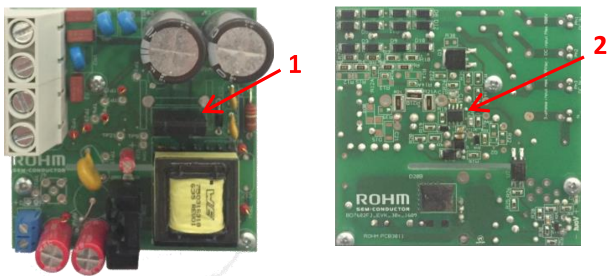
BD7682FJ-EVK-301 EV BOARD USER GUIDE

High voltage input aux power supply ev. Board



1 – 1700V SiC MOSFET SCT2H12NZ
2 – Quasi-resonant controller BD7682FJ-LB
Board dimensions 80mm x 80mm

Figure 1 – Top and Bottom views

Param.	Description	Value
V_{IN}	Input voltage	210…480 V_{AC} 300…to 900 V_{DC}
V_{OUT}	Output voltage	12 V_{DC} ± 3%
P_{OUT}	Output power	30 W @ $V_{IN.MIN}$ 40 W @ $V_{IN.MAX}$
f_{sw}	Switching frequency	90..120 kHz

Table 1- main electrical parameters.

The AUX board is able to operate with both AC and DC input voltages. It is therefore possible to derive the power directly from the grid or from the system DC link, e.g. after the PFC stage. In case of AC input, the accepted input voltage range goes from 210 V_{AC} to 480 V_{AC}. In case of DC input, the input range goes from 300 V_{DC} to 900 V_{DC}. This board version "301" mounts screw connections to facilitate the cabling to 3phase input or Vdc input. It is possible to remove the connectors and use vertical mounting connectors as an example of module board for Aux power supply in a power system.
The simplified schematic of the AUX board is shown in Figure 2.

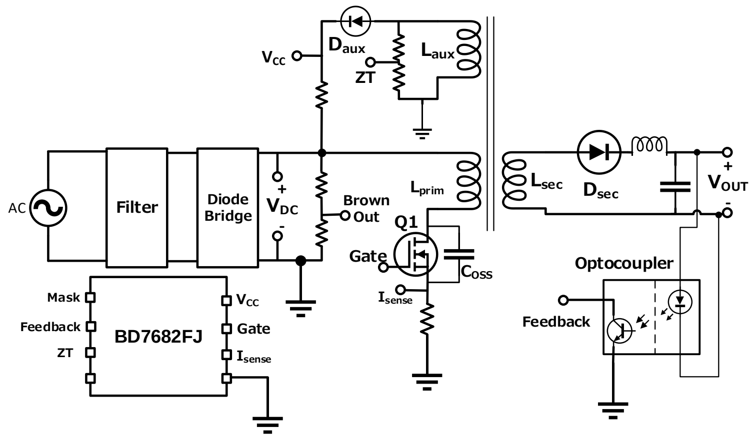


Figure 2 – Simplified schematic of the AUX board.

No. 60UG064E Rev.001
19 Feb 2018

Contents

This evaluation board is intended for research and development and for expert use in the research and development facility only. This board is not intended for use for volume production.

1 Board information

1.1 Schematics

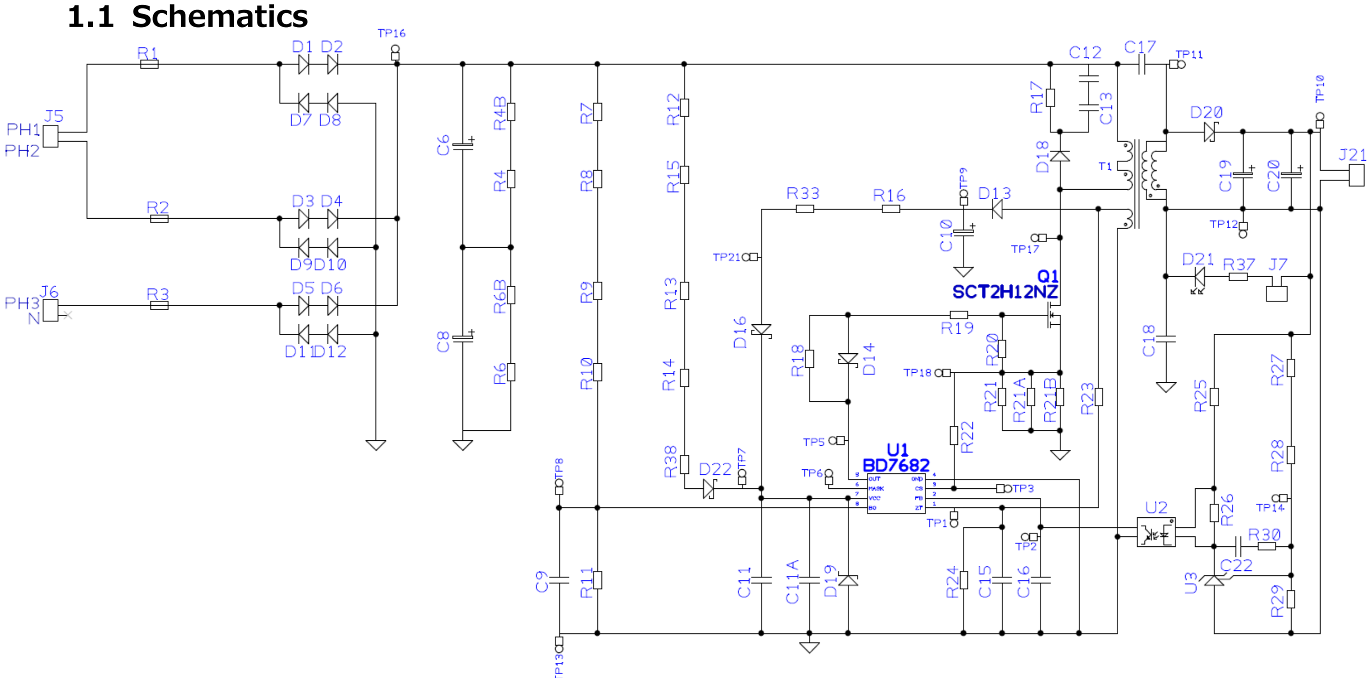


Figure 3 - Full schematic of the AUX board

Please refer to Appendix B for BOM, Appendix C for Layout and Appendix D for alternative startup circuit to improve efficiency.

1.2 Flyback Transformer

A customized transformer manufactured by Würth Elektronik (www.we-online.com), has been designed.
It is possible to order and get all the information by contacting the producer referring code n. 750316318.
The datasheet of the transformer can be found in Appendix A.
The primary side is composed by two windings in series, while the secondary side has been implemented with two windings in parallel. The half-windings are interposed, in order to reduce the leakage inductance around 1% of L_{pri}. This will impact the switching behavior of the MOSFET. In addition, the windings have been implemented with Litz wire to reduce the losses due to skin effect.

Parameter	Calculated	Transformer (E25)
Primary inductance	1.07 mH	0.95 mH ±10%
Leakage inductance	--	1% (9 µH)
Maximum primary current	0.86 A	1.5 A *
Turn-ratio primary to secondary	10	10 ± 1%
Turn-ratio secondary to auxiliary	1.92	2 ± 1%

* Core saturation current

Table 2 - Calculated parameters and characteristics of the used transformer.

2 Board usage

2.1 General information before cabling and powering the board:

- Check carefully that the input voltages are within the maximum input range in table 1.
- Double check the cabling before powering the board.
- This board is protected against overload and short circuit.
- Avoid any imperfect connection that can create sparks
- Check the isolation class and section of the cables.
- Apply all appropriate checks and precautions for use of a high voltage board.
- Refer to the notice at the end of this document for proper usage of this board.
- Only use in a technical environment by professionals trained to safely manage high voltage boards.
- This board is only for evaluation purposes and it's not guaranteed for prolonged usage or usage in any final product

2.2 Cabling

2.2.1 3 Phase AC connections:

The board can be connected directly to 3 Phase mains as for the below connection guide.

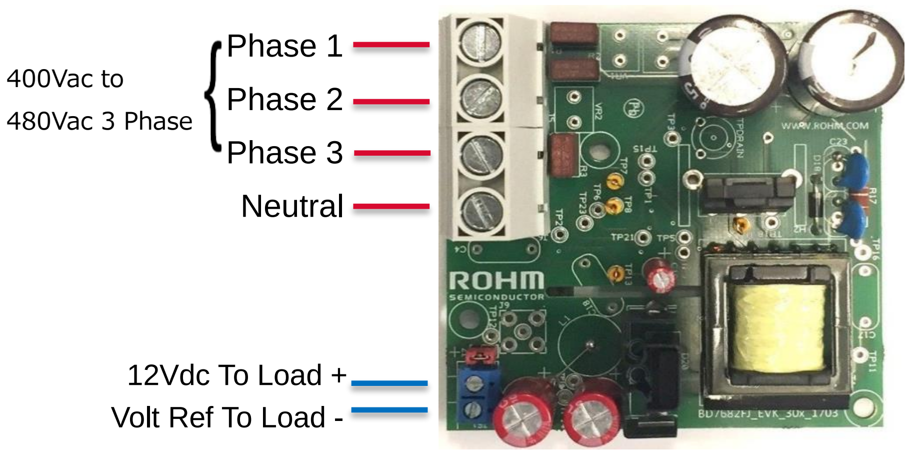


Figure 4 - 3Phase AC connection

2.2.2 DC connections:

If the board is connected to an DC source please follow the below connection guide

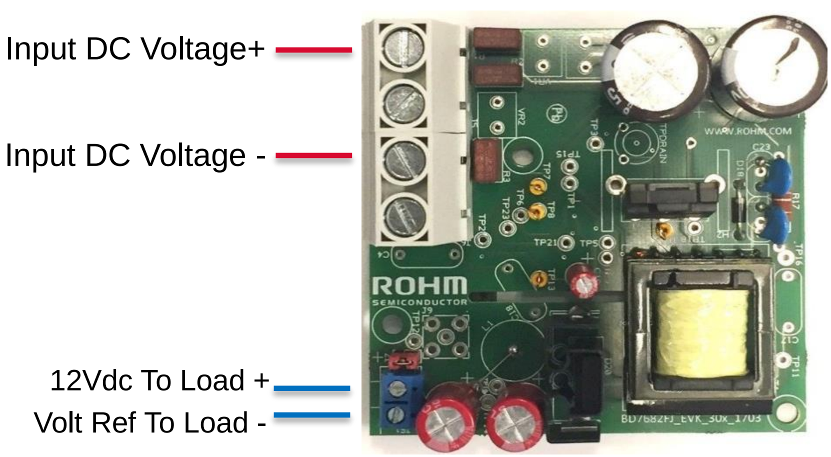


Figure 5 – DC Voltage input connection

Please note that the board mounts diodes for the possibility to be supplied by AC. Due to high voltage input compatibility are used 2 diodes in series. To avoid the drop of diodes effect on functionalities (i.e. efficiency measurements) connect directly to the positive of Capacitor C6 and negative of capacitor C8

2.3 Test points

The AUX board contains several testing points, from which it is possible to observe the board operation. The test points and the related signals are given in the following table.

Test Point	Signal***
TP1	Controller ZT pin
TP2	Controller FB pin
TP5	Controller OUT pin
TP7	Controller $V_{CC\ pin}$
TP8	Controller Brown-out pin
TP10	Board V_{OUT}
TP11	Trafo sec. terminal
TP13	Controller GND pin
TP16	Input voltage V_{IN}
TP18	Controller CS pin

Table 3 – Testing points in AUX board.

3 Implementation and practical tests with AUX Board

The AUX board has been implemented in a printed circuit board (PCB), whose dimensions are 8 cm x 8 cm – see Figure 6. All surface mount devices (SMD) components have been assembled on the bottom side. On the top side were soldered the thru hole devices (THD) and connectors. The layout of both sides is given in Appendix C. In the following sections, experimental results at different input voltages and output power are presented and discussed.

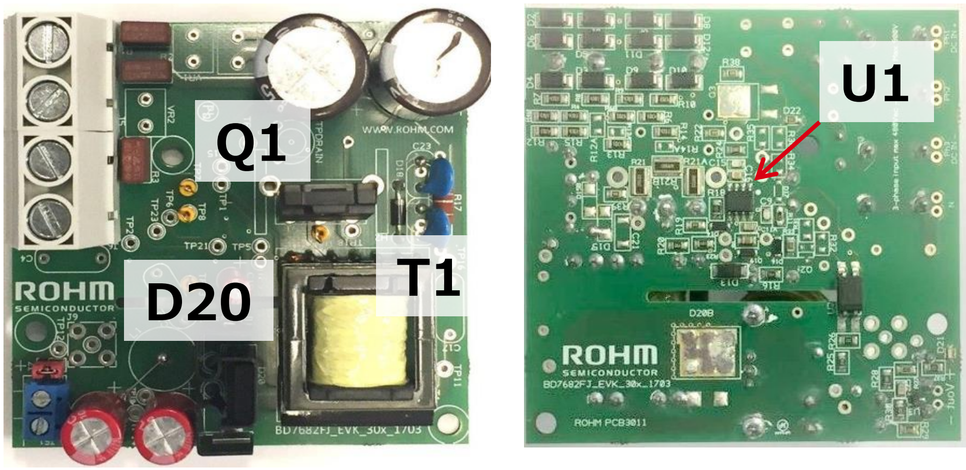
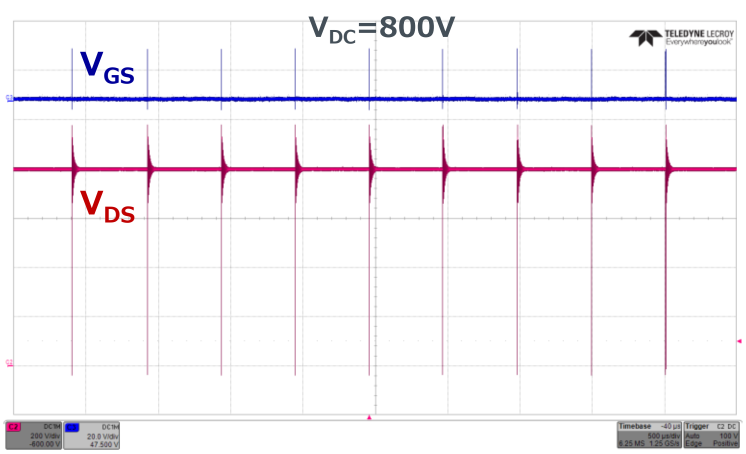


Figure 6 – Top side (left) and bottom side (right) of the AUX board.

3.1 Operation at no load

At no load operation, the controller goes in burst mode – see Figure 16 – and the switching frequency is reduced to some kHz. The dynamic losses of the Flyback components are consequently reduced. Measured stand-by losses are given in the table on the right side of Figure 7. They are expected to come mainly from the resistive dividers present on the circuit: input capacitor balance, start-up and input voltage sense.



DC voltage	Stand-by losses
300 V	0.372 W
900 V	1.7 W

Figure 7 – Waveforms from Flyback switch during burst mode, for V_{DC} = 800 V.

3.2 Normal operation

Figure 8 presents the waveforms from SCT2H12NZ during normal operation of the Flyback circuit, for V_{DC} = 800 V and different values of output power. Time periods t_{on}, t_{decay} and t_{delay} are indicated, according to the description in **Error! eference source not found.**.

For light power – left side – the controller waits several valleys to switch the MOSFET on. Therefore, the switching frequency is quite low, eventually below the defined frequency range.

As the output power increases, the number of oscillations is reduced. As consequence, t_{delay} is reduced, and the switching frequency increases. At nominal power, the turn-on occurs already in the first valley.

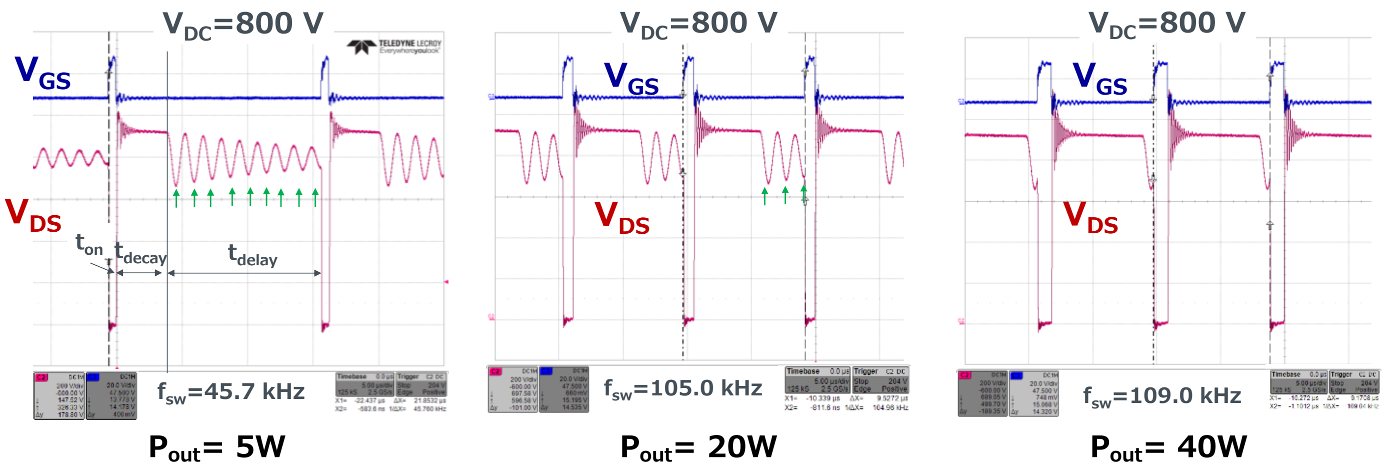


Figure 8 – Waveforms from Flyback switch during different output power conditions, V_{DC} = 800 V.

3.3 Efficiency and temperature measurements

The efficiency of the AUX board has been measured for three different input voltage values. The efficiency curves are shown in Figure 9. As a DC power source was used, it was connected directly to the input capacitors. This way, the rectifying bridge is by-passed, saving the losses that would otherwise come from the bridge diodes.

Efficiency is increasing with the output power, and it is higher for lower levels of input voltage. For V_{DC} = 300 V, the measured peak efficiency η=88% at P_{OUT}=33W – above that the overload protection was activated.

The temperature of the main components of AUX board has been measured, namely the SiC MOSFET (**Q1**), the Flyback transformer and the secondary diode (**D20)**. The measurements were performed using an infrared camera. The thermal images are presented in Figure 10. They were taken at room temperature, V_{DC}=800 V and P_{OUT}=40W. The case temperature of the SiC MOSFET (Sp1) is around 84°C, even without the use of an external heatsink and without forced ventilation. The temperature of the Flyback transformer (Sp2), registered on the winding corner, is slightly above 70°C. The measured temperature of the output diode (Sp3) was around 95°C.

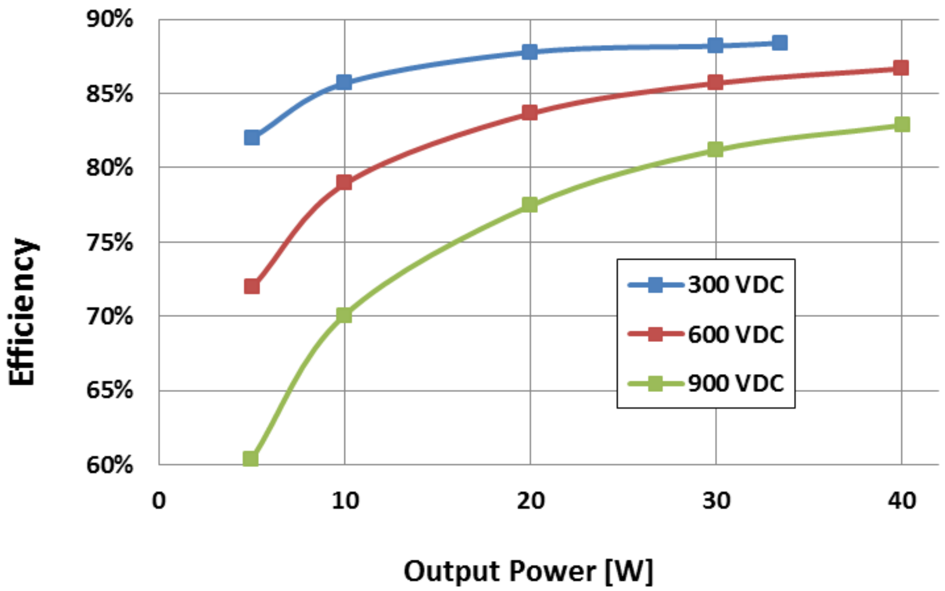


Figure 9 – Efficiency curve of the AUX board for several DC input voltage values.

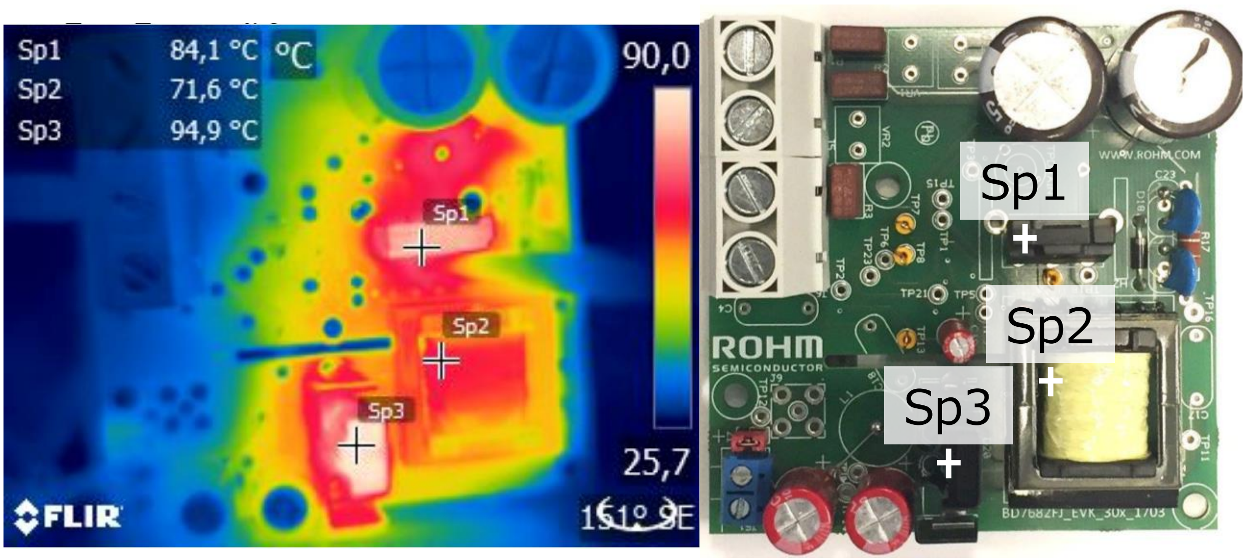


Figure 10 – Temperature measurements from main components of the AUX board.

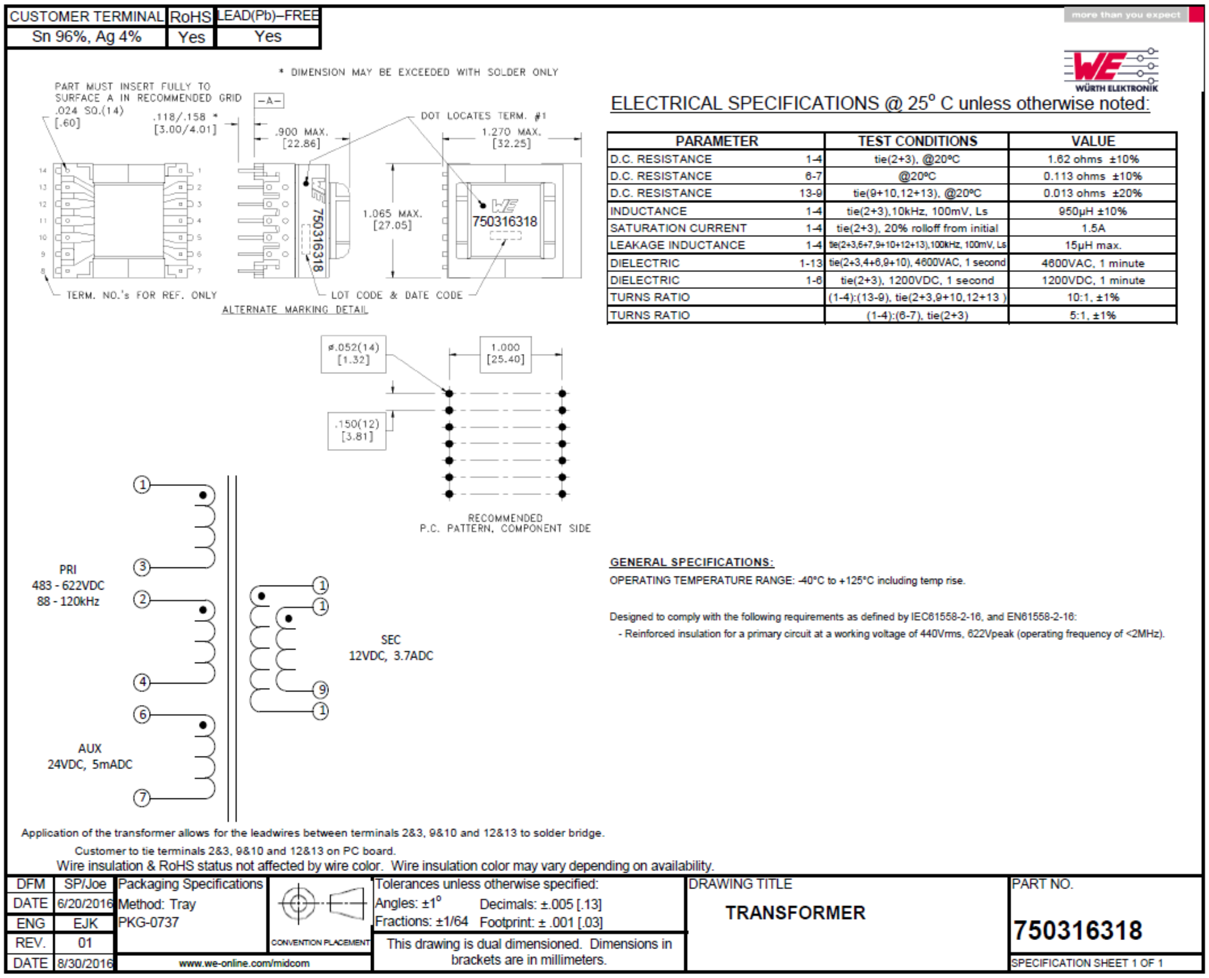
4 Summary

This document presented the design procedure of an auxiliary power supply, based on Flyback topology, focused on industrial applications as auxiliary power supply. Main devices of this design are the SiC MOSFET SCT2H12NZ, with very low on resistance, and the quasi resonant controller BDF768xFJ-LB. They enable a simple electrical and thermal design, reducing the amount of devices, and avoiding the use of heat-sink for the Flyback switch.
Experimental tests in the AUX board proved the operation principle of the quasi resonant controller. Thermal and efficient measurements showed also the reduced amount of losses in the SiC MOSFET, proving it is the right choice for auxiliary supplies in 3-phase industrial systems.

5 References

[1] Datasheet of SCT2H12NZ http://www.rohm.com/web/global/datasheet/SCT2H12NZ/sct2h12nz-e
[2] Datasheet of BDF768xFJ-LB controller family, available at: http://www.rohm.de/web/de/products/-/product/BD7682FJ-LB
[3] Application Note "BD768xFJ-LB series Quasi-Resonant converter Technical Design", available at: http://rohmfs.rohm.com/en/products/databook/applinote/ic/power/acdc_converter/bd768xfj-lb_appli-e.pdf

Appendix A. Transformer datasheet and pictures



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

* DIMENSION MAY BE EXCEEDED WITH SOLDER ONLY

PART MUST INSERT FULLY TO SURFACE A IN RECOMMENDED GRID

TERM. NO.'s FOR REF. ONLY

DOT LOCATES TERM. #1

LOT CODE & DATE CODE

ALTERNATE MARKING DETAIL

RECOMMENDED P.C. PATTERN, COMPONENT SIDE

PRI 483 - 622VDC 88 - 120kHz

SEC 12VDC, 3.7ADC

AUX 24VDC, 5mADC

ELECTRICAL SPECIFICATIONS @ 25° C unless otherwise noted:

PARAMETER		TEST CONDITIONS	VALUE
D.C. RESISTANCE	1-4	tie(2+3), @20ºC	1.62 ohms ±10%
D.C. RESISTANCE	6-7	@20ºC	0.113 ohms ±10%
D.C. RESISTANCE	13-9	tie(9+10,12+13), @20ºC	0.013 ohms ±20%
INDUCTANCE	1-4	tie(2+3),10kHz, 100mV, Ls	950µH ±10%
SATURATION CURRENT	1-4	tie(2+3), 20% rolloff from initial	1.5A
LEAKAGE INDUCTANCE	1-4	tie(2+3,6+7,9+10+12+13),100kHz, 100mV, Ls	15µH max.
DIELECTRIC	1-13	tie(2+3,4+6,9+10), 4600VAC, 1 second	4600VAC, 1 minute
DIELECTRIC	1-6	tie(2+3), 1200VDC, 1 second	1200VDC, 1 minute
TURNS RATIO		(1-4):(13-9), tie(2+3,9+10,12+13)	10:1, ±1%
TURNS RATIO		(1-4):(6-7), tie(2+3)	5:1, ±1%

GENERAL SPECIFICATIONS:

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

Designed to comply with the following requirements as defined by IEC61558-2-16, and EN61558-2-16:

- Reinforced insulation for a primary circuit at a working voltage of 440Vrms, 622Vpeak (operating frequency of <2MHz).

Application of the transformer allows for the leadwires between terminals 2&3, 9&10 and 12&13 to solder bridge.

Customer to tie terminals 2&3, 9&10 and 12&13 on PC board.

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

DFM	SP/Joe	Packaging Specifications	Tolerances unless otherwise specified:	DRAWING TITLE
DATE	6/20/2016	Method: Tray	Angles: ±1° Decimals: ±.005 [.13]	TRANSFORMER
ENG	EJK	PKG-0737	Fractions: ±1/64 Footprint: ± .001 [.03]	PART NO. 750316318
REV.	01	CONVENTION PLACEMENT	This drawing is dual dimensioned. Dimensions in brackets are in millimeters.	
DATE	8/30/2016	www.we-online.com/midcom		SPECIFICATION SHEET 1 OF 1

Fig. A.1 – Datasheet of the constructed Flyback transformer.

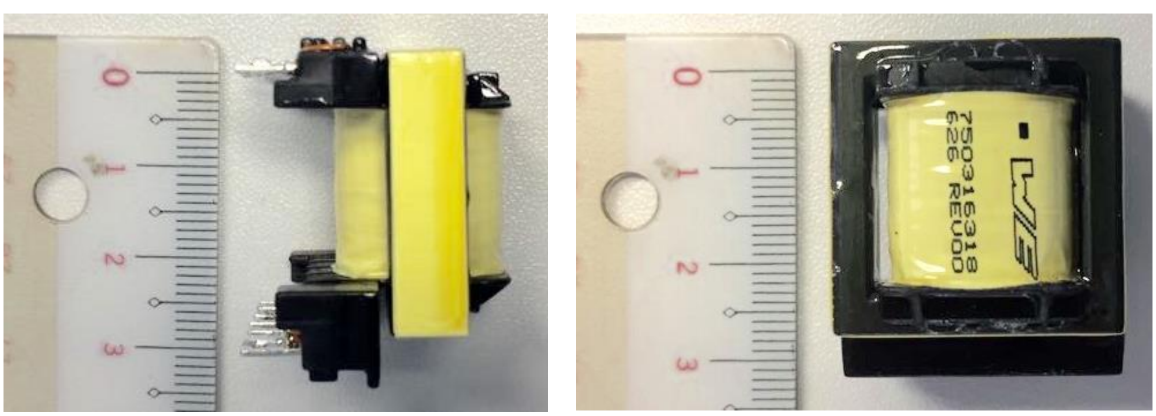


Fig. A.2 – Side view (left) and top view (right) of the Flyback transformer.

Appendix B. Bill of Materials

Position Name	Value	Description	Manufacturer	Manufacturer's Code	Mounted
C4, C17, C18, C23	---	----	----	---	**No**
C6, C8	100 uF	Electrolytic capacitor 450V 7.5mm pitch 18mm diameter	NICHICON	UCY2W101MHD	**Yes**
C9, C15	47 pF	Ceramic capacitor 0805 10% 50V COG	WURTH	885012007055	**Yes**
C10	22 uF	Electrolytic capacitor 50V 2mm pitch 5mm diameter	WURTH	860040672001	**Yes**
C11	2.2 uF	Ceramic capacitor 0805 35V X7R	TDK	C2012X7R1V225K085AC	**Yes**
C11A, C22	100nF	Ceramic capacitor 0805 50V X7R	WURTH	885012207098	**Yes**
C12, C13	2.2 nF	Ceramic capacitor 1kV 5mm pitch 8.5mm diameter	TDK	CK45-B3AD222KYNNA	**Yes**
C16	2.2 nF	Ceramic capacitor 0805 50V X7R	WURTH	885012207088	**Yes**
C19, C20	470 uF	Electrolytic Aluminium capacitor 35V 5mm pitch 10mm diameter	WURTH	860080575017	**Yes**
C21	---	----	----	---	**No**
D1, D2, D3, D4, D5, D6, D7, D8, D9, D10, D11, D12	1A 1000V	Rectifier Diode S1M Vishay	VISHAY	S1M-E3/61T	**Yes**
D13	---	Fast Diode 400V 1A	ROHM	RF101L4S	**Yes**
D14, D16	---	Schottky Diode 60V 1A	ROHM	RB160M-60	**Yes**
D15, D15B	---	----	----	---	**No**
D17	---	Zener Diode 20V 1W	ROHM	KDZVTR20B	**No**
D18	---	Ultrafast Diode 1200V 1A	STM	STTH112RL	**Yes**
D19	---	Zener Diode 24V 1W	ROHM	KDZVTR24B	**Yes**
D20	---	Schottky Barrier Diode 200V 30A	SANGDEST	MBRF30200CT	**Yes**
D20B	---	----	----	---	**No**
D21	---	SML-A12P8T Side LED Green 20mA	ROHM	SML-A12P8T	**Yes**
D22	0 Ohm	Resistor 0805 footprint	ROHM	MCR10EZPJ000	**Yes**
D22 (ASC)	---	Schottky Diode 60V 1A	ROHM	RB160M-60	**No**
H1	---	Heatsink for TO220 Transistor	AAVID	574602B03700G	**Yes**
H2	---	Heatsink for TO247 Transistor	OHMITE	WA-T247-101E	**No**
J5, J6	---	Connector pitch 10.16mm 2 pins	Wurth	691 219 610 002	**Yes**
J7	---	Header connector male pitch 2.54mm	3M	961102-6404-AR	**Yes**
J21	---	Connector pitch 5mm 2 pins	Wurth	691102710002	**Yes**
Q1	---	1700V 3.7A SIC MOSFET	ROHM	SCT2H12NZ	**Yes**
Q2	---	NPN transistor 50V 0.5A	ROHM	2SD1484KT146R	**No**
Q3	---	500V 800mA Normally on MOSFET	IXYS	IXTY08N50D2	**No**
R1, R2, R3	3.15 A	Fuse 250V	Littelfuse	4001315	**Yes**

Position Name	Value	Description	Manufacturer	Manufacturer's Code	Mounted
R4, R4B, R6, R6B, R7, R8, R9, R10	470kOhm	Resistor 1206 footprint	ROHM	MCR18ERTF4703	**Yes**
R11	10kOhm	Resistor 0805 footprint	ROHM	MCR10ERTF1002	**Yes**
R12A, R13A, R14A, R35, R39	0 Ohm	Resistor 0805 footprint	ROHM	MCR10EZPJ000	**No**
R16	4.7kOhm	Resistor 0805 footprint	ROHM	MCR10ERTF4701	**Yes**
R17	330kOhm	Resistor 2W V	VISHAY	PR02000203303JR500	**Yes**
R18	100 Ohm	Resistor 0805 footprint	ROHM	MCR10ERTF1000	**Yes**
R19	10 Ohm	Resistor 0805 footprint	ROHM	MCR10ERTF10R0	**Yes**
R20	47kOhm	Resistor 0805 footprint	ROHM	MCR10ERTF4702	**Yes**
R21, R21A	3 Ohm	Resistor footprint 1020 Wide	ROHM	LTR50UZPF3R00	**Yes**
R21B	6.8 Ohm	Resistor footprint 1020 Wide	ROHM	LTR50UZPF6R80	**Yes**
R22, R38	0 Ohm	Resistor 0805 footprint	ROHM	MCR10EZPJ000	**Yes**
R23	120kOhm	Resistor 0805 footprint	ROHM	MCR10ERTF1203	**Yes**
R24, R30	12kOhm	Resistor 0805 footprint	ROHM	MCR10ERTF1202	**Yes**
R25	300 Ohm	Resistor 0805 footprint	ROHM	MCR10ERTF3000	**Yes**
R26, R37	1kOhm	Resistor 0805 footprint	ROHM	MCR10ERTF1001	**Yes**
R27	15kOhm	Resistor 0805 footprint	ROHM	MCR10ERTF1502	**Yes**
R28	180kOhm	Resistor 0805 footprint	ROHM	MCR10ERTF1803	**Yes**
R29	51kOhm	Resistor 0805 footprint	ROHM	MCR10ERTF5102	**Yes**
R31	---	----	----	---	**No**
R34	4.7kOhm	Resistor 0805 footprint	ROHM	MCR10ERTF4701	**No**
R36	10kOhm	Res 0805 footprint	ROHM	MCR10ERTF1002	**No**
T1	---	FLyback Transformer	WURTH	750316318	**Yes**
U1	---	ACDC flyback driver for SIC MOSFET	ROHM	BD7682	**Yes**
U2	---	5kV Optocoupler	SHARP	PC817XNNIP0F	**Yes**
U3	---	Voltage reference 2.49V	TI	TL431AIDBZR	**Yes**

Appendix C. AUX Board layout

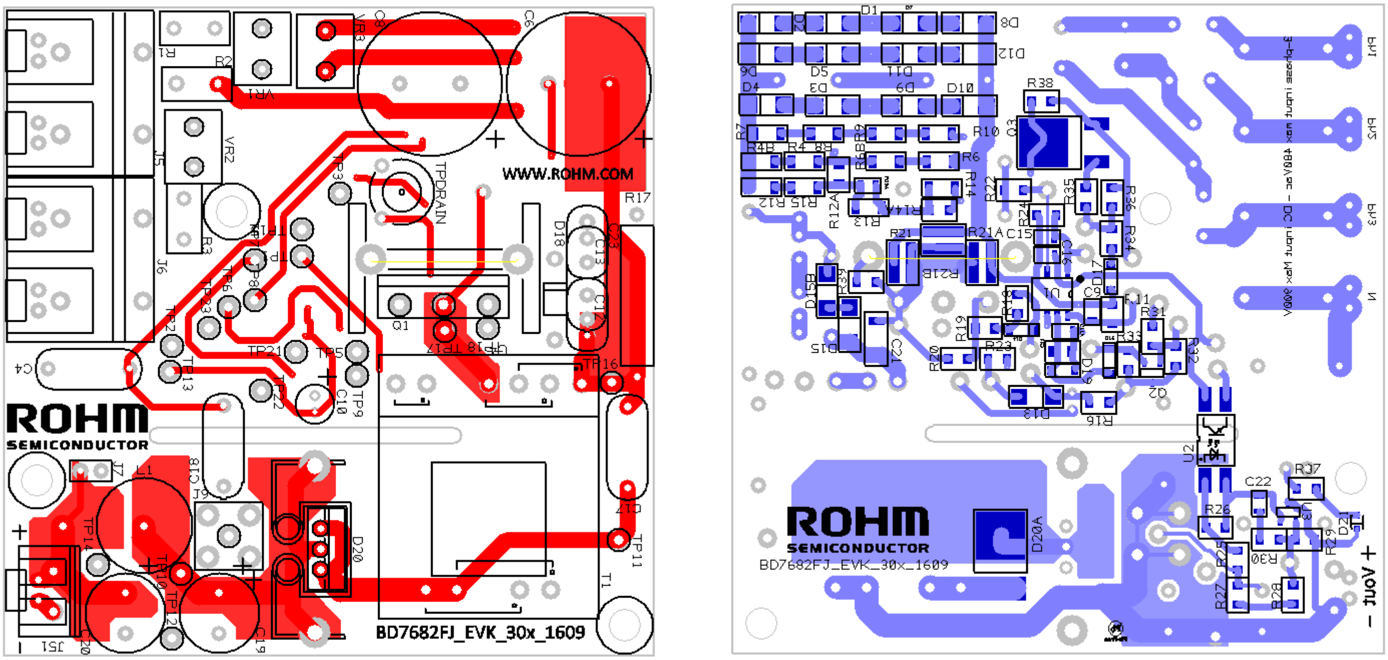


Fig. C.1 – Layout of top side (left) and bottom side (right) of the AUX board.

Appendix D. Alternative Start-up Circuitry

This section presents an alternative start-up circuitry (ASC) for the AUX board. It aims to reduce the start-up time, avoiding at the same time extra losses coming from the start-up resistor divider. The working principle of the ASC is depicted in Fig. D.1.

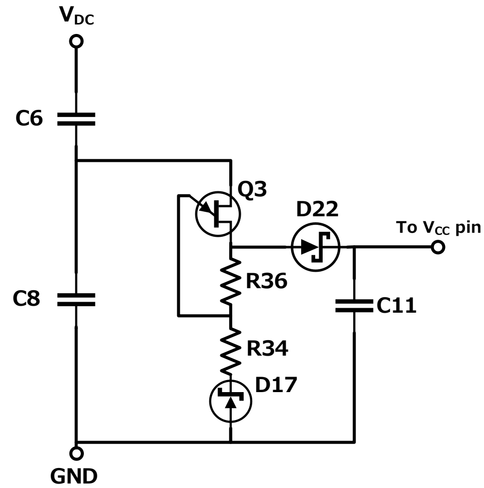


Fig. D.1 – Work principle of the alternative start-up circuitry (ASC).

During start-up a current flows from input capacitor **C8** through the depletion mode MOSFET **Q3** (normally-on). This current will charge the V_{CC} capacitor **C11**. The gate pin of **Q3** is connected in the middle of the resistor divider formed by **R36** and **R34**. As the voltage over **C11** increases, the gate voltage of **Q3** becomes negative with respect to its source voltage. When threshold voltage of **Q3** is achieved, it turns off. Resistors **R36** and **R34**, and Zener diode **D17** are dimensioned so that V_{CC} achieves the minimum value (UVLO) for the controller to start. From this point, controller will be fed by the auxiliary winding, and **Q3** will stay off until the next start-up. Diode **D22** is placed to avoid losses through **R36** and **R34** after start-up.

The dimensioning of ASC starts from the choice of the MOSFET **Q3**. Since silicon FETs rated for 900 V are not available, **Q3** is connected to the middle point between the input capacitors **C6** and **C8**. This enables the MOSFET to be rated to 500 V. The recommended part is IXTY08N50D2, from IXYS. According to datasheet, the threshold voltage has minimum and maximum levels of -4 V and -2 V, respectively. The minimum V_{CC} voltage for the controller to start is *UVLO* = 20 V (max), and the overvoltage protection of V_{CC} is OVP = 27.5 V (min).

During start-up, the voltage over resistor **R36** is the voltage between gate and source of **Q3**. By setting **R36** = 10 kΩ:

$$R36 \cdot i_{R36} < 2\,V \text{ only if } V_{C11} > 19.5\,V \rightarrow i_{R36} < 0.2\,mA \text{ for } V_{C11} = 19.5\,V \quad (1)$$

$$R36 \cdot i_{R36} > 4\,V \text{ only if } V_{C11} < 27.5\,V \rightarrow i_{R36} > 0.4\,mA \text{ for } V_{C11} = 27.5\,V \quad (2)$$

By using a 20 V Zener diode as **D17**, the first condition is automatically satisfied.

For the second condition, the current through **R36** can be calculated as:

$$i_{R36} = \frac{V_{C11} + V_{D22} - V_{D17}}{R36 + R34} \quad (3)$$

Which leads to:

$$R34 < \frac{27.5\,V + 0.3\,V - 20V}{0.4\,mA} - 10\,k\Omega \rightarrow R34 < 9.5\,k\Omega \quad (4)$$

Chosen value for **R34** = 4.7 kΩ.

Fig. D.2 presents the waveforms of the start-up of the AUX board, done by standard configuration and with ASC. It is possible to observe that the start-up time is reduced by a factor of 100. Moreover, since the start-up resistive divider is not used in ASC, the losses caused by those resistors are not present in the ASC configuration

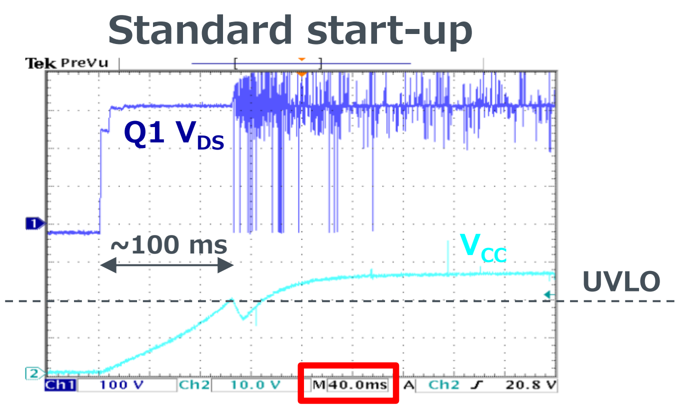


Fig. D.2 – Schematics of the AUX board with alternative start-up circuitry (ASC).

The full schematic of AUX board with implemented ASC is depicted in Fig. D.3. Devices different from original schematics are drawn in a different color. Please note they are not assembled in the original board. However, their respective footprints are present on the board, assuming the devices given in the bill of materials list – see Appendix B.

In addition to extra components, the resistors **R38** and **R12** must be removed. Finally, before **D22** is placed, the originally soldered 0 Ω resistor must be removed.

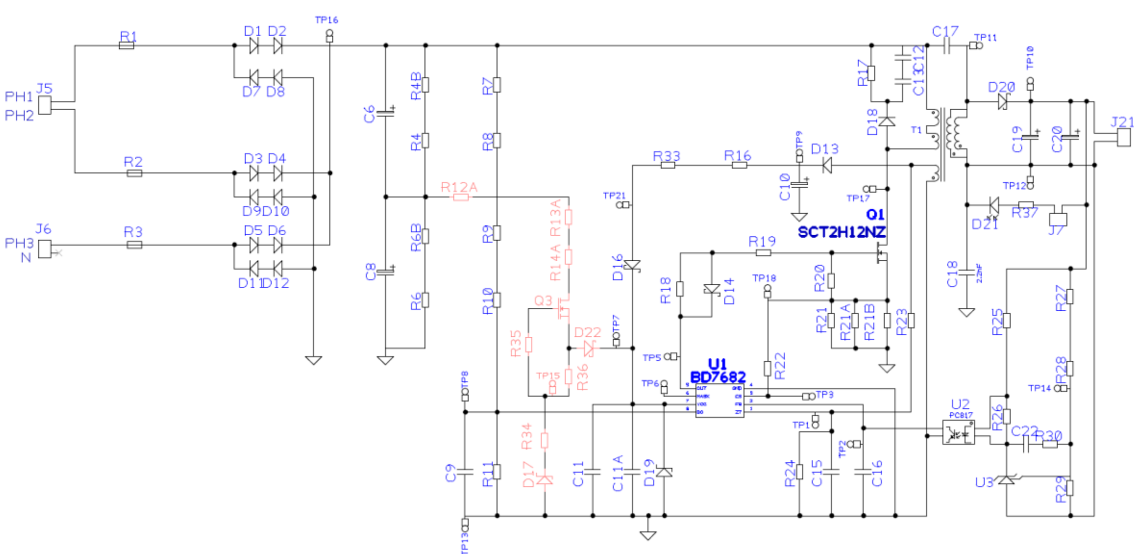


Fig. D.3 – Schematics of the AUX board with alternative start-up circuitry (ASC).

Notes

1) The information contained herein is subject to change without notice.

2) Before you use our Products, please contact our sales representative and verify the latest specifications :

3) Although ROHM is continuously working to improve product reliability and quality, semiconductors can break down and malfunction due to various factors.
Therefore, in order to prevent personal injury or fire arising from failure, please take safety measures such as complying with the derating characteristics, implementing redundant and fire prevention designs, and utilizing backups and fail-safe procedures. ROHM shall have no responsibility for any damages arising out of the use of our Poducts beyond the rating specified by ROHM.

4) Examples of application circuits, circuit constants and any other information contained herein are provided only to illustrate the standard usage and operations of the Products. The peripheral conditions must be taken into account when designing circuits for mass production.

5) The technical information specified herein is intended only to show the typical functions of and examples of application circuits for the Products. ROHM does not grant you, explicitly or implicitly, any license to use or exercise intellectual property or other rights held by ROHM or any other parties. ROHM shall have no responsibility whatsoever for any dispute arising out of the use of such technical information.

6) The Products specified in this document are not designed to be radiation tolerant.

7) For use of our Products in applications requiring a high degree of reliability (as exemplified below), please contact and consult with a ROHM representative : transportation equipment (i.e. cars, ships, trains), primary communication equipment, traffic lights, fire/crime prevention, safety equipment, medical systems, servers, solar cells, and power transmission systems.

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ROHM SEMICONDUCTOR

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■<High Voltage Safety Precautions>

◇ Read all safety precautions before use

Please note that this document covers only the BD7682FJ & SCT2H12NZ evaluation board (BD7682FJ-EVK-301) and its functions. For additional information, please refer to the datasheet.

To ensure safe operation, please carefully read all precautions before handling the evaluation board

Depending on the configuration of the board and voltages used,

Potentially lethal voltages may be generated.

Therefore, please make sure to read and observe all safety precautions described in the red box below.

Before Use

[1] Verify that the parts/components are not damaged or missing (i.e. due to the drops).
[2] Check that there are no conductive foreign objects on the board.
[3] Be careful when performing soldering on the module and/or evaluation board to ensure that solder splash does not occur.
[4] Check that there is no condensation or water droplets on the circuit board.

During Use

[5] Be careful to not allow conductive objects to come into contact with the board.
[6] **Brief accidental contact or even bringing your hand close to the board may result in discharge and lead to severe injury or death.**
Therefore, DO NOT touch the board with your bare hands or bring them too close to the board.
In addition, as mentioned above please exercise extreme caution when using conductive tools such as tweezers and screwdrivers.
[7] If used under conditions beyond its rated voltage, it may cause defects such as short-circuit or, depending on the circumstances, explosion or other permanent damages.
[8] Be sure to wear insulated gloves when handling is required during operation.

After Use

[9] The ROHM Evaluation Board contains the circuits which store the high voltage. Since it stores the charges even after the connected power circuits are cut, please discharge the electricity after using it, and please deal with it after confirming such electric discharge.
[10] Protect against electric shocks by wearing insulated gloves when handling.

This evaluation board is intended for use only in research and development facilities and should by handled **only by qualified personnel familiar with all safety and operating procedures.**

We recommend carrying out operation in a safe environment that includes the use of high voltage signage at all entrances, safety interlocks, and protective glasses.