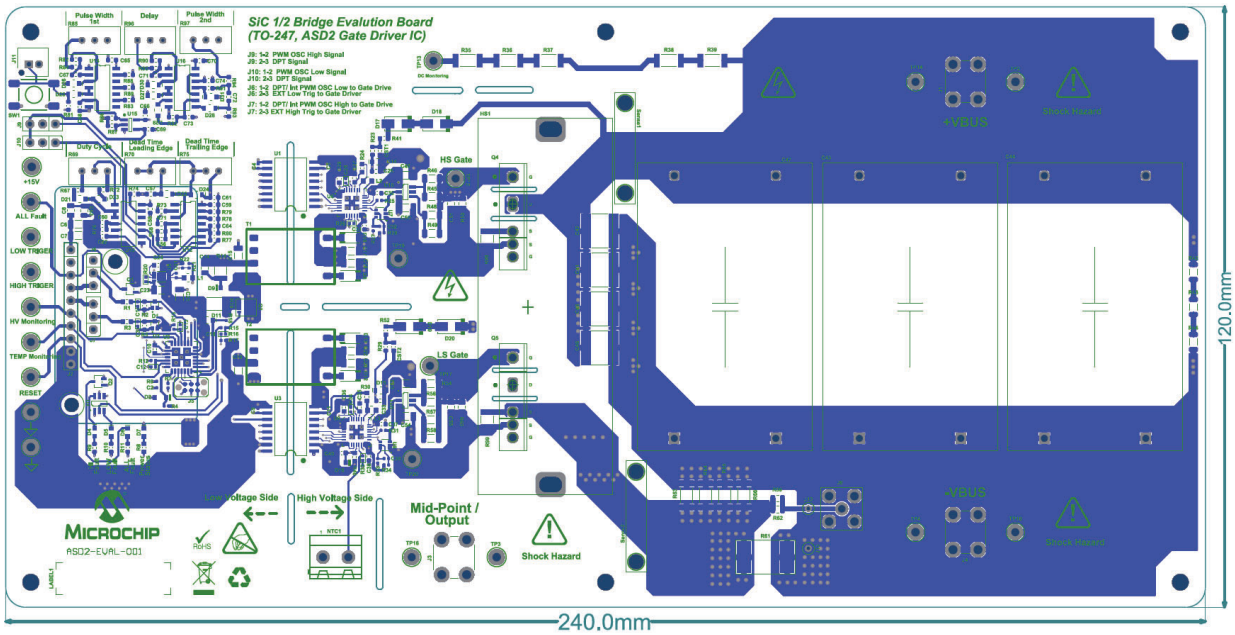


Figure 4-9. ASD2-EVAL-001 Evaluation Board—Inner (Voltage) Layer 1

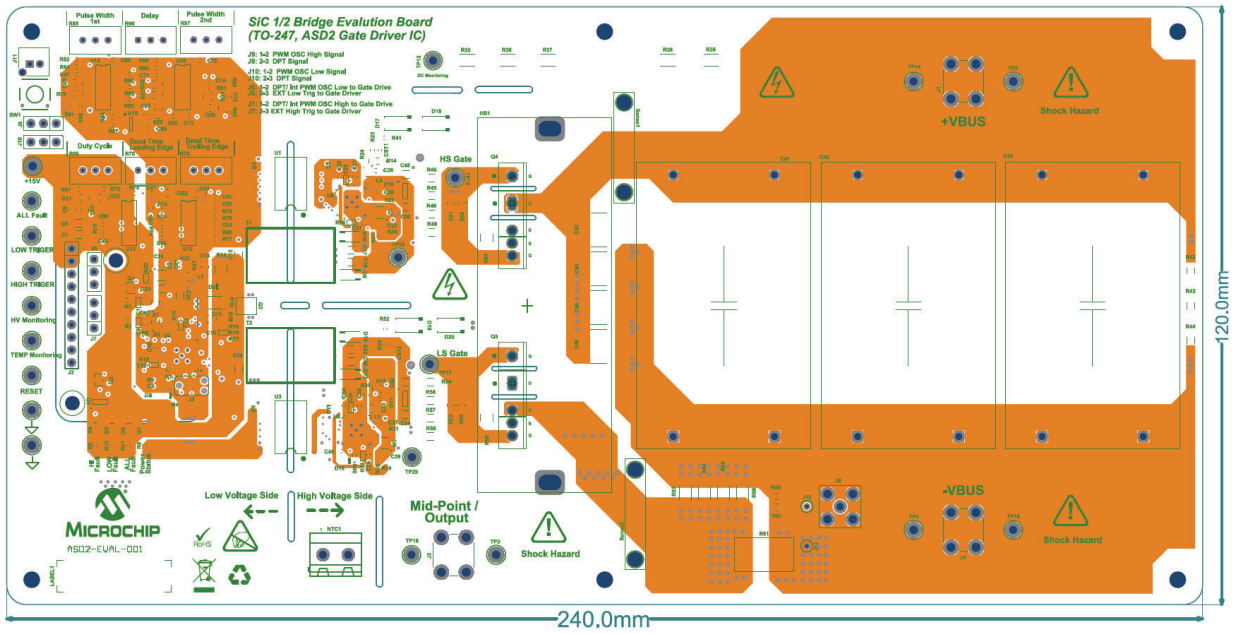


Figure 4-10. ASD2-EVAL-001 Evaluation Board—Inner (Signal) Layer 2

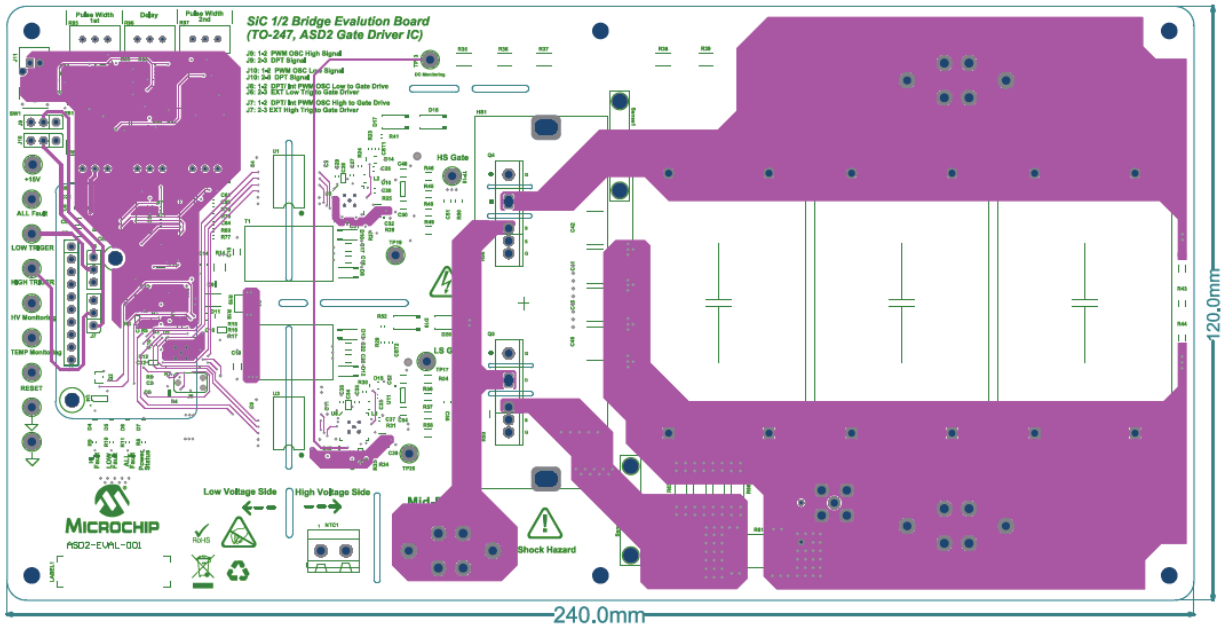


Figure 4-11. ASD2-EVAL-001 Evaluation Board—Bottom Layer

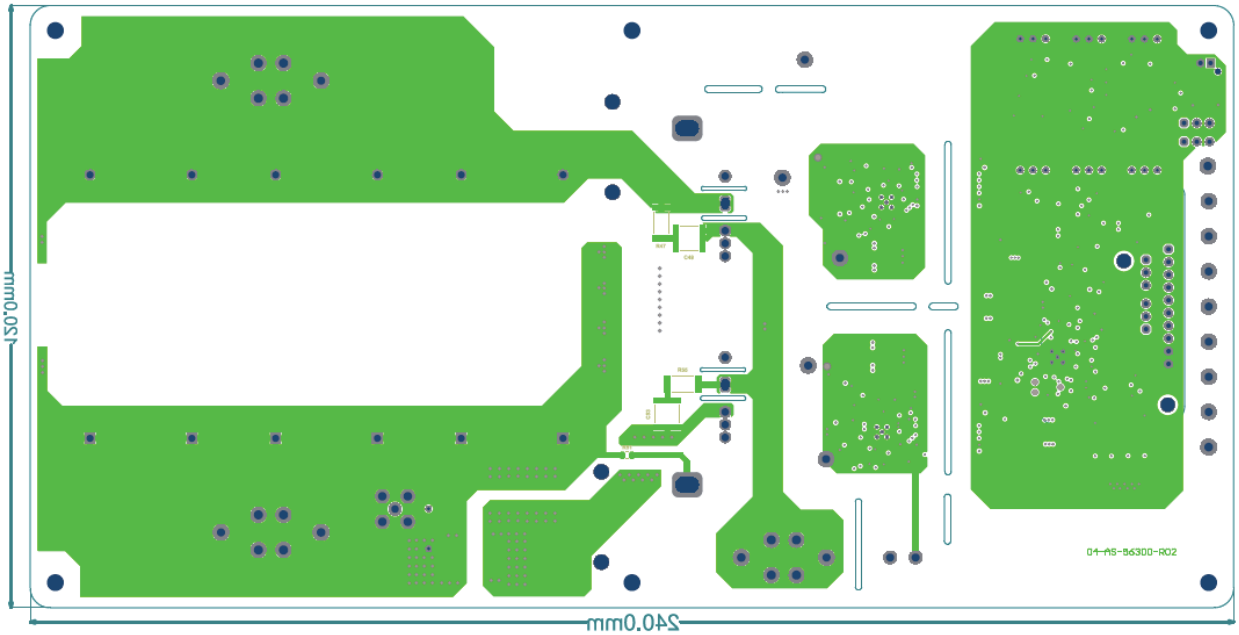
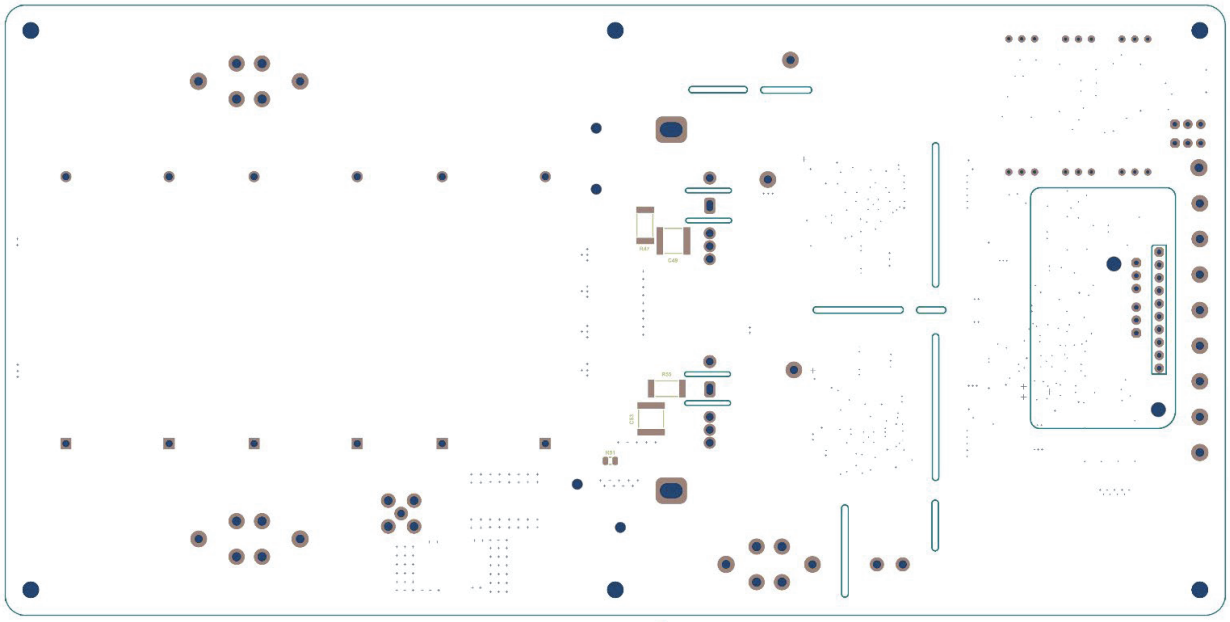


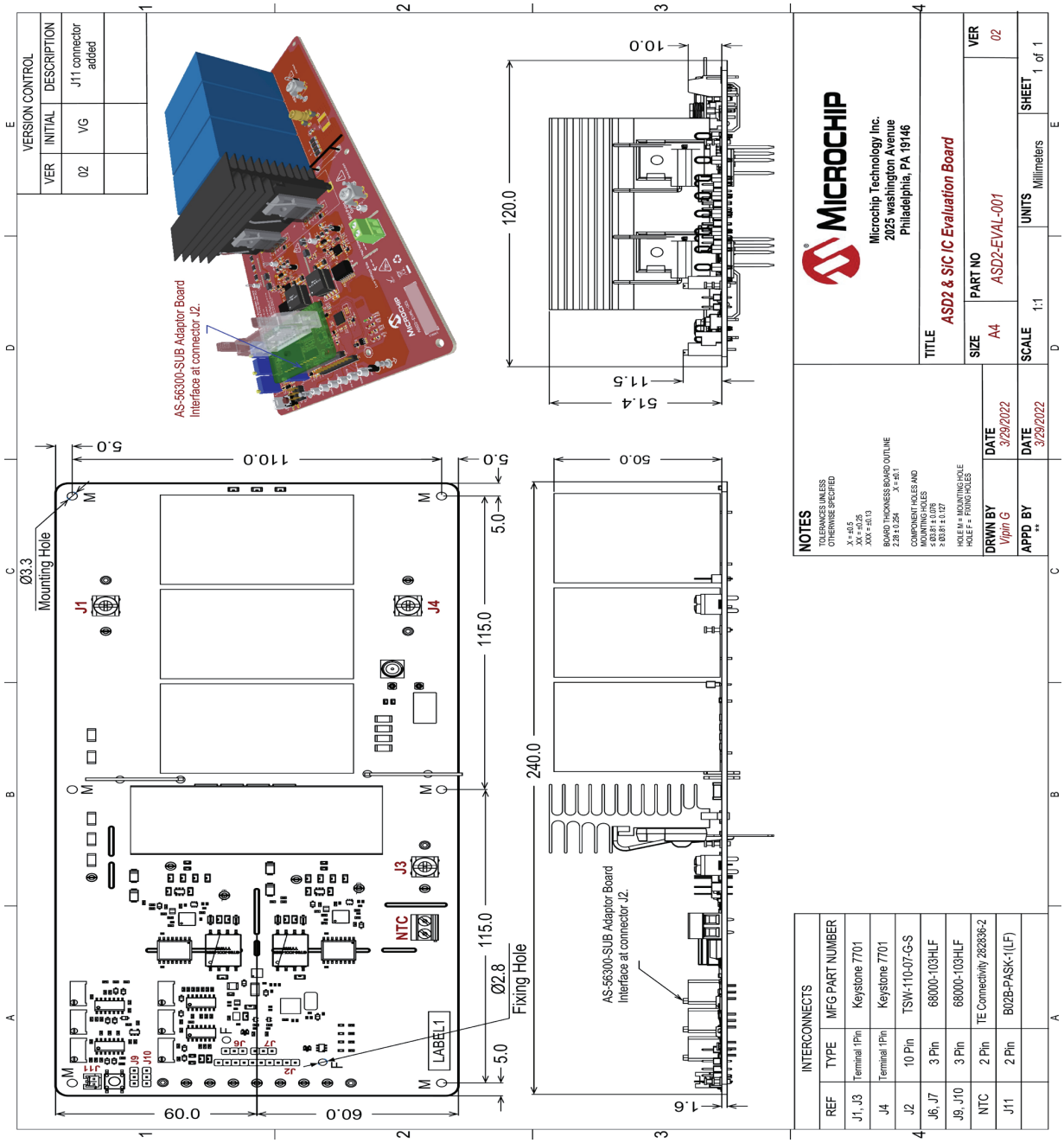
Figure 4-12. ASD2-EVAL-001 Evaluation Board—Bottom Silk Layer



4.4 Package Outline

The following drawing shows the placement and mounting of the AS-56000-SUB Adapter Board at the connector J2 on the ASD2-EVAL-001 Evaluation Board.

Figure 4-13. ASD2 Evaluation Board (ASD2-EVAL-001) Mechanical Drawing



5. Appendix B: Bill of Materials

This chapter contains the bill of materials (BOM) for the ASD2-EVAL-001 Evaluation Board.

Table 5-1. ASD2 Evaluation Board Bill of Materials

Quantity	Designator	Description	Manufacturer	Manufacturer Part Number
2	C1, C3	CAP CER 150 pF 50V 5% NP0 SMD 0402	Murata Electronics	GCM1555C1H151JA16D
8	C2, C4, C5, C9, C11, C21, C32, C39	CAP CER 0.1 uF 25V 10% X7R SMD 0402	TDK Corporation	C1005X7R1E104K050BB
14	C6, C7, C15, C16, C17, C19, C20, C22, C23, C25, C48, C50, C52, C54	CAP CER 10 uF 35V 20% X7R SMD 1206	TDK Corporation	C3216X7R1V106M160AC
2	C8, C14	CAP CER 0.1 uF 50V 10% X7R SMD 0805	KEMET	C0805F104K5RACTU
6	C10, C24, C27, C29, C35, C36	CAP CER 2.2 uF 10V 10% X7R SMD 0603	TDK Corporation	C1608X7R1A225K080AC
2	C12, C13	CAP CER 470 pF 50V 1% NP0 SMD 0402	Murata Electronics	GRM1555C1H471FA01D
1	C18	CAP CER 68 pF 50V 5% NP0 SMD 0402	Murata	GRM1555C1H680JA01D
2	C26, C33	CAP CER 47 pF 50V 5% C0G/NP0 SMD 0603	Murata Electronics North America	GCM1885C1H470JA16D
2	C28, C34	CAP CER 0.47 uF 10V 10% X7R SMD 0402	Murata Electronics	GRM155R71A474KE01D
4	C30, C31, C37, C38	CAP CER 0.22 uF 50V 10% X7R SMD 0603 AEC-Q200	Murata Electronics North America	GCM188R71H224KA64D
1	C40	CAP CER 1000 pF 50V 5% NP0 SMD 0603	Murata Electronics	GRM1885C1H102JA01J
4	C41, C42, C45, C46	CAP CER 0.1 uF 1500V 10% X7R SMD 2225	KEMET	C2225X104KFRACTU
3	C43, C44, C47	CAP FILM 22 uF 1500V 5% RAD P52.5L57.5W35H50	KEMET	C4AQSBW5220A3NJ
9	C56, C57, C60, C61, C62, C64, C68, C69, C74	CAP CER 22 pF 50V 5% NP0 SMD 0603	Cal-Chip	GMC10CG220J50NTLF
2	C58, C59	CAP CER 0.1 uF 50V 20% X7R SMD 0603	TDK	C1608X7R1H104M
1	C63	CAP CER 2200 pF 25V 5% NP0 SMD 0805	AVX	08053A222JAT2A

.....continued

Quantity	Designator	Description	Manufacturer	Manufacturer Part Number
4	C65, C66, C70, C73	CAP CER 100 pF 50V 1% C0G SMD 0603	TDK	C1608C0G1H101F
3	C67, C71, C72	CAP CER 510 pF 50V 5% C0G SMD 0603	Murata Electronics North America	GRM1885C1H511JA01D
2	CP1, CP2	MECH HW HEATSINK CLIP CAM FOR TO-247/TO-264 CLA-TO-21E	Ohmite	CLA-TO-21E
2	CST1, CST2	CAP CER 47 pF 50V 5% NP0 SMD 0603	Murata Electronics	GCM1885C1H470JA16D
2	D1, D3	DIODE ARRAY SCHOTTKY 30V EMD3/SOT-416	Rohm Semiconductor	RB558WTL
1	D2	DIO ZNR PDZ5.6B,115 5.6V 400mW SOD-323	Nexperia USA Inc.	PDZ5.6B,115
3	D4, D5, D6	DIO LED RED 2V 30mA 12mcd Clear SMD 0603	Kingbright	APT1608EC
1	D7	DIO LED GREEN 2.2V 25mA 15mcd Clear SMD 0603	Kingbright	APT1608SGC
4	D8, D10, D12, D13	DIO SCHOTTKY MBR0580S1-7 80V 500mA SOD-123	Diodes Incorporated	MBR0580S1-7
1	D9	DIO GEN PURP BAV20WS-7-F 150V 200mW SOD-323	Diodes Incorporated	BAV20WS-7-F
3	D11, D14, D15	DIO SCTKY NSR0240H 710mV 250mA 40V SMD SOD-323	ON Semiconductor	NSR0240HT1G
1	D16	DIO ZNR PDZ3.6B,115 3.6V 400mW SOD-323	Nexperia USA Inc.	PDZ3.6B,115
4	D17, D18, D19, D20	DIO GP GF1M 1KV 1A DO214BA	Vishay	GF1M-E3
8	D21, D22, D23, D24, D25, D27, D28, D29	DIO RECT 1N4148 855mV 300mA 75V SOD-323	Diodes Incorporated	1N4148WS-7-F
3	D26, D30, D31	DIO SCTKY B0540WS 480mV 500mA 40V SOD-323	Diodes Incorporated	B0540WS-7
1	HS1	MECH HW HEATSINK TO-247 for 2 Switch	Ohmite	CR101-75AE
3	J1, J3, J4	CON TERMINAL 15A Female 1x1 TH VERT	Keystone Electronics	7701
1	J2	CON HDR-2.54 Male 1x10 Gold 5.84MH TH VERT	Samtec Inc.	TSW-110-07-G-S
1	J5	CON PROGRAM TAG CONNECT INCIRCUIT CABLE NO LEGS TC2030-MCP-NL	Microchip Technology	TC2030-MCP-NL

.....continued

Quantity	Designator	Description	Manufacturer	Manufacturer Part Number
4	J6, J7, J9, J10	CON HDR-2.54 Male 1x3 Gold 5.84MH TH VERT	FCI	68000-103HLF
1	J11	CON HDR-2.00 Male 1x2 3.20MH TH VERT	JST Sales America Inc.	B02B-PASK-1(LF)(SN)
2	J12, J13	CON HDR-2.54 Female 1x1 Tin TH VERT	Samtec Inc	SS-101-TT-2
4	JP1, JP2, JP3, JP4	MECH HW JUMPER 2.54mm 1x2 w/ Handle	TE Connectivity AMP Connectors	880584-4
1	L1	INDUCTOR 22uH 240mA 20% SMD 0806	Taiyo Yuden	CBC2016T220M
2	L2, L3	INDUCTOR 100uH 110mA 20% SMD 0806	Taiyo Yuden	CBC2016T101M
1	NTC1	CON TERMINAL 5.08mm 1X2 Female 16-30AWG 13.5A TH RA	TE Connectivity	282836-2
2	Q1, Q2	TRANS FET N-CH 2N7002W 60V 115mA 200mW SOT-323-3	Fairchild Semiconductor	2N7002W
1	Q3	TRANS FET N-CH FDMC86116LZ 100V 7.5A 19W MLP-8	ON Semiconductor	FDMC86116LZ
2	Q4, Q5	TRANS FET N-CH SiC MSC025SMA120B4 1200V 103A 500W TO-247-4	Microchip Technology	MSC025SMA120B4
2	R1, R3	RES TKF 2K 1% 1/10W SMD 0603	Vishay Dale	CRCW06032K00FKEA
2	R2, R5	RES TKF 10k 1% 1/10W SMD 0603	ROHM	MCR03EZPFX1002
1	R4	RES TKF 15k 1% 1/10W SMD 0402	Panasonic Electronic Components	ERJ-2RKF1502X
1	R6	RES TKF 3k 1% 1/10W SMD 0402	Panasonic Electronic Components	ERJ-2RKF3001X
3	R7, R12, R13	RES TKF 3.3k 1% 1/10W SMD 0402	Panasonic - ECG	ERJ-2RKF3301X
1	R8	RES TKF 1K 1% 1/10W SMD 0603	Vishay Dale	CRCW06031K00FKEA
3	R9, R10, R11	RES TKF 5.1k 1% 1/10W SMD 0603 AEC-Q200	Vishay / Dale	CRCW06035K10FKEA
1	R14	RES TKF 510R 3/4W SMD 1210	Vishay Dale	CRCW1210510RFKEAHP

.....continued

Quantity	Designator	Description	Manufacturer	Manufacturer Part Number
1	R15	RES TKF 0R SMD 0402 AEC-Q200	Panasonic	ERJ-2GE0R00X
1	R16	RES TKF 20R 1/10W SMD 0402	Panasonic Electronic Components	ERJ-2RKF20R0X
1	R17	RES TKF 20k 1% 1/10W SMD 0402 AEC-Q200	Panasonic Electronic Components	ERJ-2RKF2002X
1	R18	RES TKF 4.7k 1% 1/10W SMD 0402 AEC-Q200	Panasonic Electronic Components	ERJ-2RKF4701X
1	R19	RES TKF 0.22R 5% 1/2W SMD 2010	Panasonic Electronic Components	ERJ-12ZQJR22U
1	R20	RES TKF 1M 5% 1/10W SMD 0402	Panasonic Electronic Components	ERJ-2GEJ105X
1	R21	RES TKF 52.3k 1% 1/10W SMD 0402	Panasonic Electronic Components	ERJ-2RKF5232X
1	R22	RES TKF 10k 1% 1/10W SMD 0402	Panasonic	ERJ-2RKF1002X
2	R23, R29	RES TKF 200R 1% 1/10W SMD 0603	Panasonic	ERJ-3EKF2000V
2	R24, R30	RES TKF 2.2R 1/10W SMD 0603	Vishay Dale	CRCW06032R20FKEA
2	R25, R31	RES TKF 100R 1% 1/10W SMD 0402	Panasonic Electronic Components	ERJ-2RKF1000X
2	R26, R32	RES TKF 1.33K 1% 1/10W SMD 0402	Panasonic Electronic Components	ERJ-2RKF1331X
2	R27, R33	RES TKF 27k 1% 1/10W SMD 0402	Panasonic	ERJ-2RKF2702X
2	R28, R34	RES TFK 51k 1% 1/10W SMD 0402	Panasonic Electronic Components	ERJ-2RKF5102X
5	R35, R36, R37, R38, R39	RES TKF 200K 1% 3/4W SMD 2010	Vishay Dale	CRCW2010200KFKEF
1	R40	RES TKF 2.94K 1% 1/10 SMD 0603	Vishay Dale	CRCW06032K94FKEA

.....continued

Quantity	Designator	Description	Manufacturer	Manufacturer Part Number
2	R41, R52	RES TKF 220R 1% 1/10 SMD 0603	Vishay Dale	CRCW0603220RFKEA
3	R42, R43, R44	RES TKF 2M 1% 1/4W SMD 1206 AEC-Q200 HV	Rohm Semiconductor	KTR18EZPF2004
8	R45, R46, R48, R49, R54, R56, R57, R58	RES TF 2.2R 1% 1/2W SMD 1206	SUSUMU	RL1632R-2R20-F
2	R50, R60	RES TKF 10K 1% 1/8 SMD 0805	Vishay Dale	CRCW080510K0FKEA
1	R59	RES TKF 0R 1/8W SMD 0805	Panasonic	ERJ-6GEY0R00V
4	R63, R64, R65, R66	RES MF 0.1R 1% 1W SMD 2010	Vishay	WSL2010R1000FEA18
6	R67, R71, R72, R77, R81, R92	RES TKF 1k 1% 1/10W SMD 0603	Panasonic	ERJ-3EKF1001V
9	R68, R74, R76, R78, R79, R80, R83, R88, R89	RES TKF 49.9k 1% 1/10W SMD 0603	Panasonic	ERJ-3EKF4992V
2	R69, R85	RES TRIMMER Cermet 100k 10% 500mW TH 3296W	Murata Electronics North America	PV36W104C01B00
2	R70, R75	RES TRIMMER Cermet 1k 10% 500mW TH 3296W	Murata Electronics North America	PV36W102C01B00
4	R73, R82, R90, R91	RES TKF 100R 1% 1/10W SMD 0603	Panasonic	ERJ-3EKF1000V
1	R84	RES TF 1.5k 1% 1/8W SMD 0603	Stackpole Electronics Inc	RNCP0603FTD1K50
3	R86, R87, R93	RES TF 10k 1% 1/8W SMD 0603	Vishay Beyschlag	MCT06030C1002FP500
1	R94	RES TKF 4.7K 1% 1/10W SMD 0603	Panasonic Electronic Components	ERJ-3EKF4701V
1	R95	RES TKF 8.2k 1% 1/10W SMD 0603	Panasonic	ERJ-3EKF8201V
2	R96, R97	RES TRIMMER Cermet 200k 10% 500mW TH 3296W	Murata Electronics North America	PV36W204C01B00
1	SW1	SWITCH TACT SPST 12V 50mA PTS645SM43SMTR92 LFS SMD	Wurth Electronics Inc	4.30182E+11
2	T1, T2	TRANS GATE DRIVE Forward 1:1.58:0.58 SMD GT16002r2	Ice Components	GT16002r2
2	TH_P1, TH_P2	MECH HW THERMAL PAD Bergquist Rectangular 21.84 x18.79mm GRAY	Bergquist	HF115AC-0.0055-AC-90

.....continued

Quantity	Designator	Description	Manufacturer	Manufacturer Part Number
5	TP1, TP2, TP3, TP4, TP5	CON TP PIN Tin TH	Harwin	H2121-01
10	TP6, TP7, TP8, TP9, TP10, TP12, TP13, TP15, TP16, TP17	CON TP LOOP White TH	Keystone	5012
4	TP11, TP18, TP19, TP20	CON TP LOOP Black TH	Keystone	5011
1	TP14	CON TP LOOP Red TH	Keystone	5010
2	U1, U3	IC ISOLATOR ISO7842FDW 8kV 4CH 100Mbps SOIC-16_300mil	Texas Instruments	ISO7842FDW
1	U2	MCHP MCU 8-BIT 32MHz 14kB 1KB PIC16F1776-E/MX UQFN-28	Microchip Technology	PIC16F1776-E/MX
3	U4, U7, U9	TRANS FET DUAL N+N DMN63D8LDW-7	Diodes Incorporated	DMN63D8LDW-7
1	U5	MCHP ANALOG SWITCHER Buck 2V to 24V MCP16311-E/MNY TDFN-8	Microchip Technology	MCP16311T-E/MNY
2	U6, U8	IC GATE DRIVER ASD2 QFN-28	Agile Switch	ASD2
2	U10, U11	IC FET DRIVER ZXGD3006E6TA 40V 10A SOT-26	Diodes Incorporated	ZXGD3006E6TA
1	U12	IC LOGIC AND GATE x4 Schmitt trigger SN74HC7001DR SOIC-14	Texas Instruments	SN74HC7001DR
3	U13, U14, U16	IC BUFFER INVERTER SN74LVC14ADR SOIC-14	Texas Instruments	SN74LVC14ADR
1	U15	IC LOGIC SN74AHC1G86 SINGLE 2 INPUT XOR GATE SOT-23-5	Texas Instrument	SN74AHC1G86QDBVRQ1

6. Revision History

The revision history describes the changes that were implemented in the document. The changes are listed by revision, starting with the most current publication.

Revision	Date	Description
A	06/2022	Initial Revision.

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