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Research Article

Monitoring of Train Location with Arduino Based Control System

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ABSTRACT

In this study, an Arduino-based prototype has been developed to teach the structure and working principle of the Centralized Traffic Control (CTC) system that enables the monitoring and control of railway traffic to students studying in the field of Rail Systems Electrical and Electronics Technology. The developed system consists of four stations. The line in which the stations are located is divided into the blocks with the fixed block signalling system. At the fixed block signalling system, block, can only be occupied by one train at a time. The TCRT5000 IR (infrared) sensor gives the information that the train has entered the block. When the program embedded in the Arduino controller is operated, the relevant relay at its output activated and that block or station is shown on the centralized commander panel in red. If the relay is active, it not only shows the relevant block line on the central control panel as red, but also ensures that the signal on the line is red. Thus, the information is given for trains coming from behind that the line is full. If the leading train leaves the corresponding block, the signal on the line is converted automatically from red to green to indicate that the corresponding block is empty. In the designed system, the movement of the trains is provided by manual driving. In the system, two different trains were used, both receiving energy from the catenary line and using the third rail system. 433MHz RF transmitter and receiver pair provide giving or cutting the energy to the train on the line and controlling the railway points.

Keywords: Arduino, Central traffic control (CTC) system, Railway

Arduino Tabanlı Kontrol Sistemi ile Tren Konumunun İzlenmesi

ÖZET

Bu çalışmada, Raylı Sistemler Elektrik ve Elektronik Teknolojisi alanında okuyan öğrencilere demiryolu trafiğinin izlenmesini ve kontrolünü sağlayan Merkezi Trafik Kontrol (CTC) sisteminin yapısını ve çalışma prensibini öğretmek için Arduino tabanlı bir prototip geliştirilmiştir. Geliştirilen sistem dört istasyondan oluşmaktadır. İstasyonların bulunduğu hat, sabit blok sinyalizasyon sistemi ile bloklara ayrılmıştır. Sabit blok sinyalizasyon

sisteminde, blok aynı anda sadece bir tren tarafından işgal edilebilir. TCRT5000 IR (kızılötesi) algılayıcısı, trenin bloğa girdiği bilgisini verir. Arduino kontrolörüne gömülü program çalıştırıldığında çıkışındaki ilgili röle aktif olur ve o blok veya istasyon merkezi kumanda panosunda kırmızı ile gösterilir. Rölenin aktif olması sadece merkezi kumanda panosundaki ilgili blok hattını kırmızı olarak göstermekle kalmayıp aynı zamanda hat üzerinde bulunan sinyalinde kırmızı olmasını sağlar. Böylelikle arkadan gelen trenler için o hattın dolu olduğu bilgisi verilmiş olur. Öndeki trenin ilgili bloğu terk etmesi durumunda hat üzerindeki sinyal ilgili bloğun boş olduğunu belirtmek için kırmızıdan yeşile döndürülür. Tasarımı gerçekleştirilen sistemde trenlerin hareketi manuel sürüş ile sağlanır. Sistemde hem katener hattından enerji alan hem de üçüncü ray sistemi kullanan iki farklı tren kullanılmıştır. 433MHz RF verici ve alıcı çifti, hat üzerinde trene enerji verilmesini veya kesilmesini ve demiryolu noktalarının kontrol edilmesini sağlar.

Anahtar Kelimeler: Ardunio, Merkezi Trafik Kontrol Sistemi, Demiryolu Hattı

1. INTRODUCTION

Railway systems are between the most important types of public transportation due to their unique features. The important features that distinguish rail systems from their alternatives are that they offer a comfortable transportation opportunity, they provide travel directly between the city centres unlike airlines in intercity travel, they are much more economical than their competitors and the trips are safely and planned on time (Canpolat, 2019; Cheedella et al., 2020; Dick et al., 2019; Söylemez, 2019).

The obligation to ensure traffic safety in rail transportation and the economic values of this obligation caused the birth and development of the signal system in railways (Gülener, 2009). The signal system, which was applied with the idea of distance between trains in certain amounts, continued to develop in the 1900s with different systems such as, the block system operated manually by the control operators, the controlled manually operated block system, the semi-automatic block system, the automatic block system and the mechanical block system (Temiz et al., 2015). Lights and electric telegraph used for signalling is the beginning of railway signalling. Over time, the reason for the special signs and their placement at certain points increased traffic safety and train speed. Later, the ways of managing the signs and railway switches from a certain place in the stations were investigated. Railway points and semaphores were operated by electricity controlled motors. As the development continues, semaphores have been replaced by electric lamp signals (Gülener, 2009).

Central traffic control (CTC) system means the management and administration of trains from a center without train orders, based on remote control by means of electrical signals in a certain railway area. CTC line locking circuits are divided into two parts, the stations and the parts between the stations. The parts between the stations are divided into certain line segments

in order to increase the traffic density and speed, and each part is called a block (Gülener, 2009). In other words, a certain road section in which only one train or machine is allowed to exist at the same time, in which train and machine movements are managed by signal notifications and whose boundaries are controlled or automatic signals, is called a block.

Today, basically three types of signalling systems are established:

- Fixed block manual driving,
- Fixed block automatic driving,
- Moving block automatic driving.

Fixed block signalling is the traditional and most widely used type of signalling (Pachl, 2020). The locations of trains must always be known in order to guide rail traffic safely (Alikoç et al., 2013; Kaymakçı, 2017; Mutlu et al., 2012). At fixed block signalling system, only one train is allowed to occupy a block at any time. Because of this reason, signals are very important. In this study, fixed block manual driving signalling system has been used. As shown in Figure 1 (a-d), four different signalling situations are given for three-fixed block signalling system on the line.

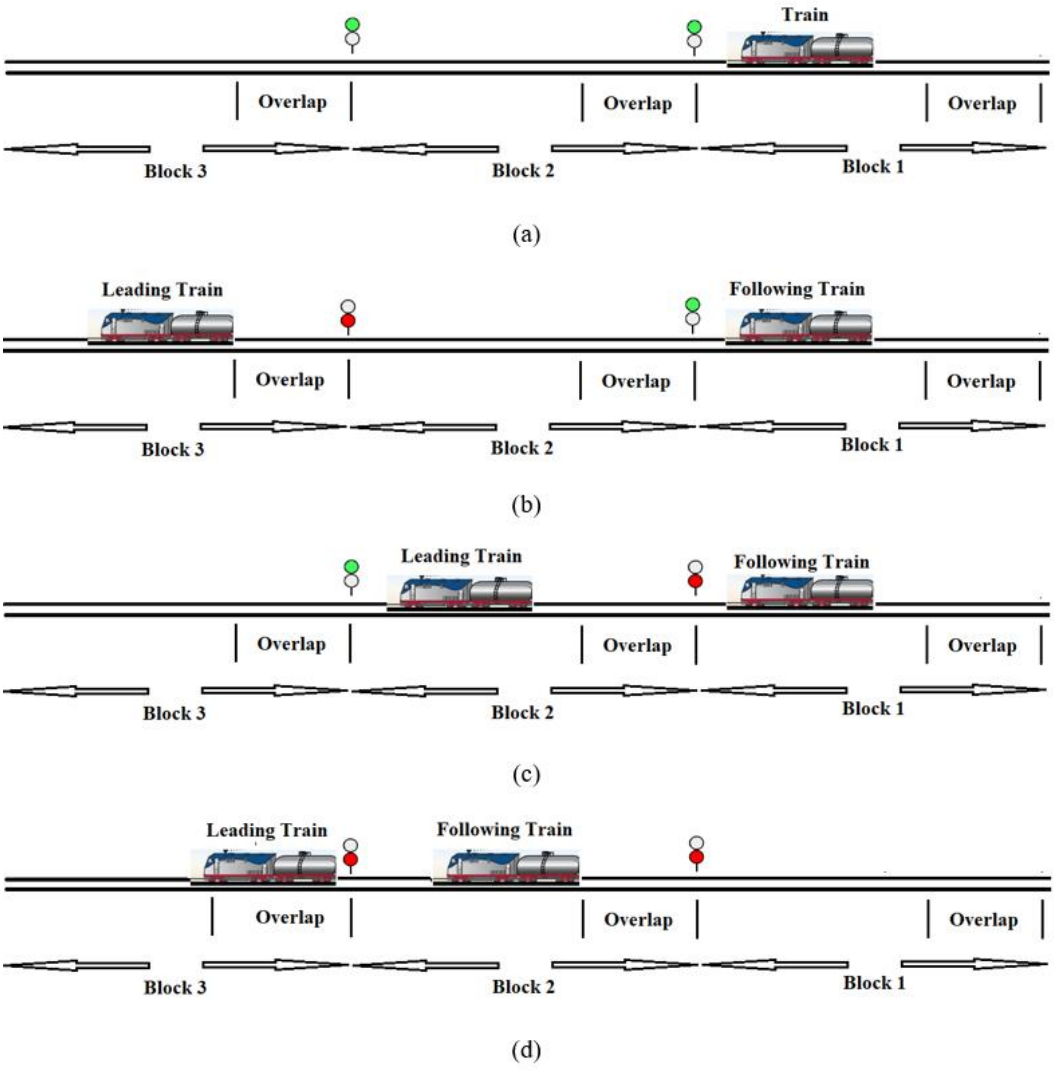

Figure 1. Fixed block system in railways

To clear the signal of a train entering a block section, the following conditions must be met:

- The train in front must have passed the block section
- The leading train must have cleared the overlaps on the further side of the next signal
- The leading train have to be protected by a stop signal (Pachl, 2020).

The overlap supplies a reliable braking distance for any train, which exceeds a signal so that there is no hazard of it come into collision with a stopped train in front (Pachl, 2020).

The basis of the signalling system of the metro railroad transportation in Turkey is root on fixed block system (Canpolat, 2019). This signalling system is used by the central traffic control system. The Central Traffic Control System, which provides the monitoring and control of railway traffic, have combined innovative ideas based on field experience with the latest

technology. Railway points and signal arrangements are made with the commands sent from the central traffic control room. (Görgülü, 2017).

One of the railway section, which also includes many stations connected to a traffic centre, is given in Figure 2. There are rail blocks, junction zones, railway switches, station zones and trains on the line.

In the literature, there are lots of study about the tracking and monitoring of the railway machines. Some of them are given below.

- Nahid et.al (2013) recommended rail-tracking system using GSM technology. GPS system is used for communication between rail tracking system and control room.
- Rajkumar et.al (2013) proposed train-tracking system using Global positioning system and transmission link ensured using Ethernet concepts.

Figure 2. Railway part, including many stations connected to a traffic control centre (Görgülü, 2017).

- Azim et.al (2014) adopted GPS –GPRS based train-monitoring system.
- Vidyasagar et al. (2015) presented tracking of the line and monitoring of the train location using infrared and radio frequency technology.
- Malekjafarian et al. (2019) used the GPS system in the study to determine the location of the train and its rough forward speed.

In the literature, RFID, IR sensors, GPS and GSM systems are generally used in the tracking and monitoring of trains, but no information about block usage and block signalling is included. In this study, this paper will introduce an Arduino-based prototype has been developed to teach the structure and working principle of the Centralized Traffic Control (CTC) system that enables the monitoring and control of railway traffic to students studying in the field of Rail Systems Electrical and Electronics Technology.

2. MATERIALS AND METHODS

In the work carried out, Arduino Mega, TCRT 5000 IR sensor, relay, 433 MHz transmitter-receiver pairs and led / strip led are included as hardware material. The developed software was embedded in the Arduino Mega board using the Arduino IDE program interface. The brief information about hardware materials can be reachable with the following sub-section 2.1. Section 2.2 is given the information about used method.

2.1 Materials

2.1.1 Arduino Mega Controller

Arduino is a platform built on Atmel's AVR series microcontrollers, facilitating the prototyping phase, with connectors for additional extensions and add-ons called shields that can be attached to these connectors. Arduino Mega is a low cost, smart and can be used for developing small circuits using electrical components (Mallikarjun et al., 2017).

Figure 3. Arduino Mega

Through the digital and analog input/output pins, the hardware components are bonded to the Arduino. Figure 3 shows the Arduino Mega controller.

2.1.2 TCRT 5000 IR Sensor Card

The TCRT 5000 Sensor Card can be used as an object detection sensor in a short distance, as well as a sensor that you can use as a line sensor in sumo, mini sumo and line follower robots. There is a high speed and precision TCRT 5000 sensor on the board. Sensor sensitivity can be adjusted with the help of potentiometers. This digitally output sensor card sees the bright white ground between 0-30 cm and the matt black ground between 0-10 cm. The led on the card starts to light when it sees the sensor. TCRT 5000 IR sensor card is given in Figure 4.

Figure 4. TCRT 5000 IR sensor card

2.1.3 433MHz RF Transmitter-Receiver

This card and control set operating at a frequency of 433 MHz allows you to set up a remotely controllable system that can be used in various electronic and robotic cards, systems requiring remote intervention and also remotely controlled structures. The card has a single channel and it can be adjusted whether the relay on it is normally open or closed. However, thanks to its encryption and transmitter identification features, it enables the use of more than one receiver-transmitter on the same frequency. Figure 5 shows the 433 MHz RF transmitter and receiver with relay card. In this study, this system has been used to control the railway switches and energy transfer to the train.

Figure 5. 433 MHz RF transmitter-receiver pairs

2.2 Methods

In this study, a prototype design in which the train location information can be monitored has been made by using the fixed block signalling system. The line created for the designed system consists of four stations and two railway switches systems. The TCRT 5000 sensor is used to detect the train entering the stations and blocks. In addition, the system has been made suitable for two different types of trains using both the catenary line and the third rail system. Catenary systems are the name given to the line system used to transport the energy required in train movements. A third rail is a rail that supplies electrical power to rail vehicles by means of a semi-continuous solid conductor placed between or next to the rails of a railway track.

The status of the signals of the blocks according to the trains located in different blocks along the line of the design which has been used both the catenary line and the third rail system are given in Figure 6. The hardware structure of the designed CTC prototype is given in Figure 7. In this study, 433 MHz RF transmitter-receiver pairs is given before in Figure 5 have been used to control of the railway points and send command start or stop the train manually.

In order for each train on the line to proceed safely, the commands indicated by the signals must be followed.

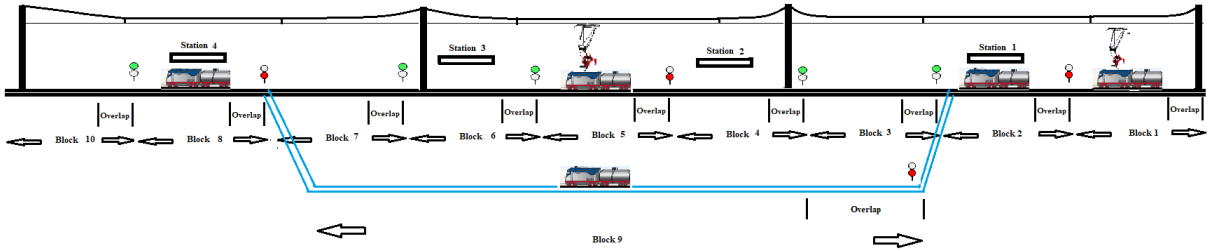

Figure 6. Fixed block system for developed prototype using both catenary and third rail system.

Figure 7. Hardware structure of the designed CTC prototype.

Since the fixed block signalling system is used in this study, it is important whether the signal is green or red, since the signals at the beginning of the block give information about the availability of the relevant block. The flow chart that each train must follow in the transition to other blocks on its route, regardless of which block it is on, is given in Figure 8.

As the first step in the realization of the design given in Figure7, the structure of monitoring of train location system was examined and it was decided to use the hardware materials given in section 2.1. After the hardware infrastructure was prepared, it was decided how the mechanical system design would be and the necessary design work was done. After the preparation of the hardware and mechanical infrastructures, one part of the electronic circuit design that will enable the system to work was drawn using the Fritzing program.

The circuit design realized in the Fritzing program is given in Figure 9. Based on this drawing, the necessary connections have been made on the system. The software, which will control the system, has been written considering the system inputs and outputs.

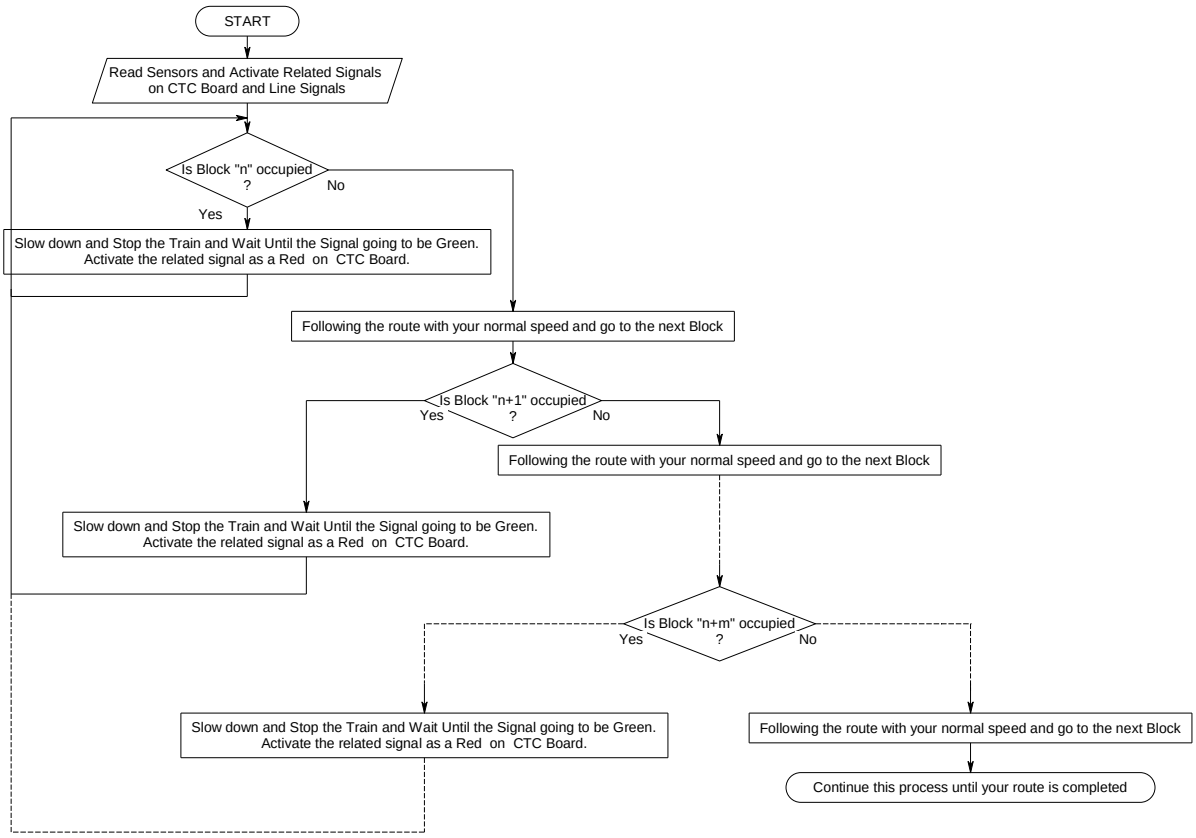

Figure 8. The flow chart that each train must follow in the transition to other blocks on its route, regardless of which block it is on.

In this study, the fixed block system has been used, the train inside the block is followed by the strip leds on the CTC control panel. The connections of the signals on the line where the train is moving and indicating whether the blocks on the line are occupied or empty are made as given in Figure 10, separately for each of the Arduino outputs.

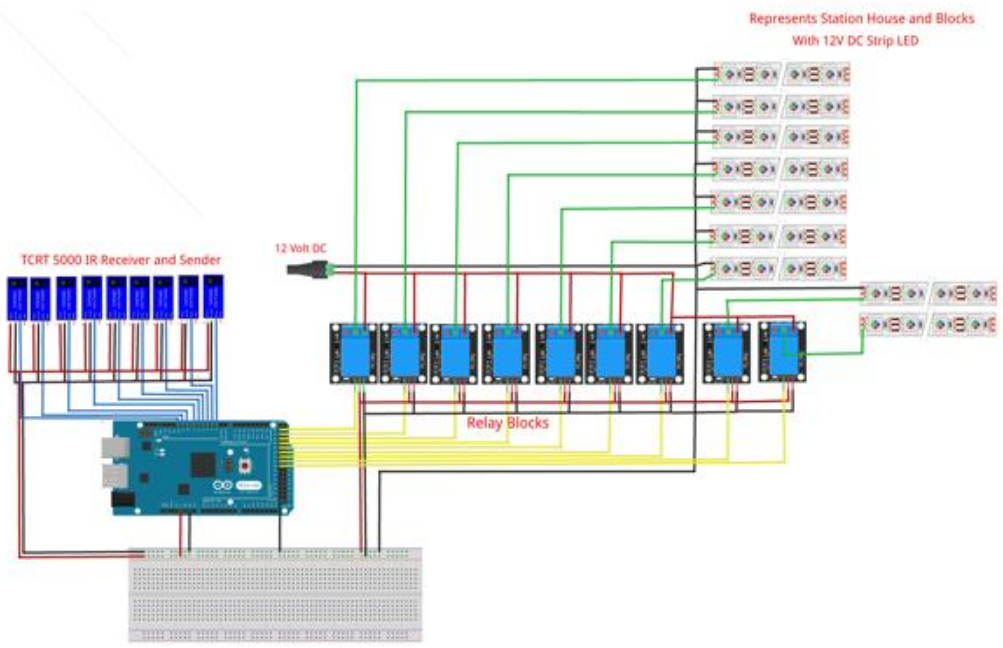

Figure 9. Implemented circuit of "Monitoring of train location system" prepared by using Fritzing program.

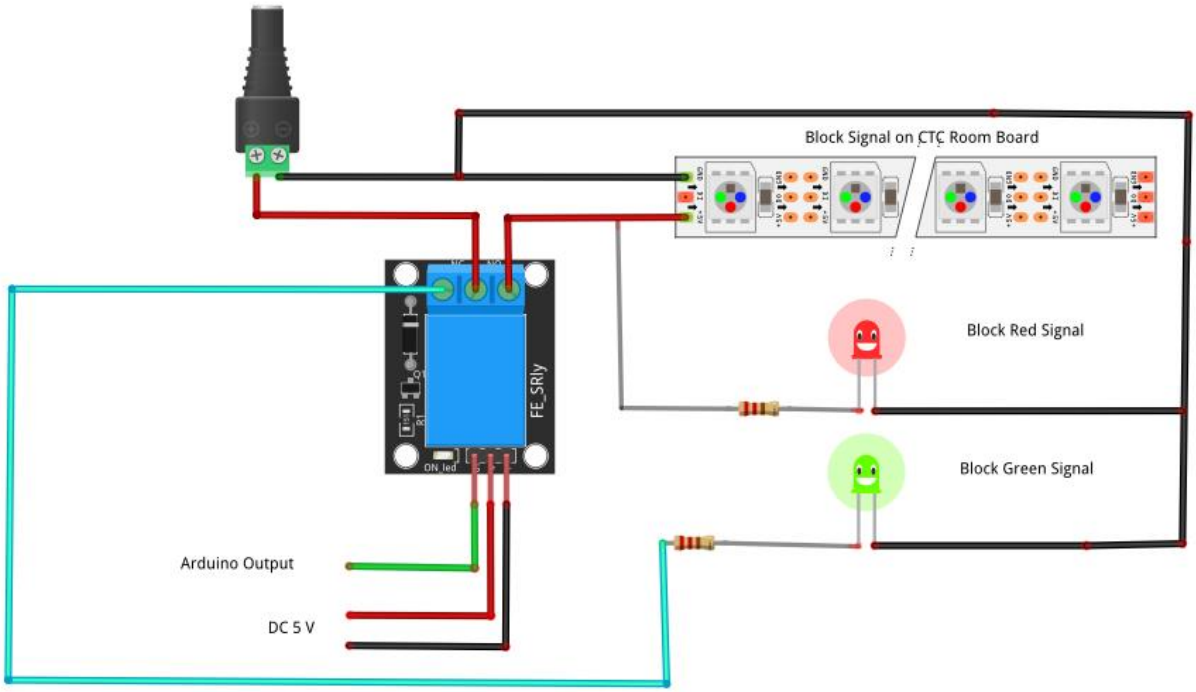

Figure 10. The connections of the signals on the line where the train is moving and indicating whether the blocks on the line are occupied or empty.

Figure 11. Monitoring of train location (red colour strip led) on CTC board

The location of the train is detected by TCRT 5000 IR sensor and transmits this information to the Arduino. Accordingly, the software constantly queries the IR sensors and decides which station or block will be red. The visual showing the location of the train is given in Figure 11.

3. DISCUSSIONS AND CONCLUSIONS

With this project, students studying in the Rail Systems Electrical and Electronic Technologies program were able to comprehend the working principle of the "train location tracking" system. In addition, with this project, the students learned the concept of blocks used in the field of rail systems, the signals in the blocks and their meanings, and the concepts of overlaps. In addition to these, they also have information about how the railway points controls are carried out remotely with RF.

Figure 12 shows the pictures, which are taken from the testing process of the designed system. It has also been determined that the TCRT 5000 IR sensor is suitable for such applications. Since the catenary system and the third rail system structures are also used in this system, the design and control of these systems are discussed with this study. In the study, 433 MHz remote-controlled transmitter and relay receiver systems were used in the energy transfer and switch controls of trains and it was predicted that these structures are suitable for such systems.

As a result, the designed structure worked as desired and the students understood the system structure and working principle with this project. Additionally, this project has set an example for new projects.

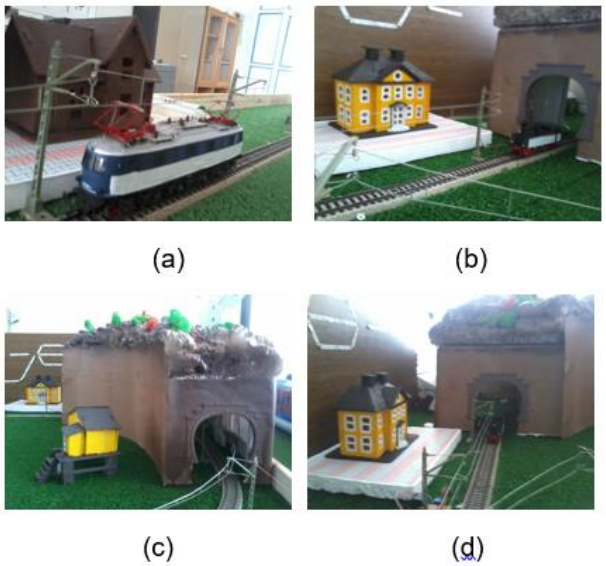

Figure 12. Images taken during the testing process of the designed system

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