*EVM User's Guide: LMG3622EVM-082*

# *Using the LMG3622EVM-082 65-W USB-C PD High-Density Quasi-Resonant Flyback Converter*

## Description

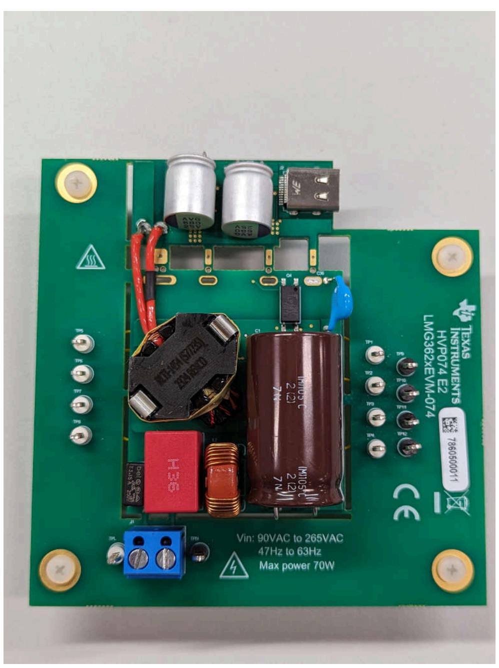
The LMG3622EVM-082 is a 65-W USB-C PD evaluation module (EVM) for evaluating an off-line quasi-resonant flyback adapter for AC/DC adapters, chargers, USB wall outlets, and other applications. The EVM meets CoC Tier 2 and DoE Level 6 efficiency requirements. The EVM is intended for evaluation purposes and is not intended to be an end product. The LMG3622EVM-082 converts input voltage of 90 $V_{RMS}$ to 265 $V_{RMS}$ down to a selectable USB-C PD output voltage 20 $V_{DC}$, with a max 3.25 A, and to 5 $V_{DC}$, 9 $V_{DC}$, and 15 $V_{DC}$, with a max 3.00-A output current rating. The main device used in this design is the LMG3622, 650-V integrated GaN FET with current sense emulation.

## Features

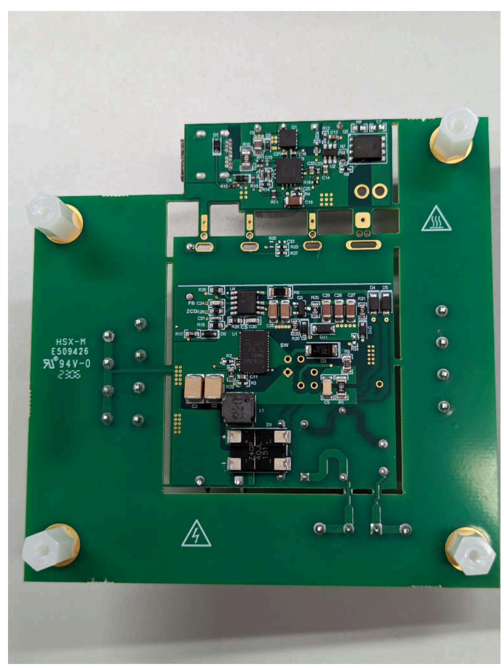
- 93-94% Efficiency under full-load operation under entire input voltage range
- 28W/in$^3$ Power density enabled by 180-kHz maximum switching frequency
- Current sense emulation greatly reduces power losses associated with traditional current sensing circuitry
- Integration of GaN, driver, OCP, and OTP simplifies design, reduces BOM count, and increases system robustness
- USB-C output enables full system-level evaluation for end-equipments like adapters, notebook chargers, USB wall outlets

## Applications

- USB-C PD Power Adapters
- AC-to-DC or DC-to-DC auxiliary power supplies
- High-density AC-to-DC converters / Adapters for notebook computers, tablet computers, TV, and set-top box
- USB-C PPS Power Adapters




**LMG3622EVM-082 (Top View)**



**LMG3622EVM-082 (Back View)**

# 1 Evaluation Module Overview

## 1.1 Introduction

The LMG3622EVM-082 facilitates the evaluation of LMG3622, Integrated GaN FET with current sense emulation, within an AC-DC QR flyback power converter. The EVM is designed for a universal AC input range of 90VAC-265VAC and follows the USB PD 3.0 output protocol of 20 V/15 V/9 V/5 V. This user guide provides a high-voltage safety overview, recommended test setup, resulting efficiency results, thermals, waveforms, and conducted EMI performance.

## 1.2 Kit Contents

- 65-W USB-C QR Flyback Evaluation Module
- Quick Start Guide
- High Voltage Notice

## 1.3 Specification

| Input | Output | Max Output Power |
|---|---|---|
| 90VAC-265VAC<br>47-63 Hz | 20 V/3.25A, 15 V/3.00A, 9 V/3.00A, 5 V/3.00A | 65 W |

## 1.4 Device Information

The LMG3622 is a 650-V 120-mΩ GaN power FET intended for switch-mode power-supply applications. The LMG3622 simplifies design and reduces component count by integrating the GaN FET and gate driver in a 8-mm by 5.3-mm QFN package. Programmable turn-on slew rates provide EMI and ringing control. The current-sense emulation reduces power dissipation compared to the traditional current sense resistor and allows the low-side thermal pad to be connected to the cooling PCB power ground. The LMG3622 supports converter light-load efficiency requirements and burst-mode operation with low quiescent currents and fast start-up times. Protection features include under-voltage lockout (UVLO), cycle-by-cycle current limit, and overtemperature protection. Overtemperature protection is reported with the open-drain FLT pin.

## 1.5 General Texas Instruments High Voltage Evaluation (TI HV EVM) User Safety Guidelines


Always follow TI’s setup and application instructions, including use of all interface components within the recommended electrical rated voltage and power limits. Always use electrical safety precautions to help ensure your personal safety and those working around you. Contact TI's Product Information Center http://support/ti./com for further information.

**Save all warnings and instructions for future reference.**

> **WARNING**
>
> Failure to follow warnings and instructions can result in personal injury, property damage or death due to electrical shock and burn hazards.

The term TI HV EVM refers to an electronic device typically provided as an open framed, unenclosed printed circuit board assembly. It is *intended strictly for use in development laboratory environments, solely for qualified professional users having training, expertise and knowledge of electrical safety risks in development and application of high voltage electrical circuits. Any other use and/or application are strictly prohibited by Texas Instruments.* If you are not qualified, then you should immediately stop from further use of the HV EVM.

1. Work Area Safety
   a. Keep work area clean and orderly.
   b. Qualified observers must be present anytime circuits are energized.
   c. Effective barriers and signage must be present in the area where the TI HV EVM and the interface electronics are energized, indicating operation of accessible high voltages can be present, for the purpose of protecting inadvertent access.
   d. All interface circuits, power supplies, evaluation modules, instruments, meters, scopes and other related apparatus used in a development environment exceeding 50Vrms/75VDC must be electrically located within a protected Emergency Power Off EPO protected power strip.
   e. Use stable and nonconductive work surface.
   f. Use adequately insulated clamps and wires to attach measurement probes and instruments. No freehand testing whenever possible.
2. Electrical Safety
   As a precautionary measure, a good engineering practice is to assume that the entire EVM can have fully accessible and active high voltages.
   a. De-energize the TI HV EVM and all the inputs, outputs and electrical loads before performing any electrical or other diagnostic measurements. Revalidate that TI HV EVM power has been safely de-energized.
   b. With the EVM confirmed de-energized, proceed with required electrical circuit configurations, wiring, measurement equipment connection, and other application needs, while still assuming the EVM circuit and measuring instruments are electrically live.
   c. After EVM readiness is complete, energize the EVM as intended.

> **WARNING**
>
> While the EVM is energized, never touch the EVM or the electrical circuits, as the EVM or the electrical circuits can be at high voltages capable of causing electrical shock hazard.

3. Personal Safety
   a. Wear personal protective equipment (for example, latex gloves or safety glasses with side shields) or protect EVM in an adequate lucent plastic box with interlocks to protect from accidental touch.

**Limitation for safe use:**

EVMs are not to be used as all or part of a production unit.

# 2 Hardware

## 2.1 Additional Images

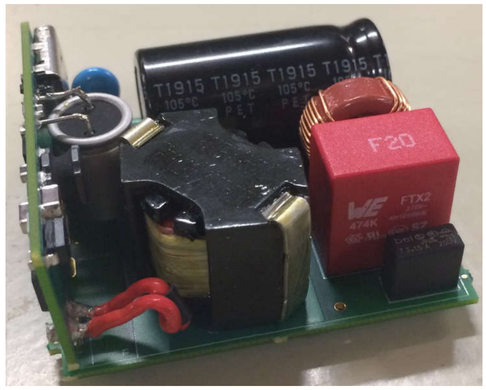



**Figure 2-1. High-Density Configuration**

## 2.2 Using the EVM on a Load with USB-C PD Communication

LMG3622EVM-082 comes populated with a USB-C PD controller and requires external connection through an on-board USB-C connector to a USB-C PD load to adjust the board output to obtain 5-V, 9-V, 15-V or 20-V. A USB-C PD communicating load is required to make the board evaluation. An example of such a load is PM125, USB Power Delivery Tester and PassMark Software. Without such a communication load, the board output USB-C connector (J2) does not provide a variable output voltage. To obtain the full load current 3.00-A from 5-V, 9-V and 15-V, a standard USB-C cable can be used, but to obtain 3.25-A at 20-V output, an "E-marker" USB-C cable has to be used. In case the EVM is desired to test on a load without USB-C PD communication, the next section describes how to modify the board to make this test.

## 2.3 Using the EVM on a Load Without USB-C PD Communication

Normally, a USB-C PD communicated load is required to make evaluation. Without a USB-C PD communication-based load, the board does not provide output voltage on USB-C (J2) connector. In such a case, the board output voltage can be obtained from C8 and C9, but only 5-V and up to 3.00-A can be obtained.

# 3 Implementation Results

## 3.1 Electrical Performance Specifications

**Table 3-1. LMG3622EVM-082 Electrical Performance Specifications[2]**

| PARAMETER | | TEST CONDITIONS | MIN | NOM | MAX | UNIT |
|---|---|---|---|---|---|---|
| **INPUT CHARACTERISTICS** | | | | | | |
| $V_{IN}$ | Input line voltage (RMS) | | 90 | 115 / 230 | 264 | V |
| $f_{LINE}$ | Input line frequency | | 47 | 50 / 60 | 63 | Hz |
| $P_{STBY}$ | Input power at no-load | $V_{IN}$ = 115/230 $V_{RMS}$, $I_{OUT}$ = 0 A | | 60/75 | | mW |
| $P_{0.25W}$ | Input power at 0.25W load | $V_{IN}$ = 115/230 $V_{RMS}$, $P_{OUT}$ = 250 mW | | 345/385 | | mW |
| **OUTPUT CHARACTERISTICS** | | | | | | |
| $V_{OUT}$ | Output voltage (USB-C PD) $V_{IN}$ = 90 to 264 $V_{RMS}$ | $I_{OUT}$ = 0 to 3.25 A | | 19.950 | | V |
| | | $I_{OUT}$ = 0 to 3.00 A | | 15.050 | | |
| | | | | 9.050 | | |
| | | | | 5.050 | | |
| $I_{OUT}$ | Full load rated output current $V_{IN}$ = 90 to 264 $V_{RMS}$ | $V_{OUT}$ = 20.0 V | | 3.250 | | A |
| | | $V_{OUT}$ = 5.0, 9.0, or 15.0 V | | 3.000 | | |
| $V_{OUT\_pp}$ | Output ripple voltage $V_{IN}$ = 115 V / 230 $V_{RMS}$ | $V_{OUT}$ = 20.0 V, $I_{OUT}$ = 0 to 3.25 A | | 150 | | mVpp |
| | | $V_{OUT}$ = 15.0 V, $I_{OUT}$ = 0 to 3.00 A | | 150 | | |
| | | $V_{OUT}$ = 9.0 V, $I_{OUT}$ = 0 to 3.00 A | | 150 | | |
| | | $V_{OUT}$ = 5.0 V, $I_{OUT}$ = 0 to 3.00 A | | 150 | | |
| $V_{OUT\_\Delta}$ | Output voltage deviation due to load step Up / Down ($I_{OUT}$ step change between 0 and 100% load at 100 Hz rate) | $V_{OUT}$ = 20.0 V | | -604 / 340 | | mVpp |
| | | $V_{OUT}$ = 15.0 V | | -584 / 360 | | |
| | | $V_{OUT}$ = 9.0 V | | -404 / 304 | | |
| | | $V_{OUT}$ = 5.0 V | | -404 / 304 | | |
| $P_{OUT\_opp}$ | Over-power protection threshold | $V_{IN}$ = 90 to 264 $V_{RMS}$ | | 75 | | W |
| **SYSTEMS CHARACTERISTICS** | | | | | | |
| η | Full-load efficiency ($V_{IN}$= 115/230$V_{RMS}$) | $V_{OUT}$ = 20 V, $I_{OUT}$ = 3.25A | | 94.2 / 94.0 | | % |
| | | $V_{OUT}$ = 15 V, $I_{OUT}$ = 3.00A | | 94.4 / 94.0 | | |
| | | $V_{OUT}$ = 9 V, $I_{OUT}$ = 3.00A | | 94.0/ 93.9 | | |
| | | $V_{OUT}$ = 5 V, $I_{OUT}$ = 3.00A | | 90.2/ 88.1 | | |
| η | 4-point average efficiency[1] $V_{IN}$= 115/230 $V_{RMS}$ | $V_{OUT}$ = 20 V (CoC Tier 2, 89.0%) | | 94.2 / 93.5 | | % |
| | | $V_{OUT}$ = 15 V (CoC Tier 2, 88.9%) | | 94.2 / 92.9 | | |
| | | $V_{OUT}$ = 9 V (CoC Tier 2, 87.3%) | | 93.3 / 91.2 | | |
| | | $V_{OUT}$ = 5 V (CoC Tier 2, 81.8%) | | 89.5 / 87.0 | | |
| η | Efficiency at 10% Load $V_{IN}$= 115/230 $V_{RMS}$ | $V_{OUT}$ = 20 V (CoC Tier 2, 79.0%) | | 92.0/ 90.1 | | % |
| | | $V_{OUT}$ = 15 V (CoC Tier 2, 78.9%) | | 91.5 / 87.5 | | |
| | | $V_{OUT}$ = 9 V (CoC Tier 2, 77.3%) | | 92.0 / 88.0 | | |
| | | $V_{OUT}$ = 5 V (CoC Tier 2, 72.5%) | | 86.5 /83.5 | | |
| $T_{AMB}$ | Ambient operating temperature range | $V_{IN}$ = 90 to 264 $V_{RMS}$, $I_{OUT}$ = 0 to 3.00A (5V/9V/ 15V), or 3.25A (20V) | | 25 | | °C |

(1) Average efficiency of four load points, $I_{OUT}$ = 100%, 75%, 50% and 25% of rated full-load current for each respective output voltage.
(2) The performance listed in this table is achieved using secondary resonance and based on the test results from a single board.

## 3.2 Test Setup

### 3.2.1 Test Setup Requirements

**Safety:** This evaluation module is not encapsulated and there are accessible voltages that are greater than 50 $V_{DC}$.

**Isolation Input Transformer:** A good rated 1:1 isolation transformer shall be used on the inputs to this EVM and be constructed in a manner in which the primary winding are separated from the secondary windings by reinforced insulation, double insulation, or a screen connected to the protective conductor terminal.

**WARNING**

- If the user is not trained in the proper safety of handling and testing power electronics, then please do not test this evaluation module.
- While the EVM is energized, never touch the EVM or the electrical circuits, as the EVM or the electrical circuits can be at high voltages capable of causing electrical shock hazard.
- Caution: Hot surface. Contact can cause burns. Do not touch!
- Read this user's guide thoroughly before making test.

**Voltage Source:** Isolated AC source or variable AC transformer capable of 264 $V_{RMS}$ and capable of handling 100 W power level. **Warning: Do not apply DC voltage to this board when making test, or damage can happen**.

**Voltmeter:** Digital voltage meter

**Power Analyzer:** Capable of measuring 1 mW to 100 W of input power and capable of handling 264-$V_{RMS}$ input voltage. Some power analyzers can require a precision shunt resistor for measuring input current to measure input power of 5 W or less. Please read the power analyzer's user manual for proper measurement setups for full power and for stand-by power.

**Oscilloscope:**

- 4-Channel, 500 MHz bandwidth.
- Probes capable of handling 600 V.

**Output Load:** Resistive or electronic load capable of handling 100 W at 20 V.

**Recommended Wire Gauge:** Insulated 22 AWG to 18 AWG.

**WARNING**

Caution: Do not leave EVM powered when unattended.

Do not apply DC voltage source to this board or damage can happen.

### 3.2.2 Test Setup Diagram

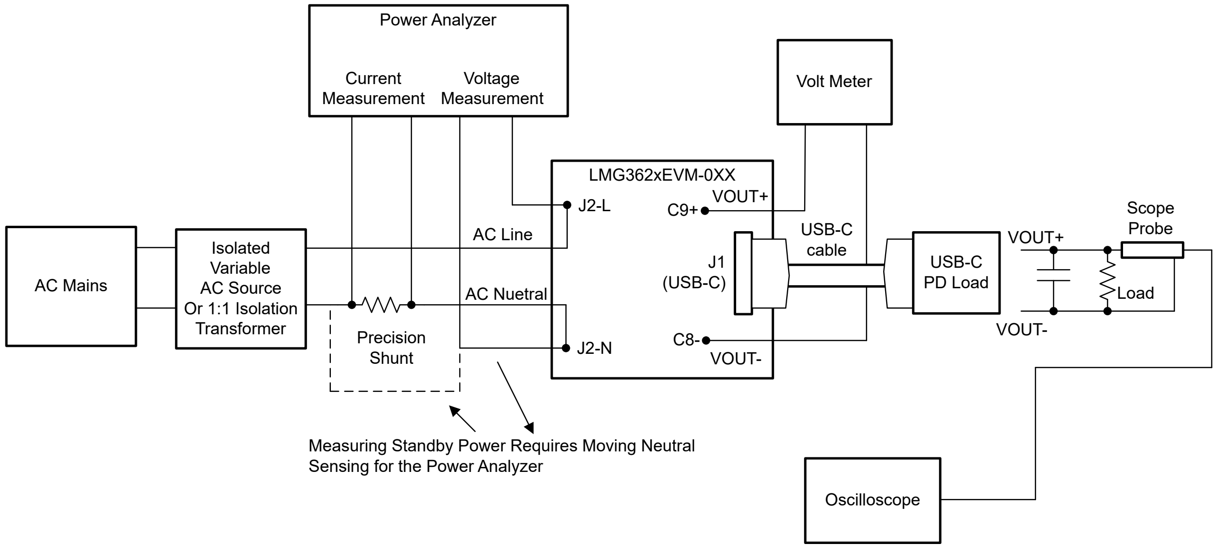



**Figure 3-1. LMG3622EVM-082 Test Setup Diagram**

### 3.2.3 Test Points

**Table 3-2. Input / Output Terminals and Test Point Functions**

| Terminals and TEST POINTS | | NAME | DESCRIPTION |
|---|---|---|---|
| J2 | J2 Terminal | J2 | USB-C |
| J1-L | J1 Terminal | L | AC voltage input - Line |
| J1-N | | N | AC voltage input - Neutral |
| TPL | Input test points | TPL | AC input monitor - Line |
| TPN | Input test points | TPN | AC input monitor - Neutral |
| TP1 to TP4 | Floating test points | TP1, TP2, TP3, TP4 | Floating, need to solder connections, leave floating if not used. |
| TP5 to TP8 | Floating test points | TP5, TP6, TP7, TP8 | Floating, need to solder connections, leave floating if not used. |

## 3.3 Performance Data and Typical Characteristic Curves

### 3.3.1 Efficiency Result of 4-Point Average on 20-Vout

| VIN (VRMS) | PIN (W) | VOUT (V) | IOUT (A) | POUT (W) | PLOSS (W) | Pout % | EFFICIENCY | 4-PT AVERAGE EFFICIENCY |
|---|---|---|---|---|---|---|---|---|
| 89.9 | 69.6800 | 20.03 | 3.248 | 65.06 | 4.62 | 100% | 93.4% | |
| 90.0 | 51.86 | 20.04 | 2.441 | 48.93 | 2.93 | 75% | 94.4% | |
| 90.0 | 34.53 | 20.02 | 1.630 | 32.62 | 1.91 | 50% | 94.5% | |
| 90.1 | 17.50 | 19.99 | 0.822 | 16.43 | 1.07 | 25% | 93.9% | |
| 90.1 | 7.40 | 19.98 | 0.334 | 6.68 | 0.73 | 10% | 90.2% | |
| 115.0 | 69.0000 | 20.08 | 3.249 | 65.23 | 3.77 | 100% | 94.5% | 94.5% |
| 115.0 | 51.56 | 20.05 | 2.441 | 48.93 | 2.63 | 75% | 94.9% | |
| 115.1 | 34.45 | 20.02 | 1.630 | 32.64 | 1.81 | 50% | 94.7% | |
| 115.1 | 17.52 | 19.99 | 0.822 | 16.43 | 1.09 | 25% | 93.8% | |
| 115.1 | 7.24 | 19.98 | 0.334 | 6.68 | 0.56 | 10% | 92.3% | |
| 230.2 | 68.9300 | 20.07 | 3.250 | 65.23 | 3.70 | 100% | 94.6% | 93.7% |
| 230.2 | 52.08 | 20.04 | 2.441 | 48.93 | 3.15 | 75% | 93.9% | |
| 230.3 | 34.97 | 20.02 | 1.632 | 32.66 | 2.31 | 50% | 93.4% | |
| 230.3 | 17.69 | 19.99 | 0.822 | 16.43 | 1.26 | 25% | 92.9% | |
| 230.3 | 7.41 | 19.97 | 0.336 | 6.71 | 0.70 | 10% | 90.6% | |
| 265.3 | 69.2700 | 20.07 | 3.250 | 65.21 | 4.06 | 100% | 94.1% | |
| 265.3 | 52.2900 | 20.04 | 2.442 | 48.92 | 3.37 | 75% | 93.6% | |
| 265.3 | 35.29 | 20.01 | 1.630 | 32.62 | 2.67 | 50% | 92.4% | |
| 265.3 | 17.79 | 19.98 | 0.821 | 16.42 | 1.37 | 25% | 92.3% | |
| 265.3 | 7.52 | 19.97 | 0.334 | 6.67 | 0.85 | 10% | 88.7% | |
| CoC Tier 2, 4-pt average | | | | | | | | 89.0% |
| CoC Tier 2, 10%-load | | | | | | | | 79.0% |

### 3.3.2 Efficiency Result of 4-Point Average at 15-Vout

| VIN (VRMS) | PIN (W) | VOUT (V) | IOUT (A) | POUT (W) | PLOSS (W) | Pout % | EFFICIENCY | 4-PT AVERAGE EFFICIENCY |
|---|---|---|---|---|---|---|---|---|
| 90.0 | 48.10 | 15.09 | 3.003 | 45.31 | 2.79 | 100% | 94.2% | |
| 90.0 | 35.97 | 15.06 | 2.256 | 33.97 | 2.00 | 75% | 94.4% | |
| 90.0 | 24.01 | 15.04 | 1.507 | 22.67 | 1.34 | 50% | 94.4% | |
| 90.1 | 12.20 | 15.02 | 0.760 | 11.41 | 0.79 | 25% | 93.5% | |
| 90.1 | 5.06 | 15.00 | 0.311 | 4.67 | 0.39 | 10% | 92.2% | |
| 115.0 | 47.76 | 15.09 | 3.002 | 45.30 | 2.46 | 100% | 94.8% | 94.4% |
| 115.1 | 35.81 | 15.06 | 2.256 | 33.99 | 1.82 | 75% | 94.9% | |
| 115.1 | 23.98 | 15.04 | 1.507 | 22.67 | 1.31 | 50% | 94.5% | |
| 115.1 | 12.22 | 15.01 | 0.759 | 11.40 | 0.83 | 25% | 93.3% | |
| 115.1 | 5.06 | 15.00 | 0.310 | 4.65 | 0.41 | 10% | 91.9% | |
| 230.2 | 48.10 | 15.09 | 3.002 | 45.30 | 2.80 | 100% | 94.2% | 93.1% |
| 230.3 | 36.35 | 15.06 | 2.256 | 33.97 | 2.38 | 75% | 93.5% | |
| 230.3 | 24.48 | 15.04 | 1.506 | 22.65 | 1.83 | 50% | 92.5% | |
| 230.3 | 12.36 | 15.01 | 0.760 | 11.41 | 0.95 | 25% | 92.3% | |
| 230.3 | 5.26 | 15.00 | 0.310 | 4.65 | 0.62 | 10% | 88.3% | |
| 265.3 | 48.40 | 15.08 | 3.002 | 45.29 | 3.11 | 100% | 93.6% | |
| 265.3 | 36.70 | 15.06 | 2.254 | 33.94 | 2.76 | 75% | 92.5% | |
| 265.3 | 24.77 | 15.03 | 1.508 | 22.67 | 2.10 | 50% | 91.5% | |
| 265.3 | 12.44 | 15.01 | 0.759 | 11.39 | 1.05 | 25% | 91.6% | |
| 265.3 | 5.35 | 15.00 | 0.310 | 4.64 | 0.70 | 10% | 86.9% | |
| CoC Tier 2, 4-pt average | | | | | | | | 88.9% |
| CoC Tier 2, 10%-load | | | | | | | | 78. |

### 3.3.3 Efficiency Result of 4-Point Average at 9-Vout

| VIN (VRMS) | PIN (W) | VOUT (V) | IOUT (A) | POUT (W) | PLOSS (W) | Pout % | EFFICIENCY | 4-PT AVERAGE EFFICIENCY |
|---|---|---|---|---|---|---|---|---|
| 90.0 | 29.0900 | 9.09 | 3.005 | 27.30 | 1.79 | 100% | 93.9% | |
| 90.0 | 21.73 | 9.06 | 2.257 | 20.45 | 1.28 | 75% | 94.1% | |
| 90.1 | 14.51 | 9.04 | 1.509 | 13.63 | 0.88 | 50% | 94.0% | |
| 90.1 | 7.43 | 9.01 | 0.763 | 6.87 | 0.56 | 25% | 92.5% | |
| 90.1 | 3.06 | 9.00 | 0.312 | 2.81 | 0.25 | 10% | 91.8% | |
| 115.1 | 28.9500 | 9.08 | 3.004 | 27.29 | 1.66 | 100% | 94.3% | |
| 115.1 | 21.70 | 9.06 | 2.257 | 20.45 | 1.25 | 75% | 94.2% | |
| 115.1 | 14.53 | 9.04 | 1.509 | 13.64 | 0.89 | 50% | 93.9% | 93.6% |
| 115.1 | 7.37 | 9.01 | 0.762 | 6.87 | 0.50 | 25% | 93.2% | |
| 115.1 | 3.05 | 9.00 | 0.313 | 2.82 | 0.23 | 10% | 92.4% | |
| 230.3 | 29.3300 | 9.08 | 3.004 | 27.29 | 2.04 | 100% | 93.0% | |
| 230.3 | 22.21 | 9.06 | 2.257 | 20.44 | 1.77 | 75% | 92.0% | |
| 230.3 | 14.74 | 9.04 | 1.509 | 13.64 | 1.10 | 50% | 92.5% | 91.5% |
| 230.3 | 7.55 | 9.01 | 0.762 | 6.87 | 0.68 | 25% | 91.0% | |
| 230.3 | 3.16 | 9.00 | 0.312 | 2.81 | 0.35 | 10% | 88.8% | |
| 265.3 | 29.5800 | 9.08 | 3.005 | 27.30 | 2.28 | 100% | 92.3% | |
| 265.3 | 22.5000 | 9.06 | 2.258 | 20.46 | 2.04 | 75% | 90.9% | |
| 265.3 | 14.84 | 9.03 | 1.510 | 13.64 | 1.20 | 50% | 91.9% | |
| 265.3 | 7.68 | 9.01 | 0.762 | 6.87 | 0.81 | 25% | 89.5% | |
| 265.3 | 3.20 | 9.00 | 0.313 | 2.82 | 0.38 | 10% | 88.0% | |
| CoC Tier 2, 4-pt average | | | | | | | | 87.3% |
| CoC Tier 2, 10%-load | | | | | | | | 77.3% |

### 3.3.4 Efficiency Result of 4-Point Average at 5-Vout

| VIN (VRMS) | PIN (W) | VOUT (V) | IOUT (A) | POUT (W) | PLOSS (W) | Pout % | EFFICIENCY | 4-PT AVERAGE EFFICIENCY |
|---|---|---|---|---|---|---|---|---|
| 90.1 | 16.7900 | 5.06 | 2.993 | 15.14 | 1.65 | 100% | 90.2% | |
| 90.1 | 12.48 | 5.03 | 2.246 | 11.30 | 1.18 | 75% | 90.6% | |
| 90.1 | 8.29 | 5.01 | 1.498 | 7.51 | 0.79 | 50% | 90.5% | |
| 90.1 | 4.17 | 4.98 | 0.751 | 3.74 | 0.42 | 25% | 89.9% | |
| 90.1 | 1.68 | 4.97 | 0.302 | 1.50 | 0.18 | 10% | 89.4% | |
| 115.1 | 16.7400 | 5.06 | 2.994 | 15.14 | 1.60 | 100% | 90.5% | 90.0% |
| 115.1 | 12.49 | 5.03 | 2.246 | 11.30 | 1.19 | 75% | 90.5% | |
| 115.1 | 8.38 | 5.01 | 1.498 | 7.51 | 0.87 | 50% | 89.6% | |
| 115.1 | 4.18 | 4.98 | 0.751 | 3.74 | 0.44 | 25% | 89.6% | |
| 115.1 | 1.70 | 4.97 | 0.302 | 1.50 | 0.20 | 10% | 88.3% | |
| 230.3 | 17.1100 | 5.06 | 2.992 | 15.13 | 1.98 | 100% | 88.5% | 87.5% |
| 230.3 | 12.90 | 5.03 | 2.246 | 11.30 | 1.60 | 75% | 87.6% | |
| 230.3 | 8.57 | 5.01 | 1.498 | 7.51 | 1.06 | 50% | 87.6% | |
| 230.3 | 4.34 | 4.98 | 0.753 | 3.75 | 0.59 | 25% | 86.4% | |
| 230.3 | 1.78 | 4.97 | 0.302 | 1.50 | 0.28 | 10% | 84.3% | |
| 265.3 | 17.3100 | 5.06 | 2.993 | 15.14 | 2.17 | 100% | 87.5% | |
| 265.3 | 13.0900 | 5.03 | 2.246 | 11.30 | 1.79 | 75% | 86.3% | |
| 265.3 | 8.68 | 5.01 | 1.498 | 7.50 | 1.18 | 50% | 86.4% | |
| 265.3 | 4.40 | 4.98 | 0.750 | 3.74 | 0.66 | 25% | 84.9% | |
| 265.3 | 1.81 | 4.97 | 0.302 | 1.50 | 0.31 | 10% | 83.0% | |
| CoC Tier 2, 4-pt average | | | | | | | | 81.8% |
| CoC Tier 2, 10%-load | | | | | | | | 72.5% |

### 3.3.5 Efficiency Typical Results

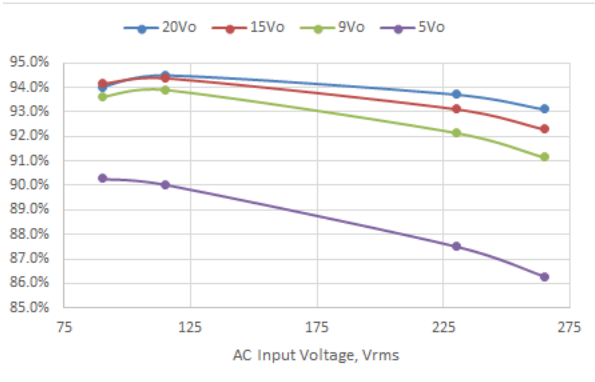



**Figure 3-2. 4pt-Average Efficiency vs. Input Voltage**

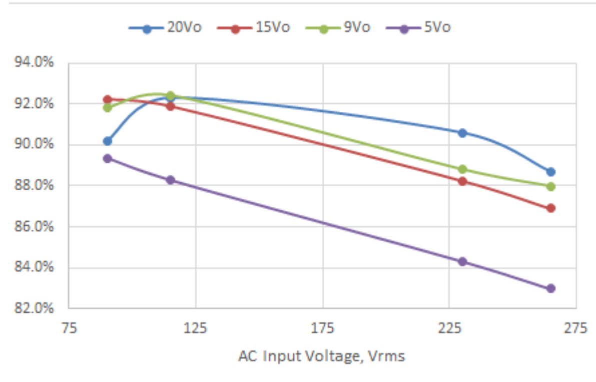



**Figure 3-3. Efficiency of 10%-Load vs. Input Voltage**

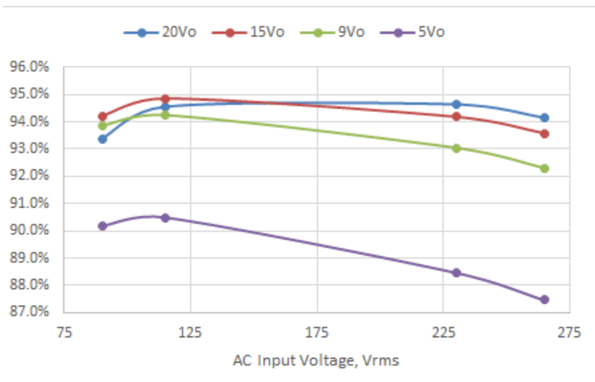



**Figure 3-4. Full-load Efficiency vs. Input Voltage**

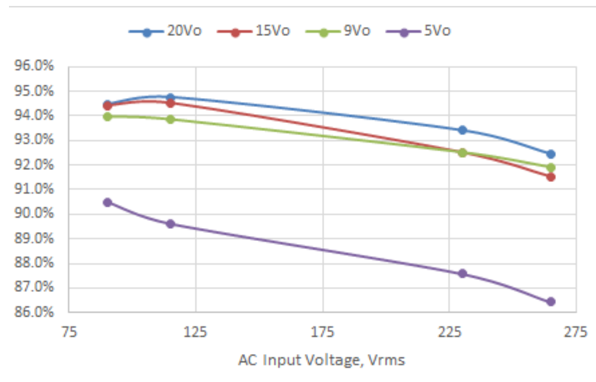



**Figure 3-5. Efficiency of 50%-load vs. Input Voltage**

### 3.3.6 Output Characteristics

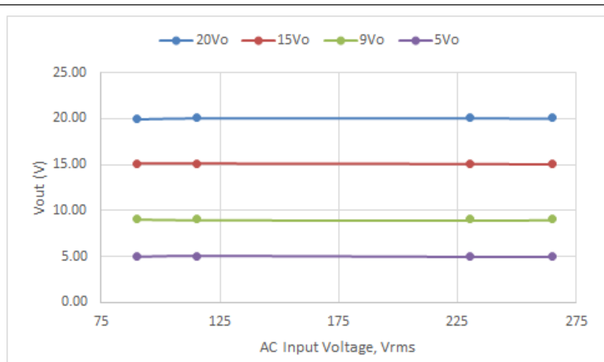



**Figure 3-6. $V_{OUT}$ at Full-Load vs Input Voltage**

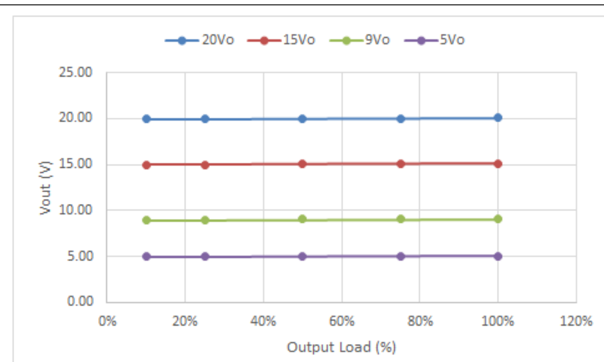



**Figure 3-7. $V_{OUT}$ vs Output Current**

### 3.3.7 Switching Frequency

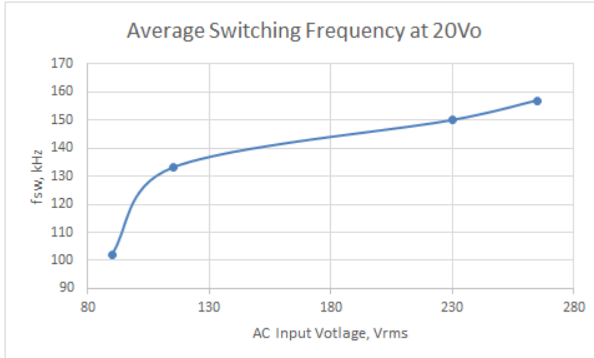



**Figure 3-8. Average Switching Frequency vs. Input at 20-Vo Full Load**

### 3.3.8 Key Switching Waveforms

This section shows typical switching waveforms at full load. Yellow = Switch Node, Blue = LMG362X voltage on CS emulation resistor.

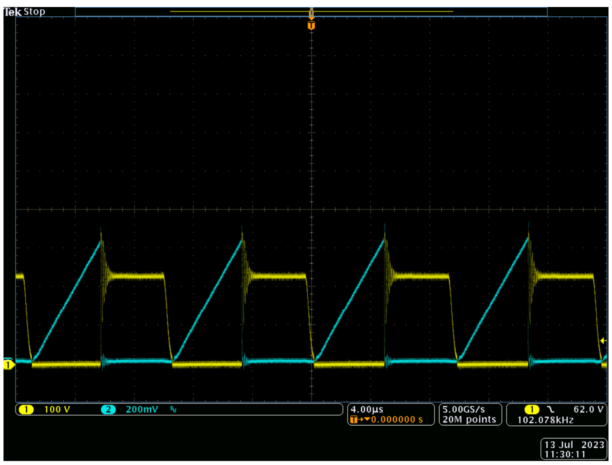



**Figure 3-9. Vin = 90Vac, Vout = 20 V**

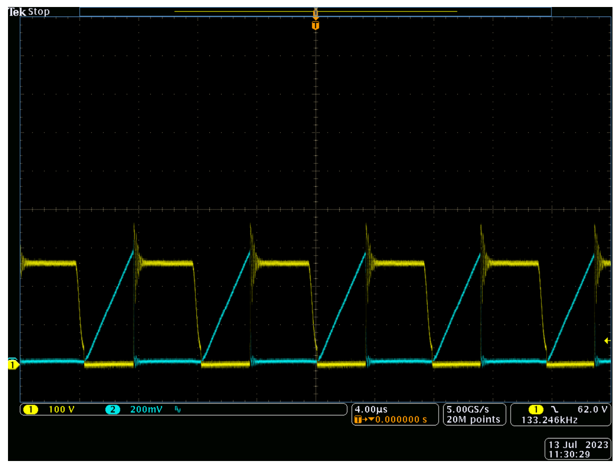



**Figure 3-10. Vin = 115Vac, Vout = 20 V**


**Figure 3-11. Vin = 230Vac, Vout = 20 V**


**Figure 3-12. Vin = 265Vac, Vout = 20 V**

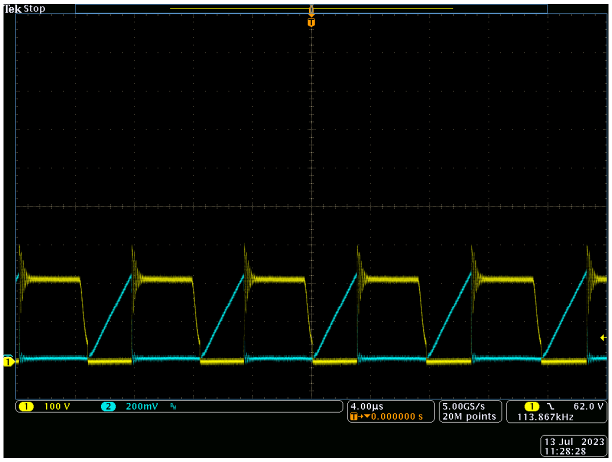



**Figure 3-13. Vin = 90Vac, Vout = 15 V**

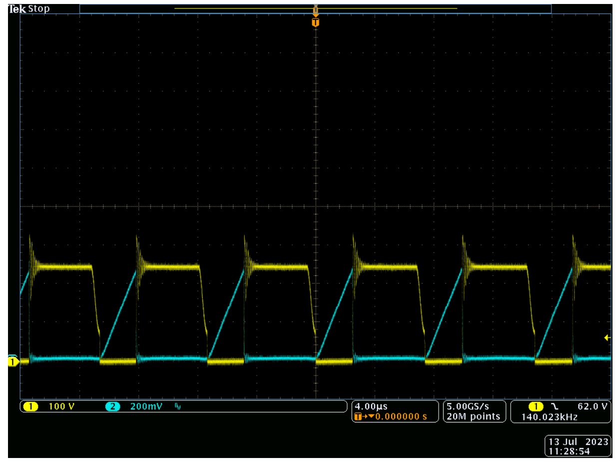



**Figure 3-14. Vin = 115Vac, Vout = 15 V**


**Figure 3-15. Vin = 230Vac, Vout = 15 V**


**Figure 3-16. Vin = 265Vac, Vout = 15 V**

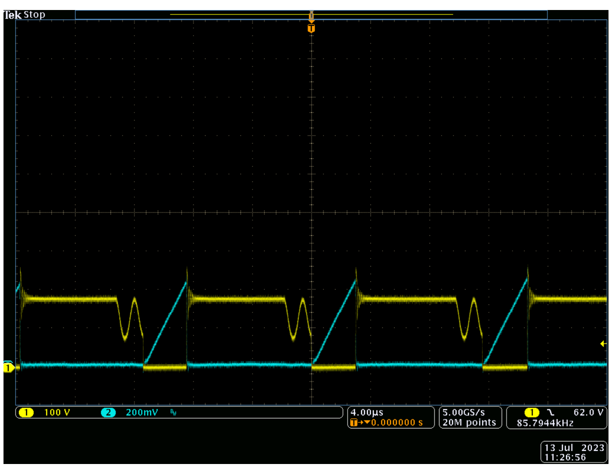



**Figure 3-17. Vin = 90Vac, Vout = 9 V**

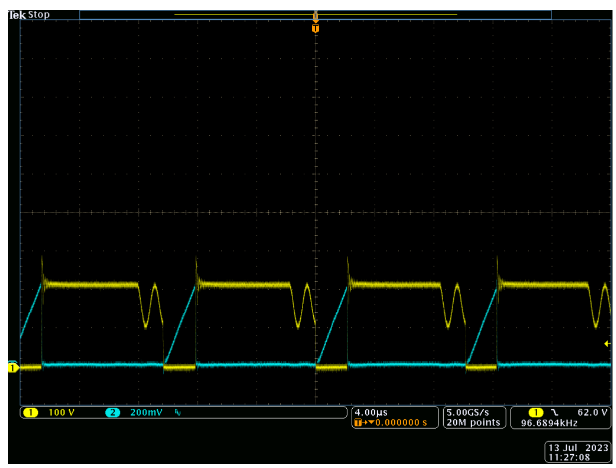



**Figure 3-18. Vin = 115Vac, Vout = 9 V**

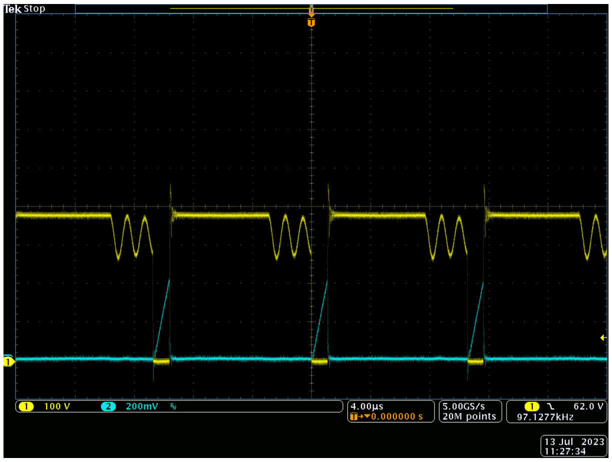



**Figure 3-19. Vin = 230Vac, Vout = 9 V**

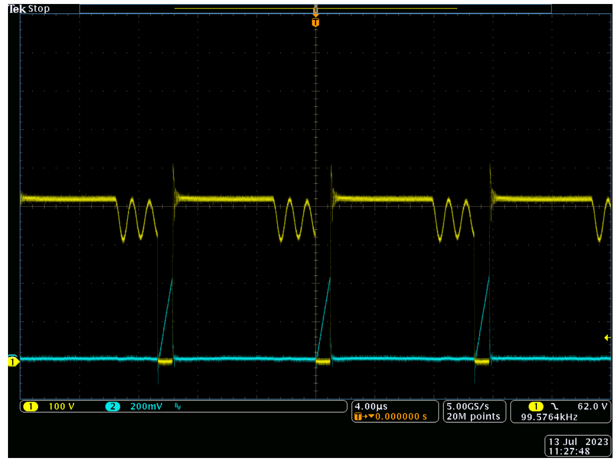



**Figure 3-20. Vin = 265Vac, Vout = 9 V**


**Figure 3-21. Vin = 90Vac, Vout = 5 V**

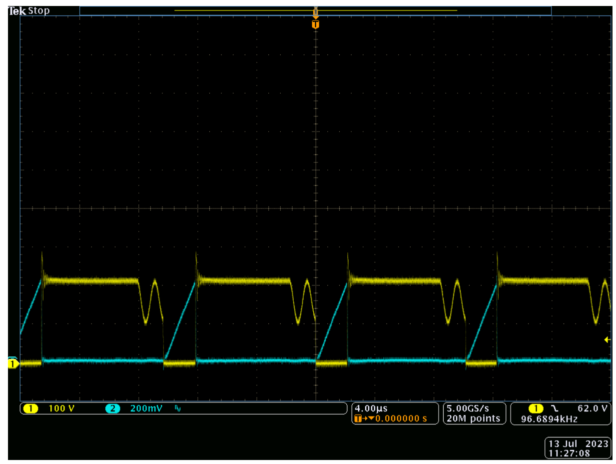



**Figure 3-22. Vin = 115Vac, Vout = 5 V**

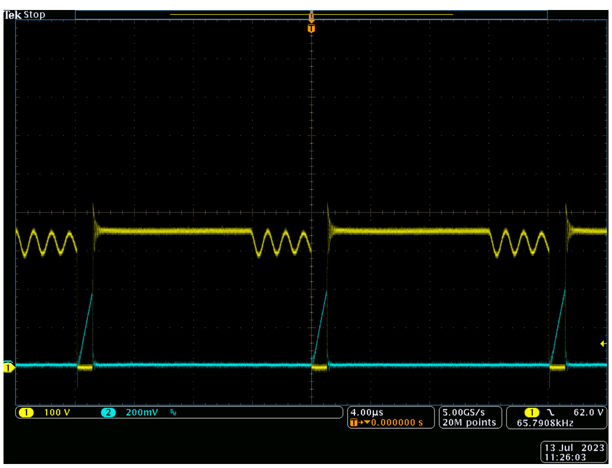



**Figure 3-23. Vin = 230Vac, Vout = 5 V**

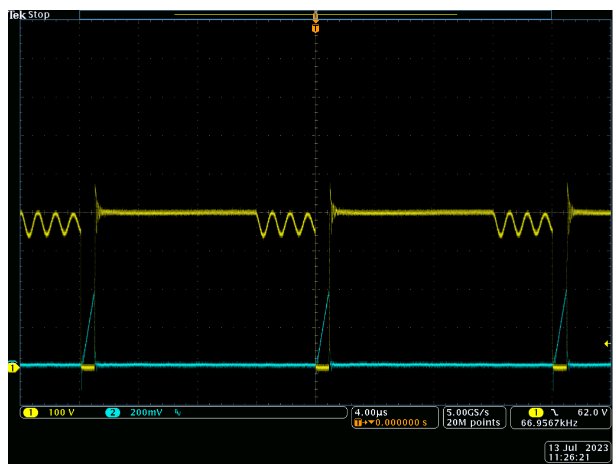



**Figure 3-24. Vin = 265Vac, Vout = 5 V**

### 3.3.9 Output Ripple Voltage

Blue = Output Voltage Ripple, Oscilloscope Channel Bandwidth = 20 MHz, Voltage span between two dashed lines is 150 mV. The ripples are with the 100% load condition unless specified in the associated figures.

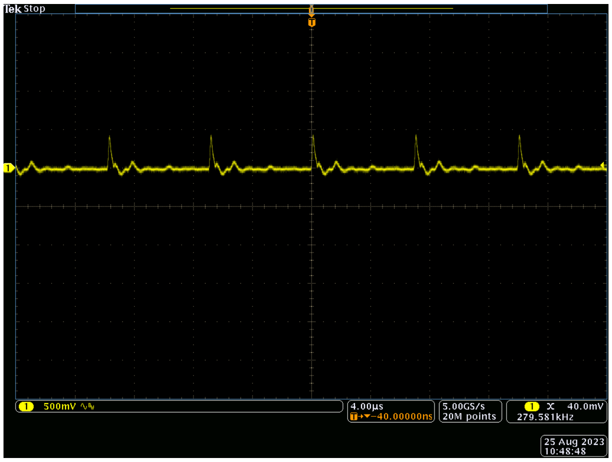



**Figure 3-25. Typical Ripple Voltage of $V_{OUT}$ = 20 V**

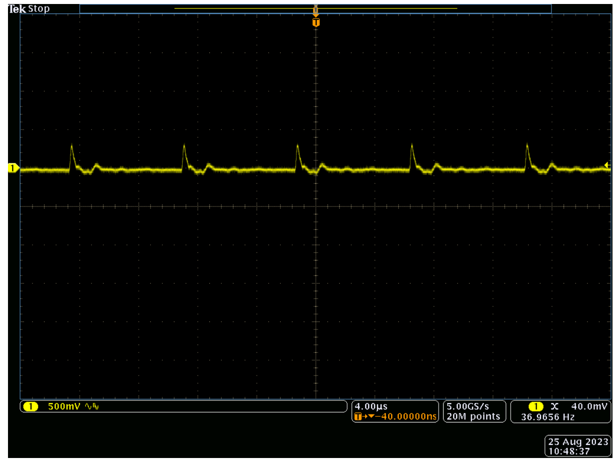



**Figure 3-26. Typical Ripple Voltage of $V_{OUT}$ = 15 V**

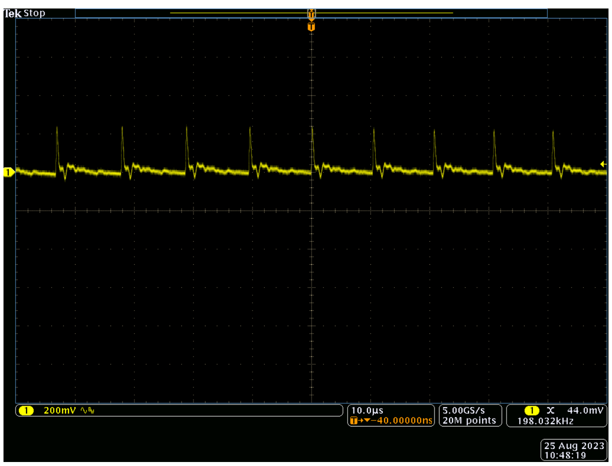



**Figure 3-27. Typical Ripple Voltage of $V_{OUT}$ = 9 V**

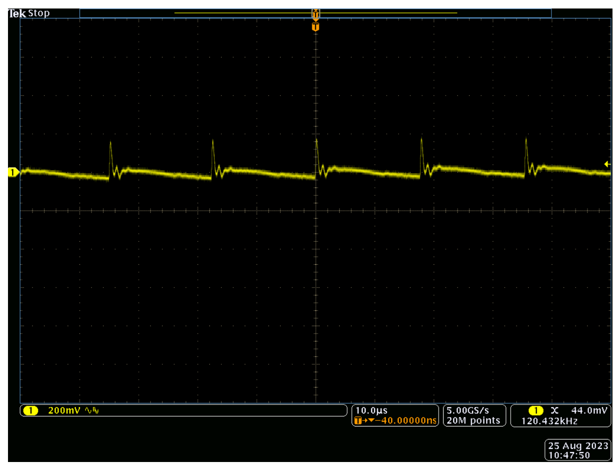



**Figure 3-28. Typical Ripple Voltage of $V_{OUT}$ = 5 V**

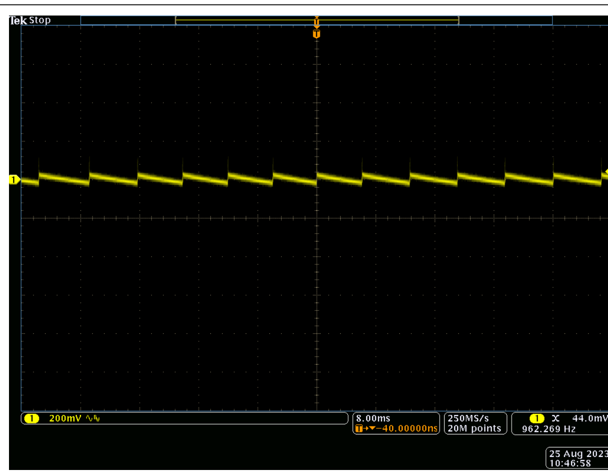



**Figure 3-29. Typical Ripple Voltage of $V_{OUT}$ = 5 V at No Load**

### 3.3.10 Load Transient Response

Figure 3-30 to Figure 3-33 show output voltage $V_{OUT}$ deviation when load current step change is between 0 and 100%, at 100-Hz rate.

Blue = $V_{OUT}$, Green = Load Current.

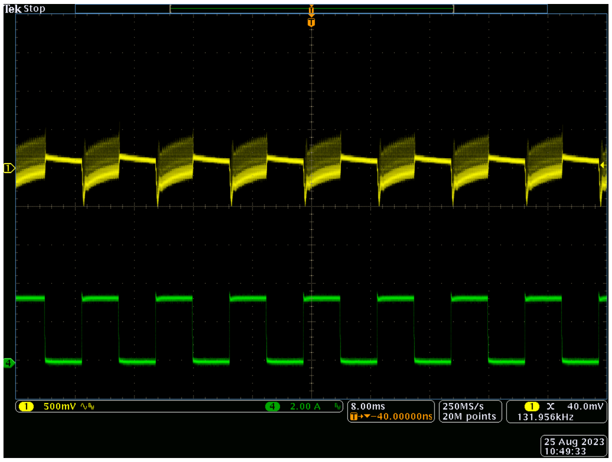



**Figure 3-30. Load Transient Response at $V_{OUT}$ = 20 V Overshoot / Undershoot = 357 mV / -619 mV**

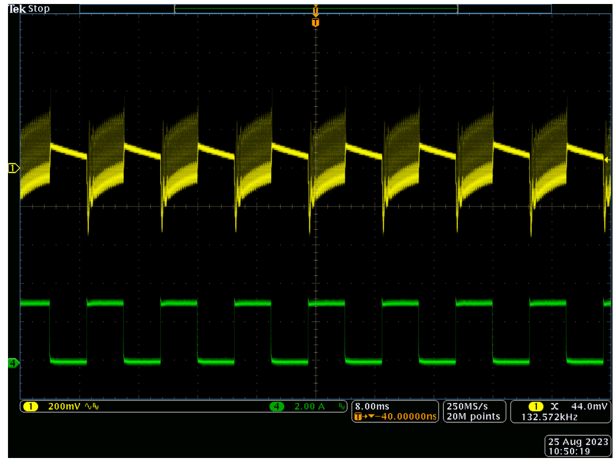



**Figure 3-31. Transient Response at $V_{OUT}$ = 15 V Overshoot / Undershoot = 366 mV / -562 mV**

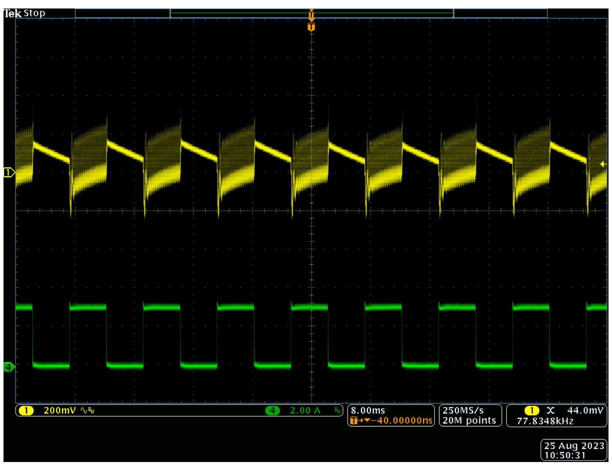



**Figure 3-32. Transient Response at $V_{OUT}$ = 9 V Overshoot / Undershoot = 326 mV / -426 mV**

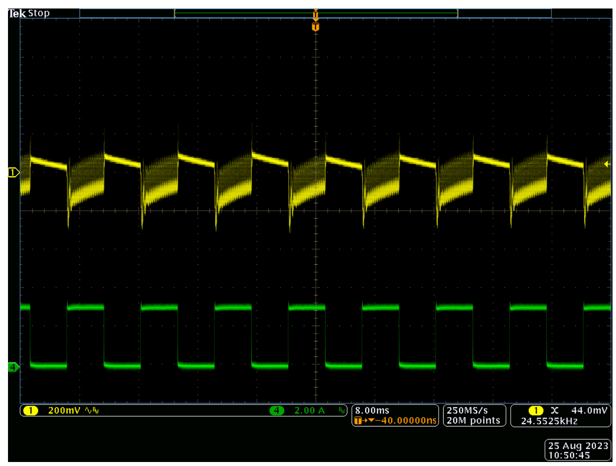



**Figure 3-33. Transient Response at $V_{OUT}$ = 5 V Overshoot / Undershoot = 326 mV / -426 mV**

### 3.3.11 EN55022 Class B Conducted EMI Test Result

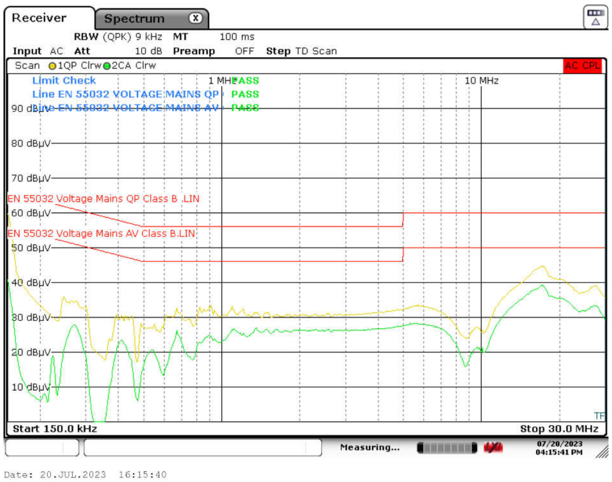



**Figure 3-34. VIN = 115 $V_{RMS}$, VOUT = 20 V, Load = 3.25 A (Output Not Grounded to LISN Ground)**

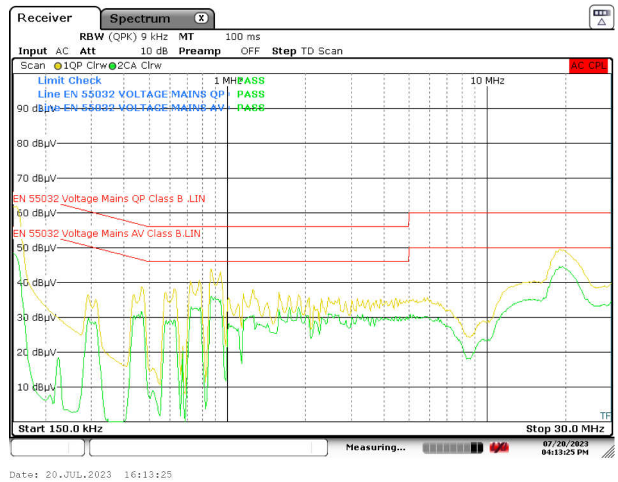



**Figure 3-35. VIN = 230 $V_{RMS}$, VOUT = 20 V, Load = 3.25 A (Output Not Grounded to LISN Ground)**

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**Note**

Please note this was evaluated on an EMI station for pre-qualification purpose only. TI recommends that all final designs be verified by an agency-qualified EMI test house.

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### 3.3.12 Thermal Images at Full Load (20 V and 3.25 A)


Figure 3-36. $V_{IN}$ = 90 $V_{AC}$, Top Side

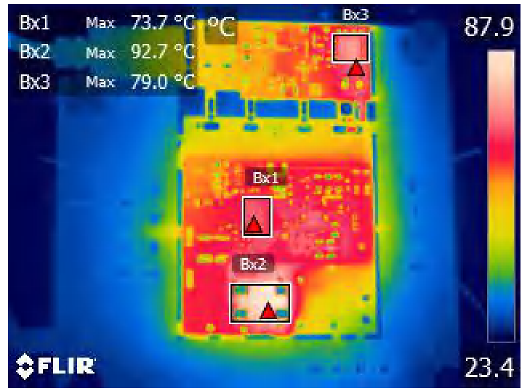


Figure 3-37. $V_{IN}$ = 90 $V_{AC}$, Bottom Side

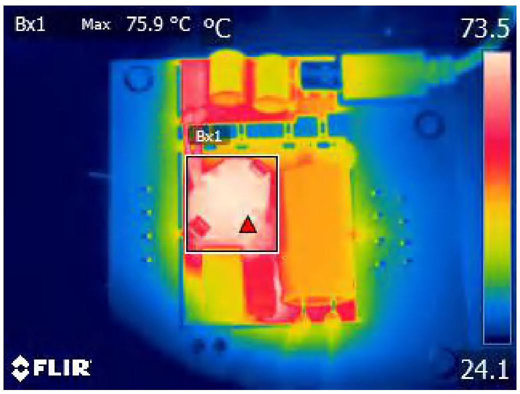


Figure 3-38. $V_{IN}$ = 115 $V_{AC}$, Top Side

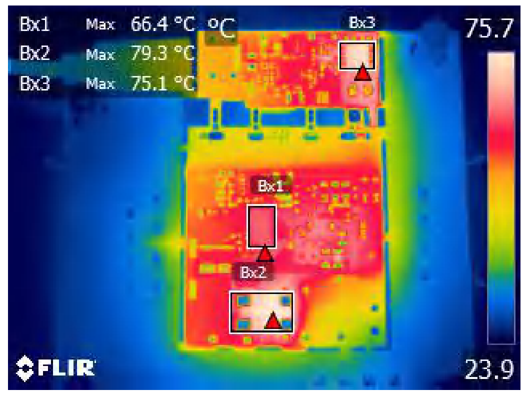


Figure 3-39. $V_{IN}$ = 115 $V_{AC}$, Bottom Side

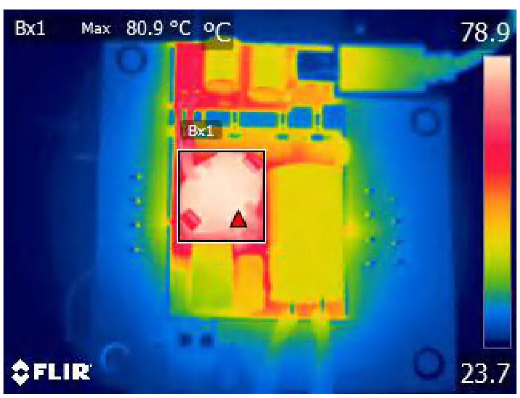


Figure 3-40. $V_{IN}$ = 230 $V_{AC}$, Top Side

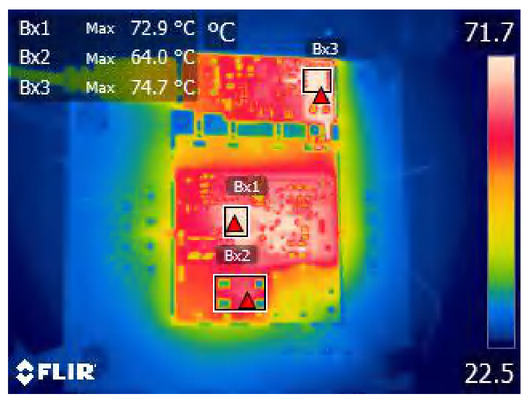


Figure 3-41. $V_{IN}$ = 230 $V_{AC}$, Bottom Side

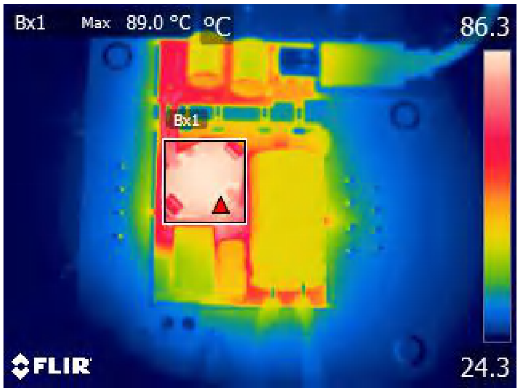


Figure 3-42. $V_{IN}$ = 265 $V_{AC}$, Top Side

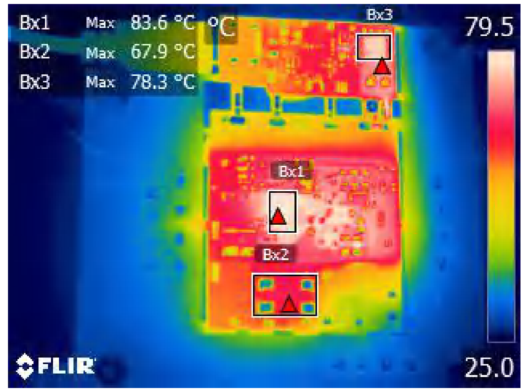


Figure 3-43. $V_{IN}$ = 265 $V_{AC}$, Bottom Side

# 4 Hardware Design Files

## 4.1 Schematics

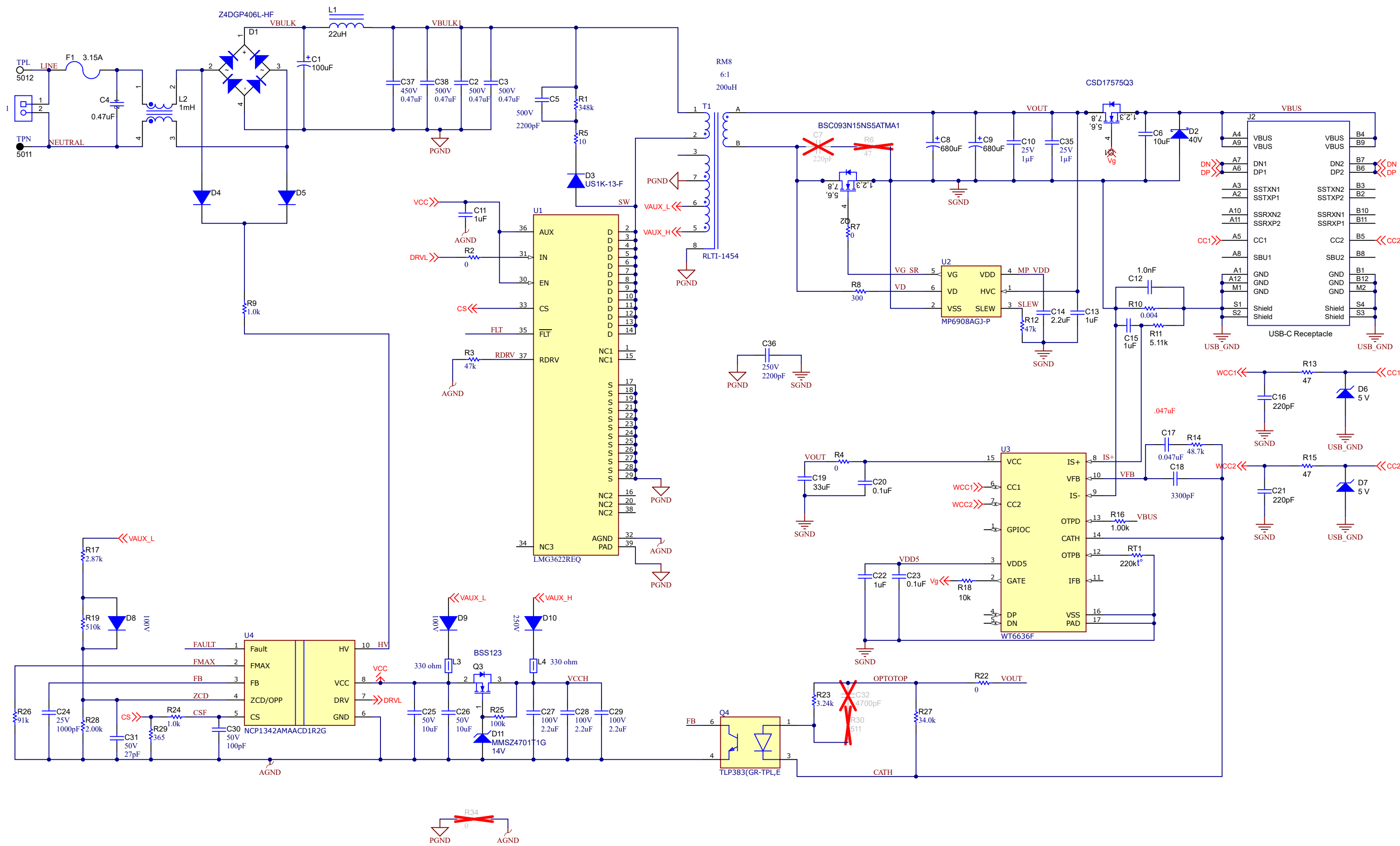

**Figure 4-1. LMG3622EVM-082 Schematic Diagram**

## 4.2 PCB Layouts

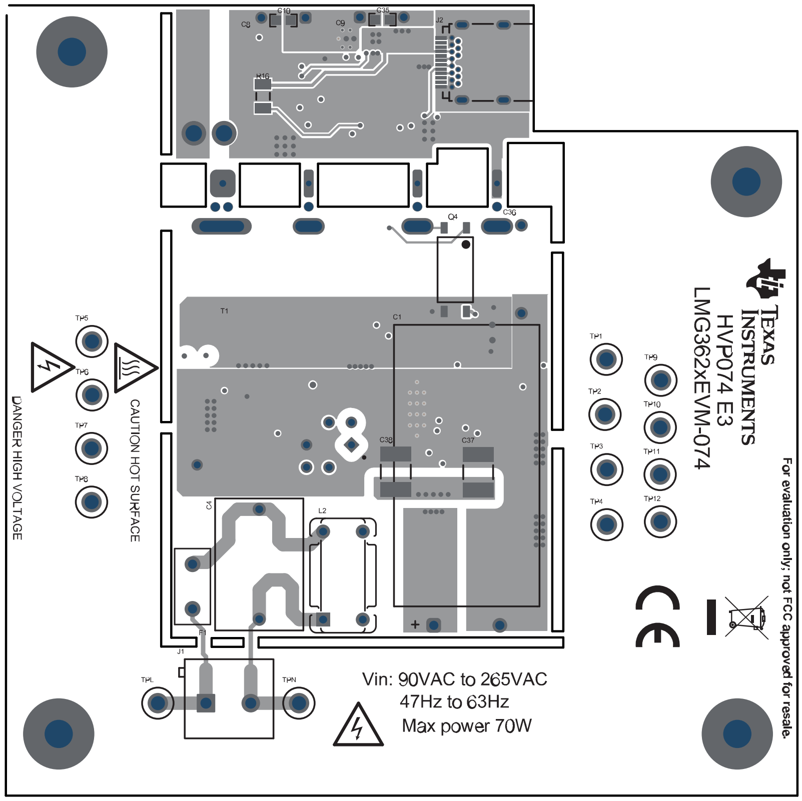


**Figure 4-2. EVM Assembly (Top View)**

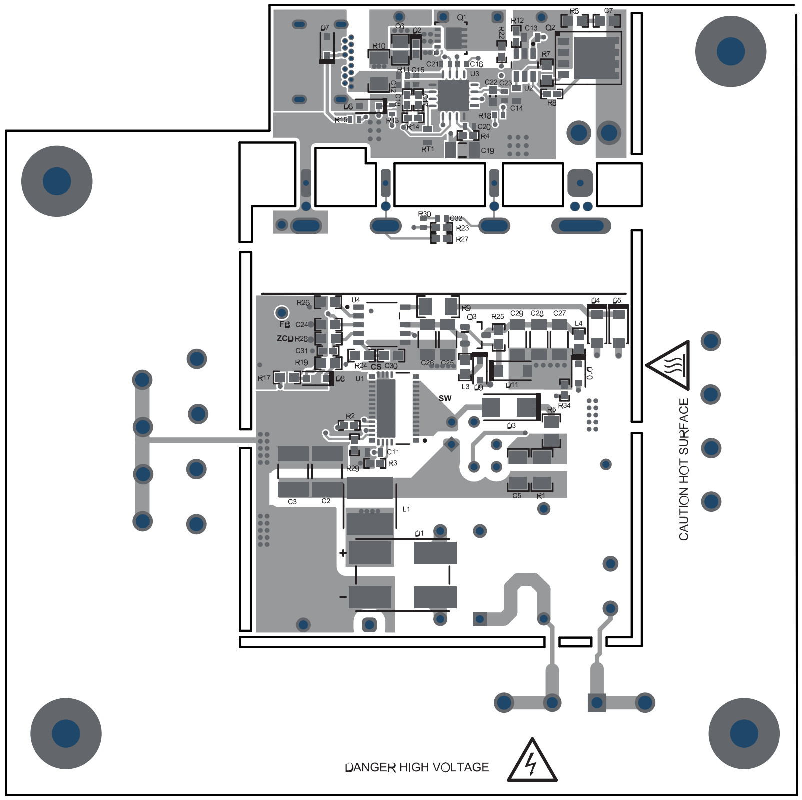


**Figure 4-3. EVM Assembly (Bottom View)**

### 4.2.1 Transformer Details

Renco Electronics transformer part number RLTI-1454 is used on this design and wound on an RM8 core set.

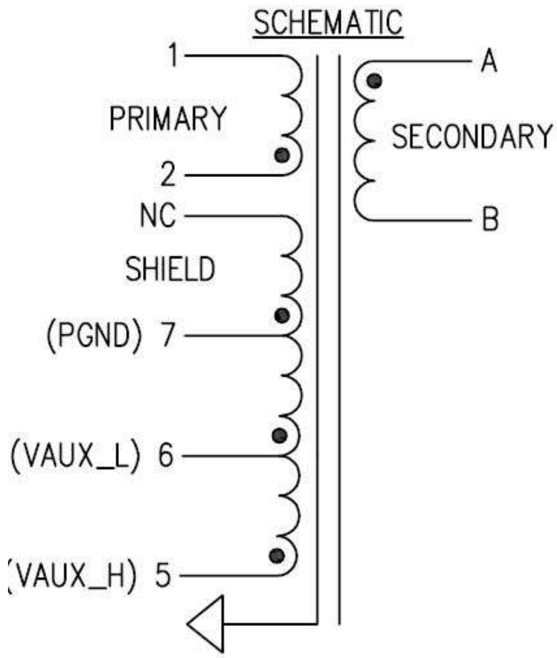


**Figure 4-4. Transformer Schematic Diagram**

**Table 4-1. Transformer Specifications at 25°C**

| PARAMETER | VALUE | PINS/LEADS | TEST CONDITIONS |
|---|---|---|---|
| Inductance (µH) | 200, ± 15% | 1 – 2 | Open all other pins, 100 kHz, 0.1V |
| Leakage Inductance (µH) | 3.5 Max. | 1 – 3 | Short A - B, 100 kHz, 0.1V |
| D.C. resistance (Ω) | 0.220, ±15% | 1 – 2 | |
| D.C. resistance (Ω) | 0.007 Max. | A – B | |
| D.C. resistance (Ω) | 0.046, ±20% | 6 – 7 | |
| D.C. resistance (Ω) | 0.100, ±15% | 5 - 6 | |
| Dielectric (VAC, 60Hz) | 3000 | 1, 6 – A | 1 mA, 60 Hz, 1 s |
| Turns-ratios | 6:1:1:2 | (1-2):(A-B):(6-7):(5-6) | 1.0V @ 10 kHz to 1 - 3 |

### 4.3 Bill of Materials

Table 4-2 lists the bill of materials for LMG3622EVM-082.

**Table 4-2. Bill of Materials**

| Designator | Qty | Value | Description | Part Number | Manufacturer |
|---|---|---|---|---|---|
| C1 | 1 | 100uF | CAP, AL, 100 µF, 400 V, +/- 20%, TH | 400BXW100MEFR16X30 | Rubycon |
| C2, C3, C38 | 3 | 0.47uF | CAP, CERM, 0.47 uF, 500 V, +/- 10%, X7R, 1812 | 1812Y5000474KXTWS2 | Knowles Capacitors |
| C4 | 1 | 0.47uF | CAP, Film, 0.47 µF, 275 V, +/- 10%, TH | 8.90324E+11 | Wurth Elektronik |
| C5 | 1 | 2200 pF | CAP, CERM, 2200 pF, 500 V, +/- 10%, X7R, 1206 | VJ1206Y222KXEAT5Z | Vishay-Vitramon |
| C6 | 1 | 10uF | CAP, CERM, 10 µF, 35 V,+/- 10%, X5R, 0805 | GRM21BR6YA106KE43L | MuRata |
| C8, C9 | 2 | 680uF | CAP, Aluminum Polymer, 680 µF, 25 V,+/- 20%, 0.29256 ohm, TH | 687AVG025MGBJ | Illinois Capacitor |
| C10, C35 | 2 | 1uF | CAP, CERM, 1 µF, 25 V,+/- 10%, X7R, 0603 | C1608X7R1E105K080AE | TDK |
| C11 | 1 | 1uF | CAP, CERM, 1 µF, 25 V, +/- 10%, X7R, 0603 | C1608X7R1E105K080AB | TDK |
| C12 | 1 | 1000 pF | CAP, CERM, 1000 pF, 50 V, +/- 10%, X7R, 0402 | 8.85012E+11 | Wurth Elektronik |
| C13 | 1 | 1uF | CAP, CERM, 1 uF, 25 V, +/- 10%, X5R, 0603 | GRM188R61E105KA12D | MuRata |
| C14 | 1 | 2.2uF | CAP, CERM, 2.2 uF, 16 V, +/- 10%, X5R, 0603 | GRM188R61C225KAAD | MuRata |
| C15 | 1 | 1uF | CAP, CERM, 1 µF, 6.3 V, +/- 20%, X7R, 0402 | GRM155R70J105MA12D | MuRata |
| C16, C21 | 2 | 220 pF | CAP, CERM, 220 pF, 50 V, +/- 10%, X7R, 0402 | GRM155R71H221KA01D | MuRata |
| C17 | 1 | 0.047uF | CAP, CERM, 0.047 uF, 25 V, +/- 10%, X7R, 0402 | GRM155R71E473KA88D | MuRata |
| C18 | 1 | 3300 pF | CAP, CERM, 3300 pF, 50 V, +/- 10%, X7R, 0402 | GRM155R71H332KA01D | MuRata |
| C19 | 1 | 33uF | CAP, CERM, 33 µF, 25 V, +/- 20%, X5R, 1206 | C3216X5R1E336M160AC | TDK |
| C20, C23 | 2 | 0.1uF | CAP, CERM, 0.1 µF, 25 V, +/- 10%, X7R, 0402 | GRM155R71E104KE14D | MuRata |
| C22 | 1 | 1uF | CAP, CERM, 1 µF, 25 V,+/- 10%, X7R, 0603 | GCM188R71E105KA64D | MuRata |
| C24 | 1 | 1000 pF | CAP, CERM, 1000 pF, 25 V, +/- 10%, C0G/NP0, 0603 | C0603C102K3GACTU | Kemet |
| C25, C26 | 2 | 10uF | CAP, CERM, 10 uF, 50 V, +/- 10%, X5R, 1206 | GRM31CR61H106KA12L | MuRata |
| C27, C28, C29 | 3 | 2.2uF | CAP, CERM, 2.2 uF, 100 V, +/- 10%, X7S, 1206 | C3216X7S2A225K160AB | TDK |
| C30 | 1 | 100 pF | CAP, CERM, 100 pF, 50 V, +/- 5%, C0G/NP0, 0603 | GRM1885C1H101JA01D | MuRata |

**Table 4-2. Bill of Materials (continued)**

| Designator | Qty | Value | Description | Part Number | Manufacturer |
|---|---|---|---|---|---|
| C31 | 1 | 27 pF | CAP, CERM, 27 pF, 50 V, +/- 5%, C0G/NP0, 0402 | GRM1555C1H270JA01D | MuRata |
| C36 | 1 | 2200 pF | CAP, CERM, 2200 pF, 250 V,+/- 20%, E, Dia 9 mm | DE1E3RA222MN4AN01F | MuRata |
| C37 | 1 | 0.47uF | CAP, CERM, 0.47 uF, 450 V, +/- 10%, X7T, 1812 | C4532X7T2W474K230KA | TDK |
| D1 | 1 | 600 V | Diode, P-N-Bridge, 600 V, 4 A, Z4-D | Z4DGP406L-HF | Comchip Technology |
| D2 | 1 | 40 V | Diode, Schottky, 40 V, 0.2 A, SOD-523 | RB521SM-40T2R | Rohm |
| D3 | 1 | 800 V | Diode, Fast Rectifier, 800 V, 1 A, SMA | US1K-13-F | Diodes Inc. |
| D4, D5 | 2 | 600 V | Diode, Ultrafast, 600 V, 1 A, SOD-123FL | UFM15PL-TP | Micro Commercial Components |
| D6, D7 | 2 | 5 V | TVS, 5 V, bidirectional, SOD-323 | PESD5V0L1BA,115 | NXP Semiconductor |
| D8, D9 | 2 | 100 V | Diode, Switching, 100 V, 150 A, AEC-Q101, SOD-323 | 1N4148WS-HG3-08 | Vishay-Semiconductor |
| D10 | 1 | 250 V | Diode, Switching, 250 V, 0.25 A, AEC-Q101, SOD-323 | BAV21WS-7-F | Diodes Inc. |
| D11 | 1 | 14 V | Diode, Zener, 14 V, 500 mW, SOD-123 | MMSZ4701T1G | ON Semiconductor |
| F1 | 1 | 3.15A | Fuse, 3.15 A, 250VAC/VDC, TH | RST 3.15-BULK | Bel-Fuse |
| H1, H2, H3, H4 | 4 | | Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead | NY PMS 440 0025 PH | B&F Fastener Supply |
| H5, H6, H7, H8 | 4 | | Standoff, Hex, 0.5"L #4-40 Nylon | 1902C | Keystone |
| J1 | 1 | | Terminal Block, 5.08 mm, 2x1, Brass, TH | ED120/2DS | On-Shore Technology |
| J2 | 1 | USB-C Receptacle | Connector, Receptacle, USB Type C, R/A | 6.32723E+11 | Wurth Elektronik |
| L1 | 1 | 22uH | Inductor, Shielded, Ferrite, 22 µH, 1.8 A, 0.089 ohm, SMD | 74404064220 | Wurth |
| L2 | 1 | 1mH | Coupled inductor, 1 mH, 2 A, 0.045 ohm, TH | 744821201 | Wurth Elektronik |
| L3, L4 | 2 | 330 ohm | Ferrite Bead, 330 ohm @ 100 MHz, 1.5 A, 0603 | BLM18SG331TN1D | MuRata |
| Q1 | 1 | 30 V | MOSFET, N-CH, 30 V, 60 A, DQG0008A (VSON-CLIP-8) | CSD17575Q3 | Texas Instruments |
| Q2 | 1 | 150 V | MOSFET, N-CH, 150 V, 87 A, PG-TDSON-8 | BSC093N15NS5ATMA1 | Infineon Technologies |
| Q3 | 1 | 100 V | MOSFET, N-CH, 100 V, 0.17 A, SOT-23 | BSS123 | Fairchild Semiconductor |
| Q4 | 1 | | Optoisolator Transistor Output 5000Vrms 1 Channel 6-SO | TLP383(GR-TPL,E | Toshiba |
| R1 | 1 | 348k | RES, 348 k, 1%, 0.25 W, 1206 | CRCW1206348KFKEA | Vishay-Dale |
| R2, R22 | 2 | 0 | RES, 0, 5%, 0.063 W, 0402 | CRCW04020000Z0ED | Vishay-Dale |
| R3, R12 | 2 | 47k | RES, 47 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402 | CRCW040247K0JNED | Vishay-Dale |
| R4 | 1 | 0 | RES, 300R, 1%, 0.063 W, 0402 | CRCW0402300RFKEDC | Vishay-Dale |

**Table 4-2. Bill of Materials (continued)**

| Designator | Qty | Value | Description | Part Number | Manufacturer |
|---|---|---|---|---|---|
| R5 | 1 | 10 | RES, 10, 5%, 0.125 W, 0805 | CRCW080510R0JNEA | Vishay-Dale |
| R7 | 1 | 0 | RES, 0, 5%, 0.1 W, AEC-Q200 Grade 0, 0603 | CRCW06030000Z0EA | Vishay-Dale |
| R8 | 1 | 300 | RES, 300, 0.1%, 0.063 W, 0402 | RG1005P-301-B-T5 | Susumu Co Ltd |
| R9 | 1 | 1.0k | RES, 1.0 k, 5%, 0.25 W, 1206 | CRCW12061K00JNEA | Vishay-Dale |
| R10 | 1 | 0.004 | RES, 0.004, 1%, 1 W, AEC-Q200 Grade 0, 1206 | CRF1206-FZ-R004ELF | Bourns |
| R11 | 1 | 5.11k | RES, 5.11 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402 | CRCW04025K11FKED | Vishay-Dale |
| R13, R15 | 2 | 47 | RES, 47, 5%, 0.063 W, 0402 | CRCW040247R0JNED | Vishay-Dale |
| R14 | 1 | 48.7k | RES, 48.7 k, 1%, 0.063 W, 0402 | CRCW040248K7FKED | Vishay-Dale |
| R16 | 1 | 1.00k | RES, 1.00 k, 1%, 0.25 W, 1206 | RC1206FR-071KL | Yageo America |
| R17 | 1 | 2.87k | RES, 2.87 k, 1%, 0.1 W, 0603 | CRCW06032K87FKEA | Vishay-Dale |
| R18 | 1 | 10k | RES, 10 k, 5%, 0.063 W, AEC-Q200 Grade 0, 0402 | CRCW040210K0JNED | Vishay-Dale |
| R19 | 1 | 510k | RES, 510 k, 5%, 0.1 W, 0603 | CRCW0603510KJNEA | Vishay-Dale |
| R23 | 1 | 3.24k | RES, 3.24 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402 | CRCW04023K24FKED | Vishay-Dale |
| R24 | 1 | 1.0k | RES, 1.0 k, 5%, 0.1 W, 0603 | CRCW06031K00JNEA | Vishay-Dale |
| R25 | 1 | 100k | RES, 100 k, 5%, 0.1 W, 0603 | CRCW0603100KJNEA | Vishay-Dale |
| R26 | 1 | 91k | RES, 91 k, 5%, 0.1 W, 0603 | CRCW060391K0JNEA | Vishay-Dale |
| R27 | 1 | 34.0k | RES, 34.0 k, 1%, 0.063 W, 0402 | CRCW040234K0FKED | Vishay-Dale |
| R28 | 1 | 2.00k | RES, 2.00 k, 1%, 0.1 W, 0603 | CRCW06032K00FKEA | Vishay-Dale |
| R29 | 1 | 365 | RES, 365, 1%, 0.063 W, AEC-Q200 Grade 0, 0402 | CRCW0402365RFKED | Vishay-Dale |
| RT1 | 1 | 220k | Thermistor NTC, 220k ohm, 5%, 0603 | NCP18WM224J03RB | MuRata |
| T1 | 1 | | T1 for LMG362xEVM-074 | RLTI-1454 | Renco |
| TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TPL | 9 | | Test Point, Multipurpose, White, TH | 5012 | Keystone, Keystone Electronics |
| TP9, TP10, TP11, TP12, TPN | 5 | | Test Point, Multipurpose, Black, TH | 5011 | Keystone Electronics |
| U1 | 1 | | 650-V GaN FET With Integrated Driver and Current Sense Emulation | LMG3622REQ | Texas Instruments |
| U2 | 1 | | FAST TURN-OFF INTELLIGENT RECTIF | MP6908AGJ-P | Monolithic Power Systems |
| U3 | 1 | | USB PD/QC4/QC4+ Controller | WT6636F | Weltrend |
| U4 | 1 | | Converter Offline Flyback Topology 50 kHz | NCP1342AMAACD1R2G | onsemi |
| C7 | 0 | 220 pF | CAP, CERM, 220 pF, 250 V, +/- 10%, X7R, 0603 | GRM188R72E221KW07D | MuRata |
| C32 | 0 | 4700 pF | CAP, CERM, 4700 pF, 50 V, +/- 10%, X7R, 0402 | GRM155R71H472KA01D | MuRata |
| R6 | 0 | 47 | RES, 47, 5%, 0.1 W, 0603 | CRCW060347R0JNEA | Vishay-Dale |

**Table 4-2. Bill of Materials (continued)**

| Designator | Qty | Value | Description | Part Number | Manufacturer |
|---|---|---|---|---|---|
| R30 | 0 | 511 | RES, 511, 1%, 0.063 W, AEC-Q200 Grade 0, 0402 | CRCW0402511RFKED | Vishay-Dale |
| R34 | 0 | 0 | RES, 0, 5%, 0.063 W, 0402 | CRCW04020000Z0ED | Vishay-Dale |

# 5 Additional Information

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