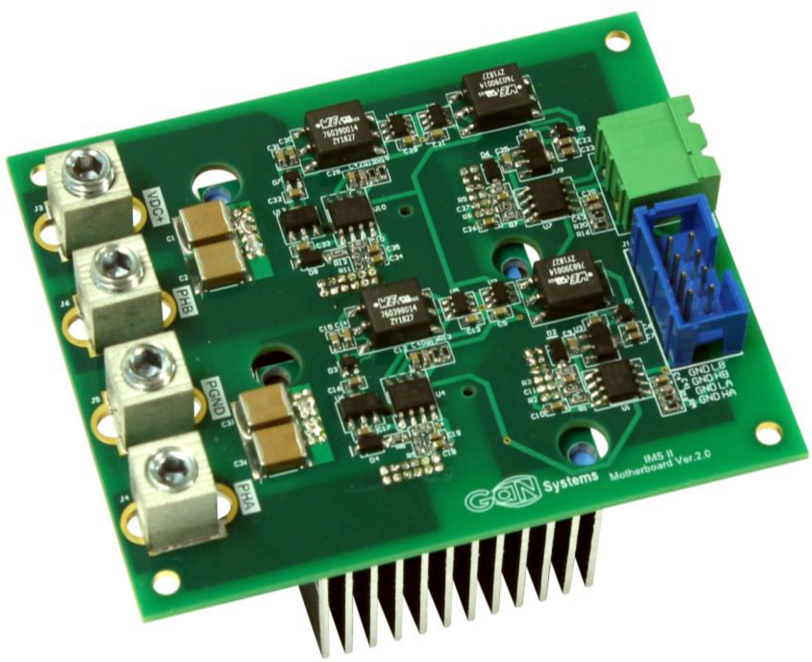
IMS 2 Evaluation Platform

Technical Manual

GSP665HPMB-EVBIMS2
GSP66508HB-EVBIMS2
GSP66516HB-EVBIMS2



Visit www.gansystems.com for the latest version of this technical manual.

Please refer to the Evaluation Board/Kit Important Notice on page 22

DANGER

DO NOT TOUCH THE BOARD WHEN IT IS ENERGIZED AND ALLOW ALL COMPONENTS TO DISCHARGE COMPLETELY PRIOR HANDLING THE BOARD.

HIGH VOLTAGE CAN BE EXPOSED ON THE BOARD WHEN IT IS CONNECTED TO POWER SOURCE. EVEN BRIEF CONTACT DURING OPERATION MAY RESULT IN SEVERE INJURY OR DEATH.

Please sure that appropriate safety procedures are followed. This evaluation kit is designed for engineering evaluation in a controlled lab environment and should be handled by qualified personnel ONLY. Never leave the board operating unattended.

WARNING

Some components can be hot during and after operation. There are NO built-in electrical or thermal protection on this evaluation kit. The operating voltage, current and component temperature should be monitored closely during operation to prevent device damage.

CAUTION

This product contains parts that are susceptible to damage by electrostatic discharge (ESD). Always follow ESD prevention procedures when handling the product.

Contents

List of Figures

List of Tables

1 Overview

1.1 Introduction

A frequent challenge for power designers is to engineer a product that has excellent power density and reduced cost of the system simultaneously.

This IMS evaluation platform demonstrates an effective way to improve heat transfer, to increase power density and reduce system cost. An Insulated Metal Substrate PCB (IMS PCB) is used to cool GaN Systems' bottom-side cooled power transistors. An IMS PCB is also known as Metal Core/Aluminum PCB.

Examples of applications that have successfully used this approach include:

- **Automotive:** 3.3kW-22kW on board charger, DC/DC, 3-Φ inverter, high power wireless charger
- **Industrial:** 3-7kW Photovoltaic Inverter and Energy Storage System (ESS), Motor Drive / VFD
- **Server/Datacenter:** 3kW Server ACDC power supply.
- **Consumer:** Residential Energy Storage System (ESS)

This evaluation platform consists of two parts: the IMS 2 EVB board (mother board) and the IMS 2 half bridge power board, as show in Figure 1. The IMS 2 half bridge power board is available in 2 power levels: 3kW and 6kW.

⚠ A suitable heatsink is included for lower power applications. For higher power applications additional heatsinking may be required. To prevent device damage, ensure adequate heatsinking through design and by monitoring the component temperatures during operation.

⚠ To assemble a heatsink, apply thermal grease to the heatsink / IMS board interface before screwing the units together. Enough thermal grease should be applied so that a small amount extrudes on all four sizes as the screws are tightened. Wipe the assembly clean.

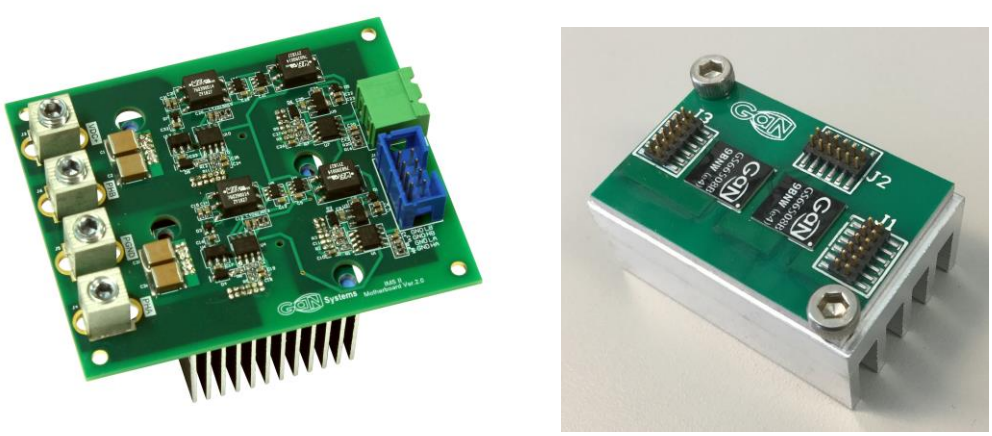


Figure 1 IMS 2 EVB mother board and IMS 2 half bridge power module with heatsink

With these building blocks, the evaluation platform can be purchased in 4 different configurations: low power and high power, half bridge and full bridge. Table 1 lists the ordering options.

Table 1 Ordering configuration and part numbers

CONFIGURATION	IMS 2 HALF BRIDGE MODULE	IMS 2 EVB Mother Board
3 kW Half Bridge	QTY 1 - GSP66508HB-EVBIMS2	QTY 1: GSP665HPMB-EVBIMS2
6 kW Half Bridge	QTY 1 - GSP66516HB-EVBIMS2	
3 kW Full Bridge	QTY 2 - GSP66508HB-EVBIMS2	
6 kW Full Bridge	QTY 2 - GSP66516HB-EVBIMS2	

Table 2 Part numbers and Description

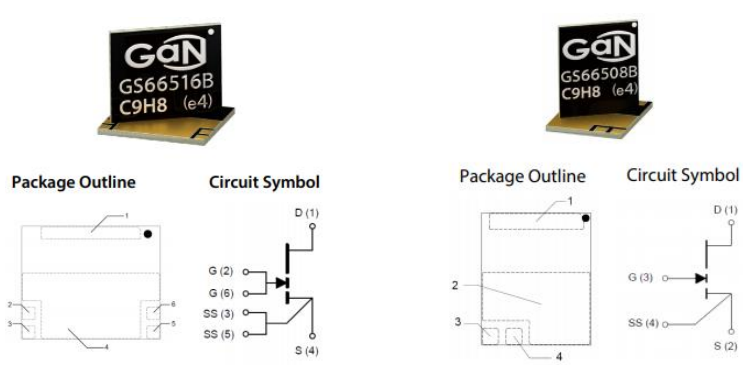
PART NUMBER	DESCRIPTION	GaN E-HEMT
GSP665HPMB-EVBIMS2	Optimized Dual HB Gate Driver Motherboard with isolated driver and PSU for use with GSP66516HB-EVBIMS2 or GSP66508HB-EVBIMS2 half bridge boards	N/A
GSP66508HB-EVBIMS2	Optimized IMS 2 Half Bridge based on GS66508B GaN*PX*® bottom-cooled E-HEMTs	GS66508B
GSP66516HB-EVBIMS2	Optimized IMS 2 Half Bridge based on GS66516B GaN*PX*® bottom-cooled E-HEMTs	GS66516B

1.2 IMS 2 Evaluation Platform Overview

1.2.1 Technical Description

Using this platform, power designers can evaluate the performance of GaN Systems' E-HEMTs (Enhancement mode High Electron Mobility Transistors) in high power, high efficiency applications. The IMS 2 half bridge power board is populated with GaN Systems' GS66516B (bottom-side cooled E-HEMT, rated at 650 V / 25 mΩ) or GS66508B (bottom-side cooled E-HEMT, rated at 650 V / 50 mΩ). The embedded GaN*PX*® SMD package has the following features:

- Large power source/thermal pad for improved thermal dissipation.
- Bottom-side cooled packaging for conventional PCB or advanced IMS/Cu inlay thermal design.
- Ultra-low inductance for high frequency switching.



a) GS66516B b) GS66508B

Figure 2 - GS66516B and GS66508B GaN*PX*® packaged E-HEMTs

The IMS 2 half bridge power board is designed for users to gain hands-on experience in the following ways:

- Evaluate the GaN E-HEMT performance in any half bridge based topology, over a range of operating conditions. This can be done using either the accompanying power motherboard (P/N: GSP665HPMB-EVBIMS2) or with the users' own board for in-system prototyping.
- Use as a thermal and electrical design reference of the GS66516B or GS66508B GaN*PX*® package in demanding high-power and high efficiency applications.

1.2.2 IMS Board thermal design

An IMS board assembly uses metal as the PCB core, to which a dielectric layer and copper foil layers are bonded. The metal PCB core is often aluminum. The copper foil layers can be single or double-sided. An IMS board offers superior thermal conductivity to standard FR4 PCB. It's commonly used in high power, high current applications where most of heat is concentrated in a small footprint SMT device.

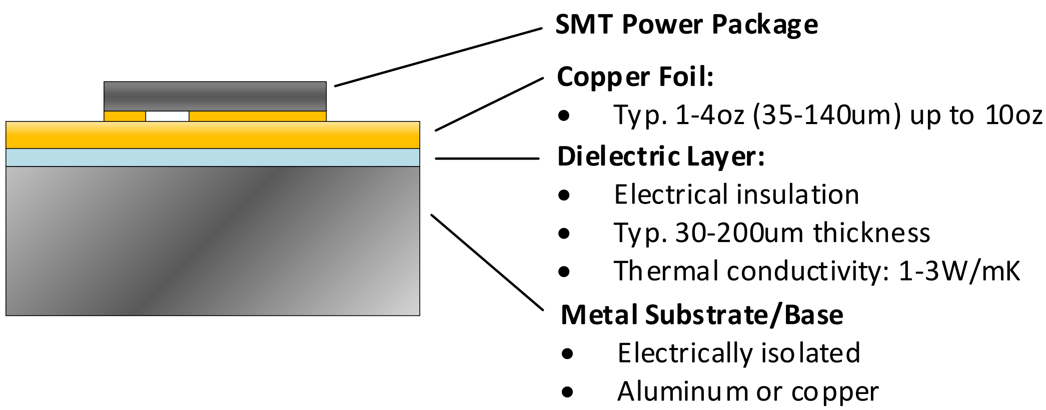


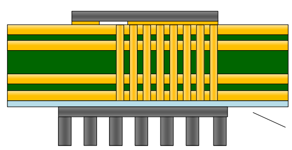
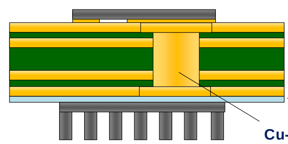
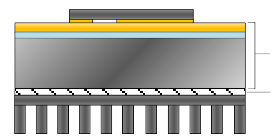
Figure 3 Cross-section view of a single layer IMS board

As high-speed Gallium Nitride power devices are adopted widely, the industry is trending away from through-hole packaging (TH), towards surface mount packaging (SMT). Traditional TH devices, such as the TO-220, are no longer the appropriate choice because their high parasitic inductance and capacitance negate the performance benefits offered by GaN E-HEMTs. SMT packaging, such as PQFN, D2PAK and GaN Systems' GaN*PX*®, by comparison, offer low inductance and low thermal impedance, enabling efficient designs at high power and high switching frequency.

Thermal management of SMT power transistors must be approached differently than TH devices. TO packages are cooled by attaching them to a heatsink, with an intermediary Thermal Interface material (TIM) sheet for electrical high voltage insulation. The traditional cooling method for SMT power devices is to use thermal vias tied to multiple copper layers in a PCB. The IMS board presents designers with another option which is especially useful for high power applications. The IMS board has a much lower junction to heatsink thermal resistance (R_{thJ-HS}) than FR4 PCBs, for efficient heat transfer out of the transistor. As well, assembly on an IMS board has lower assembly cost and risk than the TH alternative. The manual assembly process of a TO package onto a heatsink is costly and prone to human error.

Table 3 compares 3 different design approaches for cooling discrete SMT power devices. While the cost is lower for a FR4 PCB cooling with thermal vias, the IMS board offers the best performance for thermal management. Figure 4 provides a quantitative comparison of the thermal resistance for the 3 design options. The IMS board clearly comes out ahead.

Table 3 Performance comparison of 3 thermal design options for SMT power devices

	FR4 PCB Cooling with Vias 	**FR4 PCB with Cu inlay** 	**IMS PCB** 
Thermal resistance	**Good**	**Better**	Best
Electrical Insulation	No, additional TIM needed	No, additional TIM needed	Yes
Cost	Lowest	High	Low
Advantages	• Standard process • Lowest cost • Layout flexibility	• Layout flexibility • Improved thermal compared to thermal vias	• Lowest thermal resistance • Electrically isolated
Design challenges	• High PCB thermal resistance	• Cu-inlay surface coplanarity • High TIM thermal resistance	• Layout limited to 1 layer • Parasitic inductance • Coupling capacitances to the metal substrate

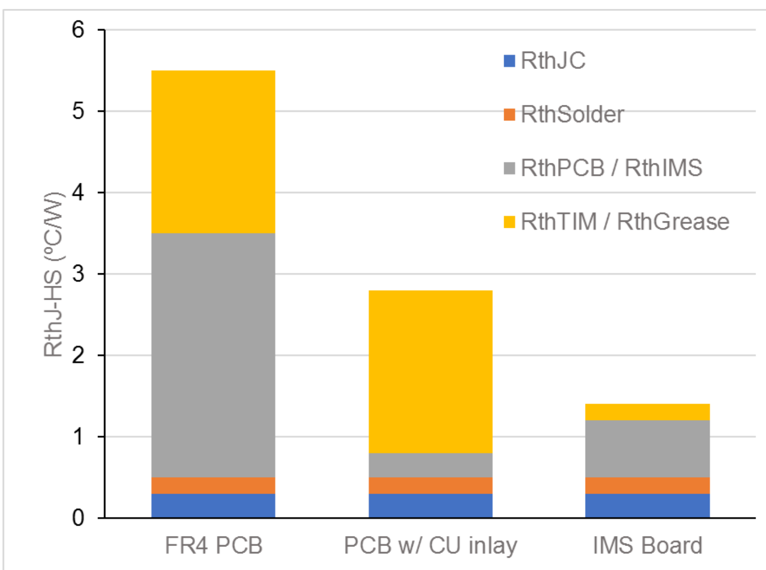


Figure 4 Comparison of Junction to Heatsink thermal resistance (R_{thJ-HS}) (Estimated based on GS66516B)

Please refer to the Evaluation Board/Kit Important Notice on page 22

The following additional measures are taken to optimize the design further.

- The IMS 2 evaluation platform is implemented as a two-board asssembly. The gate drive circuitry is assembled on the GSP665HPMB-EVBIMS2, a multi-layer FR4 PCB mother board. This includes the gate driver ICs, an isolated push-pull power supply to power the driver IC, and DC decoupling capacitors. The GaN E-HEMTs are mounted to the IMS half bridge board (GSP66508HB-EVBIMS2 and GSP66516B-EVBIMS2). This approach addresses the shortcomings of implementing the design on a single layer IMS board.

- While a large copper area is preferred to maximize heat spreading and handle high current, the area of copper at the switching node (high dv/dt) needs to be minimized to reduce the parasitic coupling capacitance to the metal substrate. An IMS board with thicker dielectric layer (100um) is chosen on this design to further reduce this effect.

1.3 IMS 2 Half Bridge Board Design

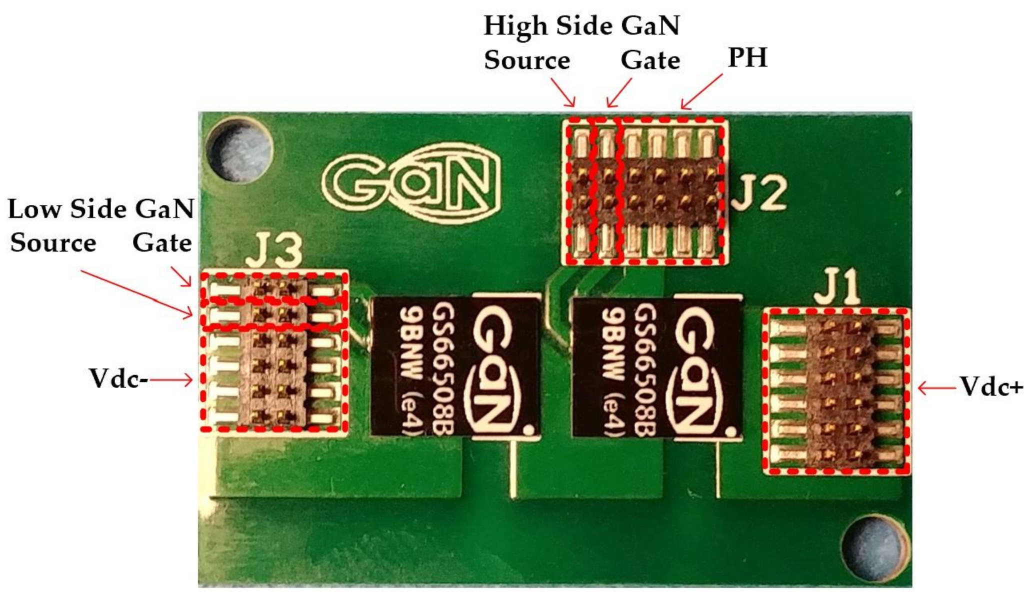


Figure 5 IMS 2 half bridge power board (GSP66508HB-EVBIMS2)

The IMS 2 half bridge power board is populated with the following components:

- **Q1 and Q2:** GS66516B or GS66508B E-HEMTs in a half bridge configuration.
    - 6kW GSP66516HB-EVBIMS2: Q1/Q2 GS66516B.
    - 3kW GSP66508HB-EVBIMS2: Q1/Q2 GS66508B.
- **J1, J2, J3:**
    - Connector Header Surface Mount 12 position 0.050" (1.27mm) (Samtec Inc., P/N: FTS-106-02-F-DV).
    - These terminals are designed to carry the main current and gate signals.

1.4 IMS 2 EVB Mother Board

GaN Systems offers a high-power IMS 2 evaluation board that can be purchased separately. The ordering part number is GSP665HPMB-EVBIMS2. It can be used as a platform for evaluating the IMS board in any half or full bridge topology.

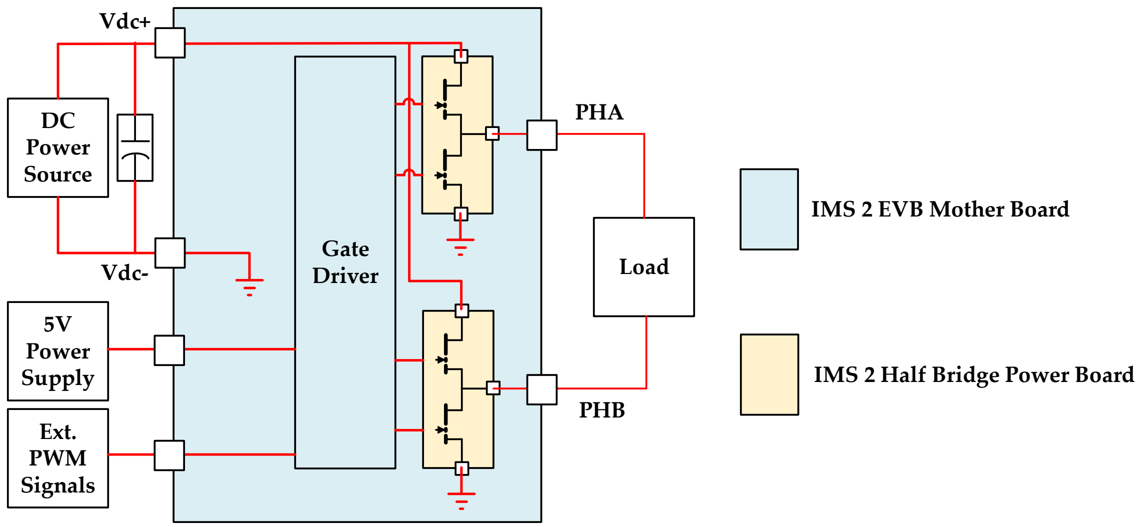


Figure 6 Circuit block diagram of IMS 2 EVB board

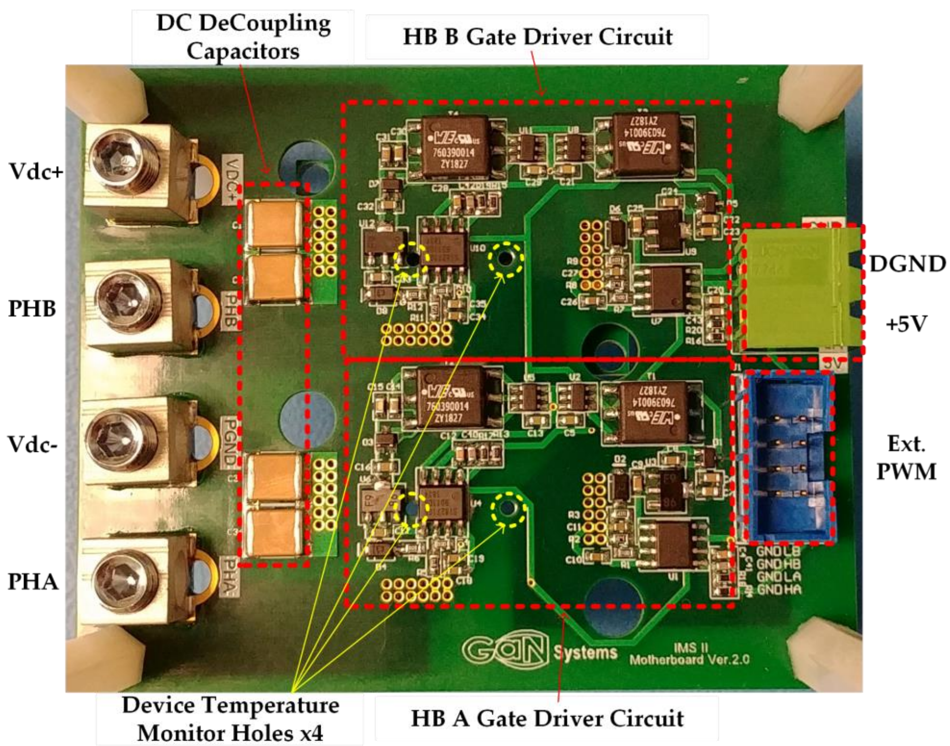


Figure 7 GSP665HPMB-EVBIMS2

1.4.1 Gate Driver Circuit

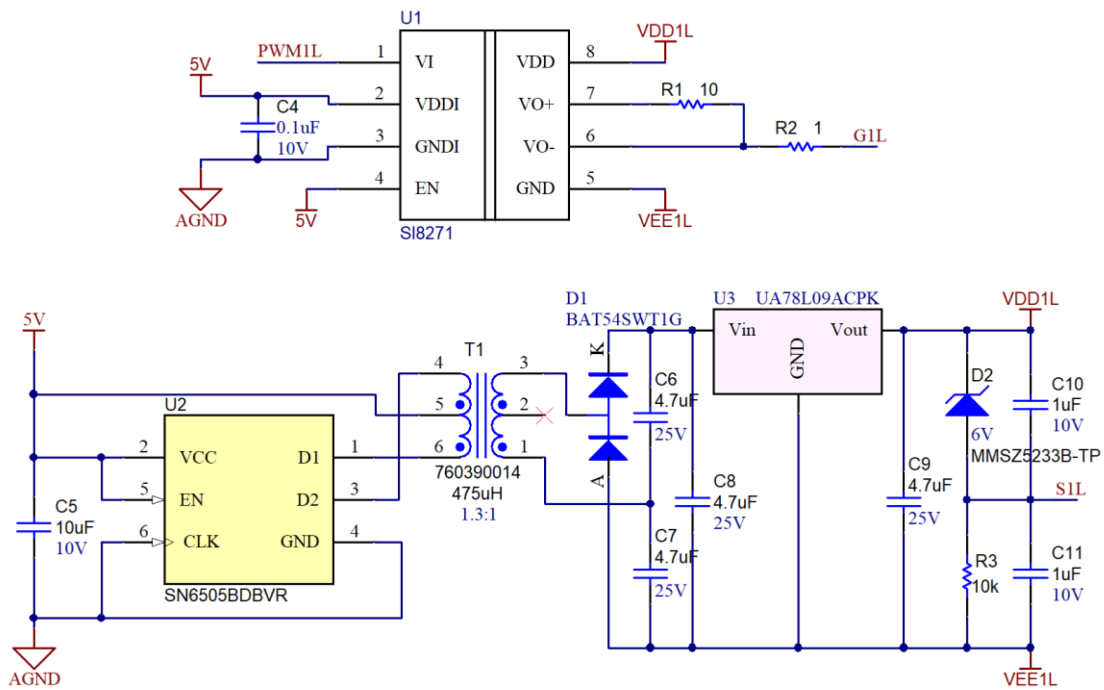


Figure 8 Gate driver circuit

A low cost isolated gate driver circuit is used in the IMS 2 EVB board for each GaN device, which is shown in Figure 8:

- U1 is the isolated gate driver (Silicon Labs P/N: Si8271)
- U2, T1, D1, C6, C7, C8 and U3 are the isolated push-pull power supply for the gate driver; after the LDO chip U3, the output is divided to +6/-3V to power the gate driver.
- R1 and R2 are gate turn-on and off resistors.

1.4.2 5V input

The gate driver circuit on the IMS 2 EVB mother board is powered from a 5V DC source, through connector J2.

1.4.3 Temperature monitoring holes

4 holes are located on the center of 4 GaN E-HEMTs to assist with the temperature monitoring during operation. A thermal camera can be used to monitor the case temperature through these holes. The temperature measured at the center of GaN*PX*® package will be close to the T_J.

NOTE: Thermal performance of the transistors is dependent on a number of factors including circuit configuration, ambient temperature, airflow, and heatsinking. The user is responsible for monitoring the temperature of the devices to ensure operation remains within specification.

1.4.4 External PWM Signals Input

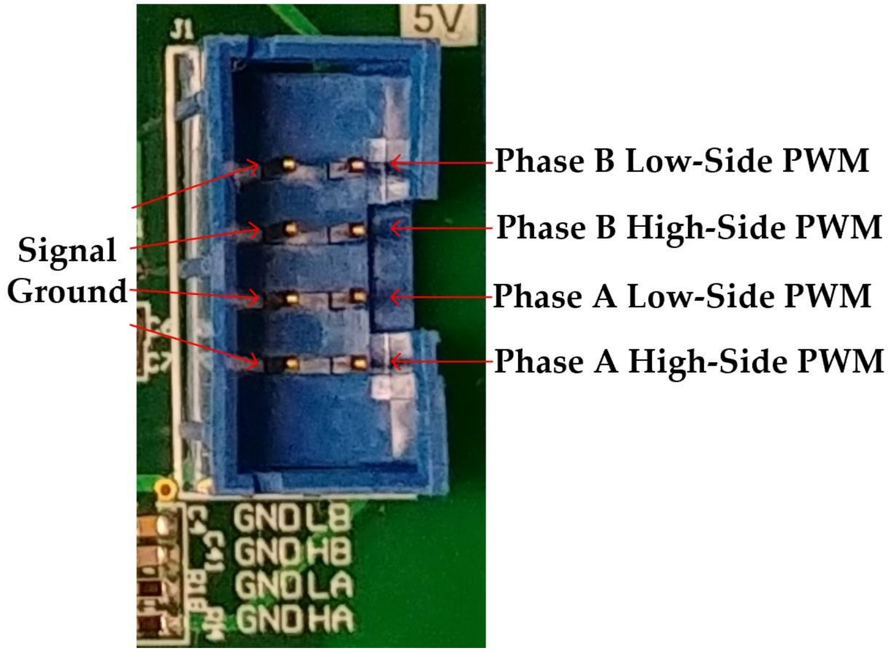


Figure 9 External PWM signals connector

The PWM signals of all four GaN devices come from the external PWM connector J1, as shown in Figure 9. The deadtime of PWM signals are required and should be provided from the external source.

1.4.5 Installation of IMS 2 Half Bridge Power Board

To achieve the lowest power loop parasitics, it is suggested to solder the IMS 2 half bridge power board to the IMS 2 EVB motherboard.

1.4.6 DC link decoupling capacitors

As it is challenging to create low inductance power loop on single-layer IMS board, DC decoupling capacitors are placed on multi-layer IMS 2 EVB PCB. The power loop path is highlighted as below.

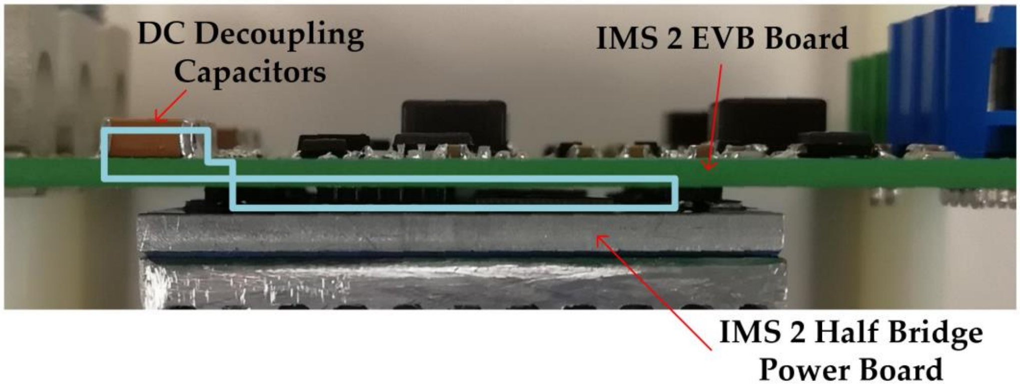
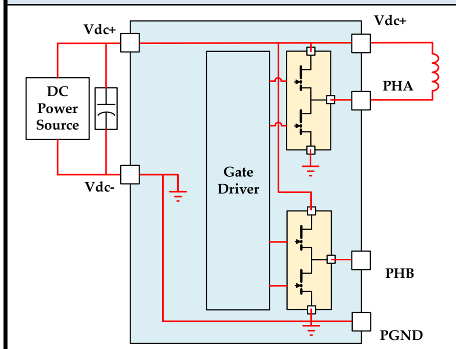
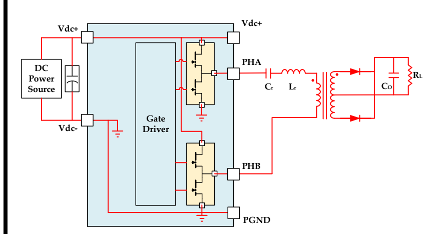
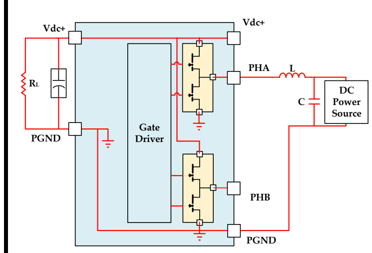


Figure 10 - Cross section view of IMS assembly showing the power Loop path

1.4.7 Operation modes

The Evaluation Platform can be configured into different topologies and operation modes as shown below

Table 4 Evaluation Platform Configurations

<table>
<tr><th>HALF BRIDGE</th><th>FULL BRIDGE</th><th>BOOST MODE</th></tr>
<tr><td>Double Pulse Test</td><td>Full Bridge LLC</td><td>Synchronous Boost DC/DC</td></tr>
<tr><td>
</td><td>
</td><td>
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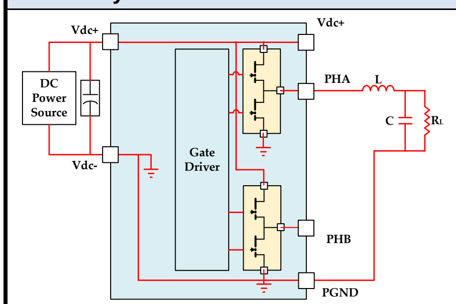
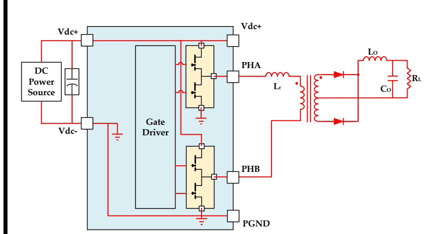
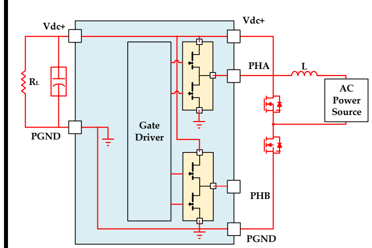
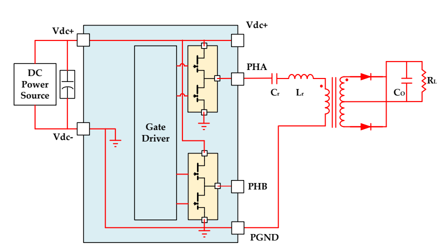
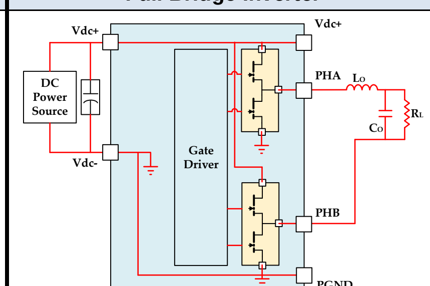
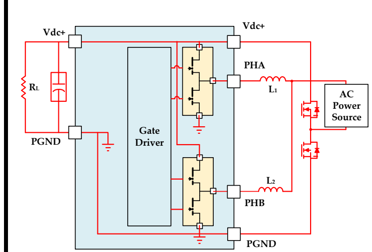
<tr><td>Synchronous Buck DC/DC</td><td>Phase Shift Full Bridge</td><td>Totem Pole PFC</td></tr>
<tr><td>
</td><td>
</td><td>
</td></tr>
<tr><td>Half Bridge LLC</td><td>Full Bridge Inverter</td><td>Interleaved Totem Pole PFC</td></tr>
<tr><td>
</td><td>
</td><td>
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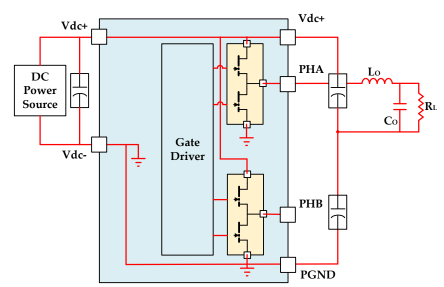
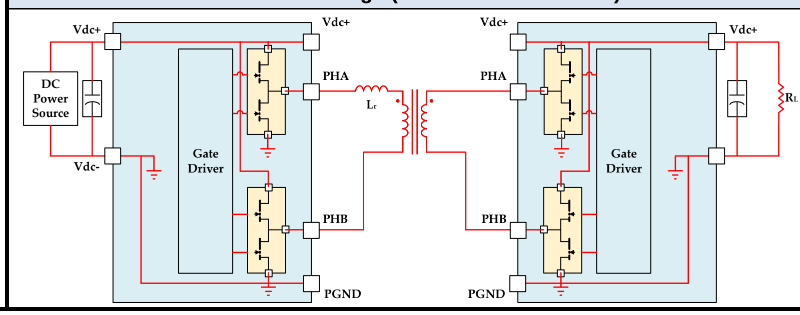
<tr><td>Single Phase Half Bridge Inverter</td><td colspan="2">DUAL ACTIVE BRIDGE</td></tr>
<tr><td></td><td colspan="2">Dual Active Bridge (with 2 mother boards)</td></tr>
<tr><td>
</td><td colspan="2">
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2 Test Results

2.1 Double pulse test (GSP665HPMB-EVBIMS2 + GSP66508HB-EVBIMS2)

- Test condition: V_{DS} = 400V, I_D = 30A, V_{GS} = +6V/-3V, L = 37uH, No RC Snubber, T_J =25℃
- Measured peak V_{DS} = 550V and 95.5V/ns peak dV/dt
- Reliable hard switching with GS66508B is achieved at full rated current

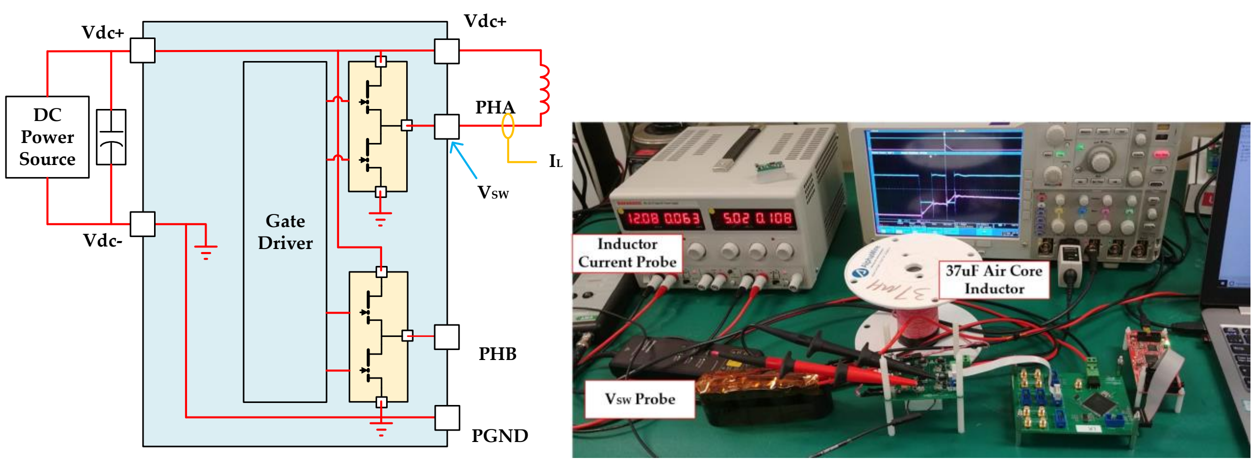


Figure 11 Double pulse test setup

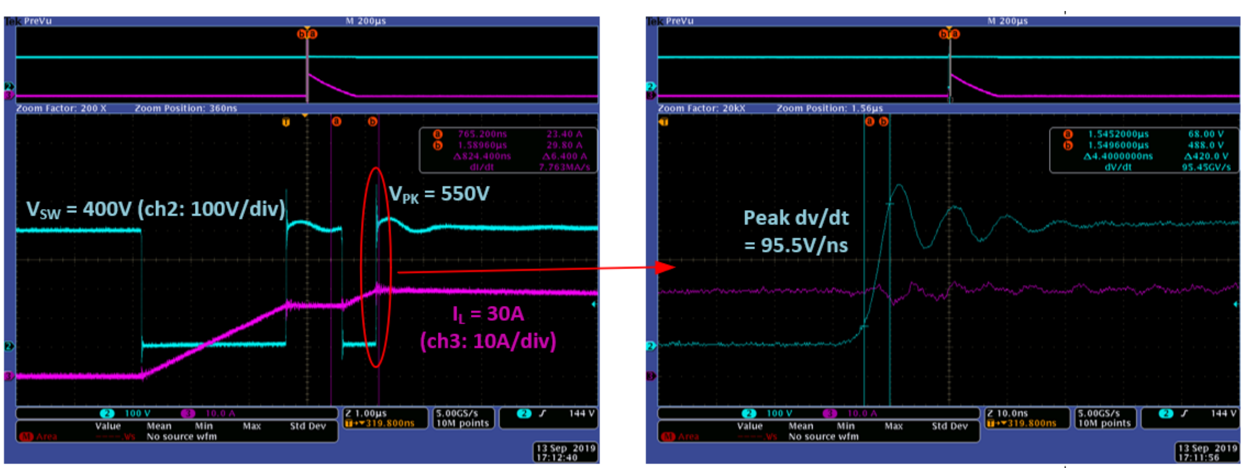


Figure 12 Double pulse test waveforms (400V/30A)

2.2 Full power emulation test (GSP665HPMB-EVBIMS2 + GSP66508HB-EVBIMS2)

- Test condition: V_{IN} = 400V, f_{SW}=500kHz, Po=1kW, T_{AMB} = 25°C.
- Device case temperature 57°C

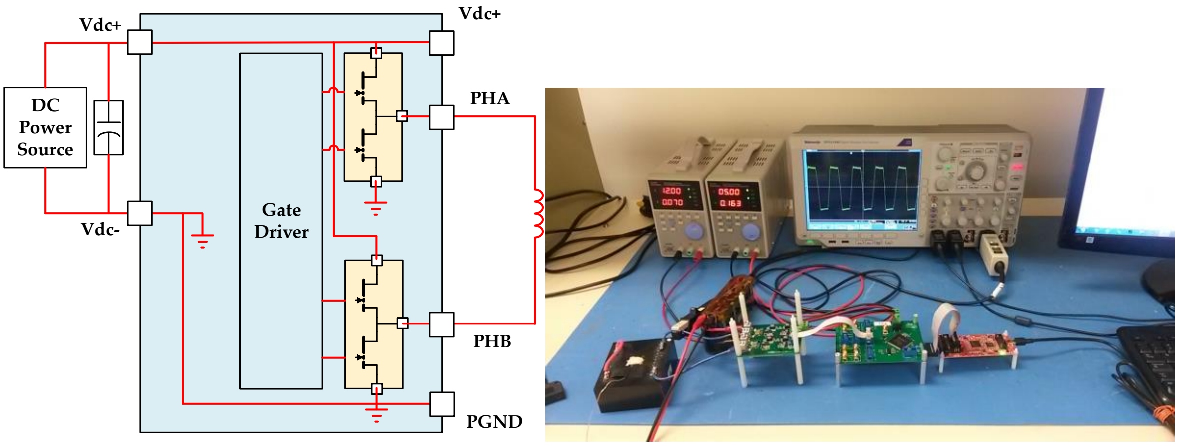


Figure 13 Full Power Emulation Test Setup

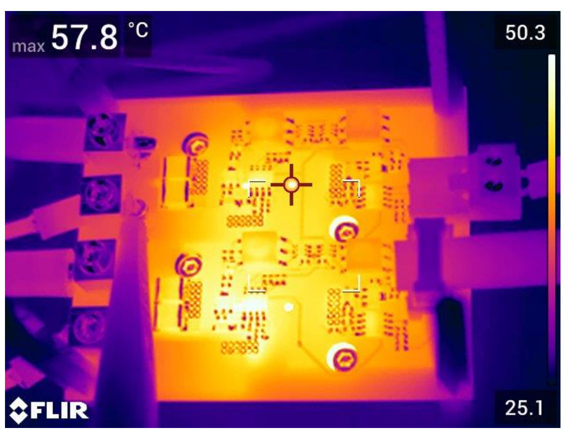
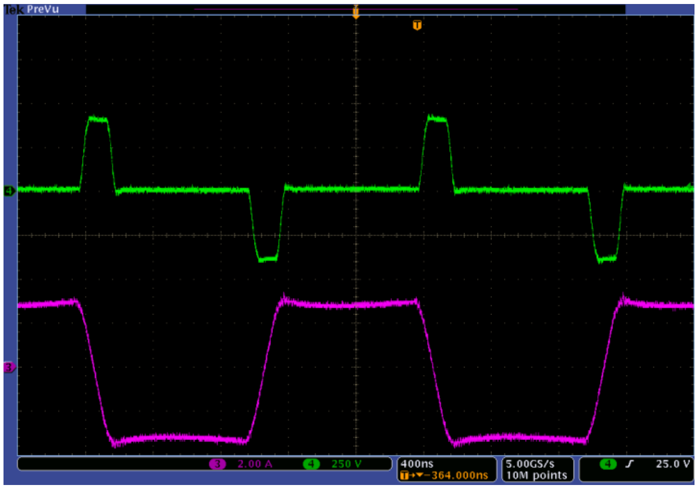


Figure 14 Full power emulation test thermal measurement result

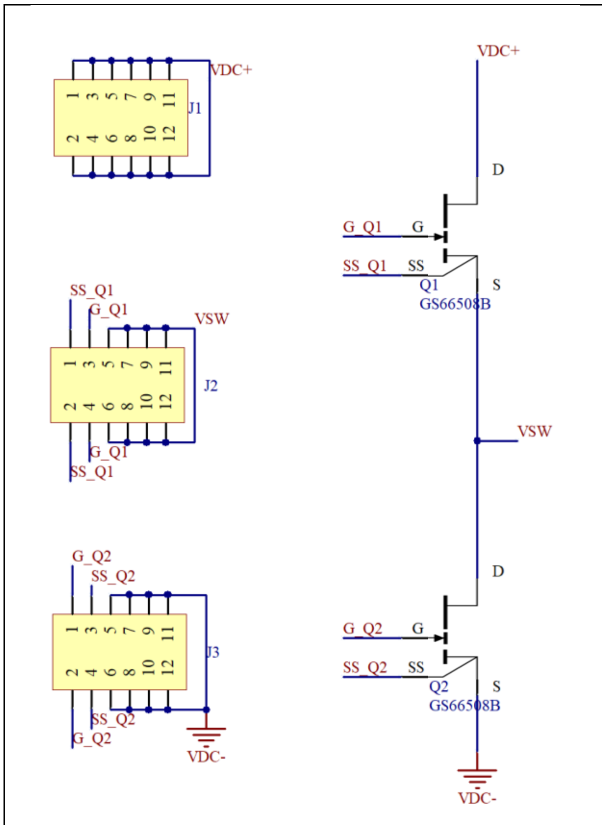


Ch#3 (purple): Inductor current, 2A/div
Ch#4 (green): Switching node Voltage, 250V/div

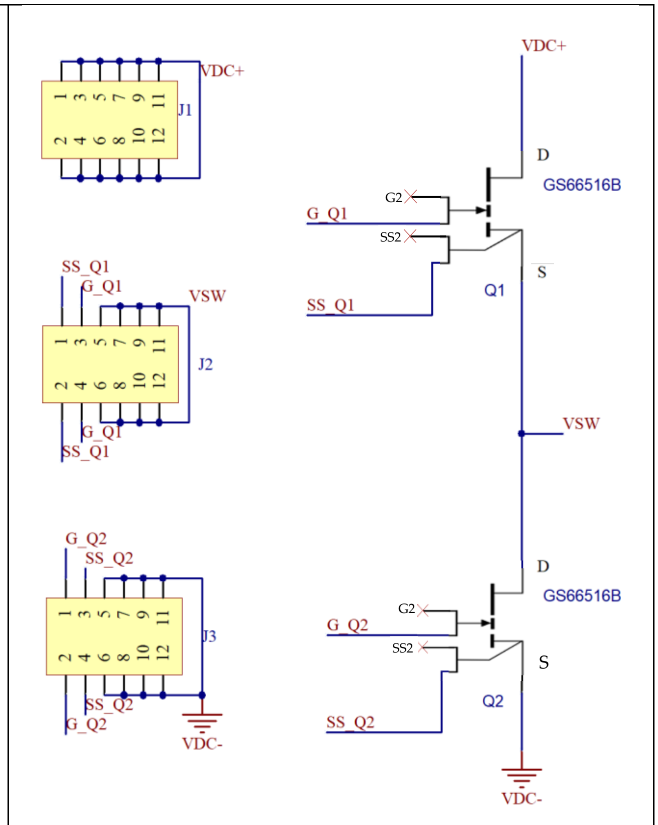
Figure 15 Test waveforms (400Vin, 500kHz, Po=1.2kW)

3 Appendix

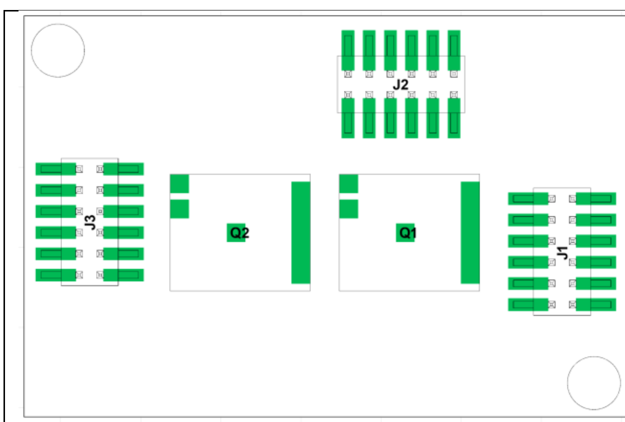
3.1 IMS 2 Half Bridge Power Board



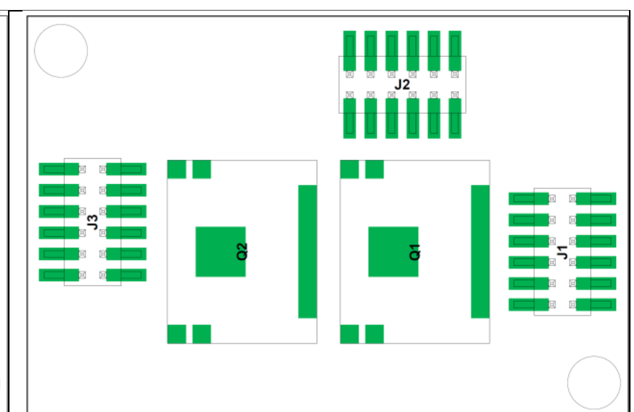
IMS 2 half bridge power board schematics (for GSP66508HB-EVBIMS2)



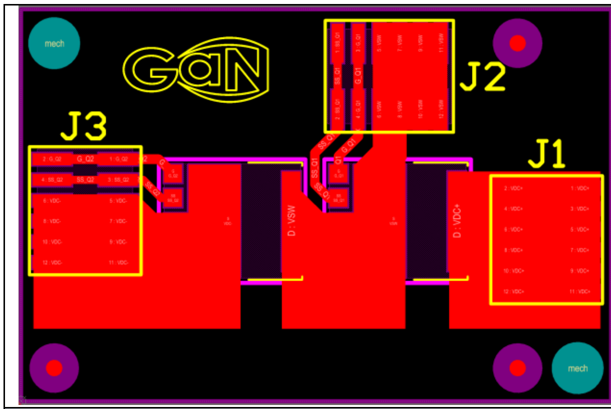
IMS 2 half bridge power board schematics (for GSP66516HB-EVBIMS2)



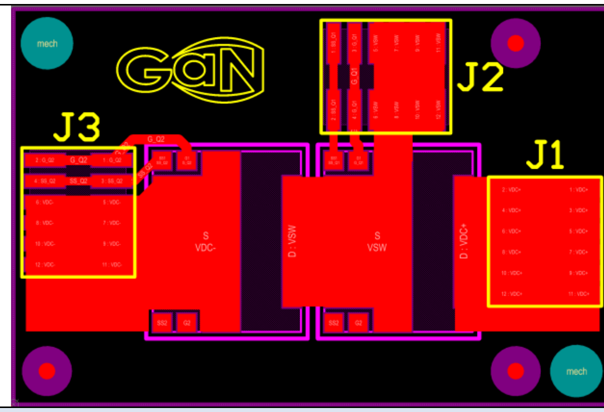
IMS 2 half bridge power board assembly drawing (for GSP66508HB-EVBIMS2)



IMS 2 half bridge power board assembly drawing (for GSP66516HB-EVBIMS2)



IMS 2 half bridge power board PCB layout top layer (for GSP66508HB-EVBIMS2)



IMS 2 half bridge power board PCB layout top layer (for GSP66516HB-EVBIMS2)

IMS 2 Half Bridge Power Board Bill of Materials (BOM)

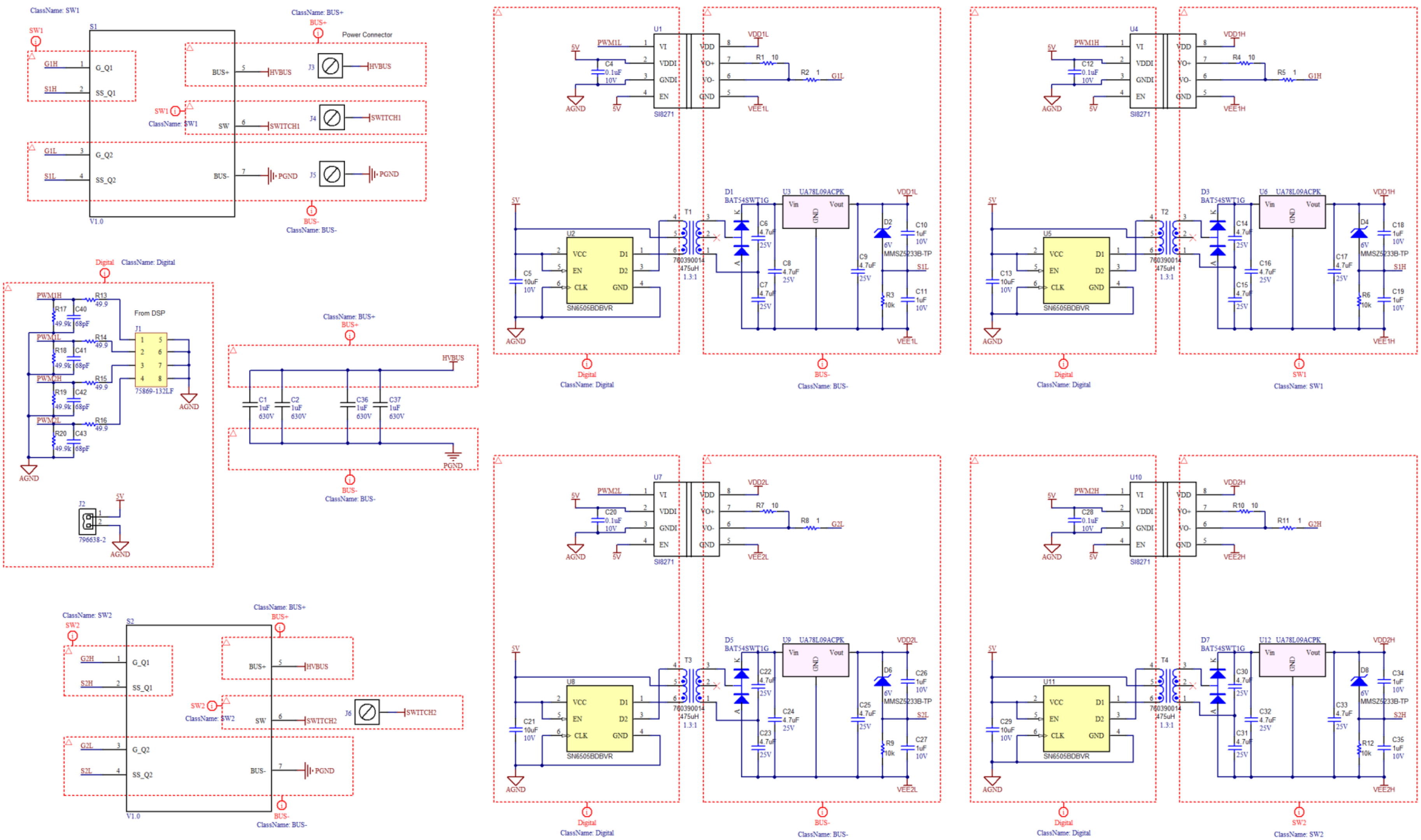
GSP66508HB-EVBIMS2

Comment	Description	Designator	Quantity	Manufacturer	Manufacturer Part Number
FTS-106-02-X-DV	CONN HEADER SMD 12POS 1.27MM	J1, J2, J3	3	Samtec Inc.	FTS-106-02-F-DV
GS66508B	GAN TRANS E-MODE 650V 30A	Q1, Q2	2		

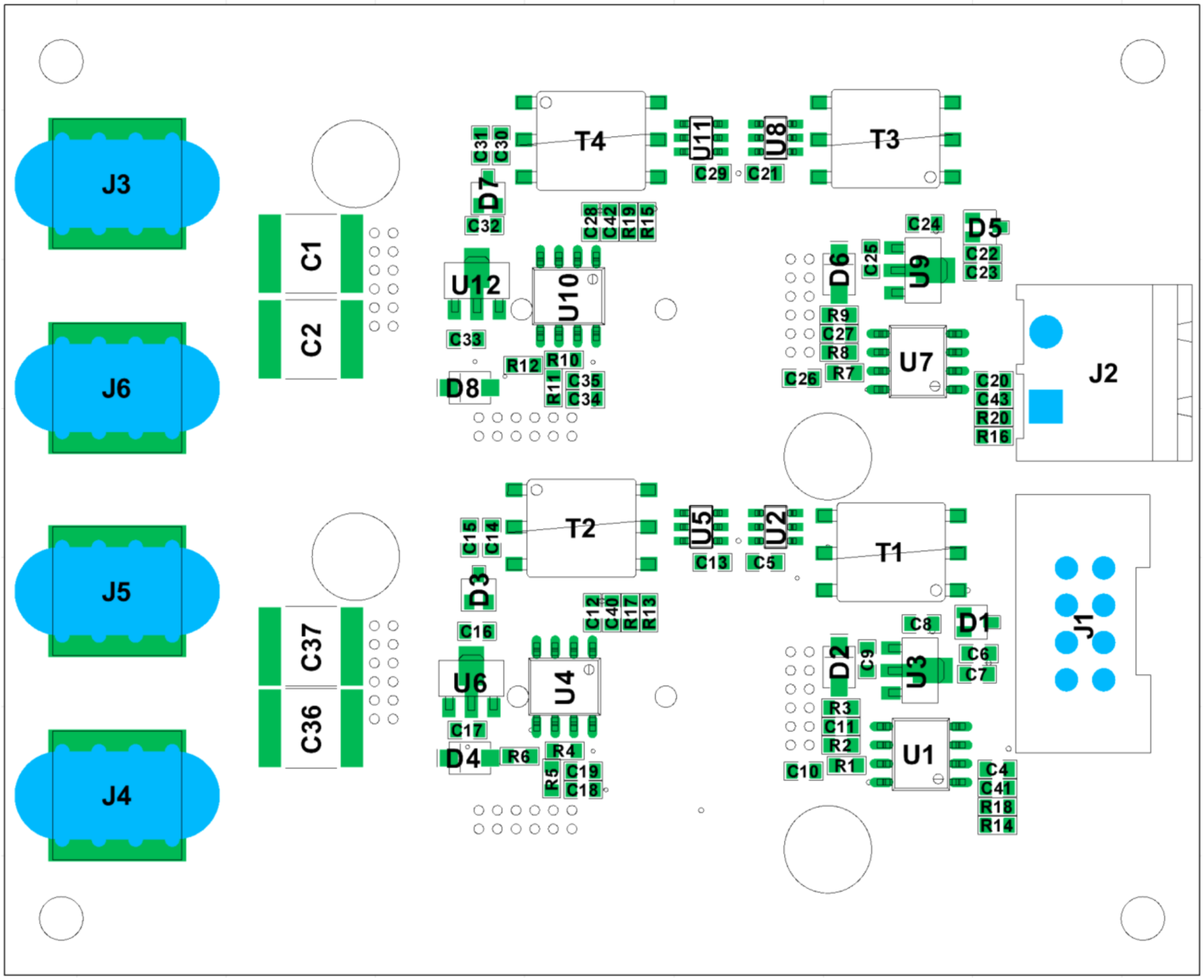
GSP66516HB-EVBIMS2

Comment	Description	Designator	Quantity	Manufacturer	Manufacturer Part Number
FTS-106-02-X-DV	CONN HEADER SMD 12POS 1.27MM	J1, J2, J3	3	Samtec Inc.	FTS-106-02-F-DV
GS66516B	GAN TRANS E-MODE 650V 60A	Q1, Q2	2		

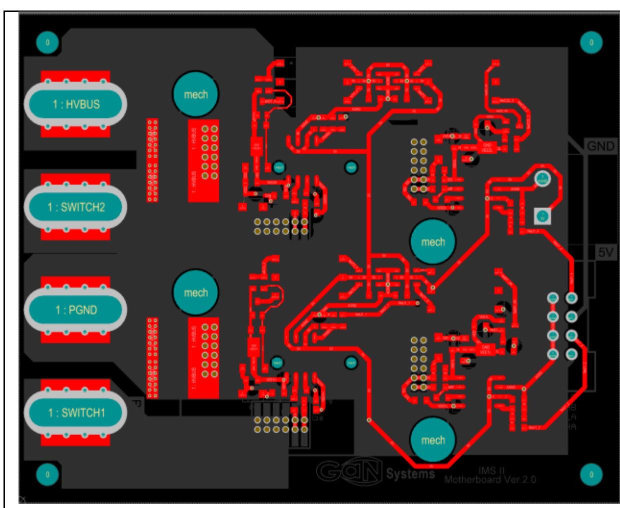
3.2 IMS 2 EVB Mother board - GSP665HPMB-EVBIMS2



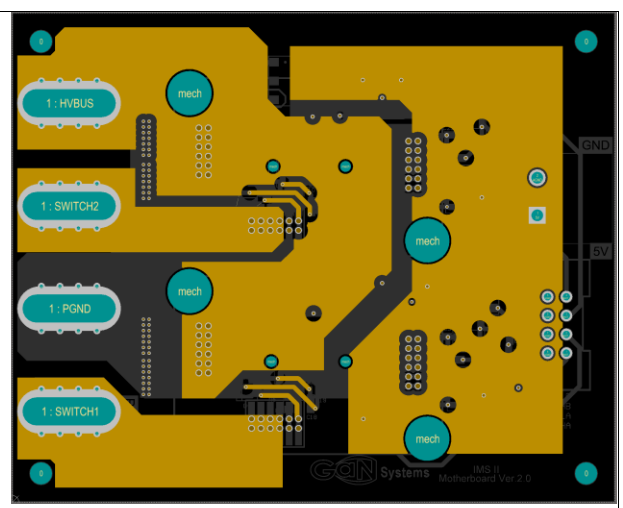
IMS 2 EVB mother board schematics – GSP665HPMB-EVBIMS2



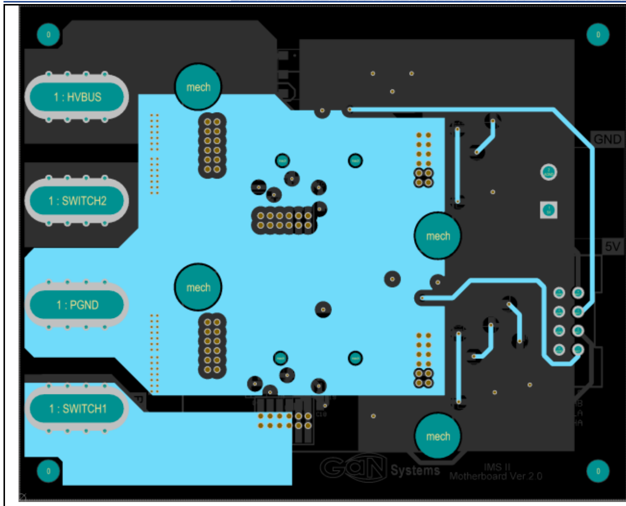
IMS 2 EVB mother board assembly drawing (top layer) - GSP665HPMB-EVBIMS2



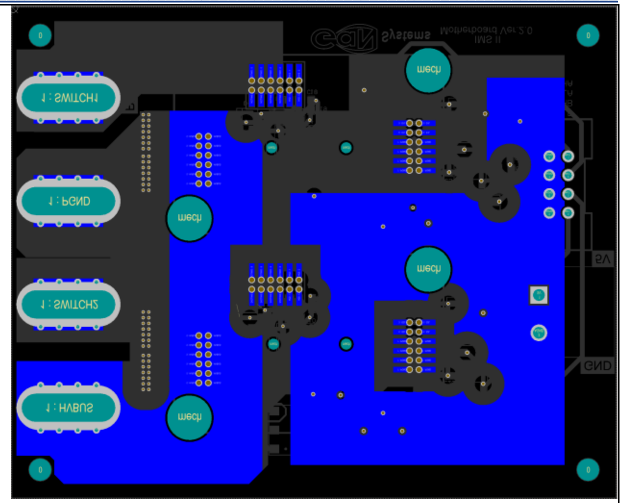
Top Layer



Mid Layer 1



Mid Layer 2



Bottom Layer

IMS 2 EVB mother board PCB layout (4-layer PCB) - GSP665HPMB-EVBIMS2

IMS 2 EVB mother board Bill of Materials (BOM) – GSP665HPMB-EVBIMS2

Designator	Description	Quantity	Manufacturer	Manufacturer Part Number
C1, C2, C36, C37	CAP CER 1UF 630V X7R 2220	4	KEMET	C2220X104KBRACAUTO
C4, C12, C20, C28	CAP CER 0.1UF 10V X7R 0603	4	Wurth Electronics	885012206020
C5, C13, C21, C29	CAP CER 10UF 10V X5R 0603	4	Murata	GRM188R61A106KE69J
C6, C7, C8, C9, C14, C15, C16, C17, C22, C23, C24, C25, C30, C31, C32, C33	CAP CER 4.7UF 25V X5R 0603	16	Samsung	CL10A475MA8NQNC
C10, C11, C18, C19, C26, C27, C34, C35	CAP CER 1UF 10V X5R 0603	8	Samsung	CL10A105KP8NNNC
C40, C41, C42, C43	CAP CER 68PF 50V C0G/NP0 0603	4	Sams	CL10C680JB8NNNC
D1, D3, D5, D7	DIODE ARRAY SCHOTTKY 30V SOT323	4	ON Semiconductor / Fairchild	BAT54SWT1G
D2, D4, D6, D8	DIODE ZENER 6V 500MW SOD123	4	MCC	MMSZ5233B-TP
J1	CONN HEADER VERT 8POS 2.54MM	1	Amphenol FCI	75869-132LF
J2	TERM BLOCK HDR 2POS 90DEG 5.08MM	1	TE Connectivity	796638-2
J3, J4, J5, J6	6 AWG Lug	4	LugsDirect	B6A-PCB-HEX
R1, R4, R7, R10	RES SMD 10 OHM 5% 1/10W 0603	4	Panasonic	ERJ3GEYJ100V
R2, R5, R8, R11	RES SMD 1 OHM 5% 1/10W 0603	4	Panasonic	ERJ3GEYJ1R0V
R3, R6, R9, R12	RES SMD 10K OHM 5% 1/10W 0603	4	Panasonic	ERJ3GEYJ103V
R13, R14, R15, R16	RES SMD 49.9 OHM 1% 1/10W 0603	4	Panasonic	ERJ3EKF49R9V
R17, R18, R19, R20	RES SMD 49.9K OHM 1% 1/10W 0603	4	Panasonic	ERJ3EKF4992V
T1, T2, T3, T4	TRANSFORMER 475UH SMD	4	Wurth Electronics	760390014
U1, U4, U7, U10	DGTL ISO 2.5KV GATE DRVR 8SOIC	4	Silicon Labs	SI8271GB-IS
U2, U5, U8, U11	Low-Noise 1 A, 420 kHz Transformer Driver, DBV0006A (SOT-6)	4	Texas Instruments	SN6505BDBVR
U3, U6, U9, U12	IC REG LINEAR 9V 100MA SOT89-3	4	Texas Instruments	UA78L09ACPK

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