AN4604
Application note

Evaluation board for the SEA01 constant voltage and current controller with online digital trimming

Introduction

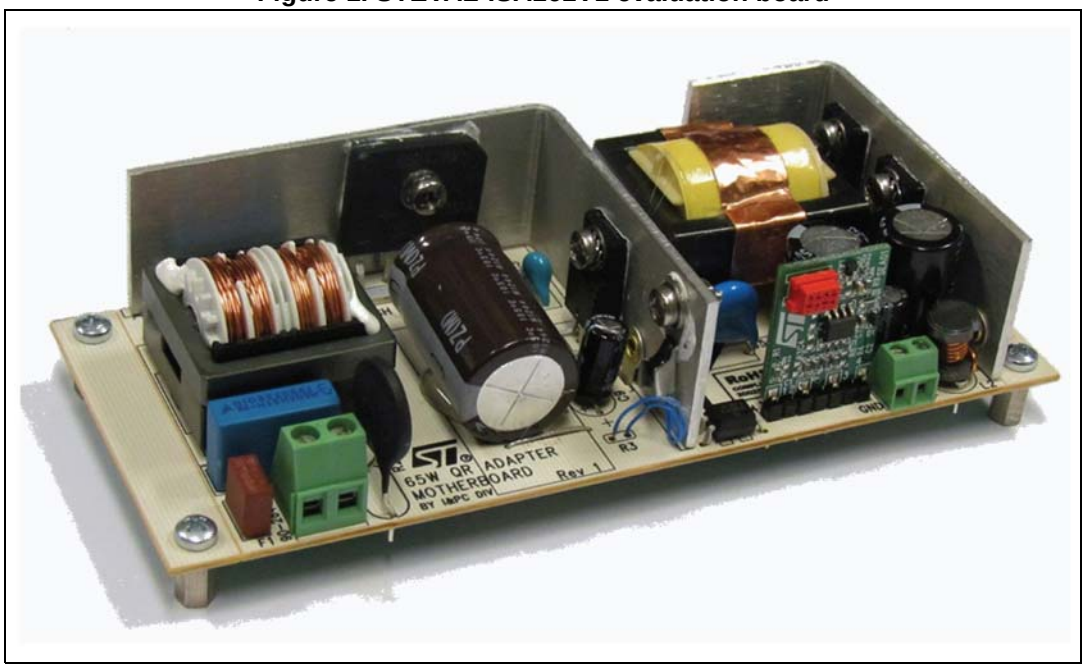
This application note describes a 65 W wide range input SMPS designed for use in adapters for typical hi-end portable computer power supplies.

The design is based on the EVL6566B-65W-QR demonstration board from ST (ref. AN3089), with the principal difference located on the secondary side, where the SEA01 digital constant voltage & current controller featuring online trimming replaces the constant voltage & constant current (CV-CC) controller (TSM1014) found on the older board.

The new board is therefore ideal for testing the features and benefits of the online digital trimming technology recently introduced by STMicroelectronics on the SEA01 controller.

Since the EVL6566B-65W-QR and STEVAL-ISA161V1 boards are very similar, this document will focus on the SEA01 and the new trimming feature. For a detailed description and performance analysis of the complete board, please refer to AN3089.

Figure 1. STEVAL-ISA161V1 evaluation board



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1 Main characteristics and circuit description

The main characteristics of the power supply are:

- Input mains range: Vin: 90 ~ 264 Vrms; f: 45 ~ 66 Hz
- O/P voltage (CV mode): +19 Vdc ± 2% (native value), ± 0.1% (after trimming)
- O/P current (CC mode): 3.75 Adc ± 15% (native value), ± 1.67% (after trimming)
- Standby consumption: < 100 mW @ 230 Vac
- Average efficiency: greater than 89%
- EMI: in accordance with EN55022 - class B
- Safety: in accordance with EN60950
- PCB type: CEM-1, single side, 35 µm
- Board size: 58 x 121 mm, 25 mm maximum component height

1.1 Power stage

The STEVAL-ISA161V1 features a quasi resonant (QR) flyback stage driven by the L6566B controller. The converter implements peak current mode control, detecting the demagnetization of the power transformer by sensing its auxiliary winding through the L6566B ZCD pin.

The maximum switching frequency is set at approximately 165 kHz. If the load decreases further, the system enters valley skipping mode: always turning the power MOSFET on with its drain valley voltage. For very light loads, the converter enters burst mode for the maximum efficiency.

Approximately 150 V is selected for the reflected voltage to benefit from the small capacitive turn-on losses associated with QR operation and still retain a good margin on the maximum breakdown voltage of the power MOSFET.

All the power components are thus selected according to the voltages and the output power.

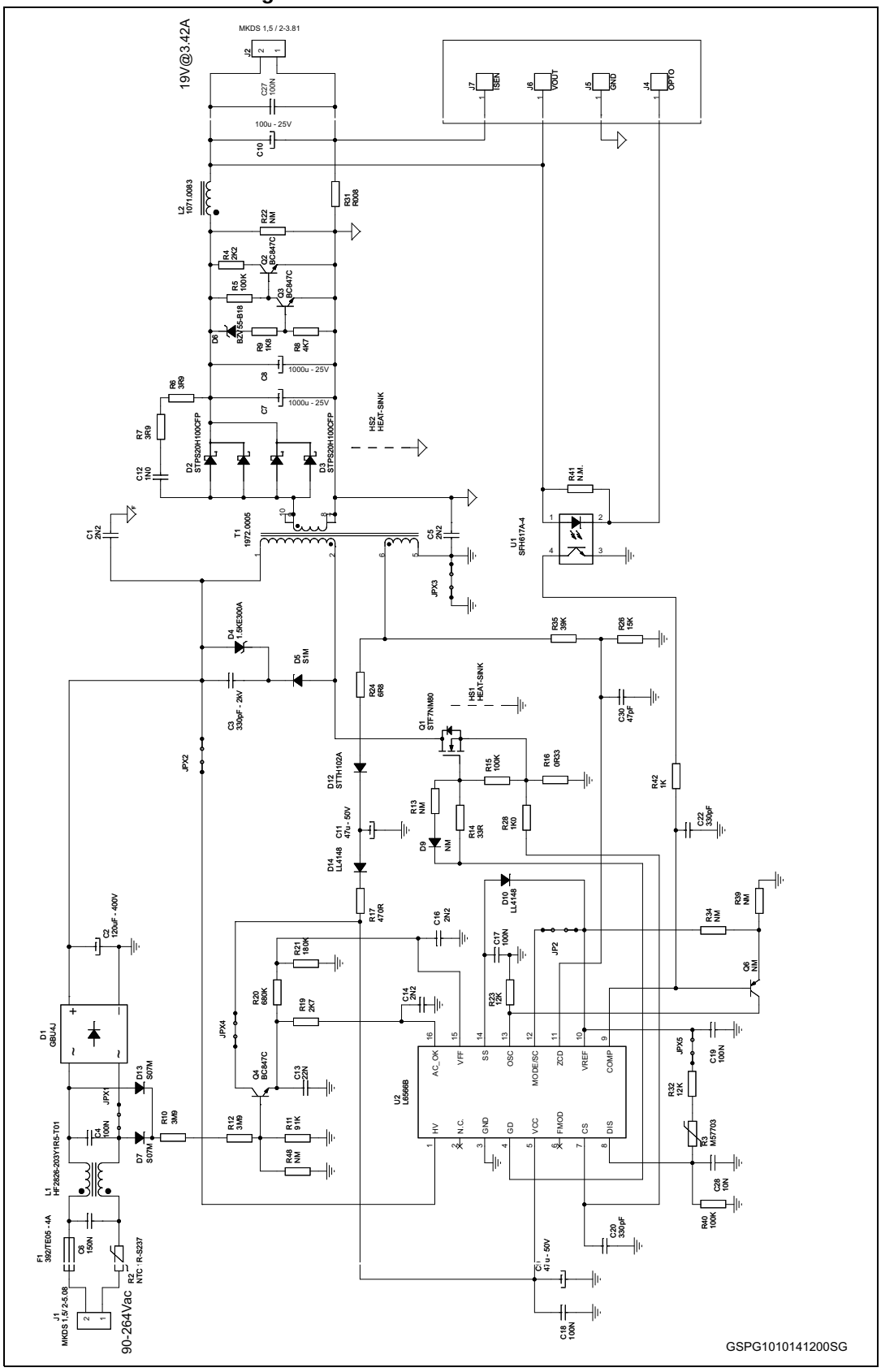
The converter also includes a brown-out circuit that senses the mains voltage before the bridge diodes, reducing power consumption and allowing fast restarts when latched protections are triggered.

Finally, a fast discharge circuit is present on the output bus voltage to quickly discharge the output capacitors on circuit turn off under a no-load condition.

The adapter has a full set of protection features, including output short-circuit, output overvoltage, output diode short-circuit and board overtemperature.

The converter has a modular configuration. All the power stage is housed on a motherboard (see schematic in *Figure 2*) with a socket on the secondary side to accommodate a small daughterboard containing the CC-CV controller and the corresponding compensation networks.

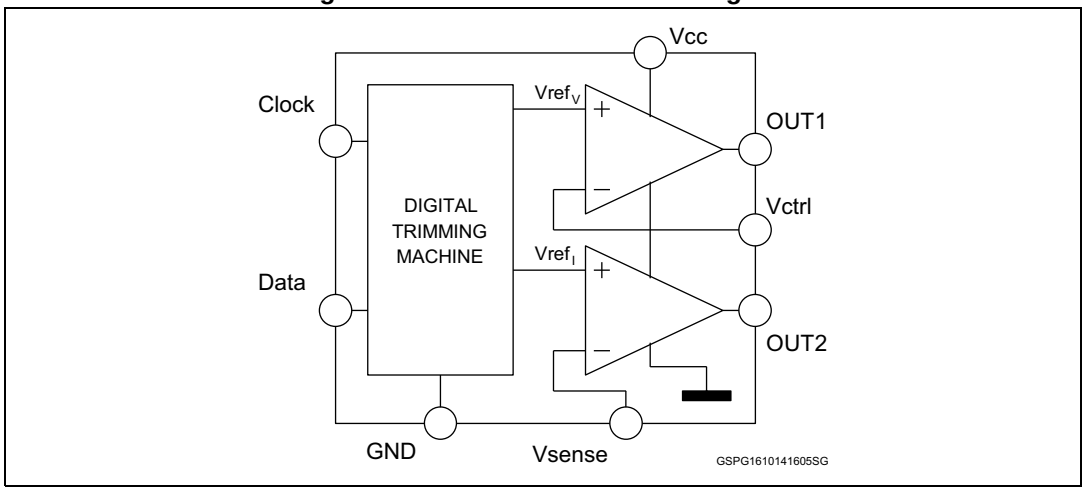
Figure 2. 65 W motherboard schematic



1.2 Closing the loop

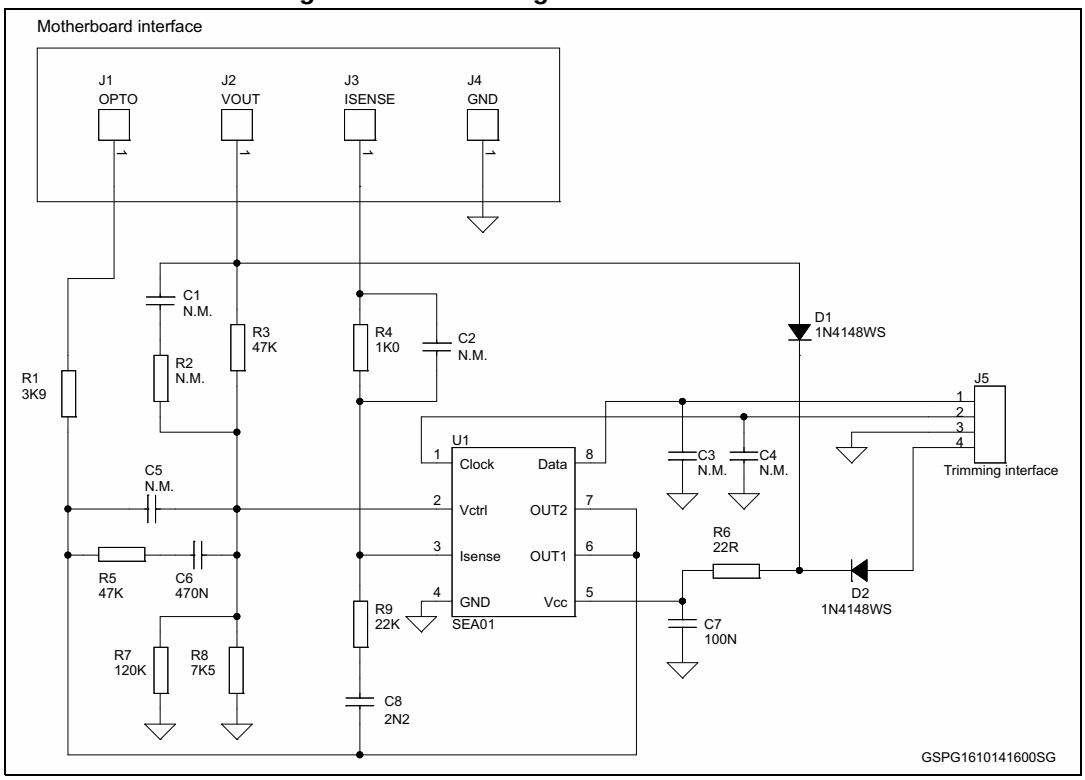
The daughterboard on the secondary side of the STEVAL-ISA161V1 includes the SEA01: the latest CV-CC controller from STMicroelectronics. Besides the usual analog circuitry (two transconductance op-amps with their references), it includes a digital block that features an I²C interface, a redundant OTP (two OTP memories) and two digitally trimmable references for the two op-amps. The IC block diagram is shown in *Figure 3*.

Figure 3. SEA01 internal block diagram



The SEA01 is housed on a small daughterboard which is mounted vertically on the main evaluation board. The schematic for the daughterboard is shown in *Figure 4*.

Figure 4. SEA01 daughterboard schematic



The simple daughterboard includes the output voltage divider and the compensation for the CV section, the compensation for the CC section, the connector for the trimming interface cable and a couple of small signal OR-ing diodes to select the higher supply voltage between the motherboard output voltage and the programming voltage supplied through J5.

The device supply must be 17 V $\leq V_{CC} \leq$ 20 V in order to correctly burn the OTP memory. On this demo board, the V_{CC} is the output voltage of the adapter (minus one diode drop), and is therefore already in the correct range for burning.

If the daughterboard is used in a lower out voltage application, the supply from pin 4 of J5 is used to provide the necessary voltage for the burning operation.

The feedback loop component values are the same as those on the original board described in AN3089.

2 Digital trimming operation

The aim of this board is to help demonstrate how the digital trimming operation works. For this reason, two trimming tools have also been developed:

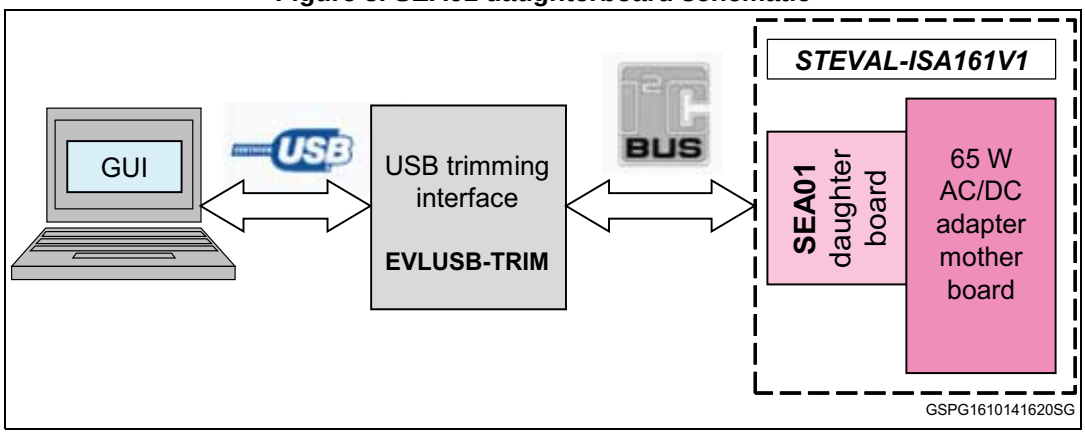
- EVLUSB-TRIM is the simpler version with just a USB-I²C interface and a 19 V supply intended for manual operation.
- STEVAL-PCC019V1 is more functional, including three I²C interfaces with relevant 19 V supplies and an electronic load on the board. This tool allows for fully automated trimming of the SMPS.

In this document, we will refer to the first tool, EVLUSB-TRIM.

It connects the SEA01 to a PC through an interface board and allows control of the trimming operation through a user-friendly Graphic User Interface (GUI). A detailed user manual provided with the trimming tool explains how to setup the debug environment.

Figure 5 shows the complete setup environment for the trimming operation.

Figure 5. SEA01 daughterboard schematic



Through the GUI, the EVLUSB-TRIM sends all the available commands to the SEA01. The changes in the STEVAL-ISA161V1 output can be monitored with a multimeter or an oscilloscope. The messages returned from the SEA01 can be easily read on the PC GUI.

Figure 6 shows an example Emulate Vrefv command with a 0.6% value. The I²C frame is acquired with an oscilloscope and decoded with the “Prodigy Solutions I²C Decode solution” software installed on the oscilloscope.

This software greatly simplifies analysis of the data received (or sent) by SEA01.

According to the I²C protocol, we can find the following sequential data:

- start bit
- I²C address
- r/w bit
- acknowledge bit
- 1st data byte
- acknowledge bit
- 2nd data byte

- acknowledge bit
- stop bit

In the example:

- I²C address = 0x52, correct SEA01 address
- 1st data = 0x90, “Emulate Vrefv” command for SEA01
- 2nd data = 0x06, +0.6% information with 1 bit parity check

Figure 6. “Emulate Vrefv + 0.6%” command

Once the right set of values for both loops has been determined, the SEA01 can be burned and the trimming tool can be disconnected. At this point, the adapter functions like any other standard adapter, but with a very accurate output voltage and current.

3 Functional check

As the board is very similar to the EVL6566B-65W-QR, all the functions are the same; only a few aspects associated with the compensation network have been re-tested.

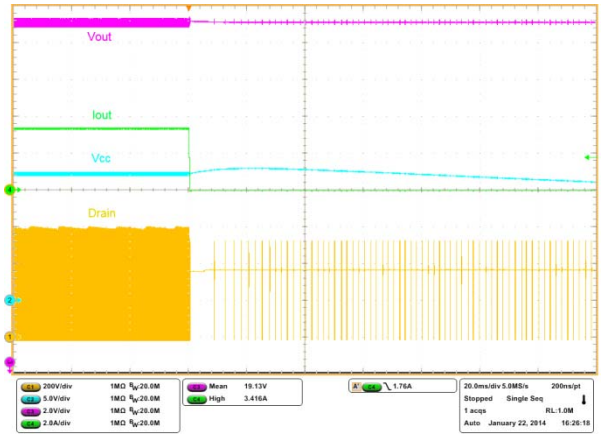
First, the transient behavior was checked. Like in the AN3089, the most critical transition was tested with a setup having a maximum input voltage (i.e. 265 Vac) and maximum load swing (0 A to 3.42 A)

The results are shown in *Figure 7* and *Figure 8*.

Also with this board, the transitions are clean, output is stable and there are no dips in the self-supply (V_{CC}) voltage.

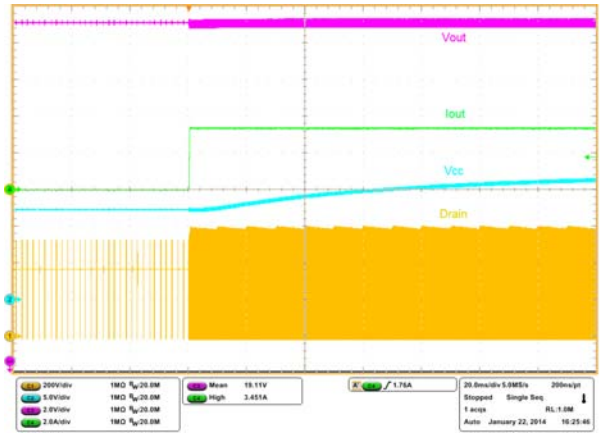
The response time is given by the RC compensation network across the voltage op-amp and is thus independent of the CV-CC controller used.

Figure 7. Transition from full load to no load at 265 Vac - 50 Hz



CH1: Drain voltage CH2: L6566B VCC
CH3: Output voltage CH4: Output current

Figure 8. Transition from no load to full load at 265 Vac - 50 Hz



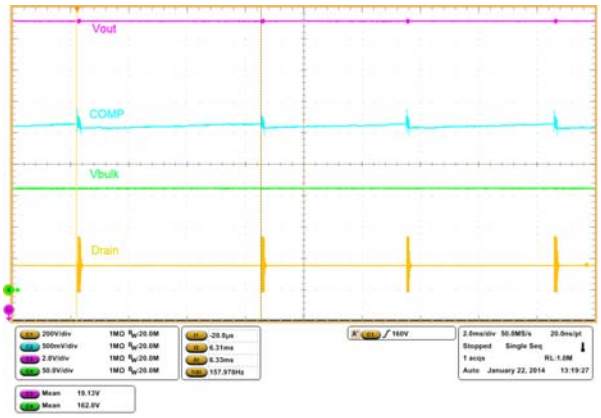
CH1: Drain voltage CH2: L6566B VCC
CH3: Output voltage CH4: Output current

Another aspect that can be influenced by the CV-CC controller is the no-load behavior and relevant consumption. Thanks to the low SEA01 quiescent current, we have very similar operation with respect to the EVL6566B-65W-QR board.

The no-load consumption is below 100 mW at all nominal voltages (89.8 mW at 230 Vac).

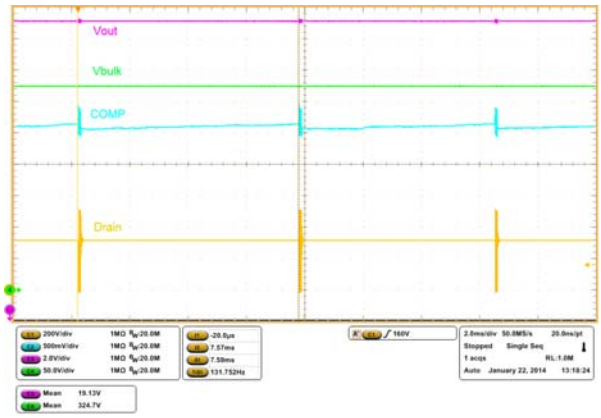
The burst mode operation at zero load is shown in *Figure 9* and *Figure 10*.

Figure 9. No load operation at 115 Vac - 60 Hz



CH1: Drain voltage CH2: COMP pin
CH3: Output voltage CH4: Bulk voltage

Figure 10. No load operation at 230 Vac - 50 Hz



CH1: Drain voltage CH2: COMP pin
CH3: Output voltage CH4: Bulk voltage

In all the other conditions, the converter works like the original board EVL6566B-65W-QR. For this reason, performance and features are the same and their description is not repeated in this document.

4 Bill of material

Table 1. 65 W motherboard BOM

Ref.	Part type / Value	Description	Manufacturer
C1	2N2	Y1 - safety cap. CD12-E2GA222MYGS	TDK
C2	120 µF - 400 V	400 V - aluminum elcap - KXW series - 105°C	Rubycon
C3	330 pF - 2 kV	2 kV - disc cercap	Murata
C4	100N	X2 - flm cap - B32922C3104M000	EPCOS
C5	2N2	Y1 - safety cap. CD12-E2GA222MYGS	TDK
C6	150N	X2 - flm cap - B32922C3154M000	EPCOS
C7	1000 µ - 25 V	25 V - aluminum elcap - ZL series - 105°C	Rubycon
C8	1000 µ - 25 V	25 V - aluminum elcap - ZL series - 105°C	Rubycon
C9	47 µ - 50 V	50 V - aluminum elcap - YXF series - 105°C	Rubycon
C10	100 µ - 25 V	25 V - aluminum elcap - YXF series - 105°C	Rubycon
C11	47 µ - 50 V	50 V - aluminum elcap - YXF series - 105°C	Rubycon
C12	1N0	200 V cercap - general purpose - 1206	AVX
C13	22N	50 V cercap - general purpose - 0805	AVX
C14	2N2	50 V cercap - general purpose - 0805	AVX
C16	2N2	50 V cercap - general purpose - 0805	AVX
C17	100N	50 V cercap - general purpose - 0805	AVX
C18	100N	50 V cercap - general purpose - 1206	AVX
C19	100N	50 V cercap - general purpose - 1206	AVX
C20	330 pF	50 V cercap - general purpose - 1206	AVX
C22	330 pF	50 V cercap - general purpose - 1206	AVX
C27	100 N	50 V cercap - general purpose - 0805	AVX
C28	10 N	50 V cercap - general purpose - 1206	AVX
C30	47 pF	5 0V cercap - general purpose - 1206	AVX
D1	GBU4J	Single phase bridge rectifier	Vishay
D2	STPS20H100CFP	High voltage power Schottky rectifier	STMicroelectronics
D3	STPS20H100CFP	High voltage power Schottky rectifier	STMicroelectronics
D4	1.5KE300A	Transil	STMicroelectronics
D5	S1M	High voltage rectifier	Vishay
D6	BZV55-B18	Zener diode	NXP
D7	S07M	High voltage diode	Vishay
D9	NM	Fast switching diode	-
D10	LL4148	Fast switching diode	Vishay

Table 1. 65 W motherboard BOM (continued)

Ref.	Part type / Value	Description	Manufacturer
D12	STTH102A	Fast switching diode	STMicroelectronics
D13	S07M	High voltage diode	Vishay
D14	LL4148	Fast switching diode	Vishay
F1	392/TE05 - 4A	Fuse T4A - time delay	Littelfuse
HS1	HEAT-SINK	Bridge rectifier and MOSFET heatsink	-
HS2	HEAT-SINK	Output rectifiers heatsink	-
J1	MKDS 1.5/ 2-5.08	PCB term. block, screw conn., p5.08 mm - 2 W.	Phoenix Contact
J2	MKDS 1.5/ 2-3.81	PCB term. block, screw conn., p3.81 mm - 2 W.	Phoenix Contact
JP2	SHORTED	SMD standard film res - jumper - 1206	-
JPX1	SHORTED	Wire jumper	-
JPX2	SHORTED	Wire jumper	-
JPX3	SHORTED	Wire jumper	-
JPX4	SHORTED	Wire jumper	-
JPX5	SHORTED	Wire jumper	-
L1	HF2826-203Y1R5-T01	Input EMI filter	TDK
L2	1071.0083	1.1 µH-5 A - radial inductor	Magnetica
Q1	STF7NM80	N-channel power MOSFET	STMicroelectronics
Q2	BC847C	NPN small signal BJT	Zetex
Q3	BC847C	NPN small signal BJT	Zetex
Q4	BC847C	NPN small signal BJT	Zetex
Q6	NM	PNP small signal BJT	-
R2	NTC 1R-S237	NTC resistor P/N B57237S0109M000	EPCOS
R3	M57703	Thermistor - B57703M103G	EPCOS
R4	2K2	SMD standard film res - 1/4W - 5% - 250ppm/°C	Vishay
R5	100K	SMD standard film res - 1/8W - 5% - 250ppm/°C	Vishay
R6	3R9	SMD standard film res - 1/4W - 5% - 250ppm/°C	Vishay
R7	3R9	SMD standard film res - 1/4W - 5% - 250ppm/°C	Vishay
R8	4K7	SMD standard film res - 1/8W - 5% - 250ppm/°C	Vishay
R9	1K8	SMD standard film res - 1/8W - 5% - 250ppm/°C	Vishay
R10	3M9	SMD standard film res - 1/4W - 1% - 100ppm/°C	Vishay
R11	91K	SMD standard film res - 1/4W - 1% - 100ppm/°C	Vishay
R12	3M9	SMD standard film res - 1/4W - 1% - 100ppm/°C	Vishay
R13	NM	SMD standard film res - 1/8W - 5% - 250ppm/°C	-
R14	33R	SMD standard film res - 1/8W - 5% - 250ppm/°C	Vishay
R15	100K	SMD standard film res - 1/8W - 5% - 250ppm/°C	Vishay

Table 1. 65 W motherboard BOM (continued)

Ref.	Part type / Value	Description	Manufacturer
R16	0R33	MSR1 SMD film res - 1W - 5% - 250ppm/°C	Meggit
R17	470R	SMD standard film res - 1/4W - 5% - 250ppm/°C	Vishay
R19	2K7	SMD standard film res - 1/4W - 1% - 100ppm/°C	Vishay
R20	680K	SMD standard film res - 1/4W - 1% - 100ppm/°C	Vishay
R21	180K	SMD standard film res - 1/4W - 1% - 100ppm/°C	Vishay
R22	NM	SMD standard film res - 1/4W - 5% - 250ppm/°C	-
R23	12K	SMD standard film res - 1/8W - 1% - 100ppm/°C	Vishay
R24	6R8	SMD standard film res - 1/4W - 5% - 250ppm/°C	Vishay
R26	15K	SMD standard film res - 1/4W - 5% - 250ppm/°C	Vishay
R28	1K0	SMD standard film res - 1/8W - 5% - 250ppm/°C	Vishay
R31	0R008	MSR1 SMD FILM RES - 1W - 5% - 250ppm/°C	Meggit
R32	12K	SMD standard film res - 1/8W - 5% - 250ppm/°C	Vishay
R34	NM	SMD standard film res - 1/4W - 1% - 100ppm/°C	-
R35	39K	SMD standard film res - 1/4W - 5% - 250ppm/°C	Vishay
R39	NM	SMD standard film res - 1/8W - 1% - 100ppm/°C	-
R40	100K	SMD standard film res - 1/4W - 5% - 250ppm/°C	Vishay
R41	NM	SMD standard film res - 1/8W - 5% - 250ppm/°C	Vishay
R42	1K	SMD standard film res - 1/4W - 5% - 250ppm/°C	Vishay
R48	NM	SMD standard film res - 1/4W - 1% - 100ppm/°C	-
T1	1972.0005	Power transformer	Magnetica
U1	SFH617A-4	Optocoupler	Infineon
U2	L6566B	Multi-mode PWM controller	STMicroelectronics

Table 2. SEA01 daughterboard BOM

Ref.	Part type / value	Description	Manufacturer
C6	470N	50 V cercap - X7R general purpose	AVX
C7	100N	50 V cercap - X7R general purpose	AVX
C8	2N2	50 V cercap - X7R general purpose	AVX
D1	1N4148WS	Fast switching diode	Vishay
D2	1N4148WS	Fast switching diode	Vishay
J1		Pin connector	
J2		Pin connector	
J3		Pin connector	
J4		Pin connector	
J5	7-0215079-4	AMP micro match connector	TE connectivity
R1	3K9	SMD standard film res - 1/8W - 5% - 250ppm/°C	Vishay
R3	47K	SMD standard film res - 1/8W - 1% - 100ppm/°C	Vishay
R4	1K0	SMD standard film res - 1/8W - 5% - 250ppm/°C	Vishay
R5	47K	SMD standard film res - 1/8W - 5% - 250ppm/°C	Vishay
R6	22R	SMD standard film res - 1/8W - 5% - 250ppm/°C	Vishay
R7	120K	SMD standard film res - 1/8W - 1% - 100ppm/°C	Vishay
R8	7K5	SMD standard film res - 1/8W - 1% - 100ppm/°C	Vishay
R9	22K	SMD standard film res - 1/8W - 5% - 250ppm/°C	Vishay
U1	SEA01	Digitally trimmable CV/CC controller	STMicroelectronics

5 Revision history

Table 3. Document revision history

Date	Revision	Changes
24-Oct-2014	1	Initial release.