# Infineon Mobile Robot (IMR) power distribution

## DEMO_IMR_PWR_V1 board

## About this document

### Scope and purpose

This document provides a comprehensive functional description and user guide for the DEMO_IMR_PWR_V1 demonstration board. Both hardware and software are shown and explained in detail with additional flowcharts where necessary. Furthermore, a basic quick-start guide is provided for the intended use as the Infineon Mobile Robot (IMR) main processor.

### Intended audience

This document is intended for design engineers, technicians, and developers of electronic systems.

### Infineon components featured

- XMC1404-F064X0200 AA: XMC™ 32-bit Microcontrollers with Arm® Cortex®-M0 with focus on low-cost embedded control applications
- IRS25411SPBF: High-voltage, high-frequency buck controller
- XDPE12254C-0000: XDP™ 4+1 phase dual-loop digital multiphase controller
- TDA21490: OptiMOS™ integrated power stage, reliable voltage regulator
- ISC080N10NM6: OptiMOS™ 6 power MOSFET
- BTS71033-6ESA: SPI power controller, six high-side switches with diagnostics and protection functions
- TLF1963TE: Low dropout voltage of 340 mV; adjustable output voltage from 1.21 V to input voltage
- TLS208D1EJV33: 3.3 V fixed linear voltage regulator
- TLE9351BVSJ: High-speed automotive CAN transceiver (CAN and CAN FD)

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## Safety precautions

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

**Table 1 Safety precautions**

| | |
|---|---|
| | **Warning:** *The DC link potential of this board is up to 1000 VDC. When measuring voltage waveforms by oscilloscope, high-voltage differential probes must be used. Failure to do so may result in personal injury or death.* |
| | **Warning***: The evaluation or reference board contains DC bus capacitors, which take time to discharge after removal of the main supply. Before working on the drive system, wait 5 minutes for capacitors to discharge to safe voltage levels. Failure to do so may result in personal injury or death. Darkened display LEDs are not an indication that capacitors have discharged to safe voltage levels.* |
| | **Warning:** *The evaluation or reference board is connected to the grid input during testing. Hence, high-voltage differential probes must be used when measuring voltage waveforms by an oscilloscope. Failure to do so may result in personal injury or death. Darkened display LEDs are not an indication that capacitors have discharged to safe voltage levels.* |
| | **Warning:** *Remove or disconnect power from the drive before you disconnect or reconnect wires, or perform maintenance work. Wait five minutes after removing power to discharge the bus capacitors. Do not attempt to service the drive until the bus capacitors have discharged to zero. Failure to do so may result in personal injury or death.* |
| | **Caution:** *The heat sink and device surfaces of the evaluation or reference board may become hot during testing. Hence, necessary precautions are required while handling the board. Failure to comply may cause injury.* |
| | **Caution:** *Only personnel familiar with the drive, power electronics and associated machinery should plan, install, commission and subsequently service the system. Failure to comply may result in personal injury and/or equipment damage.* |
| | **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:** *A drive that is incorrectly applied or installed can lead to component damage or reduction in product lifetime. Wiring or application errors such as undersizing the motor, supplying an incorrect or inadequate AC supply, or excessive ambient temperatures may result in system malfunction.* |
| | **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.* |

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# 1 Introduction

## 1.1 Mobile robot general description

Mobile robots are now common in applications from logistics, warehouse centers, production sites, hospitals, restaurants, schools, and as last-mile package-delivery vehicles. On a high level, mobile robots are of two main types:

- **Automated guided vehicles (AGV):** “Fixed” vehicles that follow predefined paths using lasers, barcodes, radio waves, vision sensors, or magnetic tapes for navigation
- **Autonomous mobile robots (AMR):** “Not fixed”, and do not need external paths as these use autonomous mapping, localization, navigating, and obstacle avoidance by using sensors

Usually, the robots are battery-powered where the voltage level depends on the size and weight characteristics.

## 1.2 IMR description

The board described in this document is primarily targeted to be used in combination with the Infineon Mobile Robot (IMR). The IMR is a comprehensive robotic platform intended to be used with a wide variety of different boards (sensors, motor control, wireless communication, battery management, etc.).

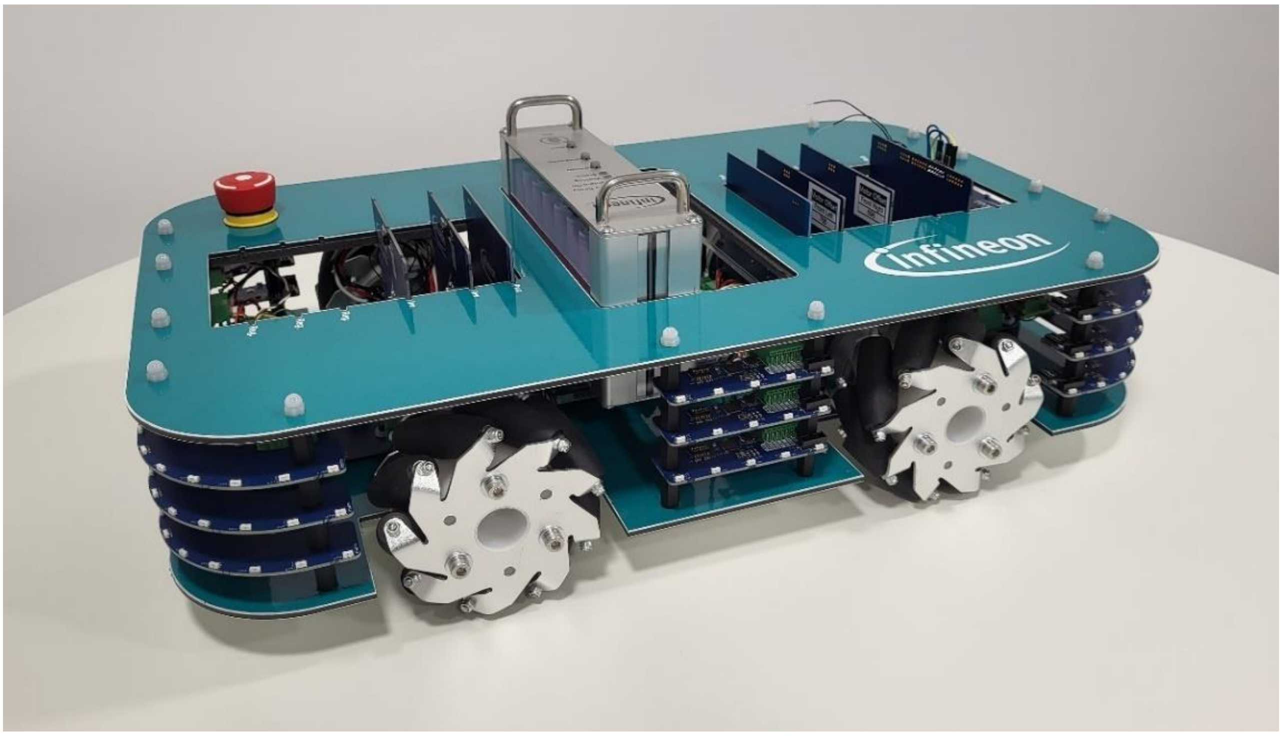


**Figure 1** **Isometric view of the IMR**

The overall target of the IMR is to provide a demonstration platform for autonomous service robot functionalities using Infineon components.

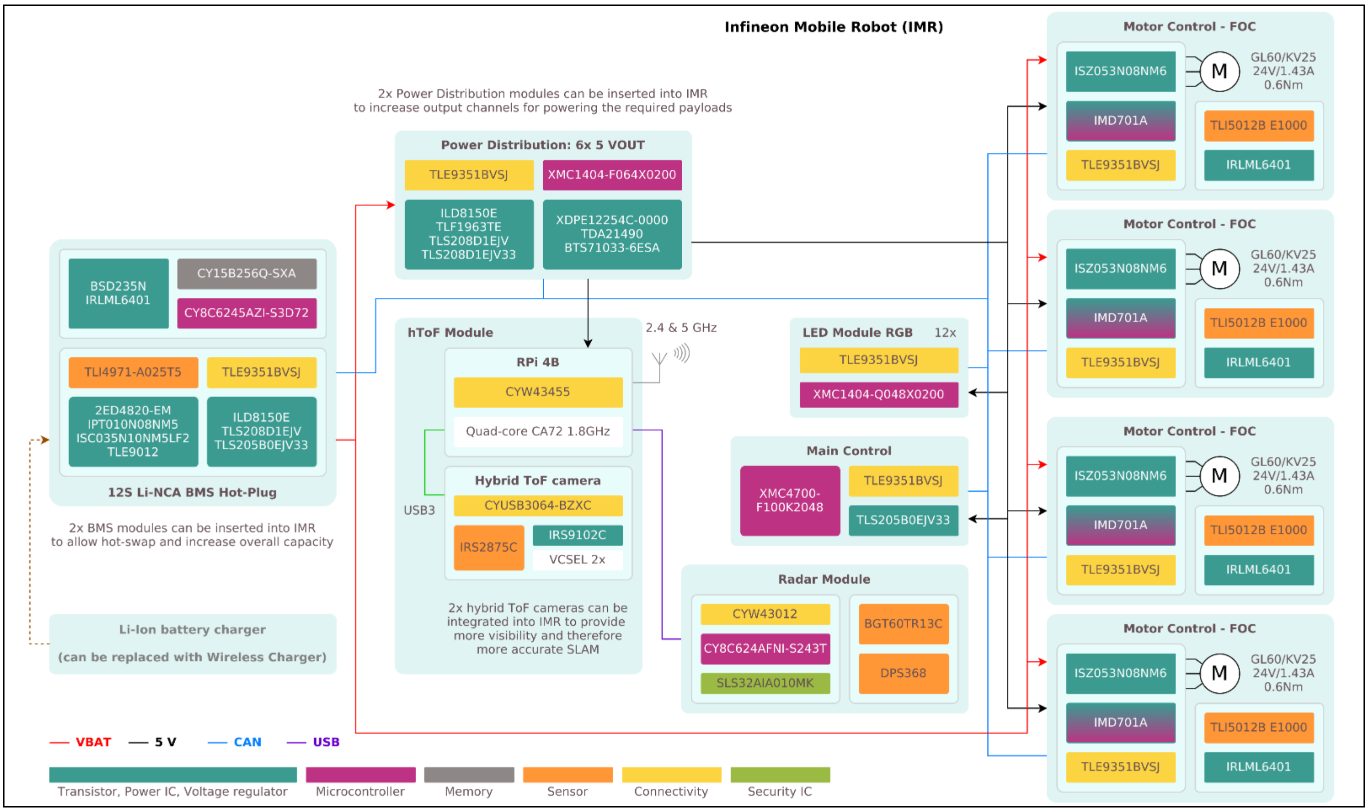


**Figure 2** Overview of the IMR with the board described in this document highlighted in red

## 1.3 Demo board description

The DEMO_IMR_PWR_V1 board serves as a specialized modular power distribution (PD) solution designed to easily integrate with the IMR via the card-edge connector available on the IMR motherboard (see IMR structural boards user guide). The XMC1404 series Arm® Cortex®-M0 MCU on the board controls the operation of the multiphase buck converter and power controller, and reads current measurements at the output. The board is powered by the IRS25411SPBF buck converter, which processes input voltages up to 100 V and provides a 12 V output. This output powers the four power stages of TDA21490.

After the initial step-down conversion, a TLF1963TE linear regulator regulates the 12 V down to 5 V. This regulation is required to provide the VDD and VCC supplies of the TDA21490 integrated power stage and the TLE9351VSJ CAN transceiver. In addition, the TLS208D1EJV33 linear regulator regulates the 5 V supply voltage down to 3.3 V. This voltage supports the following:

- XMC1404 MCU
- BTS71033-6ESA power controller
- XDPE12254C-0000 digital dual-rail 4+1 phase controller

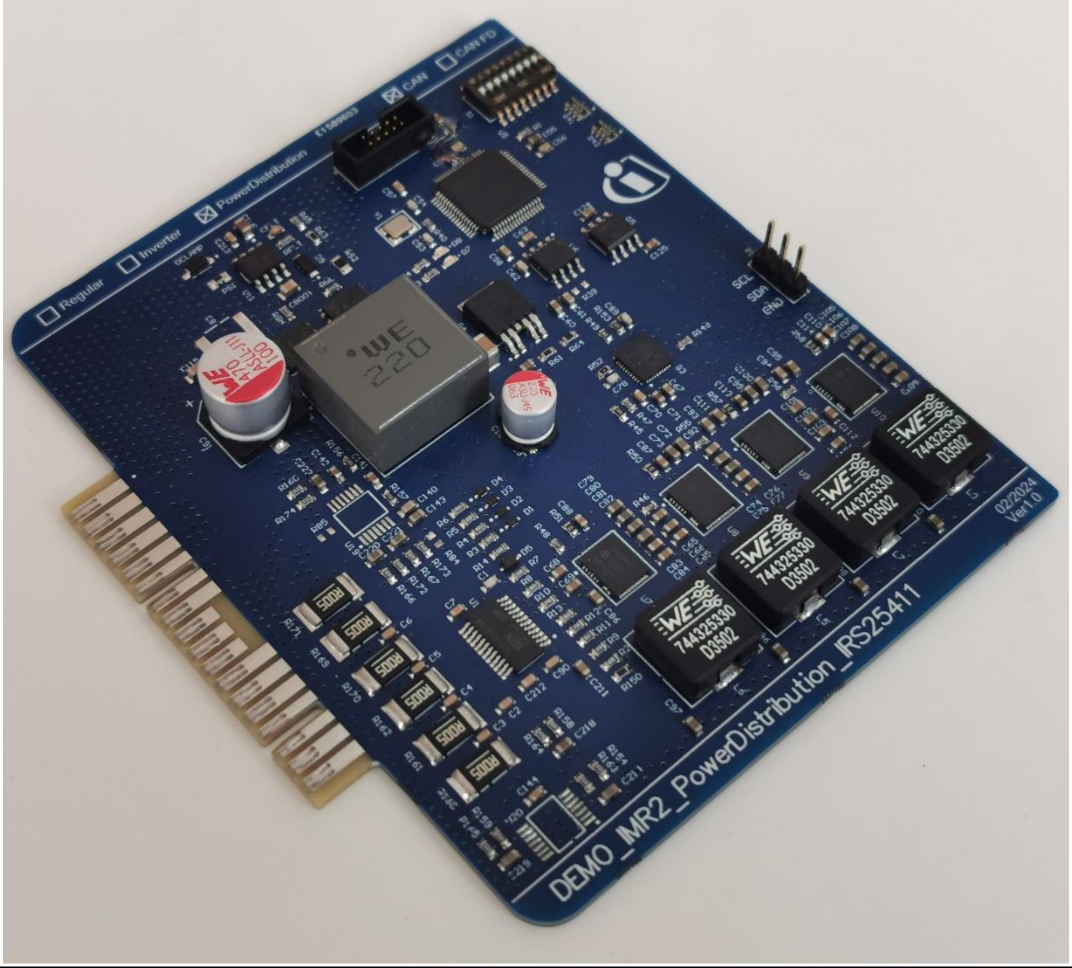


**Figure 3** **DEMO_IMR_PWR_V1 board top view**

## 1.4 Card edge header

The main interface to the IMR is a card edge header on the bottom of the board, as Figure 4 shows; it has 18 pins on the top and bottom sides, so in total 36 pins.


**Figure 4** **Card edge header - top view (18 pins symmetrical, top and bottom)**

The selected counterpart for the card edge header is the EBC18DCWN-S371 board-to-board receptacle connector from Sullins Connector Solutions. Because the CAN interface (CAN_H and CAN_L) is used for all communication, these are the only interface pins required in addition to power connections, as Table 2 shows.

**Table 2** **Pinout of power distribution board slot on the IMR motherboard with the thick row lines marking polarizing key positions**

| PIN | Function | PIN | Function |
|---|---|---|---|
| A1 | CAN_L | B1 | – |
| A2 | CAN_H | B2 | GND |
| A3 | Reserved (for CAN_FD_L) | B3 | Reserved (for CAN_FD_L) |
| A4 | Reserved (for CAN_FD_H) | B4 | Reserved (for CAN_FD_H) |
| A5 | GND | B5 | GND |
| A6 | GND | B6 | GND |
| A7 | Battery voltage (48 V nominal) | B7 | Battery voltage (48 V nominal) |
| A8 | Battery voltage (48 V nominal) | B8 | Battery voltage (48 V nominal) |
| A9 | – | B9 | – |
| A10 | – | B10 | – |
| A11 | – | B11 | – |
| A12 | GND | B12 | GND |
| A13 | 5V_OUT6 (for motor drive 1) | B13 | 5V_OUT6 (for motor drive 1) |
| A14 | 5V_OUT5 (for motor drive 2) | B14 | 5V_OUT5 (for motor drive 2) |
| A15 | 5V_OUT4 (for regular slot inside) | B15 | 5V_OUT4 (for regular slot inside) |
| A16 | 5V_OUT3 (for regular slot middle) | B16 | 5V_OUT3 (for regular slot middle) |
| A17 | 5V_OUT2 (for regular slot outside) | B17 | 5V_OUT2 (for regular slot outside) |
| A18 | 5V_OUT1 (for sensor and LEDs boards) | B18 | 5V_OUT1 (for sensor and LEDs boards) |

# 2 Hardware

This chapter describes the most important hardware parts of the DEMO_IMR_PWR_V1 board.

## 2.1 Input supply voltage

The IRS25411SPBF high-voltage, high-frequency buck controller handles the 48 V supply voltage from batteries. This device is a time-delayed hysteretic synchronous step-down regulator. The output voltage is detected via a voltage divider, which is fed back to the IFB pin and compared with an internal high-precision bandgap reference voltage ($V_{IFBTH}$ = 500 mV). The gate driver outputs (HO and LO of the IC) change state when $V_{IFB}$ rises above and falls below $V_{IFBTH}$. To prevent shoot-through, a fixed dead-time of 140 ns is provided, which is caused by overlapping the switching transitions of MOSFETs [1].

This step-down regulator IC is designed for constant-voltage regulation for an input voltage of up to 100 V and generates an output voltage of 12 V. The OptiMOS™ 6 ISC080N10NM6 MOSFETs used have an $R_{DS(on)}$ = 8.05 mΩ, drain-source voltage ($V_{DS}$) = 100 V, and a drain current ($I_D$) = 75 A [2].

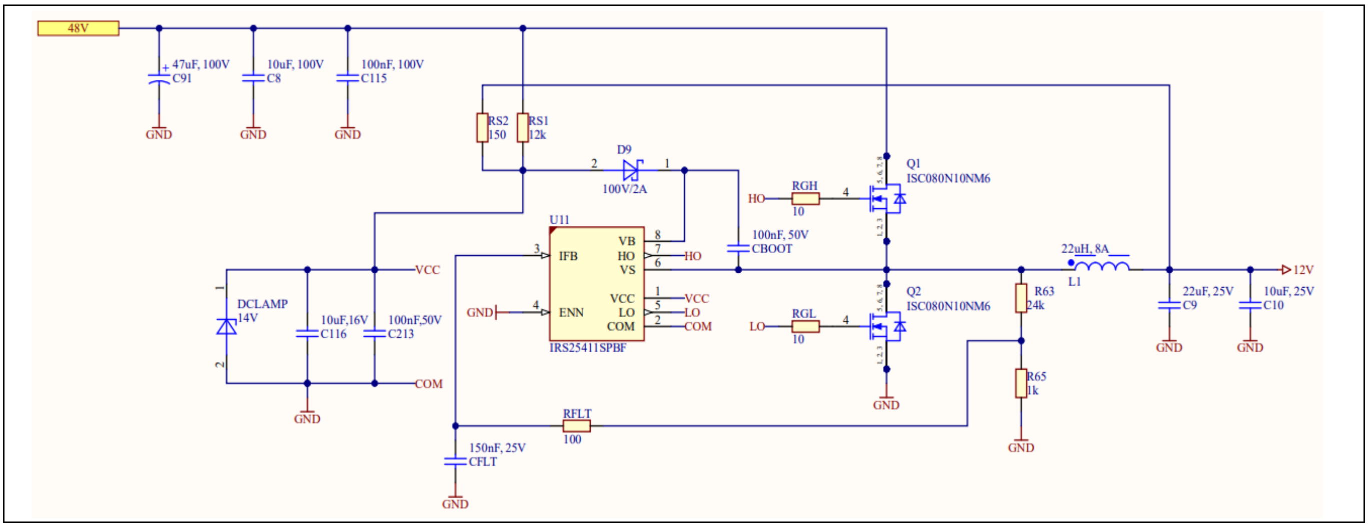


**Figure 5** **IRS25411SPBF voltage regulated synchronous buck converter**

## 2.2 5 V and 3.3 V linear regulator circuits

A TLF1963TE linear voltage regulator is used to provide the required 5 V voltage for additional devices on the board. The 3.3 V voltage for the XMC1404 MCU, power controller, ADC converter etc. is also provided by the TLS208D1EJV33 post regulator.

The TLF1963TE LDO has a very low dropout voltage of 340 mV and is suitable for an output current of up to 1.5 A. The output voltage is adjustable; however, in this application, it is designed for an output voltage of 5 V. The input voltage range can be up to 20 V [4].

TLS208D1EJV33 is selected for ICs with lower $V_{CC}$. This LDO regulates the 5 V input voltage to a fixed 3.3 V output voltage with an accuracy of ±2 %. It supports a static output current of 800 mA and has a very low current consumption (typically 90 µA) [3].

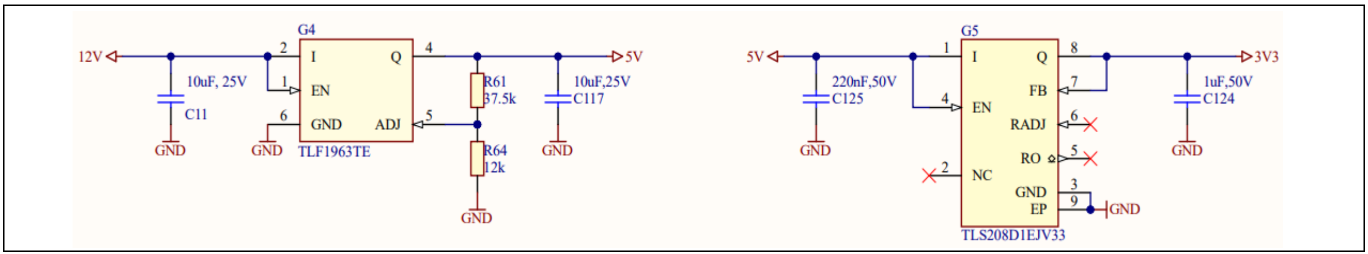


**Figure 6** **Left-side 5 V and on the right-side 3.3 V linear regulator**

## 2.3 Multiphase buck converter

The XDPE12254C-0000 digital multiphase regulator is used in combination with the OptiMOS™ TDA21490 power stage to smooth the residual ripple on the output side and to manage load transients. This regulator is a digital 4+1 phase controller with two rails; only one of the rails with four phases is used in the current application. The phases can be configured so that they can be added or removed autonomously. Command and monitoring functions are controlled via the PMBus®/I2C interface, which supports dynamic voltage identification (DVID) at 10 mV/steps, power states (PS), VR data, and operating register requests [5].

The TDA21490 power stage contains a low quiescent current synchronous buck-gate driver IC packaged together with high-side and low-side MOSFETs. This integration optimizes the operation of the power stage and increases its overall performance. The input voltage range is 4.25 V to 16 V and the output voltage range is 0.25 V to 5.5 V. Several protective functions such as overcurrent protection, thermal shutdown, and phase fault detection are integrated [6].

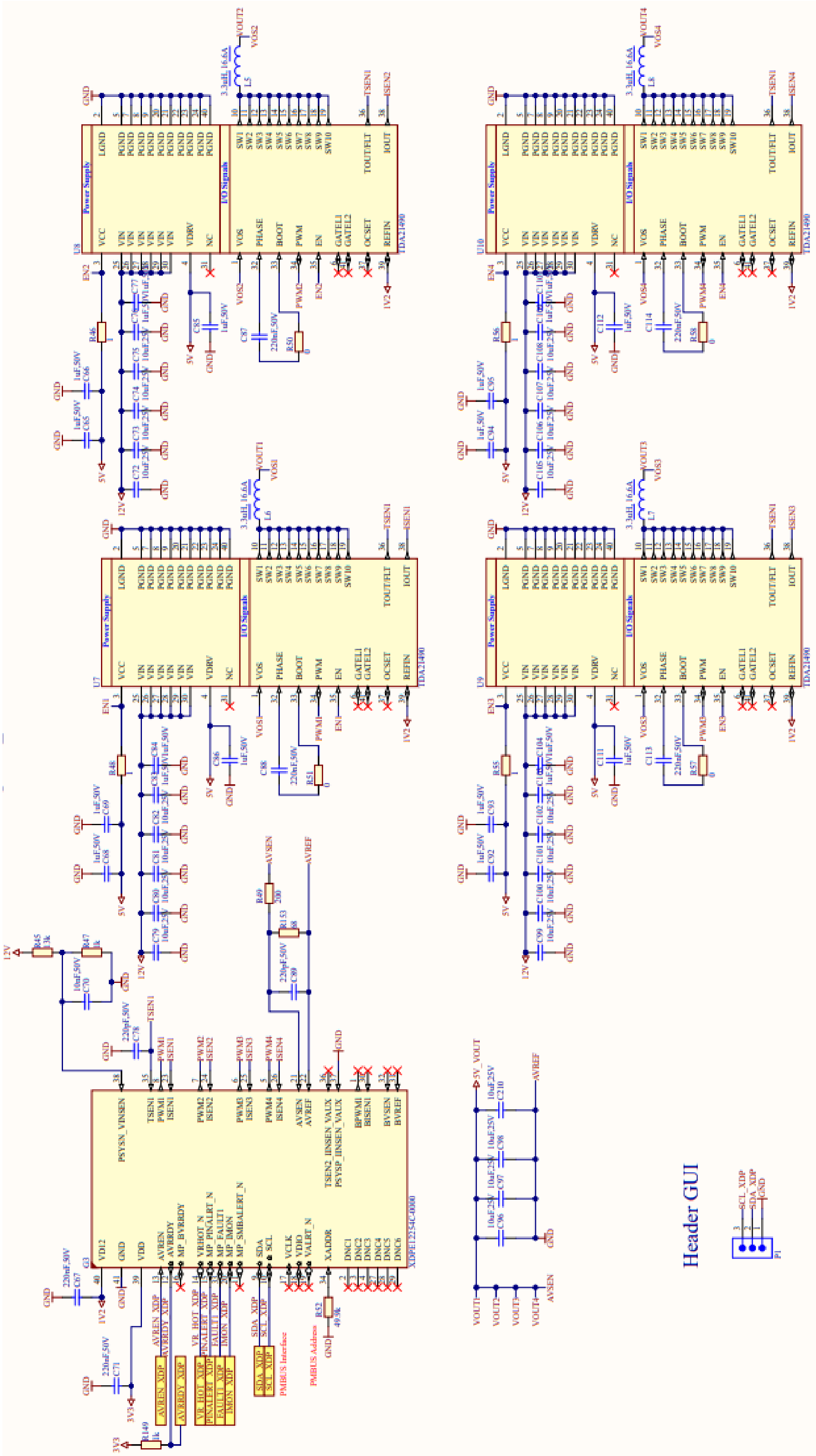

**Figure 7 XDPE12254C-0000 multiphase controller with four power stages TDA21490**

The actual output voltage range is from 0.2 V to 3.04 V, but the feedback path has been changed. A voltage divider was placed between AVSEN and AVREF (see Figure 8). A 200 Ω resistor is placed on the AVSEN track, while a 68 Ω resistor is placed between AVSEN and AVREF. In this configuration, it is possible to obtain an output voltage of 5 V. It is also necessary to make a small change in the software, but this is described later in the Software section.

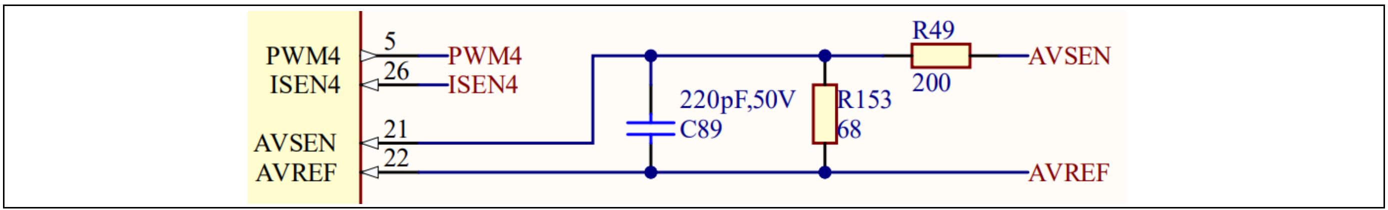


**Figure 8 Voltage divider between AVSEN and AVREF to get 5 V output voltage**

## 2.4 Power controller

The BTS71033-6ESA SPI power controller switches the six output channels OFF or ON; this device is a high-side switch that offers diagnostic and protective functions, and provides six output channels with three outputs at 1.5 A (in channel 0, 4 and 5) and three outputs at 3 A (in channel 1 to 3). Each channel can be switched ON/OFF via the SPI interface. The minimum operating voltage is 4.1 V, and the maximum operating voltage is 28 V. See Figure 9 for the circuit diagram [7].

It is also possible to switch the channels from 0-3 ON and OFF via the IN0 to IN3 pins with the GPIO pins of XMC1404.

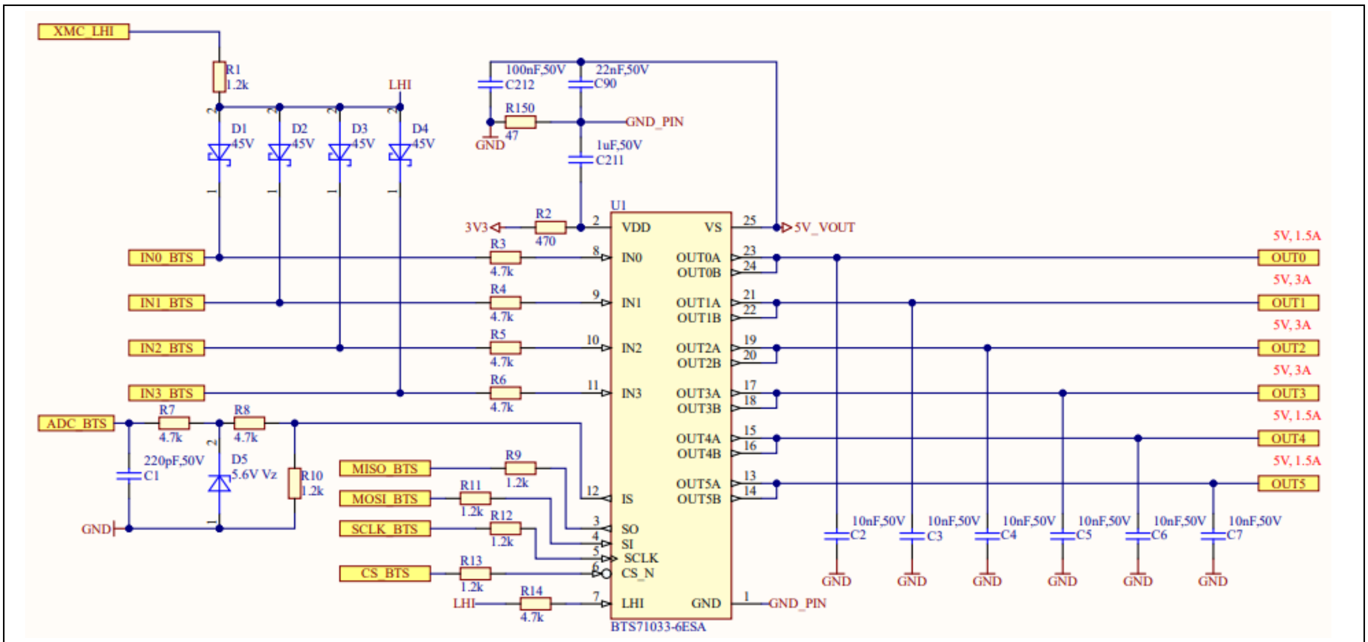


**Figure 9 BTS71033-6ESA SPI power controller with six channels**

## 2.5 Current measurement

The output current of each channel is measured with the integrated current sensing of the BTS71033-6ESA. With the IS pin, the analog signal is transferred to the ADC of the XMC1404-F064X0200 AA. The selection of the channel is done via software.

## 2.6 CAN ID selector

The following dip switch has been implemented to uniquely identify each card connected via the CAN bus. Each pin is pulled up via a 20 kΩ resistor and therefore provides an inverted logic that must be taken into account when reading the pin via the XMC1404 microcontroller. The DIP switch for the power board must be configured as shown in Table 3.

**Table 3 DIP switch S1 – CAN node identifier logic and pin assignment**

| CAN ID Bit | ID8 | ID7 | ID6 | ID5 | ID4 | ID3 | ID2 | ID1 |
|---|---|---|---|---|---|---|---|---|
| XMC™ pin | P2_6 | P2_7 | P2_8 | P2_9 | P2_10 | P2_11 | P2_12 | P2_13 |
| DIP Switch | 0 | 0 | 0 | 0 | 0 | 0 | 0 | PWR[0] |

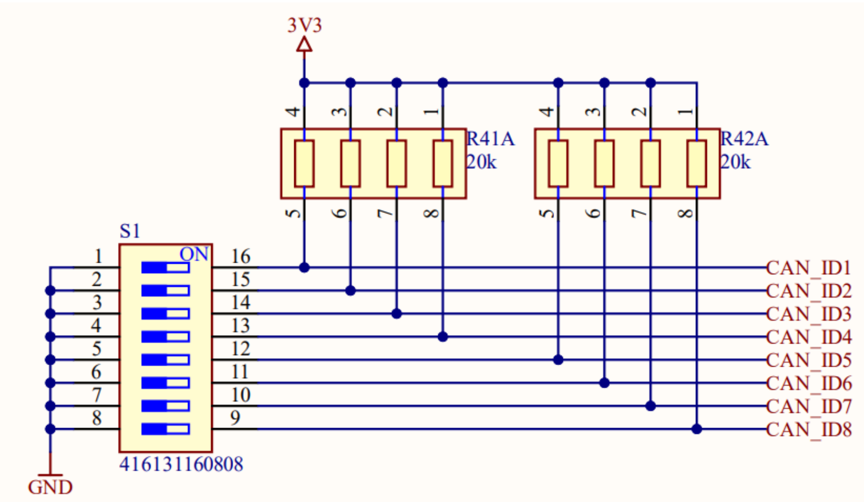


**Figure 10 CAN node ID circuit with 8-pin DIP switch**

## 2.7 Microcontroller unit

The main controller on this board is the XMC1404 F064X0200 AA MCU. This device is a 32-bit microcontroller with Arm® Cortex®-M0 with focus on low-cost embedded control applications [8].

Table 4 shows only the main connection assignment for the power distribution board.

**Table 4 XMC1404-F064X0200 AA main pin assignment overview**

| Port number | Pin name | Description |
|---|---|---|
| P0_0 | MISO_BTS | MISO pin from BTS71033-6ESA |
| P0_1 | MOSI_BTS | MOSI pin from BTS71033-6ESA |
| P0_3 | SCLK_BTS | Clock pin from BTS71033-6ESA |
| P0_4 | CS_BTS | Chip Select pin from BTS71033-6ESA |
| P0_6 | AVREN_XDP | Active HIGH Output Enable input from XDPE12254C |
| P0_7 | AVRRDY_XDP | Voltage regulator “Ready” output signal from XDPE12254C |
| P0_14 | SWD | Single bidirectional data pin, debug interface |
| P0_15 | SWCLK | Clock signal to target CPU, debug interface |
| P1_7 | FAULT1_XDP | Multi-purpose pin configurable as FAULT1, or PICAL from XDPE12254C |

| Port number | Pin name | Description |
|---|---|---|
| P1_8 | XMC_LHI | Limp Home Input pin from BTS71033-6ESA |
| P2_1 | IMON_XDP | Current monitoring from XDPE12254C |
| P2_2 | ADC_BTS | Analog pin from BTS71033-6ESA for current measurement |
| P2_3 | PINALERT_XDP | Multi-purpose pin configurable as PINALRT#, PCRIT#, LPM#, or Fast OC Warning from XDPE12254C |
| P2_4 | VR_HOT_XDP | Active LOW external temperature indicator from XDPE12254C |
| P2_6 | CAN_ID8 | CAN node identification pin 8 |
| P2_7 | CAN_ID7 | CAN node identification pin 7 |
| P2_8 | CAN_ID6 | CAN node identification pin 6 |
| P2_9 | CAN_ID5 | CAN node identification pin 5 |
| P2_10 | CAN_ID4 | CAN node identification pin 4 |
| P2_11 | CAN_ID3 | CAN node identification pin 3 |
| P2_12 | CAN_ID2 | CAN node identification pin 2 |
| P2_13 | CAN_ID1 | CAN node identification pin 1 |
| P3_3 | SDA_XDP | SDA pin from XDPE12254C I2C interface |
| P3_4 | SCL_XDP | SCL pin from XDPE12254C I2C interface |
| P4_0 | LED_GREEN | Status LED (green) for XMC1404 |
| P4_1 | LED_RED | Status LED (red) for XMC1404 |
| P4_2 | STB | Standby input pin from TLE9351BVSJ |
| P4_4 | IN3_BTS | Input pin 3 from BTS71033-6ESA to activate Output Channel 3 |
| P4_5 | IN2_BTS | Input pin 2 from BTS71033-6ESA to activate Output Channel 2 |
| P4_8 | CAN_RXD | CAN receive pin from TLE9351BVSJ |
| P4_9 | CAN_TXD | CAN transmit pin from TLE9351BVSJ |
| P4_10 | IN1_BTS | Input pin 1 from BTS71033-6ESA to activate Output Channel 1 |
| P4_11 | IN0_BTS | Input pin 0 from BTS71033-6ESA to activate Output Channel 0 |

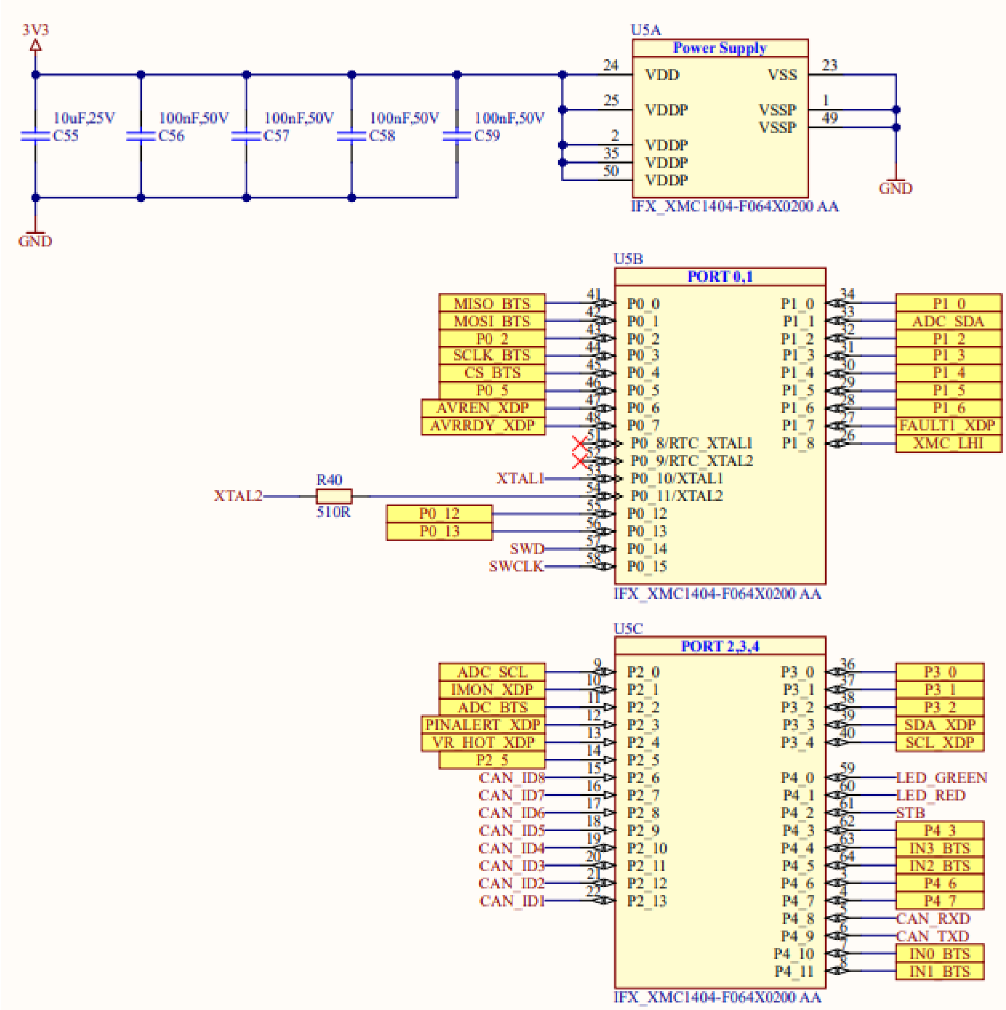


**Figure 11** XMC1404-F064X0200 AA microcontroller

# 3 Software

This chapter focuses on the software of the power distribution board in more detail and how to set up and run.

## 3.1 Software description and flowchart

The initialization process commences with the configuration of peripheral devices using settings derived from the ModusToolbox™, which are stored in the project repository. The overall process is illustrated in the flowchart shown in Figure 12. This is followed by the comprehensive initialization of all devices on the board, in tandem with the state machine. During this phase, various parameters are set, including the current measurement configuration and the power controller's error restart behavior.

Upon completion of the initialization, the program enters the main while loop, where it defaults to the STATE_IDLE state. In this idle state, the program executes a series of checks to verify the operational readiness of the multiphase buck converter and power controller and set both green and red LEDs to be OFF. Additionally, it monitors for fault occurrences. If an error is detected, the program transitions to the STATE_RESET state otherwise, it proceeds to the STATE_RUN state.

In the run state, the program retrieves current measurement values, component states, and error status. It also switches ON the green LED to indicate that the board is functional and currently it enables all output channels. If an error or warning is encountered, the program first clears the error by transitioning to the STATE_RESET state and then re-reads the values. This STATE_RESET is indicated by the green LED that starts to go OFF. If the error persists for ten consecutive occurrences, the state shifts from STATE_RESET to STATE_STOP, which disables all output channels and therefore results in a complete system shutdown. In the STATE_STOP, the red LED will light up to indicate something is wrong with the board.

To reset the persistent errors which cause the system to be in STATE_STOP, the user can simply disconnect and reconnect the power supply. If the error persists, a more in-depth analysis is required. To facilitate this, the user must enter debug mode and step through the program incrementally. Alternatively, the error may be indicative of a hardware issue.

Additionally, during the operation in STATE_RUN, the red LED will blink at a slow rate (currently set at 1 Hz) indicating CAN message transmission for the output current of all 6 switchable outputs. If a CAN message has been received, it will switch off the red LED very shortly, and then the red LED control will be taken over again by the CAN message transmission. However, if the red LED starts to be ON permanently, STATE_STOP may have been entered.

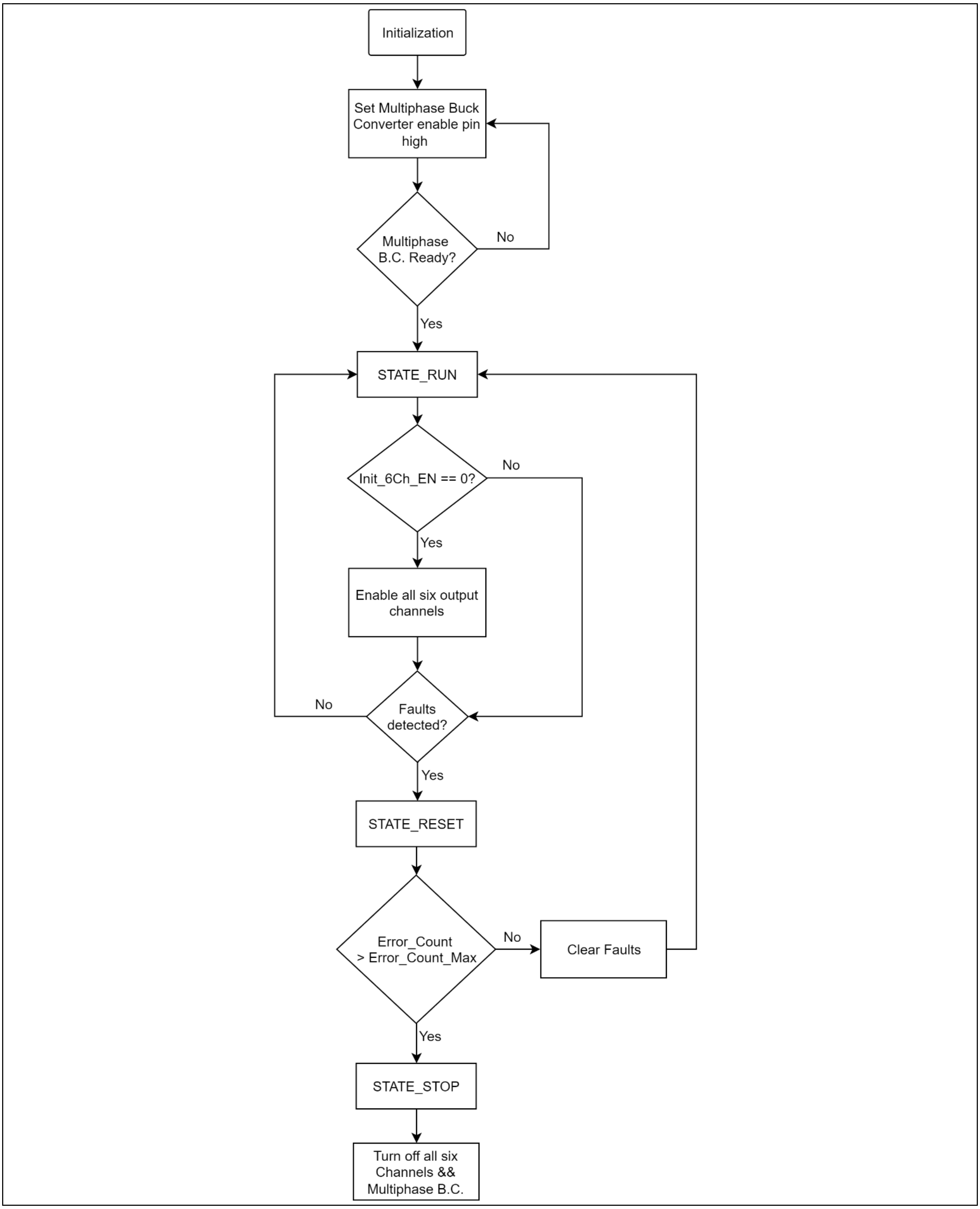


**Figure 12 Flowchart of the power distribution system**

## 3.2 Multiphase buck converter message structure

The communication protocol of the multiphase buck converter is power management bus revision 1.3 (PMBus®). This is an open-standard protocol based on I2C interface. The data formats used for this application of the PMBus® is as follows:

- Send Byte
- Read/Write Byte
- Read/Write Word

**Write type:** XMC1404 sends data to XDPE12254C

The initial stage of the transaction involves sending a start bit, followed by the 7-bit slave address, and concluding with a write bit to signify a write operation. If the slave acknowledges the address by sending an ACK signal, the host proceeds to transmit the 8-bit command. This is then followed by a stop condition, marking the end of the command transmission.

**Read type:** XDPE12254C sends data to XMC1404

To initiate a read transaction, it begins with a normal I2C write transaction, where the slave address is sent along with a write bit. This can be confusing for those new to I2C, as a write bit is used to initiate a read command. The second byte contains the command code, which specifies the data to be retrieved.

Next, a repeated start condition is sent, followed by the slave address and a read bit. This signals the device to return the requested data corresponding to the command code. The slave then transmits the requested byte value.

Here is where the process may seem unusual: the host does not acknowledge (NACK) the received data byte. This may be confusing at first, but it is a deliberate design choice to indicate that the host has finished requesting data. If the host were to NACK the data during the transaction, the slave would stop transmitting data and would not trigger a Clock Mode Lock (CML) fault.

The following section outlines the various protocols involved in this application. Specifically, the slave address used in this context is 0xB0, which corresponds to a resistance value of 49.9 kΩ. Additionally, the command code refers to the specific register of interest that is being targeted.

**Note:**

- **S:** Start bit
- **P:** Stop bit
- **Ack:** Acknowledge bit
- **Nack:** Not acknowledge bit
- **W:** Write bit
- **R:** Read bit

**1-8:** The number above the fields indicates the length in bits

**:** Driven by XMC1404 (Master)

**:** Driven by XDPE12254C (Multiphase Buck Controller)

**Send Byte:** This protocol is used to send the CLEAR_FAULTS command. This command clears all faults, which have been set to the multiphase buck converter.

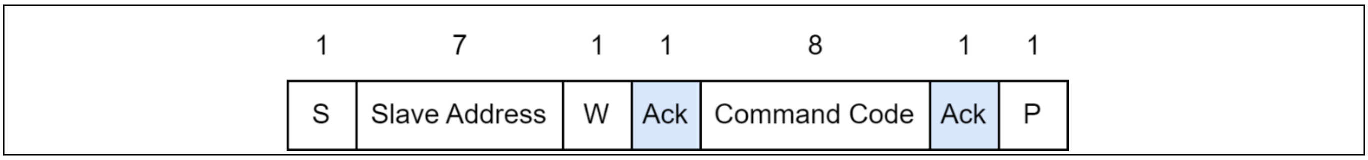


**Figure 13 Send Byte**

**Write Byte:** This protocol is used to send a single byte data to the multiphase buck controller. The 8-bit data byte will be sent to the specific register (command code).

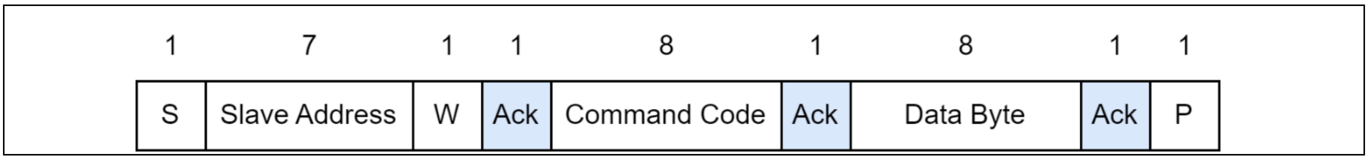


**Figure 14 Write Byte**

**Write Word:** This protocol is used to send two bytes to the multiphase buck controller.

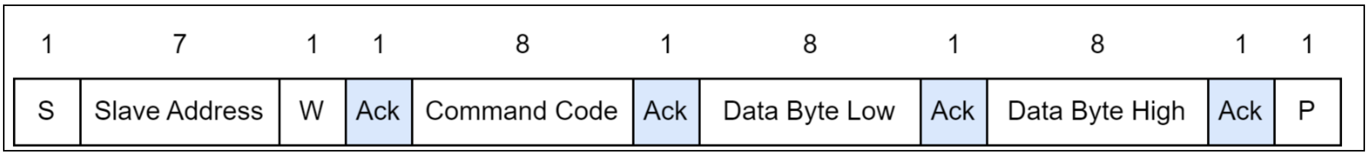


**Figure 15 Write Word**

**Read Byte:** The read byte protocol is used to read out a one byte data from the multiphase buck converter.

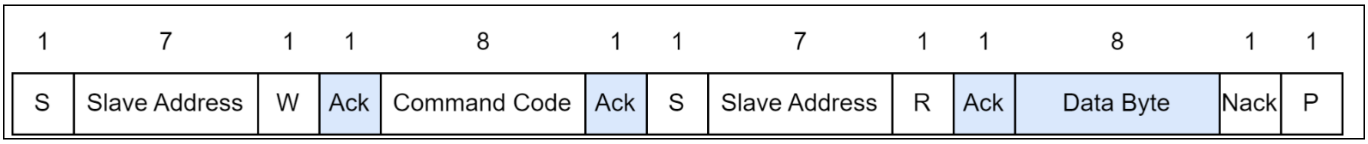


**Figure 16 Read Byte**

**Read Word:** The read word protocol is used to read out two bytes from the multiphase buck converter.

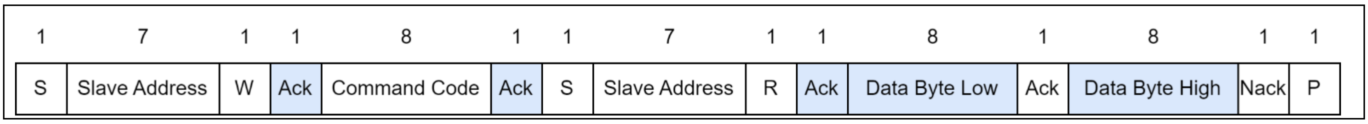


**Figure 17 Read Word**

It is important to know the bit order, which is used for the PMBus® protocol. The most significant bit (MSB) is bit '7' and the least significant bit (LSB) is bit '0' as shown in Figure 18.

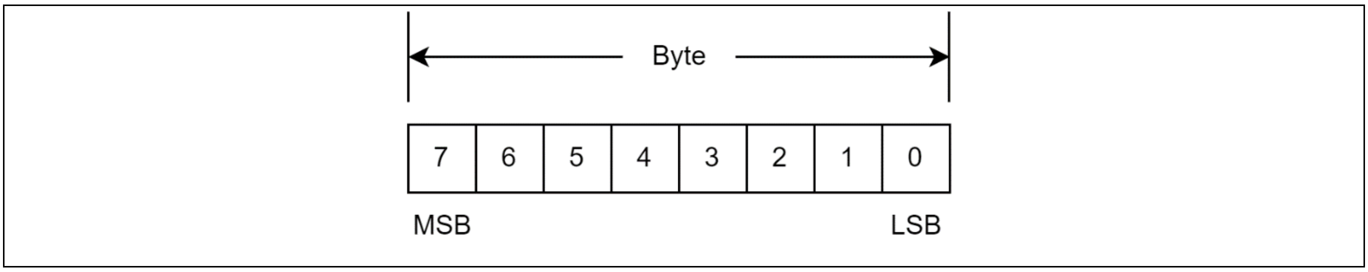


**Figure 18 Bit order**

The whole PMBus® library can be downloaded at the Infineon website by inserting PMBus® Library into the search window or click on the link. Here the detailed documentation for the PMBus® is included under the file *Doc*. The user can also visit [9] and [10] for further information on PMBus®.

## 3.3 Power controller message structure

The serial peripheral interface (SPI) is used to communicate with the power controller (BTS71033-6ESA). The SPI is a synchronous serial communication protocol that enables full-duplex data transfer between devices. This interface utilizes four signal lines to facilitate communication [7]:

- SO (Serial Output): Carries data from the slave device to the master device
- SI (Serial Input): Carries data from the master device to the slave device
- SCLK (Serial Clock): Provides the clock signal that governs the data transfer rate
- CSN (Chip Select): Acts as a control signal to initiate and terminate data transfer

The data transfer process in SPI [7] is as follows:

1. The falling edge of CSN indicates the start of a data transfer cycle
2. Data is transmitted over the SI and SO lines at the rate determined by the SCLK signal
3. The slave device samples the incoming data on the SI line at the falling edge of SCLK
4. The slave device shifts out data on the SO line at the rising edge of SCLK
5. Each data transfer cycle must be terminated by a rising edge of CSN

To ensure data integrity, a modulo 8 counter is employed to guarantee that data is only transferred in multiples of 8 bits. This mechanism prevents incomplete data transfers and maintains data consistency [7].

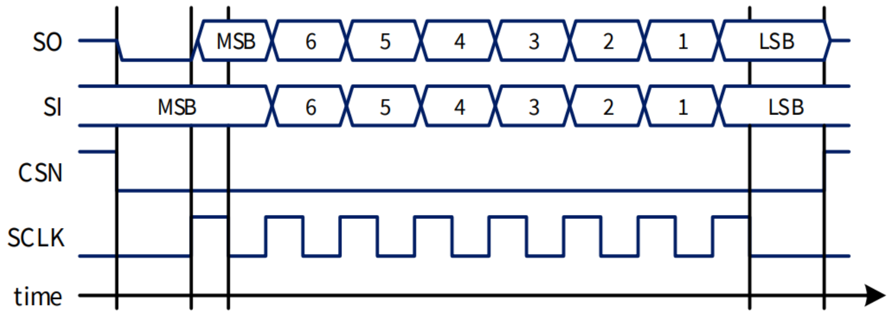


**Figure 19 SPI signals [7]**

**SPI Communication: Understanding the relationship between SI and SO Lines**

Figure 19 illustrates the correlation between the SI and SO line content during SPI communication between the microcontroller (µC) and the BTS71033-6ESA device [7].

**SI Line: Command frames from the microcontroller**

The SI line carries the command frames sent by the microcontroller to the BTS71033-6ESA device. These command frames initiate specific actions or requests for data from the device[7].

**SO Line: Response frames from the BTS71033-6ESA**

The SO line carries the response frames sent by the BTS71033-6ESA device back to the microcontroller. These response frames are generated based on the command frames received from the microcontroller in the previous transmission cycle [7].

**SPI Protocol: Command-response mechanism**

The SPI protocol operates on a command-response principle, where the response to a command frame is only provided during the next transmission cycle triggered by the microcontroller. This means that the BTS71033-6ESA device does not respond immediately to a command frame. Instead, it waits for the next transmission cycle to send its response[7].

**Decoding response frames**

The response frames from the BTS71033-6ESA device can be decoded into specific formats depending on the type of command frame sent by the microcontroller. For write commands, the responses are deterministic and can be decoded into STDDIAG or WRNDIAG frames. However, for read commands, the previous transmission cycle must be considered when decoding the response frame [7].

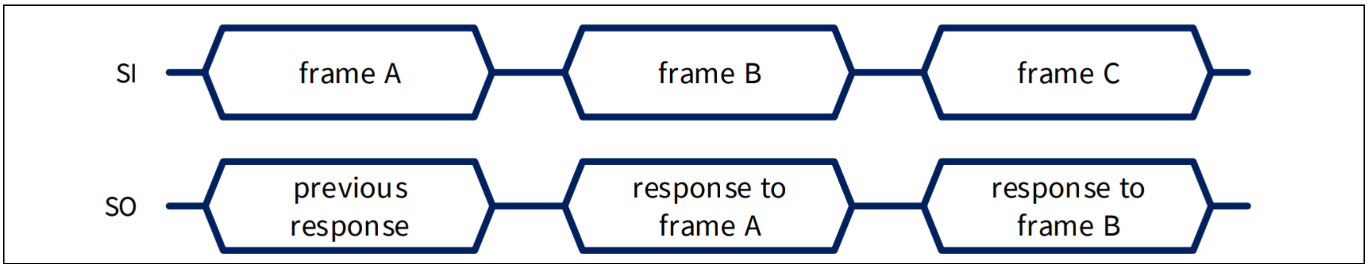


**Figure 20 SPI Protocol [7]**

For more information, see the BTS71033-6ESA datasheet [7].

## 3.4 CAN communication

Currently the PD board is set to transmit the output current of each switchable 5 V channel regularly. Output current of all 6 channels are currently broadcast every 1 second. Additionally, the board is set to receive a CAN message containing enable or disable message for each switchable 5 V channel. Table 5 shows the CAN messages relevant for this board. For every physical signal contained in the data portion, the decoding description is given in italics:

- U/S: Unsigned/Signed
- Factor: Factor with which the value in the CAN data has to be multiplied to arrive at the physical value
- Unit: The unit of the signal

All signals use Big Endianness ("Motorola" convention) for their byte order.

The DIP switch setting on the board is used to differentiate between the PD board located in the front and in the back of the IMR. DIP switch 1 = 0 indicates the front board while DIP switch 1 = 1 indicates the back board. From this setting, each board determines an individual CAN ID for OUTPUT_CURRENT and SET (disable or enable).

**Table 5 CAN messages for PD board**

| | | Byte # | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Command** | **ID** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **Description** | **Rate** |
| PD_CH1TO3_ OUTPUT_CURRENT (front\|back) | 0x280 \|0x281 | Output Current CH1 U, mA | | Output Current CH2 U, mA | | Output Current CH3 U, mA | | | | Output current of each channel from 1 to 3 | 1 Hz |
| PD_CH4TO6_ OUTPUT_CURRENT (front\|back) | 0x290 \|0x291 | Output Current CH4 U, mA | | Output Current CH5 U, mA | | Output Current CH6 U, mA | | | | Output current of each channel from 1 to 3 | 1 Hz |
| PD_CHANNEL_SET (front\|back) | 0x300 \|0x301 | CH1 | CH2 | CH3 | CH4 | CH5 | CH6 | | | Disable (=0) / Enable (=1) each channel | On demand |

# 4 Quick start guide

## 4.1 Equipment

To flash the XMC1404 and the XDPE12254C-0000 the following equipment will be used:

- XMC™ link isolated debug probe
- USB005 USB dongle – interface between GUI and multiphase controller

The USB005 is used to configure the XDPE12254C-0000.

### 4.1.1 XMC™ Link isolated debug probe

The software for the power distribution board was developed utilizing the DAVE™ Integrated Development Environment (IDE). This IDE is available for download at no cost from the Infineon website. Programming and debugging are facilitated through the XMC™ Link isolated debug probe, as depicted in Figure 21 To establish a connection, the DEMO_IMR_PWR_V1 board is linked to the debug probe via the smaller 1.27 mm pitch ribbon cable and the 10-pin box header X1 (note that the larger ribbon cable is not utilized in this setup). It is essential to note that an additional external power supply is required when employing an isolated debugging probe.

**Figure 21 XMC™ Link isolated debug probe [11]**

### 4.1.2 USB005 USB dongle

To initiate the configuration process of the multiphase buck converter, it is necessary to utilize the PowerClient GUI. To establish a connection between the Power Distribution board and the PC, the USB005 dongle (see Figure 22) is required. Notably, the programmer derives its power from the USB port, eliminating the need for an external power supply. Simply connect a USB cable between your PC and the programmer to complete the setup. The next section provides a step-by-step guide on how to download the PowerClient GUI and configure the multiphase buck controller.


**Figure 22 USB005 overview**

## 4.1.3 PowerClient GUI

To begin, you need to download and install the PowerClient GUI on your system. This is a crucial step to access the program's features.

### 4.1.3.1 Activating the PowerClient license

After successfully installing the PowerClient GUI, you need to insert an activation license to run the program. Figure 23 shows how to activate the license.

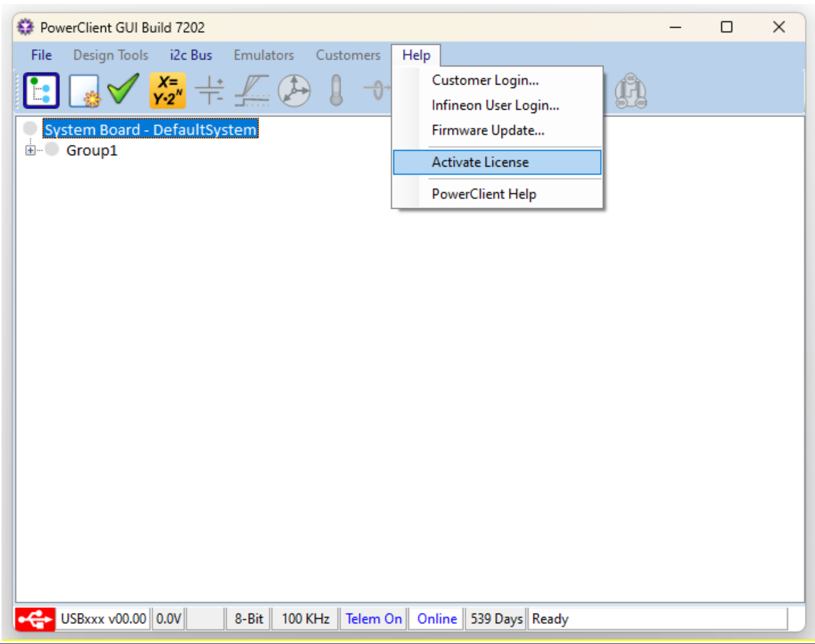


**Figure 23 PowerClient GUI activation license**

The license for the PowerClient GUI is located in the following file part under *Libraries/PMBus/Config_Files/PowerClient_license.txt*.

Also, an initial xsf file (*PMBus_XDPE12254C_Config.xsf*) is located in this folder. This file serves as the configuration file for the multiphase buck controller.

#### 4.1.3.2 Connecting the multiphase buck controller

To establish a connection with the multiphase buck controller, it is essential to utilize the USB005 dongle. Consequently, the cable should be connected to the 3-pin header in such a manner that the black cable is linked to the GND pin, as illustrated in Figure 24 and Figure 25.

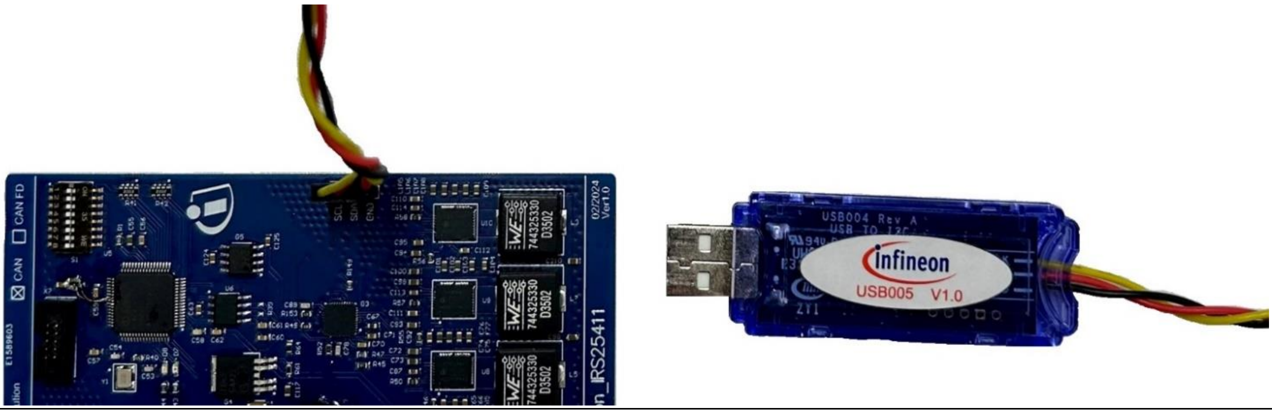


**Figure 24 Connection between power distribution board and USB005**

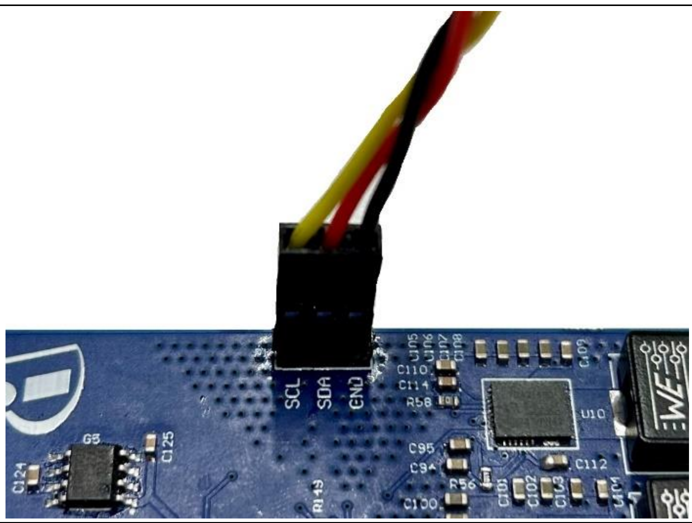


**Figure 25 Pin header to program the digital multiphase controller**

#### 4.1.3.3 Loading the system file to PowerClient

1. Navigate to the **File** menu and select the **Load System File…**

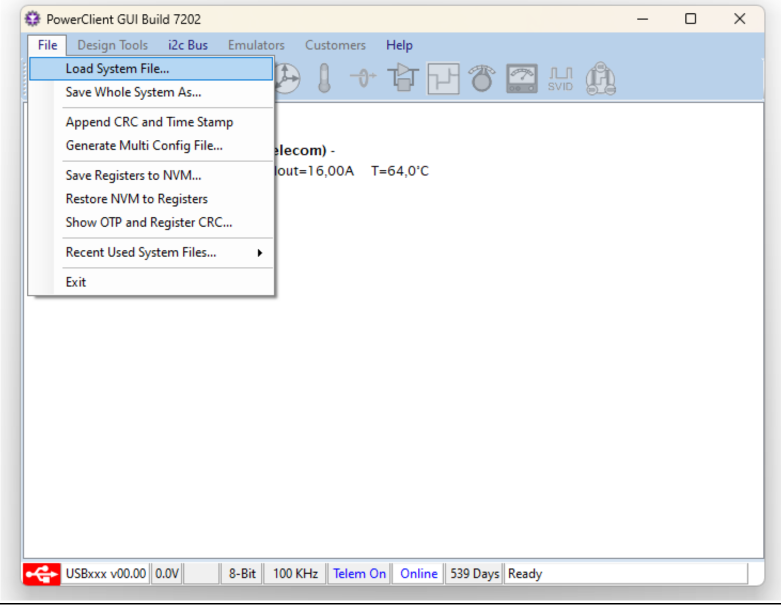


**Figure 26** **Load System File**

2. Select the corresponding configuration file, specifically *PMBus_XDPE12254C_Config.xsf*, and click **Open**. Once the file is loaded, you will notice that black dots are highlighted, indicating that the GUI is currently in offline mode
3. To switch to online mode, click on the yellow-highlighted **Offline** window located at the bottom of the screen

   This action will toggle the GUI to online mode, and the black highlighted dots will subsequently change to green highlighted dots, signifying the transition. A **GuiDeviceSync** window will appear

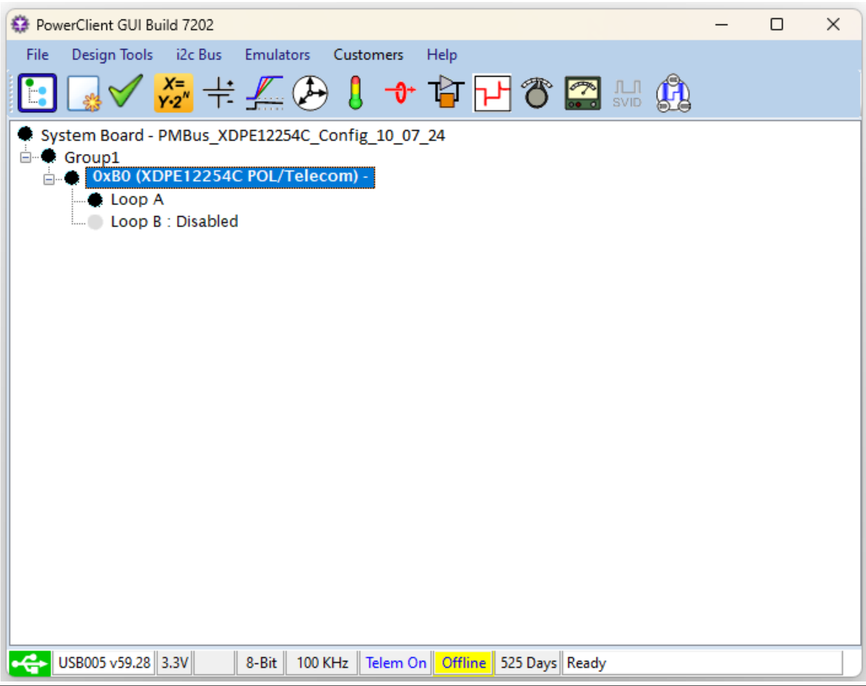


**Figure 27** **Switching from Offline to Online**

4. In the **GuiDeviceSync** window, click **Write to Device 0xB0**
   You now have the option to customize the multiphase buck controller to suit your specific requirements

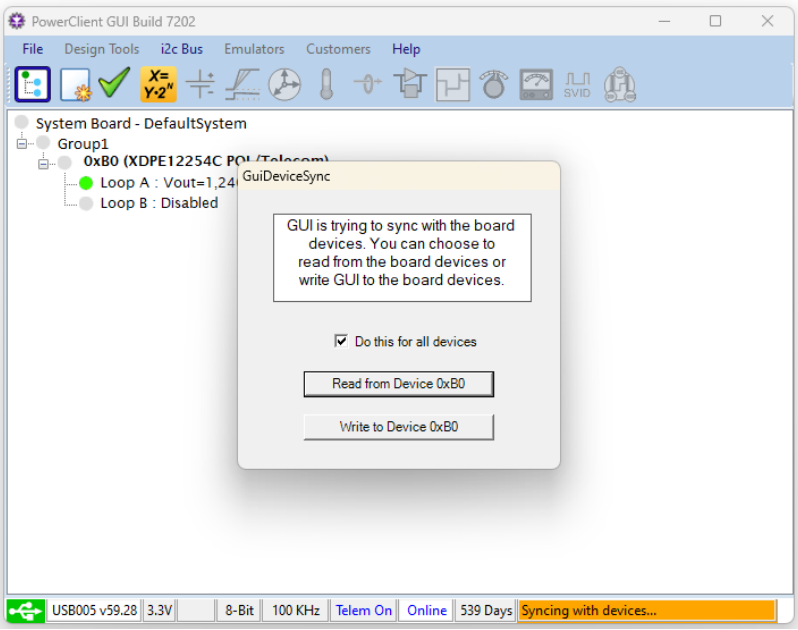


**Figure 28 GUI device synchronization**

To customize the multiphase buck controller, navigate through the buttons at the top bar of the PowerClient GUI, as illustrated in Figure 29.

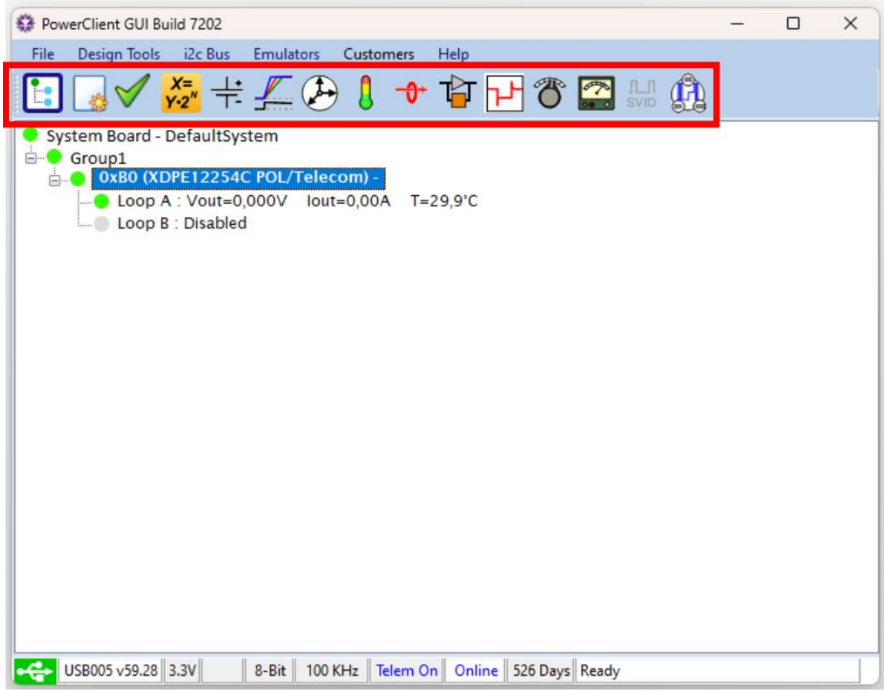


**Figure 29 How to configure the multiphase buck converter**

5. After the tuning the multiphase buck controller is complete, save the updated configuration file to the Non-Volatile Memory (NVM) by navigating to the **File** menu and select **Save Registers to NVM**
   A **Saving to Memory** window will appear, displaying the number of times you can store or restore the configuration file to the Non-Volatile Memory (NVM), with a maximum of 27 instances

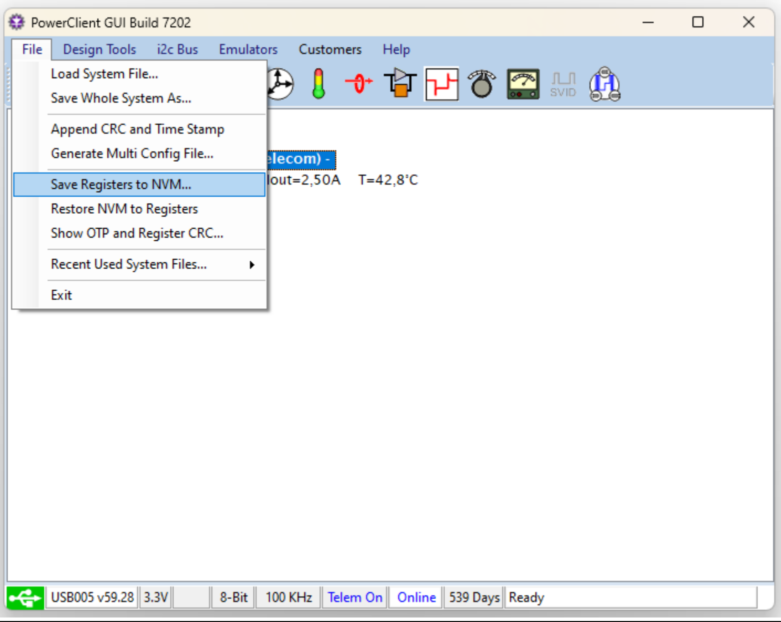


**Figure 30 Save configuration file to NVM (non-volatile memory)**

6. Click **Upload** to program the multiphase buck controller permanently, storing the configuration file in the NVM

With the configuration file successfully uploaded to the NVM, the PowerClient GUI is no longer required, and the multiphase buck converter can now operate independently. If any adjustments or modifications are needed for the multiphase buck controller, you can simply revisit the PowerClient GUI to make the necessary changes.

### 4.1.4 Import the ModusToolbox™ project

To import the software into the ModusToolbox™, navigate to the **File** menu, select **Import**, choose the **ModusToolbox™** and then click **Import Existing Application In-Place**.

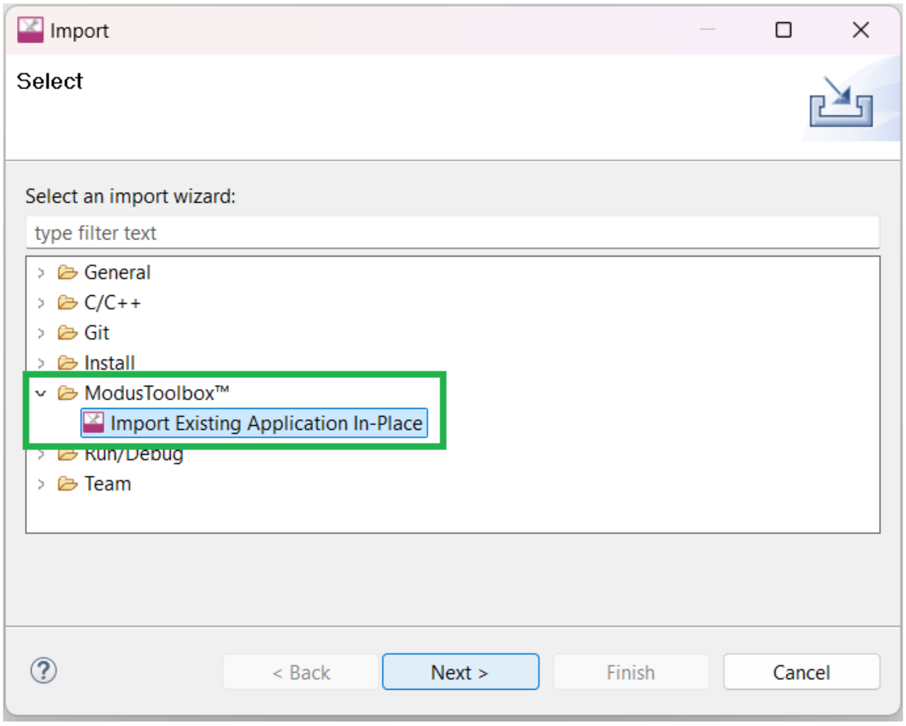


**Figure 31 Import Project into ModusToolbox™ IDE**

Once the project has been successfully imported into the ModusToolbox™, its contents can be located in the **C/C++ Projects** tab, as illustrated in the following figure.

The *main.c* file contains the primary source code, while the **Libraries** folder houses additional subfolders, which in turn contain the *.c* and *.h* files specific to the BTS71033-6ESA, CAN, PMBus®, and State Machine components, in addition to the ADC driver for current measurement and SPI driver to connect the XMC™ 1404 microcontroller and BTS71033-6ESA.

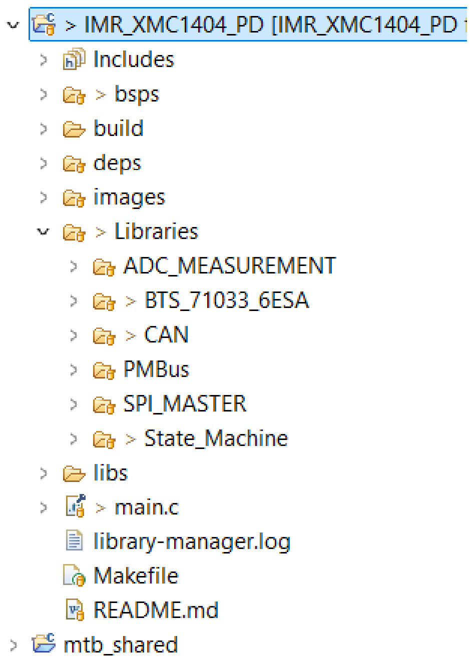


**Figure 32 ModusToolbox™ Project tree**

## 4.2 Update libraries and build the application

In ModusToolbox™, generic libraries are located in *mtb_shared* folder and it is sometimes necessary to update the libraries of the project prior to building it.

To update the libraries of the project, **right click on the project folder** and select **ModusToolbox™** followed by **Library Manager**, depending on the current version, as shown in Figure 33. In the Library Manager window, click **Update** and when the update is done and successful, the window can be closed (see Figure 34).

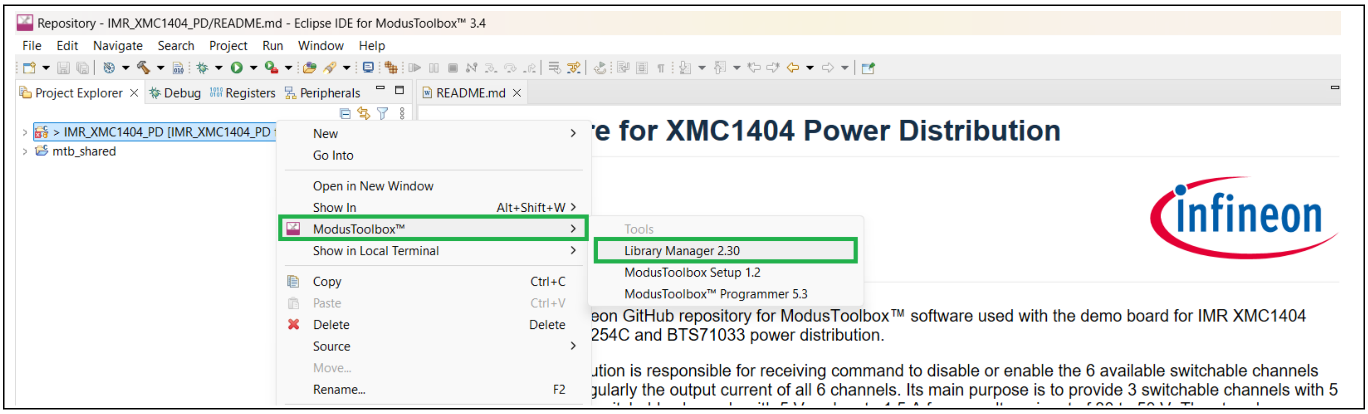


**Figure 33 Updating libraries of the project via Library Manager**

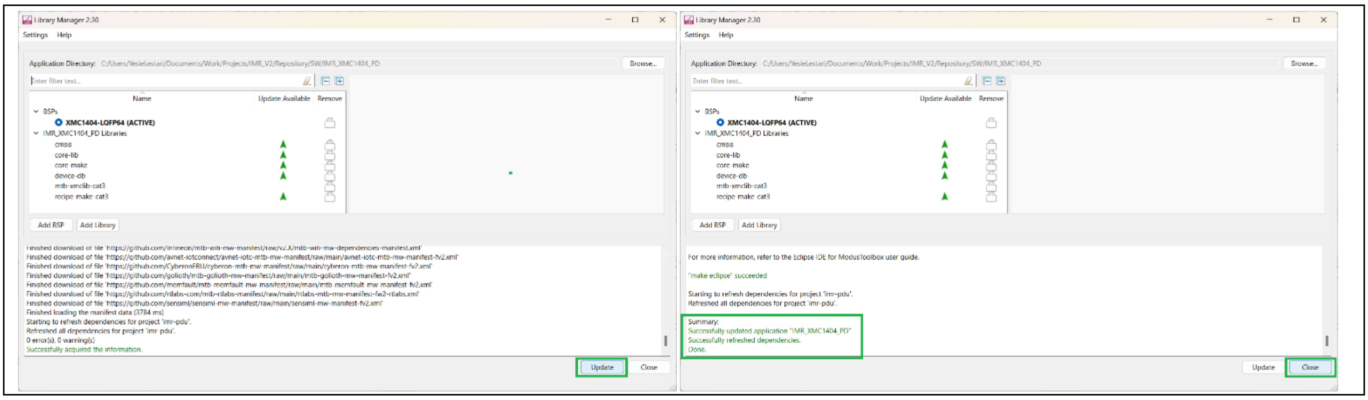


**Figure 34 Libraries update process and result summary**

When the libraries are updated, the project can now be cleaned and compiled to allow the program to be flashed to the microcontroller.

Under the **Quick Panel of ModusToolbox™**, click **Clean Application** followed by **Build Application** to compile the software.

To flash the compiled result, go to **Launches** section and click **IMR_XMC1404_PD Program (JLink)** while ensuring that the XMC™ Link programmer is connected to the SWD connector of the board and the board is powered separately.

## 4.3 CAN node identification

Before using the board in a system e.g., IMR, it is essential to set the unique ID of the CAN node. This is accomplished using the 8-pin DIP switch S1, which was previously described in the hardware section. Each switch pin is connected to the XMC1404 microcontroller, with a 20 kΩ pull-up resistor to 3.3 V. Notably, the switch pins operate with inverted logic, where the ON state corresponds to a logic low and the OFF state corresponds to a logic high on the XMC1404 side.

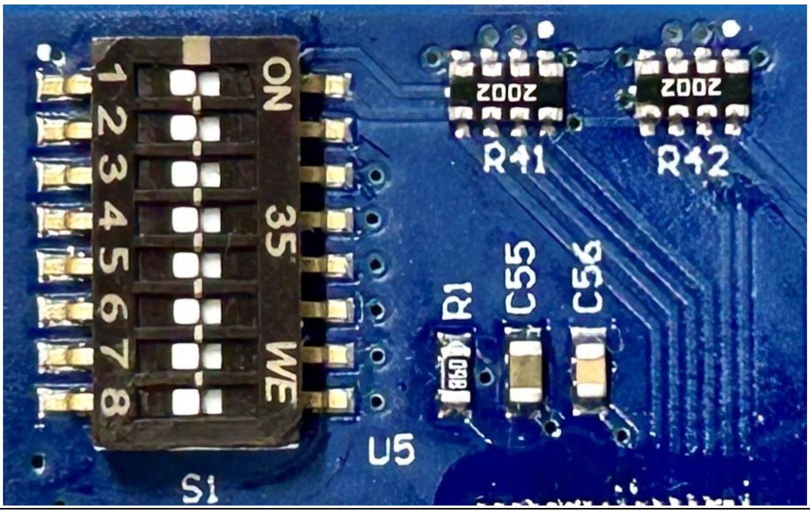


**Figure 27 CAN ID 8-pin DIP Switch selection**

**Example:** This example describes the result of the following switch position on the CAN node identifier module.

**Table 7 DIP switch S1 – board identifier example**

| CAN ID Bit | Pin 8 – MSB | Pin 7 | Pin 6 | Pin 5 | Pin 4 | Pin 3 | Pin 2 | Pin 1 – LSB |
|---|---|---|---|---|---|---|---|---|
| Switch number | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| Switch position | OFF | OFF | OFF | OFF | OFF | OFF | OFF | ON |
| PD ID | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

This example DIP switch configuration sets the CAN node identifier for the DEMO_IMR_PWR_V1 board as [1] and together with the CAN message IDs that are shown in Table 5, particular message identifiers are clearly specified and this helps all boards in the system to communicate well in the CAN bus.

# 5 Bill of materials (BOM)

**Table 6 Bill of materials**

| Designator | Manufacturer | Part number | Quantity | Value |
|---|---|---|---|---|
| C60, C63, C64, C65, C66, C68, C69, C76, C77, C83, C84, C85, C86, C92, C93, C94, C95, C103, C104, C109, C110, C111, C112, C124, C211 | Würth Elektronik | 885012206126 | 25 | 1µF, 50VDC |
| C53, C54 | TDK Corporation | C1608C0G1H080D080AA | 2 | 8pF |
| C2, C3, C4, C5, C6, C7, C70 | Würth Elektronik | 885012206089 | 7 | 10nF, 50VDC |
| C116 | Würth Elektronik | 885012107014 | 1 | 10µF, 16VDC |
| C55, C72, C73, C74, C75, C79, C80, C81, C82, C96, C97, C98, C99, C100, C101, C102, C105, C106, C107, C108, C117, C210 | Würth Elektronik | 885012106031 | 22 | 10µF, 25VDC |
| C11 | Würth Elektronik | 885012209028 | 1 | 10µF, 25VDC |
| C90, CFLT | Würth Elektronik | 885012206091 | 2 | 22nF, 50VDC |
| C10, C91 | Würth Elektronik | 865060857005 | 2 | 47µF, 100V |
| C56, C57, C58, C59, C61, C62, C212, C213 | Würth Elektronik | 885012206095 | 8 | 100nF, 50VDC |
| CBOOT | Würth Elektronik | 885012207098 | 1 | 100nF, 50VDC |
| C115 | Würth Elektronik | 885012207128 | 1 | 100nF, 100VDC |
| C67, C71, C87, C88, C113, C114, C125 | Würth Elektronik | 885012206125 | 7 | 220nF, 50VDC |
| C1, C78, C89 | Würth Elektronik | 885012006059 | 3 | 220pF, 50VDC |
| D5 | Vishay | BZX584C3V3-V-G-08 | 1 | 3.3V Vz |
| DCLAMP | Diodes Incorporated | DDZ9701-7 | 1 | 14V |
| D1, D2, D3, D4 | Infineon Technologies | BAS52-02V | 4 | 45V |
| D9 | ROHM Semiconductors | RB068MM100TFTR | 1 | 100V/2A |
| D8 | Würth Elektronik | 150060GS55040 | 1 | Green |
| D7 | Würth Elektronik | 150060RS55040 | 1 | Red |
| G3 | Infineon Technologies | XDPE12254C-0000 | 1 | XDPE12254C-0000 |
| G4 | Infineon Technologies | TLF1963TE | 1 | TLF1963TE |
| G5 | Infineon Technologies | TLS208D1EJV33 | 1 | TLS208D1EJV33 |
| L5, L6, L7, L8 | Würth Elektronik | 744325330 | 4 | 3.3uH, 16.6A |
| L1 | Würth Elektronik | 74439370220 | 1 | 22uH, 8A |

| Designator | Manufacturer | Part number | Quantity | Value |
|---|---|---|---|---|
| P1 | Würth Elektronik | 61300311121 | 1 | |
| Q1, Q2 | Infineon Technologies | ISC080N10NM6 | 2 | ISC080N10NM6 |
| R50, R51, R57, R58 | Vishay | CRCW06030000Z0EB | 4 | 0R |
| RS2 | Vishay | CRCW08051K00FKEAHP | 1 | 1k |
| R47, R149 | Vishay | CRCW06031K00FK | 2 | 1k |
| R43, R44, R65 | Yageo | RC0603FR-071KL | 3 | 1k |
| R46, R48, R55, R56 | Vishay | CRCW06031R00FK | 4 | 1R |
| R1, R9, R10, R11, R12, R13 | Yageo | RC0603FR-071K2L | 6 | 1.2k |
| RS1 | Vishay | RCS08053K00FKEA | 1 | 3.00k |
| R3, R4, R5, R6, R7, R8, R14 | Yageo | RC0603FR-074K7L | 7 | 4.7k |
| R17 | Vishay | CRCW06037K50FK | 1 | 7.5k |
| R15, R16 | Yageo | RC0603FR-0710KL | 2 | 10k |
| RGH, RGL | Yageo | RC0603FR-0710RL | 2 | 10R |
| R64 | Yageo | RC0603FR-0712KL | 1 | 12k |
| R45 | Vishay | CRCW060313K0FK | 1 | 13k |
| R41, R42 | Bourns | CAT16A-2002F4LF | 2 | 20k |
| R63 | Yageo | RC0603FR-071KL | 1 | 24k |
| R61 | Vishay | CRCW060337K4FK | 1 | 37.4k |
| R150 | Yageo | RC0603FR-0747RL | 1 | 47R |
| R52 | Vishay | CRCW060349K9FK | 1 | 49.9k |
| R153 | Vishay | CRCW060368R0FK | 1 | 68R |
| RFLT | Yageo | AC0603FR-072KL | 1 | 100 |
| R49 | Vishay | CRCW0603200RFK | 1 | 200R |
| R2 | TE Connectivity | CRGCQ0603F470R | 1 | 470R |
| R40 | Vishay | CRCW0603510RFK | 1 | 510R |
| R39 | Yageo | RC0603FR-07120RL | 1 | DNP |
| S1 | Würth Elektronik | 416131160808 | 1 | 416131160808 |
| U1 | Infineon Technologies | BTS71033-6ESA | 1 | BTS71033-6ESA |
| U5 | Infineon Technologies | XMC1404-F064X0200 AA | 1 | IFX_XMC1404-F064X0200 AA |
| U6 | Infineon Technologies | TLE9351BVSJ | 1 | TLE9351BVSJ |
| U7, U8, U9, U10 | Infineon Technologies | TDA21490 | 4 | TDA21490 |
| U11 | Infineon Technologies | IRS25411SPBF | 1 | IRS25411SPBF |
| X1 | Sullins | EBC18DCWN-S371-Card | 1 | EBC18DCWN-S371-Card |
| X2 | - | 3220-10-0100-00 | 1 | 3220-10-0100-00 |
| Y1 | ECS Inc | ECS-200-8-33Q-RES | 1 | 20MHz |

| Designator | Manufacturer | Part number | Quantity | Value |
|---|---|---|---|---|
| | Infineon Technologies | USB005 dongle | 1 | USB005 |

## References

[1] Infineon Technologies AG: *Datasheet (2029-02-08): IRS25411S datasheet. V2.0.0*; Available online

[2] Infineon Technologies AG: *Datasheet (2023-02-07): ISC080N10NM6 datasheet. V2.2*; Available online

[3] Infineon Technologies AG: *Datasheet (2015-02-26): TLS208D1EJV33 datasheet. V1.0*; Available online

[4] Infineon Technologies AG: *Datasheet (2012-11-08): TLE1963TE datasheet. V1.0*; Available online

[5] Infineon Technologies AG: *Datasheet (2021-07-15): XDPE12254C datasheet. V1.0*; Available online

[6] Infineon Technologies AG: *Datasheet (2020-12-01): TDA21490 datasheet. V1.0*; Available online

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# Glossary

**IMR**
*Infineon Mobile Robot*

**PD**
*power distribution*

## Revision history

| Document revision | Date | Description of changes |
|---|---|---|
| V 1.0 | 2024-06-03 | Initial release |
| V.2.0 | 2025-07-30 | Updated software and quick start guide sections |

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