AND8300/D

NCP4302 Increasing a Notebook Adaptor's Efficiency using Synchronous Rectification

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Prepared by: Terry Allinder
ON Semiconductor

Introduction

The NCP4302 is a full featured controller and driver that provide all the control and protection functions necessary for implementing a synchronous rectifier operation in a flyback converter. With the use of the NCP4302, the space conscious flyback applications such as Adaptors, chargers, and set top boxes can achieve significant efficiency improvements at minimal extra cost. In addition to the synchronous rectifier control, the IC incorporates an accurate TL431 type shunt regulator, current monitoring circuit, and optocoupler driver to provide a single IC secondary solution. The NCP4302 works with any type of flyback topology (continuous, Quasi−resonant, or discontinuous mode) − providing a high level of versatility.

Key Features

Supply voltage up to 28 Vdc, allows the V_{CC} input to be connected directly to the output of a Notebook Adaptor.

True secondary side current sensing with a low propagation delay, from the time, the secondary side transformer current is sensed to the time the Driver output is enabled.

High current drive output (2.5 A), provides improved efficiency with an internal gate clamp voltage of 13.5 V to prevent larger excursion of gate voltage when V_{CC} is operating from a 28 Vdc output.

The NCP4302 is designed to operate in Discontinuous Conduction, Continuous Conduction, or Quasi−resonant mode.

Externally programmable t_{on} and t_{off} delays prevent the driver output from falsely turning on due to ringing on the SYNC/CS input, or turning off. When the system is operating under light load conditions the transformer secondary voltage can ring below ground when there is no current flowing.

Internal TL431 Shunt Regulator which is used to provide power supply output voltage regulation.

General Description

The demonstration board for the NCP4302 is a 90 W Notebook Adaptor operating from the Universal input line. The off−line converter is implemented using the NCP1230 in a flyback topology operating in Discontinuous Conduction Mode. The details for this design can be found in applications note AND8154/D.

Design Specification

This Demo Board is configured as an Offline Notebook Adaptor power supply. The input stage operates off of the universal input line, 85−265 Vac, 50−60 Hz. The output of the Notebook Adaptor is 19.0 V, producing 90 W of output power. Table 1 shows the complete design specification.

The Offline Converter is fully self contained and includes a bias supply that operates off of the Auxiliary winding of the transformer. The design is a re−use from the AND8154/D, refer to this application note for the design details. The Demo Board was modified to add synchronous rectification to the secondary to improve the efficiency of the power supply. Refer to Figure 1 for the circuit details.

Table 1. Demo Board Specifications

Parameter	Symbol	Min	Max
Input Voltage	Vac	85	265
Frequency	Hz	47	63
Output Voltage	Vdc	18.6	19.4
Output current	Adc	−	4.74
Output Power	W	−	90
Efficiency	%	86	−
Stand−By Power V_{in} 230 Vac	mW	−	150
Input power, during an output short circuited	mW		100
Input power with a 0.5 W Load	mW	−	0.8

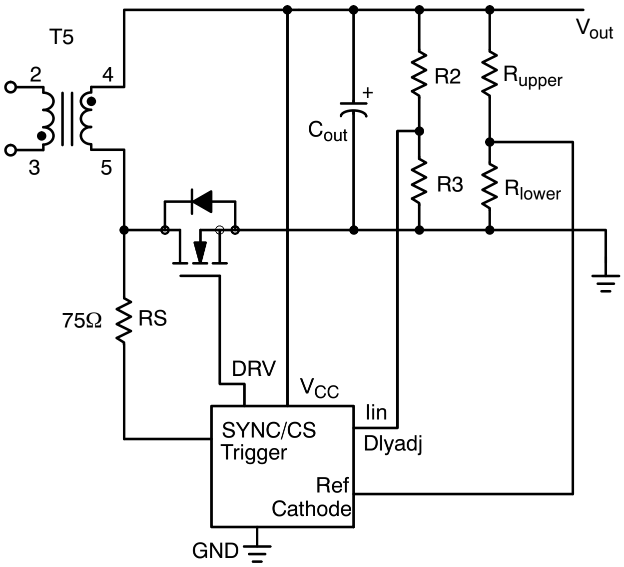

Figure 1. Simplified NCP4302 Implementation

Implementing the NCP4302

The SYNC/CS input is connected to the Drain of the Synchronous Rectification MOSFET through a 75 Ω resistor, RS. No other components are necessary to implement true secondary side current sensing.

The trigger input is used if the power supply will operate in Continuous Conduction Mode (CCM). If the power supply will only be operates in Discontinuous Conduction Mode (DCM) the pin should be connected to ground.

In applications where the power supply is operating in CCM, a timing signal which precedes the primary side Flyback MOSFET turning−on needs to be sent to the Trigger input of the NCP4302. The trigger input will turn−off the NCP4302 driver output disabling the Synchronous Rectification MOSFET. This prevents the primary and the secondary side MOSFETs from conducting simultaneously. Figure 1 show how one possible circuit can be implemented.

D_{LAYADJ} − The D_{LAYADJ} pin allows the user to set the minimum t_{on} and t_{off} time.

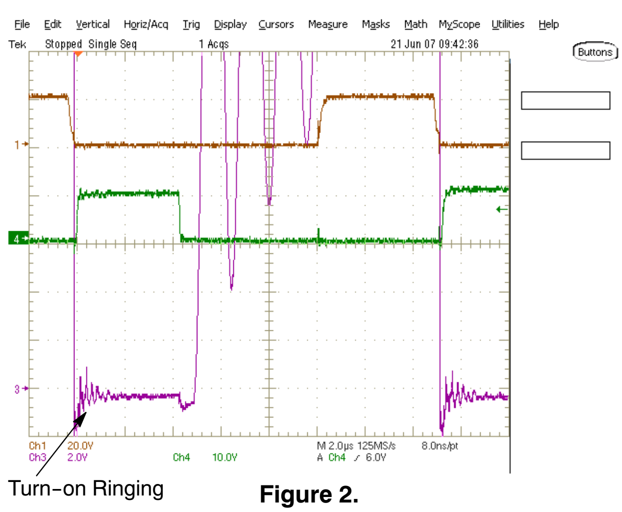

Figure 2.

Synchronous Rectifier Drain Voltage

As current starts to flow in the secondary of the flyback transformer, the parasitic inductance (Printed Wiring Board traces, or component lead)causes the voltage at the SYNC/CS input to ring above ground (as shown Figure 2). This ringing, if not ignored, may cause the controller drive output to turn−off. To eliminate this problem the NCP4302 has a programmable t_{on} time which blanks the secondary voltage ringing by adding a minimum controller drive on time.

Set up: Determine the minimum t_{on} delay time by measuring the period in which the high peak current in the secondary causes the voltage at the Drain of the SYNC FET to ring above ground.

The ringing period for this application is approximately 300 ns. The t_{on} delay is selected to be 500 ns to ensure under all conditions that the turn on ringing would be ignored. This is measured a full load and minimum input ac line voltage.

The second step is to determine the required minimum t_{off} delay time. This normally occurs under light load conditions, refer to Figure 1. Under light load conditions the transformer secondary voltage rings below ground when no current flows on the secondary side. This ringing has to be ignored to prevent turning on the synchronous rectifier drive output.

For this application the t_{off} delay is selected to be 1 μs, this is measured under light load and high line conditions.

Once both boundary conditions have been determined, the delays are set using an external resistive divider using equation 1.

A proprietary delay circuit allows for independent control over both delays times.

$$I_{in\ DLYON} = \frac{\left(V_{out}\frac{R3}{R2+R3} - 0.7\right)}{R_{th}} \qquad \text{(eq. 1)}$$

Where Rth is the Thevenin equivalent resistance, it is calculated using equation (2)

$$Rth = \frac{1}{\frac{1}{R2} + \frac{1}{R3}} \qquad \text{(eq. 2)}$$

$$t_{ONdelay} = 10\ pF\ \frac{4\ V}{I_{in}}$$

The t_{off} delay is calculated using equation (3):

$$I_{in\ DLYOFF} = \frac{\left(V_{out}\frac{R3}{R2+R3} - 0.7\right)}{100k} \qquad \text{(eq. 3)}$$

$$t_{OFFdelay} = 10\ pF\ \frac{3.35\ V}{I_{in}}$$

Alternatively, a single resistor between the Reference pin of the NCP4302 and the Dlyadj pin can be used. This results in a reduced adjustment range for t_{on} and t_{off}. For this application a single 43 kΩ resistor could have been used. If a single 43 kΩ resistor were used, the ton delay would have been 930 ns and the toff delay would have been 2.17 μs.

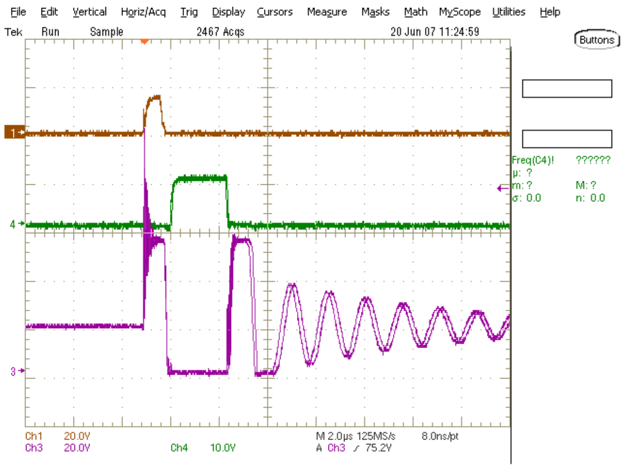

Figure 3. Synchronous Rectifier Drain Voltage Waveform during Turn−off

GATE − The NCP4302 Gate output has a high source and sink current (2.5 Apk) drive capability. This results in a fast turn−on and turn−off of the synchronous rectifier. Having a high gate drive current enables fast turn−on when SYNC/CS signal is received (to minimize body diode conduction at the peak of the current waveform) and fast turn−off when zero current or a Trig signals is received (to prevent current reversal or cross conduction).

V_{CC} − The maximum supply voltage for the NCP4302 is 28 Vdc. In most application the V_{CC} pin can be directly connected to the output of the power supply. It is recommended that the V_{CC} pin should be decoupled with at least a 0.1 μF capacitor for noise immunity.

Internal to the NCP4302 is a TL431 type shunt regulator.

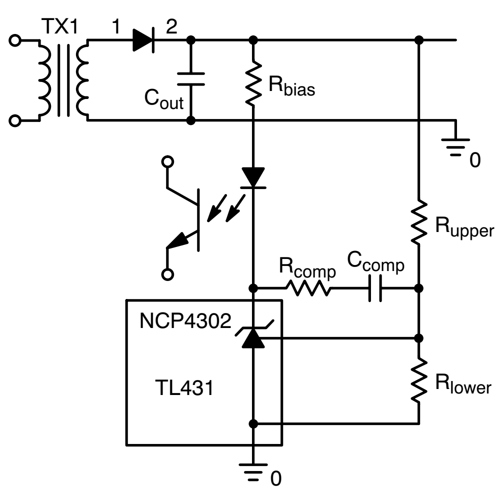

Figure 4. Typical TL431 Implementation

When the TL431 is being used to regulate the output of a power supply it is typically configured as shown in Figure 4. The output from the power supply is sensed and divided down with a resistive divider made up of R_{upper} and R_{lower}. The center point of the divider is connected to the reference pin of the NCP4302. The divider ratio scales down the output voltage to match the reference voltage. The NCP4302A has a 2.5 V reference and the NCP4302B has a 1.25 V reference.

$$V_{REF} = V_{out} \frac{R_{LOWER}}{R_{LOWER} + R_{UPPER}}$$

Output

One of the disadvantages of a Flyback converter operating in the Discontinuous mode is the high peak current in the secondary which can significantly reduce the power supply efficiency.

The peak current is determined by the transformer primary inductance as given by equation 4. The primary inductance is 220 μH. In this application the transformer primary peak current is:

$$I_{pk} = \sqrt{\frac{P_{out} \cdot 2}{L_p \cdot freq}} \qquad \text{(eq. 4)}$$

Where:

P_{out} = 90 W
Lp = 220 μH
Freq = 65 kHz
N = 6.77

$$I_{pk} = \sqrt{\frac{90 \cdot 2}{220\ \mu H \cdot 65\ kHz}} = 3.55\ A$$

The transformer secondary peak current is calculated by using equation 5.

$$I_{SEC\_PK} = I_{PRIM\_PK} \cdot n \qquad \text{(eq. 5)}$$

$$I_{SEC\_PK} = 3.55 \cdot 6.77 = 24\ Apk$$

Where: n is the transformer turns ratio

The losses in the secondary are calculated by using equation 6.

$$P_{Tsecondary} = P_{ON} + P_{SW} + P_{DIODE} \qquad \text{(eq. 6)}$$

The Synchronous Rectification MOSFET is an IRFB4410 with a V_{DSS} of 100 V, an $R_{DS(on)}$ of 10 nΩ (typical), maximum current of 96 A, and an output capacitance of 420 pF (C_{OSS}).

$$I_{out} = \frac{I_{pk}}{2}(1 - D_{on}) \qquad \text{(eq. 7)}$$

$$I_{out} = \frac{24\ Apk}{2}(1 - 0.4) = 7.2\ A$$

$$I_{rms} = I_{pk}\sqrt{\frac{1 - D_{on}}{3}} \qquad \text{(eq. 8)}$$

Combining eq. 7 and eq. 8

$$I_{rms}{}^2 = \frac{4 \cdot I_{out}{}^2}{3(1 - D_{on})} \qquad \text{(eq. 9)}$$

$$P_{ON} = \frac{4 \cdot I_{out}{}^2}{3(1 - D_{on})} \cdot R_{DS(on)} \qquad \text{(eq. 10)}$$

$$P_{ON} = \frac{4 \cdot 7.2^2}{3(1 - 0.2)} \cdot 10\ m\Omega = 1.15\ W$$

$$P_{SW} = \frac{1}{2} \cdot C_{OSS} \cdot {V_S}^2 \cdot freq \qquad \text{(eq. 11)}$$

$$P_{SW} = \frac{1}{2} \cdot 420\ pF \cdot 38\ V^2 \cdot 65\ kHz = 0.02\ W$$

Where:

$$V_S = \frac{Vdc}{n} + V_{out}$$

$$V_S = \frac{127\ V}{6.77} + 19.0\ V = 38\ V$$

$$Vdc = 90 \cdot \sqrt{2} = 127\ Vdc$$

V_{out} 19.0 V

$$P_{DIODE} = V_D \cdot I_D \cdot tp1 \qquad \text{(eq. 12)}$$

$$P_{DIODE} = 1.3\ V \cdot 24 \cdot 100\ ns = 1.56\ \mu W$$

Where: tp1 is the propagation delay from the time current is flowing in the secondary of the transformer, to the time the synchronous MOSFET is turned-on shorting out the MOSFETs internal body diode.

$$P_{TSECONDARY} = 1.15\ W + 0.02\ W + 1.56\ \mu W = 1.17\ W$$

If this is compared to the calculated losses with a conventional Schottky rectification diode on the output:

$$P_{SECONDARY} = I_{OUT\_dc} \cdot V_f = 4.77\ Adc \cdot 0.7\ V = 3.34\ W$$

Based on the calculations we should expect to see a 2.18 W improvement in the overall systems efficiency.

Continuous Conduction Mode

When using Synchronous Rectification and operating in Continuous Conduction Mode (CCM) the current in the transformer secondary doesn't fall to zero prior to turning on the primary side MOSFET. As a result, cross conduction (having the primary side MOSFET and secondary side Synchronous Rectification MOSFET conducting current at the same time) will occur and there will be a loss in efficiency.

To avoid cross conduction, a signal which leads the primary side FET turning-on should be applied to the TRIG input of the NCP4302 (refer to Figure 5 below for timing details). The TRIG input directly controls the DRV logic Flip-Flop inside of the NCP4302. When a 3 V (typical) signal with a pulse width greater than 75 ns is applied to the TRIG pin, the DRV output logic is Reset within 25 ns (typical) and the Sync FET is turned-off. By correctly using the TRIG signal, cross conduction will be eliminated and there will be an improvement in the efficiency while operating in CCM.

Figure 5 also shows one possible solution for generating a TRIG pulse. The circuit was built and tested in a 90 W Notebook Adaptor Demo Board and the results as shown in Figure 6 below.

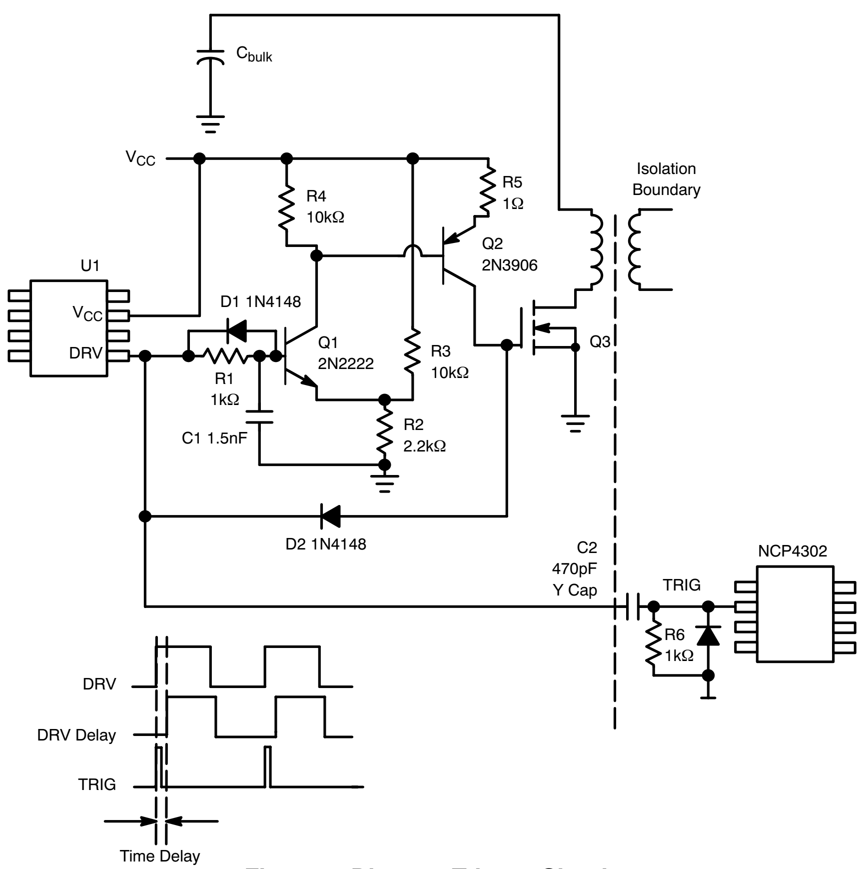

Figure 5. Discreet Trigger Circuit

For the circuit in Figure 5, when the output DRV signal from U1 is applied to the input of the differentiator circuit R6 (1 kΩ) and C2 (C2 is a 470 pF “Y” capacitor) a pulse is generated on the TRIG pin of the NCP4302. At the same time the U1 DRV signal is delayed by R1 and C1, this sets the delay time. When C1 has charges to:

$$V_{Q1Base} = \frac{R2}{R2 + R3} V_{CC} + 0.7\ V$$
$$= 15\ V \frac{2.2\ k\Omega}{2.2\ k\Omega + 10\ k\Xi} + 0.7\ V = 3.4\ V$$

V_{CC} = 15 V

Q1 is forward biased which turns on transistor Q2 and provides the gate drive signal to the MOSFET Q3.

When Q1 is forward biased the voltage on VQ1 emitter ramps from 2.7 V to:

$$V_{CC} - VCE_{SATQ1} - VR4 \approx 13\ V$$

Where: VR4 is 1 V

Resistor R4 sets up the base drive for transistor Q2, R5 is the MOSFET (Q3) gate resistor; this is typically a value of 1 Ω to 10 Ω. Diode D2 is used to pull the charge out of MOSFET Q3 for a fast MOSFET turn−off time.

Figure X1 shows the resulting waveforms of the discreet circuit in the 90 W Demo Board. The delay from the U1 DRV output to the TRIG input is around 800 ns. The results show that this turns−off the NCP4302 Sync DRV output 800 ns prior to the U1 DRV turning on the MOSFET Q3.

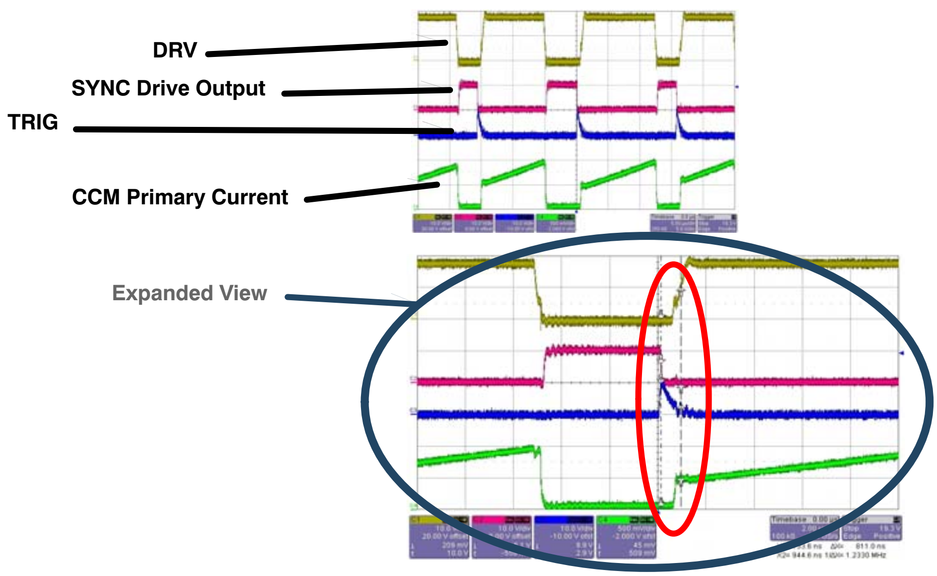

Figure 6. Discreet Trigger Circuit Waveforms

Demo Board

The NCP4302 Demo Board has both Synchronous Rectification (a MOSFET) and a conventional Schottky diode so an easy comparison of the advantages of Synchronous Rectification can be made. The Schottky diode is in parallel with the Synchronous MOSFET, when jumper SW1 is installed, the NCP4302 is disabled and the Schottky rectifier is in the circuit. When jumper SW1 is removed the NCP4302 is enabled and will short out the Schottky diode when current is sensed in the transformer secondary.

If you refer to Table 2 and 3 they show the efficiency data with and without synchronous rectification. We can see that at full load and 90 Vac input and full load, with the Synchronous MOSFET enabled that the input power is 102.82 W and with the Synchronous MOSFET disabled (current flowing through the MBR20H100 Schottky diode) the input power is 104.64 W, or a 1.82 W reduction in power loss.

When the ac input line is raised to 230 Vac, the input power with the Synchronous MOSFET enabled is 101.61 W and with the Synchronous MOSFET disabled the input power is 104.24 W, this is a power savings of 1.82 W. This is very close to our calculated losses in the analysis above.

Synchronous Rectification MOSFET Snubber

A snubber was added across the Sync MOSFET to reduce the ringing and voltage stress during the time when the Sync FET is turning−off. A 20 Ω 1/2 W resistor is used along with a 4700 pF 250 Vac capacitor.

Hold−off Circuit

During startup the Notebook Adaptor is operating in CCM. To avoid cross conduction of the primary side MOSFET, Q1, and the Synchronous MOSFET so they can’t be on at the same time a hold−off circuit has been added. To avoid this either a trigger pulse leading Q1 turning on needs to be inputted to the NCP4302, or a Hold−Off circuit needs to be added.

For this application the simplest solution was to add a Hold−off circuit. The hold circuit pulls the trigger pin high disabling the NCP4302 drive output until the Notebook Adaptor output is up and operating in DCM. The circuit is made up of transistor Q4, R35, R6, R36, and C4. Refer to Figure 7.

When the Notebook Adaptor turns-on and the output capacitor is charged, (with J1 installed) capacitor C4 will charge through R6. During the time it is charging, transistor Q4 is reverse biases and the trigger input of the NCP4302 is pulled high. After C4 has charged above 0.7 V transistor Q4 will turn-on pulling the trigger input below 0.5 V enabling the NCP4302 drive output.

Demo Board Test Procedure

Connect an ac power source to the J4 connector. Connect the dc load to the J2 connector. Place a Digital Voltage Meter (DVM) directly across the J2 output terminals. Set the ac power source to 115 Vac, and turn on the ac source. The NCP1230 controller will turn-on and supply 19.0 Vdc to the load (refer to Table 1 for load regulation). Vary the load from 0 to 4.73 Adc and monitor the output voltage. Adjust the ac power source from 85-265 Vac and monitor the output voltage.

The Demo Board comes with the Jumper Header J1 installed; this will disable the NCP4302 driver output. To enable the Synchronous Rectifier, turn-off the ac input power and remove jumper J1, this will enable the NCP4302 driver output.

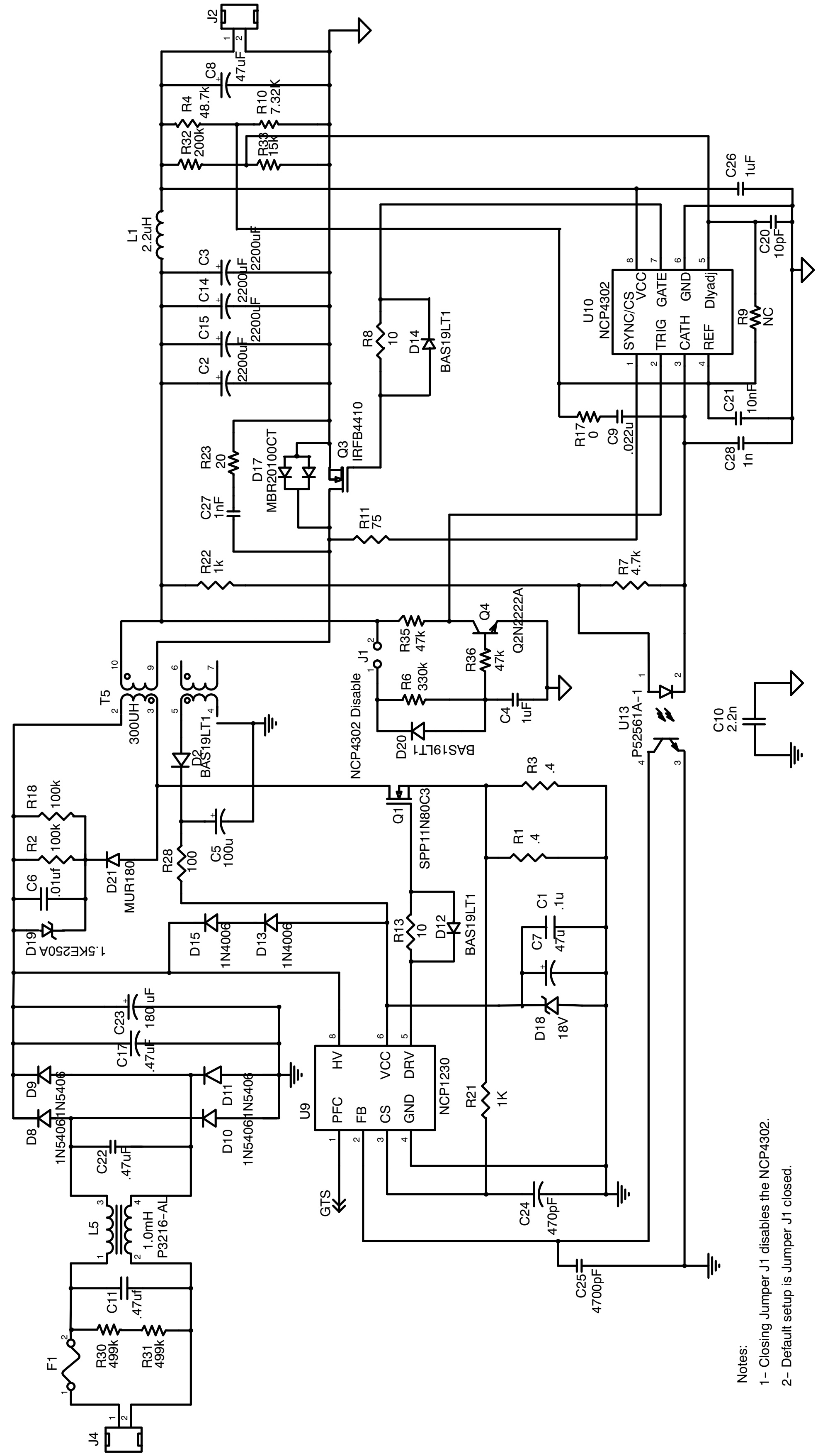

Figure 7. NCP4302 Demo Board Schematic

Table 2. Demo Board Synchronous MOSFET Enabled (Test Results with synchronous rectification)

V_{in} (Vac)	Pin (W)	V_{out} (Vdc)	I_{out} (Adc)	P_{out} (W)	Eff (%)	P_{out} %
90	25.9	18.94	1.19	22.54	87.02	25
90	51.12	18.91	2.37	44.82	87.67	50
90	76.8	18.87	3.57	67.37	87.72	75
90	102.82	18.83	4.77	89.82	87.36	100
230	26.36	18.87	1.19	22.46	85.19	25
230	51.16	18.81	2.37	44.58	87.14	50
230	76.73	18.77	3.57	67.01	87.33	75
230	101.61	18.71	4.772	89.28	87.87	100

Table 3. Demo Board Synchronous MOSFET Disabled (Test Results without synchronous rectification)

		MBR20H100 Schottky Diode				
V_{in} (Vdc)	Pin (W)	V_{out} (Vdc)	I_{out} (Adc)	P_{out} (W)	Eff (%)	P_{out} %
90	27	18.83	1.19	22.41	82.99	25
90	52.3	18.73	2.37	44.39	84.88	50
90	77.5	18.66	3.57	66.62	85.96	75
90	104.64	18.65	4.77	88.96	85.02	100
230	27.37	18.8	1.19	22.37	81.74	25
230	52.49	18.66	2.37	44.22	84.25	50
230	79.97	18.5	3.57	66.05	82.59	75
230	104.24	18.5	4.77	88.25	84.66	100

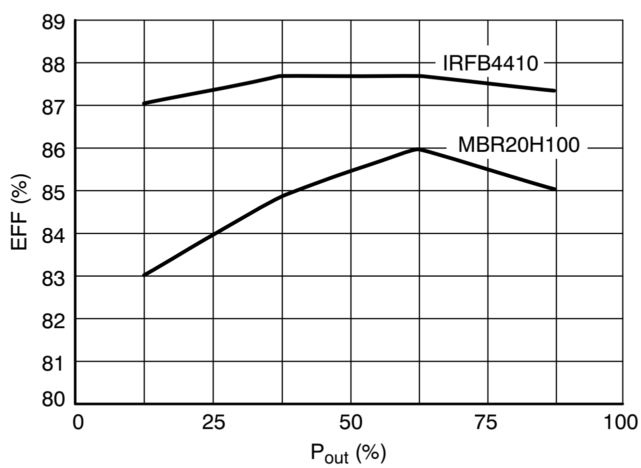

Figure 8. Synchronous Rectification (IRFB4410) vs. MBR20H100 Schottky Rectifier with 90 Vac Input

Table 4. Bill of Materials for the NCP4302 Demo Board

Designator	Qty	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number	Substitution Allowed	Lead Free
C1	1	Ceramic chip capacitor	0.1 μF, 50 V	10%	1206	Vishay	VJ01206Y104KXAA	Yes	Yes
C9	1	Ceramic chip capacitor	0.022 μF, 50 V	10%	805	Vishay	VJ0805Y223KXXA	Yes	Yes
C10	1	Capacitor, Y2 class	2.2 nF, 500 Vac	10%	10 mm X 5 mm	RIFA	ER610RJ4220M	Yes	Yes
C11, C17, C22	3	Capaitor, X2 class	0.47 μF, 300 V	10%	13.0 mm x 31.3 mm	Vishay	F1772-447-3000		Yes
C21	1	Ceramic cap	0.01 μF, 50 V	10%	805	Vishay	VJ0805Y103KXAA	Yes	Yes
C25	1	Ceramic cap	4700 pF, 50 V	10%	1206	Vishay	VJ01206Y472KXXA		
C23	1	Cap. Aluminum	180 μF, 450Vdc	20%	25 mm x 40 mm	Panasonic	ECO-S2GP181BA		Yes
C28	1	Ceramic cap	1000 pF, 25 V	10%	805	Vishay	VJ1206A102KXXA	Yes	Yes
C2, C3, C14, C15	4	Cap. Aluminum Elec., 2200 μF, 25 V	2200 μF, 25 V	20%	16.0 mm x 25.0 mm	Panasonic	EKB00JG422F00	Yes	Yes
C24	1	Ceramic chip capacitor	470 pF, 50 V	10%	1206		VJ01206470KXAA	Yes	Yes
C20	1	Ceramic chip capacitor	10 pF, 50 v	10%	1206	Vishay	VJ01206Y100KXAA	Yes	Yes
C5	1	Capacitor, Aluminum Elect.	100 μF, 35 V	20%		Vishay	EKB00BA310F00	Yes	Yes
C27	1	Ceramic chip capacitor	1000 pF, 250 V	20%		Murata	DE2E3KH102MA3B	Yes	Yes
C4, C26	2	Ceramic chip capacitor	1 μF, 50 V	10%	1206	Vishay	VJ01206Y106KXXA		Yes
C6	1	Cap, Ceramic	0.01 μF, 1000 V			Vishay	225261148036	Yes	Yes
C7, C8	2	Cap. Aluminum Elec 47 μF, 25 V	47 μF, 25 V	20%	5.0 mm x 11.0 mm	Vishay	EKB00AA247F00	Yes	Yes
D13, D15	2	Diode, rectifier	800 V, 1 A	NA	DO41	ON Semiconductor	1N4006		Yes
D18	1	Zener Diode, SM	18 V, 0.3 W	NA	SOT-23	VISHAY	AZ23C18		Yes
D17	1	Diode, schottky, 100 V, 20 amps	100 V, 20 A	NA	TO220AB	ON Semiconductor	MBR20100CT	Yes	Yes
D2, D12, D14, D17, D20	5	Diode, signal	75 V, 100 ma	NA	SOT-23	ON Semiconductor	BAS19LT1		Yes
D21	1	Diode, ultra fast	800 V, 1 A	NA	DO41	ON Semiconductor	MUR180		Yes
D19	1	TRANSORB	250 V		41A	ON Semiconductor	1.5KE250A		

Table 4. Bill of Materials for the NCP4302 Demo Board

Designator	Qty	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number	Substitution Allowed	Lead Free
D8, D9, D10, D11	4	Diode, rectifier	1000 V, 3 A	NA	DO201AD	ON Semiconductor	1N5408		Yes
F1	1	FUSE	250 Vac, 2 Amps	NA	10 mm x 2.5 mm	Bussman	1025TD2A-TR		Yes
H1	2	Shoulder Washer	NA	NA	NA	Keystone	3049	Yes	Yes
H1-H2	2	Male Header	N/A	N/A	N/A	Molex	26-60-4030		Yes
H2	2	Insulator	NA	NA	NA	Keystone	4672	Yes	Yes
J1	1	Header				Molex	SD-42375-001		
J2	1	PCB Connector	10 A, 300 V	NA	5.08 mm	Weidmuller	171602	Yes	Yes
J4	1	PCB Connector	2.5 A, 250 V	NA		Qualtek	770W-00/02	Yes	Yes
L1	1	Inductor	2.2 μH, 7.5 A	10%	0.52 mm x 0.39 mm	Coilcraft	DO33316P-222	Yes	Yes
L5	1	Common Mode Inductor, 1 mH	1 mH, 3.2 A	30%	NA	Coilcraft	P3216-A	No	Yes
Q1	1	MOSFET, 11 amp, 800 V, 0.8 OHMS	800 V, 11 A	NA	TO-22131	Infineon	SPP11N80C3	Yes	Yes
Q3	1	MOSFET, 100 V, 73 A	100 V, 73 A	NA	TO220AB	IR	IRFB4410PBF	No	Yes
Q4	1	Transistor, NPN	75 V, 600 mA		SOT-23	ON Semiconductor	MMBT2222ALT1	No	
R1, R3	2	Resistor, SM	0.4 Ω	1%	2512	VISHAY	WSL2512R4000F EK	No	Yes
R6	1	Resistor, SM	330 kΩ, 1/8 W	1%	1206	VISHAY	CRCW012063303F	Yes	Yes
R10	1	Resistor, SM	7.32 kΩ, 1/8 W	1%	1206	VISHAY	CRCW012067321F	Yes	Yes
R2, R18	2	Resistor	100 k, 3 W	5%	Axial	VISHAY	CPF3100k00JNE14	Yes	Yes
R21, R22	2	Resistor, SM	1 kΩ, 1/4 W	5%	1206	VISHAY	CRCW12061K00FKTA	Yes	Yes
R28	1	Resistor	100 Ω, 1/4 W	5%	1206	VISHAY	CRCW1206100RJNTA	Yes	Yes
R23	2	Resistor	20 Ω, 1/2 W	5%	Axial	Ohmite		Yes	Yes
R8, R13	2	Resistor, SM	10 Ω, 1/4 W	5%	1206	VISHAY	CRCW120610R0JNTA	Yes	Yes
R4	1	Resistor, SM	48.7 kΩ, 1/4 W	1%	1206	VISHAY	CRCW12064872F	Yes	Yes
R11	1	Resistor, SM	75 Ω	5%	1206	VISHAY	CRCW1206750RJNTA	Yes	Yes
R7	1	Resistor, SM	4.7 k	5%	1206	VISHAY	CRCW120647K0JNTA	Yes	Yes
R32	1	Resistor, SM	200 k, 1/4 W	1%	1206	VISHAY	CRCW12062003F	Yes	Yes
R17	1	Resistor, SM	0 Ω, 1/4 W	1%	805	VISHAY	CRCW08050R00F	Yes	Yes

Table 4. Bill of Materials for the NCP4302 Demo Board

Designator	Qty	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number	Substitution Allowed	Lead Free
R30, R31	2	Resistor	499 k	5%	Axial	VISHAY	RN65D4993FR36	Yes	Yes
R33	1	Resistor, SM	15 k, 1/4 W	5%	1206	VISHAY	CRCW120615K3JNTA	Yes	Yes
R35, R36	2	Resistor, SM	47 k, 1/4 W	5%	1206	VISHAY	CRCW120647K3JNTA	Yes	Yes
T5	1	Flyback Transformer	300 μH, 6 A	N/A	Custom	Cooper Electronics	CTX22−16134	No	
U12	1	Syncronous Rectification Controller	2.5 V	NA	SOIC 8	ON Semiconductor	NCP4302	Yes	Yes
U13	1	OPTO COUPLER				NEC	P52561A−1	Yes	Yes
U9	1	Flyback Controller	18 V, 0.5 A	NA	SOIC 8	ON Semiconductor	NCP1230D65R2		Yes

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