LM5115 HV DC Evaluation Board

National Semiconductor
Application Note 1367
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Introduction

The LM5115 HV DC evaluation board provides a synchronous buck dc-dc converter using the LM5115 Secondary Side Post Regulator control IC.

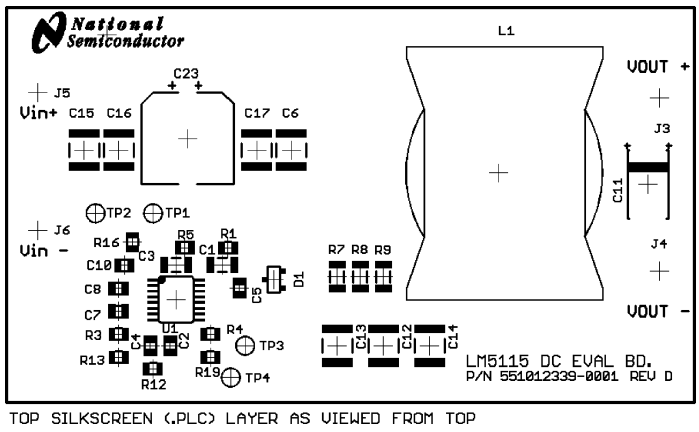
The evaluation board specifications are:

- DC Input voltage range: 7V to 70V
- Regulated Output voltage: 5V
- Output current range: 0 to 6A
- Measured efficiency: 94% at 1.5A, VIN = 24V
- Load regulation: 0.1% (1A-6A)
- Switching Frequency: 215kHz, typical
- Onset of current limiting: ≅ 8A
- Board Size: 3.0 x 1.7 x 0.43in

The printed circuit board consists of 4 layers of 2 oz copper on FR4 material, with a thickness of 0.050 in. It is designed for continuous operation at rated load with a minimum airflow of 200 LFPM.

Theory of Operation

The LM5115 is a secondary side post regulator (SSPR) controller that can be configured as a high voltage DC buck controller. In the buck application, the power input of the LM5115 is a dc voltage instead of a pulsed signal from the transformer secondary winding of an isolated converter (SSPR configuration). The free running oscillator within the LM5115 sets the clock frequency for the high and low side drivers of external synchronous buck power MOSFETs. The LM5115 controls the buck power stage with leading edge pulse width modulation (PWM) to hold off the high side driver until the necessary volt*seconds is established for regulation. A resistor from the VCC bias voltage to the SYNC pin sets the current that charges a RAMP pin capacitor for voltage mode PWM control. The internal oscillator terminates the buck switch pulse and discharges the RAMP capacitor before initiating another cycle. Adaptive deadtime control delays the top and bottom drivers to avoid shoot through currents. See typical & adaptive delay waveforms in Figures 10 & 11.



TOP SILKSCREEN (.PLC) LAYER AS VIEWED FROM TOP

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FIGURE 1. DC Evaluation Board Top Side

Theory of Operation (Continued)

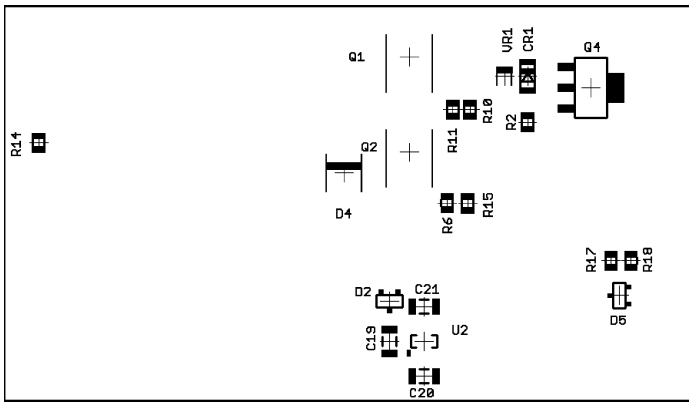


FIGURE 2. Evaluation Board Bottom Side

Board Layout and Probing

Figures 1 and 2 shows the board layout, main components, and critical probe points for testing the LM5115 DC mode evaluation board. The following notes should be considered prior to applying power to the board:

1. Main input power (7V to 70V) is applied to points J5 and J6, connected to VIN and GND respectively.
2. 2. The main current carrying components (L1, Q1, and Q2) will be hot to the touch at maximum load current. USE CAUTION. When operating at load currents in excess of 3A the use of a fan to provide forced air flow **IS NECESSARY**.
3. 3. The diameter and length of the wire used to connect the load is important. To ensure that there is not a significant voltage drop in the wires, a minimum of 14 gauge wire is recommended.

Board Connections/Start-Up

The input connections are made to terminals J5 (+) and J6 (-). The input source must be capable of supplying the load dependent input current shown in Figure 3. The load is connected to terminals J3 (+) and J4 (-). Before start-up, a voltmeter should be connected to the input terminals and to the output terminals. The input current should be monitored with an ammeter or a current probe. Soft-start provided by the LM5115 will insure that the output rises with a smooth turn on without overshoot (Figure 8). The LM5115 evaluation board will operate in the continuous conduction mode even with a light or no load.

Performance LM5115 DC - DC Regulator

Performance of the LM5115 evaluation board can be seen in the following figures:

1. Power Conversion Efficiency (Figure4)
2. Load Regulation (Figure 5)
3. Step Load Response (Figure 6)
4. Ripple Voltage (Figure 7)
5. Gate Delays (Figure 7 & 8)
6. Startup and Shutdown Response (Figure 8 & 9)
7. Operational Waveforms (Figures 10-13)
8. Output Short Circuit Response (Figure 14)

V_{BIAS}

V_{BIAS} is initially powered up by the input supply through a 6.2V clamp and an NPN. Once VOUT is regulating the voltage doubler will supply a doubled output voltage (10V) to Vbias.

V_{CC}

The LM5115 produces a LDO 7V regulated output (V_{CC}) that can supply up to 40mA of DC current. In the DC evaluation board, the V_{CC} supplies the control current that sets the frequency of the oscillator. The V_{CC} regulator also supplies power for the high current gate drive for the low side MOSFET and the bootstrap capacitor of the high side MOSFET driver.

Current Limit Operation

Inductor current is sensed through the parallel resistances of R7, R8, and R9. The resistor values are designed for a current limit of ≋8A. Current limiting occurs when the sense resistor voltage exceeds 45mV threshold causing the current sense amplifier to pull down the CO and COMP pins. Pulling CO and COMP low reduces the width of pulses to the high side driver, limiting the output current of the converter. After reaching the current limit, the voltage feedback causes the COMP pin to rise and turn on the high side driver until the inductor current again reaches the ≋8A current limit threshold. (Figure 14).

Foldback Current Limit

Current limit foldback can be implemented with the following components: R17, R18, D5, and R16 (see Figure 15b). At nominal output voltage (VOUT > 3V) D5 is reversed biased and the current limit threshold is still ≅45mV. At lower output voltage the resistor divider network along with the forward biased diode (D5) will increase the voltage across R16. In order to reach the 45mV current limit threshold, the voltage across the sense resistor (R7-R9) is reduced due to the increase in voltage across R16. Thus, the current limit is reduced providing current limit foldback. The resistor divider sets the voltage when current limit foldback kicks in and R16 sets the amount of current limit foldback.

Internal Oscillator

The frequency of the dc-dc converter system is set by the VCC voltage, the SYNC pin resistor (R4), and the RAMP pin capacitor (C4) according to the following equation:

$$F_{CLK} = \frac{1}{\frac{(C4 \times 2.25V)}{(VCC/R4 \times 3)} + 300\ ns} \approx 215\ kHz$$

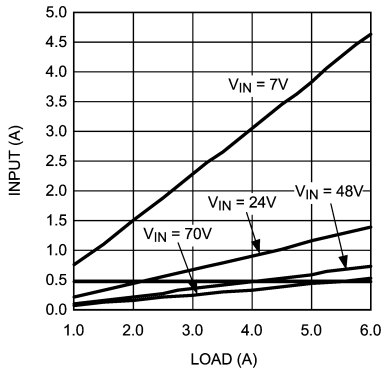


FIGURE 3. Input Current vs Load Current

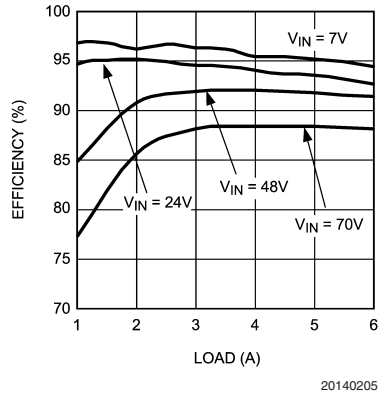


FIGURE 4. System Efficiency vs. Load Current and V_{IN}

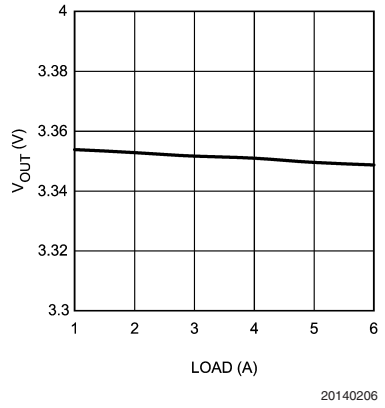
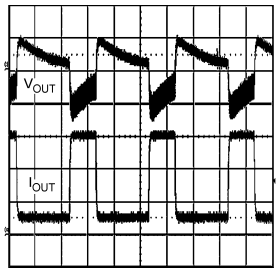
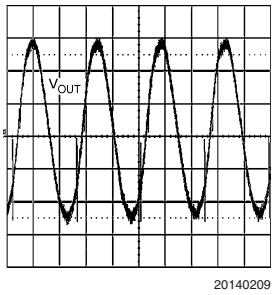


FIGURE 5. Output Voltage vs. Load Current



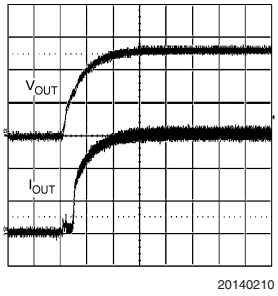
Conditions: VIN = 24V
CH1= 5V output, 200mV/div (AC mode)
CH4 = Output current load (1A to 5A), 2A/div
Horizontal Resolution = 1ms/div

FIGURE 6. Step Load Response



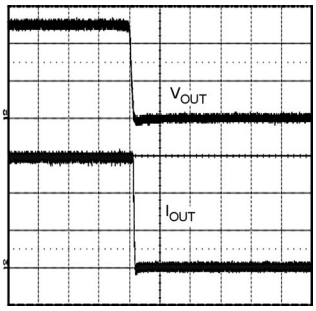
Conditions: VIN = 24V, 6A load
CH1= 5V output, 20mV/div (AC mode)
Horizontal Resolution = 2µs/div

FIGURE 7. Ripple Voltage



Conditions: VIN=24V; Load=6.0A
CH1 = 5V Output, 2V/div
CH4 = Output Current load, 2A/div
Horizontal Resolution = 10ms/div

FIGURE 8. Startup Response



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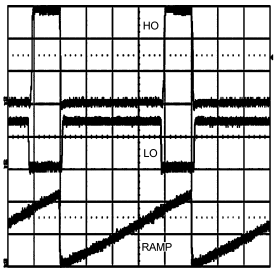
Conditions: VIN=24V; Load=6.0A
CH1 = 5V Output, 2V/div
CH4 = Output Current load, 2A/div
Horizontal Resolution = 10ms/div

FIGURE 9. Shutdown Response



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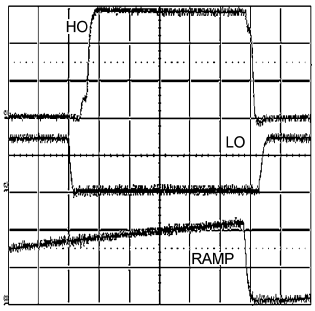
Conditions: VIN = 24V, 1A
CH1= High Side Gate Driver (HO), 10V/div
CH2= Low Side Gate Driver (LO), 5V/div
CH3= RAMP, 1V/div
Horizontal Resolution = 1µs/div

FIGURE 10. Typical Waveforms



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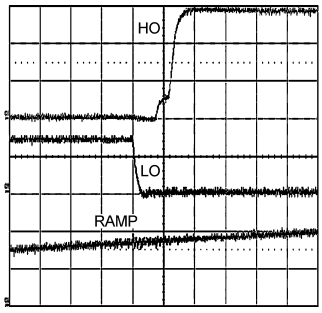
Conditions: VIN = 24V, 1A
CH1= High Side Gate Driver (HO), 10V/div
CH2= Low Side Gate Driver (LO), 5V/div
CH3= RAMP, 1V/div
Horizontal Resolution = 200ns/div

FIGURE 11. Adaptive Delays



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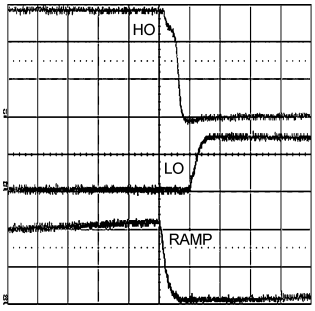
Conditions: VIN = 24V, 1A
CH1= High Side Gate Driver (HO), 10V/div
CH2= Low Side Gate Driver (LO), 5V/div
CH3= RAMP, 1V/div
Horizontal Resolution = 100ns/div

FIGURE 12. Gate Turn-on Delay



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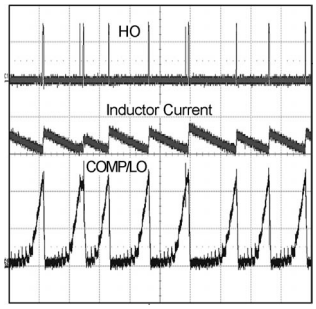
Conditions: VIN = 24V, 1A
CH1= High Side Gate Driver (HO), 10V/div
CH2= Low Side Gate Driver (LO), 5V/div
CH3= RAMP, 1V/div
Horizontal Resolution = 100ns/div

FIGURE 13. Gate Turn-off Delay



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Conditions: VIN = 24V, Short Circuit Load
CH1= High Side Gate Driver (HO), (20V/div)
CH2= COMP/CO, (1V/div)
CH4= Inductor current (2A/div)
Horizontal Resolution = 50µs/div

FIGURE 14. Output Short Circuit Response

Application Circuit Schematic

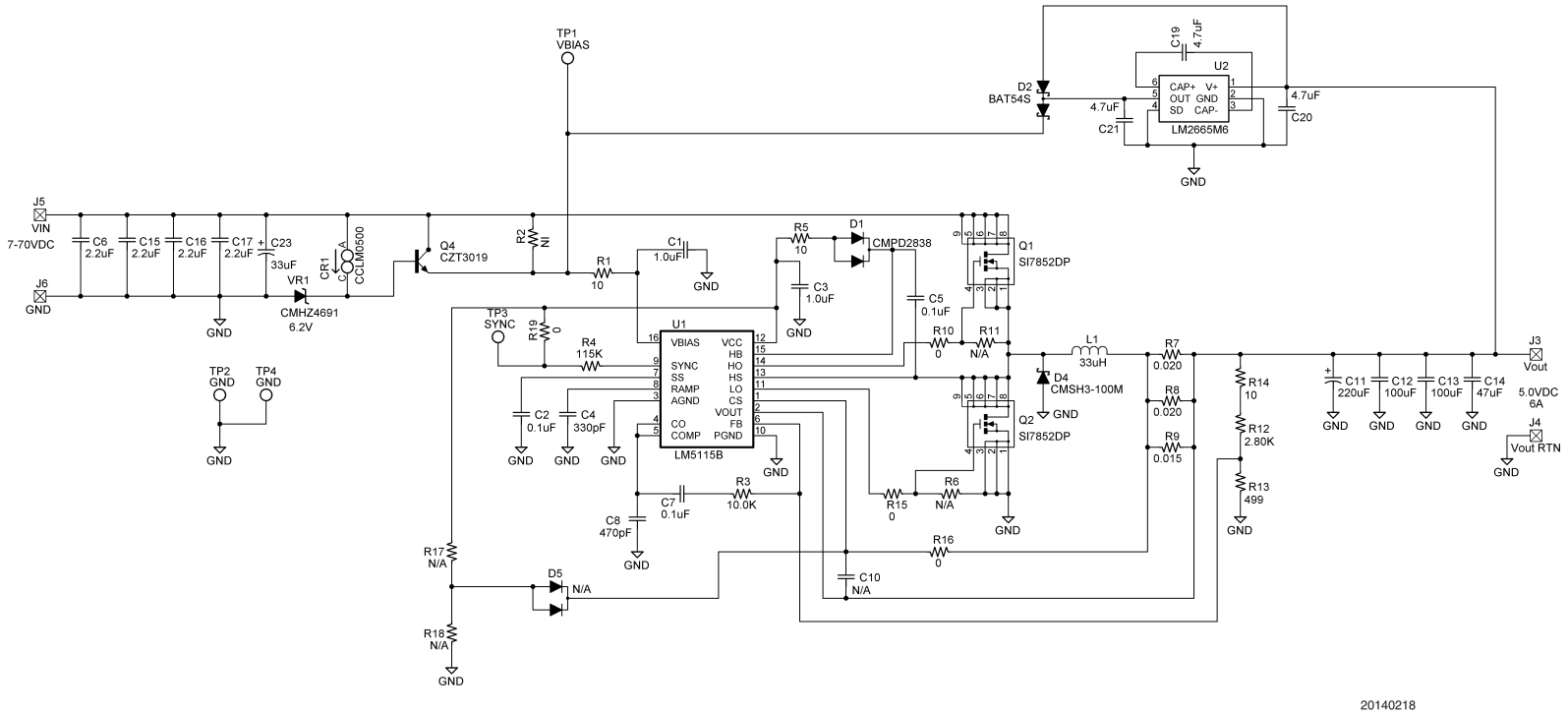

FIGURE 15. LM5115 HV DC Evaluation Board

Application Circuit Schematic (Continued)

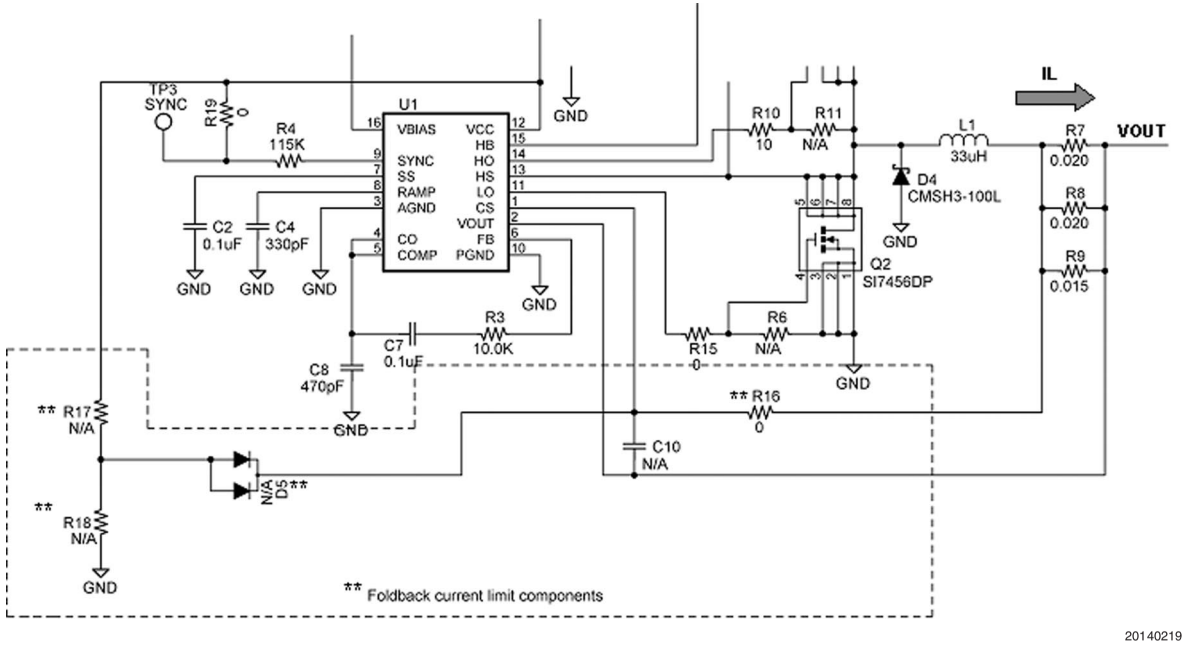

FIGURE 16. Foldback Current Limit

Bill of Materials

ITEM		PART NUMBER	DESCRIPTION	VALUE
C	1	C3216X7R1C105K	CAPACITOR, CER, TDK	1.0 µF, 16V
C	2	C2012X7R1H104K	CAPACITOR, CER, TDK	0.1 µF, 50V
C	3	C3216X7R1C105K	CAPACITOR, CER, TDK	1.0 µF, 16V
C	4	C2012C0G1H331K	CAPACITOR, CER, TDK	330 pF, 50V
C	5	C2012X7R1H104K	CAPACITOR, CER, TDK	0.1 µF, 50V
C	6	C4532X7R2A225M	CAPACITOR, CER, TDK	2.2µF, 100V
C	7	C2012X7R1H104K	CAPACITOR, CER, TDK	0.1µF, 50V
C	8	C2012C0G1H471K	CAPACITOR, CER, TDK	470 pF, 50V
C	10			Not Used
C	11	EEFUE0J221R	CAPACITOR, SP, PANASONIC	220µF, 6.3V
C	12	C4532X7R0J107M	CAPACITOR, CER, TDK	100 µF, 6.3V
C	13	C4532X7R0J107M	CAPACITOR, CER, TDK	100µF, 6.3V
C	14	C4532X7R0J476M	CAPACITOR, CER, TDK	47µF, 6.3V
C	15	C4532X7R2A225M	CAPACITOR, CER, TDK	2.2µF, 100V
C	16	C4532X7R2A225M	CAPACITOR, CER, TDK	2.2µF, 100V
C	17	C4532X7R2A225M	CAPACITOR, CER, TDK	2.2µF, 100V
C	19	C3216X7R1C475M	CAPACITOR, CER, TDK	4.7µF, 16V
C	20	C3216X7R1C475M	CAPACITOR, CER, TDK	4.7µF, 16V
C	21	C3216X7R1C475M	CAPACITOR, CER, TDK	4.7µF, 16V
C	23	EEVFK2A330P	CAPACITOR, CER,	33µF, 100V
CR	1	CCLM0500	CURRENT REGULATOR, CENTRAL, SEMI	0.5mA, 100V
D	1	CMPD2838E-NSA	DIODE, SIGNAL, CENTRAL, SEMI	200mA, 120V
D	2	BAT54S	DIODE SHOTTKY, CENTRAL, SEMI	200mA, 30V
D	4	CMSH3-100M	DIODE SHOTTKY, CENTRAL, SEMI	3A, 100v
D	5			Not Used
J	3	2515-1-01-01-00-00-07-0	SOLDER TERMINAL SLOTTED, MILL-MAX	VOUT
J	4	2515-1-01-01-00-00-07-0	SOLDER TERMINAL SLOTTED, MILL-MAX	VOUT RTN
J	5	3104-2-00-01-00-00-08-0	TERMINAL, SOLDER, .040" MILL-MAX	VIN
J	6	3104-2-00-01-00-00-08-0	TERMINAL, SOLDER, .040" MILL-MAX	GND
TP	1	5002	TERMINAL, SMALL TEST POINT, KEYSTONE	VBIAS
TP	2	5002	TERMINAL, SMALL TEST POINT, KEYSTONE	GND
TP	3	5002	TERMINAL, SMALL TEST POINT, KEYSTONE	SYNC
TP	4	5002	TERMINAL, SMALL TEST POINT, KEYSTONE	GND
R	1	CRCW080510R0J	RESISTOR, VISHAY	10
R	2			Not Used
R	3	CRCW08051002F	RESISTOR, VISHAY	10.0kΩ
R	4	CRCW08051153F	RESISTOR, VISHAY	115kΩ
R	5	CRCW080510R0J	RESISTOR, VISHAY	10Ω
R	6			Not Used
R	7	CRCW1206R02F	RESISTOR, VISHAY ,	0.02Ω
R	8	CRCW1206R02F	RESISTOR, VISHAY ,	0.02Ω
R	9	CRCW1206R015F	RESISTOR, VISHAY ,	0.015Ω
R	10	CRCW08050000Z	RESISTOR, VISHAY	0Ω

Bill of Materials (Continued)

ITEM		PART NUMBER	DESCRIPTION	VALUE
R	11			Not Used
R	12	CRCW08052801F	RESISTOR, VISHAY	2.80kΩ
R	13	CRCW08054990F	RESISTOR, VISHAY	499Ω
R	14	CRCW080510R0J	RESISTOR, VISHAY	10Ω
R	15	CRCW08050000Z	RESISTOR, VISHAY	0Ω
R	16	CRCW08050000Z	RESISTOR, VISHAY	0Ω
R	17			Not Used
R	18			Not Used
R	19	CRCW08050000Z	RESISTOR, VISHAY	0Ω
Q	1	SI7852DP	MOSFET, N-CH, POWER S0-8 PKG, VISHAY	80V, 11A
Q	2	SI7852DP	MOSFET, N-CH, POWER S0-8 PKG, VISHAY	80V, 11A
Q	4	CZT3019	NPN, CENTRAL SEMI	120V, 2W
L	1	D1787-AL	CUSTOM INDUCTOR, COILCRAFT	33 µH - 6A
U	1	LM5115	IC, SECONDARY SIDE CONTROLLER	LM5115
U	2	LM2665M6	IC, CHARGE PUMP CONVERTER	LM2665
VR	1	CMHZ4691	DIODE, ZENER,	6.2V

PCB Layout(s)

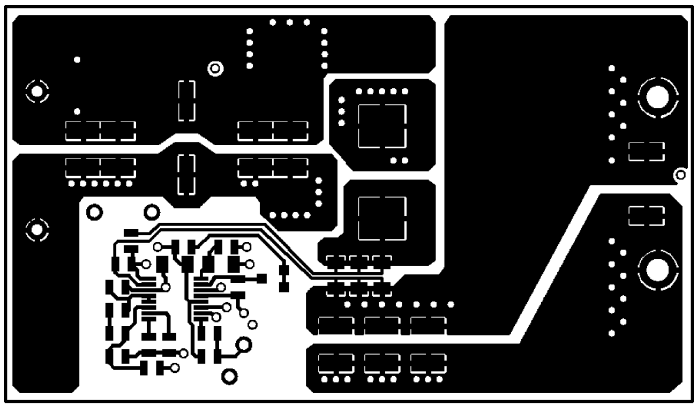

FIGURE 17. Top Layer

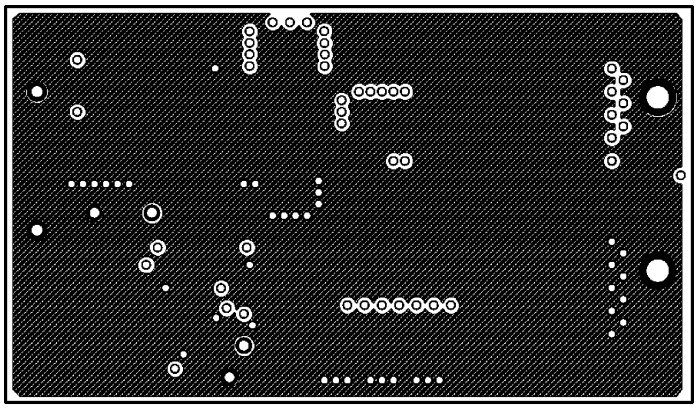

FIGURE 18. Layer 2

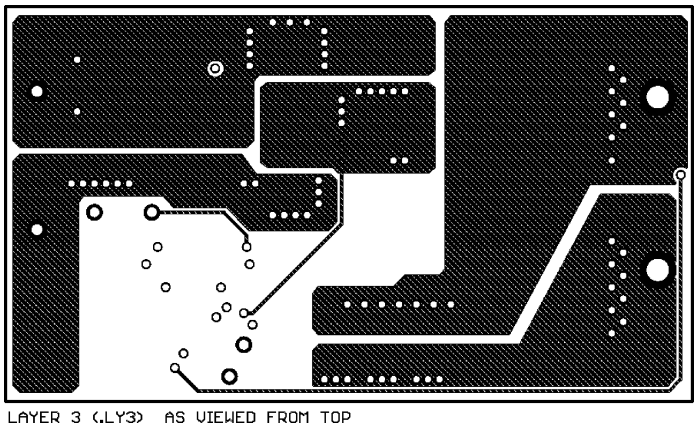

FIGURE 19. Layer 3

PCB Layout(s) (Continued)

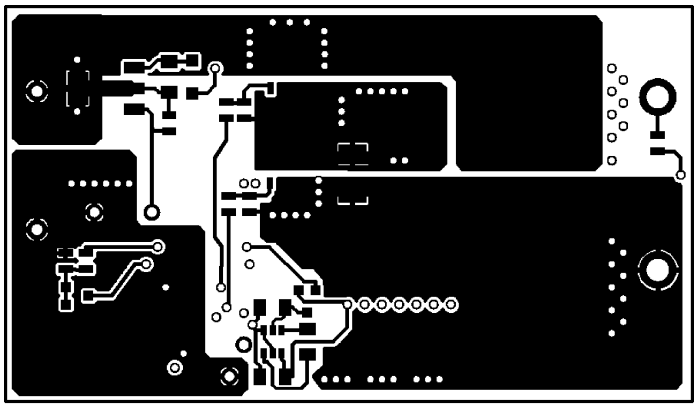

FIGURE 20. Bottom Layer LM5115, as Viewed from Top

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