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Design and Implementation of Automatic Railway Gate Control System

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Abstract

Railway is one of the major means of transportation in developed and developing countries. Railway gates are usually opened or closed manually by a gate keeper. Many railway crossings are not manned because of lack of manpower. The few railway gates that are energized usually face the challenge of unavailability of electricity especially in developing countries. This and in the event that there is no one to operate the railway gate when a train approaches railway crossing, accidents could occur at such crossings. To avoid such accident and other forms of human intervention at railway crossings, an automatic railway gate control system has been designed and presented in this work. This paper describes the railway gate system operations and control involving track switching stage and level crossing stage using ATMEGA A328P for simulation. The work can be divided into hardware and software developments. The former includes the power supply unit (PSU), sensing system unit (SSU), general notification system unit (GNU) and manual override unit (MOU), while the latter essentially involves the necessary programming to operate the hardware components. The program for the system is based on ATMEGA A328P microcontroller with Arduino C programming language. Besides, the work introduced a light display system for basic operations and notifications such as stop, ready and go. Other forms of improvement on the existing railway gate control systems carried out in this work include sound initialization for notification count and also a locker sensor for manual override implementation. Reliability and continuity tests were carried out at every stage of the design and simulation for efficiency and effectiveness of the automatic railway gate systems, and to reduce the occurrence of railway accidents.

Keywords: *Arduino, microcontroller, railway, IR-sensor, transportation, automatic.*

1. Introduction

Railway system is one of the most commonly used transportation modes in developed and developing countries. All over the world, the safety of railway system is a very important aspect of the railway operation. Unfortunately, some fatal accidents have been reported (Muhammed, 2015 & Brown, 1986) especially at unmanned railway line crossings (RLC). The RLC is the area where the railway or rail line intersects with road used by vehicles and other forms of automobiles.

Some of the main factors contributing to accidents at RLC include human factor, engineering factor, and environmental factor (ABERG, 1988) such as snow, heavy rain and fog. While the engineering factor can be linked to highway and railway characteristics, the human factor can be in form of train visibility advance signs, active warning, drivers' behavior, distraction and risk taking. Francisco (2010) created taxonomy of railway intersection accident contributors to generate hypotheses and deduction about specific cases and common patterns of accident contributors.

Generally, the railway control system may be manual, semi-automatic or automatic. For the manually controlled method which is akin to an open loop control system, the gate keeper communicates both as the transmitter and the receiver. In open loop control system, errors cannot be compensated and the specific time a train

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will move from one station to another cannot be ascertained. This gives room for poor management and high accidents rate (Muhammed & Gillispie, 2015).

For semi-automatic method, different signs are used in different locations of the railway gates. The gate master board and marker light which aim at indicating the arrival of the train also use different signs. Here, the only difference between the manual and semi-automatic is that there is a feedback which can compensate for error, but at a very slow rate. However, microcontroller technology, i.e. automatic method, with external devices like sensor, buzzer, speakers, display device and servo motor can be used to solve this problem.

The automatic railway gate control system is an arrangement of physical components to sense train arrival and departure and allow the railway gate to automatically open and close. As a train approaches the RLC, IR-sensors detect the train approaching and controls the operation of the gate accordingly. Also, the signal about the train departure is sent to the microcontroller. In turn, it operates the motor and opens the gate.

Thus, this work is aimed at designing an efficient, reliable and automatic railway gate control system for railway level cross using microcontroller, IR sensors, servomotors and LED devices. The use of sound initialization countdown and override are not common in railway gate opening, closing and crossing control system. This project aims at improving the existing railway gate control system by introducing sound initialization for notification, count down for the people within the railway station, and a locker sensor for manual override implementation.

So, a light display will be used for some basic operations like stop, ready and go. Also, sound initialization for notification and countdown which will bring the attention of the people around the railway track to the fact that the gates will be closed at the end of the countdown. This will be achieved using microcontroller that will receive and input signal that will be compared with some set of instructions and this will give an output to control the external connected devices such as sensors, speakers, servomotors and LED device.

The remaining sections of the paper are organized such that Section 2 gives a review of related previous works and theoretical background. Section 3 describes the methodology and implementation of the railway gate automation system. Results and Discussion are presented in Section 4, while a conclusion is given in Section 5.

2. Related Works

2.1 Theory

In this section, theoretical background of necessary components and units such as the Power Supply Unit (PSU), Sensing System Unit (SSU), and General Notification System Unit (GNU) is presented. Also, a review of related works is carried out in this section.

The most available power supply source is an AC supply of 50Hz, 220V. Most electronic components require DC voltage to operate, hence the need to convert the AC voltage to DC voltage. The process of converting AC supply to DC supply involves four stages which include transformation, rectification, filtration and voltage regulation. Figure 1 shows a typical component of a linear power supply and conversion from AC to DC.

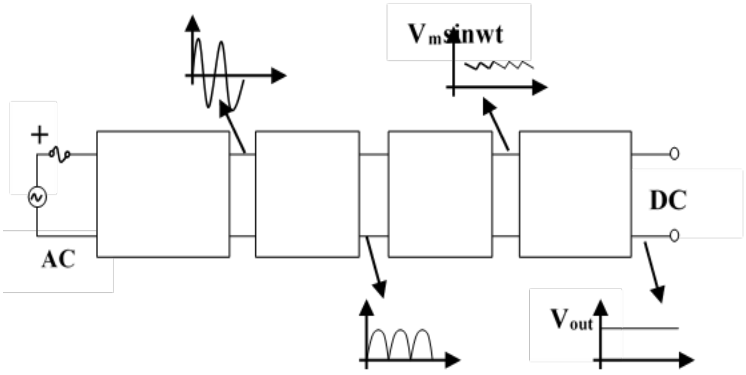


Figure 1: Typical components of linear power supply

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The Sensing System Unit (SSU) is a unit made up of infrared (IR) sensors to sense the arrival and departure of train. An IR sensor is an electronic device that emits and senses the surrounding. An IR sensor can measure the heat of an object as well as detect motion.

IR Sensors work by using a specific light sensor to detect a selected light wavelength in the IR spectrum. When an object is close to the sensor, the light from the LED bounces off the object and into the light sensor. This results in a large jump in the intensity, and can be detected.

The General Notification Unit (GNU) is made up of different components such as buzzer and light indicator. A loudspeaker is an electroacoustic transducer that converts an electrical audio signal into a corresponding sound. Dynamic speaker is one of the most widely used types of speaker. It operates on the same basic principle as a dynamic microphone, but in reverse, to produce sound from an electrical signal. When an alternating current electrical audio signal is applied to its voice coil, a coil of wire suspended in a circular gap between the poles of a permanent magnet, the coil is forced to move rapidly back and forth due to Faraday's law of induction, pushing on the air to create sound waves (Divya & Østergaard, 2009).

Besides, there are other alternative technologies that can be used to convert an electrical signal into sound. The sound source (e.g., a sound recording or a microphone) must be amplified or strengthened with an audio power amplifier before the signal is sent to the speaker. This buzzer device brings the attention of the people around the train stations to the fact that a certain activity is about to happen within the train terminal.

Typical LED shown in Figure 2 uses a forward voltage of about 2V and current of 5mA to 10mA. The LED produces infra-red light while red, green and orange lights are produced by gallium arsenide phosphide (GaAs) and gallium phosphide (Gap).



Figure 2: Light emitting diode (LED) and its symbol.

A fluid gem show LCD is a thin, level electronic visual show that uses the light tweaking properties of fluid precious stones. LCDs are difficult to interface with a small scale controller due to an inserted controller (the dark blob on the back of the board). This controller is standard crosswise over many showcases (HD 44780). They have many miniaturized scale controllers with libraries that make showing messages as simple as a solitary line of code.

A machine language set that is readable, and gives instructions that directs a computer's processor to undergo a specific operation is generally referred to as software. This is done by complementing the hardware i.e. the physical component of digital computer systems. The major aim of the software design is to give desired functionality, using a set of primitive components that are subject to constraints. Software design involves all the activities in conceptualizing, framing, implementing and finally modifying computer system. Software design entails problems solving and planning in which low-level algorithm and high-level architecture design are involved.

2.1 Review of Related Works

Automatic railway gate controllers with advanced technology have been introduced to make the level crossing risk free. Kottalil, et. al. (2015) designed an automatic railway gate control system using ATmega 16A microcontroller and IR sensor. The system allows monitoring and operation of the railway gate as train arrives or leaves a level crossing. Mahdi (2013) also proposed a microcontroller based railway gate and crossing control system using a microcontroller and IR sensor. The IR sensor senses the presence of train and sends the signal to the microcontroller to control the gate crossing. However, the limitation of this system include low accuracy and low performance in the presence of daylight.

Shikder (2015) designed an automatic operation of railway gates using RF technology. Though economically feasible to implement, the major issue of this technique was that every train could be provided with RF technology. Banuchandar, et.al. (2012) proposed an unmanned railway level crossing system. In this system, the IR sensor (transmitter) senses and generates signal when the train arrives in a given direction. The second IR

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sensor (receiver) also receives signal and generates an interrupt. However, the interrupt signal can be generated even with a small object crossing the IR Sensor; thereby making it a drawback of the system.

Anti-collision and secured level crossing system was proposed by Vidyasagar, et. al. (2015) using two vibration sensors to open or close the gate at level crossing. The system has an ultrasonic sensor positioned to detect an unauthorized object on the track. The drawback of this system lies in its complexity, cost and low performance. Thus, a model to control railway tracks using anti-collision techniques was proposed by Krishna, et. al. (2015). The techniques involved use of 8952-microcontroller and a sensor placed at a distance from the gate to detect an approaching train and control the gate operations. A GPS based anti-collision device was used to prevent collision between two trains. The system also has indicating light to notify motorists of any train approaching.

Using sensor networks, Anil, et. al. (2016) and Jian-hua, et. al. (2008) proposed advanced railway accident prevention systems. The work in Jian-hua, et. al. (2008) conveyed a technique to control the railway tracks by using anti-collision techniques. The authors in Krishnamurthi, et. al. (2016) also proposed sensor based automatic control of railway gates. In this technique, a laser beam and Light Dependent Resistor (LDR) were used to detect the obstacle between the railway gates. Also, Kumar, et. al. (2016) used IR LED and photodiodes to detect the arrival and departure of the trains. This work introduced a high speed alerting system to automatically control the railway gates.

Wireless communication system for automatic control of railway gates was anticipated in Kiruthiga, et. al. (2015). The authors used obstacle sensor to detect any hindrance on the level crossing of the moving train. Efficient Zig-Bee based train anti-collision technology for railways was implemented in Banuchandar, et. al. (2012). The work proposed a system to identify collision points and report cases to main control room, nearby station and grid control stations.

3. Methodology and Implementation

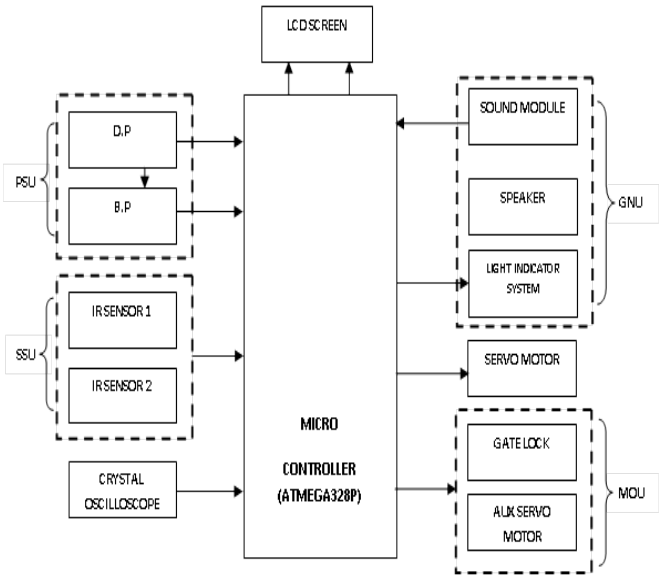


Figure 3: Block diagram of an automatic railway gate control system

There are six broad stages of implementation of this work. They include (i) design of Power Supply Unit (PSU), (ii) design of Sensing System Unit (SSU), (iii) design of General Notification Unit (GNU), (iv) design of Manual Override Unit (MOU), (v) integration of the various units and other components like microcontroller, crystal oscillator, and (vi) construction and testing of the circuit. Figure 3 is the block diagram of the automatic railway gate, while Figure 4 shows the circuit diagram of the automatic rail way system.

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The automatic gate control system makes use of micro controller to perform all the operations as instructed by the program and the servo motor were connected to the data pin of the micro controller and to the power source and ground. The IR sensor was connected to the microcontroller for the purpose of transmission and receiver of information that will enable the micro controller to execute the next set of instructions.

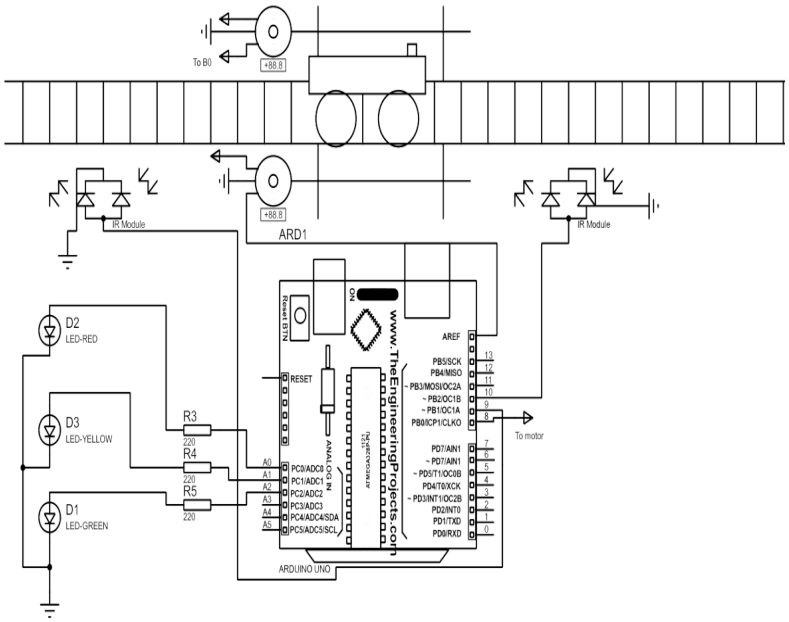


Figure 4: Circuit diagram of automatic rail way system

3.1 Power Supply Unit

AC power source is converted to DC power source. The power supply use two DC voltage types: +5 V to supply power to the microcontroller and other devices that require 5 V, and +12 V to supply the battery charger circuit. Besides, the power supply unit is divided into two basic types, namely: direct power supply (DPS) and battery power supply (BPS). Figure 5 shows circuit diagram of the power supply unit.

From the circuit diagram, 220V AC power supply is fed into step down transformer (220/12V 50HZ). Then the positive terminal of the primary leg of the transformer is connected to a fuse and the connection point of cathode and anode of D1 and D2. The negative terminal of the transformer is connected to the point where the cathode and anode D4 and D3 are connected. Diodes D1 to D4 are of 1N4007 diodes (Boopala & Kamalanathan, 2016). The point where D1 and D2 meet are connected to ground and point where D2 and D3 meet is connected to C1 (capacitor 470 µF), C2 (capacitor 0.1 µF) and C3 (capacitor 0.1 µF). A voltage regulator LM 7805 of three pin terminal is connected between C3 and C2. Pin 1 of the voltage regulator (LM 7805) is connected to C2, pin 3 is connected to C3 and pin 2 is grounded. The positive 5V DC is taken from the terminal of C3 and LM pin 3, while the negative 5V DC is taken from the ground.

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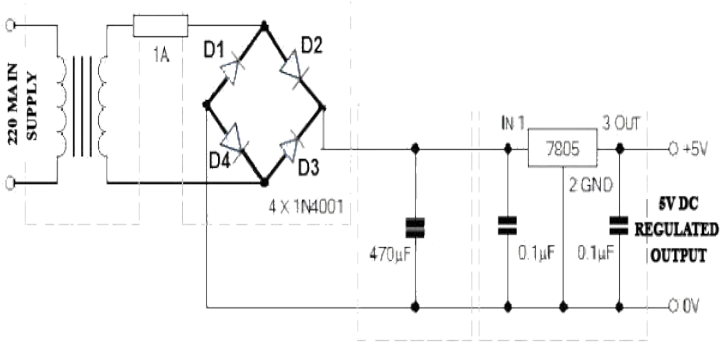


Figure 5: Circuit diagram of a direct power supply

3.2 Sensing System Unit

The sensing system unit and how light sensor works is already discussed briefly in Section Two. IR sensor works by using a specific light sensor to detect a selected light wavelength in the Infra-Red (IR) spectrum. By using an LED which produces light at the same wavelength as what the sensor is looking for, one can see the intensity of the received light. When an object is close to the sensor, the light from the LED bounces off the object and into the light sensor. This results in a large jump in the intensity which can be detected using a threshold. Figure 6 shows the circuit diagram of the IR sensor (Chaum, 1981).

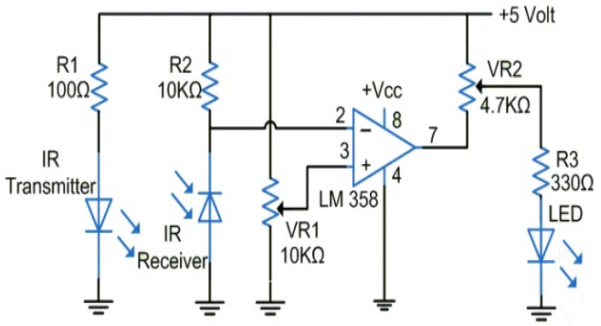


Figure 6: IR Sensor Circuit Diagram

3.3 General Notification Unit

The General Notification Unit (GNU) is an incorporation of the sound and the LED lights for notifying people within the train stations. It is a new and novel addition in this work for better output and efficient productivity. This addition addresses the problem of time spent closing the gate for long time and enables activities to continue within and beyond the train stations.

The light indicator is a combination of three LED lights (red, yellow and green) for the purpose of controlling people's movement. It is connected to the microcontroller and works in the same time frame with the sound module output i.e. the speaker. The function of the red light is to notify people that movement of any kind is not allowed. The green light indicates that movement is allowed, while the yellow light indicates that a certain action is about to occur. This action could be red or green light coming up.

The general notification circuit diagram shown in Figure 7 consists of three LED light. Each LED is anode and connected to a 220 Ω resistor of R_3, R_4 and R_5 after which R_3, R_4 and R_5 are connected to the leg of the microcontroller pin A_0, A_1, A_2. The cathode leg of the LED is connected to the ground.

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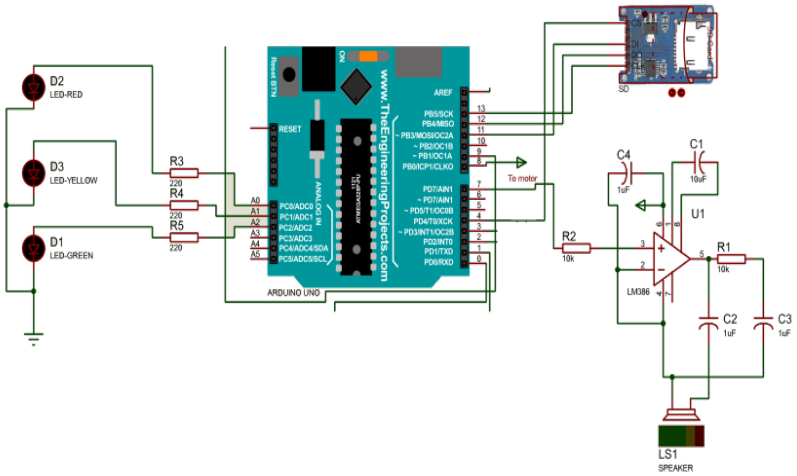


Figure 7: Circuit diagram of the general notification unit

For sound module, the module storage device is connected to the microprocessor pin 4, 11, 12, 13. Also, the sound output device (e.g. speaker) is connected to an amplifier set. The amplifier set is made up of an OP Amp, which has 8 output legs with pin number 1 to 8. It has a passive component connected to them.

The amplifier signals come from pin 7 of the micro controller and the pin is connected to resistor R_2 of 10 KΩ before being connected to the positive leg of OP Amp. The positive leg of capacitor C_4 is connected to OP Amp pin 6, while the leg of C_4 is connected to pin 2. Pin 4 is connected to the negative leg of the speaker and capacitor C_3 (1 µF) coming from R_1 of 10 KΩ.

Resistor R_1 (10 KΩ) is connected to OP Amp pin 5 and capacitor C_3 (1 µF). The positive terminal of the speaker is connected to the terminal of capacitor C_2 (1µF) before being connected to terminal 2 of the speaker. Pin 1 and pin 8 are connected to a 10 µF capacitor while pin 6 is connected to pin 8 of the microcontroller.

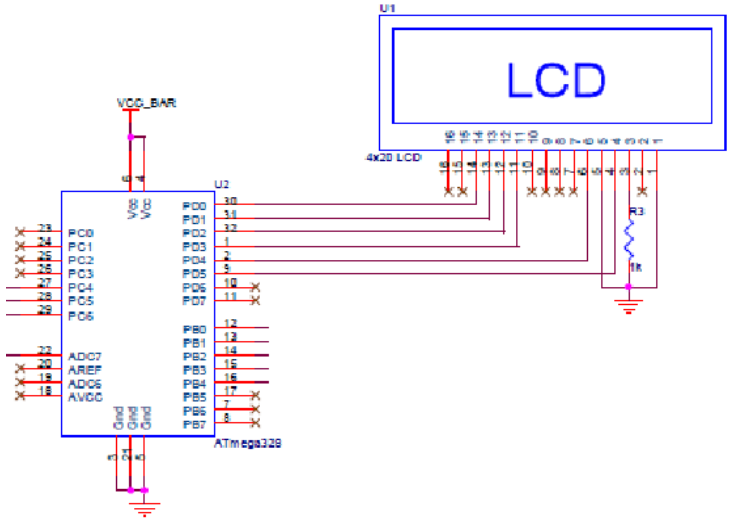


Figure 8: Circuit diagram of an LCD device

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In the LCD, the VSS is grounded (which is the negative output) and the VDD is connected to a variable resistor Rv_1 of 5KΩ. The V_{EE} of pin 3 is connected to the variable adjuster of R_{V1}. Pin 4 and pin 6 of the LCD are connected to the microcontroller pin 5 and pin 6, while RW pin of the LCD is connected to ground. In the LCD, pin D_0 to D_3 are not used. But pin D_4 to D_7 are connected to pin 3 to pin 0 of the microcontroller.

For manual override system, pin 6 of the microcontroller is connected to one end of the push button while the other leg is grounded. Figure 8 is a circuit diagram of an LCD device.

3.4 Manual Override Unit (MOU)

The Manual Override Unit (MOU) is another new ideal added to this project for the purpose of controlling the closing and opening of the gate in the case of failure of the automatic servo motor. The components involved in this unit include Aux servo motor, gate locker sensor (push button) and manual control button.

Aux servo motor is a secondary motor made available for the purpose of a backup in case of failure to primary servo motor, or if it does not function as expected. In that case, the proposed system's microcontroller will give an indication through a speaker and display unit that the primary servo motor did not engage. The gate is then closed or opened using the MOU.

The Gate Locker Sensor (or Push Button) is a sensor located within the gate locker for the purpose of sensing closing of the gate. The sensor is made up of a push button, connected to the microcontroller to send signal at every time closing and opening occur.

3.5 Other Individual Unit (OIU)

The other individual units are units that maybe said to perform their tasks independently. They crystal oscillator, microcontroller and primary servo motor.

a. Crystal Oscillator

Oscillator is used to provide clock to microcontroller. Clock is used to carry all the functions that microcontroller provides. There is no need to give a separate voltage because the microcontroller has dedicated pin which excites the crystal oscillator. It takes voltage from the assigned pin. However, a circuit is built for the crystal oscillator to work. Figure 9 is a diagram of ATMEGA A328P microcontroller chip with its crystal oscillator attached to its pin 9 and pin 10.

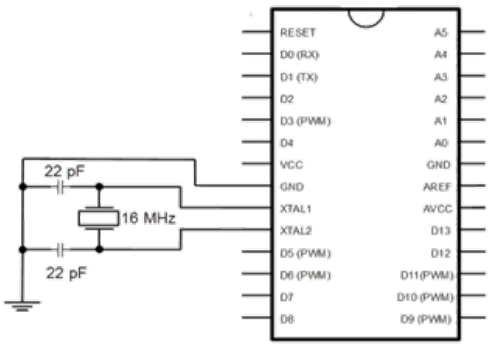


Figure 9: ATMEGA A328p microcontroller chip with its crystal oscillator

b. Microcontroller (ATMEGA328P)

A small computer on a single IC, 10 KΩ resistor was connected from its pin 1 (master clear) to 5 V supply. A crystal oscillator of 16 MHz is connected from pin 9 to pin 10 with 22 pF ceramic capacitor to the negative terminal.

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Pin 8 and pin 22 were joined together and grounded to negative terminal. Pin 7 and pin 20 joined and connected to 5 V supply terminal.

The microcontroller (Atmega328p) was programmed using Arduino programmer board, while the code was written in the same environment. Arduino is a customizable microcontroller of an open source. The Arduino UNO microcontroller programmer board was used as it has multiple I/O ports for sensors and other modules. The I/O point is to control the different units present in this work, and the reset button.

c. Primary Servo Motor

For closing and opening the gate, servo motor is used. The servo motor gives a degree of angular rotation control and accuracy of the system. A servo motor is basically a DC motor with some other special purpose components that make a DC motor a servo. In a servo unit, there is a small DC motor, a potentiometer, gear arrangement and an intelligent circuitry. The intelligent circuitry along with the potentiometer makes the servo to rotate accordingly.

3.6 Implementation

The implementation stage can be divided into two namely: hardware implementation and software implementation. Instructional programme for the ATMEGA A328P was developed for the interfacing part. For the hardware part and instruction programmed built, we have an integrated step that allows the ATMEGA A328P to simulate all the system operations that are required to perform the task.

a. Hardware Implementation

The components were first assembled on a breadboard to test the performance of the components. The components were then assembled on the predesigned printed circuit board (PCB) in accordance with the circuit diagram. The components were well soldered using a thinned soldering bit along with soldering lead to correct flux. In order to achieve portability of the project, the placement of the various components was done in such a way to occupy lesser space on the PCB. This was achieved by placing the ICs which are major components side by side. The pin terminal of the ICs was linked using a non-insulated single strand copper wire, all resistors and capacitors were placed in accordance with the fitted space.

b. Software Implementation

The software used to programme the microprocessor was Arduino C programming language widely used in embedded system software engineering for scientific applications. The Arduino software code can be found in Appendix. All the pins used on the microcontroller were firstly declared in the global variable while functions mode was also set in setup function, however; all the instructions and command code were written in void loop function. The code was written using Arduino C programming language which was developed in ARDUINO environment, this same environment was used to verify if the code is free from logical and syntax error; after verifications the code was uploaded to the microcontroller using ARDUINO development board.

Application software, Arduino environment was used to provide the software development tools. This software was used to simulate the Arduino C language code to be sure the code is free from syntax and logic error and finally generate hexadecimal source file (HEX)file on the microcontroller chip to perform the control function of the project.

4. Results and Discussion

The project is made up of an embedded system consisting of a microcontroller, passive and active elements, 12V battery, LED, sensors, servomotor, modules, push button, control button and speakers. Modelling material include glass for the housing and railway toys with tracks.

The microcontroller and other integrated circuits are interfered to one another, power by Power Supply Unit (PSU) with backup rechargeable battery and the train movements will trigger the sensor which will inform the microcontroller about the arrival and departure of the train. The microcontroller will then initiate the next action

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which is to make the sound module active and send notification that will enable the gate to be closed or opened at a given time.

The gate locker has a sensor for feedback system that the gate is closed. If the feedback is not received, then a manual override has been designed to ensure that the gate remain close. The control is handled in an automated way in a case where by automation fails then manual approach is taken just to ensure that it's reliable and maintains a high level of operation.

The system is practically experimented as a working model of the real world through construction of a prototype according to the design specifications. The operational efficiency of each components was ascertained using a digital multi-meter before, during and after construction. Construction on breadboard was used in testing the circuit. Reliability and continuity tests were carried out at every stage to ensure that the required performance of each circuit is achieved. During each stages of the construction, the Arduino was tested and confirmed to work as required independently.

All the components were carefully coupled together and visual inspection was done to double check. Every likely short-circuit and open-circuit faults were addressed by using multi-meter to check for continuities in the path of the circuits where necessary and for discontinuities where contacts were not required.

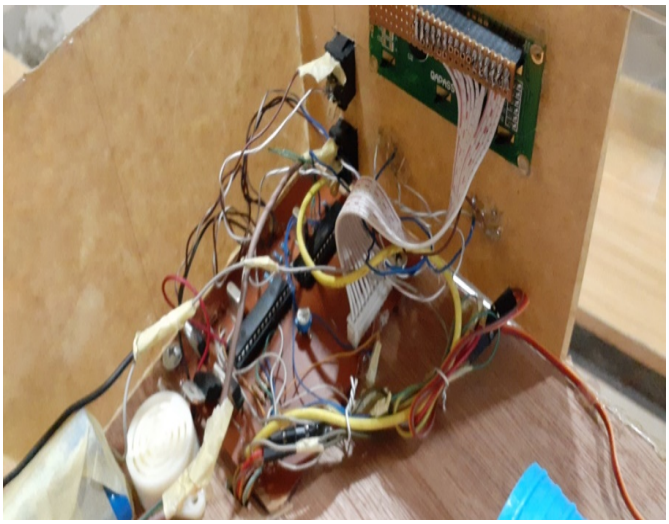


Figure 10: Picture of the completed connection of the circuits

Figure 10 shows the completed connection of the circuits. The result of the careful integration of the developed components is a functional automatic railway gate control system. To evaluate the performance of the proposed system, several experiments and test running were conducted. Some cases on railway level crossing were designed for simulation. Apart from the train detector sensor with no stuck, some of the cases included where the train is crossing the detector sensor, passing the level crossing and has passed a certain distance away from the level crossing. The desired results with high accuracy were obtained in all the cases experimented.

It was observed that the performance of the railway system is not a function of the speed of the train, the weather and/or the temperature.

5. Conclusion

Automatic control of railway gate offers an effective way of reducing hazard and occurrence of accidents. In this work, automatic railway gate control system has been designed and a prototype constructed. This is aimed at contributing to railway management even in remote villages where no station master or line man is present. Railway sensors are placed at the two sides of railway gate to sense the arrival and departure of the train. The system uses DC motor for opening and closing of the gate automatically. There is an LCD display which shows the status of the

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railway gate control system. The system can also generate buzzer and light indicators while the train is passing through the level crossing. A prototype construction and test show that the system is reliable and accurate.

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