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Wi-Fi Based Signalling in Railways

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Abstract: The proposed system is an alternative to the conventional hardware section of the interlocking and signalling methodologies adopted by Indian Railways, which are largely composed of relays and cables. In this paper, sensors, controllers and Wi-Fi modules, made to work in an integrated fashion to replace these otherwise inefficient (both in terms of energy and space) systems is presented. The presence of trains in railway tracks, detected by sensors, is used to control the railways signals, via microcontrollers. Further, this information is used to switch the siding tracks and level crossing gates through various motors. The utility of microcontrollers in this area also warrant several other additional features like pre-acknowledging loco pilots about upcoming signals, stopping the trains directly from control rooms in case of emergency, etc., which also adds to the security aspect of the entire system.

Keywords: Indian Railways; signalling; interlocking; energy efficiency; safety factors in railway; embedded systems.

I. INTRODUCTION

A unique feature of rail network for it to circulate in total safety, unlike road network, is that it must be controlled. The obvious reason for this is that trains don't have the possibility of avoiding each. This entire control of rail network is taken care of interlocking, which, by definition, is the arrangement of signal and signal appliances, so interconnected, such that the trains' movement must succeed in proper sequence. Considering the large length of trains, the entire rail network is divided into sections (called blocks) and each of them is controlled by an interlocking system. The entire rail network is guided by one prime safety rule, viz. only one train must be present in a block at a particular point of time. For this, along the track sides, various systems that authorizes the train whether to continue its journey or not are placed [1]. The presence of trains is anticipated by various systems and its output is used in track switchers, gate crossing and various other scenarios.

One example of a conventional type of interlocking methodology (as adopted by Indian Railways) is shown in Fig. 1. In both Fig. 1(a) and Fig. 1(b), where a *12 V* dc supply is exciting a relay through the rails. When the train is not present in the track, the circuit is completed through the rails and the signal shows the green/clear aspect. However, when a train is present in the block, its axle shorts the circuit and thus de-energizing the relay. The LED signal indication corresponding to this situation is through a red/stop aspect [2].

II. TOWARDS A NEW SIGNALLING MODEL

In this respect the following points are worth observing, which may be deemed as the disadvantages of the convectional system mentioned in the last section.

- The relays and cable circuits are very bulky and consume large space. The energy consumption associated with them are very high.
- There are large losses in the cable circuits that spans a large area (probably a block or two).
- In electrified tracks, where ac current of different frequencies are used to excite the relays, appearance of parasitic oscillations may give misguided information.

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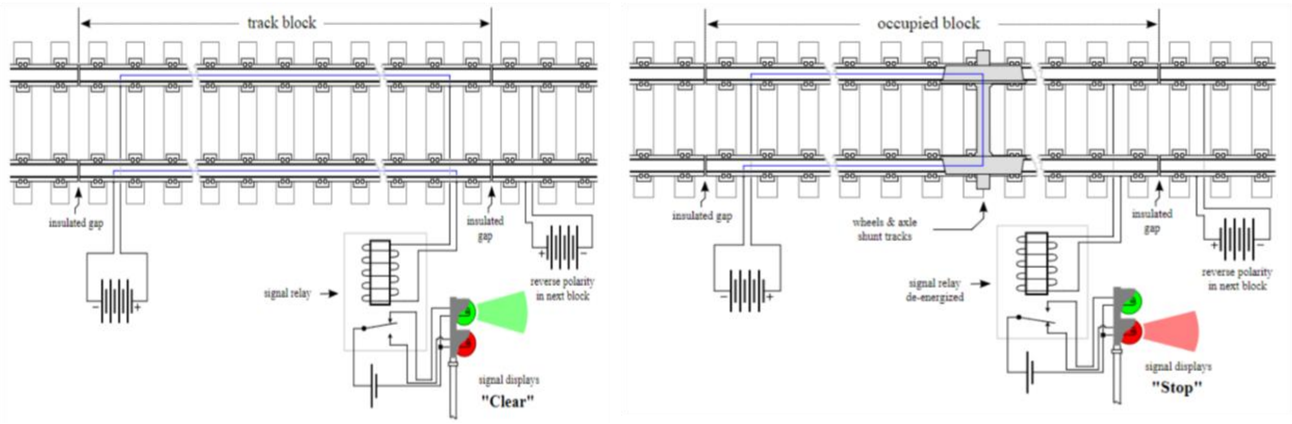
- When insulation breaks the circuit by-passes the relay sections, giving the same signal indication irrespective of the presence/absence of trains.
- Sanders, used in locomotives during rainy and misty seasons, isolated the axle of the train from the wheel. This further makes the train virtually ‘invisible’ to the signalling system.



(a) (b)

Fig. 1 Schematic drawing of a track circuit - unoccupied (a) and occupied (b).

These are some of the issues which the proposed system of signalling must address. Specifically, the signalling system must have only reduced number of relays and cables, considering the amount of losses and the space consumption they demand. Also, the signalling must be more economical, so that cost of maintenance can be reduced significantly. The scope for automating the associated processes in signalling, like opening and closing of level crossing gates, track switching, must be utilized. It will be shown how the aforesaid points can be made possible in this paper. Further, although not within the scope of this work, the system can have additional utility for safety like acknowledging the loco pilot about the upcoming signals, emergency control of train from control rooms etc. It must be stated that these additional functionalities can be added any time into the proposed system after its commissioning without much effort.

III. LED SIGNALLING, TRACK SWITCHING AND GATE CONTROL

A. *Sensing the Train*

The present system of signalling utilizes the trains’ cutting of relay excitation path for detecting its presence. This, as mentioned in I, has its own disadvantages. In the proposed system of signalling, suitable sensors are used to detect a train. These sensors can be of ultrasonic or infrared type and are suitably placed so that it cut only the passing trains. These can be commissioned sidewise, or as any other suitable mechanical arrangement. Also, delays must be provided so that it could distinguish cutting a train from some other instantaneous means of blocking (say, a bird). In both ultrasonic and infrared types, a distance of detection can be preset. Having this value in hand, the sensors won’t misinterpret the trains of other tracks as a valid output. However, considering the advantages that ultrasonic sensors have in detecting obstacles irrespective of whether it is day time or night time, and that its detection is independent of whether fog, mist, smoke, etc. are present, it’s a preferable choice. But, as far as showing the system in an exhibit model, both does the same job equally well.

B. *Methodology and Algorithm*

Having detected a train, this data is directly fed to a microcontroller (either directly or through Wi-Fi modules). Through suitable programs in the microcontrollers, this input can be utilized to perform various actions like changing the signals, switching the tracks or controlling the level crossing gates. The block diagram representation of each of those functions is shown in Fig. 2. As a practical component for each block, an LPC2148 is used as the microcontroller, ESP8266 as the Wi-Fi module, IR sensors as the sensor and servo motors for both controlling the track and gate position. The design considerations of these elements shall be dealt at a later section. In Fig. 2 note that the detection point may not be necessarily connected electrically to the microcontrollers that directly control the gate and track motors. They can be interfaced through Wi-Fi module, hence avoiding the need for any cables.

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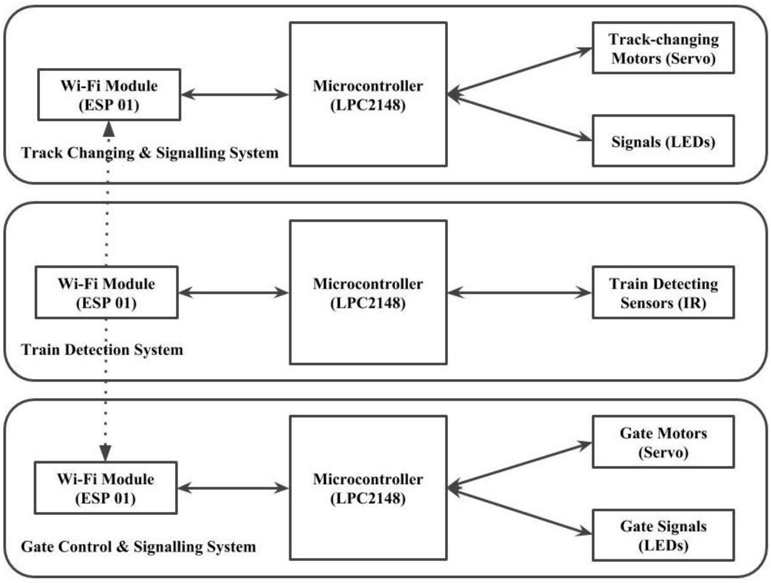

Fig. 2 Block diagram approach of changing the LED signals, switching the tracks and controlling the gate level crossing motors based on the output from the IR sensors.

Now, an algorithm shall be developed restricting the analysis to a track section shown in Fig. 3. Here, a main track (or priority track) and a siding track have been shown. The presence of trains in these tracks are sensed by the sensors labelled IRS_1, IRS_2 and IRS_3. The aspects indicated by various signalling LEDs are marked as L_1, L_2 and L_3. The track changing motor is shown by M_1. Enlisting out all the outcomes, a truth table as in Table 1 can be formed, which mention what are the corresponding states IRS_1, IRS_2, IRS_3, L_1, L_2, L_3 and M_1 could take.

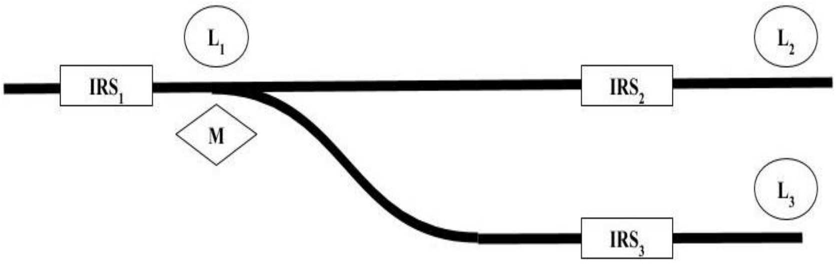

Fig. 3 A track section consisting of train detecting sensors, signalling points and track changing motors.

TABLE. 1 A TRUTH TABLE SHOWING VARIOUS OUTCOMES.

IRS_1	IRS_2	IRS_3	L_1	L_2	L_3	M
0	0	0	G	G	G	M
0	0	1	G	G	R	M
0	1	0	Y	G	R	S
0	1	1	R	G	R	S
1	0	0	G	G	G	M
1	0	1	G	G	R	M
1	1	0	Y	G	R	S
1	1	1	R	R	R	S

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IRS_1 senses whether a train is approaching the main track or not whereas IRS_2 and IRS_3 senses in the later part of the main track and siding track. In the table, a '0' indicate the absence of train and '1' otherwise. One assumption made here is that, by default, the signals indicate the green aspect when all the blocks are empty. However, this may vary depending on the railway preferences. Also, in the table, 'M' stands for that configuration of the track switcher when it is aligned to the main track, and 'S' to the siding track. 'R', 'Y' and 'G' are illustrated with their respective colours as they are supposed to be in their corresponding signals.

Now consider the combination 010 [3]. This means that a train is present in the priority track (either stopped due to some emergency or passing that signal) and the other track is empty. This would imply that any train following it must slow down and enter the siding track, if approached. Hence the track switch must be aligned 'S' to direct the following train into the siding track. L_1 and L_3 must be 'Y' and 'R' respectively so that the following train slows down, enter into the siding track and wait until the main train has passed by. However, L_3 must be shown 'G' indicating its permission to move with line speed.

C. *Circuit Diagram*

The circuit level implementation is shown in Fig. 4. For the microcontroller part, an LC2148 is used. For convenience, the signalling, motoring and train detection points are all shown at the same place, so that only one microcontroller controls them. Here six IR sensors are shown, of which three are used for detecting the trains, two for conforming whether the gates in the level crossings have been completely closed and the last one for ensuring that the tracks are properly switched. All these sensors are fed to the Port 0 of LPC2148. The LED signals are sourced from Port 1. Their indication logic is already mentioned in Table 1. The servo motors for controlling the gate and the track switch are connected to the PWM pins. This is because, in order to control the positions of the servo motor, suitable PWM waves are to be fed as control signals into it. The duty ratio of the PWMs are to be computed beforehand, depending on the load, and are to be suitably programmed into the microcontroller. It must be remembered that in the actual case, the microcontroller may not be able to source a high load driven motor. In such cases, the motor is fed through a driver circuit (either IC based or otherwise). A Wi-Fi module (ESP8266) is also connected to the microcontroller, in order to communicate with the neighboring ones (or as stated earlier, with loco pilot).

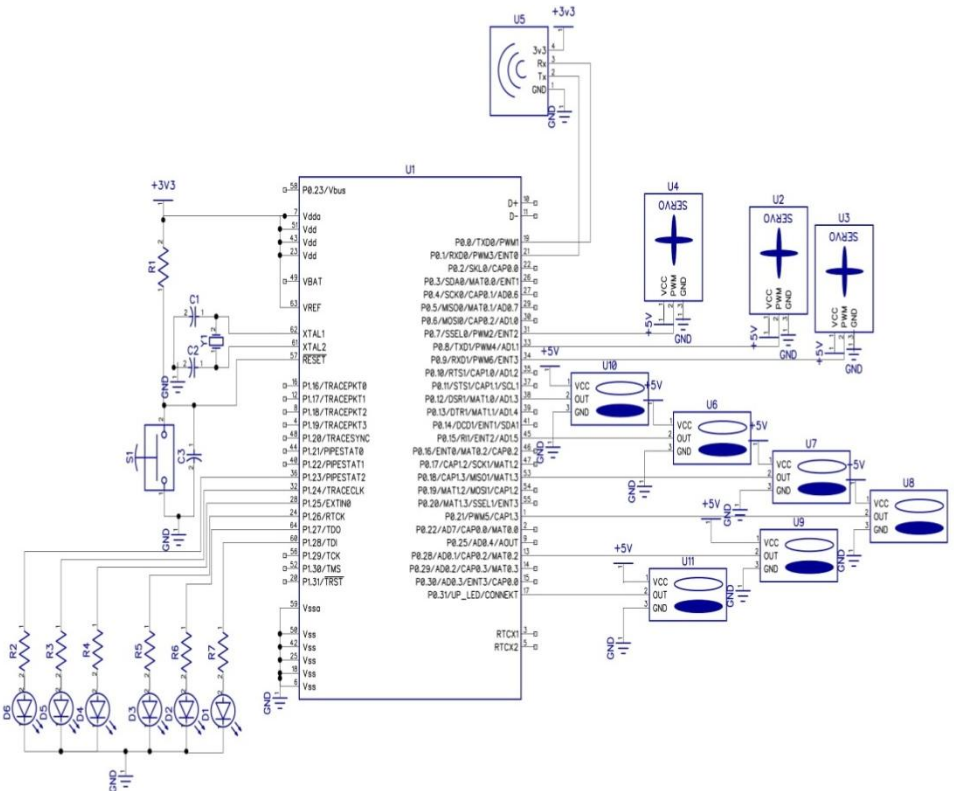

Fig. 4 Circuit level implementation

The choice of LPC2148 is by no means strict. One could equally use an ATmega16. But since a common controller for signaling, motoring and train detection have been used, an increase in the number of pins has to be accounted for. In the motor side, a stepper motor could have been used owing it its high torque capability and less power consumption. The other associated circuits are those as mentioned in the datasheet of LPC2148. C_1 and C_2 are capacitors connected to remove the surface charges from the crystal that clocks the controller. A reset circuit is also designed, which by default connected to *3 V* through a current limiting resistance. When the push button is pressed, it is directly connected to the ground.

IV. MODEL TESTING AND SUMMARY

A model, implementing all the facts mentioned, was constructed as shown in Fig. 5. All the conditions of the truth table were tested and the results conformed to what was designed.

Fig. 5 Model of the track section constructed on an exhibit.

This model is just an indication of the utility of embedded system into the area of signalling in railways. This new approach to signalling can serve as a replacement to the present system and weed out all the associated disadvantages. This space is utilized to mention some of the future scopes of this work. The foremost one is the utility of Internet of Things (IoT) in railways [4]. This would further make railways more connected, safe and pave ways for easy fault detection techniques. The increasing bandwidth of internet and data security would only aid this process. Further, since this method of signalling is based on low power semiconductor devices, the power required for it can be generated utilizing solar energy. Solar panels built around the stations is one example towards this step. Since DC supply is what is actually needed in these devices, the energy from solar can be utilized directly without conversion.

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