Self-starting Safety Check Procedure of Autonomous Car Using Sensor Technology

ECE 59500
Autonomous Embedded Systems

Submitted by:

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Introduction:

According to a report by AAA, 87 percent of drivers exhibit unsafe behaviors while driving [1]. Therefore, autonomous cars are being hailed as the future of safe commute. Most vehicles right now offer second level of autonomy (only certain features such as acceleration or steering are automated in certain conditions), while some car manufacturers have previously announced level three autonomous cars to launch in 2018 [2]. Recent researches in the autonomous driving domain have focused on ensuring the safety of driver, passengers, other cars and pedestrians on road.

For level three autonomous vehicles, a driver still must be ready to intervene in case of emergency situations that this generation of autonomous cars cannot handle yet. Therefore, before an autonomous car starts itself, it is important to ensure that the driver is safely in his seat and is not under the influence of alcohol. In this project, we propose a sensor-based safety check procedure before an autonomous car starts itself. When the car receives an instruction to start, the driver seat belt is fastened, and the driver is alcohol free. If these two conditions are satisfied, the motor will start itself.

We have developed a simple prototype of this project using NXP S32K144EVB Evaluation Board. Alcohol gas sensor MQ-3 checks that the driver is not under the influence of alcohol. The seat belt is represented using a small magnet, and a hall effect sensor checks whether the seat belt is fastened based on the proximity of the magnet to the hall sensor. The evaluation board takes input from these two sensors. The car motor is represented by a DC motor. If both ‘alcohol free’ and ‘seat belt fastened’ conditions are satisfied, then the board sends an ON signal to the motor switching circuit (comprising of two BJTs and a diode) and the motor is started.

Hardwire Specifications and Technical Details:

- NXP S32K144EVB Evaluation Board
- MQ-3 Alcohol Ethanol Gas Sensor Module
- Hall Effect KY-003 Magnetic Sensor Module
- BC547B NPN General Purpose Transistors (2 pieces)
- 1N4007 General Purpose Rectifier (1 piece)
- DC Motor
- S32 Design studio for ARM v1.3

System Block Diagram:

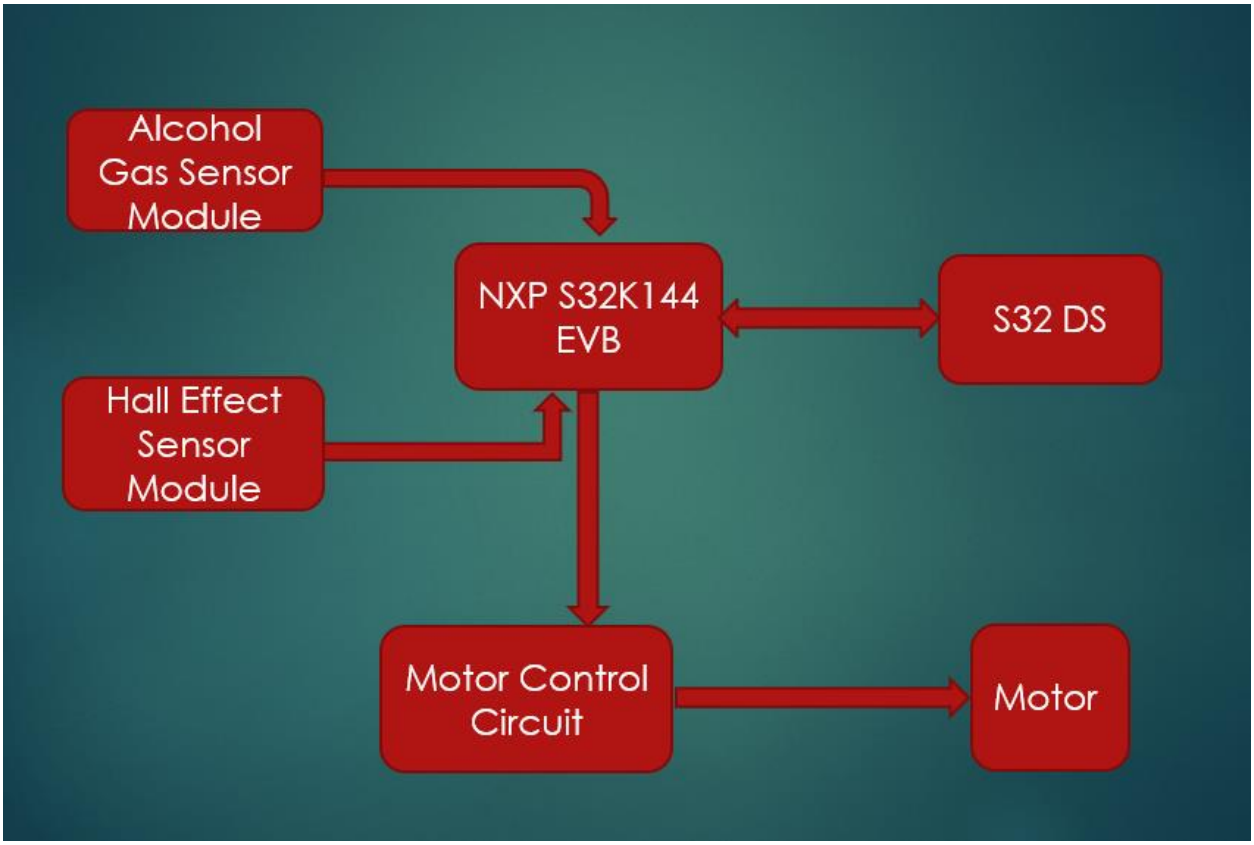


Figure 1: Block diagram of the system

NXP S32K144EVB Evaluation Board:

NXP Semiconductors S32K144EVB Evaluation Board provides a powerful and flexible development system for the NXP S32K144 Microcontroller (MCU). The S32K144EVB features test headers, CAN and LIN communication Bus, user buttons, a potentiometer, touch electrodes, and a pre-mounted S32K144 MCU. The S32K144EVB comes with the MSD Flash Programmer Open SDA Application preinstalled. Open SDA is an open-standard serial and debug adapter. This GUI debug utility provides an easy and convenient way to program applications into the S32K144 MCU. S32 Design Studio IDE can also be used with the S32K144EVB. S32 Design Studio IDE is a complimentary integrated development environment for Automotive and Ultra-Reliable MCUs that allows editing, compiling, and debugging of designs.

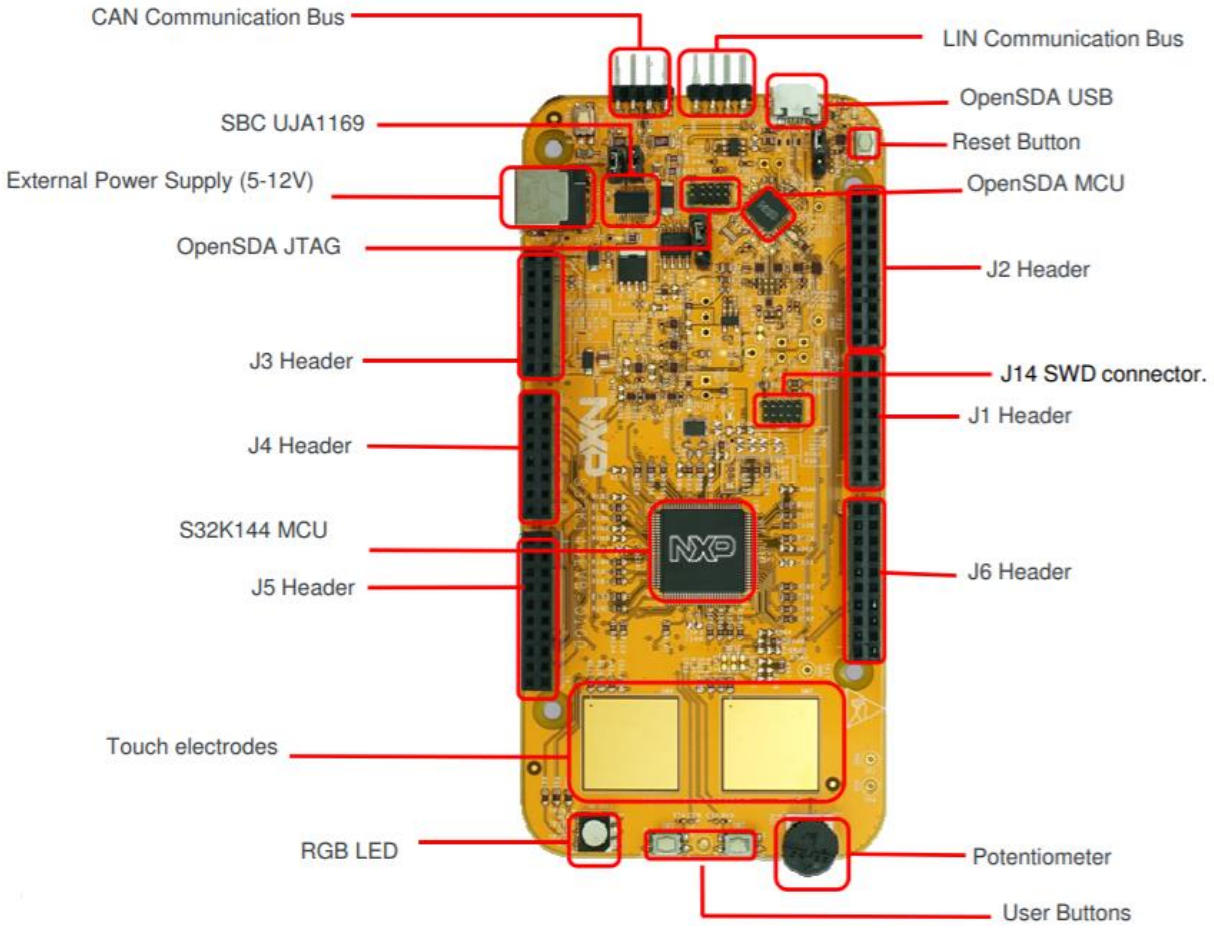


Figure 2: S32K144EVB Evaluation Board

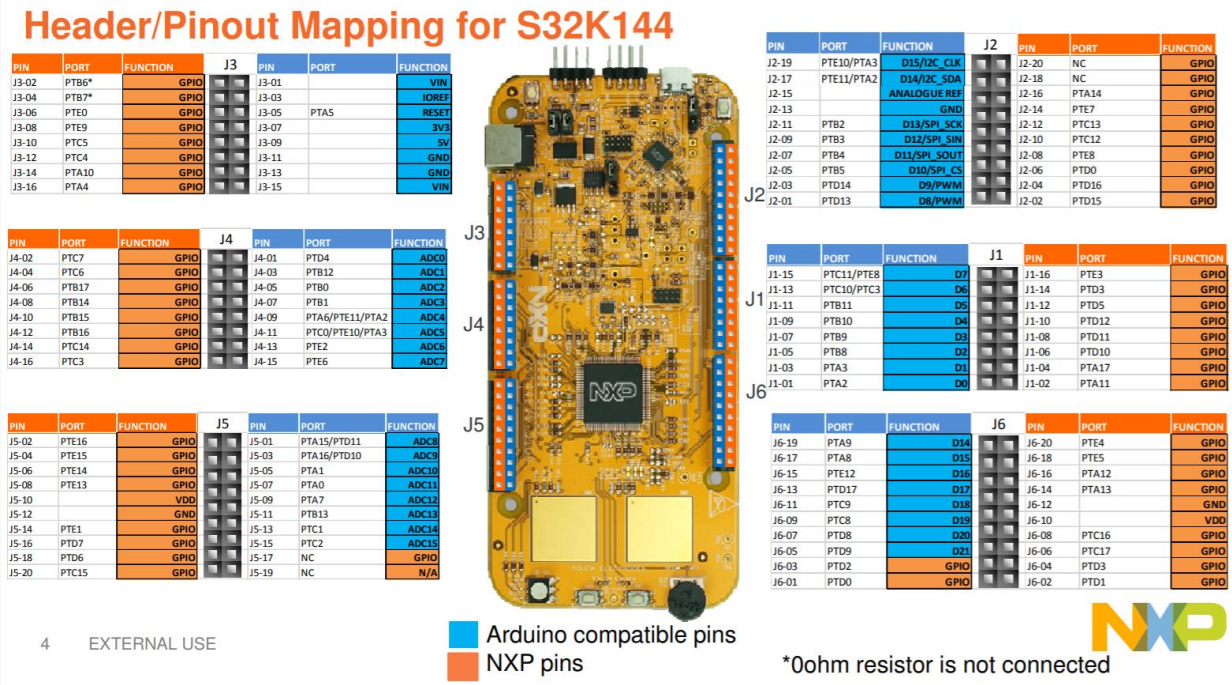


Figure 3: Header/Pinout Mapping for S32K144

MQ-3 Alcohol Ethanol Gas Sensor Module:

The MQ-3 Alcohol Ethanol Gas Sensor Module is a low-cost semiconductor sensor which can detect the presence of alcohol gases at concentrations from 0.05 mg/L to 10 mg/L. The sensitive material used for this sensor is SnO2, whose conductivity is lower in clean air. Its conductivity increases as the concentration of alcohol gases increases. It has high sensitivity to alcohol and has a good resistance to disturbances due to smoke, vapor and gasoline. This module provides both digital and analog outputs.

This alcohol sensor is suitable for detecting alcohol concentration in a person's breath. It has a high sensitivity and fast response time. This sensor provides an analog resistive output based on alcohol concentration. The drive circuit is very simple, all it needs is one resistor. A simple interface could be a 0-3.3V ADC.

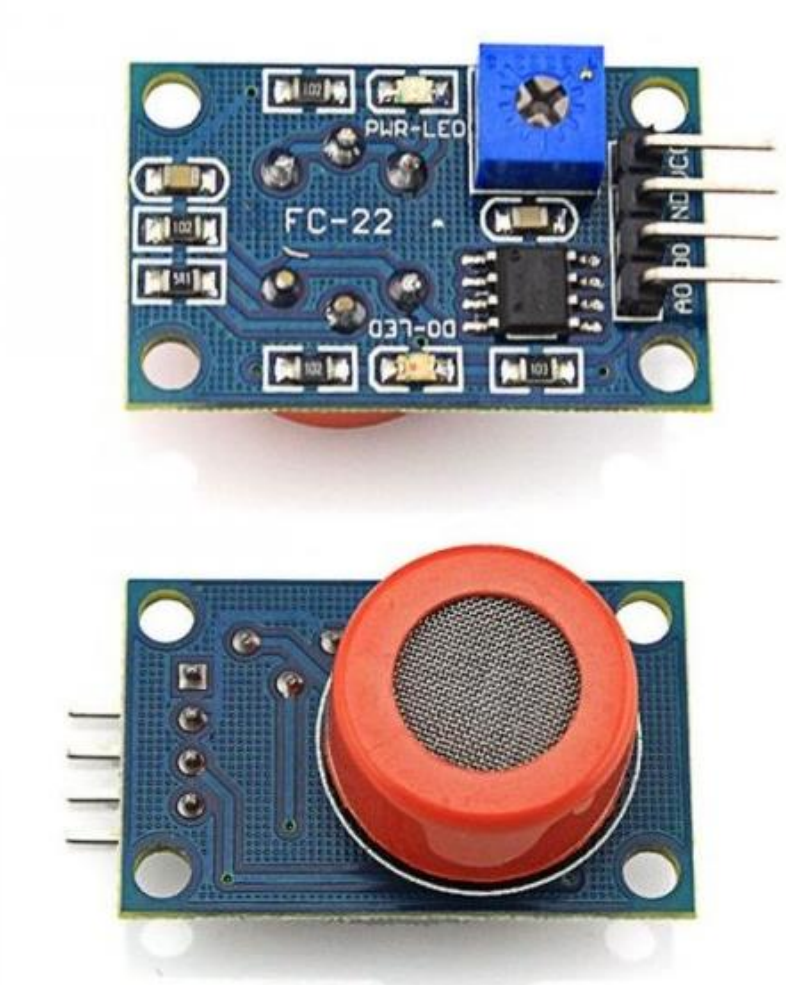


Figure 4: MQ-3 Alcohol Gas sensor

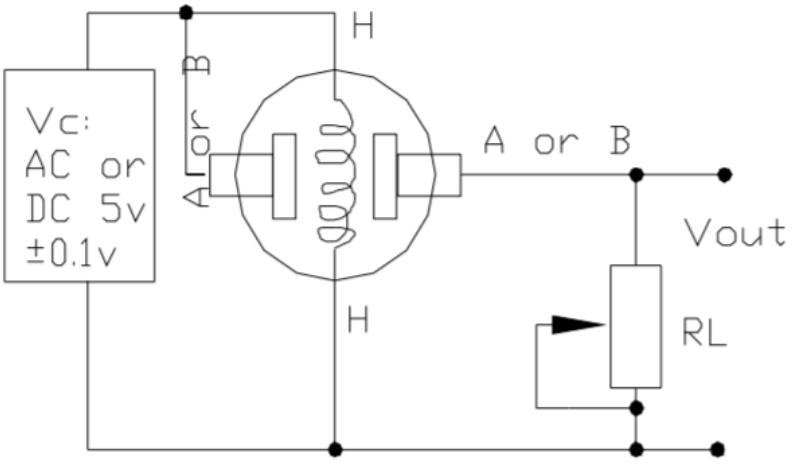


Figure 5: MQ-3 Circuitry

KY-003 Hall Magnetic Sensor Module:

The KY-003 is a magnetic switch. If no magnetic field is present, the signal line of the sensor is HIGH (3.5 V). If a magnetic field is presented to the sensor, the signal line goes LOW, at the same time the LED on the sensor lights up. The polarity of the magnetic field influences the switching action. The front side of the sensor needs the opposite polarity as the back of the sensor to switch on.

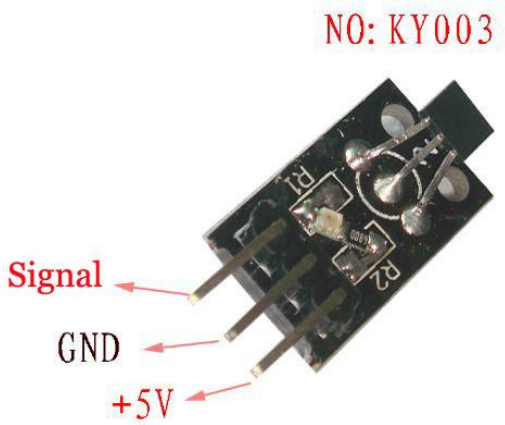


Figure 6: KY-003 Hall magnetic sensor module and pin layout

DC Motor:

We used a standard 130-size DC hobby motor. The rated voltage is 4.5 V and the operating range is 3-6 V.

Figure 7: DC motor

Motor Switching Circuit:

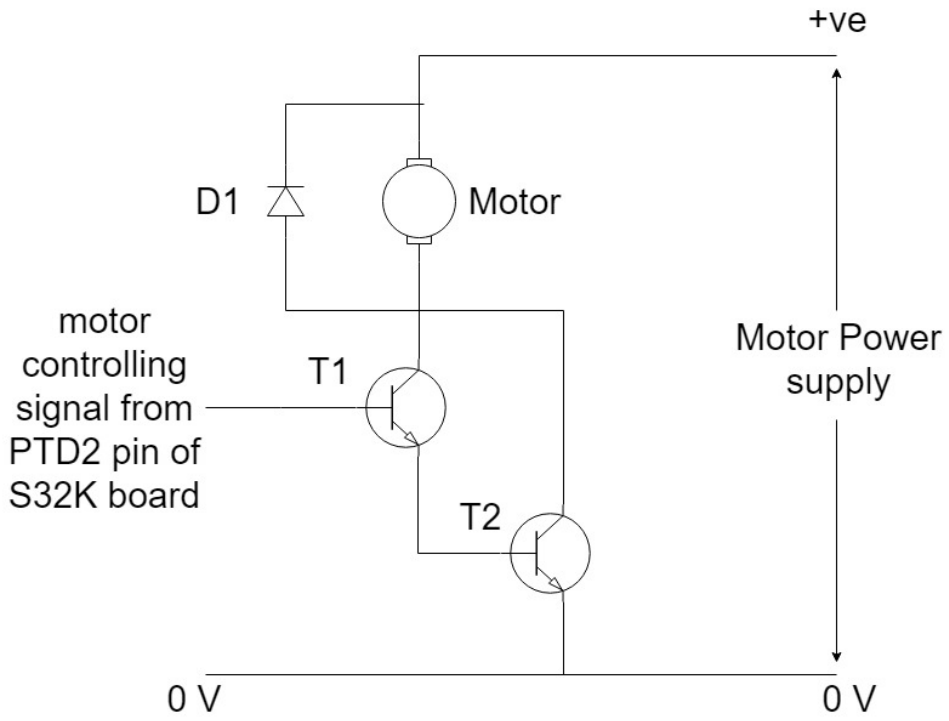


Figure 8: Motor switching circuit

Here two transistors have been used in a configuration known as a Darlington pair. The load current is taken by T2 and T1 is used to turn it on. Note that the ground has to be common (connected together) between your external supply and the Arduino. A motor is basically and electromagnet or coil, in electronic terms this is an inductor. When the power is suddenly removed, the magnetic field collapses because there is no current flowing to keep it up. This collapsing field then produces a back EMF or reverse voltage that can be several hundred volts in size. This can damage the electronics connected to the rest of the circuit. To avoid this, a diode is placed across the motor to short this out. In our case, we used two BC547B Transistors and one 1N4007 diode.

System Implementation procedure:

1. MQ-3 alcohol gas sensor has four pins: 5V Voltage, Ground, Digital output (D0), and analog output (A0). Connect 5V pin, Ground pin and digital output pin to S32k144 board where D0 should be connected to PTC12 pin of S32k144 board.
2. KY-003 Magnetic sensor has four pins: 5V Voltage, Ground, Digital output (D0), and analog output (A0). Connect 5V pin, Ground pin and digital output pin to S32k144 board where D0 should be connected to PTC13 pin of S32k144 board.
3. In S32 Design studio IDE PTC12, PTC13 pins of S32k144 board will be declared as input and PTD2 pin of S32k144 board will be declared as output. Register level Embedded C programming is used in S32 Design studio to develop logic to get desired output.
4. Motor needs motor controlling circuit for switching and current controlling. Darlington pair circuit was used. Two N-P-N transistors are connected back to back. A general-purpose diode is used in reverse connection and in parallel to motor. Motor's positive is connected to positive 5V supply from board and negative is connected to common keeping scope of arrangement for Darlington pair and reversed diode. Output pin PTD2 is connected to motor through motor control circuit.

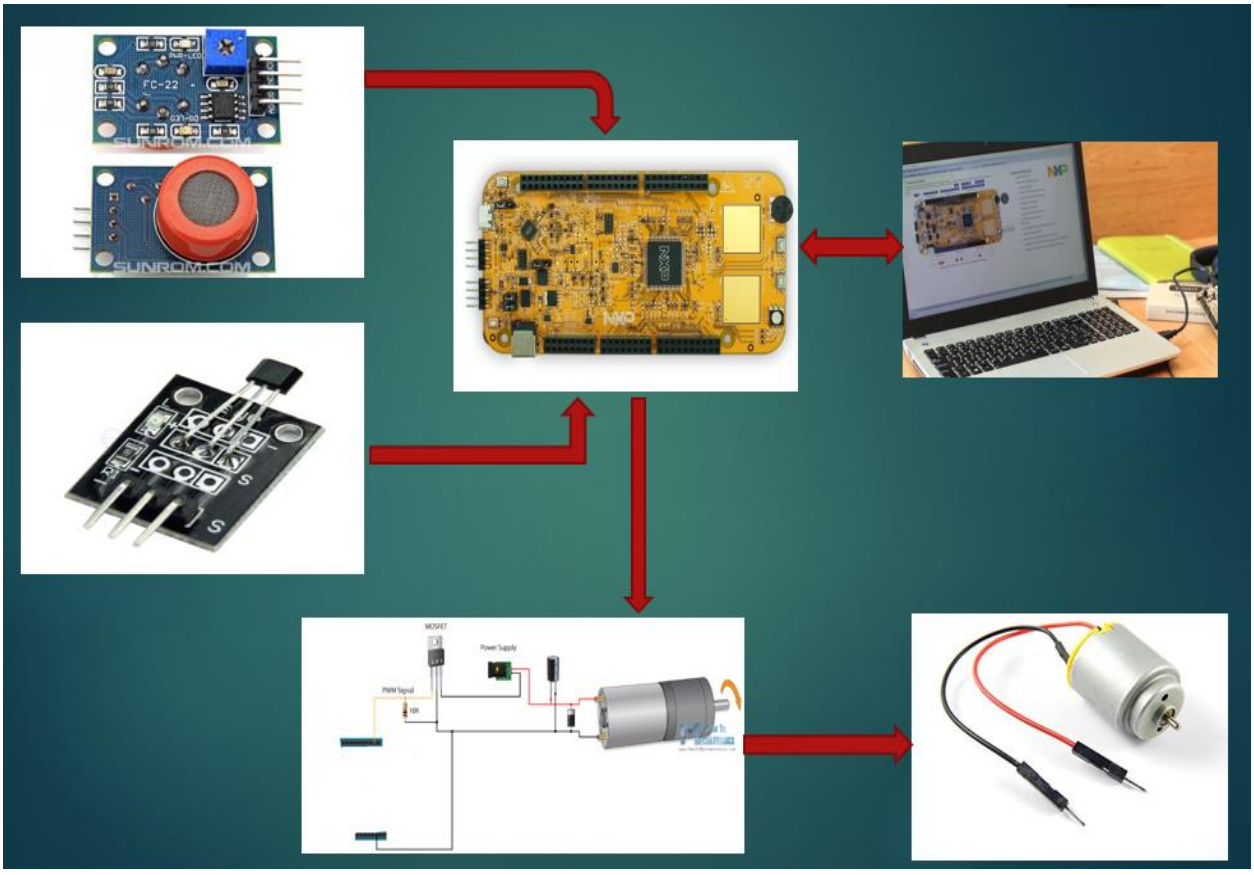


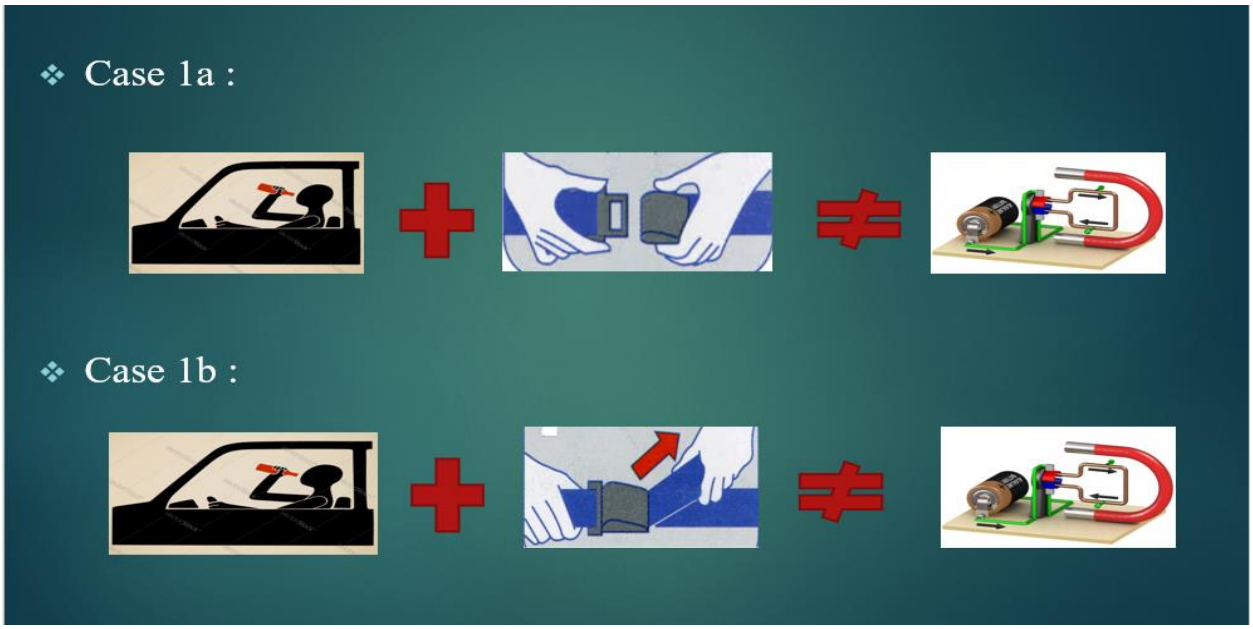
Figure 9: System Implementation procedure.

5. S32 DS IDE from laptop is connected using a USB cable to S32k144 board.
6. From S32 DS IDE code is built and debugged to have the logical instructions for working the S32k144 board with motor.
7. The whole project is saved in specific path in c drive and can be opened from “Autonomous Project” folder and opening the main.c file.
8. For specific conditions if the motor runs then it can be verified that project is running successfully.

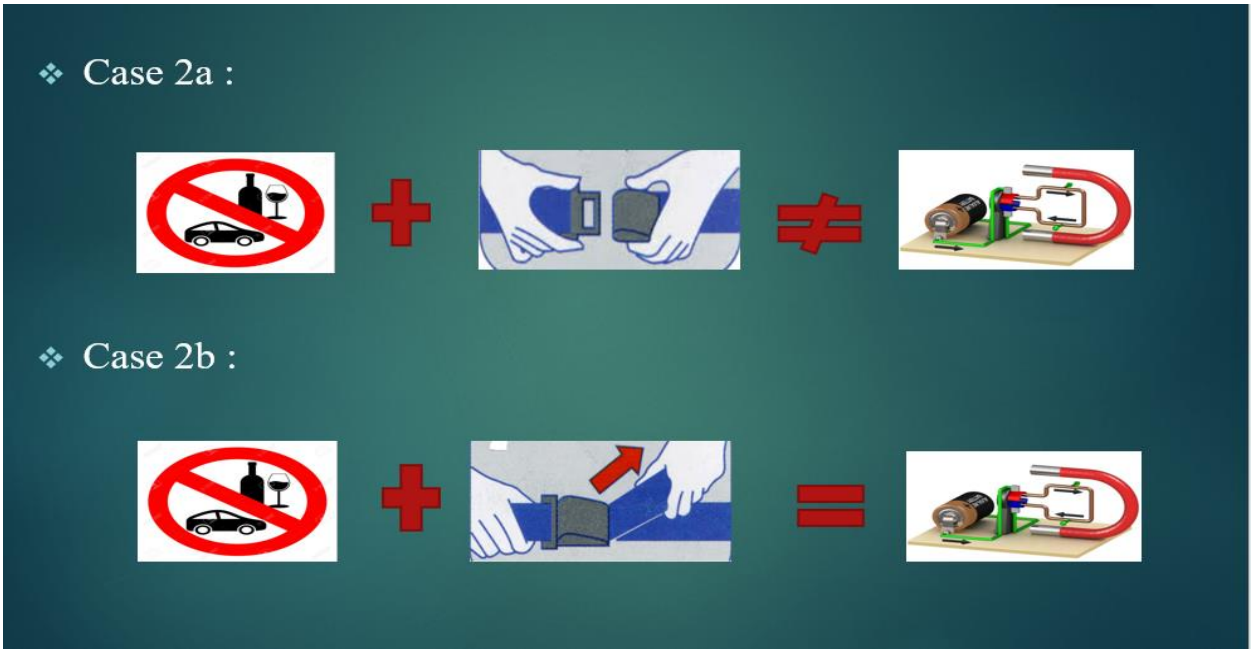
Result Evaluation:

Total result can be divided into two cases, which are described below.

- Case 1: It has two more sub sections:
  - I. Case 1a: When driver is drunk and no seat belt so, motor is off
  - II. Case 1b: When driver is drunk and seat belt so, motor is off



- Case 1: It has two more sub sections:
  - III. Case 2a: When driver is not drunk and no seat belt so, motor is off
  - IV. Case 2b: When driver is not drunk and seat belt so, motor is on



Challenges Faced:

- Interfacing Sensors with S32k144 EVB.
- Sensitivity of sensors.
- Register level coding for S32k144 using Embedded C.

Conclusion and Future Scope:

Our motive was to design a working prototype of the safety check procedure of a self-starting autonomous car. We have incorporated two sensors to ensure that the driver is alcohol free and the seat belt is fastened. We believe these safety measures can increase the possibility of a safe commute.

There is lot of scope for making this system more robust. One possible direction can be to incorporate even more safety check procedures (such as checking tire pressure, fuel level, door lock, wiper, parking brake etc.) by means of using more sensors. Besides, there is room for communication between the MCU and the GPS navigations system, where the safety check procedure will start after the passenger/driver has given a destination address. Besides, motor controller shield can be used for motor control to ensure that the car is within the speed limit in certain special places (such as parking lots, school zones etc.).

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[3] NXP S32K144 EVB User Manual

[4] ECE 59500 Autonomous Embedded Systems Course Laboratory Manual