Using the UCC28630EVM-572

User's Guide

Texas Instruments

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UCC28630EVM-572, 65-W Nominal, 130-W Peak, Primary-Side Regulated Adapter Module

1 Introduction

The UCC28630EVM-572 evaluation module is a 65-W nominal, 130-W peak off-line flyback converter. It provides constant-voltage (CV) and constant-current (CC) output regulation using the bias winding to sense a scaled proportion of the output voltage and the primary current sense resistor to sense a scaled version of the secondary current. Output voltage regulation within 1% is maintained down to no-load by reducing the switching frequency and the device bias current consumption.

2 Description

This evaluation module uses the UCC28630 High-Power Flyback Controller with Primary-Side Regulation and Peak-Power Mode in a 65-W converter to provide a regulated output voltage of 19.5 V. The input accepts a voltage range of 90 VAC to 265 VAC. The output is designed for 19.5 V when in constant voltage mode and 3.34-A nominal output current.

The EVM transiently delivers ~7 A of constant charge down to an output voltage of ~12 V. The unit can only transiently operate at > 140% of the nominal output power. The operation of the overload timer is explained in detail in the UCC28630 datasheet. Sustained operation above this power level causes the device to inhibit switching and enter hiccup fault mode until the overload is removed.

The modulation of peak current and frequency results in excellent no-load power (<70 mW), no audible noise and small core size to deliver the 130-W peak power.

The UCC28630 also employs frequency dithering to reduce conducted emissions and therefore reduce the size and cost of the EMI filter.

This user’s guide provides the schematic, component list, assembly drawing, art work, and test set up necessary to evaluate the UCC28630EVM-572.

2.1 Typical Applications

The UCC28630 is suited for use in mid-to-high power off-line flyback converters requiring excellent no-load power, low component count, high reliability (no opto-coupler) and fault protection features.

- Consumer Electronics
  - Laptops
  - Tablet Computers
  - Printers
- Stand-By Supply for TV and Desktop
- White Goods

2.2 Features

The UCC28630EVM-572 features include:

- AC Input Range 90 VAC to 265 VAC
- DC Output of 19.5 V, 3.34 A
- No-Load Power Consumption Less than 70 mW
- Primary-Side feedback for Constant Voltage and current Regulation
- ±1% Output Voltage Regulation
- ±10% Output Current Regulation
- Average Efficiency > 88%
- Output Over-Load Timer
- Short Circuit Protection
- Transient Power Delivery of >130 W
- Output Over Voltage Protection
- Input Brown-Out Protection
- Fault Protections Including Over Temperature, Output Over-Voltage and Output Overload, Input Brownout
- Class B EMI Compliance

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, C5 and C7, and the output capacitors, C11 and C12, 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

UCC28630EVM-572 Electrical Performance Specifications

PARAMETER	TEST CONDITIONS	MIN	NOM	MAX	UNITS
INPUT CHARACTERISTICS					
Voltage range, V_{IN}		90	115/230	265	VRMS
Maximum input current	$V_{IN} = V_{IN(min)}$, $I_{OUT} = I_{OUT(max)}$			2	ARMS
Line frequency		47	60/50	63	Hz
No-load power consumption	$V_{IN(min)} \le V_{IN} \le V_{IN(max)}$, $I_{OUT} = 0$ A			70	mW
AC turn-on voltage			80		VRMS
AC turn-off voltage			65		VRMS
OUTPUT CHARACTERISTICS					
Output voltage, V_{OUT}	$V_{IN(min)} \le V_{IN} \le V_{IN(max)}$, 0 A $\le I_{OUT} \le I_{OUT(nom)}$ [(1)]	18.5	19.5	20.5	V
Output load current, CV mode	$V_{IN(min)} \le V_{IN} \le V_{IN(max)}$	0	3.34	7	A
Output load current, CC mode, $I_{OUT(max)}$	$V_{IN(min)} \le V_{IN} \le V_{IN(max)}$	7		7.75	A
Output voltage regulation	Line regulation: $V_{IN(min)} \le V_{IN} \le V_{IN(max)}$, 0A $\le I_{OUT} \le I_{OUT(nom)}$ (3.34 A)		1%		
	Load Regulation: 0 A $\le I_{OUT} \le I_{OUT(nom)}$ (3.34 A)		3		%
Output voltage ripple	$V_{IN(min)} \le V_{IN} \le V_{IN(max)}$, 0A $\le I_{OUT} \le I_{OUT(nom)}$ (3.34 A)		250		mVpp
Steady-state output over current threshold, I_{OCC}	$V_{IN(min)} \le V_{IN} \le V_{IN(max)}$			5.25	A
Minimum output voltage, CC mode	$V_{IN(min)} \le V_{IN} \le V_{IN(max)}$, $I_{OUT} = I_{OUT(max)}$ (7.75 A)	11.25	12		V
Transient response undershoot	I_{OUT} = 10% - 90% $I_{OUT(nom)}$	18.0		21.00	V
SYSTEMS CHARACTERISTICS					
Switching frequency, f_{SW}	Includes frequency dithering	0.2		126.7	kHz
Average efficiency	25%, 50%, 75%, 100% load average at nominal input voltages		88		%
Operating temperature			25		ºC

(1) Unless otherwise specified all measurements are taken at the end of a 1.8 m #18 AWG cable across a R&N measurement setup consisting of a 10-µF aluminum electrolytic capacitor and a 1-µF high-frequency ceramic capacitor.

4 Schematic

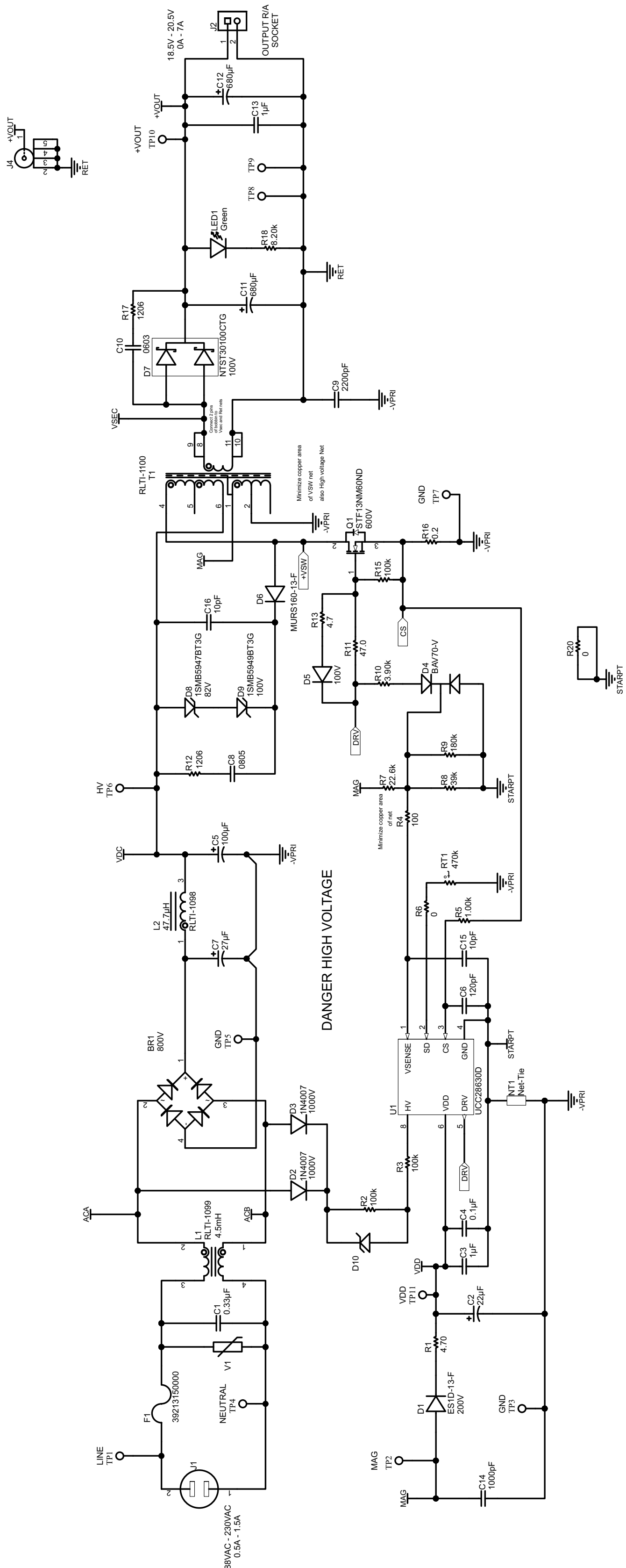

Figure 1. Typical Application Circuit for 19.5-V, 65-W Adapter

5 Test Setup - No Load

Figure 2 shows the equipment setup when testing at no load. It is important to note in this setup that the current flowing through the input impedance of the voltmeter does not flow through shunt resistor which is used to measure the input current of the EVM. This is important because a power meter having an input impedance of 1 MΩ draws a current of 230 μA at 230 V_{RMS}. This equates to a power dissipation of ~59 mW, it is important that this current is not measured as EVM input current.

Also, do not connect the oscilloscope probes or any other sensing devices to the unit while measuring no-load power as these can provide a path for common mode current to flow. This causes an error in the measurement.

During the no-load test, the power analyzer should be set for long-averaging mode in order to include several cycles of operation and an appropriate current scale factor when using an external shunt. Alternatively a power meter with an internal shunt can be used but it must be configured such that the shunt current is not supplied in series with the EVM input current.

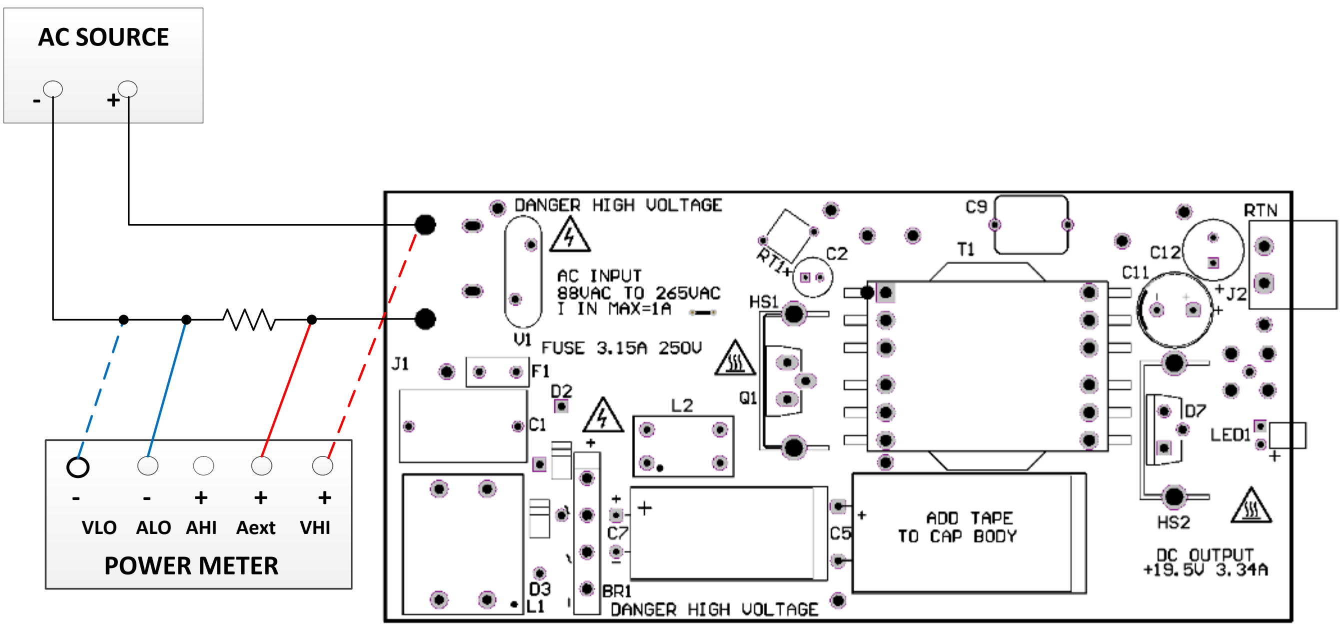

Figure 2. Test Setup

6 Test Setup with EVM Under Load

Figure 3 shows the equipment test setup when testing with load. Here the voltage sense has been moved to the other side of the shunt resistance This is because the error in the input current reading caused by the input impedance of the voltmeter reduces as the input current increases.

However as the input current increases, the voltage drop across the current shunt causes an error in the voltage measurement with the setup shown in Figure 3. Moving the VLO connection to the opposite side of the shunt as shown removes this error.

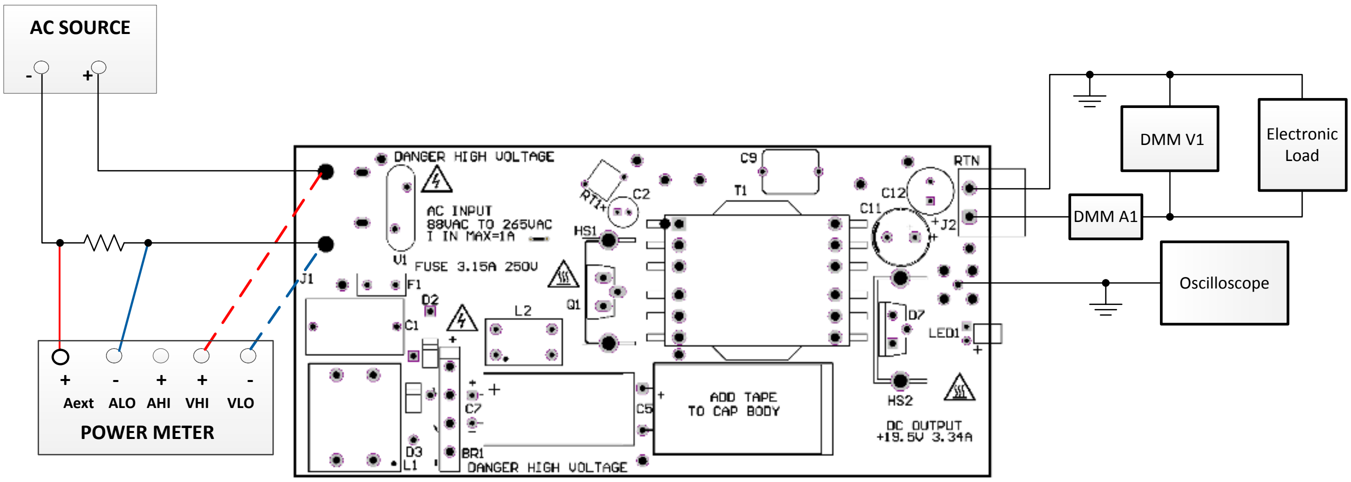

Figure 3. Test Setup

> **NOTE:** This setup can also be used for no-load testing as long as the power consumption of the voltmeter is subtracted from the power meter reading.

6.1 Test Equipment

AC Voltage Source: The input source shall be an isolated variable AC source capable of supplying between 90 VAC and 265 VAC at no less than 200 W and connected as shown in Figure 2 and Figure 3. For accurate efficiency calculations, a power meter should be inserted between the AC source and the EVM as shown in Figure 2 and Figure 3.

Output Load: A programmable electronic load capable of sinking 0 A to 10 A shall be used. For constant current mode testing of the EVM, the electronic load should be set to constant resistance mode.

Power Meter: A power analyzer shall be capable of measuring low input power, typically less than 5 mW and a long averaging mode, if low-power standby mode input-power measurements are to be taken.

Multimeters: For highest accuracy, VOUT can be monitored by connecting a DC voltmeter, DMM V1, directly across the +VOUT and –VOUT terminals as shown in Figure 3. A DC current meter, DMM A1, should be placed in series with the electronic load for accurate output current measurements.

Oscilloscope: A digital or analog oscilloscope with 500-MHz scope probes is recommended.

Fan: Forced air cooling is not required at the nominal operating point of 65-W load. If the unit is to be run in sustained overload (>100% P_{NOM}) a fan is required.

Recommended Wire Gauge: a minimum of AWG #18 wire is recommended on the input. The wire connections between the AC source and the EVM, should be less than two feet long.

A 1.8m #18 AWG cable is recommended on the output.

WARNING

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

6.2 List of Test Points

Test Point Functional Description

TEST POINT	NAME	DESCRIPTION
TP1	Live	Live terminal of the AC input
TP2	Mag	Positive end of V_{BIAS} (magnetic sense) winding
TP3, TP5, TP7	GND / -V_{PRI}	Primary-side ground
TP4	Neutral	Neutral terminal of the AC input
TP6	HV	Positive terminal of bulk capacitor
TP8, TP9	Secondary ground / Ret	Secondary-side ground
TP10	+V_{OUT}	Positive terminal of the output voltage
TP11	VDD	Bias voltage of the device.

6.3 Applying Power to the EVM

1. Set up the EVM as shown in Figure 3.
2. Set the electronic load to the desired setting. If testing the constant current characteristic of the unit, set the load to constant resistance mode.
3. Set the AC source voltage between 90 VAC and 265 VAC.
4. Monitor the output voltage on DMM V1.
5. Monitor the output current on DMM A1.

6.4 No-Load Power Consumption

1. Use the test setup shown in Figure 3.
   (a) Set the power analyzer for long-averaging time or integration mode (to include several cycles of operation) and the appropriate setup for measuring no-load power.
   (b) Allow the unit run at the line voltage where the no-load power will be measured for ~5 minutes. This is to allow the leakage current of the high-voltage bulk capacitors to decay to the steady-state value.
2. Apply power to the EVM per Section 6.4.
3. Monitor the input power on the power analyzer while varying the input voltage.
4. Make sure the EVM is off and the bulk capacitors and output capacitors are completely discharged before handling the EVM.

6.5 Line/Load Regulation and Efficiency Measurement Procedure

1. For load regulation, use the test set up shown in Figure 3.
   (a) Set the power analyzer to normal mode.
   (b) Set the AC source to a constant voltage between 90 VAC and 265 VAC.
   (c) Vary the load so that the output current varies from 0 A up to 3.34 A, as measured on DMM A1.
   (d) Observe that the output voltage on DMM V1 remains within 3% of the 19.5 V constant voltage regulation value.
   (e) Observe that if the constant resistance level of the electronic load is decreased lower than the maximum load value, the EVM maintains constant current regulation within 10% of the constant current limit until the bias voltage drops below bias UV. As mentioned above, the EVM can only operate in this region transiently. The delay before the overload timer trips depends on the state of the timer before entering the overload region. Refer to the UCC28630 datasheet, (TI Literature Number SLUSBW3). The EVM automatically restarts after 1 s.
2. For line regulation, use the test setup shown in Figure 3
   (a) Set the load to $I_{OUT(nom)}$
   (b) Vary the AC source from 90 VAC to 265 VAC
   (c) Observe that the output voltage on DMM V1 stays within 3% of the 19.5 V constant voltage regulation value.

6.6 Output Voltage Ripple

An external 10-µF aluminum capacitor and 1-µF ceramic noise decoupling capacitor network should be connected to the output to measure the output ripple and noise. This network should be connected to the end of the cable specified above (Section 3) but can be clipped across the test points on +VOUT and RTN if desired for convenience. The loop area between the scope probe tip and ground should be minimized for accurate ripple and noise measurements.

6.7 Equipment Shutdown

1. To quickly discharge the output and bulk capacitors, make sure there is a load greater than 1 A on the EVM.
2. Turn off the AC source.

7 Performance Data and Typical Characteristic Curves

Figure 4 through Figure 14 present typical performance curves for UCC28630EVM-572.

7.1 Efficiency

The average efficiency at 115-VAC, 60-Hz nominal input and 230-VAC, 50-Hz nominal input exceeds 88% efficiency at the end of the cable as specified in . Further increases in efficiency could be achieved with a transformer made with an increased core size and by designing for a lower peak power.

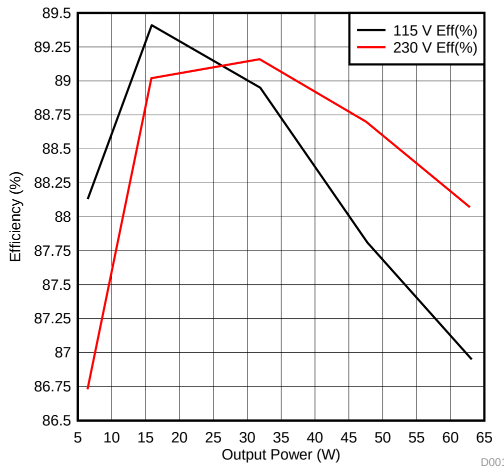

Figure 4. UCC28630EVM-572 Efficiency

Table 1. Average Efficiency

AVERAGE EFFICIENCY TEST							
V_{IN} (V)	F (Hz)	% LOAD	P_{IN} (W)	P_{OUT} (W)	EFFICIENCY (%)	AVG EFFICIENCY (%)	SPEC (%)
115	60	10	7.324	6.45	88.13		79
		25	17.78	15.90	89.41	88.28	88
		50	35.89	31.92	88.95		
		75	54.37	47.74	87.81		
		100	72.62	63.14	86.95		
230	50	10	7.409	6.43	86.73		79
		25	17.81	15.85	89.02	88.74	88
		50	35.69	31.82	89.16		
		75	53.6	47.54	88.70		
		100	71.38	62.86	88.07		

7.2 Load Regulation – Including Output Cable Drop

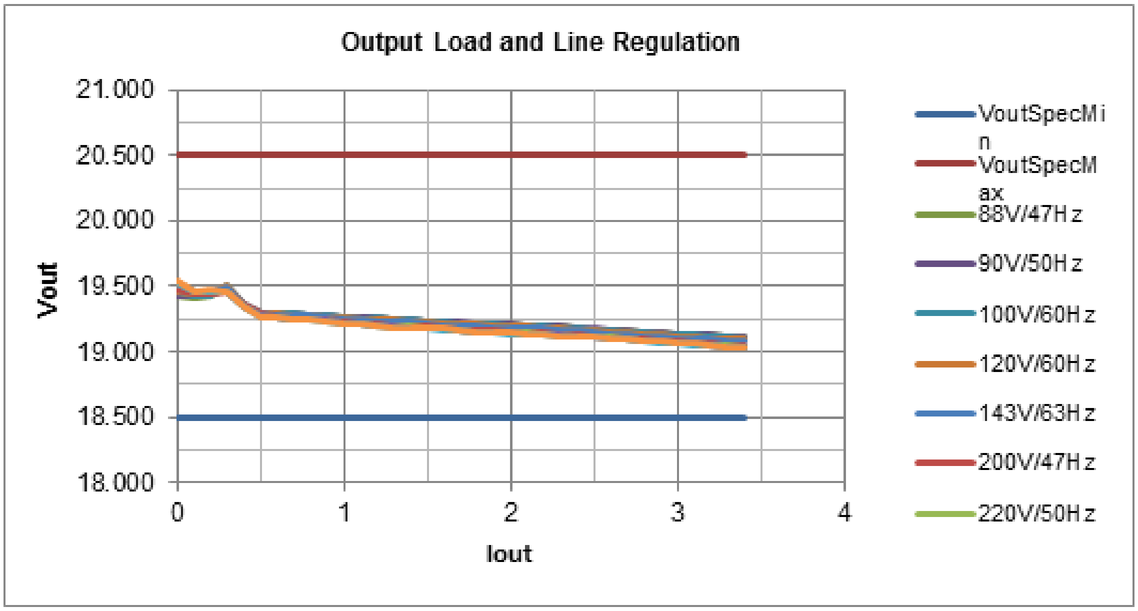

Figure 5. UCC28630EVM-572 Measured Load and Line Regulation at Cable End

7.3 Load Regulation – Not Including Output Cable Drop

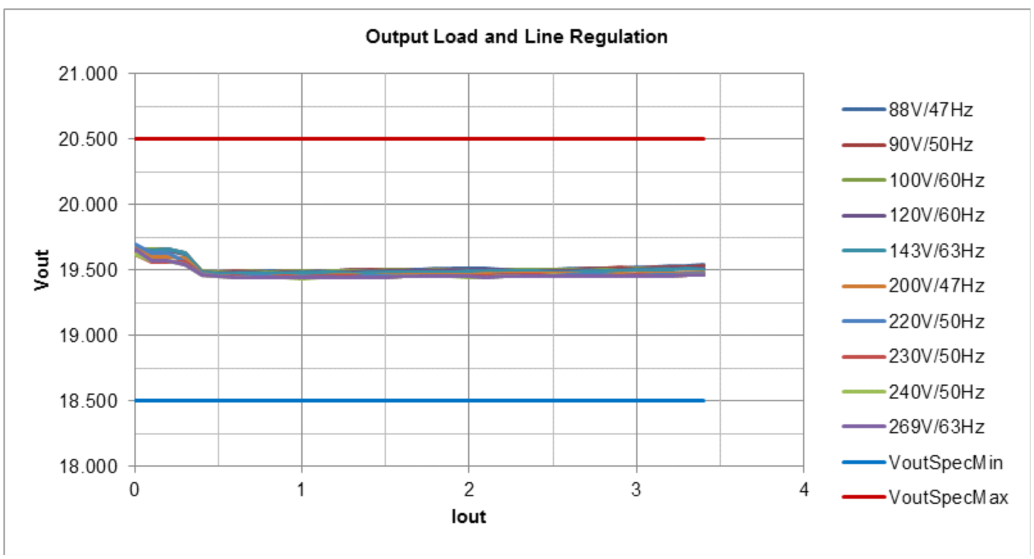

Figure 6. UCC28630EVM-572 Measured Load and Line Regulation at PCB End

7.4 No-Load Power Consumption

No-load power consumption measured less than 70 mW over the entire line input range.

UCC28630EVM-572 No-Load Power Consumption

V_{IN} (V)	F (Hz)	P_{IN} (W) MEASURED	P_{IN} (W) MAX SPEC	V_{OUT} (V)(Load_1)
115	60	0.057	0.070	19.58
230	50	0.060	0.070	19.69

7.5 Output Voltage vs Output Current

The curves in Figure 7 are generated by running the converter in constant-voltage mode at 100-mA load in steady state. The load resistance is then pulsed for 20 ms every second to increase the load current. Once load constant-current threshold is reached, the converter transitions into constant-current mode where the load current is regulated until the bias voltage falls below the bias UV threshold (~8.0 V), at which point the converter shuts down. The unit then enters hiccup mode until the load is decreased (resistance is increased).

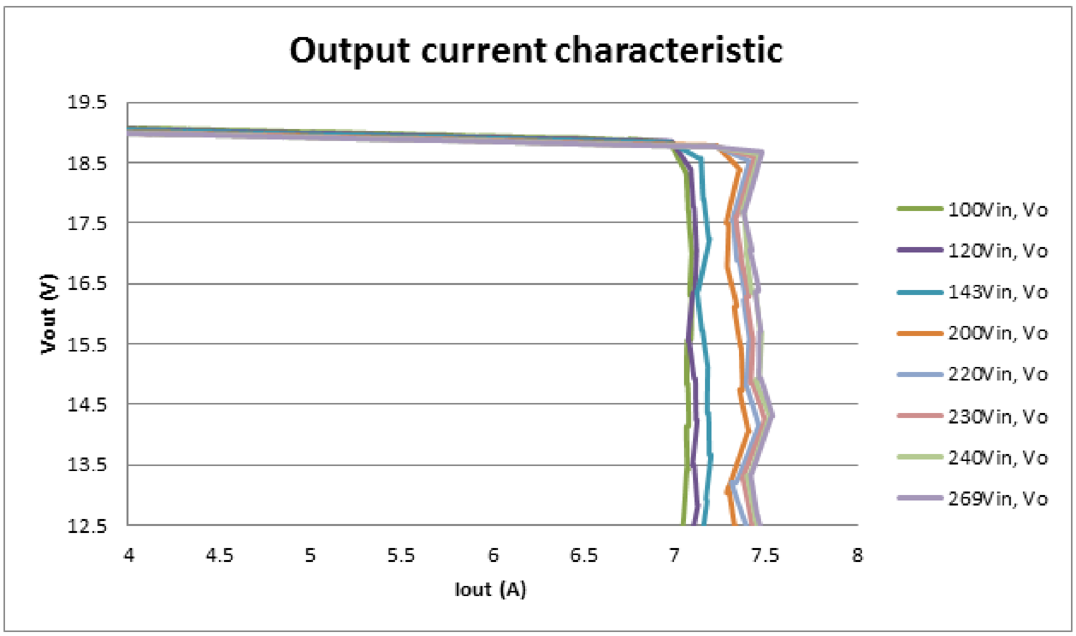

Figure 7. UCC28630EVM-572 Output Voltage as a Function of Load Current

7.6 Transient Response

The transient response shown in Figure 8 and Figure 9 was taken with a load transition from 10% to 90% of full load.

- Channel 1 is the output voltage at 2-V per division. The cursors show the transient response specification limits of 18 V and 21 V.
- Channel 2 shows the input line voltage.
- Channel 3 is the output current on a scale of 1-A per division.

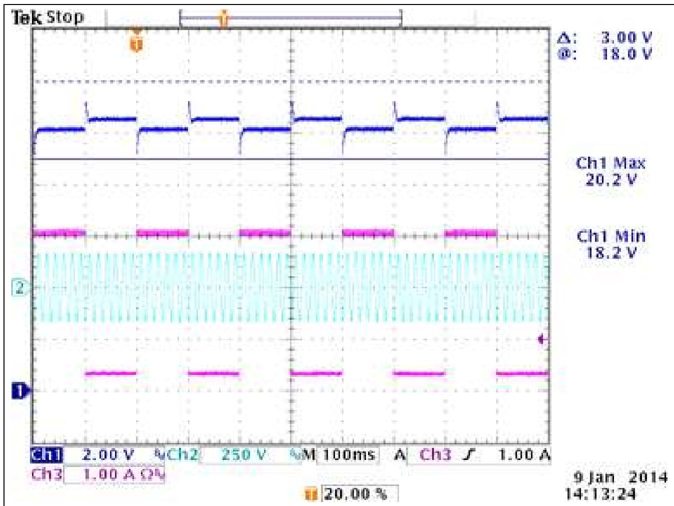

Figure 8. UCC28630EVM-572 Load Transient (10% to 90% Full Load Transient at 230 V)

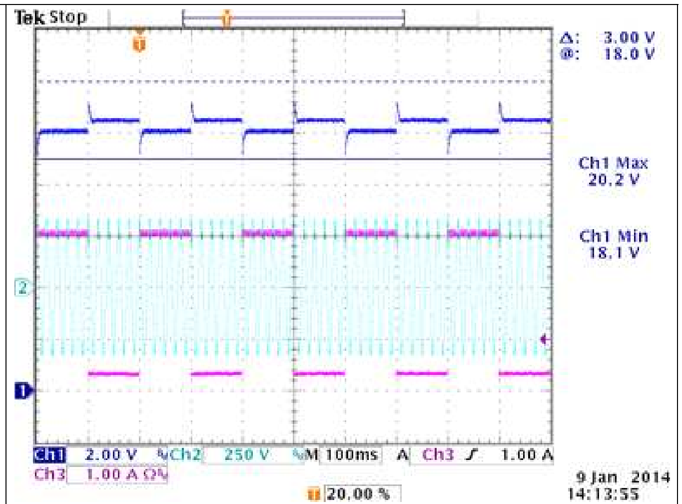

Figure 9. UCC28630EVM-572 Load Transient (10% to 90% Full Load Transient at 230 V_{AC})

7.7 Output Ripple

Figure 10 and Figure 11 shows the output voltage ripple, measured across the noise decoupling caps at the end of the cable.

- Channel 1 is the output voltage at 200-mV per division. The cursors show the output ripple specification limits of 600 mV pk-pk
- Channel 2 shows the input line voltage.
- Channel 3 is the output current on a scale of 1-A per division.

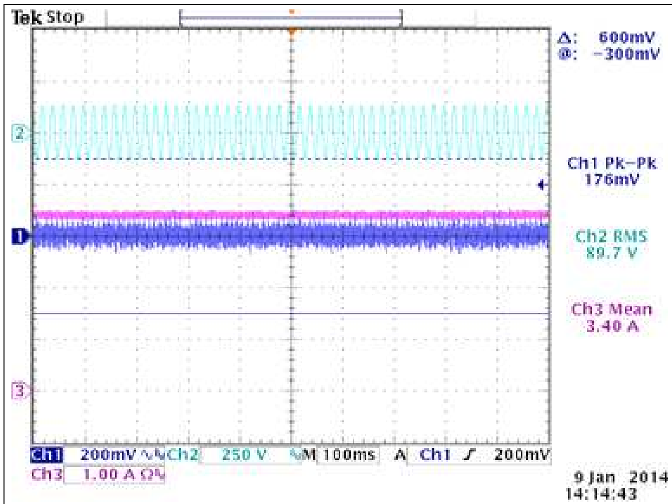

Figure 10. UCC28630EVM-572 Output Ripple and Noise (90 V/50 Hz, Load = 65 W)

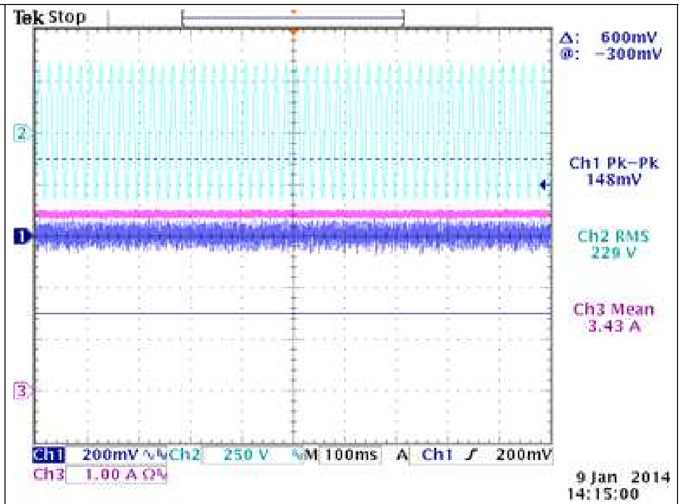

Figure 11. UCC28630EVM-572 Output Ripple and Noise (230 V/63 Hz, Load = 65 W)

7.8 Turn-On Waveform

Figure 12 shows the output voltage at turn on under full load conditions with an input voltage of 230 V_{AC}, 50 Hz.

V_{BIAS} is charged via the internal high-voltage start-up FET until it reaches the V_{BIAS} turn-on threshold of ~15 V.

The device enables the gate drive and charges the output voltage. During the initial period of this charging the bias capacitor supplies the device and gate-drive currents so the bias voltage falls.

When the rectified bias-winding voltage exceeds the bias-capacitor voltage, the supply current is supplied from the winding and the bias voltage is maintained at ~12.5 V.

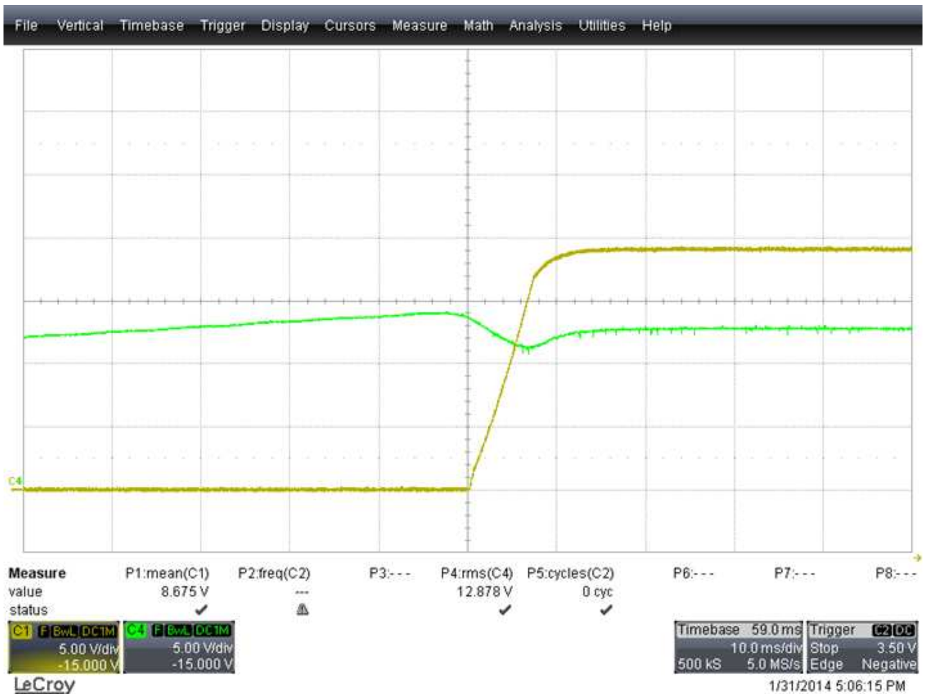

Figure 12. Output Voltage Turn-On Waveform

7.9 Bias Winding and VSENSE Pin Voltage

NB: Probing the VSENSE pin voltage adds capacitance to the pin and affects the voltage sampled by the device, This affects the output voltage regulation. Probing the VSENSE pin is not recommended in normal operation or during testing.

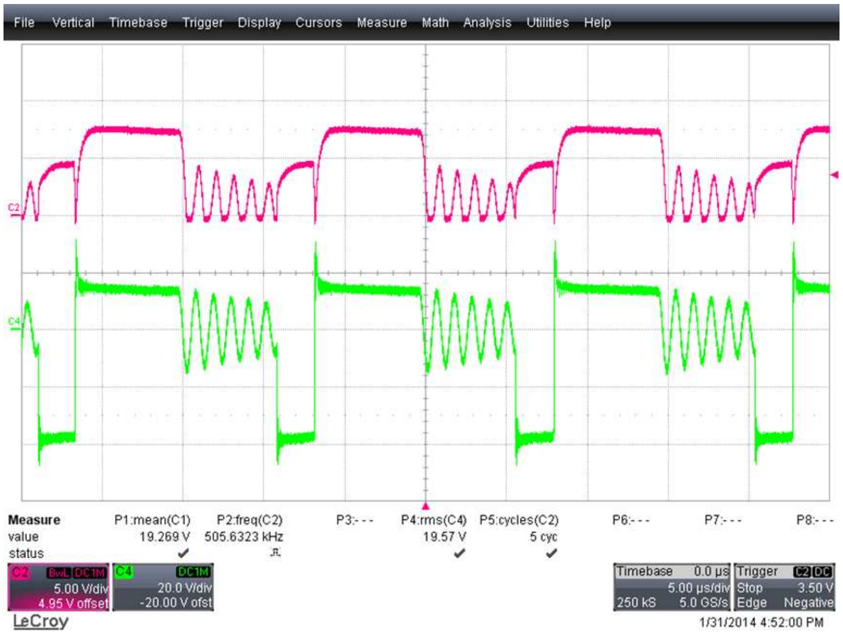

Figure 13. Bias Winding and VSENSE Pin Voltage Waveforms

7.10 Switching Node and Current Sense Waveforms

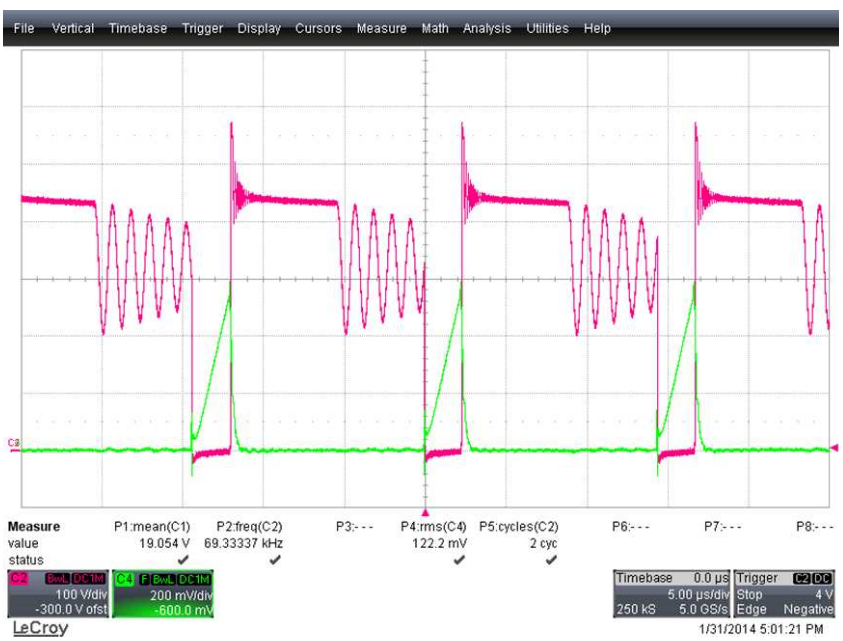

Figure 14. Drain and CS Voltages

7.11 EMI Plots

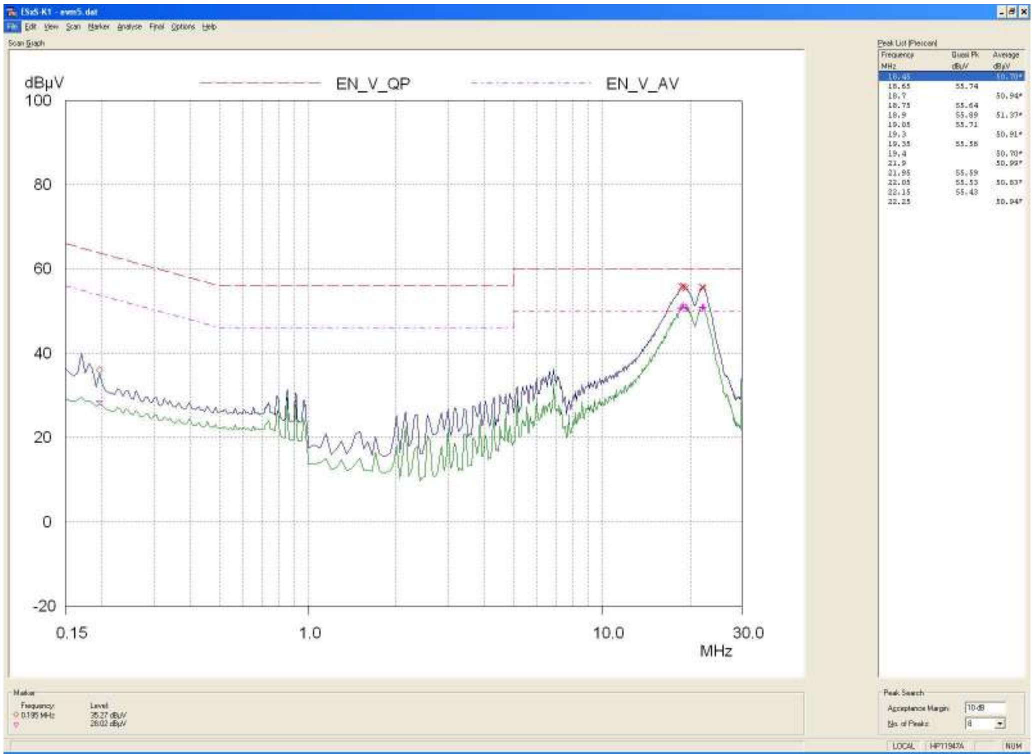

Figure 15. 115-V_{AC} Conducted Emissions Plot

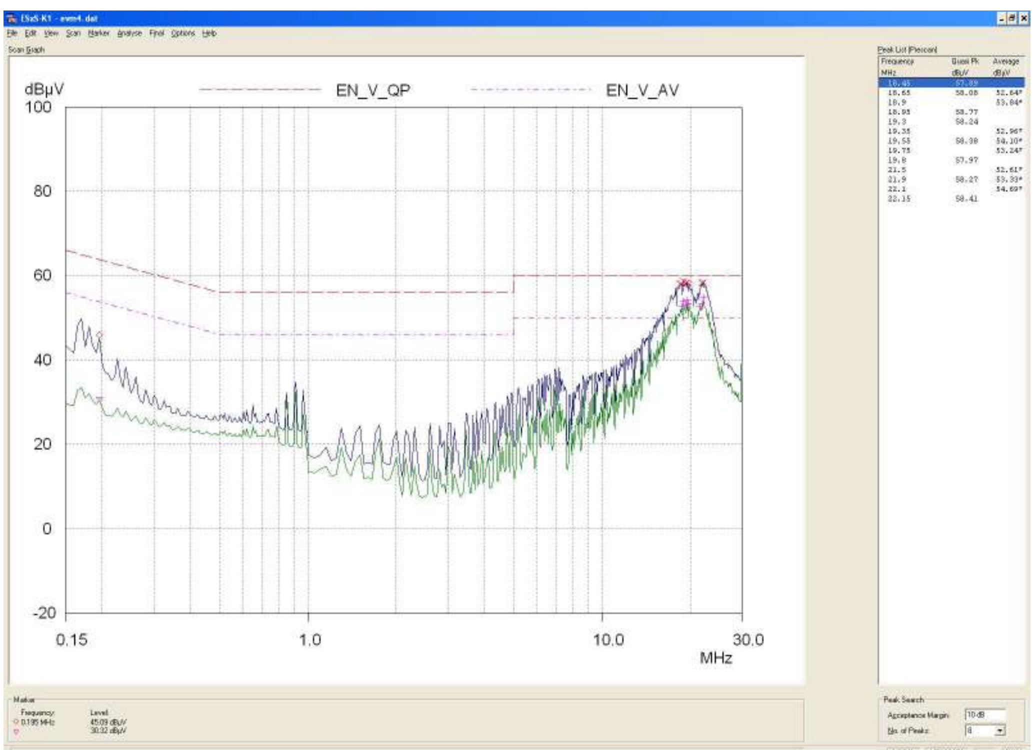

Figure 16. 230-V_{AC} Conducted Emissions Plot

8 EVM Assembly Drawing and PCB Layout

The following figures (Figure 17 through Figure 20) show the design of the UCC28630EVM-572 printed circuit board.

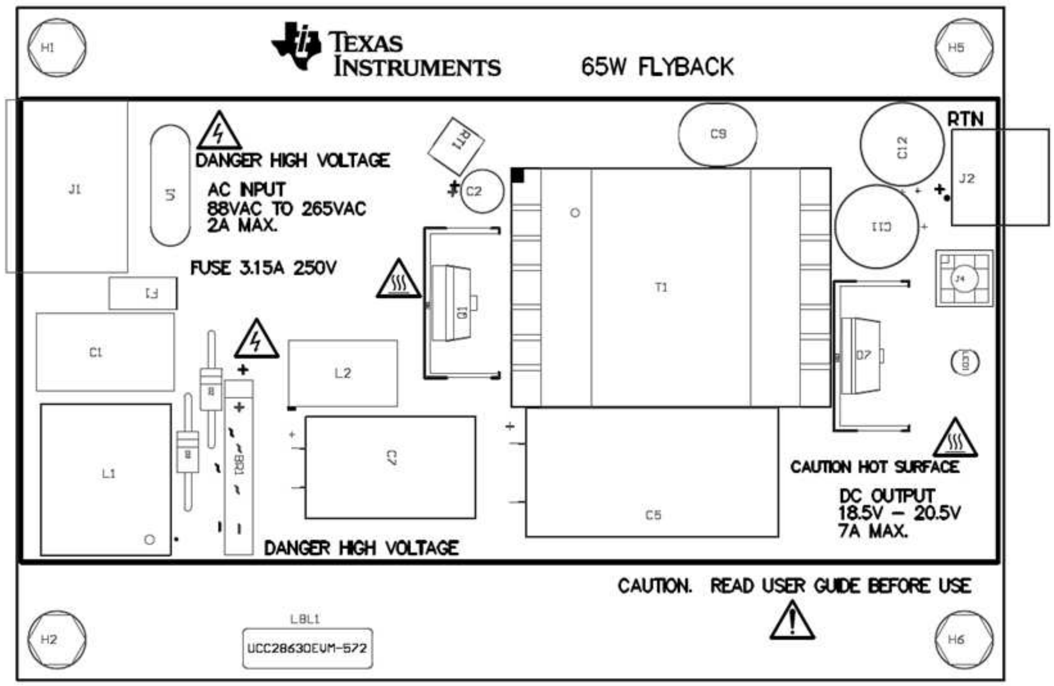

Figure 17. UCC28630EVM-572 Top Layer Assembly Drawing (top view)

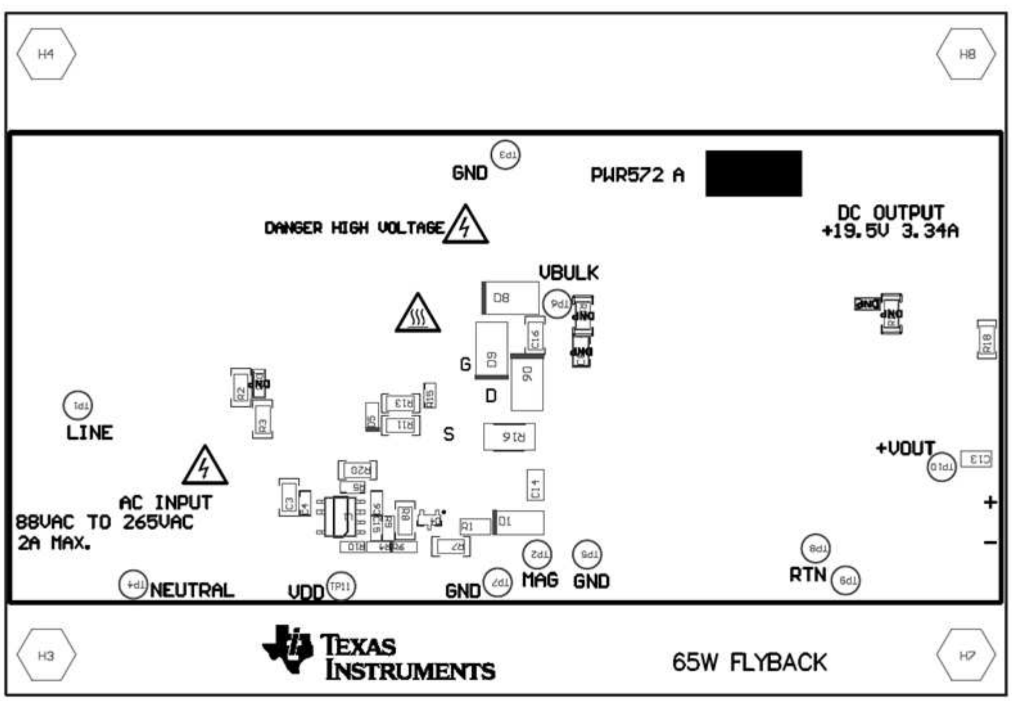

Figure 18. UCC28630EVM-572 Bottom Layer Assembly Drawing (bottom view)

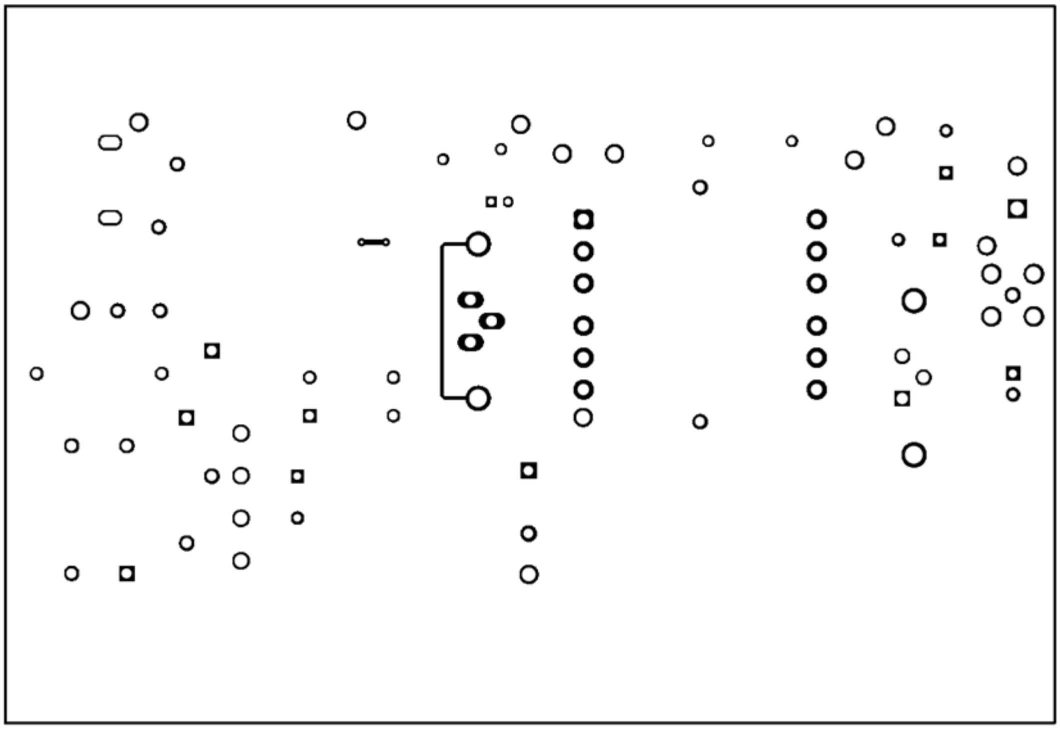

Figure 19. UCC28630EVM-572 Top Copper (top view)

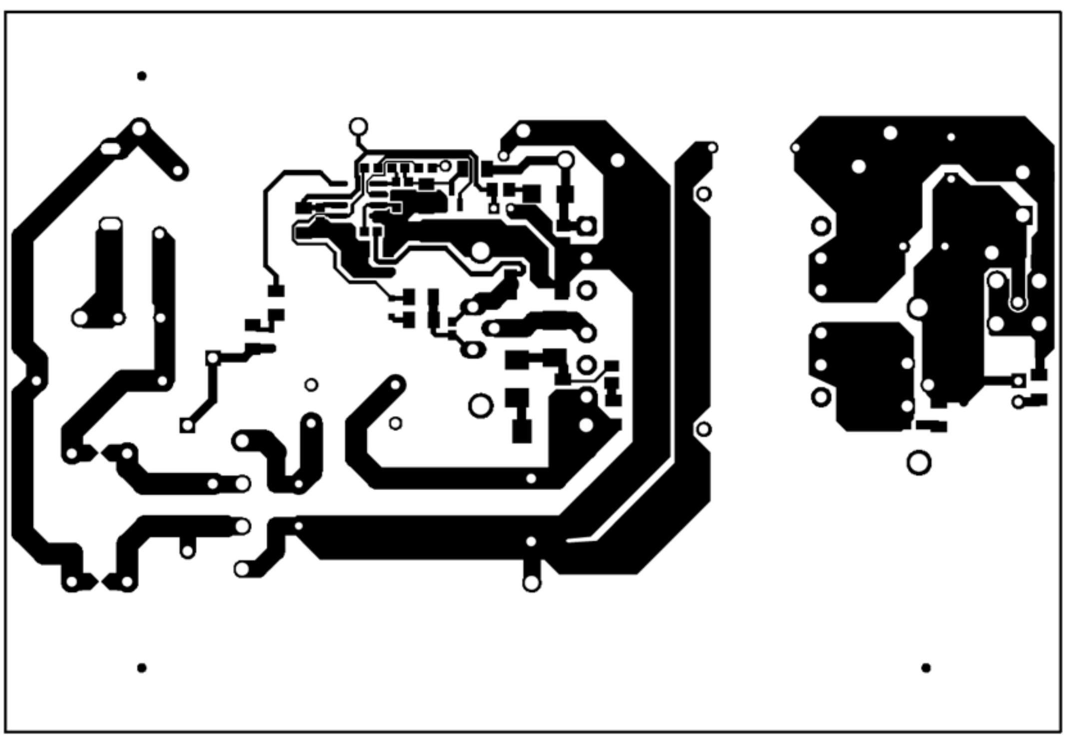

Figure 20. UCC28630EVM-572 Bottom Copper (bottom view)

9 List of Materials

9.1 Transformer Information

9.1.1 Materials

- Ferroxcube RM10/1 core set 3C95 material of equivalent, 225 nH aluminum.
- Ferroxcube CPV-RM10/1-1S-12PD coil former or equivalent.
- 15 strands of 0.1 mm ECW twisted, 100 turns/meter.
- 0.2 mm ECW.
- 7 mm x 0.2 mm Furukawa TEX-E triple insulated wire or equivalent.
- 1 oz (66 µm thick) adhesive copper foil.
- Mylar tape.

9.1.2 Construction

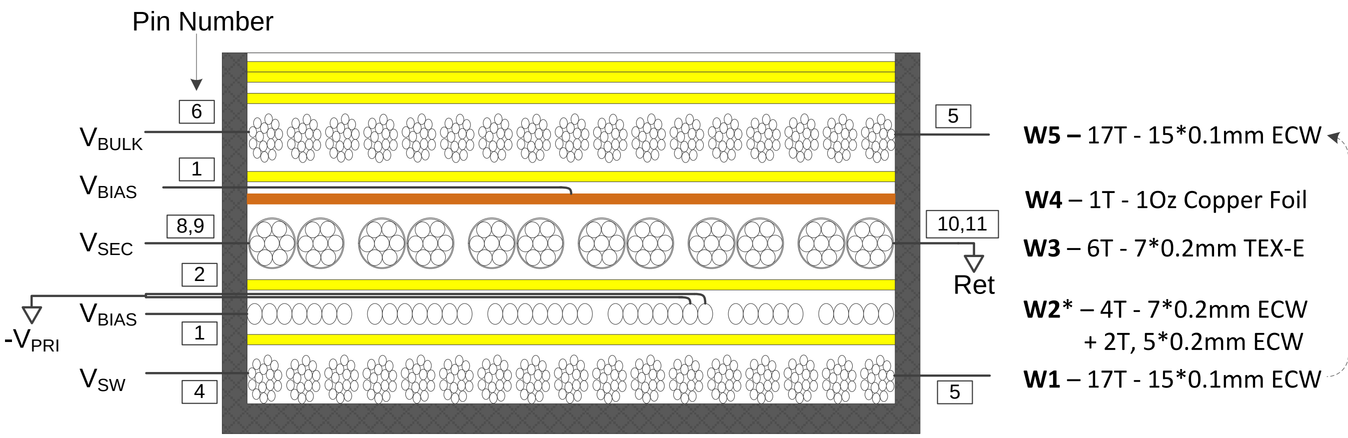

Figure 21. Transformer Construction

- W1, One layer across bobbin. Return at 90º to pin 5. One layer of mylar tape over winding.
- W2, Return two strands of W2 to pin 2 after 4 turns. The other five strands can be cut and left floating after six turns. W2 is to act as a shield so the strands should be evenly spaced across the winding window. One layer of mylar tape over winding.
- W3, start one strand at pin 8 and one strand at pin 9, wind byfilar in a single layer across the winding window. Leave ends floating.
- W4 is a copper foil shield the width of the winding window. This shield should be covered with tape which folds over the edges of the foil. The middle of the winding is connected to pin 1. The two ends should be taped/cut so that they do not short. One layer of mylar tape over winding.
- W5, One layer across bobbin. Return at 90º to pin 6. One layer of mylar tape over winding.
- Return ends of W3 to pins 10 and 11.

NOTE: Depending on the safety requirements of the design it may be necessary to terminate the ends of W3 in the PCB as flying leads (rather than terminating them on the bobbin) to increase the spacing from the exposed secondary to the primary referenced core.

- Two layers of mylar tape on top.
- One layer of copper tape around assembled core, connect to pin 2.
- Cover copper tape with Mylar tape.
- Varnish completed assembly.

Detailed List of Materials

Table 2 EVM component list according to the schematic shown in Figure 12.

Table 2. UCC28630EVM-572 List of Materials

QTY	DES	DESCRIPTION	MANUFACTURER	PART NUMBER
1	BR1	Diode, switching-bridge, 800 V, 4 A, TH	Vishay-Semiconductor	GBU4K-E3/45
1	C1	Capacitor, film, 0.33 µF, 630 V, ±20%, TH	Vishay-Bccomponents	BFC233840334
1	C2	Capacitor, aluminum, 22 µF, 25 V, ±20%, TH	Rubycon	25ML22MEFC5X5
1	C3	Capacitor, ceramic, 1 µF, 25 V, ±10%, X7R, 1206	AVX	12063C105KAT2A
1	C4	Capacitor, ceramic, 0.1 µF, 25 V, ±10%, X7R, 0603	Kemet	C0603C104K3RACTU
1	C5	Capacitor, aluminum, 100 µF, 400 V, ±20%, TH	Rubycon	400KXW100MEFC16X30
1	C6	Capacitor, ceramic, 120 pF, 50 V, ±5%, C0G/NP0, 0603	AVX	06035A121JAT2A
1	C7	Capacitor, aluminum, 27 µF, 400 V, ±20%, TH	Nichicon	UCY2G270MHD1TO
1	C9	Capacitor, ceramic, 2200 pF, 250 V, ±20%, E, Disc 10mm x 8 mm	MuRata	DE1E3KX222MA5BA01
2	C11, C12	Capacitor, aluminum, 680 µF, 35 V, ±20%, 0.019 Ω, TH	Nichicon	UHW1V681MPD6
1	C13	Capacitor, ceramic, 1 µF, 50 V, ±10%, X7R, 0805	AVX	08055C105KAT2A
1	C14	Capacitor, ceramic, 1000 pF, 100 V, ±10%, X7R, 0805	AVX	08051C102KAT2A
1	C15	Capacitor, ceramic, 10 pF, 50 V, ±5%, C0G/NP0, 0603	AVX	06035A100JAT2A
1	C16	Capacitor, ceramic, 10 pF, 200 V, ±5%, C0G/NP0, 1206	AVX	12062A100JAT2A
1	D1	Diode, ultrafast, 200 V, 1 A, SMA	Diodes Inc.	ES1D-13-F
2	D2, D3	Diode, P-N, 1000 V, 1 A, TH	Fairchild Semiconductor	1N4007
1	D4	Diode, switching, 70 V, 0.25 A, SOT-23	Vishay-Semiconductor	BAV70-V
1	D5	Diode, ultrafast, 100 V, 0.25 A, SOD-323	NXP Semiconductor	BAS316,115
1	D6	Diode, ultrafast, 600 V, 1 A, SMB	Diodes Inc.	MURS160-13-F
1	D7	Diode, Schottky, 100 V, 15 A, TH	ON Semiconductor	NTST30100CTG
1	D8	Diode, Zener, 82 V, 550 mW, SMB	ON Semiconductor	1SMB5947BT3G
1	D9	Diode, Zener, 100 V, 550 mW, SMB	ON Semiconductor	1SMB5949BT3G
1	F1	Fuse, 3.15 A, 250 V, TH	Littelfuse	39213150000
4	H1, H2, H5, H6	Standoff, Hex, 1"L #6-32 nylon, M-F	Keystone	4820
4	H3, H4, H7, H8	Standoff, Hex, 1"L #4-40 nylon	Keystone	1902E
2	H10, H13	Machine screw pan phillips, 5/16", 4-40	B-F Fastener Supply	PMSSS 440 0031 PH
2	H11, H14	Washer, split lock, #4	Keystone	4693
2	H12, H15	Nut, Hex, 1/4" Thick, #4-40	B-F Fastener Supply	HNSS440
2	HS1, HS2	Board level heatsink .375" TO-220	Aavid Thermalloy	7173DG
1	J1	AC receptacle, 2.5 A, R/A, TH	Qualtek Electronics Corporation	770W-X2/10
1	J2	Terminal block, 2 x 1, 5.08 mm, TH	FCI	20020110-H021A01LF
1	J3	Terminal block plug 2 positive 5.08MM	FCI	20020006-H021B01LF
1	J4	Connector, SMB, vertical RCP 0 to 4 GHz, 50 Ω, TH	Emerson Network Power	131-3701-261
1	L1	Inductor, toroid, 4.5 mH, A, 0.05 Ω, TH	Renco Electronics	RLTI-1099
1	L2	Inductor, toroid,, 47.7 µH, A, 0.04 Ω, TH	Renco Electronics	RLTI-1098
1	LED1	LED, green, TH	Everlight	HLMP1523

Table 2. UCC28630EVM-572 List of Materials (continued)

QTY	DES	DESCRIPTION	MANUFACTURER	PART NUMBER
1	Q1	MOSFET, N-channel, 600 V, 11 A, TO-220 FullPAK	ST Microelectronics	STF13NM60ND
1	R1	Resistor, 4.70 Ω, 1%, 0.125 W, 0805	Panasonic	ERJ-6RQF4R7V
2	R2, R3	Resistor, 100 kΩ, 1%, 0.25 W, 1206	Yageo America	RC1206FR-07100KL
1	R4	Resistor, 100 Ω, 1%, 0.1 W, 0603	Vishay-Dale	CRCW0603100RFKEA
1	R5	Resistor, 1.00 kΩ, 1%, 0.1 W, 0603	Vishay-Dale	CRCW06031K00FKEA
1	R6	Resistor, 0 Ω, 5%, 0.1 W, 0603	Vishay-Dale	CRCW06030000Z0EA
1	R7	Resistor, 22.6 kΩ, 1%, 0.25 W, 1206	Vishay-Dale	CRCW120622K6FKEA
1	R8	Resistor, 39 kΩ, 5%, 0.25 W, 1206	Vishay-Dale	CRCW120639K0JNEA
1	R9	Resistor, 180 kΩ, 1%, 0.1 W, 0603	Yageo America	RC0603FR-07180KL
1	R10	Resistor, 3.90 kΩ, 1%, 0.1 W, 0603	Yageo America	RC0603FR-073K9L
1	R11	Resistor, 47.0 Ω, 1%, 0.25 W, 1206	Yageo America	RC1206FR-0747RL
1	R13	Resistor, 4.7 Ω, 5%, 0.25 W, 1206	Vishay-Dale	CRCW12064R70JNEA
1	R15	Resistor, 100 kΩ, 1%, 0.1 W, 0603	Vishay-Dale	CRCW0603100KFKEA
1	R16	Resistor, 0.2 Ω, 1%, 2 W, 2512	Stackpole Electronics Inc	CSRN2512FKR200
1	R18	Resistor, 8.20 kΩ, 1%, 0.25 W, 1206	Yageo America	RC1206FR-078K2L
1	R20	Resistor, 0 Ω, 5%, 0.25 W, 1206	Vishay-Dale	CRCW12060000Z0EA
1	RT1	Thermistor NTC, 470 , 5%, disc, 5.5 mm x 5 mm	EPCOS Inc	B57164K474J
1	T1	Transformer, 260 µH, TH	Renco Electronics	RLTI-1100
5	TP1, TP4, TP6, TP10, TP11	Test point, compact, red, TH	Keystone	5005
1	TP2	Test point, compact, white, TH	Keystone	5007
5	TP3, TP5, TP7, TP8, TP9	Test point, compact, black, TH	Keystone	5006
1	U1	Green-Mode Flyback Controller, D0007A	Texas Instruments	UCC28630D
1	V1	Varistor, 430 V, 4.5KA, TH	EPCOS Inc	B72214S0271K101

Revision History

Changes from Original (February 2014) to A Revision — **Page**

Changes from A Revision (May 2014) to B Revision — **Page**

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

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2 *Limited Warranty and Related Remedies/Disclaimers*:
   2.1 These terms and conditions do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.
   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for any defects that are caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI. Moreover, TI shall not be liable for any defects that result from User's design, specifications or instructions for such EVMs. Testing and other quality control techniques are used to the extent TI deems necessary or as mandated by government requirements. TI does not test all parameters of each EVM.
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3 *Regulatory Notices:*
   3.1 *United States*
      3.1.1 *Notice applicable to EVMs not FCC-Approved:*

      This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

      3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

      CAUTION

      This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

      Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

      FCC Interference Statement for Class A EVM devices

      NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d’usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。
http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

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If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required by Radio Law of Japan to follow the instructions below with respect to EVMs:

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry’s Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

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