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Full Automation in Driverless Trains: A Microcontroller-Based Prototype

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ABSTRACT: Driverless trains are equipped with a control system, which is programmed to make them following a specific path. Stations on such a path, timings of the train and distances between stations are all predefined. Messages and warnings are automatically generated and announced to the passengers. This paper presents the development process of a prototype for a driverless train implemented using a PIC microcontroller. Simulation for the system's circuits is done with the aid of Proteus software. The hardware circuits, which are built on printed circuit boards (PCB) are interfaced with actuators and sensors for automation purposes. The hardware is assembled in a toy-like prototype train. The C programming language is used for programming the microcontroller.

KEYWORDS: Driverless train; Automatic train operation; Full automation; Unmanned train operation.

I.INTRODUCTION

Modern technologies are being integrated in almost all aspects of our life including transportation, where a lot of advancement has been made. Railroad transport, for instance, has undergone a huge transformation, starting with the early steam operated engines to the most recent bullet train.

Many developments in railroad transport has utilized the existing infrastructure, where the existing metro system is being modernized and equipped with automatic train control and safety system in order to make them more efficient. Driverless automated concepts have been adopted, and the first recorded implementation was the London underground Victoria line, opened in 1967 [1]. Many other rail lines are then automated with the aim of reducing operational costs and improving the frequency of service. In automated train control (ATC) systems, different grades of automation (GoA) have been incorporated. The grades of automation (GoA2, GoA3, GoA4) are corresponding to Semi-automated Train Operation (STO), Driverless Train Operation (DTO), and Unmanned Train Operation (UTO) respectively [2]. Grades of automation (GoA) are defined according to which basic functions of train operation are responsibility of staff, and which are the responsibility of the system itself. For example, a Grade of Automation 0 (GoA 0) would correspond to on-sight operation, like a bus running on street traffic. GoA 4 would refer to a system in which trains are run fully automatically without any operating staff onboard. Systems work within the GoA4 are normally having an overall signalling system with the necessary connections, automatic train supervision, track vacancy detection and communication functions [3]. In fact any new metro system constructed and implemented today integrates at least some level of automation reaching out to new fully driverless technologies.

The Unmanned Train Operation (UTO), which is featured by the highest degree of automation is not a very recent development with the first UTO lines date from 1981 [3,4]. However a fully driverless system was only implemented in 2003 in Singapore, while the 75 Km Dubai line is the longest metro line in the world [5].
There has been a continuous research intended to enhance the overall automation system functions and performance of the trains. In [6], Han *et al* present the development of Korean standards of an on board train automatic control and

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show results of running test on a Korean train line. Jun *et al* in [7], suggest a development strategy of a multi-train operation simulator to support R&D works for future railway system, where a computer-based simulation models of train, station, rail and railway operation system as an agent is designed. Regarding the Communications-Based Train Control (CBTC), Georgescu [8], proposes a systematic approach that may be used to determine the most efficient way to fulfil the requirements specific to each customer faced with driverless operation. Georgescu's paper also defines required functionality to obtain the desired performance and cost, as well as issues related to the operability, maintainability, and availability of different types of driverless CBTC systems implementations. In the paper of H. Yun and K. Lee [9], a data transmission technology that is capable of calculating the required frequency bandwidth, having the transmission capacity of the communication-based train control system, and that also uses the wireless mesh network, is proposed.

II. DRIVERLESS TRAIN IMPLEMNTATIONS

The duty of any train transportation system is to provide secure, consistent, efficient and high-quality service to passengers. As many rail lines run at or near their capacity limits, automation is often the only way to maximize the operational performance of a train service system. Implemented on existing lines, automation is in many cases more cost-effective than constructing new lines or extending platforms. Fully automated metros in cities like Kuala Lumpur, Dubai, Tokyo and Copenhagen, have been running for several years. Other major cities across Europe, North America and Asia are following the example and have partly automated their systems.

The move to train automation can be justified by their numerous benefits: Schedules of train operations become more exact and timely, the frequency of the trains can be improved, especially in low traffic hours, as more and shorter trains can be inserted in traffic without the need for more operational staff, and the enhanced safety, where the element of human error is taken out completely. Besides, automation can reduce the wear-and-tear of train by optimizing energy consumption and potentially reduce operating costs through more effective and regular train operation.
In a fully automatic driving system, care should be taken for all the processes that are normally requiring human intervention. The initial train departure, trips between two stations, timing of train stoppage at individual stations, and controlling the train doors are examples of such processes. In addition, there are normally more activities that should be automated too. The safety systems represents important activities that driverless trains must have; like fire alarms with automatic fire fighting systems, sensing of any possible damage in the track and providing the information to the next train on the same track as well as to the base [10].

In this project, part of this automation tasks are considered, and a microcontroller-based prototype is developed. Actions such as; traveling through a given path with predefined stations, sensing the arrival at the station and hence, proper stopping are implemented in the prototype. Messages that are synchronized with the train's progression through its path are announced to passengers via a display. Moreover, there are alarm signals produced as appropriate. Controlling of the doors in terms of open and close and timings of such actions are considered.

III. DRIVELESS TRAIN PROTOTYPE: DESIGN AND SIMULATION

The development activities of the driverless train prototype can be broadly grouped into simulation and hardware implementation. The Proteus software is used in system simulation, with the basic elements involved in the automation represented in the block diagram shown in fig 1.

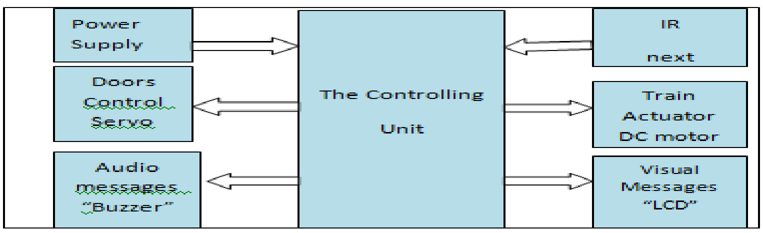

Fig 1. Block Diagram of the system.

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The blocks shown in the above figure are put together as a design to form the automated functions of the driverless train, and the ISIS schematic capture of the Proteus software is used to edit this design. Actions of automation are performed by developing a program using microC [11], a language that is used for programming microcontrollers. Fig. 2 is showing the schematic diagram of the circuit that is used for simulation. In this figure, it's apparent that PIC16F887 is used as the main controlling unit. This microcontroller is chosen because of its availability in the market, and the well known popularity of the PIC series of microcontrollers. Another fact is that PIC16F887 is having both analog and digital ports, and this feature is actually suiting our system that has both analog and digital inputs and outputs.
After having the program loaded to the microcontroller, the behavior of the system is observed throughout the simulation process and adjustments are made to the design and operation activities. On the simulated LCD appearing in fig 2, a welcoming message is displayed, where the train is still stopping at the first station with its doors open for passengers to enter. At this situation, the actuator simulating the motion of the train is OFF, and the doors' control actuator is at OPEN state.

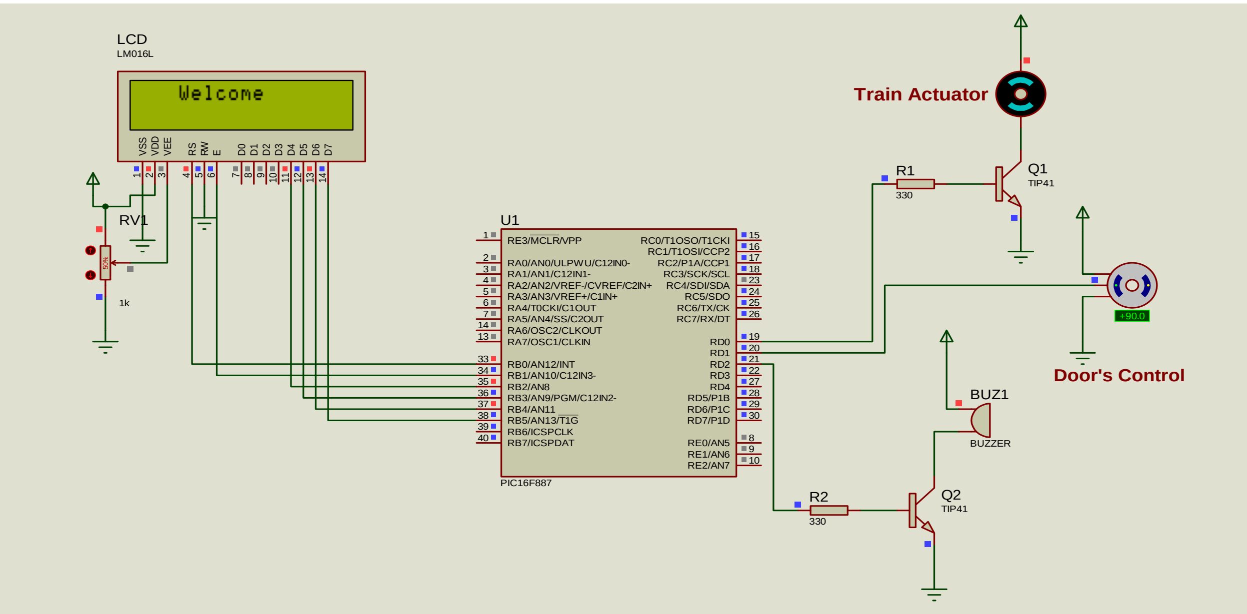

Fig 2. Schematic diagram showing the system simulation using Proteus software.

Further train activities, while its departing a station and/or arriving at a station are considered in the simulation. Such activates, and their flow are shown in the state diagrams of fig. 3 and fig. 4.

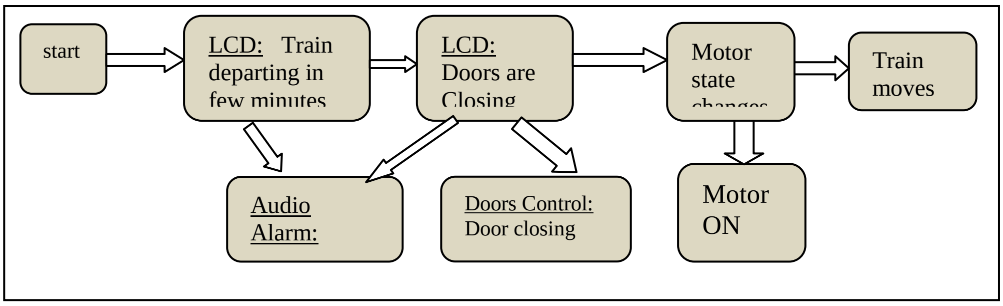

Fig 3. State diagram showing the train activities during departure

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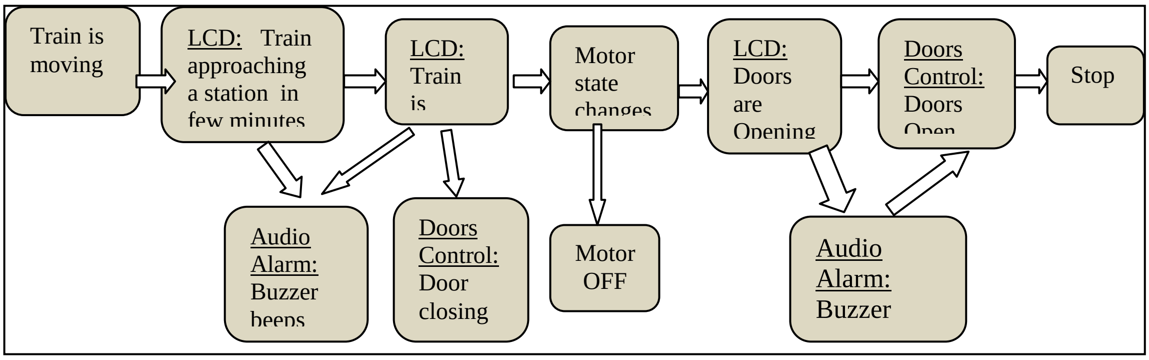

Fig 4. State diagram showing the train activities during arrival

For the train to automatically and reliably stops at stations, different techniques may be applied. Distances between stations, for instance, may be used to manage such actions by providing them as information to the control unit. In our system, we have used IR sensors, where at appropriate locations with respect to each station, an IR transmitter is positioned. Whereas the other part of the IR sensor, the receiver, is installed on the train. Whenever a train travelling between stations, decodes a relevant IR signal, it will start its preparation to stop at the coming station. The Proteus simulation of the IR circuits are shown in fig. 5. In this figure, it can be noticed that three pieces of a smaller microcontroller chips are used (PIC16F628). This type of PIC16 series has only 18 pins and two ports, which are found enough for the task of IR transmission and reception circuits.

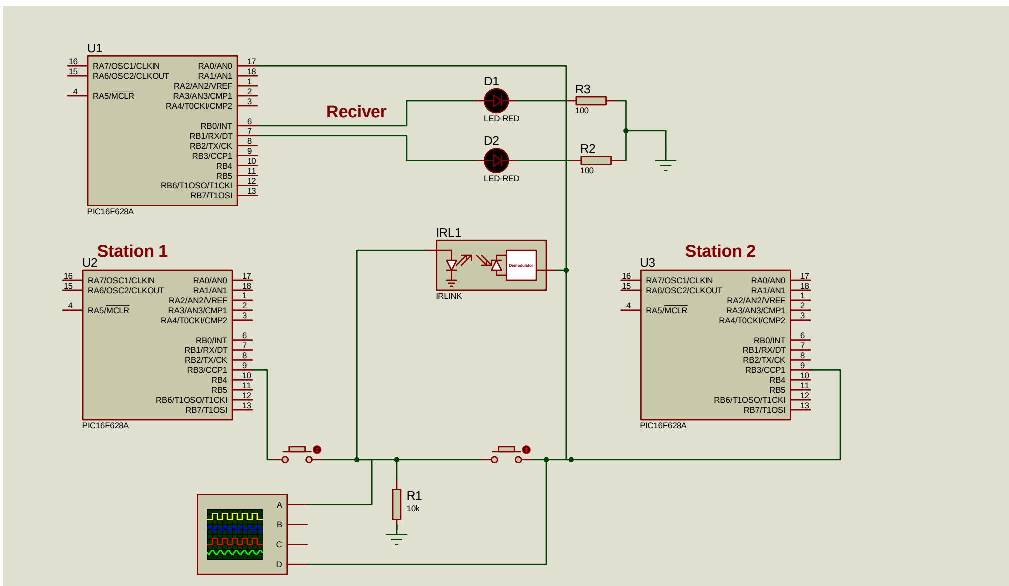

Fig 5. Schematic diagram showing the simulation of the IR sensors

IV.THE HARDWARE IMPLEMNTATION

After testing the circuits with simulation, hardware implementation started by assembling the components on printed circuit boards (PCB). ARES software, which is part of Proteus is used to produce the schematic for three PCBs that are used in implementing the hardware system. One PCB is designed to hold the main

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controller circuit components, and two small identical PCBs are used to implement the IR sensors. A PIC microcontroller unit is used in each of the three circuits. The main controller circuit is installed in a toy-train representing the prototype and interfaced with a dc motor to actuate the train movement, another actuator to control the opening and closing of the door, an LCD to display messages, and a buzzer to announce audio warnings. An IR detector is also incorporated in the main control circuit, while the two IR transmitters are located along the path of the train to present stations at which the train has to stop. The assembled hardware system is illustrated in fig. 6.

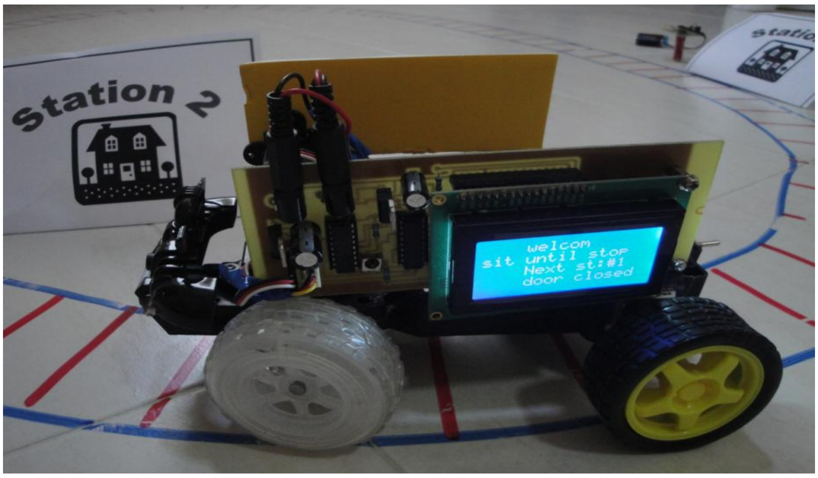

Fig 6. The assembled driverless train prototype

V. RESULTS AND DISCUSSION

An example of how embedded technology is used in application, specifically in the transport sector is presented in this paper. A driverless train prototype has been developed as a microcontroller-based system. Both software and hardware parts are included in the development process. The programs which are written using micro C language were simulated together with other system components using the Proteus software. In the hardware part, all the circuitry required to interface with the PIC microcontroller are designed and built. The development of the prototype has passed through stages which ended up with a working system representing many features of automation. The prototype train is following a prescheduled path in terms of proper stations' starts and stops, announcing messages to passengers, and issuing alerts.

Despite the incorporation of all the presented features, a room still there for more improvements to be added. Currently, the train is driving forward following a circular path. The path, however can be reprogrammed in such a way that the train, for the same path follows forward and reverse journeys. Another improvement can be added such that more than a single path for the train to follow is offered to choose from. Alternative paths may have different stations to stop at, and consequently different timings.

VI. CONCLUSION

The driverless train prototype that is presented in this paper is in fact a final year project. A general conclusion that can be said about such engineering projects is that they are introducing students to an open horizon of developments. Such projects can only represent a minor part of what the future and technology integration may look like for the modernization of different service sectors including transport. Researching and developing a working prototype enhance self confidence and assure that it is possible to design a system and apply it for solving a particular problem by acquiring the necessary information. Moreover, developing a prototype system can serve as a basis of a far more sophisticated and advance form of control system such as a real driverless train system.

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