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# Development of a Level-Crossing Advisory Prototype Using Wireless Sensor Network

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***Abstract:*** *This paper presents the development of an advisory system prototype for level crossings. The study aimed at helping undergraduate students to understand the basic application of wireless sensor network, for safety of road users at a railway level crossing. The system design consists of a three-level detection rack, within which the approaching train is detected and the signal logic transmitted wirelessly for indication to the level crossing road users. The road users at every instance are advisedly alerted of the approaching train, and its speed conditions. The wireless units were first selected with best comparative advantages and robust integration capacity. The hardware and software units were developed for optimal performance. The sensing unit employed passive infrared technology. The transceiver unit consists of Xbee module, and RF connectivity was used in signal communication. Arduino variants were used as microcontroller to set up an interface. The design demonstrates the gains of wireless communication, infrared technology, simplicity, and cost effectiveness in the implementation. About 50 randomly selected students were taught using the module. The identifiable problems with most of the students include: correct setting up of the interface, coding of the Arduino boards, and developing the sensor nodes.*

***Keywords:*** *Level-Crossing, Advisory System, Sensor Network, Wireless, Prototype*

## 1. INTRODUCTION

A railway is often designed and constructed with level crossing for road intersections at different locations within its stretch. The priority of right-of-way is always given to the train over the road users at such junctions. For safety purpose, it is however required that the road users are advised on the caution of approaching these junctions in line with the possible dangers involved [1].

A rail/road intersections as shown in Fig. 1 are potentially dangerous and yet unavoidable in rail transportation systems. Level crossings can be dangerous if there is presence of any of: poor sight distance to a signal display or to approaching trains, inadequate traffic control, and vehicles queue across tracks due to congestion, lacks of pedestrian facilities, and so on. The two different entities (road and rail) with entirely different responsibilities and performances come together and converge for a single cause of providing a safe facility to the road user. During the normal operation also, there is every possibility of accidents occurring even with very little negligence in procedure and the result is of very high risk. The potential for accidents is made higher as the railways control only half the problem. The other half, meanwhile, cannot really be said to be controlled by one entity, as even though traffic rules and road design standards supposedly exist, the movements of road users are not organized and monitored by one specific entity as rigidly as rail movements [5, 7, 8].

It is the railway which must bear the responsibility for ensuring that it is protected from the encroachment by road users (despite the fact that in many countries, the law gives it priority of passage over road users), it is the railway which also has to shoulder most of the financial burden of providing this protection. Similarly, it is the railway, which has most of the responsibility for educating road users on the safe use of its level crossings. Notwithstanding this, it appears that in many regions, railways are ill-equipped to be in a position to monitor level crossing safety effectively and to take both corrective and pro-active measures to improve the safety of their level crossing installations. Various measures and designs have been introduced to caution road users at level crossings, with their respective drawbacks [10]. Wireless sensor network (WSN) is howbeit introduced in developing a road users' safety-ensuring system at such crossings with obvious advantages [1].

Figure 1. Typical Level Crossings [1]

This paper presents the development of an advisory system module aimed at helping undergraduate students understand the basic application of wireless sensor network for safety of road users at railway level crossing. The development of the various units of WSN and the specific application of interest are highlighted in a step-by-step approaches.

An in-vehicle system uses GPS, server systems and an alarm to give warning to the user. The basic functionality of the system is to provide warning of an approaching train to the driver of a car nearing a level crossing. The in-vehicle system has the coordinates of all level crossings in tabular format. As the vehicle moves along the road network, the in-vehicle system continuously calculates distances between the vehicle and the nearest level crossings using GPS positioning and the level crossing coordinates to detect situations in which the car is approaching a level crossing. When an approaching situation is detected, the in-vehicle device sends a query to the server with the number of the level crossing. The server receives continual real-time information on the positions of trains on the rail network and calculates the status of level crossings accordingly [4, 5, 11,12]. When a query is received with the number of a particular level crossing, the server responds with the current status of the level crossing as: “No information”, “Coming”, “Alarm” or “Passed”. If the in-vehicle system that has sent the query receives the response “Alarm”, it warns the driver both visually and audibly. The warning functionality provided by the system is based on both the distance between the vehicle and the level crossing and the direction in which the vehicle is travelling. If the distance between the vehicle and level crossing is less than 1500 metres but more than 200 metres and the vehicle is travelling towards the level crossing, the in-vehicle device warns the driver. If the distance between the level crossing and vehicle is less than 200 metres, the direction of travel has no effect and the system issues a constant audible warning with a continuous and visual indication if the status of the level crossing is “alarm” [7, 8, 11].

Onibonoje *et al.* [3] explained that Wireless Sensor Network (WSN) has been applied in vast areas that include monitoring, control and automation. WSN is a network of sensing nodes deployed to collect data and wirelessly transmit the gathered data to an access node. A sensor node consists of sensing, computing, communication, actuation, and power components. The access node is generally similar to the sensor node in terms of component composition except that it does not include sensing unit and it is programmed to collect data from the sensors and logs it appropriately. [16] presented a resourceful selection-based design of wireless units for granary monitoring systems. The system consisted of network of wireless sensor nodes with well selected components and resourceful capabilities for monitoring the environmental factors. [14] had proposed industrial automation using wireless sensor network cluster with low cost MSP430 processor and radio frequency transceivers. The author established the network for easy modification to suit the needs of a particular process. [2] had developed an integrated approach to automated control for air-conditioned home apartments using WSN.

## 2. METHODOLOGY

The system is implemented in two categories: the wireless sensor network (WSN) and the advisory system application. The system design consists of a three-level detection rack within which the approaching train is detected and the signal logic transmitted wirelessly for indication to the level crossing road users. The road users at every instance are advisedly alerted of the approaching train and its speed conditions. This work was designed from a combination of hardware units, software units and advisory indicators unit. The block diagram of the designed system is as shown in Fig. 2.

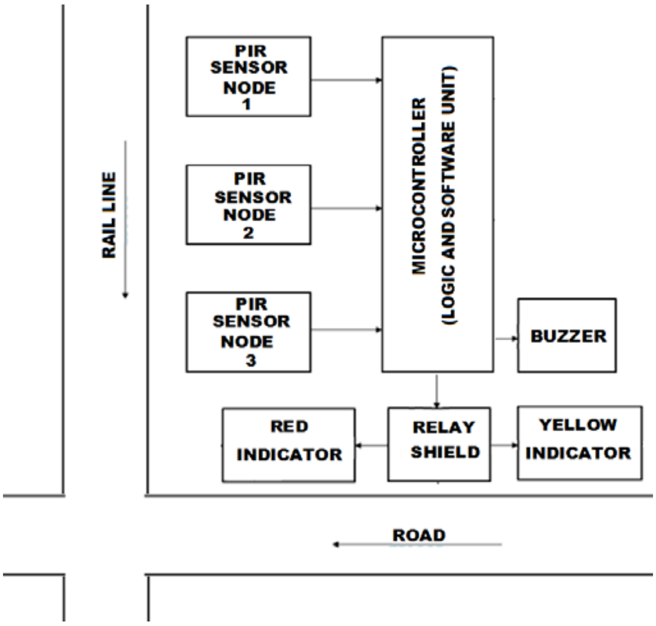



Figure 2. Block diagram of the system

## 2.1 Hardware Unit

The hardware unit of the system is designed by sectionalizing the system into various stages and designing each stage separately. The four major subunits are the sensing, transceiving, controlling and indicating sections. The sensing section consists of sensors which detect the presence of vehicles within their sensing range, convert this signal into an electrical signal and send it to a microcontroller. The microcontroller thereby works on the logic of the sensors combination to control the indicators. There are three sensors, being equally spaced apart and combined together within a 'rack'. The output logic of the rack is indicated 'high' when a vehicle is detected by all the three sensors in a correct sequence, else the logic is indicated as 'low'. The transceivers interconnect the output of the sensing unit and the input to the microcontroller wirelessly. The controlling section consists of a microcontroller which receives signal from the sensor. Depending on the signal received from the sensor, the microcontroller sends out instructions to the relay to either sound the alarm or not. The indicating section consists of two lamps (red and yellow 60 watt bulbs), a buzzer and a relay shield. The yellow light comes on when a vehicle has been detected at relatively normal speed, while the red light comes on when the vehicle detected exceeds the speed limit.

### a. Sensing Unit

This unit is designed to transmit light radiation with monochromatic and coherent characteristics over a distance of not less than seven meters for which it would be adequately or effectively detected at the other end. Prior considerations for the design of this stage include the power input, the driving resistor, power output, wavelength, bandwidth etc. The selected sensor was the Passive Infrared (PIR) Sensor. The parameters are as shown in Table 1.

**Table 1.** Characteristic features of a PIR sensor

| **Parameters** | **Value/Range** |
|---|---|
| Operating Voltage | 3V–5V |
| Operating Current(VCC = 3V) | 100uA |
| Operating Current(VCC = 5V) | 150uA |
| Measuring Range | 0.1 - 6m |
| Default detecting distance | 3m |
| Holding Time | 1 - 25s |
| Working Wave Length | 7 - 14um |
| Detecting Angle | 120 degrees |

### b. Transceiver Unit

This unit basically consist of the radio transceivers and the antenna. The connectivity medium selected was Zigbee with standard IEEE 802.15.4. XBee S1 transceivers were selected with attention AT-commands configuration. The connectivity provides reliability, low power tendency, low cost and scalability advantages.

**c. Microcontroller Unit**

This unit houses the brain (the control mechanism) of the system. The unit is designed to consist of a 14 digital pin Arduino Uno with a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button and relay unit. This implies that it samples each executable statement in the algorithm at every 100µs since PIC execute at 4 clocks per instruction. It is being programmed to execute the algorithm of the systems operation. The outcome of the executed logic from the input signals determines which of the outputs is placed HIGH.

The relay driving circuit was being fed from the output of the microcontroller. Relays are components, which allow a low power circuit to switch a relatively high current ON and OFF, or to control signals that must be electrically isolated from the controlling circuit itself. It is an electromechanical device, which transforms an electrical signal into mechanical movement. As shown in Fig. 3, it consists of a coil of insulated wire on a metal core, and a metal armature with three or more contacts. When a supply voltage is delivered to the coil, current would flow and a magnetic field would be produced that moves the armature to close one set of contacts and/or open another set of contacts. When power is removed from the relay, the magnetic flux in the coil collapses and produces a fairly back voltage in the opposite direction. This voltage can damage the driver transistor and thus a reverse out the spike when it occurs.

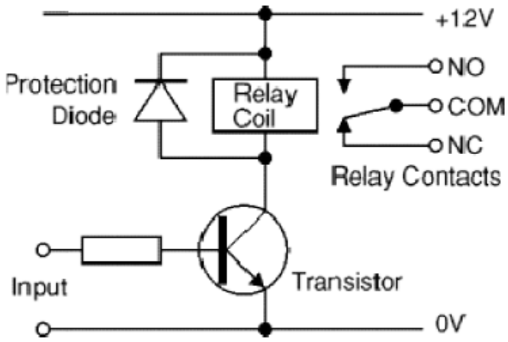



Figure 3. The relay circuit

In choosing the appropriate relays, considerations were given to: physical size and pin arrangement, coil voltage, current amplification, and switch ratings (voltage and current).

**d. Indicator Unit**

This module is designed with 60-Watt yellow and red tungsten lamps. This unit comprises of the indicating lamps which are controlled based on the two logics. The indication was based on the detection of the moving ‘train’ within the rack and the speed of the ‘train’.

**e. Determination of the detection logic**

In the module, the prototype rack comprised of three sensor-detector combinations distanced a metre apart. Whenever an approaching train breaks the line-of-sight of the reference sensor-detector, the system begins to monitor the possibility and time it takes the ‘train’ to also break the second and third line of sights all together in that sequence within a specified time. In this prototype module test:

i. A fast moving ‘train’ covers a distance of 1 m in 5 seconds (0.72 Km/h)
ii. A slow moving ‘train’ covers a distance of 1m in 10 seconds (0.36 Km/h)

## 2.2 Software Unit

The algorithm of the operation of the control unit of the system model is as shown in Fig. 4. The algorithm was implemented with codes written in C language.

## 3. Results and Discussions

The implementation results of the various designed units within the system model is highlighted and discussed in this section. Fig. 5 shows the sensing unit, indicator unit and the control unit of the model. The sensor unit was a passive infrared (PIR) sensor that didn’t generate its infrared signal but only detect the reflected infrared signal from the moving device.

The control unit consisted of the Arduino microcontroller which was programmed to execute the designed algorithms. The outcome of the executed programme by the microcontroller determines which of the lamps is triggered in the indicator unit whenever there is a moving ‘train’ in the pathway. Whenever there was no movement in the pathway, neither the indicator nor the alarm buzzer was triggered as shown in Figure 6(a). When a relatively fast moving ‘train’ was detected in the pathway, the red indicator came up and the alarm buzzer sounded at the level-crossing junction as shown in Figure 6(b). This system indicated to the users of the level crossing about an approaching train, and can be automated to close the road to the users until the train passes.

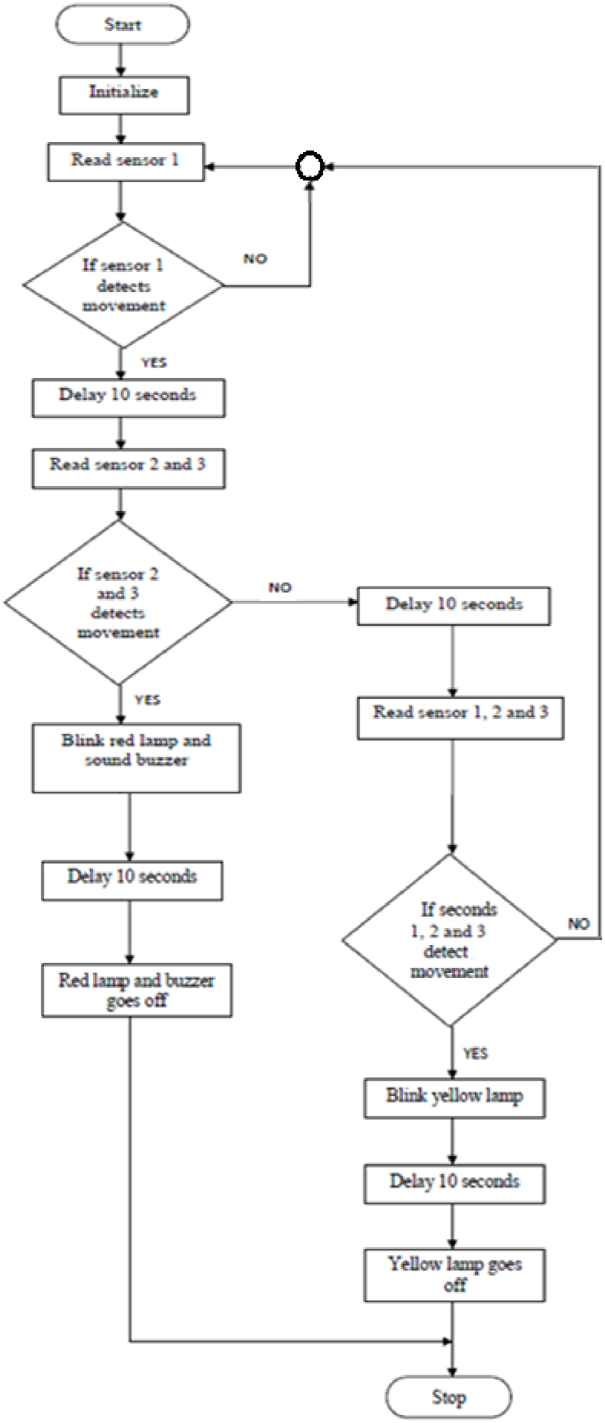
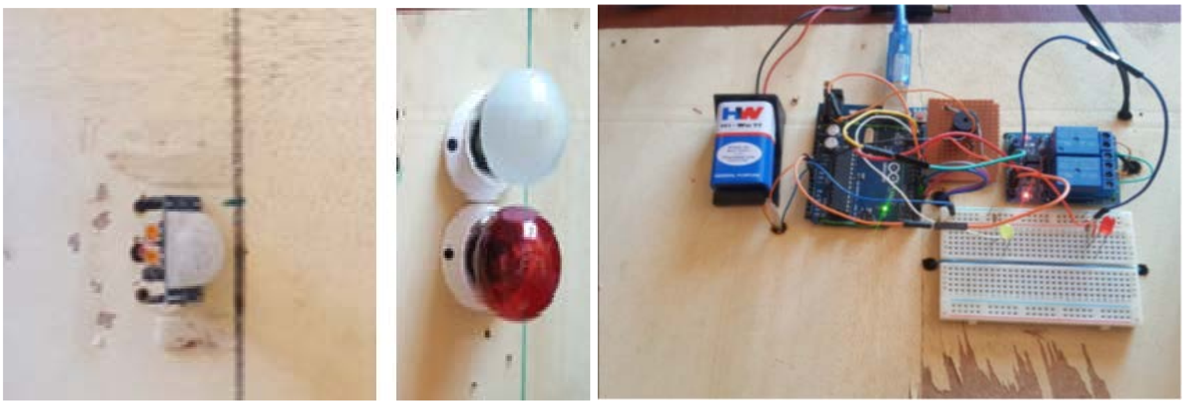



Figure 4. Flow chart of the system



(a) . (b) (c)

Figure 5. Composite units of the system (a) a unit sensor, (b) indicators, and (c) control unit

(a.) (b.)

Figure 6. The system model, (a.) with no moving 'train' detected in the pathway, (b.) with a fast moving 'train' detected

## 4. Conclusion

In the process of detecting the presence and speed of the moving device within a specified space as may be applicable in rail-road level crossing, a system has been developed comprising a rack of three equally spaced sensors and a data collection base. This was with the aim of developing a model to explain the application of wireless sensor network in a power efficient three-level train detection system to provide advisory indication for the users of such space. This work has provided an insight to the possibility of a relatively power efficient system and reliable advisory medium for users of the rail-road level crossings.

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