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Design Note – DN05107/D

3.3KW On Board EV Charger

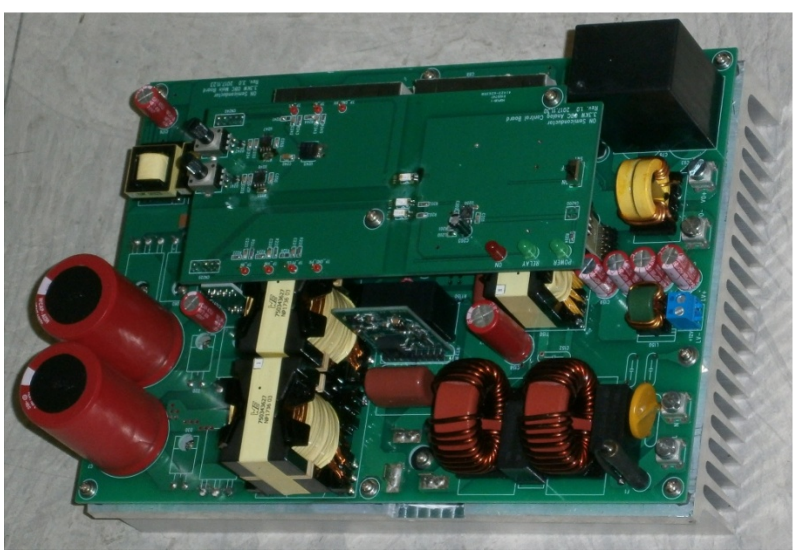
Device	Application	Input Voltage	Output Power	Topology	I/O Isolation
FAN9672Q FAN7688SJX NCP1340B3D1R2G FAN6224M FAN3224TUMX-F085 NCV890100PDR2G NCV51460SN33T1G NCV210SQT2G NCV2003SN2T1G SC431AVSNT1G FODM8801C …	On Board EV Charger	90-264Vac	3.3KW	2CH Interleave PFC + Full Bridge LLC + QR Flyback + Buck DCDC	Yes

Other Specification

	Output 1	Output 2
Output Voltage	200-450Vdc	12Vdc
Ripple	5% (Meet QCT 895 2011)	1% (Meet QCT 895 2011)
Nominal Current	-	-
Max Current	14	10
Min Current	0	0.1

PFC (Yes/No)	Yes
Minimum Efficiency	90%
Inrush Limiting	24A
Operating Temp. Range	-20-85˚C
Cooling Method	Force Air or Liquid cooling. Depend on the Heatsink
Signal Level Control	On/Off, CC, CV.

Photo Graph of the Evaluation Board



Key Features

Whole Solution:

- 2CH Interleave PFC to get high efficiency and power density. Decrease the current ripple at mean time
- Full bridge LLC to boost efficiency by high bus voltage usage
- QR flyback to boost the efficiency on the 12V/10A LV output and the auxiliary power
- Hardware PFC and LLC control approach for easily designing and less malfunction.
- Active inrush current limit circuit to decrease the PCB footprint
- Full functional solution including input/output current/voltage sensing and CC/CV PWM control interface. CAN interface will be available on next version

PFC Controller FAN9672

- Continuous Conduction Mode with Average Current Mode Control
- Two-Channel Interleave Operation
- Programmable Operation Frequency Range: 18 kHz~40 kHz or 55 kHz~75 kHz
- Programmable PFC Output Voltage
- Two Current-Limit Functions
- TriFault Detect™ Protects Against Feedback Loop Failure
- SAG Protection
- Programmable Soft-Start
- Under-Voltage Lockout (UVLO)
- Differential Current Sensing

LLC Controller FAN7688

- Secondary Side PFM Controller for LLC Resonant Converter with Synchronous Rectifier Control
- Charge Current Control for Better Transient Response and Easy Feedback Loop Design
- Adaptive Synchronous Rectification Control with Dual Edge Tracking
- Closed Loop Soft-Start for Monotonic Rising Output
- Wide Operating Frequency (39 kHz ~ 690 kHz)
- Green Functions to Improve Light-Load Efficiency
- Symmetric PWM Control at Light-Load to Limit the Switching Frequency while Reducing Switching Losses
- Protection Functions(with Auto-Restart
    - Over-Current Protection (OCP)
    - Output Short Protection (OSP)
    - NON Zero-Voltage Switching Prevention (NZS) by Compensation Cutback (Frequency Shift)
    - Power Limit by Compensation Cutback (Frequency Shift)
    - Overload Protection (OLP) with Programmable Shutdown Delay Time
    - Over-Temperature Protection (OTP)
- Programmable Dead Times for Primary Side Switches and Secondary Side Synchronous Rectifiers
- VDD Under-Voltage Lockout (UVLO)
- Wide Operating Temperature Range -40°C to +125°C

QR PWM Controller NCP1340

- QR Frequency Jittering to Reduces EMI Signature
- New Quiet-Skip Technology Ensures Operation Outside Audible Range
- Integrated HV Startup with Brownout Protection Provides an efficient power-on source and protects ageists drops in input mains voltage
- Valley Switching Operation with Valley Lockout. Maximizing the efficiency over the entire power range
- Integrated X2 Capacitor Discharge Capability Eliminates the need for a X2 resistors
- NTC Compatible Fault Pin Extra protection against high temperature or other fault conditions
- High Drive Capability: -500 mA / +800 mA Enables faster switching of primary-side MOSFET
- Latch input for OVP and OTP implementations Simple implementation of required protection functions

Synchronous Rectification Controller FAN6224

- mWSaver™ Technology
- Internal Green Mode to Stop SR Switching for Lower No-Load Power Consumption
- 300 µA Ultra-Low Green Mode Operating Current
- Suited for High-Side and Low-Side of Flyback Converters in QR, DCM, CCM Operation and Forward Freewheeling Rectification
- PWM Frequency Tracking with Secondary-Side Winding Voltage Detection
- 140 kHz Maximum Operation Frequency
- VDD Pin Over-Voltage Protection (OVP)

- LPC Pin Open/Short Protection
- RES Pin Open/Short Protection
- RP Pin Open/Short Protection
- Internal Over-Temperature Protection (OTP)

Schematics and Circuit Description

The system diagram is on Figure 1. The key elements of the OBC are marked in the color blocks.

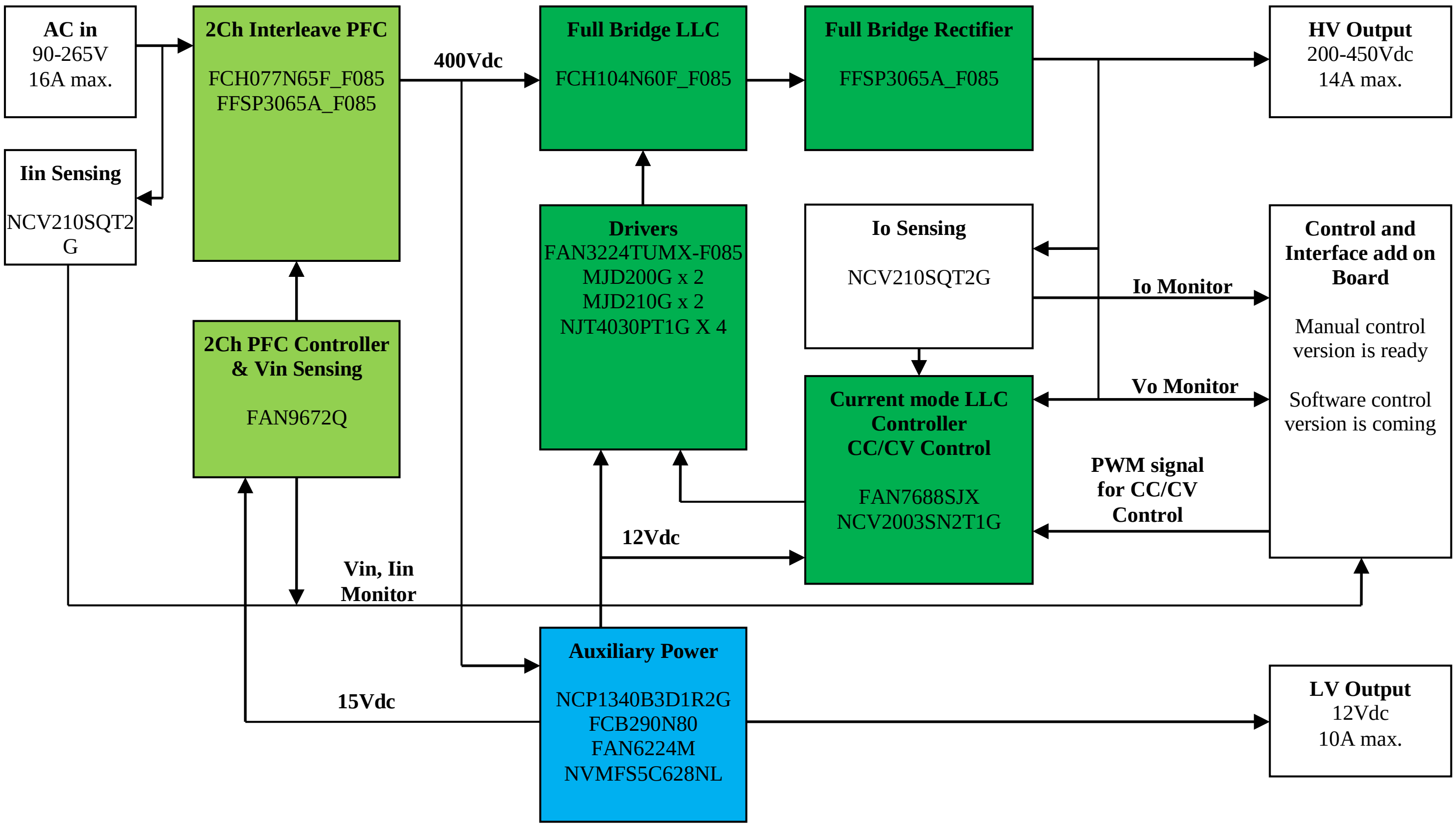


Figure 1. System diagram of the 3.3KW OBC

Following the AC input is the PFC stage. It's marked in light green. The detail schematic is shown on figure 2. The key elements of the PFC stage are the controller FAN9672 and the dual boost power devices. They are in the right hand of the figure 2. More details of the FAN9672 please refer the datasheet and the application notes of the device on the web site https://www.onsemi.cn/PowerSolutions/product.do?id=FAN9672. Among others, to avoid the CS+ signals are short circuit equivalent by C42 and C43, we placed the decouple inductors L21 and L31on the Vcc of the Totem poles.

On left hand of figure 2, there are 3 blocks in red dash line. The upper block is the inrush current limit circuit. On this reference design, there are two options: NTC and Active mode. The NTC is a traditional method to limit the charge current of the bulk E-capacitor during power on moment. RT1 and RT2 are those NTCs. After the E-cap C7, C8 are fully charged, the relay RL1 is turned on to short circuit the NTCs to decrease the power loss. On the NTC mode, the D3 is unnecessary. This method is simple but the performance is limit. So we provided an active mode for choice. The most circuits of the active inrush current limit beside D3 are on a daughter board which connects to the SW_MODE_IRCLA. The detail schematic and the operating theory we will descript later.

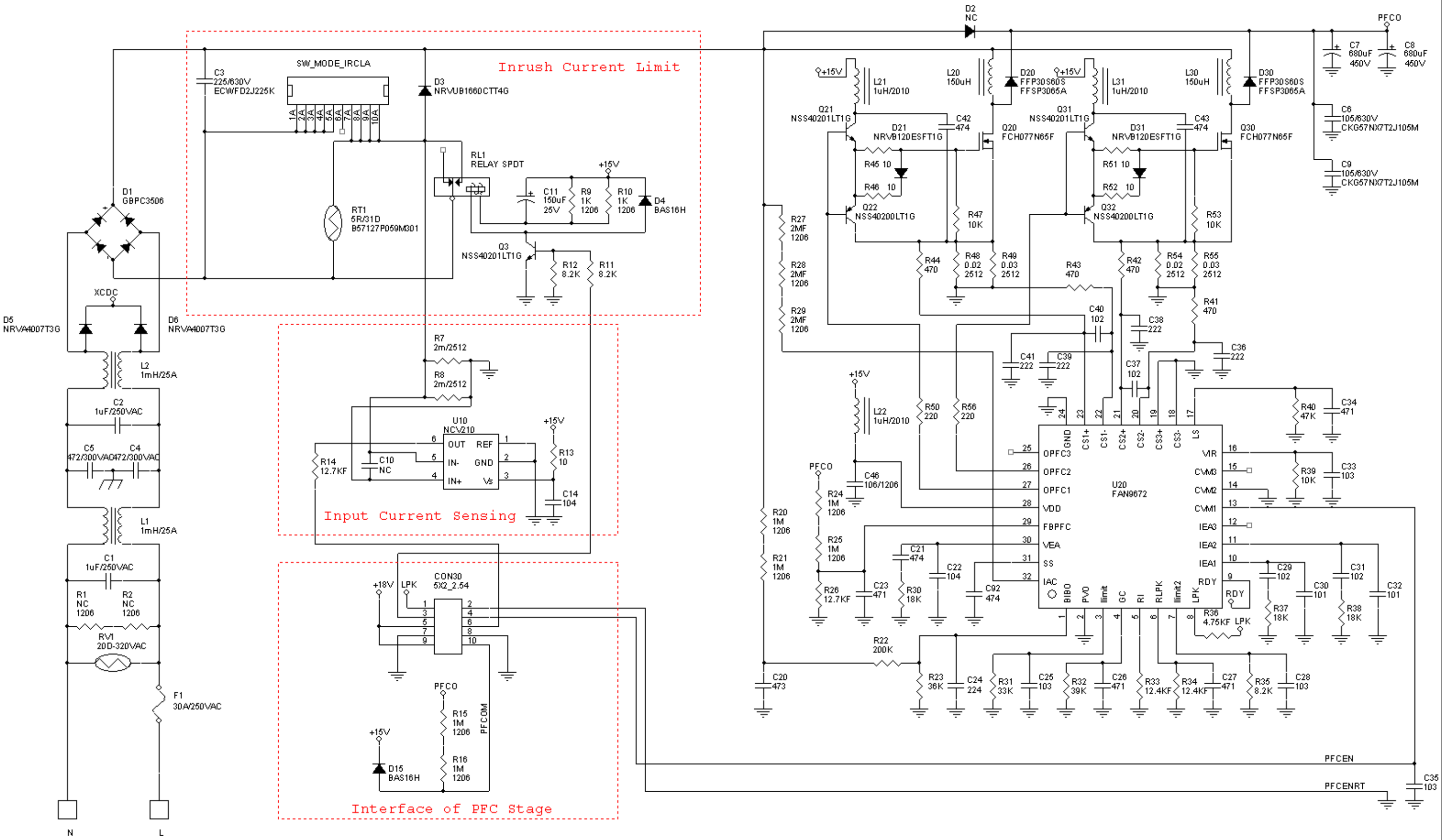


Figure 2. Schematic of the PFC

The middle block is the input current sensing circuit. The standard of the OBC required the input current must be under a safety level to prevent the power cord and the connector overheat in every condition. So the charger system must monitor the input current continually. If the input current over the limit by the reason of the input voltage get lower or any others, the system must decrease the output power. The U10 is the 200X fix-gain current sense amplifier. Co-operate with the R7 and R8, the voltage on pin6 of U10 will be 200 x 0.001x Iin. If Iin=16Arms, at peak point of the sin wave, the output of U10 is 4.525V.

The lower block is the interface of the PFC stage. The 10pin connector CON30 connects the PFC stage to the interface board. The table 1 shows the signals on the CON30.

Pin No.	Direction	Description
1	Output	Input voltage sensing.
2	-	Return of PFC enable signal. Connect to GND of FAN9672 in differential path with Pin5.
3	Input	Relay Control signal.
4	Input	PFC enable signal. Control CM1 of FAN9672.
5	Output	+18V.
6	Output	Input current sensing signal.
7	-	GND
8	-	GND
9	Output	+18V.
10	Output	PFC output voltage sensing.

Table 1. Signals of the CON30

Another key element of the OBC is the DCDC stage. It was marked in dark green in figure 1. The schematic of the DCDC stage is shown in figure 3. We adopt the full bridge LLC topology to get the high efficiency and suitable cost. It composed by U60 and Q60, Q61, Q70, Q71 etc. The FAN7688 (U60) is a current mode advanced LLC controller. More details of the FAN7688 please refer the datasheet and the application notes on the web site https://www.onsemi.cn/PowerSolutions/product.do?id=FAN7688. Because of the high output voltage (200-450Vdc), the Synchronous Rectifier cannot help too much on the rectifier conduction loss. So we omitted the SR function of the FAN7688. Find a suitable power transformer and resonate inductor on the 3KW power level is not easy. We used 2pcs EPC54 dual slot bobbin and core to make the transformer. It integrates the resonate inductor to save the room and conduction loss. On the primary side the two transformers are in series and on the secondary side, the two transformers are in parallel. Thus the voltage and current between the two transformers is balance automatically.

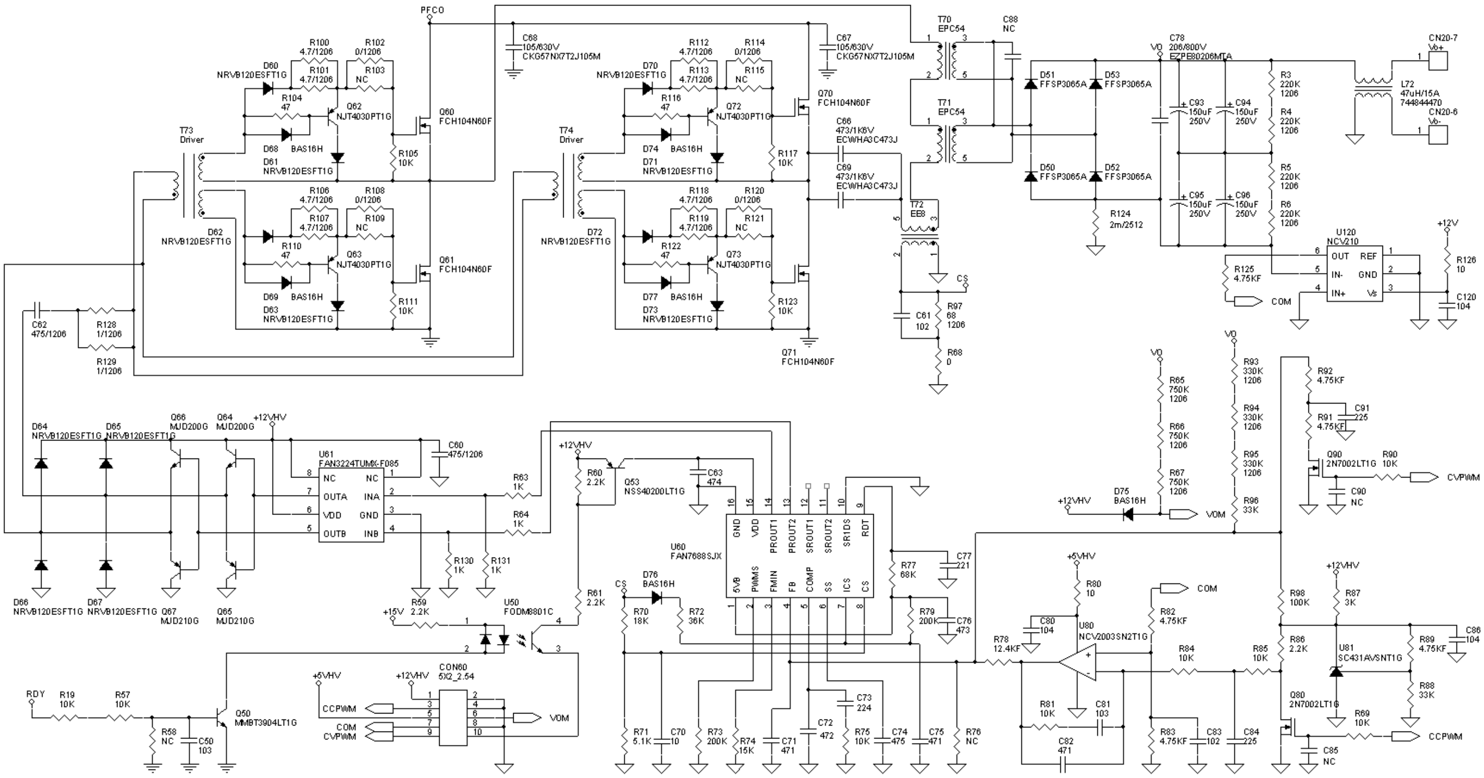


Figure 3. Schematic of the DCDC

Driving the full bridge MOSFETs with the half bridge LLC controller like FAN7688 is not difficult. Just drive the diagonal MOSFETs by the same signal is okay. To drive the low Rdson MOSFETs need strong driver ability. The PROUT signals of FAN7688 amplified by the U61 (FAN3224) and expend the current driving ability by the totem pole (Q64-Q67) then delivery to primary side trough pulse transformers T62 and T72. Emitter followers Q62, Q63, Q72 and Q73 are to speed up the turning off of the MOSFETs.

The FAN7688 integrated a voltage reference and an error amplifier inside. For the CV (Constant Voltage) control, we just follow the typical application of the FAN7688 is okay. What we need to do in the OBC application is just to add a CC (Constant Current) control loop. The U80 rail to rail amplifier and peripheral components acted as this role. During the CV mode, the U80 is in saturation. The voltage drops on the output of U80 can be ignored. On the close loop state, the output voltage determined by the voltage dividing resisters (R93, R94, R95, R96, R78, R91 and R92. We ignore the effect of R98 here for easy calculation) and the PWM duty of CV control signal CVPWM. If CVPWM duty=100%, the output voltage will be 2.4 X {R93 + R94 + R95 + R96 + [R78// (R91 + R92)}/ [R78// (R91 + R92)] . And if the CVPWM duty=0, the output voltage will be 2.4 X (R93 + R94 + R95 + R96 + R78)/ R78. Fill the value of the resistors; the output voltage will change from 458.8V to 200.4V if the CVPWM duty decreases from 100% to 0. The purpose of R98 is to add a small bias voltage on the FB pin. Without it the current on the resonate tank may increase too fast during the start up moment and trigger the over current protection. The R98 is also makes the output voltage lower a little bit than we calculate above. Please make an alignment on whichever of R93, R94, R95, R96 or R78 if necessary.

The circuit around the U120 and R124 is to sense the output current. I's quit same with the block of U10 which we discussed above. CN60 is the interface of the DCDC stage. The table 2 shows the signals on the CON30.

The FAN7688 get VDD when both of the PFC RDY and the LLC enable signal are active.

Pin No.	Direction	Description
1	Output	+12VHV.
2	-	GND
3	Input	CCPWM. PWM signal for content current setting.
4	-	GND
5	Input	+5VHV.
6	Output	VOM. Output voltage sensing.
7	Output	COM. Output current sensing.
8	-	GND
9	Input	CVPWM. PWM signal for content voltage setting.
10	Input	LLC enable signal.

Table 2. Signals of the CON60

The third key element of the OBC is the Low Voltage and Auxiliary power. Figure 4 show the schematic.

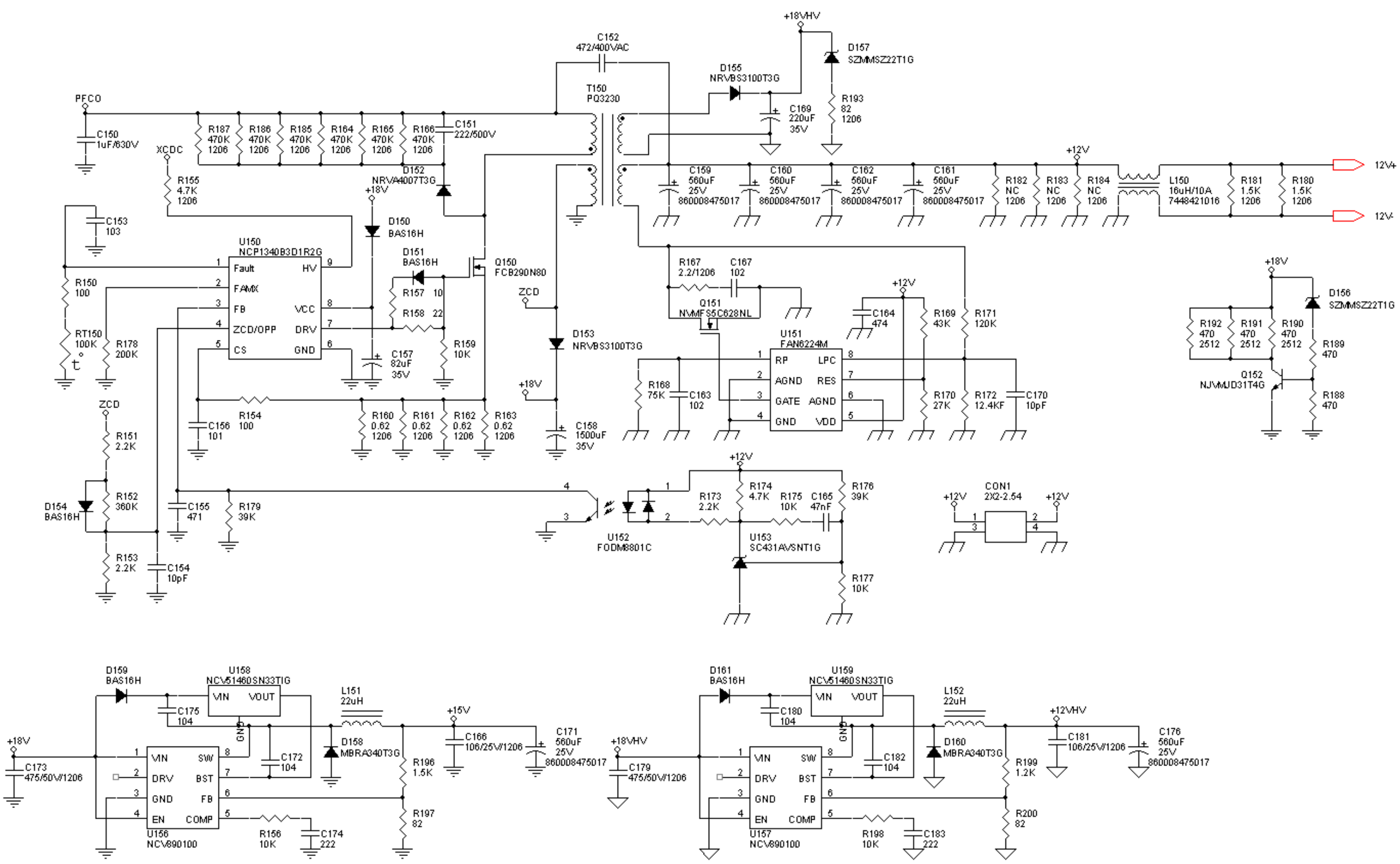


Figure 4. Schematic of the Low Voltage and Auxiliary power.

The main topology of the LV and auxiliary power is the QR fly-back. The LV output is 12V 10A. To increase the efficiency, we adopt the synchronous rectification. The detail of the PWM controller NCP1340 and the SR controller FAN6224 please refer the datasheet and application note on the web site: https://www.onsemi.cn/PowerSolutions/product.do?id=NCP1340 and https://www.onsemi.cn/PowerSolutions/product.do?id=FAN6224.

This OBC has 3 separate GNDs. They are primary GND, LV output GND, and HV output GND. They are isolating each other. The can bus connect to LV GND. The DCDC controller connects to HV GND. Besides the LV output, the fly-back converter also provides the Vcc to PFC and DCDC controllers. So it has 3 isolating outputs. The feedback output of the PWM controller is the LV output because it's the heaviest load. But the load of LV output is uncertain. So the cross regulation is a problem. To avoid the voltage of +18V and +18VHV too high on the LV heavy load situation, we placed the active dummy load on the both output. They are Q152 and D157 and their peripheral components. Both of above dummy load can adjust the load current according to the output voltage automatically then save the power loss during the LV output light load moment.

Both of the PFC controller and LLC controller need the relative regulate Vcc for stable operating. The +18V and +18VHV output cannot meet regulation requirement due to the LV output's uncertainty. So the sub-regulator is necessary. For efficiency reason, we select the buck converters made by NCV890100PDR2G. This is a non-SR buck switching regulator with SO8-EP package. The switching frequency is up to 2MHz. The performance cost ratio is high and easy for application.

On the typical application circuit of NCV890100, the Bootstrap is powered by the internal 3.3V regulator. This method has a problem on this OBC design. In case of the load of LV is very light, the voltage of 18V and +18VHV will drop and close to 15V and 12V. The duty of the buck converter will be very large. Then the bootstrap voltage will drop below the DRV POR Stop Threshold and the device stop working. To save this problem we connect the bootstrap diodes (D159, D161) to Vin of the buck converters instead of the DRV pin. And insert a 3.3V LDO (U158, U159) from the bootstrap voltage to BST pin. This way extends the maxima duty range of the converter. And if the device stops working by Vin drop, once the Vin-Vo goes up to 3.3V, the device will re-work again. But in the typical application circuit, if the device stops working, It will keep stop until the Vo drop to 0V.

The connector CN1 deliveries the +12V voltage to the interface board.

In this design, we put the interface circuits on an add-on board for the flexibility. The features of the full function interface board will include the (1) Can communication with the BMS system to report the information like: Input voltage, Input current, Output voltage, Output current, Bus voltage, Output miss-connection, LV voltage, Temperature of the Bridge Rectifier, Temperature of the PFC MOFETs and Diodes, Temperature of the PFC Inductors, Temperature of the LLC transformers, Temperature of the LLC Diodes. (2) Can communication with the BMS to receive the following command: Power-up, Output voltage, Output current, Power off. (3) Output the CC, CV PWM signals and the power-on and relay-on signals to the main board. But, the full function interface board is not ready so far. We use a simple manual control board instead of the full function one. Figure 5 show the schematic of the manual control interface board.

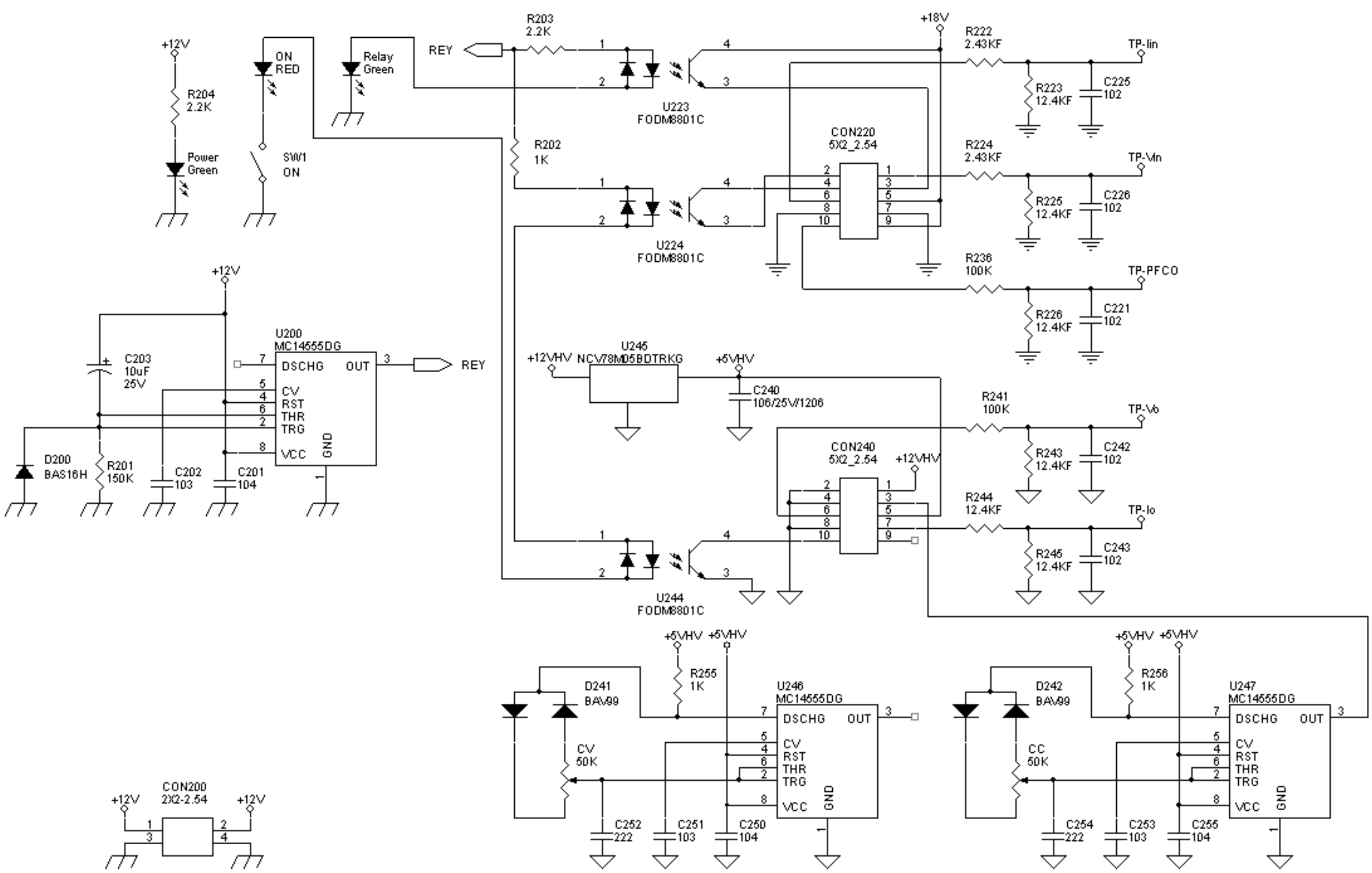


Figure 5. Schematic of the manual control interface board.

The SW1 powers ON/OFF the PFC and LLC stage in the secondary side for safety. It is delivery to the primary and HV stage by U223 and U224. The Vcc of the U223 and U224 is powered by the REY signal, thus the power-up will be AND with the relay active. The REY signal is 3 second delayed by U200 from the 12V LV active moment to guarantee the Bus Caps is full charged. The CC and CV PWM signals are generated by the U246 and U247 and the peripherals components. The variable resistors CC and CV control the duty of the PWM signals. The sensing signals like Vin, Iin, Vbus, Vo and Io was connected to the test points for customer testing by the voltage meter.

During the description of the PFC stage, we mentioned we provided two methods to limit the inrush current which charge the bus-caps on the power cord plug-in moment. The NTC is one of the most popular solutions. We will not discuss here. What we will high-light is the active inrush current limit circuit which is shown in figure 6.

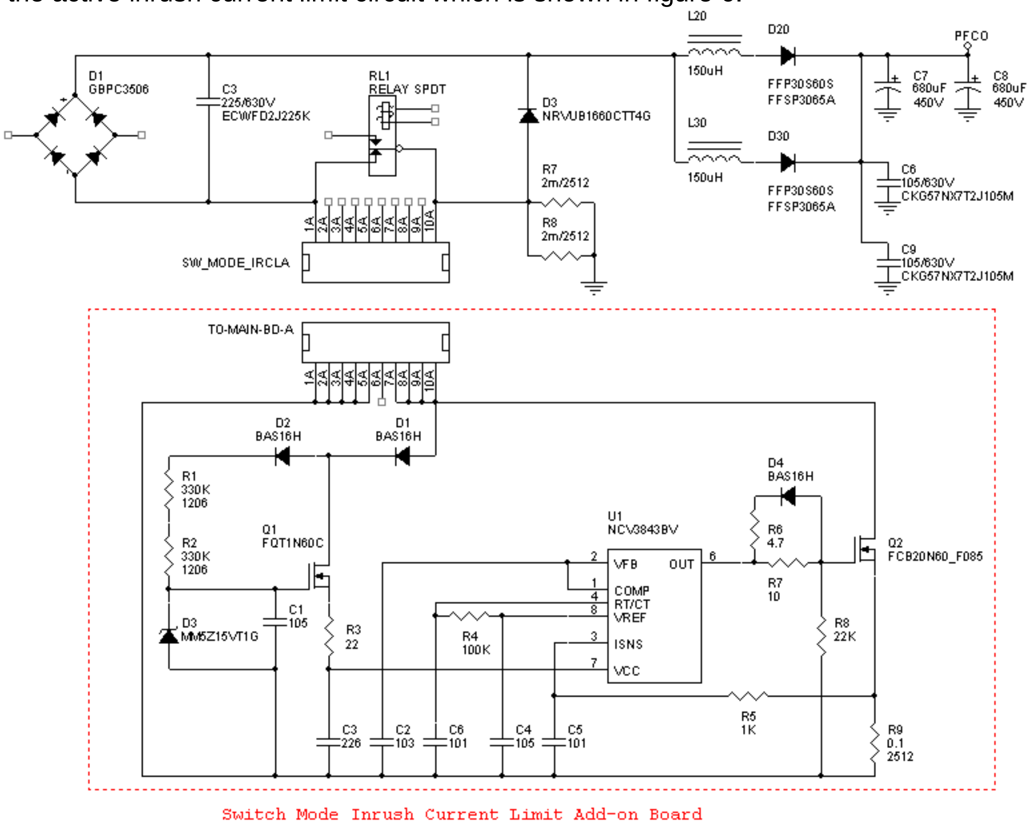


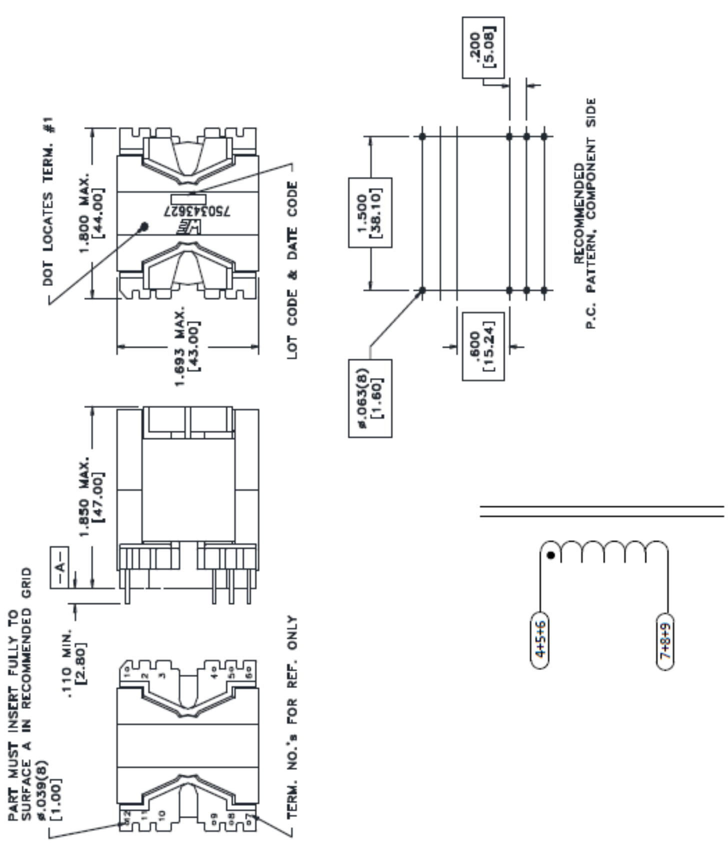
Figure 6. Schematic of switch mode inrush current limit circuit.

The circuits in the red dash-line box locate on the switch mode inrush current limit add-on board. The add-on board connects to the main board with two paths. The left path connect to the Source pin of the MOSFET Q2 through the current sense resistor R9. And the right path connects to the Drain pin of Q2 directly. The Q2 is controlled by the PWM controller U1. The U1 turns on in a fixed switching frequency and turns off triggered by the current sense signal with a fixed level. So the whole add-on board can be tread as a fixed frequency, fixed turn off current threshold switch. The circuits around Q1 provide the Vcc to U1. The switch Q2 and the freewheel diode D3; inductors L20 and L30 composed a buck converter. This buck converter charges the bus capacitors C7, C8 during the moments when the rectifier AC voltage is higher than the bus voltage. The charging speed depends on the peak current which can be programmed by the R9. If we set the peak current to a reasonable level, inrush current is limited. This inrush current limit methodology is different from the traditional methods witch use the NTC, PTC, fixed resistor or MOSFET or IGBT which working under the linear mode. It works on the switch mode. The power loss of the devices is limited. So the footprint of the circuits is small than the traditional methods. This feature is valuable for the OBC. By using the PFC inductors as the buck inductor, the cost of this solution is not higher than the traditional method so much.

MEGNATICS DESIGN DATA SHEET

PFC Inductors: L20, L30.

CUSTOMER TERMINAL	RoHS	LEAD(Pb)–FREE
Sn 96%, Ag 4%	Yes	Yes



ELECTRICAL SPECIFICATIONS @ 25° C unless otherwise noted:

PARAMETER		TEST CONDITIONS	VALUE
D.C. RESISTANCE	4-7	tie(4+5+6,7+8+9), @20°C	0.042 ohms max.
INDUCTANCE	4-7	tie(4+5+6,7+8+9),50kHz, 100mV, Ls	150.0µH ±10%
SATURATION CURRENT	4-7	tie(4+5+6,7+8+9), 20% rolloff from initial	20A

GENERAL SPECIFICATIONS:

OPERATING TEMPERATURE RANGE: -40°C to +125°C including temp rise.

Customer to tie terminals 4&5&6 and 7&8&9 internally on PC Board.

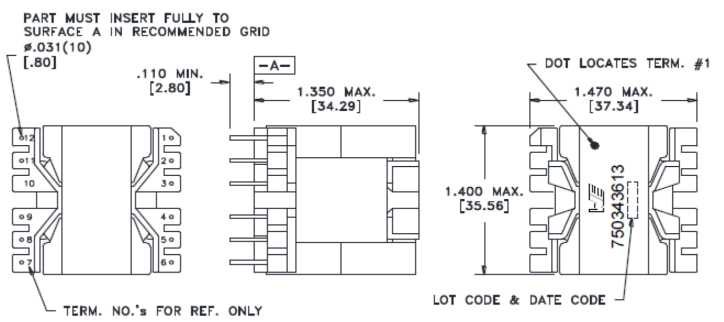
Application of transformer allows for leadwires between terminals 4&5&6 and 7&8&9 to solder bridge.

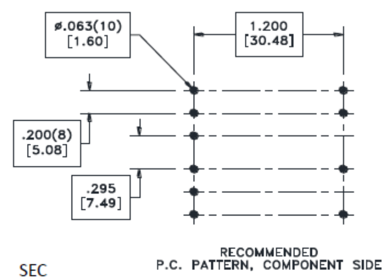
Wire insulation & RoHS status not affected by wire color. Wire insulation color may vary depending on availability.

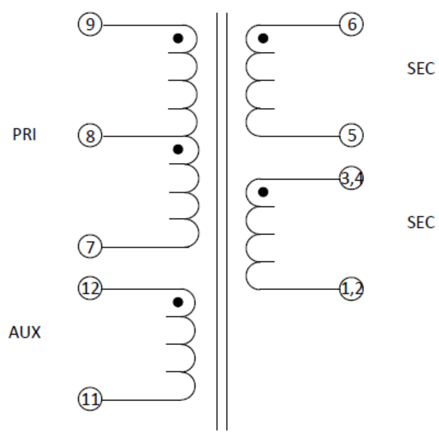
		Packaging Specifications		Tolerances unless otherwise specified:	DRAWING TITLE	PART NO.
DFM		Method: Tray		Angles: ±1° Decimals: ±.005 [.13]	INDUCTOR	750343627
DATE		PKG-TBD		Fractions: ±1/64 Footprint: ± .001 [.03]		
ENG	HWE		CONVENTION PLACEMENT	This drawing is dual dimensioned. Dimensions in brackets are in millimeters.		SPECIFICATION SHEET 1 OF 1
REV.	04					
DATE		www.we-online.com/midcom				

Auxiliary Transformer: T150.

CUSTOMER TERMINAL	RoHS	LEAD(Pb)--FREE
Sn 96%, Ag 4%	Yes	Yes







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more than you expect

ELECTRICAL SPECIFICATIONS @ 25° C unless otherwise noted:

PARAMETER		TEST CONDITIONS	VALUE
D.C. RESISTANCE	9-7	@20ºC	0.088 ohms max.
D.C. RESISTANCE	12-11	@20ºC	0.016 ohms max.
D.C. RESISTANCE	6-5	@20ºC	0.019 ohms max.
D.C. RESISTANCE	3-1	tie(3+4,1+2), @20ºC	0.005 ohms max.
INDUCTANCE	9-7	10kHz, 1V, Ls	280.00µH ±10%
LEAKAGE INDUCTANCE	9-7	tie(1thru6+11+12),100kHz, 100mV, Ls	6µH max.
DIELECTRIC	1-12	tie(9+11,4+5), 3750VAC, 1 second	
TURNS RATIO		(9-7):(12-11)	9:1, ±1%
TURNS RATIO		(9-7):(6-5)	9:1, ±1%
TURNS RATIO		(9-7):(3-1), tie(3+4,1+2)	13.5:1, ±1%

GENERAL SPECIFICATIONS:

OPERATING TEMPERATURE RANGE: -40°C to +125°C including temp rise.

Wire insulation & RoHS status not affected by wire color. Wire insulation color may vary depending on availability.

DFM		Packaging Specifications	CONVENTION PLACEMENT	Tolerances unless otherwise specified:	DRAWING TITLE	PART NO.
DATE		Method: Tray		Angles: ±1° Decimals: ±.005 [.13]	**TRANSFORMER**	**750343613**
ENG	HWE	PKG-0825		Fractions: ±1/64 Footprint: ± .001 [.03]		
REV.	00			This drawing is dual dimensioned. Dimensions in brackets are in millimeters.		
DATE	6/14/2017	www.we-online.com/midcom				SPECIFICATION SHEET 1 OF 1

CUSTOMER TERMINAL	RoHS	LEAD(Pb)--FREE
Sn 96%, Ag 4%	Yes	Yes

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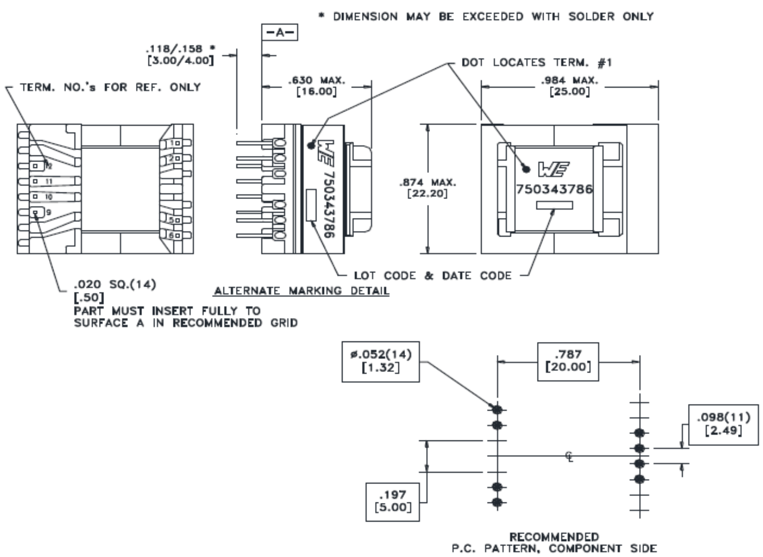
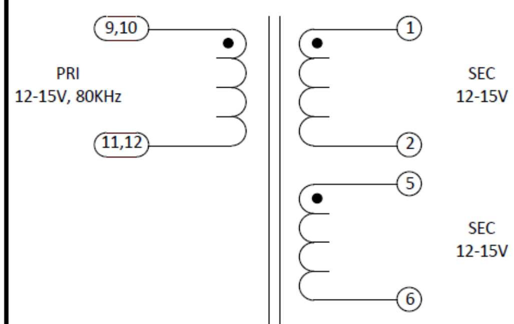
more than you expect





Application of the transformer allows for the leadwires between terminals 9&110, 11&12 to solder bridge.

Customer to tie terminals 9+10 and 11+12 on PC board.

ELECTRICAL SPECIFICATIONS @ 25° C unless otherwise noted:

PARAMETER		TEST CONDITIONS	VALUE
D.C. RESISTANCE	9-11	tie(9+10,11+12), @20ºC	0.045 ohms max.
D.C. RESISTANCE	1-2	@20ºC	0.06 ohms max.
D.C. RESISTANCE	5-6	@20ºC	0.075 ohms max.
INDUCTANCE	9-11	tie(9+10,11+12),10kHz, 100mV, Ls	170.00µH min
LEAKAGE INDUCTANCE	9-11	tie(9+10,11+12,1+2+5+6),100kHz, 100mV, Ls	0.4µH max.
DIELECTRIC	1-9	tie(1+5,9+10), 3750VAC, 1 second	-
TURNS RATIO		(1-2):(9,10-11,12)	1.15:1, ±1%
TURNS RATIO		(1-2):(5-6)	1:1, ±1%

GENERAL SPECIFICATIONS:

OPERATING TEMPERATURE RANGE: -40°C to +125°C including temp rise.

Wire insulation & RoHS status not affected by wire color. Wire insulation color may vary depending on availability.

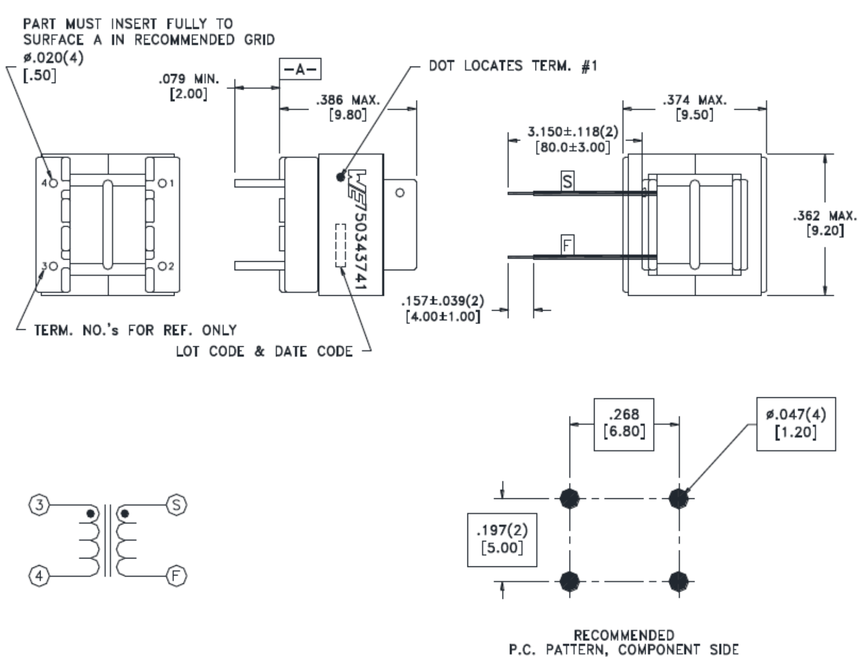
DFM		Packaging Specifications Method: Tray PKG-0736	CONVENTION PLACEMENT	Tolerances unless otherwise specified: Angles: ±1° Decimals: ±.005 [.13] Fractions: ±1/64 Footprint: ± .001 [.03]	DRAWING TITLE TRANSFORMER	PART NO. 750343786
DATE						
ENG						
REV.	00			This drawing is dual dimensioned. Dimensions in brackets are in millimeters.		
DATE	11/10/2017	www.we-online.com/midcom				SPECIFICATION SHEET 1 OF 1

Current Transformer: T72.

CUSTOMER TERMINAL	RoHS	LEAD(Pb)--FREE
Sn 96%, Ag 4%	Yes	Yes

more than you expect

WÜRTH ELEKTRONIK



ELECTRICAL SPECIFICATIONS @ 25° C unless otherwise noted:

PARAMETER		TEST CONDITIONS	VALUE
D.C. RESISTANCE	3-4	@20ºC	8.310 ohms max.
D.C. RESISTANCE	S-F	@20ºC	0.010 ohms max.
INDUCTANCE	3-4	50kHz, 100mV, Ls	16.0mH min.
DIELECTRIC	3-S	3750VAC, 1 second	3000VAC, 1 minute
DIELECTRIC	S-core	3750VAC, 1 second	3000VAC, 1 minute
TURNS RATIO		(3-4):(S-F)	170:1, ±2%

GENERAL SPECIFICATIONS:

OPERATING TEMPERATURE RANGE: -40°C to +125°C including temp rise.

Designed to comply with the following requirements as defined by IEC60950-1, EN60950-1, UL60950-1/CSA60950-1 and AS/NZS60950.1:

- Reinforced insulation for a primary circuit at a working voltage of 265Vrms, 400Vpeak, Overvoltage Category II.

Current Rating: 4A(Pin S-F)

Wire insulation & RoHS status not affected by wire color. Wire insulation color may vary depending on availability.

DFM	
DATE	
ENG	NWA
REV.	00
DATE	9/15/2017

Packaging Specifications
Method: Tray
PKG-0542

CONVENTION PLACEMENT

www.we-online.com/midcom

Tolerances unless otherwise specified:
Angles: ±1° Decimals: ±.005 [.13]
Fractions: ±1/64 Footprint: ± .001 [.03]

This drawing is dual dimensioned. Dimensions in brackets are in millimeters.

DRAWING TITLE

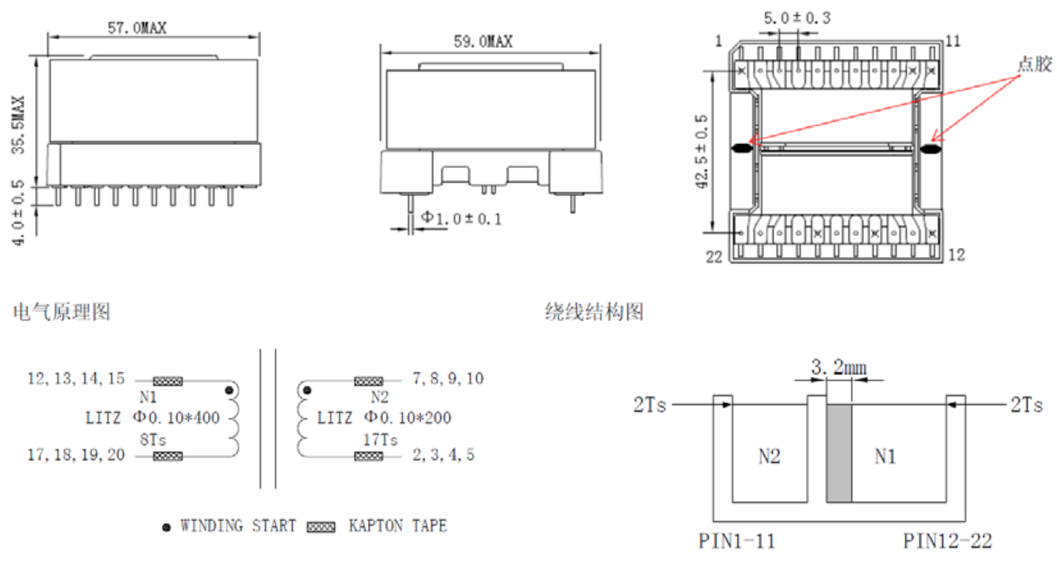
TRANSFORMER

PART NO.

750343741

SPECIFICATION SHEET 1 OF 1

LLC Transformers: T70, T71.



电气参数

NO.	名　　称	测量端	测量值	测试条件	测试仪器
1	电感量	L(N1)	60uH±10%	10KHz 1V 25°C	HP4980
2	漏感	L(N1)	9.5uH±20%短 N2		
3	抗电强度	初级对次级	3000V AC	1mA, 50Hz 60Sec.	CJ2671
		线圈对磁芯	1500V AC		

海 宁 联 丰 东 进 电 子 有 限 公 司
HAINING LIANFENG DONGJIN ELECTRONICS CO.,LTD
地址:浙江省海宁市盐官镇园区五路1号 ADD:NO.1,NO.5 Rd,YanGuan Town Area,HaiNing,ZheJiang,China
电话:0573-87633718/87633818 TEL: +86-573-87633718/87633818
传真:0573-87681200 FAX: +86-573-87681200
E-mail:lfshen@lfgmag.com http://www.lfdjg.com
shenlifeng@lfdjg.com

Test Result

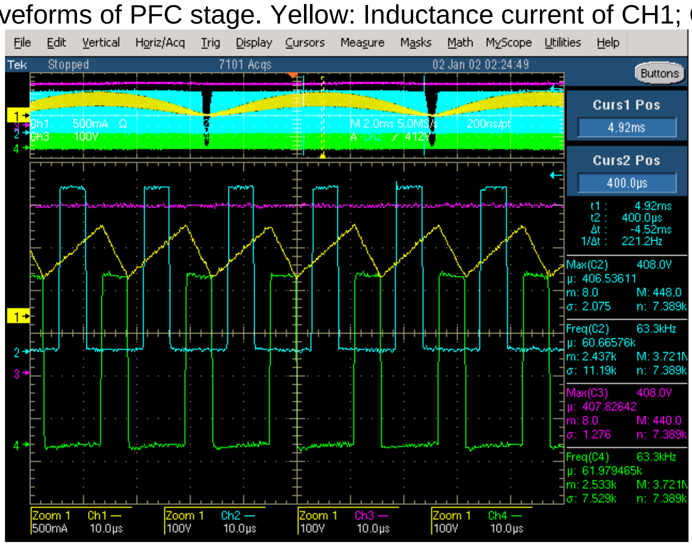
Power Factor

PF	Vin=90Vac	Vin=110Vac	Vin=220Vac	Vin=264Vac
Load=25%	0.991	0.982	0.976	0.867
Load=50%	0.996	0.996	0.987	0.912
Load=75%	-	-	0.992	0.976
Load=100%	-	-	0.996	0.995

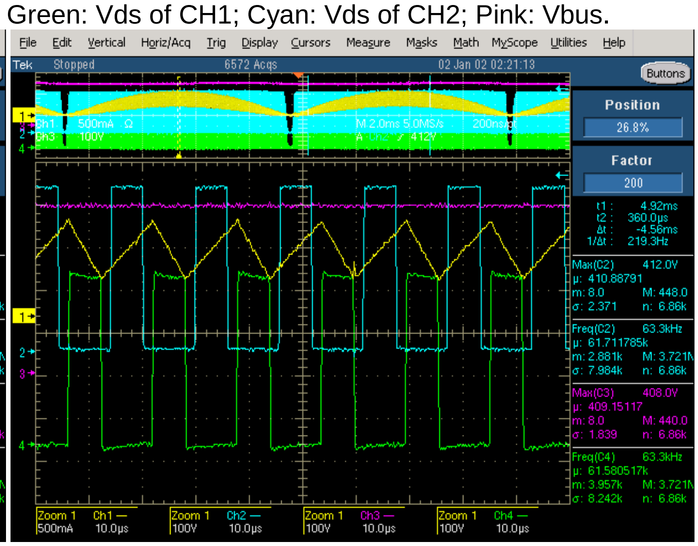
Efficiency of PFC stage

Vin (Vac)	Pin (W)	Vo (V)	Io (A)	Po (W)	Efficiency
90	1256.6	392.27	3.020	1184.66	94.27%
110	1609.2	392.27	3.905	1531.81	95.20%
220	3314.3	392.30	8.280	3248.24	98.00%
264	3296.0	392.46	8.285	3251.53	98.60%

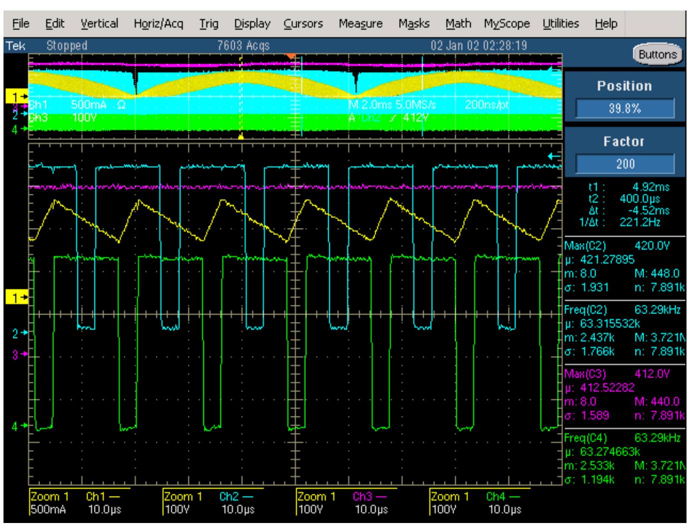
Waveforms of PFC stage. Yellow: Inductance current of CH1; Green: Vds of CH1; Cyan: Vds of CH2; Pink: Vbus.



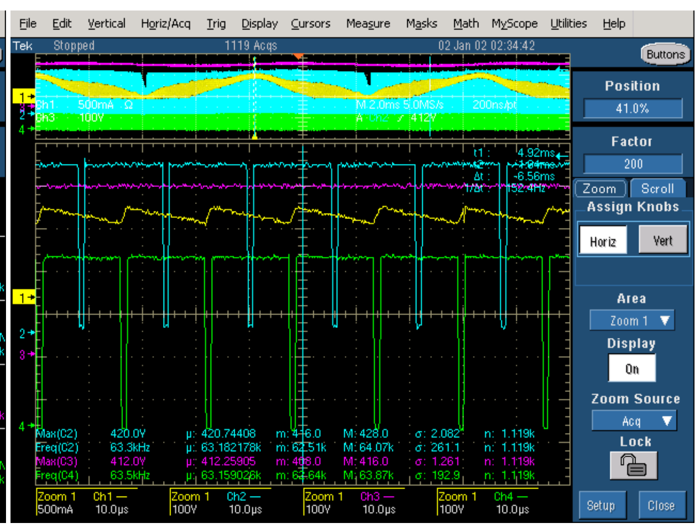
Vin=90Vac, Pin=1250W



Vin=110Vac, Pin=1610W

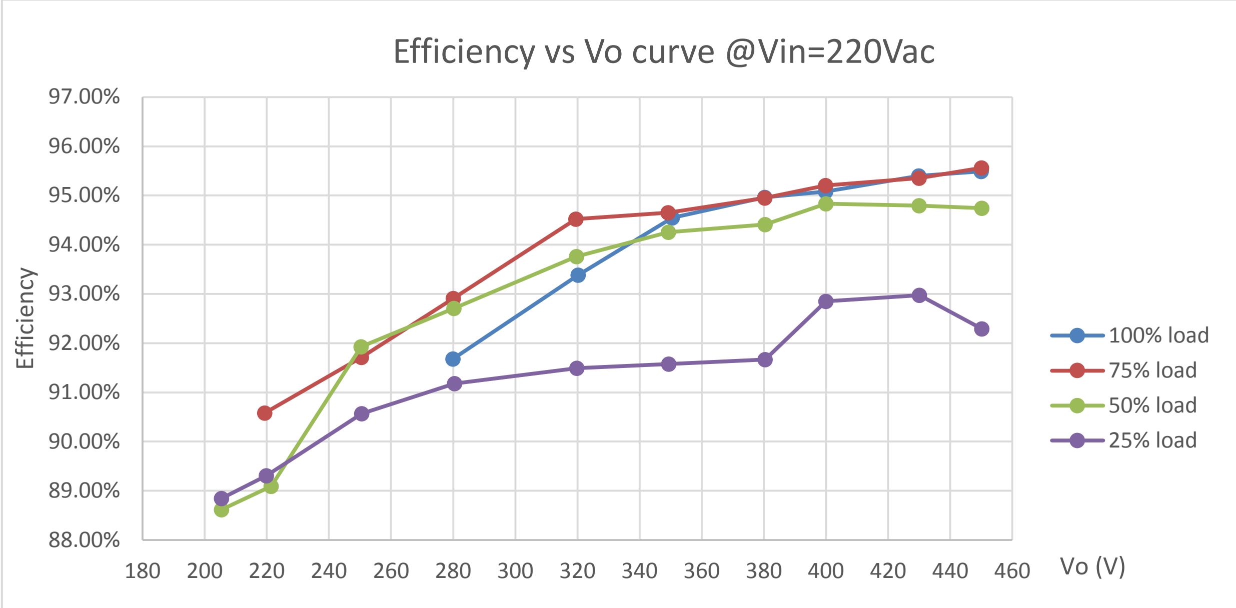


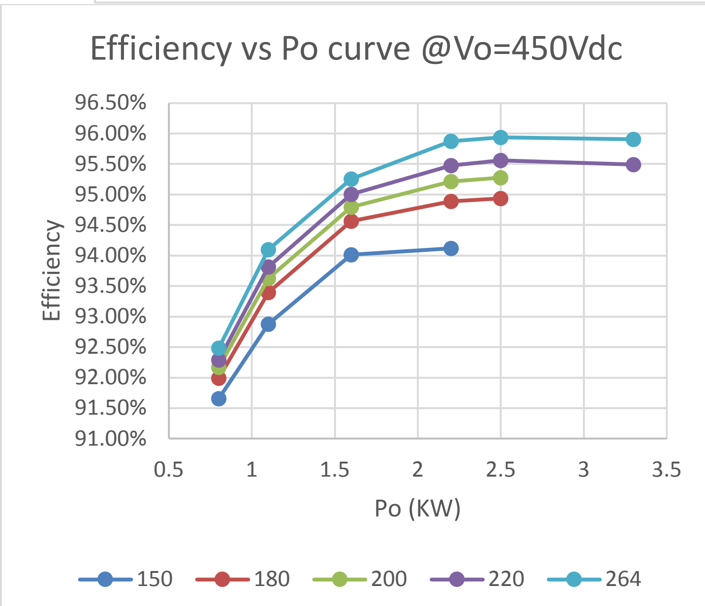
Vin=220Vac, Pin=3315W

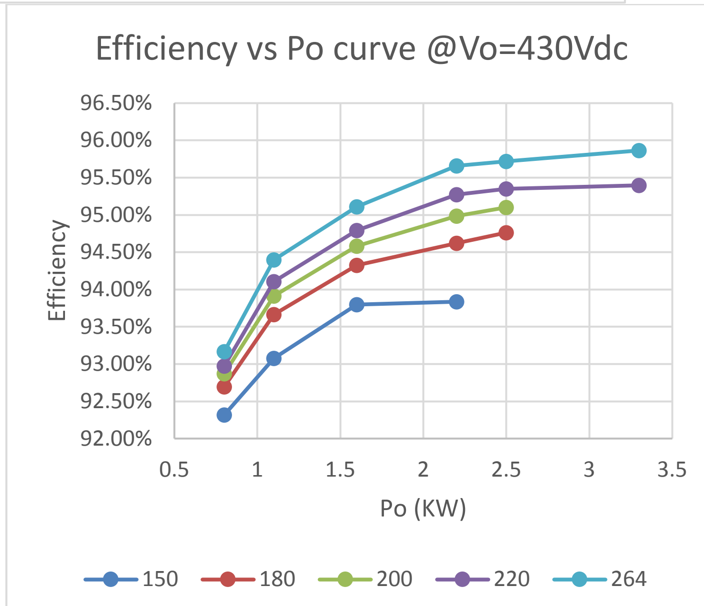


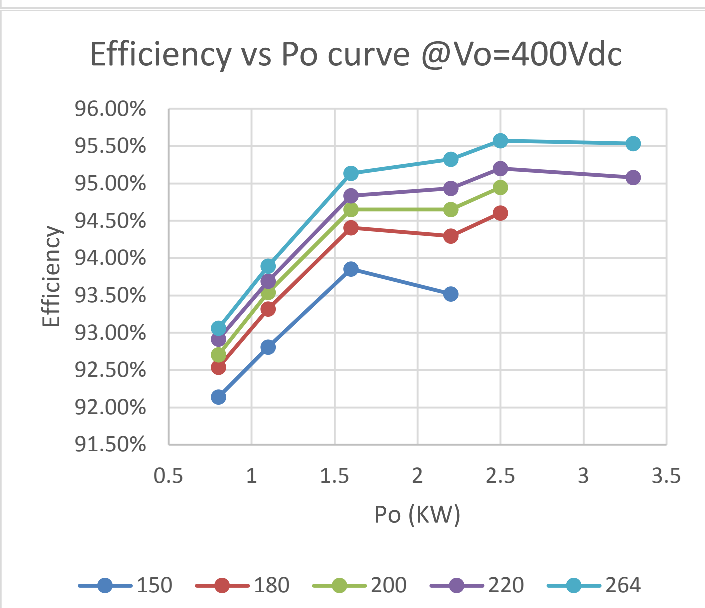
Vin=264Vac, Pin=3296W

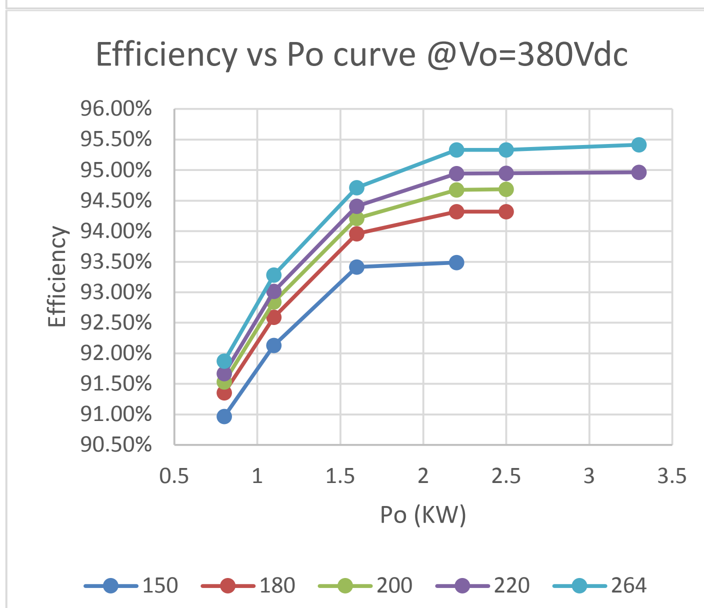
Efficiency of total set

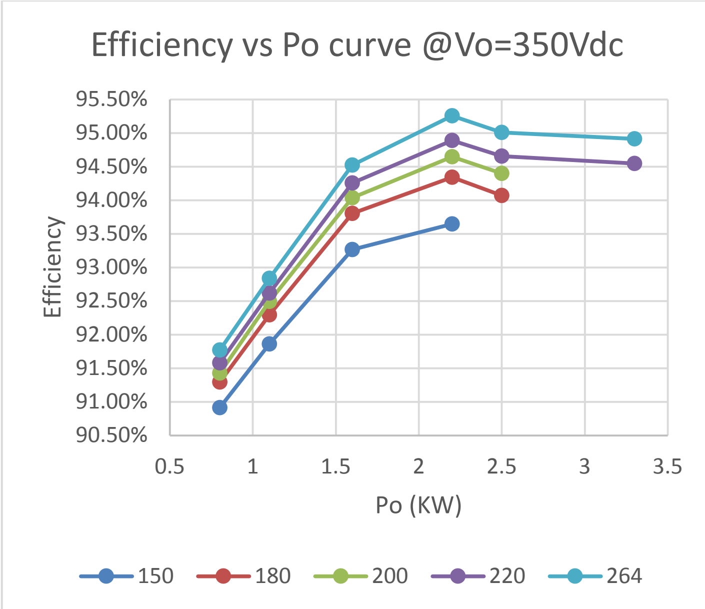


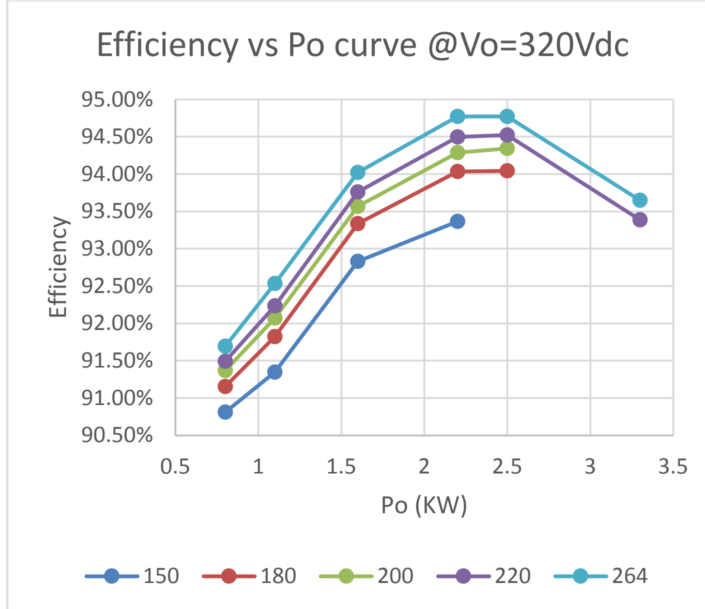


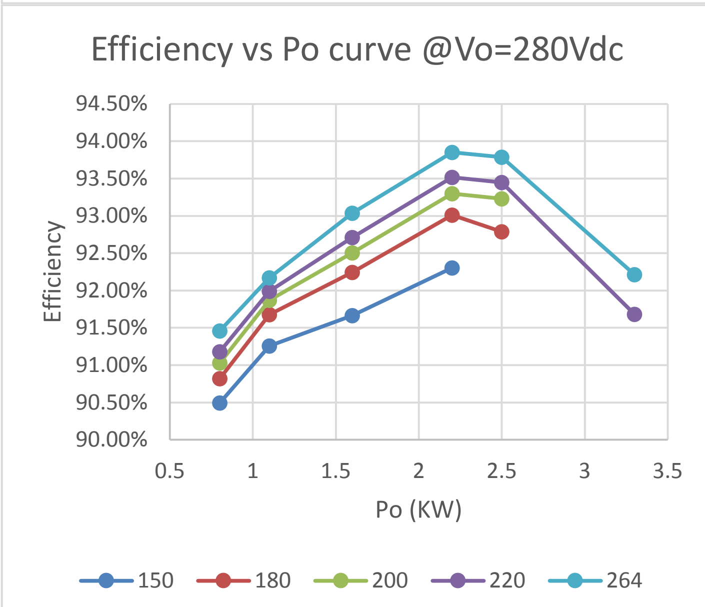


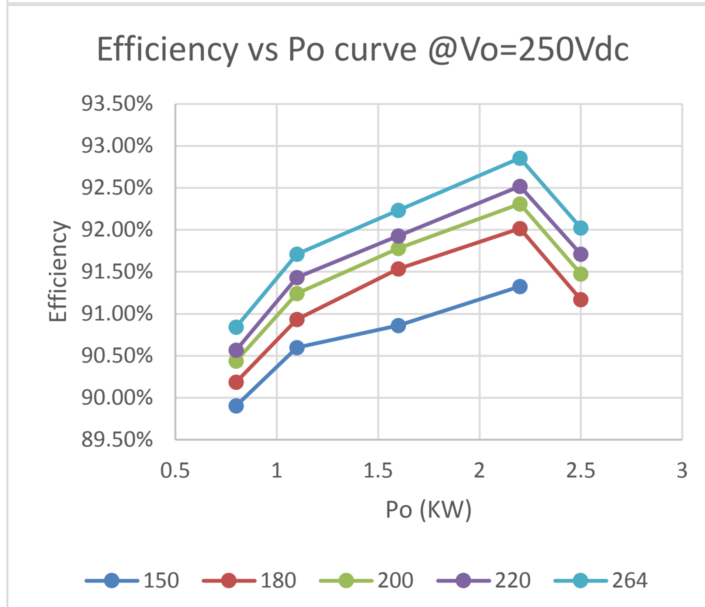


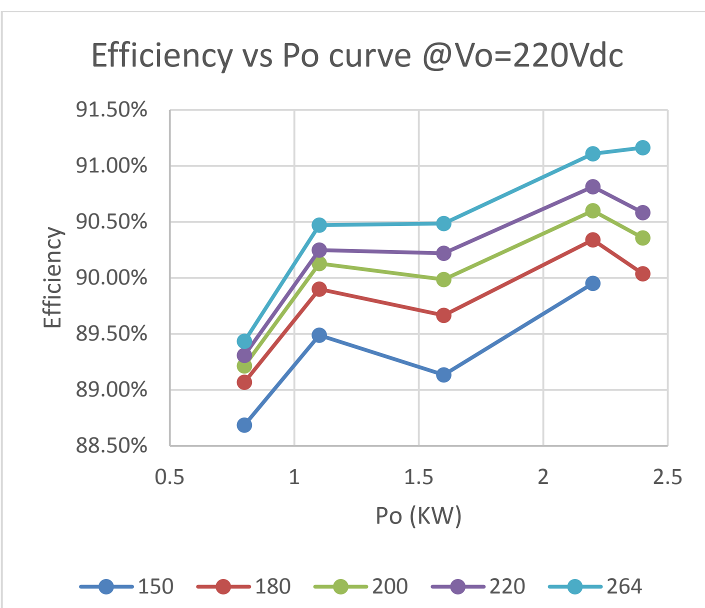


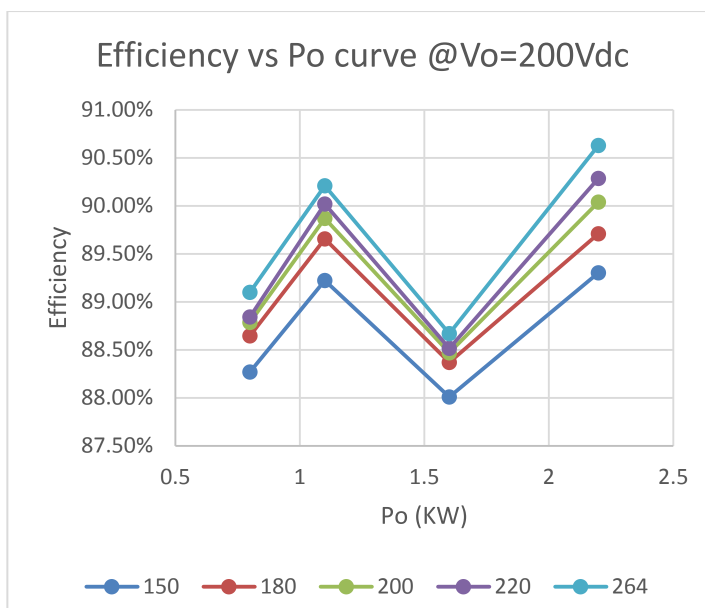

Efficiency vs Po curve @Vo=350Vdc
95.50%
95.00%
94.50%
94.00%
93.50%
93.00%
92.50%
92.00%
91.50%
91.00%
90.50%
Efficiency
0.5 1 1.5 2 2.5 3 3.5
Po (KW)
150 180 200 220 264


Efficiency vs Po curve @Vo=320Vdc
95.00%
94.50%
94.00%
93.50%
93.00%
92.50%
92.00%
91.50%
91.00%
90.50%
Efficiency
0.5 1 1.5 2 2.5 3 3.5
Po (KW)
150 180 200 220 264

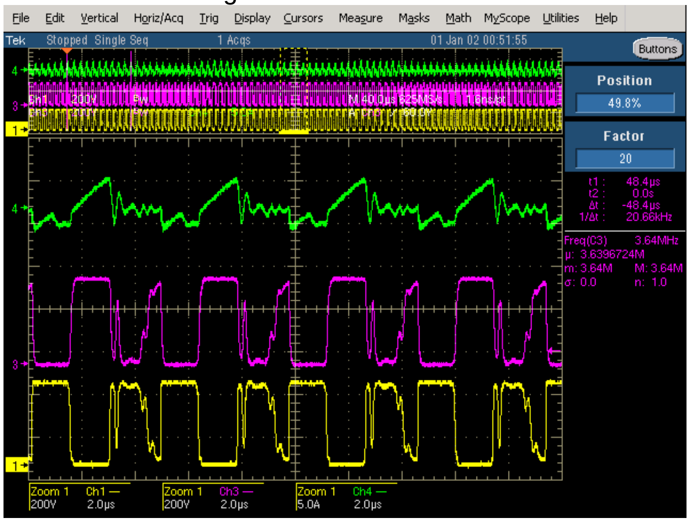

Efficiency vs Po curve @Vo=280Vdc
94.50%
94.00%
93.50%
93.00%
92.50%
92.00%
91.50%
91.00%
90.50%
90.00%
Efficiency
0.5 1 1.5 2 2.5 3 3.5
Po (KW)
150 180 200 220 264


Efficiency vs Po curve @Vo=250Vdc
93.50%
93.00%
92.50%
92.00%
91.50%
91.00%
90.50%
90.00%
89.50%
Efficiency
0.5 1 1.5 2 2.5 3
Po (KW)
150 180 200 220 264

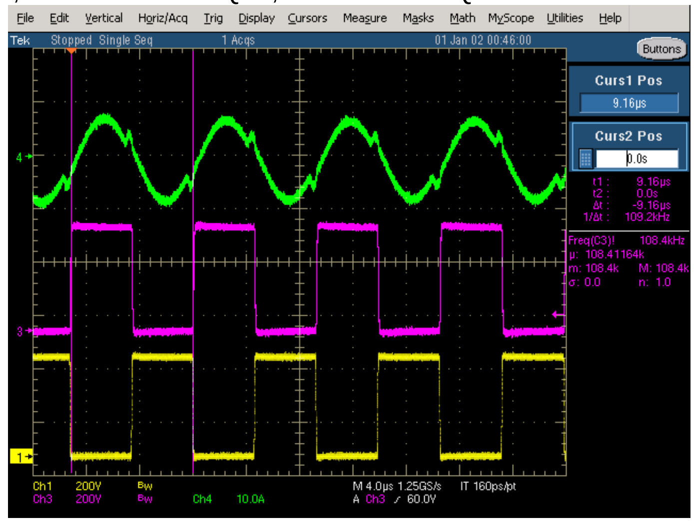

Efficiency vs Po curve @Vo=220Vdc
91.50%
91.00%
90.50%
90.00%
89.50%
89.00%
88.50%
Efficiency
0.5 1 1.5 2 2.5
Po (KW)
150 180 200 220 264


Efficiency vs Po curve @Vo=200Vdc
91.00%
90.50%
90.00%
89.50%
89.00%
88.50%
88.00%
87.50%
Efficiency
0.5 1 1.5 2 2.5
Po (KW)
150 180 200 220 264

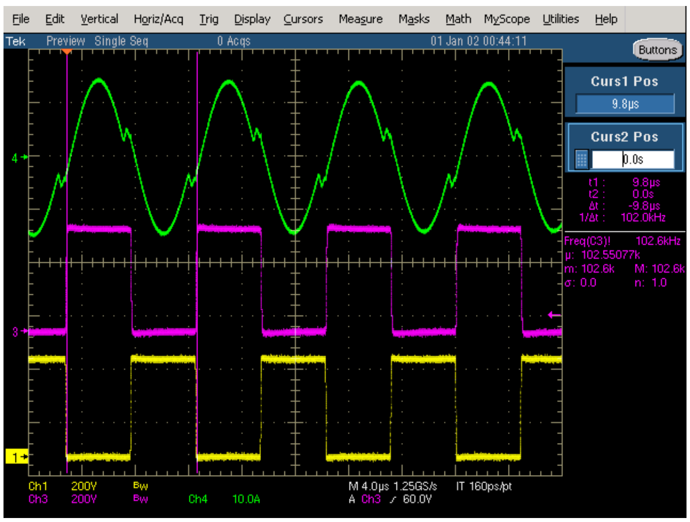
Waveforms of LLC stage. : Green: Current of the resonate tank; Yellow: Drain of Q61; Pink: Drain of Q71.



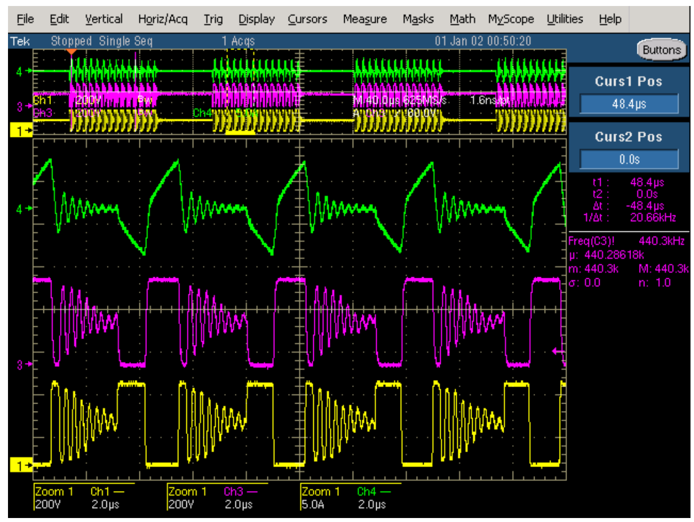
Vo=450Vdc, Load=10%



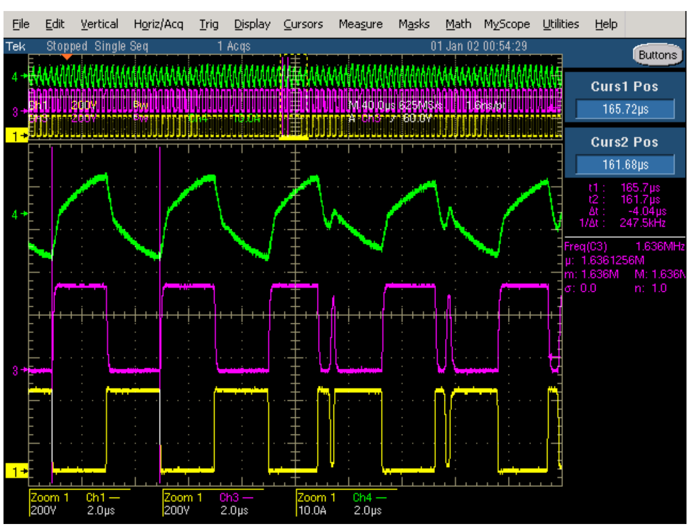
Vo=450Vdc, Load=50%



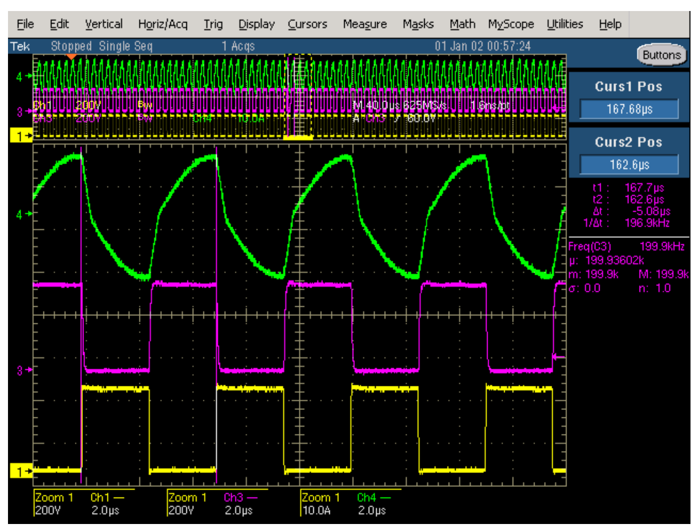
Vo=450Vac, Load=100%



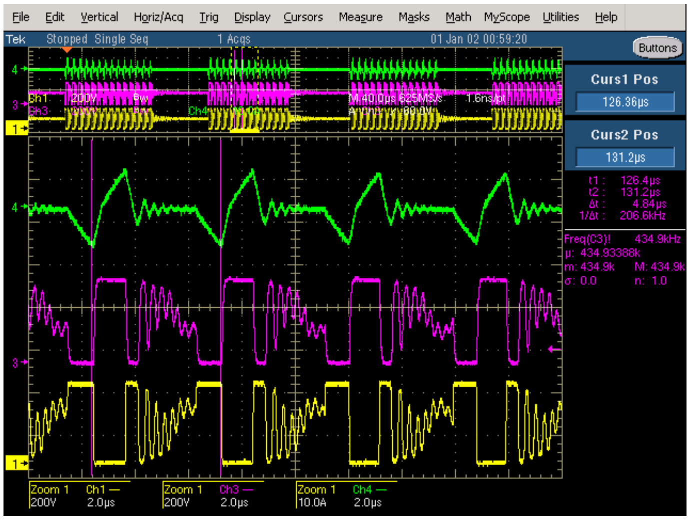
Vin=350Vac, Load=10%



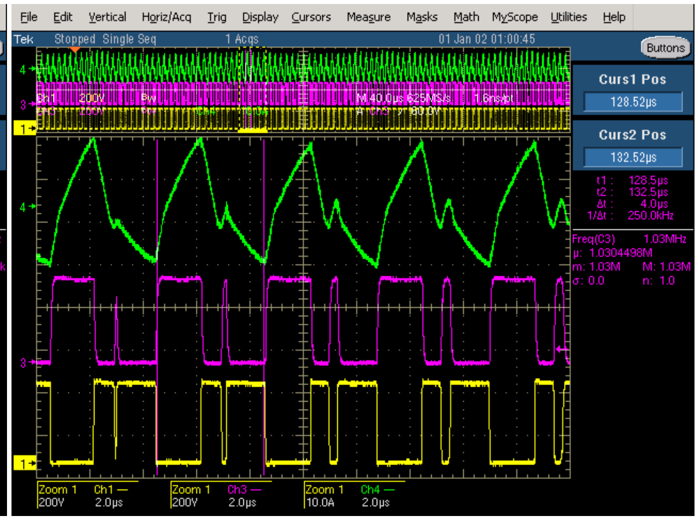
Vo=350Vac, Load=50%



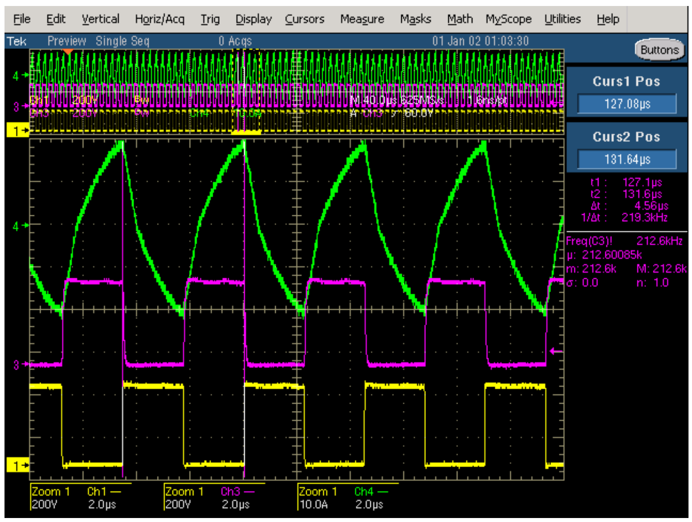
Vin=350Vac, Load=100%



Vo=250Vac, Load=10%

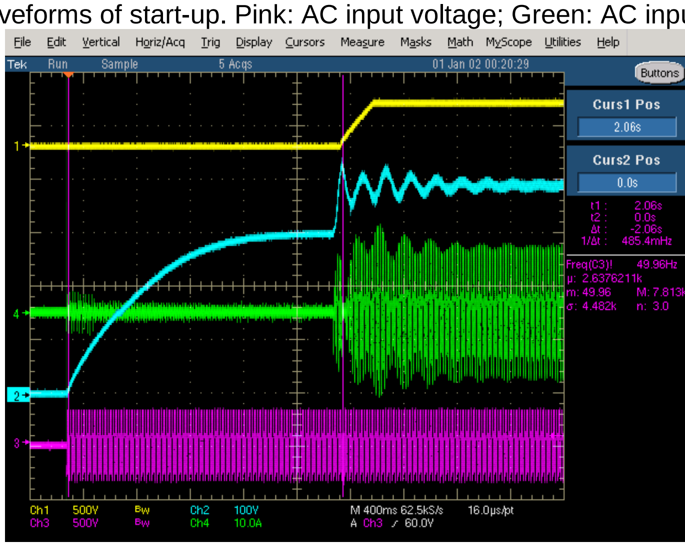


Vin=250Vac, Load=50%

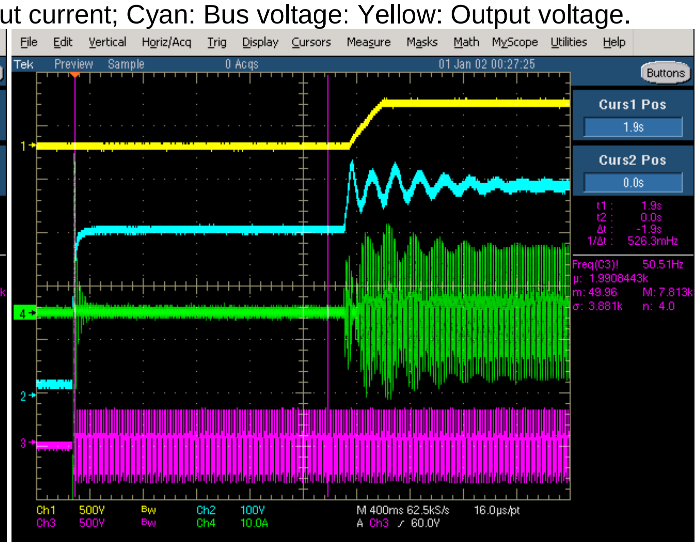


Vo=250Vac, Load=100%

Waveforms of start-up. Pink: AC input voltage; Green: AC input current; Cyan: Bus voltage: Yellow: Output voltage.



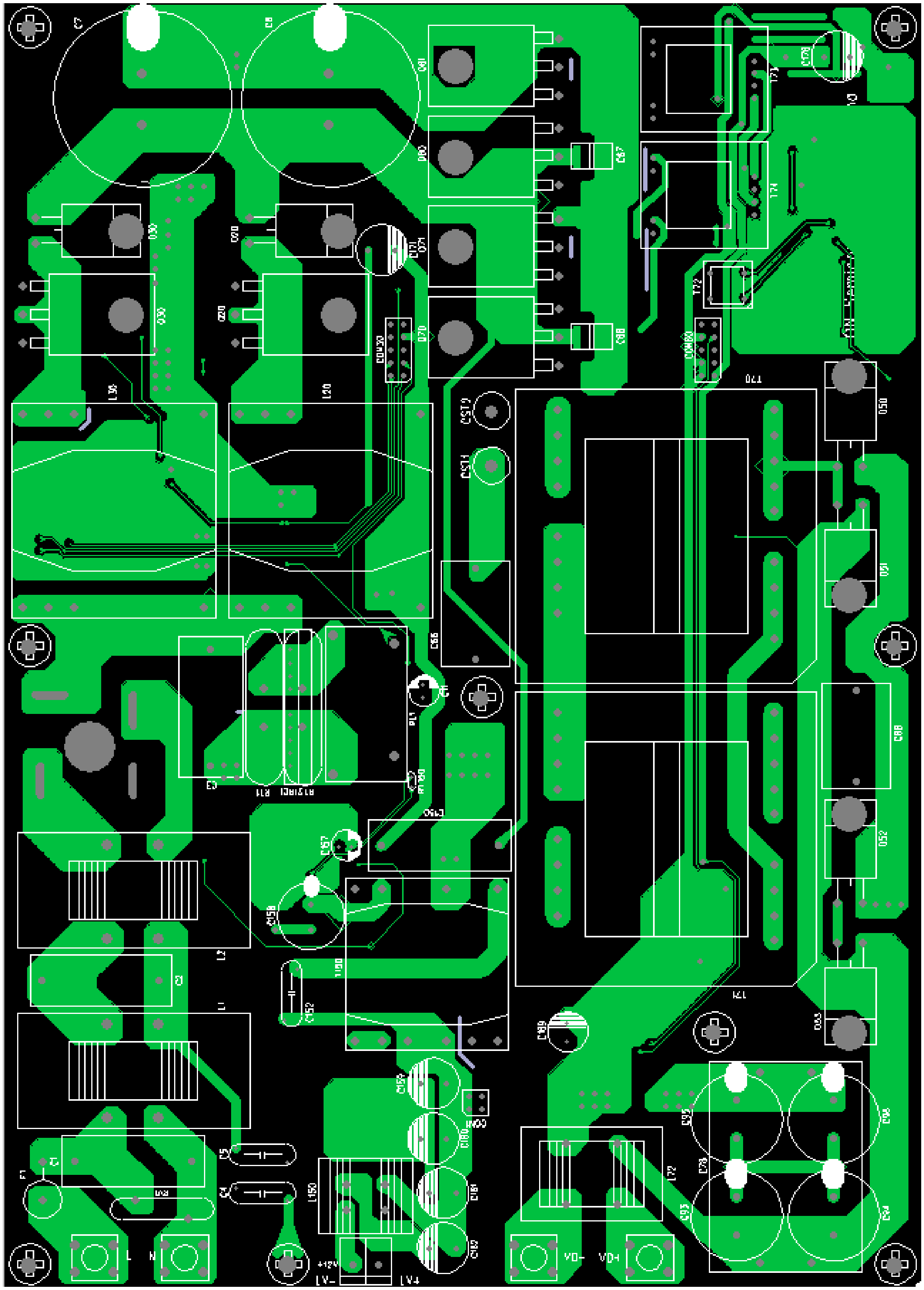
Switch mode inrush current limit board



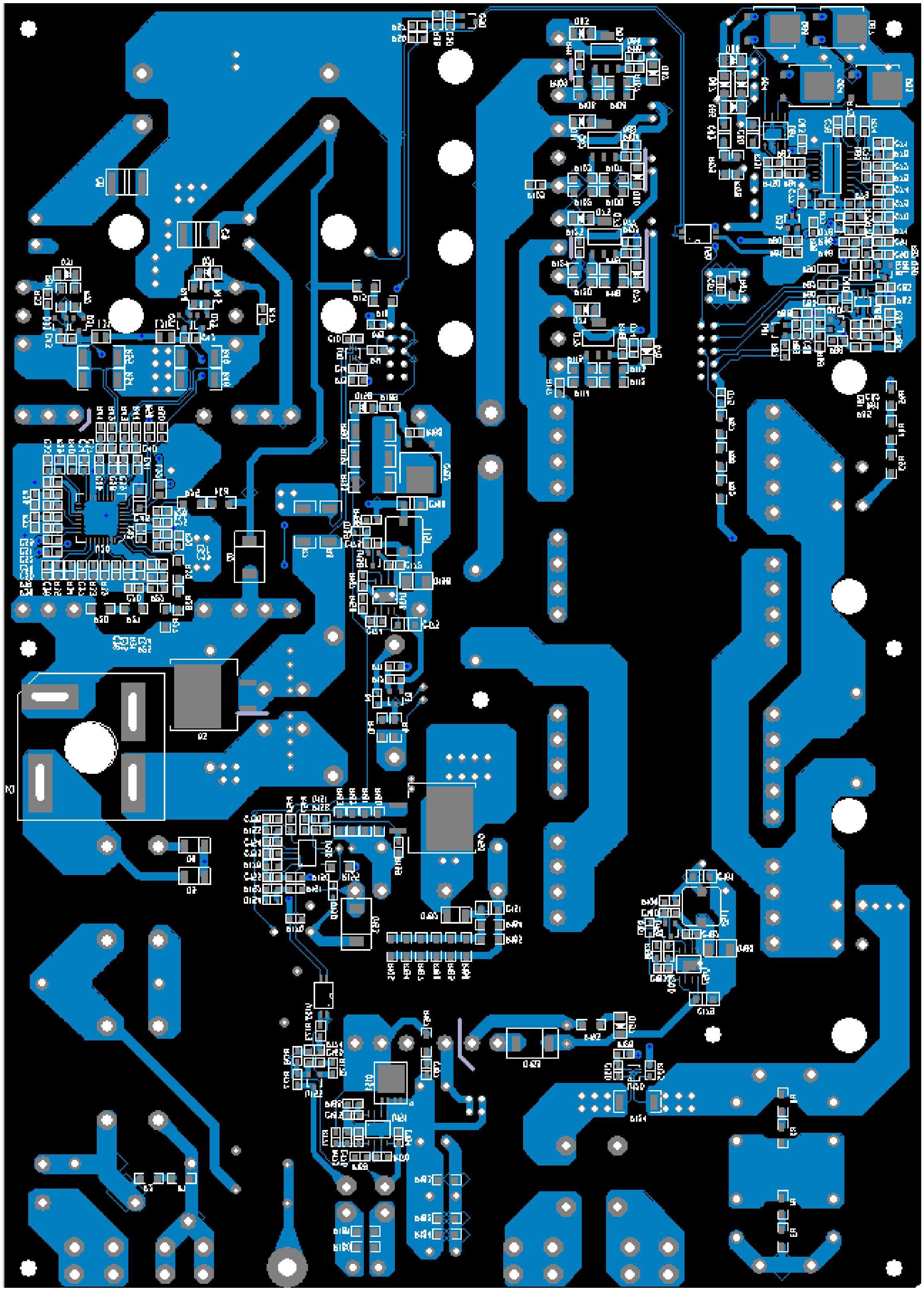
NTC

PCB Layout

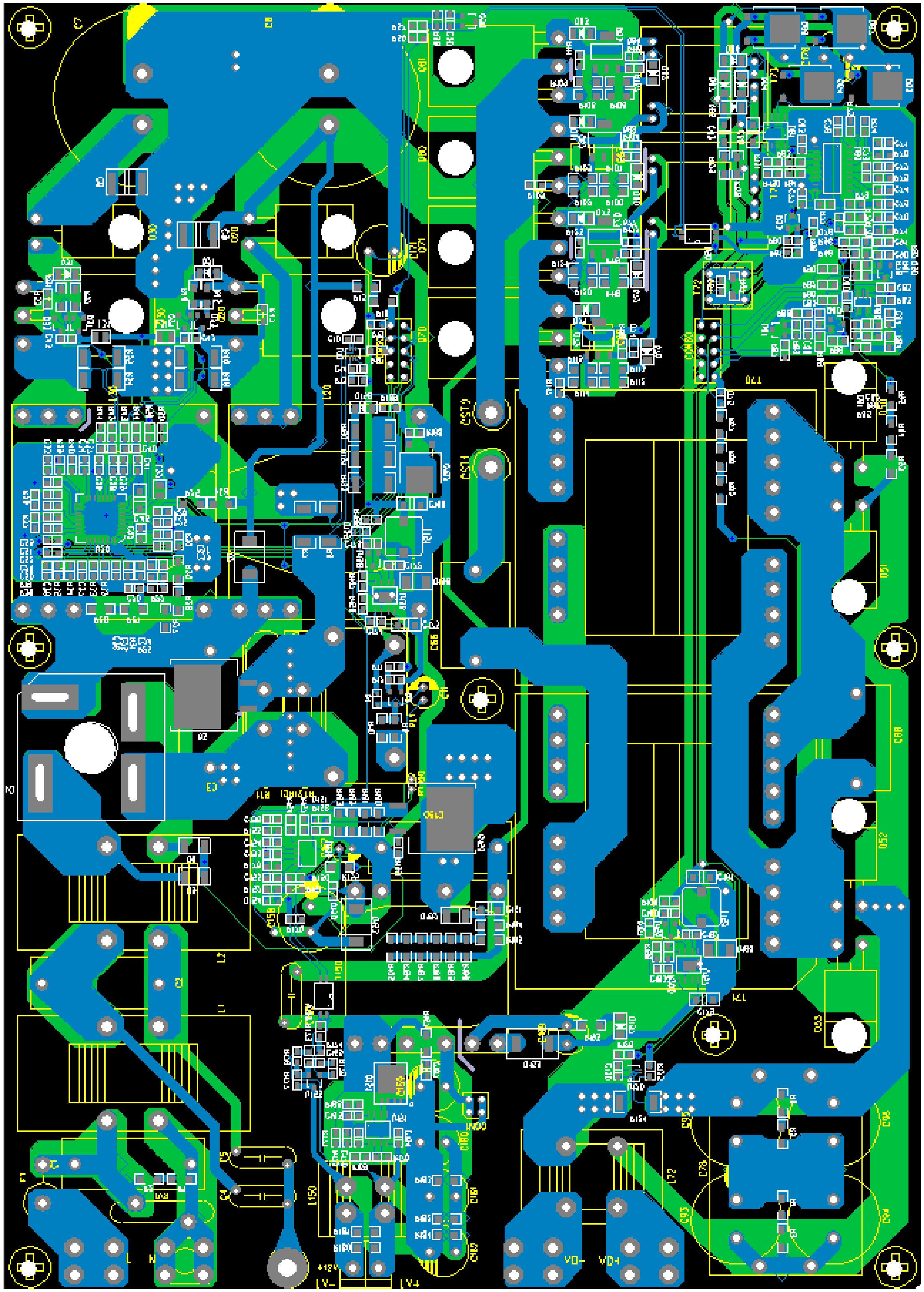
Top side of main board. 254x180.4x2mm. 2oz.



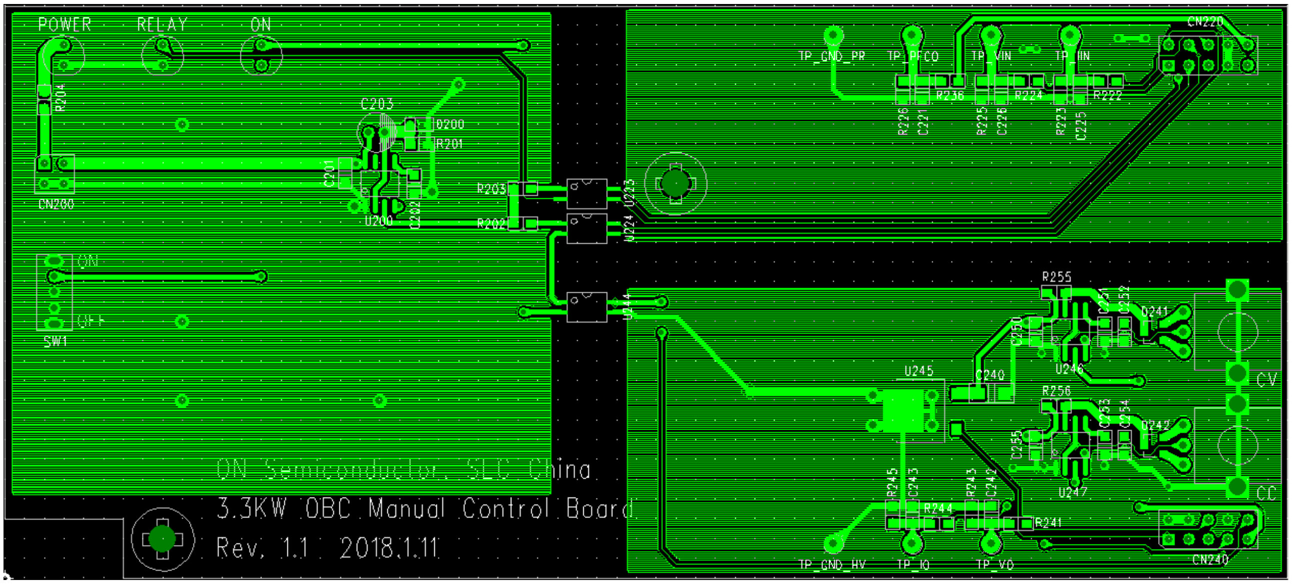
Bottom side of main board



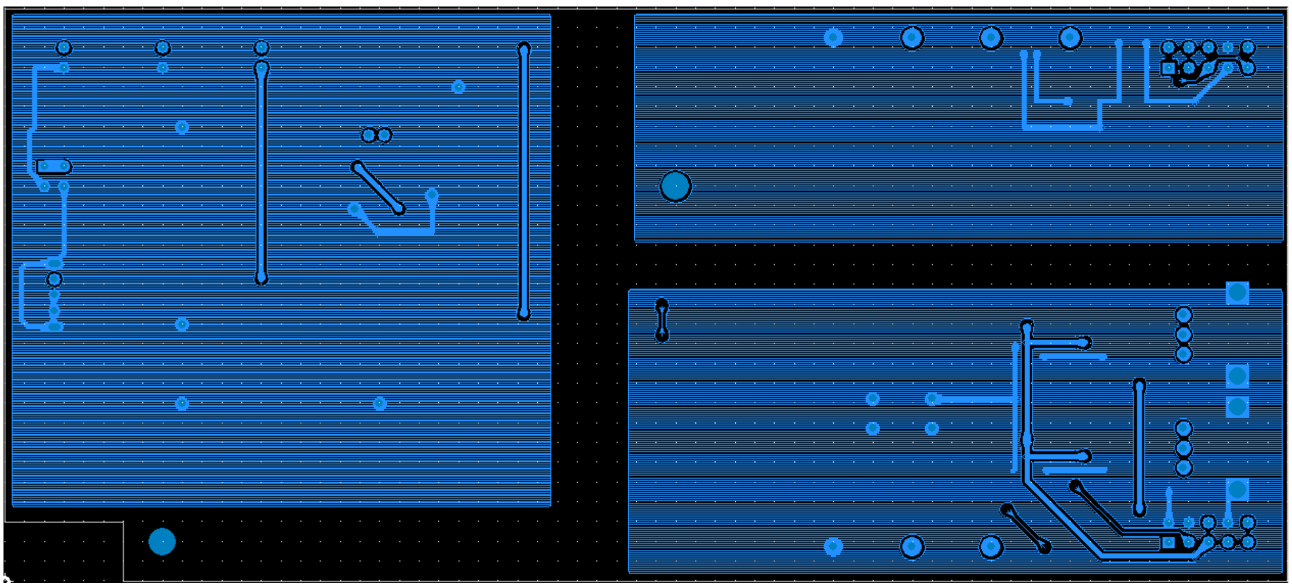
View through of main board



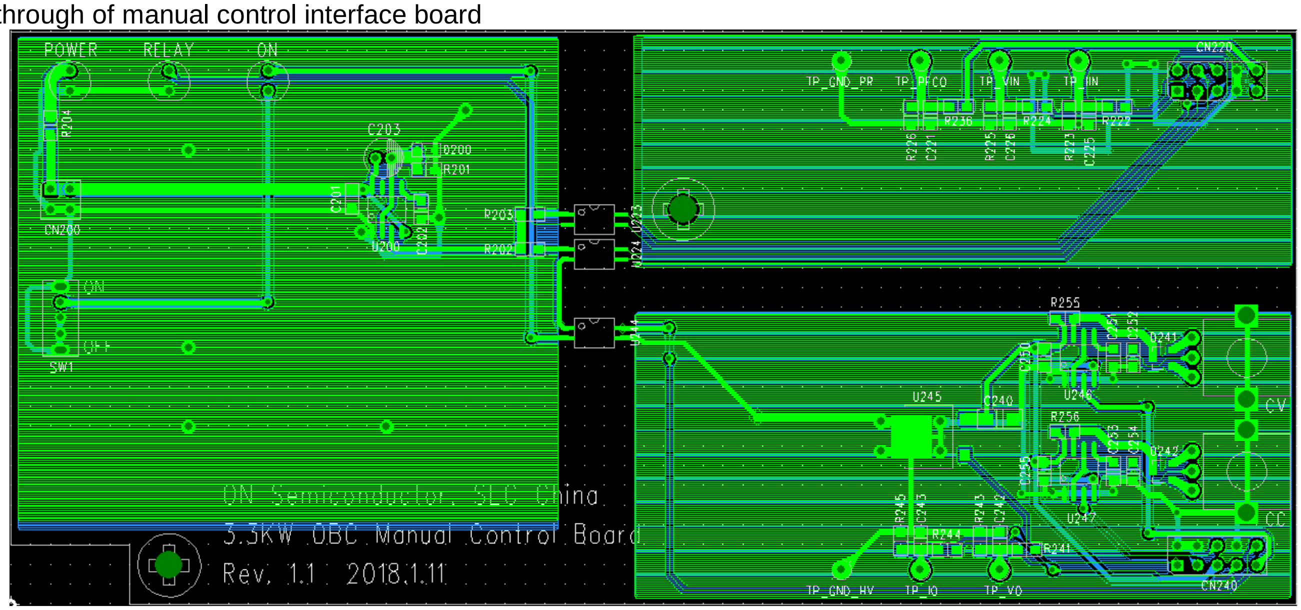
Top side of manual control interface board. 163.1x 73.7x 1.2mm.



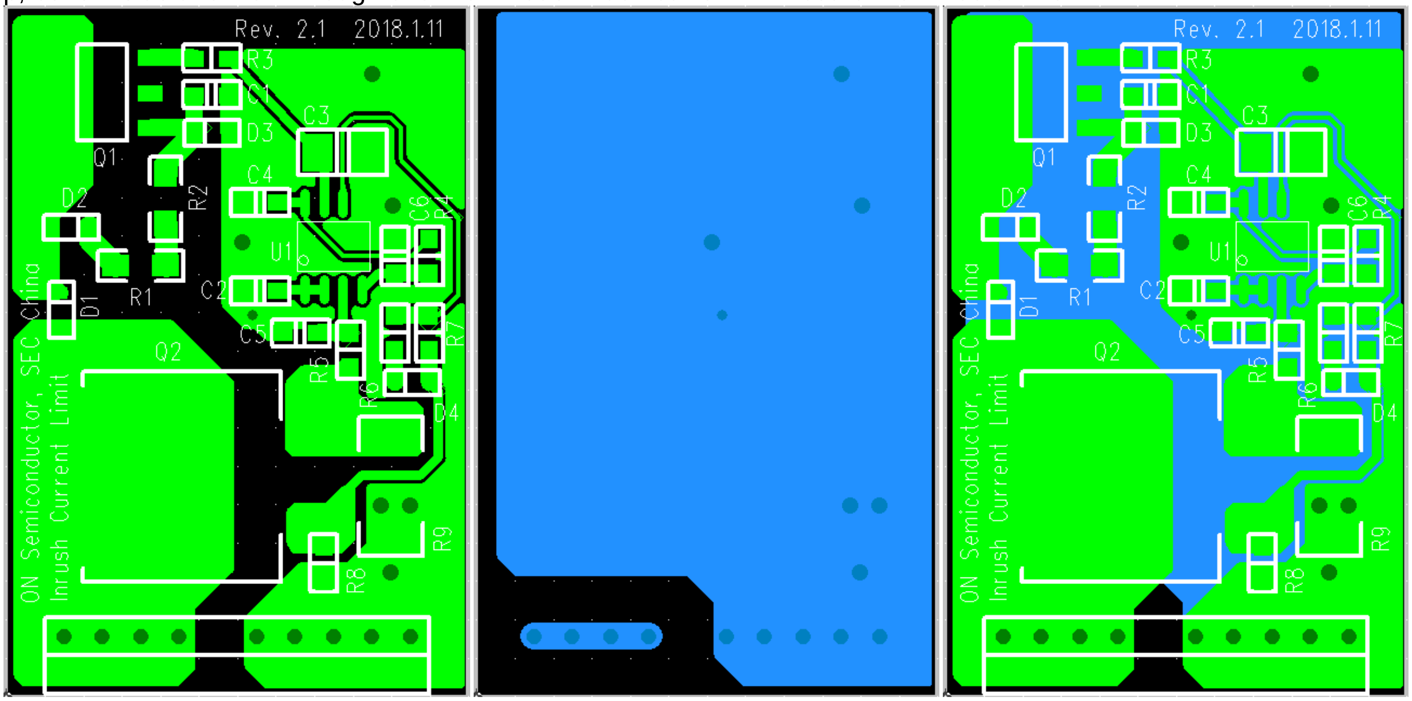
Bottom side of manual control interface board



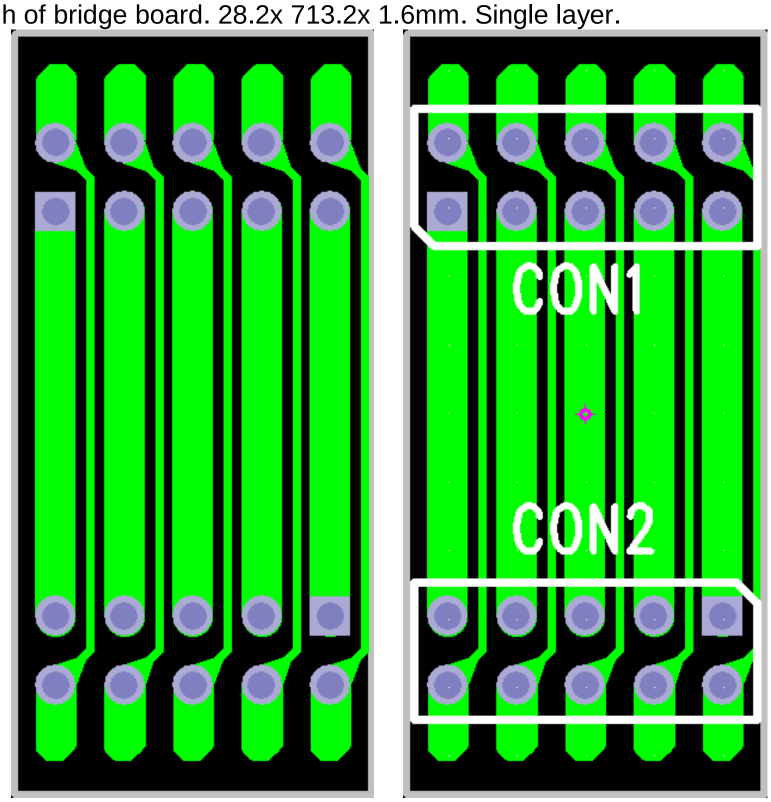
View through of manual control interface board



Top, bottom side and view through of switch mode inrush current limit board. 45.7x 30.5x 1.6mm.



Bottom view and view through of bridge board. 28.2x 713.2x 1.6mm. Single layer.



Bill of Materials

Main board

Description	Manufacturer Part Number	Manufacturer	Qty.	Designator
IC PWM Controller, QR, SOIC9	NCP1340B3D1R2G	ON Semiconductor	1	U150,
IC ICCM PFC Controller, QFP32	FAN9672Q	ON Semiconductor	1	U20,
IC Current mode LLC Controller, SOP16	FAN7688SJX	ON Semiconductor	1	U60,
IC SR Controller, SO8	FAN6224M	ON Semiconductor	1	U151,
IC Dual 4A Low-Side Gate Drivers, SO8	FAN3224TUMX-F085	ON Semiconductor	1	U61,
IC Buck Switcher, 1.2 A, 2 MHz, SO8EP	NCV890100PDR2G	ON Semiconductor	2	U156, U157,
IC 3.3V Voltage Reference, SOT-23	NCV51460SN33T1G	ON Semiconductor	2	U158, U159,
IC Current Sense Amplifier, SC70-6	NCV210SQT2G	ON Semiconductor	2	U10, U120,
IC RRO OP Amplifier, SOT-23 5L	NCV2003SN2T1G	ON Semiconductor	1	U80,
IC Shunt Regulator, SOT23-3L	SC431AVSNT1G	ON Semiconductor	2	U81, U153,
IC Photo Coupler High Temp, MFP-4L	FODM8801C	ON Semiconductor	2	U50, U152,
MOSFET 259mΩ 800V, D2PAK	FCB290N80	ON Semiconductor	1	Q150,
MOSFET 91mΩ 600V, TO-247	FCH104N60F_F085	ON Semiconductor	4	Q60, Q61, Q70, Q71,
MOSFET 2.4mΩ 60V, SO8-FL	NVMFS5C628NLT3G	ON Semiconductor	1	Q151,
MOSFET 68mΩ 650V, TO-247	FCH077N65F_F085	ON Semiconductor	2	Q20, Q30,
Transistor 40 V, 3.0 A PNP, SOT223	NJT4030PT1G	ON Semiconductor	4	Q62, Q63, Q72, Q73,
Transistor 25 V 5A NPN, DPAK	MJD200G	ON Semiconductor	2	Q64, Q66,
Transistor 25 V 5A PNP, DPAK	MJD210G	ON Semiconductor	2	Q65, Q67,
Transistor 40 V 3A NPN, DPAK	NJVMJD31T4G	ON Semiconductor	1	Q152,
Transistor 40V 2A PNP, SOT23	NSV40200LT1G	ON Semiconductor	3	Q22, Q32, Q53,
Transistor 40V 2A NPN, SOT23	NSV40201LT1G	ON Semiconductor	3	Q3, Q21, Q31,
Transistor 40V 0.2A NPN, SOT23	MMBT3904LT1G	ON Semiconductor	1	Q50,
MOSFET 60V 7.5Ω, SOT23	2V7002LT1G	ON Semiconductor	2	Q80, Q90,
Bridge Rectifier 35A 600V, GBPC-4L	GBPC3506	ON Semiconductor	1	D1,
FR Diode 16A 600V 60nS, D2PAK	NRVUB1660CTT4G	ON Semiconductor	1	D3,
SIC Diode 30A 650V, TO220	FFSP3065A	ON Semiconductor	6	D20, D30, D50, D51, D52, D53,
Diode 1A 1000V, SMA	NRVA4007T3G	ON Semiconductor	3	D5, D6, D152,
Schottky Diode 3A 100V, SMC	NRVBS3100T3G	ON Semiconductor	2	D153, D155,
Schottky Diode 3A 40V, SMA	MBRA340T3G	ON Semiconductor	2	D158, D160,
Schottky Diode 1A 20V, SOD123	NRVB120ESFT1G	ON Semiconductor	14	D21, D31, D60, D61, D62, D63, D64, D65, D66, D67, D70, D71, D72, D73,
Switching Diode 0.2A 100V, SOD323	BAS16HT1G	ON Semiconductor	13	D4, D15, D68, D69, D74, D75, D76, D77, D150, D151, D154, D159, D161,
ZENER Diode 0.5W 22V, SOD123	SZMMSZ22T1G	ON Semiconductor	2	D156, D157,
Chip resister 0805 0ohm-J		Any	1	R68,
Chip resister 0805 10ohm-J		Any	4	R13, R80, R126, R157,
Chip resister 0805 22ohm-J		Any	1	R158,
Chip resister 0805 47ohm-J		Any	4	R104, R110, R116, R122,
Chip resister 0805 82ohm-J		Any	2	R197, R200,
Chip resister 0805 100ohm-J		Any	2	R150, R154,
Chip resister 0805 220ohm-J		Any	2	R50, R56,

Chip resister 0805 470ohm-J		Any	6	R41, R42, R43, R44, R188, R189,
Chip resister 0805 1Kohm-J		Any	4	R63, R64, R130, R131,
Chip resister 0805 1.2Kohm-J		Any	1	R199,
Chip resister 0805 1.5Kohm-J		Any	1	R196,
Chip resister 0805 2.2Kohm-J		Any	7	R59, R60, R61, R86, R151, R153, R173,
Chip resister 0805 3Kohm-J		Any	1	R87,
Chip resister 0805 4.7Kohm-J		Any	1	R174,
Chip resister 0805 4.75Kohm-F		Any	7	R36, R82, R83, R89, R91, R92, R125,
Chip resister 0805 5.1Kohm-J		Any	1	R71,
Chip resister 0805 8.2Kohm-J		Any	3	R11, R12, R35,
Chip resister 0805 10Kohm-J		Any	20	R19, R39, R47, R53, R57, R69, R75, R81, R84, R85, R90, R105, R111, R117, R123, R156, R159, R175, R177, R198,
Chip resister 0805 12.4Kohm-F		Any	4	R33, R34, R78, R172,
Chip resister 0805 12.7Kohm-F		Any	2	R14, R26,
Chip resister 0805 15Kohm-J		Any	1	R74,
Chip resister 0805 18Kohm-J		Any	4	R30, R37, R38, R70,
Chip resister 0805 27Kohm-J		Any	1	R170,
Chip resister 0805 33Kohm-J		Any	3	R31, R88, R96,
Chip resister 0805 36Kohm-J		Any	2	R23, R72,
Chip resister 0805 39Kohm-J		Any	3	R32, R176, R179,
Chip resister 0805 43Kohm-J		Any	1	R169,
Chip resister 0805 47Kohm-J		Any	1	R40,
Chip resister 0805 68Kohm-J		Any	1	R77,
Chip resister 0805 75Kohm-J		Any	1	R168,
Chip resister 0805 100Kohm-J		Any	1	R98,
Chip resister 0805 120Kohm-J		Any	1	R171,
Chip resister 0805 200Kohm-J		Any	4	R22, R73, R79, R178,
Chip resister 0805 360Kohm-J		Any	1	R152,
Chip resister 1206 0ohm-J		Any	4	R102, R108, R114, R120,
Chip resister 1206 0.62ohm-J		Any	4	R160, R161, R162, R163,
Chip resister 1206 1ohm-J		Any	2	R128, R129,
Chip resister 1206 2.2ohm-J		Any	1	R167,
Chip resister 1206 4.7ohm-J		Any	8	R100, R101, R106, R107, R112, R113, R118, R119,
Chip resister 1206 10ohm-J		Any	4	R45, R46, R51, R52,
Chip resister 1206 68ohm-J		Any	1	R97,
Chip resister 1206 82ohm-J		Any	1	R193,
Chip resister 1206 1Kohm-J		Any	2	R9, R10,
Chip resister 1206 1.5Kohm-J		Any	2	R180, R181,
Chip resister 1206 4.7Kohm-J		Any	1	R155,
Chip resister 1206 220Kohm-J		Any	4	R3, R4, R5, R6,
Chip resister 1206 330Kohm-J		Any	3	R93, R94, R95,
Chip resister 1206 470Kohm-J		Any	6	R164, R165, R166, R185, R186, R187,
Chip resister 1206 750Kohm-J		Any	3	R65, R66, R67,
Chip resister 1206 1Mohm-J		Any	6	R15, R16, R20, R21, R24, R25,
Chip resister 1206 2Mohm-F		Any	3	R27, R28, R29,
Chip resister 2512 2mohm-F	SMA25A2FR002T	SART	3	R7, R8, R124,
Chip resister 2512 30mohm-J	SK25G1FR030T	SART	2	R49, R55

Chip resister 2512 20mohm-J	SK25G1FR020T	SART	2	R48, R54,
Chip resister 2512 470ohm-J		Any	3	R190, R191, R192,
NTC 100Kohm 1%, AEC-Q200	B57540G1104F000	TDK	1	RT150,
Disk Varistor 320V D20	820423211	WURTH	1	RV1
MLCC 0805-50V-10pFK-NP0	‘885012007051	WURTH	3	C70, C154, C170,
MLCC 0805-50V-100pFK-NP0	885012007057	WURTH	3	C30, C32, C156,
MLCC 0805-450V-100pFK-NP0	CGA4C4C0G2W101J060AA	TDK	3	C30, C32, C156,
MLCC 0805-50V-220pFK-NP0	885012007059	WURTH	1	C77,
MLCC 0805-450V-220pFK-NP0	CGA4C4C0G2W221J060AA	TDK	1	C77,
MLCC 0805-50V-471J-NP0	885012007061	WURTH	8	C23, C26, C27, C34, C71, C75, C82, C155,
MLCC 0805-450V-471J-NP0	CGA4C4C0G2W471J060AA	TDK	8	C23, C26, C27, C34, C71, C75, C82, C155,
MLCC 0805-50V-102M-X7R	885012207086	WURTH	8	C29, C31, C37, C40, C61, C83, C163, C167,
MLCC 0805-100V-102M-X7R	CGA4C2C0G2A102J060AA	TDK	8	C29, C31, C37, C40, C61, C83, C163, C167,
MLCC 0805-50V-222M-X7R	885012207088	WURTH	6	C36, C38, C39, C41, C174, C183,
MLCC 0805-50V-222M-X7R	CGA4C2C0G1H222J060AA	TDK	6	C36, C38, C39, C41, C174, C183,
MLCC 0805-50V-472M-X7R	‘885012207090	WURTH	1	C72,
MLCC 0805-50V-472M-X7R	CGA4C2C0G1H472J060AA	TDK	1	C72,
MLCC 0805-50V-103M-X7R	885012207092	WURTH	7	C25, C28, C33, C35, C50, C81, C153,
MLCC 0805-50V-103M-X7R	CGA4C2C0G1H103J060AA	TDK	7	C25, C28, C33, C35, C50, C81, C153,
MLCC 0805-50V-473M-X7R	’885012207096	WURTH	3	C20, C76, C165,
MLCC 0805-100V-473M-X7R	CGA4J2X7R2A473M125AA	TDK	3	C20, C76, C165,
MLCC 0805-25V-104M-X7R	885012207072	WURTH	9	C14, C22, C80, C86, C120, C172, C175, C180, C182,
MLCC 0805-100V-104M-X7R	CGA4J2X7R2A104K125AA	TDK	9	C14, C22, C80, C86, C120, C172, C175, C180, C182,
MLCC 0805-25V-224M-X7R	885012207074	WURTH	2	C24, C73,
MLCC 0805-25V-224M-X7R	CGA4J2X7R1H224K125AA	TDK	2	C24, C73,
MLCC 0805-25V-474M-X7R	885012207076	WURTH	6	C21, C42, C43, C63, C92, C164,
MLCC 0805-25V-474M-X7R	CGA4J2X7R1E474K125AA	TDK	6	C21, C42, C43, C63, C92, C164,
MLCC 0805-25V-225M-X7R	’885012207079	WURTH	2	C84, C91,
MLCC 0805-25V-225M-X7R	CGA4J3X7R1E225K125AB	TDK	2	C84, C91,
MLCC 0805-16V-475M-X7R	’885012207052	WURTH	1	C74,
MLCC 0805-16V-475M-X7R	CGA4J3X7R1C475K125AB	TDK	1	C74,
MLCC 1206-25V-106M-X7R	885012208069	WURTH	3	C46, C166, C181
MLCC 1206-25V-106M-X7R	CGA5L1X7R1E106K160AC	TDK	3	C46, C166, C181
MLCC 1206-50V-475M-X7R	885012208094	WURTH	4	C60, C62, C173, C179
MLCC 1206-630V-222M-X7R	CGA5H4X7R2J222K115AA	TDK	1	C151,
MLCC 2220-630V-105M-X7T	CKG57NX7T2J105M500JJ	TDK	4	C6, C9, C67, C68,
E-Cap 25V-150uF-105(6.3X11mm)	860020473010	WURTH	1	C11,
E-Cap 35V-82uF-105-10Kh(6.3X15mm)	860160573010	WURTH	1	C157,
E-Cap 35V-220uF-105-LI(8X16mm)	86080574011	WURTH	1	C169,
E-Cap 35V-1500uF-105-LI(13X35mm)	860080578024	WURTH	1	C158,
E-Cap 25V-560uF-105-LI(10X20mm)	860080475017	WURTH	6	C159, C160, C161, C162, C171, C176,
E-Cap 250V-150uF-105-10Kh (18X31.5mm)	860241181007	WURTH	4	C93, C94, C95, C96,
E-Cap 450V-680uF-105 (35X57mm)	861141486026	WURTH	2	C7, C8,

Film Cap 630V 1uF PP	ECWFD2J105K	Panasonic	1	C150,
Film Cap 630V 2.2uF PP	ECWFD2J225K	Panasonic	1	C3,
Film Cap 1600V 47nF MPP	ECWHA3C473J	Panasonic	2	C66, C69,
Film Cap 800V 20uF PP	EZPE80206MTA	Panasonic	1	C78,
X-Cap 275VAC 1uF X2	890324026027CS	WURTH	2	C1, C2,
X-Cap 275VAC 1uF X2	ECQUAAF105K	Panasonic	2	C1, C2,
Y-Cap 400VAC 4700pF Y2	CD45-E2GA472M-NKA	TDK	3	C4, C5, C152,
Common Choke 1.0mH 25A	7448262510	WURTH	2	L1, L2
Common Choke 47uH 15A	744844470	WURTH	1	L72,
Common Choke 16uH 10A	7448421016	WURTH	1	L150,
Aux. Transformer PQ3230, 12-Pin, THT.	750343613	WURTH	1	T150,
LLC Transformer EPC54		HNDJ	2	T70, T71,
Current Transformer EE8	750343741	WURTH	1	T72,
Pulse Transformer EF20/10/6, THT	750343786	WURTH	2	T73, T74,
SMD Inductor 7X7X3.5mm-22uH-1.6A	784778220	WURTH	2	L151, L152,
SMD Inductor 7X7X4.5mm-22uH-1.7A	SPM7045VT-220M-D	TDK	2	L151, L152,
Chip Inductor 2016-1uH	74438343010	WURTH	3	L21, L22, L31,
Chip Inductor 2016-1uH Automotive	TFM201610ALMA1R0MTAA	TDK	3	L21, L22, L31,
PFC Inductor PQ4040 150uH	750343627	WURTH	2	L20, L30,
Connector 5mm 2Pins Screw type	691101710002	WURTH	1	12V
Connector 5mm Screw type. 200X300mil	74760050	WURTH	4	VO+, VO-, L, N,
Connector 2.54mm Dual Socket Header 4Pns	61300421821	WURTH	1	CON1,
Connector 2.54mm Dual Socket Header 10Pns	61301021821	WURTH	2	CON30, CON60,
RELAY 25A 250VAC	PCF-11202M	OEG	1	RL1
RELAY 20A 250VAC	ALF1P12	Panasonic	1	RL1
Spacer Plastic, metric, internal/external, 8mm	971080365	WURTH	6	
Spacer Brass, metric, internal/external, 8mm	971080324	WURTH	1	
FUSE 30A 250V 6X30mm		Any	1	F1

* The adjacent items in same shadow are optional in different manufacturer.

Manual control interface board.

Description	**Manufacturer Part Number**	**Manufacturer**	**Qty.**	**Designator**
IC Single Timer, SO8	NCV1455BDR2G	ON Semiconductor	3	U200, U246, U247,
IC 5V 0.5A Voltage Regulator, DPAK	NCV78M05BDTRKG	ON Semiconductor	1	U245,
Photo Coupler High Temp MFP-4L	FODM8801C	ON Semiconductor	3	U223, U224, U244,
Switching Diode 0.2A 100V, SOD323	BAS16HT1G	ON Semiconductor	1	D200,
Schottky Diode 0.2A 100V, SOT23	SBAV99LT3G	ON Semiconductor	2	D241, D242,
LED D=5mm THT Green	151051VS04000	WURTH	2	POWER, RELAY,
LED D=5mm THT Red	151051RS11000	WURTH	1	ON,
Chip resister 0805 1Kohm-J		Any	3	R202, R255, R256,
Chip resister 0805 2.2Kohm-J		Any	2	R203, R204,
Chip resister 0805 2.43Kohm-F		Any	2	R222, R224,
Chip resister 0805 12.4Kohm-F		Any	6	R223, R225, R226, R243, R244, R245,

Chip resister 0805 100Kohm-J		Any	2	R236, R241,
Chip resister 0805 150Kohm-J		Any	1	R201,
Potentiometer 50Kohm 10X11mm Vertical		Any	2	CC, CV,
MLCC 0805-50V-102M-X7R	885012207086	WURTH	5	C221, C225, C226, C242, C243,
MLCC 0805-100V-102M-X7R	CGA4C2C0G2A102J060AA	TDK	5	C221, C225, C226, C242, C243,
MLCC 0805-50V-222M-X7R	885012207088	WURTH	2	C252, C254,
MLCC 0805-50V-222M-X7R	CGA4C2C0G1H222J060AA	TDK	2	C252, C254,
MLCC 0805-50V-103M-X7R	885012207092	WURTH	3	C202, C251, C253,
MLCC 0805-50V-103M-X7R	CGA4C2C0G1H103J060AA	TDK	3	C202, C251, C253,
MLCC 0805-25V-104M-X7R	885012207072	WURTH	3	C201, C250, C255,
MLCC 0805-100V-104M-X7R	CGA4J2X7R2A104K125AA	TDK	3	C201, C250, C255,
MLCC 1206-25V-106M-X7R	885012208069	WURTH	1	C240,
MLCC 1206-25V-106M-X7R	CGA5L1X7R1E106K160AC	TDK	1	C240,
E-Cap 35V-10uF-105(5X11mm)	860020572003	WURTH	1	C203,
2.54mm Dual Socket Header 4Pns	61300421821	WURTH	1	CON200,
2.54mm Dual Socket Header 10Pns	61301021821	WURTH	2	CON220, CON240,
Test Pin		Any	7	TP_PFCO, TP_IIN, TP_VIN, TP_GND_PR, TP_GND_HV, TP_IO, TP_VO,
Switch 1 Connecter 2 Position, 8.6X4.4mm		Any	1	SW1,
Spacer Plastic, metric, internal/external, 15mm	971150365	WURTH	6	

* The adjacent items in same shadow are optional in different manufacturer.

Switch mode inrush current limit board.

Description	Manufacturer Part Number	Manufacturer	Qty.	Designator
IC Current Mode PWM Controller SO8	NCV3843BVD1R2G	ON Semiconductor	1	U1,
MOSFET 11.5Ω 600V QFET, SOT223	FQT1N60CTF-WS	ON Semiconductor	1	Q1,
MOSFET 173m Ω 600V SuperFET, D2PAK	FCB20N60-F085	ON Semiconductor	1	Q2,
Switching Diode 0.2A 100V, SOD323	BAS16HT1G	ON Semiconductor	3	D1, D2, D4,
ZENER Diode 0.5W 15V, SOD323	MM5Z15VT1G	ON Semiconductor	1	D3,
Chip resister 0805 4.7ohm-J		Any	1	R6,
Chip resister 0805 10ohm-J		Any	2	R7,
Chip resister 0805 22ohm-J		Any	1	R3,
Chip resister 0805 1Kohm-J		Any	1	R5,
Chip resister 0805 22Kohm-J		Any	1	R8,
Chip resister 0805 100Kohm-J		Any	1	R4,
Chip resister 1206 330Kohm-J		Any	2	R1, R2,
Chip resister 2512 0.1ohm-F		Any	1	R9,
MLCC 0805-50V-100pFK-NP0	885012007057	WURTH	2	C5, C6,
MLCC 0805-450V-100pFK-NP0	CGA4C4C0G2W101J060AA	TDK	2	C5, C6,
MLCC 0805-50V-103M-X7R	885012207092	WURTH	1	C2,
MLCC 0805-50V-103M-X7R	CGA4C2C0G1H103J060AA	TDK	1	C2,
MLCC 0805-25V-105M-X7R	885012207078	WURTH	2	C1, C4,

MLCC 0805-25V-105M-X7R	CGA4J3X7R1E105K125AB	TDK	2	C1, C4,
MLCC 1206-25V-106M-X7R	885012208069	WURTH	3	C46, C166, C181
MLCC 1206-25V-106M-X7R	CGA5L1X7R1E106K160AC	TDK	3	C46, C166, C181
2.54mm Header 10Pns 90Deg	61301011021	WURTH	1	

* The adjacent items in same shadow are optional in different manufacturer.

Bridge board.

Description	Manufacturer Part Number	Manufacturer	Qty.	Designator
2.54mm THT Angled Dual Pin Header 10P	61301021021	WURTH	2	CON1, CON2,