Technical note

AEKD-TRUNKL1 test report

Introduction

With the electrification mega-trend, more and more body and convenience applications are electrifying the actuations that used to be manual. Among these automotive applications, one with renovated interest is the power liftgate.

This technical note describes how to use the AEKD-TRUNKL1 reference design. The main goal is to ensure that the final product meets the customer's needs and requirements through a rigorous design and testing process.

Figure 1. **AEKD-TRUNKL1 reference design (1 of 4)**

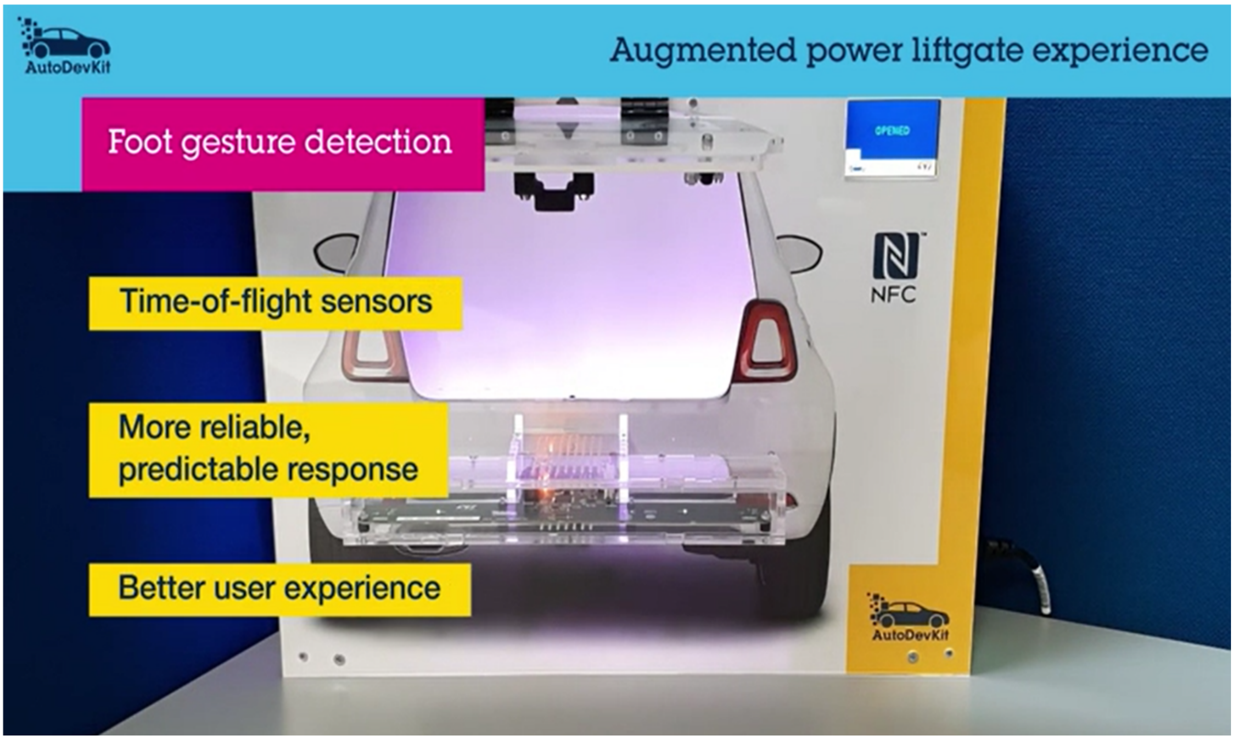


Figure 2. **AEKD-TRUNKL1 reference design (2 of 4)**

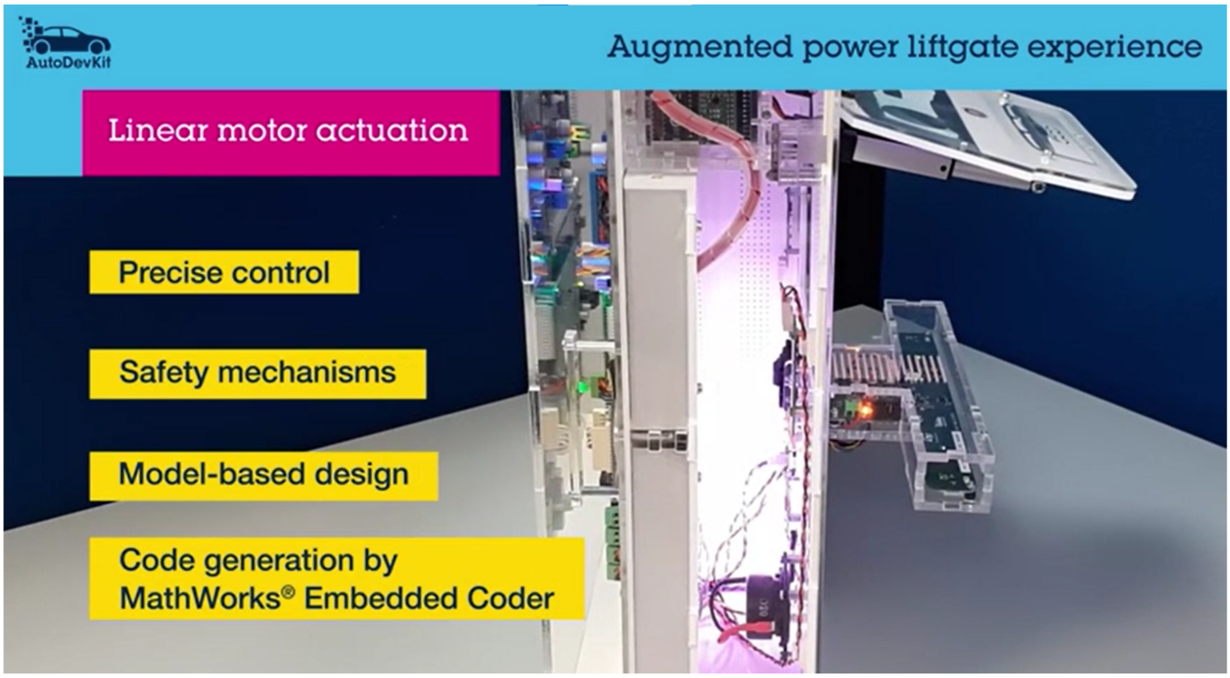


Figure 3. **AEKD-TRUNKL1 reference design (3 of 4)**

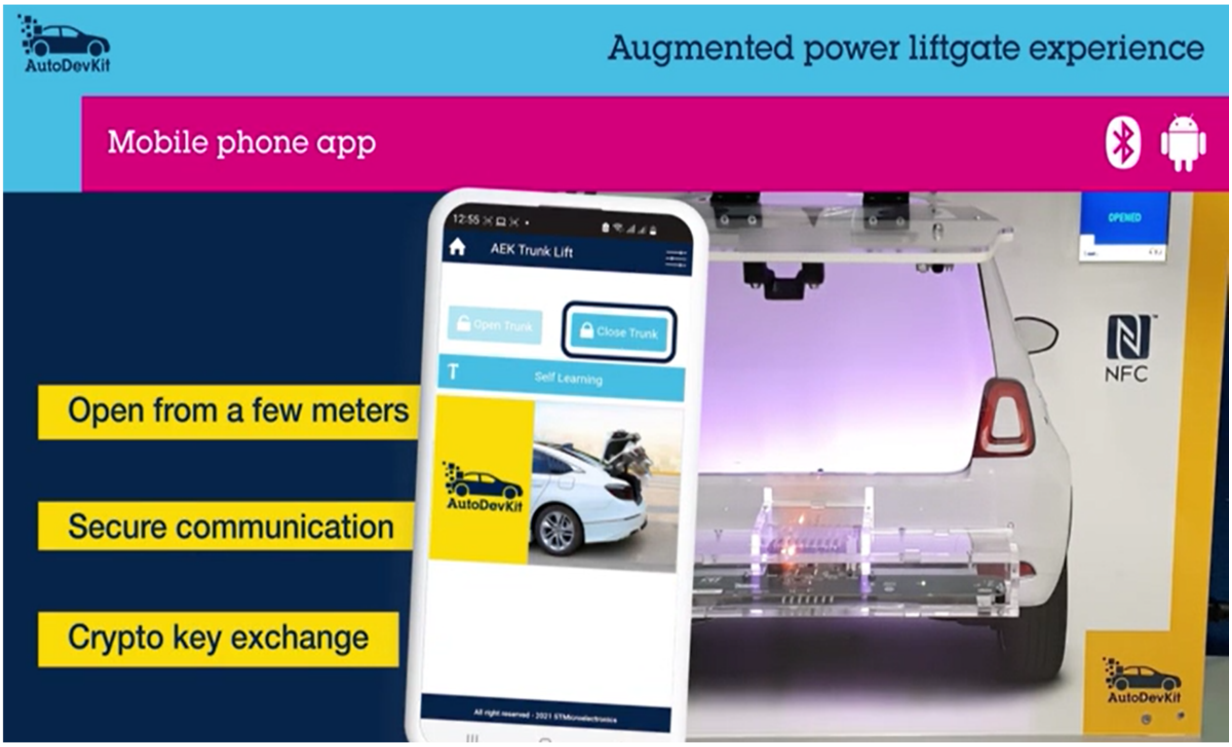
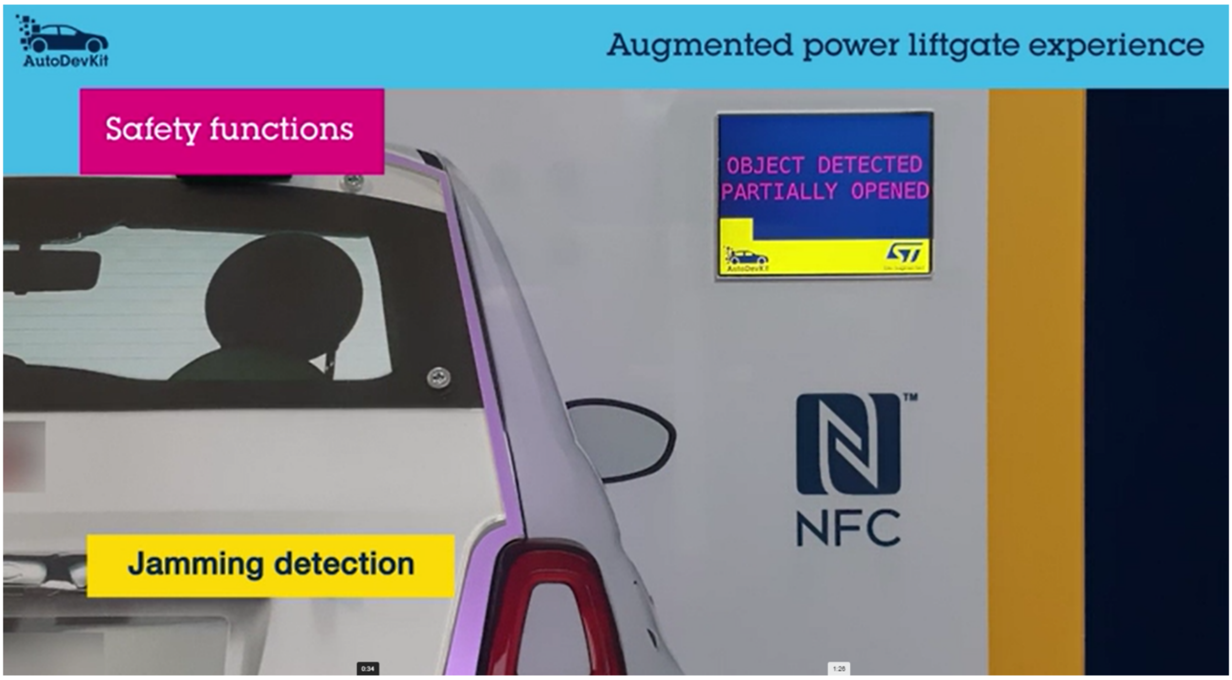


Figure 4. AEKD-TRUNKL1 reference design (4 of 4)

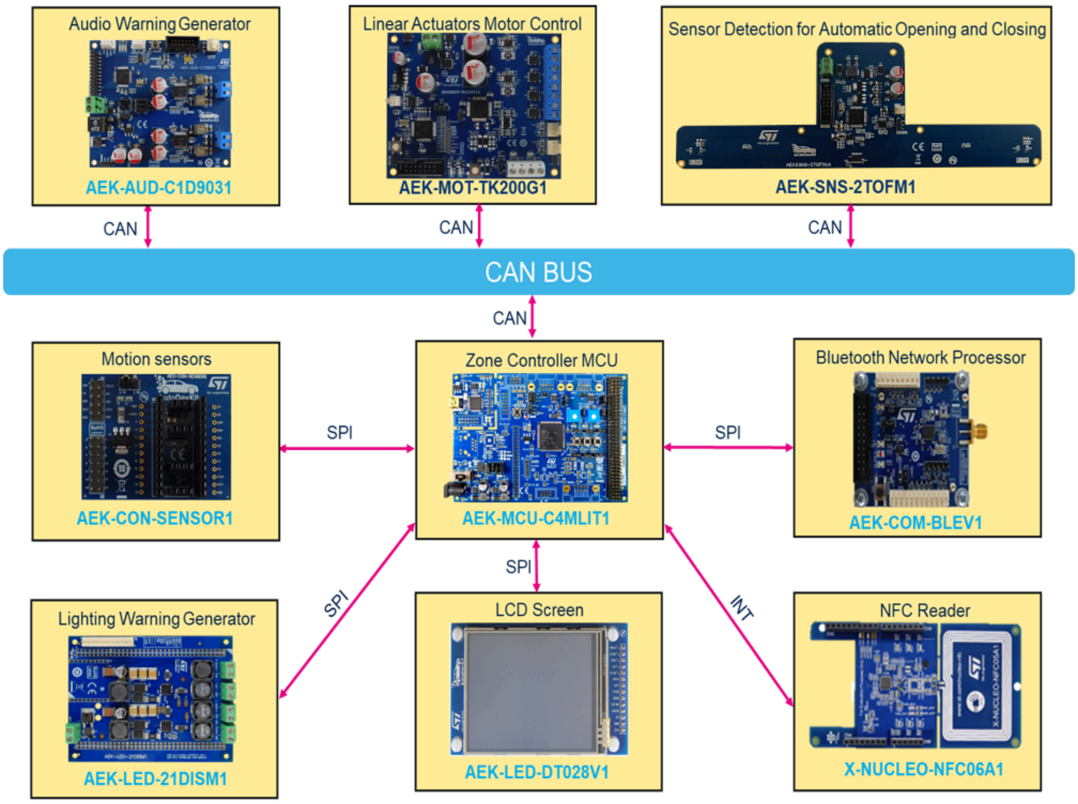


1 Overview

The AEKD-TRUNKL1 uses the following AutoDevKit boards:

- AEK-MCU-C4MLIT1
- AEK-MOT-TK200G1
- AEK-SNS-2TOFM1
- AEK-COM-BLEV1
- X-NUCLEO-NFC06A1
- AEK-CON-SENSOR1
- AEK-LCD-DT028V1
- AEK-LED-21DISM1
- AEK-AUD-C1D9031

Figure 5. AEKD-TRUNKL1 architecture



2 Specifications

AEK-MOT-TK200G1

The AEK-MOT-TK200G1 board manages the linear DC and the trunk-lock motors. It also manages the trunk interior illumination and guarantees high levels of safety and reliability. In addition, the board provides the system standby functionality, where the power outputs are turned off.

The AEK-MOT-TK200G1 features:

- Hosts the automotive-grade L99DZ200G multioutput drivers and the SPC582B60E1 Chorus 1M automotive microcontroller
- Controls up to three DC motors via the L99DZ200G H-bridge gate drivers
- Supports two additional high-side outputs to drive bulbs, relays, and LEDs
- Supports CAN bus interface for remote control
- Open-load and overcurrent detection
- Thermal warning and thermal shutdown protection

AEK-SNS-2TOFM1

The AEK-SNS-2TOFM1 board opens and closes the trunk through the foot detection algorithm. It manages the foot recognition through the two embedded Time-of-Flight (ToF) sensors. At power-on, if no error occurs in the sensor initialization, the board turns on the two LEDs placed near the sensors. When the predefined gesture is performed, the two on-board green LEDs blink three times. Upon correct recognition, the microcontroller sends a CAN message to the domain/zone controller via a CAN connector.

The AEK-SNS-2TOFM1 features:

- CAN bus interface for remote control support
- Serial interface for remote communication support
- Input voltage: 12 V battery bus

AEK-COM-BLEV1

The AEK-COM-BLEV1 board is based on the BlueNRG-1 Bluetooth® Low Energy smart system-on-chip. This board is connected to a microcontroller via SPI. It sends actuation commands to the power liftgate application via Bluetooth® Low Energy and a mobile phone app.

X-NUCLEO-NFC06A1

The X-NUCLEO-NFC06A1 NFC card reader expansion board manages the frame coding and decoding in reader mode for standard NFC applications. Upon NFC tag recognition, the power liftgate opens/closes the trunk.

AEK-LCD-DT028V1

The AEK-LCD-DT028V1 board is used as a mini-infotainment GUI that shows the system status. The screen gives a simple and fast way to display data or menus when prototyping. The displayed system status depends on different events (for example, an NFC key detection).

The AEK-LCD-DT028V1 features:

- 2.8 "(240x320 pixel) TFT SPI LCD with resistive touch managed by an SPI touch screen controller available on the board
- PCB header connector interfacing with SPC5 MCU discovery boards
- 3.3V LDO voltage regulator for I/O signals

AEK-LED-21DISM1

The AEK-LED-21DISM1 board drives two LED strings to alert about the trunk opening/closing. During the actuation, the two LED strings represent the car turning lights. The same visual alert occurs when the power liftgate system detects a failure.

The AEK-LED-21DISM1 features:

- Two embedded L99LD21 high-power LED drivers able to supply four independent channels
- Output current up to 1.69 A for each channel

- Input operating voltage range from 5.5 to 24 V
- Programmable via SPI, allowing accurate LED current setting
- Protections and diagnostics for output short-circuit and open load, overtemperature, and battery undervoltage
- Automotive limp-home mode support

AEK-CON-SENSOR1

The AEK-CON-SENSOR1 board hosts an automotive 6-axis inertial module. The accelerometer is used to detect the vehicle motion both at engine on and off.

The AEK-CON-SENSOR1 features:

- Connects the AEK-MCU-C4MLIT1 MCU discovery board to the MEMS sensor boards in a DIL 24 socket
- Supports several sensors: 2-axis and 3-axis accelerometers, inclinometers
- Hosts a 1.8 V LDO voltage regulator for MEMS board supply
- Mounts a STEVAL-MKI206V1 adapter board designed to facilitate the evaluation of the AIS2DW12 MEMS: an ultra-low-power 3-axis linear accelerometer

AEK-AUD-C1D9031

The AEK-AUD-C1D9031 is a very compact acoustic vehicle alerting system (AVAS) that emits warning sounds to alert pedestrians of the presence of e-vehicles. This board generates a beep at the beginning of the trunk opening/closing process. Moreover, the acoustic alert is generated also when failures are detected.

- Embeds two FDA903D class D automotive grade audio amplifiers and an SPC582B60E1 Chorus family MCU with 1 Mb flash
- Supports audio stream via I²S interface
- Configurable through dedicated I²C bus
- Supports CAN bus interface for remote control and diagnostics
- Dedicated DC diagnostic interrupt pin to signal malfunctions
- Dedicated MUTE pin
- Open load in play detection
- Short to VCC/GND diagnostic
- Output voltage and current detection
- Thermal protection

3 Model-based design test

The model-based design main goal is to ensure that the final product meets the customer's needs and requirements through a rigorous design and testing process. You can perform development and test tasks in parallel with the system building throughout the entire process.

A defect discovered after a product release can cost up to 10 times more than fixing the defects discovered during the requirement phase. By applying a rigorous validation process at each phase of the development process, you can drastically reduce the cost of defect fixing.

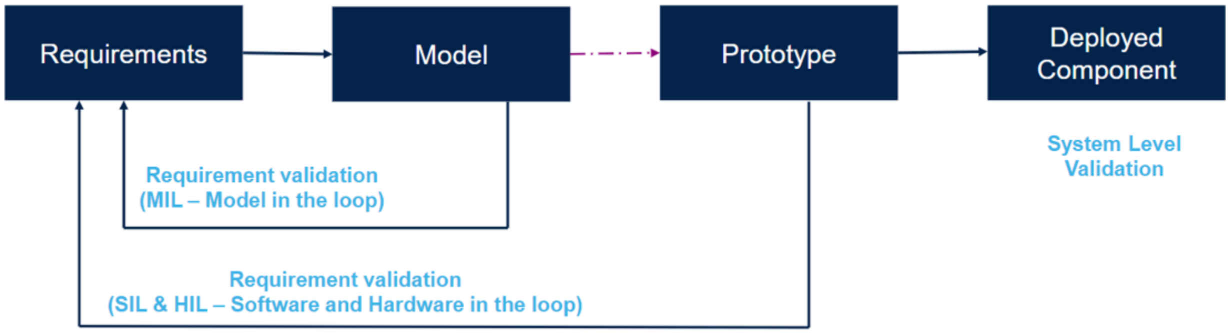
The model design approach links the requirements, design, testing, documentation, and code by using a modeling approach.

Verification and validation at every stage of the design process ensure the product quality.

Various simulation techniques are used for verification: model in the loop (MIL), software in the loop (SIL), hardware in the loop (HIL), and rapid prototyping.

The automatic code generation is another key benefit of these models. It saves costs and development time, improving the overall product quality.

Figure 6. **Model-based design workflow**

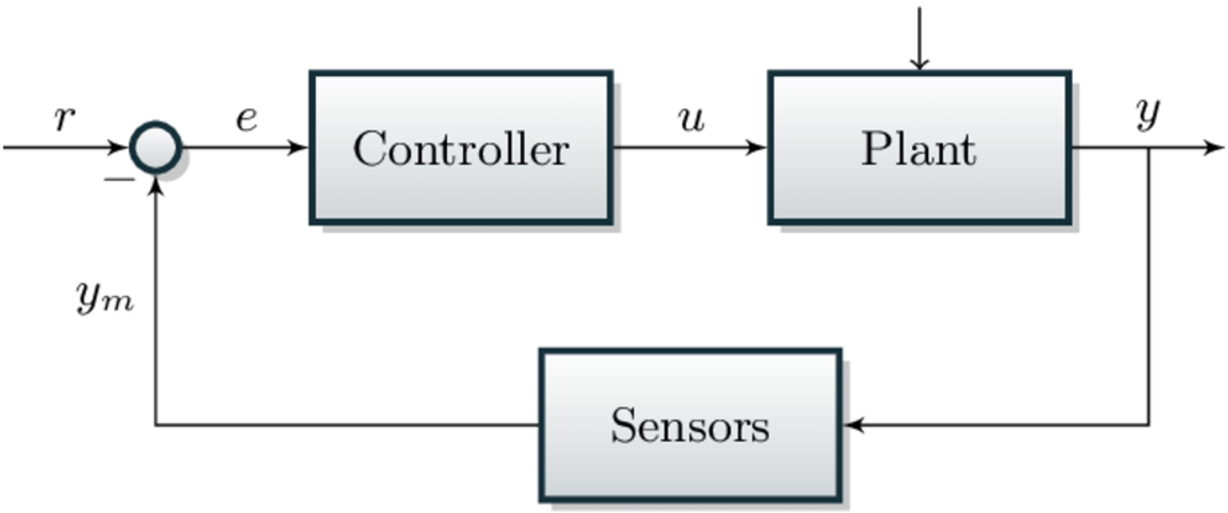


3.1 Model-in-the-loop (MIL) validation

In the model-in-the-loop (MIL) validation approach, the control algorithm model is linked to the plant in a closed loop.

This technique simulates a complete environment to test the control laws, correct mechanics, electronics. It also spots the mistakes about the model and requirements before prototyping the development phase.

Figure 7. **Closed loop system**



The reference signal (`r`) is the desired power liftgate state (locked/unlocked or open/closed). The `Sensors` block represents the linear actuators potentiometers that measure the angular position of the trunk (`Ym`). The `Controller`, implemented with the FSM modeling, generates actuations to drive both DC motors according to the error, which is calculated as the difference between `Ym` and `r`.

The MIL is a method for creating, managing, and testing the power liftgate system by using a non-intrusive test harness to evaluate the system coverage and the software requirements.

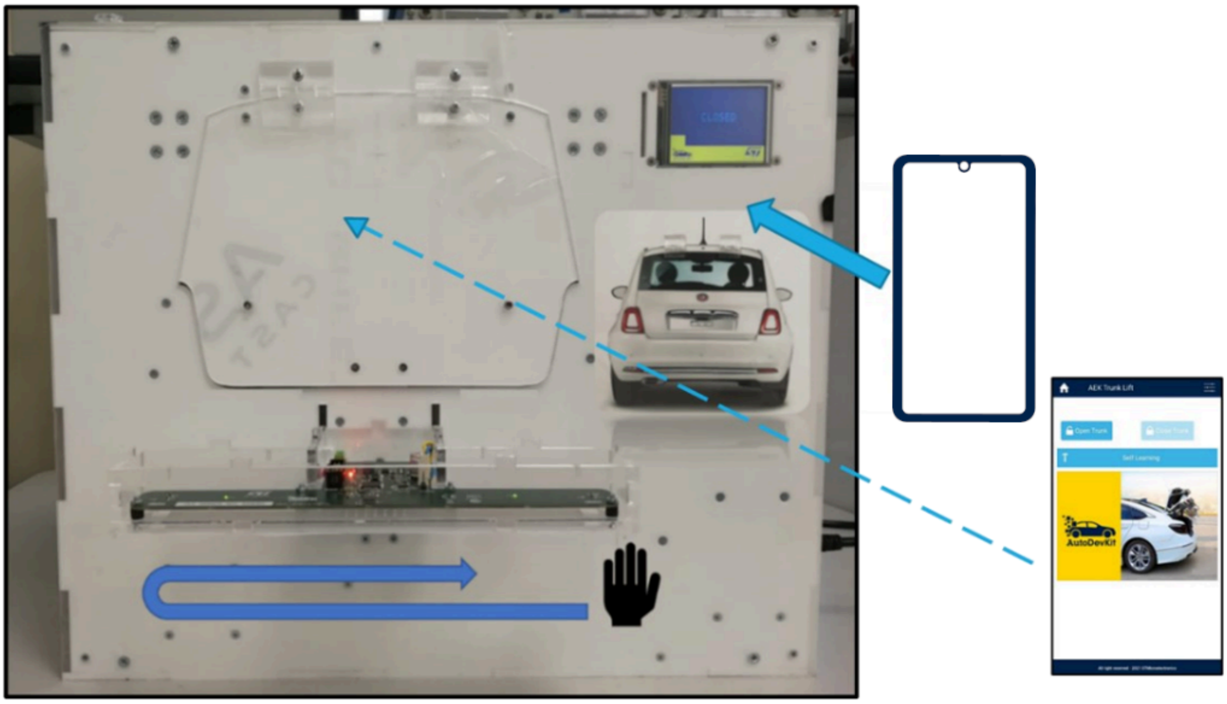
4 System validation

All the features of the power liftgate are now validated with the system mock-up.

At power-up, the power liftgate waits until an input command is received. Three different input commands can be used to open/close the trunk:

- Foot gesture detection - using the AEK-SNS-2TOFM1, you can open/close the trunk by performing a gesture with the correct sequence. The foot detection has to happen within the range of a specific time interval. For example, if it is too fast or too slow, the sequence is not recognized.

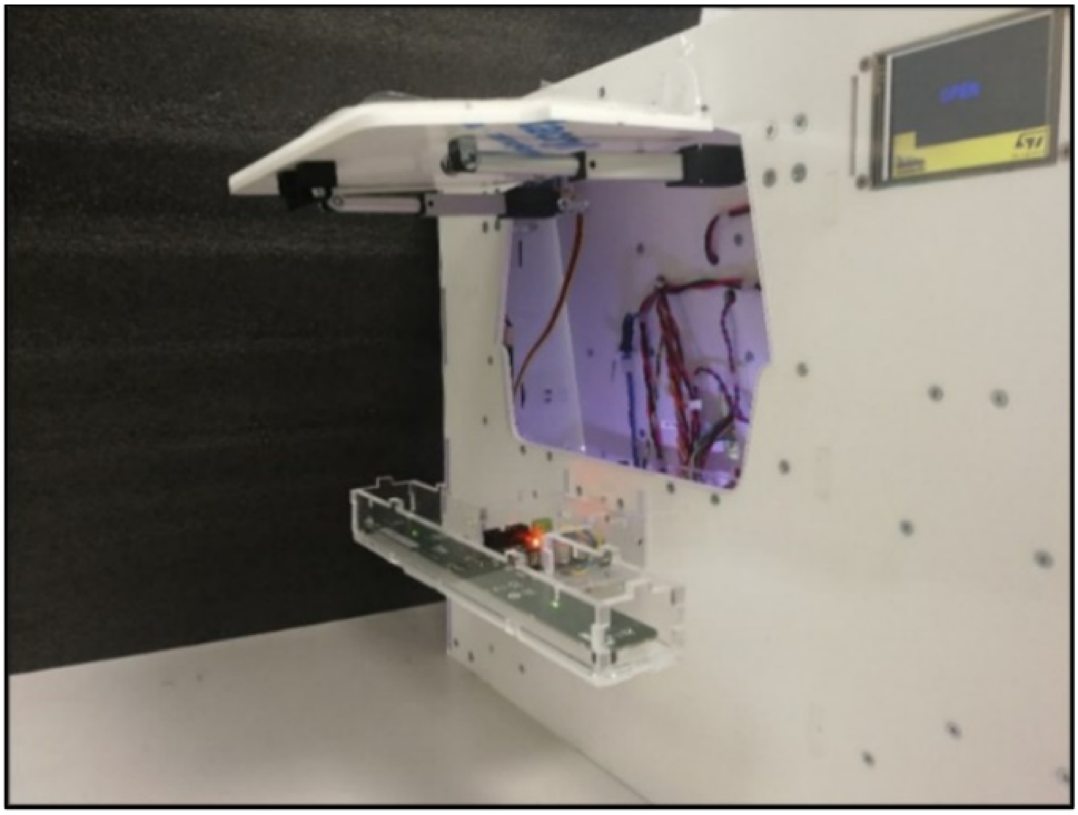
Figure 8. Trunk opening options: gesture, app, NFC



- Smartphone application - to interact with the system via Bluetooth® Low Energy (AEK-COM-BLEV1) to manage the actuations.
- NFC key - to allow a contactless tailgate opening/closing when the key is close to the power lift gate.

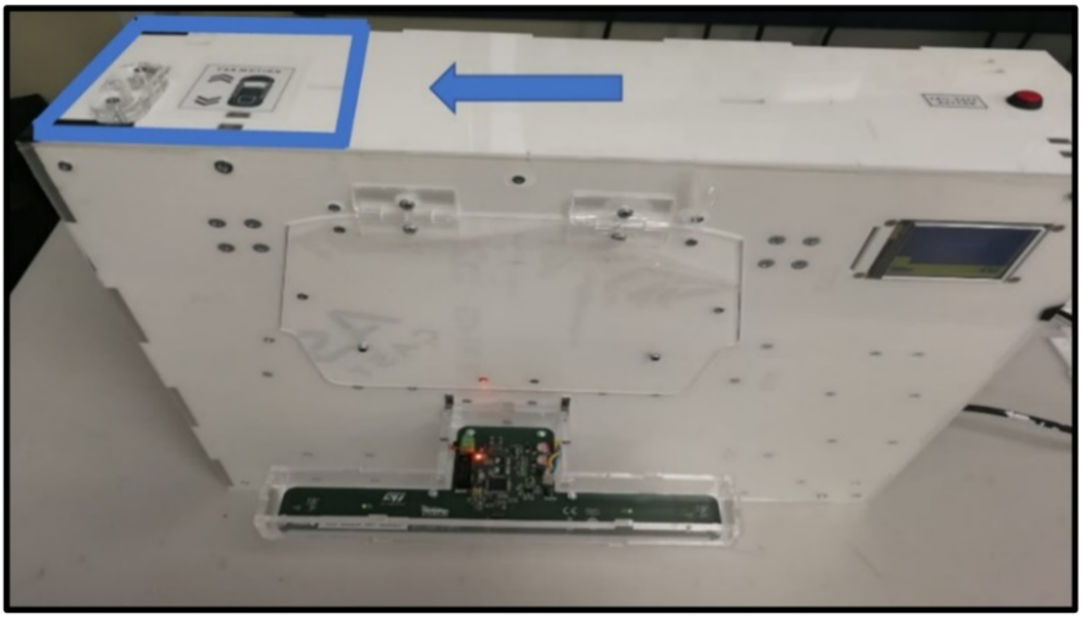
After the trunk has received the input commands, the acoustic and visual signals signal are presented and the actuation starts (opening/closing). For example, in the trunk opening phase, the power liftgate opens the trunk up to the opening thresholds. In the meantime, if another input command is received, the power liftgate stops the trunk opening. Through the same input commands, you can close the power liftgate.

Figure 9. **Power lift gate fully open**



A box that contains the motion MEMS sensor detects accelerations. This box emulates a moving car to test that the trunk actuations are disabled for safety reasons.

Figure 10. **Vehicle motion emulation**



The object detection feature has been implemented to add a safety mechanism. In fact, during the opening/closing phase, if the trunk detects an obstacle, the system stops the movement of the linear actuators and reverses the direction for a few centimeters. The next received command performs a reverse operation.

Figure 11. Obstacle detection

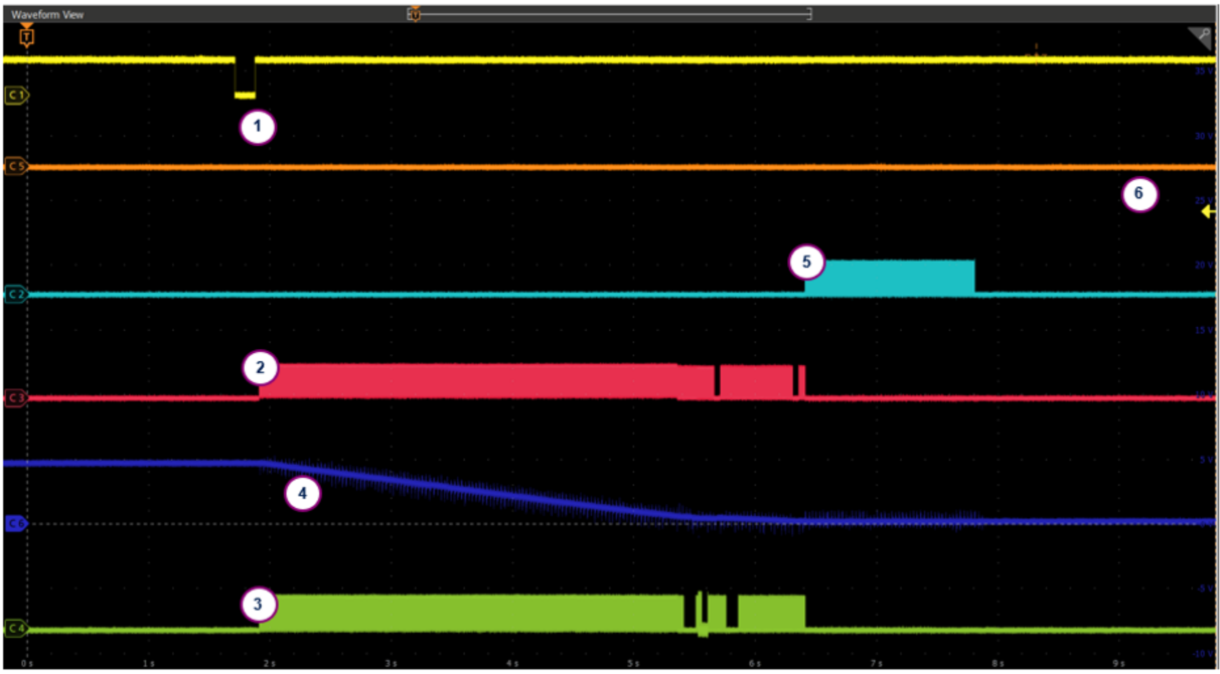
5 Power lifgate waveforms

5.1 Closing waveform

The following figure shows the waveform of the system signals in case of trunk closing via the fail-safe button.

Figure 12. Trunk closing via the fail-safe button

1. Interrupt when the fail-safe button is pushed
2. PWM signal applied to the linear actuator of the right-hand side
3. PWM signal applied to the linear actuator of the left-hand side
4. Right (or left) potentiometer signal related to the trunk positioning during the closure
5. PWM signals applied to the linear actuator during locking
6. PWM signals applied to the linear actuator in case of unlocking

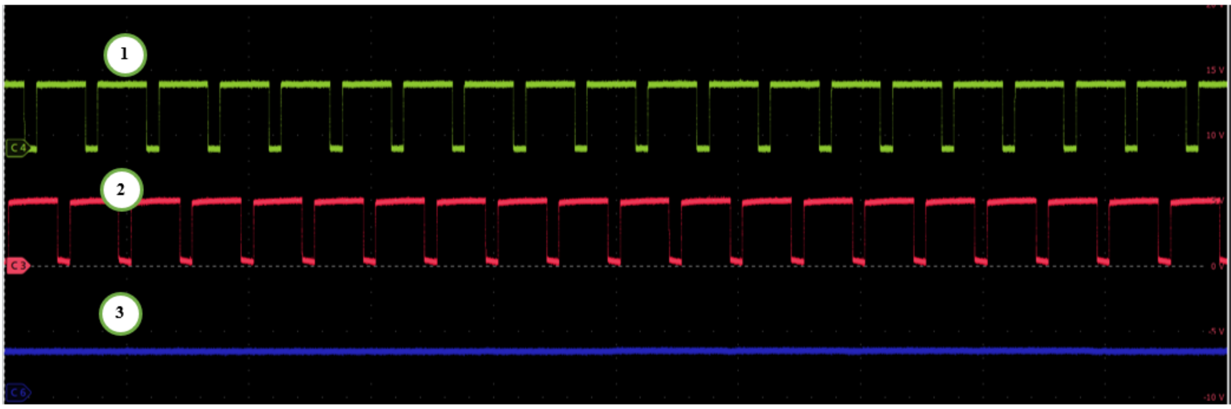


When the trunk is closed unlocking, the PWM duty cycle is equal to zero.

When the trunk is almost completely closed, the control algorithm manages the PWM signals to align perfectly with the box.

The figure below shows a zoomed view of the PWM signals applied to the right (1) and left (2) linear actuators during the closure. It also shows a zoomed view of the right (or left) potentiometer signal (3) related to the trunk positioning.

Figure 13. Zoom of the PWM signals

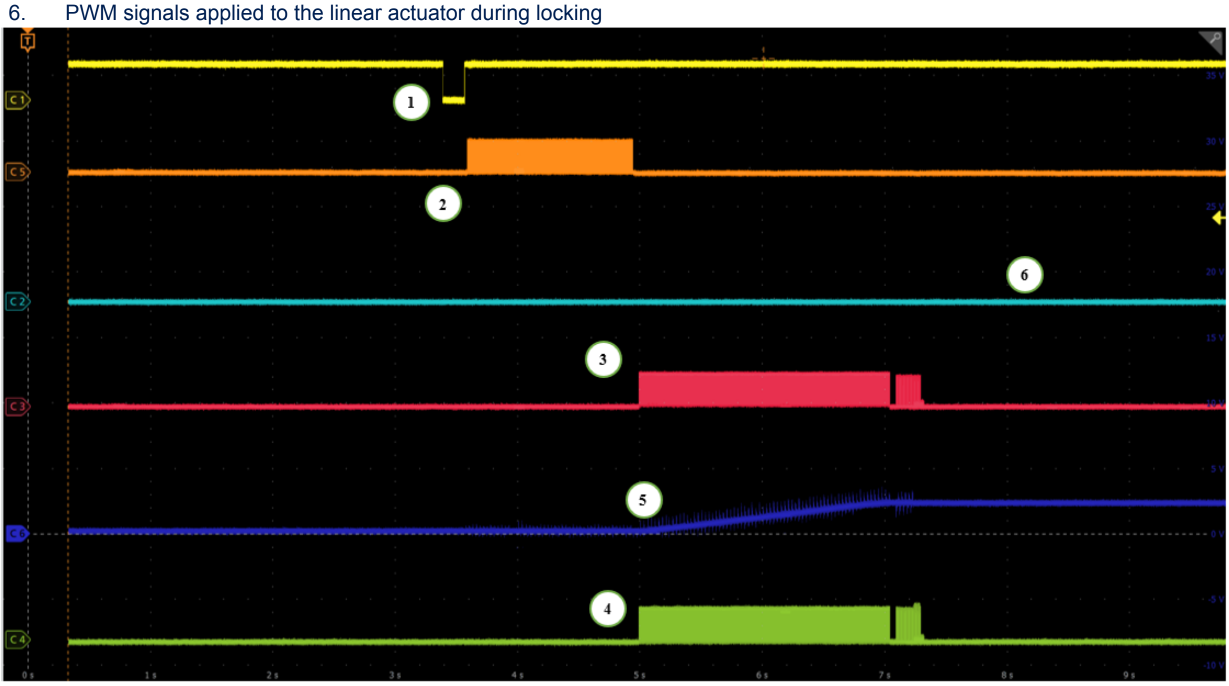


5.2 Opening waveform

The following figure shows the waveform of the system signals in case of trunk opening via the fail-safe button.

Figure 14. Trunk opening via the fail-safe button

1. Interrupt when the fail-safe button is pushed
2. PWM signals applied to the linear actuator during unlocking
3. PWM signal applied to the linear actuator of the right-hand side
4. PWM signal applied to the linear actuator of the left-hand side
5. Right (or left) potentiometer signal related to the trunk positioning during the closure
6. PWM signals applied to the linear actuator during locking

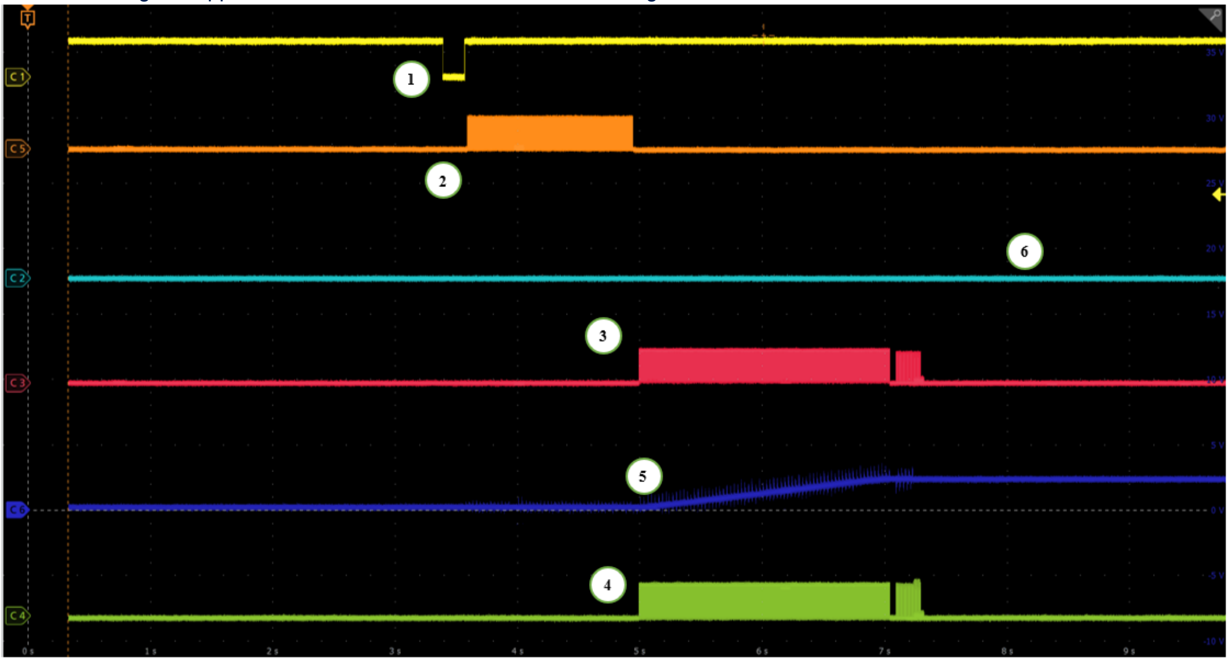


5.3 Object detection during the closing waveform

The following figure shows the waveform of the system signals when an object is detected during the trunk closing.

Figure 15. **Object detection**

1. Interrupt when the fail-safe button is pushed
2. PWM signal applied to the linear actuator of the right-hand side
3. PWM signal applied to the linear actuator of the left-hand side
4. Right (or left) potentiometer signal related to the trunk positioning during the closure
5. PWM signals applied to the linear actuator during locking
6. PWM signals applied to the linear actuator in case of unlocking



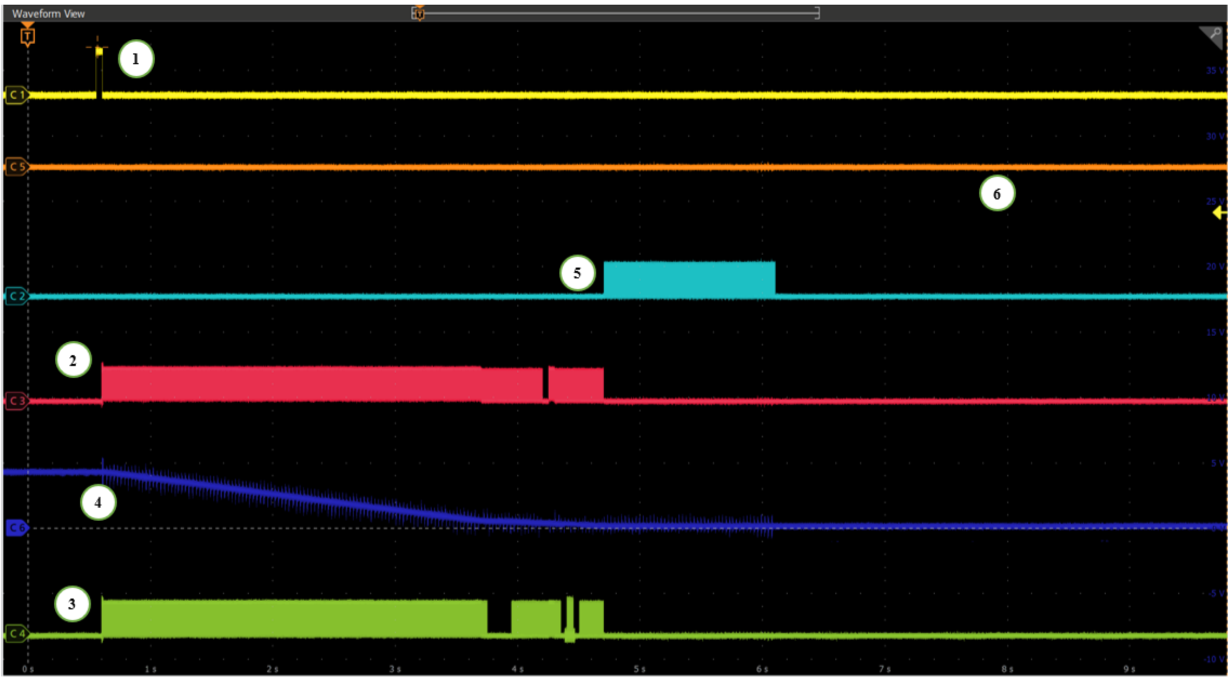
Due to the detected object during the closing, the position of the linear actuators does not reach the set point. Thus, the PWM duty cycle related to the locking is equal to zero.

5.4 NFC closing waveform

The following figure shows the waveform of the system signals in case of trunk closing via NFC.

Figure 16. Trunk closing via NFC

1. NFC interrupt signal
2. PWM signal applied to the linear actuator of the right-hand side
3. PWM signal applied to the linear actuator of the left-hand side
4. Right (or left) potentiometer signal related to the trunk positioning during the closure
5. PWM signals applied to the linear actuator during locking
6. PWM signals applied to the linear actuator in case of unlocking



6 Schematic diagrams

Note: The AEKD-TRUNKL1 kit consists of the following demo boards: AEK-MCU-C4MLIT1, AEK-MOT-TK200G1, AEK-SNS-2TOFM1, X-NUCLEO-NFC06A1, AEK-CON-SENSOR1, AEK-LCD-DT028V1, AEK-LED-21DISM1 and AEK-AUD-C1D9031. You can find their detailed schematic diagrams at the related web pages:

- *AEK-MCU-C4MLIT1 schematic diagrams*
- *AEK-MOT-TK200G1 schematic diagrams*
- *AEK-SNS-2TOFM1 schematic diagrams*
- *X-NUCLEO-NFC06A1 schematic diagrams*
- *AEK-CON-SENSOR1 schematic diagrams*
- *AEK-LCD-DT028V1 schematic diagrams*
- *AEK-LED-21DISM1 schematic diagrams*
- *AEK-AUD-C1D9031 schematic diagrams*

7 Bill of materials

Note: The AEKD-TRUNKL1 kit consists of the following demo boards: AEK-MCU-C4MLIT1, AEK-MOT-TK200G1, AEK-SNS-2TOFM1, X-NUCLEO-NFC06A1, AEK-CON-SENSOR1, AEK-LCD-DT028V1, AEK-LED-21DISM1 and AEK-AUD-C1D9031. You can find their detailed bill of materials at the related web pages:

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- *AEK-MOT-TK200G1 bill of materials*
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- *X-NUCLEO-NFC06A1 bill of materials*
- *AEK-CON-SENSOR1 bill of materials*
- *AEK-LCD-DT028V1 bill of materials*
- *AEK-LED-21DISM1 bill of materials*
- *AEK-AUD-C1D9031 bill of materials*

8 Conclusions

The aim of the AEKD-TRUNKL1 mockup is to manage and automate the car trunk opening/closing while simplifying the trunk access.

We have also shown that a model-based design approach allows a final product to meet the customer's needs and reduce any design and testing errors.

Appendix A Reference design warnings, restrictions and disclaimer

Important: The reference design is not a complete product. It is intended exclusively for evaluation in laboratory/ development environments by technically qualified electronics experts who are familiar with the dangers and application risks associated with handling electrical/mechanical components, systems and subsystems.

Danger: *Exceeding the specified reference design ratings (including but not limited to input and output voltage, current, power, and environmental ranges) may cause property damage, personal injury or death. If there are questions concerning these ratings, contact an STMicroelectronics field representative prior to connecting interface electronics, including input power and intended loads. Any loads applied outside of the specified output range may result in unintended and/or inaccurate operation and/or possible permanent damage to the reference design and/or interface electronics. During normal operation, some circuit components may reach very high temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be identified in the reference design schematic diagrams.*

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You further acknowledge and agree that the reference designs may not be used in or in connection with any legal or administrative proceeding in any court, arbitration, agency, commission or other tribunal or in connection with any action, cause of action, litigation, claim, allegation, demand or dispute of any kind.

Revision history

Table 1. **Document revision history**

Date	Revision	Changes
04-Jul-2022	1	Initial release.

Contents

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