GS65011-EVBEZ

GaN E-HEMT EZ Drive® Open Loop Boost Evaluation Board

Technical Manual

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Please refer to the Evaluation Board/Kit Important Notice on page 17

DANGER!

Electrical Shock Hazard - Hazardous high voltage may be present on the board during the test and even brief contact during operation may result in severe injury or death. Follow all locally approved safety procedures when working around high voltage.

Never leave the board operating unattended. After it is de-energized, always wait until all capacitors are discharged before touching the board.

This board should be handled by qualified personnel ONLY.

PCB surface can become hot. Contact may cause burns. Do not touch!

CAUTION:
This product contains parts that are susceptible to damage by electrostatic discharge (ESD) or exposure to voltages in excess of the specified voltage. Always follow ESD prevention procedures when handling the product. Avoid applying excessive voltages to the power supply terminals or signal inputs or outputs

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Introduction

The GS65011-EVBEZ Evaluation Board (EVB) is an open loop Boost converter and was designed to help customers evaluate GaN Systems' EZDrive® solution with a GaN Systems' E-HEMT.

The EZDrive® circuit is a low-cost, easy way to implement a GaN driving circuit using a standard MOSFET controller with integrated driver. The EZDrive® circuit provides design control for the optimization of efficiency and EMI. It is adaptable to any power level, any frequency, and any LLC and PFC controller.

The board is populated with GaN Systems' GS-065-011-1-L, a 5×6 mm PDFN package Enhancement-Mode High Electron Mobility Transistor (E-HEMT).

Evaluation Board Contents and Requirements

Kit Contents

The GS65011-EVBEZ includes the following hardware.

Table 1 • GS65011-EVBEZ Evaluation Kit Contents

Quantity	Description
1	GS65011-EVBEZ GaN E-HEMT evaluation board assembly

Hardware Requirements

In order to evaluate the performance of the evaluation board, the following equipment is required:

- High speed digital oscilloscope
- DC load (power resistor or electrical load)
- High voltage DC power supply
- Low voltage DC power supply
- DC test leads

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Evaluation Board Assembly Overview

The EVB is assembled with the EZDrive® circuit and one GS-065-011-1-L GaN E-HEMT. Headers are included for power connections. A probe connecter and vias are included for waveform measurements.

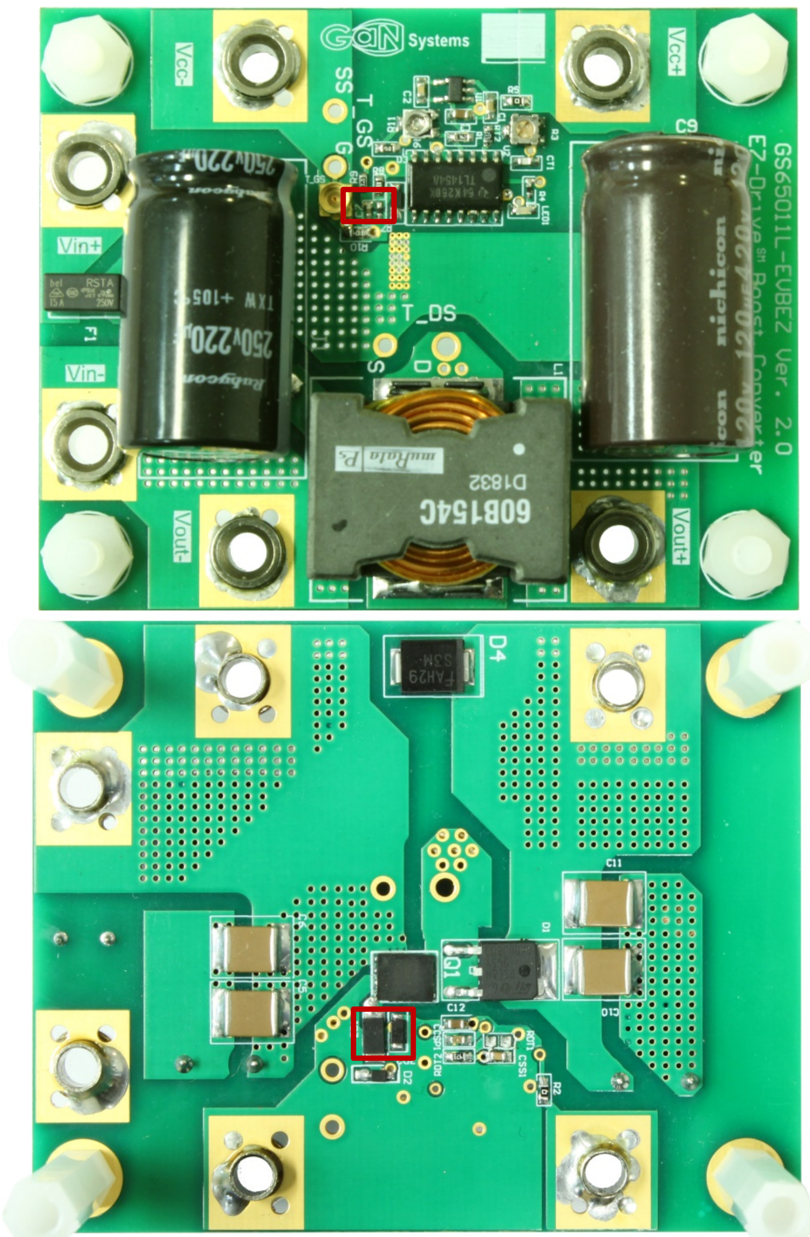

Figure 1 • GS65011-EVBEZ Evaluation Board Assembly

Block Diagram and Schematic

The block diagram and schematic of the evaluation board are provided in **Figures 2** and **3**.

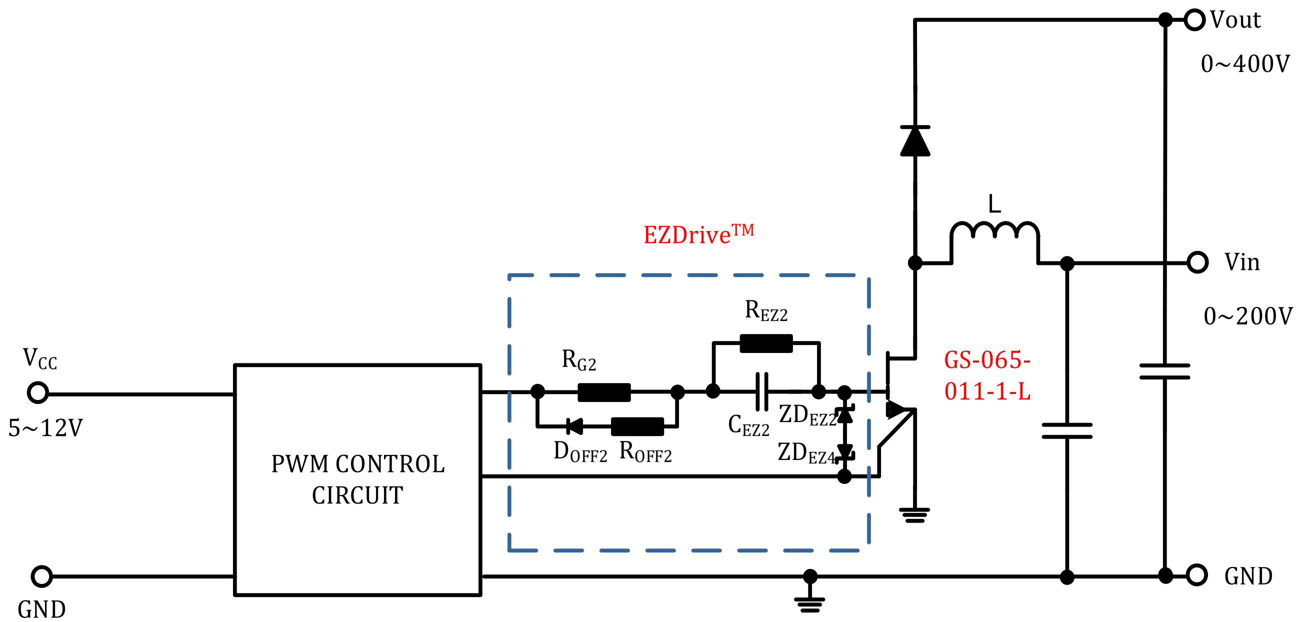

Figure 2 • GS65011-EVBEZ Block Diagram

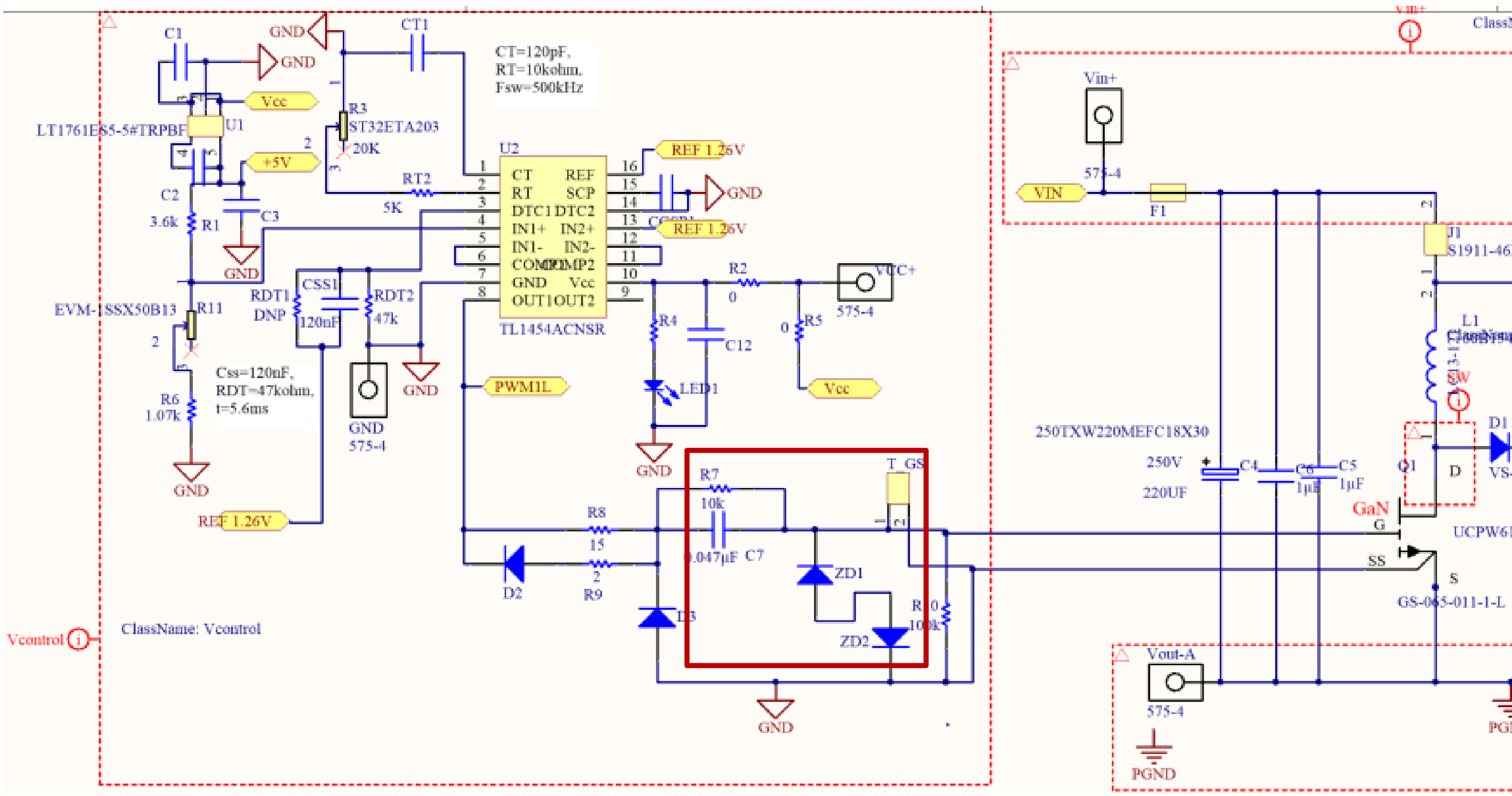

Figure 3 • GS65011-EVBEZ Schematic

Circuit Description

The GS65011-EVBEZ EVB is a GaN-based open-loop DC/DC Boost converter. It is assembled with the EZDrive® GaN driving circuit, a Si MOSFET PWM controller (TL1454ACNSR) and a 650V 5×6 mm PDFN package GaN E-HEMT, (GS-065-011-1-L). The PWM control signal is generated internally by the PWM controller, U2.

The EZDrive® uses a Si MOSFET controller to drive a GaN HEMT which has a lower threshold voltage than a Si MOSFET. The EZDrive® circuit is shown in the dotted box in Figure 2. It is a low-cost, low component-count circuit composed of two Zener diodes, one capacitor, three resistors and one diode.

ZD_{EZ1}, ZD_{EZ2} clamp the positive and negative gate drive voltages. C_{EZ} holds a negative voltage for GaN E-HEMT turn-off. R_{EZ} sets the minimum driving current required to keep the GaN E-HEMT fully turned on. R_G controls the turn-on speed and R_{OFF} controls the turn-off speed.

The two operation modes for EZDrive® are:

- Mode 1: Assuming the Vcc of the controller is 12V and the controller output is ON, the driving voltage on the GaN E-HEMT is clamped to 6V by Zener diode ZD_{EZ}. The rest of the Vcc, 6V, is stored across the capacitor C_{EZ}.
- Mode 2: The voltage stored in C_{EZ} is applied to the gate in reverse, allowing the GaN E-HEMT e to be turned off quickly.

This circuit converts the Si MOSFET PWM controller's output voltage to the proper voltage thresholds for driving GaN Systems' E-HEMTs.

Cautionary Notes

A Boost converter's output voltage is higher than the input voltage, V_{IN}. When operating at a high duty cycle and low load/no load operating conditions, the output voltage will rise and has the potential of damaging the GaN device. To avoid an overvoltage on the GaN device, two actions are recommended.

First, always apply a load at the output voltage, V_{OUT}.

Secondly, pre-set the PWM signal before applying power to V_{IN}. Figure 4 shows the block diagram of PWM signal generation inside the TL1454ACNSR.

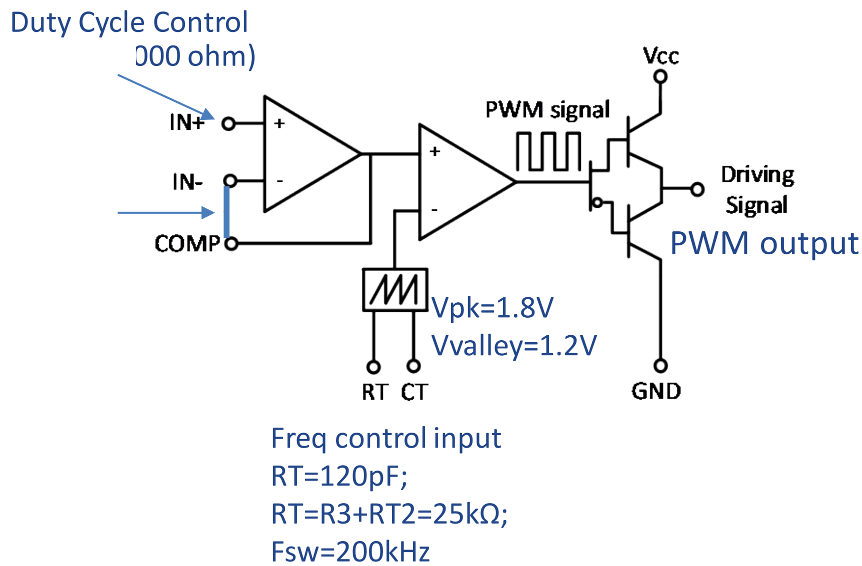

Figure 4 • GS65011-EVBEZ PWM signal adjustment diagram

The PWM signal is adjusted by tuning the controller's peripheral resistors, R11 and R3. Use the **Table 1** to set the duty cycle with R11. Use **Table 2** to set the switching frequency with R3. Select the appropriate values according to your own specifications and requirements. For a safe start up, 10% duty cycle and frequency 250kHz is recommended.

Table 1 • PWM Duty Cycle Setting up table

	R11 (Ω)	IN1+ (V)	Duty Cycle
Case 1	1000	1.83	0 %
Case 2	850	1.74	10 %
Case 3	500	1.52	47 %
Case 4	0	1.15	100 %

Table 2 • PWM Frequency Setting up table

	f_{SW_MIN}	f_{SW}	f_{SW_MAX}
R3 (kΩ)	20	5	0
CT (pF)	120	120	120
f_{SW} (kHz)	200	500	900

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Quick Start Guide

This chapter will guide the user through the evaluation board overview, hardware operation, test setup and test results.

Evaluation Board Overview

The evaluation board contains:

- Connectors for both high voltage (0Vdc < V_{IN} < 200Vdc) and low voltage (5Vdc < V_{CC} < 12Vdc) power supplies
- Connector for the output load
- User-friendly probe connector and vias for V_{GS}, V_{DS} measurement and other performance verification
- The jumper for current sensing

The operating specifications of the evaluation board are as follows:

- The recommended input voltage operating range is 0 V < V_{IN} < 200 V. (The maximum input voltage is limited by the output voltage of the Boost converter, which is further subject to operating mode, the duty cycle and the load value.)
- Frequency of operation of 200 kHz - 900 kHz.
- The maximum load current depends on die temperature and is further subject to switching frequency and operating voltage. Forced air cooling or heat sinking can increase current rating.

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Evaluation Test Setup

Figure 5 shows the test setup for the GS65011-EVBEZ evaluation board. Make sure that the specified safety precautions mentioned in "**Safety Precautions**" on page 2 are followed.

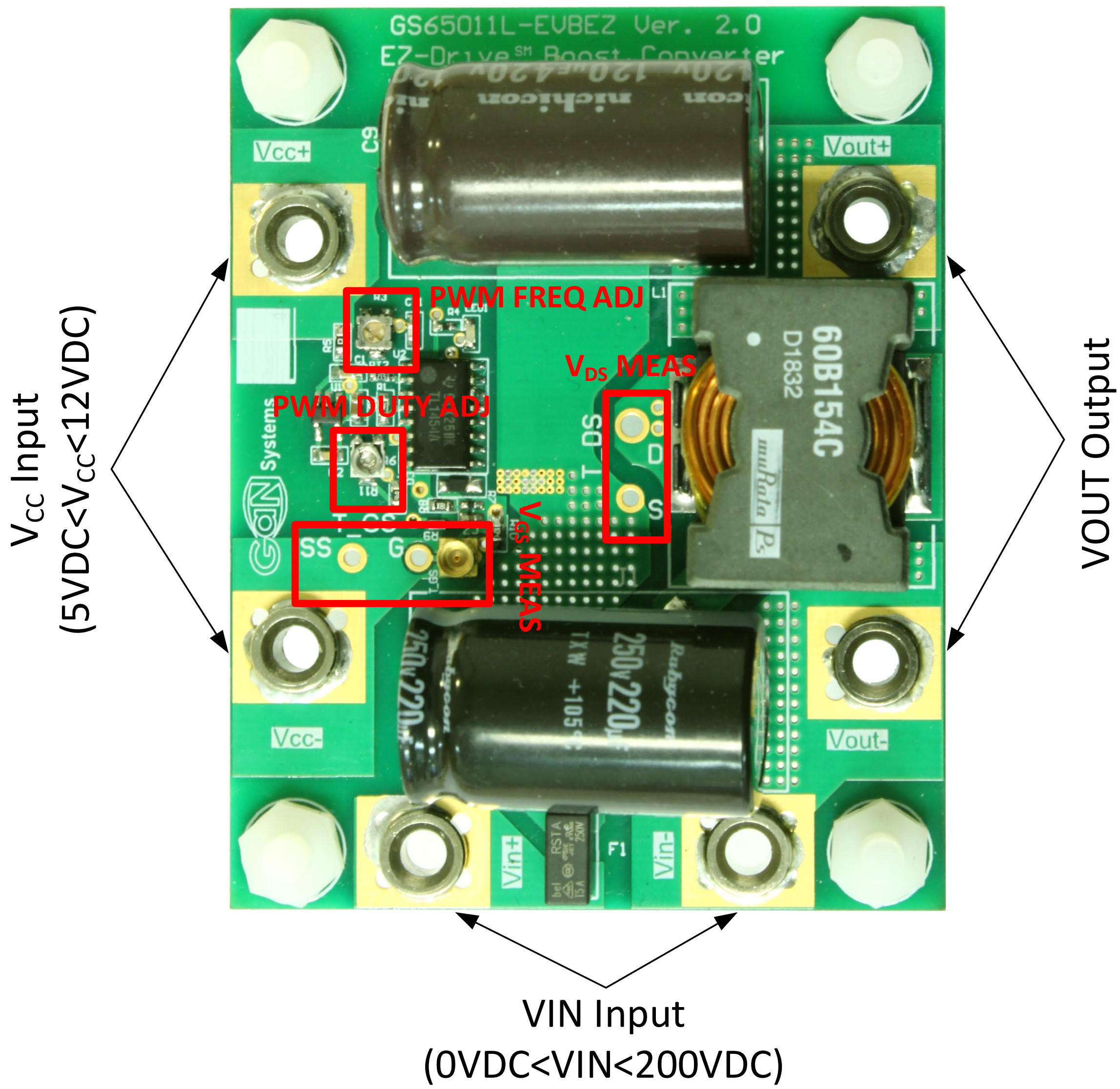

Figure 5 • GS65011-EVBEZ Test Setup

Hardware Operation

The general guidelines for operating the evaluation board are listed in this section. Follow the steps to configure the hardware properly.

1) Always connect a load (E-load) to Vout+ and Vout-.
2) Pre-set the PWM frequency and the duty cycle (by tuning R3 and R11), according to the PWM signal look-up tables. Start with 10% duty cycle and frequency 250kHz.
3) Apply V_{CC} ($5V_{DC} < V_{CC} < 12V_{DC}$) to Vcc+ and Vcc-, use T_GS (MMCX JACK) or G/SS (VIAS) for V_{GS} monitoring
4) Check the V_{GS} waveform and fine-tune the PWM frequency (by tuning R3) and duty cycle (by tuning R11)
5) For taking an efficiency measurement, add a current meter and use Vin+ and Vin- for V_{IN} and use Vout+ and Vout- for V_{OUT} measurement.
6) Apply V_{DC} to Vin+ and Vin- and sweep the voltage from low (0V) to max. Monitor the output voltage and device temperature. Make sure V_{OUT} is lower than 400V, and the GaN device temperature is lower than 150°C. Note: the maximum input voltage is limited by the output voltage of the Boost converter, which is dependent on the operating mode, the duty cycle and the load value.
7) After testing, turn off V_{IN} first, then V_{CC} across Vcc+ and Vcc- last.

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Note: When measuring the high frequency content switch node, care must be taken to avoid long ground leads. Measure the switch node by placing the oscilloscope probe tip through the Drain via and Source via (designed for this purpose). See **Figure 6** for proper probe technique and **Figure 5** for the location of V_{GS} and V_{DS} measure vias. Use a high voltage passive/differential probe for the V_{DS} measurement.

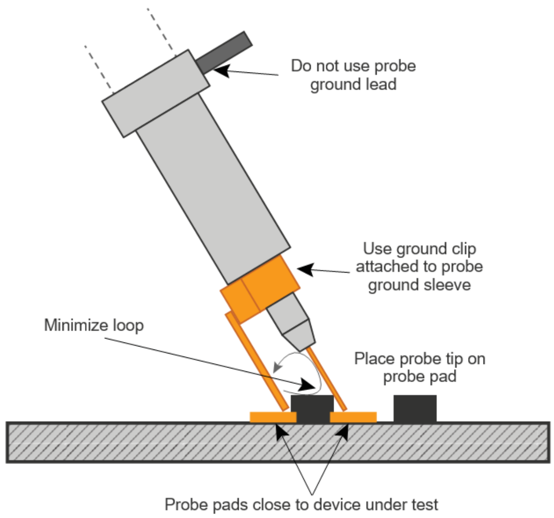


Figure 6 • Proper Oscilloscope Probe Measurement Technique

Note: A jumper is placed between the Vin+ signal and the inductor (beneath the input capacitor C4) The jumper can be replaced by a loop of jumper wire to take the inductor current measurement.

Figure 7 shows the jumper location. **Figure 8** shows how to replace the jumper with a loop of jumper wire to take the current measurement with a current probe. The jumper wire loop and the current probe are not included in the Evaluation Kit.

Figure 7 • Current Sensing Jumper Location

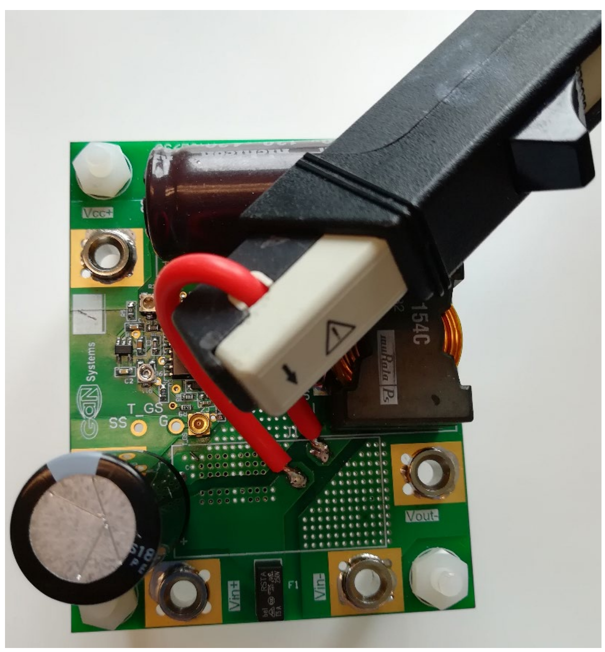
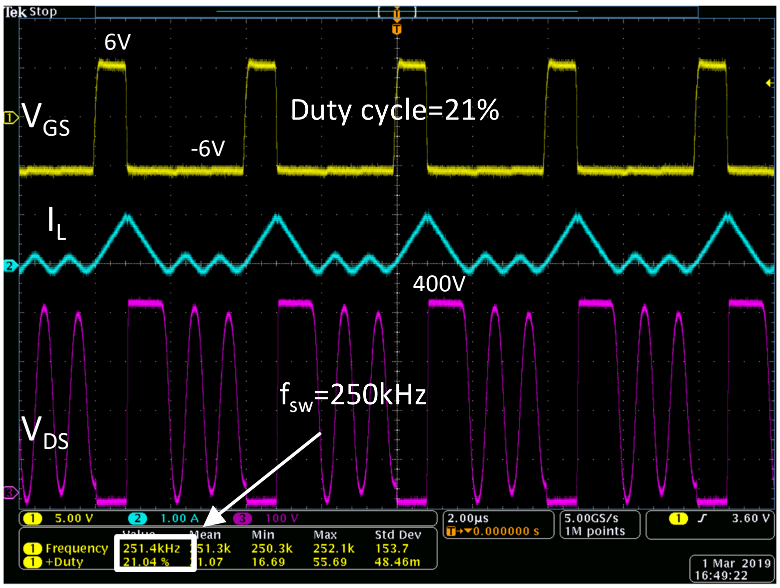


Figure 8 • Inductor Current Probe Insert Example

Evaluation Results

The evaluation results are shown in **Figures 7** through **10.**

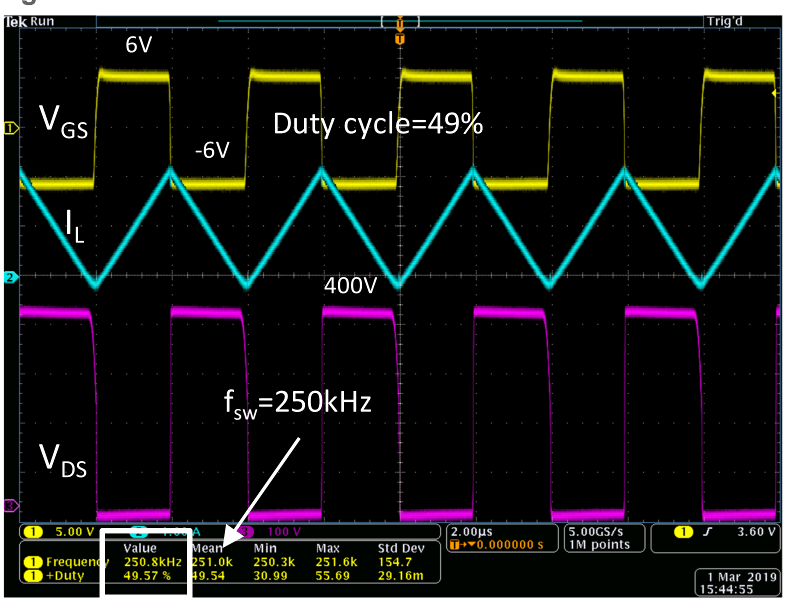
Figure 7 • Test Results at half load



P_{OUT}	Half load (100W)
V_{IN}	200V
V_{OUT}	400V
Duty cycle	21%
f_{SW}	250kHz
Efficiency	96%

Test conditions: V_{IN}=200V; V_{OUT}=400V; I_{OUT}=0.25A; P_{OUT}=100W (half load); f_{SW}=250kHz

Figure 8 • Test Results at full load



P_{OUT}	Full load (200W)
V_{IN}	200V
V_{OUT}	400V
Duty cycle	49%
f_{SW}	250kHz
Efficiency	97.3%

Test conditions: V_{IN}=200V; V_{OUT}=400V; I_{OUT}=0.5A; P_{OUT}=200W (full load); f_{SW}=250kHz

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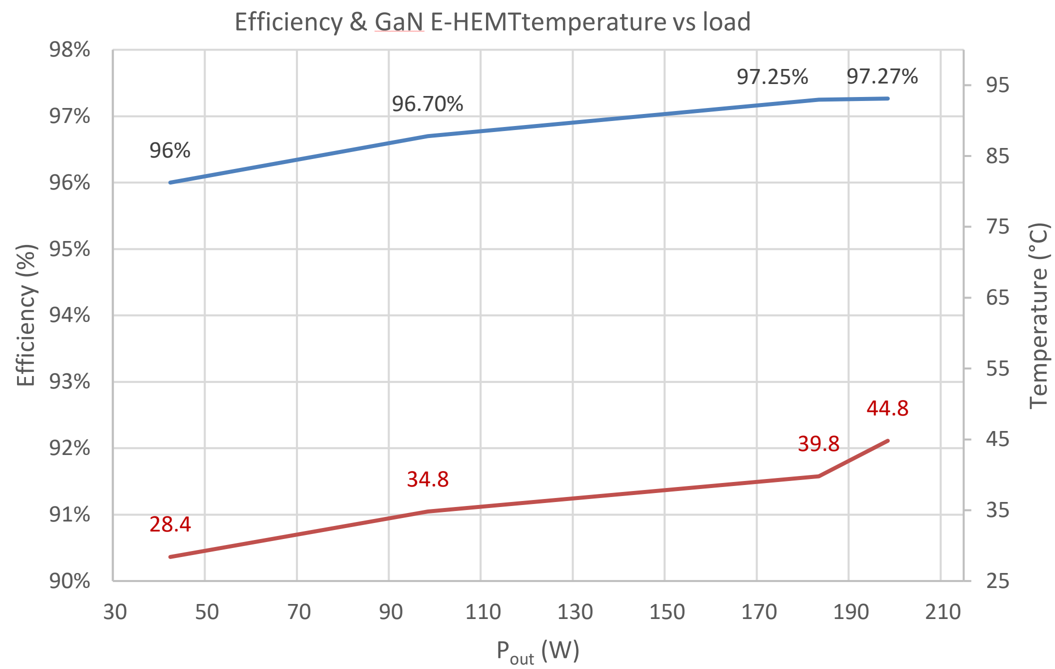
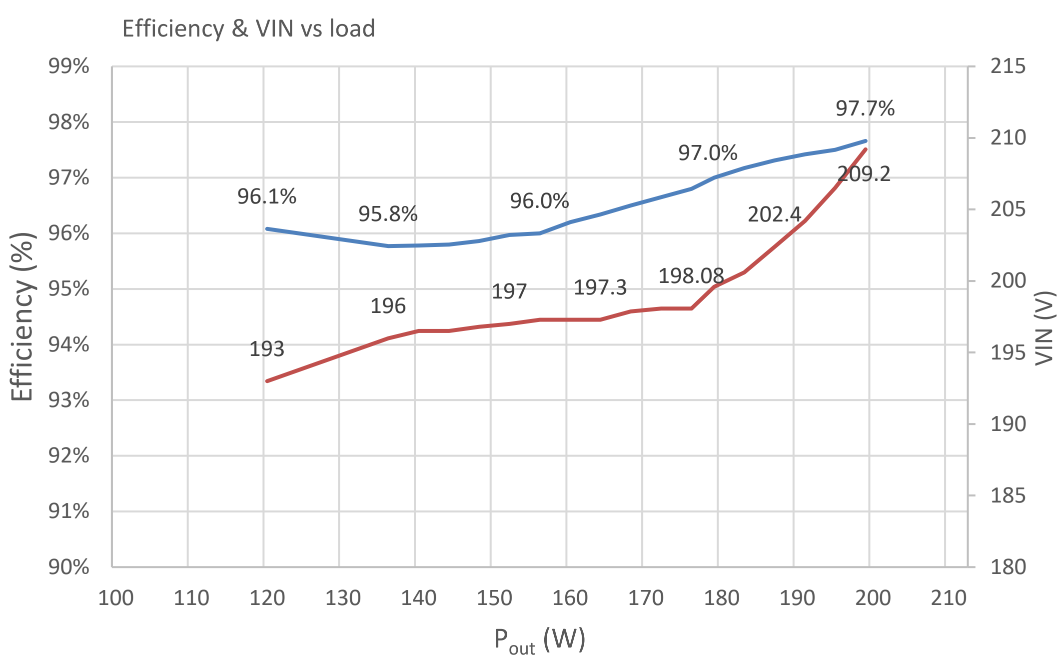
Figure 9 • Efficiency & GaN E-HEMT temperature vs load



Test conditions: V_{IN}=200V, V_{OUT}=400V, f_{SW}=250kHz

Figure 10 • Efficiency & V_{IN} vs load



Test conditions: Duty cycle=40.8%, V_{OUT}=400V, f_{SW}=250kHz

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Thermal Considerations

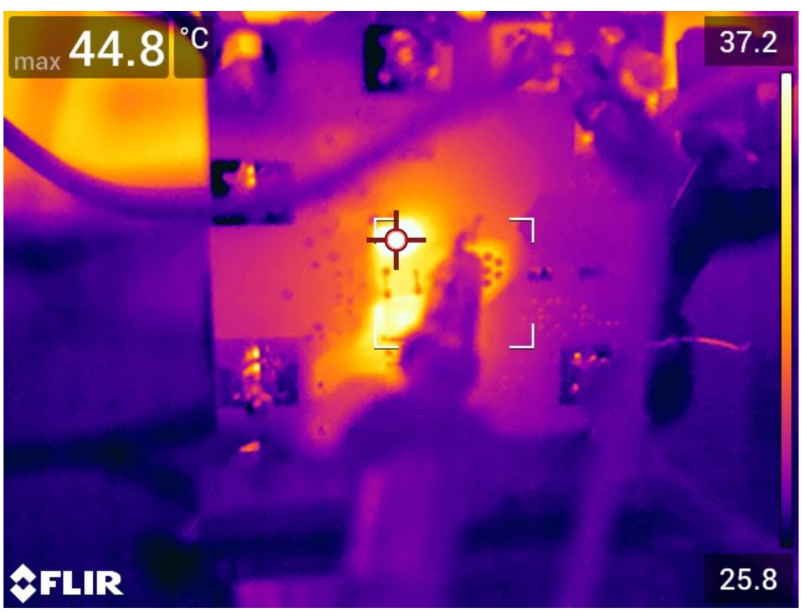
The EVB includes one GS-065-011-1-L GaN E-HEMT. Although the electrical performance surpasses that for traditional silicon devices, their relatively smaller size does magnify the thermal management requirements. The evaluation board is intended for bench evaluation under low ambient temperature and with convection cooling. The addition of heat-sinking and forced air cooling can significantly increase the current rating of these devices, but care must be taken to not exceed the absolute maximum junction temperature of +150 °C.

Note: The EVB does not include any on-board current or thermal protection.

The thermal performance of the EVB is shown in **Figure 10** and **Figure 11**. Infrared thermography was performed under the following conditions, with a fan on at room-ambient temperature:

- V_{IN} = 200V
- V_{OUT} = 400V
- I_{OUT} = 0.5A
- f_{SW} = 250 KHz

Figure 11 • Thermal imaging with an external fan (T_{MAX} = 44.8˚C)



Technical Resources

This document and additional technical resources are available for download from www.gansystems.com.

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Please read the Technical Manual and, specifically, the Warnings and Restrictions notice in the Technical Manual prior to handling the product. Persons handling the product(s) must have electronics training and observe good engineering practice standards.

This notice contains important safety information about temperatures and voltages. For further safety concerns, please contact a GaN Systems' application engineer.

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