Using the UCC25710EVM-654

User's Guide

Literature Number: SLUU487A
March 2011–Revised March 2011

98-W Resonant LLC, 4-String LED Driver

1 Introduction

The UCC25710 Evaluation Module (EVM) was design to demonstrate how the UCC25710 could be used in a multi-transformer LLC half-bridge configuration for driving multiple strings of LEDs, in a high-efficiency application, for the back lighting of a digital TV, with Pulse With Modulation (PWM) dimming.

2 Description

This 98-W evaluation module (EVM) was designed to drive four 98-V, 250-mA LED strings from an isolated 370-V to 410-V input voltage. The EVM was designed to achieve PWM dimming with a 270-Hz to 330-Hz TTL dimming signal capable of dimming down to 1% duty cycle.

2.1 Typical Applications for Multi-String LED Driver

- LED Backlight for LCD Digital TVs and Monitors
- LED General Lighting

2.2 Features

- Zero Voltage Switching
- PWM Dimming
- Accurate LED Current Sharing with Signal Current Control Signal

3 Electrical Performance Specifications

Table 1. UCC285710 EVM-654 Electrical Specifications

PARAMETER		MIN	TYP	MAX	UNITS
Input Characteristics					
V_{IN}	Input voltage	370	390	410	V
I_{IN}	Input current		0.275		A
OUTPUT1, OUTPUT2, OUTPUT3, OUTPUT4 Characteristics					
V_{LED1}, V_{LED2}, V_{LED3}, V_{LED4}	Output voltage set by LED load	96	98	100	V
I_{LED1}, I_{LED2}, I_{LED3}, I_{LED4}	Output current ripple			0.0125	A_{P-P}
I_{LED1}, I_{LED2}, I_{LED3}, I_{LED4}	Output current	0.245	0.25	0.255	A
I_{LED1}, I_{LED2}, I_{LED3}, I_{LED4}	Line regulation	0.245	0.25	0.255	
I_{LED1}, I_{LED2}, I_{LED3}, I_{LED4}	Load regulation	0.245	0.25	0.255	
V_{OVP}	Single output OVP		136		V
V_{UV}	Single output under voltage		43		
	Dimming range	1%		100%	
	Dimming frequency	270	300	330	Hz
	Current matching between strings (10% to 100% dimming)	-2%		2%	
	Output power single output			24.5	W
	Full output power			98	
Systems Characteristics					
F_{SW}	Switching frequency	84		156	kHz
η	Full load efficiency	91%	93%		

4 Schematics

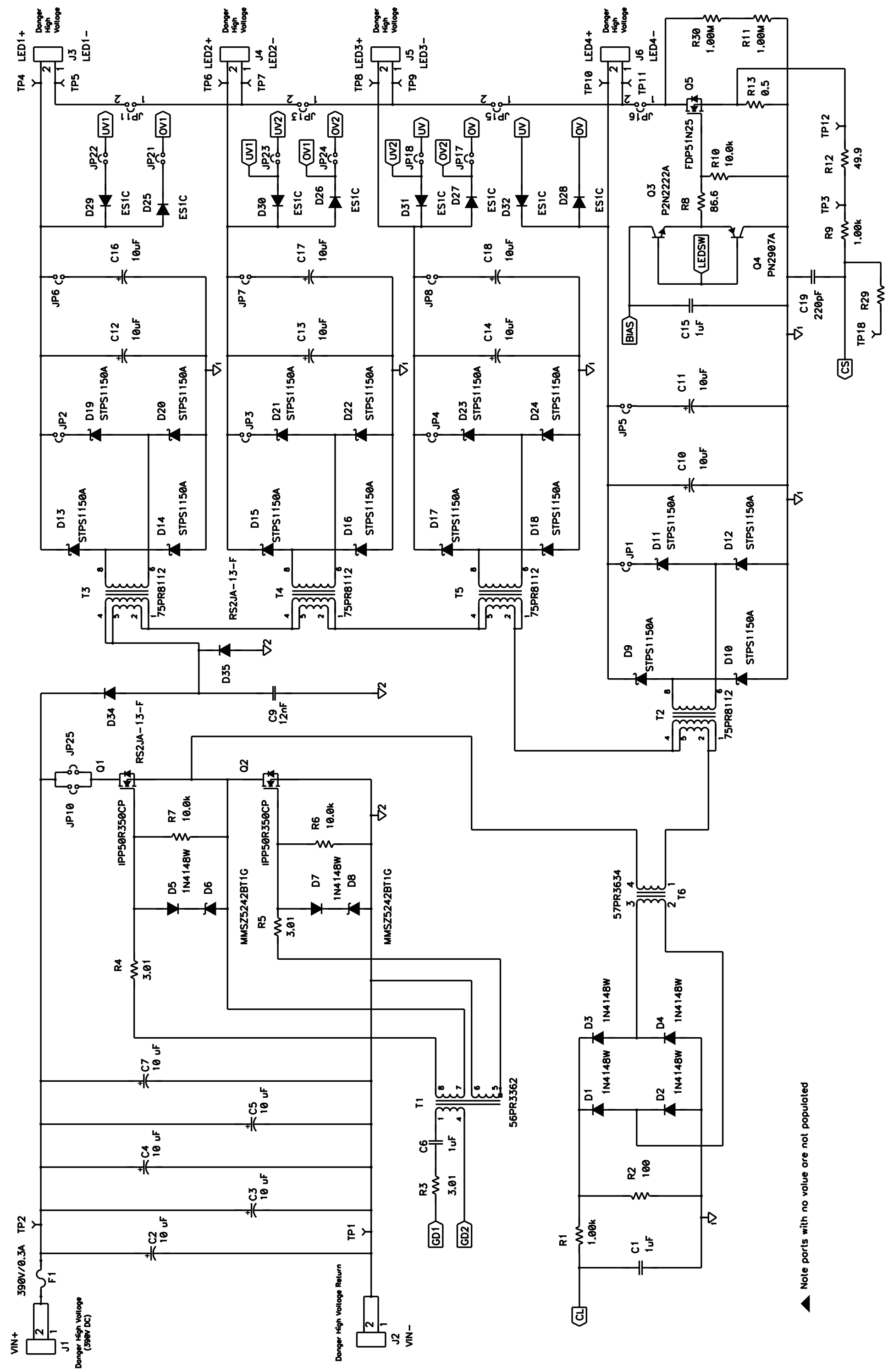

Figure 1. UCC25710EVM-654 Power Stage Schematic

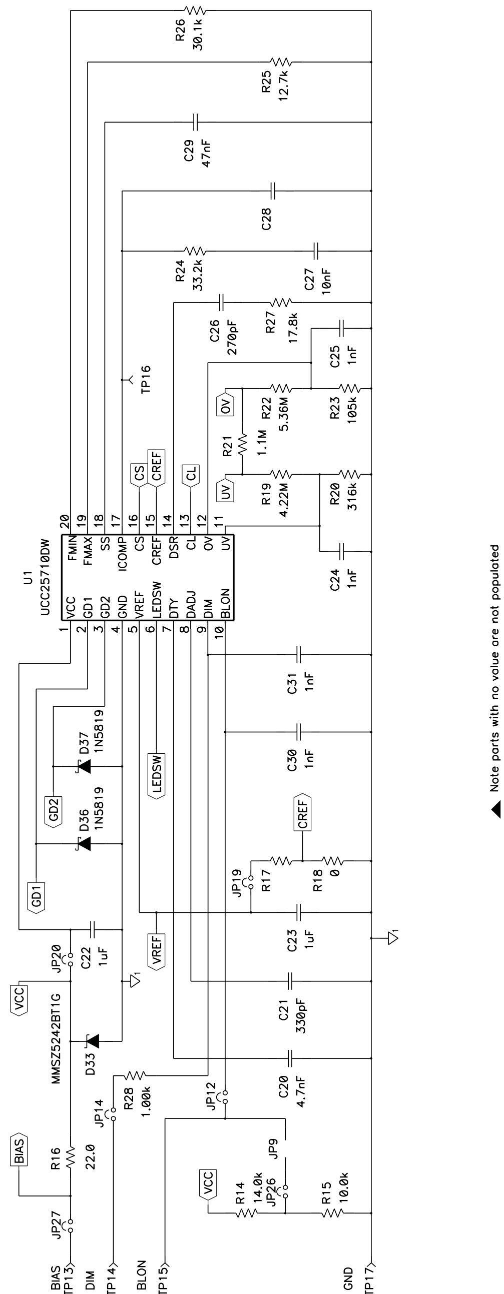

Figure 2. UCC25710EVM-654 Controller Circuitry Schematic

5 Recommended Test Equipment

5.1 Voltage Sources

- 500-V DC Source Capable of 150 W
- 0-V to 20-V DC Power Supply Capable of 2 W

5.2 Volt Meters

- Two Volt Meters
- Five Current Meters

5.3 Square Wave Generator

- Capable of generating a 270-Hz to 330-Hz square wave with a 0-V to 5-V signal.
- Capable of duty cycles from 1% to 100% (DC).

5.4 Network Analyzer

- Needed to measure voltage loop stability if interested.

5.5 Output Loads

This EVM was design to power LED diode loads only, for proper operation it is recommend that LED diodes be used. Please refer to Figure 3 and Figure 4 for example test setups.

- The EVM feedback circuitry was designed based on an LED load. If another load is used the feedback circuitry will not operate correctly and the EVM will not function properly.
- It is recommended that 32 LEDs be used on each output as a load with the following characteristics.
  - Capable of handling 275 mA.
  - With a $V_f \approx 3.06$ V at 250 mA.
  - Note that different diodes with a different V_f can be used as long as the total voltage drop across the output is 98 V +/- 2 V at 250 mA.
- Note to evaluate performance and save on the number of diodes used. All four outputs can be used in parallel to power one string of LEDs.
  - Capable of handling 1.1 A
  - With a $V_f \approx 3.06$ V at 1 A
  - Note that different diodes with a different V_f can be used as long as the total voltage drop across the output is 98 V +/- 2 V at 1 A.

5.6 Oscilloscope

- 4-Channel, 100 MHz
- Probes Capable of 500 V or Differential Probes

5.7 Recommended Wire Gauge

- 20 AWG

6 Recommended Test Setups

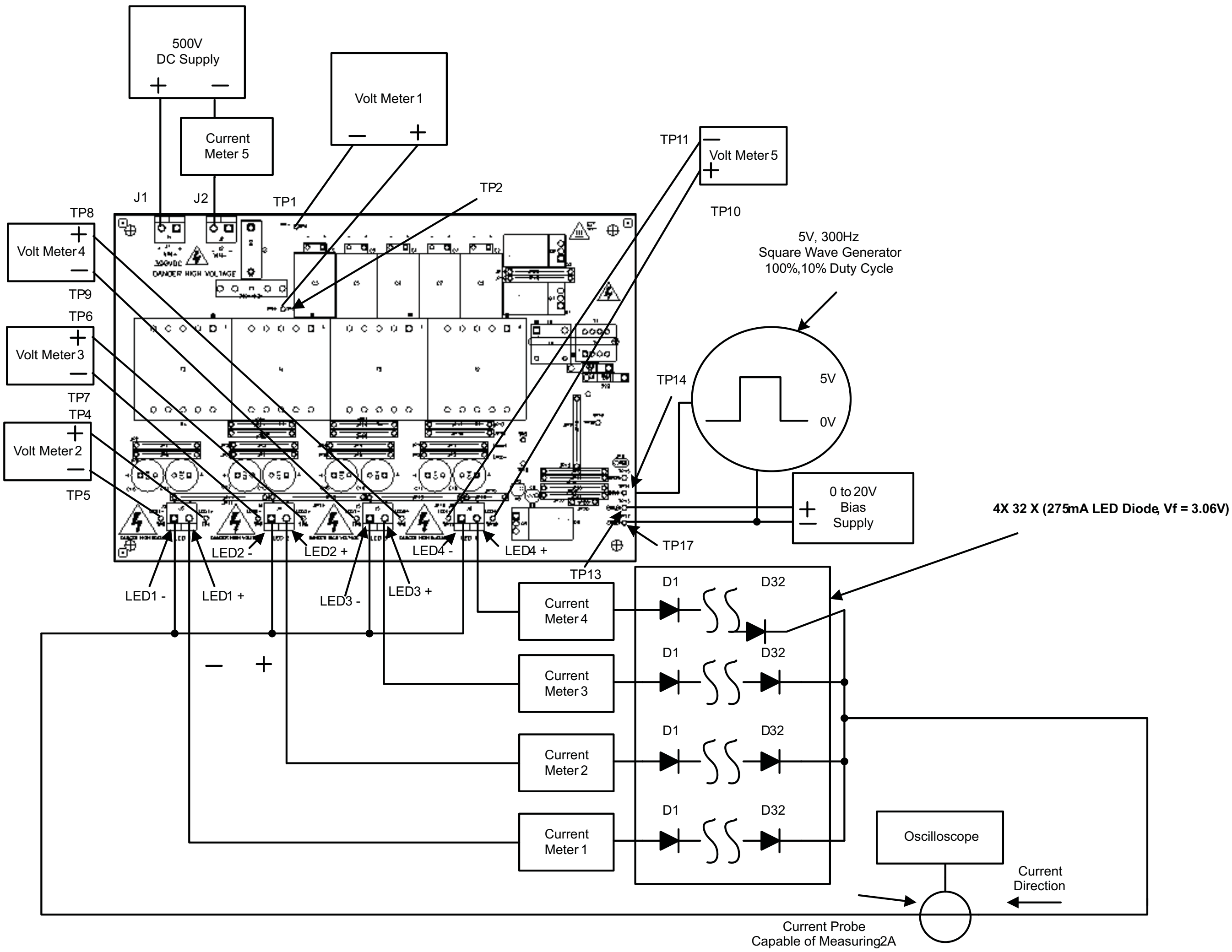

Figure 3. Setup 1 Evaluate Current Sharing With 4 x 32 x 275-mA LED Strings

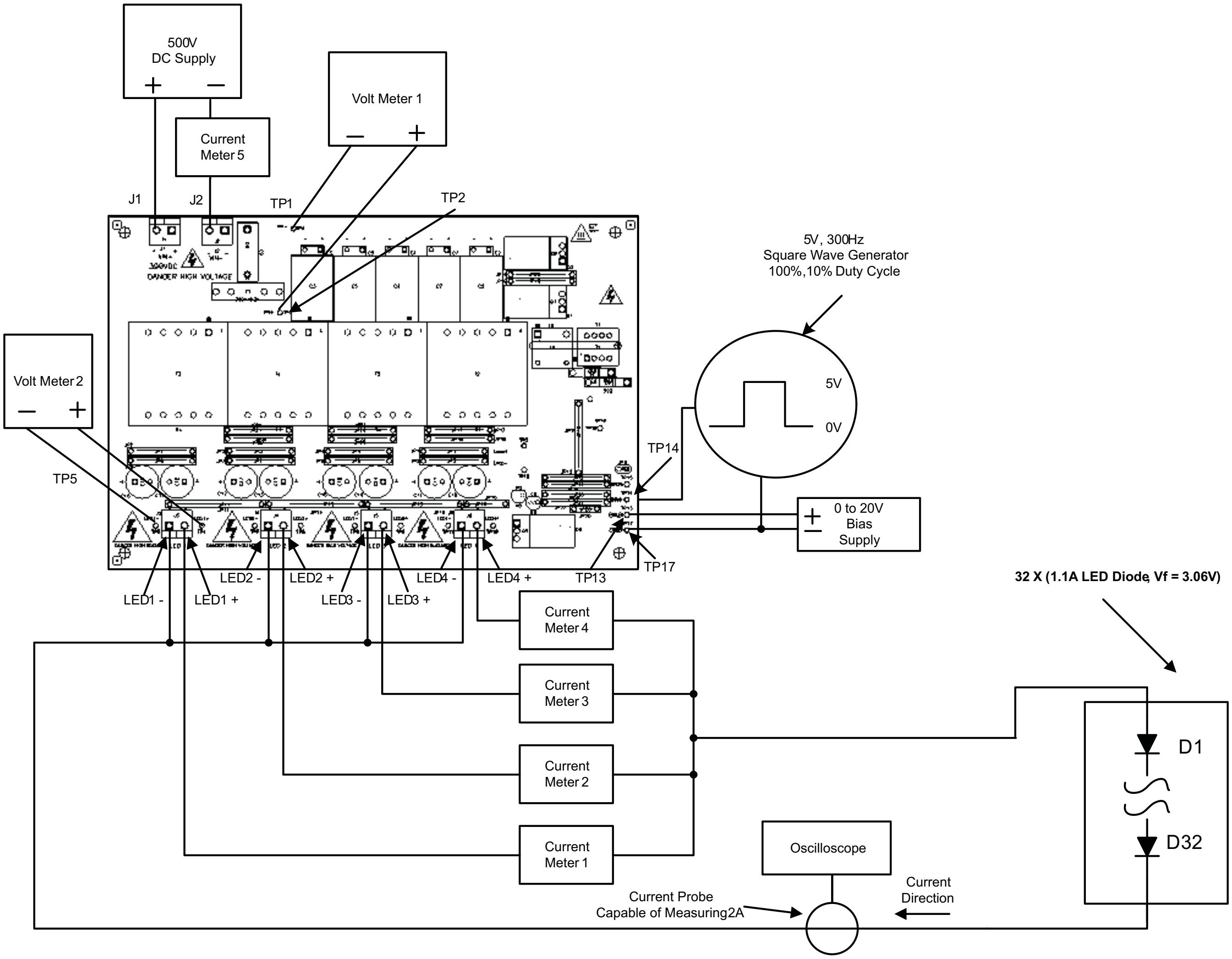

Figure 4. Test Setup 2 Evaluate Current Sharing With 1 x 32 x 1.1-A LED String

7 List of Test Points

Table 2. Test Point Description

TEST POINTS	NAME	DESCRIPTION
TP1	VIN -	Input return
TP2	VIN +	Input supply
TP3, TP12	N/A	Current loop injection point (20-mV injection max)
TP4	LED1 +	LED string 1 supply
TP5	LED1 -	LED string 1 return
TP6	LED2 +	LED string 2 supply
TP7	LED2 -	LED string 2 return
TP8	LED3 +	LED string 3 supply
TP9	LED3 -	LED string 3 return
TP10	LED4 +	LED string 4 supply
TP11	LED4 -	LED string 4 return
TP13	BIAS	Positive input for 12-V bias supply
TP14	DIM	PWM Dimming Input
TP15	BLON	Back light on control (remove jp9 before using)
TP16	ICOMP	Compensation output
TP17	GND	Logic ground
TP18	N/A	Current sense offset

8 Power On/Off Procedure

WARNING

Failure to follow the Power On/Off Procedure may result in unexpected operation and/or irreversible damage to the EVM and/or individual.

1. It is important to follow the power up and power down procedure to ensure the EVM does not get damaged
2. This EVM was designed to show the performance of the UCC25710 in a four-string LED driver application using an LLC resonant converter and does not include all the circuitry required for this application.
   (a) Generally this power converter would be preceded by an EMI filter and a PFC pre-regulator. The complete system would also included input Under Voltage Lockout (UVLO) circuitry; which this EVM does not.
3. Connect all bias supplies, loads and test equipment before applying power. Please look at Figure 3 and Figure 4 for examples of test setups that could be used.
4. The EVM was not designed to startup from 0-V input voltage. Please make sure the input voltage is in-between 370 V and 410 V before applying the bias voltage.
5. Apply 370-V to 410-V DC to the input of the power converter with the 500-V DC source.
6. Set the 0-V to 20-V power supply to 12 V, (This powers the UCC25710 LLC controller).
7. When powering down the unit set the 0-V to 20-V DC supply to 0 V before powering down the 500-V DC Supply.
8. Set the 500-V DC Supply to 0 V.
9. For safety before handling the EVM make sure there are not voltages present on the EVM greater than 50 V, (Observe Volt Meter 1 and Volt Meter 2).

9 Test Data

9.1 Current Matching With PWM Dimming

The following table was taken with a 300-Hz PWM dimming frequency. Each LED output was loaded with 32 Cree XLamp XR-E diodes. At full load the current was controlled to a target current of 250 mA through each LED output string.

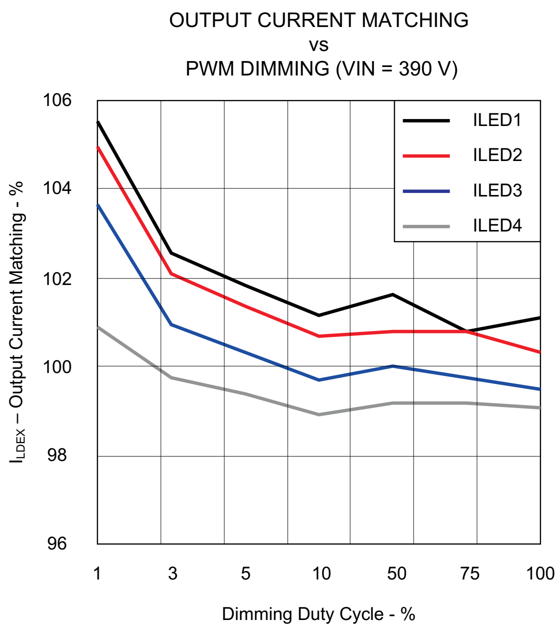

Figure 5. V_{IN} = 390 V, Current Matching

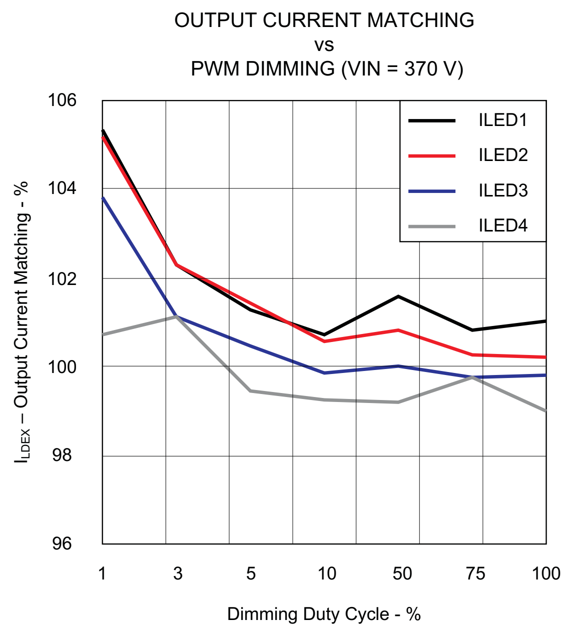

Figure 6. V_{IN} = 370 V, Current Matching

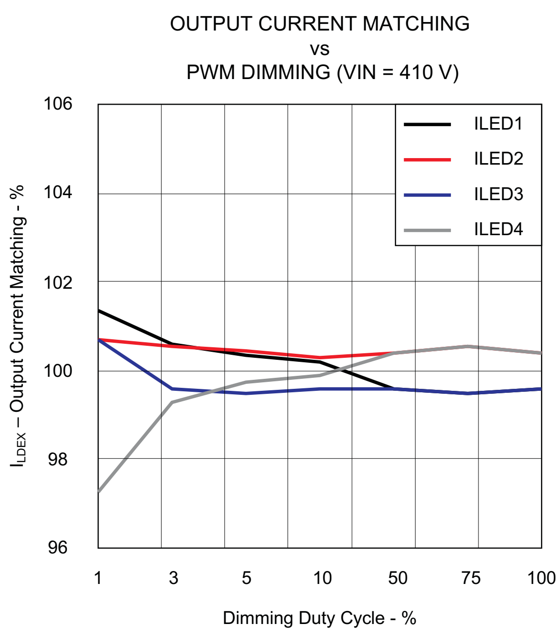

Figure 7. V_{IN} = 410 V, Current Matching

9.2 Efficiency

Measuring efficiency with PWM dimming requires the use of power analyzers on the LED output/s. The following efficiency table was taken with LED voltage strings set to roughly 98 V.

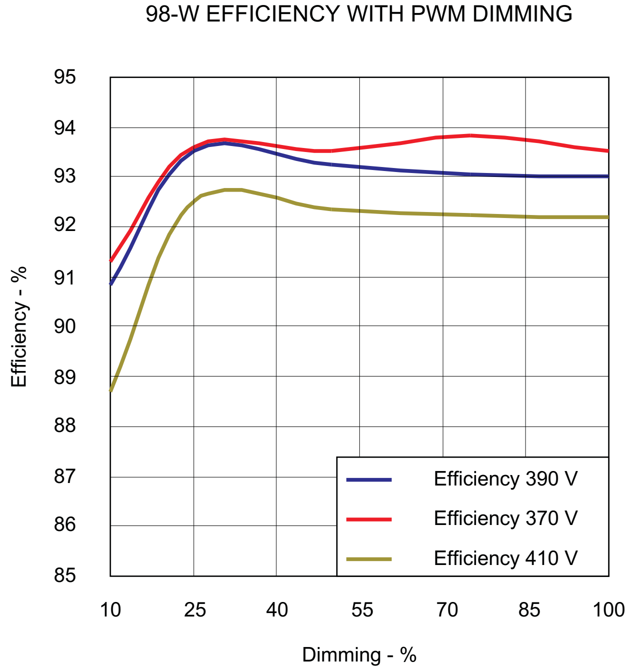

Figure 8. Efficiency 10% to 100% PWM Dimming

9.3 Control Loop Frequency Response

Current loop crossed over at roughly 5 kHz with greater than 45 degrees of phase margin. Each LED output was loaded with 32 Cree XLamp XR-E diodes. At full load the current was controlled to a target current of 250 mA through each LED output string.

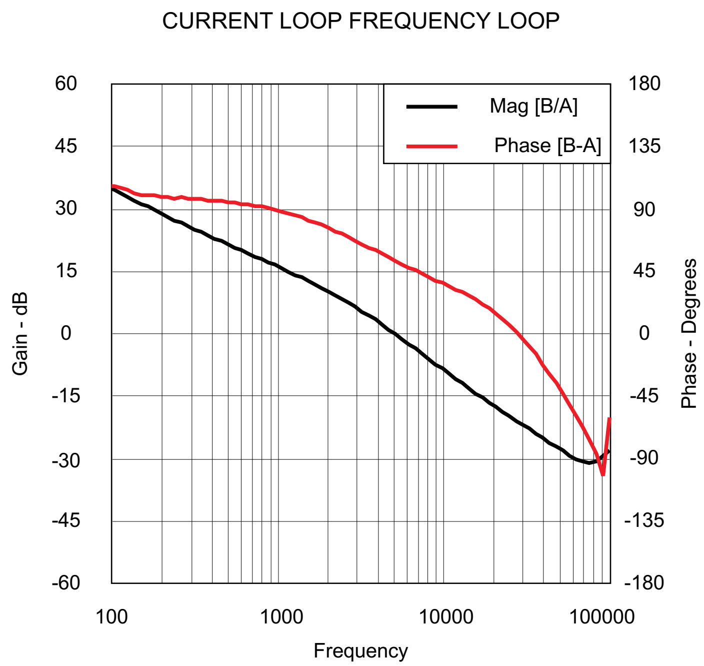

Figure 9. Loop Gain, V_{IN} = 390 V, Outputs Loaded with 32 LEDs (98 V) and No PWM Dimming

9.4 Zero Voltage Switching

One of the major benefits of a LLC resonant half-bridge converter is the ability to achieve Zero Voltage Switching (ZVS) at the primary switch node. Figure 10 shows the primary transformer current (CH4), the current sense voltage (CH3), the switch node on the primary at the drain of FET Q2 (Q2g) and the gate drive signal to FET Q2 (Q2g). The gate drive signal going to FET Q1 is the inverse of CH1. From the waveform in Figure 10 it can be observed that the gate drive signals do not transition until after the switch node has transitioned achieving zero voltage switching.

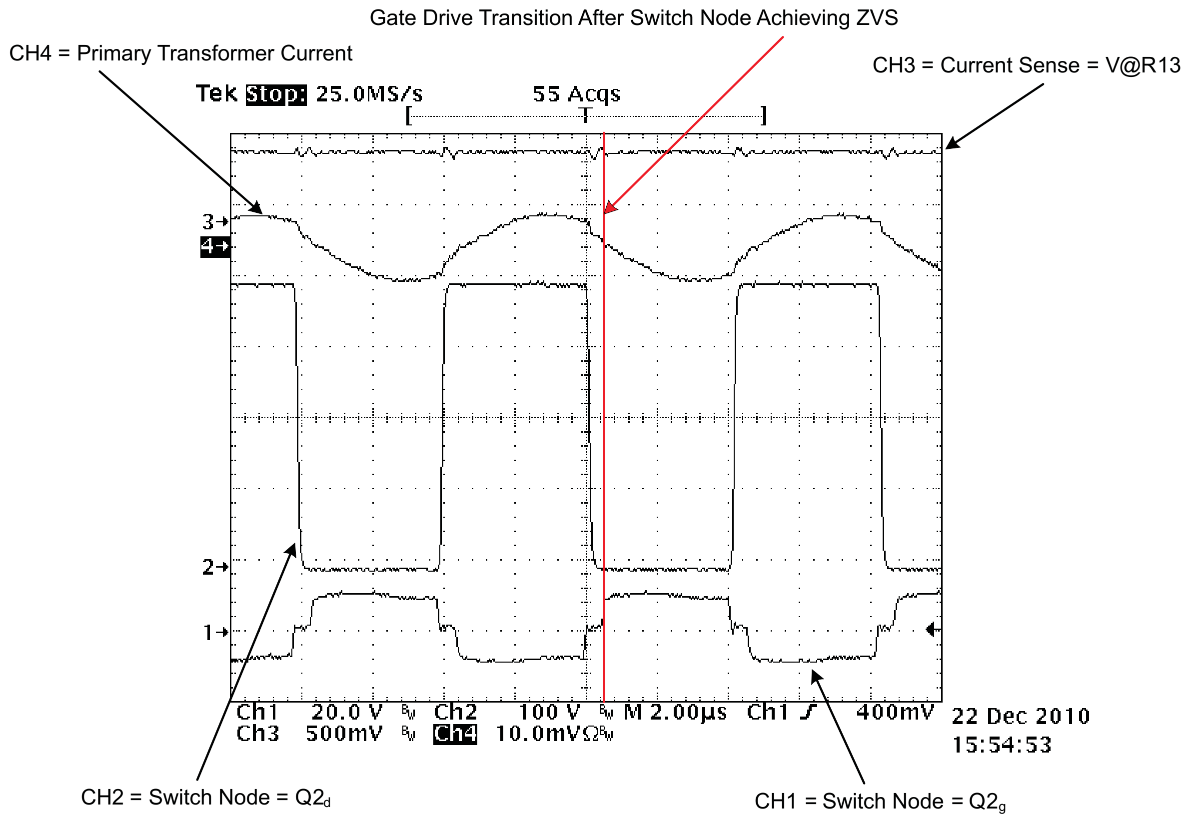

Figure 10. V_{IN} = 390 V, Outputs Loaded with 32, Cree XLamp CR-E , LEDs

9.5 LED Current Startup Behavior (V_{IN} = 390 V)

9.5.1 Total LED Current = 1 A, Individual LED Current ≈ 0.25 A

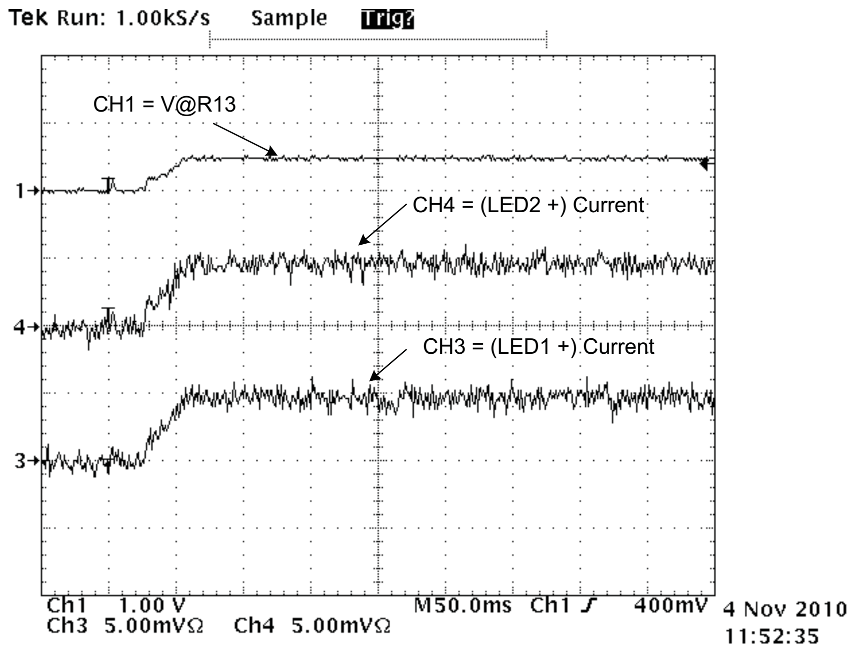

Figure 11. Current LED1 (CH3) and LED2 (CH4)

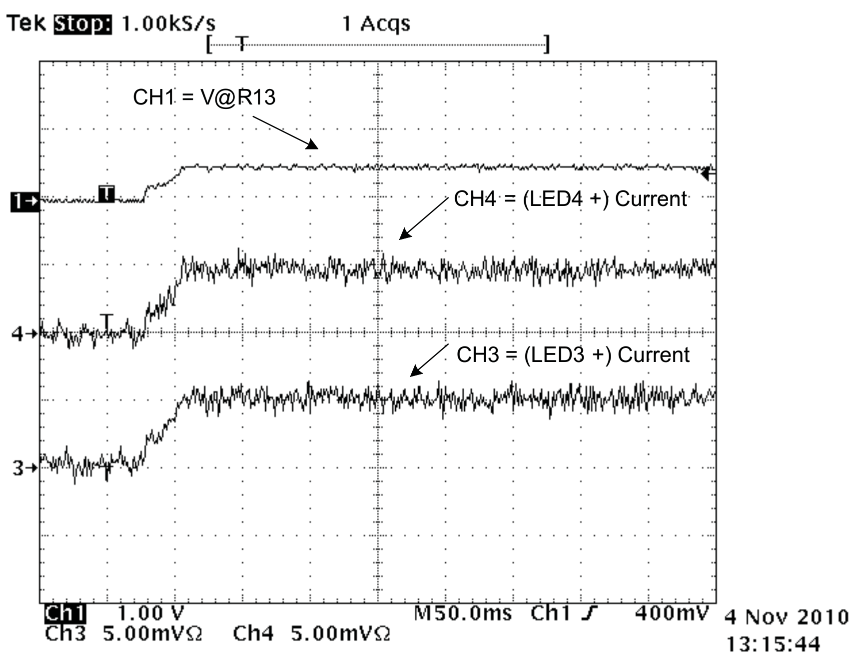

Figure 12. Current LED3 (CH3) and LED4 (CH4)

9.6 LED Current During 300-Hz PWM Dimming (V_{IN} = 390 V)

9.6.1 90% PWM Dimming

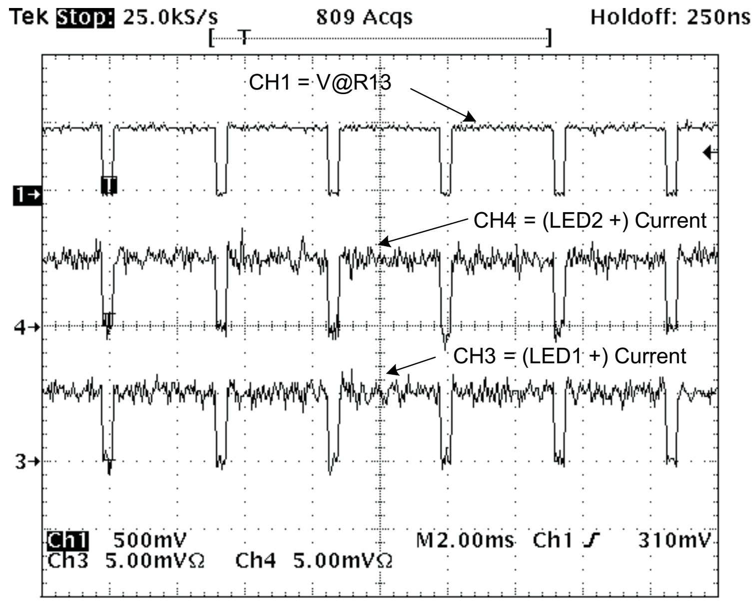

Figure 13. Current LED1 (CH3) and LED2 (CH4)

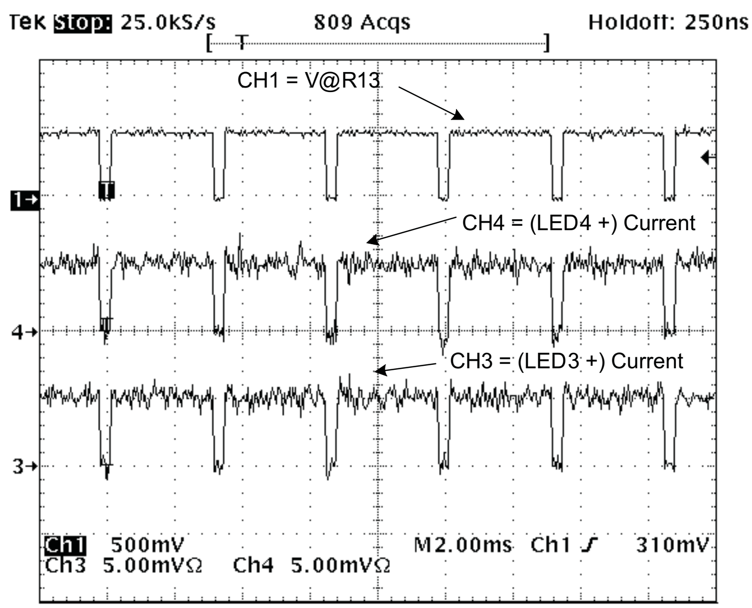

Figure 14. Current LED3 (CH3) and LED4 (CH4)

9.6.2 1% PWM Dimming, Peak LED Current ≈ 0.25 A

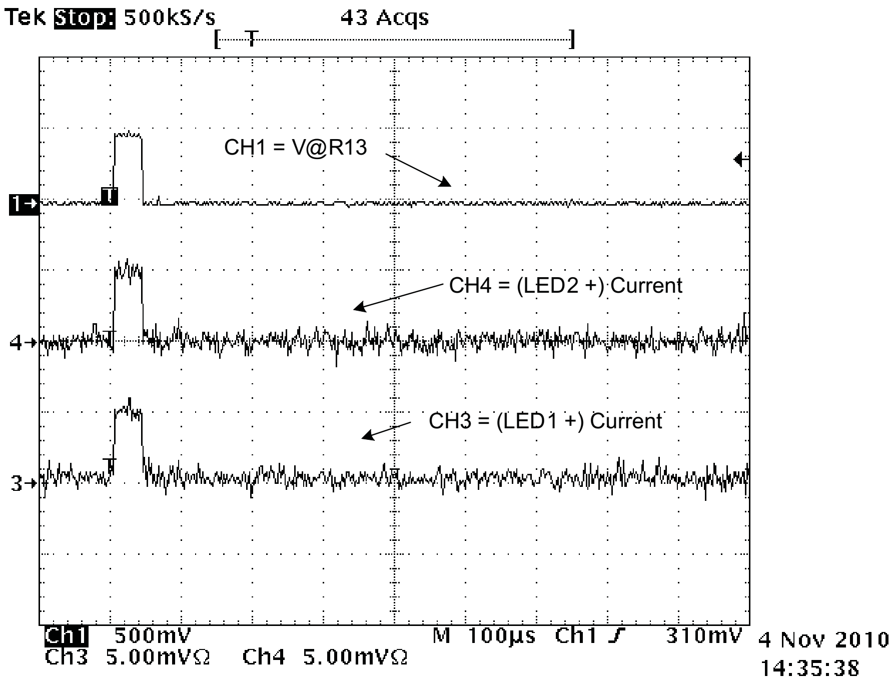

Figure 15. Current LED1 (CH3) and LED2 (CH4)

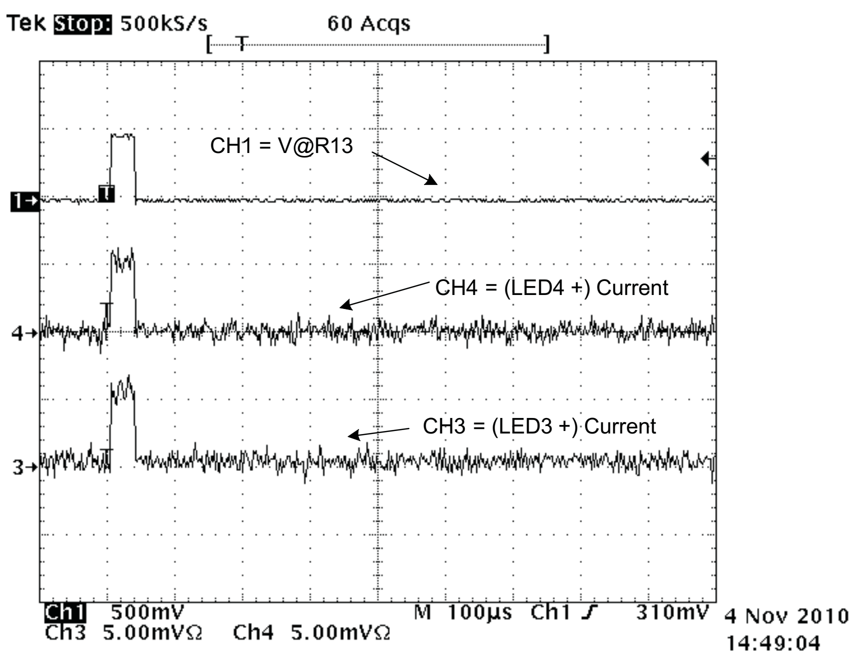

Figure 16. Current LED3 (CH3) and LED4 (CH4)

10 Assembly Drawings and Layout

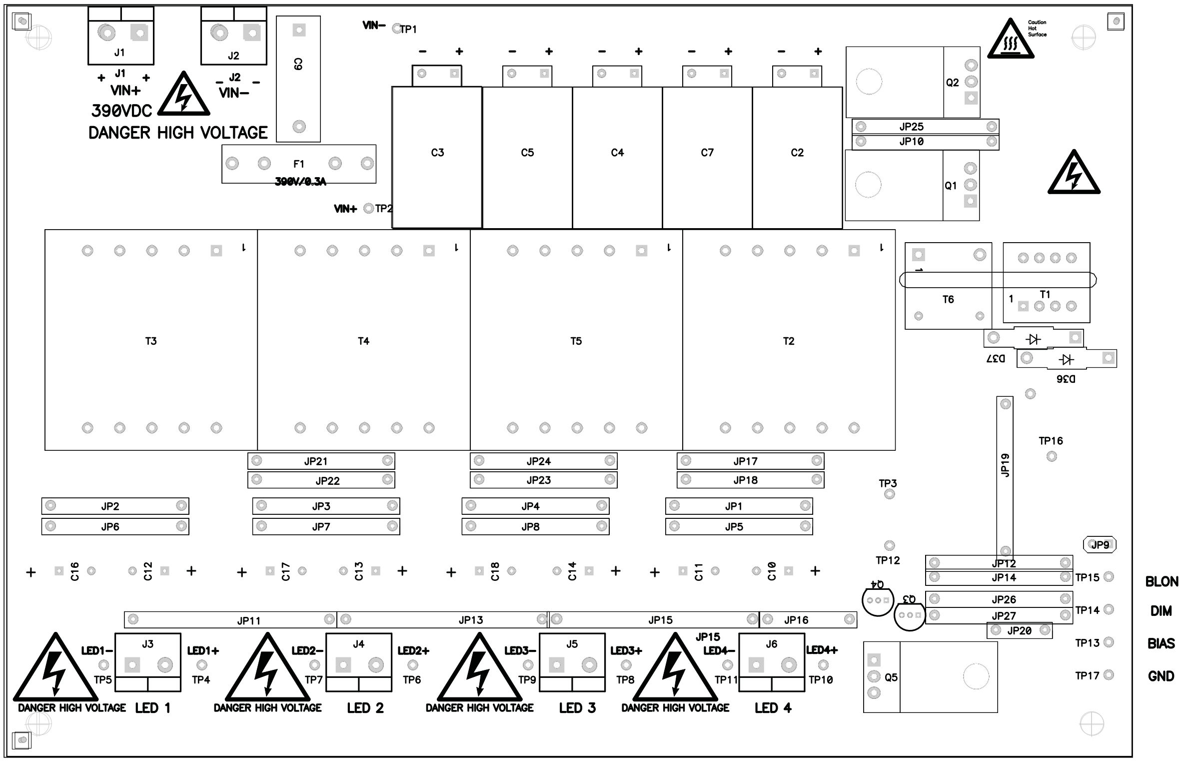

Figure 17. Top Assembly

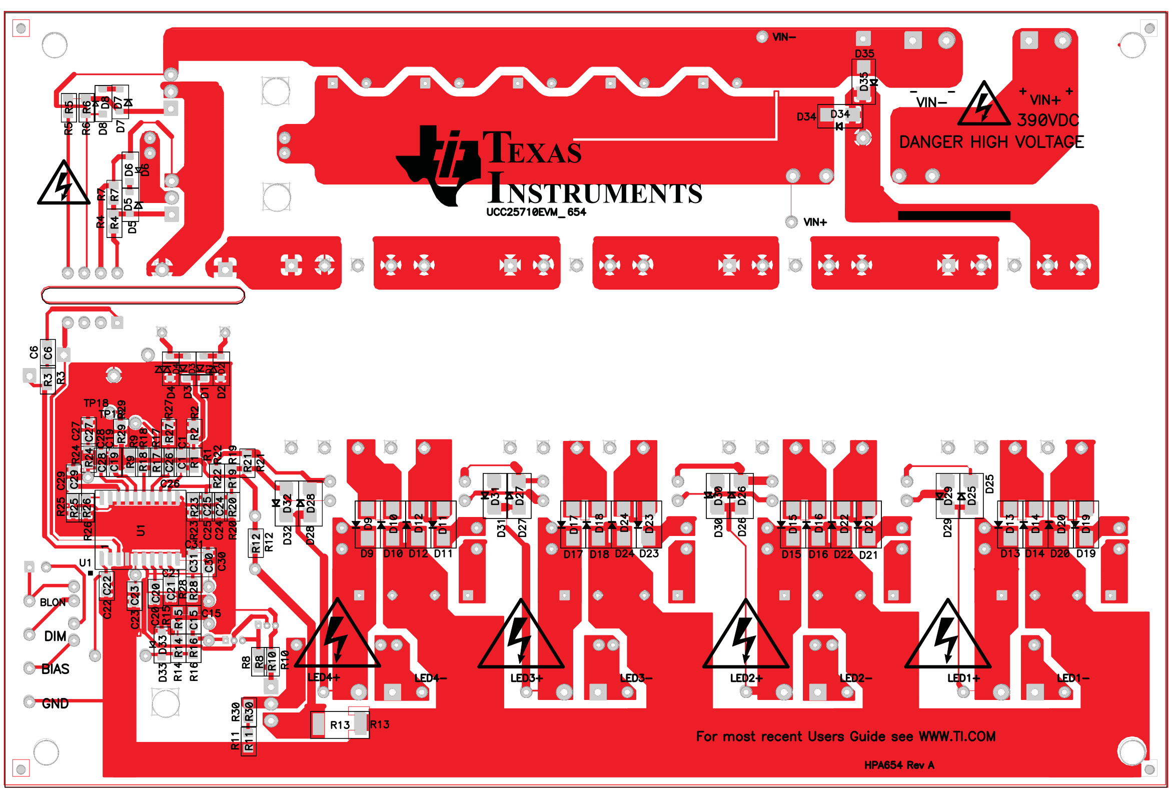

Figure 18. Bottom Assembly/Layout

11 List of Materials

Table 3. UCC25710EVM-654 98-W LLC 4-String LED Driver

COUNT	REF DES	DESCRIPTION	PART NUMBER	MFR
5	C1, C6, C15, C22, C23	Capacitor, ceramic, 1 µF, 50 V, X7R, +/- 10%, 0805	Std	Std
8	C10, C11, C12, C13, C14, C16, C17, C18	Capacitor, aluminum, 10 µF ,160 V, +105°C, 20%, 10.00 mm	ECA2CM100	Panasonic
1	C19	Capacitor, ceramic, 220 pF, 50 V, X7R, +/- 10%, 0805	Std	Std
5	C2, C3, C4, C5, C7	Capacitor, aluminum, 10 µF, 450 V, ±20%, 12.5 x 20.00 mm	EEUEB2W100	Panasonic
1	C20	Capacitor, ceramic, 4.7 nF, 50 V, X7R, +/- 10%, 0805	Std	Std
1	C21	Capacitor, ceramic, 330 pF, 50 V, X7R, +/- 10%, 0805	Std	Std
4	C24, C25, C30, C31	Capacitor, ceramic, 1 nF, 50 V, X7R, +/- 10%, 0805	Std	Std
1	C26	Capacitor, ceramic, 270 pF, 50 V, X7R, +/- 10%, 0805	Std	Std
1	C27	Capacitor, ceramic, 10 nF, 50 V, X7R, +/- 10%, 0805	Std	Std
0	C28	Capacitor, ceramic, No Pop, 50 V, X7R, +/- 10%, 0805	Std	Std
1	C29	Capacitor, ceramic, 47 nF, 50 V, X7R, +/- 10%, 0805	Std	Std
1	C9	Capacitor, metalized polypropylene film, 12 nF, 1000 VDC, 450 VAC, 0.709 x 0.236 inch	BFC238330123	Vishay/BC Components
6	D1, D2, D3, D4, D5, D7	Diode, signal, 200 mA, 100 V, 350 mW, SOD-123	1N4148W-7-F	Diodes
8	D25, D26, D27, D28, D29, D30, D31, D32	Diode, Schottky, 1 A, 150 V, SMA	ES1C	Diodes Inc.
2	D34, D35	Diode, rectifier, 1500 mA, 600 V,SMA	RS2JA-13-F	Diodes Inc
2	D36, D37	Diode, Schottky, 1 A, 40 V, DO 41	1N5819	Motorola
3	D6, D8, D33	Diode, Zener, 12 V, 500 mW, SOD-123	On Semiconductor	MMSZ5242BT1G
16	D9, D10, D11, D12, D13, D14, D15, D16, D17, D18, D19, D20, D21, D22, D23, D24	Diode, Schottky, 1 A, 150 V, SMA	STPS1150A	ST
2	F1	Fuse clip, 5 x 20 mm, 0.205 x 0.220 inch x2	0100056H	Wickmann
6	J1, J2, J3, J4, J5, J6	Terminal block, 2 pin, 15 A, 5.1 mm, 0.40 x 0.35 inch	ED120/2DS	OST
20	JP1, JP2, JP3, JP4, JP5, JP6, JP7, JP8, JP10, JP12, JP14, JP17, JP18, JP21, JP22, JP23, JP24, JP25, JP26, JP27	Jumper, 0.800 inch length, PVC insulation, AWG 22, 0.035 inch Dia.	923345-08-C	3M
3	JP11, JP13, JP15	Jumper, 1.000 inch length, PVC insulation, AWG 22, 0.035 inch diameter	923345-10-C	3M
1	JP16	Jumper, 0.600 inch length, PVC insulation, AWG 22, 0.035 inch diameter	923345-06-C	3M
1	JP19	Jumper, 0.900 inch length, PVC insulation, AWG 22, 0.035 inch diameter	923345-09-C	3M
1	JP20	Jumper, 0.300 inch length, PVC insulation, AWG 22, 0.035 inch diameter	923345-03-C	3M
1	JP9	Header, 2 pin, 100-mil spacing, (36-pin strip), 0.100 inch x 2	PTC36SAAN	Sullins

Table 3. UCC25710EVM-654 98-W LLC 4-String LED Driver (continued)

COUNT	REF DES	DESCRIPTION	PART NUMBER	MFR
2	Q1, Q2	MOSFET, N-channel, 550 V, 10 A, 350 mΩ, TO-220V	IPP50R350CP	Infineon
1	Q3	Transistor, NPN, 40 V, 600 mA, TO 92	P2N2222A	On Semi
1	Q4	Transistor, PNP, 60 V, 600 mA, TO 92	PN2907A	"Micro Commercial Components
1	Q5	MOSFET, N-channel, 250 V, 51 A, 60 mΩ, TO-220V	STD	STD
2	R1, R9	Resistor, chip, 1.00 kΩ, 1/10 W, 1%, 0805	Std	Std
2	R11, R30	Resistor, chip, 1.00M, 1/10 W, 1%, 0805	Std	Std
1	R12	Resistor, chip, 49.9 Ω, 1/10 W, 1%, 0805	Std	Std
1	R13	Resistor, chip, 0.5 Ω, 1 W, 1%, 2512	STD	Std
1	R14	Resistor, chip, 14.0 kΩ, 1/10 W, 1%, 0805	Std	Std
1	R15	Resistor, chip, 10.0 kΩ, 1/10 W, 1%, 0805	Std	Std
1	R16	Resistor, chip, 22 Ω, 1/10 W, 1%, 0805	Std	Std
0	R17	Resistor, chip, No Pop, 1/10 W, 1%, 0805	Std	Std
1	R18	Resistor, chip, 0 Ω, 1/10 W, 1%, 0805	Std	Std
1	R19	Resistor, chip, 4.22 M, 1/10 W, 1%, 0805	Std	Std
1	R2	Resistor, chip, 100 Ω, 1/10 W, 1%, 0805	Std	Std
1	R20	Resistor, chip, 316 kΩ, 1/10 W, 1%, 0805	Std	Std
1	R21	Resistor, chip, 1.1 M, 1/10 W, 1%, 0805	Std	Std
1	R22	Resistor, chip, 5.36 M, 1/10 W, 1%, 0805	Std	Std
1	R23	Resistor, chip, 105 kΩ, 1/10 W, 1%, 0805	Std	Std
1	R24	Resistor, chip, 33.2 kΩ, 1/10 W, 1%, 0805	Std	Std
1	R25	Resistor, chip, 12.7 kΩ, 1/10 W, 1%, 0805	Std	Std
1	R26	Resistor, chip, 30.1 kΩ, 1/10 W, 1%, 0805	Std	Std
1	R27	Resistor, chip, 17.8 kΩ, 1/10 W, 1%, 0805	Std	Std
1	R28	Resistor, chip, 1.00 kΩ, 1/10 W, 1%, 0805	Std	Std
1	R29	Resistor, chip, 9.09 kΩ, 1/10 W, 1%, 0805	Std	Std
3	R3, R4, R5	Resistor, chip, 3.01 Ω, 1/10 W, 1%, 0805	Std	Std
3	R6, R7, R10	Resistor, chip, 10.0 kΩ, 1/10 W, 1%, 0805	Std	Std
1	R8	Resistor, chip, 86.6 Ω, 1/10 W, 1%, 0805	Std	Std

Table 3. UCC25710EVM-654 98-W LLC 4-String LED Driver (continued)

COUNT	REF DES	DESCRIPTION	PART NUMBER	MFR
1	T1	Transformer, gate drive, 0.453 x 0.492 inch	56PR3362	Vitec Electronics
4	T2, T3, T4, T5	Transformer 1:2, 1.213 x 1.276 inch	75PR8112	Vitec Electronics
1	T6	Current transformer 1:100, 0.495 x 0.495 inch	57PR3634	Vitec Electronics
18	TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11, TP12, TP13, TP14, TP15, TP16, TP17, TP18	Pin, thru hole, tin plate, for 0.062 PCB's, 0.039 inch	K24A/M	Vector
1	U1	LLC Half-Bridge LED Multi-String Controller, SO-20	UCC25710DW	TI
1	PCB	Printed circuit board, HPA654	Any	
ADDITIONAL HARDWARE				
1	X1 @ F1	Fast acting fuse, 0.3, 5 mm x 20 mm	5MF 300R	Bel Fuse Inc
1	X1 @ JP9	Sockets jumper closed black	151-8010	Kobiconn
4	X1 @ PCB	Standoff hex 0.500/#6-32 threaded nylon, mount on bottom of PCB	1903C	Keystone Electronics
4	X1 @ PCB	Nut, mount to top of PCB	4824	Keystone Electronics
3	X1 @ Q1, Q2, Q5	Split lock washer #6(steel)	Std	Std
3	X1 @ Q1, Q2, Q5	Pan head screw #6-32 x 3/8 (steel)	Std	Std
3	X1 @ Q1, Q2, Q5	Nut #6-32 (steel)	Std	Std

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EVM Warnings and Restrictions

It is important to operate this EVM within the input voltage range of 370 V to 410 V and the output voltage range of 96 V to 100 V .

Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the EVM. If there are questions concerning the input range, please contact a TI field representative prior to connecting the input power.

Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. Please consult the EVM User's Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative.

During normal operation, some circuit components may have case temperatures greater than 50° C. The EVM is designed to operate properly with certain components above 50° C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.