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Design Note – DN05096/D

Implementing multiple-output power supply for home appliances with FAN6605

Devices	Applications	Input voltage	Output power	Topology	Board Size
FAN6605MX FCD1300N80Z NCV8715	Home appliances	80 – 290 Vac	25 W	CCM Flyback	131 x 55 x 26 mm 2.2 W/inch^3
Output voltage	**Output current**	**Efficiency**	**Operating temperature**	**Cooling**	**Standby power**
12V (isolated)	0.05~2 A	above 87 % @ full load	0 – 50 °C	Convection open frame	< 50 mW
5V (isolated)	0.01~0.25 A				
15V (PGND)	5~15 mA				
5V (PGND)	20~40 mA				

Description

This design note provides elementary information about a multiple output, low no-load power consumption reference design that is targeting power supply for home appliances, such as refrigerator or similar types of equipment.

The power supply implements current-mode controlled Flyback power stage for low cost and ease of having multiple-output capability. This design focuses mainly on the FAN6605 current-mode PWM controller. Please refer to FCD1300N80Z and NCV8715's materials to get more information about these devices.

The FAN6605 is a current-mode PWM controller crafted for better light-load efficiency and lower no-load power consumption. At light-load condition, switching frequency of FAN6605 decreases, with pulse skipping, to reduce switching loss. For no-load condition, a special feedback-impedance switching mechanism is introduced to further reduce power consumption of feedback circuitry and switching frequency of burst-mode operation.

While light-load efficiency is improved, excellent transient response of a current-mode controlled Flyback converter is still unchanged for regulating output voltage in various load conditions.

Key Features

- Wide input voltage range
- Low no-load power consumption
- Good light-load efficiency
- Fast startup
- AC input brown-out protection
- AC input over-voltage protection
- Overload protection
- Thermal protection
- Regulated output under any conditions
- Excellent load and line transient response

Detail demo-board schematic description

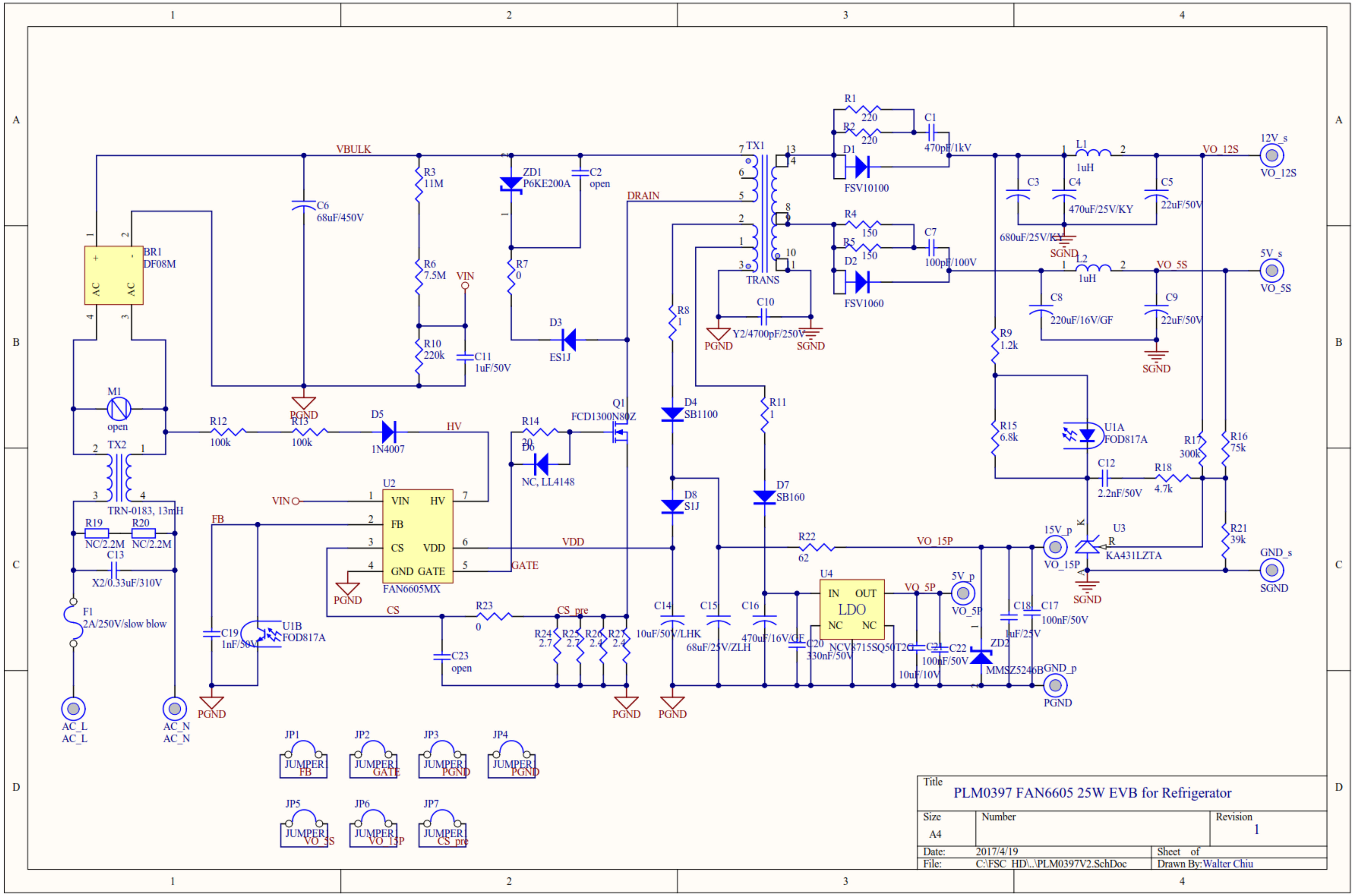


Figure 1 – FEBFAN6605MX_CS22U25A demo-board – main board schematic

The input EMI filter is formed by components TX2, C10, and C13. Bleeder for X-cap, R19 and R20, are left not connected.

The Flyback power stage primary side is composed from these devices: TX1 and Q1. FCD1300N80Z is applied as Q1 for its high voltage rating, low on-resistance, and low gate charge. D3 and ZD1 forms TVS snubber to protect Q1 from voltage spike. The controller U2 (FAN6605MX) drives Q1 through a resistor R14, which can be adjusted to optimize EMI signature. Current through Q1 is sensed by R24-27 and the signal is fed into CS pin of U2. The current-sensing signal is used for pulse-by-pulse current limit and current-mode PWM control. Since Q1 has built-in leading-edge blanking time, low-pass filter formed by R23 and C23 are no used. For fast start-up of the controller, HV pin of U2 is connected to AC input through R12, R13, and D5 to charge C14, which provides biasing voltage to U2. VIN pin of U2 is connected to V_{BULK} through a voltage divider formed by R3, R6 and R10. FAN6605MX uses this signal for brown out, input over-voltage protection, and constant power limit over wide input-voltage range. A capacitor, C11, is connected to VIN pin for suppressing noise on this pin. FB pin takes control voltage of PWM with internal pull-high resistor to bias opto-coupler. C19 connected to FB pin forms a low-pass filter for adjusting response of feedback loop.

The primary-side outputs share same ground reference with U2. That is, ground reference is negative terminal of output of bridge rectifier BR1. Transformer windings for these outputs is also used for providing VDD voltage in normal operation. The 15-V output is clamped by ZD2 to avoid voltage overshoot. The 5-V output is regulated by NCV8715, which features low drop-out voltage and low quiescent power consumption. Thus, the 5-V output is tightly regulated while no-load power consumption can still be low.

The secondary-side outputs are regulated by a shunt regulator, U3. Both outputs are taken into account for generating feedback signal with network formed by R16, R17, and R21. R9, R18, and C12 are used to adjust feedback response and bias U3. R15 provides additional biasing current for U3 to keep its required operating current. Cathode current of U3 is coupled to primary side by an opto coupler, U1. This cathode current is then converted to control voltage of PWM by internal pull-high resistor of FB pin in U2.

Circuit Layout

The PCB consists of a single layer FR4 board with 2 oz. copper cladding.

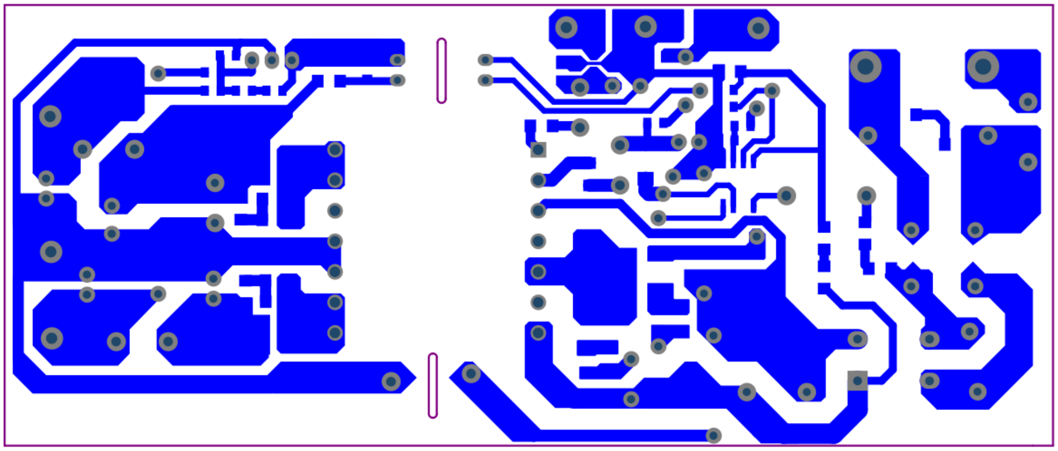


Figure 2 - Main board bottom layer

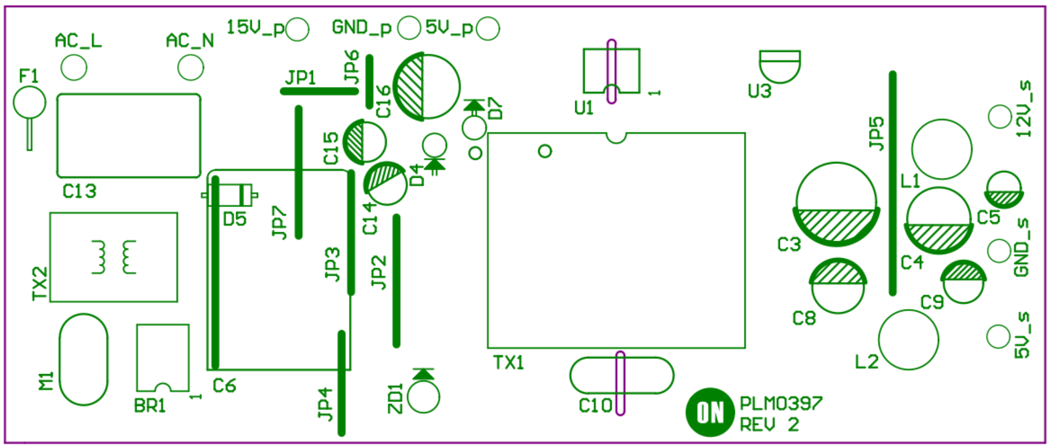


Figure 3 - Main board top side components

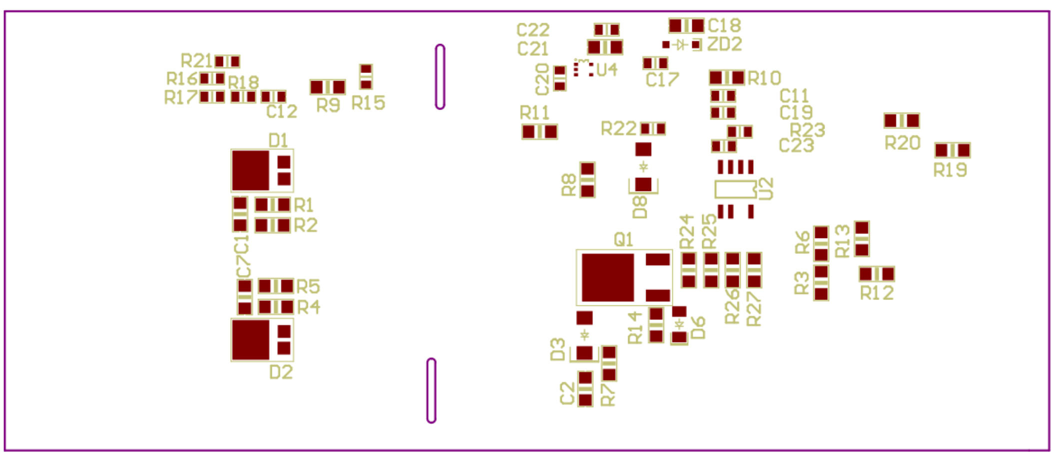


Figure 4 - Main board bottom side components

Board Picture

Figure 5 - Main board photo - Top side

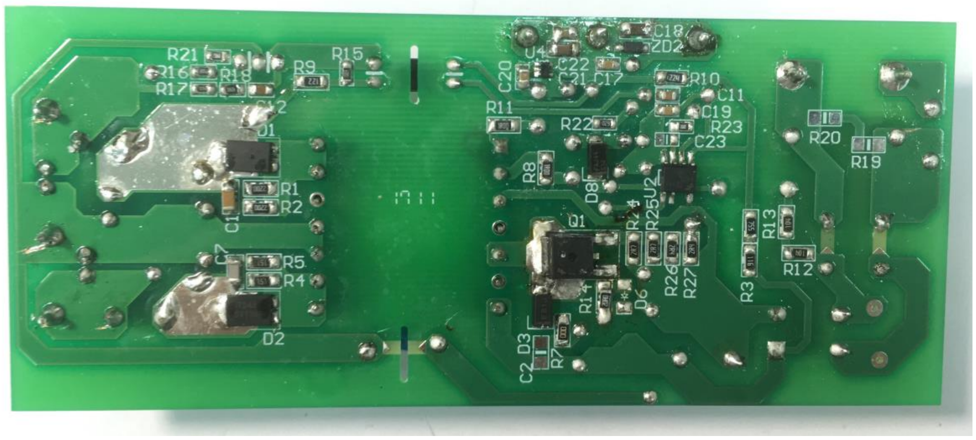
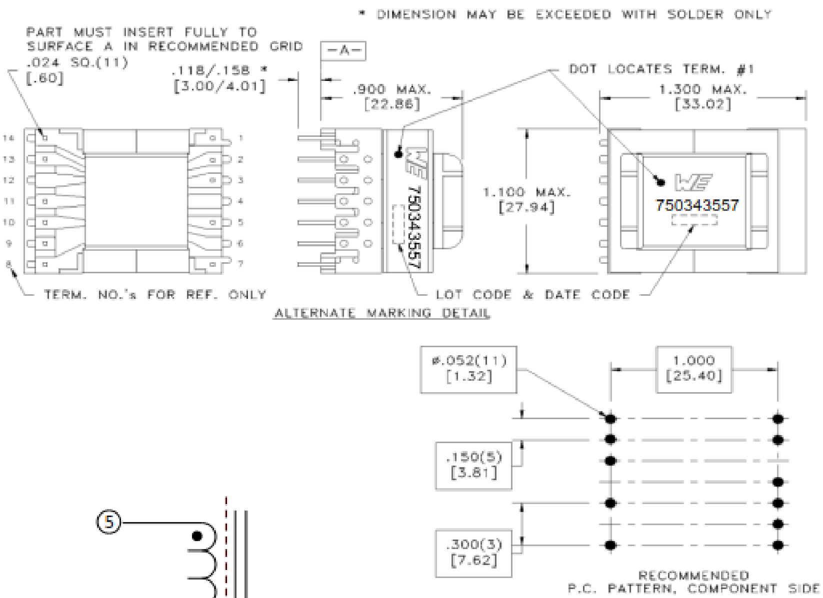
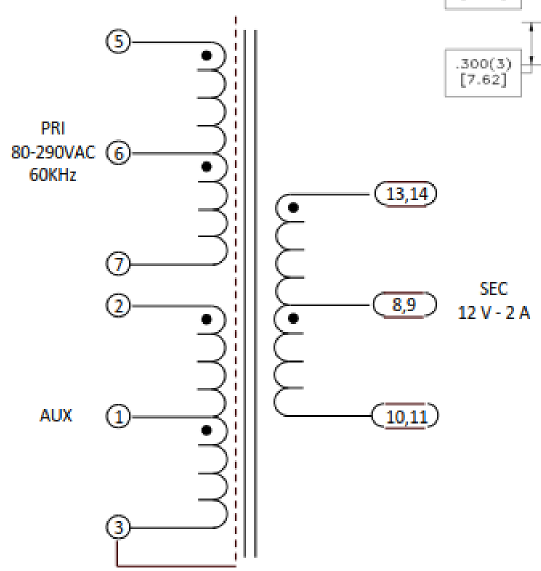


Figure 6 - Main board photo - Bottom side

Transformer Data

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





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

WÜRTH ELEKTRONIK — more than you expect

ELECTRICAL SPECIFICATIONS @ 25° C unless otherwise noted:

PARAMETER		TEST CONDITIONS	VALUE
D.C. RESISTANCE	5-7	@20°C	0.660 ohms max.
D.C. RESISTANCE	13-8	tie(13+14,8+9), @20°C	0.015 ohms max.
D.C. RESISTANCE	8-10	tie(8+9,10+11), @20°C	0.015 ohms max.
D.C. RESISTANCE	2-1	@20°C	0.170 ohms max.
D.C. RESISTANCE	1-3	@20°C	0.130 ohms max.
INDUCTANCE	5-7	10kHz, 100mV, Ls	1050.00µH ±10%
LEAKAGE INDUCTANCE	5-7	tie(1+2+3+8THRU14),100kHz, 100mV, Ls	7µH typ., 11µH max.
DIELECTRIC	1-14	tie(1THUR7,8THRU14), 3750VAC, 1 second	3000VAC, 1 minute
DIELECTRIC	14-CORE	tie(8THRU14), 3750VAC, 1 second	3000VAC, 1 minute
TURNS RATIO		(5-7):(13-8), tie(13+14,8+9)	14.4:1, ±2%
TURNS RATIO		(5-7):(8-10), tie(8+9,10+11)	18:1, ±2%
TURNS RATIO		(5-7):(2-1)	10.29:1, ±2%
TURNS RATIO		(5-7):(1-3)	14.4:1, ±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.

DFM		Packaging Specifications Method: Tray PKG-0737	CONVENTION PLACEMENT
DATE			
ENG	HWE		
REV.	00		
DATE	4/20/2017	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.: **750343557**

SPECIFICATION SHEET 1 OF 1

Test Data

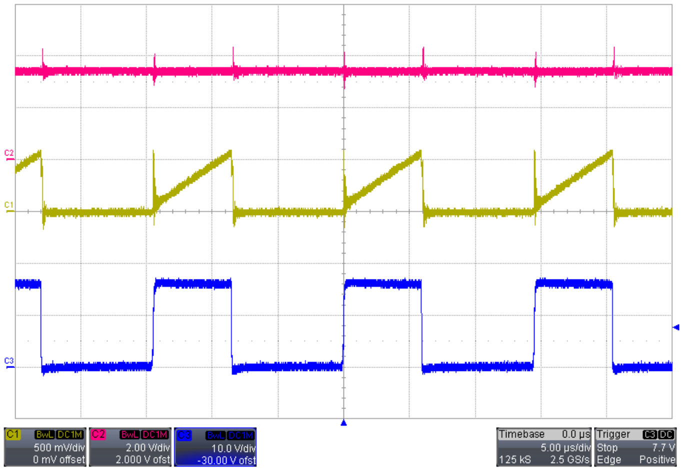


Figure 7 – Operation, Full load, 110Vac (Ch1: CS, Ch2: FB, Ch3: GATE)

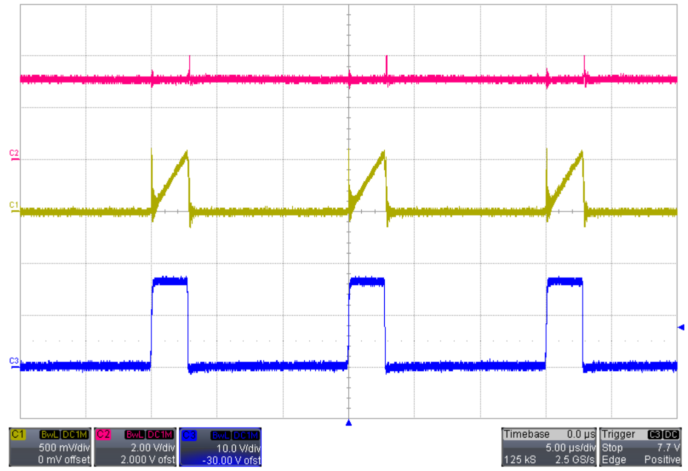


Figure 8 – Operation, Full load, 230Vac (CH1: CS, Ch2: FB, Ch3: GATE)

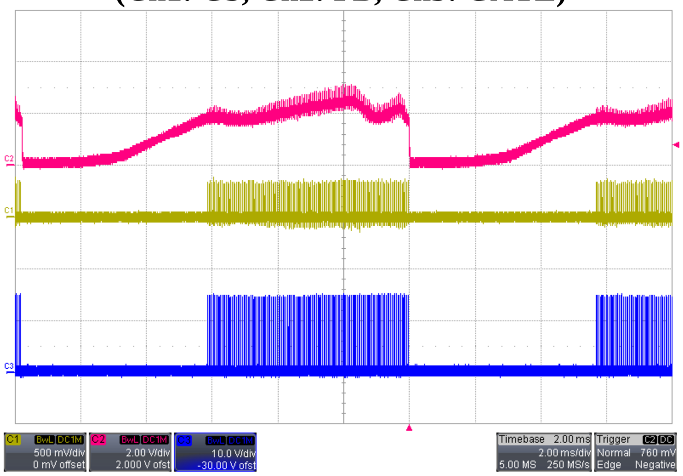


Figure 9 – Operation, Minimum load, 110Vac (Ch1: CS, Ch2: FB, CH3: GATE)

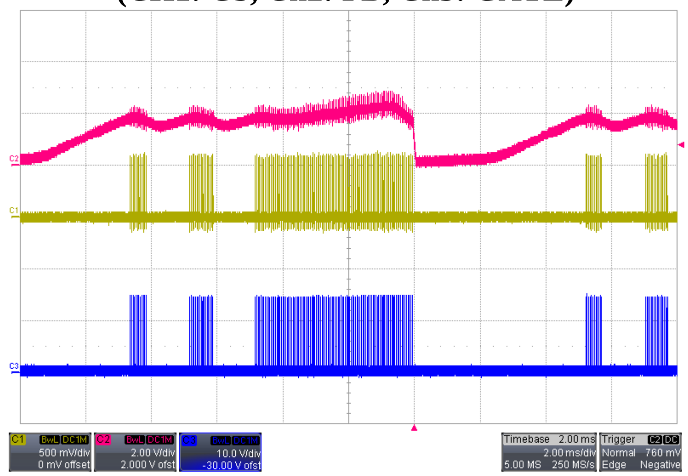


Figure 10 – Operation, Minimum load, 230Vac (Ch1: CS, Ch2: FB, Ch3: GATE)

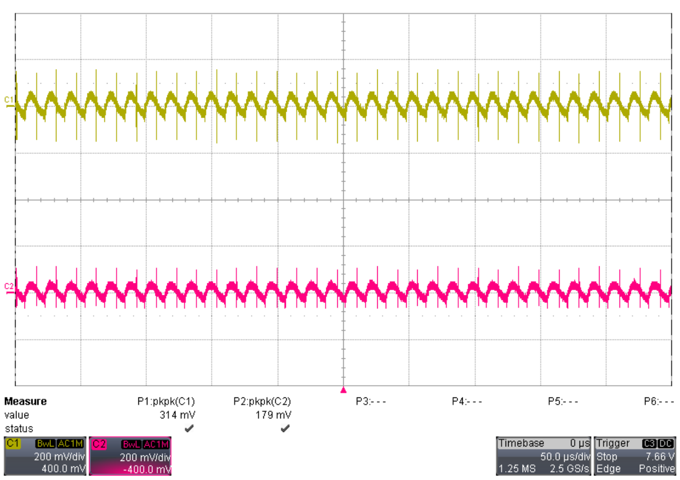


Figure 11 – Secondary-side output ripple, full load, 110Vac (Ch1: 12V_s, Ch2: 5V_s)

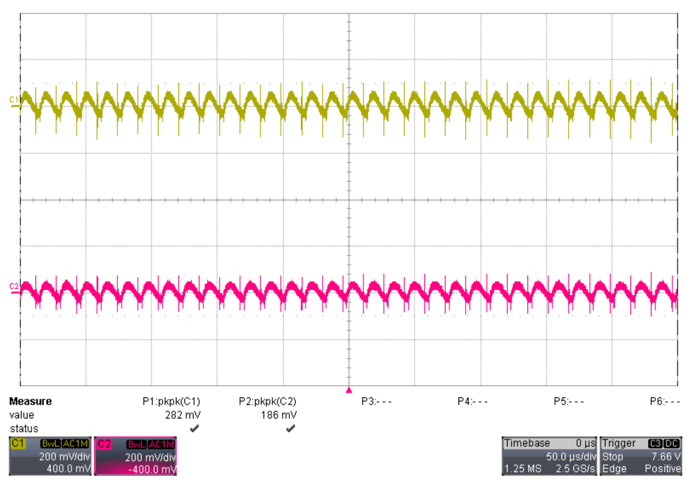


Figure 12 – Secondary-side output ripple, full load, 230Vac (Ch1: 12V_s, Ch2: 5V_s)

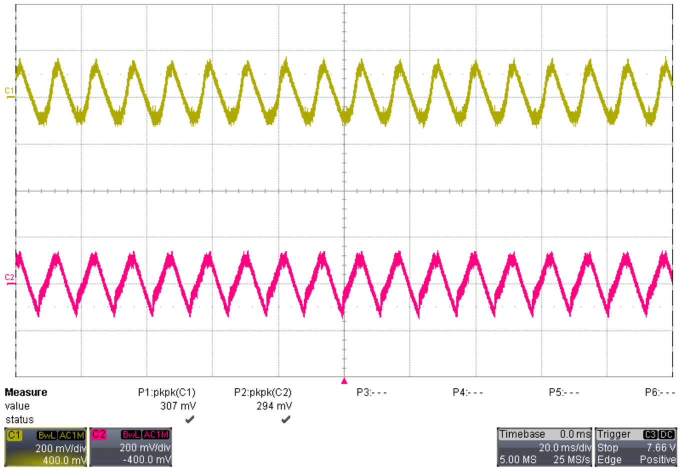


Figure 13 – Secondary-side output ripple, minimum load, 110Vac (Ch1: 12V_s, Ch2: 5V_s)

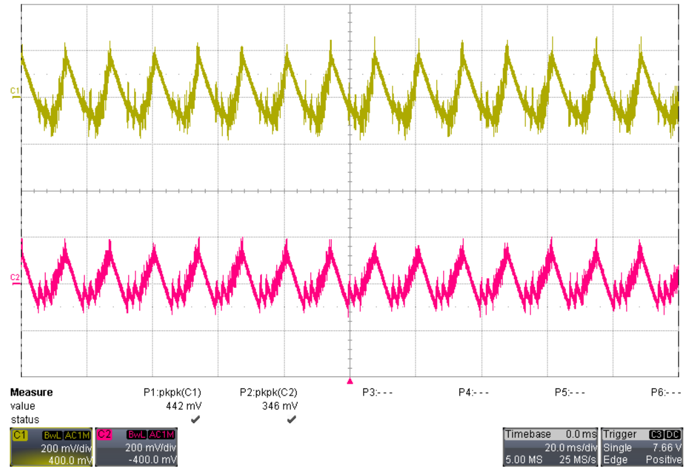


Figure 14 – Secondary-side output ripple, minimum load, 230Vac (Ch1: 12V_s, Ch2: 5V_s)

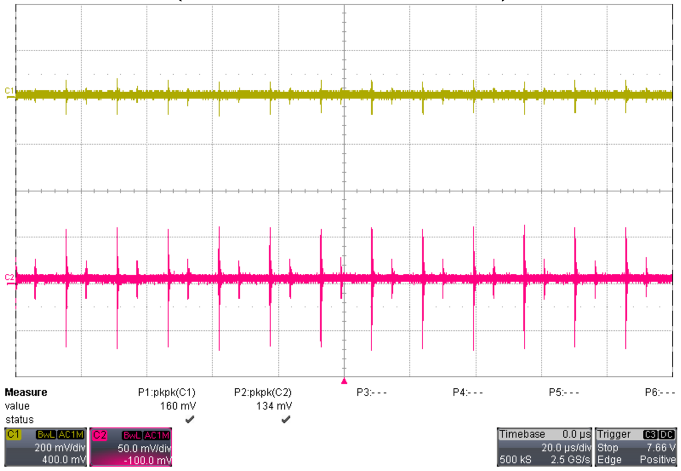


Figure 15 – Primary-side output ripple, full load, 110Vac (Ch1: 15V_p, Ch2: 5V_p)

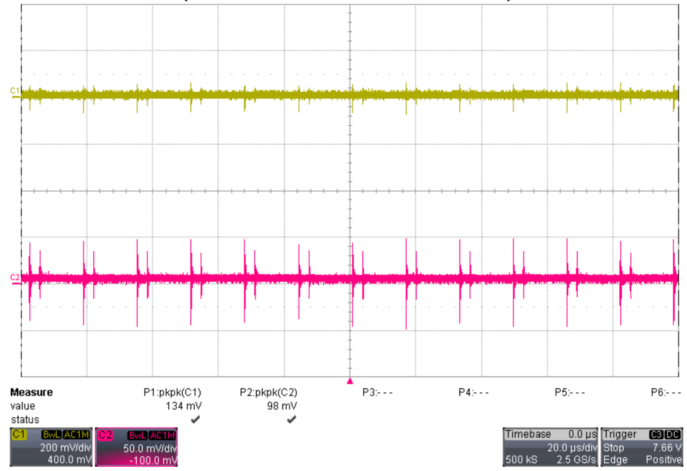


Figure 16 – Primary-side output ripple, full load, 110Vac (Ch1: 15V_p, Ch2: 5V_p)

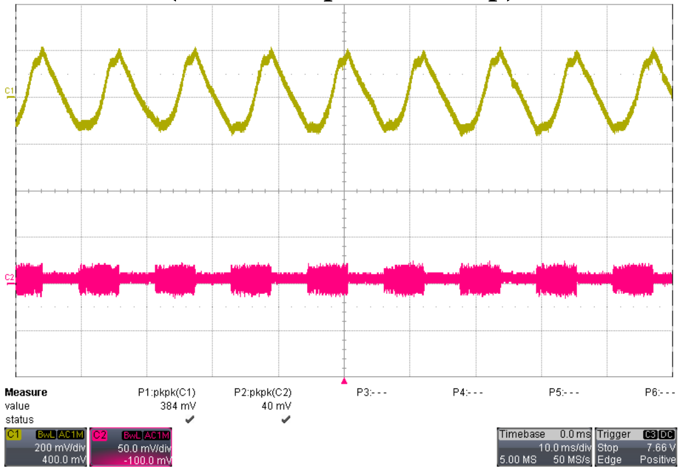


Figure 17 – Primary-side output ripple, minimum load, 110Vac (Ch1: 15V_p, Ch2: 5V_p)

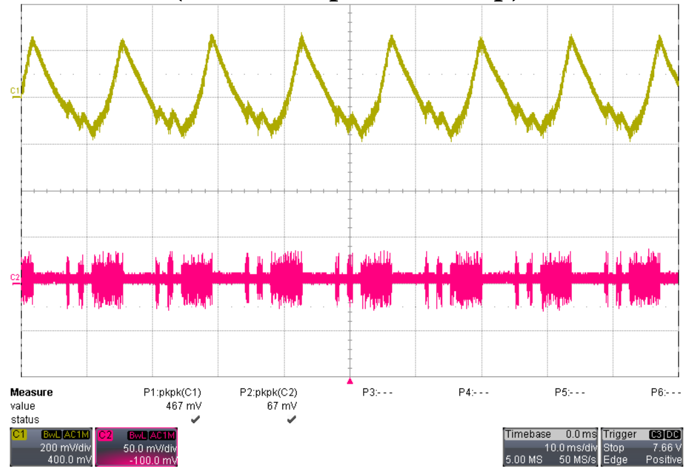


Figure 18 – Primary-side output ripple, minimum load, 110Vac (Ch1: 15V_p, Ch2: 5V_p)

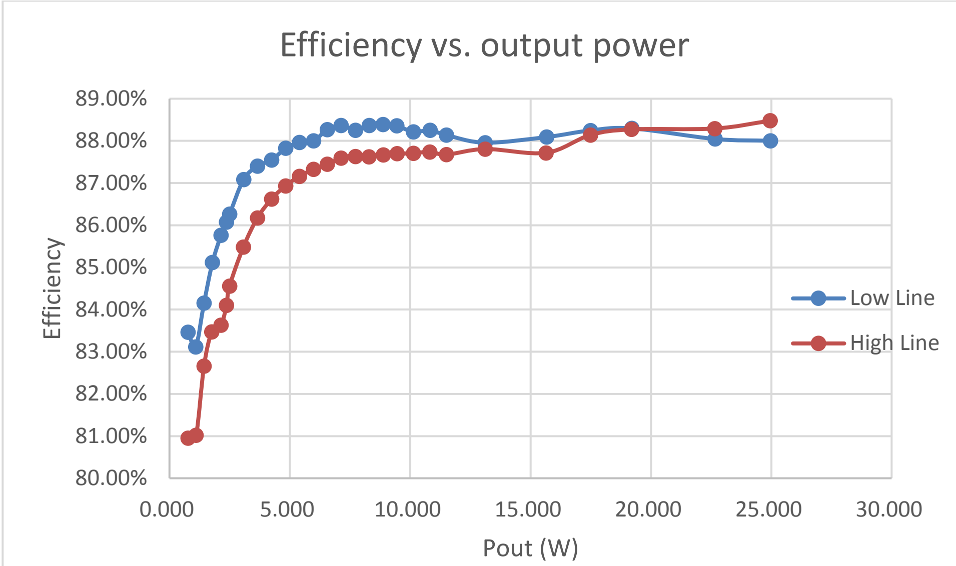


Figure 19 - Board efficiency

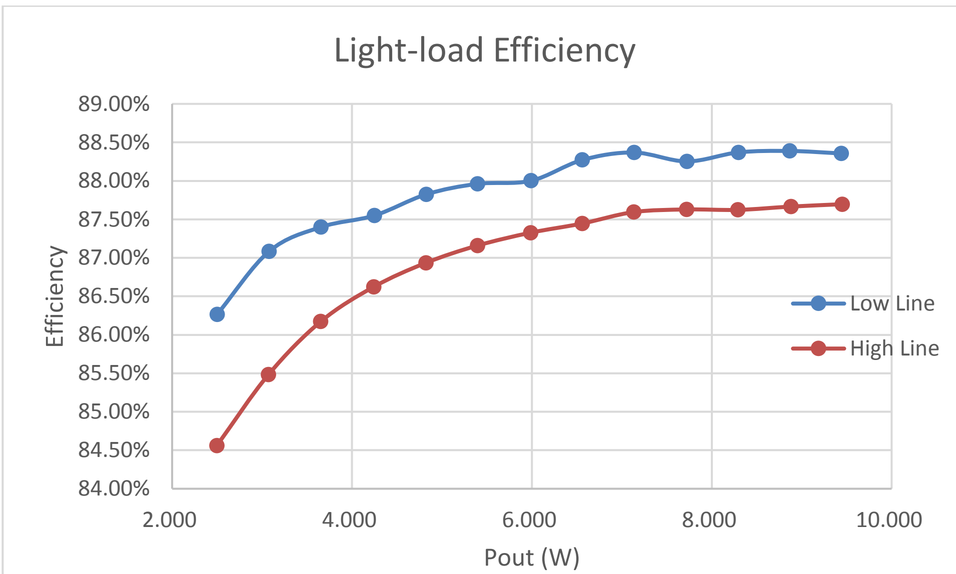


Figure 20 – Light-load Efficiency

Table 1 - No-load input power consumption

Input voltage [Vac]	Power consumption [mW]
110 Vac	11.838
230 Vac	33.462
Test condition: Outputs are connected to electronic load, but loading is not applied. Input power is integrated over three minutes. Note: LDO at primary-side 5V output consumes quiescent current up to 5.8µA. More, its minimum dropout voltage is no more than 0.35V.	

Table 2 – Brown in/out

Behavior	Vin (Vrms)
Brown in	48
Brown out	43
Note: Test condition is minimum load.	

Table 3 – Output voltage

Input voltage [Vac]		12V_s		5V_s		15V_p		5V_p	
	Pout (W)	VOUT (V)	IOUT (A)	VOUT (V)	IOUT (A)	VOUT (V)	IOUT (A)	VOUT (V)	IOUT (A)
110 Vac	0.78	11.553	0.049	5.026	0.010	15.184	0.004	5.028	0.020
	1.79	11.794	0.100	5.086	0.060	15.195	0.010	5.028	0.030
	2.50	11.796	0.151	5.085	0.081	15.355	0.010	5.028	0.030
	5.40	11.685	0.400	5.113	0.081	15.875	0.010	5.028	0.030
	7.13	11.649	0.550	5.120	0.081	16.192	0.010	5.028	0.030
	9.44	11.618	0.750	5.125	0.081	16.366	0.010	5.028	0.030
	13.12	11.675	1.000	5.109	0.220	16.544	0.010	5.029	0.030
	17.49	11.651	1.351	5.113	0.250	16.396	0.016	5.028	0.041
	22.67	11.617	1.801	5.117	0.250	16.544	0.016	5.028	0.041
	24.97	11.604	2.001	5.118	0.250	16.612	0.016	5.028	0.041
Load regulation		±1.07%		±0.98%		±4.49		±0.01%	
230 Vac	0.77	11.478	0.049	4.997	0.010	15.045	0.004	5.028	0.020
	1.76	11.641	0.100	4.974	0.060	14.930	0.010	5.028	0.030
	2.50	11.786	0.151	5.083	0.081	15.333	0.010	5.028	0.030
	5.40	11.680	0.400	5.110	0.081	15.994	0.010	5.028	0.030
	7.13	11.646	0.550	5.117	0.081	16.322	0.010	5.029	0.030
	9.45	11.614	0.751	5.123	0.081	16.438	0.010	5.029	0.030
	13.12	11.676	1.000	5.106	0.220	16.626	0.010	5.029	0.030
	17.48	11.647	1.351	5.110	0.250	16.490	0.016	5.028	0.041
	22.65	11.612	1.800	5.116	0.250	16.654	0.016	5.028	0.041
	24.97	11.601	2.001	5.118	0.250	16.724	0.016	5.028	0.041
Load regulation		±1.32%		±1.48%		±5.67%		±0.01%	
Note		Equation of load regulation is ±(max-min)/(max+min). Measured within load range shown in specification. No-load condition is not considered.							

Bill of materials

Parts	Qty	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number	Substitution Allowed	Lead Free
C11	1	MLCC Capacitor	105pF, 50V	±20%	0805	any		Yes	Yes
C12	1	MLCC X7R Capacitor	222pF, 50V	±10%	0805	any		Yes	Yes
C17 C22	2	MLCC X7R Capacitor	104pF, 50V	±10%	0805	any		Yes	Yes
C19	1	MLCC X7R Capacitor	102pF, 50V	±10%	0805	any		Yes	Yes
C20	1	MLCC Capacitor	334pF, 50V	±10%	0805	any		Yes	Yes
C1	1	MLCC X7R Capacitor	471pF, 1kV	±10%	1206	any		Yes	Yes
C7	1	MLCC X7R Capacitor	101pF, 100V	±10%	1206	any		Yes	Yes
C18	1	MLCC X7R Capacitor	105pF, 25V	±10%	1206	any		Yes	Yes
C21	1	MLCC X7R Capacitor	106pF, 10V	±10%	1206	any		Yes	Yes
R15	1	Chip Resistor	6.8kΩ	±5%	0805	any		Yes	Yes
R16	1	Chip Resistor	75kΩ	±1%	0805	any		Yes	Yes
R17	1	Chip Resistor	300kΩ	±5%	0805	any		Yes	Yes
R18	1	Chip Resistor	4.7kΩ	±1%	0805	any		Yes	Yes
R21	1	Chip Resistor	39kΩ	±1%	0805	any		Yes	Yes
R22	1	Chip Resistor	62Ω	±5%	0805	any		Yes	Yes
R23	1	Chip Resistor	0Ω	±5%	0805	any		Yes	Yes
R1 R2	2	Chip Resistor	220Ω	±5%	1206	any		Yes	Yes
R3	1	Chip Resistor	11MΩ	±5%	1206	any		Yes	Yes
R4 R5	2	Chip Resistor	150Ω	±5%	1206	any		Yes	Yes
R6	1	Chip Resistor	7.5MΩ	±5%	1206	any		Yes	Yes
R7	1	Chip Resistor	0Ω	±5%	1206	any		Yes	Yes
R8 R11	2	Chip Resistor	1Ω	±5%	1206	any		Yes	Yes
R9	1	Chip Resistor	1.2kΩ	±5%	1206	any		Yes	Yes
R10	1	Chip Resistor	220kΩ	±5%	1206	any		Yes	Yes
R12 R13	2	Chip Resistor	100kΩ	±5%	1206	any		Yes	Yes
R14	1	Chip Resistor	20Ω	±5%	1206	any		Yes	Yes

Parts	Qty	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number	Substitution Allowed	Lead Free
R24 R25	2	Chip Resistor	2.7Ω	±5%	1206	any		Yes	Yes
R26 R27	2	Chip Resistor	2.4Ω	±5%	1206	any		Yes	Yes
C14	1	Electrolytic Capacitor	10µF, 50V, 105°C		5*11mm	Jackon	LHK	Yes	Yes
C5 C9	2	Electrolytic Capacitor	22µF, 50V, 105°C		5*11mm	Jackon	LHK	Yes	Yes
C15	1	Electrolytic Capacitor	68µF, 25V, 105°C		5*11mm	Rubycon	ZLH	Yes	Yes
C3	1	Electrolytic Capacitor	680µF, 25V, 105°C		10*20mm	Nippon Chemi-con	KY	Yes	Yes
C16	1	Electrolytic Capacitor	470µF, 16V, 105°C		8*12mm	Samxon	GF	Yes	Yes
C6	1	Electrolytic Capacitor	68µF, 450V, 105°C		18*26mm	Nippon Chemi-con	KXG	Yes	Yes
C8	1	Electrolytic Capacitor	220µF, 16V, 105°C		6.3*11mm	Samxon	GF	Yes	Yes
C4	1	Electrolytic Capacitor	470µF, 25V, 105°C		8*20mm	Nippon Chemi-con	KY	Yes	Yes
C10	1	Y1 Capacitor	472pF, 250V	±20%		TDK	CD12ZU2GA472MYPK	Yes	Yes
C13	1	X2 Capacitor	0.33µF, 310V	±10%				Yes	Yes
L1 L2	2	Inductor, Ferrite core	1µH		DR 6x8	Sen Huei Industrial		Yes	Yes
TX2	1	Common-mode choke	13mH		T18X10X10	Sen Huei Industrial	TRN0183	Yes	Yes
TX1	1	Transformer	1050µH, Np:Ns1:Ns2:Na1:Na2=72:5:4:7:5	±10%	EE25/13/7	Wurth Electronics Midcom	TRN0354 (Wurth: 750343557)	No	Yes
D5	1	General Purpose Rectifier	1A, 1000V		DO-41	ON Semiconductor	1N4007	Yes	Yes
D8	1	General Purpose Rectifier	1A, 600V		DO-214AC	ON Semiconductor	S1J	Yes	Yes
D3	1	Fast Rectifier	1A, 600V		DO-214AC	ON Semiconductor	ES1J	Yes	Yes
D7	1	Schottky diode	1A, 60V		DO-41	ON Semiconductor	SB160	Yes	Yes
D4	1	Schottky diode	1A, 100V		DO-41	ON Semiconductor	SB1100	Yes	Yes
D2	1	Ultra-Low VF Schottky Diode	10A, 60V		TO-277	ON Semiconductor	FSV1060V	Yes	Yes
D1	1	Ultra-Low VF Schottky Diode	10A, 100V		TO-277	ON Semiconductor	FSV10100V	Yes	Yes
BR1	1	Bridge rectifier	VRRM=800V; IF=1.5A@100°C		MDIP 4L	ON Semiconductor	DF08M	Yes	Yes

Parts	Qty	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number	Substitution Allowed	Lead Free
ZD1	1	TVS	Breakdown Voltage=190~210V		DO-15	ON Semiconductor	P6KE200A	Yes	Yes
ZD2	1	Zener diode	16V, 0.5W	5%	SOD-123	ON Semiconductor	MMSZ5246B	Yes	Yes
Q1	1	N-Channel SF2 MOSFET	800V, 4A, 1.3Ω		D-pak	ON Semiconductor	FCD1300N80Z	Yes	Yes
U1	1	Opto Coupler	CTR=80-160%		DIP 4-pin	ON Semiconductor	FOD817A	Yes	Yes
U3	1	Shunt Regulator	Adjustable, 2.5V	0.5%	TO-92	ON Semiconductor	KA431LZTA	Yes	Yes
U4	1	Linear Voltage Regulator	5V, 50mA	±2%	SC-88-A	ON Semiconductor	NCV8715SQ50T2G	No	Yes
U2	1	PWM Controller				ON Semiconductor	FAN6605MX	No	Yes
F1	1	Fuse	GLASS 2A / 250V 36SG slow-blow			Sleetech		Yes	Yes
JP1 JP2 JP3 JP4 JP5 JP6 JP7	7	Jumper wire				Any		Yes	Yes
12V_s 15V_p 5V_p 5V_s AC_L AC_N GND_p GND_s	8	Connector	SG004-05 Pin ψ2.2*18.2mm OEM-10			Kang Yang	42-0M00405-00	Yes	Yes
	1	PCB					PLM0397V2	No	Yes
JP1 JP2 JP3 JP4 JP5 JP6 JP7 C6	8	Teflon tube	17L					Yes	Yes

Design note created by Walter Chiu