Using the UCC28910FBEVM-526 6W Universal Off-Line Flyback Converter with Primary Side Regulation

1. Introduction:

The UCC28910FBEVM-526 evaluation module is an offline flyback power supply that provides isolated output voltage and current regulation without the use of an optocoupler. The input accepts a voltage range of $85V_{AC}$ to $265V_{AC}$.

The evaluation module uses the UCC28910 CV/CC PWM HV Switcher. This device integrates a 700 V power FET and controller that processes operating information from an auxiliary flyback winding and from the power FET to provide precise output voltage and current control. Control algorithms in the UCC28910 allow operating efficiencies to meet or exceed applicable standards. Discontinuous conduction mode (DCM) with valley switching is used to reduce switching losses. A combination of switching frequency and peak primary current amplitude modulation is used to keep conversion efficiency high across the full load and input voltage range. Fig.1 below details the output V-I characteristic

Low system parts count and built in advanced protection features result in a cost-effective solution that meets stringent world-wide energy efficiency requirements.

This user's guide provides the schematic, component list, assembly drawing, art work, and test set up necessary to evaluate the UCC28910 in a typical off-line converter application.

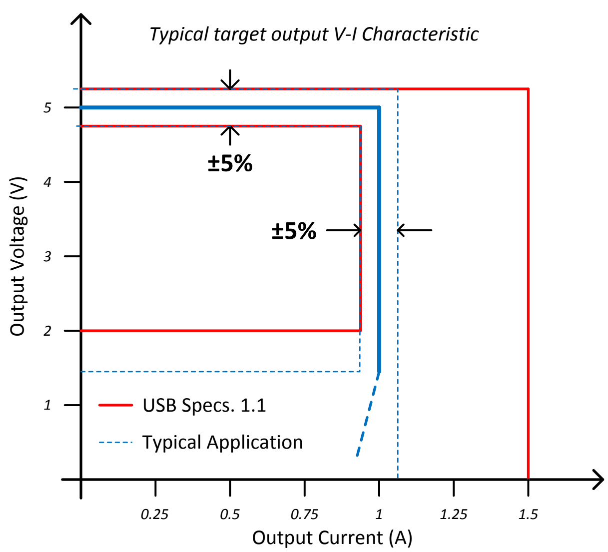

Figure1 Output voltage as a function of output load for the UCC28910EVM-526

2.1 Applications:

The UCC28910 is suited for use in isolated off-line systems requiring high efficiency and advanced fault protection features including:

- USB compliant adapters for cell phones, tablets and cameras
- 5-7 W AC/DC power supplies

2.2 Features:

The UCC28910FBEVM-526 features include:

- Isolated 6W, 5V output
- Universal off-line input voltage range
- Exceeds Energy Star™ EPS Version 2.0 requirements for active load efficiency and no-load power consumption
- Meets USB specification 1.1
- Meets EN 55022 Class B conducted emissions requirements
- Multiple operating modes and valley switching for optimum efficiency over entire operating range
- Primary side control eliminates need for optocoupler
- Output over voltage protection
- Input under voltage protection
- Primary over current protection
- Thermal Shutdown
- Controlled start up and restart after fault Protection

Caution

High voltage levels are present on the evaluation module whenever it is energized. Proper precautions must be taken when working with the EVM. The large bulk capacitors, C1 and C2, and the output capacitors, C7 and C8, must be completely discharged before the EVM can be handled. Serious injury can occur if proper safety precautions are not followed.

3. Electrical Performance Specifications

Table1. UCC28910FBEVM-526 Electrical Performance Specifications

Parameter	Symbol	Notes and Conditions	Min	Nom	Max	Units
INPUT CHARACTERISTICS						
Input Voltage	V_{IN}		85	115/230	265	V
Frequency	f_{LINE}		47	50/60	64	Hz
No Load Power	P_{NL}	$V_{in} = V_{nom}$ $I_{out} = 0A$		15	20	mW
Brownout Voltage	V_{INUVLO}	$I_{OUT} = I_{NOM}$		70		V
Brownout Recovery Voltage	V_{INOV}			80		V
Input Current	I_{IN}	$V_{in} = V_{min}$ I_{out} = max		0.2		A
OUTPUT CHARACTERISTICS						
Output Voltage	V_{OUT}	$V_{in} = V_{min}$ to V_{MAX} $I_{out} = 0$ to I_{NOM}	4.75	5	5.25	V
Maximum Output Current	$I_{OUT(MAX)}$	$V_{in} = V_{min}$ to V_{MAX}	1.14	1.2	1.26	A
Minimum Output Current	$I_{OUT(MIN)}$	$V_{in} = V_{min}$ to V_{MAX}		0		A
Output Voltage Ripple	ΔV_{OUT}	$V_{in} = V_{min}$ to V_{MAX} $I_{out} = 0$ to I_{NOM}		150		mV
Output Power	P_{OUT}	$V_{in} = V_{min}$ to V_{MAX}				
SYSTEM CHARACTERISTICS						
Average Efficiency	η	$V_{in} = V_{nom}$ I_{out} = 25%,50%,75%,100% of I_{OUT}		75		%
ENVIRONMENTAL						
Conducted EMI			Meets CISPR22B/EN55022B			
MECHANICAL						
DIMENSIONS	W	Width		3.5		in
	L	Length		5		in
	H	Component Height		1		in

4. Schematic:

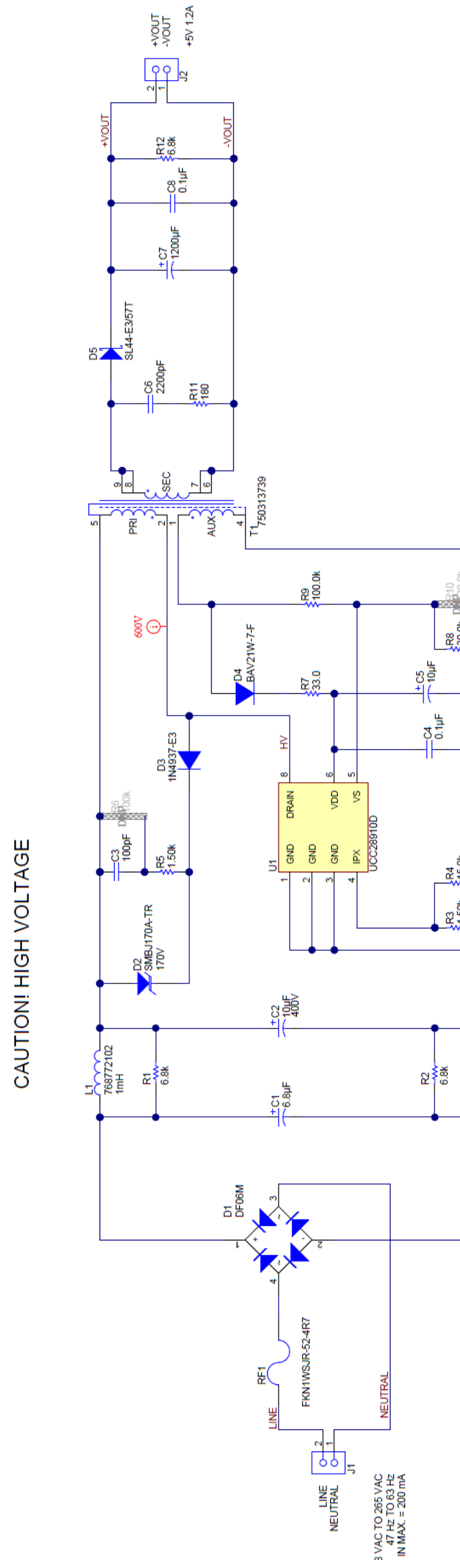

Figure2. UCC28910FBEVM-526 schematic

4.1 Circuit Description:

A brief description of the circuit elements follows:

- Diode Bridge D1, input capacitors C1 and C2, transformer T1, UCC28910 switcher U1, Schottky rectifier D5 and capacitor C7 form the power stage of the converter. Note that the UCC28910 U1 is also part of the power stage since the high voltage mosfet is internal to U1
- Capacitor C8 filters the high frequency noise directly across the electrolytic output capacitor.
- The input EMI filter is made up of C1 and C2 and differential mode inductors, L2 and L3.
- R1,R2 serve the dual function of dampening input filter oscillations and prevent a large voltage being developed across L2 and L3 in the event of an ESD pulse.
- Input current protection is provided by fusible resistor, RF1.
- Resistors R5 and R6, capacitor C3, and diodes D2 and D3 make up the primary side voltage clamp. The clamp prevents the drain voltage on U1 from exceeding its maximum rating.
  A secondary function of the clamp is to alleviate the EMI currents associated with the turnoff voltage of U1.
- Operating bias to the controller is provided by the auxiliary winding on T1, diode D4, resistor R7 and bulk capacitor C5.
- Capacitor C4 is a decoupling capacitor which should always be good quality low ESR/ESL type capacitors placed as close to the IC pins as possible and returned directly to the IC ground reference.
- Secondary side snubber C6 and R11are used to reduce the effects switching noise of D5.
- Resistor R9 programs the start up voltage threshold.
- Resistors R8 and R10 program the output voltage set point
- Resistors R3 and R4 program the maximum output current
- Resistor R12 is used to adjust the no load output voltage

5. EVM Test Set Up:

Figure 3 shows the equipment set up when measuring the input power consumption during no load. During the no-load test, the power analyzer should be set for long averaging in order to include several cycles of operation and an appropriate current scale factor should be used. Figure 4 shows the basic test set up recommended to evaluate the UCC28910FBEVM-526 with a load.

Warning

High voltages that may cause injury exist on this evaluation module (EVM). Please ensure all safety procedures are followed when working on this EVM. Never leave a powered EVM unattended.

5.1 Test Equipment:

See Figures 3 and 4 for recommended test set ups.

- **AC Input Source:** The input source shall be an isolated variable AC source capable of supplying between 85Vrms and 265Vrms at no less than 15W and connected as shown in Figures 3 and 4. For accurate efficiency calculations, a power meter should be inserted between the AC source and the EVM. For highest accuracy, connect the voltage terminals of the power meter directly across the power source. (*Connecting the voltage terminals directly to the EVM will result in a small current error. This is very significant when measuring no load power*)
- **Load:** For the output load, a programmable electronic load set to constant current mode and capable of sinking 0 to $1.5A_{DC}$ at $10V_{DC}$ shall be used. For highest accuracy, V_{OUT} can be monitored by connecting a DC voltmeter, DMM V_1, directly across the +Vout and –Vout terminals as shown in Figure3 and Figure4. A DC current meter, DMM A_1, should be placed in series with the electronic load for accurate output current measurements.
- **Power Meter:** The power analyzer (PM1) shall be capable of measuring low input current, typically less than 100 uA, and a long averaging mode if low power standby mode input power measurements are to be taken. An example of such an analyzer is the Yokogawa WT210 Digital Power Meter. To measure the intermittent bursts of current and power drawn from the line during no-load operation, the WT210 should be set to integrate
- **Multimeters:** Two digital multimeters are used to measure the regulated output voltage (DMM $_{V1}$) and load current (DMM $_{A1}$).
- **Oscilloscope:** A digital or analog oscilloscope with a 500MHz scope probe is recommended
- **Recommended Wire Gauge:** a minimum of AWG 24 wire is recommended. The wire connections between the AC source and the EVM, and the wire connections between the EVM and the load should be less than two feet long.

5.2 Recommended Test Set Up for Operation Without a Load:

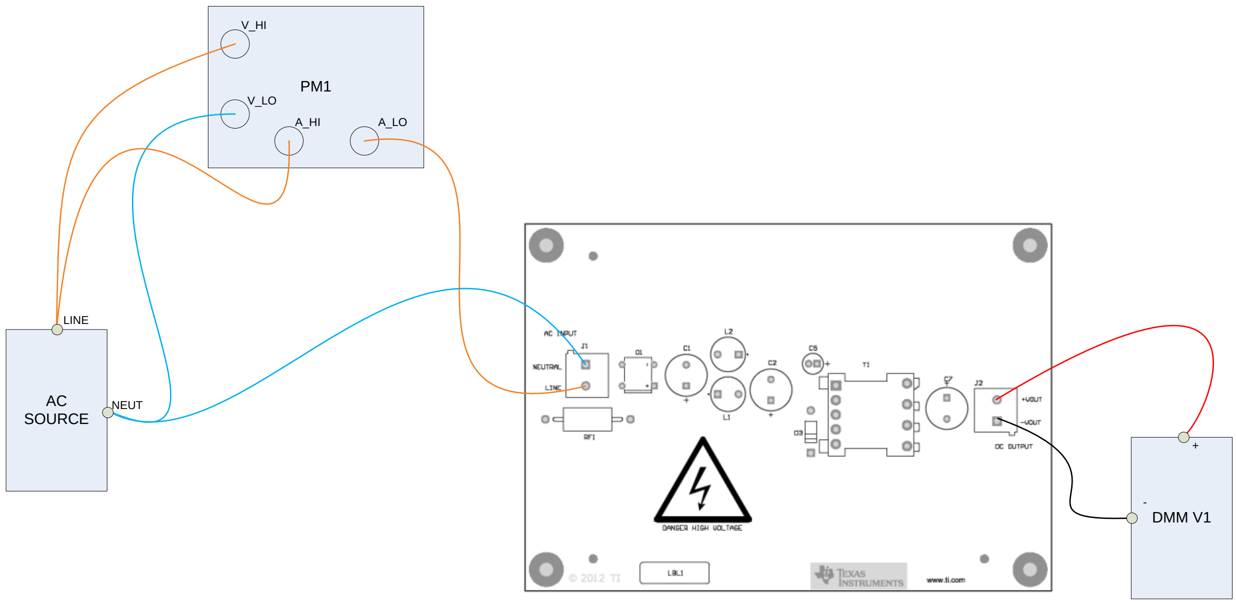

Figure3. UCC28910FBEVM-526 recommended test set up without a load.

5.3 Recommended Test Set Up for Operation With a Load:

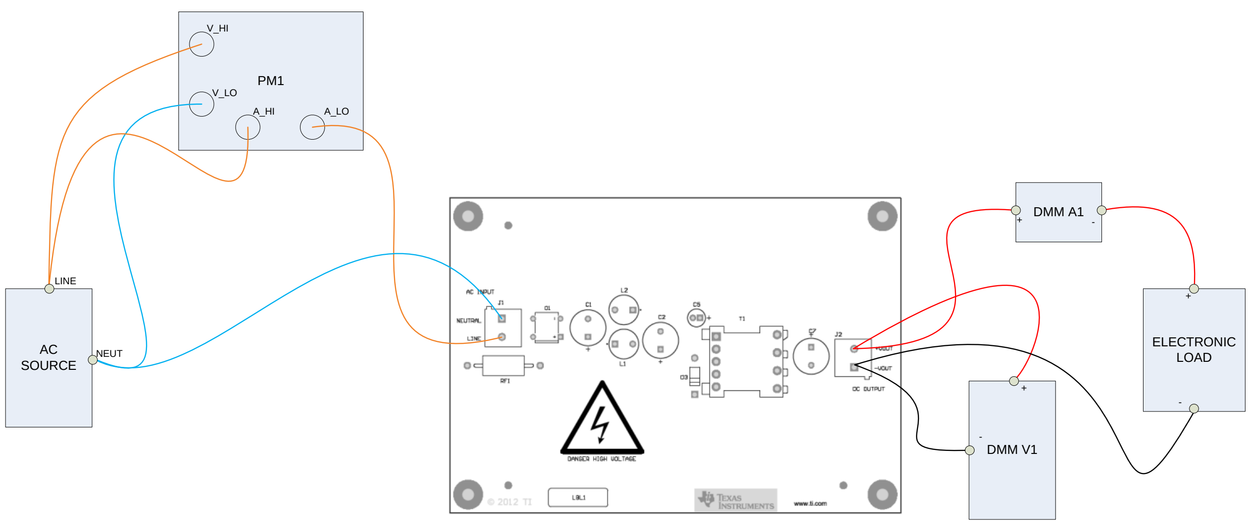

Figure4. UCC28910FBEVM-526 recommended test set up with a load.

6. Test Procedure:

All tests should use the set up as described in Section 5 of this user's guide. The following test procedure is recommended primarily for power up and shutting down the evaluation module. Never leave a powered EVM unattended for any length of time.

6.1 Applying Power to the EVM:

1. Set up the EVM as shown in Section 5 of this user's guide
    a. If no-load input power measurements are to be made, set the power analyzer to long averaging or integrating power measurement mode.
    b. For operation with a load, as shown in Figure 4, set the electronic load to constant current mode to sink 0A.
2. Prior to turning on the AC source, set the voltage to between 85V_{AC} and 265V_{AC}.
3. Turn on the AC source.
4. Monitor the output voltage on DMM V_1.
5. Monitor the output current on DMM A_1.
6. The EVM is now ready for testing.

6.2 No-Load Power Consumption:

1. Use the test set up shown in Figure 3
    a. Set the power analyzer to integrating average power mode.
    b. Set the current measurement scale to 0.25A
    c. Set the voltage range to 300V
    d. Set the measurement mode to RMS
2. Apply power to the EVM per Section 6.1.
3. Monitor the input power on the power analyzer while varying the input voltage.
4. Make sure the input power is off and the bulk capacitor and output capacitors are completely discharged before handling the EVM.

6.3 Output Voltage Regulation and Efficiency:

1. For load regulation:
    a. Use the test set up shown in Figure 4
    b. Set the AC source to a constant voltage between 85V_{AC} and 265V_{AC}.
    c. Apply power to the EVM per Section 6.1.
    d. Vary the load current from 0A up to 1.2A, as measured on DMM A_1.
    e. Observe that the output voltage on DMM V_1 remains between 4.75V and 5.25V from no load up to 1.2A and thereafter the current remains between 1.14A and 1.26A until the output voltage drops to 2V or lower. See Figure 1 for details.
2. For line regulation:
    a. Set the load to sink 1.2A.
    b. Vary the AC source from 85V_{AC} to 265V_{AC}.
    c. Observe that the output voltage on DMM V_1 remains between 4.75V and 5.25V.

3. Make sure the input power is off and the bulk capacitor and output capacitors are completely discharged before handling the EVM.

6.4 Output Voltage Ripple:

1. For output ripple measurements, solder a 0.1uF, 50V ceramic and 4.7uF, 35V tantalum on a BNC adapter as shown in figure 5 below. Connect the red test lead to the +Vout output and the black test lead to the –Vout on the EVM
2. Connect the other end of the BNC cable to the oscilloscope and monitor the output ripple on the oscilloscope.
3. Apply power to the EVM per Section 6.1.

Figure5. Typical example of tip measurement technique.

6.5 Equipment Shutdown:

1. Ensure the load is at maximum; this will quickly discharge the output capacitors.
2. Turn off the AC source.

7. Performance Data and Typical Characteristic Curves:

Figures 6 through 21 present typical performance curves for the UCC28910FBEVM-526.

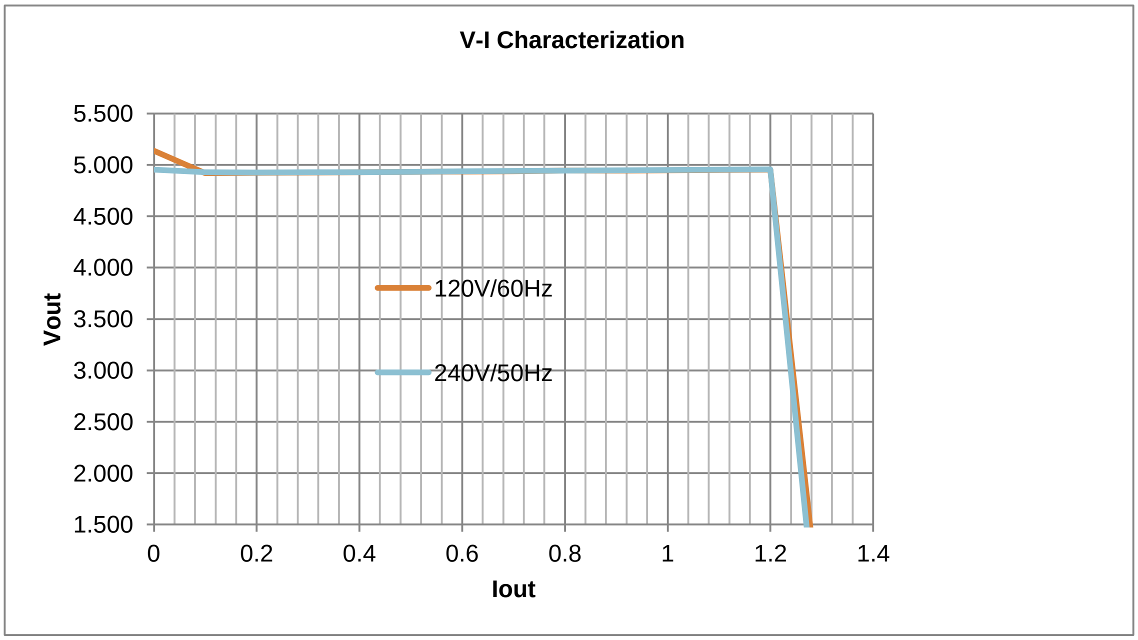

Figure6. Typical V-I Characteristic at 25°C

88Vin, Io	88Vin	115in, Io	115Vin	230Vin, Io	230Vin	265Vin, Io	265Vin
0.993	4.951	0.994	4.953	0.994	4.955	0.994	4.955
1.013	4.950	1.014	4.952	1.014	4.955	1.015	4.955
1.013	4.950	1.014	4.952	1.014	4.955	1.014	4.955
1.034	4.949	1.035	4.952	1.035	4.955	1.035	4.955
1.056	4.949	1.057	4.953	1.057	4.955	1.058	4.955
1.056	4.949	1.057	4.953	1.057	4.955	1.057	4.955
1.079	4.949	1.080	4.953	1.080	4.956	1.080	4.955
1.079	4.949	1.080	4.953	1.080	4.955	1.080	4.955
1.103	4.949	1.104	4.954	1.104	4.956	1.104	4.956
1.103	4.949	1.104	4.954	1.104	4.955	1.104	4.956
1.128	4.949	1.129	4.955	1.130	4.957	1.130	4.956
1.128	4.949	1.129	4.955	1.130	4.956	1.130	4.956
1.154	4.950	1.156	4.956	1.156	4.957	1.156	4.956
1.154	4.950	1.156	4.956	1.156	4.957	1.156	4.957
1.181	4.950	1.183	4.956	1.183	4.958	1.183	4.958
1.182	4.950	1.183	4.956	1.183	4.957	1.183	4.958
1.211	4.951	1.212	4.956	1.212	4.958	1.212	4.958
1.211	4.951	1.212	4.956	1.212	4.958	1.212	4.958
1.238	4.939	1.242	4.957	1.243	4.959	1.243	4.959
1.238	4.937	1.242	4.957	1.243	4.959	1.243	4.959
1.239	4.820	1.245	4.842	1.272	4.947	1.275	4.960
1.239	4.821	1.245	4.841	1.272	4.948	1.275	4.960
1.240	4.701	1.246	4.722	1.274	4.828	1.282	4.860
1.240	4.700	1.246	4.721	1.274	4.826	1.282	4.860
1.241	4.580	1.247	4.602	1.275	4.706	1.284	4.740
1.242	4.582	1.247	4.603	1.275	4.706	1.284	4.738
1.243	4.463	1.248	4.482	1.276	4.583	1.285	4.614
1.243	4.462	1.248	4.481	1.276	4.582	1.285	4.615
1.243	4.340	1.250	4.362	1.277	4.458	1.286	4.491
1.243	4.338	1.249	4.361	1.277	4.460	1.286	4.491
1.244	4.220	1.250	4.240	1.278	4.336	1.288	4.367
1.244	4.220	1.250	4.241	1.278	4.333	1.288	4.368
1.246	4.100	1.251	4.119	1.279	4.211	1.288	4.239
1.245	4.100	1.251	4.118	1.279	4.212	1.288	4.239
1.247	3.981	1.253	3.998	1.280	4.086	1.288	4.112
1.247	3.981	1.252	3.998	1.280	4.085	1.288	4.114
1.248	3.861	1.254	3.877	1.282	3.964	1.291	3.991
1.248	3.860	1.254	3.877	1.282	3.963	1.291	3.990
1.249	3.737	1.255	3.755	1.282	3.837	1.291	3.866
1.248	3.735	1.255	3.756	1.282	3.839	1.292	3.866
1.250	3.615	1.256	3.632	1.284	3.714	1.293	3.740
1.250	3.615	1.255	3.631	1.283	3.714	1.293	3.740
1.250	3.493	1.256	3.510	1.285	3.589	1.294	3.614
1.251	3.493	1.256	3.510	1.284	3.587	1.294	3.615
1.251	3.370	1.257	3.386	1.285	3.462	1.295	3.487
1.251	3.369	1.257	3.385	1.286	3.463	1.295	3.487
1.252	3.246	1.258	3.262	1.287	3.339	1.296	3.362
1.252	3.248	1.258	3.262	1.287	3.337	1.296	3.361

1.253	3.124	1.258	3.139	1.288	3.209	1.296	3.234
1.252	3.123	1.259	3.139	1.287	3.212	1.297	3.235
1.252	2.998	1.259	3.014	1.288	3.086	1.297	3.107
1.253	3.000	1.259	3.013	1.288	3.083	1.298	3.106
1.253	2.875	1.259	2.888	1.288	2.957	1.298	2.980
1.252	2.873	1.258	2.887	1.289	2.958	1.298	2.980
1.253	2.752	1.260	2.763	1.289	2.830	1.299	2.850
1.253	2.751	1.260	2.765	1.289	2.829	1.299	2.849
1.253	2.626	1.260	2.639	1.289	2.702	1.298	2.720
1.252	2.623	1.260	2.639	1.289	2.701	1.299	2.721
1.253	2.501	1.260	2.514	1.290	2.574	1.299	2.592
1.253	2.500	1.260	2.514	1.290	2.574	1.299	2.592
1.253	2.376	1.260	2.388	1.290	2.445	1.300	2.464
1.253	2.375	1.260	2.387	1.290	2.446	1.299	2.464
1.253	2.250	1.260	2.262	1.289	2.316	1.299	2.334
1.253	2.249	1.259	2.262	1.290	2.316	1.299	2.334
1.252	2.123	1.259	2.136	1.289	2.186	1.298	2.202
1.252	2.122	1.259	2.136	1.289	2.187	1.299	2.203
1.251	1.997	1.258	2.009	1.289	2.057	1.298	2.072
1.251	1.997	1.258	2.008	1.288	2.056	1.297	2.071
1.250	1.871	1.258	1.882	1.287	1.927	1.296	1.940
1.250	1.870	1.258	1.882	1.288	1.926	1.296	1.940
1.249	1.744	1.256	1.755	1.285	1.796	1.295	1.809
1.249	1.745	1.256	1.755	1.286	1.796	1.295	1.809
1.248	1.618	1.254	1.627	1.285	1.666	1.294	1.678
1.248	1.618	1.255	1.627	1.284	1.665	1.293	1.677
1.246	1.492	1.253	1.500	1.283	1.535	1.291	1.546
1.246	1.492	1.253	1.500	1.283	1.537	1.291	1.548
1.244	1.364	1.250	1.372	1.280	1.405	1.289	1.415
1.244	1.365	1.251	1.372	1.280	1.405	1.289	1.415
1.241	1.238	1.248	1.246	1.278	1.275	1.287	1.284
1.242	1.239	1.248	1.246	1.278	1.275	1.287	1.284
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Figure7. Typical V-I Test Data at 25°C

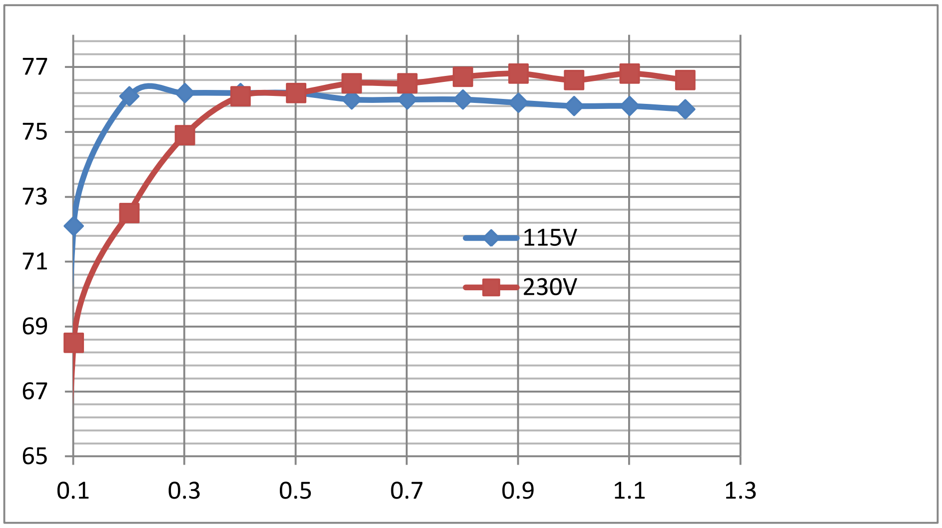

Figure8. Efficiency Vs Iout

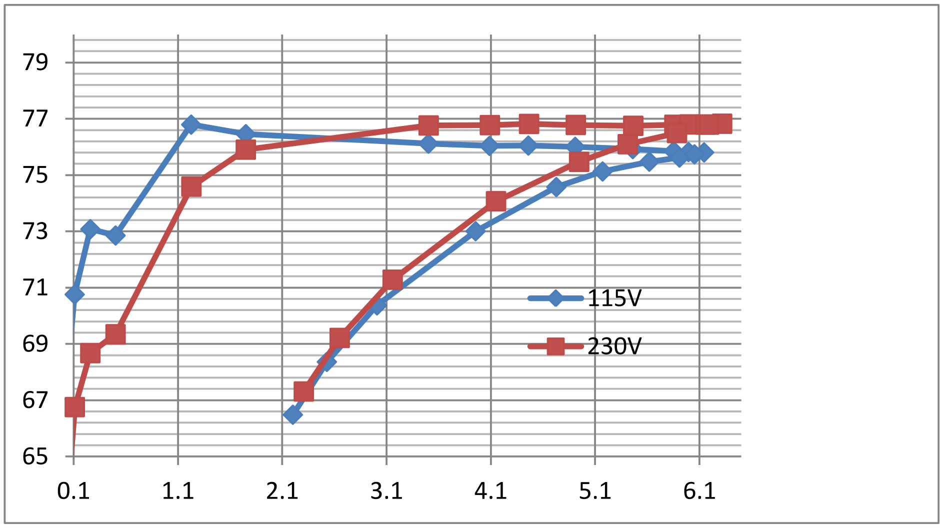

Figure9. Efficiency Vs Pout

Vin(V)	f(Hz)	Pin(W)	Iout(A)	Vout(V)	Pout(W)	Eff (%)	Avg Eff (%)
115	60	7.826	1.201	4.950	5.943	75.94	76.25
		5.845	0.901	4.942	4.451	76.15	
		3.889	0.601	4.934	2.964	76.19	
		1.930	0.301	4.927	1.481	76.73	
230	50	7.721	1.201	4.956	5.950	77.06	76.68
		5.783	0.901	4.948	4.457	77.07	
		3.853	0.601	4.938	2.966	76.97	
		1.960	0.301	4.930	1.482	75.60	

Table 1 Average Efficiency

Vin (V)	f(Hz)	Pin(mW)	Vout(V)
88	60	10	5.02
115	60	10	5.02
230	50	10	5.02
265	50	12	5.02

Table 2 No Load Power Consumption

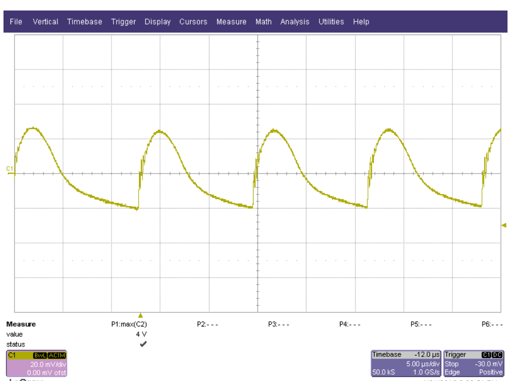

Figure 10 Ripple with 5V,1.2A out 85Vac in 20mV/div 5uS/div

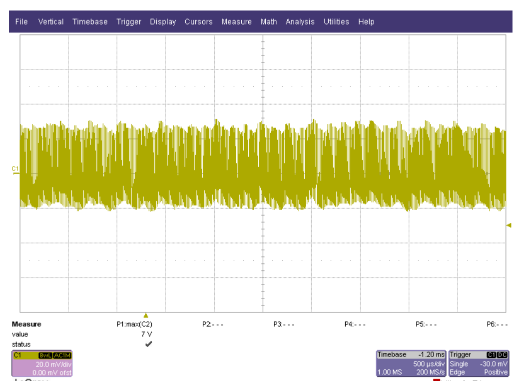

Figure 11 Ripple with 5V,1.2A out 85Vac in 20mV/div 500uS/div

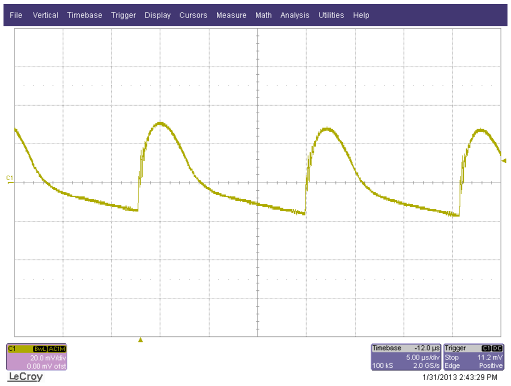

Figure12 Ripple with 5V,1.2A out 265Vac in
20mV/div 5uS/div

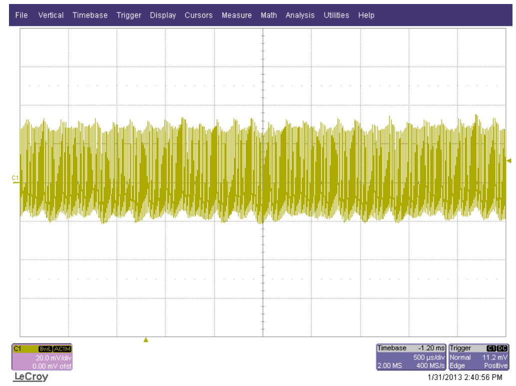

Figure 13 Ripple with 5V,1.2A out 265Vac in
20mV/div 500uS/div

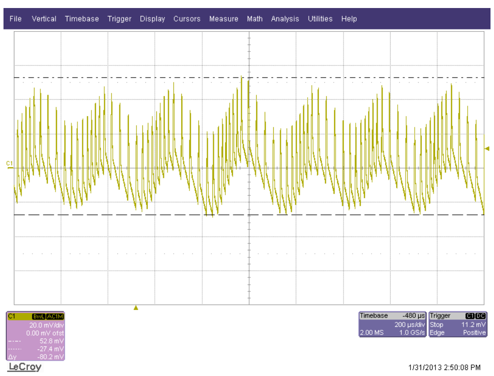

Figure 14 Ripple with 5V,700mA out 265Vac in
20mV/div 500uS/div

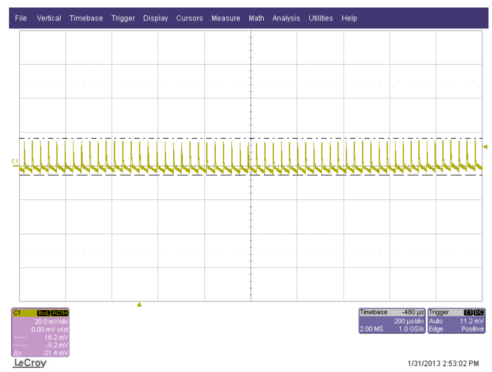

Figure 15 Ripple with 5V,100mA out 265Vac in
20mV/div 500uS/div

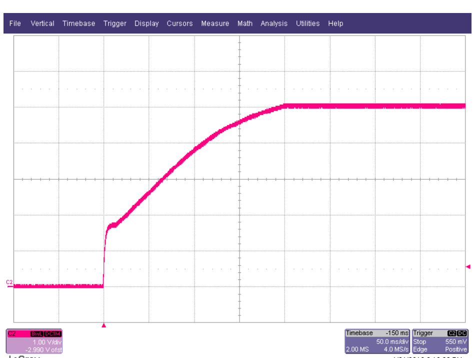

Figure 16 Output voltage start 115Vac,1.2A load

1V/div 50mS/div

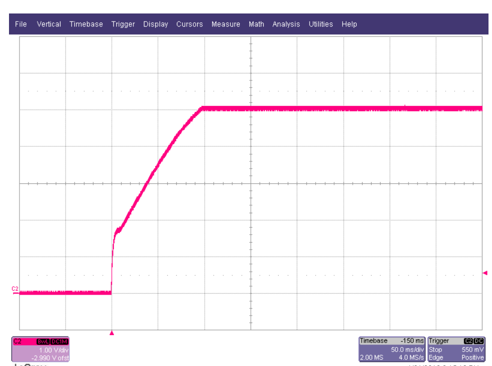

Figure 17 Output voltage start, 230Vac, 1.2A load

1V/div 50mS/div

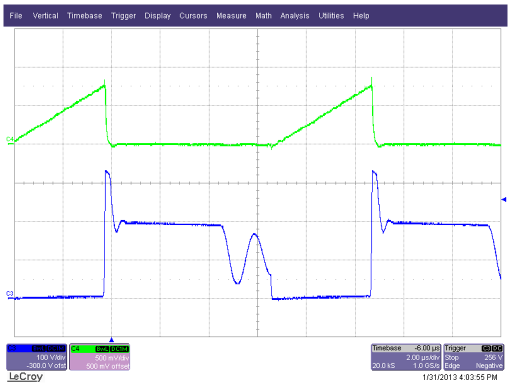

Figure 18 Primary side switching waveforms
85Vac 1.2A load
Drain voltage (CH 3 100V/div) IPK voltage (CH4 0.5V/div)
2uS/div

Figure 19 Primary side switching waveforms
265Vac 1.2A load
Drain voltage (CH 3 /div) IPK voltage (CH4 /div)
2uS/div

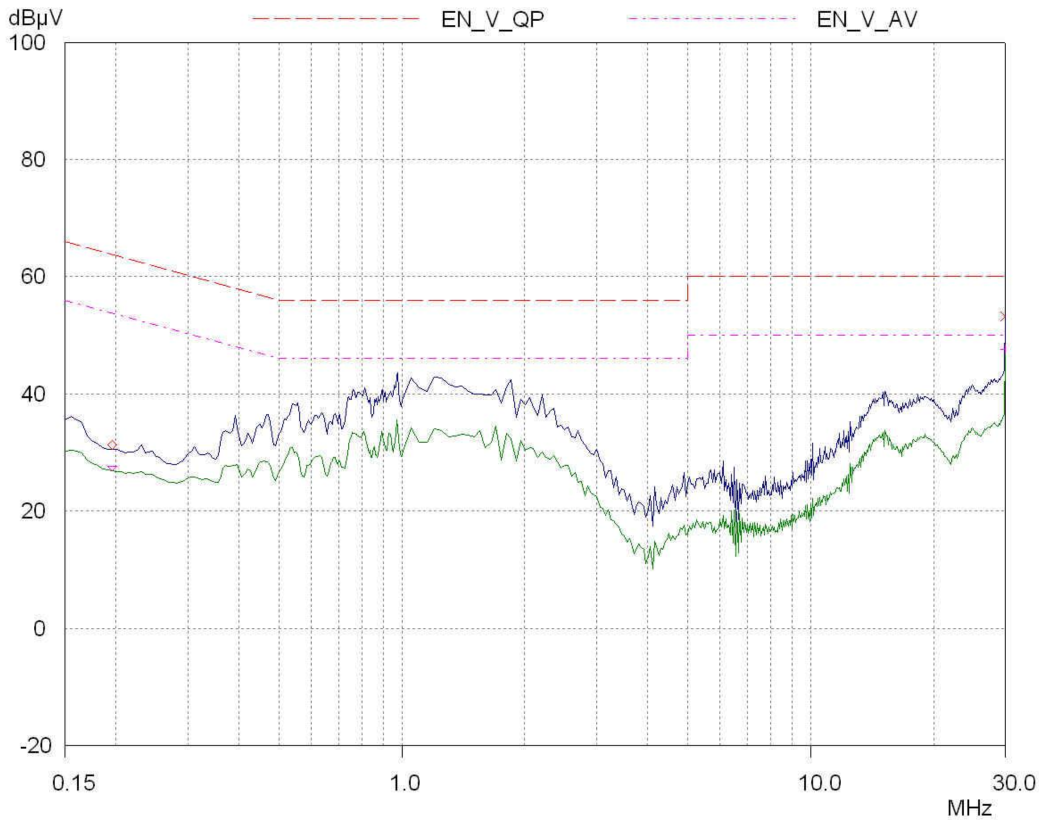

Figure20. EMI test results per EN55022, Class B. 115V_{AC} input

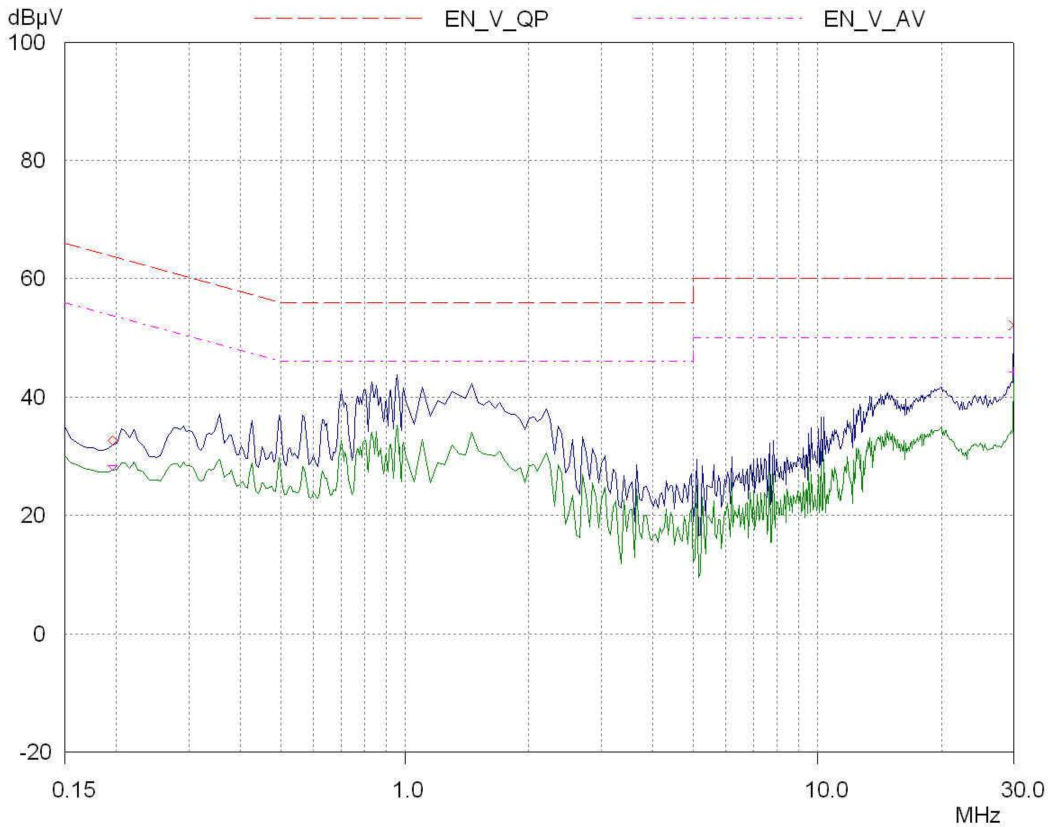

Figure21. EMI test results per EN55022, Class B. 230V_{AC} input

8. EVM Assembly Drawing and Layout:

The following figures show the design of the UCC28910FBEVM-526 printed circuit board.

Figure22. Top side view of UCC28910FBEVM-526

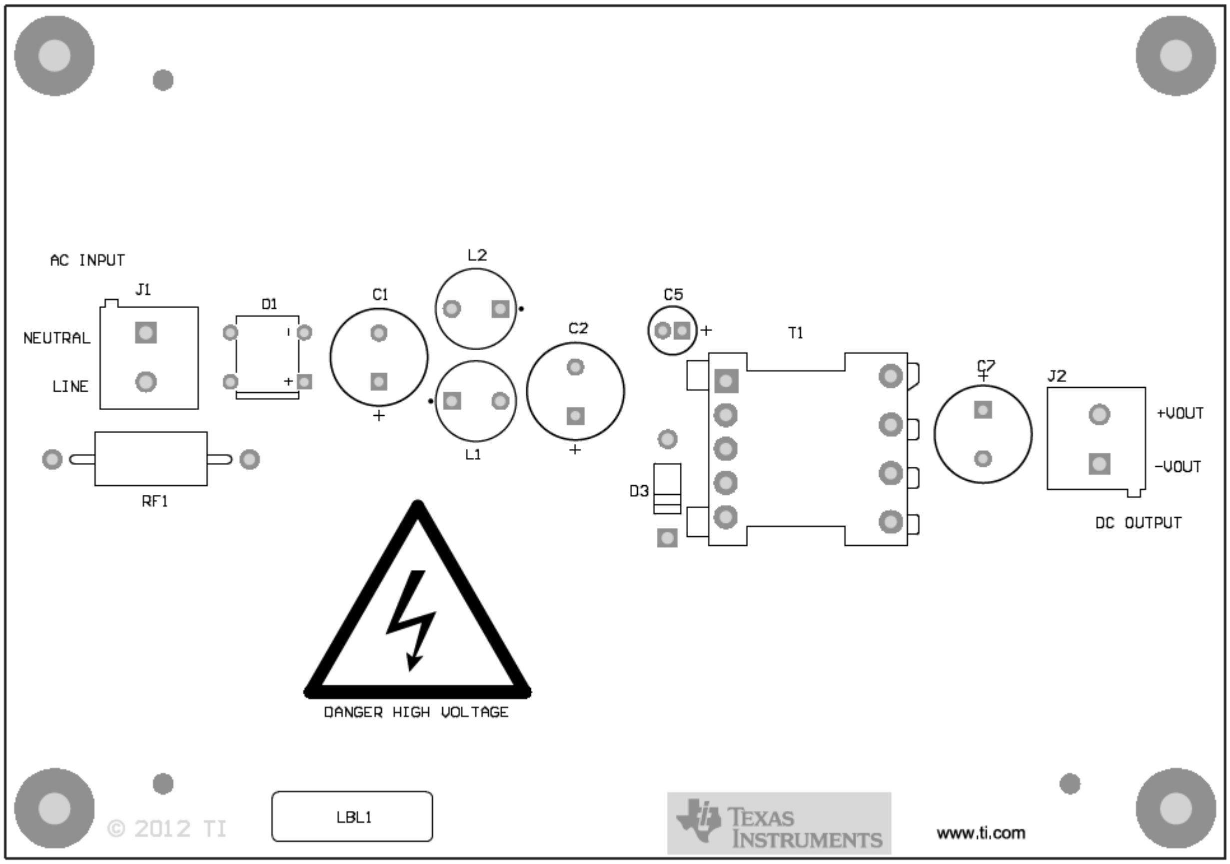

Figure23. Top layer component placement.

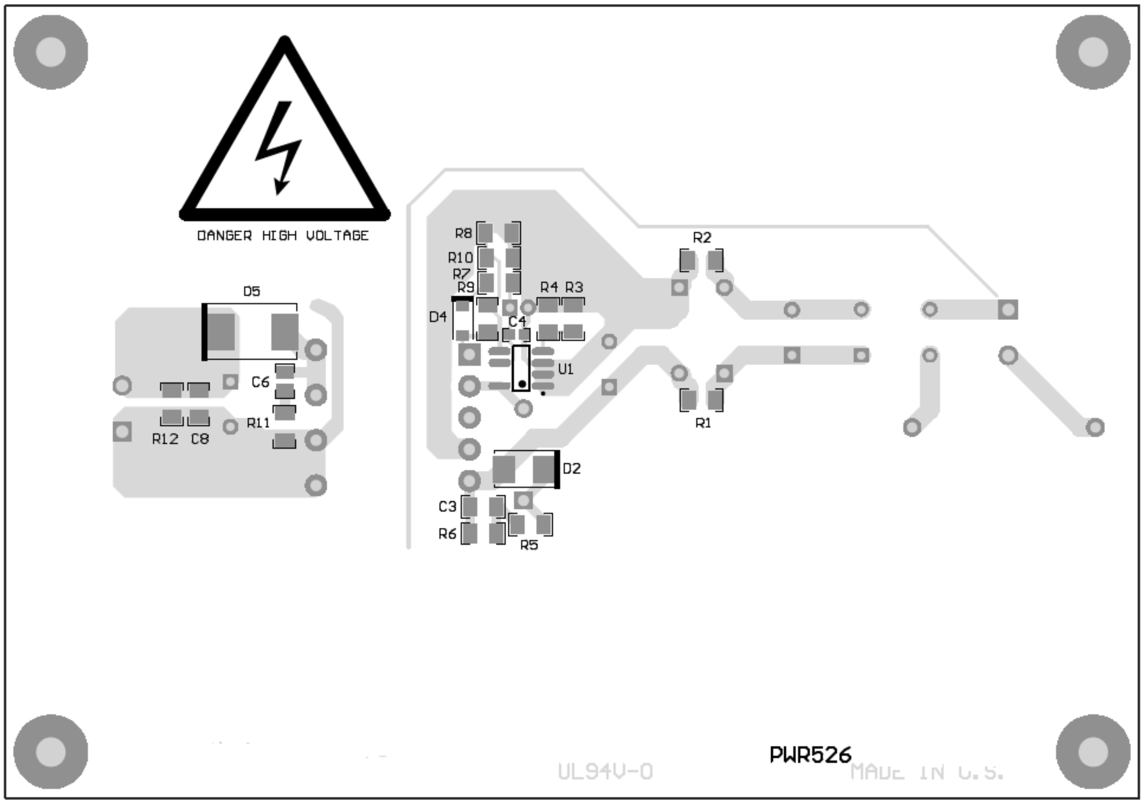

Figure24. Bottom layer.

9. List of Materials:

	Description	Manufacturer	PartNumber	Quantity
C1	CAP, AL, 6.8uF, 400V, +/-20%	Nichicon	UCA2G6R8MPD1TD	1
C2	CAP, AL, 10uF, 400V, +/-20%, 2.864788 ohm	Panasonic	EEUED2G100	1
C3	CAP, CERM, 100pF, 500V, +5/%, C0G/NP0, 1206	Kemet	C1206C101JCGACTU	1
C4	CAP, CERM, 0.1uF, 25V, +10/%, X5R, 0603	AVX	06033D104KAT2A	1
C5	CAP, AL, 10uF, 35V, +/-20%	Nichicon	UVR1V100MDD1TA	1
C6	CAP, CERM, 2200pF, 50V, +/-10%, X7R, 0805	AVX	08055C222KAT2A	1
C7	CAP, AL, 1200uF, 10V, +/-20%	Panasonic	EEUFM1A122	1
C8	CAP, CERM, 0.1uF, 50V, +/-5%, X7R, 1206	AVX	12065C104JAT2A	1
D1	Diode, Switching-Bridge, 600V, 1A	Diodes Inc.	DF06M	1
D2	Diode, TVS, Uni, 128V, 600W, SMB	ST Microelectronics	SM6T150A	1
D3	Diode, Switching, 600V, 1A	Vishay-Semiconductor	1N4937-E3	1
D4	Diode, Ultrafast, 100V, 0.15A, SOD-123	Diodes Inc.	1N4148W-7-F	1
D5	Diode, Schottky, 40V, 4A, SMC	Vishay	SL44-E3/57T	1
J1, J2	Conn Term Block, 2POS, 5.08mm PCB	Phoenix Contact	1715721	2
L1, L2	Inductor, Drum Core, Metal Composite, 1mH, 0.5A	Wurth Elektronik eiSos	768772102	2
R1, R2, R12	RES, 6.8k ohm, 5%, 0.25W, 1206	Vishay-Dale	CRCW12066K80JNEA	3
R3,R5	RES, 1.50k ohm, 1%, 0.25W, 1206	Vishay-Dale	CRCW12061K50FKEA	2
R4	RES, 15.0k ohm, 1%, 0.25W, 1206	Vishay-Dale	CRCW120615K0FKEA	1
R7	RES, 33.0 ohm, 1%, 0.25W, 1206	Panasonic	ERJ-8ENF33R0V	1
R8	RES, 30.0k ohm, 1%, 0.25W, 1206	Panasonic	ERJ-8ENF3002V	1
R9	RES, 100.0k ohm, 1%, 0.25W, 1206	Vishay-Dale	CRCW1206100KFKEA	1
R10	RES, 430.0k ohm, 1%, 0.25W, 1206	Yageo America	RC1206FR-07430KL	1
R11	RES, 180 ohm, 5%, 0.25W, 1206	Vishay-Dale	CRCW1206180RJNEA	1
RF1	RES, 4.7 ohm, 5%, 1W, Fusible	Yageo America	FKN1WSJR-52-4R7	1
T1	Transformer, EF16, 1.1mH	Wurth Elektronik	750313739	1
U1	LOW STAND-BY POWER, CV / CC PWM HV SWITCHER WITH PRIMARY SIDE REGULATION	Texas Instruments	UCC28910D	1

Table3. Bill of Materials for UCC28910FBEVM-526

10. References:

1. UCC28910 Datasheet

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