EVAL-PS-DP-MAIN-M5

Evaluation platform for 600 – 1200 V SiC MOSFETs and IGBTs in TO-247 4pin/3pin packages

About this document

Scope and purpose

This document describes an evaluation board suitable for SiC MOSFETs and IGBTs in various TO-247 packages with compact gate driver ICs. Board can be controlled wirelessly using the XMC4800 control board to provide a double-pulse signal with different dead times or a constant pulse width modulation signals. This user guide explains the board's hardware and GUI. It provides a detailed explanation on various features of the board that can be used for measurements.

Intended audience

This board is intended for engineers who want to use TO-247 devices and respective gate driver IC in applications with a half-bridge topology.

Evaluation board

This board is to be used during the design-in process for evaluating and measuring characteristic curves, and for checking datasheet specifications.

Note: PCB and auxiliary circuits are NOT optimized for final customer design.

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Safety precautions

Note: Please note the following warnings regarding the hazards associated with development systems

Table 1 Safety precautions

	Warning: *The DC link potential of this board is up to 1000 VDC. When measuring voltage waveforms by oscilloscope, high voltage differential probes must be used. Failure to do so may result in personal injury or death.*
	Warning: *The evaluation or reference board contains DC bus capacitors which take time to discharge after removal of the main supply. Before working on the drive system, wait five minutes for capacitors to discharge to safe voltage levels. Failure to do so may result in personal injury or death. Darkened display LEDs are not an indication that capacitors have discharged to safe voltage levels.*
	Warning: *The evaluation or reference board is connected to the grid input during testing. Hence, high-voltage differential probes must be used when measuring voltage waveforms by oscilloscope. Failure to do so may result in personal injury or death. Darkened display LEDs are not an indication that capacitors have discharged to safe voltage levels.*
	Warning: *Remove or disconnect power from the drive before you disconnect or reconnect wires, or perform maintenance work. Wait five minutes after removing power to discharge the bus capacitors. Do not attempt to service the drive until the bus capacitors have discharged to zero. Failure to do so may result in personal injury or death.*
	Caution: *The heat sink and device surfaces of the evaluation or reference board may become hot during testing. Hence, necessary precautions are required while handling the board. Failure to comply may cause injury.*
	Caution: *Only personnel familiar with the drive, power electronics and associated machinery should plan, install, commission and subsequently service the system. Failure to comply may result in personal injury and/or equipment damage.*
	Caution: *The evaluation or reference board contains parts and assemblies sensitive to electrostatic discharge (ESD). Electrostatic control precautions are required when installing, testing, servicing or repairing the assembly. Component damage may result if ESD control procedures are not followed. If you are not familiar with electrostatic control procedures, refer to the applicable ESD protection handbooks and guidelines.*
	Caution: *A drive that is incorrectly applied or installed can lead to component damage or reduction in product lifetime. Wiring or application errors such as undersizing the motor, supplying an incorrect or inadequate AC supply, or excessive ambient temperatures may result in system malfunction.*
	Caution: *The evaluation or reference board is shipped with packing materials that need to be removed prior to installation. Failure to remove all packing materials that are unnecessary for system installation may result in overheating or abnormal operating conditions.*

Table of contents

About this document ... **1**
Important notice ... **2**
Safety precautions ... **3**
Table of contents ... **4**
1 The board at a glance ... **5**
1.1 Purpose of the board ... 6
1.2 Block diagram ... 6
1.3 Scope of the delivery content ... 7
1.4 Board parameters and technical data ... 7
2 System and functional description ... **8**
2.1 Circuit and main components ... 8
2.2 Commissioning ... 10
2.3 Description of the functional blocks ... 10
2.4 Getting started ... 11
2.5 Modes of operation ... 11
2.6 Settings ... 13
2.6.1 Tuning gate voltages ... 14
2.6.2 Adjusting the heatsink temperature ... 15
2.6.3 Configuring the double-pulse test ... 15
2.6.4 Configuring the efficiency measurement ... 16
3 System design ... **18**
3.1 Schematic drawings ... 18
3.2 Board layout ... 20
References ... **21**
Revision history ... **22**

1 The board at a glance

The evaluation platform was developed to help users investigate the switching behavior of SiC MOSFETs or IGBTs, and their corresponding gate drivers using through-hole universal sockets. This board is an improved version of the existing double-pulse platform, EVAL-PS-DP_MAIN [1] with additional features for easy and efficient evaluations.

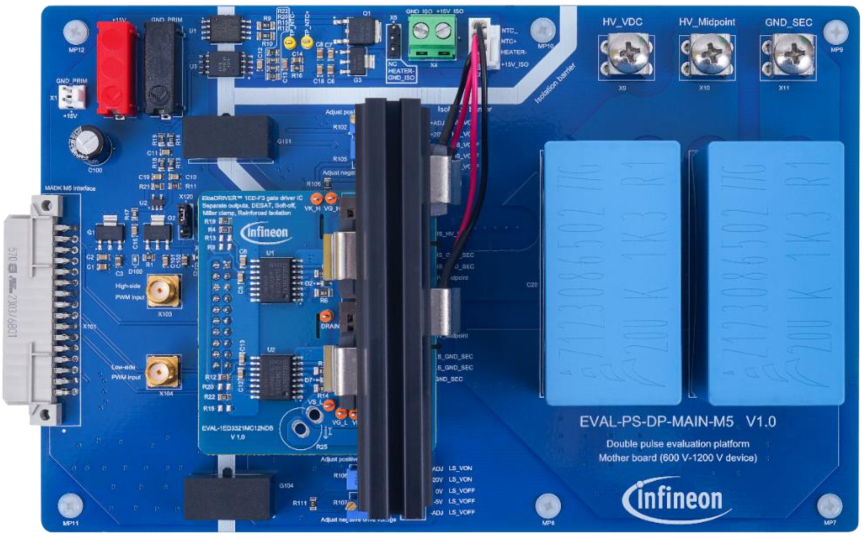


Figure 1 EVAL-PS-DP-MAIN-M5 evaluation board

The EVAL-PS-DP-MAIN-M5 evaluation board has the following features:

- Through-hole universal sockets instead of solder points for the DUTs. This provides easy replacement of DUTs for repetitive measurements

  Note: *To reduce the lead inductance, it is recommended to reduce the leads length to a minimum.*

- Surface-mounted shunt resistor in parallel to coaxial shunt. It provides the freedom to choose one or the other for current measurement
- Supports an external controller board, XMC4800. It can provide double-pulse or constant pulse-width modulated (PWM) signals, enabling wireless connectivity
- Two SMA connectors on the board. This provides direct gate driver control without using an external microcontroller
- Test points for easy probing during measurements
- Turn-off gate voltage can be adjusted using a 0 V to -5 V resistor
- Bus voltage can withstand a voltage of up to 800 V

Temperature is an important factor that influences the switching behavior of devices. To investigate the switching behavior at high temperatures, EVAL-PS-DP-MAIN_M5 is equipped with a heating function through which temperature can be monitored and adjusted according to test requirements.

1.1 Purpose of the board

The evaluation board illustrated in Figure 1**Error! Reference source not found.** is primarily designed to serve as a global test platform for SiC MOSFETs and IGBTs in through-hole TO-247 and PLUS packages, both 4pin and 3pin. This board is designed for all 600 – 1200 V devices and is an improved version of the EVAL-PS-DP_MAIN evaluation board [1].

Similar to the EVAL-PS-DP_MAIN [1] board, this newly designed board supports two distinct operating modes. Using this board, the switching behavior and switching losses of the devices can be analyzed under various conditions. It is simple to alter variables such as the gate voltage, load current, device temperature, and DC-link voltage. The board can also be used as a step-up or step-down DC-DC converter-. As a result, the same configuration can be used to characterize and operate devices in continuous mode.

1.2 Block diagram

Figure 2 shows the block diagram of the motherboard where the core is a half-bridge consisting of power switches S1 and S2.

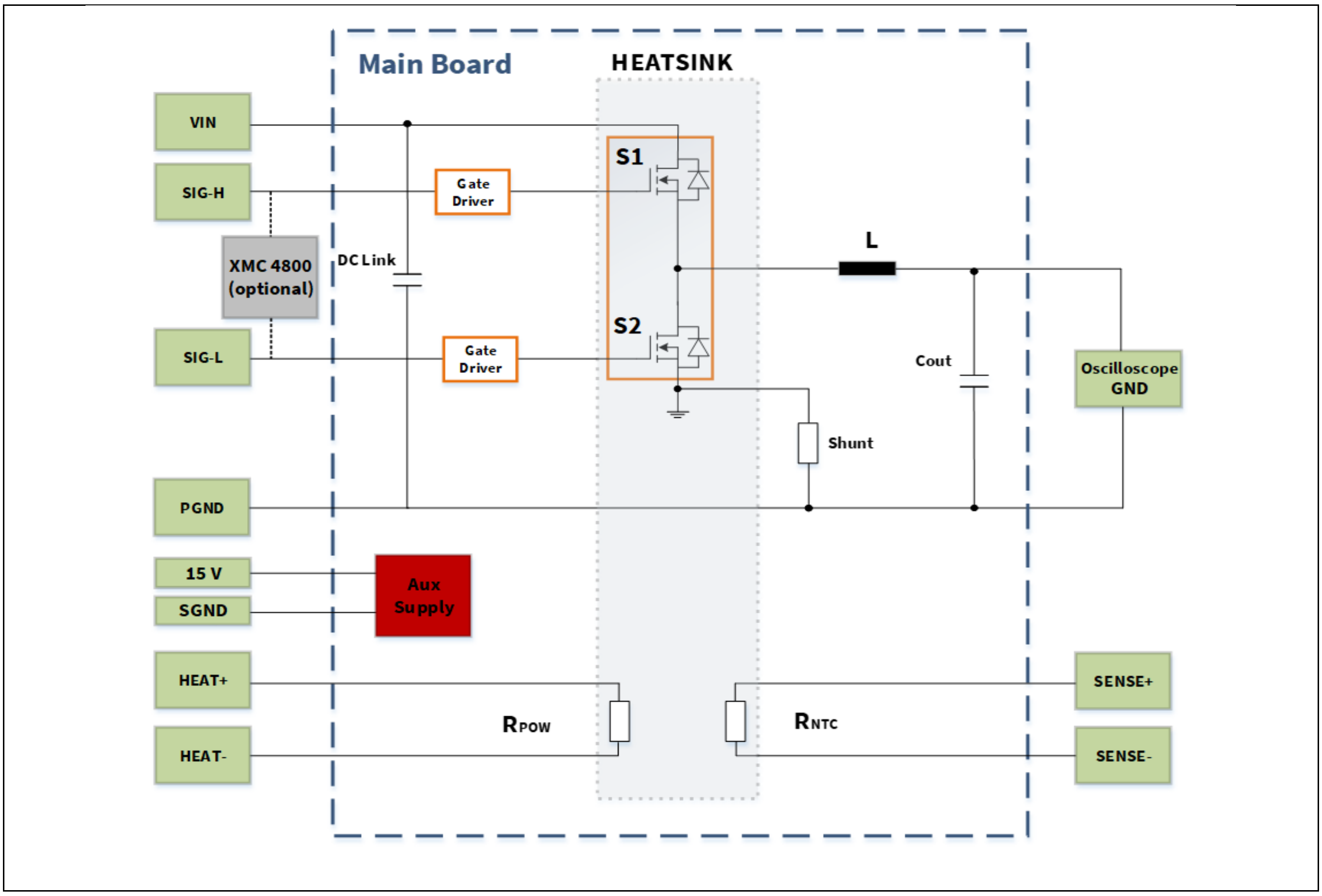


Figure 2 Block diagram

1.3 Scope of the delivery content

Table 1**Error! Reference source not found.** lists the deliverables included with the EVAL_PS_DP_MAIN_M5 b oard. The delivery kit contains the EVAL_PS_DP_MAIN_M5 motherboard, a daughter card, a 400 uH inductor, four samples of power switches, a unit with heatsink, a power resistor, and a negative temperature coefficient (NTC) resistor.

Table 1 Delivery kit contents

Item	Description	Quantity
EVAL PS DM MAIN M5	Double-pulse motherboard	1
EVAL-1ED3321MC12NDB	Gate-driver daughter card	1
Inductor	Load for the double-pulse test	1
Heatsink	Heatsink for dissipating device heat	1
Heating resistor	Element to regulate the device temperature	1
NTC	NTC resistor for temperature sensing	1
IMZC120R026M2H	CoolSiC™ MOSFET DUTs for testing	4
TO-247 heatsink clips	Metal clips to attach the device to the heatsink mechanically	2

1.4 Board parameters and technical data

The technical parameters are listed in Table 2.

Table 2 Technical data

Parameter	Symbol	Conditions	Value	Unit
High-voltage input	+Vin		800	V
Maximum pulsed current	Imax		200	A
Mechanical dimensions	Length Width		189 123	mm mm

2 System and functional description

The complete design package is available in the Download section of Infineon's website. Log in with myInfineon credentials to download this material. A brief overview of the board's hardware, shown in Figure 3, is provided in this chapter.

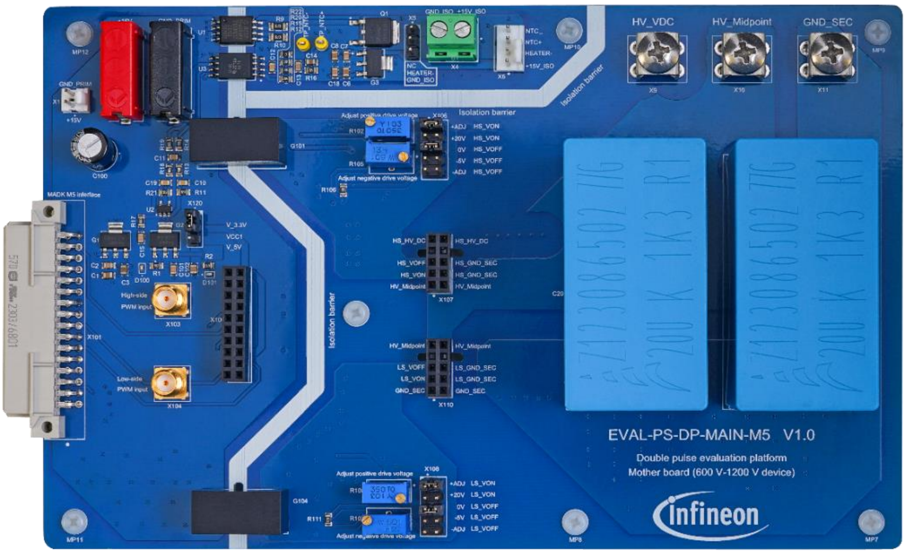


Figure 3 Top view of the evaluation board

This evaluation board contains the control, heater, and power connection parts.

Note: *For accurate and reliable high-side voltage measurements, differential probes are mandatory.*

2.1 Circuit and main components

This evaluation board is essentially a half-bridge converter comprising two power switches, as shown in Figure 4. Due to the clip-based heatsink installation and the universal sockets on the PCB, 4pin or 3pin TO-247 and PLUS packages can be used.

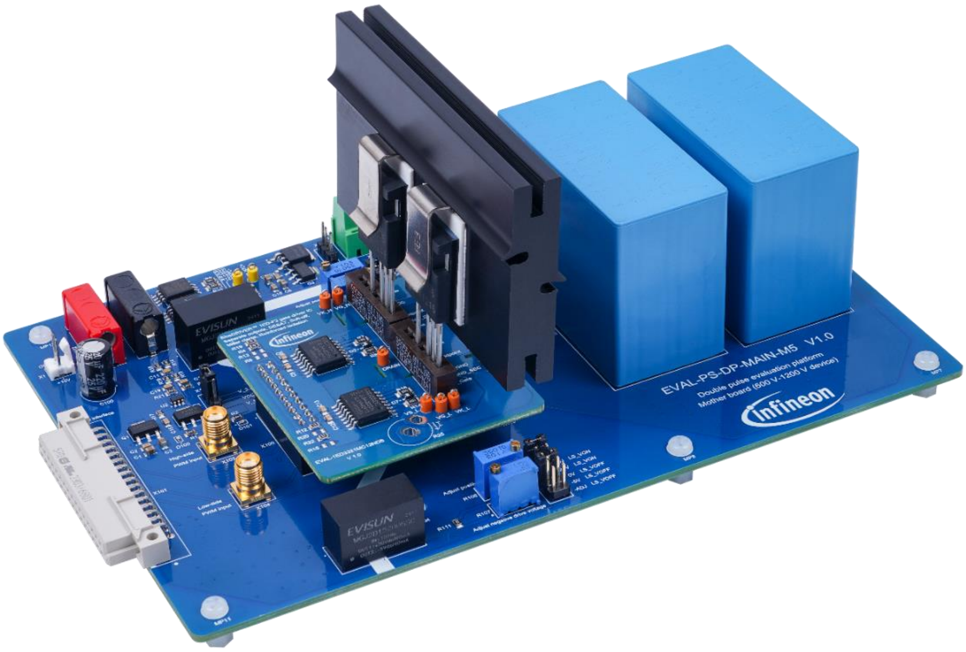


Figure 4 Evaluation board with daughter card and DUTs

The switches are driven by compact driver ICs from the respective daughter card. The two drivers are independently controlled by PWM signals on the connectors X103 for the high-side and X104 for the low-side PWM. Additionally, this evaluation board supports an external XMC4800 controller board to supply double-pulse or constant PWM signals enabling wireless connectivity. The process for using and connecting the XMC4800 controller to the evaluation board is provided in the user guide for the EVAL_XMC4800PSOC6M5 board [4].

A heating feature is implemented on the board to analyze switching losses at high temperatures. The power resistor, RPOW, and the thermistor, RNTC, can be used to adjust and monitor the heatsink temperature.

The gate voltage, the drain-source voltage, and the drain current can be measured using an oscilloscope to investigate the device's switching behavior. Measuring the voltage is simple, but measuring the current is more challenging, especially when there are high current slopes. A surface-mounted device shunt resistor is provided on the evaluation board to make measuring the current easier.

2.2 Commissioning

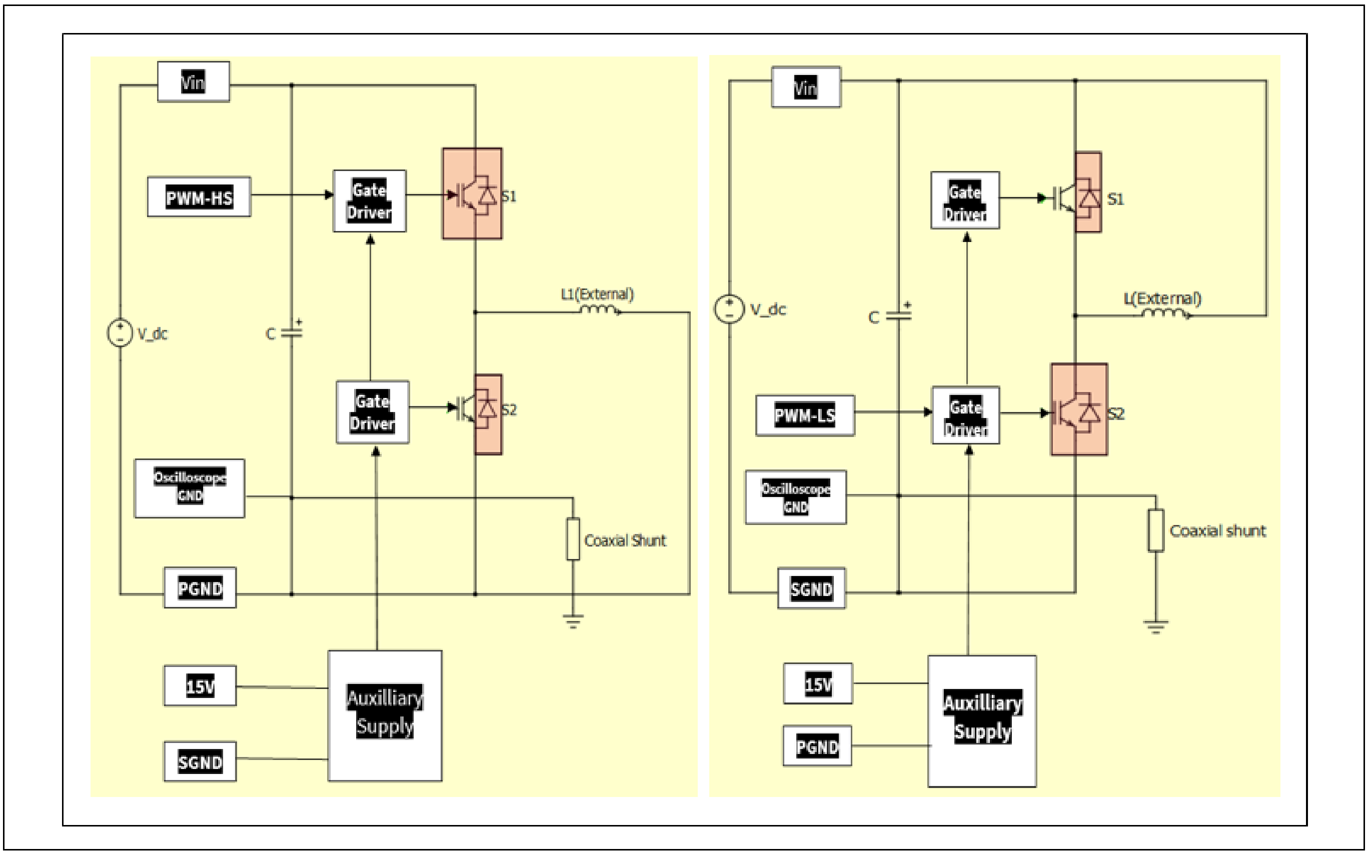


Figure 5 Circuit composition

The DC source should be connected to +HV_VDC and GND-SEC. The inductor is plugged into the HV_Midpoint and depending on the test to be used either to the +HV_VDC or the GND-SEC, as displayed in Figure 5. The left-hand side portion of Figure 5 shows the connection for testing the high-side switch or low-side diode. The right-hand side portion shows the testing configuration for the high-side diode or the low-side switch.

2.3 Description of the functional blocks

The +15 V auxiliary supply connectors can be seen on the top-left side of Figure 6. Their functioning is indicated by two LEDs D100 and D101 for +15 V for +5 V respectively. These can be connected using a jumper on X120 (highlighted in Figure 6) to the drive card that bridges pin 2 and pin 3. Another possibility can be to bridge pin 1 and pin 2 for suppling the driver via the µController.

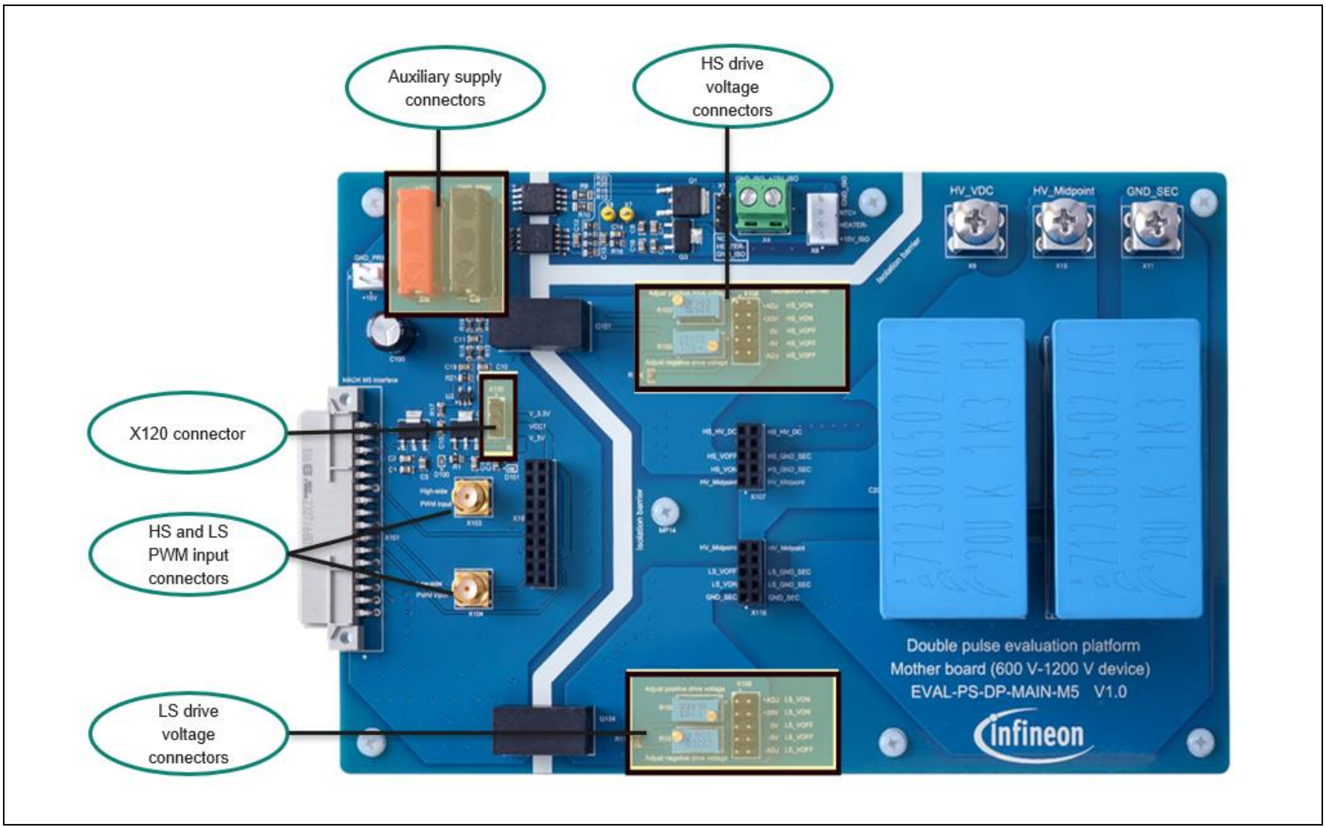


Figure 6 Auxiliary-power and drive-voltage connectors

Additionally, X106 and X108, shown in Figure 6, are for setting the correct drive voltage on the daughter cards, ranging from +20 V to - 5 V. +ADJ and -ADJ are set via the blue potentiometers R102, R105, R107, and R108. The PWM comes either from the coaxial connectors X103 and X104 or from the microcontroller via X101.

2.4 Getting started

The evaluation board is adaptable to deal with various measuring setups. This section provides instructions on setting up and using the board.

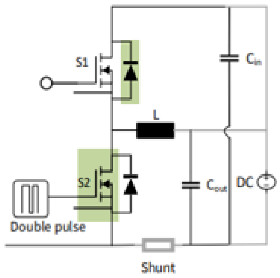
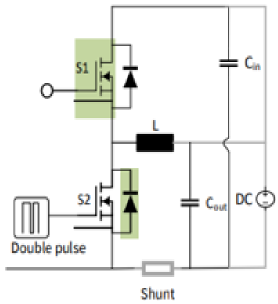
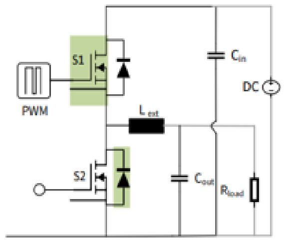
2.5 Modes of operation

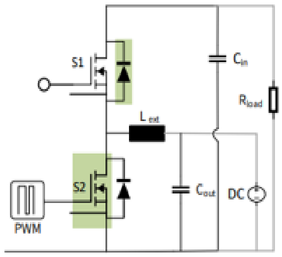
The evaluation board implements a half-bridge circuit with independent driver stages for the high-side and low-side semiconductor devices, as mentioned in Section **2.2**. The board can be used in various operational modes thanks to the universal nature of this architecture. The potential measurement configurations and methods are described in the Table 4.

Note: *Before measuring, ensure that all the board settings are correct. Make sure that no physical short circuits or floating gates are present. Increase the input voltage slowly and check if the circuit behaves as expected.*

The configurations of the primary board are summarized in Table 3**Error! Reference source not found.**. S witching losses of the devices can be estimated by measuring the current and voltage waveforms on an oscilloscope. Configuration 1 can be used to analyze the semiconductor device and Configuration 2 to analyze the diode. For maximum accuracy, using the low-side device, S2, is recommended for oscilloscope measurements. Configuration 3 and Configuration 4 can be used for buck and boost converters, respectively. As these converters process power continuously. The heatsink and the inductor must fulfill specific voltage, power, and switching frequency specifications. The maximum current in continuous-mode operation is up to 5 A. This limitation comes from the board traces and connectors. During continuous operation, cooling should be applied to the active power components.

Table 3 Different modes of operation and their configurations

Configuration	DUT	Parameter	Limit	Simplified technology
Switching (Switch characterization)	Switch S2 Diode S1	V_{DS} I_D T_C V_{GS} Package	< 800 V < 200 A < 150°C - TO-247	
Switching (Switch characterization)	Diode S2 Switch S1	V_{DS} I_D T_C V_{GS} Package	< 800 V < 200 A < 150°C - TO-247	
(1) Converter (Buck)	Switch S1 Diode S2	V_{DS} F_{SW} P_{out} V_{GS} Package	< 800 V - - - TO-247	

(1) Converter (Boost)	Switch S1 Diode S2	V_{DS} F_{sw} P_{out} V_{GS} Package	< 800 V - Note 1 - - TO-247	

Notes:

1. Parameter limits for continuous operation are determined by the chosen device and the board's cooling capabilities.

2.6 Settings

The evaluation board can help perform numerous tests on 4pin and 3pin TO-247 and PLUS packages. This section offers instructions for performing the necessary modifications, particularly in the driving circuits.

Note: *To prevent potential exposure to hazardous voltages, turn off all power supplies and discharge the DC-link capacitors before undertaking any of the modifications described in this section.*

2.6.1 Tuning gate voltages

The driver bias circuitry used to operate both the high-side and low-side switches is shown in**Error! Reference source not found.** Figure 7.

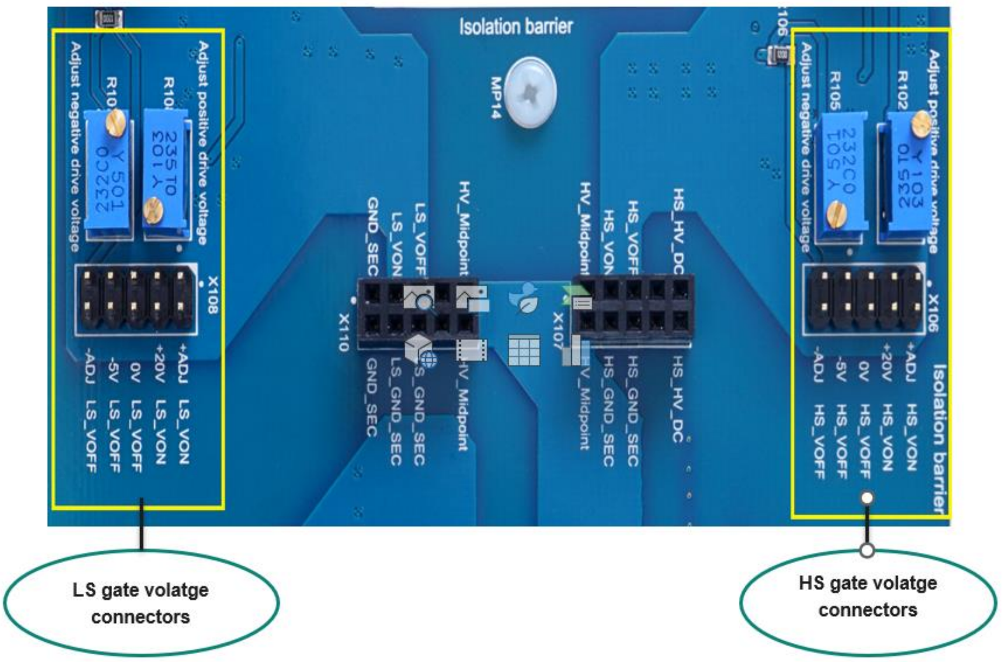


Figure 7 Gate voltage settings

To modify the low-side gate voltage levels, follow these steps:

1. Set the jumper, X108, to **+ADJ** and tune the potentiometer, R108, with a flat screwdriver until the recommended value is reached.
2. Using the jumper, X108, choose either -5 V or 0 V as the turn-off voltage. The turn-off voltage can be changed from 0 V to -5 V by tuning the potentiometer, R107.
3. Using an oscilloscope or multimeter, track the gate voltage values.

To modify the high-side gate voltage levels, follow these steps:

1. Set the jumper, X106, to **+ADJ** and tune the potentiometer, R108, with a flat screwdriver until the recommended value is reached.
2. Using the jumper, X106, choose either -5 V or 0 V as the turn-off voltage. The turn-off voltage can be changed from 0 V to -5 V by tuning the potentiometer, R105.
3. Using an oscilloscope or multimeter, track the gate voltage values.

2.6.2 Adjusting the heatsink temperature

Besides room temperature, switching losses can also be measured at 100°C and more. Therefore, the measuring setup should help users control and track the case temperature of a test device. A small heatsink that functions as a tiny heating element is included on this test board. The temperature of this heatsink can be controlled and monitored using the power resistor and the negative temperature coefficient (NTC) thermistor, respectively. Alternatively, the heatsink's temperature can also be monitored and adjusted using the XMC4800 controller.

To adjust the heatsink's temperature manually, follow these steps:

1. Short the pins 2 and 3 of X5 to power the heater or alternatively use the IOT XMC4800 controller card.
2. Connect the power supply to X4, +15V_ISO, and GND_ISO.
3. Connect the heating element to +15V_ISO/HEATER- (i.e., pin 1 and 2 terminals of X6), and the NTC to NTC+/GND_ISO (i.e., pin 3 and 4 terminals of X6).
4. Use the power supply to adjust the temperature of the heatsink.
5. Monitor the actual temperature value using the ohmmeter and the NTC characteristic. Alternatively, measure the voltage at test points X7 and X8 (i.e., NTC_VSENSE+ and NTC_VSENSE-) to calculate the temperature.

2.6.3 Configuring the double-pulse test

Switching losses of the devices can be analyzed using a double-pulse test. It generates both a turn-off and a turn-on event by applying two consecutive pulses on the gate terminal of the switch – hence the expression double pulse. This section explains how to conduct a double-pulse test using Configuration 1 and Configuration 2.

To perform a double-pulse test on the evaluation board:

1. Assemble the devices under tests S1 and S2.
2. Connect the driver to the proper emitter pin.
3. Adjust the driving voltages for S2, and if necessary, also for S1, as per Section **2.6.1**.
   a. Set the jumper X108/X106 to **+ADJ**.
   b. Use the jumper X106/X108 to set the turn-off voltage to 0 V or -5 V.
   c. Adjust the turn-on and turn-off gate resistors R102/R108 for a positive drive voltage and R105/R107 for a negative drive voltage for high-side and low-side respectively.
4. Connect the oscilloscope probes to measure V_{DS}, V_{GS}, and I_D of S2.
   a. Use probe adapters to measure V_{DS} and V_{GS} with ordinary voltage probes.
   b. Measure I_D current.
5. Connect an auxiliary supply to the 15 V/SGND terminal of the board to provide a voltage of 15 V.
6. Connect a signal generator to X103/X104 and provide a double-pulse pattern if not using the XMC4800 controller for generating the pulse.
7. If required, connect a power supply to the GND_ISO/+15V_ISO (X4 pin 1 and 2) terminals and set the voltage level.
8. Monitor the temperature using the ohmmeter connected to X7 and X8 as explained in Section **2.6.2**.
9. Connect a high-voltage source to HV_VDC (X9) and GND_SEC (X11), and short HV_VDC (X9) and HV_Midpoint (X10).
10. Slowly increase the voltage and monitor the current and voltage waveforms on the oscilloscope.

2.6.4 Configuring the efficiency measurement

To comprehend the switching behavior of a semiconductor device fully, it must be tested inside a switching cell. Additional analysis is required to convert the received switching-loss data into values that are more useful for an application, such as the efficiency of the converter, the temperature of the devices, or the cooling effort required. This section outlines the steps necessary to set up and operate the board as a buck converter under Configuration 3 as listed in Table 4 **Error! Reference source not found.**.

To prepare the test setup for measuring efficiency, follow these steps:

1. Assemble the devices under tests S1 and S2.
   a. Adjust the driving voltages for S2, and if necessary, also for S1, according to Section **2.6.1**.
   b. Set the jumper X108/X106 to **+ADJ**.
   c. Use the jumper X108/X106 to set the turn-off voltage to 0 V or -5 V.
   d. Adjust the turn-on and turn-off gate resistors, R102/R108 and R105/R107 respectively.
2. Connect the oscilloscope probes to measure V_{DS}, V_{GS}, and I_D of S2.
   a. Use the probe adapters to measure V_{DS} and V_{GS} with ordinary voltage probes.
   b. Measure I_D using a shunt.
3. Connect an auxiliary supply to the 15 V/SGND terminal of the board and provide a voltage of 15 V.
4. Connect a signal generator to X103/X104 and provide a double-pulse pattern manually. Alternatively, the double-pulse pattern can also be provided automatically using the XMC4800 controller.
5. Connect a high-voltage source to X9 and X11.
6. Connect an ohmic load to X10 and X11.
7. Measure the input and output power using a power meter and the device's temperatures using an infrared camera.
8. Slowly increase the input voltage while monitoring the waveforms and device temperatures.

The start-up procedure includes the following steps:

1. Mount the drive card on the motherboard and set the jumpers to the required supply voltage.
2. Plug the DUTs into the connectors on the daughter board connected to X100, X107, and X110.
3. Connect the power source (V_{DC} up to 800 V), 15 V auxiliary supply, and function generator (for double pulse). Setting current limits is recommended for safety reasons.
4. Connect the load inductor, either high-side or low-side HS or LS.
5. Plug in the desired probes (voltage, current).
6. To begin the turn-on procedure:
    a. Apply 15 V and double pulse.
    b. Gradually apply high voltage till the desired level is reached.
    c. Proceed with measurements.
7. To begin the turn-off procedure:
    a. Switch off the high-voltage source.
    b. Switch off the auxiliary supply and function generator.

Additional guidance on double-pulse control using the controller card is available in [4].

3 System design

Visit Infineon's website for complete design files. They are available on the board's webpage in the "Design support" section. MyInfineon login credentials are required to access the files.

3.1 Schematic drawings

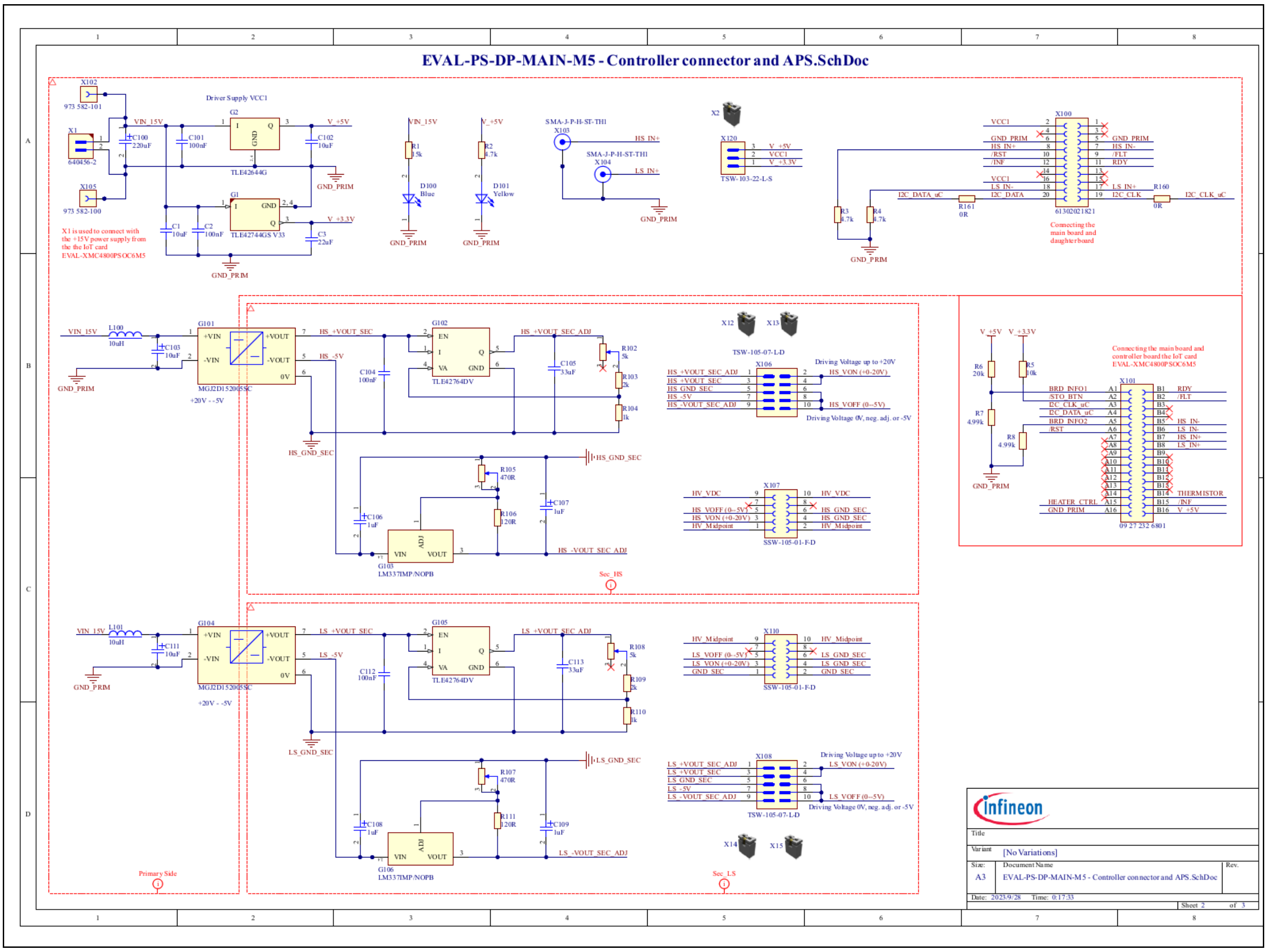


Figure 8 Controller connector and auxiliary power schematics

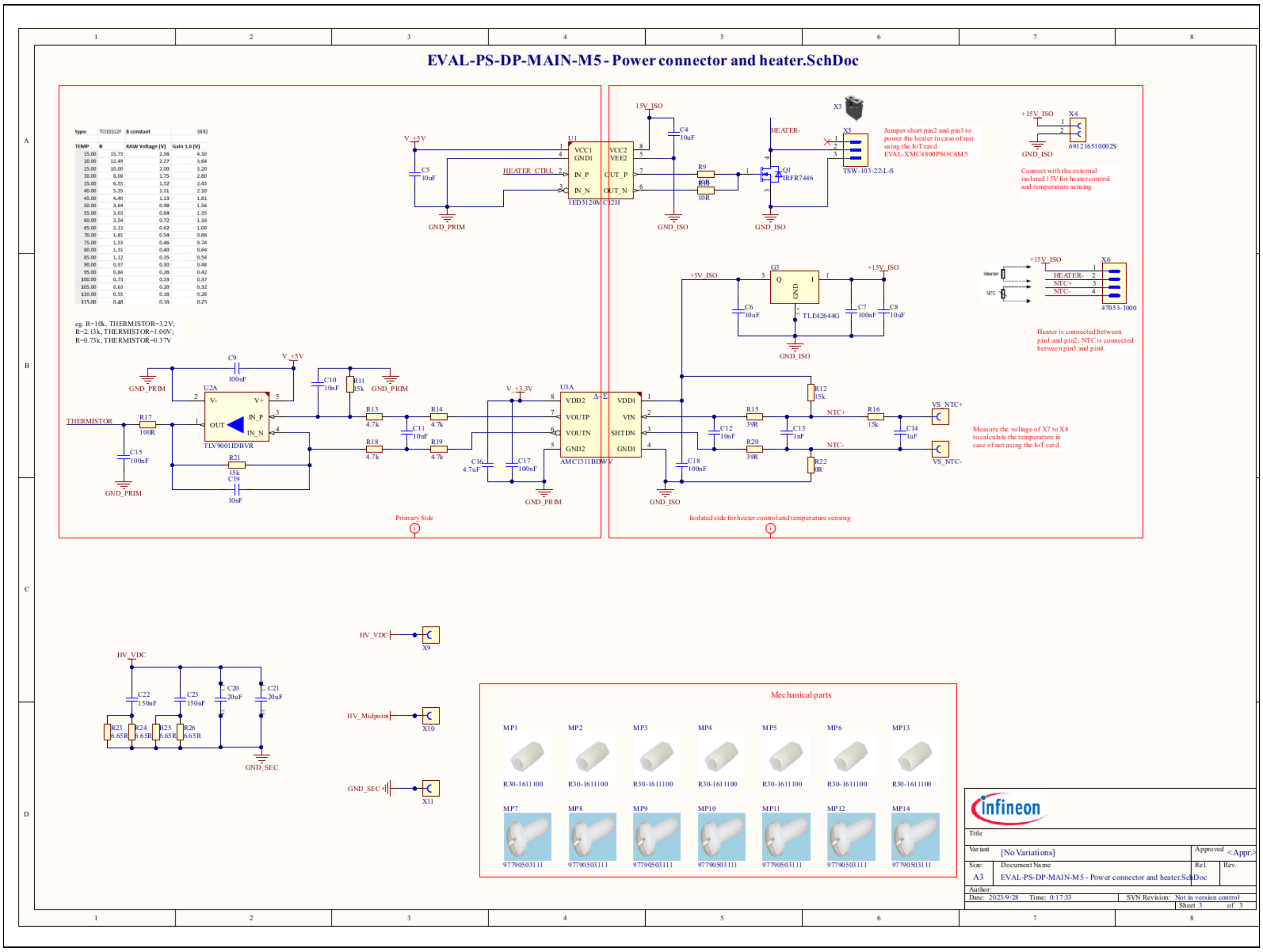


Figure 9 Power connector and heater schematics

3.2 Board layout

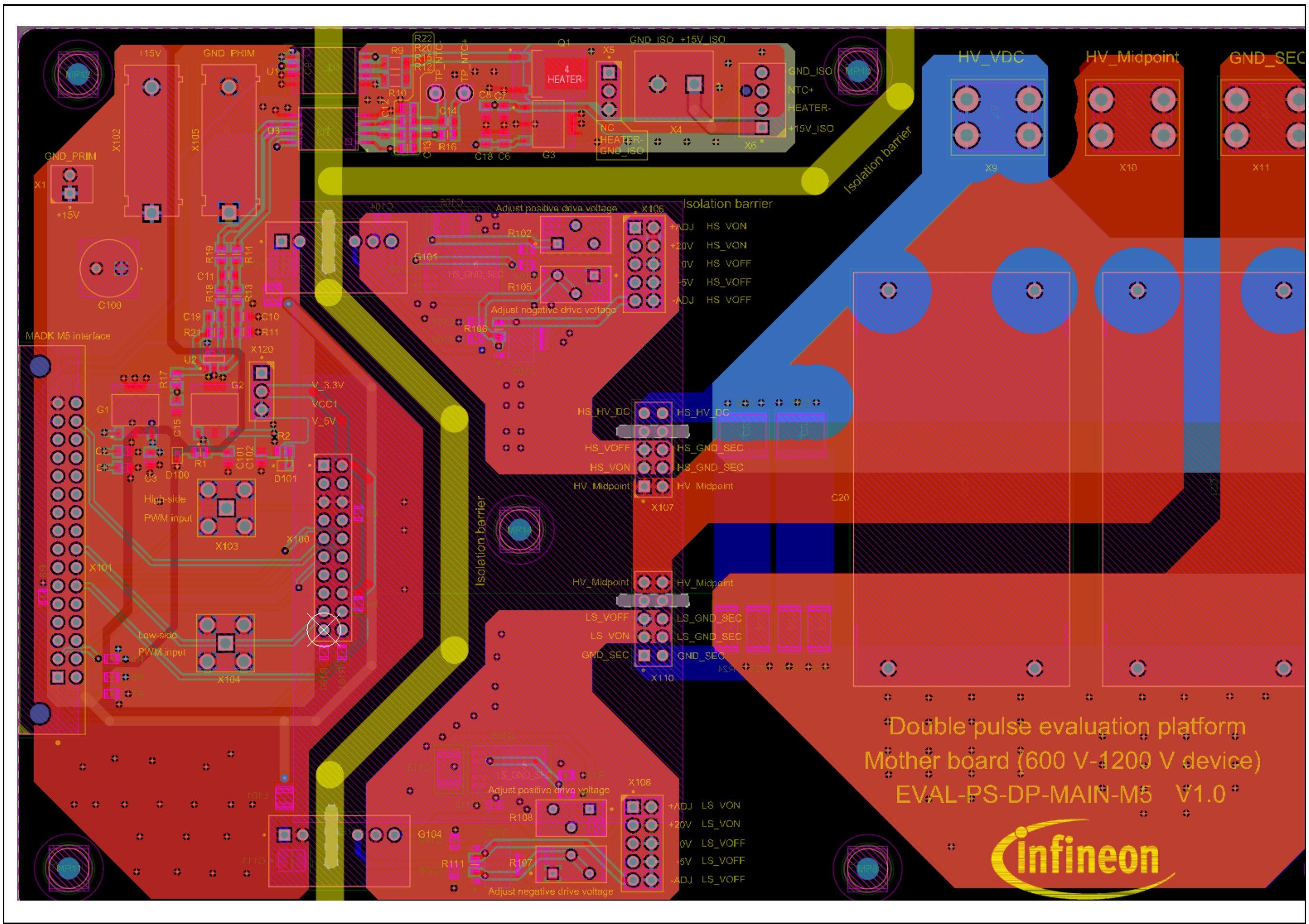


Figure 10 Layout of the EVAL-PS-DP_MAIN_M5 board

References

[1] Infineon Technologies AG. User guide 2.0 (2021): EVAL-PS-DP_MAIN: [https://www.infineon.com/dgdl/Infineon-UG-2021-32_EVAL_PS_DP_MAIN-UserManual-v01_00-EN.pdf?fileId=8ac78c8c7c03edb4017c271760fa40]

[2] Infineon Technologies AG. User guide 1.0 (2023): EVAL-COOLSIC-2KVHCC: [https://www.infineon.com/dgdl/Infineon-UG-2023-06-EVAL-COOLSIC-2KVHCC-UserManual-v01_00-EN.pdf?fileId=8ac78c8c8779172a0187dbcae33a43c2]

[3] Infineon Technologies AG. AppNote 1.0 (2017): [https://new-origin.infineon.com/dgdl/Infineon-EvalBoard_TO247_PLUS-ApplicationNotes-v01_00-EN.pdf?fileId=5546d4625fe36784015fee4ae76260d0]

[4] Infineon Technologies AG. User guide 1.0 (2017): EVAL-XMC4800PSOC6M5 user guide [https://www.infineon.com/dgdl/Infineon-UG-2023-07-EVAL-XMC4800PSOC6M5-UserManual-v01_00-EN.pdf?fileId=8ac78c8c8d2fe47b018e12871028537c]

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