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Title	***Reference Design Report for a 150 W Power Factor Corrected LLC Power Supply for LED Street Lighting***
Specification	90 VAC – 265 VAC Input; 150 W (48 V at 0 - 3.125 A) Output
Application	LED Streetlight
Author	Applications Engineering Department
Document Number	RDR-292
Date	November 19, 2013
Revision	6.1

Summary and Features

- Integrated PFC stage using
  - PFS708EG from HiperPFS family of ICs
  - LQA05TC600 ultrafast soft recovery QSpeed diode
- Integrated LLC stage using
  - LCS702HG from HiperLCS family of ICs
- Simple snubberless bias supply using
  - LNK302DG from LinkSwitch-TN family of ICs
- CAPZero (CAP002DG) IC used to discharge X capacitors for higher efficiency compared to resistive solution
- High frequency (250 kHz) LLC for small transformer size
- >95% full load PFC efficiency at 115 VAC
- >95% full load LLC efficiency
- System efficiency 91% / 93% at 115 VAC / 230 VAC

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Important Note:
Although this board is designed to satisfy safety isolation requirements, the engineering prototype has not been agency approved. Therefore, all testing should be performed using an isolation transformer to provide the AC input to the prototype board.

1 Introduction

This engineering report describes a 48 V, 150 W reference design power supply for 90 VAC - 265 VAC LED street lights which can also serve as a general purpose evaluation board for the combination of a PFS power factor stage with an LCS output stage using devices from the Power Integration's HiperPFS and HiperLCS device families.

The design is based on the PFS708EG IC and LQA05TC600 diode for the PFC front end, with a LNK302DG utilized in a non-isolated flyback bias supply. An LCS702HG IC is used for the LLC output stage.

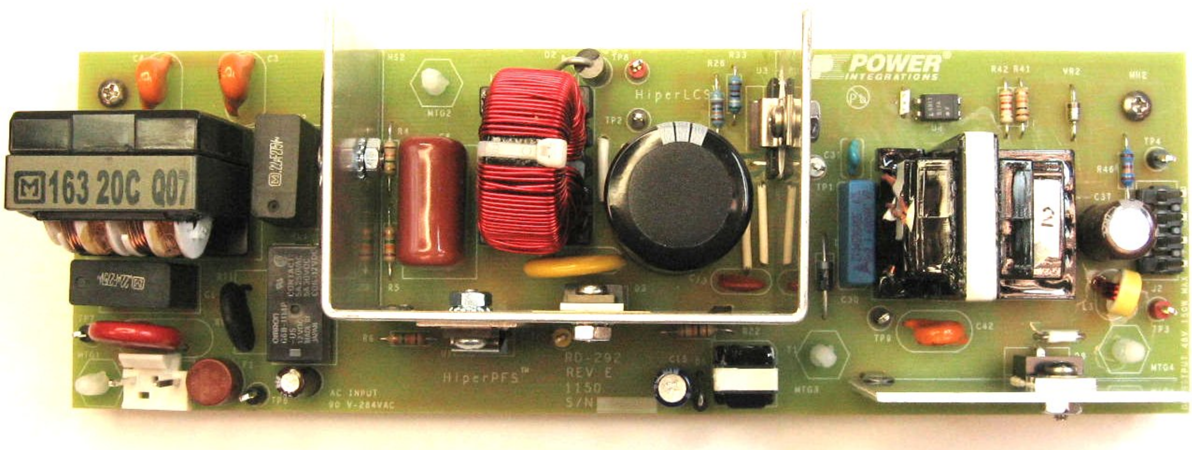

Figure 1 – RD-292 Photograph, Top View.

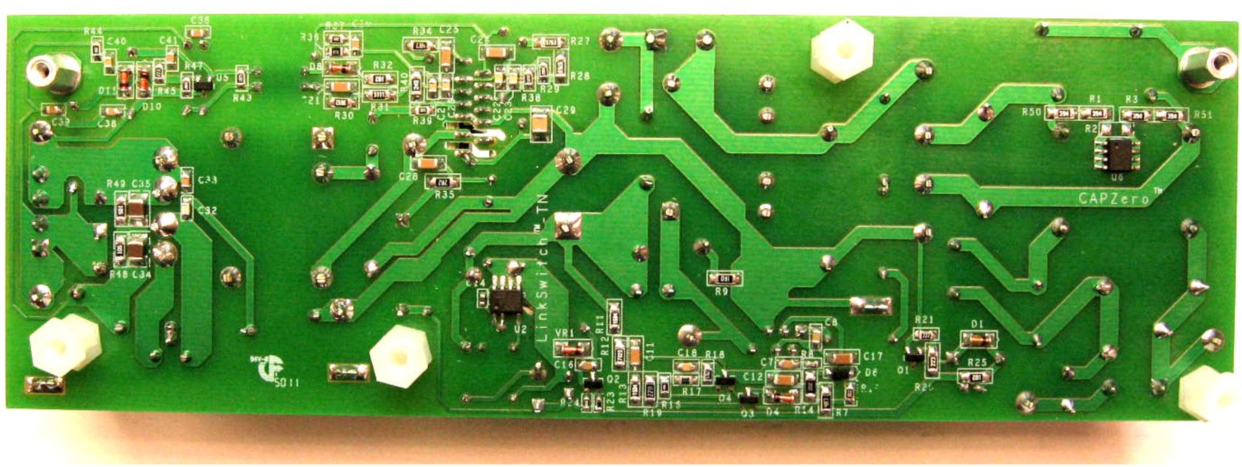

Figure 2 – RD-292 Photograph, Bottom View.

The circuit shown in this report is optimized for >0.9 power factor, over an input voltage range of 90 VAC - 230 VAC, at both 100% load and 50% load. If >0.9 power factor is not required at 50% load, the circuit can be cost reduced by downsizing common mode filter L1 and PFC input capacitor C6. Contact Power Integrations for more details.

This power supply is designed to be mounted inside a grounded enclosure for streetlight service, with the input AC safety ground connected to the chassis. EMI and line surge tests should be performed with the supply screwed down to a ground plane with the input AC safety ground connected to this plane. See set-up photographs in sections 14.1 and 16.1.

2 Power Supply Specification

The table below represents the minimum acceptable performance of the design. Actual performance is listed in the results section.

Description	Symbol	Min	Typ	Max	Units	Comment
Input						
Voltage	V_{IN}	90		265	VAC	3 Wire input.
Frequency	f_{LINE}	47	50/60	64	Hz	
THD				<10 <15	% %	Full Load, 115 VAC Full Load, 230 VAC
Power Factor	PF	0.97				Full load, 230 VAC
Main Converter Output						
Output Voltage	V_{LG}	45.6	48	50.4	V	48 VDC ± 5%
Output Ripple	$V_{RIPPLE(LG)}$			480	mV P-P	20 MHz bandwidth
Output Current	I_{LG}	0.00	3.13	3.13	A	Supply is protected under no-load conditions
Total Output Power						
Continuous Output Power	P_{OUT}		150		W	
Peak Output Power	$P_{OUT(PK)}$			N/A	W	
Efficiency						
Total system at Full Load	η_{Main}	91 93			%	Measured at 115 VAC, Full Load Measured at 230 VAC, Full Load
Environmental						
Conducted EMI		Meets CISPR22B / EN55022B				
Safety		Designed to meet IEC950 / UL1950 Class II				
Surge						1.2/50 μs surge, IEC 1000-4-5,
Differential		2			kV	Differential Mode: 2 Ω
Common Mode		4			kV	Common Mode: 12 Ω
100 kHz Ring Wave		4			kV	500 A short circuit current
Harmonic Currents		EN 61000-3-2 Class C				
Ambient Temperature	T_{AMB}	0		60	°C	See thermal section for conditions

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3 Schematic

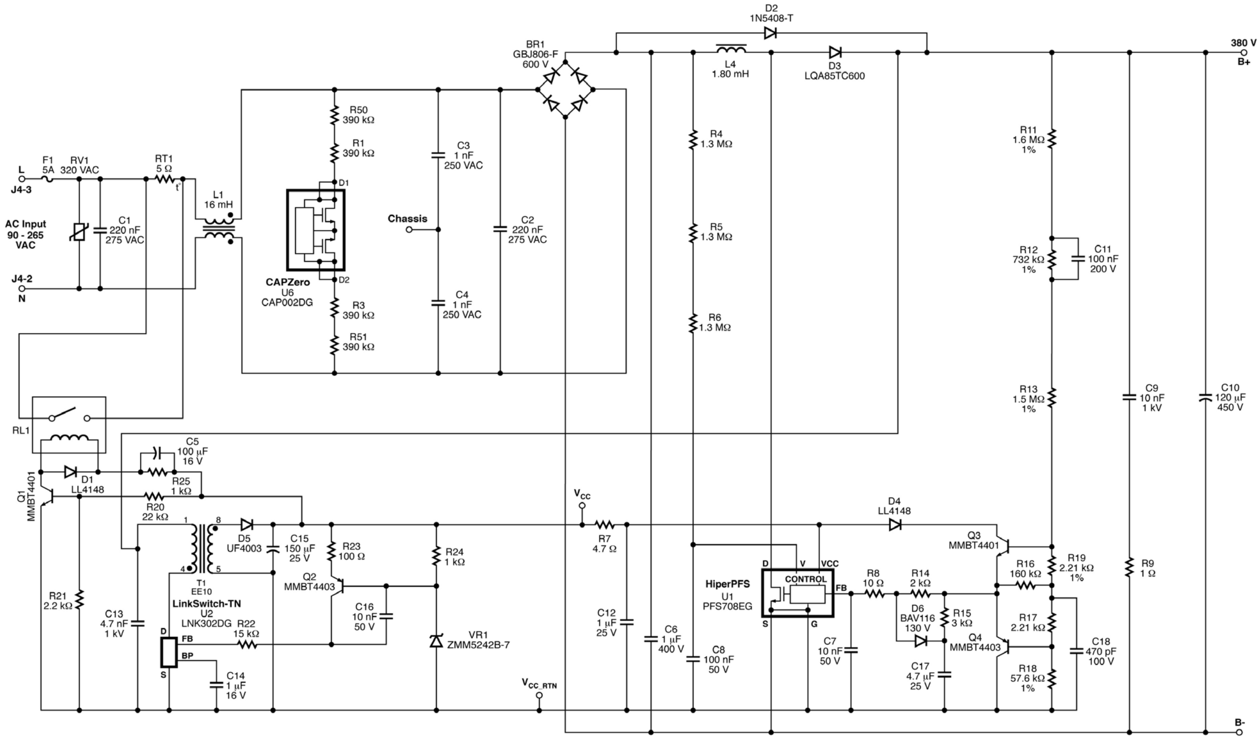

Figure 3 – Schematic RD-292 Streetlight Power Supply Application Circuit - Input Filter, PFC Power Stage, and Bias Supply.

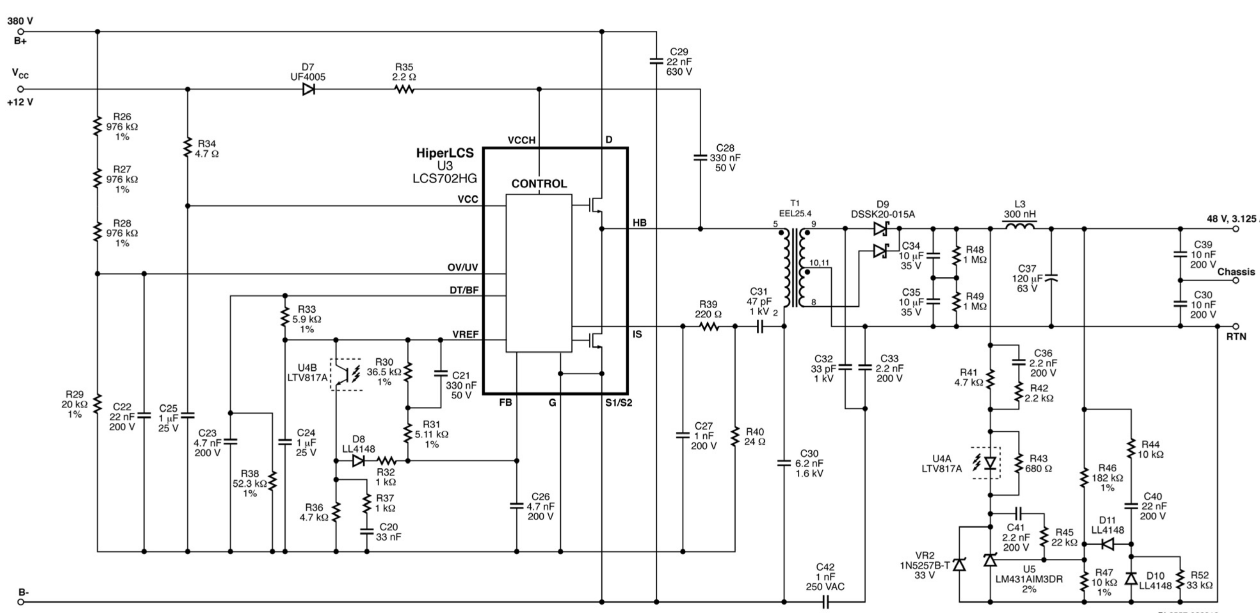

Figure 4 – Schematic of RD-292 Streetlight Power Supply Application Circuit, LLC Stage.

4 Circuit Description

The circuit shown in Figures 3 and 4 utilizes the PFS708EG, the LQA05TC600, the LCS702HG, the LNK302DG, and the CAP002DG (optional) devices from Power Integrations in a 48 V, 150 W power factor corrected LLC power supply intended to power an LED streetlight.

4.1 Input Filter / Boost Converter / Bias Supply

The schematic in Figure 3 shows the input EMI filter, PFC stage, and primary bias supply/start-up circuit. The power factor corrector utilizes the PFS708EG PFC controller with integrated power MOSFET and the LQA05TC600 low Q_{RR}, soft switching diode. The bias supply is a non-isolated flyback using the LNK302DG. The CAP002DG discharges X capacitors C1 and C2 only when the AC input voltage is not present, eliminating the static power loss of resistors R1, R3, R50, and R51.

4.1.1 EMI Filtering

Capacitors C3 and C4 are used to control common mode noise. Inductor L1 controls EMI at low and mid-band (~10 MHz) frequencies. Capacitors C1 and C2 together with leakage reactance of inductor L1 provide differential mode EMI filtering. To meet safety requirements resistors and to increase system efficiency, R1, R3 and R50-51 discharge these capacitors via U6 only when AC is removed. If U6 is not used, resistor R2 (390 kΩ, 1206) can be added for conventional resistive discharge (place is reserved for R2 on PCB). The primary heat sink for U1, U3, D3 and BR1 is connected to primary return to eliminate the heat sink as a source of radiated/capacitively coupled noise and EMI.

4.1.2 Inrush limiting

Thermistor RT1 provides inrush limiting. It is shorted by relay RL1 during normal operation, gated by activation of the internal bias supply (see components Q1, R20-21), increasing efficiency by approximately 1 - 1.5%. Capacitor C5 and resistor R15 are used to provide a short pulse of higher current to close relay RL1, followed by a smaller holding current determined by the value of R25. This reduces the power consumption of the relay coil.

4.1.3 Main PFC Stage

Components C6, C10, L4, U1, and D3 form a boost power factor correction circuit. Components Q3-4, D4, and R16 form a non-linear feedback sense circuit (R11-13, R17-19, C11, and C16) to drive the U1 feedback pin. This configuration achieves extremely fast transient response while simultaneously enabling a slow feedback loop to achieve the low gain-bandwidth product for high power factor. A Qspeed ultrafast soft recovery diode was selected for D3 as a lower cost alternative to a silicon carbide diode.

Capacitor C6 is used to filter the output of diode bridge BR1, and was chosen for optimum power factor at 50% load. Components R7 and C12 filter the VCC supply for U10. Diode D2 charges the PFC output capacitor (C10) when AC is first applied. This routes the inrush current around the PFC inductor L4, preventing it from saturating and causing stress to U1 when the PFC stage begins to operate. It also routes the bulk of the

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inrush current away from PFC rectifier D3. Capacitor C9 and R9 are used to shrink the high frequency loop around components U1, D3 and C10 to reduce EMI. A resistor in series with C9 damps mid-band EMI peaks. The incoming AC is rectified by BR1 and filtered by C6. Capacitor C6 was selected as a low-loss polypropylene type to provide the high instantaneous current through L4 during U1 on-time.

4.1.4 Primary Bias Supply / Start-up

Components U2, T1, D5, C14-16, R22-R24, Q2, and VR1 comprise a simple low power non-isolated flyback supply to provide auxiliary power. Transformer T1 is very small, utilizing an EE10 core. Careful transformer design allows operation without a drain snubber for U2. Components Q2, VR1 R22-24, and C16 comprise the voltage sense, error amplifier, and feedback for U2. Capacitor C13 provides local high-voltage bypassing for U2.

Transistor Q1 switches on relay RL1 when the primary bias supply reaches regulation, shorting out thermistor RT1.

4.2 LLC Converter

The schematic in Figure 4 depicts a 24 V, 150 W LLC DC-DC converter implemented using the LCS702HG.

4.3 Primary

Integrated circuit U3 incorporates the control circuitry, drivers and output MOSFETs necessary for an LLC resonant half-bridge (HB) converter. The HB output of U3 drives output transformer T2 via a blocking/resonating capacitor (C30). This capacitor was rated for the operating ripple current and to withstand the high voltages present during fault conditions.

Transformer T2 was designed for a leakage inductance of 50 μH. This, along with resonating capacitor C30, sets the primary series resonant frequency at ~286 kHz according to the equation:

$$f_R = \frac{1}{6.28\sqrt{L_L \times C_R}}$$

f_R is the series resonant frequency in Hertz, L_L is the transformer leakage inductance in Henries, and C_R is the value of the resonating capacitor (C30) in Farads.

The transformer turns ratio was set by adjusting the primary turns such that the operating frequency at nominal input voltage and full load is close to, but slightly less than, the previously described resonant frequency.

An operating frequency of 250 kHz was found to be a good compromise between transformer size, output filter capacitance (enabling ceramic capacitors), and efficiency.

The number of secondary winding turns was chosen to provide a good compromise between core and copper losses. AWG #44 Litz wire was used for the primary and AWG #42 Litz wire, for the secondary, this combination providing high-efficiency at the operating frequency (~250 kHz). The number of strands within each gauge of Litz wire was chosen as a balance between winding fit and copper losses.

The core material selected was NC-2H (from Nicera). This material yielded acceptable (low-loss) performance. However, selecting a material more suited for high-frequency operation, such as PC95 (from TDK), would further reduce core loss and increase efficiency.

Components D7, R35, and C28 comprise the bootstrap circuit to supply the internal high-side driver of U1.

Components C25 and R34, provide filtering and bypassing of the +12 V input which is the V_{CC} supply for U3. *Note: V_{CC} voltage of >15 V may damage U3.*

Voltage divider R26-29 sets the high-voltage turn-on, turn-off, and overvoltage thresholds of U3. The voltage divider values are chosen to set the LLC turn-on point at 360 VDC and the turn-off point at 285 VDC, with an input overvoltage turn-off point at 473 VDC.

Capacitor C29 is a high-frequency bypass capacitor for the +380 V input, connected with short traces between the D and S1/S2 pins of U3.

Capacitor C31 forms a current divider with C30, and is used to sample a portion of the primary current. Resistor R40 senses this current, and the resulting signal is filtered by R39 and C27. Capacitor C31 should be rated for the peak voltage present during fault conditions, and should use a stable, low-loss dielectric such as metalized film, SL ceramic, or NPO/COG ceramic. The capacitor used in the RD-292 is a ceramic disc with "SL" temperature characteristic, commonly used in the drivers for CCFL tubes. The values chosen set the 1 cycle (fast) current limit at 5.5 A, and the 7-cycle (slow) current limit at 3 A, according to the equation:

$$I_{CL} = \frac{0.5}{\left(\frac{C31}{C30 + C31}\right) \times R40}$$

I_{CL} is the 7-cycle current limit in Amperes, R40 is the current limit resistor in Ohms, and C30 and C31 are the values of the resonating and current sampling capacitors in nanofarads, respectively. For the one-cycle current limit, substitute 0.9 V for 0.5 V in the above equation.

Resistor R39 is set to 220 Ω, the minimum recommended value. The value of C27 is set to 1 nF to avoid nuisance tripping due to noise, but not so high as to substantially affect

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the current limit set values as calculated above. These components should be placed close to the IS pin for maximum effectiveness. The IS pin can tolerate negative currents, the current sense does not require a complicated rectification scheme.

The Thevenin equivalent combination of R33 and R38 sets the dead-time at 290 ns and maximum operating frequency for U1 at 934 kHz. The F_{MAX} input of U1 is filtered by C23. The combination of R33 and R138 also selects burst mode “2” for U3. This sets the lower and upper burst threshold frequencies at 366 kHz and 427 kHz, respectively.

The FEEDBACK pin has an approximate characteristic of 2.6 kHz per μA into the FEEDBACK pin. As the current into the FEEDBACK pin increases so does the operating frequency of U3, reducing the output voltage. The series combination of R30 and R31 sets the minimum operating frequency for U3 to ~187 kHz. This value was set to be lower than the frequency required for regulation a full load and minimum bulk capacitor voltage. Resistor R30 is bypassed by C21 to provide output soft start during start-up by initially allowing a higher current to flow into the FEEDBACK pin when the feedback loop is open. This causes the switching frequency to start high and then decrease until the output voltage reaches regulation. Resistor R31 is typically set at the same value as the combination of R33 and R38 so that the initial frequency at soft-start is equal to the maximum switching frequency as set by R33 and R38. If the value of R31 is less than this, it will cause a delay before switching occurs when the input voltage is applied.

Optocoupler U4 drives the U3 FEEDBACK pin through R32 which limits the maximum optocoupler current into the FEEDBACK pin. Capacitor C26 filters the FEEDBACK pin. Resistor R36 loads the optocoupler output to force it to run at a relatively high quiescent current, increasing its gain. Resistors R32 and R36 also improve large signal step response and burst mode output ripple. Diode D8 isolates R36 from the F_{MAX}/soft start network.

4.4 Output Rectification

The output of transformer T1 is rectified and filtered by D9 and C34-35. These capacitors are X5R dielectric, carefully chosen for output ripple current rating. Standard Z5U capacitors will *not* work in this application. Output Rectifier D9 is a 150 V Schottky rectifier chosen for high efficiency, Intertwining the transformer secondary halves (see transformer construction details in section 8) reduces leakage inductance between the two secondary halves, reducing the worst-case PIV and allowing use of a 150 V rated Schottky diode with consequent higher efficiency. Additional output filtering is provided by L3 and C37. Capacitor C37 also damps the LLC output impedance peak at ~30 kHz caused by the LLC “virtual” output series R-L and ceramic output capacitors C34 and C35. It also improves the response to fast, high amplitude load steps. Resistors R48-49 force equal voltage across C34 and C35 by swamping out the effects of any internal or external leakage currents.

Resistors R46 and R47, along with the U5 reference voltage, set the output voltage of the supply. Error amplifier U5 drives the feedback optocoupler U4 via R41. Zener diode VR2 clamps the voltage across U5 to a value below its maximum 35 V rating. Components C20, C36, and C41, R37, R42, R45, and R41 determine the gain-phase characteristics of the supply. These values were chosen to provide stable operation at nominal and extreme load/input voltage combinations. Resistor R43 allows the minimum required operating current to flow in U5 when no current flow occurs in the LED of optocoupler U4. Components C40, R44 and D10-11 are a soft finish network used to eliminate output overshoot at turn-on.

4.5 Secondary EMI Components

Capacitor C42 is a Y1 capacitor that provides common mode filtering for frequencies up to ~15 MHz.Capacitors C32 and C33 couple a small amount of signal from the output of T1 into the secondary side of C42 to provide partial neutralization of the fundamental and harmonic frequencies of the LLC converter. This allows use of a smaller, less complicated EMI filter. Capacitors C30 and C39 are connected from the +48 V output and return to chassis ground through an aluminum standoff which would be fixed to the streetlight enclosure in the end application. These capacitors suppress common mode mid-to-high frequencies.

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5 PCB Layout

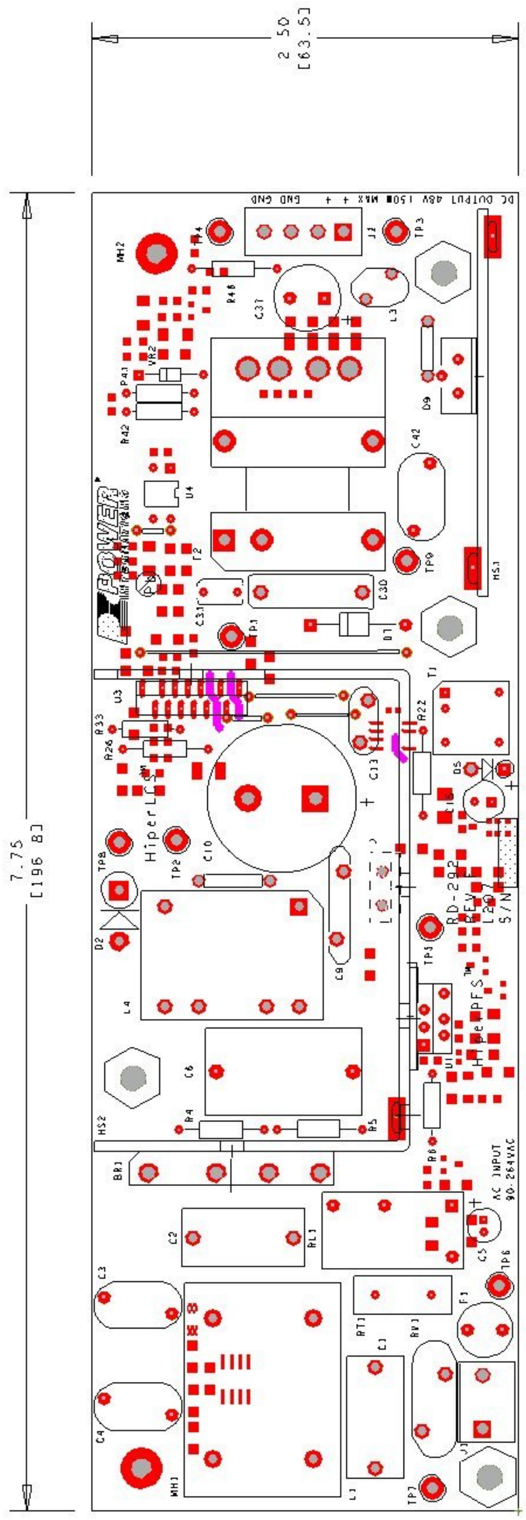

Figure 5 – Printed Circuit Layout, Top Side.

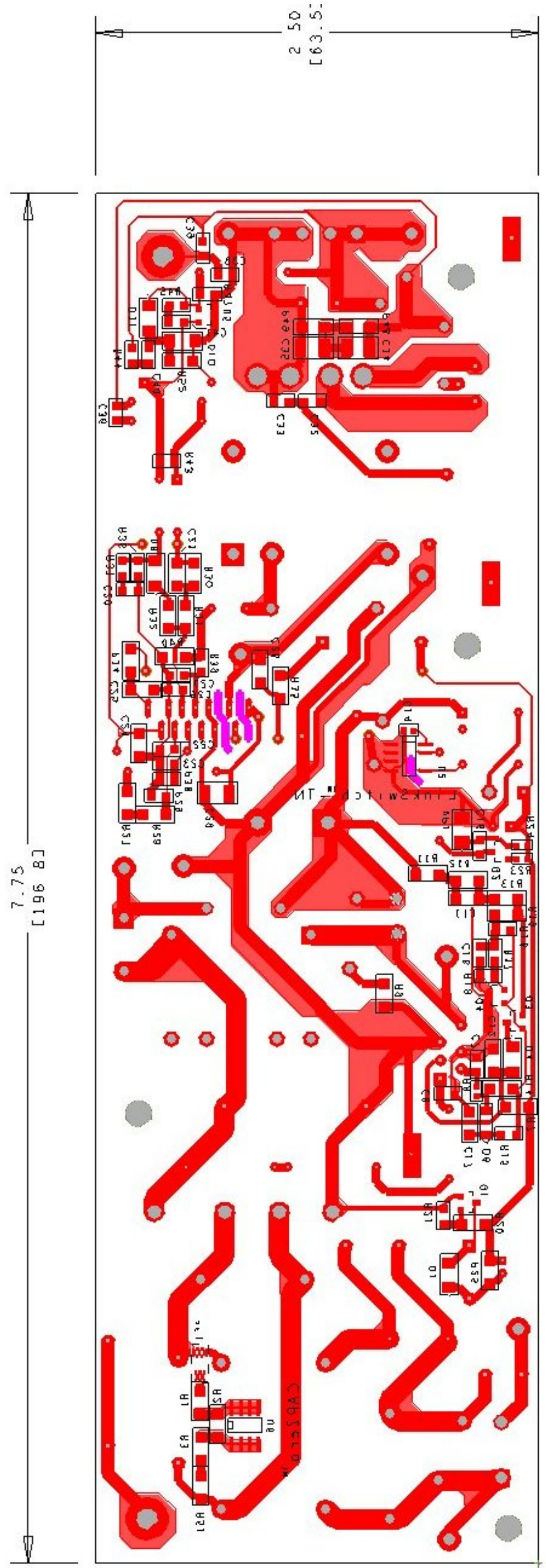

Figure 6 – Printed Circuit Layout, Bottom Side.

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6 Bill of Materials

Item	Qty	Ref Des	Description	Mfg Part Number	Mfg
1	1	BR1	600 V, 8 A, Bridge Rectifier, GBJ Package	GBJ806-F	Diodes, Inc.
2	2	C1 C2	220 nF, 275 VAC, Film, X2	ECQ-U2A224ML	Panasonic
3	3	C3 C4 C42	1 nF, Ceramic, Y1	440LD10-R	Vishay
4	1	C5	100 μF, 16 V, Electrolytic, Gen. Purpose, (5 x 11)	EKMG160ELL101ME11D	Nippon Chemi-Con
5	1	C6	1 μF, 400 V, Polypropylene Film	ECW-F4105JL	Panasonic
6	2	C7 C16	10 nF, 50 V, Ceramic, X7R, 0805	C0805C103K5RACTU	Kemet
7	1	C8	100 nF, 50 V, Ceramic, X7R, 0805	CC0805KRX7R9BB104	Yageo
8	1	C9	10 nF, 1000 V, Disc Ceramic	S103K75Y5PN83K0R	Vishay
9	1	C10	120 μF, 450 V, Electrolytic, (22 x 430)	EET-ED2W121BA	Panasonic
10	1	C11	100 nF, 200 V, Ceramic, X7R, 1206	C1206C104K2RACTU	Kemet
11	3	C12 C24 C25	1 μF, 25 V, Ceramic, X7R, 1206	HMK316B7105KL-T	Taiyo Yuden
12	1	C13	4.7 nF, 1 kV, Thru Hole, Disc Ceramic	562R5GAD47	Vishay
13	1	C14	1 μF, 16 V, Ceramic, X5R, 0603	GRM188R61C105KA93D	Murata
14	1	C15	150 μF, 25 V, Electrolytic, Low ESR, 180 mΩ, (6.3 x 15)	ELXZ250ELL151MF15D	Nippon Chemi-Con
15	1	C17	4.7 μF, 25 V, Ceramic, X7R, 1206	ECJ-3YB1E475M	Panasonic
16	1	C18	470 pF, 100 V, Ceramic, X7R, 0805	08051C471KAT2A	AVX
17	1	C20	33 nF, 50 V, Ceramic, X7R, 0805	ECJ-2VB1H333K	Panasonic
18	2	C21 C28	330 nF, 50 V, Ceramic, X7R, 1206	12065C334KAT2A	AVX
19	2	C22 C40	22 nF, 200 V, Ceramic, X7R, 0805	08052C223KAT2A	AVX
20	2	C23 C26	4.7 nF, 200 V, Ceramic, X7R, 0805	08052C472KAT2A	AVX
21	1	C27	1 nF, 200 V, Ceramic, X7R, 0805	08052C102KAT2A	AVX
22	1	C29	22 nF, 630 V, Ceramic, X7R, 1210	GRM32QR72J223KW01L	Murata
23	1	C30	6.2 nF, 1600 V, Film	B32672L1622J000	Epcos
24	1	C31	47 pF, 1 kV, Disc Ceramic	DEA1X3A470JC1B	Murata
25	1	C32	33 pF, 1000 V, Ceramic, COG, 0805	0805AA330KAT1A	AVX
26	3	C33 C36 C41	2.2 nF, 200 V, Ceramic, X7R, 0805	08052C222KAT2A	AVX
27	2	C34 C35	10 μF, 35 V, Ceramic, X5R, 1210	GMK325BJ106KN-T	Taiyo Yuden
28	1	C37	120 μF, 63 V, Electrolytic, Gen. Purpose, (10 x 16)	EKZE630ELL121MJ16S	United Chemi-con
29	2	C38 C39	10 nF, 200 V, Ceramic, X7R, 0805	08052C103KAT2A	AVX
30	5	D1 D4 D8 D10 D11	75 V, 0.15 A, Fast Switching, 4 ns, MELF	LL4148-13	Diodes, Inc.
31	1	D2	1000 V, 3 A, Recitifier, DO-201AD	1N5408-T	Diodes, Inc.
32	1	D3	600 V, 5 A, TO-220AC	LQA05TC600	Power Integrations
33	1	D5	200 V, 1 A, Ultrafast Recovery, 50 ns, DO-41	UF4003-E3	Vishay
34	1	D6	130 V, 5%, 250 mW, SOD-123	BAV116W-7-F	Diodes, Inc.
35	1	D7	600 V, 1 A, Ultrafast Recovery, 75 ns, DO-41	UF4005-E3	Vishay
36	1	D9	150 V, 20 A, Schottky, TO-220AB	DSSK 20-015A	IXYS
37	2	ESIPCLIP M4 METAL1 ESIPCLIP M4 METAL2	Heat sink Hardware, Edge Clip, 20.76 mm L x 8 mm W x 0.015 mm Thk	NP975864	Aavid Thermalloy
38	1	F1	5 A, 250V, Slow, TR5	37215000411	Wickman
39	1	HS1	Heat sink, RDK292-Diode, Alum 1.300 H x 2.270 W x 0.062" Thk"	61-00071-01	Custom
40	1	HS2	Heat sink, RDK292-eSIP,Alum 1.85 L x 2.840 W x 0.062" Thk"		Custom
41	1	HSPREADER_ESIPPFISW1	Heat Spreader, Custom, Al, 3003, 0.030 Thk"	61-00040-00	Custom

42	1	J1	3 Position (1 x 3) header, 0.156 pitch, Vertical	B3P-VH	JST
43	1	J2	4 Position (1 x 4) header, 0.156 pitch, Vertical	26-48-1045	Molex
44	1	L1	16 mH, 2 A, Common Mode Choke	ELF-22V020C	Panasonic
45	1	L3	Custom, 300 nH, ±15%, constructed on Micrometals T30-26 toroidal core	SNX-R1621	Santronics USA
46	1	L4	Custom, 1.8 mH, constructed on VTM-1050-10 base	SNX-R1623	Santronics USA
47	4	MTG1 MTG2 MTG3 MTG4	Post, Circuit Board, Female, Hex, 6-32, snap, 0.375L, Nylon	561-0375A	Eagle Hardware
48	5	NUT1 NUT2 NUT3 NUT4 NUT5	Nut, Hex, Kep 4-40, S ZN Cr3 plateing RoHS	4CKNTZR	Any RoHS Compliant Mfg.
49	2	Q1 Q3	NPN, Small Signal BJT, GP SS, 40 V, 0.6 A, SOT-23	MMBT4401LT1G	Diodes, Inc.
50	2	Q2 Q4	PNP, Small Signal BJT, 40 V, 0.6 A, SOT-23	MMBT4403-7-F	Diodes, Inc.
51	4	R1 R3 R50 R51	390 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ394V	Panasonic
52	3	R4 R5 R6	1.3 MΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-1M3	Yageo
53	2	R7 R34	4.7 Ω, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ4R7V	Panasonic
54	1	R8	10 Ω, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ100V	Panasonic
55	1	R9	1 Ω, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ1R0V	Panasonic
56	1	R11	1.60 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF1604V	Panasonic
57	1	R12	732 kΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF7323V	Panasonic
58	1	R13	1.50 MΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF1504V	Panasonic
59	1	R14	2 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ202V	Panasonic
60	1	R15	3 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ302V	Panasonic
61	1	R16	160 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ164V	Panasonic
62	1	R17	2.21 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF2211V	Panasonic
63	1	R18	57.6 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF5762V	Panasonic
64	1	R19	2.21 kΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF2211V	Panasonic
65	1	R20	22 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ223V	Panasonic
66	1	R21	2.2 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ222V	Panasonic
67	1	R22	15 kΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-15K	Yageo
68	1	R23	100 Ω, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ101V	Panasonic
69	1	R24	1 kΩ, 5%, 1/10 W, Thick Film, 0603	ERJ-3GEYJ102V	Panasonic
70	2	R25 R32	1 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ102V	Panasonic
71	1	R26	976 kΩ, 1%, 1/4 W, Metal Film	MFR-25FBF-976K	Yageo
72	2	R27 R28	976 kΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF9763V	Panasonic
73	1	R29	20 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF2002V	Panasonic
74	1	R30	36.5 kΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF3652V	Panasonic
75	1	R31	5.11 kΩ, 1%, 1/4 W, Thick Film, 1206	ERJ-8ENF5111V	Panasonic
76	1	R33	5.9 kΩ, 1%, 1/4 W, Metal Film	MFR-25FBF-5K90	Yageo
77	1	R35	2.2 Ω, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ2R2V	Panasonic
78	1	R36	4.7 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ472V	Panasonic
79	1	R37	1 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ102V	Panasonic
80	1	R38	52.3 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF5232V	Panasonic
81	1	R39	220 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ221V	Panasonic
82	1	R40	24 Ω, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ240V	Panasonic
83	1	R41	10 kΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-10K	Yageo
84	1	R42	2.2 kΩ, 5%, 1/4 W, Carbon Film	CFR-25JB-2K2	Yageo
85	1	R43	680 Ω, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ681V	Panasonic
86	1	R44	10 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ103V	Panasonic
87	1	R45	22 kΩ, 5%, 1/8 W, Thick Film, 0805	ERJ-6GEYJ223V	Panasonic

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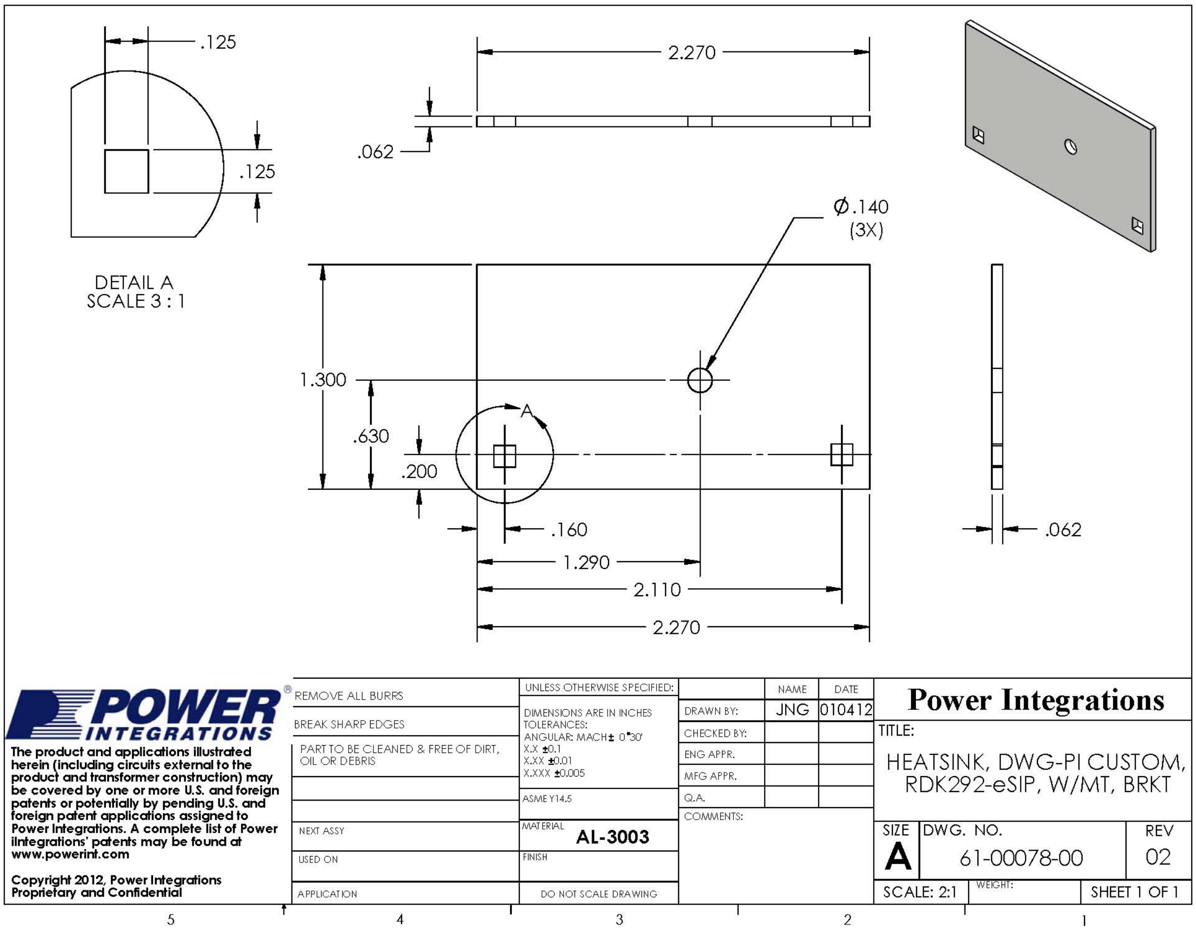
88	1	R46	182 kΩ, 1%, 1/4 W, Metal Film	MFR-25FBF-182K	Yageo
89	1	R47	10 kΩ, 1%, 1/8 W, Thick Film, 0805	ERJ-6ENF1002V	Panasonic
90	2	R48 R49	1 MΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ105V	Panasonic
91	1	R52	33 kΩ, 5%, 1/4 W, Thick Film, 1206	ERJ-8GEYJ333V	Panasonic
92	1	RL1	SPST-NO, 5 A 12 VDC, PC MNT	G6B-1114P-US-DC12	OMRON
93	1	RT1	NTC Thermistor, 5 Ohms, 4.7 A	CL-150	Thermometrics
94	5	RTV1 RTV2 RTV3 RTV4 RTV5	Thermally conductive Silicone Grease	120-SA	Wakefield
95	1	RV1	320 V, 80 J, 14 mm, RADIAL	V320LA20AP	Littlefuse
96	3	SCREW1 SCREW2 SCREW3	Screw Machine Phil 4-40 X 5/16 SS	PMSSS 440 0031 PH	Building Fasteners
97	2	SCREW4 SCREW5	Screw Machine Phil 4-40 X 3/8 SS	PMSSS 440 0038 PH	Building Fasteners
98	2	SCREW6 SCREW7	Screw Machine Phil 4-40 X 1/4 SS	PMSSS 440 0025 PH	Building Fasteners
99	2	STDOFF1 STDOFF2	Standoff Hex, 4-40, 0.375 L	1892	Keystone
100	1	T1	Custom Transformer, LinkSwitch, EE10, Vertical, pins 3, 6 & 7 removed	SNX-R1619	Santronics USA
101	1	T2	Custom Transformer, LLC, 48V, EEL25.4, Vertical	SNX-R1620	Santronics USA
102	1	TO-220 PAD3	THERMAL PAD TO-118, TO-220, TO-247, .006 K10"	SPK10-0.006-00-90	Bergquist
103	1	TO-220 PAD1	HEATPAD TO-247 .006" K10	K10-104	Bergquist
104	1	TP1	Test Point, WHT,THRU-HOLE MOUNT	5012	Keystone
105	5	TP2 TP4 TP6 TP7 TP9	Test Point, BLK,THRU-HOLE MOUNT	5011	Keystone
106	2	TP3 TP8	Test Point, RED,THRU-HOLE MOUNT	5010	Keystone
107	1	TP5	Test Point, YEL,THRU-HOLE MOUNT	5014	Keystone
108	1	U1	HiperPFS, eSIP7/6-TH	PFS708EG	Power Integrations
109	1	U2	LinkSwitch-TN, SO-8	LNK302DG	Power Integrations
110	1	U3	HiperLCS, Overmolded, ESIP16/13,	LCS702HG	Power Integrations
111	1	U4	Optocoupler, 35 V, CTR 80-160%, 4-DIP	LTV-817A	Liteon
112	1	U5	IC, REG ZENER SHUNT ADJ SOT-23	LM431AIM3/NOPB	National Semic
113	1	U6	CAPZero, SO-8C	CAP002DG	Power Integrations
114	1	VR1	12 V, 5%, 500 mW, DO-213AA (MELF)	ZMM5242B-7	Diodes, Inc.
115	1	VR2	33 V, 5%, 500 mW, DO-35	1N5257B-T	Diodes, Inc.
116	2	WASHER1 WASHER3	Washer,Shoulder, #4, 0.095 Shoulder x 0.117 Dia , Polyphenylene Sulfide PPS	7721-10PPSG	Aavid Thermalloy
117	1	WASHER2	Washer Teflon #6, ID 0.156, OD 0.312, Thk 0.031	FWF-6	See Distributor
118	5	WASHER4 WASHER5 WASHER6 WASHER7 WASHER8	Washer FLAT #4 SS	FWSS 004	Building Fasteners

7 Heat Sink Assemblies

7.1 Diode Heat Sink Assembly

7.1.1 Diode Heat Sink Drawing



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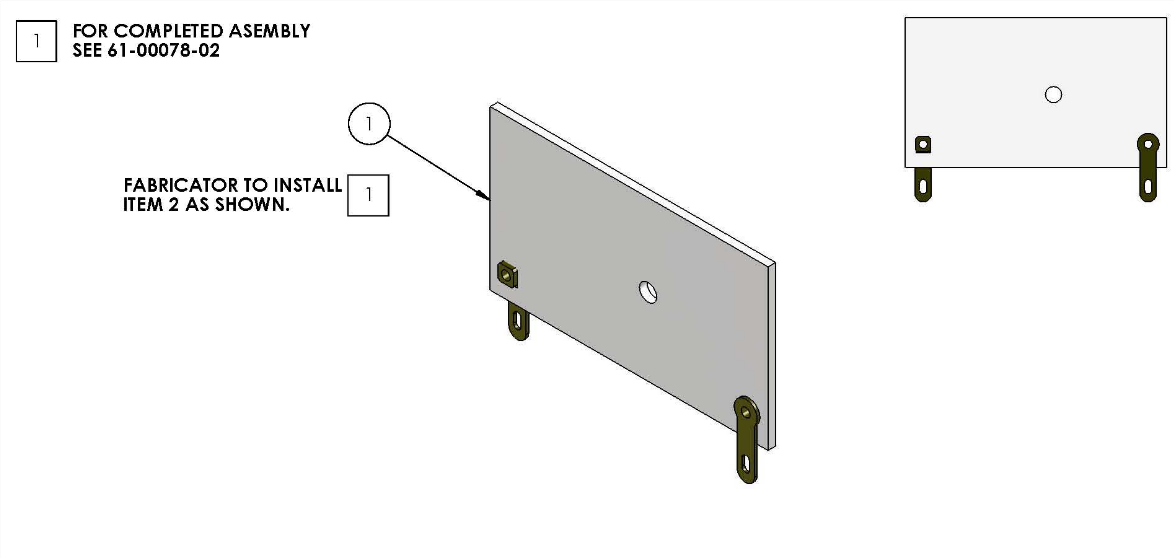
7.1.2 Diode Heat Sink Fabrication Drawing



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	61-00078-00	HEATSINK, RDK292-DIODE, AL 1.300" H x 2.270 W x 0.062" thk	1
2	60-00016-00	TERMINAL, EYELET, ZIERICK 190	2

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REMOVE ALL BURRS
BREAK SHARP EDGES
PART TO BE CLEANED & FREE OF DIRT, OIL OR DEBRIS
NEXT ASSY
USED ON
APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH± 0°30'
X.X ±0.1
X.XX ±0.01
X.XXX ±0.005
ASME Y14.5
MATERIAL
FINISH
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN BY:	JNG	010412
CHECKED BY:		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

Power Integrations

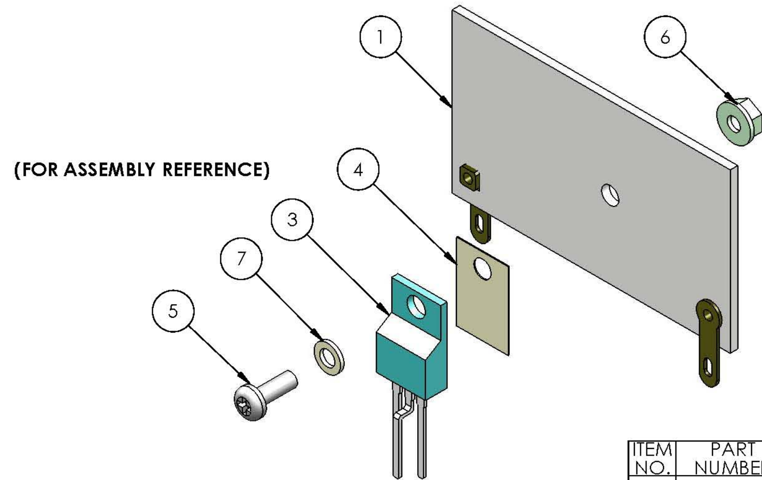
TITLE:
HEATSINK, FAB, DIODE, WITH BRKTS, PI CUSTOM

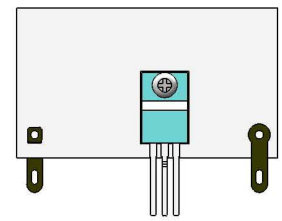
SIZE A DWG. NO. 61-00078-01 REV 02

SCALE: 1:1 WEIGHT: SHEET 1 OF 1

5 4 3 2 1

7.1.3 Diode and Heat Sink Assembly Drawing





ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	61-00078-00	HEATSINK, RDK292-DIODE, AL 1.300" H x 2.270 W x 0.062" thk	1
3	15-00401-00	150 V, 20 A, SCHOTTKY, TO-220AB	1
4	60-00035-00	THERMAL GREASE, SILICONE, 5 OZ TUBE	1
5	75-00002-00	SCREW MACHINE PHIL 4-40 X 5/16 SS	1
6	75-00068-00	NUT,HEX,KEP4-40, ZINC PLATE	1
7	75-00167-00	WASHER FLAT #6 SS, Zince Plate, 0.267 OD X 0.143 x 0.032 Thk	1

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APPLICATION

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DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH± 0°30'
X.X ±0.1
X.XX ±0.01
X.XXX ±0.005
ASME Y14.5
MATERIAL
FINISH
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN BY:	JNG	010412
CHECKED BY:		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

Power Integrations

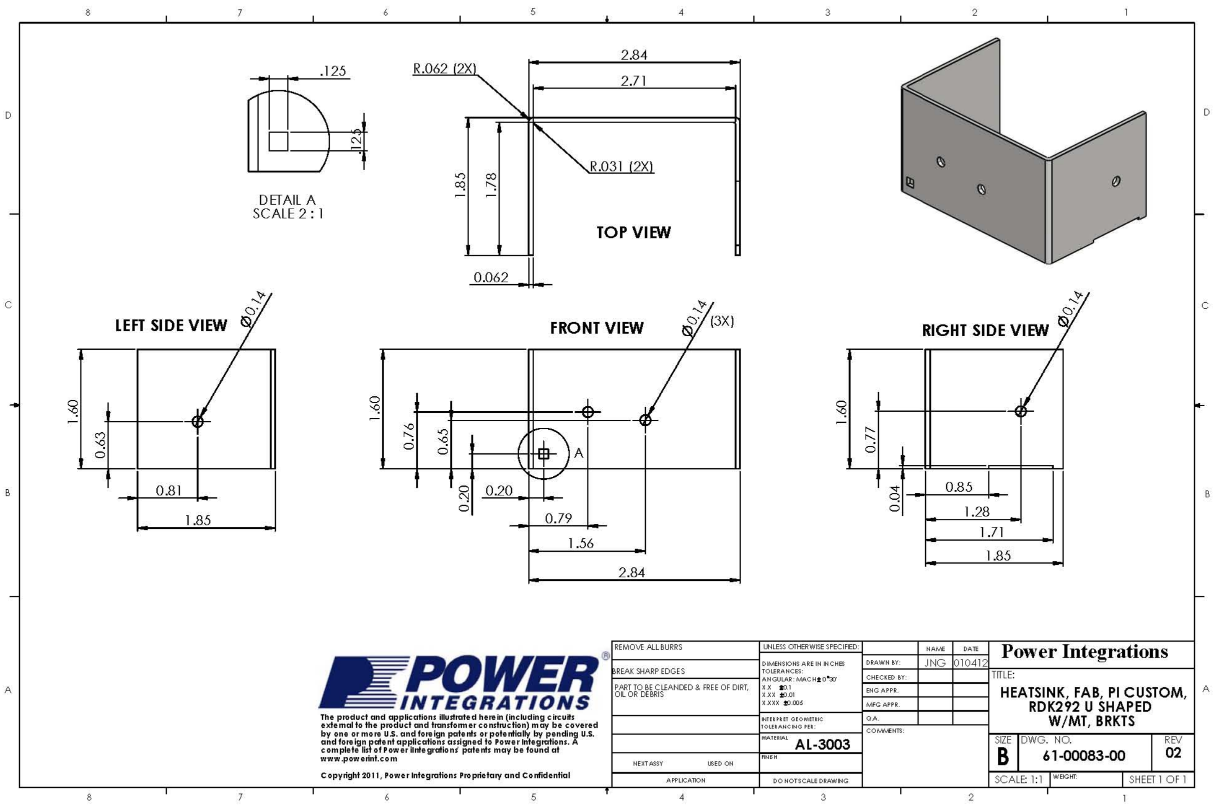
TITLE:
HEATSINK, ASSY,DIODE WITH BRKTS, RDK292, PI CUSTOM

SIZE A | DWG. NO. 61-00078-02 | REV 02
SCALE: 1:2 | WEIGHT: | SHEET 1 OF 1

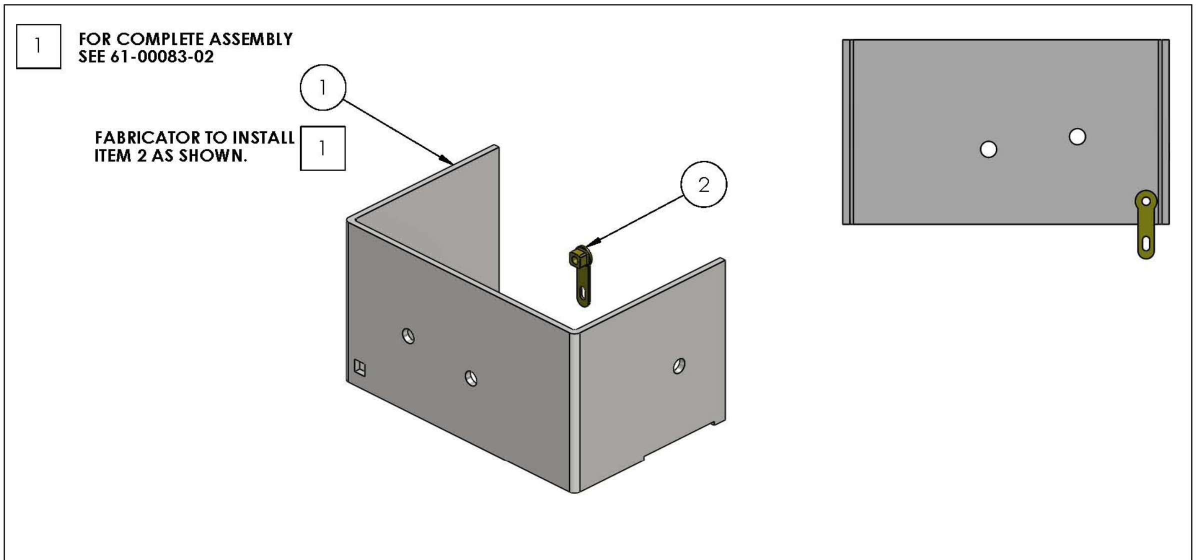
5 4 3 2 1

7.2 Primary Heat Sink Assembly

7.2.1 Primary Heat Sink Drawing



7.2.2 Primary Heat Sink Fabrication Drawing



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	61-00079-00	HEATSINK, RDK292, AL 2.84" L x 1.60" H x 0.062" THK	1
2	60-00016-00	TERMINAL, EYELET, ZIERICK 190	1

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NEXT ASSY
USED ON
APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH± 0°30'
X.X ±0.1
X.XX ±0.01
X.XXX ±0.005
ASME Y14.5
MATERIAL
FINISH
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN BY:	JNG	010512
CHECKED BY:		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

Power Integrations
TITLE:
HEATSINK, FAB, eSIP, WITH BRKT, PI CUSTOM

SIZE A | DWG. NO. 61-00083-01 | REV 02
SCALE: 1:1 | WEIGHT: | SHEET 1 OF 1

5 4 3 2 1

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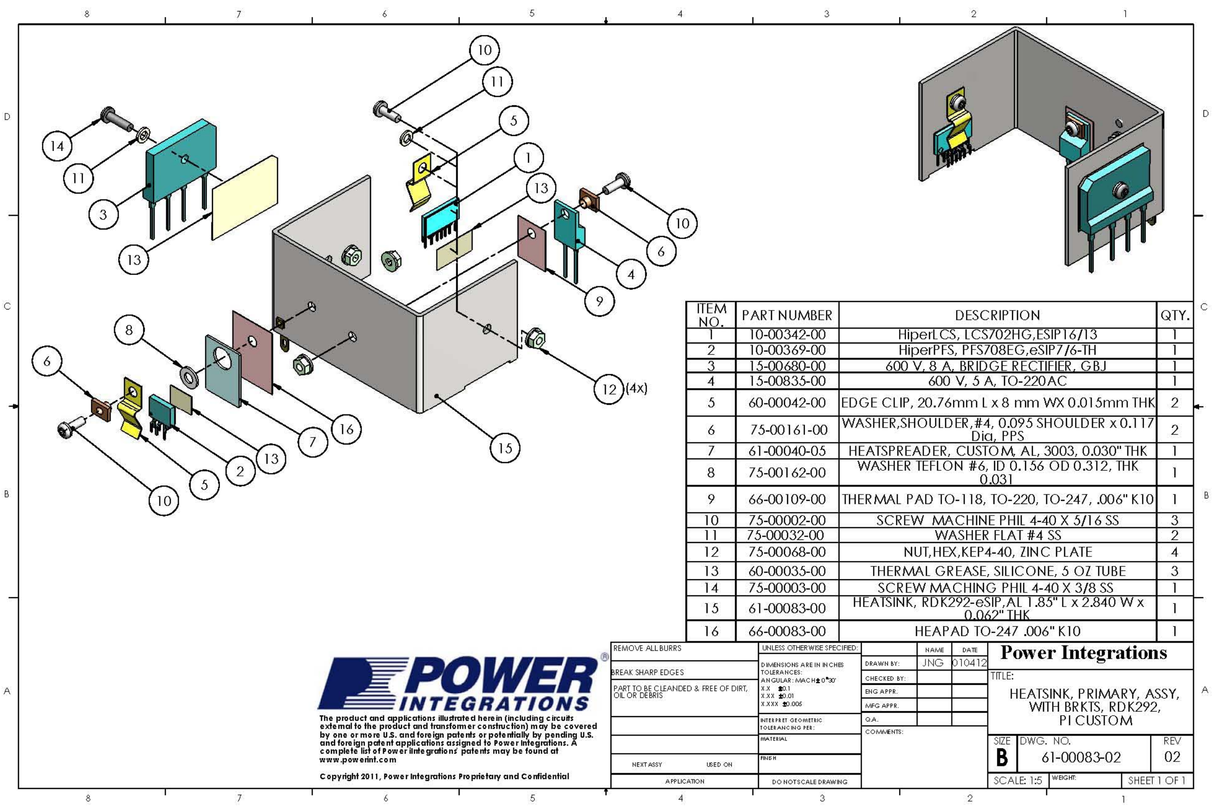
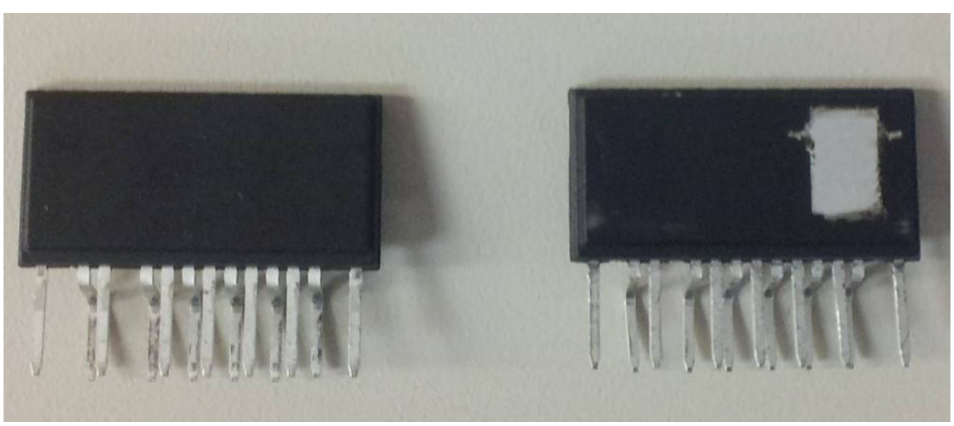
7.2.3 Primary and Heat Sink Assembly Drawing



Note: The above heat sink drawing is designed for the overmolded version of the LCS IC. A SIL pad must be substituted, instead of thermal grease (Item 13) if the exposed-pad version of the LCS IC is used. The picture below identifies the two versions of the IC.



Overmolded LCS IC　　Exposed Pad LCS IC

8 Magnetics

8.1 PFC Choke (L2) Specification

8.1.1 Electrical Diagram

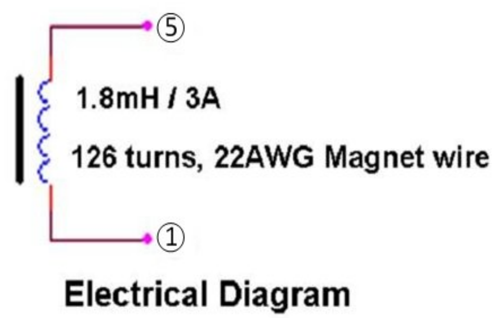


Figure 7 – Transformer Electrical Diagram.

8.1.2 Electrical Specifications

Inductance	Pins 1-5 measured at 100 kHz, 0.4 V_{RMS}	1.8 mH, ±8%

8.1.3 Materials

Item	Description
[1]	Core: Chang Sung, Inc.: Sendust core: CS270090; Alternate: Magnetics Inc., Mfg: 77934-A7.
[2]	Magnet wire: 22AWG insulated magnet wire. VTM1050-1D.
[3]	Base: Toroid mounting base, Lodestone Pacific, P/N VTM160-4, or similar. See Figure 2. PI P/N: 76-00019-00.
[4]	High Temperature Epoxy, Mfg: MG Chemicals, P/N: 832HT-375ML, Digikey: 473-1085-ND, or similar, PI P/N: 66-00087-00.
[5]	Divider: Tie-wrap, Panduit, P/N: PLT.7M-M or similar.

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