Getting started with the AEK-MCU-C4MINI1 MCU and motor control evaluation board based on the Chorus SPC58EC80E5 automotive microcontroller

Introduction

Several key trends are promoting a change in the way vehicles are designed and built. The number of electronic control units (ECUs) in a vehicle is growing, creating complexity in the wiring needed for power and data distribution. At the same time, electrical power requirements are evolving to enable greater electrification, towards hybrid and full battery electric vehicles.

The automotive sector natural evolution is represented by new domain and zone architectures. The first one, based on domain controllers, is related to coordination and consolidation of functional domains, such as body domain, powertrain domain, and ADAS domain, while the second one, based on zone controllers, aims at reducing the complexity of the wiring harness and thereby vehicle weight and cost.

Zone controllers are hubs for power distribution and data connection requirements for sensors, peripherals, and actuators, within a physical section of the vehicle. A mix of both architectural approaches is also envisaged.

Our new AEK-MCU-C4MINI1 MCU and DC motor control evaluation board fits well in this framework, as it can be exploited as a domain/zone controller. It can also be used as an automotive gateway and general purpose automotive MCU board.

Indeed, our board provides more than a standard MCU board features. Leveraging on a user-friendly interface, it allows ECU fast prototyping with basic motor control drives included.

The AEK-MCU-C4MINI1 is designed to address Automotive and Transportation applications as well as other applications requiring automotive safety and security levels. A cryptography MCU core, employed as hardware secure module (HSM), is paired with dual 180 MHz general-purpose 32-bit cores, all hosted by the on board SPC58EC80E5 MCU, featuring a total of 4 MB of flash memory.

The board layout has been conceived to speed up the user development offering an easy prototyping evaluation tool.

Despite several connection possibilities due to the MCU numerous peripherals, the user-friendly interface facilitates the interconnection of pre-configured and pin pre-mapped peripherals.

The general-purpose and serial connectors have been standardized and grouped by peripheral function types.

The MCU peripherals are extended with the VNH7040AY embedded H-bridge motor driver for DC motor control, featuring advanced diagnostic features (short-to-ground, short-to-battery, and open load conditions). The board has a dedicated supply capacity for an external 5 V or 3.3 V load with maximum current capability of 2.75 A.

The AEK-MCU-C4MINI1 allows plugging an AEK-LCD-DT028V1 touch display board for multiple application and debug purposes, such as monitoring the motor current, printing serial data, or for hardware debugging, without the need of connecting any PC terminal console. For this LCD board, two connectors are provided on the board, one on the top and one on the bottom. The two connectors shall not be connected and used at the same time.

The top connection facilitates the debugging phase (for example, when testing signal connections and data exchange), while the bottom one reduces the total occupied space by the two boards, making it the preferred choice for deployment purposes.

The MCU ADC reference voltage is provided by a stable linear voltage regulator (LDO) embedded in the L5963 IC.

The board hosts an OpenOCD debugger/programmer, several MCU peripheral connectors as well as various general-purpose buttons and LEDs.

For system reset during the development phase, a reset button was added to the board layout. In addition, a reverse battery protection circuit has been integrated for higher safety.

Warning: *The AEK-MCU-C4MINI1 evaluation board has not to be used in a vehicle as it is designed for R&D laboratory use only.*

Figure 1. **AEK-MCU-C4MINI1 evaluation board top view**

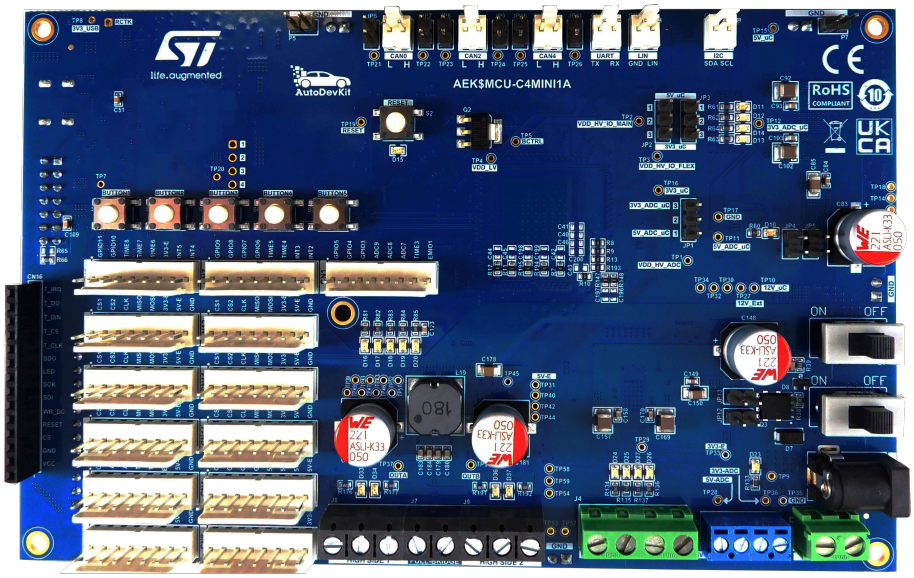
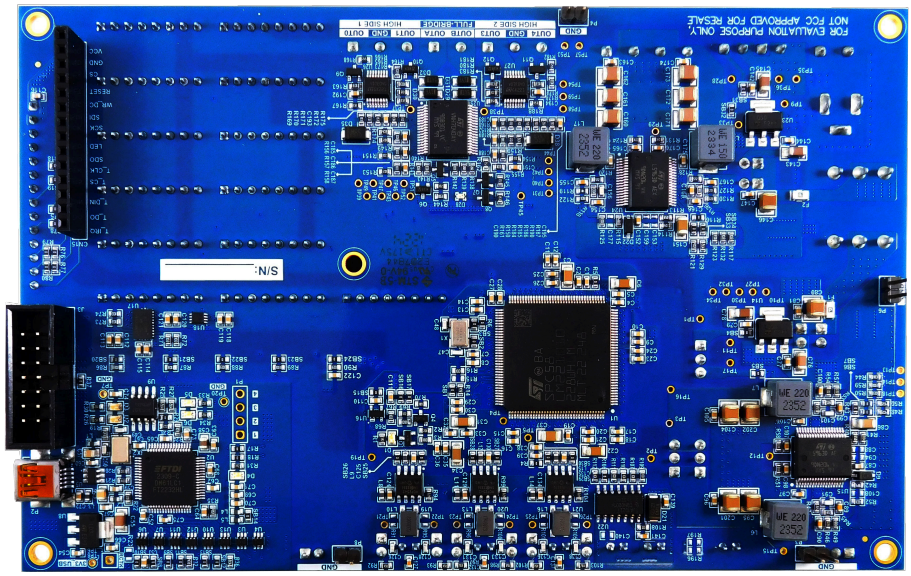


Figure 2. **AEK-MCU-C4MINI1 evaluation board bottom view**



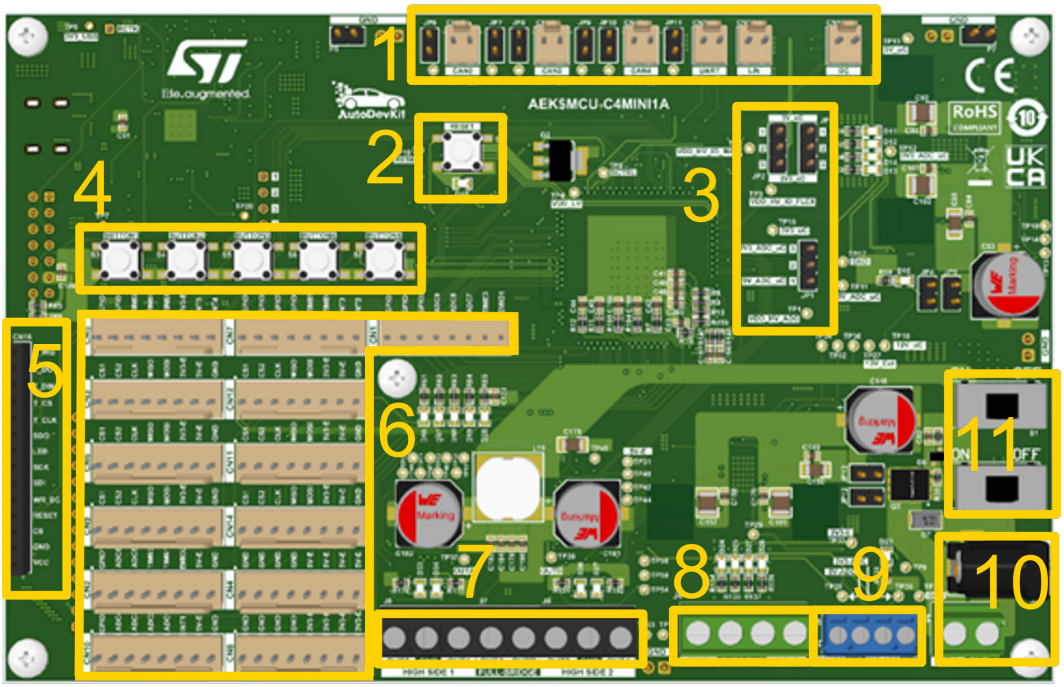
Notice: For dedicated assistance, please submit a request through our online support portal at ***www.st.com/support****.*

1 Hardware overview

1.1 Board main components

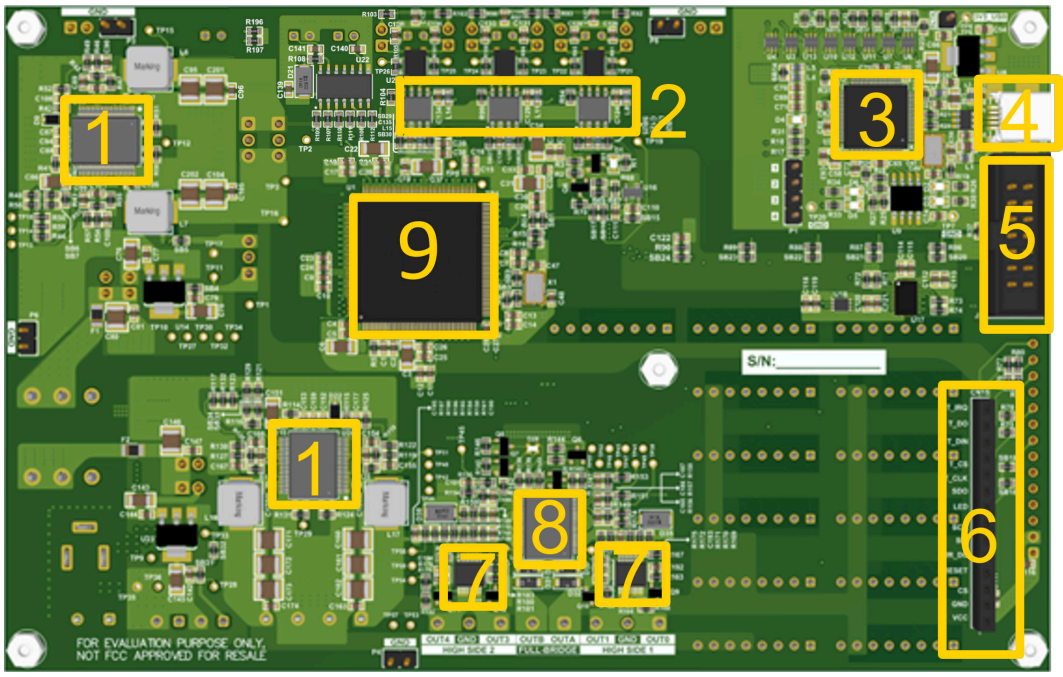
1. CAN, UART, LIN and I2C connectors
2. Reset button
3. Voltage configurations for the microcontroller (5 V or 3.3 V)
4. Generic buttons
5. Plug connector for the AEK-LCD-DT028V1 board
6. Generic I/O connectors (SPI, GPIO, exc.) and external supply voltage connectors
7. H-bridge/HS connectors
8. External supply voltage connectors
9. External supply ADC connectors
10. 12 V DC power supply connectors
11. Switches ON/OFF 12 V DC power supply

Figure 3. AEK-MCU-C4MINI1 evaluation board, top view: main components



1. L5963 driver
2. CAN transceiver
3. FTDI chip
4. OpenOCD debugger/programmer connector
5. JTAG connector
6. Plug connector for the AEK-LCD-DT028V1 board
7. VND7E040AJ actuators
8. VNH7040AY H-bridge driver
9. SPC58EC80E5 microcontroller

Figure 4. AEK-MCU-C4MINI1 evaluation board, bottom view: main components



1.2 SPC58EC80E5

The AEK-MUC-C4MINI1 evaluation board hosts a Chorus 4M SPC58EC80E5 microcontroller that belongs to the SPC58 Chorus family.

The main MCU features are:

- AEC-Q100 qualified
- 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
- 176 KB HSM dedicated flash memory
- 384 KB on-chip general-purpose SRAM
- 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
- Enhanced modular IO subsystem (eMIOS): up to 64 timed I/O channels with 16-bit counter resolution
- Enhanced analog-to-digital converter system with:
  - 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 (SPI) modules
- Low power capabilities:
  - Versatile low power modes

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

1.3 L5963

The L5963 chip belongs to the STMicroelectronics *Power Management IC and System Basis Chip* family. It consists of 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 standby regulator or normal LDO. This IC is fit for the automotive segment, where load dump protection and wide input voltage range are mandatory.

The AEK-MCU-C4MINI1 hosts two L5963 devices to offer an internal and an external supply voltage.

The L5963 features available in the AEK-MCU-C4MINI1 are:

- Two step-down synchronous switching voltage regulators with internal power switches
  - Wide input voltage range (from 3.5 V to 26 V)
  - 2.75A load current
  - Output voltage programmable with external resistor divider
  - 250 kHz free-run frequency
  - Integrated soft-start
  - 180° PWM output phase shift
  - Programmable switching frequency divider by 1, 2, 4 or 8 between the two DC/DC regulators
- One standby / linear regulator
  - Output voltage programmable with external resistor divider
  - 250 mA maximum current capability
- Load dump protection
- All the regulators come with the following protections:
  - Independent thermal protection
  - Independent current limit

Some of the L5963 features are not implemented in the AEK-MCU-C4MINI1:

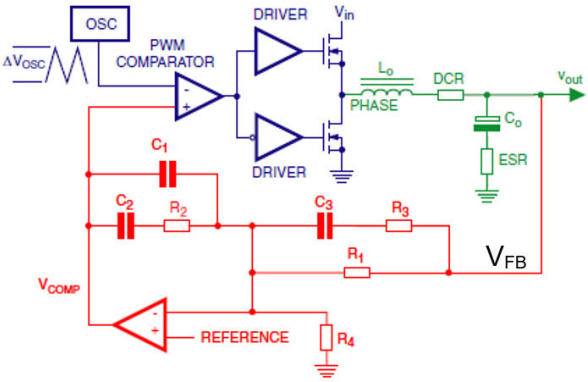
- On the board, we do not consider the Power-good reset and the Power-good function and the low voltage warning monitor that have the function of monitoring, respectively, the linear regulator, the DC/DC1 output and DC/DC2.
- The high-side output is not connected and left floating.
- The external free running frequency is not connected and left floating.

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

1.3.1 L5963 control

To assure stability and dynamic performance, the L5963 output voltage can be regulated through a closed feedback loop system with a TYPE III compensation network, as shown in the figure below. The relative stability control was built to manage a load up to 2.75 A.

Figure 5. Closed loop system with TYPE III network

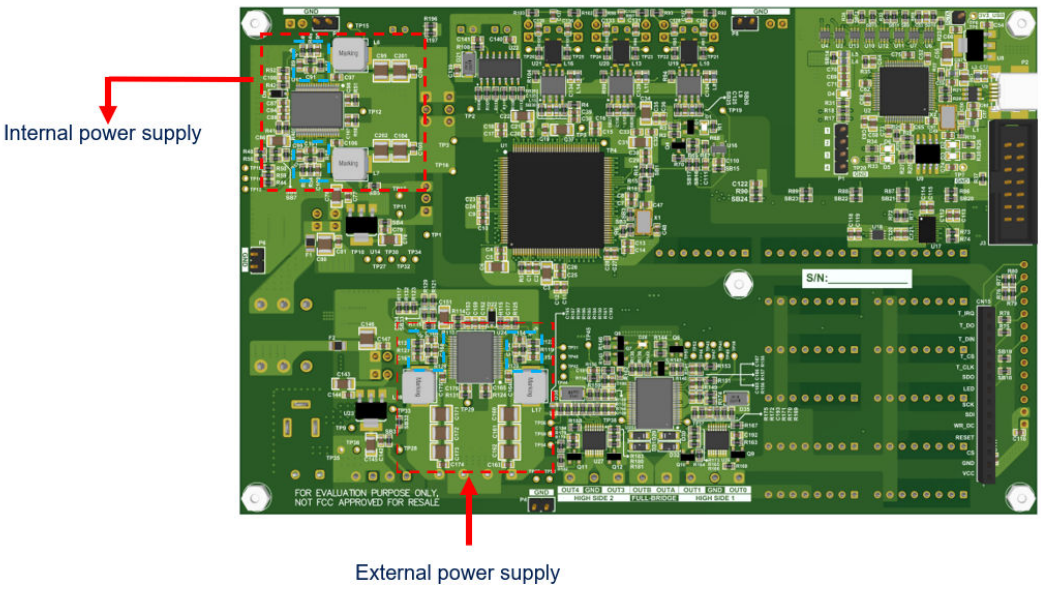


For example, in the figure above, when the output voltage V_{OUT} increases, the feedback voltage V_{FB} increases and the output of the negative feedback error amplifier decreases. So, the duty cycle decreases. As a result, V_{OUT} is pulled back to make V_{FB} = REFERENCE.

The compensation network of the error op-amp can be a Type I, Type II or Type III feedback amplifier network. To optimize a voltage mode PWM converter, a Type III compensation network is usually needed to design a fast loop with a sufficient phase margin that ensures robustness and stability.

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

Figure 6. **External ed internal power supply**



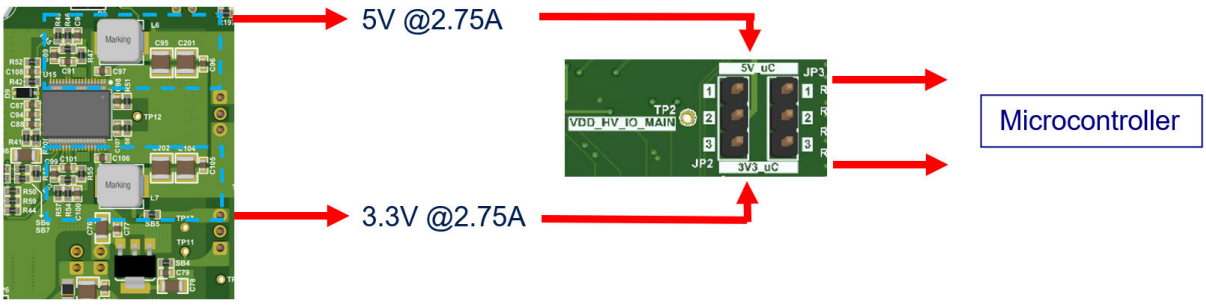
The two L5963 DC-DC controllers embed two switching regulators and a linear regulator. The internal and the external supply provide 5 V and 3.3 V with a capability of 2.75 A, ensuring stability and reaching the lowest voltage ripple.

As shown in the figure above, the AEK-MCU-C4MINI1 board supply can be divided into two parts (*external* and *internal*) to ensure high-level safety. Indeed, the external supply does not manage the internal one. *They are completely separated*.

1.3.2 Internal supply

The internal supply provides power source to the microcontroller that, in turn, provides power supply to the internal peripheral. Moreover, the microcontroller supplies the CAN and LIN transceivers and the level shifting transceiver used for the AEK-LCD-DT028V1 board, as well as the various LEDs and buttons.

Figure 7. **Internal power supply**



The DC-DC converter of the L5963, also called switching converter, provides two output voltages: 5 and 3.3 V. The two voltages converge in the final supply of the microcontroller that is called VDD_HV_IO_MAIN.

The board features other two internal supply voltages which provide 3.3 and 5 V to the internal ADC supply voltage. You can choose the voltage through JP1 selector.

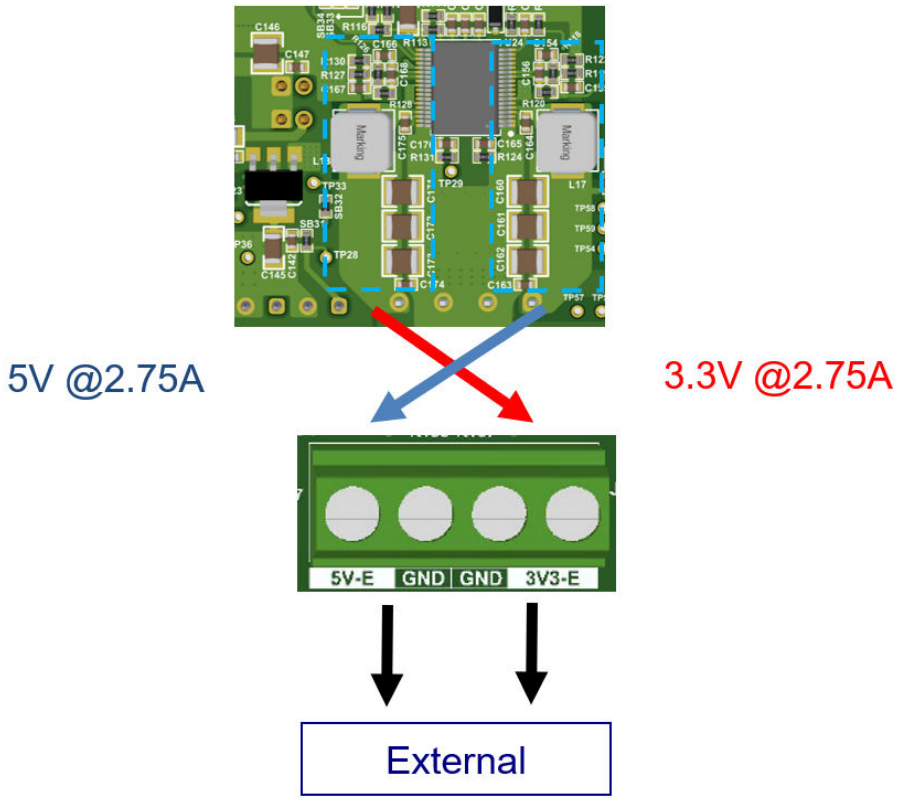
1.3.3 External supply

J4, J5 and J6 connectors are used for external supply. The 5 V and 3.3 V voltages have a capability of 2.75 A each and are called *5V*-E (5V-External) and 3V3-E (3V3-External). They are also available in the KKK connector as shown in section 1.6.

The DC-DC converter of the L5963 provides two output voltages: 5 and 3.3 V.

The board features other two external supply voltages, which provide 3.3 V (through J6) and 5 V (through J5) to the external ADC supply voltage.

Figure 8. External power supply



1.4 VNH7040AY

The VNH7040AY chip belongs to the *VIPower M0-7 H-bridge* family. The device is a full-bridge motor driver intended for a wide range of automotive applications. The device embeds a dual monolithic high-side driver and two low-side switches. They are designed to drive low or medium power automotive DC motors.

The VNH7040AY features available in the AEK-MCU-C4MINI1 are:

- Output current: 3 A
- PWM operation up to 20 KHz
- Very low standby power consumption
- Half-bridge operation
- Multisense monitoring functions:
  - Analog motor current feedback
  - Chip temperature monitoring
  - Battery voltage monitoring
- Multisense diagnostic functions:
  - Output short to ground detection
  - Thermal shutdown indication
  - OFF-state open-load detection
  - High-side power limitation indication
  - Low-side overcurrent shutdown indication
  - Output short to VCC detection
- The VNH7040AY come with the following protection features:
  - Undervoltage shutdown
  - Overvoltage clamp
  - Thermal shutdown
  - Open load protection
  - Cross-conduction protection
  - Protection against loss of ground and loss of V_{CC}
  - Output protected against short to ground and short to V_{CC}

1.4.1 VNH7040AY in the AEK-MCU-C4MINI

In the AEK-MCU-C4MINI board, the embedded VNH7040AY allows the user to access the full functionality of an half-bridge or a full bridge driver, performing small tests without having to buy a motor control board.

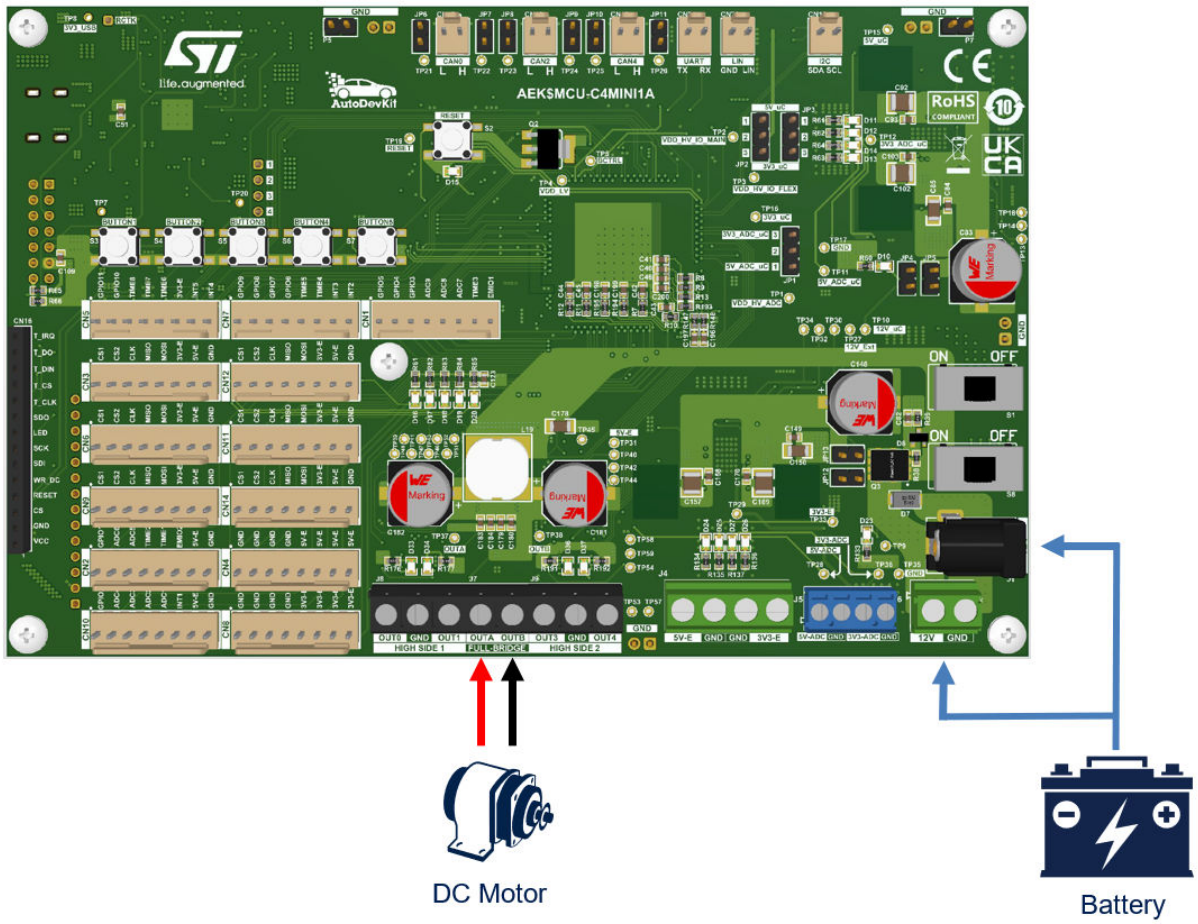
The AEK-MCU-C4MINI1 microcontroller board allows using a resistive or inductive load up to 3 A.

To exploit the full functionality of an H-bridge or drive a high current load, we recommend using a dedicated board, such as the AEK-MOT-2DC40Y1 board.

During laboratory tests, a resistive load of 4Ω @36W was used to test the board.

Note: For further information about the compensation network, refer to AN5026 or the VNH7040AY datasheet.

Figure 9. **AEK-MCU-C4MINI1 VNH7040AY block diagram**

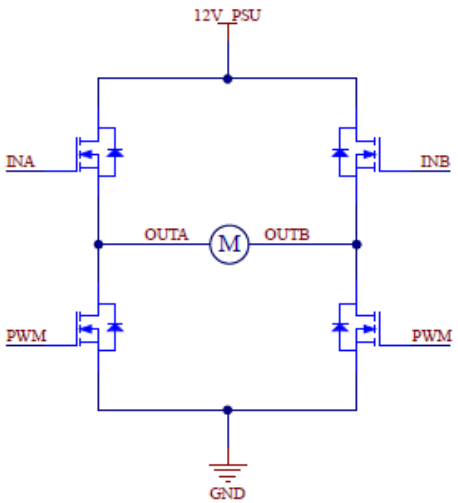


The figure above shows the block diagram allowing the motor connection.

1.4.2 Working principle

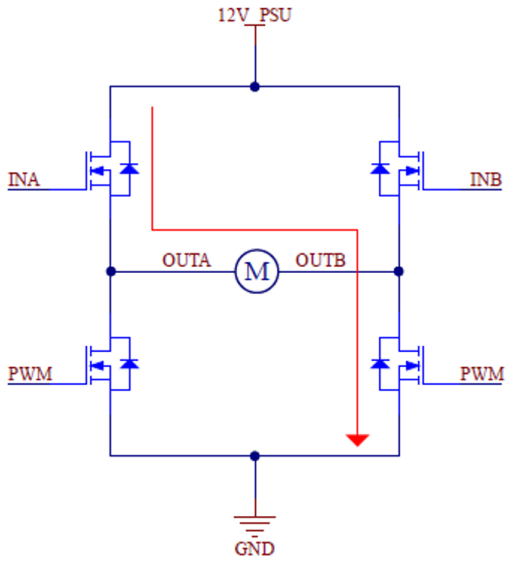
The motor can be independently controlled through specific combinations of INA, INB and PWM on the H-bridge. With the help of these digital pins, we can turn the motor clockwise or counterclockwise or brake it.

Figure 10. **H-bridge from the electrical point of view**



1.4.2.1 *Clockwise direction*

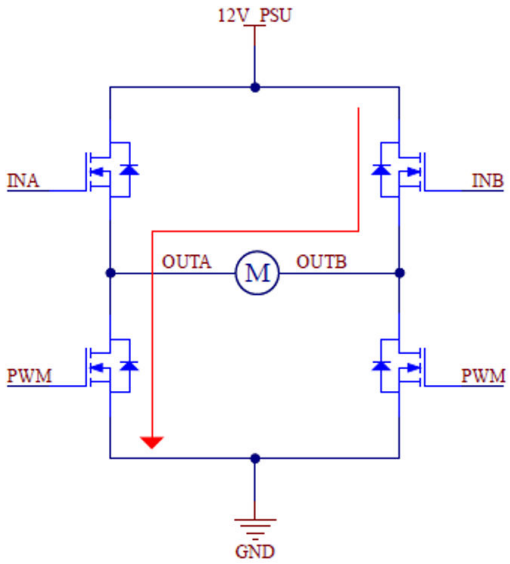
Figure 11. Clockwise direction



Set INA=H, INB=L and PWM=Duty cycle to a given % on H-B left to activate the M motor clockwise. Use PWM pin to vary the rotational speed.

1.4.2.2 *Counterclockwise direction*

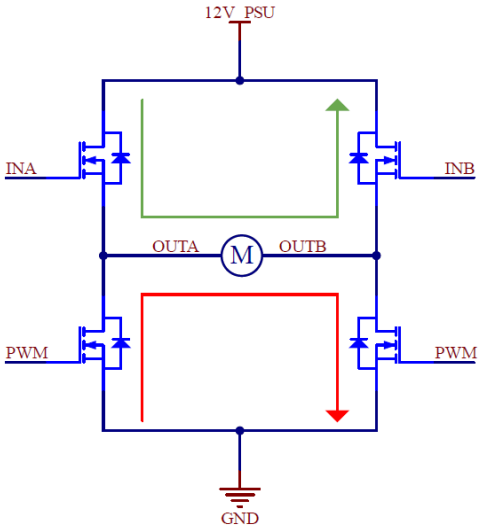
Figure 12. Counterclockwise direction



Set INA=L, INB=H and PWM=Duty cycle to a given % on H-B left to activate the M motor counterclockwise. Use PWM pin to vary the rotational speed.

1.4.2.3 *Brake*

Figure 13. Braking the motor



Set INA=L, INB=L and PWM=Duty cycle (100%) on H-B left to brake the M motor (as indicated by the red arrow in the figure above). In this case, the motor is braked to GND. Essentially, since there is no difference in polarity at the ends of the motor, it will be stopped. The same behavior can be obtained by braking it to 12_PSU (supply voltage), setting INA=H, INB=H and PWM=Duty cycle (0%) as shown in the figure above through the green arrow.

1.4.3 MultiSense considerations

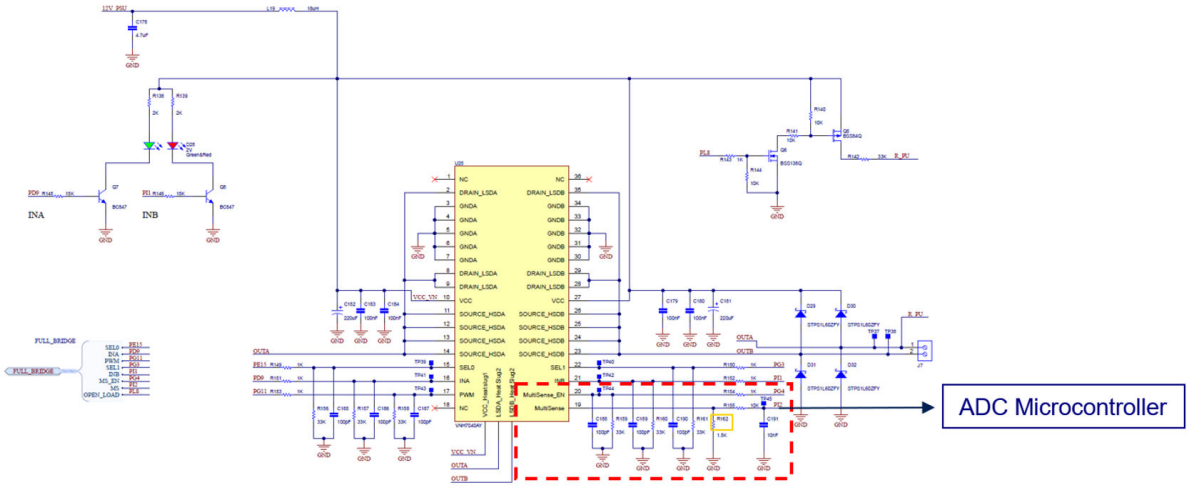
The VNH7040AY embeds Multisense diagnostic functions that are used to sense the current or to protect the device against open load, etc. These data are available in an analog monitoring output called MultiSense. It multiplexes several analog signals, controlled by the SELx and actived by MultiSense_EN pin.

1.4.3.1 *Current monitoring*

The Multisense pin delivers a current proportional to the ON state of the high side driver (HSA or HSB) according to the selection pin SEL0 (SEL0=H selects HSA, SEL0=L selects HSB) and SEL1=L. During normal operation, the current will be proportional to the load current flowing over the activated high side, selected by SEL0. This current can be easily converted to a voltage by using an external sense resistor (R162, 1.5 K, as shown in the figure below in the yellow rectangle inside the red dashed line box), allowing continuous load monitoring and abnormal condition detection.

After that, the sensing current will be sent to the ADC of the microcontroller as shown in the figure below.

Figure 14. **Current monitoring**



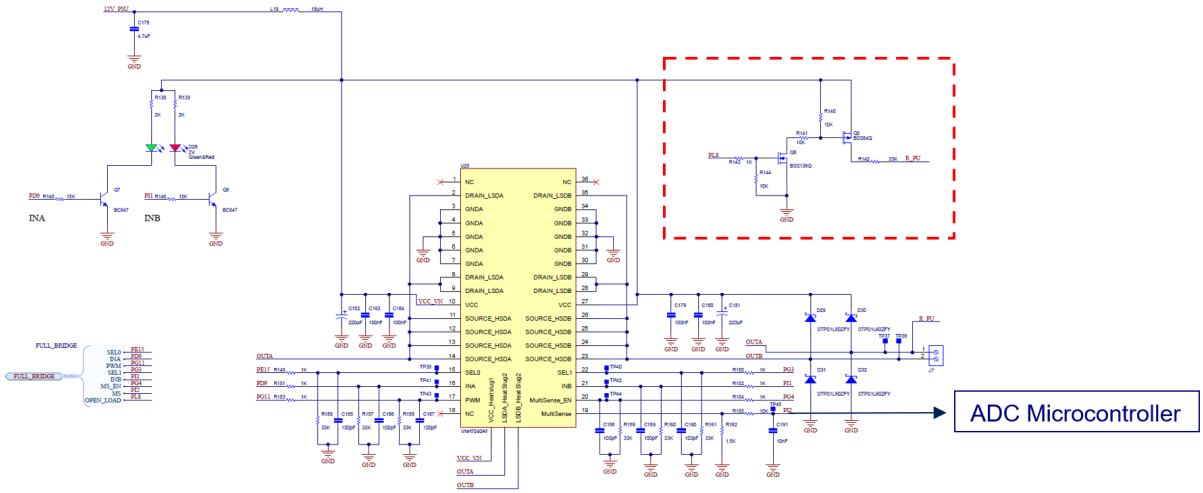
1.4.3.2 *Embedded protection*

VNH7040AY driver integrates advanced protection functions to protect both the power stage and the load. The device must be protected against overvoltage, overcurrent and overtemperature events outside the safe operating area. The power MOSFET is protected against high temperature events both by thermal shutdown and by a power limitation block that limits the junction temperature gradient in time. The device, through an external circuitry, exploits also the short to V_{CC} and the open load protection in off-state.

1.4.3.2.1 Open load detection in off-state/short to V_{CC}

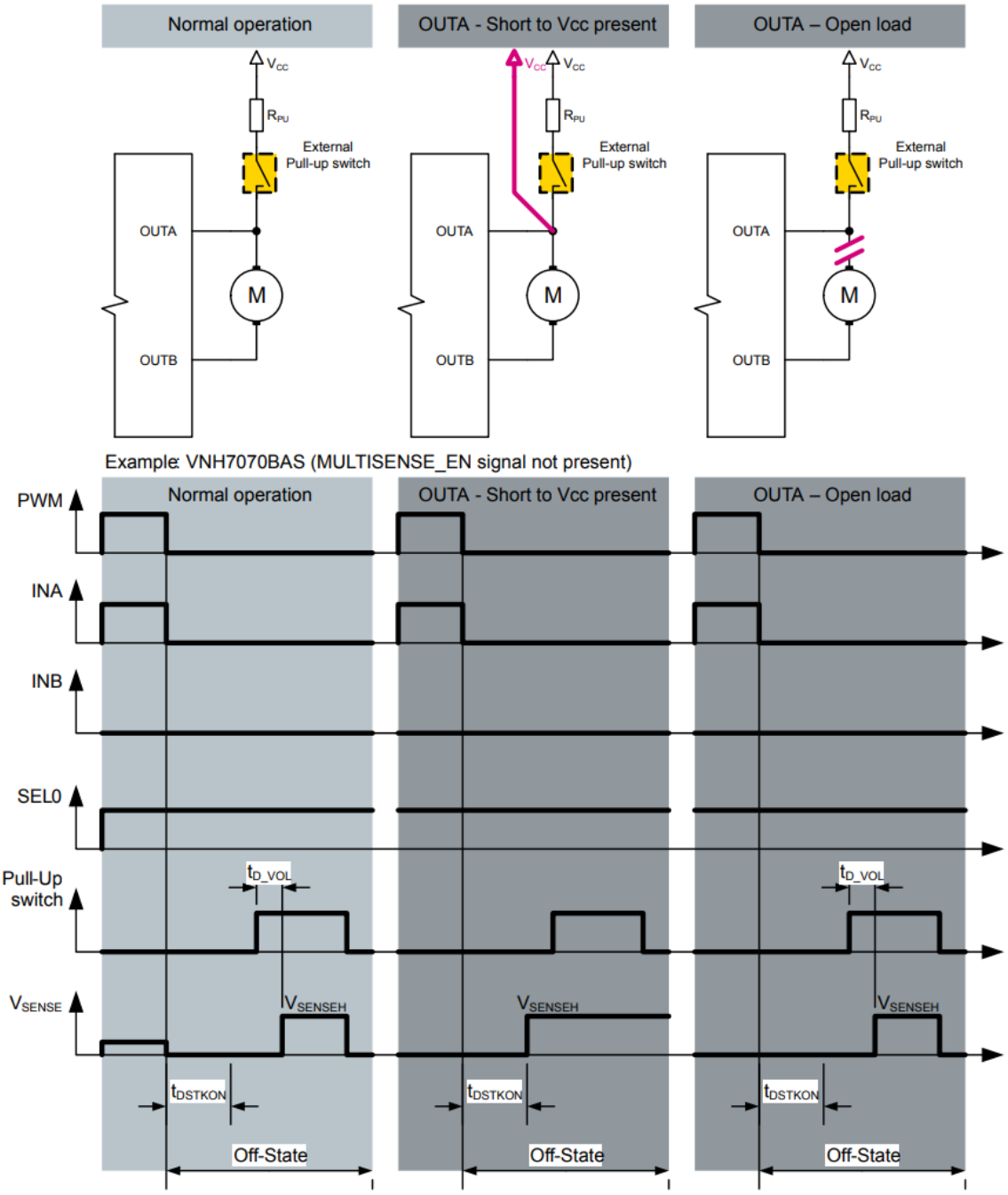
The open-load (OL) detection in off-state operates in the condition where the device is OFF (INA, INB and PWM all set to low and SEL0 is high). The OL detection and the short to V_{CC} is performed by reading the MultiSense pin output. So, both conditions need a pull up resistor (R_{PU}) (in this case, R142) applied over switched circuitry, as shown in the red rectangle of the figure below.

Figure 15. **Open load/SH to V_{CC} circuitry**



An open load or short-circuit to V_{CC} can be detected by checking the V_{SENSE} output during activated/inactivated external pull up switch (R_{PU}). The following figures below depict the cases applying OFF state diagnostics on OUTA with external pull-up switch. If an open load condition occurs, with the R_{PU} resistor, we can control the Multisense outpin pin. Indeed, in this case, we will have $V_{SENSE} = V_{SENSEH}$. If a short to V_{CC} condition occurs, V_{SENSE} will be always equal to V_{SENSEH}, no matter if R_{PU} is opened or closed. The information about V_{SENSE} will be acquired by the microcontroller ADC.

Figure 16. **MultiSense in OUTA off-state diagnostic in a full-bridge configuration**



1.5 VND7E040AJ

The VND7E040AJ chip belongs to the VIPower M0-7 enhanced family. The device is a double channel high-side driver intended for a wide range of automotive applications. The device is designed to drive 12 V automotive grounded loads as resistive, inductive, and capacitive or also automotive lamps. The chip can provide protection and diagnostics.

The VND7E040AJ features available in the AEK-MCU-C4MINI1 are:

- Output current: 3 A
- Double channel smart high-side driver with Current Sense analog feedback
- Very low standby current

- Current Sense diagnostic functions:
  - Analog feedback of load current with high precision proportional current mirror
  - Thermal shutdown indication
  - OFF-state open-load detection
  - Output short to VCC detection
  - Overload and Short-to-GND detection
- The VND7E040AJ come with the following protection features:
  - Undervoltage shutdown
  - Overvoltage clamp
  - Protection against loss of ground and loss of VCC
  - Output protected against short to ground and short to VCC
  - Electrostatic discharge protection
  - Load current limitation
- In the AEK-MCU-C4MINI1 the FaultRST pin was kept low to set the faults in auto-restart mode.

Note: For further information about the compensation network, refer to the VND7E040AJ datasheet.

1.5.1 VND7E040AJ in the AEK-MCU-C4MINI

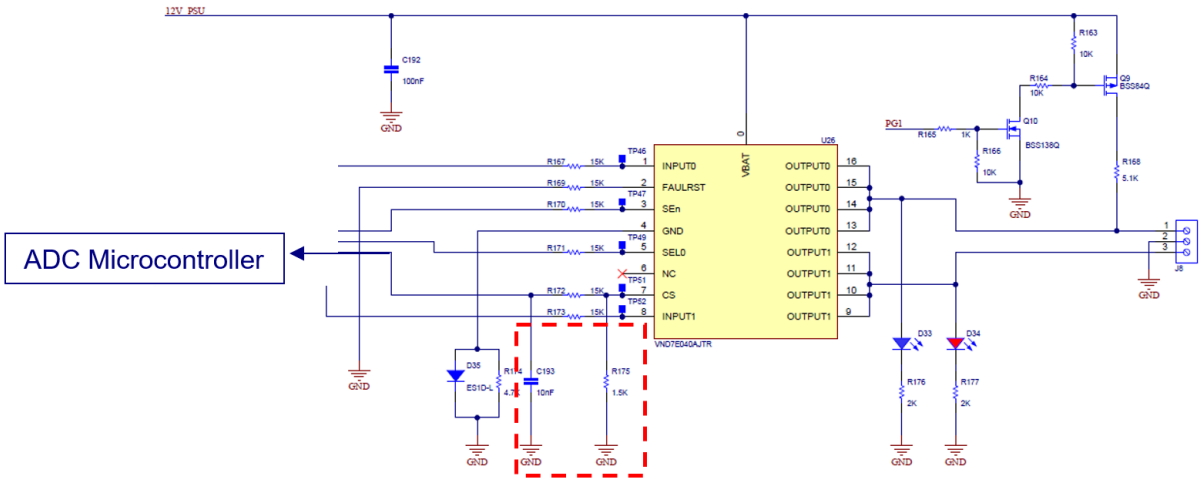
In the AEK-MCU-C4MINI board, the VND7E040AJ was included to give the user access to the full functionality of a double high side driver, so that they can have the opportunity to perform small tests without the need of buying a load actuator board.

The AEK-MCU-C4MINI board hosts two VND7E040AJ drivers to manage different and parallel loads.

The board is designed to connect loads of up to 3 A.

During laboratory tests, a resistive load of 4 Ω @36 W was used to test the board.

Figure 17. AEK-MCU-C4MINI1 VND7E040AJ block diagram



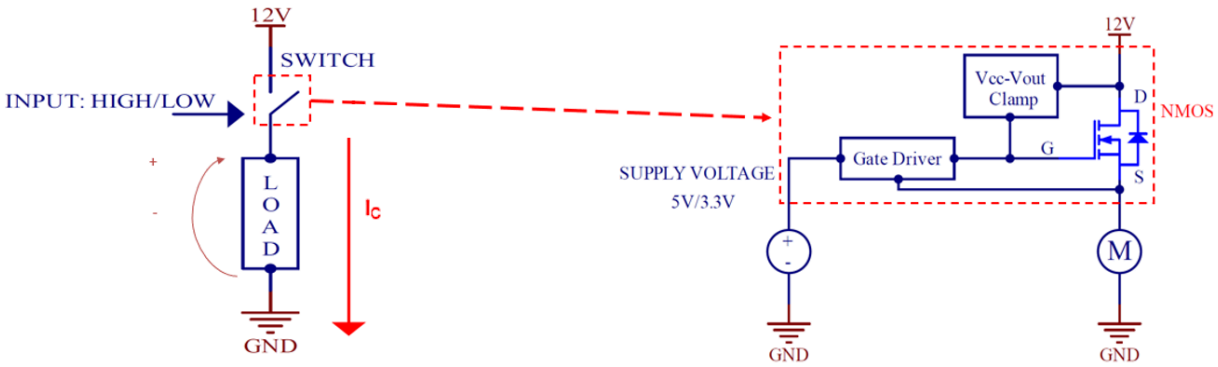
1.5.2 Working principle

The device, disregarding the protection and diagnostic functions, can be represented as a switch, which embeds an NMOS.

The NMOS (see the red dashed rectangle on the right), properly driven, can handle resistive, inductive, and capacitive automotive loads.

The loads can be independently controlled through INPUT0 or INPUT1 to activate the OUT0 or OUT1 of the first or second VND7E040AJ drivers embedded on the board. Through these digital pins, we can switch drivers on/off.

Figure 18. **High-side configuration on the VND7E040AJ**



If the input is high, the switch will close, and the current will flow; otherwise, the opposite behavior will occur.
The onboard LEDs (D33, D34, D36 and D37) indicate if the outputs are on or off.

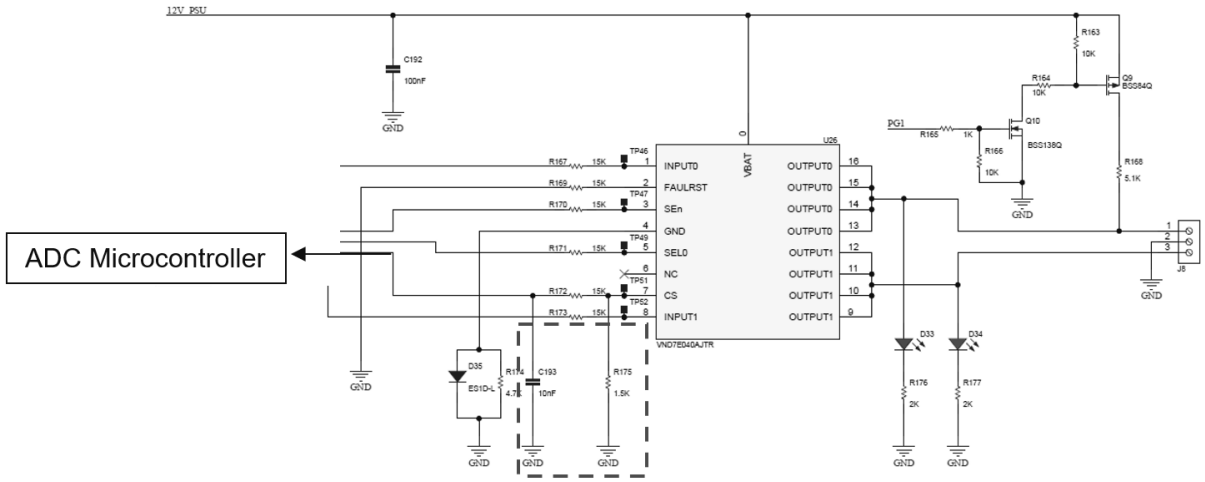
1.5.3 MultiSense considerations

The VND7140AJ embeds Multisense diagnostic functions that are used to sense the current, i.e. current monitor, or to protect the device against open load, etc. All these data are available in an analog monitoring output called MultiSense [CS pin]. It multiplexes several analogue signals, controlled by the SELx and activated by SEn pin.

1.5.3.1 Current monitoring

The Multisense [CS pin] delivers current proportional to the ON state of the high side driver according to the selection pin SELx of the VND7140AJ. During the normal operation, the current will be proportional to the load current flowing over the activated high side, selected by SELx. This current can be easily converted to a voltage by using an external sense resistor (R175), allowing continuous load monitoring and abnormal condition detection.
After that, the sensing current will be sent to the ADC of the microcontroller as shown in the figure below.

Figure 19. **Current monitoring for the high-side configuration**



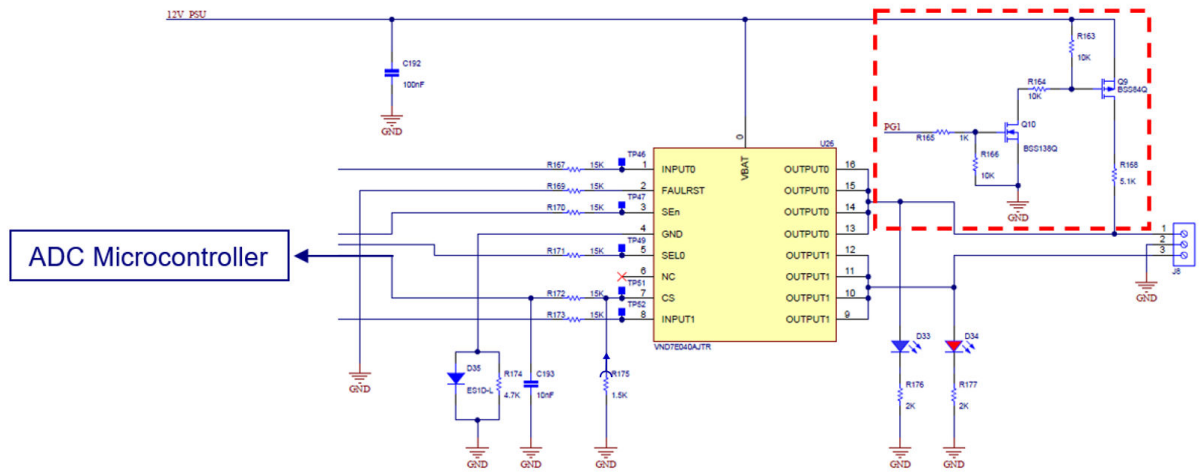
1.5.3.2 Embedded protection

VND7140AJ driver integrates advanced protection functions to protect both the power stage and the load. The device must be protected against overvoltage, overcurrent, and overtemperature events outside the safe operating area. The power MOSFET is protected against high temperature events by thermal shutdown and other embedded features. The device, through external circuitry, also exploits the short to V_{CC} and the open load protection in off-state. Both can be available only in one output.

1.5.3.2.1 Open load detection in off-state / Short to V_{CC}

The open load (OL) detection in off-state operates in the condition where the device is OFF (INPUT0 set low and SEL0 is high). The OL detection and the short to VCC is performed by reading the CS pin output. So, both conditions need a pull up resistor (R_{PU}) (in this case, R168), applied over switched circuitry, as shown in the red rectangle below.

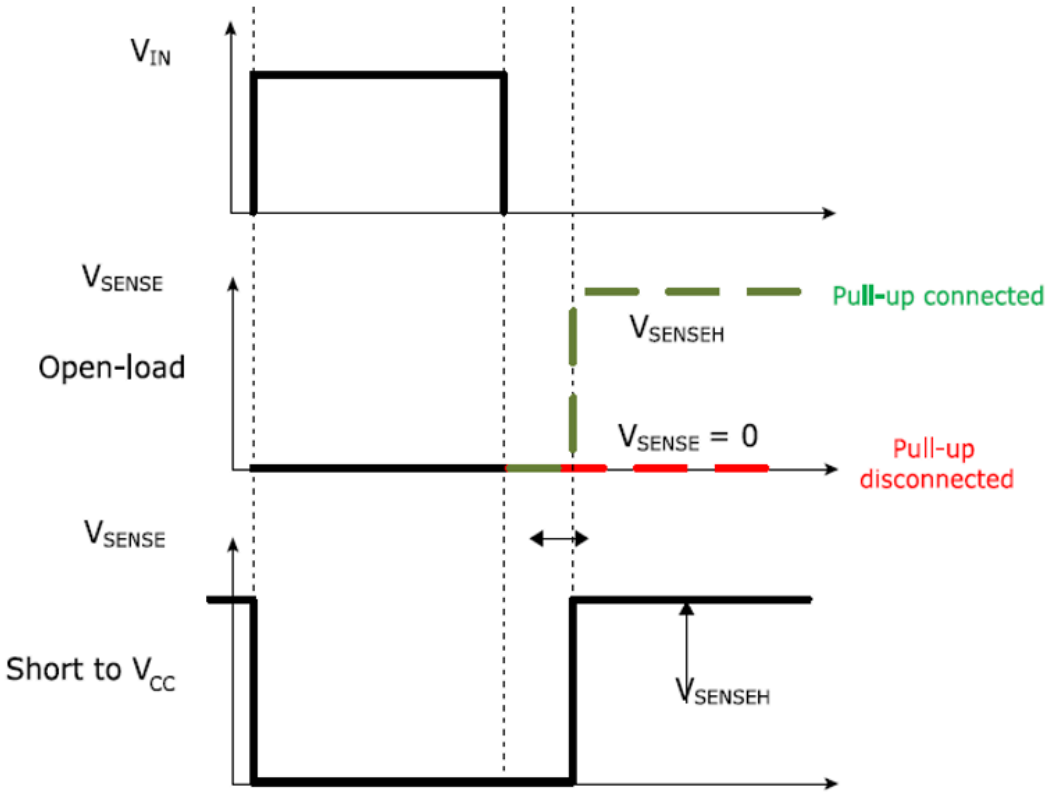
Figure 20. Open load/SH to V_{CC} circuitry



An open load or short-circuit to V_{CC} can be detected by checking the V_{SENSE} output during activated/inactivated external pull up switch (R_{PU}). The figures below depict the cases applying OFF state diagnostics on OUT0 with external pull-up switch. If an open load condition occurs, with the R_{PU} resistor, we can control the CS output pin. Indeed, in this case, we will have $V_{SENSE} = V_{SENSEH}$, if $V_{OUT} > V_{OL}$, where V_{SENSE} indicates the voltage on the R_{SENSE} resistor, V_{SENSEH} indicates voltage on R_{SENSE} in fault conditions, and V_{OL} indicates voltage in case of open load.

If $V_{OUT} < V_{OL}$ CS will be zero. On the other side, if a short to V_{CC} condition occurs, V_{SENSE} will always be equal to V_{SENSEH} , no matter if R_{PU} is opened or closed. Indeed, if $V_{OUT} > V_{OL}$, we will have $V_{SENSE} = V_{SENSEH}$. The information about V_{SENSE} will be acquired by the MCU ADC.

Figure 21. **Open-load /short to V_{CC} condition**



1.6 Other ICs

The board AEK-MCU-C4MINI1 hosts other noteworthy third-party integrated circuits (ICs).

1.6.1 FTDI chip

The FTDI chip is a USB 2.0 hi-speed (480 Mb/s) to UART/FIFO IC. It has the capability of being configured in a variety of industry standard serial or parallel interfaces. In the AEK-MCU-C4MINI1 board, the FTDI chip allows programming/debugging the application in conjunction with the JTAG connector or the mini-USB 2.0 Type B connector. The supported license is for host OpenOCD open-source debugger.

1.6.2 CAN FD transceiver chip

The CAN transceiver IC is designed for high-speed CAN FD applications up to 8 Mbps communication speed. It supports also CAN 2.0. The device meets the automotive requirements for CAN FD bit rates exceeding 2 Mbps, low quiescent current, electromagnetic compatibility (EMC) and electrostatic discharge (ESD). In the AEK-MCU-C4MINI1 board, there are three of these CAN transceivers.

1.6.3 LIN transceiver chip

The device is a dual LIN transceiver that provides the interface between a Local Interconnect Network (LIN) leader/follower protocol controller and the physical bus in a LIN network. It is primarily intended for in-vehicle subnetworks using baud rates up to 20 kBauds and is compliant with LIN 2.0, LIN 2.1, LIN 2.2, LIN 2.2A and SAE J2602. In the AEK-MCU-C4MINI1 board, the LIN transceiver was used to build a master configuration in the LIN protocol.

1.7 Connector overview

Connectors are grouped by type, to facilitate the connection and simplify the identification of the pins that can be used according to the user's application. The microcontroller peripherals are already mapped on the connector by direct connection of the pin.

1. CAN connectors:
   - CN17: CAN0 peripheral
   - CN18: CAN2 peripheral
   - CN19: CAN4 peripheral
2. Serial connectors:
   - CN13: I2C peripheral
   - CN20: LIN peripheral
   - CN21: UART peripheral
3. Connector for display board:
   - CN16: top view
4. Generic I/O connectors:
   - CN1: emios, gpio, adc, timer
   - CN2: gpio,adc,timer,emios,external supply
   - CN5: gpio, timer, interrupt
   - CN7: gpio,timer, interrupt
   - CN10: gpio,adc, interrupt
5. SPI connectors:
   - CN3: DSPI1 peripheral (only master config.)
   - CN6: DSPI2 peripheral (only master config.)
   - CN9: DSPI3 peripheral (only master config.)
   - CN11: DSPI5 peripheral (master-slave config.)
   - CN12: DSPI0 peripheral (master-slave config.)
   - CN14: DSPI7 peripheral (master-slave config.)
6. External power connectors:
   - CN4: 5V external power connector
   - CN8: 3.3V external power connector
7. OpenOCD debugger/programmer connector
8. JTAG connector
9. Plug connector for the AEK-LCD-DT028V1 board
   - CN15: bottom view

Figure 22. **Connector overview (top view)**

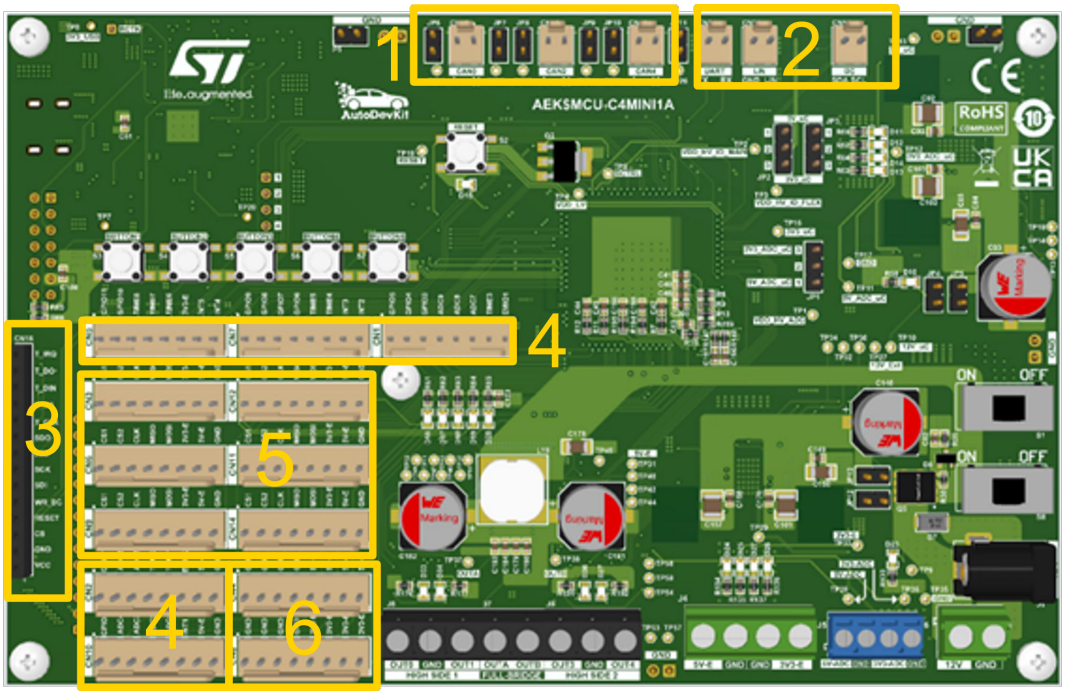
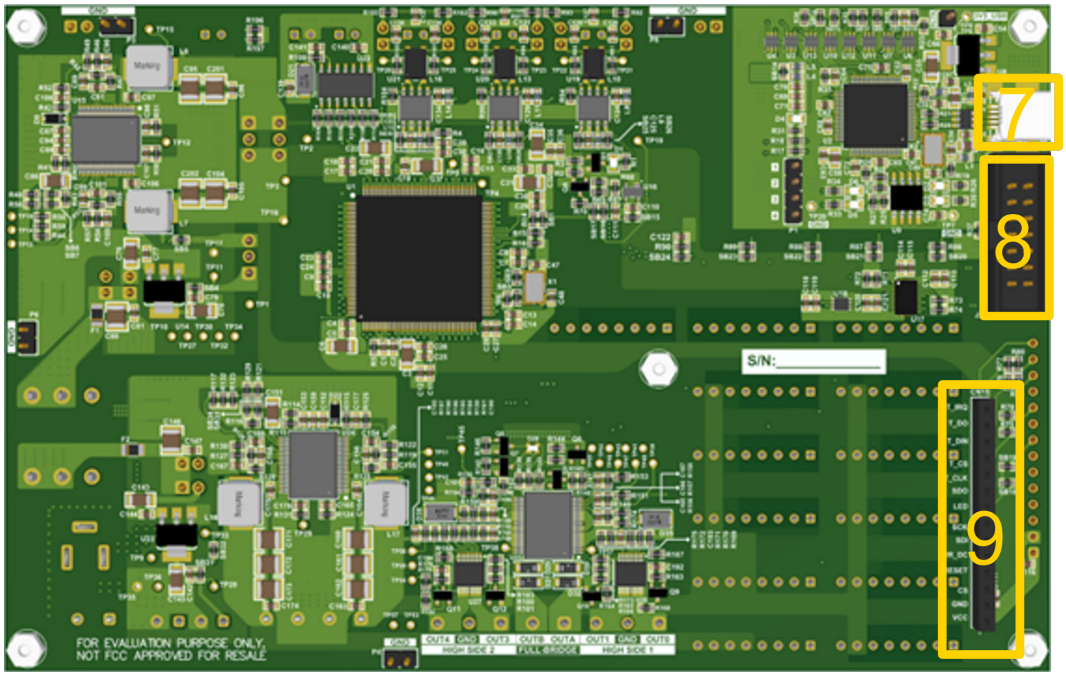


Figure 23. **Connector overview (bottom view)**

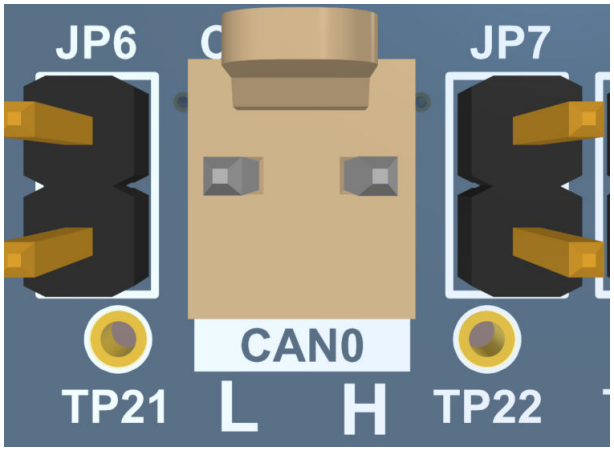


1.7.1 CAN connectors

CAN connectors implement the CAN protocol that is a vehicle bus standard designed to allow microcontrollers and devices to communicate with each other. All the nodes are connected to each other through a physically conventional two-wire bus. The wires are a twisted pair with a 120 Ω (nominal) characteristic impedance.

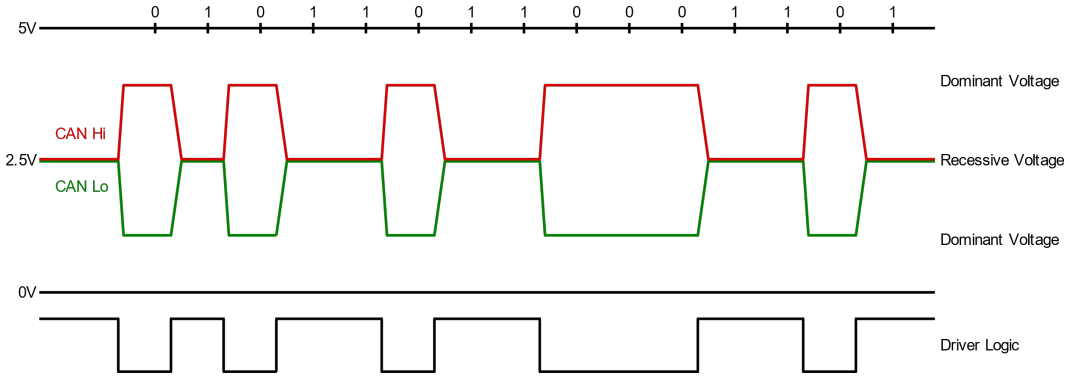
The CAN bus needs this impedance of 120 Ω to work correctly. Onboard, each CAN line has a resistor of 120 Ω. To enable the line, and avoid problems during communication, the jumpers (JP6 and JP7, in case you are using CAN0 connector, as shown in the figure below) associated with the CAN connector should be closed. The same applies to the other onboard CAN connectors.

Figure 24. Example of CAN connector



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 25. Example of CAN signals

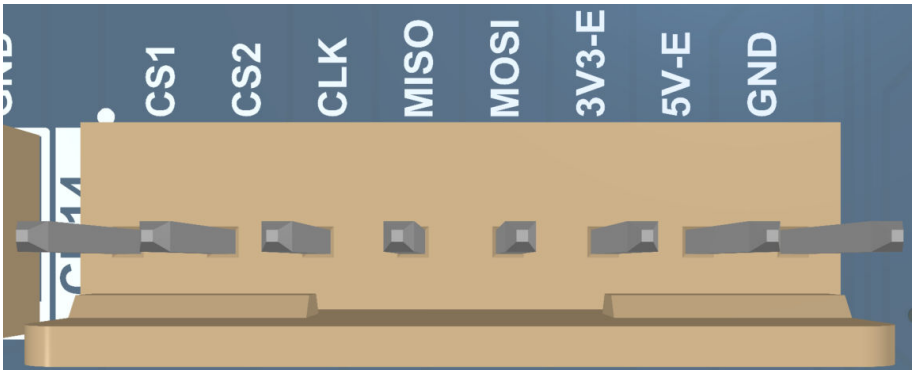


The AEK-MCU-C4MINI1 hosts three CAN connectors with respective CAN-FD transceivers able to support high-speed applications. Each connector has two pins that indicate high and low signals, as shown in the figure above.

1.7.2 SPI connectors

SPI connectors implement the SPI protocol for synchronous serial communication, used primarily in embedded systems for short-distance wired communication between integrated circuits. SPI uses a master-slave architecture, where one main device (master) manages communication among peripheral devices (slave) by driving the clock and chip select signals. In our case, we can drive a maximum of two slaves through CS1 and CS2 signals with only one master.

Figure 26. **Example of SPI connector**



- CLK : Serial Clock (clock signal from master)
- MOSI : Master Output Slave Input (data output from master)
- MISO : Master Input Slave Output (data output from slave)
- CS : Chip Select (active low signal from master to address the slave and initiate)

To start communication, the main SPI 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, and then each of them reads the corresponding incoming bit. This sequence is maintained even when only one-directional data transfer is intended.

The AEK-MCU-C4MINI1 hosts six SPI connectors. Each connector has 8 pins. 5 pins are dedicated to the SPI protocol. 3.3 V external and 5 V external power supplies and a GND pin are also present.

1.7.3 External power connector

Important: The cables inside the AEK-MCU-C4MINI1 blister have a maximum current capability of 200 mA.

Figure 27. **3.3 V External power connector**

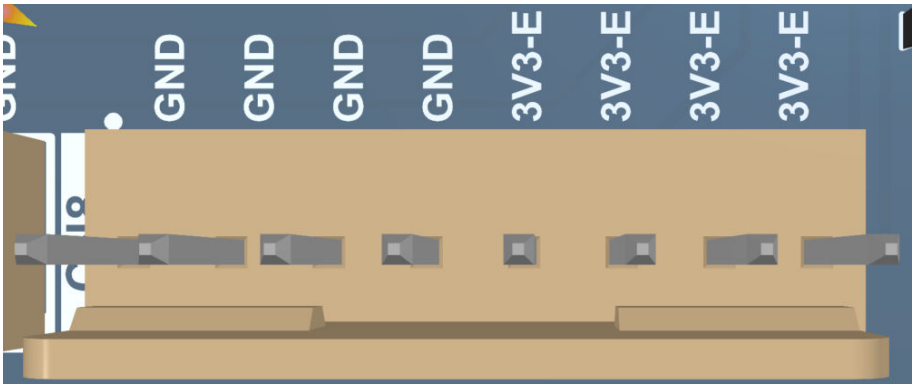
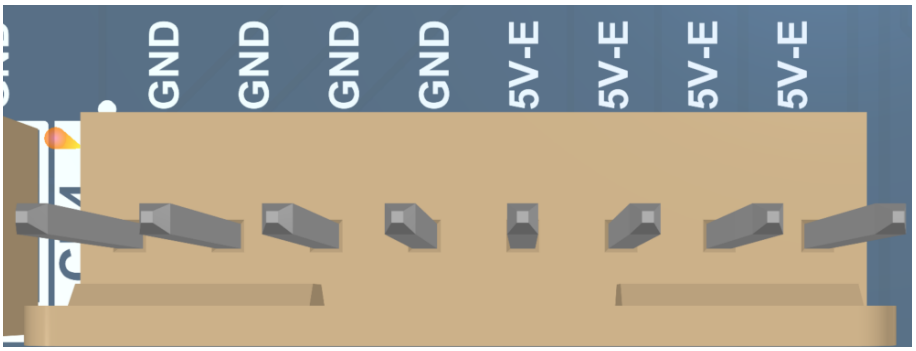


Figure 28. **5 V External power connector**

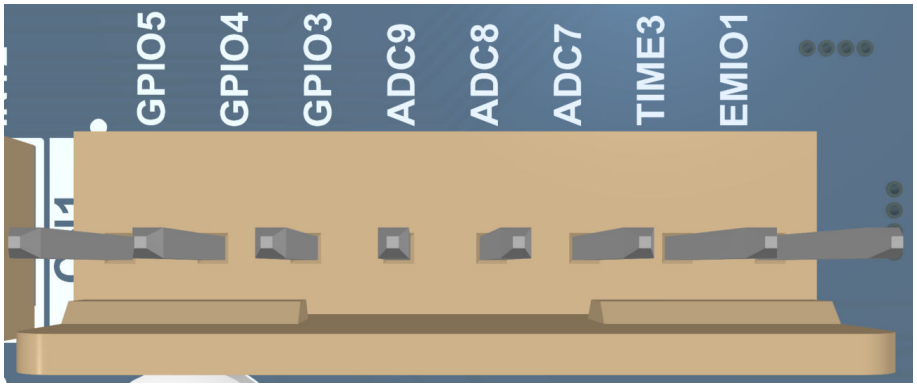


The AEK-MCU-C4MINI1 hosts two power connectors with 3.3 V and 5 V external power supplies. Moreover, for each connector, there are four GND pins.

1.7.4 Generic I/O connectors

The AEK-MCU-C4MINI1 hosts five generic I/O connectors. These connectors are a combination of different functionalities of the microcontroller: general purpose I/O, ADC, TIMER, EMIOS and INTERRUPT, as shown as example below.

Figure 29. Generic I/O connector



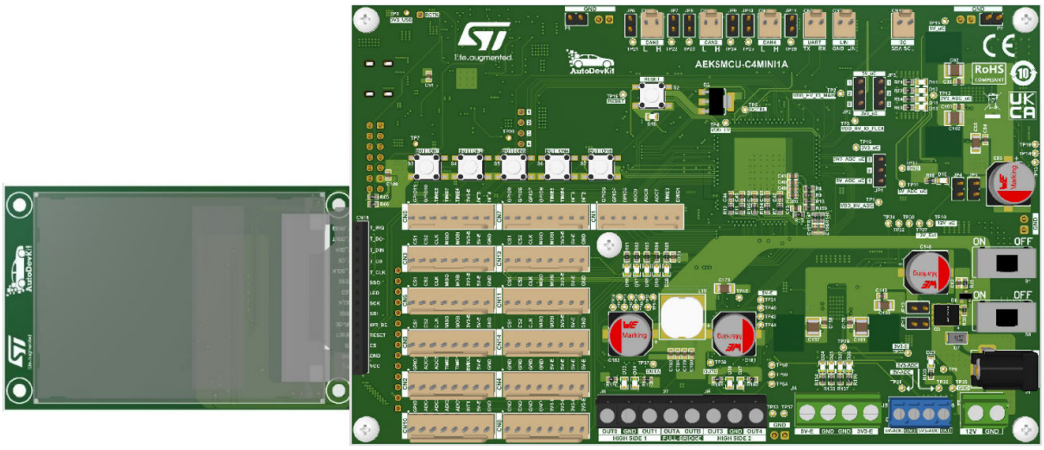
On this board, the number and type of these pins offer a wide range of options to take advantage of the microcontroller potential and to meet the needs of the final user during programming or firmware development.

The more experienced user may decide to remap the functionality of the microcontroller through these pins. For example, a GPIO can be transformed into another INTERRUPT by configuring the microcontroller pin map editor through AutoDevKit Studio.

CN2, CN5 and CN10 connectors also host GND and external power supply.

1.7.5 Display connector

Figure 30. Display connector top view

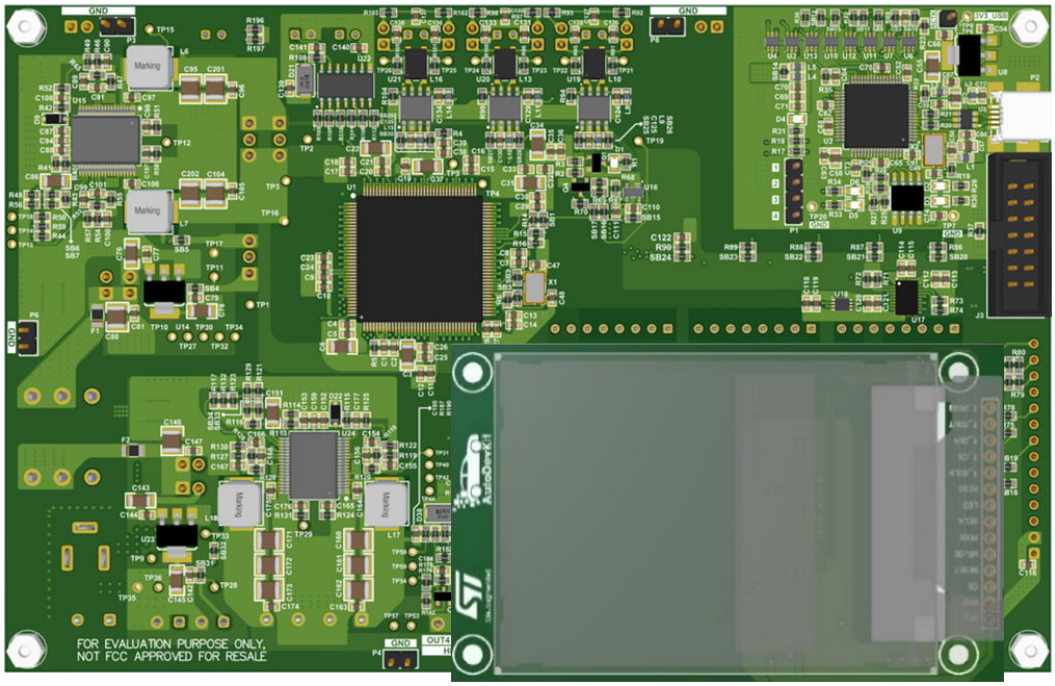


As shown in the figure above, the AEK-MCU-C4MINI1 hosts two customized display connectors that allow the connection of the AEK-LCD-DT028V1, which features a 2.8” LCD display with resistive touch and a graphical user interface (GUI) to interact with the AEK-MCU-C4MINI1.

The AEK-LCD-DT028V1 can be connected at the board top or bottom through CN15 and CN16 connectors.

Note: The two connectors cannot be used simultaneously.

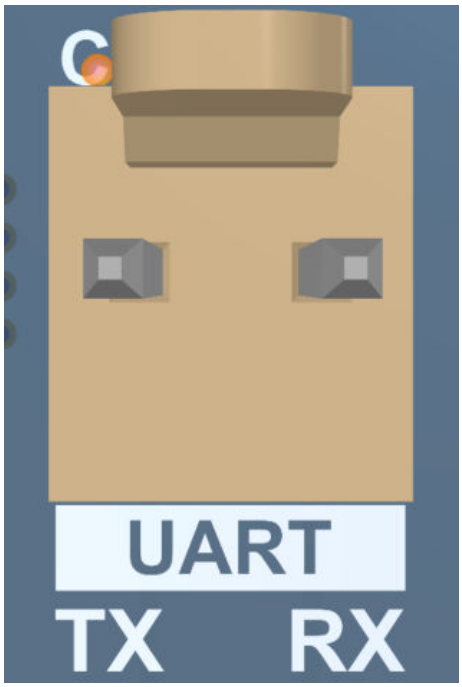
Figure 31. **Display connector bottom view**



1.7.6 Serial connectors

1.7.6.1 UART connector

Figure 32. **UART connector**



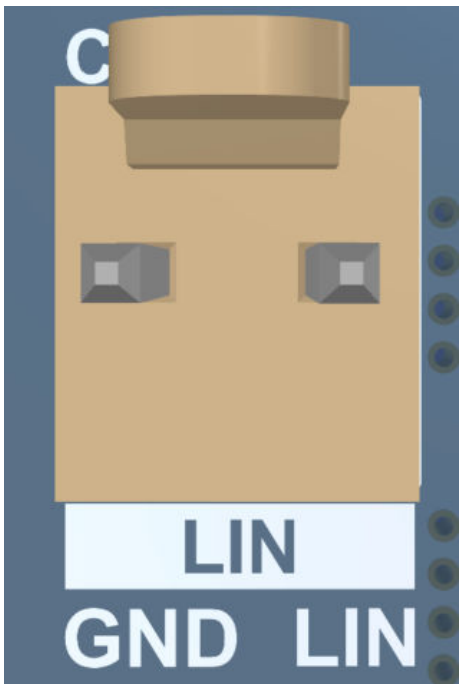
The UART connector implements the UART protocol used for asynchronous serial communication, which allows configuring data format and transmission speeds. It sends data bits one by one, from the least significant to the most significant, framed by start and stop bits so that precise timing is handled by the communication channel.

The AEK-MCU-C4MINI1 hosts a UART connector, which has two pins. TX pin is used for data transmission and RX pin is used for data reception.

Referring to Figure 4, you can notice that there is another UART connector (OpenOCD debugger/programmer connector, indicated by number 4), which allows you to flash the board or use the serial line integrated in the FTDI chip (indicated by the number 3 in the figure).

1.7.6.2 *LIN connector*

Figure 33. LIN connector

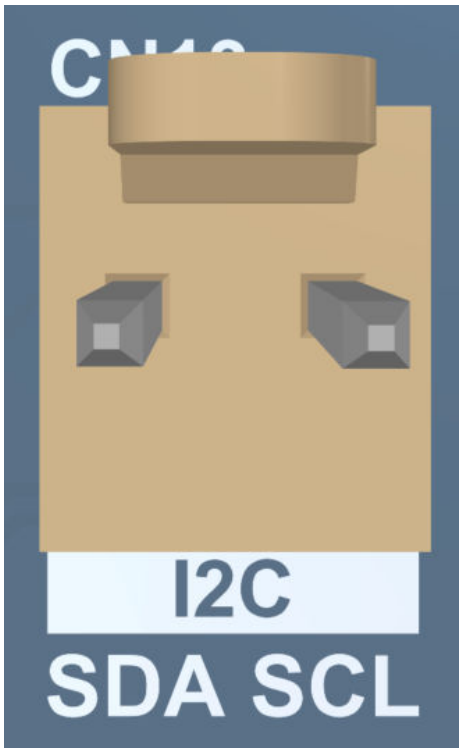


The LIN connector implements the LIN protocol that is a serial network protocol used for communication between components in vehicles. It is a single wire, serial network protocol that supports communication up to 19.2 Kbit/s with a bus length of 40 meters.

The AEK-MCU-C4MINI1 hosts a LIN connector with a LIN transceiver able to convert the double transmission (TX-RX) line in input as one single wire, thanks to the microcontroller that manages the LIN protocol as serial transmission with two pins. Each connector has two pins that indicate the GND and LIN signals, as shown in Figure 33.

1.7.6.3 I2C connector

Figure 34. **I2C connector**



The I2C connector implements the I2C protocol that is a synchronous, multi-master/multi-slave, single-ended, serial communication bus. It is widely used to connect lower-speed peripheral ICs to microcontrollers in short-distance (so, for intra-board communication).

The AEK-MCU-C4MINI1 hosts an I2C connector and has two pins that indicate the SDA (serial data line) and SCL signal (serial clock line), as shown in Figure 34. Both signals need pull-up resistors, which are not mounted on the board.

2 AutoDevKit ecosystem

The application development employing the AEK-MCU-C4MINI1 takes full advantage of the AutoDevKit ecosystem, whose basic components are:

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

AutoDevKit Studio is an integrated development environment (IDE) based on Eclipse.

The aim of AutoDevKit Studio is to maximize developer productivity of embedded applications based on SPC5 Power Architecture 32-bit microcontrollers with a single tool for evaluation, development, design, and production.

AutoDevKit Studio includes an application wizard to simplify project creation and configuration, it automatically solves component dependencies and generates support files.

Other advantages of AutoDevKit Studio include:

- the ability to integrate other software products from the Eclipse standard marketplace
- the availability of a free license GCC GNU C Compiler component
- the possibility to support industry-standard compilers
- support of multi-core microcontrollers
- a PinMap editor to facilitate MCU pin connections

2.1 How to create a new project with AutoDevKit Studio using the AEK-MCU-C4MINI1

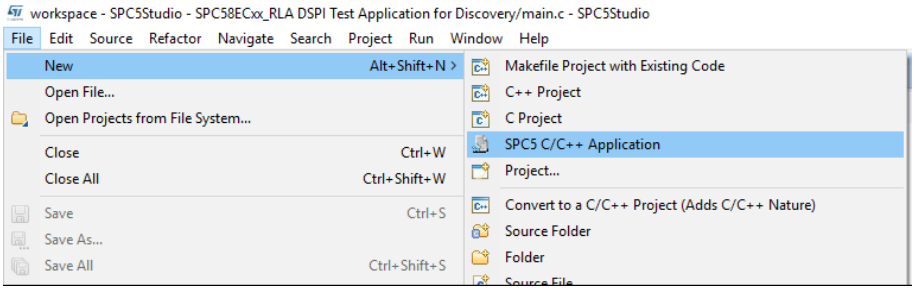
The following procedure provides step-by-step guide to create a new project in AutoDevKit Studio using the AEK-MCU-C4MINI1.

Step 1. Install AutoDevKit Studio (downloadable from www.st.com/autodevkitsw).

Step 2. Create a new SPC5 application:

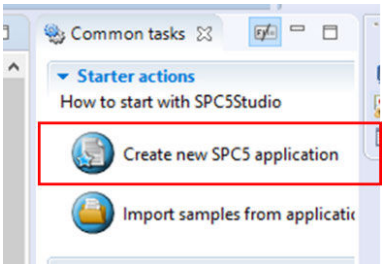
– Select [File] [New] [SPC5 C/C++ Application]

Figure 35. New Project menu



– Or select the icon “Create a new SPC5 application” present in the Starter actions tab.

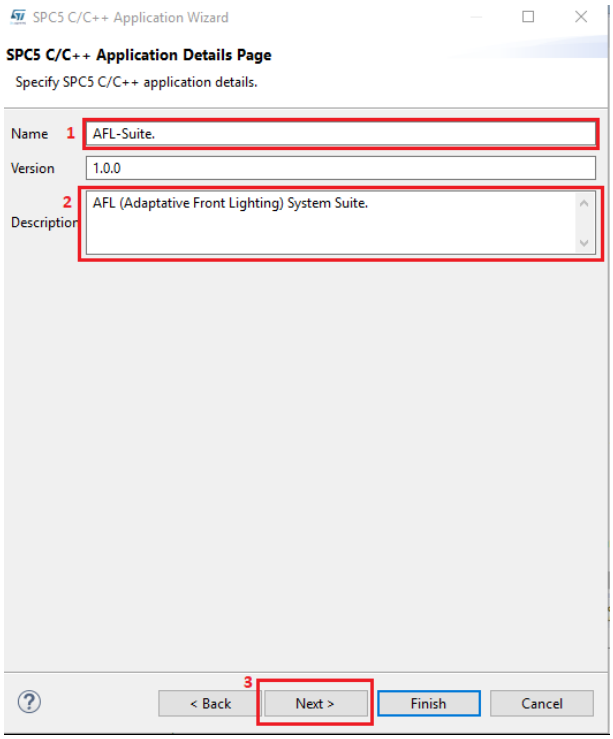
Figure 36. Starter actions tab



A window appears, prompting application details.

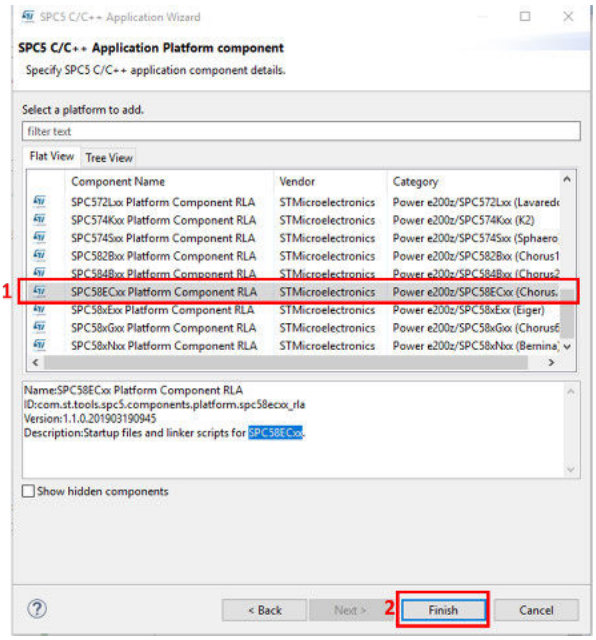
Step 3. Fill in the application details and then click on the [Next] Button.

Figure 37. New application details page



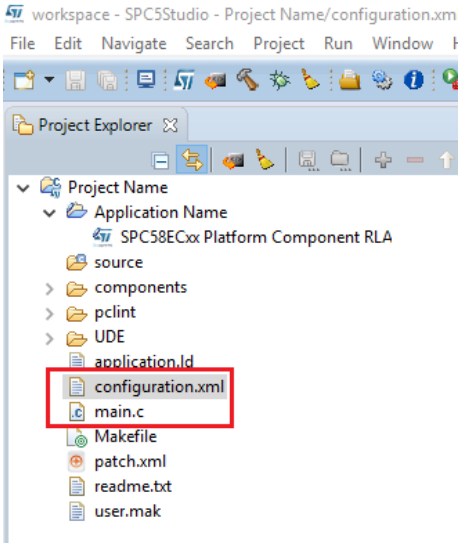
Step 4. Select the SPC58ECxx component and select the [Finish] button.

Figure 38. New application MCU platform



Step 5. Click on the [Generate application code] button.
A base C project is created in the workspace.

Figure 39. New SPC5 application files in outline view

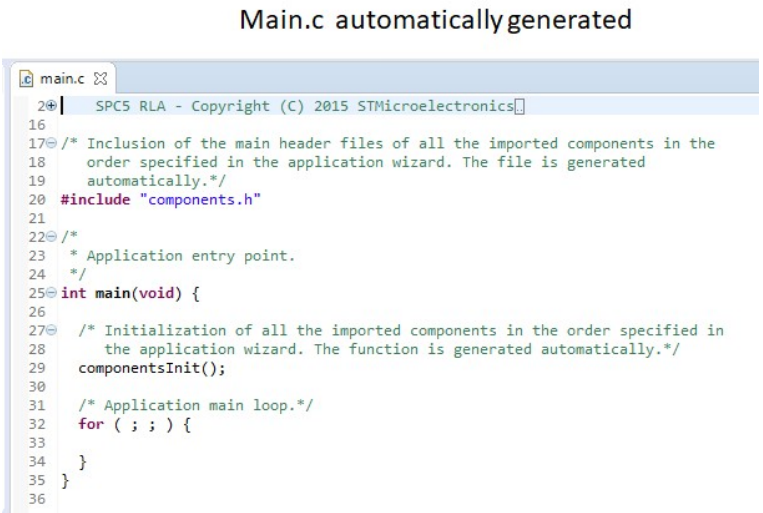


There are two fundamental files visible in the application tree view:

– *configuration.xml* with project configuration information that is updated every time the project is changed.

– *main.c* in which the actual application is implemented. The main.c file only contains a basic initialization section and an infinite loop when it is first created.

Figure 40. main.c application file



2.2 How to add components to an AutoDevKit Studio project for AEK-MCU-C4MINI

The following procedure shows how to add an available component to a project.

Step 1. In the Project Explorer tab, select the SPC58ECxx Platform component RLA.

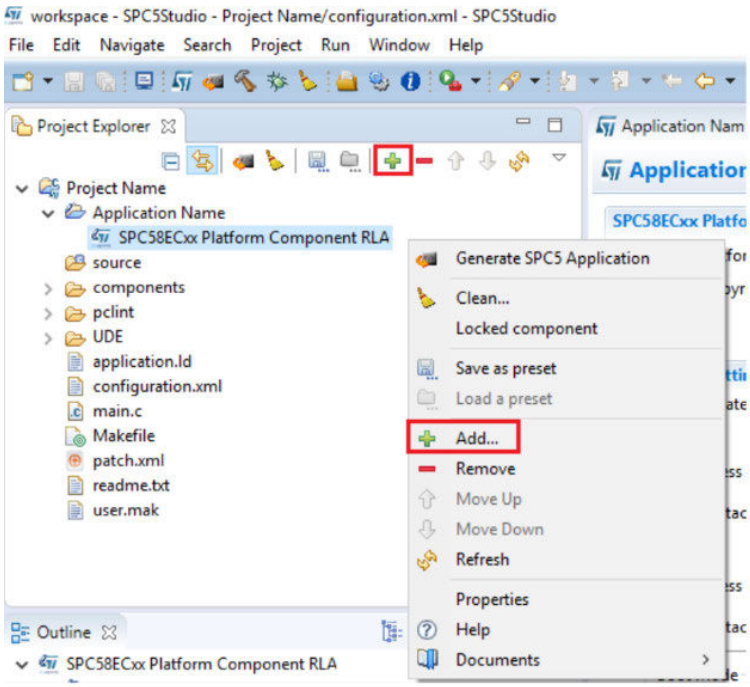
Step 2. To view the available components for the chosen platform:

– right click on the mouse and select add

or

– select the + icon in the project explorer

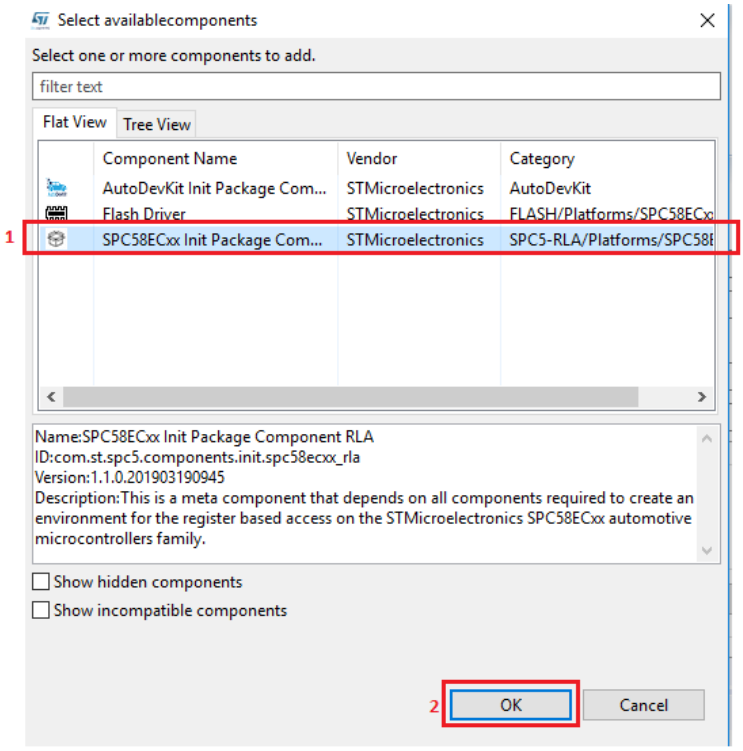
Figure 41. Open available components list



Step 3. Select the components listed below and click the [OK] button.

- SPC58ECxx Init Package Component
- Low Level Driver
- AutoDevKit AEK-C4MINI1 Board Component

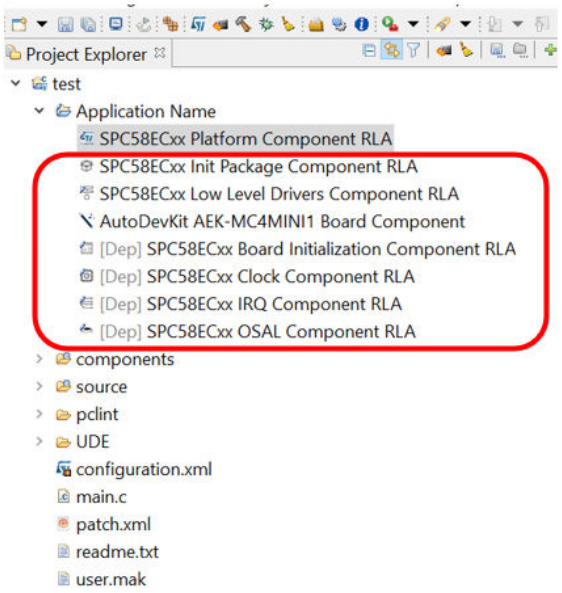
Figure 42. Select available components for platform



The added components appear in the Application Name Folder:

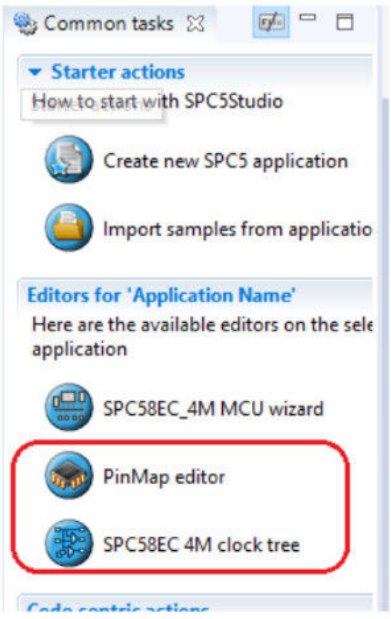
- SPC58ECxx Board Initialization Component RLA
- SPC58ECxx Clock Component RLA: for the configuration of the MCU clock tree
- SPC58ECxx IRQ Component RLA: to set and configure interrupt Request QUEUE
- SPC58ECxx OSAL Component RLA: operating system abstraction
- AutoDevKit AEK-C4MINI1 Board Component

Figure 43. **New components visible in project tree**



In addition, the PinMap Editor icon also becomes selectable in the Editors tab:

Figure 44. **PinMap editor icon in Editors tab**



Step 4. Open Pin Map Editor to check all Pins have been allocated.

Step 5. Close Pin Map Editor.

2.3 How to select a connector on the AEK-MCU-C4MINI

As mentioned above, the AEK-MCU-C4MINI evaluation board offers among its key features not only physical connection of all connector pins but also pre-assignment of these pins in the PinMap Editor, making it easy and quick to use.

Figure 45. PinMap editor

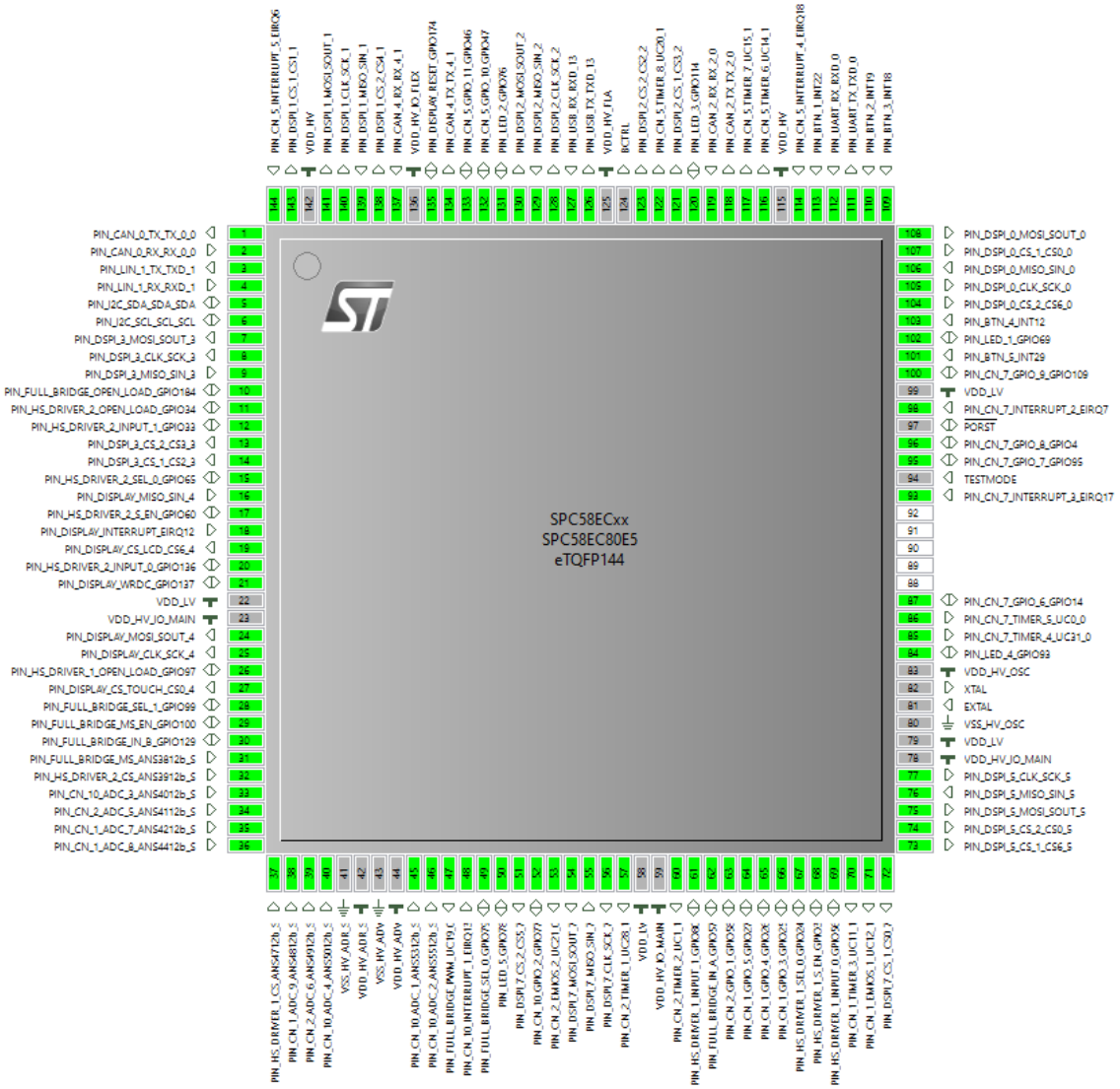


Table 1 helps you choose the connector and, therefore, pins to use according to the requirements of your application. The table lists connectors and pin names and their related connection to the PAD (the MCU physical pin), as well as the associated functionality.

For example, if your application uses an SPI, through Table 1 column Interface, you can easily select CNx as the connector whose pins are already pre-allocated in the PinMap Editor to function as an SPI.

Then, use the AutoDevKit GUI to configure the communication protocol associated with this particular connector pins as described in the next paragraph.

Table 1. Pins and related configurations

AEK-MCU-C4MINI Connector	Interface	AEK-MCU-C4MINI pin label	MCU pad	MCU pin number	Functionality
CN1	-	GPIO5	PB11	64	General purpose I/O
		GPIO4	PB10	65	General purpose I/O
		GPIO3	PB9	66	General purpose I/O
		ADC9	PB6	38	Analog-to-Digital Converter (ADC)
		ADC8	PG6	36	Analog-to-Digital Converter (ADC)
		ADC7	PG5	35	Analog-to-Digital Converter (ADC)
		TIME3	PF6	70	Emios used as a timer
		EMIO1	PF7	71	Emios used as PWM
CN2	-	GPIO1	PD10	63	General purpose I/O
		ADC6	PI6	39	Analog-to-Digital Converter (ADC)
		ADC5	PI5	34	Analog-to-Digital Converter (ADC)
		TIME2	PF1	60	Emios used as a timer
		TIME1	PB0	57	Emios used as a timer
		EMIO2	PD11	53	Emios used as PWM
		5V-E	5V_Ext		5V external supply
		GND	GND		Ground
CN3	SPI_1	CS1	PF3	143	Chip Select
		CS2	PC11	138	Chip Select
		CLK	PM0	140	Clock
		MISO	PC10	139	Master Input Slave Output (MISO)
		MOSI	PM2	141	Master Output Slave Input (MOSI)
	-	3V3-E	3V3_Ext		3.3V external supply
		5V-E	5V_Ext		5V external supply
		GND	GND		Ground
CN4	-	GND	GND		Ground
		GND	GND		Ground
		GND	GND		Ground
		GND	GND		Ground
		5V-E	5V_Ext		5V external supply

AEK-MCU-C4MINI Connector	Interface	AEK-MCU-C4MINI pin label	MCU pad	MCU pin number	Functionality
CN4	-	5V-E	5V_Ext		5V external supply
		5V-E	5V_Ext		5V external supply
		5V-E	5V_Ext		5V external supply
CN5	-	GPIO11	PC14	133	General purpose I/O
		GPIO10	PC15	132	General purpose I/O
		TIME8	PE11	122	Emios used as a timer
		TIME7	PH1	117	Emios used as a timer
		TIME6	PH0	116	Emios used as a timer
		3V3-E	3V3_Ext		3.3V external supply
		INT5	PF2	60	External interrupt
		INT4	PG15	114	External interrupt
CN6	SPI_2	CS1	PE10	121	Chip Select
		CS2	PH4	123	Chip Select
		CLK	PD0	128	Clock
		MISO	PM4	129	Master Input Slave Output (MISO)
		MOSI	PM6	130	Master Output Slave Input (MOSO)
	-	3V3-E	3V3_Ext		3.3V external supply
		5V-E	5V_Ext		5V external supply
		GND	GND		Ground
CN7	-	GPIO9	PG13	100	General purpose I/O
		GPIO8	PA4	94	General purpose I/O
		GPIO7	PF15	95	General purpose I/O
		GPIO6	PA14	87	General purpose I/O
		TIME5	PD6	86	Emios used as a timer
		TIME4	PD7	85	Emios used as a timer
		INT3	PF14	93	External interrupt
		INT2	PM14	98	External interrupt
CN8	-	GND	GND		Ground
		GND	GND		Ground
		GND	GND		Ground
		GND	GND		Ground

AEK-MCU-C4MINI Connector	Interface	AEK-MCU-C4MINI pin label	MCU pad	MCU pin number	Functionality
CN8	-	3V3-E	3V3_Ext		3.3V external supply
		3V3-E	3V3_Ext		3.3V external supply
		3V3-E	3V3_Ext		3.3V external supply
		3V3-E	3V3_Ext		3.3V external supply
CN9	SPI_3	CS1	PE0	14	Chip select
		CS2	PC0	13	Chip select
		CLK	PC4	8	Clock
		MISO	PC3	9	Master Input Slave Output (MISO)
		MOSI	PC5	7	Master Output Slave Input (MOSI)
	-	3V3-E	3V3_Ext		3.3V external supply
		5V-E	5V_Ext		5V external supply
		GND	GND		Ground
CN10	-	GPIO2	PE13	52	General purpose I/O
		ADC4	PI7	40	Analog-to-Digital Converter (ADC)
		ADC3	PI4	33	Analog-to-Digital Converter (ADC)
		ADC2	PG10	46	Analog-to-Digital Converter (ADC)
		ADC1	PG9	45	Analog-to-Digital Converter (ADC)
		INT1	PG12	48	External interrupt
		5V-E	5V_Ext		5V external supply
		GND	GND		Ground
CN11	SPI_5	CS1	PF8	73	Chip select
		CS2	PF9	74	Chip select
		CLK	PF12	77	Clock
		MISO	PF11	76	Master Input Slave Output (MISO)
		MOSI	PF10	75	Master Output Slave Input (MOSI)
	-	3V3-E	3V3_Ext		3.3V external supply
		5V-E	5V_Ext		5V external supply
		GND	GND		Ground
CN12	SPI_0	CS1	PE8	73	Chip Select
		CS2	PE7	71	Chip Select
		CLK	PD4	104	Clock

AEK-MCU-C4MINI Connector	Interface	AEK-MCU-C4MINI pin label	MCU pad	MCU pin number	Functionality
CN12	SPI_0	MISO	PD5	106	SPI master input slave output (MISO)
		MOSI	PE9	108	SPI master output slave input (MOSI)
	-	3V3-E	3V3_Ext		3.3V external supply
		5V-E	5V_Ext		5V external supply
		GND	GND		Ground
CN13	-	SCL	PC6	6	I2C serial clock
		SDA	PC7	5	I2C serial data
CN14	SPI_7	CS1	PA15	72	Chip Select
		CS2	PB4	51	Chip Select
		CLK	PB1	56	Clock
		MISO	PB2	55	Master Input Slave Output (MISO)
		MOSI	PB3	54	Master Output Slave Input (MOSI)
	-	3V3-E	3V3_Ext		3.3V external supply
		5V-E	5V_Ext		5V external supply
		GND	GND		Ground
CN15/CN16	-	VCC	5V_uc		5V internal supply
		GND	GND		Ground
	SPI4	CS	PE3	19	Chip select
	-	RESET	PK14	135	General purpose I/O
		WR_DC	WR_VC	21	General purpose I/O
	SPI4	SDI	PK0	24	Serial Data In (SDI) signal shared
		SCK	PK1	25	Clock signal shared
	-	LED	5V_uc		Internal supply
	SPI4	SDO	PE2	16	Serial Data In (SDI) signal shared
		T_CLK	PK1	25	Clock signal shared
		T_CS	PG2	27	Chip select
		T_DIN	PK0	24	Serial Data In (SDI) signal shared
		T_DO	PE2	16	Serial Data In (SDI) signal shared
	-	T_IRQ	PD13	18	External interrupt
CN17	-	H (CAN_H)	CAN_0_H	1	CAN0
		L (CAN_L)	CAN_0_L	2	

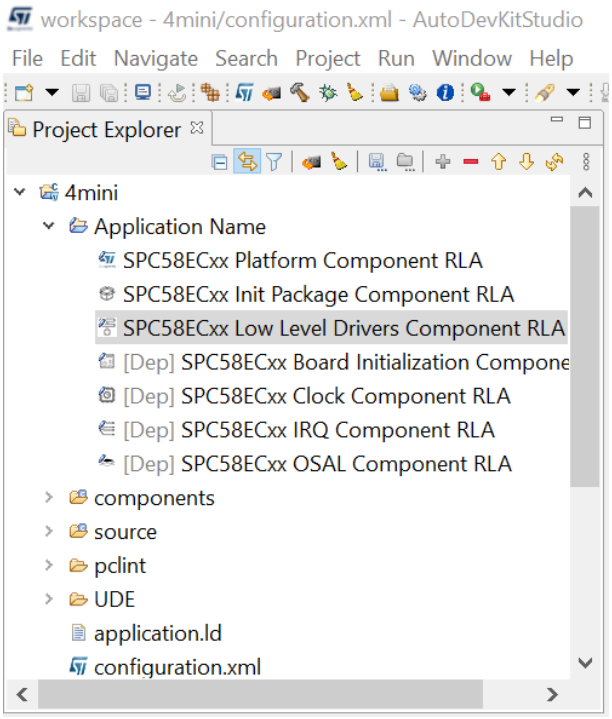
AEK-MCU-C4MINI Connector	Interface	AEK-MCU-C4MINI pin label	MCU pad	MCU pin number	Functionality
CN18	-	H (CAN_H)	CAN_2_H	118	CAN2
		L (CAN_L)	CAN_2_L	119	
CN19	-	H (CAN_H)	CAN_4_H	134	CAN4
		L (CAN_L)	CAN_4_L	137	
CN20	-	LIN	LIN1_BUS	4	LIN
		GND	GND	3	
CN21	-	RX	CN21_1	112	UART
		TX	CN21_2	111	
Buttons	-	BUTTON1	PA0	113	Wake-up to be configured as external interrupt
		BUTTON2	PA1	110	Wake-up to be configured as external interrupt
		BUTTON3	PA2	109	Wake-up to be configured as external interrupt
		BUTTON4	PE6	103	Wake-up to be configured as external interrupt
		BUTTON5	PG14	101	Wake-up to be configured as external interrupt
LEDs	-	D16	PE5	102	General purpose I/O
		D17	PE12	131	General purpose I/O
		D18	PH2	120	General purpose I/O
		D19	PF13	84	General purpose I/O
		D20	PE14	50	General purpose I/O

2.3.1 How to configure SPI protocol in AutoDevKit Studio to use the AEK-MCU-C4MINI1 with a functional board.

Step 1. In Table 1. Pins and related configurations, identify which SPI connector to use (for example, CN14 associated with SPI_7).

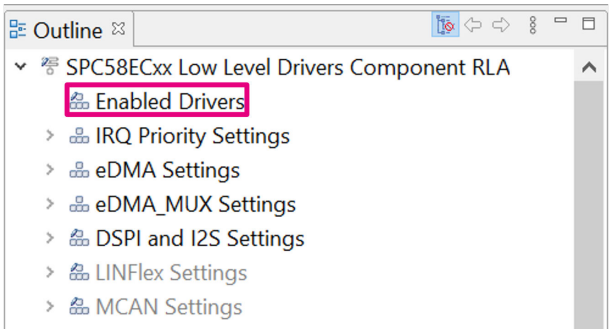
Step 2. In AutoDevKit Studio, select the low-level drivers from the Project explorer section.

Figure 46. Low-level drivers



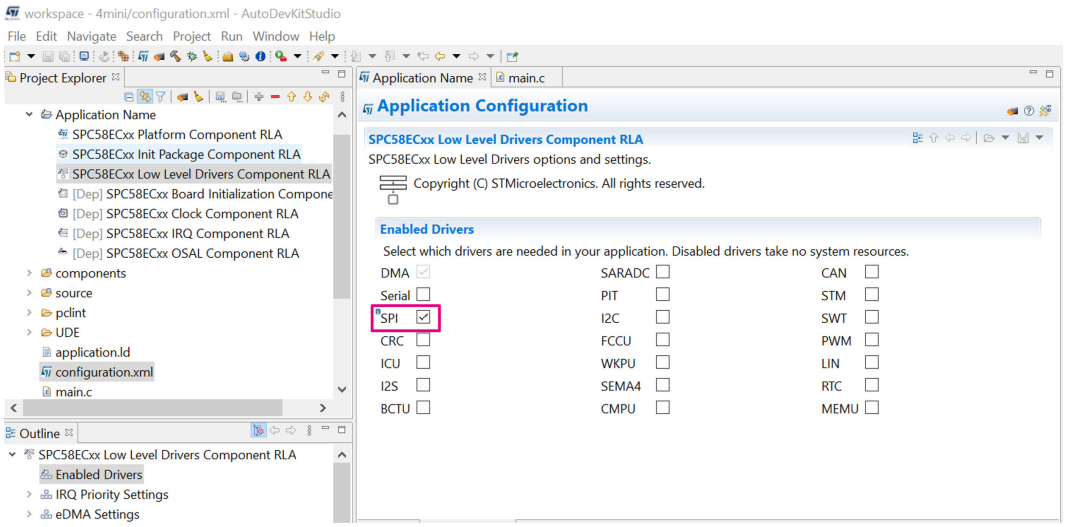
Step 3. In the Outline tab, select “Enabled drivers”.

Figure 47. Enabled drivers



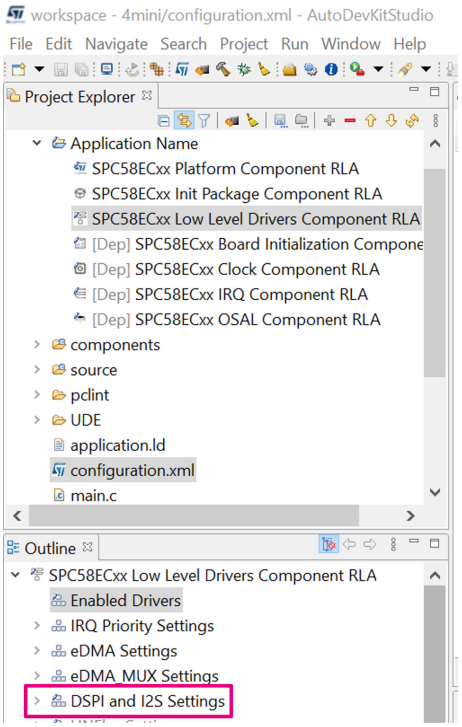
Step 4. In the “Application configuration” window, tick the SPI checkbox.

Figure 48. SPI driver enablement



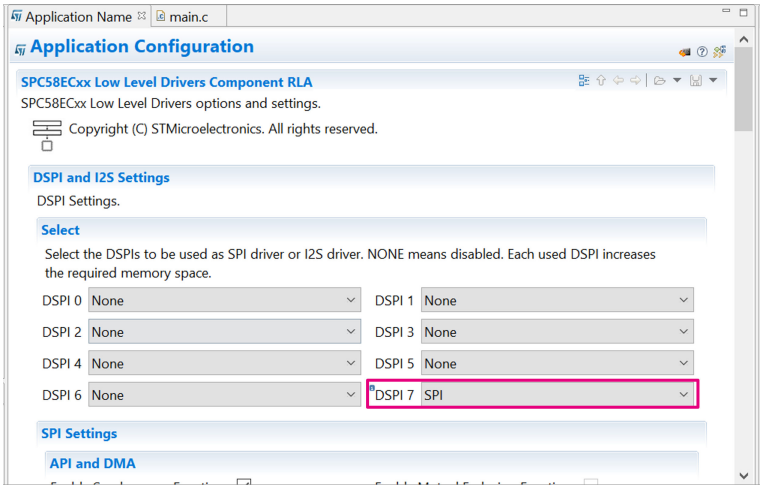
Step 5. In the “Outline” tab, double-click on “DSPI and I2S settings”.

Figure 49. DSPI and I2S settings



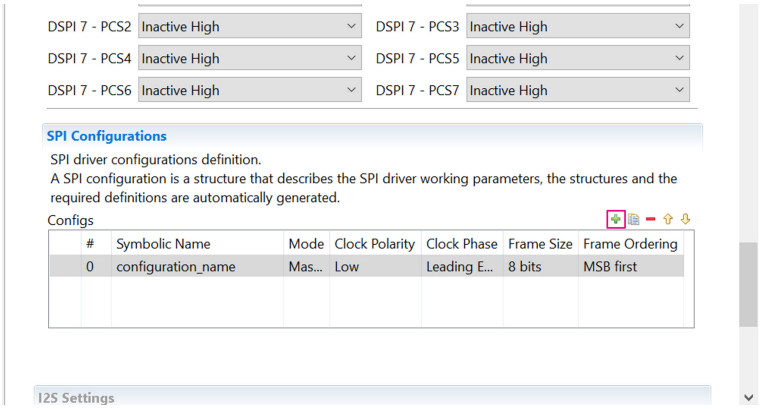
Step 6. In the “Application configuration” window, in the “Select” section, select the SPI related to the selected connector (CN14 is related to SPI7).

Figure 50. SPI selection



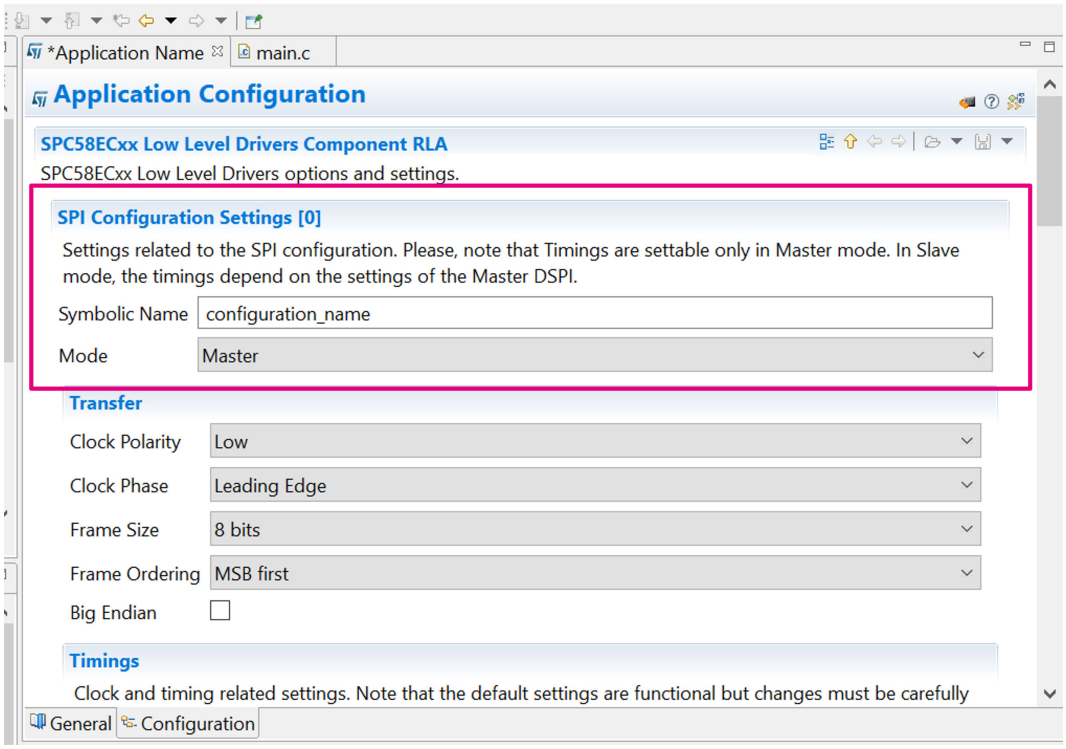
Step 7. Scroll down from the same window and, in the "SPI Configurations" section, click on the green + icon.

Figure 51. Adding new configuration



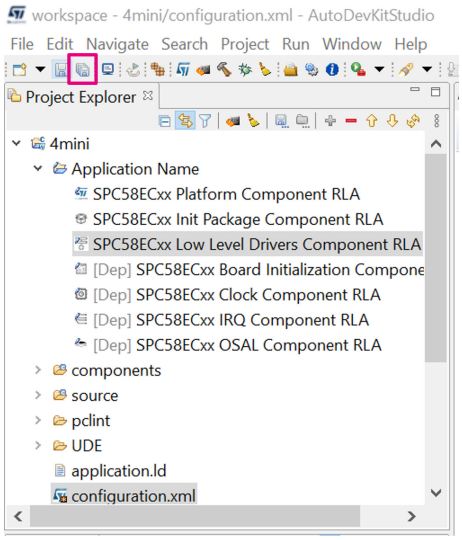
Step 8. Double-click on the newly created row to open the "Application Configuration" and configure the SPI according to your application needs.

Figure 52. SPI configuration



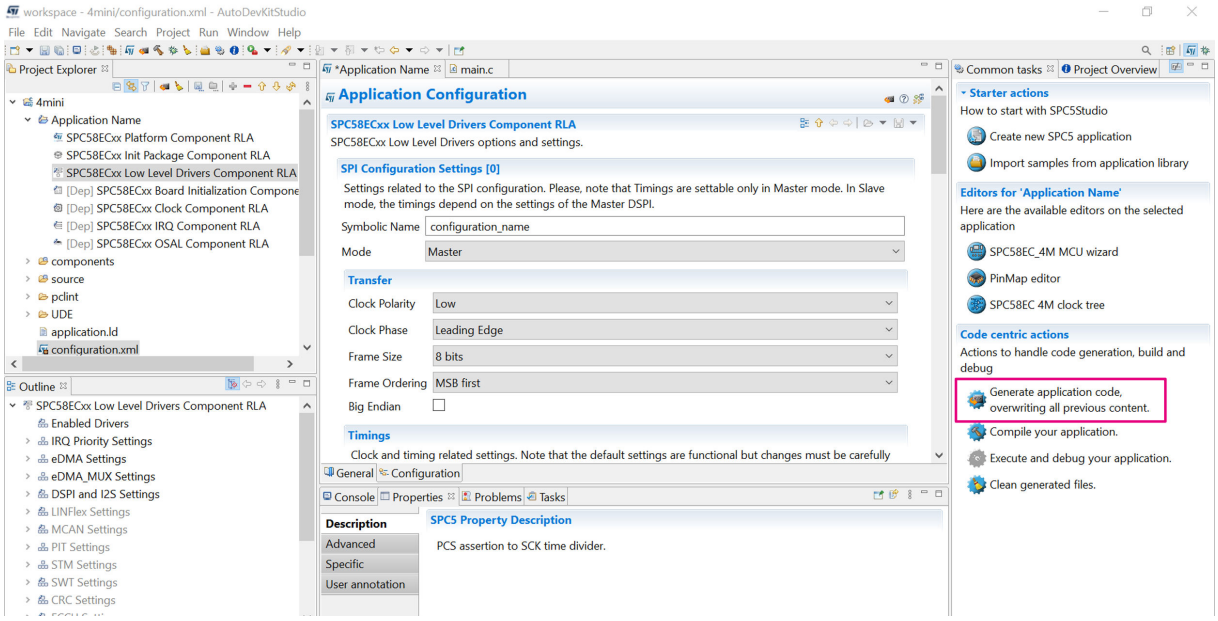
Step 9. Click on the “Save all” icon.

Figure 53. Saving your configuration



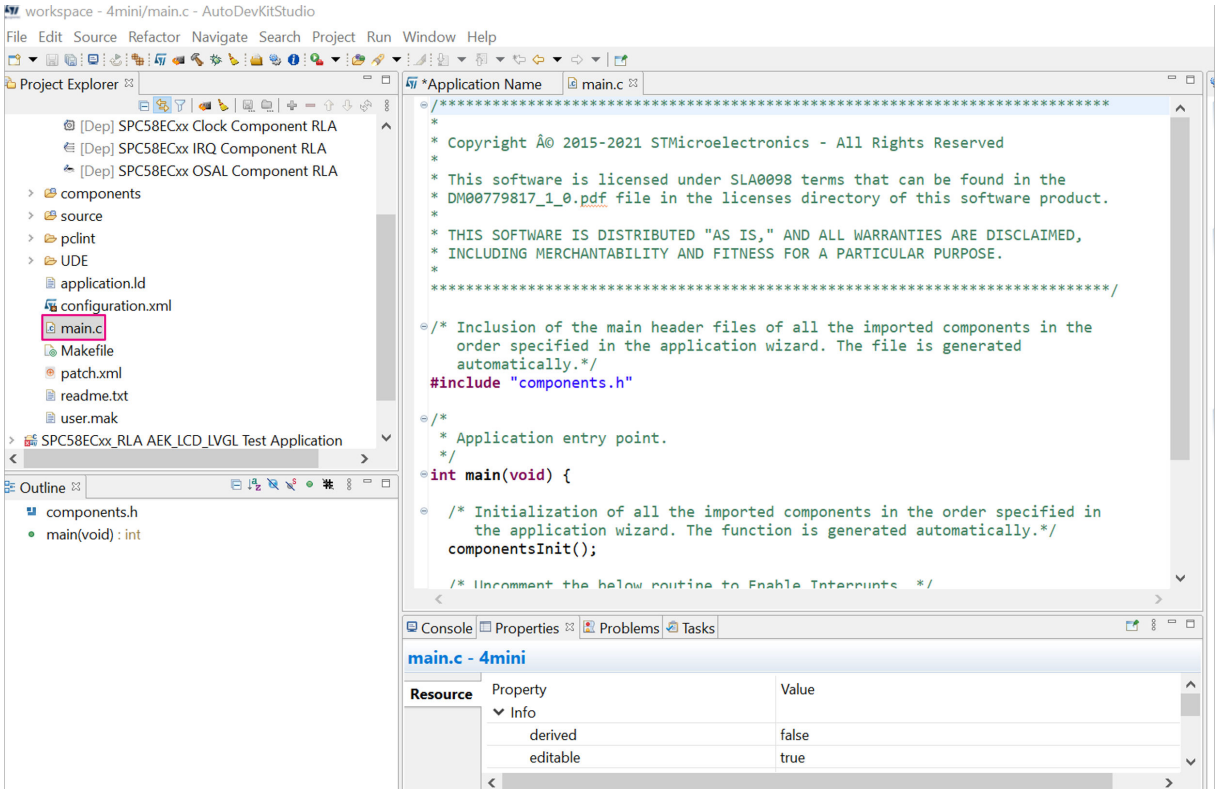
Step 10. Generate your application code.

Figure 54. Application code generation



Step 11. Open your *main.c* file under the Project Explorer and implement your application.

Figure 55. Application implementation



3 Available demos for AEK-MCU-C4MINI1

The following demos are available for the AEK-MCU-C4MINI1 board:

1. AEK_MCU_C4MINI-VNH7040AY Test Application for Discovery
2. AEK_MCU_C4MINI-AEK_MOT_2DCxxx Test Application for Discovery
3. AEK_MCU_C4MINI-AEK-COM-GNSST31 Test Application for Discovery
4. AEK_MCU_C4MINI – SPSB081 Test Application for Discovery
5. AEK_MCU_C4MINI_AEK_LCD-DT028V1 – LCD Touch – Test Application
6. AEK_MCU_C4MINI-VND7E040AJTR Test Application for Discovery
7. AEK_MCU_C4MINI-MainEcuForBLDCControl-L9908 – Test Application

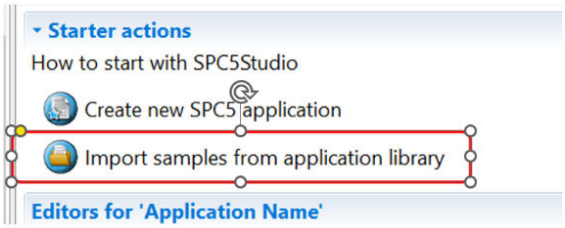
The aim of these demos is to show how to use the AEK-MCU-C4MINI1 board and to facilitate its first usage, bearing in mind that currently, to use the functional boards of the AutoDevKit ecosystem, it is necessary to start from these demos and, if necessary, modify them according to the specifications required by the application to be implemented.

4 How import a demo for AEK-MCU-C4MINI1

To import a demo into Autodevkit Studio, follow these steps:

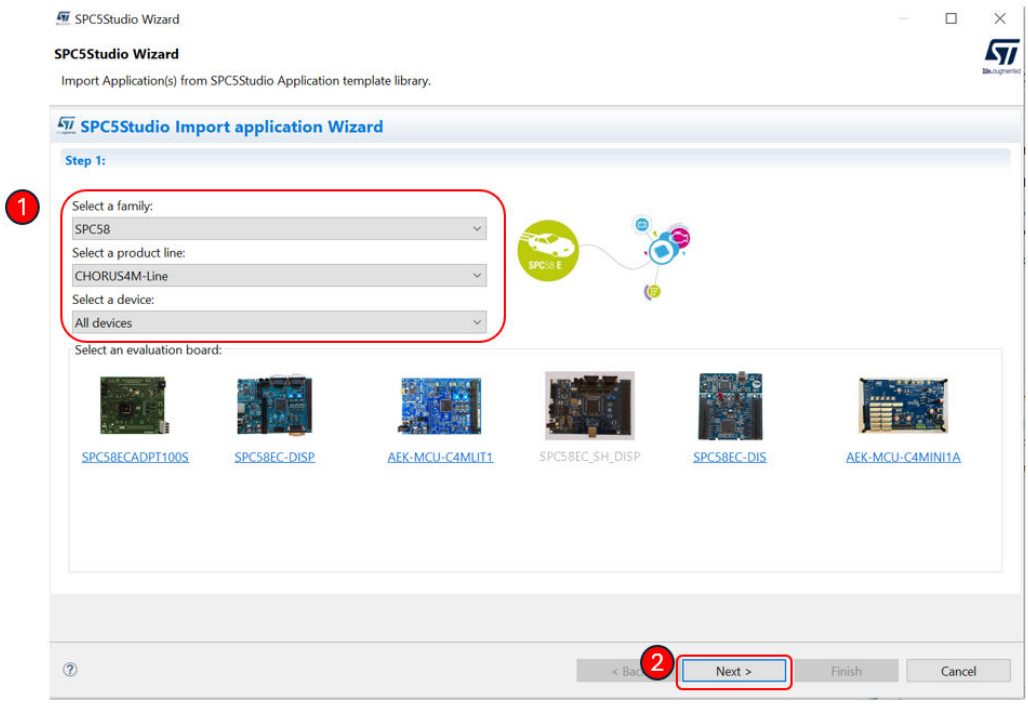
Step 1. Click on the icon Import samples from application library

Figure 56. Starter action tab



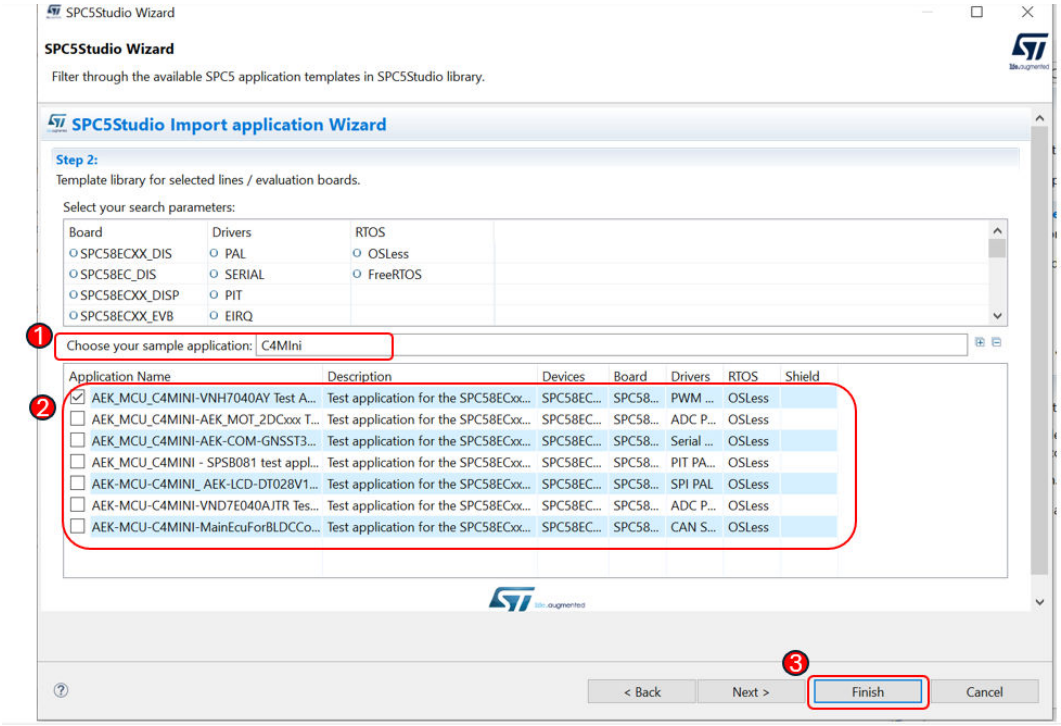
Step 2. In the SPC5Studio Wizard window, fill in all the drop-down boxes as shown in the image below in step 1, then select Next.

Figure 57. Import application wizard step1



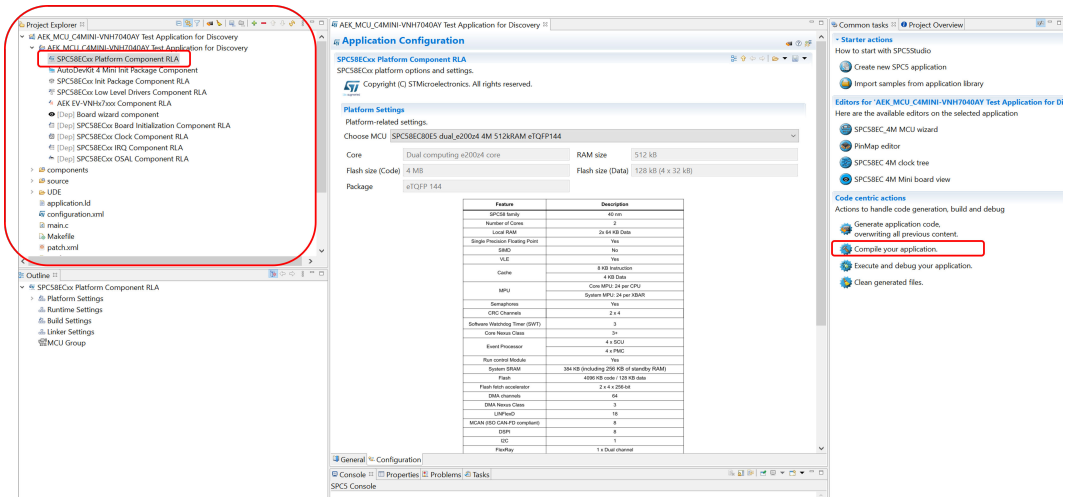
Step 3. In the SPC5Studio Wizard window, type C4Mini in the “Choose your sample application” text box, select the demo you want to import into AutoDevKit Studio and click the Finish button.

Figure 58. Import application wizard step2



Step 4. The selected project is now imported to the Project Explorer Tab, select SPC58ECxx Platform Componnet RLA and compile the project and download it to the AEK-MCU-C4MINI1.

Figure 59. AutoDevKit Studio main screen



5 Schematic diagrams

Figure 60. AEK-MCU-C4MINI1 circuit schematic (1 of 12)

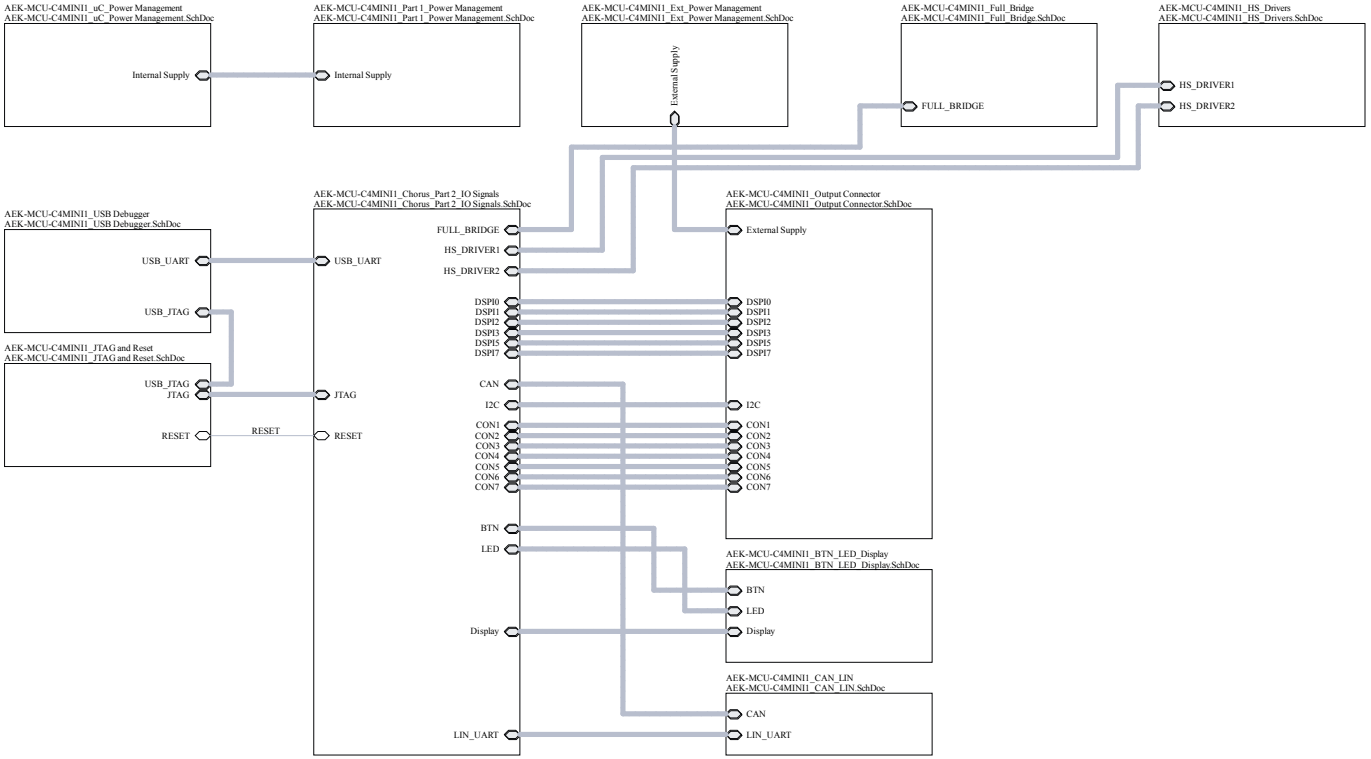


Figure 61. AEK-MCU-C4MINI1 circuit schematic (2 of 12)

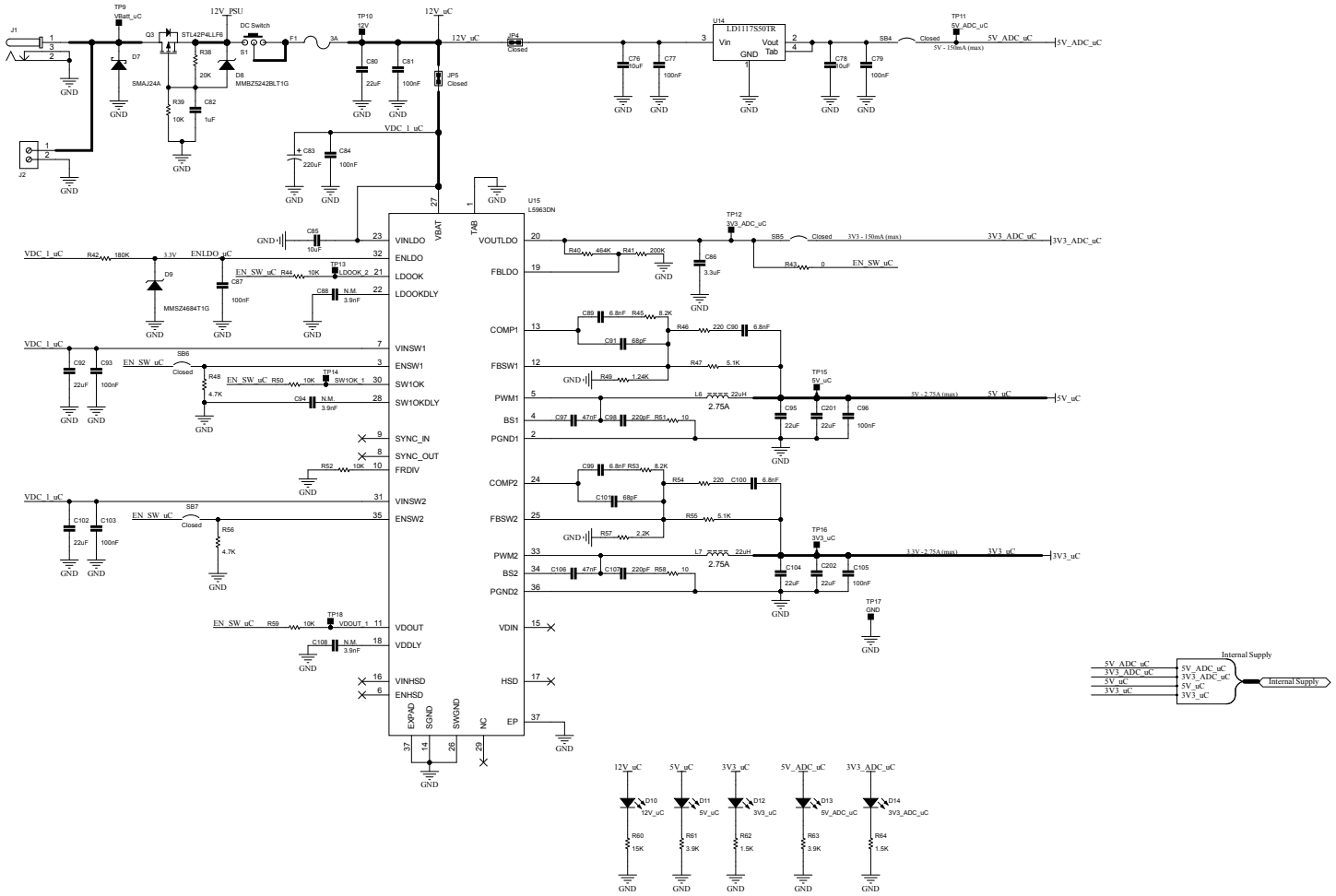


Figure 62. AEK-MCU-C4MINI1 circuit schematic (3 of 12)

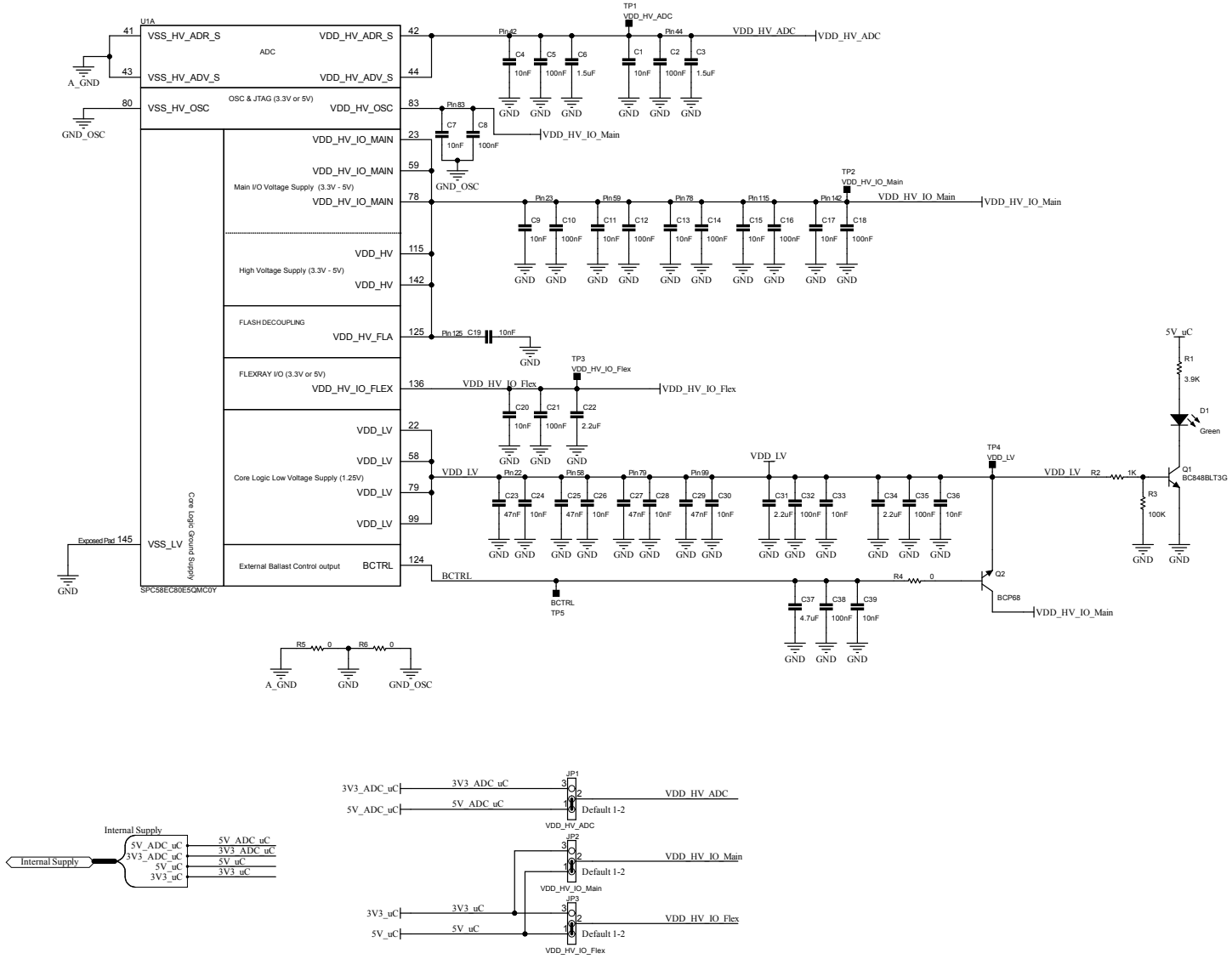


Figure 63. AEK-MCU-C4MINI1 circuit schematic (4 of 12)

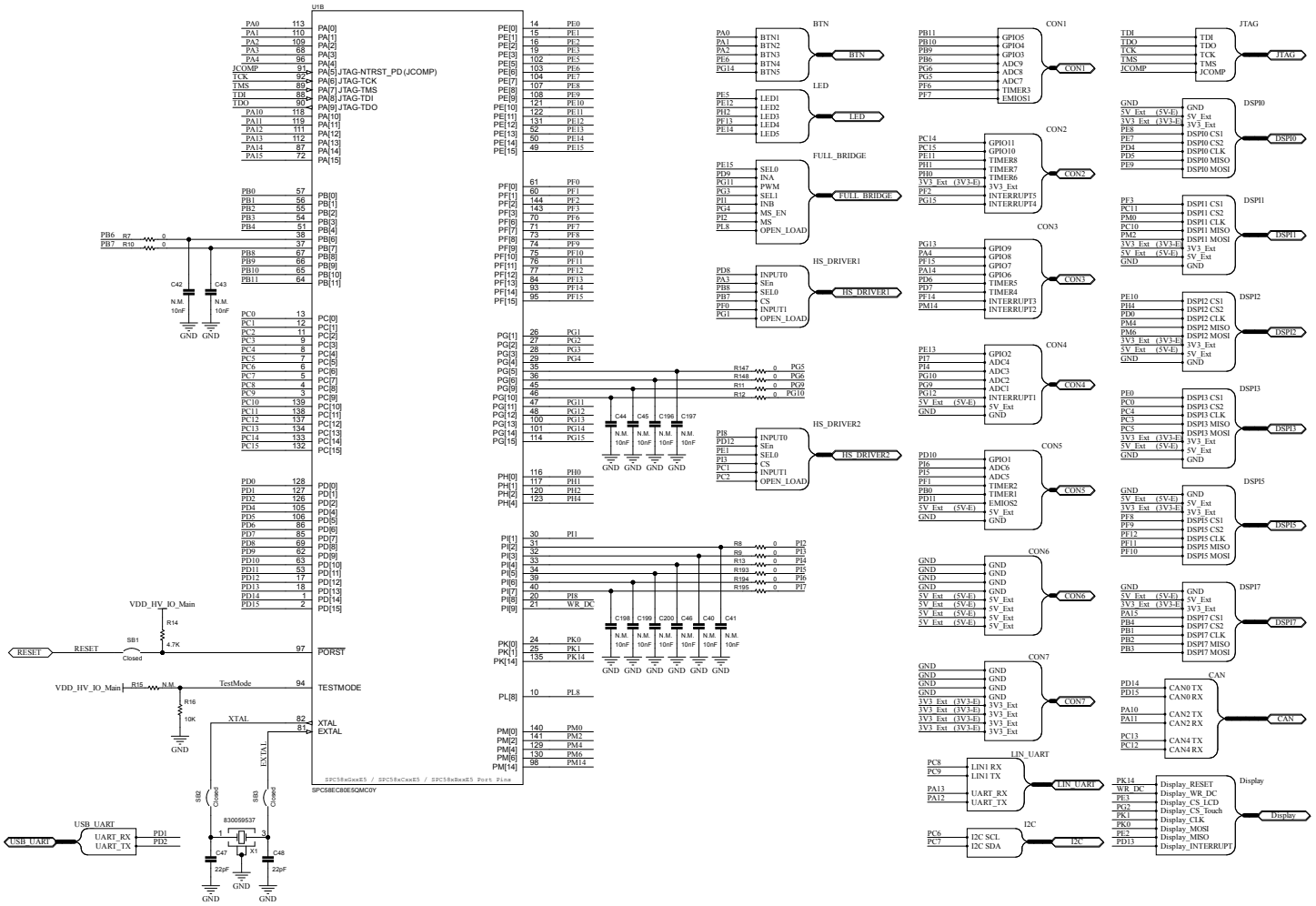


Figure 64. AEK-MCU-C4MINI1 circuit schematic (5 of 12)

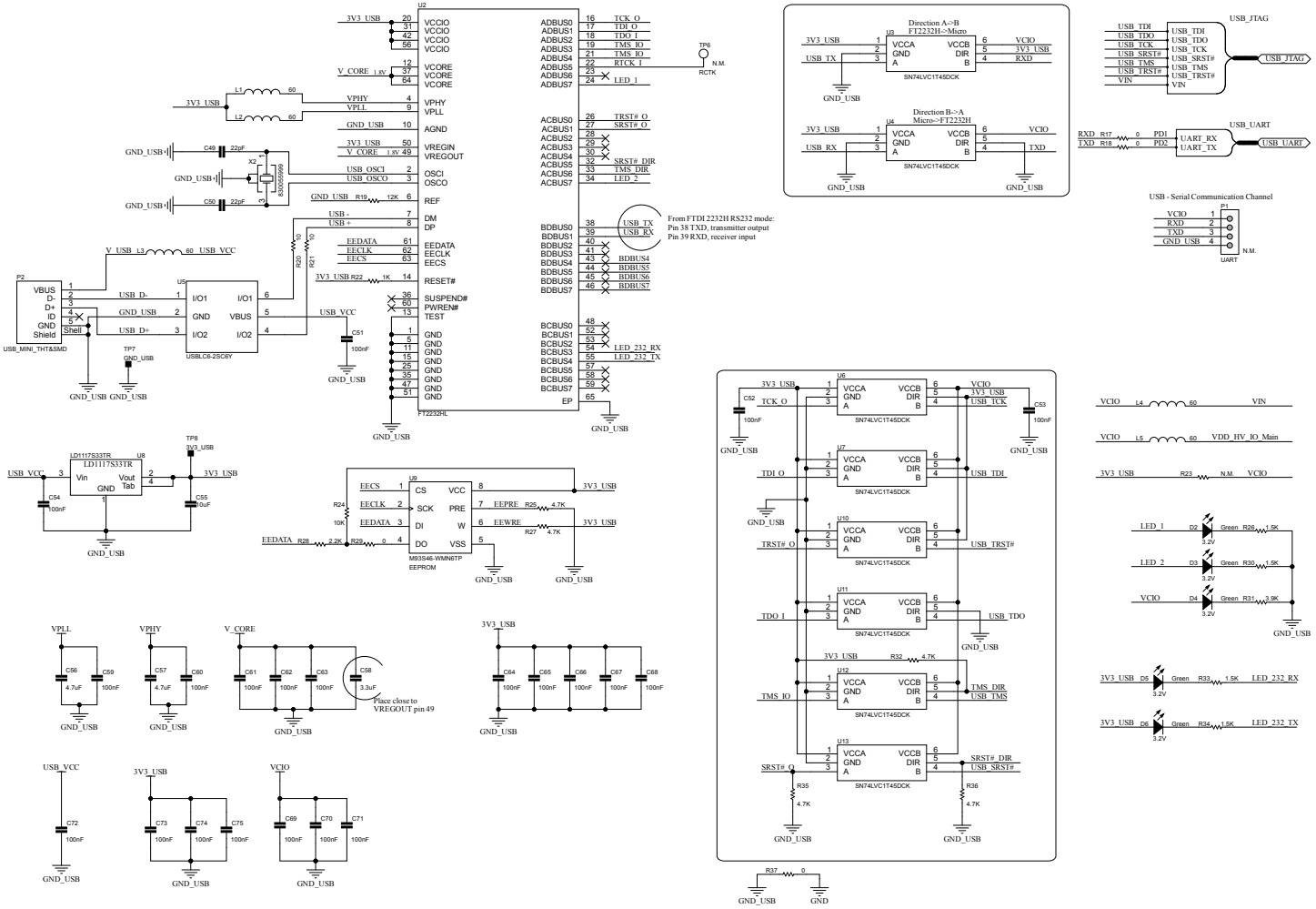


Figure 65. **AEK-MCU-C4MINI1 circuit schematic (6 of 12)**

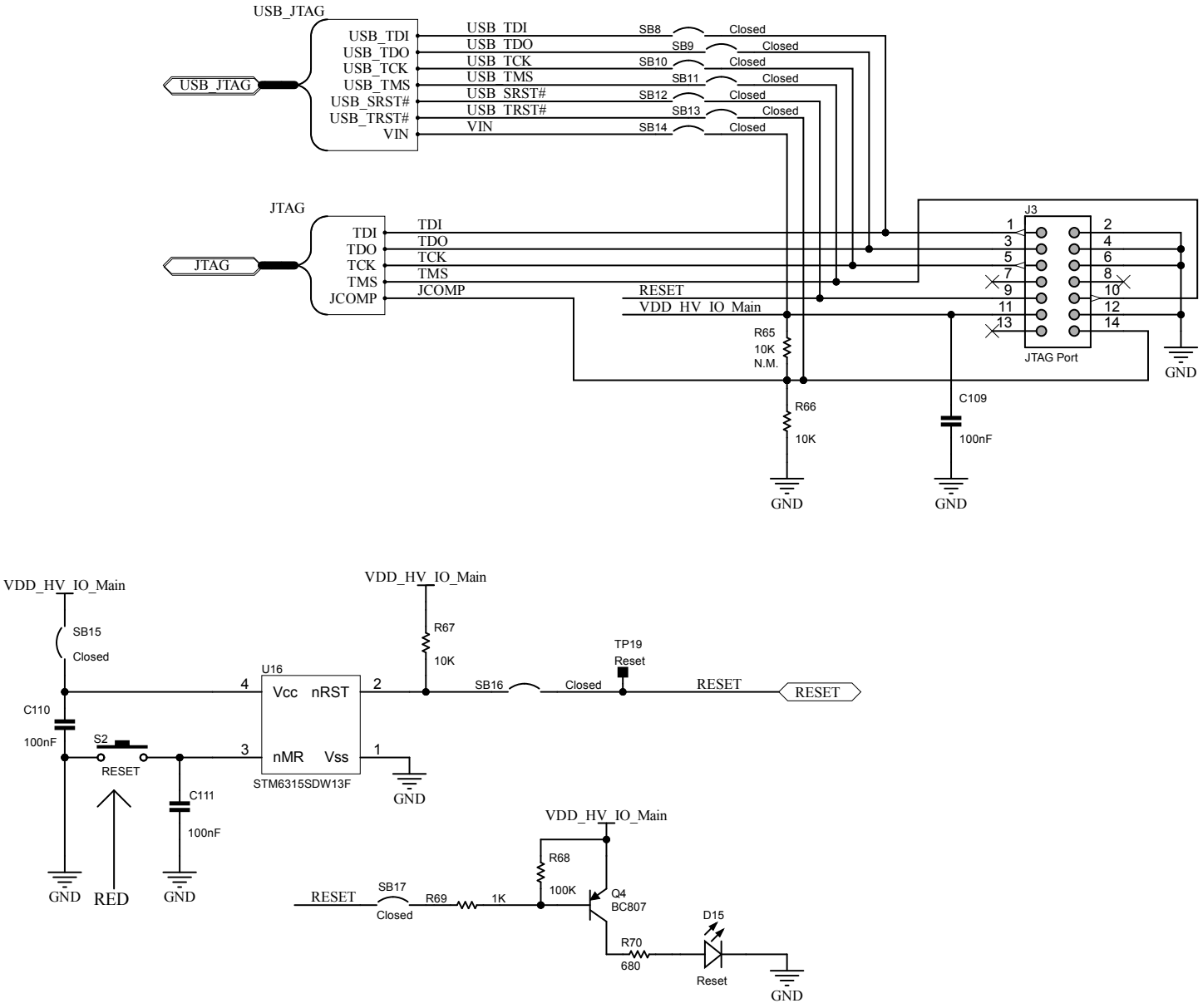


Figure 66. AEK-MCU-C4MINI1 circuit schematic (7 of 12)

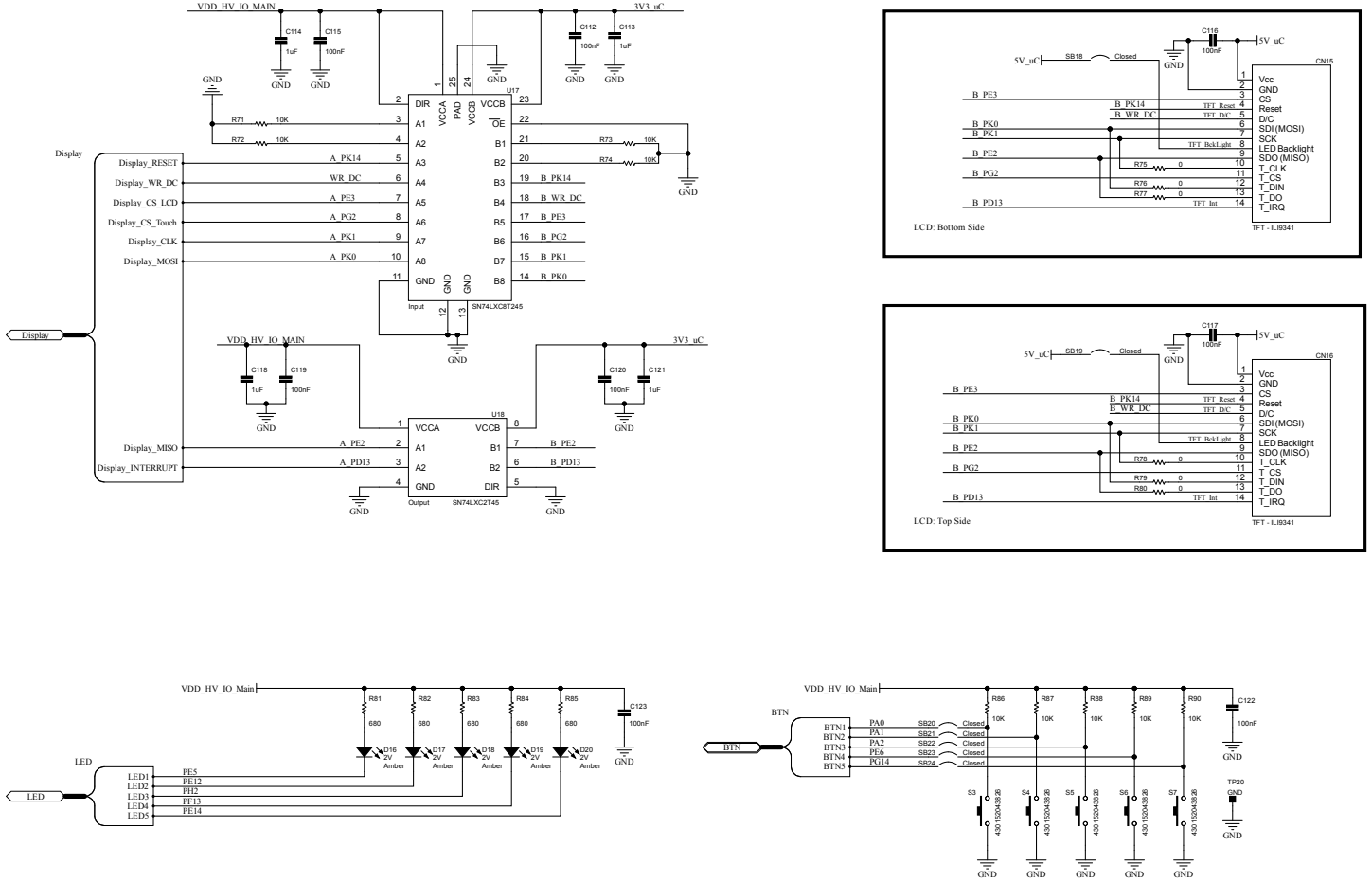


Figure 67. AEK-MCU-C4MINI1 circuit schematic (8 of 12)

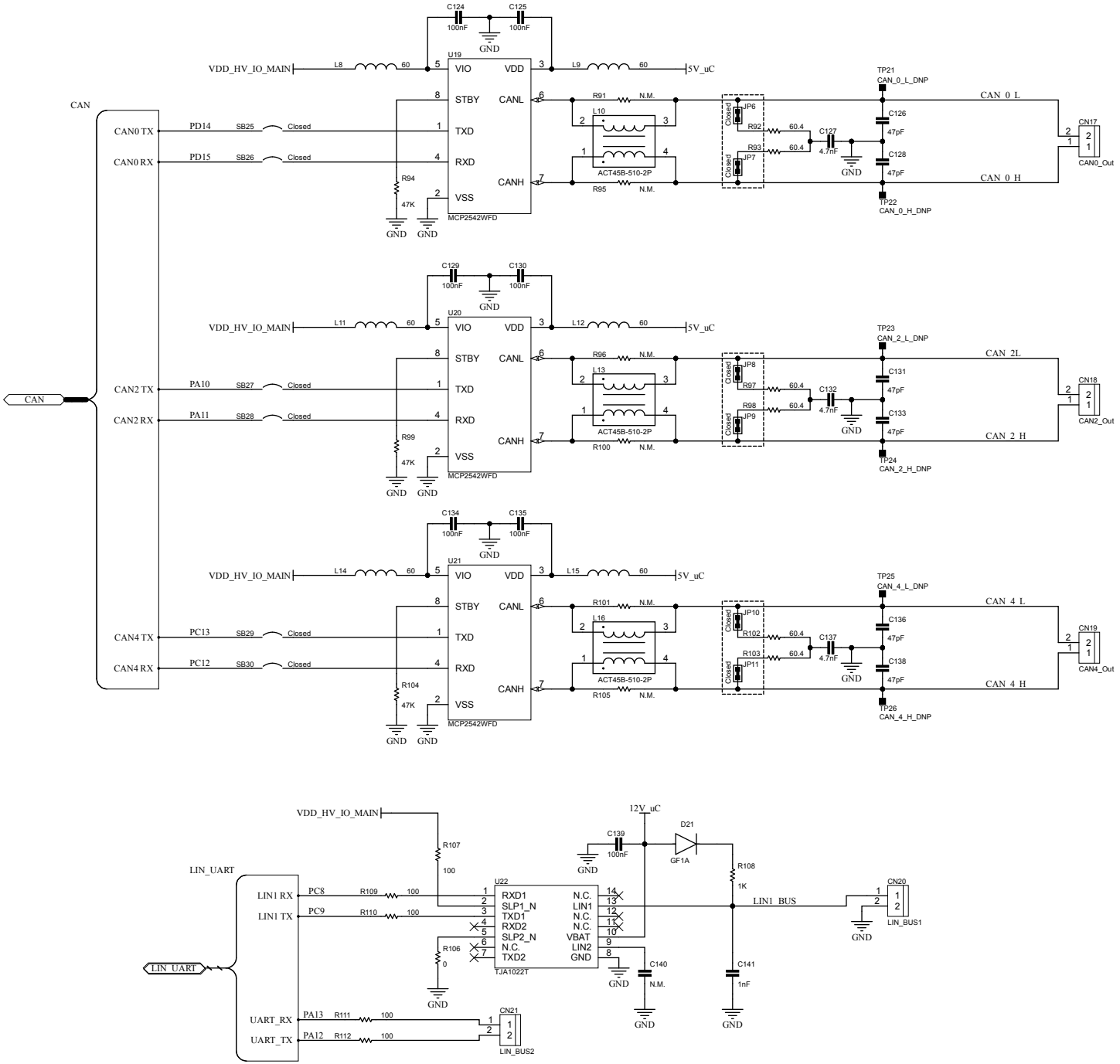


Figure 68. AEK-MCU-C4MINI1 circuit schematic (9 of 12)

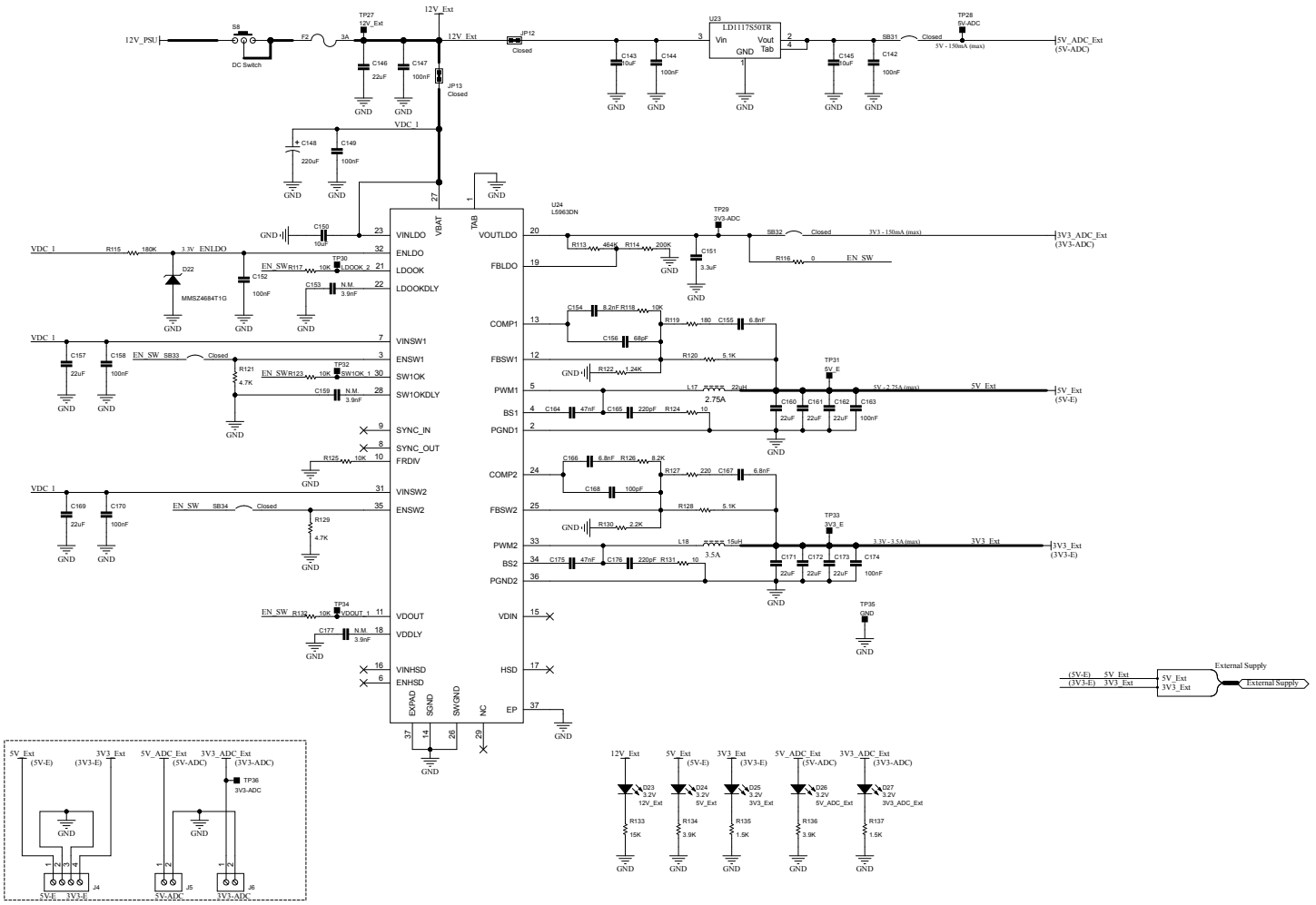


Figure 69. AEK-MCU-C4MINI1 circuit schematic (10 of 12)

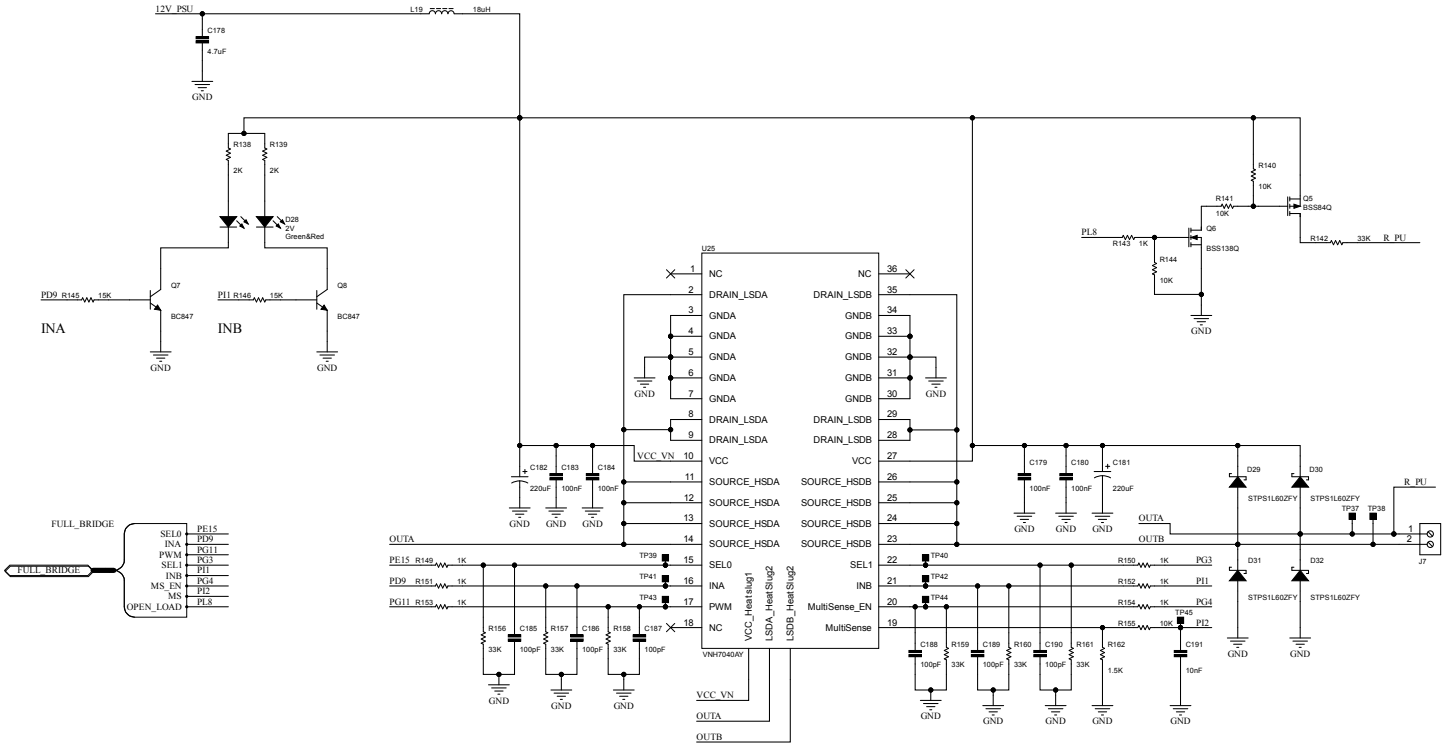


Figure 70. AEK-MCU-C4MINI1 circuit schematic (11 of 12)

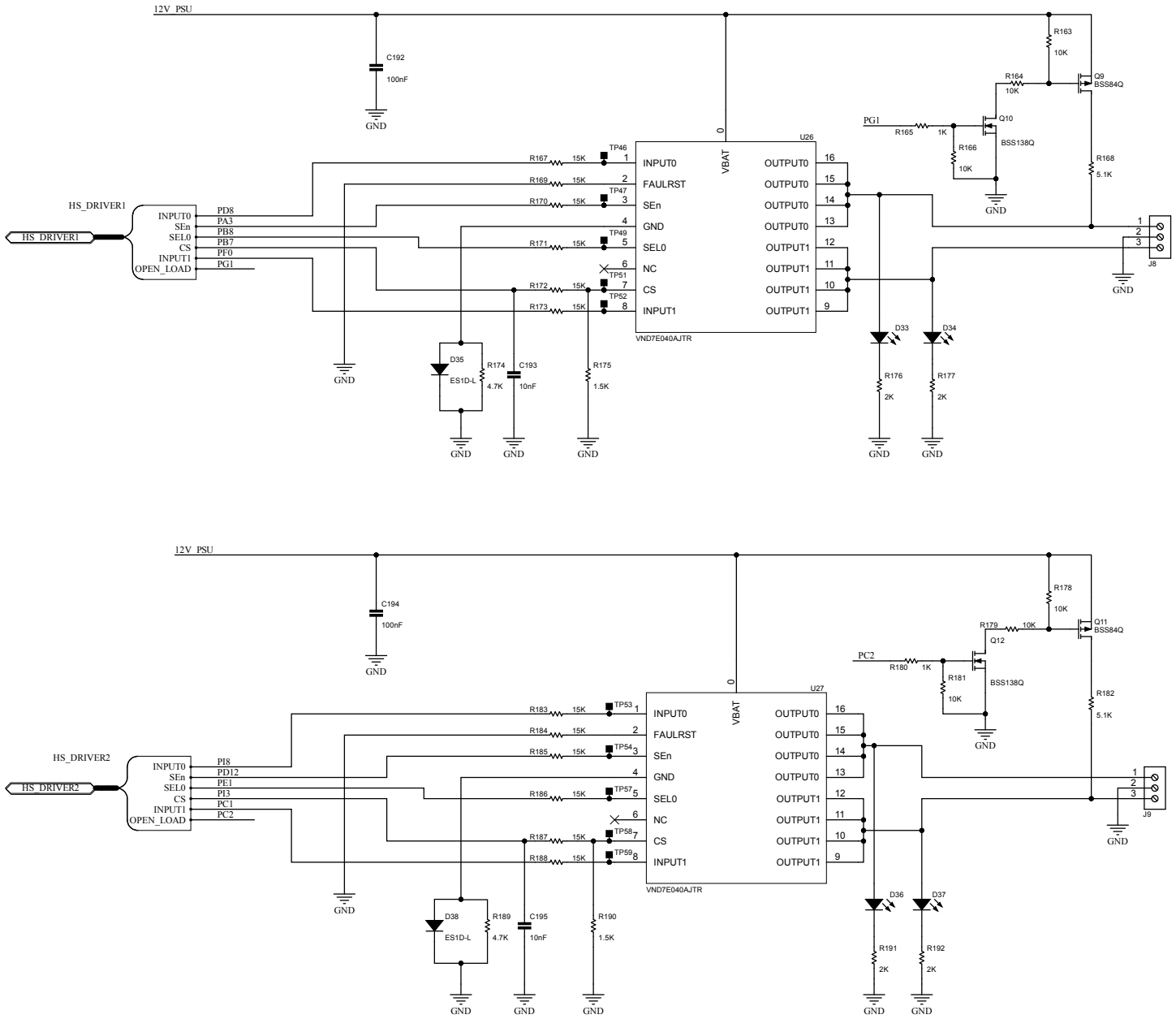
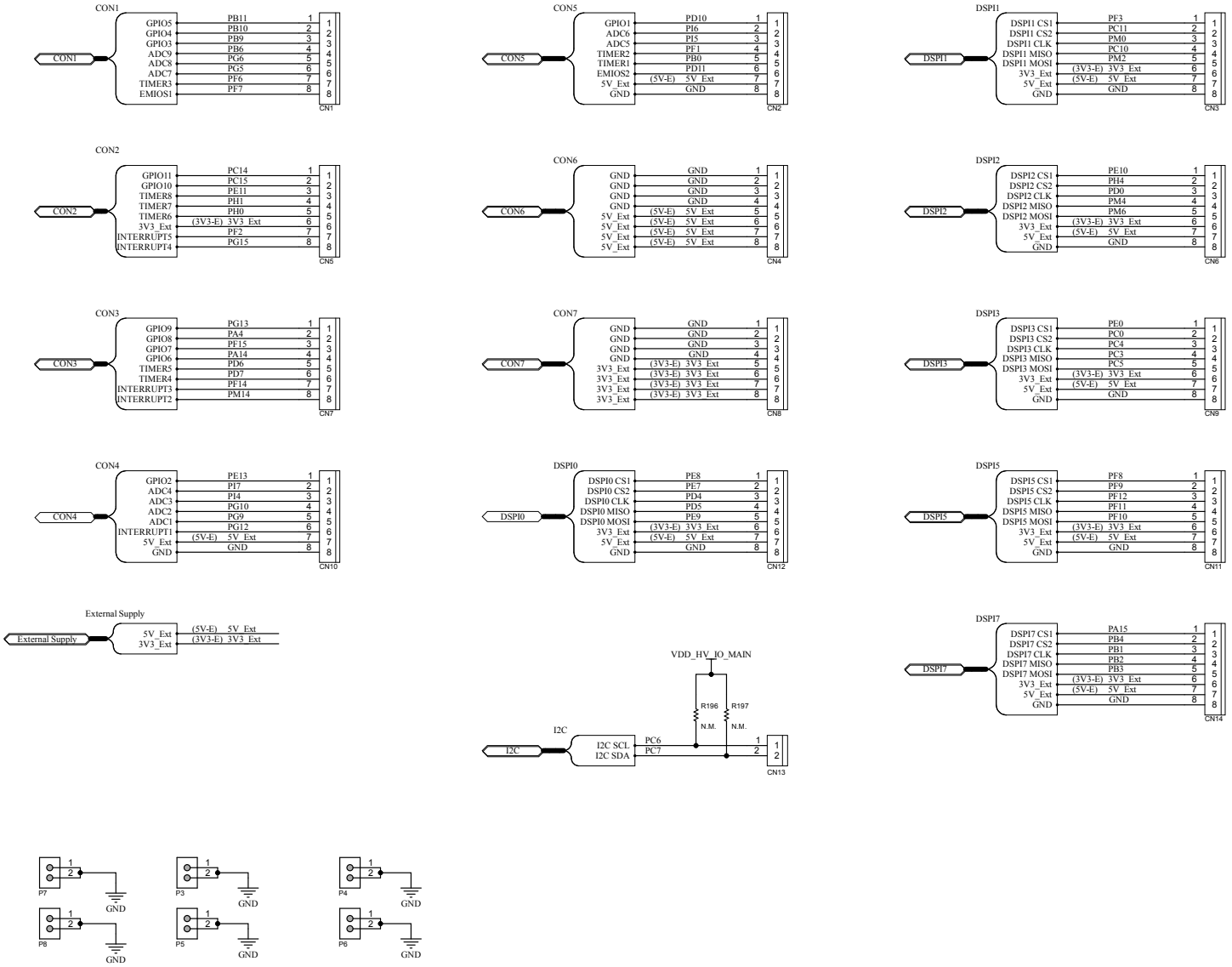


Figure 71. AEK-MCU-C4MINI1 circuit schematic (12 of 12)



6 Board versions

Table 2. **AEK-MCU-C4MINI1 versions**

Finished good	Schematic diagrams	Bill of materials
AEK$MCU-C4MINI1A(1)	AEK$MCU-C4MINI1A schematic diagrams	AEK$MCU-C4MINI1A bill of materials

1. *This code identifies the AEK-MCU-C4MINI1 evaluation board first version. It is printed on the board PCB.*

7 Bill of materials

Table 3. **AEK-MCU-C4MINI1 bill of materials**

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
1	20	C1, C4, C7, C9, C11, C13, C15, C17, C19, C20, C24, C26, C28, C30, C33, C36, C39, C191, C193, C195	10nF	0603 - 50V - X7R Class II	WE	885012206089
2	75	C2, C5, C8, C10, C12, C14, C16, C18, C21, C32, C35, C38, C51, C52, C53, C54, C59, C60, C61, C62, C63, C64, C65, C66, C67, C68, C69, C70, C71, C72, C73, C74, C75, C77, C79, C81, C84, C87, C93, C96, C103, C105, C109, C110, C111, C112, C115, C116, C117, C119, C120, C122, C123, C124, C125, C129, C130, C134, C135, C139, C142, C144, C147, C149, C152, C158, C163, C170, C174, C179, C180, C183, C184, C192, C194	100nF	0603 - 50V - X7R Class II	WE	885012206095

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
3	2	C3, C6	1.5uF	1206 - 25V - X7R Class II	WE	885012208065
4	3	C22, C31, C34	2.2uF	1206 - 25V - X7R Class II	WE	885012208066
5	8	C23, C25, C27, C29, C97, C106, C164, C175	47nF	0603 - 50V - X7R Class II	WE	885012206093
6	2	C37, C178	4.7uF	1206 - 50V - X7R Class II	WE	885012208094
7	19	C40, C41, C42, C43, C44, C45, C46, C88, C94, C108, C140, C153, C159, C177, C196, C197, C198, C199, C200	N.M.	0603 - 50V - X7R Class II, 0603 - xxV - xxxx, 0603 - 50V - X7R	WE, [NoValue]	N.A.
8	4	C47, C48, C49, C50	22pF	0603 - 50V - NP0 Class I	WE	885012006053
9	7	C55, C76, C78, C85, C143, C145, C150	10uF	1206 - 50V - X5R	WE	885012108022
10	2	C56, C57	4.7uF	0805 - 25V - X5R Class II	WE	885012107018
11	1	C58	3.3uF	0805 - 25V - X5R Class II	WE	885012107017
12	16	C80, C92, C95, C102, C104, C146, C157, C160, C161, C162, C169, C171, C172, C173, C201, C202	22uF	1210 - 25V - X5R Class II	WE	885012109014
13	5	C82, C113, C114, C118, C121	1uF	0603 - 25V - X7R Class II	WE	885012206076
14	4	C83, C148, C181, C182	220uF	Electrolytic Cap - 50V - 10x10.5	WE	865080657018
15	2	C86, C151	3.3uF	1206 - 25V - X7R Class II	WE	885012208067
16	7	C89, C90, C99, C100, C155, C166, C167	6.8nF	0603 - 50V - X7R Class II	WE	885012206088

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
17	3	C91, C101, C156	68pF	0603 - 50V - NP0 Class I	WE	885012006056
18	4	C98, C107, C165, C176	220pF	0603 - 50V - X7R Class II	WE	885012206079
19	6	C126, C128, C131, C133, C136, C138	47pF	0603 - 50V - NP0 Class I	WE	885012006055
20	3	C127, C132, C137	4.7nF	0603 - 50V - X7R Class II	WE	885012206087
21	1	C141	1nF	0603 - 50V - X7R Class II	WE	885012206083
22	1	C154	8.2nF	0603 - 50V - NP0	TDK	CGA3E2C0G1H822J080AA
23	7	C168, C185, C186, C187, C188, C189, C190	100pF	0603 - 50V - X7R Class II	WE	885012206077
24	13	CN1, CN2, CN3, CN4, CN5, CN6, CN7, CN8, CN9, CN10, CN11, CN12, CN14		2.54mm - 1 row - KK254 - Male	WE	61900811121
25	6	CN13, CN17, CN18, CN19, CN20, CN21		2.54mm - 1 row - KK254 - Male	WE	61900211121
26	2	CN15, CN16	61301411821	WR-PHD Socket Header, THT, Vertical, pitch 2.54mm, 1 Row, 14P	WE	61301411821
27	16	D1, D2, D3, D4, D5, D6, D10, D11, D12, D13, D14, D23, D24, D25, D26, D27	Green	0805 - Led Green - 3.2V	WE	150080GS75000
28	1	D7	SMAJ24A-TR, SMA	SMA TVS - 24VDC - Unidirectional	ST	SMAJ24A-TR
29	1	D8	MMBZ5242BLT1G	12V Zener Voltage Regulators, 225mW	Onsemi	MMBZ5242BLT1G
30	2	D9, D22	MMSZ4684T1G	3.3V Zener Voltage Regulators, 500mW	Onsemi	MMSZ4684T1G

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
31	3	D15, D34, D37	Red	0805 - Led Red - 2V	WE	150080RS75000
32	5	D16, D17, D18, D19, D20	Amber	0805 - Led Amber - 2V	WE	150080AS75000
33	1	D21	GF1A	Standard Rectifier, 50V, 1A	Onsemi	GF1A
34	1	D28	Green&Red	0603 - Bi-color Chip LED Compact Green&Red - 2V	WE	150060RV75240
35	4	D29, D30, D31, D32	STPS1L60ZFY, SOD123Flat	SOD-123 FLAT Automotive low drop power Schottky rectifier - 60VDC - Unidirectional	ST	STPS1L60ZFY
36	2	D33, D36	Blue	0805 - Led Blue - 3.2V	WE	150080BS75000
37	2	D35, D38	ES1D-L	1A, Super Fast Recovery Rectifier 50 to 600 Volts	MCC	ES1D-L
38	2	F1, F2	0437003.WRA	437 Series – 1206 Fast-Acting Fuse	LittleFuse	0437003.WRA
39	1	J1	694106301002	DC - Power Jack 12V 5A 2.1mm	WE	694106301002
40	1	J2		5.08mm - WR-TBL Series 2135 - Horizontal Entry Modular	WE	691213510002
41	1	J3	61201421621	2.54mm - IDC, Male Box Header WR-BHD, THT, Vertical	WE	61201421621
42	1	J4	691241710004	5.00mm - WR-TBL Series 2417 Horizontal Entry Modular, Rising Cage Clamp, THT, pitch 5mm, 4p	WE	691241710004

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
43	2	J5, J6	691103110002	3.50mm - WR-TBL Series 1031 Horizontal Entry Modular, THT, pitch 3.5mm, 2p	WE	691103110002
44	1	J7	691502710002	5.00mm - WR-TBL Serie 5027 Horizontal Entry Modular	WE	691502710002
45	2	J8, J9	691502710003	5.00mm - WR-TBL Series 5027 - Horizontal Entry Modular, Pressure Clamp, THT, pitch 5mm, 3p	WE	691502710003
46	3	JP1, JP2, JP3		THT Vertical 3 pins Header, Pitch 2.54 mm, Single Row	WE	61300311121
47	16	JP4, JP5, JP6, JP7, JP8, JP9, JP10, JP11, JP12, JP13, P3, P4, P5, P6, P7, P8	Closed, 61300211121	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
48	11	L1, L2, L3, L4, L5, L8, L9, L11, L12, L14, L15	60	WE-CBF SMT EMI Suppression Ferrite Bead. 60 Ohm, 500mA	WE	74279267
49	3	L6, L7, L17	22uH	WE-LHMI SMT Power Inductor – 6.6 x 6.6 x 4.8 - 2.75A	WE	74437349220
50	3	L10, L13, L16	51uH	Common mode filters Automotive signal line 51uH	TDK	ACT45B-510-2P
51	1	L18	15uH	WE-LHMI SMT Power Inductor – 6.6 x 6.6 x 4.8 - 3.5A	WE	74437349150

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
52	1	L19	18uH	Semi-shielded Power Inductor - 9.8x10 - 3.8A	Bourns	SRN1060-180M
53	1	P1	N.M.	2.54mm - WR-PHD Pin Header, THT, pitch 2.54mm, Single Row, Vertical, 4p	WE	N.A.
54	1	P2	65100516121 / 54819-0589	Mini USB 2.0 Type B, Receptable, Horizontal, SMT&THT, 5 Contacts	WE / MOLEX	65100516121 / 54819-0589
55	1	Q1	BC848BLT3G	NPN Bipolar Transistor 30V 100mA	Onsemi	BC848BLT3G
56	1	Q2	BCP68	NPN Bipolar Transistor 20V 2A	Nexperia	BCP68
57	1	Q3	STL42P4LLF6, PowerFLAT 5x6	P-channel -40 V, 0.0155 Ohm, -42 A, Power MOSFET in a PowerFLAT 5x6 package	ST	STL42P4LLF6
58	1	Q4	BC807	PNP Bipolar Transistor 45V 500mA	Nexperia	BC807
59	3	Q5, Q9, Q11	BSS84Q	P-Channel Enhancement Mosfet	DIODES	BSS84Q-7-F
60	3	Q6, Q10, Q12	BSS138Q	N-Channel Enhancement Mosfet	NEXPERIA	BSS138Q-7-F
61	2	Q7, Q8	BC847	NPN Bipolar Transistor 45V 100mA	Nexperia	BC847
62	6	R1, R31, R61, R63, R134, R136	3.9K	0603 - ±1% - 0.1W	Panasonic	ERJ3EKF3901V
63	13	R2, R22, R69, R108, R143, R149, R150, R151, R152, R153, R154, R165, R180	1K	0603 - ±1% - 0.25W	Panasonic	ERJPA3F1001V
64	2	R3, R68	100K	0603 - ±1% - 0.25W	Panasonic	ERJP03F1003V

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
65	62	R4, R5, R6, R7, R8, R9, R10, R11, R12, R13, R17, R18, R29, R37, R43, R75, R76, R77, R78, R79, R80, R106, R116, R147, R148, R193, R194, R195, SB1, SB2, SB3, SB4, SB5, SB6, SB7, SB8, SB9, SB10, SB11, SB12, SB13, SB14, SB15, SB16, SB17, SB18, SB19, SB20, SB21, SB22, SB23, SB24, SB25, SB26, SB27, SB28, SB29, SB30, SB31, SB32, SB33, SB34	0, Closed	0603 - ±1% - 0.1W, Circuit Breaker - 0603 - ±1% - 0.1W	Panasonic	ERJ3GEY0R00V
66	12	R14, R25, R27, R32, R35, R36, R48, R56, R121, R129, R174, R189	4.7K	0603 - ±1% - 0.25W	Panasonic	ERJPA3F4701V
67	11	R15, R23, R65, R91, R95, R96, R100, R101, R105, R196, R197	N.M.	0603 - xx% - xxxx, 0603 - ±1% - 0.2W	N.A.	N.A.

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
68	33	R16, R24, R39, R44, R50, R52, R59, R66, R67, R71, R72, R73, R74, R86, R87, R88, R89, R90, R117, R118, R123, R125, R132, R140, R141, R144, R155, R163, R164, R166, R178, R179, R181	10K	0603 - ±1% - 0.2W, 0603 - ±1% - 0.2W	Panasonic	ERJP03F1002V
69	1	R19	12K	0603 - ±1% - 0.1W	Panasonic	ERJ-3EKF1202V
70	6	R20, R21, R51, R58, R124, R131	10	0603 - ±1% - 0.25W	Panasonic	ERJPA3F10R0V
71	11	R26, R30, R33, R34, R62, R64, R135, R137, R162, R175, R190	1.5K	0603 - ±1% - 0.25W	Panasonic	ERJ-PA3F1501V
72	3	R28, R57, R130	2.2K	0603 - ±1% - 0.1W	Panasonic	ERJ-3EKF2201V
73	1	R38	20K	0603 - ±1% - 0.1W	Panasonic	ERJ-3EKF2002V
74	2	R40, R113	464K	0603 - ±1% - 0.1W	Panasonic	ERJ-3EKF4643V
75	2	R41, R114	200K	0603 - ±1% - 0.1W	Panasonic	ERJ-3EKF2003V
76	2	R42, R115	180K	0603 - ±1% - 0.25W	Panasonic	ERJ-UP3F1803V
77	3	R45, R53, R126	8.2K	0603 - ±1% - 0.1W	Panasonic	ERJ-3EKF8201V
78	3	R46, R54, R127	220	0603 - ±1% - 0.25W	Panasonic	ERJPA3F2200V
79	6	R47, R55, R120, R128, R168, R182	5.1K	0603 - ±1% - 0.1W	Panasonic	ERJ-3EKF5101V
80	2	R49, R122	1.24K	0603 - ±1% - 0.1W	Panasonic	ERJ-3EKF1241V

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
81	16	R60, R133, R145, R146, R167, R169, R170, R171, R172, R173, R183, R184, R185, R186, R187, R188	15K	0603 - ±1% - 0.25W	Panasonic	ERJ-PA3F1502V
82	6	R70, R81, R82, R83, R84, R85	680	0603 - ±1% - 0.25W	Panasonic	ERJPA3F6800V
83	6	R92, R93, R97, R98, R102, R103	60.4	0603 - ±1% - 0.1W	Panasonic	ERJ3EKF60R4V
84	3	R94, R99, R104	47K	0603 - ±1% - 0.25W	Panasonic	ERJPA3F4702V
85	5	R107, R109, R110, R111, R112	100	0603 - ±1% - 0.25W	Panasonic	ERJPA3F1000V
86	1	R119	180	0603 - ±1% - 0.1W	Panasonic	ERJ-3EKF1800V
87	6	R138, R139, R176, R177, R191, R192	2K	0603 - ±1% - 0.2W	Panasonic	ERJP03F2001V
88	7	R142, R156, R157, R158, R159, R160, R161	33K	0603 - ±1% - 0.25W	Panasonic	ERJ-PA3F3302V
89	2	S1, S8	CS12ANW03	Slide Switch 2 positions ON-NONE-ON - Set OPEN	NKK Switches	CS12ANW03
90	6	S2, S3, S4, S5, S6, S7	430152043826	Switch	WE	430152043826
91	1	TP6	N.M.	2.54mm - WR-PHD Pin Header, THT, pitch 2.54mm, Single Row, Vertical, 1p, Test Point	WE	N.A.
92	1	U1	SPC58EC80E5QMC1X, TQFP 144 20x20x1.0		ST	SPC58EC80E5QMC1X
93	1	U2	FT2232HL	USB Hi-Speed to Dual Channel Serial UART/ FIFO/ JTAG/SPI/I2C	FTDI Chip	FT2232HL

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
94	8	U3, U4, U6, U7, U10, U11, U12, U13	SN74LVC1T45DCK	Single-Bit Dual-Supply Bus Transceiver With Configurable Voltage Translation and 3-State Outputs	Texas Instruments	SN74LVC1T45DCK
95	1	U5	USBLC6-2SC6Y, SOT23-6L	Automotive ESD protection for high speed interfaces.	ST	USBLC6-2SC6Y
96	1	U8	LD1117S33TR, SOT-223	The LD1117330TR is a low drop voltage regulator able to provide up to 800 mA of output current. Vout is 3.3V.	ST	LD1117S33TR
97	1	U9	M93S46-WMN6TP, SO8	1Kbit (64x16) Serial Microwire Bus EEPROM With Block Protection	ST	M93S46-WMN6TP
98	2	U14, U23	LD1117S50TR, SOT-223	The LD1117S50TR is a low drop voltage regulator able to provide up to 800 mA of output current. Vout is 5V.	ST	LD1117S50TR
99	2	U15, U24	L5963DN-EHT, PowerSSO 36	Automotive dual monolithic switching regulator with LDO and HSD	ST	L5963DN-EHT
100	1	U16	STM6315SDW13F, SOT-143 4	STMICROELECTRONICS - STM6315SDW13F - Reset Circuit, Active-Low, Open-Drain, 1V to 5.5V, 2.93V Threshold, 1 Monitor	ST	STM6315SDW13F

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
101	1	U17	SN74LXC8T245	SN74LXC8T245 8-bit Dual-Supply Bus Transceiver with Configurable Level Shifting and 3-State Outputs	Texas Instruments	SN74LXC8T245
102	1	U18	SN74LXC2T45	SN74LXC2T45 Dual-Bit Dual-Supply Bus Transceiver with Configurable Level Shifting	Texas Instruments	SN74LXC2T45
103	3	U19, U20, U21	MCP2542WFD	CAN FD Transceiver with Wake-up Pattern (WUP) Option	Microchip	MCP2542WFD
104	1	U22	TJA1022T	SMD Dual LIN 2.2A/SAE J2602 transceiver	NXP Semiconductors	TJA1022T
105	1	U25	VNH7040AYTR, PSSO 36	Automotive fully integrated H-bridge motor driver	ST	VNH7040AYTR
106	2	U26, U27	VND7E040AJTR, PowerSSO 16	Double channel high-side driver with CurrentSense analog feedback for automotive applications	ST	VND7E040AJTR
107	1	X1	830059537	WE-XTAL Quartz Crystal, SMT, CFPX-104, 40MHz, +/-20ppm	WE	830059537
108	1	X2	830055999	WE-XTAL Quartz Crystal, SMT, CFPX-104, 12MHz, +/-30ppm	WE	830055999
109	5	for blister	971150365	WA-SPAIE Plastic Spacer Stud, metric, internal/ external	WE	971150365

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
110	5	for blister	970150365	WA-SPAII Plastic Spacer Stud, metric, internal/ internal	WE	970150365
111	13	for blister	61900811621	WR-WTB 2.54 mm Female Terminal Housing	WE	61900811621
112	6	for blister	61900211621	WR-WTB 2.54 mm Female Terminal Housing	WE	61900211621
113	116	for blister	61900113722	WR-WTB 2.54 mm Female Crimp Contact	WE	61900113722
114	14	for blister	609002115121	WR-PHD 2.54 mm Jumper with Test Point & Pullback	WE	609002115121
115	3	for blister	custom cables	cable from 8pin KK254 Female to 8pin Female Jumper wire Breadboard	by supplier	-
116	2	for blister	custom cables	cable from 2pin KK254 Female to 2pin Female Jumper wire Breadboard	by supplier	-

8 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 2015/863/EU (RoHS).

Notice for the United Kingdom

This device is in compliance with the UK Electromagnetic Compatibility Regulations 2016 (UK S.I. 2016 No. 1091) and with the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2012 (UK S.I. 2012 No. 3032).

Revision history

Table 4. **Document revision history**

Date	Revision	Changes
19-Jun-2024	1	Initial release.

Contents

List of tables

List of figures

IMPORTANT NOTICE – READ CAREFULLY

STMicroelectronics NV and its subsidiaries (“ST”) reserve the right to make changes, corrections, enhancements, modifications, and improvements to ST products and/or to this document at any time without notice. Purchasers should obtain the latest relevant information on ST products before placing orders. ST products are sold pursuant to ST’s terms and conditions of sale in place at the time of order acknowledgment.

Purchasers are solely responsible for the choice, selection, and use of ST products and ST assumes no liability for application assistance or the design of purchasers’ products.

No license, express or implied, to any intellectual property right is granted by ST herein.

Resale of ST products with provisions different from the information set forth herein shall void any warranty granted by ST for such product.

ST and the ST logo are trademarks of ST. For additional information about ST trademarks, refer to www.st.com/trademarks. All other product or service names are the property of their respective owners.

Information in this document supersedes and replaces information previously supplied in any prior versions of this document.

© 2024 STMicroelectronics – All rights reserved