KIT_PSC3M5_DP1 PSOC™ Control C3M5 Complete System Dual Buck Evaluation Kit user guide

About this document

Scope and purpose

This document describes the features and hardware details of the Dual Buck Evaluation Board. It is designed to provide an evaluation platform for digital control applications with the PSOC™ Arm® Cortex®-M33 based MCU. This board is part of Infineon's digital power evaluation platform kits.

Intended audience

This document is intended for KIT_PSC3M5_DP1 users, and this board is intended to be used under laboratory conditions.

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Safety precautions

***Note**: Please note the following warnings regarding the hazards associated with development systems.*

Table 1 Safety precautions

	Caution: *The evaluation or reference board contains parts and assemblies sensitive to electrostatic discharge (ESD). Electrostatic control precautions are required when installing, testing, servicing or repairing the assembly. Component damage may result if ESD control procedures are not followed. If you are not familiar with electrostatic control procedures, refer to the applicable ESD protection handbooks and guidelines.*
	Caution: *The evaluation or reference board is shipped with packing materials that need to be removed prior to installation. Failure to remove all packing materials that are unnecessary for system installation may result in overheating or abnormal operating conditions.*

Table of contents

1 Introduction

1.1 Kit contents

The following are the kit contents:

- Dual Buck Evaluation Board
- PSOC™ Control C3M5 Digital Power Control Card
- USB Type-A to Type-C cable
- 24 V DC power adaptor
- Quick start guide

1.2 Getting started

The following sections will help you get familiar with this evaluation kit:

- The Kit operation section describes the major features and functionalities of the Daul Buck Evaluation Board, such as two independent buck circuits, onboard transient and linear load circuits, and temperature sensors
- The Hardware section provides a detailed hardware description
- The Dual Buck Evaluation Board must be used with the PSOC™ Control C3M5 Digital Power Control Card, which is supported in ModusToolbox™ software. Using ModusToolbox™ software, you can enable and configure PSOC™ Control C3M5 MCU resources and middleware libraries, write `C/assembly` source code for the control loop implementation, program, and debug the MCU
- There are a wide range of code examples to evaluate the Dual Buck Evaluation Board using the PSOC™ Control C3M5 Digital Power Control Card. These examples help you familiarize with the Dual Buck Evaluation Board and PSOC™ Control C3M5 MCU and create your own design. These examples can be accessed through the ModusToolbox™ new application, with the appropriate BSP selected in the tool. Alternatively, you can also visit Infineon's code examples for ModusToolbox™ software page to access these examples

1.3 Key features

The Dual Buck Evaluation Board includes the following features:

- Two independent synchronous buck converters that are capable of:
  - Voltage Control Mode (VCM) and Peak Current Control Mode (PCCM)
  - Multiphase synchronous buck converter
  - Up to four buck channels by connecting a second Dual Buck Evaluation Board in a master-slave configuration with a single PSOC™ Control C3M5 Digital Power Control Card
  - Two onboard variable and transient loads for testing full load and step load responses with the option to connect external loads (that is, electronic loads) for further advanced testing

    ***Note**: The onboard load is limited to 5 W for each buck circuit; in cases of higher currents, it is requested to use an external DC load and verify the CT performance*

  - Bode plots measurement-ready – require a network analyzer
- Control card connector for plugging in:
  - Infineon PSOC™ Control C3M5 (Arm® Cortex®-M33 based) MCU PSC3M5FDS2AFQ1, 180 MHz, up to 256 KB flash/64 KB SRAM, E-LQFP-80
- Several test points for learning all the details of the buck converter

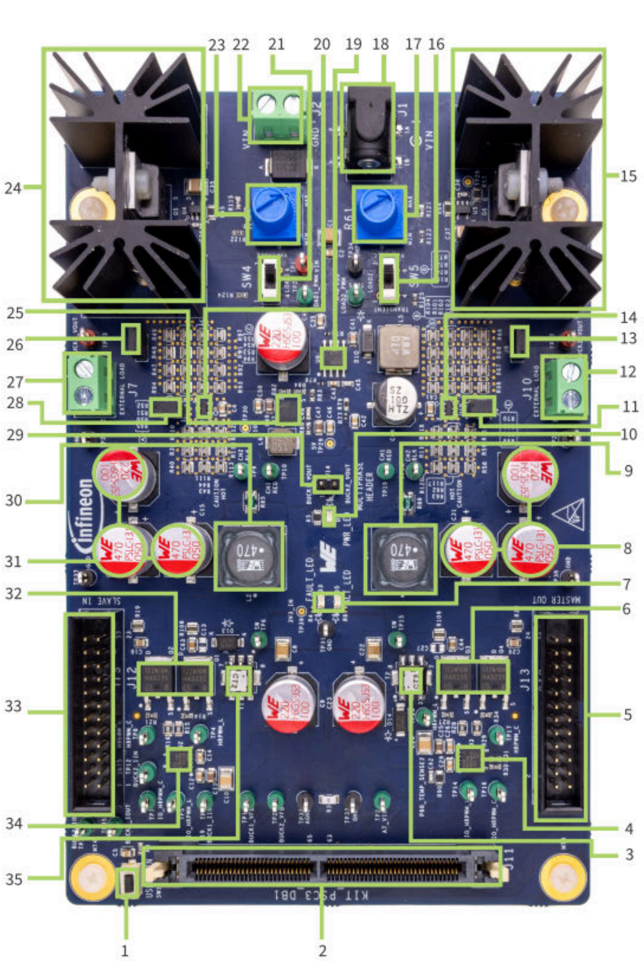
- A general purpose switch for user interaction or control
- Three LEDs:
  - POWER LED – glows when the input supply is connected
  - ACT_LED and FAULT_LED – indicate control loop activity and faulty conditions

2 Kit operation

The Dual Buck Evaluation Board is an evaluation board with the following building blocks:

- Two Independent synchronous buck circuits
- One multiphase (also known as interleaving) 2-pin header – shorting this header connects the outputs of two buck regulators (make sure to short this header only when multiphase code is running in the Digital Power Control Card; in all other cases, leave this header open)
- One PSOC™ Control C3M5 Digital Power Control Card connector compatible with PSOC™ Control C3M5 MCU PSC3M5FDS2AFQ1
- Power adapter input barell jack to plug in a 24 V DC adapter. Also, an input terminal connector to plug in an external bench power supply connection
- Two static load circuits (24 Ω) – one for each buck circuit
- Two variable and transient load circuits with heatsinks – one for each buck circuit
  - Variable load can go from 0.2 A to 1.2 A
  - Transient load can switch between 0.2 A and 2 A
- Voltage measurements - ADC: VOUT, VIN through resistive voltage dividers
- Current measurements - ADC: IOUT through current sense amplifier; inductor current through current transformer
- Four HRPWM complementary signals – two for each buck circuit
- Master-slave connectors for controlling a second Dual Buck Evaluation Board with a single PSOC™ Control C3M5 Digital Power Control Card
- 10 V boost regulator as supply for MOSFET gate drivers
- 5 V buck regulator as supply for PSOC™ Control C3M5 Digital Power Control Card

The following figures provide a detailed description of the hardware and how it can be used.



1 User button (SW1)
2 120-pin connector (J11)
3 BUCK2 current transformer (T2)
4 BUCK2 MOSFET driver (U3)
5 MASTER OUT Daisy Chain connector (J13)
6 BUCK2 Synchronous MOSFETs (Q3, Q4)
7 Fault and ACT LEDs (D3, D5)
8 BUCK2 output capacitors (C31, C32, C33)
9 BUCK2 inductor (L4)
10 Power LED (D4)
11 BUCK2 static load header (J9)
12 BUCK2 output connector (J10)
13 BUCK2 dynamic load header (J8)
14 BUCK2 temperature sensor (U10)
15 BUCK2 Load MOSFET and heatsink (Q6, HS2)
16 BUCK2 transient and variable load switch (SW5)
17 BUCK2 variable load potentiometer (R61)
18 DC Input Voltage Barrell Jack connector (J1)
19 5 V buck regulator (U6)
20 BUCK1 temperature sensor (U1)
21 BUCK1 transient and variable load switch (SW4)
22 DC input voltage terminal connector (J2)
23 BUCK1 variable load potentiometer (R42)
24 BUCK1 Load MOSFET and heatsink (Q5, HS1)
25 10 V boost regulator (U7)
26 BUCK1 dynamic load header (J5)
27 BUCK1 output connector (J7)
28 BUCK1 static load header (J6)
29 Multiphase header (J14)
30 BUCK1 inductor (L2)
31 BUCK1 output capacitors (C15, C16, C19)
32 BUCK1 Synchronous MOSFETs (Q1, Q2)
33 Slave in Daisy Chain connector (J12)
34 BUCK1 MOSFET driver (U2)
35 BUCK1 current transformer (T1)

Figure 1 **Dual Buck Evaluation Board hardware description (1)**

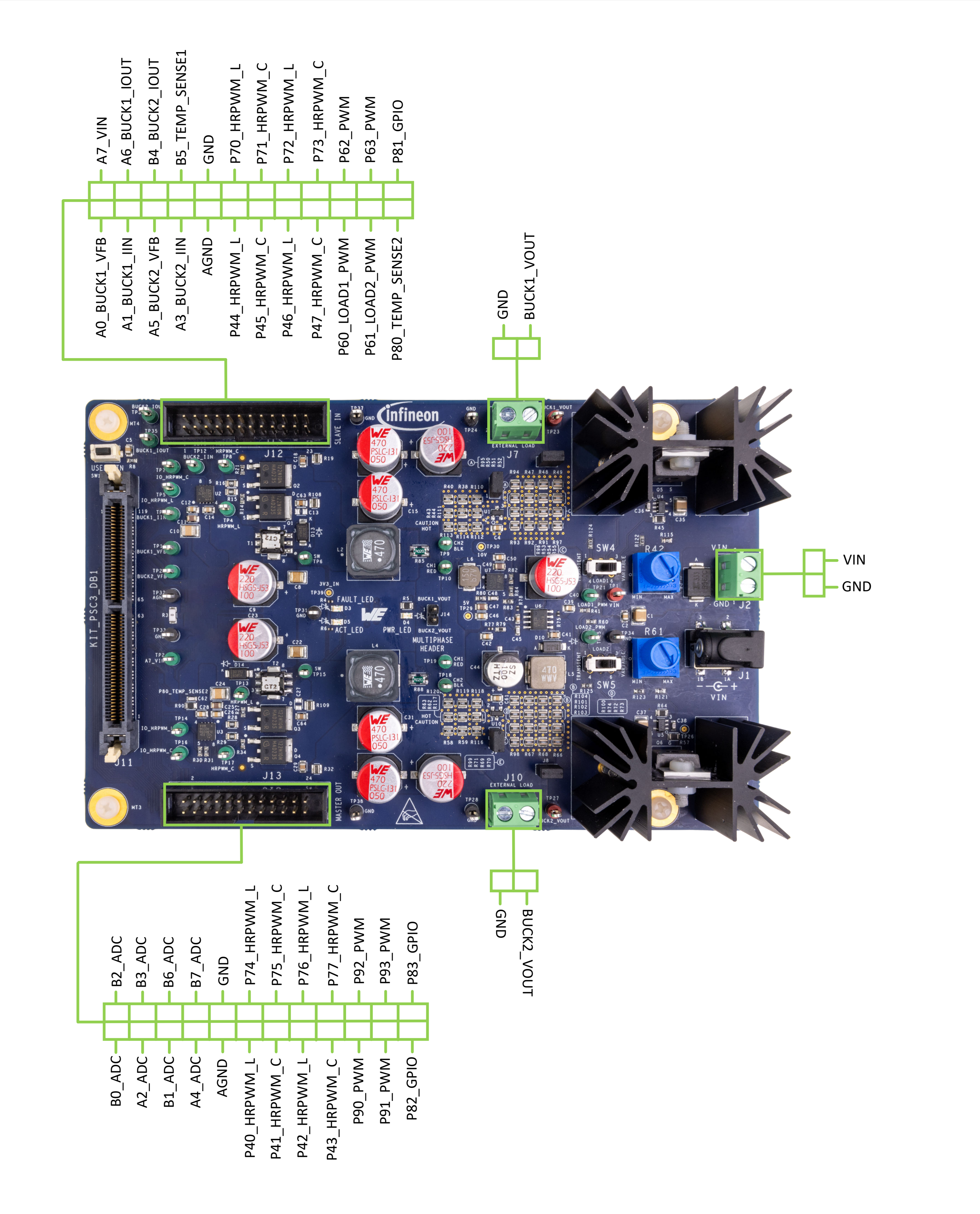


Figure 2 **Dual Buck Evaluation Board hardware description (2)**

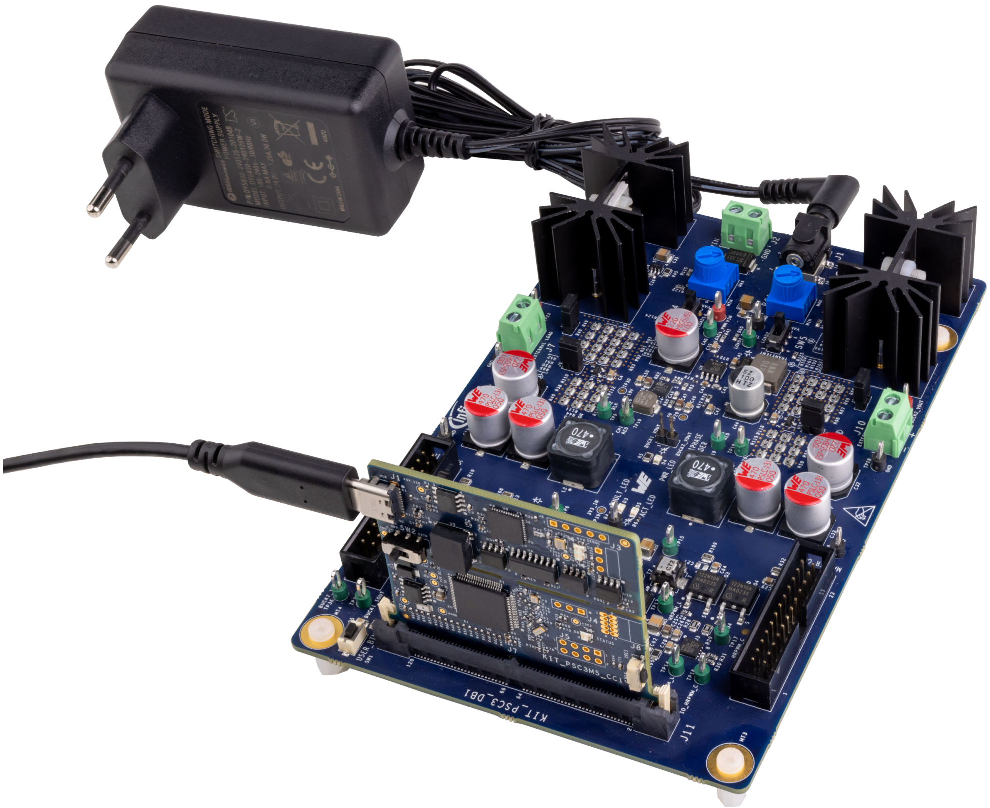


Figure 3 **Complete setup with Control Card and Dual Buck Evaluation Board**

2.1 Using out of the box example

The PSOC™ Control C3M5 Digital Power Control Card, which is included in the PSOC™ Control C3M5 Complete System Dual Buck Evaluation Kit, comes by default programmed with the code example PSOC™ Control MCU: PCCM buck converter multi-instance. For a detailed description of the project, refer to the example’s README.md file in the GitHub repository. The README.md file is also available in the application directory once the application is created using ModusToolbox™.

***Note**: At any point in time, if you overwrite the default application, you can restore it by programming the PSOC™ Control MCU: PCCM buck converter multi-instance.*

The following steps describe how to use the example:

1. Ensure that the PSOC™ Control C3M5 Digital Power Control Card is mounted on the Dual Buck Evaluation Board using the 120-pin edge connector
2. Verify that the multiphase header (J14) on the Dual Buck Evaluation Board is open
3. Connect the 24 V wall adapter to barrel jack (J1) on Dual Buck Evaluation Board
4. Verify that the power LED (D4) on the Dual Buck Evaluation Board is glowing
5. Connect the kit to your PC using the provided USB cable through the J-Link USB connector (J1) on Control Card
6. Open a terminal program and select the J-Link COM port. Set the serial port parameters to 8N1 and 115200 baud
7. Verify that the COM LED on the Digital Power Control Card is glowing

8. Press the XRES button (SW1) on the Control card and confirm that the serial terminal application displays the boot-up message as shown in Figure 4.

   The following figure shows COM48, but the port will likely be different

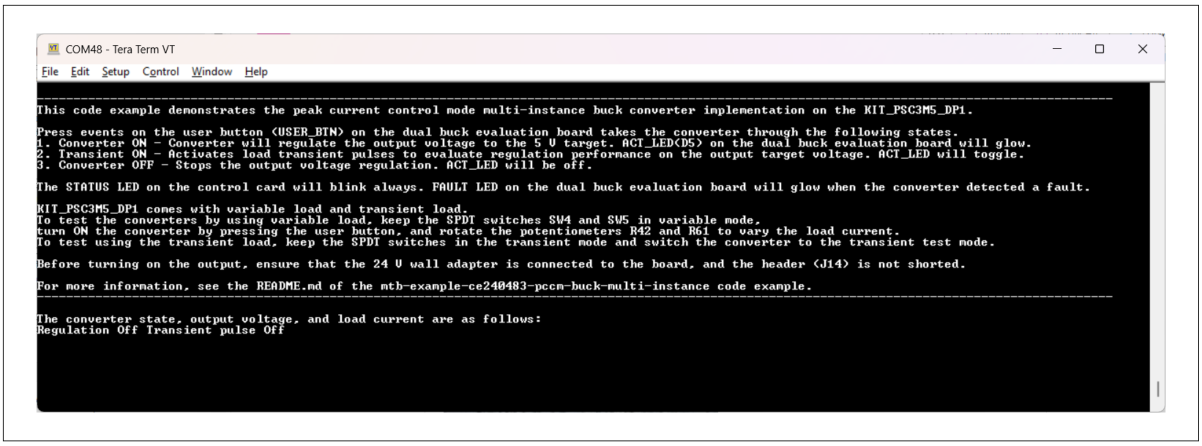


Figure 4 Serial terminal boot message

9. Press the USER_BTN on the dual buck evaluation board, to start the regulation of output voltage in the buck converter. The ACT_LED (D5) on the dual buck evaluation board will start glowing
10. To test the converters using variable load, keep the SPDT switches SW4 and SW5 in variable mode and rotate the potentiometers R42 and R61 to vary the load current
11. Measure the output voltage from both the converters with TP23 (buck 1) and TP27 (buck 2), using an oscilloscope or a multimeter. It should show 5 V DC at both TPs
12. To test the transient load, keep the SPDT switches in the transient mode and press the user button to switch the converter to the transient test mode. When the transient test is running, the ACT LED (D5) will blink
13. Press the user button again to stop the pulses for transient testing and output voltage regulation in the buck converters. The ACT_LED (D5) will turn off
14. Press the button again to repeat the sequence from Step 9

2.2 Creating a project and program/debug using ModusToolbox™ software

The PSOC™ Control C3M5 Complete System Dual Buck Evaluation Kit can be programmed and debugged using the onboard J-Link debugger. This onboard programmer/debugger supports USB-UART Bridge functionality. An XMC™ 4200 device is used to implement the J-Link functionality. For more details on the J-Link, see the J-Link debug probes.

The following steps briefly introduce project creation, programming, and debugging using ModusToolbox™ software. For detailed instructions, go to **Help** > **ModusToolbox™ General Documentation** > **ModusToolbox™ User Guide**.

1. Connect the board to the PC using the provided USB cable through the J-Link USB connector, as shown in Figure 5. It enumerates as a USB composite device if you are connecting it to your PC for the first time
2. The debugger on this kit is with J-Link and one UART. The COM LED (green) is always ON if the USB is connected

   ***Note**: The programming can be done either with the onboard J-Link debugger or by attaching an external debugger to the connector J8 on the Control Card. It is recommended to use the onboard J-Link debugger*

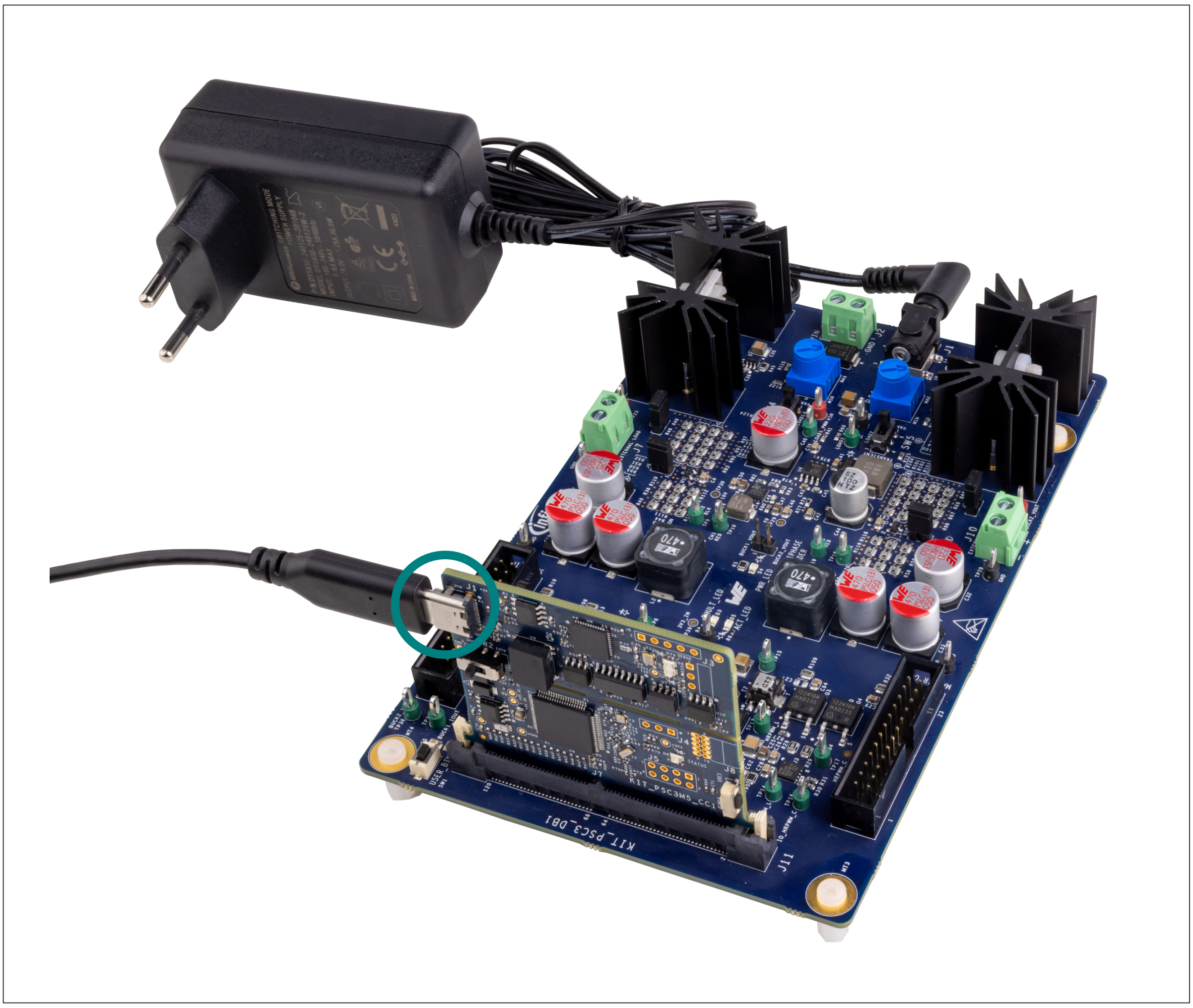


Figure 5 Connect USB cable to USB connector on the Control Card

3. In the Eclipse IDE for ModusToolbox™ software, import the desired code example (application) into a new workspace
   a. In the **Quick Panel**, click **New Application** from the **Start** section

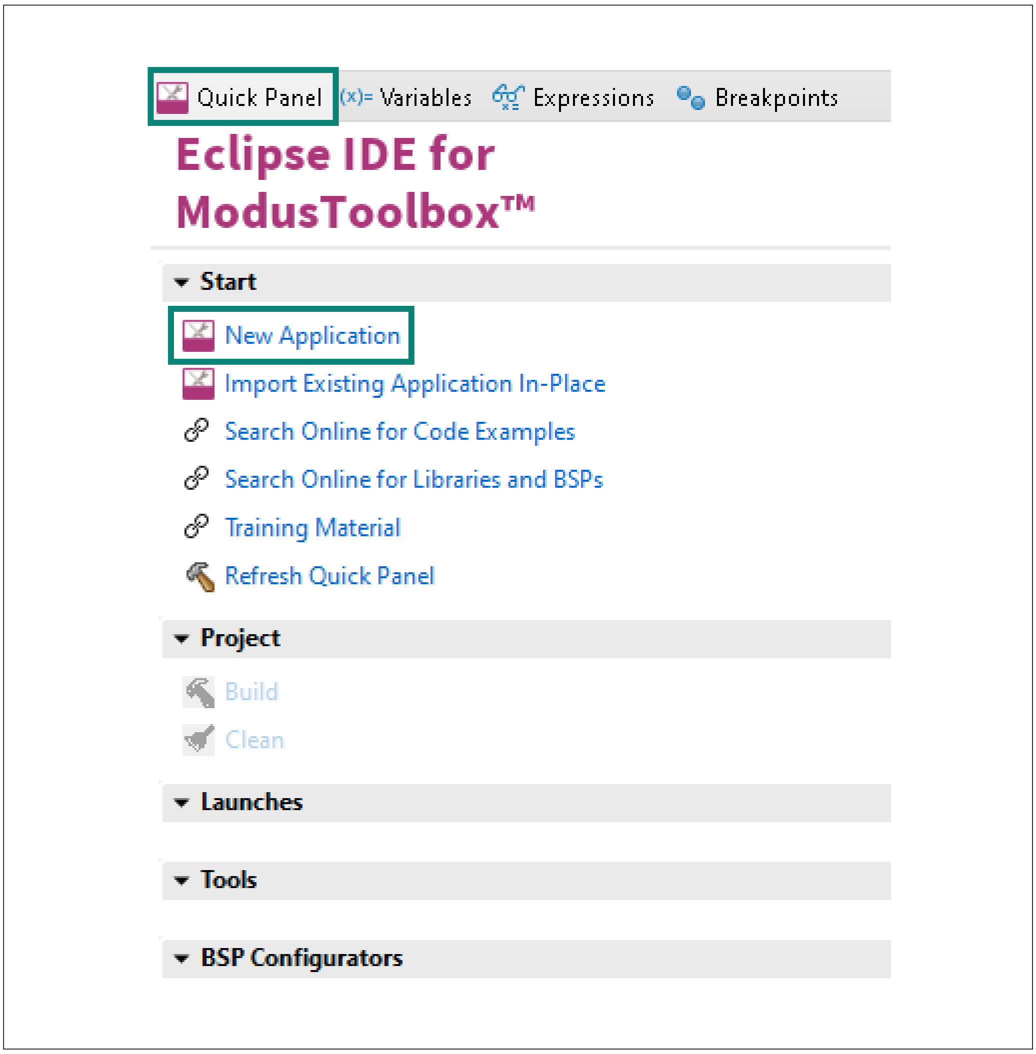


Figure 6 **Create new application**

b. Select the **BSP -KIT_PSC3M5_CC1** in the **Choose Board Support Package** window and click **Next**

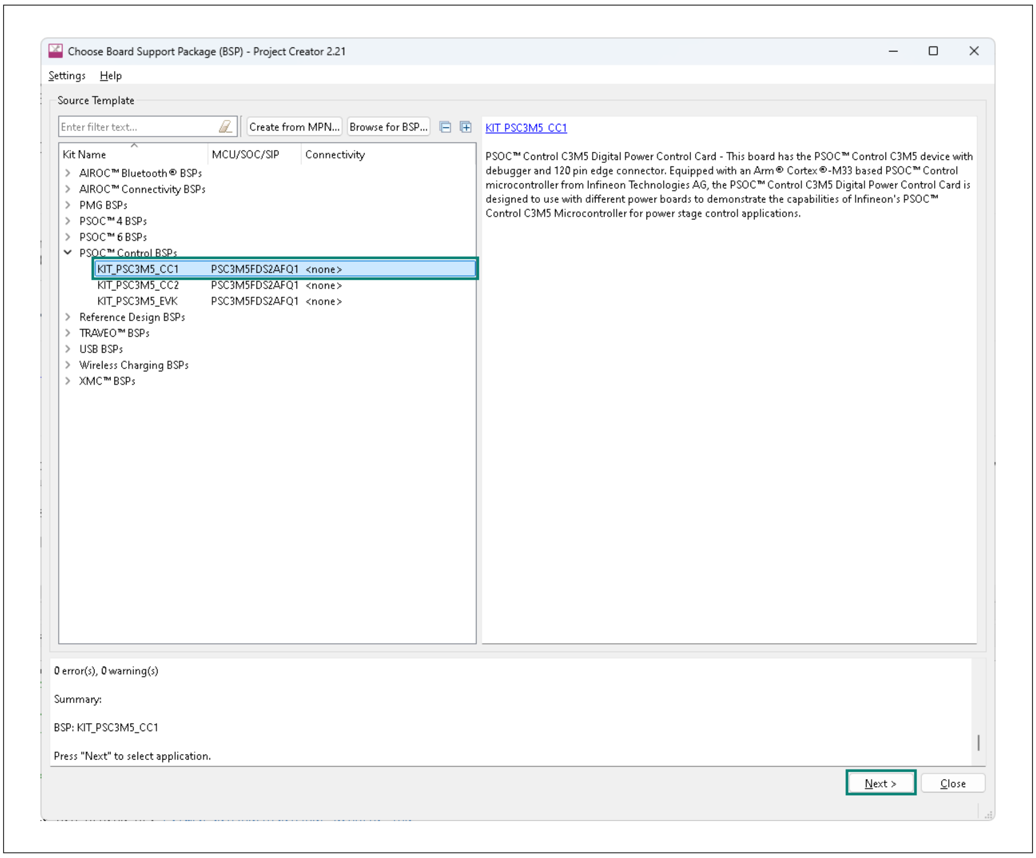


Figure 7 Creating a new application: Choose Board Support Package

c. Select the application in the **Select Application** window and click **Create**

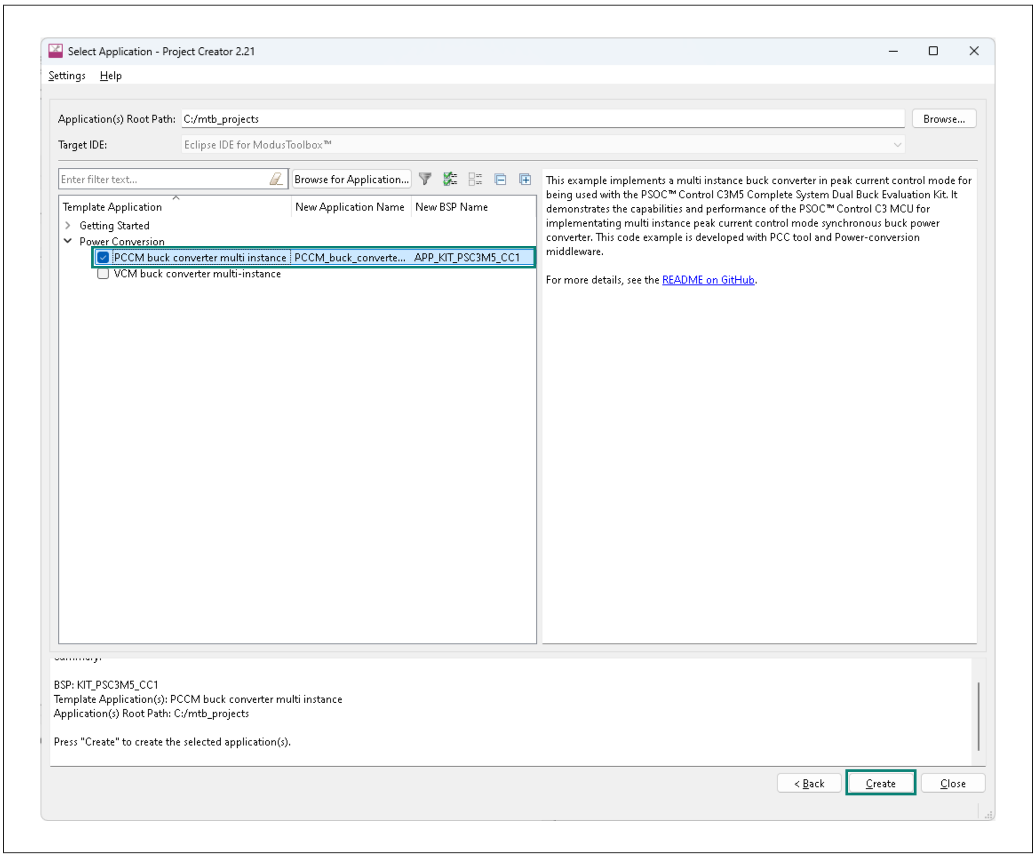


Figure 8 **Creating a new application: Select Application**

4. To build and program a PSOC™ Control C3M5 MCU application:

a. In the **Project Explorer**, select **<App_Name>** project

b. In the **Quick Panel**, click the **<App_Name> Program (J-Link)** configuration from the **Launches** section, as shown in Figure 9

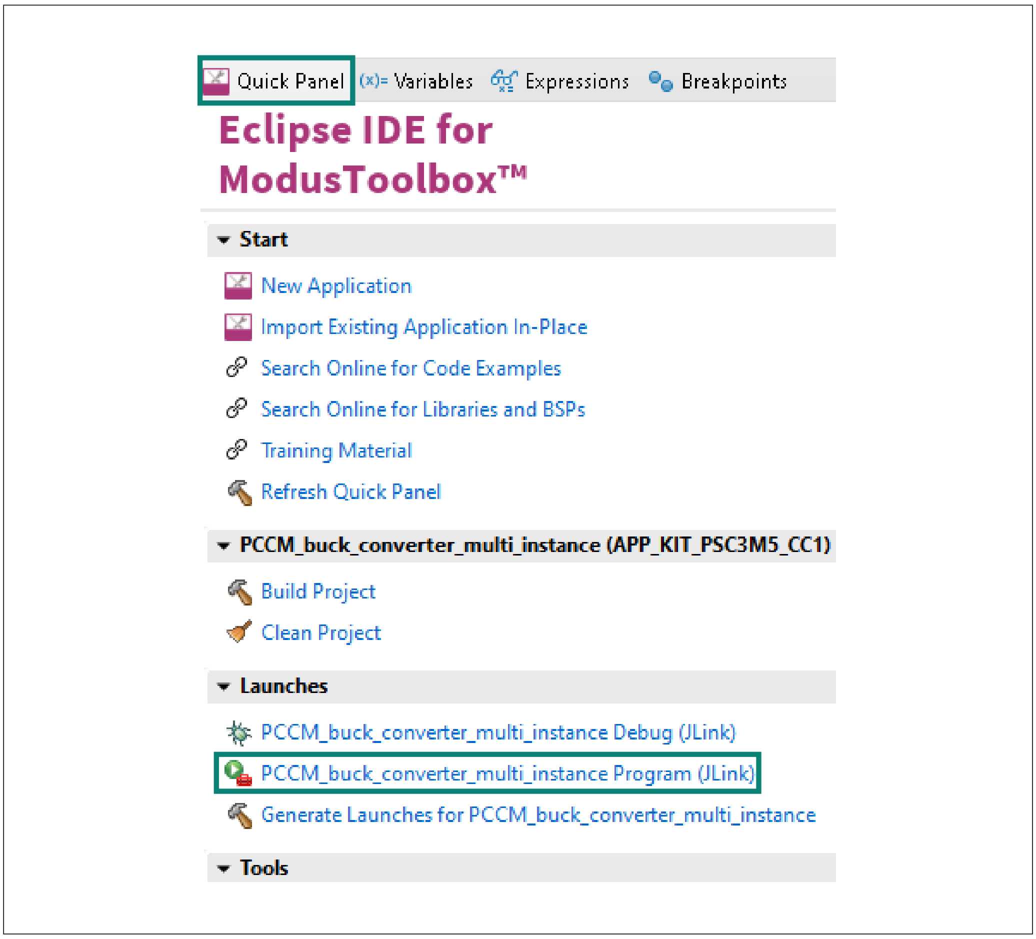


Figure 9 Programming in ModusToolbox™ software

ModusToolbox™ software has an integrated debugger

5. To debug a PSOC™ Control C3M5 MCU application:
   a. In the **Project Explorer**, select **<App_Name>** project
   b. In the **Quick Panel**, click the **<App_Name> Debug (J-Link)** configuration from the **Launches** section, as shown in Figure 10

      For more details, see the Program and debug section in the Eclipse IDE for ModusToolbox™ user guide

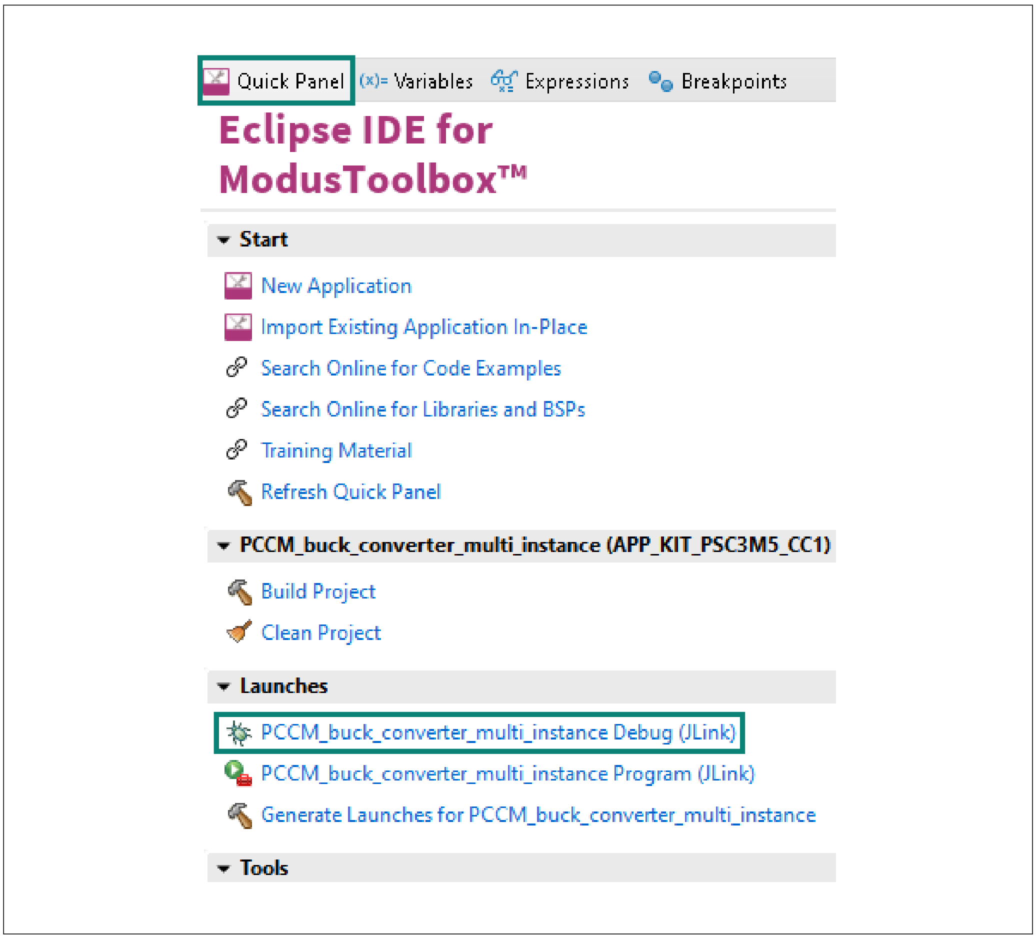


Figure 10 Debugging in ModusToolbox™ software

3 Hardware

3.1 Hardware functional description

This section explains the individual hardware blocks.

3.1.1 Dual buck evaluation board

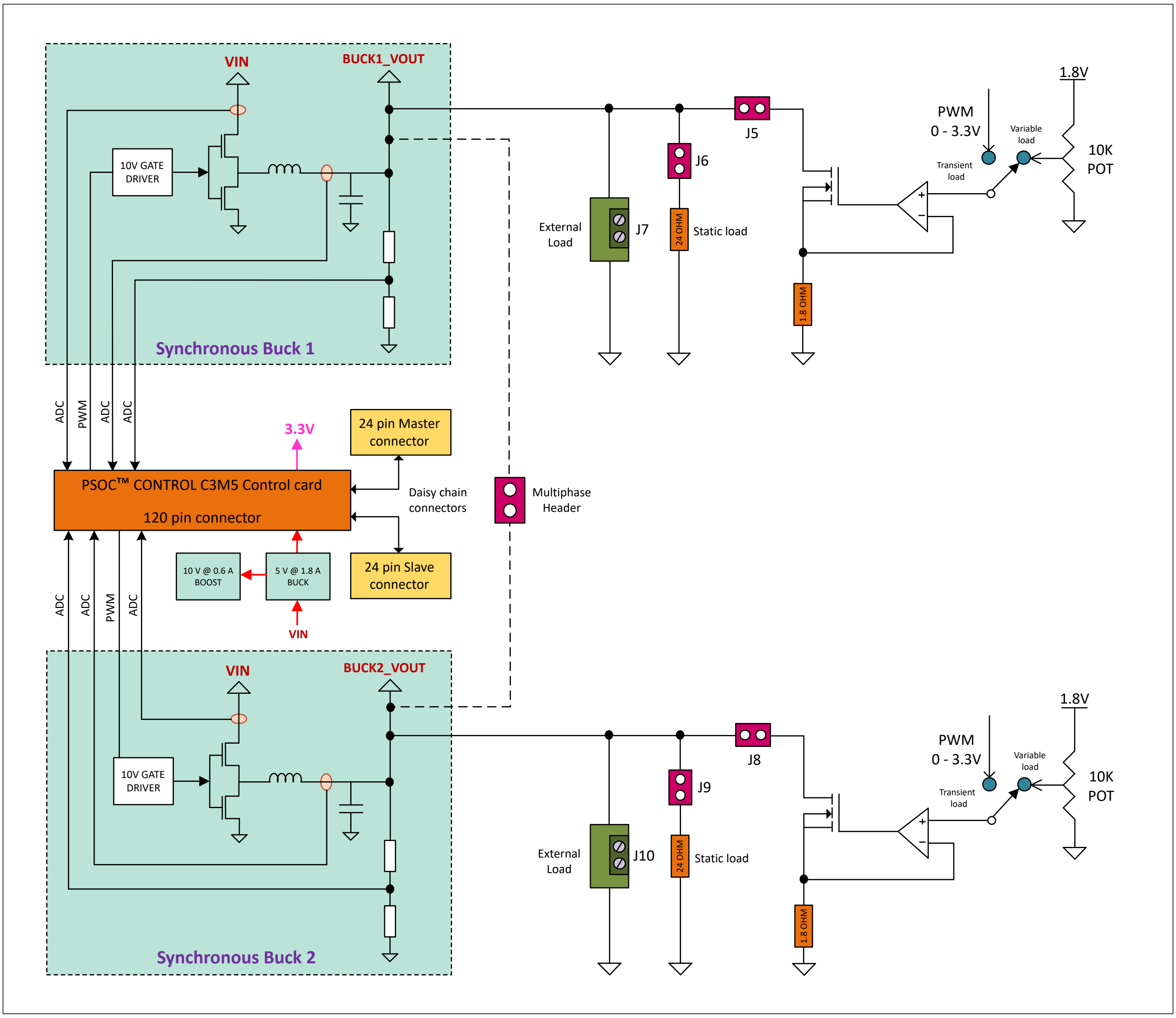


Figure 11 Block diagram of the Dual Buck Evaluation Board

The Dual Buck Evaluation Board has two independent synchronous buck regulators implemented. All the control signals (PWM, ADC) for these buck regulator circuits are routed to the Control Card through the 120-pin connector (MPN: HSEC8-160-01-L-DV-A-BL). These two buck regulators can be controlled individually or can be configured for multiphase mode with a 2-pin header (J14) on the Dual Buck Evaluation Board. There are two onboard variable and transient load circuits for testing full load and step load responses, with the option to connect external loads, such as electronic loads, for further advanced testing. A second Dual Buck Evaluation Board can be connected in daisy chain mode through master-slave 24-pin connectors using a ribbon cable MPN: H3CCH-2406G.

3.1.2 Buck converter circuit description

The Dual Buck Evaluation Board is targeted for low voltage; the specification is shown in Table 2. The schematic view of the buck converter stage is shown in the following figure. By default, the target output voltage and the current for both buck circuits is 5 V and 1.2 A max IOUT in variable load mode and 5 V and 2 A max IOUT in transient load mode. Nevertheless, as a buck converter, any voltages from 0 V to VIN are theoretically possible depending on the driving of the MOSFETs-duty cycle.

If the user intends to change either input voltage, output voltage, or output current, user must also consider recalculating passive component values and changing them on the PCB to withstand the desired voltage, current ratings, and thermal dissipation. When connecting two dual-buck evaluation boards in daisy chain mode, each evaluation board must be powered individually through its input power supply connectors.

The inductor value of 47 uH ensures continuous conduction mode (CCM) of the buck converter as far as the 2-pin headers J6 for BUCK1 (24 Ω) and J9 for BUCK2 (24 Ω) are short. In other words, DCM operation occurs only when headers J6 for BUCK1 or J9 for BUCK2 are open, assuming a 400 kHz switching frequency.

Note: *Depending on the buck converter configuration, for example, target output voltage or load connected, the board may become hot.*

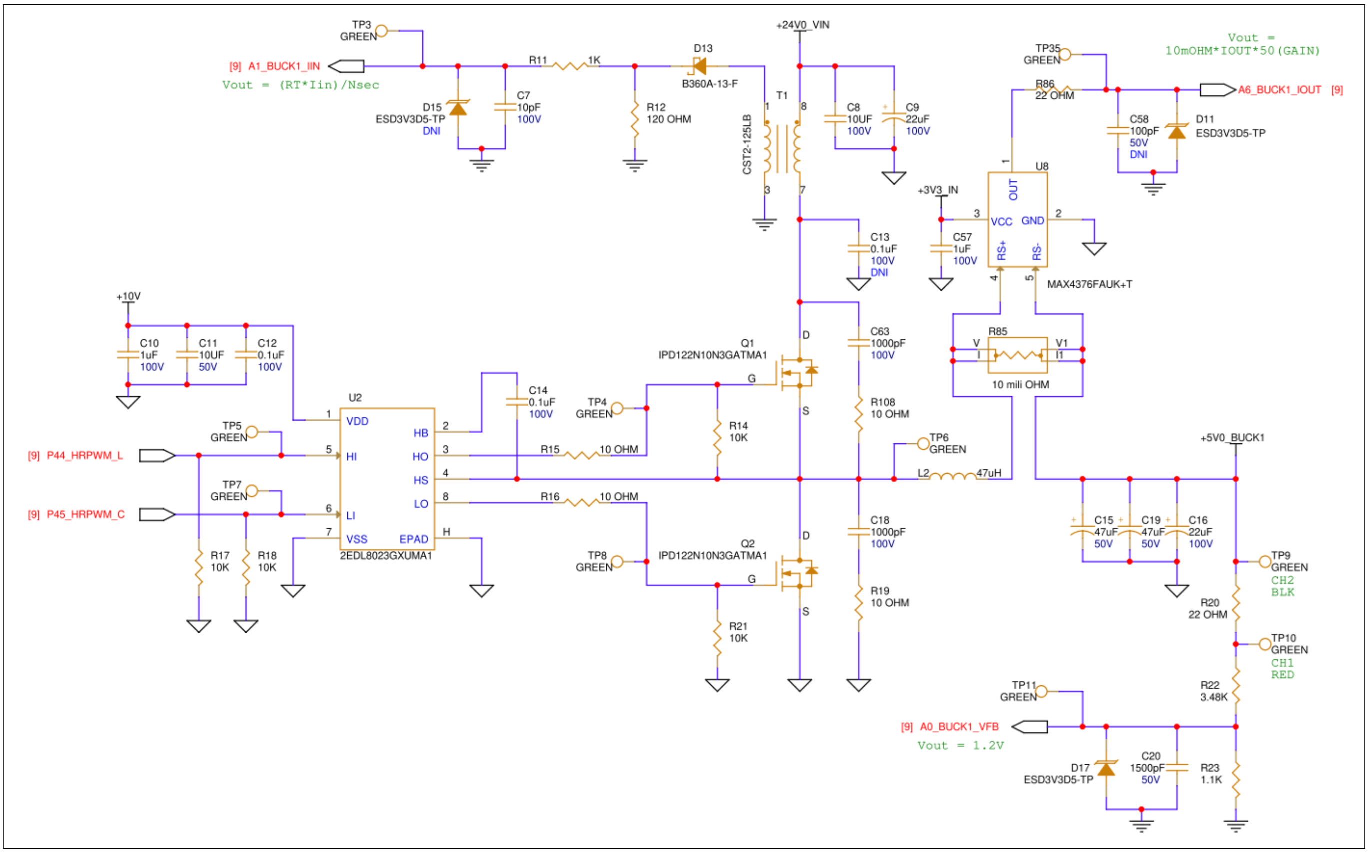


Figure 12 **Synchronous buck 1 circuit**

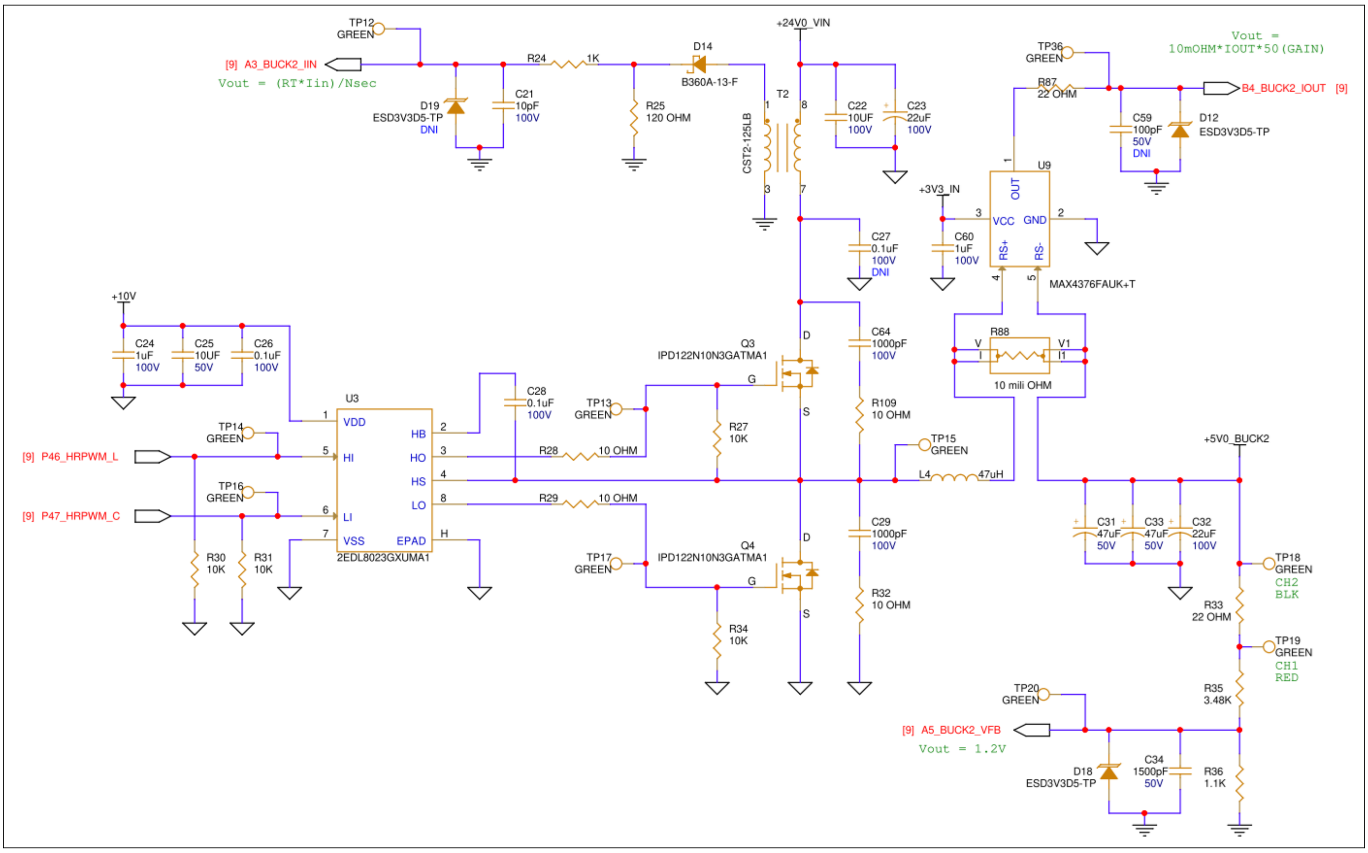


Figure 13 Synchronous buck 2 circuit

Table 2 Synchronous buck converter specification

Specification	**Name**	**Value**
Input voltage	VIN	24 V DC
Output voltage	BUCK1_VOUT (+5V0_BUCK1) BUCK2_VOUT (+5V0_BUCK2)	5 V DC 5 V DC
Maximum output current	$BUCK1\_IOUT_{max}$ $BUCK2\_IOUT_{max}$	1.2 A in variable load and 2 A in transient load 1.2 A in variable load and 2 A in transient load
Multiphase mode (short header J14)	VOUT IOUT	5 V DC 2.4 A in variable load and 4 A in transient load

Table 3 Synchronous buck converter components

Specification	**Name**	**Value**
Main inductor	BUCK1 L2 BUCK2 L4	47 uH 47 uH
Output capacitor	BUCK1 C15| |C16| |C19 BUCK2 C31| |C32| |C33	47 uF| |47 uF| |22 uF = 116 uF 47 uF| |47 uF| |22 uF = 116 uF

(table continues...)

Table 3 (continued) Synchronous buck converter components

Specification	Name	Value
Gate driver high and low side	BUCK1 U2 BUCK2 U3	2EDL8023GXUMA1
MOSFETs	BUCK1 Q1, Q2 BUCK2 Q3, Q4	IPD122N10N3GATMA1

Table 4 Onboard load specification

Specification	Header	Name	Value
Set SW4 to variable load position	Header J5 SHORT and Header J6 SHORT	BUCK1_IOUT varies from	0.2 A to 1.2 A
Set SW4 to transient load position	Header J5 SHORT and Header J6 SHORT	BUCK1_IOUT toggle between	0.2 A and 2 A
Set SW5 to variable load position	Header J8 SHORT and Header J9 SHORT	BUCK2_IOUT varies from	0.2 A to 1.2 A
Set SW5 to transient load position	Header J8 SHORT and Header J9 SHORT	BUCK2_IOUT toggle between	0.2 A and 2 A

Gate driver IC 2EDL8023GXUMA1 integrates the high-side and low-side gate drivers and requires an external bootstrap capacitor (the diode is integrated). The high-side and low-side MOSFETs selected are IPD122N10N3GATMA1 Infineon's family OptiMOS™3 Power-Transistor, TO252-3 package. The main figure of merits is shown in Table 4. The board is also prepared to be operated at different PWM frequencies.

Table 5 IPD122N10N3GATMA1 MOSFET figure of merits

Specification	Name	Value
Drain to source max voltage	VDS	100 V
Resistance drain to source at V_{GS} = 10 V	$R_{DS(on)}$, max	12.2 mΩ
Max drain current	ID	59 A
Power dissipation	P_{tot} T_c=25°C	94 W

The voltage sensing in both input voltage and output voltage is done with a resistor ladder (voltage divider). On the input current side, a current transformer is utilized and provides information during the on-time of the buck converter for peak current control mode. Output current is measured through a current sense amplifier. Sensing gains are summarized in Table 6. These values are necessary for configuring the SW that controls the power stage.

Table 6 Analog sensing gains

Gain	Value	Formula
VIN gain	0.063	R2/(R1+R2)

(table continues...)

Table 6 (continued) Analog sensing gains

Gain	Value	Formula
VOUT gain BUCK1	0.24	(R23)/(R23+(R22+R20))
VOUT gain BUCK2	0.24	(R36)/(R36+(R35+R33))
Iin current sensing gain	0.96 V/A	1:125 (transformer ratio)
BUCK1	0.96 V/A	R12 = 120 Ω
BUCK2		R25 = 120 Ω
IOUT gain BUCK1	0.5 V/A	10 mΩ*Iout*50(Gain)
IOUT gain BUCK2	0.5 V/A	10 mΩ*Iout*50(Gain)

3.1.3 Board input power supply

The Dual Buck Evaluation Board is designed to be powered by a 24 V DC power supply supplying a current of 1.25 A. The input has two connector options, barell jack and a terminal connector, as shown below. A Barell jack connector for a 24 V DC adaptor is supplied in the box, and a terminal connector for external bench power supply input. When a 24 V DC power adapter is inserted into the barell jack (J1), the terminal connector (J2) is disconnected from the input supply path on the PCB. To indicate the power-on status, one indicating LED–D4 (green color) is provided onboard.

The input 24 V DC is converted to 5 V DC, which is then supplied to the PSOC™ Control C3M5 Digital Power Control Card. The Control Card internally converts this 5 V 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 the Dual Buck Evaluation Board to supply the load circuits, LEDs, user button, current sense amplifier, and temperature sensors. Additionally, each buck converter is designed to provide 5 V up to 2 A to the VOUT connectors (J7 and J10) when the buck converters are running correctly.

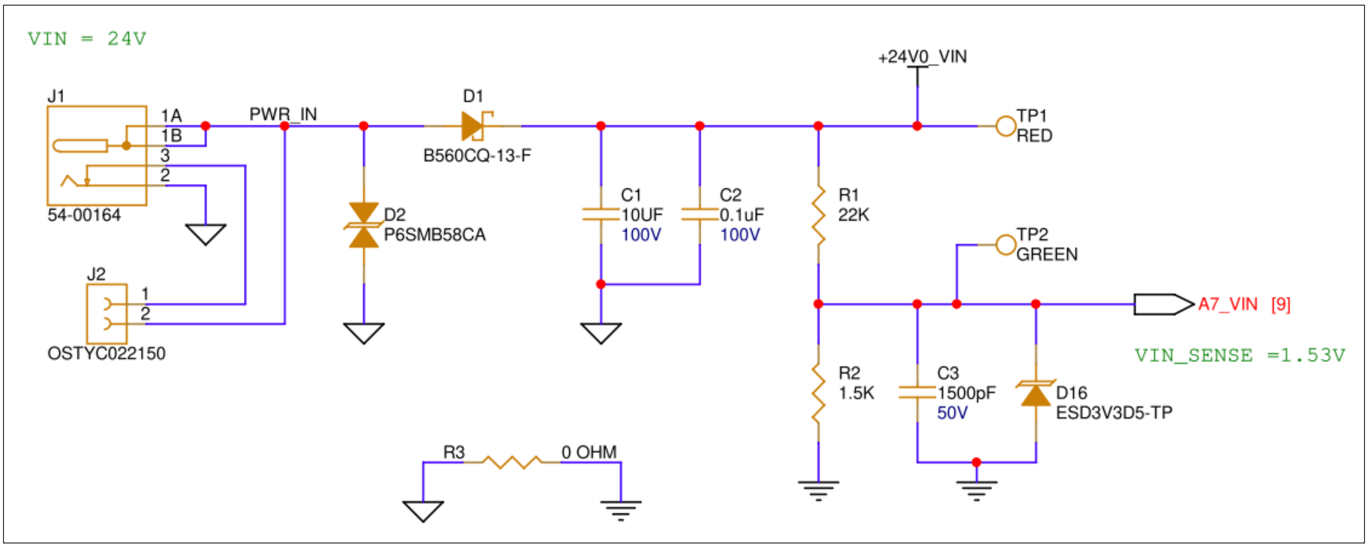


Figure 14 Input power supply

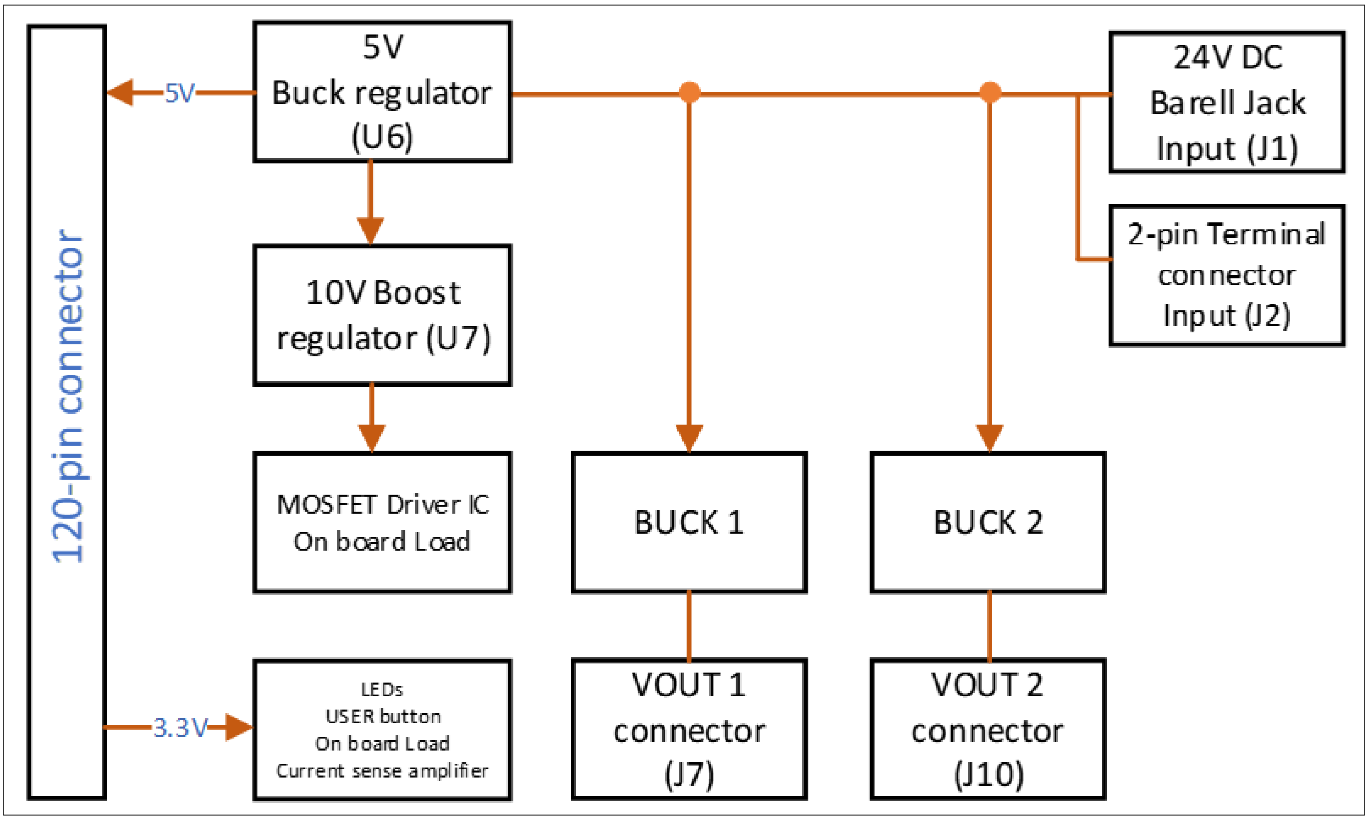


Figure 15 **Input power supply flow diagram**

3.1.4 Master and slave configuration

The Dual Buck Evaluation Board can be chained to a second Dual Buck Evaluation Board with a 24-pin ribbon cable (MPN: H3CCH-2406G) to complete a master-slave connection that can be controlled with a single Digital Power Control Card. To do that, connect the "MASTER_OUT" connector (J13) signals from the board where the Digital Power Control Card is plugged into the "SLAVE_IN" connector (J12) of the slave board. Master and slave connectors carry only ADC, PWM, and GPIO signals. When two evaluation boards are connected in daisy chain mode with a 24-pin ribbon cable, each board must be individually supplied with input voltage. In a master-slave configuration, both boards can be controlled in voltage mode, peak current mode, or a combination of both. This is dependent only on the software configuration of the Digital Power Control Card.

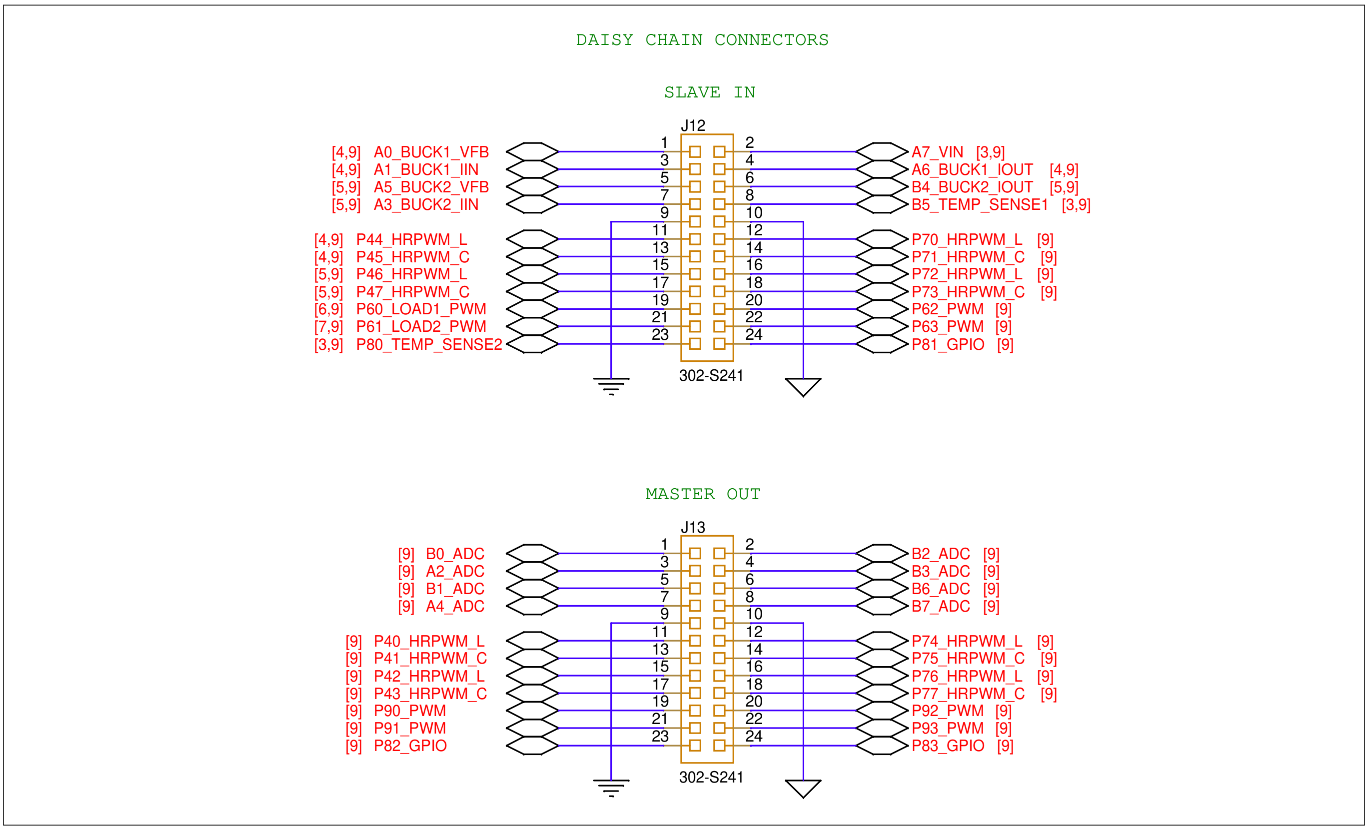


Figure 16 **Master and slave connectors pinout**

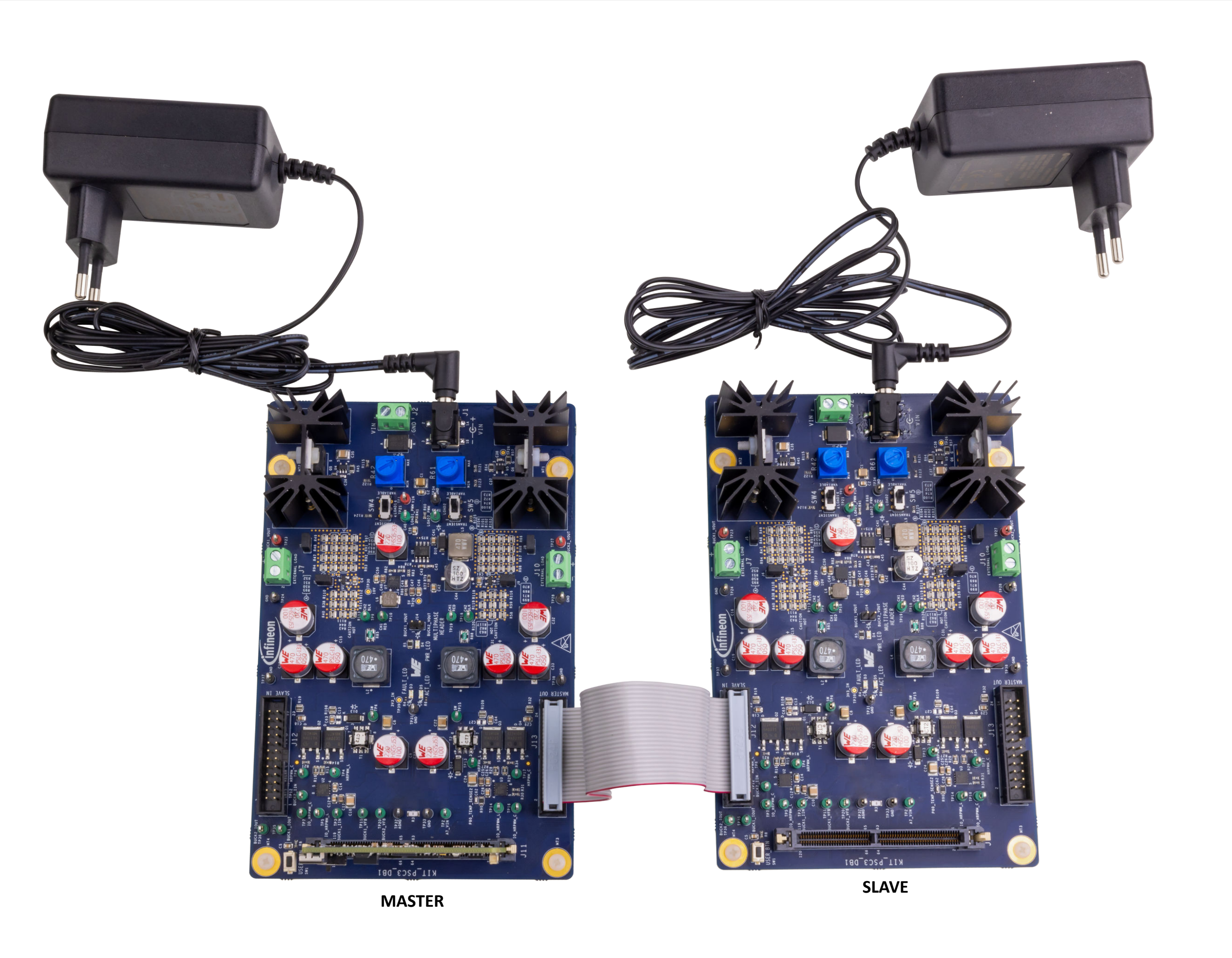


Figure 17 **Daisy chain master-slave setup**

3.1.5 Input and output current sensing

The input current of the buck converters is measured with a current transformer (T1 for Buck1 and T2 for Buck2), as shown in the following figure, located between the VIN and the buck converter high-side MOSFET. The current transformer has a 1:125 turn ratio. The secondary winding signal is half-wave rectified (D13 for Buck1 and D14 for Buck2), and the CT circuit is closed on a load resistor of 120 Ω (R12 for Buck1 and R25 for Buck2). CT operates as a current source. This results in a 120/125 gain, which means that 1 A in the buck converter translates into 0.96 V in the MCU pin. Before the signal is delivered to the MCU, an RC filter (R11, C7 for Buck1, and R24, C21 for Buck2) is added to reduce high-frequency spikes. The -3 dB frequency of this filter is slightly above 15 MHz. Therefore, only the current during the PWM ON time is reflected in the signals A1_BUCK1_IIN and A3_BUCK2_IIN. When Q1 and Q3 transistors are in an OFF state, the inductor current cannot be sensed in T1 and T2. The current signal is then transferred to the PSOC™ C3M5 Control card connector with the names A1_BUCK1_IIN and A3_BUCK2_IIN.

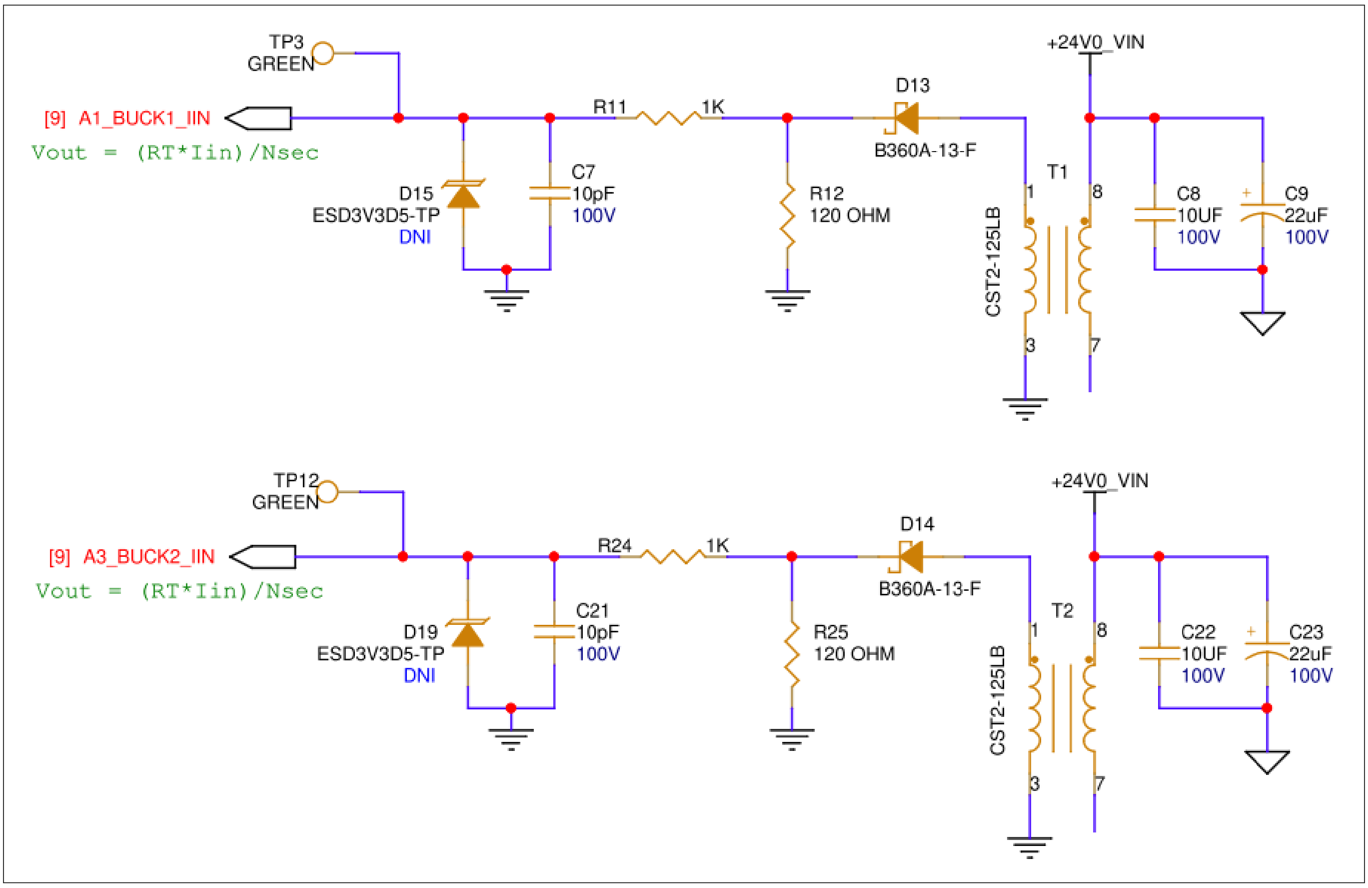


Figure 18 **Buck1 and Buck2 input current sensing**

The output current of the buck converters is measured with a current sense amplifier (U8 for Buck1 and U9 for Buck2) across a 10 mΩ sense resistor (R85 for Buck1 and R88 for Buck2) located before the output capacitors of the buck converters. This current sense amplifier has a gain of 50, which means that 1 A in the output current translates into 0.5 V in the MCU pin. This signal is then transferred to the PSOC™ C3M5 Control card connector with the names A6_BUCK1_IOUT and B4_BUCK2_IOUT.

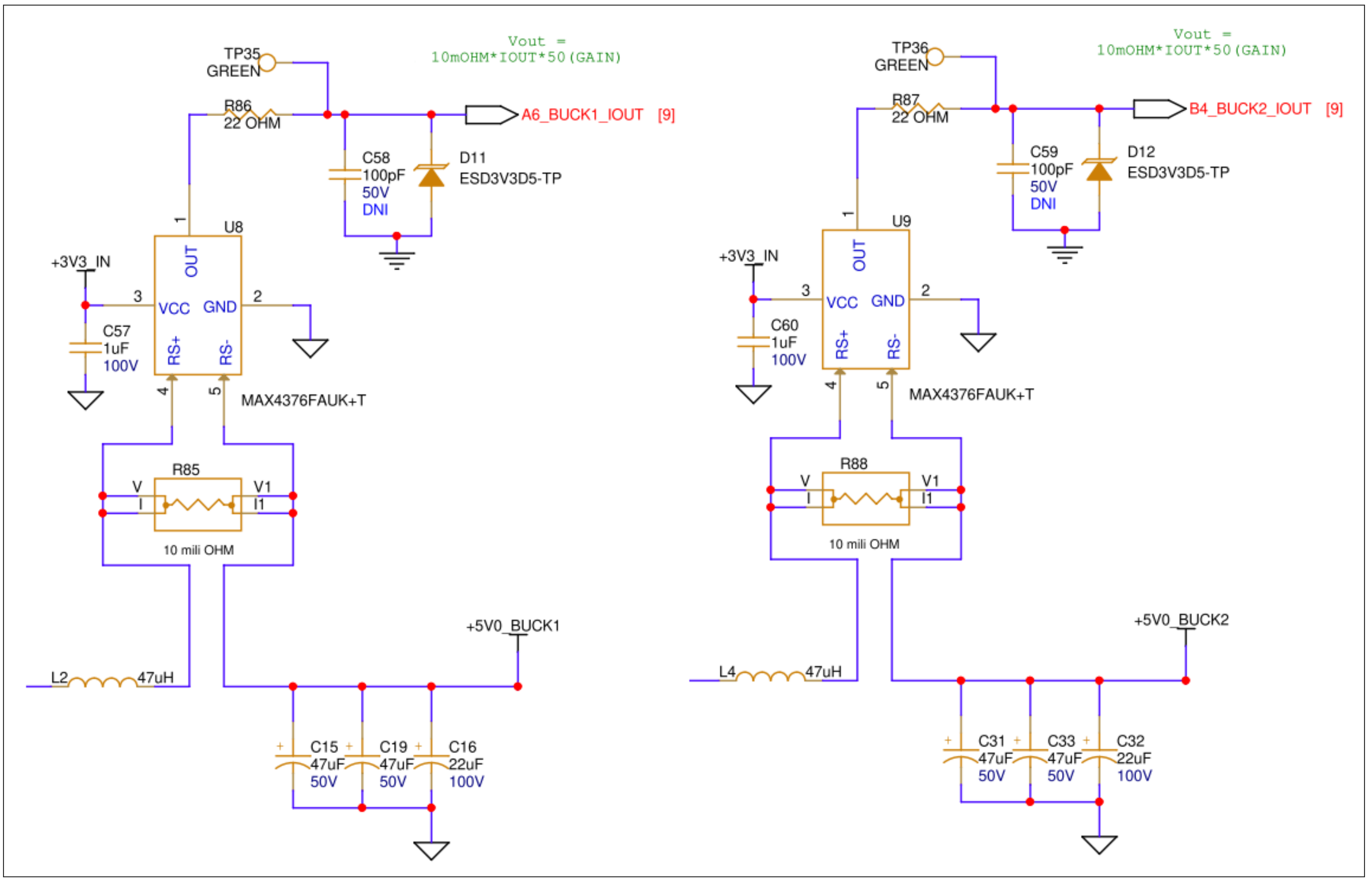


Figure 19 **Buck1 and Buck2 output current sensing**

3.1.6 Onboard load circuits

The Dual Buck Evaluation Board integrates onboard transient load and linear load circuits, providing individual load control for each buck circuit. The transient load circuit enables seamless load switching between 0.2 A and 2 A. Control for this circuit is managed by a 3.3 V PWM waveform from the PSOC™ C3M5 controller using pin P6.0 for Buck1 and pin P6.1 for Buck2. The linear DC onboard load circuit supports linear load variation from 0.2A to 1.2 A and a maximum load of 2 A through external load connectors (J7 and J10), controlled by potentiometers R42 for Buck1 and R61 for Buck2. A SPDT switch, SW4 for Buck1 and SW5 for Buck2, provides easy selection between the transient load and the variable DC load circuits, allowing for flexible load management. Header J6 for Buck1 and J9 for Buck2 default to a short with a 24 Ω at 5 V output voltage, ensuring Continuous Conduction Mode (CCM) for the buck regulator. Additionally, header J5 for Buck1 and J8 for Buck2 offer control over the connection or disconnection of the transient and linear load. It is important to note that recalculating the load circuit resistors and MOSFETs on the board is necessary if a different output voltage is desired. The onboard load resistors and MOSFET heatsink are specifically designed to handle thermal dissipation for a 5 V output at 1 A maximum IOUT under typical conditions. For higher Buck output voltages and output currents, users must disconnect the onboard load from connectors J5, J6 for Buck1 and J8, J9 for Buck2, and make use of external load on connectors J7 for Buck1 and J10 for Buck2.

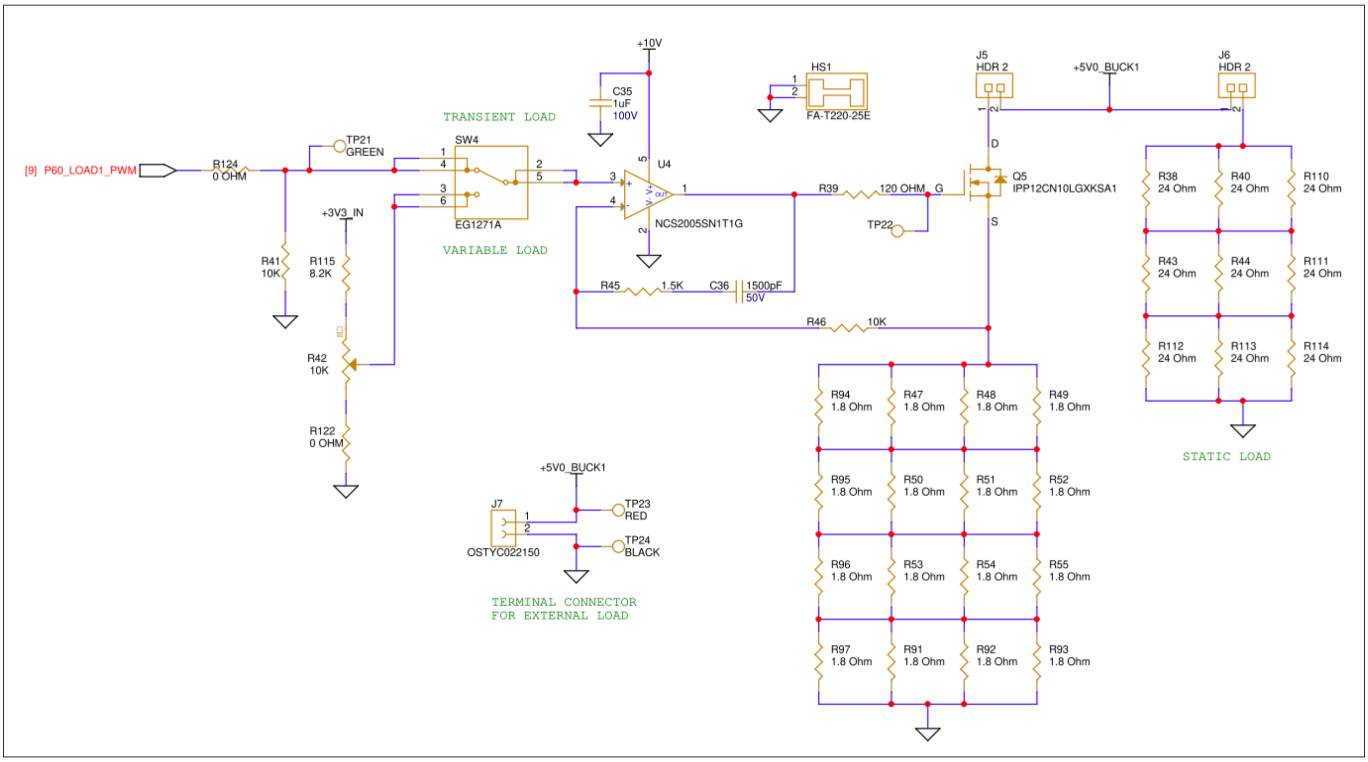


Figure 20 **Buck1 onboard load circuit**

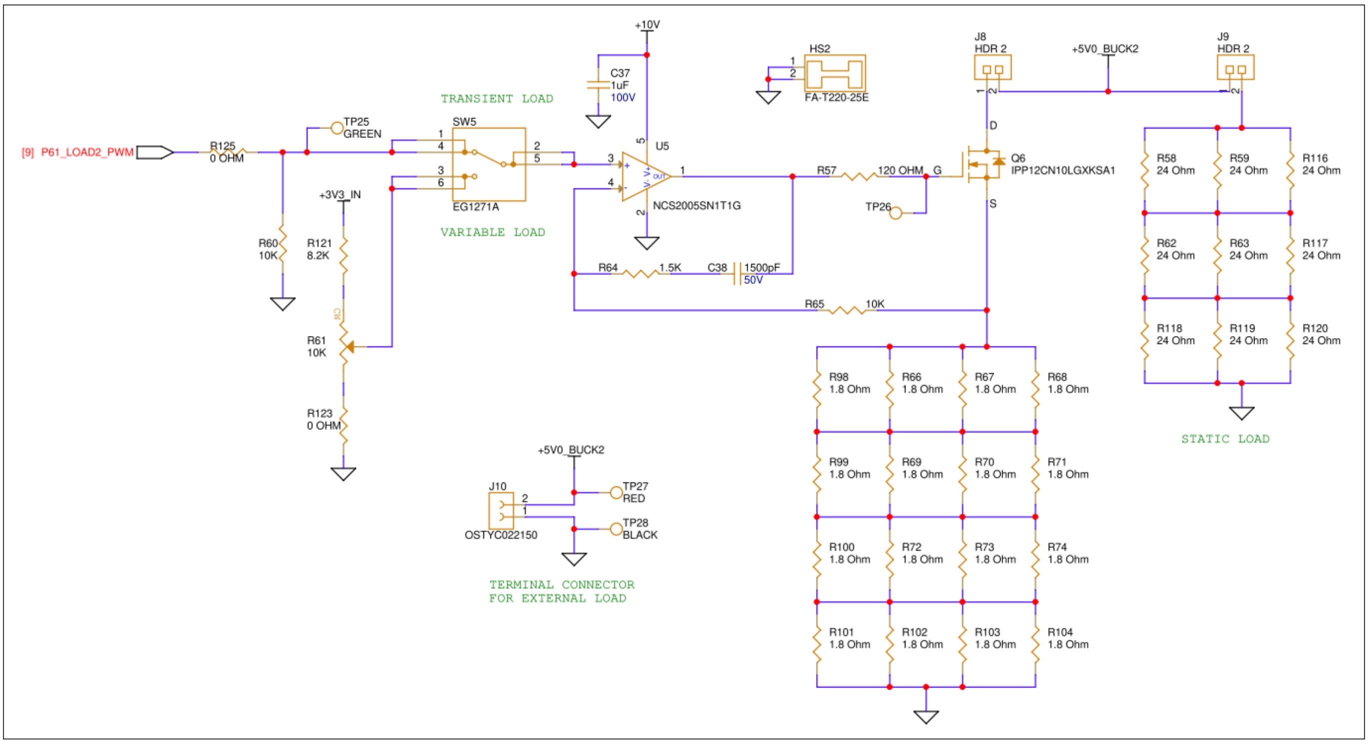


Figure 21 **Buck2 onboard load circuit**

3.1.7 Multiphase header

Two buck circuits on Dual Buck Evaluation Board can be configured to multiphase mode. To enable multiphase mode for the two buck circuits on the Dual Buck Evaluation Board, follow these steps:

- Locate the 2-pin header J14, and short the pins only when the PSOC™ C3M5 Control card is running the multiphase control loop topology. Keep the header J14 disconnected for all other loop topologies
- When in multiphase mode, measure the output voltage (VOUT) at either the Buck1 regulator output connector J7 or Buck2 regulator output connector J8
- Onboard loads J5, J6, and J8, J9 can be used to test the maximum output current IOUT of 2.4 A, with each load circuit sharing a maximum IOUT of 1.2 A in variable load and the maximum output current IOUT of 4 A, with each load circuit sharing a maximum of 2 A in transient load
- When using an external load either connected to J7 or J10, disconnect the onboard loads J5 and J6 from Buck1, as well as J8 and J9 from Buck2

It is important to carefully follow these instructions to ensure proper configuration and prevent any potential damage to the components or the board.

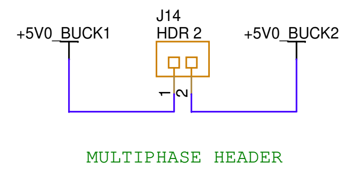


Figure 22 **Multiphase header**

3.1.8 LEDs

The following are the three LEDs on the Dual Buck Evaluation Board:

- POWER LED
- FAULT_LED
- ACT_LED

The POWER LED is connected to a 10 V rail and turns on when the input power supply is present. User-controlled LEDs D3 (red-FAULT_LED) are connected to P3.0 GPIO, and D5 (green-ACT_LED) are connected to P3.1 GPIO of the PSOC™ C3M5 MCU. These user LEDs are active low, so the P3.0 and P3.1 pins must be driven low to turn ON these LEDs. The FAULT_LED is configured to indicate any faulty conditions, such as overcurrent, undervoltage, and so on. The ACT_LED is configured to indicate control loop activity.

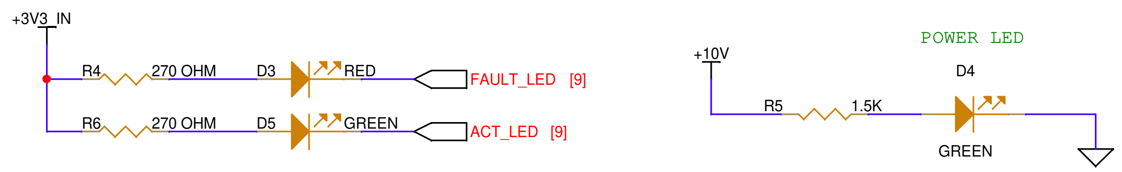


Figure 23 **LEDs**

3.1.9 User button

The Dual Buck Evaluation Board has one user button connected to the P9.4 GPIO of the PSOC™ C3M5 MCU. This general-purpose button is configured for user interaction with the control loop topologies and onboard transient load.

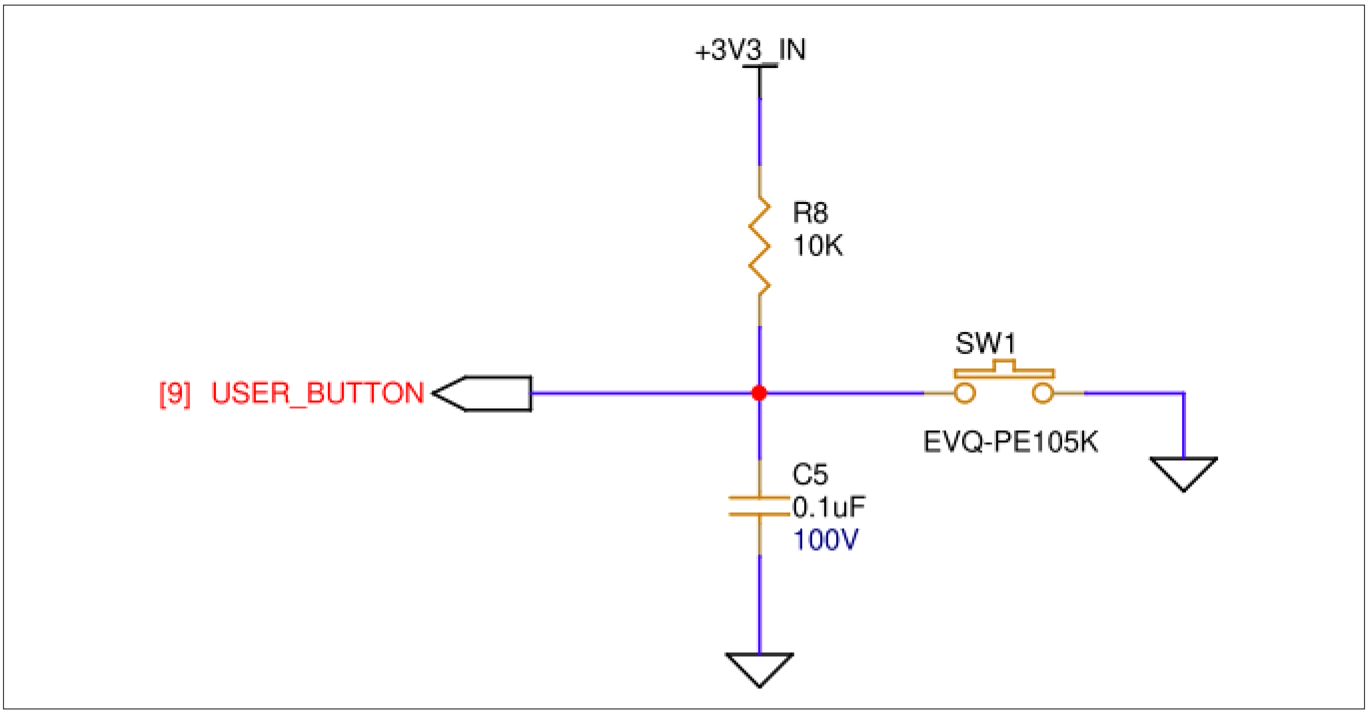


Figure 24 **User button**

3.1.10 Temperature sensors

The Dual Buck Evaluation Board has two onboard analog temperature sensors in the SOT-23 package (MPN: MCP9700T-E/TT). These sensors have a temperature range of -40°C to +125°C. The output voltage at 0°C is also scaled to 500 mV (typical). The change in voltage is scaled to a temperature coefficient of 10.0 mV/°C (typical). The voltage output pin of these sensors is directly connected to PSOC™ C3M5 MCU ADC pin B5 and pin P8.0. Temperature sensor U1 is placed close to Buck1 load circuit resistors, and temperature sensor U10 is placed close to Buck2 load circuit resistors.

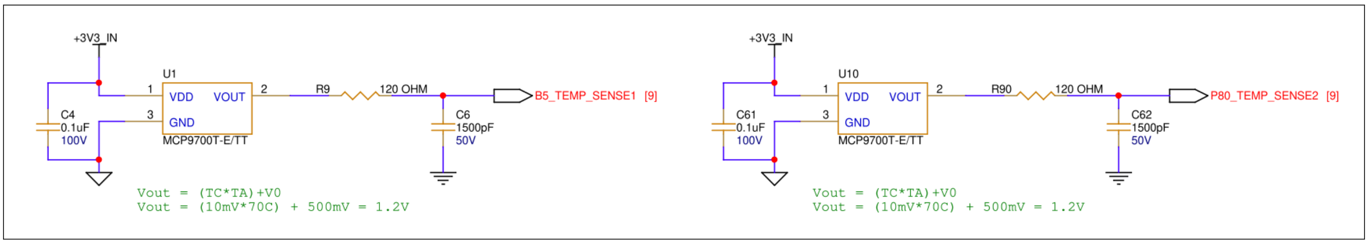


Figure 25 **Temperature sensors**

3.1.11 Test points

The following table lists a total of 39 test points within the Dual Buck Evaluation Board. This will help the user to inspect different points of interest and learn how the buck converter performs in detail.

The Dual Buck Evaluation Board also includes a user button (SW1) connected to P9.4 through a 120-pin connector. This can be used by the user to signal the C3M5 MCU when to apply a specific action, for example, enable transient load, change the control scheme, and so on.

Table 7 Test points description

Test point number	Test point description
TP1	VIN input voltage
TP2	VIN resistor divider voltage
TP3	Buck1 input current
TP4	Buck1 gate driver high-side MOSFET PWM signal
TP5	Buck1 HRPWM line signal
TP6	Buck1 switching node signal
TP7	Buck1 HRPWM complimentary signal
TP8	Buck1 gate driver low-side MOSFET PWM signal
TP9/TP10	Buck1 injection points for network analyzers
TP11	Buck1 VOUT resistor divider voltage
TP12	Buck2 input current
TP13	Buck2 gate driver high-side MOSFET PWM signal
TP14	Buck2 HRPWM line signal
TP15	Buck2 switching node signal
TP16	Buck2 HRPWM complimentary signal
TP17	Buck2 gate driver low-side MOSFET PWM signal
TP18/TP19	Buck2 injection points for network analyzers
TP20	Buck2 VOUT resistor divider voltage
TP21	Buck1 load circuit PWM signal
TP22	Buck1 load circuit opamp output signal
TP23	Buck1 VOUT voltage
TP24, TP28, TP31, TP33, TP34, TP37 and TP38	GND
TP25	Buck2 load circuit PWM signal
TP26	Buck2 load circuit opamp output signal
TP27	Buck2 VOUT voltage
TP29	5 V buck regulator output voltage
TP30	10 V boost regulator output voltage
TP35	Buck1 output current
TP36	Buck2 output current
TP32	AGND
TP39	3.3 V input voltage

3.1.12 Connection to network analyzer

It is possible to analyze the frequency response of the control loop by injecting on a small shunt resistor a frequency variable signal generated by an external network analyzer. Such a tool is responsible for determining the bandwidth and phase margin of the dual buck converter. In fact, the Dual Buck Evaluation Board includes test points (TP9/TP10 for Buck1 and TP18/TP19 for Buck2) as well as a shunt resistor (R20 for Buck1 and R33 for Buck2) with a resistance value of 22 Ω to help measure the bode diagram of the power stage. The following figure shows how to set up the connection of the Dual Buck Evaluation Board to a network analyzer. The red and black signals represent 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.

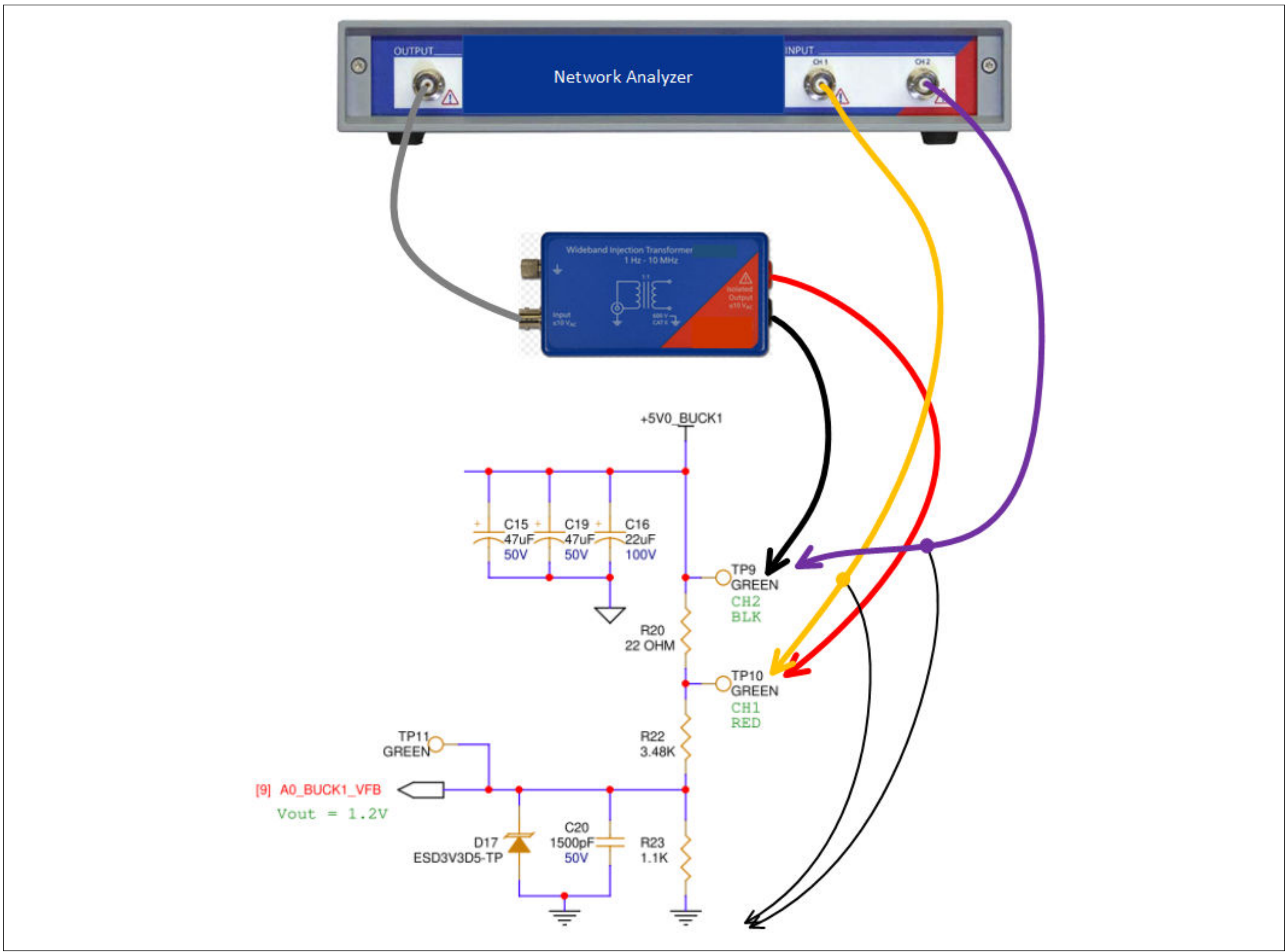


Figure 26 **Network analyzer connection diagram**

3.1.13 120-pin control card connector

The Dual Buck Evaluation Board includes a 120-pin connector compatible with the PSOC™ Control C3M5 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 converters. The signals available in the connector are as follows:

- 8 pairs of HRPWM signals (line and complementary)
- 16 ADC analog inputs
- 15 general purpose IO pins

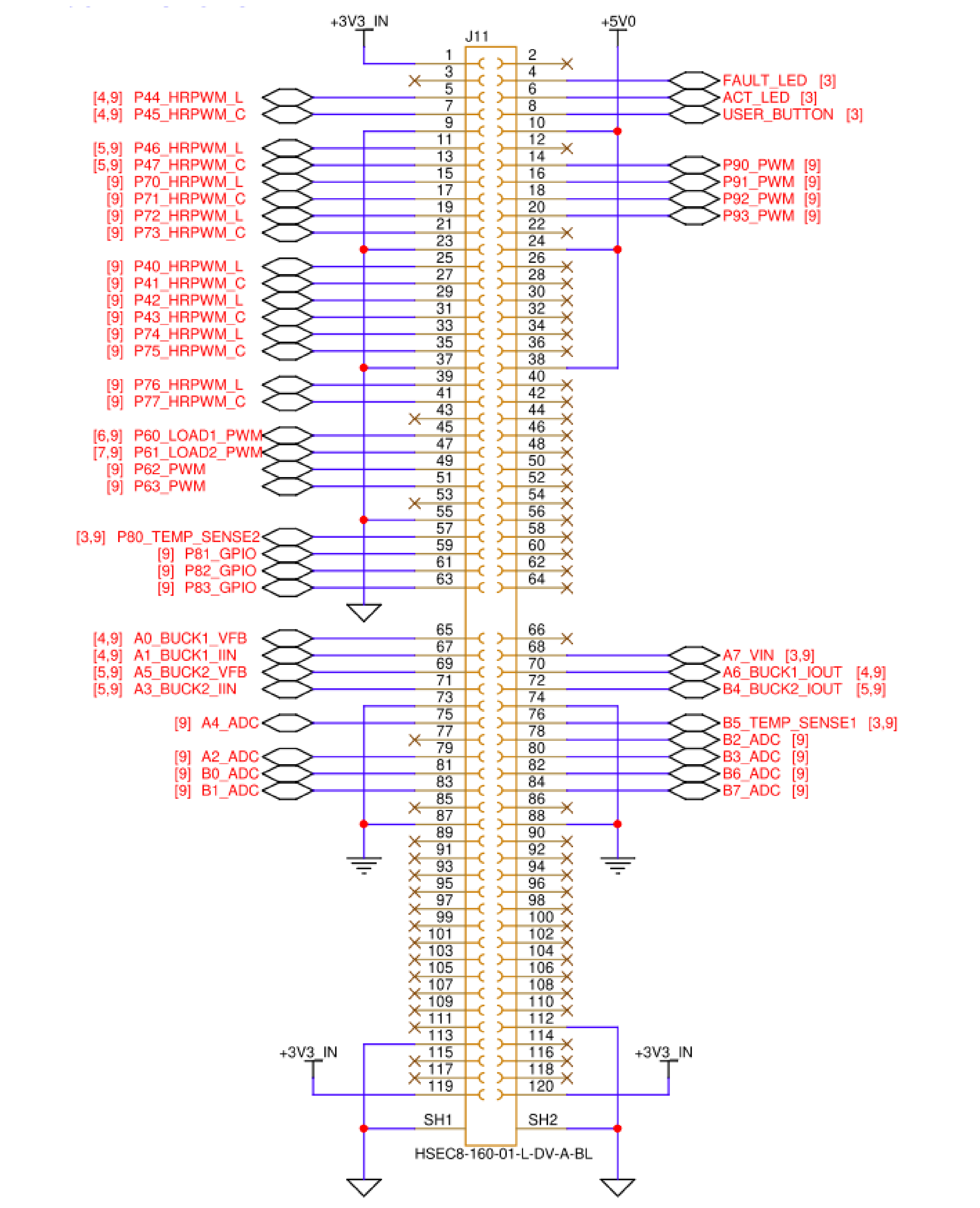


Figure 27 **120-pin connector**

Attention: ***The Dual Buck Board 120-pin connector is also providing the power supply for the MCU supply domain.***

The pin out of the connector is described in detail in the following table.

Table 8 120-pin connector pinout

Connector pin number	Dual Buck board	Control card		Control card	Dual Buck board	Connector pin number
1	3.3 V IN	3.3 V OUT		XRES	NC	2
3	NC	NC		P3.0	FAULT_LED	4
5	P44_HRPWM_L	P4.4		P3.1	ACT_LED	6
7	P45_HRPWM_C	P4.5		P9.4	USER_BUTTON	8
9	GND	GND		5V0 IN	5V0 OUT	10
11	P46_HRPWM_L	P4.6		NC	NC	12
13	P47_HRPWM_C	P4.7		P9.0	P90_PWM	14
15	P70_HRPWM_L	P7.0		P9.1	P91_PWM	16
17	P71_HRPWM_C	P7.1		P9.2	P92_PWM	18
19	P72_HRPWM_L	P7.2		P9.3	P93_PWM	20
21	P73_HRPWM_C	P7.3		P9.5	NC	22
23	GND	GND		5V0 IN	5V0 OUT	24
25	P40_HRPWM_L	P4.0		NC	NC	26
27	P41_HRPWM_C	P4.1		P0.0/ WCO_OUT	NC	28
29	P42_HRPWM_L	P4.2		P0.1/WCO_IN	NC	30
31	P43_HRPWM_C	P4.3		P1.0/ECO_IN	NC	32
33	P74_HRPWM_L	P7.4		P1.1/ ECO_OUT	NC	34
35	P75_HRPWM_C	P7.5		NC	NC	36
37	GND	GND		5V0 IN	5V0 OUT	38
39	P76_HRPWM_L	P7.6		NC	NC	40
41	P77_HRPWM_C	P7.7		P2.2	NC	42
51	NC	NC		P2.3	NC	44
45	P60_LOAD1_PWM	P6.0		P5.0/SDA	NC	46
47	P61_LOAD2_PWM	P6.1		P5.1/SCL	NC	48
49	P62_PWM	P6.2		P3.2	NC	50
51	P63_PWM	P6.3		P3.3	NC	52
53	NC	NC		P5.2/UART_RX	NC	54
55	GND	GND		P5.3/UART_TX	NC	56

(table continues...)

Table 8 (continued) 120-pin connector pinout

Connector pin number	Dual Buck board	Control card		Control card	Dual Buck board	Connector pin number
57	P80_TEMP_SENSE2	P8.0		P8.4	NC	58
59	P81_GPIO	P8.1		P8.5	NC	60
61	P82_GPIO	P8.2		NC	NC	62
63	P83_GPIO	P8.3		NC	NC	64
65	A0_BUCK1_VFB	AN_A0		VDDA	NC	66
67	A1_BUCK1_IIN	AN_A1		AN_A7	A7_VIN	68
69	A5_BUCK2_VFB	AN_A5		AN_A6	A6_BUCK1_IOUT	70
71	A3_BUCK2_IIN	AN_A3		AN_B4	B4_BUCK2_IOUT	72
73	AGND	AGND		AGND	AGND	74
75	A4_ADC	AN_A4		AN_B5	B5_TEMP_SENSE1	76
77	NC	VAREF_EXT		AN_B2	B2_ADC	78
79	A2_ADC	AN_A2		AN_B3	B3_ADC	80
81	B0_ADC	AN_B0		AN_B6	B6_ADC	82
83	B1_ADC	AN_B1		AN_B7	B7_ADC	84
85	NC	NC		NC	NC	86
87	AGND	AGND		AGND	AGND	88
89	NC	NC		NC	NC	90
91	NC	NC		NC	NC	92
93	NC	NC		NC	NC	94
95	NC	NC		NC	NC	96
97	NC	NC		NC	NC	98
99	NC	NC		NC	NC	100
101	NC	NC		NC	NC	102
103	NC	NC		NC	NC	104
105	NC	NC		NC	NC	106
107	NC	NC		NC	NC	108
109	NC	NC		NC	NC	110
111	NC	NC		GND	GND	112
113	GND	GND		P2.0/TDI	NC	114
115	NC	P1.2/TCK		P2.1/TDO	NC	116
117	NC	P1.3/TMS		VBACKUP	NC	118
119	3.3 V IN	3.3 V OUT		3.3 V OUT	3.3 V IN	120

3.1.14 Protection and fault conditions

The following tables show different fault conditions and protection features on the Dual Buck Evaluation Board.

Table 9 Protection and fault conditions

Parameter	ADC pin voltage	PSOC™ C3M5 pin	Cut off all MOSFETs PWM when any one of the below conditions is true
Input voltage	1.5 V at 24 V VIN	A7	If VIN is less than 12 V or more than 42 V
Temperature sensors	1.3 V at 75 degrees	B5	If temperature is more than 75 degrees
	1.3 V at 75 degrees	P8.0	If temperature is more than 75 degrees
Output current	1.5 V at 3 A IOUT1	A6	If IOUT1 is more than 3 A
	1.5 V at 3 A IOUT2	B4	If IOUT2 is more than 3 A
Output voltage	1.2 V at 5 V VOUT1	A0	If VOUT1 is less than 4 V and more than 6 V
	1.2 V at 5 V VOUT2	A5	If VOUT2 is less than 4 V and more than 6 V

Table 10 User button and LED status

Signal	PSOC™ C3M5 pin	Implementation
P60_LOAD1_PWM	P6.0	1 Hz PWM signal, 30% Duty cycle
P61_LOAD2_PWM	P6.1	1 Hz PWM signal, 30% Duty cycle
FAULT_LED	P3.0	Glows solid when any of the fault conditions are triggered
ACT_LED	P3.1	Glows solid when the buck converter is started Blinks when transient load is enabled OFF when the buck converter is stopped
USER_BUTTON	P9.4	At 1st press buck converter starts At 2nd press transient load is enabled At 3rd press buck converter is stopped

4 Production data

The board has been designed with Allegro. The full PCB design data (schematics, layout, and BOM) of this board can also be downloaded from the kit webpage.

Revision history

Document revision	Date	Description of changes
**	2024-06-18	Initial release
*A	2024-08-01	Updated the document name Replaced the word "Expansion" with "Evaluation" in the document
*B	2024-12-13	Updated the sections, tables, and figures.

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