Load Detecting Power Supply

National Semiconductor
RD-166
Product Applications Design Center
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1.0 Design Specifications

Inputs	Output #1
VinMin=100V	Vout1=5V
VinMax=240V	Iout1=0.5A

2.0 Design Description

Preface

Every year, millions of Watts are lost in heat from inefficient linear AC/DC wall adapters. This loss is incurred even when there is no load applied. The cause of this inefficiency is that energy is being lost from leakage elements found in the transformer and electrolytic capacitors. This reference design shows that by using a SMPS instead of a linear supply, you can drastically reduce the amount of wasted energy and by adding some additional circuitry that “wakes” up the supply when a load is applied, losses drop to a few milliwatts.

Introduction

The wake on load AC/DC power adapter is a wall mount power supply which converts 100-240 Vac to 5 Vdc at 500 mA to a USB port. The typical application for this type of AC/DC adapter is a cell phone charger. The unique feature of this power adapter is extremely low power consumption when the output is not loaded. This power adapter uses National Semiconductor's LM5021 PWM controller and has a load detection and shutdown circuit which turns off the PWM IC at no load. It won't restart until the output is loaded (wake on load) or the output capacitor is discharged to a certain level. The start up circuit is designed to consume less than 40 µA current at high line input during shutdown period. By doing so, the no load power consumption of this adapter can be greatly reduced.

Circuit Description

The start up circuit of this power supply consists of R102, R103, R109, Q101 and D106. D106 is a 36V zener diode. It clamps the base voltage of NPN transistor Q101 at 36V during start up. The base to emitter voltage V_{BE} of Q101 is around 0.6V. So the emitter voltage of Q101 is 36V – 0.6V = 35.4V. For PWM IC LM5021, the maximum enable voltage at V_{IN} pin of IC U100 is 23V and maximum current before enable is 25 µA. R103 is set to be 200KΩ. So the start up current through R103 is high enough to charge C103 to V_{CC} enable voltage. R109 is a 10MΩ resistor. The power dissipation of

$$R109 = (V_{IN} – 36V)^2/R109$$

V_{IN} is the rectified AC input. Even at high line V_{IN} = 339 Vdc, the power dissipation is only 9 mW. The current through

$$R109 = (Vin – 36V)/ R109$$

At low line, V_{IN} = 100 Vdc, the current through R109 is 7.4 µA. Q101 has minimum hFE of 50 and the leakage current of zener diode D106 is less than 1 µA. So ICE of Q101 will be high enough for the PWM IC to start.

Once the power supply starts, there is a current flowing through R121 to the diode of the optocoupler U105. The optocoupler current

$$I_{OC} = (V_{out} – Vd)/R121$$

Vd is the diode drop of the optocoupler which is around 1V. For V_{out} = 5V, I_{OC} = 0.4 mA. This current is coupled to the transistor side of the optocoupler and pulls down the base voltage of Q101. It disables the start up circuit and the power supply won't be able to restart unless the output capacitors are discharged.

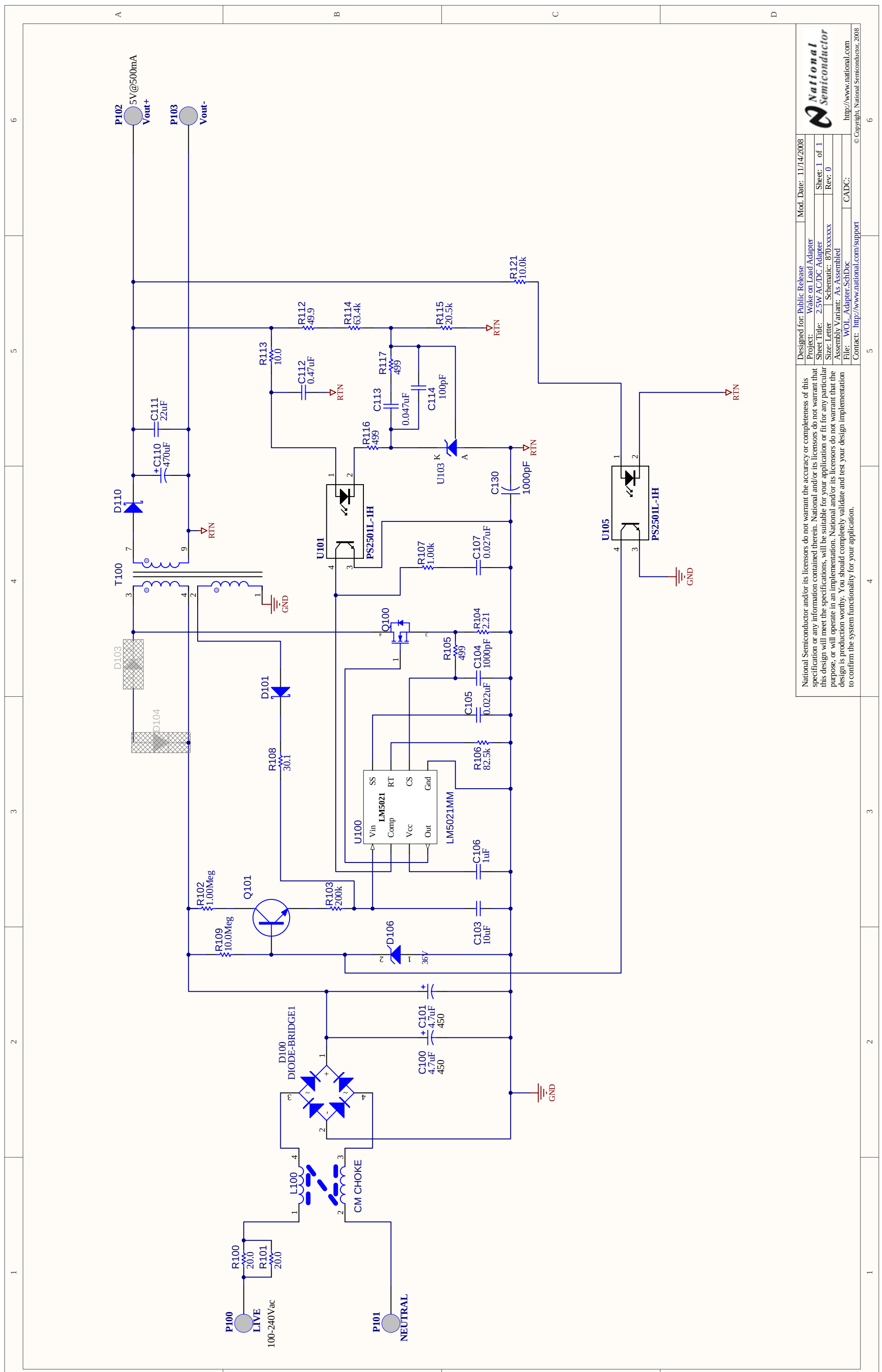
During normal operation, the power of PWM IC U100 is supplied by transformer bias winding. The turns ratio between transformer bias winding and secondary winding is 2.5:1. The bias winding output voltage is 2.5 x 5V = 12.5V during normal operation. At no load the PWM IC LM5021 goes into skip cycle operation. It produces a short burst of output pulses followed by a long skip cycle interval. C103 is charged during the short burst of output pulses and is discharged during the skip cycle interval. The charge current is controlled by R108 and the discharge current is the PWM IC supply current. So the voltage at C103 which is the PWM IC Vin voltage can be adjusted by changing R108 value. In this application R108 is set at 30.1Ω and the C103 voltage is low enough to shut down the PWM IC during no load skip cycle operation.

Once the PWM IC shuts down at no load, it can not restart because the start up circuit is disabled by the pull down current from optocoupler U105. The power supply stays in the shut down mode until the output capacitor is discharged. The total output capacitance is 492 µF. The discharge current at no load is less than 0.4 mA. It takes several seconds to discharge the capacitors and takes only a few milliseconds to charge them. So the power supply stays in the shut down mode most of the time and consumes little power. Once there is a load applied, the output capacitors are quickly discharged and the power supply starts up immediately.

3.0 Features

- Extremely low power consumption when the output is not loaded
- 100 -240 Vac input range
- Regulated 5V, 0.5A output
- Design was assembled and tested

4.0 Schematic



schematic3

FIGURE 1. WOL Adapter Schematic

5.0 Bill of Materials

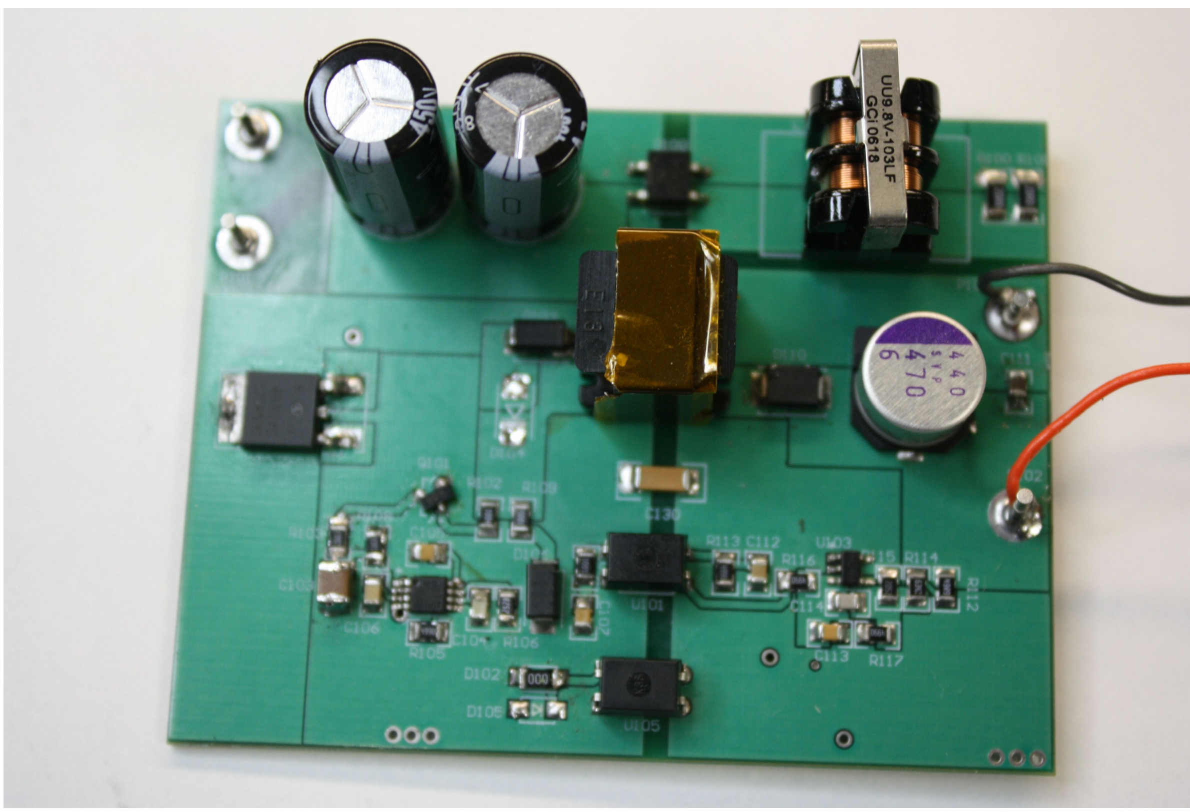
Designator	CompType	Value	Footprint	Parameters	Manufacturer	Manufacturer_PN
C100	Capacitor	4.7uF	10mm th cap		Nichicon	UVR2W4R7MPD
C101	Capacitor	4.7uF	10mm th cap		Nichicon	UVR2W4R7MPD
C103	Capacitor	10uF	1210	Ceramic, X7R, 25V, 20%	TDK	C3225X7R1E106M
C104	Capacitor	1000pF	0805	Ceramic, X7R, 50V, 10%	TDK	C2012X7R1H102K
C105	Capacitor	0.022uF	0805	Ceramic, X7R, 100V, 10%	TDK	C2012X7R2A223K
C106	Capacitor	1uF	0805	Ceramic, X5R, 25V, 10%	TDK	C2012X5R1E105K
C107	Capacitor	0.027uF	0805	Ceramic, X7R, 50V, 10%	Yageo America	CC0805KRX7R9BB273
C110	Capacitor	470uF	SM_RADIAL_F	AL, EEV-FK, 6.3V, 20%	Panasonic	EEV-FK0J471P
C111	Capacitor	22uF	0805	Ceramic, X5R, 6.3V, 20%	TDK	C2012X5R0J226M
C112	Capacitor	0.47uF	0805	Ceramic, X7R, 25V, 10%	TDK	C2012X7R1E474K
C113	Capacitor	0.047uF	0805	Ceramic, X7R, 50V, 10%	MuRata	GRM21BR71H473KA01L
C114	Capacitor	100pF	0805	Ceramic, C0G/NP0, 50V, 5%	MuRata	GQM2195C1H101JB01D
C130	Capacitor	1000pF	1808		Syfer	1808JA250102KXBSY2
D100	Diode	400V	MiniDip		Diodes Inc.	HD04
D101	Diode	100V	SOD-123	Vr = 100V, Io = 0.15A, Vf = 1.25V	Diodes Inc.	1N4148W-7-F
D103	Zener	open	SMA			
D104	Diode	open	SMA			
D106	Zener	36V	SMA		Central Semiconductor	CMZ5938B
D110	Diode	100V	SMB	Vr = 100V, Io = 2A, Vf = 0.79V	Diodes Inc.	B2100-13
L100	Common Mode Choke	10mH	BU9S		Gci Technologies	UU9.8V-103LF
Q100	MOSFET	800V	DPAK	6AA, nC, rDS(on) @4.5V=0.9	Infineon	SPD06N80C3
Q101	Bipolar Transistor	400V	SOT-23		ZETEX	FMMT458
R100	Resistor	20.0	1206	1%, 0.125W	Vishay-Dale	CRCW1206-20R0FRT1
R101	Resistor	20.0	1206	1%, 0.125W	Vishay-Dale	CRCW1206-20R0FRT1
R102	Resistor	1.00Meg	0805	5%, 0.125W	ROHM	KTR10EZPJ105
R103	Resistor	200k	0805	1%, 0.125W	Vishay-Dale	CRCW0805200kFKEA
R104	Resistor	2.21	0805	1%, 0.125W	Vishay-Dale	CRCW08052R21FNEA
R105	Resistor	499	0805	1%, 0.125W	Vishay-Dale	CRCW0805499RFKEA
R106	Resistor	82.5k	0805	1%, 0.125W	Vishay-Dale	CRCW080582k5FKEA
R107	Resistor	1.00k	0805	1%, 0.125W	Vishay-Dale	CRCW08051k00FKEA
R108	Resistor	30.1	0805	1&, 0.125W	Vishay-Dale	CRCW080530R1FKEA
R109	Resistor	10.0Meg	0805	5%, 0.125W	ROHM	KTR10EZPJ106
R112	Resistor	49.9	0805	1%, 0.125W	Vishay-Dale	CRCW080549R9FKEA
R113	Resistor	10.0	0805	1%, 0.125W	Vishay-Dale	CRCW080510R0FKEA
R114	Resistor	63.4k	0805	1%, 0.125W	Vishay-Dale	CRCW080563k4FKEA
R115	Resistor	20.5k	0805	1%, 0.125W	Vishay-Dale	CRCW080520k5FKEA
R116	Resistor	499	0805	1%, 0.125W	Vishay-Dale	CRCW0805499RFKEA
R117	Resistor	499	0805	1%, 0.125W	Vishay-Dale	CRCW0805499RFKEA
R121	Resistor	10.0k	0805	1%, 0.125W	Vishay-Dale	CRCW080510k0FKEA
T100	Transformer		PA2685NL		Pulse	PA2865NL
U100	Switcher		MUA08A		National Semiconductor	LM5021MM-1
U101	OPTOCOUPLER		FOD121		NEC	PS2501L-1H
U103	Voltage Reference		MF05A		National Semiconductor	LMV431IM5
U105	OPTOCOUPLER		FOD121		NEC	PS2501L-1H

6.0 Other Operating Values

Operating Values

Description	Parameter	Value	Unit
Modulation Frequency	Frequency	80	KHz
Total output power	Pout	2.5	W
Steady State Efficiency	Efficiency	75	%
Peak-to-peak ripple voltage	Vout p-p	65	mV
Static load regulation	static load	10	mV
Dynamic load regulation	Dynamic load	150	mV

7.0 Board Photos



boardphoto

FIGURE 3. IMG_0123

8.0 Quick Start

Recommended Equipment:

— AC Power Source

— Electronic load

— Multimeter

— Oscilloscope

Test Procedure

1. Connect the AC power source to test points P100 and P101
2. Connect test point P102 to positive terminal of the electronic load and connect test point P103 to negative terminal of the electronic load.
3. Set the AC input voltage to 120V and set the electronic load to 0.5A.
4. Turn on AC power source. Use multimeter to measure input current and use oscilloscope to measure the output voltage.
5. Turn the load current off and measure the input current and the output voltage waveform.
6. Turn the load back and measure the input current and the output voltage waveform.

9.0 Test Results

No Load Power Consumption

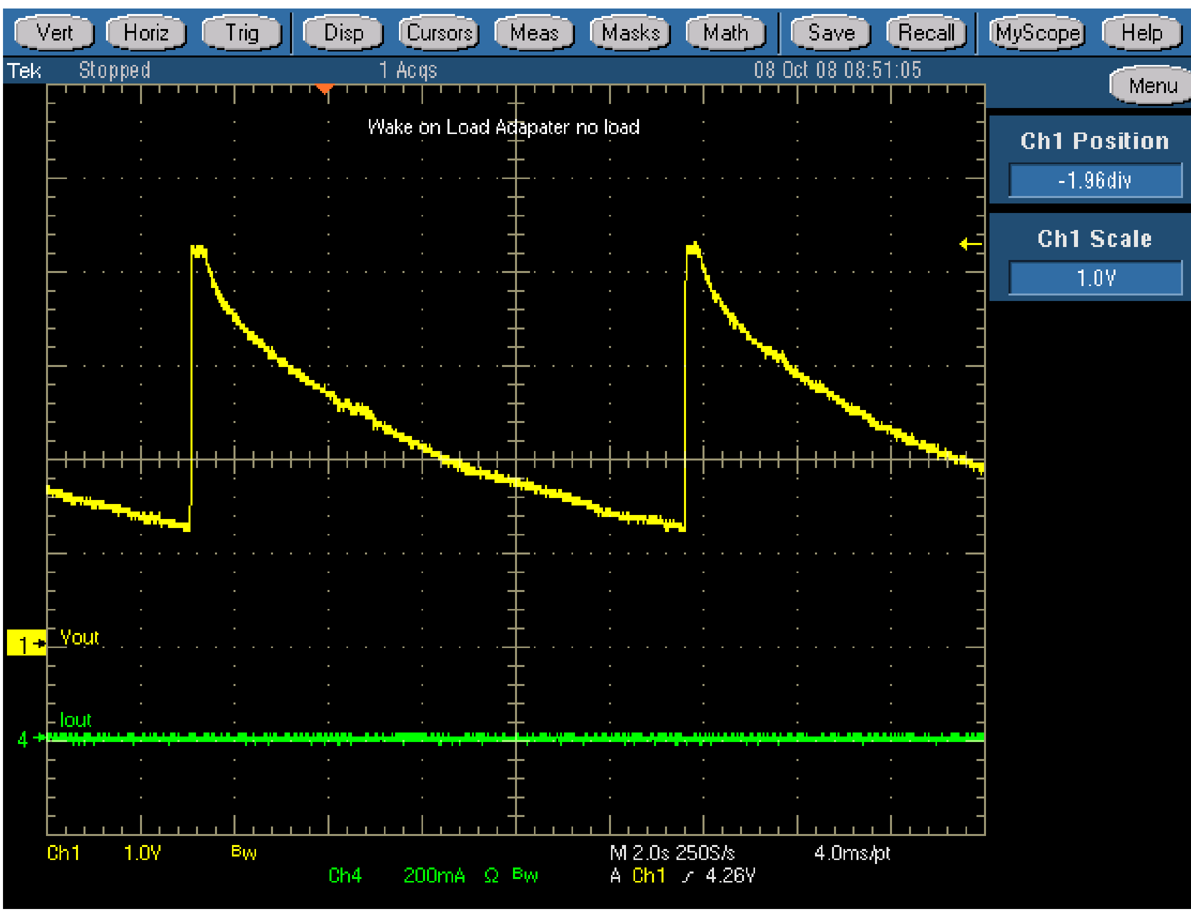
WOL Adapter

Vin (Vdc)	Iin (mA)	Pin (mW)
100	0.016	1.60
120	0.02	2.40
140	0.023	3.22
160	0.026	4.16
180	0.028	5.04
200	0.032	6.40

ST Viper22 based 9W switching adapter made by CGE

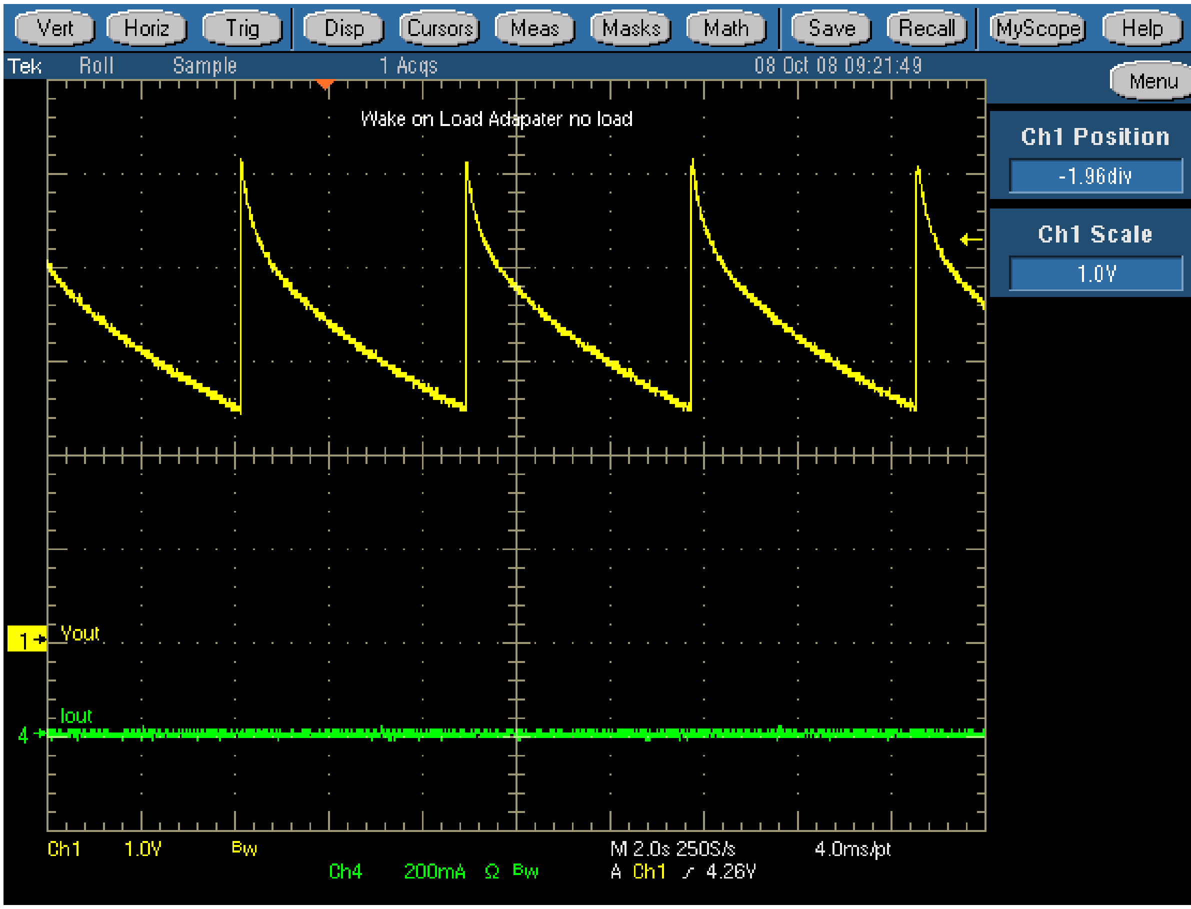
Vin (Vdc)	Iin (mA)	Pin (mW)
100	2.42	242
120	2.00	240
140	1.74	244
160	1.60	256
180	1.50	270
200	1.36	272

10.0 Waveforms



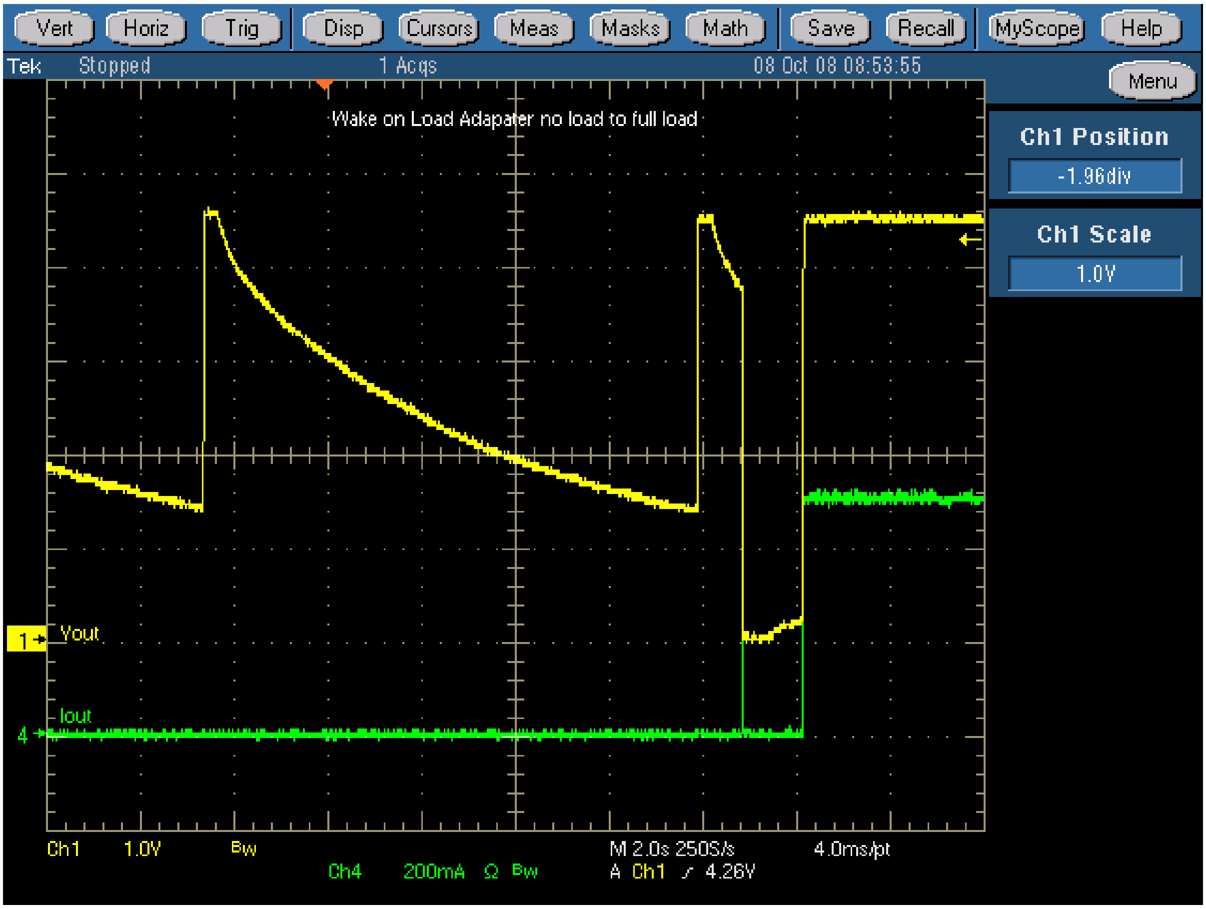
waveform

FIGURE 4. No Load Operation at 100 VDC input



waveform1

FIGURE 5. No Load Operation at 339 VDC input



waveform2

FIGURE 6. Change from no load to full load at 100VDC input

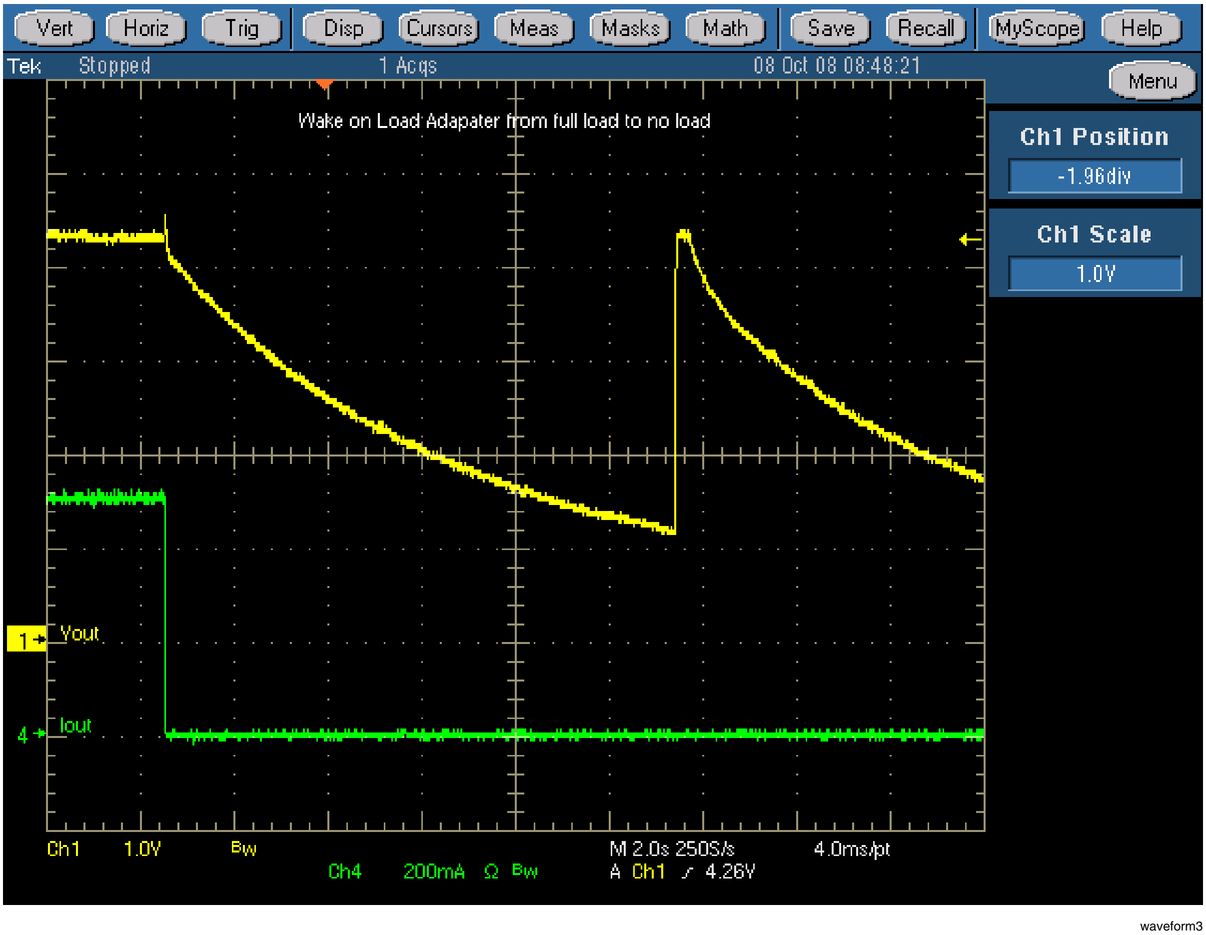
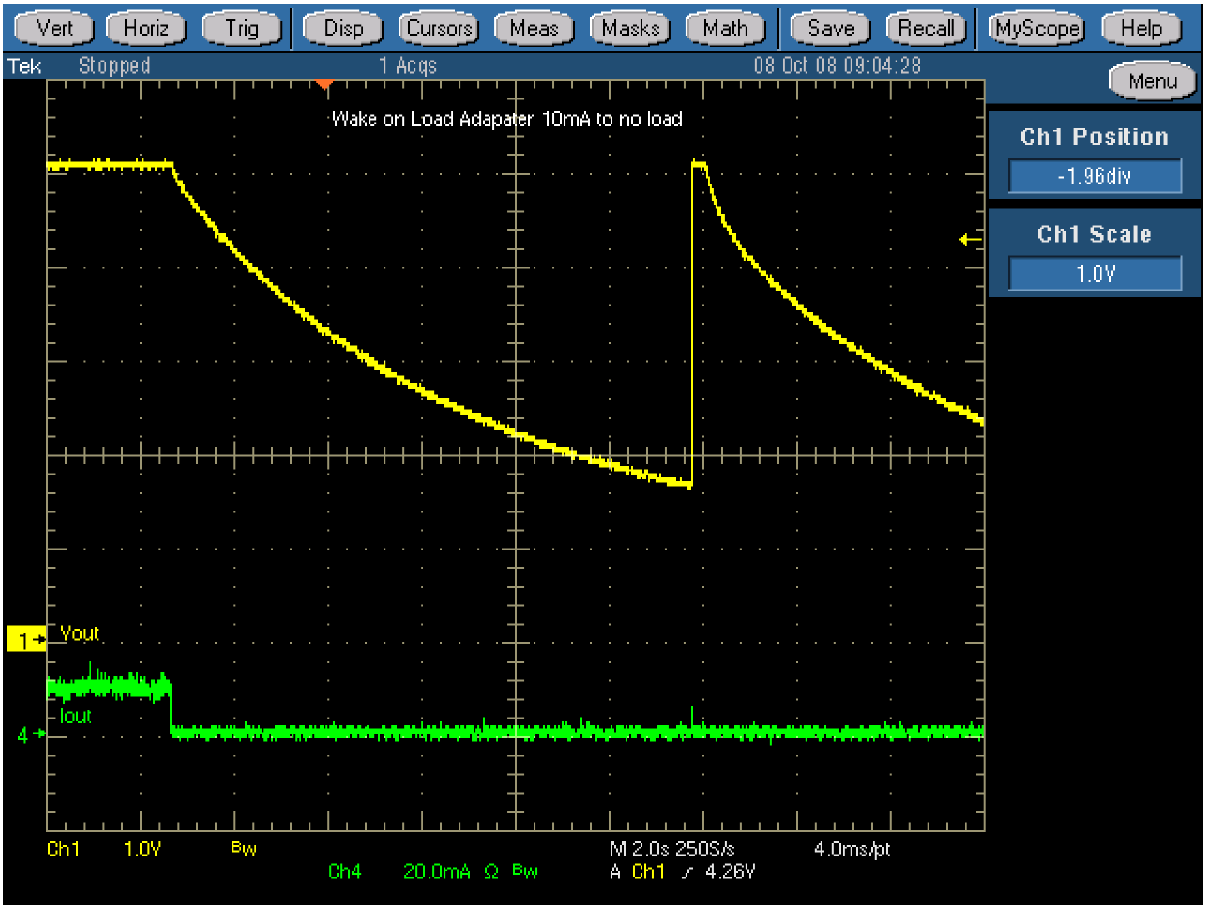


FIGURE 7. Change from full load to no load at 100 VDC input



waveform4

FIGURE 8. Change from 10mA load to no load at 100VDC input

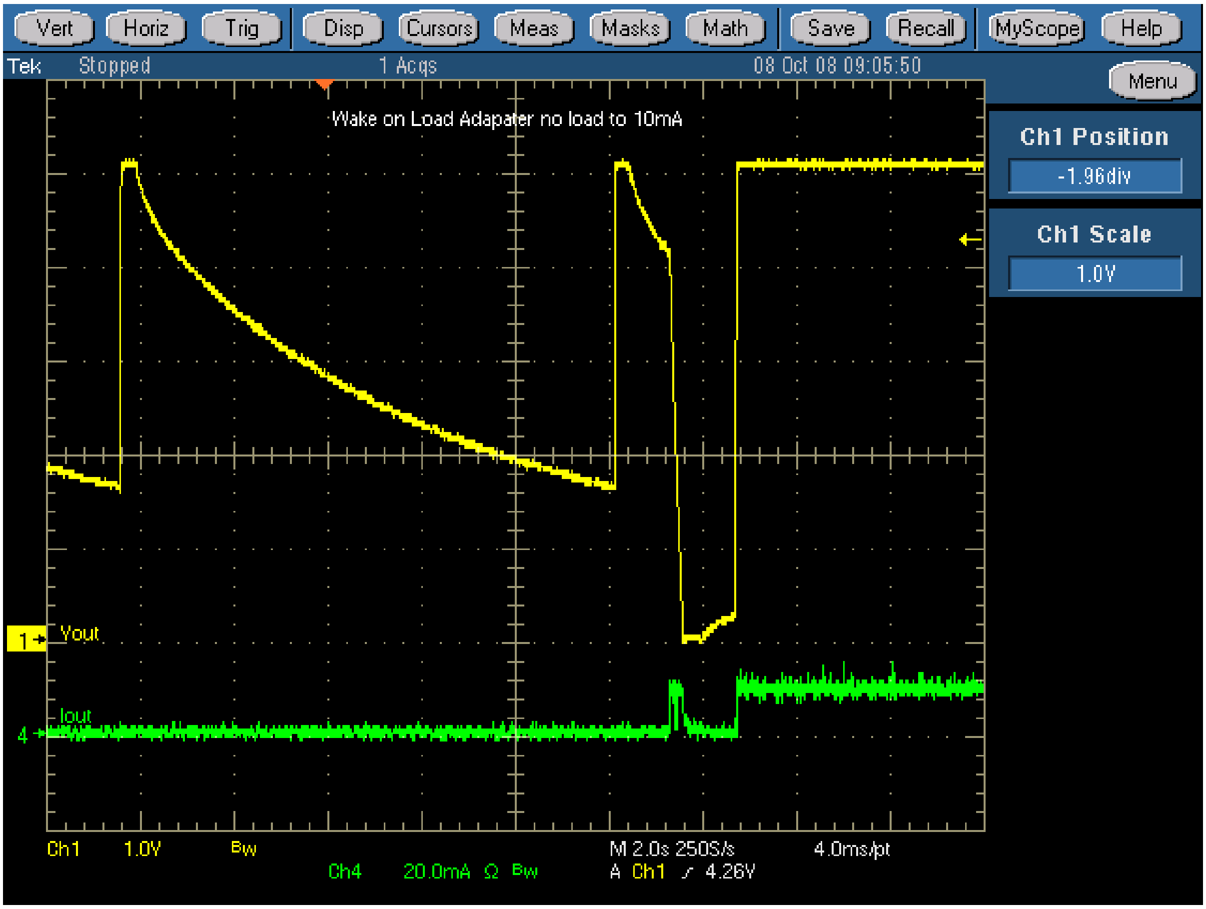
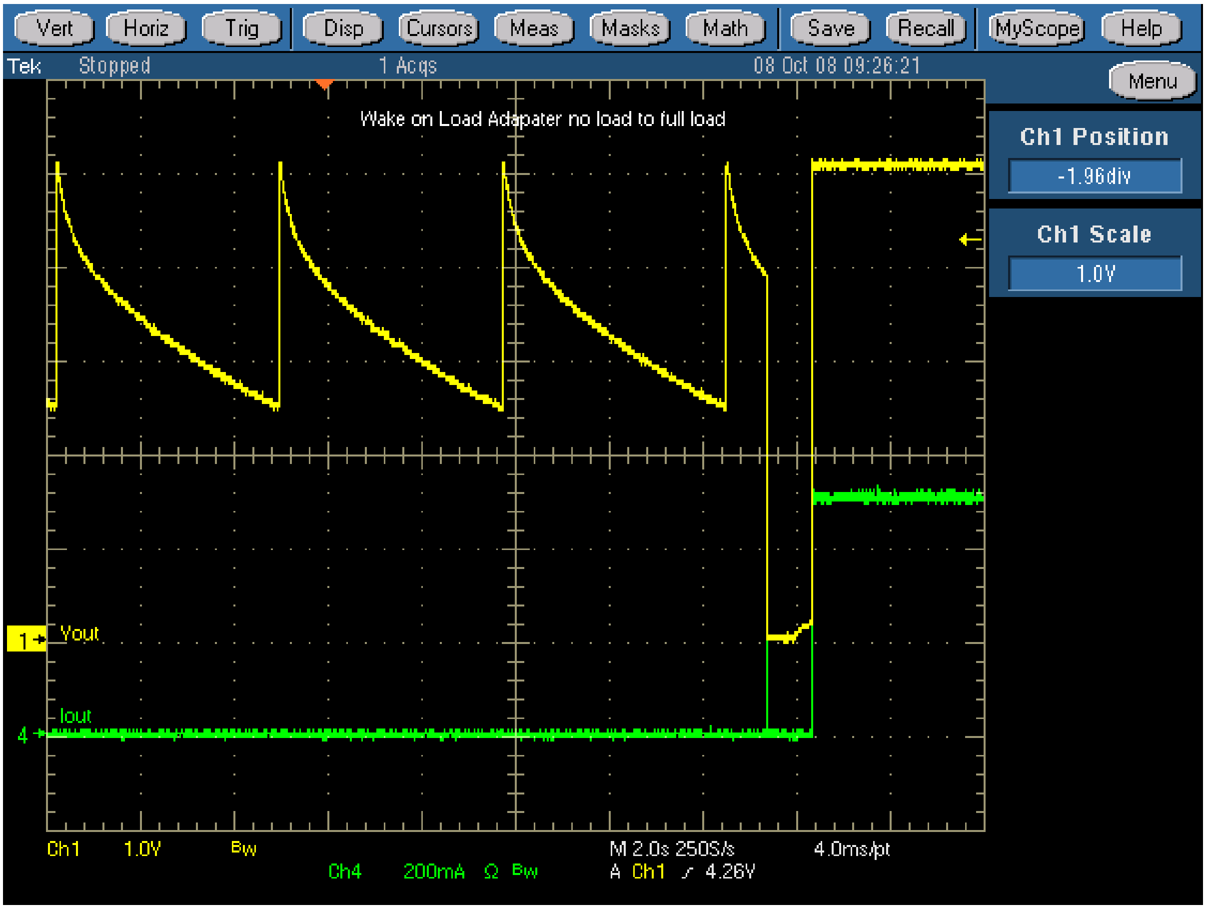
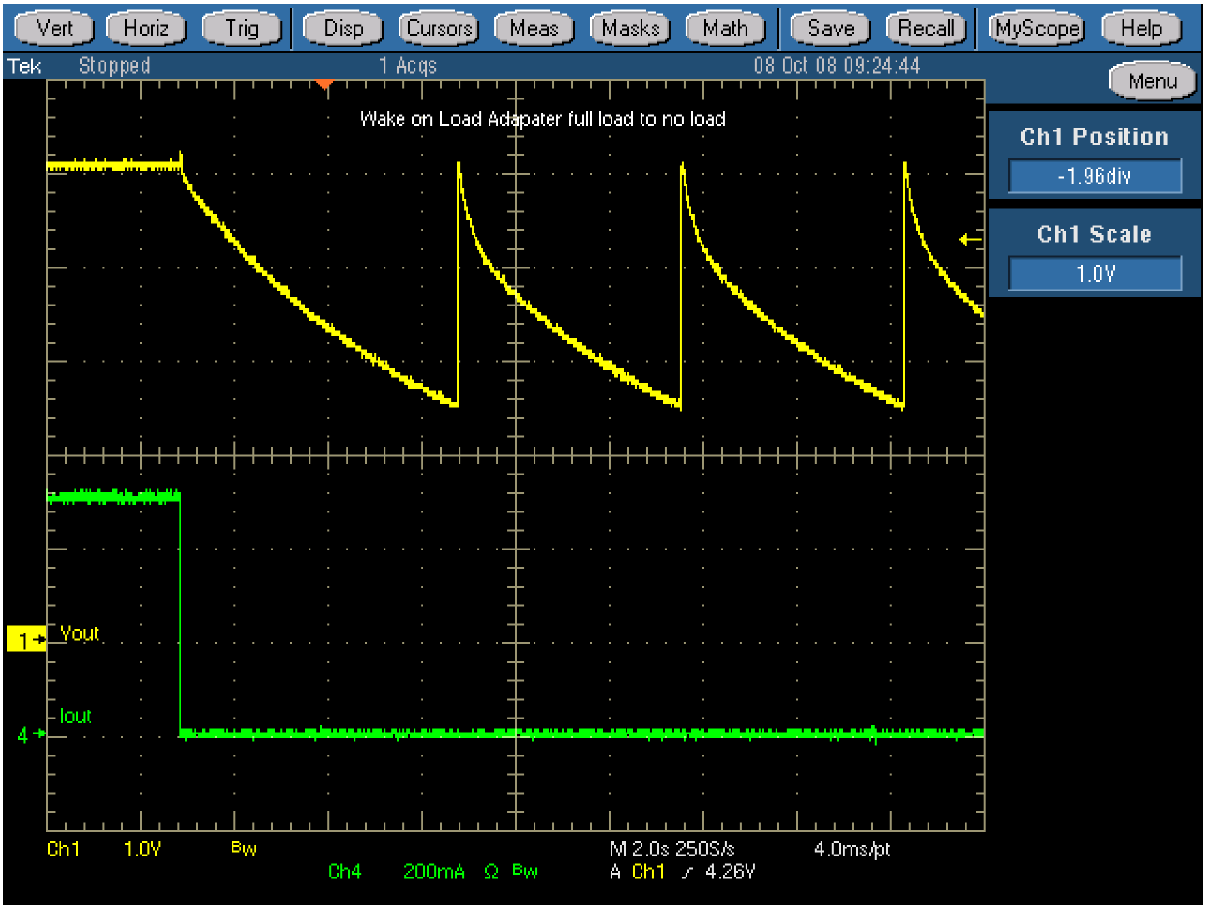


FIGURE 9. Change from no load to 10ma load at 100 VDC input



waveform6

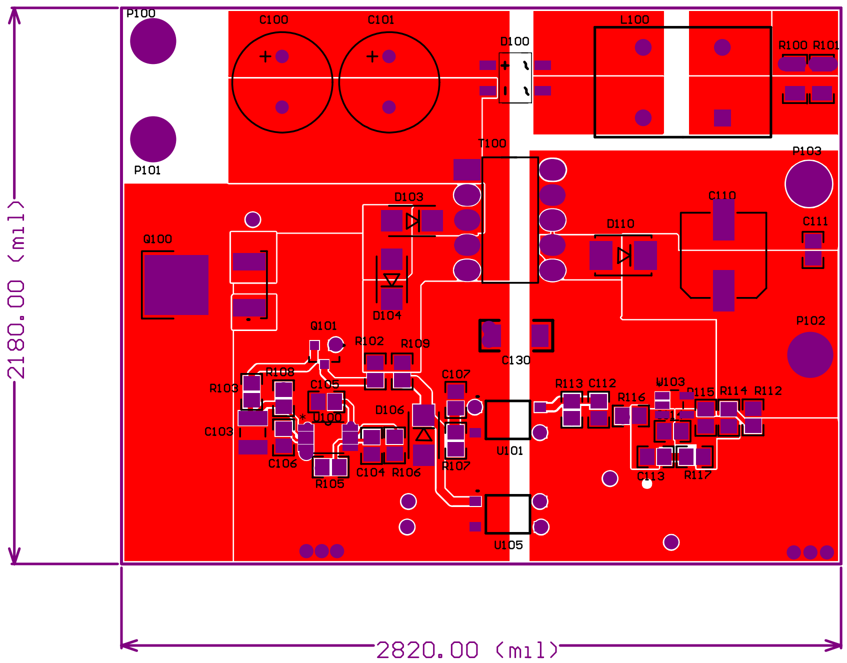
FIGURE 10. Change from no load to full load at 339 VDC input



waveform7

FIGURE 11. Change from full load to no load at 339 VDC input

11.0 Layouts



other

FIGURE 12. PCB Layout Top

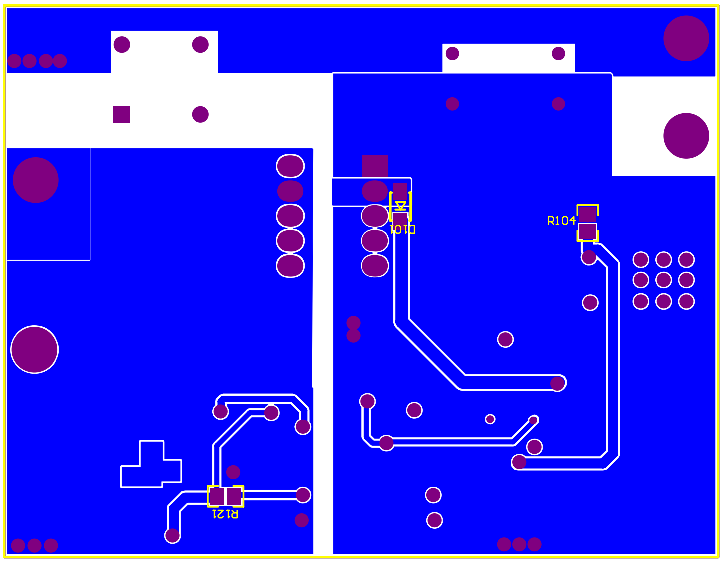


FIGURE 13. PCB Layout Bottom, as viewed from the bottom

Notes

Notes

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