ISL6745AHEVAL5Z and ISL6745ALEVAL5Z: TRIAC Dimmer Compatible LED Driver

Abstract

ISL6745AHEVAL5Z (high line) and ISL6745ALEVAL5Z (low line) are low cost, high performance LED drivers with Power Factor Correction (PFC). They use Intersil's voltage mode PWM controller ISL6745A to operate a Flyback converter in Discontinuous Conduction Mode (DCM) for PFC. The design gives high flexibility on both input and output conditions. With the same circuit configuration, they work well with wide range of TRIAC dimmers. The brightness of the LED can be well controlled by the dimmers with flicker free operation. This driver circuit can be used for various LED lighting applications. The number of LEDs in a string can be as many as 9~12. The output current can be set to different levels from 350mA to 1A. Therefore, the evaluation boards can demonstrate high performance solutions for wide range of LED lighting applications.

Features of the Board

- V_{IN}: 160~270V_{AC} (ISL6745AHEVAL5Z), 90V~144V (ISL6745ALEVAL5Z)
- I_O = 350/500/700mA/1.05A; V_O = 32/48V, $P_{O(MAX)}$ = 33W
- Isolated, Flyback Converter
- Active Single-Stage PFC, PF > 0.95
- TRIAC Dimmable (by "Open Loop Dimming") with Inrush Current Control
- OCP: Pulse-by-Pulse OCP at Switching Frequency
- OVP: OVP for Output Open Circuit Protection
- Efficiency: 80%
- Dimension (L×W×H): 129×25×29mm^3
- Recommended LED Load: 1 String of 9~12 LEDs (350mA LED)

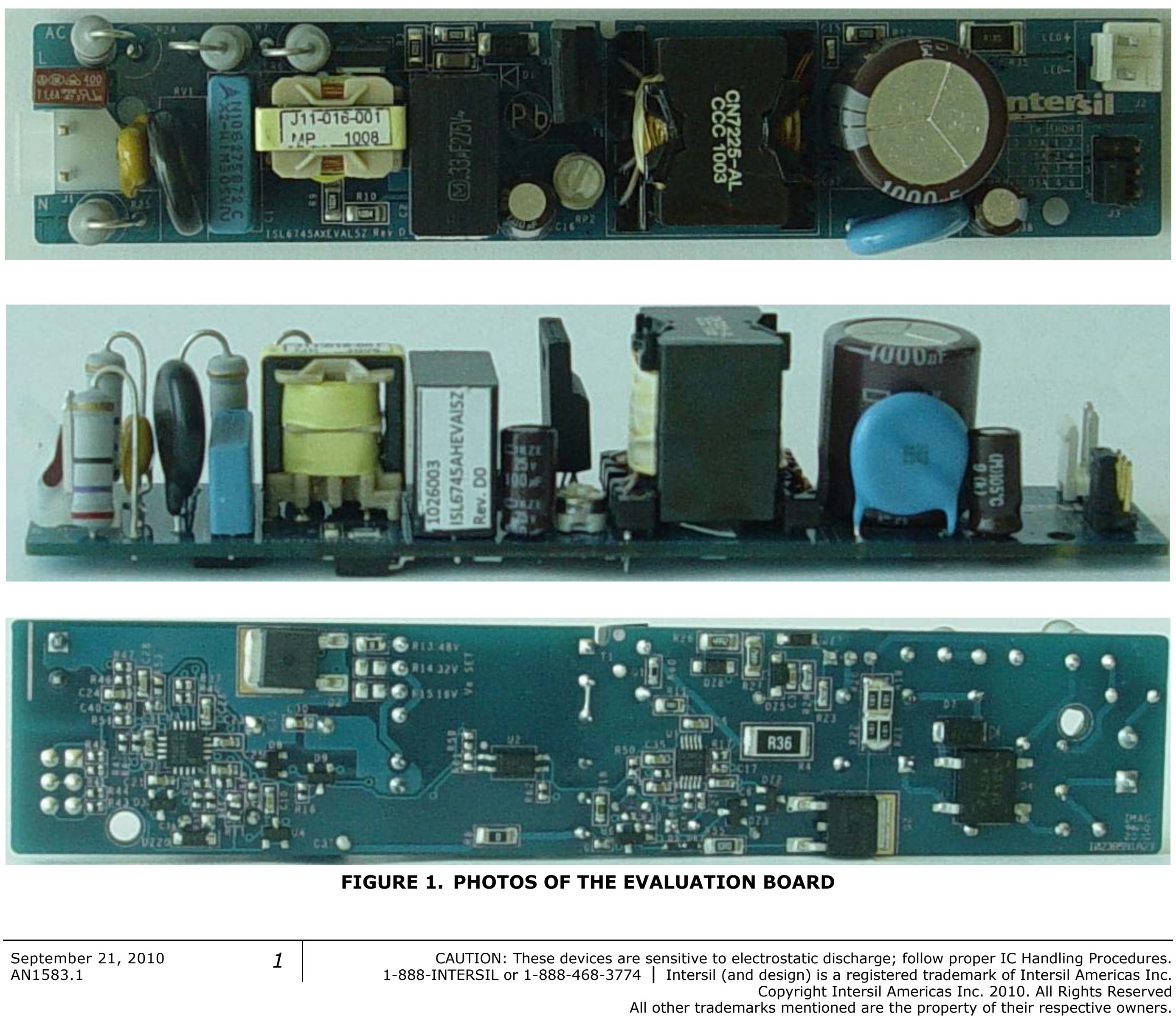

FIGURE 1. PHOTOS OF THE EVALUATION BOARD

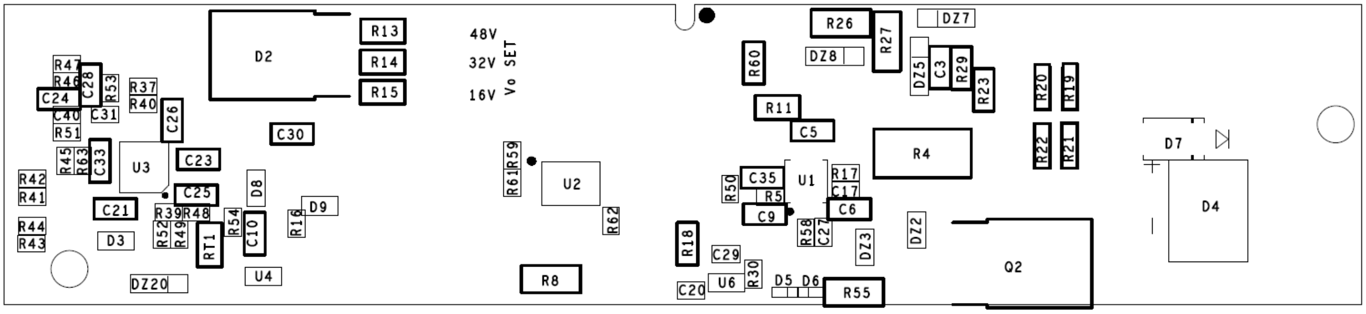

FIGURE 2. DRAWING OF ASSEMBLY ON BOTTOM

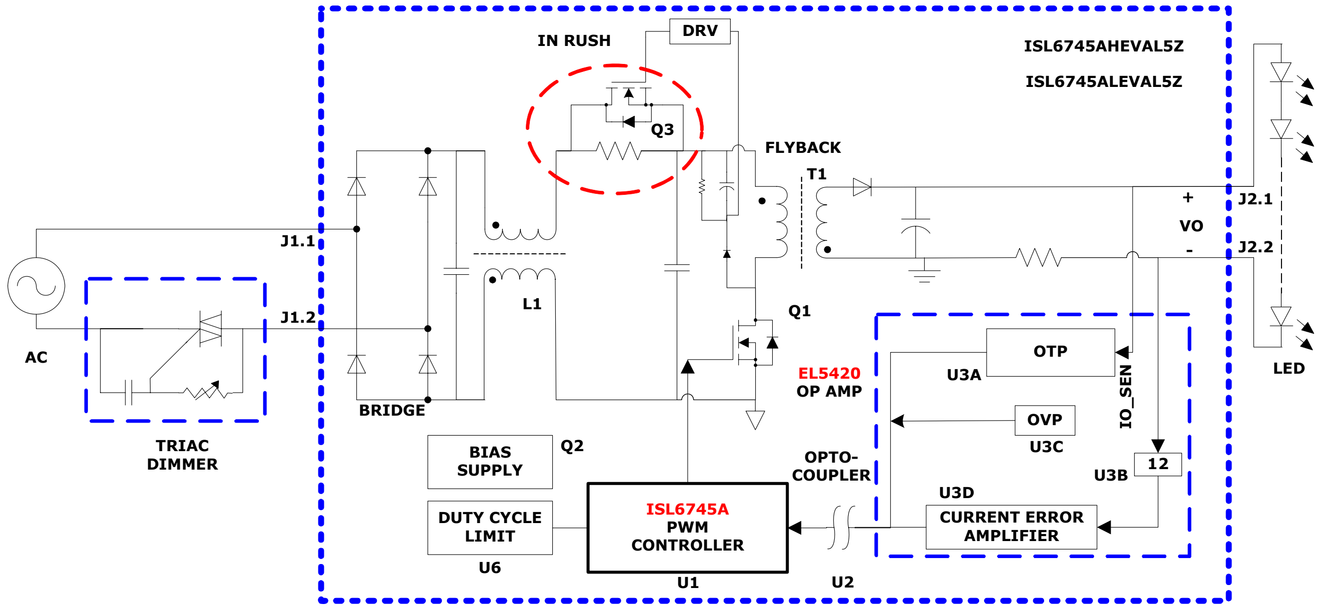

FIGURE 3. BLOCK DIAGRAM OF THE EVALUATION BOARD

Operation Theory

The block diagram of ISL6745AHEVAL5Z LED driver is shown in Figure 3. It is composed of a Flyback converter and the following circuitries: Duty Cycle Limit, In-Rush Control, OTP, OVP, Current Error Amplifier, Current Sense Signal Amplifier and Bias Supply, etc.

The PFC is implemented by running the Flyback converter in DCM. the input equivalent resistance of the driver is:

$$R_{IN} = 2 * L_p * f_S / D^2 \quad \text{(EQ. 1)}$$

Where:

L_p is the primary inductance of transformer,

f_S is the switching frequency, and

D is the duty cycle.

Since the converter runs in constant frequency and D is fixed in open loop operation, R_{IN} is constant. Therefore, the driver behaves like a pure resistive incandescent light bulb, so the driver has a built-in PFC function.

Please refer to AN1387 for more details on general LED lighting design guidelines.

Bias Supply

The bias supply in the primary side is shown in Figure 4. It has two sources; one is from the rectified DC bus (VBUS+) for start up, and the other is from the bias winding of primary side for normal operation.

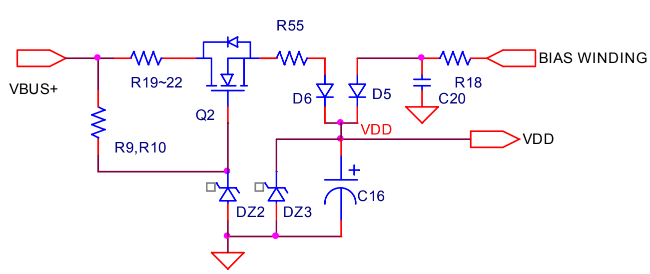

FIGURE 4. BIAS SUPPLY IN PRIMARY SIDE

The bias supply in the secondary side is shown in Figure 5; it is powered by aux winding in secondary side.

The Op Amp is supplied by VCC. The shunt regulator U4 generates 2.5V reference.

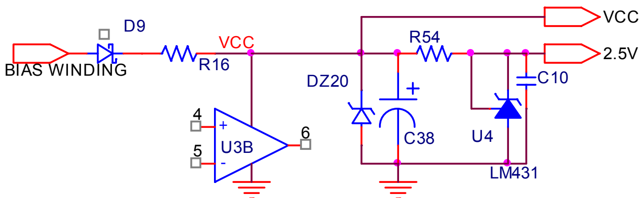

FIGURE 5. BIAS SUPPLY IN SECONDARY SIDE

Current Sense Signal Amplifier

The current sense signal amplifier circuit is shown in Figure 6, which has a gain of 12 so that we can choose a low resistance current sensing resistor R35 to reduce the power dissipation. Iosen is the current sensing signal from R35, and Ios is the output of this amplifier.

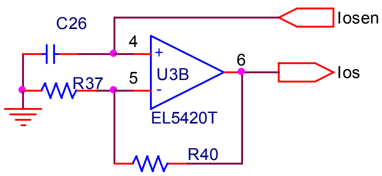

FIGURE 6. SIGNAL AMPLIFIER

Current Error Amplifier

The current error amplifier shown in Figure 7 is configured as a type-I compensator (an integrator). The input signal Ios is from the current signal amplifier. The reference signal of the output current is set by dividing the 2.5V reference. By switching the R42~R44, the reference can be easily changed. The current set point I_O is defined by R35, R63 and Rx with Equation 2:

$$2.5V*R63/(R63 + Rx) = 12*I_O*R35 \quad \text{(EQ. 2)}$$

Where, Rx is one of the R41~R44, which depend on the position of jumper J3.

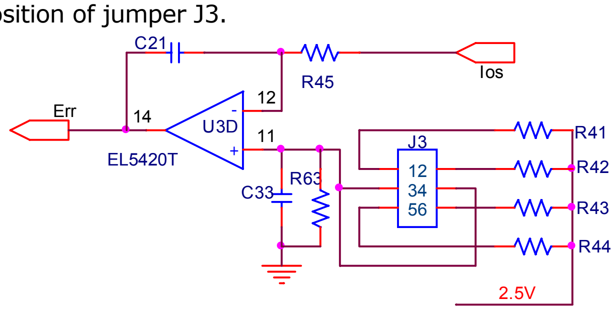

FIGURE 7. CURRENT REGULATOR

Since the maximum output power is limited to 33W, the maximum output current is limited when the output voltage is high or the number of LEDs in series is large.

The output voltage and current safe operation area is shown in Figure 8.

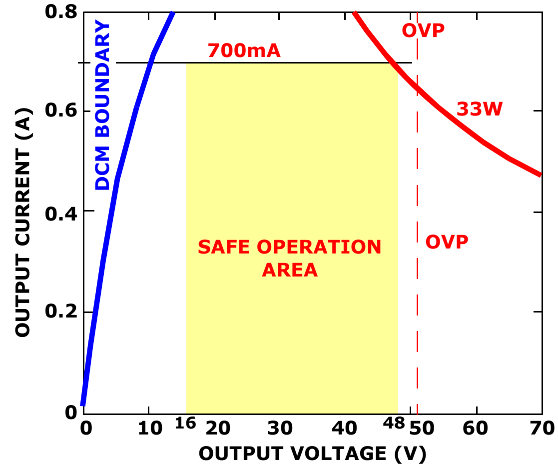

FIGURE 8. SAFE OPERATING AREA (VO IS SET TO 48V)

Overvoltage Protection

The OVP circuit is shown in Figure 9. The op amp is configured as a type-III compensator, clamping the V_O, which is V_{OUT} in the schematic, to the set point when output open circuit happens. The V_{OUT} is feedback to the inverting pin. The output signal Err controls the VERR of ISL6745A through the isolation photo-coupler (U2). Once the V_{OUT} reaches the OVP set point, the VERR of U1 is pulled down to reduce the duty cycle of the MOSFET gate drive PWM signal.

The OVP setting point is determined by Equation 3:

$$OVP = 2.5V*(1 + R56/R47) \quad \text{(EQ. 3)}$$

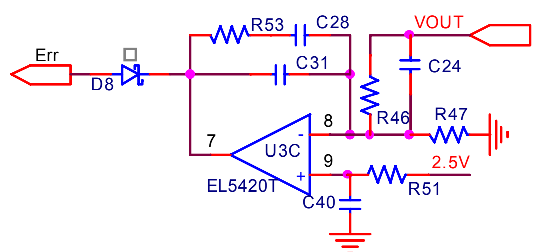

FIGURE 9. OVERVOLTAGE PROTECTION FOR OUTPUT

Over-Temperature Protection

The OTP circuit is shown in Figure 10; it's a comparator with hysteresis. RT1 is an NTC thermistor. It is placed close to the hot spot inside the driver. When the temperature rises too high, Err becomes low, and pulls down VERR to limit the power delivery.

In-Rush Control

The in-rush circuit is shown in Figure 11. In each half AC line cycle, the turn on of the TRIAC in the dimmer charges C1 and C2 and forms the high inrush current. C1 capacitance is relatively small and the charge current to it can be limited by the Rx and Ry with relatively small resistance. C2 capacitance is much larger to deliver the switching frequency current to the Flyback converter with the compliance to the EMC standard. R6 and R7 are used with larger resistance to reduce the high charge current. Q3 is used to bypass the R6 and R7 after the C2 is charged up in each half line cycle, thus to reduce the power dissipation caused by the normal operation current.

The gate drive signal of Q3 is derived from the voltage on the snubber capacitor C4. So this is a self driven scheme, which does not need the IC's support.

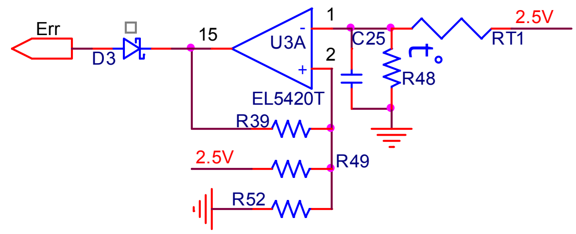

FIGURE 10. OVER-TEMPERATURE PROTECTION CIRCUIT

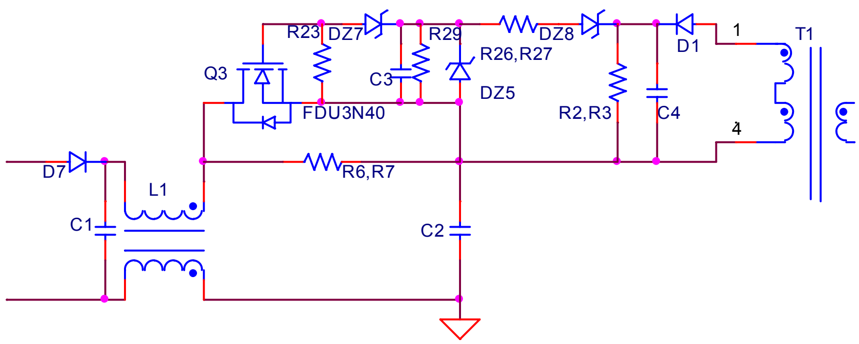

FIGURE 11. IN-RUSH CONTROL CIRCUIT

Duty Cycle Limit

The duty cycle limit circuit shown in Figure 12 sets the maximum duty cycle of the Flyback converter by adjusting the VERR pin voltage of ISL6745A through the POT RP2. U9 is used to accurately set the VERR voltage. In order to maximize the dimming range and achieve best dimming performance, RP2 needs to be adjusted for different number of LEDs and different output current.

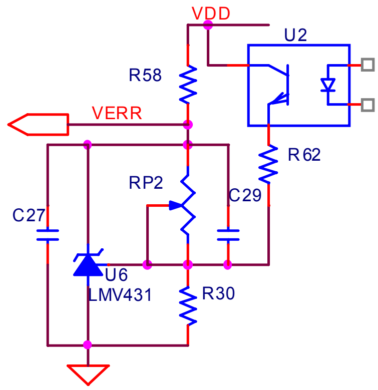

FIGURE 12. DUTY CYCLE LIMITER

Test Setup for the Driver Performance Evaluation

Note:

- Set the I_O, V_O and RP2 per the "Configuration Tables" on page 23 (Tables 12 to 14) before the test.
- If using a VARIAC instead of an AC source, a capacitor about 10µF/270V_{AC} or so may need to be connected between L and N (of J1) to avoid the interactivity between the VARIAC and input EMI filter of the LED driver.
- Some kinds of light dimmers need a minimum load, so a 40W incandescent lamp may be needed between J1.1 and J1.2 as a dummy load, otherwise the dimmer may not function well.
- Do not try to run the LED driver out of its Safe Operating Area. (For example, if set I_O/V_O to 700mA/"48V", then the output voltage shall be greater than 16V).

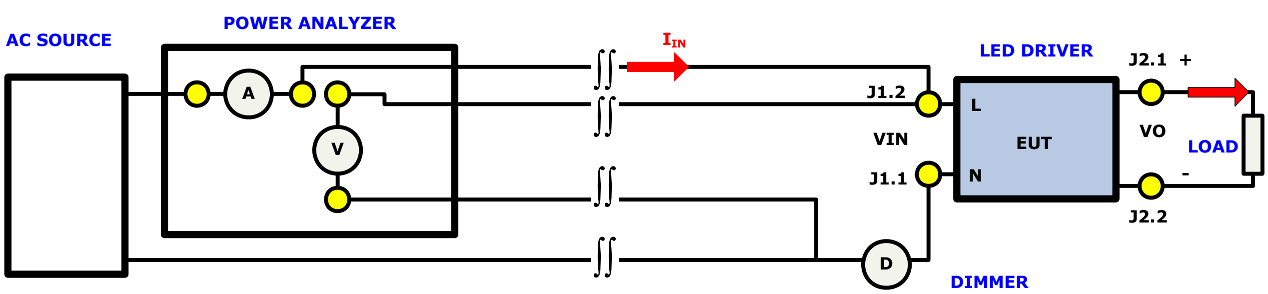

FIGURE 13. WIRING OF THE TEST

Test Data

SOURCE DIMMING

TABLE 1. SET I_O TO 350mA/48V

	V_{IN} (V)	I_{IN} (mA)	PF	P_{IN} (W)	V_O (V)	I_O (mA)	P_O (W)	EFF(%)
60	60	24.05	0.862	1.24	47.97	6.5	0.311805	25.15
80	80	29.6	0.886	2.1	47.97	17	0.81549	38.83
100	100	38.1	0.932	3.545	47.97	42.5	2.038725	57.51
120	120	49.3	0.9505	5.64	47.97	80	3.8376	68.04
140	140	53	0.9437	7.01	47.97	105	5.03685	71.85
160	160	57.1	0.945	8.64	47.97	137	6.57189	76.06
180	180	69.75	0.9616	12.08	47.97	196	9.40212	77.83
200	200	74.2	0.9593	14.23	47.97	238	11.41686	80.23
220	220	83.8	0.9628	17.76	47.97	301	14.43897	81.30
230	230	89.75	0.9662	20.06	47.97	341	16.35777	81.54
240	240	87.81	0.9581	20.21	47.97	344	16.50168	81.65
260	260	82.2	0.935	19.98	47.97	344	16.50168	82.59
270	270	79.6	0.9255	19.89	47.97	344	16.50168	82.96

TABLE 2. SET I_O TO 500mA/48V

	V_{IN} (V)	I_{IN} (mA)	PF	P_{IN} (W)	V_O (V)	I_O (mA)	P_O (W)	EFF (%)
60	60	30.9	0.8765	1.62	47.97	12	0.57564	35.53
80	80	35	0.9118	2.55	47.97	25	1.19925	47.03
100	100	43.1	0.9375	4.04	47.97	52	2.49444	61.74
120	120	63.44	0.955	7.28	47.97	112	5.37264	73.80
140	140	77.2	0.96	10.37	47.97	168	8.05896	77.71
160	160	86.1	0.966	13.32	47.97	221	10.60137	79.59
180	180	99.7	0.9726	17.45	47.97	298	14.29506	81.92
200	200	111.2	0.9744	21.65	47.97	375	17.98875	83.09
220	220	122.3	0.9751	26.23	47.97	462	22.16214	84.49
230	230	125.01	0.9741	28.02	47.97	494	23.69718	84.57
240	240	121.23	0.9687	28.21	47.97	494	23.69718	84.00
260	260	113.8	0.9619	28.42	47.97	494	23.69718	83.38
270	270	110	0.9595	28.49	47.97	494	23.69718	83.18

TABLE 3. SET I_O TO 700mA/48V

	V_{IN} (V)	I_{IN} (mA)	PF	P_{IN} (W)	V_O (V)	I_O (mA)	P_O (W)	EFF (%)
60	60	40.6	0.857	2.1	47.97	19	0.91143	43.40
80	80	64.84	0.9545	4.95	47.97	70	3.3579	67.84
100	100	73.37	0.959	7.03	47.97	107	5.13279	73.01
120	120	91.85	0.9645	10.76	47.97	173	8.29881	77.13
140	140	99.9	0.9773	13.67	47.97	228	10.93716	80.01
160	160	117.6	0.9837	18.55	47.97	315	15.11055	81.46
180	180	130.5	0.9846	22.97	47.97	396	18.99612	82.70
200	200	162.2	0.9883	32.15	47.97	561	26.91117	83.71
220	220	181.5	0.9874	39.43	47.97	697	33.43509	84.80
230	230	174.2	0.982	39.5	47.97	697	33.43509	84.65
240	240	168.3	0.9761	39.5	47.97	697	33.43509	84.65
260	260	154.6	0.9738	39.29	47.97	697	33.43509	85.10
270	270	148.2	0.9742	39.05	47.97	696	33.38712	85.50

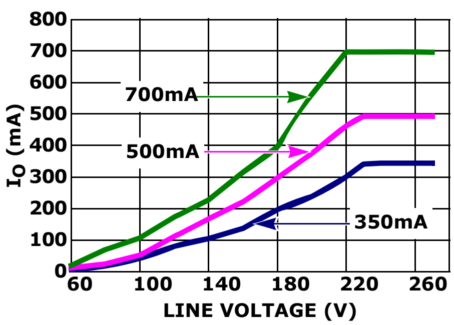

FIGURE 14A. OUTPUT CURRENT vs INPUT VOLTAGE

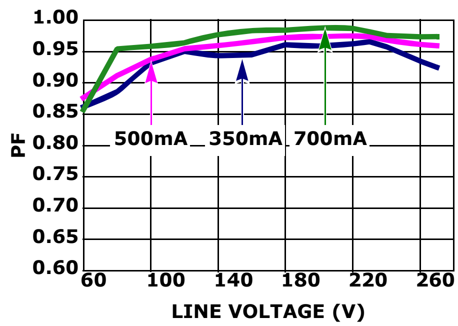

FIGURE 14B. PF vs LINE VOLTAGE

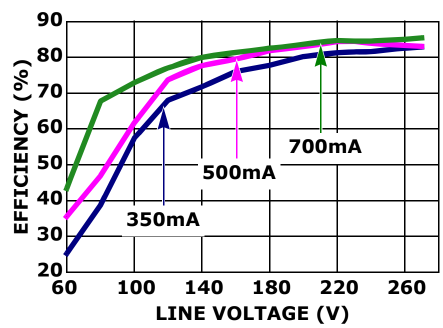

FIGURE 14C. EFFICIENCY vs LINE VOLTAGE

FIGURE 14. CHART OF THE DATA TABLE

The above test bypassed the inrush control circuit (R6, R7, R24 and R25 is shorted), which is necessary if the TRIAC dimming function is not needed. For better TRIAC dimming performance, the inrush control is necessary.

Following is efficiency test data with R6 = R7 = 100Ω and R24 = R25 = 25.5 Ω.

TABLE 4. SET I_O TO 700mA (WITH INRUSH CONTROL)

	V_{IN} (V)	I_{IN} (mA)	PF	P_{IN} (W)	V_O (V)	I_O (mA)	P_O (W)	EFF (%)
60	60	35.77	0.8944	1.85	47.97	13	0.62361	33.71
80	80	58.5	0.9651	4.52	47.97	59	2.83023	62.62
100	100	71.3	0.974	6.94	47.97	100	4.797	69.12
120	120	82.9	0.9834	9.735	47.97	150	7.1955	73.91
140	140	96.07	0.9833	13.22	47.97	211	10.12167	76.56
160	160	106.45	0.9881	16.77	47.97	275	13.19175	78.66
180	180	119.51	0.9887	21.25	47.97	353	16.93341	79.69
200	200	147.5	0.9912	28.5	47.97	477	22.88169	80.29
220	220	169.75	0.9913	36.94	47.97	622	29.83734	80.77
230	230	180.74	0.9852	41.08	47.97	696	33.38712	81.27
240	240	173.8	0.9763	41.09	47.97	696	33.38712	81.25
260	260	159.6	0.9715	40.7	47.97	696	33.38712	82.03
270	270	152.4	0.9746	40.45	47.97	693	33.24321	82.18

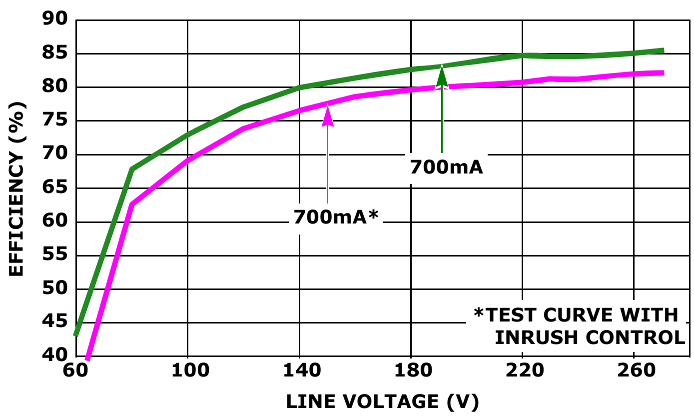

FIGURE 15. EFFECT OF INRUSH CONTROL ON EFFICIENCY

TRIAC Dimming

TABLE 5. LOAD = 1P9S (ONE STRING OF 9 LEDS IN SERIES)

IGNITION ANGLE (°)	I_{IN} (mA)	P_{IN} (W)	V_O (V)	I_O (mA)	P_O (W)	EFF (%)
0	111.1	24.81	29.84	692	20.64928	83.22967
30	120.6	25.35	30.12	696	20.96352	82.69633
60	132.5	21.95	29.29	587.7	17.21373	78.42247
90	121.5	14.1	28.23	362.8	10.24184	72.63719
120	100.1	6.31	26.41	134.9	3.562709	56.46132
130	91.7	4.54	25.86	85.9	2.221374	48.92894
140	70	2.52	24.87	36.6	0.910242	36.12071

TABLE 6. LOAD = 1P10S

IGNITION ANGLE (°)	I_{IN} (mA)	P_{IN} (W)	V_O (V)	I_O (mA)	P_O (W)	EFF (%)
0	125.3	28.15	33.88	693	23.47884	83.40618
30	134	28.31	33.77	692.2	23.37559	82.5701
60	139	24.83	33.26	592.5	19.70655	79.36589
90	125	15.76	31.97	366.7	11.7234	74.38705
120	96	6.56	30.1	136.7	4.11467	62.72363
130	86	4.6	29.34	85.8	2.517372	54.72548
140	73.1	2.81	28.33	42.7	1.209691	43.0495

TABLE 7. LOAD = 1P11S

IGNITION ANGLE (°)	I_{IN} (mA)	P_{IN} (W)	V_O (V)	I_O (mA)	P_O (W)	EFF (%)
0	139.1	31.32	37.68	693	26.11224	83.37241
30	147.1	31.53	37.62	692.5	26.05185	82.62559
60	150.5	27.13	36.9	585.7	21.61233	79.66211
90	131.5	17.2	35.6	361.1	12.85516	74.7393
120	96.5	6.83	33.28	136.6	4.546048	66.56
130	85	4.66	32.6	85.7	2.79382	59.95322
140	72	2.9	31.63	44.7	1.413861	48.75383

TABLE 8. LOAD = 1P12S

IGNITION ANGLE (°)	I_{IN} (mA)	P_{IN} (W)	V_O (V)	I_O (mA)	P_O (W)	EFF (%)
0	152.2	34.34	41.15	693.8	28.54987	83.13882
30	159.58	34.45	41.06	690.7	28.36014	82.32262
60	159.3	29.76	40.41	588.3	23.7732	79.88307
90	138.5	18.62	38.98	358.1	13.95874	74.96637
120	100.3	7.36	36.57	134.6	4.922322	66.87938
130	90	4.87	35.69	83	2.96227	60.8269
140	75.2	2.83	34.5	43.2	1.4904	52.66431

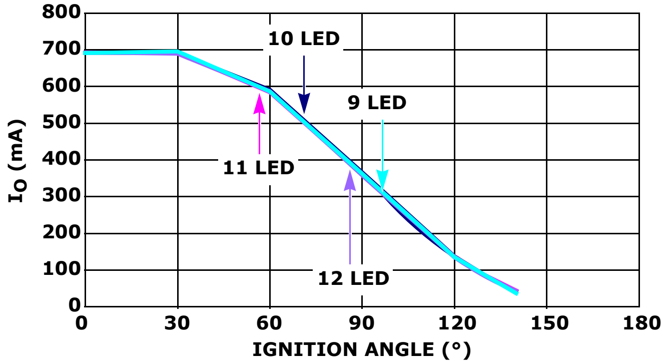

FIGURE 16A. I_O vs IGNITION ANGLE

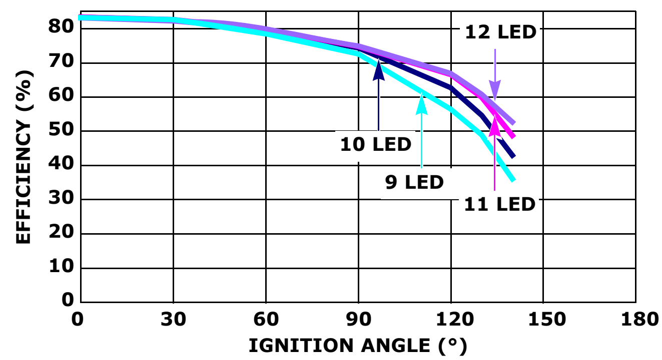

FIGURE 16B. EFFICIENCY vs IGNITION ANGLE

FIGURE 16. PLOTS OF DIMMING AND EFFICIENCY

THD of Input Current

$$THD = \frac{\sqrt{\sum_{n=2}^{\infty} I_n^{\ 2}}}{I_1} \qquad \text{(EQ. 4)}$$

TABLE 9. CURRENT THD (BY WT210, WITHOUT DIMMER) LOAD USE LED (CREE)

230V/700mA	230V/350mA
12.8%	16.9%

TABLE 10. HARMONICS OF INPUT CURRENT

ORDER	IN/I (%)	ORDER	IN/I (%)
1	/	2	0.467
3	9.89	4	0.543
5	4.453	6	0.175
7	3.296	8	0.176
9	3.191	10	0.369
11	0.285	12	0.284
13	2.965	14	0.109
15	0.77	16	0.212
17	1.003	18	0.112
19	1.255	20	0.199
21	0.529	22	0.091
23	1.007	24	0.334
25	0.61	26	0.257
27	0.913	28	0.106
29	0.492	30	0.083
31	0.783	32	0.038
33	1.332	34	0.512
35	1.02	36	0.949

TABLE 10. HARMONICS OF INPUT CURRENT (Continued)

ORDER	IN/I (%)	ORDER	IN/I (%)
37	0.249	38	0.904
39	0.594	40	0.852
41	0.124	42	0.837
43	0.065	44	0.328
45	0.179	46	0.169
47	0.377	48	0.036
49	0.688	50	0.116
		THD(%)	12.8

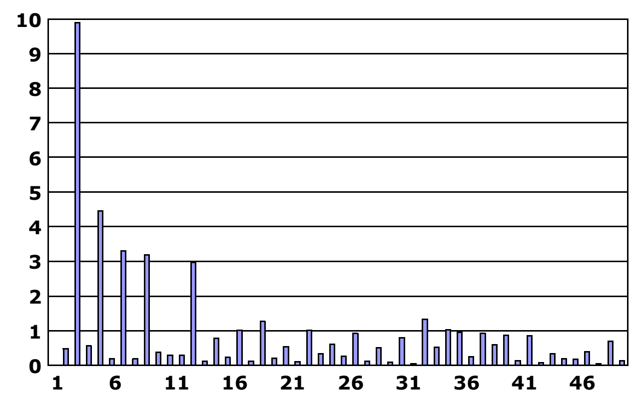

FIGURE 17. SPECTRUM OF INPUT CURRENT

Waveforms

Line Voltage and Current

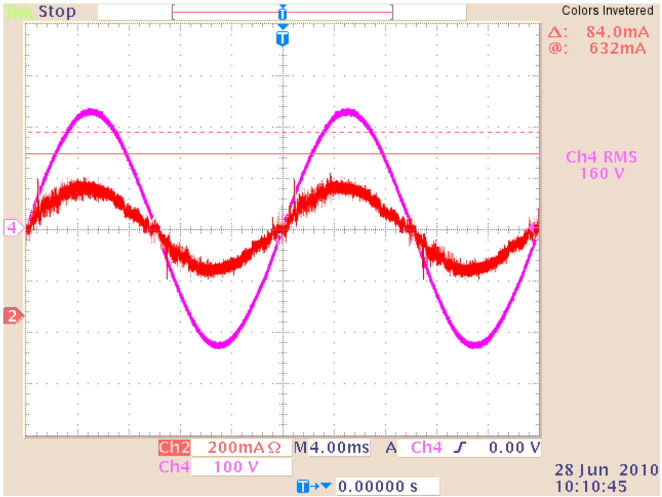

FIGURE 18A. V_{IN} = 160V

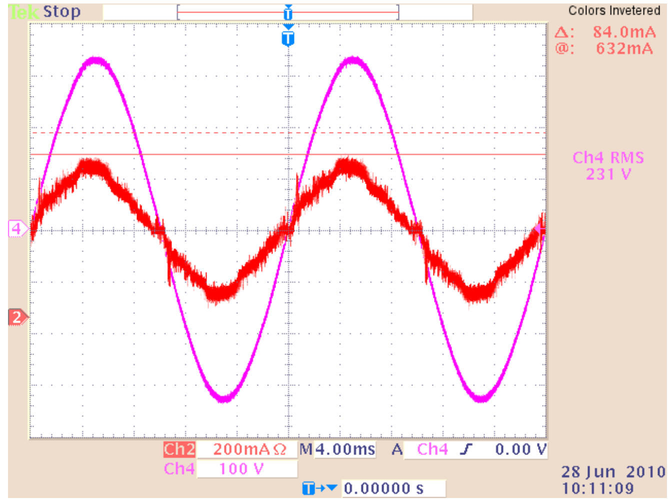

FIGURE 18B. V_{IN} = 230V

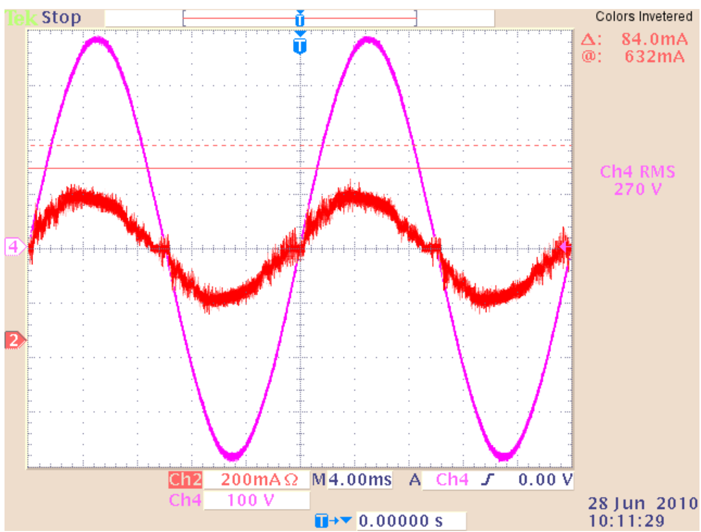

FIGURE 18C. V_{IN} = 270V

FIGURE 18. WAVEFORMS OF LINE CURRENT AND VOLTAGE; CH2: LINE CURRENT; CH4: LINE VOLTAGE; NO DIMMER

Line Voltage and Current (Continued)

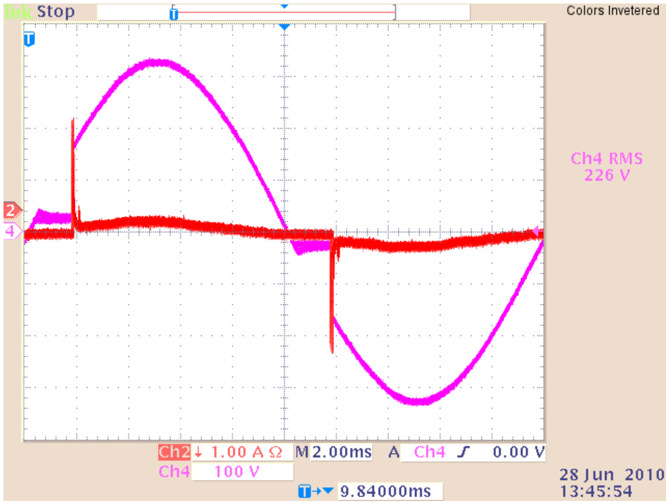

FIGURE 19A. IGNITION ANGLE IS 30°

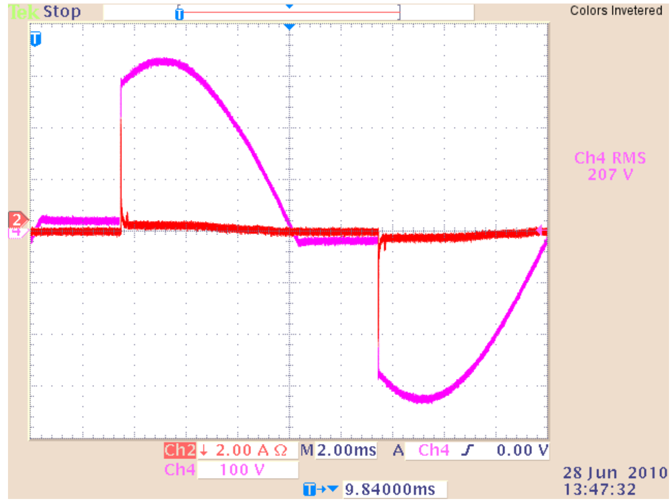

FIGURE 19B. IGNITION ANGLE IS 60°

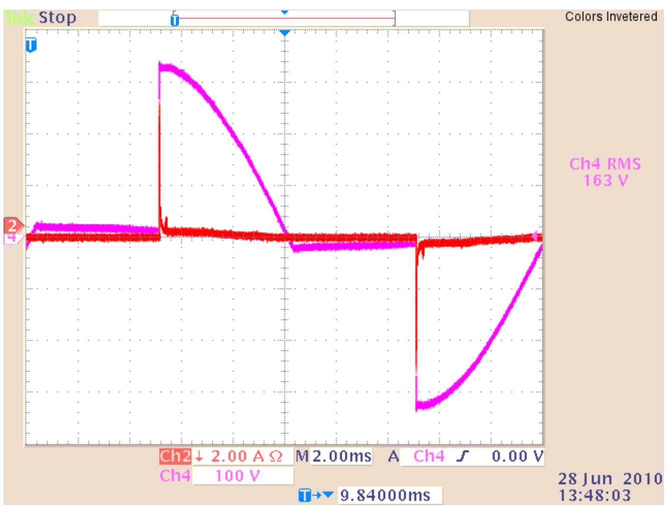

FIGURE 19C. IGNITION ANGLE IS 90°

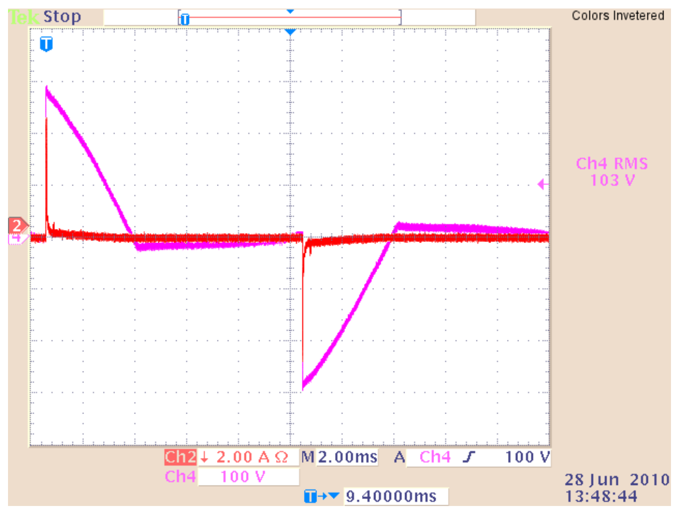

FIGURE 19D. IGNITION ANGLE IS 120°

FIGURE 19. WAVEFORM OF LINE CURRENT AND VOLTAGE (I_O = 700mA), CH2: LINE CURRENT; CH4: LINE VOLTAGE; V_{IN} = 230V_{AC}

Ripple Voltage and Output Current

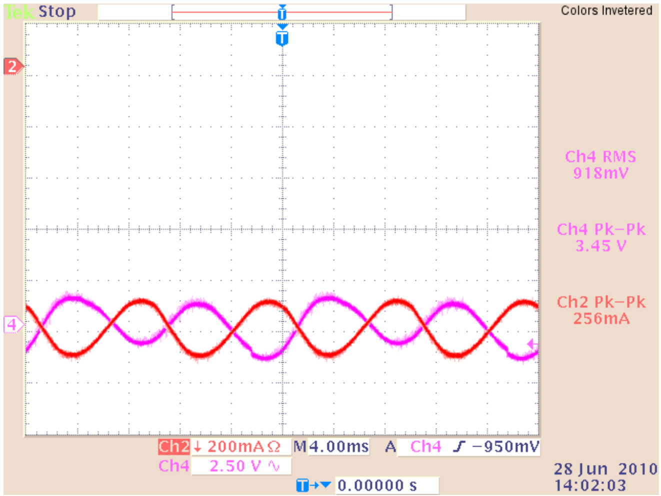

FIGURE 20A. IGNITION ANGLE IS 0°

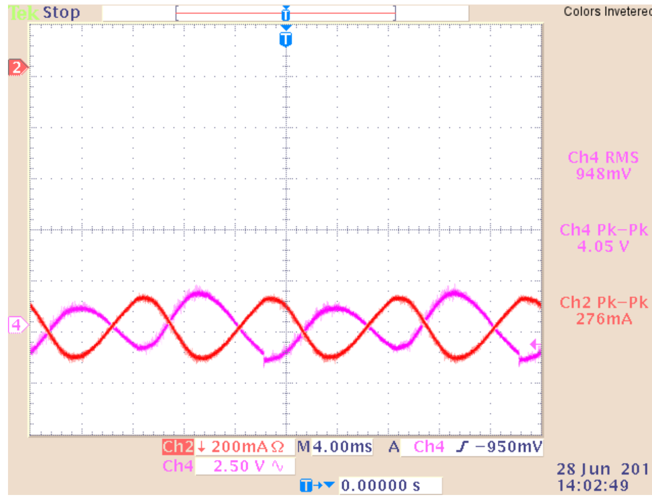

FIGURE 20B. IGNITION ANGLE IS 30°

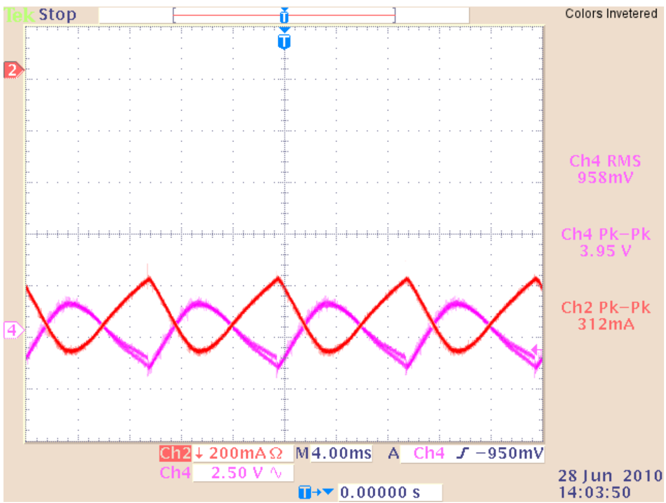

FIGURE 20C. IGNITION ANGLE IS 60°

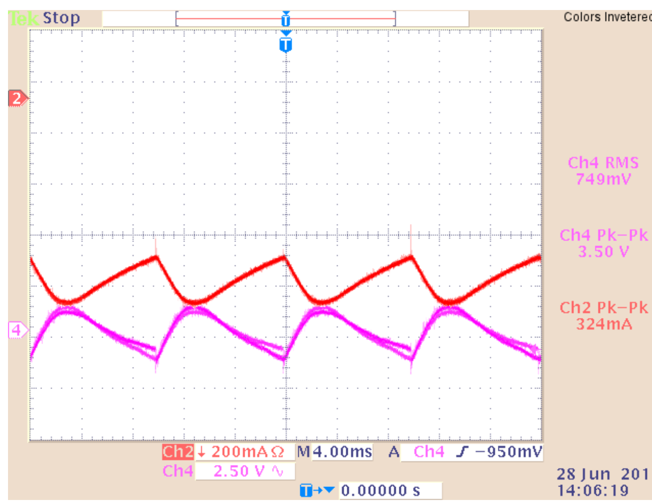

FIGURE 20D. IGNITION ANGLE IS 90°

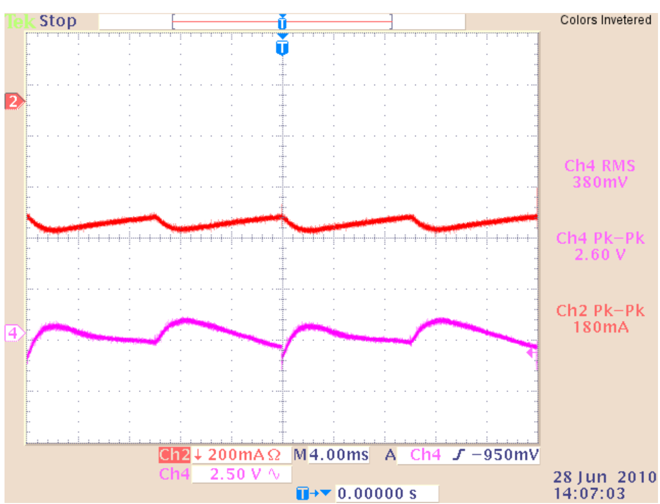

FIGURE 20E. IGNITION ANGLE IS 120°

FIGURE 20. WAVEFORM OF V_O AND I_O RIPPLE (V_{IN} = $230V_{AC}$); CH2: RIPPLE CURRENT; CH4: RIPPLE VOLTAGE

Voltage on Rectified DC Bus

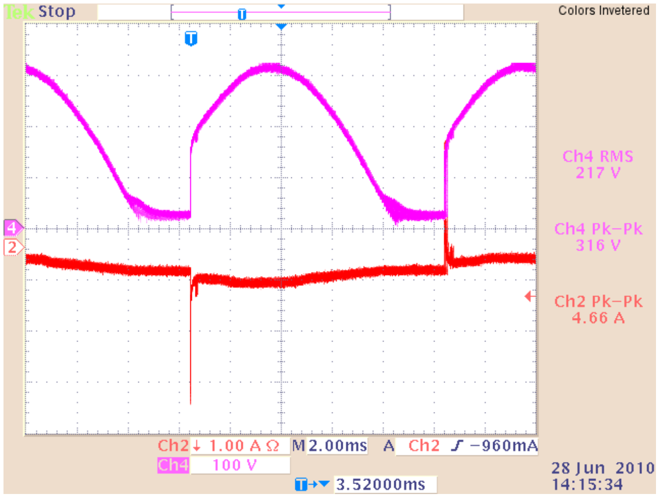

FIGURE 21A. D4(+)

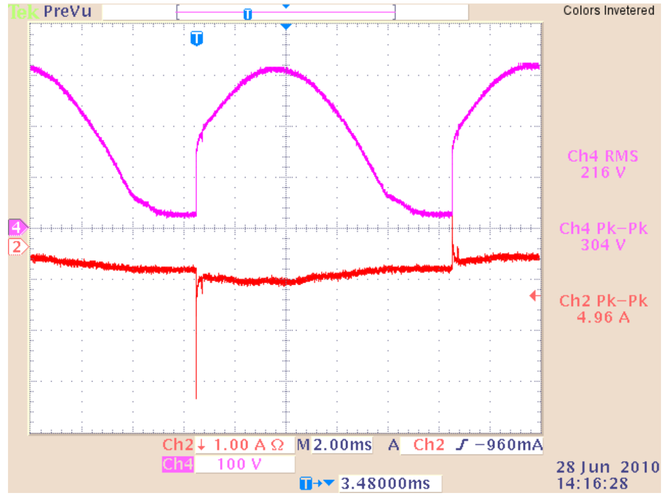

FIGURE 21B. VOLTAGE ON C1

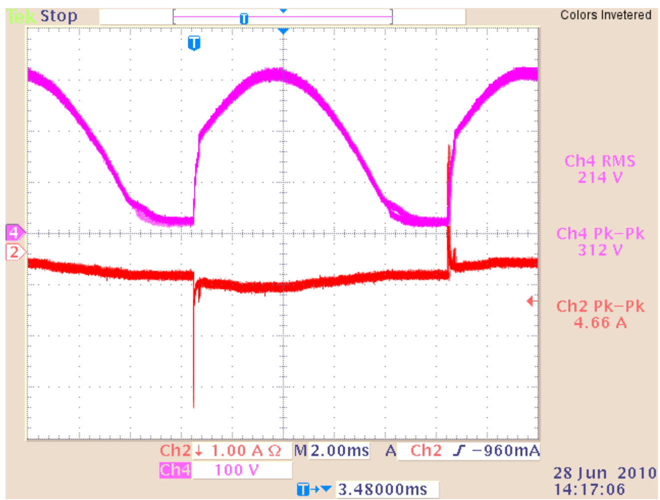

FIGURE 21C. VOLTAGE ON C2

FIGURE 21. RECTIFIED DC BUS, (IGNITION ANGLE = 30°); CH2: LINE CURRENT; CH4: VOLTAGE OF DC BUS

Voltage on Rectified DC Bus (Continued)

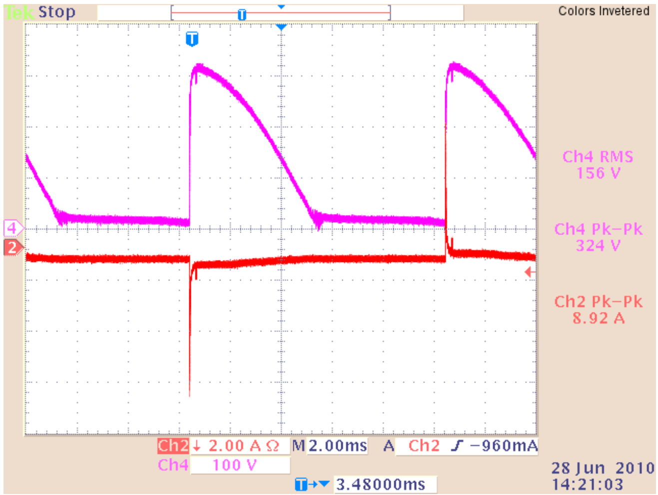

FIGURE 22A. D4(+)

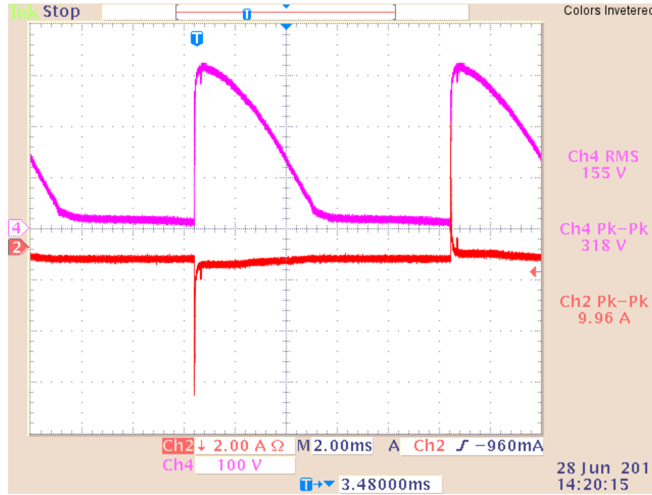

FIGURE 22B. VOLTAGE ON C1

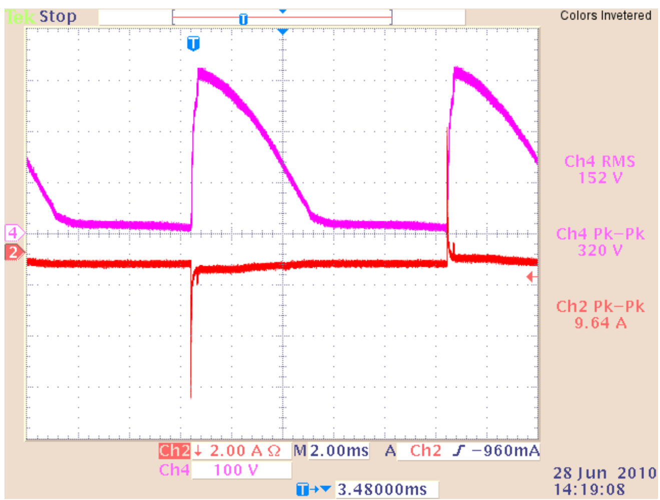

FIGURE 22C. VOLTAGE ON C2

FIGURE 22. RECTIFIED DC BUS, (IGNITION ANGLE = 90°)

Voltage on Rectified DC Bus (Continued)

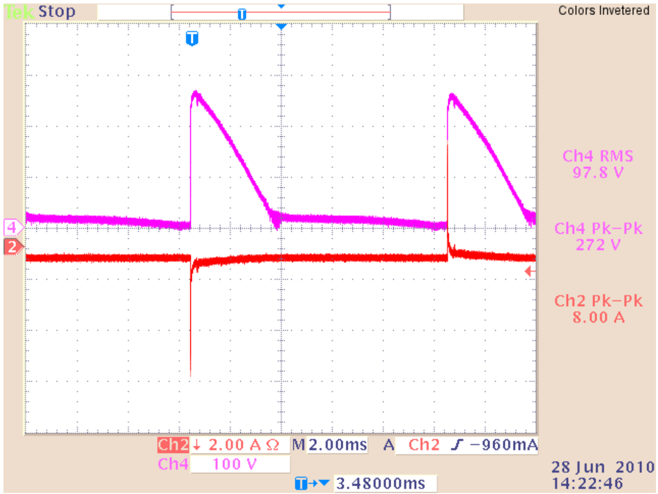

FIGURE 23A. D4(+)

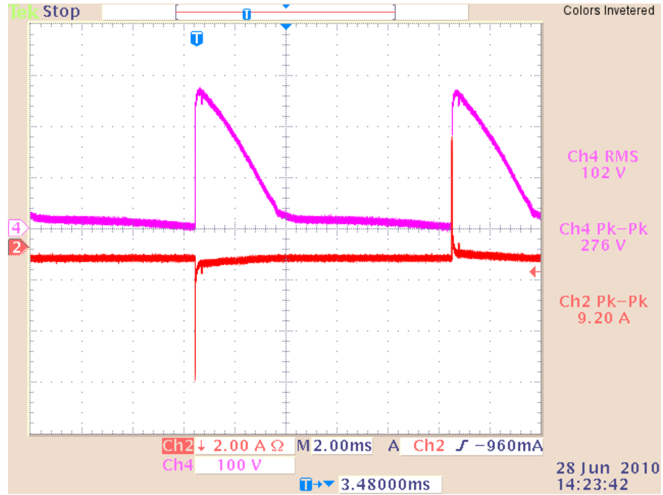

FIGURE 23B. VOLTAGE ON C1

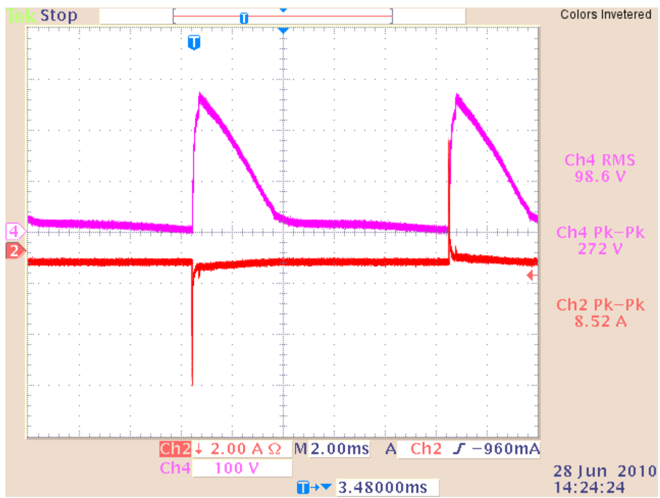

FIGURE 23C. VOLTAGE ON C2

FIGURE 23. RECTIFIED DC BUS, (IGNITION ANGLE = 120°)

Voltage on Snubber Capacitor

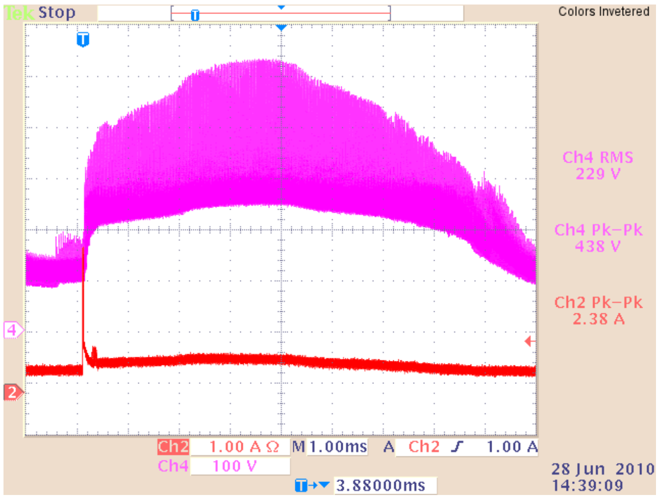

FIGURE 24A. IGNITION ANGLE = 30°

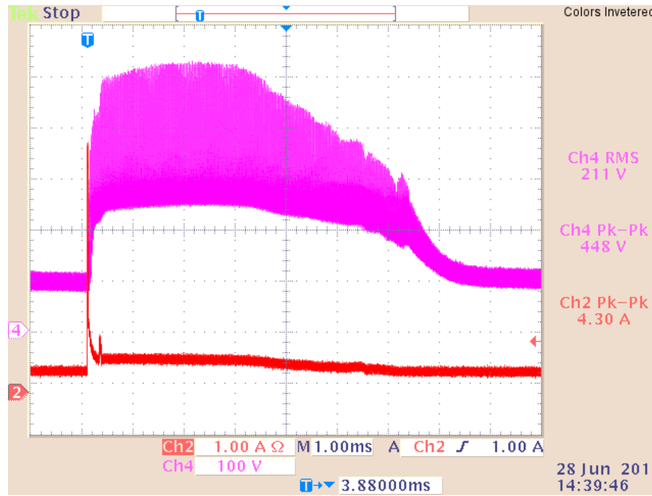

FIGURE 24B. IGNITION ANGLE = 60°

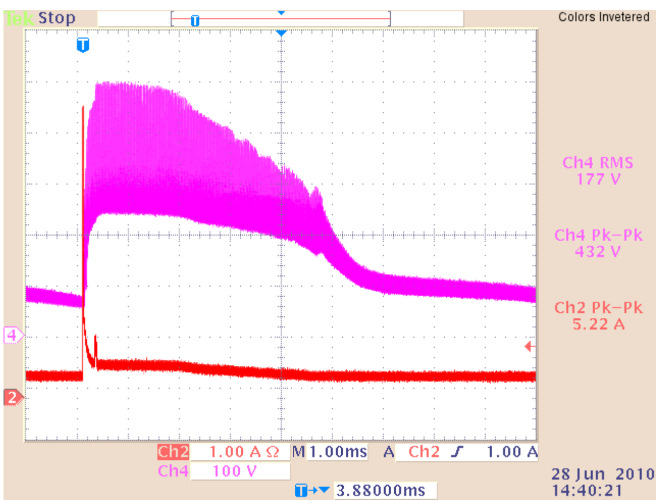

FIGURE 24C. IGNITION ANGLE = 90°

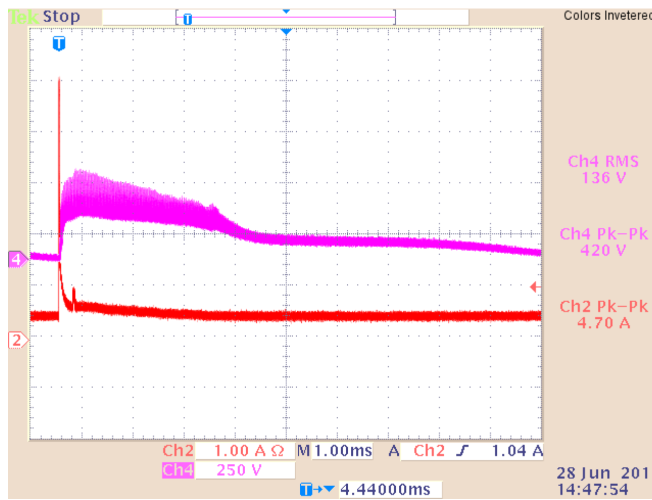

FIGURE 24D. IGNITION ANGLE = 120°

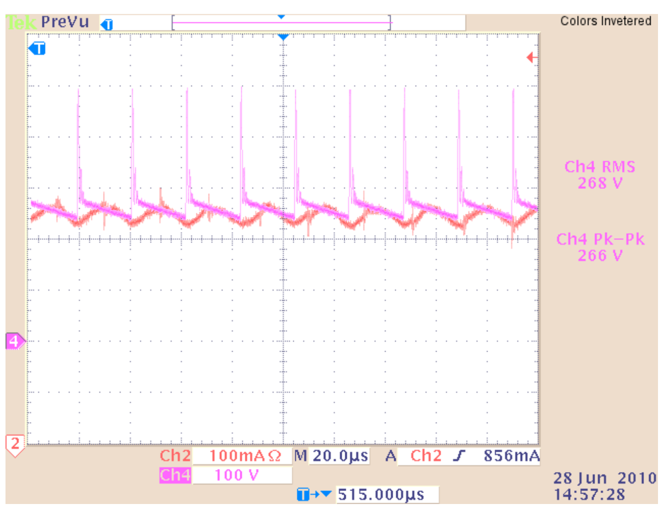

FIGURE 24E. IGNITION ANGLE = 90° (ZOOM IN)

FIGURE 24. WAVEFORM OF VOLTAGE ON SNUBBER CAPACITOR C4; CH2: LINE CURRENT; CH4: VOLTAGE ON C4

Inrush Control Circuit

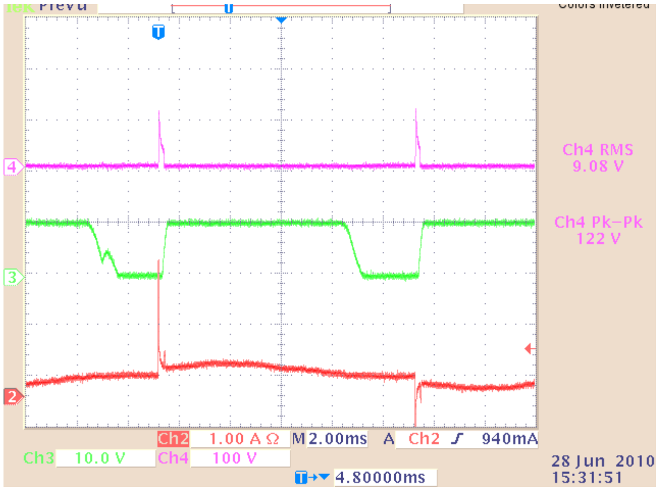

FIGURE 25A. IGNITION ANGLE = 30°

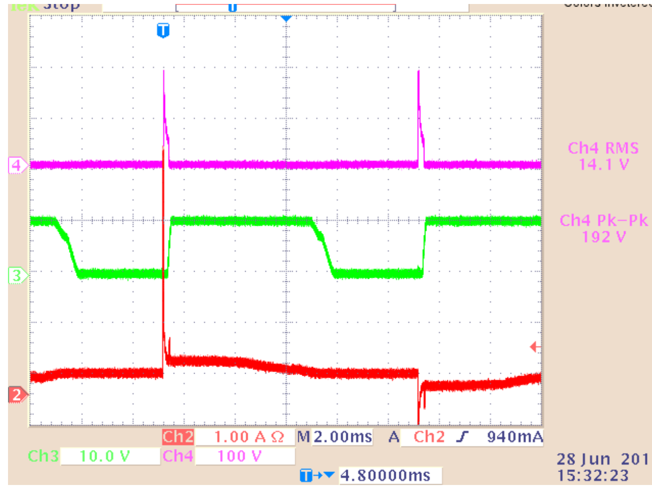

FIGURE 25B. IGNITION ANGLE = 60°

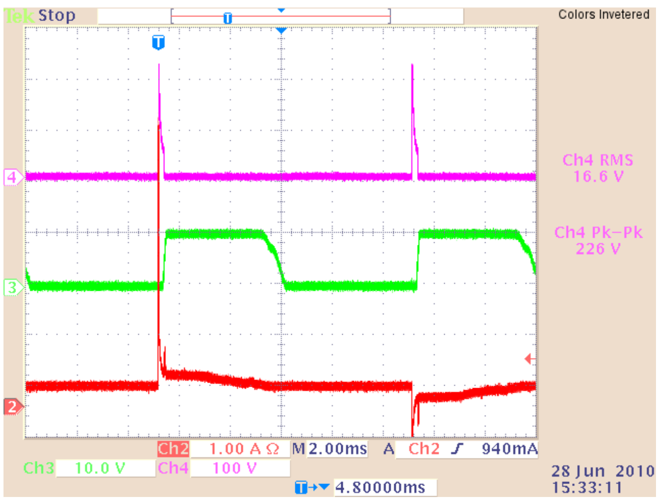

FIGURE 25C. IGNITION ANGLE = 90°

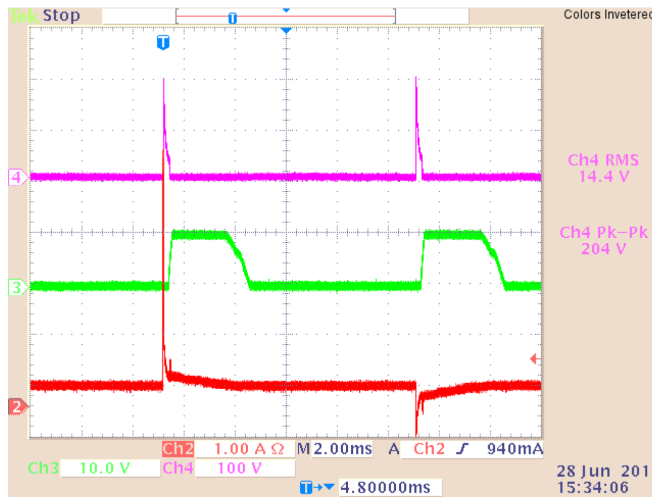

FIGURE 25D. IGNITION ANGLE = 120°

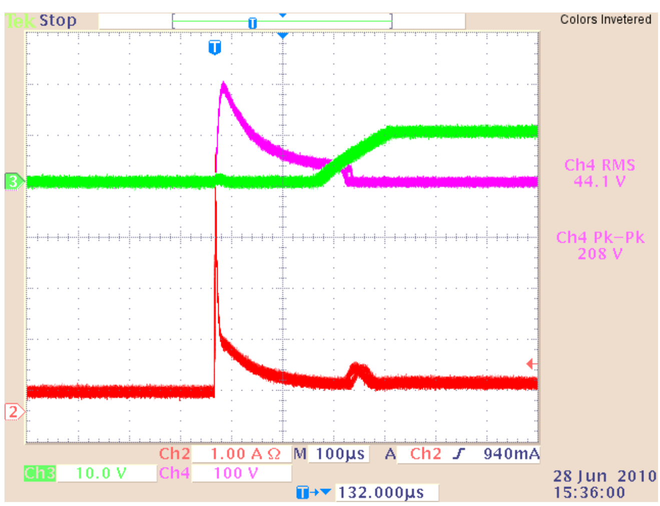

FIGURE 25E. IGNITION ANGLE = 120° (ZOOM IN)

FIGURE 25. VGS AND VDS OF Q3 (NEED AN ISOLATION TRANSFORMER TO PROBE THE WAVEFORM); CH2: LINE CURRENT; CH3:VGS; CH4: VDS

Reference

[1] Fred Greenfeld, Intersil Application Note AN1387, "White LED Driver Circuits for Off-Line Applications using Standard PWM Controllers"

Schematic [Patent Applications Pending]

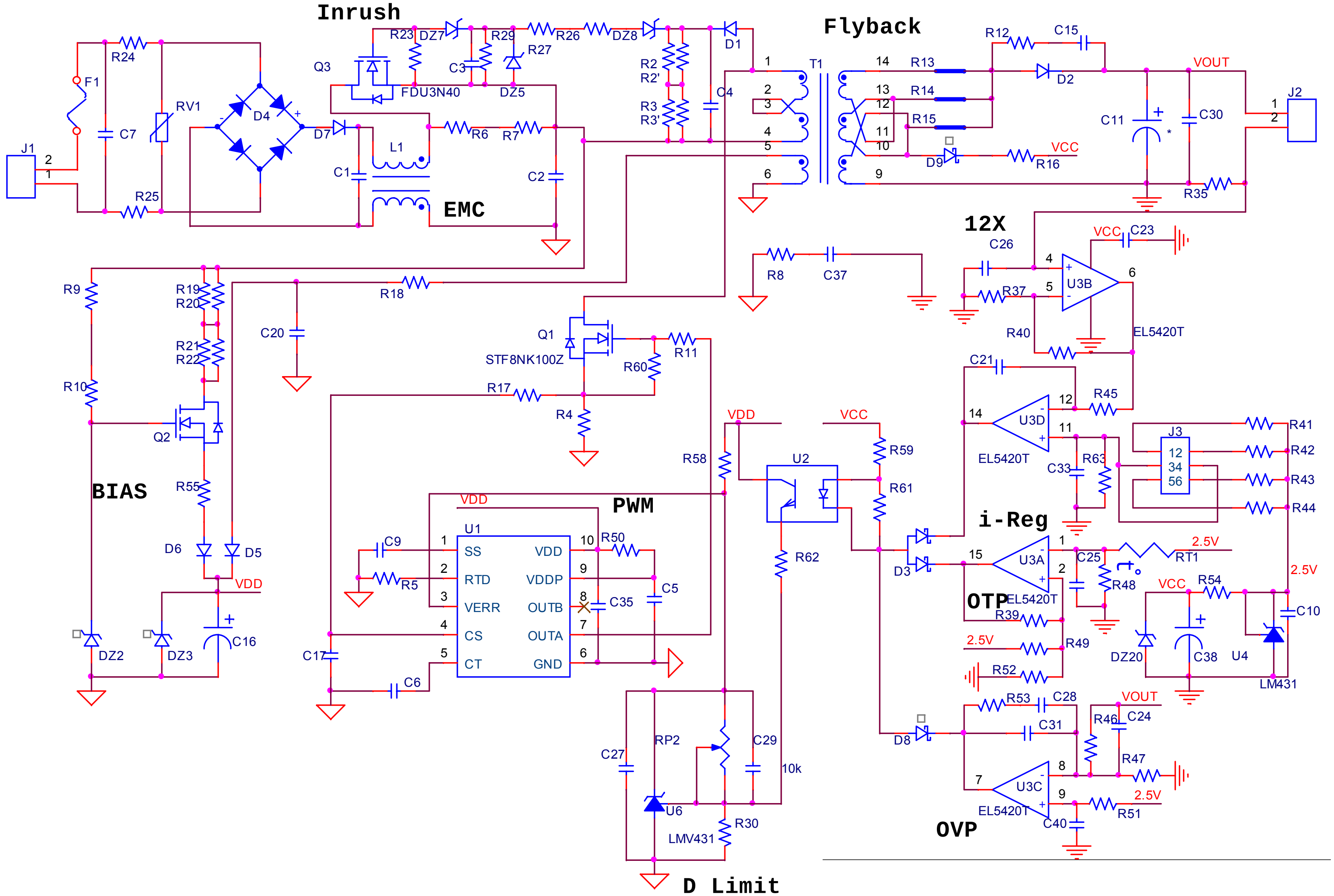

FIGURE 26. SCHEMATICS OF THE EVALUATION BOARD

TABLE 11. BILL OF MATERIALS

QTY	REFERENCE DESIGNATOR	DESCRIPTION	MANUFACTURER	MANUFACTURER PART
1	C37	CAP, RADIAL DISK, 15.5mm, 4700pF, 250V, 20%, X1Y1	TDK	CD16-E2GA472MYNS
1	C2	CAP, RADIAL, 17.5X17.5, 0.33µF, 250/275V, 20%, POLYFILM	PANASONIC	ECQ-U2A334ML
1	C31	CAP, SMD, 0402, 100pF, 25V, 10%, C0G	AVX	04023A101KA72A
2	C27, C40	CAP, SMD, 0402, 1000pF, 25V, 10%, X7R	MURATA	GRP155R71E102K
1	C29	CAP, SMD, 0402, 0.1µF, 25V, 10%, X5R	TDK	C1005X5R1E104K
1	C20	CAP, SMD, 0402, 47pF, 50V, 5%, NPO	MURATA	GRM36COG470J050AQ
1	C17	CAP, SMD, 0402, 470pF, 25V, 10%, X7R	MURATA	GRP155R71E471K
1	C3	CAP, SMD, 0603, 0.01µF, 25V, 10%, X7R	VENKEL	C0603X7R250-103KNE
6	C23, C24, C25, C26, C28, C33	CAP, SMD, 0603, 0.1µF, 25V, 10%, X7R	MURATA	GRM39X7R104K025AD
1	C30	CAP, SMD, 0603, 0.1µF, 50V, 10%, X7R	TDK	C1608X7R1H104K
1	C21	CAP, SMD, 0603, 1µF, 25V, 10%, X5R	MURATA	GRM188R61E105KA12D
1	C9	CAP, SMD, 0603, 2.2µF, 6.3V, 10%, X7R	MURATA	GCM188R70J225KE22D
1	C15	CAP, SMD, 0603, 47pF, 200V, 5%, C0G	KEMET	C0603C470J2GACTU
3	C5, C10, C35	CAP, SMD, 0603, 0.47µF, 25V, 10%, X7R	MURATA	GRM188R71E474KA12D
1	C6	CAP, SMD, 0603, 820pF, 50V, 5%, C0G	KEMET	C0603C821J5GACTU
1	C4	CAP, SMD, 1206, 2200pF, 630V, 10%, X7R	PANASONIC	ECJ-3FB2J222K
1	C7	CAP, RADIAL, DISK, 220pF, 300V, 10%, Y5S, X1/Y2, 7.5mmLS	VISHAY/BC COMPONENTS	VY2221K29Y5SS63V7
1	C11	CAP, RADIAL, 18X20, 1000µF, 50V,2 0%, ALUM.ELEC.	UNITED CHEMI-CON	EKY-500ELL102MM20S
2	C16, C38	CAP, RADIAL, 6.3X11, 100µF, 25V, 20%, ALUM.ELEC.	UNITED CHEMI-CON	EKZE250ELL101MF11D
1	J2	CONN-HEADER, 1X2,SOLID, 3.96mm, VERT, FRICTION LOCK	TYCO ELECTRONICS	1-1318300-2
1	J1	CONN-HEADER, 1X2, 5.08mm, VERT, FRICTION LOCK	MOLEX	10-32-1021
1	J3	CONN-HEADER, 2x3, BRKAWY 2X36, 2.54mm, VERTICAL	BERG/FCI	67996-272HLF
2	D5, D6	DIODE-RECTIFIER, 2P, SMD, SOD-523, 100V, 250mA	DIODES INC.	1N4148WT-7
1	D8	DIODE-SCHOTTKY, SMD, SOT23, 3P, 30V, 200mA, SINGLE DIODE	FAIRCHILD	BAT54
1	D3	DIODE-RECTIFIER, SMD, SOT23, 30V, 200mA	FAIRCHILD	BAT54A
1	DZ7	DIODE-ZENER, SMD, SOD-123, 15V, 500mW	DIODES, INC.	BZT52C15-7-F
1	DZ20	DIODE-ZENER, SMD, SOD-123, 16V, 500mW	DIODES, INC.	BZT52C16-7-F
1	DZ5	DIODE-ZENER, SMD, 2P, SOD-123, 24V, 500mW	DIODES, INC.	BZT52C24-7-F
1	DZ8	DIODE-ZENER, SMD, 2P, SOD-123F, 75V,3 75mW	DIODES, INC.	BZT52H-C75,115
1	DZ2	DIODE-ZENER, SMD, 3P, SOT23, 12V, 225mW, 5%	ON SEMICONDUCTOR	BZX84C12LT1G
1	DZ3	DIODE-ZENER, SMD, SOT-23, 3P, 18V, 0.250A	ON SEMICONDUCTOR	BZX84C18LT1G-T

TABLE 11. BILL OF MATERIALS (Continued)

QTY	REFERENCE DESIGNATOR	DESCRIPTION	MANUFACTURER	MANUFACTURER PART
1	D4	DIODE-RECTIFIER, 4P, SMD, DF-S(8.5X6.5), 1000V, 1A	DIODES, INC.	DF10S
1	D7	DIODE-RECTIFIER, SMD, 2P, SMA, 500V, 1A	FAIRCHILD	ES1H
1	D2	DIODE-RECTIFIER, SMD, DPAK(TO252), 200V, 6A	FAIRCHILD	FFD06UP20S
1	D9	DIODE-SWITCHING, SMD, SOT-23, 100V, 250mA	INFINEON TECHNOLOGY	MMBD914LT1
1	D1	DIODE-RECTIFIER, SMD, 2P, SMA, 1000V, 1A, 1.4W	FAIRCHILD	S1M
1	L1	COIL-COMMON MODE CHOKE, TH, 6P, 100mH, CUSTOM	MAIN POWER ELECTRIC CO.,LTD	J11-016-001
1	U3	IC-12MHz R/R OP AMP, 16P, QFN	INTERSIL	EL5420TILZ
1	U1	IC-BRIDGE CONTROLLER, 10P, MSOP	INTERSIL	ISL6745AAUZ
1	U4	IC-ADJ.ZENER SHUNT REGULATOR, SOT23, 2.5V	NATIONAL SEMICONDUCTOR	LM431BIM3/NOPB
1	U6	IC-ADJ.SHUNT REGULATOR, SMD, SOT-23-3, 1.24V, 0.5%	NATIONAL SEMICONDUCTOR	LMV431BIMF/NOPB
1	U2	IC-HI ISO PHOTOCOUPLER, 4P, SSOP	CALIFORNIA EASTERN LABORATORIES	PS2801-1-A
1	Q3	TRANSIST-MOS, N-CHANNEL, TH, I-PAK, 400V, 2A	FAIRCHILD	FDU3N40TU
1	Q2	TRANSISTOR-QFET, N-CHANNEL, SMD, DPAK, 600V, 1A	FAIRCHILD	FQD1N60CTM
1	Q1	TRANSIST-MOS, N-CHANNEL, TH, TO-220FP, 1000V, 6.5A	STMICROELECTRONICS	STF8NK100Z
1	RP2	POT-TRIM, 1/4 ROUND, TH, 3P, 10k, 0.5W, 10%, TOP ADJ	BOURNS	3329H-1-103LF
4	R19, R20, R21, R22	RES, SMD, 1206,100Ω, 1/2W, 1%, TF	VISHAY/DALE	CRCW1206100RFKEAHP
1	R50	RES, SMD, 0402, 10Ω, 1/16W, 1%, TF	PANASONIC	ERJ-2RKF10R0X
2	R16, R17	RES, SMD, 0402, 100Ω, 1/16W, 1%, TF	PANASONIC	ERJ-2RKF1000X
3	R48, R51, R53	RES, SMD, 0402, 1k, 1/16W, 1%, TF	VENKEL	CR0402-16W-102JT
3	R37, R58, R62	RES, SMD, 0402, 10k, 1/16W, 1%, TF	PANASONIC	ERJ-2RKF1002X
2	R45, R46	RES, SMD, 0402, 100k, 1/16W, 1%, TF	PANASONIC	ERJ2RKF1003
1	R40	RES, SMD, 0402, 110k, 1/16W, 1%, TF	VISHAY	CRCW0402110KFKED
1	R44	RES, SMD, 0402, 13k, 1/16W, 1%, TF	ROHM	MCR01MZPF1302
1	R63	RES, SMD, 0402, 20k, 1/16W, 1%, TF	PANASONIC	ERJ2RKF2001
1	R43	RES, SMD, 0402, 2.05k, 1/16W, 1%, TF	VISHAY	CRCW04022K05FKED
1	R42	RES, SMD, 0402, 26.1k, 1/16W, 1%, TF	VENKEL	CR0402-16W-2612FT
1	R49	RES, SMD, 0402, 27k, 1/16W, 1%, TF	ROHM	MCR01MZPF2702
1	R30	RES, SMD, 0402, 3.83k, 1/16W, 1%, TF	VENKEL	CR0402-16W-3831FT
1	R5	RES, SMD, 0402, 39.2k, 1/16W, 1%, TF	PANASONIC	ERJ-2RK3922X
1	R41	RES, SMD, 0402, 46.4k, 1/16W, 1%, TF	PANASONIC	ERJ2RKF4642
1	R52	RES, SMD, 0402,47kΩ, 1/16W, 1%, TF	ROHM	MCR01MZPF4702
1	R39	RES, SMD, 0402, 470k, 1/16W, 1%, TF	ROHM	MCR01MZPF4703
2	R54, R59	RES, SMD, 0402, 5.1k, 1/16W, 1%, TF	MULTICOMP	MC0402WGF5101TCE-TR
1	R47	RES, SMD, 0402, 5.11k, 1/16W, 1%, TF	PANASONIC	ERJ-2RKF5111X

TABLE 11. BILL OF MATERIALS (Continued)

QTY	REFERENCE DESIGNATOR	DESCRIPTION	MANUFACTURER	MANUFACTURER PART
0	R61	RES,SMD,0402, DNP, DNP, DNP, TF		
1	R18	RES, SMD, 0603, 10Ω, 1/10W, 1%, TF	KOA	RK73H1JT10R0F
1	R60	RES, SMD, 0603, 10k, 1/10W, 1%, TF	KOA	RK73H1JT1002F
2	R23, R29	RES, SMD, 0603, 39k, 1/10W, 1%, TF	PANASONIC	ERJ-3EKF3902V
1	R11	RES, SMD, 0805, 10Ω, 1/8W, 1%, TF	VENKEL	CR0805-8W-10R0FT
1	R13	RES, SMD, 0805, 0Ω, 1/8W, TF	YAGEO	RC0805JR-070RL
0	R14, R15	RES, SMD, 0805, DNP-PLACE HOLDER		
2	R12, R55	RES, SMD, 1206, 10Ω, 1/4W, 1%, TF	VENKEL	CR1206-4W-10R0FT
1	R8	RES, SMD, 1206, 0Ω, 1/4W, TF	VISHAY	CRCW1206-000Z
2	R9,R10	RES, SMD, 1206, 1M, 1/4W, 1%, TF	VENKEL	CR1206-4W-1004FT
4	R2', R2, R3', R3	RES, SMD, 1206, 300k, 1/4W, 1%, TF	YAGEO	RC1206FR-07300KL
2	R26,R27	RES,SMD,1206, 49.9k,1/4W,1%,TF	VENKEL	CR1206-4W-4992FT
1	R35	RES, SMD, 2512, 0.18Ω, 1W, 1%, TF	ROHM	MCR100JZHFLR180
1	R4	RES, SMD, 2512, 0.36Ω,1W, 1%, TF	VENKEL	CR2512-1W-R360FT
2	R24,R25	RES, AXIAL, 27Ω, 2W, 5%, MOF	YAGEO	RSF200JB-27R
2	R6,R7	RES, AXIAL, 100Ω, 2W, 5%, MOF	PANASONIC	ERG-2SJ101A
1	F1	FUSE-TIME-LAG, TH, 8.5X8.0, 1.60A, 250V, 601mW	LITTELFUSE	40011600440
1	C1	CAP-EMI, RADIAL, 10.5X18, 0.1µF, 305V, 20%, 15mmLS	EPCOS, INC	B32922C3104M
1	RT1	THERMISTOR-NTC, SMD, 0805, 22k, 5%, 210mW	EPCOS, INC	B57620C0223J062
1	RV1	TVS-VARISTOR, TYPE D, RADIAL, 14mm, 390V, 4500A	PANASONIC	ERZV14D391
1	T1	TRANSFORMER, TH, 23.5x20.3, 14P, 4 50µH, 5%, CUSTOM	COILCRAFT	CN7225-AL

Configuration Tables

TABLE 12. SELECT MAXIMUM OUTPUT VOLTAGE

	16V	32V	48V
NUMBER OF LEDS	3, 4	5, 6, 7, 8	9, 10, 11, 12
C11	3300µF/16V	1800µF/35V	1000µF/50V
VENDOR	Nichicon	Panasonic-ECG	United Chemi-Con
PART #	Nichicon UPW1C392MHD6 or Panasonic-ECG EEU-FC1C392S	1800µF/35V Panasonic-ECG EEU-FC1V182S	United Chemi-Con EKY-500ELL102MM20S
INTERNAL PART #	(N/A)	(N/A)	(N/A)
R47	15k(19.2V)	6.8k(39.3)	5.11k(51.4V)
VENDOR	Panasonic-ECG	Panasonic-ECG	Panasonic-ECG
PART #	ERJ-2RKF1502X	ERJ-2RKF6801X	ERJ-2RKF5111X
INTERNAL PART #	H2510-01502-1/16W1	H2510-06801-1/16W1	H2510-05111-1/16W1
R13	Open	Open	Shorted
R14	Open	Shorted	Open
R15	Shorted	Open	Open

TABLE 13. PROGRAM THE OUTPUT CURRENT

	350mA	500mA	700mA	1.05A
J3	1, 3	2, 4	3, 5	4, 6

TABLE 14. ADJUST THE RP2 FOR DIFFERENT V_O AND I_O COMBINATION

	350mA	500mA	700mA	1050mA
16V	Depending on the V_O and I_O, Adjust RP2 so that the output current can not be greater than the set value unless the input is equal to, or greater than, nominal line voltage (220 or 230 V).			
32V				
48V				

Low Line Version

TABLE 15. CHANGE FOR LOW LINE VERSION

	LOW LINE VERSION (THE PARAMETERS NEED MORE TEST FOR VERIFYING)	HIGH LINE VERSION
T1	For Pin 1~4: Pin 1, 2 connected; Pin 3, 4 connected.	For Pin 1~4: Pin 2, 3 connected.
R29	100k	30k
DZ8	0V (shorted)	75V
R6, R7	43Ω/2W,	100Ω/2W
R24, R25	5.6Ω/3W for Rev.D 16Ω/2W for Rev.B	27Ω/2W for Rev.D 36Ω/1W for Rev.B
R4	0.18Ω	0.36Ω
C1	220nF for Rev.D 100nF for Rev.B	100nF
C2	680nF for Rev.D 220nF for Rev.B	100nF for Rev.D 330nF for Rev.B