

# AC-DC Power Supply with Interleaved Power Factor Correction and Resonant LLC Converter Evaluation Board User's Manual

## 600W-ACDC-GEVB

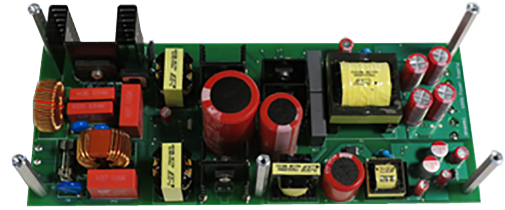


Figure 1. Evaluation Board Picture

### Description

The 600W-ACDC-GEVB is a complete EVB user's manual for a universal power supply capable of delivering 48 V/12.5 A DC. A 5 V/2 A DC output is also available for added flexibility. The PFC front end is equipped with an NCP1632 interleaved PFC controller. The main converter providing 48 V is a resonant LLC stage using the NCP1399 controller. Two NCP4305 sync controllers provide synchronous rectification in the secondary. The 5 V output is generated by a flyback converter using the NCP1076 switcher. It also provides 12 V for a cooling fan. Due to hazardous voltages present on the unit, the board is intended for functional testing under laboratory conditions and by trained specialists only.

### Features

- 48 V/12.5 A Complete Power Supply Solution with Universal Mains Input
- 5 V/2 A and 12 V/0.3 A for External Cooling Fan
- 2-channel Interleaved Power Factor Correction (PFC)
- High Efficiency Resonant LLC Stage with Synchronous Rectification
- PFC Stage Using NCP1632 Controller, NTPF165N65 NMOS Power MOSFETs and MURF860C Boost Diodes
- Resonant LLC Converter Using NCP1399AP Controller and NTPF250N65 NMOS Power MOSFETs
- Synchronous Rectification with NCP4305D Controller and FDMS86202ET120 N-Channel Shielded Gate Power MOSFETs
- Over-power, Over-current and Over-temperature Protection

### Applications

- Industrial Power Supply Unit

### Key Components

- [NC3P162](#)
- [NCP1399](#)
- [NCP1076](#)
- [NCP4305](#)
- [FDMS86202ET120](#)
- [MURF860G](#)

# 600W-ACDC-GEVB

## Scope and Purpose

This EVB user's manual provides practical guidelines for using and testing this power supply. The design was tested as described in this document, but not qualified regarding safety requirements or manufacturing and operation over the whole operating temperature range or lifetime. The development board has been laid out in a spacious manner so that it facilitates measurements and probing for the evaluation of the system and its components. The hardware is intended for functional testing under laboratory conditions and by trained specialists only.

## Hardware Revision

This EVB user's manual is compatible with version 1.0 of 600W-ACDC\_EVB.

### WARNING:

The 600W-ACDC-EVB is powered from AC Mains, and exposed to high voltage. Only trained personnel should manipulate and operate the unit. **It is mandatory to read the Safety Precautions section in Chapter 5.1 before manipulating the board.** Failure to comply with the described safety precautions may result in personal injury or death, or equipment damage.

## DESIGN OVERVIEW

This demo board is well suited to be used with any industrial application requiring 48 V DC power up to 12.5 A. A 5 V rail able to provide up to 2A is available. The main 48 V unit and the 5 V unit are powered up when mains voltage (110 Vac or 230 Vac) is applied. The development board has been laid out in a reasonably spacious manner so that it facilitates measurements and probing for the evaluation of its various components. All probing is

recommended to be performed on the top side of the board (the side with SMD components). Probing for functional testing should be done under laboratory conditions and by trained specialists only.

The foremost advantages that this demo board brings are:

- Complete system solutions for any industrial application requiring 48 V up to 12.5 A
- High efficiency

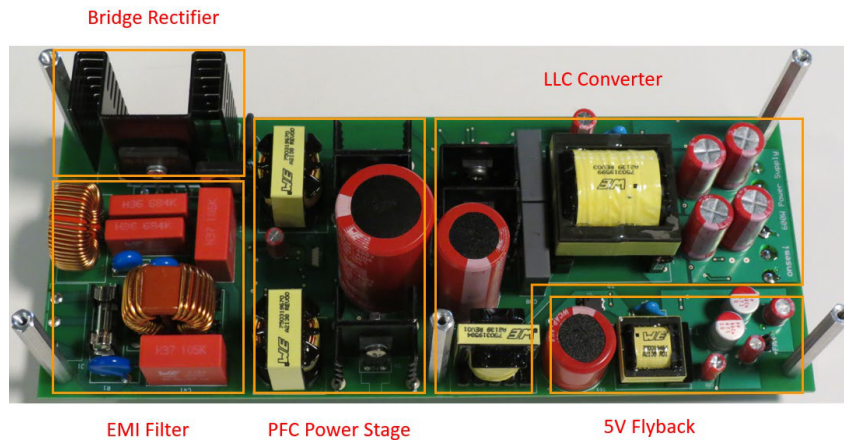


Figure 2. Picture of the Evaluation Board – Top Side

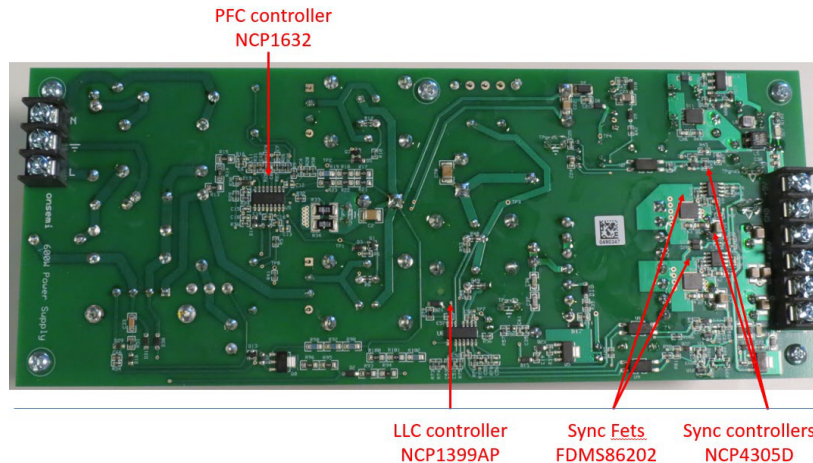


Figure 3. Picture of the Evaluation Board – Bottom Side

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## SPECIFICATIONS

The specification and main features are presented in the following table.

### SPECIFICATIONS TABLE

Parameters	Values	Conditions
<b>Input</b>		
Voltage	110 to 230 Vrms $\pm 15\%$	
<b>Output</b>		
Main rail	48 V $\pm 2\%$	Main rail load: 0 to 12.5 A
Secondary rail	5 V $\pm 2\%$	Secondary rail load: 0 to 2 A
Fan rail	12 V $\pm 15\%$	Max 0.36 A fan consumption

### BLOCK DIAGRAM

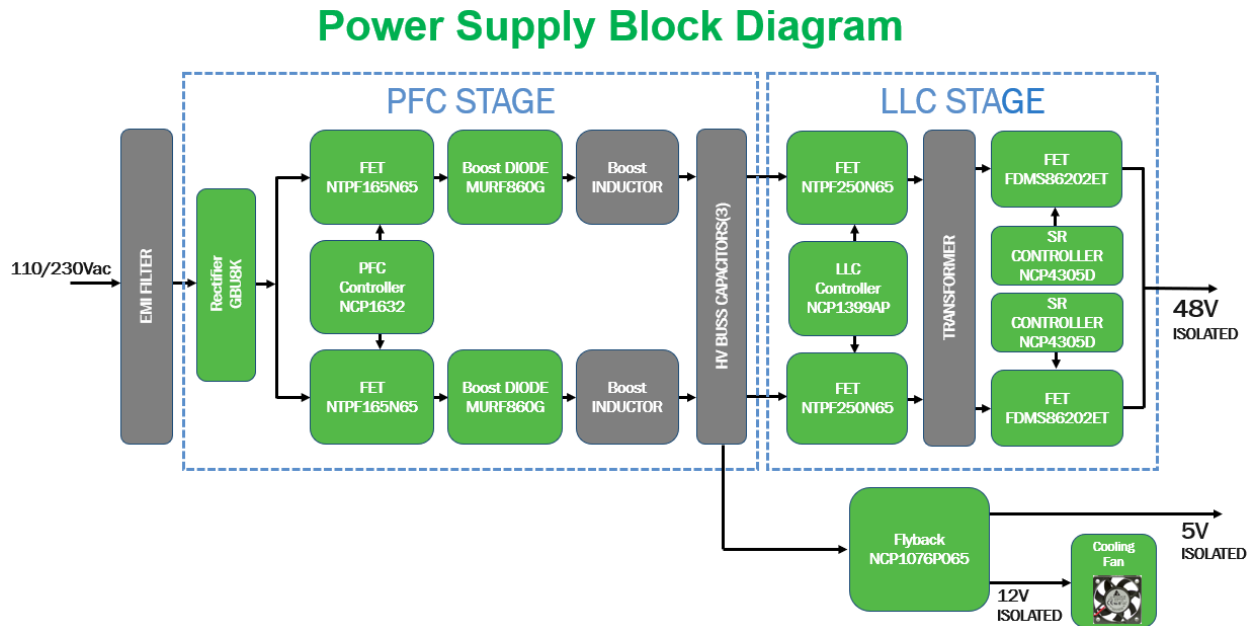


Figure 4. Block Diagram of the Evaluation Board

Mains power is fed via an EMI filter and a bridge rectifier to a two-phase interleaved Power Factor Correction (PFC) stage which boosts the voltage and maintains a high voltage buss of about 395 V across the HV buss capacitors. In order to minimize any potential interference between the three converter blocks (PFC, LLC and flyback), a total of three HV buss capacitors are used, one for each block. The LLC converter then converts the HV buss down to a 48 V DC output. The conversion involves a transformer so the output voltage is isolated from the mains. The flyback converts the

HV buss down to 5 V and also to 12 V for a cooling fan, both isolated as well.

#### EMI Filter and Bridge Rectifier

Preceding the PFC stage there is the EMI filter, which helps in ensuring compliance with the EMC regulations. Following, the asynchronous rectification is realized with the GBU8K bridge rectifier.

## Inrush Current Limiter and X Cap Discharge Circuits

These circuits minimize the inrush current when AC power is first applied and discharge the voltage that may be present across the X capacitors after AC power removal.

## Two-channel Interleaved Power Factor Correction Front End

The interleaved PFC stage utilizes several high performance components: NCP1632 Power Factor Controller, NTPF165N65S3 650V super-junction MOSFETs and MURF860G diodes. The interleaved approach has several merits like the ease of implementation, the use of smaller components and a better distribution of the heat. It also extends the power range of Critical Conduction Mode which is an efficient and cost-effective mode of operation. The NCP1632, whose drivers are 180° phase shifted for a significantly reduced current ripple, incorporates all the features necessary for building robust

and compact interleaved PFC stages, with a minimum of external components.

## Resonant LLC Stage

This stage is built around a high performance LLC controller with integrated drivers: the NCP1399AP. It drives a half bridge stage using two NTPF250N65S3 650 V super-junction MOSFET. For best possible efficiency the output uses synchronous rectification with NCP4305D controllers and two FDMS86202ET120 low R<sub>ds(on)</sub> MOSFETs.

## Flyback Converter

This is a low power flyback converter built around the NCP1076P065 switcher with integrated MOSFET. It provides 5 V at max 2 A for the secondary output and also 12 V for the cooling fan. Both rails are isolated.

## SCHEMATICS AND DESIGN

In order to facilitate explanation and understanding of operation, some portions of the schematics are organized differently than in the final schematic.

L2 together with “X” capacitors Cx1, Cx2, Cx3 and “Y” capacitors Cy1, Cy2. A transient voltage suppressor R1 is placed right after the input fuse.

## Input EMI Filter

This circuit includes a typical passive EMI filter consisting of common mode choke L1 and series inductor

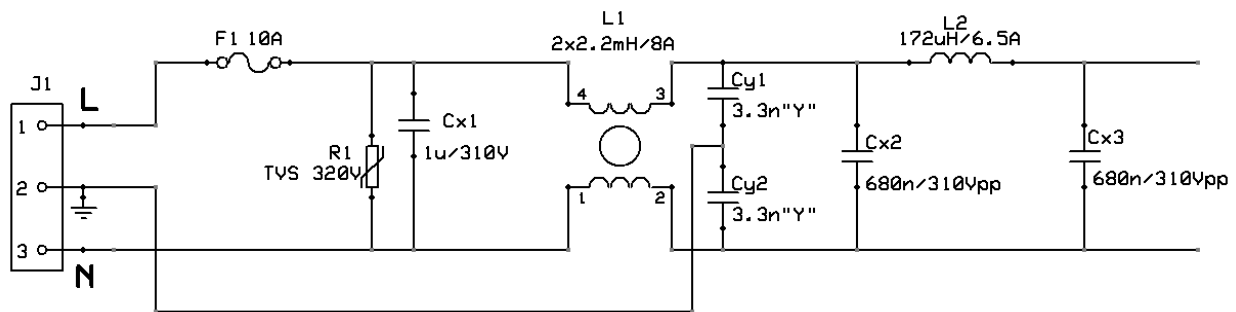


Figure 5. Schematic of EMI Filter

## Inrush Current Limiter and X Cap Discharge Circuits

In lower power / low cost applications the input inrush current is limited by using a thermistor. More often than not the thermistor is not bypassed after the power supply starts and the current flowing through it heats it up. Since it's a negative temperature coefficient device, this causes its resistance to decrease significantly thus reducing the power loss. This would have been a totally unacceptable solution for the current power supply as its high input current (7 Arms) would have caused the thermistor to reach temperatures exceeding 150°C thus creating a hazardous environment for the adjacent components. Therefore a low R<sub>ds(on)</sub> MOSFET was used to bypass the thermistor after the startup sequence is completed.

When AC mains voltage is applied to the board, the three HV buss filtering capacitors are being charged and a high

current pulse can occur. To limit its amplitude an inrush limiter is used.

Figure 6 presents the inrush limiter and X-cap discharge circuits. The charging path is highlighted using light red arrows. MOSFET Q7 is initially turned off and the charging current flows through thermistor R52 (15 Ω) which limits the peak charging current to no more than roughly 30 A. After the initial high current pulses are over, R52 needs to be bypassed in order to reduce losses. A charge pump (C33, R51, D29, D16) is used to slowly turn on MOSFET Q7 which then bypasses R52 as long as AC voltage from the mains is still present.

Upon removal of AC voltage, depending on the exact timing, the X capacitors may have some significant residual charge that can have an unpleasant effect if the user inadvertently touches the prongs of the AC power cord. To

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avoid this a circuit is used to discharge the X caps to less than 40 V within 1 sec after removal of AC power. During normal operation, the same charge pump described above maintains MOSFET Q13 turned on and MOSFET Q8 turned off. When

AC power is removed the charge pump stops working and Q13 turns off and Q8 turns on discharging the X caps via resistors R95, R96.

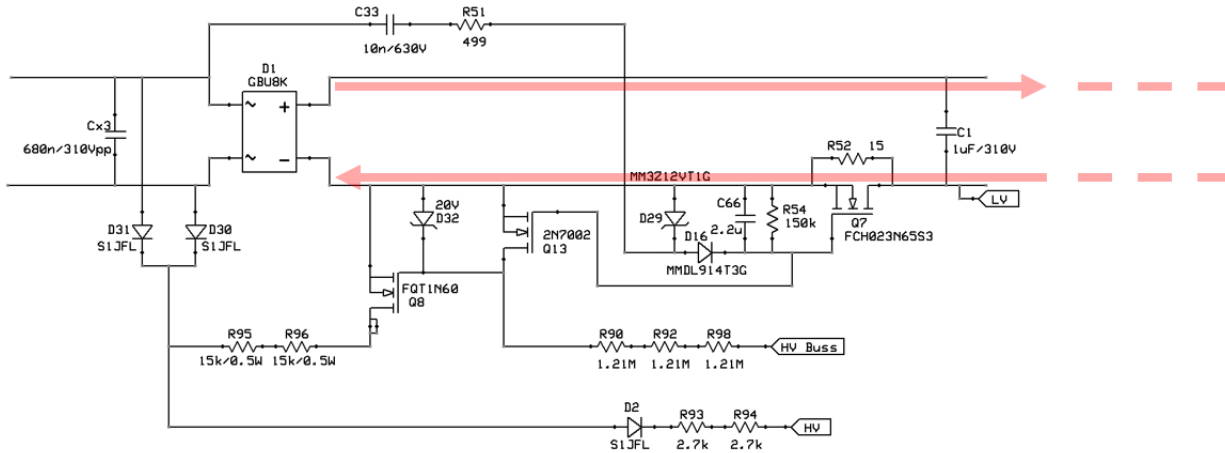


Figure 6. Schematic of Inrush Current Limiter and X-cap Discharge Circuits

The following scope shots capture the waveforms related to the inrush current limiter and X-cap discharge circuits.

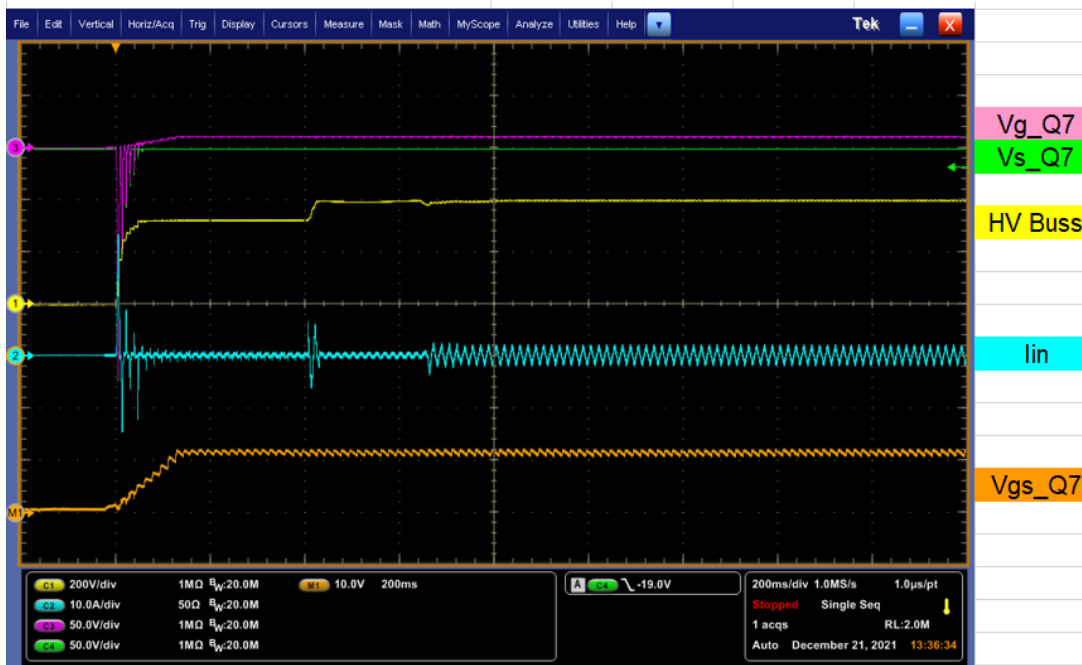


Figure 7. Zoom in On Start at 230 Vac

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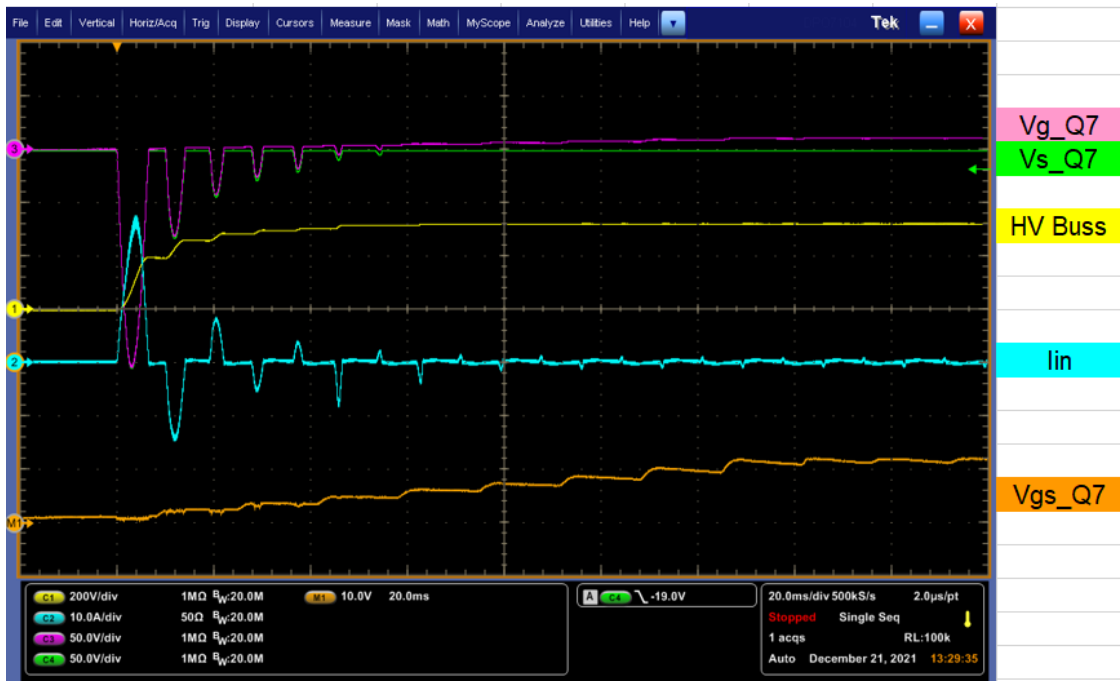


Figure 8. More Zoom

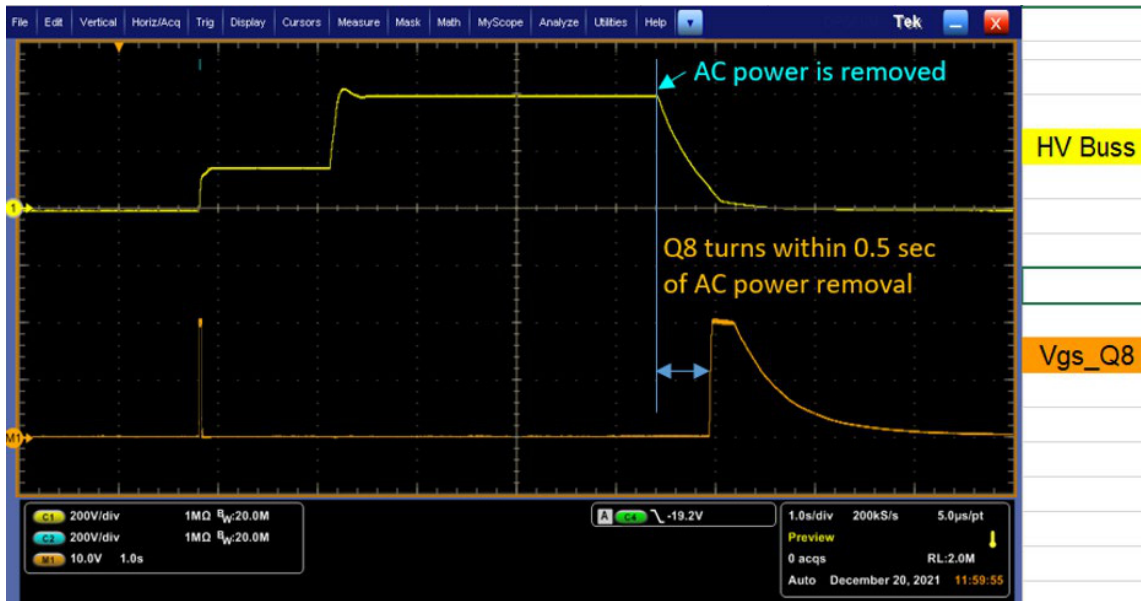


Figure 9. PFC Start / Stop and Xcap Discharge

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## Interleaved PFC Stage

A two-channel interleaved PFC front end is implemented for the several advantages that it brings: reduced inductor size and ripple current, which allows for smaller output capacitor as well as a minimized EMI filter. Interleaving also extends the power range of Critical Conduction Mode which

is an efficient and cost-effective mode of operation that does not need fast recovery boost diodes.

The PFC stage is activated when Vcc is applied to pin 12 of U5 controller.

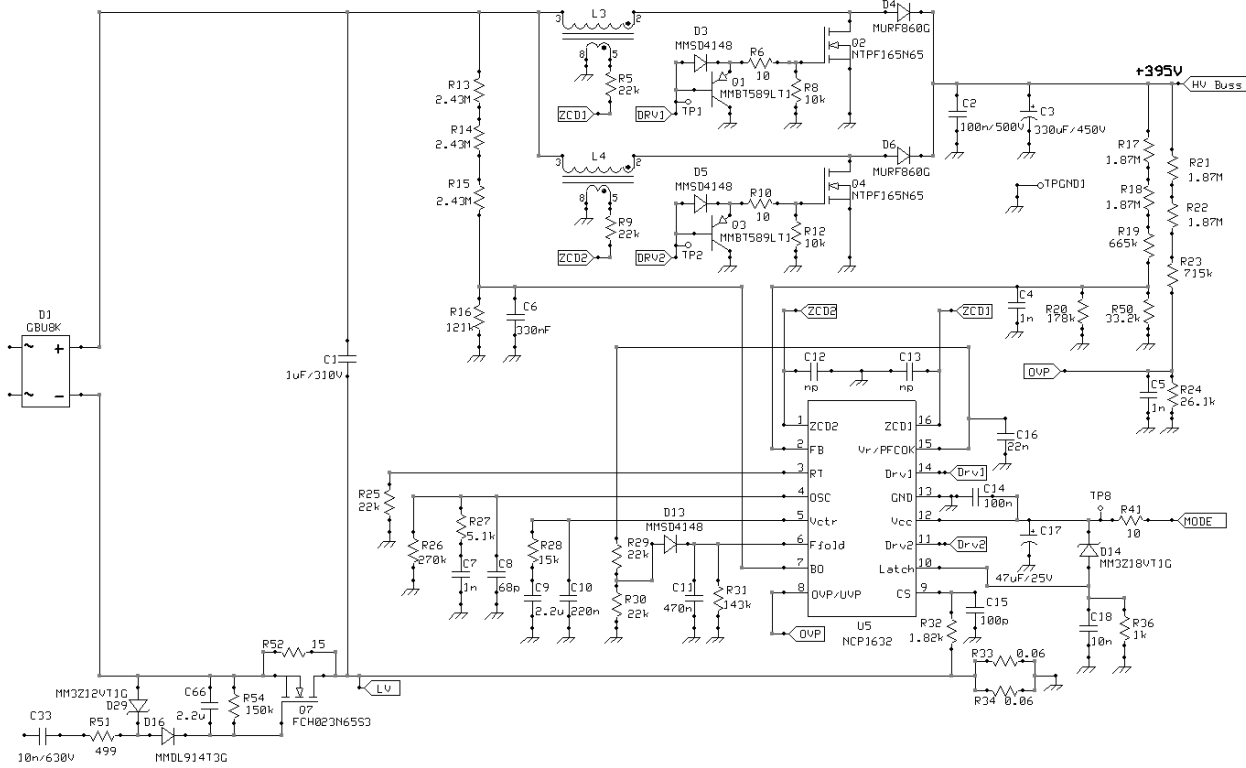


Figure 10. Schematic of Interleaved PFC Stage

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The following scope shots show some typical waveforms of the PFC.

MOSFETs Q2 and Q4 switch 180° out of phase, but their duty cycle and frequency depend on the instantaneous level

of the rectified AC voltage and also on the load as shown in the following scope captures.

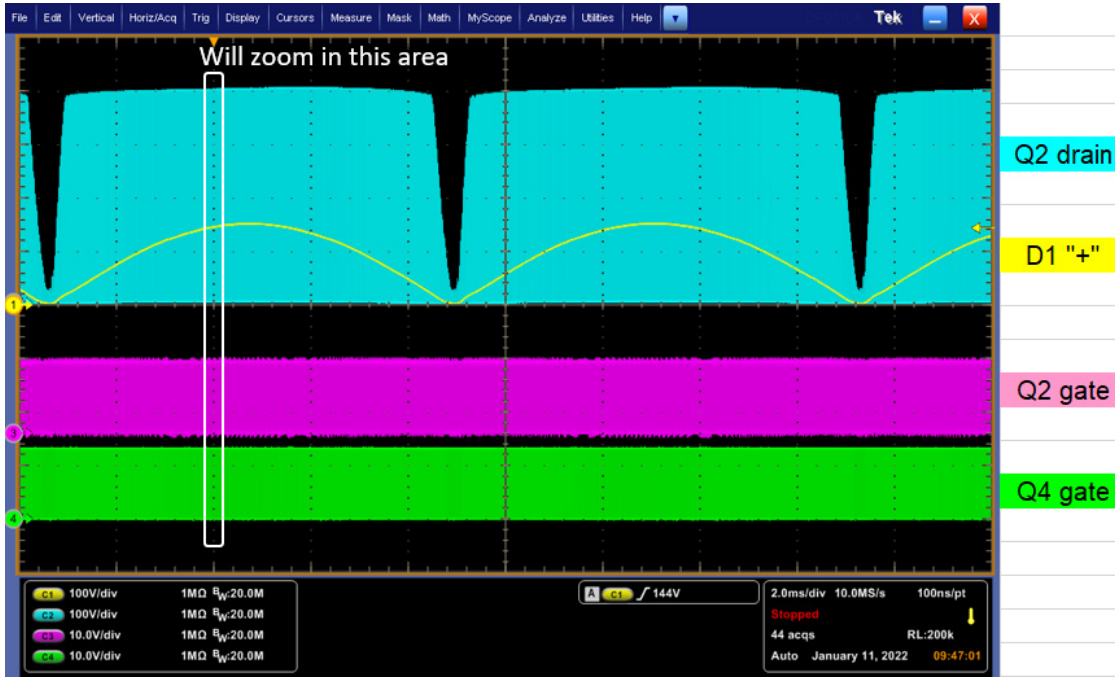


Figure 11. Typical Waveforms

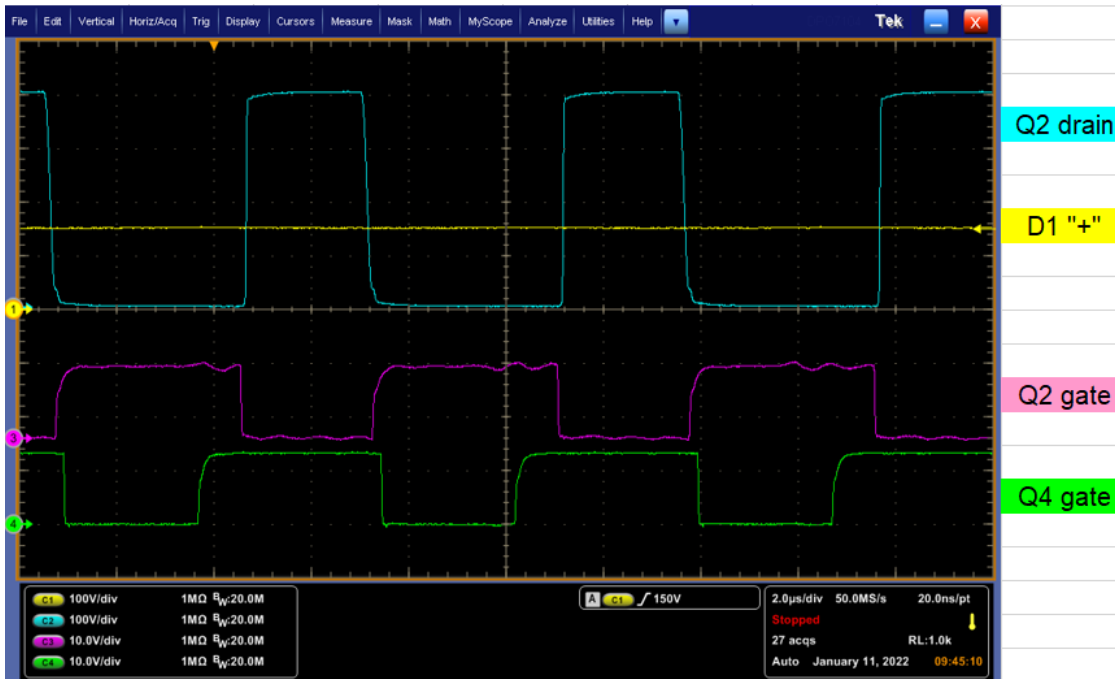


Figure 12. Typical Waveforms (Zoom)



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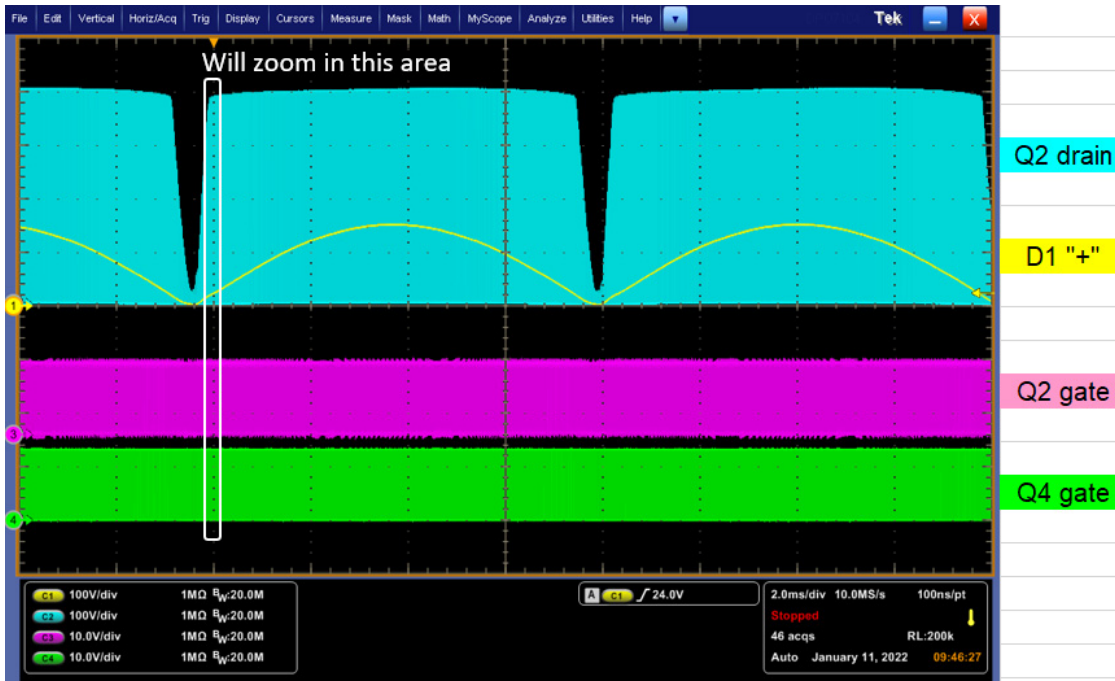


Figure 13. Typical Waveforms

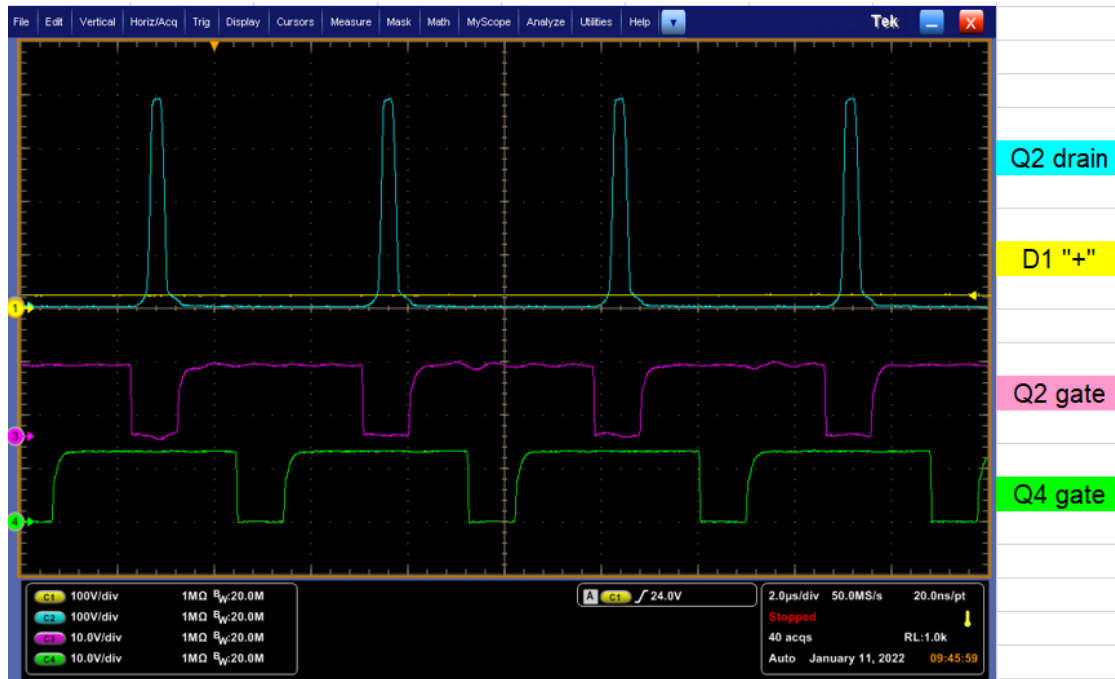


Figure 14. Typical Waveforms (Zoom)

At light load, in order to maintain good efficiency, the PFC will decrease its switching frequency, but will maintain regulation of the HV Buss.



Figure 15. PFC Waveforms at No Load

### Resonant LLC Converter Stage

The LLC converter uses an NCP1399AP controller which is a high performance current mode controller for half bridge resonant converters. This controller incorporates 600 V gate drivers, simplifying layout and reducing external component count. The built-in Brown-Out input function eases implementation of the controller in all applications. In applications where a PFC front stage is needed, the NCP1399AP features a dedicated output to provide Vcc to the PFC controller. This feature together with dedicated skip mode technique further improves light load efficiency of the

whole application. The half-bridge resonant LLC topology achieves very good efficiency without significantly increasing circuit complexity. The controller drives two NTPF250N65S3 650 V super-junction MOSFETs which are state of the art parts with very low gate charge and R<sub>ds(on)</sub>. A switching frequency of 75 kHz has been chosen to keep transformer switching losses to a minimum. The relatively low switching frequency would have not justified using GaN transistors in the power stage.

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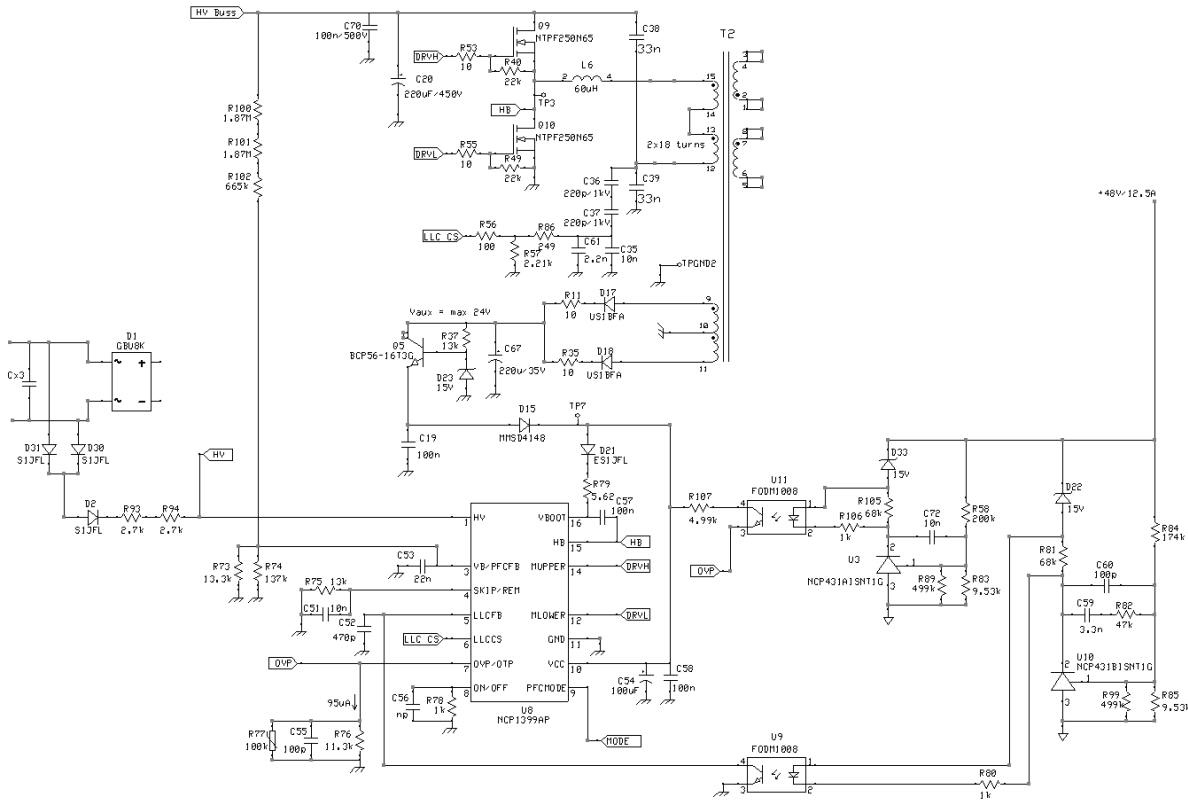


Figure 16. Schematic of LLC Stage – Primary Side

Two NCP4305D secondary side controllers are used for synchronous rectification for best possible efficiency. They drive two very low  $R_{ds(on)}$  MOSFETs: FDMS86202ET120. The 12 V rail necessary for the sync controllers is obtained from the 48 V rail by using a local regulator built around transistor Q6. Heavy filtering is provided by a combination of four low ESR electrolytic capacitors and several MLCCs.

Diodes D19, D20 and adjacent components R59, R60, C40 create a voltage level that will decrease considerably at light load thus disabling the controllers during very light load conditions in order to minimize consumption.

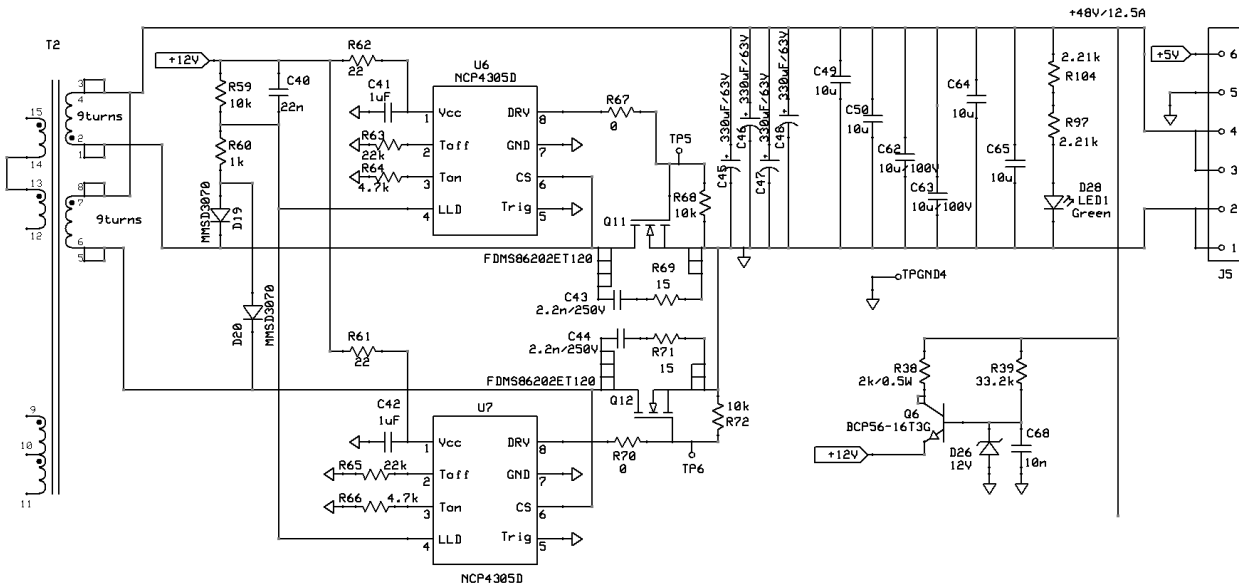


Figure 17. Schematic of LLC Stage – Secondary Side

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At power-up when AC power is applied the NCP1399AP controller receives supply voltage on pin 1 via diodes D30, D31, D2 and resistors R93, R94 (see Figure 16) and an internal current source charges capacitor C54. When a voltage of around 16 V is reached, this voltage also becomes available at pin 9 and is fed to the PFC controller which will start when this level exceeds roughly 12 V. Then the HV buss ramps up and when it reaches around 390 V the resistive divider made of R100, R101, R102, R73, R74 will

create a voltage level slightly exceeding 1 V at pin 3 of the NCP1399AP controller which will start operating and the 48V output will ramp up. Simultaneously the auxiliary winding (9-10-11) of transformer T2 will create the necessary voltage to maintain operation of the controller while the internal current source will be turned off to reduce dissipation.

The previously described start-up sequence is captured in the following scope shot.



Figure 18. Power Supply Start-up Sequence

The LLC converter transfers power to the load and maintains voltage regulation by varying its switching frequency. At maximum load the switching frequency is close to the resonant frequency of the LLC elements of the resonant tank: resonant inductor L6, transformer T2 and resonant capacitors C38, C39. At lighter load the switching frequency increases to maintain regulation. If load continues to decrease the LLC converter will start to skip cycles. The voltage across the resonant capacitor (C38, C39) is divided

down by C36, C37, C35, C61, R86, R57, R56 and fed to the current sense input of LLC controller (pin 6). The amplitude of this signal sets the maximum power the LLC converter can provide. Exceeding the maximum power will force the converter into a hiccup mode and normal function will be restored when the load will require less power.

The next scope shots capture the typical waveforms of the LLC converter.

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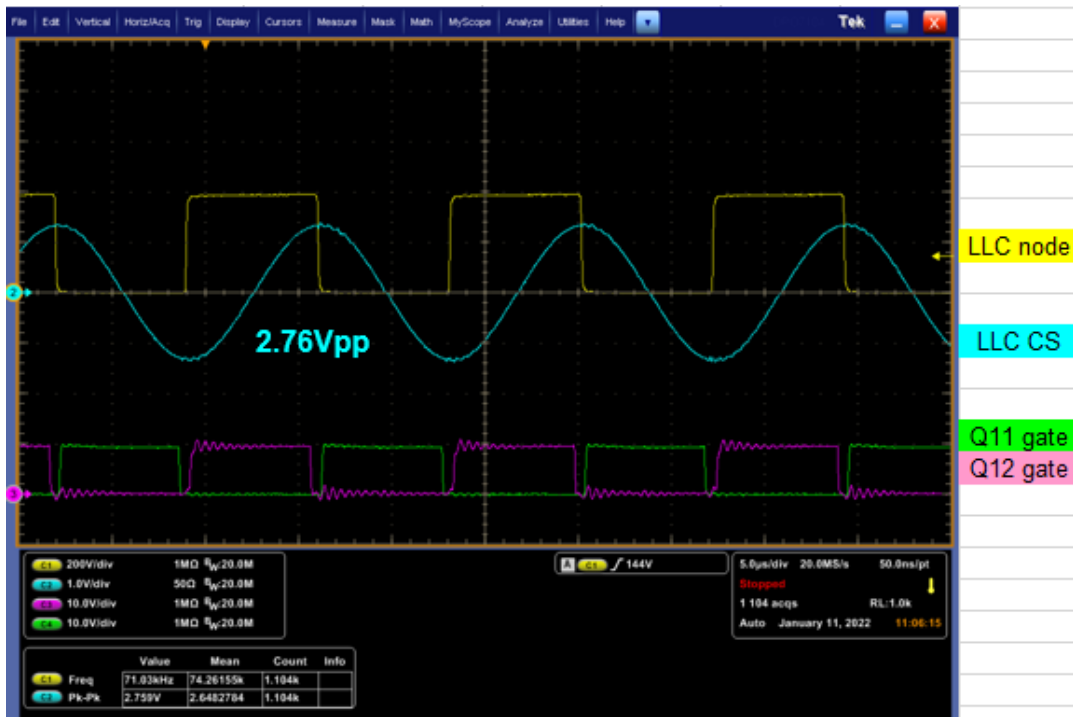


Figure 19. LCC at 12.5 A

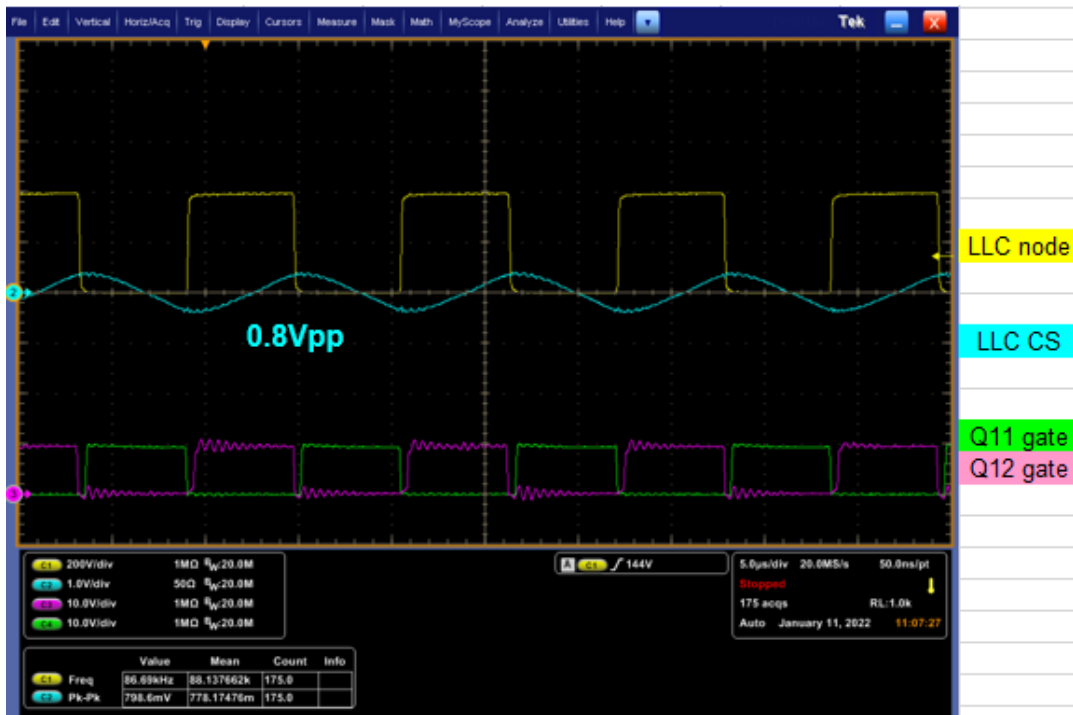


Figure 20. LCC at 4 A

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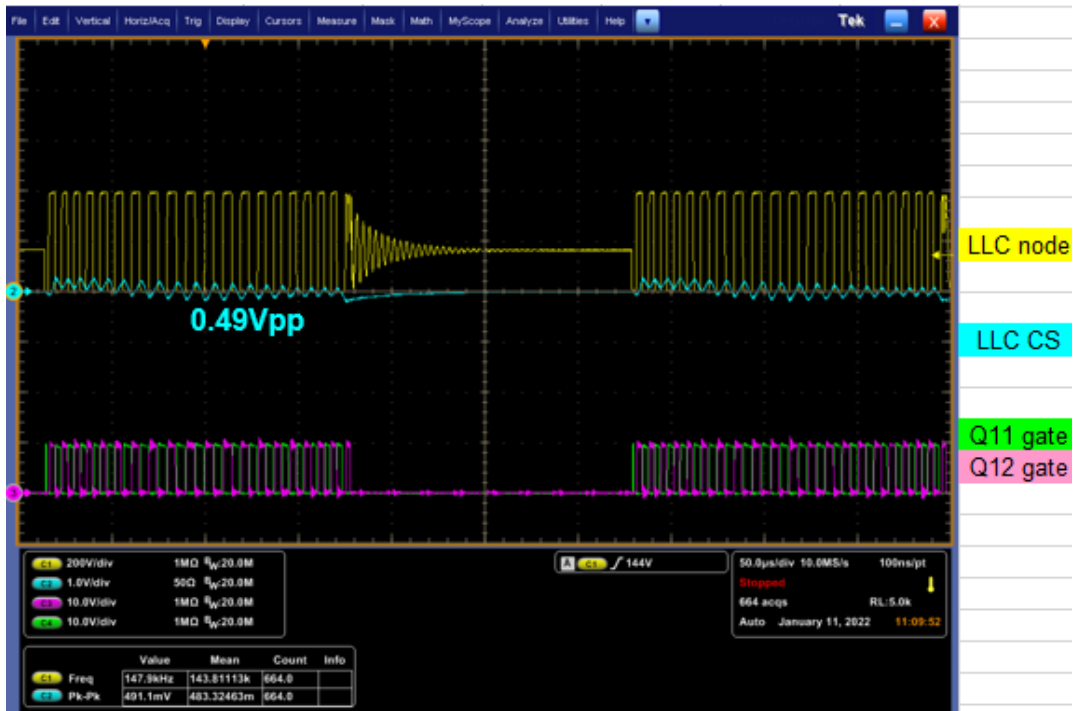


Figure 21. LCC at 1 A

At no load, in order to reduce power consumption, the secondary sync controllers stop working and there are no gate signals applied to MOSFETs Q11, Q12.



Figure 22. LCC at No Load

In case of overload or short circuit at the 48 V output, the LLC converter will enter a hiccup mode to limit power

dissipation and will resume operation upon removal of the short circuit.

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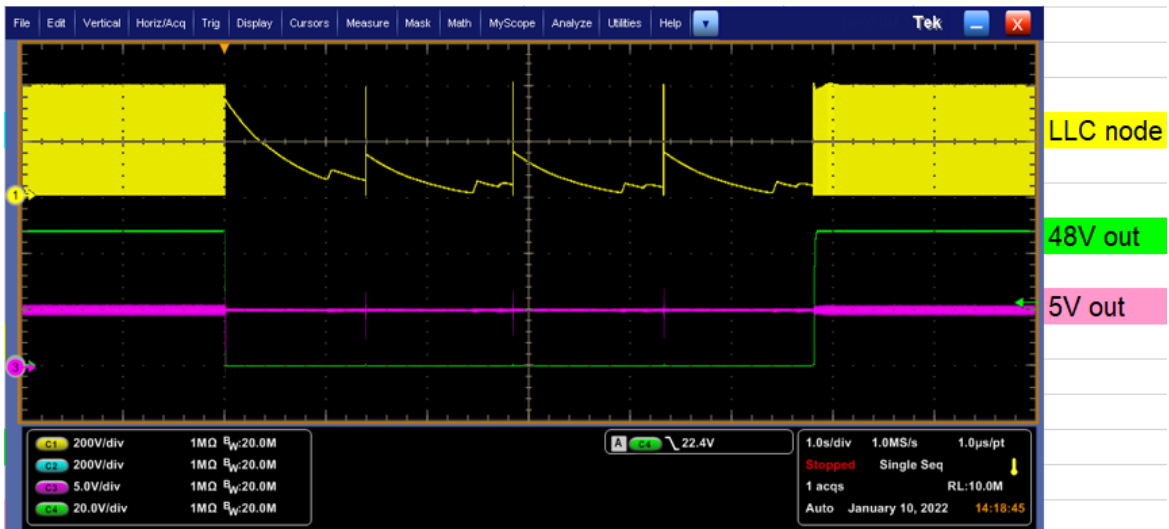


Figure 23. Shorting the 48 V Output

In case of over temperature, resistance of thermistor R77 decreases and when the voltage level at pin 7 of U8 decreases below roughly 0.8 V the converter will enter hiccup mode to

protect itself. After cooling down normal operation resumes.

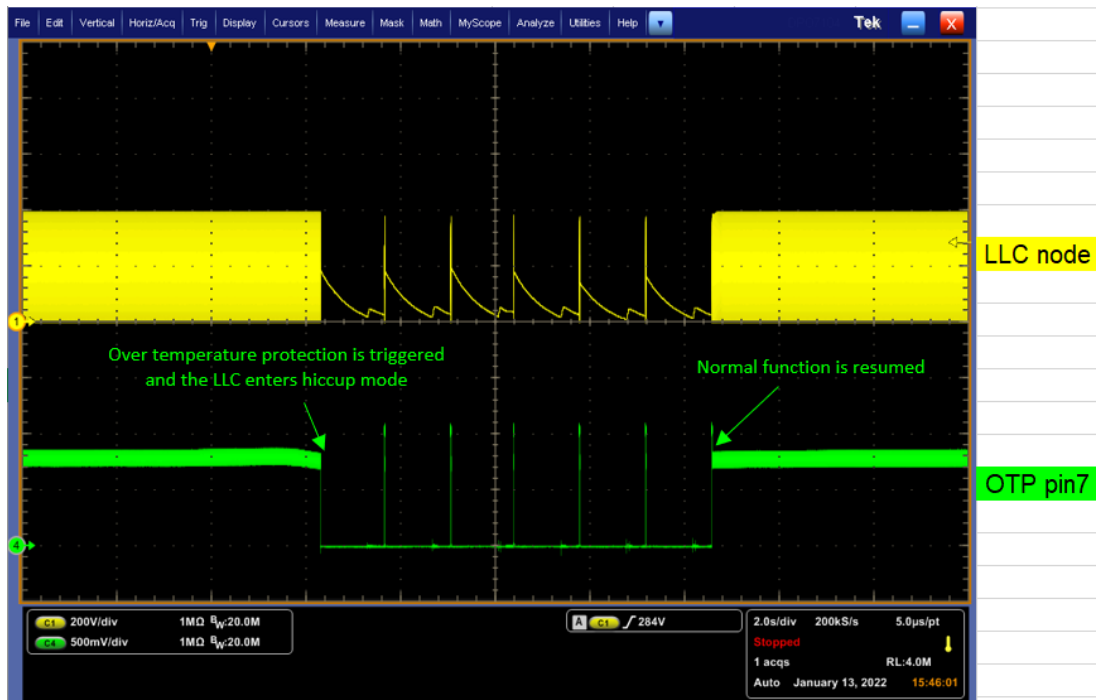


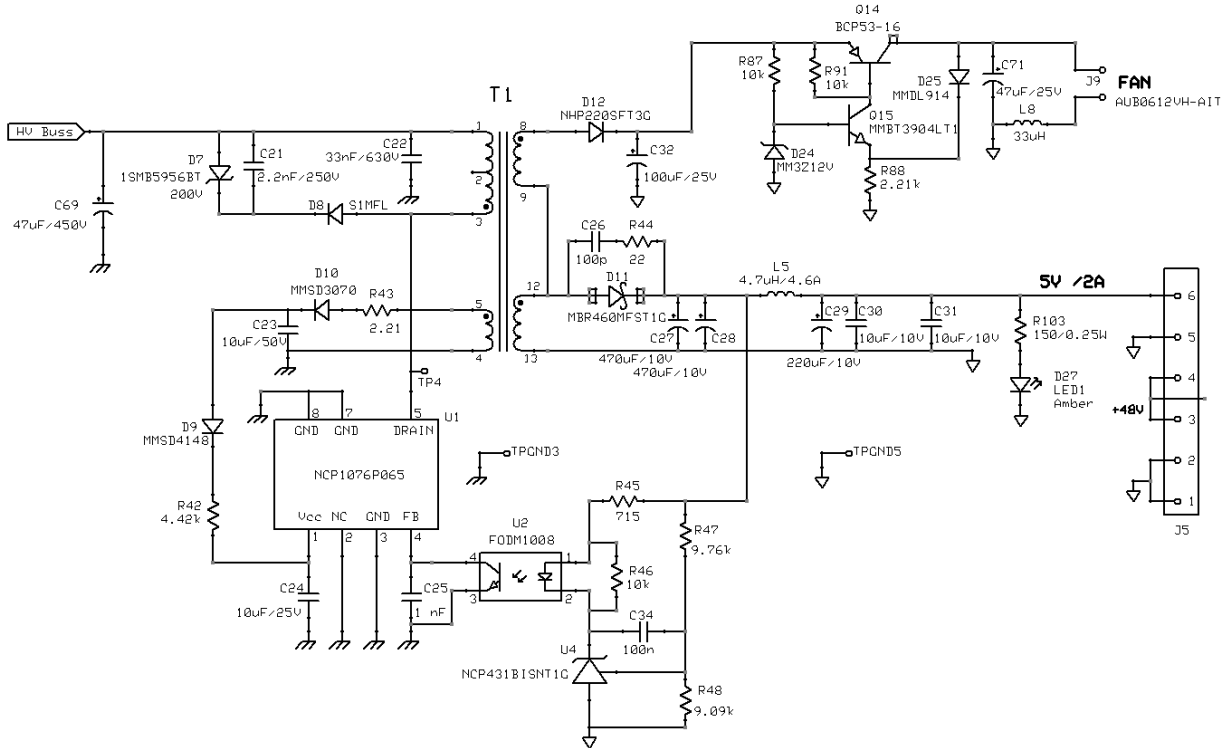
Figure 24. Over Temperature Protection

**The 5 V Flyback Converter**

The NCP1076P065 is a 75 kHz switcher with integrated MOSFET that provides a simple and robust solution capable of up to 25 W when powered from a high voltage buss of about 400 V. The current application only requires around 15 W. The topology is a flyback that runs in CCM / 65 kHz (continuous current mode) at heavy load and in DCM (discontinuous current mode) at lighter load. If load is further reduced the switching frequency will keep decreasing and it will eventually transition to hiccup mode to maintain high efficiency.

The 5 V secondary output is well regulated and can be used for any application requiring up to 2 A. There is also a roughly 14 V output which is used to power up the cooling fan via voltage regulator of about 12 V.

Components D24, Q14, Q15, D25 create a discrete low drop voltage regulator. The regulation level is set to 12 V by D24 Zener diode. The discrete solution used here for the fan regulator may seem complex, but it's cheaper than a power LDO as it would have been required by the 0.36 A consumption of the fan.



**Figure 25. Schematic of 5 V Flyback Converter and Fan Voltage Regulator**



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The typical waveforms of the 5 V flyback are captured below.

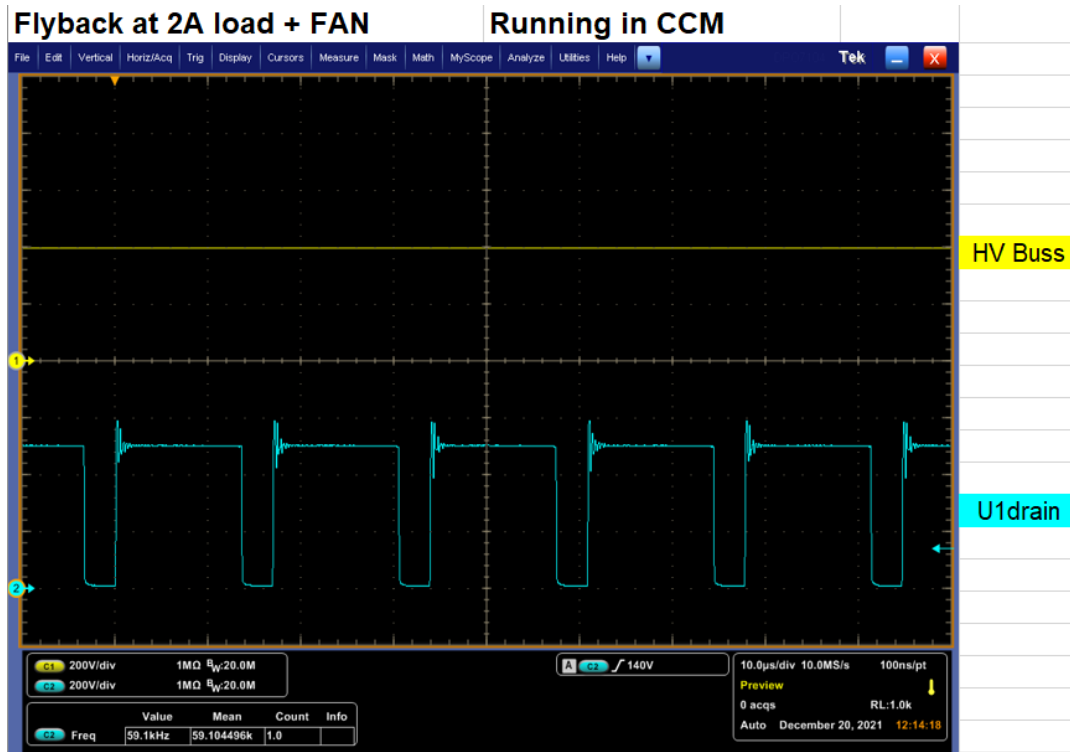


Figure 26. Typical Waveforms

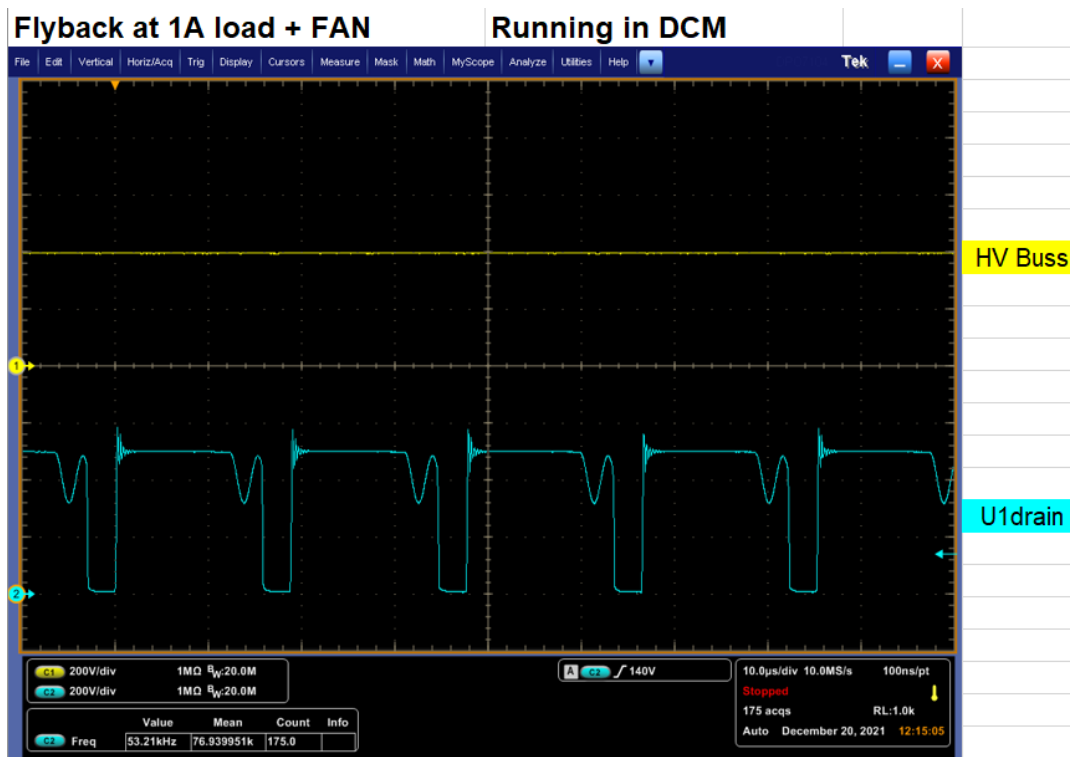


Figure 27. Typical Waveforms

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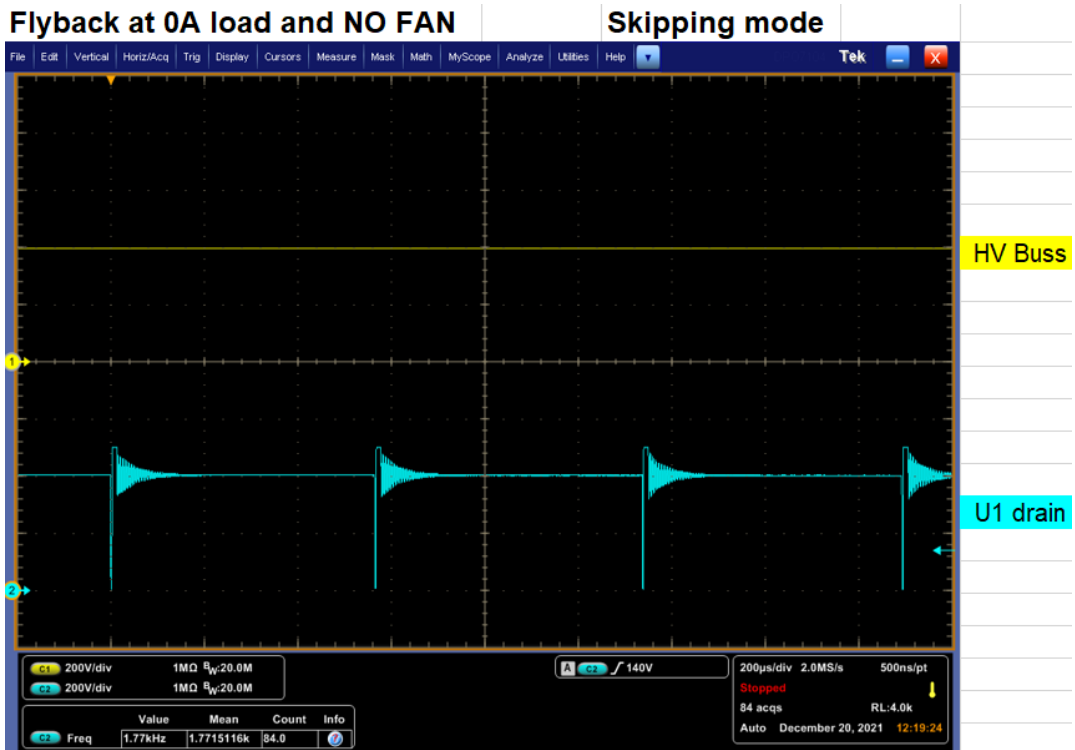


Figure 28. Typical Waveforms

In case of short circuit at output, the flyback will enter a hiccup mode to limit power dissipation and will resume normal functioning after the short circuit removal.



Figure 29. Shorting the 5 V Output

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## TESTING THE POWER SUPPLY

This section will describe how to test and operate the power supply unit and present some test results. The

following **Safety Precautions are a mandatory read before manipulating the board.**

### Safety Precautions



#### WARNING:

The 600W-ACDC-GEVB is powered by AC Mains, and exposed to high voltage. Only trained personnel should manipulate and operate on the unit. Ensure that all connections are secure before plugging the power cord into an AC outlet. It is mandatory to read the Safety Precautions section before manipulating the board. Failure to comply with the described safety precautions may result in personal injury or death, or equipment damage.

1	<b>Primary Ground Potential</b>	The primary ground or primary return of the unit is only a diode voltage drop away from lethal AC voltage potential. <b>When measuring voltage waveforms on the primary side using an oscilloscope, the unit needs to be powered from an AC power source that provides isolation from the mains or an isolation transformer needs to be used between AC mains and the unit.</b> Failure to do so may result in personal injury or death.
2	<b>DC BUS Capacitors</b>	The 600W-ACDC-GEVB unit contains three DC bus capacitors which take time to discharge after removal of the main supply. <b>Wait ten minutes for DC BUS capacitors to discharge to safe voltage levels before doing work on the unit.</b> Failure to do so may result in personal injury or death.
3	<b>Trained Personnel</b>	<b>Only personnel familiar with the offline power supply safety requirements should perform testing on the unit.</b> Failure to comply may result in personal injury and/or equipment damage.
4	<b>Hot temperature</b>	<b>The surfaces of some parts of the unit may become hot if the unit runs at full power without using a cooling fan. Running at full power without cooling is not advised for more than a couple of minutes at a time while performing various tests and measurements.</b>
5	<b>ESD</b>	The 600W-ACDC-GEVB unit contains parts that may be sensitive to Electrostatic Discharge (ESD). <b>Electrostatic control precautions are required when installing, testing, servicing or repairing this assembly.</b> Component damage may result if ESD control procedures are not followed. <b>If you are not familiar with electrostatic control procedures, refer to applicable ESD protection handbooks and guidelines.</b>
6	<b>Powering down the unit</b>	<b>Disconnect the input power cord from the AC power source before performing any service. Wait ten minutes after removing power to discharge the DC bus capacitors.</b> Do not attempt to service the unit until the HV buss capacitors have discharged to zero. Failure to do so may result in personal injury or death.

### Setup and Start-up Procedure

Ensure to follow and implement the Safety precautions described in Section 5.1 while testing and manipulating the board.

When performing tests and measurements on the unit, power the unit preferably from an AC power source or use an isolation transformer.

#### WARNING:

If the unit is directly plugged into an AC outlet, no test and measurements should be performed on the primary side of the unit due to risk of electrocution.

The use of a cooling fan is optional. Model AUB0612VH is recommended.

NOTE: If no cooling fan is used, testing while running at maximum power should be limited to 2 minutes at a time.

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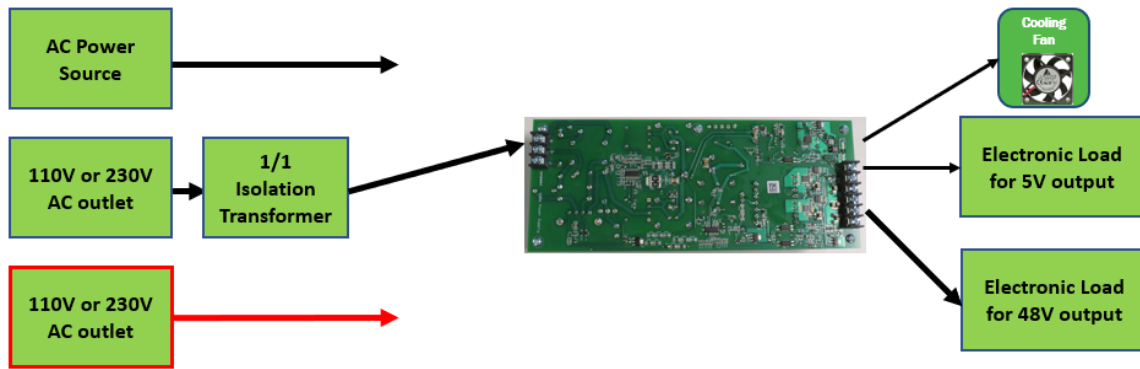


Figure 30. Test Setup Diagram

The procedure to start-up and power down the unit is described below. Please **read the mandatory Safety Precautions detailed in Section 6.1** before manipulating the board.

The board should be sitting on the bench with the bottom side up (SMT component side up).

1. Use one of the setups pictured in Figure 30.
2. Connect the outputs to the electronic loads.
3. Set the chosen AC power source to 110 Vac.
4. Turn on the AC source (or plug the AC power cord of the unit into the AC source).
5. The GREEN LED and AMBER LED should be lit meaning 48 V and 5 V respectively are present. If a cooling fan is used, this should be running too.
6. Verify 48 V is present and regulated while adjusting the current on the 48 V electronic load between 0 and 12.5 A.
7. Verify 5 V is present and regulated while adjusting the current on the 5 V electronic load between 0 and 2 A. At very light load on the 5 V output, a slight reduction of the fan speed is normal.
8. Turn off the AC source (or unplug the AC power cord from the AC source).
9. Set the chosen AC source to 230 Vac and repeat steps 4 to 8.

### Monitoring Various Signals Using the Scope Probes

#### WARNING:

Do not probe the primary circuits unless using an AC source or an isolated transformer to power up the unit.

The image below shows the power board with few scope probes attached. The board has provisions that facilitate the use of scope probes.

For the primary side the scope probe alligator can be attached to one of the three ground wire loops labelled TPgnd1, TPgnd2, TPgnd3 and the probe tip can be inserted as needed in the holes labelled TP1, TP2, TP3, TP4, or TP7.

For the secondary side the probe alligator can be attached to one of the two ground wire loops labelled TPgnd4 and TPgnd5 and the probe tip can be inserted as needed in the holes labelled TP5 and TP6.

Other circuit nodes can be probed as need by touching them with the probe tip and while attaching the probe alligator to the ground wire loop as appropriate.

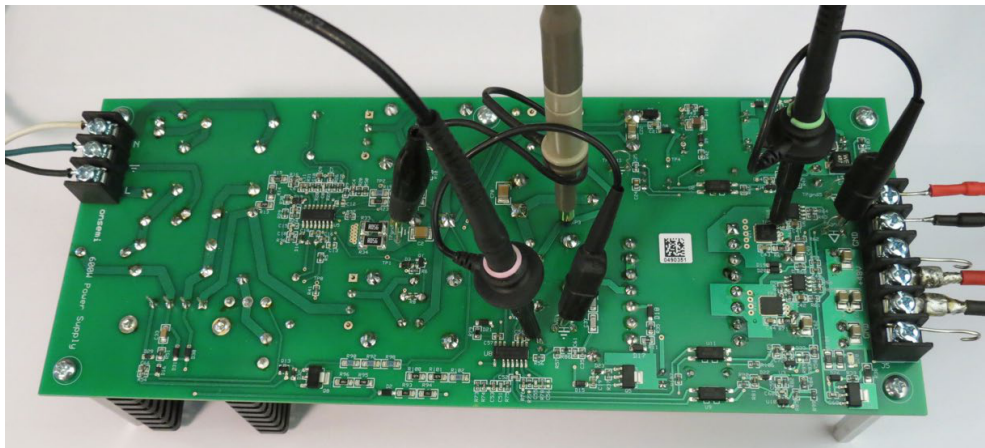


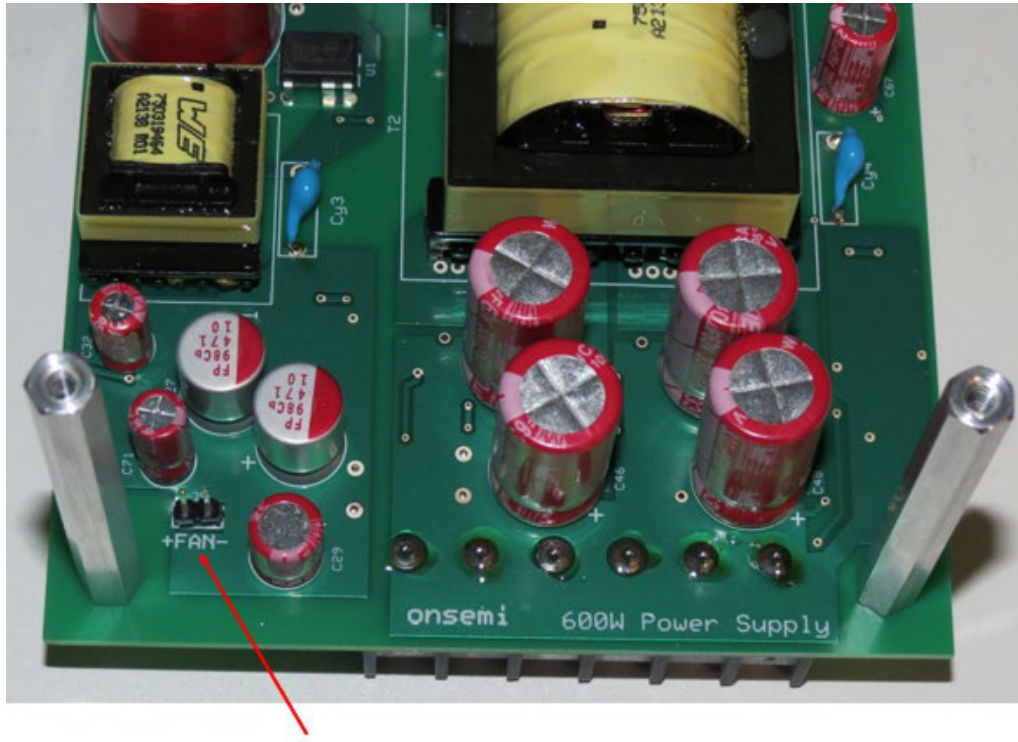
Figure 31. The Power Board with the Scope Attached

## 600W-ACDC-GEVB

### Cooling Options

Using a cooling fan is mandatory when testing the board at maximum power for extended periods. A 12 V dc fan

model AUB0612VH is recommended. The fan can be attached to connector J9.



**FAN CONNECTOR**

Figure 32.

In order to maximize the cooling effect of the fan an enclosure is recommended. The pictures below show a very simple enclosure made of foam board.

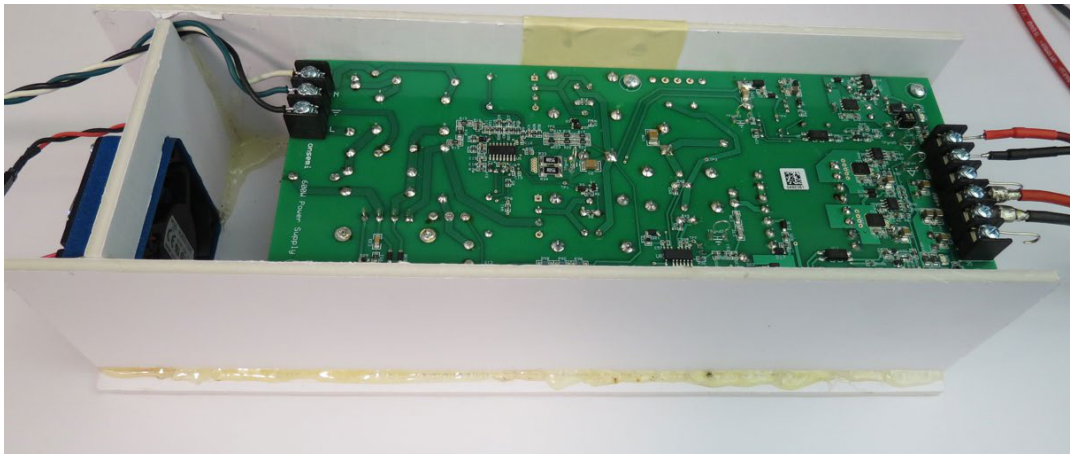


Figure 33.

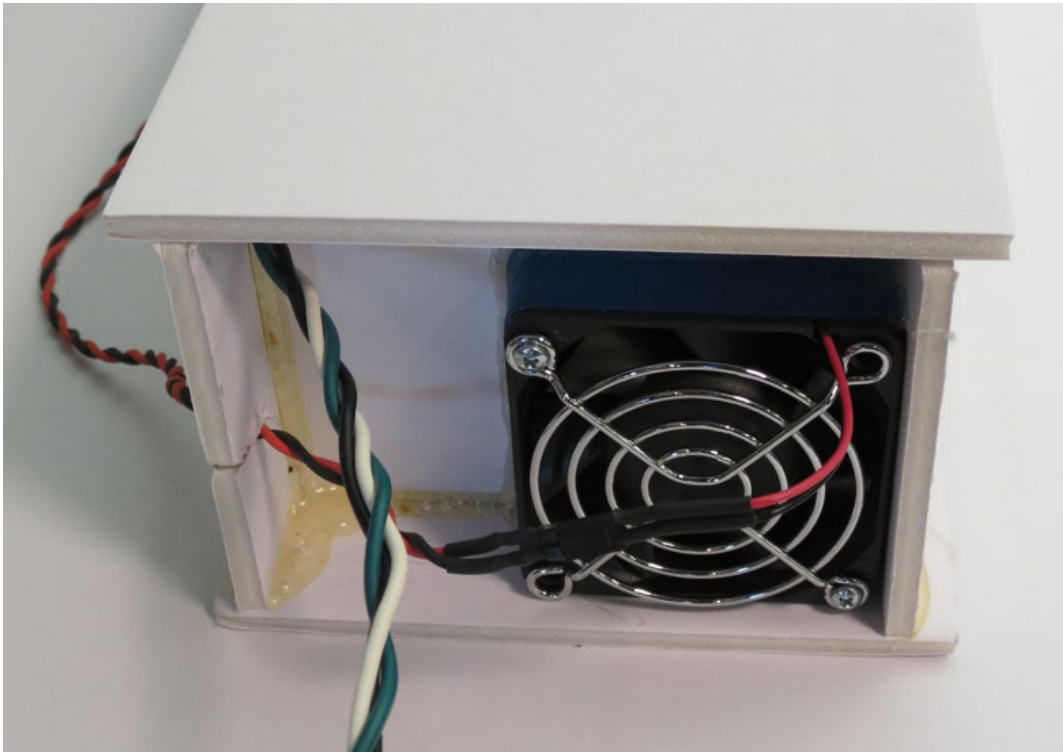


Figure 34.

#### Efficiency Test Result

Efficiency tests for the individual blocks (PFC, LLC, flyback) cannot be performed by the user as the blocks are interconnected. They had been done during the development stage when each block had been evaluated individually.

However the user can measure the overall efficiency of the power supply and the efficiency chart is presented at the end of this section.

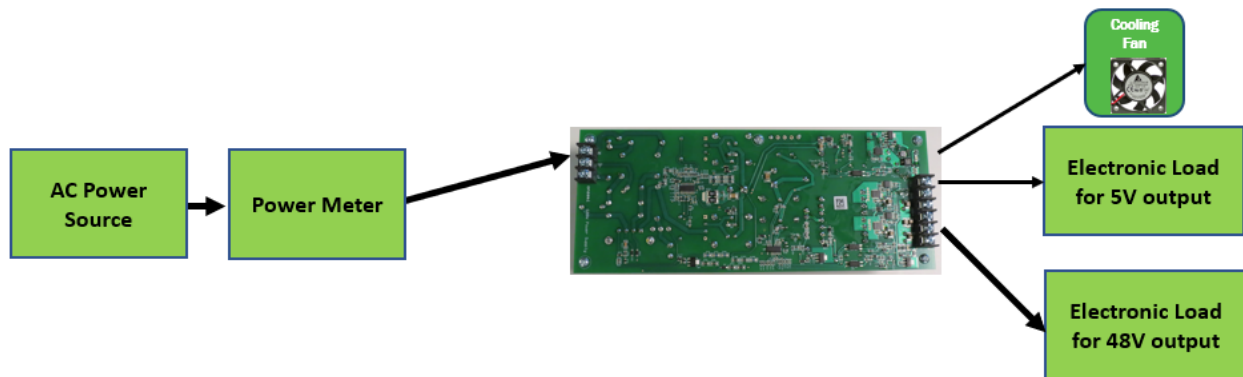
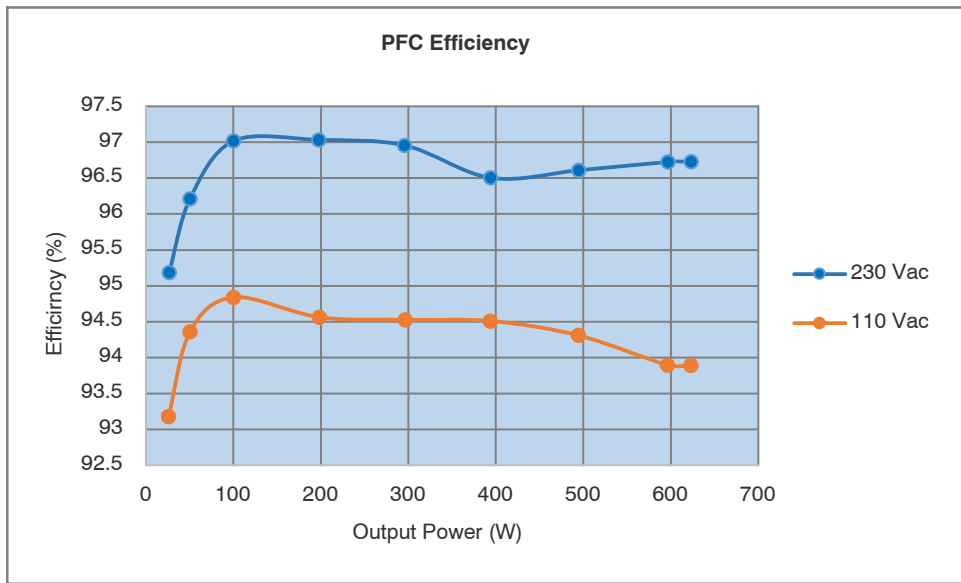


Figure 35. The Setup for Overall Efficiency Measurement

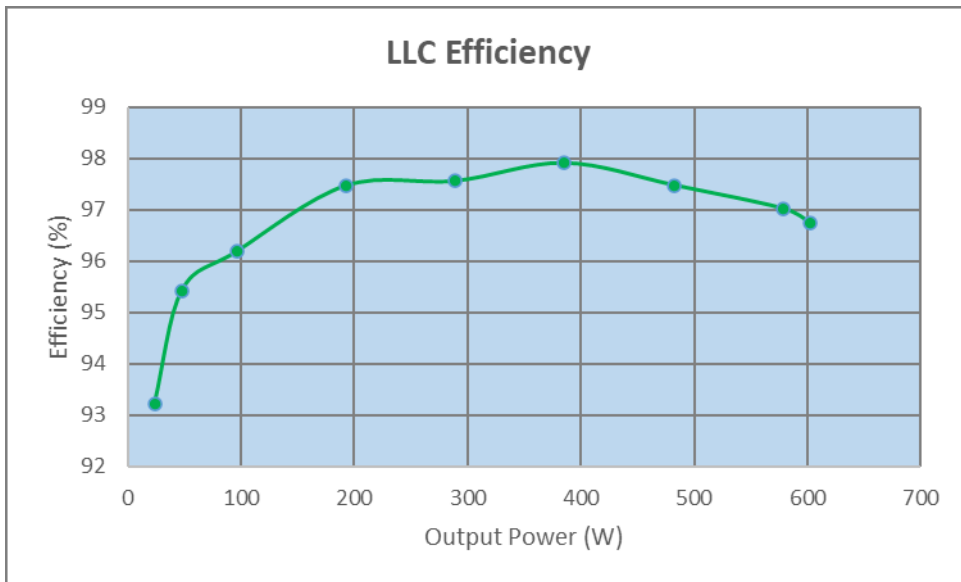
The input power is provided by a Chroma AC Power Source model 61504. Input power is measured using a Yokogawa WT210 power meter. Any electronic load with

adequate rating can be used for the 48 V and 5 V outputs. Output power is calculated by multiplying the output voltages and currents respectively.

# 600W-ACDC-GEVB



**Figure 36. PFC Efficiency**



**Figure 37. LLC Efficiency**

# 600W-ACDC-GEVB

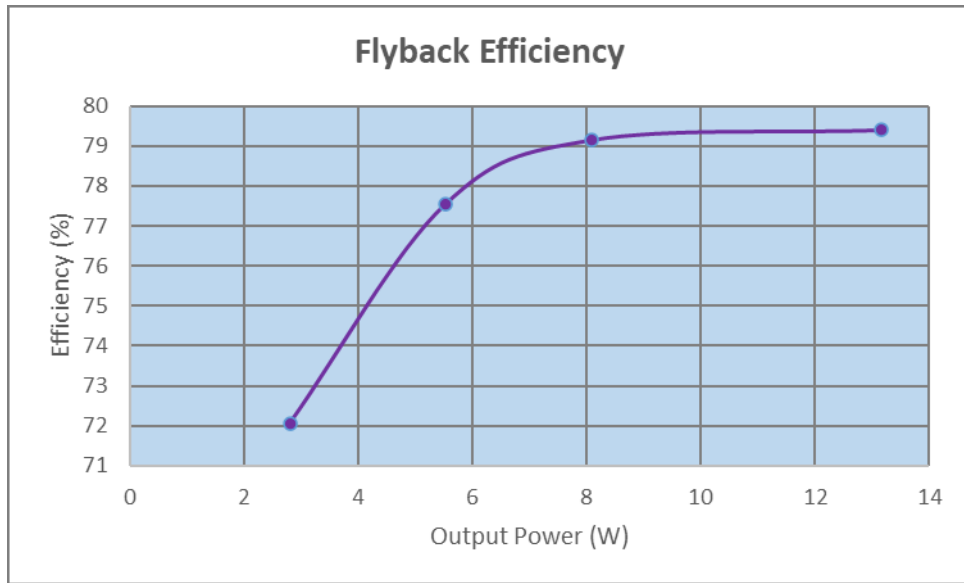


Figure 38. Efficiency of the Power Supply Blocks (PFC, LLC, Flyback)

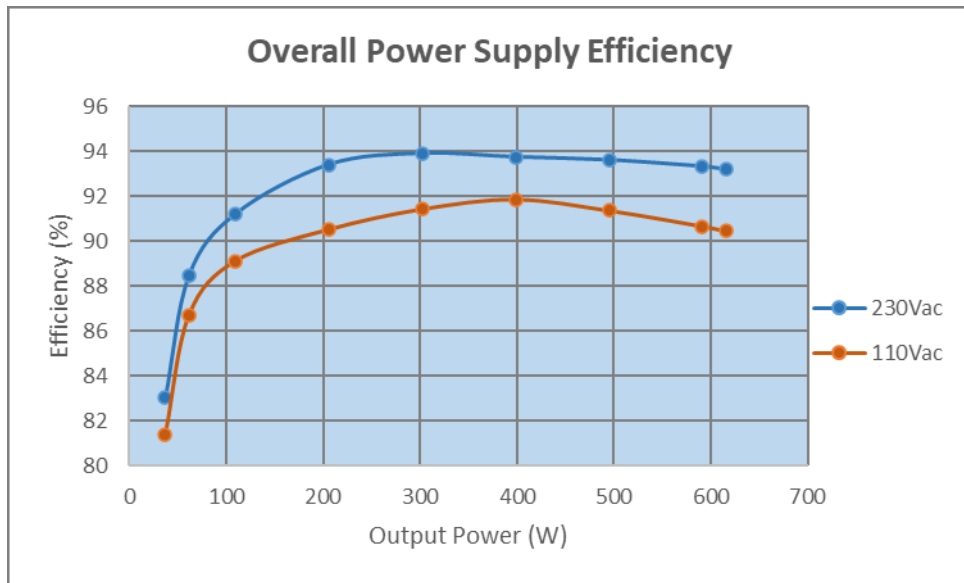


Figure 39. Overall Power Supply Efficiency



## 600W-ACDC-GEVB

### Power Factor

The PFC achieves good power factor at both low and high line.

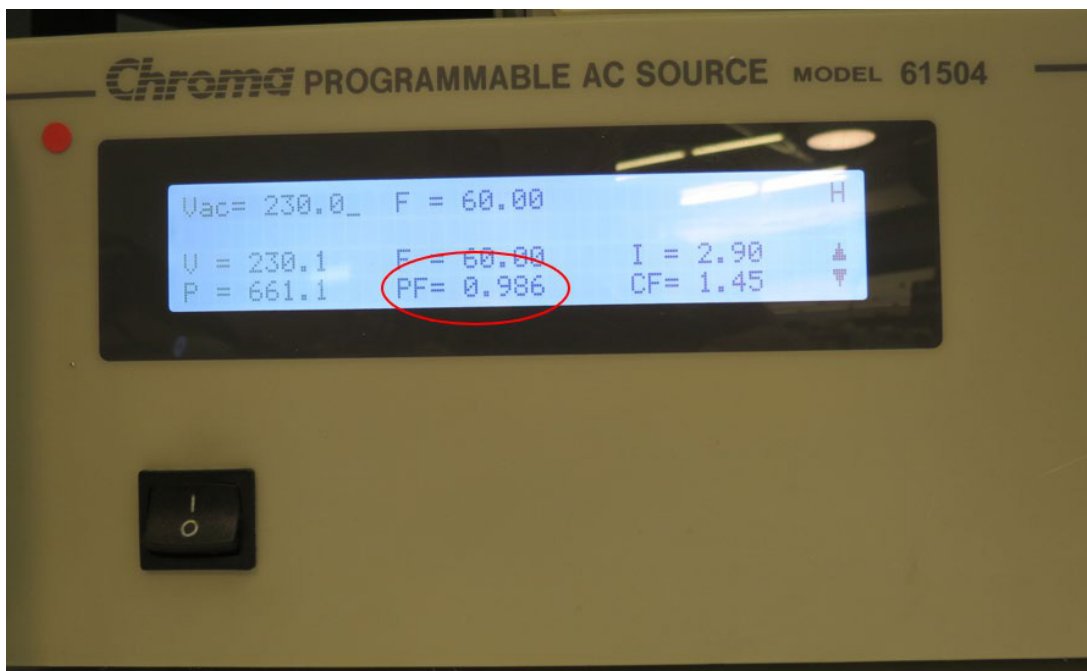
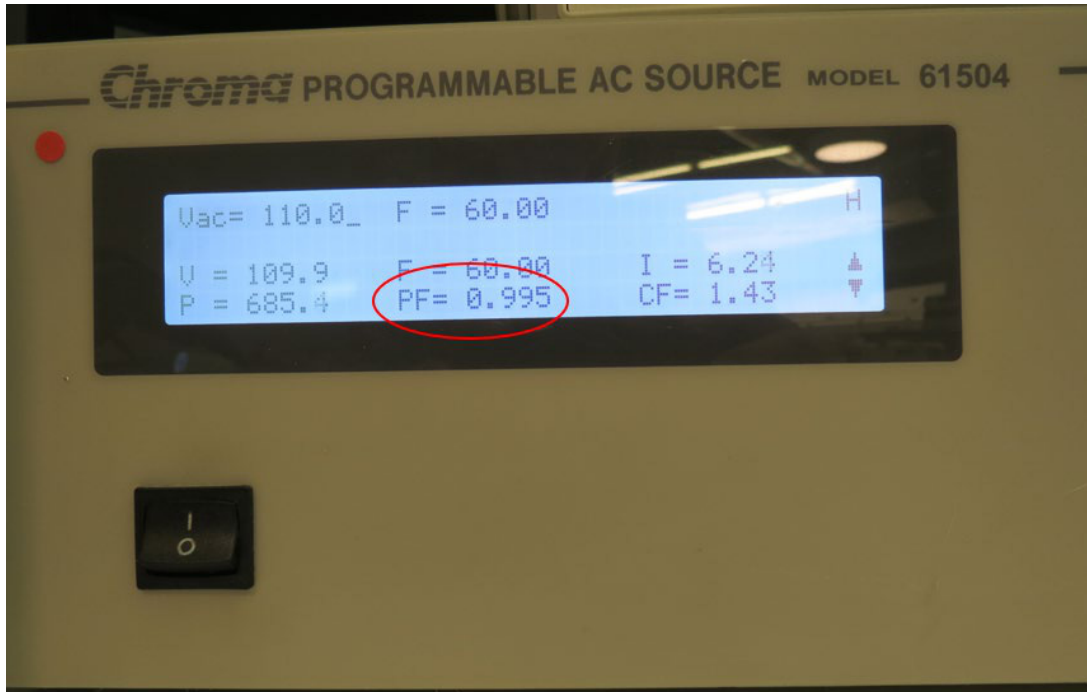


Figure 40. Power Factor

# 600W-ACDC-GEVB

## DESIGN RESOURCES

Collateral, development files are available at 600W-ACDC-GEVB.

1. [NCP1632](#) Design Worksheet.
2. [NCP1399](#) Design Worksheet.
3. [AND9654](#)-D. Key Steps to Design an Interleaved PFC Stage Driven by the NCP1632.
4. [NCP1632-D](#) datasheet .
5. [NCP1399-D](#) datasheet .
6. [NCP1076-D](#) datasheet .
7. [NTPF165N65S3H-D](#) datasheet.
8. [NTPF250N65S3H-D](#) datasheet.
9. [MURF860G-D](#) datasheet.
10. [NCP4305-D](#) datasheet.
11. [FDMS86202ET120-D](#)
12. [FCH023N65S3-D](#)

## 600W-ACDC-GEVB

**Table 1. BILL OF MATERIALS**

Ref Des	Value	Package	Description	Mfg	Mfg P/N
C1	1 $\mu$ F/310 V	26 x 11 mm	CAP FILM 1 $\mu$ F 10% 310 VAC RADIAL	Wurth	890334026027CS
C10	220 nF/50 V	0603	CAP CER 0.22 $\mu$ F 50 V X7R 0603	Murata	GRM188R71H224KAC4D
C11	470 nF	0603	CAP CER 0.47 $\mu$ F 25 V X7R 0603	Murata	GRM188R71E474KA12J
C14	100 nF/25 V	0603	CAP CER 0.1 $\mu$ F 100 V X7R 0603	Murata	GRM188R72A104MA35D
C15	100 pF/100 V	0603	CAP CER 100 pF 100 V C0G/NP0 0603	YAGEO	CC0603FRNPO0BN101
C16	22 nF/25 V	0603	CAP CER 0.022 $\mu$ F 100 V X7R 0603	Murata	GRM188R72A223KAC4D
C17	47 $\mu$ F/25 V	6.3 mm x 11 mm	CAP ALUM 47 $\mu$ F 20% 25 V RADIAL	Wurth	860130473003
C18	10 nF/25 V	0603	CAP CER 10000 pF 50 V C0G/NP0 0603	Murata	GRM1885C1H103JA01D
C19	100 nF/25 V	0603	CAP CER 0.1 $\mu$ F 100 V X7R 0603	Murata	GRM188R72A104MA35D
C2	100 nF/500 V	1812	CAP CER 0.1 $\mu$ F 630 V X7R 1812	Wurth	885342211006
C20	220 $\mu$ F/450 V	22 mm dia x 53	CAP ALUM 220 $\mu$ F 20% 450 V SNAP	Wurth	861141483007
C21	2.2 nF/250 V	0805	CAP CER 2200 pF 250 V X7R 0805	Murata	GCJ21AR72E222KXJ1D
C22	33 nF/630 V	1210	CAP CER 0.033 $\mu$ F 630 V X7R 1210	Wurth	885342209004
C23	10 $\mu$ F/50 V	1210	CAP CER 10 $\mu$ F 50 V X7S 1210	TDK	CGA6P3X7S1H106K250AB
C24	10 $\mu$ F/25 V	0805	CAP CER 10 $\mu$ F 25 V X6S 0805	Taiyo Yuden	EMK212BB7106MG-T
C25	1 nF/16 V	0603	CAP CER 1000 pF 100 V C0G/NP0 0603	Murata	GRM1885C2A102JA01D
C26	100 pF/250 V	0805	CAP CER 100 pF 250 V C0G/NP0 0805	Murata	GRM21A5C2E101JW01D
C29	220 $\mu$ F/10 V	8 mm dia x 8 mm	CAP ALUM POLY 220 $\mu$ F 20% 16 V T/H	Wurth	870235374004
C3	330 $\mu$ F/450 V	30 mm dia x 53 mm	CAP ALUM 270 $\mu$ F 20% 330 V SNAP	Wurth	861021485026
C30	10 $\mu$ F/10 V	0805	CAP CER 10 $\mu$ F 10 V X6S 0805	Murata	GRM21BC81A106KE18L
C31	10 $\mu$ F/10 V	0805	CAP CER 10 $\mu$ F 10 V X6S 0805	Murata	GRM21BC81A106KE18L
C32	100 $\mu$ F/25 V	6.3 mm dia x 11 mm	CAP ALUM 100 $\mu$ F 20% 25 V RADIAL	Wurth	860080473006
C33	10 nF/630 V	1206	CAP CER 10000 pF 630 V X7R 1206	TDK	C3216X7R2J103K115AA
C34	100 nF/25 V	0603	CAP CER 0.1 $\mu$ F 100 V X7R 0603	Murata	GRM188R72A104MA35D
C35	10 nF/25 V/2%	0603	10000 pF $\pm$ 2% 25 V Ceramic Capacitor NP0 0603	KEMET	C0603C103G3GAC7867
C36	220 pF/1 kV	1206	CAP CER 220 pF 1 kV C0G/NP0 1206	Murata	GRM31A5C3A221JW01D
C37	220 pF/1 kV	1206	CAP CER 220 pF 1 kV C0G/NP0 1206	Murata	GRM31A5C3A221JW01D
C4	1 nF/50 V	0603	CAP CER 1000 pF 50 V X7R 0603	TDK Corporation	CGA3E2X7R1H102K080AA
C40	22 nF/25 V	0603	CAP CER 0.022 $\mu$ F 100 V X7R 0603	Murata	GRM188R72A223KAC4D
C41	1 $\mu$ F/25 V	0805	CAP CER 1 $\mu$ F 25 V X7R 0805	Murata	GCM21BR71E105KA56L
C42	1 $\mu$ F/25 V	0805	CAP CER 1 $\mu$ F 25 V X7R 0805	Murata	GCM21BR71E105KA56L
C43	2.2 nF/250 V	0805	CAP CER 2200 pF 250 V X7R 0805	Murata	GCJ21AR72E222KXJ1D
C44	2.2 nF/250 V	0805	CAP CER 2200 pF 250 V X7R 0805	Murata	GCJ21AR72E222KXJ1D
C45	330 $\mu$ F/63 V	13 mm x 25 mm	CAP ALUM 330 $\mu$ F 20% 63 V RADIAL	Wurth	860080778021
C46	330 $\mu$ F/63 V	13 mm x 25 mm	CAP ALUM 330 $\mu$ F 20% 63 V RADIAL	Wurth	860080778021
C47	330 $\mu$ F/63 V	13 mm x 25 mm	CAP ALUM 330 $\mu$ F 20% 63 V RADIAL	Wurth	860080778021
C48	330 $\mu$ F/63 V	13 mm x 25 mm	CAP ALUM 330 $\mu$ F 20% 63 V RADIAL	Wurth	860080778021

## 600W-ACDC-GEVB

**Table 1. BILL OF MATERIALS** (continued)

Ref Des	Value	Package	Description	Mfg	Mfg P/N
C49	10 $\mu$ F/100 V	1210	CAP CER 10 $\mu$ F 100 V X7S 1210	Murata	GRM32EC72A106KE05L
C5	1 nF/50 V	0603	CAP CER 1000 pF 50 V X7R 0603	TDK Corporation	CGA3E2X7R1H102K080AA
C50	10 $\mu$ F/100 V	1210	CAP CER 10 $\mu$ F 100 V X7S 1210	Murata	GRM32EC72A106KE05L
C51	10 nF/25 V	0603	CAP CER 10000 pF 50 V C0G/NP0 0603	Murata	GRM1885C1H103JA01D
C52	470 pF	0603	CAP CER 470 pF 50 V NP0 0603	TDK	C1608NP01H471J080AA
C53	22 nF/25 V	0603	CAP CER 0.022 $\mu$ F 100 V X7R 0603	Murata	GRM188R72A223KAC4D
C54	100 $\mu$ F/25 V	6.3 mm x 11 mm	CAP ALUM 100 $\mu$ F 20% 25 V RADIAL	Wurth	860080473006
C55	100 pF/100 V	0603	CAP CER 100 pF 100 V C0G/NP0 0603	YAGEO	CC0603FRNPO0BN101
C57	100 nF/25 V	0603	CAP CER 0.1 $\mu$ F 100 V X7R 0603	Murata	GRM188R72A104MA35D
C58	100 nF/25 V	0603	CAP CER 0.1 $\mu$ F 100 V X7R 0603	Murata	GRM188R72A104MA35D
C59	3.3 nF/25 V	0603	CAP CER 3300 pF 50 V C0G/NP0 0603	Murata	GCM1885C1H332FA16D
C6	330 nF/16 V	0603	CAP CER 0.33 $\mu$ F 16 V X7R 0603	TDK	CGA3E1X7R1C334K080AC
C60	100 pF/100 V	0603	CAP CER 100 pF 100 V C0G/NP0 0603	YAGEO	CC0603FRNPO0BN101
C61	2.2 nF/50 V/2%	0603	2200 pF $\pm$ 2% 50 V Ceramic Capacitor NP0 0603	Murata	GCM1885C1H222GA16D
C62	10 $\mu$ F/100 V	1210	CAP CER 10 $\mu$ F 100 V X7S 1210	Murata	GRM32EC72A106KE05L
C63	10 $\mu$ F/100 V	1210	CAP CER 10 $\mu$ F 100 V X7S 1210	Murata	GRM32EC72A106KE05L
C64	10 $\mu$ F/100 V	1210	CAP CER 10 $\mu$ F 100 V X7S 1210	Murata	GRM32EC72A106KE05L
C65	10 $\mu$ F/100 V	1210	CAP CER 10 $\mu$ F 100 V X7S 1210	Murata	GRM32EC72A106KE05L
C66	2.2 $\mu$ F	0603	CAP CER 2.2 $\mu$ F 25 V X6S 0603	Murata	GRT188C81E225KE13D
C67	220 $\mu$ F/35 V	8 mm dia x 16 mm	CAP ALUM 220 $\mu$ F 20% 35 V RADIAL	Wurth	860040574006
C68	10 nF/25 V	0603	CAP CER 10000 pF 50 V C0G/NP0 0603	Murata	GRM1885C1H103JA01D
C69	47 $\mu$ F/450 V	22 mm dia x 23	CAP ALUM 47 $\mu$ F 20% 450 V SNAP	Wurth	861111483002
C7	1 nF/50 V	0603	CAP CER 1000 pF 50 V X7R 0603	TDK Corporation	CGA3E2X7R1H102K080AA
C70	100 nF/500 V	1812	CAP CER 0.1 $\mu$ F 630 V X7R 1812	Wurth	885342211006
C71	47 $\mu$ F/25 V	6.3 mm x 11 mm	CAP ALUM 47 $\mu$ F 20% 25 V RADIAL	Wurth	860130473003
C72	10 nF/25 V	0603	CAP CER 10000 pF 50 V C0G/NP0 0603	Murata	GRM1885C1H103JA01D
C8	68 pF/25 V	0603	CAP CER 68 pF 50 V C0G/NP0 0603	Kemet	C0603C680K3GAC7867
C9	2.2 $\mu$ F	0603	CAP CER 2.2 $\mu$ F 25 V X6S 0603	Murata	GRT188C81E225KE13D
Cx1	1 $\mu$ F/310 V	26 x 11 mm	CAP FILM 1 $\mu$ F 10% 310 VAC RADIAL	Wurth	890334026027CS
Cx2	680 nF/310 Vac	26 x 7.5 mm	CAP FILM 0.68 $\mu$ F 10% 310 VAC RAD	Wurth	890334026020CS
Cx3	680 nF/310 Vac	26 x 7.5 mm	CAP FILM 0.68 $\mu$ F 10% 310 VAC RAD	Wurth	890334026020CS
D1	GBU8K	Bridge	BRIDGE RECT 1PHASE 800 V 8 A GBU	onsemi	GBU8K
D10	MMSD3070	SOD-123FL	DIODE GEN PURP 200 V 200 mA SOD123	onsemi	MMSD3070
D11	MBR460MFST1G	5DFN	DIODE SCHOTTKY 60 V 4 A 5DFN	onsemi	MBR460MFST1G

## 600W-ACDC-GEVB

**Table 1. BILL OF MATERIALS** (continued)

Ref Des	Value	Package	Description	Mfg	Mfg P/N
D12	NHP220SFT3G	SOD-123FL	DIODE GEN PURP 200 V 2 A SOD123W	onsemi	NHP220SFT3G
D13	MMSD4148T1G	SOD-123	DIODE GEN PURP 100 V 200 mA SOD123	onsemi	MMSD4148
D14	MM3Z18VT1G	SOD-323	DIODE ZENER 18 V 300 mW SOD323	onsemi	MM3Z18VT1G
D15	MMSD4148T1G	SOD-123	DIODE GEN PURP 100 V 200 mA SOD123	onsemi	MMSD4148
D16	MMDL914T3G	SOD-323	DIODE GEN PURP 100 V 200 mA SOD323	onsemi	MMDL914T3G
D17	US1BFA	SOD-123FL	DIODE GEN PURP 100 V 1 A SOD123FA	onsemi	US1BFA
D18	US1BFA	SOD-123FL	DIODE GEN PURP 100 V 1 A SOD123FA	onsemi	US1BFA
D19	MMSD3070	SOD-123FL	DIODE GEN PURP 200 V 200 mA SOD123	onsemi	MMSD3070
D2	S1MFL	SOD-123FL	DIODE GEN PURP 600 V 1 A SOD123F	onsemi	S1MFL
D20	MMSD3070	SOD-123FL	DIODE GEN PURP 200 V 200 mA SOD123	onsemi	MMSD3070
D21	ES1JFL	SOD-123FL	DIODE SUPERFAST 600 V 1 A SOD123FL	onsemi	ES1JFL
D22	MM3Z15VT1G	SOD-323	DIODE ZENER 15 V 300 mW SOD323	onsemi	MM3Z15VT1G
D23	MM3Z15VT1G	SOD-323	DIODE ZENER 15 V 300 mW SOD323	onsemi	MM3Z15VT1G
D24	MM3Z12VT1G	SOD-323	DIODE ZENER 12 V 300 mW SOD323	onsemi	MM3Z12VT1G
D25	MMDL914T3G	SOD-323	DIODE GEN PURP 100 V 200 mA SOD323	onsemi	MMDL914T3G
D26	MMSZ5242BT1G	SOD-123	DIODE ZENER 12 V 500 mW SOD123	onsemi	MMSZ5242BT1G
D27	LED1 amber	1206	LED AMBER CLEAR 1206 SMD	Würth	150120AS75000
D28	LED1 green	1206	LED GREEN CLEAR 1206 SMD	Würth	150120GS75000
D29	MM3Z12VT1G	SOD-323	DIODE ZENER 12 V 300 mW SOD323	onsemi	MM3Z12VT1G
D3	MMSD4148T1G	SOD-123	DIODE GEN PURP 100 V 200 mA SOD123	onsemi	MMSD4148
D30	S1MFL	SOD-123FL	DIODE GEN PURP 600 V 1 A SOD123F	onsemi	S1MFL
D31	S1MFL	SOD-123FL	DIODE GEN PURP 600 V 1 A SOD123F	onsemi	S1MFL
D32	MM3Z20VT1G	SOD-323	DIODE ZENER 20 V 300 mW SOD323	onsemi	MM3Z20VST1G
D33	MM3Z15VT1G	SOD-323	DIODE ZENER 15 V 300 mW SOD323	onsemi	MM3Z15VT1G
D4	MURF860G	TO-220FP	DIODE GEN PURP 600 V 8 A TO220FP	onsemi	MURF860G
D5	MMSD4148T1G	SOD-123	DIODE GEN PURP 100 V 200 mA SOD123	onsemi	MMSD4148
D6	MURF860G	TO-220FP	DIODE GEN PURP 600 V 8 A TO220FP	onsemi	MURF860G
D7	1SMB5956BT3G	SMB	ZENER DIODE, 200 V, 5%, 0.55 W, UN	onsemi	1SMB5956BT3G
D8	S1MFL	SOD-123FL	DIODE GP 1000 V 1 A SOD123F	onsemi	S1MFL
D9	MMSD4148T1G	SOD-123	DIODE GEN PURP 100 V 200 mA SOD123	onsemi	MMSD4148
L1	2.2 mH	30 x 21 mm	CMC 2.2 mH 8 A 2LN TH	Würth	7448258022
L2	172 $\mu$ H	32 mm dia torroid	FIXED IND 172 $\mu$ H 6.5 A 55 m $\Omega$ TH	Würth	744154

## 600W-ACDC-GEVB

**Table 1. BILL OF MATERIALS** (continued)

Ref Des	Value	Package	Description	Mfg	Mfg P/N
L3	115 $\mu$ H	custom	PFC choke 115 $\mu$ H	Würth	750319670
L4	115 $\mu$ H	custom	PFC choke 115 $\mu$ H	Würth	750319670
L5	4.7 $\mu$ H	5040 non std	FIXED IND 4.7 $\mu$ H 4.6 A 24.5 m $\Omega$ SM	Würth	744316470
L6	60 $\mu$ H	custom	FIXED IND 60 $\mu$ H	Würth	750319584
L8	33 $\mu$ H	4019 non std	FIXED IND 33 $\mu$ H 650 mA 460 m $\Omega$ SMD	Würth	74404042330
Q1	MMBT589LT1	SOT-23	TRANS PNP 30 V 1 A SOT23-3	onsemi	MMBT589LT1G
Q10	FCPF250N65	TO-220FP		onsemi	
Q11	FDMS86202ET120	PWR56	MOSFET N-CH 120 V 13.5/102 A PWR56	onsemi	FDMS86202ET120
Q12	FDMS86202ET120	PWR56	MOSFET N-CH 120V 13.5/102 A PWR56	onsemi	FDMS86202ET120
Q13	2N7002	SOT-23	N-Channel MOSFET 60 V, 310 mA, 2.5 $\Omega$	onsemi	2N7002
Q14	BCP53-16T1G	SOT-223	Transistor PNP 80 V 1 A SOT-223	onsemi	BCP53-16T1G
Q15	MMBT3904LT1	SOT-23	TRANS NPN 40 V 200 mA SOT23-3	onsemi	MMBT3904LT1G
Q2	FCPF165N65	TO-220FP		onsemi	
Q3	MMBT589LT1	SOT-23	TRANS PNP 30 V 1 A SOT23-3	onsemi	MMBT589LT1G
Q4	FCPF165N65	TO-220FP		onsemi	
Q5	BCP56-16T1G	SOT-223	Transistor NPN 80 V 1 A SOT-223	onsemi	BCP56-16T1G
Q6	BCP56-16T1G	SOT-223	Transistor NPN 80 V 1 A SOT-223	onsemi	BCP56-16T1G
Q7	FCH023N65S3	TO-247	MOSFET N-CH 650 V 75 A TO247	onsemi	FCH023N65S3L4
Q8	FQT1N60	SOT-223	MOSFET N-CH 600 V 0.2 A SOT-223-4	onsemi	FQT1N60CTF-WS
Q9	FCPF250N65	TO-220FP		onsemi	
R10	10 $\Omega$	603	RES SMD 10 $\Omega$ 1% 1/10 W 0603	Yageo	AC0603FR-0710RL
R100	1.87 M $\Omega$	1206	RES 1.87 M $\Omega$ 1% 1/4 W 1206	Yageo	RC1206FR-071M87L
R101	1.87 M $\Omega$	1206	RES 1.87 M $\Omega$ 1% 1/4 W 1206	Yageo	RC1206FR-071M87L
R102	665 k $\Omega$	1206	RES 665 k $\Omega$ 1% 1/4 W 1206	KOA Speer Electronics, Inc.	RK73H2BTDD6653F
R103	150 $\Omega$ /0.25 W	805	RES 150 $\Omega$ 1% 1/4W 0805	Stackpole Electronics Inc	RNCP0805FTD150R
R104	2.21 k $\Omega$ /0.5 W	1206	RES 2.21 k $\Omega$ 1% 1/2 W 1206	Stackpole	RNCP1206FTD2K21
R105	68 k $\Omega$	805	RES 68 k $\Omega$ 1% 1/8 W 0805	Vishay Dale	CRCW080568K0FKEAC
R106	1 k $\Omega$	603	RES SMD 1 k $\Omega$ 1% 1/10 W 0603	Yageo	AC0603FR-131KL
R107	4.99 k $\Omega$	603	RES 4.99 k $\Omega$ 1% 1/10 W 0603	Vishay Dale	CRCW06034K99FKEAC
R11	10 $\Omega$	805	RES 10 $\Omega$ 1% 1/8 W 0805	Vishay	CRCW080510R0FKEAC
R12	10 k $\Omega$	603	RES 10 k $\Omega$ 1% 1/10 W 0603	Vishay Dale	CRCW060310K0FKECC
R13	2.43 M $\Omega$	1206	RES SMD 2.43 M $\Omega$ 1% 1/4 W 1206	Yageo	RC1206FR-072M43L
R14	2.43 M $\Omega$	1206	RES SMD 2.43 M $\Omega$ 1% 1/4 W 1206	Yageo	RC1206FR-072M43L
R15	2.43 M $\Omega$	1206	RES SMD 2.43 M $\Omega$ 1% 1/4 W 1206	Yageo	RC1206FR-072M43L
R16	121 k $\Omega$	603	RES 121 k $\Omega$ 1% 1/10 W 0603	Vishay Dale	CRCW0603121KFKEAC

## 600W-ACDC-GEVB

**Table 1. BILL OF MATERIALS** (continued)

Ref Des	Value	Package	Description	Mfg	Mfg P/N
R17	1.87 M $\Omega$	1206	RES 1.87 M $\Omega$ 1% 1/4 W 1206	Yageo	RC1206FR-071M87L
R18	1.87 M $\Omega$	1206	RES 1.87 M $\Omega$ 1% 1/4 W 1206	Yageo	RC1206FR-071M87L
R19	665 k $\Omega$	1206	RES 665 k $\Omega$ 1% 1/4 W 1206	KOA Speer Electronics, Inc.	RK73H2BTDD6653F
R20	178 k $\Omega$	603	RES SMD 178 k $\Omega$ 1% 1/10 W 0603	Yageo	RT0603FRE07178KL
R21	1.87 M $\Omega$	1206	RES 1.87 M $\Omega$ 1% 1/4 W 1206	Yageo	RC1206FR-071M87L
R22	1.87 M $\Omega$	1206	RES 1.87 M $\Omega$ 1% 1/4 W 1206	Yageo	RC1206FR-071M87L
R23	715 k $\Omega$	1206	RES SMD 715 k $\Omega$ 1% 1/4 W 1206	Vishay Dale	CRCW1206715KFKEA
R24	26.1 k $\Omega$	603	RES SMD 26.1 k $\Omega$ 1% 1/10 W 0603	Yageo	AC0603FR-0726K1L
R25	22.1 k $\Omega$	603	RES 22.1 k $\Omega$ 1% 1/10 W 0603	Vishay Dale	CRCW060322K1FKEAC
R26	270 k $\Omega$	603	RES 270 k $\Omega$ 1% 1/10 W 0603	Vishay Dale	CRCW0603270KFKEAC
R27	5.1 k $\Omega$	603	RES 5.1 k $\Omega$ 1% 1/10 W 0603	Stackpole	RMCF0603FT5K10
R28	15 k $\Omega$	603	RES SMD 15 k $\Omega$ 1% 1/10W 0603	Yageo	RC0603FR-0715KL
R29	22.1 k $\Omega$	603	RES 22.1 k $\Omega$ 1% 1/10 W 0603	Vishay Dale	CRCW060322K1FKEAC
R30	22.1k $\Omega$	603	RES 22.1 k $\Omega$ 1% 1/10 W 0603	Vishay Dale	CRCW060322K1FKEAC
R31	143 k $\Omega$	603	RES SMD 143 k $\Omega$ 1% 1/10 W 0603	Yageo	RC0603FR-07143KL
R32	1.8 k $\Omega$	603	RES 1.8 k $\Omega$ 1% 1/10 W 0603	Yageo	RC0603FR-071K8L
R33	0.06 $\Omega$	2512	RES 0.06 $\Omega$ 3.0 W 1% 2512 SMD	Vishay	WFMB2512R0600FEA
R34	0.06 $\Omega$	2512	RES 0.06 $\Omega$ 3.0 W 1% 2512 SMD	Vishay	WFMB2512R0600FEA
R35	10 $\Omega$	805	RES 10 $\Omega$ 1% 1/8 W 0805	Vishay	CRCW080510R0FKEAC
R36	1 k $\Omega$	603	RES SMD 1 k $\Omega$ 1% 1/10 W 0603	Yageo	AC0603FR-131KL
R37	13 k $\Omega$	603	RES SMD 13 k $\Omega$ 1% 1/10 W 0603	YAGEO	AC0603FR-0713KL
R38	2 k $\Omega$ /0.5 W	1206	RCS1206 100 2 k $\Omega$ 1% ET1 E3	Vishay Dale	RCS12062K00FKEA
R39	33.2 k $\Omega$	603	RES 33.2 k $\Omega$ 1% 1/10 W 0603	Vishay Dale	CRCW060333K2FKEAC
R40	22.1 k $\Omega$	603	RES 22.1 k $\Omega$ 1% 1/10 W 0603	Vishay Dale	CRCW060322K1FKEAC
R41	10 $\Omega$	603	RES SMD 10 $\Omega$ 1% 1/10 W 0603	Yageo	AC0603FR-0710RL
R42	4.42 k $\Omega$	603	RES SMD 4.42 k $\Omega$ 1% 1/10 W 0603	Stackpole Electronics Inc	RMCF0603FT4K42
R43	2.21 $\Omega$	805	RES 2.21 $\Omega$ 1% 1/8 W 0805	Stackpole	RMCF0805FT2R21
R44	22.1 $\Omega$	805	RES SMD 22.1 $\Omega$ 1% 1/8 W 0805	Panasonic	ERJ-6ENF22R1V
R45	715 $\Omega$	603	RES SMD 715 $\Omega$ 1% 1/10 W 0603	Yageo	AC0603FR-07715RL
R46	10 k $\Omega$	603	RES 10 k $\Omega$ 1% 1/10 W 0603	Vishay Dale	CRCW060310K0FKECC
R47	9.76 k $\Omega$	805	RES 9.76 k $\Omega$ 1% 1/4 W 0805	KOA Speer	RK73H2ATTD9761F
R48	9.09 k $\Omega$	805	RES 9.09 k $\Omega$ 1% 1/8 W 0805	Yageo	RC0805FR-079K09L
R49	22.1 k $\Omega$	603	RES 22.1 k $\Omega$ 1% 1/10 W 0603	Vishay Dale	CRCW060322K1FKEAC
R5	22.1 k $\Omega$	603	RES 22.1 k $\Omega$ 1% 1/10 W 0603	Vishay Dale	CRCW060322K1FKEAC
R50	33.2 k $\Omega$	603	RES 33.2 k $\Omega$ 1% 1/10 W 0603	Vishay Dale	CRCW060333K2FKEAC
R51	499 $\Omega$	805	RES 499 $\Omega$ 1% 1/8 W 0805	Vishay Dale	CRCW0805499RFKEAC
R53	10 $\Omega$	603	RES SMD 10 $\Omega$ 1% 1/10 W 0603	Yageo	AC0603FR-0710RL
R54	150 k $\Omega$	603	RES SMD 150 k $\Omega$ 1% 1/10 W 0603	Yageo	AC0603FR-07150KL
R55	10 $\Omega$	603	RES SMD 10 $\Omega$ 1% 1/10 W 0603	Yageo	AC0603FR-0710RL

## 600W-ACDC-GEVB

**Table 1. BILL OF MATERIALS** (continued)

Ref Des	Value	Package	Description	Mfg	Mfg P/N
R56	100 Ω	603	RES SMD 100 Ω 1% 1/10 W 0603	YAGEO	RC0603FR-13100RL
R57	2.21 kΩ	603	RES 2.21 kΩ 1% 1/8 W 0603	Stackpole	RNCP0603FTD2K21
R58	200 kΩ	805	RES 200 kΩ 1% 1/8 W 0805	Yageo	RC0805FR-07200KL
R59	10 kΩ	603	RES 10 kΩ 1% 1/10 W 0603	Vishay Dale	CRCW060310K0FKECC
R6	10 Ω	603	RES SMD 10 Ω 1% 1/10 W 0603	Yageo	AC0603FR-0710RL
R60	1 kΩ	603	RES SMD 1 kΩ 1% 1/10 W 0603	Yageo	AC0603FR-131KL
R61	22 Ω	603	RES 22 Ω 1% 1/10 W 0603	Stackpole Electronics Inc	RMCF0603FT22R0
R62	22 Ω	603	RES 22 Ω 1% 1/10 W 0603	Stackpole Electronics Inc	RMCF0603FT22R0
R63	22.1 kΩ	603	RES 22.1 kΩ 1% 1/10 W 0603	Vishay Dale	CRCW060322K1FKEAC
R64	4.7 kΩ	603	RES 4.7 kΩ 1% 1/10 W 0603	Stackpole	RMCF0603FT4K70
R65	22.1 kΩ	603	RES 22.1 kΩ 1% 1/10 W 0603	Vishay Dale	CRCW060322K1FKEAC
R66	4.7 kΩ	603	RES 4.7 kΩ 1% 1/10 W 0603	Stackpole	RMCF0603FT4K70
R67	0 Ω	603	RES 0 Ω JUMPER 1/10 W 0603	YAGEO	AA0603JR-070RL
R68	10 kΩ	603	RES 10 kΩ 1% 1/10 W 0603	Vishay Dale	CRCW060310K0FKECC
R69	15 Ω	1206	RES SMD 15 Ω 1% 1/4 W 1206	Stackpole Electronics Inc	RMCF1206FT15R0
R70	0 Ω	0603	RES 0 Ω JUMPER 1/10 W 0603	YAGEO	AA0603JR-070RL
R71	15 Ω	1206	RES SMD 15 Ω 1% 1/4 W 1206	Stackpole Electronics Inc	RMCF1206FT15R0
R72	10 kΩ	0603	RES 10 kΩ 1% 1/10 W 0603	Vishay Dale	CRCW060310K0FKECC
R73	13.3 kΩ	0603	RES 13.3 kΩ 1% 1/10 W 0603	Yageo	RC0603FR-0713K3L
R74	137 kΩ	0603	RES 137 kΩ 1% 1/10 W 0603	Yageo	RC0603FR-07137KL
R75	13 kΩ	0603	RES SMD 13 kΩ 1% 1/10 W 0603	YAGEO	AC0603FR-0713KL
R76	11.3 kΩ	0603	RES SMD 11.3 kΩ 1% 1/10 W 0603	Yageo	AC0603FR-0711K3L
R77	100 kΩ	0603	NTC Thermistor 100 kΩ 0603 (1608 Metric)	Murata	NCU18WF104F6SRB
R78	1 kΩ	0603	RES SMD 1 kΩ 1% 1/10 W 0603	Yageo	AC0603FR-131KL
R79	5.62 Ω	0805	RES SMD 5.62 Ω 1% 1/8 W 0805	Vishay Dale	CRCW08055R62FKEA
R8	10 kΩ	0603	RES 10 kΩ 1% 1/10 W 0603	Vishay Dale	CRCW060310K0FKECC
R80	1 kΩ	0603	RES SMD 1 kΩ 1% 1/10 W 0603	Yageo	AC0603FR-131KL
R81	68 kΩ	0805	RES 68 kΩ 1% 1/8 W 0805	Vishay Dale	CRCW080568K0FKEAC
R82	47 kΩ	0603	RES SMD 47 kΩ 1% 1/10 W 0603	Stackpole Electronics Inc	RMCF0603FT47K0
R83	9.53 kΩ	0603	RES 9.53 kΩ 1% 1/10 W 0603	Yageo	RC0603FR-079K53L
R84	174 kΩ	0805	RES 174 kΩ 1% 1/8 W 0805	Yageo	RC0805FR-07174KL
R85	9.53 kΩ	0603	RES 9.53 kΩ 1% 1/10 W 0603	Yageo	RC0603FR-079K53L
R86	249 Ω	0603	RES SMD 249 Ω 1% 1/10 W 0603	Vishay Dale	CRCW0603249RFKEB
R87	10 kΩ	0603	RES 10 kΩ 1% 1/10 W 0603	Vishay Dale	CRCW060310K0FKECC
R88	2.21 kΩ	0603	RES 2.21 kΩ 1% 1/8 W 0603	Stackpole	RNCP0603FTD2K21



## 600W-ACDC-GEVB

**Table 1. BILL OF MATERIALS** (continued)

Ref Des	Value	Package	Description	Mfg	Mfg P/N
R89	np	0603			
R9	22.1 kΩ	0603	RES 22.1 kΩ 1% 1/10 W 0603	Vishay Dale	CRCW060322K1FKEAC
R90	1.21 MΩ	1206	RES 1.21 MΩ 1% 1/4 W 1206	KOA Speer Electronics, Inc.	RK73H2BTDD1214F
R91	10 kΩ	0603	RES 10 kΩ 1% 1/10 W 0603	Vishay Dale	CRCW060310K0FKECC
R92	1.21 MΩ	1206	RES 1.21 MΩ 1% 1/4 W 1206	KOA Speer Electronics, Inc.	RK73H2BTDD1214F
R93	2.7 kΩ	1206	RES 2.7 kΩ 1% 1/2 W 1206	TE Connectivity Passive Product	CRGP1206F2K7
R94	2.7 kΩ	1206	RES 2.7 kΩ 1% 1/2 W 1206	TE Connectivity Passive Product	CRGP1206F2K7
R95	15 kΩ/0.75 W	1206	RESHIGHPOWER 1206 15 kΩ 1% 3/4 W TC	Bourns	CMP1206-FX-1502ELF
R96	15 kΩ/0.75 W	1206	RESHIGHPOWER 1206 15 kΩ 1% 3/4W TC	Bourns	CMP1206-FX-1502ELF
R97	2.21 kΩ/0.5 W	1206	RES 2.21 kΩ 1% 1/2 W 1206	Stackpole	RNCP1206FTD2K21
R98	1.21 MΩ	1206	RES 1.21 MΩ 1% 1/4 W 1206	KOA Speer Electronics, Inc.	RK73H2BTDD1214F
R99	499 kΩ	0603	RES 499 kΩ 1% 1/10W 0603	Vishay Dale	CRCW0603499KFKEAC
T1	Flyback transformer	custom	custom flyback transformer	Würth	750319464
T2	LLC transformer	custom	custom LLC transformer	Würth	750319599
U1	NCP1076P065	7-DIP	IC OFFLINE SWITCH FLYBACK 7DIP	onsemi	NCP1076P065G
U10	NCP431BISNT1G	SOT-23	IC VREF SHUNT ADJ 0.5% SOT23-3	onsemi	NCP431BISNT1G
U11	FODM1008	4-SOP	OPTOISO 5KV 1CH TRANS LSOP4	onsemi	FODM1008
U2	FODM1008	4-SOP	OPTOISO 5KV 1CH TRANS LSOP4	onsemi	FODM1008
U3	NCP431AISNT1G	SOT-23	IC VREF SHUNT ADJ 1% SOT23-3	onsemi	NCP431AISNT1G
U4	NCP431BISNT1G	SOT-23	IC VREF SHUNT ADJ 0.5% SOT23-3	onsemi	NCP431BISNT1G
U5	NCP1632	16-SOIC	PFC controller	onsemi	NCP1632
U6	NCP4305D	8-SOIC	IC SEC SIDE SYNC RECT DRV 8SOIC	onsemi	NCP4305DDR2G
U7	NCP4305D	8-SOIC	IC SEC SIDE SYNC RECT DRV 8SOIC	onsemi	NCP4305DDR2G
U8	NCP1399	16-SOIC	LLC controller	onsemi	NCP1399
U9	FODM1008	4-SOP	OPTOISO 5KV 1CH TRANS LSOP4	onsemi	FODM1008
HS1	Bridge heat sink		BOARD LEVEL HEATSINK 1.95" TO220	Aavid	7023B-MTG
HS2	TO220 heat sink		HEATSINK TO-220 4.8 W ALUMINUM	CUI Devices	HSS-B20-053H-01
HS3	TO220 heat sink		HEATSINK TO-220 4.8 W ALUMINUM	CUI Devices	HSS-B20-053H-01
HS4	TO220 heat sink		HEATSINK TO-220 4.8 W ALUMINUM	CUI Devices	HSS-B20-053H-01
HS5	TO220 heat sink		HEATSINK TO-220 4.8 W ALUMINUM	CUI Devices	HSS-B20-053H-01

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**Table 1. BILL OF MATERIALS** (continued)

Ref Des	Value	Package	Description	Mfg	Mfg P/N
HS6	TO220 heat sink		HEATSINK TO-220 4.8W ALUMINUM	CUI Devices	HSS-B20-053H-01
HS7	TO220 heat sink		HEATSINK TO-220 4.8W ALUMINUM	CUI Devices	HSS-B20-053H-01
J1	Terminal block-3 pos		CONN BARRIER STRIP 3CIRC 0.325"	TE Connectivity AMP Connectors	4DB-P108-03
J5	Terminal block-6 pos		CONN BARRIER STRIP 6CIRC 0.325"	TE Connectivity AMP Connectors	4DB-P108-06
TPGND1	Test point jumper		.200 SPACING TEST POINT JUMPER	Keystone Electronics	5026
TPGND2	Test point jumper		.200 SPACING TEST POINT JUMPER	Keystone Electronics	5026
TPGND3	Test point jumper		.200 SPACING TEST POINT JUMPER	Keystone Electronics	5026
TPGND4	Test point jumper		.200 SPACING TEST POINT JUMPER	Keystone Electronics	5026
TPGND5	Test point jumper		.200 SPACING TEST POINT JUMPER	Keystone Electronics	5026
TPGND6	Test point jumper		.200 SPACING TEST POINT JUMPER	Keystone Electronics	5026
TPGND7	Test point jumper		.200 SPACING TEST POINT JUMPER	Keystone Electronics	5026

# 600W-ACDC-GEVB

## Specifications of Custom Magnetics

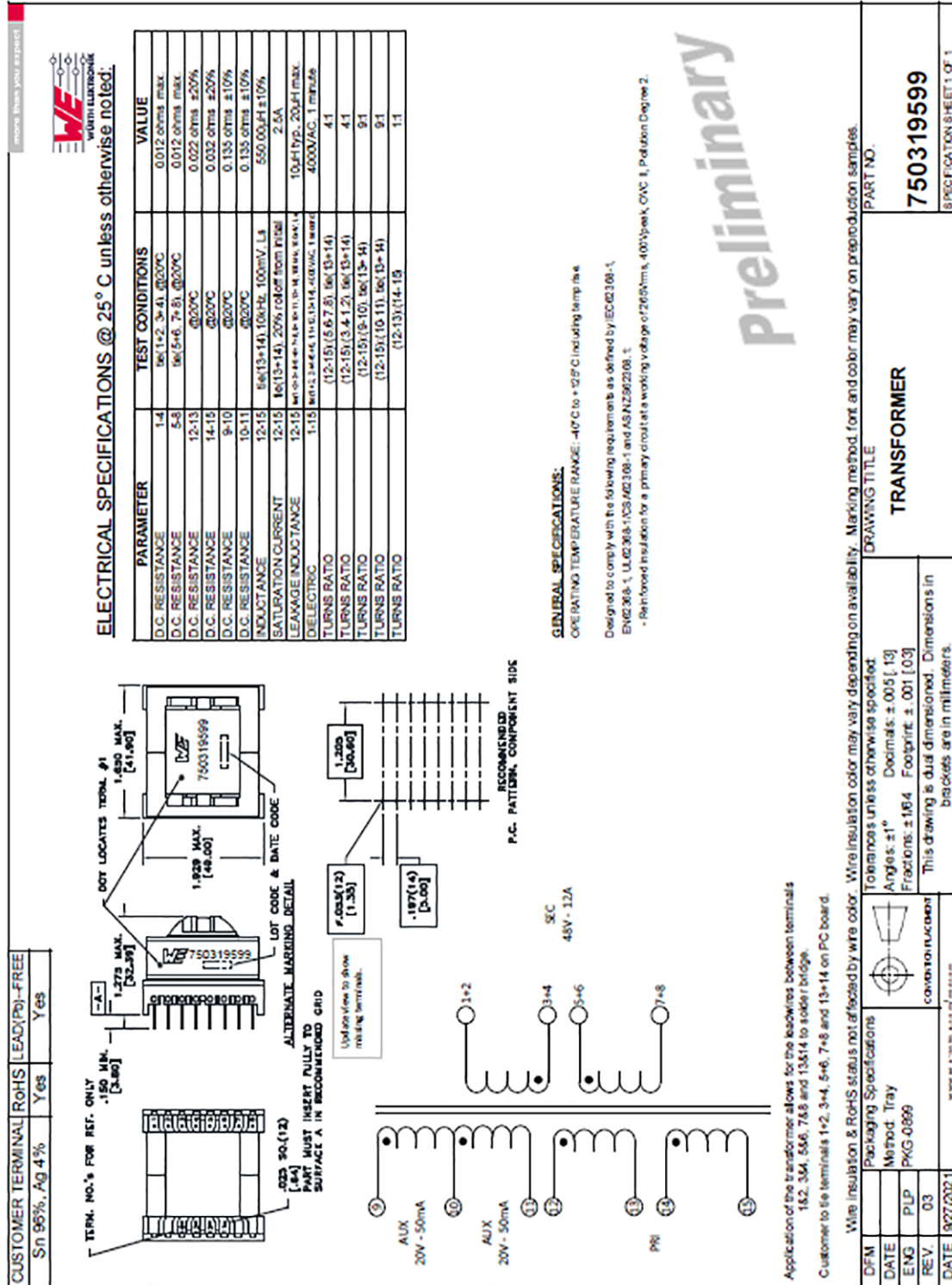


Figure 41. LLC Transformer T2

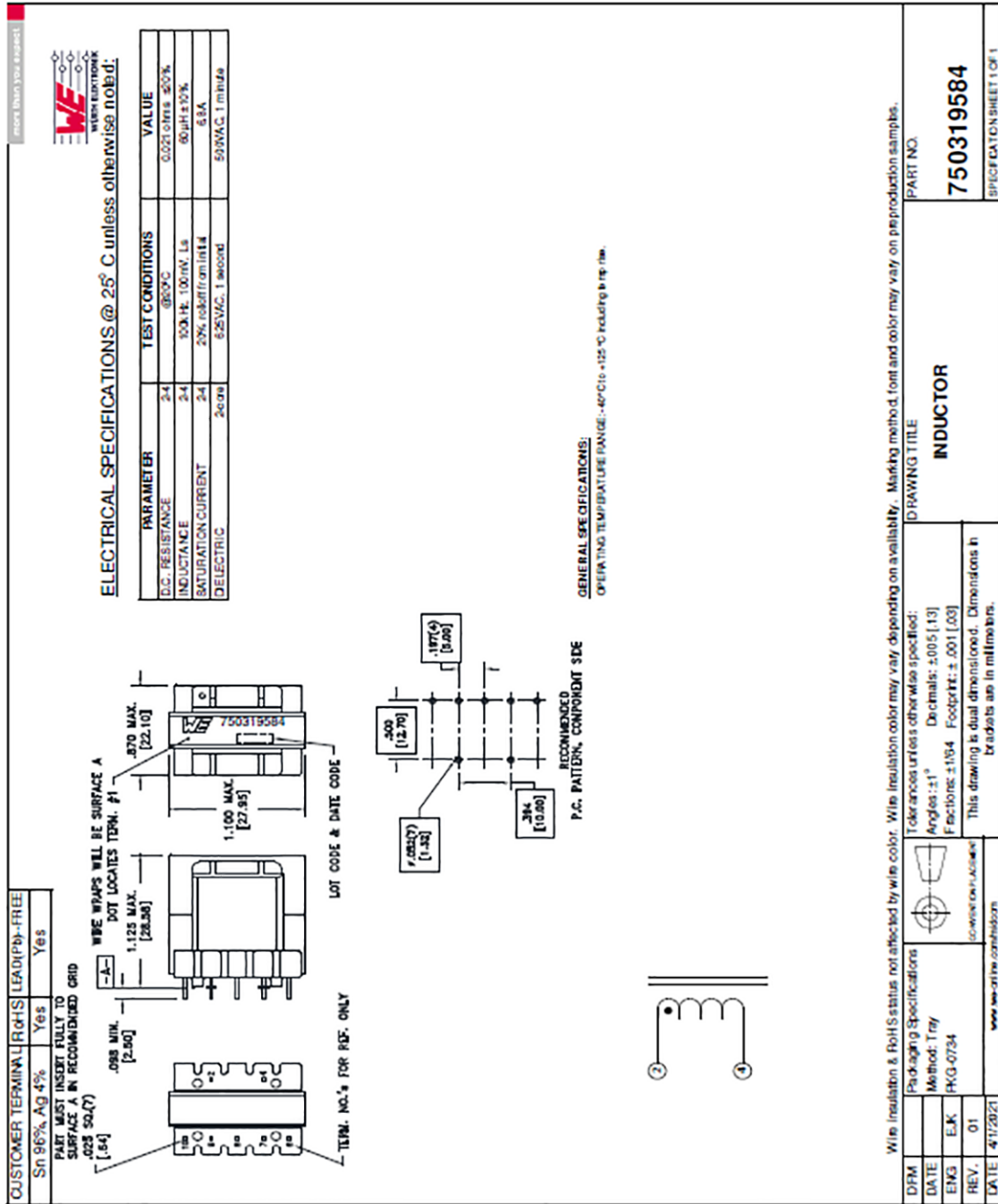


Figure 42. Resonant Inductor L6

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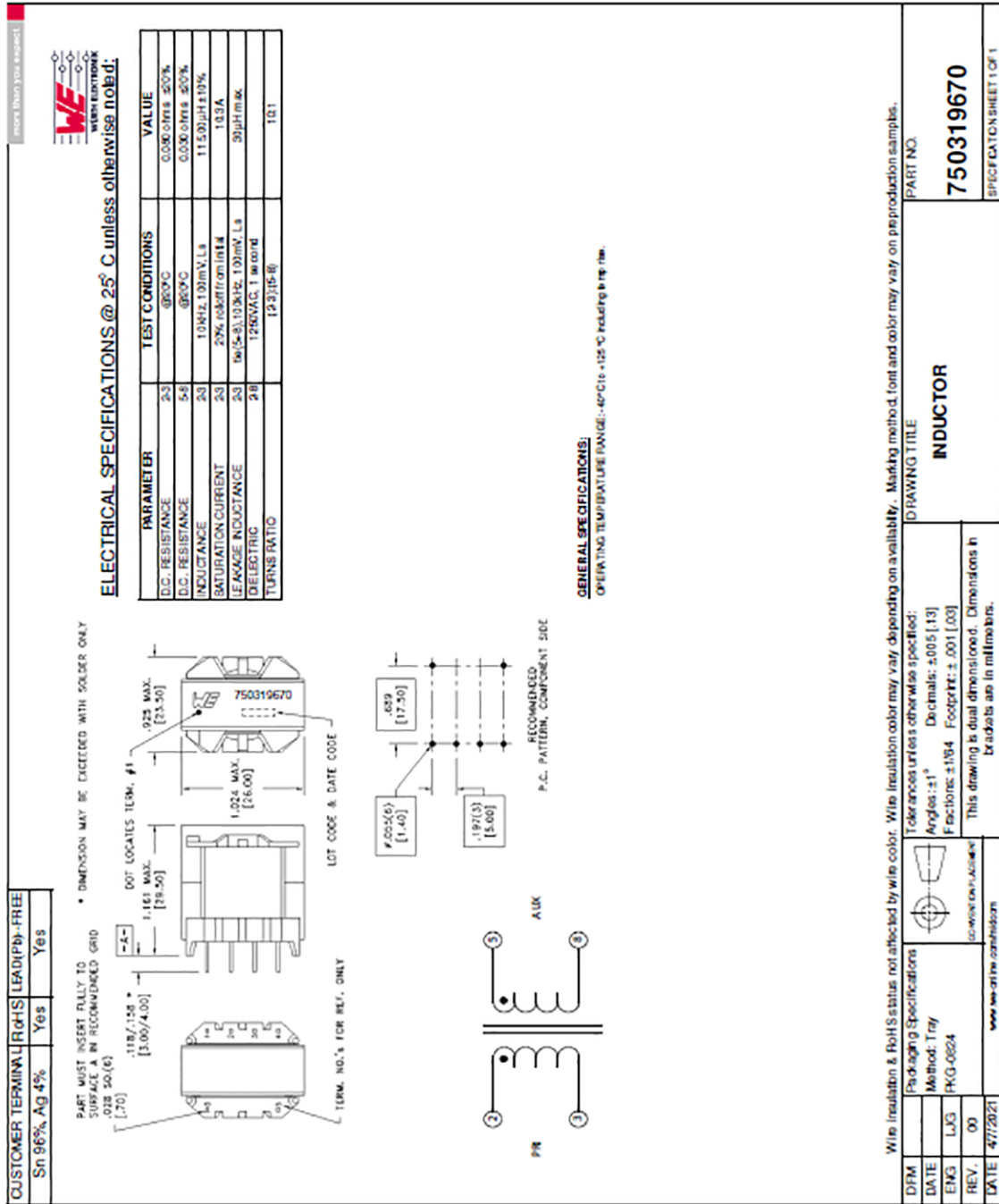


Figure 43. PFC Boost Inductors L2, L4

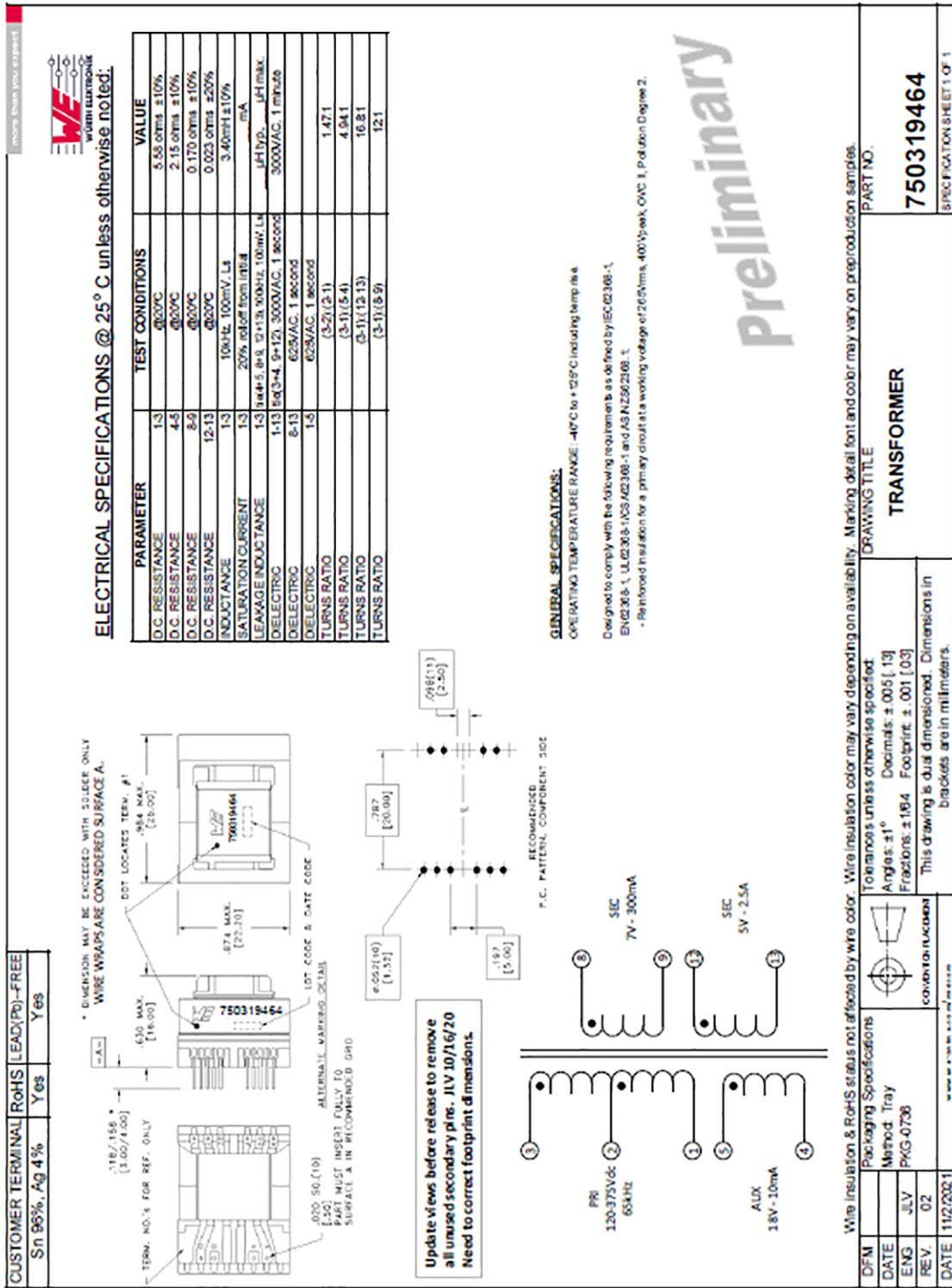


Figure 44. Flyback Transformer T1

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