UM3565

User manual

Getting started with the AEK-MCU-C4MLIT3 cost-optimized and compact size MCU discovery kit for SPC58EC80E5 Chorus 4M automotive microcontroller with CAN-FD and unified automotive connector

Introduction

Undeniable changes are occurring in the vehicle architecture of modern cars. The boost provided by the start of electrification has led most car manufacturers to reconsider and experiment with new topologies and different partitioning for implementing several typical car functions.

This trend necessitates the evolution of development tools to meet the most advanced and stringent requirements. For these reasons, we have enhanced the AutoDevKit ecosystem components to create a new family. While still relying on the same fast-prototyping strengths gained from almost ten years of experience, the ecosystem now adapts to a new development pace dictated by the speed of automotive market evolution. The evolution begins with the core element of each system: the microcontroller discovery board. For this reason, we have designed the AEK-MCU-C4M3 not simply as an evolution of the highly successful AEK-MCU-C4MLIT1 but also as a brick for multi-MCU functional blocks at the heart of the AutoDevKit ecosystem evolution.

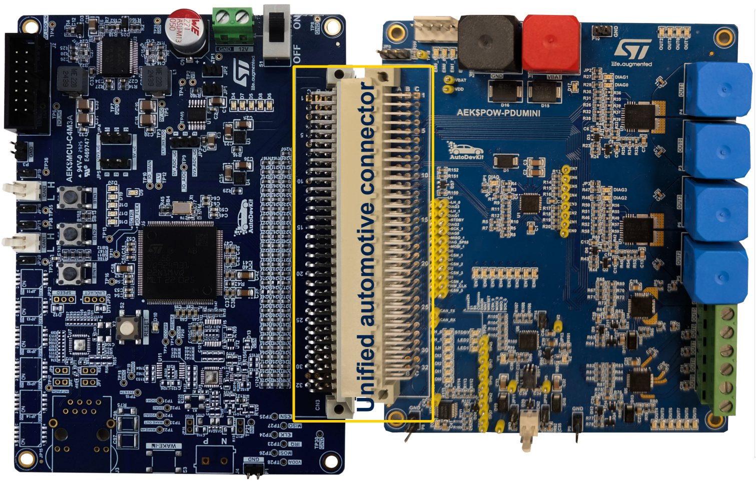
In addition to its compact and cost-optimized design, the AEK-MCU-C4M3 is equipped with a unified automotive connector, a new standard for our MCU discovery boards included in the AutoDevKit ecosystem.

The unified automotive connector is a 96-pin plug-and-play connector placed on the AEK-MCU-C4M3 board. Its main advantages include minimizing pin breakage, avoiding incorrect connections, and providing resistance to vibration and harsh environments. The unified automotive connector has supply signals on both sides, while the middle pins are reserved for mid-to-low-speed digital signals connected to the peripheral-rich SPC58EC80E5 MCU, a dual 180 MHz general-purpose 32-bit Power® architecture core featuring 4 MB of embedded flash memory.

Additionally, the AEK-MCU-C4M3 board includes two CAN-FD protocol connectors, each with its dedicated transceiver supporting up to 8 Mbps and featuring low quiescent current, electromagnetic compatibility (EMC), and electrostatic discharge (ESD). CAN and CAN-FD protocols remain the de facto standard in automotive in-vehicle communication. Finally, a dedicated JTAG connector is included to enable firmware downloads to the MCU and to debug the code. The JTAG connector can be connected to the AEK-MCU-SPC5LNK programmer/debugger to enable OpenOCD usage in AutoDevKit Studio.

An example of how to connect the AEK-MCU-C4M3 board to a power distribution board using the unified automotive connector is shown in the following figure.

Figure 1. Example of unified automotive connector usage



The figure above provides a clean and simplified view of the board connection, eliminating the need for flying wires, which are prone to disconnections and misconnections typically found in a system prototype.

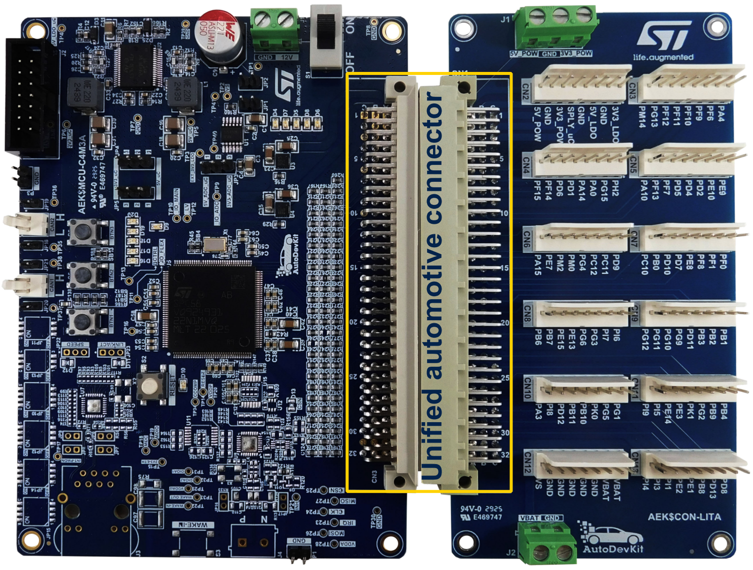
The only limitation of the male unified automotive connector on the AEK-MCU-C4M3 board is the manual inconvenience of using jump wires when the connected board does not have the equivalent female unified automotive connector. To address this need and maintain backward compatibility with existing prototypes, the AEK-MCU-C4M3 board is included in the AEK-MCU-C4MLIT3 kit. This unique orderable part number includes both the AEK-MCU-C4M3 board and the AEK-CON-LIT connector extension board.

The AEK-CON-LIT connector extension board features a female unified automotive connector that perfectly connects with the AEK-MCU-C4M3 board. Additionally, it includes a set of twelve properly labeled 8-pin KK standard connectors that remap all the unified connector pins, enabling access to the microcontroller pins.

As successfully implemented in the AEK-MCU-C4MINI1 board, the 8-pin KK male connectors allow users to crimp standard female connectors with a basic level of reliability or, in the worst case, connect single jump wires.

The AEK-CON-LIT connector extension board is included in the AEK-MCU-C4MLIT3 kit and is not available for separate sale. In the packaged AEK-MCU-C4MLIT3 kit, the AEK-MCU-C4M3 board comes with preloaded demo firmware that makes an LED blink at a fixed rate.

Figure 2. AEK-MCU-C4MLIT3 complete kit



Warning: *The evaluation kit described in this user manual is designed for R&D laboratory use only. It is not intended for field use in vehicles. Moreover, it is not a reference design. Its purpose is evaluation and not production as stated in Terms of use license.*

Note: For dedicated assistance, please submit a request in ST AutoDevKit Community.

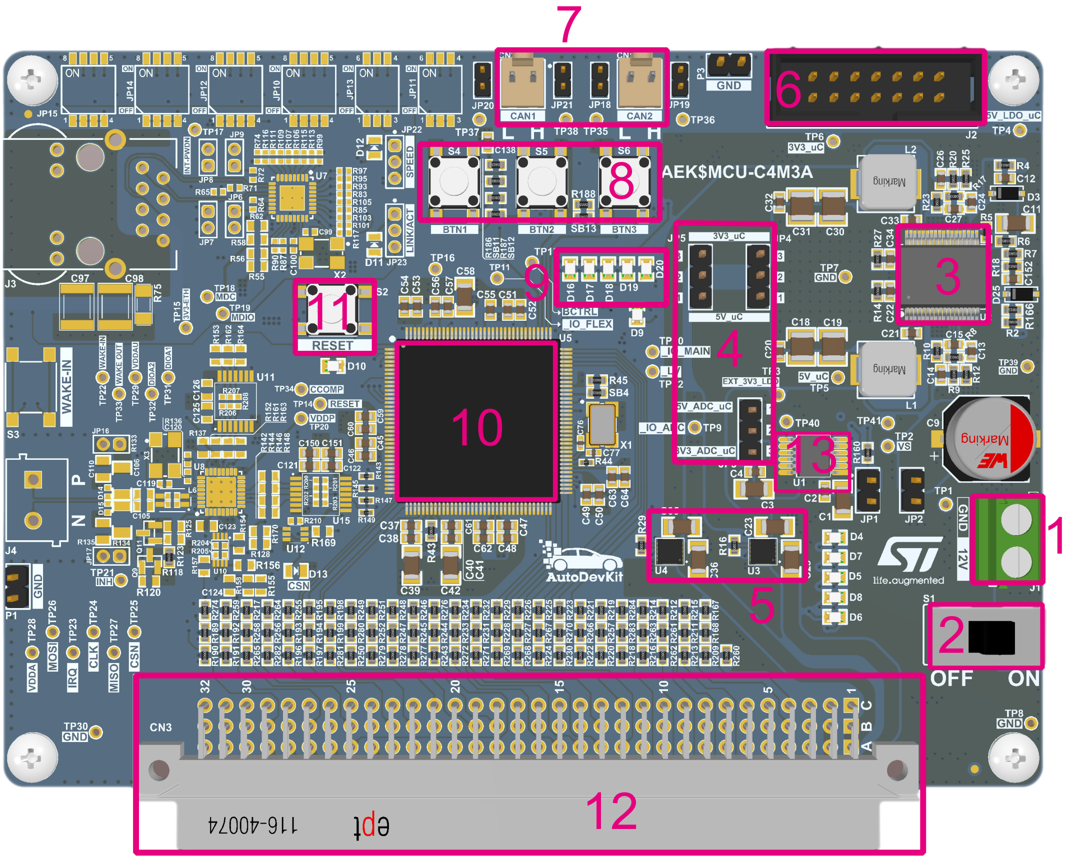
1 Hardware overview

1.1 AEK-MCU-C4M3 - MCU board main components

The board top side components are listed below and shown in Figure 3:

1. 12 V DC power supply connector
2. Switch ON/OFF 12 V DC power supply
3. L5963 automotive dual monolithic switching regulator with LDO
4. Voltage configurations for the microcontroller (5 V or 3.3 V)
5. STEF05L – STEF033 Electronic fuse for 5 V and 3.3V line
6. JTAG connector
7. CAN lines
8. User-programmable pushbuttons
9. User programmable LEDs
10. SPC58EC80E5 32-bit Power Architecture MCU for Automotive General-Purpose Applications
11. Reset button
12. 96-pin unified automotive connector
13. L99VR02J automotive linear voltage regulator with configurable output voltages

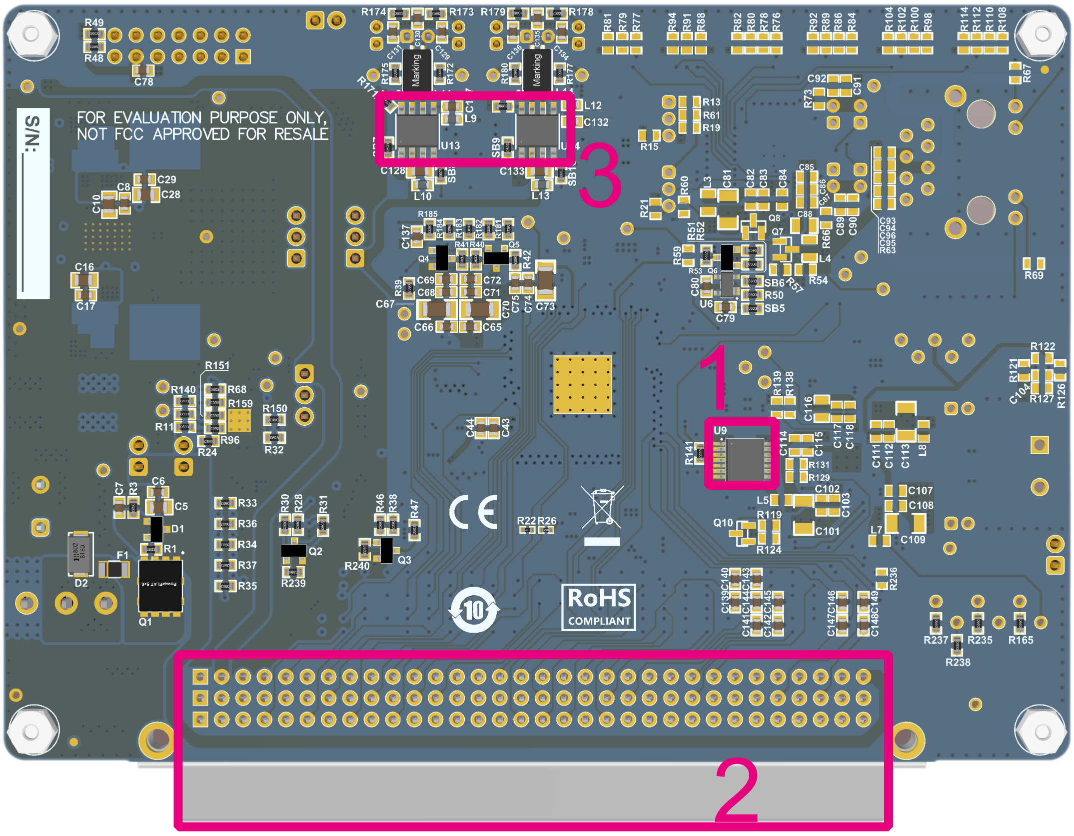
Figure 3. MCU board, top view: main components



The board bottom side components are listed below and shown in Figure 4:

1. Fixed voltage-level translator
2. 96-pin unified automotive connector
3. CAN transceivers

Figure 4. MCU board, bottom view: main components



1.2 AEK-MCU-C4M3 functional blocks

Figure 5 and Figure 6 illustrate the MCU board layout, while Figure 7 shows the overall connection scheme. Each board functionality has been highlighted by identifying the major blocks, which will be explained in detail in the dedicated sections.

Figure 5. AEK-MCU-C4M3 functional blocks

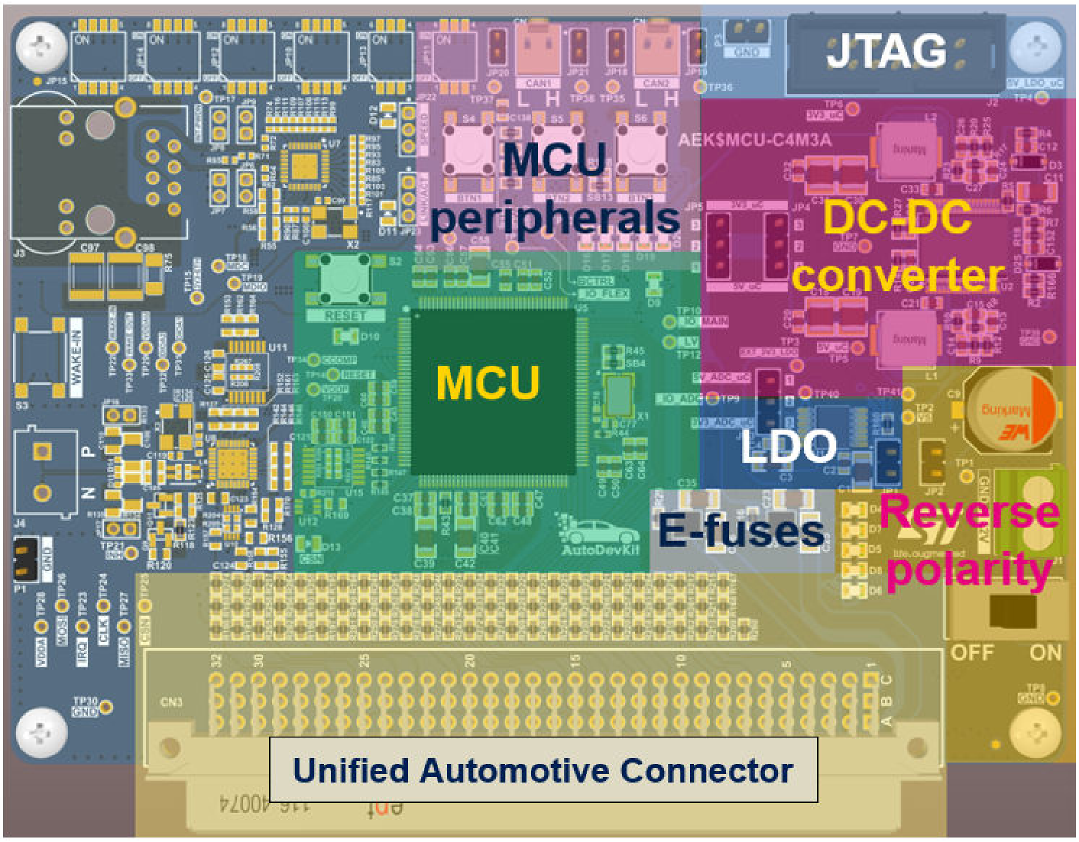


Figure 6. AEK-MCU-C4M3 overall block diagram

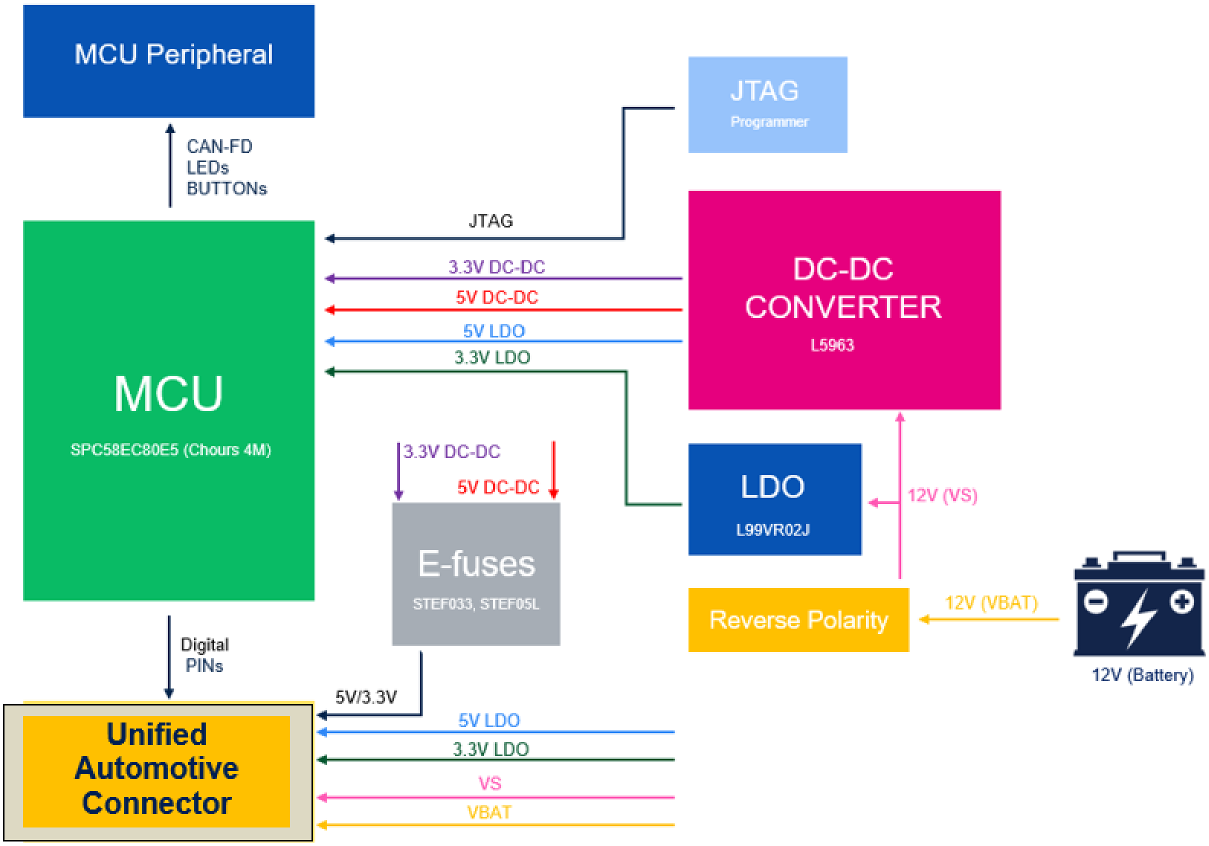
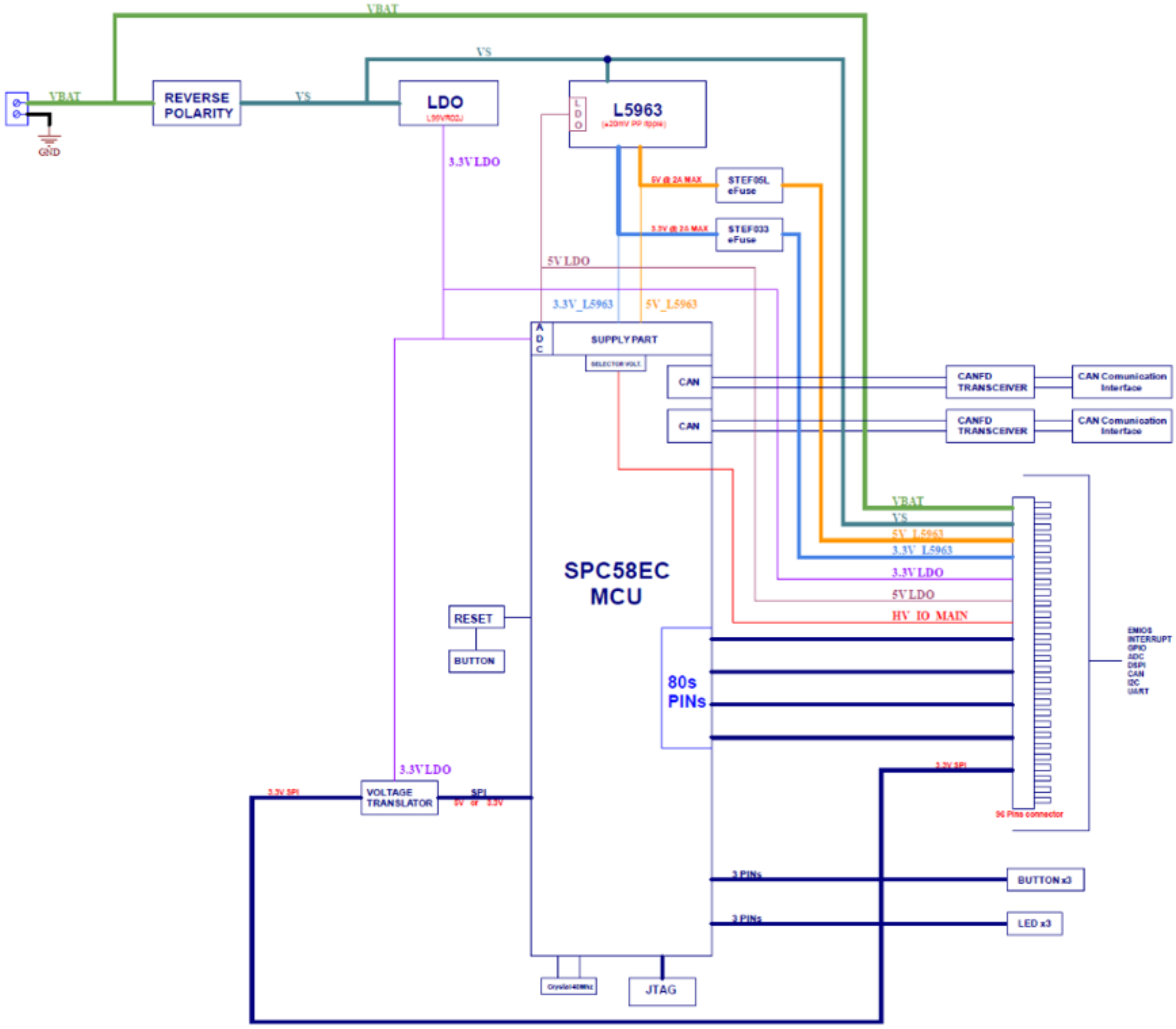


Figure 7. AEK-MCU-C4M3 overall connection scheme



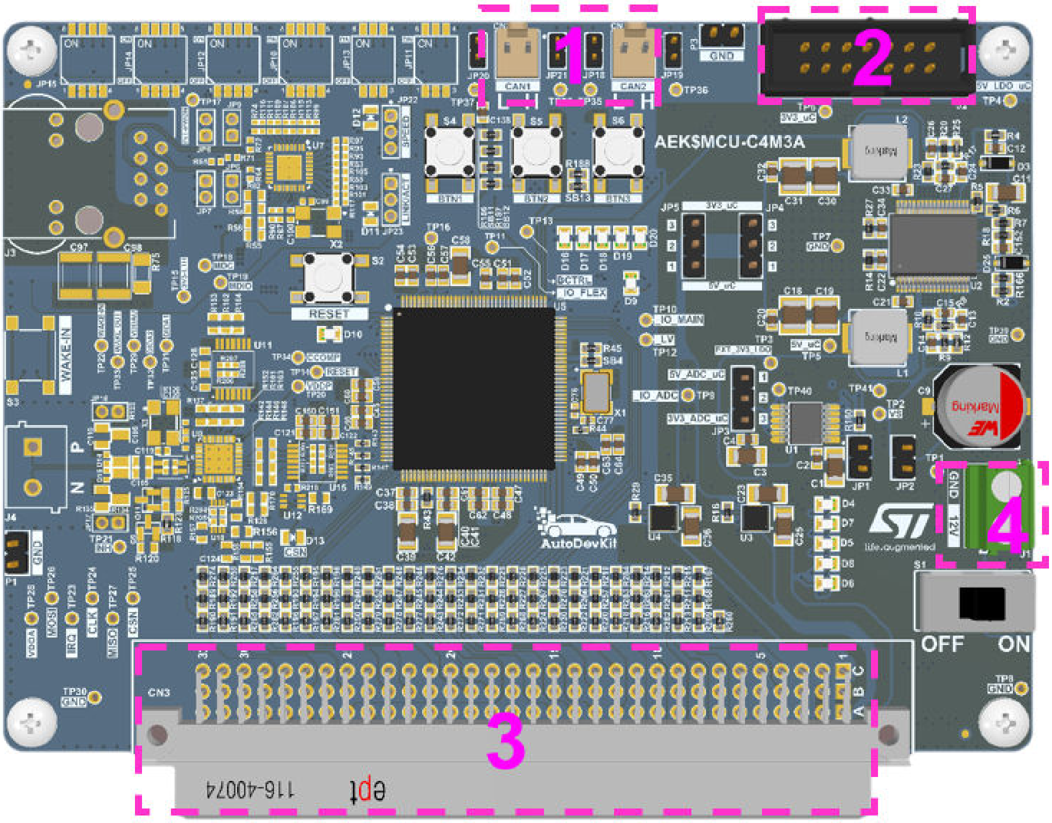
2 Connectivity blocks in AEK-MCU-C4M3

2.1 Connector overview

The AEK-MCU-C4M3 features two CAN connectors, one JTAG plug, and a 96-pin unified automotive connector for generic I/O and supply lines. In detail, referring to Figure 8, the board features the connectors listed below:

1. CAN connectors: CN1 and CN2
2. JTAG plug: J2
3. 96-pin unified automotive connector: CN3
4. Power supply board connector: J1

Figure 8. **AEK-MCU-C4M3 connector overview**



2.1.1 CN3 unified automotive connector

The main AEK-MCU-C4M3 connector is CN3 unified automotive connector. It is a 96-pin stable and reliable connector carrying both supply pins and digital pins related to the microcontroller peripherals.

A 100-Ohm resistor array in series with the board digital inputs drastically reduces noise and disturbances that may occur on digital lines. Analog voltages are placed at the connector ends, physically separated from digital voltages. This arrangement minimizes connection errors and increases noise immunity by preventing crosstalk between digital and analog sections, which is crucial for stable system design.

This new unified automotive connector provides exceptional signal integrity and power delivery for critical automotive systems, as well as resistance to corrosion, vibration, and extreme temperatures. This connector upgrade enables a more reliable and simplified connection between the MCU board and other boards through a plug-and-play interface. The need for manual wiring is thereby eliminated, minimizing interference and connection issues, and providing a stable platform for development.

Dedicated protected power lines supply the CN3 unified automotive connector with 12V, 5V, and 3.3V. A total of 13 pins in the CN3 are dedicated to power and GND. If we consider the 96-pin split in three rows (A, B, C) of 32-pin each, then we can identify the power pins as listed in the following table and shown in Figure 9.

Table 1. **CN3 unified automotive connector power pins**

CN3 Pin	Pin type	Pin description
A1	Power	3V3 generated from dedicated DC-DC power
A2	Power	5V generated from dedicated DC-DC power
A31	GND	GND
A32	Power	12V supply from VBAT before reverse polarity circuit protection
B1	Power	3V3 generated from dedicated DC-DC power
B2	Power	5V generated from dedicated DC-DC power
B31	GND	GND
B32	Power	12V supply from VBAT before reverse polarity protection circuit
C1	Power	HV_IO_MAIN, supply for all MCU peripherals
C2	Power	5V generated from dedicated LDO power
C3	Power	3V3 generated from dedicated LDO power
C31	GND	GND
C32	Power	VS, 12V after reverse polarity protection circuit

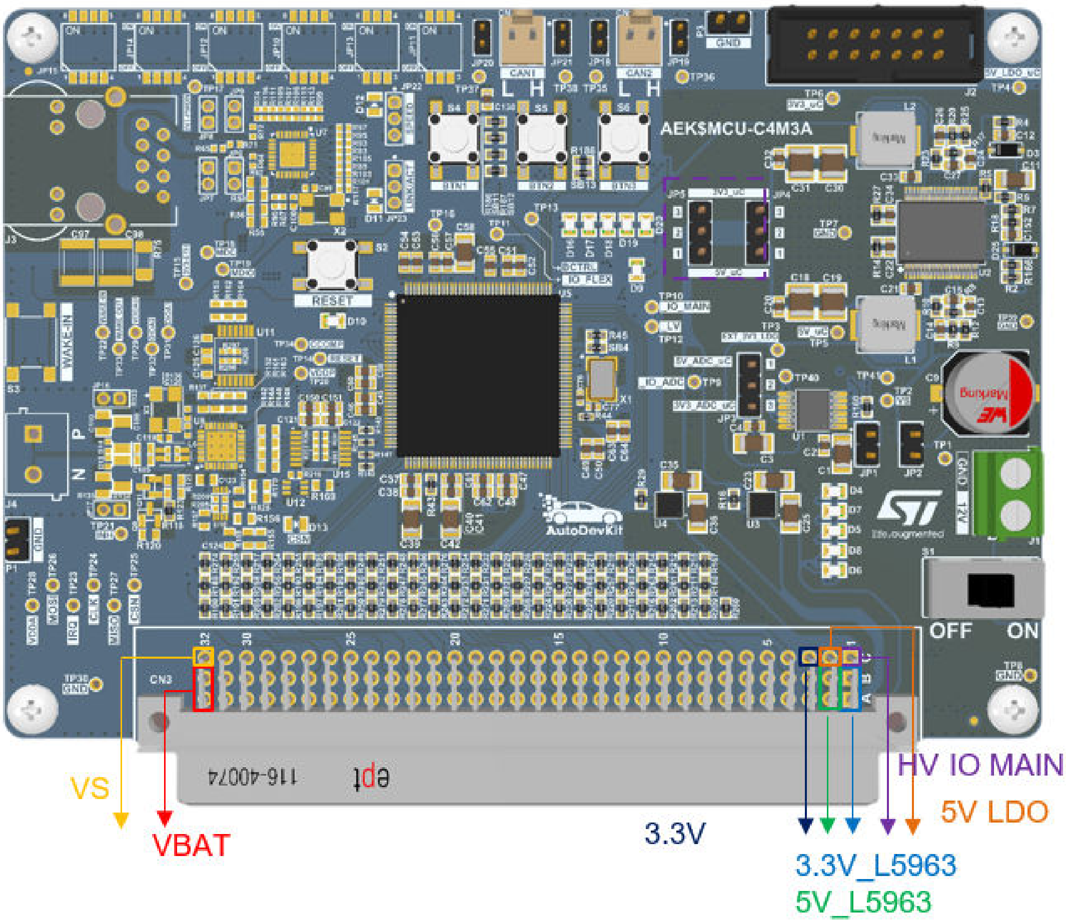


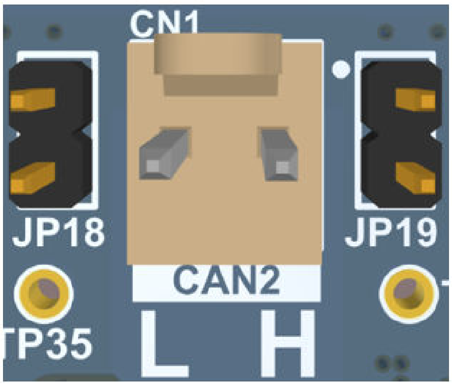
Figure 9. **CN3 unified automotive connector power pins**

For details on the other digital pins, refer to Annex B.

2.1.2 CN1 and CN2 CAN connectors

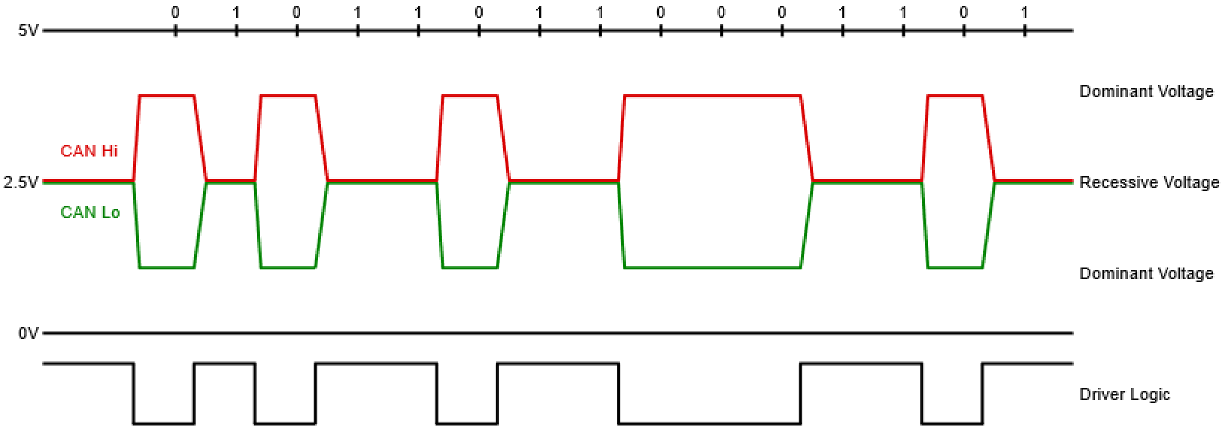
Available on the CAN connectors CN1 and CN2, the CAN protocol is a vehicle bus standard designed to allow microcontrollers and devices to communicate with each other. All nodes are connected through a standard two-wire bus. The wires are a twisted pair with a nominal characteristic impedance of 120 Ω. The CAN bus requires this 120 Ω impedance to function correctly. Onboard, each CAN line includes a 120 Ω resistor. To enable the line and avoid communication issues, as shown in the following figure, close JP18 and JP19 jumpers.

Figure 10. Example of CAN connector



The CAN protocol enables two signals, CAN high (CANH) and CAN low (CANL), which are either driven to a "dominant" state with CANH > CANL or not driven and pulled by passive resistors to a "recessive" state with CANH ≤ CANL. A 0 data bit encodes a dominant state, while a 1 data bit encodes a recessive state.

Figure 11. Theoretical CAN signals



The AEK-MCU-C4M3 hosts two CAN connectors. The on-board CAN-FD transceivers support high-speed applications. Each connector has two pins that indicate high and low signals. Two additional CAN lines, CAN7 and CAN4, are available on the AEK-CON-LIT connector board through the CN3 unified automotive connector.

Note: The two CAN ports on the connector board do not include external transceivers.

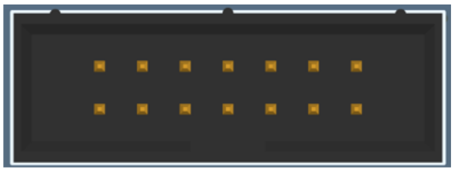
Therefore, the MCU handles them as serial signals.

The CAN transceivers present on the AEK-MCU-C4M3 board are designed for high-speed CAN-FD applications up to 8 Mbps communication speed. They also support CAN 2.0 and meet the automotive requirements for CAN-FD bit rates exceeding 2 Mbps, low quiescent current, electromagnetic compatibility (EMC) and electrostatic discharge (ESD).

2.1.3 JTAG interface

The JTAG interface is available in the JTAG connector to enable application programming/debugging, by connecting the AEK-MCU-SPC5LNK board and taking advantage of the OpenOCD driver inside AutoDevKit.

Figure 12. **JTAG connector**



2.2 LEDs and buttons

The main MCU hosted on the AEK-MCU-C4M3 board is connected to the following peripherals included to facilitate user programming, debugging and interaction with real-time applications:

- Three push buttons
- Five generic LEDs

2.3 Additional communication protocols supported by the hosted MCU

Leveraging on its integrated microcontroller, the AEK-MCU-C4M3 board supports a wide range of peripherals, enabling compatibility with numerous automotive communication protocols. These communication protocols and interfaces are:

- SPI (Serial Peripheral Interface)
- UART (Universal Asynchronous Receiver/Transmitter)
- I^2C (Inter-Integrated Circuit)
- I/O Interfaces (EMIOS, ADC, IRQ, WAKE-UP and GPIOs)

In the next chapter we introduce details about the microcontroller and the additional supported communication protocols and peripherals.

3 SPC58EC80E5 microcontroller hosted on AEK-MCU-C4M3

3.1 SPC58EC80E5 microcontroller

The main core of the AEK-MCU-C4M3 is the SPC58EC80E5 microcontroller. It is designed to address Automotive and Transportation applications as well as other applications requiring automotive safety and security levels as ASIL-B. This level of safety allows the latter to be used in numerous applications such as stability control systems, parking assistance systems, or headlight control. This SPC58EC line, 32-bit Power® Architecture automotive microcontroller, embeds two cores and a hardware security module. The main features are:

- Single-precision floating point operations
- High performance e200z420n3 dual core
  - 32-bit Power Architecture technology CPU
  - Core frequency as high as 180 MHz
- 4224 KB (4096 KB code flash + 128 KB data flash) on-chip flash memory: it supports reading during program and erase operations, while multiple blocks allow performing the EEPROM emulation
- Hardware Security Module (HSM) with hardware cryptographic co-processor
- 176 KB Hardware Secure Module (HSM) dedicated flash memory
- 384 KB on-chip general-purpose SRAM
- Multichannel direct memory access controllers
- One interrupt controller (INTC)
- Comprehensive new generation ASIL-B safety concept
  - ASIL-B of ISO 26262
  - FCCU for collection and reaction to failure notifications
  - Memory Error Management Unit (MEMU) for collection and reporting of error events in memories
- Crossbar switch architecture for concurrent access to peripherals, Flash, or RAM from multiple bus masters with end-to-end ECC
- System integration unit light (SIUL) for GPIOs, Timers and PWMs
- Enhanced modular IO subsystem (eMIOS): up to 64 timed I/O channels with 16-bit counter resolution
- Enhanced analog-to-digital converter system:
  - Three independent fast 12-bit SAR analog converters
  - One supervisor 12-bit SAR analog converter
  - One 10-bit SAR analog converter with STDBY mode support
- Communication interfaces:
  - Eight CAN interfaces with advanced shared memory scheme and ISO CAN-FD support
  - Eight serial peripheral interface (DSPI) modules
  - Eighteen LIN and UART communication interface (LINFlexD) modules
  - One Ethernet controller 10/100 Mbps compliant with IEEE 802.3-2008 standard (not used in the AEK-MCU-C4M3 board)
  - Dual-channel FlexRay controller (not used in the AEK-MCU-C4M3 board)
- Device and board test support for JTAG
- Low power capabilities:
  - Standby power domain with smart wake-up sequence

Note: For further information, refer to RM0407 and to the SPC58ECx datasheet.

3.2 SPI peripheral

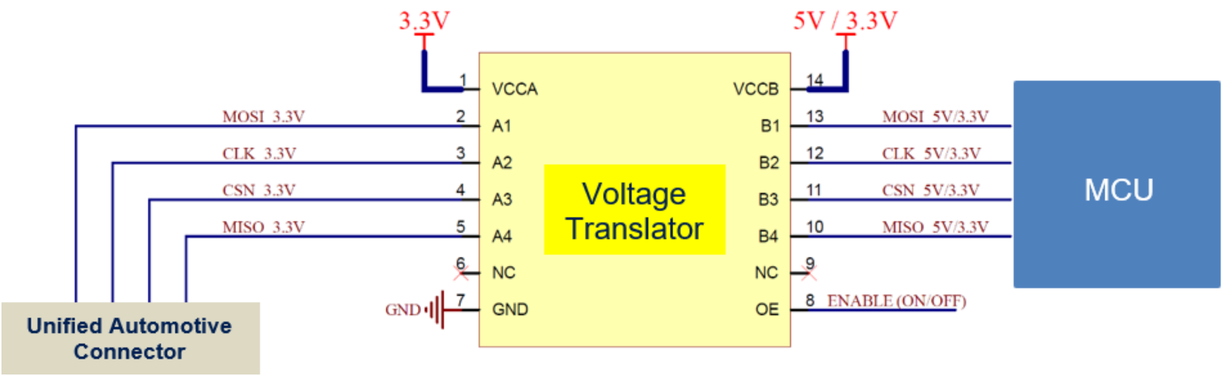
The SPC58EC80E5 microcontroller has eight SPI communication peripherals accessible via the automotive unified connector. The SPI protocol is employed for synchronous serial communication, used primarily in embedded systems for short distance wired communication between integrated circuits. The SPI protocol uses master-slave architecture, where one main device (master) manages communication among peripheral devices (slaves) by driving clock and Chip Select (CS) signals. In our case, for a given SPI group, we can drive different slaves through CSx signals from the master.

Figure 13. Example of SPI connection signals

The protocol is based on four logical signals:
- **CLK**: Serial Clock (clock signal from master)
- **SDO**: Serial Data Out or equivalently Master Output Slave Input [MOSI] (data output from master)
- **SDI**: Serial Data In or equivalently Master Input Slave Output (data output from slave)
- **CSN**: Chip Select Not (active low signal from master to address the slave and initiate)

To start communication, the SPI master selects a slave device by pulling its CS low. During each SPI clock cycle, full-duplex transmission of a single bit occurs. The master sends a bit to the MOSI line while the slave sends a bit to the MISO line. Then, master and slave read the corresponding incoming bit. This sequence is maintained even when only one directional data transfer is intended. The AEK-MCU-C4M3 features five SPI peripherals. Thanks to a fixed voltage translator, one of them is available with a 3.3 V voltage level while the other four SPI peripherals follow the microcontroller supply. Therefore, one of the SPI peripherals works at 3.3 V even if the entire board works at 5 V.

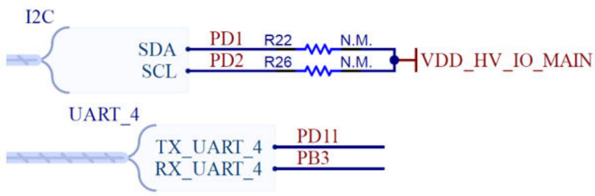
Figure 14. Fixed voltage translator



3.3 UART and I²C peripherals

The SPC58EC80E5 microcontroller supports other two additional communication protocols, UART and I²C, which are accessible via the automotive unified connector.

Figure 15. **UART and I^2C protocols**



The UART protocol is used for asynchronous serial communication, allowing configuration of data formats and transmission speeds. It sends data bits one by one, from the least significant to the most significant (LSB), framed by start and stop bits so that precise timing is handled by the communication channel. The UART protocol employs a TX pin for data transmission, while RX pin is used for data reception.

The I^2C protocol is a synchronous, multi-master/multi-slave, single-ended, serial communication bus. It is widely used to connect lower-speed peripheral ICs to microcontrollers over a short distance (i.e., for intra-board communication). It consists of SDA (serial data line) and SCL signal (serial clock line). Both signals require pull-up resistors (not mounted on the board), as both lines are open-drain. Typically, these resistors are inserted in the slave node but, if the node does not have them, two 10 K Ohms can be added for each line. For the I^2C protocol, the unit address is contained the message. This is a fundamental difference with the SPI protocol where the address is coded by physical signals i.e., Chip Selects (CS).

From the physical layer point of view, both SCL and SDA lines are open-drain (MOSFET) or open-collector (BJT) bus design. Thus, a pull-up resistor is needed for each line.

3.4 MCU I/O interfaces

The MCU I/O interfaces accessible via the automotive unified connector are listed below:

- **EMIOS** (Enhanced Modular Input/Output System): a microcontroller peripheral that allows sending and receiving digital signals. It is typically used to generate PWM (Pulse Width Modulation).
- **ADC** (Analog-Digital Converter): a microcontroller peripheral for analog-to-digital signal conversion, such as a time-varying voltage.
- **IRQ** (Interrupt Request): a peripheral that enables the microcontroller to receive external interrupts from separate units. Upon receival of an enabled given interrupt, the MCU shall stop the current program execution and jump to handle a specific procedure (called callback or interrupt handler). The program execution is resumed at the end of the callback. An example of external interrupt is the signal connecting to a user button press.
- **WAKE-UP**: a microcontroller peripheral that allows the MCU to wake up from a suspended or low-power state.
- **GPIO** (General Purpose Input/Output): a microcontroller peripheral that allows the MCU to receive or generate binary high and low signals (representing logic 1 and 0) to and from external devices.

4 Onboard supply and protection features for AEK-MCU-C4M3

The AEK-MCU-C4M3 board power is managed by a dual-channel step-down DC-DC converter, namely the L5963. The device converts the 12V board input voltage into 5V and 3V3. This device is coupled with the L99VR02J LDO for precise reference to feed for example the MCU ADCs. The board has a dedicated supply capacity for external 5 V or 3.3 V loads. The L5963 powers the entire board, and offers two user-selectable output channels (3.3 V and 5 V) available through dedicated connectors. As a switching converter, it provides robust noise immunity and delivers up to 2 A per channel. Additionally, it includes an on-board LDO that supplies 5 V for the microcontroller ADC. Instead, the L99VR02J LDO powers the microcontroller ADC, and delivers up to 500 mA while offering high noise immunity. Both device outputs are accessible via the 96-pin unified automotive connector.

Regarding protection circuits, the above-mentioned DC-DC and LDO devices have dedicated protection circuits against polarity reversal i.e., incorrect connection of the 12 V main power supply. In addition, to protect the board from a surge of inrush current from the power source to potential multiple connected loads, the two e-fuses STEF05L for 5 V and STEF033 for 3.3 V have been added on the AEK-MCU-C4M3 board design. The board design is completed with a reset button available for debug purposes.

4.1 L5963 DC-DC converter

The L5963 chip is a dual step-down switching regulator with internal power switches, a high-side driver, and a low drop-out linear regulator that can operate as a standby regulator or a normal LDO. In addition, to an adjustable voltage detector, voltage supervisors are available. The two DC-DC converters can work in free-run conditions or synchronize with an external clock. This IC fits the automotive segment, where load dump protection and wide input voltage range are mandatory. On the AEK-MCU-C4M3 board, the L5963 DC-DC device supplies the main microcontroller with its ADCs, the CAN transceiver, and e-fuses. The device consists of two switching channels that provide 5V and 3.3V, and a 5V linear voltage regulator. The two switching channels have a maximum current capability of 2 A each, while the LDO can deliver up to 250 mA. The L5963 main features are:

- AEC-Q100 qualified
- Two step-down synchronous switching voltage regulators with internal power switches:
  - Wide input voltage range (from 3.5 V to 26 V)
  - Internal high-side/ low-side power
  - 250 kHz free-run frequency with 250 kHz < f < 2 MHz as synchronization range
  - Integrated soft start
  - 180° PWM output phase shift
  - Programmable switching frequency divider by 1, 2, 4 or 8
  - Power good function
- One standby / linear regulator
  - Output voltage programmable with external resistor divider
  - 250 mA maximum current capability
- One high side driver
- All the regulators come with the following protections:
  - Independent thermal protection on all regulators
  - Independent current limit on all regulators
- Protected against short to ground and battery, loss of ground and battery, unsupplied short to battery
- Programmable under voltage battery detector and load dump protection
- Extremely low quiescent current in standby conditions
- Power good/adjustable voltage detector outputs to realize customized power up/down sequences

Note: For further information, refer to the L5963 datasheet.

All the features listed above have been implemented on the AEK-MCU-C4M3 board, except:

- The Power-good reset, the Power-good function, and the low voltage warning monitor
- The high-side output, which is left floating
- The external free running frequency, which is left floating

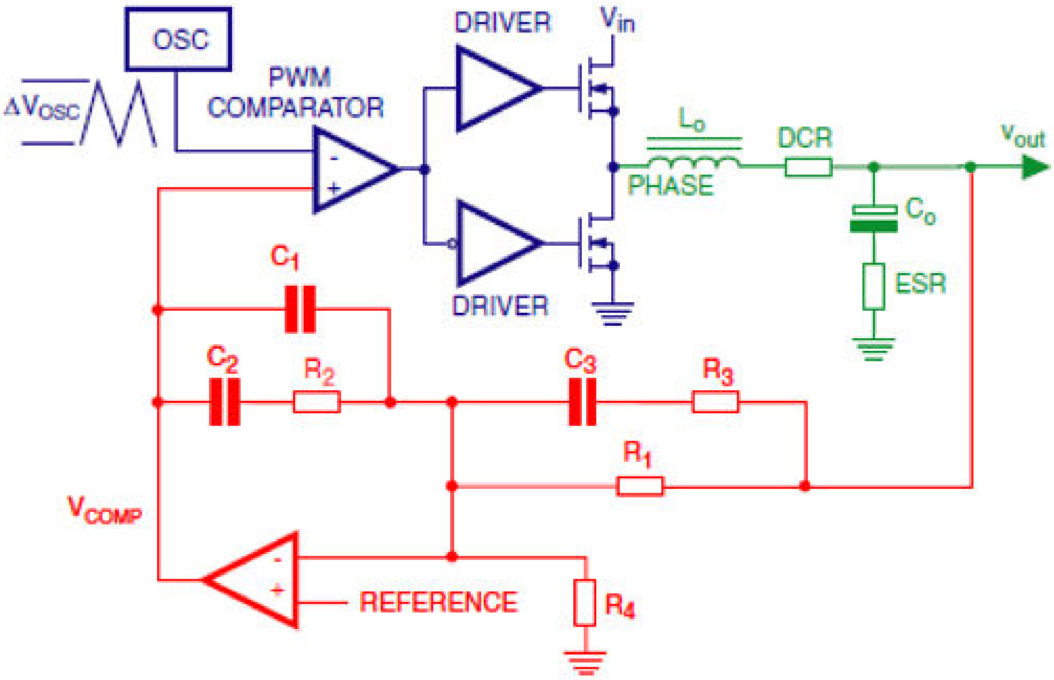
4.1.1 L5963 control mode, efficiency and ripple curves

This subsection analyzes the L5963 control mode, which is crucial for its correct operation. In switching converters, control is typically defined by the compensation network of the error operational amplifier. This network can be classified as Type I, Type II, or Type III, each offering different frequency response characteristics to ensure system stability and performance.

- **Type I** compensation provides simple integration, suitable for basic applications.
- **Type II** adds a zero to improve phase margin, enhancing stability.
- **Type III** introduces two zeros and one pole, allowing a better transient response and higher bandwidth.

L5963 implements **Type III** compensation to achieve fast transient response while maintaining stability under varying loads. In addition, closed feedback loop system with a Type III compensation network provides dynamic performance. Relative stability control was built to manage a load of up to 2 A. As shown in the below figure, when the output voltage V_{OUT} increases, the feedback voltage V_{FB} increases, and the output of the negative feedback error amplifier decreases. Thus, the duty cycle decreases. As a result, V_{OUT} is pulled back to V_{FB} = REFERENCE.

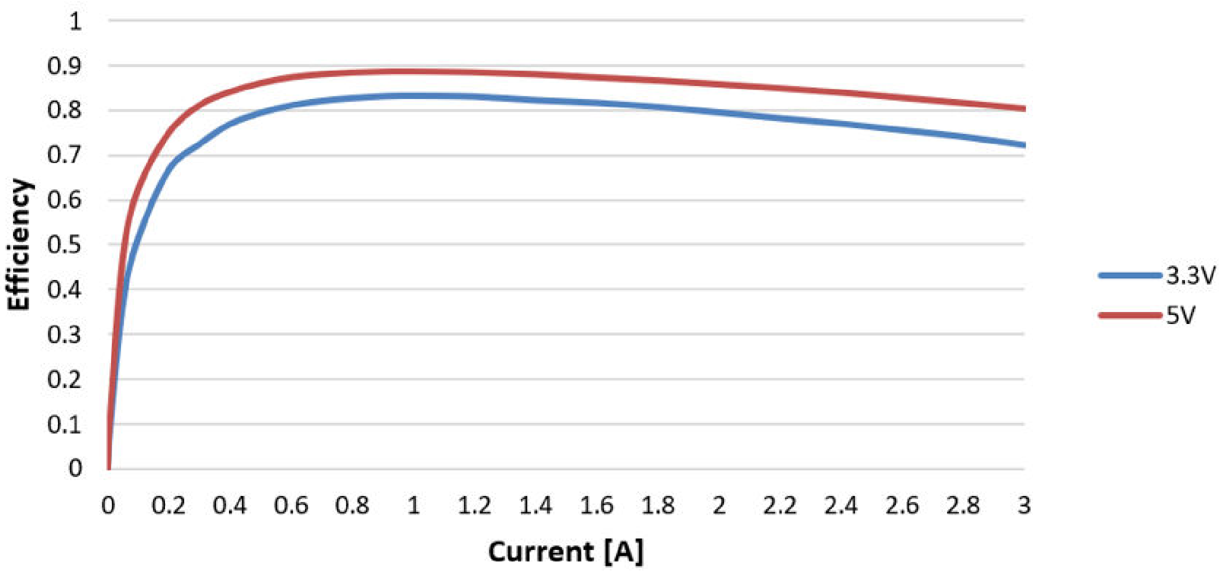
Figure 16. Closed loop system control with Type III network



Note: For further information about the compensation network, refer to the L5963 datasheet.

Figure 17 shows the L5963 efficiency curves related to 3.3 and 5 V outputs. Considering the switching losses, the two output efficiencies are close to 90% even at 2 A.

Figure 17. **L5963 efficiency curves**



The figures below show the L5963 voltage ripple. We considered only a few examples for the 5 V channel: 10 mA, 500 mA, and 2 A.

Figure 18. **Voltage ripple at 5 V with a load of 10 mA**

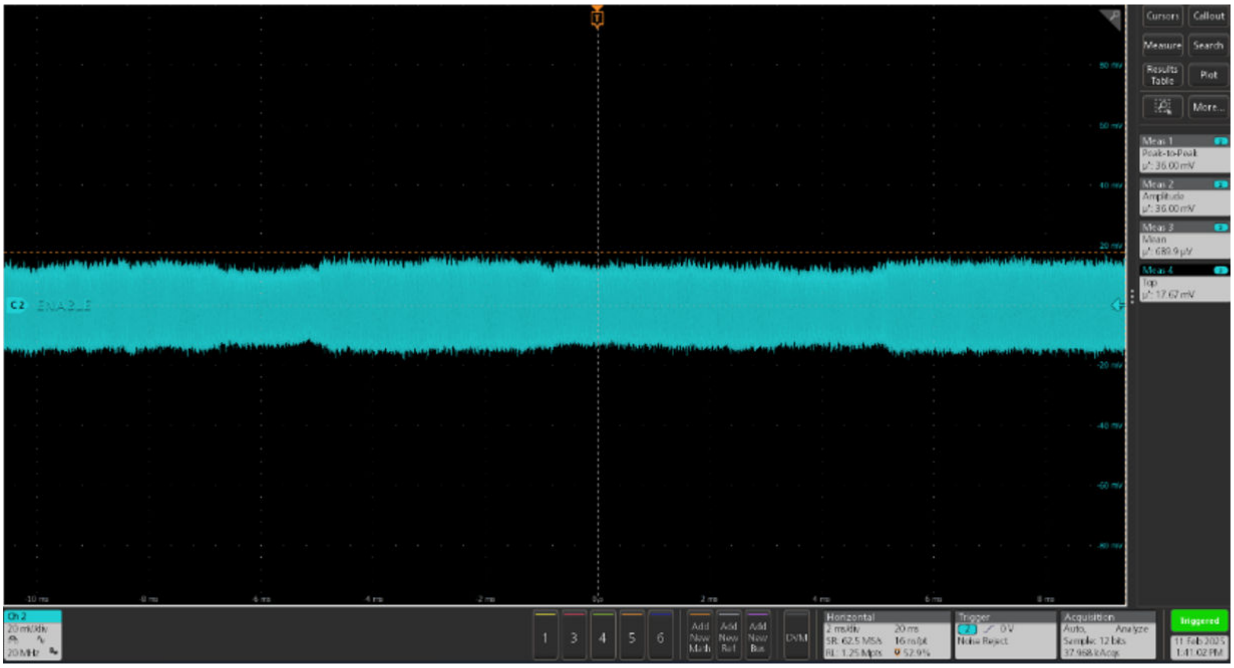


Figure 19. **Voltage ripple at 5 V with a load of 500 mA**

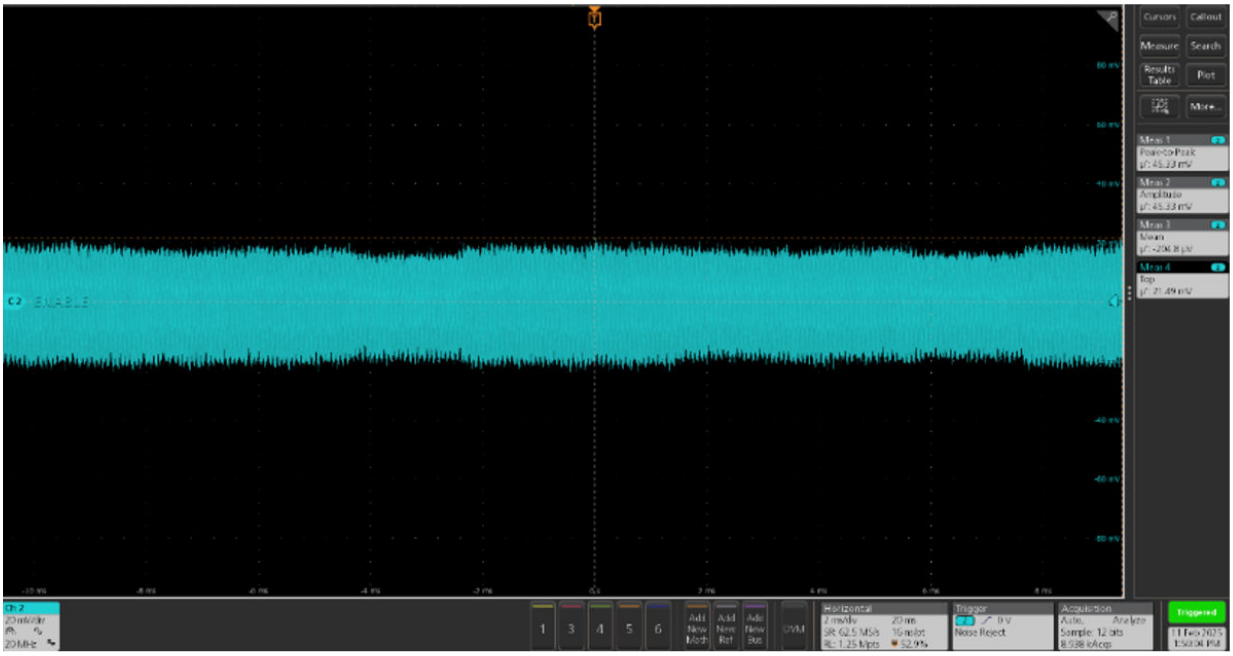
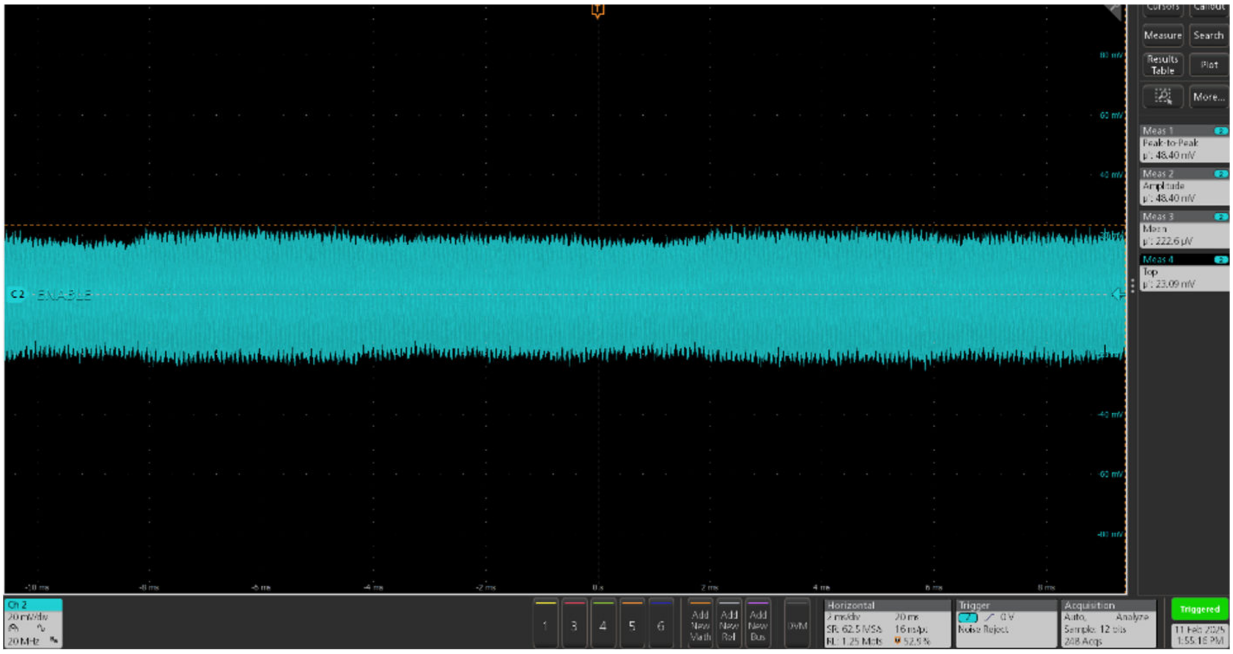


Figure 20. **Voltage ripple at 5 V with a load of 2 A**



According to the formulas below (for further details, see DS11357, section 7.2), we shall choose the right output capacitor to support the output voltage during a load transient and output ripple current, as well as to reach loop stability.

$$\Delta V_{OUT} = \text{ESR} * \Delta I_L + \frac{\Delta I_L}{8 * C_{OUT} * F_{SW}}$$

$$\Delta V_{OUT} = \frac{L}{2} * \left(\frac{I^2_{OUT(MAX)} - I^2_{OUT(MIN)}}{C_{OUT} * V_{OUT}}\right)$$

By choosing an output capacitor of 22 µH with a maximum current of 2 A, a switching frequency of 250 kHz and 44.1 µF, we obtain a ripple of ΔV_{OUT} < 200 mV that is less than 5% of V_{OUT}. In the worst case, we obtain a ripple of 50 mV Peak-to-Peak at 2 A.

4.2 L99VR02J LDO

The L99VR02J is a low dropout linear voltage regulator designed for automotive applications. It features enable, reset, autonomous watchdog, advanced thermal warning, fast output discharge, and I_{short} control.

In addition, the device features short-circuit, overload, and overtemperature protection. The short current value is configurable through external resistance. In our board, the L99VR02J is used as a pre-regulator directly connected to the battery. Through SELx pins, it can be configured to generate a selectable output voltage (from 0.8 up to 5 V). In the AEK-MCU-C4M3 board, the output voltage has been set to 3.3 V. This supply is used to power external devices: the fixed voltage translator for 3.3 V-fixed SPI and the microcontroller ADCs. This power supply is also available externally via the CN3 automotive unified connector. The L99VR02J main features are:

- AEC-Q100 qualified
- Operating DC power supply voltage ranges from 2.15 V to 28 V
- User-selectable output voltage (0.8 V; 1.2 V; 1.5 V; 1.8 V; 2.5 V; 2.8 V; 3.3 V; 5 V)
- Low dropout voltage and low quiescent current consumption with output voltage precision ±2%
- Output voltage monitoring with reset output
- Programmable autonomous watchdog through external capacitors
- Programmable short-circuit output current
- Thermal shutdown, short-circuit current limitation and undervoltage lockout UVLO
- Advanced thermal warning and output overvoltage diagnostic
- Fast output discharge
- Negligible ESR effect on output voltage stability for load capacitors

Note: *For further information, refer to the L99VR02J datasheet: DS14076.*

In the AEK-MCU-C4M3 board, all the features listed above are not implemented except for:

- User-selectable output voltage
- Output current limitation

As mentioned before, since this voltage regulator is used to supply the voltage translator and microcontroller ADCs, the output voltage is fixed at 3.3 V.

Note: *You can change the output voltage according to your specific application by replacing R11, R24, R70, R96 and R151 resistors (see the highlighted rectangle in the figure and table below). A 1 K resistor is recommended for the high logic level. Be aware that when using a voltage different from 3.3 V, the circuit might not work properly unless the L99VR02J is deactivated.*

Figure 21. Resistors to be modified for voltage selection

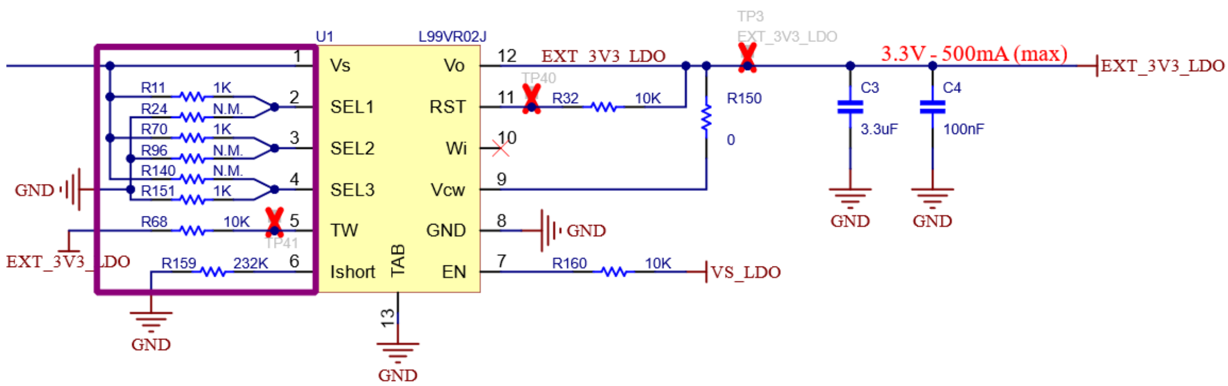


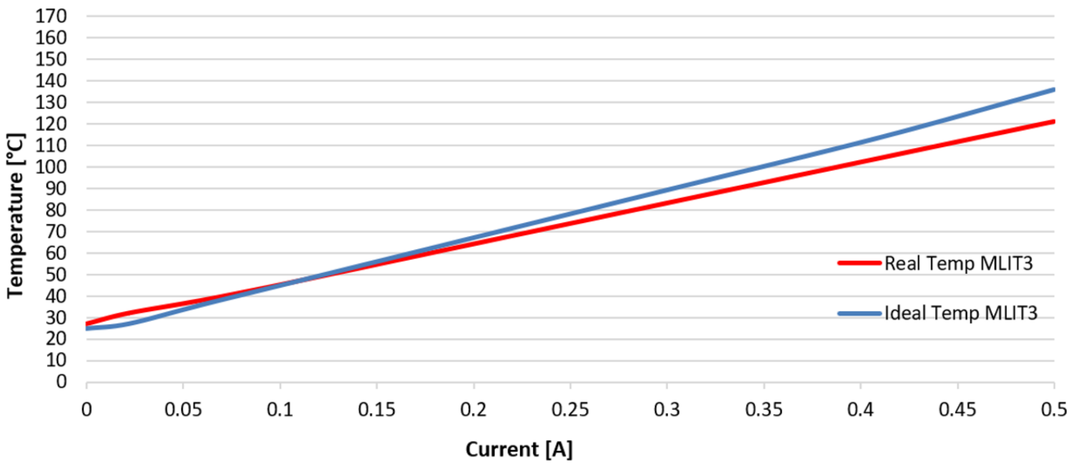
Table 2. Truth table for output voltage selection

V_O	SEL1	SEL2	SEL3
5 V	1	1	1
3.3 V	1	1	0
2.8 V	1	0	1
2.5 V	1	0	0
1.8 V	0	1	1
1.5 V	0	1	0
1.2 V	0	0	1
0.8 V	0	0	0

4.2.1 L99VR02J LDO thermal measurements

Unlike switching converters, LDOs are more susceptible to temperature rise and potentially have no ripple variation on the voltage. Therefore, to evaluate the performance, we measured the temperature variation as the load increased up to a maximum of 500 mA, which is the maximum current the device can deliver. The figure below shows the L99VR02J temperature variation at 3.3 V.

Figure 22. L99VR02J temperature at 3.3V



To evaluate the temperature variation, we used the formulas below, with the necessary approximations.

$$**(P_W) = ((V_{IN} - V_{OUT}) * I_{LOAD})$$

$$**(T_J) = T_A + (P_W * R_{TH-AMB})$$

Where:

V_{IN} = 12V

V_{OUT}=3.3V

I_{LOAD} = 0mA up to 500mA

$R_{TH\text{-}AMB}$ = 25.5°C/W

T_A = 25°C

We calculated the temperature characteristics in the ideal case (the blue line in the image above). Then, we compared it with the L99VR02J measured temperature detected by a thermal imaging camera. Even in the worst case (500 mA), we get values well within the automotive range of 175°C.

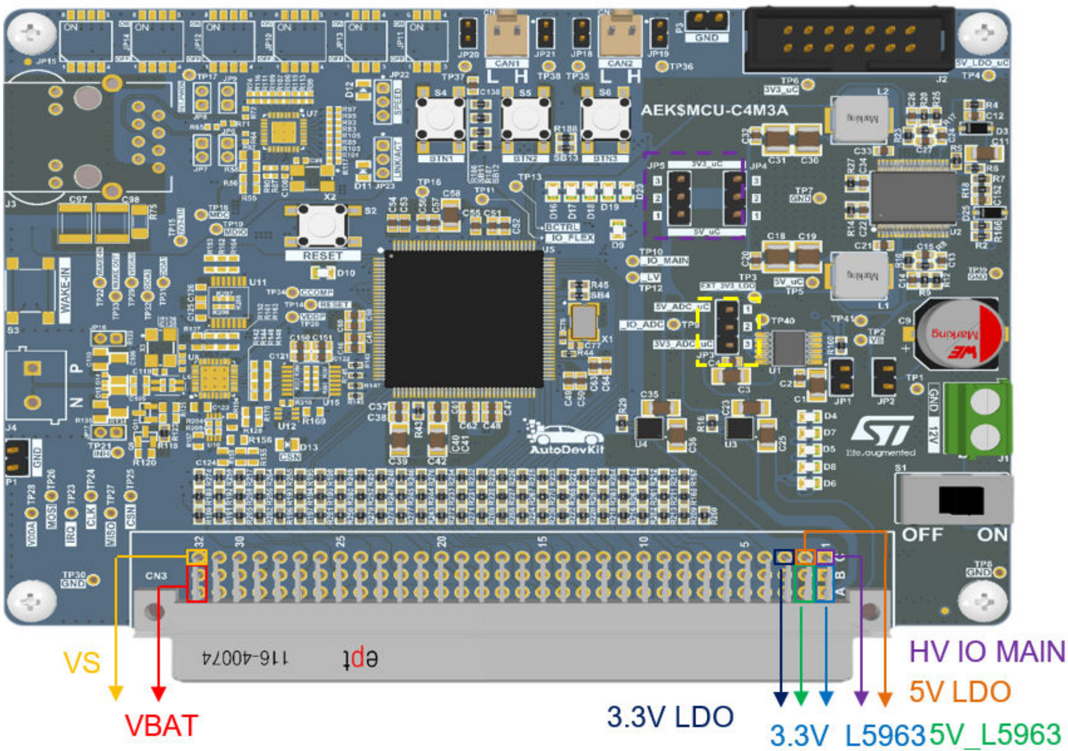
Note: The above formulas are approximated, as the junction temperature, leakage current and other minor parameters of the L99VR02J were not considered.

4.3 AEK-MCU-C3 board possible voltage configurations

As shown in the figure below, the AEK-MCU-C4M3 provides the following voltages through the CN3 unified automotive connector:

- **VBAT**, which is the board 12 V power supply
- **VS**, which is the 12 V voltage derived from the reverse polarity circuitry
- **3.3V_LDO**, which supplies the MCU ADC 3.3 V and **5V_LDO**, which supplies the MCU ADC 5 V
- **HV_IO_MAIN**, which supplies all peripherals

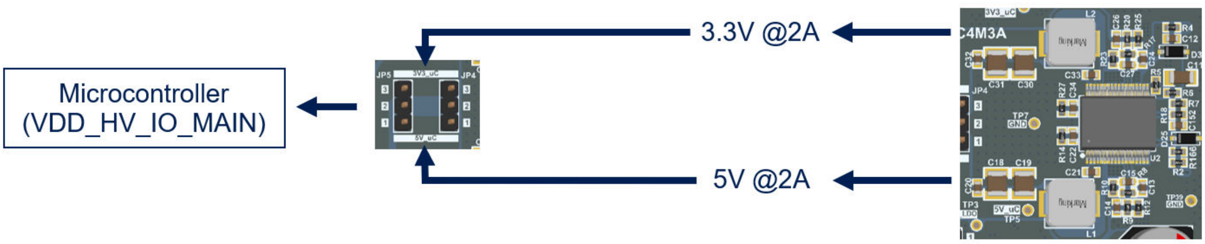
Figure 23. **Overall voltage configurations**



To select the desired voltage, connect a jumper to JP4 and JP5 as follows:

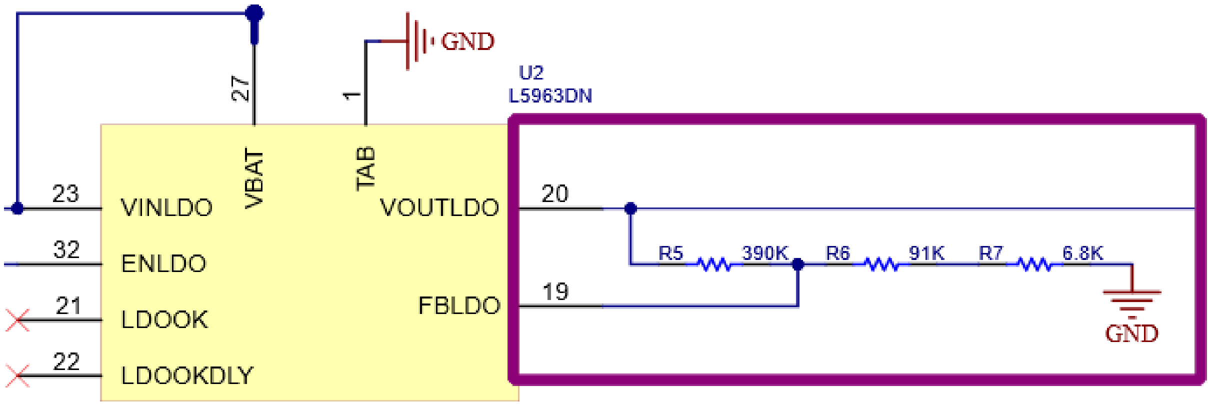
- use a jumper on positions 2-3 to use the 3.3 V line
- use a jumper on positions 1-2 to use the 5 V line

Figure 24. **L5963 voltage configurations**



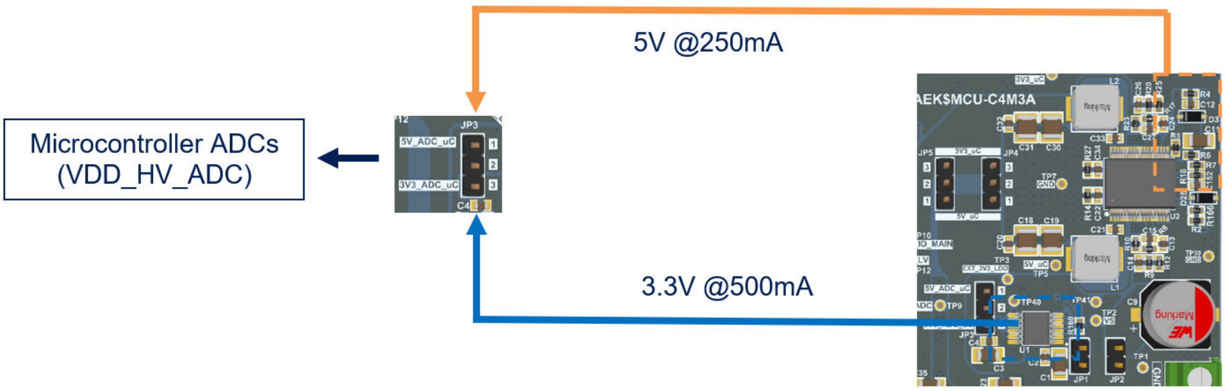
The two output voltages (5 V and 3.3 V) converge into the microcontroller final supply (VDD_HV_IO_MAIN). These voltages provide the power source to the microcontroller that, in turn, provides power to the internal peripherals. Moreover, the microcontroller supplies the CAN transceivers, various buffers, LEDs, and buttons. The board features two additional configurable voltages: one derived from the L5963, with a capability of 250 mA, built through a voltage divider based on R5, R6 and R7 resistors (Figure 25), and one derived from the L99VR02J linear regulator with a capability of 500 mA.

Figure 25. **Voltage divider from L5963 with 250mA**



To exploit these two additional voltages and select the desired voltage, connect a jumper to JP3 as follows:
- use a jumper on positions 2-3 to use the 3.3 V line
- use a jumper on positions 1-2 to use the 5 V line

Figure 26. **LDO supply configurations**



4.4 E-fuses

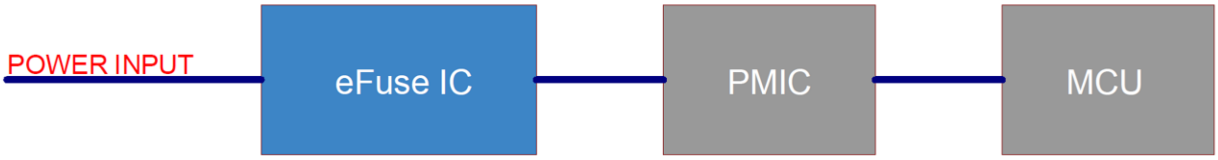
The AEK-MCU-C4M3 hosts two electronic fuses (e-fuses), STEF033 and STEF05L, which are advanced electronic protection devices designed to protect circuits and components from overcurrent and overvoltage conditions. Unlike traditional fuses, which are one-time-use components that physically break to interrupt the circuit, e-fuses are integrated circuits that can electronically monitor and control the current flow, allowing reset and reuse. When an overload occurs, these devices limit the output current to a safe value defined by the user. If the overload persists, the devices enter the open state, disconnecting the load from the power supply. The current overload limit can be programmed through an external resistor. At power-up, e-fuses manage the increase of the output voltage in a smooth and controlled manner. This careful ramp-up helps prevent a surge of inrush current from the power source to the load, thereby protecting the power supply from overload. This feature is particularly beneficial in setups where one power supply feeds multiple loads. The startup time can be adjusted by selecting a different soft start capacitor. Devices can operate in either latch-off or auto-retry modes following a fault.

In latch-off mode, the e-fuse permanently breaks the current flow until a manual reset is performed. This means that, even if the fault is recovered, an external action (for example, a manual reset) is required. In this mode, the e-fuse can be reset through an *enable* pin. Instead, in auto-retry mode the e-fuse temporarily interrupts the current flow and automatically attempts to restore it until the fault is recovered. E-fuses communicate the fault status to the system controller through a fault pin. The main advantages of e-fuses are:
- Resettable output
- No need of replacement after a fault
- Auto-retry or latch-off modes for reset
- Reduced cable length

- Improved fuse time-current characteristics
- Less variability

The figure below shows a typical e-fuse application example.

Figure 27. Typical e-fuse application



4.4.1 STEF033: 3.3 V rail e-fuse

STEF033 is an integrated electronic fuse optimized for monitoring output current and the input voltage. Connected in series to the 3.3 V rail, it protects the electronic circuitry on its output from overcurrent and overvoltage. The main features are:

- Continuous current (typ.: 3.6 A)
- Enable/Fault functions
- Output clamp voltage (typ.: 4.5 V) and undervoltage lockout
- Short-circuit limit and overload current limit
- Controlled output voltage ramp and thermal latch (typ.: 160°C)
- Latching and auto-retry versions
- Operative junction temperature: - 40°C to 125°C

Note: For further information, refer to the STEF033 datasheet.

All the above listed features have been implemented on the AEK-MCU-C4M3 board, except:

- Fault functions: thermal fault is not managed through the external MOSFET, as the latter manages the device output. Thermal faults are monitored only when the device works in auto-retry mode. In this condition, the device automatically attempts to re-apply power to the load only when the die temperature returns to a safe value.
- Controlled output voltage ramp: we did not use a capacitor to exploit the maximum rise time of the output voltage.

The figure below shows typical performance characteristics when the device is on through the *Enable* signal. The output is generated after 500 µs, while the T_{RT} (rise time) is typically 1.4 ms. The T_{RT} measures the time for the output voltage to go from 10% to 90% of the nominal voltage.

Figure 28. V_{OUT} ramp-up vs Enable for STEF033

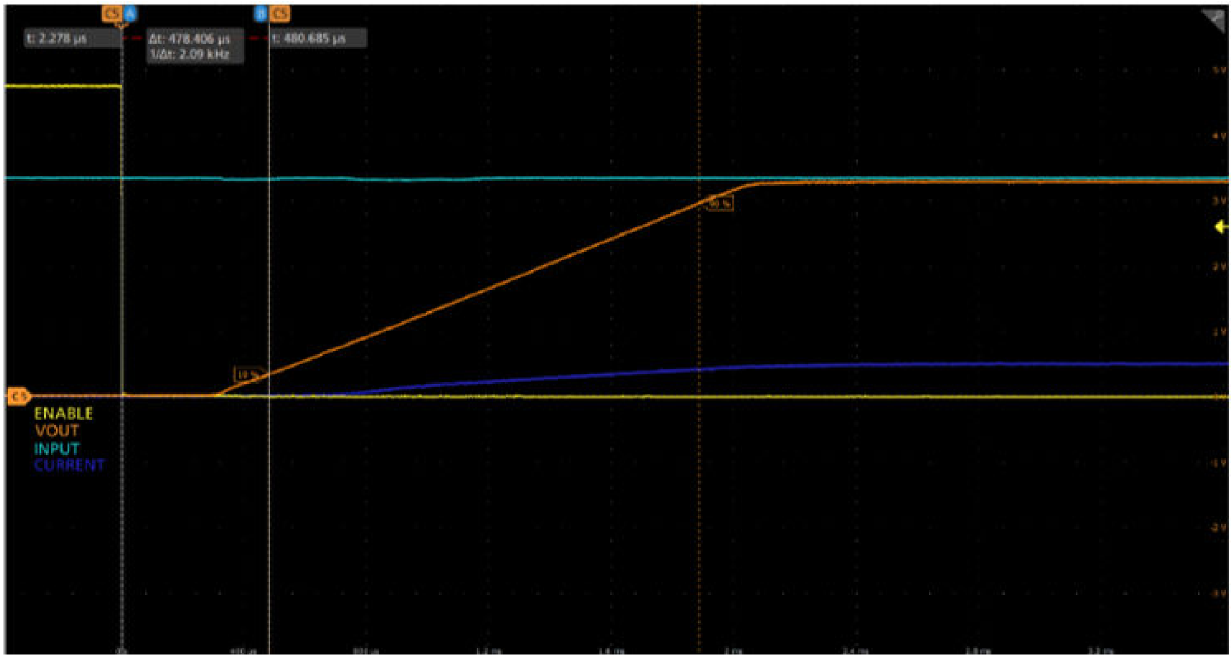


Figure 29 and Figure 30 show the e-fuse behavior upon I_{SHORT} and $I_{OVERLOAD}$. The short-circuit current limit (I_{SHORT}) is the current level that is forced when the output voltage decreases sharply (for example, when an output short-circuit occurs). The overload current limit ($I_{OVERLOAD}$), also called “current limit trip-point”, represents the current level that is recognized by the device as an overload condition. When the current limit trip point is reached, the device enters current limitation and the load current is limited to the I_{SHORT} value, which is generally lower than the trip-point value. In our board, we chose a resistance of 100 Ω to get an I_{SHORT} of ~500 mA and an $I_{OVERLOAD}$ of ~2.7 A.

Figure 29. Startup and I_{SHORT} current limit

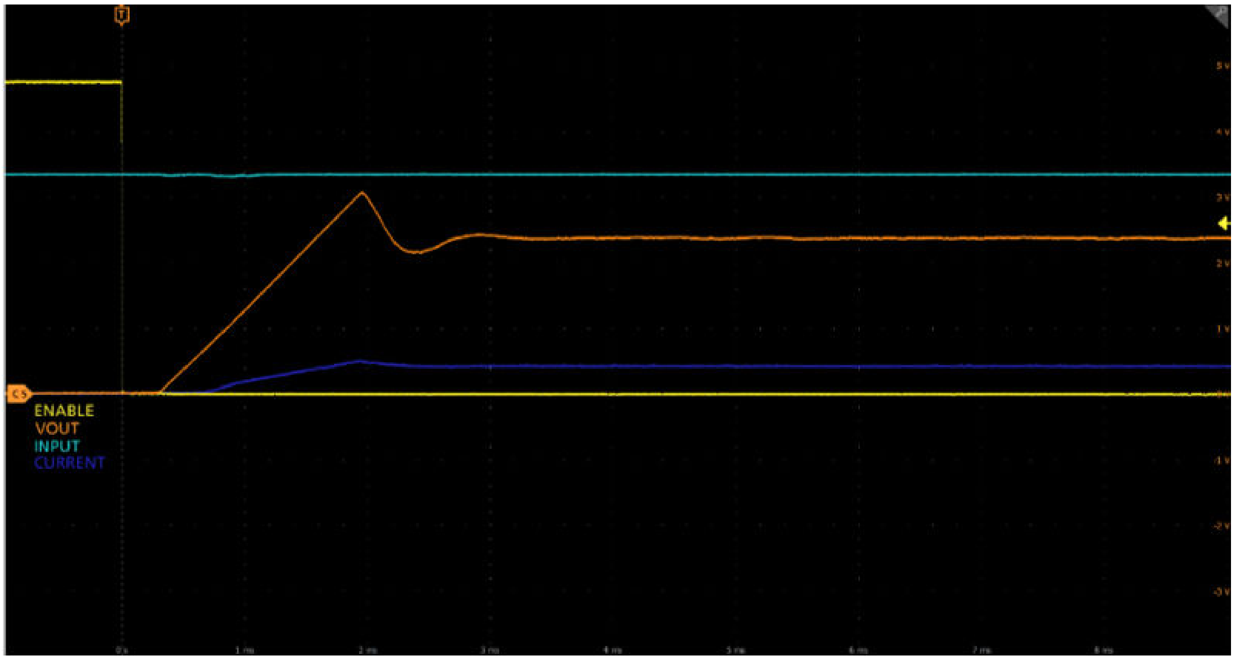
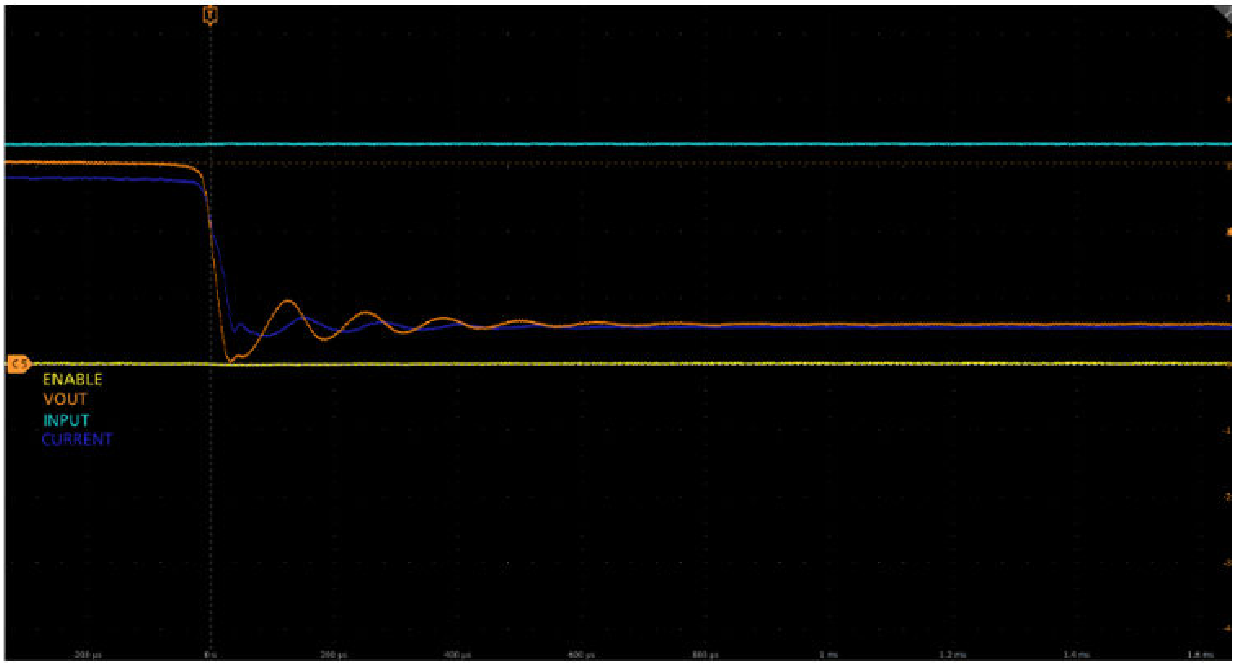


Figure 30. $I_{OVERLOAD}$ **current limit**



Note: For further information, refer to the STEF033 datasheet.

4.4.2 STEF05L: 5 V rail e-fuse

STEF05L is an integrated electronic fuse optimized for monitoring current output and input voltage. Connected in series to the 5 V rail, it protects the electronic circuitry on its output from overcurrent and overvoltage. This e-fuse is intended to protect a daughter board from any overload or overcurrent. The main features are:

- Continuous current (typ.: 3.6 A)
- Enable/Fault functions
- Output clamp voltage (typ.: 6.1 V) and undervoltage lockout
- Short-circuit limit and overload current limit
- Controlled output voltage ramp and thermal latch (typ.: 160°C)
- Latching and auto-retry versions
- Operative junction temperature: - 40°C to 125°C

Note: For further information, refer to the STEF05L datasheet.

All the above listed features have been implemented on the AEK-MCU-C4M3 board, except:

- Fault functions: thermal fault is not managed through the external MOSFET, as the latter manages the device output. Thermal faults are monitored only when the device works in auto-retry mode. In this condition, the device automatically attempts to re-apply power to the load only when the die temperature returns to a safe value.
- Controlled output voltage ramp: we did not use a capacitor to exploit the maximum rise time of the output voltage.

The figure below shows typical performance characteristics when the device is on through the *Enable* signal. The output is generated after 500 µs, while the T_{RT} (rise time) is typically 1.4 ms. The T_{RT} measures the time for the output voltage to go from 10% to 90% of the nominal voltage.

Figure 31. V_{OUT} ramp-up vs Enable for STEF05L

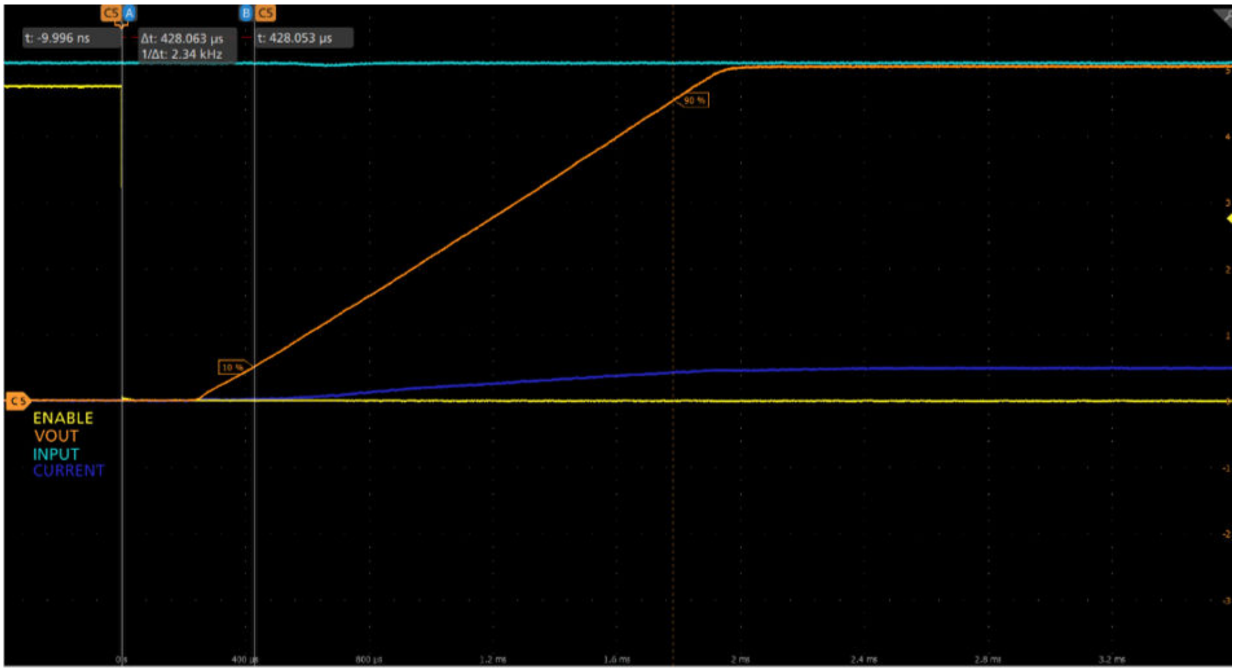


Figure 32 and Figure 32 show the e-fuse behavior upon I_{SHORT} and $I_{OVERLOAD}$. The short-circuit current limit (I_{SHORT}) is the current level that is forced when the output voltage decreases sharply (for example, when an output short-circuit occurs). The overload current limit ($I_{OVERLOAD}$), also called “current limit trip-point”, represents the current level that is recognized by the device as an overload condition. When the current limit trip point is reached, the device enters current limitation and the load current is limited to the I_{SHORT} value, which is generally lower than the trip-point value. In our board, we chose a resistance of 100 Ω to get an I_{SHORT} of ~500 mA and an $I_{OVERLOAD}$ of ~2.7 A.

Figure 32. Startup and I_{SHORT} current limit

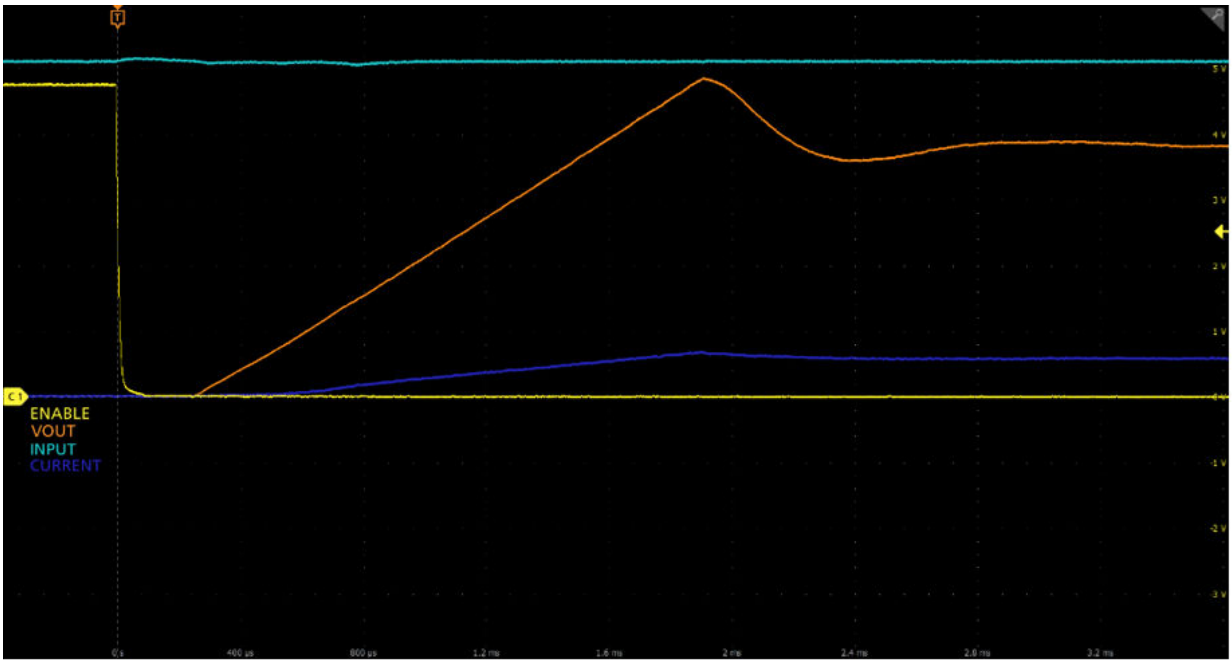
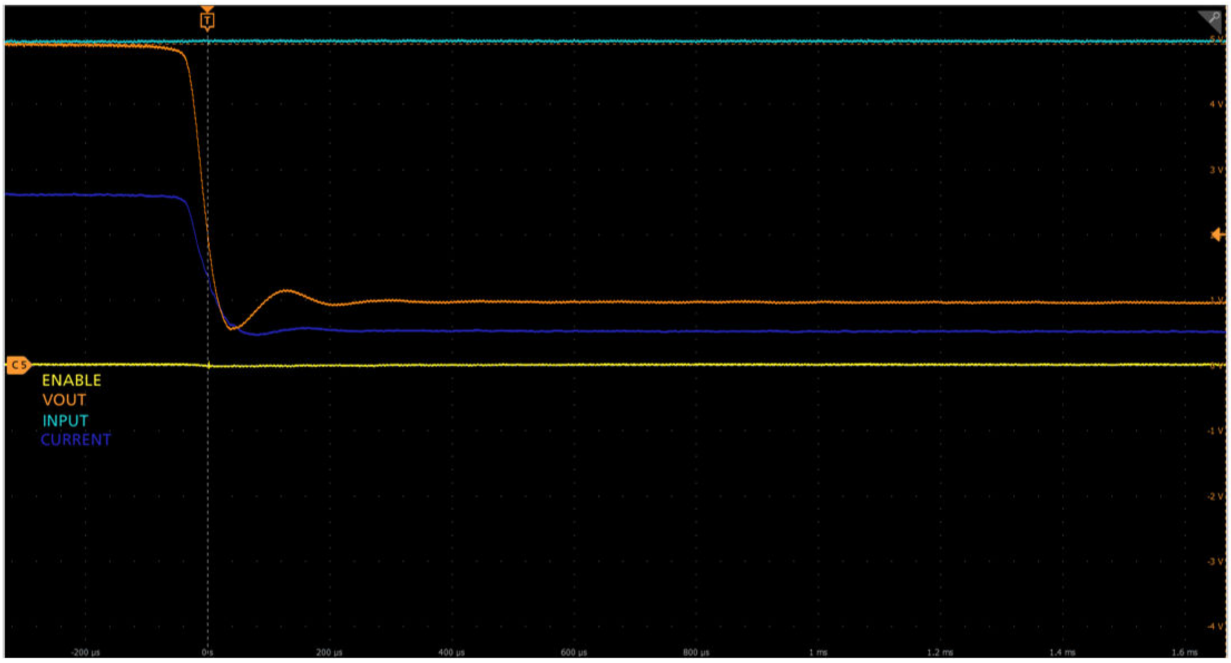


Figure 33. $I_{OVERLOAD}$ current limit

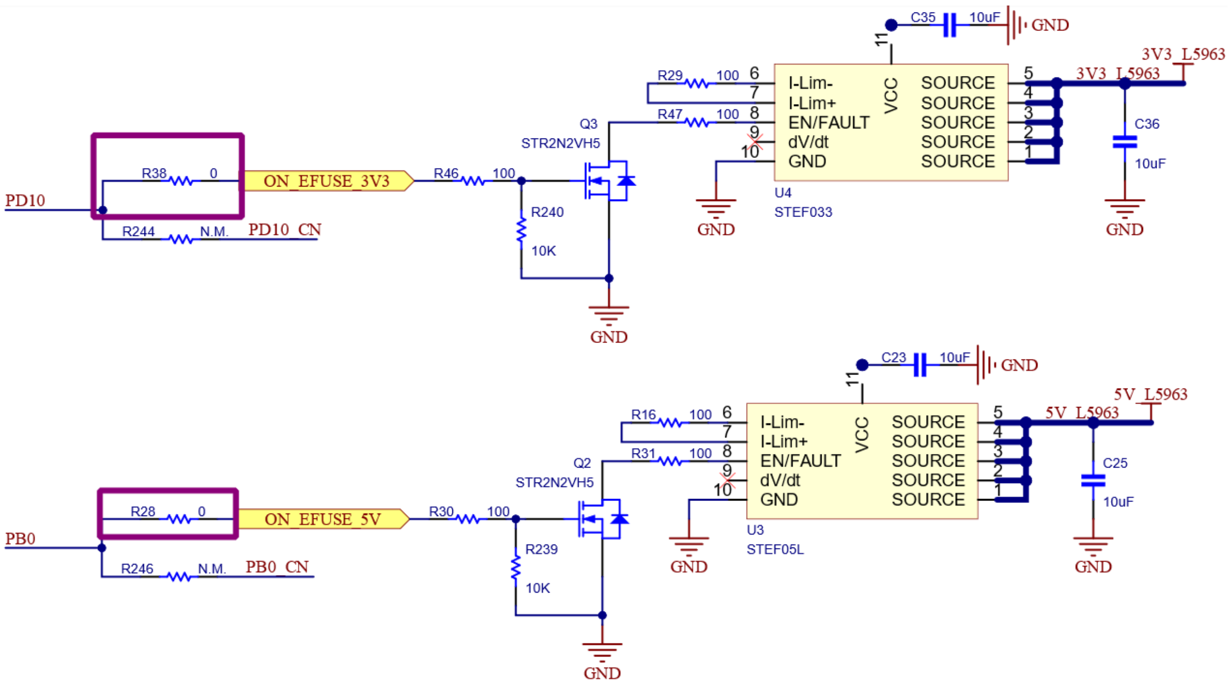


Note: For further information, refer to the STEF05L datasheet.

4.4.3 E-fuse configuration

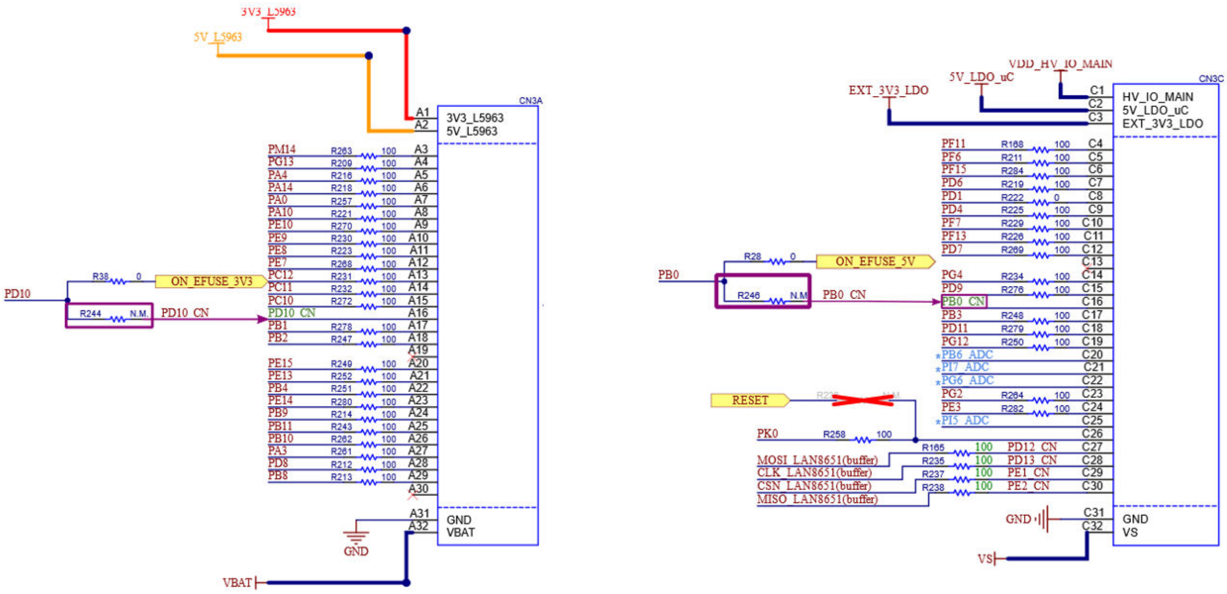
In the AEK-MCU-C4M3, the e-fuses are managed by the microcontroller i.e., as we can see in the image below, the e-fuse enablement depends on the signal value of PD10/PB0 pins. Remove R28 and R38 resistors to make the e-fuses independent from the MCU and keep them always on.

Figure 34. **Always-on e-fuse configuration**



After R28 and R38 resistors removal, you can use PD10 and PB0 as MCU GPIOs by mounting R244 and R246 resistors. These resistor lines are already connected to the AEK-CON-LIT **CN3A** and **CN3C** connectors.

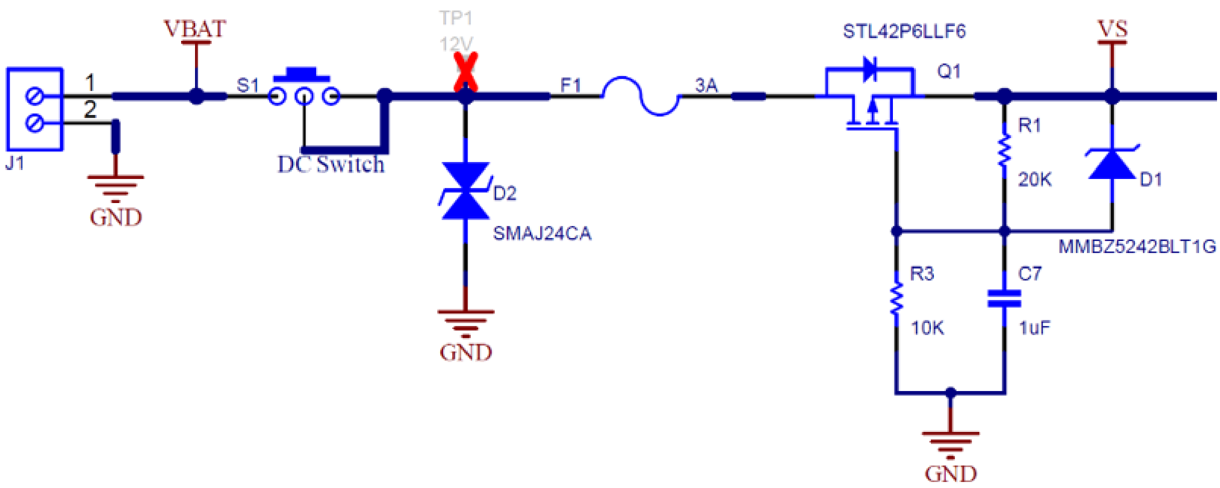
Figure 35. **Disconnecting the line from e-fuses and using them as MCU GPIOs**



4.5 External reverse battery protection

External reverse battery protection robustly protects the electrical system. The danger that all electrical systems face is reversed polarity from the power source. This can be caused by a short circuit or, more often, by simply swapping the power and ground terminals when connecting a power supply.

Figure 36. **Reverse battery protection with PMOS**



In the nominal condition, the battery conducts current into the system through the PMOS body diode while the PMOS switches on. Afterwards, the PMOS conducts the current with an extremely low-on resistance. Considering that $V_{GS} = V_G – V_S = 0 -12 = -12$ V, which is less than the PMOS V_{TH}, the PMOS will conduct. D1 Zener diode protects the PMOS gate from overvoltage by clamping the voltage to 12 V. When the battery is connected in reverse, the PMOS is switched off, with no current flowing. Considering that $V_{GS} = V_G - V_S = 0 - (-12\ V) = +12$ V, which is greater than the PMOS V_{TH}, the PMOS will be off. This technique is more efficient than using only one diode because of the power MOSFET low R_{dson}. With an R_{dson} value of milliohms or lower, the voltage drops caused by the MOSFET are often far lower than the forward voltage of a diode, resulting in better efficiency, lower loss of usable battery voltage, and less heat.

5 The AutoDevKit ecosystem

The application development employing our AEK-MCU-C4M3 evaluation board takes full advantage of the AutoDevKit ecosystem, whose basic components are:

- AutoDevKit Studio IDE (STSW-AUTODEVKIT)
- OpenOCD programmer and debugger

5.1 Available demos

In the AutoDevKit ecosystem, starting from release 2.7.0, the following demos are available for the AEK-MCU-C4M3 evaluation board testing:

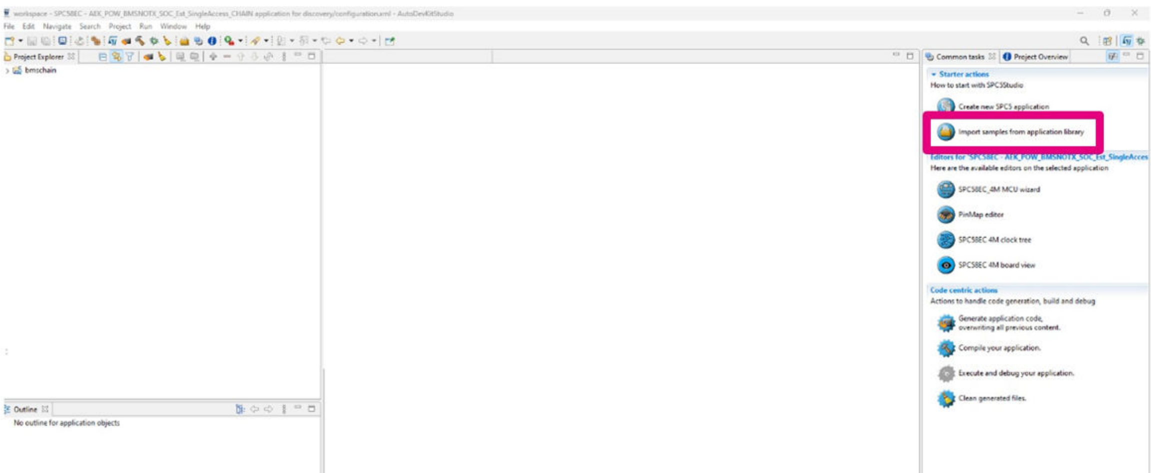
- **AEK-MCU-C4M3Lite - SPSB081 test application with board connector** test application with board connector: this demo application configures an AEK-POW-SPSB081 to drive four high-side outputs, exploiting five different working modes: OFF, ON, TIMED, PWM, and DIR. The component allocates an SPI peripheral (to configure the SPSB081 functionality) and a PIT timer (used to toggle the watchdog periodically). The DIR is configured via API as a low voltage direct driving of OUT4.
- **AEK-MCU-C4M3Lite – WINH92 test application with board connector**: this demo shows how a PWM DC Motor Control Driver works, configured in full-bridge mode using the AEK-MOT-WINH92 board. Through this demo, you can make a DC motor rotate clockwise and counterclockwise. The current measured on the H-bridge and supply voltage can be printed on a serial port (115200 bps).
- **AEK-MCU-C4M3 – STEF0xx eFuses test application**: this demo shows how to handle physical button inputs reliably and use them to control the two onboard e-fuses. Pressing BTN1 toggles the 5 V e-fuse, while pressing BTN2 toggles the 3.3 V e-fuse. The demo leverages the WKPU (Wakeup Unit) peripheral to detect button presses via interrupts. This means that the microcontroller can respond immediately to user input without constantly polling the button state, making the system more efficient and responsive.

5.2 How to import and run a demo

Step 1. Connect the AEK-MCU-SPC5LNK to the AEK-MCU-C4M3 JTAG connector. Then, connect the AEK-MCU-SPC5LNK to your PC/laptop via USB cable.

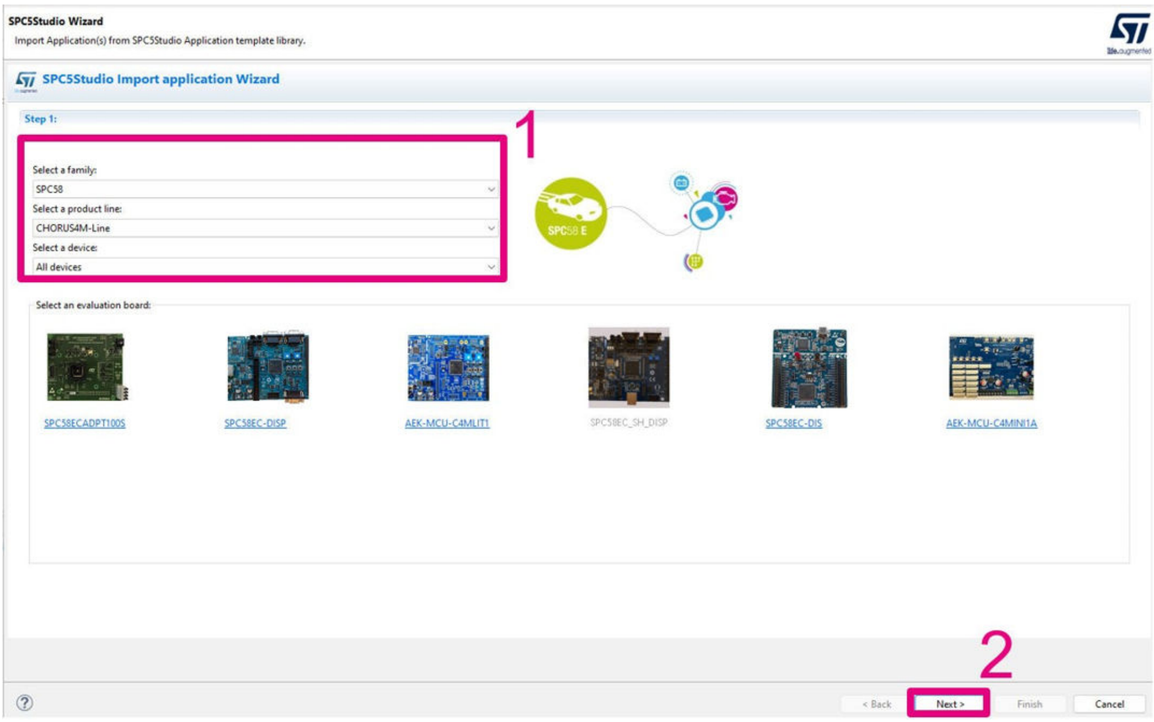
Step 2. Download and install the last version of AutoDevKit. Then, click on “Import samples from application library”.

Figure 37. **Importing sample from AutoDevkit library**



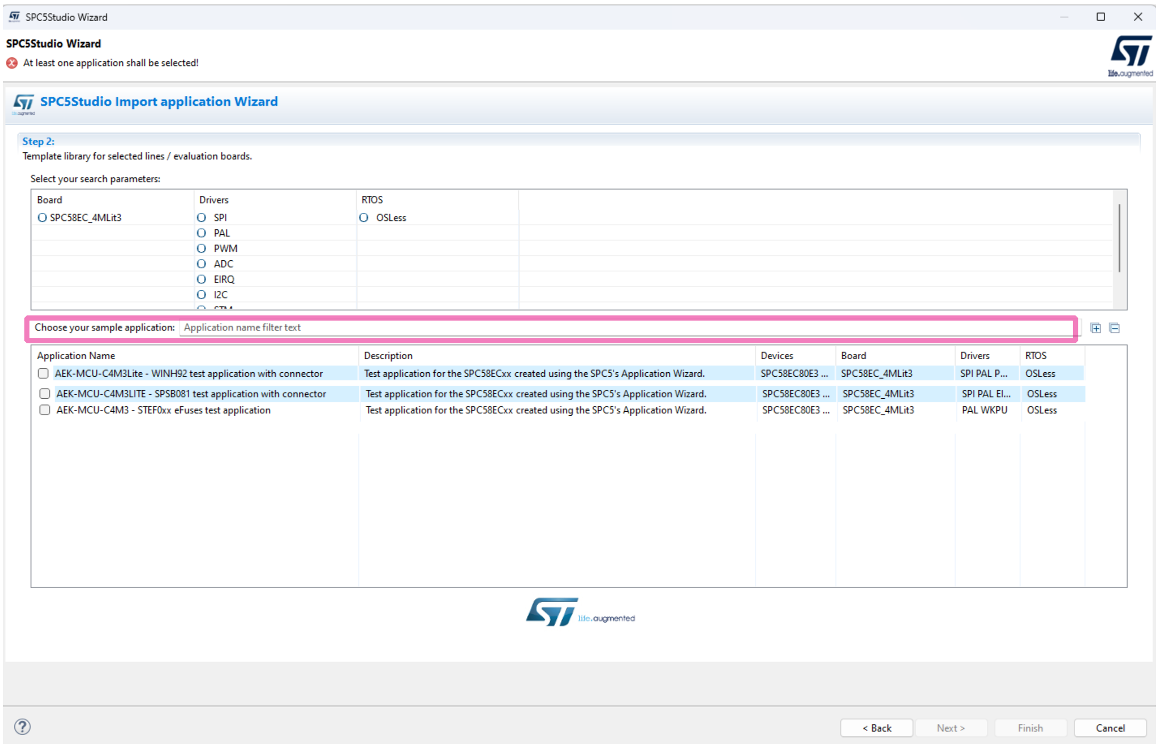
Step 3. Select the microcontroller family and the product line as shown below. Then, click on“Next”.

Figure 38. Selecting microcontroller family and product line



Step 4. Type “c4m3” in the field highlighted below and select one of the dedicated demo applications. Then, click on“Finish”.

Figure 39. Selecting the application demo



Step 5. Double-click on the main.c file. Then, clean and compile the selected project.

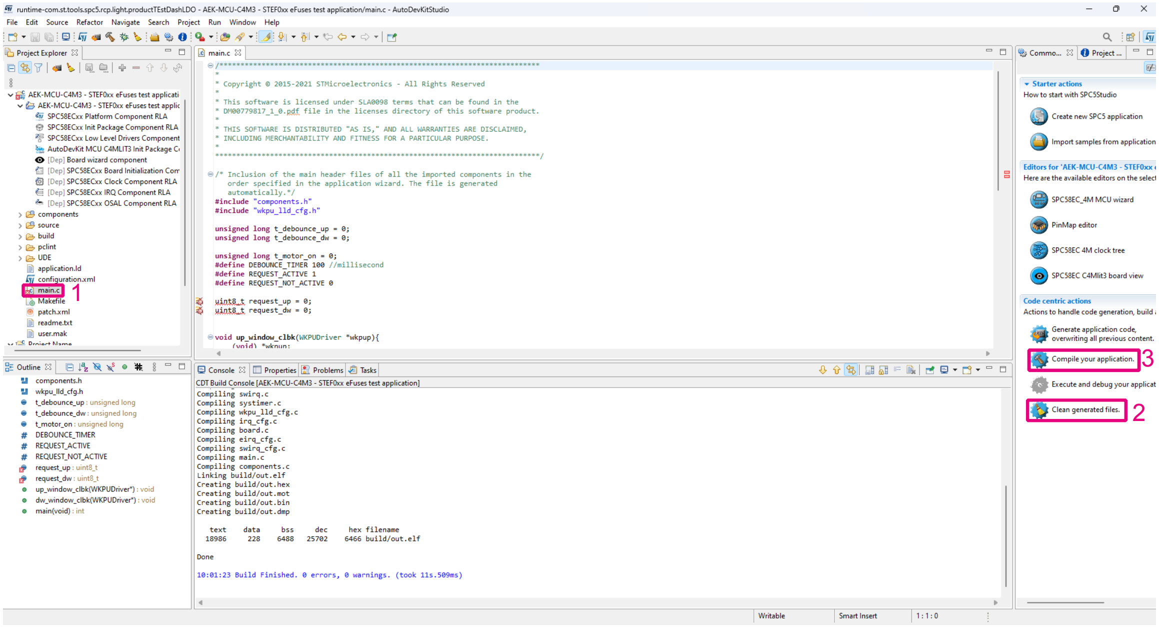


Figure 40. Cleaning and compiling the project

Step 6. Switch to "Debug" by clicking on the green beetle icon and then select the "Debug Configurations".

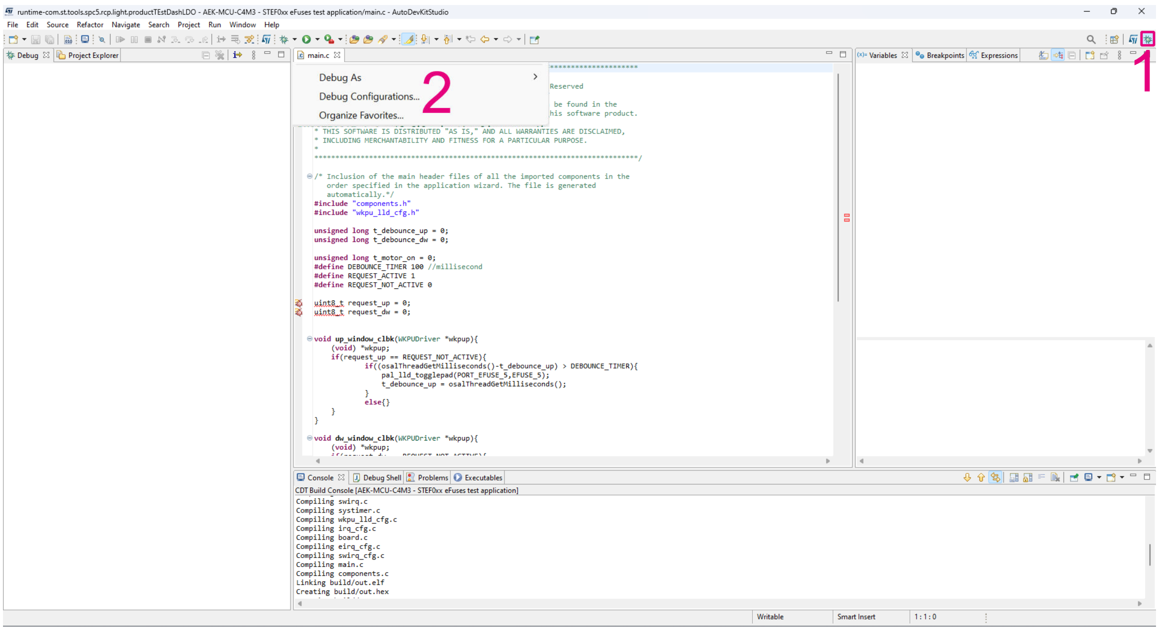
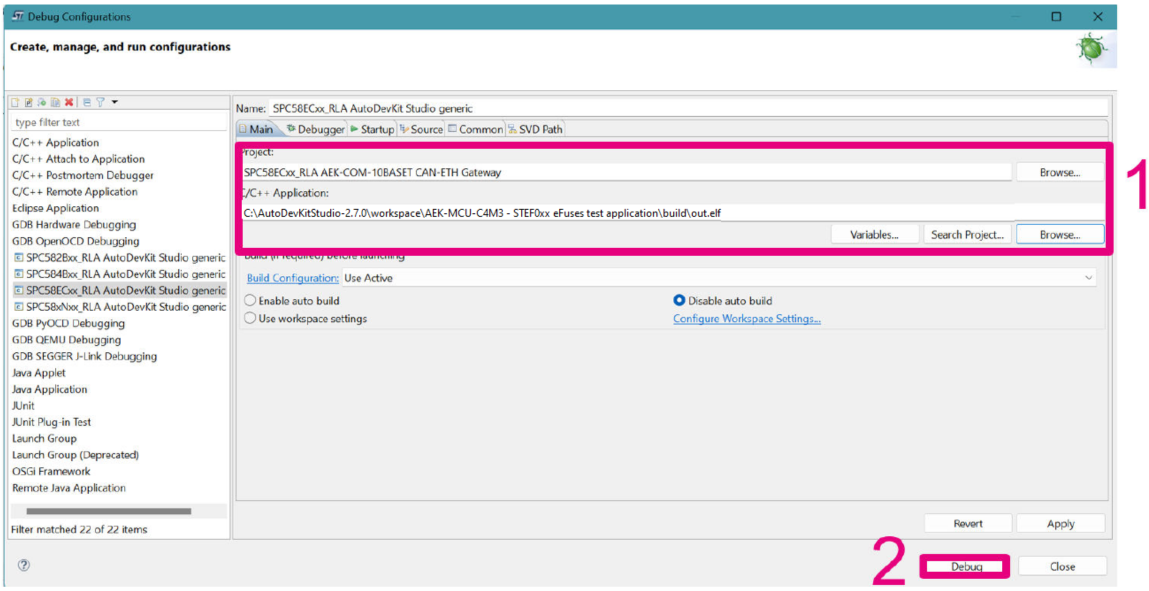


Figure 41. Debugging the project

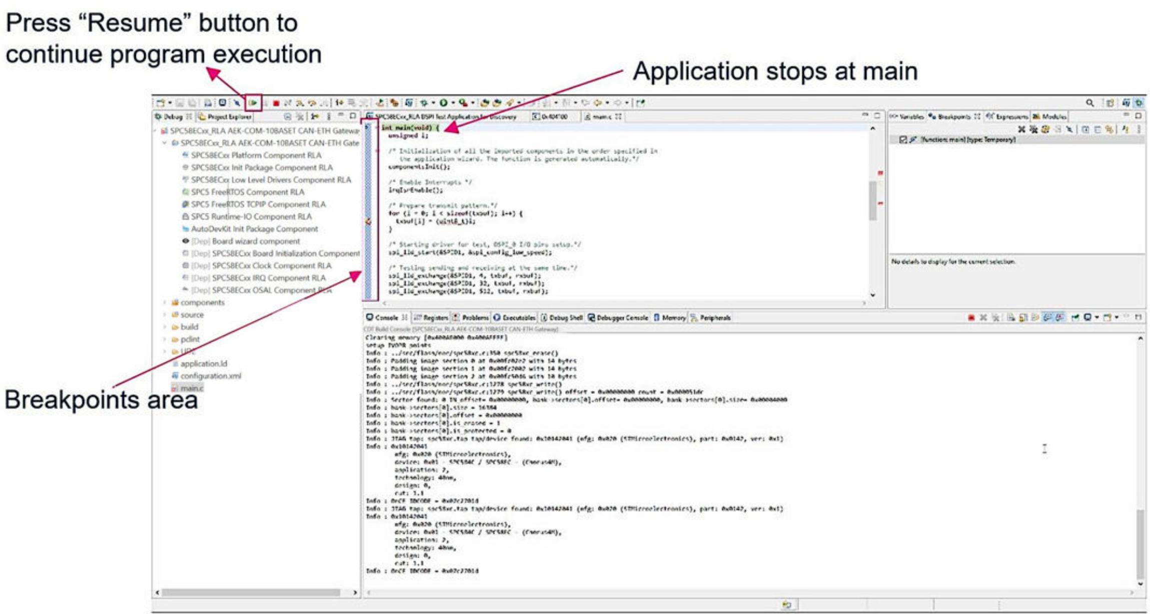
Step 7. Browse to your workspace and insert the path of the elf file in the project field. Click on Debug.

Figure 42. Debugging your out.elf file



Step 8. The console opens and shows your application code execution. The code execution stops at the main file. To continue executing the code, press resume. You can manually insert a breakpoint to stop code execution.

Figure 43. Code execution



6 Annex A

In this Annex we report a table with the details of how the AEK-CON-LIT twelve labelled 8-pin KK standard connectors map the MCU pad and pin numbers through CN1 unified automotive connector.

Figure 44. AEK-CON-LIT extension connector board overview

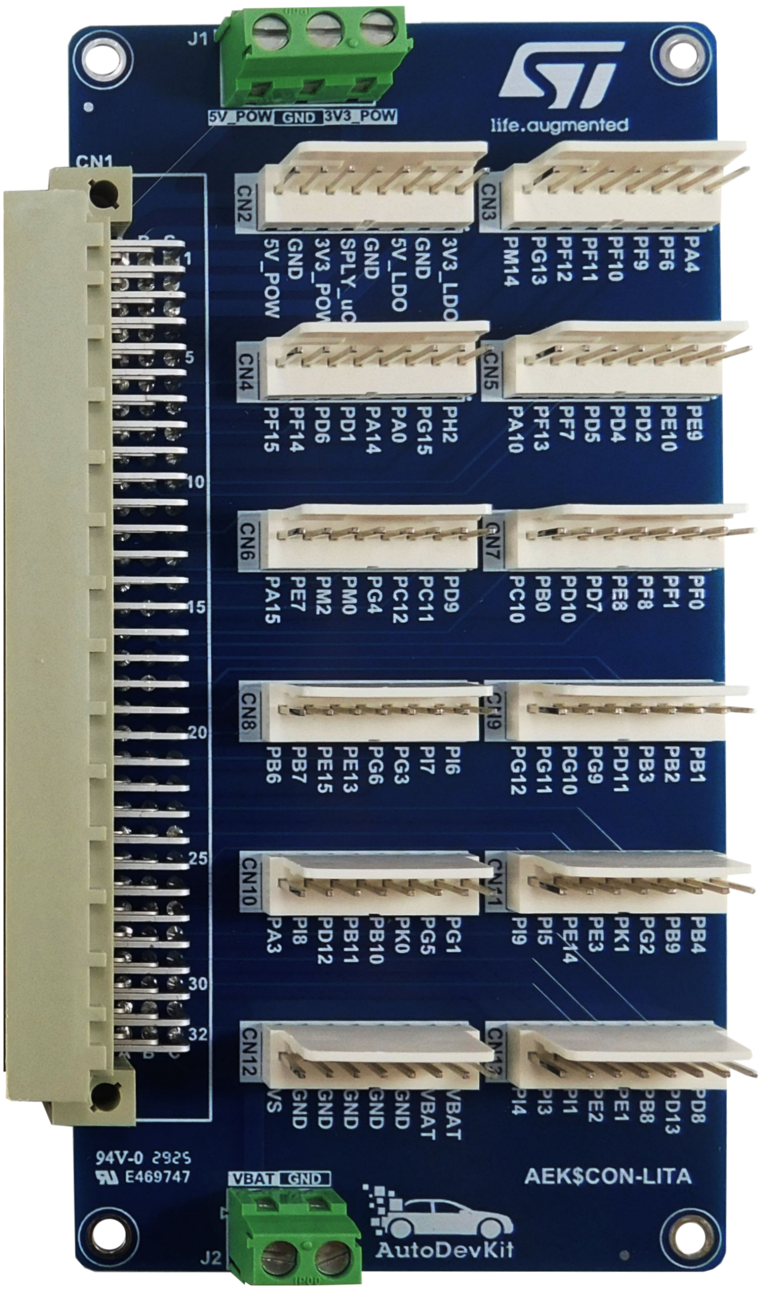


Table 3. AEK-CON-LIT general purpose pins connection to the MCU pins

AEK-CON-LIT connector	AEK-CON-LIT label	MCU pad	MCU pin number
CN3	PA4	PA4	96
	PF6	PF6	70
	PF9	PF9	74

AEK-CON-LIT connector	AEK-CON-LIT label	MCU pad	MCU pin number
CN3	PF10	PF10	75
	PF11	PF11	76
	PF12	PF12	77
	PG13	PG13	100
	PM14	PM14	98
CN4	PH2	PH2	120
	PG15	PG15	114
	PA0	PA0	113
	PA14	PA14	87
	PD1	PD1	127
	PD6	PD6	86
	PF14	PF14	93
	PF15	PF15	95
CN5	PE9	PE9	108
	PE10	PE10	121
	PD2	PD2	126
	PD4	PD4	105
	PD5	PD5	106
	PF7	PF7	71
	PF13	PF13	84
	PA10	PA10	118
CN6	PD9	PD9	62
	PC11	PC11	138
	PC12	PC12	137
	PG4	PG4	29
	PM0	PM0	140
	PM2	PM2	141
	PE7	PE7	104
	PA15	PA15	72
CN7	PF0	PF0	61
	PF1	PF1	60
	PF8	PF8	73
	PE8	PE8	107
	PD7	PD7	85
	PD10	PD10	63
	PB0	PB0	57
	PC10	PC10	139
CN8	PI6	PI6	39
	PI7	PI7	40
	PG3	PG3	28
	PG6	PG6	36

AEK-CON-LIT connector	AEK-CON-LIT label	MCU pad	MCU pin number
CN8	PE13	PE13	52
	PE15	PE15	49
	PB7	PB7	37
	PB6	PB6	38
CN9	PB1	PB1	56
	PB2	PB2	55
	PB3	PB3	54
	PD11	PD11	53
	PG9	PG9	45
	PG10	PG10	46
	PG11	PG11	47
	PG12	PG12	48
CN10	PG1	PG1	26
	PG5	PG5	35
	PK0	PK0	24
	PB10	PB10	65
	PB11	PB11	64
	PD12	PD12	17
	PI8	PI8	20
	PA3	PA3	68
CN11	PB4	PB4	51
	PB9	PB9	66
	PG2	PG2	27
	PK1	PK1	25
	PE3	PE3	19
	PE14	PE14	50
	PI5	PI5	34
	PI9	PI9	21
CN13	PD8	PD8	69
	PD13	PD13	18
	PB8	PB8	67
	PE1	PE1	15
	PE2	PE2	16
	PI1	PI1	30
	PI3	PI3	32
	PI4	PI4	33

7 Annex B

In this Annex we report the details of the CN3 unified automotive connector pinout. The 96 pins are split in three rows of 23-pin each (A, B, C).

Table 4. Unified automotive connector detailed pins: row A

Pin number	Pin type	Pin description
A1	Power	3V3 (DC-DC power)
A2	Power	5V (DC-DC power)
A3	Digital	MCU Interrupt
A4	Digital	GPIO
A5	Digital	GPIO
A6	Digital	GPIO
A7	Digital	MCU Interrupt
A8	Digital	MCU Interrupt
A9	Digital	MCU Interrupt
A10	Digital	GPIO
A11	Digital	GPIO
A12	Digital	GPIO
A13	Digital	SPI 1 Chip select 0
A14	Digital	SPI 1 Chip select 4
A15	Digital	SPI 1 MISO
A16	Digital	GPIO
A17	Digital	Timer (EMIOS)
A18	Digital	GPIO
A19	N.C.	Not connected
A20	Digital	SPI 6 Chip select 0
A21	Digital	SPI 6 MISO
A22	Digital	SPI 6 MOSI
A23	Digital	SPI 6 CLOCK
A24	Digital	SPI 2 Chip select 0
A25	Digital	SPI 2 Chip select 2
A26	Digital	SPI 2 Chip select 1
A27	Digital	SPI 2 MISO
A28	Digital	SPI 2 MOSI
A29	Digital	SPI 2 CLOCK
A30	N.C.	Not connected
A31	Power	GND
A32	Power	VBAT (12V before reverse polarity)

Table 5. Unified automotive connector detailed pins: row B

Pin description	Pin description	Pin description
B1	Power	3V3 (DC-DC power)
B2	Power	5V (DC-DC power)
B3	Digital	SPI 5 CLOCK
B4	Digital	SPI 5 MOSI
B5	Digital	SPI 5 Chip Select 0
B6	Digital	MCU Interrupt
B7	Digital	MCU Interrupt
B8	Digital	MCU Interrupt
B9	Digital	I2C Clock SCL
B10	Digital	GPIO
B11	Digital	SPI 5 Chip Select 6
B12	Digital	MCU Interrupt
B13	Digital	SPI 1 Clock
B14	Digital	SPI 1 MOSI
B15	Digital	SPI 2 Chip select 4
B16	Digital	Timer (EMIOS)
B17	Digital	ADC
B18	Digital	ADC
B19	Digital	Timer (EMIOS)
B20	Digital	ADC
B21	Digital	CAN 7 TX
B22	Digital	ADC
B23	Digital	GPIO
B24	Digital	Timer (EMIOS)
B25	Digital	Timer (EMIOS)
B26	Digital	ADC
B27	Digital	Timer (EMIOS)
B28	Digital	Timer (EMIOS)
B29	Digital	ADC
B30	Digital	ADC
B31	Power	GND
B32	Power	VBAT (12 V before reverse polarity)

Table 6. Unified automotive connector detailed pins: row C

Pin description	Pin description	Pin description
C1	Power	HVIO Main (supply MCU)
C2	Power	5V LDO
C3	Power	3V3 LDO
C4	Digital	SPI 5 MISO
C5	Digital	CAN 4 RX
C6	Digital	GPIO
C7	Digital	GPIO
C8	Digital	I2C Data SDA
C9	Digital	GPIO
C10	Digital	CAN 4 TX
C11	Digital	Interrupt
C12	Digital	GPIO
C13	N.C.	Not connected
C14	Digital	CAN 7 RX
C15	Digital	SPI 2 Chip Select 3
C16	Digital	GPIO
C17	Digital	UART / LIN 4 RX
C18	Digital	UART / LIN 4 TX
C19	Digital	Interrupt
C20	Digital	ADC
C21	Digital	ADC
C22	Digital	ADC
C23	Digital	Timer (EMIOS)
C24	Digital	Timer (EMIOS)
C25	Digital	ADC
C26	Digital	GPIO
C27	Digital	SPI 4 MOSI
C28	Digital	SPI 4 CLOCK
C29	Digital	SPI 4 Chip Select 0
C30	Digital	SPI 4 MISO
C31	Power	GND
C32	Power	VS (12V after reverse polarity)

8 Schematic diagrams

Figure 45. AEK-MCU-C4MLIT3 circuit schematic (1 of 11)

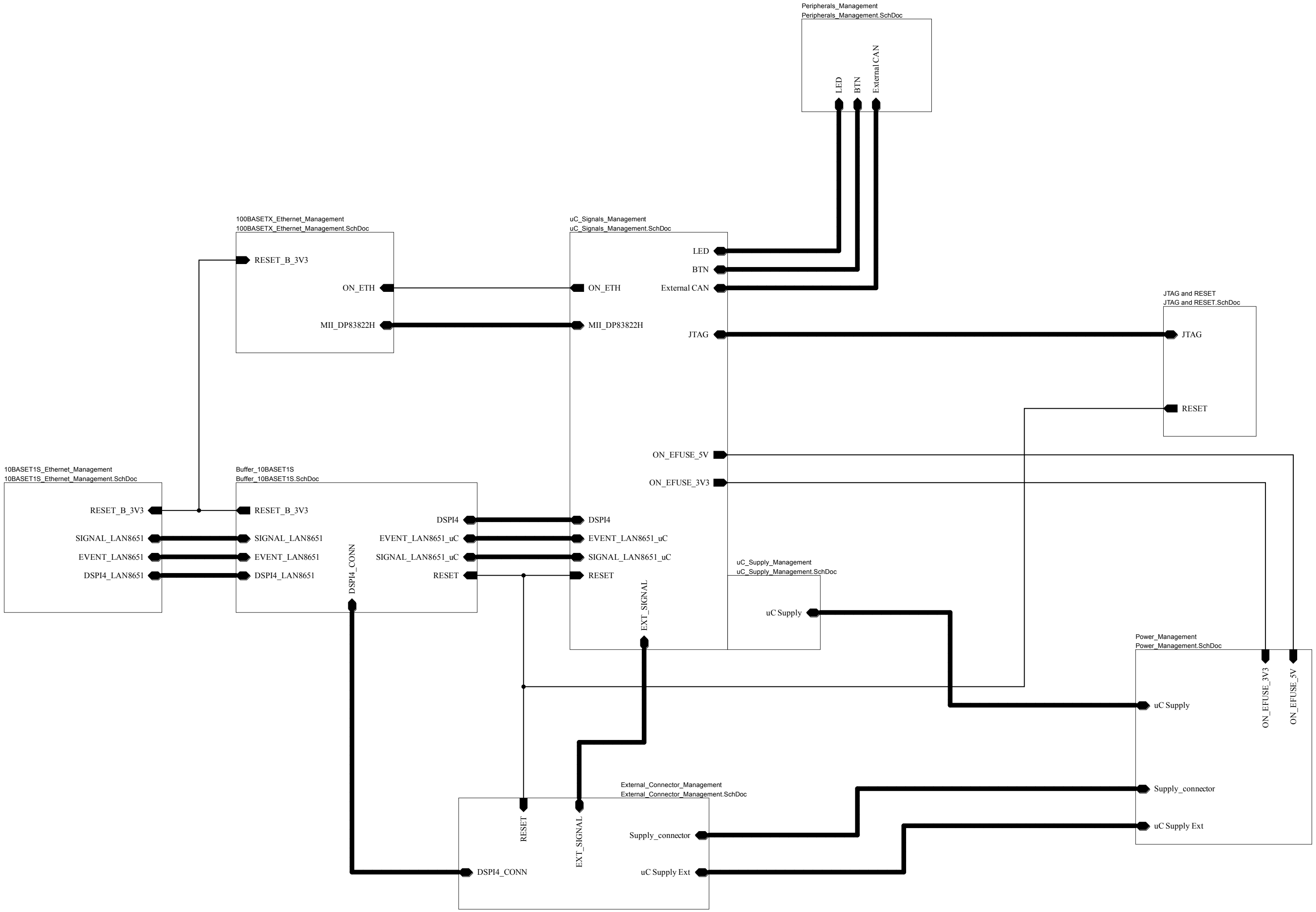


Figure 46. AEK-MCU-C4MLIT3 circuit schematic (2 of 11)

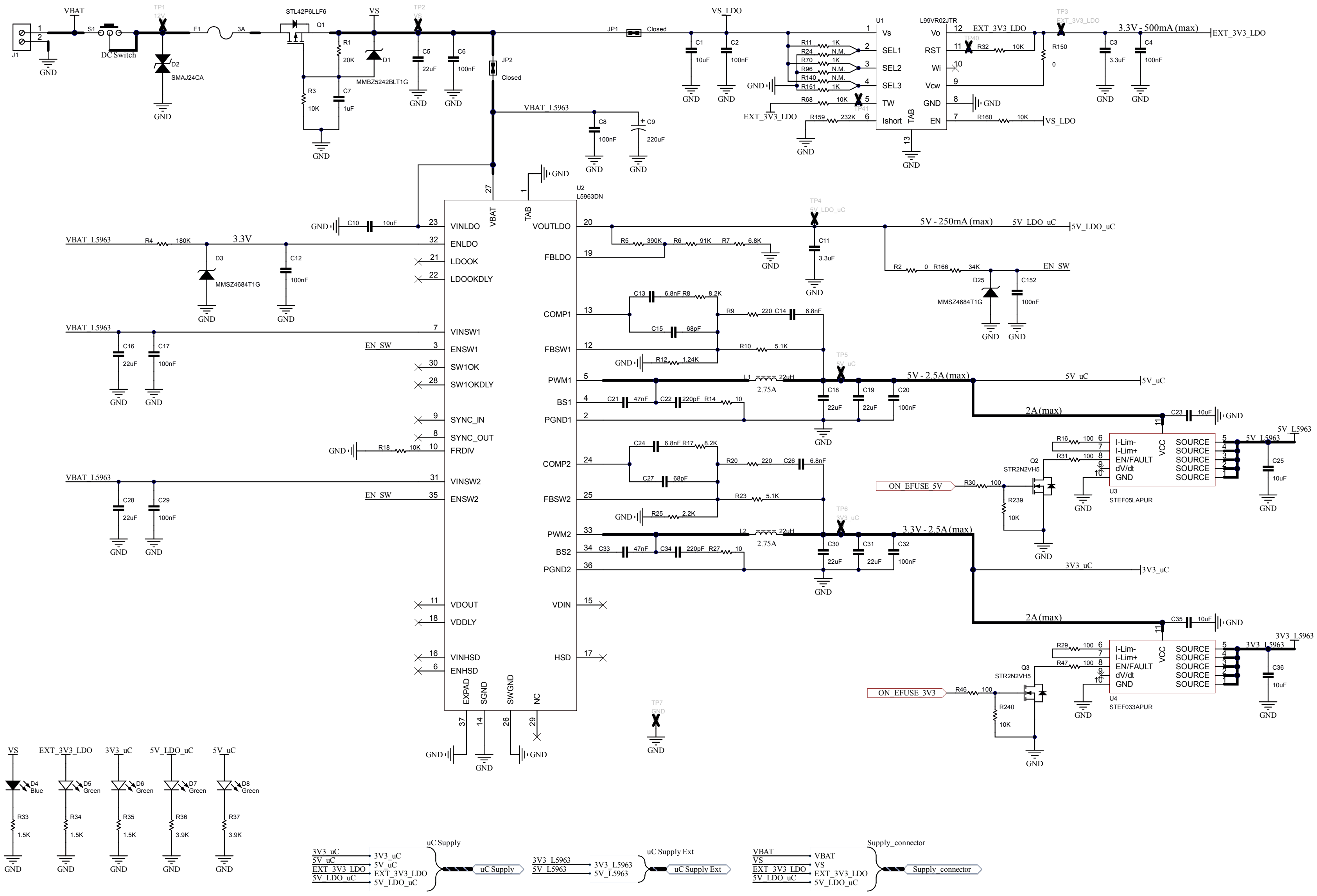


Figure 47. AEK-MCU-C4MLIT3 circuit schematic (3 of 11)

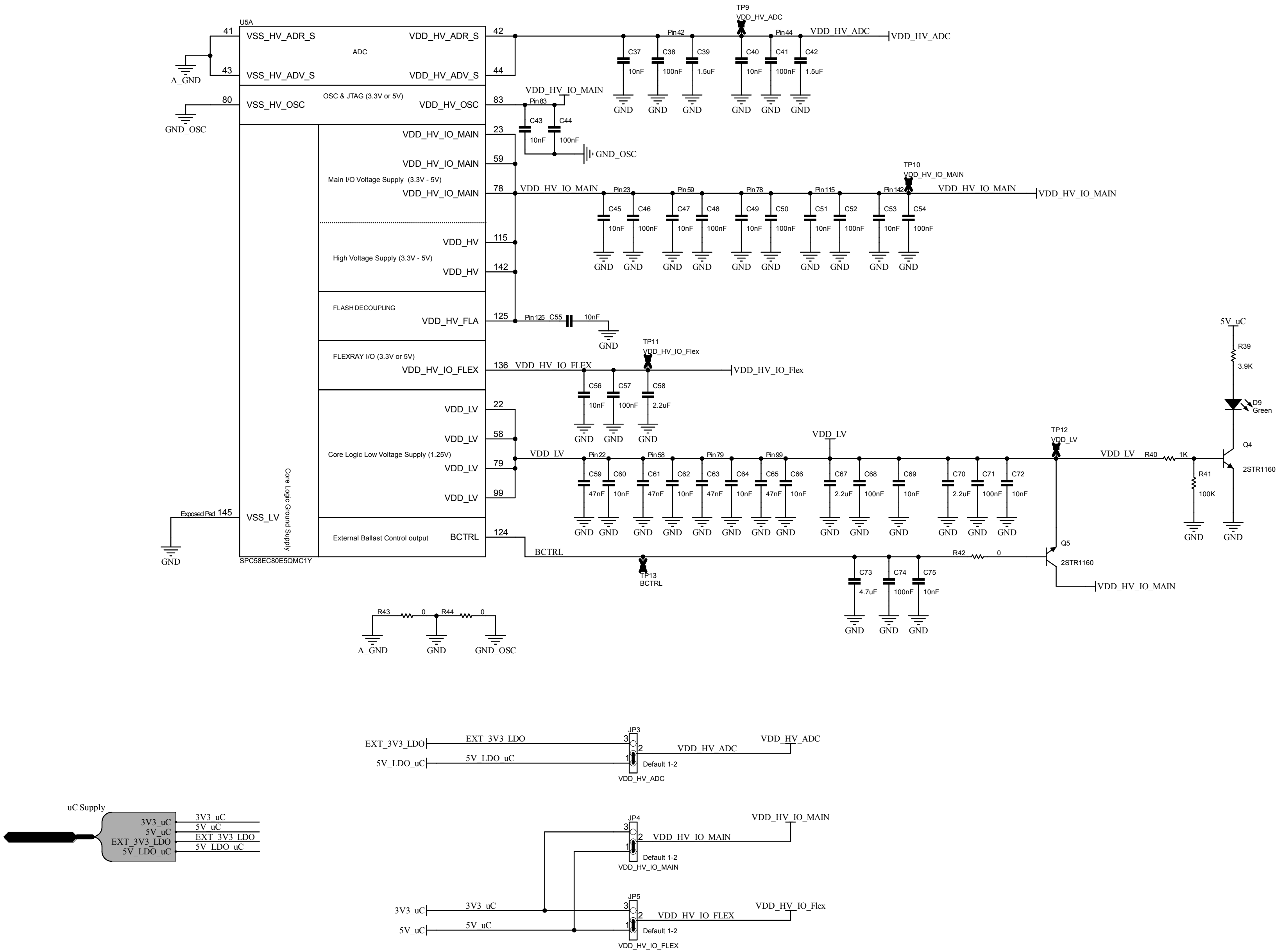


Figure 48. AEK-MCU-C4MLIT3 circuit schematic (4 of 11)

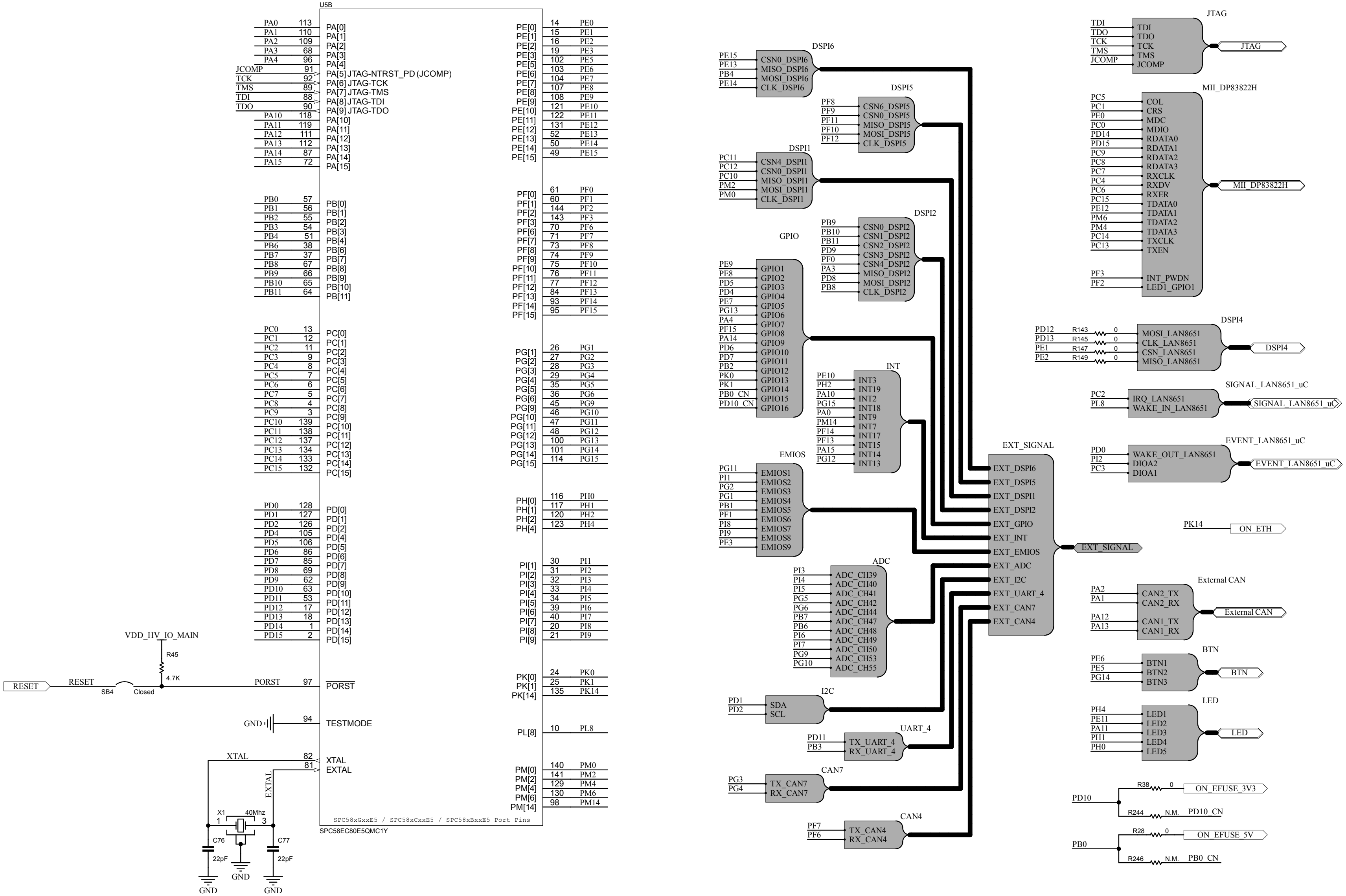


Figure 49. AEK-MCU-C4MLIT3 circuit schematic (5 of 11)

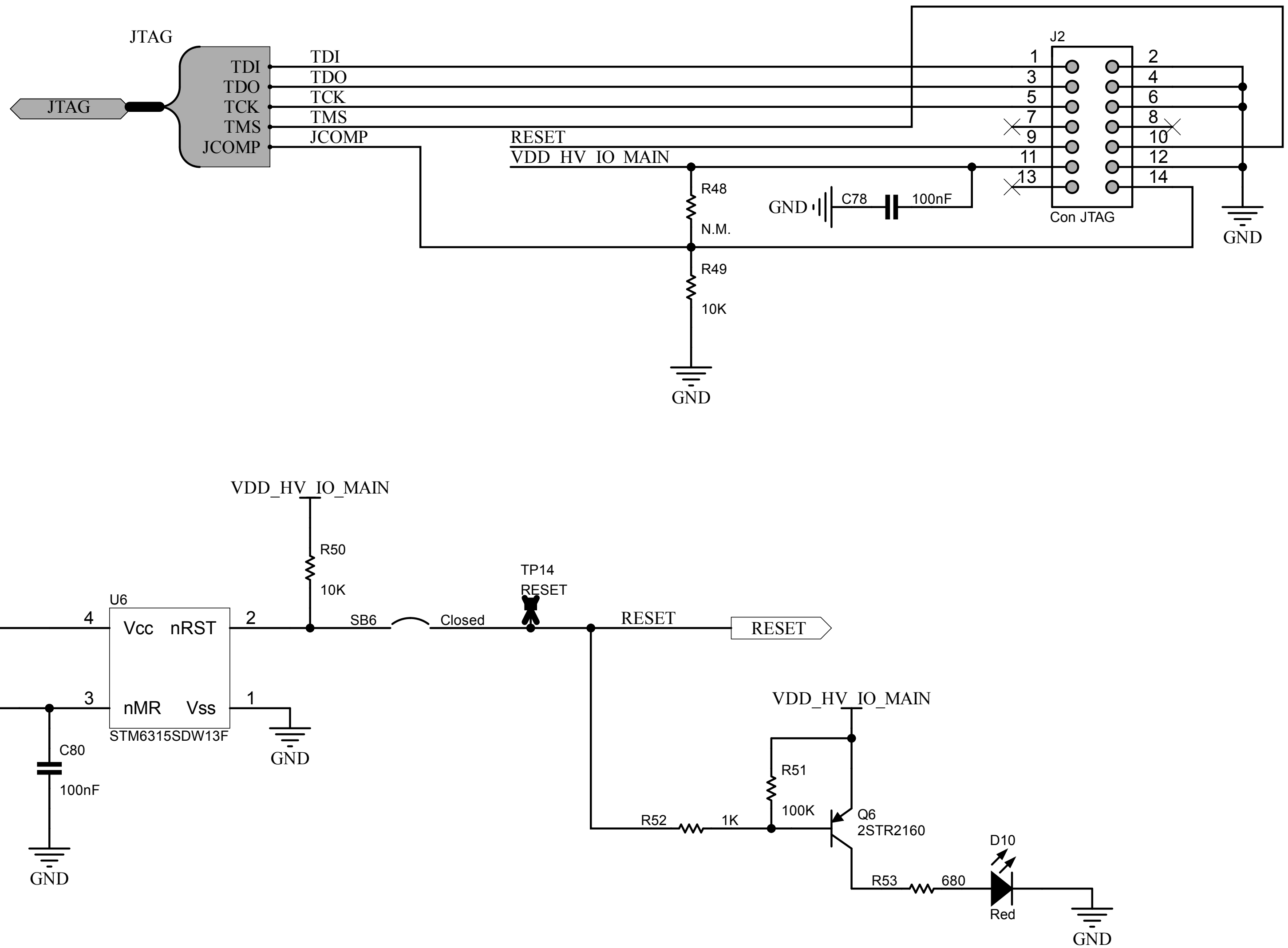


Figure 50. AEK-MCU-C4MLIT3 circuit schematic (6 of 11)

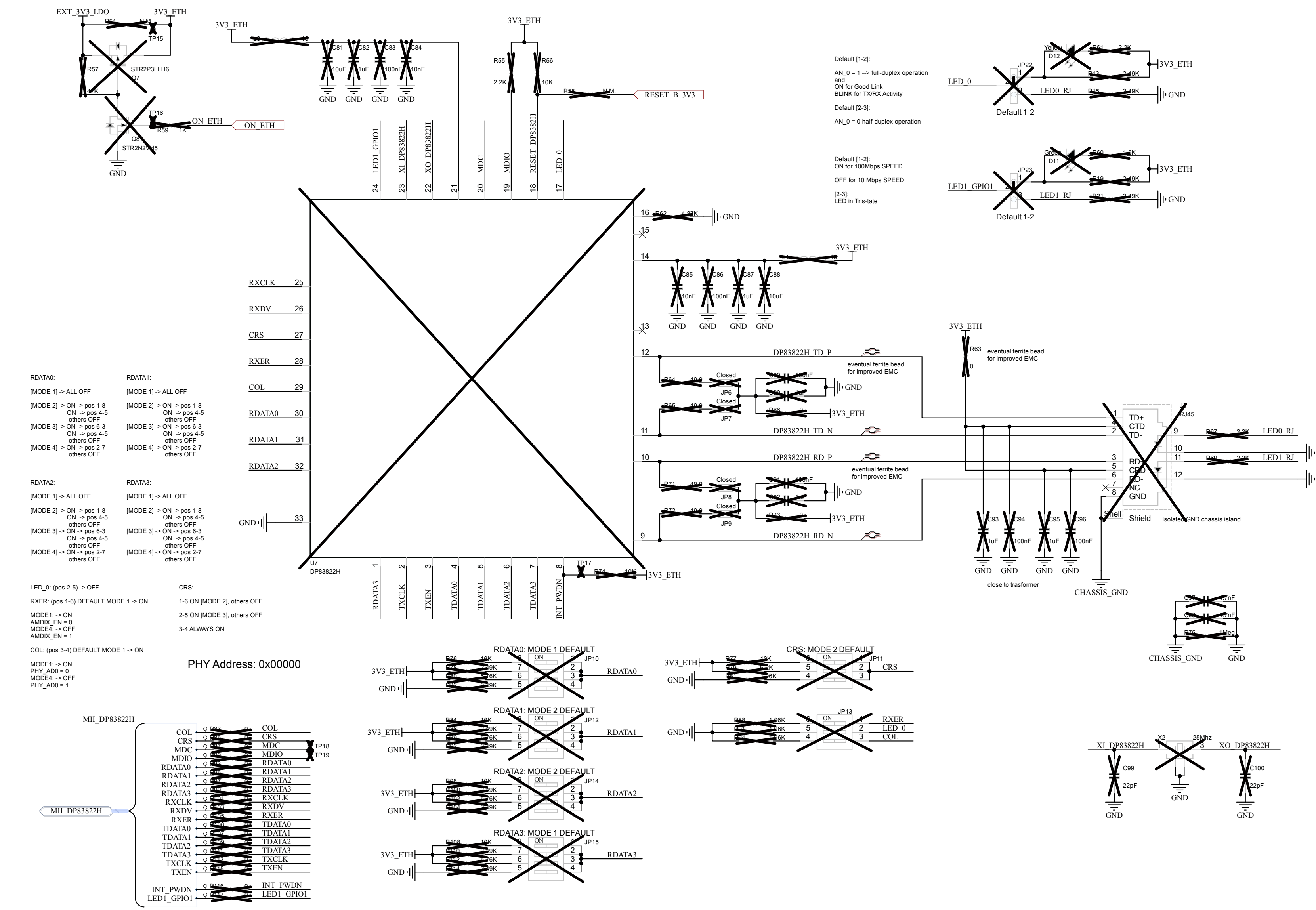


Figure 51. AEK-MCU-C4MLIT3 circuit schematic (7 of 11)

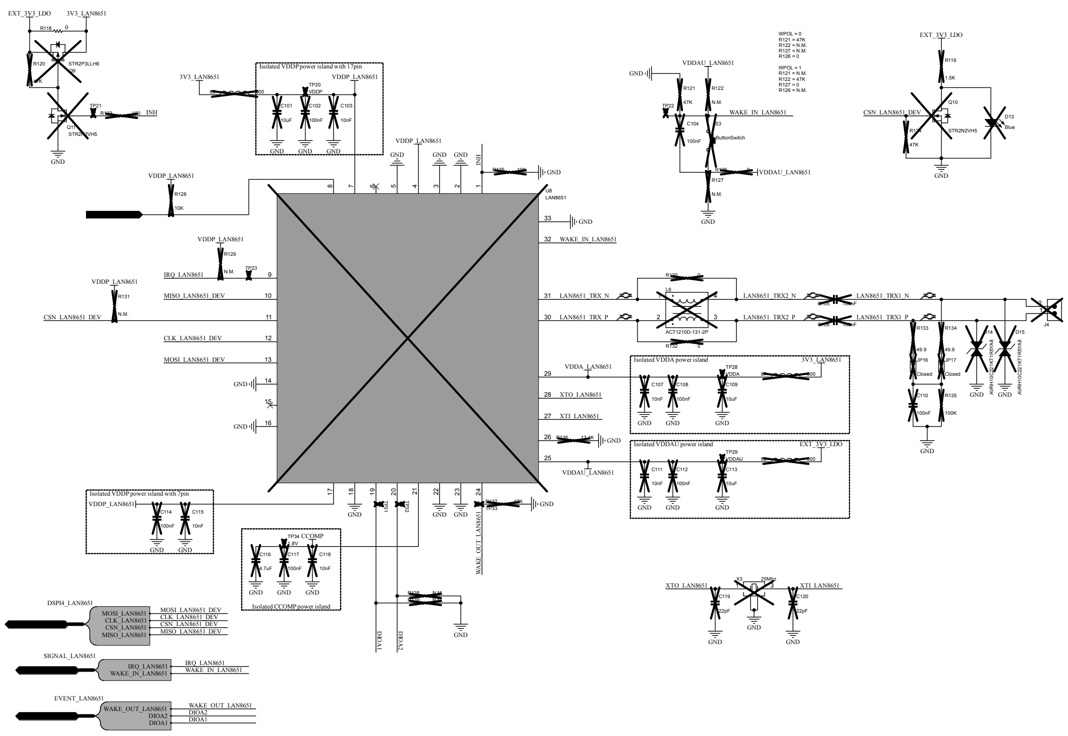
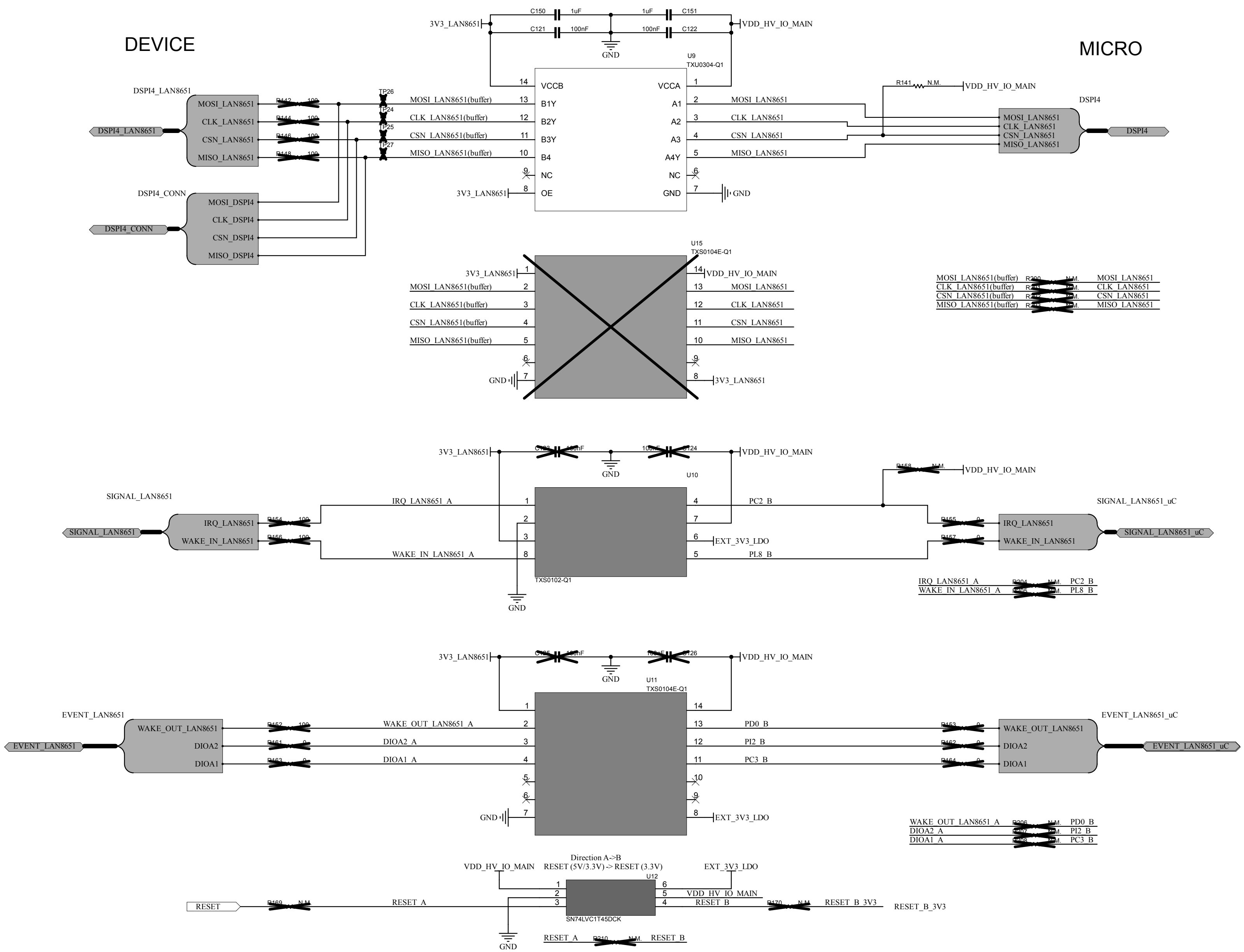


Figure 52. AEK-MCU-C4MLIT3 circuit schematic (8 of 11)



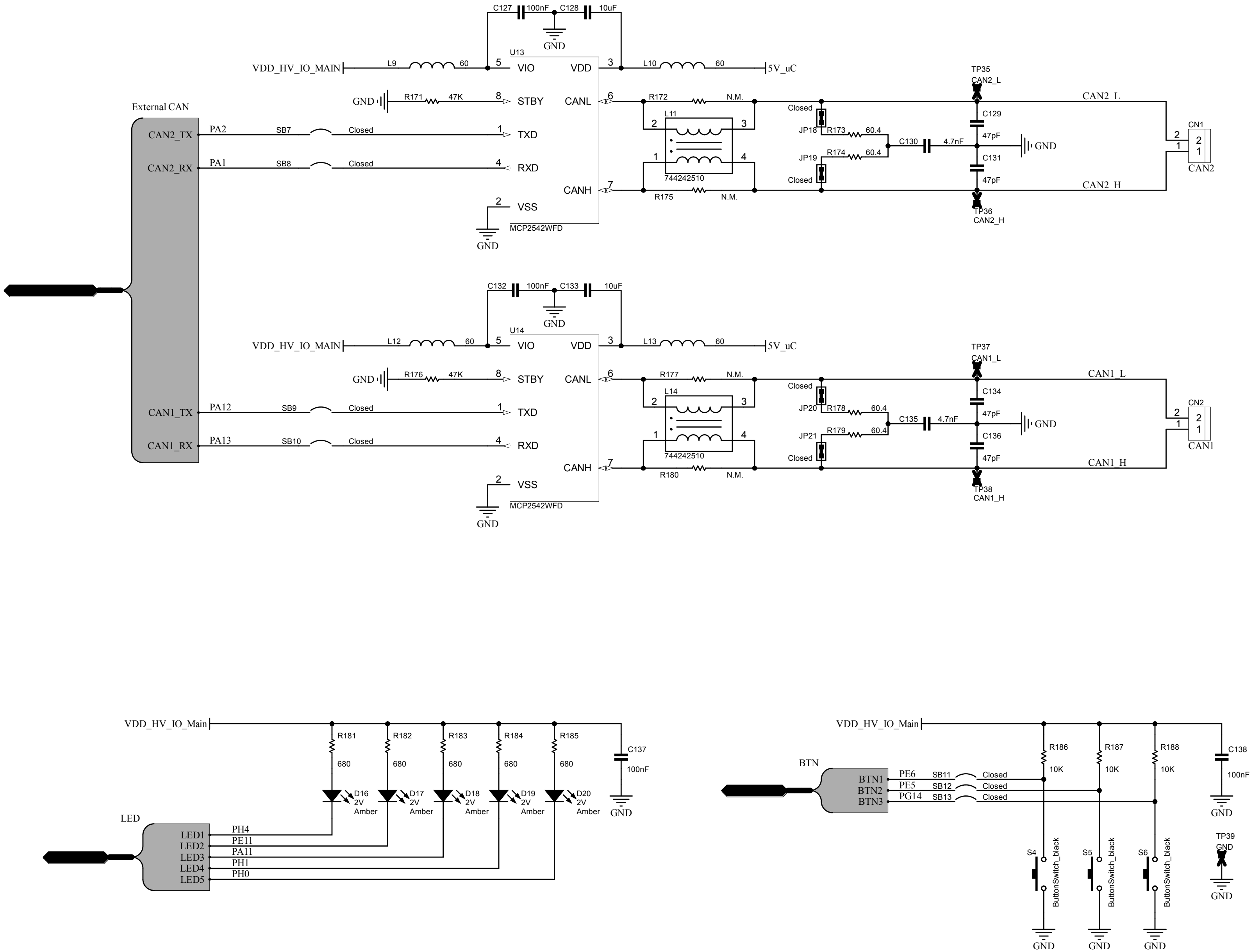


Figure 53. AEK-MCU-C4MLIT3 circuit schematic (9 of 11)

Figure 54. AEK-MCU-C4MLIT3 circuit schematic (10 of 11)

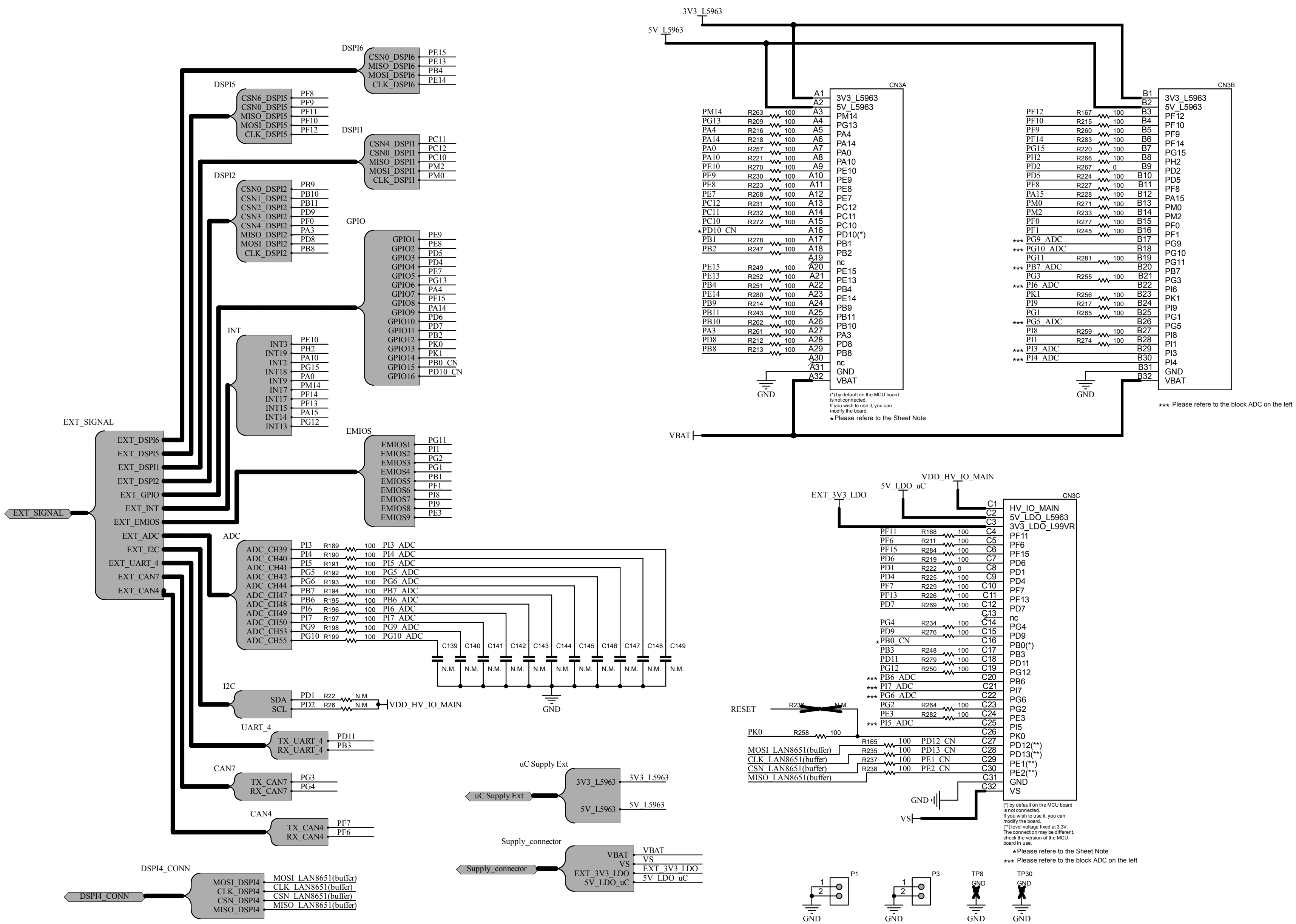
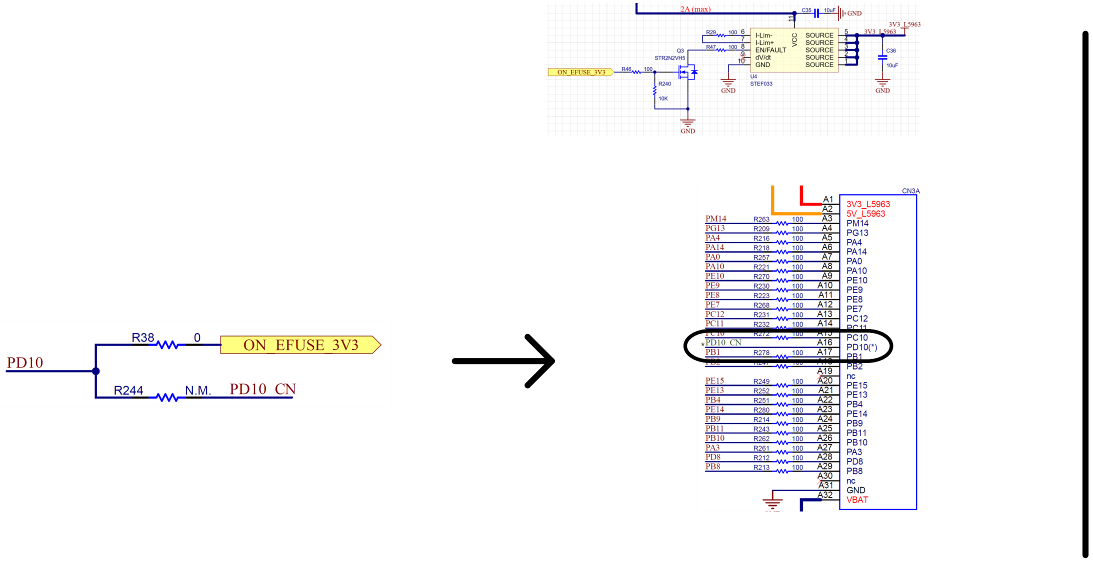
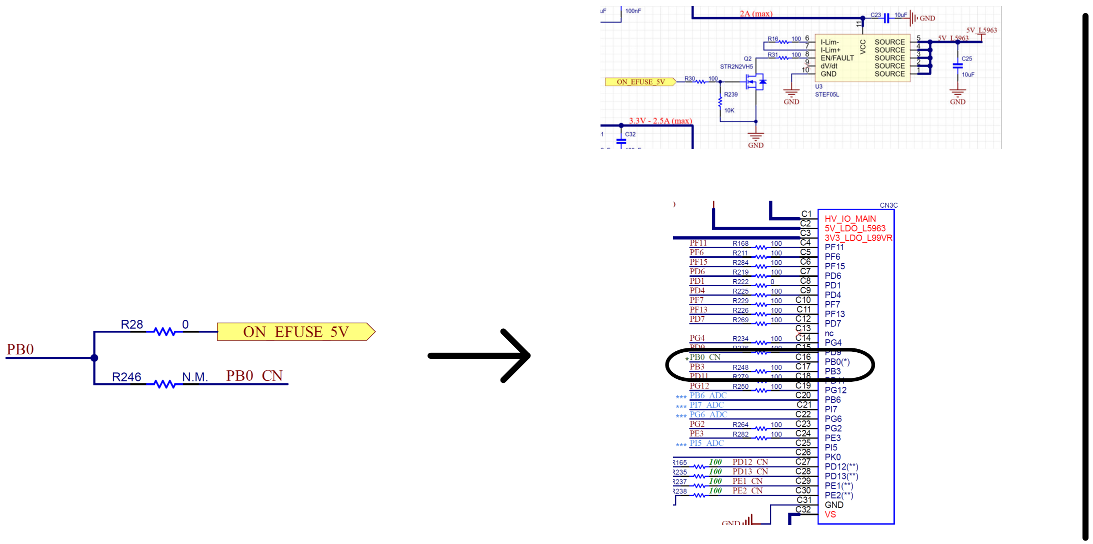


Figure 55. AEK-MCU-C4MLIT3 circuit schematic (11 of 11)



Pin not connected on the “96pin connector,” by default it is used to enable/disable the eFuse @3.3V (U4_STEF033).

To connect PD10 to the “96pin connector” remove R38 and mount a 0R on R244 (this way the eFuse always stays on and is no longer managed by the MCU).



Pin not connected on the “96pin connector,” by default it is used to enable/disable the eFuse @5V (U3_STEF05L).

To connect PB0 to the “96pin connector” remove R28 and mount a 0R on R246 (this way the eFuse always stays on and is no longer managed by the MCU)

9 Bill of materials

Table 7. AEK-MCU-C4MLIT3 bill of materials

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
1	1	AEK-MCU-C4M3	AEK-MCU-C4M3	AEK-MCU-C4M3	ST	Not available for separate sale
2	1	AEK-CON-LIT	AEK-CON-LIT	AEK-CON-LIT	ST	Not available for separate sale
3	8		970150365	WA-SPAIE Plastic Spacer Stud, metric, internal/ external	WE	970150365
4	8		97790603211	WA-SCRW Pan Head Screw w. cross slot M3	WE	97790603211
5	2		61900211621	WR-WTB 2.54 mm Female Terminal Housing	WE	61900211621
6	2		61900113722DEC	WR-WTB 2.54 mm Female Crimp Contact	WE	61900113722DEC
7	5		609002115121	WR-PHD 2.54 mm Jumper with Test Point & Pullback	WE	609002115121
8	4		60800213421	WR-PHD 2.00 mm Jumper with Test Point	WE	60800213421
9	12		61900811621	WR-WTB 2.54 mm Female Terminal Housing	WE	61900811621

Table 8. AEK-MCU-C4M3 bill of materials

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
1	5	C1, C23, C25, C35, C36	10uF	1206 - 50V - X5R Class II	WE	885012108022
2	31	C2, C4, C6, C8, C12, C17, C20, C29, C32, C38, C41, C44, C46, C48, C50, C52, C54, C57, C68, C71, C74, C78, C79, C80, C121, C122, C127, C132, C137, C138, C152	100nF	0603 - 50V - X7R Class II	WE	885012206095
3	2	C3, C11	3.3uF	1206 - 25V - X7R Class II	WE	885012208067
4	3	C5, C16, C28	22uF	0805 - 25V - X5R Class II	WE	885012107019
5	1	C7	1uF	0603 - 25V - X7R Class II	WE	885012206076
6	1	C9	220uF	Electrolytic Cap - 50V - 10x10.5	WE	865080657018
7	3	C10, C128, C133	10uF	0805 - 25V - X5R Class II	WE	885012107027
8	4	C13, C14, C24, C26	6.8nF	0603 - 50V - X7R Class II	WE	885012206088
9	2	C15, C27	68pF	0603 - 50V - NP0 Class I	WE	885012006056
10	4	C18, C19, C30, C31	22uF	1210 - 25V - X7R Class II	WE	885012209074
11	6	C21, C33, C59, C61, C63, C65	47nF	0603 - 50V - X7R Class II	WE	885012206093
12	2	C22, C34	220pF	0603 - 50V - X7R Class II	WE	885012206079
13	17	C37, C40, C43, C45, C47, C49, C51, C53, C55, C56, C60, C62, C64, C66, C69, C72, C75	10nF	0603 - 50V - X7R Class II	WE	885012206089
14	2	C39, C42	1.5uF	1206 - 25V - X7R Class II	WE	885012208065
15	3	C58, C67, C70	2.2uF	1206 - 25V - X7R Class II	WE	885012208066
16	1	C73	4.7uF	1206 - 50V - X7R Class II	WE	885012208094
17	2	C76, C77	22pF	0402 - 50V - NP0 Class I	WE	885012005057
18	4	C129, C131, C134, C136	47pF	0603 - 50V - NP0 Class I	WE	885012006055
19	2	C130, C135	4.7nF	0603 - 50V - X7R Class II	WE	885012206087

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
20	11	C139, C140, C141, C142, C143, C144, C145, C146, C147, C148, C149	N.M.	0603	N.A.	N.A.
21	2	C150, C151	1uF	0603 - 50V - X7R Class II	WE	885012206126
22	2	CN1, CN2	Con 2P	2.54mm - 1 row - KK254 - Male	WE	61900211121
23	1	CN3	116-40074TH	DIN 41612 Female 90°, type C, Part No. 116-40074TH	EPT	116-40074TH
24	1	D1	MMBZ5242BLT1G	12V Zener Voltage Regulators, 225mW	Onsemi	MMBZ5242BLT1G
25	1	D2	SMAJ24CA, SMA	SMA TVS - 24VDC - Bidrectional	ST	SMAJ24CA-TR
26	2	D3, D25	MMSZ4684T1G	3.3V Zener Voltage Regulators, 500mW	Onsemi	MMSZ4684T1G
27	1	D4	Blue	0805 - Led Blue - 3.2V	WE	150080BS75000
28	5	D5, D6, D7, D8, D9	Green	0805 - Led Green - 3.2V	WE	150080GS75000
29	1	D10	Red	0805 - Led Red - 2V	WE	150080RS75000
30	5	D16, D17, D18, D19, D20	Amber	0805 - Led Amber - 2V	WE	150080AS75000
31	1	F1	0437003.WRA	437 Series – 1206 Fast-Acting Fuse	LittleFuse	0437003.WRA
32	1	J1	Con 2p 5.08_green	5.08mm - WR-TBL Series 2135 - Horizontal Entry Modular	WE	691213510002
33	1	J2	Con JTAG	2.54mm - IDC, Male Box Header WR-BHD, THT, Vertical	WE	61201421621
34	4	JP1, JP2, P1, P3	Jumper 2p Closed, Header 2p 2.54	2.54mm - Pin Header, THT, pitch 2.54mm, Single Row, Vertical, 2p, Closed, 2.54mm - WR-PHD Pin Header, THT, pitch 2.54mm, Single Row, Vertical, 2p	WE	61300211121

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
35	3	JP3, JP4, JP5	Jumper 3p	THT Vertical 3 pins Header, Pitch 2.54 mm, Single Row	WE	61300311121
36	4	JP18, JP19, JP20, JP21	Jumper 2p Closed	2mm - WR-PHD 2.00 mm THT Pin Header Single Row, Vertical, 2p, Closed	WE	62000211121
37	2	L1, L2	22uH	WE-LHMI SMT Power Inductor – 6.6 x 6.6 x 4.8 - 2.75A	WE	74437349220
38	4	L9, L10, L12, L13	60	WE-CBF SMT EMI Suppression Ferrite Bead. 60 Ohm, 500mA	WE	74279267
39	2	L11, L14	51uH	WE-SLM SMT Common Mode Line Filter - 51uH	WE	744242510
40	1	Q1	STL42P6LLF6, PowerFLAT 5x6	P-channel -60 V, 23 mΩ typ., -42 A STripFET F6 Power MOSFET in a PowerFLAT 5x6 package	ST	STL42P6LLF6
41	2	Q2, Q3	STR2N2VH5, SOT-23	N-channel 20 V, 0.025 Ω typ., 2.3 A STripFET™ H5 Power MOSFET in a SOT-23 package	ST	STR2N2VH5
42	2	Q4, Q5	2STR1160, SOT-23	Low voltage fast-switching NPN power transistor	ST	2STR1160
43	1	Q6	2STR2160, SOT-23	Low voltage fast-switching PNP power transistor	ST	2STR2160
44	1	R1	20K	0603 - ±1% - 0.1W	Panasonic	ERJ-3EKF2002V
45	18	R2, R28, R38, R42, R43, R150, R222, R267, SB4, SB5, SB6, SB7, SB8, SB9, SB10, SB11, SB12, SB13	0, Closed	0603 - ±1% - 0.1W, Circuit Breaker - 0603 - ±1% - 0.1W	Panasonic	ERJ3GEY0R00V
46	12	R3, R18, R32, R49, R50, R68, R160, R186, R187, R188, R239, R240	10K	0603 - ±1% - 0.2W	Panasonic	ERJP03F1002V

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
47	1	R4	180K	0603 - ±1% - 0.25W	Panasonic	ERJ-UP3F1803V
48	1	R5	390K	0603 - ±0.5% - 0.25W	Panasonic	ERJ-UP3D3903V
49	1	R6	91K	0603 - ±0.5% - 0.25W	Panasonic	ERJ-UP3D9102V
50	1	R7	6.8K	0603 - ±0.5% - 0.25W	Panasonic	ERJ-UP3D6801V
51	2	R8, R17	8.2K	0603 - ±1% - 0.1W	Panasonic	ERJ-3EKF8201V
52	2	R9, R20	220	0603 - ±1% - 0.25W	Panasonic	ERJPA3F2200V
53	2	R10, R23	5.1K	0603 - ±1% - 0.1W	Panasonic	ERJ-3EKF5101V
54	5	R11, R40, R52, R70, R151	1K	0603 - ±1% - 0.25W	Panasonic	ERJPA3F1001V
55	1	R12	1.24K	0603 - ±1% - 0.1W	Panasonic	ERJ-3EKF1241V
56	2	R14, R27	10	0603 - ±1% - 0.25W	Panasonic	ERJPA3F10R0V
57	82	R16, R29, R30, R31, R46, R47, R165, R167, R168, R189, R190, R191, R192, R193, R194, R195, R196, R197, R198, R199, R209, R211, R212, R213, R214, R215, R216, R217, R218, R219, R220, R221, R223, R224, R225, R226, R227, R228, R229, R230, R231, R232, R233, R234, R235, R237, R238, R243, R245, R247, R248, R249, R250, R251, R252, R255, R256, R257, R258, R259, R260, R261, R262, R263, R264, R265, R266, R268, R269, R270, R271, R272, R274, R276, R277, R278, R279, R280, R281, R282, R283, R284	100	0603 - ±1% - 0.125W	Panasonic	ERJH3EF1000V
58	2	R22, R26	N.M.	0402	N.A.	N.A.

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
59	11	R24, R48, R96, R140, R141, R172, R175, R177, R180, R244, R246	N.M.	0603	N.A.	N.A.
60	1	R25	2.2K	0603 - ±1% - 0.1W	Panasonic	ERJ-3EKF2201V
61	3	R33, R34, R35	1.5K	0603 - ±1% - 0.25W	Panasonic	ERJ-PA3F1501V
62	3	R36, R37, R39	3.9K	0603 - ±1% - 0.1W	Panasonic	ERJ3EKF3901V
63	2	R41, R51	100K	0603 - ±1% - 0.2W	Panasonic	ERJP03F1003V
64	5	R44, R143, R145, R147, R149	0	0402 - 0.1W	Panasonic	ERJ-2GE0R00X
65	1	R45	4.7K	0603 - ±1% - 0.25W	Panasonic	ERJPA3F4701V
66	6	R53, R181, R182, R183, R184, R185	680	0603 - ±1% - 0.25W	Panasonic	ERJPA3F6800V
67	1	R118	0	0603 - jumper - 0.125W	Panasonic	ERJ-H3G0R00V
68	1	R159	232K	0603 - ±1% - 0.1W	Panasonic	ERJ-3EKF2323V
69	1	R166	34K	0603 - ±1% - 0.25W	Panasonic	ERJ-UP3F3402V
70	2	R171, R176	47K	0603 - ±1% - 0.25W	Panasonic	ERJPA3F4702V
71	4	R173, R174, R178, R179	60.4	0603 - ±1% - 0.1W	Panasonic	ERJ3EKF60R4V
72	1	S1	Switch_ON_OFF	Slide Switch 2 positions ON-ON - Set OPEN	NKK Switches	CS12ANW03
73	1	S2	RESET	Switch	WE	430152043826
74	3	S4, S5, S6	ButtonSwitch_black	Switch	WE	430182043816
75	1	U1	L99VR02J, PowerSSO 12	Automotive linear voltage regulator with configurable output voltage having 500 mA current capability	ST	L99VR02J
76	1	U2	L5963DN, PowerSSO 36	Automotive dual monolithic switching regulator with LDO and HSD	ST	L5963DN-EHT
77	1	U3	STEF05L, DFN10 3X3	Electronic fuse for 5 V line	ST	STEF05LAPUR
78	1	U4	STEF033, DFN10 3X3	Electronic fuse for 3.3 V line	ST	STEF033APUR

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
79	1	U5	SPC58EC80E5Q MC1Y, TQFP 144 20x20x1.0	32-bit Power Architecture MCU for Automotive General Purpose Applications - Chorus family	ST	SPC58EC80E5QMC1Y
80	1	U6	STM6315SDW1 3F, SOT-143 4	STMICROELE CTRONICS - STM6315SDW 13F - Reset Circuit, Active-Low, Open-Drain, 1V to 5.5V, 2.93V Threshold, 1 Monitor	ST	STM6315SDW13F
81	1	U9	TXU0304-Q1	TXU0304-Q1 Automotive 4-Bit Fixed Direction Voltage-Level Translator with Schmitt-Trigger Inputs and 3-State Outputs	Texas Instruments	TXU0304QPWRQ1
82	2	U13, U14	MCP2542WFD	CAN FD Transceiver with Wake-up Pattern (WUP) Option	Microchip	MCP2542WFD
83	1	X1	40Mhz	WE-XTAL Quartz Crystal, SMT, CFPX-104, 40MHz, +/-20ppm	WE	830059537

Table 9. AEK-CON-LIT bill of materials

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
1	1	CN1	103-40064TH	DIN 41612 Male 90°, type C, Part No. 103-40064TH	EPT	103-40064TH
2	12	CN2, CN3, CN4, CN5, CN6, CN7, CN8, CN9, CN10, CN11, CN12, CN13	Con 8p	2.54mm - 1 row - KK254 - Male	WE	61900811121
3	1	J1	Con 3p 5.08_green	5.08mm - WR-TBL Series 2135 - Horizontal Entry Modular	WE	691213510003
4	1	J2	Con 2p 5.08_green	5.08mm - WR-TBL Series 2135 - Horizontal Entry Modular	WE	691213510002

10 Board robustness enhancements

To make the board more robust, we suggest implementing the following changes in the layout:

- For D2 TVS on battery connector, mount SM4T28CAY instead of the onboard SMAJ24CA

The SM4T28CAY device is automotive grade and is designed to protect sensitive automotive circuits against surges defined in ISO 7637-2 and against electrostatic discharges according to ISO 10605.

For further information, see the related datasheet.

- For U13 and U14 CAN transceivers, enhance CAN link ESD/EOS protection by adding ESDCAN protections on CAN-L and CAN-H:
  - ESDCAN in a SOT23 or a SOT323 package

These dual-line CAN transceiver protection devices protect both CAN-H and CAN-L signals of automotive CAN PHY against ISO 7637-3 transients and ESD (electrostatic discharge).

This ESDCAN series complies with all the physical layer constraints (jump-start, reverse polarity) without compromising the low clamping voltage for an efficient CAN or LIN bus protection.

For further information:

ESDCAN in a SOT23 package

ESDCAN in a SOT323 package

11 Kit versions

Table 10. AEK-MCU-C4MLIT3 versions

Finished good	Schematic diagrams	Bill of materials
AEK$MCU-C4MLIT3A[(1)]	AEK$MCU-C4MLIT3A schematic diagrams	AEK$MCU-C4MLIT3A bill of materials

1. *This code identifies the AEK-MCU-C4MLIT3 evaluation board first version.*

12 Regulatory compliance information

Notice for US Federal Communication Commission (FCC)

For evaluation only; not FCC approved for resale

FCC NOTICE - This kit is designed to allow:

(1) Product developers to evaluate electronic components, circuitry, or software associated with the kit to determine

whether to incorporate such items in a finished product and

(2) Software developers to write software applications for use with the end product.

This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter 3.1.2.

Notice for Innovation, Science and Economic Development Canada (ISED)

For evaluation purposes only. This kit generates, uses, and can radiate radio frequency energy and has not been tested for compliance with the limits of computing devices pursuant to Industry Canada (IC) rules.

À des fins d'évaluation uniquement. Ce kit génère, utilise et peut émettre de l'énergie radiofréquence et n'a pas été testé pour sa conformité aux limites des appareils informatiques conformément aux règles d'Industrie Canada (IC).

Notice for the European Union

This device is in conformity with the essential requirements of the Directive 2014/30/EU (EMC) and of the Directive 2011/65/EU (RoHS II), including subsequent revisions and additions, as well as amended by the Delegated Directive 2015/863/EU (RoHS III). Compliance to EMC standards in Class A (industrial intended use).

Notice for the United Kingdom

This device is in conformity with the essential requirements of the Directive 2014/30/EU (EMC) and of the Directive 2011/65/EU (RoHS II), including subsequent revisions and additions, as well as amended by the Delegated Directive 2015/863/EU (RoHS III). Compliance to EMC standards in Class A (industrial intended use).

Revision history

Table 11. **Document revision history**

Date	Revision	Changes
05-Sep-2025	1	Initial release.
15-Oct-2025	2	Added Section 10: Board robustness enhancements.

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