User's Guide
SLUUB75–February 2015

Using the UCC28730EVM-552 10-W Adaptor Module With PSR and Wake-Up Monitor

The UCC28730EVM-552 evaluation module is a 10-W off-line discontinuous mode (DCM) flyback converter that provides constant-voltage (CV) and constant-current (CC) output regulation without the use of an optical coupler. The controller uses primary-side regulation (PSR) and detects a wake-up signal from the UCC24650 secondary-side voltage-droop monitor for improved transient response to large load steps. The EVM demonstrates how the UCC28730 can provide ultra-low standby power without sacrificing start-up time or output transient response with an internal 700-V start-up switch, dynamically controlled operating states, and a tailored modulation profile. The UCC28730 uses frequency modulation, peak primary current modulation, valley switching and valley skipping in its control algorithm in order to maximize efficiency over the entire operating range.

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1 Description

This evaluation module uses the *UCC28730 Constant-Voltage, Constant-Current Flyback Controller with PSR and Wake-Up Monitoring* with the *UCC24650 200-V Wake-Up Monitor for Fast Transient PSR* in a 10-W converter to provide 2 A of constant charge current. The input accepts a voltage range of 85 V_{AC} to 265 V_{AC}. The output is designed for 5 V when in constant voltage mode and will deliver 2 A of constant current down to an output voltage of less than 2 V.

Depending upon the operating conditions, the control law algorithm will modulate the switching frequency or the peak primary current to satisfy the power transfer requirements. As the load is increased from zero, the converter will transition through a frequency modulation (FM) mode where the peak primary current is held constant at one-third of its full-load peak value as the switching frequency increases from a minimum value to maintain energy transfer up to 28 kHz. When the load is increased to the level at which the switching frequency reaches 28 kHz, the controller will keep the switching frequency fixed and modulate the amplitude of peak primary current, increasing it from one-third its peak value up to its maximum full load peak current value; this area of operation is referred to as the amplitude modulation (AM) range. Further increase in load demand will transition the controller into another frequency modulation mode where the peak primary current is constant at its maximum designed value and the switching frequency is increased, as needed, up to the controller's maximum 83 kHz switching frequency.

Using PSR, the output voltage is indirectly sensed on the auxiliary winding at the end of the transfer of stored transformer energy to the secondary to maintain a tightly regulated output. The Wake-Up monitoring feature operates in conjunction with the secondary-side UCC24650 to allow light-load and no-load switching frequencies to approach 32 Hz, minimizing no-load power consumption to less than 5 mW, yet provide a fast dynamic response to load transients without requiring large output capacitance. The controller will further enhance its efficient operation with valley switching. The UCC28730 also uses dithering of the gate drive which helps to ease EMI compliance.

This user's guide provides the schematic, component list, assembly drawing, art work, and test set up necessary to evaluate the UCC28730 and UCC24650 in a typical off-line converter application.

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1.1 Typical Applications

The UCC28730 is suited for use in isolated off-line systems requiring minimal stand-by power, high efficiency, and fault protection; applications such as:

- Adapters/chargers for smart phones, tablets, and consumer electronics
- TV and monitor power supplies
- SMPS for home appliance and building automation
- Housekeeping power supply

1.2 Features

The UCC28730EVM-552 features include:

- AC input range 85 V_{AC} to 265 V_{AC}
- DC output of 5 V, 2 A
- No-load stand-by power consumption less than 5 mW (“Zero-Power”)
- Wake-up detection for fast dynamic response
- Primary-side regulation eliminates opto-coupler
- ±5% output voltage regulation
- ±5% output current regulation
- Average efficiency > 83%; exceeds Level VI and CoC Tier 2 specifications, effective 2016
- Output overcurrent and short circuit protection
- Output overvoltage protection
- Input brown-out protection
- Auto re-start on fault
- Resonant ring valley switching operation for highest overall efficiency
- Frequency dither
- Internal 700-V start-up switch to start up the supply directly from the bulk rail
- 10% efficiency > 80%; complies with CoC Tier 2 specification
- Secondary-side synchronous rectification driven by UCC24610

WARNING

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, C3 and C4, and the output capacitors, C9 and C10, must be completely discharged before the EVM can be handled. Serious injury can occur if proper safety precautions are not followed.

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2 Electrical Performance Specifications

Table 1. UCC28730EVM-552 Electrical Performance Specifications

Parameter		Test Conditions	MIN	NOM	MAX	UNIT
Input Characteristics						
V_{IN}	Voltage range		85	115/230	265	V_{RMS}
	Maximum input current	$V_{IN} = V_{INmin}$, $I_{OUT} = I_{OUTmax}$			0.250	A_{RMS}
	Line frequency		47	60/50	63	Hz
	No-load power consumption	$V_{INmin} \le V_{IN} \le V_{INmax}$, I_{OUT} = 0 A			5	mW
Output Characteristics						
V_{OUT}	Output voltage, CV mode	$V_{INmin} \le V_{IN} \le V_{INmax}$, 0 A ≤ $I_{OUT} \le I_{OUTmax}$	4.75	5	5.25	V
I_{OUTmax}	Output load current, CV mode	$V_{INmin} \le V_{IN} \le V_{INmax}$	1.95	2.05	2.15	A
	Output voltage regulation	Line Regulation: $V_{INmin} \le V_{IN} \le V_{INmax}$, $I_{OUT} = I_{OUTmax}$			5	%
		Load Regulation: 0A ≤ $I_{OUT} \le I_{OUTmax}$			5	
	Output voltage ripple	$V_{INmin} \le V_{IN} \le V_{INmax}$, 0A ≤ $I_{OUT} \le I_{OUTmax}$			80	mVpp
I_{OCC}	Output over current,	$V_{INmin} \le V_{IN} \le V_{INmax}$			2.15	A
	Minimum output voltage, CC mode	$V_{INmin} \le V_{IN} \le V_{INmax}$, $I_{OUT} = I_{OCC}$		1.4	2	V
	Brown-out protection	$I_{OUT} = I_{OUTmax}$		62		V_{RMS}
		I_{OUT} = 10% I_{OUTmax}		34		
Systems Characteristics						
f_{SW}	Switching frequency		0.05		50	kHz
	Average efficiency	25%, 50%, 75%, 100% load average	84			%
	10% efficiency	10% load	80			
	Operating temperature			25		°C

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3 Schematic

Figure 1 illustrates the UCC28730EVM-552 schematic.

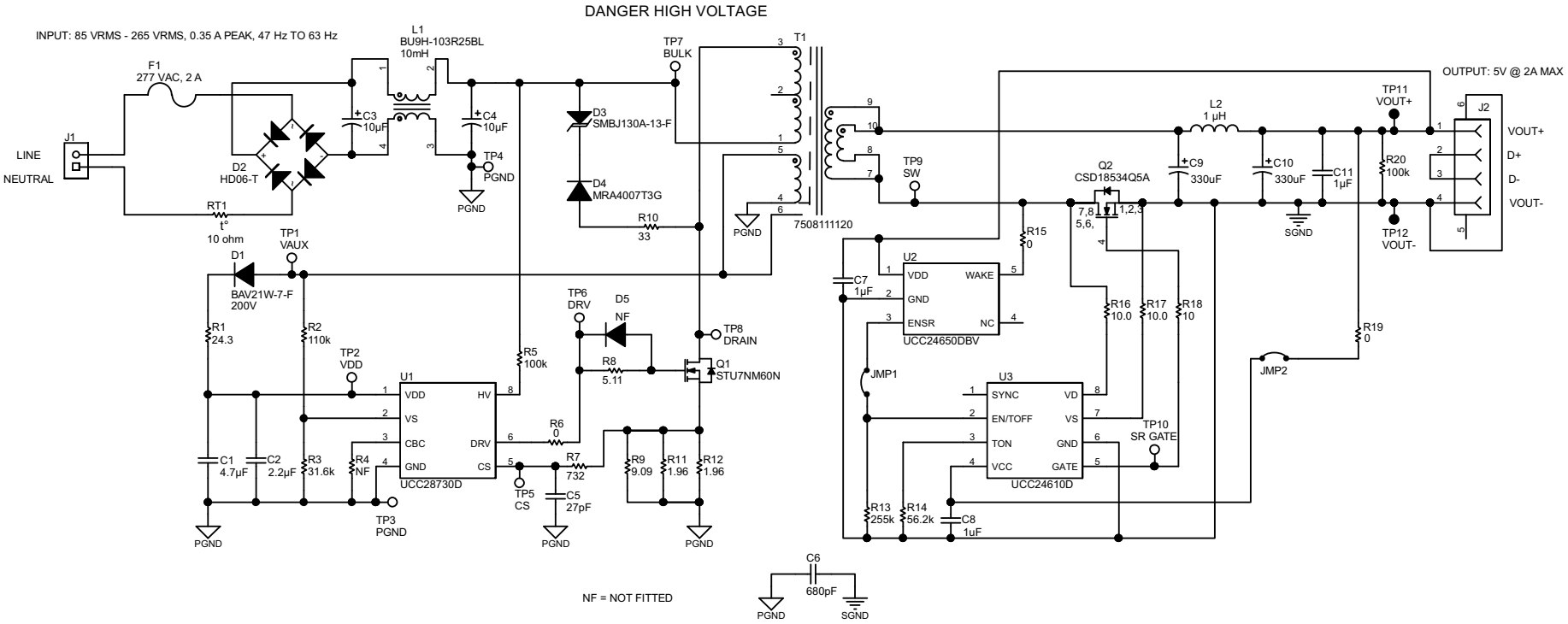


Figure 1. UCC28730EVM-552 Schematic

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4 Test Setup

Figure 2 shows the equipment set up when measuring the input power consumption during no-load operation. Note the addition of the 1-kΩ shunt resistor in Figure 2. During the no-load test, set the power analyzer for long averaging mode in order to include several cycles of operation. Use an appropriate current scale factor for the external shunt. Due to the extremely low measured values, placement of the shunt is critical and should be positioned right at the input terminals of the EVM. Figure 3 shows the recommended test equipment set up to evaluate the UCC28730EVM-552 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.

4.1 Test Equipment

AC Voltage Source: For an input source, use an isolated variable AC source capable of supplying between 85 V_{AC} and 265 V_{AC} at no less than 20 W and connected as shown in Figure 2 and Figure 3. For accurate efficiency calculations, insert a power meter between the neutral line of the AC source and the Neutral terminal of the EVM. For highest accuracy in loaded conditions, connect the voltage terminals of the power meter directly across the Line and Neutral terminals of the EVM. For highest accuracy at no-load, connect the V+ voltage terminal of the power meter at the Line terminal of the EVM and the V– terminal of the power meter ahead of the shunt resistor (refer to Figure 2).

Output Load: Use a programmable electronic load capable of sinking 0 A to 3 A. For constant current mode testing of the EVM, set the electronic load to constant resistance mode.

Power Meter: Use a power analyzer capable of measuring low input current, typically less than 1 mA, and a long integration mode, when low power standby mode input power measurements are taken. An example of such an analyzer is the Voltech PM100 Single Phase Power Analyzer. An external precision 1-kΩ shunt, with a current scale factor of 100000 mV/A, was used. The power analyzer was set to integration mode over 6 minutes for a reading of mW-hour in order to display one-tenth the averaged results (refer to Figure 2).

Multimeters: For highest accuracy, VOUT can be monitored by connecting a DC voltmeter, DMM V1, directly across the VOUT+, TP 11, and VOUT–, TP12, as shown in Figure 3. Place a DC current meter, DMM A1, 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.

Recommended Wire Gauge: a minimum of 18-AWG 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.

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4.2 Recommended Test Setup

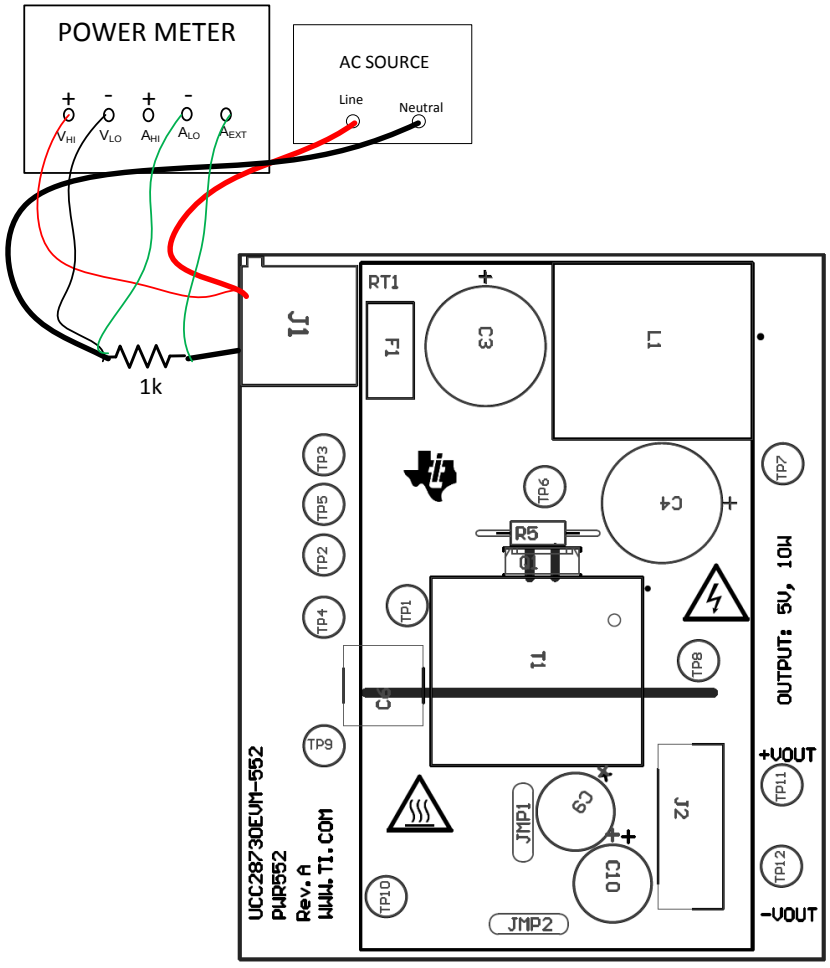


Figure 2. UCC28730EVM-552 Recommended Test Set Up For No-Load Operation

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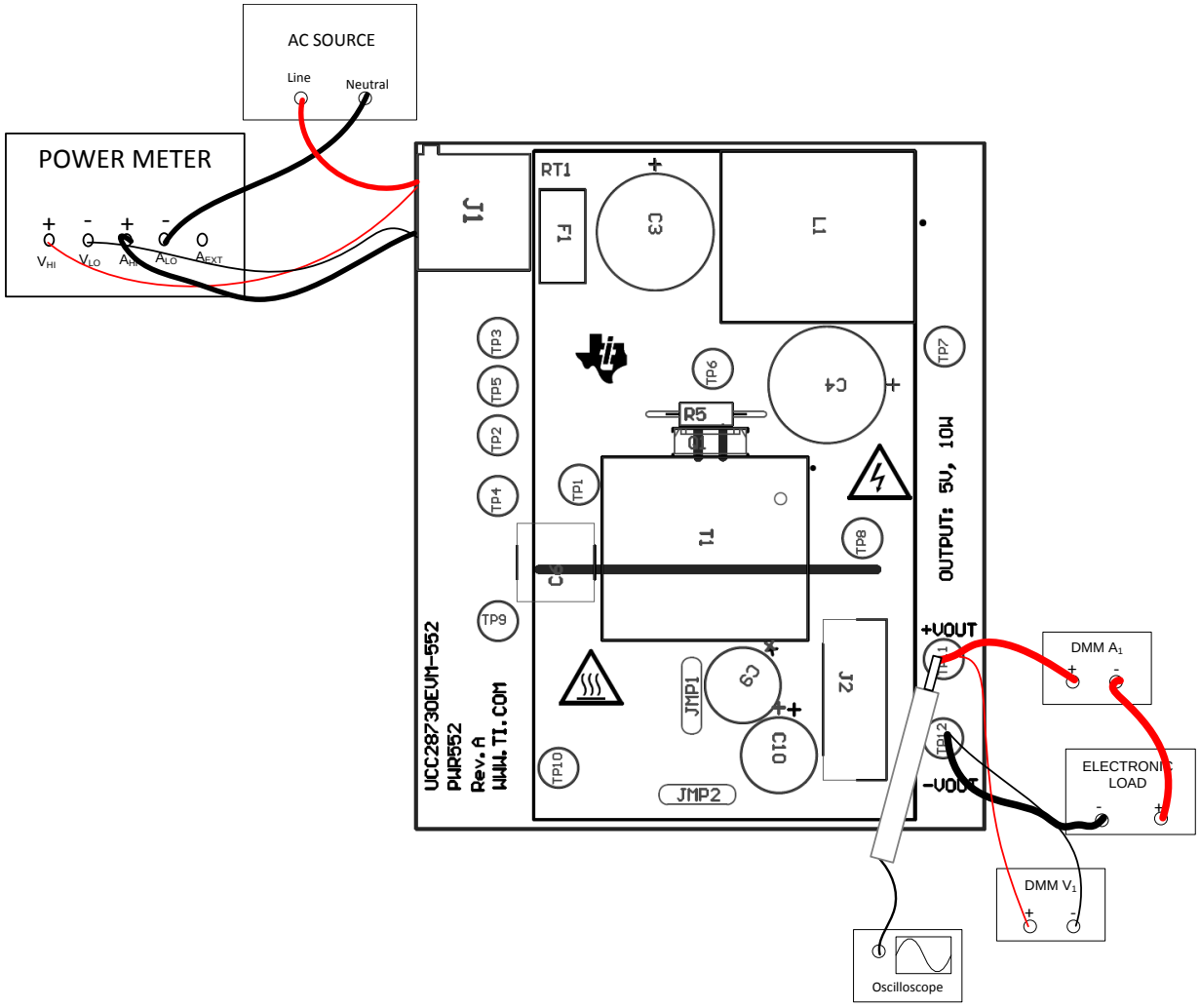


Figure 3. FUCC28730EVM-552 Recommended Test Set Up With Load

4.3 List of Test Points

Table 2. Test Point Functional Description

Test Point	Name	Description
TP1	VAUX	Auxiliary windings voltage
TP2	VDD	U1, pin 1 bias supply
TP3	PGND	Primary-side ground
TP4	PGND	Primary-side ground
TP5	CS	U1, pin 5 current sense
TP6	DRV	U1, pin 6 gate drive
TP7	BULK	Bulk input voltage
TP8	DRAIN	Q1 drain
TP9	SW	Switch node, WAKE signal
TP10	SR GATE	U3, pin 5 synchronous rectifier gate drive
TP11	VOUT+	Positive output terminal of the EVM to the load
TP12	VOUT–	Return connection of the EVM output to the load

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4.4 Applying Power to the EVM

Use the following steps when applying power to the EVM:

1. Set up the EVM as shown in Figure 2 if testing at no-load, or Figure 3 if testing with a load.
2. If testing with a load, set the electronic load to constant resistance mode.
3. Set the AC source voltage between 85 V_{AC} and 265 V_{AC}.
4. Monitor the output voltage on DMM V_1.
5. Monitor the output current on DMM A_1.

4.5 No-Load Power Consumption

Use the following steps when testing no-load power consumption:

1. Use the test set up shown in Figure 2. Careful placement of the shunt resistor is required.
   (a) Set the power analyzer to external shunt mode.
   (b) Set the appropriate current scale factor for using an external shunt on the power analyzer. A 1-kΩ shunt scales to 100000 mV/A, this is one-tenth the actual current scale factor that is needed for a 1-kΩ shunt but the value is limited by the Voltech PM100.
   (c) Using integration mode for 6 minutes for mW-hour requires multiplying the readings by 10 to obtain the input power consumption. Because the shunt must be scaled by one-tenth and the integration requires a 10x factor, the combined result is that the no-load power can be read directly from the power analyzer meter with this method.
2. Ramp up the input voltage to the EVM slowly (per Section 4.4), to avoid surge damage to the 1-kΩ sense resistor.
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.

4.6 Line/Load Regulation and Efficiency Measurement Procedure

For line/load regulation and efficiency measurement, use the following steps:

1. For load regulation, use the test set up shown in Figure 3.
   (a) Be sure to remove the external 1-kΩ shunt from the power analyzer and set the analyzer to normal mode (not long averaging).
   (b) Set the AC source to a constant voltage between 85 V_{AC} and 265 V_{AC}.
   (c) Vary the load so that the output current varies from 0 A up to 2 A, as measured on DMM A_1.
   (d) Observe that the output voltage on DMM V_1 remains within 5% of the 5-V constant voltage regulation value.
   (e) Observe that if the constant resistance level of the electronic load is decreased lower than the full load value, the EVM will maintain constant current regulation within 5% of the programed value until the output voltage drops below 2 V. The EVM will automatically restart once the constant resistance load is increased.
2. For line regulation, use the test set up shown in Figure 3.
   (a) Set the constant resistance load to sink the rated full load current.
   (b) Vary the AC source from 85 V_{AC} to 265 V_{AC}.
   (c) Observe that the output voltage on DMM V1 stays within 5% of the 5 V constant voltage regulation value.

4.7 Output Voltage Ripple

Expose the ground barrel of the scope probe and place the tip of the probe on TP11, VOUT+, and rest the exposed ground barrel of the probe on TP12, VOUT–, for output voltage ripple measurements.

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4.8 Equipment Shutdown

1. To quickly discharge the output capacitors, make sure there is a load greater than 0 A on the EVM.
2. Turn off the AC source and wait for the bulk capacitors to discharge to a safe level.

5 Performance Data and Typical Characteristic Curves

Figure 4 through Figure 16 present typical performance curves and waveforms for UCC28730EVM-552.

5.1 Efficiency

The average efficiency at 115-V_{AC}, 60-Hz nominal input and 230-V_{AC}, 50-Hz nominal input exceeds the 0.84 design goal.

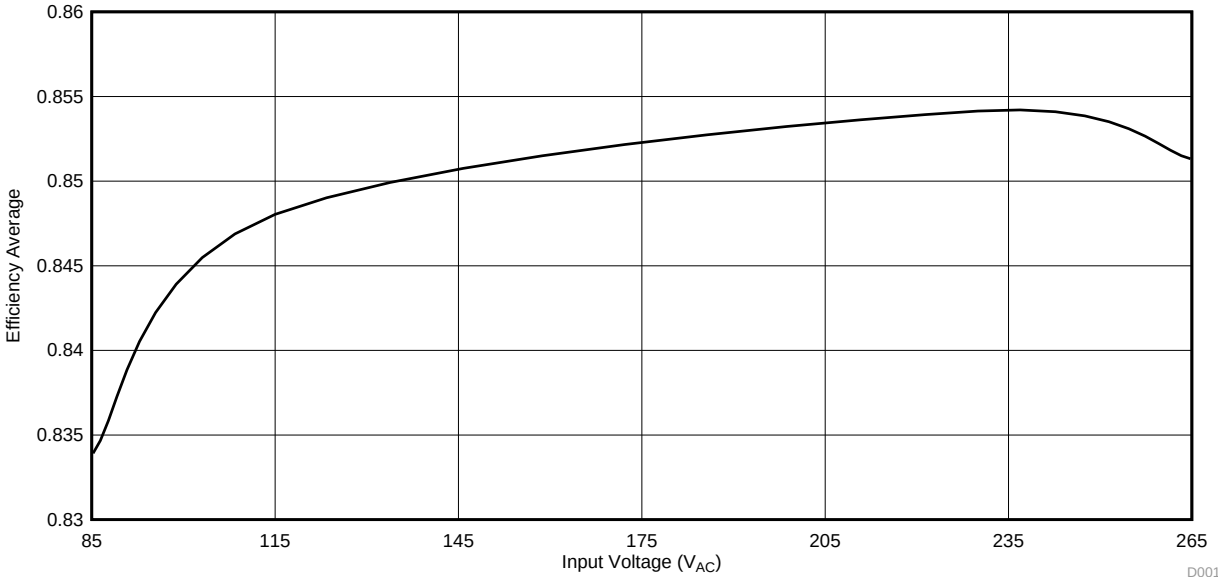


Figure 4. UCC28730EVM-552 Average Efficiency

Figure 5 shows the actual measured efficiency with respect to load.

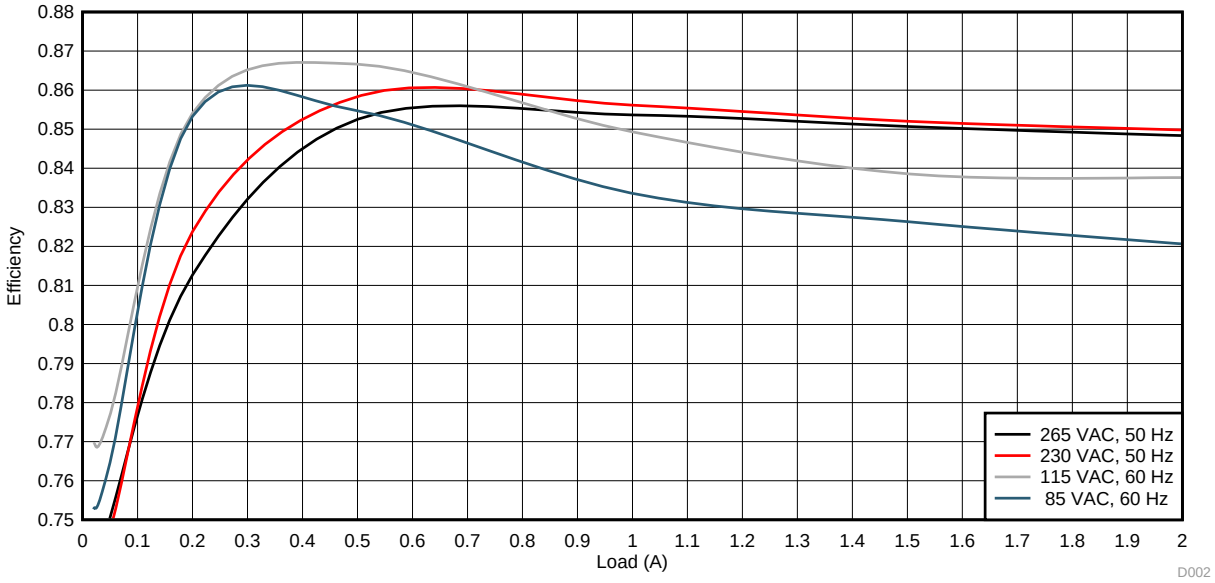


Figure 5. UCC28730EVM-552 Efficiency

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5.2 No-Load Power Consumption

No-load power consumption measured less than 4 mW over the entire line input range.

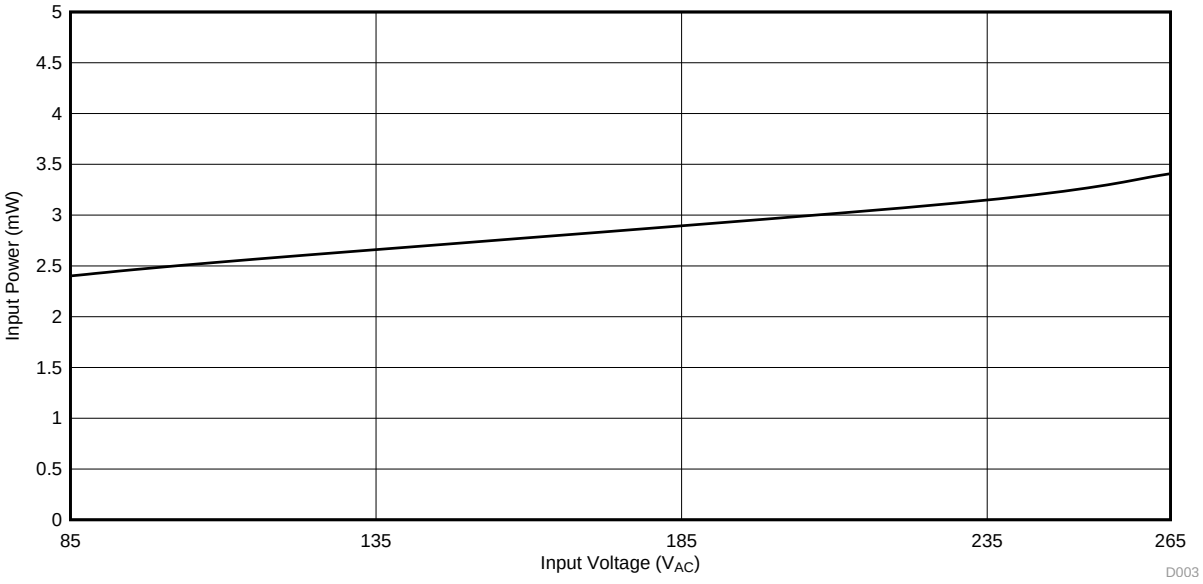


Figure 6. UCC28730EVM-552 No-Load Power Consumption

5.3 Output Voltage vs Output Current

In Figure 7, the converter is in constant-voltage operating mode from 0-A load up to approximately 2.1 A. Once reaching this output over-current threshold, the converter transitions into constant-current mode where the load current remains constant until the output voltage falls below 2 V, at which point the converter shuts down. If the load demand is decreased to the constant current operating region, the converter automatically re-starts.

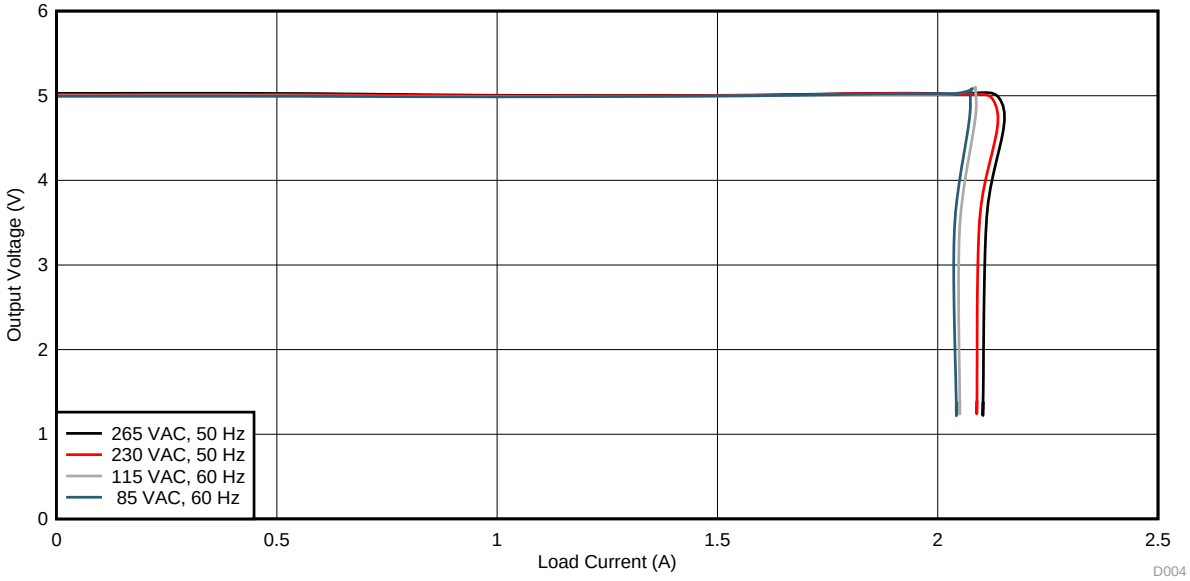


Figure 7. UCC28730EVM-552 Output Voltage as a Function of Load Current

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5.4 Transient Response

The transient response shown in Figure 8 was taken with a 115-V_{AC}, 60-Hz input voltage and a load transition from 0 A to full load. Channel 4 is the load current on a scale of 1 A per division, channel 1 is the output voltage on a scale of 200 mV per division, offset from the center line by –5.20 V. The cursors show the undershoot from the regulated output voltage, under full load transient conditions. Output voltage undershoot may vary dependent upon the specific time the transient occurs during the switching cycle.

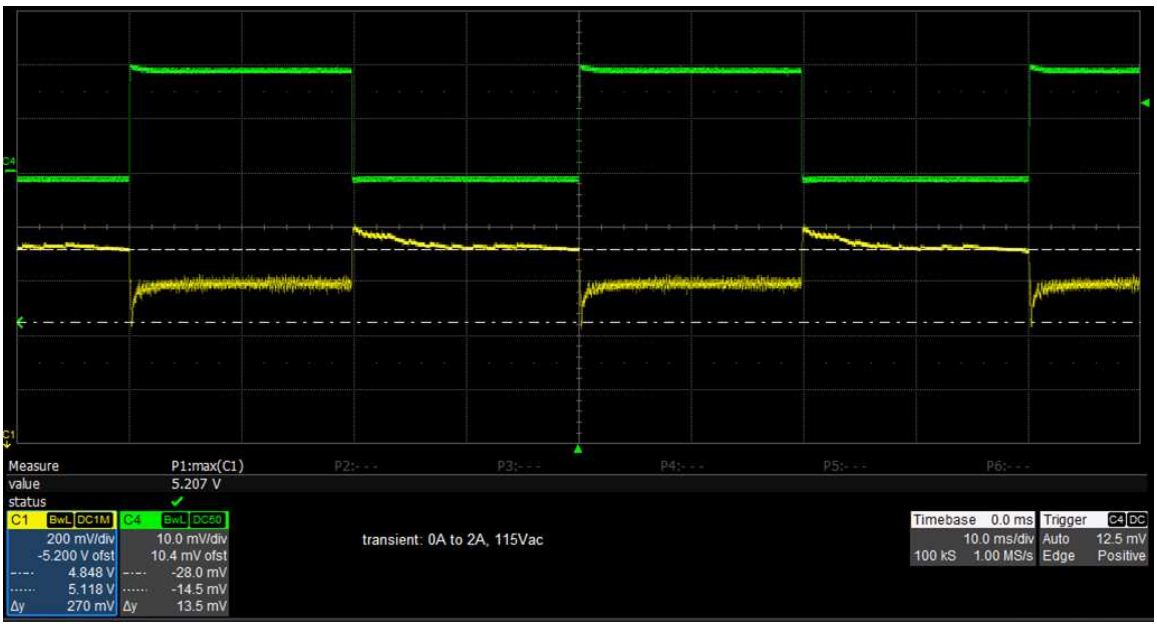


Figure 8. FUCC28730EVM-552 Load Transient

Figure 9 shows the WAKE signal from the UCC24650 Wake-Up Monitor activating when the output voltage falls below approximately 3% of its regulated value. Figure 10 shows the wake-up alert signal transmitted to the PSR controller on the AUX winding.

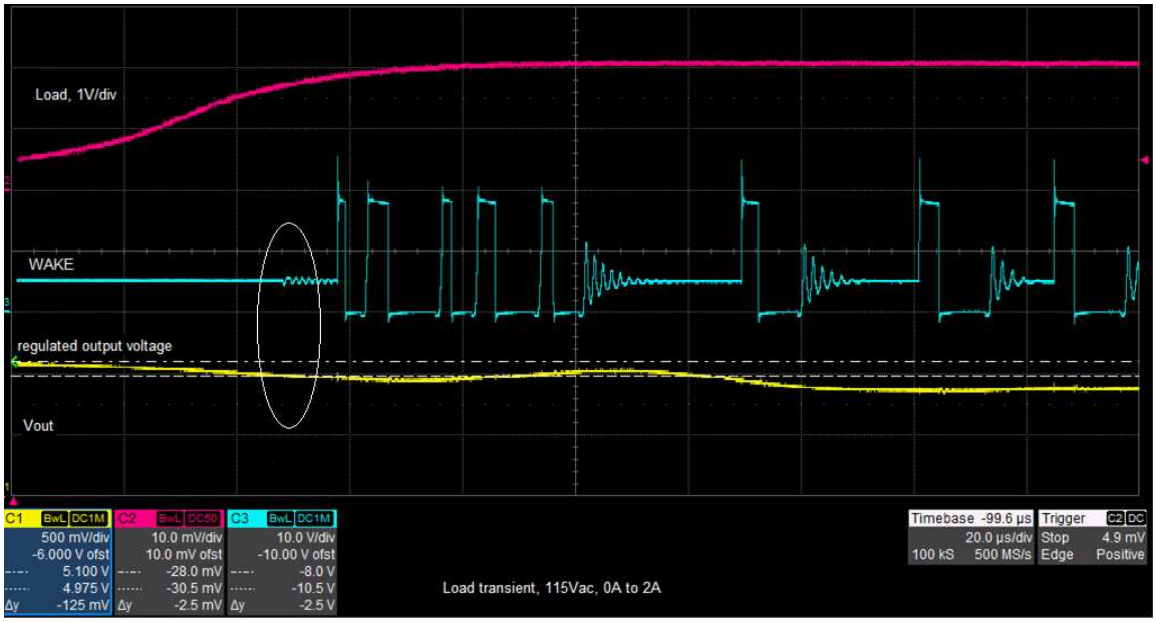


Figure 9. UCC28730EVM-552 WAKE Signal During Load Transient

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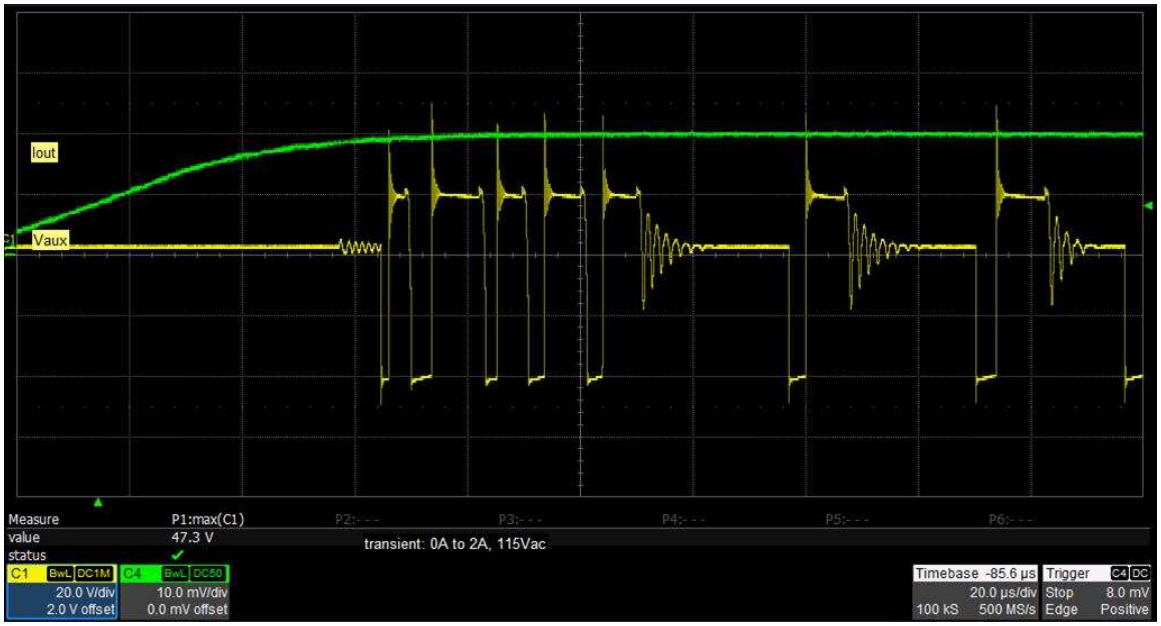


Figure 10. UCC28730EVM-552 WAKE Signal Transmitted to the AUX Winding

5.5 Output Ripple

Figure 11 shows the output voltage ripple, measured across TP11 and TP12 on the EVM. The measurement was taken at full load with an input voltage of 115-V_{AC}, 60-Hz and the waveform is AC coupled, with 20-MHz bandwidth limit. The cursor indicates the maximum peak-to-peak limit of 80 mV permitted for the design. The ripple pattern seen is characteristic of the EMI dithering method used by the UCC28730 controller.

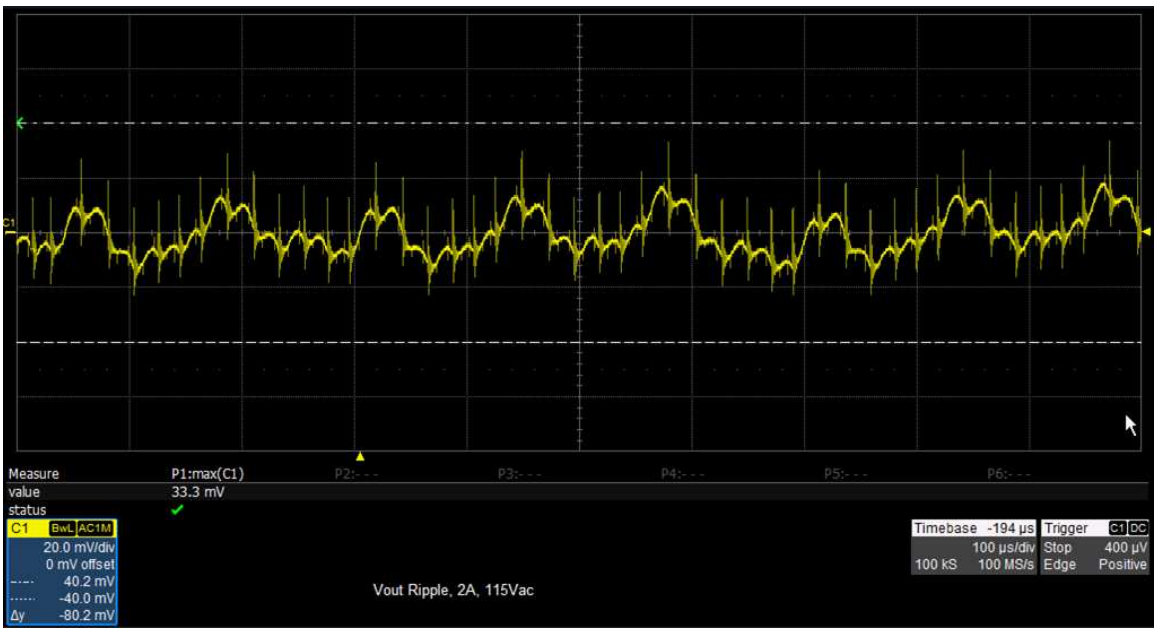


Figure 11. Output Ripple

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5.6 Turn On Waveform

Figure 12 shows the output voltage at turn on under full load conditions with an input voltage of 115 V_{AC}, 60 Hz.

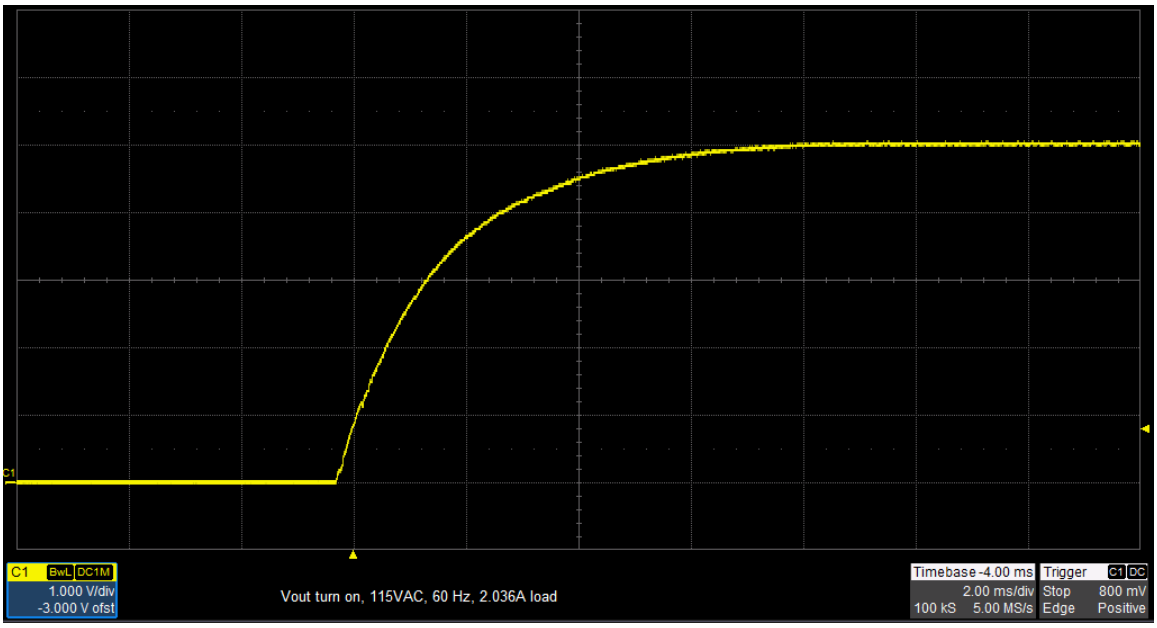


Figure 12. Output Voltage Turn On Waveform

Figure 13 shows how the UCC28730 limits the first four switching-cycle current peaks to $I_{PP(min)}$ in order to monitor for any initial input or output faults with limited power delivery. After these initial four pulses, the controller will limit the amplitude of the peak primary current to approximately 0.67 × $I_{PP(max)}$. Modifications are also made to D_{MAGCC}, increasing it from 0.432 to 0.650. These modifications during startup allow high frequency charge-up of the output capacitor to avoid audible noise. Once the VS signal is greater than 1.36 V (approximately 1.45 V on the output), D_{MAGCC} is restored to its normal value and the peak primary current resumes at $I_{PP(max)}$.

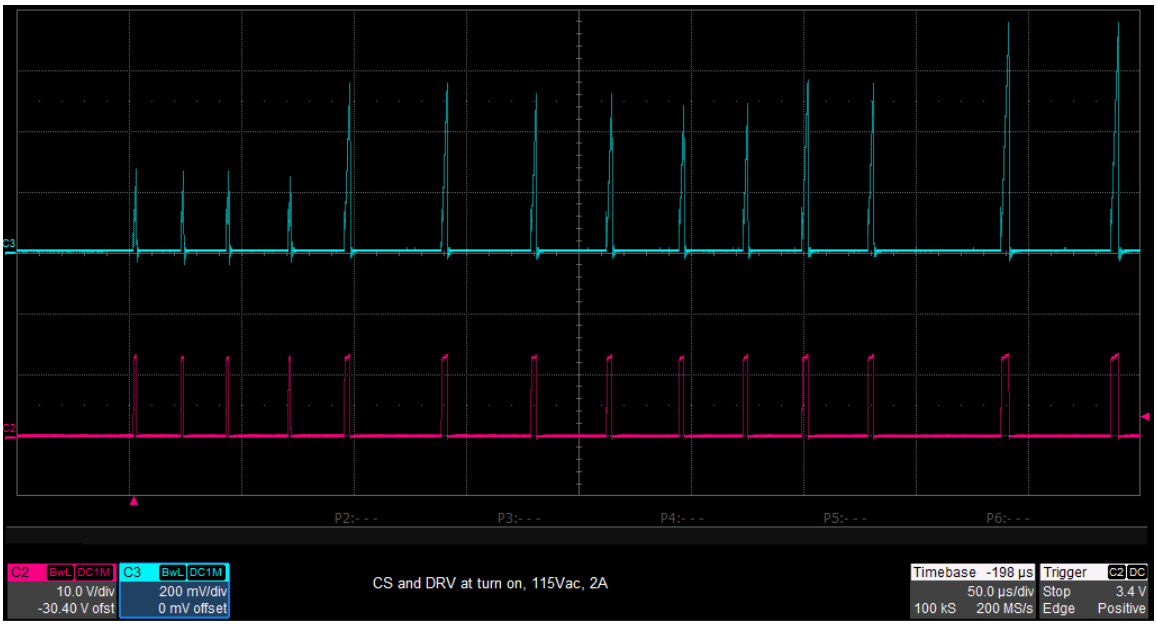


Figure 13. CS and DRV at Turn On

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5.7 Switching Waveform

The typical switching waveform can be seen in Figure 14. Channel 1 shows the MOSFET drain-to-source voltage at 100 V per division, channel 2 shows the AUX winding at 50 V per division, channel 3 is the CS waveform at 500 mV per division, and channel 4 shows the gate drive at 10 V per division. The scan was taken at 2-A load, 115-V_{AC}, 60-Hz input voltage. At this operating point, the switching frequency is dithering between 48 kHz and 40 kHz, due to valley skipping.



Figure 14. Primary-Side Switching Waveform

Figure 15 shows the switching waveforms on the secondary side, channel 1 is the SW node and channel 2 shows the UCC24610 gate drive for the secondary side synchronous rectifier.

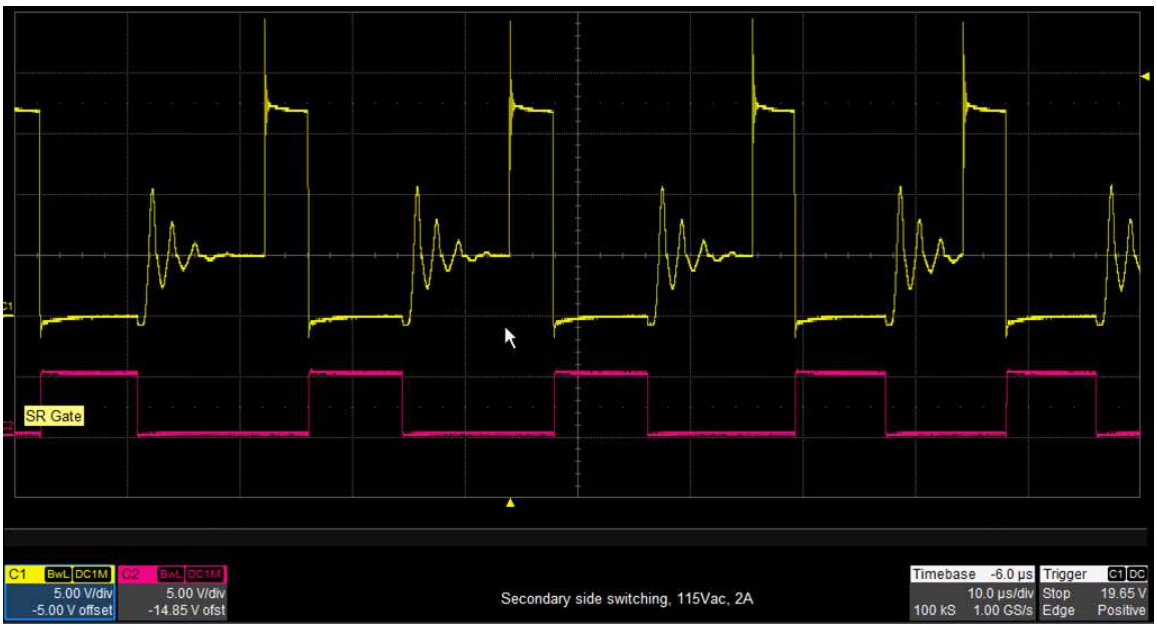


Figure 15. Secondary Side Switching Waveform

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5.8 EMI Dithering Waveform

The UCC28730 controller employs a unique control mechanism to help with EMI compliance. The DRV pin drives the gate of the MOSFET with a sequence of pulses in which there are two longer pulses, two medium pulses, and two shorter pulses at any operating point starting with the amplitude modulation mode. The EMI dithering is not enabled at light load. Figure 16 shows the result of these varying pulse widths on the CS signal, shown on channel 1. The medium length pulses are shown measured at 748 mV, the longer pulses result in a peak current slightly greater, and the shorter pulses are slightly less. This dithering adds to the frequency jitter caused by valley skipping and results in a spread spectrum for better EMI compliance.

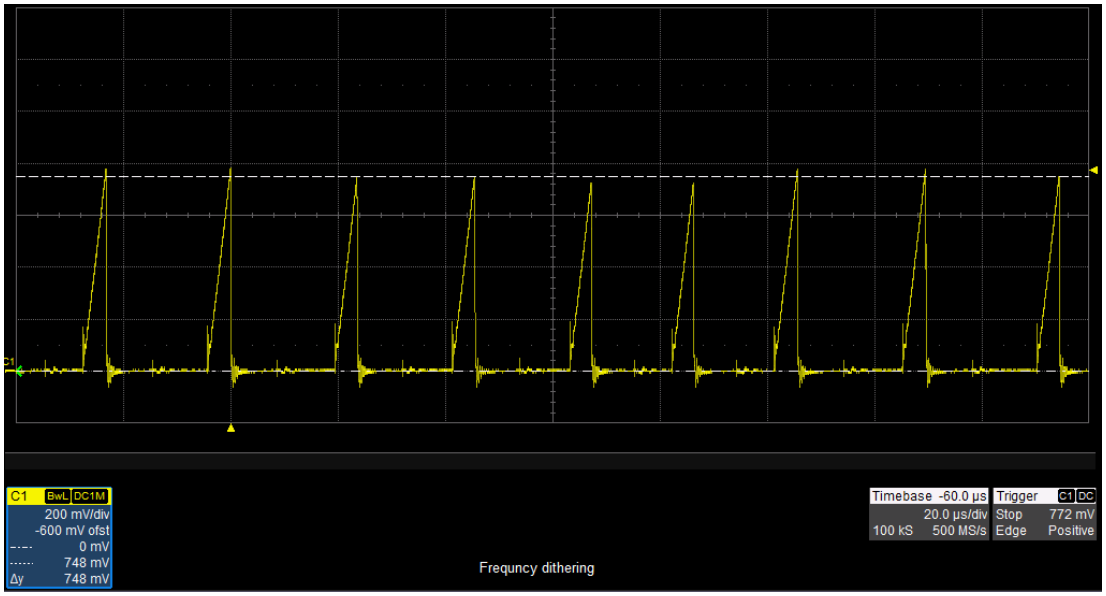


Figure 16. EMI Dithering Waveform

5.9 ENS Function

The ENS open-drain MOSFET output of the UCC24650 Wake-Up Monitor will disable the UCC24610 Synchronous Rectifier Driver when the load decreases below 0.03 A, as shown in Figure 17.

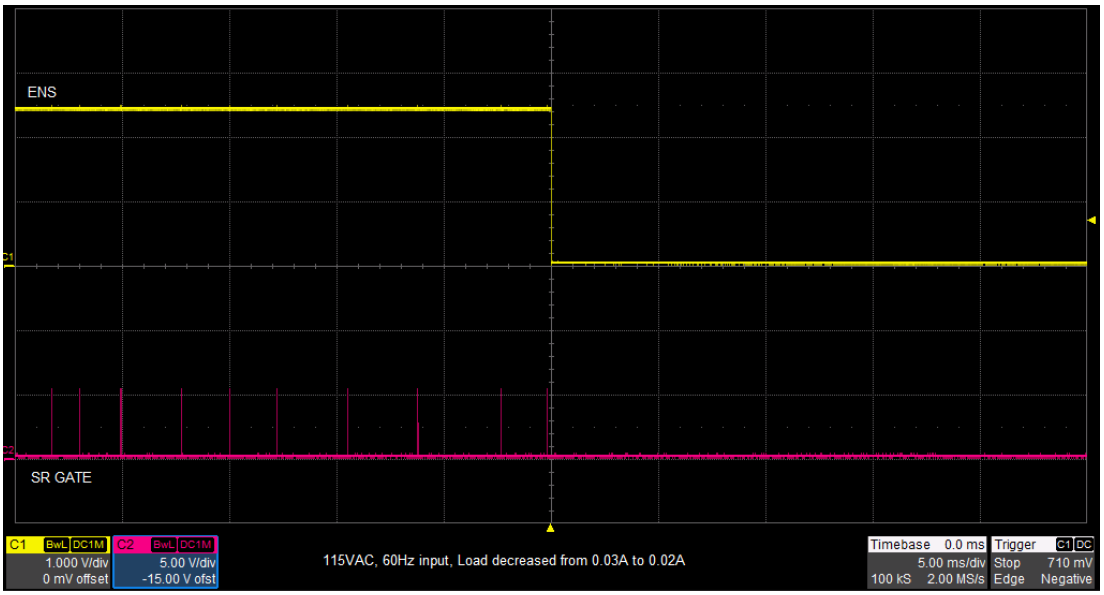


Figure 17. ENS and SR Gate as Load Decreases

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The ENS re-enables the UCC24610 when the load increases above 0.09 A, as shown in Figure 18. Controlling the secondary-side circuit during no-load and light-load conditions helps to reduce stand-by and light-load power loss.

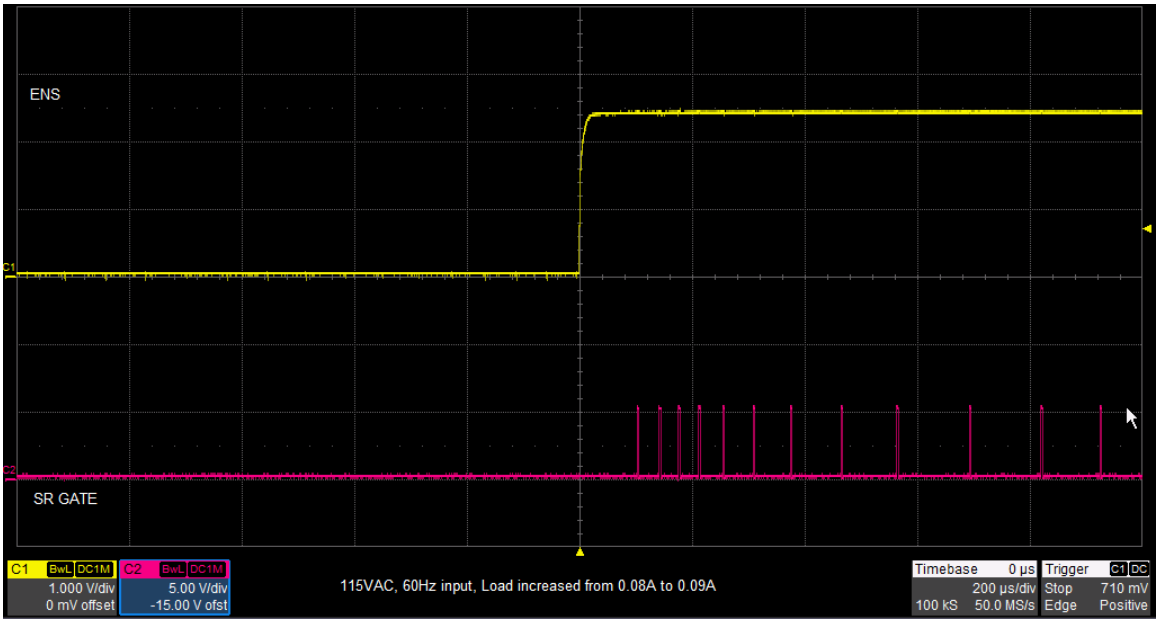


Figure 18. ENS and SR GATE as Load Increases

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6 EVM Assembly Drawing and PCB Layout

Figure 19 through Figure 22 show the design of the UCC28730EVM-552 printed circuit board. The final dimensions of the single copper layer circuit measure 2.00 in by 2.40 in.

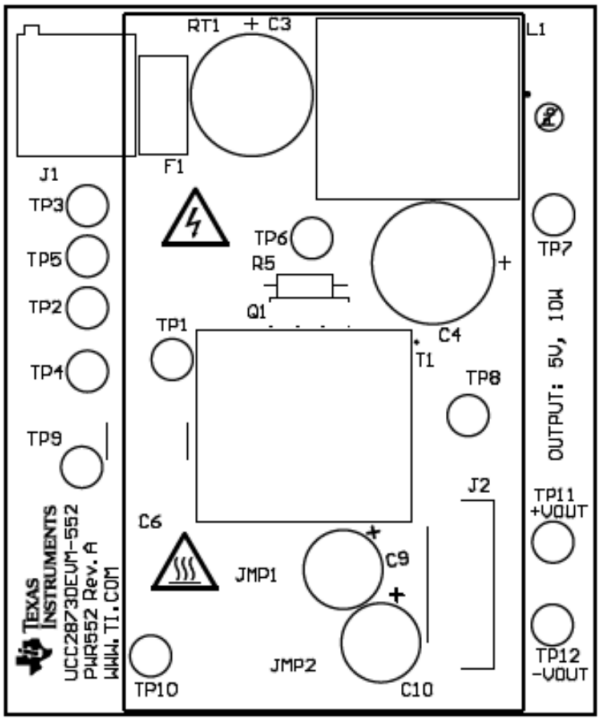


Figure 19. UCC28730EVM-552 Top Layer Assembly Drawing (Top view)

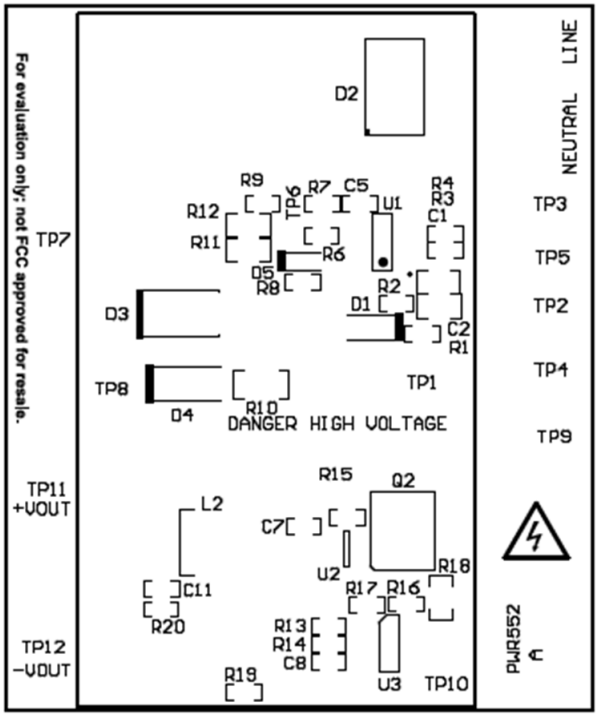


Figure 20. UCC28730EVM-552 Bottom Layer Assembly Drawing (Bottom view)

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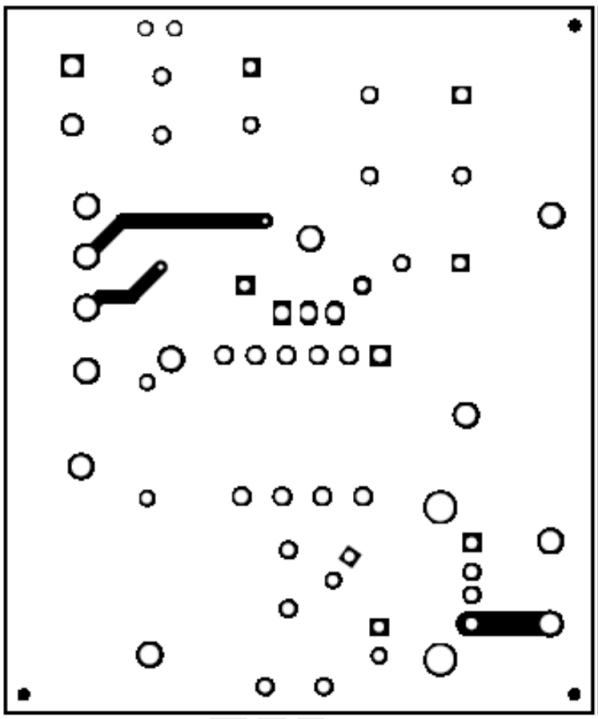


Figure 21. UCC28730EVM-552 Top Copper (Top View)

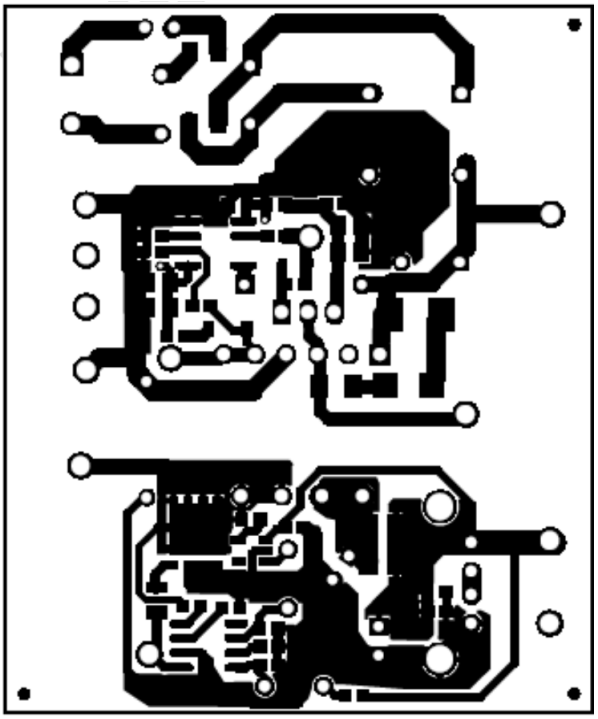


Figure 22. UCC28730EVM-552 Bottom Copper (Bottom View)

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7 Bill of Materials

The EVM components list shown in Table 3 according to the schematic shown in Figure 1.

Table 3. Bill of Materials

QTY	Designator	Description	Manufacturer	Part Number
1	C1	CAP, CERM, 4.7µF, 50V, ±10%, X5R, 0805	TDK	C2012X5R1H475K125AB
1	C2	CAP, CERM, 0.47µF, 50V, ±10%, X5R, 0805	Taiyo Yuden	UMK212BB7225KG-T
2	C3, C4	CAP, AL, 10 µF, 400 V, ±20%, TH	Nichicon	UCS2G100MPD1TD
1	C5	CAP, CERM, 27pF, 50V, ±5%, C0G/NP0, 0603	AVX	06035A270JAT2A
1	C6	CAP, CERM, 680 pF, 566 V, ±20%, CD, 7x11x7mm	TDK	CD65ZU2GA681MYNKA
3	C7, C8, C11	CAP, CERM, 1µF, 25V, ±10%, X7R, 0603	TDK	C1608X7R1E105K080AB
2	C9, C10	CAP, AL, 330µF, 6.3V, ±20%, 0.008 Ω, TH	Nichicon	RS80J331MDN1JT
1	D1	Diode, Switching, 200V, 0.2A, SOD-123	Diodes Inc.	BAV21W-7-F
1	D2	Diode, Switching-Bridge, 600 V, 0.8 A, MiniDIP	Diodes Inc.	HD06-T
1	D3	Diode, TVS, Uni, 130V, 600W, SMB	Diodes Inc.	SMBJ130A-13-F
1	D4	Diode, Standard Recovery Rectifier, 1000V, 1A, SMA	ON Semiconductor	MRA4007T3G
1	D5	Diode, Switching, 75V, 0.25A, SOD-323	Micro Commercial Components	1N4448WX-TP
1	F1	Fuse, 2 A, 250 V, TH	Bel Fuse Inc	RST 2
1	J1	Conn Term Block, 2POS, 5.08mm, TH	Phoenix Contact	1715721
1	J2	Connector, Receptable, USB Type A, Vertical, TH	CnC Tech	1002-021-01000
2	JMP1, JMP2	Jumper Wire, 200mil spacing, Red, pkg of 200	3M	923345-02-C
1	L1	Coupled inductor, 10mH, A, 3.5 Ω, TH	Coilcraft	BU9H-103R25BL
1	L2	Inductor, Shielded, Composite, 1 µH, 8.7 A, 13.25 mΩ, SMD	Coilcraft	XAL4020-102MEB
1	Q1	MOSFET, N-CH, 600V, 5A, IPAK	ST Microelectronics	STU7NM60N
1	Q2	MOSFET, N-CH, 60V, 50A, SON 5x6mm	Texas Instruments	CSD18534Q5A
1	R1	RES, 24.3 Ω, ±1%, 0.1 W, 0603	Yageo America	RC0603FR-0724R3L
1	R2	RES, 110kΩ, 1%, 0.1W, 0603	Vishay-Dale	CRCW0603110KFKEA
1	R3	RES, 31.6kΩ, 1%, 0.1W, 0603	Yageo America	RC0603FR-0731K6L
1	R4	RES, 16.0kΩ, 1%, 0.1W, 0603	Yageo America	RC0603FR-0716KL
1	R5	RES, 100kΩ, 1%, 0.25W, TH	Vishay-Dale	CMF50100K00FHEB
3	R6, R15, R19	RES, 0 Ω, ±5%, 0.1 W, 0603	Vishay-Dale	CRCW06030000Z0EA
1	R7	RES, 732 Ω, 1%, 0.1W, 0603	Yageo America	RC0603FR-07732RL
1	R8	RES, 5.11 Ω, 1%, 0.1W, 0603	Vishay-Dale	CRCW06035R11FKEA
1	R9	RES, 9.09 Ω, 1%, 0.1W, 0603	Vishay-Dale	CRCW06039R09FKEA
1	R10	RES, 33 Ω, 5%, 0.25W, 1206	Vishay-Dale	CRCW120633R0JNEA
2	R11, R12	RES, 1.96 Ω, 1%, 0.125W, 0805	Vishay-Dale	CRCW08051R96FKEA
1	R13	RES, 255k Ω, 1%, 0.1W, 0603	Vishay-Dale	CRCW0603255KFKEA
1	R14	RES, 56.2 k, 1%, 0.1 W, 0603	Vishay-Dale	CRCW060356K2FKEA
2	R16, R17	RES, 10.0 Ω, 1%, 0.1W, 0603	Vishay-Dale	CRCW060310R0FKEA
1	R18	RES, 10 Ω, 5%, 0.125W, 0805	Vishay-Dale	CRCW080510R0JNEA
1	R20	RES, 100kΩ, 5%, 0.1W, 0603	Vishay-Dale	CRCW0603100KJNEA
1	RT1	Thermistor NTC, 10 Ω, ±20%, Leaded	Ametherm	SL03 10001
1	T1	Tramformer, 667µH, TH	Wurth Elektronik eiSos	7508111120
10	TP1–TP10	Test Point, Multipurpose, White, TH	Keystone	5012
1	TP11	Test Point, Multipurpose, Red, TH	Keystone	5010
1	TP12	Test Point, Multipurpose, Black, TH	Keystone	5011
1	U1	Constant-Voltage Constant-Current Flyback Controller With PSR and Wake-Up Monitoring, D0007A	Texas Instruments	UCC28730D
1	U2	Voltage Droop Monitor with Wake-Up Output, DBV0005A	Texas Instruments	UCC24650DBV
1	U3	GREEN Rectifier Controller Device, D0008A	Texas Instruments	UCC24610D

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      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.

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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.*

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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:

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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

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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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