LM5023-2EVM Notebook Adapter

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ABSTRACT

Contents

1 Introduction

The LM5023-2 is a 65 W evaluation board for off-line Notebook Adapter applications. The LM5023-2EVM is intended for evaluation purposes only and not intended to be an end product. The LM5023-2EVM takes the 90-264 Vac input and converters it to an isolated 19 V DC output with a maximum load current of 3.43 A.

2 Theory of Operation

A Quasi-Resonant Controlled Flyback converter operates by storing energy in the transformers primary during the MOSFETs on-time. During the on-time (ton) VIN is applied across the primary of the transformer. The primary current starts out at zero and ramps towards Ipeak. When the peak primary current reaches the feedback compensation voltage the PWM comparator resets the output drive, turning-off the MOSFET. Due to the phasing of the transformer, the output diode is reversed biased.

During the MOSFETs off time the output diode is forward biased and the stored energy in the transformer primary inductor is transferred to the output. The voltage seen on the secondary inductor is V_{OUT} plus the output diodes forward voltage drop, V_F. The current in the output inductor linearly decreases from Ipeak • Ns/Np to zero.

When the current in the secondary reaches zero, the transformer is demagnetized, and there is an open circuit on the secondary, and with the primary MOSFET turned-off, there is an open on the primary. A resonant circuit is formed between the transformers primary inductance and the MOSFET output capacitance. The resonant frequency is calculated by:

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$$Freq = 2 \cdot \pi \sqrt{Lp \cdot COSS}$$

(1)

During the resonant period the Drain voltage of the MOSFET will ring down towards ground, refer to Figure 1. When the Drain voltage is at its minimum the Flyback MOSFET is turned back on. The point where the voltage is at its minimum is calculated by:

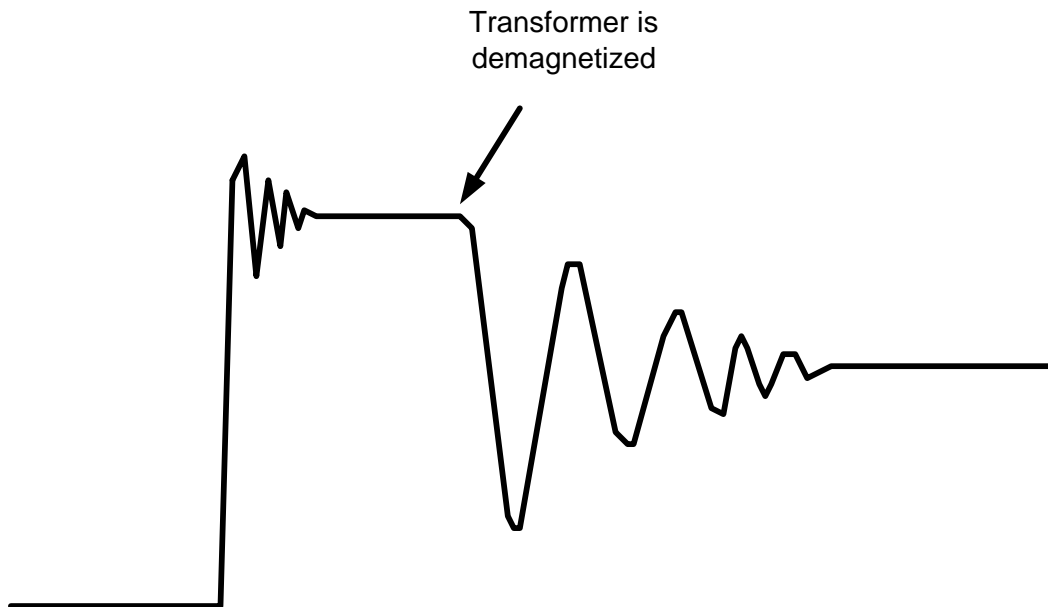$$td = \pi \cdot \sqrt{Lp \cdot COSS}$$

(2)

Figure 1. The Flyback Drain Voltage Waveform

Transformer demagnetization is detected by sensing the transformers auxiliary winding. When the transformer is demagnetized the auxiliary winding voltage follows the Drain of the MOSFET and changes from Vout•Naux/Ns to -Vin•Naux/Np. Internal to the LM5203 QR pin is a comparator with a 0.35 V reference. As the auxiliary winding voltage falls below 0.35 V, the voltage is sensed and the comparator sets the PWM Flip-Flop turning-on the Flyback MOSFET.

3   Electrical Performance Specifications

Table 1. Electrical Performance Specification

| PARAMETER		TEST CONDITION	MIN	MAX	TYP	UNITS
INPUT CHARACTERISTICS						
V_{IN}	Input Voltage		90	264	115/230	Vac
V_{IN}	No Load Input Power	V_{IN} = 230 V	30			mW
OUTPUT CHARACTERISTICS						
V_{OUT}	Output Voltage	V_{IN} = 115 V, I_{OUT} = 3.43 A	19.0	19.4	19.2	V
V_{OUT}	Line regulation	V_{IN} = min to max, I_{OUT} = max		1.0%		
V_{OUT}	Load regulation	V_{IN} = nom, I_{OUT} = no-load to max load		1.0%		
V_{OUT}	Output voltage ripple	V_{IN} = nom, I_{OUT} = max load	100			mV_{PP}
I_{OUT}	Output current			3.43		A
V_{OVP}	Output OVP		24			V
M	Load step response	I_{OUT} = 0.343 A to 3.09 A, 3.09 A to 0.343 A	18.7	19.6		V
SYSTEMS CHARACTERISTICS						
	Switching Frequency		130			kHz
η	Full Load	V_{IN} = 115/230 V, I_{OUT} = 3.43 A	88%			

4 Schematic
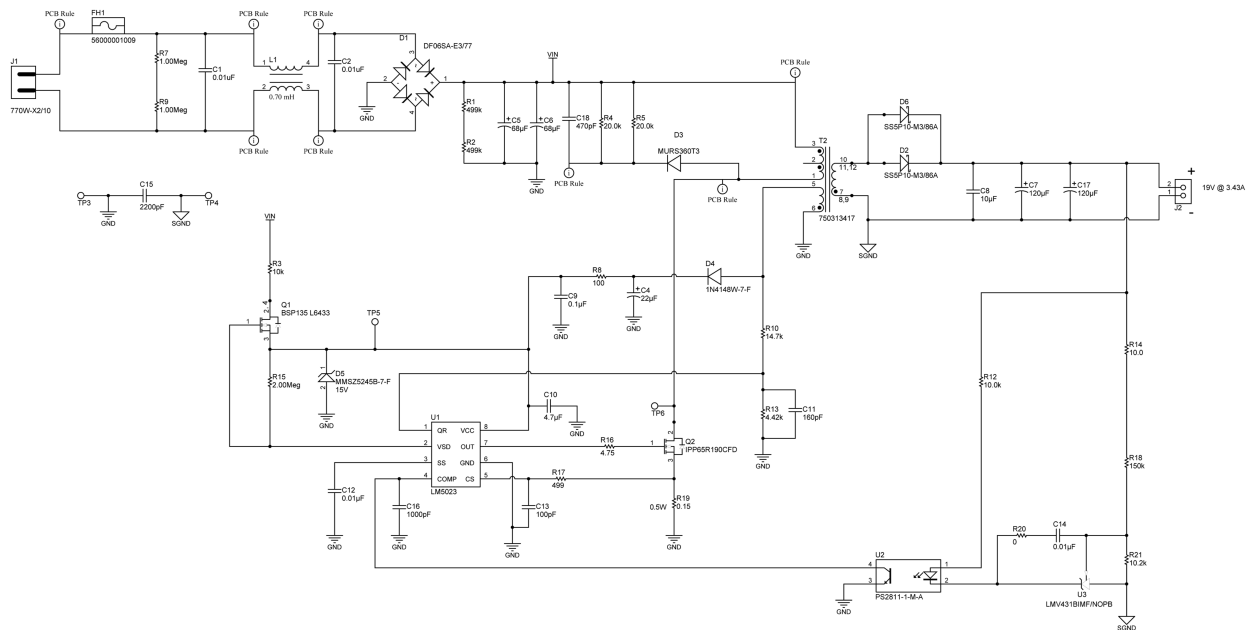
Figure 2. LM5023EVAM Schematic

5 Test Setup

Safety: This evaluation module is not encapsulated and there are voltages that are much higher than 50 VDC.

- If you are not trained in the proper safety of handling and testing power supplies please do not use this evaluation module.

Voltage Source: Isolated AC source or variable AC transformer capable of 265 Vac cable of handling 85 W.

Voltmeter: An AC Power meter and one digital volt meter.

Power Analyzer: Capable of measuring 1 mW to 85 W of input power and capable of handling 265 Vrms input voltage.

Oscilloscope:

- 4 channel, 100 MHz
- Probes capable of handling 650 V.

Output Load: Resistive or electronic load capable of handling 65 W and 20 V.

6 Powering Up

It is suggested that the load be kept low during the first power up. Set the current limit of the source supply to provide about 1.5 times the wattage of the load. As soon as the appropriate input voltage is supplied to the board, check for 19 volts at the output. A most common occurrence is when the current limit set on the source supply is insufficient for the load. The interaction of the source supply folding back and the evaluation board going into undervoltage shutdown will start an oscillation, or chatter, that may have undesirable consequences. A quick efficiency check is the best way to confirm that everything is operating properly. If something is amiss you can be reasonably sure that it will affect the efficiency adversely. Few parameters can be incorrect in a switching power supply without creating losses and potentially damaging heat.

7 Performance Characteristics

Once the circuit is powered up and running normally, the output voltage is regulated to 19 V with the accuracy determined by the feedback resistors and the voltage reference.

7.1 *Over Current Protection*

The evaluation board is configured with hiccup over-current protection. In the event of an output overload (approximately 4 A) this starts the Over Load Detection Timer, after the Over Load Detection Timer (OLDT) times out, the current limit comparator is re-checked, if the power supply is still in an overload condition, the OUT drive is Latched-off and VCC is allowed to drop to VCCOFF (7.5 V).

When VCC reaches VCC_{OFF}, the VSD open drain output is disabled allowing the Depletion Mode start-up FET to turn-on, charging up the VCC capacitor to VCC_{ON} (12.5 V). When VCC reaches VCC_{ON}, the VSD output goes low turning-off the Depletion Mode FET. The VCC capacitor is discharged from VCC_{ON} to VCC_{OFF} at a rate proportional to the VCC capacitor and the ICC_{ST} current (346 µA typical). The charging and discharging of the VCC capacitor is repeated four times (refer to Figure 8) so the total Hiccup time is:

$$t_{HICCUP} = t_{CHARGE} \cdot 4 + t_{DISCHARGE} \cdot 4$$

(3)

After allowing VCC to charge and discharge four times, the LM5023 goes through an auto re-start sequence, enabling the LM5023 SS and driver output. It's important to make the Over Load Detection Timer long enough so that under low input line and full load conditions that the power supply will have enough time to start-up.
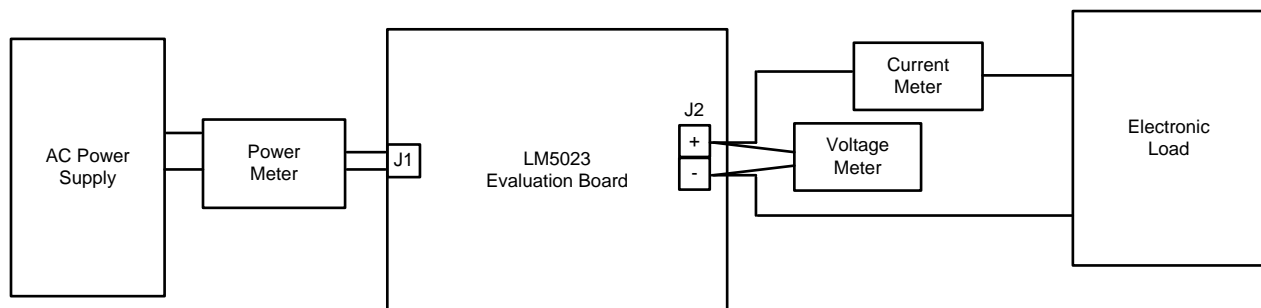

Figure 3. LM5023-2 EVM Test Setup

8 Performance Data and Typical Characteristic Curves
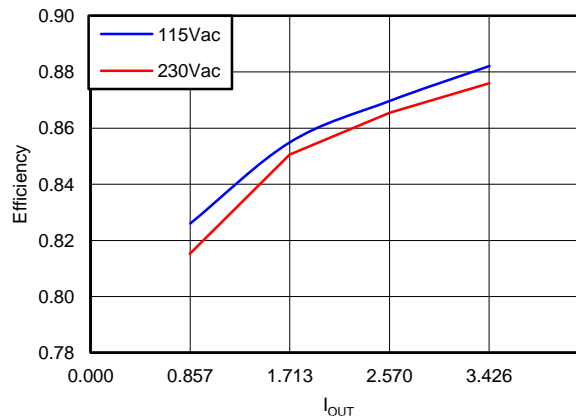
### 8.1 *Efficiency*

Figure 4. LM5023-2 EVM Efficiency

Table 2. 19V 65W Evaluation Board Data

VIN	LIN	PIN	VOUT	IOUT	POUT	EFF
115	0.001	0.020	19.230			
115	0.340	20.080	19.355	0.857	16.587	0.826
115	0.665	38.750	19.340	1.713	33.129	0.855
115	1.008	57.110	19.325	2.570	49.665	0.870
115	1.240	75.120	19.319	3.430	66.264	0.882

| VIN	LIN	PIN	VOUT	IOUT	POUT	EFF
230	0.002	0.027	19.196			
230	0.240	20.200	19.329	0.852	16.468	0.815
230	0.450	38.800	19.300	1.710	33.003	0.851
230	0.660	57.330	19.300	2.571	49.620	0.866
230	0.860	75.400	19.278	3.426	66.046	0.876

8.2 Startup at 115Vac Input

Typical start-up waveforms for 115 Vac and 230 Vac input with the load set at 0.1A and 3.43A are seen in Figure 5, Figure 6, Figure 7, and Figure 8. The oscilloscope CH1 is the LM5023-2 OUT MOSFET drive, CH2 is the LM5023-2 soft-start pin, CH3 is the bias supply from the transformer auxillary winding, and CH4 is the output of the EVM.
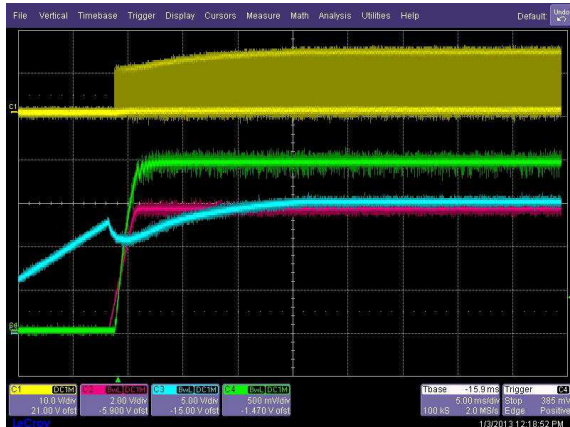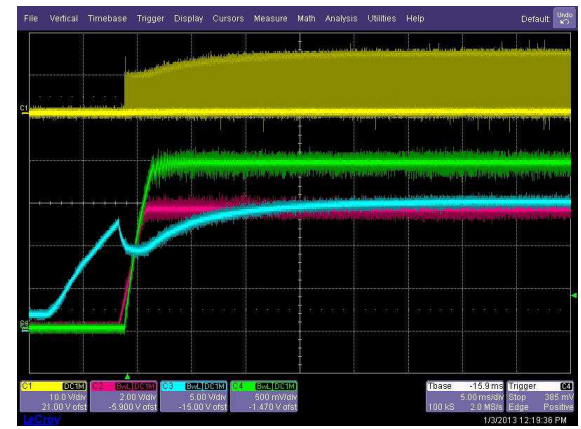

Horizontal Resolution 5ms/div
Figure 5. 0.1A Load

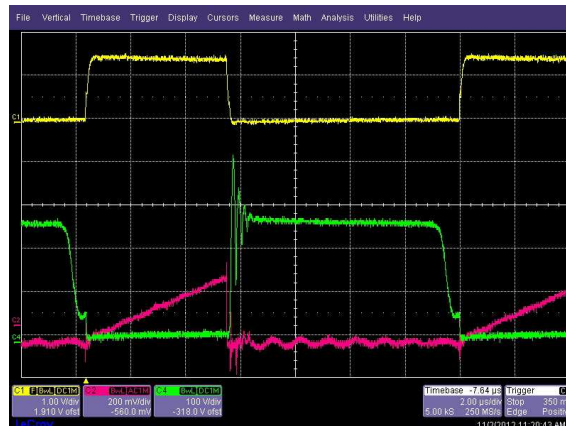Horizontal Resolution 5ms/div
Figure 6. 3.43A Load
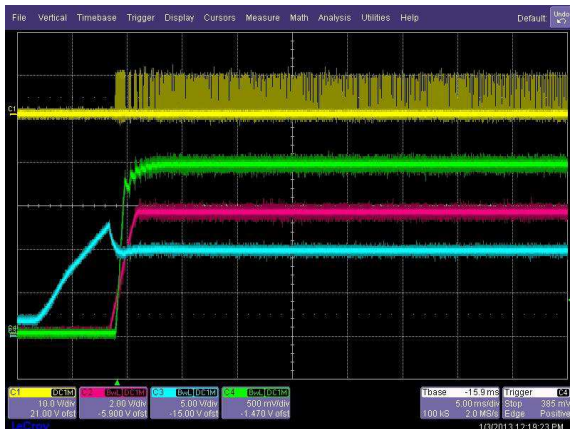
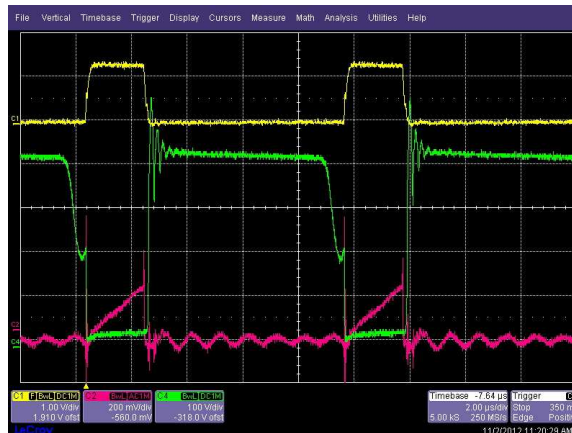Horizontal Resolution 5ms/div
Figure 7. 0.1A Load

Horizontal Resolution 5ms/div
Figure 8. 3.43A Load

8.3 QR Switching Waveforms

CH1-OUT 10V/div
CH2-CS 200mV/div
CH4-VDS 100V/div
Horizontal Resolution 2µs/div

Figure 9. QR Waveforms V$_{IN}$ 115Vac, I$_{OUT}$ 3.43A

CH1-LM5023 OUT 10V/div
CH2-VCS 200mV/div
CH4-VDS Q1 100V/div
Horizontal Resolution 2µs/div

Figure 10. QR Waveforms V$_{IN}$ 230Vac, I$_{OUT}$ 3.43A

8.4 Skip Cycle

To improve the light load efficiency the LM5023-2 enters a Skip Cycle mode during light load conditions. As the output load is decreased, the COMP pin voltage is reduced by the voltage feedback loop to reduce the Flyback converters peak primary current. The PWM comparator input tracks the COMP pin voltage through a 0.75 V level shift circuit and a 3:1 resistor divider. As the COMP pin voltage falls, the input to the PWM comparator falls proportionately. When the PWM comparator input falls to 125 mV, the Skip Cycle comparator detects the light load condition and disables output pulses from the controller. The controller continues to skip switching cycles until the power supply output falls and the COMP pin voltage increases to demand more output current. The number of cycles skipped will depend on the load and the

response time of the frequency voltage loop compensation network. Eventually the COMP voltage will increase when the voltage loop requires more current to sustain the regulated output voltage. When the PWM comparator input exceeds 135 mV (10 mV hysteresis), normal fixed frequency switching resumes. Typical light load operation power supply designs will produce a short burst of output pulses followed by a long skip cycle interval (no drive pulses); refer to Figure 11 for the EVM skip cycle waveforms.
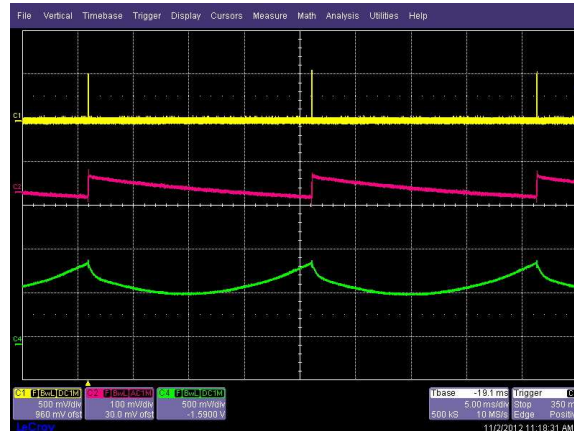
CH1-LM5023 OUT pin 10 V/div

CH2-Vout (Scope is AC Coupled) 100 mV/div

CH4-LM5023 COMP pin 500 V/div

Horizontal Resolution 5 ms/div

Figure 11. Skip Cycle Mode

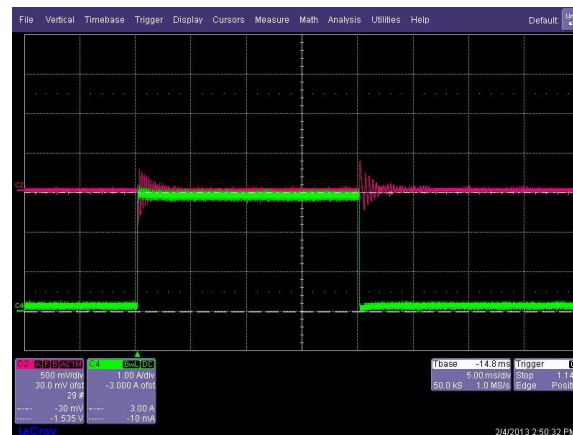## 8.5   *Output Voltage Ripple*
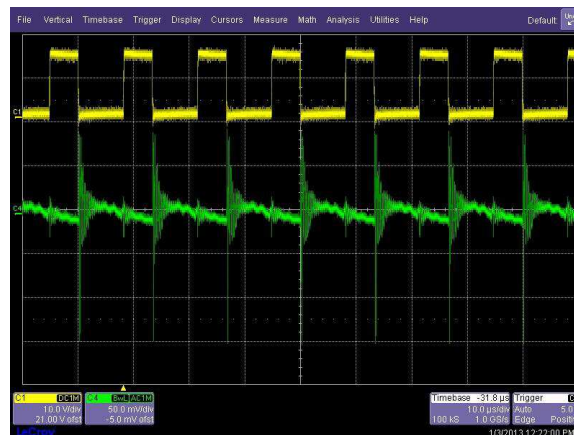
CH1-OUT 10 V/div

CH2-Vout Ripple (The scope is Coupled) 50 mV/div

Horizontal Resolution 2 µs/div

Figure 12. V_{OUT} Ripple V_{IN} 115 Vac, I_{OUT} 3.43A

8.6   *Transient Response*

Vin 115 Vac, Load-step 10% to 90% (0.343 Adc to 3.08 Adc)

CH2-Vout (ac coupled) 0.5 V/div

CH4-Iout 1.0 A/div

Horizontal Resolution 5 ms/div

Figure 13. Transient Response

8.7 *Implementing Synchronous Rectification*

The LM5023-2 Evaluation Board was modified to add Synchronous Rectification. The output diodes D2 and D6 were removed (refer to Figure 2 LM5023-2 EVAL Board schematic and Figure 14) and a SR MOSFET was installed in the RTN path of the power supply output. The UCC24610 Secondary Side Green Rectifier Controller was used to control the Synchronous MOSFET; refer to schematic in Figure 14. When the energy stored in the transformer primary is transfer to the secondary the current will flow through the Synchronous Rectifier (SR) MOSFETs (Q4) internal Body Diode. A typical MOSFETs internal body diode will have a voltage drop of 700 mV to1 V. The UCC24610 differentially monitors the voltage across Q4's Drain to Source, when the voltage sensed is <-150 mV the GATE output signal goes high turning-on Q4, reducing the power losses.

In any application there are circuit parasitics such as inductance and capacitance which affect the voltage and current waveforms. When the UCC24610 turns-on the SR MOSFET the secondary current is at its maximum, any inductance in the circuit traces, or the leads of the MOSFET can cause the sensed voltage to ring up above the -150 mV threshold. To blank these noise signals the UCC24610 has a programmable minimum on time (T_{ON}), which is triggered after the SR MOSFET is turned-on.

When all the energy has been transfer to the secondary and the current reaches zero, the second circuit is open and the voltage sensed across the Drain to Source of the SR MOSFETs will rise. When the differential voltage is > -5mV the UCC2610 turns-off the SR MOSFET. When the SR MOSFET is turned-off inductance and parasitic capacitance can cause the voltage on the secondary to ring, the ringing may cause the controller to turn back on the SR MOSFET. To eliminate a false turn-on, the UCC24610 has a programmable minimum off time (TOFF).

The UCC2610 has a maximum VCC voltage of 6.5 V, for this application the 19 V output is inputted into a zener diode regulator made up of Q1, Z2, and R3 (refer to Figure 15) which regulate the bias supply voltage to the UCC24610 to approximately 6.1 V. Care should be take when selecting the SR MOSFET, with VCC 6.1 V, the GATE drive output voltage will be approximately 5.9 V so be sure to select a MOSFET that will be fully enhanced.

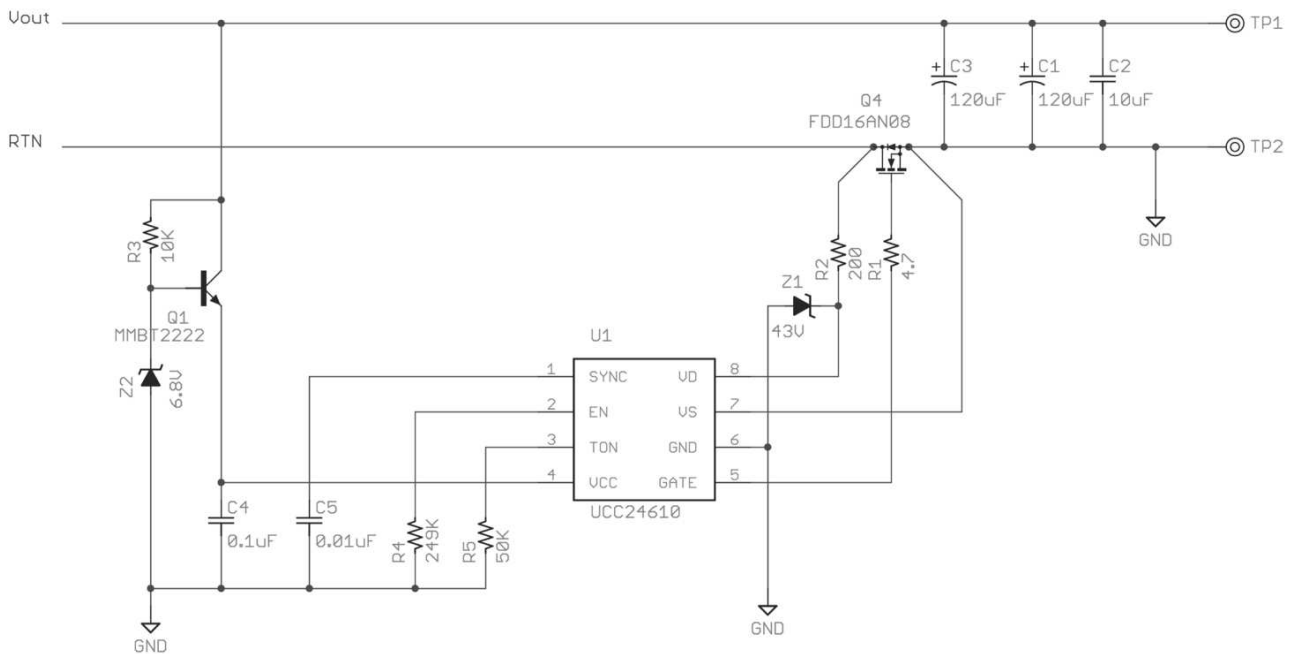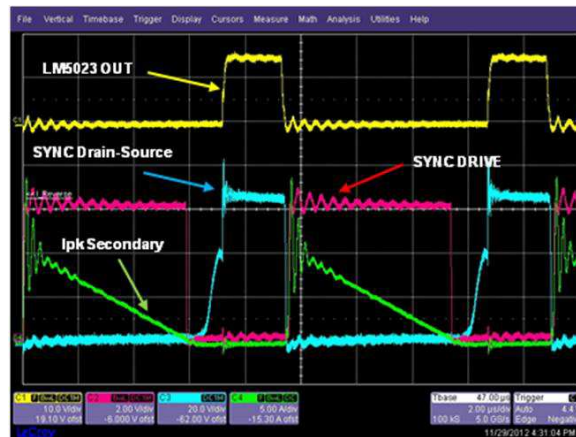The detailed operation of the UCC2610 can be found in its data sheet.

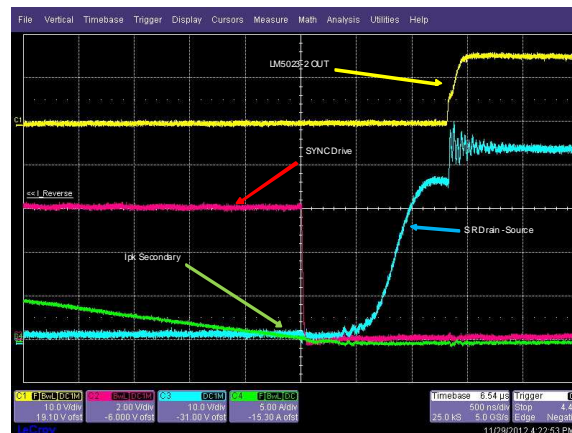**Figure 14. Schematic Synchronous Rectification Circuit**

CH1-LM5023-2 OUT Drive 10 V/div

CH2- UCC2601 GATE output 5 V/div

CH3-SR Voltage Drain to Source 20 V/div

CH4-Secondary Current 5 A/div

Horizontal Resolution 1 μs/div

Figure 15. Synchronous Rectification turn-on waveforms

The turn-on Synchronous waveforms in Figure 15 show that when the current starts to conduct through the SR MOSFETs body diode the differential voltage sensed across the Drain to Source drop is less than -150 V and the SR MOSFET is turned-on in approximately 100 ns.

The turn-off waveforms in Figure 16 show that when the current in the secondary reaches zero that the SR MOSFET turns-off after 1.25 μs with no false turn-on, or reverse current.

CH1-LM5023-2 OUT Drive 10 V/div

CH2- UCC2601 GATE output 5 V/div

CH3-SR Voltage Drain to Source 20 V/div

CH4-Secondary Current 5 A/div

Figure 16. Synchronous Rectification Turn-Off Waveforms

Table 3 shows the Evaluation board efficiency data with Synchronous Rectification. At the nominal input line and full load the efficiency is 90.22%. Comparing the EVAL board with Synchronous Rectification to the EVAL Board using rectifying diodes (Table 2) at full load the efficiency is 88.2%. Adding Synchronous Rectification improves the efficiency by 2.02%. An additional point is that the no-load standby power measured with Vin 230 Vac increase from 27 mW in the EVAL board (Table 2) to 159 mW using SR (Table 2). The conclusion is that Synchronous Reification improves the full load efficiency and increased the standby power, so in applications that have a very low standby power requirement, Synchronous Rectification may not be a viable option.

Table 3. Evaluation Board with Synchronous Rectification

VIN	LIN	PIN	VOUT	IOUT	POUT	EFF
170	9.90E-04	0.017	19.29			
170	1.81E-02	3.08	19.29	0.10	1.94	0.6313
170	1.18E-01	19.99	19.28	0.86	16.54	0.8273
170	2.25E-01	38.28	19.25	1.72	33.02	0.8624
170	3.26E-01	55.35	19.24	2.57	49.45	0.8933
170	4.31E-01	73.19	19.25	3.43	66.03	0.9022

VIN	LIN	PIN	VOUT	IOUT	POUT	EFF
325	4.90E-04	0.1593	19.271			
325	6.35E-02	20.62	19.239	0.86	16.51	0.8005
325	1.08E-01	34.97	19.22	1.50	28.83	0.8244
325	1.22E-01	39.51	19.224	1.72	32.97	0.8346
325	1.76E-01	57.30	19.207	2.57	49.36	0.8615
325	2.30E-01	74.75	19.2	3.43	65.86	0.8810

9 BILL OF MATERIALS

DESIGNATOR	QTY	VALUE	DESCRIPTION	PACKAGE REF	PART NUMBER	MANUFACTURER	ALTERNATE PART NUMBER	ALT MFR
PCB	1		Printed Circuit Board		SV600952A	Any		
C1, C2	2	10000pF	CAP CER 10000PF 300V 20% RADIAL	Radial - Disc	VY2103M63Y5US63V7	Vishay BC Components	VY2103M63Y5UG63V7	Vishay
C4	1	22uF	CAP, OS-CON, 22uF, 20V, +/-20%, 0.06 ohm, 6.3x5.8 SMD	6.3x5.8	20SVP22M	Sanyo	-	-
C5, C6	2	68µF	CAP ALUM 68UF 400V 20% RADIAL	Radial, Can	EEU-EE2G680	Panasonic Electronic Components	-	-
C7, C17	2	120µF	CAP ALUM 120UF 25V 20% RADIAL	Radial, Can	PLV1E121MCL1TD	Nichicon	-	-
C8	1	10uF	CAP, CERM, 10uF, 25V, +/-20%, X7R, 1812	1812	C4532X7R1E106M	TDK	-	-
C9	1	0.1uF	CAP, CERM, 0.1uF, 50V, +/-10%, X7R, 0805	0805	C2012X7R1H104K	TDK	-	-
C10	1	4.7uF	CAP, CERM, 4.7uF, 25V, +/-10%, X7R, 1206	1206	C3216X7R1E475K	TDK	-	-
C11	1	160pF	CAP, CERM, 160pF, 50V, +/-5%, C0G/NP0, 0402	0402	GRM1555C1H161JA01D	MuRata	-	-
C12, C14	2	0.01uF	CAP, CERM, 0.01uF, 25V, +/-5%, C0G/NP0, 0603	0603	C1608C0G1E103J	TDK	[NoValue], -	[NoValue], -
C13	1	100pF	CAP, CERM, 100pF, 50V, +/-5%, C0G/NP0, 0402	0402	GRM1555C1H101JA01D	MuRata	-	-
C15	1	2200pF	CAP, CERM, 2200pF, 2000V, +/-10%, X7R, 1812	1812	C4532X7R3D222K	TDK	-	-
C16	1	1000pF	CAP, CERM, 1000pF, 50V, +/-5%, C0G/NP0, 0402	0402	GRM1555C1H102JA01D	MuRata	-	-
C18	1	470pF	CAP, CERM, 470pF, 630V, +/-5%, C0G/NP0, 1206	1206	GRM31A5C2J471JW01D	MuRata	-	-
D1	1		DIODE GPP 1A 600V 4SMD	DF-S	DF06SA-E3/77	Diode Inc	-	-
D2, D6	2	880mV @ 5A	DIODE SCHOTTKY 5A 100V SMPC	TO-277, 3-PowerDFN	SS5P10-M3/86A	Vishay General Semiconductor	-	-
D3	1	1.25V	Diode, Ultrafast, 600V, 3A, SMC	SMC	MURS360T3	ON Semiconductor	Equivalent	Any
D4	1	1.25V	Diode, Ultrafast, 100V, 0.15A, SOD-123	SOD-123	1N4148W-7-F	Diodes Inc.	-	-
D5	1	15V	Diode, Zener, 15V, 500mW, SOD-123	SOD-123	MMSZ5245B-7-F	Diodes Inc.	-	-
F1	1		FUSE T-LAG 2.00A 250V UL TR5	Radial, Can, Vertical	37412000410	Littelfuse Inc	-	-
FH1	1		FUSEHOLDER TR5 MACHINE CONTACTS	eg: 0603, used in PnP report	56000001009	Littelfuse Inc	-	-

DESIGNATOR	QTY	VALUE	DESCRIPTION	PACKAGE REF	PART NUMBER	MANUFACTURER	ALTERNATE PART NUMBER	ALT MFR
FID1, FID2, FID3	3		Fiducial mark. There is nothing to buy or mount.	Fiducial	N/A	N/A	-	-
H1, H2, H3, H4	4		Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	Screw	NY PMS 440 0025 PH	B&F Fasteners	-	-
H5, H6, H7, H8	4		Standoff, Hex, 0.5"L #4-40 Nylon	Standoff	1902C	Keystone	-	-
J1	1		CONN RECEPT PANEL/R/A PCB PINS	eg: 0603, used in PnP report	770W-X2/10	Qualtek	-	-
J2	1	2x1	Conn Term Block, 2POS, 5.08mm PCB	PhoenixContact_1715721	1715721	Phoenix Contact	Equivalent	Any
L1	1		SMD Common Mode Power Line Choke WE-LF SMD, L=0.70 mH					
LBL1	1		Thermal Transfer Printable Labels, 0.650" W x 0.200" H - 10,000 per roll	PCB Label 0.650"H x 0.200"W	THT-14-423-10	Brady	-	-
MW1	1		WASHER SHOULDER #4 NYLON 0.047" Depth	eg: 0603, used in PnP report	7681	Keystone Electronics	-	-
MW2	1		WASHER INTERNAL TOOTH #4 STEEL	eg: 0603, used in PnP report	INTLWZ 004	B&F Fasteners	-	-
MW3	1		MACHINE SCREW PAN PHILLIPS 4-40	eg: 0603, used in PnP report	PMS 440 0031 PH	B&F Fasteners	-	-
MW4	1		WASHER FLAT #4 STEEL	eg: 0603, used in PnP report	5205820-3	TE Connectivity	-	-
MW5	1		HEX NUT 1/4" STEEL 4-40	eg: 0603, used in PnP report	9600	Keystone Electronics	-	-
PD1	1		THERM PAD TO-220 W/ADH .009" SP9	eg: 0603, used in PnP report	SP900S-0.009-AC-58	Bergquist	-	-
Q1	1		MOSFET N-CH 600V 120MA SOT-223	TO-261-4, TO-261AA	BSP135 L6433	Infineon Technologies	-	-
Q2	1		MOSFET N-CH 650V 17.5A TO220	TO-220-3	IPP65R19 0CFD	Infineon Technologies	-	-
R3	1	10k	RES 10.0K OHM 1W 1% 2512 SMD	2512 (6332 Metric)	CRCW25 1210K0F KEGHP	Vishay Dale	-	-
R4, R5	1	20.0k	RES, 20.0k ohm, 1%, 0.25W, 1206	1206	ERJ-8ENF2002V	Panasonic	-	-
R8	1	100	RES, 100 ohm, 1%, 0.125W, 0805	0805	CRCW08 05100RF KEA	Vishay-Dale	-	-
R10	1	14.7 k	RES, 14.7k ohm, 1%, 0.1W, 0603	0603	CRCW06 0314K7F KEA	Vishay-Dale	Equivalent	Any
R12	1	10.0 k	RES, 10.0k ohm, 1%, 0.1W, 0603	0603	CRCW06 0310K0F KEA	Vishay-Dale	Equivalent	Any

DESIGNATOR	QTY	VALUE	DESCRIPTION	PACKAGE REF	PART NUMBER	MANUFACTURER	ALTERNATE PART NUMBER	ALT MFR
R13	1	4.42 k	RES, 4.42k ohm, 1%, 0.063W, 0402	0402	CRCW04024K42FKED	Vishay-Dale	Equivalent	Any
R14	1	10.0	RES, 10.0 ohm, 1%, 0.1W, 0603	0603	CRCW060310R0FKEA	Vishay-Dale	-	-
R15	1	2.00 Meg	RES, 2.00Meg ohm, 1%, 0.25W, 1206	1206	CRCW12062M00FKEA	Vishay-Dale	Equivalent	Any
R16	1	4.75	RES, 4.75 ohm, 1%, 0.1W, 0603	0603	CRCW06034R75FKEA	Vishay-Dale	-	-
R17	1	499	RES, 499 ohm, 1%, 0.063W, 0402	0402	CRCW0402499RFKED	Vishay-Dale	Equivalent	Any
R18	1	150k	RES, 150k ohm, 1%, 0.1W, 0603	0603	CRCW0603150KFKEA	Vishay-Dale	Equivalent	Any
R19	1	0.15	RES, 0.15 ohm, 1%, 0.5W, 1210	1210	MCR25JZHFLR150	Rohm	-	-
R20	1	0	RES, 0 ohm, 5%, 0.1W, 0603	0603	CRCW06030000Z0EA	Vishay-Dale	Equivalent	Any
R21	1	10.2k	RES, 10.2k ohm, 1%, 0.1W, 0603	0603	CRCW060310K2FKEA	Vishay-Dale	Equivalent	Any
T2	1		XFMR, Offline In, 19V 3.5A Out	eg: 0603, used in PnP report	750313417	Wurth	-	-
TP3, TP4	2	Black	Test Point, TH, Miniature, Black	Keystone5001	5001	Keystone	-	-
TP5, TP6	2	White	Test Point, TH, Miniature, White	Keystone5002	5002	Keystone	-	-
U1	1		IC, CTLR, AC-DC Quasi Resonant PWM	SO-8	LM5023	Texas Instruments	-	-
U2	1		Low Input Current, Hight CTR Photocoupler	PS2811-1	PS2811-1-M-A	Renesas	-	-
U3	1		IC VREF SHUNT PREC ADJ SOT-23-3	TO-236-3, SC-59, SOT-23-3	LMV431BIMF/NOPB	National Semiconductor	-	-
R1, R2	0	499k	RES, 499k ohm, 1%, 0.25W, 1206	1206	CRCW1206499KFKEA	Vishay-Dale	-	-
R7, R9	0	1.00Meg	RES, 1.00Meg ohm, 1%, 0.25W, 1206	1206	CRCW12061M00FKEA	Vishay-Dale	Equivalent	Any

9.1 PWB Layout

TOP Side Assembly
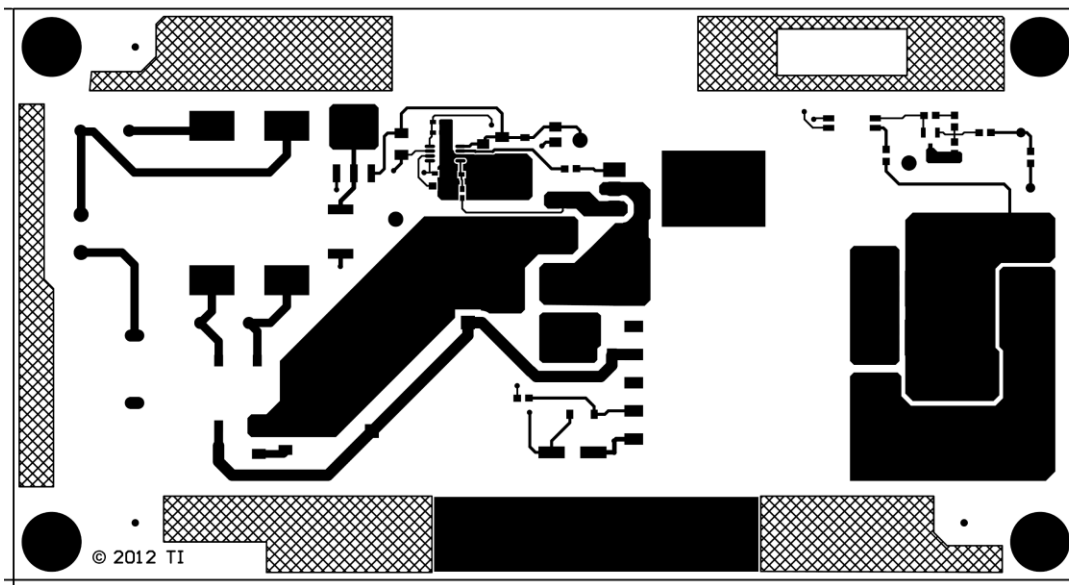
Figure 17. Top Side
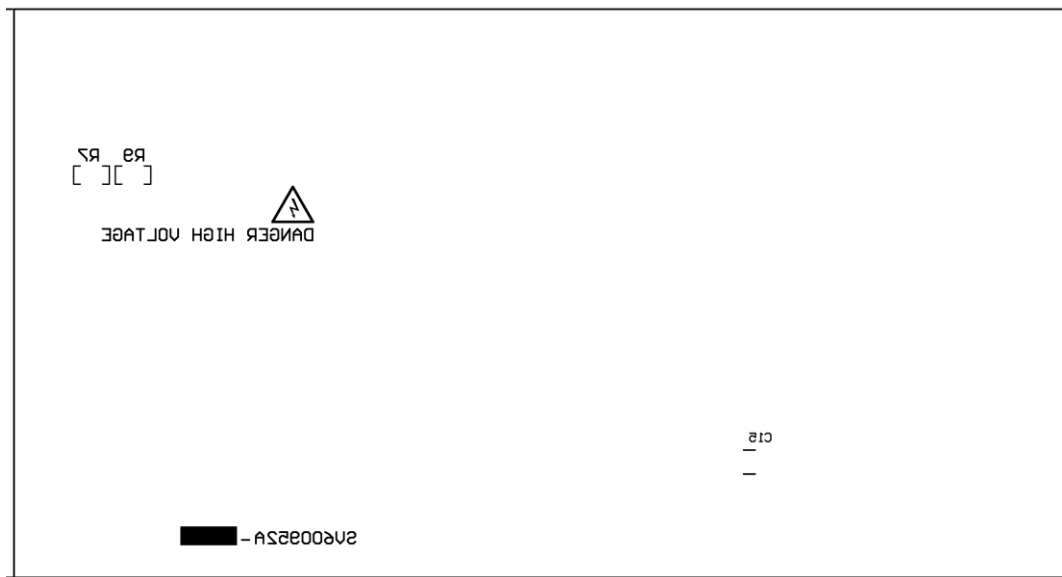
Figure 18. Bottom Side Assembly
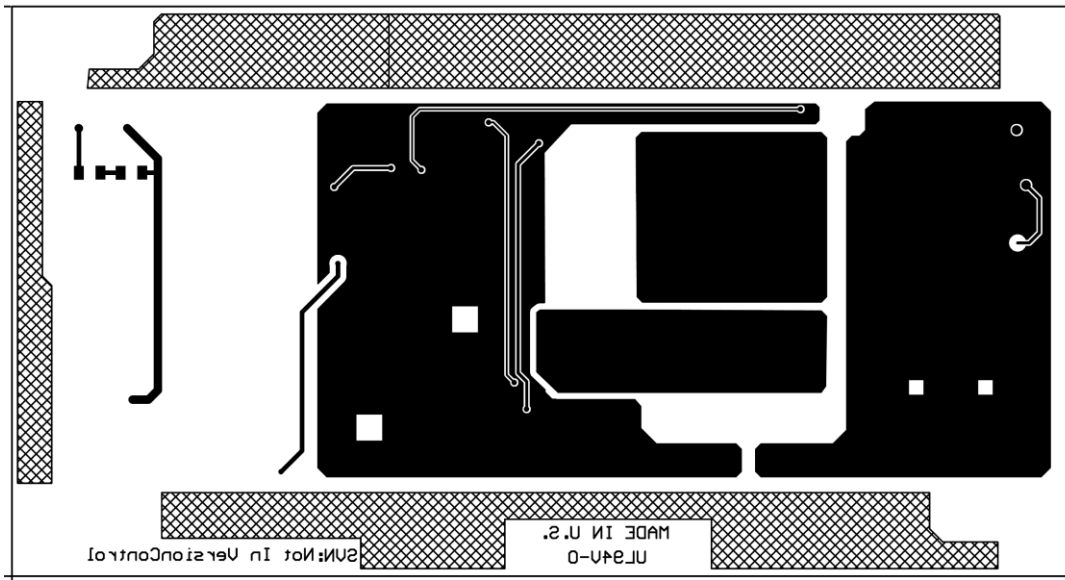
Figure 19. Bottom Side

EVALUATION BOARD/KIT/MODULE (EVM) ADDITIONAL TERMS

Texas Instruments (TI) provides the enclosed Evaluation Board/Kit/Module (EVM) under the following conditions:

The user assumes all responsibility and liability for proper and safe handling of the goods. Further, the user indemnifies TI from all claims arising from the handling or use of the goods.

Should this evaluation board/kit not meet the specifications indicated in the User's Guide, the board/kit may be returned within 30 days from the date of delivery for a full refund. THE FOREGOING LIMITED WARRANTY IS THE EXCLUSIVE WARRANTY MADE BY SELLER TO BUYER AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE. EXCEPT TO THE EXTENT OF THE INDEMNITY SET FORTH ABOVE, NEITHER PARTY SHALL BE LIABLE TO THE OTHER FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.

Please read the User's Guide and, specifically, the Warnings and Restrictions notice in the User's Guide prior to handling the product. This notice contains important safety information about temperatures and voltages. For additional information on TI's environmental and/or safety programs, please visit www.ti.com/esh or contact TI.

No license is granted under any patent right or other intellectual property right of TI covering or relating to any machine, process, or combination in which such TI products or services might be or are used. TI currently deals with a variety of customers for products, and therefore our arrangement with the user is not exclusive. TI assumes no liability for applications assistance, customer product design, software performance, or infringement of patents or services described herein.

REGULATORY COMPLIANCE INFORMATION

As noted in the EVM User's Guide and/or EVM itself, this EVM and/or accompanying hardware may or may not be subject to the Federal Communications Commission (FCC) and Industry Canada (IC) rules.

For EVMs **not** subject to the above rules, this evaluation board/kit/module is intended for use for ENGINEERING DEVELOPMENT, DEMONSTRATION OR EVALUATION PURPOSES ONLY and is not considered by TI to be a finished end product fit for general consumer use. It generates, uses, and can radiate radio frequency energy and has not been tested for compliance with the limits of computing devices pursuant to part 15 of FCC or ICES-003 rules, which are designed to provide reasonable protection against radio frequency interference. Operation of the equipment may cause interference with radio communications, in which case the user at his own expense will be required to take whatever measures may be required to correct this interference.

General Statement for EVMs including a radio

User Power/Frequency Use Obligations: This radio is intended for development/professional use only in legally allocated frequency and power limits. Any use of radio frequencies and/or power availability of this EVM and its development application(s) must comply with local laws governing radio spectrum allocation and power limits for this evaluation module. It is the user's sole responsibility to only operate this radio in legally acceptable frequency space and within legally mandated power limitations. Any exceptions to this are strictly prohibited and unauthorized by Texas Instruments unless user has obtained appropriate experimental/development licenses from local regulatory authorities, which is responsibility of user including its acceptable authorization.

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

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

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.

For EVMs annotated as IC – INDUSTRY CANADA Compliant

This Class A or B digital apparatus complies with Canadian ICES-003.

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

Concerning EVMs including radio transmitters

This device complies with Industry Canada licence-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.

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.

Cet appareil numérique de la classe A ou B est conforme à la norme NMB-003 du Canada.

Les changements ou les modifications pas expressément approuvés par la partie responsable de la conformité ont pu vider l'autorité de l'utilisateur pour actionner l'équipement.

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.

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.

【Important Notice for Users of this Product in Japan】

This development kit is NOT certified as Confirming to Technical Regulations of Radio Law of Japan

If you use this product in Japan, you are required by Radio Law of Japan to follow the instructions below with respect to this product:

1. Use this product 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 this product only after you obtained the license of Test Radio Station as provided in Radio Law of Japan with respect to this product, or

3. Use of this product only after you obtained the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to this product. Also, please do not transfer this product, unless you give the same notice above to the transferee. Please note that if you could not follow the instructions above, you will be subject to penalties of Radio Law of Japan.

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【ご使用にあたっての注】

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2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

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EVALUATION BOARD/KIT/MODULE (EVM)
WARNINGS, RESTRICTIONS AND DISCLAIMERS

For Feasibility Evaluation Only, in Laboratory/Development Environments. Unless otherwise indicated, this EVM is not a finished electrical equipment and not intended for consumer use. It is intended solely for use for preliminary feasibility evaluation in laboratory/development environments by technically qualified electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems and subsystems. It should not be used as all or part of a finished end product.

Your Sole Responsibility and Risk. You acknowledge, represent and agree that:

1. You have unique knowledge concerning Federal, State and local regulatory requirements (including but not limited to Food and Drug Administration regulations, if applicable) which relate to your products and which relate to your use (and/or that of your employees, affiliates, contractors or designees) of the EVM for evaluation, testing and other purposes.

2. You have full and exclusive responsibility to assure the safety and compliance of your products with all such laws and other applicable regulatory requirements, and also to assure the safety of any activities to be conducted by you and/or your employees, affiliates, contractors or designees, using the EVM. Further, you are responsible to assure 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.

3. You will employ reasonable safeguards to ensure that your use of the EVM will not result in any property damage, injury or death, even if the EVM should fail to perform as described or expected.

4. You will take care of proper disposal and recycling of the EVM's electronic components and packing materials.

Certain Instructions. It is important to operate this EVM within TI's recommended specifications and environmental considerations per the user guidelines. Exceeding the specified EVM ratings (including but not limited to input and output voltage, current, power, and environmental ranges) may cause property damage, personal injury or death. If there are questions concerning these ratings please contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM User's Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, some circuit components may have case temperatures greater than 60°C as long as the input and output are maintained at a normal ambient operating temperature. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during normal operation, please be aware that these devices may be very warm to the touch. As with all electronic evaluation tools, only qualified personnel knowledgeable in electronic measurement and diagnostics normally found in development environments should use these EVMs.

Agreement to Defend, Indemnify and Hold Harmless. You agree to defend, indemnify and hold TI, its licensors and their representatives harmless from and against any and all claims, damages, losses, expenses, costs and liabilities (collectively, "Claims") arising out of or in connection with any use of the EVM that is not in accordance with the terms of the agreement. This obligation shall apply whether Claims arise under law of tort or contract or any other legal theory, and even if the EVM fails to perform as described or expected.

Safety-Critical or Life-Critical Applications. If you intend to evaluate the components for possible use in safety critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, such as devices which are classified as FDA Class III or similar classification, then you must specifically notify TI of such intent and enter into a separate Assurance and Indemnity Agreement.

IMPORTANT NOTICE