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AN-1793 LM3433 4A to 20A LED Driver Evaluation Board

1 Introduction

The LM3433 is an adaptive constant on-time DC/DC buck constant current controller designed to drive a high brightness LEDs (HB LED) at high forward currents. It is a true current source that provides a constant current with constant ripple current regardless of the LED forward voltage drop. The board can accept an input voltage ranging from -9V to -14V w.r.t. GND. The output configuration allows the anodes of multiple LEDs to be tied directly to the ground referenced chassis for maximum heat sink efficacy when a negative input voltage is used.

2 LM3433 Board Description

The evaluation board is designed to provide a constant current in the range of 4A to 20A. The LM3433 requires two input voltages for operation. A positive voltage with respect to GND is required for the bias and control circuitry and a negative voltage with respect to GND is required for the main power input. This allows for the capability of using common anode LEDs so that the anodes can be tied to the ground referenced chassis. The evaluation board only requires one input voltage of -12V with respect to GND. The positive voltage is supplied by the LM5002 circuit. The LM5002 circuit also provides a UVLO function to remove the possibility of the LM3433 from drawing high currents at low input voltages during startup. Initially the output current is set at the minimum of approximately 4A with the POT P1 fully counter-clockwise. To set the desired current level a short may be connected between LED+ and LED-, then use a current probe and turn the POT clockwise until the desired current is reached. PWM dimming FETs are included on-board for testing when the LED can be connected directly next to the board. A shutdown test post on J2, ENA, is included so that startup and shutdown functions can be tested using an external voltage.

3 Setting the LED Current

The LM3433 evaluation board is designed so that the LED current can be set in multiple ways. There is a shunt on J2 initially connecting the ADJ pin to the POT allowing the current to be adjusted using the POT P1. This POT will apply a voltage to the ADJ pin between 0.3V and 1.5V w.r.t. GND to adjust the voltage across the sense resistor (R_{SENSE}) R15. The shunt may also be removed and an external voltage positive w.r.t. GND can then be applied to the ADJ test point on the board. A 5mΩ resistor comes mounted on the board so using the V_{SENSE} vs. V_{ADJ} graph in the Section 6 section the current can be set using Equation 1:

$$I_{LED} = V_{SENSE}/R_{SENSE} \tag{1}$$

Alternatively the shunt can be removed and connect the ADJ test point can be connected to the VINX test point to fix V_{SENSE} at 60mV.

4 PWM Dimming

The LM3433 is capable if high speed PWM dimming in excess of 40kHz. Dimming is accomplished by shorting across the LED with a FET(s). Dimming FETs are included on the evaluation board for testing LEDs placed close to the board. The FETs on the evaluation board should be removed if using dimming FETs remotely placed close to the LED (recommended).

To use the dimming function apply square wave to the PWM test point on the board that has a positive voltage w.r.t. GND. When this pin is pulled high the dimming FET is enabled and the LED turns off. When it is pulled low the dimming FET is turned off and the LED turns on. A scope plot of PWM dimming is included in the *Typical Performance Characteristics* section showing 30kHz dimming at 50% duty cycle.

5 High Current Operation and Component Lifetime

When driving high current LEDs, particularly when PWM dimming, component lifetime may become a factor. In these cases the input ripple current that the input capacitors are required to withstand can become large. At lower currents long life ceramic capacitors may be able to handle this ripple current without a problem. At higher currents more input capacitance may be required. To remain cost effective this may require putting one or more aluminum electrolytic capacitors in parallel with the ceramic input capacitors. Since the operational lifetime of LEDs is very long (up to 50,000 hours) the longevity of an aluminum electrolytic capacitor can become the main factor in the overall system lifetime. The first consideration for selecting the input capacitors is the RMS ripple current they will be required to handle. This current is given by Equation 2:

$$I_{RMS} = I_{LED} \frac{\sqrt{V_{LED}(|V_{EE}|-V_{LED})}}{|V_{EE}|} \quad (2)$$

The parallel combination of the ceramic and aluminum electrolytic input capacitors must be able to handle this ripple current. The aluminum electrolytic in particular should be able to handle the ripple current without a significant rise in core temperature. A good rule of thumb is that if the case temperature of the capacitor is 5°C above the ambient board temperature then the capacitor is not capable of sustaining the ripple current for its full rated lifetime and a more robust or lower ESR capacitor should be selected.

The other main considerations for aluminum electrolytic capacitor lifetime are the rated lifetime and the ambient operating temperature. An aluminum electrolytic capacitor comes with a lifetime rating at a given core temperature, such as 5000 hours at 105°C. As dictated by physics the capacitor lifetime should double for each 7°C below this temperature the capacitor operates at and should halve for each 7°C above this temperature the capacitor operates at. A good quality aluminum electrolytic capacitor will also have a core temperature of approximately 3°C to 5°C above the ambient temperature at rated RMS operating current. So as an example, a capacitor rated for 5,000 hours at 105°C that is operating in an ambient environment of 85°C will have a core temperature of approximately 90°C at full rated RMS operating current. In this case the expected operating lifetime of the capacitor will be approximately just over 20,000 hours. The actual lifetime ($Life_{ACTUAL}$) can be found using Equation 3:

$$Life_{ACTUAL} = Life_{RATED} \text{ X } 2^{\left(\frac{T_{CORE} - T_{ACTUAL}}{7}\right)} \quad (3)$$

Where $Life_{RATED}$ is the rated lifetime at the rated core temperature T_{CORE}. For example, if the ambient temperature is 85°C the core temperature is 85°C + 5°C = 90°C. (105°C - 90°C)/7°C = 2.143. 2^2.413 = 4.417. So the expected lifetime is 5,000*4.417 = 22,085 hours. Long life capacitors are recommended for LED applications and are available with ratings of up to 20,000 hours or more at 105°C.

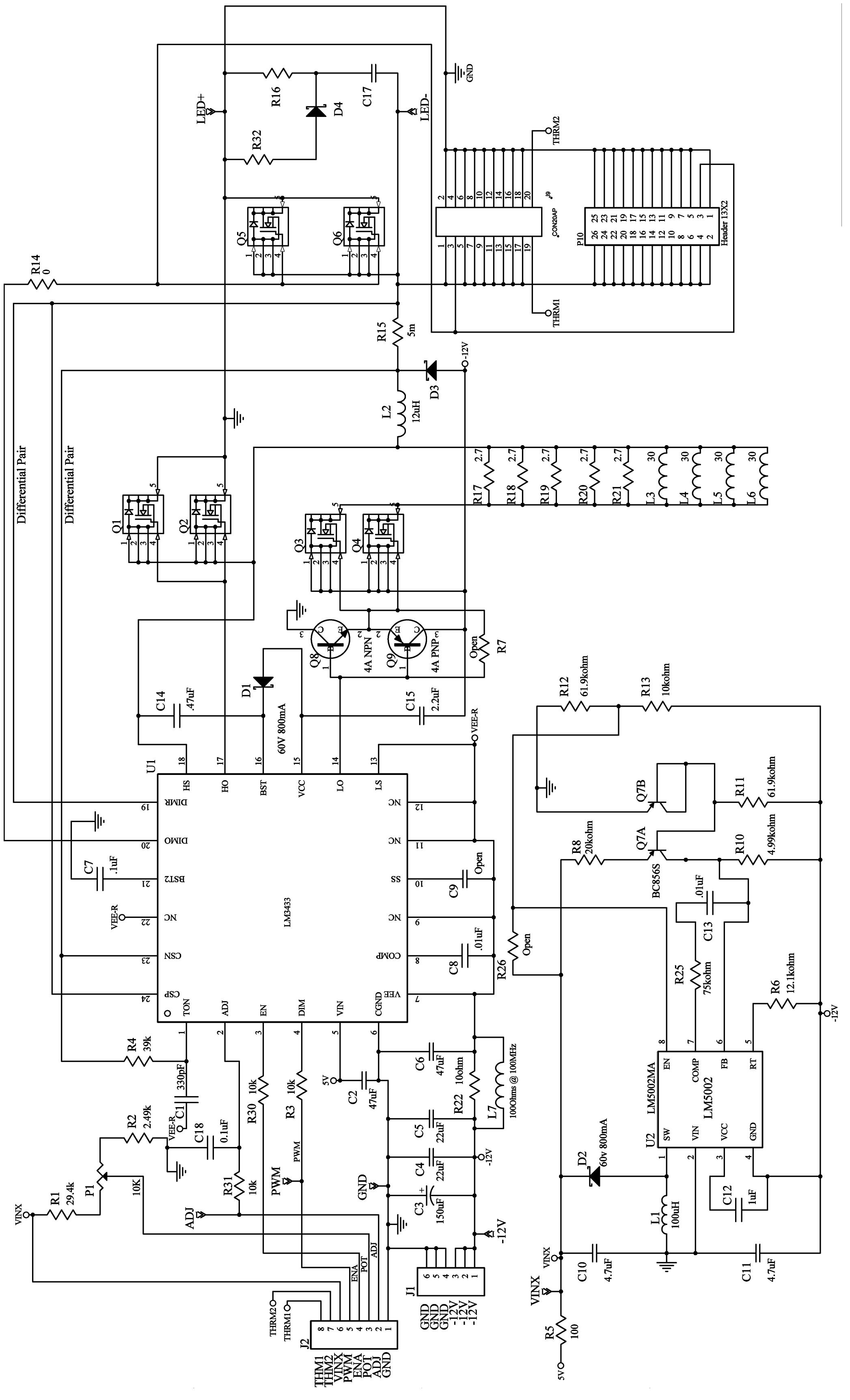


Figure 1. LM3433 Evaluation Board Schematic

Table 1. Bill of Materials (BOM)

Qty	ID	Part Number	Type	Size	Parameters	Vendor
1	U1	LM3433	LED Driver	WQFN-24		TI
1	U2	LM5002	Boost Regulator	SOIC-8		TI
1	C1	C0805C331J5GACTU	Capacitor	0805	330pF, 50V	Kemet
1	C2	GRM31CR60J476KE19L	Capacitor	1206	47µF, 6.3V	Murata
1	C3	16SA150M	Capacitor	MULTICAP	150µF, 16V	Sanyo
2	C4, C5	GRM32ER61C226KE20L	Capacitor	1210	22µF, 16V	Murata
1	C6	GRM32ER61C476ME15L	Capacitor	1210	47µF, 16V	Murata
1	C7	C0805C104J5RACTU	Capacitor	0805	0.1µF, 50V	Kemet
2	C8, C13	HMK212BJ103KG-T	Capacitor	0805	10nF, 100V	Taiyo Yuden
	C9	OPEN		0805		
2	C10, C11	GRM21BR61C475KA	Capacitor	0805	4.7µF, 16V	Murata
1	C12	0805YD105KAT2A	Capacitor	0805	1µF, 16V	AVX
1	C14	B37941K9474K60	Capacitor	0805	0.47µF, 16V	EPCOS Inc .
1	C15	GRM21BF51E225ZA01L	Capacitor	0805	2.2µF, 25V	Murata
	C17	OPEN		0805		
1	C18	08055C104JAT2A	Capacitor	0805	0.1µF, 50V	AVX
2	D1, D2	MA2YD2600L	Diode	SOD-123	60V, 800mA	Panasonic
1	D3	MBRS240LT3	Diode	SMB	40V, 2A	ON Semiconductor
	D4	OPEN		SMB		
1	J2	B8B-EH-A(LF)(SN)	Connector			JST Sales America, Inc.
1	J1	1761582001	Connector			Weidmuller
1	J9	TFML-110-02-S-D	Connector	TFM-110-02-X-D-LC		Samtec
1	L1	LPS3008-104ML	Inductor	3008	100µH, 150mA	Coilcraft
1	L2	GA3252-AL	Inductor	GA3252-AL	12µH, 14A	Coilcraft
4	L3, L4, L5, L6	MPZ2012S300A	Ferrite Bead	0805	30Ω @ 100MHz	TDK
1	L7	MPZ2012S101A	Ferrite Bead	0805	100Ω @ 100MHz	TDK
1	P1	3352T-1-103LF	Potentiometer	BOURNS2	10kΩ	Bourns
1	P10	3429-6002	Connector	HDR13x2	13X2 Pin Header	3M
2	Q1, Q2, Q3, Q4, Q5, Q6	NTMFS4841NH	FET	PowerPAK	30V, 11mΩ	ON Semiconductor
1	Q7	BC856S	Dual PNP	SOT363_N		Phillips
1	Q8	ZXTN25040DFHTA	NPN	SOT-23B		Zetex Inc.
1	Q9	ZXTP25040DFHTA	PNP	SOT-23B		Zetex Inc.
1	R1	ERJ-6ENF2942V	Resistor	0805	29.4kΩ	Panasonic
1	R2	ERJ-6ENF2491V	Resistor	0805	2.49kΩ	Panasonic
3	R3, R30, R31	ERJ-6ENF1002V	Resistor	0805	10kΩ	Panasonic
1	R4	ERJ-6GEYJ393V	Resistor	0805	39kΩ	Panasonic
1	R5	ERJ-6GEYJ101V	Resistor	0805	100Ω	Panasonic
	R7	OPEN				
2	R14	ERJ-6GEY0R00V	Resistor	0805	0Ω	Panasonic
1	R8	ERJ-6ENF2002V	Resistor	0805	20kΩ	Panasonic
1	R10	ERJ-6ENF4991V	Resistor	0805	4.99kΩ	Panasonic
2	R11, R12	ERJ-6ENF6192V	Resistor	0805	61.9kΩ	Panasonic
1	R13	ERJ-6GEYJ103V	Resistor	0805	10kΩ	Panasonic

Table 1. Bill of Materials (BOM) (continued)

Qty	ID	Part Number	Type	Size	Parameters	Vendor
1	R15	WSL25125L000FEA	Resistor	CR6332-2512	0.005Ω	Vishay
6	R16, R17, R18, R19, R20, R21	ERJ-6GEYJ2R7V	Resistor	0805	2.7Ω	Panasonic
1	R22	ERJ-6GEYJ100V	Resistor	0805	10Ω	Panasonic
1	R25	ERJ-6ENF7502V	Resistor	0805	75kΩ	Panasonic
	R26	OPEN		0805		
2	LED+, LED-	1502-2	Test Post	TP 1502	0.109"	Keystone
3	ADJ, PWM, VINX	1593-2	Test Post	TP 1593	0.084"	Keystone

6 Typical Performance Characteristics

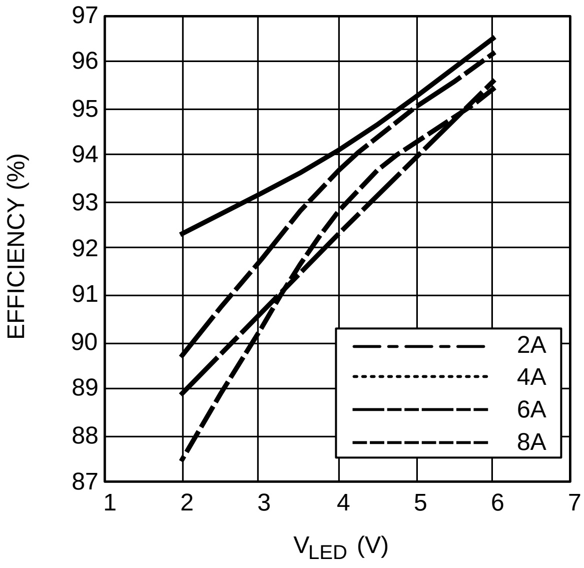


Figure 2. Efficiency vs. LED Forward Voltage (V_{CGND} - V_{EE} = 9V)

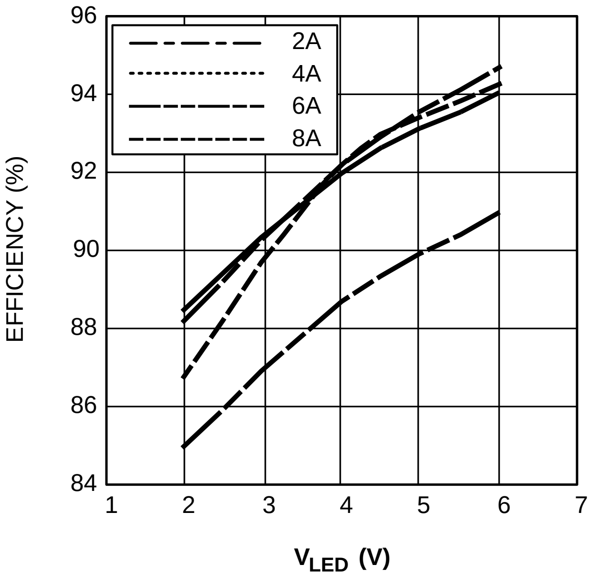


Figure 3. Efficiency vs. LED Forward Voltage (V_{CGND} - V_{EE} = 12V)

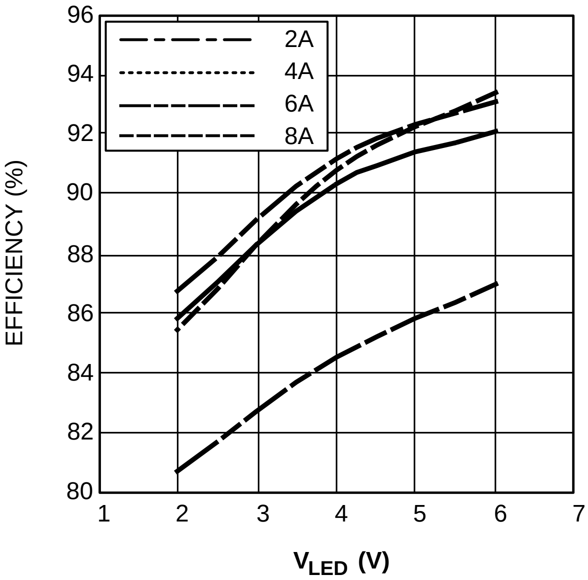


Figure 4. Efficiency vs. LED Forward Voltage (V_{CGND} - V_{EE} = 14V)

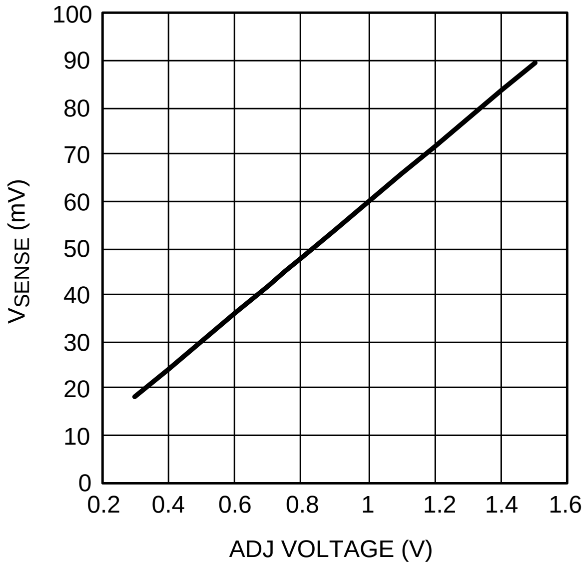
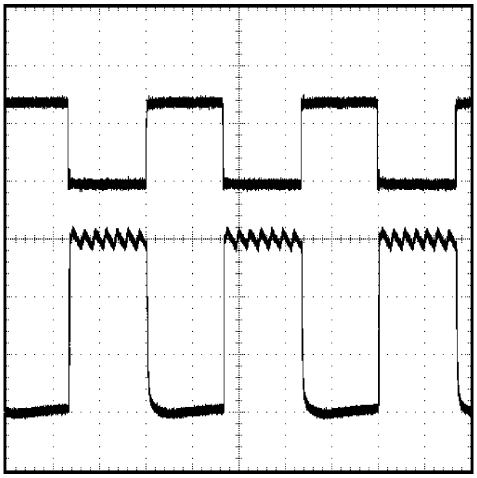


Figure 5. V_{SENSE} vs. V_{ADJ}



ILED = 6A nominal, VIN = 3.3V, VEE = -12V Top trace: DIM input, 2V/div, DC Bottom trace: ILED, 2A/div, DC T = 10µs/div

Figure 6. 30kHz PWM Dimming Waveform Showing Inductor Ripple Current

7 Layout

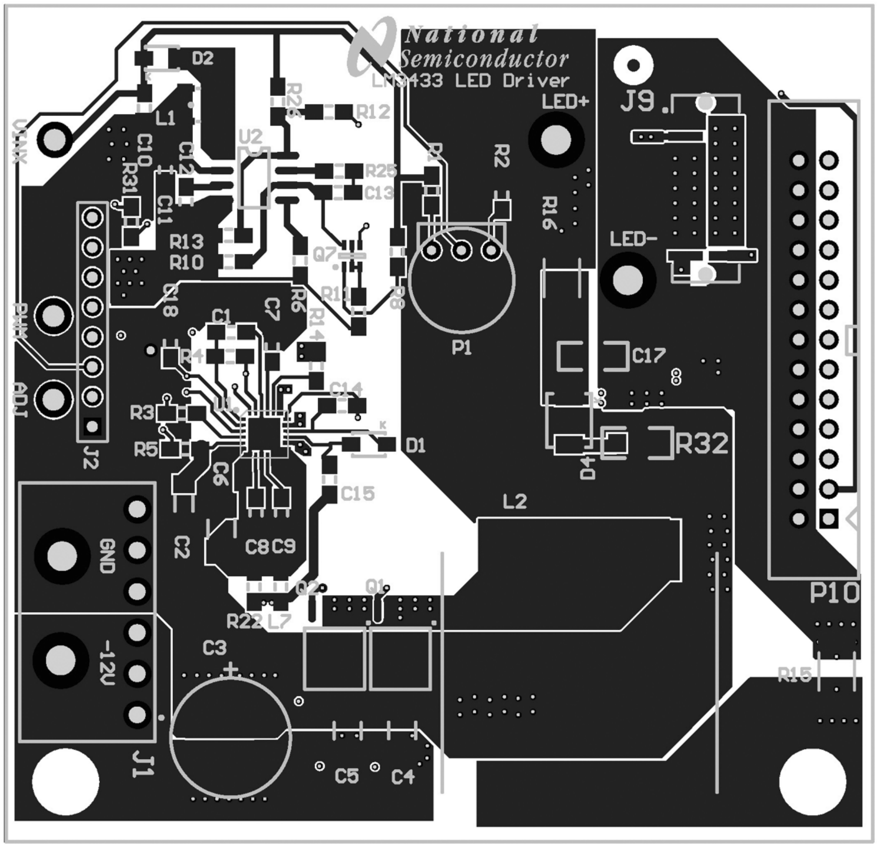


Figure 7. Top Layer and Top Overlay

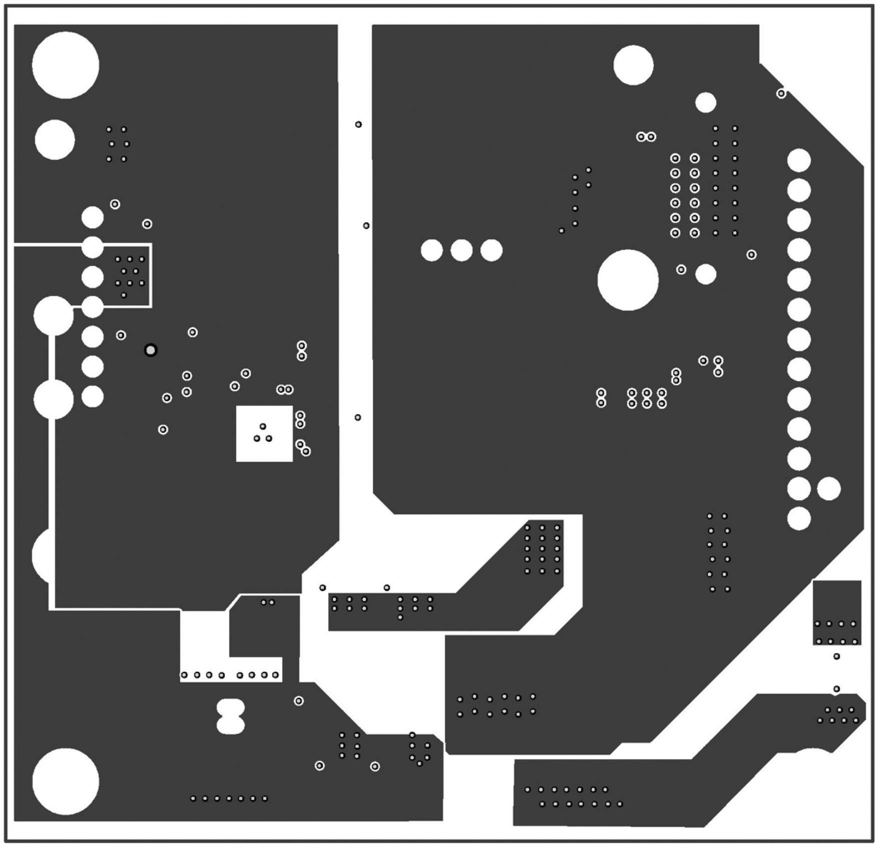


Figure 8. Upper Middle Layer

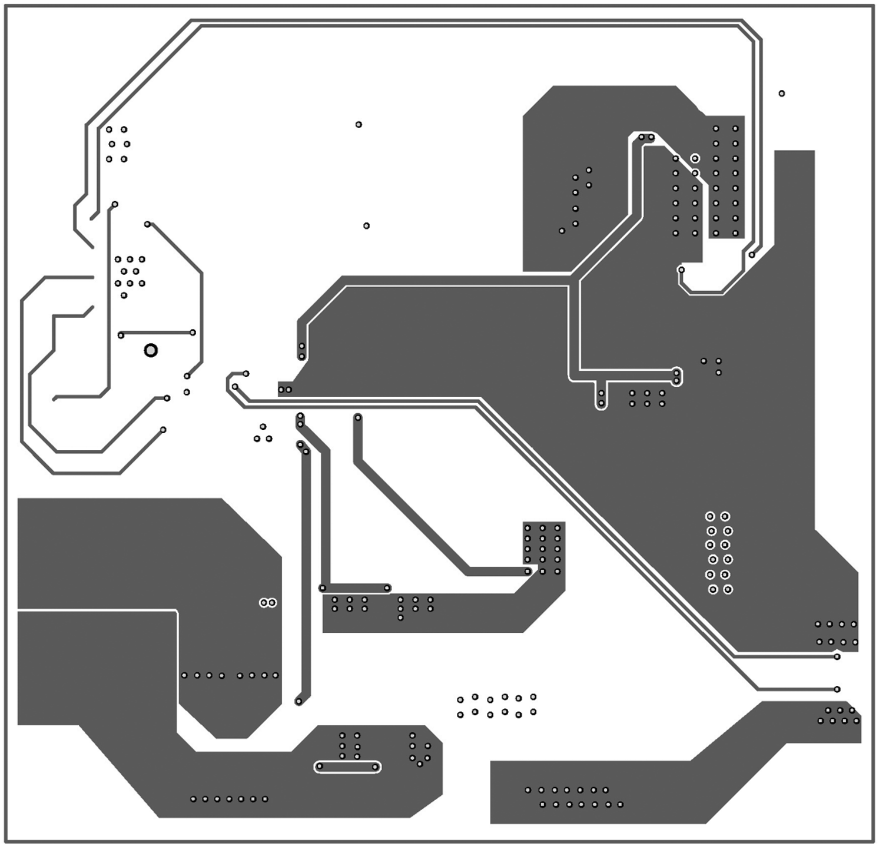


Figure 9. Lower Middle Layer

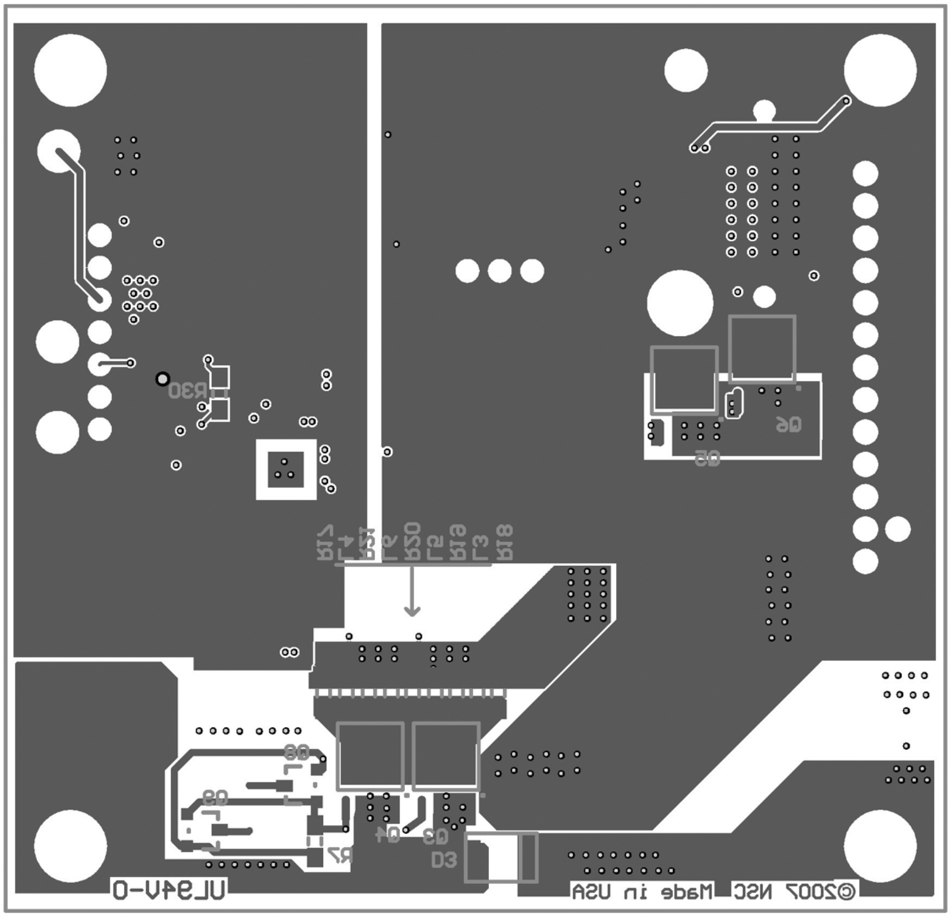


Figure 10. Bottom Layer and Bottom Overlay

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