ON Semiconductor®

GreenPoint®
From ON Semiconductor

50 W Four-Output Internal Power Supply for Set Top Box

Reference Design Documentation Package

TND334

50 W Four-Output Internal Power Supply for Set Top Box

Reference Design Documentation Package

ON Semiconductor®

http://onsemi.com

TECHNICAL NOTE

1 Overview

This reference document describes a built-and-tested, GreenPoint® solution for a 40 W (40 W nominal power, 50 W peak power) set-top box (STB) power supply. This document presents the results of various secondary rectification and regulation techniques that were used to find the highest practical efficiency scheme for a four-output, 40 watt set top box power supply.

The power supply design is built around ON Semiconductor's NCP1308 Current-Mode controller, on the primary side, using free running quasi-resonance operation. The secondary side offers four outputs (+5 V, -5 V, 3.3 V and 12 V). The +5 V output is the main channel with the closed PWM loop while the 3.3 V output is derived by using the NCP1587 in a buck (step-down) DC-DC topology with synchronous rectification. The 12 V output is derived from +5 V by stacking the 12 V secondary winding onto the 5 V winding.

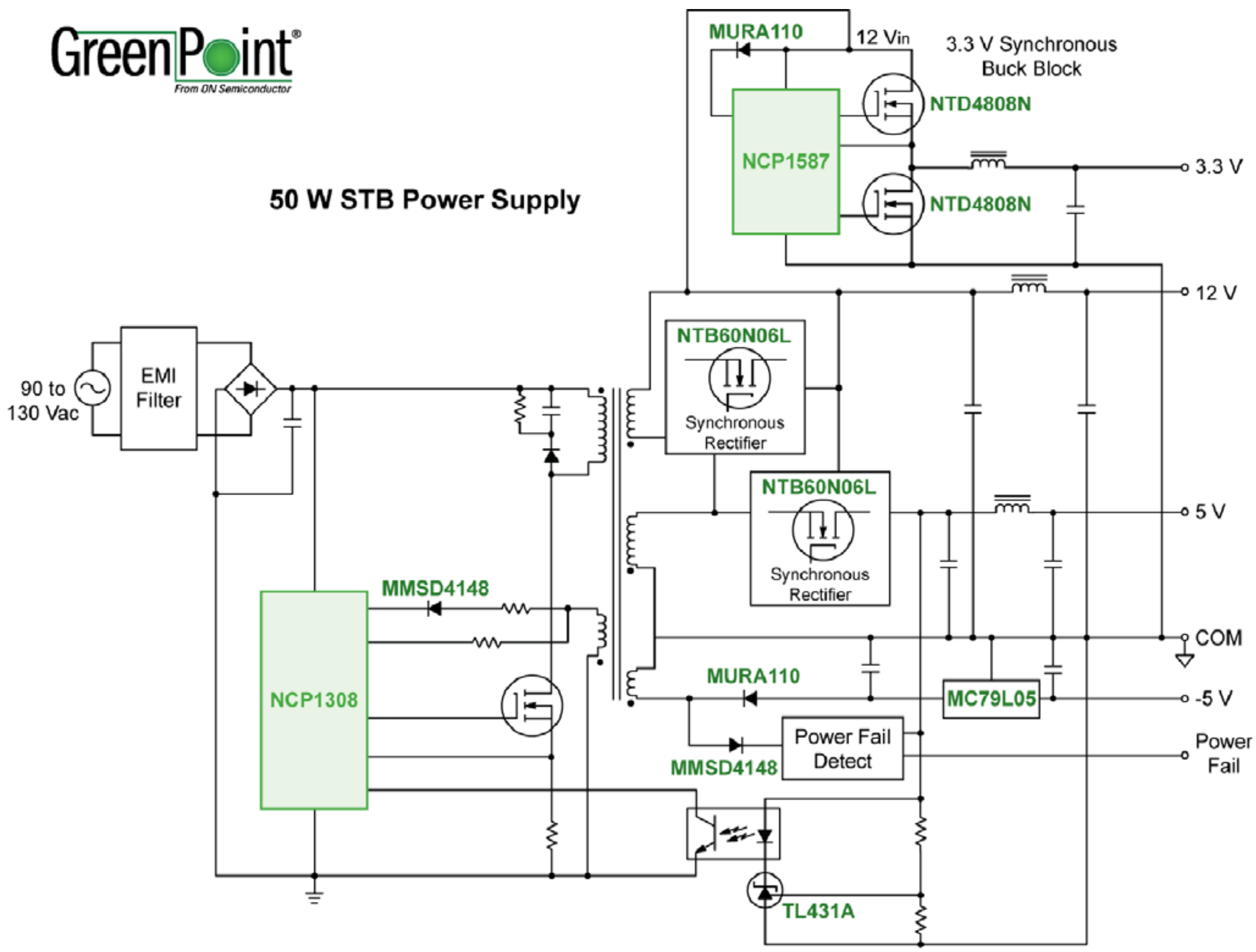


Figure 1. shows a simplified block diagram of the reference design circuit.

2 Introduction

Across the United States, millions of electronic devices help consumers enjoy pay-TV programming. Known as set-top boxes (STB), these products allow consumers to receive and display programming services like cable and satellite on their TVs. Set-top boxes now consume more energy than many common home appliances. Taken together, the box and its attached TV could easily consume more energy per year than a refrigerator. For example, a new high-definition set-top box with built-in DVR consumes about 350 kWh per year. With 1 to 2 set-top boxes in most U.S. households, it is estimated that these appliances consume over 23 billion kWh of electricity nationwide, resulting in power plant emissions of over 15 million tons of carbon dioxide (CO2), a heat-trapping greenhouse gas responsible for global warming (source: NRDC & Ecos Consulting).

These figures could double in the coming decade as many pay-TV service providers retire their older set-top boxes in favor of newer boxes with built-in digital video recorder (DVR) capabilities. This transition would require the equivalent of 7 to 8 new power plants to support the growth in electricity demand.

As the boxes are currently designed, they cannot be significantly powered down without unplugging them from the wall. It is estimated that over 10 billion kWh per year (the equivalent electricity output of three 600-MW power plants) could be saved if today's boxes could automatically drop into low power states when not being actively used, like many other consumer electronics (source: NRDC & Ecos Consulting).

For more information and facts on the current set-top box market and on the energy savings opportunities in set-top boxes, check http://www.efficientproducts.org/stbs/#efficiency

3 Definitions

The term STB can apply to any electronic device that is connected to a television. A majority of these boxes are designed to take a signal from a cable feed, satellite dish, broadcast antenna, or other source and convert it into a signal that can be viewed on a TV. These types of STBs range from simple converter devices all the way up to computer type boxes that are capable of displaying HDTV signals and incorporate digital video recorders (DVRs). Other STBs are designed to allow users to play video games (such as the X-box), or digitally record programming (e.g. TiVo™ boxes). STBs can be divided into several basic categories, also shown in the Figure 2 below in order of increasing functionality and on mode power use (source: http://www.efficientproducts.org/stbs/#stock):

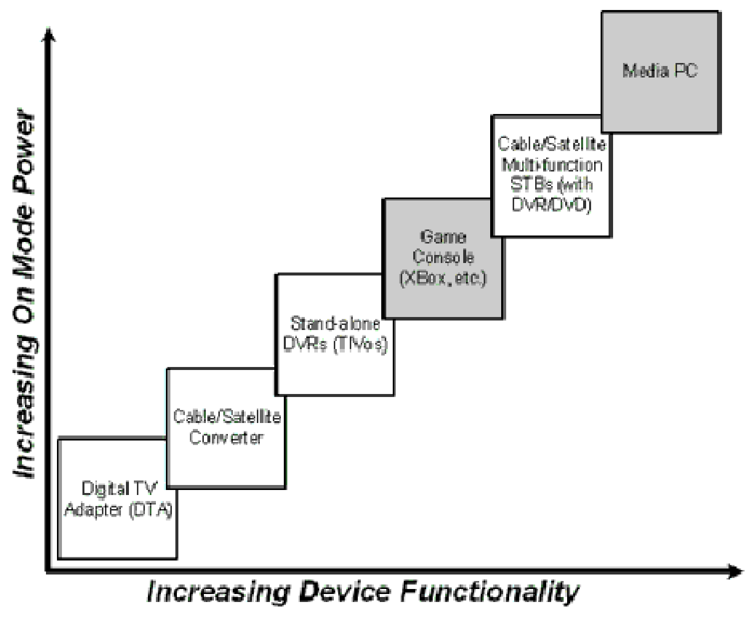


Figure 2.

- **Digital television adapter (DTA)**: form of STB designed to take broadcast digital TV signals and convert them into an analog format useable by analog TVs. For more information on DTAs, check the ENERGY STAR® guidelines for DTAs at http://www.energystar.gov/index.cfm?c=dta.pr_dta. You can also check the GreenPoint reference design for an 8 W internal power supply for DTA at http://www.onsemi.com/PowerSolutions/supportDoc.do?type=Reference%20Designs: a STB designed to convert digital or analog cable/satellite signals into digital or analog signals useable by a TV. Cable/satellite can also be used to descramble premium pay content on cable/satellite networks.)

- **Cable/satellite converter**: a STB designed to convert digital or analog cable/satellite signals into digital or analog signals useable by a TV. Cable/satellite can also be used to descramble premium pay content on cable/satellite networks.
- **Stand-alone Digital Video Recorders (DVRs)**: STBs such as the TiVo™ that are designed to digitally record TV content for instant playback
- **Game Console:** STB that allows the user to play video games, browse web pages or otherwise interact with audiovisual content displayed on a TV
- **Cable/Satellite Multi-function STBs**: a form of cable/satellite converter that may contain a DVR, DVD recorder, multiple cable/satellite tuners, etc. This type of box is one focus of discussion on Efficient Products.org
- **Media PC**: a personal computer designed to tune cable/satellite signals and that can display digital media content on a TV screen without the need for intermediary audio or video adapters

The ENERGY STAR® specification for set-top boxes is currently under revision. On its web site, ENERGY STAR® provides the following definitions for the different operational modes and power states:

- **On/Active**: An operational state in which the STB is actively delivering one or more of its principal functions and some or all of its applicable secondary functions.
- **Sleep**: A state in which the STB has less power consumption, capability, and responsiveness than in the On/Active state. The STB may enter a Sleep state from the On/Active state after:
  - a) the user pushes a power/standby button on the remote or on the unit; or
  - b) the STB auto power downs to a Sleep state. The energy consumption after auto power down to Sleep and after a user-initiated power down to Sleep may, or may not be, equivalent.

Note: EPA has decided to use the term "Sleep" rather than "Standby" to avoid confusion with other EPA specifications and international standards.

4 STB Power Supply Specification

The power supply specification called for four regulated outputs with the following general requirements:

Input: V_{in}: 90 to 135 Vac, 55 to 65 Hz

Outputs					
V_{out}	**Regulation Range**	**Ripple (p/p)**	**$I_{nominal}$**	**I_{max}**	**I_{min}**
3.3 Vdc	3.3 to 3.35 V	40 mV	3.37 A	3.9 A	1.85 A
5.0 Vdc	4.9 to 5.25 V	40 mV	1.52 A	2.2 A	0.70 A
12 Vdc	11.4 to 12.6 V	120 mV	0.78 A	1.2 A	0.24 A
-5.0 Vdc	-4.85 to -5.25 V	20 mV	38 mV	58 mA	18 mA
		Total Power Output =	28.27 W	38.56 W	12.57 W
Over-current protection on all outputs with self recovery					
Efficiency: > 80%					

Five different secondary output configurations were implemented using the same primary "front end" quasi-resonant (QR) flyback converter stage, and the efficiency and performance characteristics of each were measured.

5 Operation of Main Converter

The design of the flyback converter stage was the same for all of the different output secondary configurations and was designed around one of ON Semiconductor's quasi-resonant (QR), critical conduction mode flyback controllers. The NCP1308 was used in this particular design, however, the NCP1207, NCP1377, or NCP1337 controllers could have also been used as well. The QR flyback converter was chosen for this application because of its inherent simplicity, low cost and high conversion efficiency. The latter characteristic is achieved by operating the flyback in the critical conduction mode and allowing the primary Mosfet to switch back on only when the drain-to-source voltage is at a minimum during the flyback ring-out (quasi-resonant via valley switching). This technique insures low switching losses in both the Mosfet and the output rectifiers. Details of critical conduction mode and QR switching can be found in the numerous application notes for the above mentioned QR controllers at ON Semiconductor's website (see references at the end of this document.)

Although the primary and Vcc windings on the various flyback transformer implementations were identical, the secondary windings had to be different for each secondary configuration necessitating a different transformer design for each. The schematic of the primary part of the flyback converter is shown in Figure 3. Note that a two stage EMI filter (L1, L2 and associated "X" caps) is employed for maximum attenuation of conducted EMI. The main control loop feedback from the sensed output to the NCP1308 controller U1 is accomplished by optocoupler U2. The Vcc winding on T1 provides the operating voltage for the controller after startup and also provides the valley detection feedback signal to pin 1 of the controller. R3 is the peak current sense resistor that sets the inverter peak over current level as well as current sensing for the current mode control mechanism in U1.

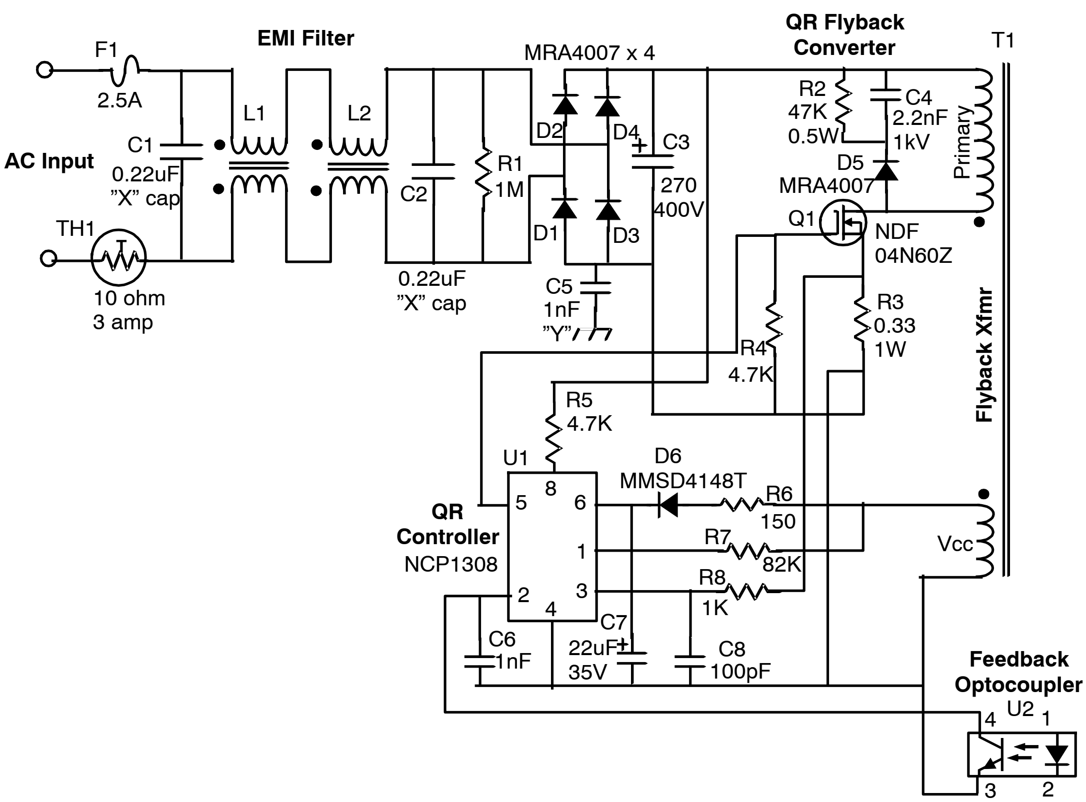


Figure 3. Quasi-resonant flyback converter design

6 Secondary Circuit Approaches

Five different secondary circuit designs were tested. The circuitry included the use of Mosfet synchronous rectifiers for the main flyback winding and synchronous Mosfet buck converters for low voltage post regulators in several different configurations which are described below.

6.1 Configuration #1

The first secondary configuration is shown in Figure 4. In this implementation the main channel is the 3.3 volt output around which the PWM loop is closed. A TLV431A programmable zener (U6) is used as the voltage sense error amplifier and feedback to the primary PWM chip (NCP1308) is accomplished via optocoupler U2. This output was selected as the main channel because it has the highest current output. A Mosfet synchronous rectifier circuit was utilized in the positive leg of the 3.3 volt secondary and is shown in the lower schematic section block of Figure 4. The synchronous rectifier circuit controls the Mosfet by sensing any significant current in the secondary winding via sense transformer T2 and then switching it on with the associated bipolar complementary driver circuit. Power for the driver is provided by the 12 volt output.

The 12 volt channel was configured as a quasi-regulated output with the lower part of the 12 volt secondary stacked on the top of the 3.3 volt secondary for improved cross regulation. Achieving an optimum integer turns ratio in the transformer was difficult because of the low number of turns required for the 3.3 V output. The transformer utilized 2 turns of copper foil for the 3.3 V winding and a multi-filar 5 turn wire winding for the 12 V which was in turn stacked on top of the 3.3 V winding. This configuration required the primary to have approximately twice as many turns as what would be necessary to satisfy the core’s maximum flux density requirements. As a consequence the 12 V output was satisfactory with full loading on the 3.3 V output, but below the minimum specified level of 11.4 V with minimum loading on the 3.3 V output. A conventional low forward voltage drop Schottky diode (D11) was initially used for the 12 V flyback rectifier. This was later replaced with a synchronous rectifier in Configuration 1A.

The 5.0 volt output was derived from the 12 volt output by using a synchronous buck converter using the NCP1587 controller (U4) and a pair of low on-state resistance Mosfets. This technique provides a well regulated, low ripple output with independent current limiting. The dc input-to-output efficiency of the buck converter section was measured at 94% at the specified full load of 2.2 amps.

Due to the very low output current (58 mA), the -5 volt output design was the same for all of the tested secondary configurations and was implemented from an auxiliary winding on T1 followed by a simple MC79L05 negative three terminal regulator (U5). This output was loaded to 50 mA for all efficiency and test measurements.

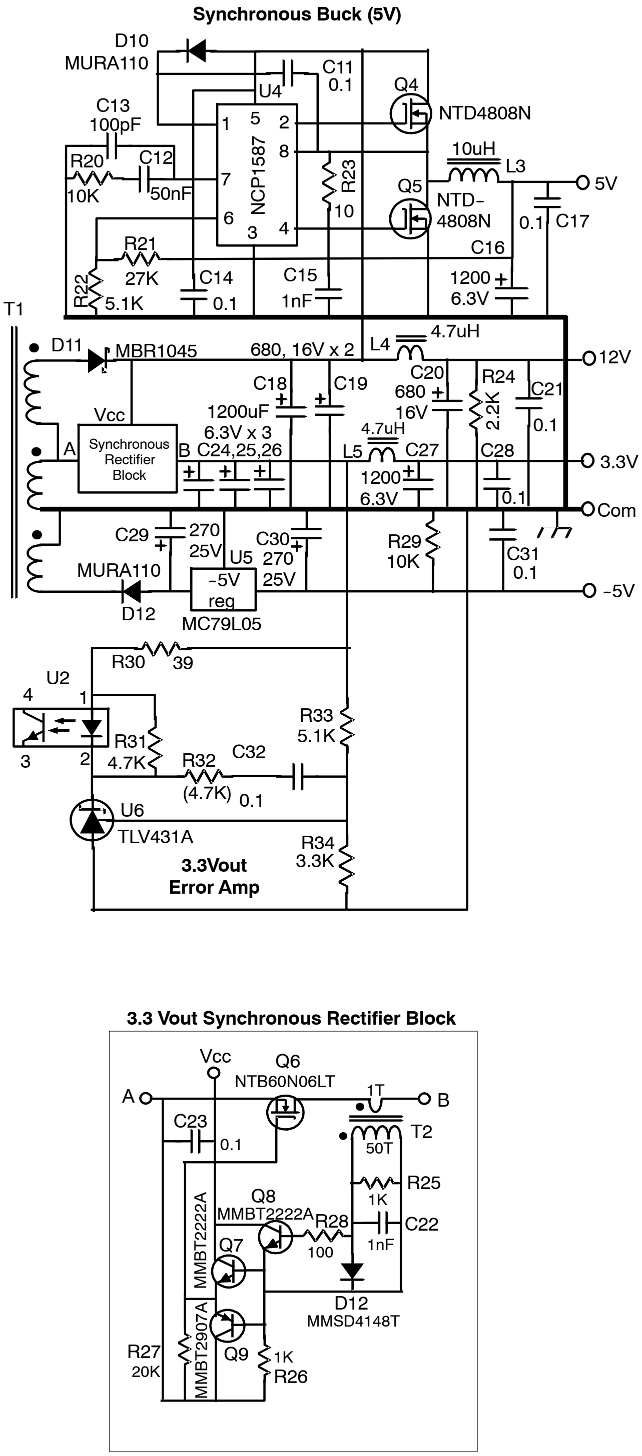


Figure 4. Secondary Configuration #1

6.2 Configuration #1A

In this configuration the Schottky rectifier for the 12 volt channel (D11) was replaced with a synchronous rectifier exactly like the one for the 3.3 V output and the efficiency was measured again. This configuration did improve the overall efficiency and placed the 3.3 V to 12 V cross-regulation just within specification limits due to the elimination of the Schottky diode forward drop that subtracts from the effective output voltage.

6.3 Configuration #2

In the second configuration, the main channel was the 12 volt output with the PWM loop closed around it. A TL431A error amp and optocoupler combination was used in a similar PWM feedback scheme as in Configuration 1. As mentioned previously, the -5 V output was the same as in Configuration 1. A current sensed synchronous rectifier circuit was also used for this output, however, the circuit was implemented in the lower leg of the secondary winding due to the fact that the operating Vcc for the sync circuit had to come from the 12 volt output also. The schematic of Configuration 2 is shown in Figure 5 and the synchronous rectifier schematic block is shown to the lower left of the main schematic.

Both the 5 volt and 3.3 volt channels were derived from the 12 volt output with NCP1587 buck converters identical to the 5.0 volt buck in Configuration 1. The detailed schematic of the buck converter block is shown at the lower right of Figure 5. The measured dc input-to-output efficiency of the 3.3 volt converter section was 92% with a load of 3.9 amps.

The principle advantage of this particular configuration was the simplicity of the flyback transformer design. Because of the higher voltage of the 12 V secondary, it was easy to configure the turns ratio of the windings for low leakage inductance and minimal winding layers. In addition the lack of quasi-regulated (slave) outputs eliminates all cross-regulation issues and all outputs are tightly regulated with low ripple and independently current limited.

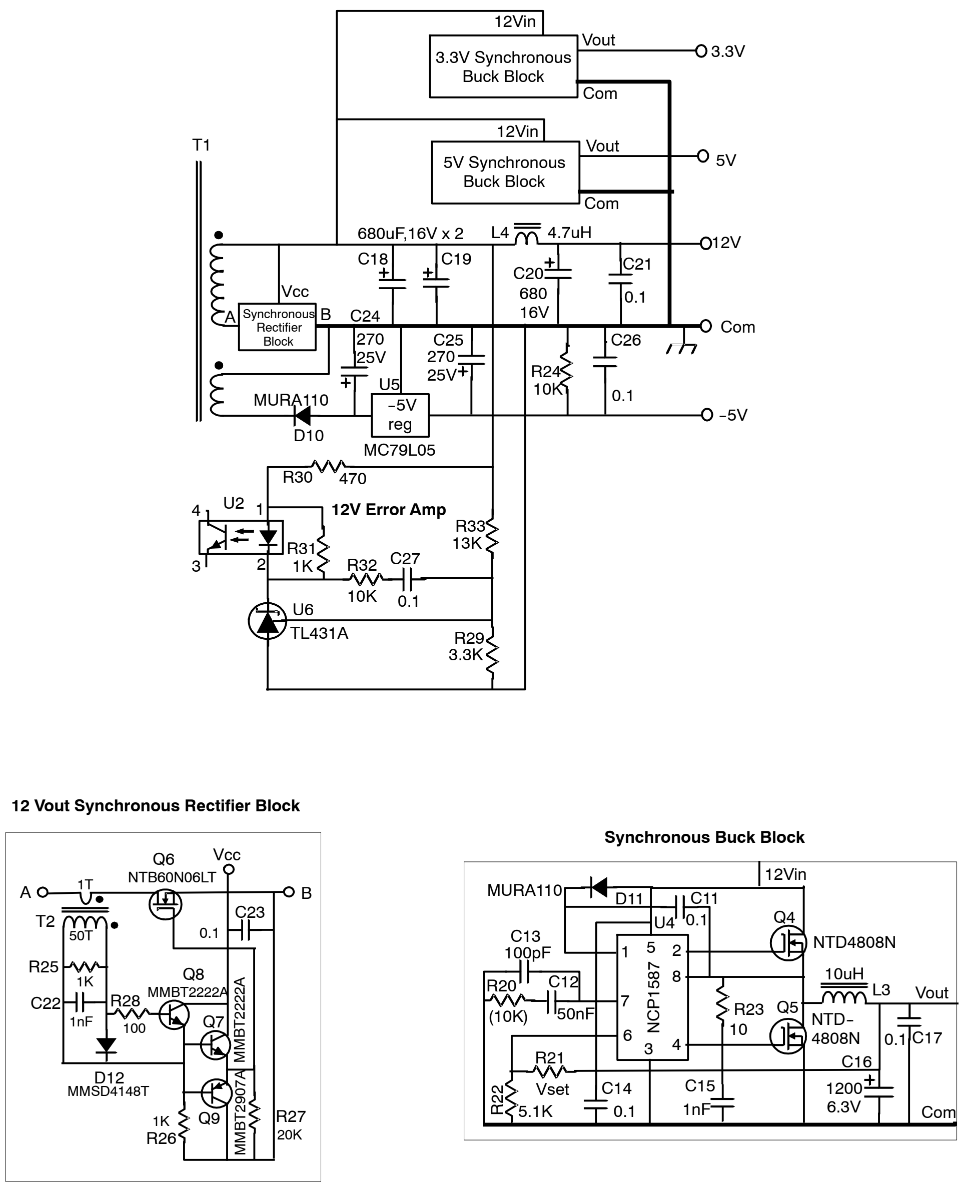


Figure 5. Secondary Configuration #2

6.4 Configuration #3

This configuration is essentially the same as Configuration 1 with the 3.3 V and 5 V channel circuit implementation swapped and is shown in Figure 6. The 5 volt output is now the main channel with the closed PWM loop while the 3.3 V output is derived from the synchronous NCP1587 buck converter. The transformer windings in this configuration were definitely easier to implement than those in Configuration 1 due to the so called “magic ratio” of 3 to 7 turns for the 5 V and 12 V outputs respectively. In this case the quasi-regulated 12 volt secondary winding was again “stacked” onto the 5 volt winding with an additional 4 turns for improved cross regulation. And indeed, the 12 volt output setpoint was just slightly above 12 volts and never exceeded 12.8 volts under asymmetrical loading.

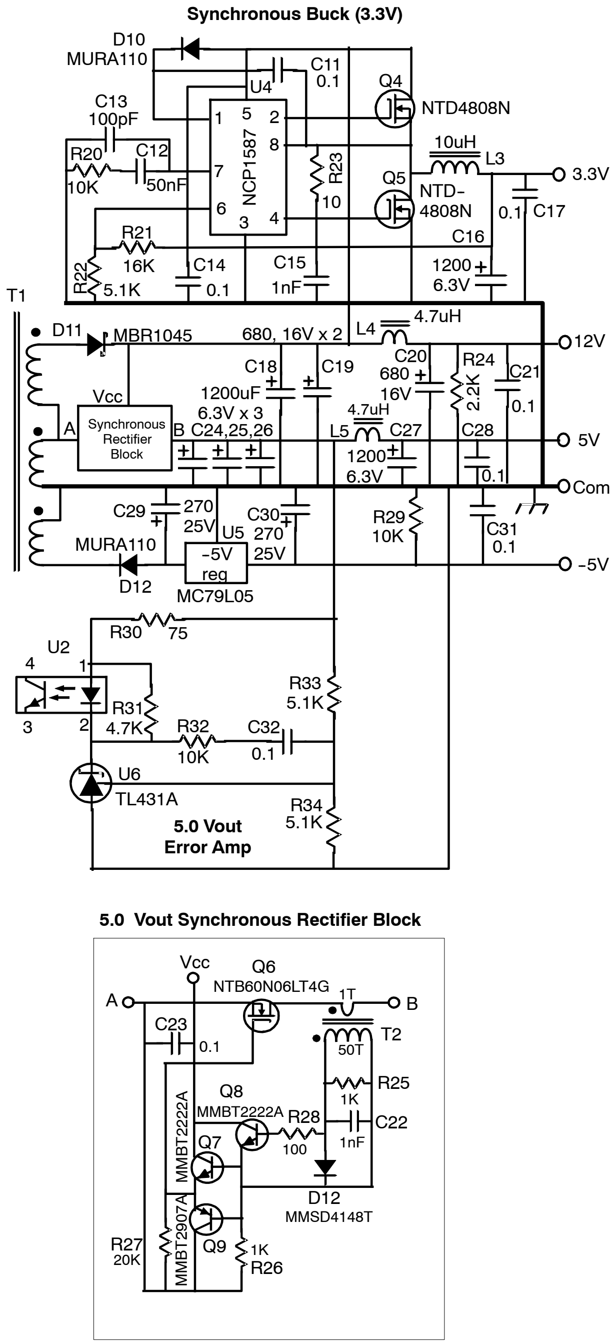


Figure 6. Secondary Configuration #3

6.5 Configuration #4

This configuration is identical to Configuration 3, however, a synchronous rectifier is substituted for the Schottky flyback rectifier (D11 of Figure 6) in the 12 V output. This implementation is shown in Figure 7. Note that in order to use the 12 V output to power the synchronous rectifier drive circuit, the synchronous rectifier circuit block had to be moved to the lower winding node where it connects to the “top” of the 5 V secondary winding. It was also necessary to configure the synchronous rectifier circuit in a “reverse” manner for the 12 V output due to the current flow direction in the bottom winding leg.

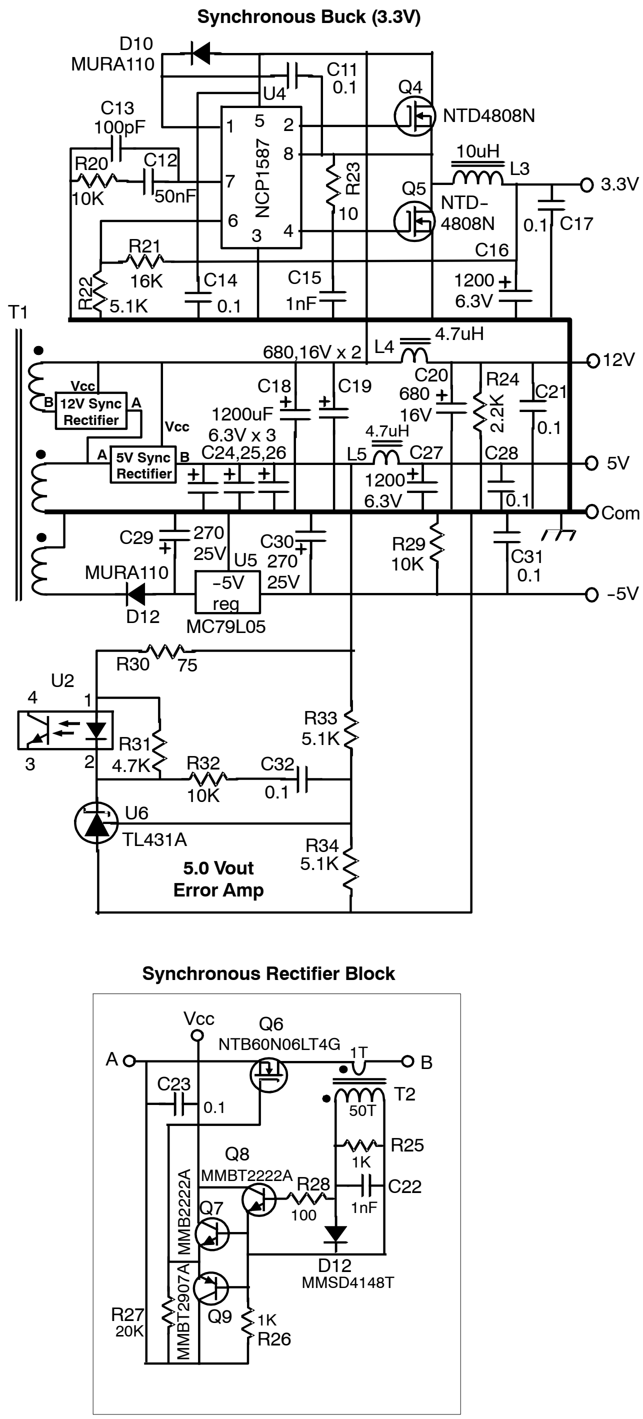


Figure 7. Secondary Configuration #4

7 Test Results

7.1 Active Mode Efficiency

The throughput efficiency of each of the configurations was measured using fixed precision resistive loads and a Voltech PM1000 line analyzer. The power supply input voltage was 117 Vac and the loads were configured for the following currents at the nominal output voltage:

Original Load Profile

V_{out} Nominal	Output Current	Watts
3.3 Vdc	3.4 A	11.22
5.0 Vdc	2.0 A	10.0
12.0 Vdc	1.2 A	14.4
−5.0 Vdc	50 mA	0.25
		Total Output Power = 35.87 W

The measured efficiency for each configuration is as follows:

Configuration	Efficiency
Configuration #1:	77.6%
Configuration #1A:	78.5%
Configuration #2:	79.5%
Configuration #3:	80.2%
Configuration #4:	81%

Since Configuration #4 produced the highest efficiency for the specified loading, a new pc board layout was implemented and optimized for this configuration. Five additional loading profiles were tested to determine the effect of the load distribution on efficiency. Tests were performed with an input of 120 Vac and a total load of 40 watts. The −5 volt output was loaded to 50 mA in each case. The results are shown in Table 1.

Table 1. Efficiency vs. Output Loading Profile

Different Load Profile of Outputs for Configuration 4	Efficiency	Wattage per Channel (Total = 40 W)		
		3.3 V	5.0 V	12 V
Original load profile	81%	11.22 W	10 W	14.4 W
1	78.20%	15 W	15 W	10 W
2	81.20%	11 W	10 W	18 W
3	81.80%	8 W	15 W	18 W
4	82.70%	8 W	10 W	24 W
5	83.60%	5.4 W	10 W	24 W

7.2 Comments and Conclusions

The efficiency results show that for the original tested load profile, which is just slightly less than the maximum specified loads but greater than the nominal load, only two configurations produced an efficiency of 80% or better. Also, the fact that the efficiency spread is concentrated around an average of about 79% indicates that it is probably difficult to obtain greater efficiencies (with the specified load distribution) without some serious circuit design compromises. Some other interesting observations are as follows:

1. Having to resort to multiple winding techniques (foil and wire), and greater than optimal primary turns to accommodate proper turns ratios as in Configuration 1, can result in detrimental leakage inductance effects (as well as more expensive magnetics). Adding the synchronous rectifier of Configuration #1A did improve the efficiency and cross-regulation but was not sufficient to achieve 80%.
2. Using synchronous buck converters to produce the two high current, low voltage outputs (5 V and 3.3 V) from the 12 V output (Configuration #2) was the “cleanest” design from the standpoint of the transformer construction and cross-regulation issues, but was still unable to attain 80% efficiency. Additional testing of Configuration #2 was performed in which the 12 V output was loaded to the full 36 watts (3 A load) and the two dc-dc synchronous bucks for 3.3 V and 5 V and the −5 V_{out} were disconnected. The efficiency of this single output configuration was 85.6%.
   The product of this efficiency, which is essentially the efficiency of the flyback conversion stage, times the average efficiency of the two dc-dc synchronous bucks (92%, see Configuration #2 in section 6.2) mentioned in the Configuration #2 description above, yields a total throughput efficiency of 79.5% (86.5% * 92% = 79.5%) which is exactly what the measured efficiency of Configuration #2 was (see test results in section 7.1).
3. Using the ideal 3 to 7 turns ratio for the 5 V and 12 V transformer windings in Configuration #3 and #4, closing the PWM loop around the 5 V output, and deriving the 3.3 V via a synchronous buck appears to be the best compromise for highest efficiency. Also replacing the 12 V_{out} Schottky rectifier with a synchronous rectifier

increased the efficiency almost an extra point for Configuration #4.

4. Higher efficiency, approaching 85%, could probably be achieved by using a secondary configuration similar to that shown in Figure 8 where no buck post regulators are used and all output rectifiers are synchronous Mosfet circuits. Unfortunately, such a configuration will require a very sophisticated secondary structure on the flyback transformer. This winding configuration will have to have the exact turns ratios to achieve the required output voltages, and a stacked and interleaved winding structure such that leakage inductance and cross-regulation issues are minimized. This would probably mean a somewhat larger and more expensive transformer than the other configurations which rely on buck post regulators to alleviate regulation issues.

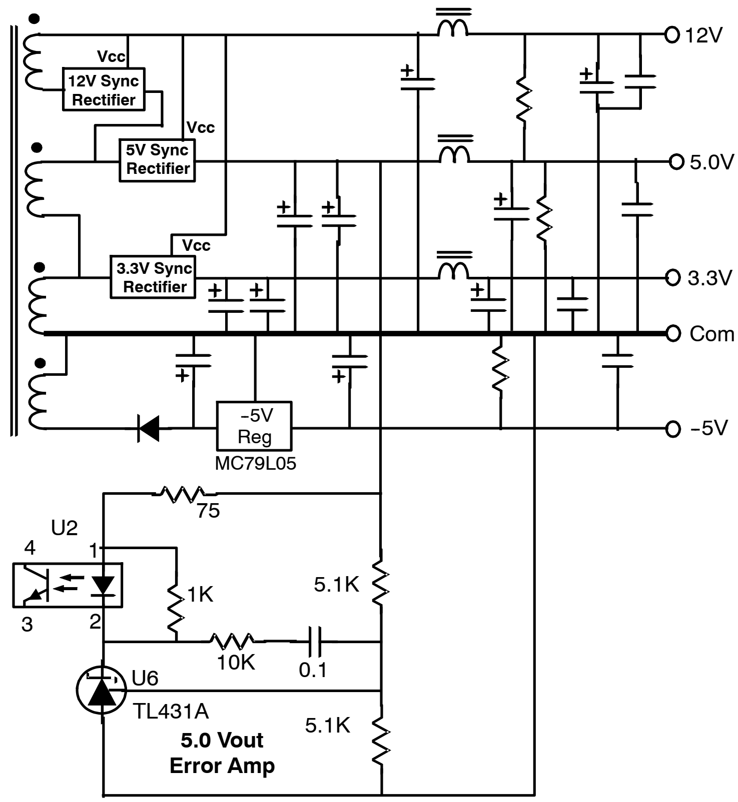


Figure 8. Possible Secondary Configuration #5 for Higher Efficiency

5. Other circuit changes that could possibly result in higher efficiency include using a flyback Mosfet (Q1) with a lower Rds(on) rating; minimizing the switching losses in Q1 by precisely tailoring the snubber circuit (R2 and C4) and the transformer primary inductance for minimal flyback ringing; and by minimizing all dc resistance losses associated with the input EMI filter and the circuit board layout of the power trains.

6. One can see from Table 1 that the loading profile on the different outputs has a significant impact on the overall efficiency. The efficiency is obviously the worst when the highest output current goes with the lowest output voltage as would be expected.

7.3 General Performance and Characteristics

The overall power supply performance of the different configurations was generally very good with the exception of the cross-regulation effects of Configuration #1 and #1A, mainly due to the more complex transformer structure and the associated leakage inductance effects. Configuration #2 was by far the "cleanest" in terms of overall performance with respect to regulation, low output ripple, over-current protection, and ease of testing due to the fact that all outputs were regulated independently.

Configuration #4 was the most efficient because only one synchronous post regulator was used and that was for the 3.3 volt output. The loop was closed around the 5 volt output and the 12 volt secondary was configured as a stacked winding with a relatively manageable transformer design which is both interleaved and multi-filar wound for the 5 volt and 12 volt winding as well as the -5 volt winding (see Figure 13 for the transformer design). Figures 9, 10, and 11 show representative waveforms for the circuit of final Configuration #4. Figure 9 is the flyback voltage on the Q1 Mosfet drain at 50% loading where the quasi-resonant valley switching at turn on can be easily seen. Figures 10 and 11 show the 3.3 V and 5 V output ripple waveforms, respectively.

Figure 12 is a complete schematic of the final set top box power supply configuration.

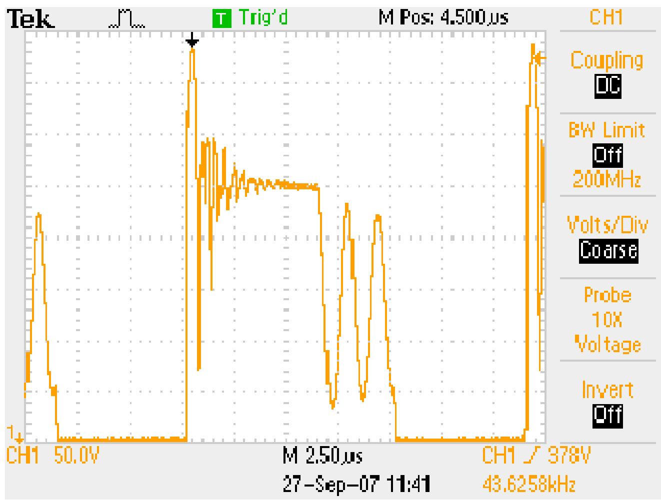


Figure 9. Flyback Q1 Mosfet Drain Waveform (50% load)

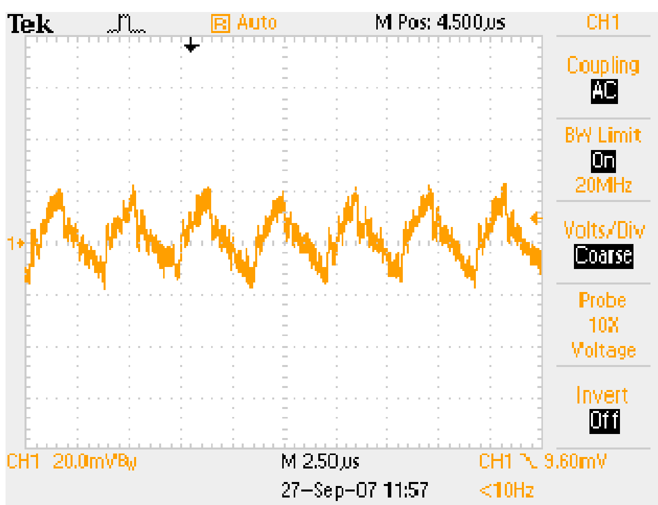


Figure 10. Synchronous Buck Output Ripple (3.3 V)

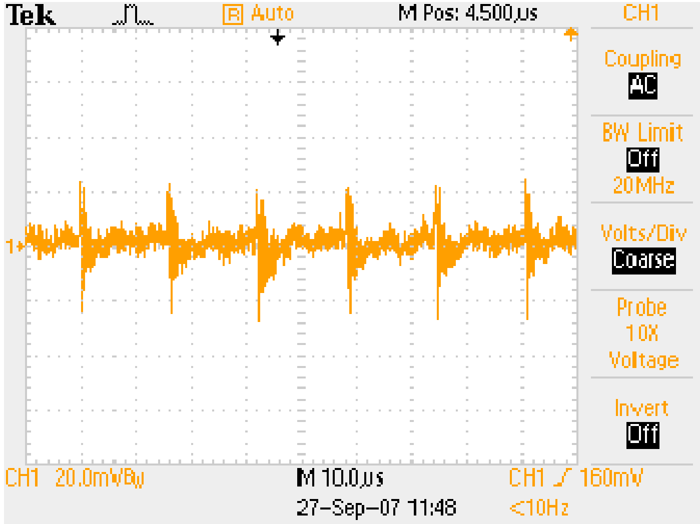


Figure 11. Main 5 Volt Output Ripple

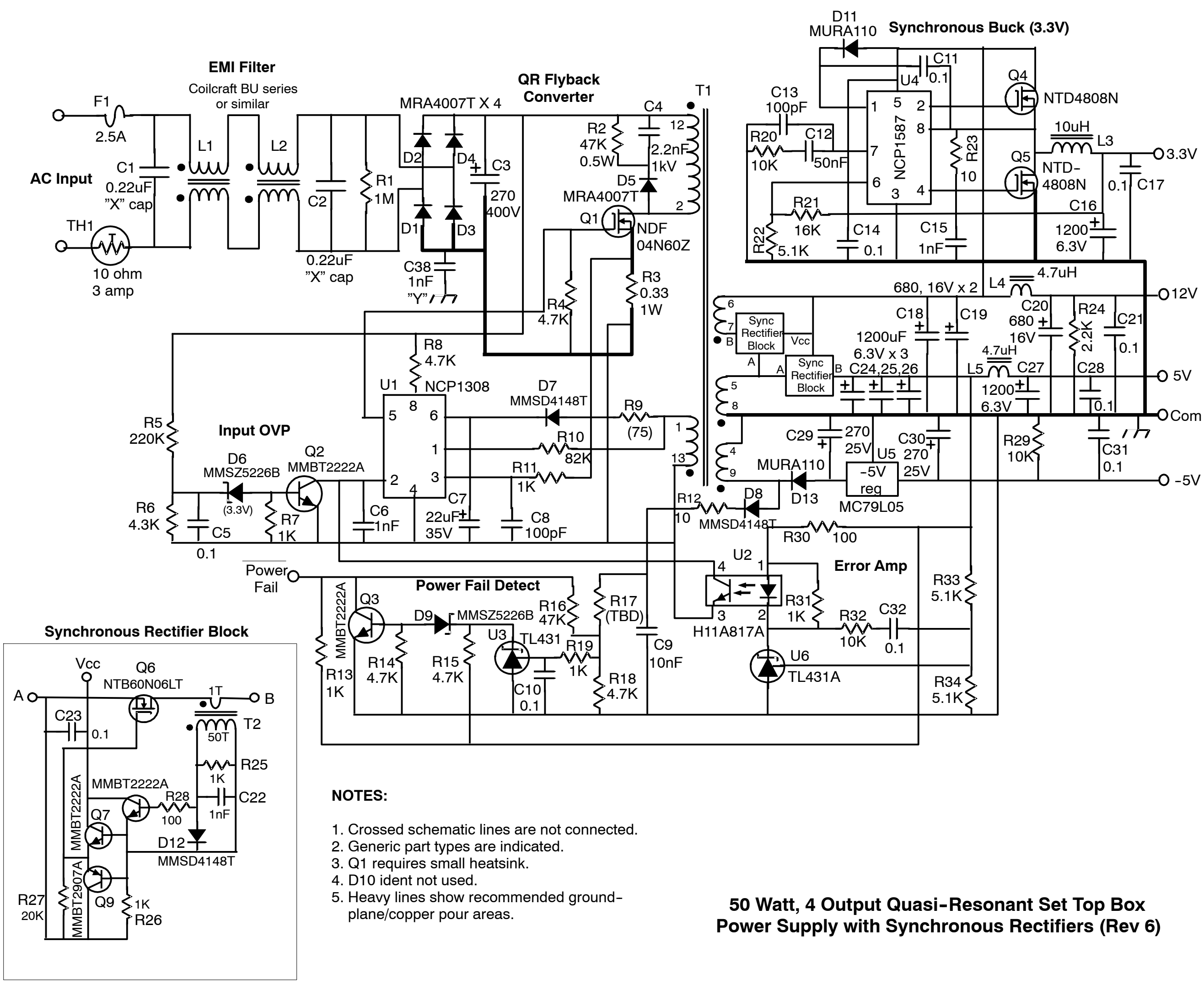


Figure 12. Schematic of Final Set Top Box Power Supply (Configuration #4)

MAGNETICS DESIGN DATA SHEET

Project / Customer: 50W, 4 Output Set Top Box PSU

Part Description: Quasi-resonant flyback transformer (type 3)

Schematic ID: T1

Core Type: ETD29 (Ferroxcube 3C90 material or equivalent)

Core Gap: Gap for 400 uH +/- 5%

Inductance: 380 to 420 uH nominal across primary (pins 13 to 1)

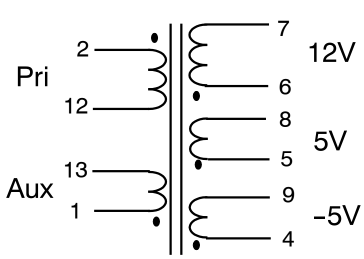
Bobbin Type: ETD29 13 pin horizontal pc mount (Ferroxcube PC1-29H)

Windings (in order):

Winding # / type	Turns / Material / Gauge / Insulation Data
Aux winding (1 - 13)	7 turns of # 26HN spiral wound over bobbin base. Self-leads to pins. Insulate for 1 kV to next winding.
Primary (2 - 12)	42 turns of #26HN over one layer; cuff ends with tape. Insulate with tape for 3 kV. Self-leads to pins
5V/-5V/12V Secondaries (5 - 8) (4 - 9) (6 - 7)	3 turns multifilar of 5 strands of #26HN with 2 brown strands (5V), 1 green strand (-5V) and 2 tan strands (12V). Flat wind over one layer and then continue with the 2 tan strands for one more turn. The tan wire is the 12V stacked winding. Center winding by allowing approximately 5 mm end margins. Self-leads to pins per schematic below. Final insulate with tape. .

Hipot: 3 kV primary/aux to all secondaries. Vacuum varnish.

Schematic



Lead Breakout / Pinout

Bottom (pin side) view

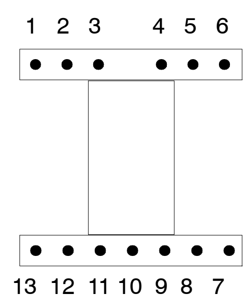
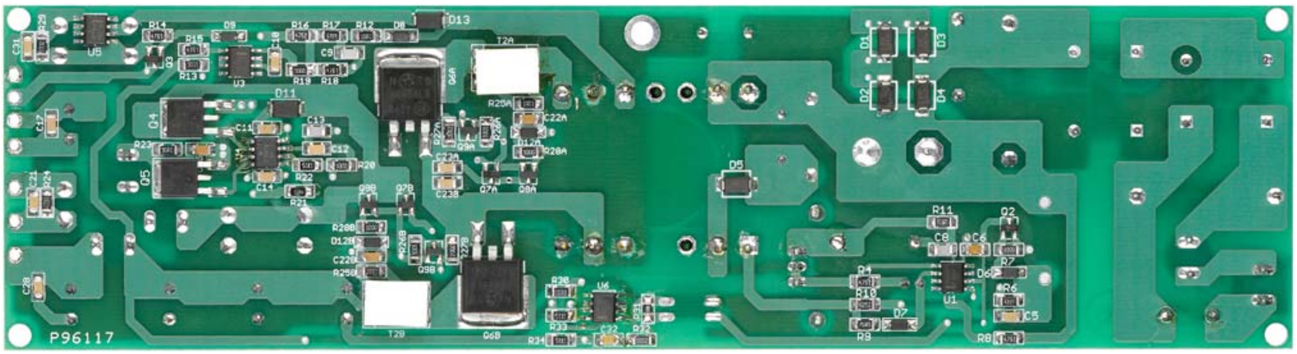


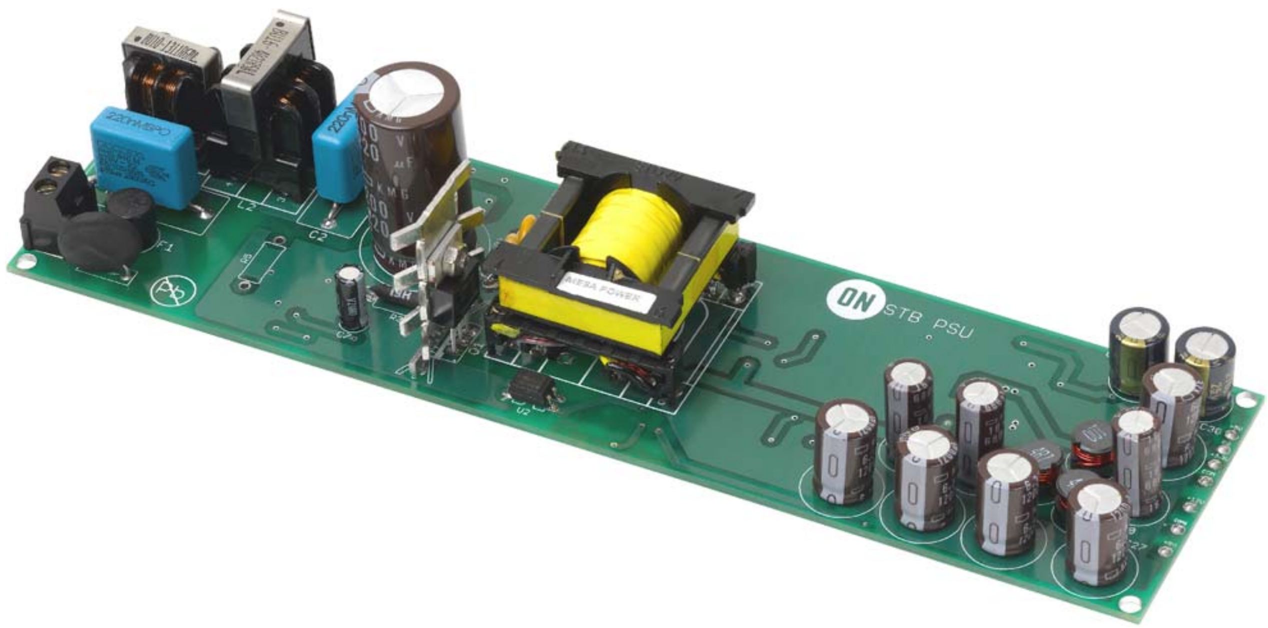
Figure 13. Flyback Transformer Design of Final STB Power Supply (Configuration #4)

8 Bill of Materials for Final Set Top Box PSU (Configuration #4)

Part	Qty	ID	Description	Comments
Semiconductors				
MRA4007T3G	5	D1, 2, 3, 4, 5	1A, 800V diode	ON Semiconductor
MMSD4148T1	4	D7, D8, D12A, D12B	100 mA signal diode	ON Semiconductor
MMBT2222AWT1	6	Q2, 3, 7A, 7B, 8A, 8B	500 mA, 40V NPN xstr	ON Semiconductor
MMBT2907AWT1	2	Q9A, Q9B	500 mA, 40V PNP xstr	ON Semiconductor
NCP1308	1	U1	Ouasi-resonant PWM controller	ON Semiconductor
NDF04N60Z	1	Q1	4 Amp, 600 V Mosfet	ON Semiconductor
NTD4808N (DPak)	2	Q4, Q5	N-channel Mosfet, 30V	ON Semiconductor
NTB60N06LT4G (D2Pak)	2	Q6A, Q6B	N-channel Mosfet, logic level	ON Semiconductor
NCP1587	1	U4	Synchronous buck controller	ON Semiconductor
Optocoupler	1	U2	H11A817A (4 pin) or similar	Vishay
MURA110	2	D11, D13	1A, 100V ultrafast diode	ON Semiconductor
MMSZ5226B	2	D6, D9	3.3V Zener diode	ON Semiconductor
MC79L05	1	U5	Negative 5V regulator, TO-92	ON Semiconductor
TL431A (SOIC8)	2	U3, U6	Programmable zener	ON Semiconductor
Capacitors				
”X” cap, (box package)	2	C1, C2	220 nF ”X2” capacitor, 270 Vac	Vishay
”Y” cap, disc package	1	C38	1 nF ”Y2” cap, 270 Vac	Vishay
Ceramic cap, disc	1	C4	2.2 nF, 1 kV capacitor (snubber)	Vishay
Ceramic cap, monolythic	11	C5,10,11,14,17, 21,23A, 23B,28,31,32	0.1 uF, 50V ceramic cap	Vishay
Ceramic cap, monolythic	1	C9	10 nF, 50V ceramic cap	Vishay
Ceramic cap, monolythic	1	C12	47 or 50 nF ceramic cap	Vishay
Ceramic cap, monolythic	2	C8, C13	100 pF, 100V ceramic	Vishay
Ceramic cap, monolythic	4	C6, C15, C22A, C22B	1 nF, 50V ceramic cap	Vishay
Electrolytic cap	2	C29, C30	270 uF, 25V	UCC, Rubycon
Electrolytic cap	1	C3	270 uF, 400Vdc	UCC, Rubycon
Electrolytic cap	5	C16,24,25,26,27	1200 uF, 6.3 V (low ESR)	UCC, Rubycon
Electrolytic cap	3	C18, C19, C20	680 uF, 16V	UCC, Rubycon
Electrolytic cap	1	C7	22 uF, 35V	UCC, Rubycon
Resistors				
Resistor, 1W	1	R3	0.33 ohm, 1W, axial lead	Ohmite
Resistor, 1/2W	1	R1	1 Meg, 1/2W, axial lead, metal film	Ohmite
Resistor, 1/2W	1	R2	47K, 1/2W, axial lead	Ohmite
Resistor, 1/2W	1	R5	220K, 1/2W, 5%, axial lead	Ohmite
Resistor, 1/4W	1	R25	1K, 1/4W, 1206 SMD	5% SMD (1206)
Resistor, 1/4W	1	R10	82K	5% SMD (1206)
Resistor, 1/4W	1	R24	2.2K	5% SMD (1206)
Resistor, 1/8W	9	R7, 11, 13, 19, 25A, 25B, 26A, 26B, 31	1K	5% SMD (1206)
Resistor, 1/8W	2	R12, R23	10 ohms	5% SMD (1206)
Resistor, 1/8W	3	R28A, R28B, R30	100 ohms	5% SMD (1206)
Resistor, 1/8W	1	R9	75 ohms	5% SMD (1206)
Resistor, 1/8W	2	R27A, R27B	20K	5% SMD (1206)
Resistor, 1/8W	1	R6	4.3K	1% SMD (1206)
Resistor, 1/8W	5	R4,8,14,15,18	4.7K	5% SMD (1206)
Resistor, 1/8W	1	R21	16K	1% SMD (1206)
Resistor, 1/8W	1	R16	47K	5% SMD (1206)
Resistor, 1/8W	3	R20, R29, R32	10K	5% SMD (1206)
Resistor, 1/8W	3	R22, R33, R34	5.11K	1% SMD (1206)
Resistor, 1/8W	1	R17	TBD (6.2K ?)	1% SMD (1206)
Miscellaneous				
Fuse (TR5 type)	1	F1	2.5A, 250 Vac	Bussmann
AC input connector	1	J1	GIT # 406015-001-99	IEC320??
Heatsink for NTP06N65	1	(Q1)	TO-220 type, # 542502d00000	Aavid
PCB double sided, 2 layers	1			
Magnetics				
EMI Inductor	1	L1	BU10-1311R6BL	Coilcraft
EMI Inductor	1	L2	BU16-4021R5BL	Coilcraft
Choke, 4.7 uH, 4A	2	L4, L5	RFB0807-4R7L	Coilcraft
Choke, 10 uH, 3A	1	L3	RFB0807-100L	Coilcraft
Flyback Transformer (custom)	1	T1	ETD-29 core, Lp = 385 uH	See drawing
Current sense transformer (1:50)	2	T2	T6522-AL	Coilcraft

9 Board Pictures





10 Appendix

References:

- ENERGY STAR®: Set-top boxes specification http://www.energystar.gov/index.cfm?c=revisions.setto p_box_spec
- EfficientProducts.org http ://www.efficientproducts.org/

Additional collateral from ON Semiconductor:

- NCP1308: Current-Mode Controller for Free Running Quasi-Resonant Operation
- NCP1587: Low Voltage Synchronous Buck Controller
- TL431A: Programmable Precision Reference
- MC79L05: 100 mA, 5 V, Negative Voltage Regulator
- MMBT2222AW: General Purpose Transistor NPN
- MMBT2907AW: General Purpose Transistor PNP
- NTD4808N: Power MOSFET 30 V, 63 A, N-Channel
- NTB60N06L: Power MOSFET 60 Amps, 60 Volts, Logic Level
- MURA110: 1 A, 100 V Ultrafast Rectifier
- MMSD4148/D: 100 V Switching Diode
- MMSZ5226B: Zener Diode 500 mW 3.3 V ±5% SOD-123
- Design note DN06008/D: NCP1308: ±18 V Dual Output Power Supply
- Application Note AND8129/D: A 30 W Power Supply Operating in a Quasi-Square Wave Resonant Mode
- Application Note AND8089/D: Determining the Free-Running Frequency for QR Systems
- Application Note AND8252/D: High Efficiency 8 Output, 60 W Set Top Box Power Supply Design
- GreenPoint® Reference Design TND332/D: 8 W DTA Power Supply Reference Design Documentation

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