AN-1764 LM3431 Evaluation Board

1 Introduction

The LM3431 is a combination switching boost voltage regulator and multi-channel LED current controller. The LM3431 Evaluation Board is designed to drive four parallel strings of eight series LEDs at 140mA per string from an input voltage range of 8V to 18V. The boost switcher regulates LED cathode voltage for optimum efficiency, while allowing the output voltage to vary according to the LED forward voltage. The LM3431 incorporates complete fault protection features including LED short and open protection, over-current protection, over-voltage and under-voltage protection, and thermal shutdown. The error detection flag can be monitored at the DLY post, which has a programmable delay time.

The board includes a DIM input terminal for a selectable digital or analog dimming control signal. PWM dimming frequencies up to 1kHz at 100:1 contrast ratio and contrast ratios up to 500:1 at 200Hz are possible.

The evaluation board is designed to operate at ambient temperatures up to 70°C.

The complete evaluation board schematic is shown in Figure 2. Typical waveforms and performance curves are shown in Figure 3 through Figure 8.

Although a wide variety of LED combinations and currents can be driven with the LM3431, the schematic must be modified to achieve optimum performance with any given array. However, for initial evaluation and demonstration, some modifications from the default settings are possible. A few of the possible variations are described below and listed in Table 2 and Table 3.

LED current can be set as low as 100mA per string without significantly degrading performance; the number of strings can be reduced from 4 to 3 or 2; and the number of series LEDs can be set between 6 and 9.

To design for LED arrays other than the default, and for complete device and design information, refer to the *LM3431/31A/31Q/31AQ 3-Channel Constant Current LED Driver With Integrated Boost Controller* (SNVS547) data sheet.

2 Before Powering Up

Before powering up the LM3431 evaluation board, a few options must be selected.

First, verify that the default LED current setting of 140mA is appropriate to drive the LEDs. To drive LEDs at other currents, refer to Table 2. If the required LED current is not listed, refer to the LM3431 data sheet (SNVS547), as more extensive modifications will be required.

By default, the LM3431 evaluation board has channels 1-4 enabled. To drive fewer channels, first remove the sense resistor or NPN on the channel to be disabled (R10-R13 or Q2-Q5). Then refer to Table 3 and make any other required changes. This table also gives options for driving fewer LEDs per string.

Finally, select the type of dimming control signal to be used. By default, R-MODE is installed, which enables digital dimming control mode. To use this mode, connect a digital PWM signal to the DIM post. The dimming signal must have a minimum high logic level of 2.3V.

To enable analog dimming, remove the MODE resistor and connect an analog voltage level to the DIM post. In analog mode, the dimming duty cycle is varied by the voltage at the DIM post within a range of 0.37V to 2.5V. The default analog dimming frequency is 1kHz. To modify this frequency, change C5 as described in the datasheet.

All trademarks are the property of their respective owners.

Any dimming frequency between 180Hz and 20kHz can be used in either digital or analog dimming control mode. However the default schematic is not designed for dimming frequencies above 1kHz.Once the evaluation board has been configured, connect the LED strings as shown in Figure 2. The first anode of each string connects to the VA post and the last cathode of each string connects to VC1 through VC4. LEDs can be connected either via the 8-pin header or to the terminal posts. Figure 1 shows the pinout of the header.
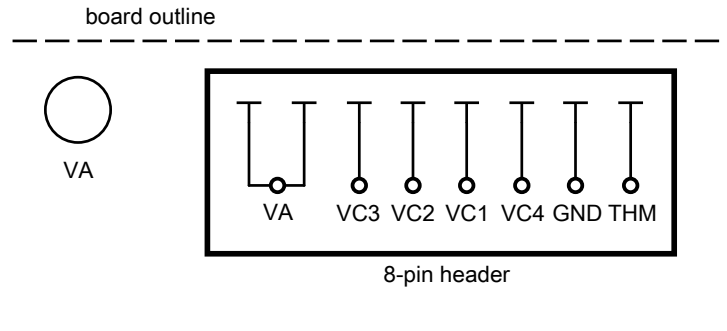

Figure 1. LED Connection, Top View Header Pinout

Connect the input voltage supply to the VIN and GND posts.

When all connections and polarities have been verified, power can be applied. When the input voltage rises above 7.7V typically, the EN pin will cross the UVLO threshold and the LM3431 will startup. EN can be pulled low (via the EN post) to shutdown the evaluation board.

8V to 18V input
700 kHz switching, 180 Hz – 1 kHz dimming
4 strings of 8 LEDs, 140 mA per string
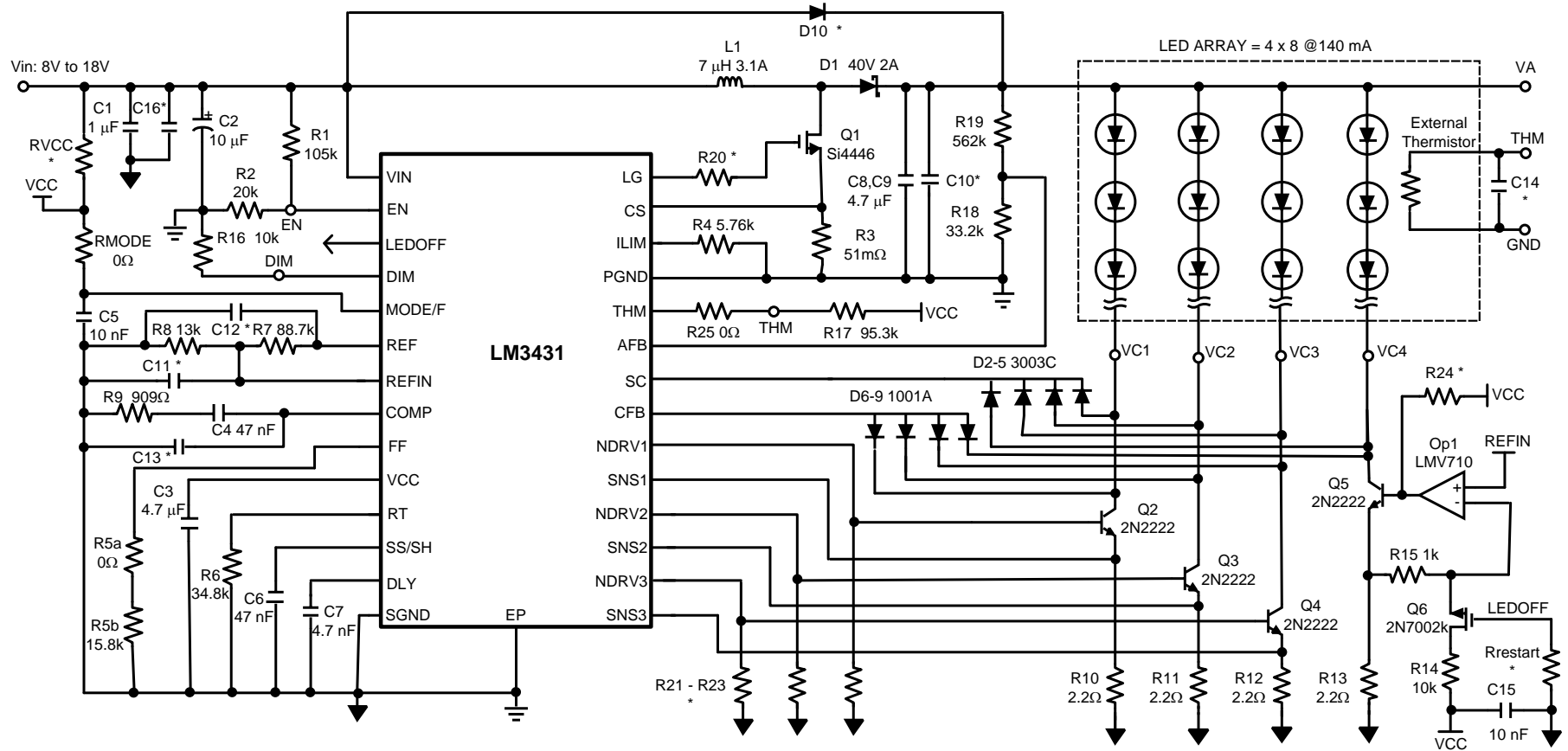
* = not installed

Figure 2. Complete LM3431 Eval Board Schematic

3 Bill of Materials

Table 1. Standard Bill of Materials

Ref #	Function	Description	Part Number	Manufacturer
IC1		Boost controller and LED driver	LM3431	Texas Instruments
C1	Cin	1µF 50V B ceramic	GRM32RB11H105KA01	Murata
C2	Cin	10µF 50V electrolytic	UUD1H100MCL	Nichicon
C3	VCC	4.7µF 10V X7R ceramic	C2012X7R1A475M	TDK
C4	Comp	47nF 50V X7R ceramic	GRM21BR71H473KA01L3K	Murata
C5	MODE/F	10nF 10V COG ceramic	GRM2195C1H103JA01D	Murata
C6	SS	47nF 50V X7R ceramic	GRM21BR71H473KA01L3K	Murata
C7	DLY	4.7nF 50V COG ceramic	GRM2165C1H472JA01D	Murata
C8	VA	4.7µF 50V X7R ceramic	GRM32ER71H475KA88L	Murata
C9	VA	4.7µF 50V X7R ceramic	GRM32ER71H475KA88L	Murata
C10	VA	not installed	-	-
C11	REFIN bypass	not installed	-	-
C12	REF bypass	not installed	-	-
C13	Comp2	not installed	-	-
C14	THM	not installed	-	-
C15	OP1	10nF 10V COG ceramic	GRM2195C1H103JA01D	Murata
C16	Cin	not installed	-	-
D1	power diode	2A 40V Schottky diode	SS24	Vishay
D2-D3	SC	600mA dual cathode diode	CMPD3003C	Central Semiconductor
D4-D5	SC	600mA dual cathode diode	CMPD3003C	Central Semiconductor
D6-D7	CFB	250mA dual anode diode	CMPD1001A	Central Semiconductor
D8-D9	CFB	250mA dual anode diode	CMPD1001A	Central Semiconductor
D10	bypass diode	not installed	-	-
L1	power coil	7µH 3.1A inductor	MSS1038-702NL	Coilcraft
Op1	ch.4	rail to rail op amp	LMV710	Texas Instruments
Q1	Power FET	4A 40V N-channel MOSFET	Si4446DY	Vishay
Q2-Q5	regulator	40V 600mA NPN transistor	CXT2222A	Central Semiconductor
Q6	ch.4	60V 200mA N-channel MOSFET	2N7002K	Vishay
R1	EN uvlo set	105k 1%		
R2	EN uvlo set	20k		
R3	I sense	51mohm 0.5W 1%	WSL2010R0510F	Vishay
R4	I limit	5.76k 1%		
R5a	FF	0Ω		
R5b	FF	15.8k 1%		
R6	RT	34.8k		
R7	REFIN set	88.7k 1%		
R8	REFIN set	13.0k 1%		
R9	Comp	909Ω 1%		
R10 - R13	LED sense	2.2Ω 1%		
R14	ch.4	10k		
R15	ch.4	1k		
R16	DIM	10k		

Table 1. Standard Bill of Materials (continued)

Ref #	Function	Description	Part Number	Manufacturer
R17	THM	95.3k		
R18	AFB	33.2k		
R19	AFB	562k		
R20	HG	not installed	-	-
R21 - R23	NDRV	not installed	-	-
R24	ch.4	not installed	-	-
R25	THM hys	0Ω		
Rmode	MODE/F	0Ω		
Rrestart	restart select	not installed	-	-
RVCC		not installed	-	-

4   Optional Components

Several of the components shown in the schematic are not installed and are optional. These components are typically not required, but may be useful in some applications.C10 is provided for adding additional output capacitance or for using more capacitors with smaller case sizes.C11 and C12 can be used to filter reference voltage noise. Noise at the REF_IN pin can appear as noise in the LED current. Whether these capacitors are required depends on the amount of switching noise, type of NPN used, and how much noise is tolerable in the LED current. C13 is a second compensation capacitor, which may be required if a high ESR output capacitor is used. Refer to the SNVS547 data sheet for details.

D10 provides a current path from VIN to VA during startup. By bypassing the inductor, D10 prevents VA from rising above VIN at the initial power-on. In some conditions an OVP fault may occur at startup without D10 installed.

R20 is a gate drive resistor for the NFET, Q1. An R20 value of up to 10Ω can be used to reduce the rise and fall time of the gate drive to reduce switching noise. To install R20, first cut the trace between the R20 pads.

R21-R23 are NDRV pull-down resistors. A value of 300Ω to 1k can reduce LED current noise. These resistors are typically most effective when driving NFET current regulators. RVCC connects VCC to VIN. For 5V input applications, a 4.7Ω resistor should be installed here to pull-up VCC. For these applications, additional input capacitance at C16 may also be required.

R-restart enables the automatic restart function. Auto-restart cannot be enabled when four LED channels are used. If three or fewer channels are being driven, install R-restart with 0Ω to enable the auto-restart function, which restarts the LM3431 after a fault shutdown.

R-MODE selects the DIM control mode as was described previously. For lower current applications, there is a second Q1 pad which fits SOT-23 size NFETs.

An external NTC thermistor can be connected either between the THM pad and SGND terminal post or via pins 7 and 8 on the 8-pin header. This thermistor is used to monitor LED temperature. With the installed R17 value, the LM3431 will enter standby when the thermistor resistance falls to 31kΩ. For example, a thermistor with a 25°C resistance of 680k and a beta constant of 4125 will yield a shutdown temperature of 110°C.

R25 is a hysteresis resistor for the THM function. The default value is 0Ω which results in a restart hysteresis of 10°C. Use R25 to increase the THM hysteresis according to the data sheet description.

C14 can be installed as a noise filter for the external thermistor voltage.

5   LED String Options

Table 2 and Table 3 give the required component changes for driving LED arrays other than the default. The values shown assume a typical LED Vf of 3.2V at 140mA. These tables are designed for simplicity and ease of modification, not optimum performance. Therefore, any of the changes listed below will result in a lower maximum contrast ratio as compared to the default LED array. For optimum performance, all component values should be reviewed. R5 in the tables refers to the sum of R5a and R5b shown on the schematic. For the best performance, R5 can be manually adjusted for the specific input voltage, dimming frequency, and LED current of each application.

Table 2. LED Current Settings (nc = no change)

LED current	R7	R8	R5
160mA	78.7k	13k	nc
130mA	100k	13k	17.4k
115mA	115k	13k	18.7k
100mA	93.1k	9.09k	20k

Table 3. LED Array Options at 140mA Setting
(nc = no change)

2 Strings				
# of LEDs	R19	R3	R5	R6
6	432k	80m	24.9k	43.2k
7	499k	90m	28.7k	26.7k
8	nc	70m	30.1k	23.2k
3 Strings				
6	432k	nc	28k	43.2k
7	499k	nc	24.3k	nc
8	nc	nc	20k	nc
9	634k	nc	19.1k	30.1k
4 Strings				
6	432k	nc	19.1k	43.2k
7	499k	nc	16.9k	nc
9	634k	40m	14.3k	nc

6   Typical Evaluation Board Performance

Unless otherwise specified, the following conditions apply: Vin = 12V, Ta = 25°C, LED array = 4 parallel strings of 8 LEDs at 140mA per string. LED part number: Nichia NFSW036BT.
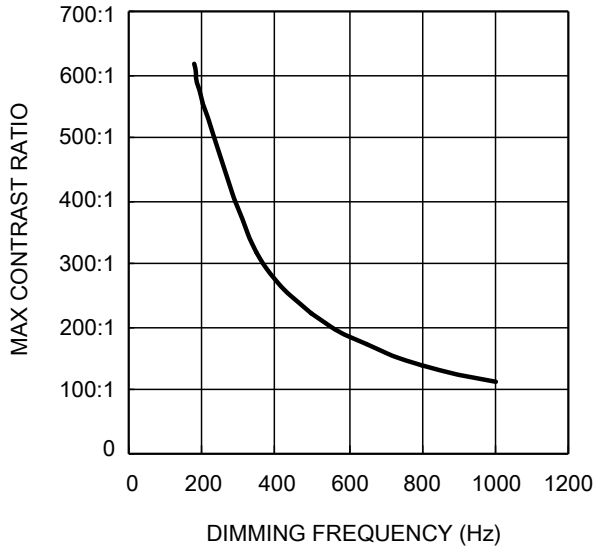
Figure 3. Maximum Contrast Ratio vs. Dimming Frequency
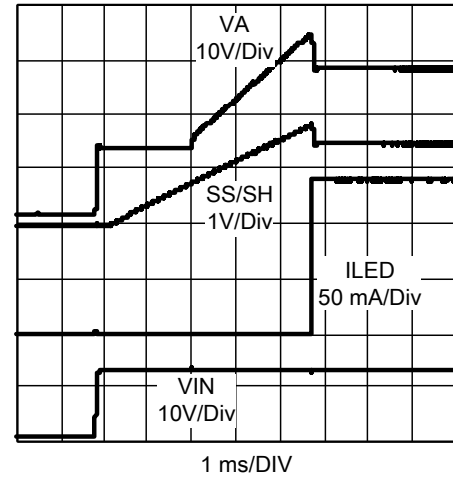
Figure 4. Power-On Startup Waveforms
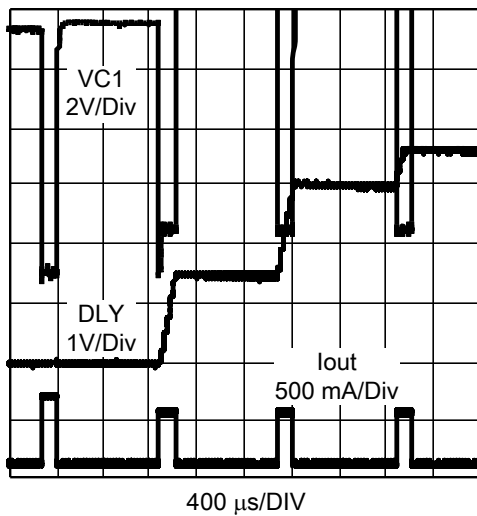
Figure 5. Fault Delay Waveforms (one LED open)
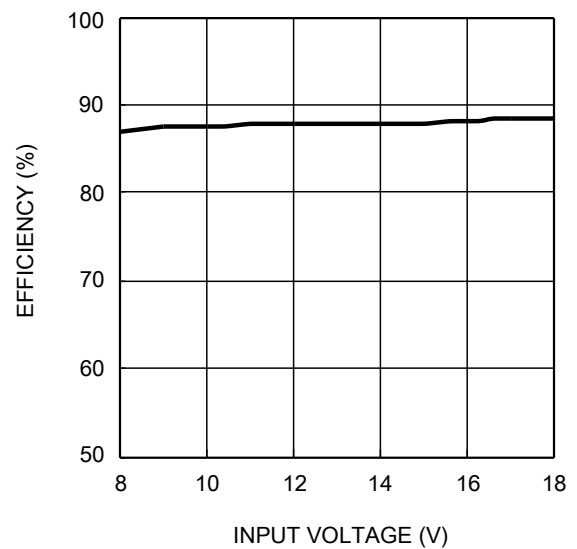
Figure 6. Efficiency vs. Input Voltage
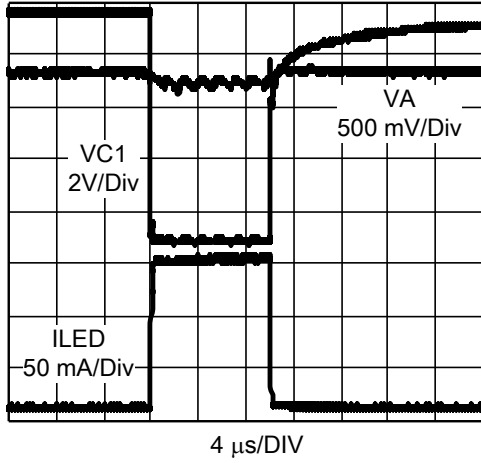
**Figure 7. Typical Dimming Waveforms
(1kHz at 1% duty)**
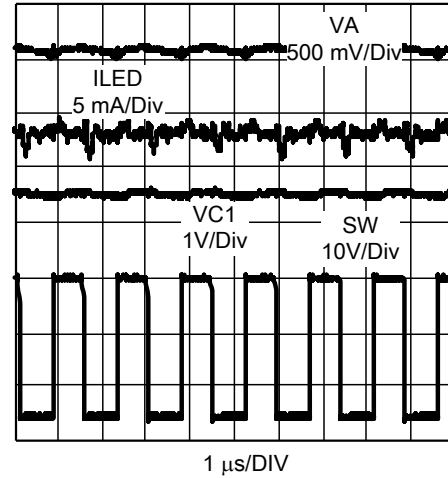
Figure 8. Boost Switching Waveforms

7   PCB Layout
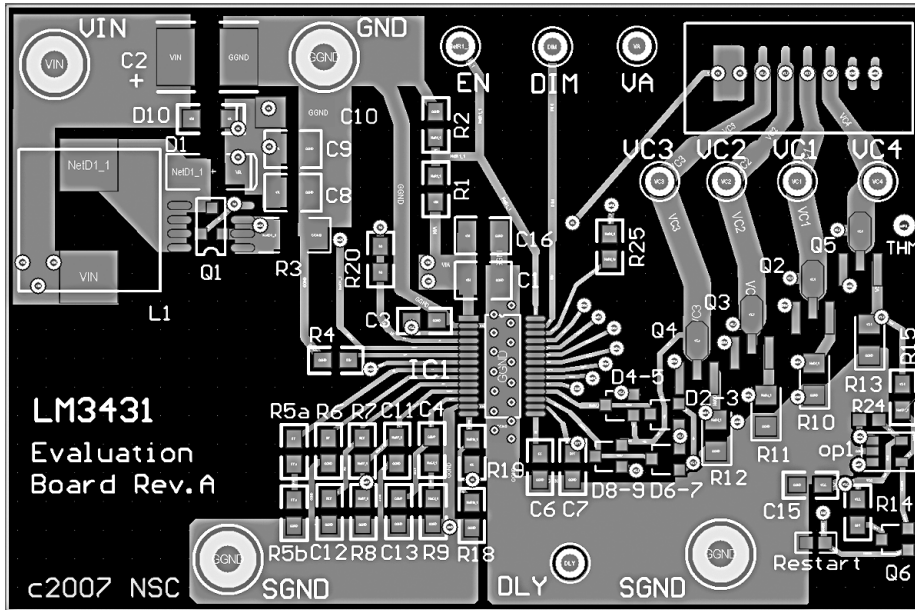
Figure 9. Top Side PCB Layout
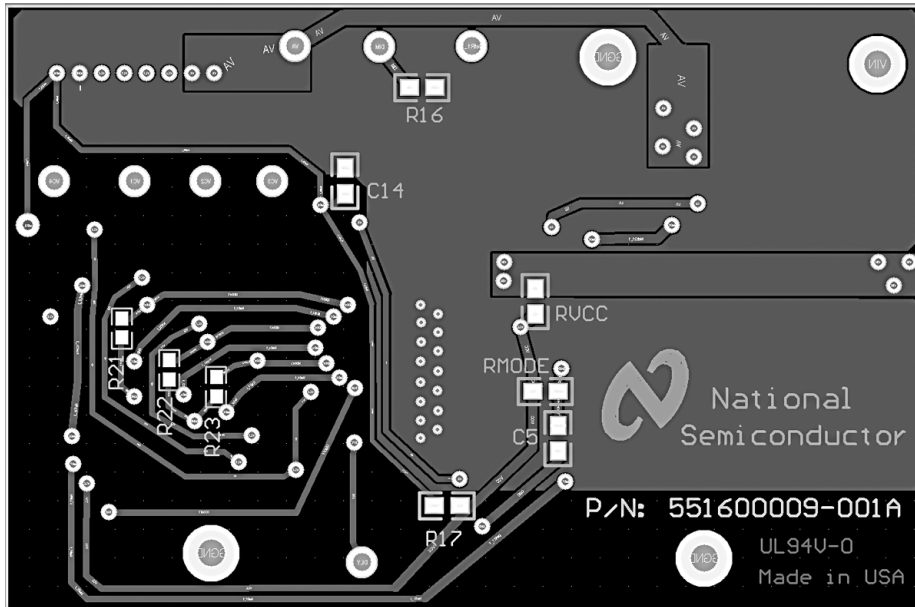
Figure 10. Bottom Side PCB Layout

IMPORTANT NOTICE

Products		Applications	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		