

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 $\pm 10\%$. Over the input voltage range of 6V to 42V the average LED current, I_F , is 1.0A $\pm 10\%$, the ripple current, Δi_F , will not exceed 400 mA_{P-P}, and the switching frequency is 450 kHz $\pm 10\%$.

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 $\pm 10\%$. Over the input voltage range of 6V to 75V the average LED current, I_F , is 1.0A $\pm 10\%$, the ripple current, Δi_F , will not exceed 400 mA_{P-P}, and the switching frequency is 200 kHz $\pm 10\%$.

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.

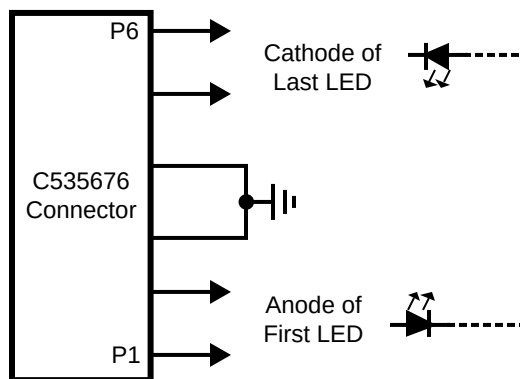


Figure 1. Connecting to LED Array

All trademarks are the property of their respective owners.

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 $(1.0 \times 0.22) = 220 \text{ mW}$, 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.

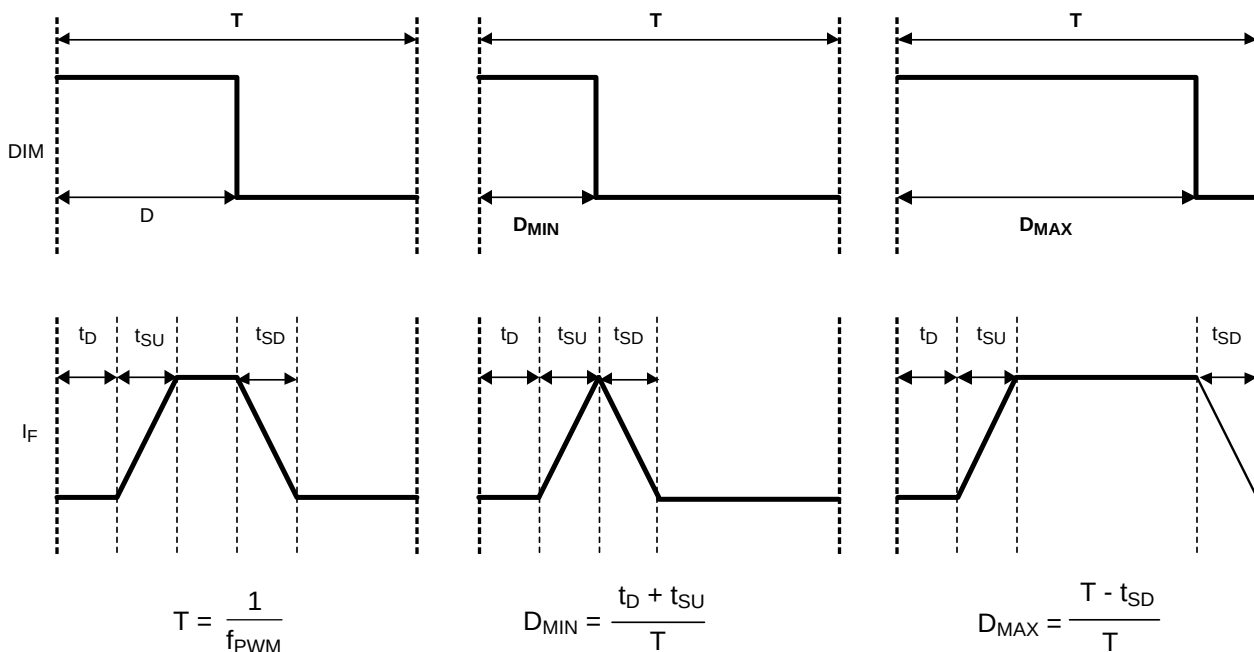


Figure 2. PWM Dimming Limits

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 μ A) 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.

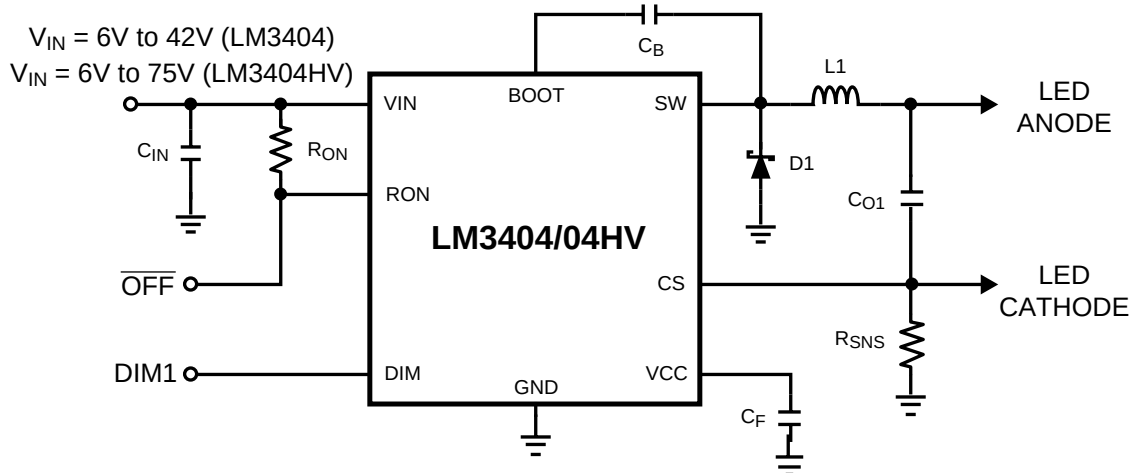


Figure 3. Standard Schematic

9 Bill of Materials

Table 1. Bill of Materials (LM3404)

ID	Part Number	Type	Size	Parameters	Qty	Vendor
U1	LM3404	LED Driver	SOIC-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, 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	SO PowerPAD-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, 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

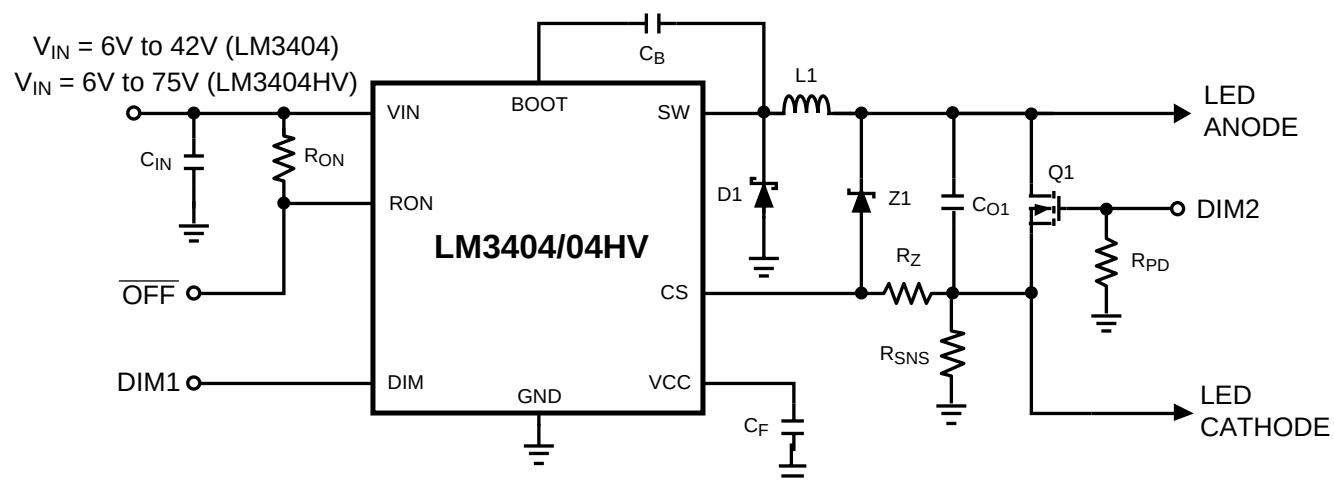
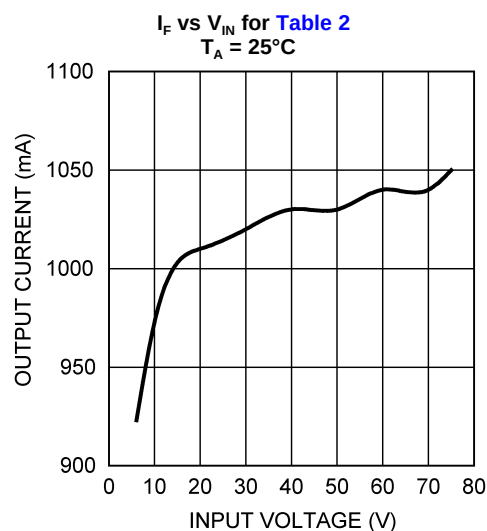
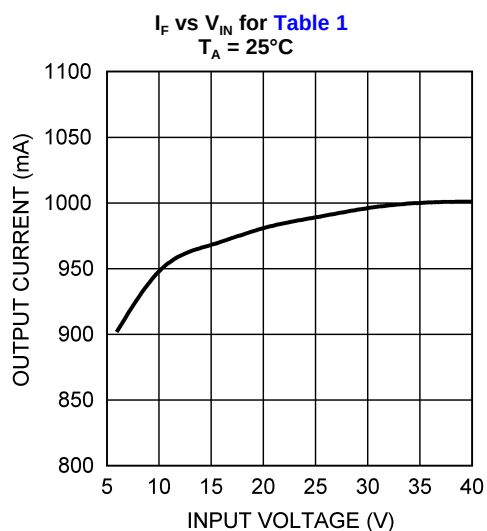
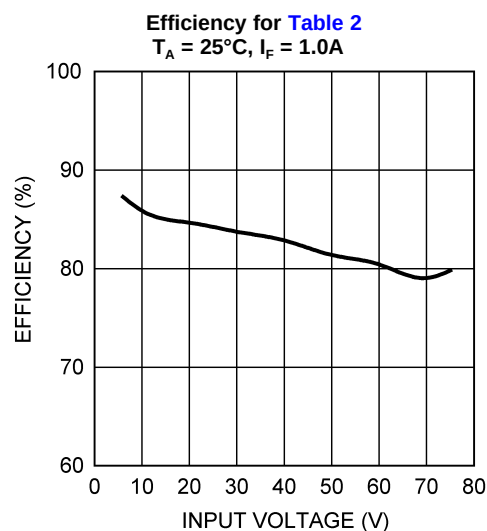
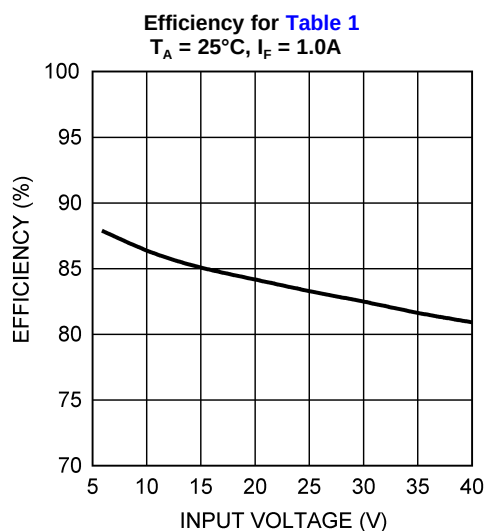
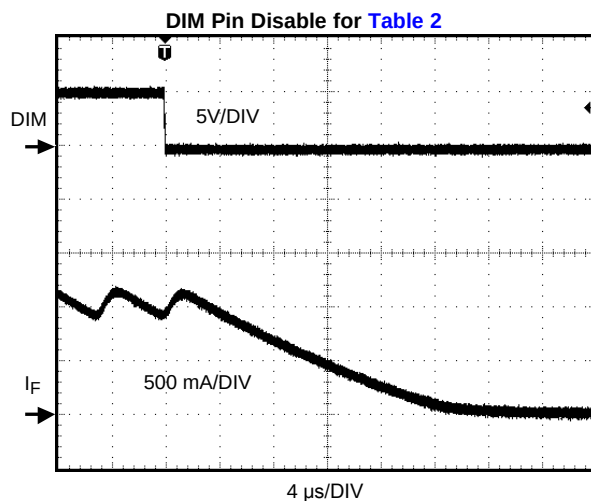
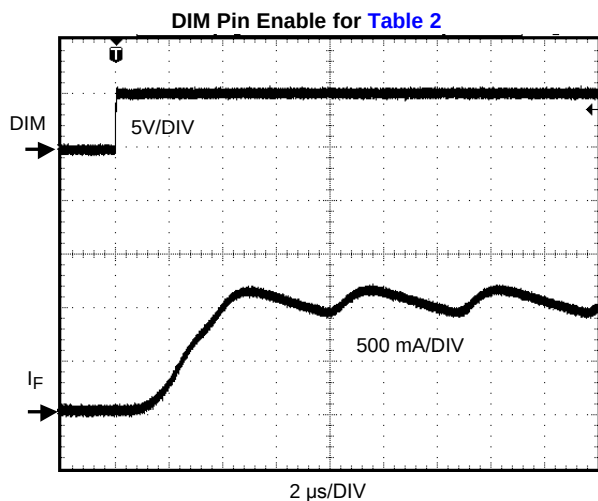
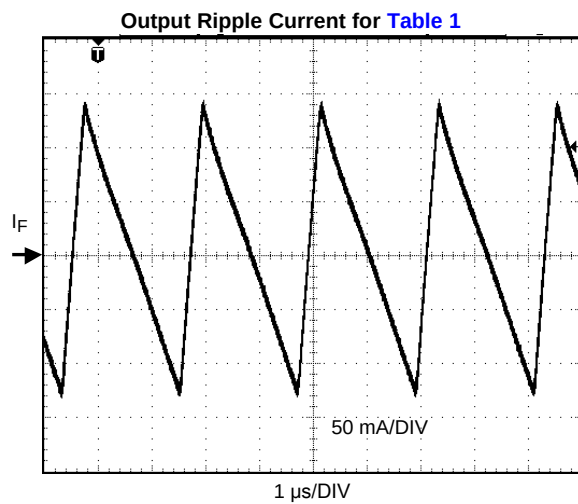
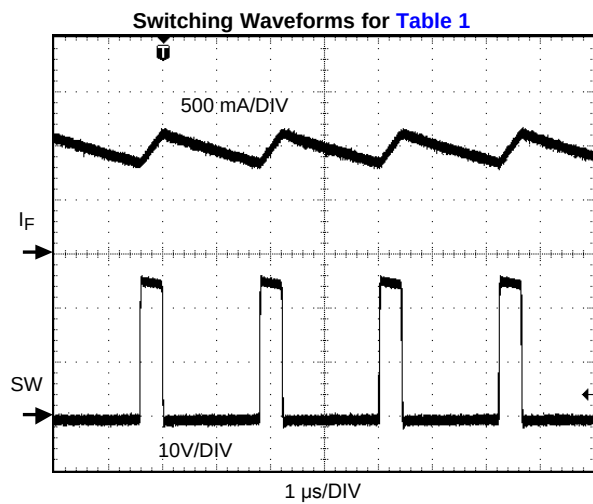
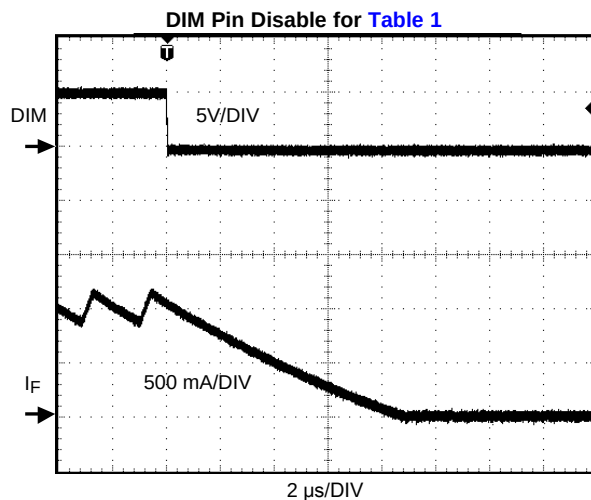
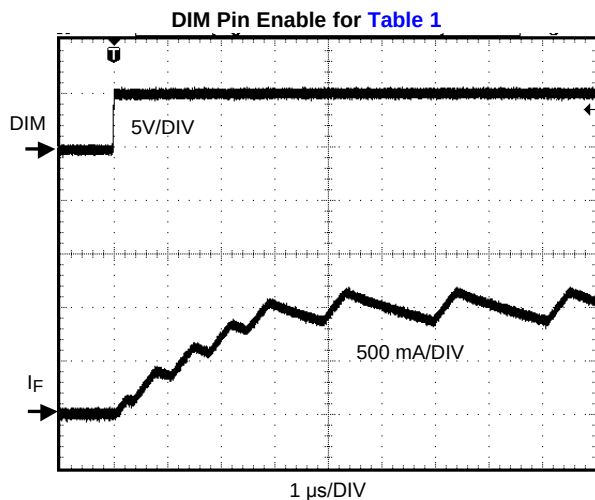
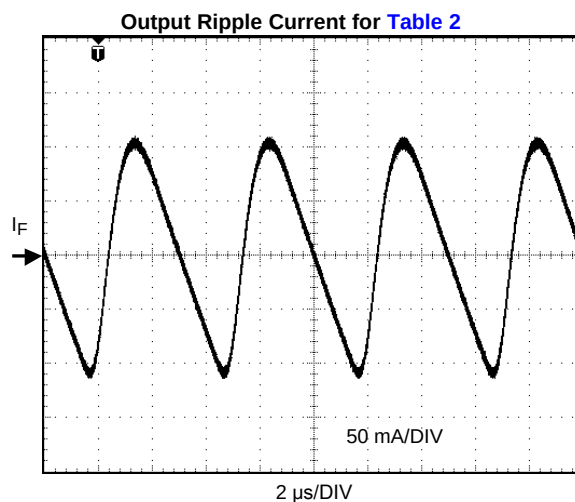
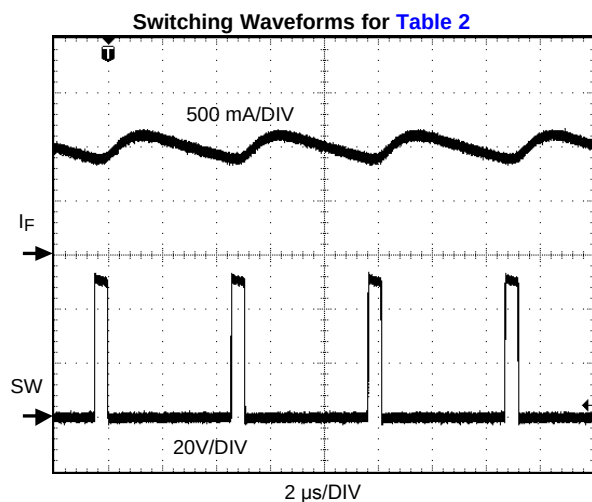


Figure 4. Complete Evaluation Board Schematic

11 Typical Performance Characteristics







12 Layout

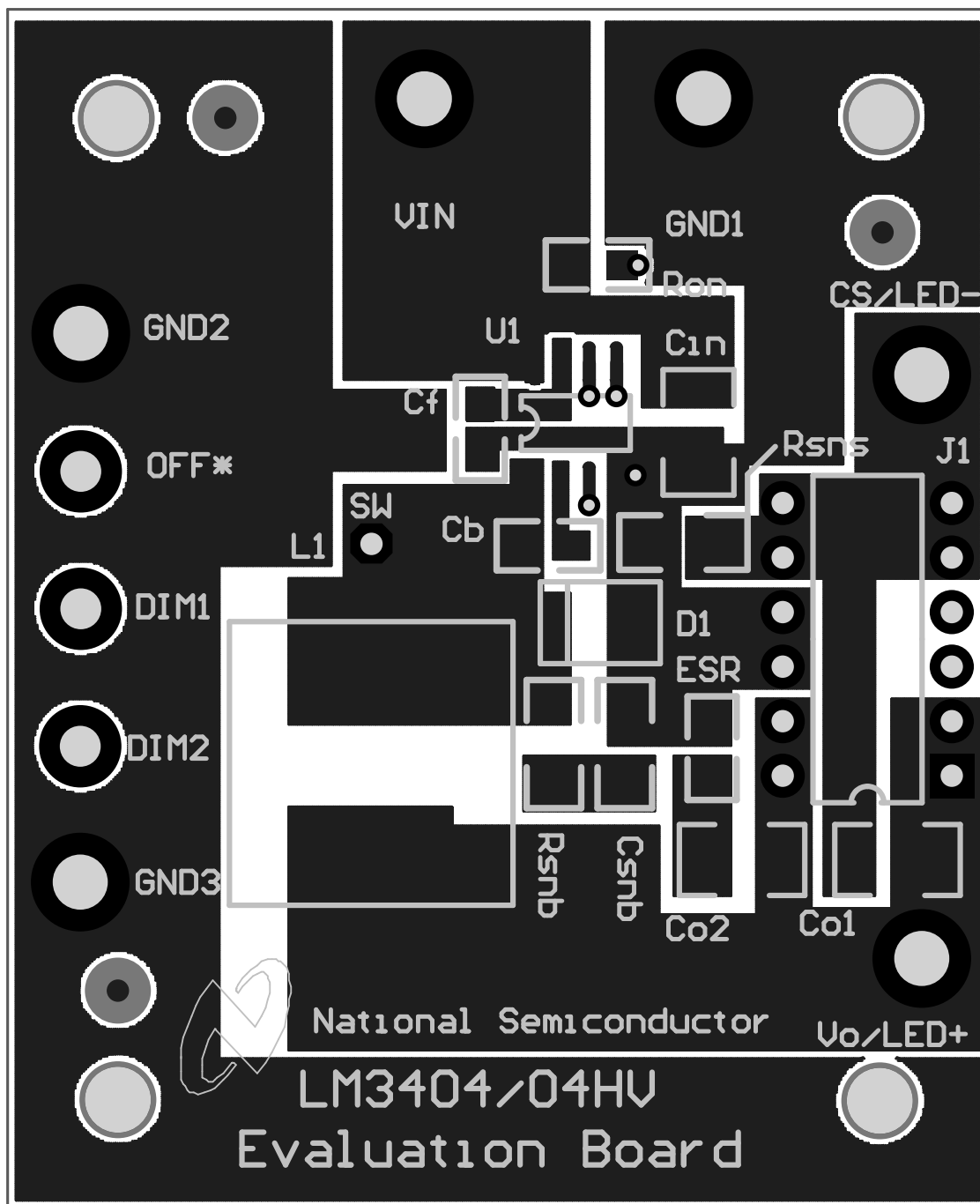


Figure 5. Top Layer and Top Overlay

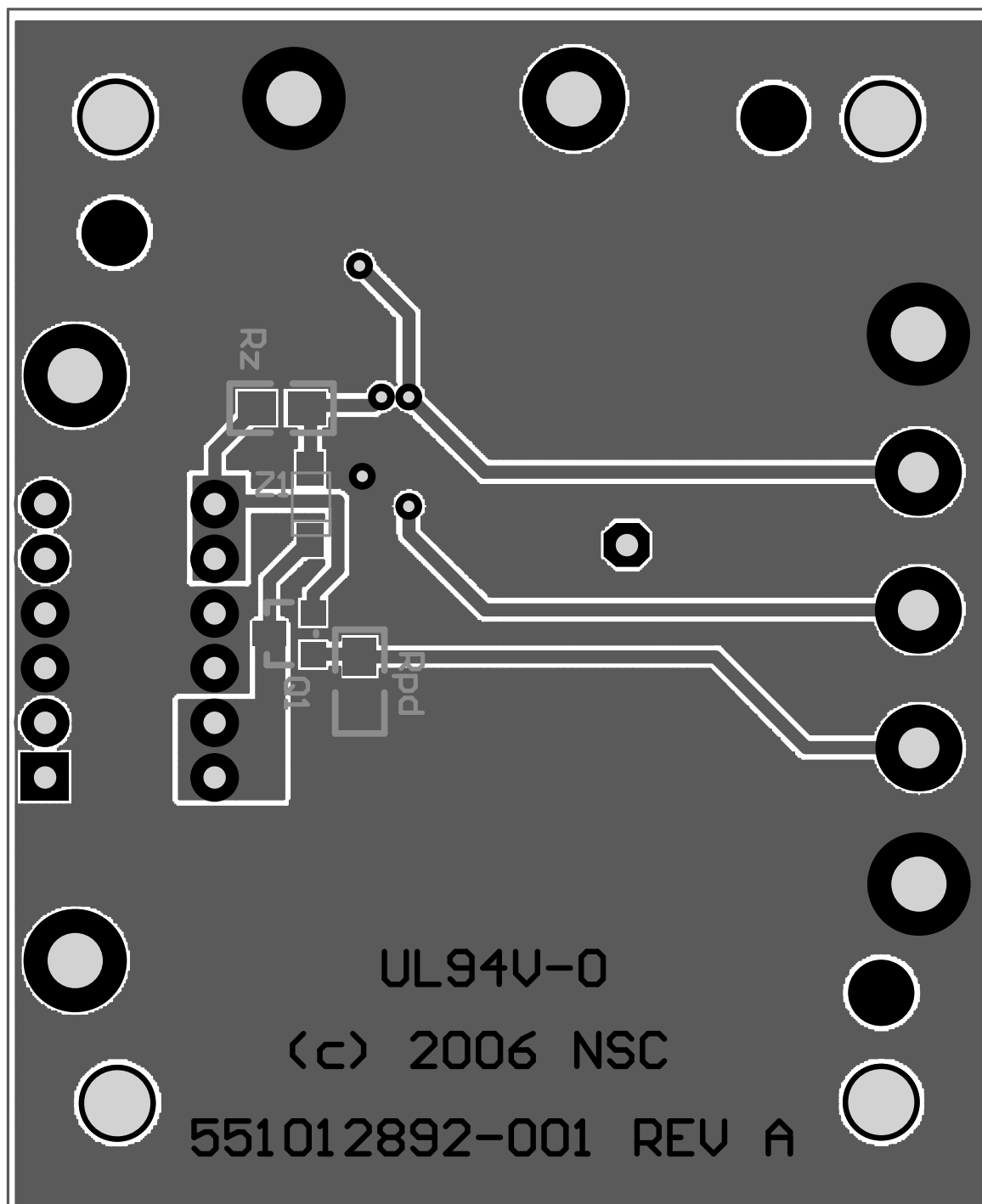


Figure 6. Bottom Layer and Bottom Overlay

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as "components") are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI's terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers' products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers' products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI's goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have **not** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products

Audio	www.ti.com/audio
Amplifiers	amplifier.ti.com
Data Converters	dataconverter.ti.com
DLP® Products	www.dlp.com
DSP	dsp.ti.com
Clocks and Timers	www.ti.com/clocks
Interface	interface.ti.com
Logic	logic.ti.com
Power Mgmt	power.ti.com
Microcontrollers	microcontroller.ti.com
RFID	www.ti-rfid.com
OMAP Applications Processors	www.ti.com/omap
Wireless Connectivity	www.ti.com/wirelessconnectivity

Applications

Automotive and Transportation	www.ti.com/automotive
Communications and Telecom	www.ti.com/communications
Computers and Peripherals	www.ti.com/computers
Consumer Electronics	www.ti.com/consumer-apps
Energy and Lighting	www.ti.com/energy
Industrial	www.ti.com/industrial
Medical	www.ti.com/medical
Security	www.ti.com/security
Space, Avionics and Defense	www.ti.com/space-avionics-defense
Video and Imaging	www.ti.com/video

TI E2E Community

e2e.ti.com