

Wide Input Range, Full Bridge Phase Shifted Topology using the **ADP1046A**

FEATURES

- 600 W phase shifted full bridge topology
- Wide input range to minimize hold up capacitor
- Wide ZVS range down to 10% rated load
- Short-circuit and fast overvoltage protection
- Remote voltage sensing
- Line voltage feedforward
- I²C serial interface to PC
- Software GUI
- Programmable digital filters for DCM and CCM
- 7 PWM outputs including auxiliary PWM
- Digital trimming
- Current, voltage, and temperature sense through GUI
- Calibration and trimming

CAUTION

This evaluation board uses high voltages and currents. Extreme caution must be taken, especially on the primary side, to ensure safety for the user. It is strongly advised to power down the evaluation board when not in use. A current-limited power supply is recommended.

ADP1046A EVALUATION BOARD OVERVIEW

This evaluation board features the **ADP1046A** in a switching power supply application. With the evaluation board and software, the **ADP1046A** can be interfaced to any PC running Windows® 2000, Windows XP, Windows Vista, Windows NT, or Windows 7 via the USB port of the PC. The software allows control and monitoring of the **ADP1046A** internal registers. The evaluation board is set up for the **ADP1046A** to act as an isolated switching power supply with a rated load of 48 V/12.5 A from an input voltage ranging from 340 V dc to 410 V dc.

ADP1046A EVALUATION BOARD PHOTOGRAPH

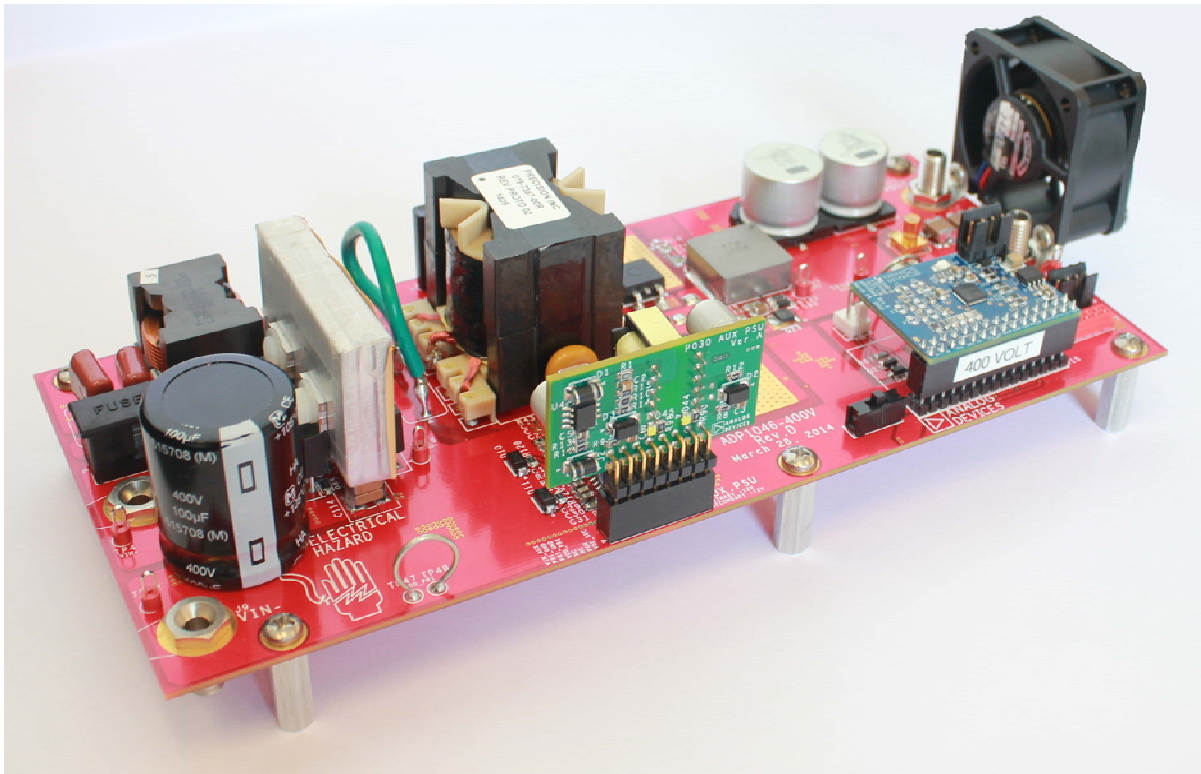


Figure 1.

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REVISION HISTORY

10/14—Revision 0: Initial Version

BOARD SPECIFICATIONS

Table 1. Target Specifications

Specification	Min	Typ	Max	Unit	Notes
V _{IN}	340	385	410	V	
V _{OUT}		48		V	
I _{OUT}	0.0	12.5	15	A	With 400 LFM air flow
Overload Current (OCP Limit)			15	A	OCP set to shut down PSU after ~10 ms
Efficiency		96.35		%	Typical reading at 385 V _{IN} , 12.5 A load
Switching Frequency		111.6		kHz	
Output Voltage Ripple		550		mV	At 12.5 A load

TOPOLOGY AND CIRCUIT DESCRIPTION

This evaluation board circuit consists of the [ADP1046A](#) in a typical isolated dc-to-dc switching power supply in a full bridge phase shifted topology with synchronous rectification. The circuit provides a rated output load of 48 V/12.5 A from a nominal input voltage of 385 V dc operated in continuous conduction mode (CCM) at all times. The [ADP1046A](#) provides functions such as output voltage regulation, output overvoltage protection, input and output current protection, primary cycle by cycle protection, and overtemperature protection. Figure 70 provides a top level schematic that describes the power flow and auxiliary power supply that starts up at 50 V dc and provides power to the [ADP1046A](#) through a 3.3 V low dropout regulator (LDO), the *iCoupler*® isolation plus gate drivers, the on-board fan, and the synchronous rectifier drivers. The auxiliary power supply using the transformer (T3) and IC (U10) generates a 12 V rail on the primary side and a 13 V rail on the secondary side. The main power transformer (T12) provides a wide input voltage range (340 V dc to 410 V dc), and the circuit has a wide zero voltage switching (ZVS) range down to 10% of the rated load.

The primary side consists of the input terminals (JP8 and JP9), the switches (Q1 to Q4), the current sense transformer (T5), and the main transformer (T1). There is also a resonant inductor that aids in zero voltage switching at lighter load conditions. The [ADP1046A](#) is situated on the secondary side and is powered via the auxiliary power supply, or the USB connector via the LDO. The gate signal for the primary switches is generated by the [ADP1046A](#) through the *iCouplers* and fed into the MOSFET drivers (U17 and U18). Bypass capacitors (C71, C72, and C114 to 116) are placed close to the primary switches. Diodes (D36 and 37) clamp the resonance between the resonant inductor and the output capacitance (COSS) of the output rectifiers.

The secondary (isolated) side of the transformer consists of a center tapped winding. The synchronous rectifier driver (U7) provides the drive signals for the switches (Q9 and Q23). The output inductor (L8) and output capacitor (C11 and C41) act as a low-pass filter for the output voltage. The output voltage is fed back to the [ADP1046A](#) using a voltage divider and has a nominal

voltage of 1 V, which is differentially sensed. Output current is measured using a sense resistor (R2), which is also differentially sensed. To protect the synchronous rectifiers from exceeding the peak reverse voltage, an RCD clamp is implemented (D58, D59, R112 to R115, and C94).

The primary current is sensed through the CS1 pin with a small RC time constant (R44 and C22) that acts as a low-pass filter to remove the high frequency noise on the signal. An additional RC can be placed; however, the internal Σ - Δ analog-to-digital converter (ADC) naturally averages the signal. The position of the current transformer is placed in series with the resonant inductor to avoid saturation.

Line voltage feedforward is implemented using an RCD circuit (D13, R59, R64, C38, and C43) that detects the peak voltage at the synchronous field effect transistor (FET). There are two time constants that can be implemented in series with each other. The time constants must be matched such that it retains the peak value during the switching frequency period, but also is not too long in case there is a step down change in the input voltage. This peak voltage is further ratioed and fed in the ACSNS pin of the controller ([ADP1046A](#)). A thermistor (RT1) is placed on the secondary side close to the synchronous FET and acts as thermal protection for the power supply. A 16.5 k Ω resistor is placed in parallel with the thermistor that allows the software GUI to read the temperature directly in degrees Celsius.

Capacitor C69 is a YCAP that reduces common-mode noise from the transformer.

Also available on the secondary side is a 4-pin connector for I²C communication. This connector allows the PC software to communicate with the IC through the USB port of the PC. The user can easily change register settings on the [ADP1046A](#) and monitor the status registers. It is recommended that the USB dongle be connected directly to the PC, and not via the external hub.

Switch SW2 acts as a hardware PS_OFF switch. The polarity is configured using the GUI to be active high.

CONNECTORS

Table 2 lists the connectors on the board. Table 3 lists the pinouts of the USB to I²C adapter, shown in Figure 2.

Table 2. Board Connectors

Connector	Evaluation Board Function
J8	DC input positive terminal
J9	DC input negative terminal
J11	Output voltage positive terminal
J12	Output voltage negative terminal
J16	Socket for auxiliary power supply
J18	I ² C connector

Table 3. I²C Connector Pinout Descriptions

Pin (Left to Right)	Function
1	5 V
2	SCL
3	SDA
4	Ground



Figure 2. I²C Connector (Pin 1 on Left)

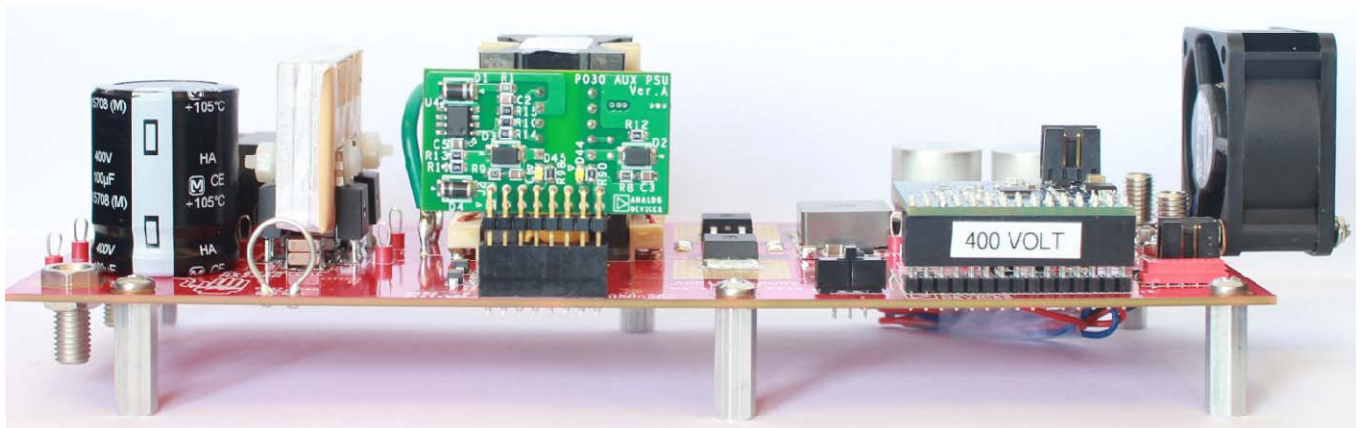


Figure 3. ADP1046A Evaluation Board (Side View)

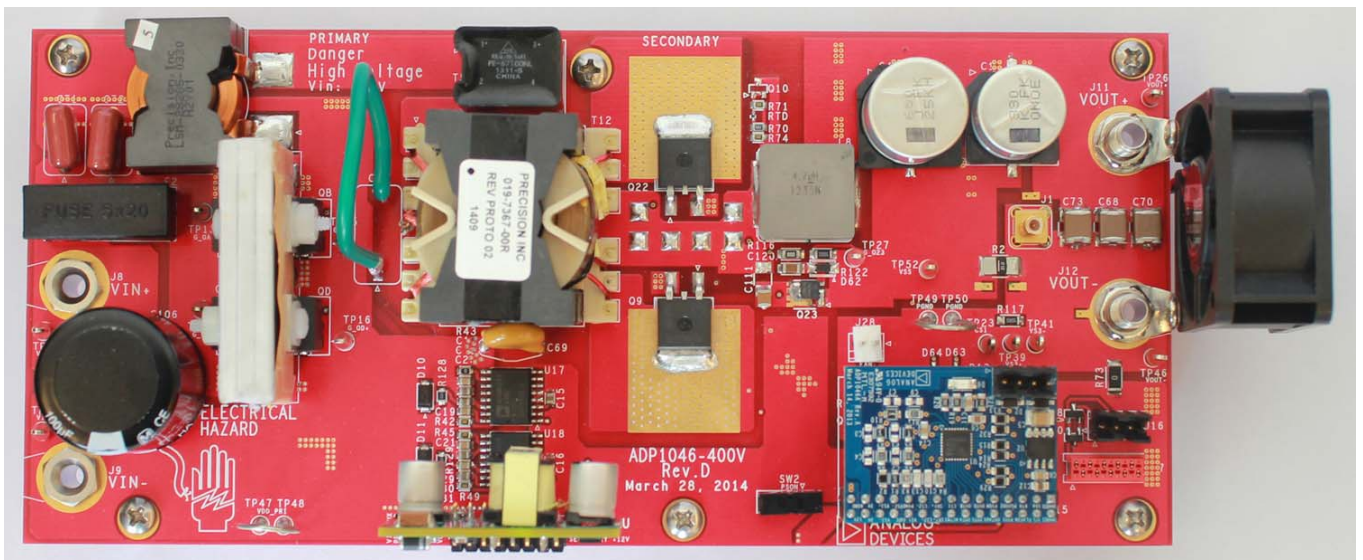


Figure 4. Evaluation Board (Top View)

SETTING FILES AND EEPROM

The [ADP1046A](#) communicates with the GUI software using the I²C bus.

The register settings (having the extension **.46r**) and the board settings (having the extension **.46b**) are two files that are associated with the [ADP1046A](#) software. The register settings file contains information such as the overvoltage and overcurrent limits, the soft start timing, and the PWM settings that govern the functionality of the device. The [ADP1046A](#) stores all its settings in the EEPROM.

The EEPROM on the [ADP1046A](#) does not contain any information about the board, such as the current sense resistor, output inductor, and capacitor values. This information is stored in the board setup file (extension **.46b**) and is necessary for the GUI to display the correct information in the **Monitor** tab as well as the **Filter Settings** window. The entire status of the power supply, such as the ORFET and synchronous rectifiers

enable/disable, primary current, output voltage, and current, can therefore be digitally monitored and controlled using the software only. Always make sure that the correct board file has been loaded for the board currently in use.

Each [ADP1046A](#) chip has trim registers for the temperature, the input current, the output voltage and current, and ACSNS. These values can be configured during production and are not overwritten when a new register settings file is loaded. Therefore, the trimming of all the ADCs for that corresponding environmental and circuit condition (such as component tolerances or thermal drift) are retained. A guided **Auto Trim Wizard** starts up, which trims the previously mentioned quantities so that the measurement value matches the values displayed in the GUI to allow ease of control through the software.

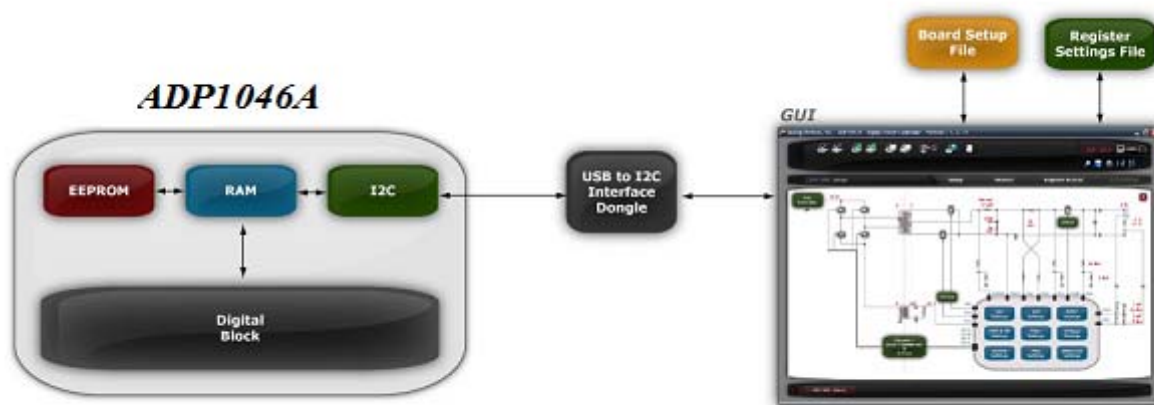


Figure 5. [ADP1046A](#) and GUI Interaction

BOARD EVALUATION

EQUIPMENT

The following equipment is required:

- A dc power supply (300 V to 400 V, 600 W)
- An electronic load (60 V/600 W)
- An oscilloscope with differential probes
- A PC with **ADP1046A** GUI installed
- Precision digital voltmeters (HP34401 or equivalent, 6 digits) for measuring dc current and voltage

SETUP

Take the following steps to set up the evaluation board. Do not connect the USB cable to the evaluation board until the software has finished installing.

1. Install the **ADP1046A** software by inserting the installation CD. The software setup starts automatically, and a guided process installs the software as well as the USB drivers for communication between the GUI and the IC using the USB dongle.
2. Insert the daughter card in Connector J16 as shown in Figure 72.
3. Ensure that the PS_ON switch (SW1 on the schematic) is turned to the off position. The switch is located on the bottom left half of the board.
4. Connect one end of USB dongle to the board and the other end to the board to the USB port on the PC using the USB to I²C interface dongle.
5. The software reports that the **ADP1046A** has been located on the board. Click **Finish** to proceed to the main software interface window. The serial number reported on the side of the checkbox indicates the USB dongle serial number, as shown in Figure 6. The windows also displays the device I²C address.



Figure 6. **ADP1046A** Address of 50h in the GUI

6. If the software does not detect the device, it enters into simulation mode. Ensure that the connector is connected to the daughter card. Click the **Scan for ADP1046A Now** icon located on the top right hand corner of the screen, as shown in Figure 7.

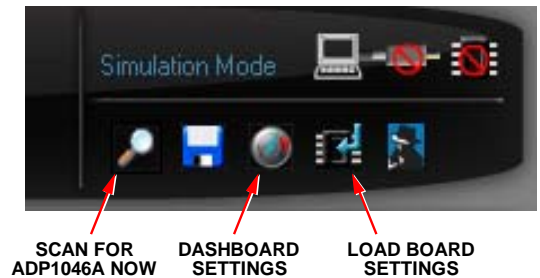


Figure 7. GUI Icons

7. Click the **Load Board Settings** icon (see Figure 7) and select the **ADP1046A_FBPS_600W_XXXX.46b** file. This file contains all the board information, including values of shunt and voltage dividers. Note that all board setting files have a **.46b** file extension.
8. The IC on the board comes preprogrammed, and this step is optional. The original register configuration is stored in the **ADP1046A_FBPS_600W_XXXX.46r** register file (note that all register files have a **.46r** file extension). The file can be loaded using the second icon from the left in Figure 8.
9. Connect a dc power source (385 V dc nominal, current limit to approximately 2 A) and an electronic load at the output set to 1 A.
10. Connect a voltmeter on test points TP26(+) and TP46(-). Ensure that differential probes are used and that the ground of the probes are isolated if oscilloscope measurements are made on the primary side of the transformer.
11. Click the **Dashboard Settings** icon (see Figure 7) and turn on the software PS_ON.
12. The board is running and ready for evaluation. The output now reads 12 V dc.
13. Click the **Monitor** tab and then click the **Flags and readings** icon. This window provides a snapshot of the entire state of the PSU in a single user friendly window.



Figure 8. Different Icons on Dashboard for Loading and Saving **.46r** and **.46b** Files

THEORY OF OPERATION DURING STARTUP

The following steps briefly describe the startup procedure of the ADP1046A, the power supply, and the operation of the state machine for the preprogrammed set of registers that are included in the design kit.

1. The on-board auxiliary power starts up at approximately 50 V dc. The on-board auxiliary power provides a drive voltage on the isolated side to an LDO (3.3 V) that powers up the ADP1046A. After VDD (3.3 V) is applied to the ADP1046A, it takes approximately 20 μs to 50 μs for VCORE to reach 2.5 V. The digital core is now activated, and the contents of the registers are downloaded in the EEPROM. The ADP1046A is now ready for operation.
2. PS_ON is applied. The power supply begins the programmed soft start ramp of 50 ms (programmable).
3. Because the soft start from precharge setting is active, the output voltage is sensed before the soft start ramp begins. Depending on the output voltage level, the effective soft start ramp is reduced by the proportional amount.

4. The PSU now is running in steady state. PGOOD1 turns on after the programmed debounce.
5. If a fault is activated during the soft start or steady state, the corresponding flag is set, and the programmed action is taken, such as **Disable Power Supply and Re-enable after 1 s**, **Disable SR and OrFET**, or **Disable OUTAUX** (see Figure 10).

FLAGS SETTINGS CONFIGURATIONS

When a flag is triggered, the ADP1046A state machine waits for a programmable debounce time before taking any action. The response to each flag can be programmed individually. The flags can be programmed in a single window by selecting the **Flag Settings** icon under the **Monitor** tab in the GUI. This monitor window shows all the fault flags (if any) and the readings in one page. The **Get First Flag** button determines the first flag that was set in the case of a fault event.

	Timing	Action	Blank flag during Soft-Start
CS1 Fast OCP	Immediately	Disable Power Supply and Remain disabled, PSON needed	<input type="checkbox"/>
CS1 Accurate OCP	2.6 ms Debounce	Disable Power Supply and Re-enable after 1 s	<input checked="" type="checkbox"/>
CS2 Accurate OCP	2.6 ms Debounce	Disable Power Supply and Remain disabled, PSON needed	<input type="checkbox"/>
Load OVP (VS2 or VS3)	Immediately	Disable all PWMs except OUTAUX	<input type="checkbox"/>
External Flag	Immediately	Ignore Flag Completely	<input checked="" type="checkbox"/>
OTP	After 100 ms Debounce	Ignore Flag Completely	<input type="checkbox"/>
UVP	After 10 ms Debounce	Ignore Flag Completely	<input type="checkbox"/>
CS2 Reverse Voltage	Immediately	Ignore Flag Completely	<input type="checkbox"/>
Voltage Continuity	Immediately	Ignore Flag Completely	<input type="checkbox"/>
Share Bus	Immediately	Ignore Flag Completely	<input type="checkbox"/>
ACSNS	Immediately	Ignore Flag Completely	<input type="checkbox"/>
VDD/VCORE OV	After 2 us Debounce	Ignore Flag Completely	Restart with EEPROM download
Accurate Local OVP (VS1)	After 2 ms Debounce	Disable all PWMs except OUTAUX	<input type="checkbox"/>
Fast Local OVP (VS1)	After 0.96us Debounce		

Additional Flag Settings

Power Supply re-enable time: 1 s OUTAUX PWM Immediate Shutdown

Apply Settings

Figure 10. Fault Configurations

12485-010

PWM SETTINGS

The ADP1046A has a fully programmable PWM setup that controls seven PWMs. Due to this flexibility, the IC can function in several different topologies, such as any isolated buck derived topology, push-pull, and flyback, and also has the control law for resonant converters.

Each PWM edge can be moved in 5 ns steps to achieve the appropriate dead time required, and the maximum modulation limit sets the maximum duty cycle.

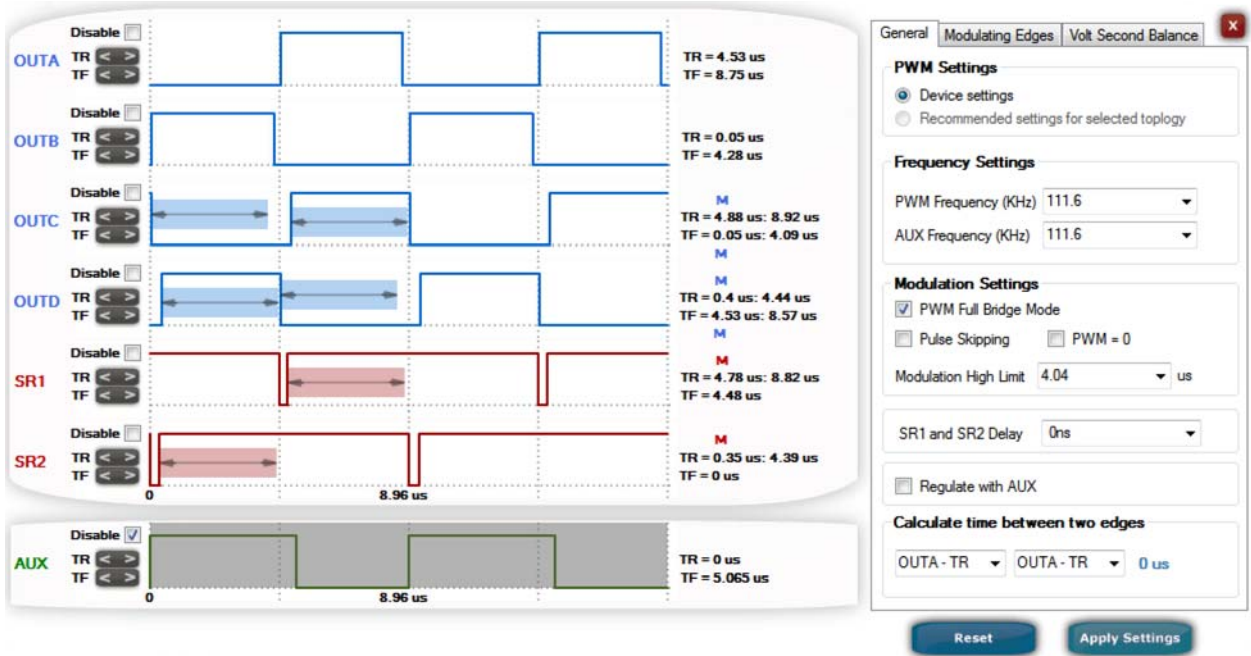


Figure 11. PWM Settings Window in the GUI

Table 4. PWMs and Their Corresponding Switching Element

PWM	Switching Element Being Controlled
OUTA to OUTD	Primary switch PWM configured for phase shifted topology
SR1, SR2	Synchronous rectifier PWMs
OUTAUX	Not applicable

BOARD EVALUATION AND TEST DATA

STARTUP

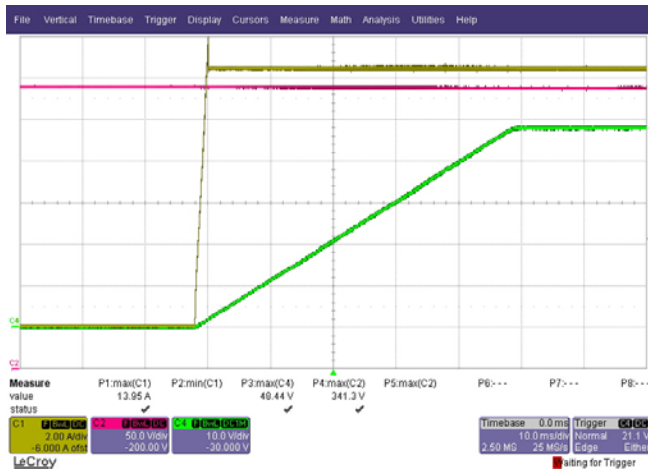


Figure 12. Startup at 340 V dc, 600 W Load (Software PS_ON)
 Green Trace: Output Voltage, 10 V/div, 10 ms/div
 Yellow Trace: Load Current, 2 A/div, 10 ms/div
 Red Trace: Input Voltage, 50 V/div, 10 ms/div

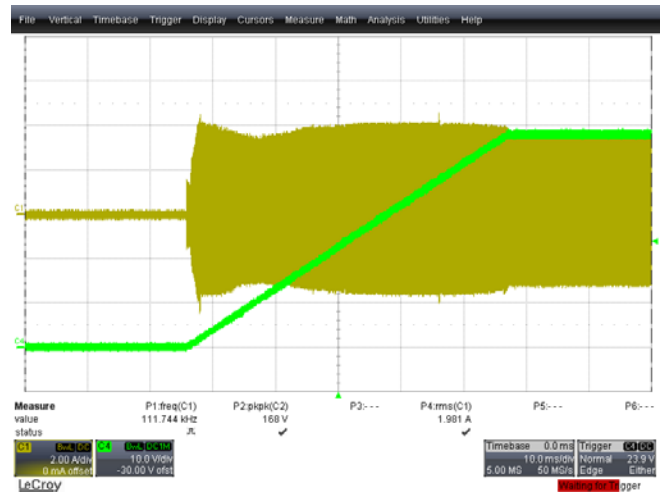


Figure 14. Startup at 385 V dc, Full Load
 Green Trace: Output Voltage, 10 V/div, 10 ms/div
 Yellow Trace: Primary Current, 2 A/div, 10 ms/div

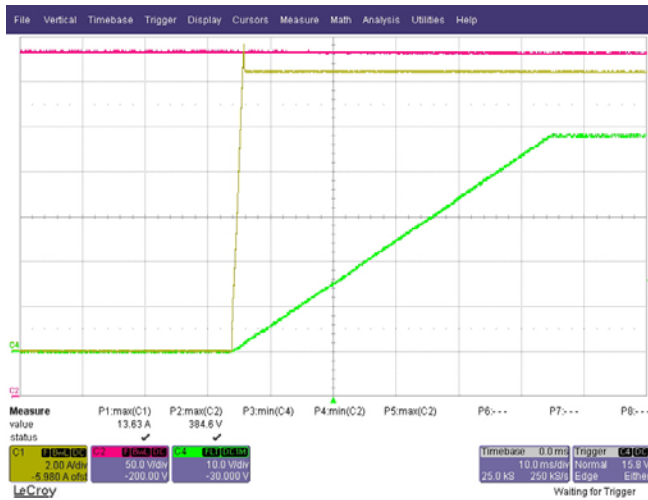


Figure 13. Startup at 385 V dc, 600 W Load (Software PS_ON)
 Green Trace: Output Voltage, 10 V/div, 10 ms/div
 Yellow Trace: Load Current, 2 A/div, 10 ms/div
 Red Trace: Input Voltage, 50 V/div, 10 ms/div

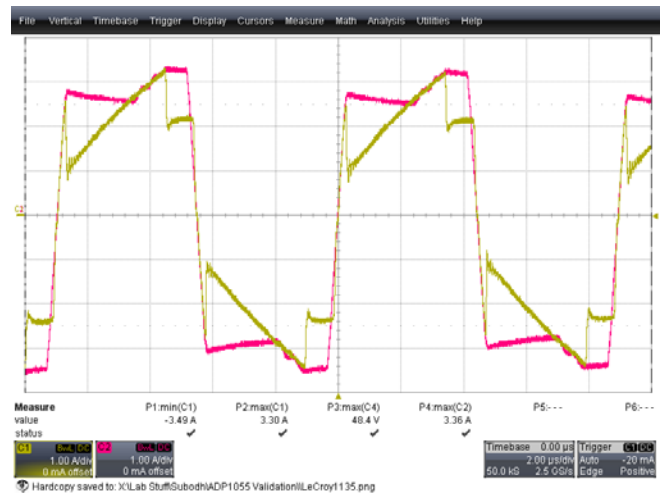


Figure 15. Primary Current at Full Load
 Red Trace: Resonant Inductor Current, 1 A/div, 2 μ s/div
 Yellow Trace: Primary Current, 1 A/div, 2 μ s/div

OVERCURRENT AND SHORT-CIRCUIT PROTECTION



Figure 16. OCP at 385 V dc, 15 A Load (Action to Shutdown After ~10 ms)
 Green Trace: Output Voltage, 10 V/div, 5 ms/div
 Yellow Trace: Load Current, 5 A/div, 5 ms/div
 Red Trace: Input Voltage, 50 V/div, 5 ms/div

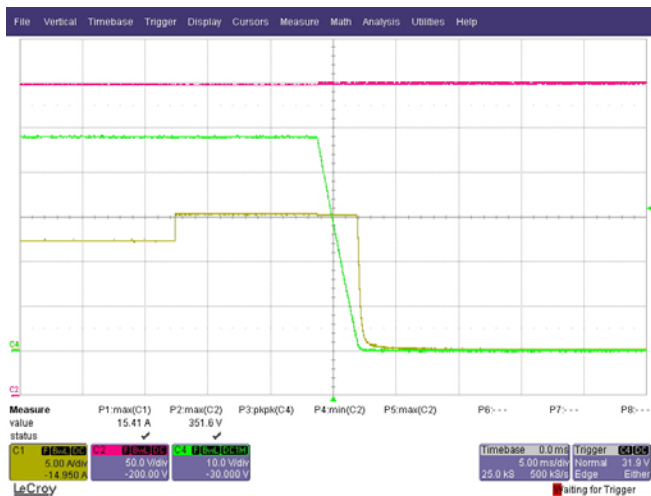


Figure 17. OCP at 350 V dc, 15 A Load (Action to Shutdown After ~10 ms)
 Green Trace: Output Voltage, 10 V/div, 5 ms/div
 Yellow Trace: Load Current, 5 A/div, 5 ms/div
 Red Trace: Input Voltage, 50 V/div, 5 ms/div



Figure 18. OCP at 385 V dc, 600 W to Output Shorted
 Red Trace: SR Drive, 5 V/div, 5 ms/div
 Green Trace: Output Voltage, 10 V/div, 200 μ s/div
 Yellow Trace: Output Current, 5 A/div



Figure 19. OCP, Hiccup Mode, 385 V dc, 600 W to Output Shorted
 Red Trace: SR Drive, 5 V/div, 5 ms/div
 Green Trace: Output Voltage, 10 V/div, 200 μ s/div
 Yellow Trace: Output Current, 5 A/div

PRIMARY GATE DRIVER DEAD TIME

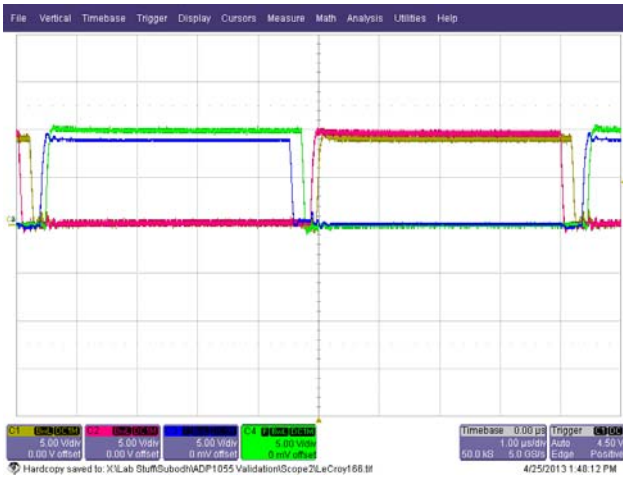


Figure 20. Primary Gate Drive Voltage at Maximum Modulation (Output of iCoupler), 5 V/div, 1 μs/div
Yellow Trace: OUTA, Red Trace: OUTB, Blue Trace: OUTC, Green Trace: OUTD

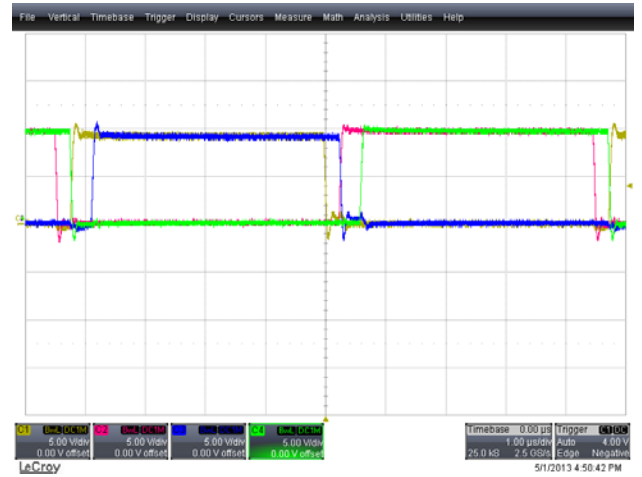


Figure 23. Primary Gate Drive Voltage at Minimum Modulation (Output of iCoupler), 5 V/div, 1 μs/div
Yellow Trace: OUTA, Red Trace: OUTB, Blue Trace: OUTC, Green Trace: OUTD

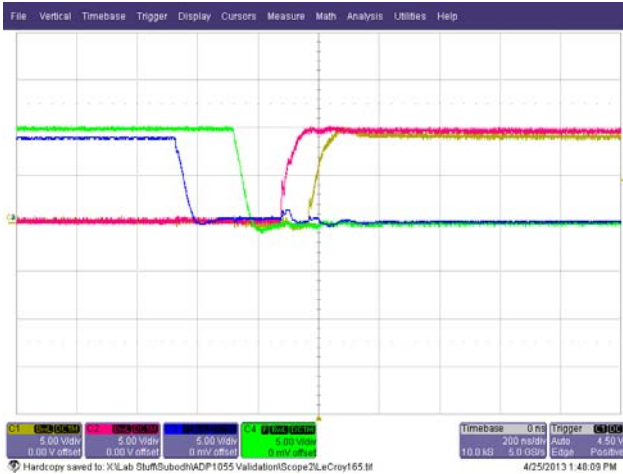


Figure 21. Primary Gate Drive Voltage at Maximum Modulation (Output of iCoupler) Showing Dead Time, Zoom In, 5 V/div, 0.2 μs/div
Yellow Trace: OUTA, Red Trace: OUTB, Blue Trace: OUTC, Green Trace: OUTD

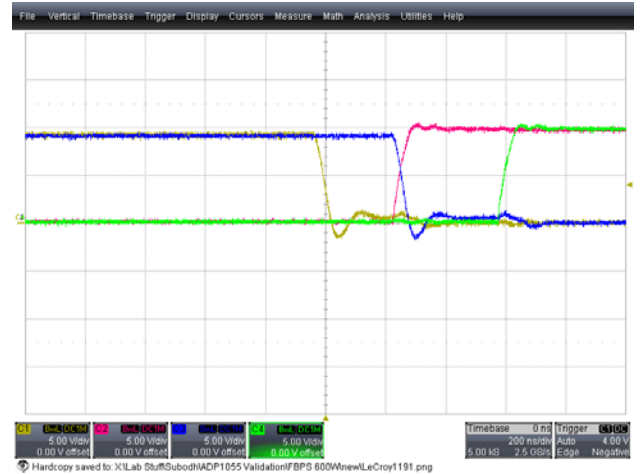


Figure 24. Primary Gate Drive Voltage at Minimum Modulation (Output of iCoupler) Showing Dead Time, Zoom In, 5 V/div, 0.2 μs/div
Yellow Trace: OUTA, Red Trace: OUTB, Blue Trace: OUTC, Green Trace: OUTD

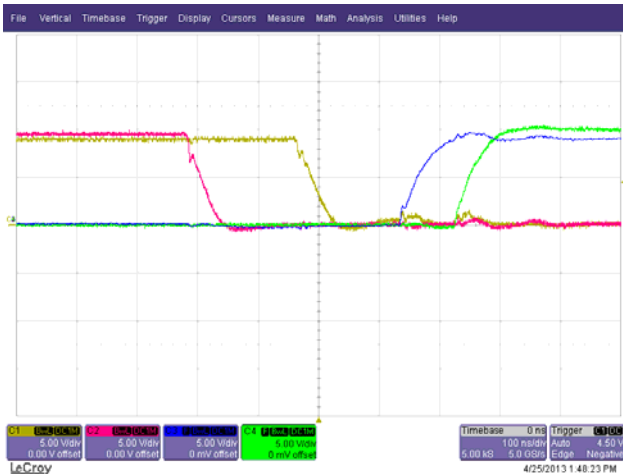


Figure 22. Primary Gate Drive Voltage at Maximum Modulation (Output of iCoupler) Showing Dead Time, Zoom In, 5 V/div, 0.2 μs/div
Yellow Trace: OUTA, Red Trace: OUTB, Blue Trace: OUTC, Green Trace: OUTD

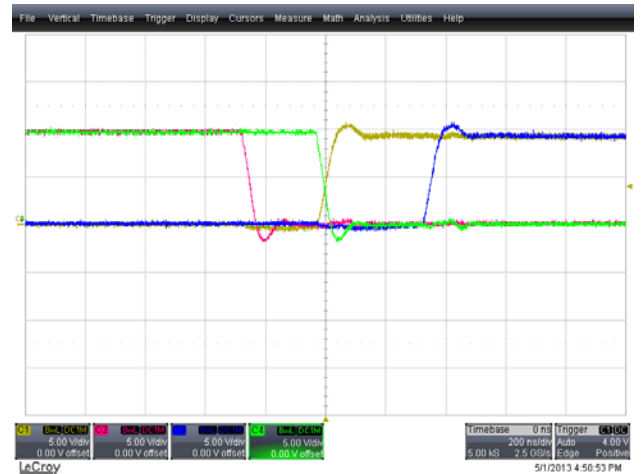


Figure 25. Primary Gate Drive Voltage at Minimum Modulation (Output of iCoupler) Showing Dead Time, Zoom In, 5 V/div, 0.2 μs/div
Yellow Trace: OUTA, Red Trace: OUTB, Blue Trace: OUTC, Green Trace: OUTD

CS1 PIN VOLTAGE (PRIMARY CURRENT)

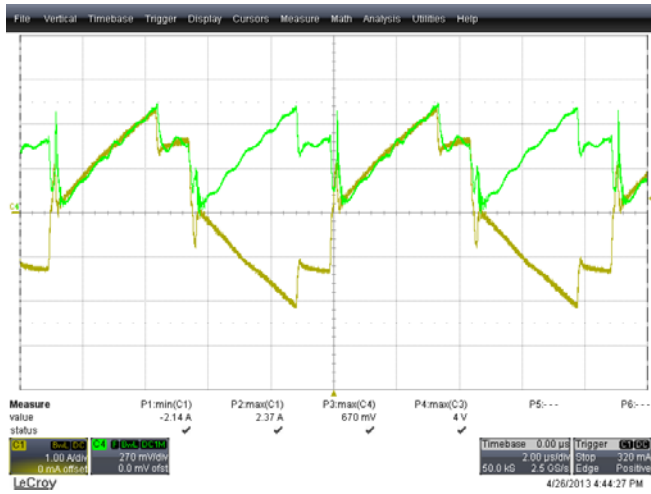


Figure 26. Primary Current at 385 V dc, 300 W Load, 2 μ s/div
 Yellow Trace: Primary Current Half Effect Probe, 1 A/div
 Green Trace: CS1 Pin Voltage, 270 mV/div

SYNCHRONOUS RECTIFIER PEAK INVERSE VOLTAGE

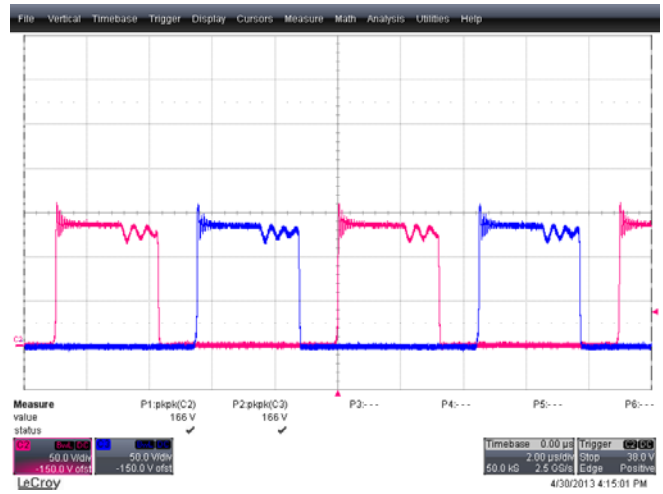


Figure 28. Synchronous Rectifier MOSFET Peak Reverse Voltage at 600 W Load, 385 V dc, 50 V/div, 2 μ s/div

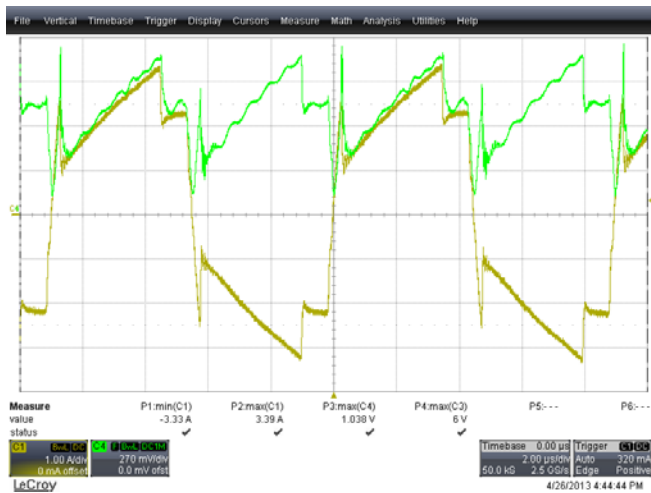


Figure 27. Primary Current at 385 V dc, 600 W Load, 2 μ s/div
 Yellow Trace: Primary Current Half Effect Probe, 1 A/div
 Green Trace: CS1 Pin Voltage, 270 mV/div

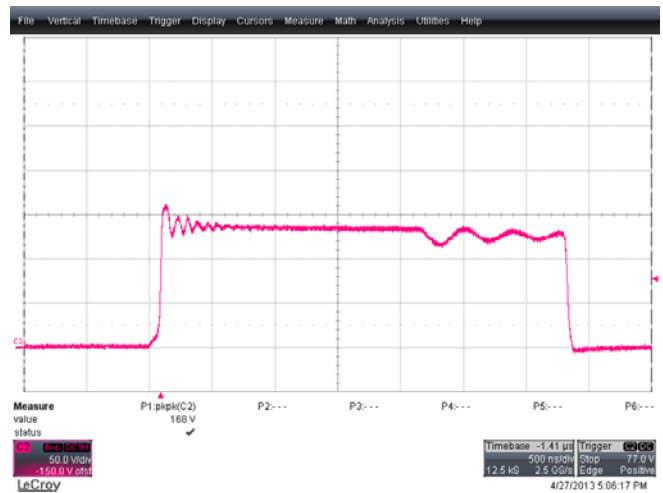


Figure 29. Synchronous Rectifier MOSFET Peak Reverse Voltage at 600 W Load, 385 V dc, 50 V/div, 500 ns/div

OUTPUT VOLTAGE RIPPLE

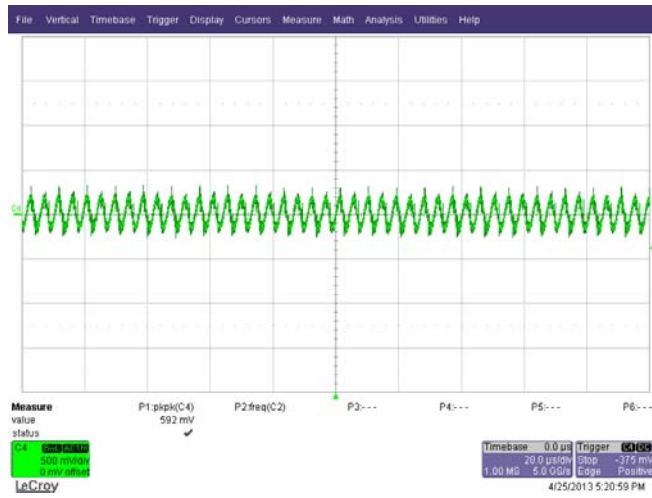


Figure 30. Output Voltage AC-Coupled, 385 V dc, 12.5 A, 500 mV/div, 20 μs/div, High Frequency Component

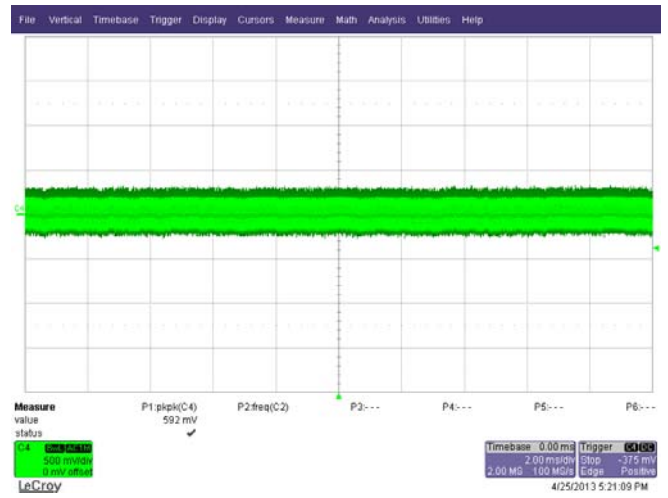


Figure 31. Output Voltage AC-Coupled, 385 V dc, 12.5 A, 500 mV/div, 2 ms/div, Low Frequency Component

TRANSIENT VOLTAGE AT 385 V dc (NOMINAL VOLTAGE)
Load Step of 15% to 50%

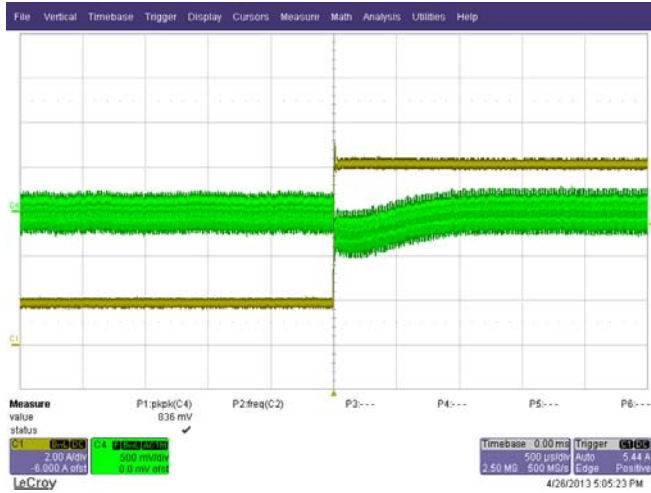


Figure 32. Output Voltage Transient, 500 μ s/div
 Yellow Trace: Load Current, 2 A/div
 Green Trace: Output Voltage (AC-Coupled), 500 mV/div

Load Step of 50% to 100%

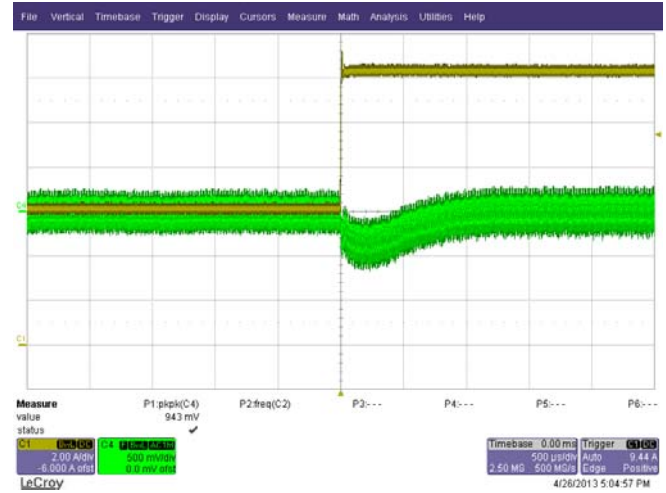


Figure 34. Output Voltage Transient, 500 μ s/div
 Yellow Trace: Load Current, 2 A/div
 Green Trace: Output Voltage (AC-Coupled), 500 mV/div

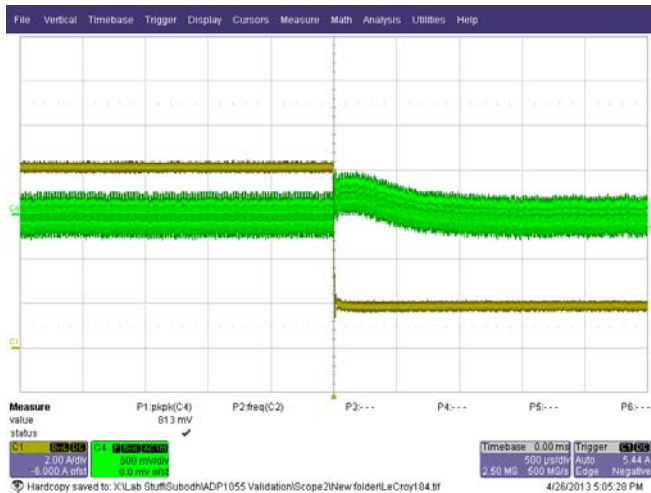


Figure 33. Output Voltage Transient, 500 μ s/div
 Yellow Trace: Load Current, 2 A/div
 Green Trace: Output Voltage (AC-Coupled), 500 mV/div

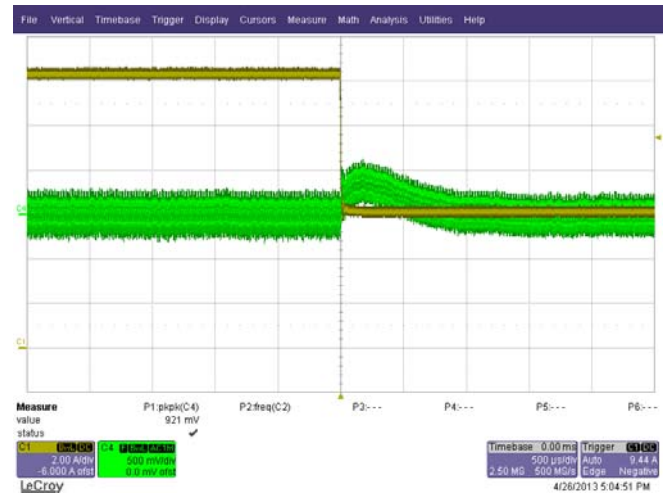


Figure 35. Output Voltage Transient, 500 μ s/div
 Yellow Trace: Load Current, 2 A/div
 Green Trace: Output Voltage (AC-Coupled), 500 mV/div

Load Step of 0% to 50%

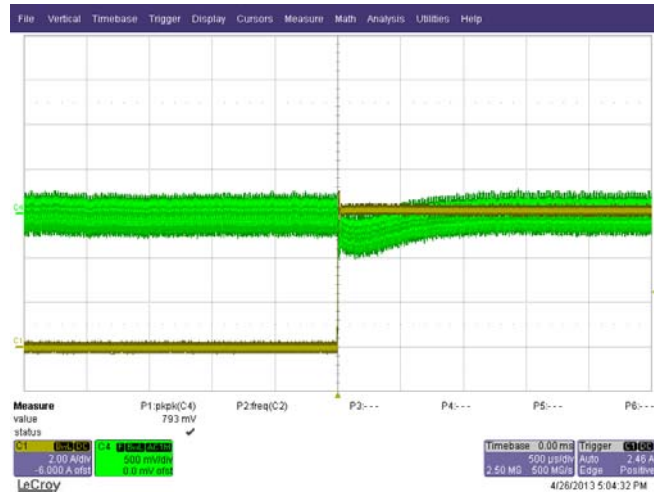


Figure 36. Output Voltage Transient, 500 μ s/div
 Yellow Trace: Load Current, 2 A/div
 Green Trace: Output Voltage (AC-Coupled), 500 mV/div

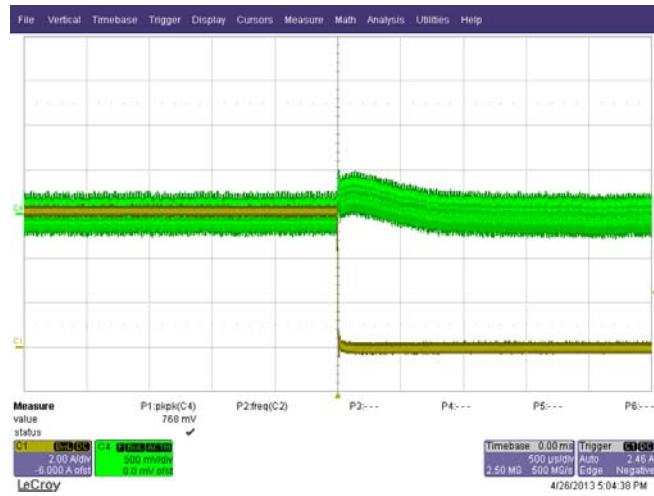


Figure 37. Output Voltage Transient, 500 μ s/div
 Yellow Trace: Load Current, 2 A/div
 Green Trace: Output Voltage (AC-Coupled), 500 mV/div

HOLD UP TIME AND VOLTAGE DROPOUT

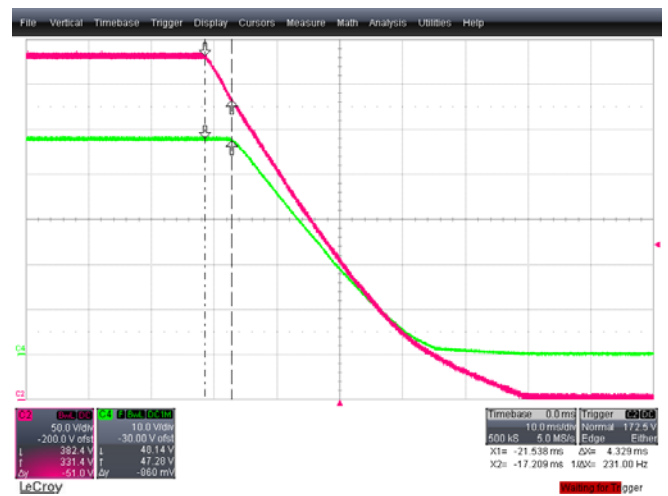


Figure 38. Minimum Input Voltage of ~330 V dc Before Output Regulation is Lost at 600 W, 10 ms/div
 Red Trace: Input Voltage Step, 50 V/div
 Green Trace: Output Voltage, 10 V/div

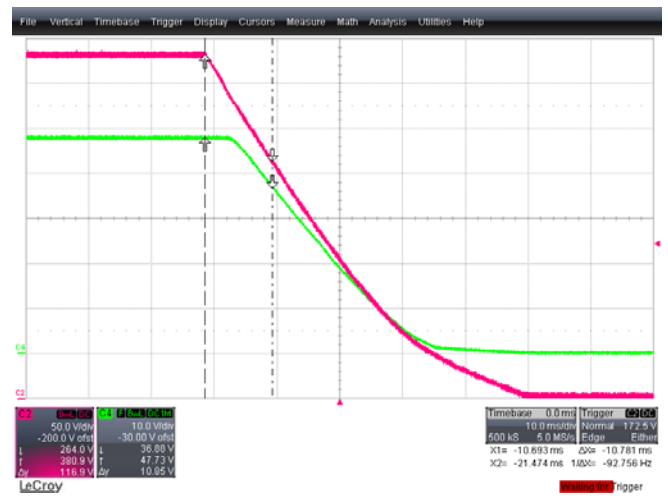


Figure 39. Hold Up Time of ~10.781 ms Before Output Voltage Reaches 36 V (Minimum Telecom Input) at 600 W, 100 μ F Input Capacitor, 10 ms/div
 Red Trace: Input Voltage Step, 50 V/div
 Green Trace: Output Voltage, 10 V/div

LINE VOLTAGE FEEDFORWARD

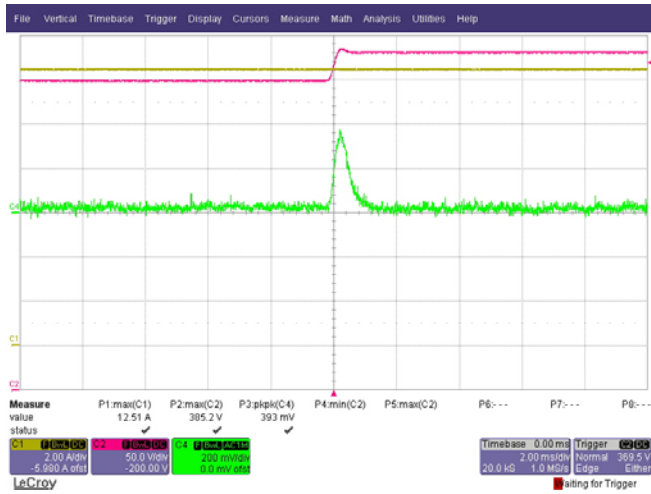


Figure 40. Line Voltage Feedforward Disabled, 600 W Load
 Red Trace: Input Voltage Step, 350 V dc to 385 V dc, 50 V/div
 Green Trace: Output Voltage (AC-Coupled), 200 mV/div



Figure 42. Line Voltage Feedforward Disabled, 600 W Load
 Red Trace: Input Voltage Step, 350 V dc to 385 V dc, 50 V/div
 Green Trace: Output Voltage (AC-Coupled), 200 mV/div

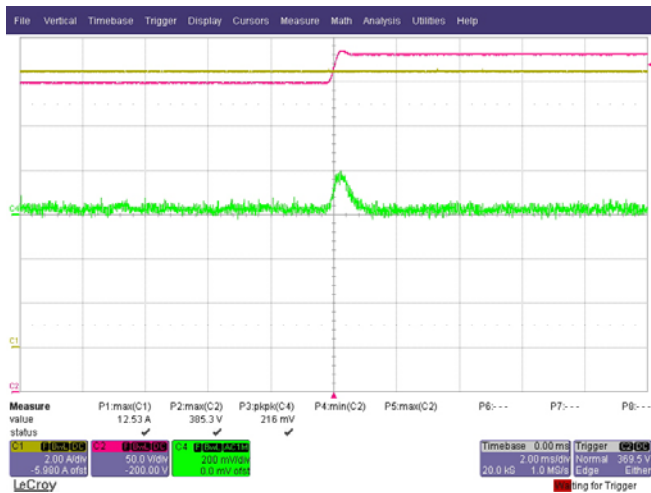


Figure 41. Line Voltage Feedforward Enabled, 600 W Load
 Red Trace: Input Voltage Step, 350 V dc to 385 V dc, 50 V/div
 Green Trace: Output Voltage (AC-Coupled), 200 mV/div



Figure 43. Line Voltage Feedforward Enabled, 600 W Load
 Red Trace: Input Voltage Step, 350 V dc to 385 V dc, 50 V/div
 Green Trace: Output Voltage (AC-Coupled), 200 mV/div

ZVS WAVEFORMS FOR QA (PASSIVE TO ACTIVE TRANSITION)

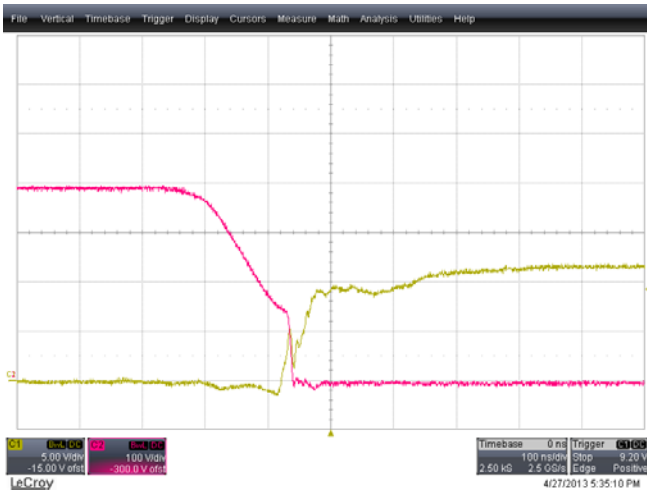


Figure 44. Resonant Transition at No Load, 100 ns/div
 Red Trace: VDS of QA, 100 V/div
 Yellow Trace: VGS of QA, 5 V/div

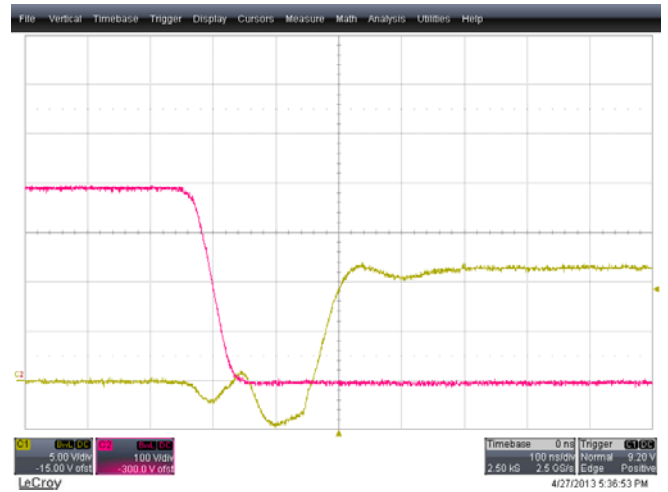


Figure 46. Resonant Transition at 300 W Load, 100 ns/div
 Red Trace: VDS of QA, 100 V/div
 Yellow Trace: VGS of QA, 5 V/div

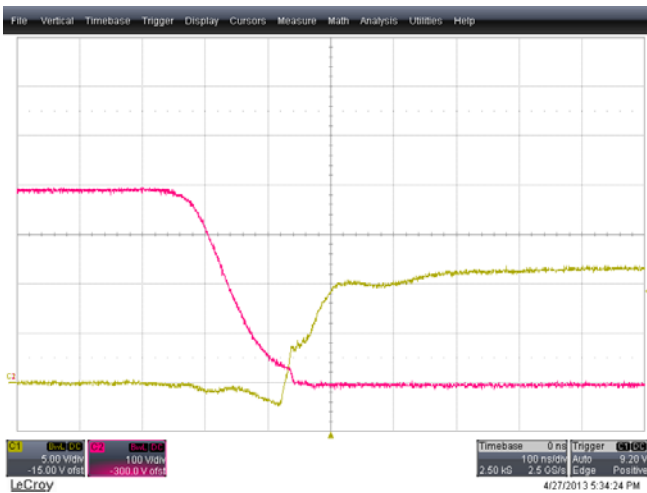


Figure 45. Resonant Transition at 48 W Load, 100 ns/div
 Red Trace: VDS of QA, 100 V/div
 Yellow Trace: VGS of QA, 5 V/div

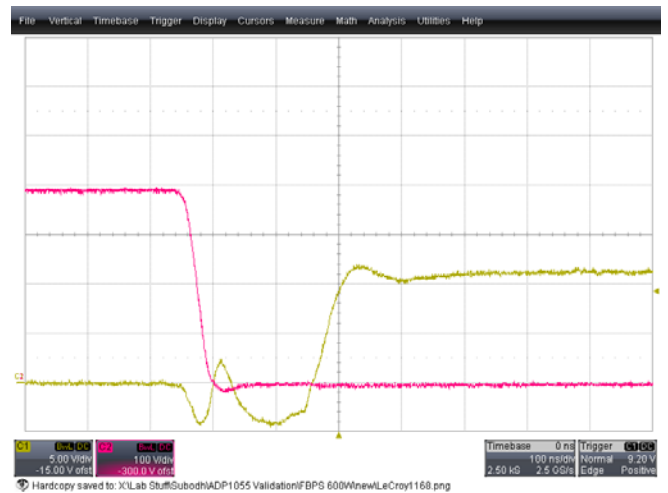


Figure 47. Resonant Transition at 600 W Load, 100 ns/div
 Red Trace: VDS of QA, 100 V/div
 Yellow Trace: VGS of QA, 5 V/div

ZVS WAVEFORMS FOR QB (PASSIVE TO ACTIVE TRANSITION)

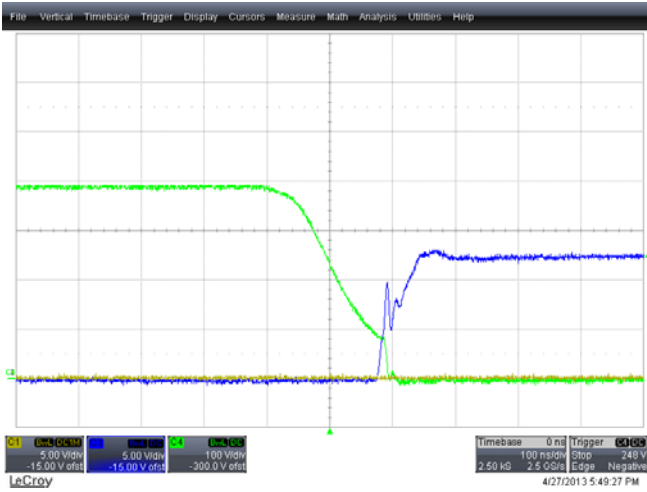


Figure 48. Resonant Transition at No Load, 100 μ s/div
 Red Trace: VDS of QB, 100 V/div
 Yellow Trace: VGS of QB, 5 V/div

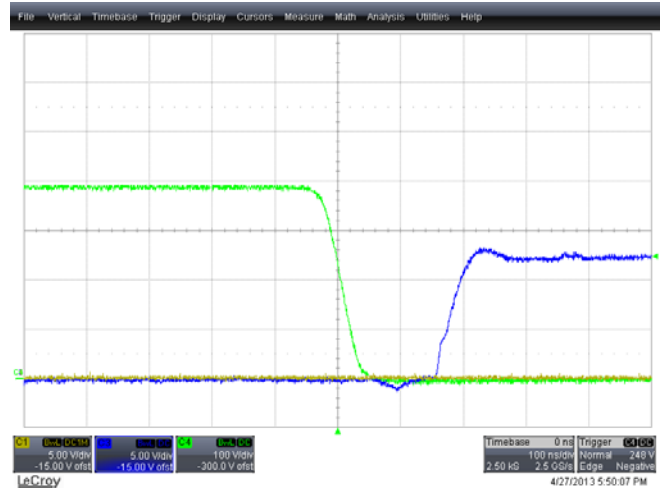


Figure 50. Resonant Transition at 300 W Load, 100 μ s/div
 Red Trace: VDS of QB, 100 V/div
 Yellow Trace: VGS of QB, 5 V/div

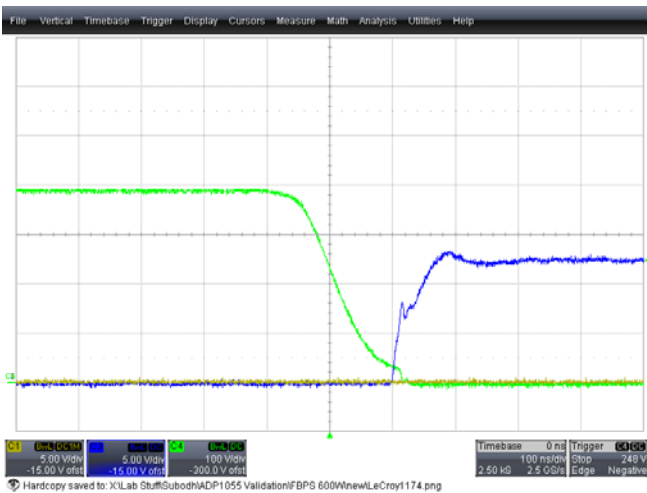


Figure 49. Resonant Transition at 48 W Load, 100 μ s/div
 Red Trace: VDS of QB, 100 V/div
 Yellow Trace: VGS of QB, 5 V/div

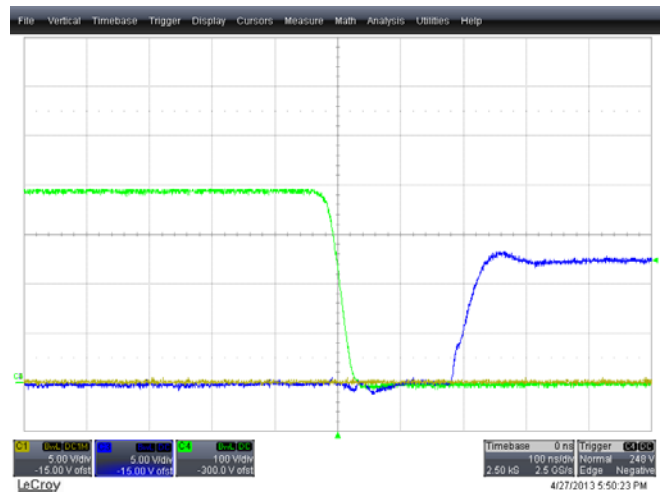


Figure 51. Resonant Transition at 600 W Load, 100 μ s/div
 Red Trace: VDS of QB, 100 V/div
 Yellow Trace: VGS of QB, 5 V/div

ZVS WAVEFORMS FOR QC (PASSIVE TO ACTIVE TRANSITION)

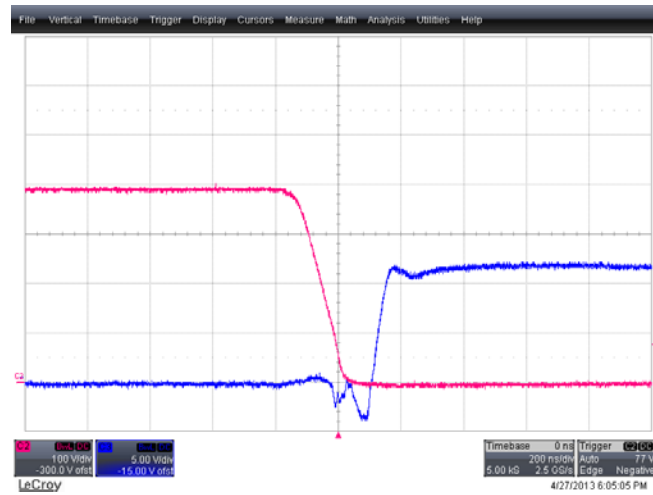


Figure 52. Resonant Transition at 300 W Load, 200 μ s/div
 Red Trace: VDS of QC, 100 V/div
 Yellow Trace: VGS of QC, 5 V/div

ZVS WAVEFORMS FOR QD (PASSIVE TO ACTIVE TRANSITION)

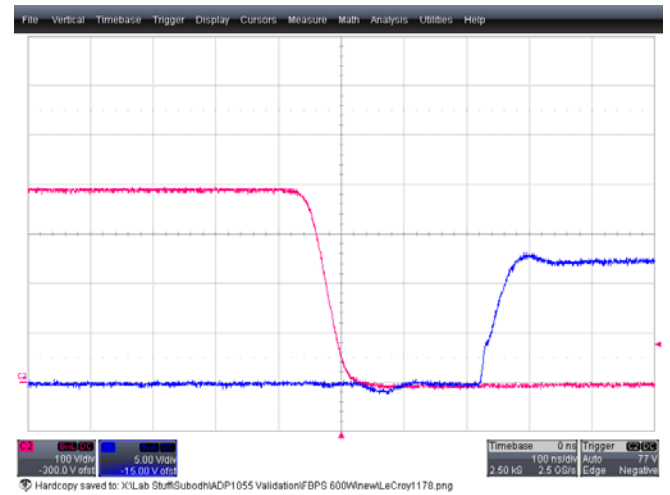


Figure 54. Resonant Transition at 0 A Load, 100 μ s/div
 Red Trace: VDS of QD, 100 V/div
 Yellow Trace: VGS of QD, 5 V/div

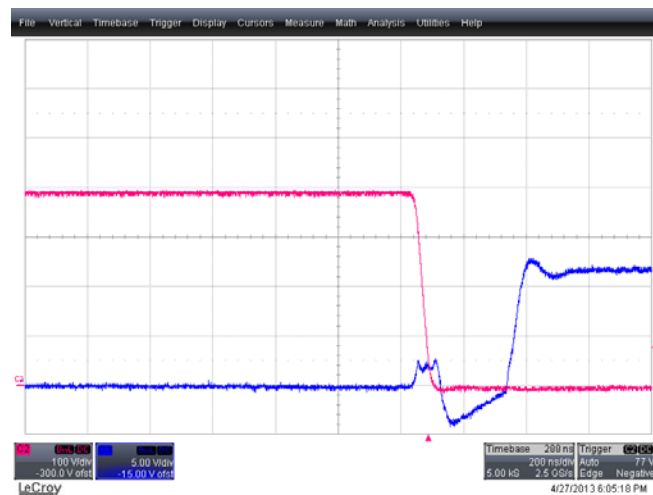


Figure 53. Resonant Transition at 600 W Load, 200 μ s/div
 Red Trace: VDS of QC, 100 V/div
 Yellow Trace: VGS of QC, 5 V/div

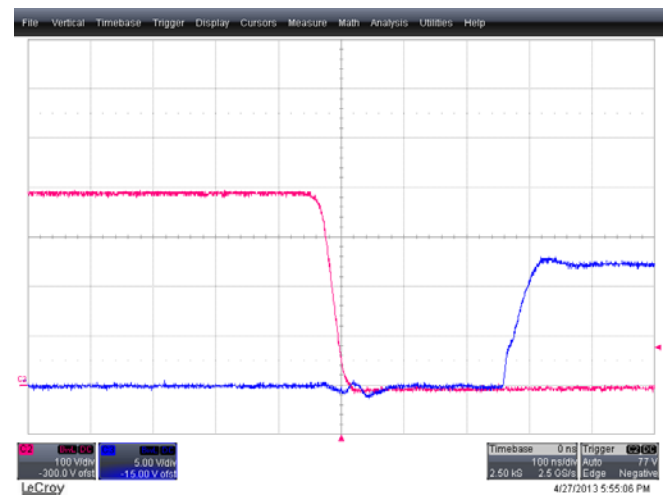


Figure 55. Resonant Transition at 300 W Load, 100 μ s/div
 Red Trace: VDS of QD, 100 V/div
 Yellow Trace: VGS of QD, 5 V/div

CLOSED LOOP FREQUENCY RESPONSE

A network analyzer (AP200) was used to test the bode plots of the system. A continuous noise signal of 300 mV was injected across the entire frequency range across a 10 Ω resistor in series (R35)

with the output voltage divider using an isolation transformer. The operating condition was 385 V dc input and a load condition of 600 W with a soaking time of 45 minutes.

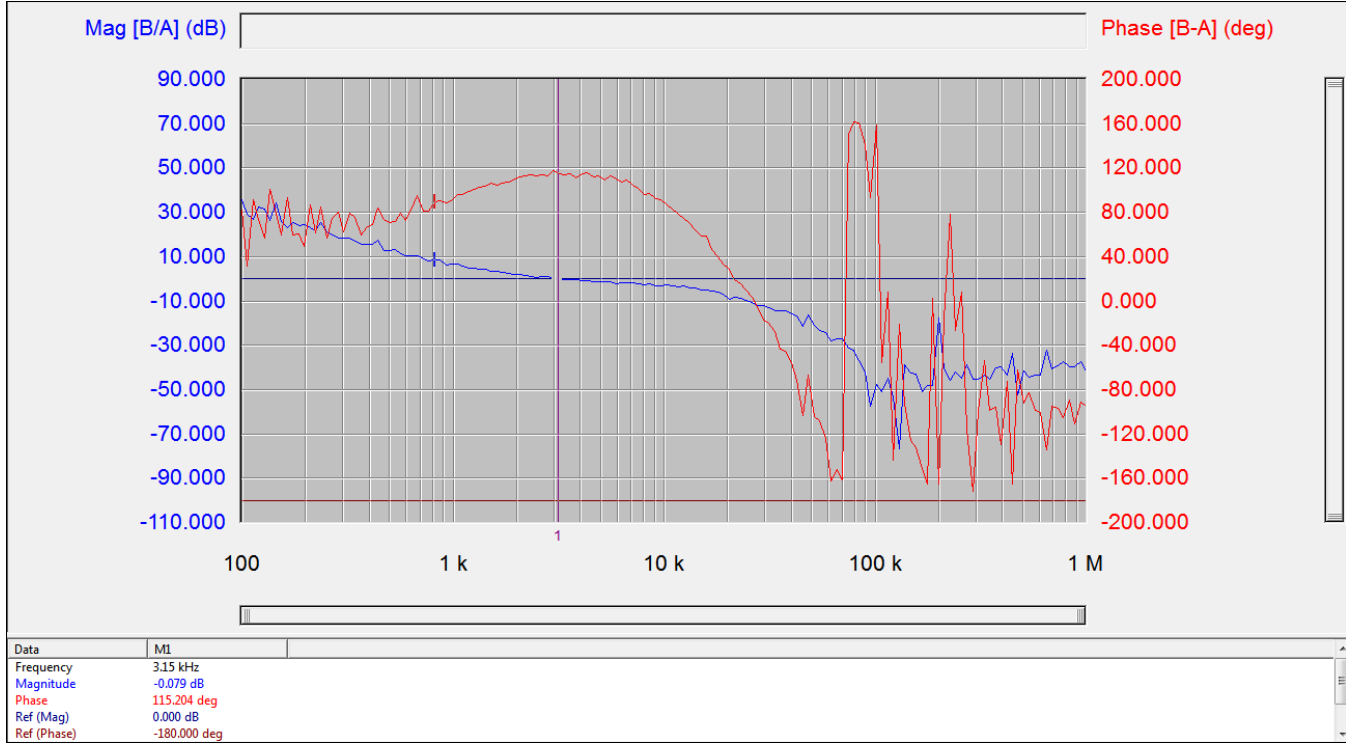


Figure 56. Bode Plots, 385 V dc Input, 12.5 A Load, Blue Trace: Gain in dB, Red Trace: Phase in Degrees, Crossover Frequency = 3.15 kHz, Phase Margin = 115.2°

EFFICIENCY

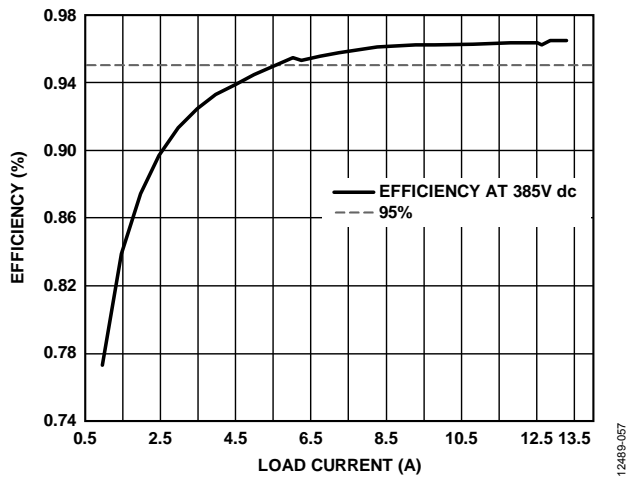


Figure 57. Efficiency vs. Load at 385 V dc, 45 Minute Soaking Time, with On-Board Airflow

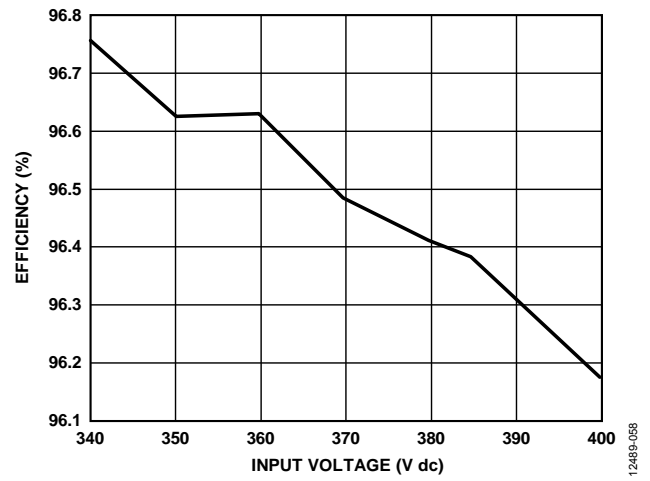


Figure 58. Efficiency vs. Line Voltage at 600 W Load

TRANSFORMER SPECIFICATIONS

Table 5. Transformer Specifications

Parameter	Min	Typ	Max	Unit	Notes
Core and Bobbin					PQ3535, Magnetics, Inc., material or equivalent
Primary Inductance		3.316		mH	Pin 1 to Pin 6
Leakage Inductance		4		μH	Pin 1 to Pin 6 with all other windings shorted
Resonant Frequency	850			kHz	Pin 1 to Pin 6 with all other windings open

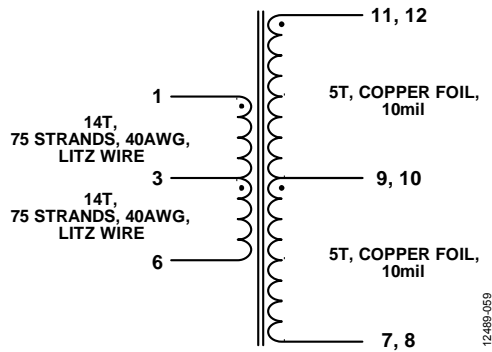


Figure 59. Transformer Electrical Diagram

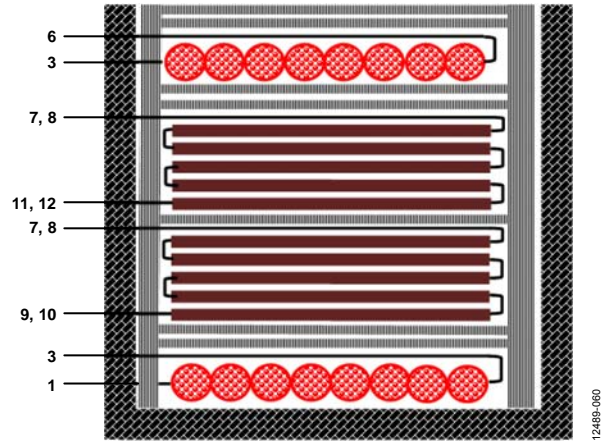


Figure 60. Transformer Construction Diagram

THERMAL TEST DATA

A thermal snapshot of the evaluation board was taken after running at 600 W with a 45 minute soaking time.

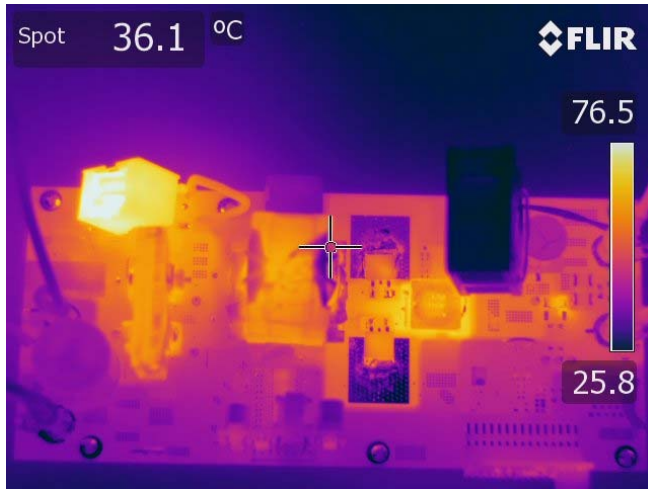


Figure 61. Thermals, Complete Board

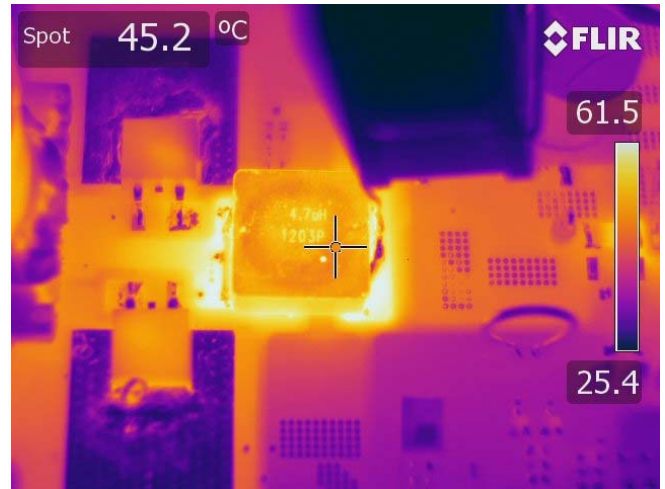


Figure 64. Thermals, Output Inductor

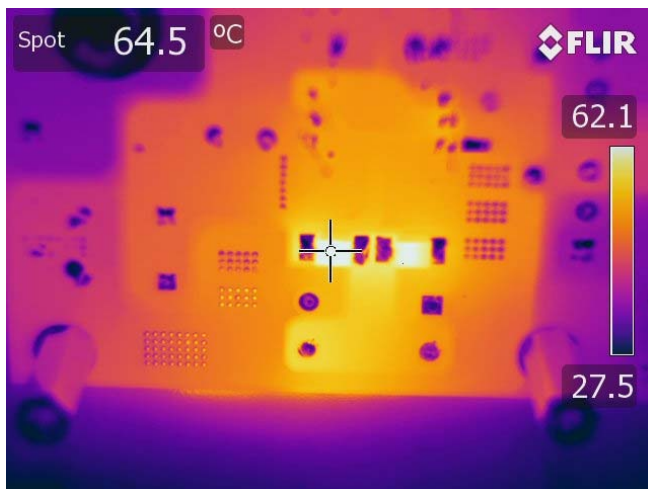


Figure 62. Thermals, Primary Clamp Diode

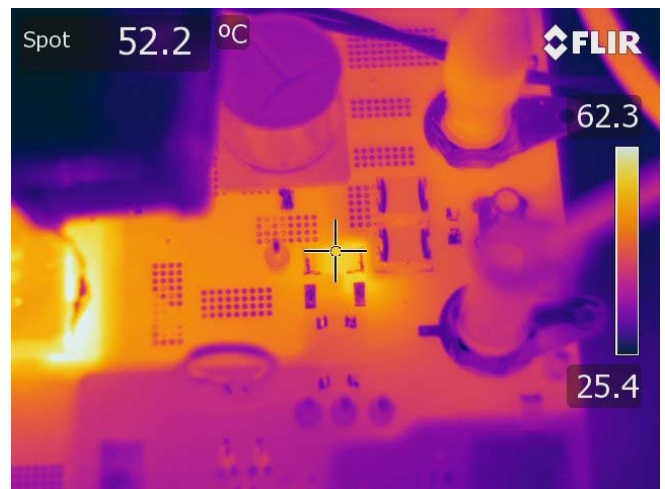


Figure 65. Thermals, Output Current Sense Resistor

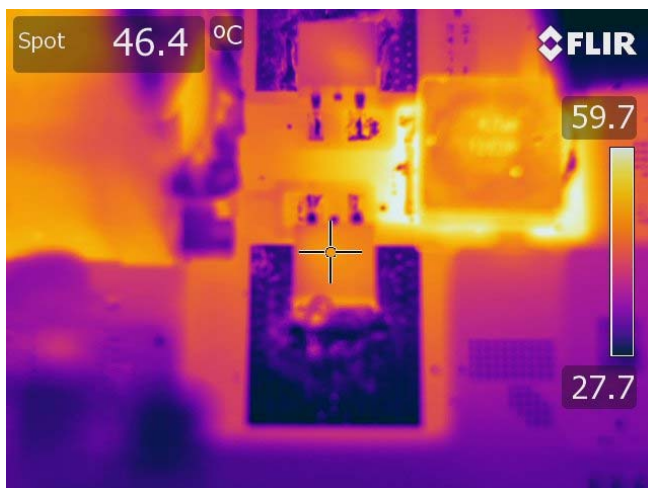


Figure 63. Thermals, Synchronous Rectifier



Figure 66. Thermals, Transformer



Figure 67. Thermals, Resonant Inductor

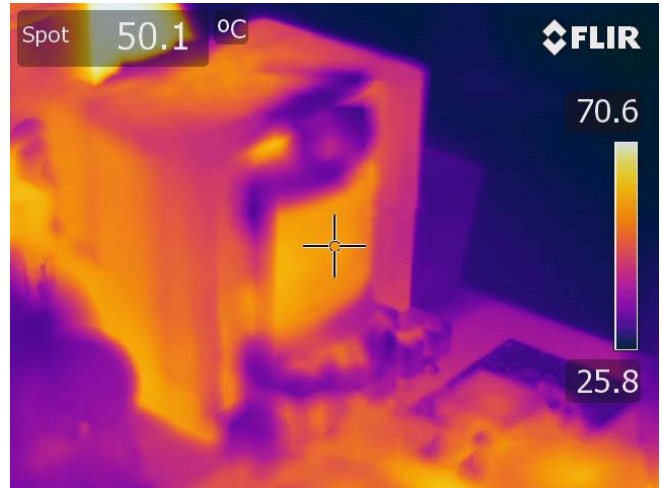


Figure 69. Thermals, Transformer



Figure 68. Thermals, Primary MOSFET

EVALUATION BOARD SCHEMATICS AND LAYOUT

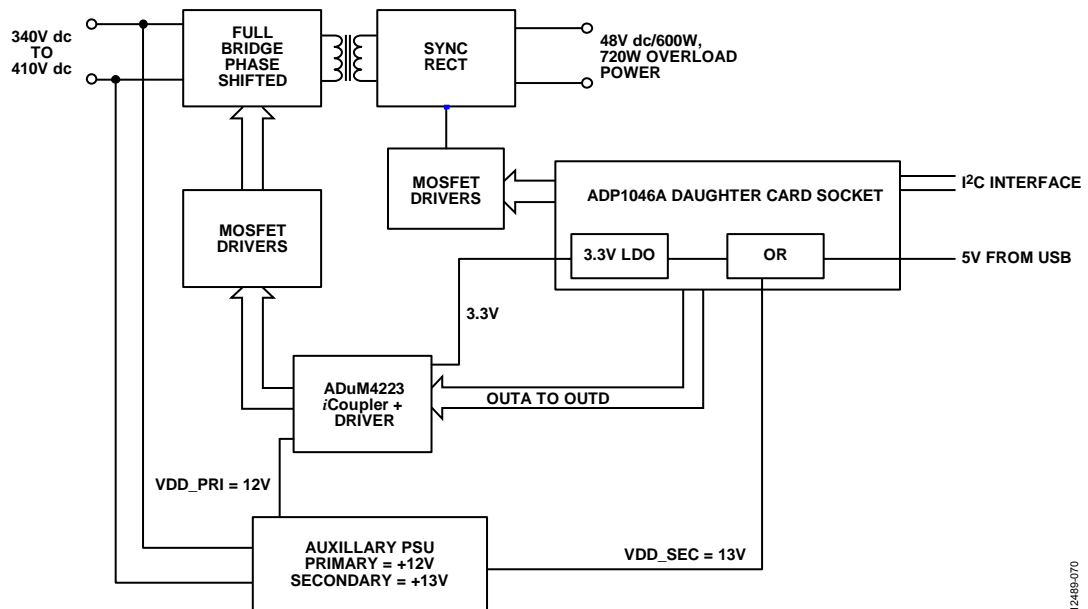


Figure 70. Schematic, Top Level

124489-070

12489-071

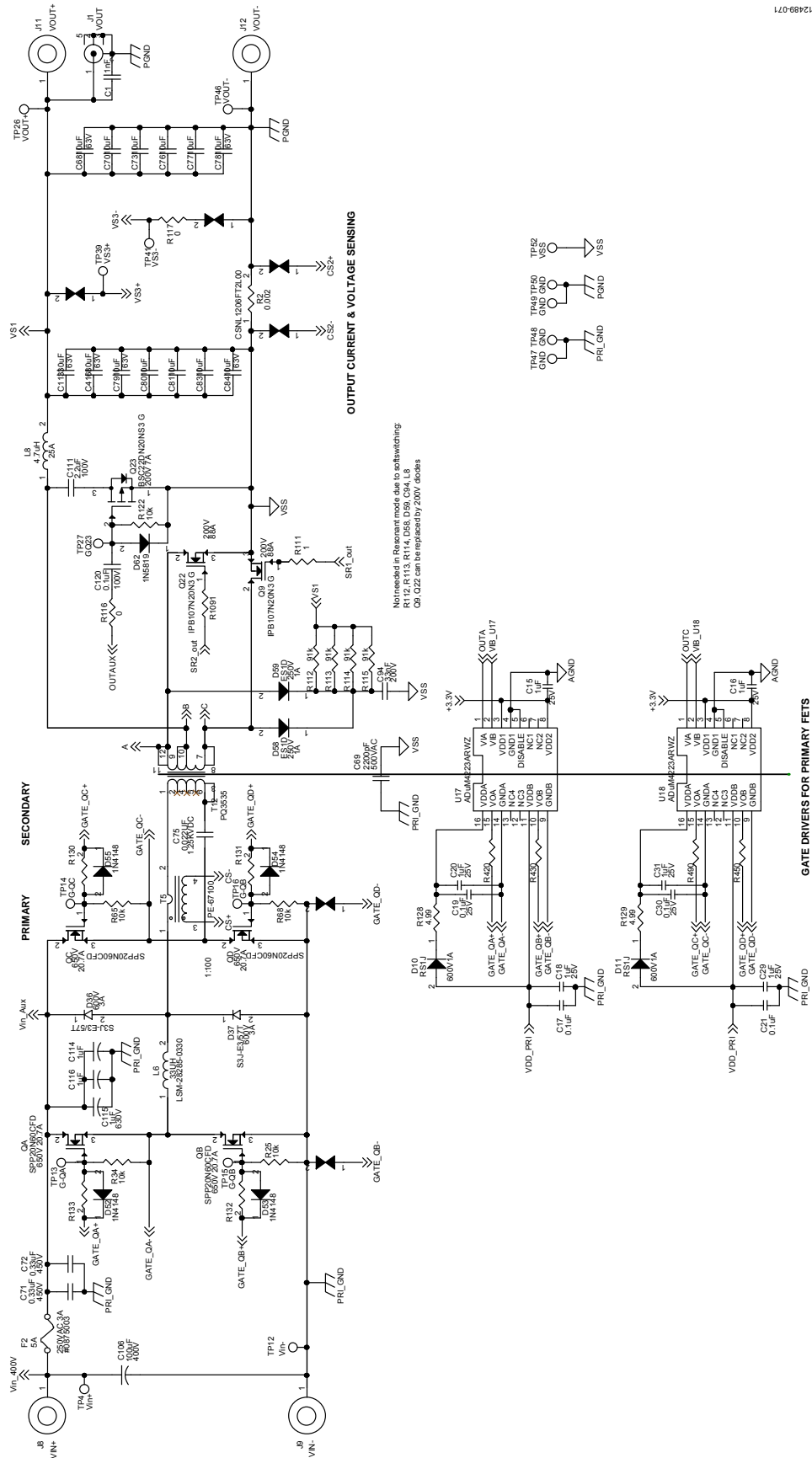


Figure 71. Schematic, Main Power Train

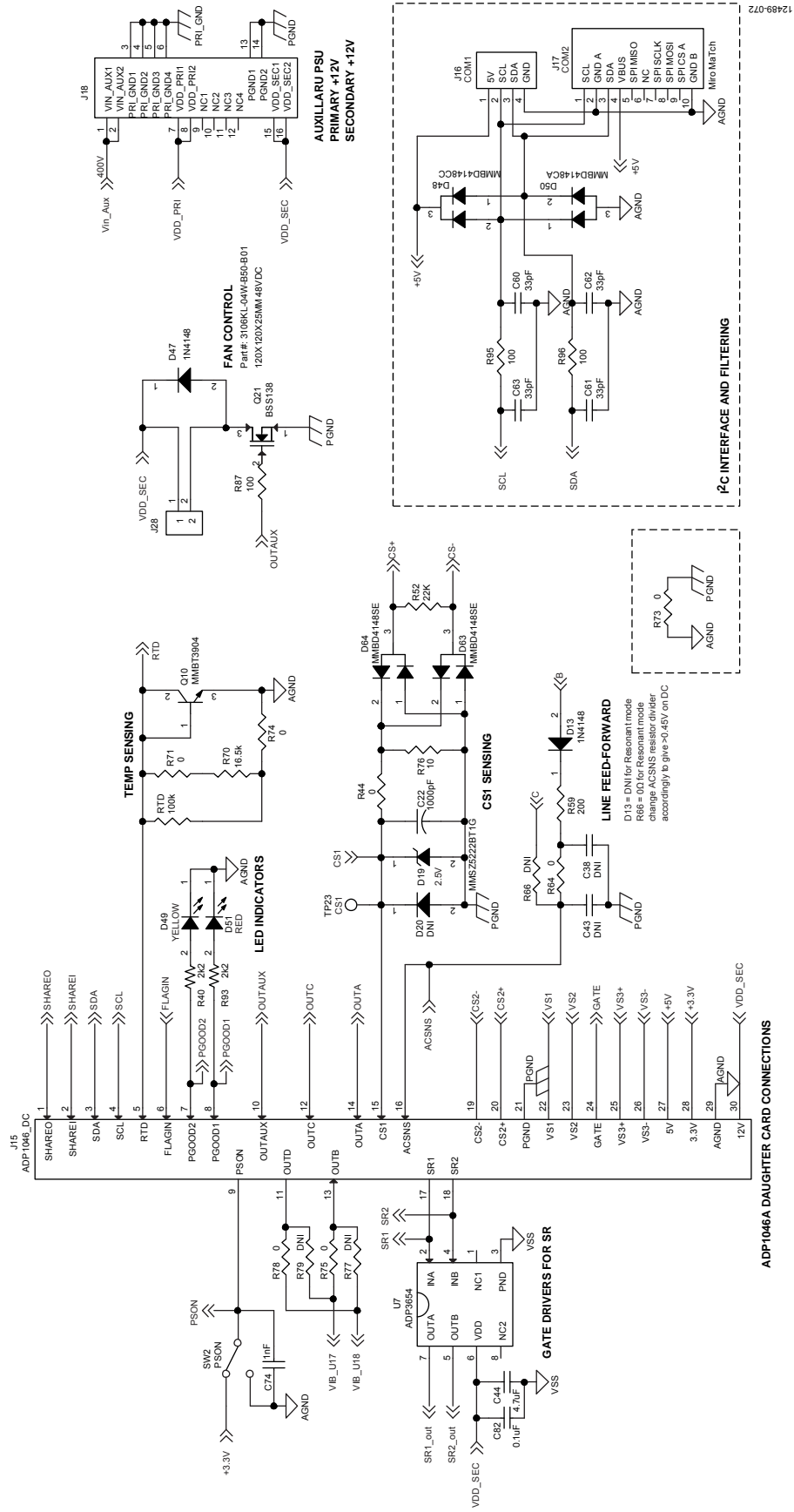


Figure 72. Schematic, Miscellaneous

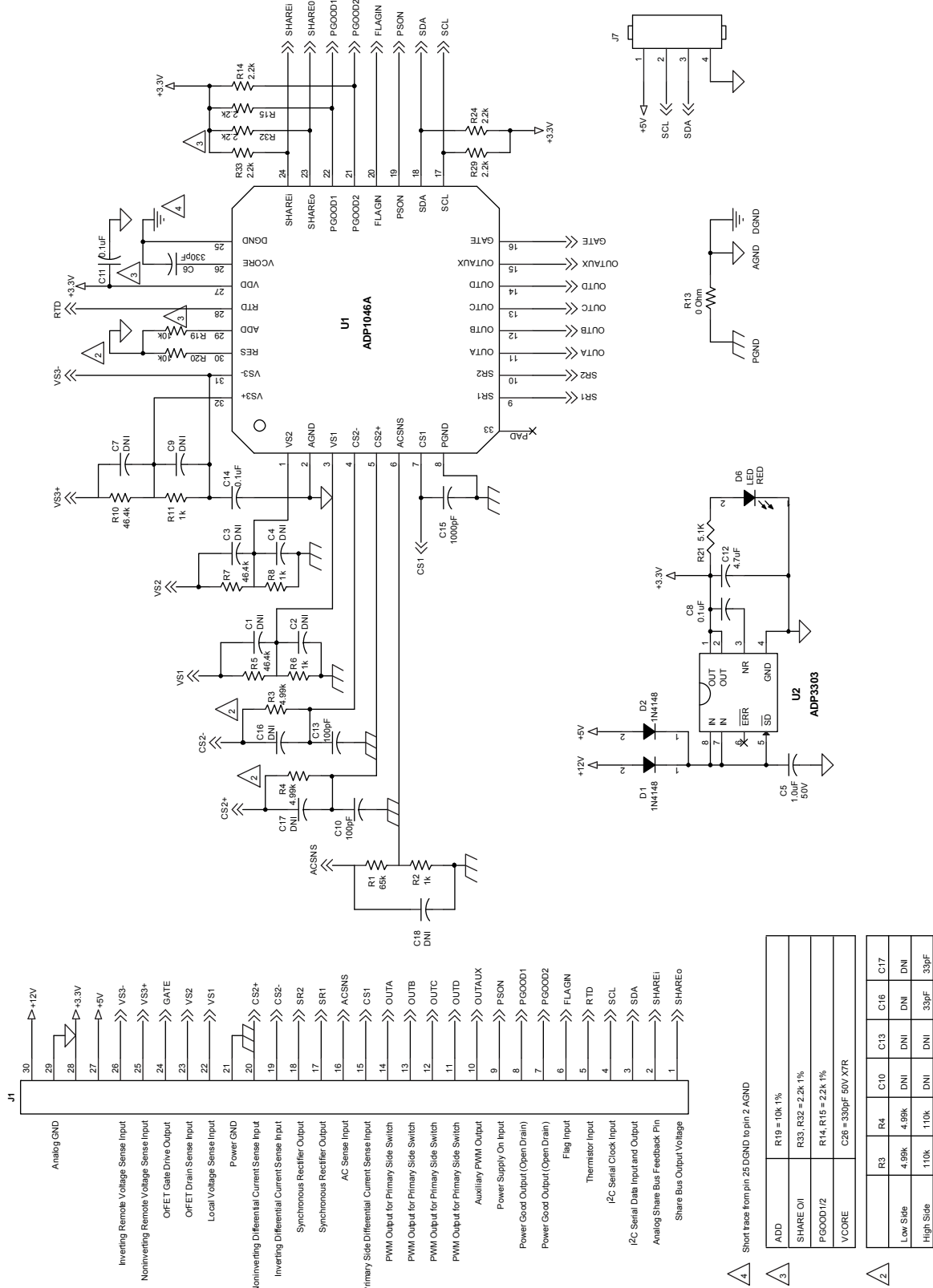


Figure 73. Schematic, ADP1046A Daughter Card

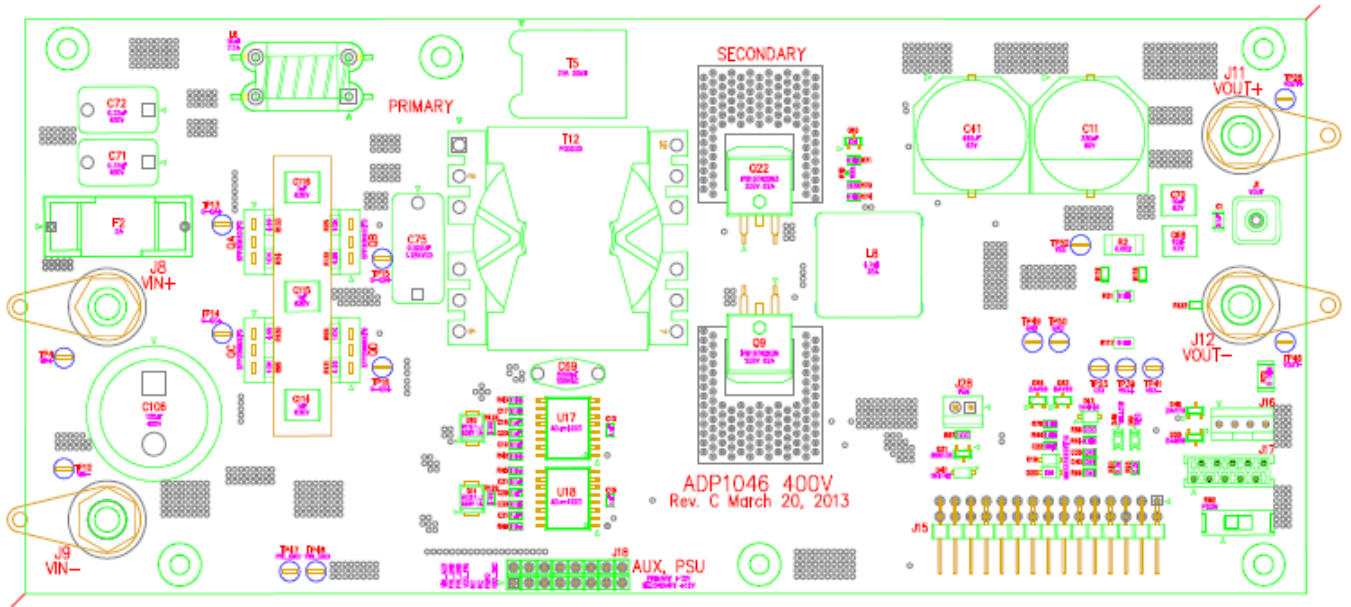


Figure 74. Top Side Placement of Components

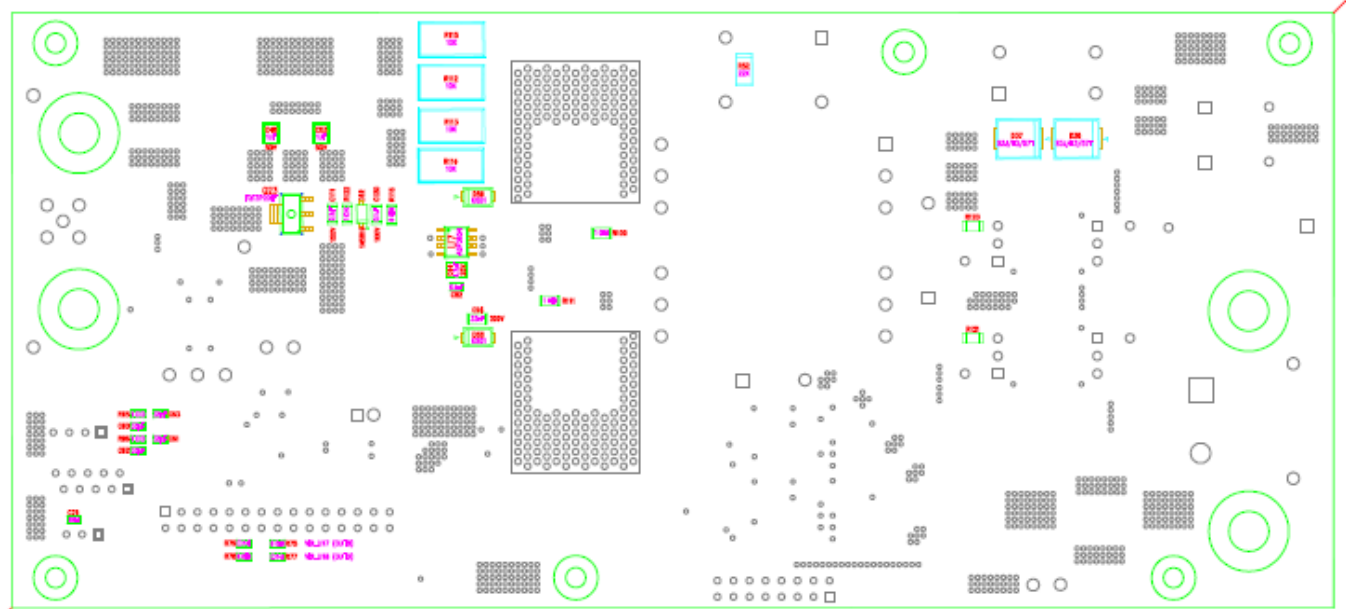


Figure 75. Bottom Side Placement of Components

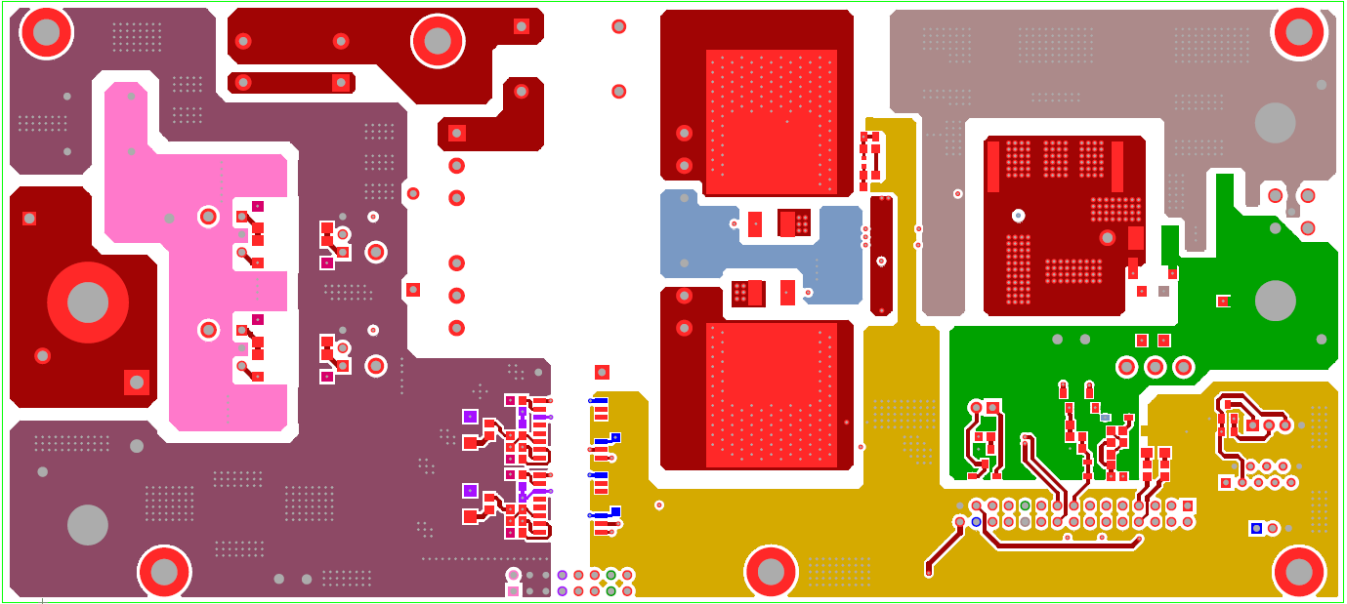


Figure 76. Layout Layer 1

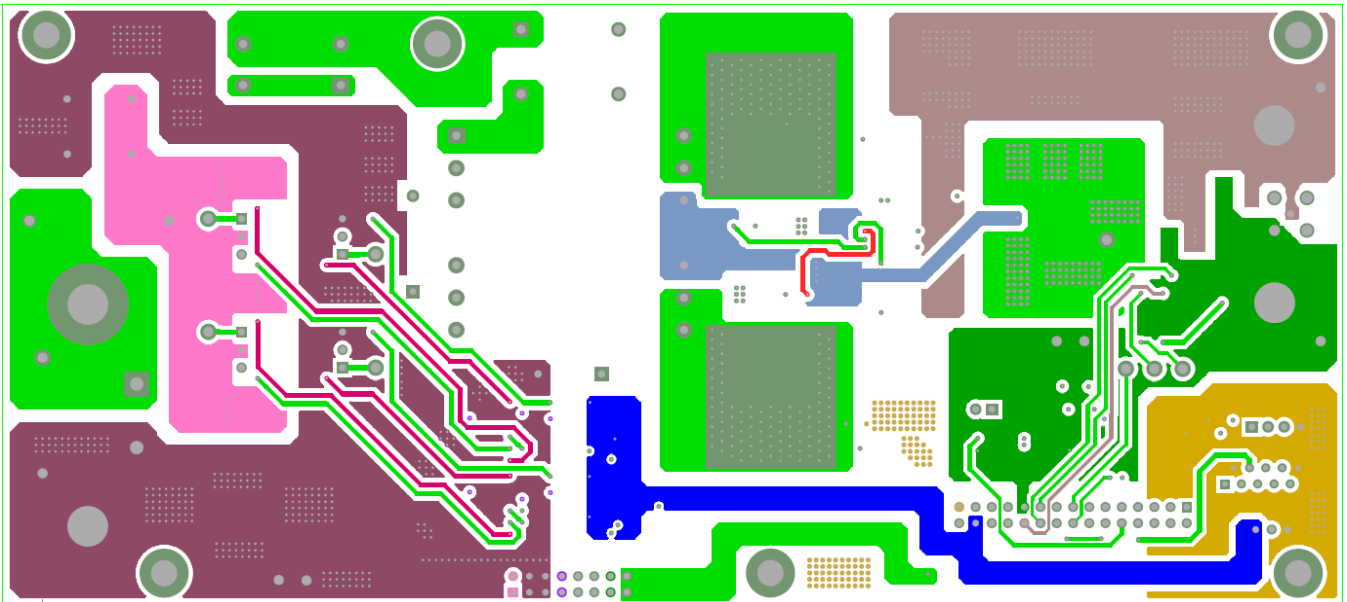


Figure 77. Layout Layer 2

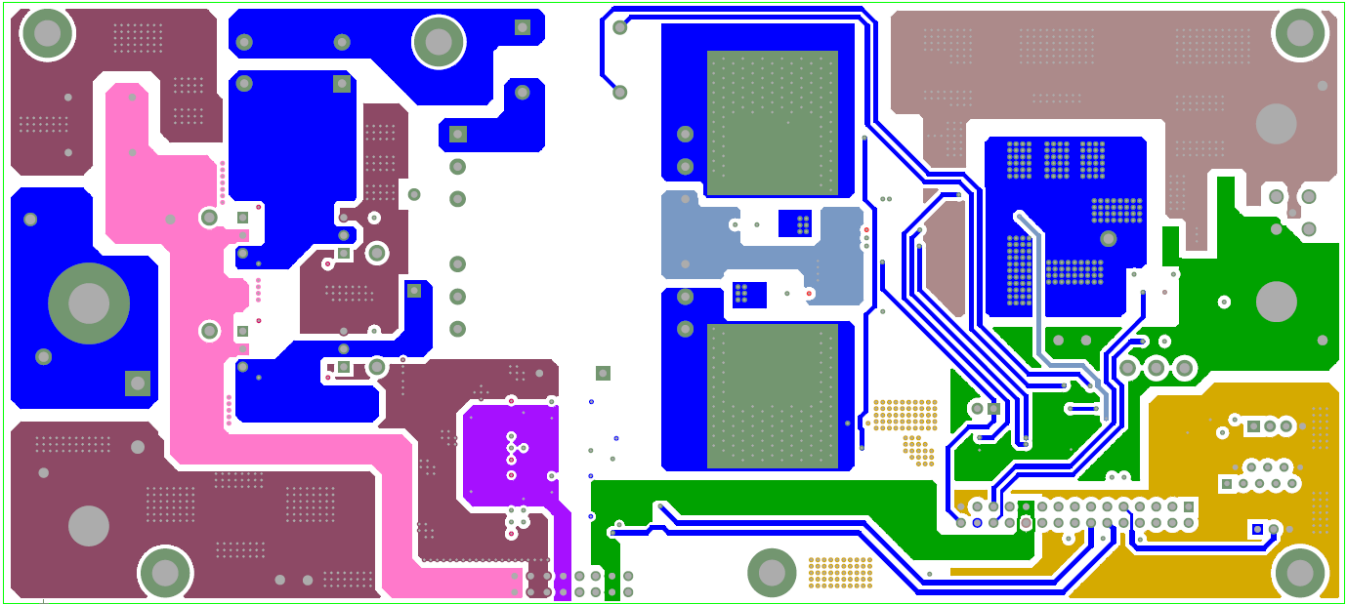


Figure 78. Layout Layer 3

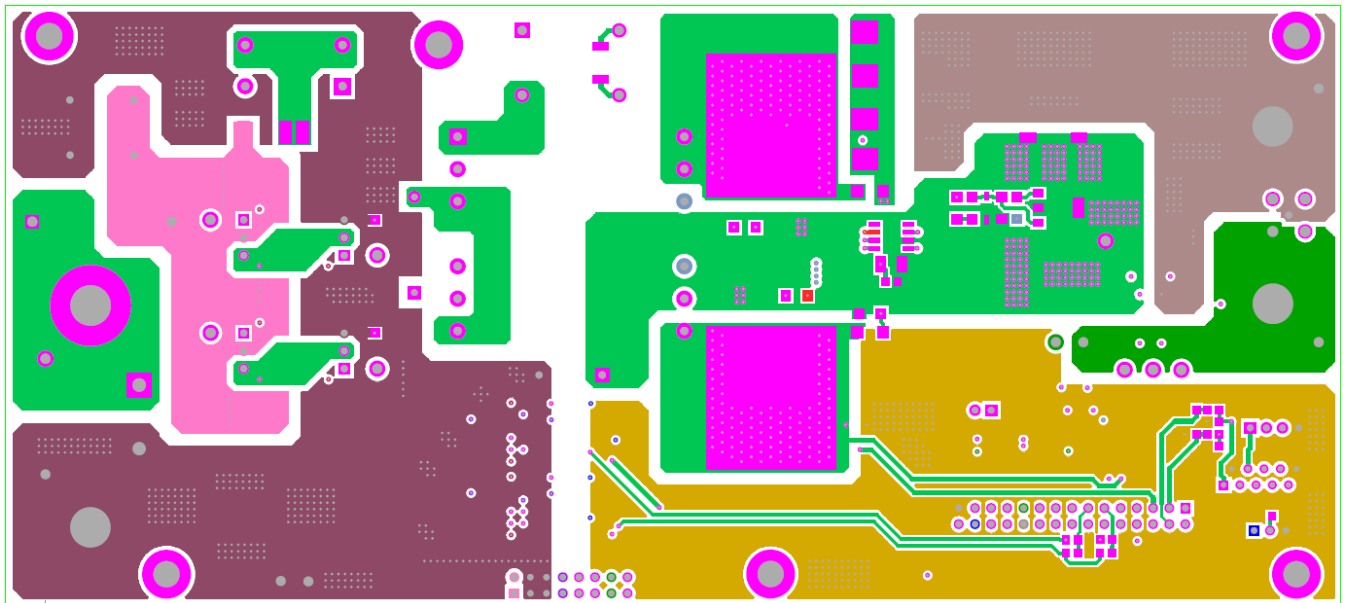


Figure 79. Layout Layer 4

DAUGHTER CARD PCB LAYOUT

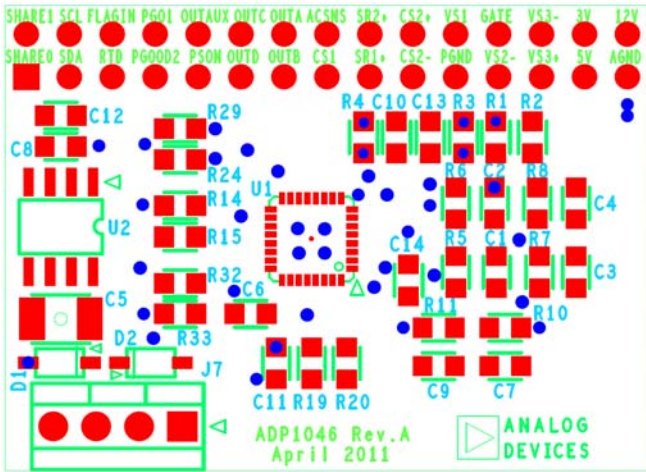


Figure 80. PCB Assembly, Top

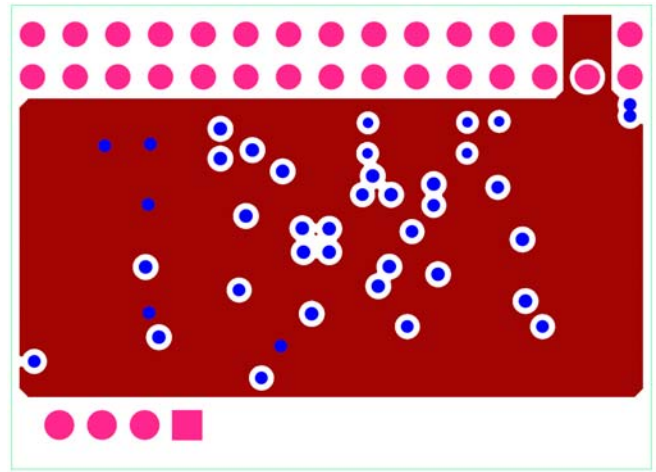


Figure 83. PCB Layout, Layer 3

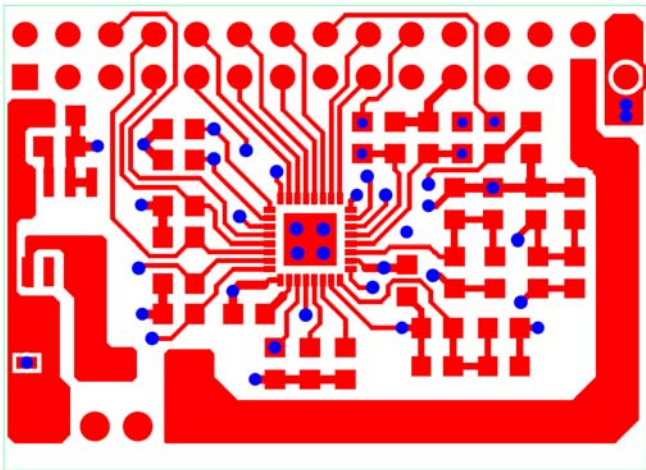


Figure 81. PCB Layout, Top Layer

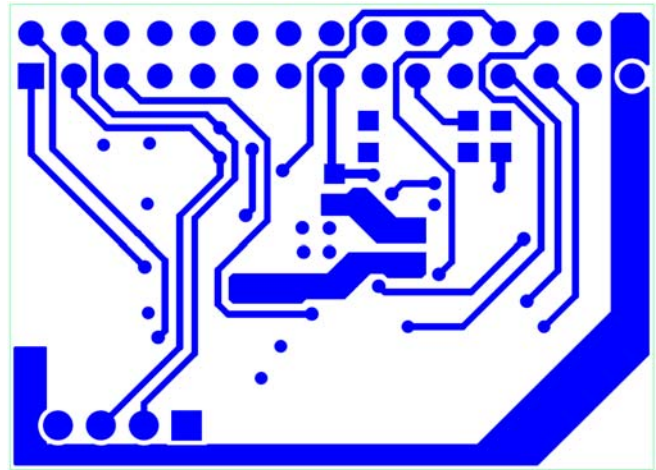


Figure 84. PCB Layout, Bottom Layer

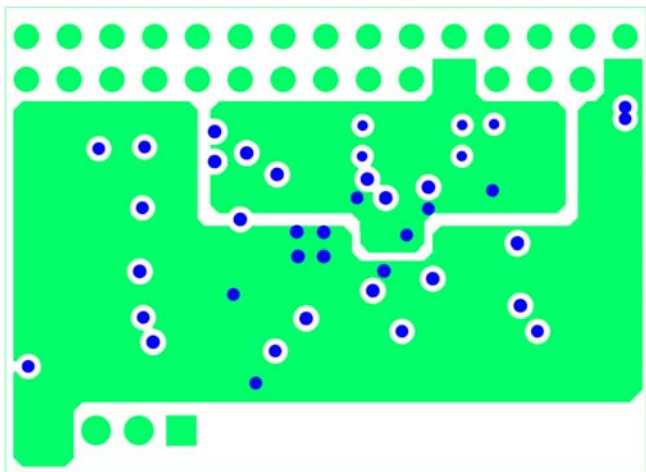


Figure 82. PCB Layout, Layer 2

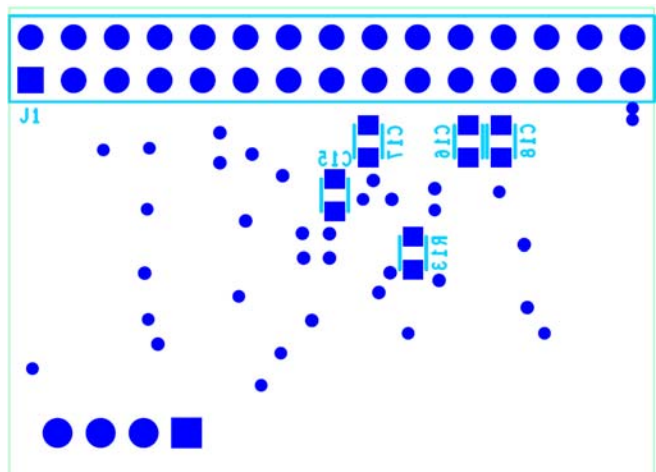


Figure 85. PCB Layout, Silkscreen Bottom

REGISTER SETTINGS FILE (.46r) FOR GUI

Copy the contents below into a text file and rename it using a **.46r** file extension. Load this file in the GUI using the **Load Register Settings** option. Ensure that the last line of the **.46r** file does not have a carriage return.

```

Reg(8h) = F3h - Fault Configuration Register 1
Reg(9h) = 7Dh - Fault Configuration Register 2
Reg(Ah) = 58h - Fault Configuration Register 3
Reg(Bh) = 0h - Fault Configuration Register 4
Reg(Ch) = 88h - Fault Configuration Register 5
Reg(Dh) = 88h - Fault Configuration Register 6
Reg(Eh) = C5h - Flag Configuration
Reg(Fh) = 22h - Soft-Start Blank Fault Flags
Reg(11h) = C0h - RTD Current Settings
Reg(22h) = 5Bh - CS1 Accurate OCP Limit
Reg(26h) = 4Fh - CS2 Accurate OCP Limit
Reg(27h) = 21h - CS1 / CS2 Settings
Reg(28h) = 23h - VS Balance Settings
Reg(29h) = 0h - Share Bus Bandwidth
Reg(2Ah) = 13h - Share Bus Setting
Reg(2Ch) = E4h - PSON/Soft Stop Settings
Reg(2Dh) = 7Eh - PGOOD Debounce and Pin Polarity Setting
Reg(2Eh) = E5h - Modulation Limit
Reg(2Fh) = 4h - OTP Threshold
Reg(30h) = 53h - OrFET
Reg(31h) = A2h - VS3 Voltage Setting
Reg(32h) = 23h - VS1 Overvoltage Limit
Reg(33h) = 27h - VS2 / VS3 Overvoltage Limit
Reg(34h) = 46h - VS1 Undervoltage Limit
Reg(35h) = FFh - Line Impedance Limit
Reg(36h) = 10h - Load Line Impedance
Reg(37h) = 5Dh - Fast OVP Comparator Settings
Reg(3Bh) = 0h - Light Load Disable Setting
Reg(3Fh) = 94h - OUTAUX Switching Frequency Setting
Reg(40h) = 14h - PWM Switching Frequency Setting
Reg(41h) = 38h - PWM 1 Positive Edge Timing
Reg(42h) = A1h - PWM 1 Positive Edge Setting
Reg(43h) = 6Dh - PWM 1 Negative Edge Timing
Reg(44h) = 60h - PWM 1 Negative Edge Setting
Reg(45h) = 0h - PWM 2 Positive Edge Timing
Reg(46h) = A1h - PWM 2 Positive Edge Setting
Reg(47h) = 35h - PWM 2 Negative Edge Timing
Reg(48h) = 80h - PWM 2 Negative Edge Setting
Reg(49h) = 3Dh - PWM 3 Positive Edge Timing
Reg(4Ah) = 8h - PWM 3 Positive Edge Setting
Reg(4Bh) = 0h - PWM 3 Negative Edge Timing
Reg(4Ch) = A8h - PWM 3 Negative Edge Setting
Reg(4Dh) = 5h - PWM 4 Positive Edge Timing
Reg(4Eh) = 8h - PWM 4 Positive Edge Setting
Reg(4Fh) = 38h - PWM 4 Negative Edge Timing
Reg(50h) = A8h - PWM 4 Negative Edge Setting
Reg(51h) = 3Dh - SR 1 Positive Edge Timing
Reg(52h) = A9h - SR 1 Positive Edge Setting
Reg(53h) = 38h - SR 1 Negative Edge Timing
Reg(54h) = 3h - SR 1 Negative Edge Setting
Reg(55h) = 5h - SR 2 Positive Edge Timing
Reg(56h) = A8h - SR 2 Positive Edge Setting
Reg(57h) = 0h - SR 2 Negative Edge Timing
Reg(58h) = 0h - SR 2 Negative Edge Setting
Reg(59h) = 0h - PWM AUX Positive Edge Timing
Reg(5Ah) = 0h - PWM AUX Positive Edge Setting
Reg(5Bh) = 3Fh - PWM AUX Negative Edge Timing
Reg(5Ch) = 50h - PWM AUX Negative Edge Setting
Reg(5Dh) = 80h - PWM and SR Pin Disable Setting
Reg(5Fh) = B7h - Soft Start and Slew Rate Setting
Reg(60h) = 10h - Normal Mode Digital Filter LF Gain Setting
Reg(61h) = D8h - Normal Mode Digital Filter Zero Setting
Reg(62h) = C3h - Normal Mode Digital Filter Pole Setting
Reg(63h) = Ah - Normal Mode Digital Filter HF Gain Setting
Reg(64h) = 4Eh - Light Load Digital Filter LF Gain Setting
Reg(65h) = AAh - Light Load Digital Filter Zero Setting
Reg(66h) = 64h - Light Load Digital Filter Pole Setting
Reg(67h) = 15h - Light Load Digital Filter HF Gain Setting
Reg(68h) = 0h - Reserved
Reg(69h) = 0h - Reserved
Reg(6Ah) = 0h - Reserved
Reg(6Bh) = 0h - Reserved
Reg(6Ch) = 0h - Reserved
Reg(6Dh) = 0h - Reserved
Reg(6Eh) = 0h - Reserved
Reg(6Fh) = 0h - Reserved
Reg(70h) = 0h - Reserved

```

Reg(71h) = 4Eh - Soft Start Digital Filter LF Gain Setting

Reg(72h) = AAh - Soft Start Digital Filter Zero Setting

Reg(73h) = 64h - Soft Start Digital Filter Pole Setting

Reg(74h) = 15h - Soft Start Digital Filter HF Gain Setting

Reg(75h) = 4h - Voltage Feed Forward Settings

Reg(76h) = 0h - Volt Second Balance OUTA/OUTB Settings

Reg(77h) = 0h - Volt Second Balance OUTC/OUTD Settings

Reg(78h) = 0h - Volt Second Balance SR1/SR2 Settings

Reg(79h) = 0h - SR Delay Offset

Reg(7Ah) = Fh - Filter Transitions

Reg(7Bh) = 40h - PGOOD1 Masking

Reg(7Ch) = FFh - PGOOD2 Masking

Reg(7Dh) = Ch - Light Load Mode Threshold Settings

BOARD SETTINGS FILE (.46b) FOR GUI

Copy the contents below into a text file and rename it using a **.46b** file extension. Load this file in the GUI using the **Load Board Settings** option. Ensure that the last line of the **.46b** file does not have a carriage return.

```

Input Voltage = 385 V
N1 = 28
N2 = 5
R (CS2) = 2.5 mOhm
I (load) = 12.5 A
R1 = 46.4 KOhm
R2 = 1 KOhm
C3 = 1 uF
C4 = 1 uF
N1 (CS1) = 1
N2 (CS1) = 100
R (CS1) = 51 Ohm
ESR (L1) = 6 mOhm
L1 = 4.7 uH
C1 = 1000 uF
ESR (C1) = 35 mOhm
ESR (L2) = 0 mOhm
L2 = 0 uH
C2 = 0 uF
ESR (C2) = 0 mOhm
R (Normal-Mode) (Load) = 3.84 Ohm
R (Light-Load-Mode) (Load) = 24 Ohm
Cap Across R1 & R2 = 0 "(1 = Yes: 0 = No)"

Topology = 1 (0 = Full Bridge: 1 = Half
Bridge: 2 = Two Switch Forward: 3 =
Interleaved Two Switch Forward: 4 = Active
Clamp Forward: 5 = Resonant Mode: 6 =
Custom)
Switches / Diodes = 0 (0 = Switches: 1 =
Diodes)
High Side / Low Side Sense (CS2) = 0 (1 =
High-Side: 0 = Low-Side Sense)
Second LC Stage = 1 (1 = Yes: 0 = No)
CS1 Input Type = 0 (1 = AC: 0 = DC)
R3 = 0 KOhm
R4 = 0 KOhm
PWM Main = 0 (0 = OUTA: 1 = OUTB: 2 = OUTC:
3 = OUTD: 4 = SR1: 5 = SR2: 6 = OUTAUX)
C5 = 0 uF
C6 = 0 uF
R6 = 65 KOhm
R7 = 1 KOhm
C7 = 0 uF
L3 = 33 uH
Lm = 0 uH
ResF = 0 kHz
R8 = 0 mOhm
R9 = 0 mOhm

```

ORDERING INFORMATION

BILL OF MATERIALS

Table 6. ADP1046A Evaluation Board Bill of Materials

Qty	Reference	Value	Description	Manufacturer	Part Number
3	C1, C22, C74	1 nF	Cap, cer, 1000 pF, 50 V, 10%, X7R, SMD	AVX Corp	08055C102KAT2A
1	C11	330 μF	Cap, alum, 330 μF, 80 V, 20%, SMD	Panasonic	EEV-FK1K331M
6	C15, C16, C18, C20, C29, C31	1 μF	Cap, cer, 1.0 μF, 25 V, 10%, X7R, SMD	TDK Corp	C2012X7R1E105K085AB
4	C17, C19, C21, C30	0.1 μF	Cap, cer, 0.1 μF, 25 V, 10%, X7R, SMD	Vishay	VJ0805Y104KXXAC
1	C38	Do not insert			
1	C41	680 μF	Cap, alum, 680 μF, 63 V, 20%, SMD	Panasonic	EEV-FK1J681M
1	C43	Do not insert			
1	C44	4.7 μF	Cap, cer, 4.7 μF, 25 V, 10%, X7R, SMD	TDK Corp	C3225X7R1E475K
1	C47	1 μF	Cap, cer, 1 μF, 25 V, ±10%, X7R	Digi-Key	490-4785-1-ND
4	C60 to C63	33 pF	Cap, cer, 33 pF, 50 V, ±5%, NPO, SMD	AVX Corp	08055A330JAT2A
11	C68, C70, C73, C76 to C81, C83, C84	10 μF	Cap, ceramic, 10 μF, 63 V, ±10%, X7R, SMD	Murata	KCM55QR71J106KH01K
1	C69	2200 pF	Cap, cer, 2200 pF, 500 V ac, 20%, radial	Vishay/BC	VY1222M47Y5UQ63V0
2	C71, C72	0.33 μF	Cap, film, 0.33 μF, 450 V dc, radial	Panasonic-ECG	ECW-F2W334JQAQ
1	C75	0.022 μF	Cap, film, 0.022 μF, 1.25 kV dc, radial	EPCOS, Inc.	B32652A7223J
1	C82	0.1 μF	Cap, cer, 0.1 μF, 50 V, 10%, X7R, SMD	Murata	GRM21BR71H104KA01L
1	C94	33 nF	Cap, cer, 0.33 μF, 200 V, 10%, X7R, SMD	AVX Corp	12062C333KAT2A
1	C106	100 μF	Cap, alum, 100 μF, 400 V, 20%, snap	Panasonic-ECG	EET-HC2G101HA
1	C111	2.2 μF	Cap, ceramic, 0.033 μF, 100 V, 5%, NPO, SMD	Kemet	C1812C333J1GACTU
3	C114 to C116	1 μF	Cap, 0.33 μF, 630 V dc, metal poly	TDK Corp	CKG57NX7T2J105M
1	C120	0.1 μF	Cap, ceramic, 0.1 μF, 100 V, 10%, X7R SMD	AVX Corp	12061C104KAT2A
2	D10, D11	RS1J	SMD diode, super fast, 200 V, 1 A	Vishay	RS1J-E3/61T
2	D13, D47	1N4148	Diode, SML, sig, 100 V, 0.15 A, SMD	Diodes, Inc.	1N4148W-13-F
1	D19	MMSZ5222BT1G	SMD diode Zener, 2.5 V, 500 mW	ON Semiconductor	SMAZ16-FDICT-ND
1	D20	Do not insert			
2	D36, D37	S3J-E3/57T	Diode glass, passivated, 3 A, 600 V, SMB	Vishay	S3J-E3/57T
1	D48	MMBD4148CC	Diode array, 100 V, 200 mA	Fairchild	MMBD4148CC
1	D49	Yellow	LED, yellow, clear, SMD	Visual	CMD15-21VYC/TR8
1	D50	MMBD4148CA	Diode array, 100 V, 200 mA	Fairchild	MMBD4148CA
1	D51	Red	LED, high efficiency, red, clear, SMD	Visual	CMD15-21VRC/TR8
4	D52 to D55	1N4148	Diode switch, 100 V, 400 mW, SMD	Diodes, Inc.	1N4148W-7-F
2	D58, D59	ES1D	Diode fast SW, 300 V, 1 A, SMA	Fairchild	ES1F
1	D62	1N5819	Diode Schottky, 40 V, 1 A, SMD	Diodes, Inc.	1N5819HW-7-F
2	D63, D64	MMBD4148SE	Diode array, 100 V, 200 mA	Fairchild	MMBD4148SE
1	F2	5A	Holder, PC fuse, 5 mm, low profile	Keystone	4527
1	J1	BNC/R	Conn jack, vertical, PCMNT, gold	Emerson	131-3701-261
1	J8	VIN+	Conn jack banana, uninsulated, panel mount	Emerson	108-0740-001
1	J9	VIN-	Conn jack banana, uninsulated, panel mount	Emerson	108-0740-001
1	J11	VOUT+	Conn jack banana, uninsulated, panel mount	Emerson	108-0740-001
1	J12	VOUT-	Conn jack banana, uninsulated, panel mount	Emerson	108-0740-001
1	J15	ADP1046_DC	Conn, header, 30 pos, 100 vert, dual	TE Connectivity	4-102973-0-15
1	J16	HDR1X4	Conn, header, 4 pos, SGL, PCB, 30, gold	FCI	69167-104HLF
1	J17	HDR1X4	Conn, female on BRD, 10 pos, vert T/H	TE Connectivity	8-215079-0
1	J18	HDR1X4	Conn, header, female, 16 PS, 0.1" DL tin	Sullins Connector	PPTC082LFBN-RC
1	J28	HDR1X2	Conn, header, 2 pos, 0.100 vert tin	Molex, Inc.	22232021
1	L6	CHOKE	Switchmode IND., 33 μH	Precision	LSM-28285-0330
1	L8	4.7 μH	High current IHLP IND 4.7 μH, 25 A	Vishay Dale	IHLP6767GZER4R7M01

Qty	Reference	Value	Description	Manufacturer	Part Number
4	QA to QD	SPP20N60CFD	MOSFET N-Ch, 650 V, 20.7 A	Infineon	SPP20N60CFD
2	Q9, Q22	IPB107N20N3 G	MOSFET N-Ch, 200 V, 88 A	Infineon	IPB107N20N3 G
1	Q10	MMBT3904	Trans, GP, NPN, 200 mA, 40 V	Fairchild	MMBT3904
1	Q21	BSS138	MOSFET N-Ch, 100 V, 170 mA, SMD	Diodes, Inc.	BSS123-7-F
1	Q23	BSZ22DN20NS3 G	MOSFET N-Ch, 200 V, 7 A	Infineon	BSZ22DN20NS3 G
1	RTD	100 k Ω	Thermister, NTC, 100 k Ω , \pm 1%, SMD	Murata	NCP15WF104F03RC
1	R2	0.002	Res, 0.002 Ω , 2 W, 1%, SMD	Stackpole Electronics	CSNL2512FT2L00
4	R25, R34, R65, R68	10 k Ω	Res, 10.0 k Ω , 1/2 W, SMD	Vishay	CRCW120610K0FKEAHP
2	R40, R93	2.2 k Ω	Res, 2.20 k Ω , 1/8W, 1%, SMD	Yageo	RC0805FR-072K2L
4	R42, R43, R45, R49	0	Res, 0 Ω , 1/8 W, 1%, SMD	Vishay Dale	CRCW08050000Z0EA
6	R44, R64, R71, R74, R75, R78	0	Res, 0.0 Ω , 1/8 W, 5%, SMD	Yageo	RC0805JR-070RL
6	R51, R118 to R121, R123	Short pin	Short pin		
1	R52	22 k Ω	Res, 22.0 k Ω , 3/4 W, 5%, SMD	Vishay Dale	CRCW201022K0JNEF
1	R59	200	Res, 200 Ω , 1/8 W, 5%, SMD	Yageo	RC0805JR-07200RL
1	R66	Do not insert			
1	R70	16.5 k Ω	Res, 16.5 k Ω , 1/8 W, 1%, SMD	Yageo	RC0805FR-0716K5L
2	R73, R116	0	SMD res, 0 Ω , 3/4 W, 5%	Vishay Dale	311-1.00CRCT-ND
1	R76	10	Res, 10.0 Ω , 1/8 W, 5%, SMD	Yageo	RC0805JR-0710RL
1	R77, R79	Do not insert			
3	R87, R95, R96	100	Res, 100 Ω , 1/8 W, 1%, SMD	Yageo	311-100CRCT-ND
2	R109, R111	1	Res, 1.0 Ω , 3/4 W, 5%, SMD	Vishay Dale	CRCW20101R00JNEF
4	R112 to R115	91 k Ω	Res, 91.0 k Ω , 2 W, 1%, SMD	TE Connectivity	352191KFT
1	R117	0	SMD, res, 0.0 Ω , 1/8 W, 5%	Digi-Key	311-0.0ARCT-ND
1	R122	10 k Ω	Res, 10.0 k Ω , 1/2 W, 1%, SMD	Stackpole	RNCP1206FTD10K0
2	R128, R129	4.99	Res, 4.99 Ω , 1/8 W, 1%, SMD	Vishay Dale	CRCW08054R99FKEA
4	R130 to R133	2	Res, 2.0 Ω , 1/2 W, 1%, SMD	Susumu	RL1632R-2R00-F
1	SW2		SW slide SPDT, 30 V, 0.2 A, PC mount	E-Switch	EG1218
6	TP4, TP12 to TP16		Test point, PC, multipurpose, red	Keystone Electronics	5010
11	TP23, TP26, TP27, TP39, TP41, TP46 to TP50, TP52		Test point, PC, mini, .040"D, red	Keystone Electronics	5010
1	T5		XFRMR, current sense, 37 A, 20 mH, T/H	Pulse	PE-67100NL
1	T12	PQ3535	Transformer full bridge, 600 W	Precision, Inc.	019-7365-00R
1	U7	ADP3654	High speed, dual, 4 A MOSFET driver	Analog Devices, Inc.	ADP3654ARDZ
2	U17, U18	ADuM4223	Digital isolated precision half-bridge driver	Analog Devices, Inc.	ADuM4223ARWZ

Table 7. ADP1046A Daughter Card Bill of Materials

Qty.	Reference	Value	Description	Manufacturer	Part Number
1	C5	1.0 μ F	Cap, cer, 1.0 μ F, 50 V, 10%, X7R	Murata	GRM32RR71H105KA01L
1	C6	330 pF	Cap, cer, 330 pF, 10%, 100 V, X7R	AVX	08051C331KAT2A
3	C8, C11, C14	0.1 μ F	Cap, cer, 0.1 μ F, 10%, 50 V, X7R	AVX	08055C104KAT2A
2	C10, C13	100 pF	Cap, cer, 0.00 μ F, 10%, 100 V, X7R	AVX	08055C101KAT2A
1	C12	4.7 μ F	Cap, cer, 4.7 μ F, +/-10%, 10 V, X7R	TY	LMK212B7475KG-T
1	C15	1000 pF	Cap, cer, 1000 pF, 10%, 100 V, X7R	TDK	C2012X7R1A475M
2	D1, D2	1N4148	Diode SW, 150 mA, 100 V	Micro Commercial	1N4448W-TP
1	D6	LED	LED, super red clear, 75 mA, 1.7 V, SMD	Chicago Lighting	CMD15-21SRC/TR8
1	J1	CON30	Conn, header, female, 30PS, 0.1" DL tin	Sullins Connector	PPTC152LFBN-RC
1	J7	HEADER4X1	Conn, header, 4 pos, SGL PCB 30 gold	FCI	69167-104HLF
1	R1	65 k Ω	Res, 65 k Ω , 1/8 W, 1%, SMD	Any	Any
1	R2	1 k Ω	Res, 1.00 k Ω , 1/8 W, 1%, SMD	Any	Any
2	R3, R4	4.99 k Ω	Res, 4.99 k Ω , 1/10 W, 0.1%, \pm 25 ppm, SMD	Any	Any
3	R5, R7, R10	46.4 k Ω	Res, 11.0 k Ω , 1/10 W, 1%, \pm 25 ppm, SMD	Any	Any
3	R6, R8, R11	1 k Ω	Res, 1.00 k Ω , 1/10 W, 1%, \pm 25 ppm, SMD	Any	Any
1	R13	0 Ω	Res, 0.0 Ω , 1/8 W, 5%, SMD	Any	Any
6	R14, R15, R24, R29, R32, R33	2.2 k Ω	Res, 2.20 k Ω , 1/8 W, SMD	Any	Any
2	R19, R20	10 k Ω	Res, 10 k Ω , 1/8 W, 0.1%, SMD	Any	Any
1	R21	5.1 k Ω	Res, 5.10 k Ω , 1/8 W, SMD	Any	Any
1	U1	ADP1046A	Secondary side power supply controller	Analog Devices, Inc.	ADP1046A
1	U2	ADP3303	IC, LDO linear regulator, 200 mA, 3.3 V	Analog Devices, Inc.	ADP3303AR-3.3-ND
9	C1 to C4, C7, C9, C16 to C18	Do not insert			

¹C refers to a communications protocol originally developed by Philips Semiconductors (now NXP Semiconductors).

**ESD Caution**

ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

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