Plumbing Leakage Detection System With Water Level Detector Controlled by Programmable Logic Controller type Omron CPM2A

Abstract

There is a chance of leakage in the plumbing caused by water pressure in the pipes, improper installation of pipe connections, or external influences, such as earthquakes. Plumbing leakage that is detected too late can cause damage to other systems. It is necessary to have a plumbing leakage detection system to detect a leak in the plumbing. Therefore, in this research, a plumbing leakage detection system is designed with a Water Level Detector (WLD) controlled by a Programmable Logic Controller (PLC) type Omron CPM2A. The method used in this research is designing the optimal model form of the system, which is distinguished by designing hardware and software, testing the devices, such as power supply, WLD, and Channel Relay Module (CRM), and making conclusions. From the results of this research, it was found that the system works well in detecting leakage of plumbing, as indicated by all transistors' ability to work well where the electrodes (E1-E2) are connected by water. The transistor in the WLD module will work as a switch or transistor in the saturation position. In this research, it can be seen that even though there is a leakage from the relay contacts of 1.8 VDC, it is still considered in a safe condition because to provide a trigger to the 3B3D Module, a minimum of 12 VDC is required. In addition, when the relay is not working or off, the measurement at the NC terminal is 12 VDC.

Keywords: Programmable Logic Controller (PLC); Water Level Detector (WLD); Leakage Detection, Channel Relay Module (CRM).

I. Introduction

Plumbing leakage is a problem because whenever there is a leakage somewhere, it cannot be found at an early stage and can become a big problem, leading to water wastage [1]. The basic principle of leakage detection is the loss of pressure on one of the sensors at a fast rate. The use of the pressure transmitter sensor changes it from a sensor to a signal that can be decoded by the controller [2]. The liquid level (as in, e.g., water level) is the height associated with the liquid-free surface, especially when it is the topmost surface. It may be measured with a level sensor [3].

The water level control is a tool that can make it easier to identify the water level in the water reservoir [4]. The automatic water level controller minimizes the need for manual switching and human interference. The machine helps to detect the level of water or any liquid [5]. Water flow sensors detect a different value during water leakage occurred [6]. The sensor module collects the relevant data to decide whether the applications to be monitored are working effectively under certain threshold values [7].

The water leakage detection system can be deployed in the already existing plumbing with flow rate sensors attached to the path of the water flow [8]. Constant leakages through pipes in walls lead to water seepage, which may damage the structural components of the building [9]. The control of all equipment has been performed through the use of computers. Most equipment uses PLC to connect with computers to monitor each load and electricity-consuming devices [10].

The programmable logic controller (PLC) constitutes one of the main architectures of manufacturing system control and is programmed with standardized languages [11]. By integrating motion control into the PLC, the control system was greatly simplified because simple motion control can be realized by the PLC without a special motion controller [12]. PLC is time-driven with time stamps defined by the I/O scanning and does not receive/emit events but logic variables. Hence, the input and output events must be defined from combinations of variables [13].

PLC plays a significant role in automatic control systems. A ladder diagram is the most widely used programming language for PLC, which is transparent and intuitive since the variables are represented as graphical symbols and each instruction is graphical [14]. PLC projects commonly use five programming languages including two textual languages, i.e. ST and IL, and three graphical languages, i.e. FBD, LD, and SFC [15]. PLC application program development is becoming crucial due to the growing complexity of control problems associated with the demand for high-quality solutions [16].

The sensor and actuator signal data are collected from the PLC memory through a single communication channel (as collecting data from the actual sensors and actuators is extremely costly); and only a fraction of those signals can be accessed at a given time [17]. The essential role of PLC is to interact with sensors and actuators [18]. PLCs are providing the bridge between the cyber and physical worlds by controlling devices such as valves, pumps, and motors in response to operator input or their preprogrammed control logic [19]. Input-output specification of the PLC-based function block for considered control law has to be compatible with the specification of the presented "Identification Block" [20]. The goal of PLC data collection is to record both the input and output values whenever there is a change in any of the input/output (I/O) values [21].

The ladder logic programming language requires the programmer to create diagrams of input and output relays to depict the order and circumstances in which connected devices are toggled and act [22]. Ladder logic is one of the most used programming languages to feed instructions into the PLC [23]. The PLC control logic process deals with the input signals before producing output to regulate the connection and disconnection of the liner circuit [24].

Therefore, in this research, a plumbing leakage detection system controlled by the PLC type Omron CPM2A was designed. In order to determine the location of leakage more precisely, it inserts the detector on the building's water line shaft or at a probable leak. This research is focused on measuring and analyzing the stability of the power supply and measuring the performance of the water level detector (WLD) in the plumbing leakage detection system controlled by the PLC type Omron CPM2A.

II. Methodology

The flowchart of this research methodology that describes the steps carried out in this research is shown in Figure 1.

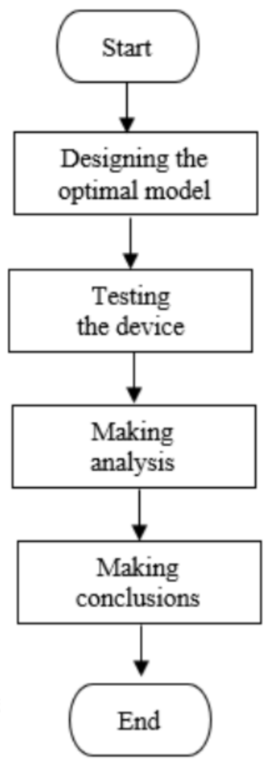

Figure 1. Re wchart

The steps carried out in this research are:

1. Designing the optimal model form of the system to be made, which is distinguished by designing hardware, which includes making the design of the device to be

made, determining the components and dimensions of the device to be made; and designing software, which includes making ladder diagrams on the CX Programmer which the PLC is then programmed with.

2. Testing the device, which measures the hardware and software that has been made.
3. Making analysis, namely analyzing the tests carried out on the system with measurements of the power supply output, electronic circuits on the WLD, and the CRM.
4. Making conclusions, namely making conclusions from research data that has been analyzed.

A. Designing The Overall Model System

A control unit usually consists of three steps: input, computing, and output, and each task is executed cyclically. In the input step, the control unit reads the values of the sensors. In the computing step, the control unit performs some computations such as numerical calculations and conditional judgment, etc. In the output steps, the control unit modifies the values of the variables that are mapped to some output points or control actuators to conduct certain mechanical actions by providing output signals to driver devices [25]. Controllers are generated for random systems with different values of the prediction horizon, the system delay, and the dimensions of the state, control input, and system output. The controller is programmed on the PLC [26].

The design of the plumbing leakage detection system controlled by the PLC type Omron CPM2A can be seen in Figure 2. In Figure 2, the designed system is divided into six parts, namely the input process using a WLD as a water level detector, which then activates the CRM as a direct bit information provider to the PLC type Omron CPM2A to be processed. The results of data processing are displayed by the Omron NB7-TW00B HMI. In addition, the power supply serves to supply power to the system via the PLC type Omron CPM2A.

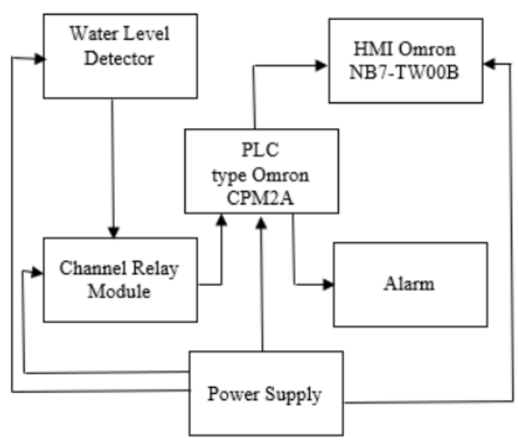

Figure 2. Block Diagram of System Design

B. Designing The Water Level Detector

The WLD as shown in Figure 3 is made with electronic components including a single pole solid relay 12 VDC as a relay that will activate dry contact NO/NC, diode 1N4001/4002 as polarity reverse current protection in the relay coil, transistor BD441/D400 NPN as a function switching, resistors, and capacitors. The WLD will work when there is induction in positive and negative polarities. The voltage source used is 12 VDC.

Two copper rods will act as electrodes when immersed in water. The existence of a resistance value of the two copper rods causes the transistor to work to open the channel from the collector to the emitter and activate the 12 VDC relay coil. The dry contact of the relay is used to provide logic 1 as a trigger for the 3B3D Module.

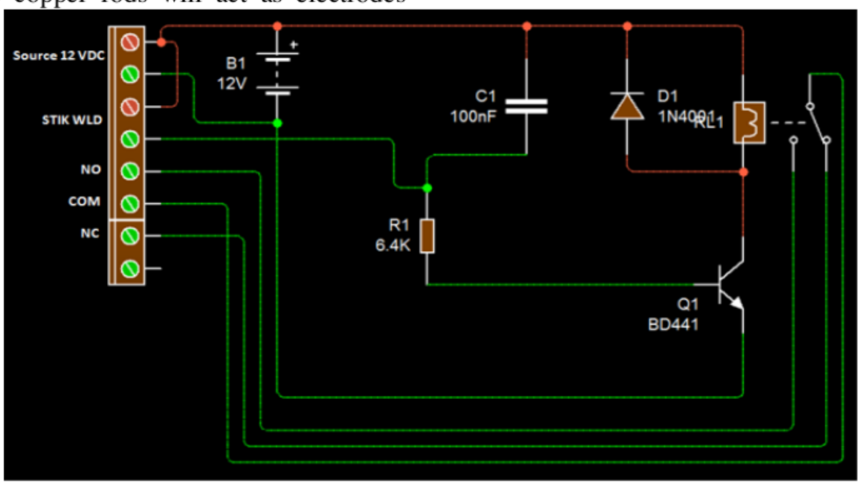

Figure 3. Electronic Circuit of WLD

The WLD as shown in Figure 4 requires a standby voltage of 12 VDC which is connected to the (+) and (-) terminals, the voltage polarity must match.

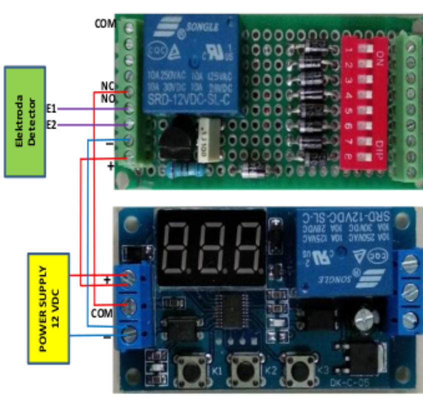

Figure 4. The Water Level Detector

At terminals E1 and E2, a cable connection is installed to the electrode stick/copper rod as a water level detector. At the NO terminal when the system is working or the WLD detects water, the terminal will issue 12 VDC which will be used as a trigger, and during normal standby, the NO standby terminal is at 0 VDC.

In this research, 10 WLDs are placed on each floor, and the distance between each WLD is 2.5 meters. All WLDs on each floor work to detect water pipe leakage by detecting waterlogging on each floor.

C. Designing The Channel Relay Module (CRM)

The circuit of CRM can be seen in Figure 5. In the CRM, there is a 3B3D Module as a digital timer that can be set from 0–999 minutes and there are 4 timer options, namely delay off, delay on, delay on and off, and consistent delays on and off. In designing the plumbing leakage detection system, the 3B3D Module is used to adjust the pulse signal.

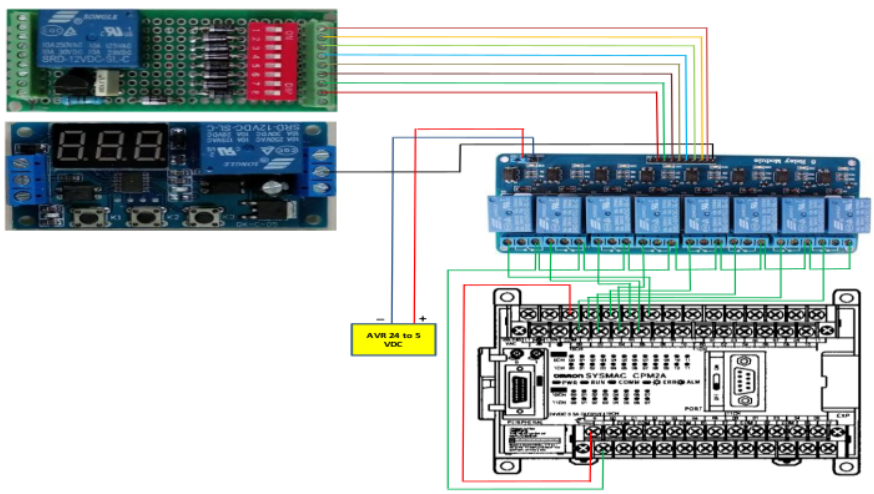

Figure 5. The Channel Relay Module

The COM terminal is the trigger input to activate this module, which is controlled by WLD as shown in Table 1:

Table 1. CRM Addressing

No.	Channel Relay Module		Address
	Relay	Logic	
1	Relay 1	1	0.00
		0	
2	Relay 2	1	0.01
		0	
3	Relay 3	1	0.02
		0	
4	Relay 4	1	0.03
		0	
5	Relay 5	1	0.04
		0	
6	Relay 6	1	0.05
		0	
7	Relay 7	1	0.06
		0	
8	Relay 8	1	0.07
		0	

D. Designing PLC type Omron CPM2A As Controller

PLC used in this system is PLC type Omron CPM2A which has the specifications shown in Table 2.

Table 2. Specification of PLC type Omron CPM2A

Spesification	Number
Input/Output	40
Input	24 DC
Output	16 Relay
Power	100-240 VAC

The PLC requires a voltage source of 220 VAC, for the COM terminal and input it uses 24 VDC which comes from the PLC's internal voltage source.

The software used to create the Ladder Diagram is CX Programmer version 9.5 and the type of PLC selected when programming the CX Programmer is PLC type Omron CPM2A. In the ladder diagram of the input detector section as shown in Figure 6 and Figure 7, the bit information that enters both logics 0 and 1 at addresses 0.00 to 0.07 is a binary value that will be converted to hexadecimal with the BCD (24) instruction on Data Memory 0 (DM0). Then the incoming bits for addresses 0.00 to 0.07 can be ascertained apart from binary with a value of 0, a value above 1 then logic 1 will activate LR9.04 which is used as a relay bit to activate the T0003 timer, where this timer functions as a time lag whether the WLD is in the area is a true alarm.

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Figure 6. Ladder Diagram 1 of Detector Input

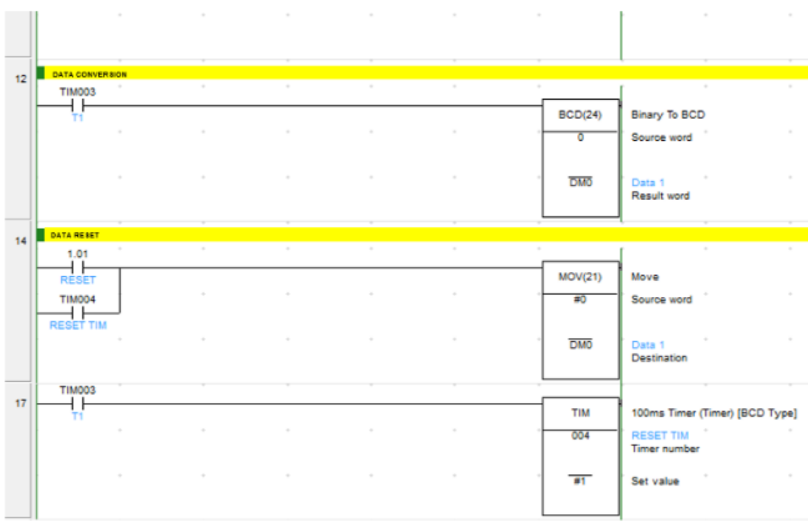

Figure 7. Ladder Diagram 2 of Detector Input

The ladder diagram was created as initials of data representing decimal constant values into initials in the Data Memory (DM), the instructions used is the MOV instruction (21), the value used is #1-#255 then initialized to DM1-DM255 which also represents Detector 1 to Detector 255. The P_On instruction is used because the command instructions in this initial data section must always be active or always on the flag as shown in Figure 8 and Figure 9.

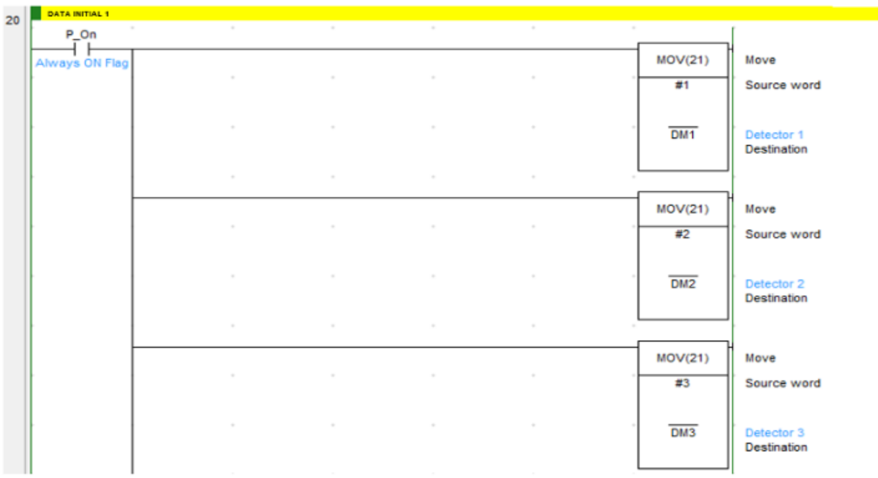

Figure 8. Ladder Diagram 1 of Initial Data

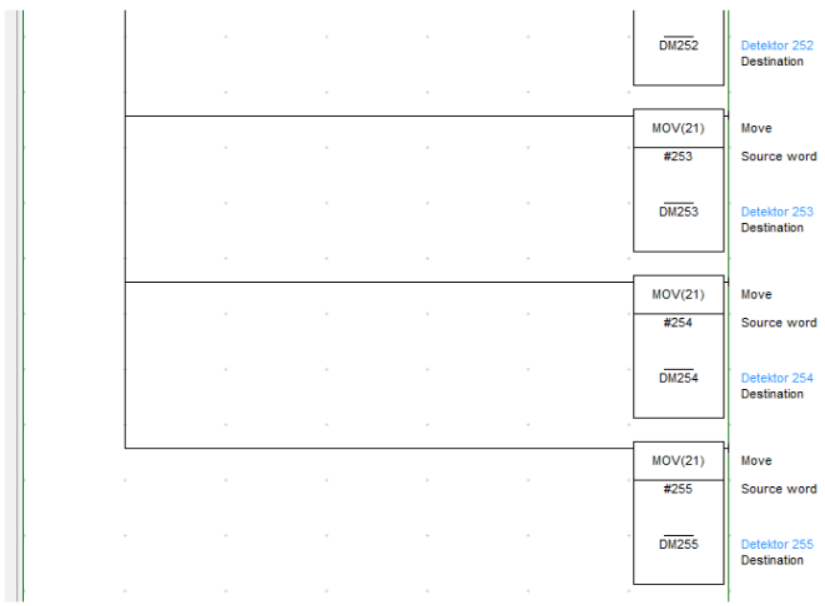

Figure 9. Ladder Diagram 2 of Initial Data

To activate the alarm there is only one option, namely when the LR9.04 alarm occurs. On the bell LR9.04 when a logic 1 will activate the 10.00 output, which is the bell output, LR9.02 is used to activate LR.9.03 which will activate T0001, i.e. the timer to pause the alarm time, thereby causing the alarm to be deactivated. If T0001 is reactivated then the 10.00 outputs will be active again or the bell will ring. When the alarm is in progress and the bell is deactivated, if a new alarm is entered, the bell can be reactivated because LR9.04 is the main input. For strobe LR9.04 will activate output 10.01 which is the strobe output address on the PLC, output 10.01 will be off if input 1.01 is a logic reset address 1. During the alarm, the strobe will remain active can be seen in Figure 10.

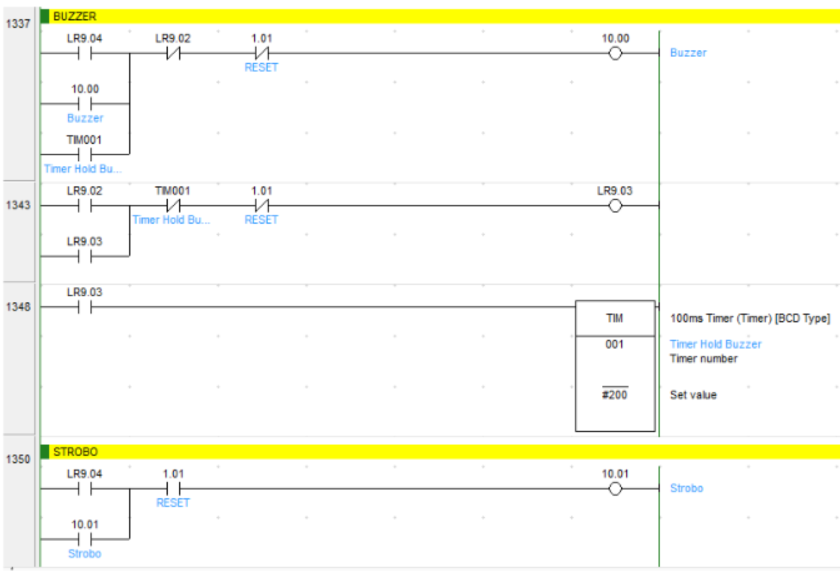

Figure 10. Ladder Diagram of Alarm

III. Results and Discussion

Testing the device is carried out to determine the performance of each component used. This test is expected to get good results where all components of the plumbing leakage detection system work.

When the start button (channel 1.00) is pressed on the main menu on the HMI screen, the system is completely disabled in monitoring status. While a waterlogging on one floor has crossed the water level limit of 30 mm, the detection rod connected to the water causes a resistance value in the WLD circuit which then puts the transistor in the saturation position. This causes the current from the collector of the transistor to flow to the emitter so that the relay coil gets a voltage of 12 VDC and the relay works.

Furthermore, the NO terminal on the WLD gives an output of +12 VDC so that it triggers the CRM. The design of this plumbing leakage detection system uses 10 WLDs with addresses 1 to 10.

Active relays on the CRM will send bits to the PLC input group, namely addresses 0.00 to 0.07 (8 bits). The 8-bit signal from the sensor circuit to the PLC is initialized with DM0 and will be compared with DM1 to DM255 which is the initial decimal address 1 to 255. If DM0 is the same as data memory 1 to 255 then the alarm will be active on the screen monitoring status of the WLD with the output address used for alarm status is IR20.00 to IR35.14. The new alarm will still be displayed on the HMI screen, even though the alarm on the other WLD is still in alarm status. While the alarm is active, the PLC activates the bell output (10.00) and strobe (10.01).

A. Power Supply Measurement

When a 220 VAC power supply which is the main power source is supplied to the system by activating a single phase MCB which supplies a 220 VAC voltage source to the power supply, the system works normally. By measuring three types of power supplies that have three types of power supplies, 12 VDC, 24 VDC, and 5 VDC which makes the PLC ON and connected to the CRM.

In the initial observations, all components after the 220 VAC power supply provided could work well or normally. Measurement of the voltage issued by the power supply is carried out when the system is working (ON) and not working (OFF).

Table 3. Measurement Results of Power Supply Voltage Performance

Measurement	V_{input} (volt)	V_{output} (volt)		Function
		No load (OFF)	Under load (ON)	
Melan Well LRS-75-24	220	24.2	24	HMI, AVR
Yamasaki	220	12.1	11.8	WLD
ETA-SEI SVM05SC24	24	5.2	5	CRM

From the results of the power supply measurements in Table 3 above, it can be analyzed that the output voltage when there is a load (the system is working) decreases by 0.15 to 0.2 VDC when compared to the output voltage when there is no load (the system is not working). This decrease is still within the safe tolerance value of the supply voltage of the components. All power supplies work well because the measurement results in no-load values of 24.2 VDC, 12.1 VDC, and 5 VDC which indicate the output voltage according to the specifications of the power supply.

B. The WLD Measurement

From Table 4 below, the results of the transistor work measurements can be analyzed. When the electrodes (E1-E2) are connected by water, the transistor in the

WLD module will work as a switch or transistor in saturation position. At saturation, the average collector current (Ic) is 1.73 mA and the base current (Ic) is 117.8 mA while the Vce voltage is 205 mV. In this position, the relay on the WLD will work because the relay coil gets a voltage of 12 VDC.

When E1-E2 is disconnected or not connected, the transistor will be cutoff, i.e. the transistor acts as a switch in the open position. In the cutoff position, it can be seen that Vce has a value of 12 VDC, Ic has a value of 0 mA and Ib has a value of 0 mA. In this position, the relay in the WLD will be off because the relay coil does not get a voltage or 0 VDC.

Table 4. Measurement Results of Transistor Performance in WLD Circuit

WLD	Condition of E1 and E2	Tr	Vcc (volt)	Ic (mA)	Ib (mA)
1	connected	Q1	0.205	117.5	1.73
	disconnected		12	0	0
2	connected	Q2	0.204	116.8	1.73
	disconnected		12	0	0
3	connected	Q3	0.206	117.8	1.73
	disconnected		12	0	0
4	connected	Q4	0.205	117.8	1.73
	disconnected		12	0	0
5	connected	Q5	0.203	116.8	1.73
	disconnected		12	0	0
6	connected	Q6	0.205	117.6	1.73
	disconnected		12	0	0
7	connected	Q7	0.206	117.8	1.73
	disconnected		12	0	0
8	connected	Q8	0.205	117.8	1.73
	disconnected		12	0	0
9	connected	Q9	0.203	117.8	1.73
	disconnected		12	0	0
10	connected	Q10	0.206	118.8	1.73
	disconnected		12	0	0

All transistors can work well because from the measurement results obtained values when saturation Vcc has a value of 0.203-207 VDC, Ic has a value of 116-118 mA, and Ib has a value of 1.73 mA and when cut off Vcc has a value of 12 VDC, Ic has a value of 0 mA, and Ib has a value of 0 mA which shows the transistor is working properly.

From the measurement results of the CRM in Table 5, it can be analyzed that the relay coil measures 11.8 to 12 VDC. When the relay does not work, the measurement of the relay coil results in 0 VDC, and the breakdown voltage at the NO terminal which should be in the open position is 1.8 VDC.

Table 5. Measurement Results of CRM

WLD	Relay (CRM)	Coil Voltage (volt)	Output Contact (volt)	
			NO	NC
1	ON	11.8	12	1.8
	OFF	0	1.8	12
2	ON	11.8	12	1.8
	OFF	0	1.8	12
3	ON	11.8	12	1.8
	OFF	0	1.8	12
4	ON	11.8	12	1.8
	OFF	0	1.8	12
5	ON	11.8	12	1.8
	OFF	0	1.8	12
6	ON	11.8	12	1.8
	OFF	0	1.8	12
7	ON	11.8	12	1.8
	OFF	0	1.8	12
8	ON	11.8	12	1.8
	OFF	0	1.8	12
9	ON	11.8	12	1.8
	OFF	0	1.8	12
10	ON	11.8	12	1.8
	OFF	0	1.8	12

Even though there is a leakage from the relay contacts of 1.8 VDC, it is still considered in a safe condition because to provide a trigger to the 3B3D Module with a minimum of 12 VDC. When the relay is not working or off, the measurement at the NC terminal is 12 VDC.

All relays on the CRM are functioning well because from the measurement results, the coil input value is 11.8 to 12 VDC and when the coil does not get a voltage input, the relay will turn off which indicates it is in accordance with the relay specifications

IV. Conclusions

This research resulted in the conclusion that all power supplies work well because the measurement results in no-load values of 24.2 VDC, 12.1 VDC, and 5 VDC which indicate the output voltage according to the specifications of the power supply; all transistors can work well because from the measurement results obtained values when saturation Vcc has a value of 0.203-207 VDC, Ic has a value of 116-118 mA, and Ib has a value of 1.73 mA and when cut off Vcc has a value of 12 VDC, Ic has a value of 0 mA, and Ib has a value of 0 mA which shows the transistor is working properly, and all relays on the CRM are functioning well because from the measurement results, the coil input value is 11.8 to 12 VDC and when the coil does not get a voltage input, the relay will turn off which indicates it is in accordance with the relay specifications. In this research, it can be seen that even though there is a leakage from the relay contacts of 1.8 VDC, it is still considered in a safe condition because to provide a trigger to the 3B3D Module, a minimum of 12 VDC is required. In addition, when the relay is not working or off, the measurement at the NC terminal is 12 VDC.

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