XMC 750 Watt Motor Control Application Kit

Part Number: KIT_XMC750WATT_MC_AK_V1

What can you move with 1 horse power?

The XMC 750 Watt Motor Control Application Kit gives you the answer. The power board includes off-the-grid supply with input filter, active PFC and high switching frequency IGBTs from Infineon to turn your 3-Phase drive. Both CPU Cards (XMC1300 and XMC4400 Drive Card) provide a galvanic isolation for the debug interface to guarantee safe operation during software development.

Features

- XMC1300 Drive Card with galvanic isolation
- XMC4400 Drive Card with galvanic isolation
- Power board:
    - 110-230 V / 750 W
    - Input Filter and Active PFC
    - 3-Phase Inverter by Reverse Conduction IGBT
- Supported control schemes
    - V/f open loop
    - Block or sinusoidal commutation with hall sensors or sensorless
    - FOC with hall sensors, encoder or sensorless
- Fully supported by DAVE™ with Motor Control APPs library

<u>PLEASE SEE THE FOLLOWING PAGES FOR THE USERS MANUAL:</u>

User manuals included below:

- Board Users Manual 3phase Power Inverter 750W
- Board Users Manual DriveCard XMC1300
- Board Users Manuals DriveCard XMC4400

Motor Control Application Kit

KIT_XMC750WATT_AK_V1

XMC 750 Watt Motor Control Application Kit
3-Phase drives evaluation with galvanic isolation

Board User‘s Manual

Revision 1.0, 2014-01-30

Microcontroller

Edition 2014-01-30

Published by
Infineon Technologies AG
81726 Munich, Germany

Revision History	
Page or Item	**Subjects (major changes since previous revision)**
Revision 1.0, 2014-01-30	Initial release

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Introduction

This document describes the features and hardware details of the “3 Phase Power Inverter 750W V1.1” which is designed to work with Infineon’s DriveCards. DriveCards are microcontroller boards with isolated debug interface best suited for motor control applications. This power board together with two drive cards (KIT_XMC1300_DC_V1 and KIT_XMC4400_DC_V1) is included in the XMC Motor Control Application Kit KIT_XMC750WATT_AK_V1.

1 Overview

The motor control application kit KIT_XMC750WATT_AK_V1 is designed for use with 230V AC mains power supply. The drive cards provide a galvanically isolated debug interface that allows safe software development. A PFC circuitry can be controlled by the on-board PFC IC or by the microcontroller at the drive card. The power inverter bridge is built by 6 discrete IGBTs in DPAK package. Each leg provides a shunt resistor with amplifier for phase current measurement. The DC-link also provides a shunt resistor with amplifier for reconstruction of the phase current with single shunt method. An additional low pass filter allows measuring the average DC-link current as well. The power supply for the control devices as well as the drive card is provided by a non isolated flyback converter which provides 5V and 15V DC. The auxiliary power board connector allows adding an inverter card in order to use the board together with the XMC4400 drive card as dual inverter.
The main use case for this board is to demonstrate the generic features of the XMC microcontroller devices including tool chain. The focus is the operation under evaluation conditions. The board is neither cost nor size optimized and does not serve as a reference design.
Software examples as well as DAVE Apps are available for download at www.infineon.com/xmc-dev.

1.1 Key Features

The XMC Motor Control Appkication Kit (KIT_XMC750WATT_AK_V1) provides the following features:

- 3 Phase Power Inverter 750W V1.1 (2013/45)
  - Power supply with line filter, NTC bypass relay and PFC circuitry
  - 3 phase bridge realized with discrete IGBTs (IKD10N60R)
  - Integrated gate driver with integrated boot strap diodes and protection features (6EDL04I06NT)
  - PFC control via control IC (ICE3PCS02), MCU or disabled
  - PFC overcurrent protection fully realized in hardware
  - On-board power supply for control components (15V and 5V) with flyback controller (ICE3B0356JG)
  - Voltage dividers for DC-link and inverter output voltage measurement (e.g. for motor back EMF detection)
  - Current sensing circuitry for
    - PFC
    - DC-link current (single shunt measurement)
    - Low side inverter leg currents (emitter shunt measurement)
  - Auxiliary power board connector for optional inverter card
- Drive Card XMC1300
  - XMC1302 (ARM® Cortex™-M0-based) Microcontroller, 200 kByte on-chip Flash, TSSOP38
  - 1 set of combined hall sensor and encoder interfaces
  - Potentiometer
  - Isolated Debug Interface
- Drive Card XMC4400
  - XMC4400 (ARM® Cortex™-M4-based) Microcontroller, 512 kByte on-chip Flash, LQFP100
  - 2 sets of combined hall sensor and encoder interfaces
  - Multi feedback interface connectors for connection of resolver circuitry, UART, SPI, I2C, USB, etc
  - Potentiometer
  - Isolated Debug Interface

1.2 Block Diagram

Figure 1 shows the functional block diagram of the KIT_XMC750WATT_AK_V1.

The drive cards have got the following building blocks:

- Power Board Connector
- 1 or 2 sets of position interface connectors (HALL, ENCODER)
- Encoder Enable signals via GPIOs
- User LEDs connected to GPIOs
- Variable resistor (POTI) connected to ADC
- Isolated On-board Debugger via Debug USB connector (Micro-USB) with UART channel
- Optional Infineon Debug interface connector for Drive Monitor USB Stick V2 (KIT_DRIVEMONI_USB_V2)

Note: Additional documentation is provided for the drive cards (Board User's Manual Drive Card XMC1300 and XMC4400).

The power board has got the following building blocks:

- EMC line filter
- PFC circuitry with over current protection, selectable with PFC IC control or MCU control
- 3phase bridge with IGBTs driver IC and shunts (DC-link single shunt as well as three low side shunts)
- Control IC power supply 15V/5V
- Drive card connector
- Auxiliary power board connector

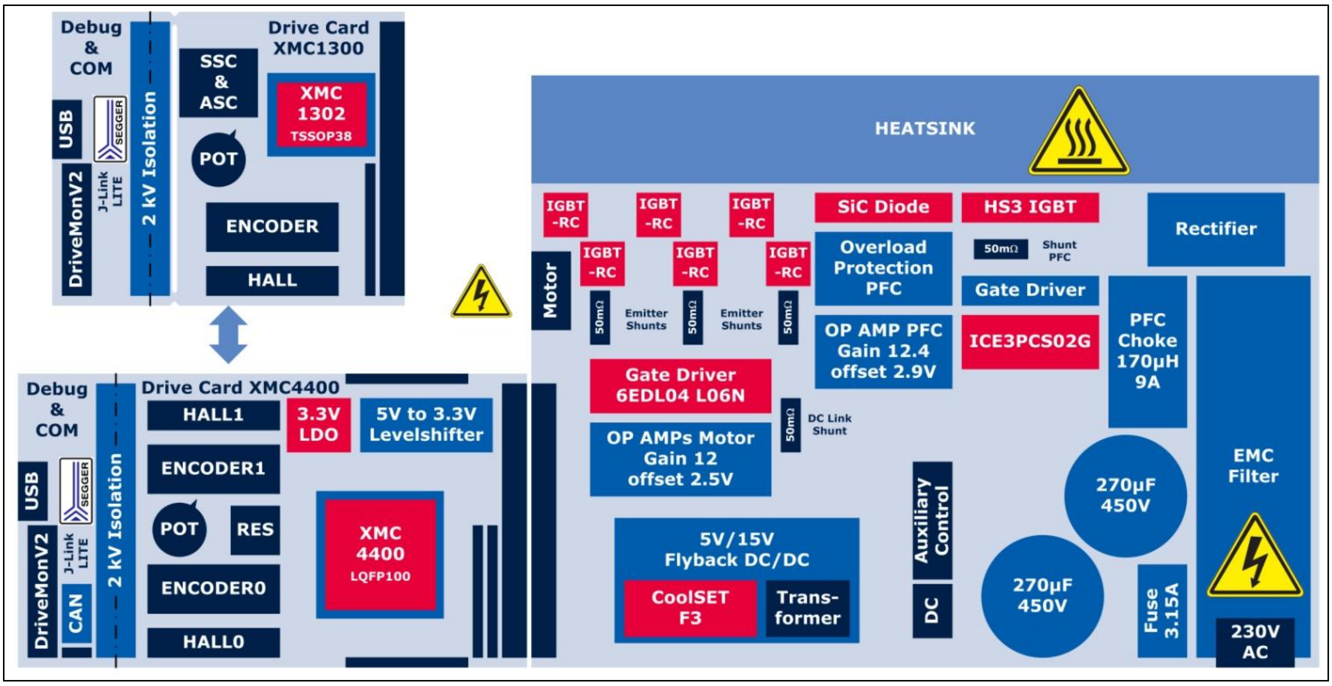


Figure 1 Block Diagram of KIT_XMC750WATT_AK_V1

Attention: Almost all signals of the kit including connectors and testpoints are referenced to power GND supply domain. Hence they may carry hazzardous voltages.

Attention: Due to large capacitors, the DC-Link voltage may provide hazzardous voltages even when the board is unplugged from power supply.

Attention: The heatsink and the power components including the PFC choke may get hot during operation.

2 Hardware Description

The following sections give a detailed description of the hardware and how it can be used.

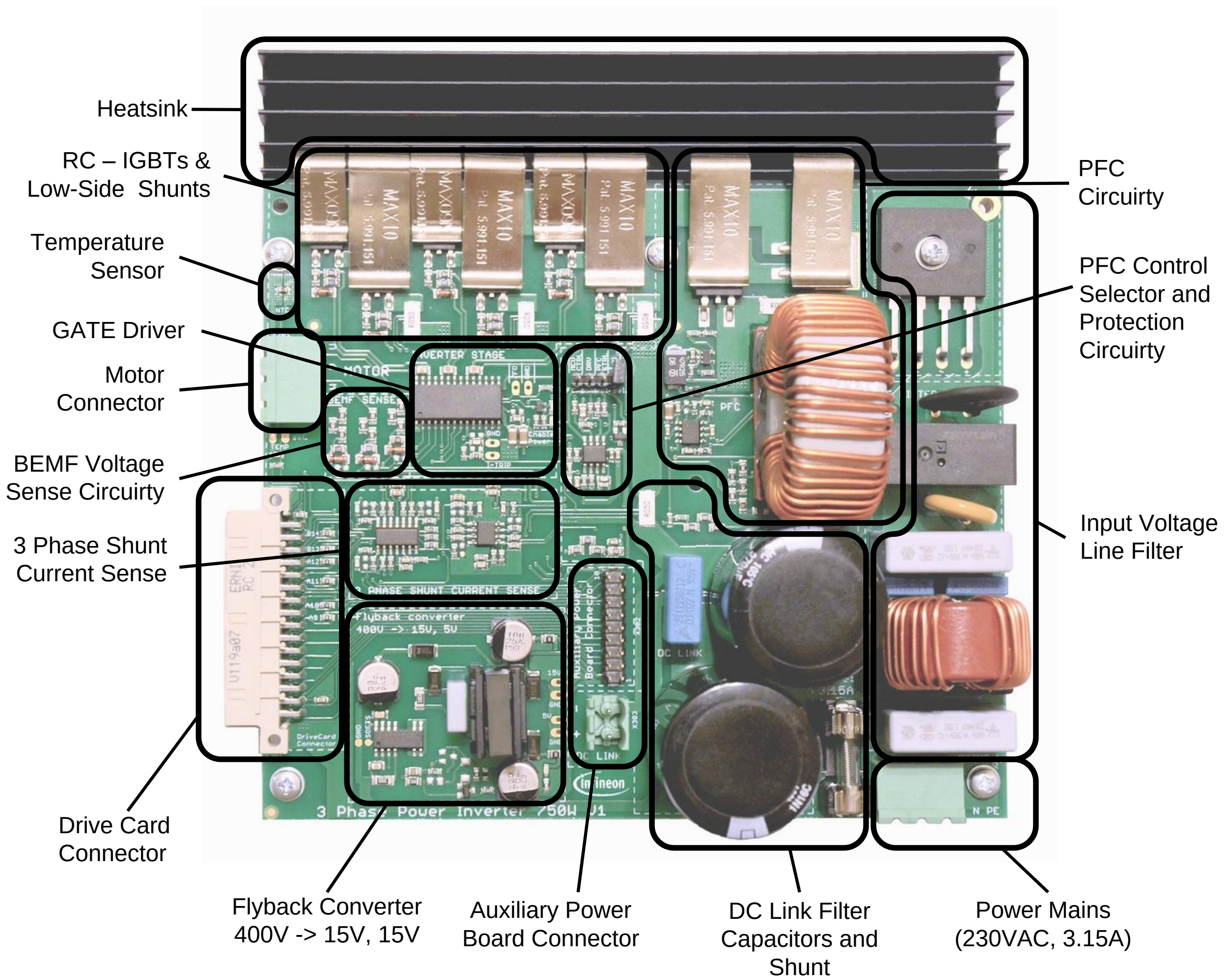


Figure 2 3 Phase Power Inverter 750W V1.1

Table 1 Maximum Ratings

Function	min	max	unit	comment
AC Input voltage without PFC	85	250	V AC	
AC input current	-	3.15	A AC	Limited by fuse F101
PFC input voltage	220	250	V AC	
PFC input current	-	3.5	A AC	Protected by PFC IC
DC-link voltage	120	450	V DC	
VCC_15V supply voltage	14	18	V	
VDD_5V supply voltage	4.65	5.35	V	
VDD_5V supply current	-	200	mA	
Inverter output continuous current	-4.16	4.16	A	
Inverter output peak current	-	9	A	Protected by gate driver IC

2.1 Power Supply

The the “3 Phase Power Inverter 750W V1.1” board is designed for use with 230V AC mains power supply. The power supply contains an EMC line filter with NTC bypass relay, an overcurrent protected PFC stage that can be controlled either by a PFC control IC or by the microcontroller and a flyback converter for 15V and 5V power supply.

2.1.1 EMC Line Filter

The input line filter design is shown in Figure 3. It is protected by a 3.15A fuse. The inrush current limiting NTC resistor R111 is by-passed by the relay K101 after a certain time. This reduces the power losses of the inverter.

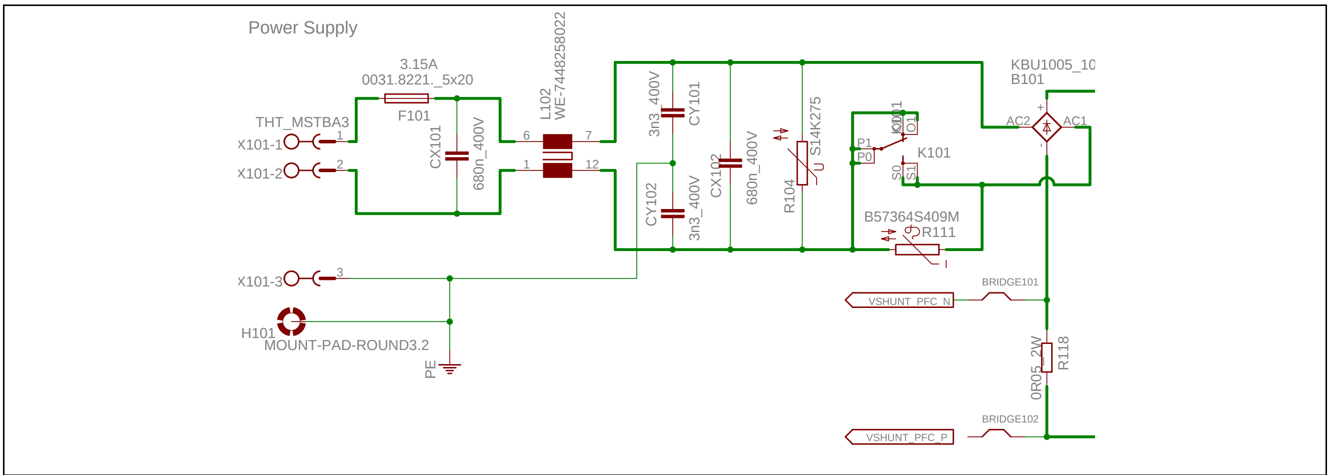


Figure 3 EMC Line Filter

The relay K101 is controlled by the circuitry of Figure 4.

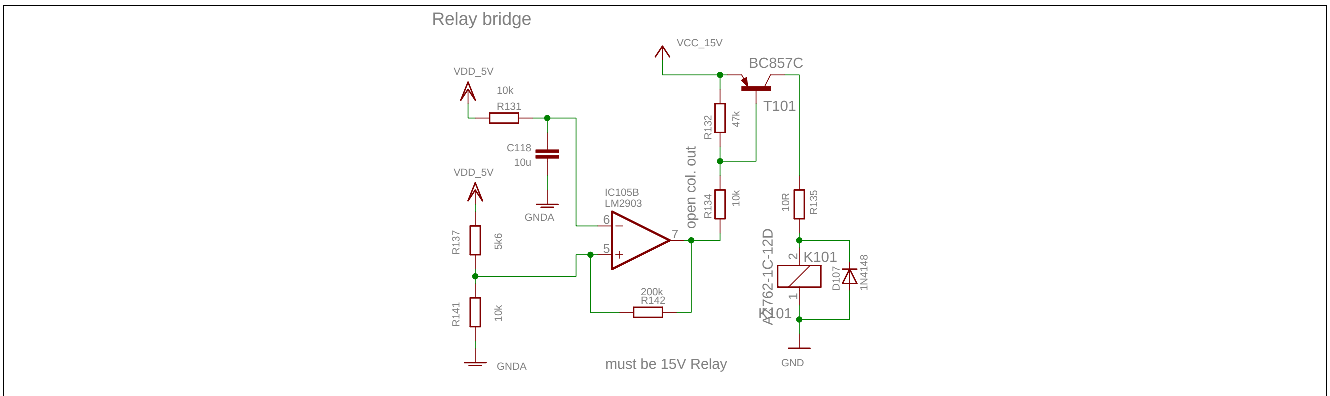


Figure 4 Control Circuitry of Relay K101

2.1.2 PFC Circuitry

The board provides a PFC circuitry which can be controlled by the on-board PFC control IC or by the microcontroller at the drive card. The PFC circuitry is designed to be controlled in continuous conduction mode for a boost voltage up to 400V DC. The maximum peak current is 4.72A. For details please refer to Figure 5 and Figure 6.

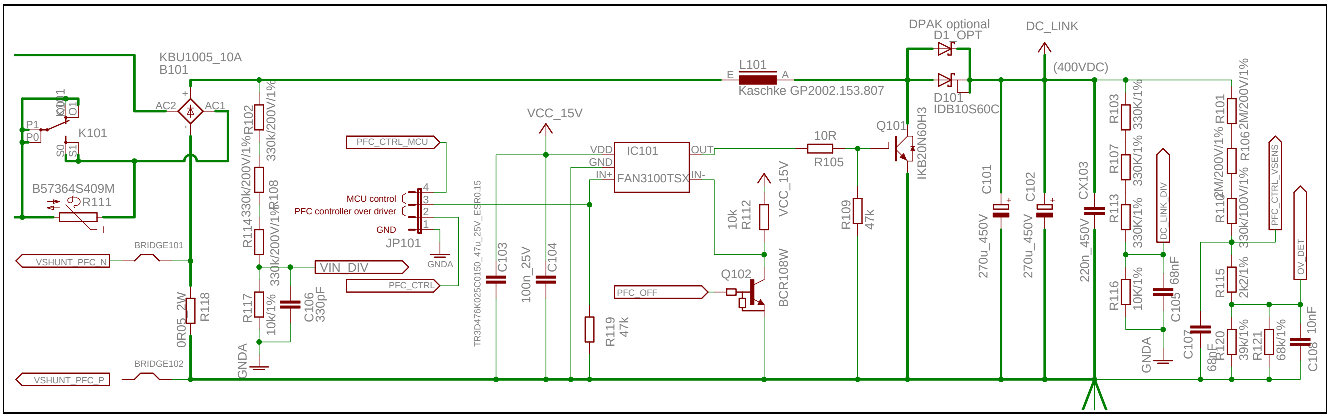


Figure 5 PFC Circuitry

The PFC control type selection is done with jumper JP101. Closed position 3-4 enables PFC control by MCU, closed position 2-3 enables control by the PFC IC. All pins of JP101 open, disables the PFC IC.

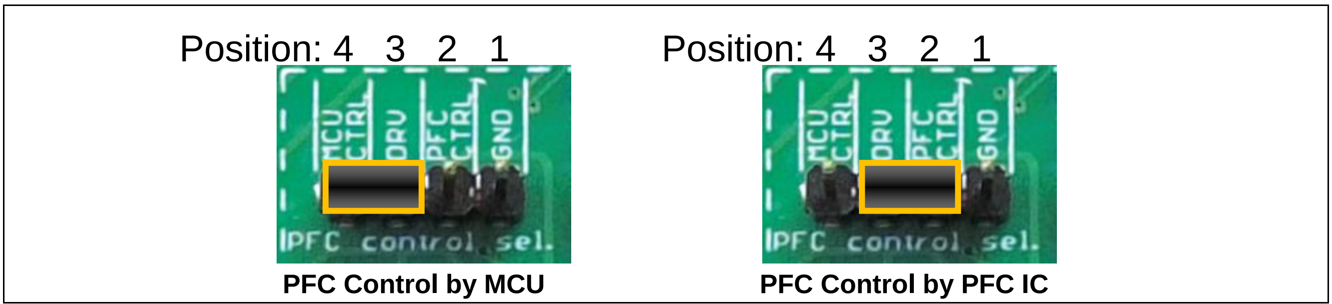


Figure 6 PFC Selector JP101

2.1.3 PFC Control IC, Current Sense and Over Current Protection

The PFC control IC (IC102) ICE3PCS02 is a wide input range (85VAC to 265VAC) controller IC for active CCM (continuous conduction mode) power factor correction. The integrated digital control voltage loop with a switching frequency of 66kHz allows efficieny up to 95% at full load for the entire input voltage range. See Figure 7 for details.

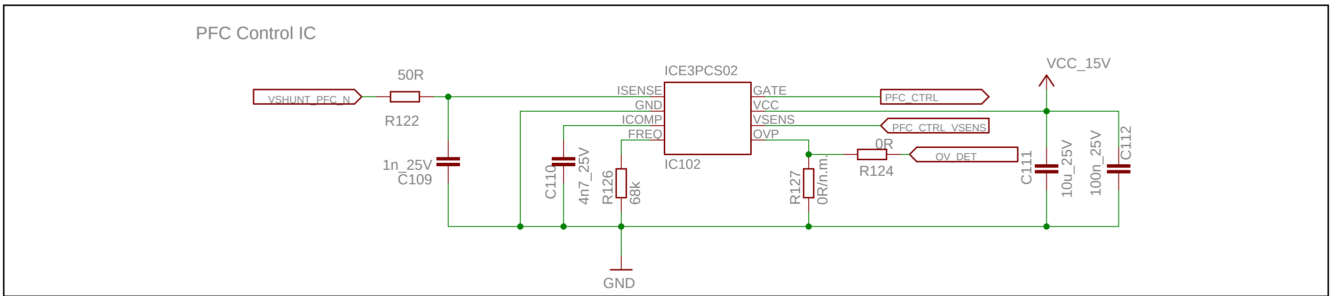


Figure 7 PFC Control IC ICE3PCS02

The PFC stage can be also controlled by the microcontroller of the drive card. There is a current sense amplifier with a gain of 12.4 available. As a result, the current sense signal from the 50mOhm shunt is amplified with a fully differential circuitry. An offset of 2.9V allows a current measurement in the range of –3.36A to +4.72A. The over current protection is realized by a comparator (IC105A) which disables the gate driver (IC101, Figure 5) in case of overcurrent. Please refer to Figure 8 for details.

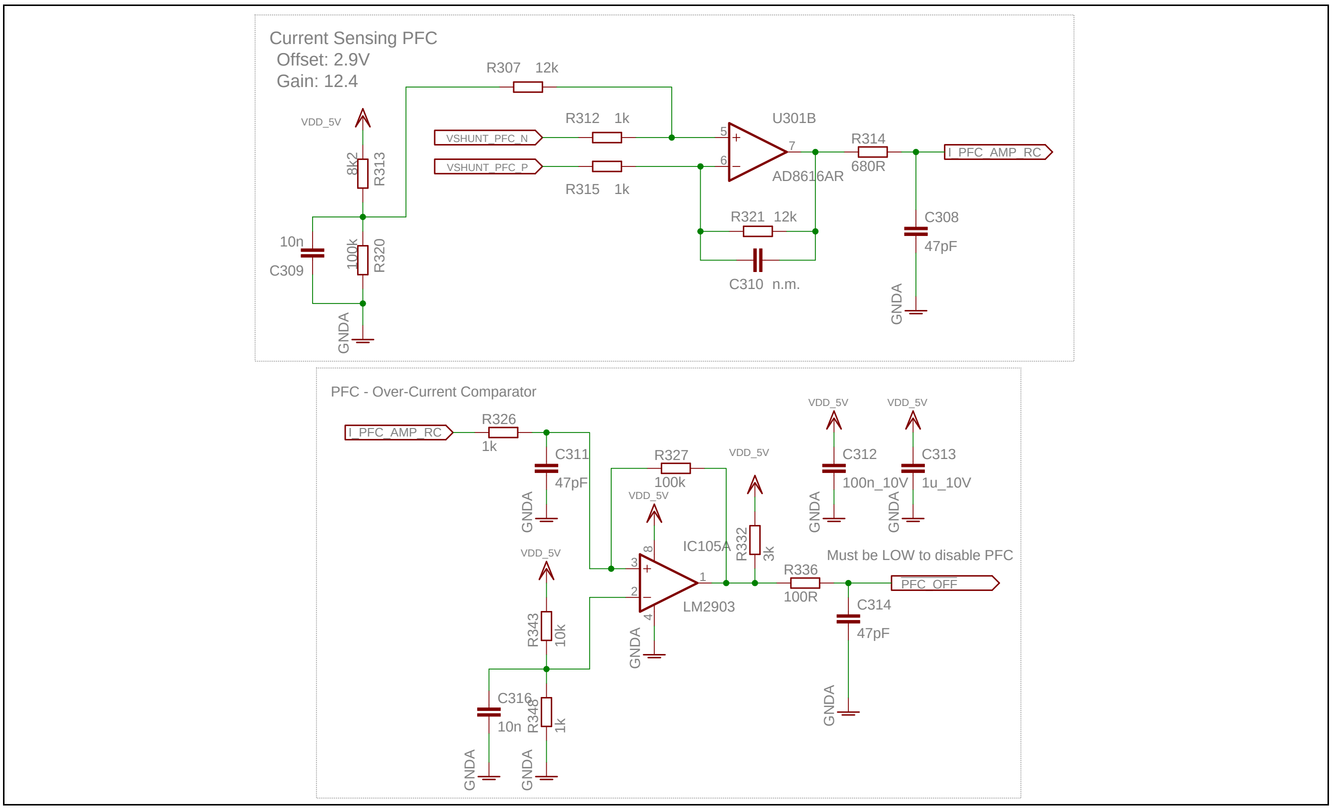


Figure 8 PFC Current Sense and Over Current Protection

The PFC current sense gain and offset can be calculated with following formulas:

$$\text{offset} = \frac{\frac{R315+R321}{R315} \cdot R312 \cdot R320}{(R307 + R312) \cdot R313 + (R307 + R312 + R313) \cdot R320} \cdot VDD\_5V$$

$$\text{gain} = \frac{\frac{R315+R321}{R315} \cdot [(R307 + R313) \cdot R320 + R307 \cdot R313]}{(R307 + R312) \cdot R313 + (R307 + R312 + R313) \cdot R320}$$

$$\text{Vout} = \text{offset} + \text{gain} \cdot \Delta\text{Vshunt} = \text{offset} - \text{gain} \cdot R118 \cdot I_{PFC}$$

The over current protection threshold can be adjusted with R313; refer to Figure 9. Please note that gain and offset values also change with different R313.

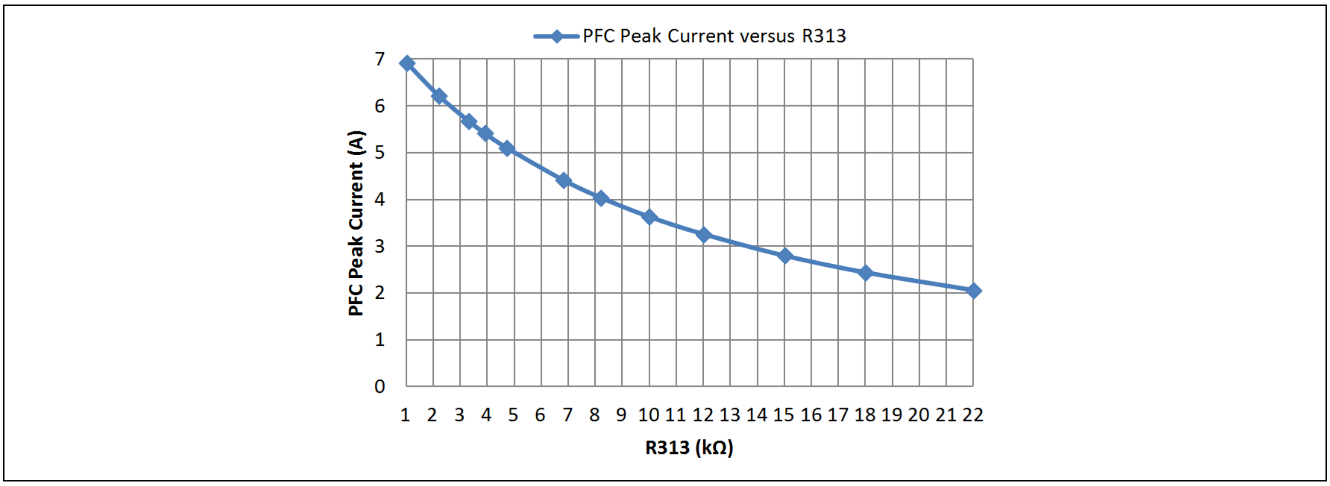


Figure 9 PFC Peak Current versus R313

2.1.4 Control Power Supply (VCC_15V and VDD_5V)

The control power supply with VCC_15V and VDD_5V is provided by a flyback switch mode power supply IC (IC103) ICE3B0356JG. The voltages can be monitored at test pins JP102 and JP103. The flyback control circuitry is shown in Figure 10. Please refer to Figure 28 for winding rules of transformer TR101.

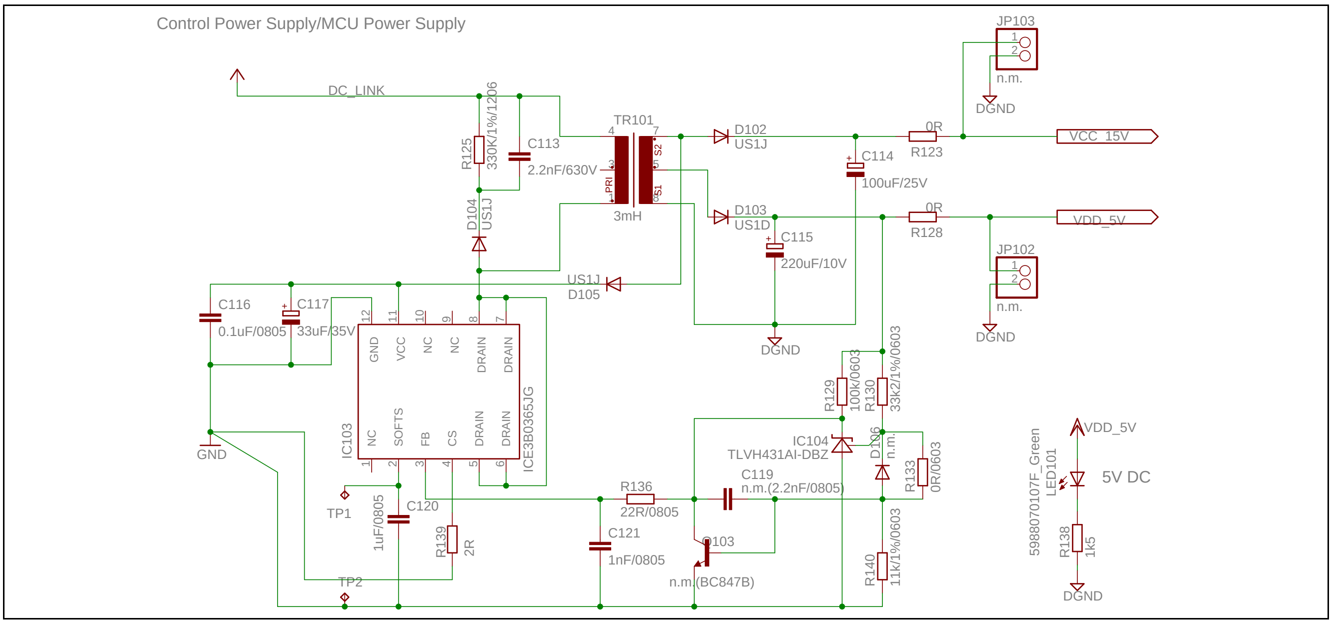


Figure 10 Control Power Supply (VCC_15V and VDD_5V)

There are two mounting options available for the feedback signal of the control loop: a) Using a shunt regulator (e.g. TLVH431AI) or b) using a zener diode. The following components are recommended for each option:

a) IC104 (TLVH431AI), R129 (100k), R130 (33.2k), R133 (0R), R140 (11.1k)

b) Q103 (BC847B), D106 (Zener diode 4.7V), C119 (2.2nF), R130 (4.3k), R140 (1k)

An external power supply for 5V as well as 15V can be used if required. Then R123 and R128 should be unmouned and the voltages can be applied at JP102 (5V) and JP103 (15V).

For test purposes it may make sense to restart the power supply. This can be achieved by connecting TP1 (SOFTS) and TP2 (GND). Please refer to 13 for details.

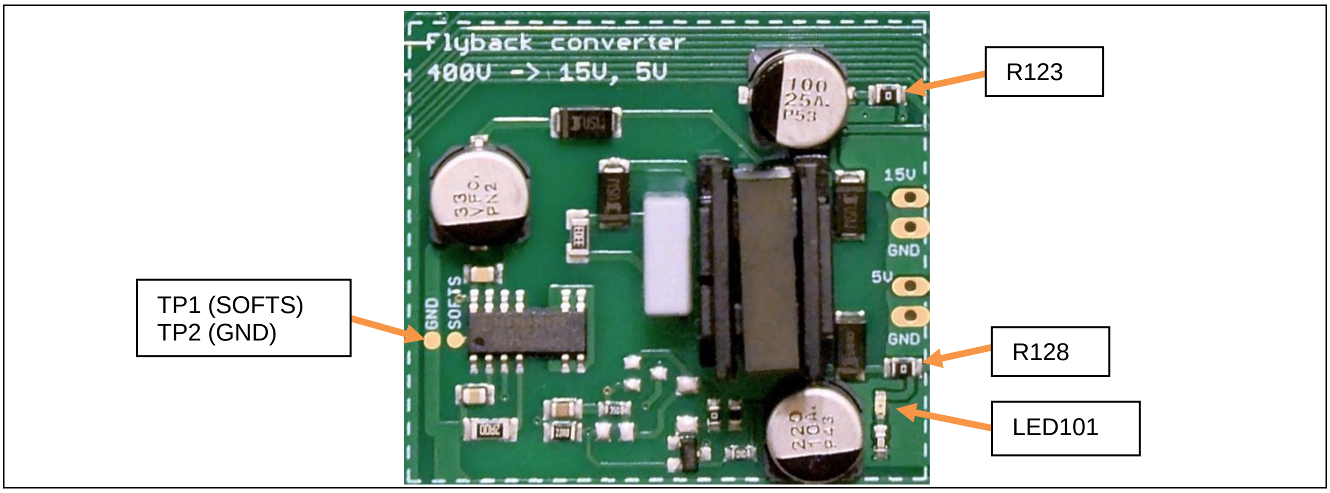


Figure 11 Restart of Control Power Supply via Testpads

The power status of VDD_5V is indicated by LED101 (see Figure 10).

2.2 3 Phase Inverter

The 3 phase power inverter is built by 6 IGBTs (IKD10N60R) and the gate driver IC (6EDL04I06NT). Each inverter leg has its own shunt in the low side path for phase current measurement. In addition the common DC-link current can be measured by its own shunt. See Figure 12 and Figure 13 for details.

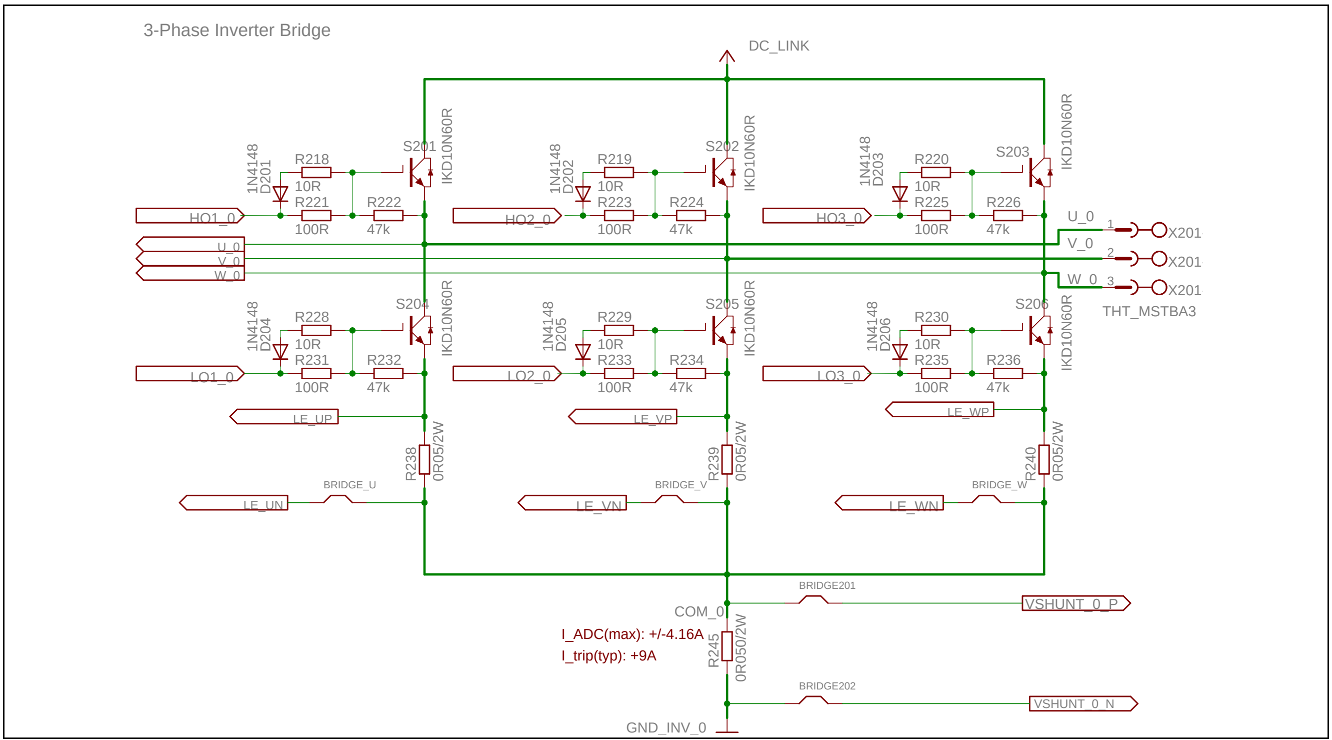


Figure 12 Power Inverter – IGBT

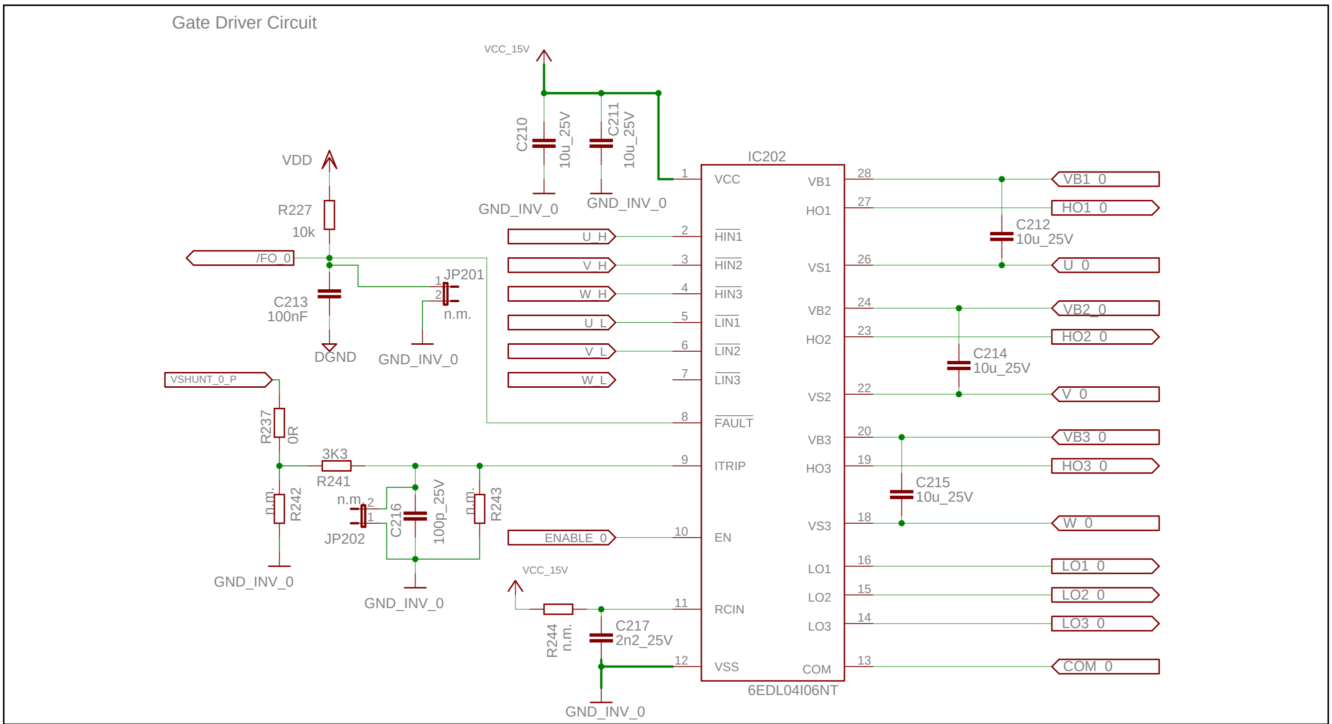


Figure 13 Power Inverter – Gate Driver

All shunt signals are amplified by operational amplifiers. The gain and offset of all amplifiers is adjusted to the same value. The offset is buffered by another operational amplifier. See Figure 14 and Figure 15 for details.

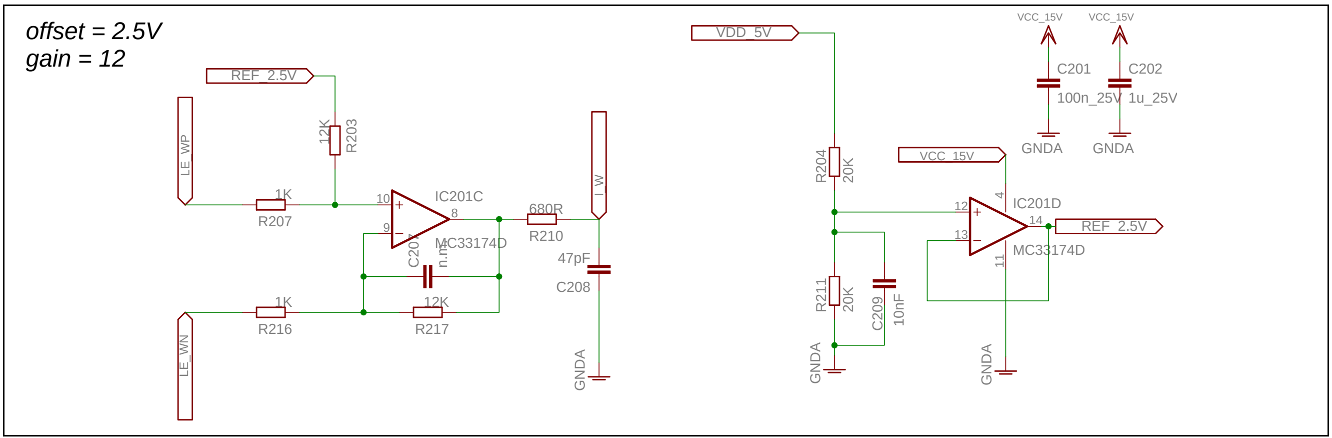


Figure 14 Phase Current Sensing and Reference Voltage Buffer (e.g. Phase W)

$$\text{offset} = \text{REF\_2.5V} = \frac{\text{R211}}{\text{R211} + \text{R204}} \cdot \text{VDD\_5V}$$

$$\text{gain} = \frac{\text{R217}}{\text{R216}} \text{ under the condition that } \frac{\text{R203}}{\text{R207}} = \frac{\text{R217}}{\text{R216}}$$

$$\text{Vout} = \text{offset} + \text{gain} \cdot \Delta\text{Vshunt} = \text{offset} - \text{gain} \cdot \text{R240} \cdot \text{I}_{\text{Phase\_W}}$$

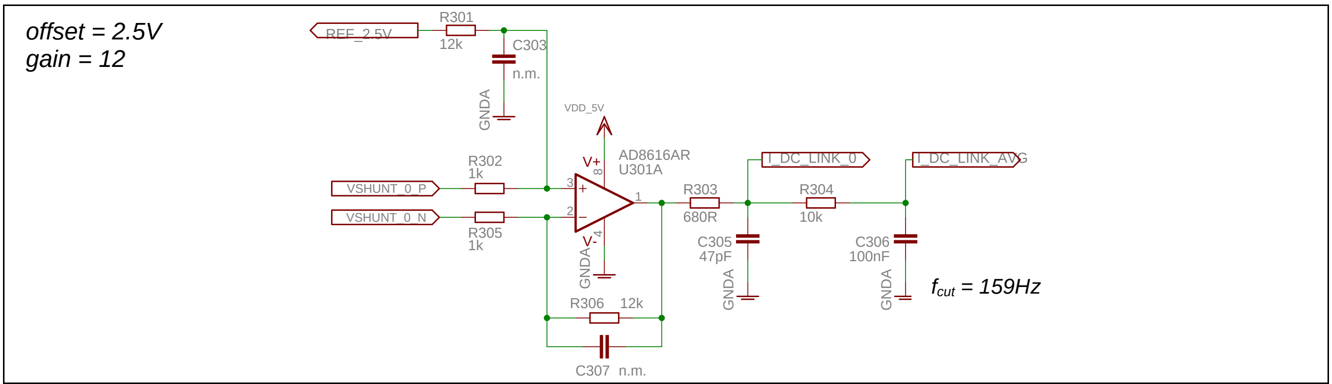


Figure 15 DC-Link Current Sensing

The gains are adjusted to measure a maximum current of 4.16A and to trigger the over voltage protection of the gate driver at 9A. There are testpoints for monitoring the itrip voltage as well as the protection output signal (/FO).

The following diagram (Figure 16) shows the timing of the gate driver for high side and low side IGBTs.

The dead time (t_{DT+} for rising and t_{DT-} for falling output signals) is the time which is required between deactivation e.g. of the high side IGBT (U_H: low to high, active to passive level, respectively) and the activation of the low side IGBT (U_L: high to low, passive to active level, respectively).

The driver delay (t_{DD+} for rising and t_{DD-} for falling output signals) is the delay time of the driver for changing the output signal from low to high after the activation of the respective IGBT driver input (high side for high output and low side for low output signal).

In the diagram (Figure 16) the delay time defined by the driver itself is shown as t_{DxOFF} and t_{DxON} (with $x{=}H$ for high side and $x{=}L$ for low side) and can be measured between microcontroller output signal and IGBT gate signal.

The total output delay time taken from the microcontroller signal edge until the inverter output level has changed is described with t_{OUT+} for low to high transition and t_{OUT-} for high to low transition.

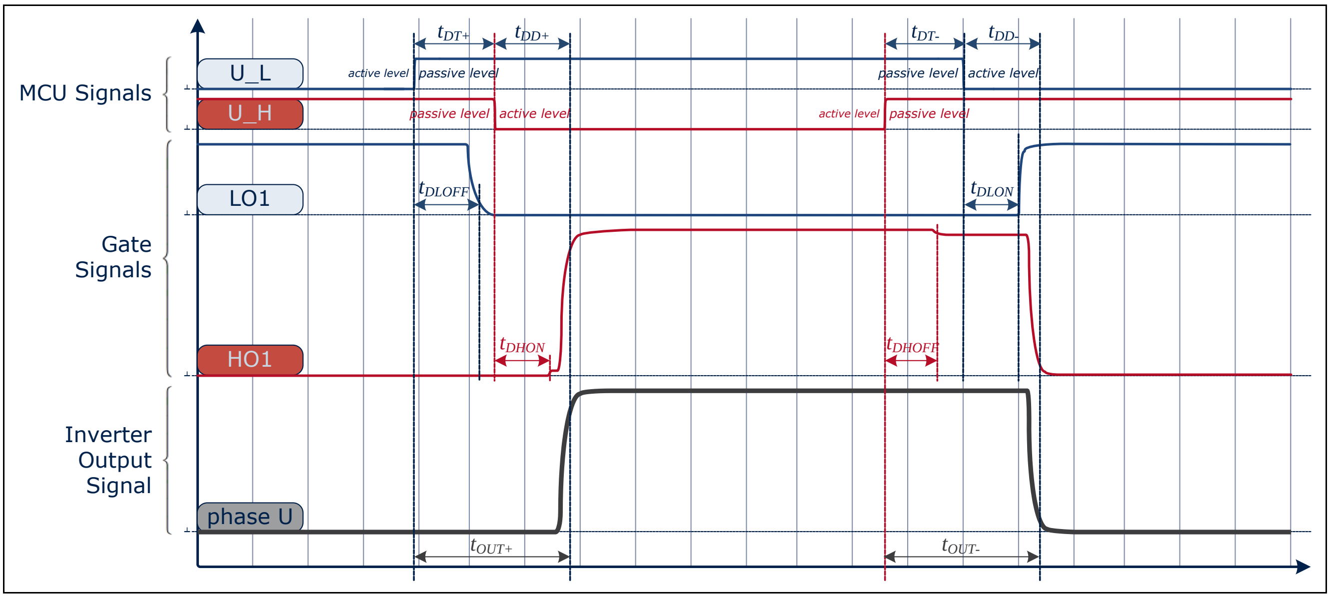


Figure 16 Inverter Timing Diagram

Please refer to Table 2 for typical values of the “3 Phase Power Inverter 750W V1.1” which have been measured under room temperature.

Table 2 Typical Inverter Timing Parameters

	Rising Output Signal		Falling Output Signal	
Dead Time	t_{DT+}	750ns	t_{DT-}	750ns
Driver Delay	t_{DD+}	800ns	t_{DD-}	800ns
Total Output Delay	t_{OUT+}	1.550µs	t_{OUT+}	1.550µs
	High Side		**Low Side**	
IGBT Drive ON delay	t_{DHON}	550ns	t_{DLON}	550ns
IGBT Driver OFF delay	t_{DHOFF}	550ns	t_{DLOFF}	650ns

The gate driver enable signal is inverted in order to provide active low behaviour. LED 301 indicates an active gate driver. The power inverter outputs can be monitored at signals BEMF_U, BEMF_V and BEMF_W with a ratio of 417.5V : 5V. Please refer to Figure 17 for details.

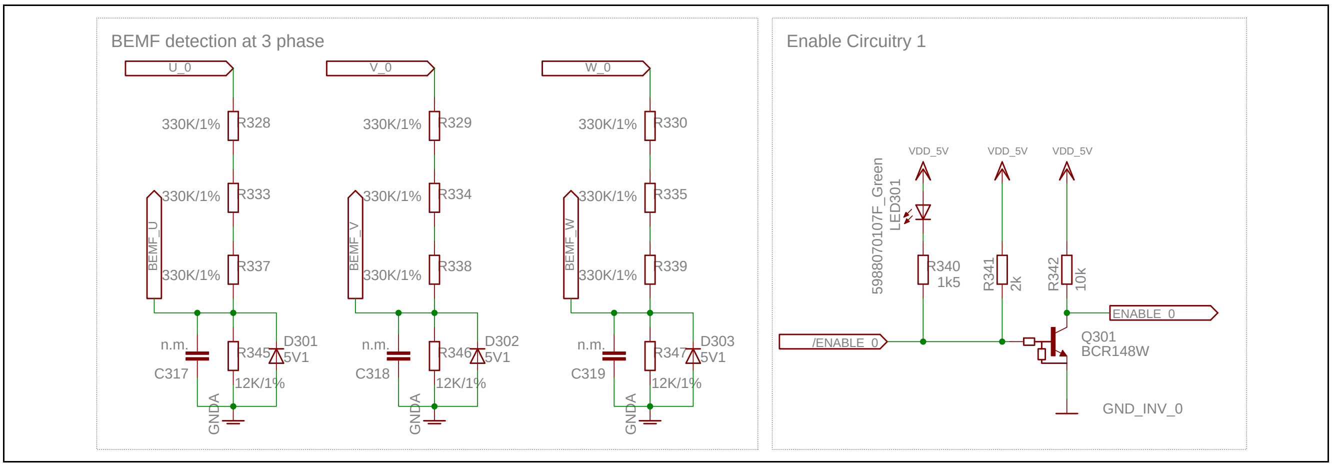
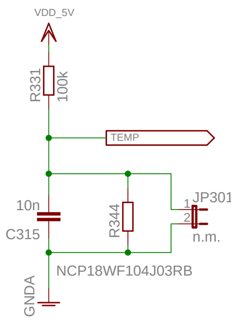


Figure 17 Output Voltage (BEMF) Signal Dividers and Inverting Gate Driver Enable Circuitry

A tempertaure sensor (R331, NTC thermistor) is placed close to the IGBTs of the inverter bridge in order to allow thermal protection by software. In addition, an external temperature sensor can be connected at JP301. Please refer to Figure 18 for details about the selected component (muRata NCP18WF104J03RB).



B-Constant	Calculated between two specified ambient temperatures by next formula. T and T_0 is absolute temperature (K). $B = \frac{\ell n (R/R_0)}{1/T - 1/T_0}$

Part Number	Resistance (25°C) (ohm)	B-Constant (25-50°C) (K)	B-Constant (25-80°C) (Reference Value) (K)	B-Constant (25-85°C) (Reference Value) (K)	B-Constant (25-100°C) (Reference Value) (K)	Permissive Operating Current (25°C) (mA)	Rated Electric Power (25°C) (mW)	Typical Dissipation Constant (25°C) (mW/°C)
NCP18WF104☐03RB	100k	4250 ±2%	4303	4311	4334	0.10	100	1

☐ is filled with resistance tolerance codes (E: ±3%, J: ±5%).

Figure 18 Temperature Sensor Circuitry and Thermistor Parameter

2.3 Drive Card Connector

The power inverter board of KIT_XMC750WATT_AK_V1 provides a drive card connector with all the signals required to control the power inverter. Next to the PWM input signals of the gate driver as well as the sense signals for current measurement, there are the power supply pins for the 5V power domain.

Figure 19 shows the signal assignment fo the drive card connector together with the pin assignment of the drive cards for XMC1300 and XMC4400. The pin and peripheral assignment can also be found in the following table.

Please note that the numbering of the power board connector at the drive card is inversed to the numbering of the drive card connector at the power board.

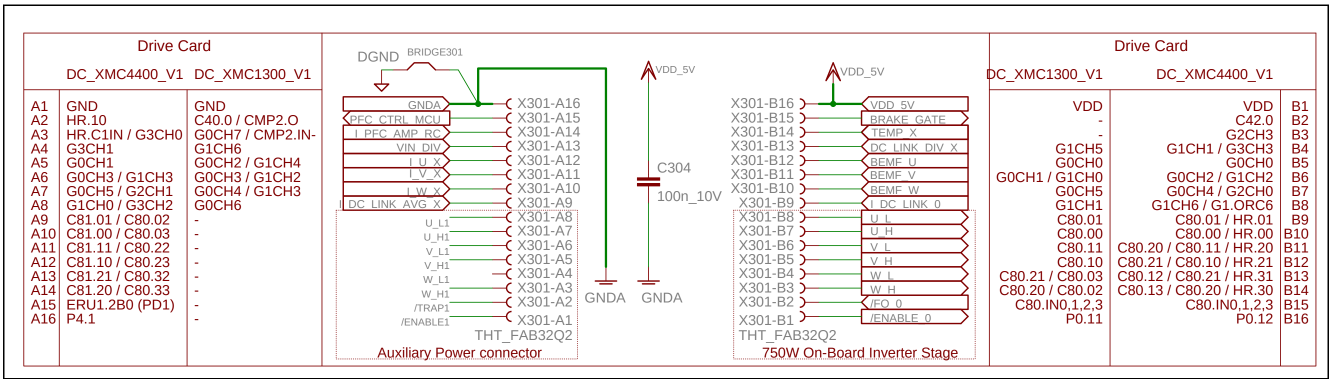


Figure 19 Drive Card Connector

Table 3 Drive Card Connector

Male MAB32B2	X301 FAB32Q2	Function	Signal of Power Inverter	Port XMC1300	Port XMC4400
A1	A16	GND	GNDA / DGND	VSS, VSSP	VSS
A2	A15	PFC Gate	PFC_CTRL_MCU	P0.5	P1.3 & P0.8
A3	A14	I_{PFC}	I_PFC_AMP_RC	P2.2	P15.8 & P0.0
A4	A13	V_{PFC}	VIN_DIV	P2.4	P15.9
A5	A12	V_{BEMF_U} / I_U (2)	I_U_X	P2.9	P14.1
A6	A11	V_{BEMF_V} / I_V (2)	I_V_X	P2.10	P14.15

A7	A10	V_{BEMF_W} / I_W (2)	I_W_X	P2.11	P14.5
A8	A9	I_AVG / I_{DClink} (2)	I_DC_LINK_AVG_X	P2.1	P14.8
A9	A8	U1_L	U_L1	-	P1.12 & P0.10
A10	A7	U1_H	U_H1	-	P1.15 & P2.7
A11	A6	V1_L	V_L1	-	P1.11 & P2.9
A12	A5	V1_H	V_H1	-	P1.5
A13	A4	W1_L	W_L1	-	P1.10 & P2.8
A14	A3	W1_H	W_H1	-	P1.4
A15	A2	CTRAP1	/TRAP1	-	P1.2
A16	A1	ENPOW1	/ENABLE1	-	P4.1
B1	B16	VCC 5V	VDD_5V	VDD, VDDP	VDD
B2	B15	Brake Gate	BRAKE_GATE	-	P3.6
B3	B14	Brake temp	TEMP_X	-	P15.3
B4	B13	V_{DClink}	DC_LINK_DIV_X	P2.3	P14.9
B5	B12	V_{BEMF_U} / I_U (1)	BEMF_U	P2.6	P14.0
B6	B11	V_{BEMF_V} / I_V (1)	BEMF_V	P2.8	P14.2
B7	B10	V_{BEMF_W} / I_W (1)	BEMF_W	P2.0	P14.4
B8	B9	I_{DClink} (1)	I_DC_LINK_0	P2.7	P14.14
B9	B8	U0_L	U_L	P0.1	P0.2
B10	B7	U0_H	U_H	P0.0	P0.5
B11	B6	V0_L	V_L	P0.6	P0.1 & P0.3
B12	B5	V0_H	V_H	P0.7	P0.4 & P2.14
B13	B4	W0_L	W_L	P0.9 & P0.3	P0.11 & P0.9
B14	B3	W0_H	W_H	P0.8 & P0.2	P0.6 & P2.6
B15	B2	CTRAP0	/FO_0	P0.12	P0.7
B16	B1	ENPOW0	/ENABLE_0	P0.11	P0.12

***Attention:** The drive card connector provides the power supply for the power GND supply domain. Hence it may carry hazzardous voltages.*

2.4 Auxiliary Power Board Connector

A second inverter card can be connected to the auxiliary power board connector. There are all necessary signals and power supplies available. Please refer to Figure 20 for details.

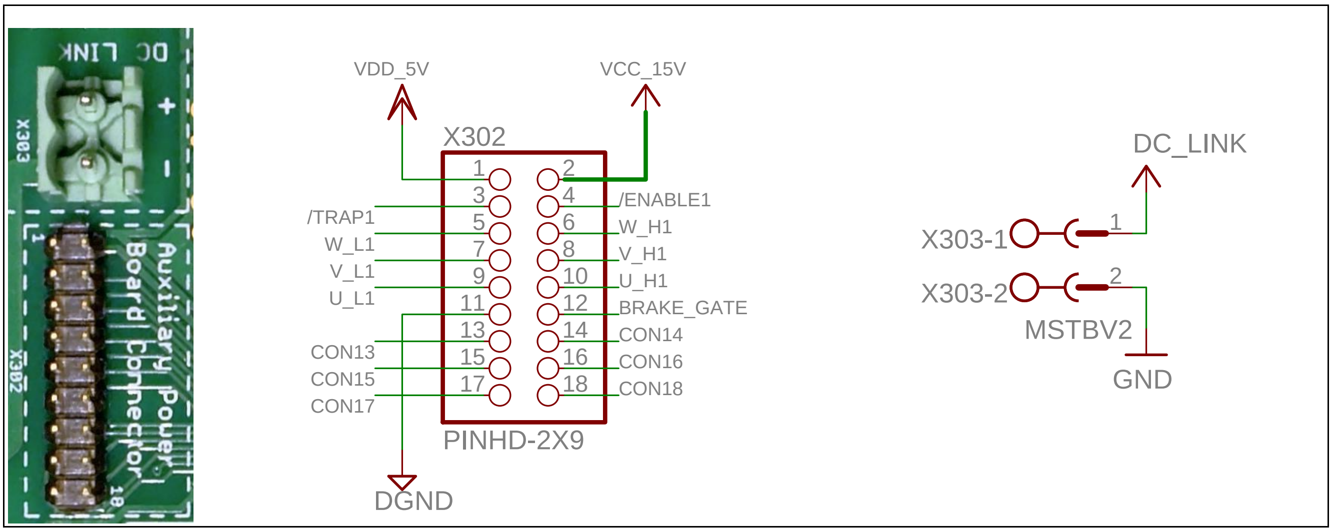


Figure 20 Auxiliary Power Board Connector

This connector is considered as an optional extension and the analog signals are shared netween the on-board power inverter and the auxiliary connector. The desired signal can be chosen by 0R resistors close to the Drive Card connector. Figure 21 and the following table give details about the optional signal selection.

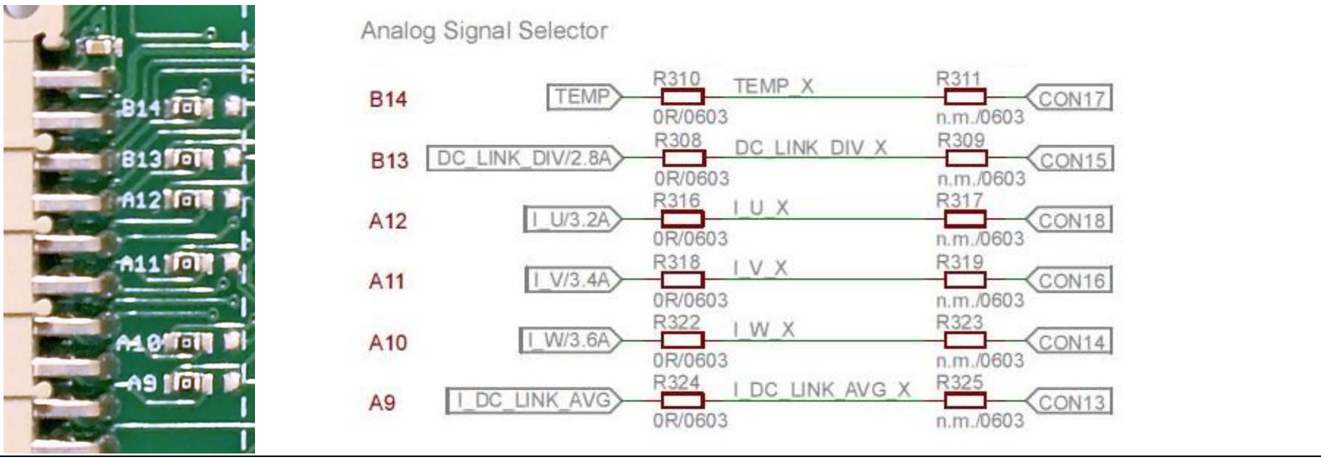


Figure 21 Analog Signal Selector

Table 4 Auxiliary Power Board Connector

X302 Auxiliary Power Board Connector	X301 Drive Card Connector	Signal at Drive Card Connector	Signal of Power Inverter	Optional Signal X302
X302-1	B16	VDD_5V	VDD_5V	VDD_5V
X302-2	-	-	VCC_15V	VCC_15V
X302-3	A2	/TRAP1	-	/TRAP1
X302-4	A1	/ENABLE1	-	/ENABLE1
X302-5	A4	W_L1	-	W_L1
X302-6	A3	W_H1	-	W_H1
X302-7	A6	V_L1	-	V_L1
X302-8	A5	V_H1	-	V_H1
X302-9	A8	U_L1	-	U_L1
X302-10	A7	U_H1	-	U_H1
X302-11	A16	GND	DGND	DGND
X302-12	B15	BRAKE GATE	-	BRAKE GATE
X302-13	(A9)	I_DC_LINK_AVG_X	I_DC_LINK_AVG	CON13
X302-14	(A10)	I_W_X	I_W	CON14
X302-15	(B13)	DC_LINK_DIV_X	DC_LINK_DIV	CON15
X302-16	(A11)	I_V_X	I_V	CON16
X302-17	(B14)	TEMP_X	TEMP	CON17
X302-18	(A12)	I_U_X	I_U	CON18

3 Production Data

3.1 Schematics

This chapter contains the schematics for the 3 phase power inverter 750W V1.1 (2013/45).

- Line Filter, PFC, DC-Link 400V, Power Supply 15V/5V
- Gate Driver, Power Bridge (IGBT), Phase Current Shunt Amplifier
- Single Shunt Amplifier, PFC Amplifier, PFC Overload Protection, Drive Card and Auxiliary Power Connector

The board has been designed with Eagle V5.7. The full PCB design data of this board can also be downloaded from www.infineon.com/xmc-dev.

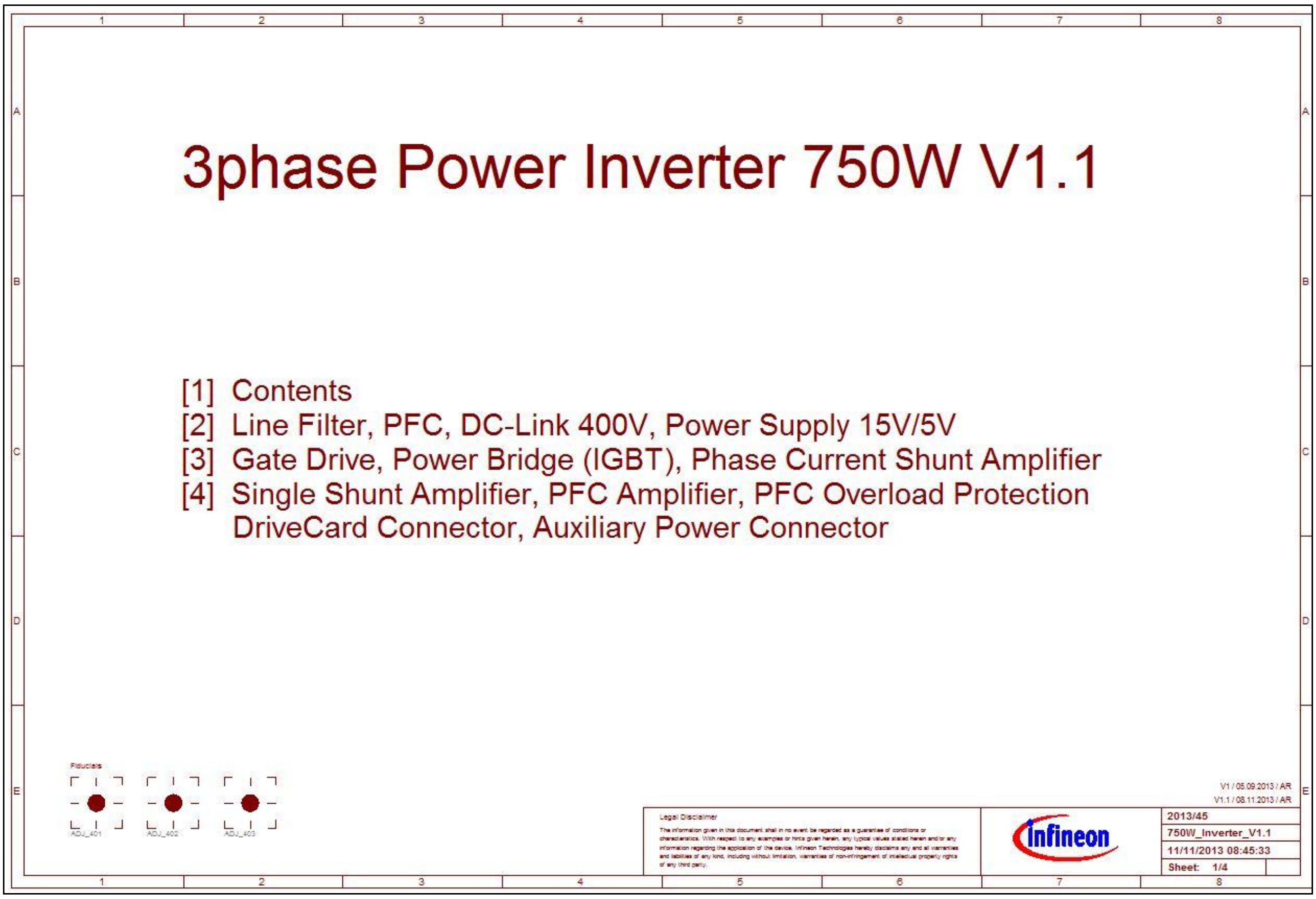


Figure 22 Schematics: Title Page (V1.1 – 2013/45)

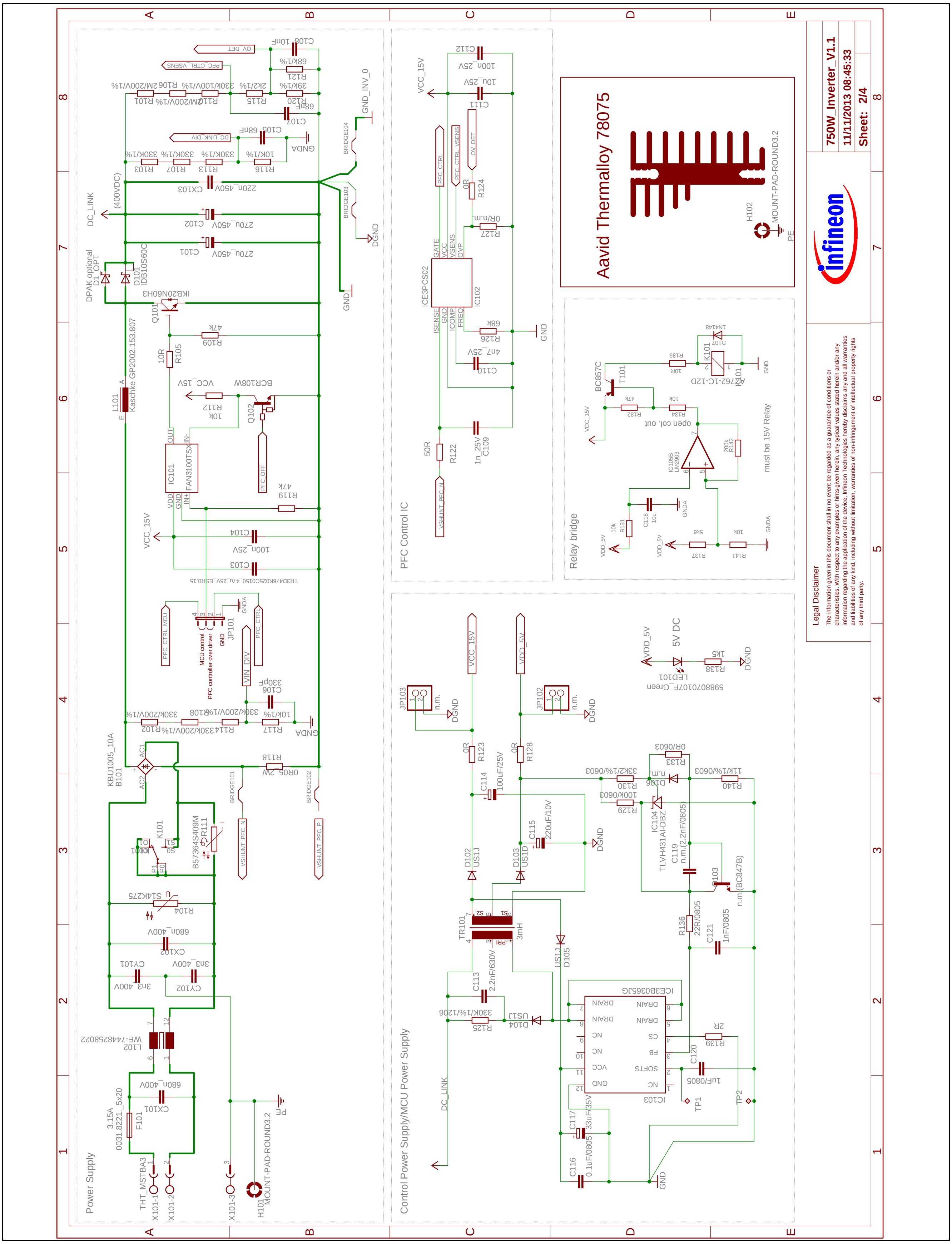


Figure 23 Line Filter, PFC, DC-Link 400V, Power Supply 15V/5V

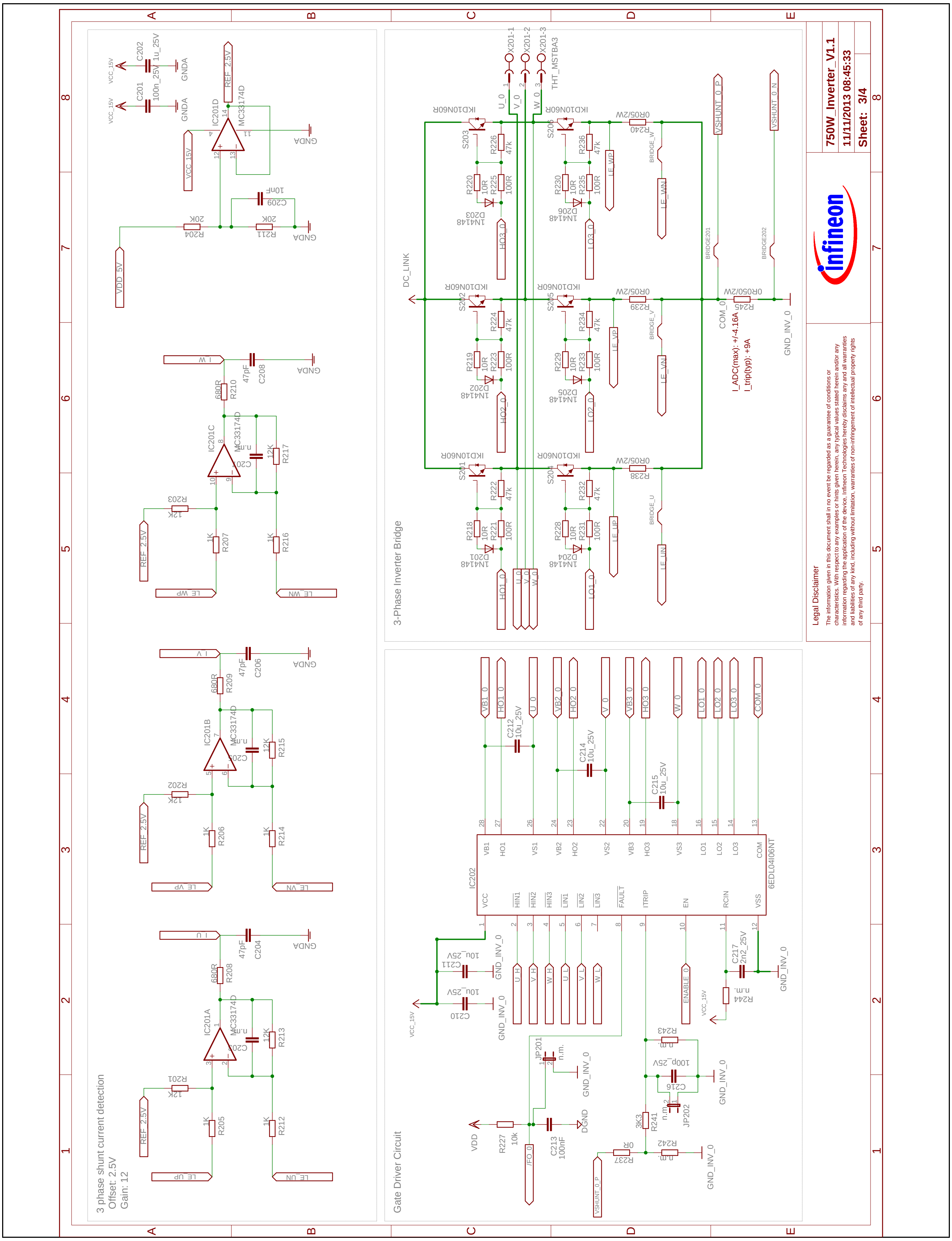


Figure 24 Gate Driver, Power Bridge (IGBT), Phase Current Shunt Amplifier

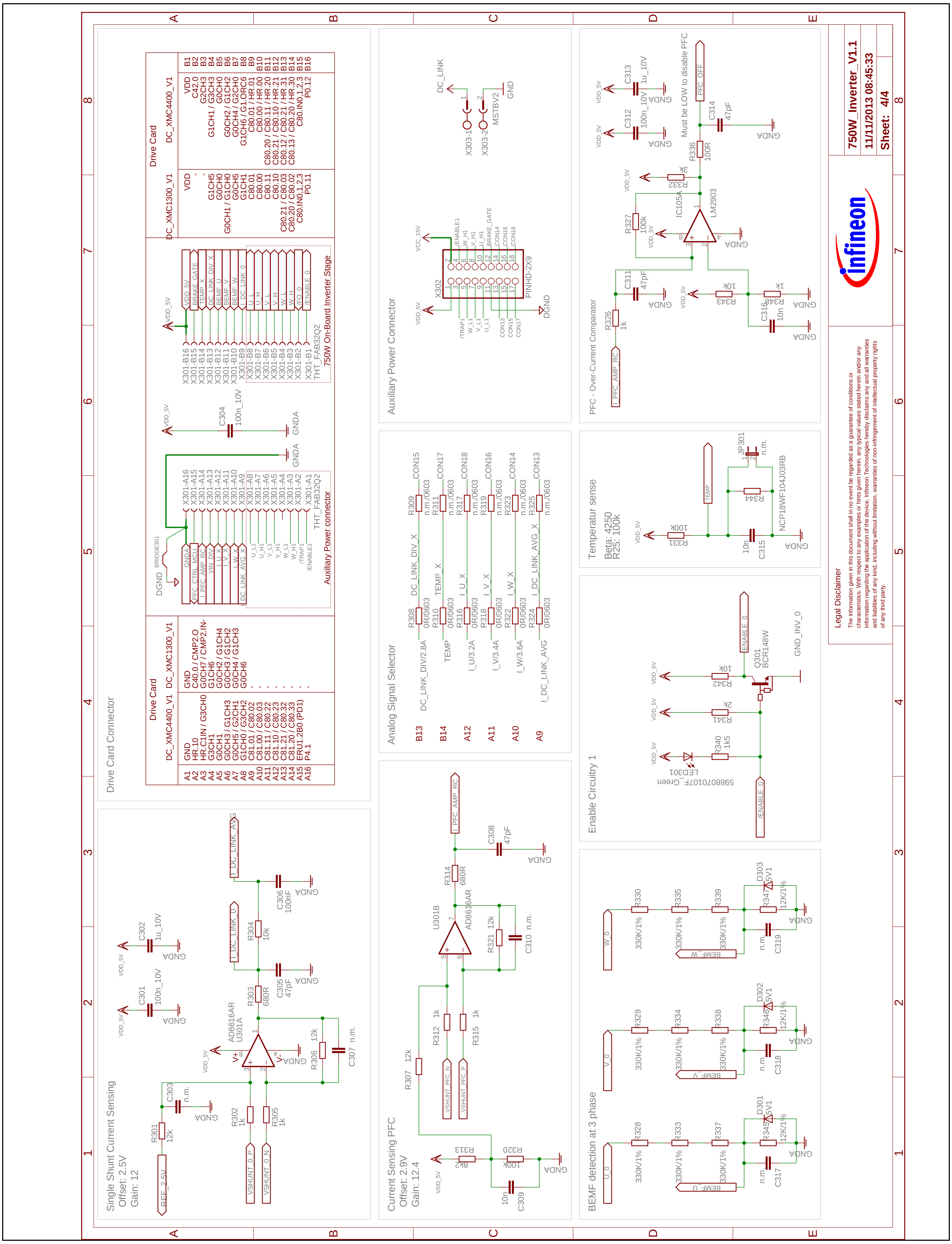


Figure 25 Single Shunt and PFC Amplifier, PFC Protection, Drive Card and Auxiliary Power Connector

3.2 Component Placement

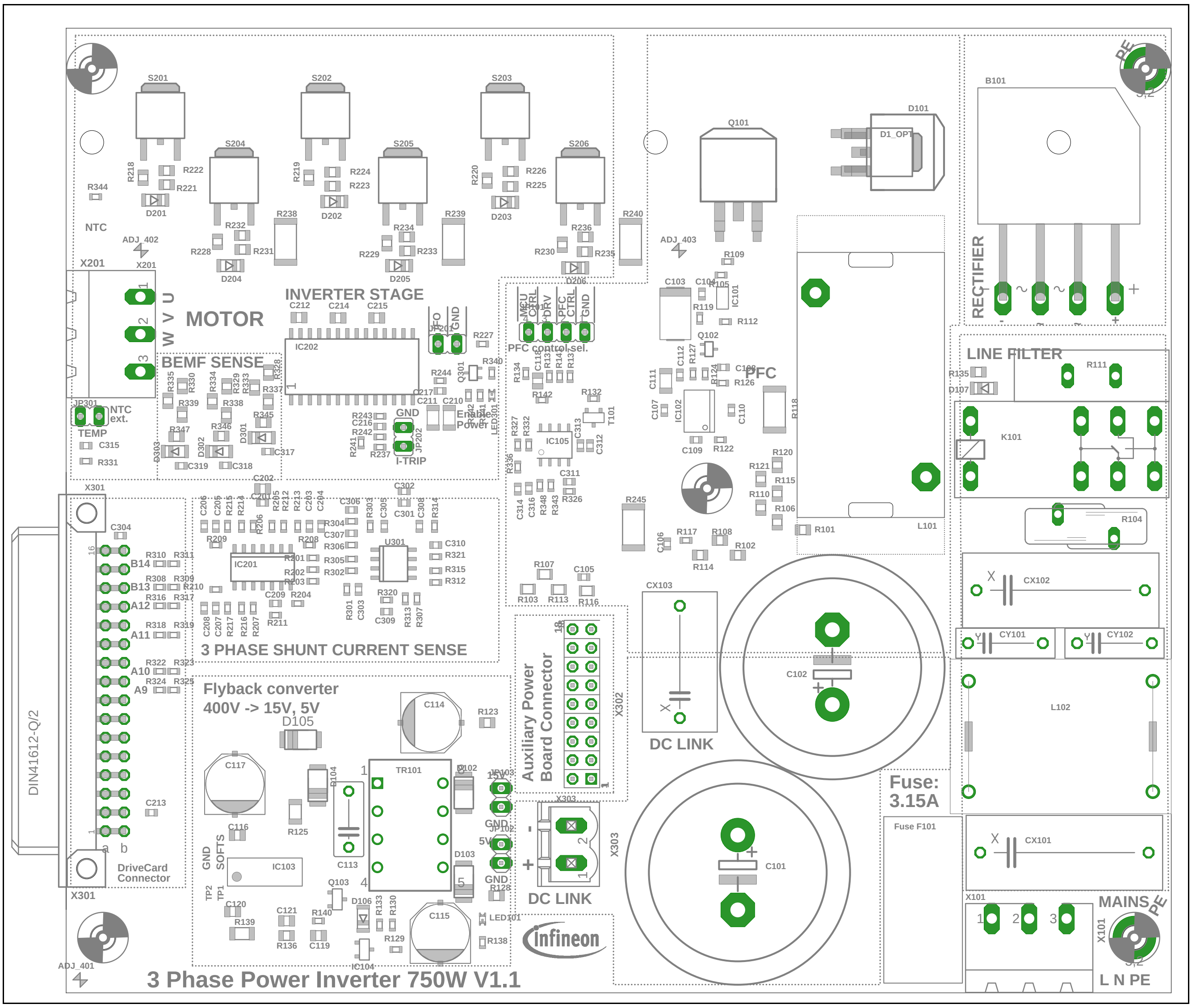


Figure 26 Component Placement

3.3 Board Dimensions and Mounting Hole Positions

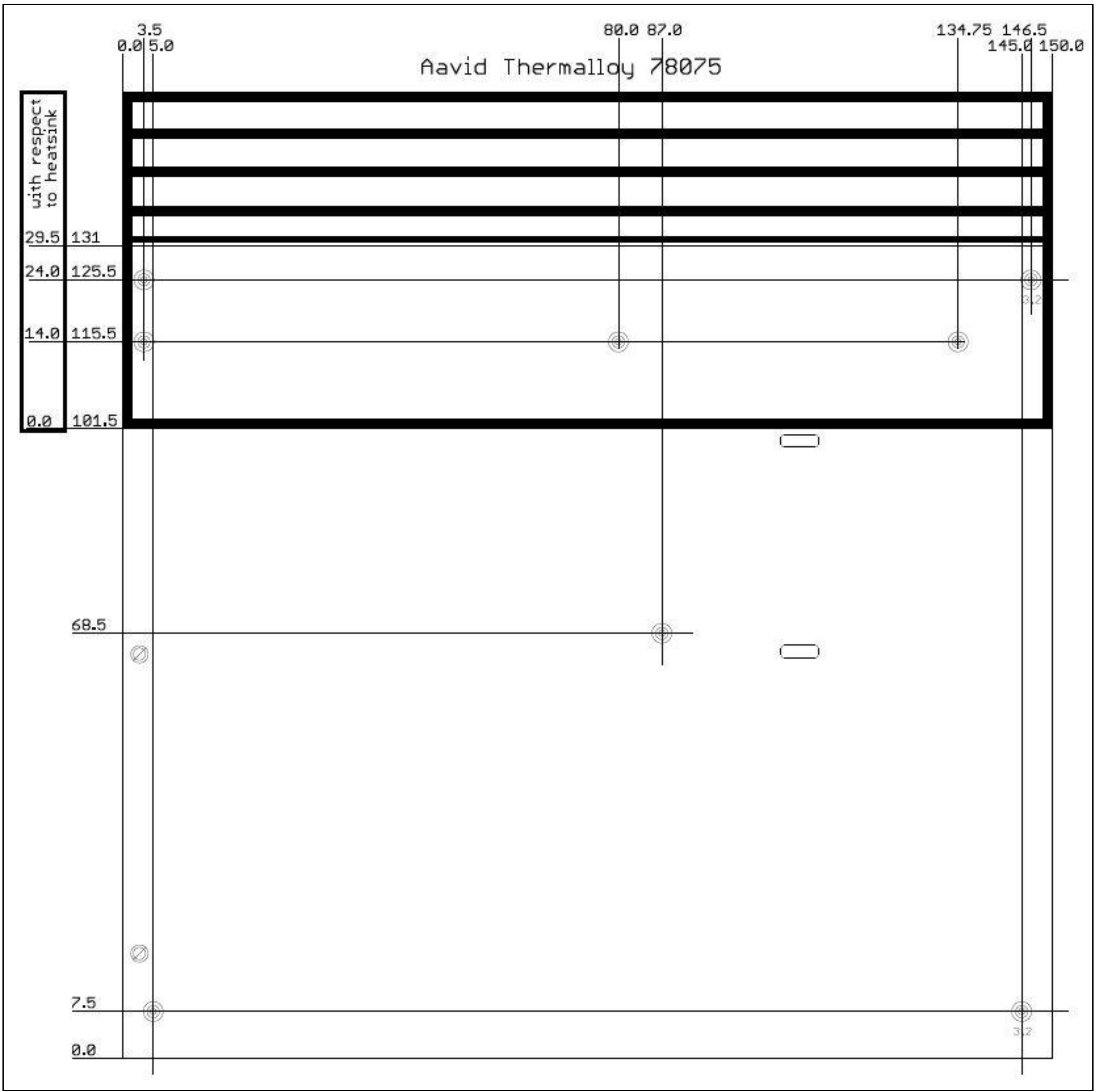
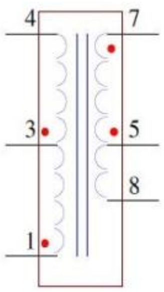


Figure 27 Board Dimensions and Mounting Hole Positions

3.4 Winding Rules for Transformer TR101



Wire size requirement :

Start	Stop	No. of turns	Wire size	Layer
4	3	53	1XAWG#30	2/3 Primary
8	5	7	2XAWG#30	Secondary1
5	7	14	2XAWG#30	Secondary2
3	1	27	1XAWG#30	1/3 Primary

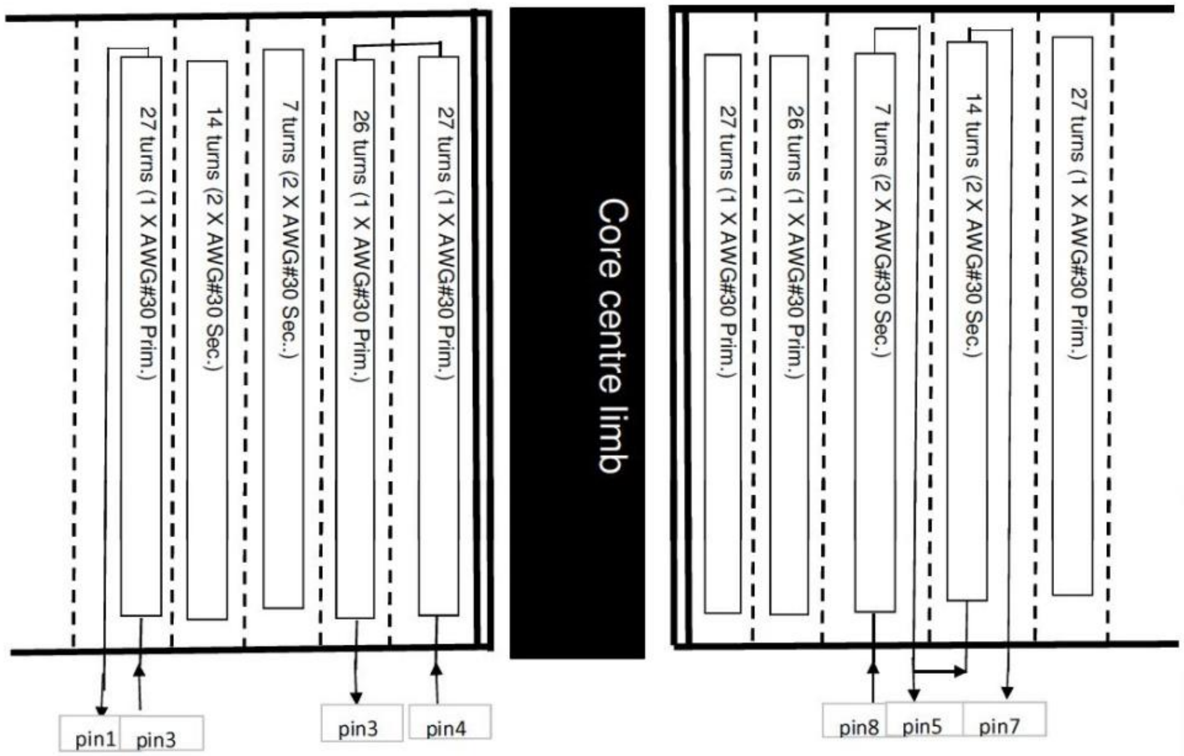


Figure 28 Winding Rules for Transformer TR101

3.5 Bill of Material (BOM)

Table 5 BOM of KIT_XMC750WATT_AK_V1 Board

Pos. No.	Qty	Value	Device	Reference Des.
1	1	KBU1005_10A	GBU4GBU4H	B101
2	2	270u_450V	CPOL-EUE10-30	C101, C102
3	1	TR3D476K025C0150_47u_25V_ESR0.15	C_EU_CASE_CCASE_D	C103
4	2	100n_25V	C_EU_CASE_C0603	C104, C112
5	2	68nF	C_EU_CASE_C0603	C105, C107
6	1	330pF	C_EU_CASE_C0603	C106
7	1	10nF	C_EU_CASE_C0603	C108
8	1	1n_25V	C_EU_CASE_C0603	C109
9	1	4n7_25V	C_EU_CASE_C0603	C110
10	3	10u_25V	C_EU_CASE_C1206	C111, C210, C211
11	1	2.2nF/630V	C-EU075-042X103	C113
12	1	100uF/25V	CPOL-EUE	C114
13	1	220uF/10V	CPOL-EUE	C115
14	1	0.1uF/0805	C-EUC0805	C116
15	1	33uF/35V	CPOL-EUE	C117
16	1	10u	C_EU_CASE_C0805	C118
17	1	1uF/0805	C-EUC0805	C120
18	1	1nF/0805	C-EUC0805	C121
19	1	100n_25V	C-EUC0603	C201
20	1	1u_25V	C-EUC0805	C202
21	7	47pF	C-EUC0603	C204, C206, C208, C305, C308, C311, C314
22	1	10nF	C-EUC0603	C209
23	3	10u_25V	C_EU_CASE_C0805	C212, C214, C215
24	1	100nF	C_EU_CASE_C0603	C213
25	1	100p_25V	C_EU_CASE_C0603	C216
26	1	2n2_25V	C_EU_CASE_C0603	C217
27	3	100n_10V	C-EUC0603	C301, C304, C312
28	2	1u_10V	C-EUC0603	C302, C313
29	1	100nF	C-EUC0603	C306
30	3	10n	C-EUC0603	C309, C315, C316
31	2	680n_400V	CXXC22B10	CX101, CX102
32	1	220n_450V	CXXC15B10	CX103
33	2	3n3_400V	CYYC10B4	CY101, CY102
34	1	IDB10S60C	IDT08S60C	D101
35	3	US1J	DIODE-DO-214AC	D102, D104, D105
36	1	US1D	DIODE-DO-214AC	D103
37	7	1N4148	DIODE-SOD80C	D107, D201, D202, D203, D204, D205, D206
38	3	5V1	DIODE-MINIMELF	D301, D302, D303
39	1	Thermalloy	78075	HEATSINK101
40	1	FAN3100TSX	FAN3100	IC101
41	1	ICE3PCS02	ICE3PCS02	IC102

42	1	ICE3B0365JG	ICE3B0365JG	IC103
43	1	TLVH431AI-DBZ	TLV431A-DBZ	IC104
44	1	LM2903	LM2903	IC105
45	1	MC33174D	LM324D	IC201
46	1	6EDL04I06NT	6ED003L06-F	IC202
47	1	AZ762-1C-12D	G2RE	K101
48	1	Kaschke GP2002.153.807	KLL_GP2002.1	L101
49	1	WE-7448258022	WE-CMB_XL	L102
50	2	5988070107F_Green	LEDCHIPLED_0603	LED101, LED301
51	1	IKB20N60H3	IKB30N60H3	Q101
52	1	BCR108W	BCR108W	Q102
53	1	BCR148W	BCR108W	Q301
54	2	2M/200V/1%	R-EU_R0805	R101, R106
55	3	330k/200V/1%	R-EU_R0805	R102, R108, R114
56	3	330K/1%	R-EU_M0805	R103, R107, R113
57	1	S14K275	S14K275	R104
58	1	10R	R-EU_R0603	R105
59	3	47k	R-EU_R0603	R109, R119, R132
60	1	330k/100V/1%	R-EU_R0805	R110
61	1	B57364S409M	NTC-B57364	R111
62	8	10k	R-EU_R0603	R112, R131, R134, R141, R227, R304, R342, R343
63	1	2k2/1%	R-EU_R0805	R115
64	1	10K/1%	R-EU_M0805	R116
65	1	10k/1%	R-EU_R0603	R117
66	1	0R05_2W	R-EU_R2512	R118
67	1	39k/1%	R-EU_R0805	R120
68	1	68k/1%	R-EU_R0805	R121
69	1	50R	R-EU_R0603	R122
70	2	0R	R-EU_R0805	R123, R128
71	2	0R	R-EU_R0603	R124, R237
72	1	330K/1%/1206	R-EU_R1206	R125
73	1	68k	R-EU_R0603	R126
74	1	100k/0603	R-EU_R0603	R129
75	1	33k2/1%/0603	R-EU_R0603	R130
76	7	0R/0603	R-EU_R0603	R133, R308, R310, R316, R318, R322, R324
77	7	10R	R-EU_R0805	R135, R218, R219, R220, R228, R229, R230
78	1	22R/0805	R-EU_R0805	R136
79	1	5k6	R-EU_R0603	R137
80	2	1k5	R-EU_R0603	R138, R340
81	1	2R	R-EU_R1206	R139
82	1	11k/1%/0603	R-EU_R0603	R140
83	1	200k	R-EU_R0603	R142
84	6	12K	R-EU_R0603	R201, R202, R203, R213, R215, R217
85	2	20K	R-EU_R0603	R204, R211

86	6	1K	R-EU_R0603	R205, R206, R207, R212, R214, R216
87	5	680R	R-EU_R0603	R208, R209, R210, R303, R314
88	6	100R	R-EU_R0805	R221, R223, R225, R231, R233, R235
89	6	47k	R-EU_R0805	R222, R224, R226, R232, R234, R236
90	3	0R05/2W	R-EU_R2512	R238, R239, R240
91	1	3K3	R-EU_R0603	R241
92	1	0R050/2W	R-EU_R2512	R245
93	4	12k	R-EU_R0603	R301, R306, R307, R321
94	6	1k	R-EU_R0603	R302, R305, R312, R315, R326, R348
95	1	8k2	R-EU_R0603	R313
96	3	100k	R-EU_R0603	R320, R327, R331
97	9	330K/1%	R-EU_R0805	R328, R329, R330, R333, R334, R335, R337, R338, R339
98	1	3k	R-EU_R0603	R332
99	1	100R	R-EU_R0603	R336
100	1	2k	R-EU_R0603	R341
101	1	NCP18WF104J03RB	R-EU_R0603	R344
102	3	12K/1%	R-EU_R0805	R345, R346, R347
103	6	IKD10N60R	IKD04N60R	S201, S202, S203, S204, S205, S206
104	1	BC857C	BC857A-PNP-SOT23-BEC	T101
105	1	3mH	EPCOS_E16V	TR101
106	1	AD8616AR	AD8616AR	U301
107	2	THT_MSTBA3	MSTBA3	X101, X201
108	1	THT_FAB32Q2	FAB32Q2	X301
109	1	PINHD-2X9	PINHD-2X9	X302
110	1	MSTBV2	MSTBV2	X303

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Published by Infineon Technologies AG

Motor Control Application Kit

For XMC1000 Family

KIT_XMC1300_DC_V1

XMC1300 Drive Card V1.0

Board User‘s Manual

Revision 1.0, 2013-11-05

Microcontroller

Edition 2013-11-05

Published by
Infineon Technologies AG
81726 Munich, Germany

Revision History	
Page or Item	**Subjects (major changes since previous revision)**
Revision 1.0, 2013-11-05	Initial release

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Introduction

This document describes the features and hardware details of the DriveCard XMC1300 V1 (KIT_XMC1300_DC_V1) designed to work with Infineon's inverter boards. This board is part of Infineon's Motor Control Application Kits.

1 Overview

The drive card KIT_XMC1300_DC_V1 houses the XMC1302 Microcontroller from Infineon Technologies, a power board connector, a set of position interface circuits with hall and encoder connectors, a USIC interface and an isolated on-board debug interface. The board along with a three phase inverter demonstrates the capabilities of the XMC1302. The main use case for this board is to demonstrate the motor control features of the XMC1302 device including tool chain. The focus is safe operation under evaluation conditions. The board is neither cost nor size optimized and does not serve as a reference design.

1.1 Key Features

The KIT_XMC1300_DC_V1 board is equipped with the following features

- Infineon XMC1302 (ARM® Cortex™-M0-based) Microcontroller, 200 kByte on-chip Flash, TSSOP38
- Connection to power inverter via the power board connector
- Combined hall sensor and encoder interface
- USIC interface connector for connection of UART, SPI or I2C
- 6 LEDs
  - 2 Power indicating LEDs
  - 1 User LED (P0.4)
  - 1 Encoder enable LED
  - 2 Debug LEDs (DEBUG, COM)
- Potentiometer, connected to analog input P2.5 (ADC group 1, channel 7)
- Isolated Debug options
  - On-Board Debugger (SEGGER J-Link LITE) via USB connector
  - Infineon Debug connector 16-pin (0.1”) with DriveMonitor USB Stick V2 (KIT_DRIVEMONI_USB_V2)
- Isolated Connectivity
  - UART channel of On-Board Debugger (SEGGER J-Link LITE) via USB connector
- Power supply of MCU domain
  - Via power board connector (5V)
- Power supply of isolated debug domain
  - Via Debug USB connector
  - Via Infineon Debug connector 16-pin

1.2 Block Diagram

Figure 1 shows the functional block diagram of the KIT_XMC1300_DC_V1 board. For more information about the power supply domains please refer to chapter 2.1.

The drive card has got the following building blocks:

- 1 Power Board Connector
- 1 set of position interface connectors (HALL, ENCODER)
- Encoder Enable signals via GPIOs (P0.10)
- 1 User LED connected to GPIOs (P0.4)
- Variable resistor (POTI) connected to GPIO P2.5 (ADC group 1, channel 7)
- USIC0 interface connector (P0.10, P0.14, P1.4, P1.5)
- Isolated On-board Debugger via Debug USB connector (Micro-USB) with UART channel (USIC0, channel 1)
- Optional Infineon Debug interface connector for Drive Monitor USB Stick V2 (KIT_DRIVEMONI_USB_V2)

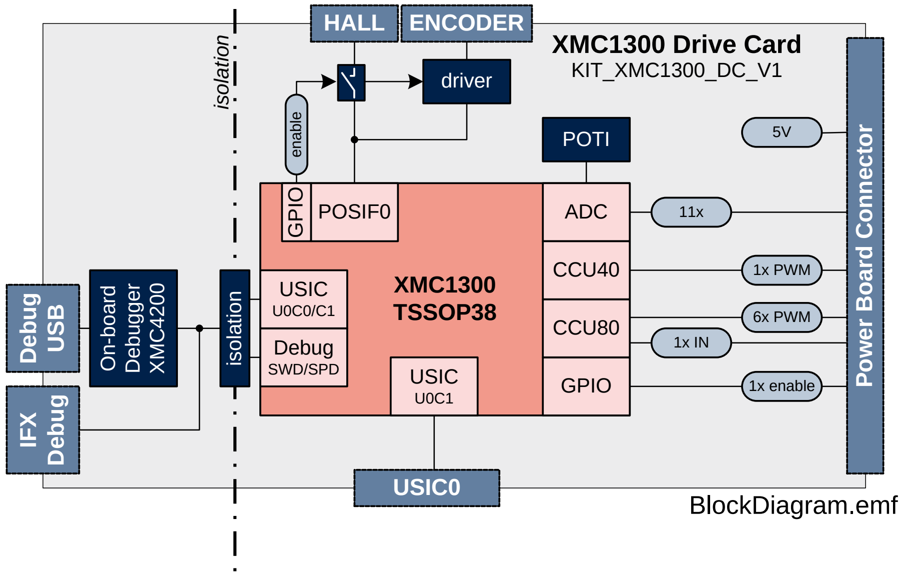


Figure 1 Block Diagram of KIT_XMC1300_DC_V1

2 Hardware Description

The following sections give a detailed description of the hardware and how it can be used.

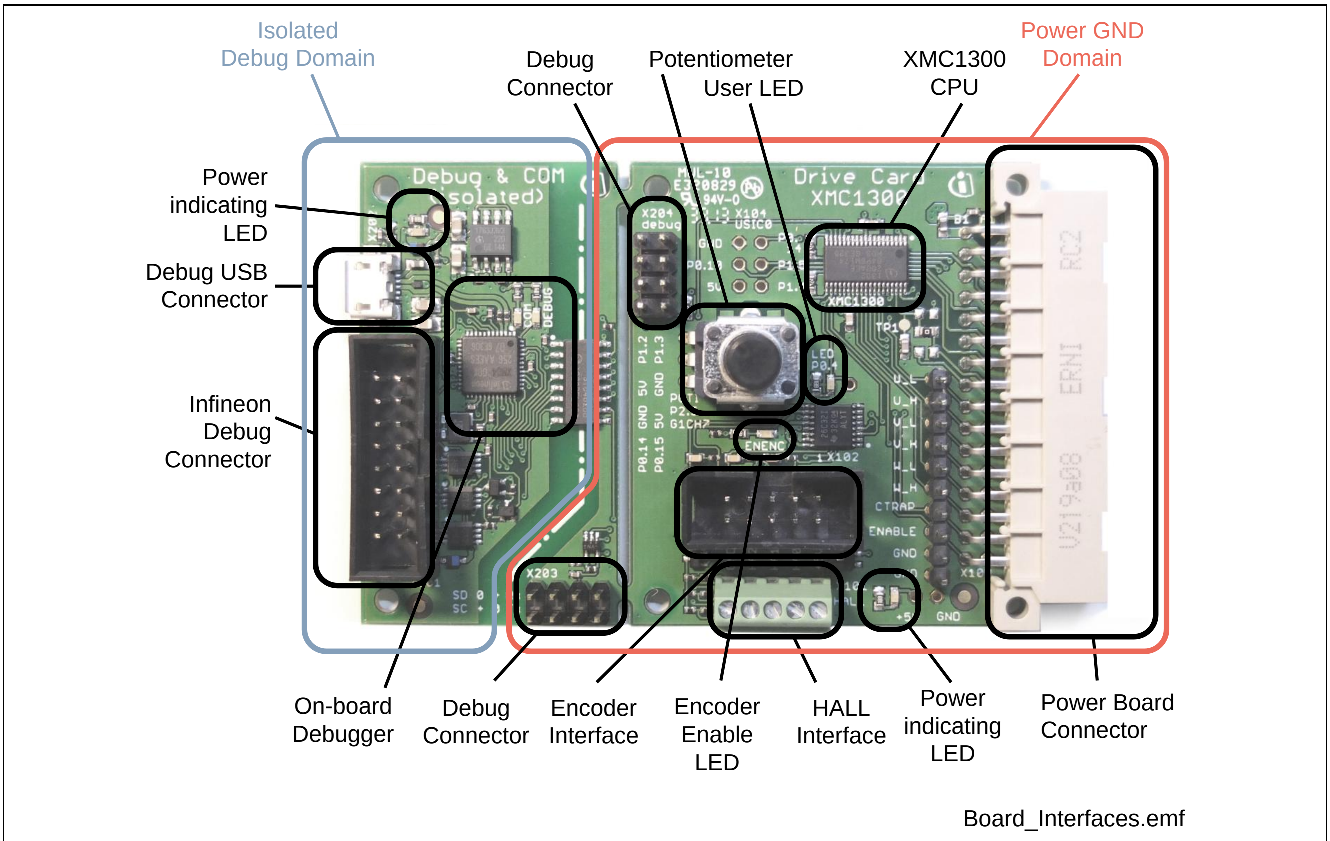


Figure 2 XMC1300 Drive Card (KIT_XMC1300_DC_V1)

2.1 Power Supply

The KIT_XMC1300_DC_V1 board is designed with two galvanically isolated supply domains. On the left side, there is the debug domain, which contains a XMC4200 MCU as on-board debug controller (OBD) as well as level shifters to a 5V debug interface like the drive monitor USB stick (KIT_DRIVEMONI_USB_V2). The debug domain can be powered via the USB plug (5V) as well as the Infineon debug connector.
On the middle to the right side there is the power GND supply domain, which provides the power supply for the MCU and the peripheral components. This supply domain is usually powered from the power board connector. The typical current drawn by the drive card at the power GND domain is about 25 mA.

To indicate the power status of the KIT_XMC1300_DC_V1 board two power indicating LEDs are provided on board (see Figure 3). The LED will be "ON" when the corresponding power rail is powered.

Table 1 Power status LED's

LED Reference	Power Rail	Voltage	Note
LED101	VDD5	5 V	Power GND domain, must always be "ON"
LED201	VISO5	5 V	Debug supply domain, "ON" if debug domain is intened to be used.

Figure 3 and Figure 4 show details of the power supply concept of the drive card.

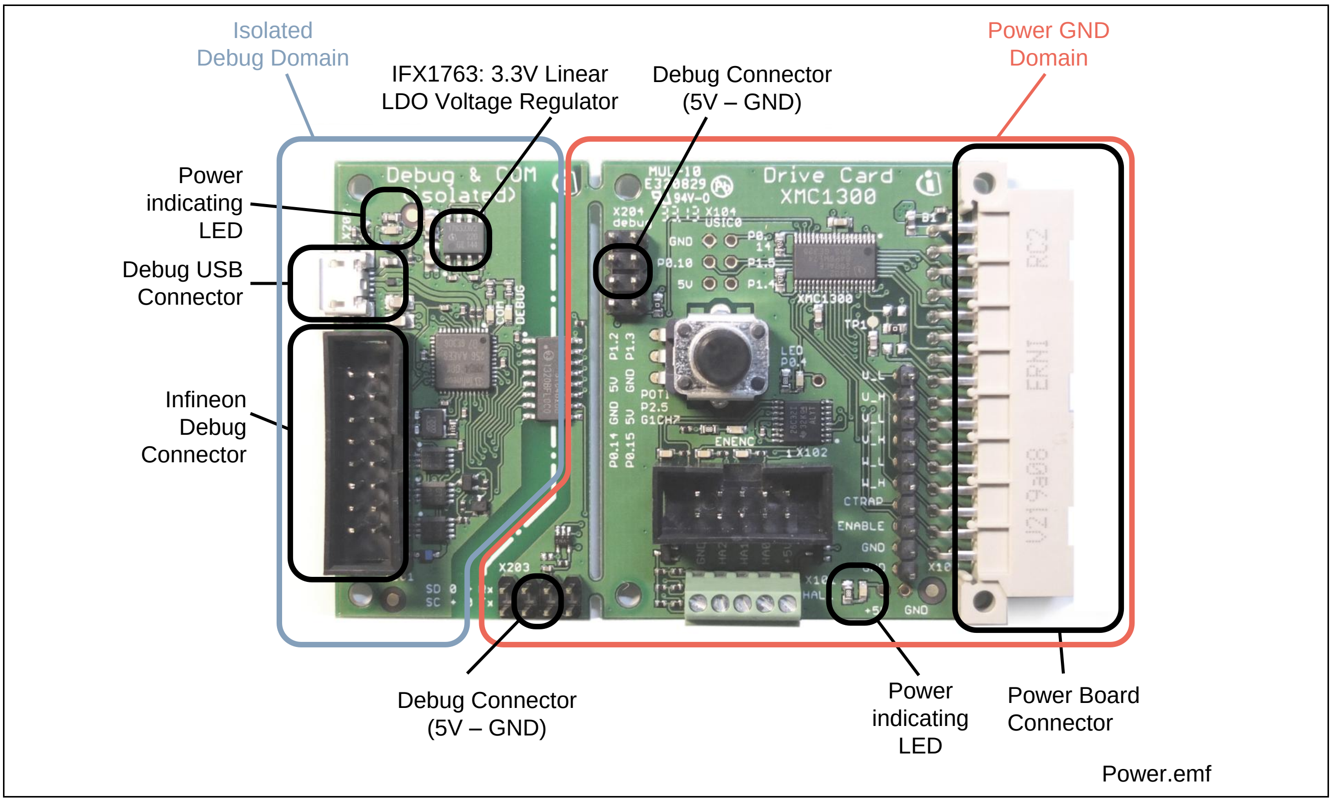


Figure 3 Power Supply Concept and Powering Options

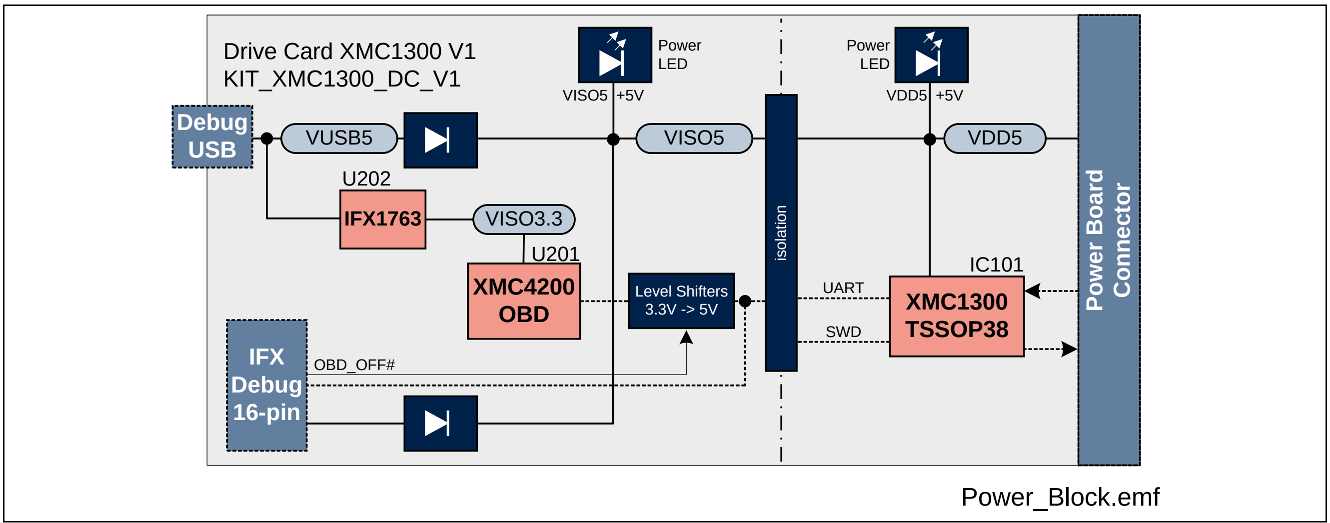


Figure 4 Block Diagram of Power Supply Concept

2.2 Clock Generation

An internal oscillator provides the clock signal to the XMC1300 microcontroller. The CPU can be adjusted to maximum 32MHz (MCLK) whereas the PWM peripherals can be configured to use double of this clock (PCLK).

2.3 Debug Interface

The KIT_XMC1300_DC_V1 is designed to use "Serial Wire Debug" (SWD) or "Single Pin Debug" (SPD) as debug interfaces. It supports debugging via different channels which are all galvanically isolated from the power GND supply domain:

- On-board Debugger
- Infineon Debug Connector (16-pin) with Debug and UART interface

2.3.1 On-board USB Debugger

The on-board debugger [1] supports

- Serial Wire Debug (SWD) [2]
  - SWIO P0.14 (SWD0)
  - SWCLK P0.15 (SWD0)

    or
  - SWIO P1.3 (SWD1)
  - SWCLK P1.2 (SWD1)

- Single Pin Debug (SPD) [2]
  - SPD P0.14 (SPD0)

    or
  - SPD P1.3 (SPD1)

- Full Duplex UART communication via a Virtual COM port
  - PC_RXD P1.2 USIC0CH1.DOUT0
  - PC_TXD P1.3 USIC0CH1.DX0A

    or
  - PC_RXD P0.15 USIC0CH0.DOUT0
  - PC_TXD P0.14 USIC0CH0.DX0A

[1] Attention: The firmware of the on-board debugger requires the latest J-Link driver (V4.62 or higher) and a Serial Port Driver (CDC driver) installed on your computer. Please check "Install J-Link Serial Port Driver" when installing the latest J-Link driver (see Figure 6)

[2] The debug interface type (SPD or SWD) is selected via boot mode index (BMI) configuration. Changing the BMI is supported by the DAVE™ IDE and the "BMI Get Set" window (see Figure 5).

Figure 5 DAVE™ - "BMI Get Set" for XMC1000 Family

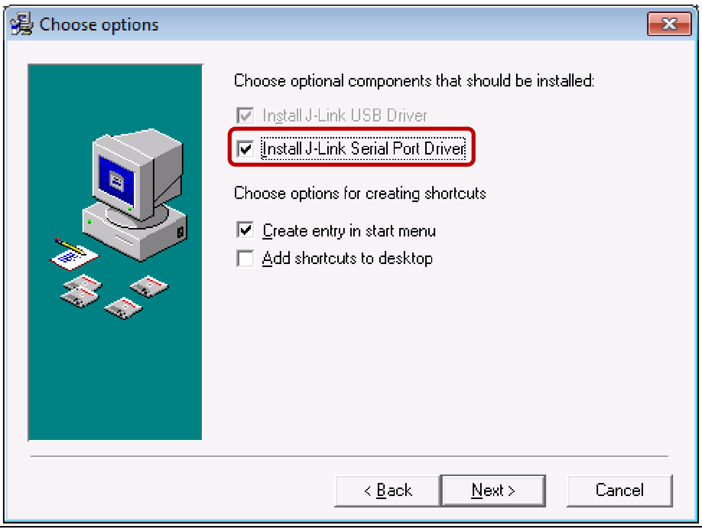


Figure 6 Installation of Serial Port Driver

The on-board debugger can be accessed through the Debug USB connector shown in Figure 7. The Debug LED (LED202) shows the status during debugging.

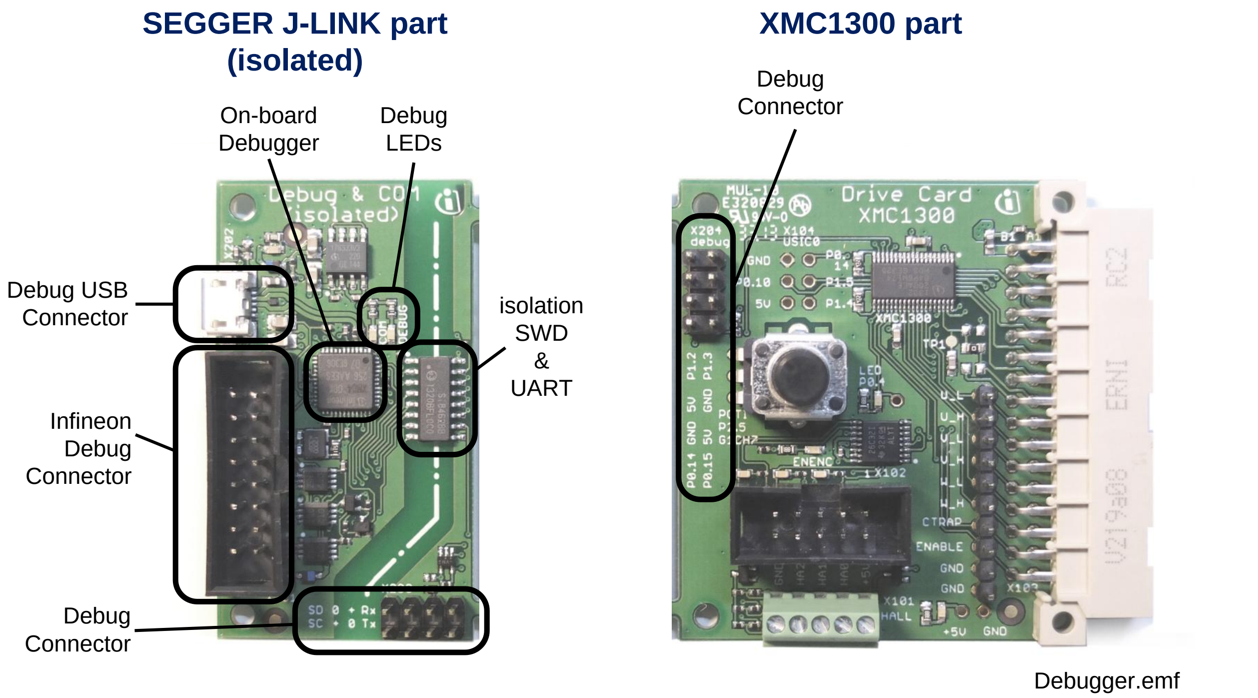


Figure 7 On-Board USB Debugger

When using an external debugger connected to the Infineon Debug Connector (16pin), the on-board debugger has to be switched off. This is done by connecting pin 6 of the Infineon Debug Connector to GNDISO.

2.3.2 Debug Connector (8-pin)

The KIT_XMC1300_DC_V1 board supports debugging via SWD and SPD with the OBD as described in section 2.3.1. The pin assignment is provided in a way that both SWD ports (SWD0 and SWD1) can be selected. Please refer to Figure 8 for details on pin assignment.

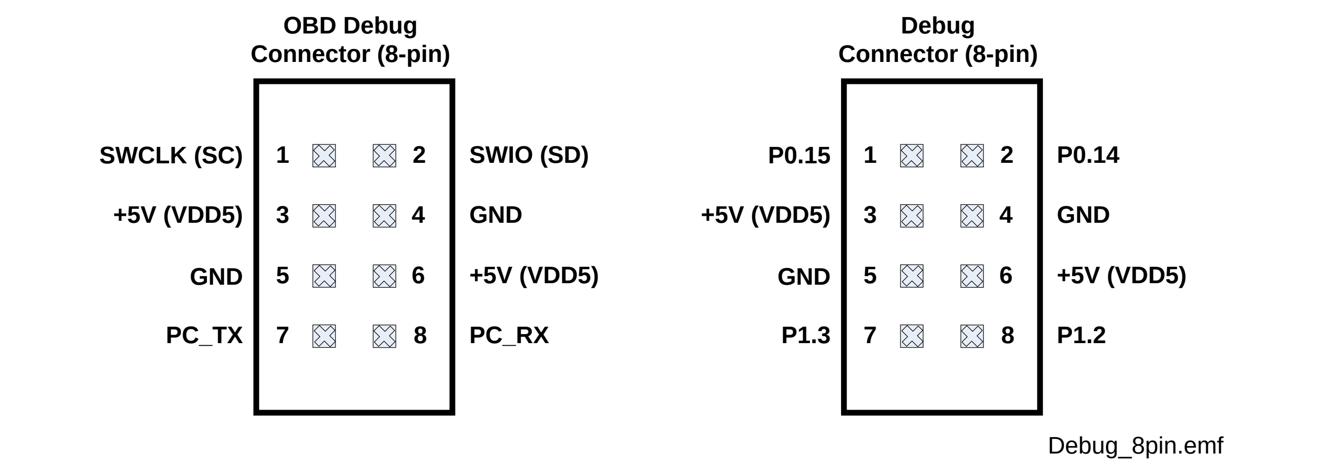


Figure 8 Pin Assignment of Debug Connector (8-pin)

The default connection will provide the following set-up:

- Serial Wire Debug (SWD)
  - SWIO/SPD P0.14 (SWD0)
  - SWCLK P0.15 (SWD0)
- Full Duplex UART communication via a Virtual COM port
  - PC_RXD P1.2 USIC0CH1.DOUT0
  - PC_TXD P1.3 USIC0CH1.DX0A

While breaking off the J-LINK part of the PCB and connecting the debug interface with a ribbon cable, the direct connection will provide the same set-up.

A reverse connection of the debug connector (pin1 to pin8) provides the other set-up:

- Serial Wire Debug (SWD)
  - SWIO/SPD P1.3 (SWD1)
  - SWCLK P1.2 (SWD1)
- Full Duplex UART communication via a Virtual COM port
  - PC_RXD P0.15 USIC0CH0.DOUT0
  - PC_TXD P0.14 USIC0CH0.DX0A

2.3.3 Infineon Debug Connector (16-pin)

The KIT_XMC1300_DC_V1 board supports debugging via Infineon's device access server (DAS), when using KIT_DRIVEMONI_USB_V2 as interface device. The latest release of DAS software can be downloaded from **http://www.infineon.com/das**. When using an external debugger, the on-board debugger (OBD) has to be switched off. This is done by connecting pin 6 to GNDISO. KIT_DRIVEMONI_USB_V2 already provides this connection and the OBD is disabled as soon as the connector is plugged in.

Next to the SWD and SPD debug signals which are provided as unidirectional signals because of the galvanic isolation, UART signals can be accessed through this connector as well. Figure 9 shows the pin assignment of the connector, the following table lists the signals as well.

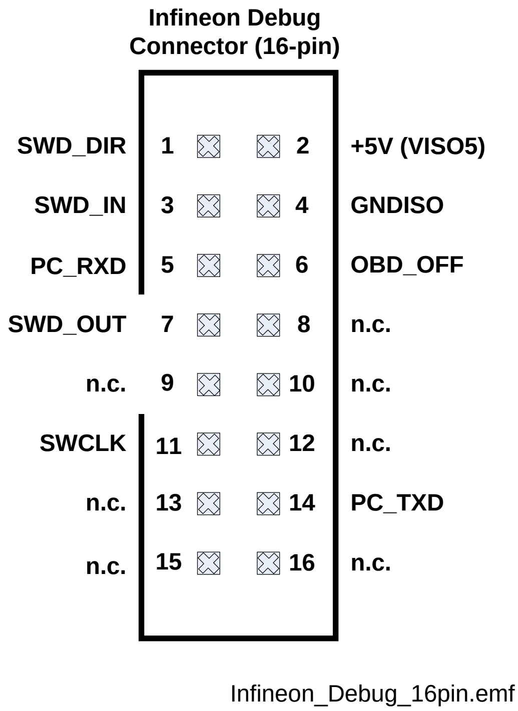


Figure 9 Infineon Debug Connector (16-pin)

Pin No.	Signal Name	I/O	Serial Wire Debug
1	SWD_DIR	O	Defines the direction of SWIO
2	+5V (VISO5)	-	+5V supply of isolated debug domain
3	SWD_IN	I	Input signal of SWIO
4	GNDISO	-	Ground of isolated debug domain
5	PC_RXD	I	UART Receive signal (P1.3, DOUT0 USIC0, channel1)
6	OBD_OFF#	I	Disable on-board debug device (Low active)
7	SWD_OUT	O	Output signal of SWIO
8	n.c.	-	Not connected
9	n.c.	-	Not connected
10	n.c.	-	Not connected
11	SWCLK	O	SWD clock signal
12	n.c.	-	Not connected
13	n.c.	-	Not connected
14	PC_TXD	I	UART Transmit signal (P1.2, DX0A, USIC0, channel1)
15	n.c.	-	Not connected
15	n.c.	-	Not connected

2.4 Potentiometer and User LEDs

The KIT_XMC1300_DC_V1 provides a potentiometer which is connected to ADC group1, channel7 and one user LED (P0.4). Next to the LED, a testpoint is available in order to easily connect an oscilloscope's probe for software controlled trigger signals.

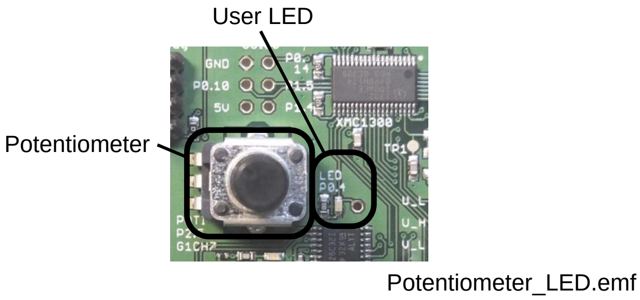


Figure 10 Potentiometer and LEDs

Table 2 Potentiometer

Potentiometer	**Connected to Port Pin**
R103	P2.5 / G1_CH7 (Group 1, channel 7)
User LEDs	**Connected to Port Pin**
LED102	P0.4 (LED)

Attention: The testpoints are referenced to power GND supply domain. Hence they may carry hazzardous voltages.

2.5 USIC0 Connector

The USIC Interface provides access to USIC 0 channel 0, which supports SPI, UART and I2C communication protocolls.

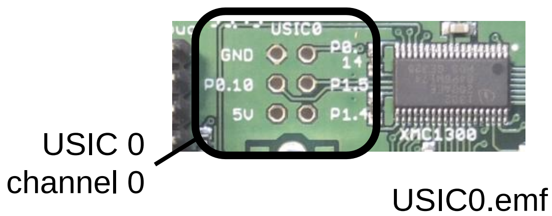


Figure 11 USIC Interface Connector

Table 3 USIC0 Connector X104

Pin	**Port**	**Peripherals**	**Comment**
X104-1	P1.4	USIC0_CH0.DX5E	
X104-2	VDD5	5V	
X104-3	P1.5	USIC0_CH0.DOUT0	
X104-4	P0.10	USIC0_CH0.SELO1 / DX2C	Overlaps with ENENC
X104-5	P0.14	USIC0_CH0.SCLKOUT	Overlaps with SWD0/SPD0
X104-6	GND	GND	

2.6 Hall Sensor and Encoder Connectors

The KIT_XMC1300_DC_V1 provides two pairs of HALL and incremental encoder connectors as indicated in Figure 12. The encoder interface connector provides a differential input which is transformed into single ended signals by an interface IC. The HALL sensor interface provides a pull-up resistor for each HALL sensor signal as well as power supply for the HALL sensors

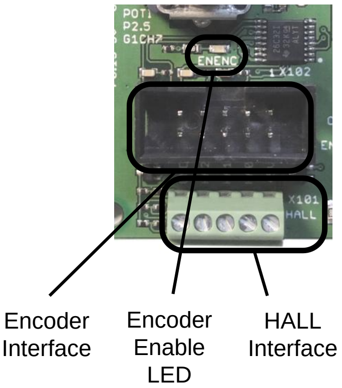


Figure 12 Hall Sensor and Encoder Connectors

Both the HALL and the encoder signals are connected to the same POSIF interface. The ENENC-signal is used to either enable the output signals of the encoder IC or to activate the power supply and pull-up resistor supply of the HALL sensor interface. As a result, both interfaces can be connected at the same time and the user can select by software which interface to use. Figure 13 shows the HALL sensor and encoder interface circuitry. Please refer to Table 4 for details on pin and peripheral assignment.

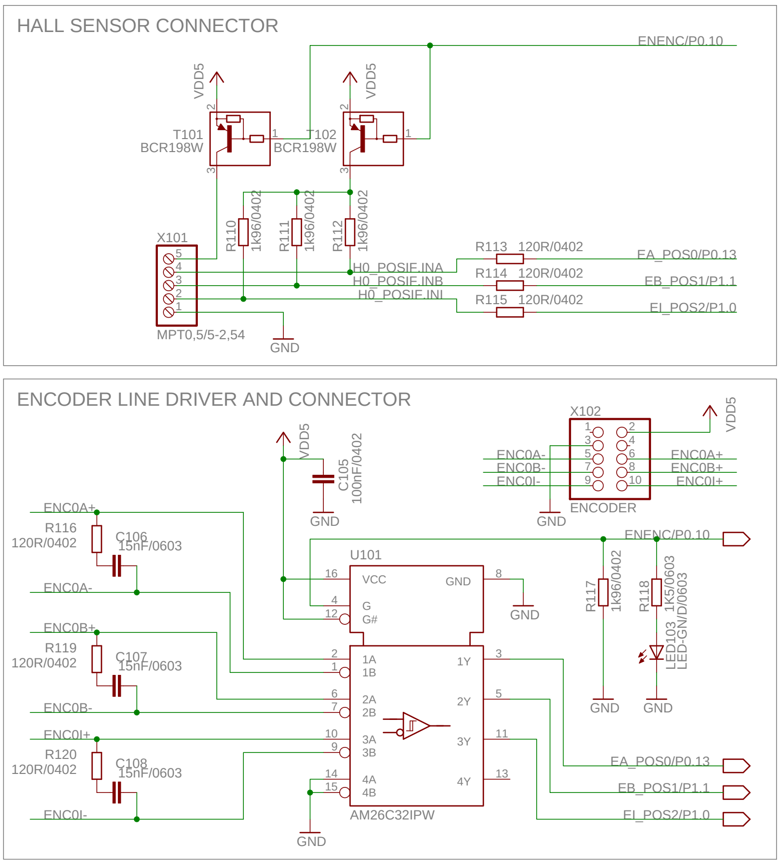


Figure 13 Hall Sensor and Encoder Interface Circuitry

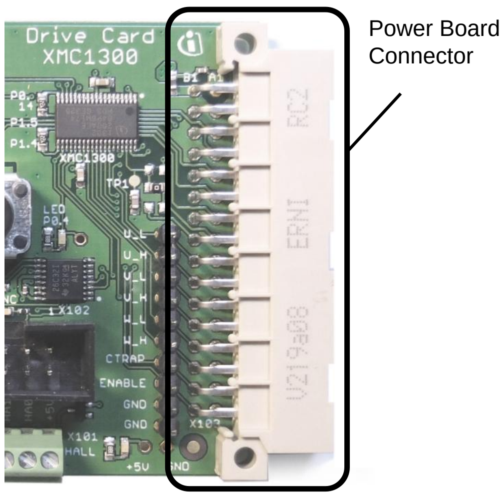
Table 4 HALL Sensor and Encoder Interfaces

Pin	Port	Peripheral
HALL Sensor Interface X101		
1	GND	
2	P1.0	POSIF0.IN2A
3	P1.1	POSIF0.IN1B
4	P0.13	POSIF0.IN0B
5	VDD5	HALL sensor power supply
Encoder Interface X102		
1	n.c.	
2	VDD5	Encoder power supply
3	GND	
4	n.c.	
5	ENCA-	POSIF0.IN0B
6	ENCA+	
7	ENCB-	POSIF0.IN1B
8	ENCB+	
9	ENCI-	POSIF0.IN2A
10	ENCI+	
Enable Encoder		
LED103	P0.10	High: Enable Encoder Interface Low: Enable HALL Interface including supply

2.7 Power Board Connector

The KIT_XMC1300_DC_V1 board provides a power board connector with all the signals required to control the power inverter. Next to the PWM output signals of CCU4 and CCU8 as well as the ADC signals, there are the power supply pins for the power GND domain.

Figure 14 shows a picture of the power board connector. The pin and peripheral assignment can be found in Table 5. In addition, different use cases for three phase inverters can be found in Table 6.



PowerBoard_Con.emf

Figure 14 Power Board Connector

Attention: The power board connector is also providing the power supply for the power GND supply domain. Hence it may carry hazzardous voltages.

Table 5 Power Board Connector

X302 MAB32B2	Female FAB32Q2	Function on Power Inverter	Port	Peripherals	
A1	A16	GND	VSS, VSSP		
A2	A15	PFC Gate	P0.5	CCU40.CC40	CMP2.OUT
A3	A14	I_{PFC}	P2.2	VADC0.G0CH7	ACMP2.INN
A4	A13	V_{PFC}	P2.4		VADC0.G1CH6
A5	A12	V_{BEMF_U} / I_U (2)	P2.9	VADC0.G0CH2	VADC0.G1CH4
A6	A11	V_{BEMF_V} / I_V (2)	P2.10	VADC0.G0CH3	VADC0.G1CH2
A7	A10	V_{BEMF_W} / I_W (2)	P2.11	VADC0.G0CH4	VADC0.G1CH3
A8	A9	I_AVG / I_{DClink} (2)	P2.1	VADC0.G0CH6	
A9	A8	U1_L	-		
A10	A7	U1_H	-		
A11	A6	V1_L	-		
A12	A5	V1_H	-		
A13	A4	W1_L	-		
A14	A3	W1_H	-		
A15	A2	CTRAP1	-		
A16	A1	ENPOW1	-		
B1	B16	VCC 5V	VDD, VDDP		
B2	B15	Brake Gate	-		
B3	B14	Brake temp	-		
B4	B13	V_{DClink}	P2.3		VADC0.G1CH5
B5	B12	V_{BEMF_U} / I_U (1)	P2.6	VADC0.G0CH0	
B6	B11	V_{BEMF_V} / I_V (1)	P2.8	VADC0.G0CH1	VADC0.G1CH0
B7	B10	V_{BEMF_W} / I_W (1)	P2.0	VADC0.G0CH5	
B8	B9	I_{DClink} (1)	P2.7		VADC0.G1CH1
B9	B8	U0_L	P0.1	CCU80.OUT01	
B10	B7	U0_H	P0.0	CCU80.OUT00	
B11	B6	V0_L	P0.6	CCU80.OUT11	
B12	B5	V0_H	P0.7	CCU80.OUT10	
B13	B4	W0_L	P0.9 & P0.3	CCU80.OUT21	CCU80.OUT03
B14	B3	W0_H	P0.8 & P0.2	CCU80.OUT20	CCU80.OUT02
B15	B2	CTRAP0	P0.12	CCU80.IN0A,IN1A,IN2A,IN3A	
B16	B1	ENPOW0	P0.11	GPIO	

Note: Please note that the numbering of the power board connector at the drive card is inverse to the numbering at the power board.

Table 6 Use Cases of PWM Signals

X302 (MAB32B2)	Function	Port	Peripheral
2-Level Inverter with CCU80			
B9	U0_L	P0.1	CCU80.OUT01
B10	U0_H	P0.0	CCU80.OUT00
B11	V0_L	P0.6	CCU80.OUT11
B12	V0_H	P0.7	CCU80.OUT10
B13	W0_L	P0.9	CCU80.OUT21
B14	W0_H	P0.8	CCU80.OUT20
B15	CTRAP0	P0.12	CCU80.IN0A,IN1A,IN2A,IN3A
B16	ENPOW0	P0.11	GPIO
2-Level Inverter with CCU80 (2 slices only)			
B9	U0_L	P0.1	CCU80.OUT01
B10	U0_H	P0.0	CCU80.OUT00
B11	V0_L	P0.6	CCU80.OUT11
B12	V0_H	P0.7	CCU80.OUT10
B13	W0_L	P0.3	CCU80.OUT03
B14	W0_H	P0.2	CCU80.OUT02
B15	CTRAP0	P0.12	CCU80.IN0A,IN1A,IN2A,IN3A
B16	Enable0	P0.11	GPIO

3 Production Data

3.1 Schematics

This chapter contains the schematics for the drive card:

- XMC1302 MCU, Power Supply, HALL and Encoder Interface, USIC0 interface
- Isolated On-board Debugger

The board has been designed with Eagle. The full PCB design data of this board can also be downloaded from www.infineon.com/xmc-dev.

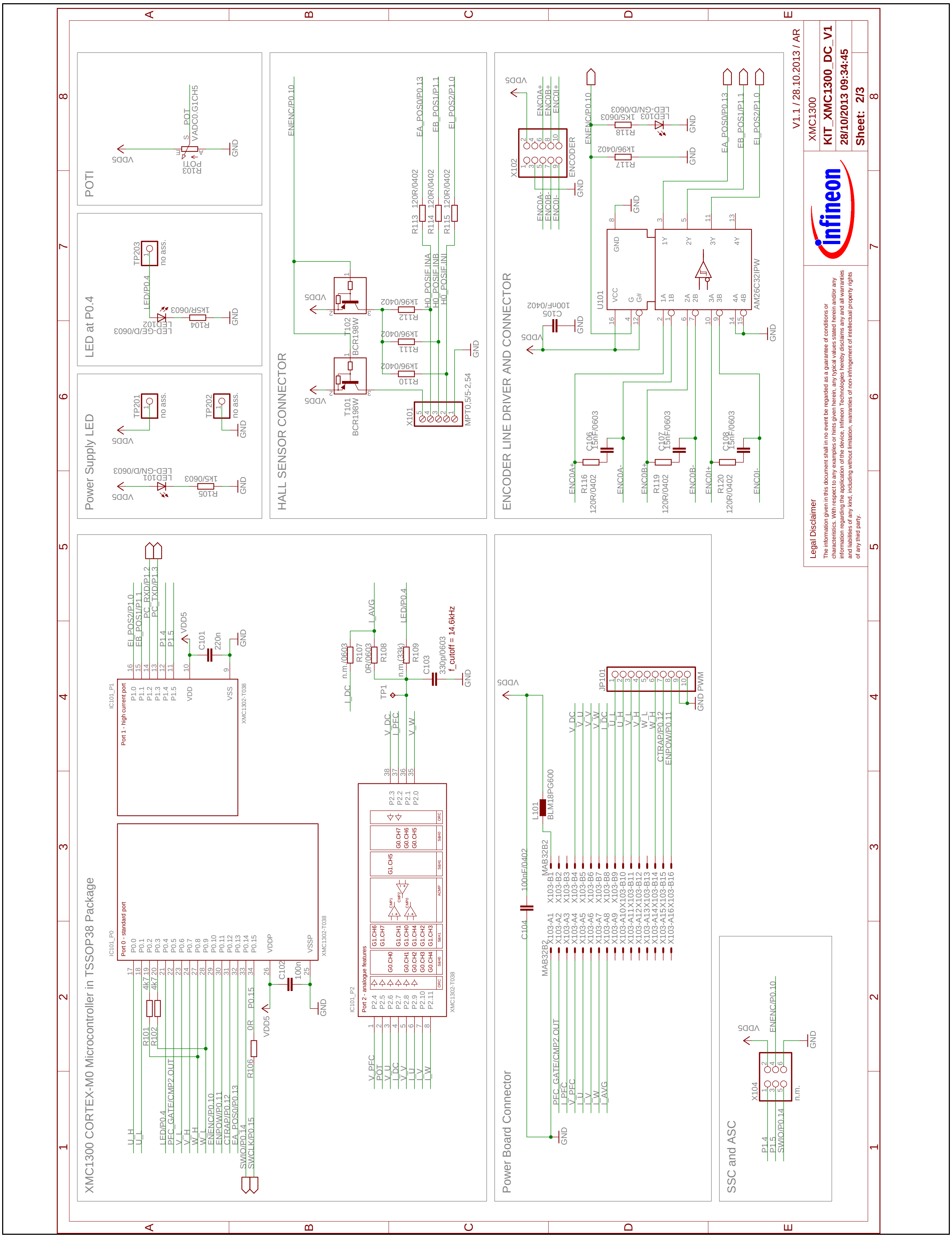


Figure 15 XMC1302 MCU, Power Supply, HALL and Encoder Interface, USIC0 interface

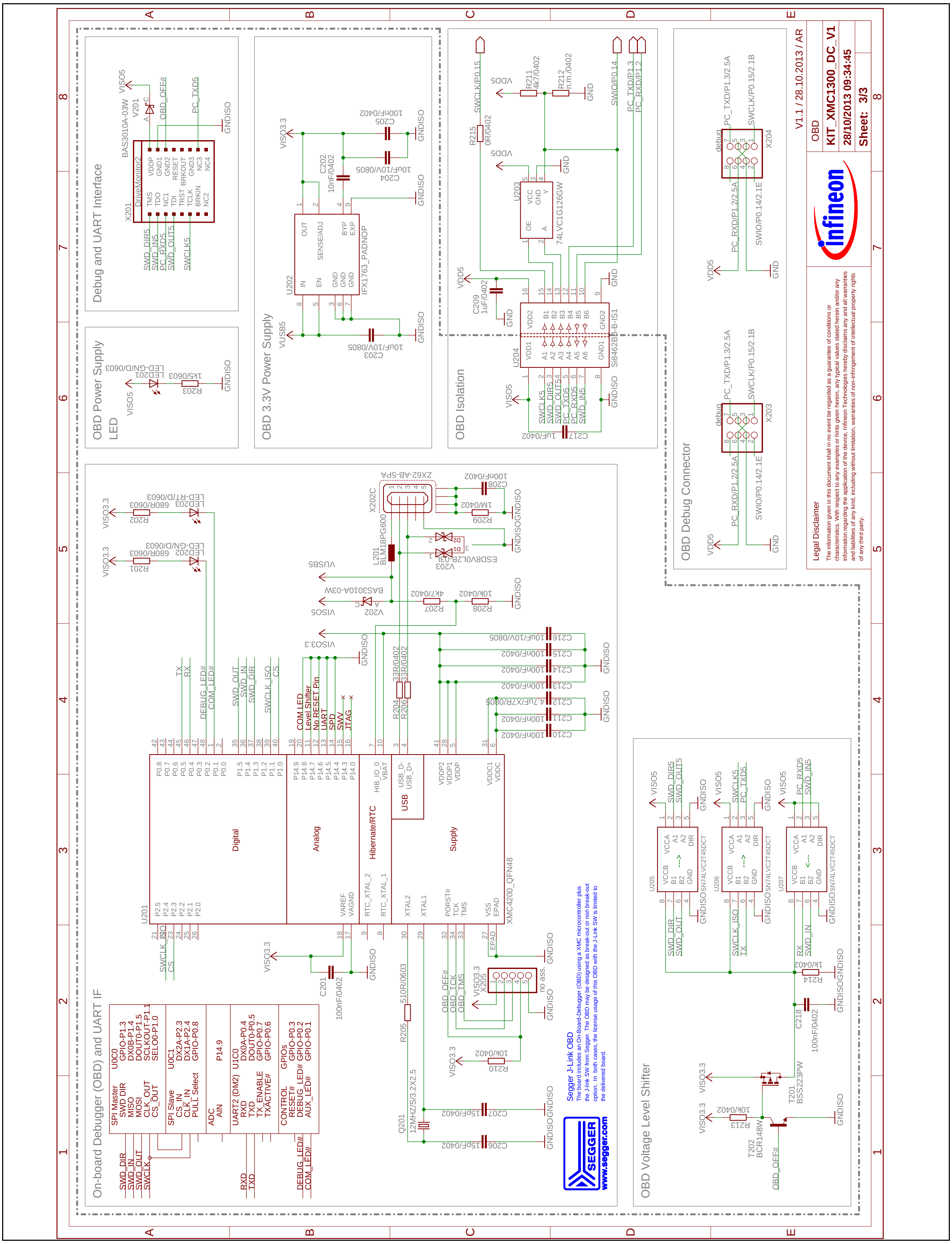


Figure 16 Isolated On-board Debugger

3.2 Component Placement

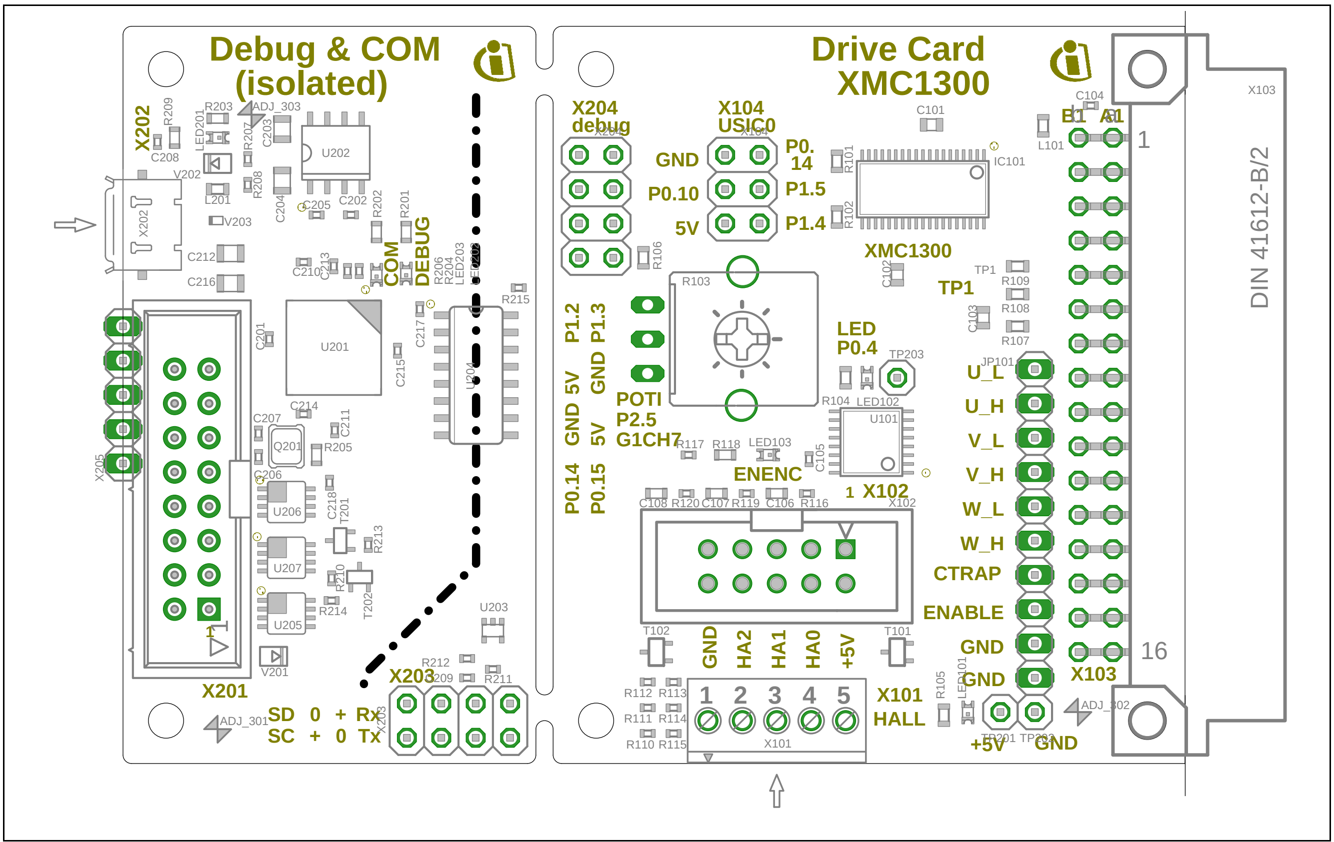


Figure 17 Component Placement

3.3 Bill of Material (BOM)

Table 7 BOM of KIT_XMC1300_DC_V1 Board

Pos. No.	Qty	Value	Device	Reference Des.
1	2	4k7	RESISTOR 0603	R101, R102
2	1	10k	potentiometer	R103
3	1	1k5R/0603	RESISTOR 0603	R104
4	2	1k5/0603	RESISTOR 0603	R105, R203
5	1	0R	RESISTOR 0603	R106
6	1	n.m./0603	RESISTOR 0603	R107
7	1	0R/0603	RESISTOR 0603	R108
8	1	n.m.(33k)	RESISTOR 0603	R109
9	4	1k96/0402	RESISTOR 0402	R110, R111, R112, R117
10	6	120R/0402	RESISTOR 0402	R113, R114, R115, R116, R119, R120
11	1	1K5/0603	RESISTOR 0603	R118
12	2	680R/0603	RESISTOR 0603	R201, R202
13	2	33R/0402	RESISTOR 0402	R204, R206
14	1	510R/0603	RESISTOR 0603	R205
15	2	4k7/0402	RESISTOR 0402	R207, R211
16	3	10k/0402	RESISTOR 0402	R208, R210, R213
17	1	1M/0402	RESISTOR 0603	R209
18	1	n.m./0402	RESISTOR 0402	R212
19	1	1k/0402	RESISTOR 0402	R214
20	1	0R/0402	RESISTOR 0402	R215
21	1	220n	CAPACITOR 0603	C101
22	1	100n	CAPACITOR 0603	C102
23	1	330p/0603	CAPACITOR 0603	C103
24	11	100nF/0402	CAPACITOR 0402	C104, C105, C201, C205, C208, C210, C211, C213, C214, C215, C218
25	3	15nF/0603	CAPACITOR 0603	C106, C107, C108
26	1	10nF/0402	CAPACITOR 0402	C202
27	3	10uF/10V/0805	CAPACITOR 0805K	C203, C204, C216
28	2	15pF/0402	CAPACITOR 0402	C206, C207
29	2	1uF/0402	CAPACITOR 0402	C209, C217
30	1	4.7uF/X7R/0805	CAPACITOR 0805K	C212
31	2	12MHZ/S/3.2X2.5	CRYSTAL	Q201
32	2	BLM18PG600	FERRIT BEAD	L101, L201
33	4	LED-GN/D/0603	LEDCHIPLED 0603	LED101, LED103, LED201, LED202
34	1	LED-GE/D/0603	LEDCHIPLED 0603	LED102
35	1	LED-RT/D/0603	LEDCHIPLED 0603	LED203
36	2	BCR198W	TRANSISTOR	T101, T102
37	1	BSS223PW	TRANSISTOR	T201
38	1	BCR148W	TRANSISTOR	T202
39	1	XMC1302_TSSOP38	INFINEON MCU	IC101
40	1	IFX1763	INFINEON LDO	U202
41	1	AM26C32IPW	ENCODER IC	U101
42	1	XMC4200_QFN48	INFINEON MCU	U201

43	1	Si8462BB-B-IS1	ISOLATED DIGITAL	U204
44	1	74LVC1G126GW	LOGIC	U203
45	3	SN74LVC2T45DCT	LOGIC	U205, U206, U207
46	2	BAS3010A-03W	BAT60	V201, V202
47	1	ESD8V0L2B-03L	ESD DIODE	V203
48	1	ZX62-AB-5PA	MICRO-USB	X202
49	1	W1*10	CONNECTOR	JP101
50	1	CONP_2X05	CONNECTOR	X102
51	1	MAB32B2	CONNECTOR	X103
52	1	MPT0,5/5-2,54	CONNECTOR	X101
53	2	W2*4	CONNECTOR (DEBUG)	X203, X204
54	1	W2*3	CONNECTOR (USIC)	X104

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Published by Infineon Technologies AG

Motor Control Application Kit

For XMC4000 Family

KIT_XMC4400_DC_V1

XMC4400 Drive Card V1.0

Board User‘s Manual

Revision 1.0, 2013-11-05

Microcontroller

Edition 2013-11-05

Published by
Infineon Technologies AG
81726 Munich, Germany

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Revision History	
Page or Item	**Subjects (major changes since previous revision)**
Revision 1.0, 2013-11-05	Initial release

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Introduction

This document describes the features and hardware details of the DriveCard XMC4400 V1 (KIT_XMC4400_DC_V1) designed to work with Infineon's inverter boards. This board is part of Infineon's Motor Control Application Kits.

1 Overview

The drive card KIT_XMC4400_DC_V1 houses the XMC4400 Microcontroller from Infineon Technologies, a power board connector, two sets of position interface circuits with hall and encoder connectors, a multi feedback interface and an isolated on-board debug interface with CAN capability. The board along with a three phase inverter demonstrates the capabilities of the XMC4400. The main use case for this board is to demonstrate the motor control features of the XMC4400 device including tool chain. The focus is safe operation under evaluation conditions. The board is neither cost nor size optimized and does not serve as a reference design.

1.1 Key Features

The KIT_XMC4400_DC_V1 board is equipped with the following features

- Infineon XMC4400 (ARM® Cortex™-M4-based) Microcontroller, 512 kByte on-chip Flash, LQFP-100
- Connection to power inverter via the power board connector
- 2 combined hall sensor and encoder interfaces
- Multi feedback interface connectors for connection of resolver circuitry, UART, SPI, I2C, USB, etc
- 8 LEDs
  - 2 Power indicating LEDs
  - 2 User LEDs (P2.2 and P2.15)
  - 2 Encoder enable LEDs
  - 2 Debug LEDs (DEBUG, COM)
- Potentiometer, connected to analog input P14.13 (ADC group 1, channel 5)
- Reset push button
- Isolated Debug options
  - On-Board Debugger (SEGGER J-Link LITE) via USB connector
  - Infineon Debug connector 16-pin (0.1") with DriveMonitor USB Stick V2 (KIT_DRIVEMONI_USB_V2)
- Isolated Connectivity
  - UART channel of On-Board Debugger (SEGGER J-Link LITE) via USB connector
  - CAN node
- Power supply of MCU domain
  - Via power board connector (5V)
  - Via multi feedback interface connector
- Power supply of isolated debug domain
  - Via Debug USB connector
  - Via Infineon Debug connector 16-pin
  - Via CAN interface connector

1.2 Block Diagram

Figure 1 shows the functional block diagram of the KIT_XMC4400_DC_V1 board. For more information about the power supply domains please refer to chapter 2.1.

The drive card has got the following building blocks:

- 1 Power Board Connector
- 2 sets of position interface connectors (HALL, ENCODER)
- Encoder Enable signals via GPIOs (P1.0 and P2.10)
- 2 User LEDs connected to GPIOs (P2.2 and P2.15)
- Variable resistor (POTI) connected to GPIO P14.13 (ADC group 1, channel 5)
- Multi Feedback Interface
- Isolated On-board Debugger via Debug USB connector (Micro-USB) with UART channel (USIC0, channel 0)
- Optional Infineon Debug interface connector for Drive Monitor USB Stick V2 (KIT_DRIVEMONI_USB_V2)
- Isolated CAN interface connector at CAN node 0

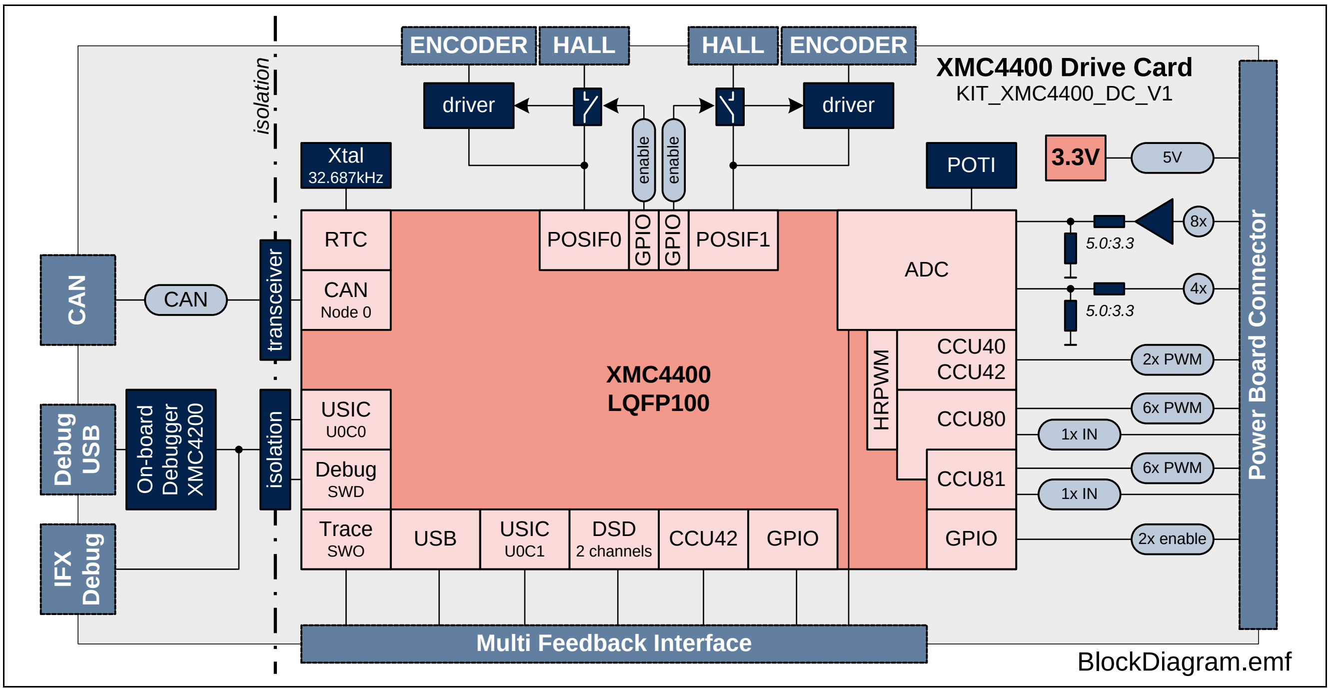


Figure 1 Block Diagram of KIT_XMC4400_DC_V1

2 Hardware Description

The following sections give a detailed description of the hardware and how it can be used.

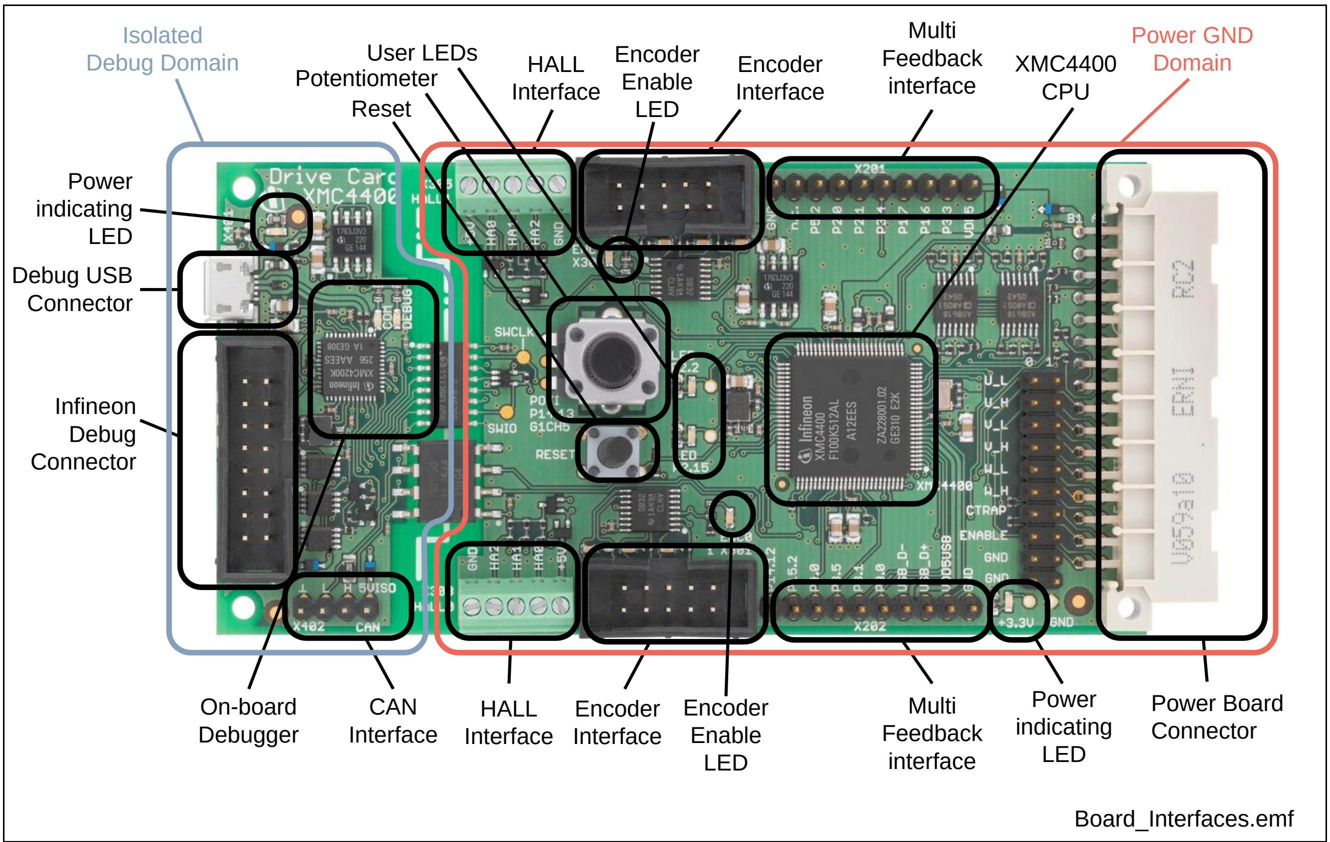


Figure 2 XMC4400 Drive Card (KIT_XMC4400_DC_V1)

2.1 Power Supply

The KIT_XMC4400_DC_V1 board is designed with two galvanically isolated supply domains. On the left side, there is the debug domain, which contains a XMC4200 MCU as on-board debug controller (OBD) as well as level shifters to a 5V debug interface like the drive monitor USB stick (KIT_DRIVEMONI_USB_V2). The debug domain can be powered via the USB plug (5V) as well as the CAN connector or the Infineon debug connector. On the middle to the right side there is the power GND supply domain, which provides the power supply for the MCU and the peripheral components. This supply domain is usually powered from the power board connector. If the current provided by the power board is not sufficient, then the multi feedback interface connectors can be used as well.
For both supply domains a separate power indicating LED is available.

The typical current drawn by the drive card at the power GND domain is about 180 mA.

To indicate the power status of the KIT_XMC4400_DC_V1 board two power indicating LED's are provided on board (see Figure 3). The LED will be "ON" when the corresponding power rail is powered.

Table 1 Power status LED's

LED Reference	Power Rail	Voltage	Note
LED201	VDD3.3	3.3 V	Power GND domain, must always be "ON"
LED401	VISO5	5 V	Debug supply domain, "ON" if debug domain is intened to be used.

Figure 3 and Figure 4 show details of the power supply concept of the drive card.

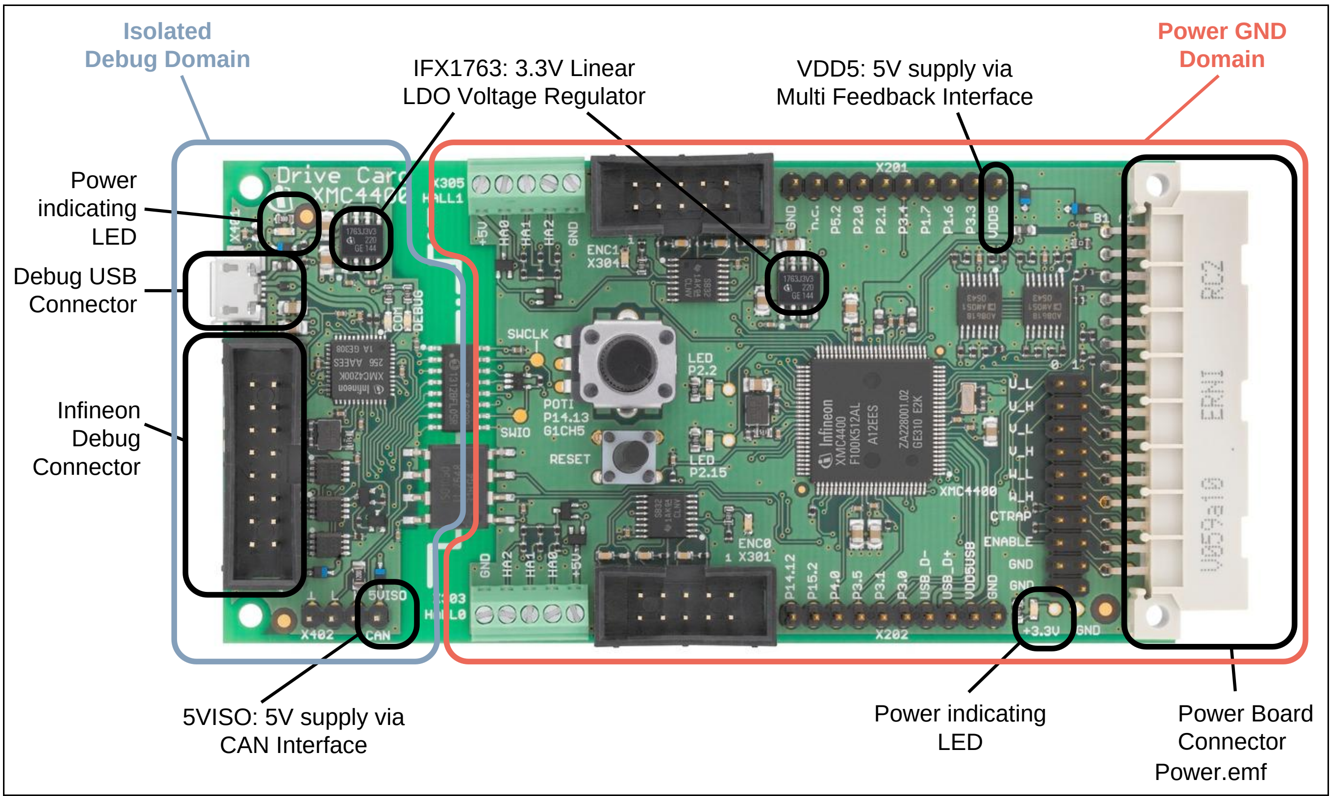


Figure 3 Power Supply Concept and Powering Options

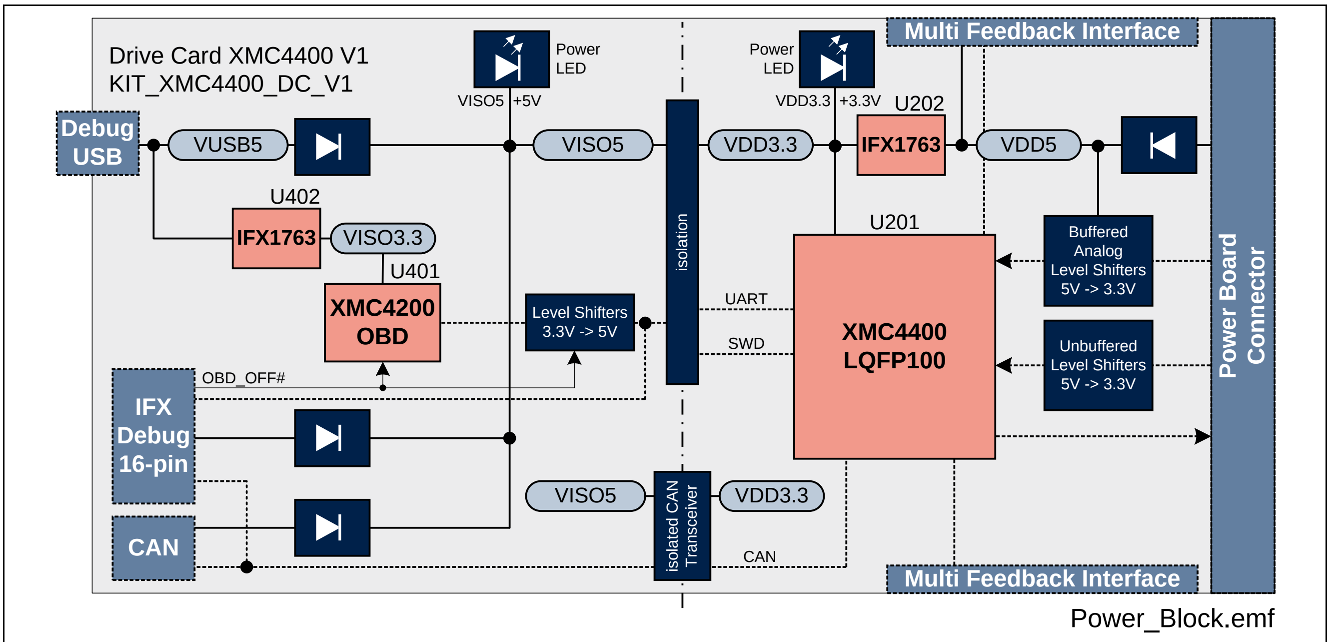


Figure 4 Block Diagram of Power Supply Concept

2.2 Reset

A reset signal connected to the low-active PORST# pin of the target CPU (U201, see Figure 4) can be issued by the on-board Reset Button (SW201, RESET) only. A reset debug command can be issued by the on-board debug device (U401) or an external debugger connected to the Infineon Debug connector. Figure 5 shows the reset button.

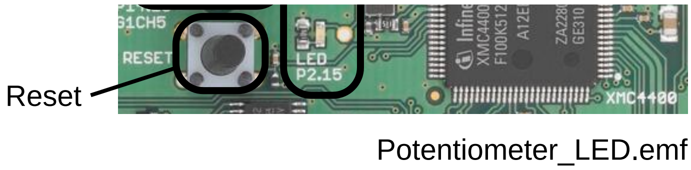


Figure 5 Reset Button

2.3 Clock Generation

An external 12 MHz crystal provides the clock signal to the XMC4400 microcontroller. The drive strength of the oscillator is set to maximum by default, in order to ensure a safe start-up of the oscillator even under worst case conditions. Therefore a serial 510 Ohm resistor will attenuate the oscillations during operations.

For the RTC clock a separate external 32.768 kHz crystal is used on board.

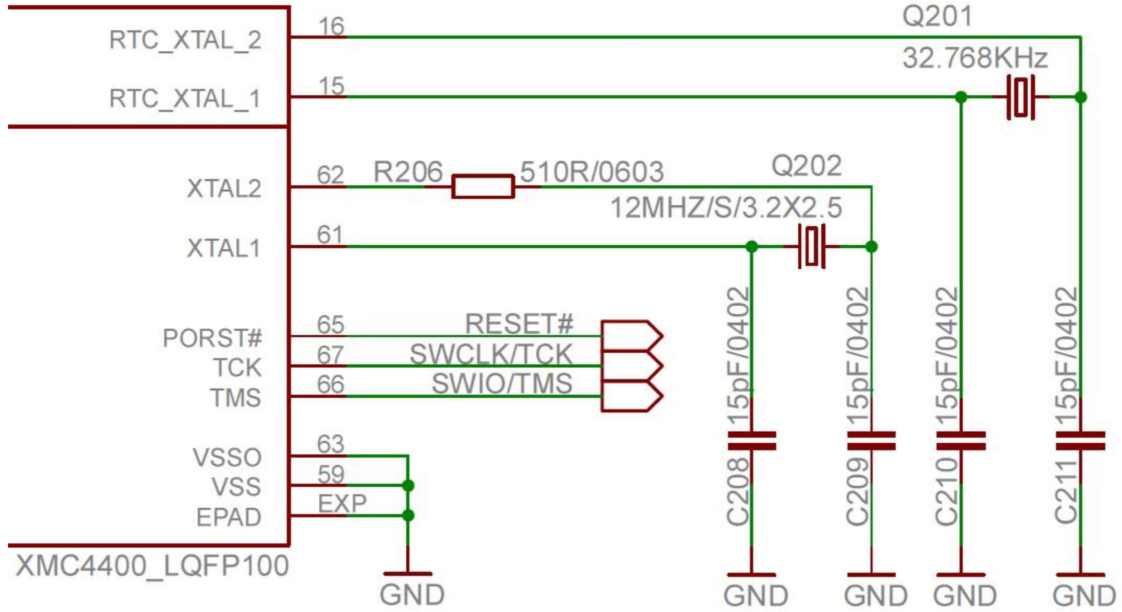


Figure 6 Clock Generation

2.4 Debug Interface

The KIT_XMC4400_DC_V1 is designed to use “Serial Wire Debug” (SWD) as debug interface and JTAG debug is not supported. It supports debugging via different channels which are all galvanically isolated from the power GND supply domain:

- On-board Debugger
- Infineon Debug Connector (16-pin) with Debug and UART interface
- CAN interface (X402)

2.4.1 On-board USB Debugger

The on-board debugger [1] supports

- Serial Wire Debug
- Full Duplex UART communication via a Virtual COM port
  - PC_RXD P5.1 USIC0CH0.DOUT0
  - PC_TXD P5.0 USIC0CH0.DX0D

[1] Attention: The firmware of the on-board debugger requires the latest J-Link driver (V4.62 or higher) and a Serial Port Driver (CDC driver) installed on your computer. Please check “Install J-Link Serial Port Driver” when installing the latest J-Link driver (see Figure 7)

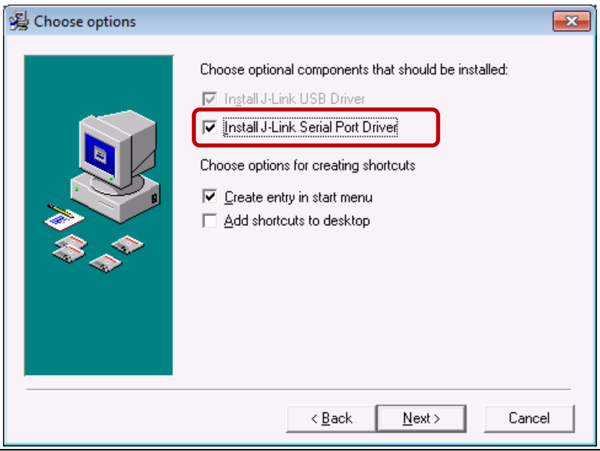


Figure 7 Installation of Serial Port Driver

The on-board debugger can be accessed through the Debug USB connector shown in Figure 8. The Debug LED V402 shows the status during debugging.

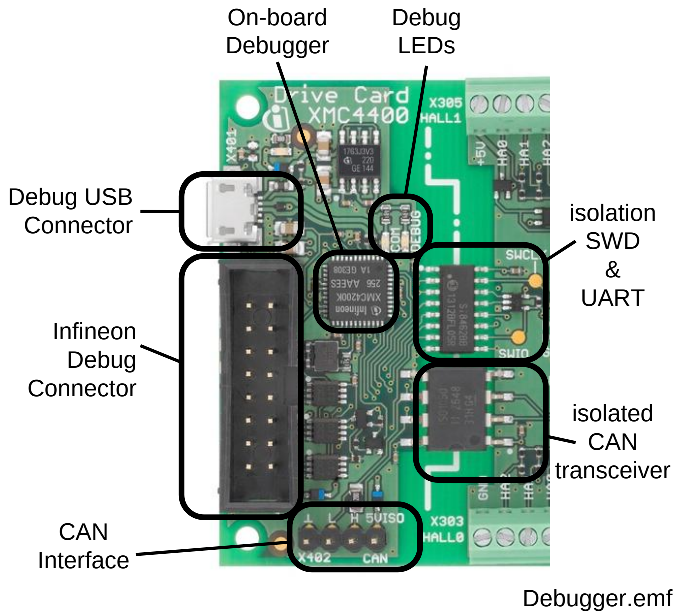


Figure 8 On-Board USB Debugger

2.4.2 Infineon Debug Connector (16-pin)

The KIT_XMC4400_DC_V1 board supports debugging via Infineon's device access server (DAS), when using KIT_DRIVEMONI_USB_V2 as interface device. The latest release of DAS software can be downloaded from **http://www.infineon.com/das**. When using an external debugger, the on-board debugger has to be switched off. This is done by connecting pin 6 to GNDISO. KIT_DRIVEMONI_USB_V2 already provides this connection and the OBD is disabled as soon as the connector is plugged in.

Next to the SWD debug signals which are provided as unidirectional signals because of the galvanic isolation, UART and CAN signals can be accessed through this connector as well. Figure 9 shows the pin assignment of the connector, the following table lists the signals as well.

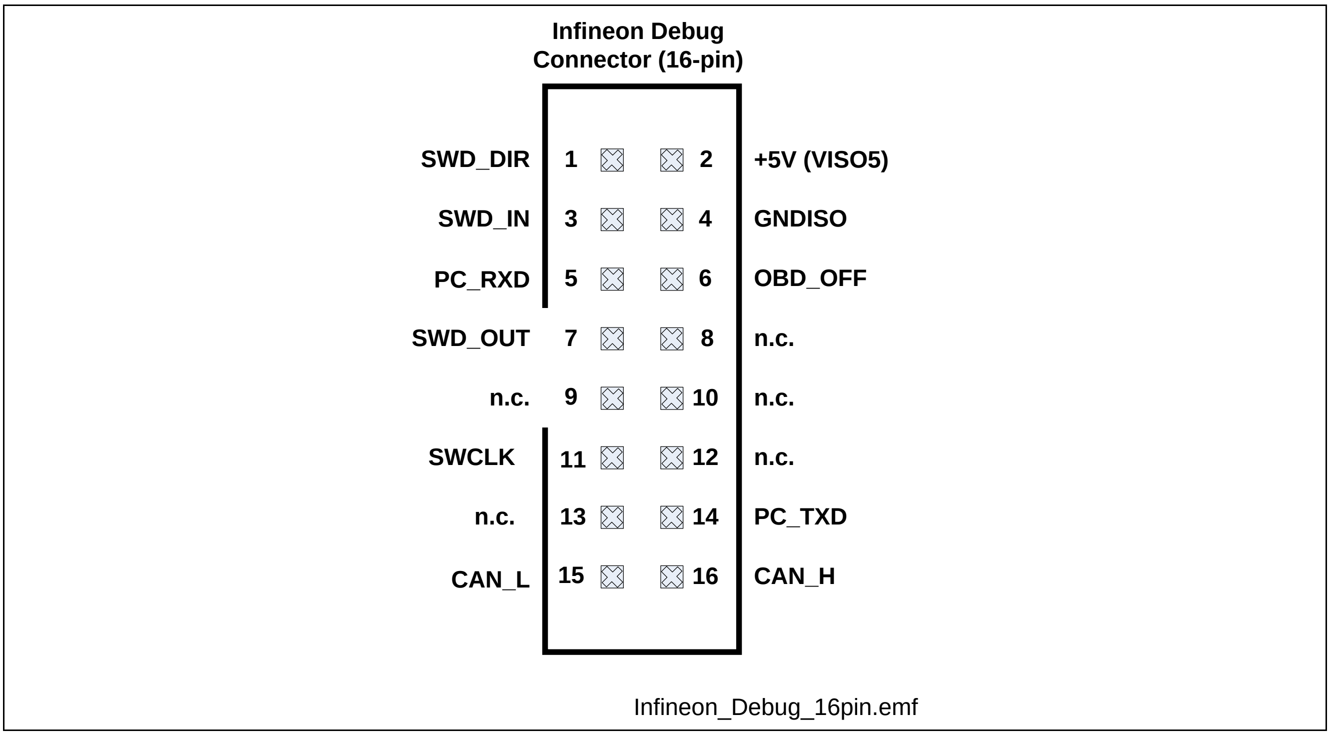


Figure 9 Infineon Debug Connector (16-pin)

Pin No.	Signal Name	I/O	Serial Wire Debug
1	SWD_DIR	O	Defines the direction of SWIO
2	+5V (VISO5)	-	+5V supply of isolated debug domain
3	SWD_IN	I	Input signal of SWIO
4	GNDISO	-	Ground of isolated debug domain
5	PC_RXD	I	UART Receive signal (P5.1, DOUT0 USIC0, channel0)
6	OBD_OFF#	I	Disable on-board debug device (Low active)
7	SWD_OUT	O	Output signal of SWIO
8	n.c.	-	Not connected
9	n.c.	-	Not connected
10	n.c.	-	Not connected
11	SWCLK	O	SWD clock signal
12	n.c.	-	Not connected
13	n.c.	-	Not connected
14	PC_TXD	I	UART Transmit signal (P5.0, DX0D, USIC0, channel0)
15	CAN_L	I/O	Low signal of CAN bus
15	CAN_H	I/O	High signal of CAN bus

2.4.3 CAN Interface (X402)

The KIT_XMC4400_DC_V1 board provides an isolated CAN interface with 120Ω termination (see Figure 10 for details).

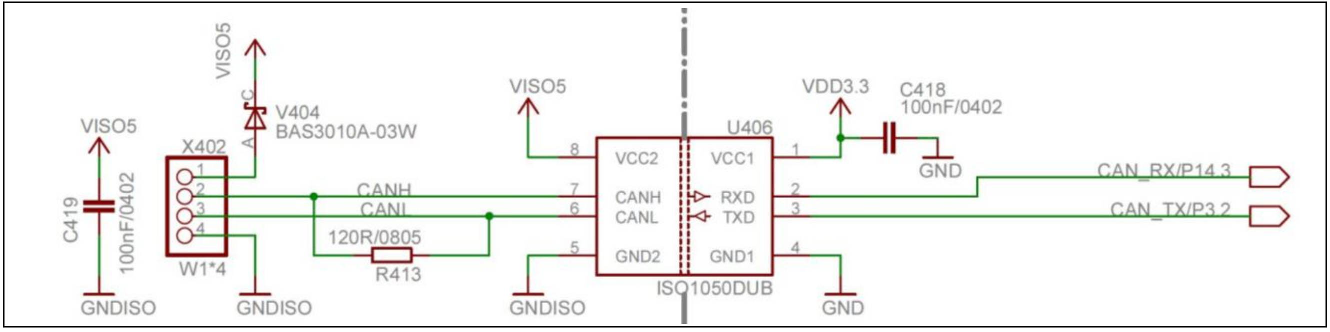


Figure 10 Isolated CAN Interface with Termimation

The isolated CAN transceiver (U406) is connected to CAN node 0 of XMC4400 via port pins P14.3 (RX) and P3.2 (TX).

2.5 Potentiometer and User LEDs

The KIT_XMC4400_DC_V1 provides a potentiometer which is connected to ADC group1, channel5 and two user LEDs (P2.2 and P2.15). Next to the LEDs, a testpoint is available in order to easily connect an oscilloscope's probe for software controlled trigger signals.

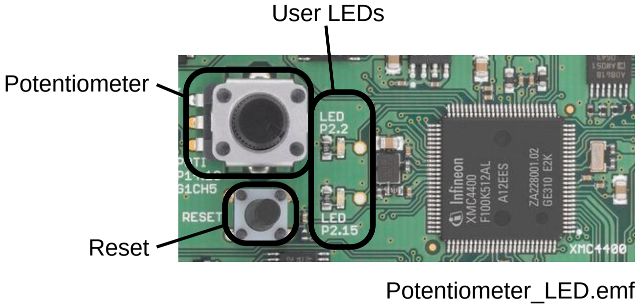


Figure 11 Potentiometer and LEDs

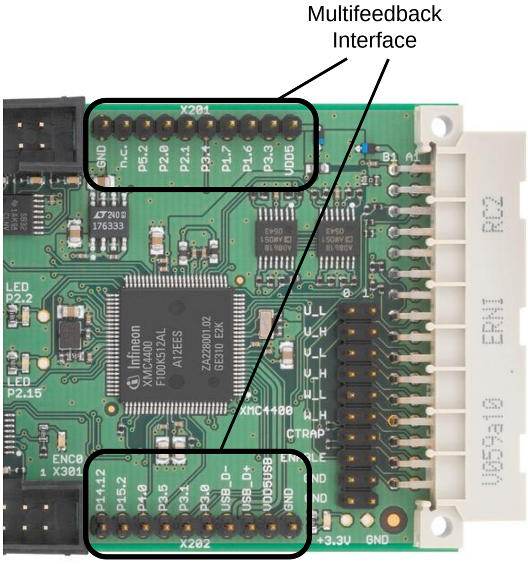
Table 2 Potentiometer

Potentiometer	**Connected to Port Pin**
R201	P14.13 / G1_CH5 (Group 1, channel 5)
User LEDs	**Connected to Port Pin**
LED202	P2.2 (LED0)
LED203	P2.15 (LED1)

Attention: The testpoints are referenced to power GND supply domain. Hence they may carry hazzardous voltages.

2.6 Multifeedback Connectors

The multifeedback interface can be used as extension to the HALL sensor and encoder interface and provides access to the DSD, USIC, ADC, CCU4, CCU8 and USB peripherals. As a result, a piggy-back board with rotary resolver interface can be easily plugged onto the drive card and extends the functionallity. The USIC channel, which supports SPI, UART I2C and IIS communication protocolls can be used to connect to dedicated position feedback ICs. Two ADC channels of different groups are available for synchronous sampling of analog signals.



Multifeedback.emf

Figure 12 Multifeedback Interface Connectors

Table 3 Multifeedback Interface Connector X201 and X202

Pin	Port	Peripherals			
Top Row X201					
X201-1	GND				
X201-2	-				
X201-3	P5.2	GPIO	CCU81.OUT23	CCU81.IN1B	
X201-4	P2.0	DSD.CGPWMN	CCU81.OUT21		
X201-5	P2.1	DSD.CGPWMP	CCU81.OUT11		TRACE.SWO
X201-6	P3.4	DSD.MCLK3B		CCU42.OUT2	CCU42.IN2A
X201-7	P1.7	DSD.MCLK2A			
X201-8	P1.6	DSD.DIN2A			
X201-9	P3.3	DSD.DIN3B	CCU80.IN3B	CCU42.OUT3	CCU42.IN3A
X201-10	VDD5				
Bottom Row X202					
X202-1	P14.12		VADC0.G1CH4		
X202-2	P15.2			VADC0.G2CH2	
X202-3	P4.0	U0C1.DX0E			
X202-4	P3.5	U0C1.DOUT0		CCU42.OUT1	
X202-5	P3.1	U0C1.SELO0	U0C1.DX2B		
X202-6	P3.0	U0C1.SCLKOUT	U0C1.DX1B	CCU42.OUT0	
X202-7	USB_DM				
X202-8	USB_DP				
X202-9	VBUS				
X202-10	GND				

2.7 Hall Sensor and Encoder Connectors

The KIT_XMC4400_DC_V1 provides two pairs of HALL and incremental encoder connectors as indicated in Figure 13. The encoder interface connector provides a differential input which is transformed into single ended signals by an interface IC. The HALL sensor interface provides a pull-up resistor for each HALL sensor signal as well as power supply for the HALL sensors

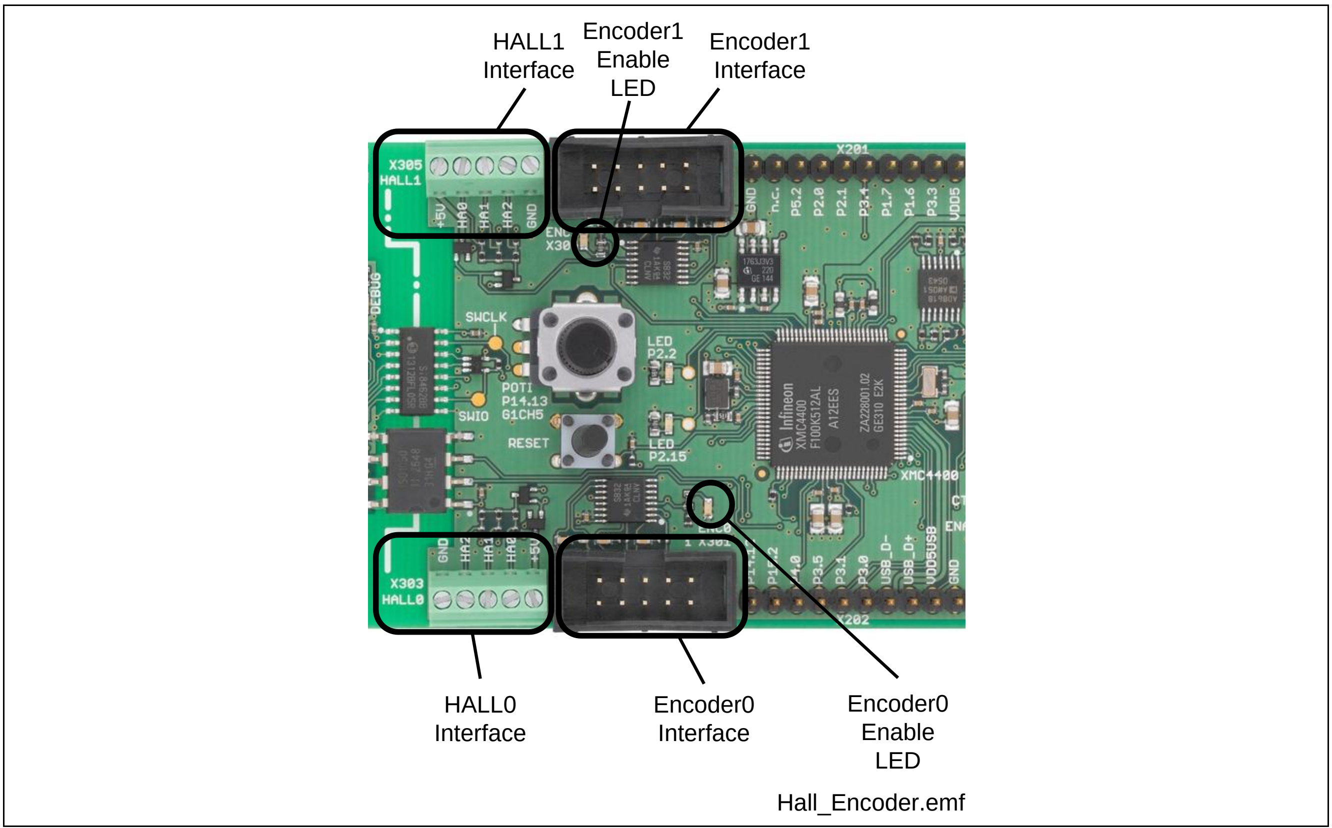


Figure 13 Hall Sensor and Encoder Connectors

Both the HALL and the encoder signals are connected to the same POSIF interface. The ENENC-signal is used to either enable the output signals of the encoder IC or to activate the power supply and pull-up resistor supply of the HALL sensor interface. As a result, both interfaces can be connected at the same time and the user can select by software which interface to use. Figure 14 shows the HALL sensor and encoder interface circuitry of interface 0. Please refer to Table 4 for details on pin and peripheral assignment.

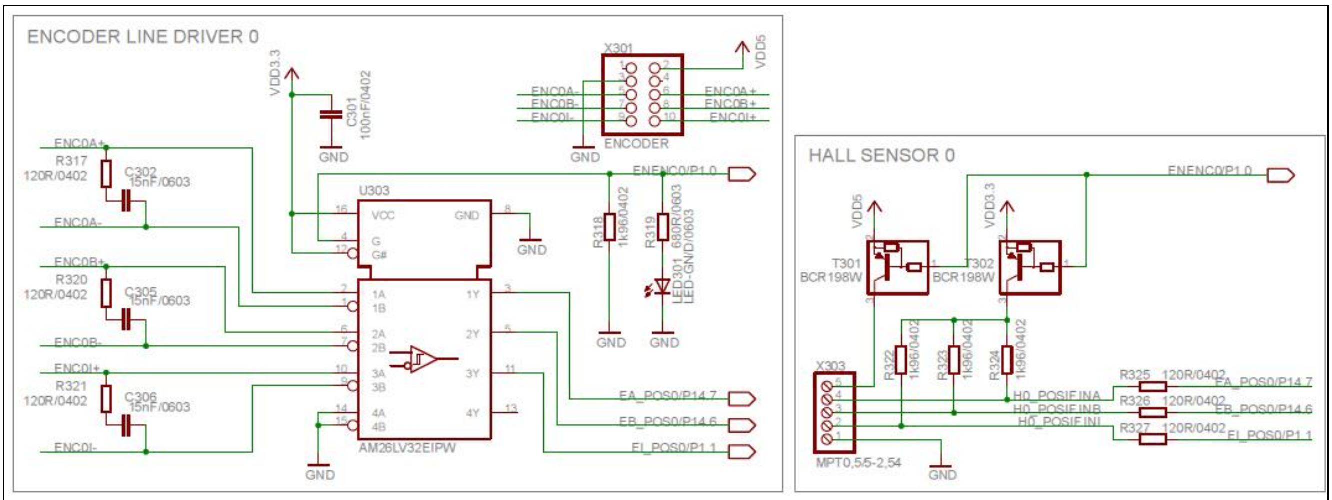


Figure 14 Hall Sensor and Encoder Interface Circuitry

Table 4 HALL Sensor and Encoder Interfaces

Pin	Port	Peripheral
HALL Sensor Interface X303		
1	GND	
2	P1.1	POSIF0.IN2A
3	P14.6	POSIF0.IN1B
4	P14.7	POSIF0.IN0B
5	VDD5	HALL sensor power supply
Encoder Interface X301		
1	n.c.	
2	VDD5	Encoder power supply
3	GND	
4	n.c.	
5	ENCA-	POSIF0.IN0B
6	ENCA+	
7	ENCB-	POSIF0.IN1B
8	ENCB+	
9	ENCI-	POSIF0.IN2A
10	ENCI+	
Enable Encoder 0		
LED301	P1.0	High: Enable Encoder Interface Low: Enable HALL Interface including supply
HALL Sensor Interface X305		
1	GND	
2	P2.3	POSIF1.IN2A
3	P2.4	POSIF1.IN1A
4	P2.5	POSIF1.IN0A
5	VDD5	HALL sensor power supply
Encoder Interface X304		
1	n.c.	
2	VDD5	Encoder power supply
3	GND	
4	n.c.	
5	ENCA-	POSIF1.IN0A
6	ENCA+	
7	ENCB-	POSIF1.IN1A
8	ENCB+	
9	ENCI-	POSIF1.IN2A
10	ENCI+	
Enable Encoder 1		
LED302	P2.10	High: Enable Encoder Interface Low: Enable HALL Interface including supply

2.8 Power Board Connector

The KIT_XMC4400_DC_V1 board provides a power board connector with all the signals required to control the power inverter. Next to the PWM output signals of CCU4, CCU8 and HRPWM as well as the ADC signals, there are the power supply pins for the power GND domain.

Figure 16 shows a picture of the power board connector. The pin and peripheral assignment can be found in Table 5. In addition, different use cases for three phase inverters can be found in Table 6.

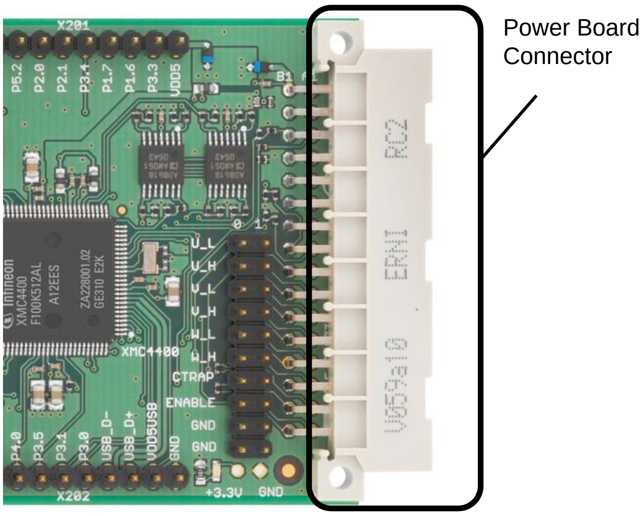


Figure 16 Power Board Connector

Attention: The power board connector is also providing the power supply for the power GND supply domain. Hence it may carry hazzardous voltages.

2.8.1 Level Shifters for Analog Signals

The board is designed to be powered by 5V although the XMC4400 is a 3.3V MCU. As a result all input signals to the MCU are connected via level shifters. For low impedance signals (A3/B3, A8/B8, A15/B15), a resistor divider is used. For high impedance signals, an additional analog buffer is provided (see Figure 17).

The level shifter ratio from power board signals towards the MCU is 0.662.

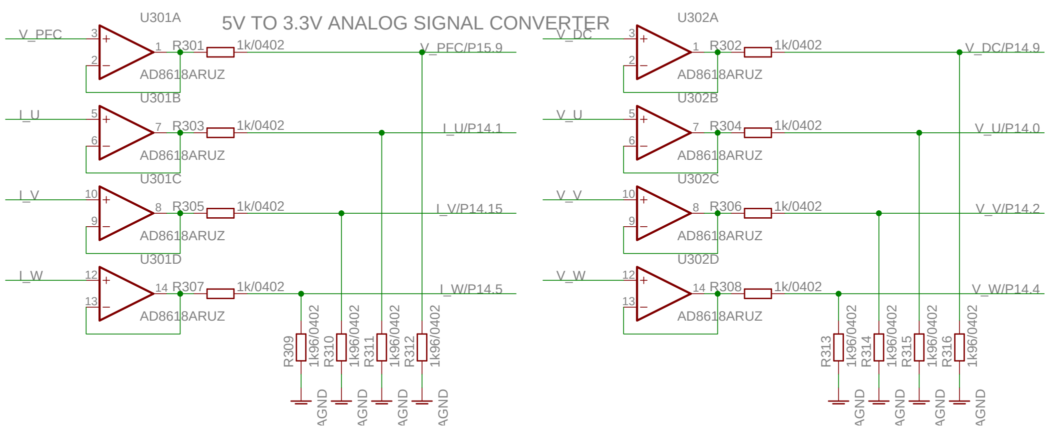


Figure 17 Buffered Level Shifter for High Impedance Analog Signals

Table 5 Power Board Connector

X302 MAB32B2	Female FAB32Q2	Function on Power Inverter	Port	Peripherals			
A1	A16	GND	VSS				
A2	A15	PFC Gate	P1.3 & P0.8	(CCU40.OUT0)	ERU1.PDOUT0	HROUT10	
A3	A14	I_{PFC}	P15.8 & P0.0			HR.C1INB	VADC0.G3CH0
A4	A13	V_{PFC}	P15.9				VADC0.G3CH1
A5	A12	V_{BEMF_U} / I_U (2)	P14.1	VADC0.G0CH1			
A6	A11	V_{BEMF_V} / I_V (2)	P14.15		VADC0.G1CH7		G1ORC7
A7	A10	V_{BEMF_W} / I_W (2)	P14.5	VADC0.G0CH5		VADC0.G2CH1	
A8	A9	I_AVG / I_{DClink} (2)	P14.8	(DAC0.OUT)	VADC0.G1CH0		VADC0.G3CH2
A9	A8	U1_L	P1.12 & P0.10	CCU81.OUT01	CCU80.OUT02		
A10	A7	U1_H	P1.15 & P2.7	CCU81.OUT00	CCU80.OUT03		
A11	A6	V1_L	P1.11 & P2.9	CCU81.OUT11	CCU80.OUT22		
A12	A5	V1_H	P1.5	CCU81.OUT10	CCU80.OUT23		
A13	A4	W1_L	P1.10 & P2.8	CCU81.OUT21	CCU80.OUT32		
A14	A3	W1_H	P1.4	CCU81.OUT20	CCU80.OUT33		
A15	A2	CTRAP1	P1.2	ERU1.2B0 (PDOUT1 -> CCU81.IN0I, IN1I,IN2I,IN3I)			
A16	A1	ENPOW1	P4.1	GPIO			
B1	B16	VCC 5V	VDD				
B2	B15	Brake Gate	P3.6	CCU42.OUT0			
B3	B14	Brake temp	P15.3			VADC0.G2CH3	
B4	B13	V_{DClink}	P14.9	(DAC1.OUT)	VADC0.G1CH1		VADC0.G3CH3
B5	B12	V_{BEMF_U} / I_U (1)	P14.0	VADC0.G0CH0			
B6	B11	V_{BEMF_V} / I_V (1)	P14.2	VADC0.G0CH2	VADC0.G1CH2		
B7	B10	V_{BEMF_W} / I_W (1)	P14.4	VADC0.G0CH4		VADC0.G2CH0	
B8	B9	I_{DClink} (1)	P14.14		VADC0.G1CH6		G1ORC6
B9	B8	U0_L	P0.2	CCU80.OUT01		HROUT01	
B10	B7	U0_H	P0.5	CCU80.OUT00		HROUT00	
B11	B6	V0_L	P0.1 & P0.3	CCU80.OUT11	CCU80.OUT20	HROUT20	
B12	B5	V0_H	P0.4 & P2.14	CCU80.OUT10	CCU80.OUT21	HROUT21	
B13	B4	W0_L	P0.11 & P0.9	CCU80.OUT31	CCU80.OUT12	HROUT31	
B14	B3	W0_H	P0.6 & P2.6	CCU80.OUT30	CCU80.OUT13	HROUT30	
B15	B2	CTRAP0	P0.7	CCU80.IN0A, IN1A,IN2A, IN3A			
B16	B1	ENPOW0	P0.12	GPIO	CCU40.OUT3	ERU0.2B2	

Note: Please note that the numbering of the power boards connector at the drive card is inverse to the numbering at the power board.

Table 6 Use Cases of PWM Signals

X302 (MAB32B2)	Function	Port	Peripheral
2-Level Inverter with CCU80			
B9	U0_L	P0.2	CCU80.OUT01
B10	U0_H	P0.5	CCU80.OUT00
B11	V0_L	P0.1	CCU80.OUT11
B12	V0_H	P0.4	CCU80.OUT10
B13	W0_L	P0.11	CCU80.OUT31
B14	W0_H	P0.6	CCU80.OUT30
B15	CTRAP0	P0.7	CCU80.IN0A,IN1A,IN2A,IN3A
B16	ENPOW0	P0.12	GPIO
2-Level Inverter with CCU81			
A9	U1_L	P1.12	CCU81.OUT01
A10	U1_H	P1.15	CCU81.OUT00
A11	V1_L	P1.11	CCU81.OUT11
A12	V1_H	P1.5	CCU81.OUT10
A13	W1_L	P1.10	CCU81.OUT21
A14	W1_H	P1.4	CCU81.OUT20
A15	CTRAP1	P1.2	ERU1.2B0 (PDOUT1 -> CCU81.IN0I,IN1I,IN2I,IN3I)
A16	ENPOW1	P4.1	GPIO
2-Level Inverter with CCU80 (2 slices only)			
B9	U0_L	P0.2	CCU80.OUT01
B10	U0_H	P0.5	CCU80.OUT00
B11	V0_L	P0.1	CCU80.OUT11
B12	V0_H	P0.4	CCU80.OUT10
B13	W0_L	P0.9	CCU80.OUT12
B14	W0_H	P2.6	CCU80.OUT13
B15	CTRAP0	P0.7	CCU80.IN0A,IN1A,IN2A,IN3A
B16	Enable0	P0.12	GPIO
2-Level Inverter with HRPWM			
B9	U0_L	P0.2	HROUT01
B10	U0_H	P0.5	HROUT00
B11	V0_L	P0.3	HROUT20
B12	V0_H	P0.4	HROUT21
B13	W0_L	P0.9	HROUT31
B14	W0_H	P0.6	HROUT30
B15	CTRAP0	P0.7	CCU80.IN0A,IN1A,IN2A,IN3A
B16	Enable0	P0.12	GPIO
3-Level Inverter with CCU80			
A9	U1_L	P0.10	CCU80.OUT02
B9	U0_L	P0.2	CCU80.OUT01
A10	U1_H	P2.7	CCU80.OUT03
B10	U0_H	P0.5	CCU80.OUT00
A11	V1_L	P2.9	CCU80.OUT22
B11	V0_L	P0.3	CCU80.OUT20
A12	V1_H	P1.5	CCU80.OUT23
B12	V0_H	P2.14	CCU80.OUT21
A13	W1_L	P2.8	CCU80.OUT32
B13	W0_L	P0.11	CCU80.OUT31
A14	W1_H	P1.4	CCU80.OUT33
B14	W0_H	P0.6	CCU80.OUT30
B15	CTRAP0	P0.7	CCU80.IN0A,IN1A,IN2A,IN3A
B16	ENPOW0	P0.12	GPIO

3 Production Data

3.1 Schematics

This chapter contains the schematics for the drive card:

- XMC4400 MCU, Power Supply, Multifeedback Interface
- Hall Sensor and Encoder Interfaces, Power Board Connector
- Isolated On-board Debugger and CAN Interface

The board has been designed with Eagle. The full PCB design data of this board can also be downloaded from www.infineon.com/xmc-dev.

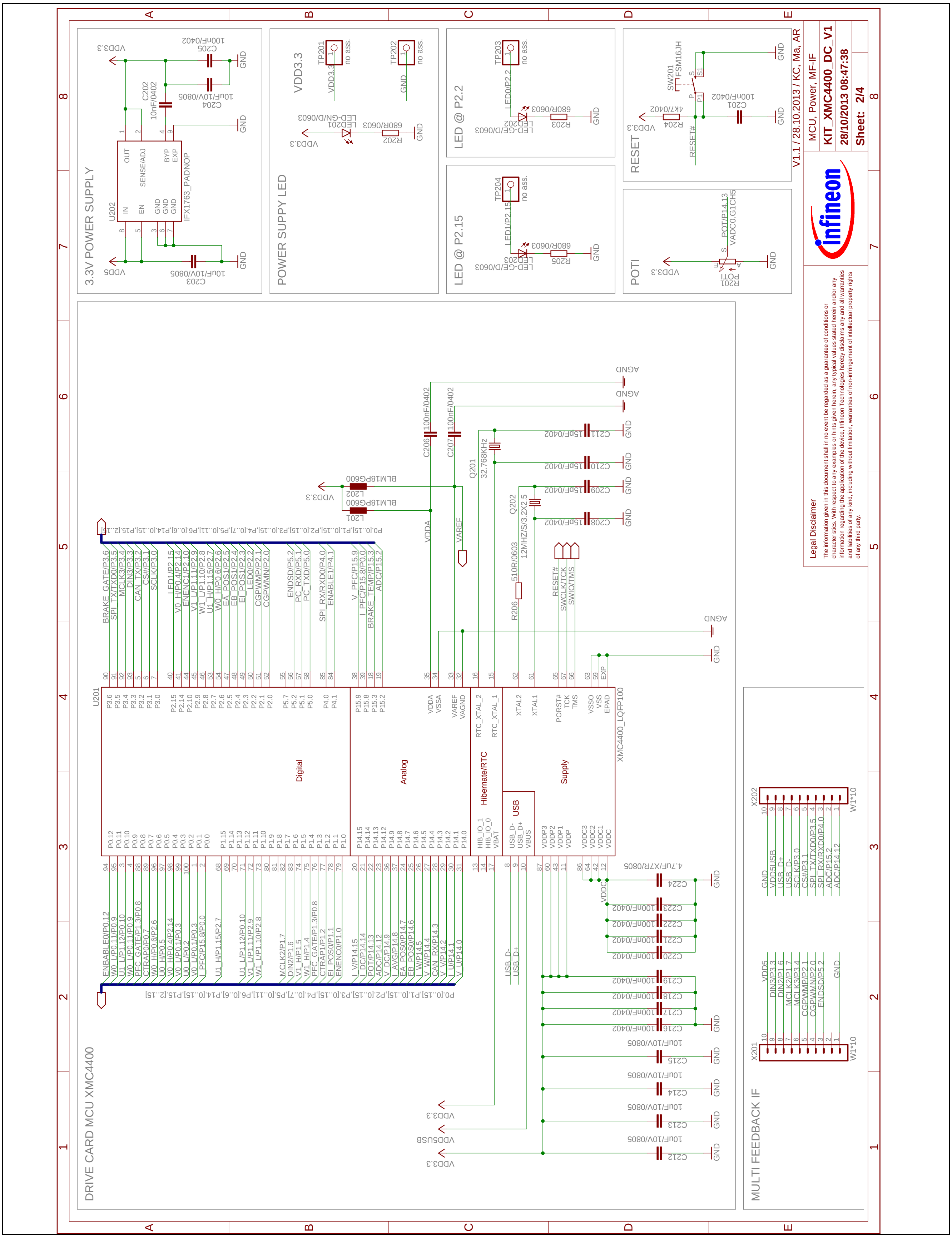


Figure 18 XMC4400 MCU, Power Supply, Multifeedback Interface

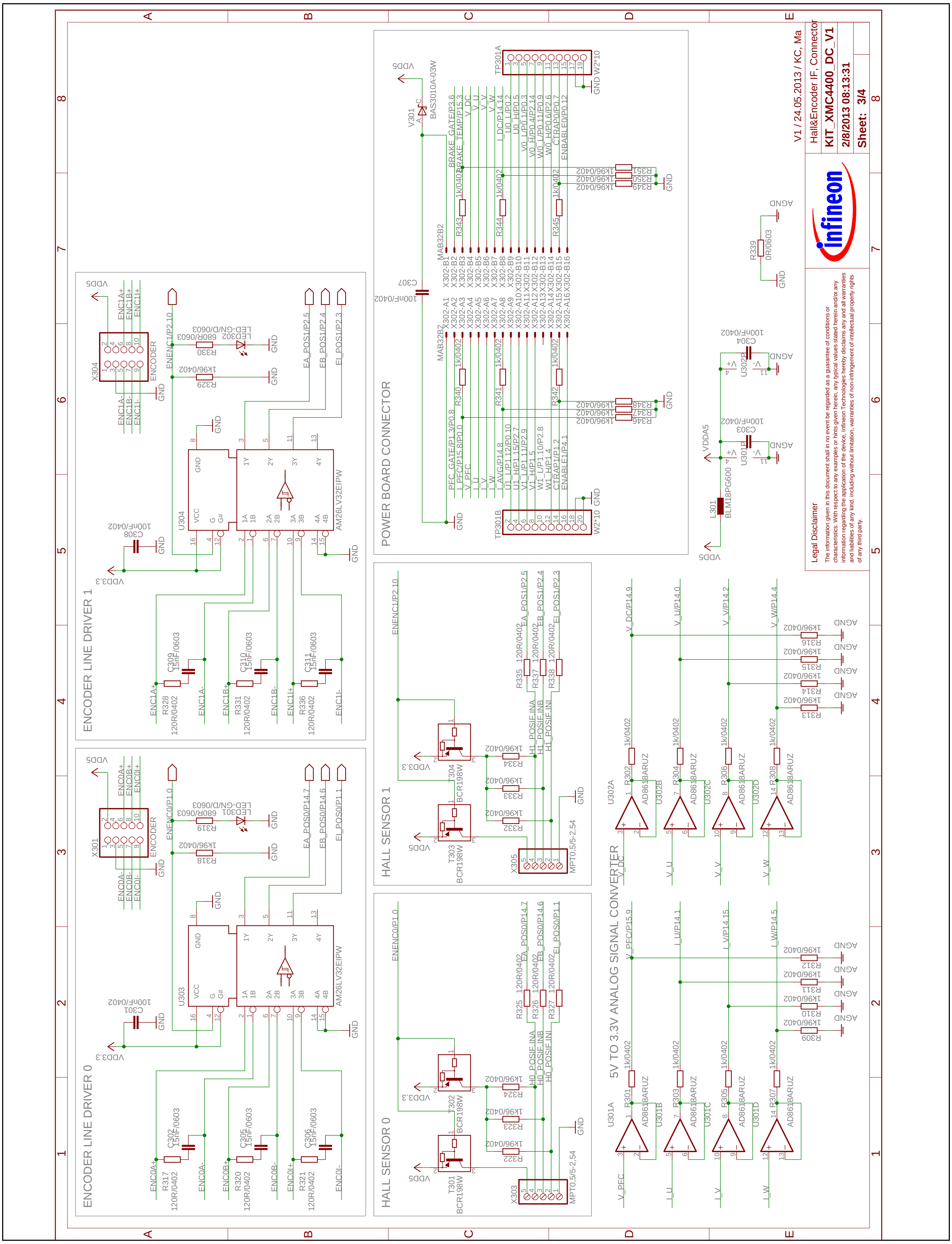


Figure 19 Hall Sensor and Encoder Interfaces, Power Board Connector

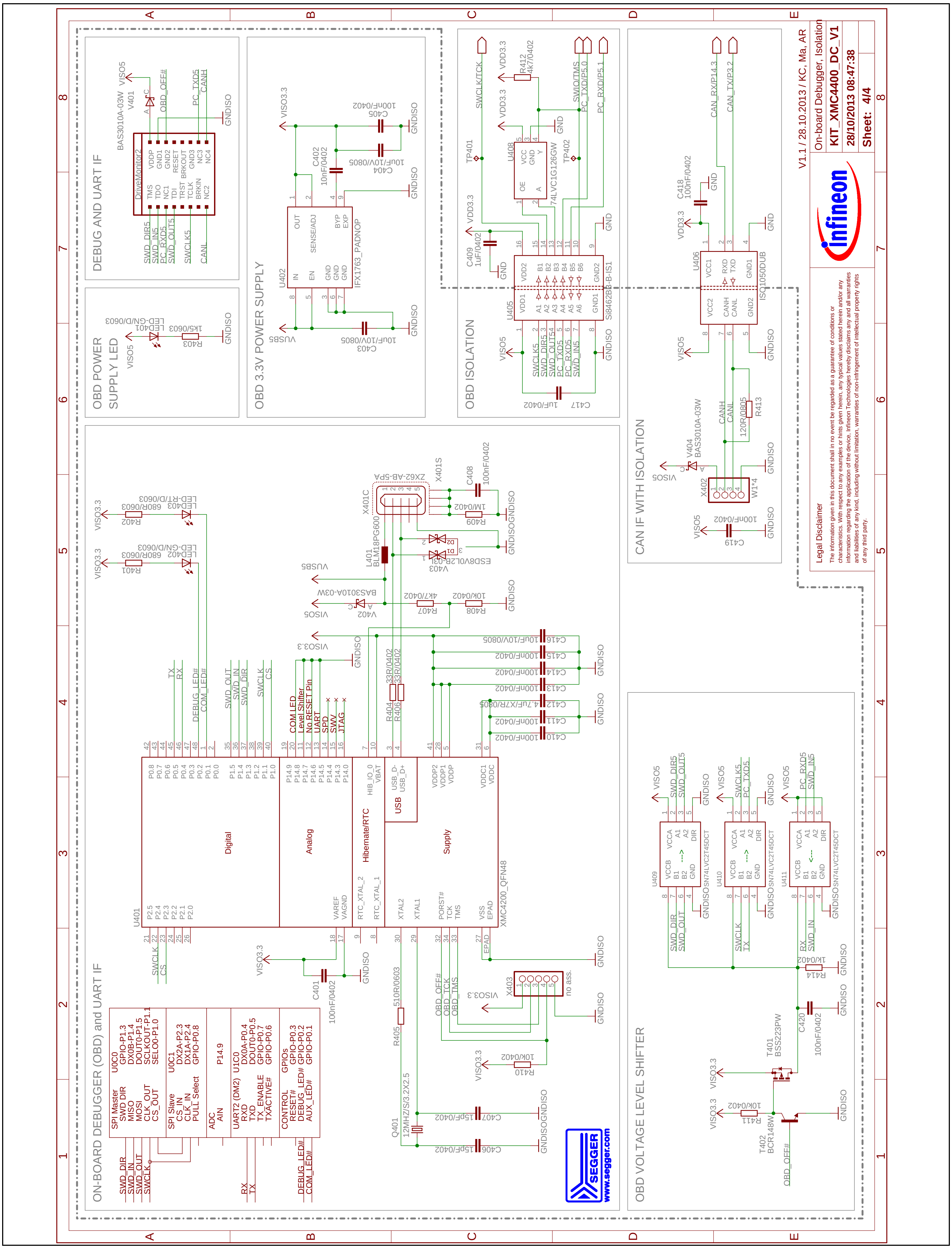


Figure 20 Isolated On-board Debugger and CAN Interface

3.2 Component Placement

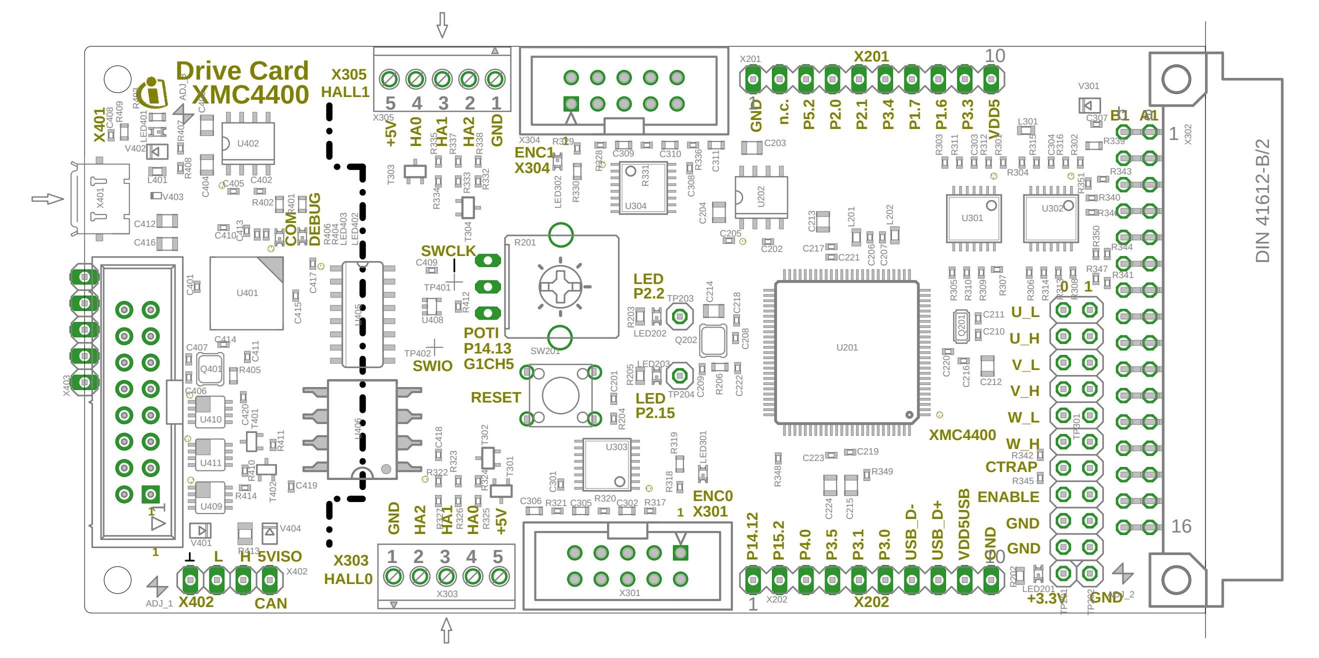


Figure 21 Component Placement

3.3 Bill of Material (BOM)

Table 7 BOM of KIT_XMC4400_DC_V1 Board

Pos. No.	Qty	Value	Device	Reference Des.
1	1	10k	potentiometer	R201
2	7	680R/0603	RESISTOR 0603	R202, R203, R205, R319, R330, R401, R402
3	3	4k7/0402	RESISTOR 0402	R204, R407, R412
4	2	510R/0603	RESISTOR 0603	R206, R405
5	15	1k/0402	RESISTOR 0402	R301, R302, R303, R304, R305, R306, R307, R308, R340, R341, R342, R343, R344, R345, R414
6	22	1k96/0402	RESISTOR 0402	R309, R310, R311, R312, R313, R314, R315, R316, R318, R322, R323, R324, R329, R332, R333, R334, R346, R347, R348, R349, R350, R351
7	12	120R/0402	RESISTOR 0402	R317, R320, R321, R325, R326, R327, R328, R331, R335, R336, R337, R338
8	1	0R/0603	RESISTOR 0603	R339
9	1	1k5/0603	RESISTOR 0603	R403
10	2	33R/0402	RESISTOR 0402	R404, R406
11	3	10k/0402	RESISTOR 0402	R408, R410, R411
12	1	1M/0402	RESISTOR 0603	R409
13	1	120R/0805	RESISTOR 0805	R413
14	28	100nF/0402	CAPACITOR 0402	C201, C205, C206, C207, C216, C217, C218, C219, C220, C221, C222, C223, C301, C303, C304, C307, C308, C401, C405, C408, C410, C411, C413, C414, C415, C418, C419, C420
15	2	10nF/0402	CAPACITOR 0402	C202, C402
16	2	4.7u/X7R/0805	CAPACITOR 0805K	C224, C412
17	9	10uF/10V/0805	CAPACITOR 0805K	C203, C204, C212, C213, C214, C215, C403, C404, C416
18	6	15pF/0402	CAPACITOR 0402	C208, C209, C210, C211, C406, C407
19	6	15nF/0603	CAPACITOR 0603	C302, C305, C306, C309, C310, C311
20	2	1uF/0402	CAPACITOR 0402	C409, C417
21	4	BLM18PG600	FERRIT BEAD 0603	L201, L202, L301, L401
22	5	LED-GN/D/0603	LEDCHIPLED 0603	LED201, LED301, LED302, LED401, LED402
23	2	LED-GE/D/0603	LEDCHIPLED 0603	LED202, LED203
24	1	LED-RT/D/0603	LEDCHIPLED 0603	LED403
25	1	32.768KHz	CRYSTAL	Q201
26	2	12MHZ/S/3.2X2.5	CRYSTAL	Q202, Q401
27	1	FSM16JH	SWITCH	SW201
28	4	BCR198W	TRANSISTOR	T301, T302, T303, T304
29	1	BSS223PW	TRANSISTOR	T401
30	1	BCR148W	TRANSISTOR	T402
31	1	XMC4400_LQFP100	INFINEON MCU	U201

32	2	IFX1763	INFINEON LDO	U202, U402
33	2	AD8618ARUZ	OPAMP	U301, U302
34	2	AM26LV32EIPW	ENCODER IC	U303, U304
35	1	XMC4200_QFN48	INFINEON MCU	U401
36	1	Si8462BB-B-IS1	ISOLATED DIGITAL	U405
37	1	ISO1050DUB	ISOLATED CAN	U406
38	1	74LVC1G126GW	LOGIC	U408
39	3	SN74LVC2T45DCT	LOGIC	U409, U410, U411
40	4	BAS3010A-03W	SCHOTTKY	V301, V401, V402, V404
41	1	ESD8V0L2B-03L	ESD DIODE	V403
42	2	W1*10	PINHEADER	X201, X202
43	2	CONP_2X05	CONNECTOR	X301, X304
44	1	MAB32B2	CONNECTOR	X302
45	2	MPT0,5/5-2,54	CONNECTOR	X303, X305
46	1	ZX62-AB-5PA	MICRO-USB	X401
47	1	W1*4	CONNECTOR	X402
48	1	W2*8	CONNECTOR	X404

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