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MAX16834 EVKit With a Two Layer PCB

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This is a reference design for a boost LED driver using the MAX16834 for long strings of LEDs. This application is for LED backlighting for large LCD TVs or displays as well as streetlights and parking garage lights. The design is similar to the standard MAX16834 EVKit, except it uses the TSSOP package on a two layer PCB and is designed for a higher voltage and current.

Vin:	24VDC +/- 5% (@1.49A)
VLED Config.:	Two parallel strings. Each string consists of 19 WLEDs and a 5Ω resistor (for current balancing). Current is 750mA per sting for a total of 1.5A into 75V.

This design has been built and tested. However, detailed testing has not occurred and there may be nuances that have yet to be discovered.

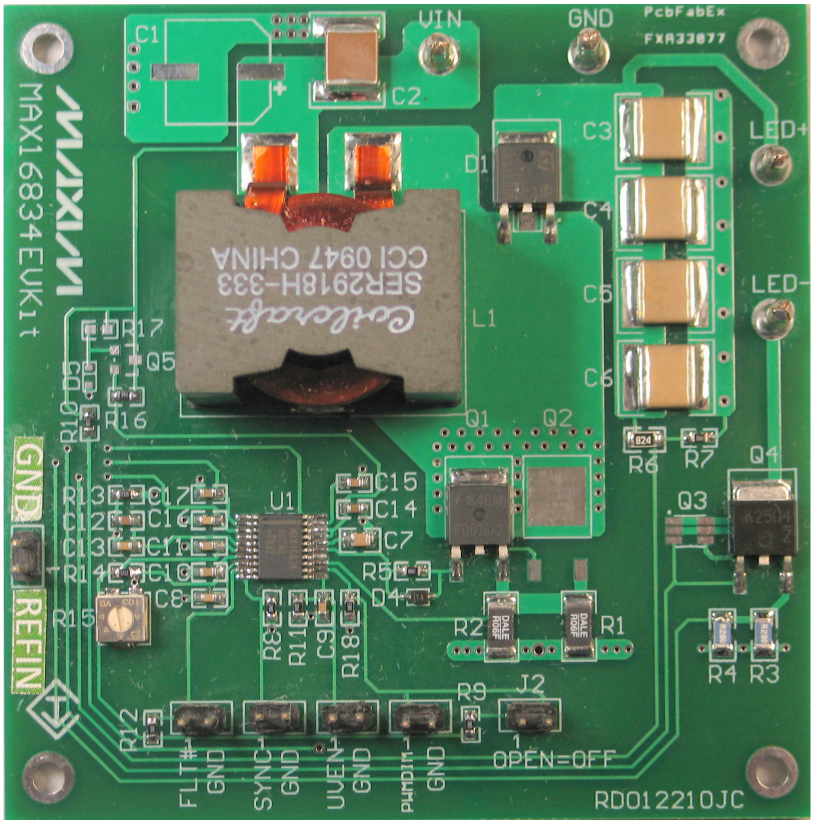


Figure 1. Picture of the Driver Board

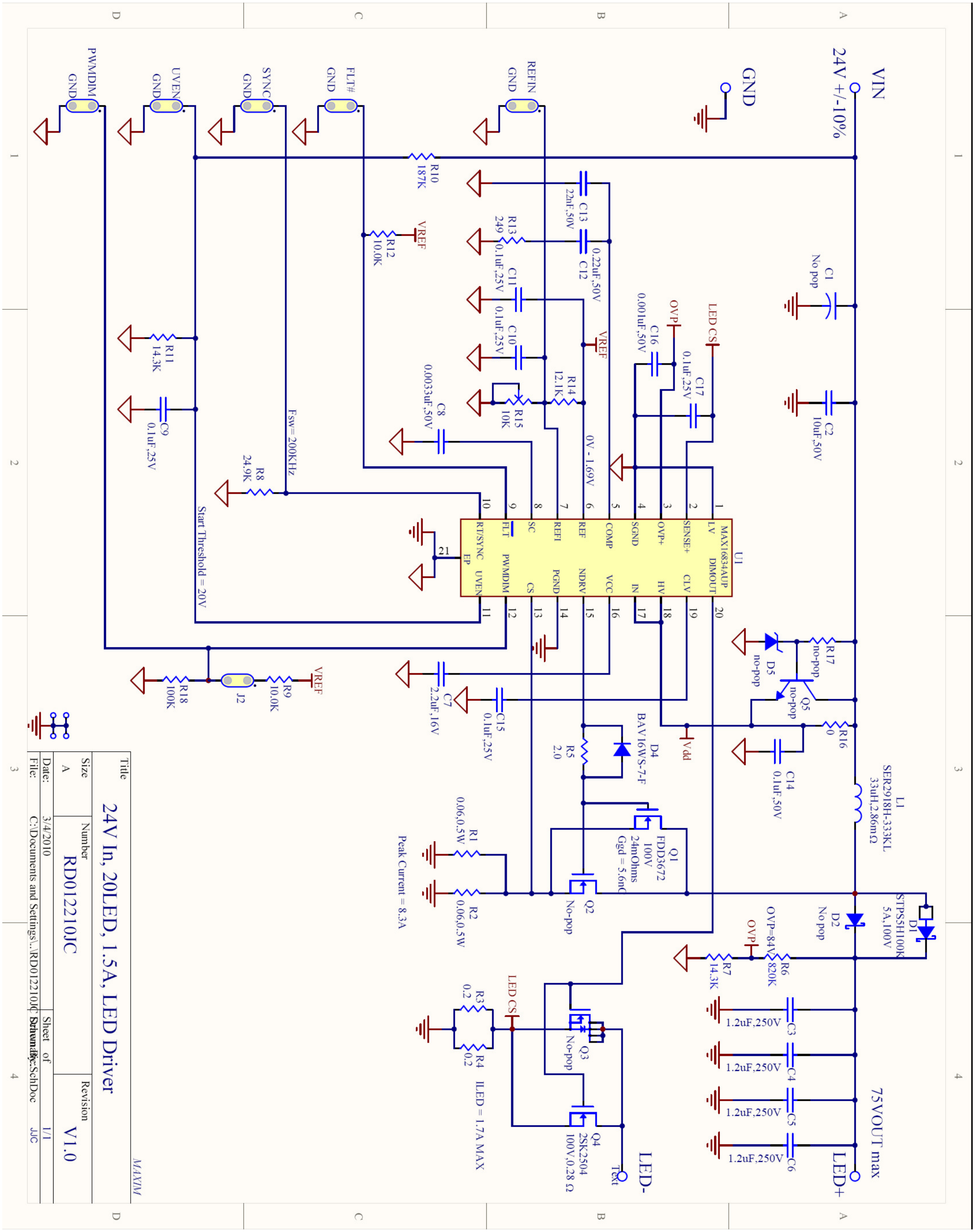


Figure 2. Schematic of the LED Driver

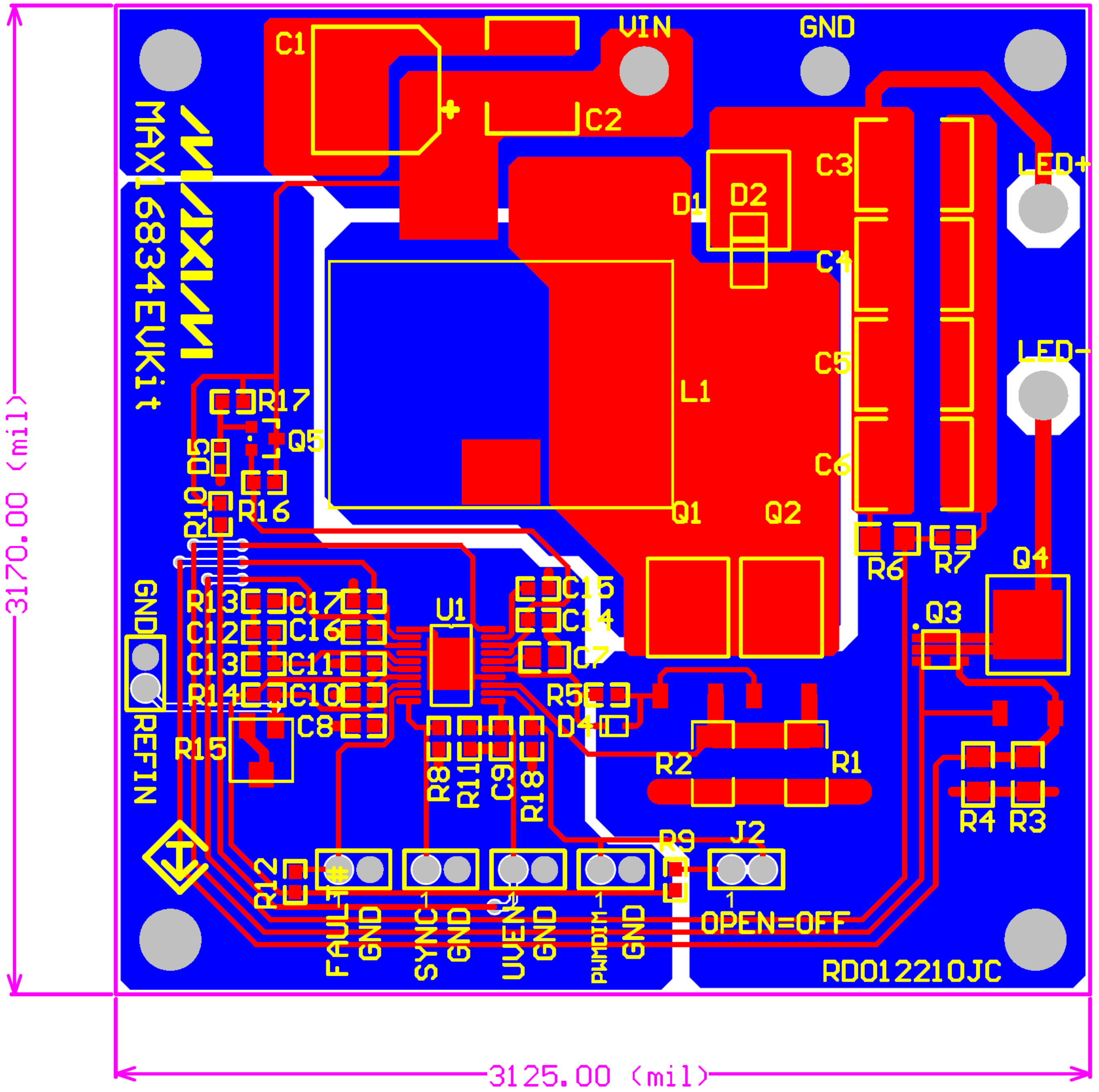
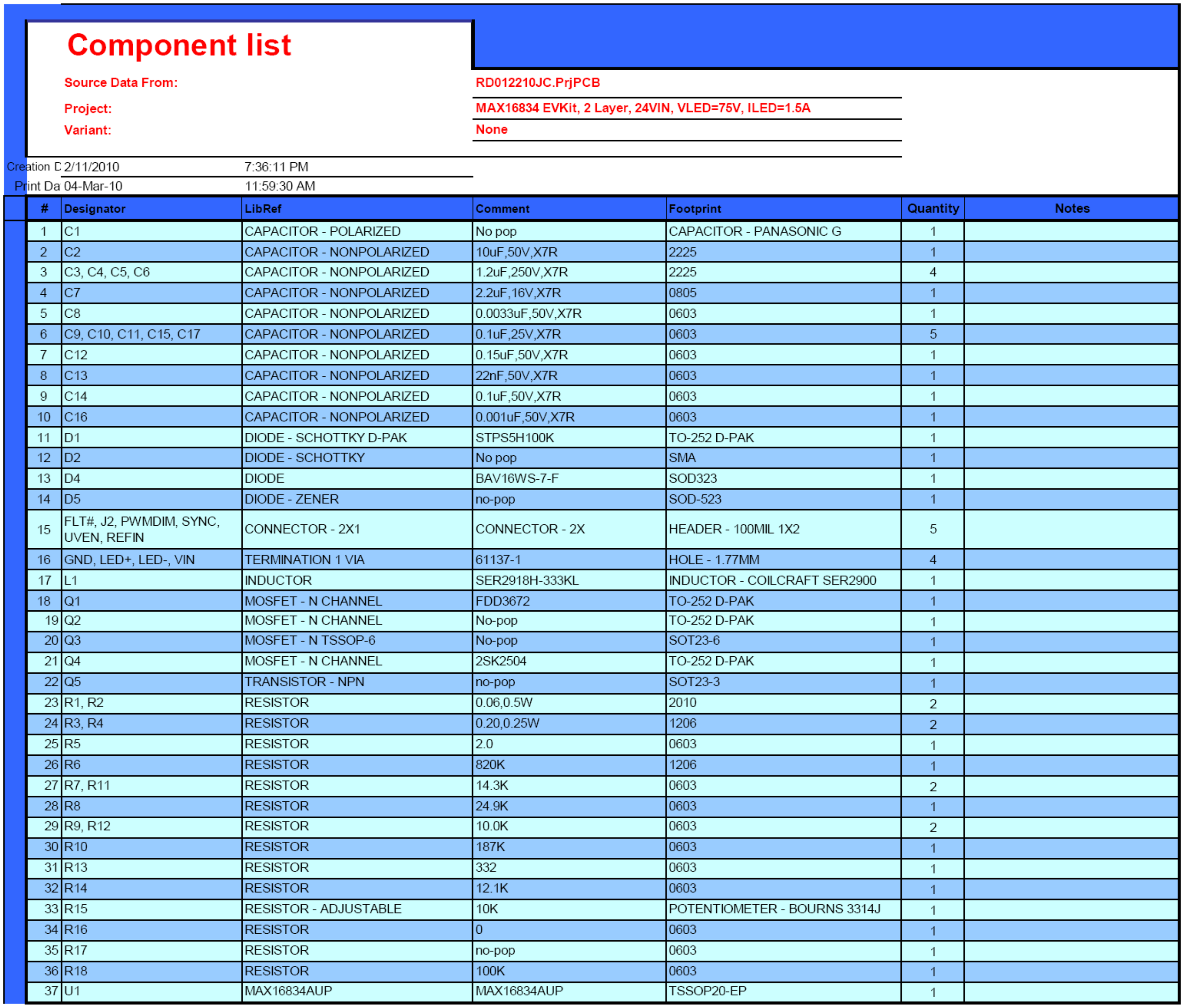


Figure 3. Layout of the LED Driver



Component list

Source Data From: RD012210JC.PrjPCB

Project: MAX16834 EVKit, 2 Layer, 24VIN, VLED=75V, ILED=1.5A

Variant: None

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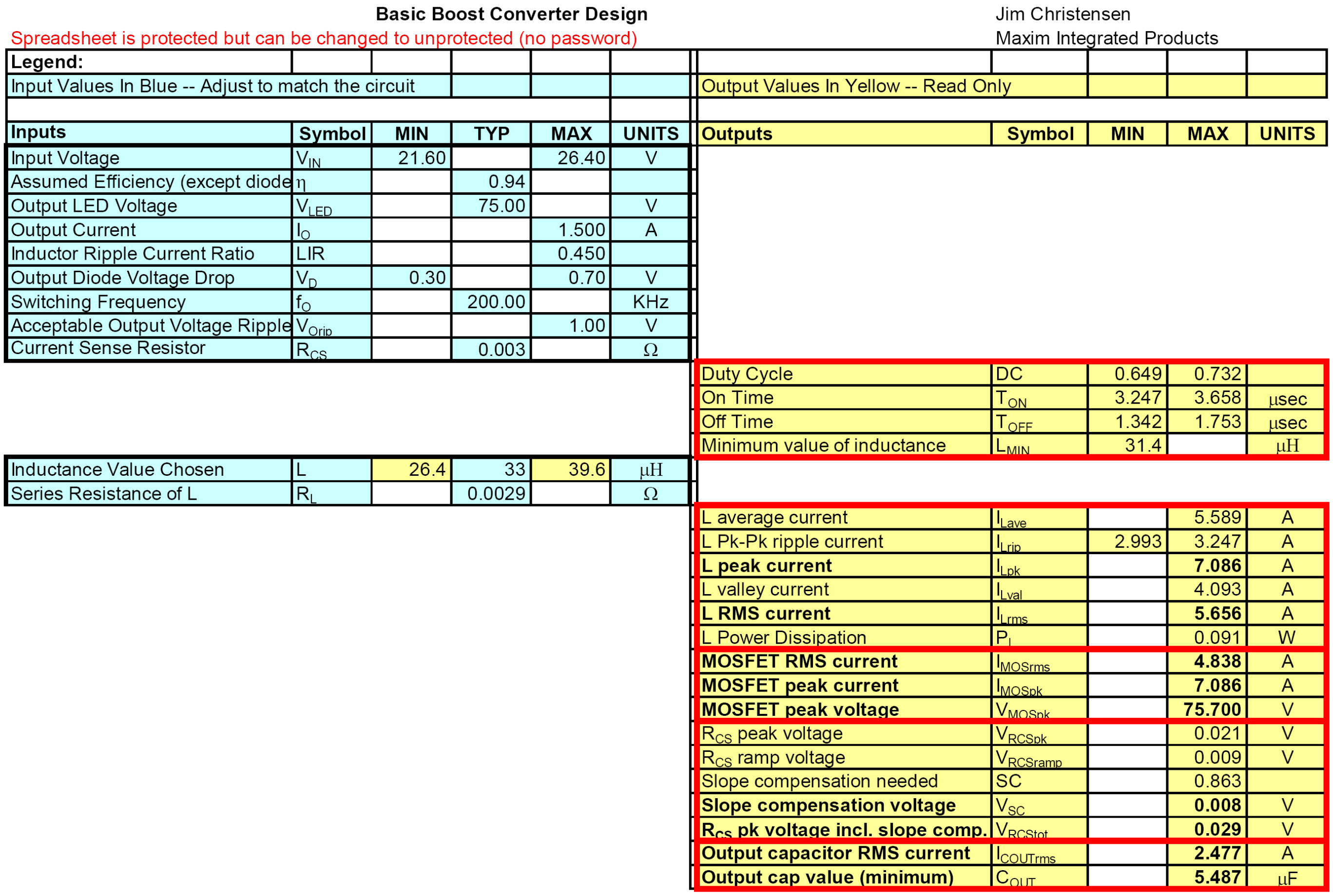
#	Designator	LibRef	Comment	Footprint	Quantity	Notes
1	C1	CAPACITOR - POLARIZED	No pop	CAPACITOR - PANASONIC G	1	
2	C2	CAPACITOR - NONPOLARIZED	10uF,50V,X7R	2225	1	
3	C3, C4, C5, C6	CAPACITOR - NONPOLARIZED	1.2uF,250V,X7R	2225	4	
4	C7	CAPACITOR - NONPOLARIZED	2.2uF,16V,X7R	0805	1	
5	C8	CAPACITOR - NONPOLARIZED	0.0033uF,50V,X7R	0603	1	
6	C9, C10, C11, C15, C17	CAPACITOR - NONPOLARIZED	0.1uF,25V,X7R	0603	5	
7	C12	CAPACITOR - NONPOLARIZED	0.15uF,50V,X7R	0603	1	
8	C13	CAPACITOR - NONPOLARIZED	22nF,50V,X7R	0603	1	
9	C14	CAPACITOR - NONPOLARIZED	0.1uF,50V,X7R	0603	1	
10	C16	CAPACITOR - NONPOLARIZED	0.001uF,50V,X7R	0603	1	
11	D1	DIODE - SCHOTTKY D-PAK	STPS5H100K	TO-252 D-PAK	1	
12	D2	DIODE - SCHOTTKY	No pop	SMA	1	
13	D4	DIODE	BAV16WS-7-F	SOD323	1	
14	D5	DIODE - ZENER	no-pop	SOD-523	1	
15	FLT#, J2, PWMDIM, SYNC, UVEN, REFIN	CONNECTOR - 2X1	CONNECTOR - 2X	HEADER - 100MIL 1X2	5	
16	GND, LED+, LED-, VIN	TERMINATION 1 VIA	61137-1	HOLE - 1.77MM	4	
17	L1	INDUCTOR	SER2918H-333KL	INDUCTOR - COILCRAFT SER2900	1	
18	Q1	MOSFET - N CHANNEL	FDD3672	TO-252 D-PAK	1	
19	Q2	MOSFET - N CHANNEL	No-pop	TO-252 D-PAK	1	
20	Q3	MOSFET - N TSSOP-6	No-pop	SOT23-6	1	
21	Q4	MOSFET - N CHANNEL	2SK2504	TO-252 D-PAK	1	
22	Q5	TRANSISTOR - NPN	no-pop	SOT23-3	1	
23	R1, R2	RESISTOR	0.06,0.5W	2010	2	
24	R3, R4	RESISTOR	0.20,0.25W	1206	2	
25	R5	RESISTOR	2.0	0603	1	
26	R6	RESISTOR	820K	1206	1	
27	R7, R11	RESISTOR	14.3K	0603	2	
28	R8	RESISTOR	24.9K	0603	1	
29	R9, R12	RESISTOR	10.0K	0603	2	
30	R10	RESISTOR	187K	0603	1	
31	R13	RESISTOR	332	0603	1	
32	R14	RESISTOR	12.1K	0603	1	
33	R15	RESISTOR - ADJUSTABLE	10K	POTENTIOMETER - BOURNS 3314J	1	
34	R16	RESISTOR	0	0603	1	
35	R17	RESISTOR	no-pop	0603	1	
36	R18	RESISTOR	100K	0603	1	
37	U1	MAX16834AUP	MAX16834AUP	TSSOP20-EP	1	

Figure 4. Bill of Materials



Basic Boost Converter Design

Jim Christensen
Maxim Integrated Products

Spreadsheet is protected but can be changed to unprotected (no password)

Legend:

Input Values In Blue -- Adjust to match the circuit

Output Values In Yellow -- Read Only

Inputs	**Symbol**	**MIN**	**TYP**	**MAX**	**UNITS**
Input Voltage	V_{IN}	21.60		26.40	V
Assumed Efficiency (except diode	η		0.94		
Output LED Voltage	V_{LED}		75.00		V
Output Current	I_O			1.500	A
Inductor Ripple Current Ratio	LIR			0.450	
Output Diode Voltage Drop	V_D	0.30		0.70	V
Switching Frequency	f_O		200.00		KHz
Acceptable Output Voltage Ripple	V_{Orip}			1.00	V
Current Sense Resistor	R_{CS}		0.003		Ω
Inductance Value Chosen	L	26.4	33	39.6	μH
Series Resistance of L	R_L		0.0029		Ω

Outputs	**Symbol**	**MIN**	**MAX**	**UNITS**
Duty Cycle	DC	0.649	0.732	
On Time	T_{ON}	3.247	3.658	μsec
Off Time	T_{OFF}	1.342	1.753	μsec
Minimum value of inductance	L_{MIN}	31.4		μH
L average current	I_{Lave}		5.589	A
L Pk-Pk ripple current	I_{Lrip}	2.993	3.247	A
L peak current	I_{Lpk}		**7.086**	A
L valley current	I_{Lval}		4.093	A
L RMS current	I_{Lrms}		**5.656**	A
L Power Dissipation	P_L		0.091	W
MOSFET RMS current	I_{MOSrms}		**4.838**	A
MOSFET peak current	I_{MOSpk}		**7.086**	A
MOSFET peak voltage	V_{MOSpk}		**75.700**	V
R_{CS} peak voltage	V_{RCSpk}		0.021	V
R_{CS} ramp voltage	$V_{RCSramp}$		0.009	V
Slope compensation needed	SC		0.863	
Slope compensation voltage	V_{SC}		**0.008**	V
R_{CS} pk voltage incl. slope comp.	V_{RCStot}		**0.029**	V
Output capacitor RMS current	$I_{COUTrms}$		**2.477**	A
Output cap value (minimum)	C_{OUT}		**5.487**	μF

Figure 5. Design Spreadsheet

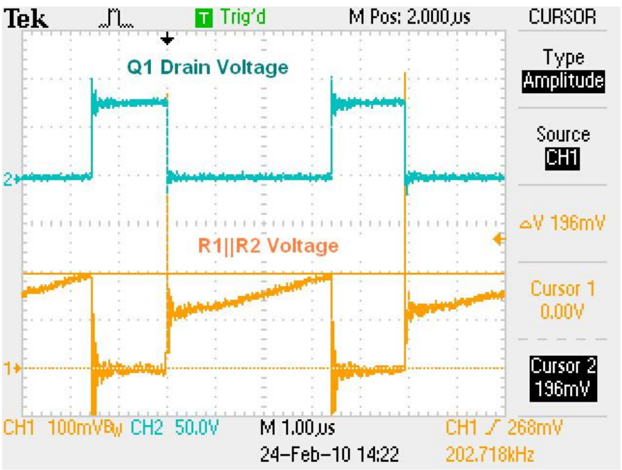


Figure 6: Switching MOSFET Voltage and Current Sense Resistor Voltage

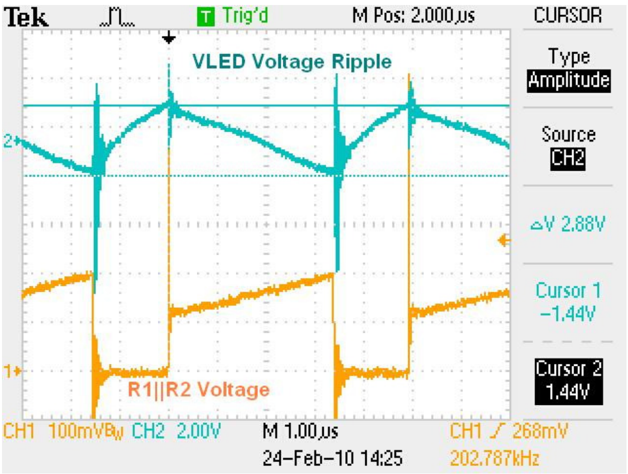


Figure 7: Output Voltage (AC Coupled) and Switching MOSFET Current Sense Resistor Voltage

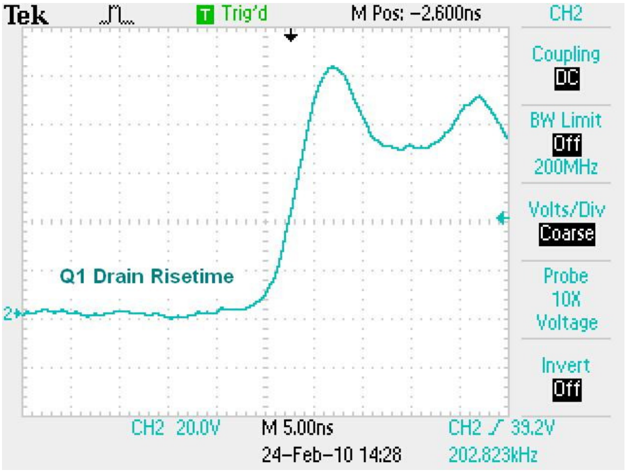


Figure 8: Drain Voltage Risetime

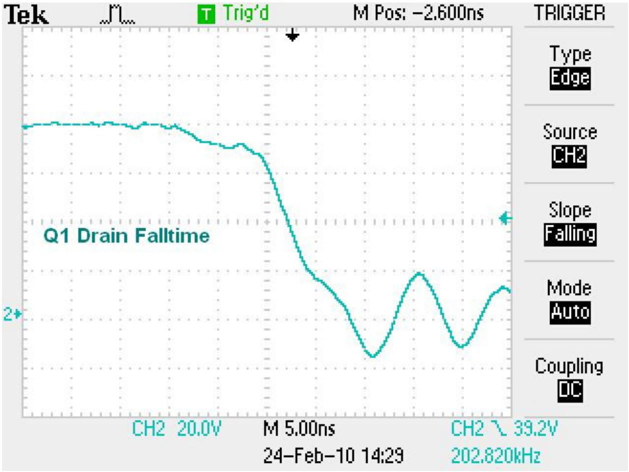


Figure 9: Drain Voltage Falltime

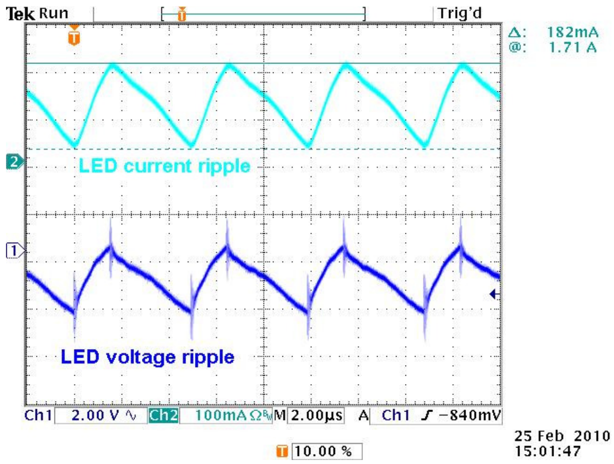


Figure 10: LED Voltage (AC coupled) and Current Ripple

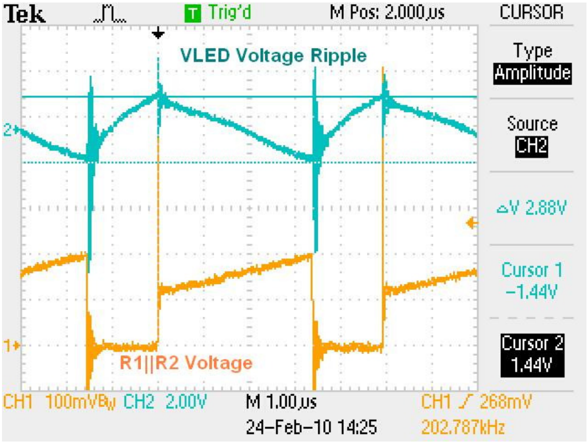


Figure 11: LED Voltage (AC coupled) and MOSFET current sense voltage

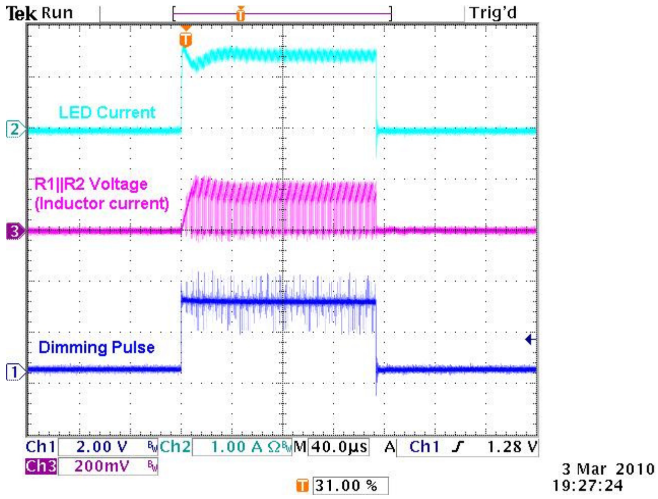


Figure 12: Dimming Pulse of ~150usec.

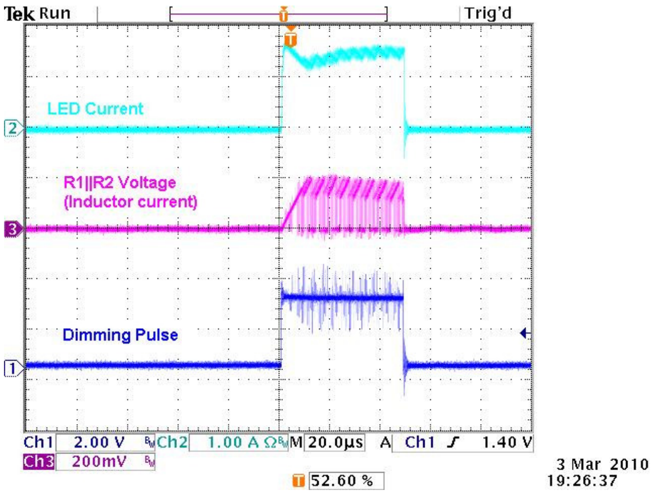


Figure 13: Dimming Pulse of ~50usec

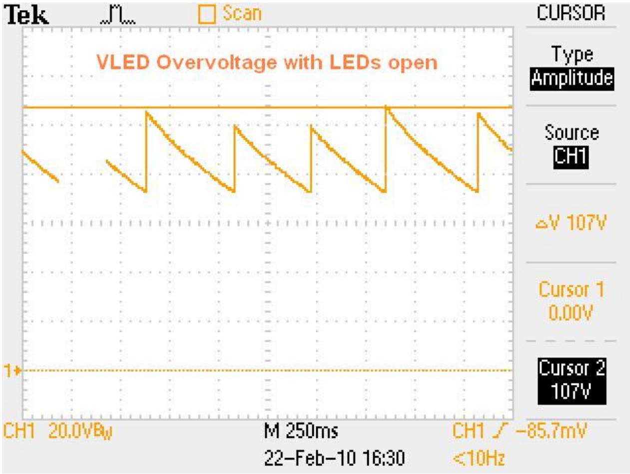
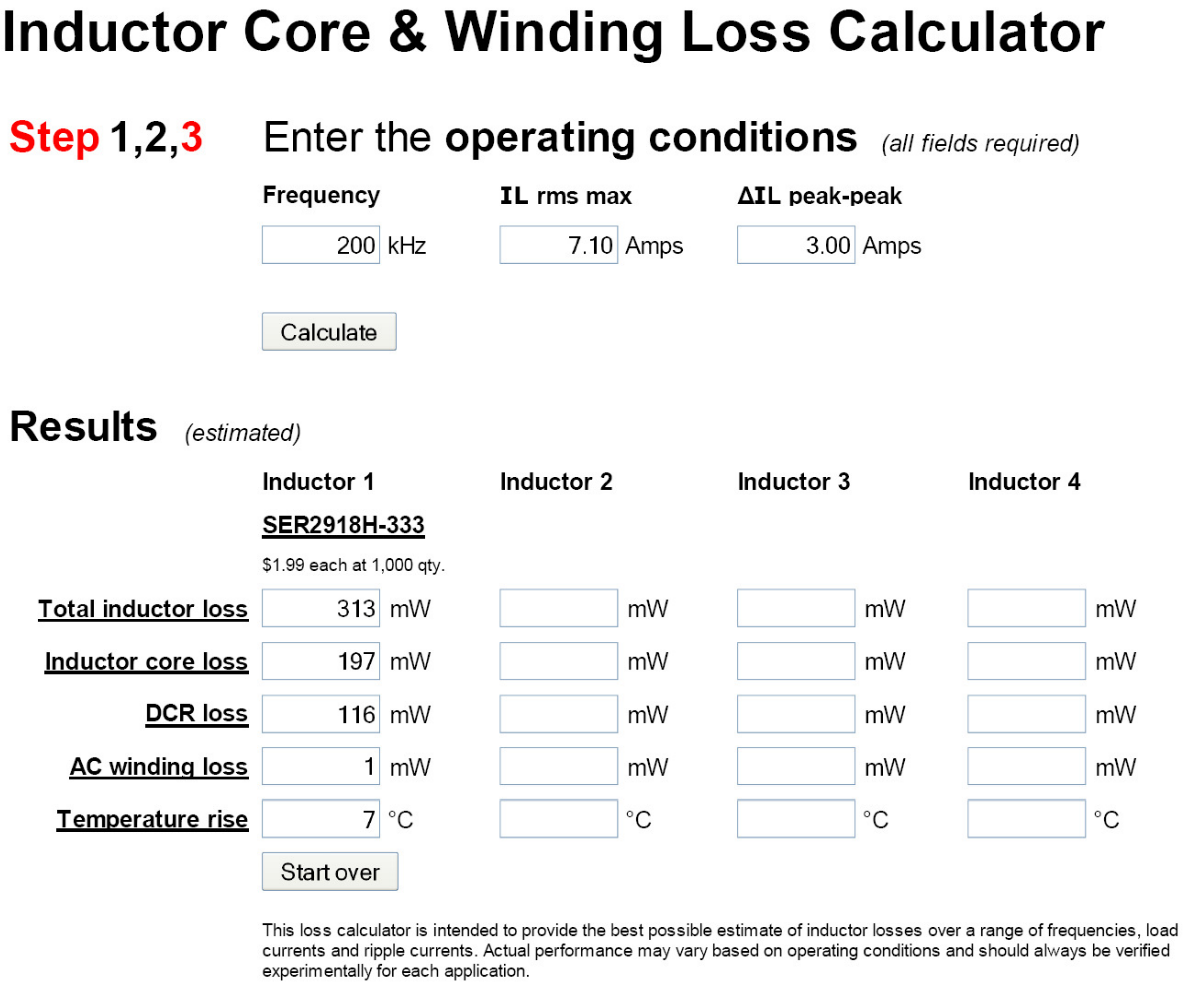


Figure 14: OVP with Open LED String



Inductor Core & Winding Loss Calculator

Step 1,2,3 Enter the **operating conditions** *(all fields required)*

Frequency	IL rms max	ΔIL peak-peak
200 kHz	7.10 Amps	3.00 Amps

Results *(estimated)*

	Inductor 1	Inductor 2	Inductor 3	Inductor 4
	SER2918H-333 $1.99 each at 1,000 qty.			
Total inductor loss	313 mW	mW	mW	mW
Inductor core loss	197 mW	mW	mW	mW
DCR loss	116 mW	mW	mW	mW
AC winding loss	1 mW	mW	mW	mW
Temperature rise	7 °C	°C	°C	°C

This loss calculator is intended to provide the best possible estimate of inductor losses over a range of frequencies, load currents and ripple currents. Actual performance may vary based on operating conditions and should always be verified experimentally for each application.

Figure 15. Inductor Temperature Rise

BRIEF CIRCUIT DESCRIPTION

Overview

This reference design is for a high voltage boost current source for very long strings of LEDs. Applications that use long LED strings include LCD TV backlighting, LCD monitor backlighting, streetlights and parking garage lights. Long LED strings can be a very cost effective way to drive LEDs. Also, since the LEDs will have exactly the same current, brightness variations are nicely controlled. This design has a 24V input, up to a 75V LED output and drives 1.5A through the LED string. The measured input power is 115.49W and the output power is 111.6W for an efficiency of about 96.6%.

PCB

The printed circuit board (PCB) is a general purpose 2 layer board for MAX16834 boost designs (Figures 1 and 3). Therefore, some features are optional and are not populated in the tested design. These are indicated on the schematic (Figure 2) as no-pop. Figure 4 shows a bill of materials for this design.

Topology

This design is for a 200KHz continuous boost regulator. In Figure 5, the spreadsheet printout shows the RMS and peak currents in the MOSFET and inductor. Continuous designs have the advantage of lower MOSFET and inductor currents, but since current flows through the output diode when the MOSFET (Q1) turns on, the reverse recovery losses in the output diode (D2) result in higher dissipation and possibly higher turn-off noise. Inspecting the circuit waveforms in Figure 6, you can see that the on-time of the MOSFET is about 3.4µsecs and the off-time is about 1.5µsecs for a 69% duty cycle. Once the MOSFET turns off, the drain voltage rises to the output voltage plus a Schottky diode drop.

MOSFET drive

Because of the continuous design, the peak MOSFET and inductor currents are less than what they would be with a discontinuous design. However, since there is current through the MOSFET during turn-on and turn-off, it experiences switching losses during both transitions. The MAX16834 drives the MOSFET hard enough for the switch to turn on in about 5nsec and turn off in 10nsec (Figures 8 and 9), keeping the temperature rise low. If EMI becomes a problem, the series resistance and diode on the MOSFET gate can be altered to adjust the switching times, and if needed, a second MOSFET, Q2, can be placed in parallel to Q1 to reduce the temperature rise.

Output capacitance

For the input and output capacitance, the driver uses ceramic capacitors. Ceramic capacitors are durable and small but they have limited capacitance. In Figure 5, the spreadsheet printout indicates that 5.4µF is needed to meet the desired output ripple voltage, but because of cost and space, this design uses four 1.2uF capacitors (4.8µF in total). Because of this, the output voltage ripple is 2.88V (Figures 10 and 11), resulting in a current ripple of 182mA. This is 12% of the output current, which is acceptable.

Dimming

The MAX16834 is well suited for dimming. When the PWMDIM (pin 12) goes low, three things happen. First, the gate drive (NDRV, pin 15) to the switching MOSFET, Q1, goes low. This prevents additional energy to be delivered to the LED string. Secondly, the gate drive (DIMOUT, pin 20) to the dimming MOSFET, Q4, goes low, immediately curtailing the LED string current, and holding the voltage on the output capacitors constant. Finally, to keep the compensation capacitance frozen at a steady state voltage, the COMP (pin 5) goes to high impedance. This ensures that the IC will start at the correct duty cycle immediately after PWMDIM returns high. Each of these actions allow for short PWM on-times, and thus, high dimming ratios. The main limitation to the dimming ratio is the charge-up time of the inductor. Looking at Figures 12 and 13, you can see that the current follows the DIM pulse very well. There is decay at the beginning of the current pulse that is due to the ramp-up time of the inductor (about 12µsec --- roughly 2-3 switching cycles). Looking at the waveforms, you can see that it takes about 40-50µsecs for the voltage to fully recover and settle. If the DIM on pulse is any shorter than 50µsecs, the output voltage would still be in deficit at the start of the next off pulse. This can cause erratic behavior that will persist until the DIM duty cycle is increased. **Therefore, under full load (1.5A), the DIM on pulse should never be less than 50µsec.** This implies that at a DIM frequency of 250Hz, the dimming ratio will be 80:1. The only way to improve on this is to increase the output capacitance, which can be expensive with high voltage ceramic capacitors. With lighter loads, the dimming ratio can be increased. Since ceramic capacitors exhibit a piezoelectric effect, there is some audible noise during dimming. This can be lessened with proper circuit board mounting techniques that reduce the speaker effects.

OVP

In Figure 14, the LED string is opened, and the overvoltage protection (OVP) circuitry of the MAX16834 shuts down the driver for about 400msecs between retry attempts. The peak voltage of 107V is higher than the design of 83V because of overshoot caused by the low output capacitance and the energy stored in the inductor.

Adjustments and other inputs/outputs

This design has an output current that can be adjusted by R15. The current can be set anywhere from 0 to about 1.7A. The EVKit also has an input (SNYC) for synchronizing the switching frequency of the controller if needed. The UVEN input allows for external control of the driver if paired with a microcontroller. The REFIN input overrides the potentiometer setting and allows control of the driver current from some external device such as a DAC. The FAULT# output goes low during the presence of a fault (such as OVP).

Temperature rise

The measured efficiency was 96.63% (VIN=24.01, I_IN=1.49A, Pin=115.49W, VLED=74.9V, I_LED=1.49A, Pout=111.60W). Due to the high efficiency of the circuit, the components of the driver remain cool. The hottest component is the dimming MOSFET, Q4, which has a temperature rise of 41°C. This is mostly due to a small PCB footprint, and can be improved if the copper area around the drain pad was increased. The inductor, which is large, has a temperature rise of 23°C, higher than the predicted 7°C (Figure 15). It is likely that some of the MOSFET heat has been absorbed by the inductor, since they both sit on a large copper pad

TEMPERATURE MEASUREMENTS

The following temperatures were measured using actual LED loads:

VIN:	**24VDC**	
Ambient:	**16ºC**	**ΔT**
L_1:	39ºC	23ºC
D_1:	51ºC	35ºC
Q_1:	51ºC	35ºC
Q_3:	57ºC	41ºC
IC:	33ºC	17ºC

POWER-UP PROCEDURE

1. Attach a string of up to 20 LEDs between the LED+ post and LED- post (Note, parallel strings may be used if the forward voltages of the LEDs are matched and/or series balancing resistors are added)
2. Attach a 24V, 6A power supply between the VIN post and GND post.
3. Insert a shunt on connector J2.
4. Turn on the 24V power supply.
5. Adjust R15 to set the current from 0 to 1.5A (Of course, a ammeter in series with the LEDs is needed to do this).
6. If dimming is desired, attach a PWM signal (0V to 3.3V) between the DIM IN post and GND post.
7. Adjust the PWM duty cycle as desired to obtain dimming.