LM3402/02HV Demo Board

National Semiconductor
Application Note 1500
Chris Richardson
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Introduction

The LM3402/LM3402HV 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™ I Emitter at forward currents of up to 500 mA. The board can accept an input voltage ranging from 6V to 42V when using the LM3402. When using the pin-for-pin compatible LM3402HV 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 LM3402/02HV 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 $V_{O(MAX)}$.

Circuit Performance LM3402

The LM3402 circuit and BOM have been designed to provide a constant forward current of 350 mA to a single LED with a forward voltage of approximately 3.5V. (Typical of white, blue, and green LEDs using InGaN technology.) When powered from a 24V ±5% input the demo board will maintain the average LED current, I_F, to within 10% of 350 mA. The ripple current, Δi_F, will not exceed 70 mA peak-to-peak. Switching frequency for the demo board is 600 kHz ± 10% over the input voltage range of 6V to 42V.

Circuit Performance LM3402HV

The LM3402HV circuit and BOM have been designed to provide a constant forward current of 350 mA to a single LED with a forward voltage of approximately 3.5V. When powered from a 48V ± 5% input the demo board will maintain I_F to within ±5% of 350 mA. Ripple current will not exceed 70 mA peak-to-peak. Switching frequency for the demo board is 250 kHz ±10% over the input voltage range of 6V to 75V.

Connecting to LED Array

The LM3402/02HV demo 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**.

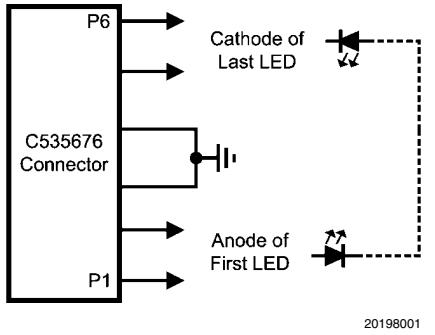


FIGURE 1.

Setting the LED Current

The default forward current I_{LED} delivered to the LED array is 350 mA, typical of many 1W LEDs. To adjust this value the current setting resistor R_{SNS} can be changed according to the following equation:

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

$$t_{SNS} = 220 \text{ ns}$$

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 350 mA is 0.56 Ω. In steady state this resistor will dissipate (0.352 x 0.56) = 69 mW, indicating that a resistor with a 1/8W power rating is appropriate.

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 LM3402/02HV 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 LM3402/02HV 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 LM3402 and LM3402HV demo boards circuits are shown in the Typical Performance Characteristics section.

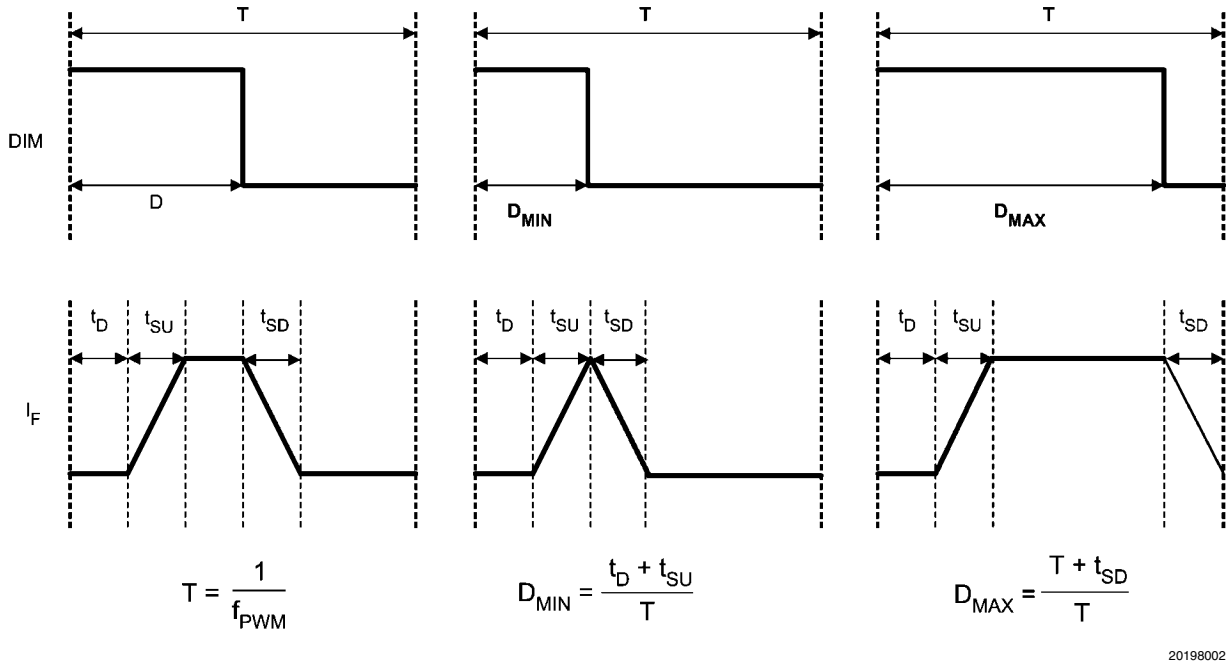


FIGURE 2. PWM Dimming Limits

The logic of **DIM1** is direct, hence the LM3402/02HV 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 LM3402/02HV is enabled if the DIM pin is open-circuited. The **DIM1** function disables only the power NFET, 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 NFET, **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 NFET can be turned on and off much more quickly than the LM3402/02HV can shutdown the internal NFET, providing faster response time for higher frequency and/or greater resolution in the PWM dimming signal. The tradeoff 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 LM3402/02HV 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 LM3402/02HV.

Low Power Shutdown

The LM3402/02HV 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.

Output Open Circuit

With either DIM terminal floating or connected to logic high, the LM3402/02HV 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 (LM3402) or 100V (LM3402HV) 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 $\mathbf{R_Z}$. 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 NFET 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 NFET, and input voltage source.

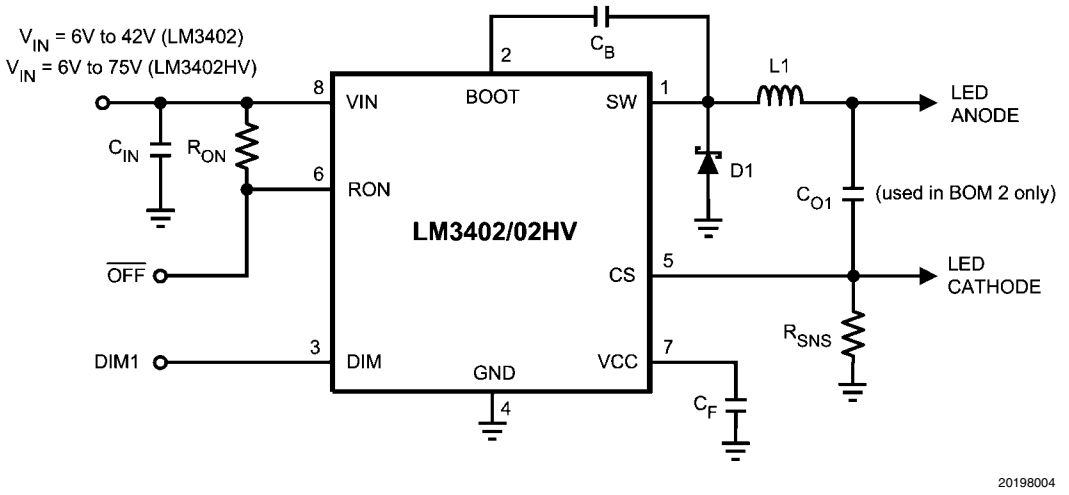


FIGURE 3. Standard Schematic

TABLE 1. BOM 1 (LM3402)

ID	Part Number	Type	Size	Parameters	Qty	Vendor
U1	LM3402	LED Driver	MSOP-8	42V, 0.5A	1	NSC
L1	SLF10145T-101M1R0	Inductor	10.1 x 10.1 x 4.5mm	100µH, 1A, 0.2Ω	1	TDK
D1	CMSH1-60M	Schottky Diode	SMA	60V, 1A	1	Central Semi
Cf	VJ0805Y104KXXAT	Capacitor	0805	100nF 10%	1	Vishay
Cb	VJ0805Y103KXXAT	Capacitor	0805	10nF 10%	1	Vishay
Cin	C3216X7R1H105M	Capacitor	1206	1µF 50V	1	TDK
Rsns	ERJ6BQFR56V	Resistor	0805	0.56Ω 1%	1	Panasonic
Ron	CRCW08054642F	Resistor	0805	46.4kΩ 1%	1	Vishay
Rz	CRCW08050R00F	Resistor	0805	0Ω	1	Vishay
DIM1, DIM2	160-1512	Terminal Silver	0.062”		2	Cambion
GND1, GND2, GND3, VIN, ISNS / C, Vo / A, SW	160-1026	Terminal Silver	0.094”		7	Cambion
J1	535676-5	Connector	Custom	6 Pins	1	Tyco/AMP

TABLE 2. BOM 2 (LM3402HV)

ID	Part Number	Type	Size	Parameters	Qty	Vendor
U1	LM3402HV	LED Driver	MSOP-8	75V, 0.5A	1	NSC
L1	SLF10145T-151MR79	Inductor	10.1 x 10.1 x 4.5mm	150µH, 0.8A, 0.2Ω	1	TDK
D1	CMSH1-100M	Schottky Diode	SMA	100V, 1A	1	Central Semi
Cf	VJ0805Y104KXXAT	Capacitor	0805	100nF 10%	1	Vishay
Cb	VJ0805Y103KXXAT	Capacitor	0805	10nF 10%	1	Vishay
Cin	C3225X7R2A105M	Capacitor	1210	1µF 100V	1	TDK
Co1	C3216X7R1E225M	Capacitor	1206	2.2µF 25V	1	TDK
Rsns	ERJ6BQFR68V	Resistor	0805	0.68Ω 1%	1	Panasonic
Ron	CRCW08051303F	Resistor	0805	130kΩ 1%	1	Vishay
Rz	CRCW08050R00F	Resistor	0805	0Ω	1	Vishay
DIM1, DIM2	160-1512	Terminal Silver	0.062”		2	Cambion
GND1, GND2, GND3, VIN, ISNS / C, Vo / A, SW	160-1026	Terminal Silver	0.094”		7	Cambion
J1	535676-5	Connector	Custom	6 Pins	1	Tyco/AMP

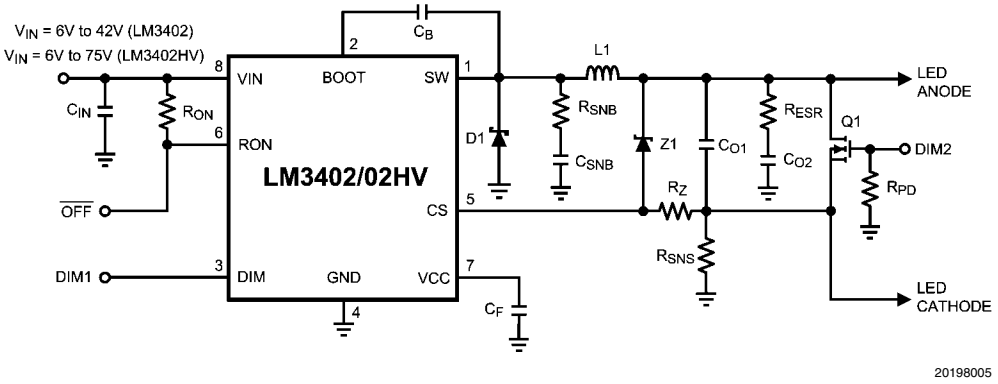
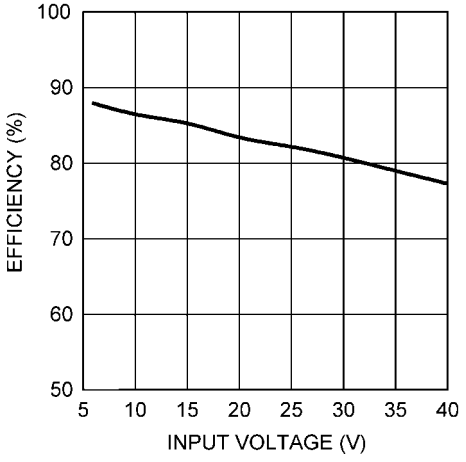


FIGURE 4. Complete Evaluation Board Schematic

Typical Performance Characteristics

Efficiency for *Table 1*
T_A = 25°C, I_F = 350 mA



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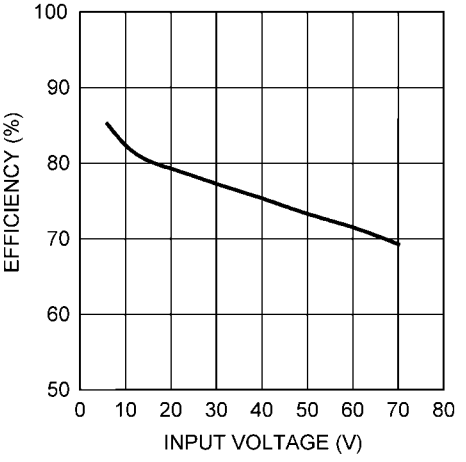
Efficiency for *Table 2*
T_A = 25°C, I_F = 350 mA



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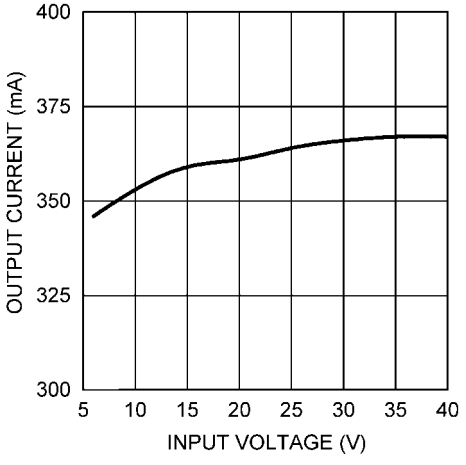
I_F vs V_{IN} for *Table 1*
T_A = 25°C



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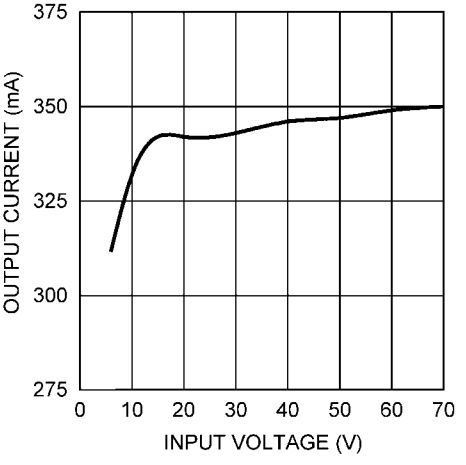
I_F vs V_{IN} for *Table 2*
T_A = 25°C



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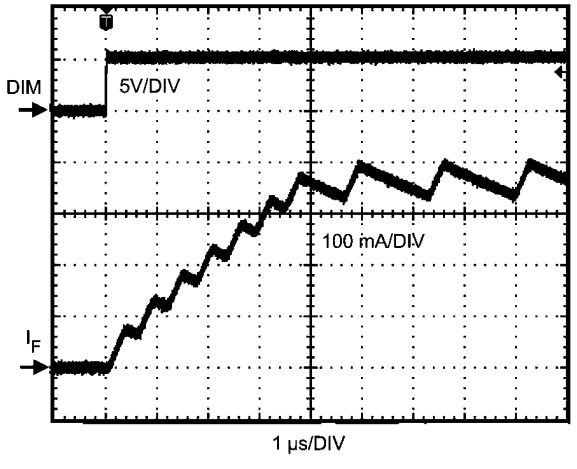
DIM Pin Enable *Table 1*



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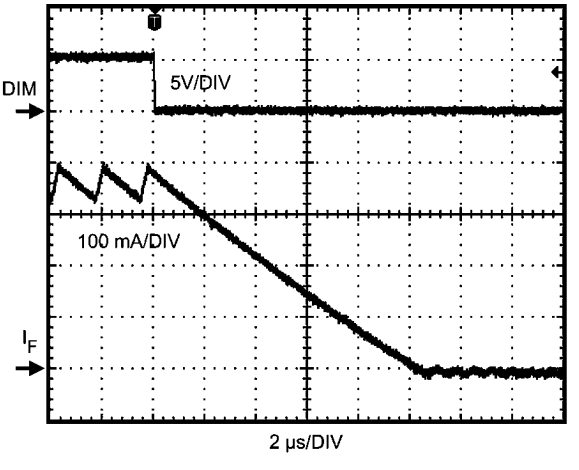
DIM Pin Disable *Table 1*



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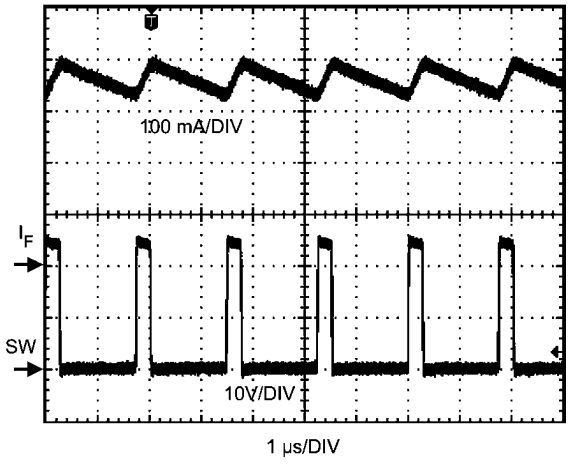
Switching Waveforms for *Table 1*



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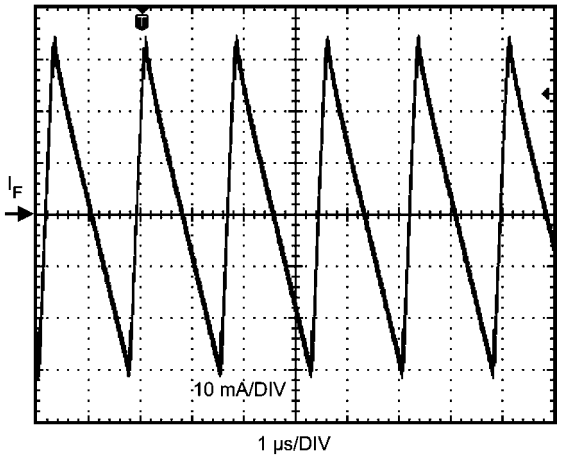
Output Ripple Current *Table 1*



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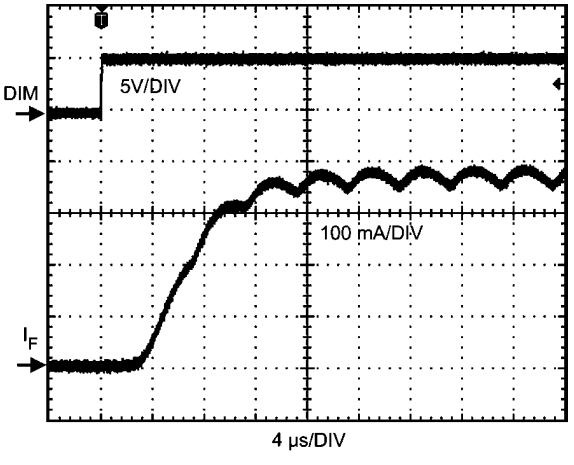
DIM Pin Enable *Table 2*



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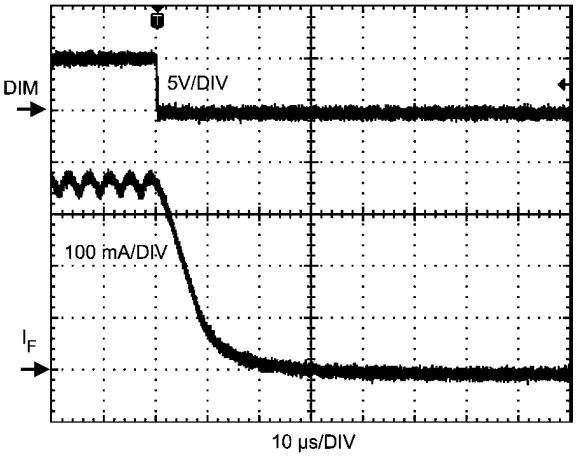
DIM Pin Disable *Table 2*



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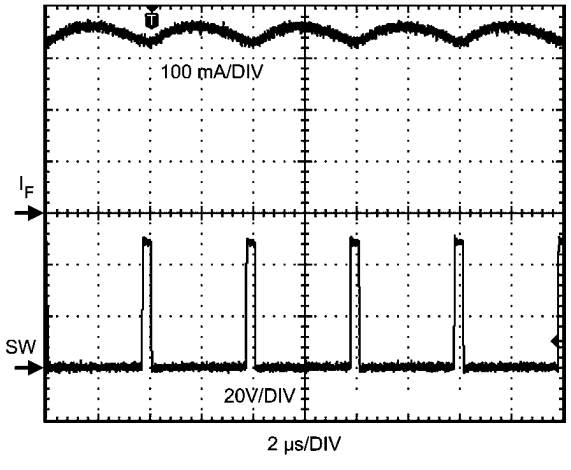
Switching Waveforms for *Table 2*



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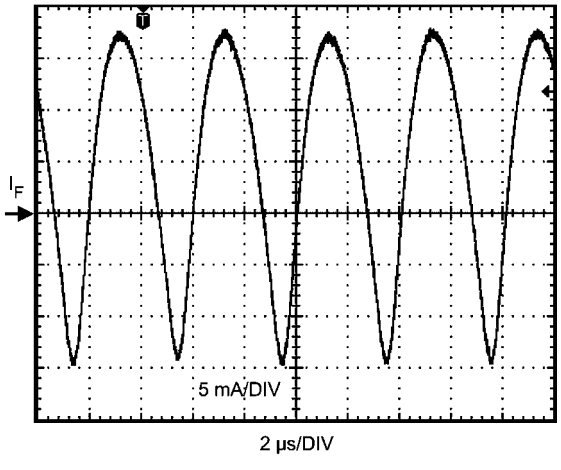
Output Ripple Current *Table 2*



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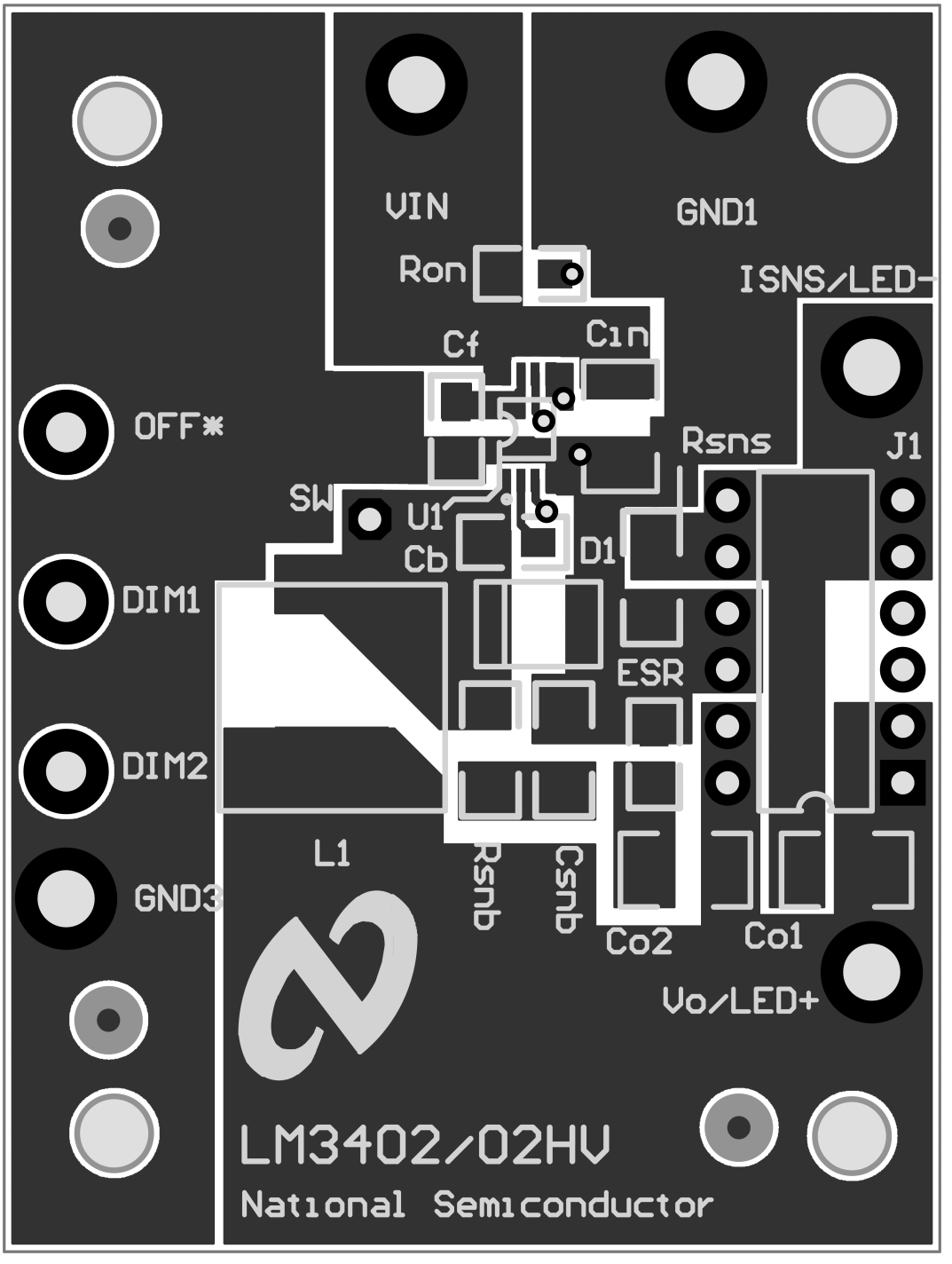
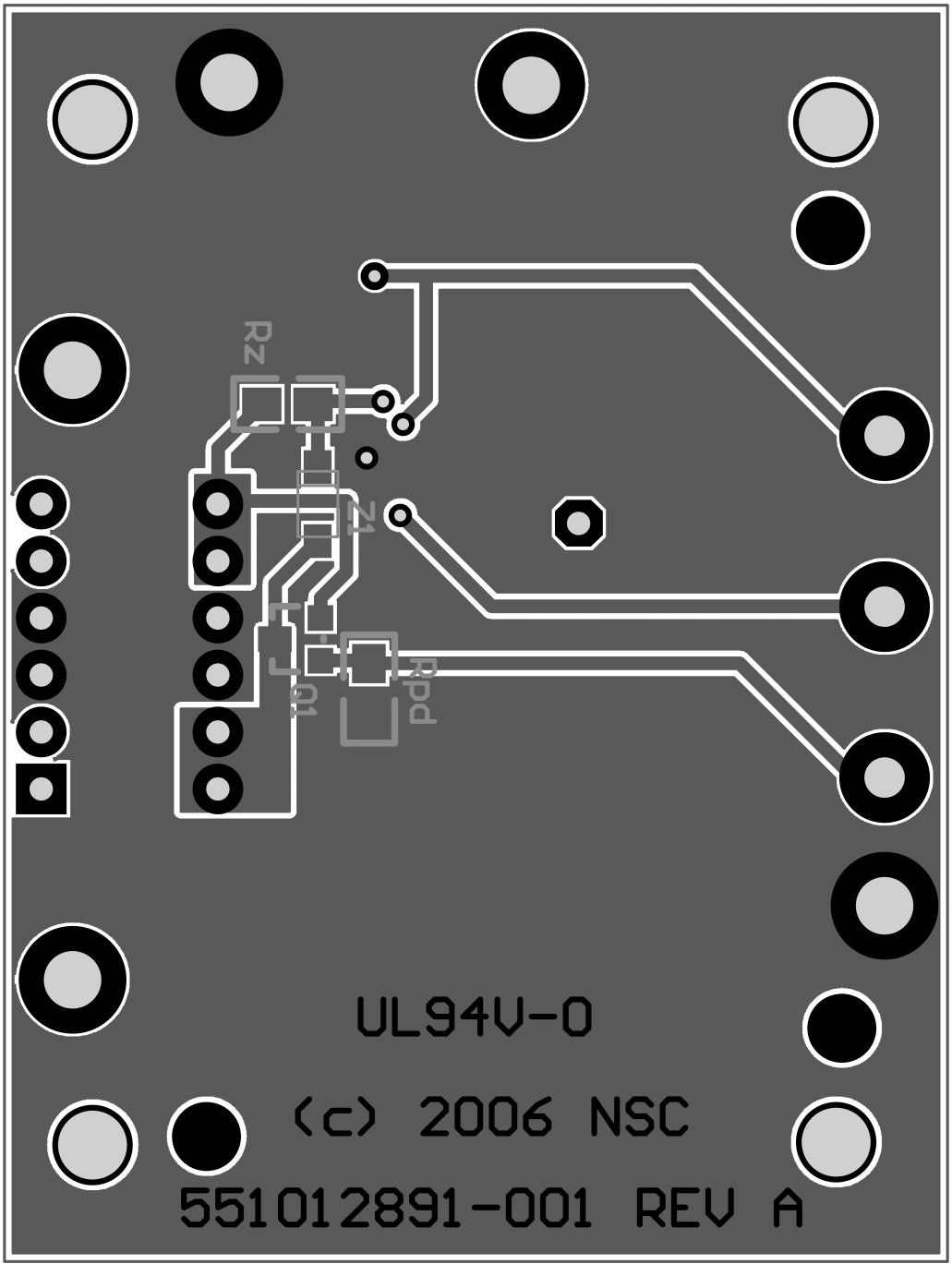
Layout



Top Layer and Top Overlay



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Bottom Layer and Bottom Overlay

Notes

Notes

National Semiconductor Americas Customer Support Center
Email: new.feedback@nsc.com
Tel: 1-800-272-9959

National Semiconductor Europe Customer Support Center
Fax: +49 (0) 180-530-85-86
Email: europe.support@nsc.com
Deutsch Tel: +49 (0) 69 9508 6208
English Tel: +49 (0) 870 24 0 2171
Français Tel: +33 (0) 1 41 91 8790

National Semiconductor Asia Pacific Customer Support Center
Email: ap.support@nsc.com

National Semiconductor Japan Customer Support Center
Fax: 81-3-5639-7507
Email: jpn.feedback@nsc.com
Tel: 81-3-5639-7560