

# Automation System For Water Leakage Detection With PLC Omron and Arduino Uno and HMI NB10-TW01 Direct Digital Bit 8 Binary I/O

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## Abstract

There are many challenges in operating a multi-story building so the building can operate well. One potential problem that has a serious risk of damaging assets and even causing disruption to building operations is water leaks. To detect the impact of leaks from water installations, a detection system is needed that can provide specific information about the location of the leak to the building control center. This system uses a water detector as detection and a digital direct bit module as 8-bit input to the PLC Omron CPM2A, then the PLC will send an 8-bit digital direct output signal to the Arduino Uno module and a graphic visualization display using the Omron NB10-TW001 HMI. This research method is to design hardware and software. Testing the accuracy of input and output (I/O) signals, testing detectors, power supplies, and relay modules. From the research results, it was found that the input and output signals correspond to the 8 I/O bits, namely 00000000 - 11111111 which are processed by the PLC and Arduino, the performance of the Water Detector functions well as proven by the functioning of the CRM.

**Keyword:** Programmable Logic Controller (PLC); Water Detector (WD); Channel Relay Module (CRM); Human Machine Interface (HMI); Arduino Uno; Digital Direct Bit.

## 1. Introduction

Building care and maintenance management is a very important issue and must be paid attention to because it is related to the comfort and safety of everyone who lives in or carries out activities in the building, apart from that, this is also to maintain the high value of the building's assets (Prof. M.B.Kumthekar, 2015).

One of the important things that needs to be done is the care and maintenance of the clean water and dirty water distribution systems in buildings. Of course, maintenance includes the pump system and piping installation. Problems that often occur in water pipe installations are leaks or blockages in drainage pipe installations (Laxmi C. Gupta, 2016).

Potential leaks will occur in several cases, such as the PRV not functioning properly, causing the output pressure to be the same as the input pressure, and then a failure of the transducer sensor

function in the booster pump control causing the booster pump to provide pressure above the maximum working pressure limit of the pipe installation. Leaks can also occur due to problems in installing pipe connections to plumbing accessories, fittings, valves, and others. In cases of leaks in dirty water installations, most cases are caused by blocked pipe installations, causing water to overflow and impacting other areas (Desmayadi, 2022).

This research uses a PLC as a data processor that receives input signals from the 8-bit input module and WD (Desmayadi, 2022), and the PLC will send 8-bit signal data to the Arduino module to activate CRM for use in motorized or solenoid valves closing the main water channel. Detector address data will be displayed on the HMI.

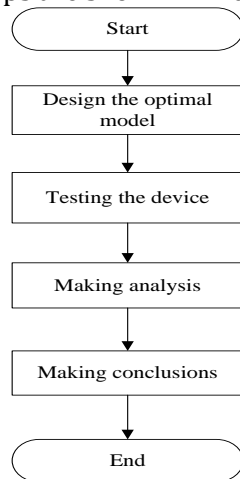
This research will focus on the accuracy of 8-bit input and output digital signals, WD performance, and also the stability of

the electricity supply. The control system is controlled by PLC CPM2A and Arduino Uno and graphic visualization is displayed by HMI Omron NB10-TW01

## 2. Methods

To design a water leak detection system using a PLC and Arduino with HMI, the following steps are shown in Picture 1, namely:

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**Picture1.** Flowchart of Research Methodology

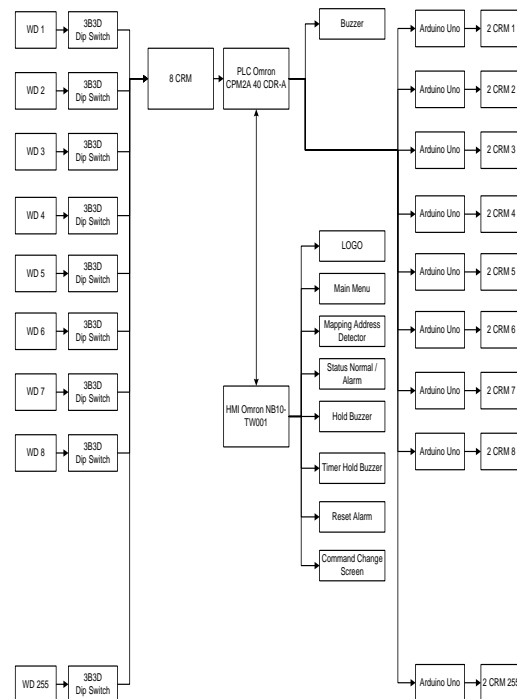
- 1) Designing the optimal model form of the system to be made, which is distinguished by designing hardware, which includes making the design of the device to be made, determining the components and dimensions of the device to be made; and designing software, which includes making ladder diagrams on the CX-Programmer which are then programmed to the PLC. making instruction program on the Arduino which are then programmed to the Arduino Uno, making graphical HMI on the NB Designer which are then programmed to the HMI NB Series.
- 2) Testing the device, which is measuring 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.

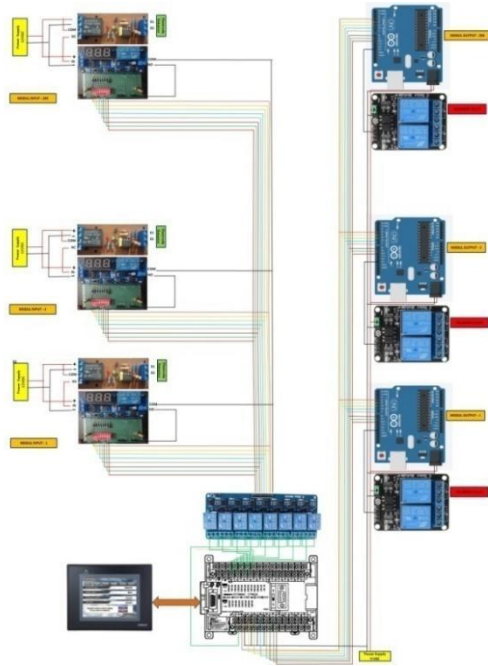
## A. Designing The Overall Model System

The design of the plumbing leakage detection system controlled by the PLC type Omron CPM2A and Arduino Uni can be seen in Picture 2 and Picture 3 below. The system design consists of a water detector to detect water leaks, then sending an 8-bit signal via 8CRM to the Omron PLC and cutting the input signal pulse by the 3B3D module.

The PLC will process the data and then send an 8-bit output signal to the Arduino Uno module, then the Arduino will issue an output signal to activate 2CRM. To set the input address 1-255, use a dip switch, while to set the output address 1-255, use programming via Arduino software. In this research, address 255 is used to reset the system. The results of data processing are displayed by the Omron NB10-TW00B HMI. In addition, the power supply serves to supply power to the system via the PLC type Omron CPM2A and external power supply 12 VDC and 5 VDC.



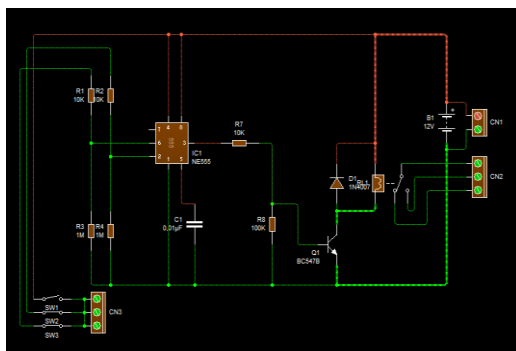
**Picture2.** Blok Diagram of System Design



**Picture3.** Component System

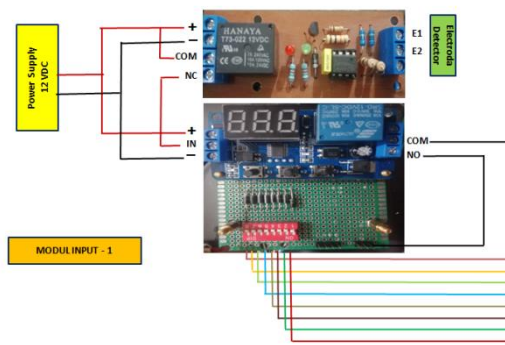
### B. Designing The Water Detector

The water detector electronic circuit design can be seen in Picture 4 and Picture 5. The circuit consists of several components, namely IC 555, 10K resistor, 100K resistor, 1M resistor, 4007 diode, 0.01µF capacitor, BC547B transistor, and 12VDC solid relay. The IC 555 output on pin 3 will be in the High position if Pin 2's value is no more than 1/3 of the voltage and reset the IC 555 by providing a low voltage value on pin 4.



**Picture4.** Electronic Circuit of WD

The WD requires a standby voltage of 12V DC which is connected to the (+) and (-) terminals, the voltage polarity must match.

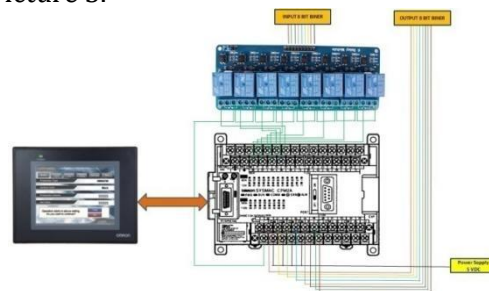


**Picture5.** Water Detector and Input Modul

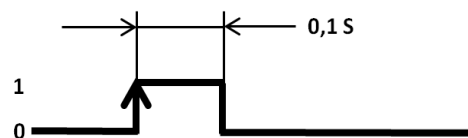
At terminals E1 and E2, a cable connection is installed to the probe as a water detector. At the NO terminal when the system is working or the WD detects water, the terminal will issue 12V DC which will be used as a trigger, and during normal standby, the NO standby terminal is at 0V DC. WD addressing uses a dip switch, which can be set with address points from 1 - 255, the on position is logic 1 and the off position is logic 0

### C. Designing The 8 Channel Relay Module (8CRM)

The circuit of CRM can be seen in Picture 6 below. 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 shown in Picture 5.



**Picture6.** The Channel Relay Modul



**Picture7.** Pulse Input and Output Signal

**Table1. 8 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	Relay5	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	

When the 3B3D Module functions, the ground data output through the NO terminal of the DIP Switch Module is connected to the COM terminal on the DIP Switch Module. The CRM serves to provide a bit signal to the PLC. The active/deactivated relay is determined from the input received from the WLD.

**D.Designing PLC type Omron CPM2A As Controller**

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

**Table 2.** Specification of PLC type omron CPM2A

Specification	Number
Input/Output	40
Input	24 DC
Output	16 Relay
Power	100-240 V AC

The PLC requires a voltage source of 220V AC, for the COM terminal and input it uses 24V DC 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 shown in Picture 6 and Picture 8 below, 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 9.04 which is used as a relay bit to activate the T0003 timer, where this timer functions as a time lag whether the WD is in the area is a true alarm.



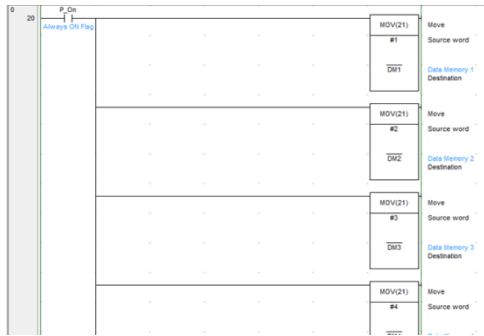
**Picture8.** Ladder Diagram 1 of Detector Input



**Picture9.** 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-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 flags shown in Picture 8 below.

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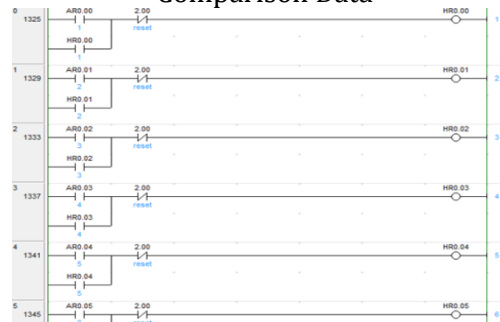


**Picture 10.** Ladder Diagram of Initial Data

The comparison ladder diagram can be seen in Picture 11. The data uses the CMP (20) instruction, where this instruction is used to compare all data entering DM0, then DM0 will be compared with DM1 – DM255, the results of this comparison will be with the P\_EQ instruction or if they are the same then it will be activated AR0.00 – AR.15.15. AR0.00 – AR15.15 will then be used to activate HR0.00 – HR15.15 which will be used as the address for point detector 1 – detector 255 in the HMI program. Safeguarding is required so that every bit HR0.00 – HR15.15 is active, it is not automatically turned off before address 2.00, which is the address for reset, is activated, this instruction can be seen in Picture 12.



**Picture 11.** Ladder Diagram of Comparison Data



**Picture 12.** Ladder Diagram of the Output bit

For 8-bit output using the BIN(23) instruction, as in Pictures 13 and 14, this instruction will convert the information data from DM0 in the hexadecimal form to binary at the target address 10.00 – 10.07 with logic 0 and 1, this output signal will be used for sends an 8-bit digital signal to the Arduino. When bits 10.00 – 10.07 are active, they will activate LR9.09, and LR9.06 will activate T006, which is used for time delay, avoiding errors in information.



**Picture 13.** Ladder Diagram 1 of Output 8-bit



**Picture 14.** Ladder Diagram 2 of Output 8-bit

### E. Designing Arduino As an Output Modul

Ardunio Modul type Arduino Uno that has the specifications as shown in Table 3.

**Table 3.** Spesification of Arduino Uno

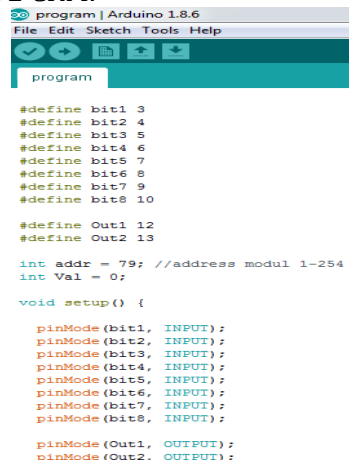
Specification	Number
Input/Output	14
Input	5 VDC
Output	Digital/Analog
Power	5 - 12 VDC

The Arduino requires a voltage source of 12 or 5 VDC; for the COM terminal and input, it uses 12V DC, which comes from the external power supply voltage source.

The Arduino module in this research is used as an output data processing module, where 8-bit data is sent by the PLC via

pins 3-10 with logic 1-0, which will then be converted to decimal and compared with each Arduino module which has previously been programmed. Address 1-255, the results of this comparison will activate Pins 12-13 of each module which corresponds to the module addressing, namely 1-255 as in Picture 3.

Instructions for Arduino can be seen in Picture 15 and Picture 16, which are divided into three parts, namely the initial data bits 1-8, which are input from pins 3-10 with logic 0-1. The second part is data conversion from binary to decimal, where the incoming input signal in bit form will be converted to decimal. The third part of this instruction is data comparison, where decimal data 1-254 will activate pins 13-14 (High), while 255 will deactivate pins 12-13 (Low). Pins 12-13 are used for output 2 CRM.



```

    #define bit1 3
    #define bit2 4
    #define bit3 5
    #define bit4 6
    #define bit5 7
    #define bit6 8
    #define bit7 9
    #define bit8 10

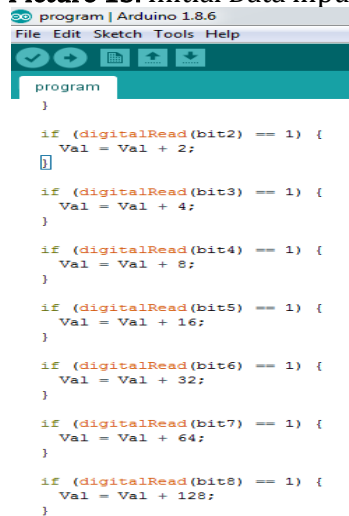
    #define Out1 12
    #define Out2 13

    int addr = 79; //address modul 1-254
    int Val = 0;

    void setup() {
        pinMode(bit1, INPUT);
        pinMode(bit2, INPUT);
        pinMode(bit3, INPUT);
        pinMode(bit4, INPUT);
        pinMode(bit5, INPUT);
        pinMode(bit6, INPUT);
        pinMode(bit7, INPUT);
        pinMode(bit8, INPUT);

        pinMode(Out1, OUTPUT);
        pinMode(Out2, OUTPUT);
    }
    
```

Picture 15. Initial Data input



```

    }

    if (digitalRead(bit2) == 1) {
        Val = Val + 2;
    }

    if (digitalRead(bit3) == 1) {
        Val = Val + 4;
    }

    if (digitalRead(bit4) == 1) {
        Val = Val + 8;
    }

    if (digitalRead(bit5) == 1) {
        Val = Val + 16;
    }

    if (digitalRead(bit6) == 1) {
        Val = Val + 32;
    }

    if (digitalRead(bit7) == 1) {
        Val = Val + 64;
    }

    if (digitalRead(bit8) == 1) {
        Val = Val + 128;
    }
    }
    
```

Picture 16. Binary to Decimal

### F. Designing HMI Omron Type NB10W-TW01B As Graphical Interface

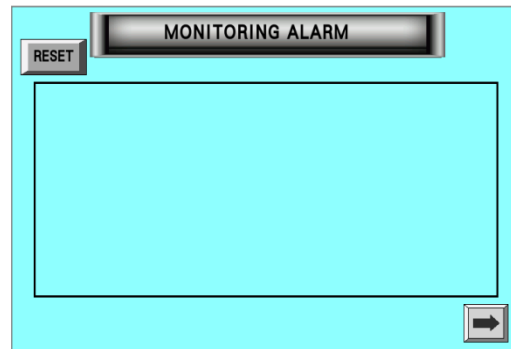
HMI Modul type Omron NB10W-TW01B has the specifications as shown in Table 4.

Table 4. Spesification of HMI Omron NB10

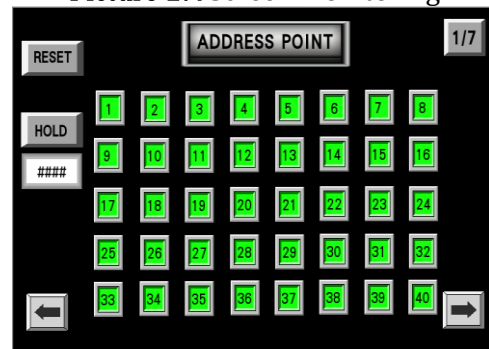
Specification	Number
Type LCD	10,1"
Communication	Ethernet, RS232
Backlight	LED
Power	24 VDC

The HMI Omron NB10 requires a voltage source of 24 VDC; for the COM terminal and input, it uses 24V DC, which comes from the external power supply voltage source.

Pictures 17 and 18 show the screen display design of the HMI screen. On the monitoring screen, detector data or address points will be displayed, complete with the time or location where the leak occurred. The reset button is used as an option if the alarm is deemed safe and under control.



Picture 17. Screen Monitoring



Picture 18. Mapping Address Point

Event settings, as in Picture 19, are used so that all PLC addresses are registered on the HMI and can be displayed on the monitoring display with a display equipped with the name of the location at

the time of the event, which is more specific and easy to know.

No.	Type	PT No.	Address inform...	Address	Trigger	Condition	Message
0	0	0	HMI0:PLCO:0	H_bit0.00	On		DETECTOR 1
1	0	0	HMI0:PLCO:0	H_bit0.01	On		DETECTOR 2
2	0	0	HMI0:PLCO:0	H_bit0.02	On		DETECTOR 3
3	0	0	HMI0:PLCO:0	H_bit0.03	On		DETECTOR 4
4	0	0	HMI0:PLCO:0	H_bit0.04	On		DETECTOR 5
5	0	0	HMI0:PLCO:0	H_bit0.05	On		DETECTOR 6
6	0	0	HMI0:PLCO:0	H_bit0.06	On		DETECTOR 7
7	0	0	HMI0:PLCO:0	H_bit0.07	On		DETECTOR 8
8	0	0	HMI0:PLCO:0	H_bit0.08	On		DETECTOR 9
9	0	0	HMI0:PLCO:0	H_bit0.09	On		DETECTOR 10
10	0	0	HMI0:PLCO:0	H_bit0.10	On		DETECTOR 11
11	0	0	HMI0:PLCO:0	H_bit0.11	On		DETECTOR 12
12	0	0	HMI0:PLCO:0	H_bit0.12	On		DETECTOR 13
13	0	0	HMI0:PLCO:0	H_bit0.13	On		DETECTOR 14
14	0	0	HMI0:PLCO:0	H_bit0.14	On		DETECTOR 15
15	0	0	HMI0:PLCO:0	H_bit0.15	On		DETECTOR 16
16	0	0	HMI0:PLCO:0	H_bit1.00	On		DETECTOR 17
17	0	0	HMI0:PLCO:0	H_bit1.01	On		DETECTOR 18
18	0	0	HMI0:PLCO:0	H_bit1.02	On		DETECTOR 19
19	0	0	HMI0:PLCO:0	H_bit1.03	On		DETECTOR 20
20	0	0	HMI0:PLCO:0	H_bit1.04	On		DETECTOR 21

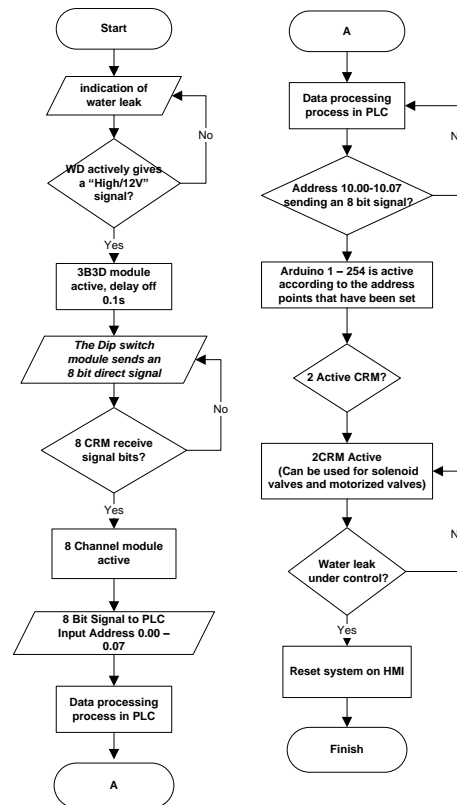
Picture 19. Event Setting

### 3. Result And Discussion

The results of the tool design and operation are shown in Pictures 20 and 21. It can be seen that the design system testing was carried out to test the performance of the water detector, the accuracy of the 8-bit input signal from the input module to the PLC, and to test the accuracy of the 8-bit output signal issued by the PLC to the module. Arduino Uno, each module has been set to address points 1 - 244. Address 255 is used to reset the Arduino so that it returns to the standby position.



Picture 20. Results of System Design



Picture 21. Flowchart Diagram And Logic A. Measurement of power supply performance

Measurements for power supply performance in this research were carried out by confirming the main input source of AC electricity and then measuring the 24 VDC, 12 VDC, and 5 VDC power supplies. Measurements are carried out at no load and with load to ensure that the input voltage to all components is within specifications.

Table 5. Measurement Results of Power Supply Voltage Performance

Measurement	Vinput (volt)	V output (volt)		Function
		No load (OFF)	Under load (ON)	
Melan Well LRS-350-12	223	12.4	12,1	WD, 3B3D, Arduino
Melan Well LRS-75-24	223	12.2	12,0	HMI
Melan Well LRS-35-5	223	5.2	5,1	8CRM
PLC Omron Internal Power Supply	220	24	24	Input PLC

From the measurement results, the single-phase AC input voltage is still within tolerance, where the measured value is 223 VAC. For the DC power supply voltage value, when under loading conditions, a drop occurs, namely 0.2 VDC – 0.3 VDC; however, this is still within the safe limit value because components and modules can work with a tolerance value of  $\pm 10\%$  of the equipment specifications.

**B. The WD Measurement**

From Table 6 below, the result 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 (Ib) is 117.8 mA, while the Vce voltage is 205 mV. In this position, the relay on the WD will work because the relay coil gets a voltage of 12V DC.

When E1-E2 is disconnected or not connected, the transistor will be cut off, i.e., the transistor acts as a switch in the open position. In the cut-off position, it can be seen that Vce has a value of 12V DC, 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 0V DC.

**Table 6.** Measurement Results of Transistor Performance In WD Circuit All transistors can work well because

W D	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

from the measurement results obtained values when saturation Vcc has a value of 0.203-207V DC, 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 12V DC, Ic has a value of 0 mA, and Ib has a value of 0 mA which shows the transistor is working properly.

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

**C. Digital Direct Bit 8 CRM – Input PLC**

**Table 7.** Results Of Measuring The Relay Function On 8CRM

No	Input Signal (VDC)	8CRM							
		1	2	3	4	5	6	7	8
1	0	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
2	5	ON	ON	ON	ON	ON	ON	ON	ON

From the results of the 8 CRM measurements, it can be analyzed that the relay works when it gets an input of 5 VDC. The relay numbers (1-8) will work by the sequence on the terminals (1-8), which have a voltage of 5 VDC. All CRM relays work well because the measurement results show that when the signal input is 0 Vdc, all relays are inactive, and when the signal input is 5 VDC, all relays are active, which shows that the 8 CRM are functioning according to their specifications.

**Table 8.** Measurement Results For Relay Simultaneity In 8 CRM

No	3B3 D (s)	8CRM (Logic)							
		1	2	3	4	5	6	7	8
1	0,01	1	0	0	1	1	0	0	1
2	0,02	1	1	1	1	0	1	1	1
3	0,03	1	0	1	1	0	0	0	1
4	0,04	1	0	1	1	1	0	1	1
5	0,05	1	1	1	0	1	1	0	1
6	0,06	1	1	1	0	0	0	1	1
7	0,07	1	0	0	1	1	0	1	1
8	0,08	1	1	0	1	1	0	1	0
9	0,09	1	1	0	0	1	1	1	0
10	0,1	1	1	1	1	1	1	1	1
11	0,11	1	1	1	1	1	1	1	1
12	0,12	1	1	1	1	1	1	1	1



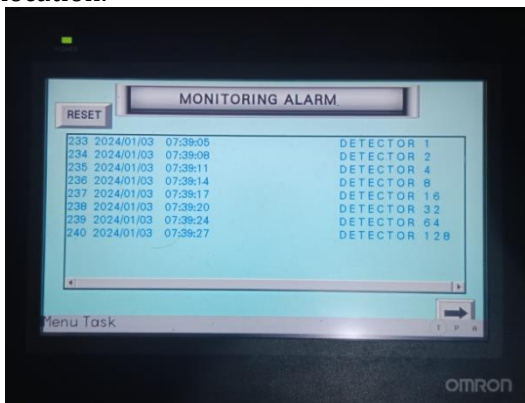
13	0,13	1	1	1	1	1	1	1	1
14	0,14	1	1	1	1	1	1	1	1
15	0,15	1	1	1	1	1	1	1	1
16	0,16	1	1	1	1	1	1	1	1
17	0,17	1	1	1	1	1	1	1	1
18	0,18	1	1	1	1	1	1	1	1
19	0,19	1	1	1	1	1	1	1	1
20	0,2	1	1	1	1	1	1	1	1

Measuring the synchronization of relay work is carried out to ensure that the bit signal received by the PLC is accurate. 8 CRM is a solid relay type relay module, which in this research is used to send 8 bits to the input. PLC CH 0.00 – 0.07.

From the test results in Table 8, the accurate value for setting the time for the 3B3D module in sending accurate 8-bit values via 8 CRM is 0.1s to 0.2s. Below a value of 0.1s, the bits sent are potentially invalid.

**D. Event Data Monitoring**

Testing the detector function to send an alarm signal displayed on the HMI monitoring screen. Testing the address of detector 1- detector 254 is functioning properly, it can be seen in Picture 22, where the data is equipped with the number, date, and time of the incident as well as the detector name or detector location.



**Picture 22.** Screen Monitoring Alarm

Address mapping can be seen in Picture 23, where during standby status, the point address on the HMI is green. However, when an alarm occurs, the address point on the HMI will flash and be red, and the reset, hold, and change screen buttons can function properly.



**Figure.23** Mapping Address Point  
**E. Digital Direct Bit – Output PLC**

Testing the direct bit digital signal from the PLC output to the Arduino, by measuring the input voltage on Pins 3 – 10, where this Pin represents bit 1 – bit 8. When the Pin receives 5 V DC, then the value is considered High and has logic 1, and When the Arduino pin receives less than 1 VDC, it is considered Low and has logic 0.

The results of the test are as in Table 9; it can be seen that all address points that have been programmed into the Arduino module when receiving an 8-bit digital signal correspond to each address point on the module

**Table 9.** Testing PLC Bit Output To Arduino.

Modul Arduino	Address	(Pin Number)								Logic (VDC)	
		3	4	5	6	7	8	9	10	0	1
1	1	1	0	0	0	0	0	0	0	0	5,0
2	2	0	1	0	0	0	0	0	0	0	5,0
3	4	0	0	1	0	0	0	0	0	0	5,1
4	8	0	0	0	1	0	0	0	0	0	4,9
5	16	0	0	0	0	1	0	0	0	0	5,1
6	32	0	0	0	0	0	1	0	0	0	5,0
7	64	0	0	0	0	0	0	1	0	0	5,2
8	128	0	0	0	0	0	0	0	1	0	5,1
9	255	1	1	1	1	1	1	1	1	0	5,0

**4. Conclusion**

From the results of the design, manufacture, and testing of the system, it can be concluded that the detector can detect leaks and standing water in less than 0.2 s, the input signal to the PLC with a time delay of 0.1 s – 0.2 s to ensure the accuracy of the received bit value by PLC. Setting the address on the input module via a dip switch with a combination of 8 binary bits, and setting the address to the Arduino module via the Arduino program functions as designed.

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