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# 300 W High Performance SLIM LCD TV Power Solution

Jean-Paul Louvel
LCD TV System Applications

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# Overview

This reference document describes a built-and-tested, GreenPoint® solution for an LCD-TV power solution that combines the main system power without a backlight power converter. In this architecture, the backlight power converter is designed on a separated board to allow full design flexibility and easier adaptation to any backlight solution and technology (Classical 24 V Hall Bridge resonance Power Supply or LIPS / High Voltage Inverter for CCFL, Power converter for Fronts or Edge LED Backlight or finally Power converter for PDP / Plasma panel).

This reference design circuit consists of a 290 mm x 310 mm printed circuit board designed to fit into the chassis of a Flat-TV. The height is limited to 8 mm to allow advanced Slim & low depth LCD TV design. All the circuitry is resident in on a single-sided PCB as might be found on an LCD-TV but with FR4 / Glass Epoxy material. This allows large holes in the PCB without adding issues in drop or vibration tests.

The low profile design has a direct impact on the passive component definitions. The overall winding parts (common mode EMI filters, PFC coils, Standby and Flyback transformers) have been defined with a low profile ferrite core and a new bobbin, allowing the parts to be lower than 8 mm with holes in the PCB included. The large electrolytic capacitors have been split into multiple lower values and inserted flat on the board. They measure a diameter of 10 mm, and also include holes in the PCB. The heat sinks have been designed with a new low profile allowing them to be below 7 mm.

The ON Semiconductor devices utilized are from the latest generation of controllers. This design has been engineered to achieve optimum performance compared to traditional LCD-TV power architectures, while simplifying the overall bill of materials. This is done by selecting a proprietary high performance low power mode standby integrated switcher, a high efficiency interleaved Frequency Clamp Critical Conduction Mode (FCCrM) PFC, and a Flyback controller topology that provides the power to the overall TV signal processing and audio amplifiers. To provide higher design flexibility, 2 types of Flyback controllers have been considered requiring minimal changes to move from one to the other. The first one is a new Quasi Resonance (QR) mode while the second is a fixed frequency PWM.

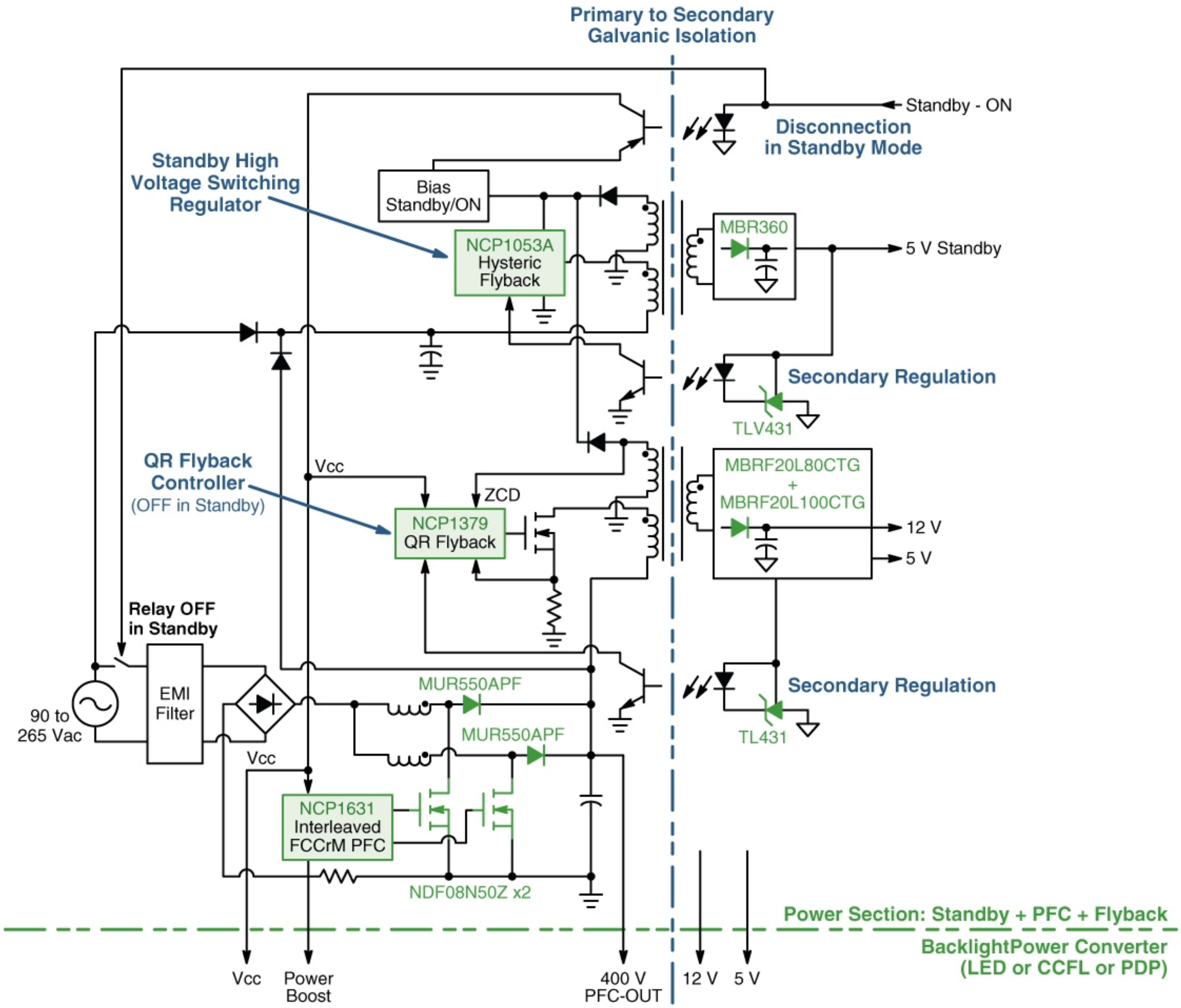



Figure 1. System architecture of the 46” Power solution

# LCD-TV Power Architecture and Evolution

One of the key differentiating factors of new large flat screen TV sizes over previous ones is the thickness of the cabinet - the thinner the better. This requires several considerations for the power supply design:

- The amount of power to be delivered is relatively large: the number of watts per $cm^3$ is much larger compared to a smaller screen size flat TV.
- Because the TV will be used in the living room, audible noise can be a problem, and the use of fans is limited / prohibited.
- Overall cost in the competitive environment of the consumer electronics world is critical.
- The panel, the power supply, and the audio amplifiers are close to each other. Therefore the generation of EMI and susceptibility to EMC might have an impact on the picture and sound quality.

Flat TVs require the generation of several voltage rails to power the different system blocks such as audio, backlighting, and signal processing. The power supply does not generate all the voltages required within the set. Instead, local linear and DC-DC converters on the signal processing board are used to provide the low voltage rails. It is fairly common for manufacturers to use a universal power supply that supports 90-265 Vac. This allows a single power supply design based on a specific TV size to be used for a series of models for different regions, simplifying logistics and reducing development cost. If the LCD-TV is intended for global use and the power is over 75 W, it is necessary to comply with IEC 61000-3-2, the EU standard for harmonic reduction, so an active power factor control stage is used.

The largest power consuming sub-system within the flat TV is the backlight. Plasma technology was the first historical solution, however, Cold Cathode Fluorescents Lamps (CCFL) with LCD panels previously used for note books rapidly took the leadership. These florescent lamps started with only medium sized screen TVs, but are now used at every size point.
Starting last year, the LED backlight solution for LCD TVs has become a very popular way to allow small depth design with SLIM cabinets, particularly with Edge LED solutions.

Newer backlight converters should be dedicated to providing full design capability, and allowing the use of any backlight technology. Designed on a separated board allows for fast evolution supporting all backlight requests and new developments (Plasma, CCFL with classical 24V or LIPS solution and new LED backlight for both Front and Edge technology). Also, an added converter dedicated to the audio amplifier and signal processing, is designed on the power board to provide similarity to any backlight technology.

The Power architecture solution is intended to improve overall system efficiency. This is done with a high efficiency Flyback converter (signal processing and audio amplifiers) and a backlight conversion stage directly powered from the high voltage low profile Interleaved FCCrM PFC rail. This has three primary benefits:

- Increases overall system efficiency.
- Reduces active power consumption and heat generation which enhances system reliability and reduces component stress.
- Reduces the total number of parts to improve the overall bill of materials cost.

Other drivers for this architecture are the increased consumer awareness of the cost of energy, and new regulatory considerations. These are intended to address overall power consumption of TVs and their impact on the environment and energy infrastructure.

Historically, standby losses in consumer electronics were the primary concern of government and power conservation agencies. This is because the devices are always connected to the AC main and constantly consuming some power, even in off mode. As a result, there are numerous voluntary and regulatory standards around the globe intended to reduce standby power consumption with the lowest limit of 0.3 W.
As this consumption is becoming more and more critical, key TV brand names are looking for further improved performances with standby consumption < 0.1 W. If this is still not a mandatory performance, it is becoming an important key feature which should help promote ECO Standby mode.

An alternative to this ECO Standby mode is an OFF mode which allows for < 50 mW or even 0.0 W in OFF mode. If the most conventional solution is to use a mains switch, we will see later in this document, that there are alternatives which provide better solutions for both cost and safety criteria.

As the screen size of direct view flat TVs increase, so does the ON mode power consumption. As a result, regulatory agencies have become concerned about the cumulative impact on the power grid of ON state power as flat TVs gain market share and consumers switch from CRT and projection TVs to large display direct view technologies such as Plasma and LCD-TV. In the US, the Environmental Protection Agency (EPA) started a process in 2006 to revise the existing voluntary Energy Star standard for TVs to include active power consumption requirements as part of its criteria for qualifying energy efficiency in TVs. This standard was revised and went into effect in November 2008 and now incorporates maximum active power requirements as a function of screen size. As part of the specification development process, existing TVs were evaluated to the proposed standards and at the time, less than 30% of the TVs tested on the market met the active and standby test requirements. The active power limits in the Version 4 Energy Star standard, effective in May

2010, are listed in the table below. As illustrated, there are a series of equations based on screen area and vertical resolution to determine the active power limit. For example, a 50” High Definition TV can consume no more than 153 W out of the box when tested against an internationally approved audio/video test signal set which is meant to represent a common viewing environment.

| Version 4.0: Effective May 1, 2010 | | |
|---|---|---|
| **Screen Area** | **Maximum On Mode Power Consumption in Watts (A expressed in square inches)** | **Maximum On Mode Power Consumption in Watts (A expressed in square centimeters)** |
| A < 275 square inches (1774 square centimeters) | $P_{Max} = 0.190*A + 5$ | $P_{Max} = 0.029*A + 5$ |
| A ≥ 275 square inches (1774 square centimeters) | $P_{Max} = 0.120*A + 25$ | $P_{Max} = 0.019*A + 25$ |
| **Version 5.0: Effective May 1, 2012** | | |
| **Screen Area** | **Maximum On Mode Power Consumption in Watts (A expressed in square inches)** | **Maximum On Mode Power Consumption in Watts (A expressed in square centimeters)** |
| A < 275 square inches (1774 square centimeters) | $P_{Max} = 0.130*A + 5$ | $P_{Max} = 0.020*A + 5$ |
| 275 ≤ A ≤ 1068 square inches (6890 square centimeters) | $P_{Max} = 0.084*A + 18$ | $P_{Max} = 0.013*A + 18$ |
| A > 1068 square inches (6890 square centimeters) | $P_{Max} = 108$ | |

Table 1: Version 4 Energy Star Active Power Limits

Other countries have or are considering changes to their energy regulations to drive the adoption of more power efficient TV products. For example, the Japan Top Runner program takes a holistic approach which considers total energy consumption (kWh/year) on an annual basis assuming 4.5 hours of active use per day. This focuses the attention of TV manufacturers on methods to optimize their system architectures for both active and standby power consumption.

Finally TV manufacturers are starting to market the green aspects of their products to highlight and differentiate their offerings and appeal to consumers who are concerned about the rising cost of energy. While improvements in active power go beyond the power supply including the display, backlight source, video and audio signal processing, and control architectures. The Power architecture in this reference design is designed from the ground up to save power over the traditional architecture. Moreover, it is designed to reduce the total system cost at the complete bill of materials level.

# Critical Design Objectives

## Input Voltage

- Universal input 90-264 V ac, 47-63 Hz

## PFC

- Active Power Factor Corrected, IEC61000-3-2 Compliant
- Up to 280 W input power capability
- OFF in Standby mode

## Standby Supply

- Standby $P_{in}$ < 90 mW with 40 mW load (8 mA on 5 V)
- OFF mode $P_{in}$ < 25 mW with added low power functional switch
- Up to 1.5 A / 7.5 W Output power in ON mode

## System Supply

- Maximum steady state power 50 W, 70 $W_{peak}$ overall
- 12 V / 4 $A_{peak}$
- 5 V / 4 $A_{peak}$
- 24 V option on the PCB (not inserted on the first application)
- Flexibility to be modified and support other voltage / current configurations
- OFF in Standby mode

## Backlight Supply

- Maximum steady state power 150 W, 200 $W_{peak}$
- 400 V from PFC Output for any backlight power converter build on separated board
- OFF in Standby mode

## Height of parts

- < 8 mm on top of PCB
- < 12.5 mm total (Above PCB + PCB + Below PCB)

# Standby Power Supply

## Introduction

This converter has been primarily designed to provide a very low power consumption allowing promotion of a very good ECO mode. The converter also supports full standby performances allowing for remote control, IR function, and peripheral control to start the TV (SCART specification in Europe). The current consumption in Standby should remain below 8 mA / 40 mW to keep the overall TV consumption under 90 mW. This may ask for dedicated Standby µP which is becoming a greater state of the art technology for an ECO Standby mode.

Conventional fixed frequency switchers provide very good performances for the Max output power due to the skip mode with current compression used to reduce the possible noise issues. They do not however, provide the best results for very low output power.
We did select hysteretic mode switcher NCP1053A to reduce the number of switching cycles by light load and limiting the switching looses. This represents the highest issue for high supply voltage applications (350 V). The reduced features of this part also allow for a smaller internal consumption, which is a key factor for high performances in OFF mode.

If a mains switch were widely used in Europe and Asia as with CRT TVs, Flat TVs would not need the parts to be in line with safety / standard regulation (no voltage > 4 kV). Despite it is not mandatory, we can see more and more flat-TVs built with a mains switch to allow “Green OFF mode”. If this looks to be the easiest / simplest solution, the high peak of inrush current and the requested isolation needed around the switch (main isolation between switch + cable to metal parts of the TV cabinet) make the mechanical design complex and costly in order to avoid safety issues and risk of fire (witch may ask for VO cabinet plastic material). The position of the switch in the cabinet is also critical as this may increase the EMI issues with possible “by-pass” of the EMI filter due to the cables position.
Thanks to the very good performances for the no load condition of our switcher NCP1053A, we are able to provide an OFF mode below 25 mW consumption on mains. This OFF mode is controlled through a small low voltage/cost switch connected on the secondary side, without adding any isolation and EMI issues. The solution is in line with the strongest safety requirements, does not allow the TV to be switch ON (else the switch is closed), and never uses above 15 W consumption for any safety tests.

To be able to keep such low power consumption in both Standby and OFF mode, a relay is used to disconnect all parts which are not used in those modes (Mains filters, X2 capacitors and associated discharged resistances, PFC with Brown Out and Feedback, Flyback and Backlight converter). The relay, directly supplied by 5 V Standby and controlled by TV µP, will avoid ~100 mW parasitic consumption in Standby.

With mains disconnected from the PFC, the Standby SMPS should be supplied with a dedicated diode directly connected to the mains input (before the relay). As the power in Standby is limited, a single phase rectification is enough and the “take over” from PFC output supplies the Standby SMPS with 400 V in ON Mode to provide up to 7.5 W on the 5 V Standby output (1.5 A).

## NCP1053A / 44 kHz

The NCP1053 is a monolithic high voltage Gated Oscillator Power Switching regulator that enables end product equipment to be compliant with low standby power requirements. This device series combines the required converter functions allowing a simple and economical power system solution for consumer products.
This device features an active startup regulator circuit that simplifies the starting behaviors and reduces the consumption with an auxiliary bias winding on the converter transformer, a fault detector and a programmable timer for converter overload and Open Loop protection, unique gated oscillator configuration for extremely fast loop response with double pulse suppression, power switch current limiting, thermal shutdown, and auto restart fault detection. The design is done with the lowest 44 kHz switching frequency to reduce switching looses as much as possible. This device is available in an economical 8−pin dual−in−line package.

## Mains supply for Standby SMPS

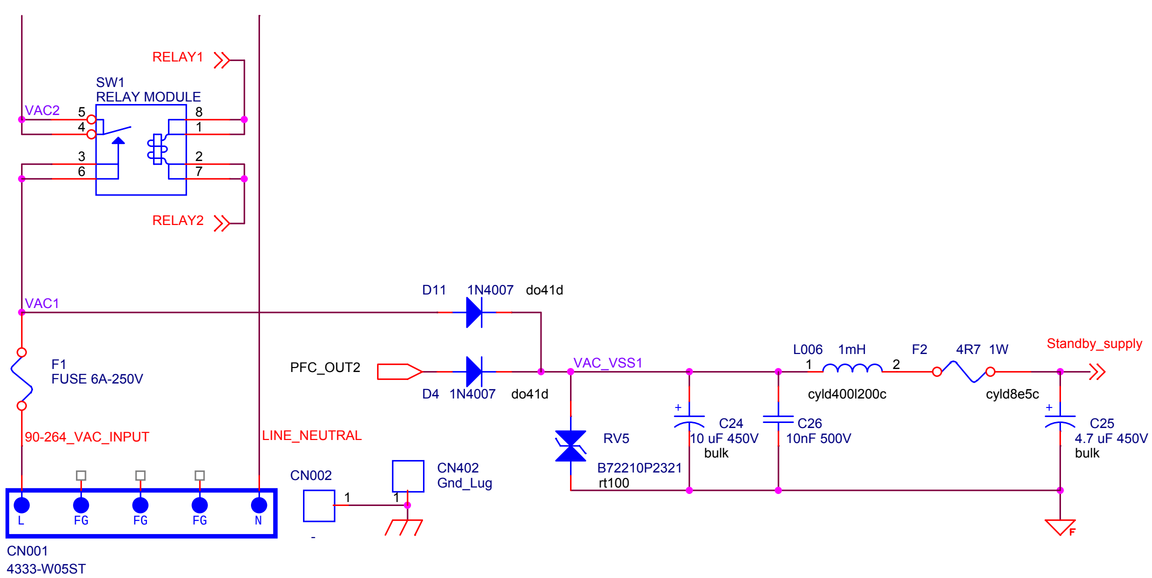



Figure 2. Standby Power Supply mains supply schematic

Despite the wide range of input supply (from 90 to 264 Vrms), thanks to the limited standby consumption, a single diode rectification D11 from mains supply is enough to keep the 10 µF 450 V input capacitor C24 charged. As the relay SW1 is switched OFF in Standby mode, the mains overvoltage protection with the varistor RV5 should be placed on Standby supply line to keep this protection also in Standby. If the 6 A fuse F1 has the right value to protect the 300 W Power converter, this is much too large to correctly protect a low power SMPS. An added small F2 4.7 R 1 W 500 V Fuse resistance protects the Standby SMPS in case of safety issues. To avoid possible reliability issues due to inrush current stress, the capacitor C25 should be limited to 4.7 µF. The serial coil L006 provides the requested filtering to avoid EMI in Standby and also act as an inrush limiter.
To be able to provide much higher power in ON mode (Up to 7.5 W), the PFC Output takes over the supply through D4 with regulated 400 V.

Primary side of Standby SMPS

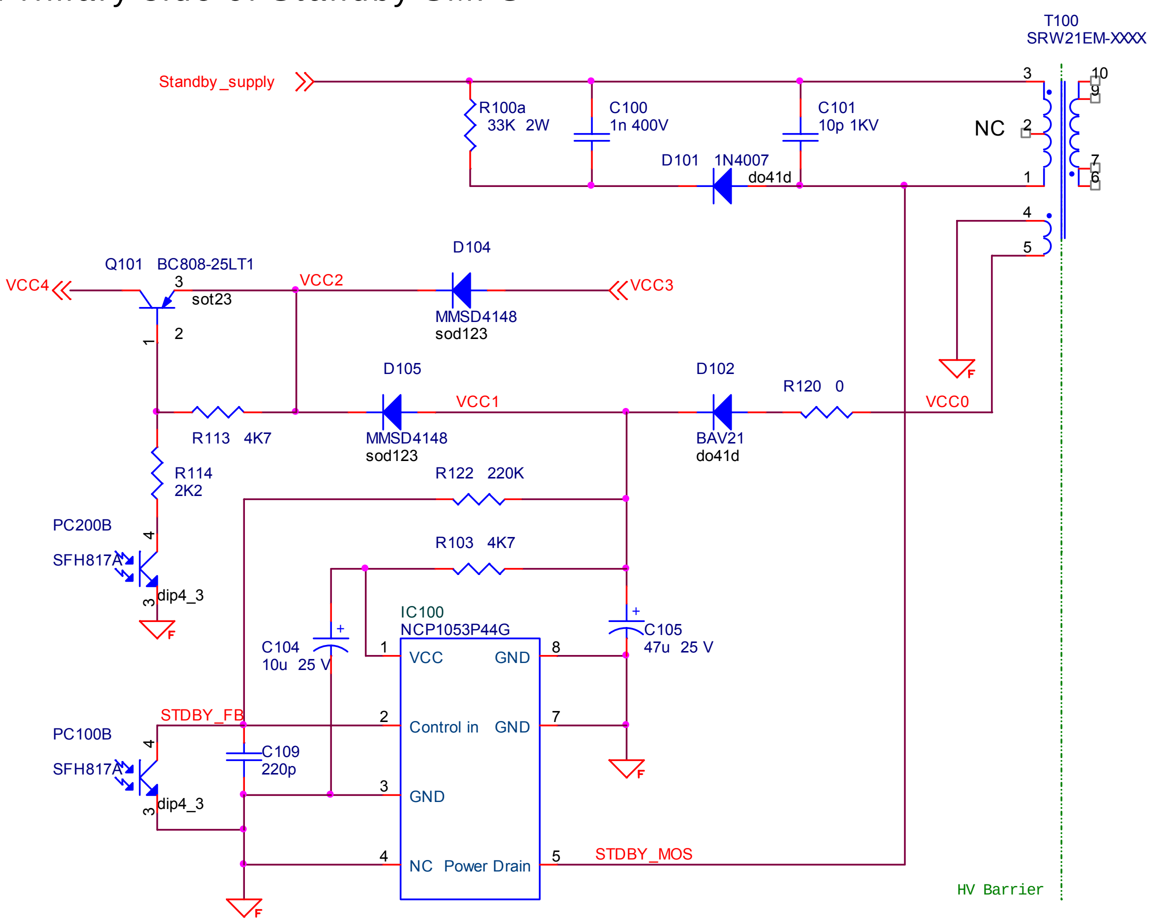
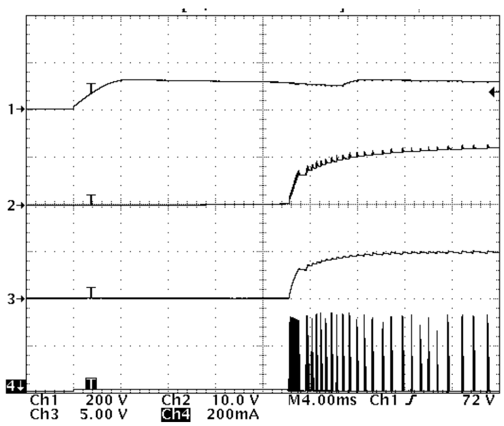



Figure 3. Standby Power Supply primary side schematic

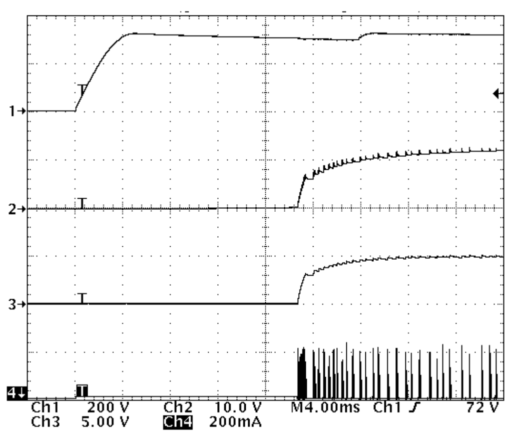
Thanks to the embedded startup regulator, the Standby switcher IC100 is able to start in short time over mains voltage range. As soon as the Vcc reaches 8.5 V Vcc-start on C104, the IC starts switching, allowing energy to be transferred to the secondary 5 V Standby. The auxiliary winding from the transformer, which provides a voltage close to 15 V on C105, allows the switcher to be supplied with better efficiency than when keeping the high voltage startup. The large value of C105 keeps the IC supplied, even by light load and very low switching frequency. A serial resistance R103 to the Vcc limits the current in the internal voltage clamp build in the IC due to the variation of auxiliary voltage directly linked to large output power range.

<u>Starting phase</u> (Independent from mains voltage and < 20 ms)




Vin = 90 V ac

CH1 => Vin DC
CH2 => VCC1
CH3 => 5 V output
CH4 => I primary



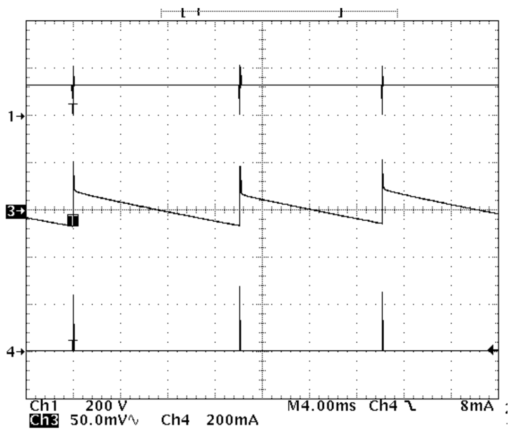

Vin = 230 V ac

CH1 => Vin DC
CH2 => VCC1
CH3 => 5 V output
CH4 => I primary

A classical RCD voltage clamp (R100, C100 and D101) limits the Max voltage on the switcher. To avoid any possible reliability issues with short voltage transient, the solution should be designed with an up to 100V margin and limited voltage up to 600 V by Max output power. The size of the resistance could be reduced down to ½ W. The added capacitor C101 is used to limit switching speed (or dV/dt) and reduces EMI.
When the energy transferred to the secondary side is enough to provide the right 5 V, the opto coupler PC100 provides the regulation information directly applied to “Control in” pin 2 of the IC. The IC, which works in hysteretic mode with

constant Max primary current internally limited, will provide the regulation and adjust the energy transferred with variable number of missing cycles. For very low output power in Standby mode, the controller will work with very low frequencies, keeping the same Max current for each cycle, strongly reducing the switching looses and so provides very good efficiency for low power / ECO mode.

<u>OFF mode (No load) and Standby mode</u>

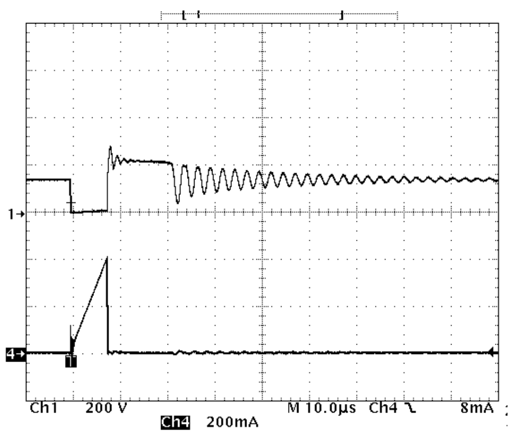



Vin = 90 V ac

CH1 => V drain
CH3 => 5 V out (ripple)
CH4 => I primary

I out = 0 mA (No load)

5 V Output Ripple = 40 mV
F burst = 71 Hz

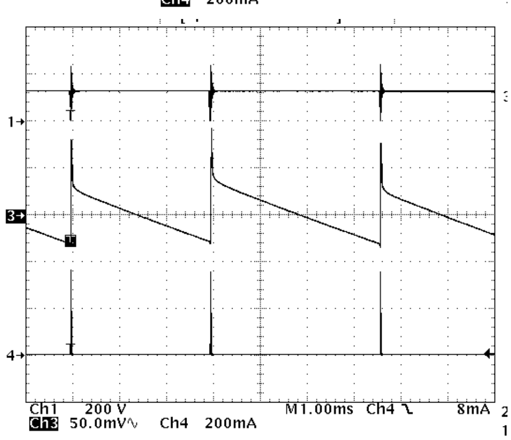



Vin = 90 V ac

CH1 => V drain
CH4 => I primary

I out = 0 mA (No load)

Nb cycles = 1
Expend of previous with 10 µs/div

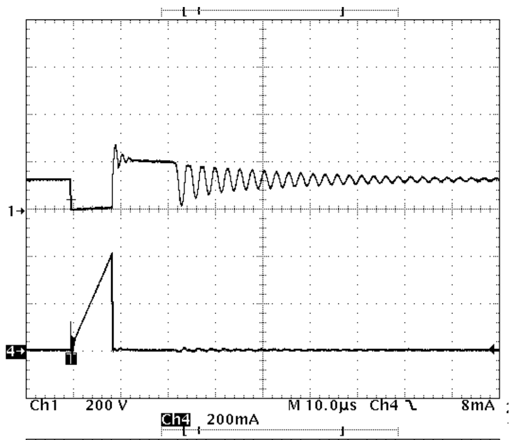



Vin = 90 V ac

CH1 => V drain
CH3 => 5 V out (ac mode)
CH4 => I primary

I out = 8 mA

5 V Output Ripple = 80 mV
F burst = 322 Hz

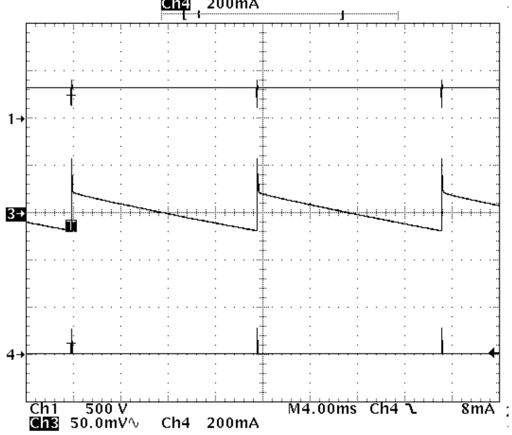



Vin = 90 V ac

CH1 => V drain
CH4 => I primary

I out = 8 mA

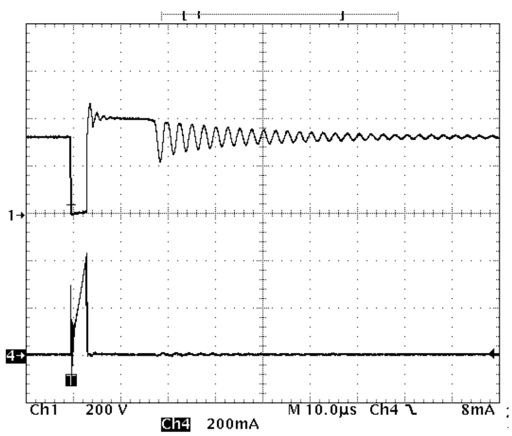
Nb cycles = 1
Expend of previous with 10 µs/div




Vin = 230 V ac

CH1 => V drain
CH3 => 5 V out (ripple)
CH4 => I primary

I out = 0 mA (No load): Ripple = 42 mV
F burst = 64 Hz

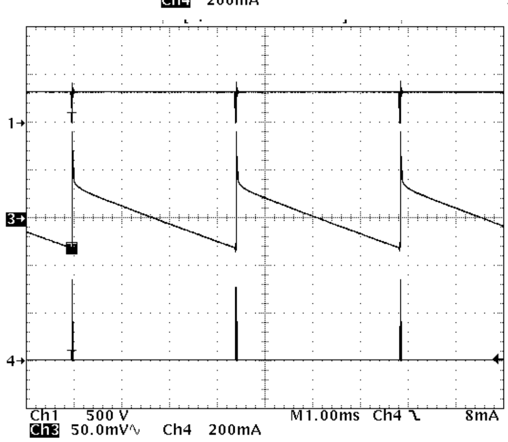



Vin = 230 V ac

CH1 => V drain
CH4 => I primary

I out = 0 mA (No load)

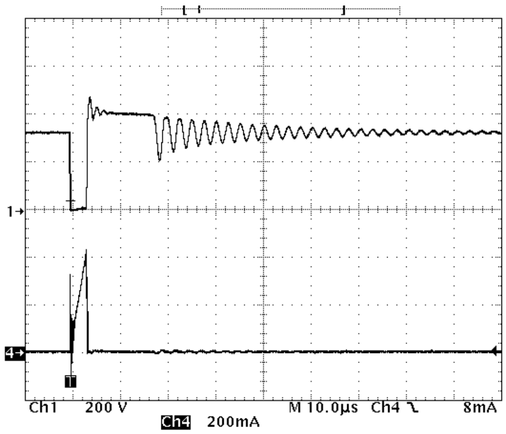
Nb cycles = 1
Expend of previous with 10 µs/div




Vin = 230 V ac

CH1 => V drain
CH3 => 5 V out (ac mode)
CH4 => I primary

I out = 8 mA
Ripple = 73 mV
F burst = 291 Hz



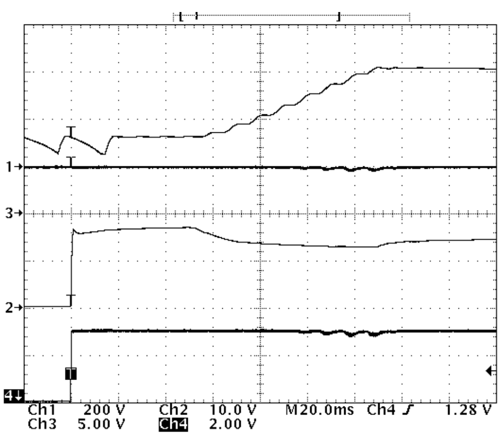

Vin = 230 V ac

CH1 => V drain
CH4 => I primary

I out = 8 mA

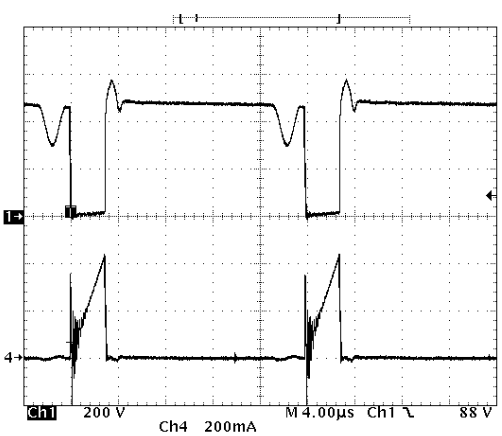
Nb cycles = 1
Expend of previous with 10 µs/div

Standby to ON mode
With PFC "take over" by 90 V ac with **270 mA Output current on 5 V Standby** on top of the 80 mA for the relay to allow 9 mA on Vcc > 14 V (to supply PFC and Inverter controllers)




Vin = 90 V ac

CH1 => Vin DC
CH2 => VCC4
CH3 => 5 V output
CH4 => STANDBY
ON mode with 400 V PFC Supply and Max output current




5 V out = 4.85 V
I out = 1.82 A + I relay (80 mA)

IC100
V drain max = 580 V
I drain peak = 440 mA

V RCD clamp = 75 V
P RCD clamp = 170 mW

## Secondary side of Standby SMPS

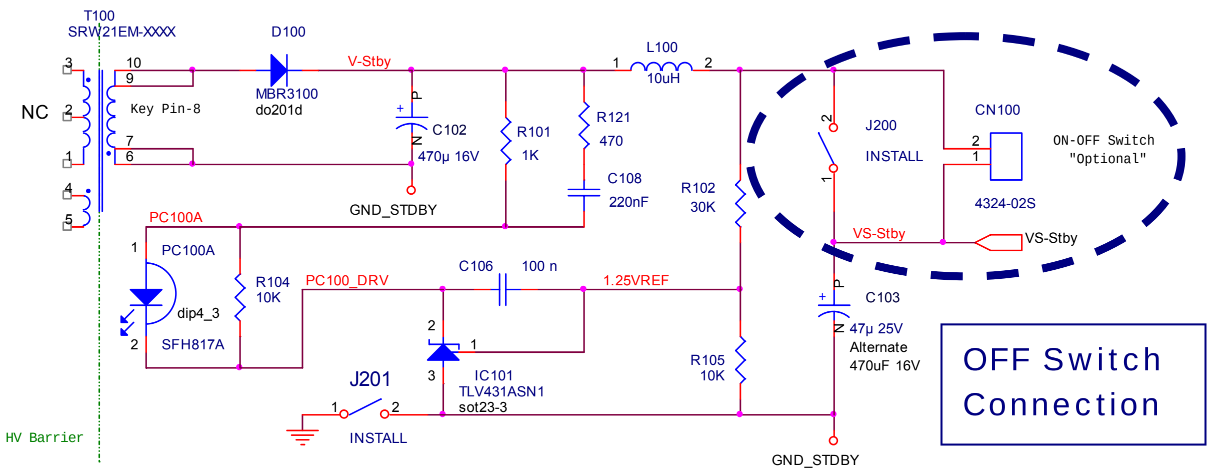
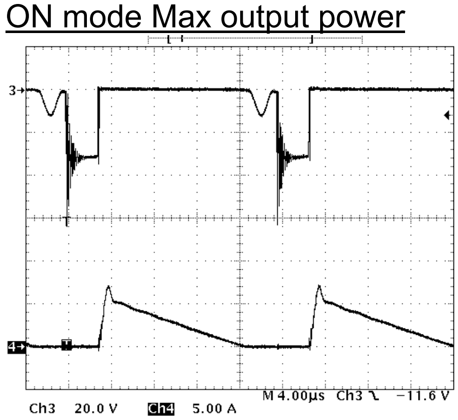



Figure 4. Standby Power Supply secondary side schematic

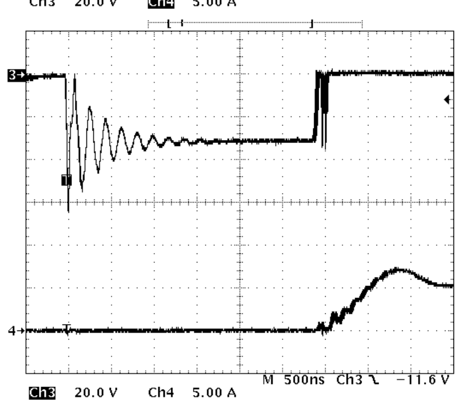
The power supply has been designed to provide a single 5 V Standby up to 1.5 A in ON mode. The rectifier diode D100 is a 3 A axial Schottky diode with 100 V reversed voltage to keep a 20% margin even with 400 V PFC supply.
A TLV431, shunt regulator IC101, is used for the regulation (instead of TL431) to reduce ECO mode consumption (lower current needed for polarization), and have a greater voltage margin with a 5 V supply. An added RC network (R121 & C108) provides output ripple information to the regulation and speeds up the regulation by light load. This avoids double pulse in ECO mode and keeps the switching frequency high enough to reduce ripple on the 5 V Output.

<u>ON mode Max output power</u>




5 V out = 4.85 V
I out = 1.82 A + I relay (80 mA)

D100
V max = 64 V (should be 100 V type)
I peak = 7.2 A




Expend of previous with 500 ns/div
5 V out = 4.85 V
I out = 1.82 A + I relay (80 mA)

D100
V max = 64 V (should be 100 V type)
I peak = 7.2 A

## Functional OFF Switch

The switch can be much smaller than mains switch, requesting only 10 V and 2 $A_{dc}$ capabilities. Connected on the secondary side, there is no need of isolation with any of the metal parts of the TV cabinet and does not represent any risk of fire with voltage < 10 V. When used, the switch should be connected in series to the filter coil L100 to reduce possible EMI issues (A 2 poles switch CN100 has been put on PCB to allow easy connection of the OFF Switch). This switch will interrupt the supply line of the TV µP, IR, and supply of the relay which can switch ON the supply of the overall PFC and power converter.

The overall solution fulfills the safety requirements. It does not allow the TV set to be switched to ON without an action on the switch and keeps consumption < 15 W on mains for any safety tests (short circuit or open circuit of any electrical parts).

The Standby power supply will keep running without output load, with a consumption < 25 mW on the mains by 230 V ac. This is a great alternative to the mains switch which provides very good performances for much lower costs and avoids possible safety issues.

## Standby / ON control and over voltage protection

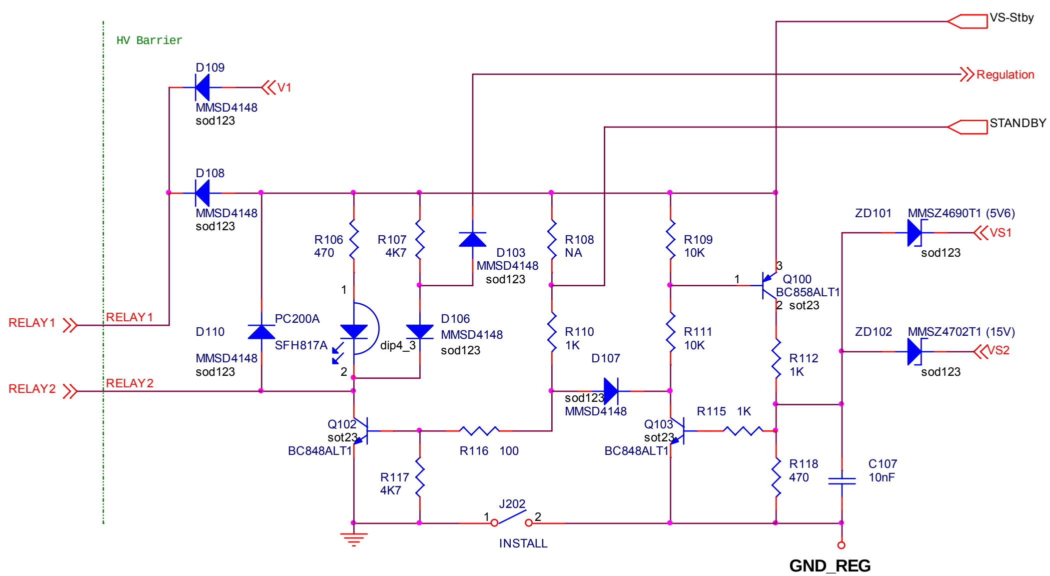



Figure 5. Standby / ON secondary side schematic

The “STAND BY” control, coming from TV µP will control the power supply allowing the system to go into ON mode or forcing it to stay in Standby.
A pull up resistance R108 (planned on the PCB) should be avoided in order to reduce consumption in low power mode. To be able to drive the transistor Q102

correctly (witch should drive the relay with ~100 mA collector current capability), the resistance R108 should be down to 1K which represents 5 mA consumption when Standby control line is grounded through an open collector transistor. To avoid that added power, we use a push pull output on the µP side allowing R108 to be removed.
With “STAND BY” control high up to 5 V, Q102 drives both the relay to supply the PFC with mains voltage and the opto coupler P200 to supply all primary controllers / ICs from Standby power supply auxiliary voltage VCC1 (Figure 3).
On the primary side, the opto coupler PC100 drives the PNP transistor Q101 which supplies all controllers (PFC, Flyback and backlight).
To get the correct Auxiliary voltage / Vcc1 (14 V minimum with 9 mA) needed to be able to start the primary controllers, there is a need of a minimum output current on 5 V Standby during the starting phase; 270 mA on top of the 80 mA already requested to drive the relay. If the current is lower than the 270 mA, the transformer should be modified (with more turns on auxiliary winding) to provide the requested voltage.
To reduce power delivered from Standby SMPS in ON mode, the diode D104 takes over and provides the energy to those overall controllers from Flyback auxiliary winding.
When the TV goes into Standby mode, both relay and opto will be switched OFF when the Standby control line is going down.
To speed up the OFF switch of the flyback SMPS, the diode D103 will provide a 5 V on Flyback regulation input that will stop the converter immediately, avoiding voltages to be kept a longer time and  decreasing slowly without control.
This complete circuit will not be supplied (VS-Stby is null) if the “OFF Switch” is OFF such that the TV set is blocked in OFF mode.

### Secondary over voltage protection

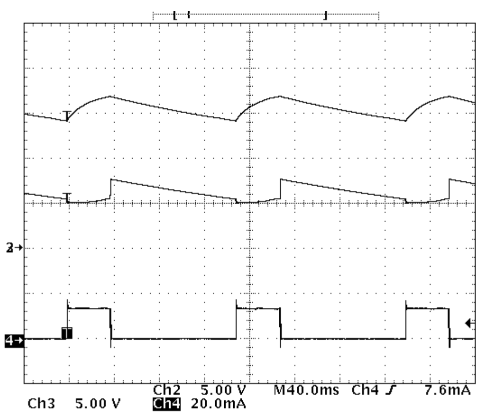
Both Flyback Output VS1 and VS2 are monitored with Zener diodes ZD101 and ZD102. If for any reasons, one of those voltages goes over the limit defined by the respective Zener diode, the transistor Q103 will be switched ON and latch with Q100, Q102 will be switched OFF through D107 and both relay and opto should be immediately switched OFF avoiding further energy transferred from the Flyback converter to signal processing and Audio amplifiers. The overall system including PFC and backlight converter will be switched OFF as well. The Standby SMPS should be switched OFF to allow possible restart (Latch OFF of both Q100 and Q103).

### Secondary 5 V Standby Output short-circuit to GND

In case of output short circuit to Ground, the current in the IC will be kept to the same peak value, but since the transfer of energy cannot be completed, the

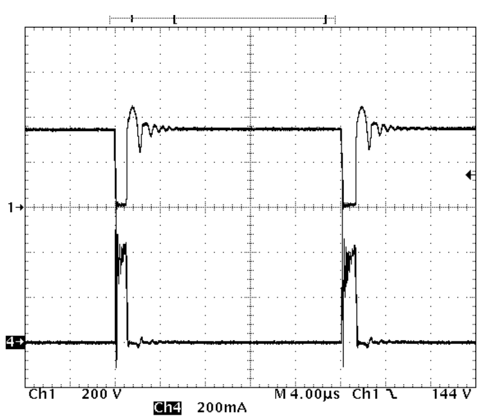
system will work in continuous mode with much higher rms current in the transformer, IC, and diode. This will have direct impact on the temperature of the parts with possible risks of safety issues. If the reflected voltage from the secondary side should be low enough to avoid Vcc to supply the IC, the voltage developed by the leakage inductance is enough to supply the IC thanks to its extremely low consumption (this advantage is becoming an issue for safety tests). As the regulation is OFF, there is no feedback to the controller which drives down the regulation pin.
With an added pull-up resistance R122 of 220 K, we provide an “over voltage” (voltage going out of regulation window) on the control in, since the opto does not provide any feedback from secondary regulation (5 V is much too low). Thanks to this new solution, the IC stops until Vcc decreases enough to allow re-start. The power supply keeps running in low frequency (~ 7 kHz) burst or skip mode with 70% OFF time which avoids any over temperatures and safety issues.
This added resistance is mandatory in order to avoid the controller from running with a secondary short circuit when supplying through leakage inductance effect (enough to supply very low consumption controller).

<u>Short circuit from 5 V Output to GND</u>




Low frequency Burst mode
with 27% duty cycle / ON mode

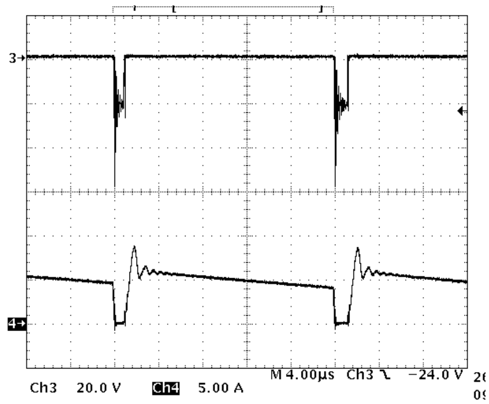
CH2 => FB pin
CH3 => $V_{CC1}$
CH4 => I Short circuit on 5 V




Expend of previous during ON time
Continuous Conduction Mode with 4 µs/div

IC100

V drain max = 450 V
I drain peak = 440 mA

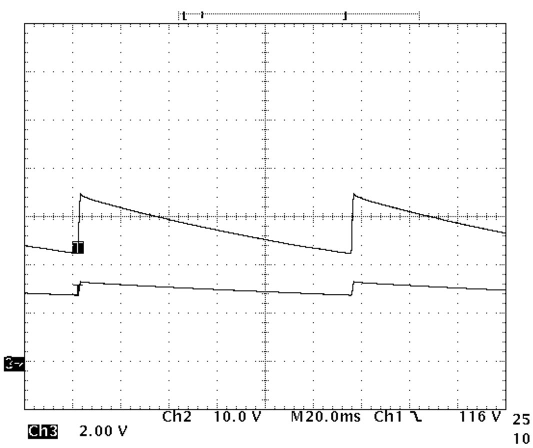



Continuous Conduction Mode with 4 µs/div
D100

V max = 64 V (should be 100 V type)
I peak = 9 A

Regulation open loop behaviors (Safety tests)

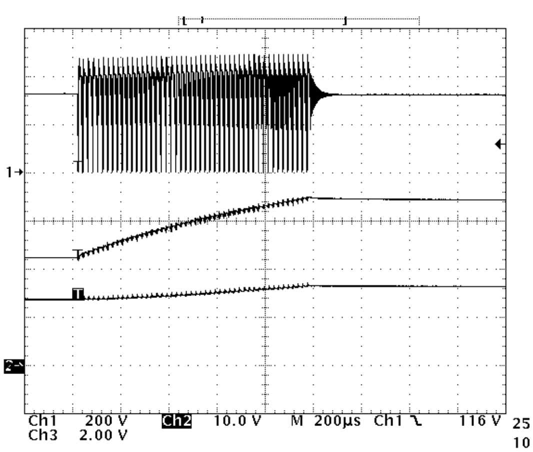
The same added resistance R122 avoids open loop regulation issues with switch OFF of the power supply keeping the system working in low frequency burst mode.




Open circuit of Opto transistor PC200B in ON mode
I out = 0 mA (worst case)
V out max = 7 V

CH3 => 5 V Standby
CH2 => Vcc1

Low frequency 8 Hz burst mode




Expend of previous during ON time

Iout = 0 mA (worst case)
Vout max = 7V

CH1 => V drain
CH3 => 5 V Standby
CH2 => Vcc1

ON time limited to 1 ms
Overall Power and efficiency performances

Overall Power and efficiency performances

| | | 90 Vac | 230 Vac |
|---|---|---|---|
| 0A | Vout (V) | 4.94 | 4.94 |
| | Pin (mW) | 19 | 24 |
| | Pout (mW) | 0 | 0 |
| | Efficiency (%) | xxx | xxx |
| | Vcc1 (V) | 10.9 | 10.1 |
| 8mA | Vout (V) | 4.94 | 4.94 |
| | Pin (mW) | 84 | 86 |
| | Pout (mW) | 40 | 40 |
| | Efficiency (%) | 48 | 47 |
| | Vcc1 (V) | 12.5 | 12.3 |
| 100mA | Vout (V) | 4.93 | 4.93 |
| | Pin (mW) | 846 | 819 |
| | Pout (mW) | 500 | 500 |
| | Efficiency (%) | 59 | 61 |
| | Vcc1 (V) | 17.9 | 17.6 |
| Pmax | Vout (V) | 4.9 | 4.85 |
| | Iout | 583mA | 1.82A |
| | Pin (W) | 4.72 | 12.37 |
| | Pout (W) | 2.85 | 8.85 |
| | Efficiency (%) | 61 | 71 |
| | Vcc1 (V) | 23.3 | 24.6 |

Table 2. Standby Power supply efficiency and performances

- Pin < 25 mW for OFF mode / No load
- Pin < 90 mW for 40 mW output on 5 V Standby

- Up to 500 mA on 5 V Standby by 90 V ac in Standby mode
- Up to 1.5 A on 5 V Standby by 230 V ac in Standby mode

- Up to 1.5 A in ON mode

## Transformer design

Parameters / Criteria

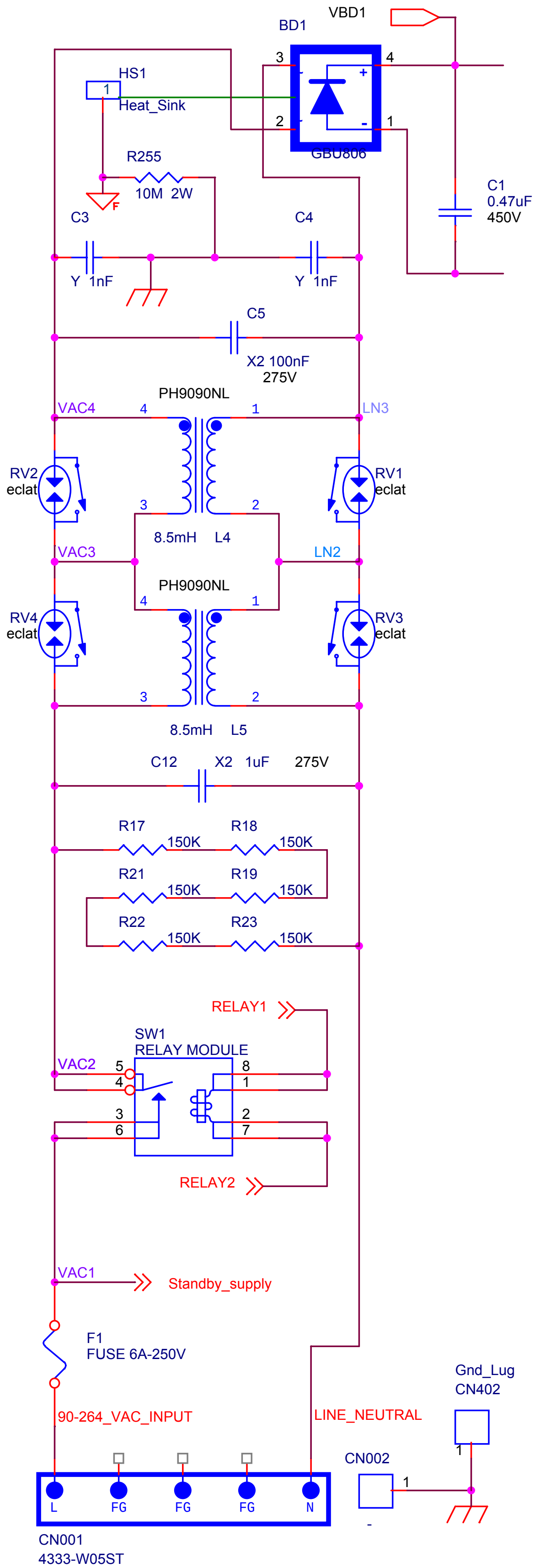
- 7.5 W Max Output on 5 V with 0.75% efficiency and 400 V supply from PFC.
- NCP1053A with 50 kHz switching frequency and 400 mA minimum current (high value than IC spec due to propagation delay and di/dt).
- To reduce possible noise issues, the transformer should be designed with inductances low enough to keep it in discontinuous mode.

Specification

- Primary inductance of 2.5 mH for Saturation current of 0.5 A.
- Based on SRW2125 with PC40 EEM2125 core from TDK.
- Np = 77 + 81 = 158 turns of 0.16 mm wire (secondary in sandwich between both primary to reduce leakage inductance).
- Ns = 2 x 11 turns of TEX 0.3 mm wire to provide requested isolation to primary without isolation tape.
- Nb = 26 turns of TEX 0.2 mm for auxiliary / Vcc winding.

- The size of the transformer could have been smaller but there are very few types of core and bobbin < 8 mm height capable of providing the requested mains isolation with enough distance from ferrite to output connections. Despite we use TEX wire which avoids margin tape, the secondary output pin and connection should be 6 mm away from ferrite to guarantee by construction the requested isolation to the primary side (Ferrite is like a short circuit for isolation characteristics). Moving up from 8 to 13 mm height will provide a much larger number of possible solutions with smaller bobbin and ferrite size.

# EMI filter




The overall function is placed after the relay SW1 (OFF in Standby mode) such that overall power parts are disconnected from the mains. This is particularly important for both X2 capacitors (1 µF / C12 and 100 nF / C05) with their discharge resistances R17 to R23 and the 60 mW consumption at 230 V ac. The PFC Brown Out and Feedback are also disconnected avoiding consumption in Standby mode.

The input stage consists of two serial common mode filters (L5 + L4) combined to provide the right inductance for such low profile parts.
A single capacitor filter 470 nF / C1, placed after the bridge diodes rectification is enough for differential mode.

Thanks to the interleaved PFC and the much lower mains current ripple, the classical differential mode filter (position L1 and C2), used with conventional single CrM PFC. can be removed.

Varistor RV3, used to suppress high energy pulses and mains surges which may disturb overall operation, has been moved to Standby supply to be present in Standby when relay is open.

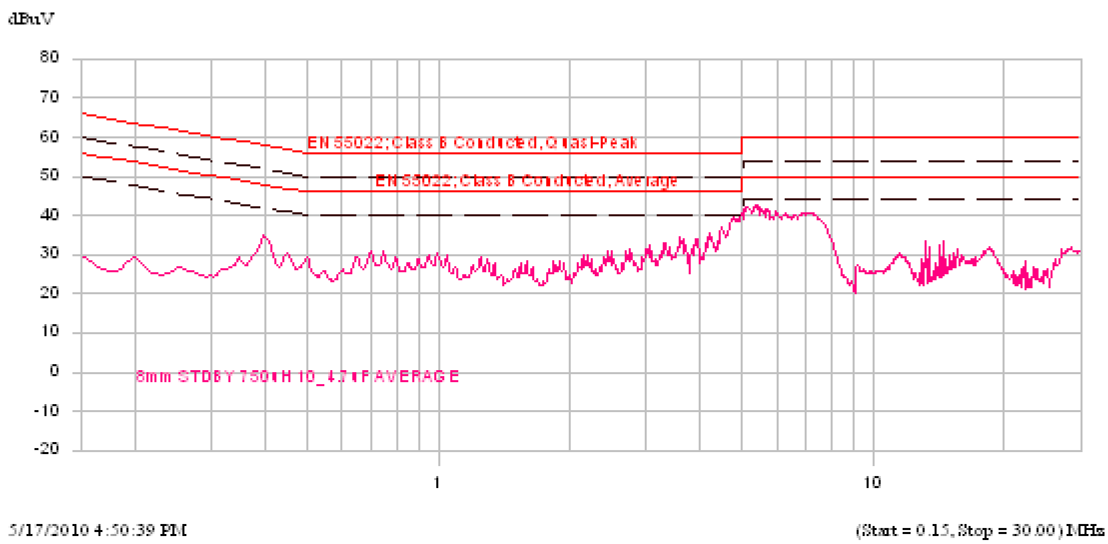
Figure 6. AC Input stage

# EMI tests results

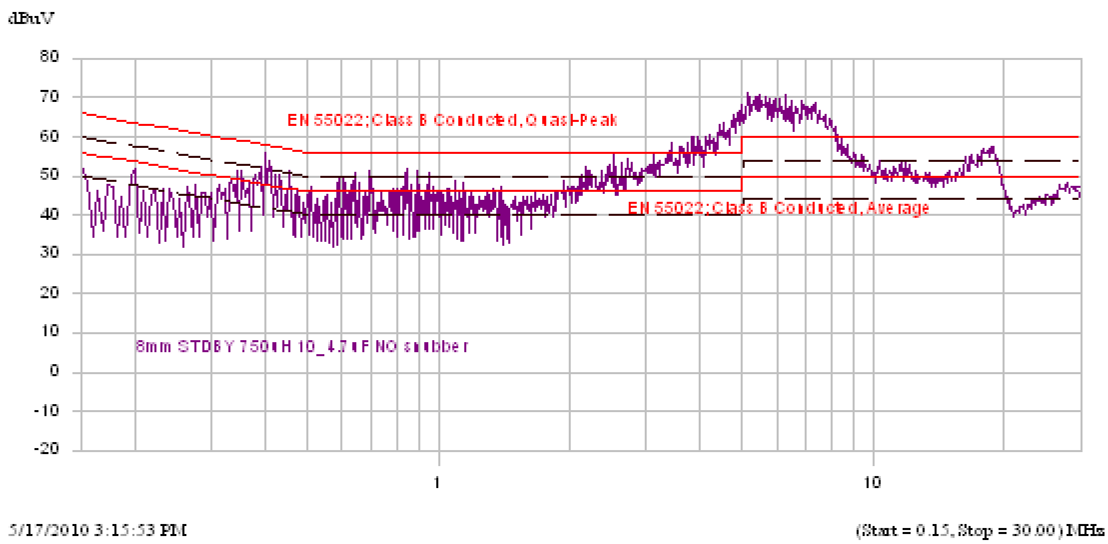
## Standby mode

- 230 Vac
- 0.5 W output

Average The limit line is the lower solid line.



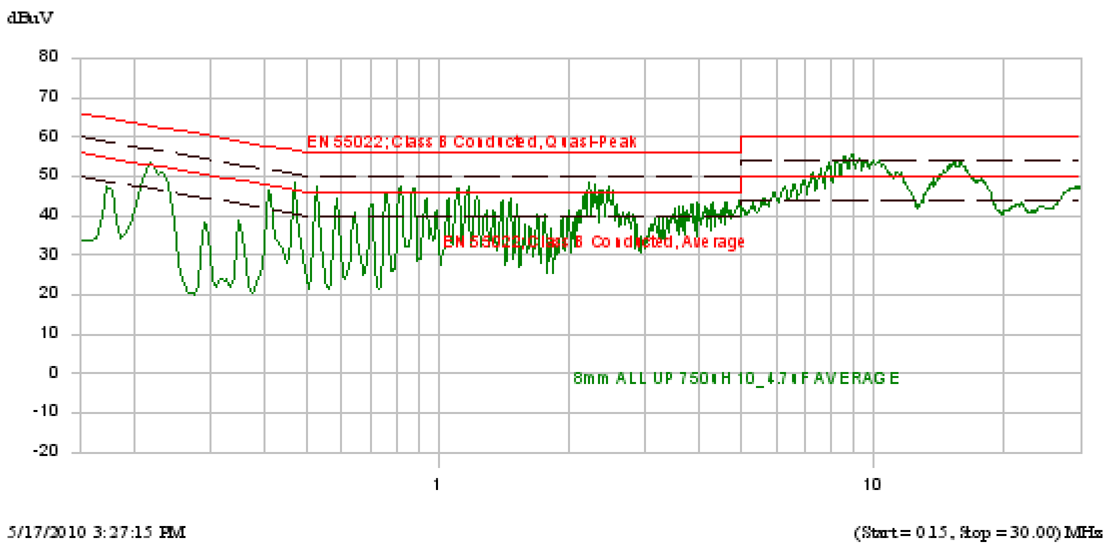

Peak The limit line is the upper solid line.



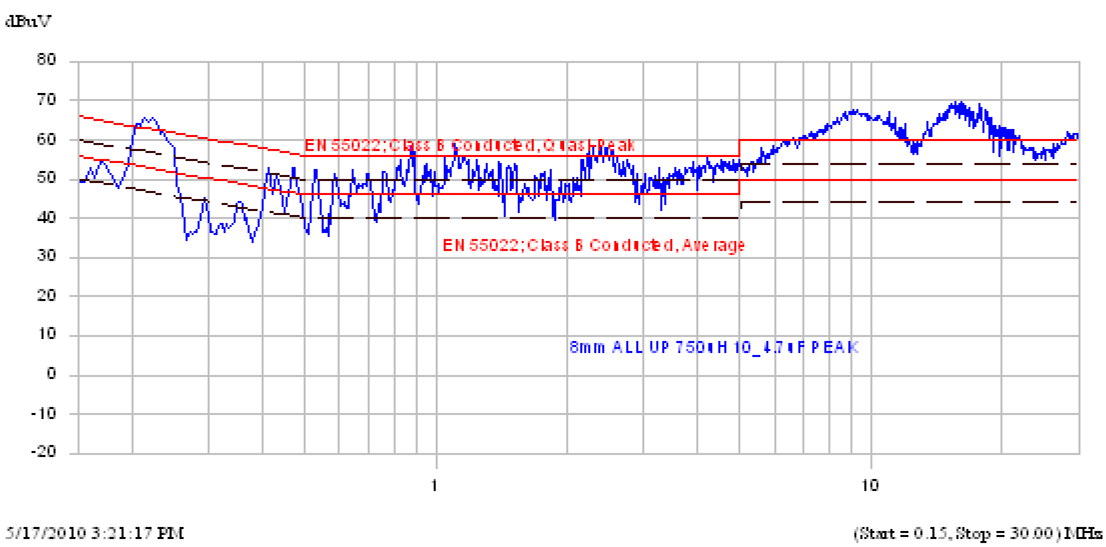
## ON mode

- 230 Vac
- STDBY 4.93 Vdc 0.10 A 0.5 W
- +5V 5.01 Vdc 3.27 A 16.4 W
- +12V 12.38 Vdc 2.56 A 31.7 W
- 150 W on 400 V PFC for backlight

Average The limit line is the lower solid line.




Peak The limit line is the upper solid line.



## PFC stage

The active PFC front-end boost stage fulfils two requirements. First, it allows the design to meet the harmonic content requirements of IEC61000-3-2 which applies to power supplies with input power above 75 W. Secondly, it provides a regulated 400 V high voltage rail for the overall converter including the backlight.

The *Cr*itical conduction *M*ode (*CrM*) PFC solution, also named *boundary* or *border-line* or *transient conduction mode*, is a very popular operation mode for low to medium power applications. If this is the base of our concept, our newest ON Semi controller NCP1631 provides 2 newly added key features which improve our PFC function.

### *F*requency *C*lamped *Cr*itical conduction *M*ode (*FCCrM*)

Frequency Clamped CrM (FCCrM) is a unique technique developed by ON Semiconductor and embedded in controllers like the NCP1631. This controller embeds an oscillator that sets the maximum frequency and operates:

- In Critical Conduction Mode when the current is longer than a preset time. This duration threshold is the oscillator period that is programmed by an external capacitor. Hence, the PFC stage operates in CrM in the most stressful conditions.
- In Fixed Frequency (DCM) when the current cycle is short. The switching frequency is that of the oscillator.

FCCrM controllers do not simply clamp the frequency.
Clamping the frequency of a CrM circuit dramatically affects the power factor. That is why FCCrM controllers also modulate the on-time in DCM operation in order to continue properly shaping the input current. More specifically, they permanently monitor the dead-time relative duration over each switching period and as a function of this information, modulate the on-time to compensate them (see NCP1631 data sheet for more details). Thus, FCCrM PFC stage still exhibits near-unity power factor even if the switching frequency is clamped.
More generally, they transition from CrM to DCM and vice versa without discontinuity in the power transfer and without power factor degradation.

In addition, such a PFC stage can permanently operate in fixed frequency if the inductor value is low enough, making the current cycle frequency remain below the frequency clamp. However, this is not a recommended option. Because of the dead-times, DCM needs higher peak inductor currents compared to CrM ones for the same delivered power. Hence, DCM causes the current ripple and its rms level to be larger. This creates heavy load conditions, reduces efficiency and applies higher power stress on the inductor and on the MOSFET.

Instead, the inductor is designed to operate in CrM in the most stressful conditions while DCM limits the switching frequency at light load and near the line zero crossing. This option combines the merits of CrM and DCM.

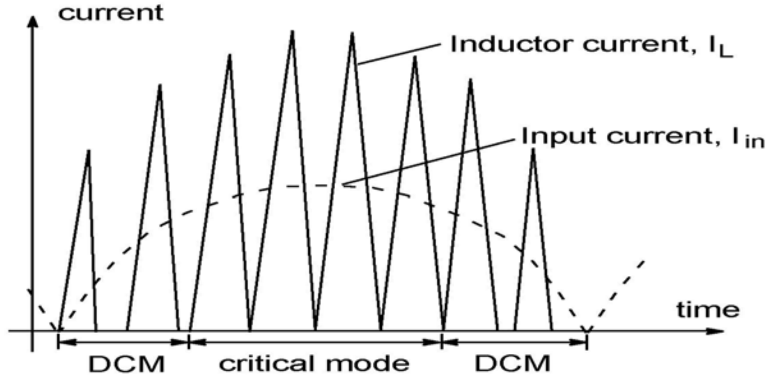



Figure 7 - DCM and CRM Operation within a sinusoid cycle.

The (maximum) peak and rms inductor current are approximately the same as the CrM, since the converter operates in CrM for the most stressful condition (low line, full load).

$$\left(I_{L,pk}\right)_{\max} = \frac{2\sqrt{2}\cdot\left(P_{in,avg}\right)_{\max}}{\left(V_{in,rms}\right)_{LL}} = \frac{2\sqrt{2}\cdot 300}{85} \cong 10\ A$$

$$\left(I_{L,rms}\right)_{\max} = \frac{\left(I_{L,pk}\right)_{\max}}{\sqrt{6}} \cong \frac{10}{\sqrt{6}} \cong 4\ A$$

As aforementioned, the boost inductor must be large enough so that the system operates in CrM at the top of the sinusoid when in low line, full load design that is, in the most severe conditions. The equation is the same as the CrM one except that the minimum frequency can be higher. Practically, the oscillator frequency is generally set to 120 kHz. The minimum frequency has to be lower or equal to this value, $\left((f_{sw})_{\min}\right)$ and is actually set to about 20% to 50% lower for the sake of margin and optimized efficiency .

$$L \geq \frac{\left(V_{in,rms}\right)_{LL}^{\ 2}\cdot\left(\frac{V_{out}}{\sqrt{2}} - \left(V_{in,rms}\right)_{LL}\right)}{\sqrt{2}\cdot V_{out}\cdot\left(P_{in,avg}\right)_{\max}\cdot\left(f_{sw}\right)_{\min}} = \frac{85^2\cdot(\frac{390}{\sqrt{2}} - 85)}{\sqrt{2}\cdot 390\cdot 300\cdot 70000} \cong 119\ \mu H$$

A single 120 µH can then do the job instead of the two parts necessary for the CrM option due to the higher inductance requested to keep the frequency low enough.

Interleaved PFC is an emerging solution that becomes particularly popular in applications where a strict form factor has to be met, like for instance in the Slim LCD TVs. Interleaving consists in paralleling two “small” stages in lieu of a bigger one, which may be more difficult to design. Practically, two 150 W PFC stages are combined to form our 300 W PFC pre-regulator.
Furthermore, if the two stages are operated out-of-phase, the current ripple is significantly reduced. In particular, the input current looks like that of a Continuous Conduction Mode (CCM) one and the rms current within the bulk capacitor is dramatically reduced.
This approach has several merits like the ease of implementation, the use of more but smaller components and a better heat distribution. In particular, an interleaved PFC stage uses two small inductors instead of a larger one.
The NCP1631 is an FCCrM controller for 2-phase interleaved PFC applications. Unlike master / slave controllers, it utilizes an interactive-phase approach where the two branches operate independently in FCCrM. In addition, the NCP1631 unique interleaving technique substantially maintains the wished 180° phase shift between the 2 branches, in all conditions including start-up, fault or transient sequences.

In our application of interest (wide-mains, 300 W application), two identical FCCrM 150 W PFC stages are to be designed. For each inductor, the (maximum) peak and rms current are the same as the CrM but they must be computed for half the total power. In other words:

$$\left(I_{L,pk}\right)_{\max} = \frac{2\sqrt{2}\cdot\dfrac{\left(P_{in,avg}\right)_{\max}}{2}}{\left(V_{in,rms}\right)_{LL}} = \frac{2\sqrt{2}\cdot\left(\dfrac{300}{2}\right)}{85} \cong 5\ A$$

$$\left(I_{L,rms}\right)_{\max} = \frac{\left(I_{L,pk}\right)_{\max}}{\sqrt{6}} \cong \frac{5}{\sqrt{6}} \cong 2\ A$$

For each channel of the interleaved PFC, the boost inductor must be computed as done for a 1-phase FCCrM PFC but for half the total power. Again, $\left(\left(f_{sw}\right)_{\min}\right)$ is set about 20% to 50% below the 120 kHz oscillator frequency for the sake of margin. This leads to:

$$L \geq \frac{\left(V_{in,rms}\right)_{LL}^{2}\cdot\left(\dfrac{V_{out}}{\sqrt{2}} - \left(V_{in,rms}\right)_{LL}\right)}{\sqrt{2}\cdot V_{out}\cdot\dfrac{\left(P_{in,avg}\right)_{\max}}{2}\cdot\left(f_{sw}\right)_{\min}} = \frac{85^{2}\cdot(\dfrac{390}{\sqrt{2}} - 85)}{\sqrt{2}\cdot 390\cdot 150\cdot\left(f_{sw}\right)_{\min}}$$

Provided the limited stress in the inductor, one 220 µH inductor per branch can be implemented, for a 75 kHz minimal frequency (about 62% of the 120 kHz clamp frequency). A more economical option consists in selecting a 150 µH inductor per branch that corresponds to a 110 kHz minimal frequency or 92% of the clamp frequency with direct impact of lower low-line efficiency.

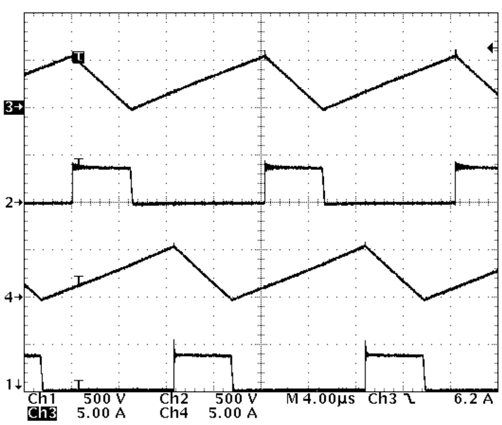
This Frequency Clamped Critical conduction Mode (FCCrM) associated with the interleaved approach allows for the use of smaller inductors in a PFC stage which is a key advantage for Slim design requested for the new LCD TV design.
The additional advantages links to smaller rms input and output current allow substantial cost reduction with much smaller output boost capacitors and avoid completely differential mode EMI filter (like for CCM PFC).

## PFC Coils

- 220 µH with up to $6A_{peak}$ current without saturation
- PQM3811 from TDK with PC47PQM3811 A230 ferrite ($A_L$ = 230 nH)
- 31 turns of main coil and 3 turns for auxiliary ZCD control winding

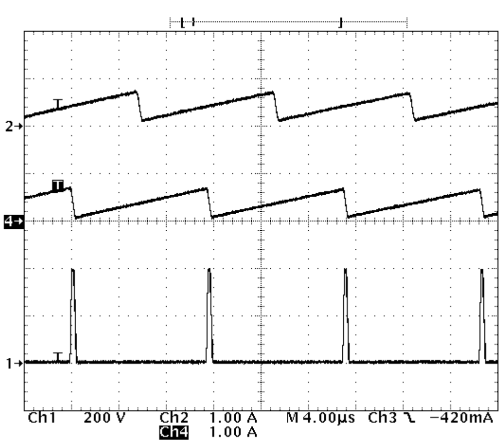
- A smaller 150 µH coil could have been used but due to the few possible type of ferrite and bobbin < 8 mm, we keep this one with 220 µH such we have better efficiency.

<u>85 V 300 W ON Mode</u>



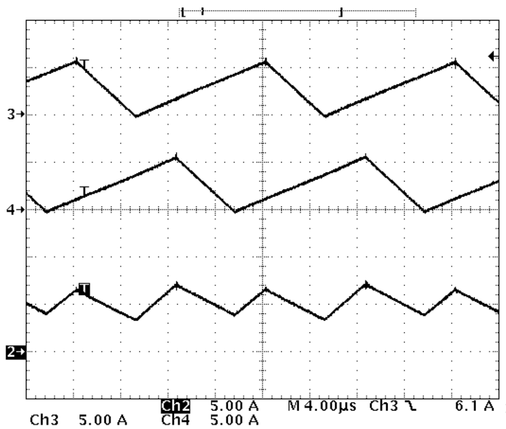

CH1 and CH2 => V drain
CH3 and CH4 => I drain

Fsw min = 62 kHz
I peak = 5 A



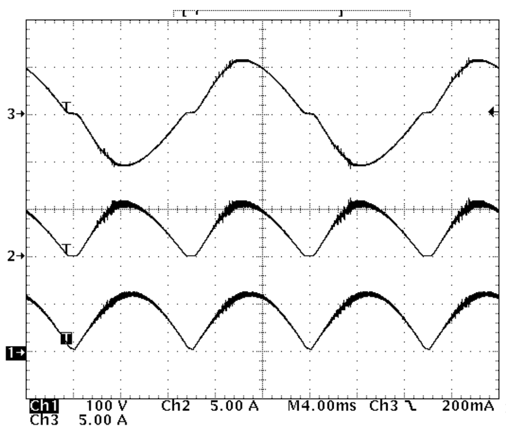

CH1 => V drain
CH3 and CH4 => I drain

I peak = 750 mA
Fsw MAX = 86 kHz




CH3 and CH4 => I drain

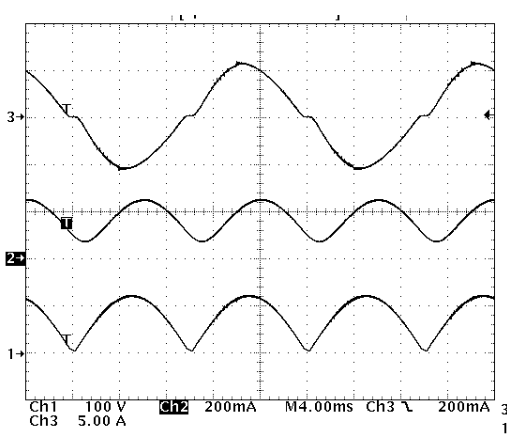
CH2 => I Sense through R3 with added current of both PFC




Current on the mains input supply line

With L1 differential filter

CH3 => I mains input
CH2 => I after L1
CH1 => VRM

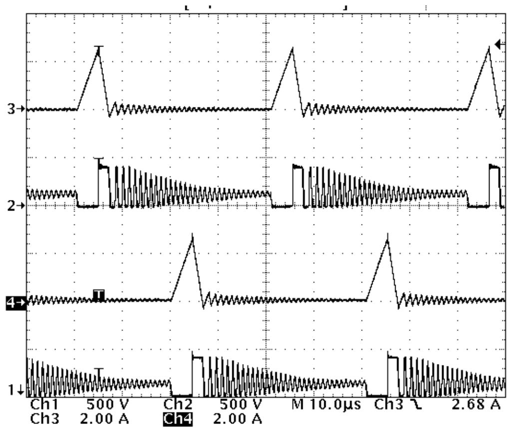



Current on the mains input supply line

Without L1 differential filter (short circuit)

CH3 => I mains input
CH2 => I after L1
CH1 => VRMS

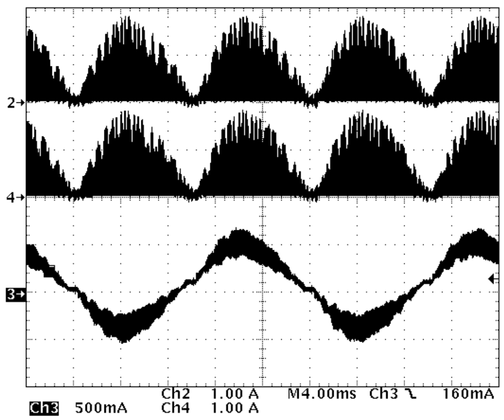
85 V 20 W ON Mode




CH1 and CH2 => V drain of both Power MOS

CH3 and CH4 => I drain of both Power MOS

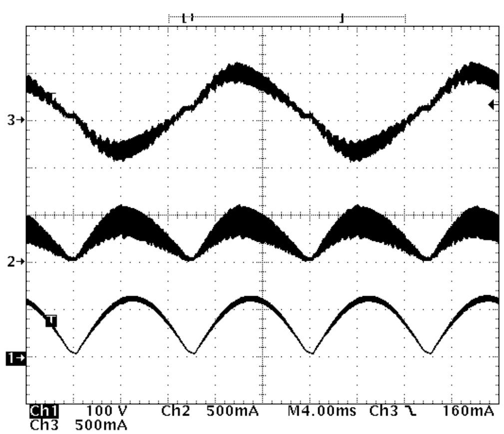
Fsw = Min fixed 25 kHz
I peak = 2.8 A




Low mains frequency resolution

CH2 and CH4 => I drain of both Power MOS

CH3 => I mains input



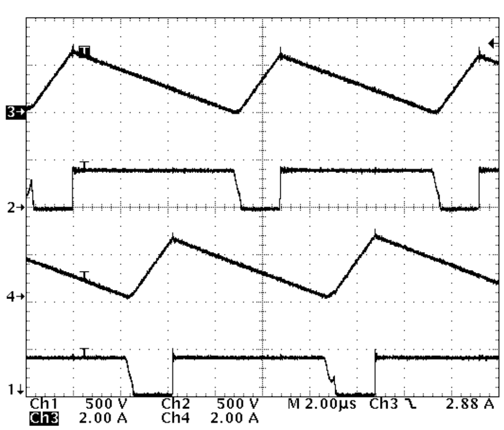

Low mains frequency resolution

CH3 => I mains input

CH2 => I after L1

CH1 => VRMS

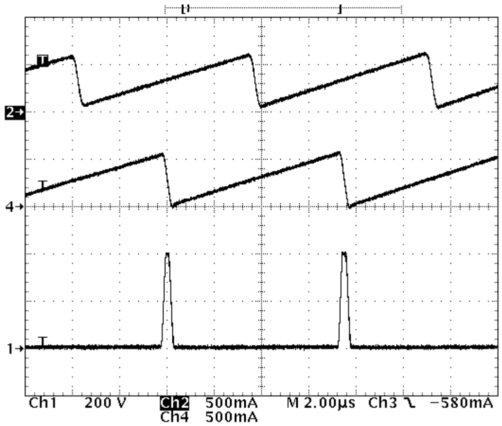
230 V 300W ON Mode




CH1 and CH2 => V drain of both Power MOS

CH3 and CH4 => I drain of both Power MOS

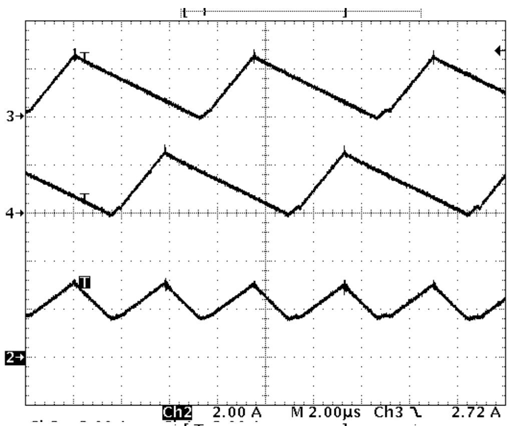
Fsw min = 112 kHz
I peak = 2.84 A




CH1 => V drain of 1 Power MOS

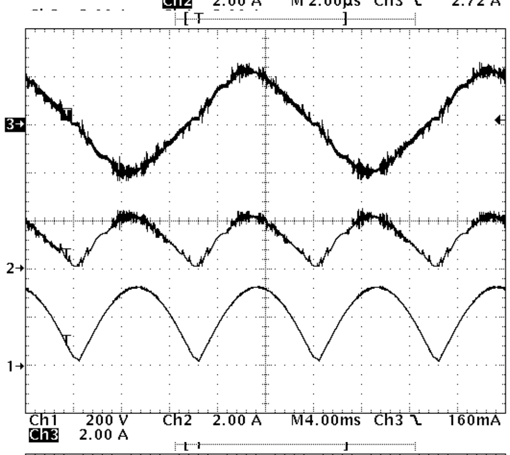
CH3 and CH4 => I drain of both Power MOS

Fsw Max = 134 kHz
I peak = 630 mA




CH3 and CH4 => I drain of both Power MOS

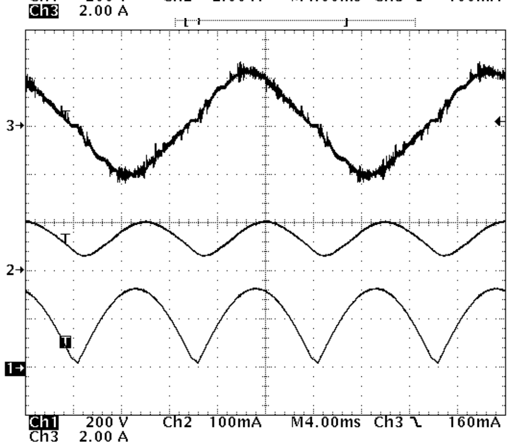
CH2 => I Sense through R3 with added current of both PFC




Current on the mains input supply line

With differential filter

CH3 => I mains input
CH2 => I after L1
CH1 => VRMS

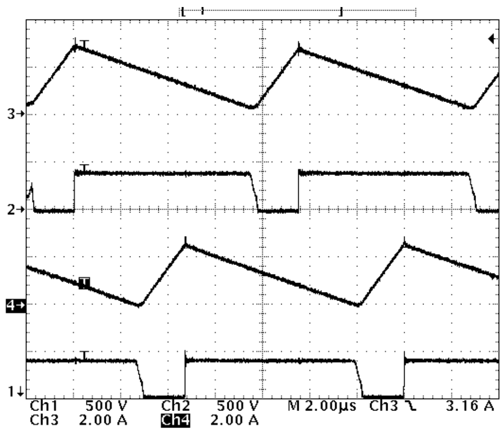



Current on the mains input supply line

Without L1 differential filter (short circuit)

CH3 => I mains input
CH2 => I after L1
CH1 => VRMS

230 V P MAX ON Mode

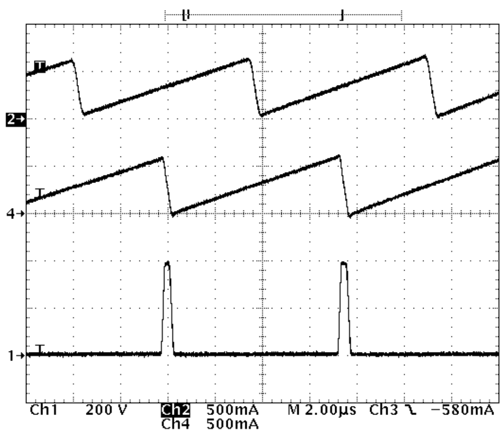



0.88 A / 350 W Max output power

CH1 and CH2 => V drain of both Power MOS
CH3 and CH4 => I drain of both Power MOS

Fsw min = 106 kHz

I peak = 2.96 A

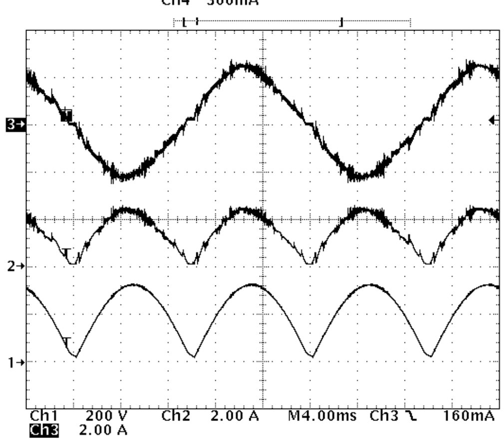



CH1 => V drain of 1 Power MOS

CH3 and CH4 => I drain of both Power MOS

I peak = 660 mA

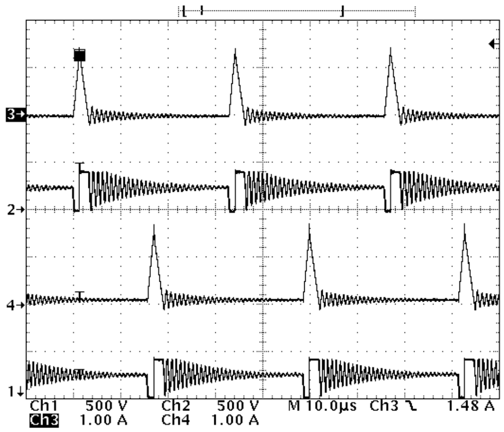
Fsw Max = 134 kHz




Current on the mains input supply line

CH3 => I mains input
CH2 => I after L1
CH1 => VRMS

230 V 20 W ON Mode

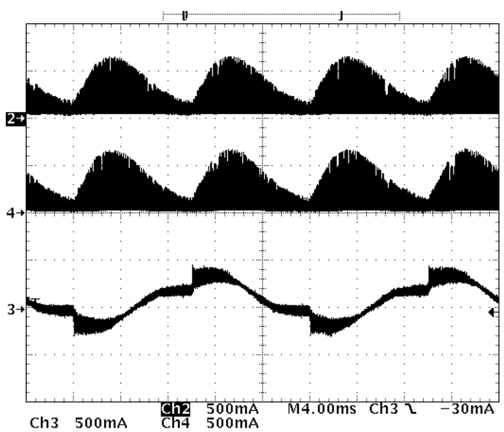



CH1 and CH2 => V drain of both Power MOS

CH3 and CH4 => I drain of both Power MOS

Fsw = 30 kHz

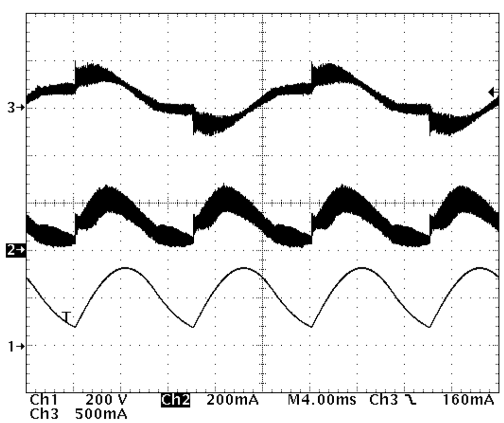
I peak = 1.7 A




Low mains frequency resolution

CH2 and CH4 => I drain of both Power MOS

CH3 => I mains input




Low mains frequency resolution

CH3 => I mains input
CH2 => I after L1
CH1 => VRMS

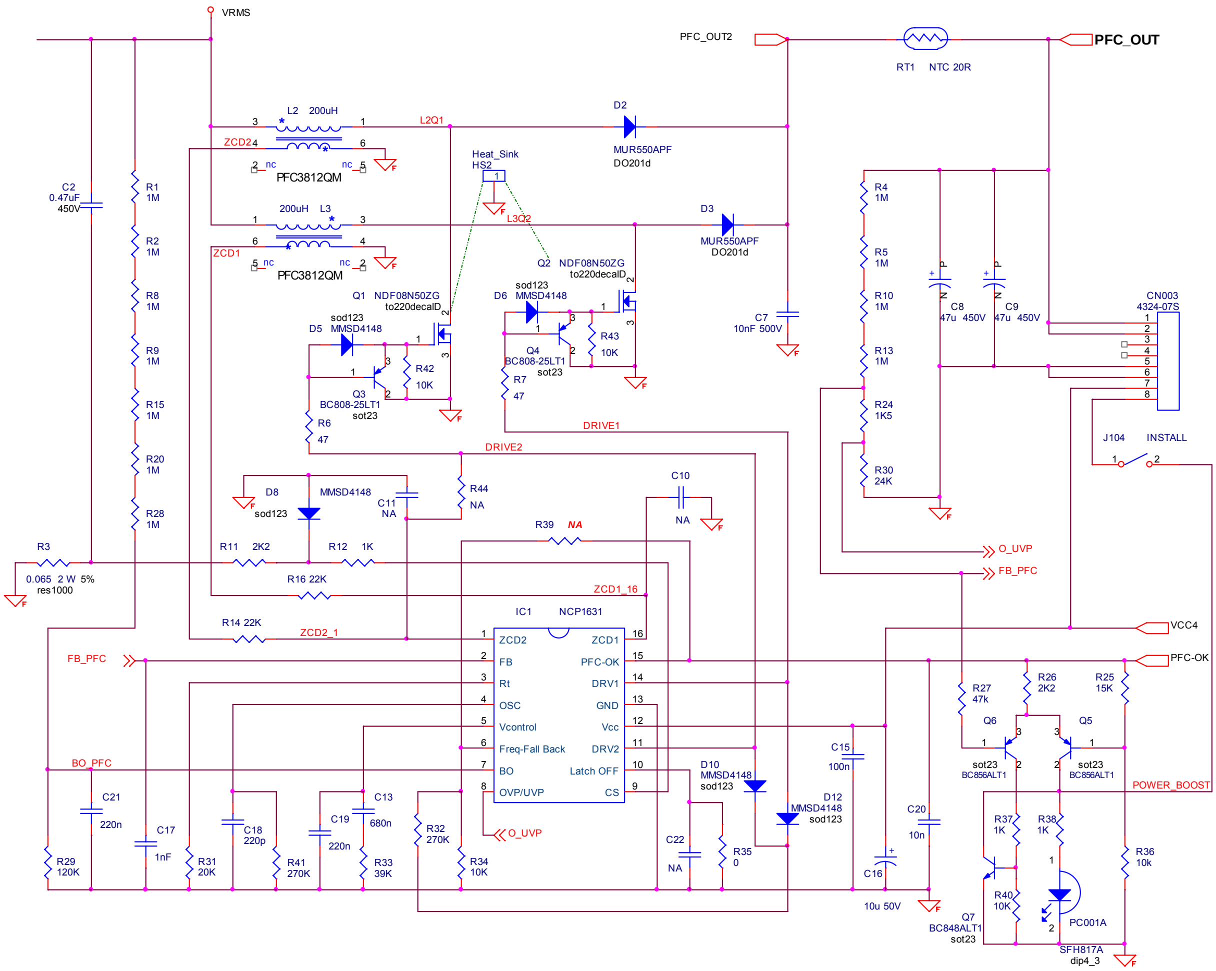



Figure 8. Interleaved Frequency Clamped CrM PFC schematic

## Key parts size and design

Thanks to the interleaved PFC which splits the power in 2 PFC stages, both Power MOS and diodes should be design only for 150 W (P/2) PFC. This allows us to use standard and smaller size ON Semiconductors parts:

- Power MOS Q1 and Q2: NDF08N50ZG 0.72 $R_{typ}$ 8 A 500 V TO220FP New ON Semi parts now released.
- Ultra fast boost diode D2 and D3: MUR550APF Axial 5 A 520 V Ultra fast diode specially designed by ON Semi for CrM PFC with lower Vf to reduce power dissipation.
- BC808-25LT1 PNP transistor Q3 and Q4 to speed up the Power MOS switch OFF.

The output capacitors, designed to support output boost rms current, have reduced value thanks to interleaved advantages. Only 2 capacitors C8 and C9

are built on the Power board considering that a third one should be on the backlight power converter (and directly in parallel to those 2).
The total overall rms current of 1 A (calculated for 250 W average power), divided by 3, allows to use 39 or 47 µF 450 V 105°C 0.375 $A_{rms}$ type with 10 mm diameter to fit below the 8 mm Max height of the board.

## Inrush current limiter

The sudden application of the mains to a PFC circuit can result in a large in-rush current and voltage overshoot. To resize the power components to handle this transient event is cost prohibitive. Furthermore, since the PFC is configured in a boost topology, the controller cannot do anything further to protect against this inrush since the voltage is applied through the inductor and rectifier to the output capacitor of the boost converter.
To address this, two rectifier diodes D1 and D13 have been added on the PCB from the input voltage to the output voltage bypassing the inductor and diverting the startup current to the bulk capacitor. The bulk capacitor is then charged to the peak AC line voltage without resonant overshoot and without excessive inductor current. After startup, both $D_{BYPASS}$ will be reversed biased and will not interfere with the boost converter.
If a single diode should normally be enough, two are used in series to avoid over heating of the overall PFC parts with short circuit of the single bypass diode which connects the output to the input of the boost.

Moreover, to further reduce the in-rush current which can be critical for the mains fuse (limited $I^2$ x t), a 20 R NTC (negative temperature coefficient) thermistor (RT1) is placed in series with the mains connection (before the bridge) to limit the in-rush current. The resistance value drops from a few ohms to a few milliohms as the device is heated by the $I^2R$ power dissipation. Alternatively (as used in our application), this NTC can be placed in series with the boost diode. This improves the active efficiency as the resistor only sees the output current instead of the input current (particularly interesting for low US mains supply). This allows using larger cold resistance NTC as current in ON mode is much reduced < 1 A for 300 W on 400 Vdc.

If above solution is used for single CCM or CrM PFC, thanks to the double interleaved PFC structure, the inrush current divided by 2 allows MUR550 CrM diodes D2 and D3 to support the Inrush current with 75 A peak current $I_{FSM}$ capability each.
The interleaved CrM PFC, combined with high cold impedance of the NTC, allows designers to remove the 2 bypass diodes.

## PFC-OK and POWER BOOST

The NCP1631 can communicate with the downstream converter. The signal PFC-OK is high (5 V) when the PFC stage is in normal operation (its output voltage is stabilized at the nominal level) and low otherwise.
This signal will become active when the starting phase is over and output voltage well regulated. If any issues or fault occurs in ON mode, this signal will go down to GND but will not go down when mains supply disappear.

If this behavior is right for the Flyback converter allowing the system to discharge the boost PFC output cap keeping both 5 V and 12 V present as long as possible, for backlight converter using Half Bridge Resonance LLC solution, this may cause some additional stress on the power MOS which should be avoided.

An additional circuit (Q5, Q6 and Q7) provides a new signal "POWER BOOST".
Supply by the PFC-OK, the starting phase with signal going up is the same than original signal PFC-OK from IC. This added circuit acts for switch OFF phase with direct control of PFC Output voltage. When PFC-OUT / FB-PFC are going down to 2V (80% of nominal 2.5 V), Q6 conducts and switch OFF Q5 so that POWER BOOST starts to fall. To speed up this signal, the transistor Q7, which is switched ON, will pull down POWER BOOST further and faster down providing info to the down stream converter of backlight that PFC-OUT is out of range.

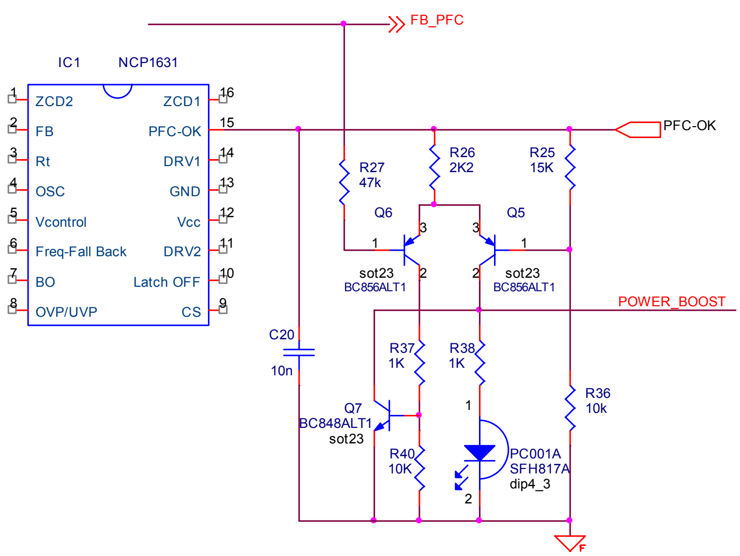



Figure 9. POWER-BOOST provides PFC-OUT status to Backlight

This signal provided through opto coupler PC001 to secondary side, call POWER-OK, allows full control of the TV µP for switch OFF sequence when mains disappear. This may allow getting similar switch OFF behavior than going to Standby.

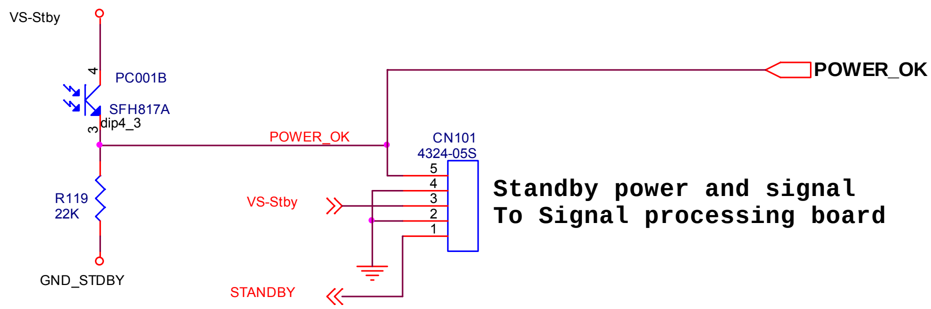
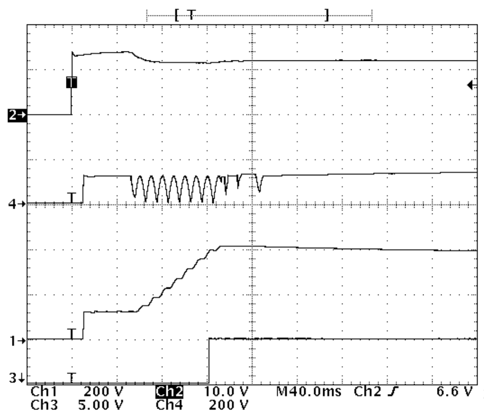


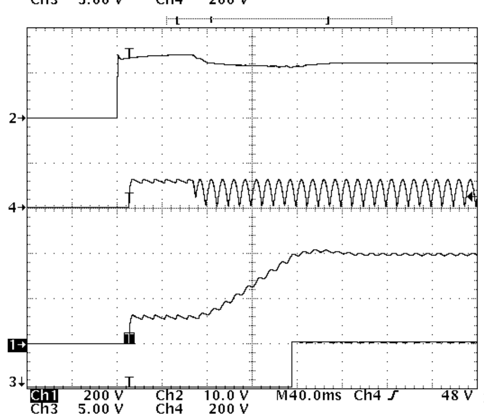

Figure 10. POWER-OK provides PFC-OUT status to TV µP

## Starting phase



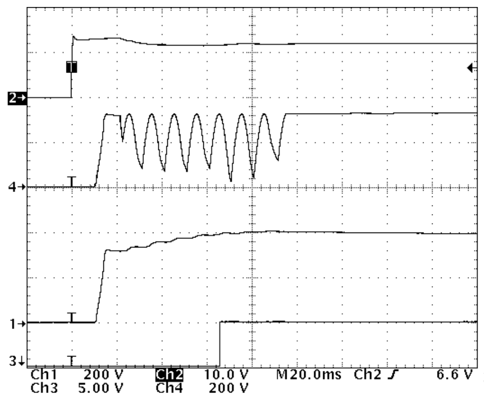

V in = 90 V ac
No load

CH2 => VCC4
CH4 => VRMS
CH1 => PFC OUT
CH3 => PFC OK after 120 ms



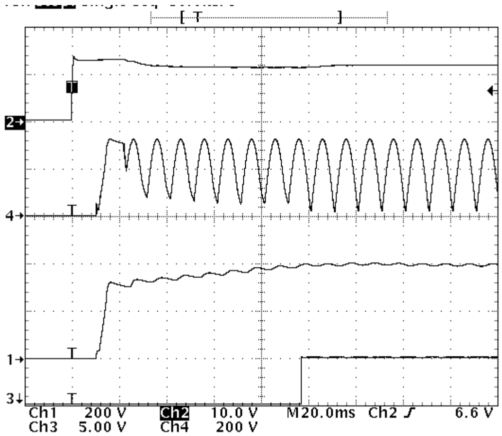

V in = 90 V ac
Load => 100 W

CH2 => VCC4
CH4 => VRMS
CH1 => PFC OUT
CH3 => PFC OK after 160 ms



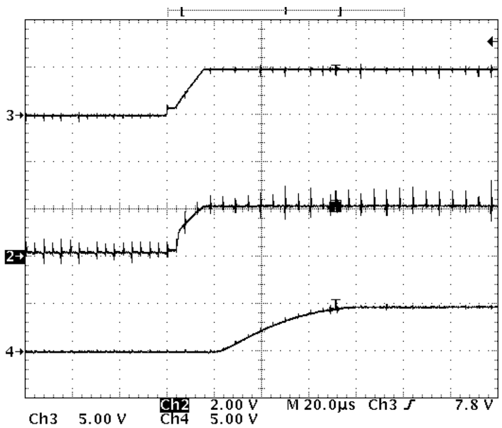

V in = 230 V ac
No load

CH2 => VCC4
CH4 => VRMS
CH1 => PFC OUT
CH3 => PFC OK after 65 ms




V in = 230 V ac
Load => 100 W

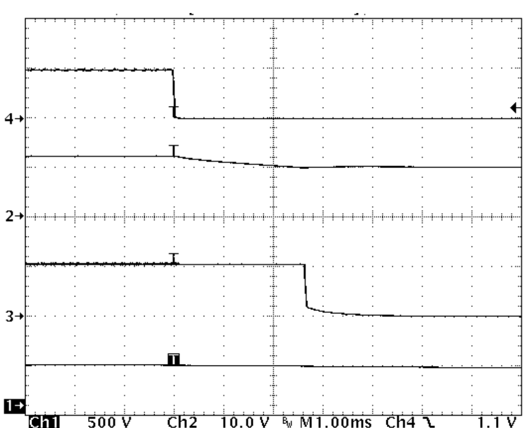
CH2 => VCC4
CH4 => VRMS
CH1 => PFC OUT
CH3 => PFC OK after 100 ms



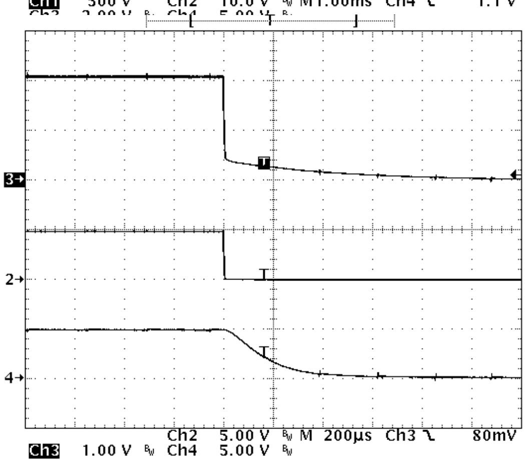

V in = 230 V ac
CH3 => PFC OK
CH2 => POWER BOOST
CH4 => POWER OK

Same for 90 V ac, with or without load
Delay of 60 µs for POWER OK compared to PFC OK

<u>From ON to Standby</u>



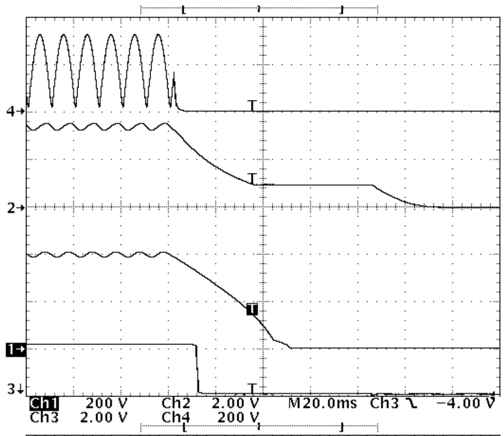

CH4 => STANDBY
CH2 => VCC4
CH3 => POWER BOOST
CH1 => PFC OUT




CH3 => PFC OK
CH2 => POWER BOOST
CH4 => POWER OK

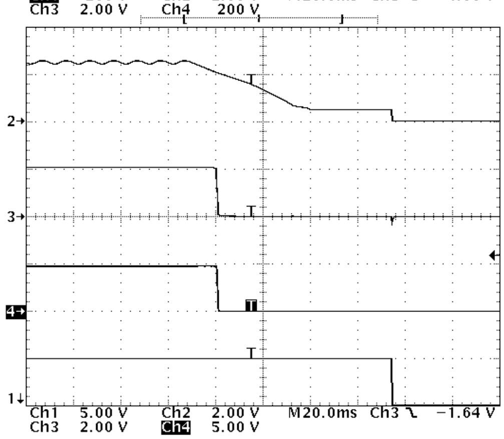
POWER BOOST is going down when PFC OK is going down as Vcc4 is going down below 10 V and PFC IC switch OFF

## Mains or Switch OFF




CH4 => VRMS
CH2 => BO
CH1 => PFC OUT
CH3 => POWER BOOST

POWER BOOST is going down when
PFC OUT drops below 80% / 320 V



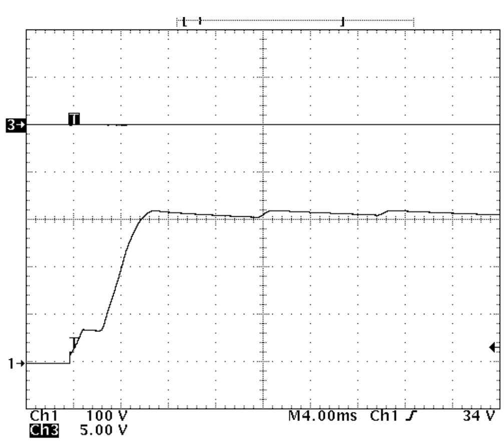

CH2 => FB PFC
CH3 => POWER BOOST
CH4 => POWER OK
CH1 => PFC OK

POWER BOOST is going down when
FB PFC drops below 80% / 2 V
PFC OK stay ON until PFC IC switch OFF

## OVP and UVP

The NCP1631 has been designed with dedicated OVP pin (on top of Feedback one) allowing high level of protection for open regulation loop.
To reduce overall power dissipation if the relay is not inserted, both resistances divider have been combined in our application. If this reduces the power, we now have a direct link between both FB and OVP/UVP pins.

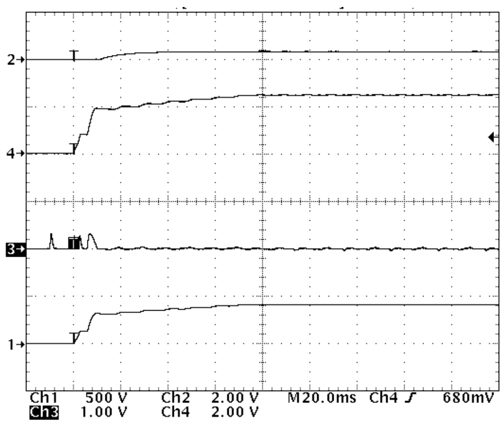
### Regulation feedback to GND in ON mode




CH2 => FB PFC
CH4 => OVP / UVP
CH3 => POWER BOOST
CH1 => PFC OUT

OVP/UVP pin is also grounded: UVP is activated and PFC switch OFF, PFC-OUT is equal to mains peak rectified voltage (320 V for 230 V ac)

Regulation feedback Open in ON mode




CH2 => FB PFC
CH4 => OVP / UVP
CH3 => POWER BOOST
CH1 => PFC OUT

Without Feedback information, the OVP pin takes the regulation over with highest Output voltage defined by the resistances divider.

## Detailed function and design of the Interleaved CrM PFC

Please refer to the application note of NCP1631 which provides all information and design tools necessary for the PFC design. They are all listed at the end of this documentation.

# Flyback converter

## Introduction

With a dedicated converter to supply the backlight (on separated board), the flyback SMPS is used to provide power to all the analog and digital blocks used for control, signal processing, and audio amplification.
With an overall requested power up to 70 W, it is better to use a separated Standby power supply to provide high ECO Standby performances: it is not possible to be < 100 mW in Standby with a 70 W SMPS capable and all parasitic consumption from mains filters and PFC.
With Flyback power supply completely OFF in Standby mode, there is no need of added switches to disconnect output voltages and so avoid possible safety issues with overheating of those switches with output overload or short circuit to GND.

The Flyback converter has been designed to support general types of TV applications with up to 3 output voltages which can be selected by transformer design with adapted turn's ratio of each secondary winding. The first application that has been developed supports the most common application working with 5 V and 12 V, with 50 W continuous power, up to 70 W peak with up to 4 A on each of the 2 outputs.
The third output could be used for a 24 V most likely dedicated to Audio amplifiers with lower current capability limited to 1 A or 2 $A_{peak}$.

To be able to support wider concept requests, the Flyback power converter has been developed with the 2 basic Flyback possible solutions:

- QR variable frequency with minimum voltage switching solution, working in discontinuous critical mode
- PWM Fix frequency allowing both discontinuous or continuous mode according to output power conditions and transformer design

The design has been done with PCB supporting both controller positions allowing fast change from one to the other, keeping the same power parts (transformer, Power MOS, current sense and voltage clamp) and the same complete secondary side solution: Less than 10 parts changed allow the modifications with possibility to easily compare both solutions' merits!

## QR Flyback with new NCP1379

The NCP1379 is a high-performance circuitry aimed to powering quasi resonant converters. Capitalizing on a proprietary valley lockout system, the controller reduces the switching frequency as the power loading becomes lighter. This results in a stable operation despite switching events always occurring in the drain source valley. This system works down to the 4th valley and toggles to a variable frequency mode beyond, ensuring an excellent low power mode performance.

To improve the safety in overload situations, the controller includes an Over Power Protection (OPP) circuit which clamps the delivered power at high line. Safety wise, a fixed internal 80 ms timer relies on the feedback voltage to detect a fault. Once the timer elapses, the controller stops and enters auto recovery mode.

Particularly well suited for TV applications, the controller features a pin to implement a combined brown out / overvoltage protection such that

- The converter starts switching only when supply voltage from PFC is at the right level.
- The controller stops switching with detection of auxiliary overvoltage following regulation open loop.

The NCP1379 has been designed without High Voltage Start connection, especially for application with extra Standby SMPS with a low Vcc start of 12 V directly applied from Standby SMPS.

The timer protection with auto restart allows the system to restart and work in burst mode without switching OFF the Standby power supply.

## Fix frequency PWM Flyback with NCP1252A

The NCP1252 controller offers everything needed to build cost effective and reliable ac-dc PWM Fixe frequency current controlled switching power supplies. Thanks to the use of an internally fixed timer, NCP1252 detects an output overload by control of feedback regulation without relying on the auxiliary Vcc drop (Mandatory when supplied from Standby SMPS). A Brown Out input offers protection against low input voltages and improves the converter reliability and safety behaviors. The switching frequency is adjustable with a single external resistance allowing the optimum use of the transformer performances. An external capacitor provides full flexibility of Soft start definition.

The NCP1252 is especially designed for application with extra Standby SMPS. It has a low Vcc start of 12V directly applied from Standby SMPS.

The timer protection with latch asks the system to go in Standby to allow possible restart (Vcc going down provides NCP1252 reset).

## Design of the transformer

The design of the transformer has been done for the QR mode has this is the most critical one.
All below equations are from NCP1379 / 1380 applications notes and documentations.

$$N_{ps} = \frac{k_c(V_{out}+V_f)}{B_{Vdss}k_D - V_{in,max} - V_{os}} = \frac{3\times(5+0.8)}{800\times 0.85 - 400 - 10} \quad \Rightarrow \quad N_{ps} \approx 0.064444$$

$$I_{pri,peak} = \frac{2P_{out}}{\eta}\left(\frac{1}{V_{in,min}} + \frac{N_{ps}}{V_{out}+V_f}\right) + \pi\sqrt{\frac{2P_{out}C_{lump}F_{sw}}{\eta}}$$
$$= \frac{2\times 75}{0.8}\left(\frac{1}{375} + \frac{0.064444}{5.8}\right) + \pi\sqrt{\frac{2\times 75\times 100p\times 45k}{0.8}} \quad \Rightarrow \quad I_{pri,peak} = 2.6745\,A$$

$$L_{pri} = \frac{2P_{out}}{I_{pri,peak}{}^2 F_{sw}\eta} = \frac{2\times 75}{2.6745^2\times 45k\times 0.8} \quad \Rightarrow \quad L_{pri} = 582\,\mu H$$

$$d_{max} = \frac{I_{pri,peak}L_{pri}}{V_{in,min}}F_{sw,min} = \frac{2.67\times 582\mu}{375}45k \quad \Rightarrow \quad d_{max} = 0.187$$

$$I_{pri,rms} = I_{pri,peak}\sqrt{\frac{d_{max}}{3}} = 2.67\sqrt{\frac{0.187}{3}} \quad \Rightarrow \quad I_{pri,rms} = 0.667\,A$$

$$I_{sec,rms} = \frac{I_{pri,peak}}{N_{ps}}\sqrt{\frac{1-d_{max}}{3}} = \frac{2.67}{0.064444}\sqrt{\frac{1-0.187}{3}} \quad \Rightarrow \quad I_{sec,rms} = 21.6\,A$$

As results of above calculation, the transformer has been designed on SRW4549 bobbin and core from TDK as this was the right size < 8 mm height.

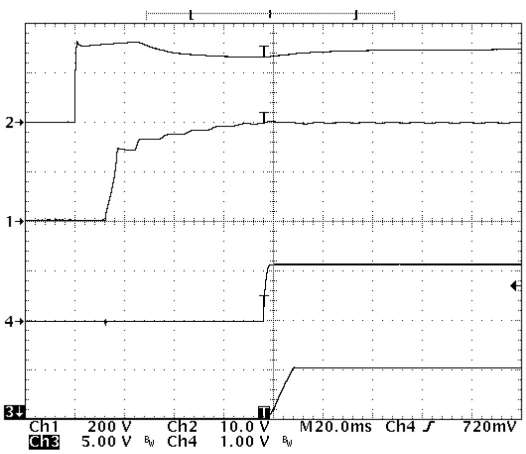
Specification:

- Primary inductance of 0.65 mH for Saturation current > 3 A
- Np = 45 + 45 = 90 turns of 0.3 mm wire (secondary in sandwich between both primary to reduce leakage inductance)
- Ns 5 V = 2 x 6 turns of 4 x 0.3 mm wire to provide requested current capability
- Ns 12 V = 2 x 8 turns of 4 x 0.2 mm wire to provide requested current capability. This 12 V is build on top of the 5 V to improve cross regulation
- Nb = 15 turns of 0.14 mm for auxiliary / Vcc winding
- Isolation tap of 6.5 mm on both side to provide the requested isolation

## Starting phase

The Flyback (Same behavior for both QR and PWM) is only starting from Standby mode. As soon as Vcc4 is available for all primary ICs through the Standby switch Q101, the PFC controller will be supplied so that PFC-OUT is at 400 V after 80 ms by 230 V ac (longer time for lower mains supply).
At that time, the PFC-OK is going up, allowing BO to be over 1 V threshold so that Flyback (already supply from Vcc4) is starting with 5 V output, well regulated after ~10 ms.

<u>Flyback starting phase from Standby to ON</u>




CH2 => VCC4

CH1 => PFC OUT

CH4 => BO

CH3 => VS1 / 5 V

Primary side circuit of QR Flyback with NCP1379

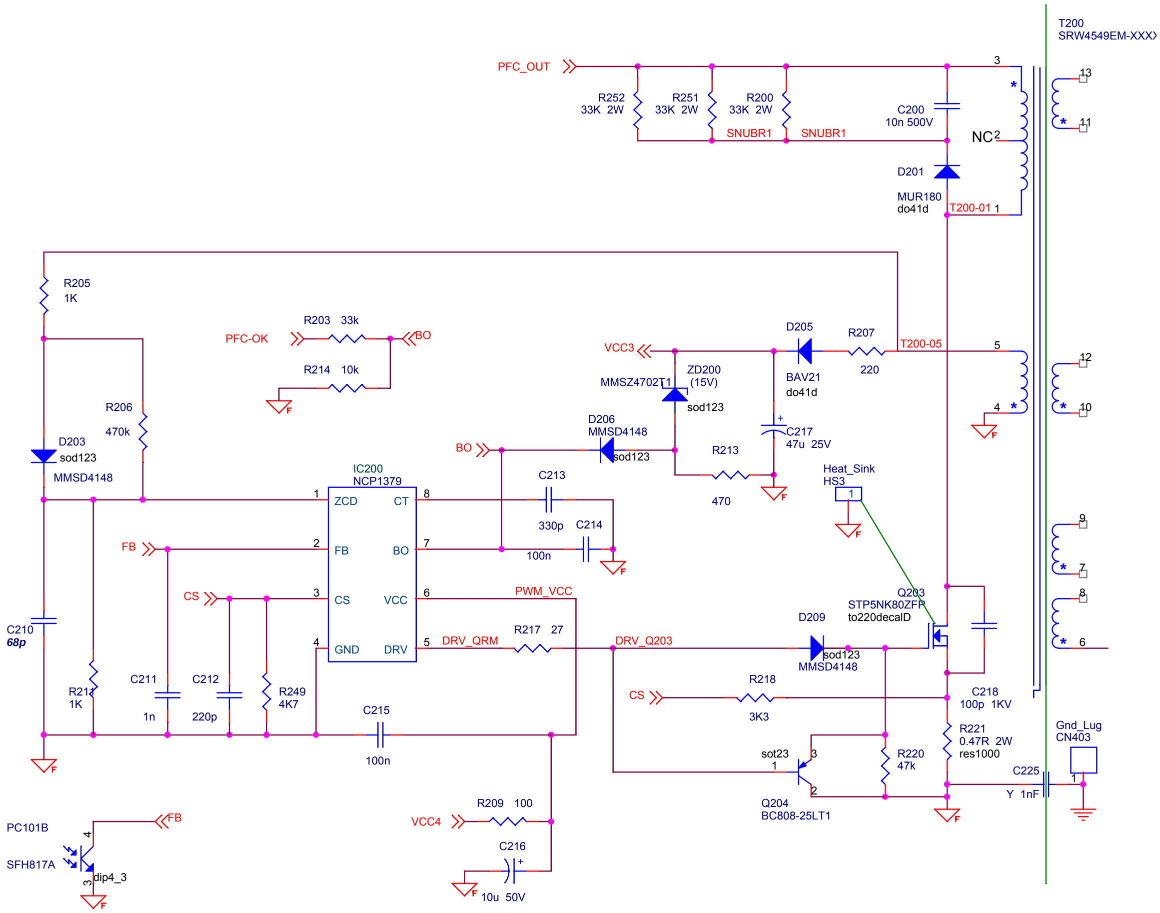



Figure 11. Primary side of QR Flyback with NCP1379

Connected to the auxiliary winding through R205, the ZCD / pin 1 detects the core reset event such that the controller will always drive the system with full demagnetization. The value of the small capacitor C210 (with both R205 and R211) will set the delay to switch by the minimum voltage and reduce as much as possible switching looses and EMI. This will be true even by the fourth valley when the output power is low.

Also, injecting a negative voltage smaller than 0.3 V on this pin during the conduction of the power MOS will perform over power protection defined by R206. The diode D203 allows both ZCD and OPP individual adjustment.

The secondary feedback opto coupler collector connected to the FB / pin 2 will allow regulation via primary current regulation, lower voltage on this pin will immediately reduce the output power.

The CS / pin 3 monitors the primary peak current going through the Power MOS Q203 and the primary of the transformer. If the first level of 0.8 V limits the current cycle by cycle and start the internal timer, the second level of 1.2 V (150%) will switch OFF immediately and latch the IC as this is the result of strong secondary diode short circuit.

The GND / pin 4 is connected to the primary ground.

The DRV / pin 5 is the driver's output which directly drives the gate of external Power MOS Q203. Although the IC is designed to directly drive large Power MOS, an added external PNP transistor Q204 is used to reduce current loop and possible EMI related to the high di/dt necessary to switch OFF the Power MOS in a small amount of time.

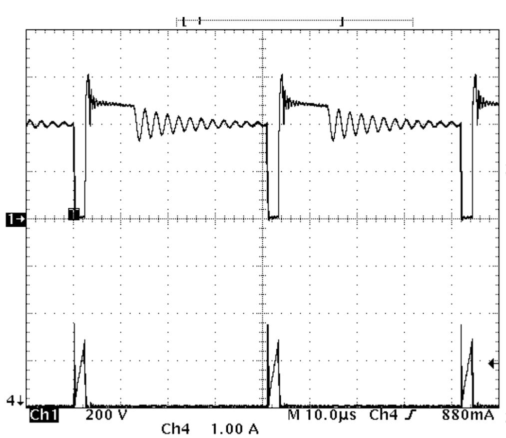
The Vcc / pin 6 is the supply pin of the IC connected to the general supply Vcc4 through a dedicated filter (R209), after standby switch Q101 with energy coming from Standby (Vcc1) or Flyback (Vcc3) SMPS.
To avoid direct impact of output power though leakage inductance on the primary auxiliary voltage Vcc3, a large resistance R207 has been inserted in series to the rectifier diode to get the closest voltage to the plateau which is the image from output regulated voltage. This voltage Vcc3 is also used to detect over voltage and acts to latch the IC through the BO pin protection.

The BO / pin 7 observes the HV rail or the voltage coming from PFC OK (through the divider R203 and R214) to allow starting phase only when PFC-OUT supply line is correct. It also offers a way to latch the circuit in case of over voltage event through the diode D206 when the zener diode ZD200 is switch ON (Open regulation loop protection) and provide 2.5 V to pin 7.

A capacitor connected to the CT / pin 8 acts as the timing capacitor in foldback mode and adjusts the frequency in VCO mode.

As for general Flyback application, a voltage clamp is used to reduce the Max voltage on the Power MOS linked to the leakage inductance of the transformer. To avoid over temperature, up to 3 power resistances R200, R251 and R252 can be used.

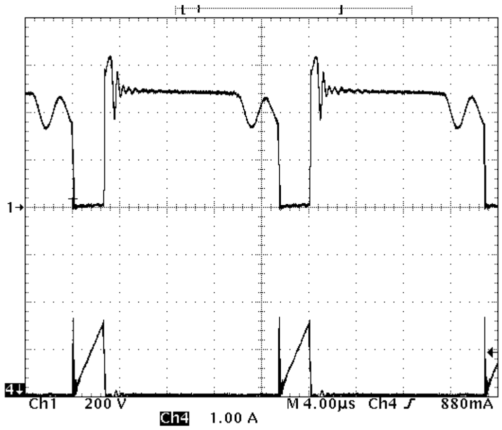
<u>ON Mode with 400 Vdc supply for PFC</u>




Low power mode
1 A on 5 V and 0.5 A on 12 V

V Drain
I Drain

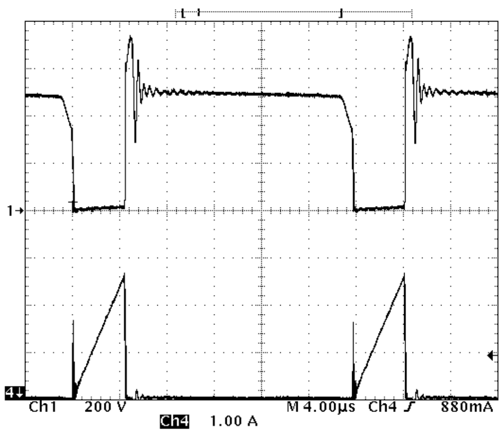
Fix and low frequency of 24 kHz




½ Output power mode
2 A on 5 V and 2 A on 12 V

V Drain
I Drain

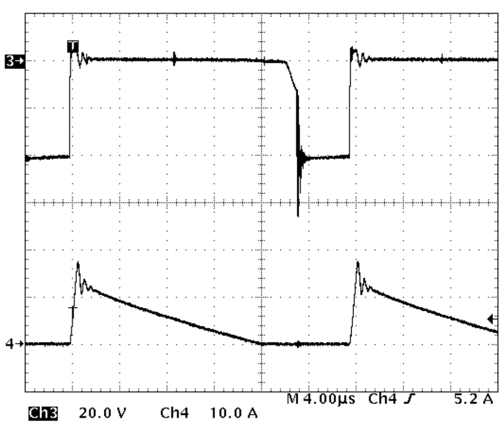
QR by second valley at 57 kHz




Full power mode
4 A on 5 V and 4 A on 12 V

V Drain
I Drain

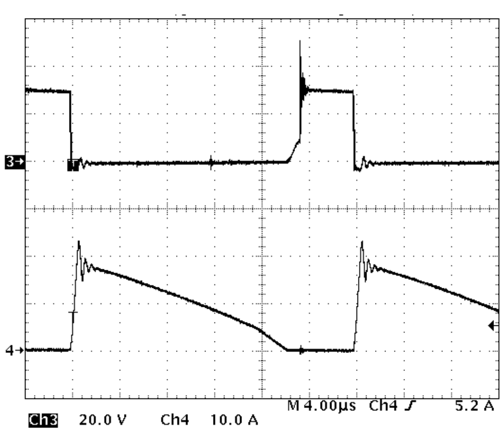
QR mode by first valley at 42 kHz




Full power mode
4 A on 5 V and 4 A on 12 V

Secondary 5 V Diode voltage and current

V D210 < 52 V
I D210 up to 23 A peak




Full power mode
4 A on 5 V and 4 A on 12 V

Secondary 12 V Diode voltage and current

V D207 < 65 V
I D207 up to 17.5 A peak

Primary side circuit of Fix Frequency PWM Flyback with NCP1252

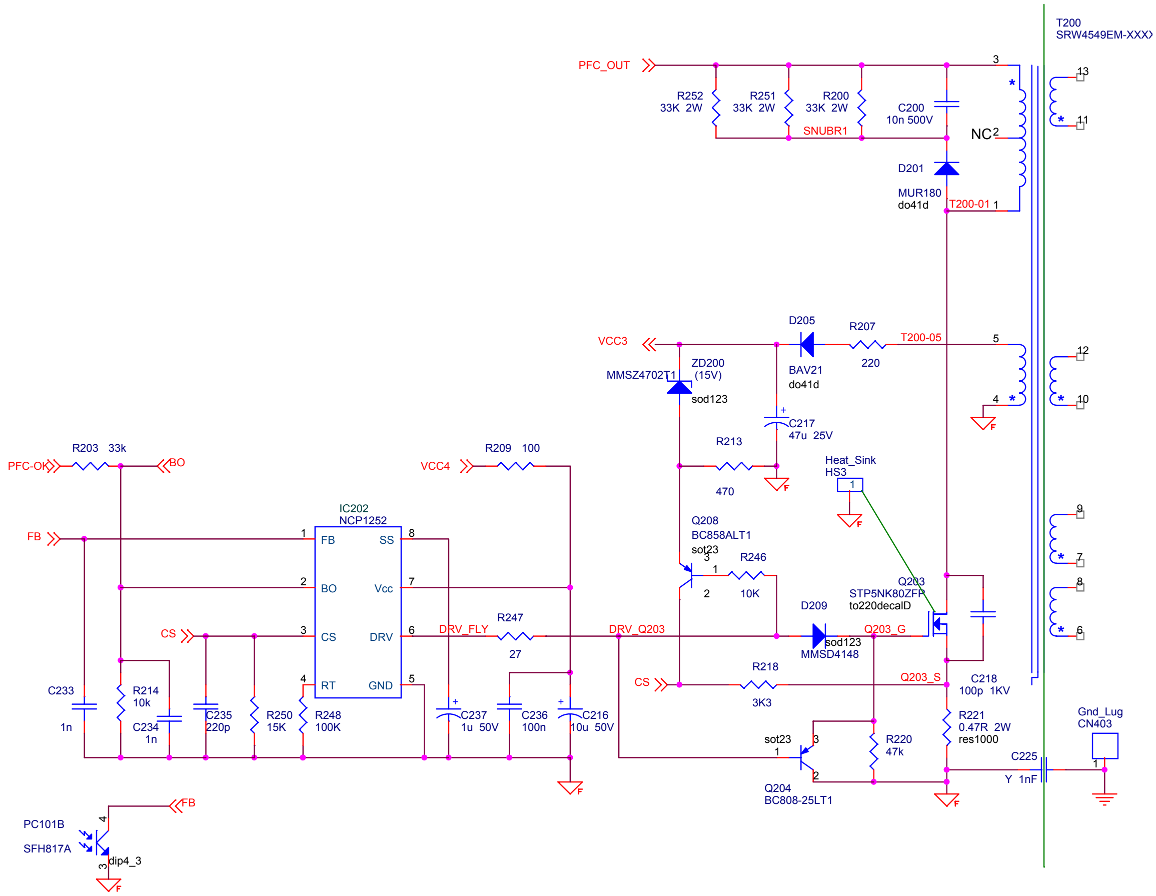



Figure 12. Primary side of PWM Flyback with NCP1252

The secondary feedback opto coupler collector connected to the FB / pin 1 will allow regulation via primary current regulation, lower voltage on this pin will immediately reduce the output power.

The BO / pin 2 observes the HV rail or the voltage coming from PFC OK (through the divider R203 and R214) to allow a starting phase only when PFC-OUT supply line is correct.

The CS / pin 3 monitors the primary peak current going through the Power MOS Q203 and the primary of the transformer. If the first level of 1V limits the current cycle by cycle and start the internal timer with latch−off at the end. This allows accurate overload or short−circuit detection which is not dependant on the auxiliary winding. Reset occurs when: a) a BO reset is sensed, b) VCC is cycled down to VCC (min) level. If the short circuit or the fault disappear before the fault timer ends, the fault timer is reset only if the CS pin voltage level is below 1 V at least during 3 switching frequency periods. This delay before resetting the fault timer prevents any false or missing fault or over load detection.

It also offers a way to latch the circuit in case of an over voltage event through the transistor Q208 when the Zener diode ZD200 is switch ON (Open regulation loop protection) and provide 2.5 V to pin 3 during OFF time of Power MOS Q203.

A resistor connected from pin RT / 4 to ground fixes the switching frequency.

The GND / pin 5 is connected to the primary ground.

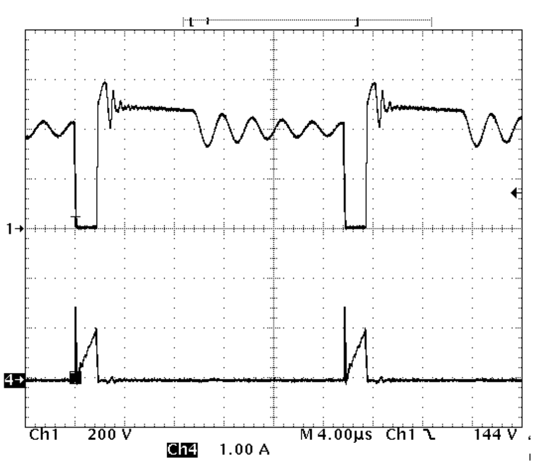
The DRV / pin 6 is the driver's output which directly drives the gate of external Power MOS Q203. Although the IC is designed to directly drive large Power MOS, an added external PNP transistor Q204 is used to reduce current loop and possible EMI related to the high di/dt necessary to switch OFF the Power MOS in a very short time.

The Vcc / pin 7 is the supply pin of the IC connected to the general supply Vcc4 through a dedicated filter (R209), after standby switch Q101 with energy coming from Standby (Vcc1) or Flyback (Vcc3) SMPS.
To avoid direct impact of output power though leakage inductance on the primary auxiliary voltage Vcc3, a large resistance R207 has been inserted in series to rectifier diode to get voltage close to the plateau which is the image from output regulated voltage. This voltage Vcc3 is also used to detect over voltage and acts to latch the IC through the CS pin protection.

The SS / pin 8 allows external capacitor C237 connection which defines the soft start of the IC.

As the switching frequency has been chosen to be close to the QR Flyback one in order to keep the same transformer, the same voltage clamp is used to reduce the Max voltage on the Power MOS linked to the leakage inductance of the transformer. To avoid over temperature, up to 3 power resistances R200, R251 and R252 can be used.

<u>ON Mode with 400 Vdc supply from PFC</u>

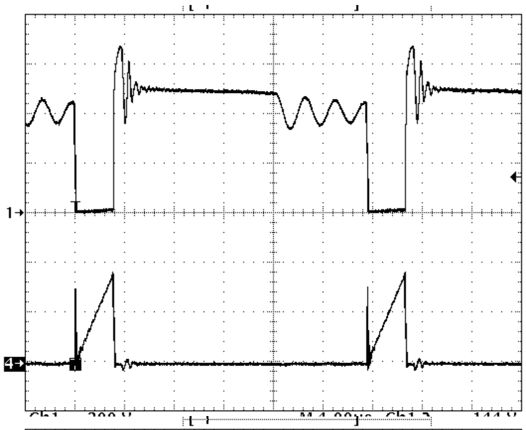



Low power mode
1 A on 5 V and 0.5 A on 12 V

V Drain
I Drain

V drain max = 592 V

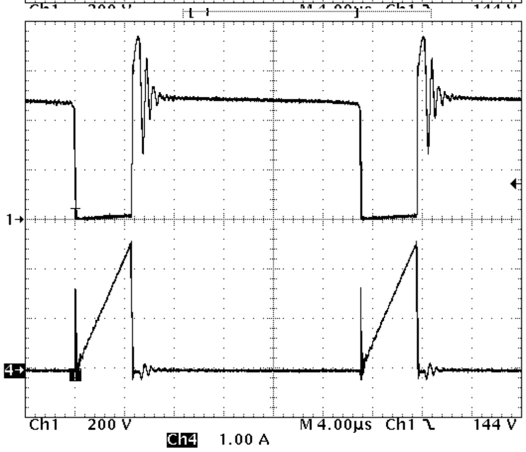
Fsw = 46 kHz



½ Output power mode
2 A on 5 V and 2 A on 12 V

V Drain
I  Drain

V drain max = 672 V
Fsw = 42 kHz
I peak = 1.84 A

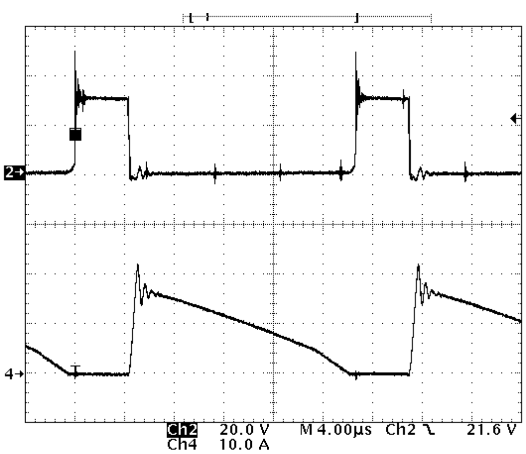



Full power mode
4 A on 5 V and 4 A on 12 V

V Drain
I Drain

V drain max  = 742 V
Fsw = 43 kHz
I peak = 2.61 A

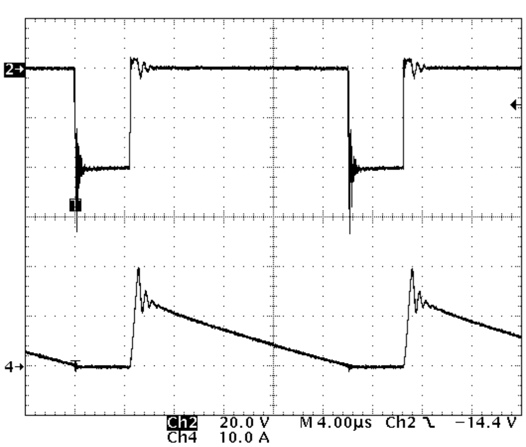
$V_{RCD}$ = 235 V  $P_{RCD}$ = 1.67 W




Full power mode
4 A on 5 V and 4 A on 12 V

Secondary 5V Diode voltage and current

V D210 < 49 V
I D210 up to 22 A peak




Full power mode
4 A on 5 V and 4 A on 12 V

Secondary 12V Diode voltage and current

V D207 < 65 V
I D207 up to 20 A peak

Secondary side circuit of Flyback (Same for both QR and PWM)

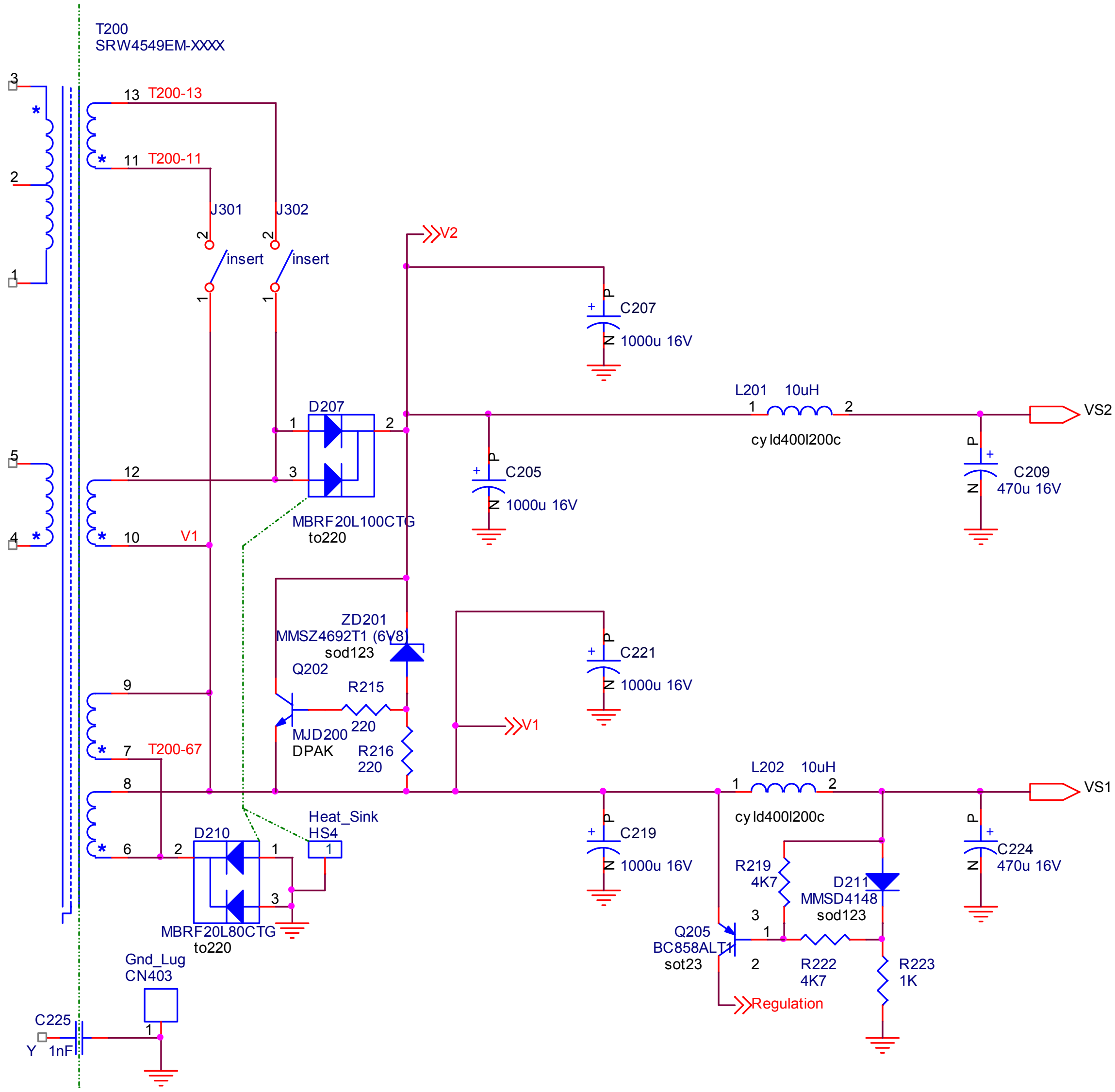



Figure 13. Secondary side of Flyback (same for both solutions)

## Cross Regulation Considerations

Achieving good cross regulation is a design challenge in LCD-TV applications as the tolerances are tight, typically +/- 5% and the dynamic operation can vary widely due to the high dynamic range of the audio amplification and the variety of signal processing power load depending on the input video source. Below is the typical output voltage and load range for the baseline reference design.

+5 V from 1 to 4 A

+12 V from 0.5 to 4 A

To improve the overall cross regulation performance, the +5 V diode is connected in the ground (GND) of the winding with +12 V on top of the 5 V winding. The drawback of that is that both +5 V and +12 V current go through the 5 V diode and winding (increasing power loses mainly in the +5 V diode), the advantage of this configuration is that the 12 V only sees 7 V of variation. An additional advantage of this construction is that the reverse voltage of the 12 V diode D207 is limited by the same difference. Note the transformer was designed with a low turn's ratio thus reducing the effective current but increasing the reverse voltage of the diode. In the reference design, a 100 V is used for the 12 V to ensure adequate design margin and avoid the possibility of any reliability issues while an 80 V type is used for the 5 V to reduce the power looses thanks to lower $V_f$.

On top of this winding construction, the transformer has been designed to avoid too much difference of coupling from primary winding to each secondary one: a better coupling of the 12 V winding will unbalance the conduction of both secondary 5 V and 12 V diodes which has an immediate direct impact on the cross regulation performances. The transformer has been specially designed on these criteria, but unfortunately with a direct impact on the overall primary leakage inductance which asks for an 800 V Power MOS (Instead of the 700 V type expected).

To be able to support a further larger range of output power / currents (Request to be confirmed according to output power range and expected cross regulation performances), an added voltage clamp has been inserted on the PCB. Monitored by the zener diode ZD201, the difference between both 12 V and 5 V is now limited, avoiding the 12 V to go up or the 5 V to go down. As soon as the difference exceeds 7.5 Vtyp, the bipolar NPN transistor Q202 will start conducting to derive a current from 12 V to 5 V and so keep "under control" the difference. The serial resistance R215 is in to limit the gain and avoid possible oscillations. The transistor Q202 is a DPAK type allowing power dissipation with a large surface of PCB (This part should be changed to TO220 type and put on diodes heat sink if more power dissipation is requested).

### Secondary regulation

The secondary regulation is done on both 5 V / VS1 and 12 V / VS2 allowing better overall performances.
As the 5 V asks for lower tolerance, 2/3 of the regulation is coming form the 5 V with only 1/3 from the 12 V.
The IC201 / TL431 will drive the current in opto PC101 according to output voltage such that high voltage will increase the current in the opto to drop down the FB pin of the primary controller such that power transferred is decreased allowing correct regulation.

## Output current sense

To be able to fulfill all possible safety tests, the Switch Mode Power Supply should be able to manage short circuit or over load on each Output.
Direct short circuit is not an issue as this will result in a very high current dropping down all output voltages and detectable by primary over current protection such that IC will stop and restart if not latched. Working by very low frequency should avoid any over temperatures issues (for QR mode).
Much more critical for SMPS are short circuits far-away on the circuit after serial impedances such like copper tracks, cables and even filter coils. The serial impedances will limit the current and may not allow activating the primary over current protection. This is an unlikely risk on the 12 V as voltage is large enough, but this is a major issue for low voltage like 5 V. If for any reason, the 12 V is not loaded when overload on 5 V happens, the total 70 W will be available with up to 14 A on 5 V before primary start to limit! In that case we will have up to 3 times the nominal current on 5 V without any stop which results in high temperatures on 5 V parts creating possible risks of fire on the board.

To avoid thi safety issues, a current sense has been developed on 5 V using the voltage drop of filtering coil to avoid any added power parts and added voltage drop which has a direct impact on output regulation performances (regulation is done before the filter coil).

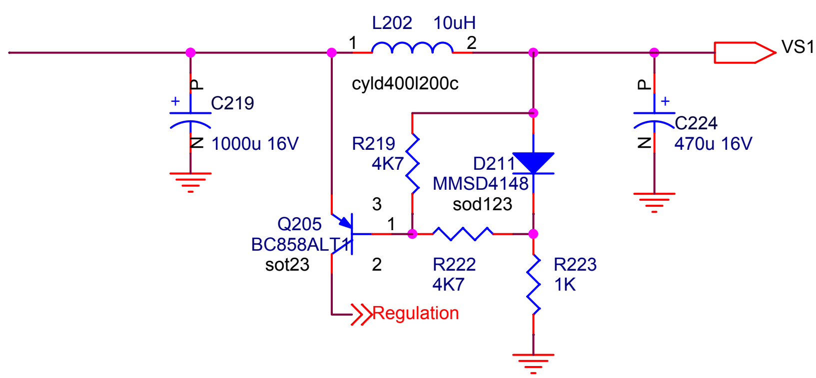



Figure 14. Low voltage / 5V Output current limitation

To be able to adjust the level according to the requested limit, a pre-polarization of the sense PNP bipolar transistor Q205 has been done with an added diode D211 such that only 0.3 V drop on L202 provides the 0.6 V on Q205 Base Emitter and so provides an added level of information on “Regulation”. The resistances divider R219 / R222 should be adjusted according to the impedance of L202 and the defined current limitation (adjusted to limit by 6 / 7 A on our application to provide up to 4 A without any issues).

The added information provided to “Regulation” will change the regulation from “Voltage control” to “Current control” such that the current on the 5 V will be limited to the defined value.

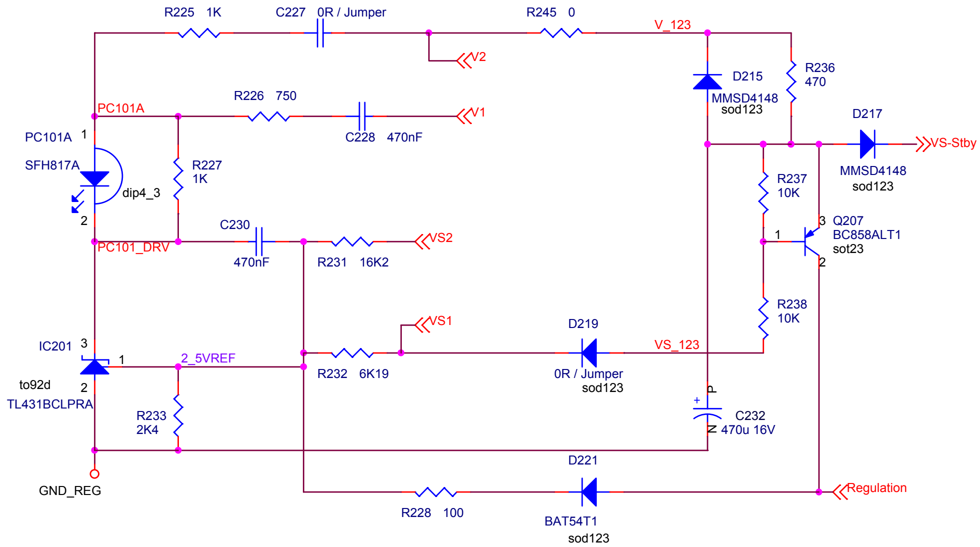



Figure 15. Regulation with Output Under Voltage Protection

To avoid too strong working conditions, an additional under voltage protection has been inserted to switch OFF completely the power supply when 5 V Output is below a defined limit.

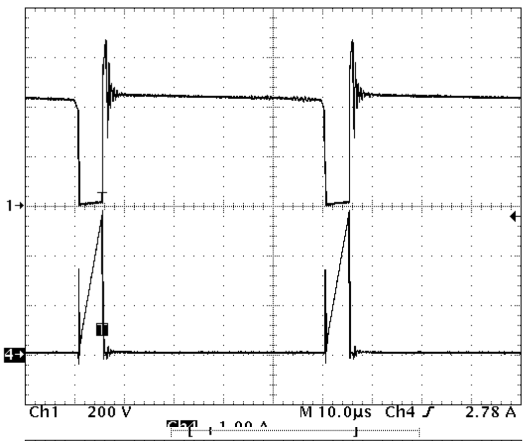
Q207 is used as a comparator which is switch ON as soon as VS1 is below:
5 V Standby + 0.6 V (D217) – 1.2 V (Q207$_{junction}$ and R divider R237/238) = 4.5 V
As soon as Q207 is switched ON, an added voltage is applied through D221 on TL431 regulation such that primary controller will reduce the power transferred to secondary and even stop completely when Q207 is ON applying more than 3 V on TL431 $V_{ref}$. This solution will keep the SMPS in OFF mode until secondary 12 V is down such that the secondary protection circuit is not supply any more, allowing the primary IC to restart again.
As this circuit should not be activated during the starting phase, the supply will come from the 12 V Output (through R236) going up with the same slop than the 5 V with an added delay defined by R236 and C232.
This circuit has some limitations. Due to the good cross regulation of the transformer, the 12 V will not be able to reach this nominal value if the overload on 5 V happens during the starting phase. With reduced 12 V, the voltage applied through Q207 on TL431 reference will be smaller so that the time needed to switch OFF completely the power supply will be longer. To reduce this effect, D221 (mandatory for the starting phase) has been changed to Schottky (reduced Vf).

The PCB has been design to allow under voltage control also on VS2 (not inserted on our developed solution).

## Overload on 5 V / VS1

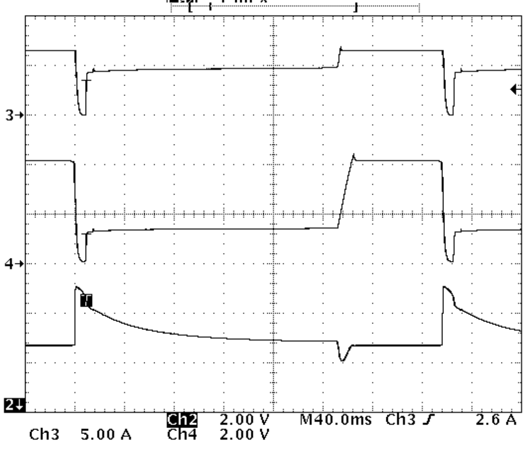
Tests done on QR Flyback with NCP1379
(Similar behavior with PWM Flyback and NCP1252)

Output current I = 6.5 A (4 A is the maximum nominal current)



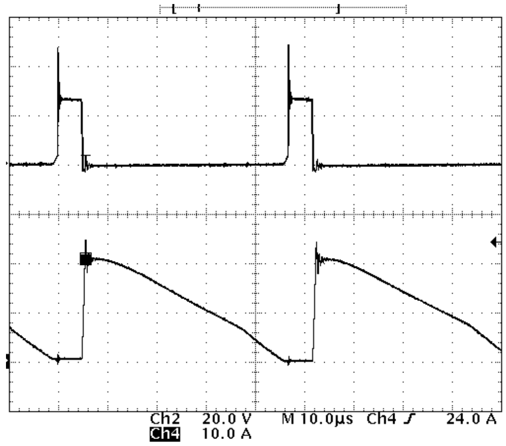

Primary side:
CH1 => V drain
CH4 => I primary

I peak = 2.90 A
Fsw = 20 kHz
V drain max = 670 V




Secondary side:

CH3 => I 5 V
CH4 => 5 V Out
CH2 => V Collector Q205



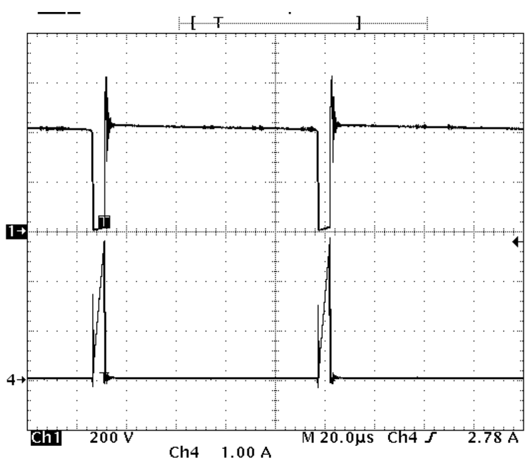

Working conditions of the secondary rectifier diode D210

CH2 => V D210 (V max = 50 V)

CH4 => I D210 I peak = 24 A

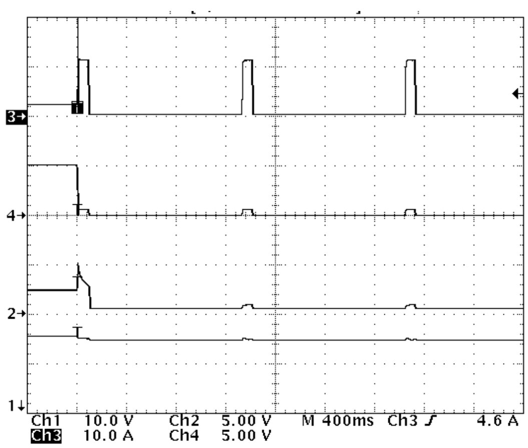
Short circuit on 5 V / VS1

Tests done on QR Flyback with NCP1379
(Similar behavior with PWM Flyback and NCP1252)



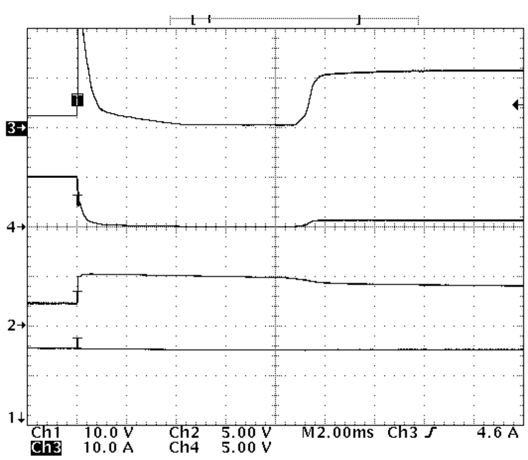

Primary side:
CH1 => V drain
CH4 => I primary

I peak = 2.90 A
F sw = 11 kHz
V drain max = 620 V thanks to lower reflected voltage




Secondary side:

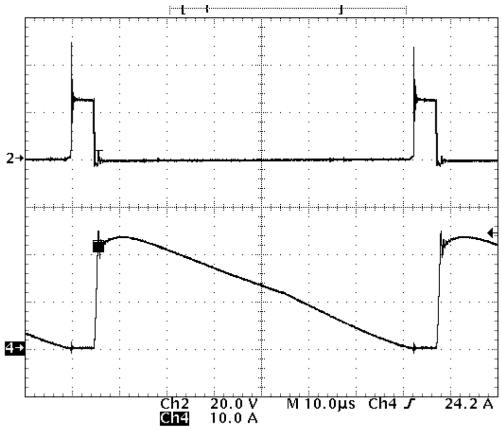
CH3 => I 5 V
CH4 => 5 V Out
CH2 => V Collector Q205
CH1 => VCC3




Expend of previous waveforms

CH3 => I 5 V
CH4 => 5 V Out
CH2 => V Collector Q205

CH1 => VCC3




Working conditions of the secondary rectifier diode D210

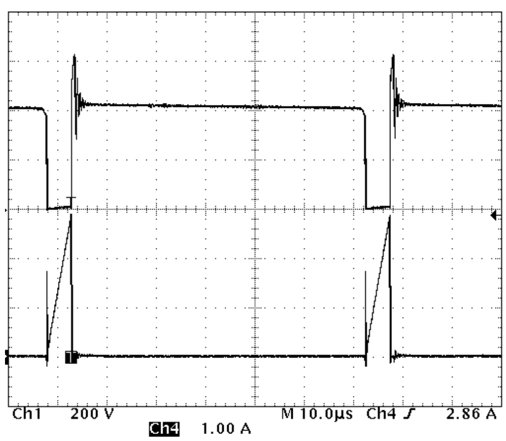
CH2 => V D210 (V max = 52 V)

CH4 => I D210 I peak = 25 A

## Overload on 12 V / VS2

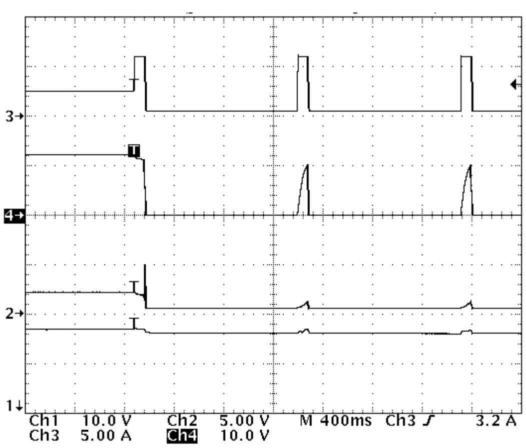
Tests done on QR Flyback with NCP1379
(Similar behavior with PWM Flyback and NCP1252)

Output current I = 5.5 A (4 A is the maximum nominal current)
There is no need of dedicated output current sense: thanks to the higher voltage, the overall power is high enough to reach the limit and activate embedded primary controller safety behavior.



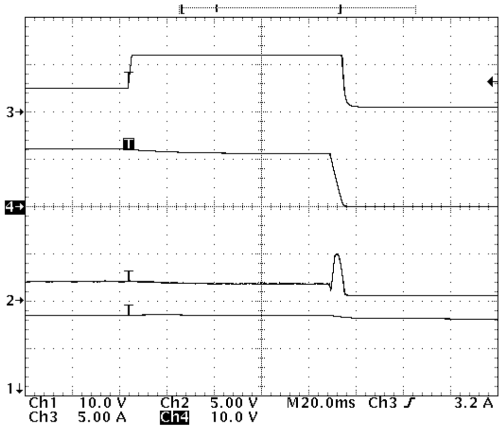

Primary side:
CH1 => V drain
CH4 => I primary

I peak = 2.90 A
Fsw = 15 kHz
V drain max < 650 V



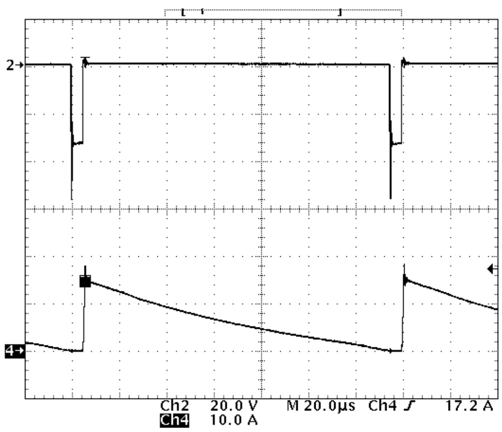

Secondary side:

CH3 => I 12 V
CH4 => 12 V Out
CH2 => V Collector Q205
CH1 => VCC3




Expend of previous waveforms

CH3 => I 12 V
CH4 => 12 V Out
CH2 => V Collector Q205
CH1 => VCC3



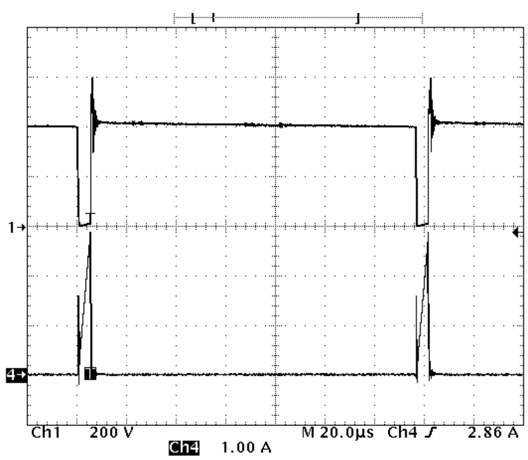

Working conditions of the secondary rectifier diode D207

CH2 => V D207 (V max = 60 V)

CH4 => I D207 I peak = 18.2 A

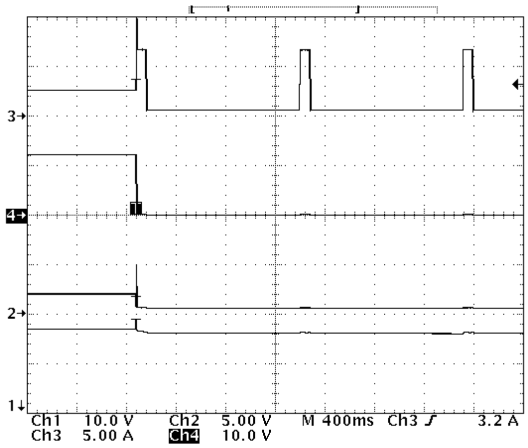
## Short circuit on 12 V / VS2

Tests done on QR Flyback with NCP1379
(Similar behavior with PWM Flyback and NCP1252)



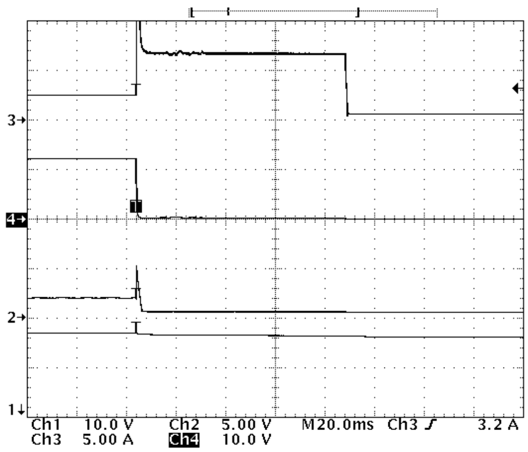

Primary side:
CH1 => V drain
CH4 => I primary

I peak = 2.90 A
Fsw = 7.3 kHz
V drain max < 600 V thanks to lower reflected voltage



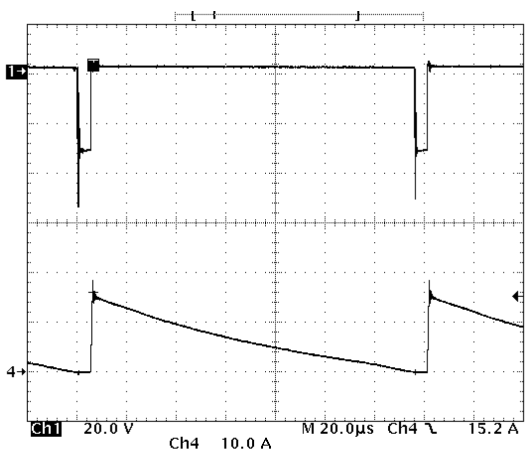

Secondary side:

CH3 => I 12 V
CH4 => 12 V Out
CH2 => V Collector Q205
CH1 => VCC3




Expend of previous waveforms
20 ms/div

CH3 => I 12 V
CH4 => 12 V Out
CH2 => V Collector Q205
CH1 => VCC3




Working conditions of the secondary
rectifier diode D207

CH2 => V D207 (V max = 54 V)

CH4 => I D207 I peak = 18.5 A

## Open regulation loop and Over Voltage Protection

As part of standard safety tests, the open regulation loop is one of the most critical because it can create output over voltages on most of the down parts and destroy the signal processing.

The overall application has a double Flyback output voltages protection.

The first one, located on the secondary side, will be able to directly measure output voltages and act to switch OFF in Standby mode.

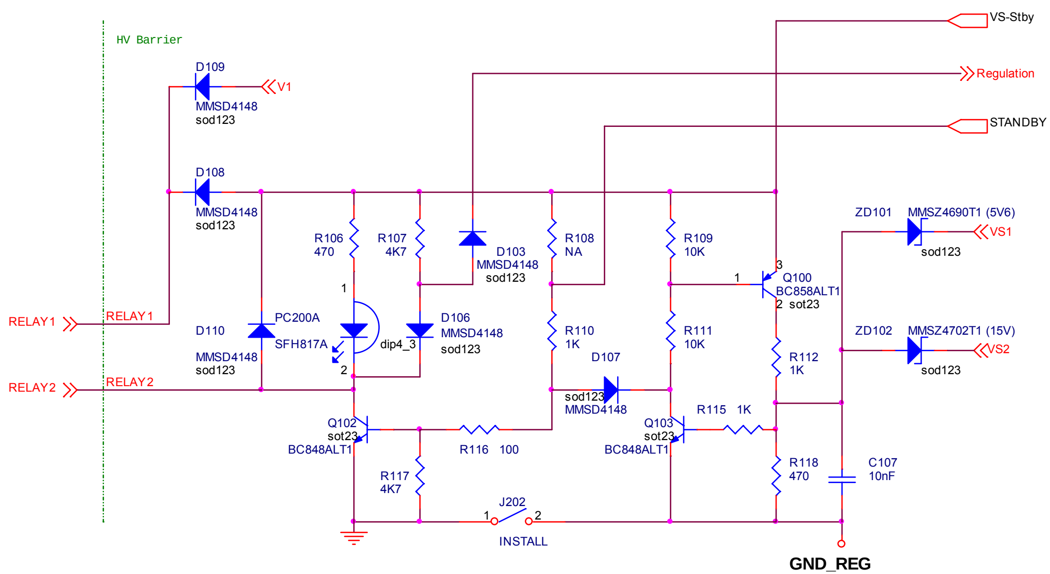



Figure 16. Secondary Flyback Over Voltage Protection

As soon as one of the output voltages (VS1 or VS2) is going over the limit defined by Zener diodes (ZD101 or ZD102), the transistors Q103 will be switched ON, forcing the system to go in Standby mode by switching OFF the transistor Q102. The relay is switched OFF such that mains voltage is disconnected from the board. The system is locked by the transistor Q100 which provides a “thyristor” effect to keep both Q103 and Q100 saturated until 5 V Standby is going down.
This solution is accurate thanks to direct / secondary side voltage control.

If this solution reacts quickly on the secondary side, it is unfortunately slow on the primary side: the large bulk capacitors on the PFC Output keep stored energy for the overall system (including the Flyback) such that converters keep running until the voltage is too low to supply them. This allows the Flyback to work open loop with further increased output over voltages on secondary side.

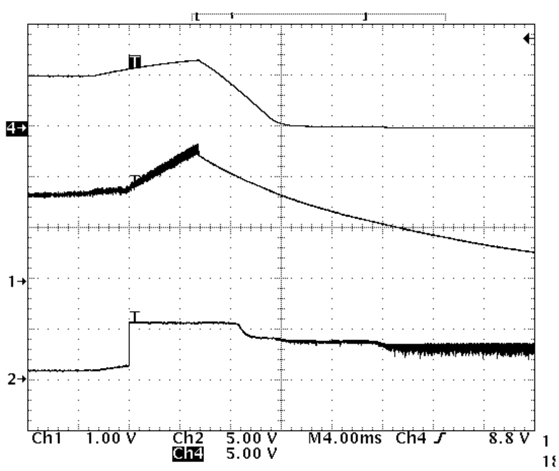
An added / second circuit located on the primary side will act to switch OFF immediately the Flyback converter as soon as Over Voltage is detected on the auxiliary Vcc supply.

With QR solution (Figure 11), the over voltage detected by the Zener diode ZD200 will be applied through the diode D208 to the BO input (pin 7) of the controller NCP1379. As soon as the voltage is over 2.5 V on BO, the controller is latch OFF until Vcc resets (Standby mode to disconnect the supply from Standby SMPS) allowing possible restart.

With PWM solution (Figure 12), the over voltage detected by the Zener diode ZD200 will be applied through the transistor Q208 to the CS input (pin 3) of the controller NCP1252 during the OFF mode of Power MOS to avoid any current limitation impact (and avoid on going primary regulation). As soon as the voltage is over 1 V on CS, the internal Timer will be started and the controller will latch OFF after 15 ms. A Vcc reset (Standby mode to disconnect the supply from Standby SMPS) allows possible restart.

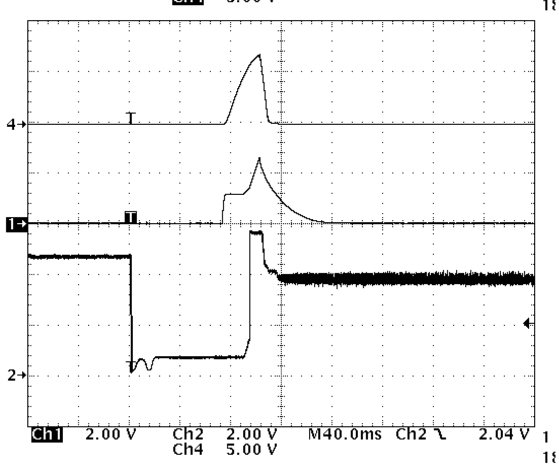
## Tests result with the QR NCP1379 open loop regulation

Tests been done with 2 A on both 5 V and 12 V output



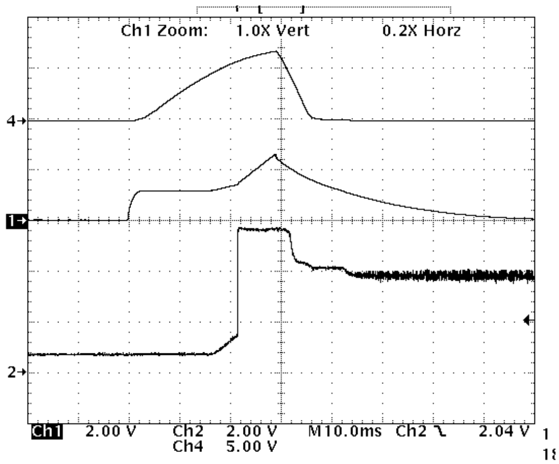

Tests done in ON mode (after starting)

CH4 => 5 V Out (6.7 V Max)
CH1 => BO / Latch Flyback IC
CH2 => RELAY2 switch OFF




Tests done in before starting
40 ms/div

CH4 => 5 V Out (6.9 V Max)
CH1 => BO / Latch Flyback IC
CH2 => RELAY2 switch OFF




Tests done in before starting
Expend of previous:10 ms/div

CH4 => 5 V Out (6.9 V Max)
CH1 => BO / Latch Flyback IC
CH2 => RELAY2 switch OFF

# Overall Edge LED LCD TV solution

A backlight power solution has been developed by On-Semiconductor to provide with the 46” Power a complete Edge LED LCD TV solution (Both boards have been designed to be interconnected).

Directly supplied by PFC output, a Half Bridge LLC converter (new NCP1397 Half Bridge LLC controller) supplies all LED segments with a DC output voltage (100-300 V).

The new CAT4026, 6-channel Edge LED linear driver provides

- Current regulation for each separated segments
- Voltage Feedback Control to External DC-DC converter
- Current Feedback Control to primary power supply Half-Bridge Resonant Converter (NCP1397)
- PWM and Analog Dimming
- Auto-Recovery Fault Detection (All Modes)
- Shorted Cathode-Anode (SCA) Fault Protection
- Open Cathode-Anode (OCA) Fault Protection
- Over-Voltage Protection (OVP)
- Thermal Shutdown Protection

The overall design is also a Low Profile Design 8 mm thickness.

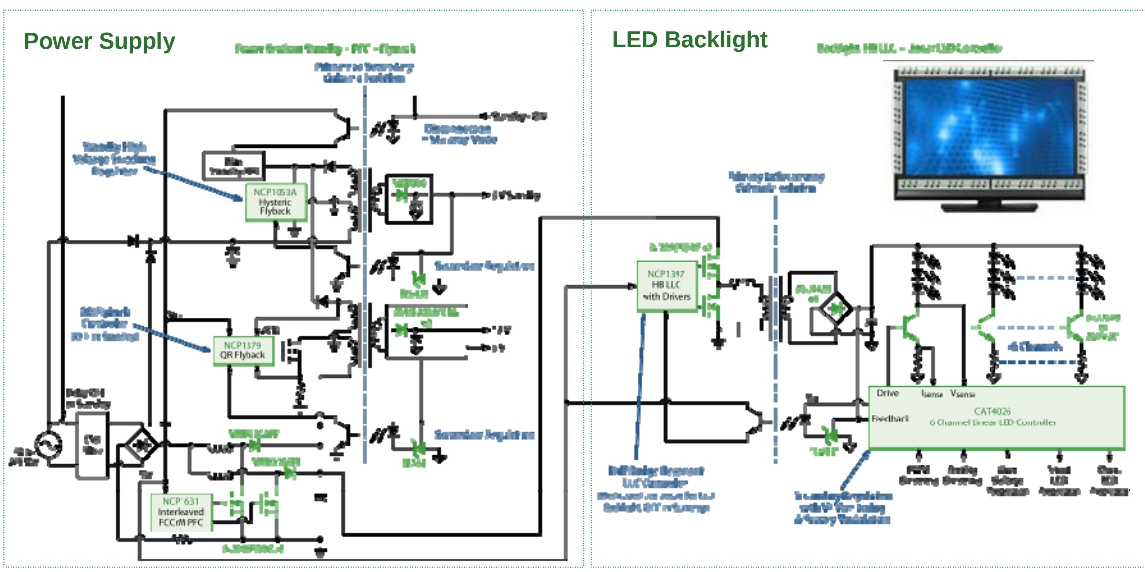



Figure 17. Overall Edge LED LCD TV bloc diagram

This LED Backlight solution will also be very soon available.

# The 13 mm version

## Introduction

To be low profile below the requested 8 mm height, most of the larger parts (winding parts, capacitors) and the PCB design should be specific:

- All winding parts (mains filters, PFC coils, Standby and Flyback transformers) should be based on specific / very low profile bobbin with dedicated ferrite form factor
- All large capacitors should be split to multiple lower value's one connected in parallel, with lower diameter case and inserted horizontally / flat on the board
- All heat sinks should be designed with low profile allowing components to be easily removed for service without the need to de-solder all the parts
- The PCB design should be done:
    - With large holes allowing the larger parts (above coils, transformers and capacitors) to be partly below the PCB to reduce the height on top of PCB plan
    - Those high numbers of holes have a strong impact on PCB mechanical performances such that glass epoxy / FR4 material is mandatory despite we have a single layer design
    - The lower height of the used parts asks for larger PCB surface

All above design constraints have a direct impact on solution cost which makes a lower profile solution much more expensive. If moving from 25 to 13 mm height has a limited impact, moving further down to 8 mm asks for very specific parts, limited possible suppliers with possible procurement difficulties, and in any case strong overall solution cost impact.

To reduce this height impact on the overall solution cost, a pre-design has been done to provide a similar solution with 13 mm height allowing the use of more standard parts

- With same performances (ECO Standby…) and power capabilities
- With the same overall concept, controller / ICs, Power MOS and diodes
- With more standard larger diameters capacitors with radial auto insertion when possible (secondary Flyback filtering)
- With more standard higher profile heat sink allowing surface reduction
- With single sided PCB design, without holes for parts insertion allowing reduction of the total surface and classical CEM1 lower cost PCB material

## Mains filters

The 2 common mode filters use a higher, more standard core compared to the very low profile one used for the 8 mm version (should be very low to avoid holes in the PCB which makes the fixation very difficult).
If we keep the same inductance L > 8.5 mH, for the 13 mm, the resistance of each winding goes down to 85 mR (to be compare with 105 mR for the 8 mm) allowing higher current / power capability.
The single differential mode filter (when used) also has the same inductance L > 50 µH, for the 13 mm, the resistance of the winding goes down to 75 mR (to be compare with 95 mR for the 8 mm) allowing higher current / power capability.
The X2 capacitors are the same but the larger 1 µF can be inserted without creating holes in the PCB for the 13 mm version.
Both types of common mode and differential mode filters for the 8 and 13 mm versions are from the same supplier Pulse, but with different reference and cost (~ + 25% for the 8 mm).

The same applies to the relay, inserted horizontally / flat on the board, for both versions but without holes in the PCB for the 13 mm version.

## PFC

With the 13 mm version, we have been able to use the standard EFD30 bobbin and ferrite without any holes in the PCB for both PFC coils. The inductance L is 200 µH (220 µH for the 8 mm) with the same 6 A current capability.

- Wurth Electronik provides the 13 mm version.
- TDK provides the SLIM 8 mm version with a special low profile PQM3811 (~ + 60% added cost compare to the EFD30).

If the 450 V Output capacitors should be inserted horizontally / flat on the board for both versions, we are able to use 12.5 mm diameter / 40 mm length without holes in the PCB for the 13 mm where a 10 mm diameter / 45 mm length with holes is mandatory for the 8 mm.
We have used the same type and suppliers with different reference for both versions with expected added cost for the smaller 10 mm diameter capacitors.

## Standby SMPS

If in the 13 mm version the capacitors can be inserted vertically / automatically radial, then the main difference is the transformer.
For the 8 mm version, we have been forced to use an oversized transformer to get the limited height with respect of the requested mains isolation (with enough distance from ferrite to pin despite we use TEX wire for secondary winding).

For the 13 mm version, we use a smaller transformer based on E12 ferrite which provides the right isolation thanks to special bobbin design and TEX wire. The primary inductance is the same 2.5 mH. The same current capability and the same controller NCP1053A allow the solution to provide the same 7.5 W in ON mode thanks to the take-over which supplies the Standby SMPS with 400 V from PFC.
Transformers are from different suppliers:

- The E12 (13 mm) is from Wurth Electronik.
- The EEM2125 (8 mm) is from TDK (~ + 200% added cost compare to the E12 which is due to the lower profile and the larger size).

## Flyback

For the 13 mm, all output capacitors have been limited to 470 µF 16 V allowing vertical / radial insertion. Some of those capacitors are in parallel to each other to acquire the right value and rms current capability.

Similar to the Standby, the main difference is again the transformer:

- With a primary inductance L = 650 µH for up to 2.8 A for both type.
- For the 13 mm, we are able to use the same EFD30 bobbin and core than for the PFC from the same supplier Wurth Electronik.
- For the 8 mm, we use a new low profile bobbin and EEM4549 core from the same supplier TDK (~ + 75% added cost compare to the EFD30 which is due to the lower profile and the larger size).

The vertical / radial inserted output filter coils could also be different but as the price is similar, it is favorable to use only the 8 mm type from Wurth Electronik with L = 10 µH for 4 A current capability.

## Heat sink

To be able to improve the cooling as much as possible with the smallest possible surface on the PCB, 2 type of profiles have been developed to support both height versions.
To be able to keep both PCB designs as similar as possible, we have changed “only” the width to compensate for the height reduction allowing us to keep the same thermal performances and the same position of the parts on the length of the heat sinks:

- The wide is 60 mm for the 7 mm height.
- The wide is 50 mm for the 12.5 mm height.
- The lengths are the same for both versions and link to function / position and power dissipation.

## PCB

With the 20 holes we have in the 8 mm PCB, used to reduce the total height < 8 mm, the PCB material should be a glass Epoxy FR4 to provide the right mechanical performances. Due to the lower parts profile, the surface of the PCB is larger, up to 310mm x 290 mm = 89 900 $mm^2$

Without any holes in the PCB, the 13 mm design allows to use CEM1 material (which provides better mechanical performances than standard FR1 or FR2). The size of the board is 230 mm x 290 mm = 66 700 $mm^2$

Due to the material and process (drilled), the $m^2$ of FR4 is ~ 3 x the CEM1's one.
Considering also the larger surface, the 8 mm PCB price is ~ 4 time the 13 mm's one.

## Conclusion

This power solution can be designed using the same concept for both heights of 8 mm and 13 mm providing the same performances. If the 8 mm provides a much more attractive SLIM solution, the need of special parts and specific PCB design will have a direct impact on overall solution cost. The 13 mm version is an alternative allowing cost improvement when the 8 mm height is not mandatory. Further on, total solution cost improvement (with the same concept) could be considered if the height moves up from the 13 mm to 25 mm as this will allow the use of even more standard parts (mainly for heat sinks, capacitors and transformers).

The 13 mm design has not been completed to provide boards to our customers but information and support are available on request (All key parts are defined and approved allowing easy spin-off from the 8 mm version).

Data sheets, applications information and samples for the ON Semiconductor components are available at www.onsemi.com .
Links to the datasheets of the main components used in this design are included in the below references.

Author of this document is:
Jean-Paul Louvel   CCPG - LCD TV System Applications Manager

# References


ECO Standby SMPS

NCP1053A specification
http://www.onsemi.com/pub_link/Collateral/NCP1050-D.PDF

Interleaved Frequency Clamped CrM PFC

NCP1631 specification
http://www.onsemi.com/pub_link/Collateral/NCP1631-D.PDF

NCP1631 Design Worksheet
http://www.onsemi.com/pub_link/Collateral/NCP1631%20DWS.XLS

iPFC - Interleaved Power Factor Controller Tutorial
http://www.onsemi.com/pub_link/Collateral/TND380-D.PDF

Key Steps to Design an Interleaved PFC by the NCP1631
http://www.onsemi.com/pub_link/Collateral/AND8407-D.PDF

Improve the Low-Power Efficiency of NCP1631-D Interleaved PFC
http://www.onsemi.com/pub_link/Collateral/AND8456-D.PDF

QR Flyback

NCP1379 specification
http://www.onsemi.com/pub_link/Collateral/NCP1379-D.PDF

NCP1379, NCP1380 Design Worksheet in MathCad
NCP1380 DWS.MCD

Designing a Quasi-Resonant Adapter Driven by the NCP1380
http://www.onsemi.com/pub_link/Collateral/AND8431-D.PDF

AD2 - Adapter Less than 75 W
http://www.onsemi.com/pub_link/Collateral/TND355-D.PDF

LCD - AC-DC Power Architecture in LCD TV
http://www.onsemi.com/pub_link/Collateral/TND353-D.PDF

PWM Flyback

NCP1252 specification
http://www.onsemi.com/pub_link/Collateral/NCP1252-D.PDF

## Our partners to design this application

I would like here to thanks all of our suppliers working with us as partners, providing very good support with samples to support our customers despite the very challenging request and schedule. They all commit to provide the same support to our customers for all needed information and samples related to parts been used in our Power design.

Heat sink (New design for both 8 mm and 13 mm)

**Columbia Staver** Ltd
Tel: + 44 1268733346
Designer: John Norwood [john@columbia-staver.co.uk]
Managing Director: Anthony Smith [a.smith@columbia-staver.co.uk]

Mains filters (For both 8 mm and 13 mm)

**Pulse** Europe
Gerard Healy
Email: ghealy@pulseeng.com
website: http://www.pulseeng.com/

PFC coils, Standby and Flyback transformers (For 8 mm)

**TDK** Electronics Europe GmbH
Martin Appel
Tel: + 49 211 9077 104
Email: Appel@eu.tdk.com
http://www.tdk-components.de

PFC coils, Standby and Flyback transformers (For 13 mm)

**Würth** Elektronik eiSos GmbH & Co. KG
*Contacts:* eiSos@we-online.com

Flyback output filter coils (For both 8 mm and 13 mm)

**Würth** Elektronik eiSos GmbH & Co. KG
*Contacts:* eiSos@we-online.com

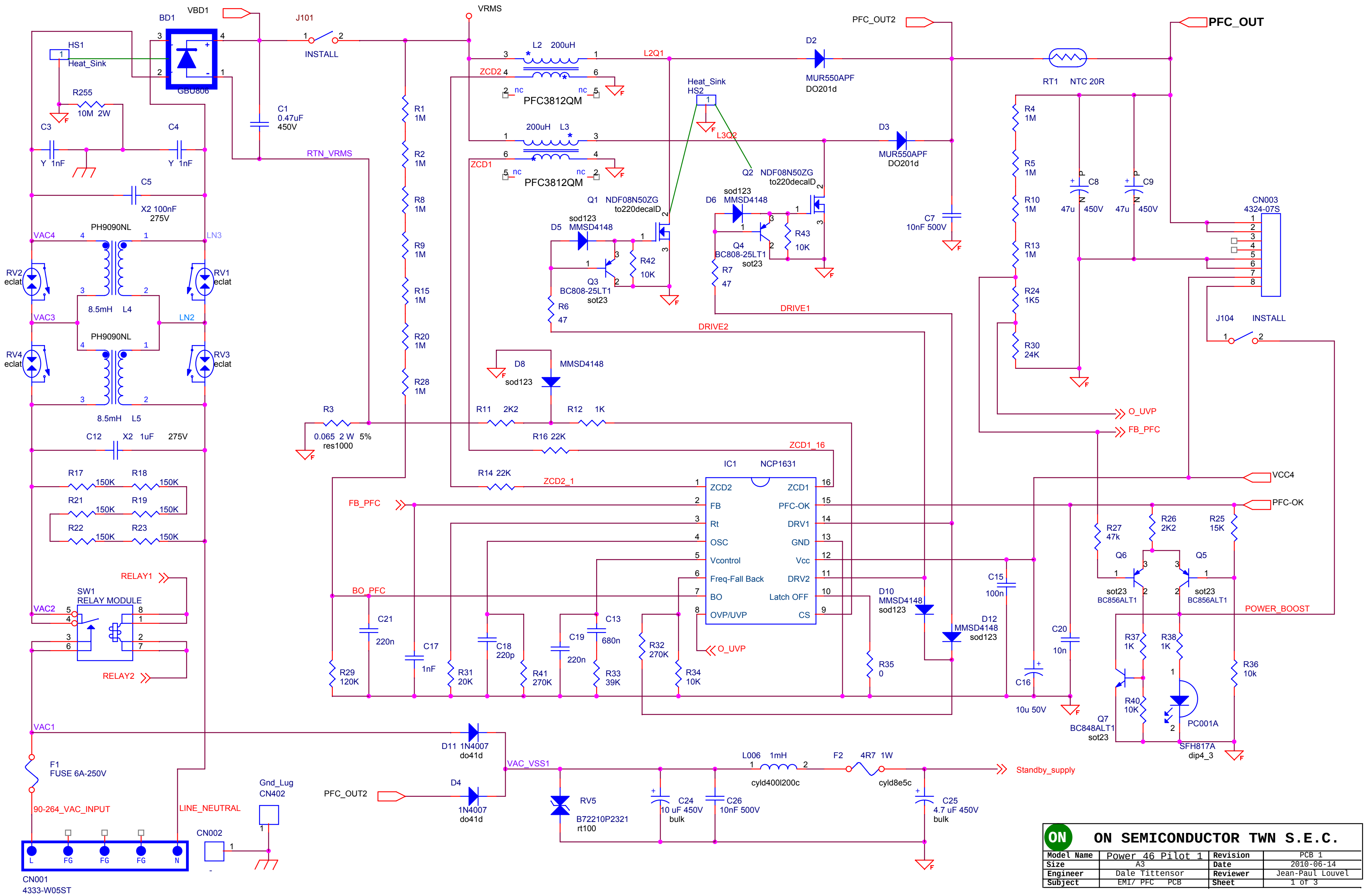
Electrolytic capacitors (For both 8 mm and 13 mm)

**Rubycon** Corporation (Japan) Branch Munich
Takayuki KAWAKAMI
Tel:  + 49 89 930 86 250
e-mail:tkawakami@rubycon.co.jp

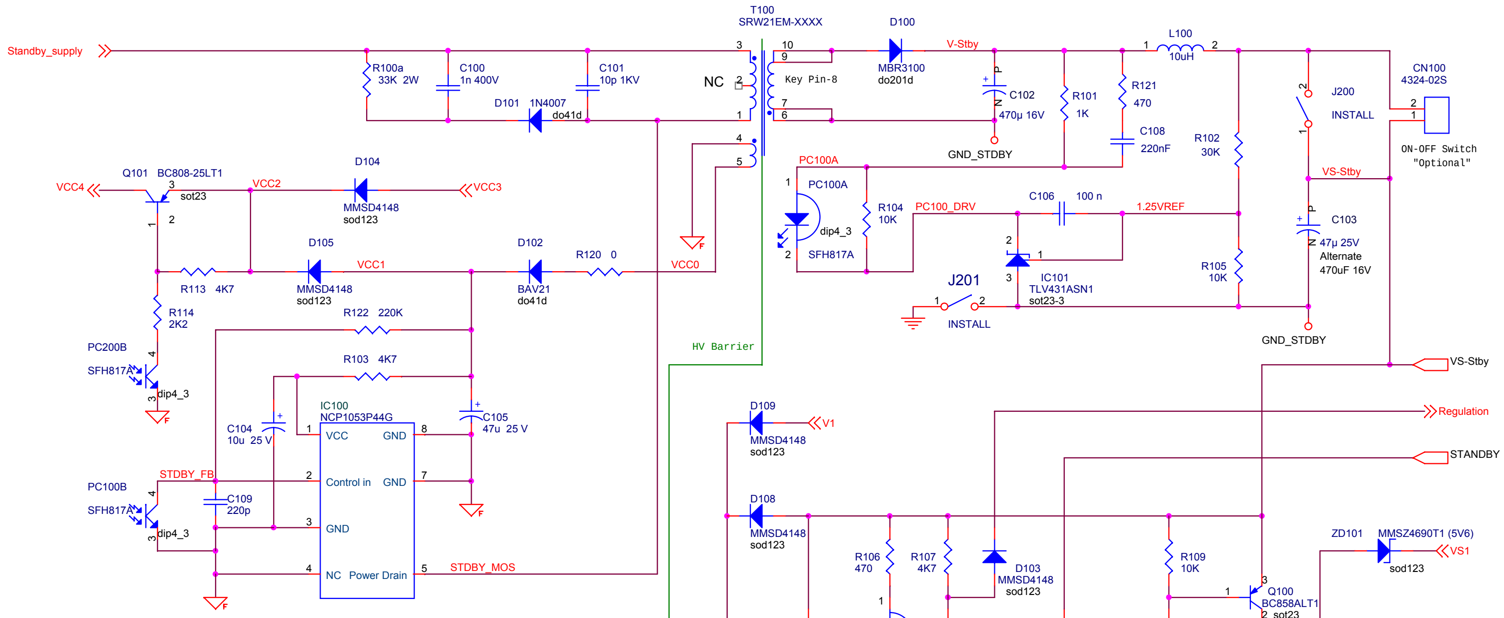
Europe **Chemi-Con**
Christian MICHEL
Tel : + 33 1 64 16 02 19
email : michel@EuropeChemiCon.de
web : www.EuropeChemiCon.de

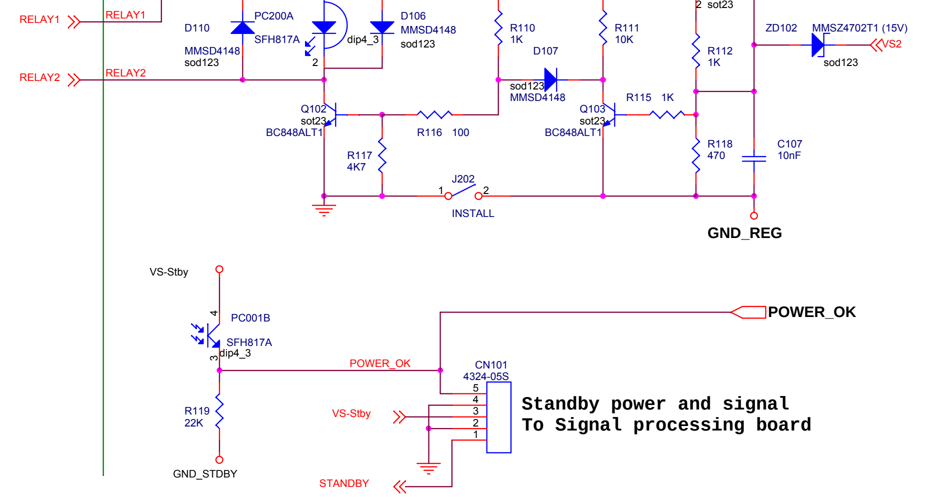
Inrush current limiter and Varistor (For both 8 mm and 13 mm)
**EPCOS SAS**
Jacques Levéziel
Tel. +33 1 49 46 67 85
email : jacques.leveziel@epcos.com
web : www.epcos.fr

# 8 mm SLIM Mains filters and PFC schematic



# 8 mm SLIM ECO Standby Power Supply



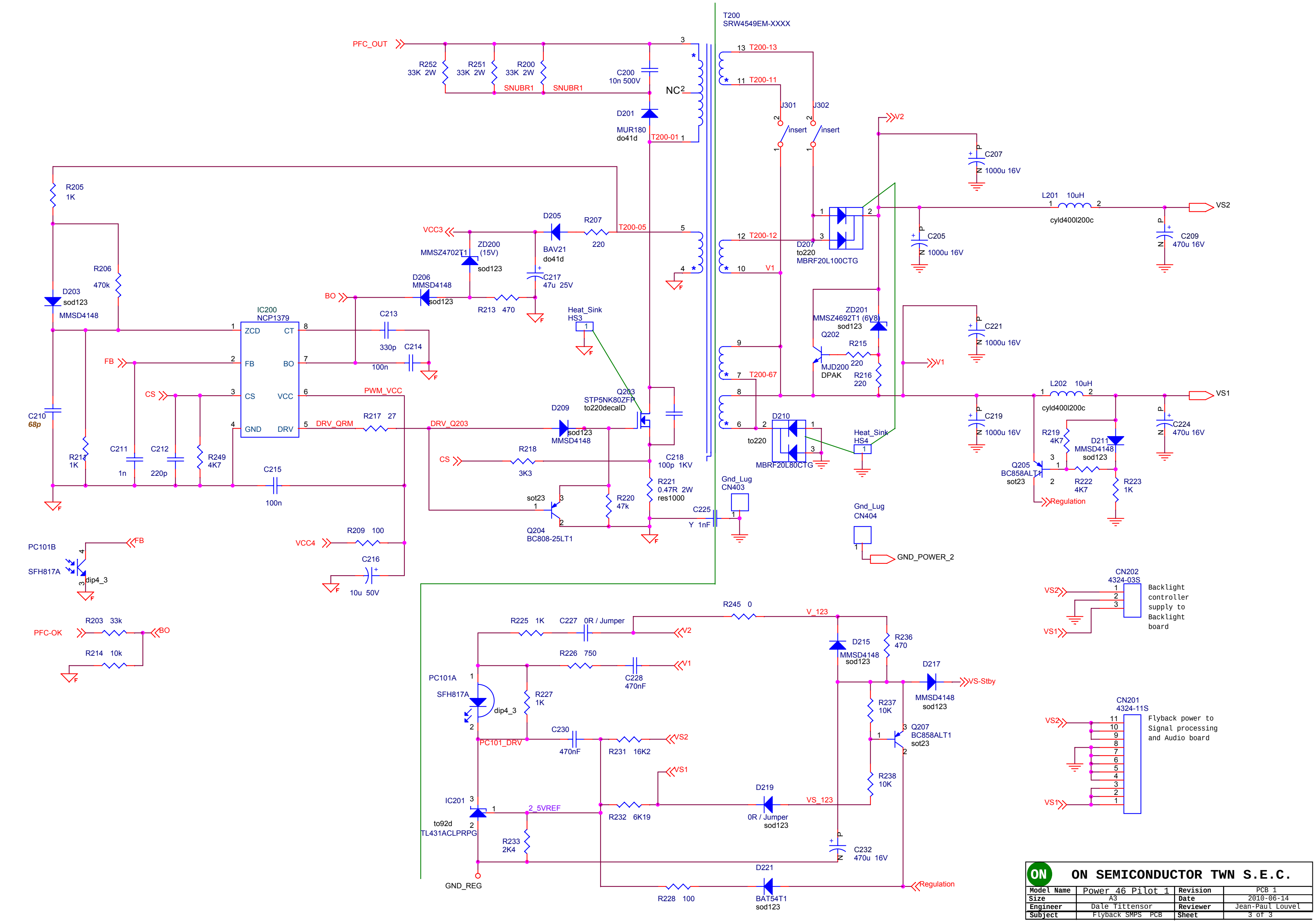




```
JT-xx jumpers are 0.75mm wire on the TOP layer.
JB-xx jumpers are 1206 SMT zero ohm on the BOTTOM layer.
---------------------------------------------------------
Design (layout) Jumpers
Pattern Quantity Component
1206          40 JB1,  JB2, JB3, JB4, JB5, JB6, JB7, JB8,
                 JB9,  JB10, JB11, JB12, JB13, JB14, JB15,
                 JB16, JB17, JB18, JB19, JB20, JB21, JB22,
                 JB23, JB24, JB25, JB26, JB27, JB28, JB29,
                 JB30, JB31, JB32, JB33, JB34, JB35, JB36,
                 JB37, JB38, JB39, JB40, JB41, JB42, JB43

JUMP 10MM     27 JT4, JT5, JT9, JT10, JT17, JT18, JT23,
                 JT24, JT25, JT26, JT28, JT29, JT31, JT32,
                 JT38, JT39, JT41, JT42, JT43, JT44, JT45,
                 JT49, JT50, JT51, JT51, JT56, JT59,

JUMP-12_5MM    9 JT3,  JT7, JT12, JT13, JT14, JT16, JT34,
                 JT52, JT54,

JUMP-22MM     26 JT1, JT2, JT6, JT8, JT11, JT15, JT19,
                 JT20, JT21, JT22, JT27, JT29, JT30,
                 JT33, JT35, JT36, JT37, JT40, JT46, JT47,
                 JT48, JT53, JT55, JT57, JT58, JT60,

---------------------------------------------------------
Schematic Jumpers are referenced from J100 upward.
Pattern Quantity Component
1206           1 J105

JUMPER-10MM   12 J101, J102, J102b, J102c, J103, J104,
                 J200, J202, J300, J301, J302, J303

JUMP-22MM      2 J201, J304
```

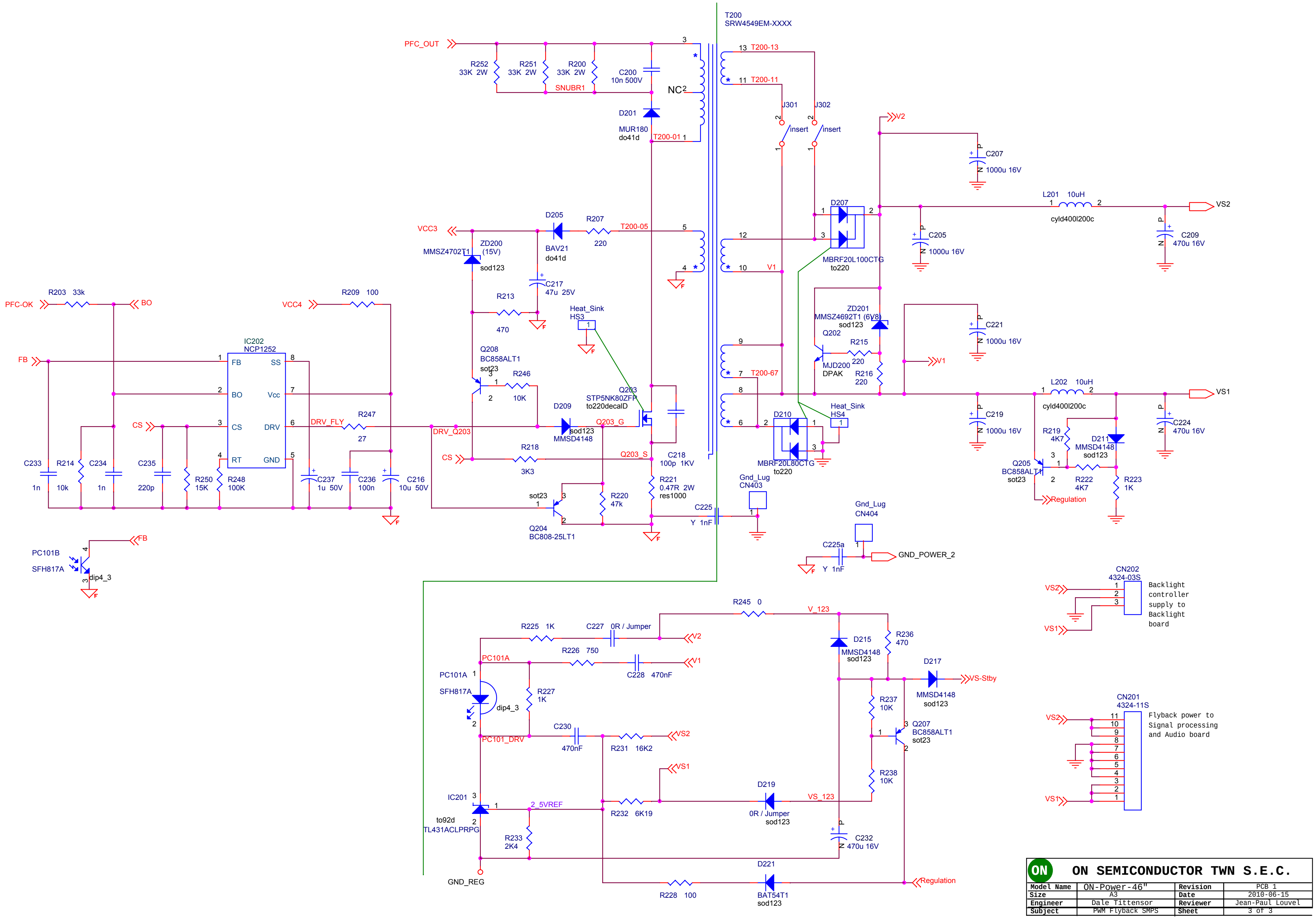
**ON SEMICONDUCTOR TWN S.E.C.**

| | | | |
|---|---|---|---|
| Model Name | Power 46 Pilot 1 | Revision | PCB 1 |
| Size | A3 | Date | 2010-06-14 |
| Engineer | Dale Tittensor | Reviewer | Jean-Paul Louvel |
| Subject | Standby SMPS PCB | Sheet | 2 of 3 |

# 8 mm SLIM QR Flyback Power Supply



# 8 mm SLIM PWM Flyback Power Supply



# 8 mm SLIM BOM with QR Flyback

| Position (note) | Component Type | Value | Rating | Pkg / Dimensions | Reference | Supplier |
|---|---|---|---|---|---|---|
| BD01 | Bridge Rectifier | 8A-600V | 8A-600V | | GBU806 | Taiwan Semiconductor |
| Screw1 | Screw | | | 3mm x0.5p x8mm thread length | W950 | Columbia-Staver |
| HS1 | Heat Sink | | | Length 120mm Height 7mm | TP209ST,120,7.0,NA--,02BB | Columbia-Staver |
| C001 | CFS | 470 nF | 450V | Radial 15mm | MES474K450VDC | Joey Electronics |
| C003 | CCS-Y1 | 1 nF | 400V / 4KV | Radial 10mm | 5SE102MT402A97E | SUCCESS |
| C004 | CCS-Y1 | 1 nF | 400V / 4KV | Radial 10mm | 5SE102MT402A97E | SUCCESS |
| C005 | CPMX-X2 | 100 nF | 275V | Radial 15mm | HQX104K275I04SANYAY | Shanghai Ultra Tech (UTX) |
| C007 | Ceramic Cap | 10 nF | 500V | Radial 5mm | 3x10 | SUCCESS |
| C008 | Electrolytic 105°C | 47 uF | 450V | Radial 5mm D10x45mm 0.44A | 450QXW47M10X45 | Rubycon |
| C008a | Electrolytic 105°C | 39 uF | 450V | Radial 5mm D10x50mm 0.375A | EKXJ451BC390MJ50S | Nippon Chemicon |
| C009 | Electrolytic 105°C | 47 uF | 450V | Radial 5mm D10x45mm 0.44A | 450QXW47M10X45 | Rubycon |
| C009a | Electrolytic 105°C | 39 uF | 450V | Radial 5mm D10x50mm 0.375A | EKXJ451BC390MJ50S | Nippon Chemicon |
| C012 | CPMX-X2 | 1 uF | 275V | Radial 22.5mm | HQX5x10K275N04SANYAY | Shanghai Ultra Tech (UTX) |
| C013 | Ceramic Chip Cap | 680 nF | 10V | 0805 | 4x68 | Synton-Tech Corporation. |
| C015 | Ceramic Chip Cap | 100 nF | 25V | 0805 | 4x10 | Synton-Tech Corporation. |
| C016 | Electrolytic 105°C | 10 uF | 50V | Radial 5mmx11mm | 50YXA10M5X11 | Rubycon |
| C016a | Electrolytic 105°C | 10 uF | 50V | Radial 5mmx11mm | EKMG500Exx100ME11D | Nippon Chemi Con |
| C017 | Ceramic Chip Cap | 1 nF | 10V | 0805 | 2x10 | Synton-Tech Corporation. |
| C018 | Ceramic Chip Cap | 220 pF | 10V | 0805 | 1x22 | Synton-Tech Corporation. |
| C019 | Ceramic Chip Cap | 220 nF | 10V | 0805 | 4x22 | Synton-Tech Corporation. |
| C020 | Ceramic Chip Cap | 10 nF | 10V | 0805 | 3x10 | Synton-Tech Corporation. |
| C021 | Ceramic Chip Cap | 220 nF | 10V | 0805 | 4x22 | Synton-Tech Corporation. |
| C024 | Electrolytic 105°C | 10 uF | 450V | Radial 5mm D10mm H20mm | 450PY00010M10X20 | Rubycon |
| C024a | Electrolytic 105°C | 10 uF | 450V | Radial 5mm D10mm H20mm | EKMQ451ELL100MJC5S | Nippon Chemi Con |
| C025 | Electrolytic 105°C | 4.7 uF | 450V | Radial 5mm D10mm H12.5mm | 400YXA3R3M10X12.5 | Rubycon |
| C026 | Ceramic Cap | 10 nF | 500V | Radial 5mm | 3x10 | SUCCESS |
| C100 | Ceramic Cap | 1 nF | 400V | Radial 5mm | 2x10 | |
| C101 | Ceramic Cap | 10 pF | 1 kV | Radial 5mm | 0x10 | SUCCESS |
| C102 | Electrolytic 105°C Low Z | 470 uF | 16V | Radial 5mm D10mmx12.5mm 1A | 16ZL470M10X12.5 | Rubycon |
| C102a | Electrolytic 105°C Low Z | 470 uF | 16V | Radial 5mm D10mmx12.5mm 1A | EKZE160Exx471MJC5S | Nippon Chemi Con |
| C103 | Electrolytic 105°C | 47 uF | 25V | Radial 5mm D8mm | 25YXA47M5X11 | Rubycon |
| C103a | Electrolytic 105°C | 47 uF | 25V | Radial 5mm D8mm | EKMG1x10Exx470ME11D | Nippon Chemi Con |
| C104 | Electrolytic 105°C | 10 uF | 50V | Radial 5mmx11mm | 50YXA10M5X11 | Rubycon |
| C104a | Electrolytic 105°C | 10 uF | 50V | Radial 5mmx11mm | EKMG500Exx100ME11D | Nippon Chemi Con |
| C105 | Electrolytic 105°C | 47 uF | 25V | Radial 5mm D8mm | 25YXA47M5X11 | Rubycon |
| C105a | Electrolytic 105°C | 47 uF | 25V | Radial 5mm D8mm | EKMG1x10Exx470ME11D | Nippon Chemi Con |
| C106 | Ceramic Chip Cap | 100 nF | 25V | 0805 | 4x10 | Synton-Tech Corporation. |
| C107 | Ceramic Chip Cap | 10 nF | 10V | 0805 | 3x10 | Synton-Tech Corporation. |
| C108 | Ceramic Chip Cap | 220 nF | 10V | 0805 | 4x22 | Synton-Tech Corporation. |

| Position (note) | Component Type | Value | Rating | Pkg / Dimensions | Reference | Supplier |
|---|---|---|---|---|---|---|
| C109 | Ceramic Chip Cap | 220 pF | 10V | 0805 | 1x22 | Synton-Tech Corporation. |
| C200 | Ceramic Cap | 10 nF | 500V | Radial 5mm | 3x10 | |
| C205 | Electrolytic 105°C Low Z | 1000 uF | 16V | Radial 5mm D10mmx20mm 1.82A | 16ZL1000M10X20 | Rubycon |
| C205a | Electrolytic 105°C Low Z | 1000 uF | 16V | Radial 5mm D10mmx20mm 1.82A | EKZE160Exx102MJ20S | Nippon Chemi Con |
| C207 | Electrolytic 105°C Low Z | 1000 uF | 16V | Radial 5mm D10mmx20mm 1.82A | 16ZL1000M10X20 | Rubycon |
| C207a | Electrolytic 105°C Low Z | 1000 uF | 16V | Radial 5mm D10mmx20mm 1.82A | EKZE160Exx102MJ20S | Nippon Chemi Con |
| C209 | Electrolytic 105°C Low Z | 470 uF | 16V | Radial 5mm D10mmx12.5mm 1A | 16ZL470M10X12.5 | Rubycon |
| C209a | Electrolytic 105°C Low Z | 470 uF | 16V | Radial 5mm D10mmx12.5mm 1A | EKZE160Exx471MJC5S | Nippon Chemi Con |
| C210 | Ceramic Chip Cap | 68 pF | 10V | 0805 | 0x68 | Synton-Tech Corporation. |
| C211 | Ceramic Chip Cap | 1 nF | 10V | 0805 | 2x10 | Synton-Tech Corporation. |
| C212 | Ceramic Chip Cap | 220 pF | 10V | 0805 | 1x22 | Synton-Tech Corporation. |
| C213 | Ceramic Chip Cap | 330 pF | 10V | 0805 | 1x33 | Synton-Tech Corporation. |
| C214 | Ceramic Chip Cap | 100 nF | 25V | 0805 | 4x10 | Synton-Tech Corporation. |
| C215 | Ceramic Chip Cap | 100 nF | 25V | 0805 | 4x10 | Synton-Tech Corporation. |
| C216 | Electrolytic 105°C | 10 uF | 50V | Radial 5mmx11mm | 50YXA10M5X11 | Rubycon |
| C216a | Electrolytic 105°C | 10 uF | 50V | Radial 5mmx11mm | EKMG500Exx100ME11D | Nippon Chemi Con |
| C217 | Electrolytic 105°C | 47 uF | 25V | Radial 5mm D8mm | 25YXA47M5X11 | Rubycon |
| C217a | Electrolytic 105°C | 47 uF | 25V | Radial 5mm D8mm | EKMG1x10Exx470ME11D | Nippon Chemi Con |
| C218 | Ceramic Cap | 100 pF | 1 kV | Radial 5mm | 1x10 | SUCCESS |
| C219 | Electrolytic 105°C Low Z | 1000 uF | 16V | Radial 5mm D10mmx20mm 1.82A | 16ZL1000M10X20 | Rubycon |
| C219a | Electrolytic 105°C Low Z | 1000 uF | 16V | Radial 5mm D10mmx20mm 1.82A | EKZE160Exx102MJ20S | Nippon Chemi Con |
| C221 | Electrolytic 105°C Low Z | 1000 uF | 16V | Radial 5mm D10mmx20mm 1.82A | 16ZL1000M10X20 | Rubycon |
| C221a | Electrolytic 105°C Low Z | 1000 uF | 16V | Radial 5mm D10mmx20mm 1.82A | EKZE160Exx102MJ20S | Nippon Chemi Con |
| C224 | Electrolytic 105°C Low Z | 470 uF | 16V | Radial 5mm D10mmx12.5mm 1A | 16ZL470M10X12.5 | Rubycon |
| C224a | Electrolytic 105°C Low Z | 470 uF | 16V | Radial 5mm D10mmx12.5mm 1A | EKZE160Exx471MJC5S | Nippon Chemi Con |
| C225 | CCS-Y1 | 1 nF | 400V / 4KV | Radial 10mm | 5SE2x10MT402A97E | SUCCESS |
| C227 | Carbon Chip Resistor | 0R0 | | 0805 | 0x00 | Synton-Tech Corporation. |
| C228 | Ceramic Chip Cap | 470 nF | 10V | 0805 | 4x47 | Synton-Tech Corporation. |
| C230 | Ceramic Chip Cap | 470 nF | 10V | 0805 | 4x47 | Synton-Tech Corporation. |
| C232 | Electrolytic 105°C Low Z | 470 uF | 16V | Radial 5mm D10mmx12.5mm 1A | 16ZL470M10X12.5 | Rubycon |
| C232a | Electrolytic 105°C Low Z | 470 uF | 16V | Radial 5mm D10mmx12.5mm 1A | EKZE160Exx471MJC5S | Nippon Chemi Con |
| CN001 | Mains Connector | 4333-W05RT | 250V 5A | Right Angle 15mm with 2 ext. pins | 4333-W05RT | LEAMAX Enterprise |
| CN002 | GND Connector | To be defined | x | x | x | |
| CN003 | Signal conector | 4324- 8R | 8 pins | Right Angle 2.5mm | 4324- 8R | LEAMAX Enterprise |
| CN100 | Signal conector | 4324- 2R | 2 pins | Right Angle 2.5mm | 4324- 2R | LEAMAX Enterprise |
| CN101 | Signal conector | 4324- 5R | 5 pins | Right Angle 2.5mm | 4324- 5R | LEAMAX Enterprise |
| CN200 | | | | | | |
| CN201 | Signal conector | 4324-11R | 11 pins | Right Angle 2.5mm | 4324-11R | LEAMAX Enterprise |
| CN202 | Signal conector | 4324- 3R | 3 pins | Right Angle 2.5mm | 4324- 3R | LEAMAX Enterprise |
| CN401 | Gnd Lug | tbd | | 3.175mm x 8mm | | |

| Position (note) | Component Type | Value | Rating | Pkg / Dimensions | Reference | Supplier |
|---|---|---|---|---|---|---|
| CN402 | Gnd Lug | tbd | | 3.175mm x 8mm | | |
| CN403 | Gnd Lug | tbd | | 3.175mm x 8mm | | |
| CN404 | Gnd Lug | tbd | | 3.175mm x 8mm | | |
| D002 | Diode Ultra Fast | MUR550APF | 520V 5A | DO-201 TOP Manual Axial 22.5mm | MUR550APF | ON Semiconductor |
| D003 | Diode Ultra Fast | MUR550APF | 520V 5A | DO-201 TOP Manual Axial 22.5mm | MUR550APF | ON Semiconductor |
| D004 | Diode | 1N4007 | 1000V 1A | DO-41 Axial 12.5mm | 1N4007 | PANJIT |
| D005 | Diode | MMSD4148 | 100V 0.2A | SOD-123 | MMSD4148 | ON Semiconductor |
| D006 | Diode | MMSD4148 | 100V 0.2A | SOD-123 | MMSD4148 | ON Semiconductor |
| D008 | Diode | MMSD4148 | 100V 0.2A | SOD-123 | MMSD4148 | ON Semiconductor |
| D010 | Diode | MMSD4148 | 100V 0.2A | SOD-123 | MMSD4148 | ON Semiconductor |
| D011 | Diode | 1N4007 | 1000V 1A | DO-41 Axial 12.5mm | 1N4007 | PANJIT |
| D012 | Diode | MMSD4148 | 100V 0.2A | SOD-123 | MMSD4148 | ON Semiconductor |
| D100 | Diode Fast | MBR3100 | 100V 3A | DO-201 TOP Manual Axial 22.5mm | MBR3100 | ON Semiconductor |
| D101 | Diode | 1N4007 | 1000V 1A | DO-41 Axial 12.5mm | 1N4007 | PANJIT |
| D102 | Diode Fast | BAV21 | 600V 1A | DO-41 Axial 12.5mm | BAV21 | PANJIT |
| D103 | Diode | MMSD4148 | 100V 0.2A | SOD-123 | MMSD4148 | ON Semiconductor |
| D104 | Diode | MMSD4148 | 100V 0.2A | SOD-123 | MMSD4148 | ON Semiconductor |
| D105 | Diode | MMSD4148 | 100V 0.2A | SOD-123 | MMSD4148 | ON Semiconductor |
| D106 | Diode | MMSD4148 | 100V 0.2A | SOD-123 | MMSD4148 | ON Semiconductor |
| D107 | Diode | MMSD4148 | 100V 0.2A | SOD-123 | MMSD4148 | ON Semiconductor |
| D108 | Diode | MMSD4148 | 100V 0.2A | SOD-123 | MMSD4148 | ON Semiconductor |
| D109 | Diode | MMSD4148 | 100V 0.2A | SOD-123 | MMSD4148 | ON Semiconductor |
| D110 | Diode | MMSD4148 | 100V 0.2A | SOD-123 | MMSD4148 | ON Semiconductor |
| D201 | Diode Fast | MUR180 | 800V 1A | DO-41 Axial 12.5mm | MUR180 | ON Semiconductor |
| D203 | Diode | MMSD4148 | 100V 0.2A | SOD-123 | MMSD4148 | ON Semiconductor |
| D205 | Diode Fast | BAV21 | 600V 1A | DO-41 Axial 12.5mm | BAV21 | ON Semiconductor |
| D206 | Diode | MMSD4148 | 100V 0.2A | SOD-123 | MMSD4148 | ON Semiconductor |
| D207 | Diode Dual Schottky | MBRF20L100CTG | 100V 20A | TO-220AB | MBRF20L100CTG | ON Semiconductor |
| Screw4 | Screw | | | 3mm x0.5p x8mm thread length | | |
| HS4 | Heat Sink | | | Length 80mm Height 7mm | TP209ST,80.0,7.0,NA,--,02B | Columbia-Staver |
| D209 | Diode | MMSD4148 | 100V 0.2A | SOD-123 | MMSD4148 | ON Semiconductor |
| D210 | Diode Dual Schottky | MBRF20L80CTG | 80V 20A | TO-220AB | MBRF20L80CTG | ON Semiconductor |
| Screw5 | Screw | | | 3mm x0.5p x8mm thread length | | |
| D211 | Diode | MMSD4148 | 100V 0.2A | SOD-123 | MMSD4148 | ON Semiconductor |
| D215 | Diode | MMSD4148 | 100V 0.2A | SOD-123 | MMSD4148 | ON Semiconductor |
| D217 | Diode | MMSD4148 | 100V 0.2A | SOD-123 | MMSD4148 | ON Semiconductor |
| D219 | Carbon Chip Resistor | 0R0 | | 1206 | 0x00 | Synton-Tech Corporation. |
| D221 | Diode Schottky | BAT54T1 | 30V 0.2A | SOD-123 | BAT54T1 | ON Semiconductor |
| F001 | Fuse | 6A | 250V | Axial 5x20mm | UBM-A006 | CONQUER |
| F002 | HV Fuse resistance | 4.7R 1W | 450V | Radial 5mm D10 | FRN 100S J 4R7 FK | Synton-Tech Corporation. |

| Position (note) | Component Type | Value | Rating | Pkg / Dimensions | Reference | Supplier |
|---|---|---|---|---|---|---|
| IC001 | PFC Controller | NCP1631 | | SOIC-16 | NCP1631 | ON Semiconductor |
| IC100 | 44Khz GTO Switch-Reg. | NCP1053P44G | | PDIP-8 | NCP1053P44G | ON Semiconductor |
| IC101 | Voltage Ref. | TLV431A | 0.01 | SOT-223 | TLV431ASN1 | ON Semiconductor |
| IC200 | QR Controller | NCP1379 | | SOIC-8 | NCP1379 | ON Semiconductor |
| IC201 | Voltage Ref. | TL431ACLPRPG | 0.01 | TO-92 | TL431ACLPRPG | ON Semiconductor |
| J101 | 0.75mm wire | 0R0 | | Axial 10mm | 0x00 | Synton-Tech Corporation. |
| J104 | 0.75mm wire | 0R0 | | Axial 10mm | 0x00 | Synton-Tech Corporation. |
| J200 | 0.75mm wire | 0R0 | | Axial 10mm | 0x00 | Synton-Tech Corporation. |
| J201 | 0.75mm wire | 0R0 | | Axial 22mm | 0x00 | Synton-Tech Corporation. |
| J202 | 0.75mm wire | 0R0 | | Axial 10mm | 0x00 | Synton-Tech Corporation. |
| J301 | 0.75mm wire | 0R0 | | Axial 10mm | 0x00 | Synton-Tech Corporation. |
| J302 | 0.75mm wire | 0R0 | | Axial 10mm | 0x00 | Synton-Tech Corporation. |
| L002 | PFC Coil | 220uH | | TOP Manual | PFC3812QM-221k04B-01 | TDK |
| L003 | PFC Coil | 220uH | | TOP Manual | PFC3812QM-221k04B-01 | TDK |
| L004 | Common Mode Filter | 8.5mH | 3.3A | TOP Manual | PH9090NL | PULSE |
| L005 | Common Mode Filter | 8.5mH | 3.3A | TOP Manual | PH9090NL | PULSE |
| L100 | Inductance filter | 10uH | 5A | Radial 5mmD10mmH8mm | 744732100 | WURTH ELEKTRONIK |
| L201 | Inductance filter | 10uH | 5A | Radial 5mmD10mmH8mm | 744732100 | WURTH ELEKTRONIK |
| L202 | Inductance filter | 10uH | 5A | Radial 5mmD10mmH8mm | 744732100 | WURTH ELEKTRONIK |
| PC001 | Opto-coupler | SFH817A | | DIP-4 | SFH817A | SHARP |
| PC100 | Opto-coupler | SFH817A | | DIP-4 | SFH817A | SHARP |
| PC101 | Opto-coupler | SFH817A | | DIP-4 | SFH817A | SHARP |
| PC200 | Opto-coupler | SFH817A | | DIP-4 | SFH817A | SHARP |
| Q001 | Power MOS | NDF08N50ZG | 500V 8A | TO220FP | NDF08N50ZG | ON Semiconductor |
| Screw2 | Screw | | | 3mm x0.5p x8mm thread length | | |
| HS2 | Heat Sink | | | Length 120mm Height 7mm | TP209ST,120,7.0,NA,--02B | Columbia-Staver |
| Q002 | Power MOS | NDF08N50ZG | 500V 8A | TO220FP | NDF08N50ZG | ON Semiconductor |
| Screw6 | Screw | | | 3mm x0.5p x8mm thread length | | |
| Q003 | PNP transistor | BC808-25LT1 | | SOT-23 | BC808-25LT1 | ON Semiconductor |
| Q004 | PNP transistor | BC808-25LT1 | | SOT-23 | BC808-25LT1 | ON Semiconductor |
| Q005 | PNP transistor | BC856ALT1 | | SOT-23 | BC856ALT1 | ON Semiconductor |
| Q006 | PNP transistor | BC856ALT1 | | SOT-23 | BC856ALT1 | ON Semiconductor |
| Q007 | NPN | BC848ALT1 | | SOT-23 | BC848ALT1 | ON Semiconductor |
| Q100 | PNP transistor | BC858ALT1 | | SOT-23 | BC858ALT1 | ON Semiconductor |
| Q101 | PNP transistor | BC808-25LT1 | | SOT-23 | BC808-25LT1 | ON Semiconductor |
| Q102 | NPN | BC848ALT1 | | SOT-23 | BC848ALT1 | ON Semiconductor |
| Q103 | NPN | BC848ALT1 | | SOT-23 | BC848ALT1 | ON Semiconductor |

| Position (note) | Component Type | Value | Rating | Pkg / Dimensions | Reference | Supplier |
|---|---|---|---|---|---|---|
| Q202 | Power NPN transistor | MJD200 | 25V 5A | DPAK | MJD200 | ON Semiconductor |
| Q203 | Power MOS | STP8NK80ZFP | 800V 5A | TO220FP | STP8NK80ZFP | STMicroelectronics |
| Screw3 | Screw | | | 3mm x0.5p x8mm thread length | | |
| HS3 | Heat Sink | | | Length 40mm Height 7mm | TP207ST,40.0,7.0,NA,--,02B | Columbia-Staver |
| Q204 | PNP transistor | BC808-25LT1 | | SOT-23 | BC808-25LT1 | ON Semiconductor |
| Q205 | PNP transistor | BC858ALT1 | | SOT-23 | BC858ALT1 | ON Semiconductor |
| Q206 | NPN | BC848ALT1 | | SOT-23 | BC848ALT1 | ON Semiconductor |
| Q207 | PNP transistor | BC858ALT1 | | SOT-23 | BC858ALT1 | ON Semiconductor |
| R001 | Carbon Chip Resistor | 1M | | 0805 | 6x10 | Synton-Tech Corporation. |
| R002 | Carbon Chip Resistor | 1M | | 0805 | 6x10 | Synton-Tech Corporation. |
| R003A | Wirewound Resistor | 0.065 5% | 2W | TOP Manual Axial 22.5mm | 1R65 | Synton-Tech Corporation. |
| R004 | Carbon Chip Resistor | 1M | | 0805 | 6x10 | Synton-Tech Corporation. |
| R005 | Carbon Chip Resistor | 1M | | 0805 | 6x10 | Synton-Tech Corporation. |
| R006 | Carbon Chip Resistor | 47 | | 0805 | 0x47 | Synton-Tech Corporation. |
| R007 | Carbon Chip Resistor | 47 | | 0805 | 0x47 | Synton-Tech Corporation. |
| R008 | Carbon Chip Resistor | 1M | | 0805 | 6x10 | Synton-Tech Corporation. |
| R009 | Carbon Chip Resistor | 1M | | 0805 | 6x10 | Synton-Tech Corporation. |
| R010 | Carbon Chip Resistor | 1M | | 0805 | 6x10 | Synton-Tech Corporation. |
| R011 | Carbon Chip Resistor | 2.2K | | 0805 | 2x22 | Synton-Tech Corporation. |
| R012 | Carbon Chip Resistor | 1K | | 0805 | 2x10 | Synton-Tech Corporation. |
| R013 | Carbon Chip Resistor | 1M | | 0805 | 6x10 | Synton-Tech Corporation. |
| R014 | Carbon Chip Resistor | 22K | | 0805 | 3x22 | Synton-Tech Corporation. |
| R015 | Carbon Chip Resistor | 1M | | 0805 | 6x10 | Synton-Tech Corporation. |
| R016 | Carbon Chip Resistor | 22K | | 0805 | 3x22 | Synton-Tech Corporation. |
| R017 | Carbon Chip Resistor | 150K | | 0805 | 4x15 | Synton-Tech Corporation. |
| R018 | Carbon Chip Resistor | 150K | | 0805 | 4x15 | Synton-Tech Corporation. |
| R019 | Carbon Chip Resistor | 150K | | 0805 | 4x15 | Synton-Tech Corporation. |
| R020 | Carbon Chip Resistor | 1M | | 0805 | 6x10 | Synton-Tech Corporation. |
| R021 | Carbon Chip Resistor | 150K | | 0805 | 4x15 | Synton-Tech Corporation. |
| R022 | Carbon Chip Resistor | 150K | | 0805 | 4x15 | Synton-Tech Corporation. |
| R023 | Carbon Chip Resistor | 150K | | 0805 | 4x15 | Synton-Tech Corporation. |
| R024 | Carbon Chip Resistor | 1.5K | | 0805 | 2x15 | Synton-Tech Corporation. |
| R025 | Carbon Chip Resistor | 15K | | 0805 | 3x15 | Synton-Tech Corporation. |
| R026 | Carbon Chip Resistor | 2.2K | | 0805 | 2x22 | Synton-Tech Corporation. |
| R027 | Carbon Chip Resistor | 47K | | 0805 | 3x47 | Synton-Tech Corporation. |
| R028 | Carbon Chip Resistor | 1M | | 0805 | 6x10 | Synton-Tech Corporation. |
| R029 | Carbon Chip Resistor | 120K | | 0805 | 4x12 | Synton-Tech Corporation. |
| R030 | Carbon Chip Resistor | 24K | | 0805 | 3x24 | Synton-Tech Corporation. |
| R031 | Carbon Chip Resistor | 20K | | 0805 | 3x20 | Synton-Tech Corporation. |

| Position (note) | Component Type | Value | Rating | Pkg / Dimensions | Reference | Supplier |
|---|---|---|---|---|---|---|
| R032 | Carbon Chip Resistor | 270K | | 0805 | 4X27 | Synton-Tech Corporation. |
| R033 | Carbon Chip Resistor | 39K | | 0805 | 3x39 | Synton-Tech Corporation. |
| R034 | Carbon Chip Resistor | 10K | | 0805 | 3x10 | Synton-Tech Corporation. |
| R035 | Carbon Chip Resistor | 0R0 | | 0805 | 0x00 | Synton-Tech Corporation. |
| R036 | Carbon Chip Resistor | 10K | | 0805 | 3x10 | Synton-Tech Corporation. |
| R037 | Carbon Chip Resistor | 1K | | 0805 | 2x10 | Synton-Tech Corporation. |
| R038 | Carbon Chip Resistor | 1K | | 0805 | 2x10 | Synton-Tech Corporation. |
| R040 | Carbon Chip Resistor | 10K | | 0805 | 3x10 | Synton-Tech Corporation. |
| R041 | Carbon Chip Resistor | 270K | | 0805 | 4x27 | Synton-Tech Corporation. |
| R042 | Carbon Chip Resistor | 10K | | 0805 | 3x10 | Synton-Tech Corporation. |
| R043 | Carbon Chip Resistor | 10K | | 0805 | 3x10 | Synton-Tech Corporation. |
| R100a | Metal Film Resistor | 33K 5% | 2W | TOP Manual Axial 22.5mm | 3x33 | Synton-Tech Corporation. |
| R101 | Carbon Chip Resistor | 1K | | 0805 | 2x10 | Synton-Tech Corporation. |
| R102 | Carbon Chip Resistor | 30K | | 0805 | 3x30 | Synton-Tech Corporation. |
| R103 | Carbon Chip Resistor | 4.7K | | 0805 | 2x47 | Synton-Tech Corporation. |
| R104 | Carbon Chip Resistor | 10K | | 0805 | 3x10 | Synton-Tech Corporation. |
| R105 | Carbon Chip Resistor | 10K | | 0805 | 3x10 | Synton-Tech Corporation. |
| R106 | Carbon Chip Resistor | 470 | | 0805 | 1x47 | Synton-Tech Corporation. |
| R107 | Carbon Chip Resistor | 4.7K | | 0805 | 2x47 | Synton-Tech Corporation. |
| R109 | Carbon Chip Resistor | 10K | | 0805 | 3x10 | Synton-Tech Corporation. |
| R110 | Carbon Chip Resistor | 1K | | 0805 | 2x10 | Synton-Tech Corporation. |
| R111 | Carbon Chip Resistor | 10K | | 0805 | 3x10 | Synton-Tech Corporation. |
| R112 | Carbon Chip Resistor | 1K | | 0805 | 2x10 | Synton-Tech Corporation. |
| R113 | Carbon Chip Resistor | 4.7K | | 0805 | 2x47 | Synton-Tech Corporation. |
| R114 | Carbon Chip Resistor | 2.2K | | 0805 | 2x22 | Synton-Tech Corporation. |
| R115 | Carbon Chip Resistor | 1K | | 0805 | 2x10 | Synton-Tech Corporation. |
| R116 | Carbon Chip Resistor | 100 | | 0805 | 1x10 | Synton-Tech Corporation. |
| R117 | Carbon Chip Resistor | 4.7k | | 0805 | 2x47 | Synton-Tech Corporation. |
| R118 | Carbon Chip Resistor | 470 | | 0805 | 1x47 | Synton-Tech Corporation. |
| R119 | Carbon Chip Resistor | 22K | | 0805 | 3x22 | Synton-Tech Corporation. |
| R120 | Carbon Chip Resistor | 0R0 | | 0805 | 0x00 | Synton-Tech Corporation. |
| R121 | Carbon Chip Resistor | 470 | | 0805 | 1x47 | Synton-Tech Corporation. |
| R122 | Carbon Chip Resistor | 220K | | 0805 | 4X22 | Synton-Tech Corporation. |
| R200 | Metal Film Resistor | 33K 5% | 2W | TOP Manual Axial 22.5mm | 3x33 | Synton-Tech Corporation. |
| R203 | Carbon Chip Resistor | 33K | | 0805 | 3x33 | Synton-Tech Corporation. |
| R205 | Carbon Chip Resistor | 1K | | 0805 | 2x10 | Synton-Tech Corporation. |
| R206 | Carbon Chip Resistor | 470K | | 0805 | 4x47 | Synton-Tech Corporation. |

Notes:
Resistor tolerances are +/- 5% unless noted otherwise
Capacitor tolerances are +/- 10% unless noted otherwise
Electrolytic capacitor tolerances are +/- 20% unless noted otherwise

| Position (note) | Component Type | Value | Rating | Pkg / Dimensions | Reference | Supplier |
|---|---|---|---|---|---|---|
| R207 | Carbon Chip Resistor | 220 | | 1206 | 0x22 | Synton-Tech Corporation. |
| R209 | Carbon Chip Resistor | 100 | | 0805 | 1x10 | Synton-Tech Corporation. |
| R211 | Carbon Chip Resistor | 1K | | 0805 | 2x10 | Synton-Tech Corporation. |
| R213 | Carbon Chip Resistor | 470 | | 0805 | 1x47 | Synton-Tech Corporation. |
| R214 | Carbon Chip Resistor | 10K | | 0805 | 3x10 | Synton-Tech Corporation. |
| R215 | Carbon Chip Resistor | 220 | | 0805 | 1x22 | Synton-Tech Corporation. |
| R216 | Carbon Chip Resistor | 220 | | 0805 | 1x22 | Synton-Tech Corporation. |
| R217 | Carbon Chip Resistor | 27 | | 0805 | 0x27 | Synton-Tech Corporation. |
| R218 | Carbon Chip Resistor | 3.3K | | 0805 | 2x33 | Synton-Tech Corporation. |
| R219 | Carbon Chip Resistor | 4.7K | | 0805 | 2x47 | Synton-Tech Corporation. |
| R220 | Carbon Chip Resistor | 47K | | 0805 | 3x47 | Synton-Tech Corporation. |
| R221 | Wirewound Resistor | 0.47R 5% | 2W | TOP Manual Axial 22.5mm | 0R47 | Synton-Tech Corporation. |
| R222 | Carbon Chip Resistor | 4.7K | | 0805 | 2x47 | Synton-Tech Corporation. |
| R223 | Carbon Chip Resistor | 1K | | 0805 | 2x10 | Synton-Tech Corporation. |
| R225 | Carbon Chip Resistor | 1K | | 0805 | 2x10 | Synton-Tech Corporation. |
| R226 | Carbon Chip Resistor | 750 | | 0805 | 1X75 | Synton-Tech Corporation. |
| R227 | Carbon Chip Resistor | 1K | | 0805 | 2x10 | Synton-Tech Corporation. |
| R228 | Carbon Chip Resistor | 100 | | 0805 | 1x10 | Synton-Tech Corporation. |
| R231 | Carbon Chip Resistor | 16.2K 1% | | 0805 | 2x162 | Synton-Tech Corporation. |
| R232 | Carbon Chip Resistor | 6.19K 1% | | 0805 | 1x619 | Synton-Tech Corporation. |
| R233 | Carbon Chip Resistor | 2.40K 1% | | 0805 | 1x249 | Synton-Tech Corporation. |
| R236 | Carbon Chip Resistor | 1K | | 0805 | 2x10 | Synton-Tech Corporation. |
| R237 | Carbon Chip Resistor | 10K | | 0805 | 3x10 | Synton-Tech Corporation. |
| R238 | Carbon Chip Resistor | 10K | | 0805 | 3x10 | Synton-Tech Corporation. |
| R245 | Carbon Chip Resistor | 0R0 | | 0805 | 0x00 | Synton-Tech Corporation. |
| R249 | Carbon Chip Resistor | 4.7K | | 0805 | 2x47 | Synton-Tech Corporation. |
| R251 | Metal Film Resistor | 33K 5% | 2W | TOP Manual Axial 22.5mm | 3x33 | Synton-Tech Corporation. |
| R252 | Metal Film Resistor | 33K 5% | 2W | TOP Manual Axial 22.5mm | 3x33 | Synton-Tech Corporation. |
| R255 | Metal Film Resistor | 10M 5% | 2W | TOP Manual Axial 22.5mm | 6x10 | Synton-Tech Corporation. |
| RT1 | Thermistor | 20 ohm | 3W | TOP Manual Rad 5mm | B57153S0200M000 20R | EPCOS |
| RV5 | Varistor | | 420V | TOP Manual Rad 7.5mm | B72210P2321K101 | EPCOS |
| SW1 | Relay | 5V 50mA | 10A / 250V | TOP Manual | HF36F/005-HSLT | HONGFA |
| T100 | Standby Transformer | 2.5mH | EPC17 | TOP Manual | SRW2125EM-X03H015 | TDK |
| T200 | Switch Mode Transformer | 680uH | EEM | TOP Manual | SRW4549EM-X01H017 | TDK |
| ZD101 | Diode, Zener | MMSZ4690T1 | 5.6V | SOD-123 | MMSZ4690T1 | ON Semiconductor |
| ZD102 | Diode, Zener | MMSZ4702T1 | 15V | SOD-123 | MMSZ4702T1 | ON Semiconductor |
| ZD200 | Diode, Zener | MMSZ4702T1 | 15V | SOD-123 | MMSZ4702T1 | ON Semiconductor |
| ZD201 | Diode, Zener | MMSZ4692T1 | 6.8V | SOD-123 | MMSZ4692T1 | ON Semiconductor |

Notes:
- Resistor tolerances are +/- 5% unless noted otherwise
- Capacitor tolerances are +/- 10% unless noted otherwise
- Electrolytic capacitor tolerances are +/- 20% unless noted otherwise

| Position (note) | Component Type | Value | Rating | Pkg / Dimensions | Reference | Supplier |
|---|---|---|---|---|---|---|
| PCB1 | 8mm_Power46_PCB | | | | | |
| RELAY_MODULE_1 | 8mm_Relay_PCB | | | | | |
| JB1, JB2, JB3, JB4, JB5, JB6, JB7, JB8, JB9, JB10, JB11, JB12, JB13, JB14, JB15, JB16, JB17, JB18, JB19, JB20, JB21, JB22, JB23, JB24, JB25, JB26, JB27, JB28, JB29, JB30, JB31, JB32, JB33, JB34, JB35, JB36, JB37, JB38, JB39, JB40, JB41, JB42, JB43 | Carbon Chip Resistor | 0R0 | | 1206 | 0x00 | Synton-Tech Corporation. |

| Position (note) | Component Type | Value | Rating | Pkg / Dimensions | Reference | Supplier |
|---|---|---|---|---|---|---|
| JT4, JT5, JT9, JT10, JT17, JT18, JT23, JT24, JT25, JT26, JT28, JT29, JT31, JT32, JT38, JT39, JT41, JT42, JT43, JT44, JT45, JT49, JT50, JT51, JT51, JT56, JT59 | 0.75mm wire | 0R0 | | Axial 10mm | 0x00 | Synton-Tech Corporation. |
| JT3, JT7, JT12, JT13, JT14, JT16, JT34, JT52, JT54 | 0.75mm wire | 0R0 | | Axial 12.5mm | 0x00 | Synton-Tech Corporation. |
| JT1, JT2, JT6, JT8, JT11, JT15, JT19, JT20, JT21, JT22, JT27, JT29, JT30, JT33, JT35, JT36, JT37, JT40, JT46, JT47, JT48, JT53, JT55, JT57, JT58, JT60 | 0.75mm wire | 0R0 | | Axial 22mm | 0x00 | Synton-Tech Corporation. |

Notes:
Resistor tolerances are +/- 5% unless noted otherwise
Capacitor tolerances are +/- 10% unless noted otherwise
Electrolytic capacitor tolerances are +/- 20% unless noted otherwise

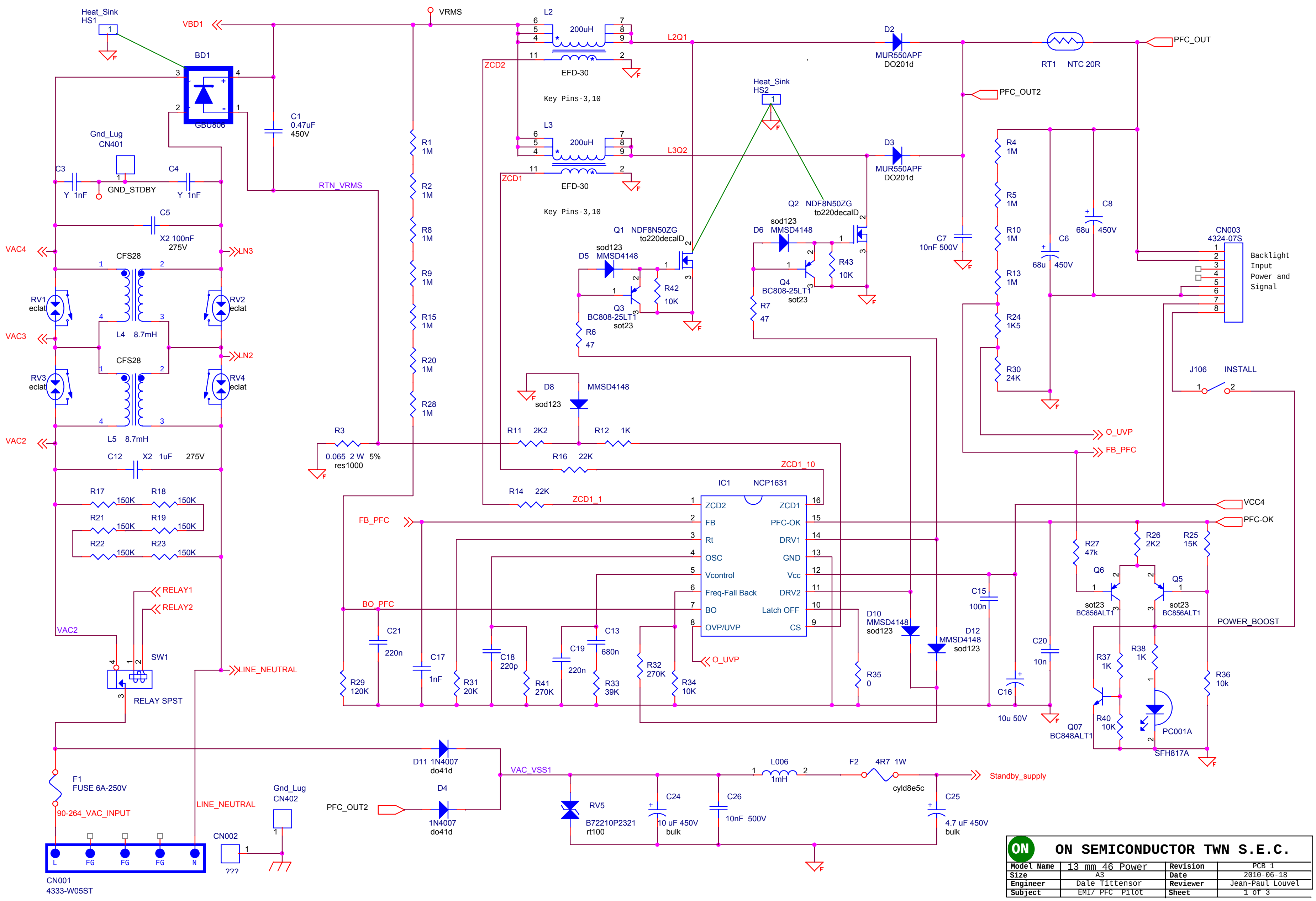
# Flyback BOM modifications from QR NCP1379 to PWM NCP1252

(Same for both 8 and 13 mm)

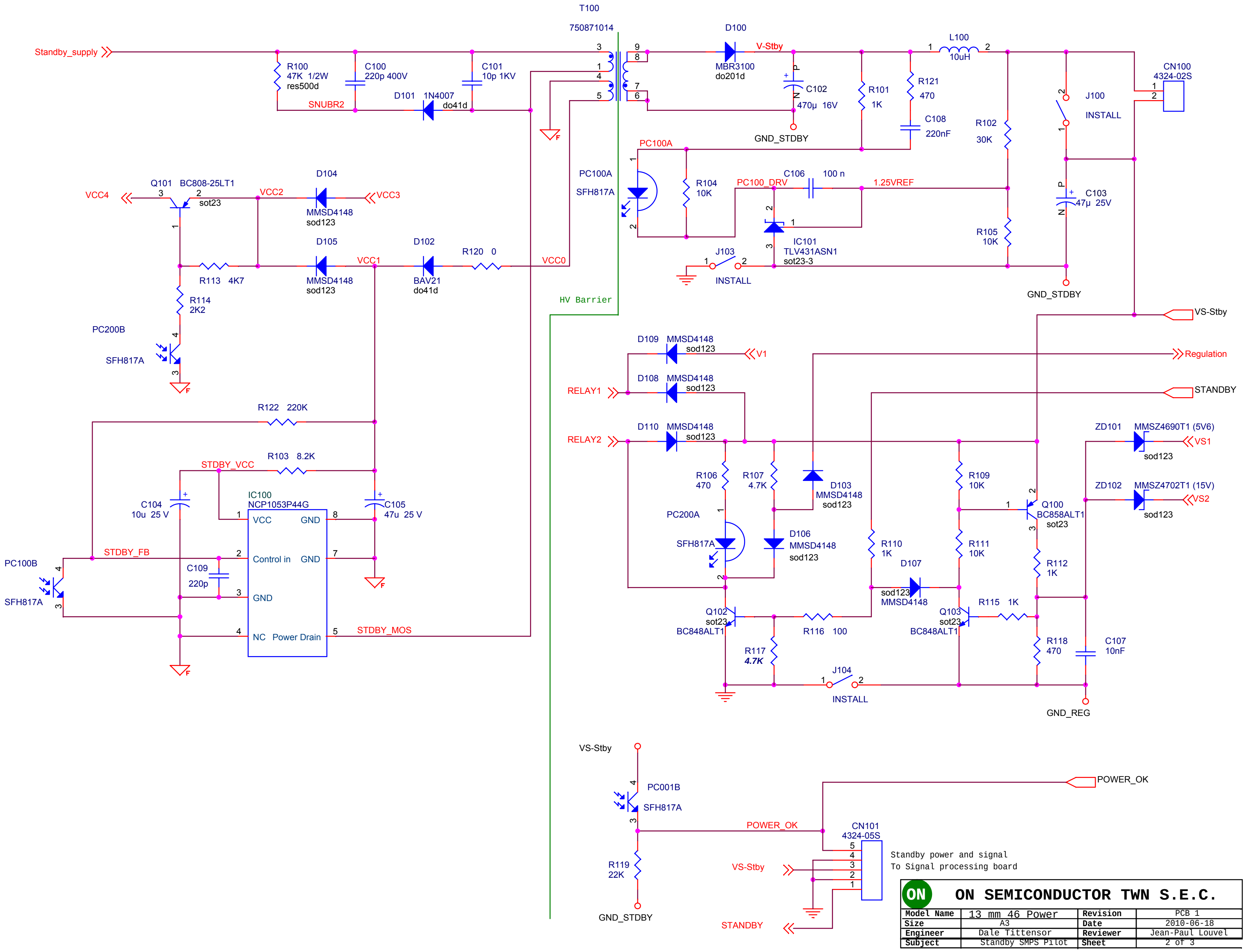
| Section | Position | Component Type | Value | Rating | Pkg / Dimensions | Reference | Supplier |
|---|---|---|---|---|---|---|---|
| QR Flyback | C210 | Ceramic Chip Cap | 68 pF | 10V | 0805 | 0x68 | Synton-Tech Corporation. |
| QR Flyback | C211 | Ceramic Chip Cap | 1 nF | 10V | 0805 | 2x10 | Synton-Tech Corporation. |
| QR Flyback | C212 | Ceramic Chip Cap | 220 pF | 10V | 0805 | 1x22 | Synton-Tech Corporation. |
| QR Flyback | C213 | Ceramic Chip Cap | 330 pF | 10V | 0805 | 1x33 | Synton-Tech Corporation. |
| QR Flyback | C214 | Ceramic Chip Cap | 100 nF | 25V | 0805 | 4x10 | Synton-Tech Corporation. |
| QR Flyback | C215 | Ceramic Chip Cap | 100 nF | 25V | 0805 | 4x10 | Synton-Tech Corporation. |
| QR Flyback | D203 | Diode | MMSD4148 | 100V 0.2A | SOD-123 | MMSD4148 | ON Semiconductor |
| QR Flyback | D206 | Diode | MMSD4148 | 100V 0.2A | SOD-123 | MMSD4148 | ON Semiconductor |
| QR Flyback | IC200 | QR Controller | NCP1379 | | SOIC-8 | NCP1379 | ON Semiconductor |
| QR Flyback | R205 | Carbon Chip Resistor | 1K | | 0805 | 2x10 | Synton-Tech Corporation. |
| QR Flyback | R206 | Carbon Chip Resistor | 470K | | 0805 | 4x47 | Synton-Tech Corporation. |
| QR Flyback | R211 | Carbon Chip Resistor | 1K | | 0805 | 2x10 | Synton-Tech Corporation. |
| QR Flyback | R217 | Carbon Chip Resistor | 27 | | 0805 | 0x27 | Synton-Tech Corporation. |
| QR Flyback | R249 | Carbon Chip Resistor | 4.7K | | 0805 | 2x47 | Synton-Tech Corporation. |
| | | | | | | | |
| PWM Flyback | C233 | Ceramic Chip Cap | 1 nF | 10V | 0805 | 2x10 | Synton-Tech Corporation. |
| PWM Flyback | C234 | Ceramic Chip Cap | 1 nF | 10V | 0805 | 2x10 | Synton-Tech Corporation. |
| PWM Flyback | C235 | Ceramic Chip Cap | 220 pF | 10V | 0805 | 1x22 | Synton-Tech Corporation. |
| PWM Flyback | C236 | Ceramic Chip Cap | 100 nF | 25V | 0805 | 4x10 | Synton-Tech Corporation. |
| PWM Flyback | C237 | Electrolytic 105°C | 1 uF | 50V | Radial 5mmx11mm | 6x10 | |
| PWM Flyback | IC202 | Fix Frequency Controller | NCP1252 | | SOIC-8 | NCP1252ADR2G | ON Semiconductor |
| PWM Flyback | Q208 | PNP transistor | BC858ALT1 | | SOT-23 | BC858ALT1 | ON Semiconductor |
| PWM Flyback | R246 | Carbon Chip Resistor | 10K | | 0805 | 3x10 | Synton-Tech Corporation. |
| PWM Flyback | R247 | Carbon Chip Resistor | 27 | | 0805 | 0x27 | Synton-Tech Corporation. |
| PWM Flyback | R248 | Carbon Chip Resistor | 10K | | 0805 | 3x10 | Synton-Tech Corporation. |
| PWM Flyback | R250 | Carbon Chip Resistor | 10K | | 0805 | 3x10 | Synton-Tech Corporation. |

Notes:
Resistor tolerances are +/- 5% unless noted otherwise
Capacitor tolerances are +/- 10% unless noted otherwise
Electrolytic capacitor tolerances are +/- 20% unless noted otherwise

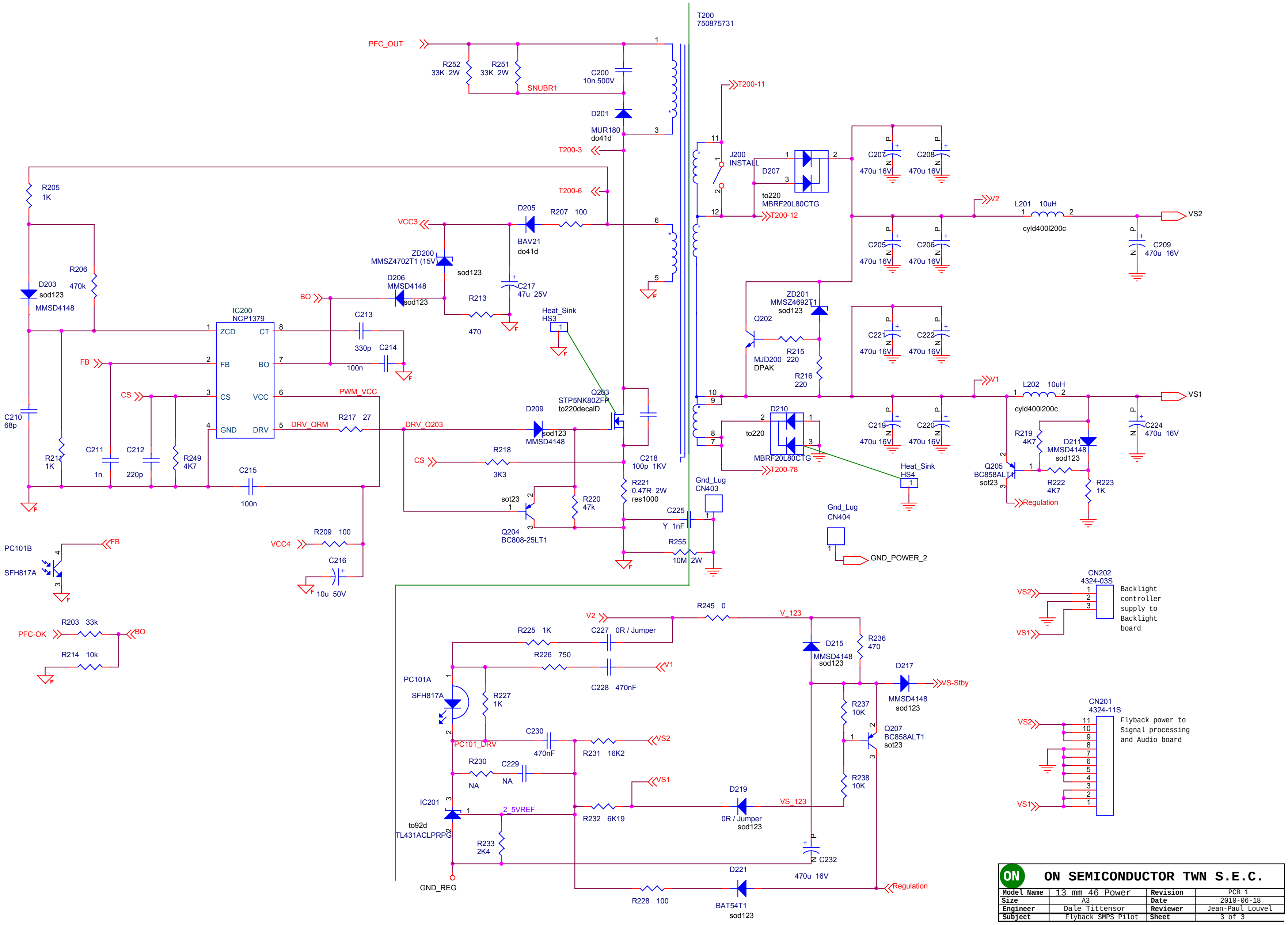
# 13 mm Mains filters and PFC schematic



# 13 mm ECO Standby Power Supply schematic



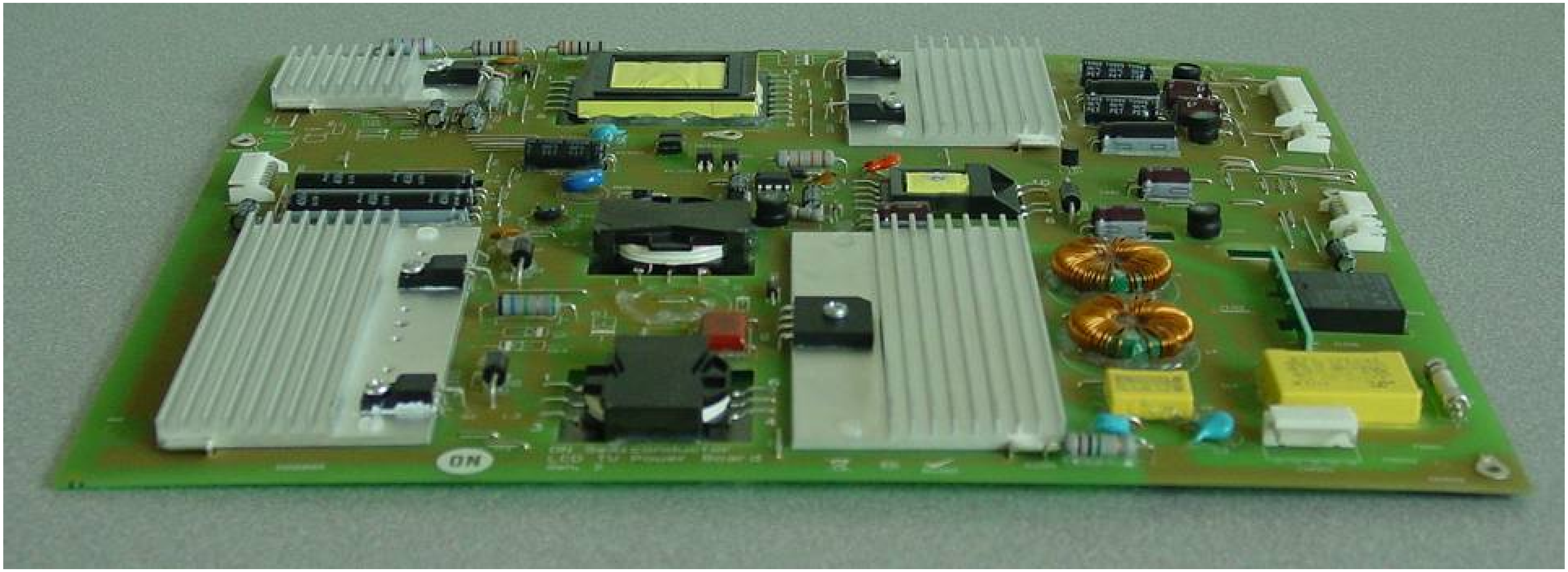
# 13 mm QR Flyback Power Supply schematic



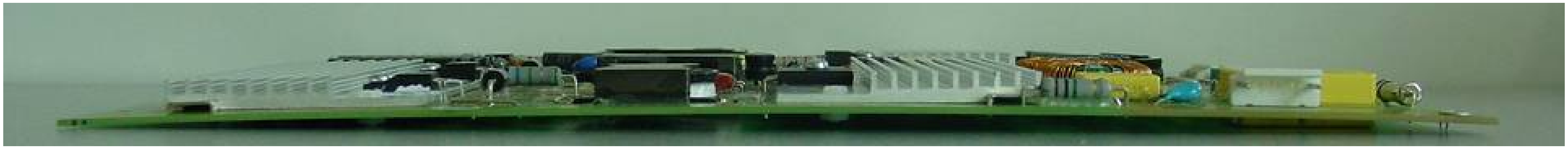
## Key parts modification for the 13 mm version (heat sink, filters, coils and transformers)

| Position | Component Type | Value | Rating | Pkg / Dimensions | Reference | Supplier |
|---|---|---|---|---|---|---|
| HS1 | Bridge Rectifier Heat Sink | | | Length 120mm Height 12.5 mm | TP207ST,120.0,12.5, NA,SP, 02B | Columbia-Staver |
| HS2 | PFC Heat Sink | | | Length 120mm Height 12.5mm | TP207ST,120.0,12.5, NA,SP, 01 | Columbia-Staver |
| HS3 | Flyback MOS Heat Sink | | | Length 40mm Height 12.5 mm | TP207ST,40.0,12.5, NA,SP, 01 | Columbia-Staver |
| HS4 | Flyback Diodes Heat Sink | | | Length 80mm Height 12.5 mm | TP207ST,80.0,12.5, NA,SP, 01 | Columbia-Staver |
| L002 | PFC Coil | 200uH | EFD30 | TOP Manual | 750370081 | WURTH ELEKTRONIK |
| L003 | PFC Coil | 200uH | EFD30 | TOP Manual | 750370081 | WURTH ELEKTRONIK |
| L004 | Common Mode Filter | 8.5mH | 3.3A | TOP Manual | PH9080NL | PULSE |
| L005 | Common Mode Filter | 8.5mH | 3.3A | TOP Manual | PH9080NL | PULSE |
| T100 | Standby Transformer | 2.5mH | EF12.6 | TOP Manual | 750871014 Rev 04 | WURTH ELEKTRONIK |
| T200 | Switch Mode Transformer | 680uH | EFD30 | TOP Manual | 750875731 | WURTH ELEKTRONIK |
| IC100 | 44Khz GTO Switch-Reg. | NCP1052P44G | | PDIP-8 | NCP1053P44G | ON Semiconductor |

# 8 mm SLIM Power solution pictures (310 mm x 290 mm)

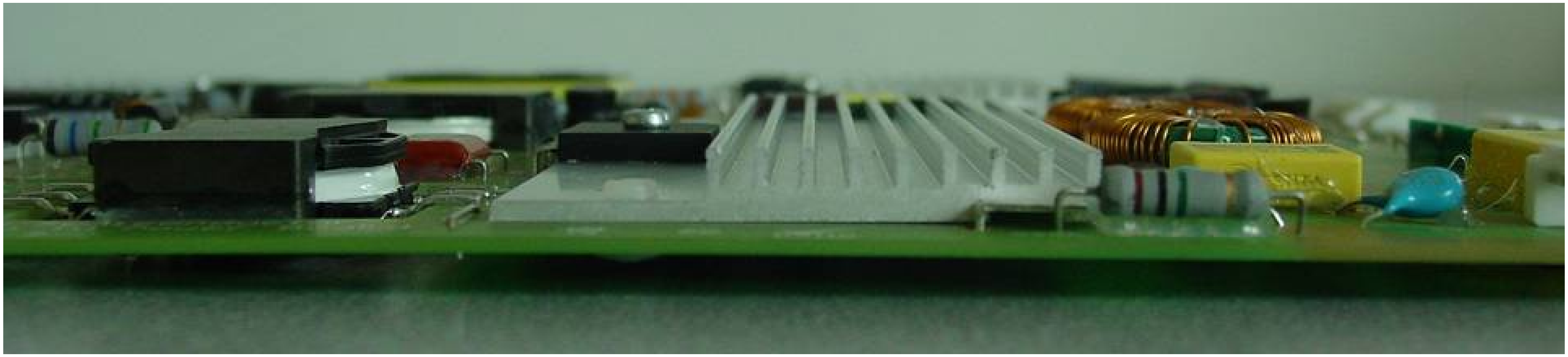


Overview

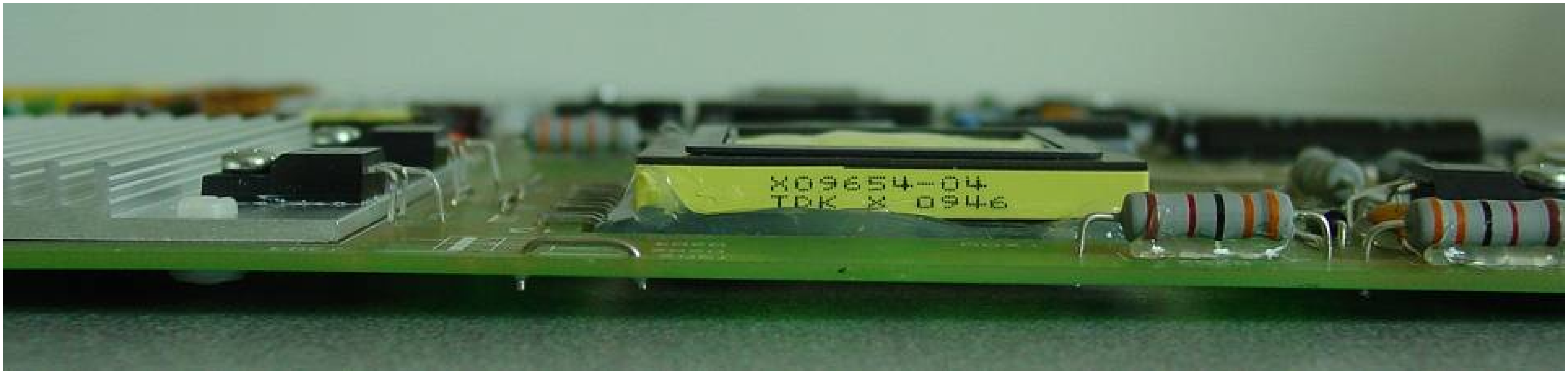


PFC side

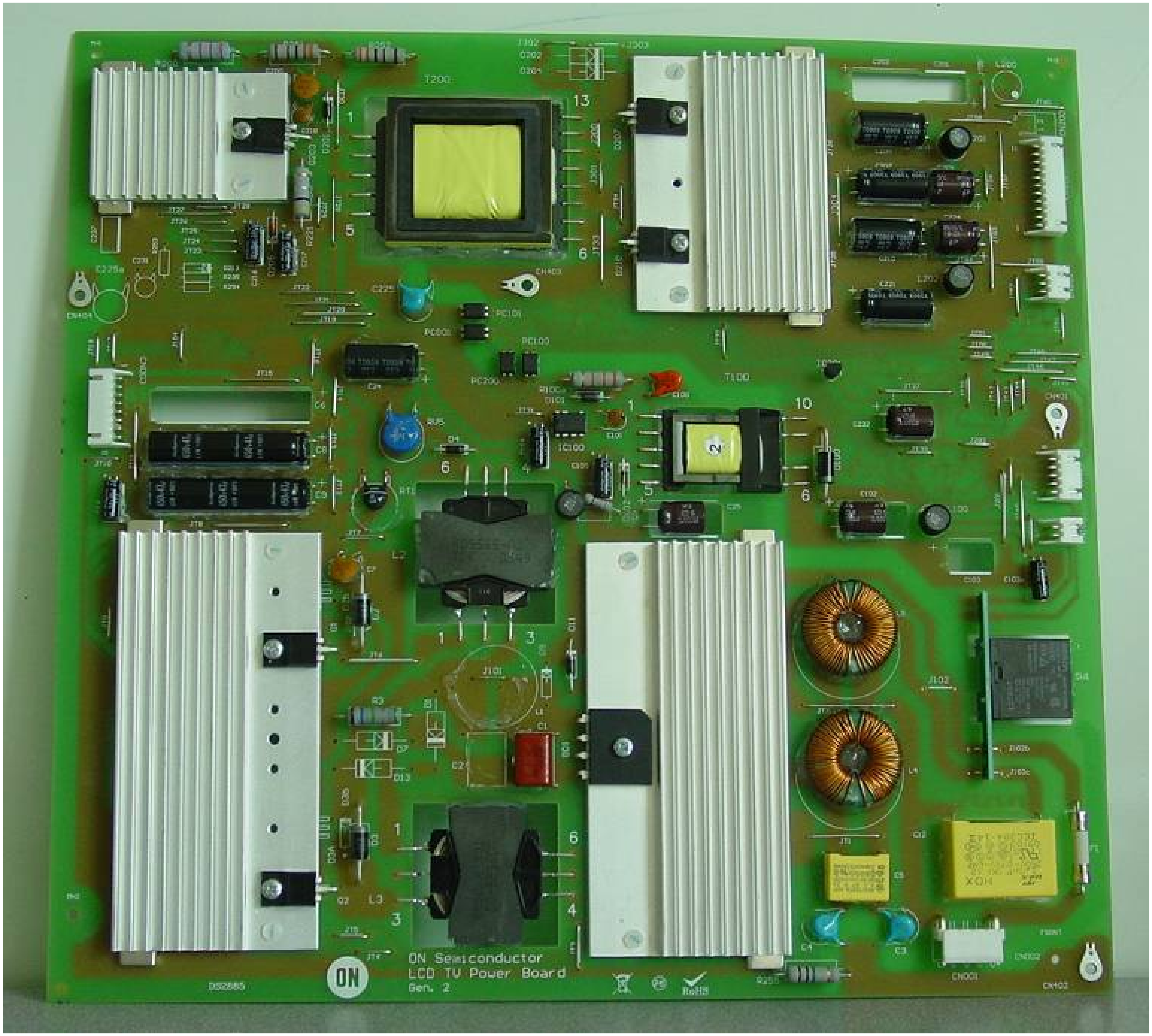
Flyback side

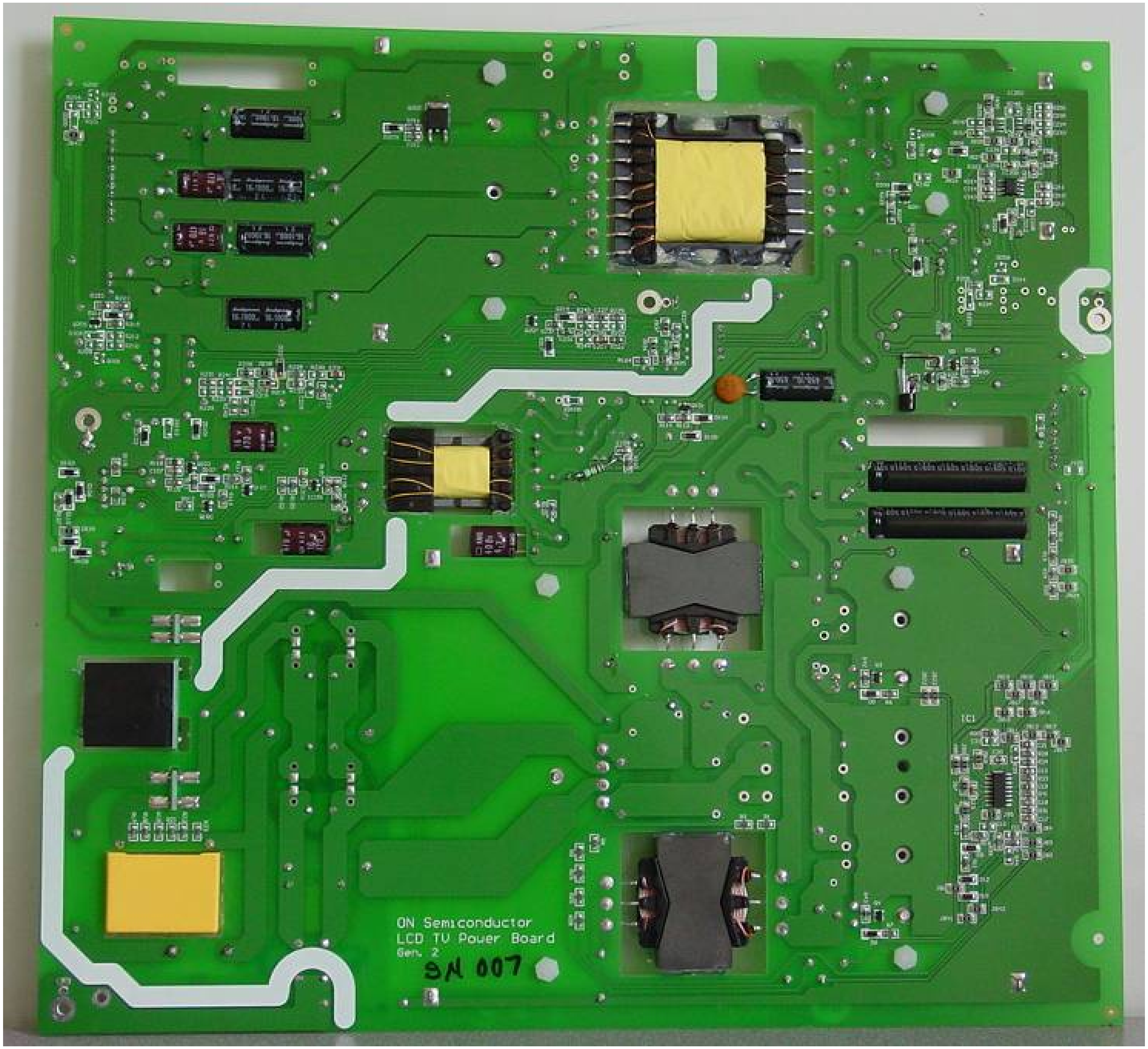


Zoom PFC side



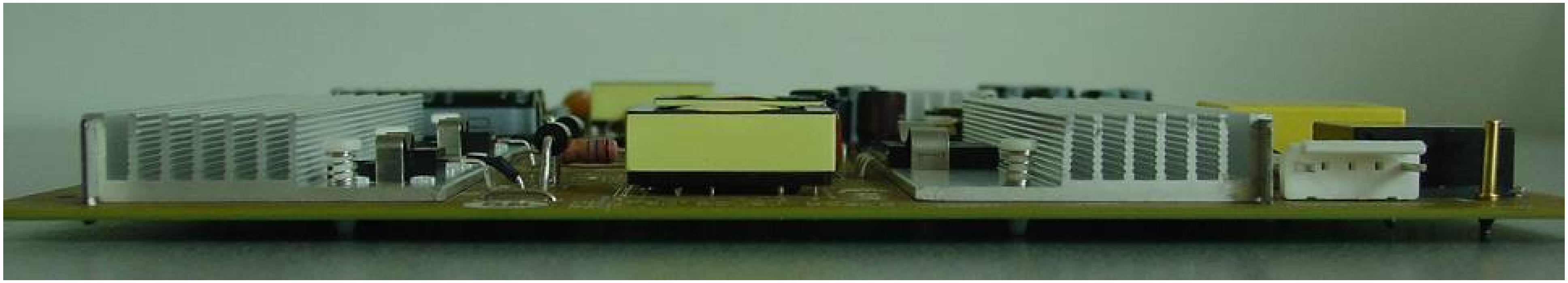

Zoom Flyback side


ON Semiconductor
LCD TV Power Board
Gen. 2

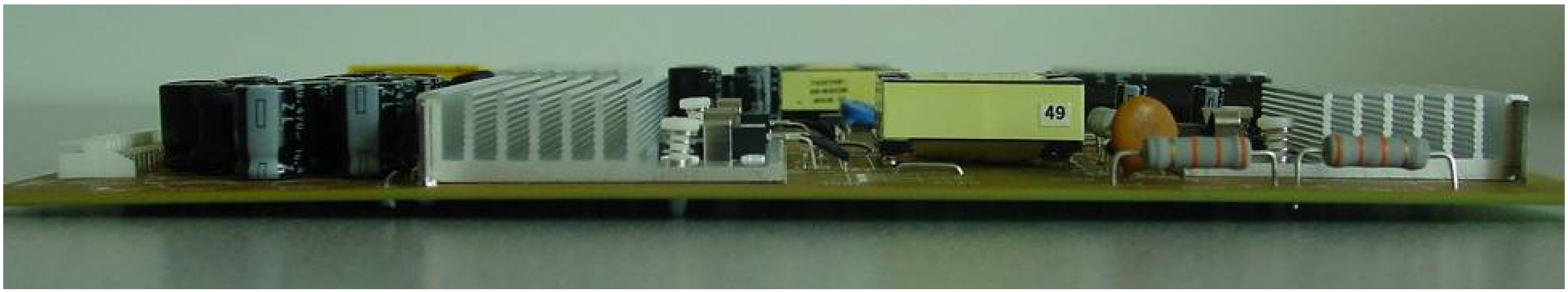

ON Semiconductor
LCD TV Power Board
Gen. 2
SN 007

13 mm Power solution pictures (230 mm x 290 mm)

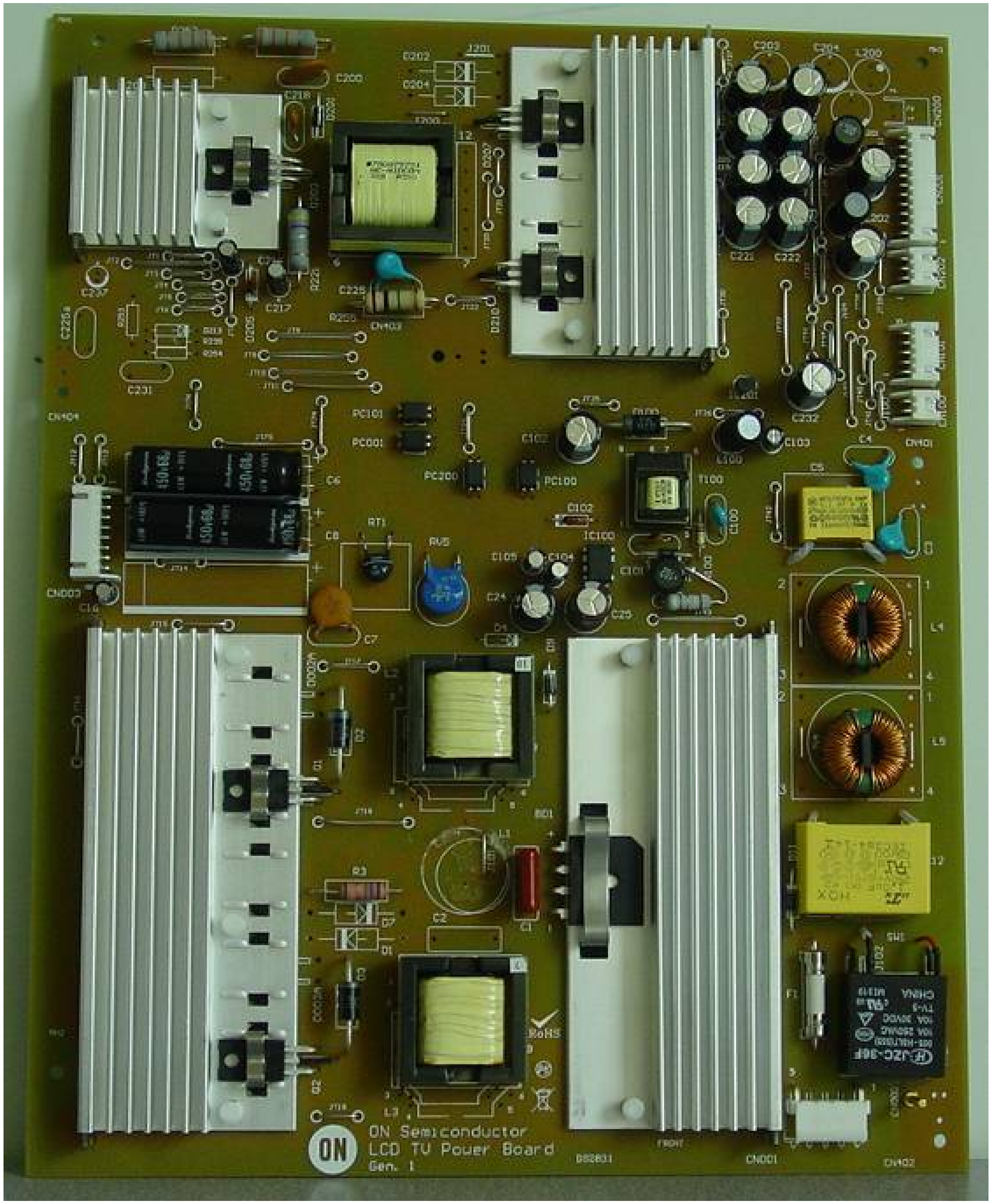

Overview

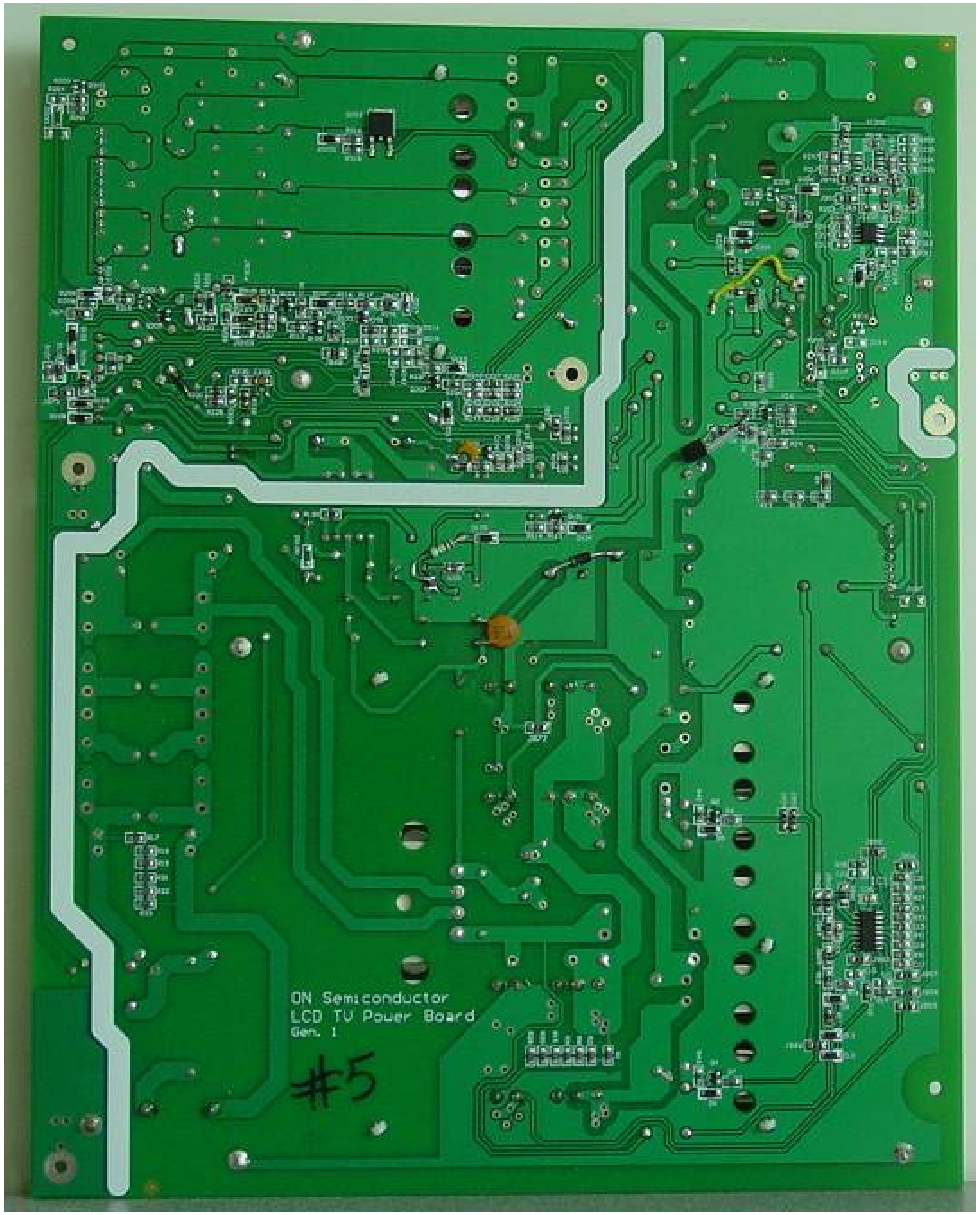


PFC side



Flyback side


ON Semiconductor
LCD TV Power Board
Gen. 1


ON Semiconductor
LCD TV Power Board
Gen. 1
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