AVR® Functional Safety - Hardware User's Guide

Introduction

This document is the hardware user's guide of AVR® Functional Safety board based on ATtiny3217 microcontroller (MCU). It gives details about the overall board design and the hardware function blocks. The AVR Functional Safety board is designed to easily demonstrate and evaluate the safety and reliability peripherals on ATtiny3217 MCU and firmware based safety features, such as:

- Watchdog Timer (WDT)
- Cyclic Redundancy Check (CRC)
- Brown-out Detection (BOD)
- Voltage Level Monitoring (VLM)
- Power-on Reset (POR)
- Timer/Counter Type D (TCD) Fault Detection
- Class B Self Tests

Features

- Core Independent Operation Using Configurable Custom Logic (CCL) and 16-bit Timer/Counter Type A to Create a Heartbeat Signal
- Core Independent Cyclic Redundancy Check Memory Scan (CRCSCAN)
- Core Independent Operation Using 12-bit Timer/Counter Type D (TCD) to Drive a Fan Motor
- Core Independent TCD Fault Handling Using Event System (EVSYS), Analog Comparator (AC) and Digital-to-Analog Converter (DAC)
- Using Charlieplexing Technique to Drive a Large Number of LEDs with a Low Number of Pins, Using 16-bit Timer/Counter Type B (TCB) and Priority Interrupt
- Demonstrating Core Independent Watchdog Timer (WDT) in Window mode
- Demonstrating Real-Time Counter Periodic Interrupt (RTC) (PIT)
- Board Controller with (PTC) Touch Slider to Adjust the Voltage to ATtiny3217, Demonstrating Voltage Level Monitor (VLM) Interrupt, Brown-out Detector (BOD) and Power-on Reset (POR)
- On-board Mini Embedded Debugger (mEDBG) for Programming and Debugging.

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1. Overview

1.1 Block Diagram

There are three MCUs on this board:

- Target MCU - ATtiny3217:
    - The main MCU that demonstrates the safety and reliability functions.
- Board controller - ATtiny1617:
    - It simulates external conditions to trigger the target MCU safety and reliability functions.
- Mini Embedded Debugger:
    - On-board debugger and programmer for target MCU and board controller.

Depending on different safety and reliability functions, the hardware design can be divided into the following function blocks:

- Reset Register and Class B status
- Operation Voltage
- Window Watchdog Timer
- Cyclic Redundancy Check
- Fault Detection Using Event System

These function blocks are clearly noted on the top side of the AVR Functional Safety board. Refer to Figure 1-2 for more details.

The block diagram of the AVR Functional Safety board can be seen below.

Figure 1-1. AVR® Functional Safety Board Block Diagram
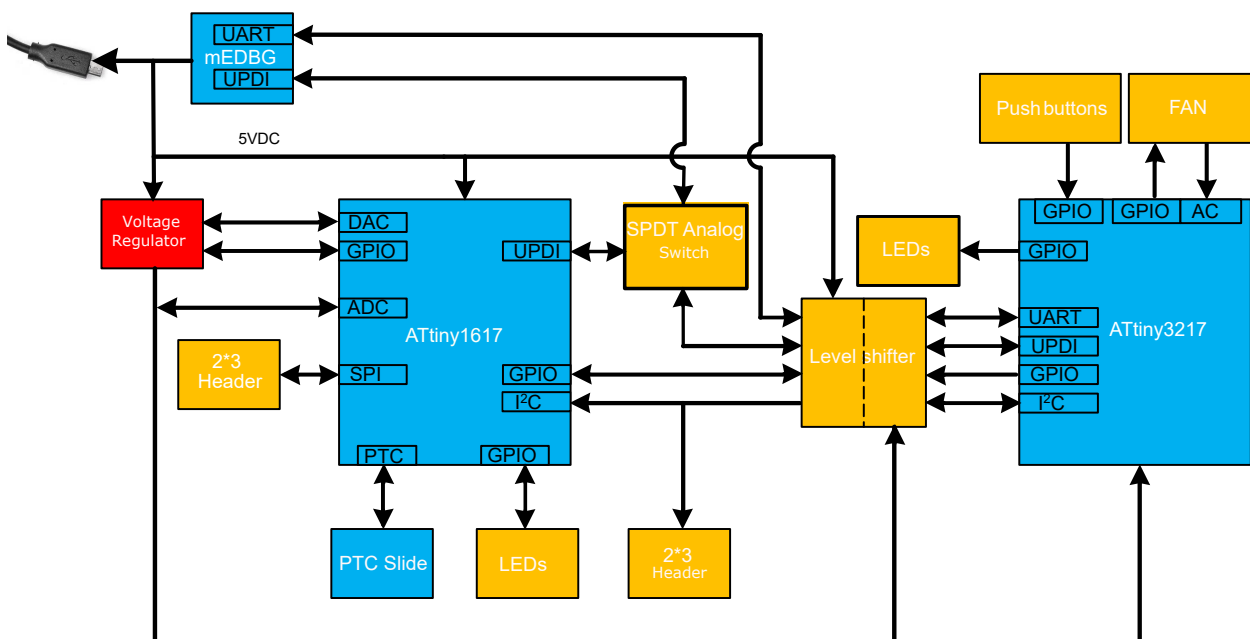
1.2   Board Overview

Here is a brief overview of the AVR Functional Safety board.

Figure 1-2. AVR® Functional Safety Board Overview - Top Side
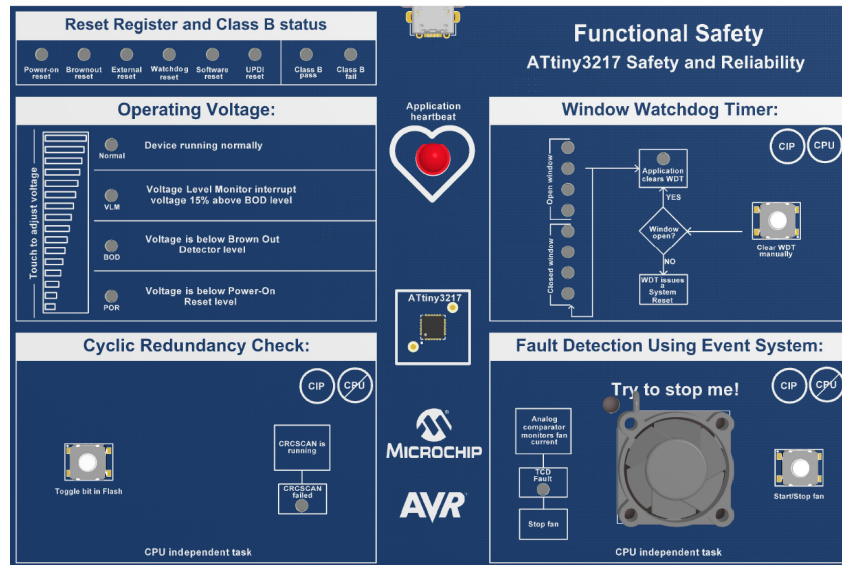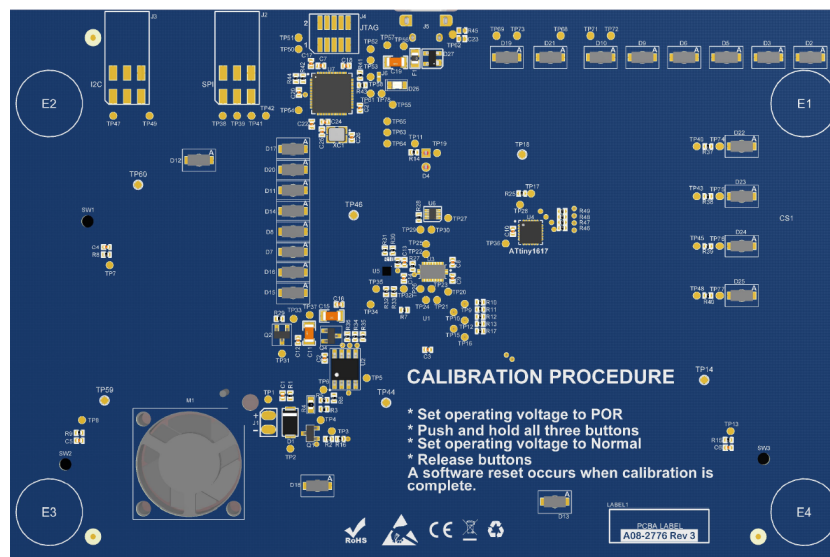

Figure 1-3. AVR® Functional Safety Board Overview - Bottom Side

2. Design Documents and Related Links

The design documents and relevant links are available here:

- AVR Functional Safety website: Board information, the latest documents and design files.
- microchipDIRECT: Where to buy this board online.
- ATtiny3217 website: Target MCU information, documentation and development tools, etc.
- ATtiny1617 website: Board controller MCU information, documentation and development tools, etc.

3.   Quick Start

The AVR Functional Safety boardis powered by a 5.0V USB voltage. The on-board programming and debugging function relies on the same USB connection. Refer to Mini Embedded Debugger Implementation for more information about programming and debugging.

Steps to start exploring the AVR Functional Safety board:

1.   Download and install Atmel Studio.
2.   Launch Atmel Studio.
3.   Connect a USB cable (Standard-A to Micro-B or Micro-AB) between the PC and the USB port on the board.

When the AVR Functional Safety board is connected to the computer for the first time, the operating system will perform a driver software installation. The drivers for the board are included with Atmel Studio. Once the driver is successfully installed and the board is correctly powered, it will be automatically detected and recognized as a mEDBG tool by Atmel Studio.

Before using the board with default firmware, calibrating the board first is recommended. The calibration steps are listed on the backside of the board as shown in Figure 1-3.

4.   Hardware Blocks

In this chapter, the hardware designs are described in detail. There are three MCUs on this board and different hardware peripherals are built around them, so this chapter is further divided into three sections according to the MCU and peripheral connections.

4.1   Target MCU Peripherals

ATtiny3217 is the target MCU on the AVR Functional Safetyboard. All the safety and reliability functions demonstrated on this board are from ATtiny3217 MCU. The hardware peripherals around the target MCU are designed for the user to trigger different abnormal conditions, so that the reaction of each safety and reliability module can be easily observed.

4.1.1   Charlieplexed LEDs

On this board, there are 19 LEDs Charlieplexed and driven by only five I/O pins. On this board, PC0, PC1, PC2, PC3 and PC4 are used to drive these LEDs. Compared with traditional LED connection method, Charlieplexing saves a lot of I/O pins. In theory, five I/O pins can drive up to 20 LEDs. More details about Charlieplexing can be found here: https://en.wikipedia.org/wiki/Charlieplexing.

Below are the names of 19 LEDs and their functions.

Table 4-1. Charlieplexed LEDs

LED Description	LED Name	LED Function
LED1	D2	Power-on Reset
LED2	D3	Brown-out Reset
LED3	D5	External Reset
LED4	D6	Watchdog Reset
LED5	D9	Software Reset
LED6	D10	UPDI Reset
LED7	D15	Watchdog Timer Indicator
LED8	D16	Watchdog Timer Indicator
LED9	D7	Watchdog Timer Indicator
LED10	D8	Watchdog Timer Indicator
LED11	D14	Watchdog Timer Indicator
LED12	D11	Watchdog Timer Indicator
LED13	D20	Watchdog Timer Indicator
LED14	D17	Watchdog Timer Indicator
LED15	D12	Watchdog Timer Cleared
LED16	D13	CRCSCAN Error
LED17	D18	TCD Fault Detected

LED Description	LED Name	LED Function
LED18	D19	Class B Fail
LED19	D21	Class B OK

The schematic of Charlieplexed LEDs is shown below.

Figure 4-1. LED Charlieplexing
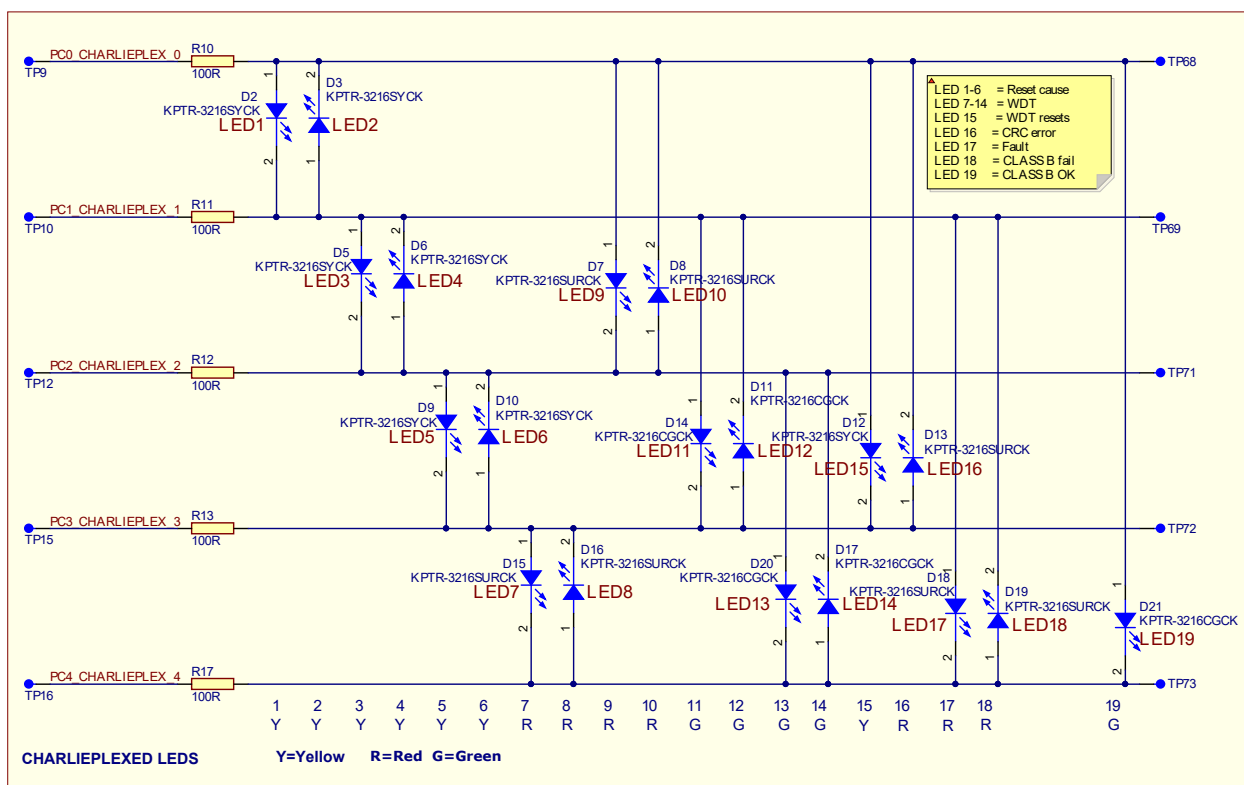
4.1.2 Heartbeat LED

There is an LED on this board simulating a heartbeat pattern. It is connected to the Configurable Custom Logical (CCL) output pin, so that the heartbeat pattern is easily generated with the timer/counter and the CCL without the intervention of the CPU. This LED is ON when the connected I/O pin output is low.

Table 4-2. Heartbeat LED

ATtiny3217 Pin	Pin Function	Comment
PB4	Heartbeat LED D4	LUT0-OUT on alternative pin

Figure 4-2. Heartbeat LED
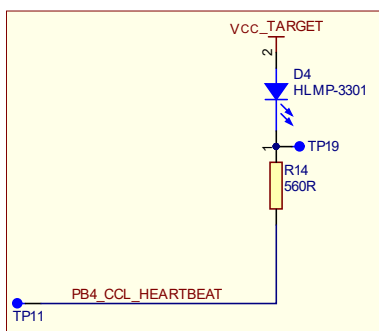

4.1.3 Buttons

There are three mechanical buttons on this board. They are used to trigger different target MCU actions. Their functions are listed below.

Table 4-3. Buttons

ATtiny3217 Pin	Pin Function	Button Function
PB5	SW1	Clear Watchdog (WDT)
PB6	SW2	Start/Stop Fan
PB7	SW3	Modify Flash Memory Bit

The buttons are implemented to be low active. When a button is pressed, a low level can be detected on the connected I/O pin.

Their connection is shown below.

Figure 4-3. Buttons
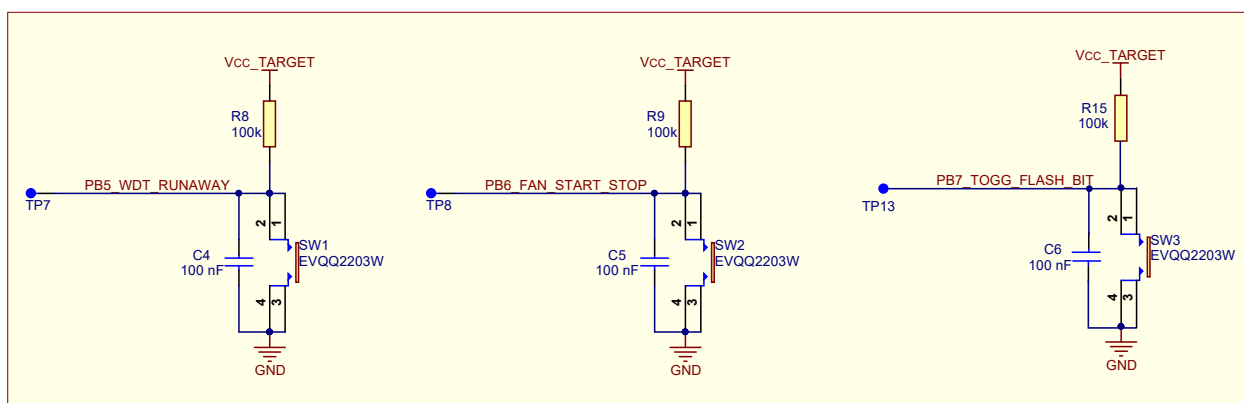
4.1.4 Fan

A small DC fan is attached on this board. It is driven by a MOSFET via an I/O pin control. The fan motor current is amplified by an op amp MCP6002 and fed back to the ATtiny3217 Analog Comparator (AC) input. If the current is above safety value (For example, the fan motor is forced to stop by putting a finger on it) then the fan control signal will be stopped immediately thanks to a Timer/Counter Type D (TCD)

fault control function. According to different input modes, fault detection puts TCD outputs into a predefined state without CPU intervention.
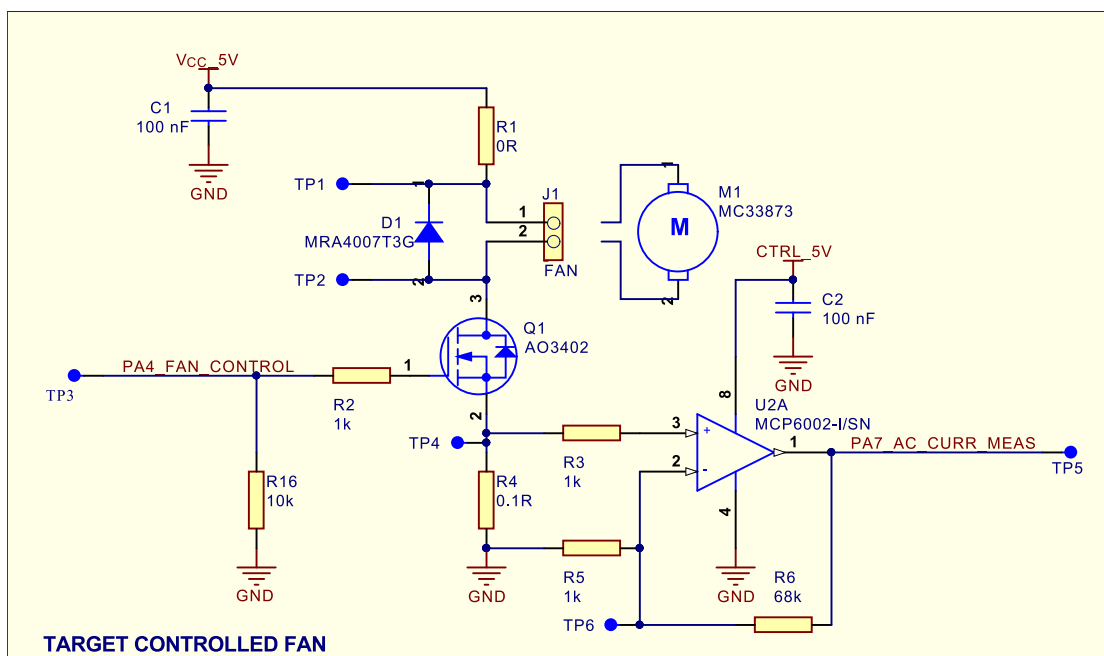
Please see below the table with details on the fan control pin and on the current detection pin connection.

Table 4-4. FAN Control

ATtiny3217 Pin	Pin Function	Comment
PA4	Fan MOSFET control	WOA of TCD0
PA7	Fan current detect	AC0 positive input

Below is the fan control schematic.

Figure 4-4. Fan

4.2   Board Controller Peripherals

The purpose of the board controller is to simulate different external conditions to trigger different safety and reliability functions of the target MCU. There are several hardware blocks built around the board controller to make this easier. On this board, an ATtiny1617 is used as the board controller.

4.2.1   Variable Target Voltage

A simple variable voltage circuit is designed to generate the target MCU V_{CC}. Ideally, it varies between 0~5V if the MOSFET on-resistance is considered as 0Ω. The board controller, ATtiny1617, controls the ON/OFF and output level of this variable voltage. The pin functions are listed below.

Table 4-5. Variable Target Voltage

ATtiny1617 Pin	Pin Function	Comment
PA6	Controls variable voltage level	DAC output
PA7	Controls ON/OFF of voltage	I/O output

The controlled variable voltage circuit is shown below.

Figure 4-5. Variable Target Voltage

4.2.2 Touch Slider

A touch slider is implemented on this board for an easy user input. It is based on the Peripheral Touch Controller (PTC) module in ATtiny1617. On this board, the touch slider is implemented with four self-capacitance sensors (Y-line). For further information about PTC touch usage, refer to QTouch® Modular Library User's Guide and Glossary of Touch Terms. In default firmware, this slider is used to control the output voltage of Variable Target Voltage.

The connection of touch slider is shown below.

Table 4-6. Touch Slider

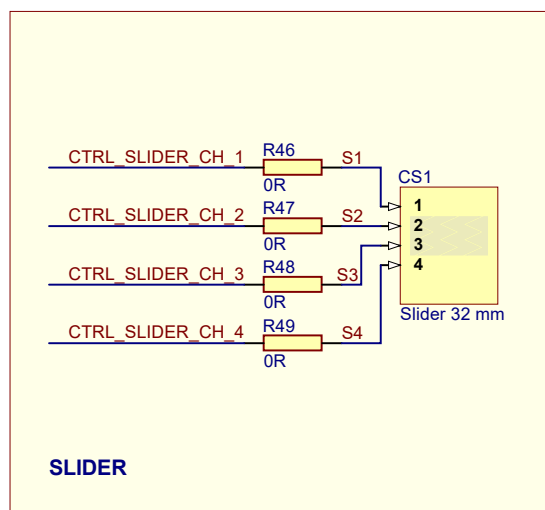| ATtiny1617 Pin	Pin Function	Comment
PC0	Touch slider sensor 1	PTC Y6
PC1	Touch slider sensor 2	PTC Y7
PC2	Touch slider sensor 3	PTC Y8
PC3	Touch slider sensor 4	PTC Y9

Figure 4-6. Touch Slider

Figure 4-7. Touch Slider PCB Layout Pattern

4.2.3 Status LED

Four LEDs are controlled by a board controller to indicate the target MCU voltage described in Variable Target Voltage. There are four segments of the target MCU voltage. These LEDs are designed to be low active.
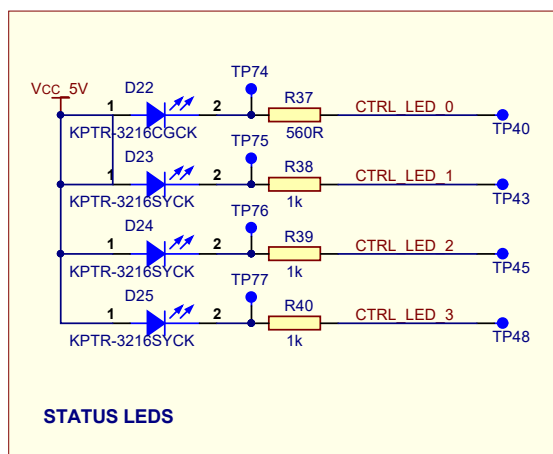
Table 4-7. Status LED

ATtiny1617 Pin	Pin Functions	Target MCU Voltage
PB2	D22	Normal voltage
PB3	D23	15% above BOD level

ATtiny1617 Pin	Pin Functions	Target MCU Voltage
PB4	D24	Below BOD level
PB5	D25	Below POR level

The schematic is shown below.

**Figure 4-8. Status LED**

4.2.4 **Level Shifter**

As the voltage of the target MCU is controlled by the board controller, the voltage between them can be different. Level shifters are used to make sure that the MCUs can talk to each other when they operate under different voltages. The UPDI pin and mEDBG UART pins are also connected via level shifter, thus the target MCU can be programmed and debugged under any working voltage. The following pins are connected via level shifters.

Refer to the table below for more details.

Table 4-8. Pin Connections via Level Shifter

ATtiny1617 Pin	ATtiny3217 Pin	mEDBG Pin	Pin Function
PB0	PB0	--	I^{2}C SCL
PB1	PB1	--	I^{2}C SDA
PB6	PA6	--	Target BOD indicator
PB7	PA2	--	Target VLM indicator
--	PB2	PD2	UART Tx
--	PB3	PD3	UART Rx
--	PA0	PE6	mEDBG UPDI

Figure 4-9. Level Shifter Connections

LEVEL SHIFT & MEDBG SELECTOR
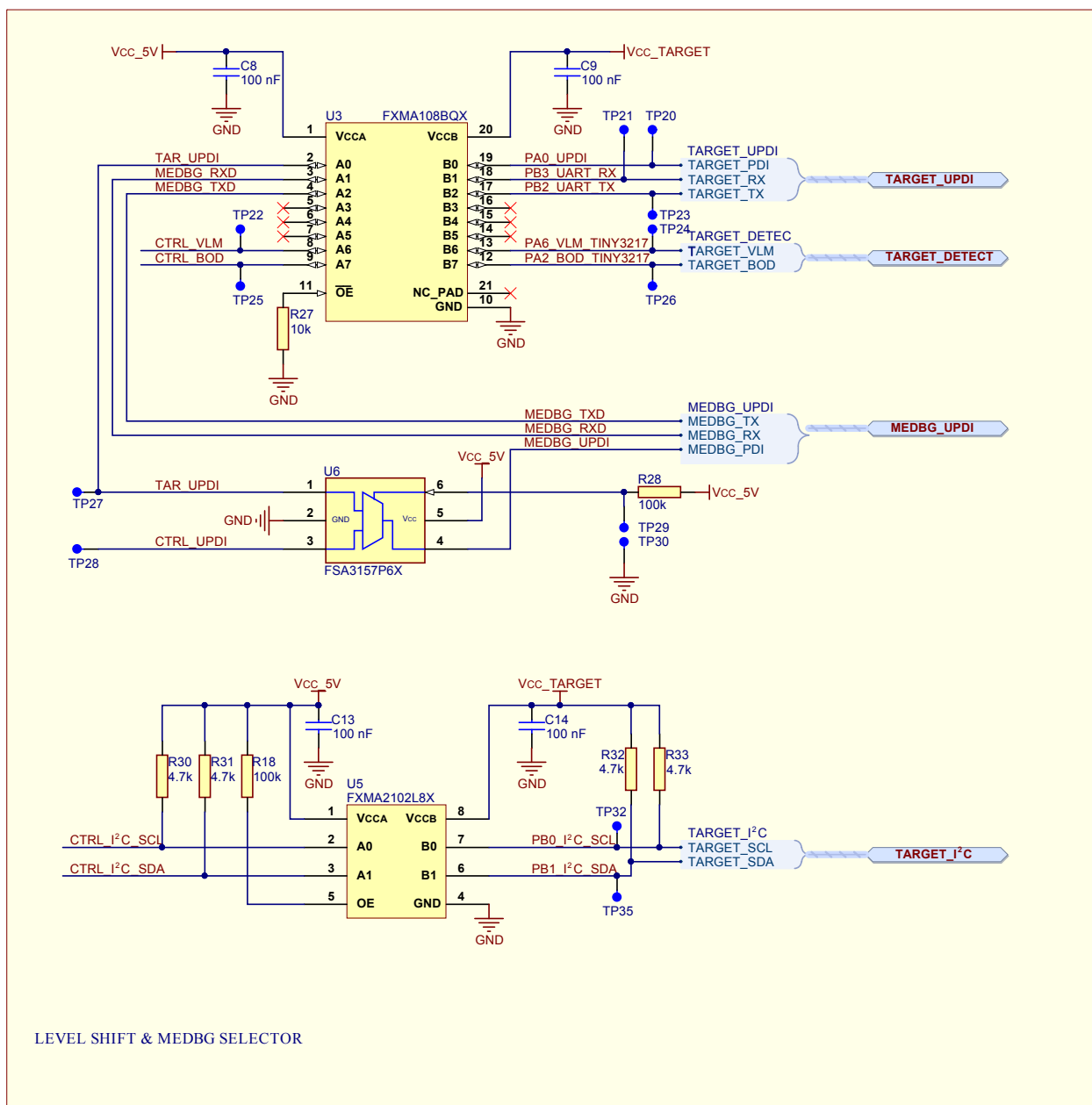
4.2.5 Reserved Interfaces

The SPI and I²C pins are also reserved on two unmounted headers. The user can use them conveniently if such functions are necessary.

Table 4-9. Reserved Interfaces

ATtiny1617 Pin	Pin Function	Comment
PA1	SPI MOSI	Board controller SPI interface
PA2	SPI MISO	

ATtiny1617 Pin	Pin Function	Comment
PA3	SPI SCK	
PA4	SPI SS	
PB0	I^{2}C SCL	Board controller I^{2}C interface
PB1	I^{2}C SDA	

Figure 4-10. Reserved Interface
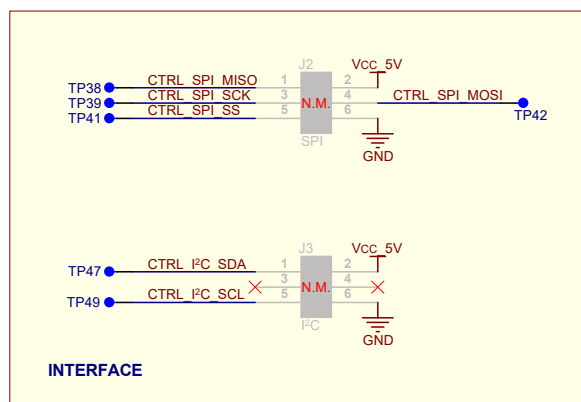
4.3 Mini Embedded Debugger Implementation

On the AVR Functional Safety board, the Mini Embedded Debugger (mEDBG) is used as an easy way to program and debug the target MCU. It features a virtual COM port for serial communication to a host PC. Atmel Studio can be used as a front end for the mEDBG.

4.3.1 Mini Embedded Debugger

The AVR Functional Safety board contains the Mini Embedded Debugger (mEDBG) for on-board programming. The mEDBG is a composite USB device of two interfaces: a debugger and a virtual COM port.

Together with Atmel Studio, the mEDBG debugger interface can program the ATtiny3217. On AVR Functional Safety board, the UPDI interface is connected between the mEDBG and the ATtiny3217.

The virtual COM port is connected to a UART on the ATtiny3217 and provides an easy way to communicate with the target application through the terminal software. It offers variable baud rate, parity, and Stop bit settings.
Note: The settings on the ATtiny3217 must match the settings given in the terminal software.

Info: The virtual COM port in the mEDBG requires the terminal software to set the Data Terminal Ready (DTR) signal to enable the UART pins connected to the ATtiny3217. If the DTR signal is not enabled, the UART pins on the mEDBG are kept in high-z (tri-state) rendering the COM port unusable. The DTR signal is automatically set by some terminal software, but it may have to be manually enabled in the target terminal.

The mEDBG controls one status LED on the AVR Functional Safety board. The table below shows how the LED is controlled in different operation modes.

Table 4-10. mEDBG LED Control

Operation mode	Status LED
Power-up	LED is briefly lit
Normal operation	LED is not lit
Programming	Activity indicator; the LED flashes when programming/debugging with the mEDBG

4.3.2 UPDI Interface

The Unified Program and Debug Interface (UPDI) uses one pin to communicate with the target. The actual connection of UPDI line between mEDBG and MCU is decided by UPDI Selection.

Table 4-11. UPDI Interface

ATtiny3217	ATtiny1617	Function
PA0 (default connection)	PA0	UPDI/RESET

4.3.2.1 UPDI Selection

On this board, both the target MCU ATtiny3217 and the board controller ATtiny1617 use the same programming and debugging interface (UPDI). It is supported by the on-board program and debug chip mEDBG. An UPDI selection circuit is used to switch the UPDI lines between these two MCUs. By default, the mEDBG UPDI interface is connected to ATtiny3217. To program and debug ATtiny1617, the hardware has to be modified by the user.

Table 4-12. UPDI selection

UPDI Line Target	Hardware Connection	Comment
ATtiny3217	TP29 and TP30 open circuit	Default
ATtiny1617	TP29 and TP30 short circuit	Modified by user

Figure 4-11. UPDI Selection
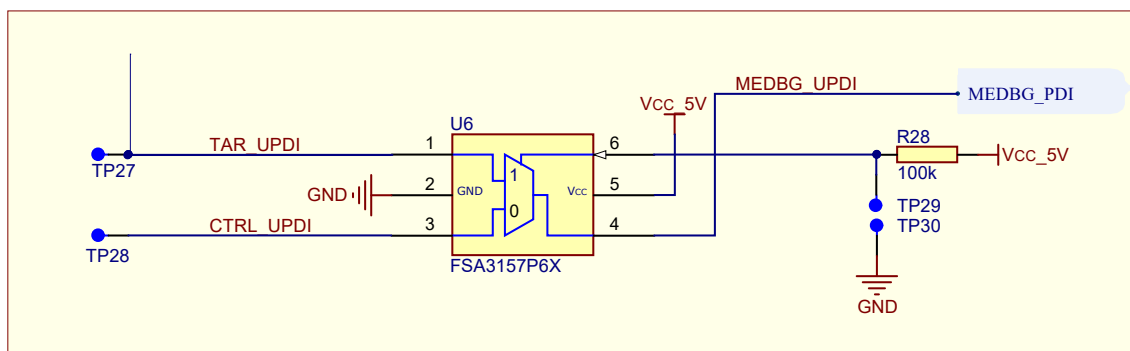
4.3.3 Virtual COM Port

The Mini Embedded Debugger (mEDBG) acts as a virtual COM port gateway by using the ATtiny3217 UART pins. As the target MCU may work at different voltage with mEDBG, the pins are connected via a Level Shifter.

Table 4-13. Virtual COM Port

ATtiny3217 Pin	Pin Function	mEDBG Pin Function
PB2	UART Tx	mEDBG CDC Rx
PB3	UART Rx	mEDBG CDC Tx

5. Revision History

Doc Rev.	Date	Comments
DS40002013A	2/2018	Initial document release.

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