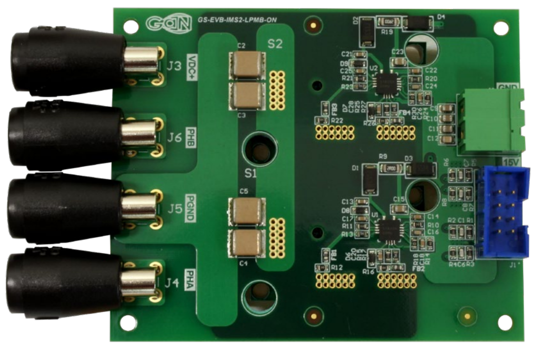
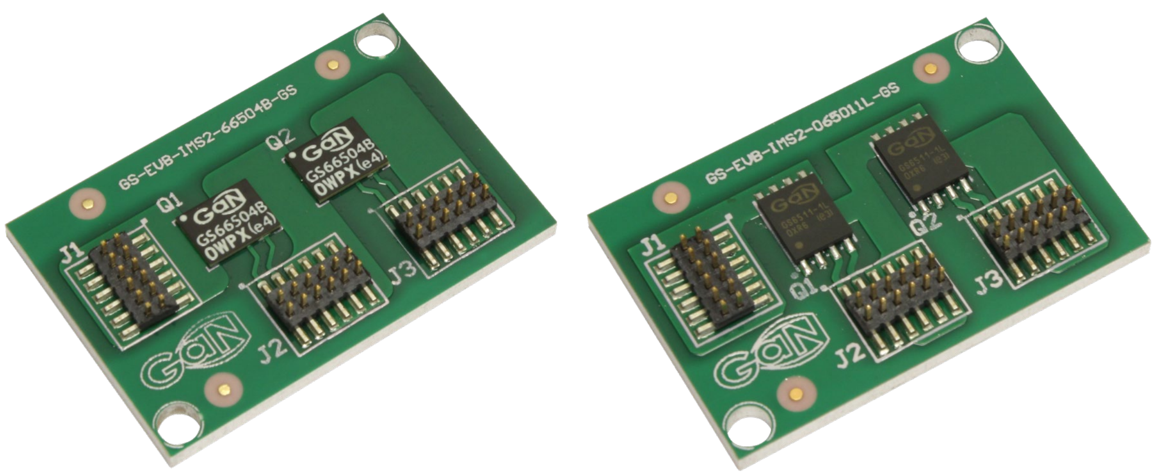
IMS 2 Evaluation Platform

Technical Manual

GS-EVB-IMS2-LPMB
GS-EVB-IMS2-065011L-GS
GS-EVB-IMS2-66504B-GS





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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.

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

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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 :** Wireless power charger
- **Industrial:** Photovoltaic Inverter and Appliance Motor Drive / VFD
- **Server/Datacenter:** Server AC/DC power supply
- **Consumer :** High Power Adapters, 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: 300W and 500W.

Heatsink is not included for lower power applications. However, for higher power applications, cusotmized heatsink 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.

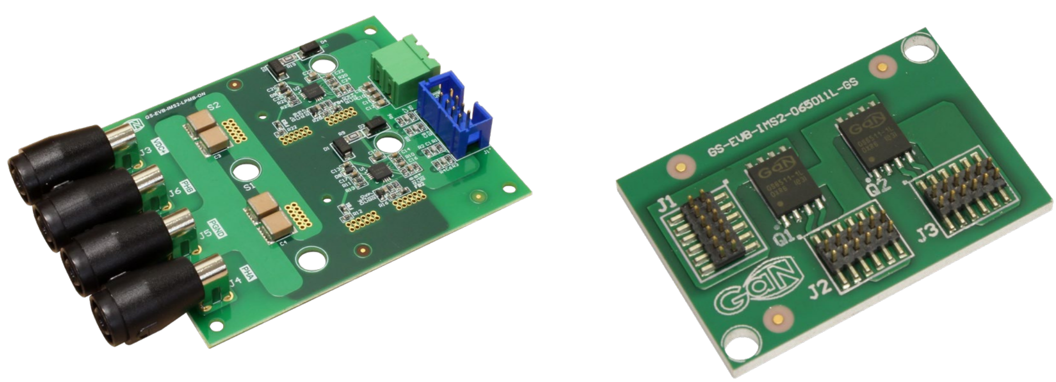


Figure 1 IMS 2 EVB mother board and IMS 2 half bridge power module

With these building blocks, the evaluation platform can be purchased in 4 different configurations: 300W and 500W, half bridge and full bridge. Table 1 lists the ordering options.

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

Table 1 Ordering configuration and part numbers

CONFIGURATION	IMS 2 HALF BRIDGE MODULE	IMS 2 EVB Mother Board
300W Half Bridge	QTY 1 - GS-EVB-IMS2-065011L-GS	GS-EVB-IMS2-LPMB
500W Half Bridge	QTY 1 - GS-EVB-IMS2-66504B-GS	
300W Full Bridge	QTY 2 - GS-EVB-IMS2-065011L-GS	
500W Full Bridge	QTY 2 - GS-EVB-IMS2-66504B-GS	

Table 2 Part numbers and Description

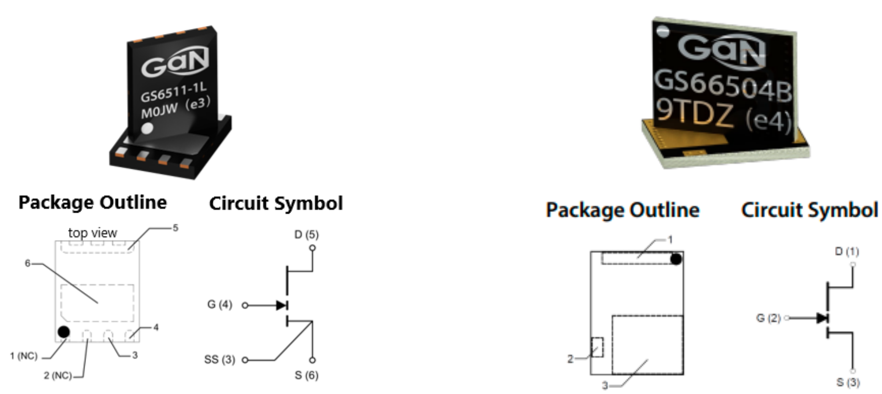
PART NUMBER	DESCRIPTION	GaN E-HEMT
GS-EVB-IMS2-LPMB	Optimized Dual HB Non-Isolated Gate Driver Motherboard for use with GS-EVB-IMS2-065011L-GS or GS-EVB-IMS2-66504B-GS half bridge boards	N/A
GS-EVB-IMS2-065011L-GS	IMS2 Half Bridge Power Module with bottom-cooled GS-065-011-1-L PDFN for low power applications	GS-065-011-1-L
GS-EVB-IMS2-66504B-GS	IMS2 Half Bridge Power Module with bottom-cooled GS66504B GaN*PX*® for low power applications	GS66504B

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 low power, high efficiency applications. The IMS 2 half bridge power board is populated with GaN Systems' GS-065-011-1-L (bottom-side cooled E-HEMT, rated at 650 V / 150 mΩ) or GS66504B (bottom-side cooled E-HEMT, rated at 650 V /100 mΩ). This product 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) GS-065-011-1-L b) GS66504B

Figure 2 - GS-065-011-1-L PDFN and GS66504B 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: GS-EVB-IMS2-LPMB) or with the users' own board for in-system prototyping.
- Use as a thermal and electrical design reference of the GS-065-011-1-L PDFN or GS66504B GaN*PX*® package in demanding high power density 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.

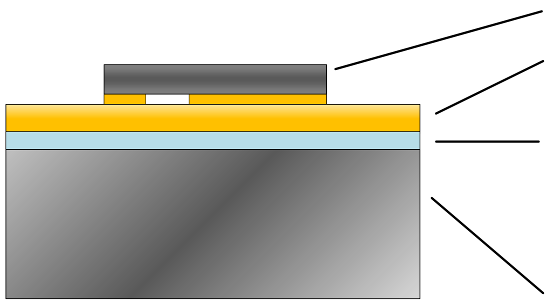


Figure 3 Cross-section view of a single layer IMS board

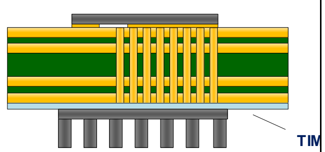
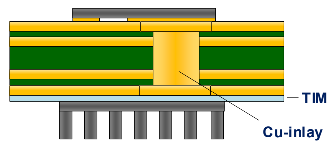
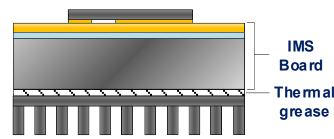
As high-speed Gallium Nitride power devices are adopted widely, the industry is trending away from through-hole packaging (TH), towards surface mount packaging (SMT). Traditional TH devices, such as the TO-220, are no longer the appropriate choice because their high parasitic inductance and capacitance 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.

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

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 using GS66516T as an example. 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

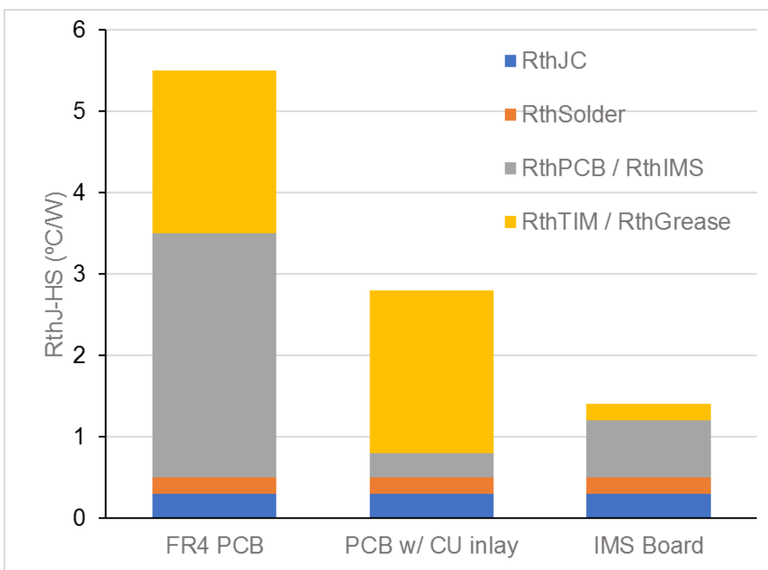


Figure 4 Comparison of Junction to Heatsink thermal resistance (R_{thJ-HS}) (Estimated based on GS66516B as an example)

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 GS-EVB-IMS2-LPMB, a multi-layer FR4 PCB mother board. This includes the high-speed half-bridge drivers for GaN power switches and DC decoupling capacitors. The GaN E-HEMTs are mounted to the IMS half bridge board (GS-EVB-IMS2-065011L-GS and GS-EVB-IMS2-66504B-GS). 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

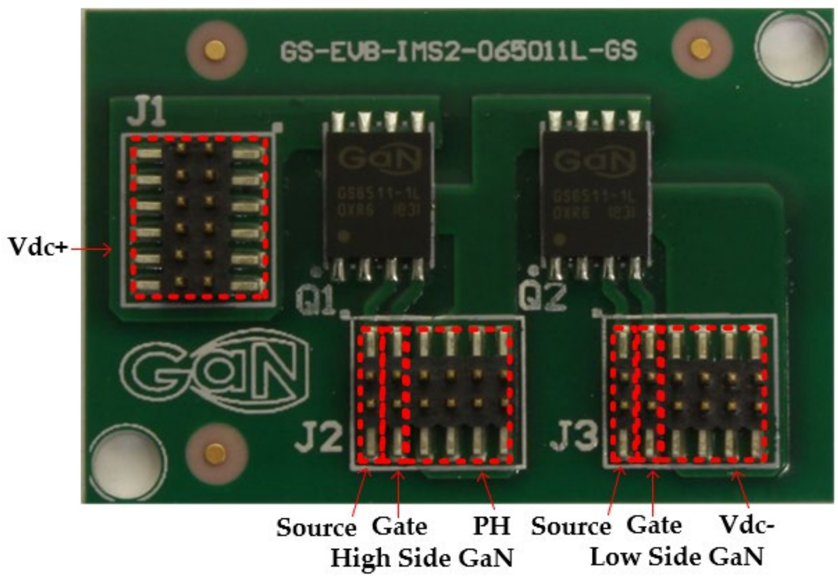


Figure 5 IMS 2 half bridge power board (GS-EVB-IMS2-065011L-GS)

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

- **Q1 and Q2:** GS-065-011-1-L or GS66504B E-HEMTs in a half bridge configuration.
  - 300W GS-EVB-IMS2-065011L-GS: Q1/Q2 GS-065-011-1-L .
  - 500W GS-EVB-IMS2-66504B-GS : Q1/Q2 GS66504B.
- **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.

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

1.4 IMS 2 EVB Mother Board

GaN Systems offers a low-power IMS 2 evaluation board that can be purchased separately. The ordering part number is GS-EVB-IMS2-LPMB. It can be used as a platform for evaluating the IMS board in any half or full bridge topology.

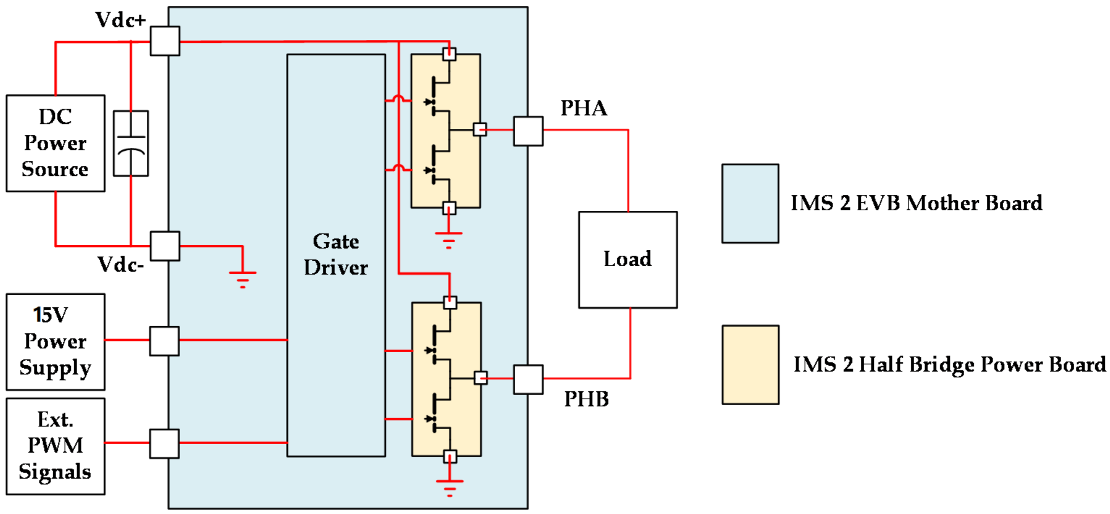


Figure 6 Circuit block diagram of IMS 2 EVB board

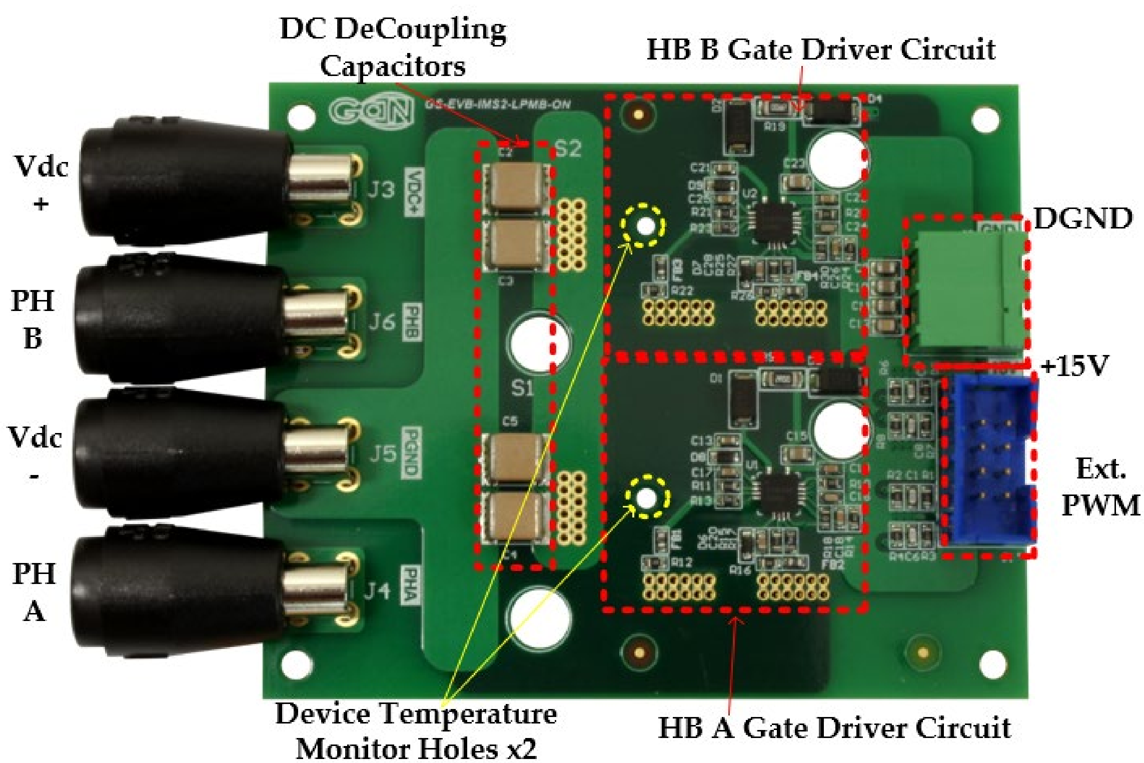


Figure 7 GS-EVB-IMS2-LPMB

1.4.1 Gate Driver Circuit

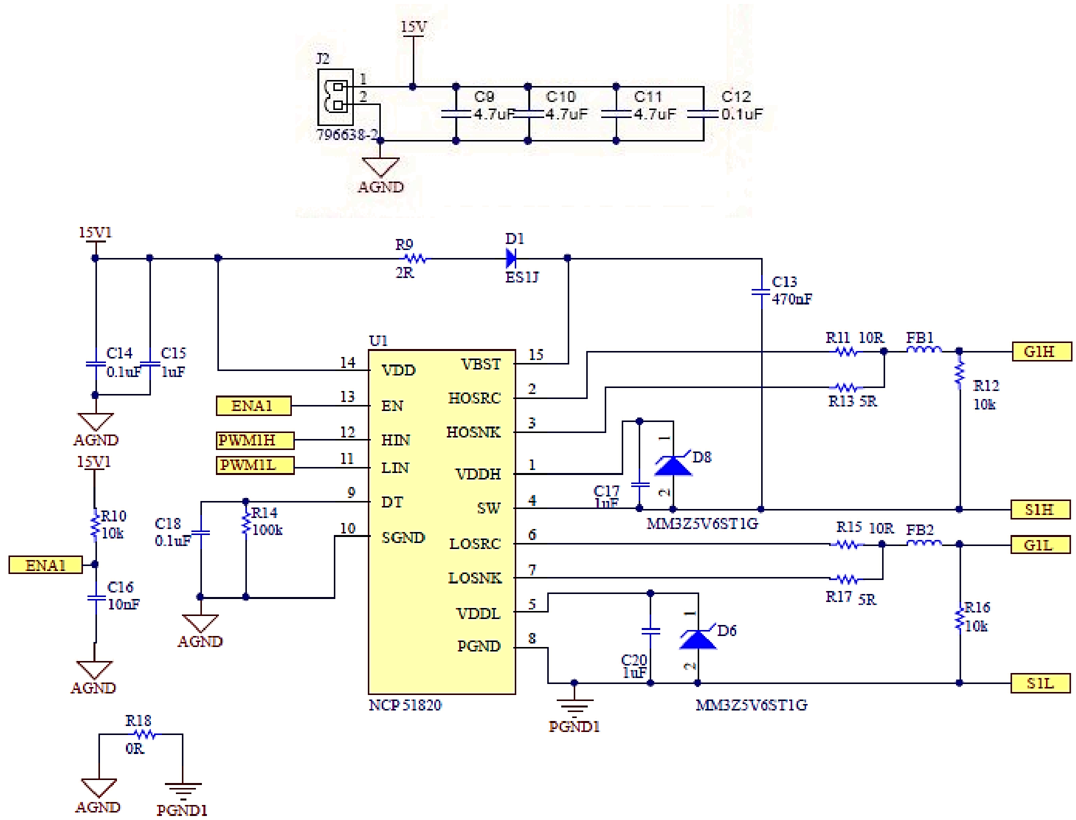


Figure 8 Gate driver circuit

A low-cost half-bridge gate driver is used in the IMS 2 EVB board for GaN half bridge, which is shown in Figure 8:

- U1 is the half-bridge gate driver (ON Semiconductor P/N: NCP51820). It outputs +6V/0V gate-driving signal.
- R11 and R13 are gate turn-on and off resistors for high-side GaN E-HEMT, R15 and R17 are for low-side GaN E-HEMT.
- FB1 FB2 are ferrit beads for filtering the gate signal noise.
- D6 and D8 are to protect E-HEMT gate from over-voltage.
- The peripheral circuit refers to the NCP51820 half bridge example in its datasheet (for more information: https://www.onsemi.com/pub/Collateral/NCP51820-D.PDF)

1.4.2 15V input

The gate driver circuit on the IMS 2 EVB mother board is powered from a 15V DC source, through connector J2.

1.4.3 Temperature monitoring holes

Two holes are located on the center of two high-side 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 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

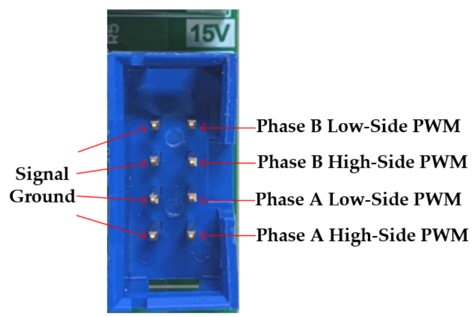


Figure 9 External PWM signals connector

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.

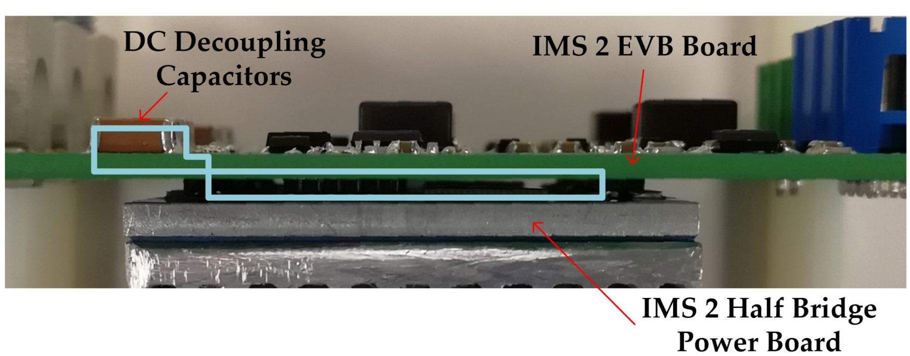
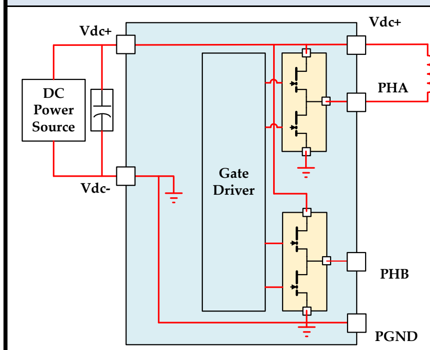
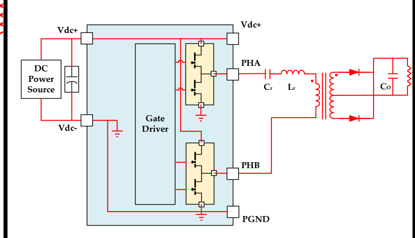
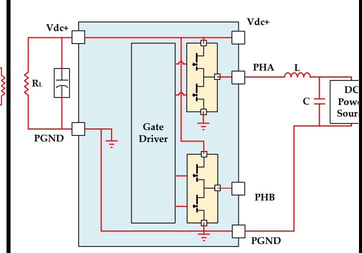


Figure 10 - Cross section view of IMS assembly showing the power Loop path

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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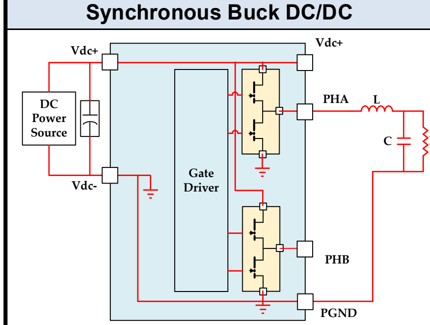
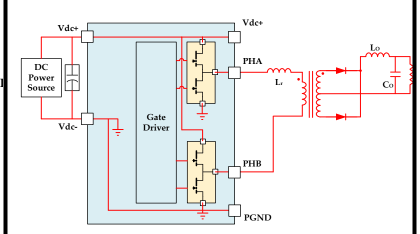
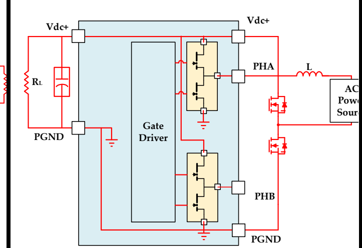
<tr><td>Synchronous Buck DC/DC</td><td>Phase Shift Full Bridge</td><td>Totem Pole PFC</td></tr>
<tr><td>
</td><td>
</td><td>
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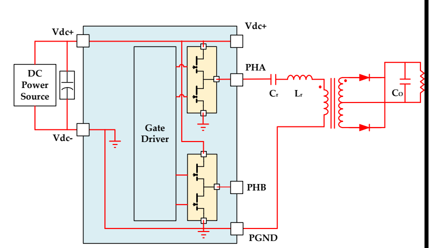
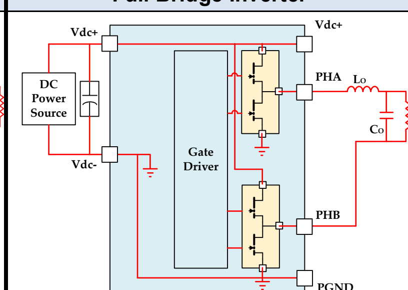
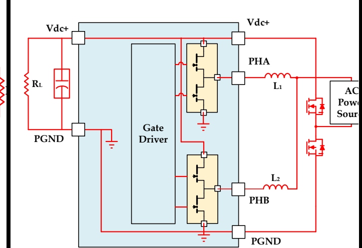
<tr><td>Half Bridge LLC</td><td>Full Bridge Inverter</td><td>Interleaved Totem Pole PFC</td></tr>
<tr><td>
</td><td>
</td><td>
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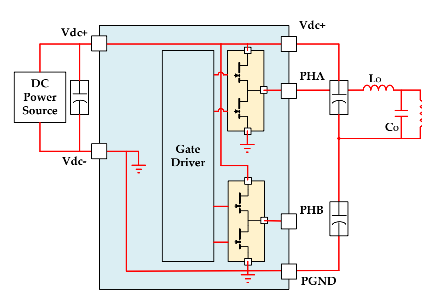
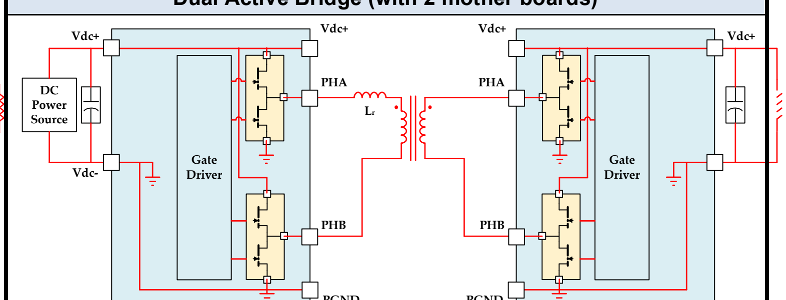
<tr><td>Single Phase Half Bridge Inverter</td><td colspan="2">DUAL ACTIVE BRIDGE</td></tr>
<tr><td rowspan="2">
</td><td colspan="2">Dual Active Bridge (with 2 mother boards)</td></tr>
<tr><td colspan="2">
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2 Test Results

2.1 Double pulse test (GS-EVB-IMS2-LPMB + GS-EVB-IMS2-065011L-GS)

- Test condition: V_{DC}= 400V, I_D= 13A, V_{GS}= +6V/0V, L = 81.6uH, No RC Snubber, T_J =25℃
- Measured peak V_{DS} = 568V and 50.26V/ns peak dV/dt
- Reliable hard switching with GS-065-011-1-L is achieved at full rated current

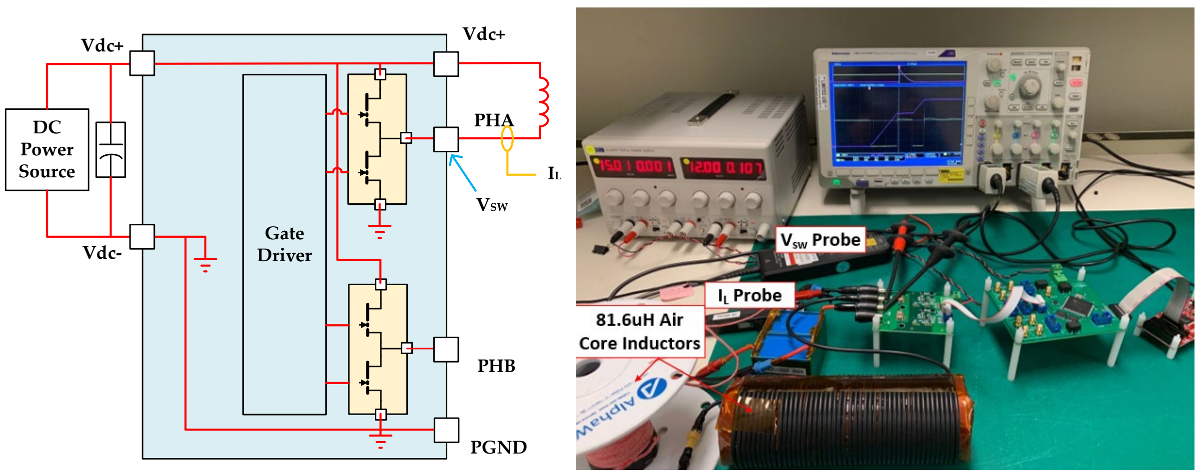


Figure 11 Double pulse test setup

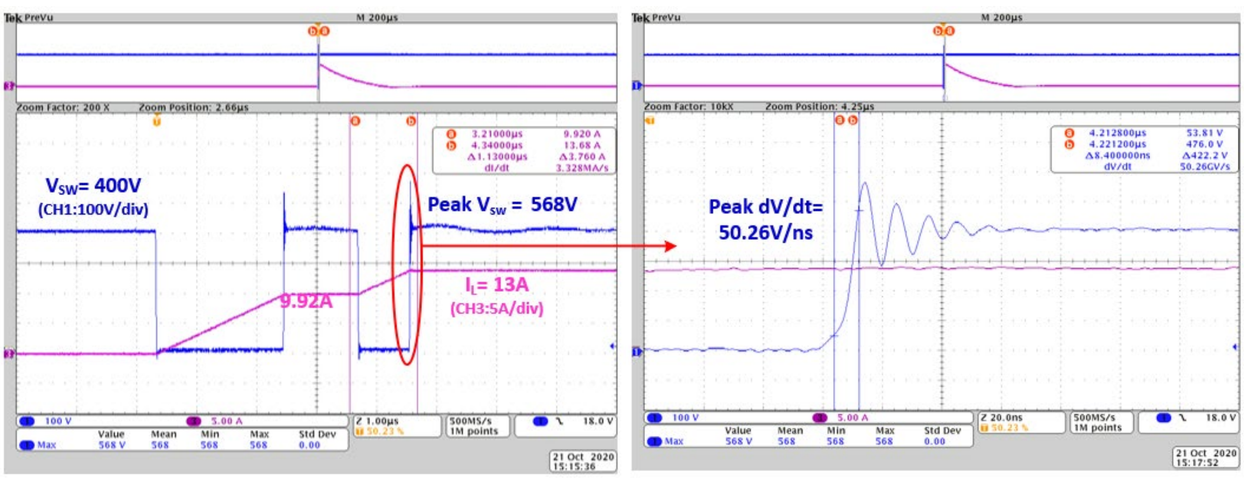


Figure 12 Double pulse test waveforms (400V/13A)

2.2 Full power emulation test (GS-EVB-IMS2-LPMB + GS-EVB-IMS2-065011L-GS)

- Test condition: V_{DC} = 400V, fsw=250kHz, Po=400W, T_{AMB} = 25℃
- Device case temperature 30℃

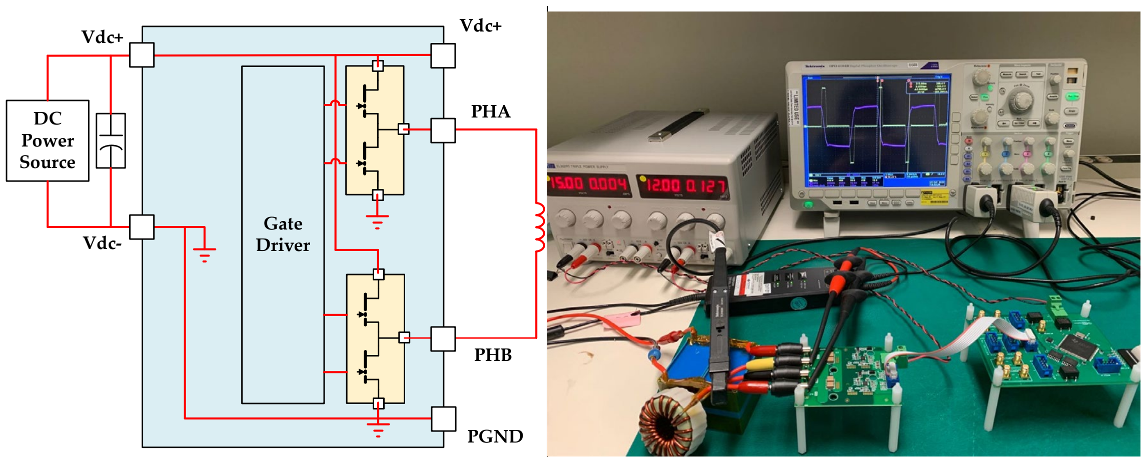


Figure 13 Full Power Emulation Test Setup

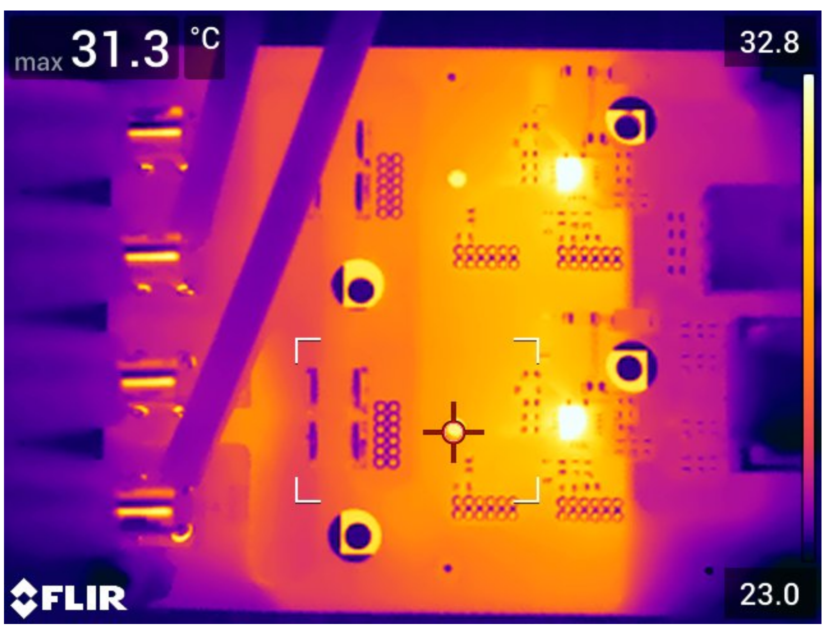
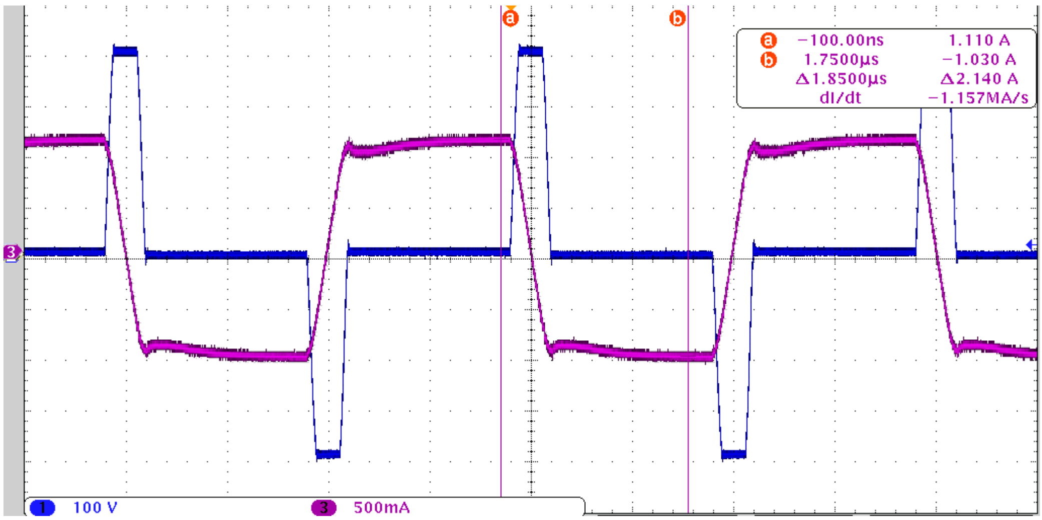


Figure 14 Full power emulation test thermal measurement result

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

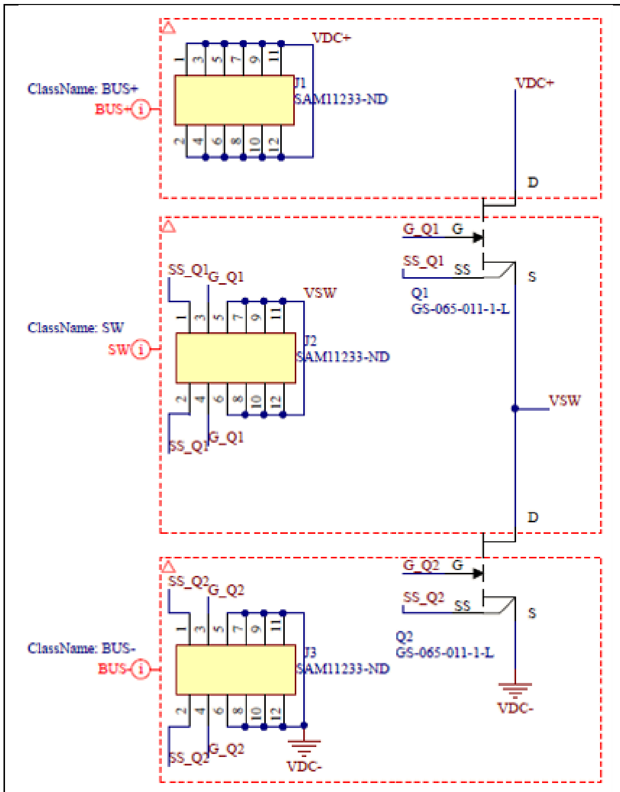


Ch#1 (blue): Switching node Voltage, 100V/div
Ch#3 (purple): Inductor current, 0.5A/div

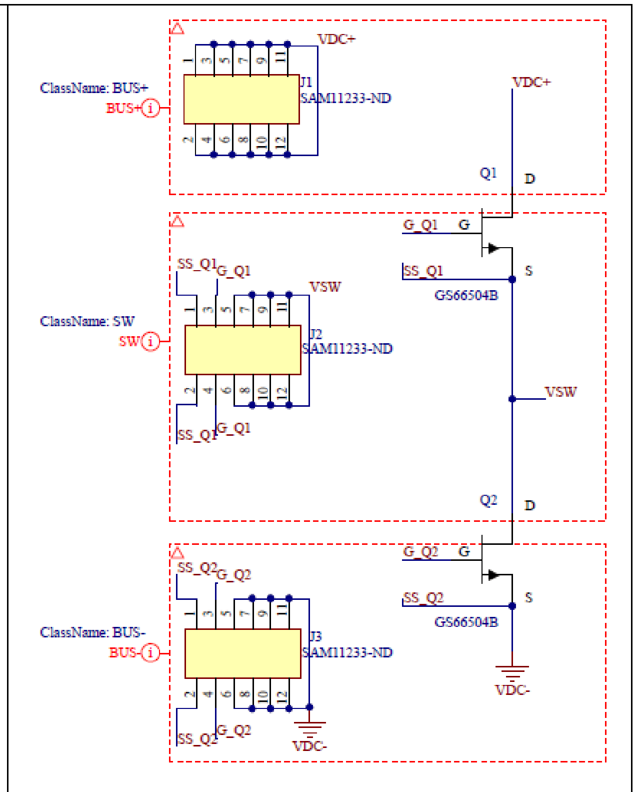
Figure 15 Test waveforms (400V_{DC}, 250kHz, Po=400W)

3 Appendix

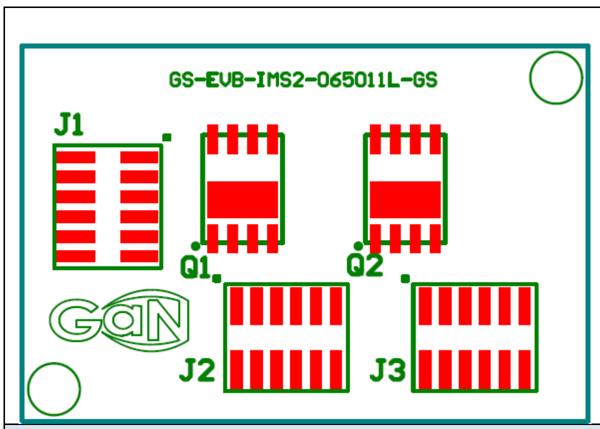
3.1 IMS 2 Half Bridge Power Board



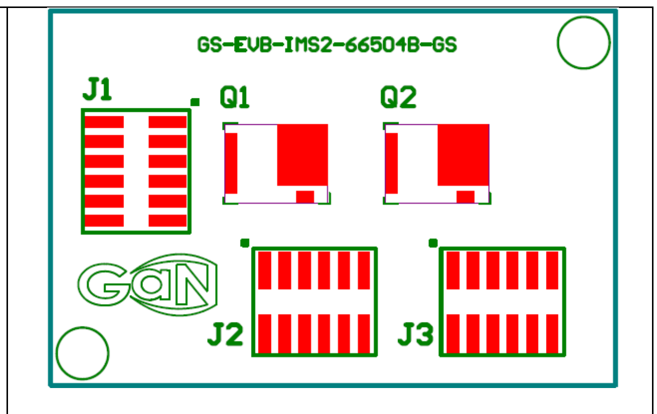
IMS 2 half bridge power board schematics (for GS-EVB-IMS2-065011L-GS)



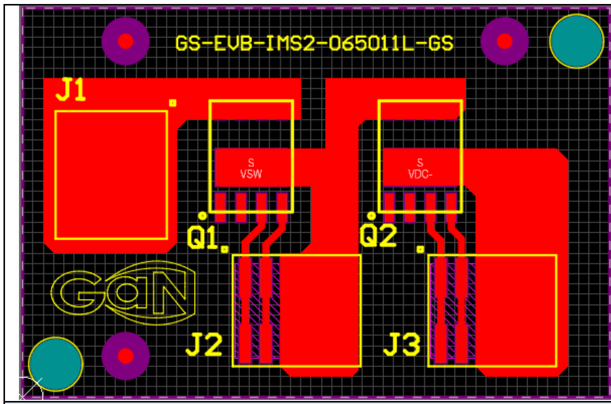
IMS 2 half bridge power board schematics (for GS-EVB-IMS2-66504B-GS)



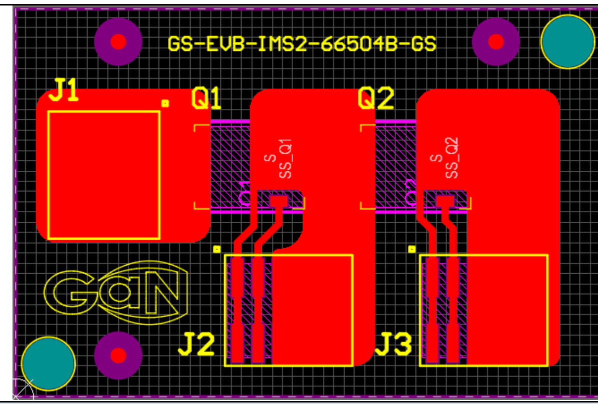
IMS 2 half bridge power board assembly drawing (for GS-EVB-IMS2-065011L-GS)



IMS 2 half bridge power board assembly drawing (for GS-EVB-IMS2-66504B-GS)



IMS 2 half bridge power board PCB layout top layer (for GS-EVB-IMS2-065011L-GS)

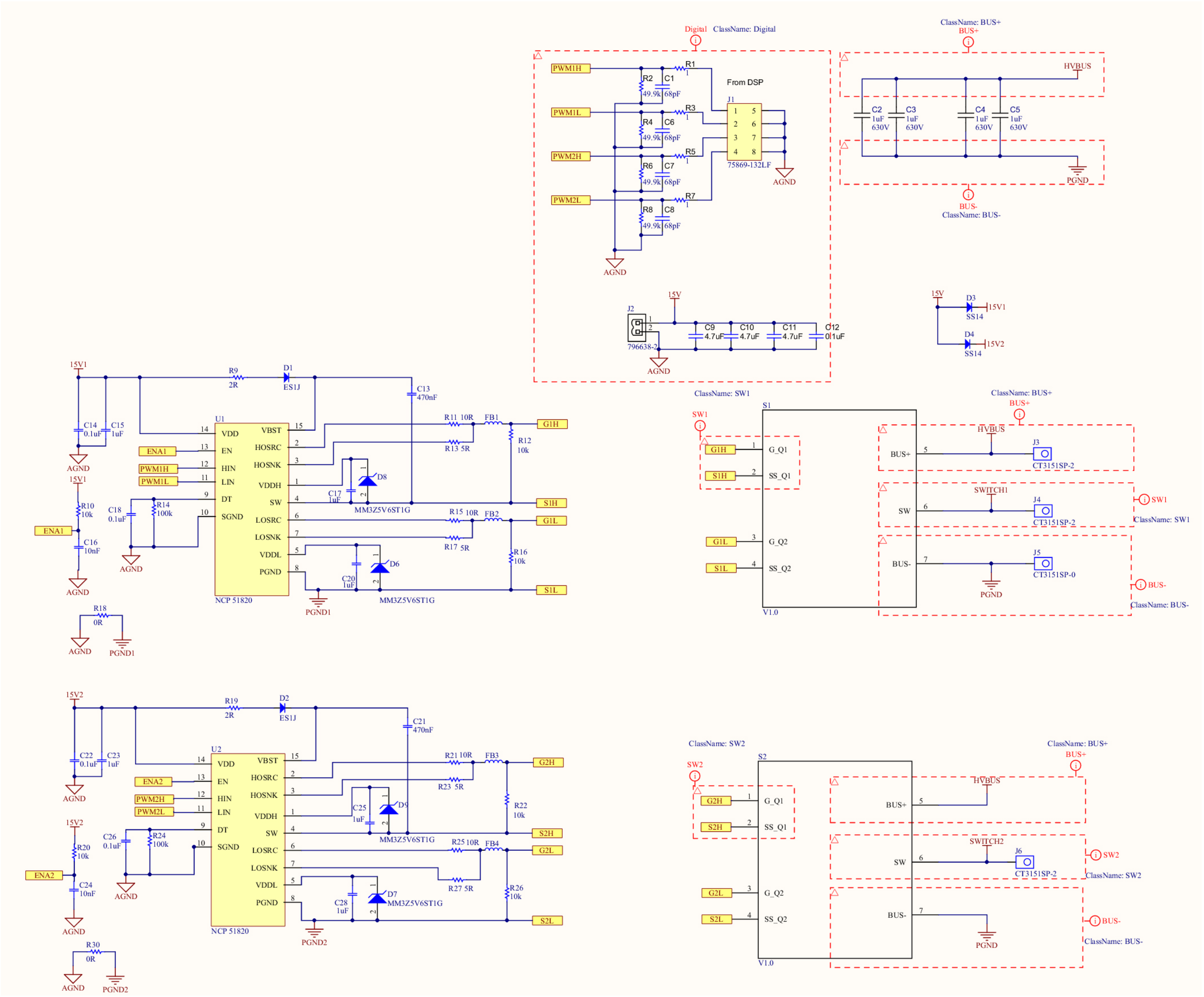


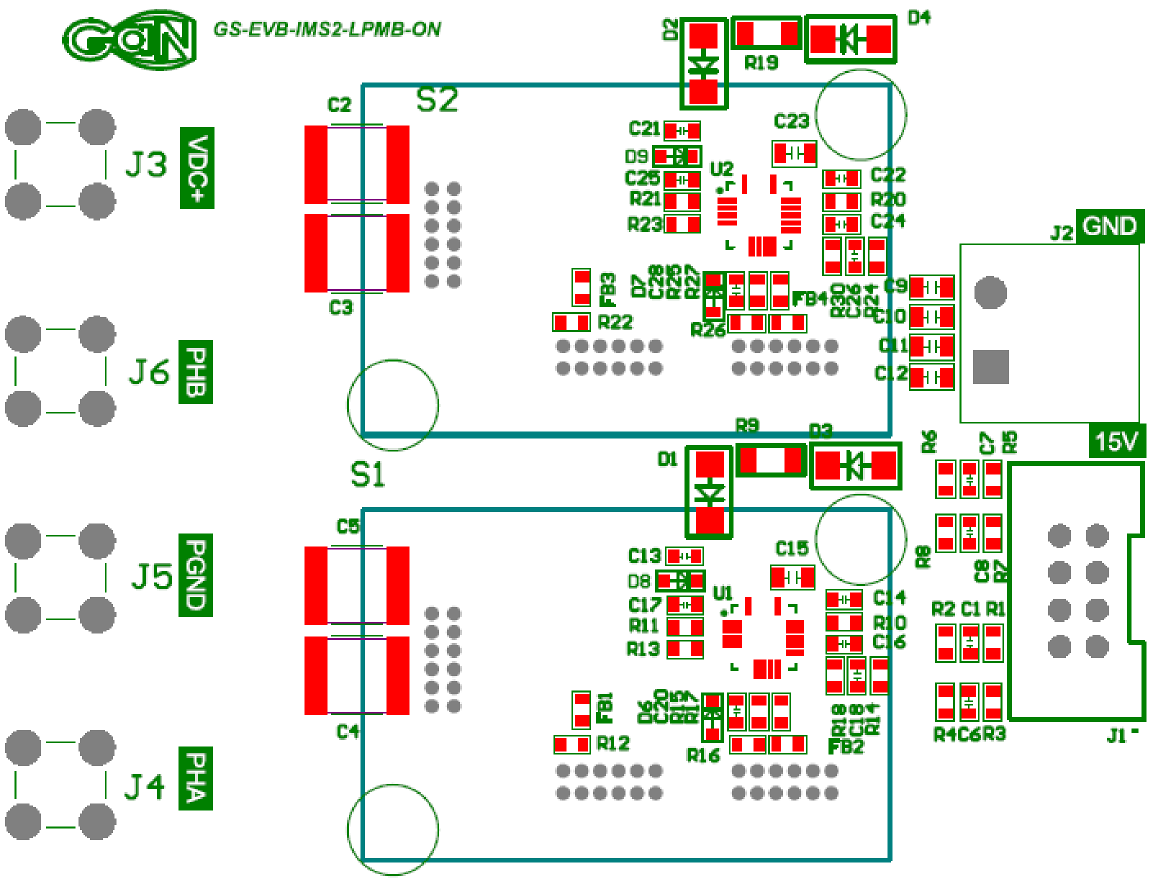
IMS 2 half bridge power board PCB layout top layer (GS-EVB-IMS2-66504B-GS)

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

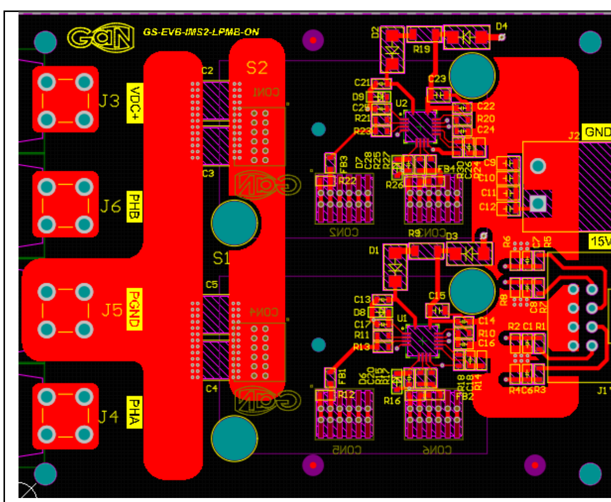
GS-EVB-IMS2-065011L-GS			
Comment	Description	Designator	Quantity
SAM11233-ND	CONN HEADER SMD 12POS 1.27MM FTS-106-02-F-DV	J1, J2, J3	3
GS-065-011-1-L	GAN TRANS E-MODE 650V 11A	Q1, Q2	2
GS-EVB-IMS2-66504B-GS			
Comment	Description	Designator	Quantity
SAM11233-ND	CONN HEADER SMD 12POS 1.27MM FTS-106-02-F-DV	J1, J2, J3	3
GS66504B	GAN TRANS E-MODE 650V 15A	Q1, Q2	2

3.2 IMS 2 EVB Mother board - GS-EVB-IMS2-LPMB Schematics

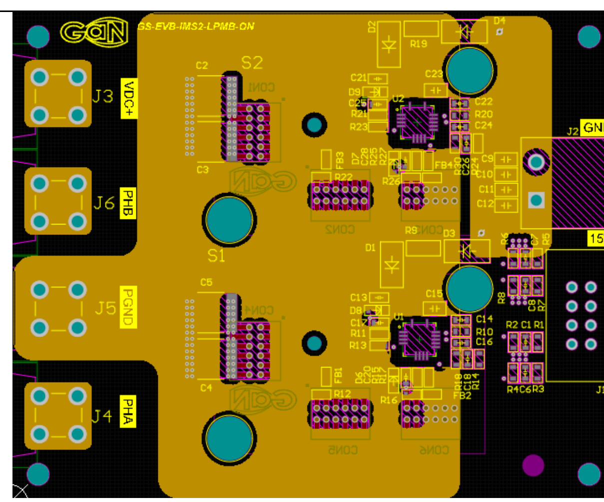




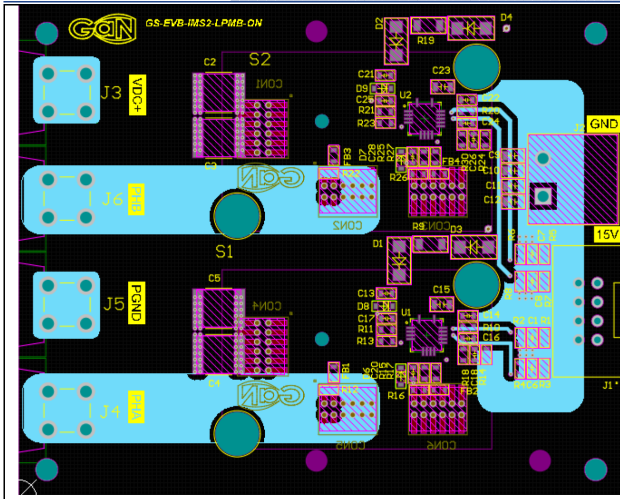
IMS 2 EVB mother board assembly drawing (top layer) - GS-EVB-IMS2-LPMB



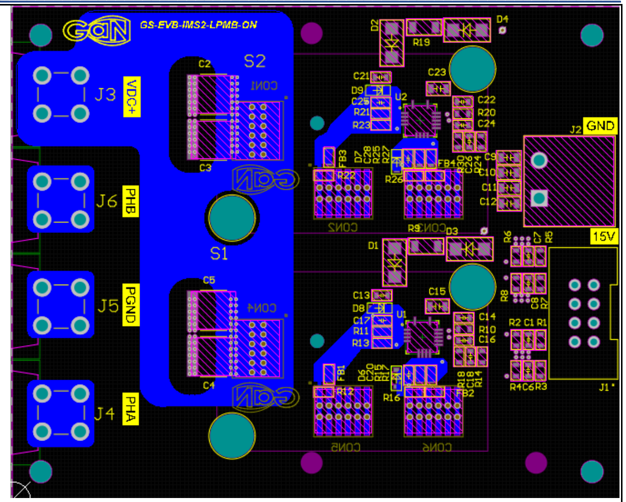
Top Layer



Mid Layer 1



Mid Layer 2



Bottom Layer

IMS 2 EVB mother board PCB layout (4-layer PCB) - GS-EVB-IMS2-LPMB

IMS 2 EVB mother board Bill of Materials (BOM) – GS-EVB-IMS2-LPMB

Designator	Description	Quantity	Manufacture	Manufacture Part Number
C1, C6, C7, C8	CAP CER 68PF 50V C0G/NP0 0603	4	KEMET	C0603C680J5GACTU
C2, C3, C4, C5	CAP CER 1UF 630V X7R 2220	4	Knowles Syfer	2220Y6300105KXTWS2
C9, C10, C11	CAP CER 4.7UF 25V X7R 0805	3	Yageo	CC0805KKX5R8BB475
C12	CAP CER 0.1UF 25V X7R 0805	1	Yageo	CC0805KRX7R8BB104
C13, C21	CAP CER 470nF 25V X7R 0603	2	Yageo	CC0603KRX7R8BB474
C14, C18, C22, C26	CAP CER 100nF 25V X7R 0603	4	Yageo	CC0603KRX7R8BB104
C15, C23	CAP CER 1uF 25V X7R 0805	2	KEMET	C0805C105K3RACTU
C16, C24	CAP CER 10nF 25V X7R 0603	2	Yageo	CC0603KPX7R9BB103 CAP
C17, C20, C25, C28	CAP CER 1uF 25V X7R 0603	4	KEMET	C0603C105K3RACTU
D1, D2	600V 1A Schottky Barrier Diode	2	ON Semiconductor	ES1J
D3, D4	40V 1A Schottky Barrier Diode	2	ON Semiconductor	SS14
D6, D7, D8, D9	Zener Voltage Regulator, 300 mW, 2-Pin SOD-323, Pb-Free, Tape and Reel	4	ON Semiconductor	MM3Z5V6ST1G
FB1, FB2, FB3, FB4	FERRITE BEAD 120 OHM 0603 1LN	4	Murata Electronics	BLM18PG121SN1D
J1	CONN HEADER VERT 8POS 2.54MM	1	Amphenol ICC (FCI)	75869-132LF
J2	TERM BLOCK HDR 2POS 90DEG 5.08MM	1	TE Connectivity	796638-2
J3, J4, J6	Cal Test Electronics 'CT3151SP-2	3	Cal Test Electronics	CT3151SP-2
J5	Cal Test Electronics 'CT3151SP-0	1	Cal Test Electronics	CT3151SP-0
R1, R3, R5, R7	RES SMD 1OHM 1% 1/10W 0603	4	Yageo	RC0603FR-071RL
R2, R4, R6, R8	RES SMD 49.9K OHM 1% 1/10W 0603	4	Yageo	RC0603FR-0749K9L
R9, R19	RES SMD 2 OHM 1% 1206	2	Yageo	RC1206JR-072RL
R10, R12, R16, R20, R22, R26	RES SMD 10k OHM 1% 1/10W 0603	6	Yageo	RC0603JR-0710KL
R11, R15, R21, R25	RES SMD 10 OHM 1% 1/10W 0603	4	Yageo	RC0603JR-0710RL
R13, R17, R23, R27	RES SMD 5 OHM 1% 1/10W 0603	4	Yageo	RC0603JR-075R1L

R14, R24	RES SMD 100k OHM 1% 1/10W 0603	2	Yageo	RC0603JR-07100KL
R18, R30	RES SMD 0 OHM 1% 1/10W 0603	2	Yageo	RC0603JR-070RL
CON1,CON2,CON3,CON4,CON5,CON6,	CLP-106-02-L-D-K-TR CONN RCPT 12POS 0.05 GOLD SMD	6	Samtec Inc.	SAM13405CT-ND
U1, U2	NCP51820AMNTWG	2	ON Semiconductor	NCP51820AMNTWG

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