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Design and Construction of Automatic Railway Crossing Gate Control Using Proximity and Infrared Sensors Based on Omron CP1E E30-SDRA PLC

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ABSTRACT

Railway crossing gates are one of the railway infrastructure facilities. Currently, there are still many problems, especially in traffic accidents. The cause of traffic accidents at railway crossings generally occurs due to the lack of facilities and infrastructure (rail crossing gates) and negligence of guards in carrying out their duties. Therefore, it is necessary to design an automatic railway crossing gate. The prototype of the automatic railway crossing controller uses proximity and infrared sensors to detect the arrival and departure of trains. When the infrared or proximity sensor detects the arrival of a train, the Programmable Logic Controller (PLC) activates Pulse Width Modulation (PWM), buzzer, and Light Emitting Diode (LED), so that the crossing motor goes down. After the crossing touches the limit switch, the motor stops and the buzzer and Light Emitting Diode (LED) remain on. The infrared or proximity sensor detects the departure of the train so that it reverses the motor so that the crossing goes up, then turns off the buzzer and Light Emitting Diode (LED). In this way, it is hoped that this design can be used to increase the efficiency of the system's operational costs and optimize the railway crossing system and is expected to reduce the number of traffic accidents at railway crossings.

Keywords: *Programmable Logic Controller, Infrared Sensor, Proximity Sensor, Train Barrier*

1. INTRODUCTION

The safety and efficiency of railway transportation systems are critical to modern infrastructure. Railway crossings represent one of the most hazardous interfaces between rail and road traffic. According to the [1], accidents at railway crossings account for a significant percentage of all rail-related incidents, underscoring the urgent need for effective control mechanisms to enhance safety measures. Automatic railway crossing gate systems have emerged as a viable solution to mitigate these risks by preventing unauthorized vehicle access during train approaches. This research focuses on designing and constructing an automatic railway crossing gate control system utilizing proximity and infrared sensors, managed by the Omron CP1E E30-SDRA Programmable Logic Controller (PLC).

The integration of automation in railway crossing gates is not merely a technical advancement but also a necessary step towards achieving greater safety. Traditional manual systems often depend on human vigilance, which can be compromised due to distraction or fatigue. By implementing an automated system, we can minimize human error, thereby reducing the likelihood of accidents [2]–[4]. Previous studies have demonstrated that automated systems can significantly enhance the reliability and efficiency of railway operations [5]–[7]. This research aims to address the limitations of current manual systems by developing a robust automatic gate control solution.

Proximity and infrared sensors play a pivotal role in the proposed system. Proximity sensors detect the presence of trains and trigger the gate mechanism accordingly. They offer the advantage of non-contact detection, ensuring accurate and timely responses without physical interaction [8]. Meanwhile, infrared sensors serve to enhance safety by providing an additional layer of detection, especially in low-visibility conditions. Their capacity to detect heat signatures allows for reliable operation during adverse weather, further improving safety at railway crossings [6]. The combination of these sensors will be essential in developing a comprehensive automatic railway crossing gate control system.

The Omron CP1E E30-SDRA PLC serves as the brain of the control system, offering a programmable platform that enables flexibility and adaptability in design. PLCs have gained popularity in industrial applications due to their reliability and ease of programming [3]. The choice of the Omron CP1E E30-SDRA PLC is motivated by its advanced features, including multiple I/O options and compatibility with various sensor types, making it well-suited for real-time control applications in railway systems.

In terms of methodology, this research will follow a systematic design and construction approach. The initial phase involves extensive literature review and analysis of existing railway crossing systems, identifying gaps that the proposed system can fill. The design process will incorporate theoretical frameworks and engineering principles to ensure functionality and safety. Following the design phase, construction will involve assembling the physical components, including sensors, gates, and PLCs, leading to a prototype that can be tested under simulated conditions.

The anticipated contributions of this research extend beyond mere technical improvements. By developing a reliable automatic railway crossing gate control system, the research seeks to enhance safety for both train passengers and road users. Moreover, it aims to provide insights that can inform future designs of automated traffic control systems across various applications. The outcomes of this research could also serve as a model for other regions with similar safety challenges, promoting broader adoption of automated safety measures in transportation.

This introduction outlines the significance of the research and sets the stage for the ensuing sections, which will delve into the detailed design, construction, and testing processes of the proposed automatic railway crossing gate control system. By addressing existing safety challenges with innovative solutions, this research aims to contribute to the ongoing discourse on improving railway safety and operational efficiency.

2. METHODS

2.1 Types of Research

This type of research explains the design and construction of an automatic railway crossing gate controller using the OMRON CP1E-E30 SDRA PLC.

2.2 Flow Diagram

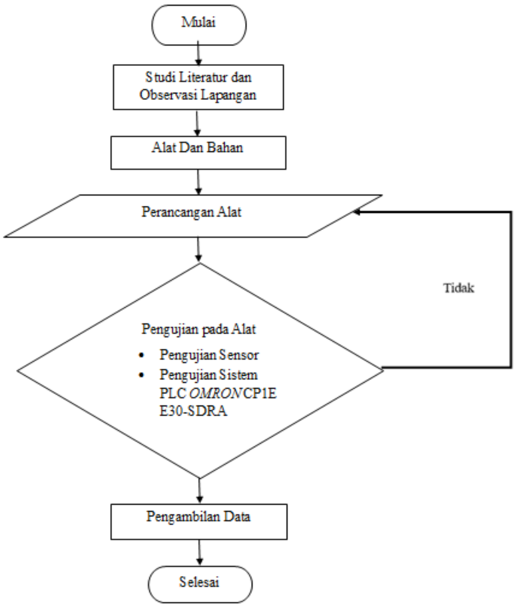

Figure 1. Flow Diagram

The flowchart begins with reading literature studies and conducting field observations. After that, determine the tools and materials, conduct sensor testing and system testing. If the design has been tested and is successful, the next step is to collect data by measuring the voltage magnitude on each component.

2.3 Research methods

The procedure in design research as in the flow diagram above consists of several stages as follows:

1. Literature Study
2. Tools and materials
3. Tool Testing
4. Data Restore

3. RESULTS AND DISCUSSION

3.1 How The Design and Construction of Automatic Train Doorstops Works

After designing and manufacturing a prototype of a PLC-based automatic train stop door, it is necessary to test the tool produced and conduct a thorough analysis of the test results.

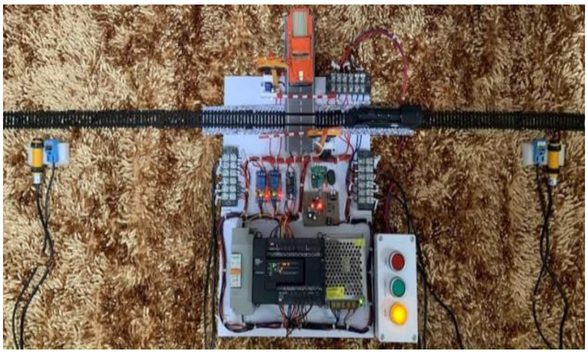

Figure 2. Prototype of Automatic Train Doorstop

The hardware uses two types of sensors, namely infrared sensors and proximity sensors such as train arrival and departure sensors, DC motors to open and close door covers, buzzers and LED alarms such as train alarms.

The CP1E-E30 SDR-A PLC processes sensor signals and can open and close doors and provide warnings to the train.

3.2 Flow Chart Diagram

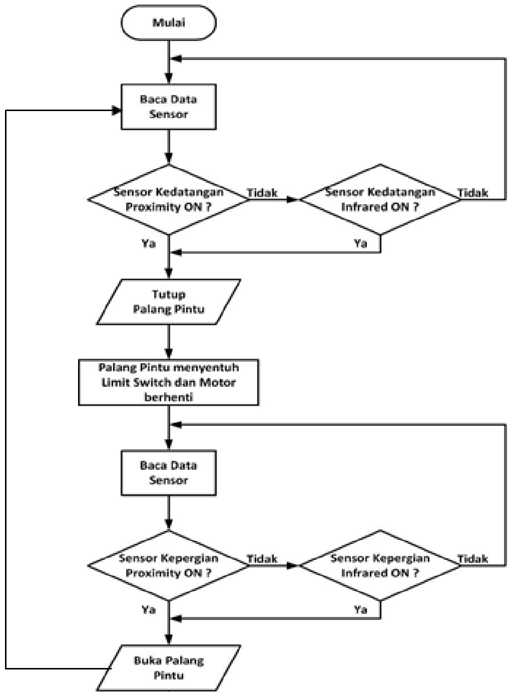

Figure 3. Flow Chart Diagram

After the departure sensor detects a train passing, the DC motor then reverses direction to raise the barrier.

3.3 Instrument and Voltage Measurement

In the design of the prototype model of the automatic railway crossing gate controller based on the OMRON CP1E PLC, voltage measurements were carried out on each component to determine the amount of input voltage received by each component such as measuring the AC source voltage, measuring the PLC internal power supply voltage, measuring the input voltage on the PWM, measuring the input voltage on the siren module, measuring the relay voltage, measuring the output voltage of the proximity and infrared sensors.

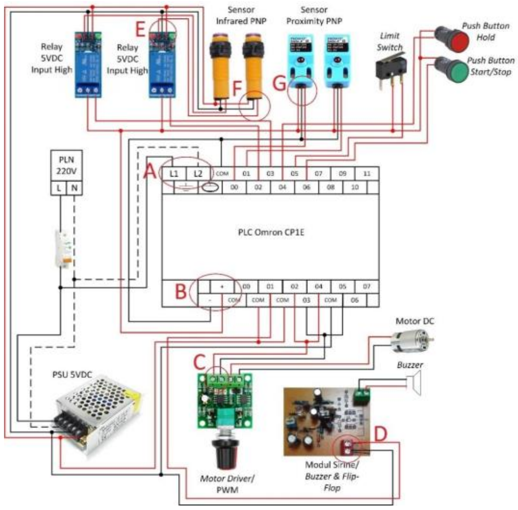

Figure 4. Voltage Measurement Points on the Tool

In Figure 4, the test section for measuring the voltage of the tool has been determined, which is carried out using a digital multimeter, to determine the voltage in the specified section.

Tabel 1. Voltage Measurement Results on the Tool

No	Titik Pengukuran	Kondisi	Tegangan	Tegangan Perancangan	Berhasil
1	A	ON	217,9 VAC	220 VAC	Ya
		OFF	0 VAC	0 VAC	Ya
2	B	ON	24,05 VDC	24 VDC	Ya
		OFF	0 VDC	0 VDC	Ya
3	C	ON	5,52 VDC	5 VDC	Ya
		OFF	0 VDC	0 VDC	Ya
4	D	ON	5,51 VDC	5 VDC	Ya
		OFF	0 VDC	0 VDC	Ya
5	E	ON	5,51 VDC	5 VDC	Ya
		OFF	0 VDC	0 VDC	Ya
6	F	ON	4,81 VDC	5 VDC	Ya
		OFF	0 VDC	0 VDC	Ya
7	G	ON	23,29 VDC	24 VDC	Ya
		OFF	0 VDC	0 VDC	Ya

Test section A measures the source voltage from PLN that enters the PLC, test section B measures the internal power supply voltage on the PLC, test section C measures the voltage on the motor driver or PWM input, test section D measures the voltage on the siren or buzzer module input and flip-flop, test section E measures the voltage on the relay module, test section F measures the voltage on the proximity sensor, and test section H measures the voltage on the infrared sensor.

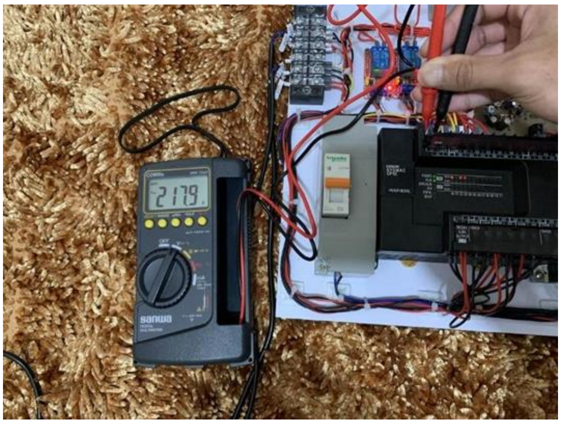
Figure 5. PLN Source Voltage Measurement

The measurement results show a voltage value of 217.9 VAC as seen in Figure 4. The output voltage measurement test point of the internal power supply on the PLC which is used for switching input ports on the PLC.

Figure 6. PLC Power Supply Voltage Measurement

Measuring the voltage at point C is done by attaching the tip of the red probe cable to the positive terminal.

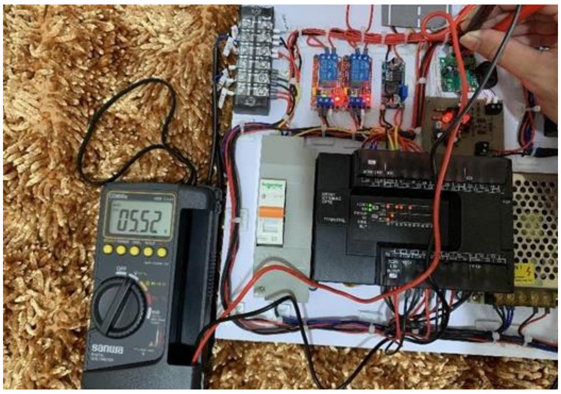

Figure 7. PWM or Motor Driver Voltage Measurement

Voltage measurement at point B is done by attaching the end of the probe cable to the module input terminal. The measurement results show a voltage value of 5.52 VDC as seen in Figure 7.

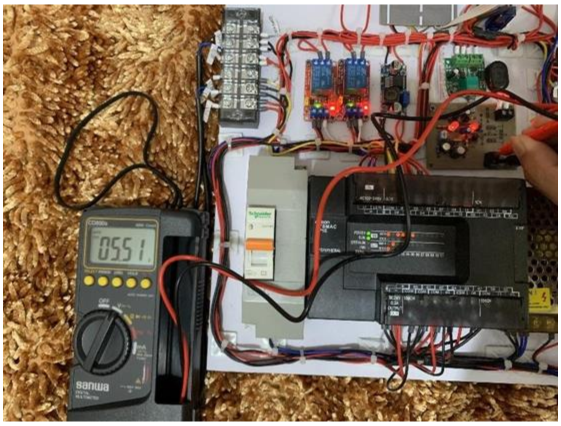

Figure 8. Measuring the Voltage of the Siren or Buzzer Module

Voltage measurement at point D is done by attaching the end of the probe cable to the module input terminal. The measurement results show a voltage value of 5.51 VDC as seen in Figure 8.

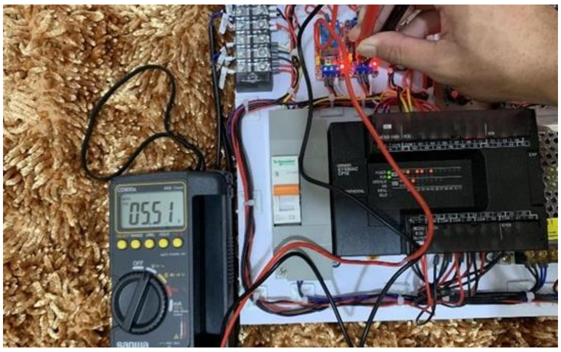

Figure 9. Relay Module Voltage Measurement

Measurement at point E is the measurement of voltage on the HIGH active Relay module which refers to the type of relay if activated the input signal has a positive voltage level. Voltage measurement at point E is by attaching the end of the probe cable to the module input terminal.

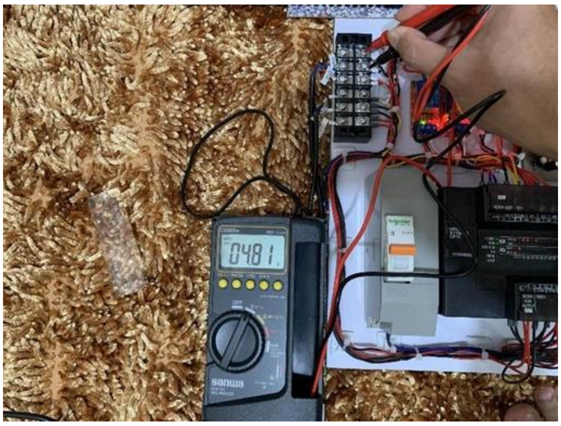

Figure 10. Infrared Sensor Output Voltage Measurement

Measurement at point F is the measurement of the voltage at the output of the HIGH active PNP infrared sensor which refers to the type of sensor if activated the input signal has a positive voltage level. It can be concluded that when the infrared sensor is active there is a voltage difference between the input and output of 0.7 V.

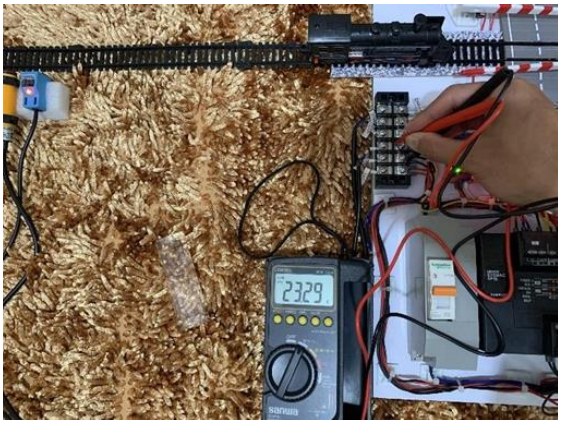

Figure 11. Proximity Sensor Output Voltage Measurement

Measurement at point G is the measurement of the voltage at the output of the active PNP proximity sensor HIGH which refers to the type of sensor if activated the input signal has a positive voltage level. After determining the measurement point, then measure the output voltage using a multimeter. The voltage measurement at point G is by attaching the end of the probe cable to the module output terminal. The measurement results show a voltage value of 23.29 VDC as seen in Figure 11.

CONCLUSION

The design and construction of an automatic railway crossing gate controller using proximity sensors and infrared sensors based on the Omron CP1E E30-SDRA PLC is expected to reduce the operational costs of the manual railway crossing gate system.

The design and construction of an automatic railway crossing gate controller using proximity sensors and infrared sensors based on the Omron CP1E E30-SDRA PLC is expected to optimize the current railway crossing gate system.

The design and construction of an automatic railway crossing gate controller using proximity sensors and infrared sensors based on the Omron CP1E E30-SDRA PLC is expected to reduce the risk of traffic accidents at railway crossings.

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