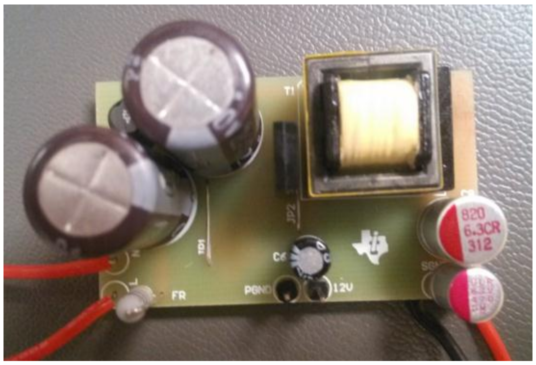
TIDA-00583 Test Report

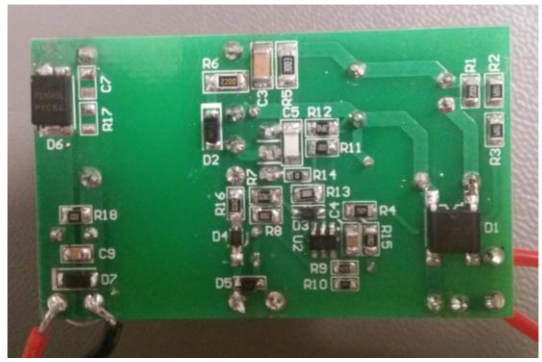
TEXAS INSTRUMENTS

May, 2015

1 Introduction

This design is a Flyback converter which can operate in very low AC line input (Minimum 45Vac) and provide a regulated, fully-isolated 5V@1.6A output for communication model of E-meter, as well as another low-power 12V non-isolated output. Featuring TI's UCC28722 PSR controller which provides accurate voltage and constant current regulation with primary-side feedback, and BJT power switch the design eliminates opto-coupler feedback circuits and reduces system cost.





2 Description

The UCC28722 is a PSR flyback controller which provides accurate voltage and constant current regulation with primary-side feedback, eliminating the need for opto-coupler feedback circuits. The controller operates in discontinuous conduction mode with valley-switching to minimize switching losses. The modulation scheme is a combination of frequency and primary peak current modulation to provide high conversion efficiency across the load range. The control law provides a wide-dynamic operating range of output power which allows the power designer to achieve low stand-by power.

2.1 Typical Applications

- E-Meter Power Supply
- Standby Supply for TV and Desktop
- White Goods

2.2 Features

- Wide Input range from 45Vac to 265Vac
- Multi outputs with 5V/1.6A (2.2A peak) and 12V/10mA(non-isolated)
- Average 4-point efficiency of 73.8% or higher
- 72% or higher efficiency at full power (5V/2.2A)
- Low output ripple at full load, less than 150mV
- Low system cost due to use of PSR control, BJT switch and single layer PCB

3 Electrical Performance Specifications

Table 1. Electrical Performance Specifications

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Input Characteristics					
Voltage range		45		265	V
Maximum input current	VIN = 45Vac, Io1= 1.6A, Io2 = 10mA			0.435	A
No load input current	VIN = 265Vac, no load		2.8		mA
Output Characteristics					
Output voltage, Vo1	Io1 = 1.6A		5		V
Output load current, Io1			1.6	2.2	A
Output voltage regulation	Line Regulation: Input voltage = 90V to 265V		1.5		%
	Load Regulation of 5V: Vin = 90V to 265V, Io1 = 0A to 2.2A, Io2 = 0mA to 10mA			6.7	%
	Load Regulation of 5V: Vin = 90V to 265V, Io1 = 0A to 2.2A, Io2 = 0mA to 10mA			7.3	%
Output voltage ripple	At VIN = 90Vac, Io1 = 1.65A			135	mVpp
Output over current				2.25	A

4 Schematic

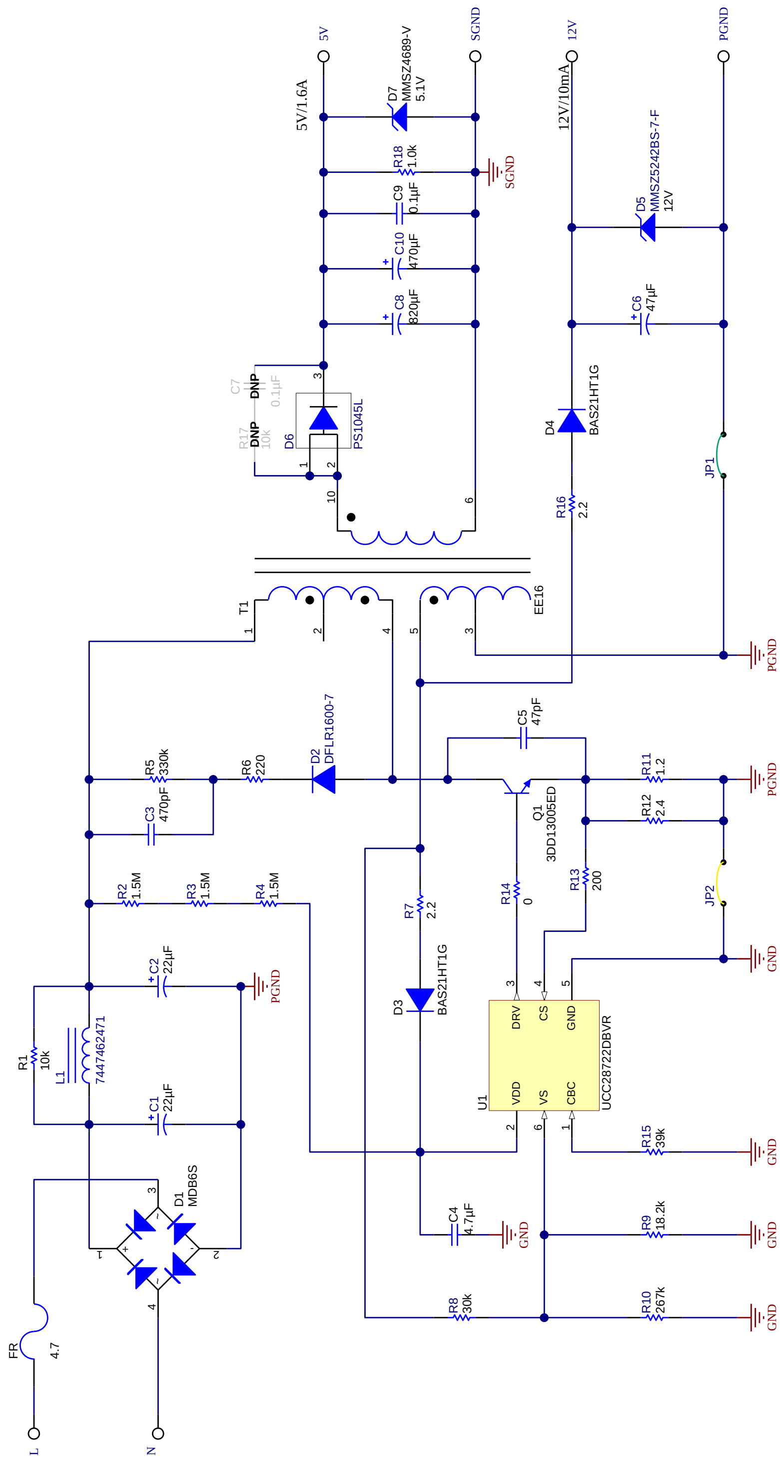


Figure 1. Schematic

5 Performance Data and Typical Characteristic Curves

5.1 Efficiency

5.1.1 Efficiency Data

Table 2. Efficiency Data Test at Board End

Vin	FREQ	Pin(W)	Vo1(V)	Io1(A)	Vo2(V)	Io2(A)	EFF	Avg
265	50	0.460	5.308	0.000	9.703	0.010	20.93%	-
265	50	1.846	4.974	0.219	10.953	0.010	64.95%	-
265	50	3.911	4.986	0.549	12.160	0.010	73.12%	74.00%
265	50	7.581	5.015	1.100	12.541	0.010	74.40%	
265	50	11.361	5.037	1.650	12.951	0.010	74.30%	
265	50	15.190	5.061	2.200	13.334	0.010	74.15%	
230	50	0.403	5.307	0.000	9.693	0.010	23.88%	-
230	50	1.746	4.976	0.219	10.943	0.010	68.71%	-
230	50	3.847	4.987	0.549	12.135	0.010	74.35%	74.74%
230	50	7.507	5.016	1.100	12.529	0.010	75.16%	
230	50	11.283	5.037	1.650	12.941	0.010	74.80%	
230	50	15.089	5.060	2.200	13.318	0.010	74.63%	
180	50	0.337	5.302	0.000	9.734	0.010	28.70%	-
180	50	1.653	4.976	0.219	10.975	0.010	72.59%	-
180	50	3.747	4.986	0.549	12.123	0.010	76.31%	75.45%
180	50	7.462	5.013	1.100	12.512	0.010	75.56%	
180	50	11.238	5.042	1.650	12.928	0.010	75.17%	
180	50	15.062	5.059	2.200	13.297	0.010	74.76%	
115	50	0.283	5.297	0.000	9.758	0.010	34.26%	-
115	50	1.584	4.976	0.219	10.943	0.010	75.71%	-
115	50	3.710	4.988	0.549	12.055	0.010	77.08%	74.93%
115	50	7.516	5.007	1.100	12.473	0.010	74.92%	
115	50	11.376	5.035	1.650	12.873	0.010	74.16%	
115	50	15.267	5.045	2.200	13.230	0.010	73.55%	
90	50	0.270	5.294	0.000	9.764	0.010	35.91%	-
90	50	1.574	4.974	0.219	10.902	0.010	76.14%	-
90	50	3.732	4.986	0.549	12.016	0.010	76.58%	73.84%
90	50	7.606	5.002	1.100	12.445	0.010	73.95%	
90	50	11.567	5.027	1.650	12.834	0.010	72.82%	
90	50	15.587	5.043	2.200	13.183	0.010	72.01%	

5.1.2 Standby Power

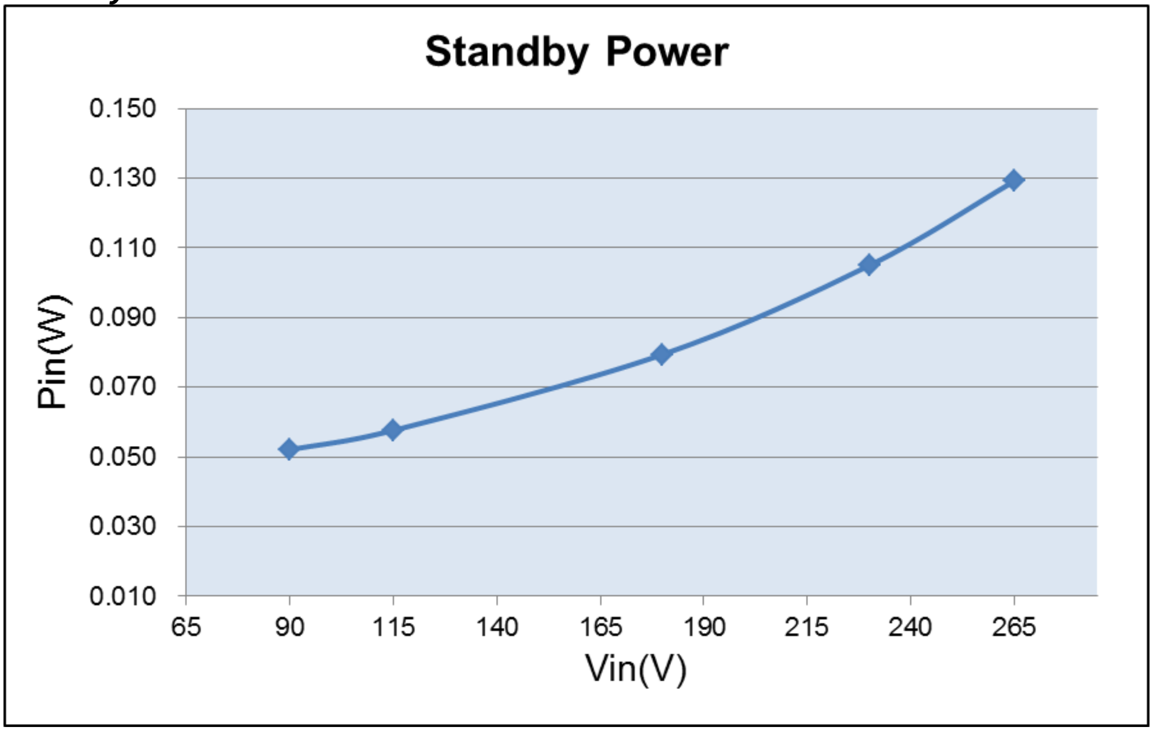


Figure 2. Standby Power

5.1.3 Efficiency Vs Load Curve at Different Lines

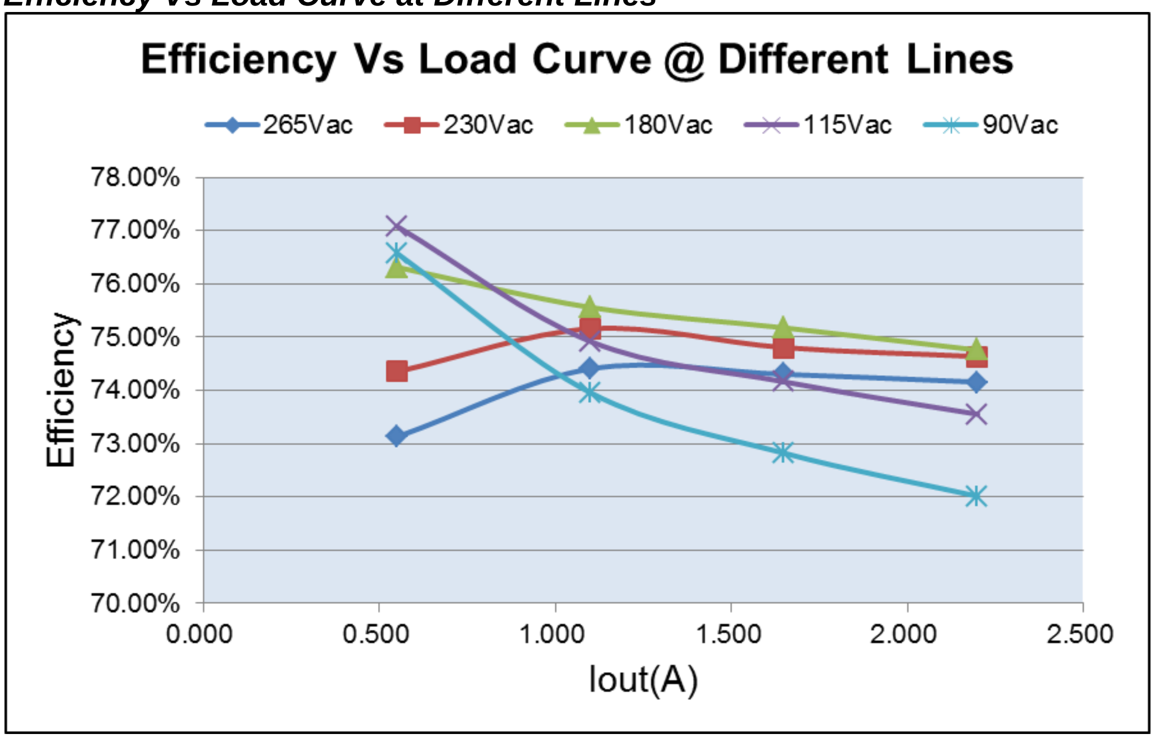


Figure 3. Efficiency Vs Load Curve at Different Lines

5.1.4 *Efficiency Vs Line at different Loads*

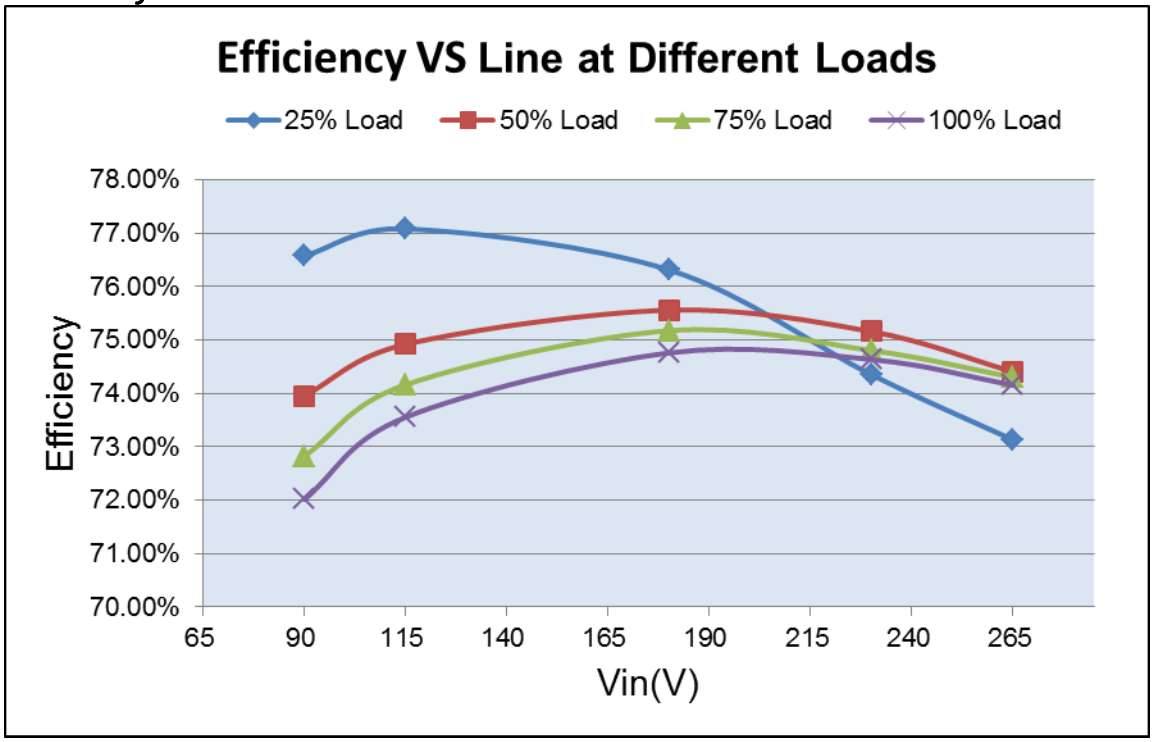


Figure 4. Efficiency Vs Line Curve at Different Loads

5.1.5 *Average Efficiency*

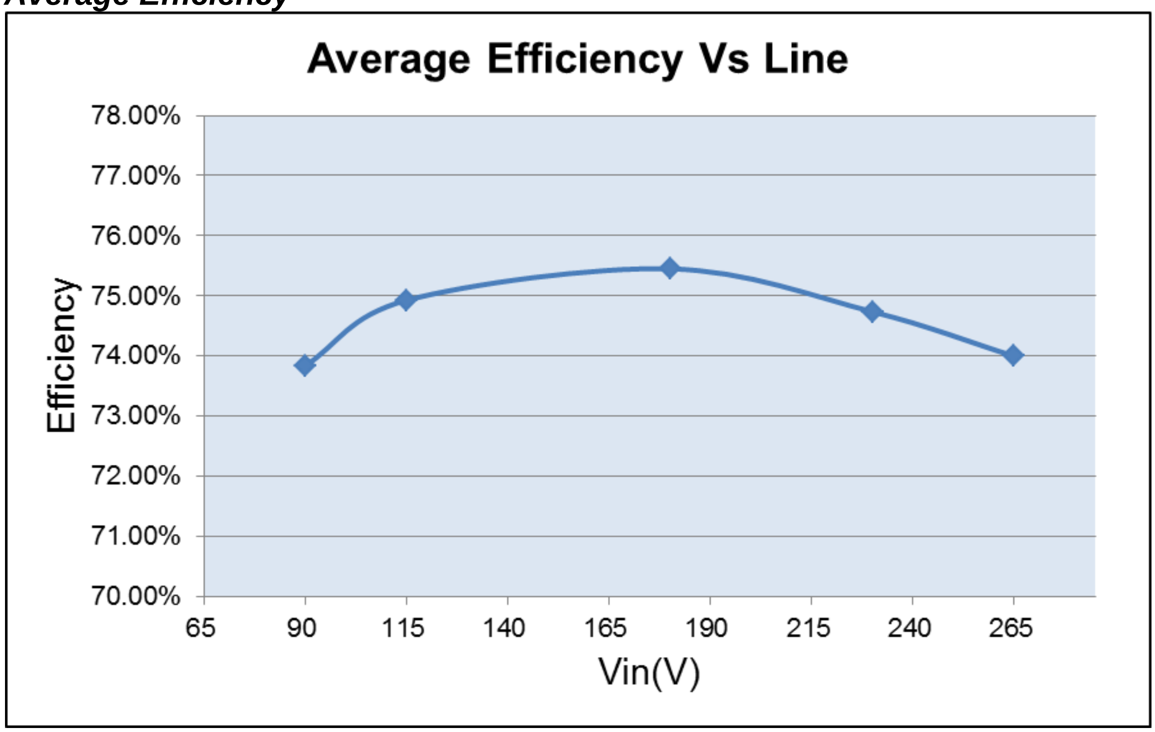


Figure 5. Average Efficiency Vs Line

5.2 Load Regulation

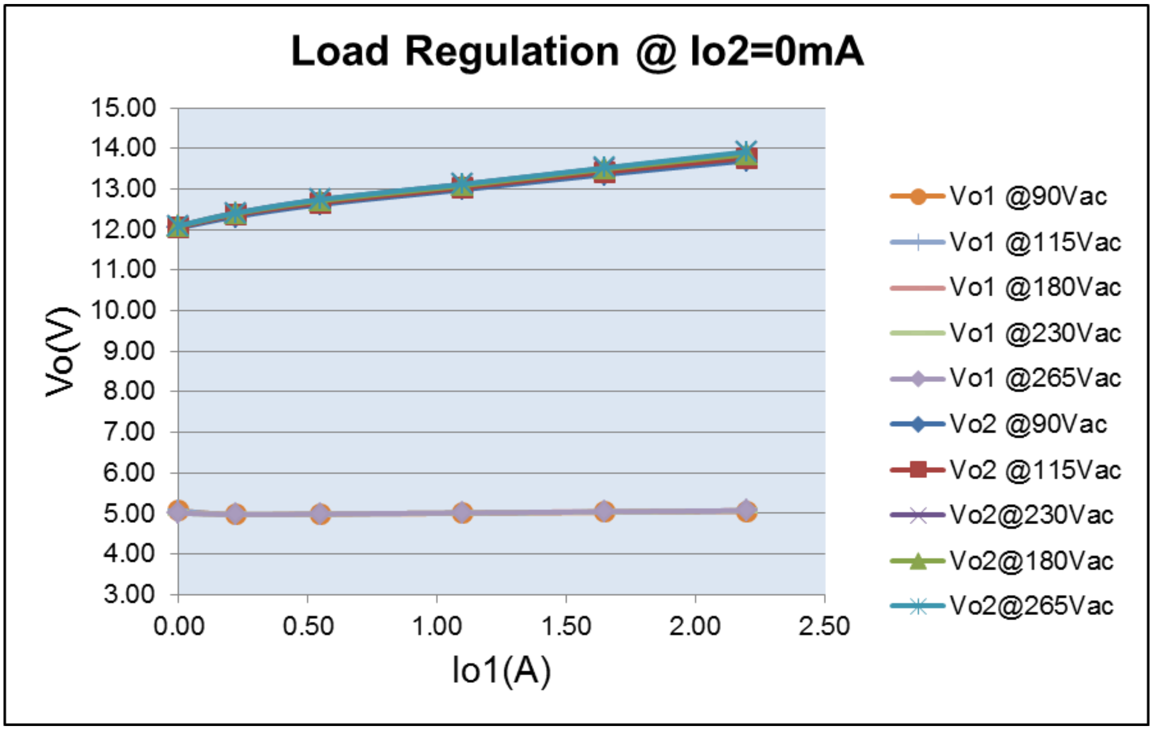


Figure 6. Load Regulation at Io2 = 0mA

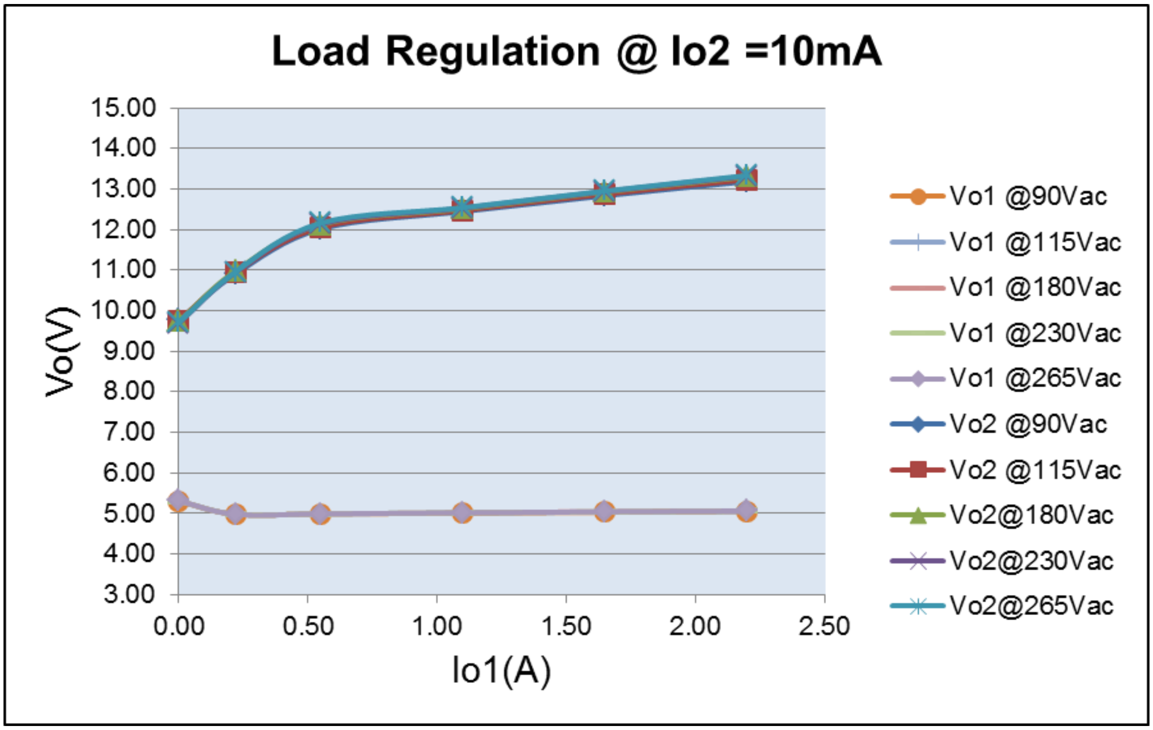
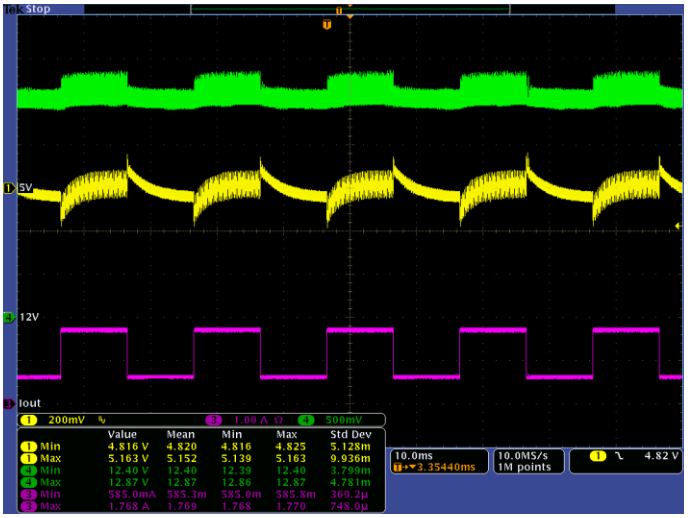


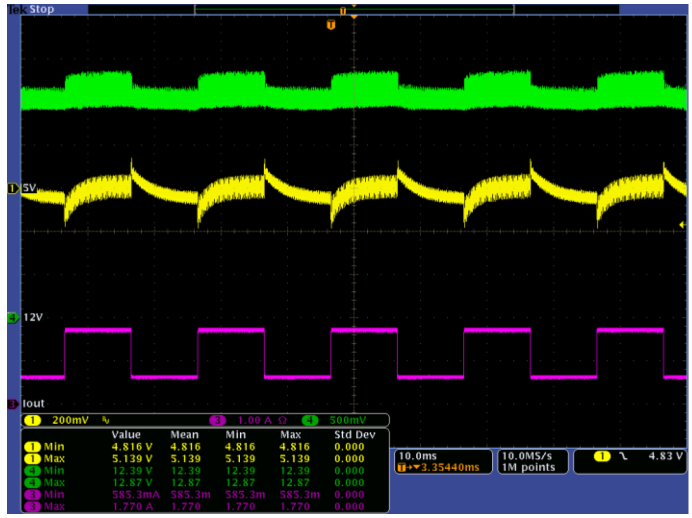
Figure 7. Load Regulation at Io2 = 10mA

5.3 Transient Response

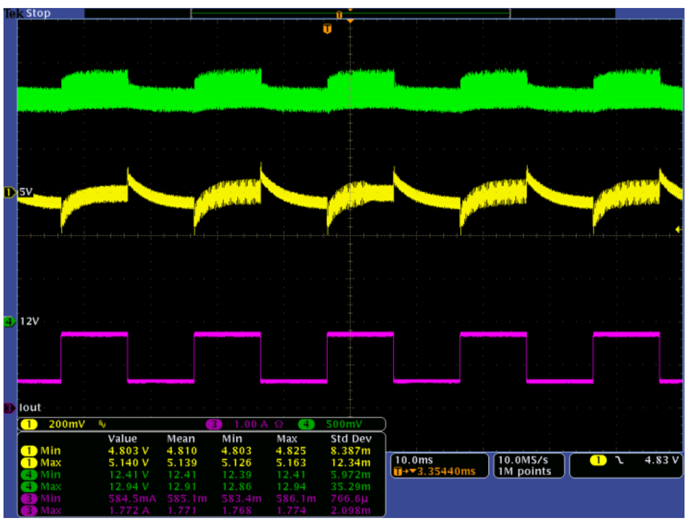
5.3.1 25% Load – 75% Load



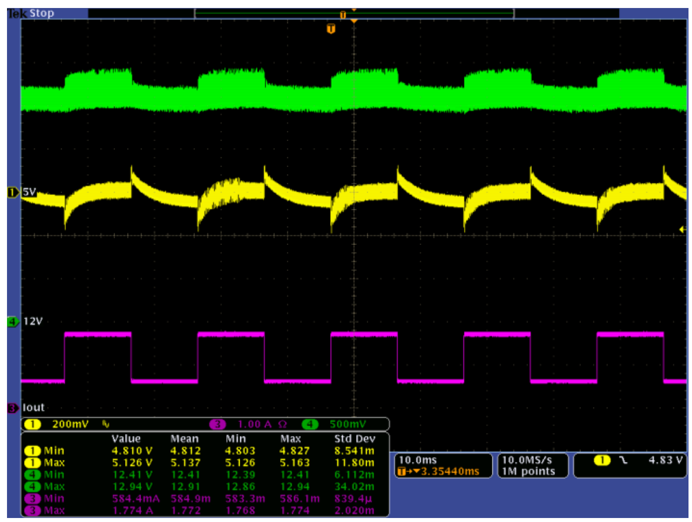
Vin = 90Vac



Vin = 115Vac



Vin = 230Vac



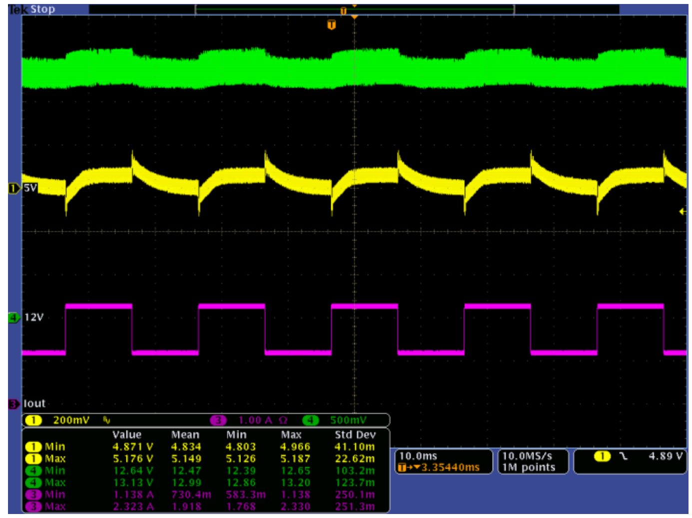
Vin = 265Vac

Figure 8. Load Transient From 25% Load to 75% Load

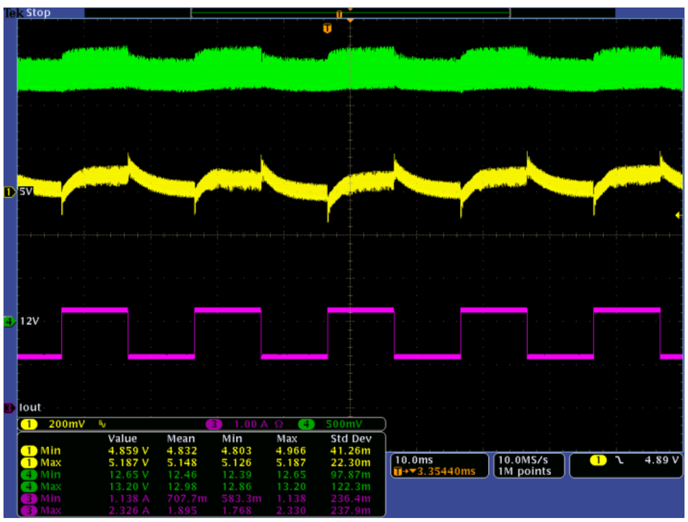
Test condition: 0.55-1.65A, 0.25A/us, 10ms cycle, 100cm cable
CH1: 5V output voltage, 0.2V/div,5V offset
CH3: Output current, 0.5A/div
CH4:12V output current, 0.5V/div, 10V offset

5.3.2 Half Load – Full Load

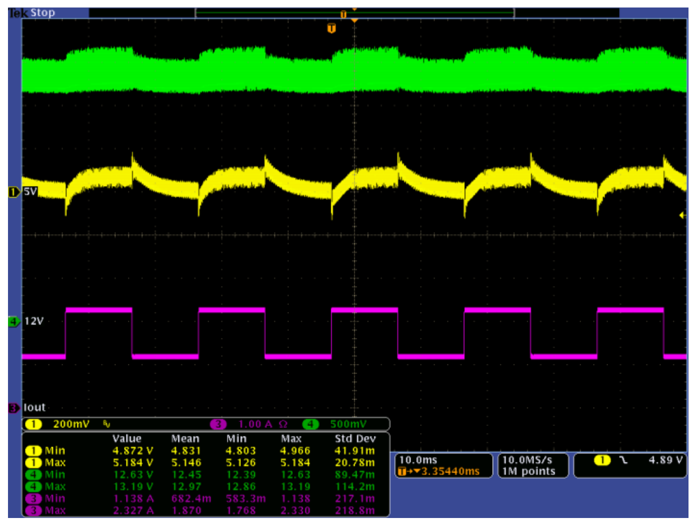
Vin = 90Vac



Vin = 115Vac



Vin = 230Vac



Vin = 265Vac

Figure 9. Load Transient From Half Load to Full Load

Test condition: 1.1-2.2A, 0.25A/us, 10ms cycle, 100cm cable
CH1: 5V output voltage, 0.2V/div,5V offset
CH3: Output current, 0.5A/div
CH4:12V output voltage, 0.5V/div, 10V offset

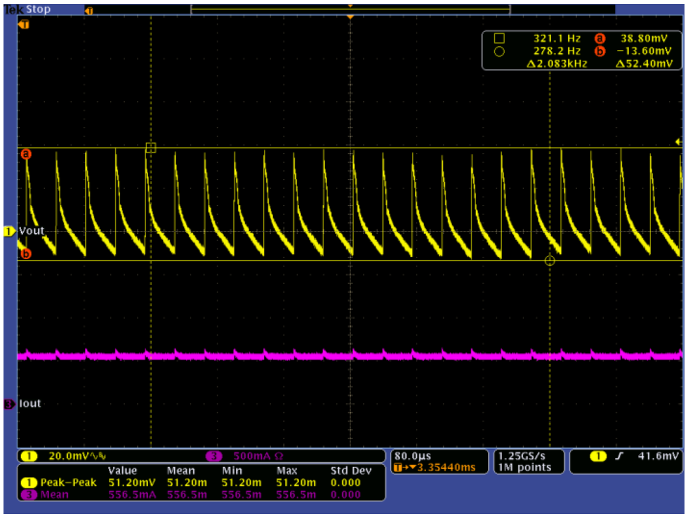
5.4 Output Ripple

Table 3 shows the output voltage ripple at different line and load conditions, measured across the noise decoupling caps at the end of the 100cm output cable.

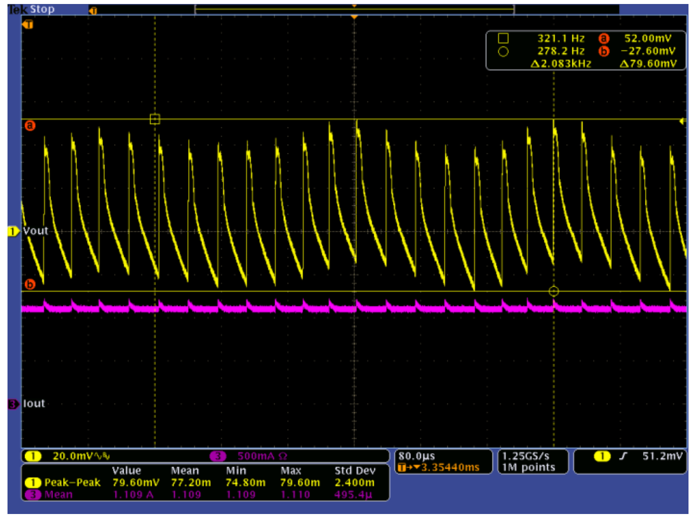
Table 3. Output Voltage Ripple

Input Voltage(Vac)	Output Current(A)	Output Voltage Ripple(mVpp)	Pass/Fail
90	0.55	52.4	Pass
90	1.10	76.9	Pass
90	1.65	135.6	Pass
90	2.20	100.0	Pass
115	0.55	63.2	Pass
115	1.10	71.2	Pass
115	1.65	109.2	Pass
115	2.20	76.0	Pass
230	0.55	56.0	Pass
230	1.10	79.2	Pass
230	1.65	116.4	Pass
230	2.20	88.0	Pass
265	0.55	54.5	Pass
265	1.10	84.8	Pass
265	1.65	80.8	Pass
265	2.20	102.4	Pass

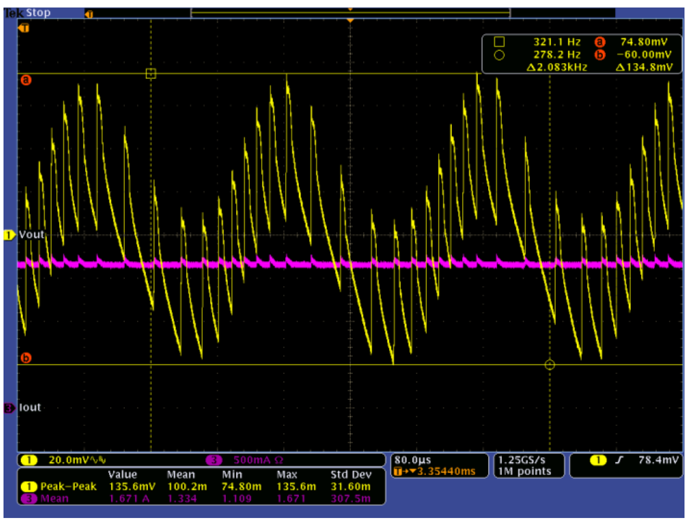
5.4.1 90Vac Input



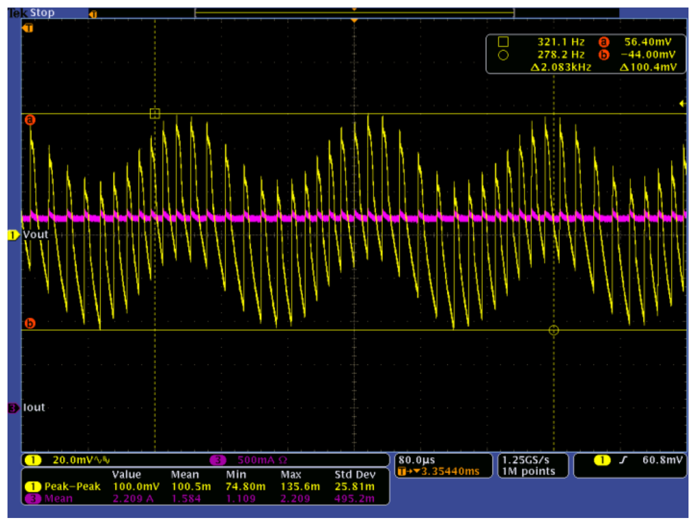
Iout = 0.55A



Iout = 1.10A



Iout = 1.65A

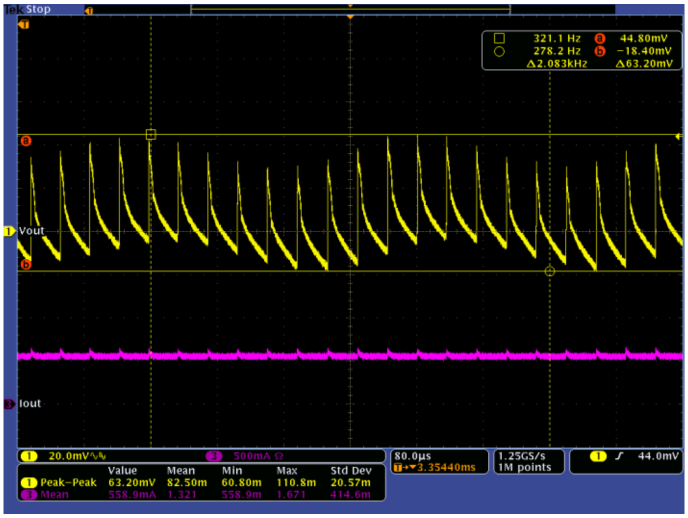


Iout = 2.2A

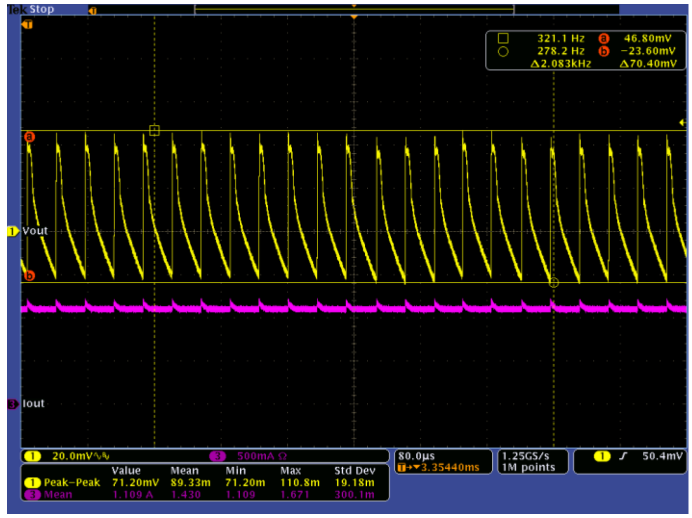
Figure 10. Output Ripple at 90Vac Input

Test condition: 100cm cable end with an external 10-µF aluminum capacitor and 1-µF ceramic noise decoupling capacitor network connected to the output to measure the output ripple and noise.
CH1: 5V output voltage, 20mV/div, AC couple, 20MHz Bandwidth
CH3: Output current, 0.5A/div

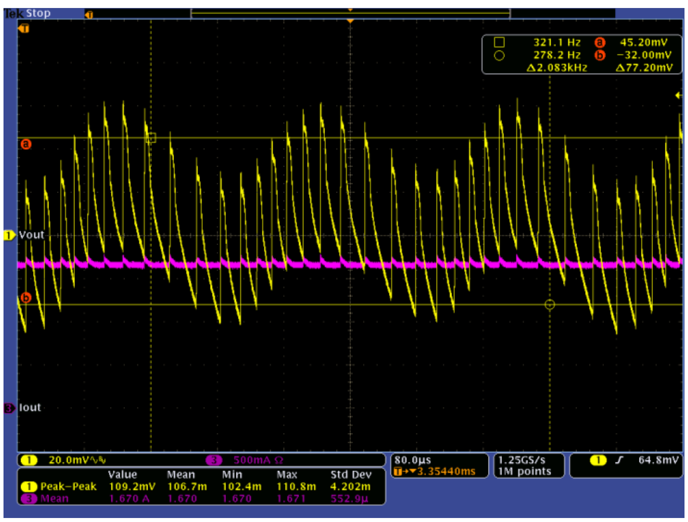
5.4.2 115Vac Input



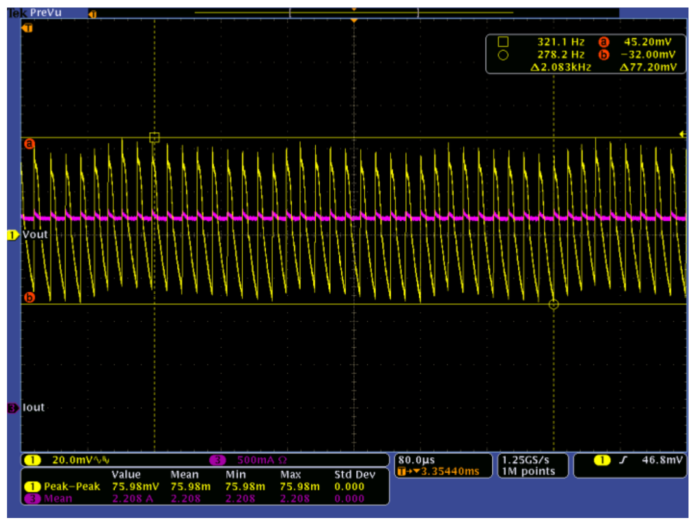
Iout = 0.55A



Iout = 1.10A



Iout = 1.65A

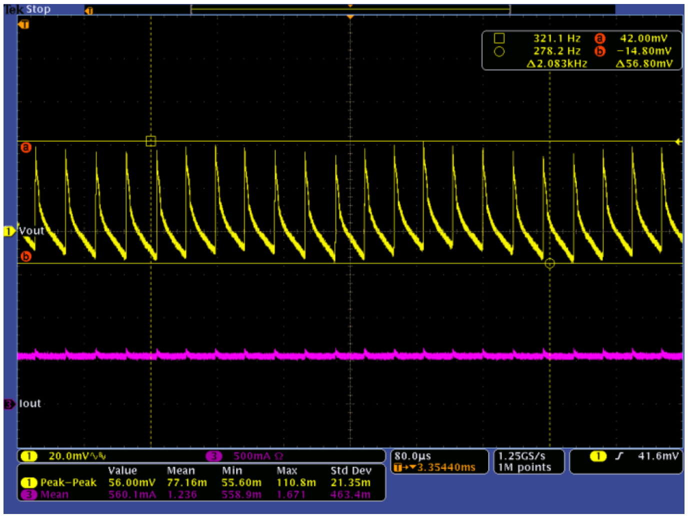


Iout = 2.2A

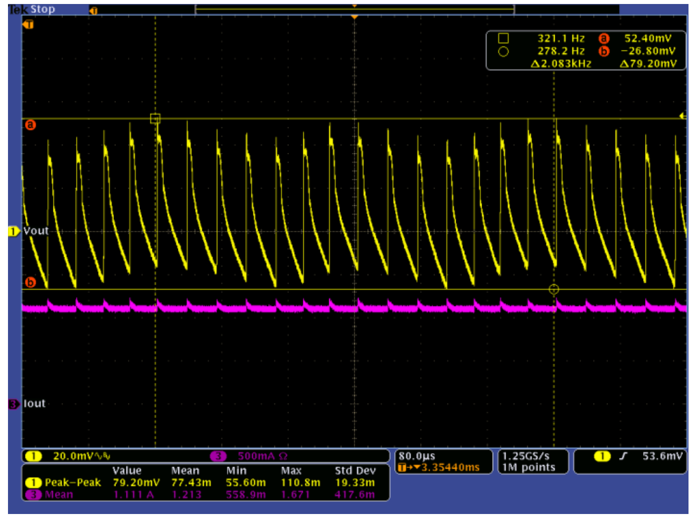
Figure 11. Output Ripple at 115Vac Input

Test condition: 100cm cable end with an external 10-µF aluminum capacitor and 1-µF ceramic noise decoupling capacitor network connected to the output to measure the output ripple and noise.
CH1: 5V output voltage, 20mV/div, AC couple, 20MHz Bandwidth
CH3: Output current, 0.5A/div

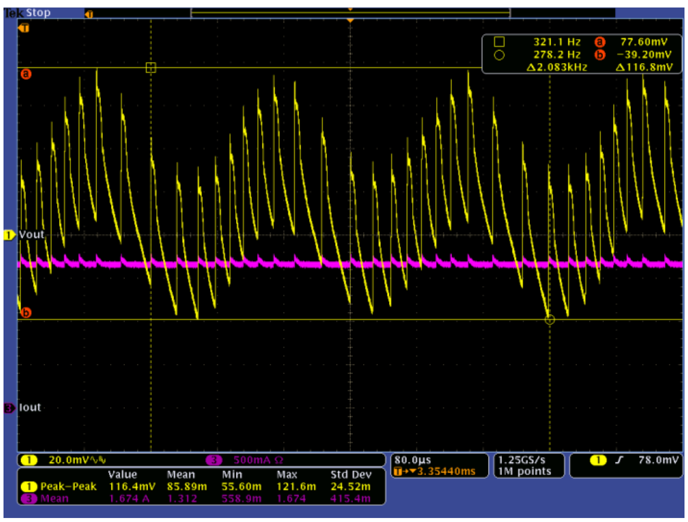
5.4.3 230Vac Input



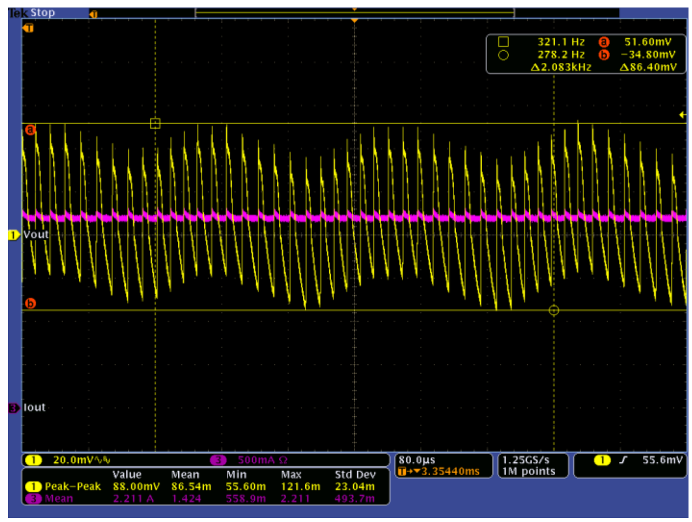
Iout = 0.55A



Iout = 1.10A



Iout = 1.65A

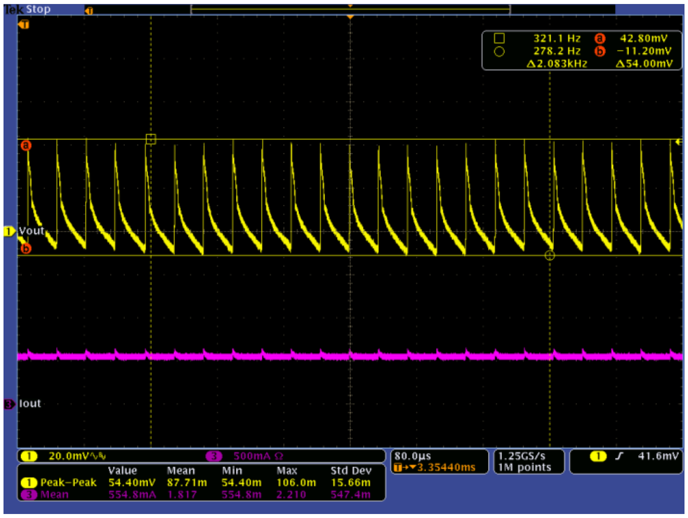


Iout = 2.2A

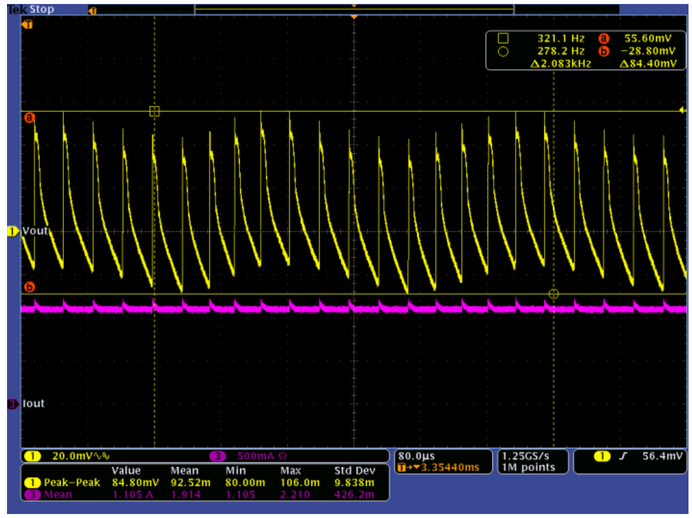
Figure 12. Output Ripple at 230Vac Input

Test condition: 100cm cable end with an external 10-µF aluminum capacitor and 1-µF ceramic noise decoupling capacitor network connected to the output to measure the output ripple and noise.
CH1: 5V output voltage, 20mV/div, AC couple, 20MHz Bandwidth
CH3: Output current, 0.5A/div

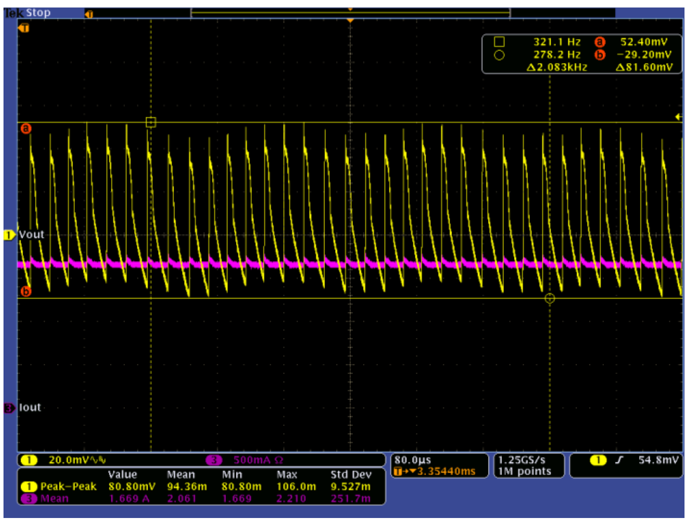
5.4.4 265Vac Input



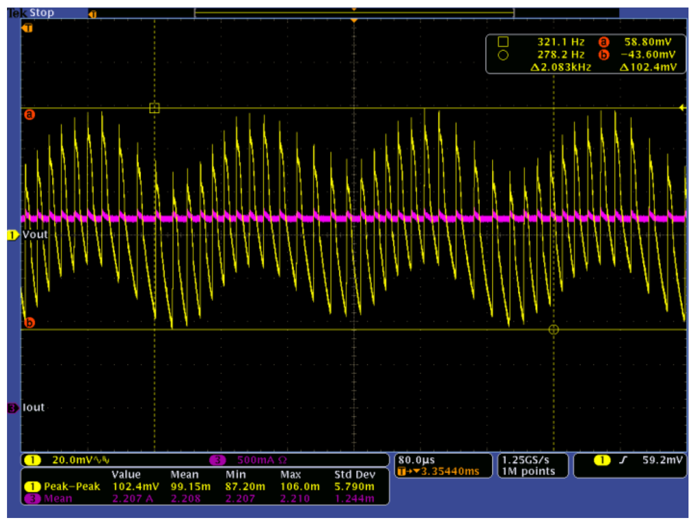
Iout = 0.55A



Iout = 1.10A



Iout = 1.65A



Iout = 2.2A

Figure 13. Output Ripple at 265Vac Input

Test condition: 100cm cable end with an external 10-µF aluminum capacitor and 1-µF ceramic noise decoupling capacitor network connected to the output to measure the output ripple and noise.
CH1: 5V output voltage, 20mV/div, AC couple, 20MHz Bandwidth
CH3: Output current, 0.5A/div

5.5 Turn On Waveform

5.5.1 Input Rush Current

Figure 16 shows the maximum Input rush at high line and full load condition.

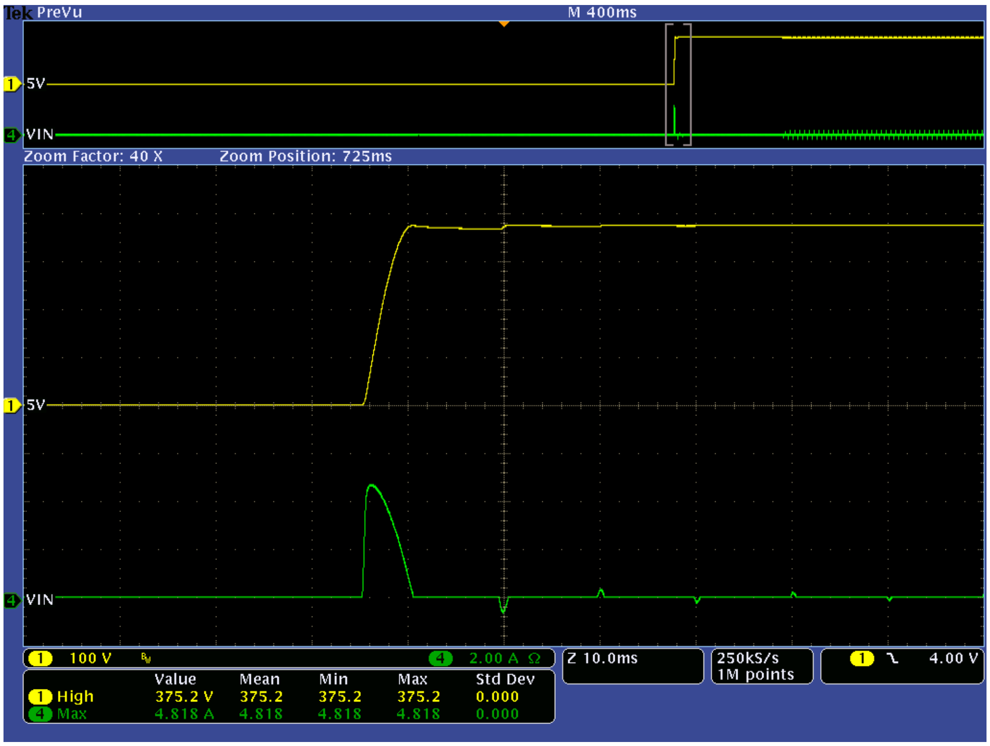


Figure 14. Input Rush Current

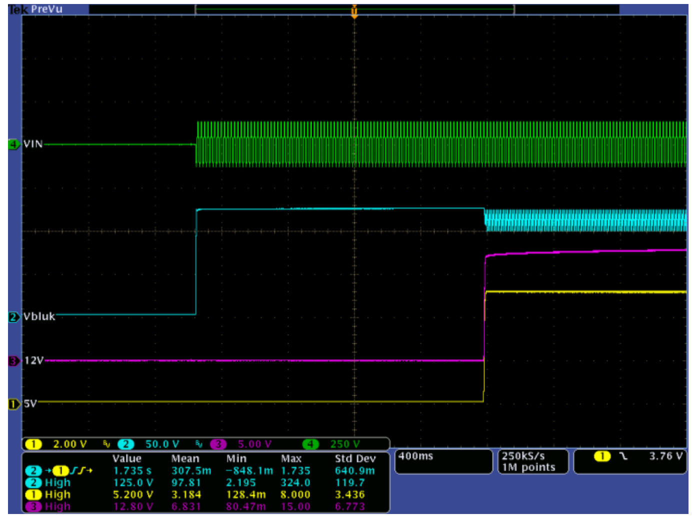
Test condition: Vin = 265Vac/50Hz, Iout = 2.2A
CH1: Bulk Capacitor Voltage, 100V/div
CH4: Input Current, 2A/div

5.5.2 Start-up Time

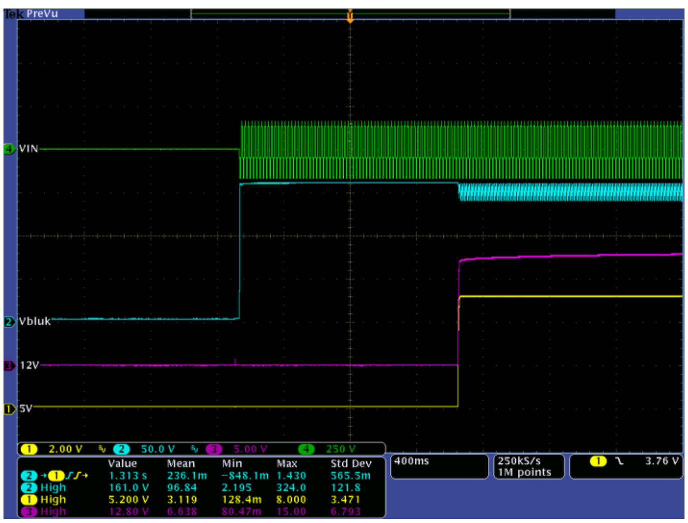
Table 4. Start-up Time

Input Voltage	Output Current	Startup time	Pass/Fail
55Vac	1.6A	3.298s	Pass
90Vac	2.2A	1.735s	Pass
115Vac	2.2A	1.313s	Pass
230Vac	2.2A	0.682s	Pass
55Vac	0.0A	3.431s	Pass
90Vac	0.0A	1.864s	Pass
115Vac	0.0A	1.430s	Pass
230Vac	0.0A	0.716s	Pass

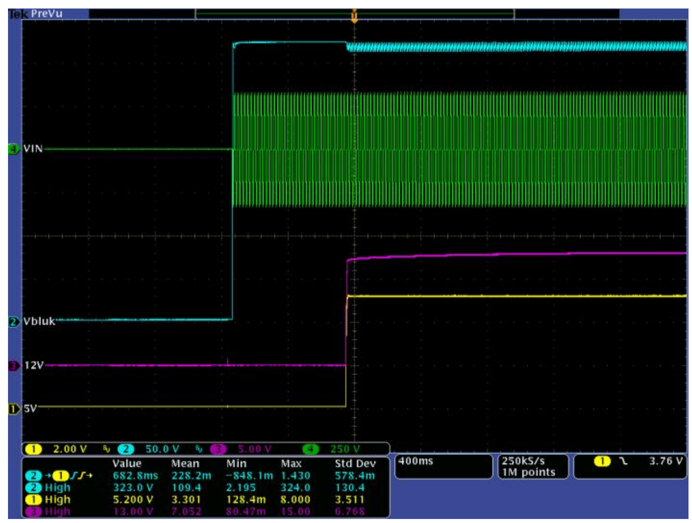
Vin = 55Vac , Iout=1.6A



Vin = 90Vac, Iout=2.2A



Vin = 115Vac, Iout=2.2A

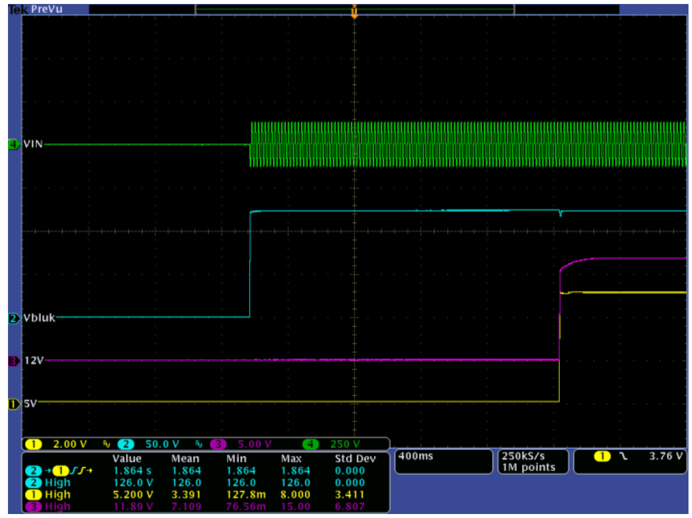


Vin = 230Vac, Iout=2.2A

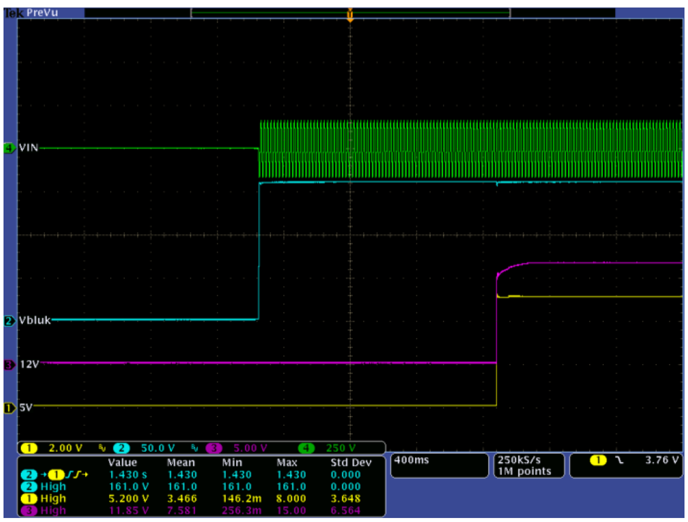
Figure 15. Start-up Time With Full Load

CH1: 5V output voltage, 2V/div
CH2: Bulk Capacitor Voltage, 50V/div
CH3: 12 output voltage, 5V/div
CH4: Input Voltage, 250V/div

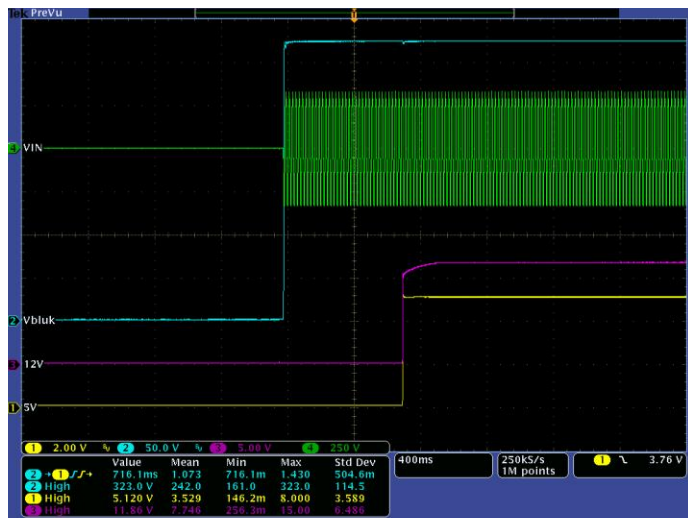
Vin = 55Vac, Iout=0A



Vin = 90Vac, Iout=0A



Vin = 115Vac, Iout=0A



Vin = 230Vac, Iout=0A

Figure 16. Start-up Time With No Load

CH1: 5V output voltage, 2V/div
CH2: Bulk Capacitor Voltage, 50V/div
CH3: 12V output voltage, 5V/div
CH4: Input Voltage, 250V/div

5.6 Switching waveforms

The images below show key switching waveforms of PMP10335 RevB. The waveforms are measured with 5V/2.2A load at 90Vac and 265Vac Input.

CH1: Bulk capacitor voltage, 100V/div
CH2: Auxiliary winding voltage, 50V/div
CH3: CS voltage, 0.5V/div
CH4: DRV output voltage from UCC28722, 1V/div

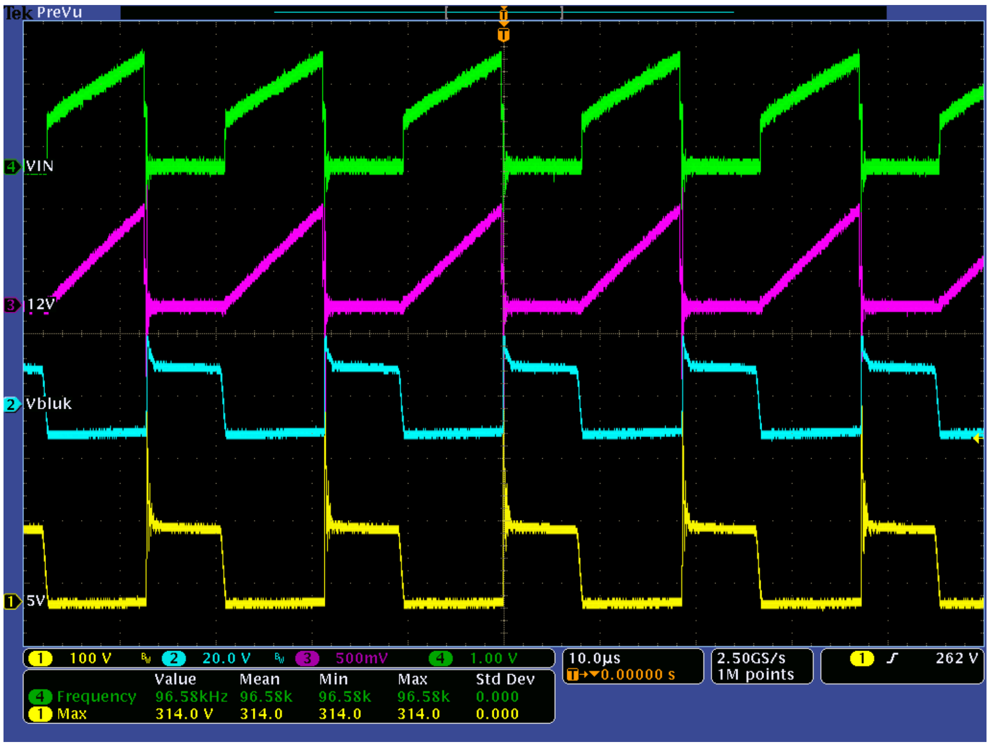


Figure 17. Vin=55Vac，Iout=1.6A

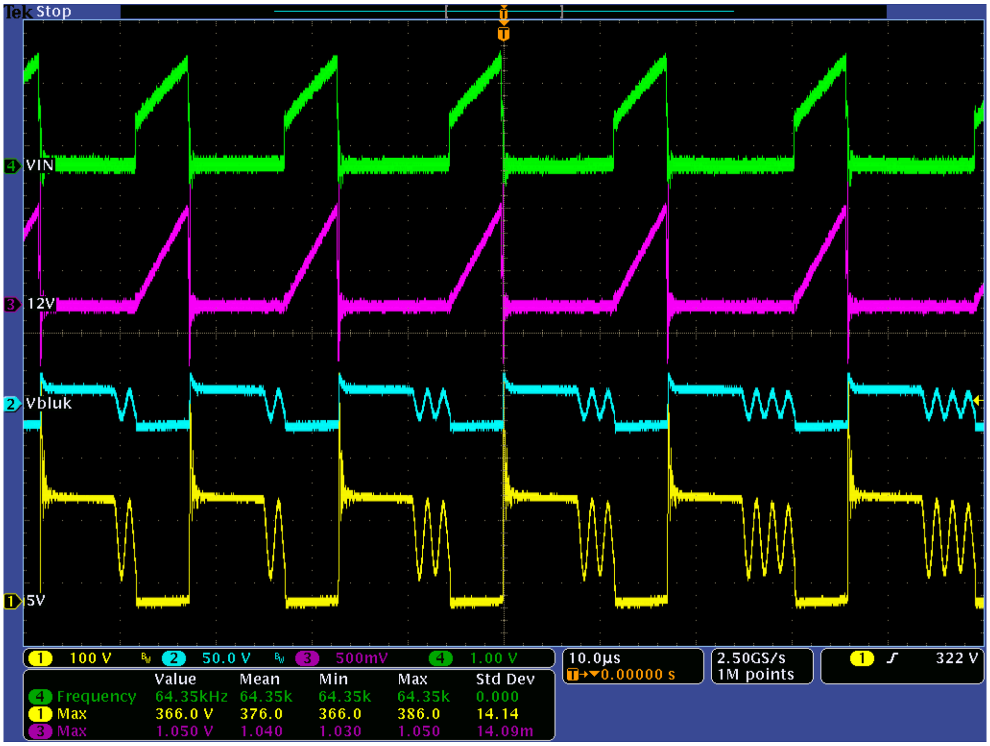


Figure 18. Vin=265Vac，Iout=2.2A

Figure 19. Vin=265Vac，Iout=2.2A

5.7 TIDA-00583 Assembly Drawing and PCB layout

The following figures (Figure 20 through Figure 23) show the design of the printed circuit board.

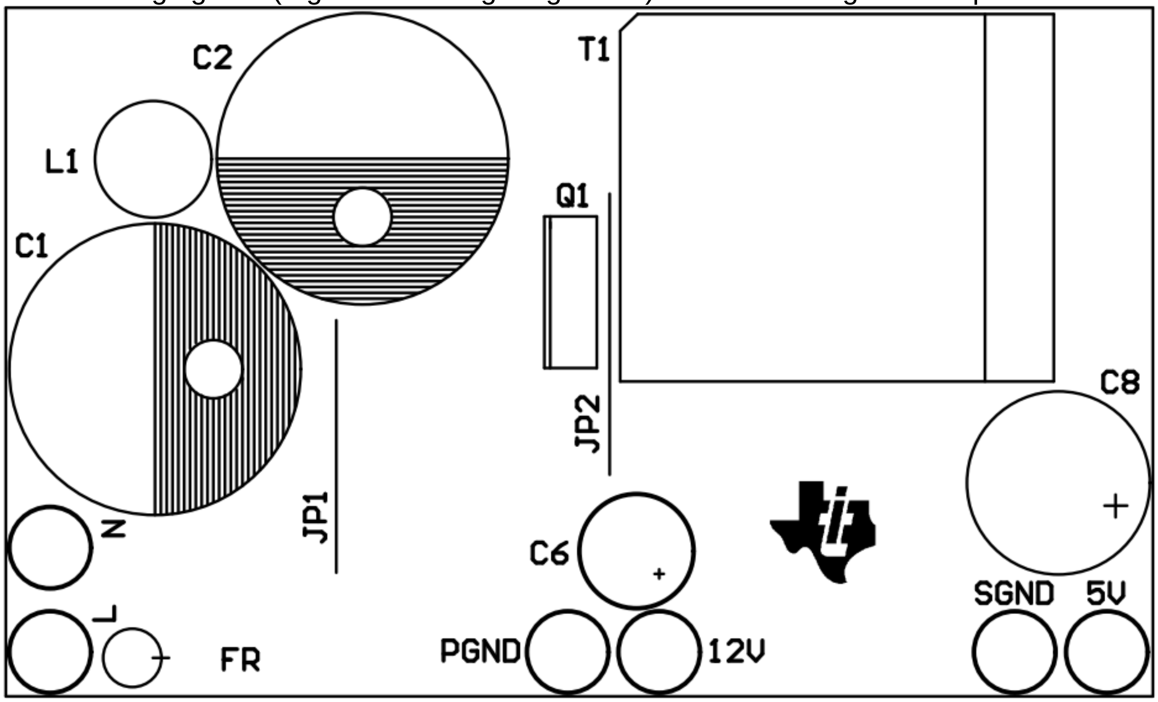


Figure 20. Top Layer Assembly Drawing (Top view)

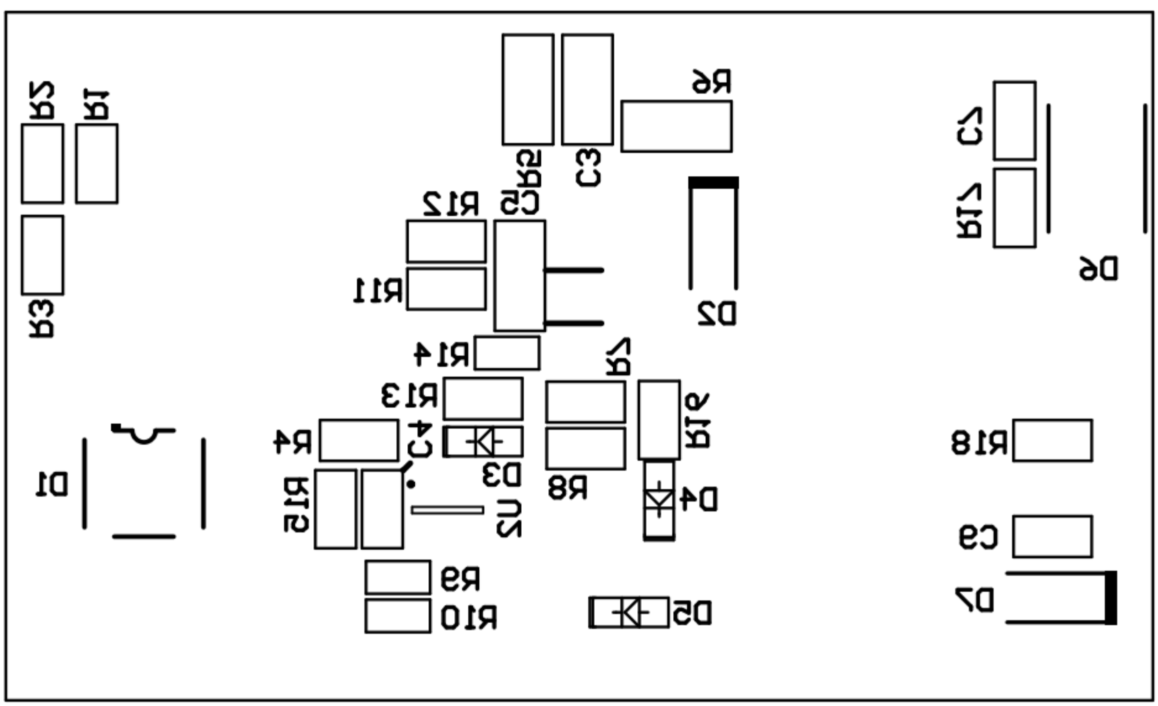


Figure 21. Bottom Assembly Drawing (Bottom view)

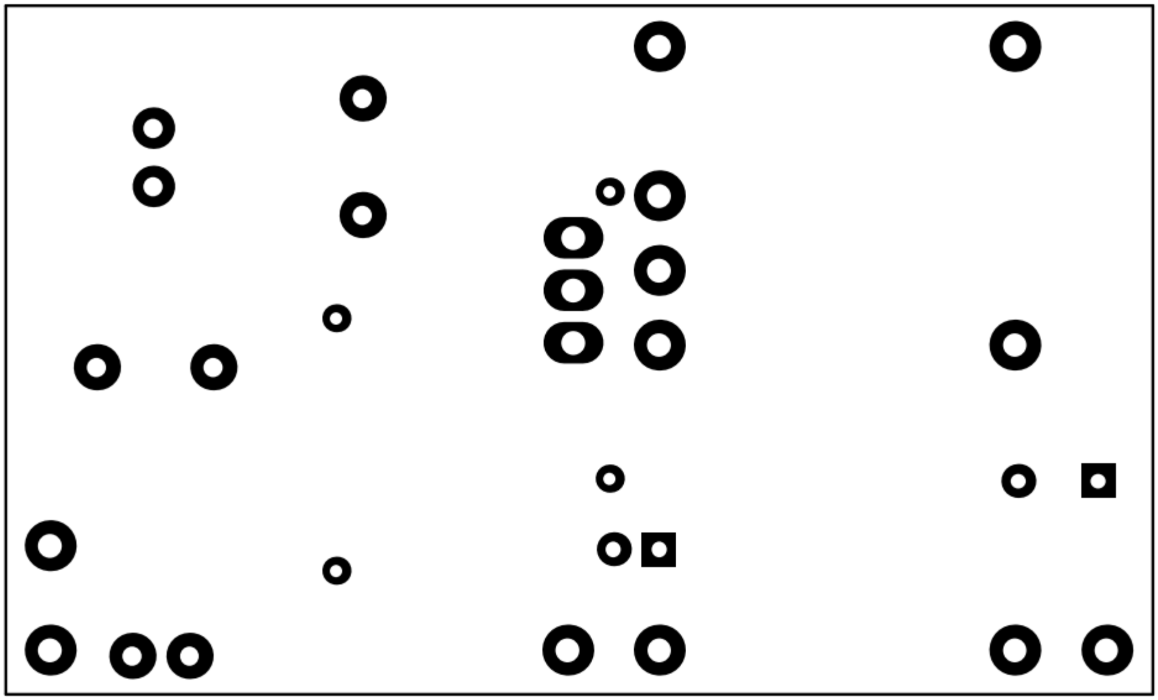


Figure 22. Top Copper (Top View)

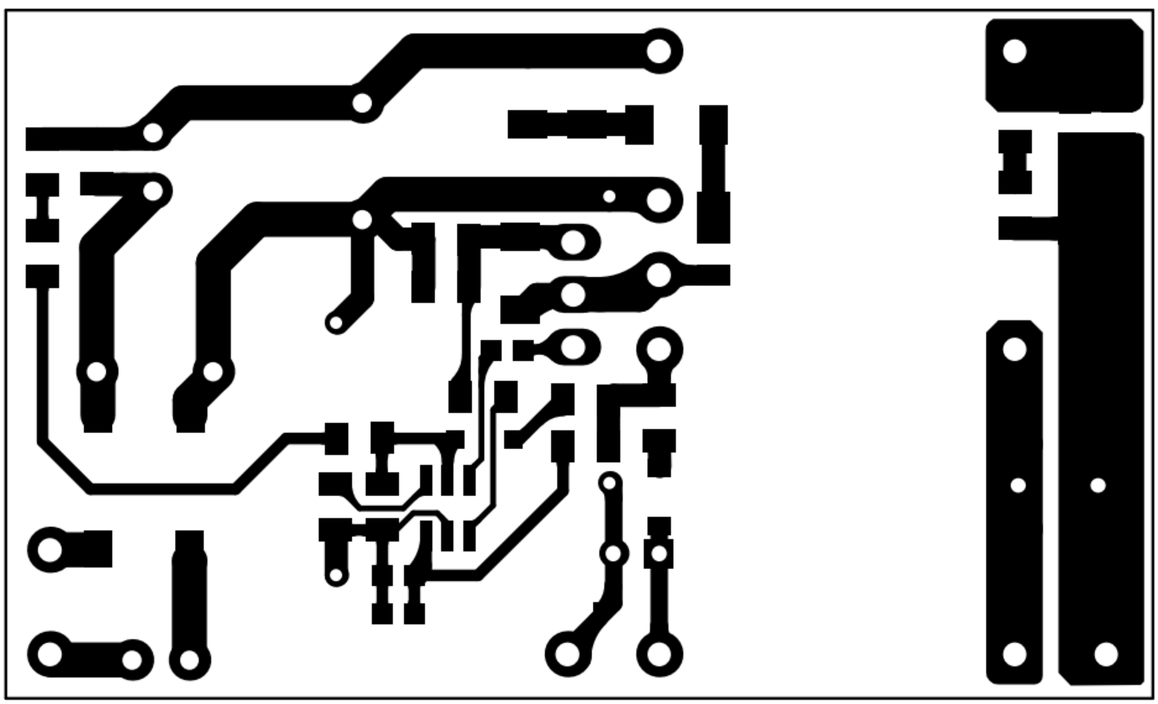


Figure 23. Bottom Copper (Top View)

6 Bill of Materials

Table 5. The TIDA-00583 components list according to the schematic shown in Figure 1

QTY	REFDES	DESCRIPTION	MFR	PART NUMBER
6	5V, 12V, L, N, PGND, SGND	Test Point, Miniature, White, TH	Components Corporation	TP105-01-09
2	C1, C2	CAP, AL, 22 µF, 400 V, +/- 20%, 1.302176 ohm, TH	Panasonic	EEUED2G220
1	C3	CAP, CERM, 470 pF, 630 V, +/- 5%, U2J, 1206	MuRata	GRM31A7U2J471JW31D
1	C4	CAP, CERM, 4.7 µF, 25 V, +/- 10%, X5R, 0805	MuRata	GRM21BR61E475KA12L
1	C5	CAP, CERM, 47 pF, 1000 V, +/- 5%, C0G/NP0, 1206	Vishay-Vitramon	VJ1206A470JXGAT5Z
1	C6	CAP, AL, 47 µF, 35 V, +/- 20%, TH	Panasonic	ECA-1VM470
1	C8	CAP, AL, 820 µF, 6.3 V, +/- 20%, 0.008 ohm, TH	Nichicon	RL80J821MDN1KX
1	C9	CAP, CERM, 0.1 µF, 16 V, +/- 10%, X7R, 0805	Kemet	C0805C104K4RACTU
1	C10	CAP, AL, 470 µF, 6.3 V, +/- 20%, 0.008 ohm, TH	Nichicon	RL80J471MDNASQKX
1	D1	Diode, Switching-Bridge, 600 V, 1 A, Diode Bridge,6.5x1.3x5.0mm, SMT	Fairchild Semiconductor	MDB6S
1	D2	Diode, Standard Recovery Rectifier, 600 V, 1 A, PowerDI123	Diodes Inc.	DFLR1600-7
2	D3, D4	Diode, Switching, 250 V, 0.2 A, SOD-123	Onsemi	BAS21HT1G
1	D5	Diode, Zener, 12 V, 200 mW, SOD-323	Diodes Inc.	MMSZ5242BS-7-F
1	D6	Diode, Schottky, 45 V, 10 A, PowerDI5	Pingwei	PS1045L
1	D7	Diode, Zener, 5.1 V, 500 mW, SOD-123	Vishay-Semiconductor	MMSZ4689-V
1	FR	RES, 4.7, 5%, 1 W, Fusible, TH	Yageo America	FKN1WSJR-52-4R7
1	JP1	Jumper Wire, 500mil spacing, Green, pkg of 200	3M	923345-05-C
1	JP2	Jumper Wire, 400 mil Spacing, Yellow, Pkg of 200	3M	923345-04-C
1	L1	Inductor, Unshielded Drum Core, Ferrite, 470 µH, 0.35 A, 1.58 ohm, TH	Wurth Elektronik eiSos	7447462471
1	Q1	Transistor, NPN, 400 V, 4 A, TO-126	Sino-Microelectronics	3DD13005ED
1	R1	RES, 10 k, 5%, 0.1 W, 0603	Yageo America	RC0603JR-0710KL
3	R2, R3, R4	RES, 1.5 M, 5%, 0.125 W, 0805	Panasonic	ERJ-6GEYJ155V
1	R5	RES, 330 k, 5%, 0.25 W, 1206	Vishay-Dale	CRCW1206330KJNEA
1	R6	RES, 220, 5%, 0.25 W, 1206	Vishay-Dale	CRCW1206220RJNEA
2	R7, R16	RES, 2.2, 5%, 0.125 W, 0805	Panasonic	ERJ-6GEYJ2R2V

QTY	REFDES	DESCRIPTION	MFR	PART NUMBER
1	R9	RES, 18.2 k, 1%, 0.1 W, 0603	Vishay-Dale	CRCW060318K2FKEA
1	R10	RES, 267 k, 1%, 0.1 W, 0603	Vishay-Dale	CRCW0603267KFKEA
1	R11	RES, 1.2, 5%, 0.125 W, 0805	Vishay-Dale	CRCW08051R20JNEA
1	R12	RES, 2.4, 5%, 0.125 W, 0805	Yageo America	RC0805JR-072R4L
1	R13	RES, 200, 5%, 0.125 W, 0805	Panasonic	ERJ-6GEYJ201V
1	R14	RES, 0, 5%, 0.1 W, 0603	Yageo America	RC0603JR-070RL
1	R15	RES, 39 k, 5%, 0.125 W, 0805	Vishay-Dale	CRCW080539K0JNEA
1	R18	RES, 1.0 k, 5%, 0.125 W, 0805	Vishay-Dale	CRCW08051K00JNEA
1	T1	EE16-7-5, 10-Pin EXT, THT, Vertical		
1	U1	Constant-Voltage, Constant-Current Controller With Primary-Side Regulation, DBV0006A	Texas Instruments	UCC28722DBVR

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