# Full GaN 65 W active clamp flyback evaluation board

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### About this document

#### Scope and purpose

This engineering report explains how to set up and run Full GaN 65 W active clamp flyback (ACF) universal charger/adapter evaluation board featuring ICQ800NLS CoolGaN™ SG HEMT as well as CoolGaN™ integrated power stage (IPS) half-bridge as shown in **Figure 1**. The board converts the universal AC input voltage to a constant 20 V DC output. At full load, the average operating frequency of this unit varies from 290 kHz to 350 kHz depending on the input voltage level. To demonstrate the operation of the board, some test points are provided to observe the signals with proper test equipment. Finally, some of the unit's performance metrics, such as hardware thermal imaging, and efficiency vs. load, are evaluated.

#### Intended audience

This engineering report is intended for power electronic design engineers, application engineers, and students who are familiar with power converters.

#### Infineon components featured

- **IQC0800NLS**
- **IGI60F2020A1L**
- **BSS126**

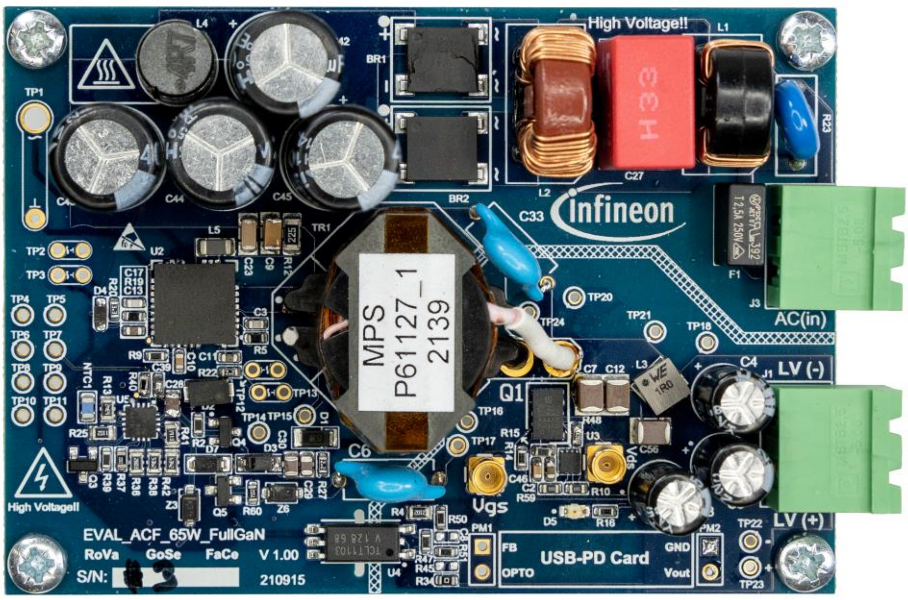


**Figure 1** Full GaN 65 W ACF evaluation board featuring ICQ800NLS CoolGaN™ SG HEMT

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# 1 Introduction

This hardware provides a quick way to evaluate the Infineon CoolGaN™ technology both in primary and secondary sides in the low-power adapter application in high-frequency ACF topology (for more information refer to [1] and [2]). As shown in **Figure 2**, the main switch and the clamp switch in an ACF converter can be replaced with low- and high-side devices in a half-bridge IPS device. The hardware features the easy-to-use IPS chipset in a small PCB area interfacing with the ACF controller, as shown in **Figure 3**.

To observe the thermal performance of the components installed on the PCB, the PCB layout is designed in a non-compact form factor with least occupied space. This board is an evaluation board and not a reference design; therefore, the PCB layout optimization and the hardware volume reduction depend on the designers' preference in terms of manufacturing approach.

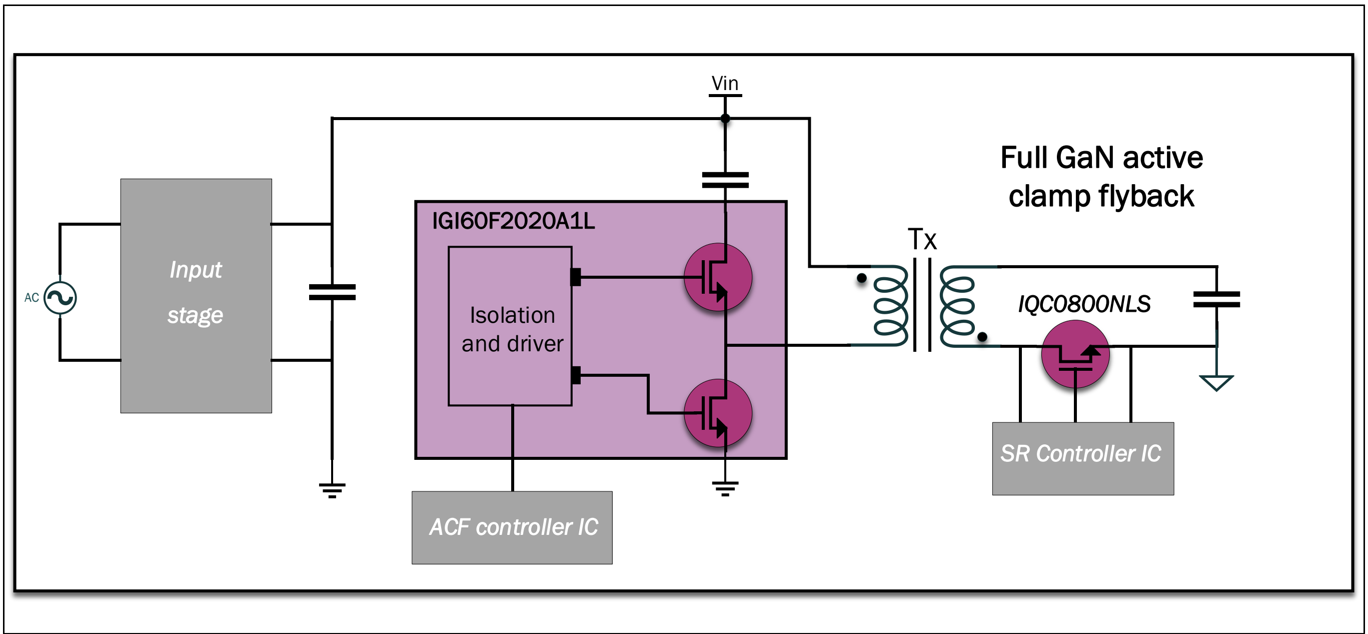



**Figure 2 CoolGaN™ technology in ACF topology**

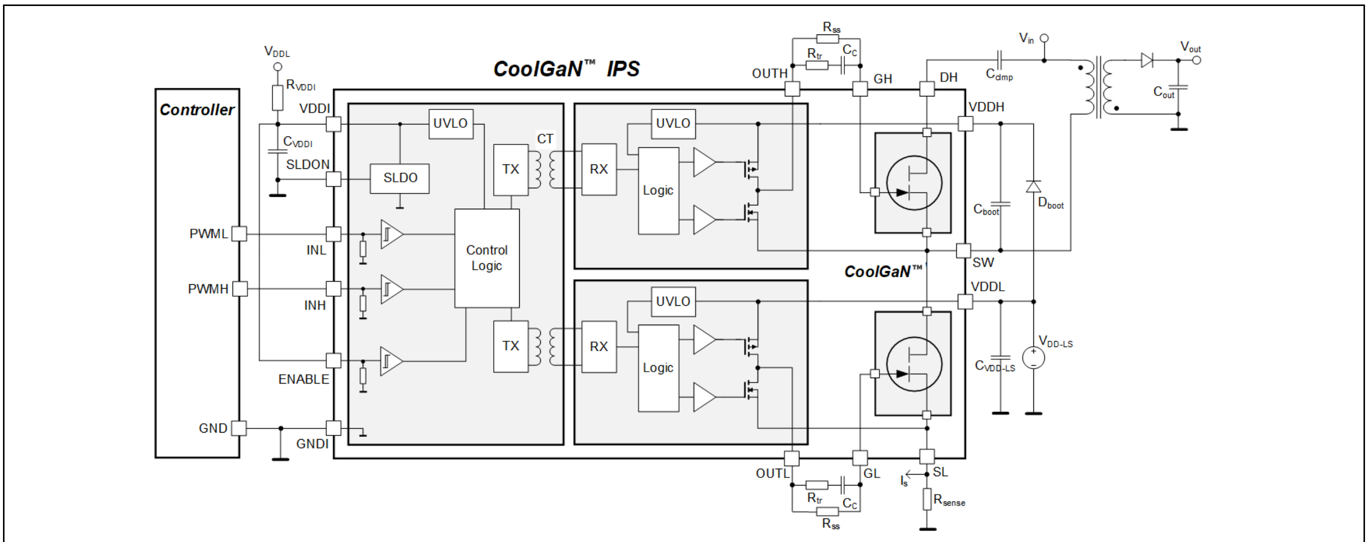



**Figure 3 CoolGaN™ IPS circuitry in ACF topology [3]**

## 1.1 Evaluation board specifications

**Table 1 Evaluation board specifications and limits**

| Parameter | Values | | | Unit | Notes |
|---|---|---|---|---|---|
| | Min. | Typ. | Max. | | |
| AC input voltage | 100 | | 240 | V | |
| AC input voltage frequency | 49 | | 62 | Hz | |
| AC input current | | | 2 | A | |
| DC output voltage | 19 | 20 | 21 | V | |
| DC output current | 0 | | 3.25 | A | |
| Efficiency (peak) | | | 93.3 | % | |
| Standby power consumption | | | < 300 | mW | |
| Rated power | | | 65 | W | |
| Operating frequency at full power | 300 | | 500 | kHz | Changes based on the input voltage |
| Operating ambient temperature | | 25 | | °C | |

*Note:* The PCB dimensions are 59 x 84 mm (max.).

# 2 Functional description

The block diagram of the hardware and their functions is shown in **Figure 4**. The AC input stage includes the protection fuse, EMI filter and rectifier stage. The CoolGaN™ IPS includes the main and clamp switches. The ACF controller drives the high-side and low-side through the PWM signals generated referred to the DC bus negative rail. The feedback signals to the controller are provided by the current sensing resistor and the optocoupler. The optocoupler is regulated by an analog shunt regulator, and it is set to regulate the output DC voltage at 20 V. The SR FET is driven by its individual controller referred to the output voltage negative rail. **Figure 5** shows a different section of the evaluation board.

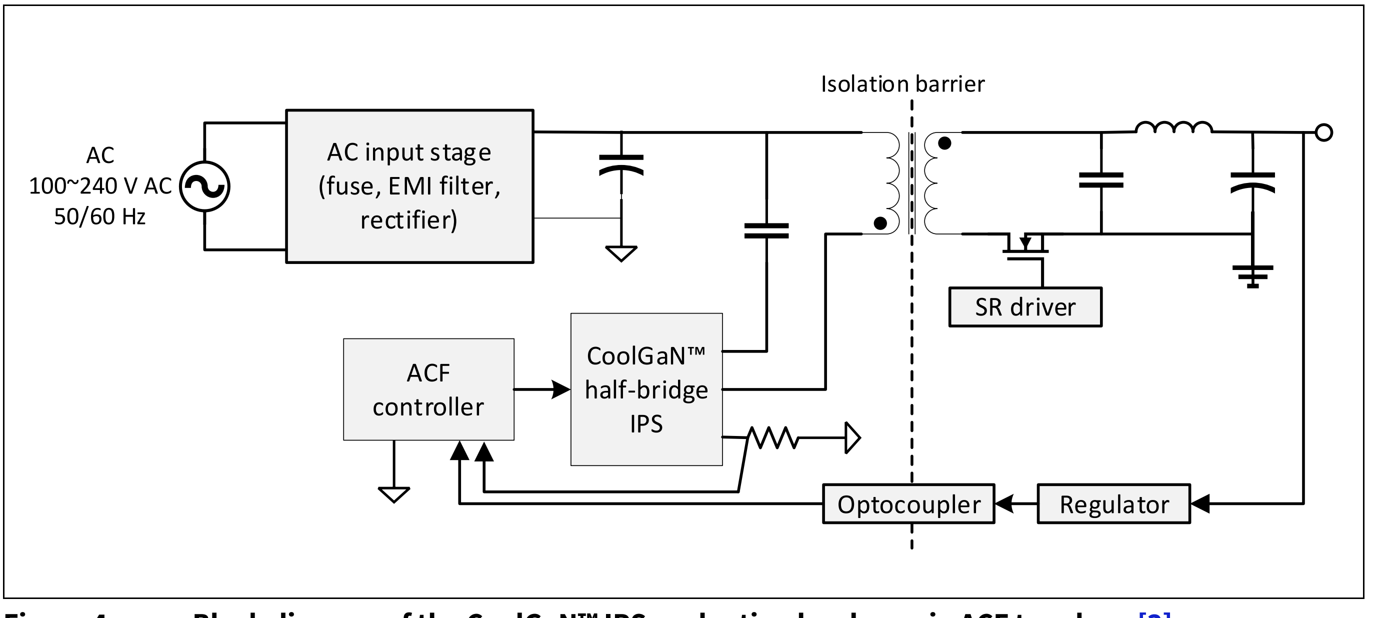



**Figure 4 Block diagram of the CoolGaN™ IPS evaluation hardware in ACF topology [3]**

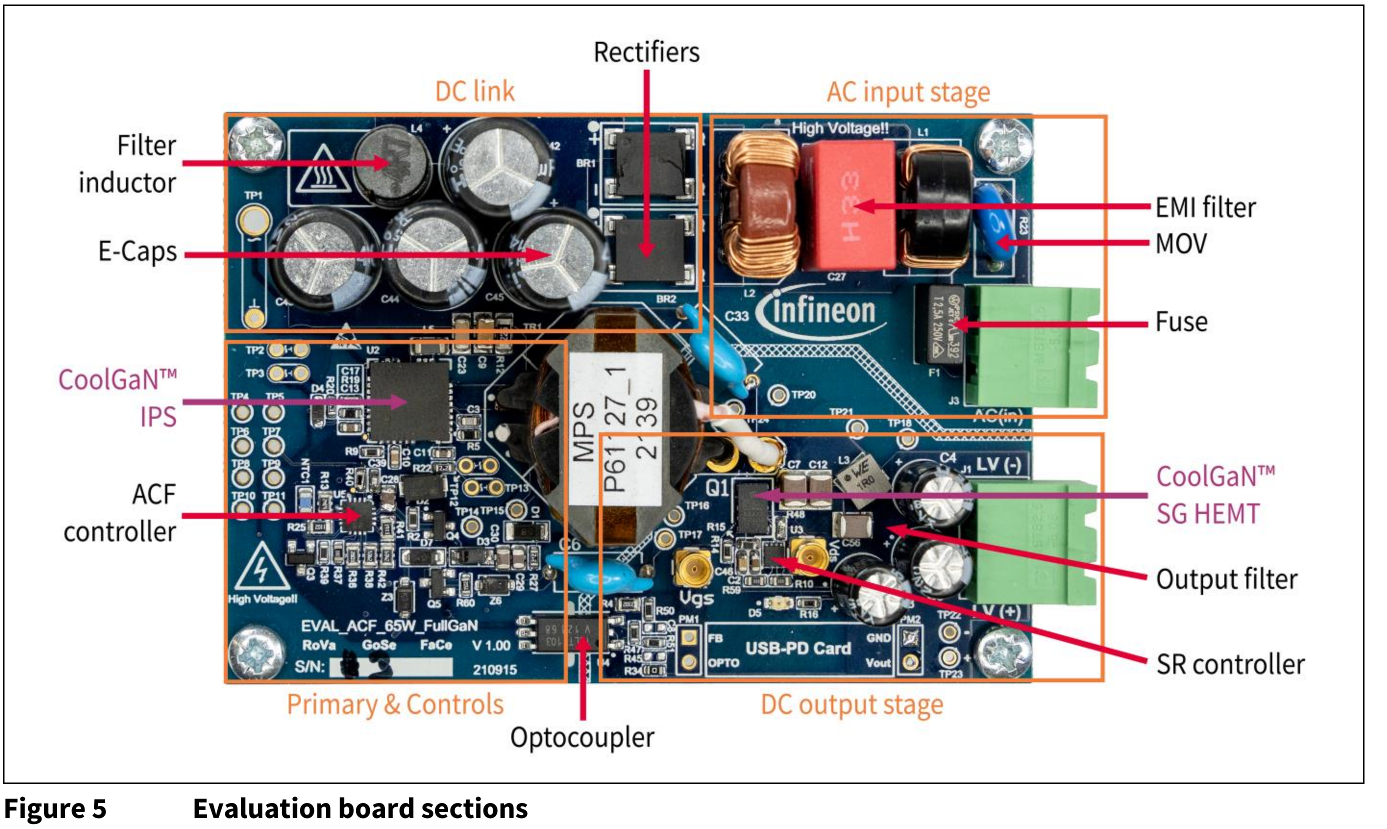



**Figure 5 Evaluation board sections**

The schematic is shown in **Figure 6**. The following sections explain each item of hardware in detail.

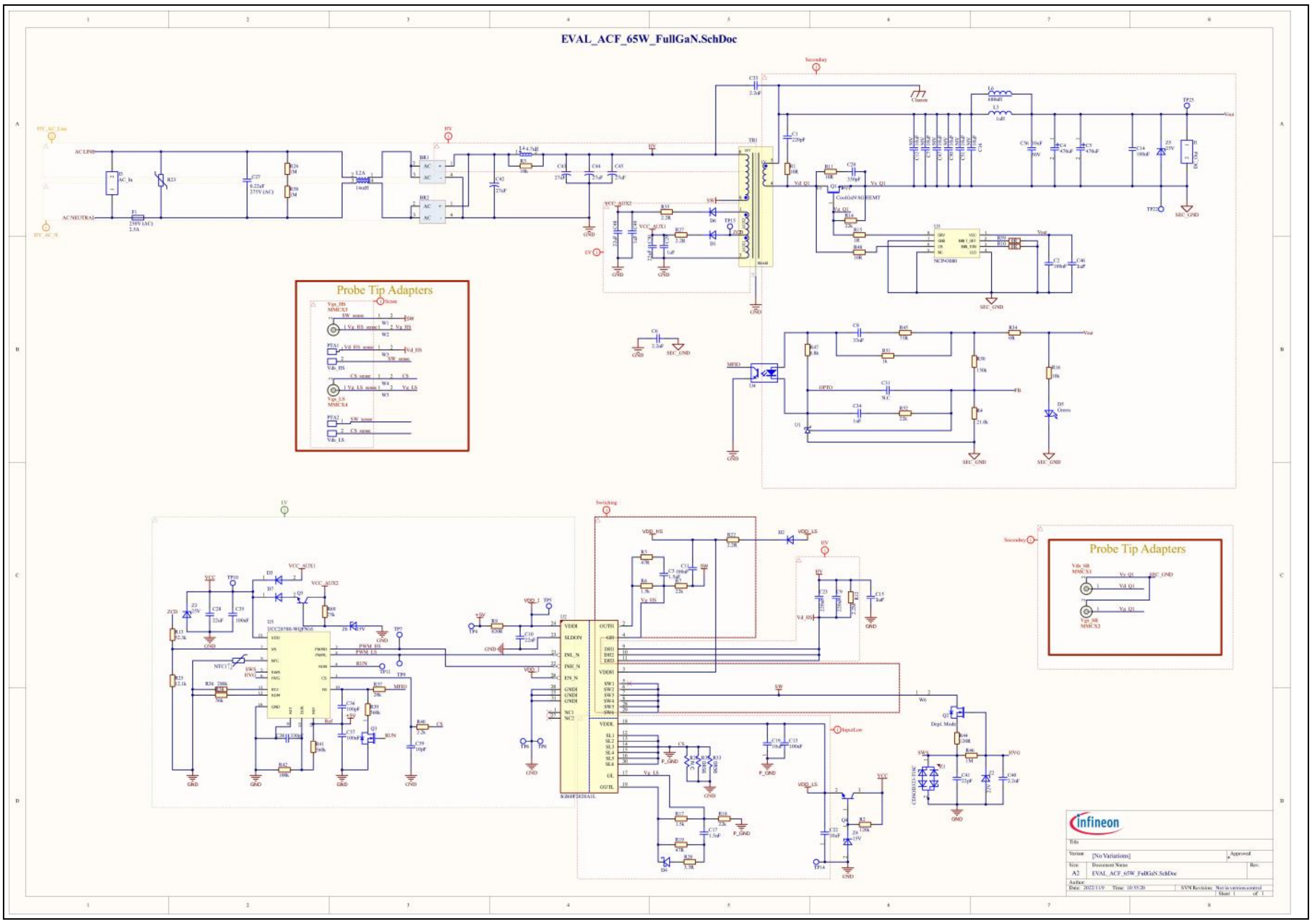



**Figure 6** **Full GaN 65 W ACF evaluation board hardware schematic**

## 2.1 CoolGaN™ half-bridge IPS circuitry

**Figure 7** shows the circuitry around the CoolGaN™ IPS half-bridge IGI60F2020A1L in this evaluation board. The ACF controller drives the logic inputs of the IPS chipset. In this application, the 3.3 V regulator inside the IPS is activated by pulling down SLDON pin 23, and the 5 V reference ACF controller is used to supply the VDDI pin through the shunt resistor (R9). The R9 value will provide about 2 mA supply to the VDDI pin, which is sufficient to operate the chipset in this application.

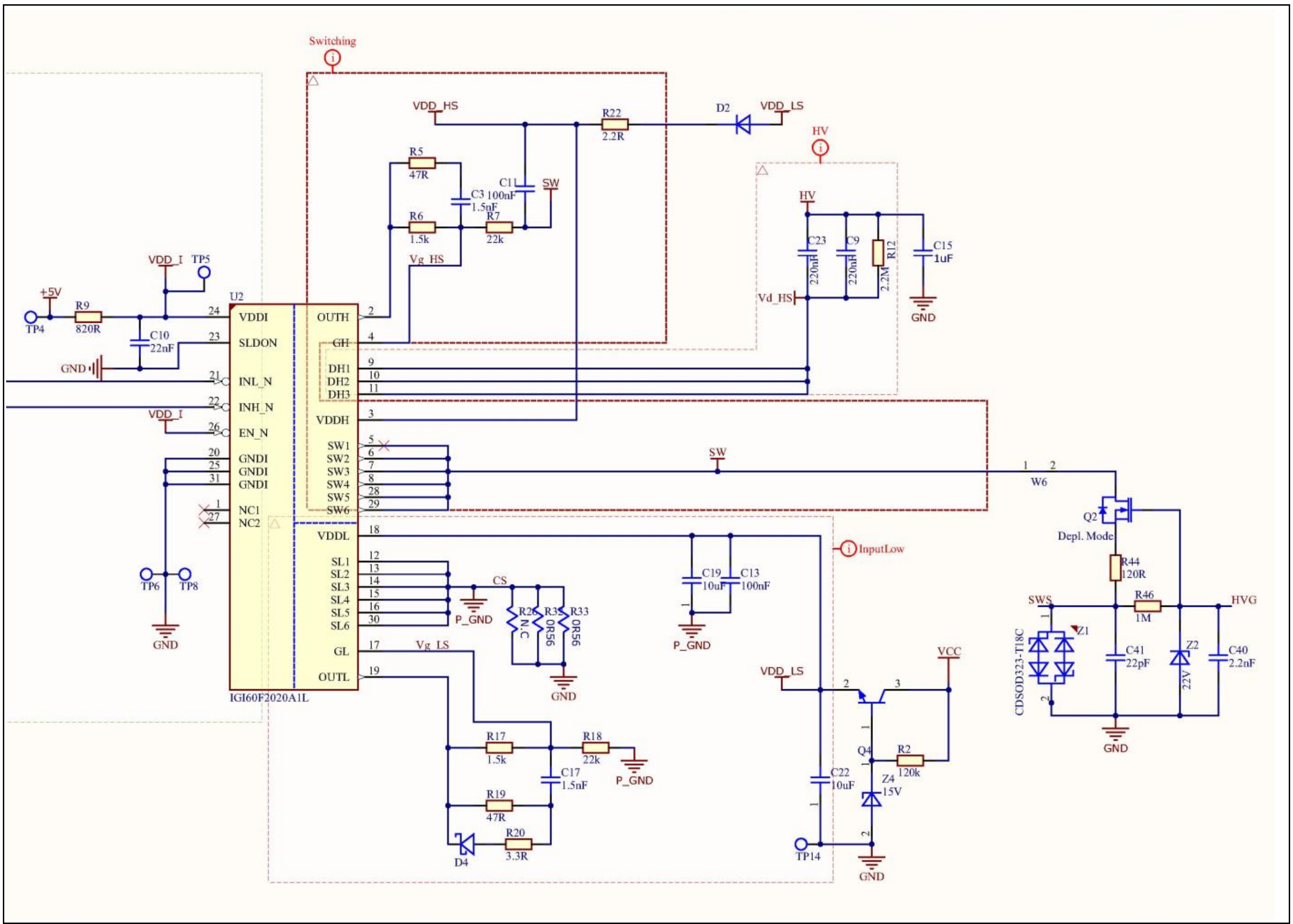


**Figure 7** **CoolGaN™ IPS circuitry in ACF adapter topology**

### 2.1.1 Low-side gate driver

Low-side gate driver power is provided by Q4 and Z5 supplied by $V_{CC}$ (supplied by transformer AUX winding rectified output). The RRC network consists of R17, R19, R20, D4, and C17 is used to drive the low-side GaN gate. For sizing of the circuit values refer to the **IGI60F2020A1L** datasheet. R18 is a standard 22k gate pull-down resistor to ensure the gate-source voltage remains at zero even when the gate driver is unpowered during start-up.

### 2.1.2 High-side gate driver

A bootstrap circuit consisting of D2, inrush limiter R22 and C11 is used to supply the high-side gate driver sourced by VDD_LS. The RRC network for this channel consists of R5, R6 and C3. As for the low-side, a standard 22k resistor is used to ensure pull-down of the high-side GaN gate during start-up.

# 3 Setup and use

Figure 8 shows the recommended configuration to measure the efficiency of the evaluation board using two channels of a power analyzer. If a power analyzer is not used, connect the AC source directly to the AC(in) terminal (J3) and the DC load to LV(+) and LV(-) on the J1 terminal. If the DC load is an electronic load, note the polarity to avoid damaging the load.

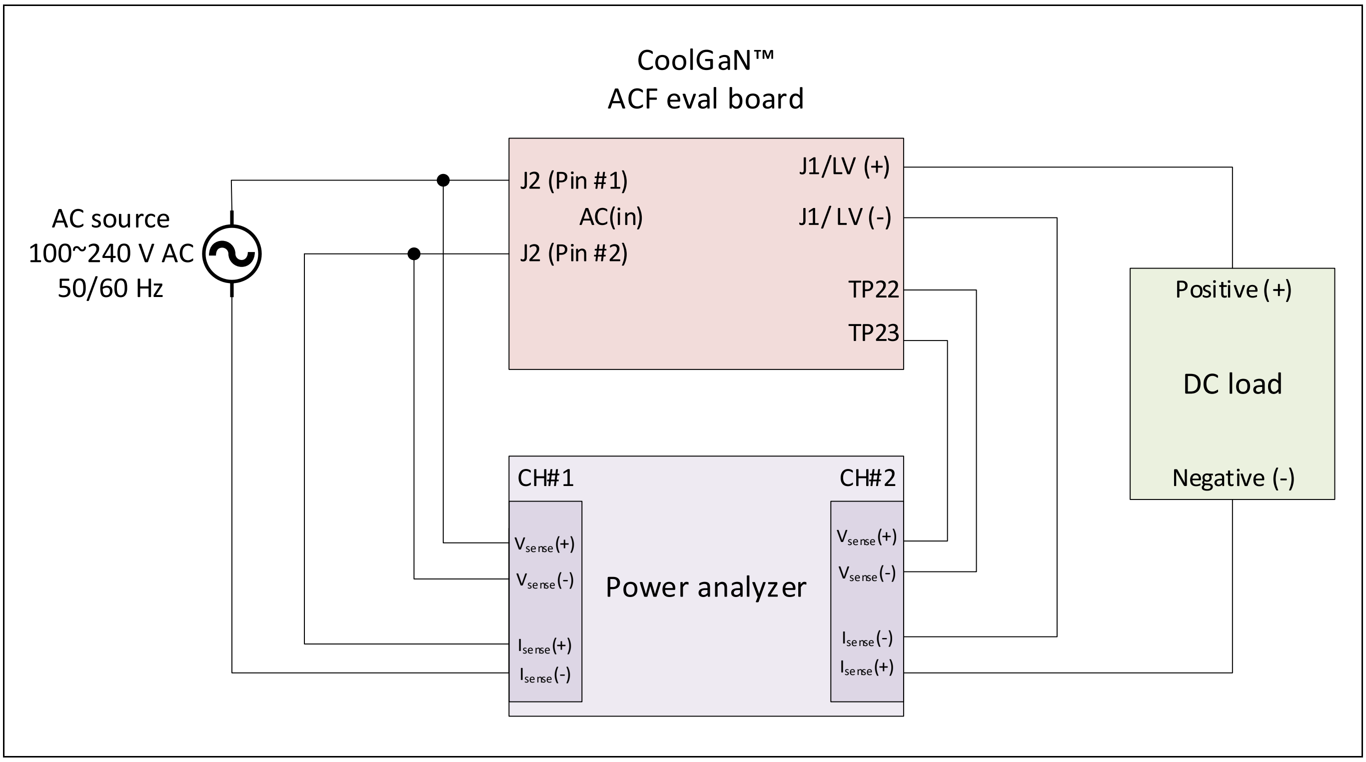



**Figure 8 Recommended connections for efficiency measurements [3]**

***Attention:*** ***This evaluation board has high-voltage terminals and exposed areas. To avoid electric shock, take appropriate measures. The hardware does not have any overvoltage protection system. Use an appropriate protective epoxy shield or box to cover the hardware to prevent any possible injury.***

***Attention:*** ***Always observe the input and output voltages. Do not operate the board above the specified input voltage (240 V AC). Use a lab test power supply with a current limit and set it to a proper value to avoid catastrophic damage to the board in case of any failure. Eye and ear protection are recommended for safety, as all power electronic labs employ it. For any safety concerns and technical questions reach out to your sales team.***

## 3.1 Test equipment needed

- AC power supply up to 240 V with sufficient current (~2 $A_{RMS}$) and with proper high-voltage cables.
- Oscilloscope for measurements and observations with standard passive probes.
- Power analyzer (two channels) to measure efficiency.
- Isolated current probe (Rogowski type) to observe the transformer current.
- Voltmeter to measure the output DC voltage.
- DC electronic load.

## 3.2 Measurement points

There are multiple test points to connect the oscilloscope for observation (either through-hole pad-pair, or single-point access). **Table 2** describes the test points.

**Table 2 Test point descriptions**

| Test point label | Description |
|---|---|
| TP4 | ACF controller +5 V reference voltage signal |
| TP5 | This test point is to observe if the VDDI logic supply of the chipset is active with about 3.3 V voltage level with respect to the digital ground |
| TP10 | $V_{CC}$ test point for the ACF controller voltage monitoring |
| TP7 | Input to the high-side logic of the IPS (INH) – ACF controller PWMH signal |
| TP6,TP8 | GND reference point (for TP3) |
| TP9 | Input to the low-side logic of the IPS (INL) – ACF controller PWML signal |
| TP23 | Adapter DC output positive |
| TP22 | Adapter DC output negative (secondary ground) |

## 3.3 Power-up and power-down sequencing

**Power up:**

Because the DC bus of the adapter is discharged at start-up, to avoid the inrush current in powering up, the AC source must be programmed to ramp up its output voltage (1~5 V/ms). Disconnect or turn off the DC load. The adapter might not start up under the load (the controller OCP might trigger). Turn on the AC source with 120 V AC/60 Hz and observe the output DC voltage (it should be around 20.3 V at no load). **Figure 9** shows the start-up of the adapter with 240 V AC supply turn-on. To apply load, DC load can be turned on after adapter power-up (we suggest using current mode and applying 0 A to 3.25 A for full-power test). **Figure 10** shows the output voltage transient when a full load-step change is applied and also when the load is turned off. Less than 1 V overshoot and undershoot is observed in a full load-step change.

**Power down:**

To power off the adapter, simply turn off the AC source. Because the DC bus has no bleeder resistor, the DC bus will remain energized if the adapter is turned off in no-load condition; therefore, we suggest turning off the AC source while the load is connected with less than 1 W load. This will de-energize the DC bus.

***Attention:*** ***This evaluation board does not have bleeder resistors, so the DC bus might remain energized. To avoid electric shock and discharge the DC bus, always turn off the source when the DC load is applied.***

***Do not touch any exposed area on the PCB even when the hardware is not operating.***

***If the LED (D5) is off, it does not indicate that the DC bus is discharged. The controller will be off when the voltage is above 50 V and below 75 V, and touching the hardware can cause electric shock.***

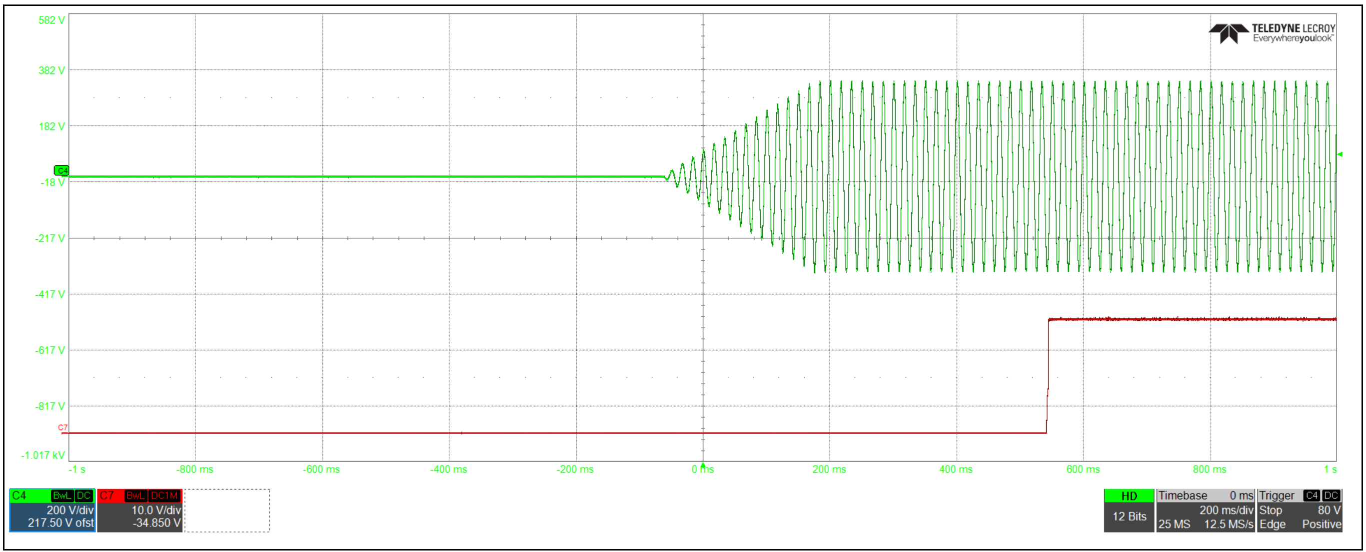



**Figure 9** DC output start-up transient with 240 V AC input (Ch4: AC input, Ch7: DC output)

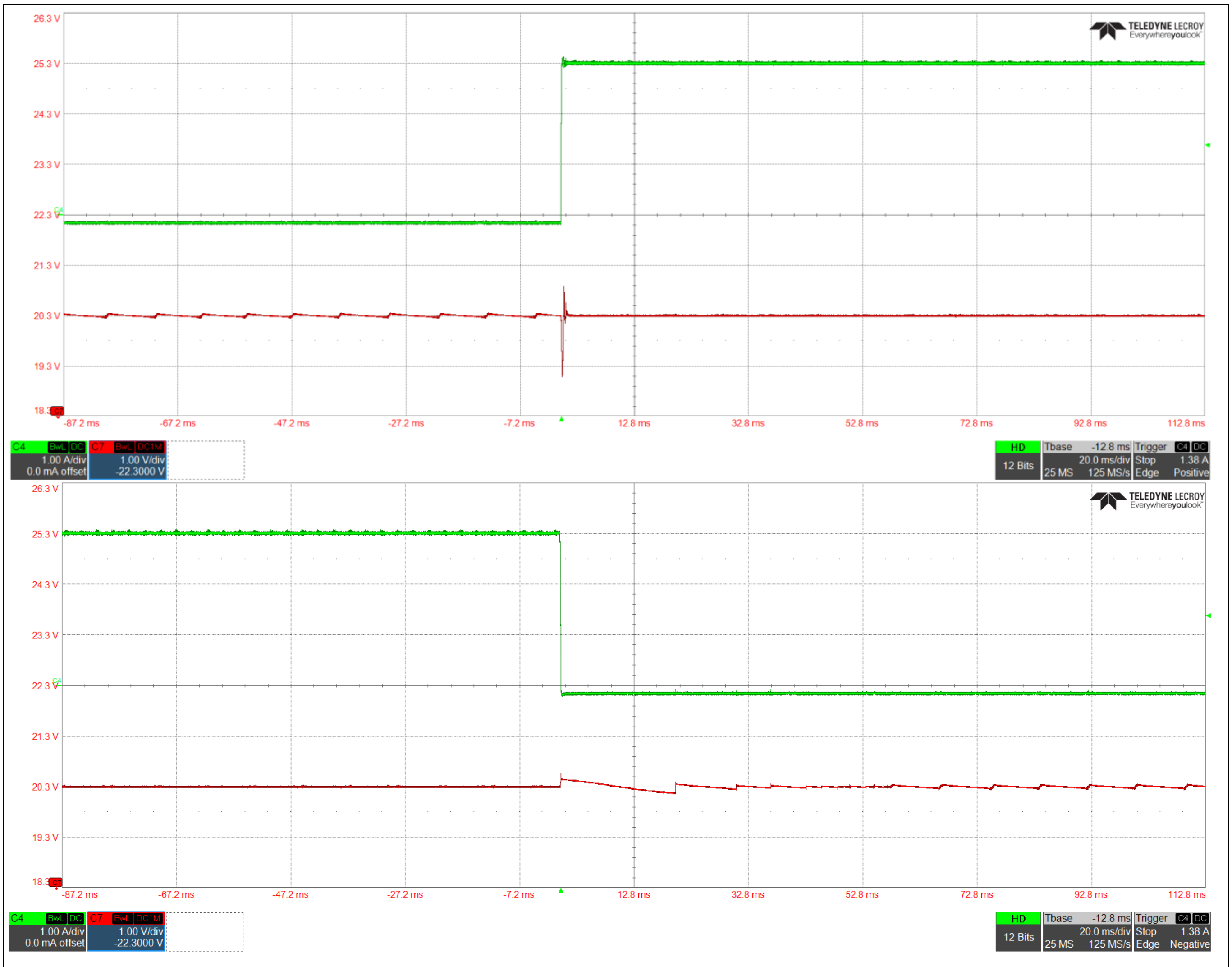



**Figure 10** DC output transient with full load-step change under 240 V AC input (Ch4: DC output load current, Ch7: DC output with 20 V offset)

## 3.4 Full-power test

After power-up at no load, different loads (0~3.25 A) can be applied. Note that the temperature of the set-up will rise depending on the load, and the efficiency measurement will be most accurate when the hardware has reached its steady-state thermal condition (transformer core has minimal loss at 70°C to 90°C). We suggest at least 30 minutes' running time to capture any efficiency data. The electrical signals can be observed immediately on the oscilloscope. **Figure 11** shows some of the waveforms captured at full power with 240 V AC input voltage.

In this condition the adapter operates at full ZVS condition at around 300 kHz. Because the current probes used here are Rogowski coil type (AC), the DC offsets are eliminated by the current probes. The active clamp resonance can be observed on the transformer secondary current when the low-side pulse-width modulation PWM signal is off.

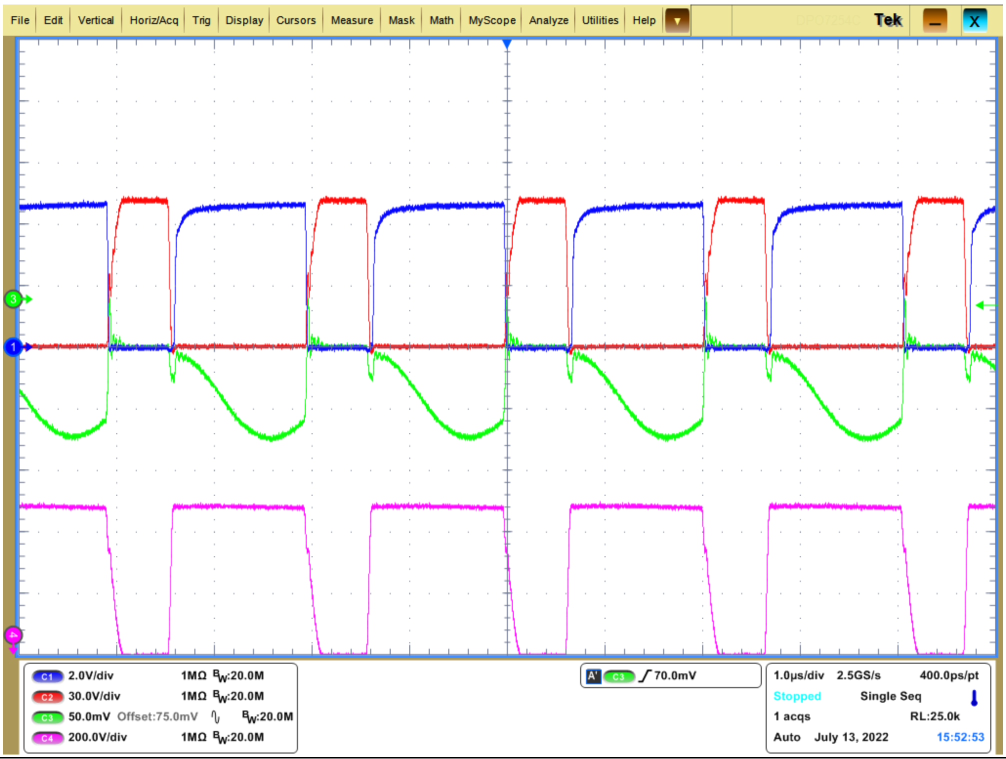



**Figure 11 ACF waveforms at full load and 240 V AC input (Ch1: SR gate voltage, SR drain-source voltage, Ch3: SR drain current (10mV/A) Ch4: Primary switching point)**

**Figure 12** shows the waveforms with 90 V AC and 120 V AC input. This evaluation board is tuned to operate at ZVS in all voltage ranges from 55 percent to full-power level. Note that increasing the input voltage increases the frequency. **Figure 13** shows the waveforms with 240 V AC input and different load conditions. Below 55 percent load the adapter operation mode changes to burst mode (the hysteresis to enter and exit burst mode might be different for each of the tested units depending on component tolerances).

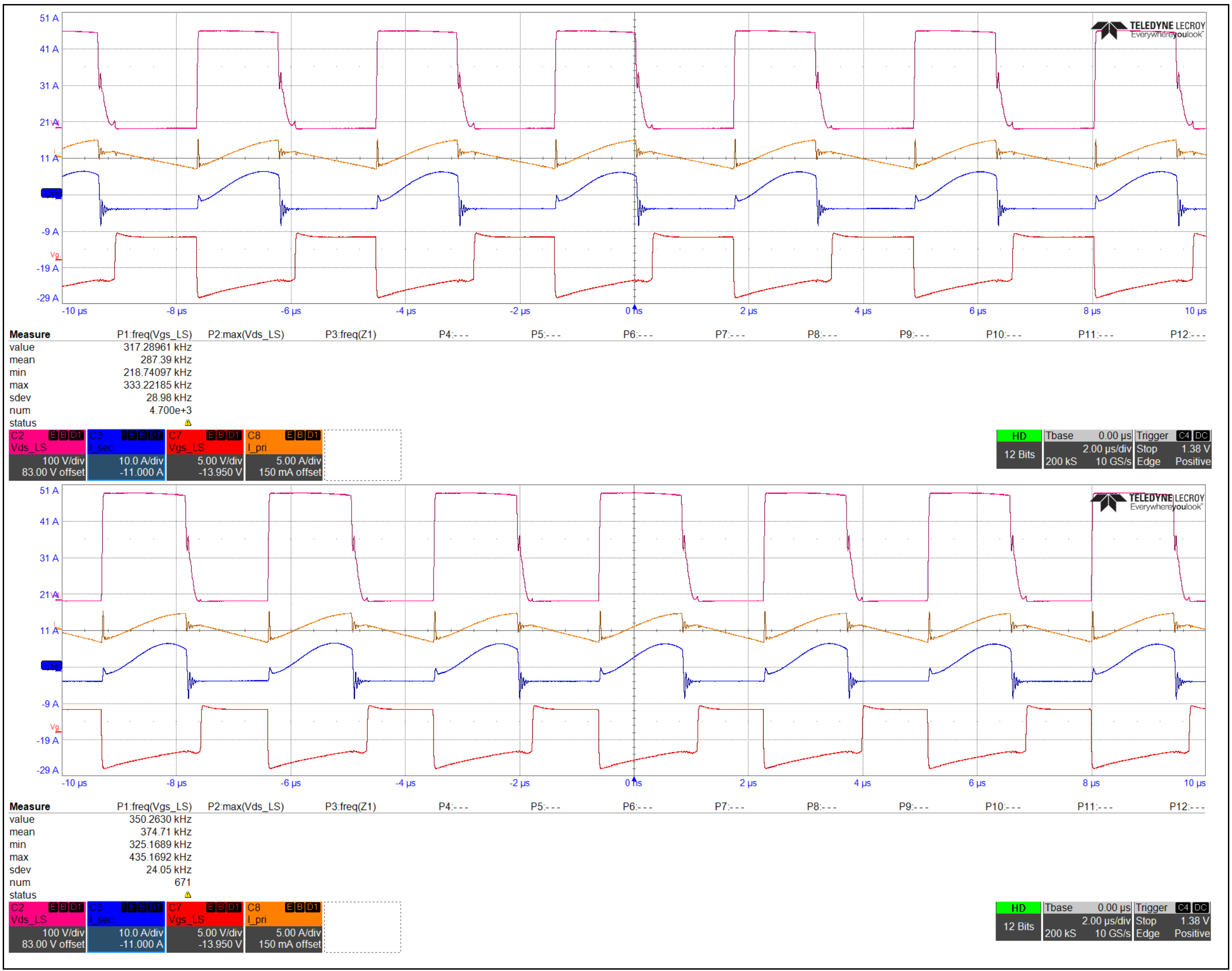
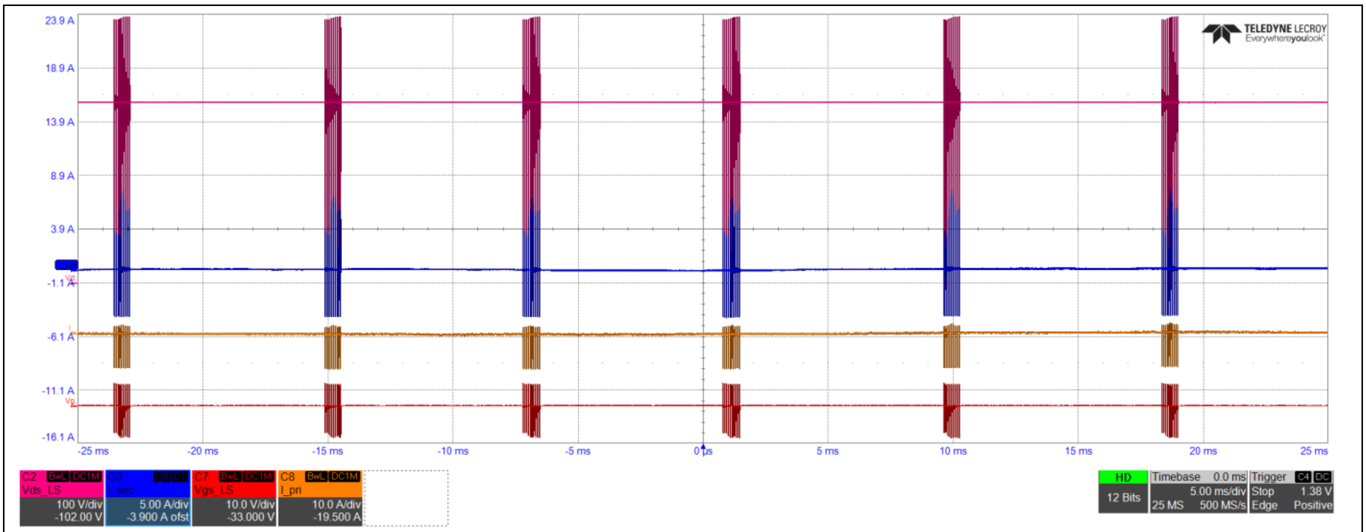
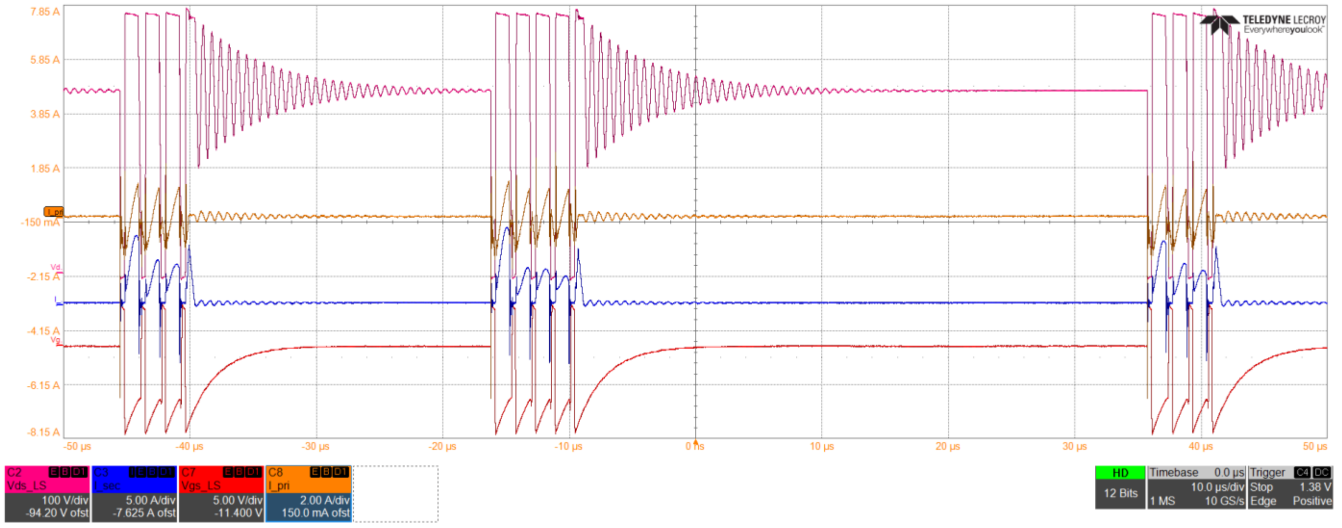


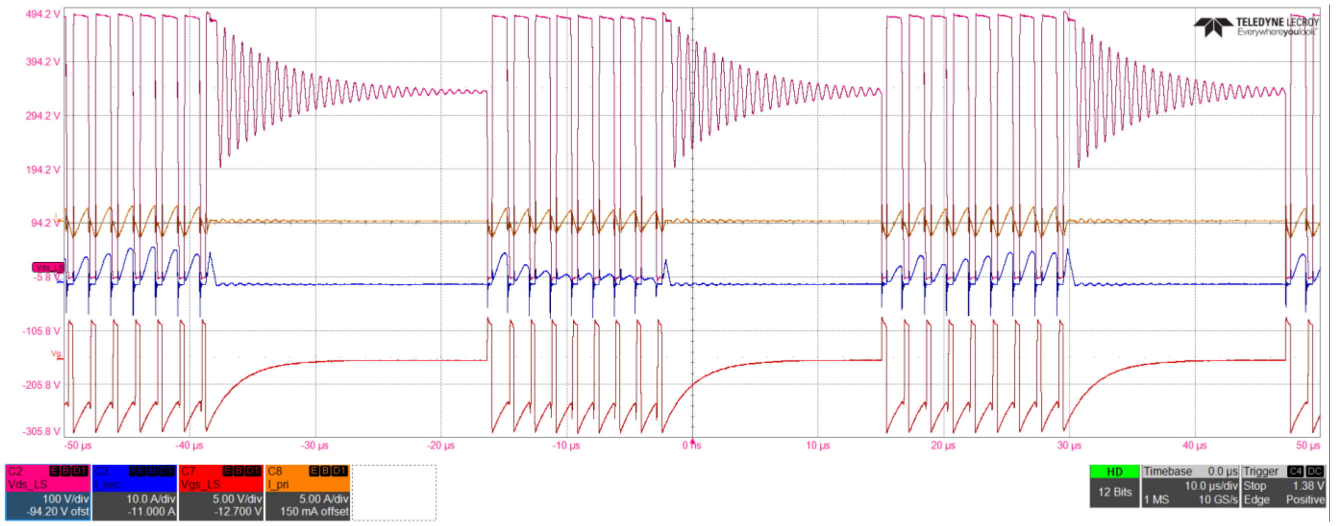

**Figure 12** **ACF waveforms at full load with 90 V AC (left/$F_{SW}$ = 317 kHz) and 120 V AC (right/$F_{SW}$ = 350 kHz) (Ch8: transformer primary current 5 A/div, Ch3: transformer secondary current 10 A/div, Ch2/Ch7: low-side GaN $V_{DS}$/PWM)**



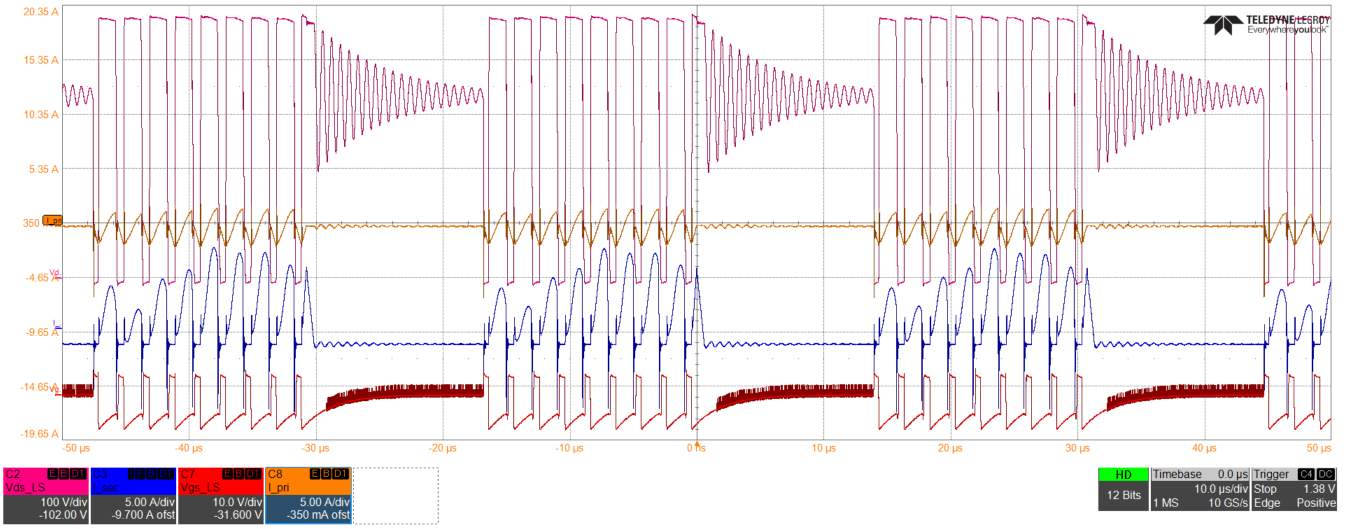

(a)


TELEDYNE LECROY
C2 Vds_LS 100 V/div -94.20 V ofst
C3 I_sec 5.00 A/div -7.625 A ofst
C7 Vgs_LS 5.00 V/div -11.400 V
C8 I_pri 2.00 A/div 150.0 mA ofst
HD 12 Bits
Timebase 0.0 µs 10.0 µs/div 1 MS 10 GS/s
Trigger Stop 1.38 V Edge Positive

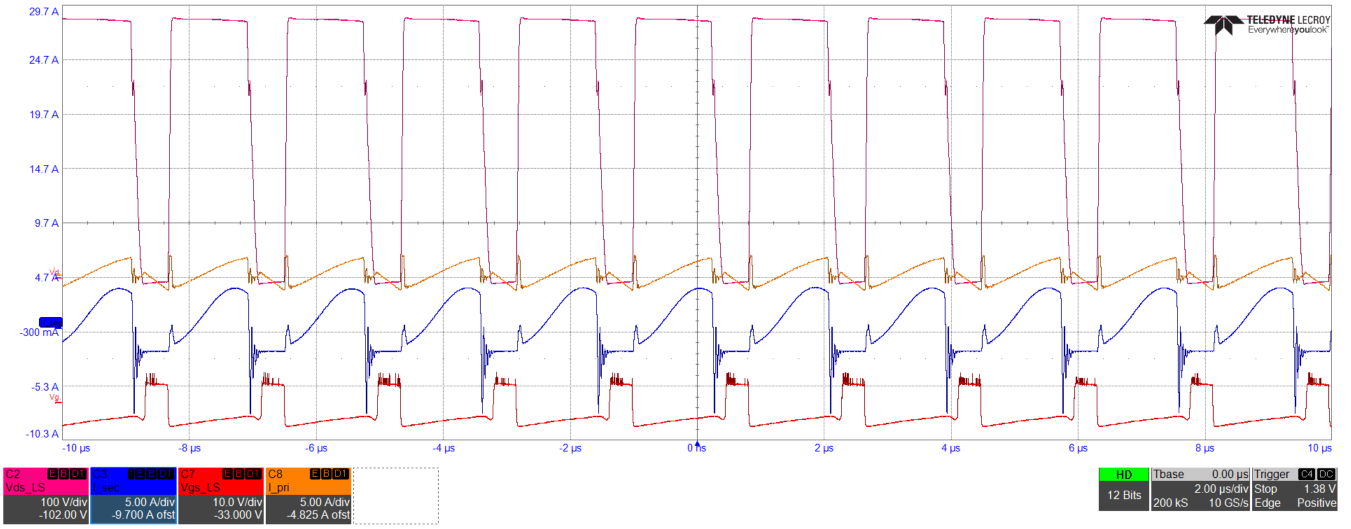
(b)


TELEDYNE LECROY
C2 Vds_LS 100 V/div -94.20 V ofst
C3 I_sec 10.0 A/div -11.000 A
C7 Vgs_LS 5.00 V/div -12.700 V
C8 I_pri 5.00 A/div 150 mA offset
HD 12 Bits
Timebase 0.0 µs 10.0 µs/div 1 MS 10 GS/s
Trigger Stop 1.38 V Edge Positive

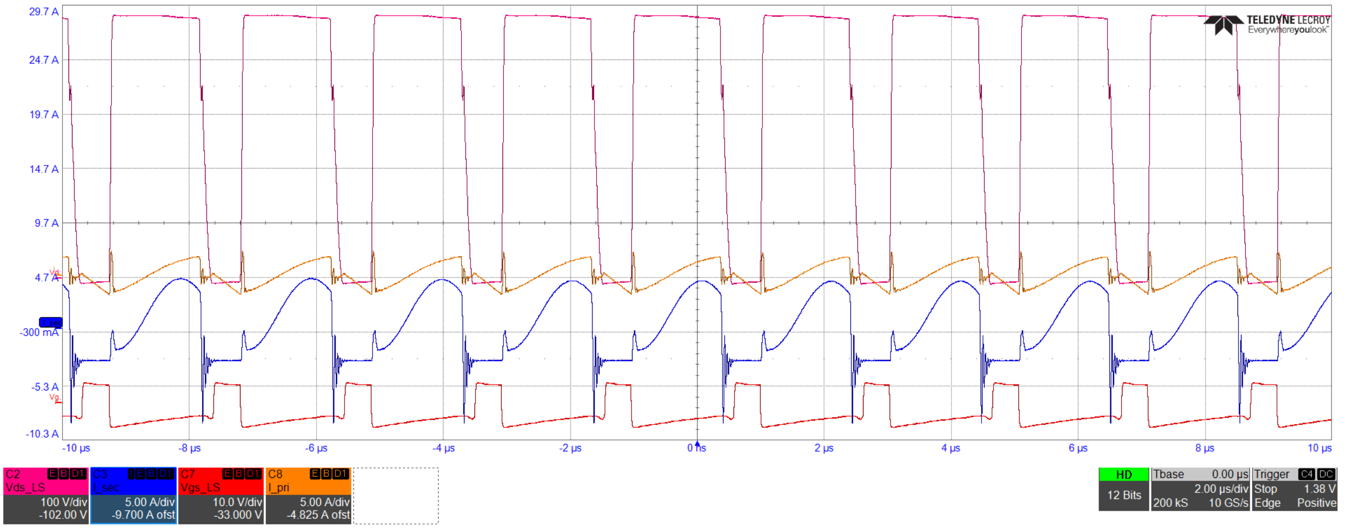
(c)


TELEDYNE LECROY
C2 Vds_LS 100 V/div -102.00 V
C3 I_sec 5.00 A/div -9.700 A ofst
C7 Vgs_LS 10.0 V/div -31.600 V
C8 I_pri 5.00 A/div -350 mA ofst
HD 12 Bits
Timebase 0.0 µs 10.0 µs/div 1 MS 10 GS/s
Trigger Stop 1.38 V Edge Positive

(d)




(e)




(f)

**Figure 13** **ACF waveforms operating under 240 V AC input and different load conditions: (a) no load, (b) 10 percent load, (c) 25 percent load, (d) 50 percent load, (e) 75 percent load and (f) 100 percent load (Ch8: transformer primary current , Ch3: transformer secondary current , Ch2/Ch7: low-side GaN $V_{DS}$/PWM)**

## 3.5 Efficiency performance

Efficiency of the evaluation board is measured with various load and input voltage conditions. **Table 3** and **Table 4** show the results with 120 V AC and 240 V AC input voltages, respectively. **Figure 14** shows the efficiency curves.

**Table 3 Efficiency performance with 120 V AC supply**

| $V_{IN}$ (AC) | $P_{OUT}$ (W) | $V_{OUT}$ (V) | $I_{OUT}$ (A) | $P_{OUT}$ (%) | Efficiency (%) | Four-point average efficiency | Full-load switching frequency |
|---|---|---|---|---|---|---|---|
| 120 | 65.246 | 20.31 | 3.2125 | 100 | 93.182 | 91.566 | 350kHz |
| 120 | 52.81 | 20.31 | 2.6 | 75 | 92.91 | | – |
| 120 | 33.012 | 20.31 | 1.6254 | 50 | 91.93 | | – |
| 120 | 19.814 | 20.31 | 0.9756 | 25 | 91.143 | | – |
| 120 | 6.6231 | 20.31 | 0.3261 | 10 | 88.663 | – | – |

**Table 4 Efficiency performance with 240 V AC supply**

| $V_{IN}$ (AC) | $P_{OUT}$ (W) | $V_{OUT}$ (V) | $I_{OUT}$ (A) | $P_{OUT}$ (%) | Efficiency (%) | Four-point average efficiency | Full-load switching frequency |
|---|---|---|---|---|---|---|---|
| 240 | 65.496 | 20.31 | 3.2248 | 100 | 92.312 | 88.56 | 477 kHz |
| 240 | 52.82 | 20.31 | 2.6007 | 75 | 91.51 | | – |
| 240 | 33 | 20.31 | 1.6247 | 50 | 89.595 | | – |
| 240 | 19.804 | 20.31 | 0.9751 | 25 | 87.244 | | – |
| 240 | 6.621 | 20.31 | 0.326 | 10 | 82.147 | – | – |

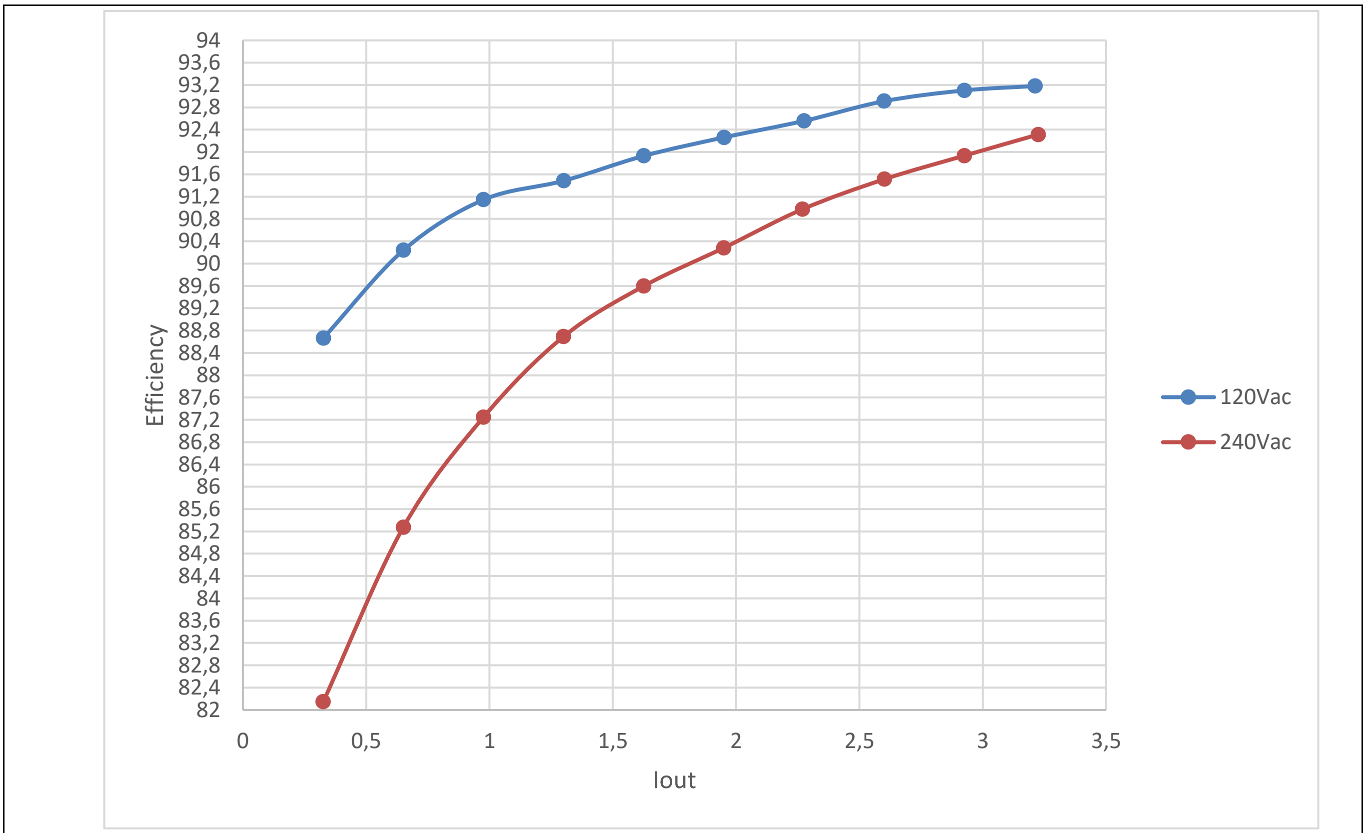



**Figure 14 ACF evaluation board efficiency curve under different input voltage and load conditions**

## 3.6 Thermal performance

Thermal images of this evaluation board are captured operating at full load and different input AC voltages. **Figure 15** shows the thermal image of the unit under test with low-line 90 V AC input and operating at full power. Due to the higher input current at low-line condition, the AC input section (AC rectifier) shows a higher temperature on the hardware. **Figure 16** and **Figure 17** show the thermal images in 120 V AC and 240 V AC input voltages, respectively.

In high-line condition (240 V AC), due to the higher switching frequency, the transformer core loss increases and operates at a high temperature (the transformer has a rated temperature of 120°C). Without any active cooling solution in all cases the CoolGaN™ IPS chipset operates around 70°C. In high-line operating condition (240 V AC) the transformer loss and SR FET loss are high due to the higher switching frequency; meanwhile, in the low-line conditions, the conduction loss in the AC rectifier is dominant.

These thermal images show that all the components run at a safe temperature with a significant safety margin.

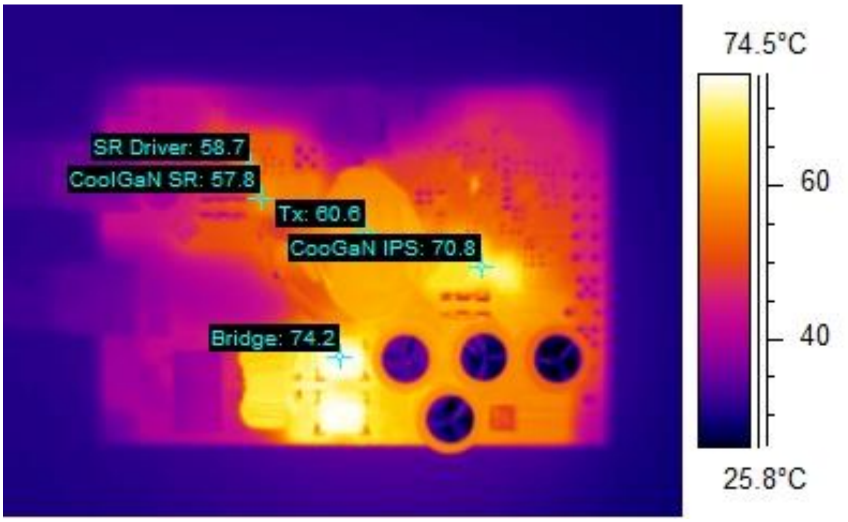



**Figure 15 Thermal image of the Full GaN ACF EVB at full power with 90 V AC input voltage**

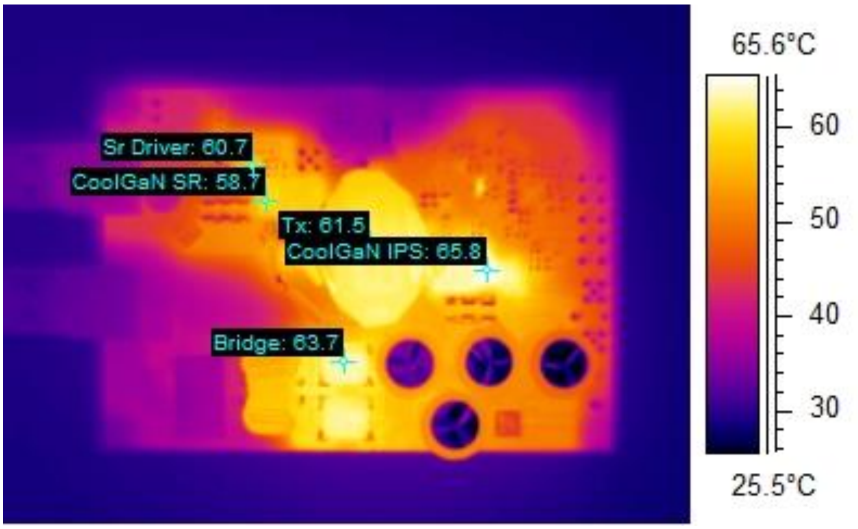



**Figure 16 Thermal image of the Full GaN ACF EVB at full power with 120 V AC input voltage**

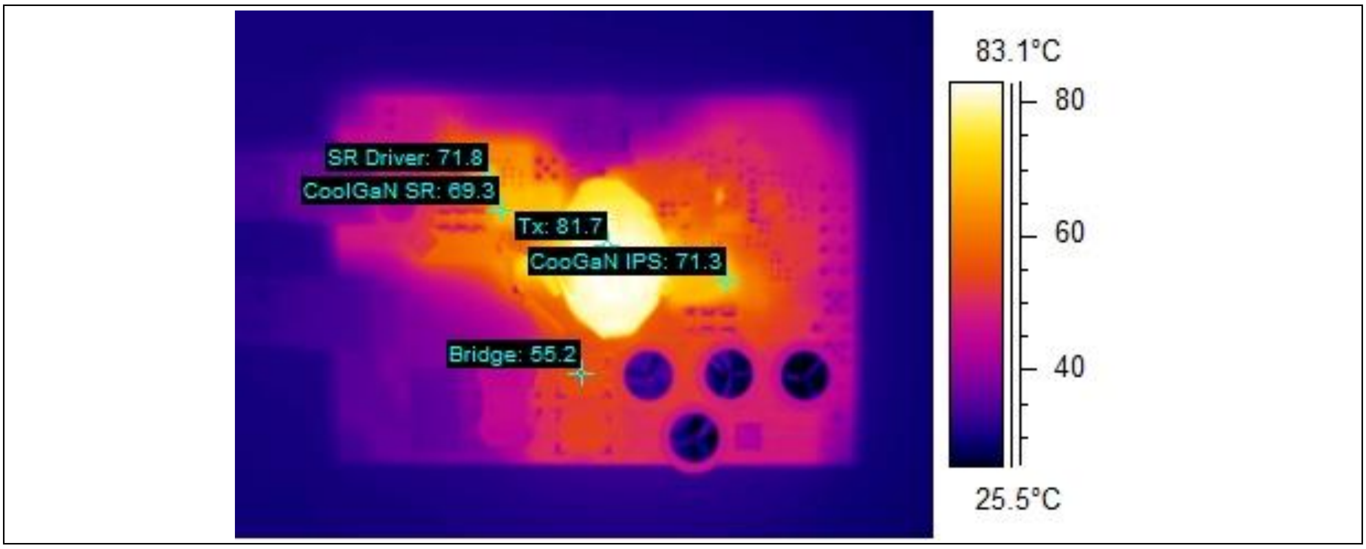



**Figure 17 Thermal image of the ACF evaluation board at full power with 240 V AC input voltage**

# 4 PCB layout

The evaluation board is 1.0 mm thick, with four layers – 70 µm thick copper on the outer layers, and 35 µm on the middle layers. The layers are shown from **Figure 18** to **Figure 21**.

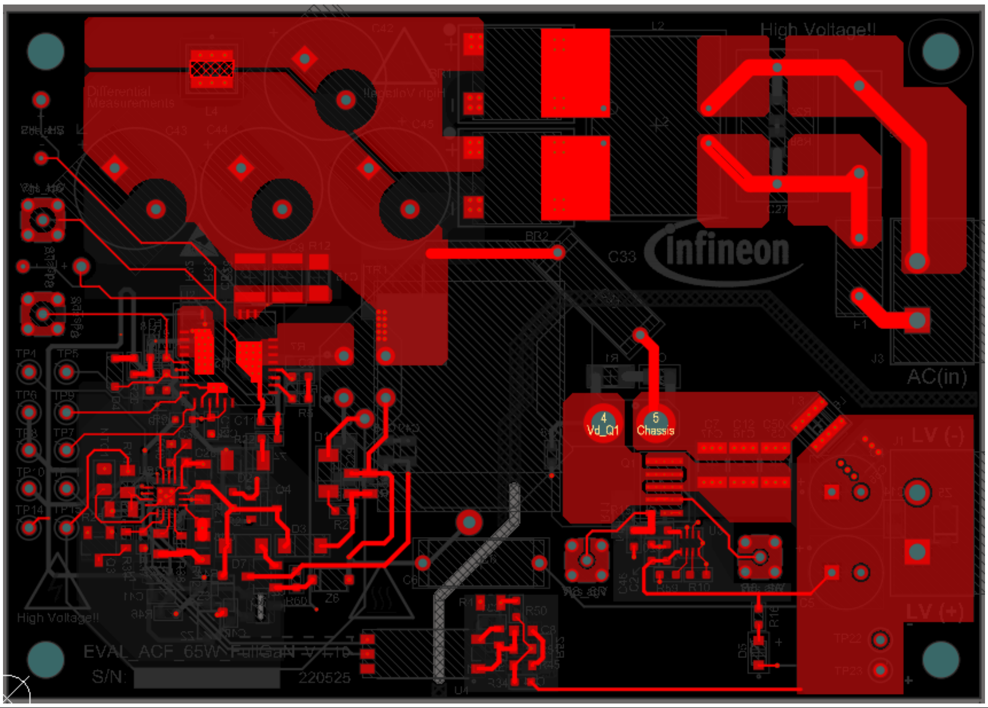



**Figure 18 Top copper layer**

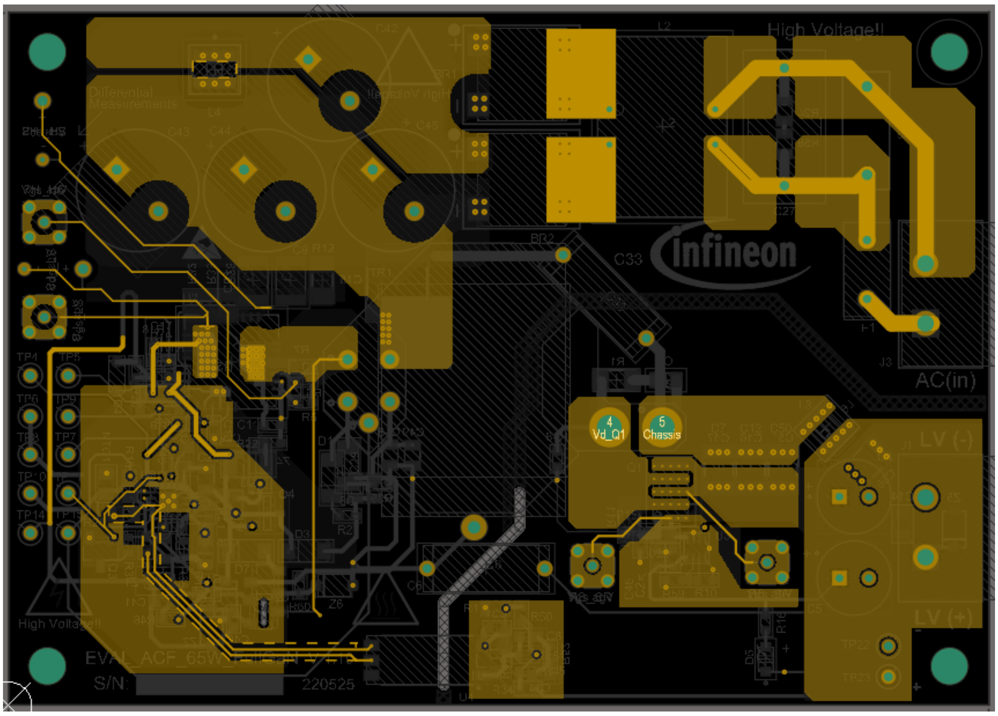



**Figure 19 Upper middle copper layer**

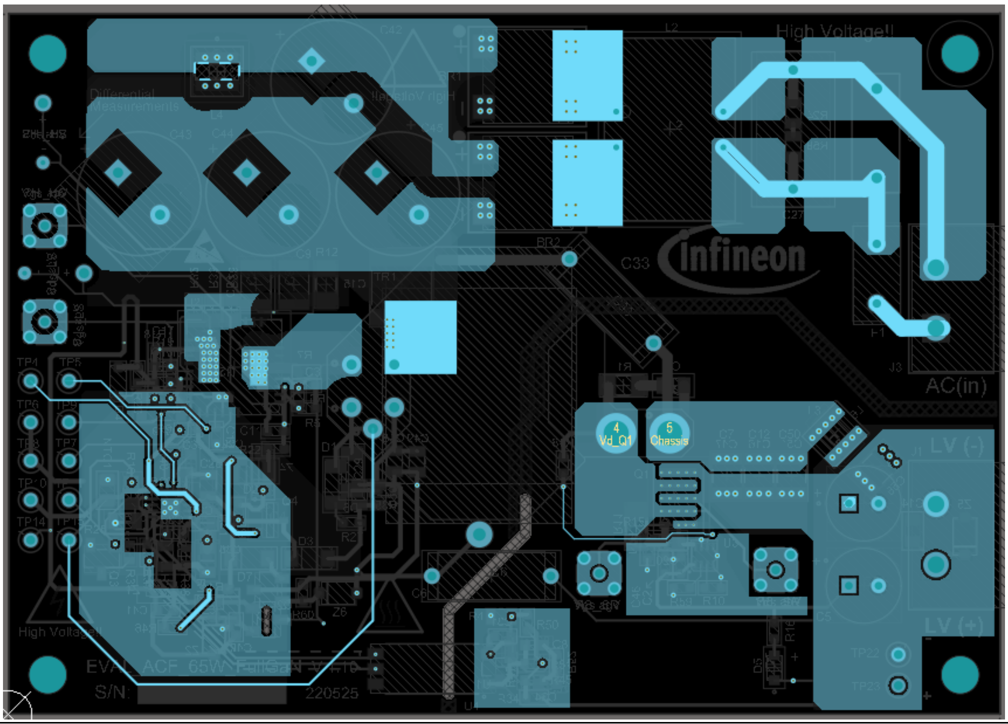


Figure 20 Lower middle copper layer

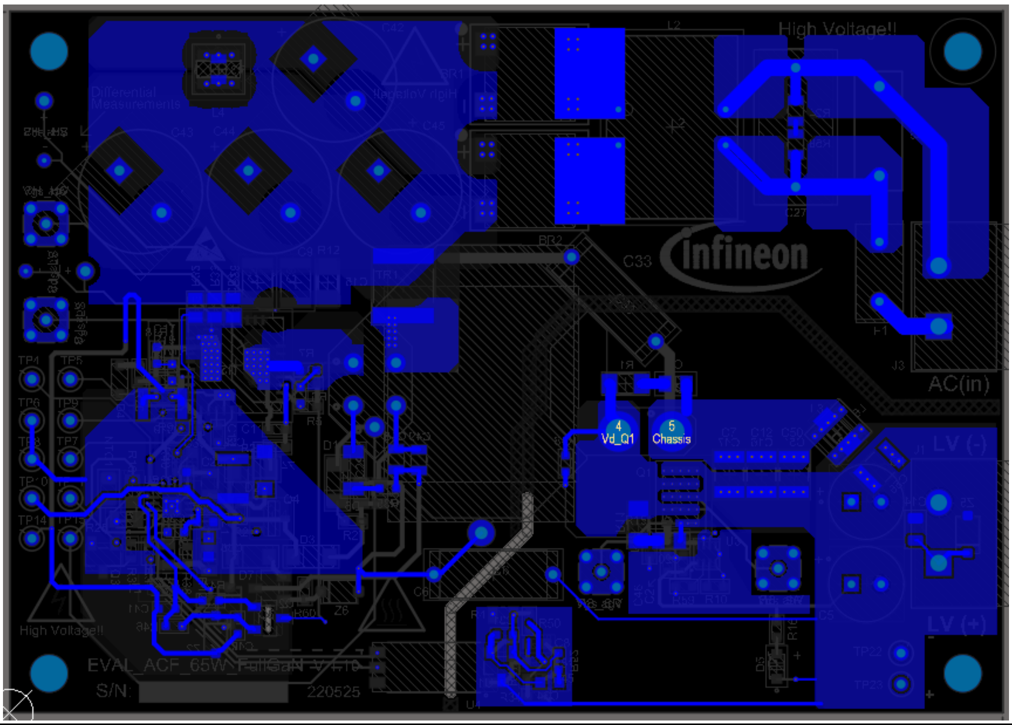


Figure 21 Bottom copper layer

# 5 Bill of materials

**Table 5** describes all of the components on the PCB.

**Table 5 PCB bill of materials**

| Designator | Description | Vendor | Quantity |
|---|---|---|---|
| BR1, BR2 | YBS bridge rectifier, single-phase 600 V 3 A | YBS3005GTR-ND | 2 |
| C1 | Ceramic capacitor 220 pF 200 V COG/NPO 0805 | GRM21A5C2D221JW01 | 1 |
| C2, C11, C13, C35, C37 | Ceramic capacitor 100 nF 35 V X7R 0603 | GMK107B7104KAHT | 5 |
| C3, C17 | Ceramic capacitor 1.5 nF 25 V COG/NPO 0603 | C0603C152J3GAC7867 | 2 |
| C4 | Aishi aluminum solid electrolytic capacitor 470 µF 25 V PZ series (6.3x 14mm) | SPZ1EM471E14O00RAXXX | 1 |
| C6, C33 | Safety capacitors 10x9x4mm 250 V AC 2200 pF | DE1E3RA222MA4BN01F | 2 |
| C7, C12, C16, C47, C50, C51, C56 | Ceramic capacitor 10 µF 50 V X7R 1210 | 12105C106K4T2A | 7 |
| C42, C43, C44, C45 | Aishi aluminum capacitor 400 V 27 µF | EWH2GM270G20OT | 4 |
| C8 | Ceramic capacitor 33 nF 25 V X7R 0603 | GRM188R71E333KA01 | 1 |
| C9, C23 | Ceramic capacitor 220 nF 200 V X7R 1210 | GRM32DR72D224KW01 | 2 |
| C10 | Ceramic capacitor 22 nF 16 V X7R 0603 | C0603C223K4RACTU | 1 |
| C14 | Ceramic capacitor 100 nF 50 V X7R 0805 | C0805C104K5RACTU | 1 |
| C15 | Ceramic capacitor 1 µF 630 V X7T 2J-Lead | CKG57NX7T2J105M500JH | 1 |
| C19, C22 | Ceramic capacitor 10 µF 50 V X7R 1210 | GRM32ER71H106KA12 | 2 |
| C20 | Ceramic capacitor 330 pF 200 V COG/NPO 0805 | GRM21A5C2D331JW01 | 1 |
| C27 | Film capacitor 0.22 µF 275V Polypropylene Metallized Radial | 890324023028 | 1 |
| C28 | Ceramic capacitor 22 µF 35 V X5R 0805 | C2012X5R1V226M125AC | 1 |
| C29, C49 | Ceramic capacitor 1 µF 35 V X7R 0805 | GRM219R7YA105KA12D | 2 |
| C30, C48 | Ceramic capacitor 22 µF 35 V X5R 0805 | C2012X5R1V226M125AC | 2 |
| C34 | Ceramic capacitor 1 nF 25 V X7R 0603 | GRM188R71E102JA01 | 1 |

| | | | |
|---|---|---|---|
| C36 | Ceramic capacitor 100 pF 25 V COG/NPO 0603 | C0603C101K3GACTU | 1 |
| C38 | Ceramic capacitor 330 pF 50 V X7R 0603 | GRM188R71H331KA01 | 1 |
| C39 | Ceramic capacitor 10 pF 50 V COG/NPO 0603 | C0603C100K5GACAUTOS | 1 |
| C40 | Ceramic capacitor 2.2 nF 25 V COG/NPO 0603 | C0603C222J3GACTU | 1 |
| C41 | Ceramic capacitor 22 pF 50 V X7R 0603 | C0603C220K5RACTU | 1 |
| C46 | Ceramic capacitor 1 µF 25 V X7R 0603 | GCJ188R71E105KA01D | 1 |
| D1, D6 | General-purpose diode 600 V 1 A SOD-123H | CSFMT108-HF | 2 |
| D2 | General-purpose diode 600 V 1 A SMA | ES1JAF | 1 |
| D3 , D7 | General-purpose diode 200 V 200m A SOD-123 | MMSD103T1G | 2 |
| D4 | Diode Schottky 30V 200mA SOD-323 | BAT54HT1G | 1 |
| D5 | LED GREEN CLEAR 0805 SMD | 150080VS75000 | 1 |
| F1 | Board-mounted fuse 2.5 A 250 V AC radial | 39212500000 | 1 |
| J1, J3 | Terminal block HDR two-position 90 degrees 5.08 mm | 1748167 | 2 |
| L2 | CMC through-hole 14 mH 94 MΩ | P5320 | 1 |
| L3 | Shielded Molded Inductor 1uH 15 MΩ | 74438356010 | 1 |
| L4 | Inductor 4.7uH 3.9A 15 MΩ | 74438357047 | 1 |
| L6 | Inductor 680nH 190mA 938 MΩ | LQH31MNR68K03 | 1 |
| NTC1 | Thermistor NTC 50 kΩ 3890k 0805 | NTHS0805N01N5002JE | 1 |
| Q1 | 100 V CoolGaN™ SG HEMT | ICQ800NLS | 1 |
| Q2 | MOSFET N-channel 600 V 0.021 A SOT-23 | BSS126H6906XTSA1CT-ND | 1 |
| Q3 | MOSFET N-channel 60 V 115 mA SOT-23-3 | 2N7002-FDICT-ND | 1 |
| Q4, Q5 | Transistor NPN 300 V 0.5 A SOT-23-3 | MMBTA42-FDICT-ND | 2 |
| R1, R11 | Resistor SMD 10 Ω 5% 1/4 W 1206 | ERJ-8GEYJ100V | 2 |
| R2 | Resistor SMD 120 kΩ 1% 1/10 W 0603 | ERJ-3EKF1203V | 1 |
| R3 | Resistor SMD 10 kΩ 1% 1/8 W 0805 | ERJ-6ENF1002V | 1 |
| R4 | Resistor SMD 21kΩ 1% 1/8 W 0805 | ERJ-6ENF2102V | 1 |
| R5, R19 | Resistor SMD 47Ω 1% 1/10 W 0603 | ERJ-3EKF47R0V | 2 |
| R6, R17 | Resistor SMD 1.5 kΩ 1% 1/10 W 0603 | ERJ-3EKF1501V | 2 |
| R7, R14, R18, R52 | Resistor SMD 22 kΩ 1% 1/10 W 0603 | ERJ-3EKF2202V | 4 |

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|---|---|---|---|
| R9 | Resistor SMD 820 Ω 1% 1/10 W 0603 | ERJ-3EKF8200V | 1 |
| R10, R59 | Resistor SMD 0 Ω 1% 1/10 W 0603 | ERJ-3GEY0R00V | 2 |
| R12 | Resistor SMD 2.2 MΩ 5% 1/4 W 1206 | ERJ-8GEYJ225V | 1 |
| R13 | Resistor SMD 52.3 kΩ 1% 1/8 W 0805 | ERJ6ENF5232V | 1 |
| R15 | Resistor SMD 1 Ω 1% 1/10 W 0603 | ERJ-3RQF1R0V | 1 |
| R16 | Resistor SMD 10 kΩ 1% 1/10 W 0603 | ERJ-3EKF1002V | 1 |
| R20 | Resistor SMD 3.3 Ω 1% 1/10 W 0603 | ERJ-3RQF3R3V | 1 |
| R22 , R27, R35 | Resistor SMD 2.2 Ω 1% 1/10 W 0603 | ERJ-3RQF2R2V | 3 |
| R23 | Varistor 430V 1.2kA Disc 7mm | B72207S0271K101 | 1 |
| R24, R58 | Resistor SMD 1 MΩ 5% 1/2 W 0805 | ERJ-P06J105V | 2 |
| R25 | Resistor SMD 12.1 kΩ 1% 1/8 W 0805 | CRCW080512K1FK | 1 |
| R32, R33 | Resistor 0.56 Ω 1% 1/3 W 0805 | RL1220S-R56-F | 2 |
| R34 | Resistor SMD 0 Ω 1% 1/10 W 0603 | RC0603FR-070RL | 1 |
| R36 | Resistor SMD 280 kΩ 1% 1/8 W 0805 | ERJ-6ENF2803V | 1 |
| R37 | Resistor SMD 20 kΩ 1% 1/10 W 0603 | ERJ-3EKF2002V | 1 |
| R38 | Resistor SMD 56 kΩ 1% 1/10 W 0603 | CRCW060356K0FK | 1 |
| R39 | Resistor SMD 560 kΩ 1% 1/10 W 0603 | CRCW0603560KFK | 1 |
| R40 | Resistor SMD 2.2 kΩ 1% 1/10 W 0603 | RC0603FR-072K2L | 1 |
| R41 | Resistor SMD 560 kΩ 1% 1/8 W 0805 | CRCW0805560KFK | 1 |
| R42 | Resistor SMD 100 kΩ 1% 1/8 W 0805 | CRCW0805100KFKEA | 1 |
| R44 | Resistor SMD 120 Ω 1% 1/10 W 0603 | ERJ-3EKF1200V | 1 |
| R45 | Resistor SMD 75 Ω 1% 1/10 W 0603 | RC0603FR-0775RL | 1 |
| R46 | Resistor SMD 1 MΩ 1% 1/10 W 0603 | ERJ-3EKF1004V | 1 |
| R47 | Resistor SMD 6.8 kΩ 1% 1/10 W 0603 | CRCW06036K80FK | 1 |
| R48 | Resistor SMD 10 Ω 1% 1/10 W 0603 | ERJ-3EKF10R0V | 1 |
| R50 | Resistor SMD 150 kΩ 1% 1/10 W 0603 | ERJ-3EKF1503V | 1 |
| R51 | Resistor SMD 1 kΩ 1% 1/10 W 0603 | RC0603FR-071KL | 1 |
| R60 | Resistor SMD 75 kΩ 1% 1/10 W 0603 | ERJ-3EKF7502V | 1 |
| TR1 | ACF RM8 65 W transformer 75 µH | 750841142r00 | 1 |

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|---|---|---|---|
| U1 | Shunt Voltage Reference IC 2.5V 100mA SOT-23-3 | ATL431BQDBZR | 1 |
| U2 | CoolGaN™ IPS 600 V 200 mΩ | IGI60F2020A1L | 1 |
| U4 | Vishay TCLT1103 DC input phototransistor output optocoupler SMD five-pin SOP | TCLT1103CT-ND | 1 |
| U3 | ON Semiconductor NCP43080 SR PWM controller WDFN8 (DRV clamp 4.7 V) | NCP43080AMTTWG | 1 |
| U5 | Adaptive ZVS Controller UCC28780 | UCC28780RTET | 1 |
| Z1 | TVS Diode Array Series,18V, 45VC | CDSOD323-T18C | 1 |
| Z3, Z5 | ON Semiconductor SMD Zener diode 25 V 500 mW SOD-123 two-pin | SZMMSZ5253BT1GOSCT-ND | 2 |
| Z2 | ON Semiconductor Zener diode 22 V 5% 500 mW SMT two-pin SOD-123 | SZMMSZ5251BT1GOSCT-ND | 1 |
| Z4 | Zener Diode 15V 500mW ±5% SOD-123 | DDZ9702-7 | 1 |
| Z6 | Zener Diode 15V 500mW ±5% SOD-123 | MMSZ4702T1G | 1 |

# References


[1] Vartanian,R./ Veereddy, D/Medina-Garcia, A: *GaN based Integrated Power Stages (IPS) for Low Power Adapter/Charger Applications*; PCIM Europe digital days 2021; International Exhibition and Conference for Power Electronics, Intelligent Motion, Renewable Energy and Energy Management; 2021, pp. 1–6

[2] Infineon Technologies AG: *600 V CoolMOS™ PFD7 SJ MOSFET for high power density adapters and motor drive*; **Available online**

[3] Infineon Technologies AG: *ACF 65 W adapter evaluation board with CoolGaN™ IPS half-bridge evaluation board with IGI60F2020A1L*

# Revision history

| Document version | Date of release | Description of changes |
|---|---|---|
| V 1.0 | 2023-01-26 | Initial release |
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