

XMC4000/XMC1000

32-bit Microcontroller Series for Industrial Applications

XMC Digital Power Explorer Power Board User Manual

UG_201511_PL30_001

Board User Manual

Scope and purpose

This document describes the features and hardware details of XMC Digital Power Explorer, designed to provide an evaluation platform for digital control applications with Infineon XMC ARM® Cortex™ microcontrollers. This board is part of Infineon's Digital Power Control Application Kit.

Applicable Products

- XMC4200 Microcontroller
- XMC1300 Microcontroller
- XMC Digital Power Explorer Kit
- DAVE™

References (optional, may be shifted to Appendix)

Infineon: DAVE™, <http://www.infineon.com/DAVE>

Infineon: XMC Family, <http://www.infineon.com/XMC>

XMC Digital Power Explorer, http://www.infineon.com/xmc_dp_exp

Example codes for this board, www.infineon.com/DAVE

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1 Overview

The XMC Digital Power Explorer is an evaluation board with the goal to help engineers in the learning and testing of digital power control applications. The board features a synchronous buck converter that can be controlled digitally with XMC microcontrollers. Synchronous buck converter is one of the most well known power topologies and many of the concepts of it can be ported to other power stages, what makes the synchronous buck converter a great platform for leaning and experimenting.

Different control cards can be plugged in to allow the user to select between different price/performance combinations available in XMC family of microcontrollers.

Both voltage control and peak current control with slope compensation can be implemented in this board. This board includes loads on board for easy test of step response. Frequency behaviour can be analyzed with the help of a network analyser. XMC Digital Power Explorer is ready for signal injection from network analyser equipment to study the frequency response of the buck stage.

This board is built with best in class Infineon Technologies components and with the collaboration of Biricha Digital and Würth Elektronik .

1.1 Key features

The XMC Digital Power Explorer power board is equipped with the following features:

- Synchronous buck converter capable of:
 - Synchronous and non-synchronous buck converter modes
 - Voltage and peak current control methods
 - 2 channel bucks with 1 XMC. Connecting a second XMC Digital Power Explorer in master-slave configuration (see section 2.3)
 - 3 on board loads for testing step response with option to connect external loads -i.e. electronic loads- for further advanced testing.
 - Bode diagram measurement ready - requires network analyzer
 - Dual channel serial communication including PMBus™ (I2C)communication
- Control card connector for plugging in:
 - Infineon XMC4200 Digital Power Control Card with XMC4200 (ARM® Cortex™-M4F-based) Microcontroller, 256 kByte on-chip Flash, LQFP64
 - Infineon XMC1300 Digital Power Control Card with XMC1300 (ARM® Cortex™-M0-based) Microcontroller, up to 200 kByte on-chip Flash, TSSOP38
- Single package high side and low side MOSFET
- Plenty of test points for learning all details of the buck converter
- General purpose switch for user interaction or control

1.2 Block diagram

Figure 1 shows the functional block diagram of the XMC Digital Power Explorer. For more information about the power supply domains please refer to chapter 0.

The buck converter board is comprised of the following building blocks:

Overview

- 1 XMC Digital Power Control Card Connector compatible with XMC4200 and XMC1300 control cards. XMC Digital Power Explorer includes 2 PCB openings to the sides of the control card connector. This hinders wrong connection of the control card.
- Power adapter input jack to plug in 12 V DC adapter. Includes switch to interrupt the supply
- PMBus™ and UART communication options. Pull up resistors included on board for I2C communication support. Pulls up are supplied from XMC Digital Control Card Connector side
- 3 switchable loads (45%, 45%, 10%). Each is signaled with an LED→LED ON means load is active.
- Voltage measurements - ADC: Vout, Vin through resistive voltage dividers
- Current measurements - Comparators: inductor current through current transformer. Options for blanking (CCU) and slope compensation by HW components using provided jumper (SV5). For more details on current sensing consult section 2.5.
- 2PWM complementary signals – CCUx - to high and low side switches
- Master-Slave connectors for controlling a second XMC Digital Power Explorer with a single XMC Digital Power Control Card

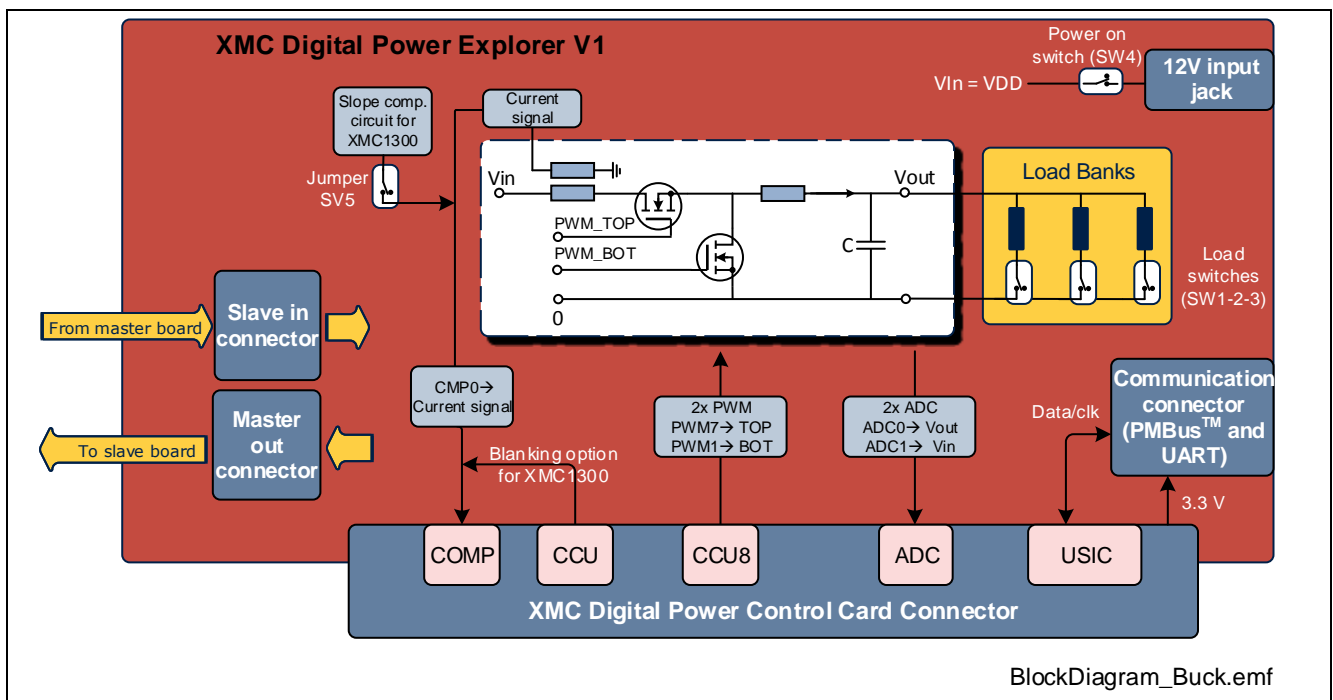


Figure 1 Block Diagram of XMC Digital Power Explorer

2 Hardware Description

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

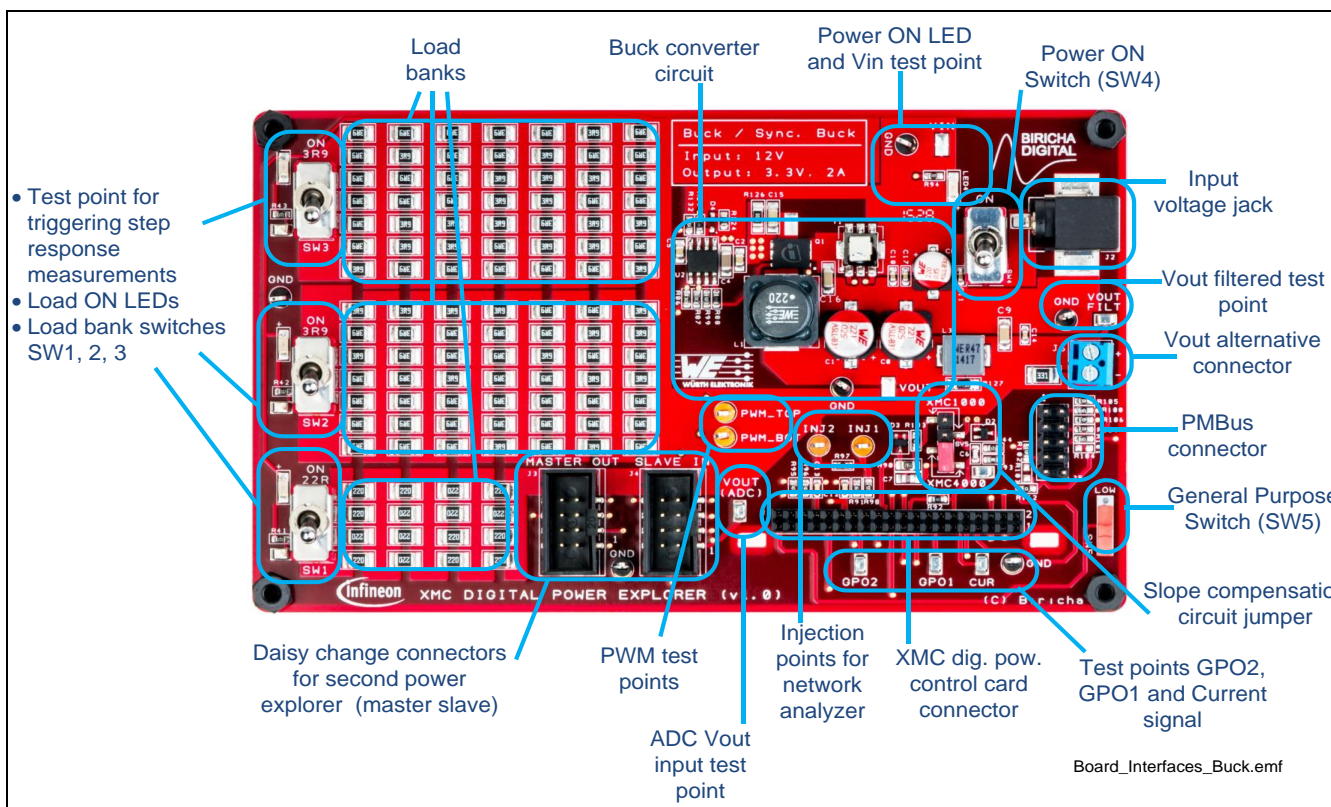


Figure 2 XMC Digital Power Explorer hardware description

2.1 Buck converter circuit description

XMC Digital Power Explorer buck converter is targeted for low voltage. Specification is shown in Table 1. The schematic view of the buck converter stage is shown in Figure 3. The target output voltage is 3.3V. Nevertheless, as a buck converter, any voltages from 0V to V_{in} are theoretically possible depending on the driving of the MOSFETs –duty cycle.

The inductor value ensures continuous conduction mode (CCM) of the buck converter as far as any of SW3 or SW2 load switches are in the “ON” position. In other words, DCM operation occurs only when SW1 load switch is activated assuming 200 kHz switching frequency.

Note: Depending on the buck converter configuration, for example target output voltage or load connected, the board might become hot. Read carefully the disclaimer.

Table 1 Synchronous buck converter specification

Specification	Name	Value
Input voltage	V_{in}	12V DC
Output voltage	V_{out}	3.3V DC (depending on SW)
Maximum output current	$I_{out,max}$	2 A
On board load values	-	3.9Ω (SW3, SW2)→45% load 22Ω (SW1)→ 10% load

Hardware Description

Specification	Name	Value
Main inductor	L1	22uH
Output capacitor	C0 C1	200uF 200uF → 400uF
Gate driver high and low side	U2	IRS2011SPBF (International Rectifier)
Dual MOSFET (high and low side)	Q1	BSC0924NDI (Infineon Technologies)

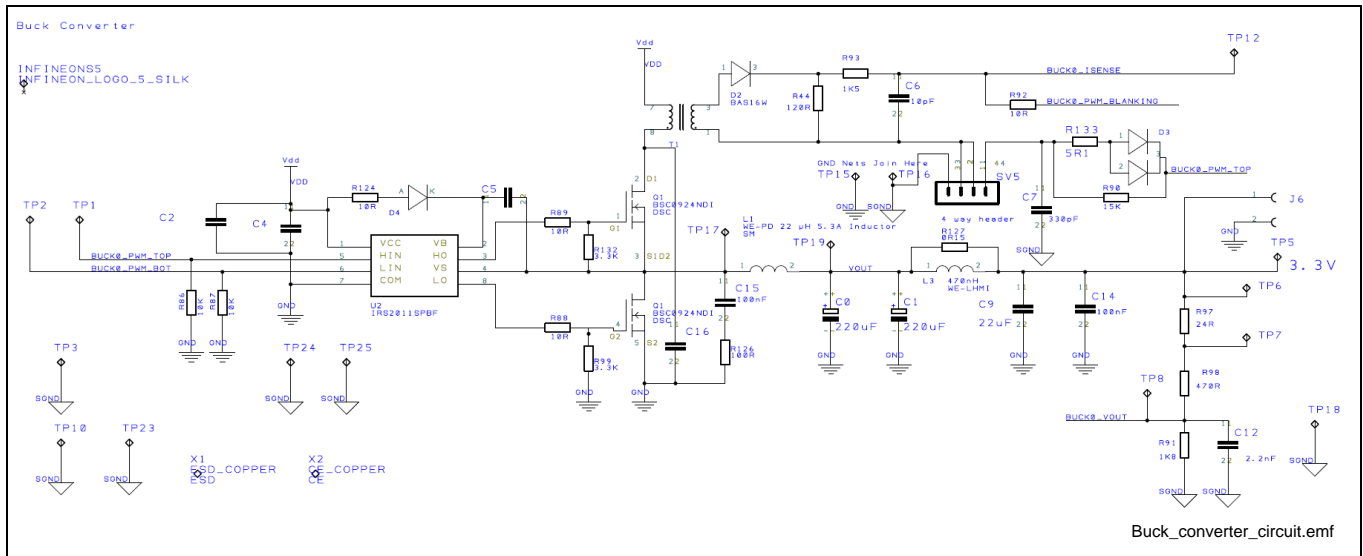


Figure 3 Synchronous buck converter circuit

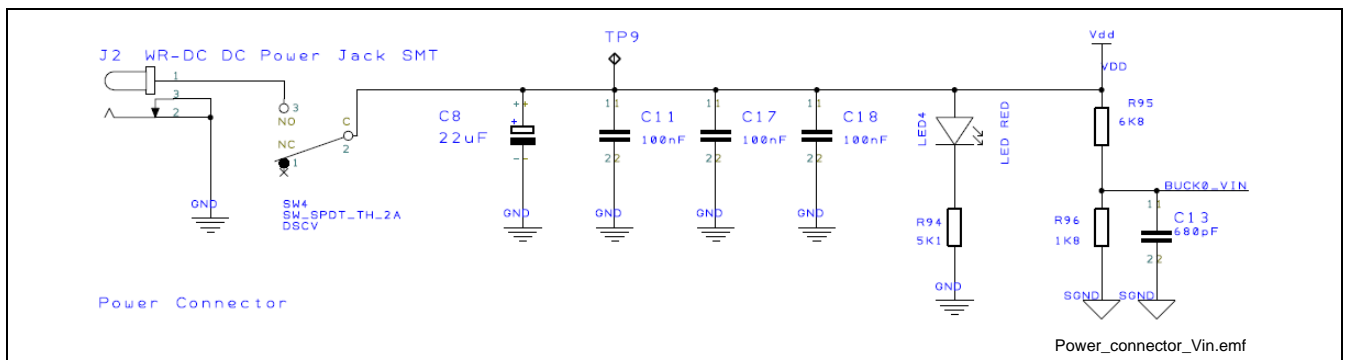


Figure 4 Synchronous buck converter power connector an Vin detail

Gate driver IC integrates the high side and low side gate driver and requires external bootstrap capacitor and diode.

The MOSFET selection is a dual MOSFET in PG-TISON-8 (SuperSO8) package from OPTIMOS™ Infineon’s family. Main figure of merits are shown in Table 2. The board is prepared as well to be operated at different PWM frequencies. However, example codes are typically set up for PWM frequencies between 100 kHz and 300 kHz.

Table 2 Dual MOSFET - BSC0924NDI -figure of merits

Specification	Name	Value Q1 (high side)	Value Q2 (low side)
Drain to source max voltage	V_{DS}	30V	30V

Hardware Description

Specification	Name	Value Q1 (high side)	Value Q2 (low side)
Resistance drain to source at $V_{GS} = 10V$	$R_{DS(on), max}$	5m Ω	3.7m Ω
Resistance drain to source at $V_{GS} = 4.5V$	$R_{DS(on), max}$	7m Ω	5.2m Ω
Max drain current	I_D	40A	40A

The voltage sensing in both input voltage and output voltage, is done with a resistor ladder (voltage divider). On the current side, a current transformer is utilized and provides information during the on time of the buck converter for peak current control mode. Sensing gains are summarized in Table 3. Those values are necessary for configuring the SW controlling the power stage.

More detailed information on current sensing can be found in section 2.5.

Table 3 Analog sensing gains

Gain	Value	Formula
Vout gain	0,78466	$(R91) / (R91+(R97+R98))$
Vin gain	0,20930	$R96/(R96+R95)$
Current sensing gain	0.96 V/A	1:125 (transformer ratio) R44=120ohm

2.2 Board power supply

The XMC Digital Power Explorer board is designed to be powered from a 12 V DC power supply supplying a current of 2A. The input jack is shown in Figure 2. Sw4 switch enables the supply of the board after plugging the power adapter. To indicate the status, one indicating LED –LED4- is provided on board (see Figure 2). The LED will be “ON” when the corresponding power rail is powered.

The 12 V from VDD power rail are supplied to the XMC Digital Power Control Card. The control card internally converts that into 3.3 V to supply the MCU and other components in the control card. At the same time, the control card provides 3.3 V to XMC Digital Power Explorer board to supply the communication pin header (PMBus™ connector).

Additionally, the buck converter is designed to provide 3.3 V up to 2A to the Vout connector when the buck converter is running correctly.

Figure 5 shows details of the power supply concept of the control card. More detailed circuitry can be found in the section 3.1.

Hardware Description

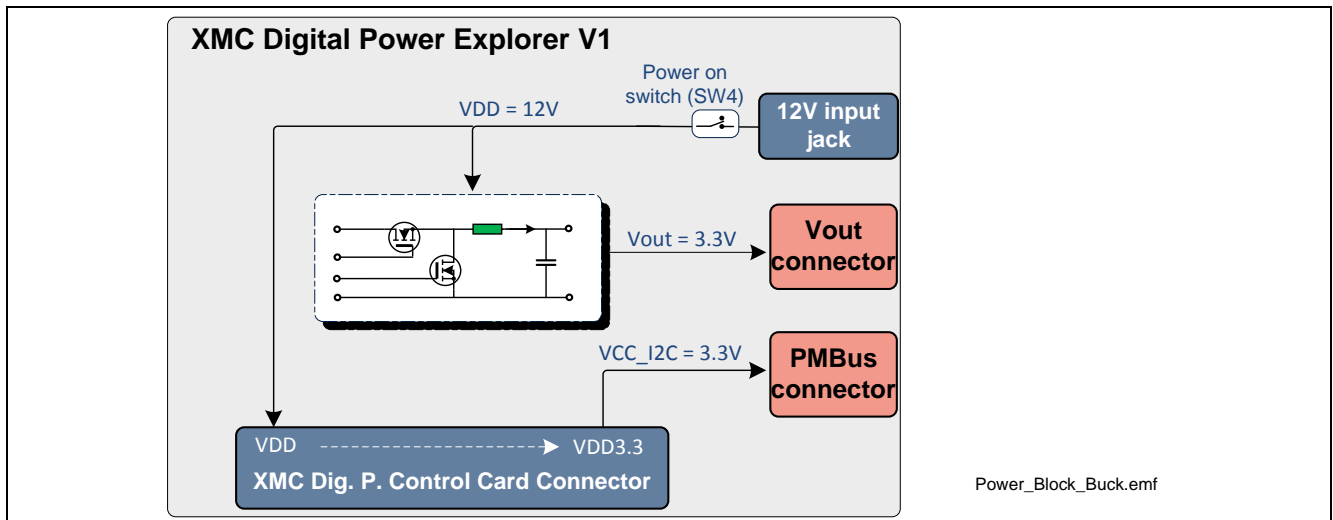


Figure 5 Block Diagram of Power Supply Concept

2.3 Master and slave configuration

XMC Digital Power Explorer can be chained to a second XMC Digital Power Explorer board to complete a master slave connection that can be controlled with a single XMC control card. To do that, connect “MASTER_OUT” signals from the board where the XMC control card is plugged, into the “SLVE_IN” connector of the slave board. This is shown in Figure 6.

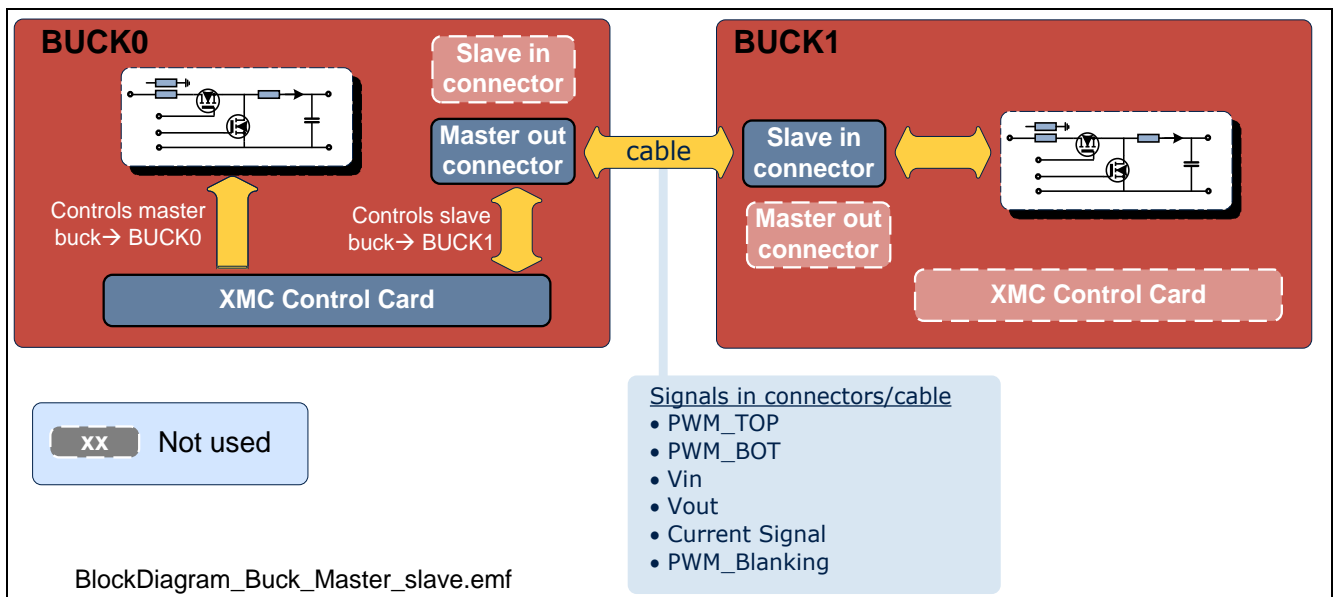


Figure 6 Diagram for a master slave connection. Control 2 Buck converters with a single XMC

In a master-slave configuration, both bucks can be controlled in voltage mode, peak current mode or a mixture of both. This is dependent only in the SW configuration of XMC in the control card side.

If communication is required –i.e. PMBus™- the connector in the master board must be used for that purpose, as there are no signals transferred from the slave board to the master for communication and the salvaged communication connector is not powered on.

Hardware Description

2.4 PMBus™ and UART Interface

XMC Digital Power Explorer includes a connector for communicating the buck converter with an external interface. The connector is supplied with 3.3V from the XMC control card connector as can be seen in Figure 7. There are 2 communication options:

- PMBus™ through I2C interface. Pull up resistors are provided on board (R109, R105)
- General purpose serial communication. In case of I2C is required, it is possible to mount resistors R103 and R104 to provide the pull up functionality. Those resistors are not populated in the PCB (DNP)

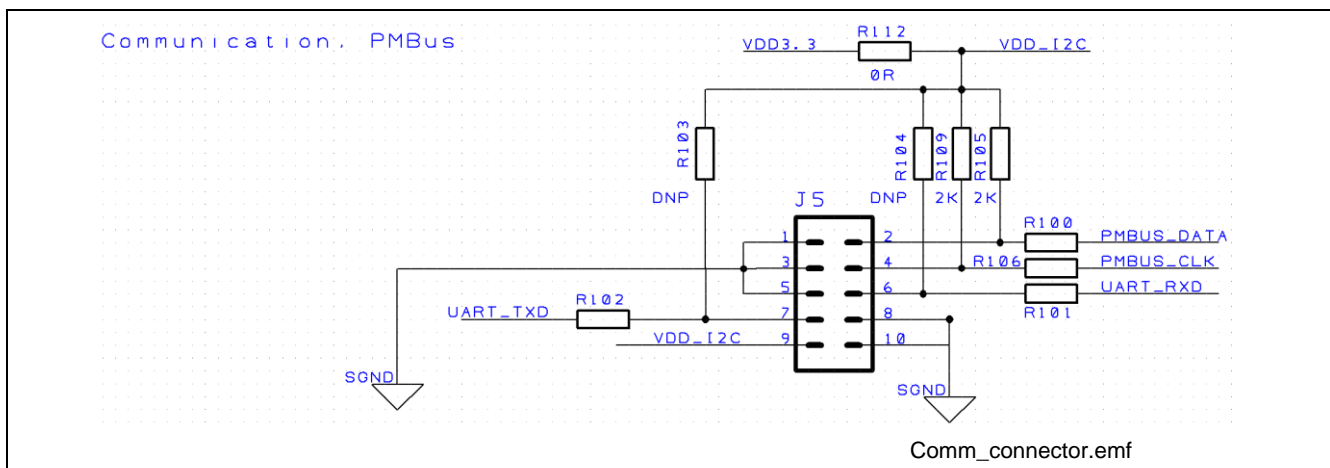


Figure 7 Communication connector schematic detail - (DNP = not populated component)

The communication can be used to send commands to XMC Digital Power Explorer. For example it is possible to modify the Vout target value, or to read the status of the converter.

2.4.1 Test points

Within XMC Digital Power Explorer card there are a total of 22 test points that are listed in Table 4. This will help the user to inspect different points of interest and learn how the buck converter behaves in detail.

Table 4 Test points description

Test point name	Test point number	Description	Type of test point
PWM_TOP	TP1	High side MOSFET PWM signal	Orange
PWM_BOT	TP2	Low side MOSFET PWM signal	Orange
INJ1/INJ2	TP7/TP6	Injection points for network analyzers	Orange
GND	TP3,TP10, TP15, TP16 TP18, TP23, TP24, TP25	8 GND test points for oscilloscope probe grounding	Black/SMD
VIN	TP9	Input voltage	Not mounted SMD
VOUT	TP19	Output voltage	Not mounted SMD
VOUT_FILT	TP5	Output voltage after additional filtering	SMD
VOUT (ADC)	TP8	Vout signal delivered to XMC ADC	SMD

Hardware Description

Test point name	Test point number	Description	Type of test point
SW1-SW3	TP20, TP21, TP22	Used for triggering oscilloscope while testing step response of buck	SMD
Switching node	TP17	Node between both MOSFETs and buck inductor	Not mounted SMD (positioned next to Q1)
GPO1, GPO2	TP13, TP14	General purpose test points connected to general purpose pins of XMC for signalization (i.e. CPU load)	SMD
CUR	TP12	Current signal out of current transformer (only during ON time) delivered to XMC comparator input	SMD

Additionally to test points, XMC Digital Power Explorer power board includes a general purpose switch –SW5 connected to GP3 in connector (see Figure 2). This can be used by the user to signalize XMC, when to apply a specific action, for example, change the control scheme.

2.5 Current signal conditioning

The current of the buck converter is measured with a current transformer –T1- as shown in Figure 8 , located between Vdd and the buck converter high side transistor. The current transformer has a turn ratio of 1:125. The secondary winding signal is half wave rectified –D2- and divided with a 120Ω resistor-R44. This results in a 120/125 gain which means that 1A in the buck converter translate into 0.96V in the MCU pin. Before the signal is delivered to the MCU, an RC filter (R93 and C6) is constructed to reduce high frequency spikes. The -3dB frequency of this filter is slightly above 10MHz. As a consequence, only the current during the PWM ON time is reflected in the signal BUCK0_ISENSE. When Q1 transistor is in OFF state, the inductor current cannot be sensed in T1

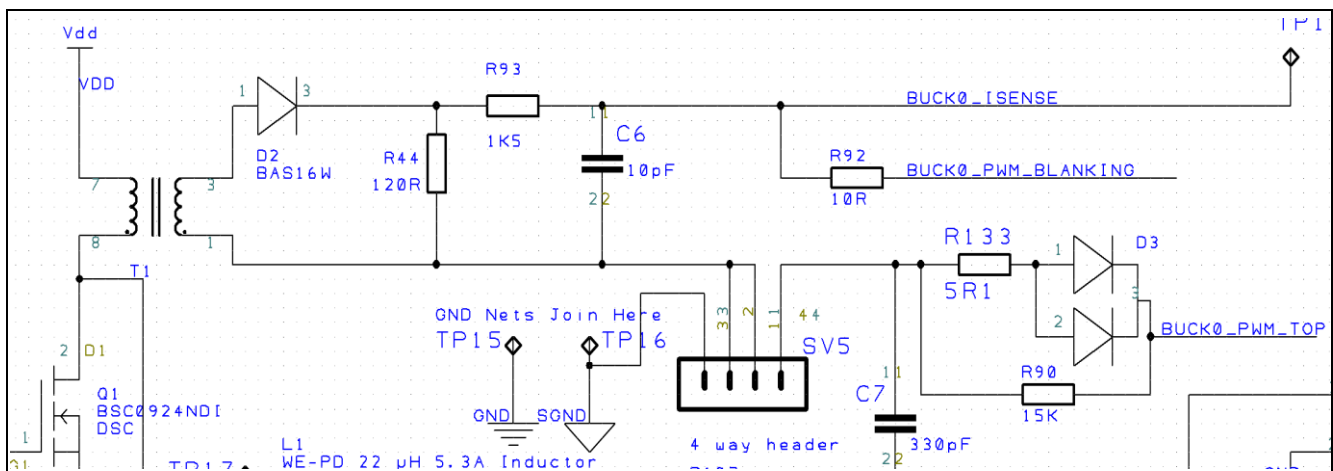


Figure 8 Current sensing circuit

The current signal is then transferred to the XMC control card connector with the name BUCK0_ISENSE. This can be connected to a comparator to detect the peak current of the buck converter. The current signal can as well be suppressed with the help of signal BUCK0_PWM_BLANKING. This signal must be connected to a

Hardware Description

port pin in XMC configured as open drain. A resistor is in series to this signal to limit the current t flowing into XMC port pin.

During the active time of that port pin, the current signal will be forced to GND and therefore not detected in the comparator. This is an implementation of the blanking time that can avoid early switching of the comparator. However this is not always necessary as in most cases RC filter (R93-C6) effect is enough.

2.5.1 Jumper SV5 usage for slope compensation

XMC Digital Power Explorer includes a jumper to select between 2 different ways of generating slope compensation as shown in Figure 9:

- **XMC4000 position:** in this case, GND is connected to pin 1 of the current transformer. This will permit XMC4200 (for example) to implement internally slope compensation. This is done by using Comparator and Slope Generation peripheral (CSG) in XMC4200 microcontroller. This module includes a Comparator and a DAC with automatic slope generation. Therefore there is no need to implement slope compensation in buck converter hardware.
- **XMC1000 position:** in this position, the generated voltage ramp on C7 connects to pin 1 of the current transformer. This will add that ramp voltage to the current signal with the effect that a slope is added. The slope increases while BUCK_PWM_TOP is active and decreases the rest of the time. This is useful for devices like XMC1300 where the comparators do not have an automatic slope generation that can be supplied to the comparator integrated in it.

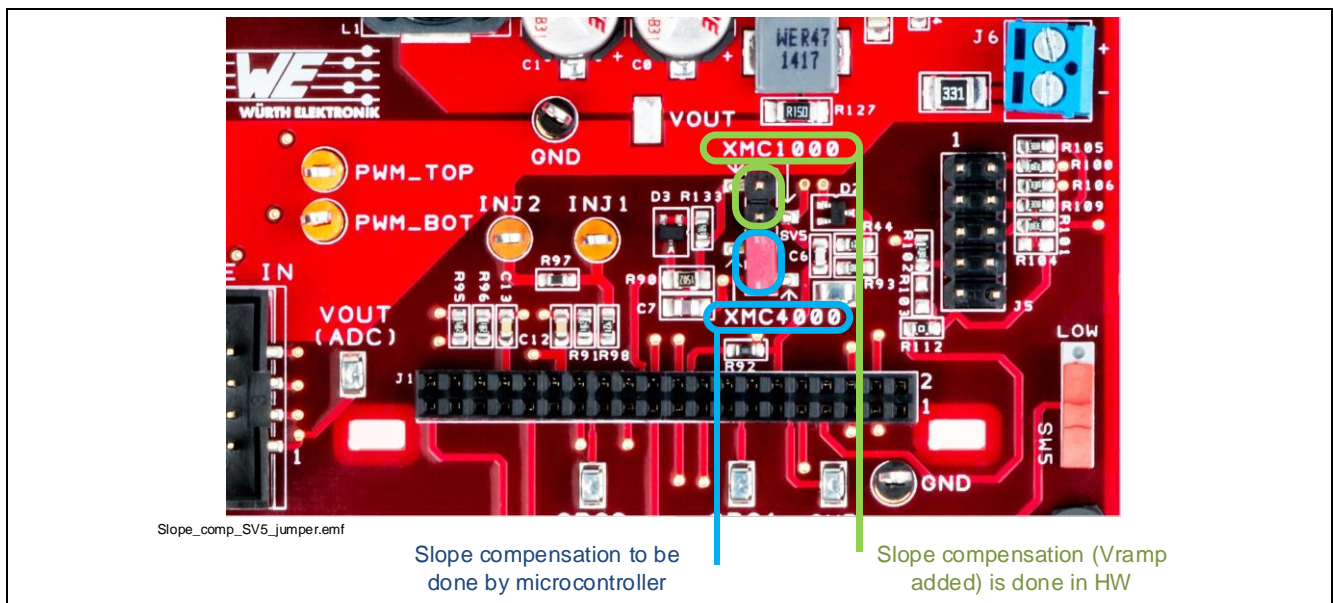


Figure 9 Slope compensation selection jumper (SV5)

Figure 9 depicts a detail schematic view of the 2 different jumper positions and how the signals are routed to build an automatic slope generation. In the blue position-XMC4000-, the microcontroller must take care of the slope compensation, if necessary. This is labeled as XMC4000 because XMC4000 family includes the HRPWM module with its CSG – comparator and slope generation- submodule. This peripheral includes a DAC capable of automatically generate the necessary ramp to compensate the peak current signal

Hardware Description

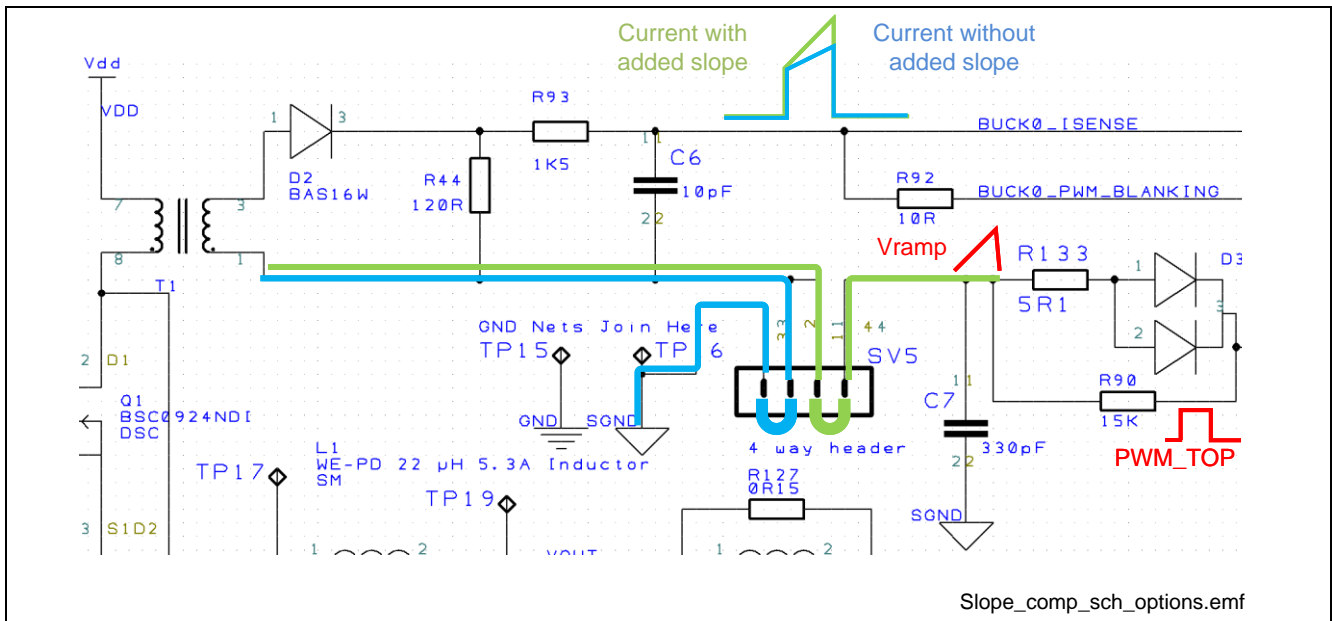


Figure 10 Slope compensation option schematic detail. Depending on the jumper position, a ramp will be added or not to the current signal

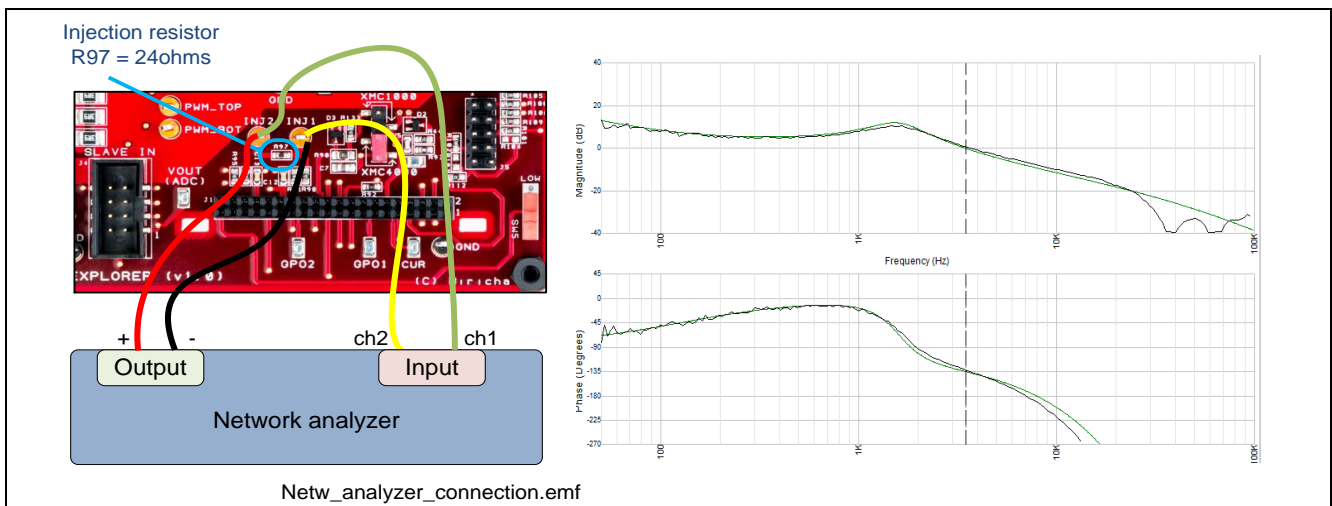
2.6 Connection to network analyzer

Typically, during the design of power supplies, a verification step is to analyze the frequency response of the system. In this way, it is possible to measure gain margin and phase margin and design for a robust control loop.

A network analyzer is responsible to inject a variable frequency signal into a small shunt in the circuit. At the same time, the network analyzer can measure transfer function for each given frequency of the input. In that way it is able to plot the bode diagram of that power supply.

XMC Digital Power Explorer is prepared to be used with network analyzer and includes test points (INJ1/2) as well as a shunt resistor –R97- with a resistance value of 24Ω to help measuring the bode diagram of the power stage.

Figure 11 shows how to set up the connection of XMC Digital Power Explorer to a network analyzer. Red and black signal represents the injected voltage with variable frequency, whereas the yellow and purple lines represent the measurement paths for the analyzers to capture the amplitude of the transfer function.



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Figure 11 Network analyzer connection diagram

2.7 XMC Digital Power Control Card Connector

The XMC Digital Power Explorer includes a control card connector compatible with XMC4200 Digital Power Control Card and with XMC1300 Digital Power Control Card. This connector provides to and receives from the control card, relevant signals for the control, supply or communication of the buck converter. The signals available in the connector are:

- 2 pairs of complementary PWM signals: buck0 (master) and buck1 (slave).
- 4 ADC analog inputs: Vout and Vin for both buck0 and buck1.
- 2 comparator inputs: peak current detection for both buck0 and buck1.
- 2 serial channels
- 4 general purpose pins

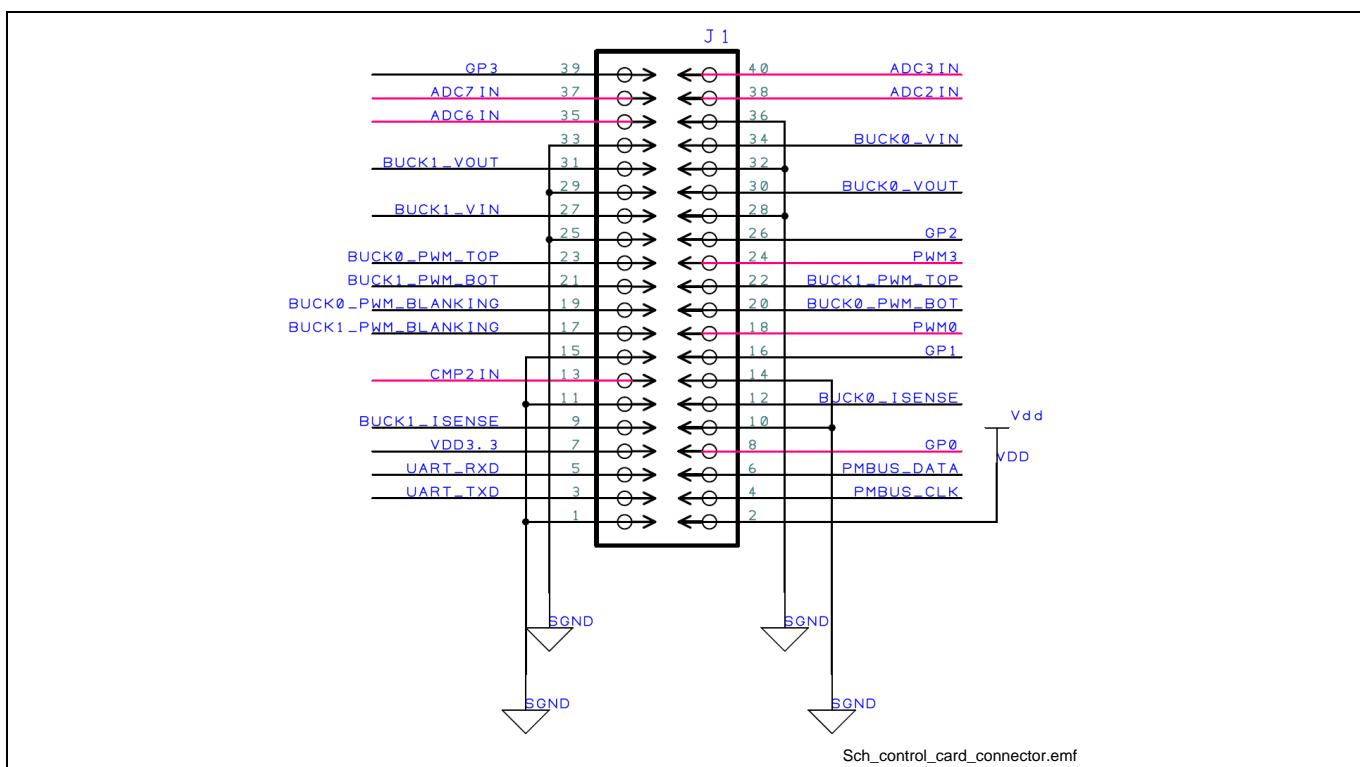


Figure 12 Control card power connector schematic

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

The pin out of the connector is described in detail in Table 5.

Table 5 Power board connector pin out

Pin number	Signal Name	Control card port	Note
1	SGND	-	Digital GND
2	VDD	VDD	12V supply to the control card
3	UART_TXD	USIC2/GP5	Can be used as serial port or user port pin
4	PMBUS_CLK	USIC0	PMBus clock signal (I2C)
5	UART_RXD	USIC3/GP4	Can be used as serial port or user port

Hardware Description

Pin number	Signal Name	Control card port	Note
			pin
6	PMBUS_DATA	USIC1	PMBus data signal (I2C)
7	VDD3.3	VDD3.3	3.3 V output to power board
8	GP0	GP0	User port pin
9	BUCK1_ISENSE	CMP1IN	Current signal from slave buck
10	SGND	GND	
11	SGND	GND	
12	BUCK0_ISENSE	CMP0IN	Current signal of master buck
13	-	CMP2IN	
14	SGND	GND	
15	SGND	GND	
16	GP1	GP1	User port pin
17	BUCK1_PWM_BLANKING	PWM4	Leading edge blanking option for slave buck
18	-	PWM0	
19	BUCK0_PWM_BLANKING	PWM5	Leading edge blanking option for master buck
20	BUCK0_PWM0_BOT	PWM1	Low side PWM (master buck)
21	BUCK1_PWM0_BOT	PWM6	Low side PWM (slave buck)
22	BUCK1_PWM0_TOP	PWM2	High side PWM (slave buck)
23	BUCK0_PWM0_TOP	PWM7	High side PWM (master buck)
24	-	PWM3	
25	SGND	GND	
26	GP2	GP2	User port pin
27	BUCK1_VIN	ADC4OUT	Slave buck input voltage value
28	SGND	GND	
29	SGND	GND	
30	BUCK0_VOUT	ADC0OUT	Master buck output voltage value
31	BUCK1_VOUT	ADC5OUT	Slave buck output voltage value
32	SGND	GND	
33	SGND	GND	
34	BUCK0_VIN	ADC1OUT	Master buck input voltage value
35	-	ADC6OUT	
36	SGND	GND	
37	-	ADC7OUT	
38	-	ADC2OUT	
39	GP3	GP3	User port pin
40	-	ADC3OUT	

3 Production Data

3.1 Schematics

This chapter contains the schematics of XMC Digital Power Explorer
 The board has been designed with Design Spark (RS Online). The full PCB design data of this board can also be downloaded from www.infineon.com/xmc-dev.

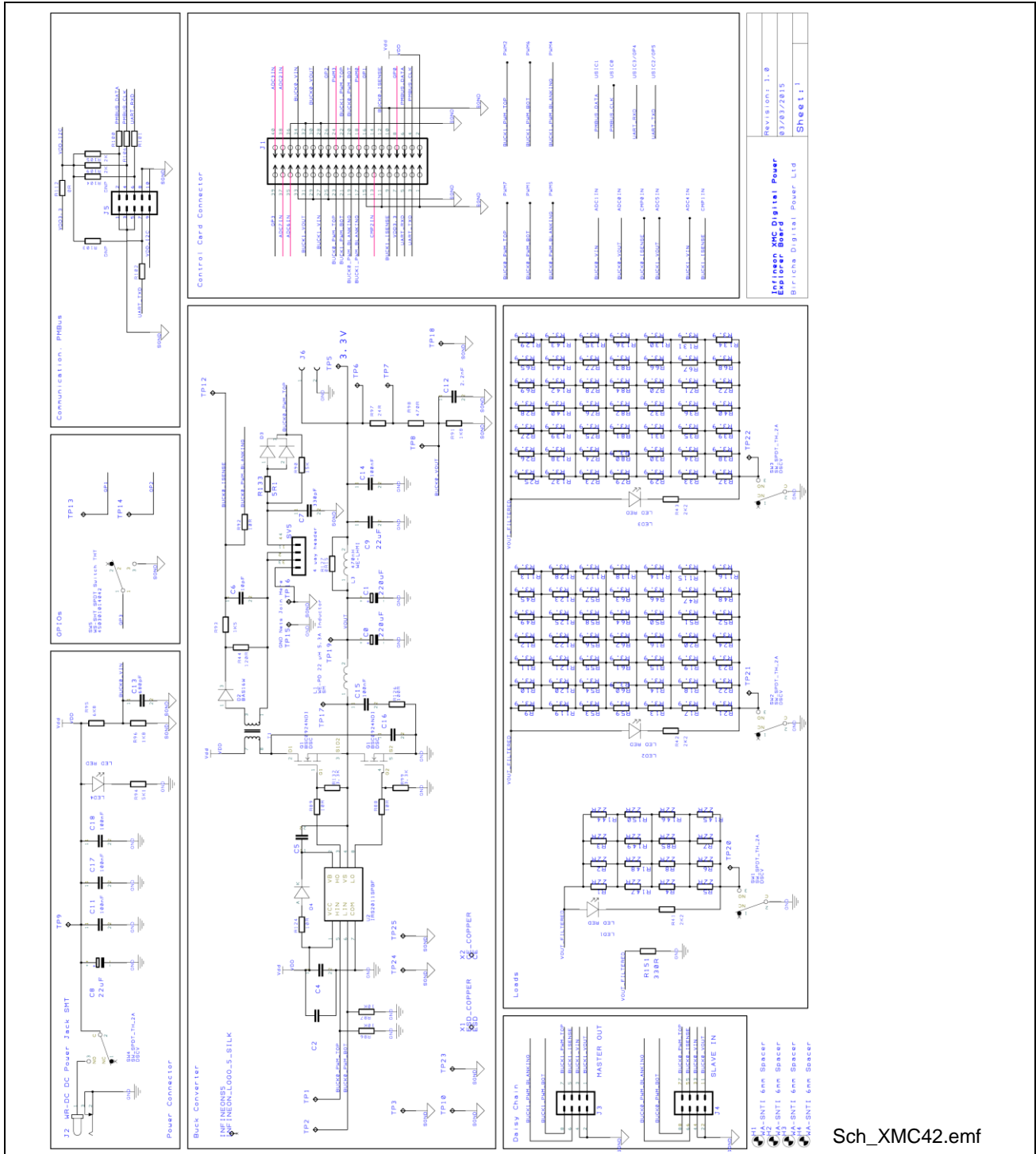


Figure 13 Schematic of XMC Digital Power Explorer

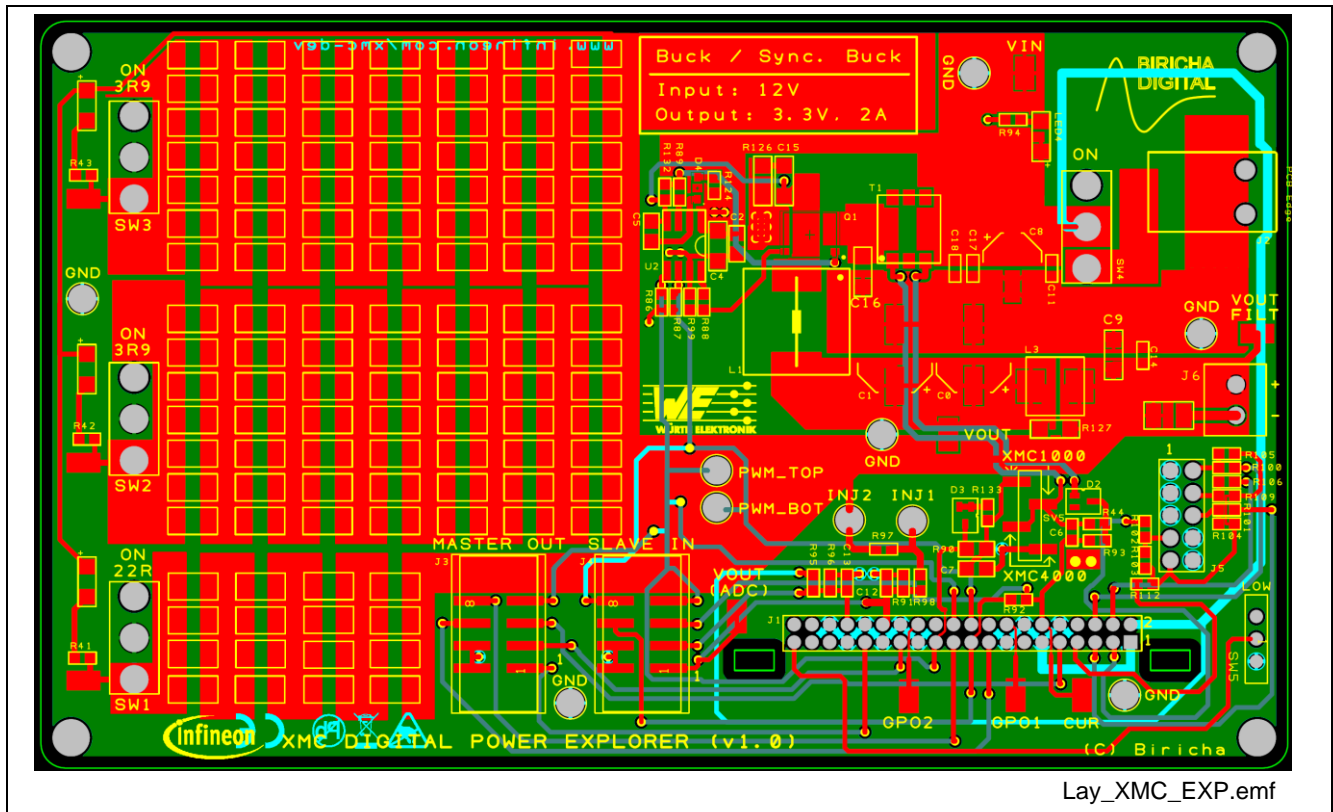


Figure 14 Layout top view of XMC Digital Power Explorer

3.2 Component Placement

In Figure 15 the placement of components is shown in a layout view of the top layer of XMC Digital Power Explorer

Production Data

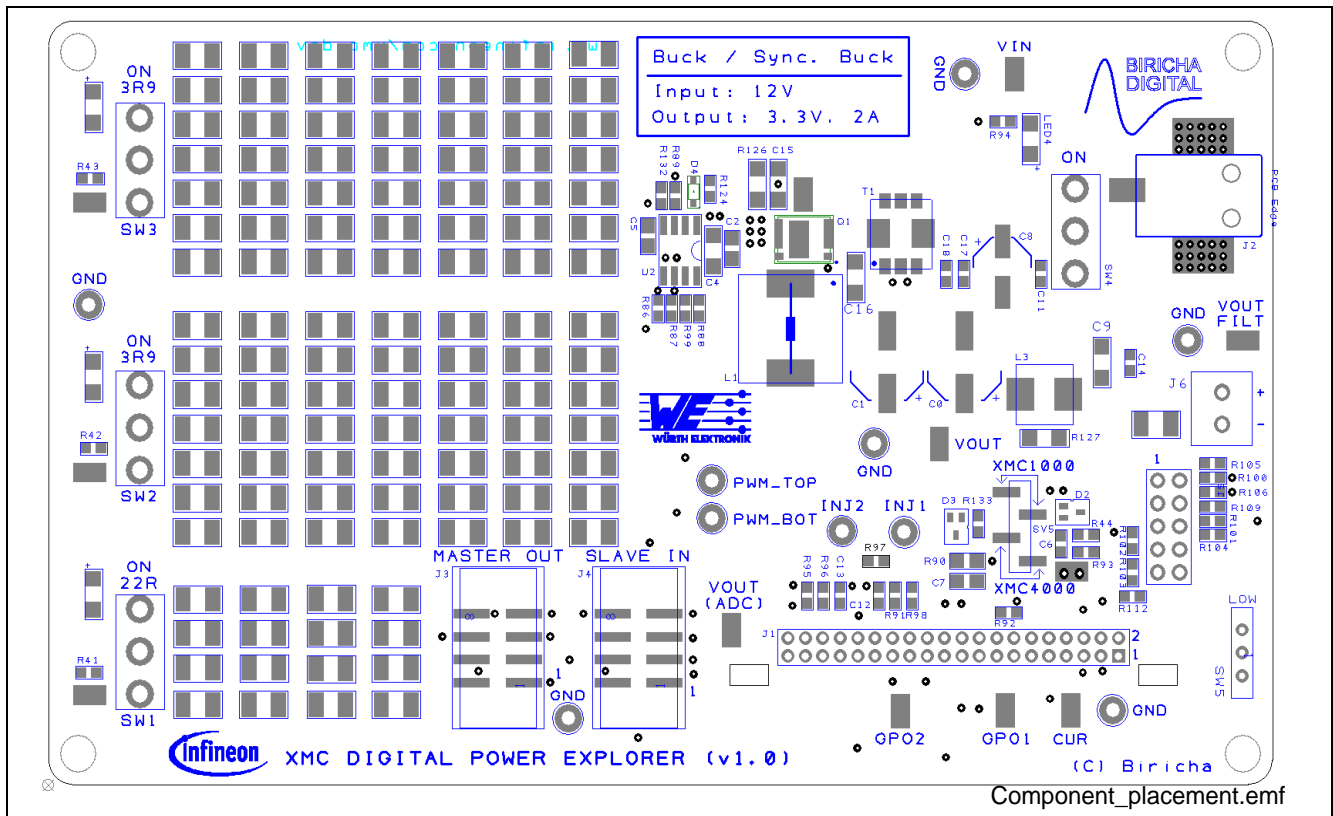


Figure 15 Layout top level view of XMC Digital Power Explorer

3.3 Bill Material (BOM)

This board has been done in collaboration with Würth Elektronik. In Figure 16, the different components from Infineon and Würth Elektronik are highlighted. In Table 6 a complete bill of material is given.

Production Data

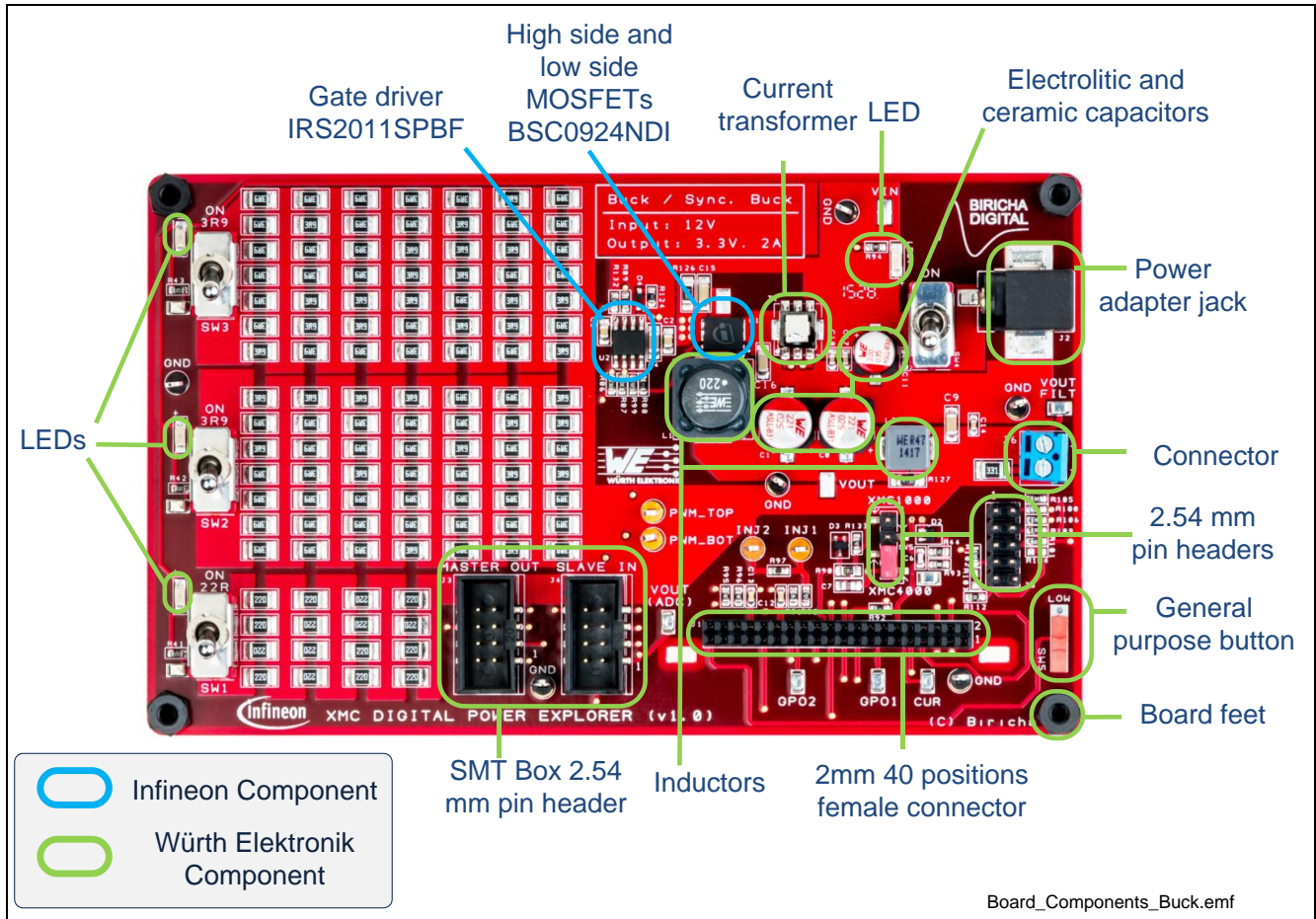


Figure 16 Components from Infineon and Würth Elektronik

Table 6 Bill of Material List

No.	Device / Description	Quantity	Position
1	SW_SPDT_TH_2A	1	SW1, SW2, SW3, SW4
2	Test Pin SM	9	TP5, TP8, TP12, TP13, TP14, TP16, TP20, TP21, TP22
3	BAS16W	1	D2
4	BAT54-05W	1	D3
5	BAS30	1	D4
6	BSC0924NDI	1	Q1
7	IRS2011SPBF	1	U2
8	TP_THT_Orange	4	TP1, TP2, TP6, TP7
9	TP_THT_Black	6	TP3, TP10, TP18, TP23, TP24, TP25
10	C-2.2uF-1206-50V	1	C4
11	SMD Resistor 22R 1210	16	R1-R8, R144-R150, R85
12	SMD Resistor 3R9 1210	98	R9-R40, R45-R84, R113-R123, R125, R128-R131, R134-R143
13	SMD Resistor 33R 0603	4	R100-R102, R106
14	SMD Resistor 2K 0603	2	R105, R109
15	SMD Resistor 0R 0603	1	R112
16	SMD Resistor 10R 0603	4	R124, R88, R89, R92
17	SMD Resistor 100R 1206	1	R126
18	SMD Resistor 0R15 1206	1	R127
19	SMD Resistor 3K3 0603	2	R132, R99

Production Data

20	SMD Resistor 5R1 0603	1	R133
21	SMD Resistor 330R 1210	1	R151
22	SMD Resistor 2K2 0603	3	R41, R42, R43
23	SMD Resistor 120R 0603	1	R44
24	SMD Resistor 10K 0603	2	R86, R87
25	SMD Resistor 15K 0805	1	R90
26	SMD Resistor 1K8 0603	2	R91, R96
27	SMD Resistor 1K5 0603	1	R93
28	SMD Resistor 5K1 0603	1	R94
29	SMD Resistor 6K8 0603	1	R95
30	SMD Resistor 24R 0603	1	R97
31	SMD Resistor 470R 0603	1	R98
32	C-WE-220uF-SMD-25V	2	C0, C1
33	C-WE-100nF-0603-50V	4	C11, C14, C17, C18
34	C-WE-2.2nF-0603-50V	1	C12
35	C-WE-680pF-0603-16V	1	C13
36	C-WE-100nF-1206-50V	2	C15, C16
37	C-WE-100nF-0805-50V	2	C2, C5
38	C-WE-10pF-0603-50V	1	C6
39	C-WE-330pF-0805-50V	1	C7
40	C-WE-22uF-SMD-35V	1	C8
41	C-WE-22uF-1206-10V	1	C9
42	WA-SNTI 6mm Spacer	4	H1-H4
43	WR-PHD 40 way Header	1	J1
44	WR-DC DC Power Jack 5.5/2.5	1	J2
45	WR-BHD 8 way SMT Box Header	2	J3, J4
46	WR-PHD 10 way Header THT	1	J5
47	WR-TBL 2 Way Terminal Block	1	J6
48	WE-PD 22 μ H 5.3A Inductor	1	L1
49	WE-LHMI 0.47 μ H 11.5A SMD	1	L3
50	LED-WE-RED-1206	4	LED1-LED4
51	WR-PHD 4 way Header	1	SV5
52	WS-SHT SPDT Switch THT	1	SW5
53	WE-CST 1:125 Current Sense	1	T1

Revision History

4 Revision History

Current Version is V1.0, 2015-10

Page or Reference	Description of change
V1.0, 2015-10	
	Public version

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