Using the TPS92075 BUCK Converter

The TPS92075EVM is a 14-W maximum, 120-V_{AC} non-isolated dimmable LED driver whose form factor intended for A-15, A-19, A-21, A-23, R-20, R-25, R-27, R-30, R-40, PS-25, PS-30, PS-35, BR-30, BR-38, BR-40, PAR-20, PAR-30, PAR-30L, G-25, G-30, G-40, and other LED bulbs..

Contents

List of Figures

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List of Tables

1 Description

The TPS92075EVM is a 14-W maximum, 120-VAC non-isolated dimmable LED driver whose form factor is intended for A-15, A-19, A-21, A-23, R-20, R-25, R-27, R-30, R-40, PS-25, PS-30, PS-35, BR-30, BR-38, BR-40, PAR-20, PAR-30, PAR-30L, G-25, G-30, G-40, and other LED bulbs.

2 Description

The TPS92075EVM implements a dimming solution using the TPS92075 integrated circuit from Texas Instruments (TI). The TPS92075 is a hybrid power-factor controller with a built-in phase dimming decoder. Line cycles are analyzed continuously by an internal low-power digital controller for shape and symmetry. An analog current reference is then generated and used by the power converter stage to regulate the output current. The analog reference is manipulated using control algorithms developed to optimize dimmer compatibility, power factor, and THD.

Using constant off-time control, the solution achieves a low part count, high efficiency and inherently provides variation in the switching frequency. This variation creates an emulated spread-spectrum effect easing the converters EMI signature and allowing a smaller input filter.

2.1 Typical Applications

Triac-compatible LED lighting, including forward- and reverse-phase compatibility.

2.2 TPS92075 Features

- Controlled reference derived Power Factor Correction (PFC)
- Integrated digital phase angle decoder
- Digital PLL with active 50 Hz, 60 Hz sync
- Phase-symmetry balancing
- Leading and trailing edge dimmer compatibility
- Dimming implemented via an analog reference
- Smooth dimming transitions
- Overvoltage protection
- Output short-circuit protection
- Low BOM cost and small PCB footprint
- Patent pending digital architecture
- 6-pin SOT and 8-pin SOIC available

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3 Electrical Performance Specifications

Table 1 presents the electrical performance specifications of the TPS92075 EVM.

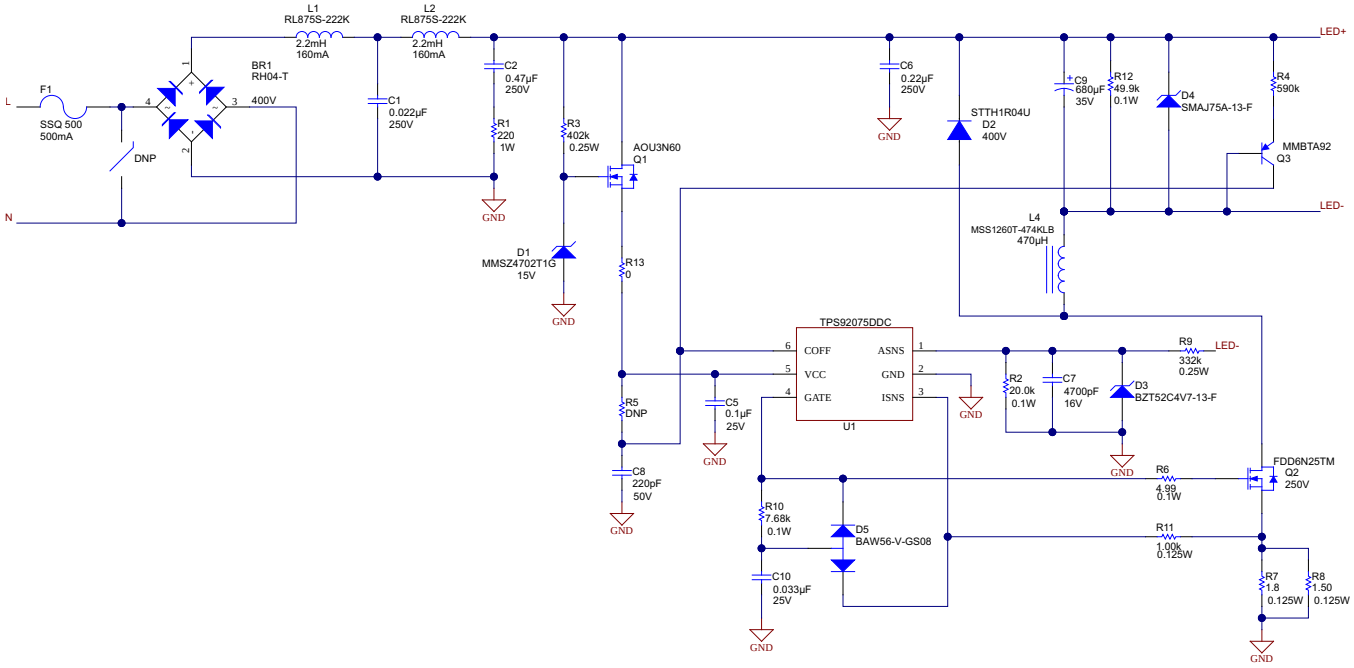
Table 1. TPS92075 Buck REF DESIGN-001 Electrical Performance Specifications(1)

Parameter	Test Conditions	MIN	TYP	MAX	Units
Input Characteristics					
Voltage range		90	120	135	V
Maximum Input current				0.140	A
Output Characteristics					
Output voltage, V_{OUT}	< 15 V with modification	15		35	V
Output voltage regulation	Line Regulation: Input voltage = 90 to 135		±7		%
	Line Regulation: Input voltage = 100 to 135		±5		%
	Load Regulation: 25- to 30-V change		±1.5		%
	120-Hz LED Ripple, Typical		300		mApp
Systems Characteristics					
Switching frequency			90		kHz
Peak efficiency			88.1		%
Operating temperature			25	125	ºC
Solution Volume			17		cm^3
Solution Volume per Watt	Based on 14 W maximum		1.2		W/cm^3

(1) All performance results are for this design configuration only. Many opportunities exist to balance one performance factor for another in this design.

4 Schematic

Figure 1 is the EVM schematic, and Figure 2 shows suggested dimming connections.



For VLED < 15 V, replace R13 with a diode (DFLS1200 or similar) and modify C5 ≥ 22 µF.

Figure 1. TPS92075 Buck EVM Schematic

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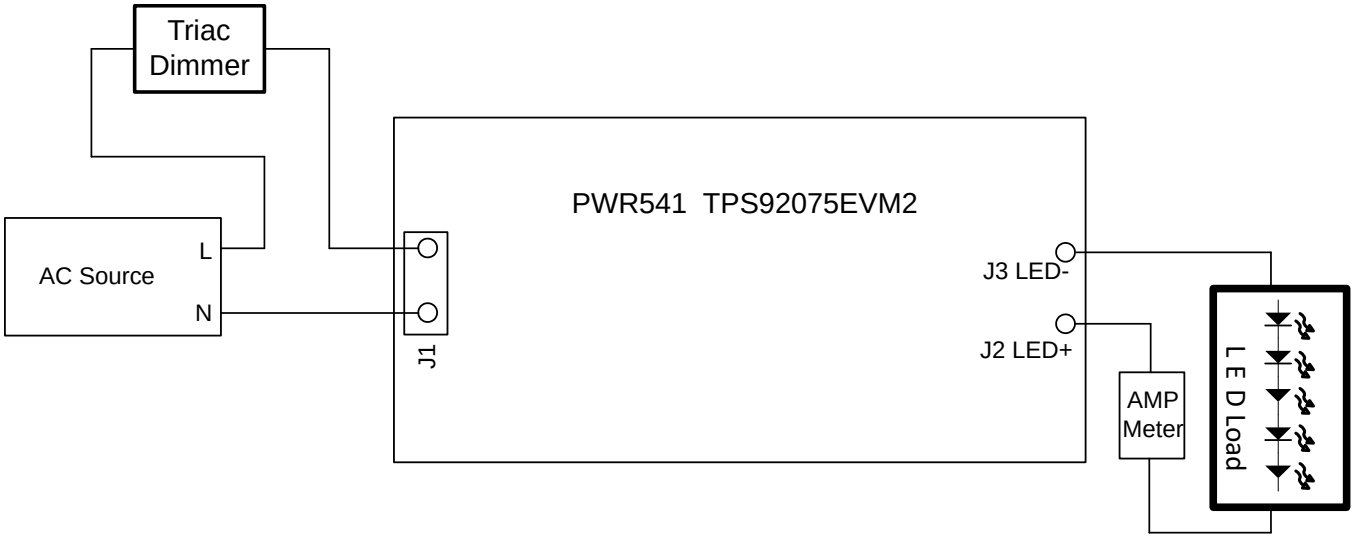

Figure 2. Dimming Wiring Diagram

5 Performance Data and Typical Characteristic Curves

Figure 3 through Figure 12 present typical performance curves for TPS92075 Buck EVM.

5.1 Efficiency

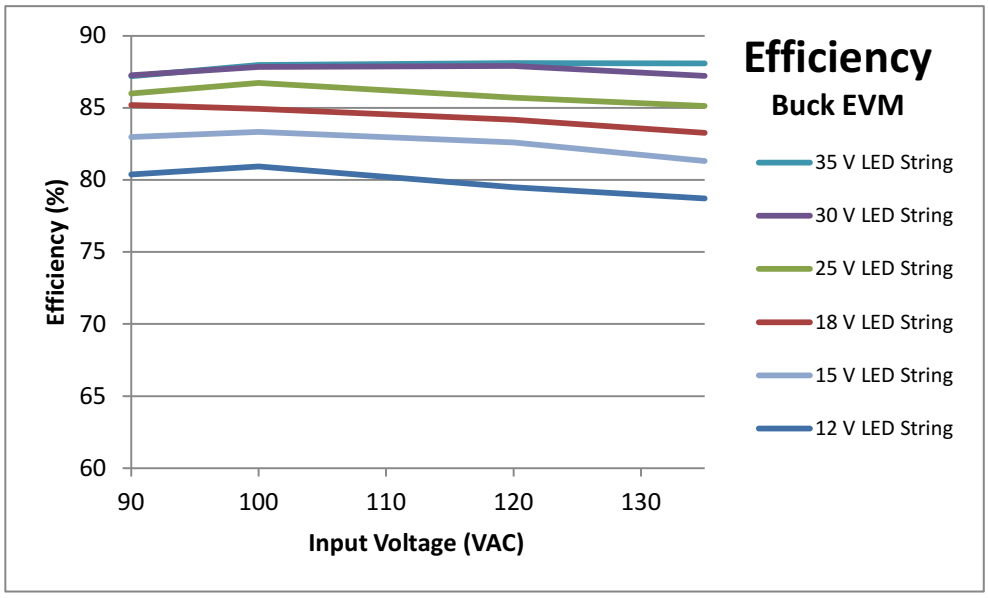

Figure 3. TPS92075 Buck EVM Efficiency

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5.2 Line Regulation

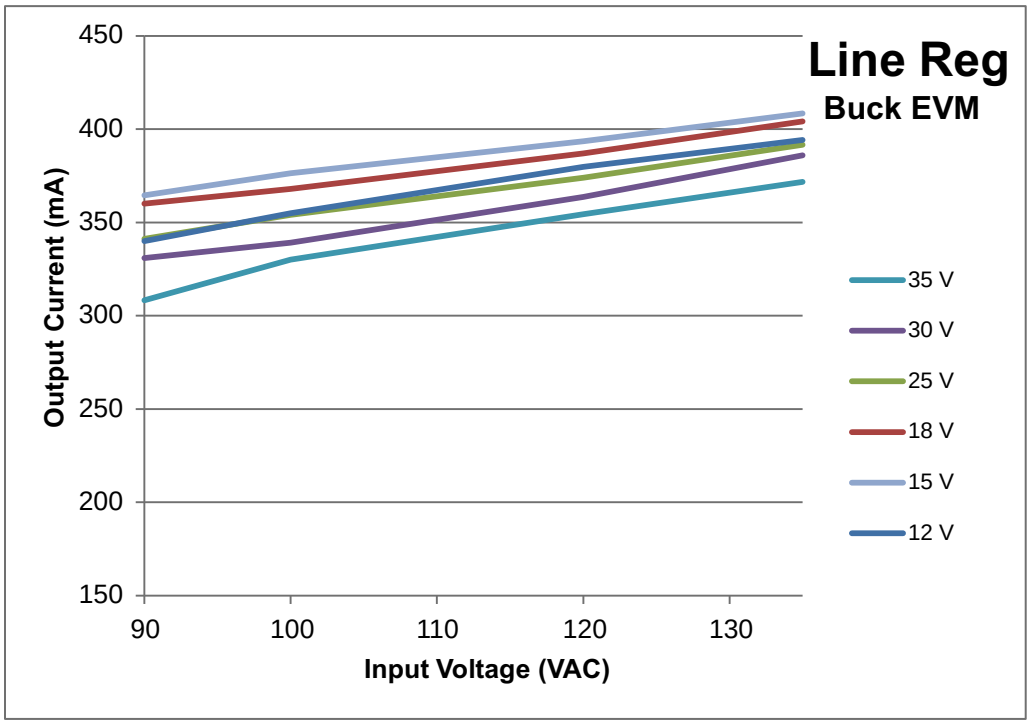

Figure 4. TPS92075 Buck EVM Line Regulation

5.3 Load Regulation

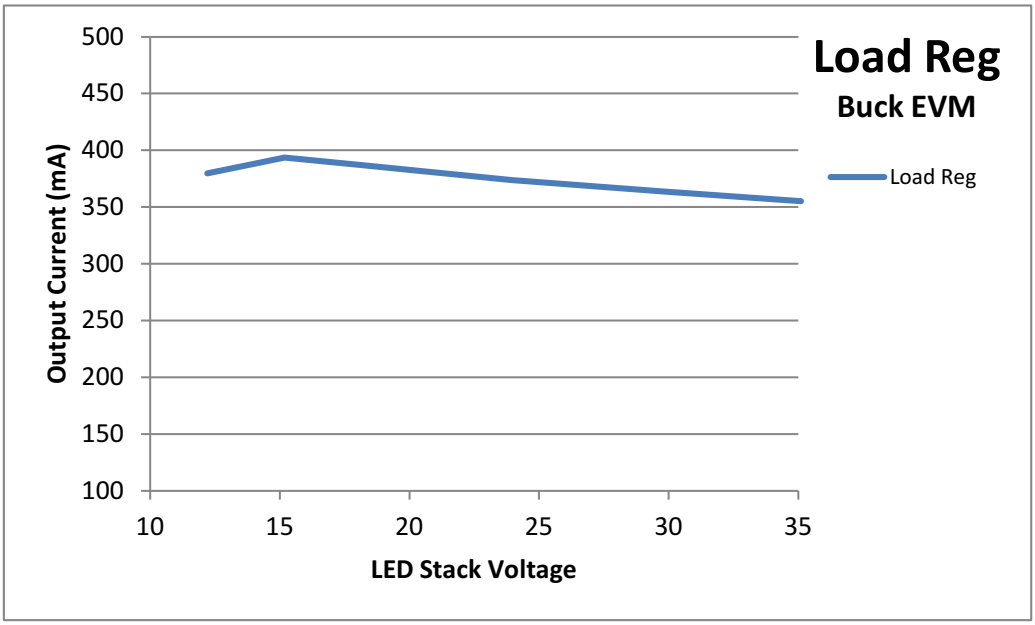

Figure 5. TPS92075 Buck EVM Load Regulation

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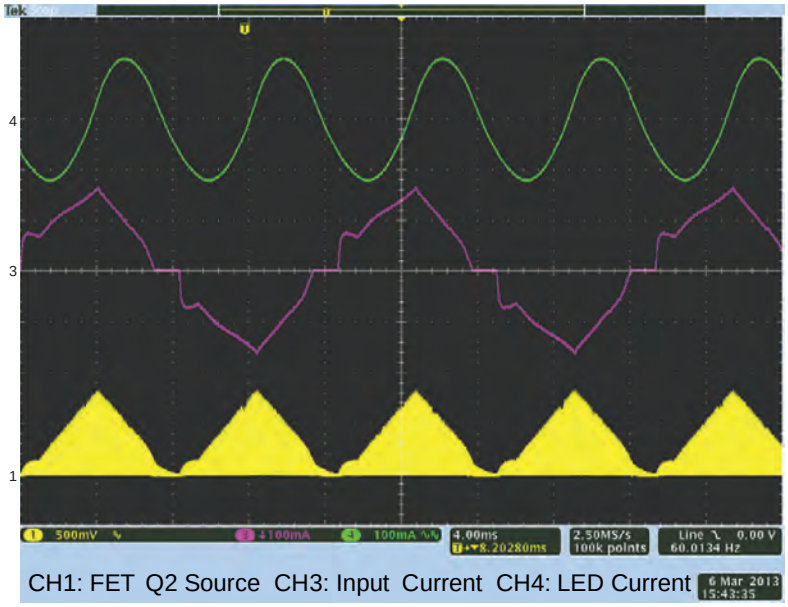
5.4 Output Ripple



Output Ripple (V_{OUT}: 26.2 V, I_{OUT} 380 mA, THD 13.8%)

Figure 6. TPS92075 Buck EVM Typical Operation Waveforms, Non-Dimming

5.5 Turn On Waveform

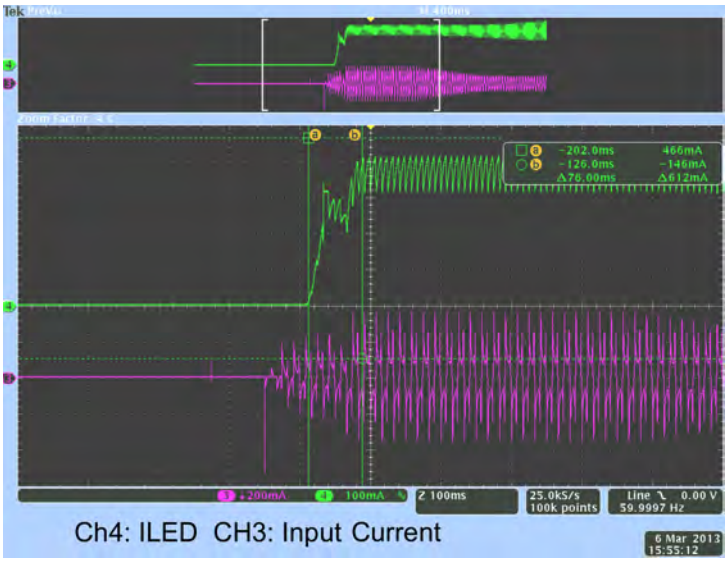


Figure 7. TPS92075 Buck EVM Start-Up

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5.6 Turn Off Waveform

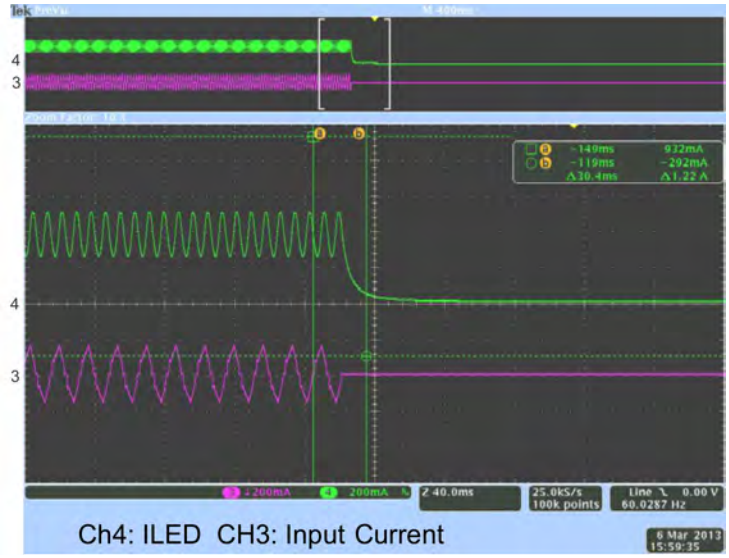

Figure 8. TPS92075 Buck EVM Output Ripple

5.7 Dimming – Lutron Rotary Triac Dimmer at One Position

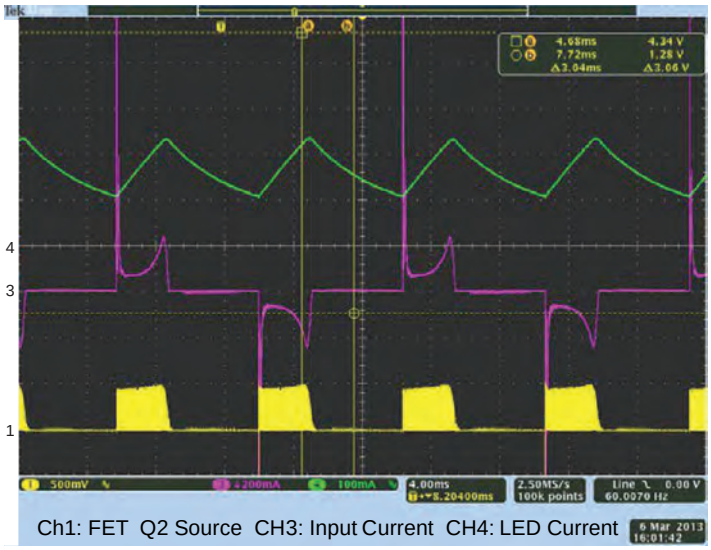

Figure 9. Lutron Leading-Edge Rotary Dimmer, Output = 150 mA, V_{LED} = 26 V

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5.8 Dimming – Leviton 6684 Triac Dimmer at Minimum Position

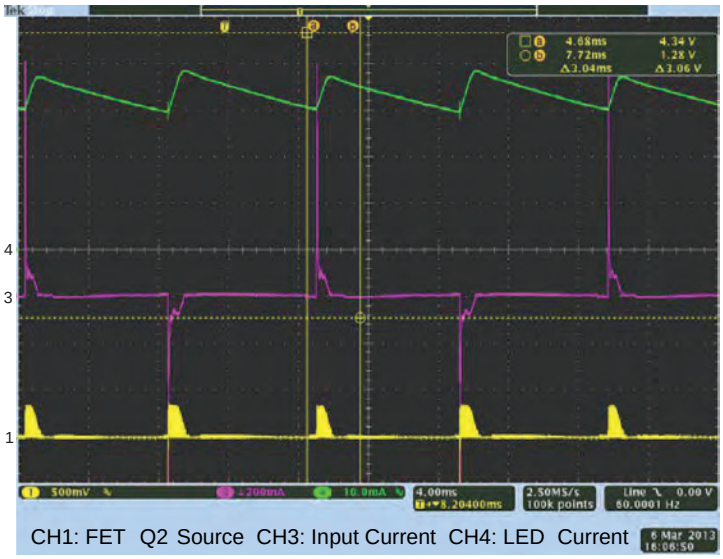
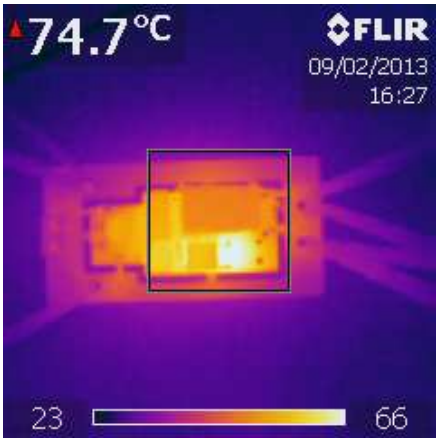


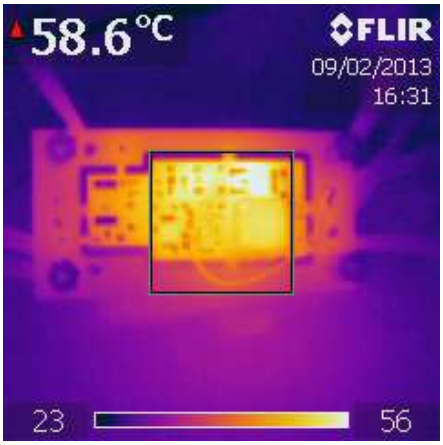
Figure 10. Leviton Leading-Edge 6684, Output = 20 mA, V_{LED} = 26 V

5.9 Thermal Scans



20-Minutes Soak, 9-LED Load,
Top View,
Hottest Point in Box: 74.7°C

Figure 11. Thermal Scan 1



20-Minutes Soak, 9-LED Load,
Bottom View,
Hottest Point in Box: 58.6°C

Figure 12. Thermal Scan 2

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5.10 EMI Scan – 9 LEDs

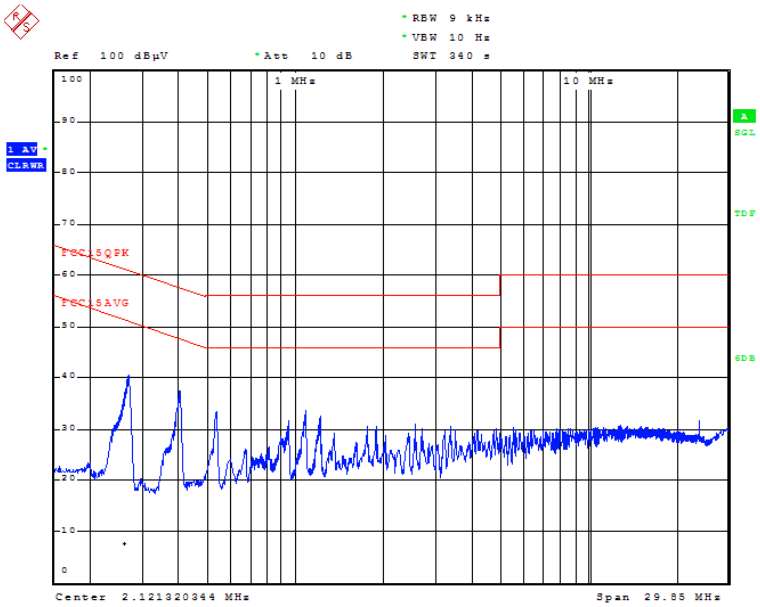

Figure 13. Conducted EMI Scan, 9 LEDs

5.11 Dimmer Testing

Table 2. Dimmer Testing

Make	Model	Flicker-Free	NEMA SSL6 Curve
Decora	RP106	Y	Y
Decora	6631	Y	Y
Leviton	6683	Y	Y
DIVA	DV-600PR-LA	Y	Y
Diva	DVELV-303P	Y	Y
Leviton	6161	Y	Y
Abella	AB-600	Y	Y
Skylark	S-600P	Y	Y
Leviton Trimatron	6684	Y	Y
Lyneo Lx	LX-600-PL	Y	Y
Lyneo Lx	LXLV-600PL-WH	Y	Y
Skylark	S-600	Y	Y
Ariadni	AYLV-600P	Y	Y
Ariadni	AY-600PNL	Y	Y

See Appendix A for a complete summary of results by individual dimmer.

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6 Reference Design, Assembly Drawing, PCB layout, and Bill of Materials

6.1 Reference Design, Assembly Drawing and PCB Layout

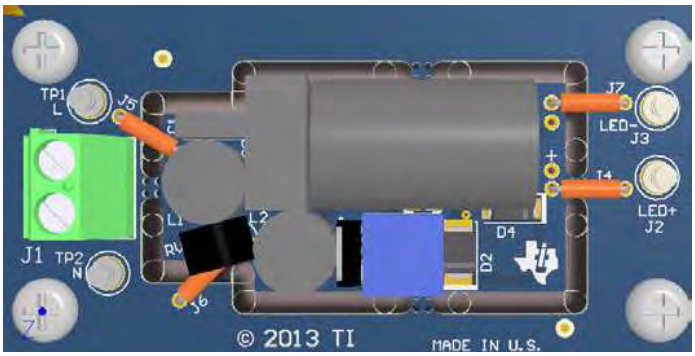

Figure 14. Typical Top Overall View

Figure 15 and Figure 16 show the design of the TPS92075 Buck EVM printed-circuit board.

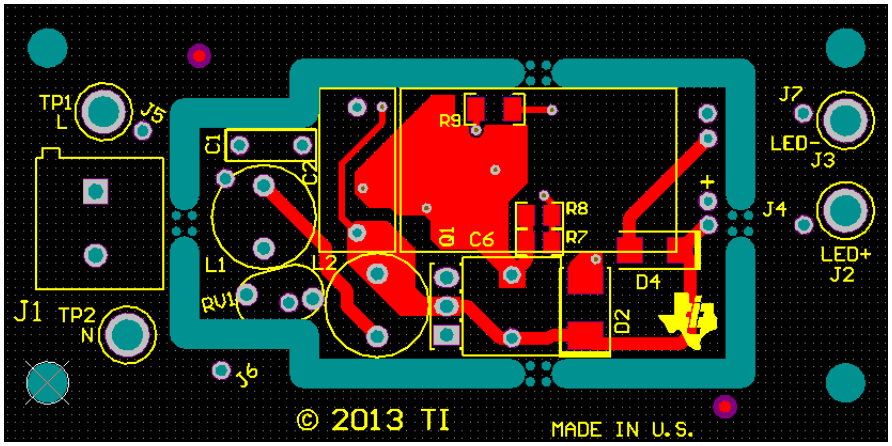

Figure 15. TPS92075 Buck EVM Top Layer Assembly Drawing (Top view)

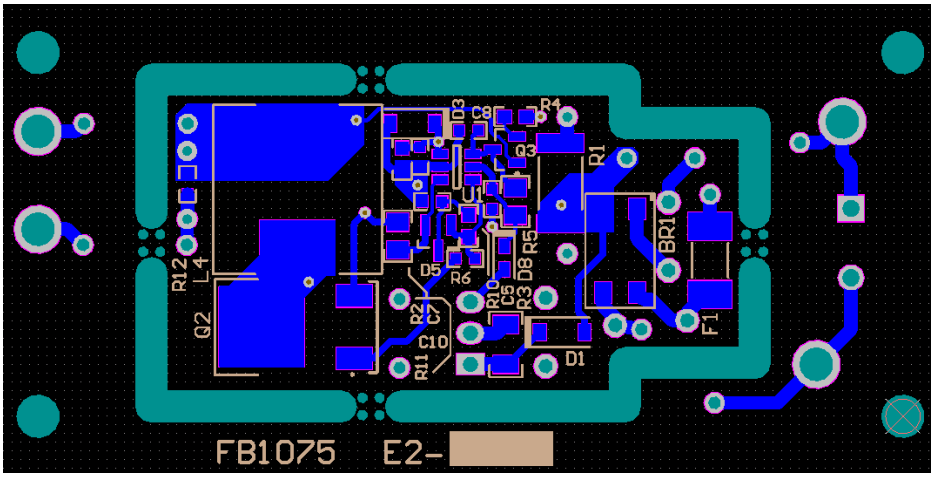

Figure 16. TPS92075 Buck EVM Bottom Assembly Drawing (Bottom view)

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6.2 Bill of Materials

Table 3 is the BOM for this EVM.

Table 3. Bill of Materials

Ref	Qty	Description	Manufacturer	PartNumber
BR1	1	Diode, Switching-Bridge, 400V, 0.5A, MiniDip	Diodes Inc	RH04-T
C1	1	Cap, Film, 0.022uF, 250VDC, 5%, Radial	EPCOS Inc	B32529C3223J
C2	1	Cap, Film, 0.47uF, 250VDC, 10%, Radial	EPCOS Inc	B32521C3474K
C5	1	CAP, CERM, 0.1uF, 25V, +/-10%, X7R, 0603	TDK	C1608X7R1E104K
C6	1	CAP, Film, 0.22uF, 250VDC, 5%, Radial	EPCOS Inc	B32529D3224J
C7	1	CAP, CERM, 4700pF, 16V, X7R, 10%, 0603	Kemet	C0603C472K4RACTU
C8	1	CAP, CERM, 220pF, 50V, +/-5%, C0G/NP0, 0603	MuRata	GRM1885C1H221JA01D
C9	1	CAP, Alum, 680uF, 35V, +/-20%, Radial	Panasonic	EEU-FR1V681
C10	1	CAP, CERM, 0.033uF, 25V, X7R, 20%, 0603	TDK Corporation	C1608X7R1E333M
D1	1	Diode, Zener, 15V, 500mW, SOD-123	ON Semiconductor	MMSZ4702T1G
D2	1	Diode, Ultra Fast, 400V, 1A, SMB	STMicroelectronics	STTH1R04U
D3	1	Diode, Zener, 4.7V, 500mW, SOD-123	Diodes Inc	BZT52C4V7-13-F
D4	1	Diode, TVS, 75V, 400W, SMA	Diodes Inc	SMAJ75A-13-F
D5	1	Diode, Sw Dual, 75V, 350mW, SOT23	Vishay	BAW56-V-GS08
F1	1	Fuse, Fast SSQ, 500mA, 125V, Radial	Bel Fuse Inc	SSQ 500
L1, L2	2	Inductor, 2.2mH, 0.16A, 7.56 ohm, Radial	Bourns Inc.	RL875S-222K
L4	1	Inductor, 470uH, 0.96A, 0.72 ohm, SMD	Coilcraft	MSS1260T-474KLB
Q1	1	MOSFET, N-CH, 600V, 2.5A, IPAK	A & O Semi Inc	AOU3N60
Q2	1	MOSFET, N-CH, 250V, 4.4A, DPAK	Fairchild	FDD6N25TM
Q3	1	Transistor, PNP, 300V, 0.2A, SOT-23	Fairchild	MMBTA92
R1	1	RES, 220 ohm, 5%, 1W, 2512	Vishay	CRCW2512220RJNEG
R2	1	RES, 20.0k ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW060320K0FKEA
R3	1	RES, 402k ohm, 1%, 0.25W, 1206	Vishay-Dale	CRCW1206402KFKEA
R4	1	RES, 590k ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW0603590KFKEA
R6	1	RES, 4.99 ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW06034R99FKEA
R7	1	RES, 1.8 ohm, 5%, 0.125W, 0805	Vishay-Dale	CRCW08051R80JNEA
R8	1	RES, 1.50 ohm, 1%, 0.125W, 0805	Vishay-Dale	CRCW08051R50FKEA
R9	1	RES, 332k ohm, 1%, 0.25W, 1206	Vishay-Dale	CRCW1206332KFKEA
R10	1	RES, 7.68k ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW06037K68FKEA
R11	1	RES, 1.00k ohm, 1%, 0.125W, 0805	Vishay-Dale	CRCW08051K00FKEA
R12	1	RES, 49.9k ohm, 1%, 0.1W, 0603	Vishay-Dale	CRCW060349K9FKEA
R13	1	RES, 0 ohm, 5%, 0.1W, 0603	Vishay-Dale	CRCW06030000Z0EA
U1	1	LED Driver	Texas Instruments	TPS92075DDC
Total	34			
Hardware for EVM				
H1, H2, H3, H4	4	Machine Screw, Round, #4-40 x 1/4, Nylon, Philips panhead	B&F Fastener Supply	NY PMS 440 0025 PH
H5, H6, H7, H8	4	Standoff, Hex, 0.5"L #4-40 Nylon	Keystone	1902C
J1	1	Conn Term Block, 2POS, 5.08mm PCB	Phoenix Contact	1715721
J2,J3, TP1,TP2	4	Terminal, Turret, TH, Double	Keystone	1502-2
J4, J5, J6, J7	4	Jumper Wire, 300mil spacing, Orange, pkg of 200	3M	923345-03-C
Not Populated				
R5	0	RES, 280k ohm, 1%, 0.125W, 0805	Vishay-Dale	CRCW0805280KFKEA
RV1	0	Varistor, 130VAC, 170VDC, 6J, 5mm, Radial	Panasonic Electronic Components	ERZ-V05D201

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Appendix A Table Data

P_{OUT} Eff = Efficiency Calculated using P_{OUT} = P_{OUT} reading on power meter

Calc P_{OUT} Eff = Efficiency Calculated using P_{OUT} = V_{OUT} × I_{OUT}

Test Data ~12 V LED Load

Input Measurement						Load Measurement			Calculation		
Vin (Vrms)	Iin (mArms)	Pin (W)	PF	%ATHD	Vout (Vdc)	Iout (mAdc)	Pout (W)	Pout Eff (%)	Pout Calc (W)	Calc Pout Eff (%)	Loss (W)
90	0.059	5.2	0.974	18.77	12.1	340	4.18	80.4	4.1	79.1	1.02
100	0.056	5.4	0.967	18.03	12.1	355	4.37	80.9	4.3	79.5	1.03
120	0.052	5.9	0.944	19.28	12.2	379.8	4.69	79.5	4.6	78.5	1.21
135	0.05	6.2	0.919	22.22	12.2	394.2	4.88	78.7	4.8	77.6	1.32

Test Data ~15 V LED Load

Input Measurement						Load Measurement			Calculation		
Vin (Vrms)	Iin (mArms)	Pin (W)	PF	%ATHD	Vout (Vdc)	Iout (mAdc)	Pout (W)	Pout Eff (%)	Pout Calc (W)	Calc Pout Eff (%)	Loss (W)
90	0.075	6.7	0.987	15.66	15.1	364.6	5.56	83.0	5.5	82.2	1.14
100	0.07	6.9	0.986	13.8	15.1	376.3	5.75	83.3	5.7	82.3	1.15
120	0.063	7.3	0.969	15.83	15.18	393.5	6.03	82.6	6.0	81.8	1.27
135	0.06	7.7	0.951	17.53	15.2	408.5	6.26	81.3	6.2	80.6	1.44

Test Data ~18 V LED Load

Input Measurement						Load Measurement			Calculation		
Vin (Vrms)	Iin (mArms)	Pin (W)	PF	%ATHD	Vout (Vdc)	Iout (mAdc)	Pout Meas (W)	Pout Eff (%)	Pout Calc (W)	Calc Pout Eff (%)	Loss (W)
90	0.087	7.7	0.987	15.92	18	360	6.56	85.2	6.5	84.2	1.14
100	0.08	7.9	0.987	14.9	18.1	368	6.71	84.9	6.7	84.3	1.19
120	0.072	8.4	0.98	13.94	18.1	387	7.07	84.2	7.0	83.4	1.33
135	0.068	8.9	0.969	15.18	18.2	404.1	7.41	83.3	7.4	82.6	1.49

Test Data ~25 V LED Load

Input Measurement						Load Measurement			Calculation		
Vin (Vrms)	Iin (mArms)	Pin (W)	PF	%THD	Vout (Vdc)	Iout (mAdc)	Pout Meas (W)	Pout Eff (%)	Pout Calc (W)	Calc Pout Eff (%)	Loss (W)
90	0.107	9.5	0.983	18.71	23.8	341.2	8.17	86.0	8.1	85.5	1.33
100	0.1	9.8	0.986	16.84	23.9	354	8.5	86.7	8.5	86.3	1.3
120	0.088	10.5	0.987	13.62	23.94	373.9	9	85.7	9.0	85.2	1.5
135	0.083	11.1	0.983	12.87	24	391.6	9.45	85.1	9.4	84.7	1.65

Test Data ~30 V LED Load

Input Measurement						Load Measurement			Calculation		
Vin (Vrms)	Iin (mArms)	Pin (W)	PF	%THD	Vout (Vdc)	Iout (mAdc)	Pout Meas (W)	Pout Eff (%)	Pout Calc (W)	Calc Pout Eff (%)	Loss (W)
90	0.128	11.3	0.973	23.45	29.7	330.9	9.86	87.3	9.8	87.0	1.44
100	0.118	11.5	0.979	21.04	29.7	339.2	10.1	87.8	10.1	87.6	1.4
120	0.105	12.4	0.986	16.26	29.8	363.6	10.9	87.9	10.8	87.4	1.5
135	0.1	13.3	0.989	13.6	29.9	386	11.6	87.2	11.5	86.8	1.7

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Test Data ~35 V LED Load

Input Measurement						Load Measurement			Calculation		
Vin (Vrms)	Iin (mArms)	Pin (W)	PF	%THD	Vout (Vdc)	Iout (mAdc)	Pout Meas (W)	Pout Eff (%)	Pout Calc (W)	Calc Pout Eff (%)	Loss (W)
90	0.143	12.5	0.962	28.16	35.3	308.2	10.9	87.2	10.9	87.0	1.6
100	0.136	13.3	0.972	23.7	35.4	330	11.7	88.0	11.7	87.8	1.6
120	0.122	14.3	0.984	17.96	35.5	354.4	12.6	88.1	12.6	88.0	1.7
135	0.113	15.1	0.989	14.6	35.6	371.7	13.3	88.1	13.2	87.6	1.8

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Appendix B Table Data – Dimmer Testing

7 LED Load

Dimmer: Lutron	NonDim Max-->	381	Maestro Duo	MAW-600H-LA
Input Voltage	Output Current	% Output Current	Input Power	Output Voltage
25.8	27.4	7.19	0.71	18.9
50.6	118.4	31.08	3.35	19.9
69.7	163.1	42.81	4.7	20.1
89.4	213.8	56.12	6.02	20.4
112.3	300	78.74	7.82	20.8

Dimmer: L*	NonDim Max-->	381	Decora	RP106
Input Voltage	Output Current	% Output Current	Input Power	Output Voltage
17.9	8.9	2.34	0.048	17.5
50	76.4	20.05	2.33	19.5
70.7	129.6	34.02	3.89	19.9
90.5	204.5	53.67	5.8	20.3
118.5	350	91.86	8.74	20.9

Dimmer: L*	NonDim Max-->	381	Skylark Contour	CTCL-153PDH
Input Voltage	Output Current	% Output Current	Input Power	Output Voltage
25.4	19.2	5.04	0.586	18.7
50.6	107.1	28.11	3.07	19.6
70.7	153.4	40.26	4.47	20.1
90	202	53.02	5.76	20.3
111.1	280	73.49	7.38	20.7

Dimmer: Leviton	NonDim Max-->	381	Decora	6631
Input Voltage	Output Current	% Output Current	Input Power	Output Voltage
18.80	3.35	0.88	0.10	17.80
50.30	107.50	28.22	3.07	19.80
70.40	153.40	40.26	4.47	20.10
90.60	205.60	53.96	5.83	20.40
114.50	302.30	79.34	7.77	20.80

Dimmer: Leviton	NonDim Max-->	381	Leviton	6683
Input Voltage	Output Current	% Output Current	Input Power	Output Voltage
17.40	0.28	0.07	0.03	17.10
50.50	106.30	27.90	3.06	19.80
70.20	151.90	39.87	4.44	20.10
90.60	204.40	53.65	5.81	20.40
118.80	341.70	89.69	11.70	29.70

Dimmer: Lutron	NonDim Max-->	381	DIVA	DV-600PR-LA
Input Voltage	Output Current	% Output Current	Input Power	Output Voltage
28.00	32.20	8.45	0.91	19.00
50.30	108.80	28.56	3.11	19.80
70.10	154.10	40.45	4.47	20.10
90.10	205.10	53.83	5.83	20.40
112.60	290.00	76.12	7.54	20.60

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Dimmer: Lutron	NonDim Max-->	381	Diva	DVELV-303P
Input Voltage	Output Current	% Output Current	Input Power	Output Voltage
31.10	49.70	13.04	1.22	19.20
50.00	124.20	32.60	3.07	19.90
70.10	180.70	47.43	4.47	20.30
90.40	236.80	62.15	5.88	20.50
112.10	303.00	79.5	3 7.53	20.80

Dimmer: Leviton	NonDim Max-->	381	Leviton	6161
Input Voltage	Output Current	% Output Current	Input Power	Output Voltage
22.87	21.80	5.72	0.50	18.60
38.40	74.00	19.42	2.06	19.50
53.20	121.90	31.99	3.47	19.90
83.00	192.80	50.60	5.51	20.30
114.40	306.10	80.34	7.87	20.80

Dimmer: Lutron	NonDim Max-->	381	Abella	AB-600
Input Voltage	Output Current	% Output Current	Input Power	Output Voltage
30.10	42.30	11.10	1.07	19.10
46.70	113.20	29.71	3.15	19.80
70.10	169.80	44.57	4.86	20.20
91.60	226.70	59.50	6.37	20.50
110.60	298.00	78.22	7.88	20.80

Dimmer: Lutron	NonDim Max-->	381	Skylark	S-600P
Input Voltage	Output Current	% Output Current	Input Power	Output Voltage
25.00	2.30	0.60	0.12	25.40
50.50	90.40	23.73	3.36	27.90
70.80	143.80	37.74	5.42	28.40
90.20	194.60	51.08	7.22	28.90
111.70	275.20	72.23	9.70	29.40

Dimmer: Leviton	NonDim Max-->	381	Trimatron	6684
Input Voltage	Output Current	% Output Current	Input Power	Output Voltage
27.40	10.70	2.81	0.42	26.20
50.40	88.00	23.10	3.28	27.80
70.40	142.20	37.32	5.35	28.40
90.40	194.60	51.08	7.24	28.80
118.70	339.80	89.19	11.60	29.70

Dimmer: Lutron	NonDim Max-->	381	Lyneo Lx	LX-600-PL
Input Voltage	Output Current	% Output Current	Input Power	Output Voltage
36.20	28.70	7.53	1.13	26.80
50.40	86.50	22.70	3.21	27.80
70.00	141.50	37.14	5.30	28.40
90.70	196.00	51.44	7.25	28.80
114.70	294.40	77.27	10.22	29.40

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Dimmer: Lutron	NonDim Max-->	381	Lyneo Lx	LXLV-600PL-WH
Input Voltage	Output Current	% Output Current	Input Power	Output Voltage
26.401	8.20	2.15	0.31	26.10
50.70	92.10	24.17	3.42	27.90
70.20	143.20	37.59	5.38	28.40
90.00	195.10	51.21	7.23	28.80
112.00	277.80	72.91	9.76	29.40
Dimmer: Lutron	NonDim Max-->	381	Skylark	S-600
Input Voltage	Output Current	% Output Current	Input Power	Output Voltage
23.70	0.14	0.04	43.10	24.20
50.10	86.00	22.57	3.20	27.80
70.10	141.00	37.01	5.29	28.40
90.40	194.20	50.97	7.20	28.80
110.10	266.50	69.95	9.43	29.30
Dimmer: Lutron	NonDim Max-->	381	Ariadni	AYLV-600P
Input Voltage	Output Current	% Output Current	Input Power	Output Voltage
25.70	5.93	1.56	0.23	26.00
50.40	89.30	23.44	3.33	27.90
70.00	142.70	37.45	5.38	28.40
90.20	196.00	51.44	7.28	28.90
111.70	276.10	72.47	9.73	29.40
Dimmer: Lutron	NonDim Max-->	381	Ariadni	AY-600PNL
Input Voltage	Output Current	% Output Current	Input Power	Output Voltage
29.207	14.10	3.70	0.55	26.40
50.00	88.20	23.15	3.29	27.90
70.80	144.70	37.98	5.44	28.50
90.80	197.20	51.76	7.33	28.90
113.00	283.00	74.28	9.97	29.50

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Appendix C EVM

Figure 17 illustrates the EVM board and an LED light as a size reference.

Figure 17. EVM Board and LED Bulb

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EVALUATION BOARD/KIT/MODULE (EVM) ADDITIONAL TERMS

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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.

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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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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.

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