65 W QUASI-RESONANT FLYBACK REFERENCE BOARD

USER GUIDE

CGD-UG2403

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COMPANY CONFIDENTIAL

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CAMBRIDGE GaN DEVICES

Safety Warning

DANGER: Do not touch the board when high voltages are applied. There are exposed locations of high voltage on the board when connected to a power source. Brief contact may result in serious injury or death. Always operate from an electrically isolated power source, and after power down allow all components to fully discharge before handling the board. This Reference board is designed for use by qualified, experienced engineers only. Appropriate safety measures must be put in place before use and the board should never be left unattended when operating.

WARNING: Some components may become hot during operation and remain so afterwards. There is no built in electrical or thermal protection. Operating voltages, currents and temperatures should be monitored closely throughout operation to prevent damage to the board.

CAUTION: This product contains parts susceptible to ESD (electrostatic discharge). ESD prevention procedures must be used while handling the board.



Operating Limits and Recommendations

Operating outside this window is not recommended and may cause damage.

Voltage Limits

CGD has a recommended maximum input voltage of 264 Vrms on the Reference Board.

Heat Dissipation

Heatsinking the GaN switch device has been provided through bottom side cooling of the devices. Heatsinking of the synchronous rectifiers has been provided through the drain pad of the MOSFET. CGD makes no guarantees as to the thermal performance of the heatsinking solution provided.

User Guide Overview

This user guide will outline the capabilities and operation of the CGD 65 W Quasi-Resonant Flyback Reference Board, and detail how the customer can use the board. It will explain the operation, the rationale for using this topology and give test results from prototype boards.

Target Audience

This guide, along with the board itself, is aimed at experienced engineers and assumes a knowledge of the equipment required to analyse the performance of the board. It will assume the competence of the engineer to safely operate the design with exposed high voltages.
It is intended to enable SMPS engineers, Design Engineers and Technicians to evaluate a high power-density design using ICeGaN.

Technical Support

CGD is happy to provide expert help with any questions or problems. For support, please contact CGD at techsupport@camgandevices.com.

Revision History

Revision Number	Comments	Engineer(s)	Date
1.0	Initial Release	DV	23 Dec 2022
2.0	Updated to Revision 2 Hardware	DV	23 Jan 2024
2.1	Duplicate reference (UG2401) changed to UG2403	DV	15 Apr 2024

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1 Overview

The Cambridge GaN Devices (CGD) 65 W Reference Board highlights the performance advantages of CGD ICeGaN™ in the quasi-resonant flyback topology.

Table 1: CGD Hardware included in this design.

Assembly Name	CGD Devices Utilised	$R_{DS(on)}$	Capabilities	Device Package
CGD-ASY-RFD003FA-02	CGD65B240SH2	240 mΩ	ICeGaN	DFN5x6

Ease of use.
ICeGaN is the ideal switch for low-side current-mode controlled power supplies. The current sense scheme makes the heatsink tab available for soldering directly to the ground plane; a game-changer for power supply designers. ICeGaN therefore runs cooler than MOS or conventional GaN alternatives. The CGD ICeGaN gate enables the driving of GaN HEMTs through an extremely large range of 9 V to 20 V, allowing compatibility with readily available MOSFET controllers, without compromising GaN's excellent switching performance. In addition, CGD's ICeGaN increases the threshold voltage of the GaN to around 3 V, thereby preventing unwanted turn-on events and eliminating the need for the negative driving voltages required by other discrete enhancement mode HEMTs.
The current sense resistor selection allows the designer to set the temperature coefficient of the current sense function. Temperature protection of the device and transformer can therefore be implemented without additional components.

Best-in-class
This board demonstrates how CGD ICeGaN devices can achieve best-in-class power densities with a simple single switch topology. A unique property of ICeGaN is the current sensing arrangement. Unlike conventional GaN, it allows the source to solder directly to the ground plane. In this design, that eliminates the need for a discrete heatsink. Note that the can of the large bulk input capacitors is also connected to the ground plane. The top-side copper of the PCB can therefore extend under these capacitors with no risk of a short circuit and act as both ground plane and heatsink. The current sense pin directly drives a low-cost, miniature current transformer which allows the designer to independently select the temperature coefficient and signal magnitude as described in [1] to implement the overtemperature protection scheme. (A current sense transformer can also be used to break ground loops in higher power circuits or when paralleling devices).

Another advantage of the ICeGaN circuit is that a conventional flyback circuit, as described in [4], requires a 250 mΩ current sense resistor in series with a 210 mΩ MOSFET, the FCMT250N65S3. This resistor conducts the full primary current. The 240 mΩ ICeGaN device, CGD65B240SH2 functions as both switch and current measurement device. It samples the drain current and makes a scaled current signal available to the current sense pin. The process is lossless.

This design uses a flyback topology with quasi-resonant control (valley switching). The quasi-resonant flyback is a simple, single-switch topology which can be designed to have zero turn-on loss in the power switch at low-line. It does not recycle all leakage inductance energy, as more complex circuits can. However, at low-line, it does recycle almost all leakage energy, and is therefore as efficient at low-line as the more complex active clamp converter. As the input voltage increases, conduction losses decrease, and roughly balance the increase in switching loss. With a little design effort, notably minimising the capacitance at the HEMT drain, the high line efficiency can be made no worse than the low line efficiency. Minimising drain node capacitance is easier with a GaN device. It is not worth investing extra cost and complexity in a high power-density design to improve the efficiency at one extreme of the design range if the minimum steady-state efficiency

is lower. It is the minimum steady-state efficiency that drives the size of a high power-density design. The quasi-resonant flyback, in combination with ICeGaN, therefore lends itself to the design of low-cost, high power-density PD chargers.

There are comparable 65 W design options. Power Integrations offer a GaN device with in-built controller and a two-switch active clamp flyback circuit which also incorporates current sense [5]. It minimises turn-on loss in the power switch. They also offer a MOSFET-based solution with very high power-density [6]. These circuits both use continuous conduction mode at low-line to reduce peak switch current. Infineon propose a half-bridge flyback circuit with their proprietary controller. Both the Power Integrations and Infineon approaches require a second switch.

This design incorporates the low-cost OnSemi NCP1345 controller, conventionally used with silicon MOSFETs. The controller features two auxiliary power pins which allow the circuit to manage the large output voltage range. The board has been designed to meet international safety and EMC standards but has not been tested to these.

The thermal design utilises a single board construction. A 1 mm thick PCB is recommended with four layers of 2 oz copper. This spreads the heat around the PCB avoiding the hot spots which would result from a multi-board construction.

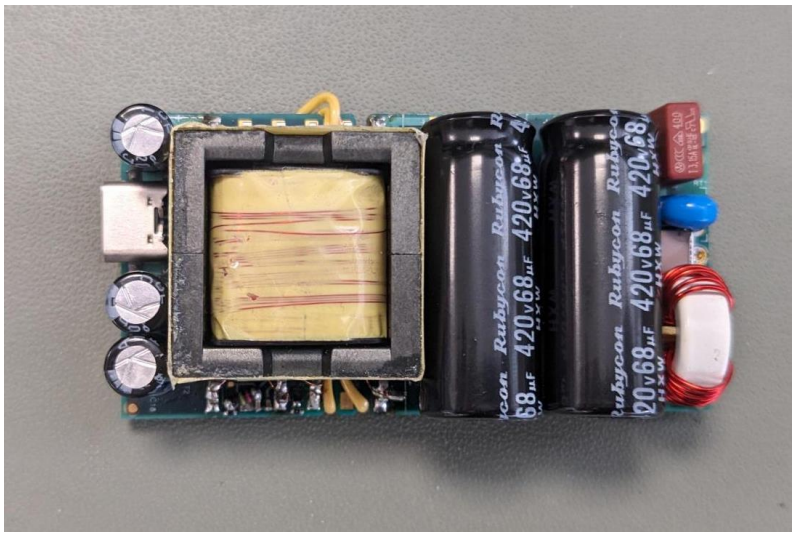


Figure 1 – 65 W Reference Design. Transformer insulation tape not used for clarity.

This User Guide explains the key design considerations for a high power-density PD charger. It explains the approach taken and the design choices made before concluding with design details and test results.

1.1 Feature List

Single output USB-C charger incorporating:

- High power-density design.
- ICeGaN gate with 9-20 V drive.
- NCP1345 quasi-resonant flyback controller.
- MP6908 synchronous rectifier controller on output with 1x120 V MOSFET.
- STUSB4710 USB controller.
- Current sense temperature coefficient selection.

1.2 Minimum Required Equipment

List of the equipment the customer will need to operate the board.

- Isolated AC source
- Suitable load

1.3 Inputs and Outputs

The Reference board has been designed to be as compact as possible with a full universal input from 90 Vrms to 264 Vrms.

Input connection points are shown in Figure 2. The output connector is USB-C.

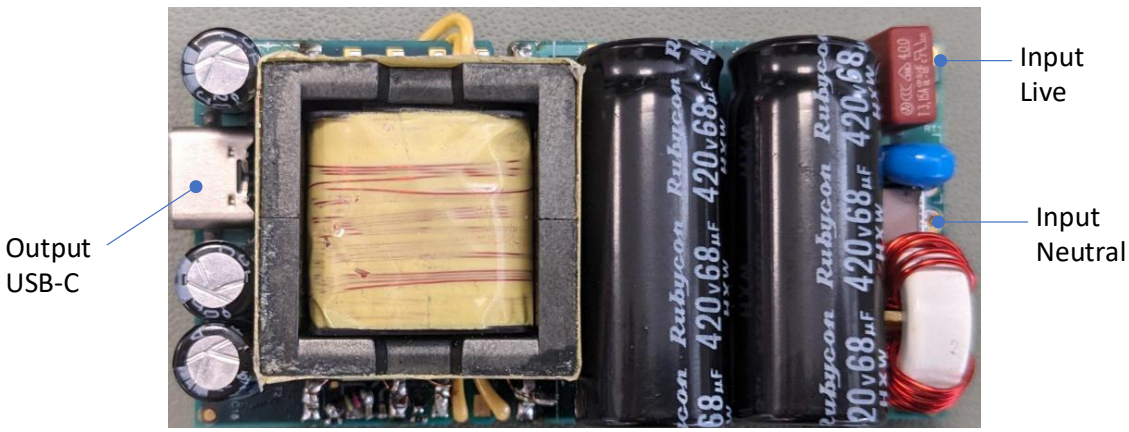


Figure 2 - Inputs and outputs.

2 Board Overview

This design uses a single PCB to simplify manufacturing.
The board includes:

- Quasi-resonant flyback control
- USB PD controller with protection
- Design for EMC
    - Common-mode chokes to isolate both input and output
    - Surge voltage protection
    - ESD protection – spark gaps

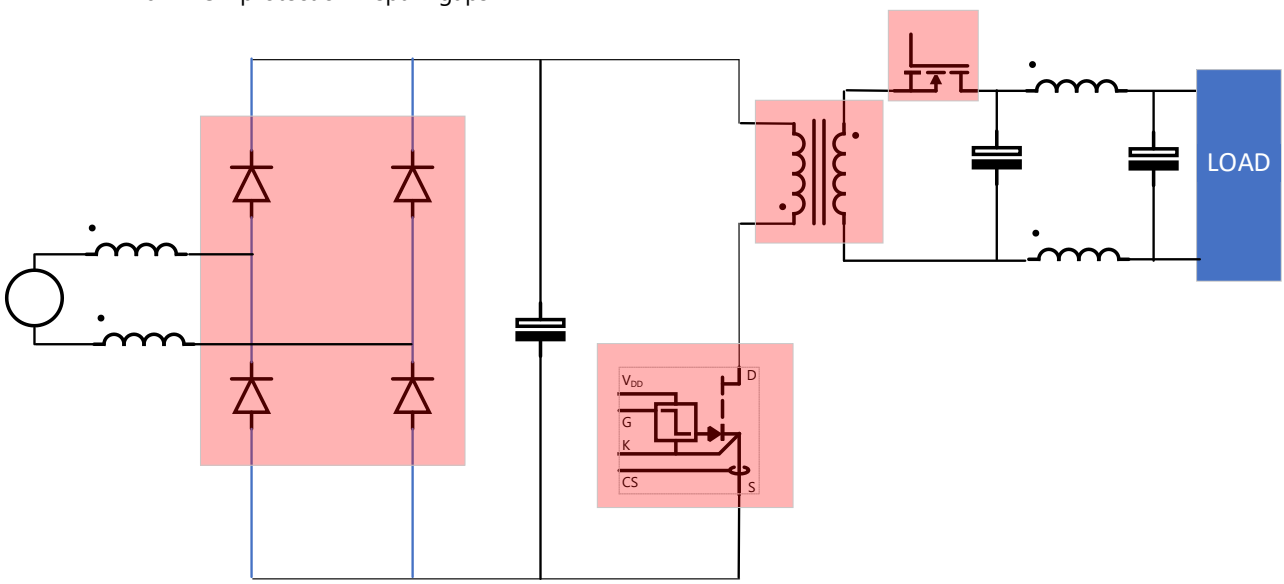


Figure 3 - Power circuit overview.

Figure 3 illustrates the key thermal elements of the power circuit:

See page 12 for a discussion on the thermal performance of the circuit as input voltage varies.

3 Design of the Power Circuit

Although there are many references already covering the design equations of the quasi-resonant flyback converter, for example [4], it is worth covering some general points here. The flyback has always been popular because of its simplicity and low cost, but the quid pro quo is that it has less design flexibility than topologies with more switches. Let's start by considering the losses in the power device.

3.1 Power switch losses

The power switch has two main components of dissipation:

1. Turn-on loss
2. Conduction loss.

At turn-off, the drain capacitance is charged by the inductor current. This can be taken as lossless. Energy rings between the inductance and the drain-node capacitance. Residual energy is dissipated at turn-on.

3.2 Turn-on loss.

When the device turns on, it discharges the capacitance seen at the drain-node. That includes the winding capacitance, the device capacitance and residual capacitance due to PCB tracking. The energy dissipated does NOT depend on switching speed. It is the total stored energy in the non-linear capacitance. This energy is dissipated every time the device turns on, so the power lost is proportional to the switching frequency.

A device with a fast turn-on discharges the capacitance quickly creating a large current spike. A slow turn-on is preferable and can be controlled with the gate resistor. The ICeGaN channel is turned off, with zero voltage across it, by an internal device which protects the gate and avoids spurious turn-on. The speed of this device is set internally.

Once energy transfer to the secondary is complete, the coupled inductor rings about the input voltage. The quasi-resonant flyback turns on at the minimum point of this ring. At low-line, the energy discharged by the device turn-on can be assumed to be zero. At high-line, the capacitor is charged close to the rectified line, and the loss is significant.

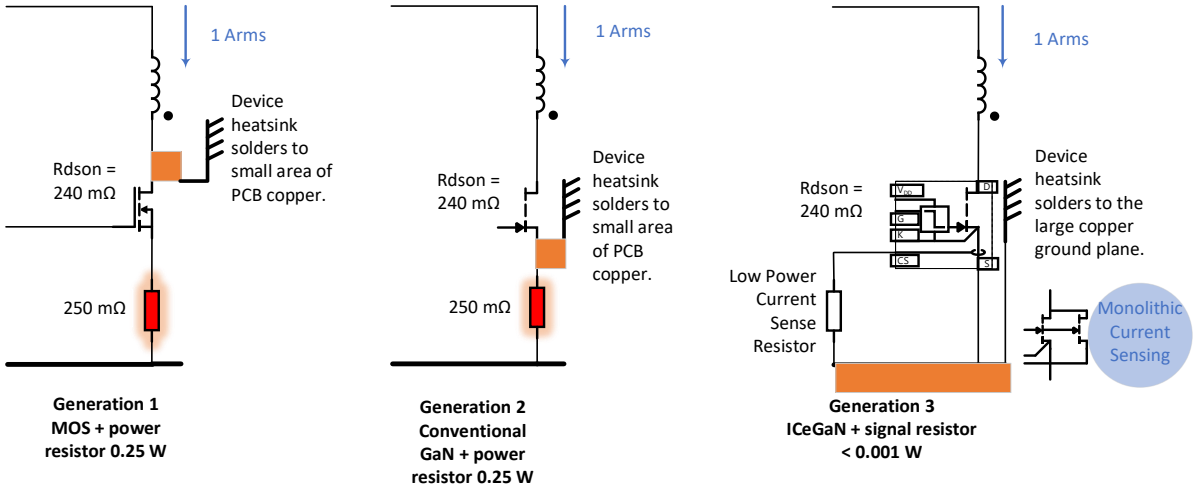
3.3 Conduction loss

The converter stage is a constant power device with an input voltage range of about 3:1. Low-line input current is therefore about three times higher than at high-line. Losses in resistive elements like the device and current sense resistor are nine times higher.

3.4 Selecting the device size

In many power topologies, it is possible to "buy" efficiency by increasing the device size. In a quasi-resonant flyback, a bigger device has a bigger capacitance and therefore more loss at high line. For a high power-density design, the aim is to minimise the total system loss at continuous operating condition, and to spread that heat as effectively as possible. The device should be sized such that it meets these criteria.

3.5 Heatsinking the device



Reduced power dissipation + Much larger (FREE) heatsink = Cooler device = ICeGaN

Figure 4 - Evolution of the flyback converter and the "ICeGaN equation."

Figure 4 illustrates the contrast between a traditional MOSFET, conventional GaN and ICeGaN in a 65 W design. For a 240 mΩ device, and a 250 mΩ sense resistor, the sense resistor dissipation is on a par with the device dissipation. With a typical low-line drain current of 1 A rms, the dissipation in the sense resistor will be 0.25 W. The resistor is normally a smaller device and therefore hotter. Conventional GaN must heatsink through its source pad to a small copper area, much smaller than the ground plane used by ICeGaN, and the small copper pad on the source of a conventional GaN HEMT is shared with an even hotter device.

The dissipation in the device will depend on how hot the device becomes, and therefore how much the resistance increases. ICeGaN will dissipate less than conventional GaN, or a MOSFET, because it is not adjacent to the sense resistor dissipation and has a much bigger heatsink.

In the quasi-resonant flyback converter, a key advantage of ICeGaN is that the current sense allows it to heatsink directly to the ground plane. It therefore eliminates the dissipation of the current sense resistor and will run cooler because it can exploit the freely available PCB copper. The reference design maximises this benefit by using a single board construction to spread the heat as widely as possible.

A further advantage of GaN over MOSFETs in this circuit is that the more linear output capacitance stores less energy at low voltage. Turn-on loss at low-line is therefore less, which is important because low-line efficiency is the hardest specification to meet.

3.6 Low-line, high-line power loss comparison.

The total system loss is about 5.2 W at both high and low-line.
Note that the leakage inductance related losses are dissipated in the HEMT when it turns on at high-line and in the primary-side RCD clamp. Leakage inductance is discussed more below in **The effect of the secondary winding fly-leads on the leakage inductance.**

Synchronous rectifier conduction losses do not change significantly over line because the output voltage is constant, but their switching loss increases at high line. Similarly, HEMT conduction losses decrease at high-line, but turn-on loss increases.
The diode bridge losses are purely conduction loss and are maximum at low line.
The transformer loss is the single biggest loss component. Copper losses decrease with increasing line but core losses increase.
The "overheads" cover auxiliary power losses, input and output filter losses. Most of these are in the secondary filter, so do not change with line. The auxiliary power dissipation rises with line but is a relatively small element.

4 Coupled Inductor Specification

The coupled inductor shown on the display model above in Figure 1 and Figure 5, has been assembled without external insulation. This allows better visibility of the wound component. To meet safety isolation requirements, the core would have to be wrapped to meet creepage and clearance requirements. The triple-insulated secondary fly-leads are soldered under the PCB while all primary circuitry is kept on the component side.

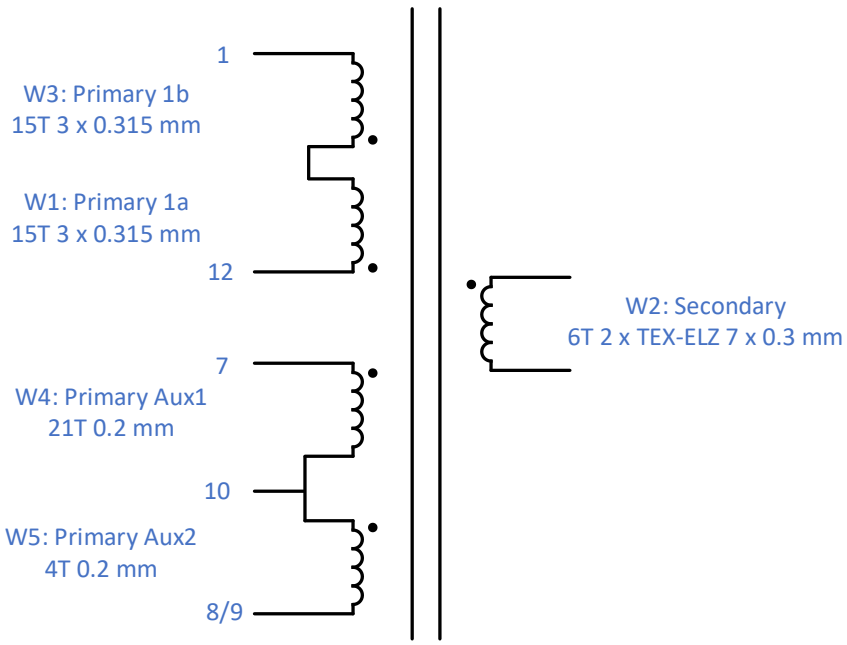


Figure 5 – Coupled Inductor Schematic.

Table 2 - Coupled inductor test specification.

Parameter	Notes	Requirement
Isolation – 50 Hz 1s	From all primary pins to both secondary fly leads	3000 Vrms
Primary inductance	From pin 1 to pin12 @ 1 kHz, 100 mV All windings open circuit.	151 µH to 156 µH
Leakage Inductance	From pin 1 to pin12 @ 1 kHz, 100 mV All windings short circuit.	<= 3.1 µH

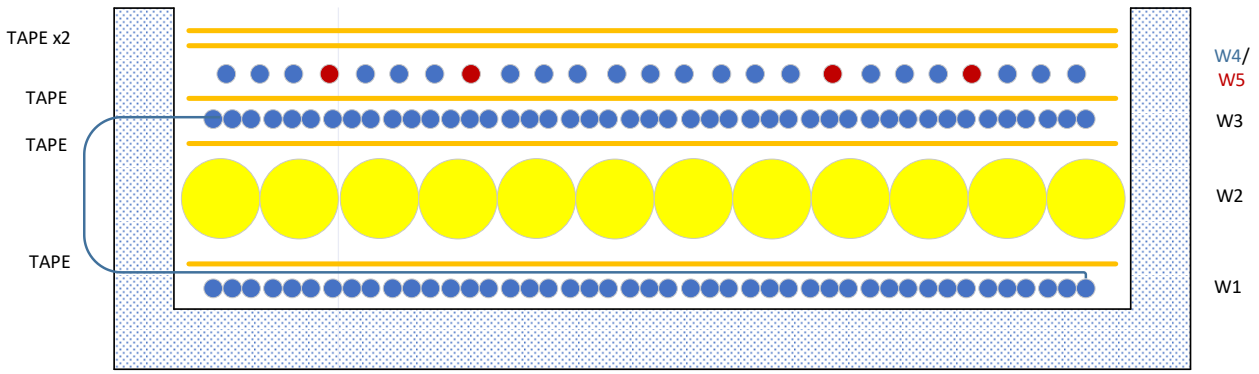


Figure 6 - Build diagram.

Table 3 - Coupled inductor parts list.

Item	Part description
1	Core set - Gateway Electronic Components - FXC-EFD25-3C96-AL156-1H-1S-UG
2	Bobbin – Ferroxcube – CSHS-EFD25-1S-12P-C
3	Enamelled copper wire – 0.315 mm
4	Furukawa – Tex-ELZ 7 x 0.3 mm
5	Enamelled copper wire – 0.2 mm
6	Polyester tape – 3M – Tape #74

5 Notes on the coupled inductor design

There are two key loss components affected by the coupled inductor design:

1. The copper and core loss of the wound component itself.
2. The losses caused by leakage inductance.

In single-switch flyback topologies, most of the primary leakage energy is lost. Some is recycled through the drain capacitance. It is therefore important to minimise this loss component, and the ratio between the magnetising inductance L_{mag}, and the leakage inductance L_{lk}, is an important figure of merit.

The power throughput of the primary is given by the following equation:

$P_{pri} = ½ L_{mag} I^2 f_{sw}$ ..... Equation 1

...where f_{sw} is the switching frequency and I is the peak current in the primary.

The power stored during the on-time in the leakage inductance is:

$P_{lk} = ½ L_{lk} I^2 f_{sw}$ ..... Equation 2

It can be seen that magnetising inductance should be maximised, and leakage inductance minimised. Magnetising inductance is limited by the operating frequency and discontinuous operation.

5.1 The effect of the secondary winding fly-leads on the leakage inductance.

Leakage inductance is reduced by selecting a core with a long bobbin winding width and then by sandwiching the secondary winding. Does it matter if the secondary fly-leads exit from the top or the bottom of the winding? The length of fly leads has a critical effect on the leakage inductance of the transformer.

To explore this, a transformer was wound with fly-leads left long. Long enough to wrap under the PCB from the top of the winding. The leakage inductance was measured. The leads were then cropped to the length required by fly-leads exiting from the bottom of the bobbin. The leakage inductance was re-measured. This simple change reduces the leakage inductance at 100 kHz, and therefore the leakage component element of the system losses, by about 25 %.

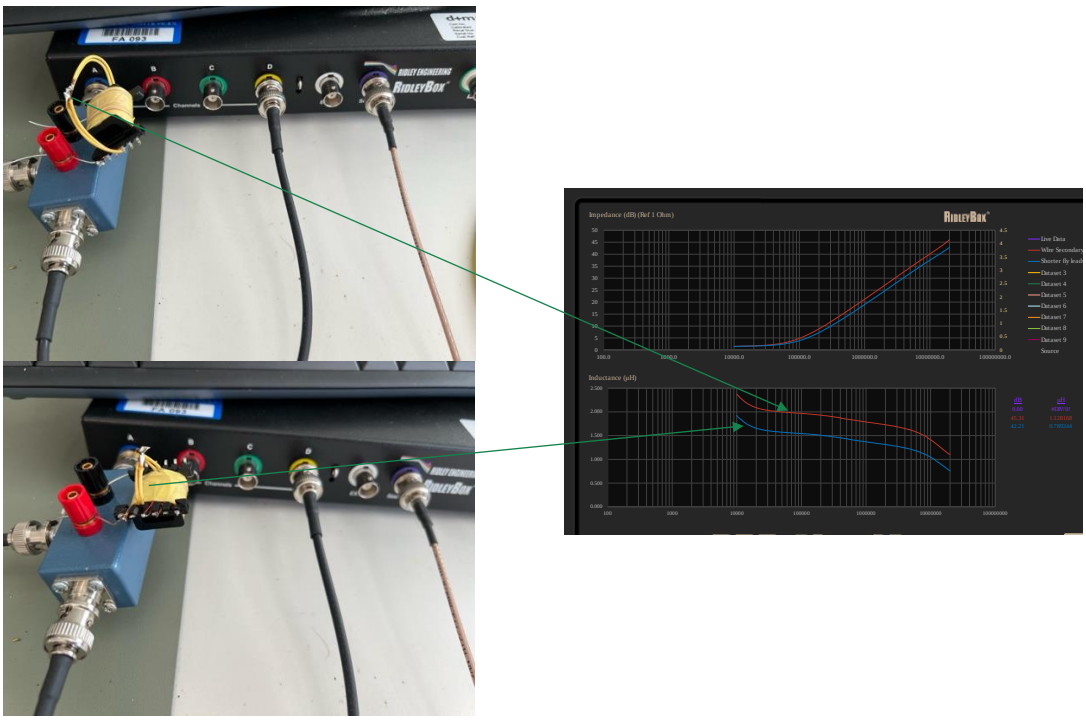


Figure 7: Impact of fly lead routing.

6 Test Results

6.1 Efficiency

The critical parameter for a high power-density design is the maximum loss under any continuous operating condition. This is challenging over a universal input range. To meet international safety requirements, the case temperature should never exceed 70 °C and most OEMs would allow significant margin on that figure. This corresponds to a minimum efficiency of 92.0% for this design.

The quasi-resonant flyback converter has an elegant property. Its maximum loss can be designed to be at minimum line and maximum line. At nominal line voltages, where the circuit will spend most of its time, the efficiency is higher.

Note: input and output voltages are measured on the connector pins on the board.

Table 4 – Efficiency.

Input voltage	10%	25%	50%	75%	100%
90 Vrms	90.64	92.04	92.62	92.65	92.12
115 Vrms	90.65	92.44	93.12	93.35	93.22
230 Vrms	87.06	90.64	91.62	92.55	93.06
264 Vrms	85.20	89.64	90.12	91.51	92.36

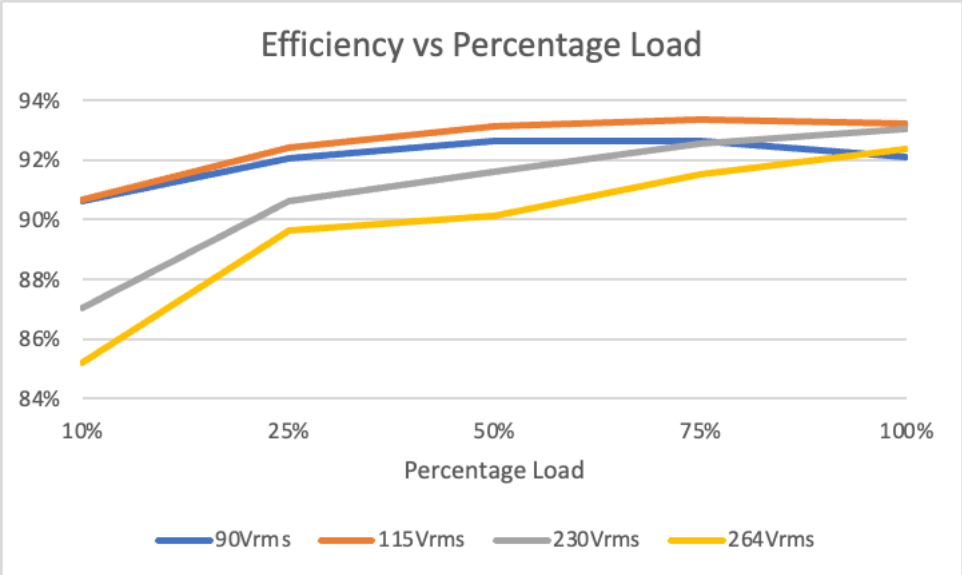


Figure 8 - Efficiency over input voltage and load.

6.2 No Load Power

Table 5 - No load power.

Input voltage	No Load Power / mW
90 Vrms	23.5
115 Vrms	24.0
230 Vrms	40.3
264 Vrms	42.8

7 Thermal images

Component side thermal images are shown at different input voltages followed by solder side components. It is not always possible to isolate the heating effect of individual components in these images.

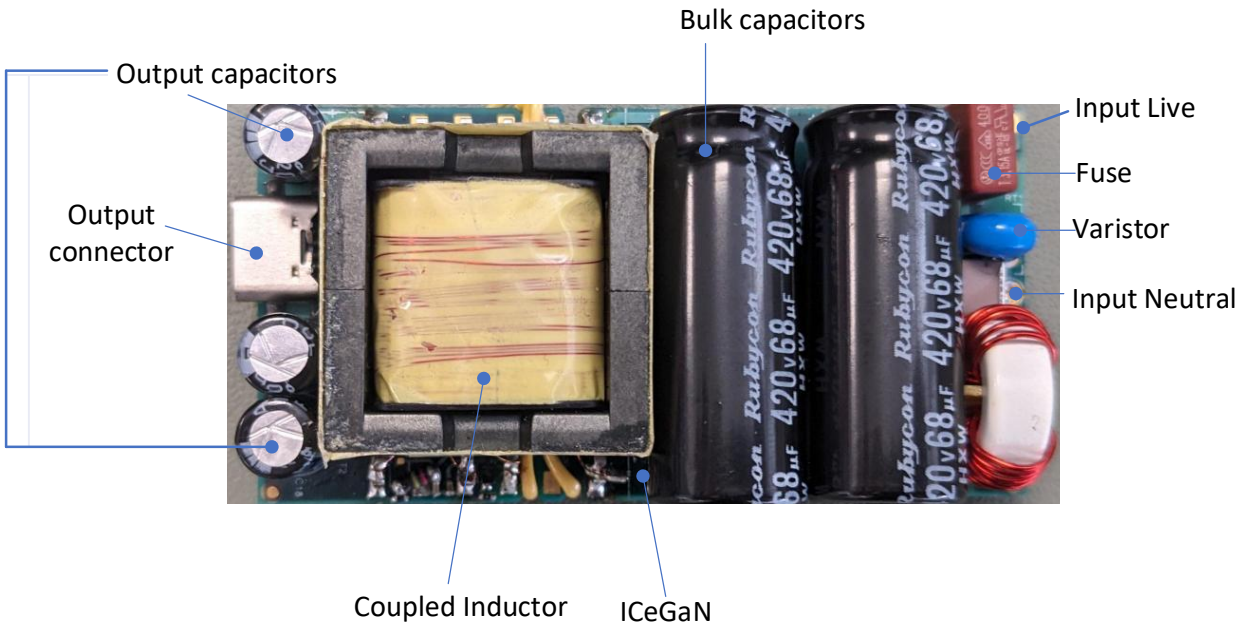


Figure 9 - Component side.

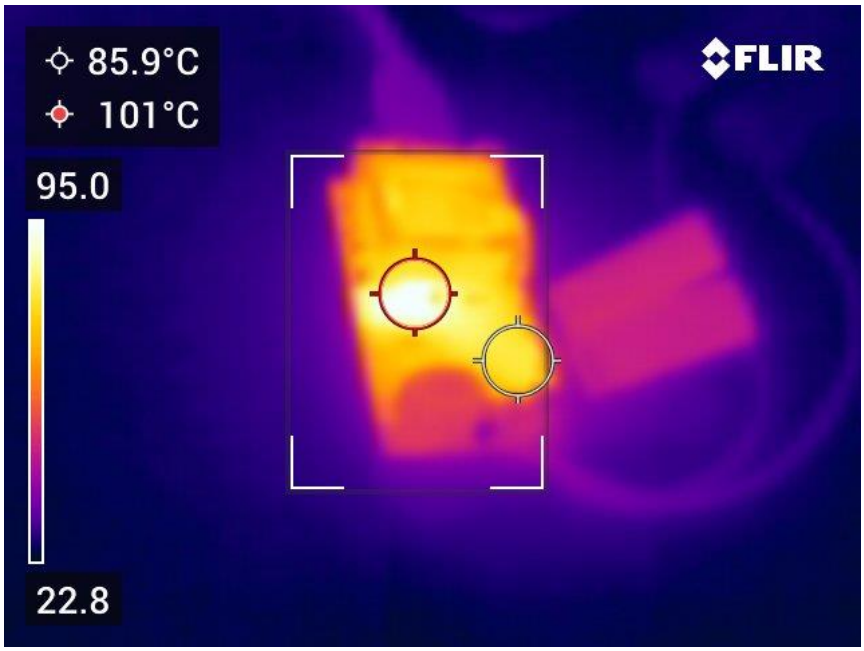


Figure 10 - Top side IR Image at Vin = 90 Vrms and Pout = 65 W. Capacitors lifted to show ICeGaN. Device temperature has potential to be reduced further by extending the top-side ground-plane.

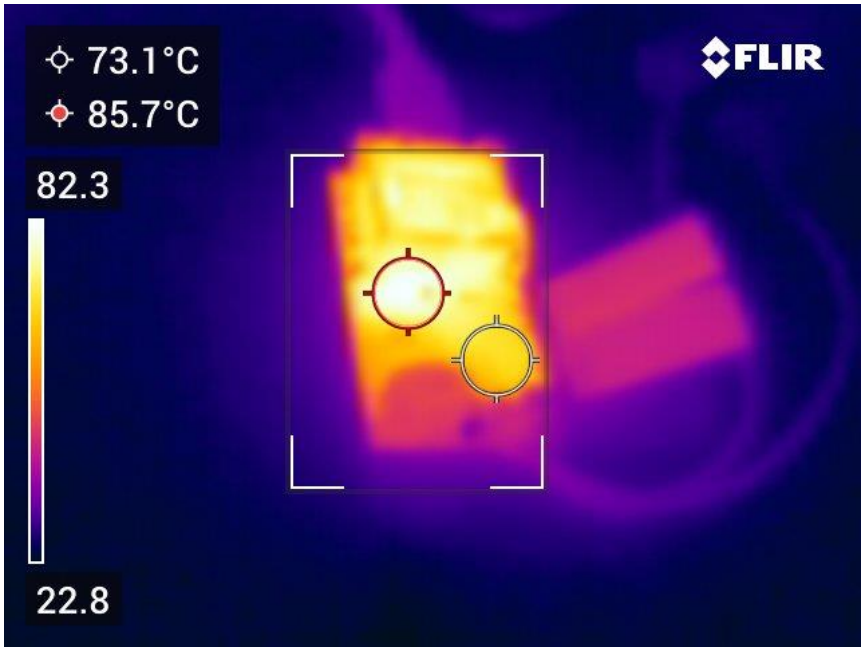


Figure 11 - Top side IR Image at Vin = 115 Vrms and Pout = 65 W. Capacitors lifted to show ICeGaN.

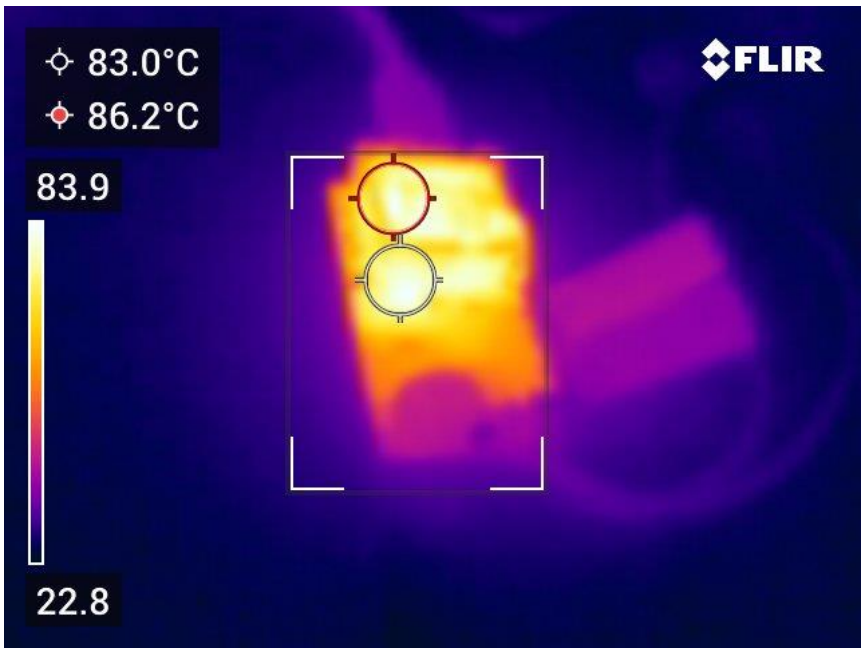


Figure 12- Top side IR Image at Vin = 230 Vrms and Pout = 65 W. Capacitors lifted to show ICeGaN.

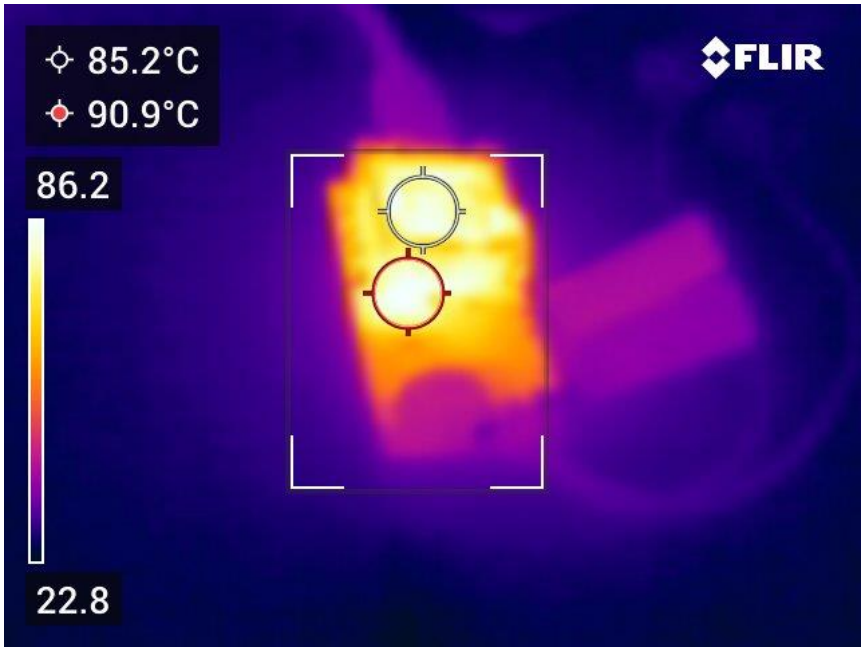


Figure 13- Top side IR Image at Vin = 264 Vrms and Pout = 65 W. Capacitors lifted to show ICeGaN.

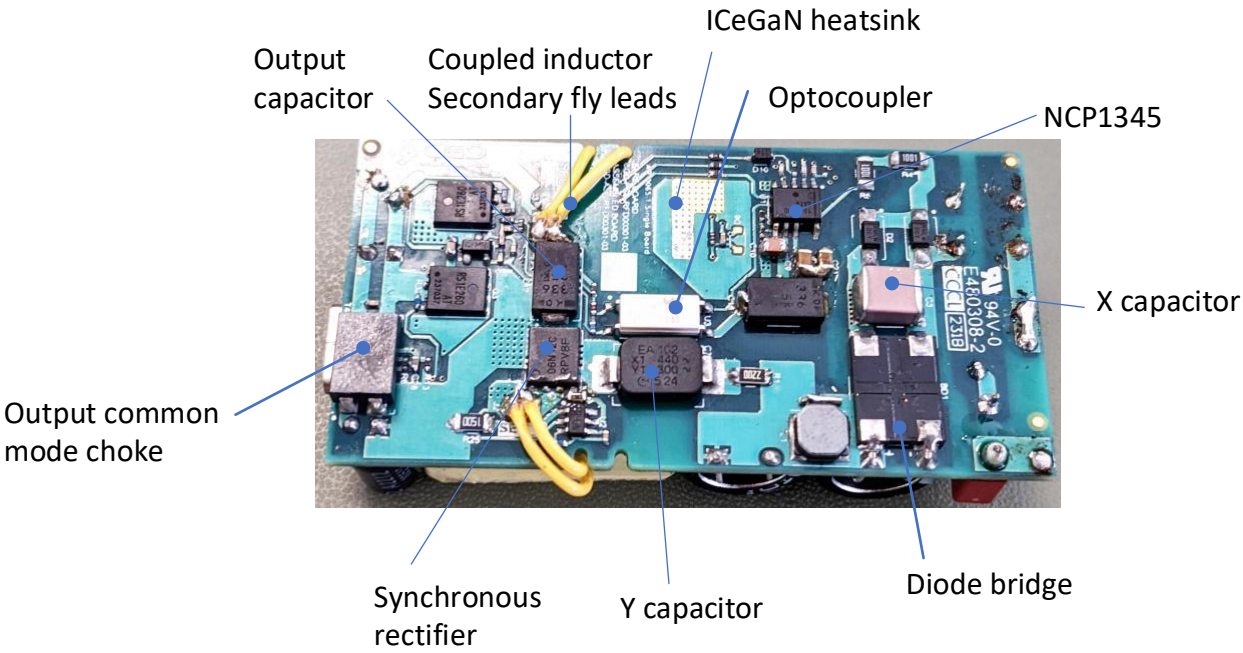


Figure 14 - Solder side.



Figure 15 - Top side IR image at Vin = 90 Vrms.



Figure 16 - Top side IR image at Vin = 115 Vrms.



Figure 17 - Top side IR image at Vin = 230 Vrms.



Figure 18 - Top side IR image at Vin = 264 Vrms.

8 Waveforms

Full load waveforms over line were recorded.

The following images show:

Top - Gate drive.

Centre - HEMT drain voltage.

Bottom - Controller current sense.

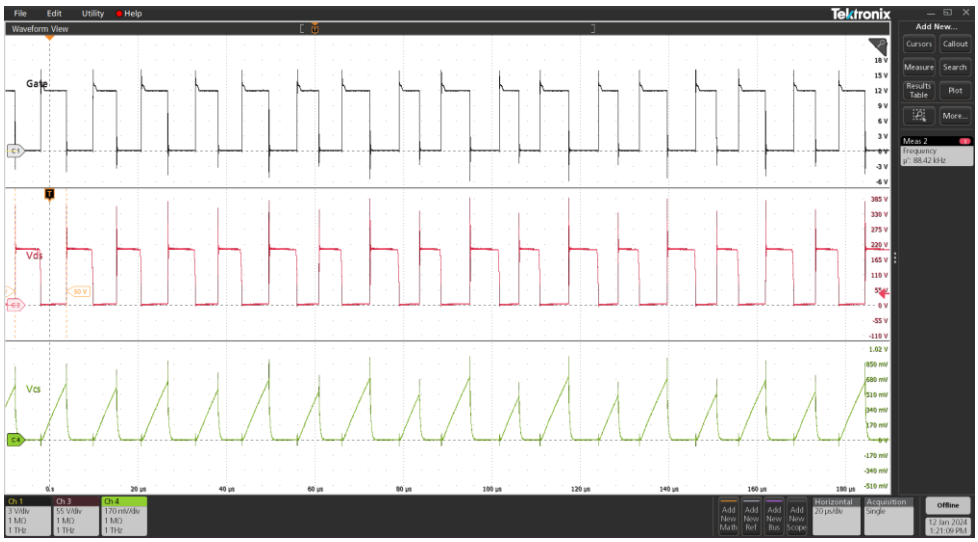


Figure 19 – Vin = 90 Vrms Full load (65W) operation

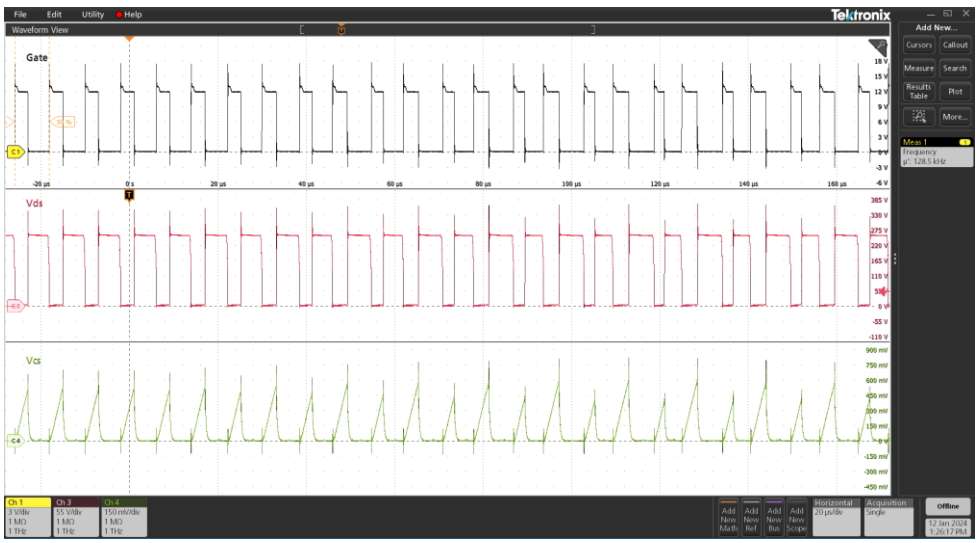


Figure 20 – Vin = 115 Vrms Full load (65W) operation

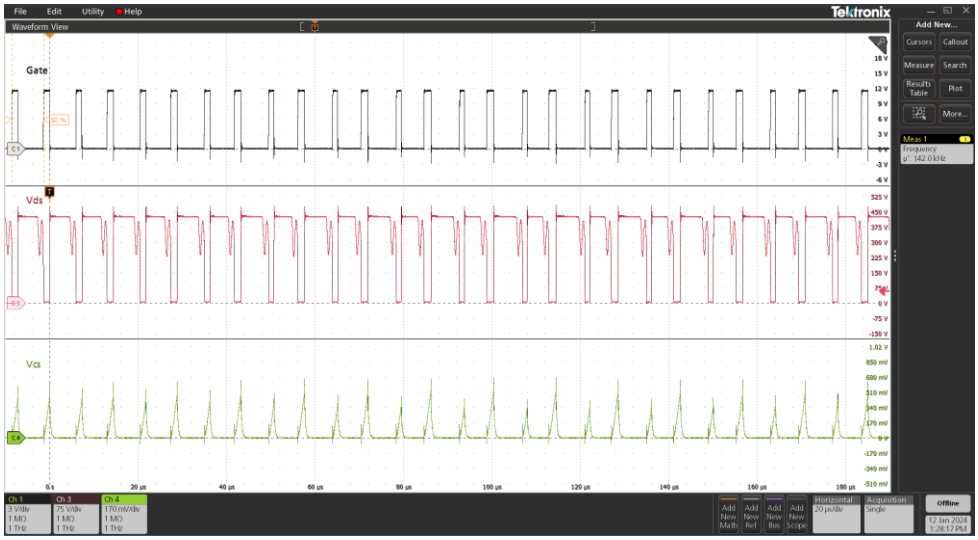


Figure 21 - Vin = 230 Vrms full load (65W) operation

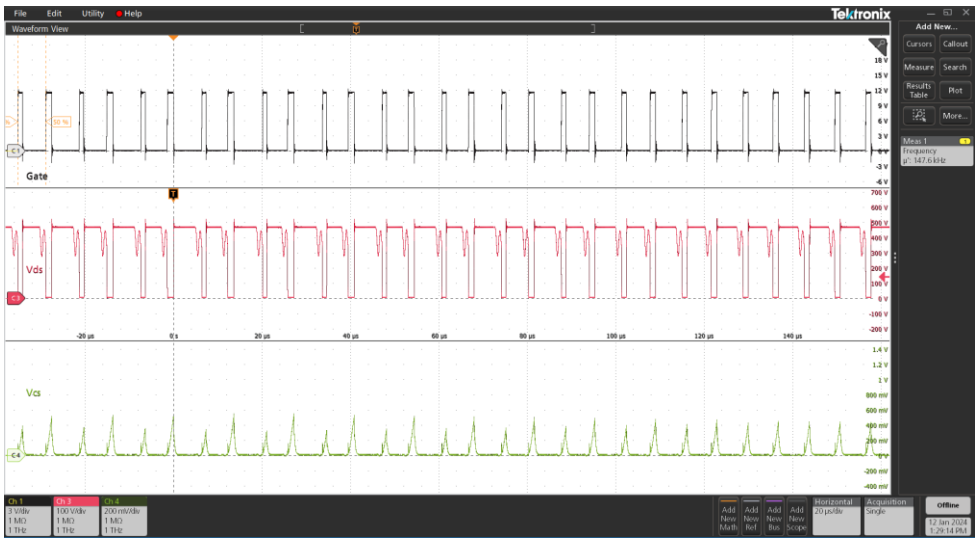


Figure 22 - Vin = 264 Vrms full load (65W) operation

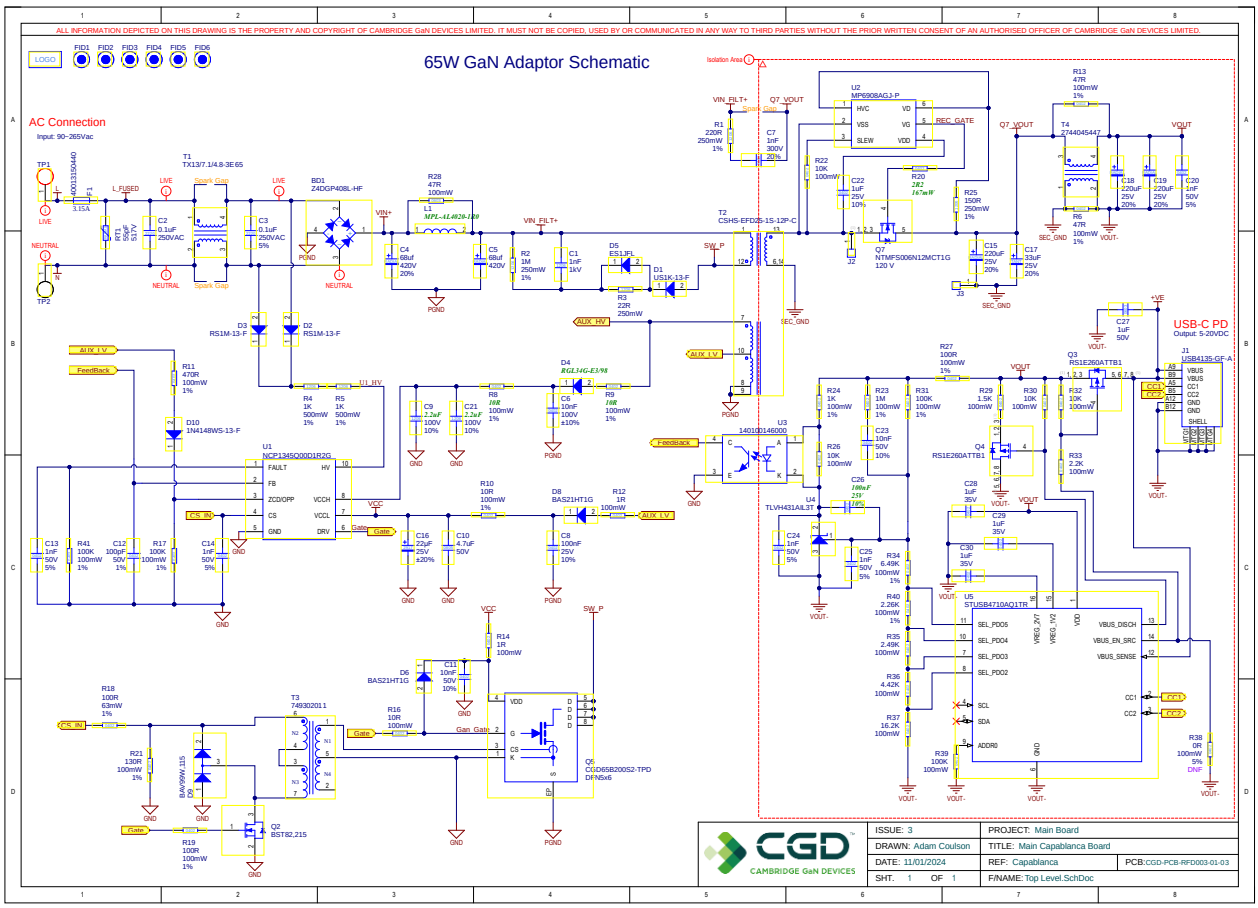


Figure 23 – Schematic.

9 PCB Layout

9.1 Top Layer

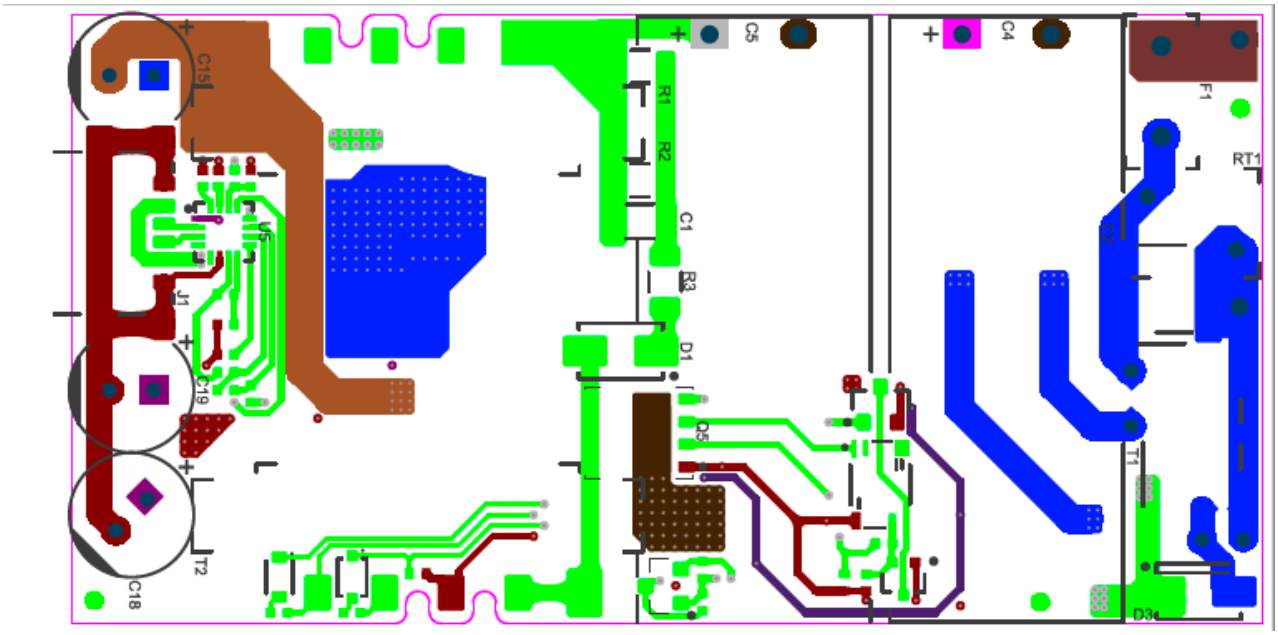


Figure 24 - PCB Top Layer.

9.2 Internal Layer 1

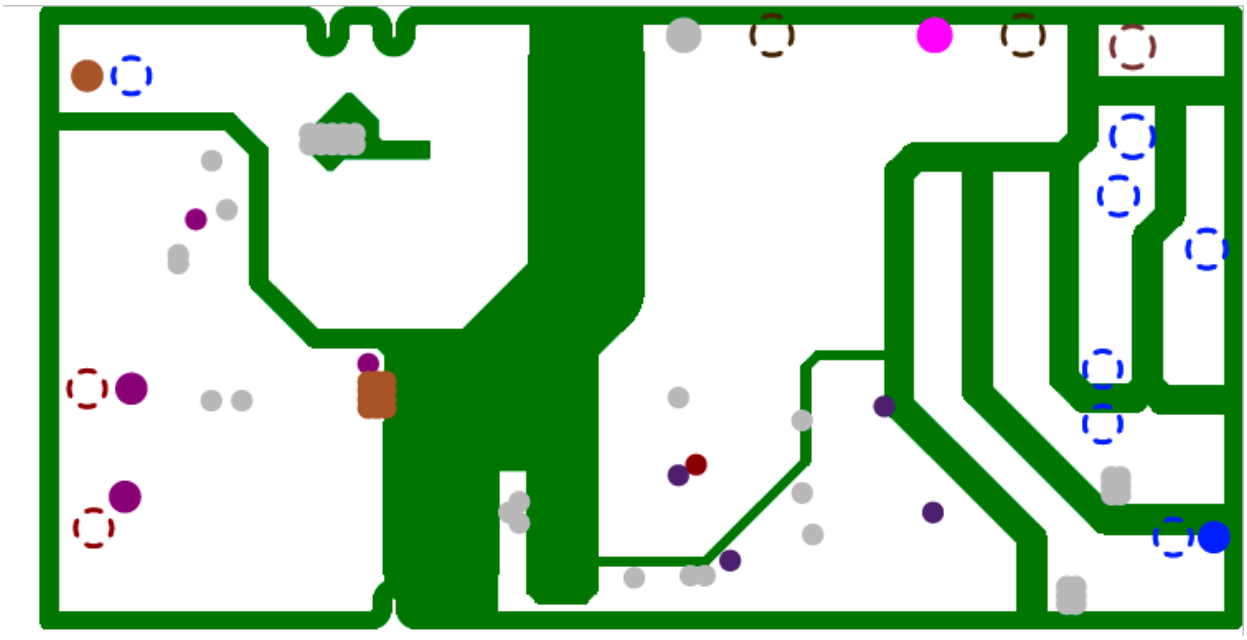


Figure 25 - PCB Internal Layer 1.

9.3 Internal Layer 2

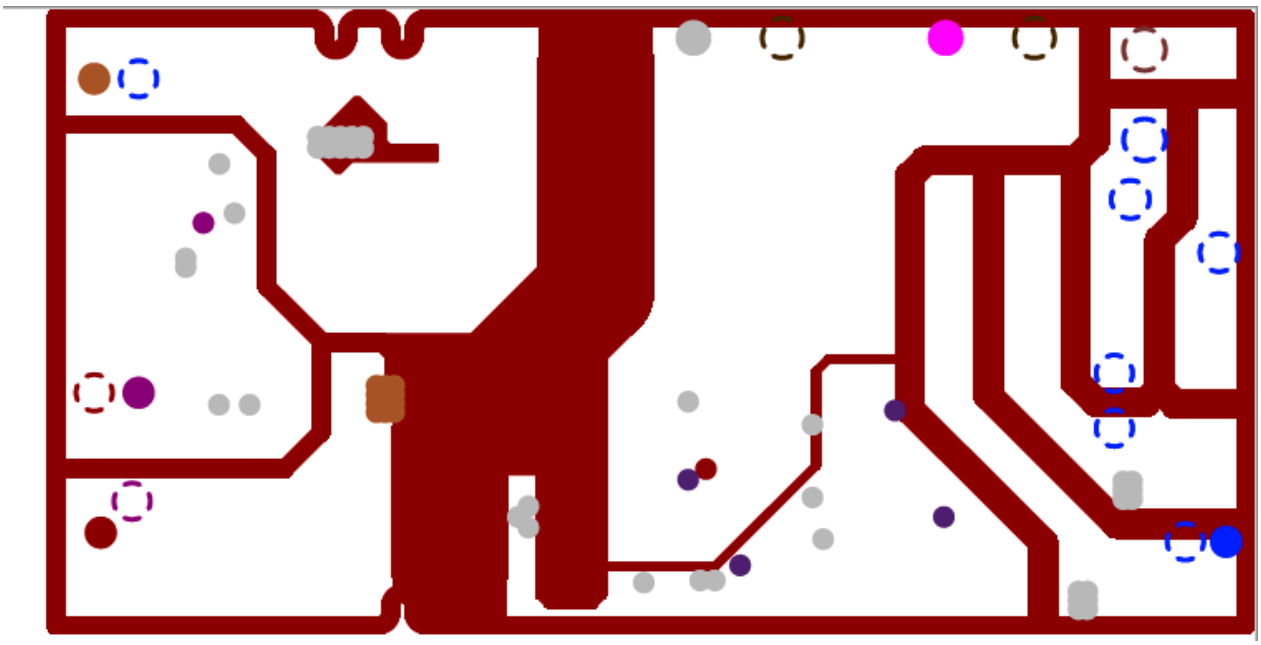


Figure 26 - PCB Internal Layer 2.

9.4 Bottom Layer

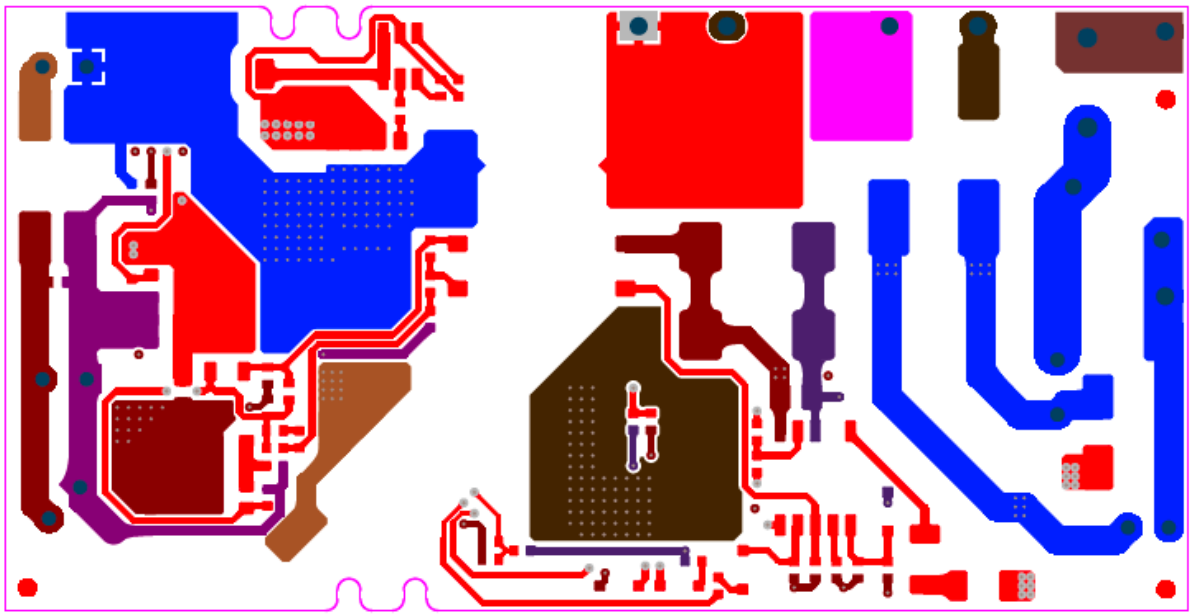


Figure 27 - PCB Bottom Layer.

10 Bill of Materials

Ref	Qty	PartType	Description	Manufacturer 1	Manufacturer Part Number 1
BD1	1	DIODE BRIDGE Z4DGP408L-HF	Bridge Rectifier Single Phase Standard 800 V Surface Mount Z4-D	Comchip	Z4DGP408L-HF
C1	1	CAP CER 1nF 1KV 10% X7R 1206	1000 pF ±10% 1000V (1kV) Ceramic Capacitor X7R 1206 (3216 Metric)	KEMET	C1206C102KDRACTU
C2, C3	2	CAP CER 0.1uF 250VAC 5% C0G 2220	0.1 µF ±5% 250VAC Ceramic Capacitor C0G 2220 (5750 Metric)	KEMET	CAN21C104JAGACTU
C4, C5	2	CAP RAD 68uF 420V 20% 12.5X32mm	68 µF 420 V Aluminum Electrolytic Capacitors Radial, Can 2000 Hrs @ 105°C	Rubycon	420HXW68MEFR12.5X30
C6	1	CAP CER 10nF 100V 10% X7R 0402	10000 pF ±10% 100V Ceramic Capacitor X7R 0402 (1005 Metric)	Yageo	CC0402KRX7R0BB103
C7	1	CAP CER 1nF 300V 20% E NSSMD	1000 pF ±20% 300VAC Ceramic Capacitor E Nonstandard SMD	Murata	DK1E3EA102M86RBH01
C8, C26	2	CAP CER 0.1uF 25V 10% X7R 0402	0.1 µF ±10% 25V Ceramic Capacitor X7R 0402 (1005 Metric)	Murata	GRM155R71E104KE14D
C9, C21	2	CAP CER 2.2uF 100V 10% X7R 1206	2.2 µF ±10% 100V Ceramic Capacitor X7R 1206 (3216 Metric)	Samsung	CL31B225KCHSNNE
C10	1	CAP CER 4.7uF 50V 10% X5R 0805	4.7 µF ±10% 50V Ceramic Capacitor X5R 0805 (2012 Metric)	TDK	C2012X5R1H475K125AB
C11, C23	2	CAP CER 10nF 50V 10% X7R 0402	10000 pF ±10% 50V Ceramic Capacitor X7R 0402 (1005 Metric)	KEMET	C0402C103K5RECAUTO
C12	1	CAP CER 100pF 50V 1% C0G/NP0 0402	100 pF ±1% 50V Ceramic Capacitor C0G, NP0 0402 (1005 Metric)	Murata	GCM1555C1H101FA16D
C13, C14, C20, C24, C25	5	CAP CER 1nF 50V 5% X7R 0402	1000 pF ±5% 50V Ceramic Capacitor X7R 0402 (1005 Metric)	Yageo	CC0402JRX7R9BB102
C15, C18, C19	3	CAP RAD 220uF 25V 20% 6.3x11mm	220 µF 25 V Aluminum Electrolytic Capacitors Radial, Can 7000 Hrs @ 105°C	Rubycon	25YXJ220M6.3X11

Ref	Qty	PartType	Description	Manufacturer 1	Manufacturer Part Number 1
C16	1	CAP POLY 22uF 25V 20% 2917	22 µF 25 V Aluminum - Polymer Capacitors 2917 (7343 Metric) 40mOhm 2000 Hrs @ 105°C	Murata	ECASD31E226M040KA0
C17	1	CAP TANT 33uF 25V 20% 2917	33 µF Molded Tantalum Polymer Capacitor 25 V 2917 (7343 Metric) 25mOhm @ 100kHz	KEMET	T521V336M025ATE025
C22	1	CAP CER 1uF 25V 10% X5R 0402	1 µF ±10% 25V Ceramic Capacitor X5R 0402 (1005 Metric)	Murata	GRT155R61E105KE01D
C27	1	CAP CER 1uF 50V 10% X7R 0603	1 µF ±10% 50V Ceramic Capacitor X7R 0603 (1608 Metric)	Taiyo Yuden	UMK107AB7105KA-T
C28, C29, C30	3	CAP CER 1uF 35V 10% X6S 0402	1 µF ±10% 35V Ceramic Capacitor X6S 0402 (1005 Metric)	Taiyo Yuden	GMK105CC6105KV-F
D1	1	DIODE STD US1K-13-F	Diode Standard 800 V 1A Surface Mount SMA	Diodes	US1K-13-F
D2, D3	2	DIODE STD RS1M-13-F	Diode Standard 1000 V 1A Surface Mount SMA	Diodes	RS1M-13-F
D4	1	DIODE STD RGL34G-E3/98	Diode 400 V 500mA Surface Mount DO-213AA (GL34)	Vishay	RGL34G-E3/98
D5	1	DIODE STD ES1JFL	Diode Ultra Fast Rectifier 600V 1A 2-Pin SOD-123F T/R	ON Semiconductor / Fairchild	ES1JFL
D6, D8	2	DIODE STD BAS21HT1G	Diode Standard 250 V 200mA (DC) Surface Mount SOD-323	ON Semiconductor	BAS21HT1G
D9	1	DIODE STD BAV99W,115	Diode Array 1 Pair Series Connection Standard 100 V 150mA (DC) Surface Mount SC-70, SOT-323	Nexperia	BAV99W,115
D10	1	DIODE STD 1N4148WS-13-F	Rectifier Diode Small Signal Switching 75V 0.3A 4ns 2-Pin SOD-323 T/R	Diodes	1N4148WS-13-F
F1	1	FUSE 40013150440	3.15 A 250 V AC DC Fuse Board Mount (Cartridge Style Excluded) Through Hole Radial, Box	Littelfuse Wickmann	40013150440
J1	1	CON USBC GCT USB4135-GF-A	USB-C (USB TYPE-C) Receptacle Connector 24 (6+18 Dummy) Position Surface Mount, Right Angle	Global Connector Technology	USB4135-GF-A
J2, J3	2	TEST LOOP 3.5x1.65MM	Natural PC Test Point Brass Tin Plating Surface Mount Mounting Type	Harwin	S1751-46R

Ref	Qty	PartType	Description	Manufacturer 1	Manufacturer Part Number 1
L1	1	L MPS 1uH 7.9A MPL-AL4020-1R0	1 µH Unshielded Molded Inductor 7.9 A 10.1mOhm 2-SMD	Monolithic Power Systems	MPL-AL4020-1R0
Q2	1	MOSFET N-CH 100V 190mA BST82,215	N-Channel 100 V 190mA (Ta) 830mW (Tc) Surface Mount TO-236AB	Nexperia	BST82,215
Q3, Q4	2	MOSFET P-CH 30V 26A/80A RS1E260ATTB1	P-Channel 30 V 26A (Ta), 80A (Tc) 3W (Ta) Surface Mount 8-HSOP	Rohm	RS1E260ATTB1
Q5	1	GAN CGD65B200S2-TPD DFN5x6	650V / 200 mΩ GaN HEMT with ICeGaN™ Gate and Current Sense	CGD	CGD65B240SH2
Q7	1	MOSFET N-CH 120V 15A NTMFS006N12MCT1G	Power MOSFET, 120V Single N channel 93A, 6m Ohm in Power56 package	ON Semiconductor	NTMFS006N12MCT1G
R1	1	RES SMD 220R 1% 1/4W 1206	220 Ohms ±1% 0.25W, 1/4W Chip Resistor 1206 (3216 Metric) Automotive AEC-Q200 Thick Film	Stackpole Electronics	RMCF1206FT220R
R2	1	RES SMD 1M 1% 1/4W HV 1206	1 MOhms ±1% 0.25W, 1/4W Chip Resistor 1206 (3216 Metric) High Voltage Thick Film	Bourns JW Miller	CHV1206-FX-1004ELF
R3	1	RES SMD 22R 1% 1/4W 1206	22 Ohms ±1% 0.25W, 1/4W Chip Resistor 1206 (3216 Metric) Automotive AEC-Q200 Thick Film	Stackpole Electronics	RMCF1206FT22R0
R4, R5	2	RES SMD 1K 1% 1/2W 1206	1 kOhms ±1% 0.5W, 1/2W Chip Resistor 1206 (3216 Metric) Anti-Sulfur Thin Film	Stackpole Electronics	RNCP1206FTD1K00
R6, R13	2	RES SMD 47R 1% 1/10W 0402	47 Ohms ±1% 0.1W, 1/10W Chip Resistor 0402 (1005 Metric) Automotive AEC-Q200 Thick Film	Panasonic	ERJ-2RKF47R0X
R8, R9, R10, R16	4	RES SMD 10R 1% 1/10W 0402	10R Ohms ±1% 0.1W, 1/8W Chip Resistor 0402 (1005 Metric) Anti Sulfur Thin Film	Panasonic	ERJ-U02F10R0X
R11	1	RES SMD 470R 1% 1/10W 0402	470 Ohms ±1% 0.1W, 1/10W Chip Resistor 0402 (1005 Metric) Anti-Sulfur, Automotive AEC-Q200 Thick Film	Panasonic	ERJ-U02F4700X
R12, R14	2	RES SMD 1R 1% 1/10W 0402	1 Ohms ±1% 0.1W, 1/10W Chip Resistor 0402 (1005 Metric) Anti-Sulfur, Automotive AEC-Q200 Thick Film	Panasonic	ERJ-U02F1R00X

Ref	Qty	PartType	Description	Manufacturer 1	Manufacturer Part Number 1
R17, R31, R39, R41	4	RES SMD 100K 1% 1/10W 0402	100 kOhms ±1% 0.1W, 1/10W Chip Resistor 0402 (1005 Metric) Automotive AEC-Q200 Thick Film	Panasonic	ERJ-2RKF1003X
R18	1	RES SMD 100R 1% 1/16W 0402	100 Ohms ±1% 0.063W, 1/16W Chip Resistor 0402 (1005 Metric) Moisture Resistant Thick Film	Yageo	RC0402FR-07100RL
R19, R27	2	RES SMD 100R 1% 1/10W 0402	100 Ohms ±1% 0.1W, 1/10W Chip Resistor 0402 (1005 Metric) Automotive AEC-Q200 Thick Film	Panasonic	ERJ-2RKF1000X
R20	1	RES SMD 2.2R 1% 1/8W 0402	2.2 Ohms ±1% 0.167W, 1/8W Chip Resistor 0402 (1005 Metric) Thin Film	Susumu	RL0510S-2R2-F
R21	1	RES SMD 130R 1% 1/10W 0402	130 Ohms ±1% 0.1W, 1/10W Chip Resistor 0402 (1005 Metric) Automotive AEC-Q200 Thick Film	Panasonic	ERJ-2RKF1300X
R22, R26, R30, R32	4	RES SMD 10K 1% 1/10W 0402	10 kOhms ±1% 0.1W, 1/10W Chip Resistor 0402 (1005 Metric) Anti-Sulfur, Automotive AEC-Q200 Thin Film	Vishay Beyschlag	MCS0402MC1002FE000
R23	1	RES SMD 1M 1% 1/10W 0402	1 MOhms ±1% 0.1W, 1/10W Chip Resistor 0402 (1005 Metric) Automotive AEC-Q200 Thick Film	Panasonic	ERJ-2RKF1004X
R24	1	RES SMD 1K 1% 1/10W 0402	1 kOhms ±1% 0.1W, 1/10W Chip Resistor 0402 (1005 Metric) Anti-Sulfur, Automotive AEC-Q200 Thick Film	Panasonic	ERJ-U02F1001X
R25	1	RES SMD 150R 1% 1/4W 1206	150 Ohms ±1% 0.25W, 1/4W Chip Resistor 1206 (3216 Metric) Moisture Resistant Thick Film	Yageo	RC1206FR-07150RL
R28	1	RES SMD 47R 1% 1/10W 0603	47 Ohms ±1% 0.1W, 1/10W Chip Resistor 0603 (1608 Metric) Moisture Resistant Thick Film	Yageo	RC0603FR-0747RL
R29	1	RES SMD 1.5K 1% 1/10W 0402	1.5 kOhms ±1% 0.1W, 1/10W Chip Resistor 0402 (1005 Metric) Automotive AEC-Q200 Thick Film	Panasonic	ERJ-2RKF1501X
R33	1	RES SMD 2.2K 1% 1/10W 0402	2.2 kOhms ±1% 0.1W, 1/10W Chip Resistor 0402 (1005 Metric) Automotive AEC-Q200 Thick Film	Panasonic	ERJ-2RKF2201X

Ref	Qty	PartType	Description	Manufacturer 1	Manufacturer Part Number 1
R34	1	RES SMD 6.49K 1% 1/10W 0402	6.49 kOhms ±1% 0.1W, 1/10W Chip Resistor 0402 (1005 Metric) Automotive AEC-Q200 Thick Film	Panasonic	ERJ-2RKF6491X
R35	1	RES SMD 2.49K 1% 1/10W 0402	2.49 kOhms ±1% 0.1W, 1/10W Chip Resistor 0402 (1005 Metric) Automotive AEC-Q200 Thick Film	Panasonic	ERJ-2RKF2491X
R36	1	RES SMD 4.42K 1% 1/10W 0402	4.42 kOhms ±1% 0.1W, 1/10W Chip Resistor 0402 (1005 Metric) Automotive AEC-Q200 Thick Film	Panasonic	ERJ-2RKF4421X
R37	1	RES SMD 16.2K 1% 1/10W 0402	16.2 kOhms ±1% 0.1W, 1/10W Chip Resistor 0402 (1005 Metric) Automotive AEC-Q200 Thick Film	Panasonic	ERJ-2RKF1622X
R38	1	RES SMD JUMPER 0R 1/10W 0402	0 Ohms Jumper 0.1W, 1/10W Chip Resistor 0402 (1005 Metric) Automotive AEC-Q200 Thick Film	Panasonic	ERJ-2GE0R00X
R40	1	RES SMD 2.26K 1% 1/10W 0402	2.26 kOhms ±1% 0.1W, 1/10W Chip Resistor 0402 (1005 Metric) Automotive AEC-Q200 Thick Film	Panasonic	ERJ-2RKF2261X
RT1	1	VARIS 55pF 400A 517V RAD7.5mm	TVS Varistor, 300 V, 385 V, 5D Series, 810 V, Disc 5mm, Metal Oxide Varistor (MOV)	Yageo	471KD05-TR
T1	1	COIL CUSTOM TX13/7.1/4.8-3E65	Epoxy Ferrite Core Toroid Type Length Width 0.510" (12.95mm) Diameter 0.198" (5.03mm) Height	Yageo Ferroxcube	TX13/7.1/4.8-3E65
T2	1	COIL CUSTOM CSHS-EFD25-1S-12P-C ALT	Coil former horizontal smd for a EFD25/13/9	Yageo Ferroxcube	CSHS-EFD25-1S-12P-C
T3	1	TRAN PULSE WURTH 749302011	2mH Pulse Transformer 1:4.5:4.5:1 Surface Mount	Wurth Electronics	749302011
T4	1	CHOKE FAIR-RITE 60R 5A 2744045447	2 Line Common Mode Choke Surface Mount 60 Ohms 5A DCR 1.4mOhm	Fair-Rite	2744045447
TP1	1	TEST KEYSTONE 5000 RED 1mm	Red PC Test Point, Miniature Phosphor Bronze Silver Plating 0.040" (1.02mm) Hole Diameter Mounting Type	Keystone Electronics	5000
TP2	1	TEST KEYSTONE 5001 BLACK 1mm	Black PC Test Point, Miniature Phosphor Bronze Silver Plating	Keystone Electronics	5001

Ref	Qty	PartType	Description	Manufacturer 1	Manufacturer Part Number 1
			0.040" (1.02mm) Hole Diameter Mounting Type		
U1	1	IC FLYBACK NCP1345Q00D1R2G SOIC-9 NB	Converter Offline Flyback Topology 9-SOIC	ON Semiconductor	NCP1345Q00D1R2G
U2	1	REG USB MP6908AGJ-P TSOT-23-6	USB Dedicated Charging Port (DCP), Power Switch PMIC TSOT-23-6	Monolithic Power Systems	MP6908AGJ-P
U3	1	OPTO 80V 50mA 140100146000 LSOP-4	Optoisolator Transistor Output 5000Vrms 1 Channel 4-LSOP	Wurth Electronics	140100146000
U4	1	REG SHUNT ADJ TLVH431AIL3T	Shunt Voltage Reference IC Adjustable 1.24V 18 VV ±0.5% 60 mA SOT-23-3	STMicroelectronics	TLVH431AIL3T
U5	1	IC USB STUSB4710AQ1TR QFN-16	USB Controller USB 2.0 I^2C Interface 16-QFN (3x3)	STMicroelectronics	STUSB4710AQ1TR

11 Conclusion

ICeGaN is the optimum low-side switch for any current-mode controlled power supply because the power switch / current sense arrangement dissipates less power than alternatives that require a sense resistor. It also allows heatsinking directly via the ground plane. Lower power dissipation and better heatsinking lead to a cooler device.

The current sense is extremely flexible allowing:

- user-selectable temperature coefficient
- transformer drive capability which
    - breaks ground loops,
    - isolates,
    - allows the signal level to be set independently of the temperature coefficient.

ICeGaN is ideally suited to the quasi-resonant flyback converter which is a good choice for universal input high power-density PD chargers. The quasi-resonant circuit combines the simplicity of a single-switch topology with the possibility to trade losses between different components as the input voltage varies. This allows the designer to minimise the system loss under any continuous operating condition.

12 References

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