AN-1305 LM5030 Evaluation Board

The AN-1305 is an evaluation board the demonstrates a fully featured push-pull converter utilizing the LM5030 100V push-pull current mode PWM controller

1 Introduction

The LM5030EVAL evaluation board provides the design engineer with a fully functional push-pull power converter using the LM5030 PWM controller. The performance of the board is:

- Input range: 36V to 75V
- Output voltage: 3.3V
- Output current: 0 to 10A
- Measured efficiency: 82% (at 48V in, 10A Load Current)
- Board size: 2.4 × 2.4 × 0.5 inches
- Load regulation: ±1.0% (1 - 10A)
- Line regulation: ±0.15% (36 - 75V)
- Shutdown input
- Synchronizing input

The printed circuit board consists of 2 layers of 2 ounce copper on FR4 material, with a total thickness of 0.062 inches. The board is designed for continuous operation at rated load.

2 Theory of Operation

Referring to Figure 10, the LM5030 controller (U1) alternately drives two N channel MOSFETs, which feed the two halves of the power transformer's primary (T1). The transformer's secondary is rectified, and filtered with an LC filter (L2, C3-5), to provide the output voltage. The feedback path starts with the LM3411 precision regulator driver (U3) which senses the output voltage, compares it to its internal reference, and drives an optocoupler (U2) based on the error voltage. The optocoupler provides isolation in the feedback path, and its open collector output drives the COMP pin on the LM5030, which controls the pulse width to the MOSFETs. The lower the voltage at the COMP pin, the smaller the MOSFET duty cycle.

Current in the main transformer's primary is monitored at the LM5030's CS pin via a current sense transformer (T2). The voltage at the CS pin is used for current mode PWM control and current limit protection.

The output inductor (L2) not only smoothes the output voltage waveform, but also generates an auxiliary voltage (by means of its secondary winding) to power the Vcc pin on the LM5030. This feature reduces power dissipation within the IC, thereby increasing reliability.

A Synchronizing input pad (SYNC) is provided on the board to synchronize the circuit's operating frequency to an external source. A Shutdown input pad (SD) permits shutting down the circuit's operation from an external switch to ground.

3 Board Layout and Probing

Figure 1 shows the placement of the significant components which may be probed in evaluating the circuit's operation. The following should be kept in mind when using scope or meter probes:

1. The board has two circuit grounds - one associated with the input power, and one associated with the output power. The grounds are capacitively coupled (C6), but are DC isolated.
2. The main current carrying components (L1, T1, T2, Q1, Q2, D1 and L2) will be hot to the touch at maximum load current. USE CAUTION. If operating at maximum load current for extended periods, the use of a fan to provide forced air flow is recommended.
3. Use care when probing the primary side at maximum input voltage. 75 volts is enough to produce shocks and sparks.
4. At maximum load current (10A), the wire size, and length, used to connect the board's output to the load becomes important. Ensure there is not a significant voltage drop in the wires. Note that two connectors are provided at the output - one for the +3.3V output (J2 Out), and one for the Ground connection (J3 IGND). It is advisable to make good use of this feature to ensure a low loss connection.
5. The input voltage conector is J1.

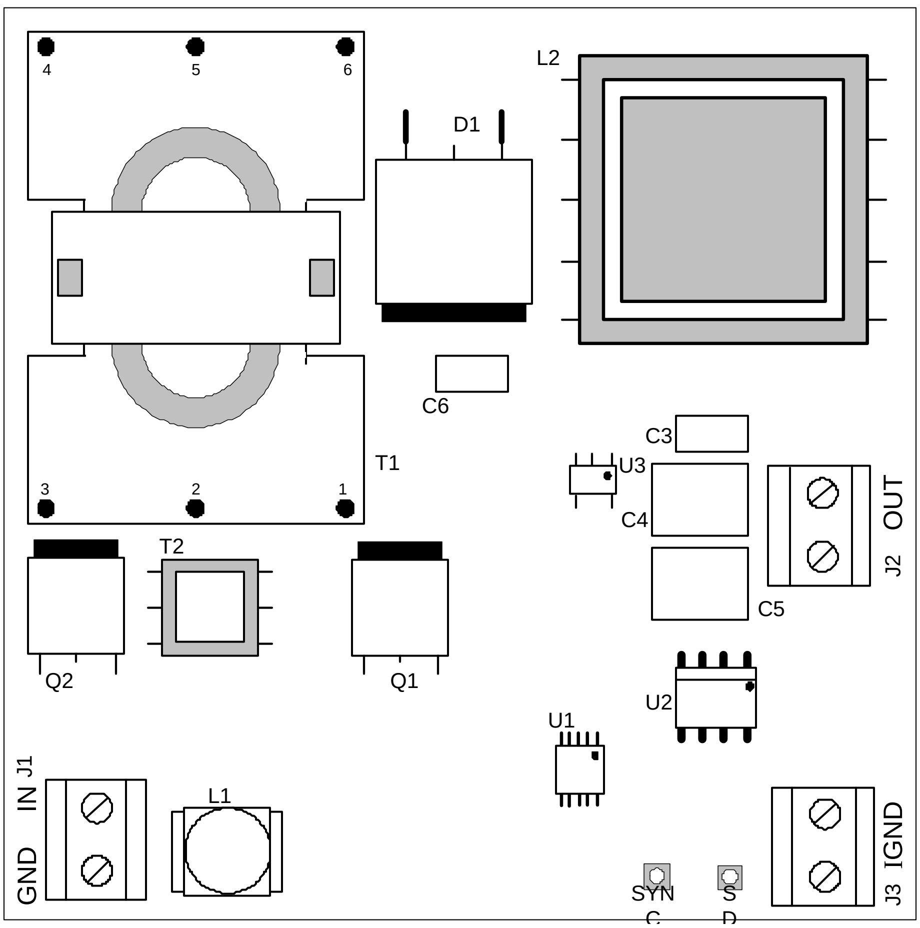


Figure 1. Evaluation Board

4 Board Connections/Start-Up

The input connection to the board from a power supply is made to connector J1. The power supply must be capable of supplying not only the current during normal operation, but also the inrush current during start-up. For example, if the load current is set to be 1.0A, the inrush current will be approximately 250 mA peak. If the load is set to 10A, the inrush current will be approximately 1.7A peak. Once the circuit is on and operating normally, the current draw from the power supply is a function of both the load current, and the input voltage, as shown in Figure 2.

The load is connected to the J2 and J3 connectors. Two connectors are provided to accommodate adequately sized wires. With a load current of 10A, the load connections should use a minimum of 16 gauge wire, preferably larger.

Before start-up, a voltmeter should be connected to the input terminals, and one to the output terminals. The input current should be monitored with either an ammeter, or a current probe. Upon turning on the power supply, these three meters should be immediately checked to ensure their readings are nominal.

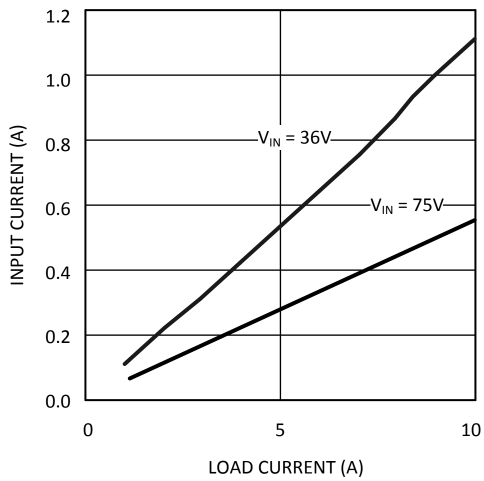


Figure 2. Input Current vs Load Current and V_{IN}

5 Performance

Once the circuit is powered up and operating normally, the output voltage will be regulated to +3.3V, with the accuracy determined by the accuracy of the LM3411 regulator driver. As the load current is varied from 1.0 to 10A, the output is regulated to within +/-30 mV (+/- 1.0%). For a given load current, the output will be regulated to within 5 mV as the input voltage is varied over its range (36 - 75V). The power conversion efficiency is shown in Figure 3.

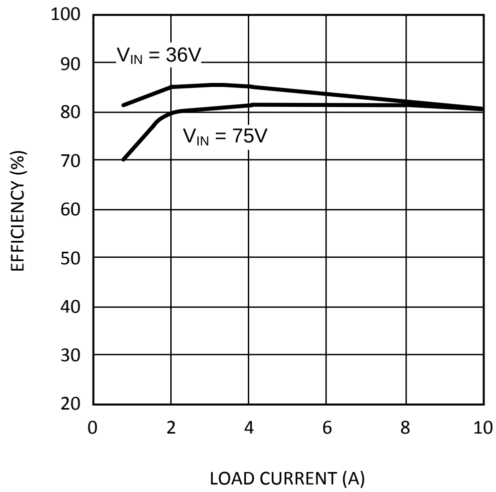
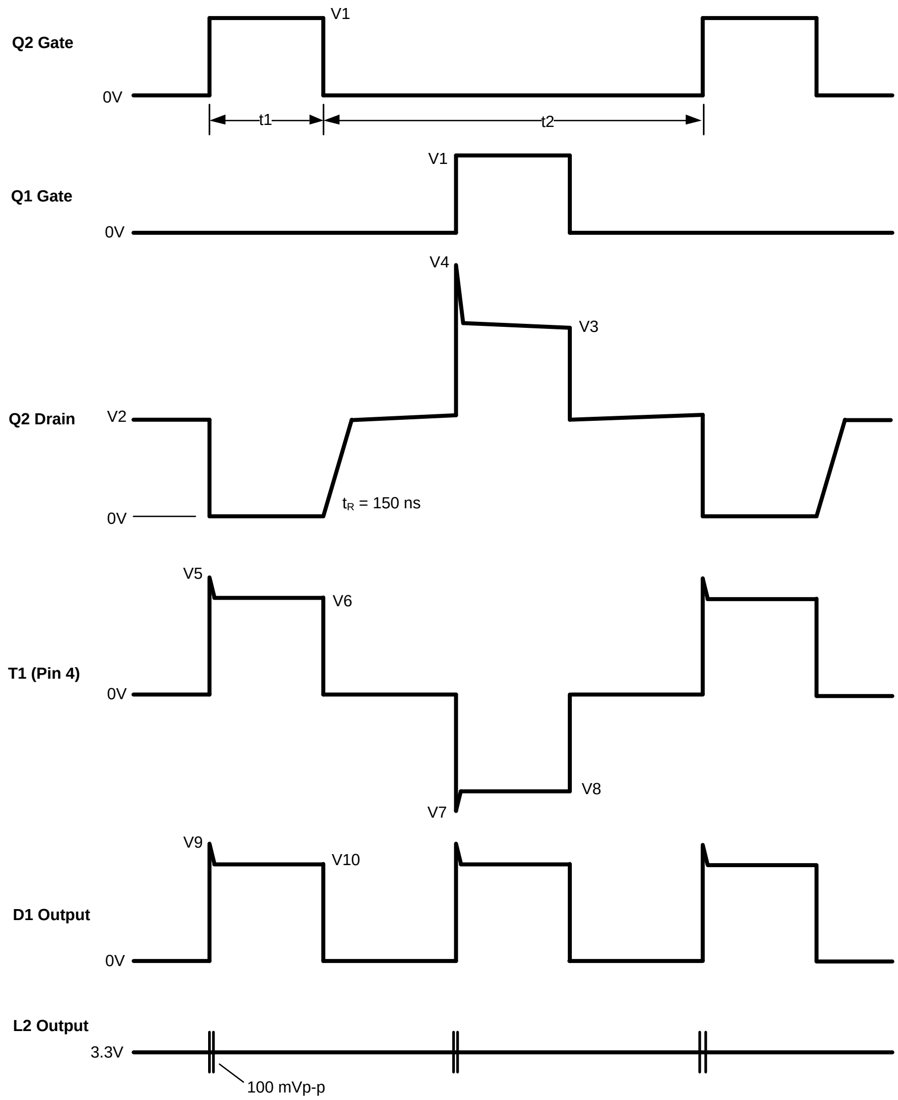


Figure 3. Efficiency vs Load Current and V_{IN}

6 Waveforms

If the circuit is to be probed, Figure 4 shows some of the significant waveforms for various input/output combinations. Remember that there are two circuit grounds, and the scope probe grounds must be connected appropriately.

In the table of Figure 4, t1 and t2 are in microseconds, while Fs is in kHz. Fs is the frequency of the internal oscillator, which is twice the switching frequency of each MOSFET. All the voltages are in volts with respect to circuit ground. L2 Output is the regulated output at J2, and typically has less than 10mV of ripple. The spikes at the rising edges of V4, V5, V7, and V9 are due to the leakage inductance in T1. The voltage rating of the MOSFETs (Q1, Q2) is determined by the amplitude of these spikes (V4). Their current rating is determined by the input current shown in Figure 2, plus a ripple component of approximately 10% in this design.



V_{IN}	I_{OUT}	t1	t2	Fs	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
36V	1.0A	2.2µS	5.3µS	266.7	10.5V	36V	72V	90V	10V	6V	-10V	-6V	10V	6V
48V	10A	1.9µS	5.5µS	270.3	11.5V	48V	96V	130V	18V	8V	-18V	-8V	13V	8V
75V	1.0A	1.2µS	6.2µS	270.3	10.5V	75V	150V	200V	20V	13V	-20V	-13V	20V	13V

Figure 4. Representative Waveforms

7 V_{CC}

While the LM5030 internally generates a voltage at V_{CC} (7.7V), the internal regulator is used mainly during the start-up sequence. Once the load current begins flowing through L2, which is both an inductor for the output filter and a transformer, a voltage is generated at L2's secondary which powers the V_{CC} pin. Once the externally applied voltage exceeds the internal value (7.7V), the internal regulator shuts off, thereby reducing internal power dissipation in the LM5030. L2 is constructed such that the voltage supplied to V_{CC} ranges from approximately 10.6V to approximately 11.3V, depending on the load current. See Figure 5.

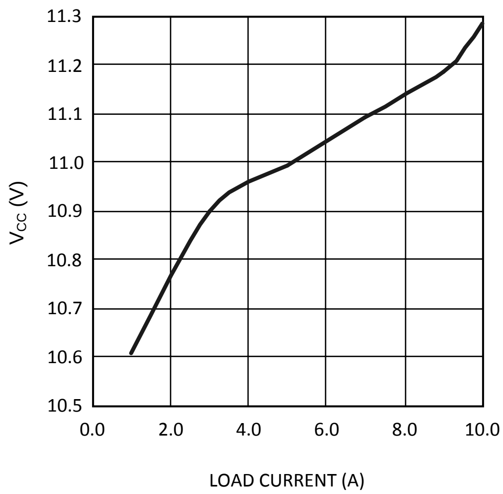


Figure 5. V_{CC} Voltage vs Load Current

8 Current Sense

Monitoring the input current provides a good indication of the circuit's operation. If an overload condition should exist at the output (a partial overload or a short circuit), the input current would rise above the nominal value shown in Figure 2. Transformer T2, in conjunction with D3, R9, R12 and C10, provides a voltage to pin 8 on the LM5030 (CS) which is representative of the input current flowing through its primary. The average voltage seen at pin 8 is plotted in Figure 6. If the voltage at the first current sense comparator exceeds 0.5V, the LM5030 disables its outputs, and the circuit enters a cycle-by-cycle current limit mode. If the second level threshold (0.625V) is exceeded due to a severe overload and transformer saturation, the LM5030 will disable its outputs and initiate a softstart sequence. However, the very short propagation delay of the cycle-by-cycle current limiter (CS1), the design of the CS filter (R9, R12, and C10), and the conservative design of the output inductor (L2), may prevent the second level current threshold from being realized on this evaluation board.

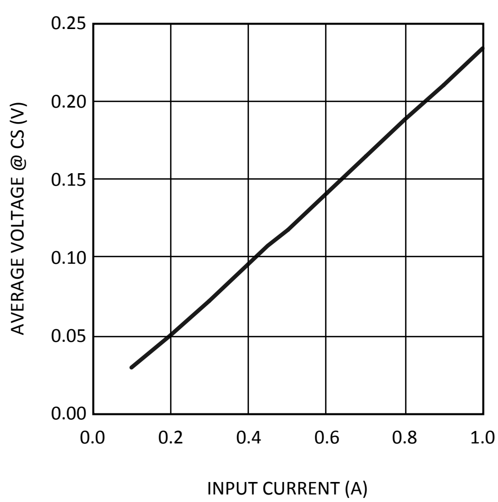


Figure 6. Average Voltage at the CS pin vs Input Current

9 Shutdown

The Shutdown pad (SD) on the board connects to the SoftStart pin on the LM5030 (pin 10), and permits on/off control of the converter by an external switch. SD should be pulled below 0.45V, with an open collector or open drain device, to shut down the LM5030 outputs and the V_{CC} regulator. If the voltage at the SD pad is between 1.0 and 1.5V, a partial-on condition results, which could be disruptive to the system. Therefore, the voltage at the SD pad should transition quickly between its open circuit voltage (4.9V) and ground.

10 External Sync

Although the LM5030 includes an internal oscillator, its operating frequency can be synchronized to an external signal if desired. The external source frequency must be higher than the internal frequency set with the RT resistor (262kHz with R_T = 20K). The sync input pulse width must be between 15 and 150 ns, and have an amplitude of 1.5 - 3.0V at the Sync pad on the board. The pulses are coupled to the LM5030 through a 100pF capacitor (C16) as specified in the data sheet.

11 Bill Of Materials

Table 1. Bill Of Materials

Item	Part Number	Description	Value
C1	C0805C472K5RAC	Capacitor, Ceramic, KEMET	4700pF, 50V
C2	C0805C103K5RAC	Capacitor, Ceramic, KEMET	0.01µF, 50V
C3	C4532X7S0G686M	Capacitor, Ceramic, TDK	68µF, 4V
C4, 5	T520D337M006AS4350	Capacitor, Tantalum, KEMET	330µF, 6.3V
C6	C4532X7R3A103K	Capacitor, Ceramic, TDK	0.01µF, 1000V
C7	C3216X7R2A104K	Capacitor, Ceramic, TDK	0.1µF, 100V
C8, 9	C4532X7R2A105M	Capacitor, Ceramic, TDK	1µF, 100V
C10	C0805C102K1RAC	Capacitor, Ceramic, KEMET	1000pF, 100V
C11	C1206C223K5RAC	Capacitor, Ceramic, KEMET	0.022µF, 50V
C12	C3216X7R1E105M	Capacitor, Ceramic, TDK	1µF, 25V
C13, 14	C3216COG2J221J	Capacitor, Ceramic, TDK	220pF, 630V
C15	C1206C104K5RAC	Capacitor, Ceramic, KEMET	0.1µF, 50V
C16, 17	C0805C101J1GAC	Capacitor, Ceramic, KEMET	100pF, 100V
C18	C3216X7R1H334K	Capacitor, Ceramic, TDK	0.33µF, 50V
D1	MBRB3030CTL	Diode, Schottky, ON Semi.	30V, 15A
D2 - 5	CMPD2838-NSA	Diode, Signal, Central Semi.	75V, 200mA
L1 [(1)]	MSS6132-103	Input Choke, Coilcraft	10µH, 1.3A
L2 [(1)]	A9785-B	Output Choke, Coilcraft	7µH, 15A
R1	CRCW12061R00F	Resistor, 1206 SMD	1.0
R2	CRCW12064990F	Resistor, 1206 SMD	499
R3, 4	CRCW2512101J	Resistor, 2512 SMD	100, 1Ω
R5	CRCW12064022F	Resistor, 1206 SMD	40.2K
R6, 7, 13	CRCW120610R0F	Resistor, 1206 SMD	10
R8	CRCW12061002F	Resistor, 1206 SMD	10K
R9	CRCW120623R7F	Resistor, 1206 SMD	23.7
R10	CRCW12062002F	Resistor, 1206 SMD	20K
R11	CRCW120649R9F	Resistor, 1206 SMD	49.9
R12	CRCW12063010F	Resistor, 1206 SMD	301
R14	CRCW12061001F	Resistor, 1206 SMD	1.0K
T1 [(1)]	A9784-B	Power Transformer, Coilcraft	33Ω, 10A

(1) Data sheets for L1, L2, and T1 are available from Coilcraft at http://www.coi1craft.com/prod_pwr.cfm.

Table 1. Bill Of Materials (continued)

Item	Part Number	Description	Value
T2[2]	P8208T	Current Transformer, Pulse Eng.	100:1, 10A
U1[3]	LM5030	PWM Regulator, Texas Instruments	
U2	MOCD207M	Opto-Coupler, Fairchild	
U3	LM3411	Reference Regulator, Texas Instruments	3.3V
Q1, 2	SUD19N20-90	FET, N Channel, Vishay	200V, 19A
J1-3	651-1727010	Dual Terminals, Mouser	3 per Assy.

(2) Data sheet for T2 is available from Pulse Engineering at http://www.pulseeng.com/default.cfm.
(3) *LM5030 100V Push-Pull Current Mode PWM Controller* (SNVS215)

12 PCB Layout Diagrams

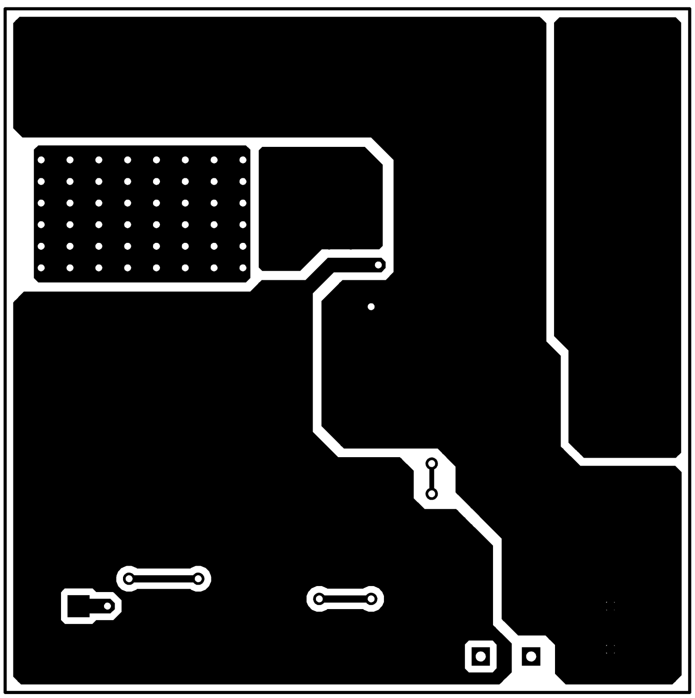
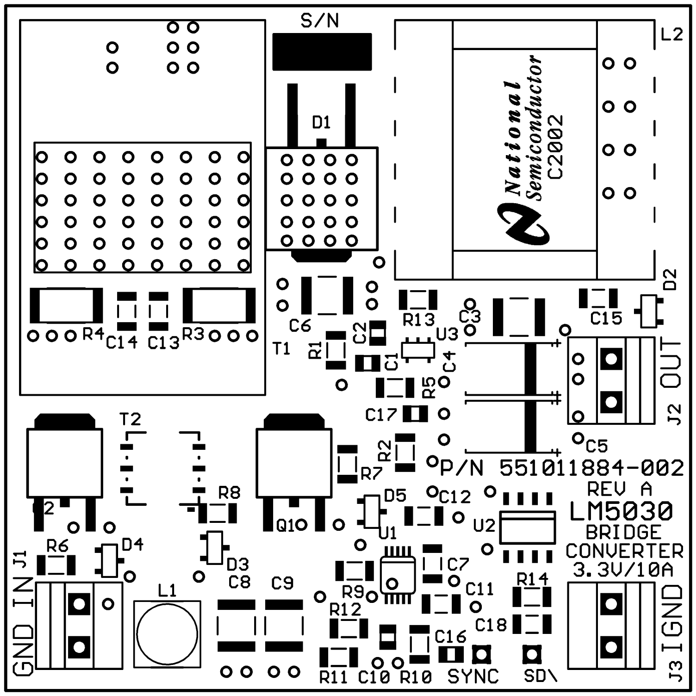


Figure 7. Bottom Layer (viewed from top)



SILKSCREEN LAYER (.PLC) AS VIEWED FROM TOP

Figure 8. Top Silk Screen

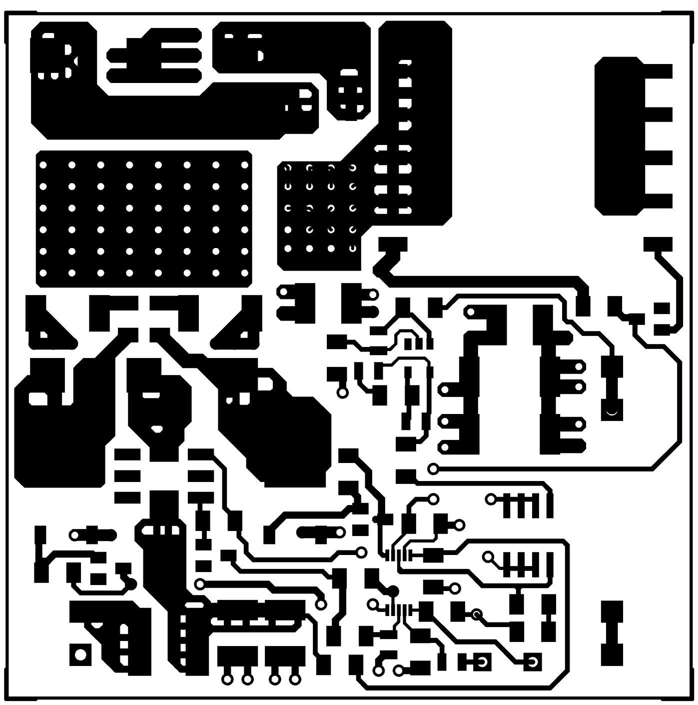


Figure 9. Top Layer

13 Board Schematic

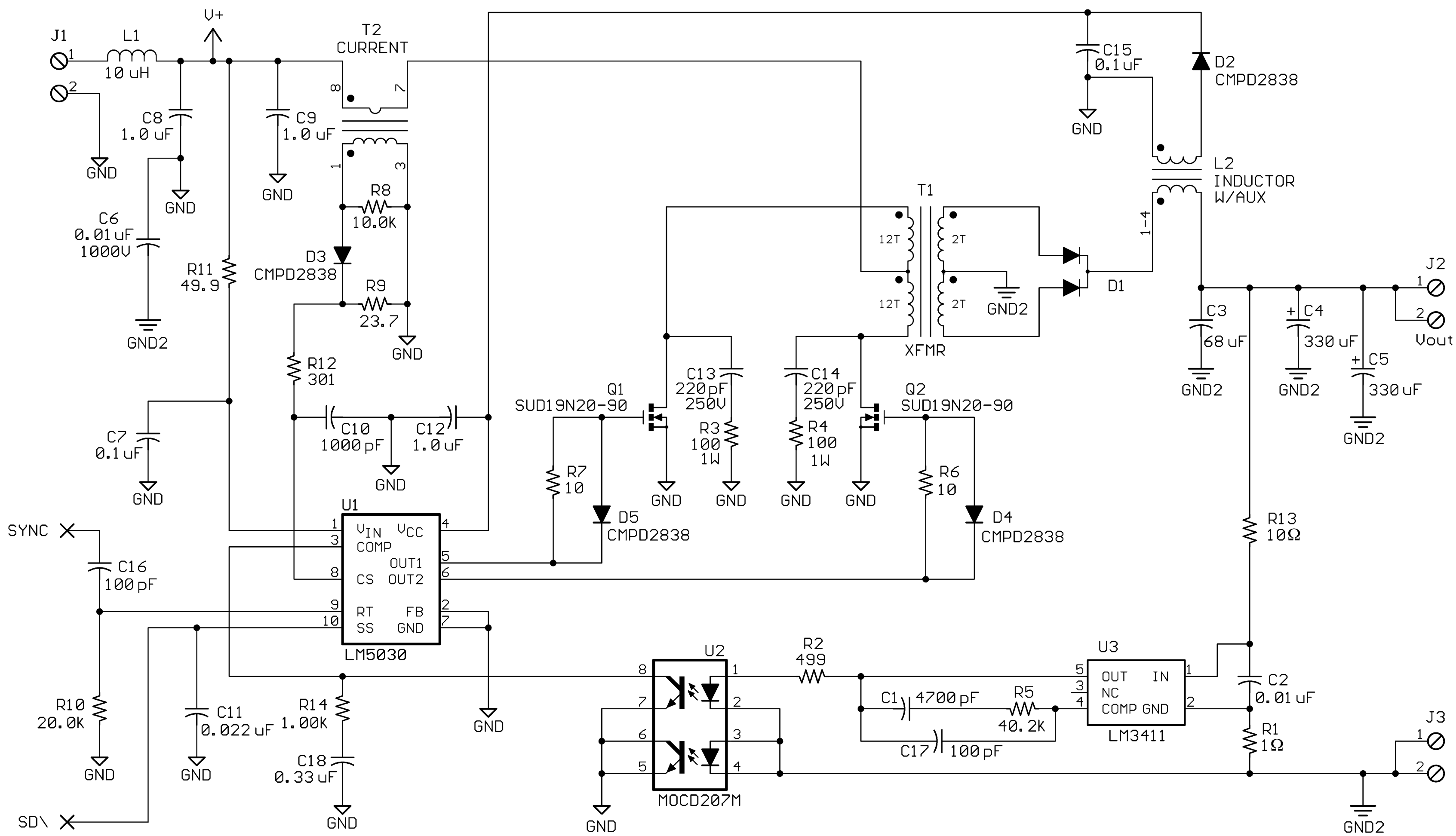


Figure 10. Board Schematic

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		

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265