AN-1545 LM3404/LM3404HV Evaluation Board

1 Introduction

The LM3404/04HV is a buck regulator derived controlled current source designed to drive a series string of high power, high brightness LEDs (HBLEDs) such as the Luxeon™ K2 Emitter at forward currents of up to 1.0A. The board can accept an input voltage ranging from 6V to 42V when using the LM3404. When using the pin-for-pin compatible LM3404HV the upper bound of input voltage is 75V. The converter output voltage adjusts as needed to maintain a constant current through the LED array. The LM3404/04HV is a true step-down regulator with an output voltage range extending from a $V_{O(MIN)}$ of 200 mV (the reference voltage) to a $V_{O(MAX)}$ determined by the minimum off time (typically 300 ns). It can maintain regulated current through any number of LEDs as long as the combined forward voltage of the array does not exceed $V_{O(MAX)}$.

2 Circuit Performance LM3404

The LM3404 circuit and BOM have been designed to provide a constant forward current of 1.0A to a single LED with a forward voltage of approximately 3.7V (Typical of white, blue, and green LEDs using InGaN technology) from an input of 24V ±10%. Over the input voltage range of 6V to 42V the average LED current, I_F, is 1.0A ±10%, the ripple current, Δi_F, will not exceed 400 mA_{P-P}, and the switching frequency is 450 kHz ± 10%.

3 Circuit Performance LM3404HV

The LM3404HV circuit and BOM have been designed to provide a constant forward current of 1.0A to a single LED with a forward voltage of approximately 3.7V from an input of 48V ±10%. Over the input voltage range of 6V to 75V the average LED current, I_F, is 1.0A ±10%, the ripple current, Δi_F, will not exceed 400 mA_{P-P}, and the switching frequency is 200 kHz ± 10%.

4 Connecting to LED Array

The LM3404/04HV Evaluation Board includes a female 6-pin SIP, J1, connector as well as two standard 94mil turret connectors for the cathode and anode connections of the LED array. Figure 1 shows the pinout of J1. Solid 18 or 20 gauge wire with about 1 cm of insulation stripped away makes a convenient, solderless connection to J1.

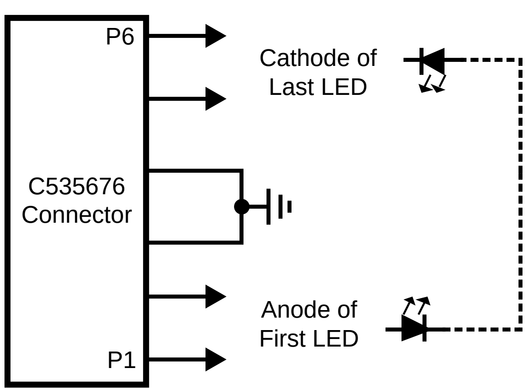


Figure 1. Connecting to LED Array

5 Setting the LED Current

The default forward current I_{LED} delivered to the LED array is 1.0A, typical of many 3W LEDs. To adjust this value the current setting resistor R_{SNS} can be changed according to the following equation:

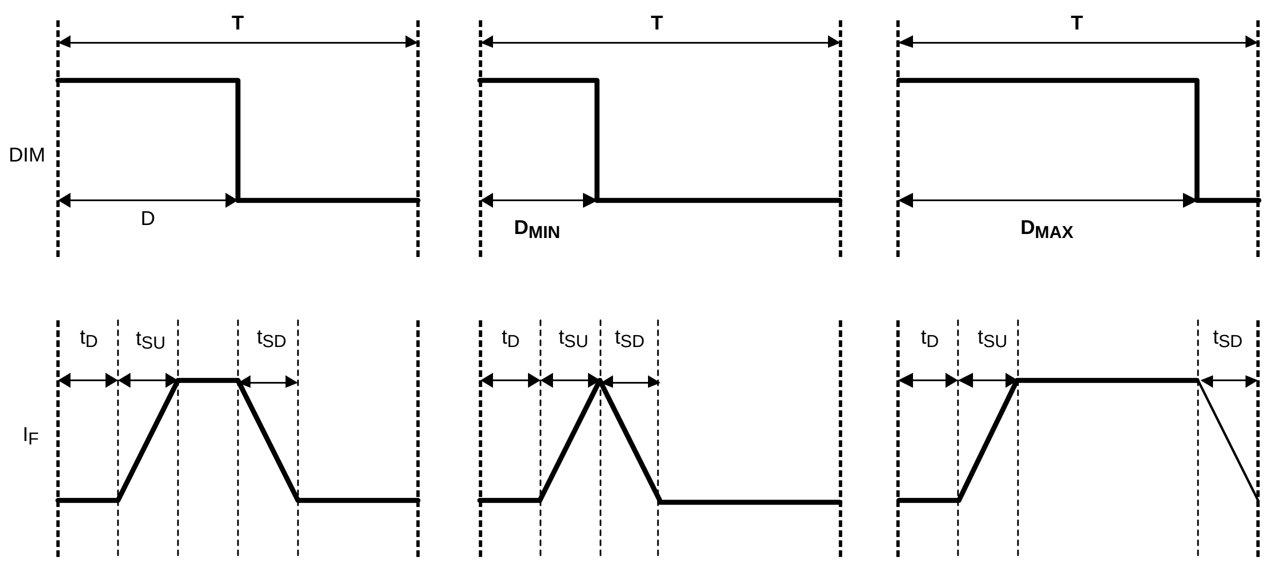
$$R_{SNS} = \frac{0.2 \times L}{I_F \times L + V_O \times t_{SNS} - \frac{V_{IN} - V_O}{2} \times t_{ON}} \quad (1)$$

$$t_{SNS} = 220 \text{ ns} \quad (2)$$

This resistor should be rated to handle the power dissipation of the LED current. For example, the closest 5% tolerance resistor to set an LED current of 1.0A is 0.22 Ω. In steady state this resistor will dissipate (1.0 x 0.22) = 220 mW, indicating that a resistor with a 1/4W power rating is appropriate.

6 PWM Dimming

The DIM1 terminal on the PCB provides an input for a pulse width modulation signal for dimming of the LED array. In order to fully enable and disable the LM3404/04HV the PWM signal should have a maximum logic low level of 0.8V and a minimum logic high level of 2.2V. The maximum PWM dimming frequency, minimum PWM duty cycle and maximum duty cycle are illustrated in Figure 2. PWM frequency should be at least one order of magnitude below the LM3404/04HV switching frequency. The interval t_D represents the delay from a logic high at the DIM pin to the onset of the output current. The quantities t_{SU} and t_{SD} represent the time needed for the output current to slew up to steady state and slew down to zero, respectively. Typical response times for the standard LM3404 and LM3404HV demo boards circuits are shown in the Typical Performance Characteristics section.



$$T = \frac{1}{f_{PWM}} \qquad D_{MIN} = \frac{t_D + t_{SU}}{T} \qquad D_{MAX} = \frac{T - t_{SD}}{T}$$

Figure 2. PWM Dimming Limits

The logic of DIM1 is direct, hence the LM3404/04HV will deliver regulated output current when the voltage at DIM1 is high, and the current output is disabled when the voltage at DIM1 is low. Connecting a constant logic low will disable the output, and the LM3404/04HV is enabled if the DIM pin is open-circuited. The DIM1 function disables only the power MOSFET, leaving all other circuit blocks functioning to minimize the converter response time.

The DIM2 terminal provides a second method for PWM dimming by connecting to the gate of an optional MOSFET, Q1. Note that Q1 is not provided on the standard BOM, and must be added for the DIM2 function to operate. Q1 provides a parallel path for the LED current. This small MOSFET can be turned on and off much more quickly than the LM3404/04HV can shutdown the internal MOSFET, providing faster response time for higher frequency and/or greater resolution in the PWM dimming signal. The trade-off in this method is that the full current flows through Q1 while the LED is off, resulting in lower efficiency.

The logic of DIM2 is inverted, hence the LM3404/04HV will deliver regulated output current when the voltage at DIM2 is low, and the current output is disabled when the voltage at DIM2 is high. Connecting a constant logic high to the DIM2 will turn off the LED but will not shut down the LM3404/04HV.

7 Low Power Shutdown

The LM3404/04HV can be placed into a low power shutdown (typically 90 µA) by grounding the OFF* terminal. During normal operation this terminal should be left open-circuit.

8 Output Open Circuit

With either DIM terminal floating or connected to logic high, the LM3404/04HV will begin to operate as soon as it has an input of at least 6V. In the case that the input is powered but no LED array is connected the output voltage will rise to equal the input voltage. The output of the circuit is rated to 50V (LM3404) or 100V (LM3404HV) and will not suffer damage, however care should be taken not to connect an LED array if the output voltage is higher than the target forward voltage of the LED array in steady state. Alternatively, a zener diode and zener current limiting resistor can be placed in the positions Z1 and R_Z. In the case of an accidental open circuit at the output Z1 will enter reverse bias and attempt to pull the CS pin voltage up to the output voltage. An internal comparator monitors the CS pin voltage and will disable the internal MOSFET in this case. The result is a low power hiccup mode, designed to prevent excessive voltage at the output and thermal stress on the inductor, internal MOSFET, and input voltage source.

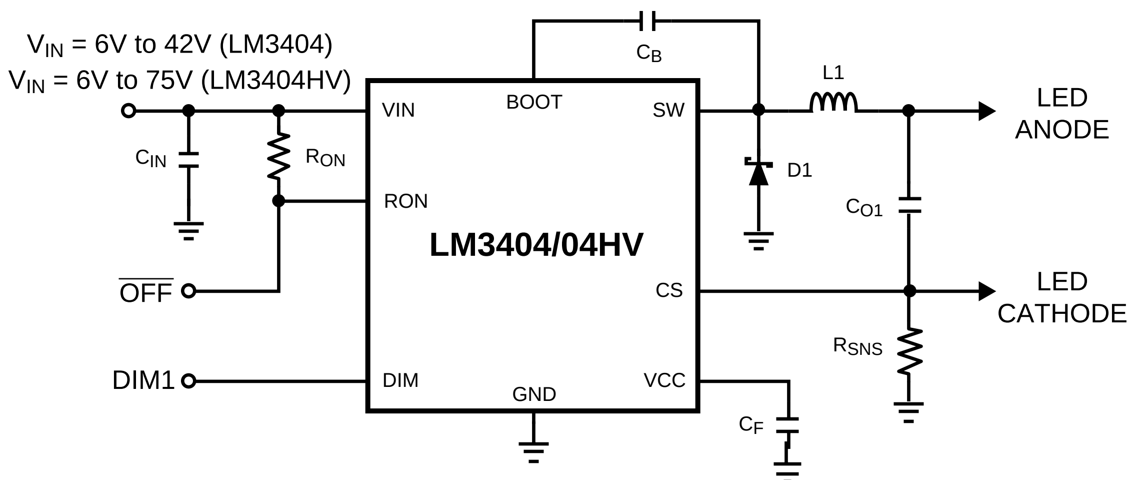


Figure 3. Standard Schematic

9 Bill of Materials

Table 1. Bill of Materials (LM3404)

ID	Part Number	Type	Size	Parameters	Qty	Vendor
U1	LM3404	LED Driver	SO-8	42V, 1.0A	1	Texas Instruments
L1	SLF10145T- 330M1R6	Inductor	10.1 x 10.1 x 4.5mm	33µH, 1.6A, 82mΩ	1	TDK
D1	CMSH2-60M	Schottky Diode	SMA	60V, 2A	1	Central Semi
Cf	VJ0805Y104KXXAT	Capacitor	0805	100nF 10%	1	Vishay
Cb	VJ0805Y103KXXAT	Capacitor	0805	10nF 10%	1	Vishay
Cin	C3225X7R1H335M	Capacitor	1210	3.3µF, 50V	1	TDK
Rsns	ERJ8BQFR22V	Resistor	1206	0.22Ω 1%	1	Panasonic
Ron	CRCW08056812F	Resistor	0805	68.1kΩ 1%	1	Vishay
Rz	CRCW08050R00F	Resistor	0805	0Ω	1	Vishay
DIM1, DIM2, $\overline{\text{OFF}}$	160-1512	Terminal	0.062”		3	Cambion
GND1, GND2, GND3, VIN, Vo/LED+, CS/LED-	160-1026	Terminal	0.094”		6	Cambion
J1	535676-5	Connector	Custom	6 Pins	1	Tyco/AMP

Table 2. Bill of Materials (LM3404HV)

ID	Part Number	Type	Size	Parameters	Qty	Vendor
U1	LM3404HV	LED Driver	MSOP-8	75V, 0.5A	1	Texas Instruments
L1	SLF12555T- 680M1R3	Inductor	12.5 x 12.5 x 5.5mm	68µH, 1.3A, 83mΩ	1	TDK
D1	CMSH2-100	Schottky Diode	SMB	100V, 2A	1	Central Semi
Cf	VJ0805Y104KXXAT	Capacitor	0805	100nF 10%	1	Vishay
Cb	VJ0805Y103KXXAT	Capacitor	0805	10nF 10%	1	Vishay
Cin	C4532X7R2A225M	Capacitor	1812	2.2µF, 100V	1	TDK
Co1	C3216X7R2A105M	Capacitor	1206	1.0µF, 100V	1	TDK
Rsns	ERJ8BQFR22V	Resistor	1206	0.22Ω 1%	1	Panasonic
Ron	CRCW08051743F	Resistor	0805	174kΩ 1%	1	Vishay
Rz	CRCW08050R00F	Resistor	0805	0Ω	1	Vishay
DIM1, DIM2, $\overline{\text{OFF}}$	160-1512	Terminal	0.062”		3	Cambion
GND1, GND2, GND3, VIN, Vo/LED+, CS/LED-	160-1026	Terminal	0.094”		6	Cambion
J1	535676-5	Connector	Custom	6 Pins	1	Tyco/AMP

10 Evaluation Board Schematic

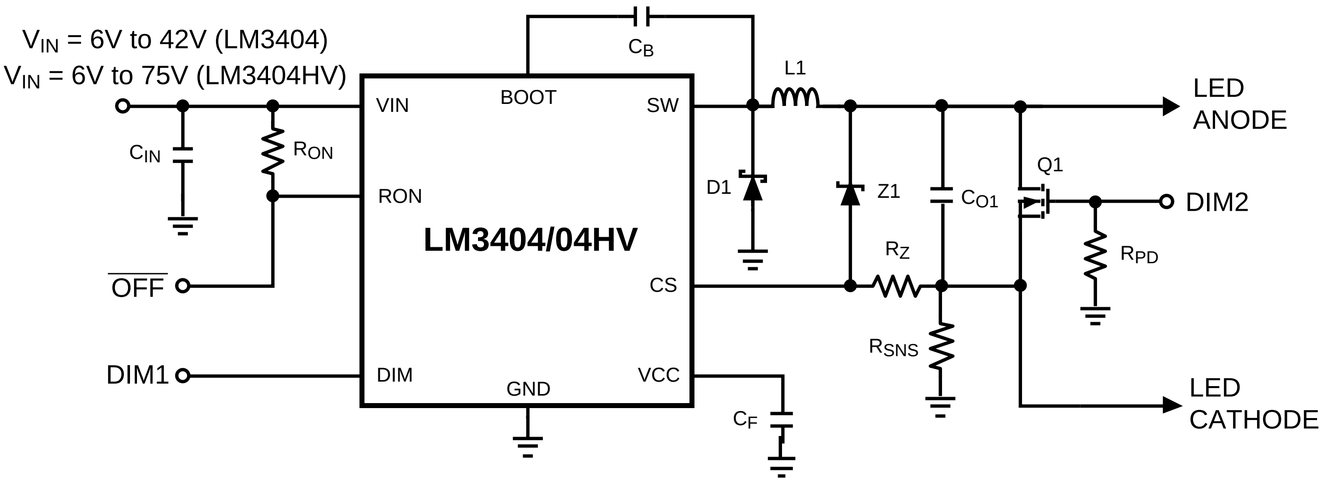
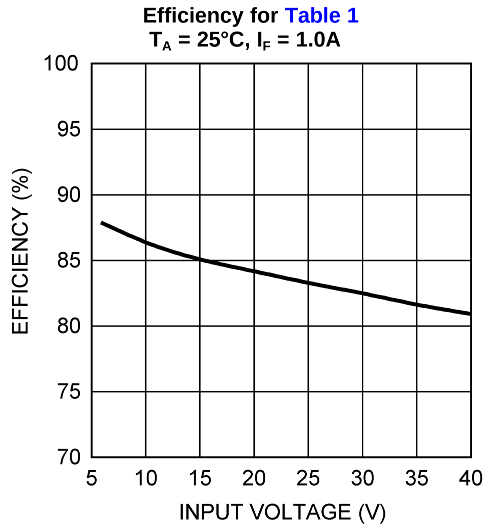
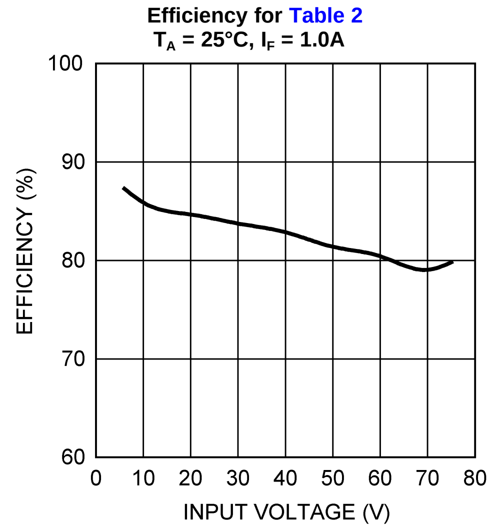
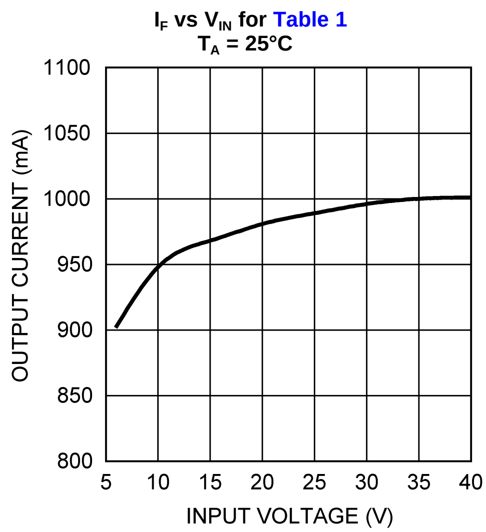


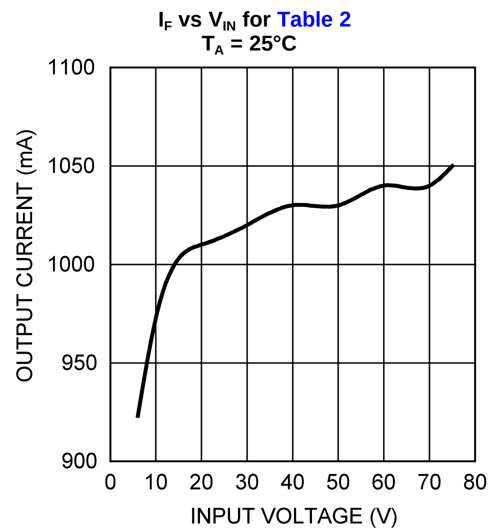
Figure 4. Complete Evaluation Board Schematic

11 Typical Performance Characteristics

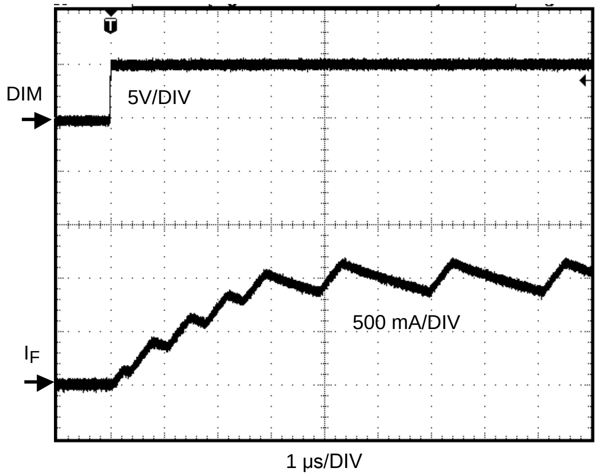




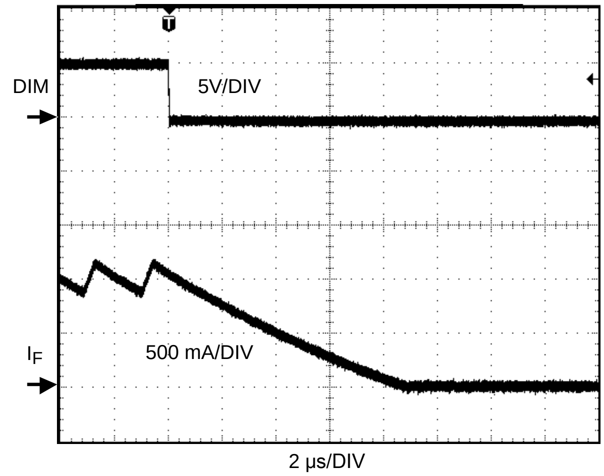




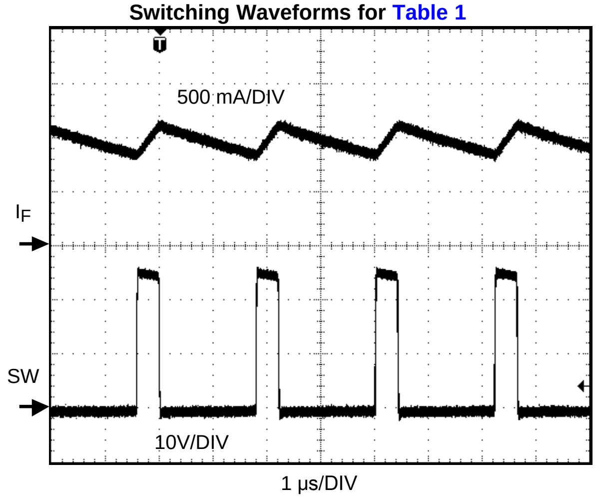
DIM Pin Enable for Table 1



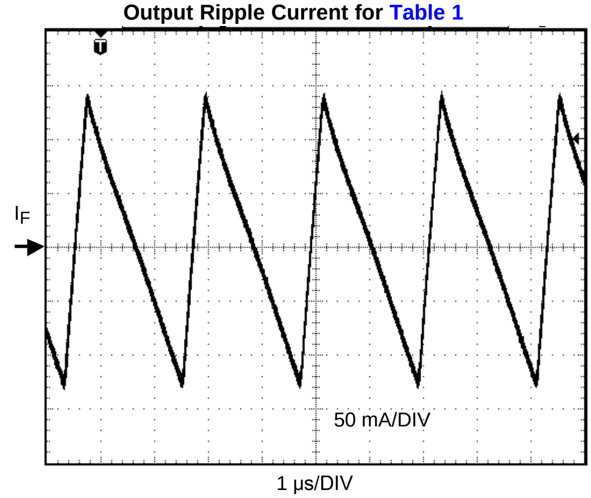
DIM Pin Disable for Table 1



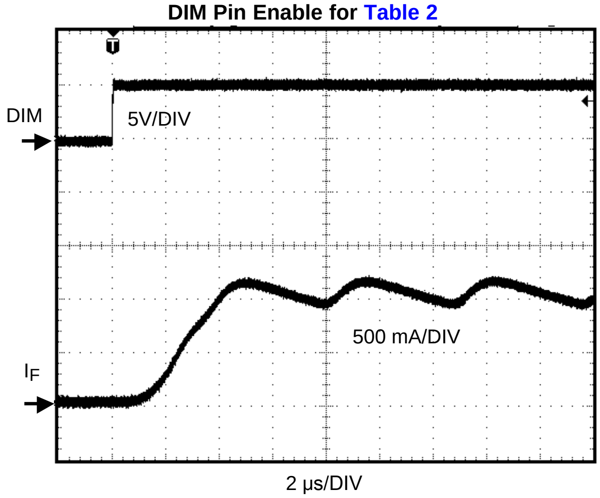
Switching Waveforms for Table 1



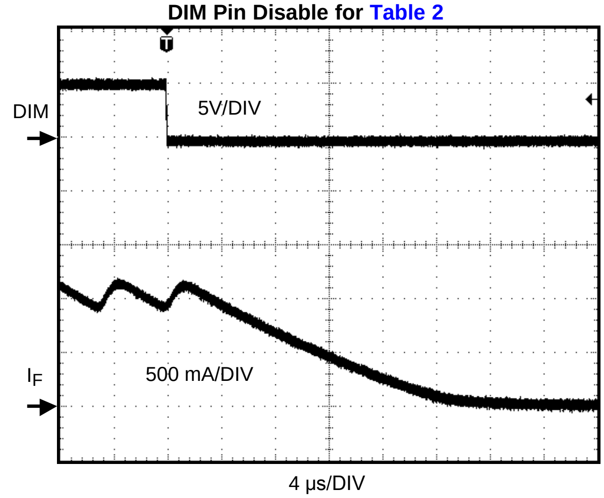
Output Ripple Current for Table 1



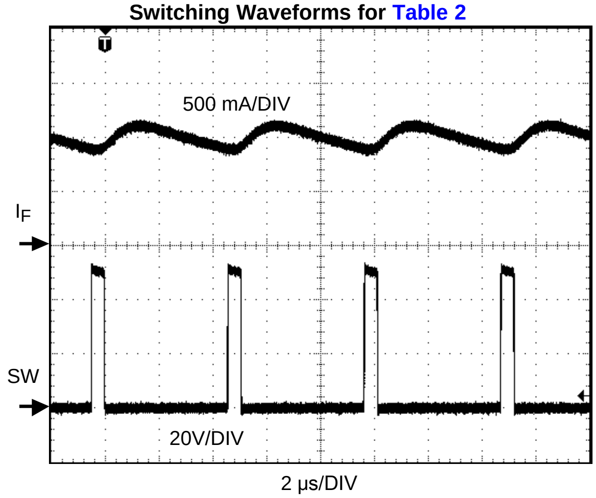
DIM Pin Enable for Table 2



DIM Pin Disable for Table 2



Switching Waveforms for Table 2



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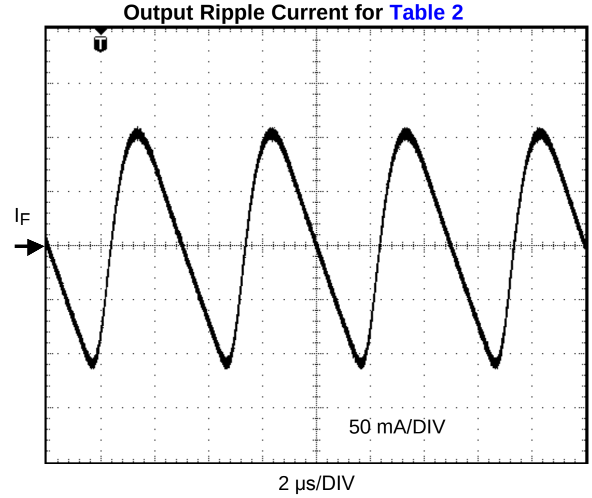

12 Layout

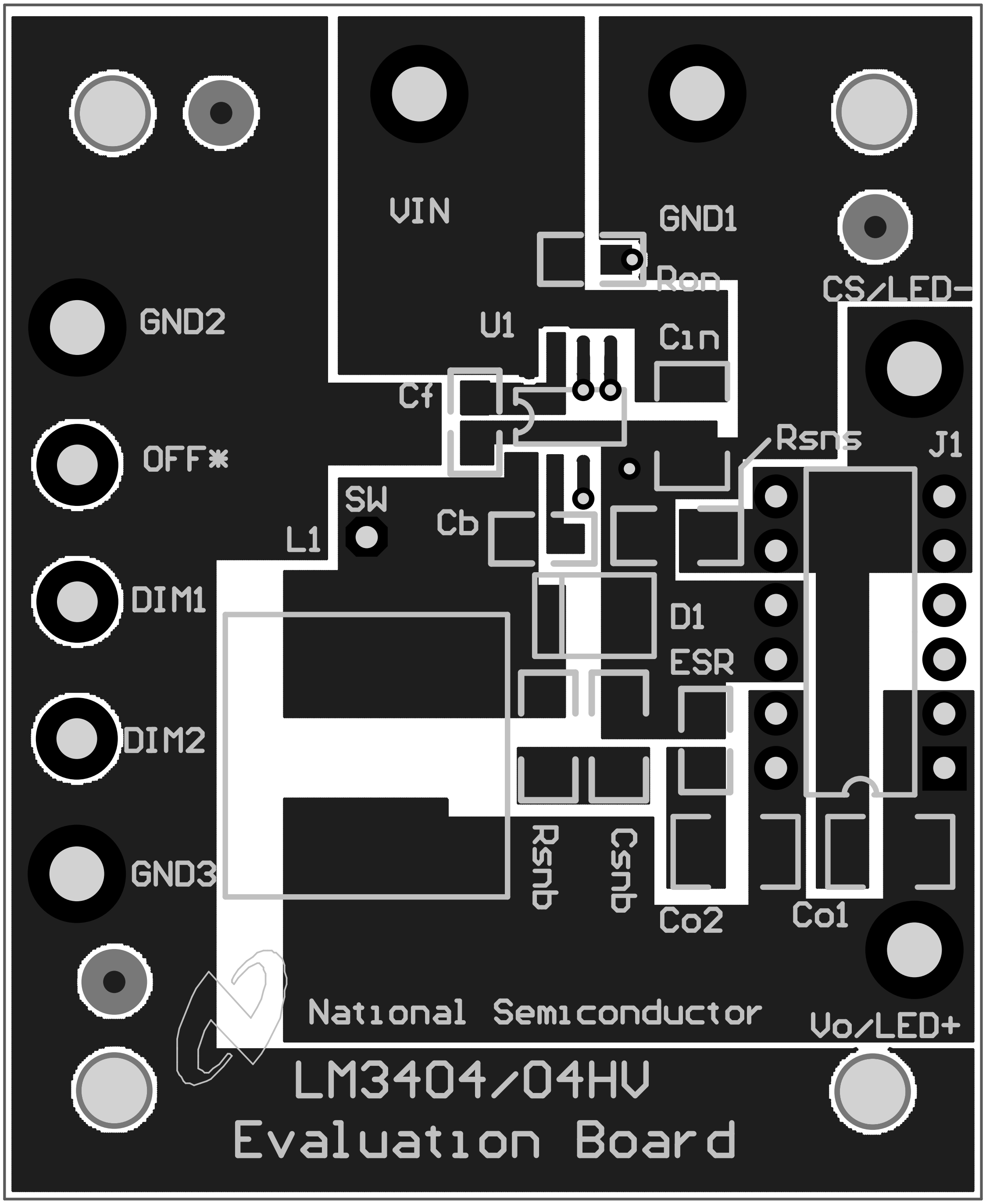

Figure 5. Top Layer and Top Overlay

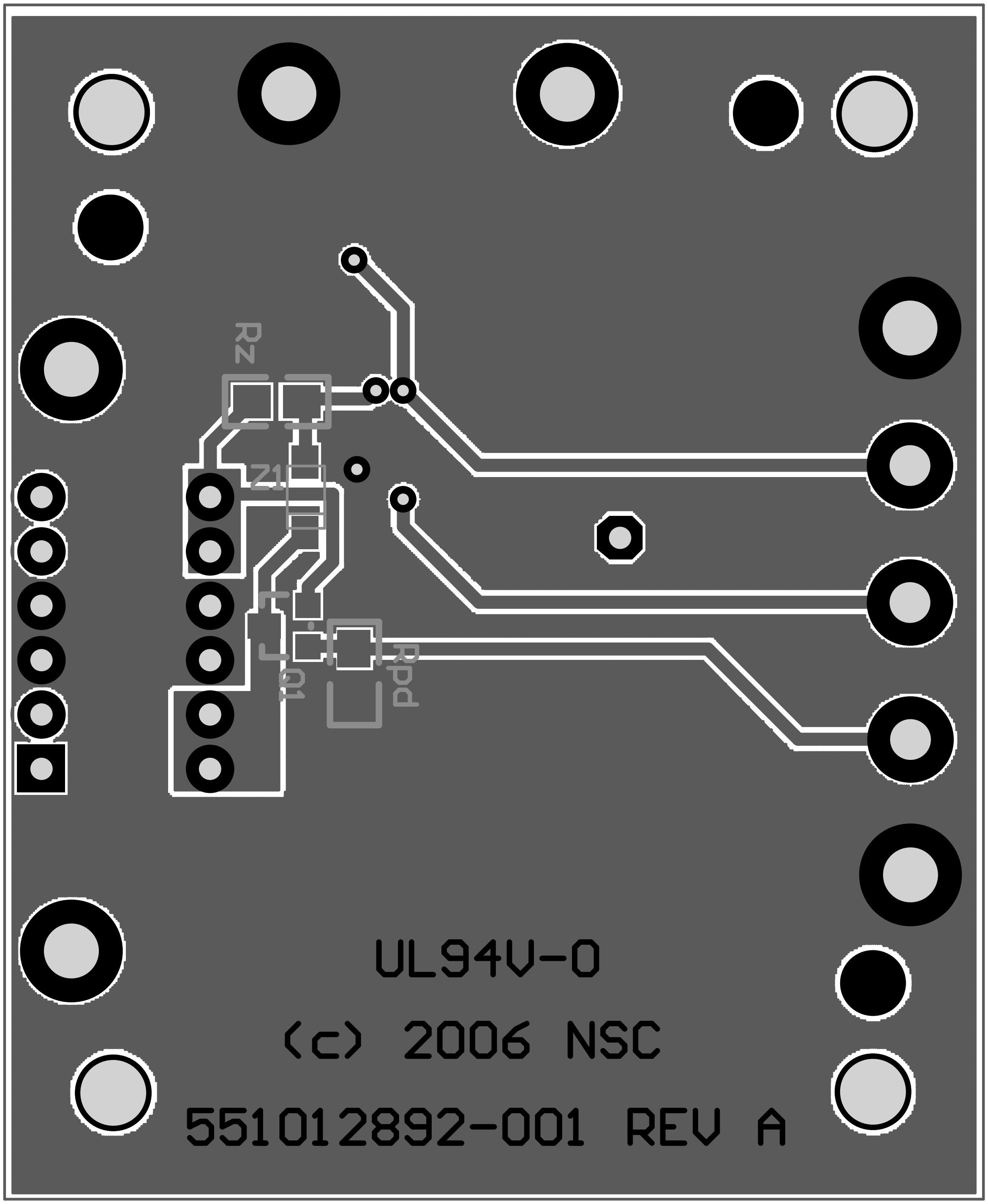

Figure 6. Bottom Layer and Bottom Overlay

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