Getting started with the AEK-MOT-MR200G1 evaluation board for the automotive side mirror module

Introduction

A growing trend in body electronics has led to more and more automated systems designed to allow passengers to feel more comfortable inside the vehicle, enabling them to adjust various settings according to their needs. For example, the heating and air conditioning systems, power windows, anti-pinch safety features, power seats, auto-dimming and side mirrors fall within this category.

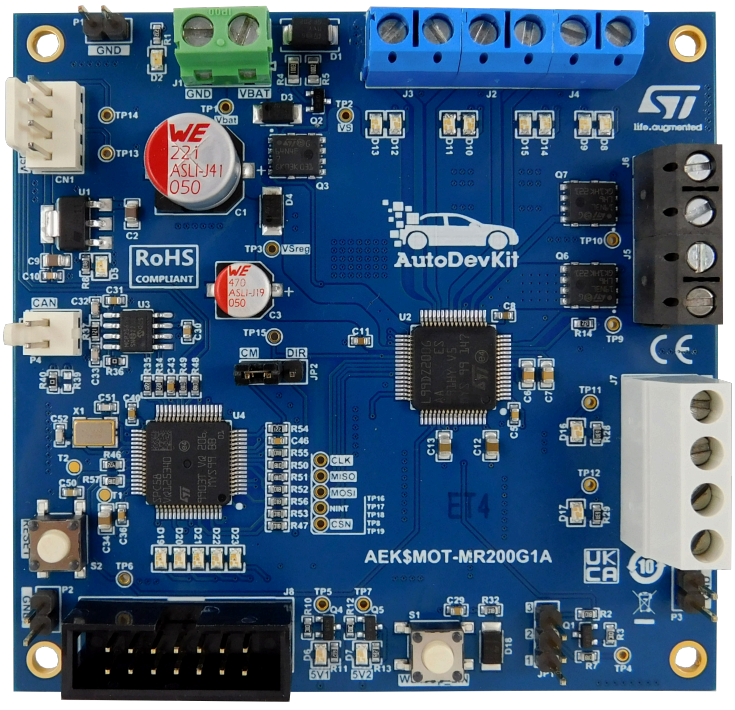
Our AEK-MOT-MR200G1 evaluation board is designed as a mini zone controller for the side mirror application.

The board allows controlling different functions related to a vehicle side mirror: folding, unfolding, X-Y mirror inclination, electrochromic dimming, and heating. It also allows driving two strings of LEDs that can be used for turning signals or puddle lights, which are the car lamps placed below the mirror to illuminate the ground near the car door and prevent you from stepping into anything murky when getting out of or into your car.

Thanks to the integrated SPC582B60E1 Chorus 1M microcontroller and the L99DZ200G automotive-grade multioutput driver, the AEK-MOT-MR200G1 also provides safety features and the possibility of creating a custom profile for each vehicle user.

Warning: *The AEK-MOT-MR200G1 evaluation board has not to be used in a vehicle as it is designed for R&D laboratory use only.*

Figure 1. AEK-MOT-MR200G1evaluation board

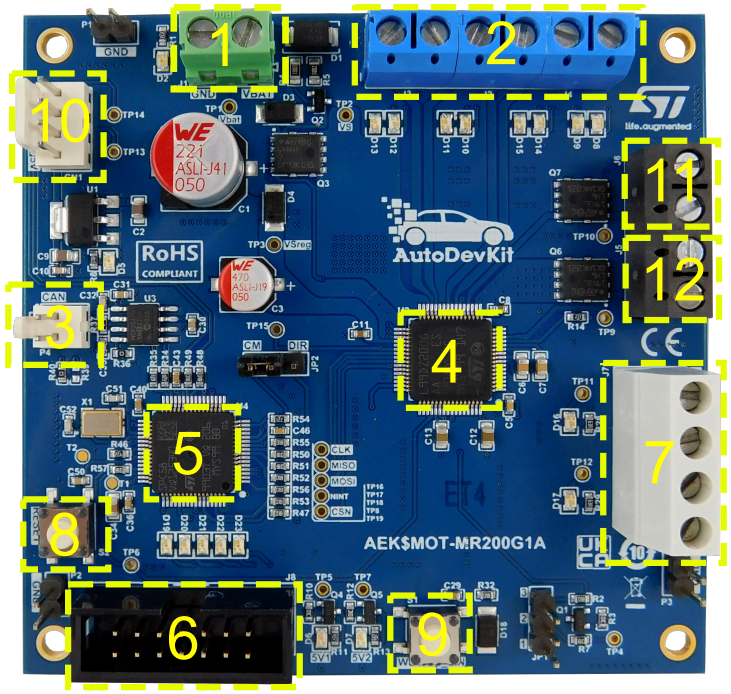


1 Hardware overview

1.1 Board main components

1. 12 V DC power supply connector
2. Connector for three DC motors
3. CAN connector
4. L99DZ200G multi-output driver
5. SPC582B60E1 microcontroller
6. JTAG connector for MCU programming
7. Connector for the two high-side outputs used for LED strings
8. Reset button
9. WakeUp_LIN button to wake up the device from VBAT_Standby
10. Position Encoder of the X - Y direction
11. Electro-chrome connector
12. Heater connector

Figure 2. AEK-MOT-MR200G1 evaluation board: main components



1.1.1 SPC582B60E1

The AEK-MOT-MR200G1 evaluation board hosts a SPC582B60E1 Chorus 1M microcontroller that belongs to the SPC58 Chorus family.

The MCU is in charge of controlling the L99DZ200G multi-output driver.

The main MCU features are:

- AEC-Q100 qualified
- High performance e200z2 single core:
  - 32-bit Power Architecture technology CPU
  - Core frequency up to 80 MHz
- 1088 KB (1024 KB code flash memory + 64 KB data flash) on-chip flash memory: it supports reading during program and erase operations, while multiple blocks allow performing the EEPROM emulation
- 96 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 the memories
- One enhanced 12-bit SAR analog-to-digital converter unit:
  - up to 27 channels (two channels for the mirror controller application used to monitor the motor position)
  - enhanced diagnostic features (such as current sensing current monitoring)
- Seven CAN interfaces
- Four serial peripheral interface (DSPI) modules (one of these DSPI is used for the communication between the MCU and the L99DZ200G chip).

Note: For further information, refer to RM0403 or to the SPC582Bx datasheet.

1.1.2 L99DZ200G

The L99DZ200G chip belongs to the STMicroelectronics *Doorzone* family. It consists of a range of system ICs, specifically designed to integrate all the main components and functions, which are required to manage advanced automotive door applications, in a single package.

The L99DZ200G is a multifunctional actuator driver, which is programmed through a microcontroller. Its main features include four half-bridges, seven high-side actuators, and two H-bridge drivers. Based on the four half-bridge drivers (configurable in the high or low resistance mode), the L99DZ200G is able to manage the motors used to control the folding and unfolding and the X-Y direction of the side mirror. The L99DZ200G can also manage the heater and the electro-chromic control blocks.

The L99DZ200G features available in the AEK-MOT-MR200G1 are:

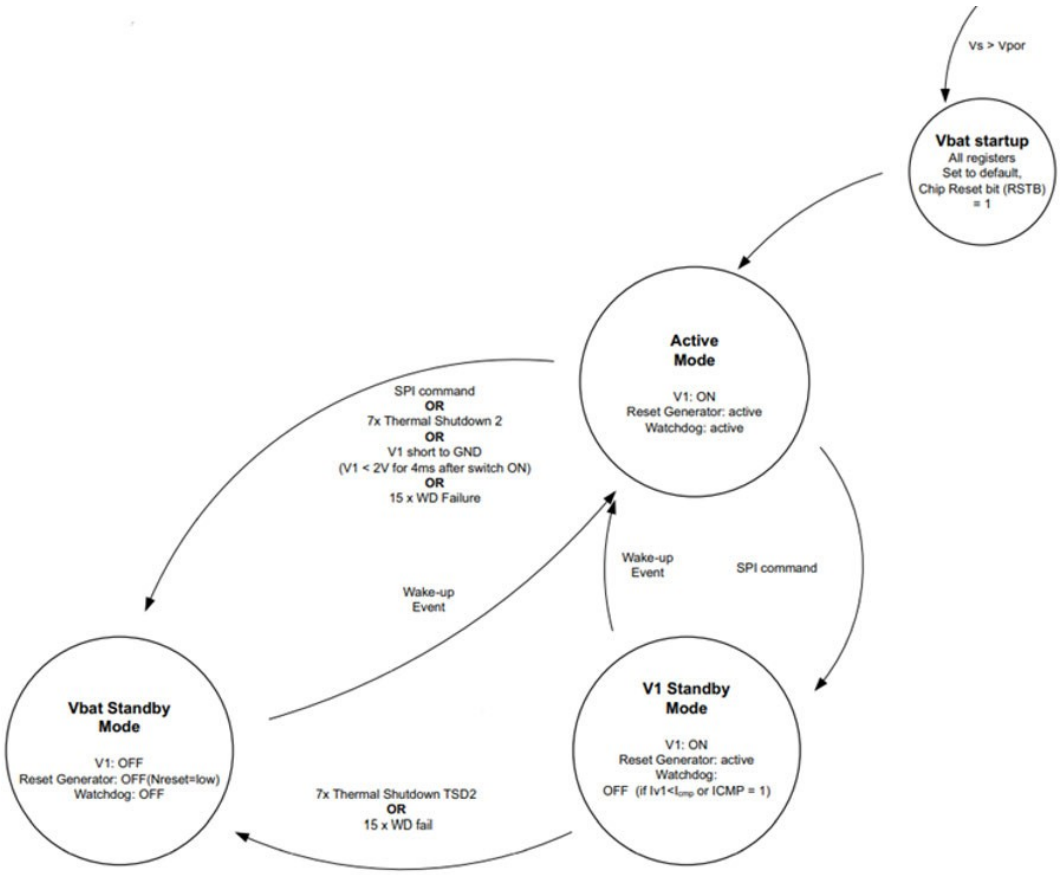
- Four half-bridges drivers for the folding and unfolding and the X-Y direction
- Heater control block
- Electro-chromic control block
- Two high-side drivers for the LED modules
- One 5 V voltage regulator for the microcontroller supply
- All the actuator outputs come with the following protection and supervisor features:
  - Current monitoring (high side only)
  - Open-load and overcurrent
  - Thermal warning and shutdown
- Configurable window watchdog
  Some of the L99DZ200G features are not implemented in the AEK-MOT-MR200G1:
- On the board, we disabled the MCU programming via the LIN and CAN transceiver by connecting the LIN pin to Vsreg (12 V), while we left all the other pins related to CAN and LIN floating. To exit from a standby condition, the L99DZ200G state machine requires at least one of the two interfaces to spot a 12 V to 0 V transition. We used LIN 1 for this purpose. A wake-up button connected to the LIN pin allows waking up the device from standby.
- All the other high-side outputs and the two H-bridges are not connected and left floating.

Note: For further information on the L99DZ200G , see the related datasheet .

1.1.2.1 L99DZ200G state machine

As we are not using all the features of the L99DZ200G, the finite state machine (FSM) of the chip is simplified as shown below.

Figure 3. Simplified L99DZ200G FSM



The main states are:

- **Vbat_startup**: the L99DZ200G enters this state when VS > VPOR, that is, when powering the device, the voltage supply exceeds a determined threshold (3.45 V typ. according to the device datasheet). All the registers are set to the default value. After about 0.1 milliseconds, the L99DZ200G enters the active mode.
- **Active mode**: to keep the device in the active state, the MCU activates a watchdog that monitors the communication between the microcontroller and the chip. In this state, all the outputs are active, including the H-bridge driver.
- **V1_Standby**: the transition from the active mode to V1_Standby mode is controlled through an SPI message, or it is a consequence of losing the watchdog signal.
- **VBAT_Standby**: the L99DZ200G enters this state in case of:
  - multiple watchdog failures
  - multiple thermal shutdowns
  - V1 regulator failures
  - an explicit SPI command
- To exit from the VBAT_Standby state and return to the active one, press the wake-up button on the LIN pin or drive the MCU pin no. 58 (PIN_WAKEUP) from high to low. You can perform this second option only if:
  - a jumper on JP1 connects pins 2 and 3
  - the wake-up pin is configured as an input pin in the L99DZ200G
  - OUT15 is on and is not driven through an internally generated PWM signal

Note: There is a software debug mode that simplifies the debugging procedure. In this mode, the watchdog requirement is turned off. For further details on how to enter the debug mode, refer to the related datasheet . Currently, this procedure is not available on this board.

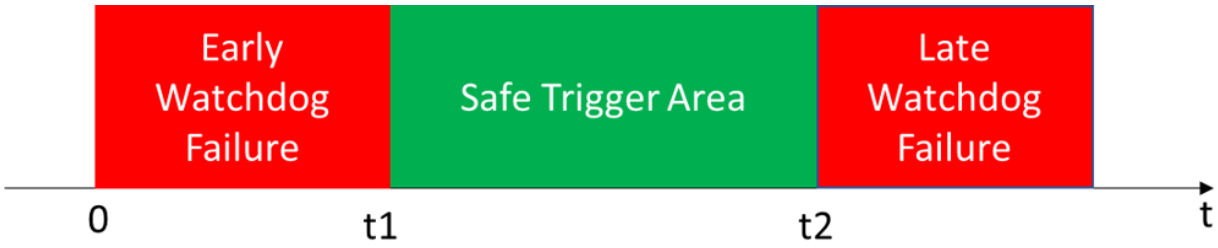
1.1.2.2 *Watchdog scheme*

The L99DZ200G state machine performs a state transition from the active mode to the standby mode when the continuity of communication between the device and the microcontroller is lost. This continuity of communication must be guaranteed by writing SPI messages into a special register that toggles a specific bit (bit 0 of the control register CR1 or Config Reg).

After the power-on or the standby mode, the watchdog has to start within a maximum timeout (long open window TLW). This window gives the microcontroller the time to run its own setup before starting the watchdog. From this moment, the microcontroller has to serve the watchdog within a safe triggering time range. The trigger time window is configurable by SPI, both at startup and runtime.

The watchdog failure happens if the watchdog trigger occurs before the t1, in the “early write" window, or after t2, in the "late write" window. In case of watchdog failures, a reset signal is sent to the MCU.

Figure 4. Watchdog timing



Note: For further details, refer to the L99DZ200G documentation on www.st.com.

1.2 Board outputs

1.2.1 OUT1, OUT2-X, OUT3-Y, OUT6-F

The AEK-MOT-MR200G1 has three couple of outputs for the motor positioning: OUT3-Y/OUT1, OUT2-X/OUT1, OUT6-F/OUT1. These outputs allow connecting and controlling three 12 V DC motors.

The current supplied by each of these OUT pins can be measured thanks to the current monitoring feature of the L99DZ200G, through the *AEK_MOT_MR200G1_CurrentMonitor_Selector()* interrupt handler callback (see table 2 for further information). This callback acquires the current data of the selected OUT, as well as the X and the Y encoder position data.

The current monitoring allows determining the motor working state (inrush current, normal, end-limit switch detection).

On these outputs a system auto-recovery feature has been implemented for overload, overvoltage, or undervoltage conditions (for further details, see the L99DZ200G datasheet, section 4.14 Power Outputs OUT1…15).

1.2.2 Heater

The AEK-MOT-MR200G1 has a dedicated output (HEATER) to connect a heating unit (i.e., a resistance). This output is located on the J5 connector and has been designed to connect a resistive load between the HEATER and the GND terminals.

The system supplies the HEATER output by 12 or 0 V, according to the GH value (bit 4 of the CR5 register of the L99DZ200G) settings.

Two diagnosis features are implemented to indicate the short-circuit (damaged heating unit) and the open load (heating unit not connected or damaged). For further information, refer to section 4.34 of the L99DZ200G datasheet.

1.2.3 EC

The on-board electro-chromic output (EC, on the J6 connector) has been designed to connect a vehicle side mirror with electro-chromic dimming function.

Based on the configuration settings of the L99DZ200G control registers, the EC voltage is driven to a target value, between 0 and 1.5 V.

The dedicated driver features three different functionalities:

- setup of the target output voltage
- fast discharge activation/deactivation to reach rapidly the target voltage
- electro-chromic function activation/deactivation

1.2.4 X and Y encoder positioning

On the CN1 connector, two inputs (X and Y) are connected to the SPC582B60E1 MCU ADCs. They can be used to measure an analog voltage, with a value in the range of 0-VS_{reg}, where VS_{reg}~=5 V.

In our application example, we used these inputs to measure the output voltage of two encoders, one for the mirror rotation on the X axis and one for the rotation on the Y axis.

1.2.5 OUT7 and OUT8

These two high-side outputs, when enabled, supply 12 V. They can be used to power LED bulbs for turning signals or puddle lights.

These outputs feature the constant current mode (CCM), which is conceived to provide a constant current to the related output (for further details, refer to section 4.21 of the L99DZ200G datasheet).

1.2.6 CAN connector

The AEK-MOT-MR200G1 hosts a CAN connector (P4) for an external domain controller to drive the board via CAN messages, that is, to manage the opening/closing of the mirror.

The CAN network has been compensated with a 120 Ω resistor as per CAN bus specification.

2 AEK-MOT-MR200G1 in AutoDevKit

The driver for the AEK-MOT-MR200G1 board is part of the AutoDevKit ecosystem.

An AutoDevKit component for the AEK-MOT-MR200G1 board has not been created, as the board hosts an MCU.

In AutoDevKit, two AEK-MOT-MR200G1 evaluation demos have been developed, one of which including L99DZ200G drivers. They represent a good starting point for user's development.

2.1 AutoDevKit ecosystem

The application development employing the AEK-MOT-MR200G1 takes full advantage of the AutoDevKit ecosystem, whose basic components are:

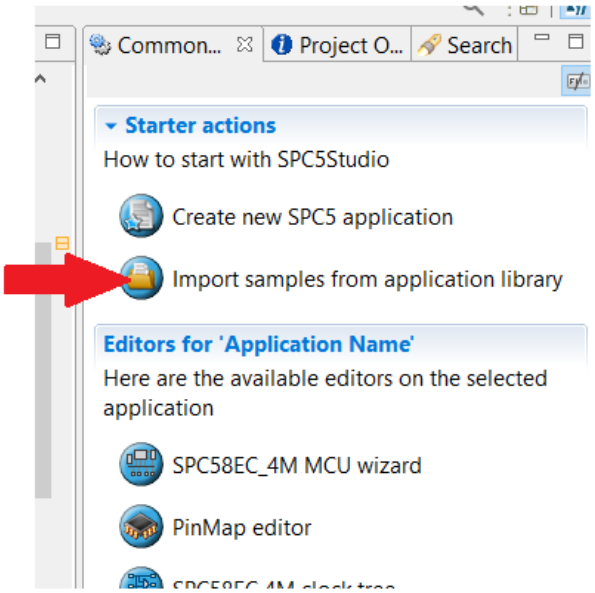
- AutoDevKit Studio IDE (STSW-AUTODEVKIT)
- PLS UDE and OpenOCD programmer and debugger

2.2 How to download demos from SPC5Studio and AutoDevKit

After downloading and installing AutoDevKit Studio, you can import the application samples related to the AEK-MOT-MR200G1 evaluation board, as per the procedure below:

Step 1. From the [**Common task**] panel, click on the [**Import sample from application library**] icon.

Figure 5. Import sample from application library

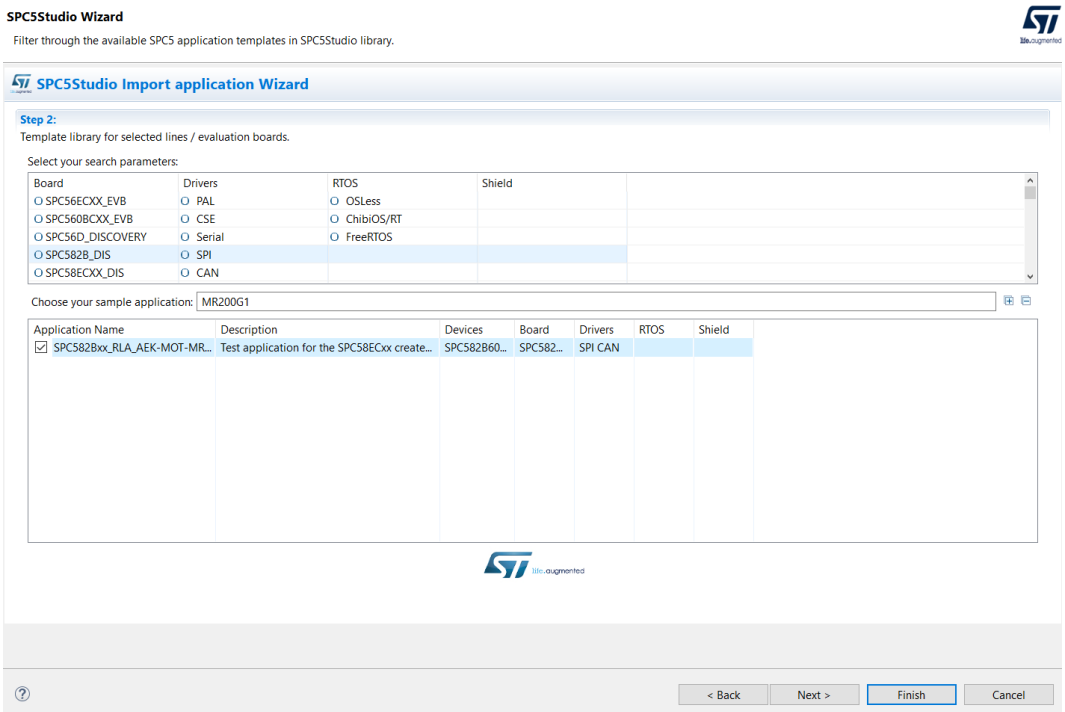


Step 2. In the Import application wizard, click “next”.

Step 3. Type “MR200G1” in the [**Choose your sample application**] textbox.

Step 4. Tick the demo to import and click on the finish button.inf

Figure 6. MCU and demo selection



3 Available demos for the AEK-MOT-MR200G1

One demo has been specifically developed for the AEK-MOT-MR200G1 board:

SPC582Bxx_RLA_AEK-MOT-MR200G1_Doorzone

A second demo has been designed to be flashed on the AEK-MCU-C4MLIT1 to transmit CAN messages to the AEK-MOT-MR200G1:

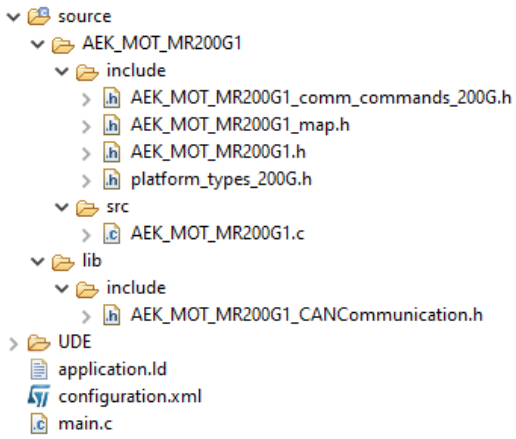
`SPC58ECxx_RLA 4M_CAN_cmd_sender_for_MR200G`

3.1 SPC582Bxx_RLA_AEK-MOT-MR200G1_ Doorzone

This first demo is preloaded on the AEK-MOT-MR200G1 and, once running, performs an activation sequence of the board outputs (motors, heater, electro-chrome voltage (ECV)). It shows how to drive up to three 12 V DC motors (one up to 7.5 A and the other two up to 500 mA), turn on/off two LED strings (at 12 V, one up to 1.5 A and the other up to 700 mA), activate the heater and the electro-chrome functions.

Importing the “SPC582Bxx_RLA_AEK-MOT-MR200G1_Doorzone” demo, users can access AEK-MOT-MR200G1 APIs.

Figure 7. Demo folders



These libraries ease the development of specific applications, allowing any user to drive easily every board output.

Once the project has been imported, you can find the following key files within the AEK_MOT_MR200G1 folder:

AEK_MOT_MR200G1_comm_commands_200G.h: contains register defines

AEK_MOT_MR200G1_map.h: contains register masks

AEK_MOT_MR200G1.h: includes defines, typedefs, and function declarations

AEK_MOT_MR200G1.c: contains all the APIs

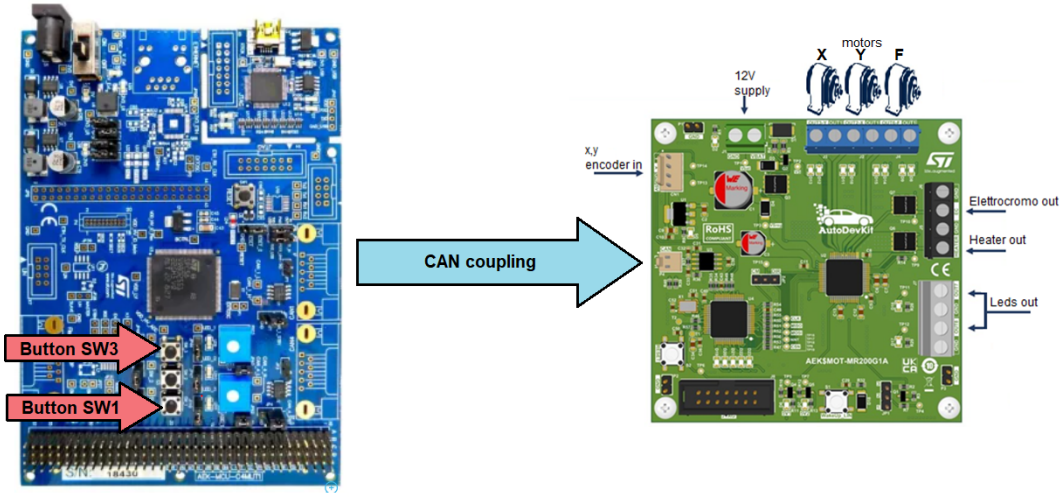
AEK_MOT_MR200G1_CANCommunication.h: contains the list of CAN commands interpreted by the board

Note: To access all board functionalities, you have to include only the AEK_MOT_MR200G1.h file in the main code.

3.2 SPC58ECxx_RLA 4M_CAN_cmd_sender_for_MR200G

The purpose of this demo is to transmit CAN commands to the AEK-MOT-MR200G1 via CAN bus. The AEK-MOT-MR200G1 has to be programmed with the “SPC58Bxx_RLA_AEK-MOT-MR200G1_Doorzone” demo.

Figure 8. CAN communication between the AEK-MCU-C4MLIT1 and the AEK-MOT-MR200G1



Every time you press the SW1 or SW3 on-board buttons, a CAN message is sent from the AEK-MCU-C4MLIT1.

The AEK-MOT-MR200G1 then interprets this message and performs the corresponding action (for further details, refer to Section 7 A real application example):

- SW1 to activate/deactivate the motors
- SW3 to activate/deactivate the ECV and heater

Note: On the AEK-MCU-C4MLIT1, JP2 must be set to position 2-3 (STBY-GND).

4 Available APIs

After importing the demo application, from “Project Explorer”, you can find all the functions needed to develop your own application. The *main.c* code includes an example of how to use them.

The APIs listed in the following tables are declared in the “AEK_MOT_MR200G.h” file.

Table 1. Key APIs for the AEK-MOT-MR200G1

Key API name	Description
`AEK_MOT_MR200G1_Init()`	Initializes the driver and clears each L99DZ200G status register.
`AEK_MOT_MR200G1_ClearAllStatusRegisters()`	Clears all status registers of the L99DZ200G.
`AEK_MOT_MR200G1_SetWDCTime()`	Sets the watchdog trigger time (10 ms, 50 ms, 100 ms, or 200 ms).
`AEK_MOT_MR200G1_CheckWDExpired()`	Checks whether the watchdog has expired.
`AEK_MOT_MR200G1_Wait()`	Delays code execution, ensuring that the L99DZ200G remains in active mode. The timing has to be specified in milliseconds.
`AEK_MOT_MR200G1_GlobalStatusByte()`	Returns the last global status byte (GSB) collected during an SPI communication event between the microcontroller and the L99DZ200G.
`AEK_MOT_MR200G1_CheckGlobalStatusByte()`	Checks if global status byte (GSB) flags an error. It indicates if the writing/reading operation via SPI on the L99DZ200G registers has been correctly performed.

`AEK_MOT_MR200G1_get_ADC_data_current()`
`AEK_MOT_MR200G1 get_ADC_data_voltage_X()`
`AEK_MOT_MR200G1_get__ADC_data_voltage_Y()`
	These functions return, respectively, the current, X voltage, and Y voltage get by the AEK_MOT_MR200G1_current_position_conversion() function.

`AEK_MOT_MR200G1_current_position_conversion()`	Used to collect X motor position, Y motor position, and the current absorbed by the active motor (selected via AEK_MOT_MR200G1_CurrentMonitor_Selector()). This function is triggered periodically by the PIT. Data collected is then averaged once every 50 consecutive samples.
`AEK_MOT_MR200G1_HSOutputsControl()`	Function used to switch on/off OUT7 or OUT8 (12 V/0 V) (i.e., LED lamps)
`AEK_MOT_MR200G1_MotorDriver()`	Drives OUT1-2-3-6 half-bridges outs to high-side or low-side, based on the desired motor state and direction.
`AEK_MOT_MR200G1_ECV_Enable()`	Enables/disables electro-chromic voltage (ECV) functionalities.
`AEK_MOT_MR200G1_ECV_FastDischarge_Enable()`	Enables/disables electro-chromic voltage (ECV) fast discharge, which reduces the time needed by the ECV output to reach the target voltage.
`AEK_MOT_MR200G1_ECV_Drive()`	Drives the ECV output to the desired target voltage (0 to 1.5 V).
`AEK_MOT_MR200G1_Heater_Enable()`	Drives high or low the heater output (12 V or 0 V).
`AEK_MOT_MR200G1_CurrentMonitor_Enable()`	Enables current monitoring capabilities of the L99DZ200G.
`AEK_MOT_MR200G1_CurrentMonitor_Selector()`	Selects which output among OUT1, OUT2, OUT3 and OUT6 has to be used by the L99DZ200G for current monitoring (CM).

Key API name	Description
	After selection, the output pin CM of the L99DZ200G sends a mirror image of the current absorbed by the selected motor output to the microcontroller ADC.

Table 2. Other APIs

API name	Description
`AEK_MOT_MR200G1_Set_PWM_Out7_8()`	Selects which PWM channel to use for OUT7-8 to switch on and off the connected LED lamps.
`AEK_MOT_MR200G1_ChangePWM()`	Selects the frequency to be configured on one of the 7 PWM channel registers.
`AEK_MOT_MR200G1_ConstantCurrentMode_Enable()`	Enables the constant current mode (CCM) for OUT7-8.
`AEK_MOT_MR200G1_OCR_Enable()`	Enables/disables overcurrent recovery.
`AEK_MOT_MR200G1_OCR_Frequency()`	Overcurrent recovery (OCR) programmable frequency controller. Sets the recovery frequency value of the selected output (used if OCR is enabled).
`AEK_MOT_MR200G1_Autorecovery_time()`	Sets the timing for autorecovery.
`AEK_MOT_MR200G1_V2_configuration()`	Configures the onboard voltage regulator (V2) in one of the following modes: - `OFF_V2` - `ON_ACTIVEMODE` - `ON_ACTIVEMODE_V1STANDBY` - `ALWAYS_ON`

For further details, refer to the API doxygen, inside the aek_MR200g1_component_rla/doc folder.

5 CAN commands

The “AEK_MOT_MR200G1_CANCommunication.h” file contains the list of CAN commands developed for the Doorzone demo application.

The following table lists AEK_MOT_MR200G1_CAN commands and the corresponding triggered behavior when the “SPC582Bxx_RLA_AEK-MOT-MR200G1_Doorzone” is running on the AEK-MOT-MR200G1.

Table 3. CAN commands

CAN Command	Board behavior when triggered

`#define MIRROR_FOLDING_CMD 0x11110000UL`
`#define MIRROR_UNFOLDING_CMD 0x11220000UL`
`#define MIRROR_X_CK_CMD 0x22110000UL`
`#define MIRROR_X_CCK_CMD 0x22220000UL`
`#define MIRROR_Y_CK_CMD 0x33110000UL`
`#define MIRROR_Y_CCK_CMD 0x33220000UL`
	Drives the two half-bridges that control a specific motor, according to the chosen direction (clockwise (CK) or counterclockwise (CCK)).

`#define MIRROR_BRK_CMD 0x33330000UL`	Brakes all the three motors.
`#define MIRROR_CENTER_CMD 0x77770000UL`	Performs a calibration routine, driving X and Y motors (out 1-2 and 3) until X-Y encoder inputs receive 2.5 Volts (in a 0-5 V range), which is the parameter threshold for this application.

`#define BULBS_ON_CMD 0x44110000UL`
`#define BULBS_OFF_CMD 0x44220000UL`
`#define BULBS_FLASH_CMD 0x44330000UL`
	Drives ON/OFF OUT7-8.

`#define HEATER_ON_CMD 0x11660000UL` `#define HEATER_OFF_CMD 0x11770000UL`	Drives High-Low Heater output (12 V or 0 V).
`#define ECV_ON_CMD 0x11440000UL` `#define ECV_OFF_CMD 0x11550000UL`	Drives to target voltage ECV output (0 V to 1.5 V).
`#define DEMO_ON_CMD 0x00001188UL`	Starts a demo routine: 1. Board LEDs are switched on sequentially 2. Motor F (folding) is driven for 6 seconds 3. Heater and ECV out are switched ON 4. Motors X and Y calibrate their orientation 5. Heater and ECV out are switched OFF 6. X motor is driven in both directions for 16 secs 7. Y motor is driven in both directions for 16 secs 8. Motor F (folding) is driven backwards for 6 seconds 9. Out7-8 are switched ON-OFF for 5 times.

6 Motor model used during the AEK-MOT-MR200G1 emission tests

The motors used during the tests are 413-0622 RS PRO.

Table 4. Motor specifications

Specification	Value
Voltage option	12 VDC
Maximum input voltage	12 V
Current rating	190 mA
Maximum speed	66 rpm/min
Maximum momentary tolerance torque	3.0 kgf-cm
Maximum speed (no load)	82 rpm/min
Reduction ratio	1/100

7 A real application example

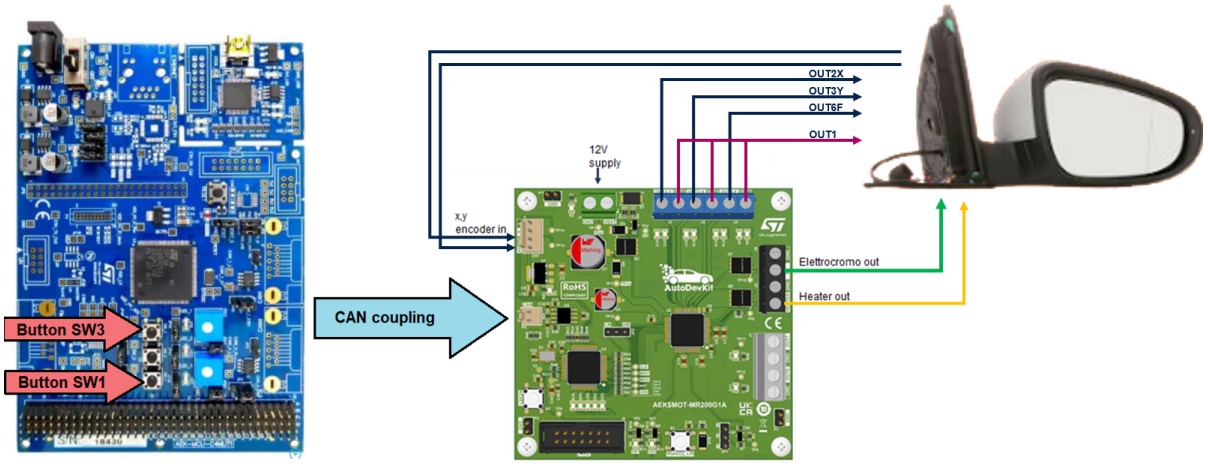
Our application example demonstrates how to control a side mirror via CAN protocol and how to implement this solution in a real vehicle.

The solution consists of:

- an AEK-MCU-C4MLIT1 MCU board
- an AEK-MOT-MR200G1 evaluation board and
- a latest generation heating mirror

The figure below shows the application example setup.

Figure 9. Real application example system setup



We flashed the “SPC582Bxx_RLA_AEK-MOT-MR200G1_Doorzone” demo on the AEK-MOT-MR200G1 board. Then, we flashed the “SPC58ECxx_RLA 4M_CAN_cmd_sender_for_MR200G” demo on the AEK-MCU-C4MLIT1 to transmit CAN commands to the AEK-MOT-MR200G1.

After power-on, the AEK-MOT-MR200G1 runs a demo routine, which performs the following operations in sequence:

1. Board LEDs are switched on sequentially
2. Folding motor (F) is driven for 6 seconds
3. Heater and ECV outputs are switched on
4. X and Y motors calibrate their orientation
5. Heater and ECV outputs are switched off
6. X motor is driven in both directions for 16 seconds
7. Y motor is driven in both directions for 16 seconds
8. Motor Folding is driven backwards for 6 seconds
9. OUT7-8 are switched on-off for 5 times

During the routine execution, you can see how the electrical side mirror position changes according to the operation performed.

In particular, during the routine execution:

- the motor that controls the mirror folding/unfolding is driven
- the motors that move the mirror on the x-y axes are driven; at the same time, the MCU on the AEK-MOT-MR200G1 receives data about the position reached by the mirror window along the two axes
- the electro-chrome is activated/deactivated
- the heating function is activated/deactivated
- the indicator LEDs of OUT7 and OUT8 switch on

When the demo routine stops, the AEK-MOT-MR200G1 enters the IDLE state, during which it waits for CAN commands.

By pressing SW1 or SW3 on the AEK-MCU-C4MLIT1, the latter sequentially sends the CAN messages included in the SPC58ECxx_RLA 4M_CAN_cmd_sender_for_MR200G demo (see table 4 for available commands).

In detail:

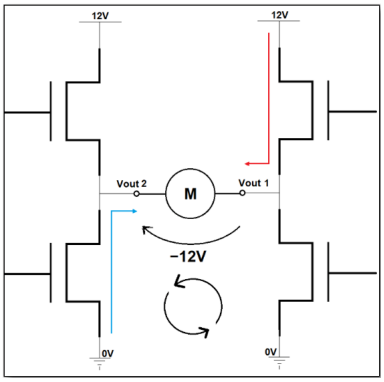
- by pressing SW1, the following commands are sent:
  1. AEK_MOT_MR200G1_MIRROR_UNFOLDING_CMD
  2. AEK_MOT_MR200G1_MIRROR_X_CK_CMD
  3. AEK_MOT_MR200G1_MIRROR_X_CCK_CMD
  4. AEK_MOT_MR200G1_MIRROR_FOLDING_CMD
- by pressing SW3, the following commands are sent:
  1. AEK_MOT_MR200G1_HEATER_ON_CMD
  2. AEK_MOT_MR200G1_HEATER_OFF_CMD
  3. AEK_MOT_MR200G1_ECV_ON_CMD
  4. AEK_MOT_MR200G1_ECV_OFF_CMD

8 Test results

During the routine demo execution, we monitored the output signals generated by the AEK-MOT-MR200G1.

The system setup consists of three 12 V DC motors connected to OUT1-OUT2X, OUT1-OUT3Y, and OUT1-OUT6F.

Figure 10. Motor functional block



According to the executed command, the AEK-MOT-MR200G1 controls MOSFETs to supply 12 or 0 V to the selected output, generating the motor rotation or braking.

Figure 11. Motor clockwise rotation

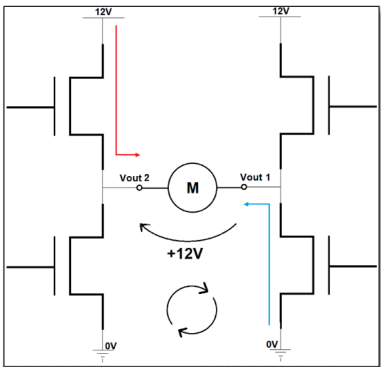


Figure 12. Motor counterclockwise rotation

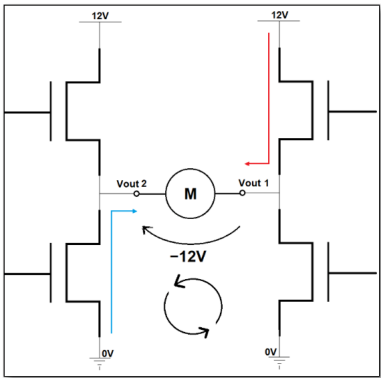
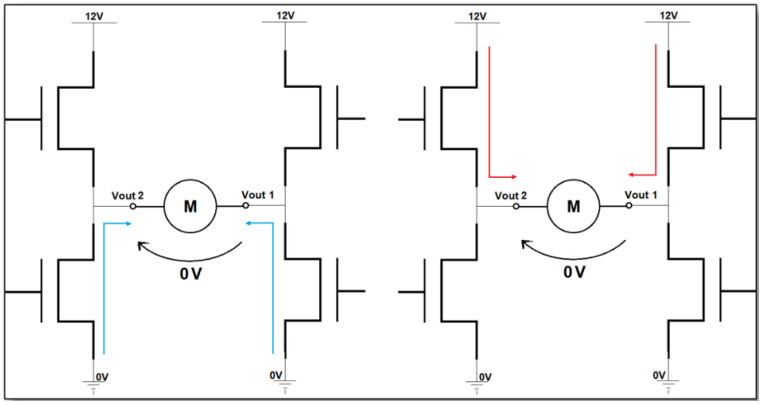


Figure 13. **Motor braking**



The following images show the test results, according to the demo routine sequence described in Section 7.

Figure 14. **Mirror opening (clockwise folding motor rotation)**

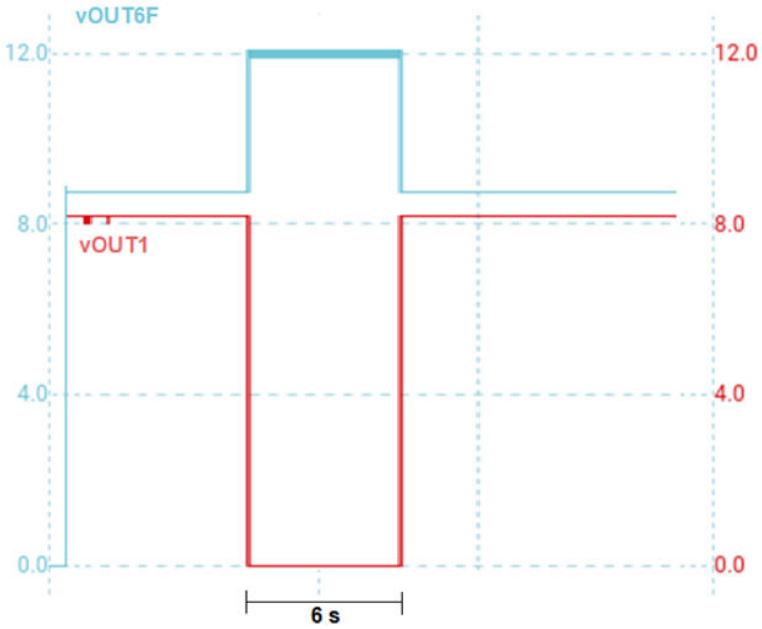


Figure 15. **Heater and ECV outputs switch-off curves**

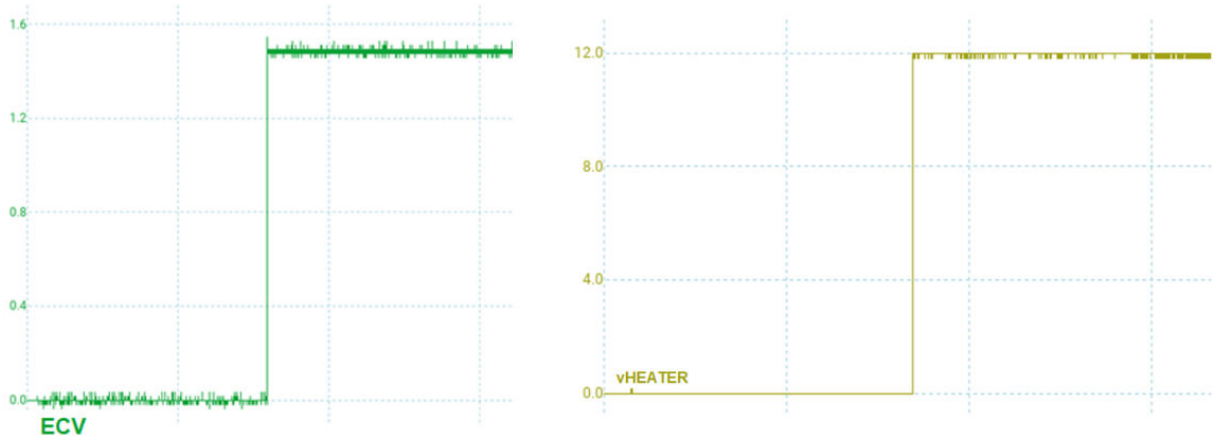


Figure 16. **X motor calibration**

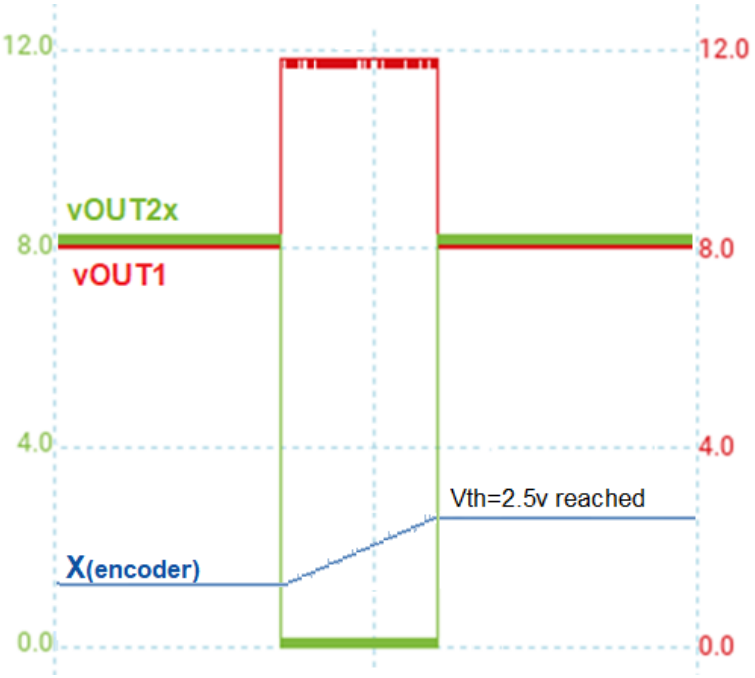


Figure 17. **Heater and ECV outputs switch-off curves**

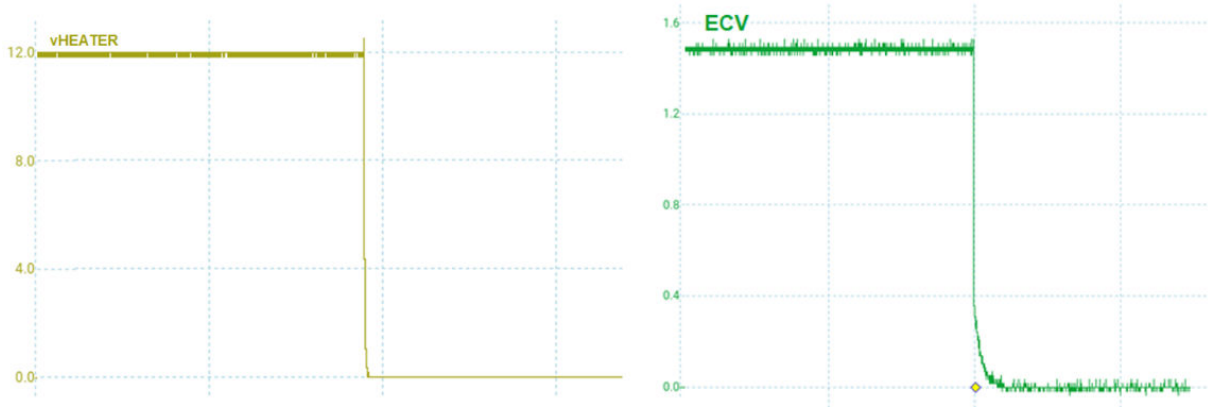


Figure 18. **Motor X activation in both directions**

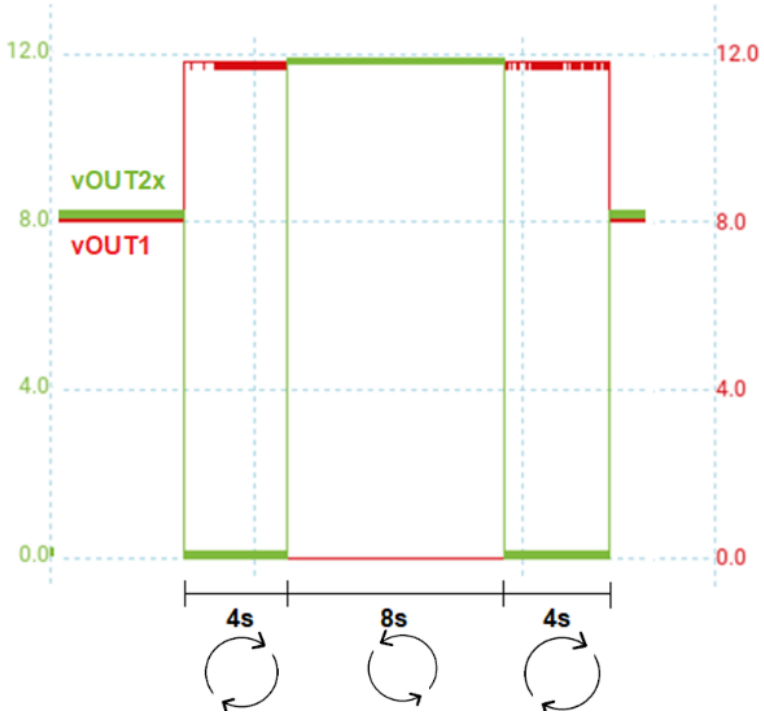


Figure 19. **Motor Y activation in both directions**

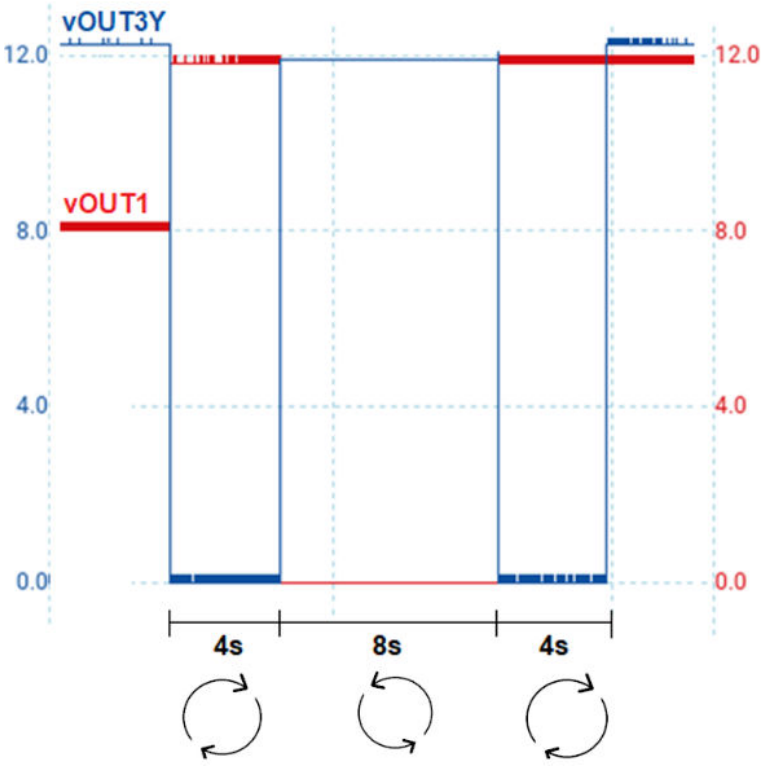


Figure 20. **Mirror closing (counterclockwise folding motor rotation)**

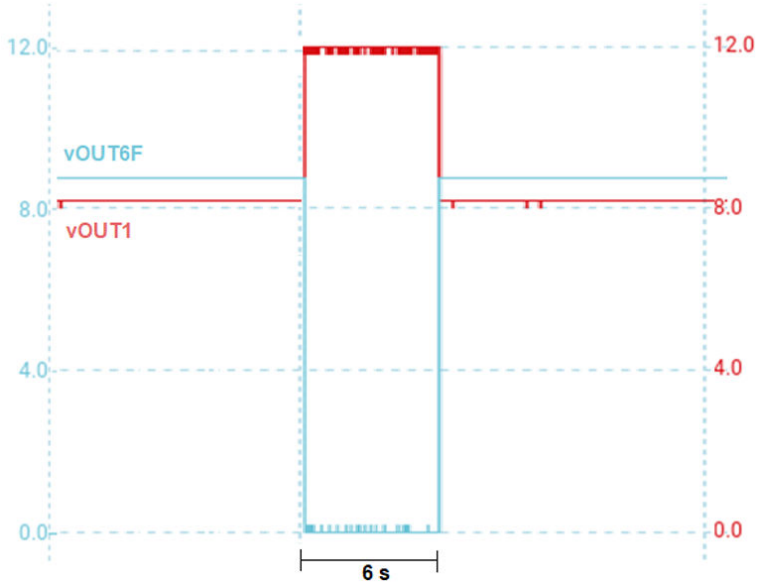
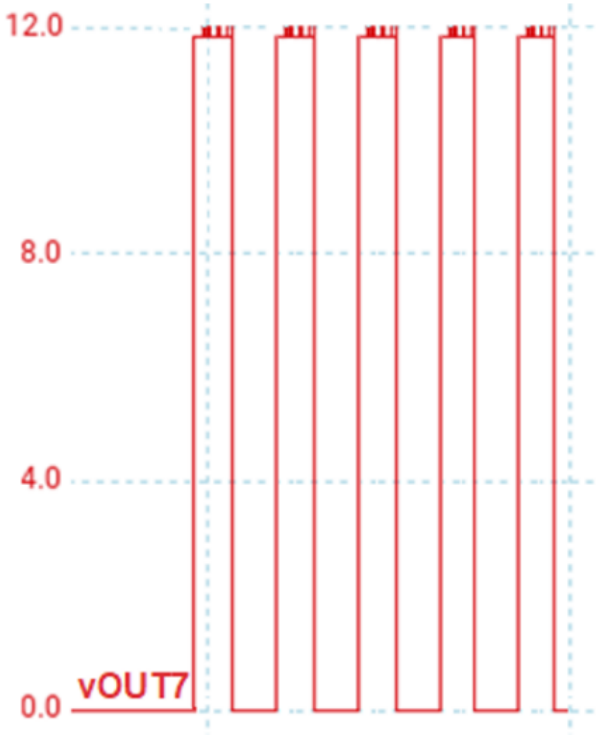


Figure 21. **VOUT7 switched on/off**



9 Schematic diagrams

Figure 22. **AEK-MOT-MR200G1 circuit schematic (1 of 6)**

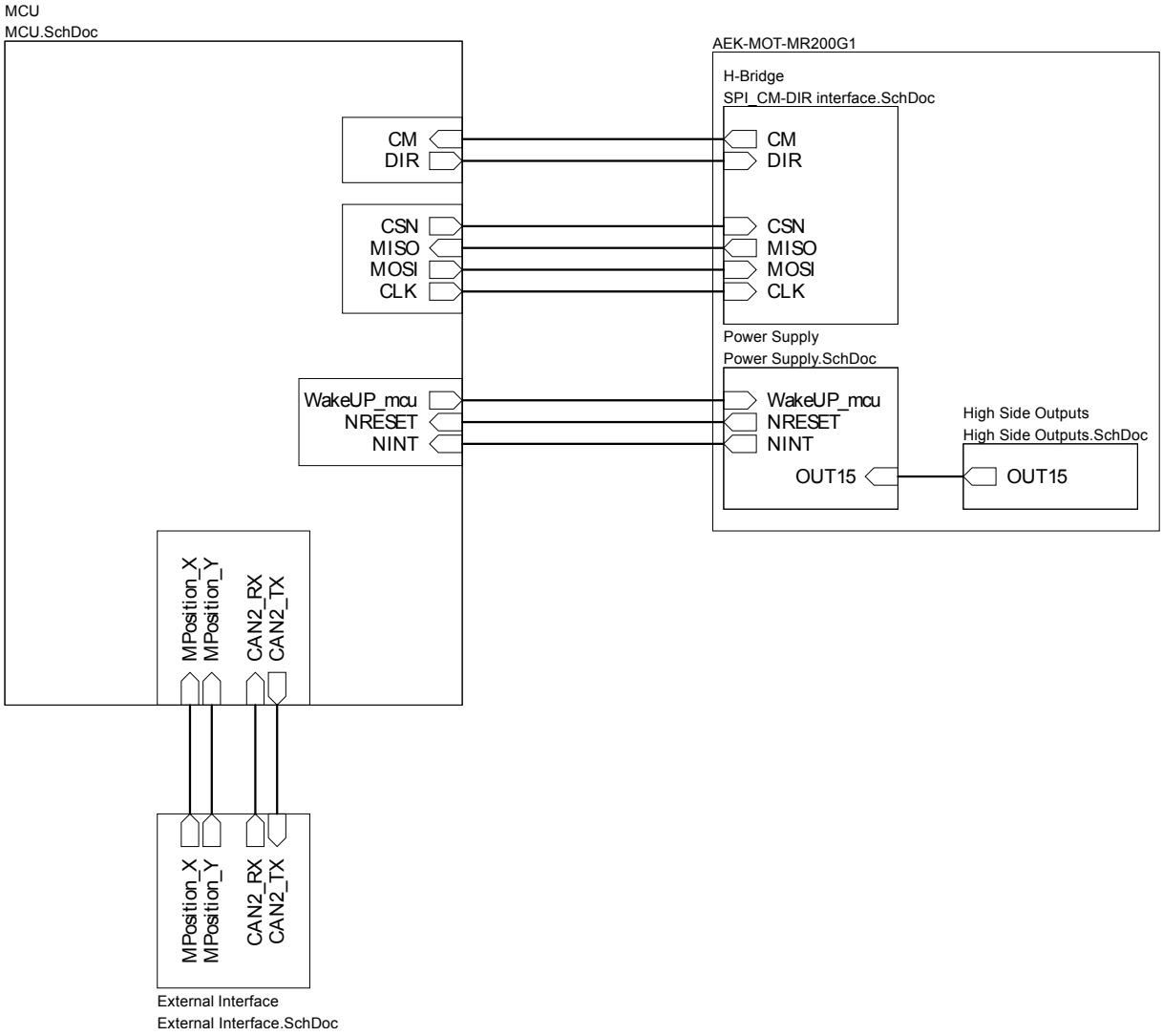


Figure 23. **AEK-MOT-MR200G1 circuit schematic (2 of 6)**

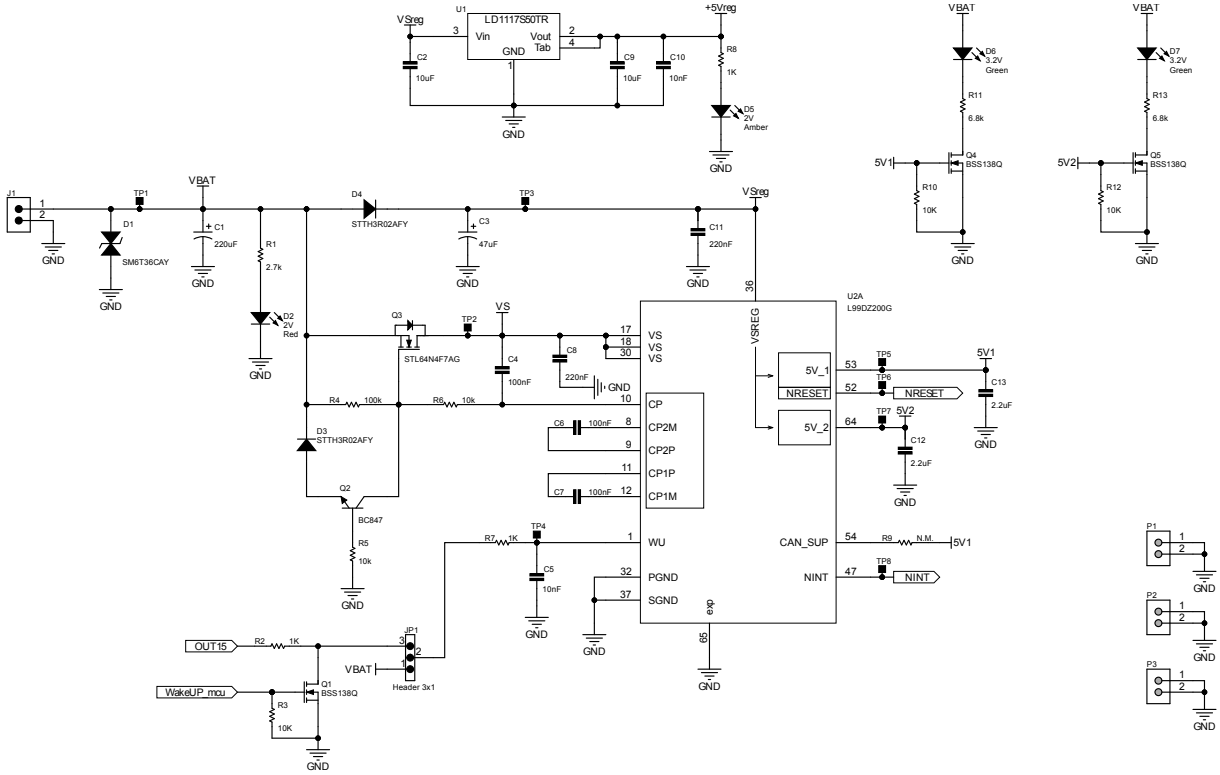


Figure 24. **AEK-MOT-MR200G1 circuit schematic (3 of 6)**

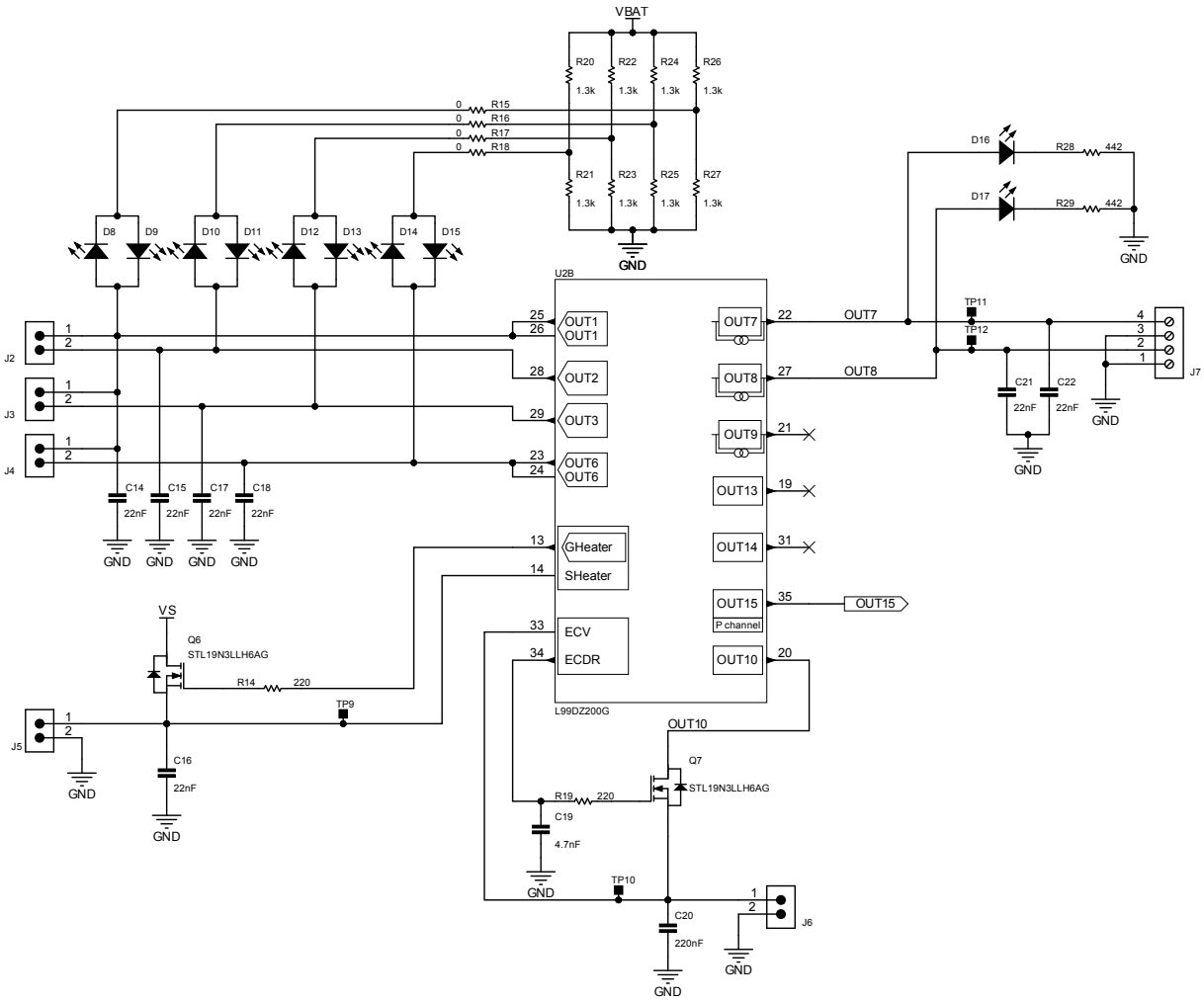


Figure 25. **AEK-MOT-MR200G1 circuit schematic (4 of 6)**

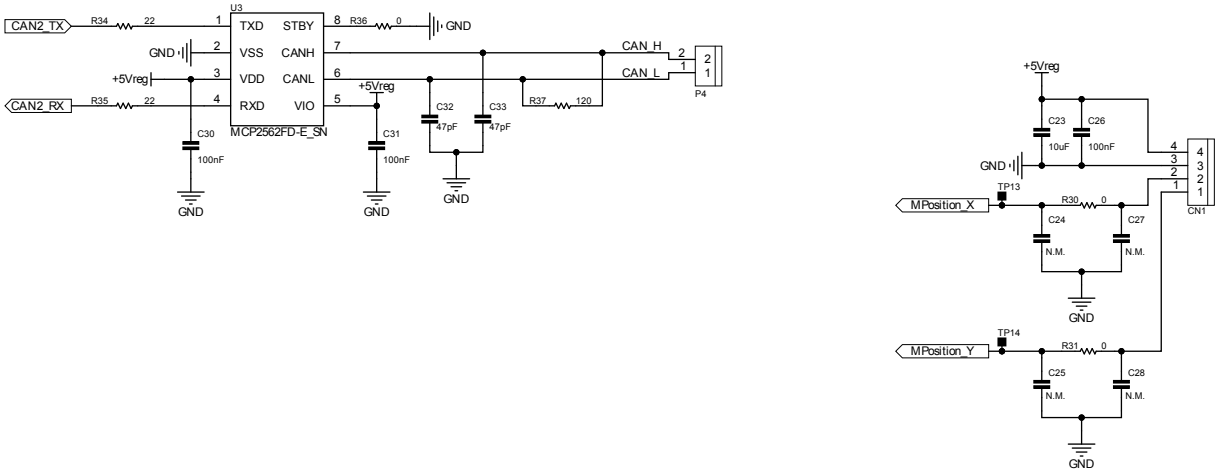


Figure 26. **AEK-MOT-MR200G1 circuit schematic (5 of 6)**

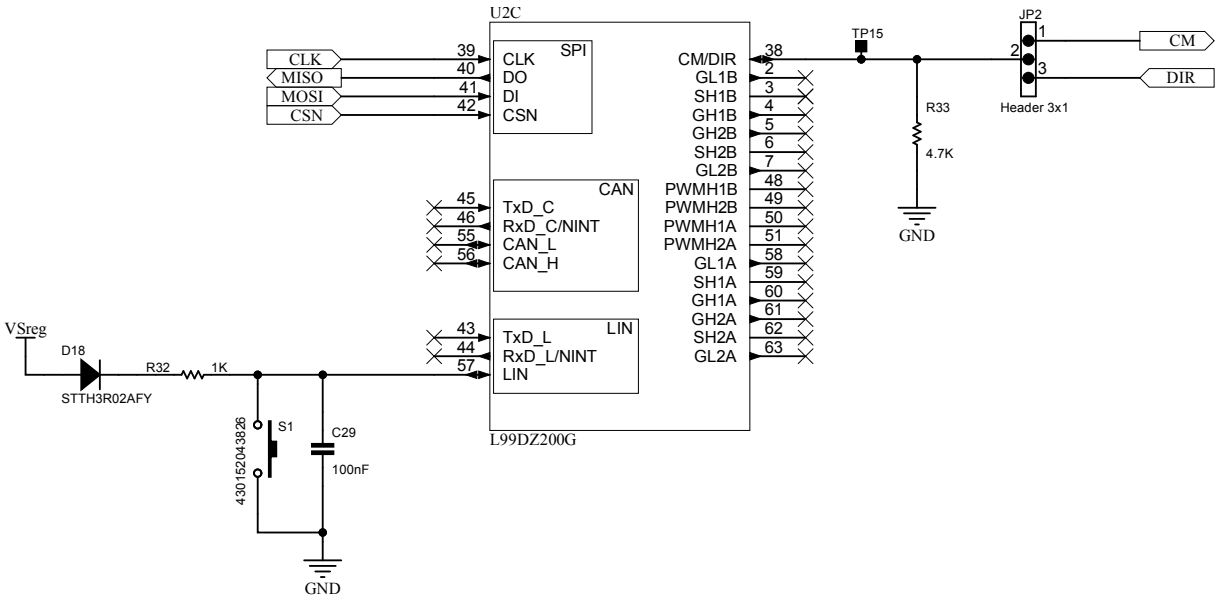
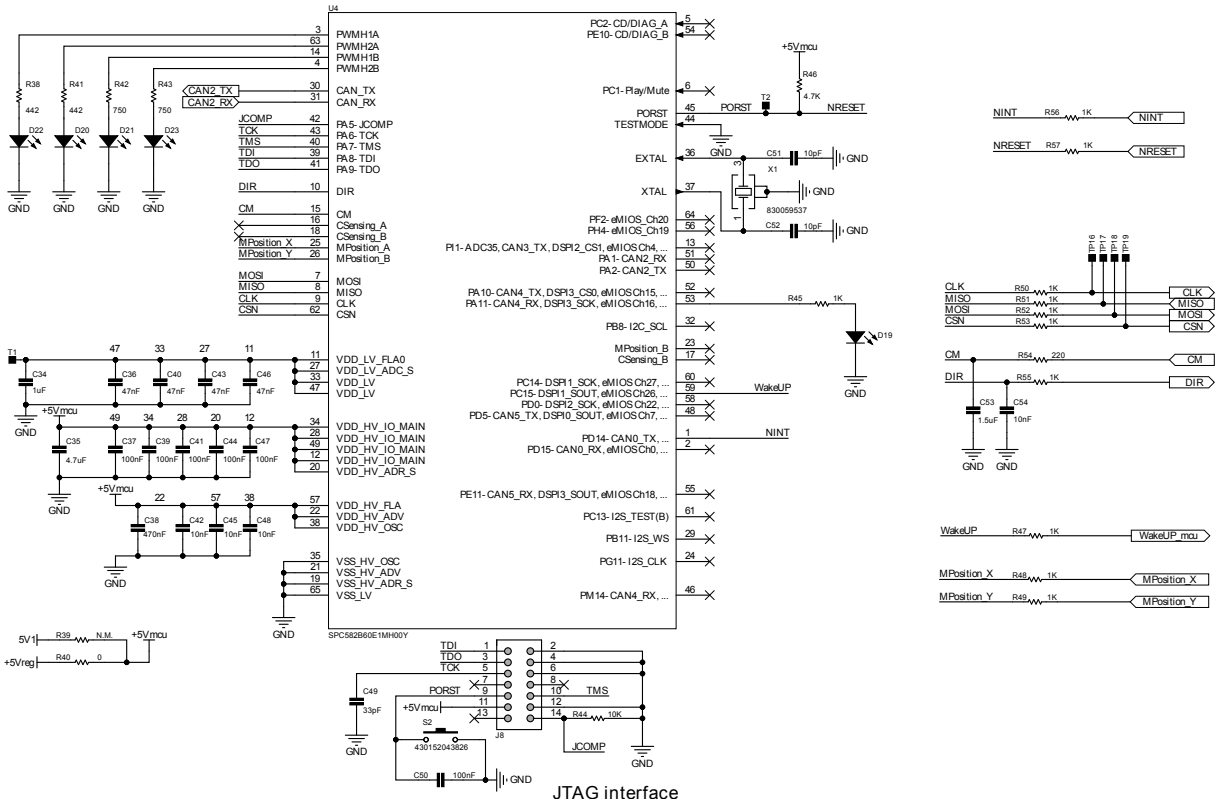


Figure 27. **AEK-MOT-MR200G1 circuit schematic (6 of 6)**



10 Bill of materials

Table 5. **AEK-MR200G1 bill of materials**

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
1	1	C1	220uF	Electrolytic Cap - 50V - 10x10.5	WE	865080657018
2	3	C2, C9, C23	10uF	0805 - 25V	TAIYO YUDEN	TMK212BC6106MG-T
3	1	C3	47uF	Electrolytic Cap - 50V - 6.3 x 7.7	WE	865080645012
4	3	C4, C6, C7	100nF	0805 - 100V - X7R Class II	WE	885012207128
5	6	C5, C10, C42, C45, C48, C54	10nF	0603 - 50V - X7R Class II	WE	885012206089
6	3	C8, C11, C20	220nF	0603 - 50V - X7R Class II	WE	885012206125
7	2	C12, C13	2.2uF	0805 - 25V - X7R Class II	WE	885012207079
8	5	C14, C15, C16, C17, C18	22nF	0603 - 50V - X7R Class II	WE	885012206091
9	1	C19	4.7nF	0603 - 50V - X7R Class II	WE	885012206087
10	2	C21, C22	22nF	0805 - 50V - X7R Class II	WE	885012207094
11	4	C24, C25, C27, C28	N.M.	0603	N.M.	N.M.
12	10	C26, C29, C30, C31, C37, C39, C41, C44, C47, C50	100nF	0603 - 50V - X7R Class II	WE	885012206095
13	2	C32, C33	47pF	0603 - 50V - NP0 Class I	WE	885012006055
14	1	C34	1uF	0805 - 50V - X7R Class II	WE	885012207103
15	1	C35	4.7uF	1210 - 50V - X7R Class II	WE	885012209048
16	4	C36, C40, C43, C46	47nF	0603 - 50V - X7R Class II	WE	885012206093
17	1	C38	470nF	0805 - 50V - X7R Class II	WE	885012207102
18	1	C49	33pF	0603 - 50V - NP0 Class I	WE	885012006054

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
19	2	C51, C52	10pF	0603 - 50V - X7R Class II	WE	885012006051
20	1	C53	1.5uF	0603 - 16V - X5R	TDK	CGA3E1X5R1C155K080AC
21	1	CN1	61900411121	2.54mm - 1 row - KK254 - Male	WE	61900411121
22	1	D1	SM6T36CAY, SMB	Automotive 600 W, 30.8 V TVS in SMB	STMicroelectronics	SM6T36CAY
23	2	D2, D21	Red	0805 - Led Red - 2V	WE	150080RS75000
24	3	D3, D4, D18	STTH3R02AFY, SOD128 Flat	Automotive 200 V, 3 A Ultrafast Diode	STMicroelectronics	STTH3R02AFY
25	2	D5, D23	Amber	0805 - Led Amber - 2V	WE	150080AS75000
26	7	D6, D7, D8, D10, D12, D14, D20	Green	0805 - Led Green - 3.2V	WE	150080GS75000
27	7	D9, D11, D13, D15, D16, D17, D22	Blue	0805 - Led Blue - 3.2V	WE	150080BS75000
28	1	D19	Yellow	0805 - Led Yellow - 2V	WE	150080YS75000
29	1	J1	691213510002	5.08mm - WR-TBL Series 2135 - Horizontal Entry Modular	WE	691213510002
30	3	J2, J3, J4	691102710002	5.00mm - WR-TBL Serie 102 Horizontal Entry Modular	WE	691102710002
31	2	J5, J6	691502710002	5.00mm - WR-TBL Serie 5027 Horizontal Entry Modular	WE	691502710002
32	1	J7	691133710004	WR-TBL Serie 1337 Horizontal Cable Entry, Pressure Clamp, THT, pitch 5mm, 4p	WE	691133710004
33	1	J8	61201421621	2.54mm - IDC, Male Box Header WR-BHD, THT, Vertical	WE	61201421621
34	2	JP1, JP2	61300311121	THT Vertical 3 pins Header, Pitch 2.54 mm, Single Row	WE	61300311121
35	3	P1, P2, P3	61300211121	2.54mm - WR-PHD Pin Header, THT, pitch 2.54mm, Single Row, Vertical, 2p	WE	61300211121
36	1	P4	61900211121	2.54mm - 1 row - KK254 - Male	WE	61900211121
37	3	Q1, Q4, Q5	BSS138Q	N-Channel Enhancement Mosfet	NEXPERIA	BSS138Q-7-F

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
38	1	Q2	BC847	NPN Bipolar Transistor 45V 100mA	Nexperia	BC847
39	1	Q3	STL64N4F7AG, PowerFLAT 5x6 WF	N-Channel_Automotive-grade 40 V, 7.0 mΩ typ., 64 A, STripFET™ F7 Power MOSFET	STMicroelectronics	STL64N4F7AG
40	2	Q6, Q7	STL19N3LLH6AG, PowerFLAT 5x6 WF	N-Channel Enhancement Power Mosfet	STMicroelectronics	STL19N3LLH6AG
41	1	R1	2.7k	0603 - ±1% - 0.125W	Vishay	MCT06030C2701FP500
42	15	R2, R7, R8, R32, R45, R47, R48, R49, R50, R51, R52, R53, R55, R56, R57	1K	0603 - ±1% - 0.25W	Panasonic	ERJPA3F1001V
43	4	R3, R10, R12, R44	10K	0603 - ±1% - 0.2W	Panasonic	ERJP03F1002V
44	1	R4	100k	0805 - ±5% - 0.25W	Panasonic	ERJT06J104V
45	2	R5, R6	10k	0805 - ±5% - 0.25W	Panasonic	ERJT06J103V
46	2	R9, R39	N.M.	0603	N.M.	N.M.
47	2	R11, R13	6.8k	0603 - ±1% - 0.25W	Panasonic	ERJH3EF6801V
48	3	R14, R19, R54	220	0603 - ±1% - 0.25W	Panasonic	ERJPA3F2200V
49	8	R15, R16, R17, R18, R30, R31, R36, R40	0	0603 - ±1% - 0.1W	Panasonic	ERJ3GEY0R00V
50	8	R20, R21, R22, R23, R24, R25, R26, R27	1.3k	0603 - ±1% - 0.25W	Panasonic	ERJ-PA3F1301V
51	4	R28, R29, R38, R41	442	0603 - ±1% - 0.125W	Panasonic	ERJH3EF4420V
52	2	R33, R46	4.7K	0603 - ±1%, - 0.25 W, 0603 - ±1% - 0.25W	Panasonic	ERJPA3F4701V

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
53	2	R34, R35	22	0603 - ±1% - 0.125W	Panasonic	ERJH3EF22R0V
54	1	R37	120	0603 - ±1% - 0.25W	Panasonic	ERJPA3F1200V
55	2	R42, R43	750	0603 - ±0.5% - 0.25W	Panasonic	ERJUP3D7500V
56	2	S1, S2	430152043826	Switch	WE	430152043826
57	1	U1	LD1117S50TR, SOT-223	The LD1117S50TR is a low drop voltage regulator able to provide up to 800 mA of output current. Vout is 5V.	STMicroelectronics	LD1117S50TR
58	1	U2	L99DZ200G, LQFP 64 10x10x1.4	Automotive front door device with LIN and CAN providing dual Hbridge driving	STMicroelectronics	L99DZ200G
59	1	U3	MCP2562FD-E/SN	High-Speed Can Bus Transceiver	Microchip	MCP2562FD-E/SN
60	1	U4	SPC582B60E1MH00Y, TQFP 64 10x10x1.0	SPC582B60E - 32-bit Power Architecture MCU	STMicroelectronics	SPC582B60E1MH00Y
61	1	X1	830059537	WE-XTAL Quartz Crystal, SMT, CFPX-104, 40MHz, +/-20ppm	WE	830059537
62	2	for blister	60900213421	WR-PHD 2.54 mm Multi-Jumper Jumper with Test Point	WE	60900213421
63	1	for blister	61900211621	WR-WTB 2.54 mm Female Terminal Housing	WE	61900211621
64	1	for blister	61900411621	WR-WTB 2.54 mm Female Terminal Housing	WE	61900411621
65	6	for blister	61910113722	WR-WTB 2.54 mm Female Crimp Contact	WE	61910113722
66	4	for blister	325-722	Distanziale filettato Esagonale Femmina/ Femmina, in Nylon Liscio, L. 8mm, M3 x M3	RS PRO	325-722
67	4	for blister	97790403111	WA-SCRW Pan Head Screw w. cross slot M3	WE	97790403111

11 Board versions

Table 6. **AEK-MOT-MR200G1 versions**

PCB version	Schematic diagrams	Bill of materials
AEK$MOT-MR200G1A (1)	AEK$MOT-MR200G1A schematic diagrams	AEK$MOT-MR200G1A bill of materials

1. *This code identifies the AEK-MOT-MR200G1 evaluation board first version. It is printed on the board PCB.*

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 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 7. **Document revision history**

Date	Revision	Changes
19-Jul-2023	1	Initial release.

Contents

List of tables

List of figures