ISSN:2229-6093

Wojciech SALABUN et al, Int.J.Computer Technology & Applications,Vol 6 (4),636-641

A Mobile Gas Detector with an Arduino Microcontroller

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Abstract

This paper describes hardware synthesis for a mobile gas detector with an Arduino microcontroller. The main aim of this project is to find the dangerous zone where many stationary detectors are unpractical or too expensive. Thus, we present a self-propelled robotic gas detector. The project specification is presented in accordance to the expected functionality of the detector. Based on this specification hardware, the proper elements are selected and described. Finally, we propose a hardware scheme for the mobile gas detector project and discuss advantages and disadvantages of this approach.

1. Introduction

The uncontrolled leak of different gasses can be very dangerous for human life and health, e.g., carbon oxides lead to suffocation and natural or liquefied petroleum gas lead to fires or explosions [12, 25]. These examples of incidents annually consume many lives and expose the company to great financial losses [13, 16]. Therefore, engineers and scientist constantly create new systems to prevent these type of incidents [15].

In this paper, we describe hardware synthesis for a mobile gas detector to find the dangerous zone where many stationary detectors are unpractical or too expensive. Therefore, we create hardware synthesis of a simple self-propelled robot to detecting dangerous gas. In the project, we put the greatest emphasis on collecting, processing, and sending data. For this purpose, the Arduino microcontroller is used as a popular, effective, low-cost device. This platform was used in many scientific projects, e.g., oceanographic research applications, sailing applications, environmental monitoring applications, wireless sensor motes for data-intensive applications, glucose measurements and micro-incubator applications [1, 3, 4, 6, 19, 24].

The rest of paper is set out as follows. Section 2 presents the project specification. There is shown the fundamental functionality and restrictions. Next, we select and describe each hardware device in Section 3. The hardware scheme for the mobile gas detector and short discussion are presented in Section 4. Finally, Section 5 presents concluding remarks.

2. The Expected Functionality

In this section, we present a project specification at a high level of generality, without details. First of all, we establish the functionality of our project. It is necessary to design the scheme of the prototype of the mobile gas detector.

The designed system has to collect data on the amount of gas in the nearest surroundings, e.g. natural gas, carbon monoxides, etc. For this purpose, electrochemical sensors should be used. Subsequently, the designed device has to have an own autonomous drive. It is very important because the detector should be moving in a larger area to find the dangerous zone. Collected data have to send to the server, where these data will be analyzed. In conclusion, the designed system has to:

- collected data,
- moving around,
- sending data to the server.

3. Hardware: Brief Preliminaries

In this section, we introduce the brief preliminaries on hardware devices which are used in proposed project. All electronics parts are selected to providing previously declared functionality.

ISSN:2229-6093

3.1 The Arduino Microcontroller

Arduino is an open-source prototyping platform designed to be easy to use for beginners who have no software or electronic high-level experience. It can be used to develop interactive objects that can respond to signals from the surrounding environment. This microcontroller can control a variety of things such as buttons, motors, GPS units, LEDs, sensors, cameras and many more [14, 22].

The Arduino microcontroller can be programmed using Arduino integrated development environment (IDE). To load a new code onto the board Arduino does not need a separate hardware – just connect the USB cable. This platform is used by many tinkerers around the world for building electronics projects, so there is a lot of information and source code available. However, this controller is also used by many scientific workers [7, 9, 14, 21, 25].

There are many different types of Arduino boards. One of them is Arduino Mega 2560 which is preferred for this project because this platform has the 4 UARTs (hardware serial ports). This microcontroller is shown in Fig. 1.

The following elements of specifications are the most important for design our project [2]:

- operating voltage is 5V, but the input voltage should be not less than 7V and not higher than 12V,
- 54 digital input/output pins is available, and 15 of them can be used as Pulse Width Modulation (PWM) outputs,
- 16 analog inputs - are used to measure electrical signal with a defined range that is generated by a sensor and received by a controller,
- 4 UARTs hardware serial ports (Universal Asynchronous Receiver and Transmitter),
- 16MHz crystal oscillator - is used to provide a clock input to Arduino microprocessor (20pF capacitance and +/- 50ppm stability),
- USB connection - is used to communication,
- power jack - is used to external power supply,
- ICSP header - provides fast prototyping,
- DC current per I/O Pin 20mA,
- DC current for 3.3V Pin 50mA,
- flash memory 256 KB.

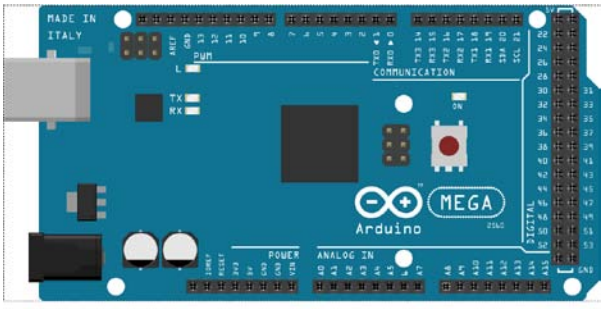

Fig. 1. The microcontroller Arduino Mega 2560.

Fig. 2. The HC-SR04 ultrasonic distance sensor.

3.2 The Ultrasonic Distance Sensor

One of the commonly used sensor for ultrasonic distance measurement is the HC-SR04 sensor [10, 17, 20, 22, 18, 23], which is presented in Fig. 2. This ultrasonic sensor provides an easy and effective method of distance measurement. The following four steps present how this device working:

1. To initiate the HC-SR04 sensor, TRIG must receive a pulse of high (5V) for at least 10us.
2. The sensor will transmit out 8 cycles of ultrasonic burst and wait for the reflected ultrasonic burst.
3. ECHO pin will set to high (5V) when a sensor detected ultrasonic from the receiver.
4. The distance depends on the duration of the high level on ECHO pin.

The following formula is used to calculate measuring distance (1):

$$d = 0.017\, t \qquad (1)$$

where: d is a distance in cm and t is a high-level time in μs.

ISSN:2229-6093

The aim elements of specifications for the HC-SR04 sensor are presented as follows [8]:

- power supply 5V DC (+/- 10%),
- working Current 15mA (+/- 10%),
- ranging distance 2cm – 400cm,
- measuring angle 30 degree.

There is an Arduino library for the HC-SR04 called NewPing library which is useful and easy-to-use. Furthermore, this library enables to work with multiple sensors and it can interface with Arduino using only one pin. If we want use only one pin we must connect echo to trigger by using a 1.8kΩ resistor or similar, then a device is connected to Arduino by a single pin.

3.3 Wi-Fi Module

Wi-Fi Module based on an ESP8266 chip offers a complete Wi-Fi networking solution for mobile platform designers, which is presented in Fig. 3. The module is designed for low power consumption therefore works in three modes:

- active mode,
- sleep mode, and
- deep sleep mode.

The ESP8266 using advanced power management techniques so it is not required to control switching between modes. Specifications of ESP8266 module [5]:

- power supply 3.3V,
- 802.11 b/g/n protocol,
- Wi-Fi direct (P2P), soft-AP,
- integrated TCP/IP protocol stack,
- power down leakage current of less than 10uA

It runs off 3.3 V only and can be powered off Arduino's 3.3V pin. One of the problems can be that Arduino speaks in 5V and ESP8266 speaks 3.3V so there are two possibilities for working together. The first one – use a voltage divider circuit to divide 5V source from Arduino to 3.3V for Wi-fi module. The second one which is recommended - logic level shifter. Fig. 5. presents the wiring diagram for the second solution. Another problem is the choice of matching baud rate for serial comms. Arduino and ESP8266 need 2 serial ports: 2 hardware serials or 1 hardware 1 software. Therefore, the Arduino Mega 2560 is preferred.

3.4 Logic Level Shifter

The sparkfunlogic level shifter is a device that can shift 3.3V up to 5V or 5V down to 3.3V. It will protect devices working on 3.3V from damage which are connected to the Arduino. Fig. 4. presents the logical wiring schematic.

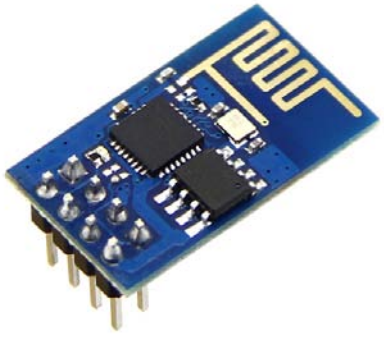

Fig. 3. Wi-Fi module based on ESP8266.

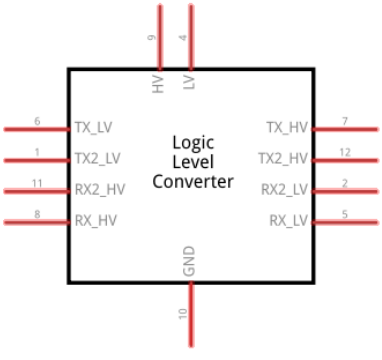

Fig. 4 The scheme of the logic level shifter.

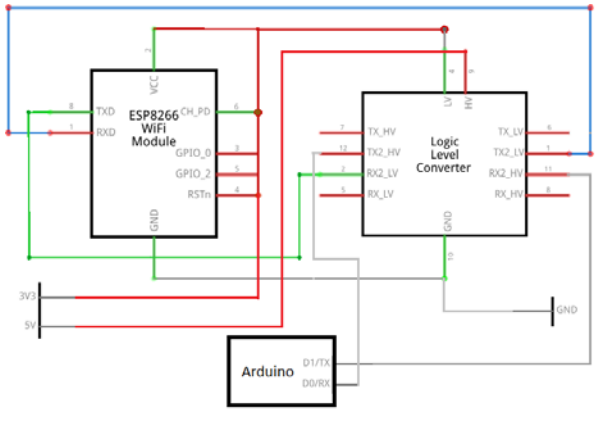

Fig. 5. Wiring diagram for ESP8266 with the Arduino by using the logic level converter.

ISSN:2229-6093

3.5 Gas Sensors

The MQ series of gas sensors use a small heater inside with an electrochemical sensor that change sensitivity for a range of gasses. When sensor works in the clean air, its conductivity is lower than when gas exists. The conductivity increases with the gas concentration rising. The Table 1. presents the list of MQ sensors with the target gas.

3.6 Motor Driver

The L9110S module is a compact board that can be used to control 2 motors at the same time. The system can change the direction of rotation of the motors by a digital output and speed regulation by PWM signal. The motor driver can be operated from 2.5 to 12V and has two a large current driving capability, each channel through 800mA of continuous current [11]. Pin configuration is as follows:

1. B-IA – Motor B input A
2. B-IB – Motor B input B
3. GND – Ground
4. VCC – 2.5V – 12V
5. A-IA - Motor A Input A
6. A-IB - Motor A Input B

Table 1. List of MQ sensors and target gas.

Model	Target Gas
MQ2	Sensitive for Methane, Butane, LPG, smoke.
MQ3	Sensitive for Alcohol, Ethanol, smoke
MQ4	Sensitive for Methane, CNG Gas
MQ5	Sensitive for Natural gas, LPG
MQ6	Sensitive for LPG, butane gas
MQ7	Sensitive for Carbon Monoxide
MQ8	Sensitive for Hydrogen Gas
MQ9	Sensitive for Carbon Monoxide, flammable gasses.
MQ135	For Air Quality. Sensitive for Benzene, Alcohol, smoke.
MQ137	Sensitive for Ammonia.

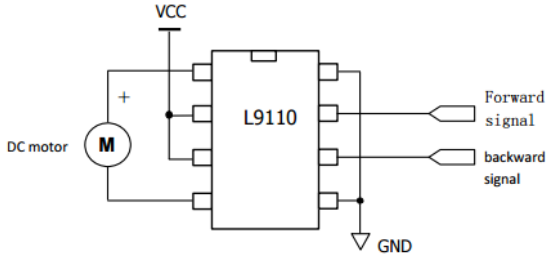

Fig. 6. The Scheme of the L9110 motor driver.

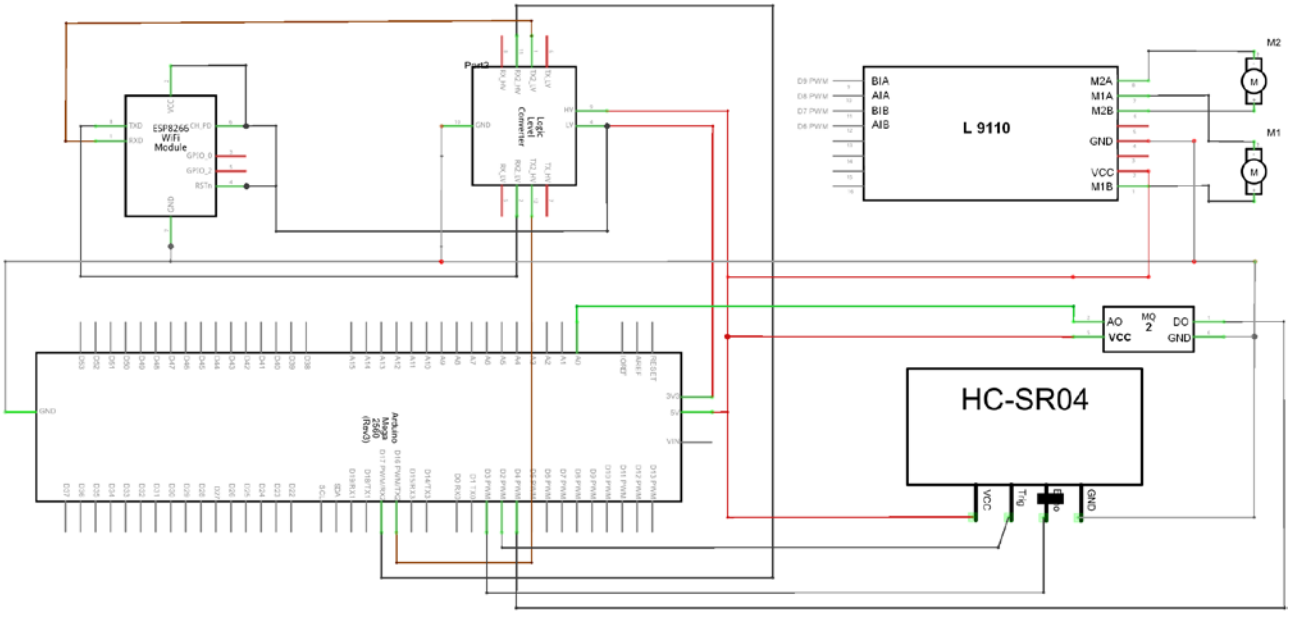

Fig. 7. The Scheme of the mobile gas detector with the Arduino Mega 2560 microcontroller.

4. The Scheme of the Mobile Gas Detector

We present the scheme of the mobile gas detector in Fig. 7. The following elements are used:

- Arduino Mega 2560 microcontroller,
- L9110 motor driver,
- two DC motors,
- Wi-Fi module ESP8266,
- logic level converter,
- MQ2 sensor,
- HC-SR04 ultrasonic distance sensor.

The Arduino controls two DC motors by using the L9110 motor driver. The HC-SR04 ultrasonic distance sensor is used to avoid a collision in an analyzing area. If the distance is too small, then the Arduino change a direction. In all the time, sensor MQ2 measures the amount of gas in the air around. This information is sent to the Arduino, and next via Wi-Fi module to the server, but there is needed using the logic level converter. In this way, we get the scheme of a low-cost mobile gas detector, that will be able to finding a dangerous zone in analyzing the area. This project is based on open source architecture. Therefore, it must be tested in practice. Moreover, in such serious applications should be considered a duplication of key components to ensure greater system reliability.

5. Conclusions

In this article, we presented the concept of hardware synthesis for the mobile gas detector with an Arduino microcontroller. The main aim of this project is finding the unsafe zone in the large area, where a big number of stationary detectors are unpractical or too expensive. Finally, we presented the scheme of the self-propelled robotic gas detector. In the future works, appropriate software must be created. A first part is a software for the Arduino microcontroller, and the second part is software for the server. These steps are necessary to make functionality tests in future.

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