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# AUTOMATIC CHANGEOVER DISCHARGE VALVES OF SEWAGE TREATMENT PLANT

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## ABSTRACT

Water containing faeces, industrial waste, and debris such as rust and plastic made up of raw sewage. The effect of sewage on the marine environment is a source of concern. Pathogens, nutrients, detergents, pesticides, and heavy metals can all pollute seawater. As much as it could contaminate the sea, the environmental and health risks are also high for humans because the community shares the seawater for recreation, swimming, and food production. The sewage treatment system on most of the ships is designed to remove pollutants from sewage water before it is discharged into the sea. The basic principle of a sewage treatment plant on board is to treat and process raw sewage through a series of steps that include breaking, filtering, settling, controlled aerobic decomposition, and chemical treatment before it is discharged into the environment. The sewage water treatment system is one of the most important systems on board. According to MARPOL 73/78 of ANNEX 1V (Prevention of Pollution by Sewage from Ships), all ships 400 gross tonnage and above that carry more than 15 persons should have an approved sewage treatment plant. If the sewage is comminuted or disinfected, it can only be discharged overboard using a permitted sewage treatment plant 3 nautical miles from the nearest land. If the sewage is not comminuted or disinfected, the sewage may be discharged at 12 nautical miles from the nearest land when the ship is en route and proceeding in not less than 4 knots (Anish, 2021).

## ARTICLE INFO

*Keywords:*
*PIC16F84A microcontroller, Discharge Valve, Liquid Crystal Display (LCD), Nautical Mile, LED indicator, ECR Module*

## 1.0 INTRODUCTION

The use of a microcontroller to automate the changeover of sewage treatment plant's discharge valves could benefit the maritime industry by preventing unnecessary fines imposed by port authorities due to ship staff's failure to follow MARPOL regulations, MARPOL Annex IV to be exact. Aside from that, our primary goal is to reduce crew working hours while also ensuring that our coastal waters are not contaminated with sewage, which could cause a variety of biological ecosystem issues. We could use this technology to automatically send a signal to the discharge valve to either switch over to the sewage holding tank or discharge it overboard according to the distance from the nearest shoreline. This system also has a fail-safe mode whereby a manual override selector is given. In the event of an emergency or maintenance, or if the ship is in a special area that does not allow overboard sewage discharge, the operator can manually operate the discharge valve. A microcontroller receives input signals from the vessel's navigation system with regard to the distance of the vessel to the nearest shoreline, as commonly found in an Electronic Chart Display and Information System (ECDIS), which then generates an output signal to change the direction of sewage discharge accordingly. Using the PROTEUS software, we are able to simulate the project's working principle as well as test the operation of the discharge valve with a visual display and indicator. The digital circuit operating using a microcontroller is programmed using the PIC C Compiler.

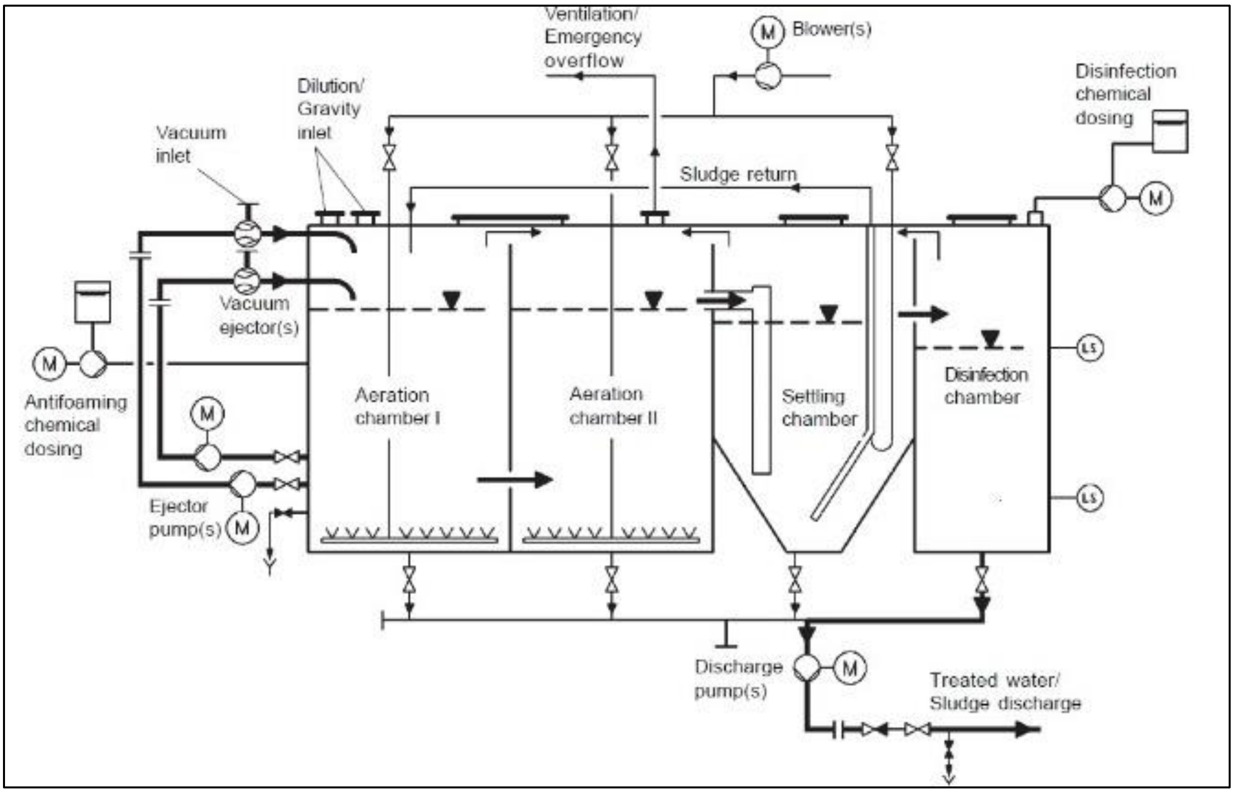


Figure 1: Sewage Treatment Plant Line Diagram (Firoz, 2015)

## 1.1 PROPOSED SYSTEM

A simple, dependable, configurable, easy-to-monitor, and electronically operated control system is proposed to provide useful assistance and improve the productivity of crew and vessels. By introducing this system, human error could be avoided, and it would benefit the environment.

## 2.0 METHODOLOGY

This intended technology is being proposed to swap discharge valves, which simplifies ship control automatically. The operator of the traditional system must manually switch valves at appropriate times to discharge wastewater overboard. This project was designed to improve and ease the burden of engineers on board ships, as there had been incidents where the crew overlooked the discharge and mistakenly left the overboard line open while the vessel was docked. This led to a major issue involving the Port Authority, and the vessel was detained until the company paid for the consequences. The research was done extensively based on current issues onboard vessels, either online or through individual experiences. It was decided to modify the manual valve system to automatically change the discharge valves that could be programmed accordingly. Knowing there could be an issue electronically and electrically, a manual override system is placed in case any emergency occurs.

## 2.1 COMPONENTS

The entire Digital Circuit consists of several components that replicate or reflect those that can and would be used in an original final product.

1. PIC16F84A, 18-pin Enhanced FLASH/EPROM 8-bit Microcontroller
2. LM018L, 40x2 Alphanumeric LCD
3. 10WATT470R, 470R 10WATT Resistor
4. LED-GREEN, Animated LED
5. LED-YELLOW, Animated LED
6. LED-RED, Animated LED
7. LED-BLUE, Animated LED
8. 4070, Quad 2-Input EXCLUSIVE-OR Gate
9. SW-ROT-3, Interactive 3 position switch
10. BUTTON, Push Button
11. MOTOR, Simple DC Motor
12. T73S5D15-5V, 10 Amp Miniature PCB Relay
13. SW-SPDT-MOM, Interactive SPDT Switch

## 2.2 OPERATION

The operation of the system can be divided into two parts, Automatic Operation and Manual Operation. The user is given the freedom to choose to operate the system either automatically

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or manually. In AUTO Operation, the Primary MCU reads and analyses the signal from the vessel's navigation system. The Primary MCU then sends out the output signals accordingly to control the discharge valve, LED indicators, and Secondary MCU. The Secondary MCU receives its input and sends the relevant output to the LCDs to indicate the distance range as well as the discharge valve status. In MANUAL operation, the system will no longer control the discharge valves, which means no output signal is sent from MCU to the discharge valves. This will allow the user to operate the valve manually. Manual operation is essential as there are Special Areas more than 12Nm from the nearest shoreline which does not allow sewage discharge into the sea. Apart from that, the 3 to 12Nm range is very subjective and crew or users may opt to operate the system as they wish when there is a manual mode. The operation is further discussed in depth in the sub-topics below.

## 2.3 TRUTH TABLE

The input and output variables are defined and shown in the table below.

| INPUT | | | | OUTPUT | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PIN A0 *NM0* | PIN A1 *NM3* | PIN A2 *NM12* | PIN B0 *ML* | PIN B3 *SOL1* | PIN B4 *SOL2* | PIN B5 *SOL3* | *CM* | PIN A3 *RL* | PIN B1 *YL* | PIN B2 *GL* | PIN B6 *BL* |
| 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

Table 1: Truth Table of System

## 2.4 MICROCONTROLLERS

PIC16F84a is an 8-bit PIC Microcontroller with enhanced EEPROM that is a successor to PIC16C84, which was introduced in 1993 by Microchip Technology to simplify electronic tasks that require no or minimal skills to achieve hands-on experience working with them. The PIC16F84a has an 8-bit timer and a serial programming interface, particularly useful for laying out serial communication with other devices. It has 64 bytes of EEPROM (primarily used for storage of data), 1K program memory (indicates the amount of code that can be burned inside the controller), and 68 bytes of data memory (RAM). It surpasses its predecessor in terms of compatibility (Microchip Technology, n.d.).

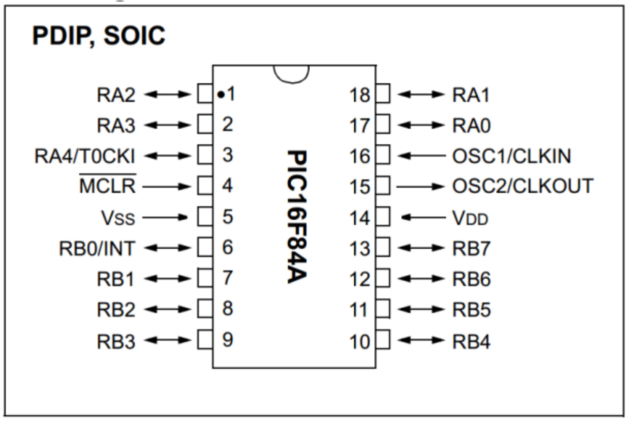

Figure 2: PIC16F84a Microcontroller Pin

## 2.5 SOFTWARE

The PIC16C84 was introduced in 1993 and is credited with being the first PIC microcontroller to include a serial programming algorithm and EEPROM memory (it was preceded by the Motorola MC68HC805B6 and MC68HC805C4 along with the MC68HC11E2 with serial bootloader and EEPROM program storage released in the late 1980s). These chips are ideal for tech enthusiasts as they only require an inexpensive programmer to program, erase, and re-program the chip. As PIC16C84 supplies became scarce due to its discontinuation, the PIC16F84 gained in popularity as a near-drop-in replacement. Since the programming algorithm was different, new programming software was required, but the programming hardware required remained the same. Even later (1998), Microchip Technology launched the improved PIC16F84A, allowing faster clock speeds (up to 20 MHz), faster programming, and a reduced current draw. The PIC16x84 microcontroller is part of Microchip's 14-bit series (the instruction word size for all instructions is 14 bits), making the '84 a good development prototype for other similar but less expensive one-time-programmable 14-bit devices (Microcontroller Lab, n.d.).

## 2.6 PROGRAMMING DESCRIPTIONS

The software PROTEUS is used to create the prototype circuit, and the program that controls the entire operation is written in the C language of the PIC16C84A microcontroller. CCS compilers are used to compile the codes, and the programs are assessed.

## 2.7 SYSTEM FLOW

The auto changeover of Sewage Plant Discharge valves works based on the principle of how far the ship is located from the nearest shoreline. The primary MCU will receive data from the vessel's navigation system, which will then be analysed by the MCU. The processed data will then send an output signal based on the distance range setting in the MCU. The discharge valve is automatically changed depending on the distance range from the nearest shoreline. The distance range and valve status will be shown in the LCD unit at both local and remote (ECR) locations. LED indicators are also installed at both locations to indicate the current distance range of the vessel (Refer to Figure 3).

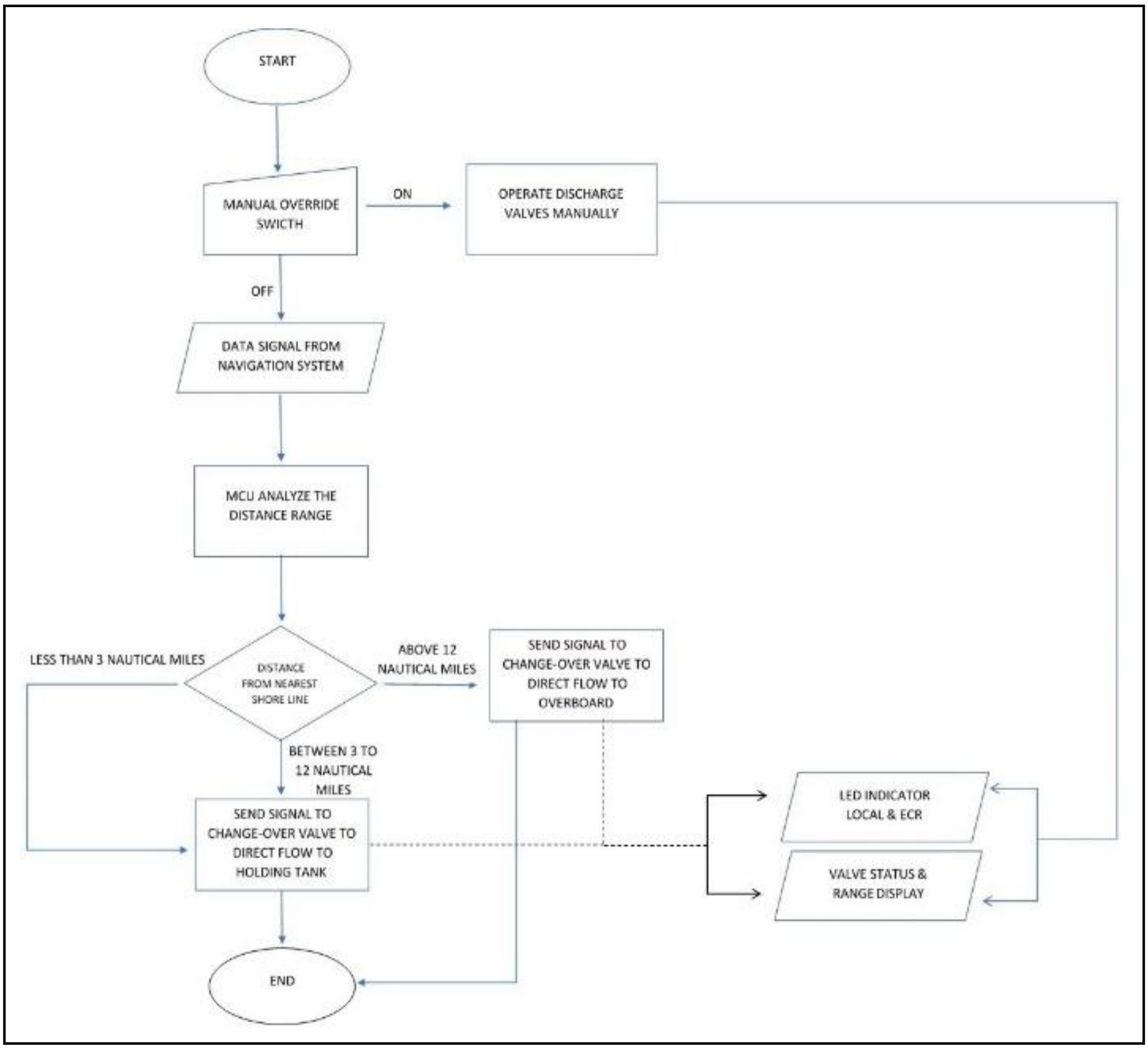


Figure 3: Flow Chart of Proposed System

## 2.8 CIRCUIT

The whole circuit is made up of two Microcontrollers, which can be divided into two different modules. One module is for the Local side, which is at the Sewage Treatment Plant itself, and the other is on the Remote side, which is the Engine Control Room. One primary MCU is responsible for the major operation of the auto changeover of the discharge valve as well as for the indicators or vessels' current distance range from the nearest shoreline in terms of LED. The input of the primary MCU is derived from the vessel's navigation system, which is then interpreted by the MCU for its relevant output. In the schematic diagram, a 3-way ROT Switch is used to represent/stimulate the different ranges of input received from the navigation system (Figure 4). The same input is extracted to the second MCU as labelled in the schematic diagram.

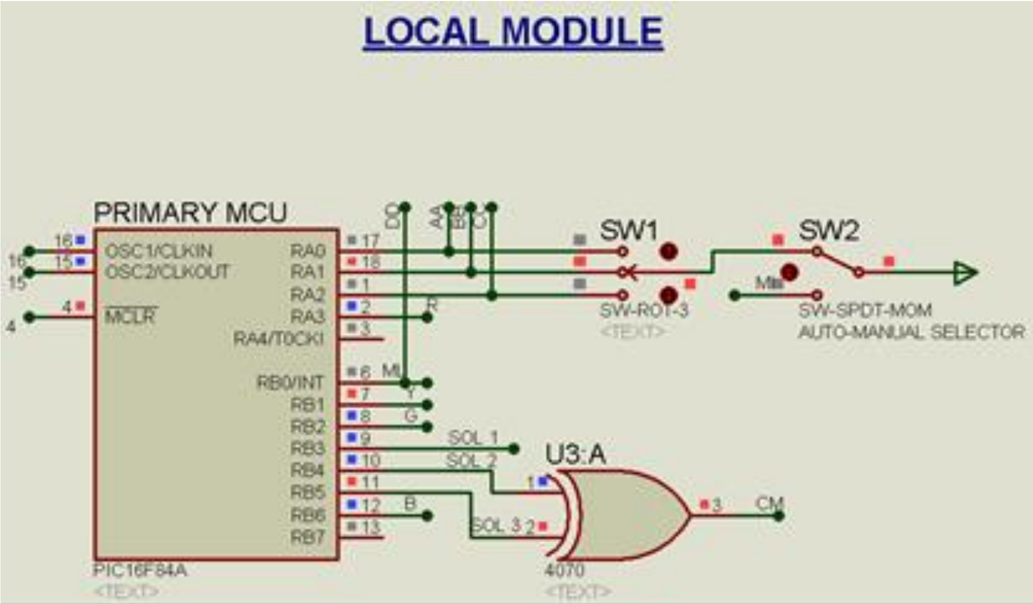


Figure 4: Primary MCU, SW1, and SW2

Depending on the input received, the output is broken down into two parts, the first part being the output to control the discharge valve changeover. An electric signal is sent to an Electro-Pneumatically operated valve (Figure 5). As two outputs are being directed to change over to the Holding Tank position, we have used a Quad 2-Input EXCLUSIVE-OR Gate so as to not interrupt the signal during the changeover between the first two ranges (Refer to Figure 5, component U3:A).

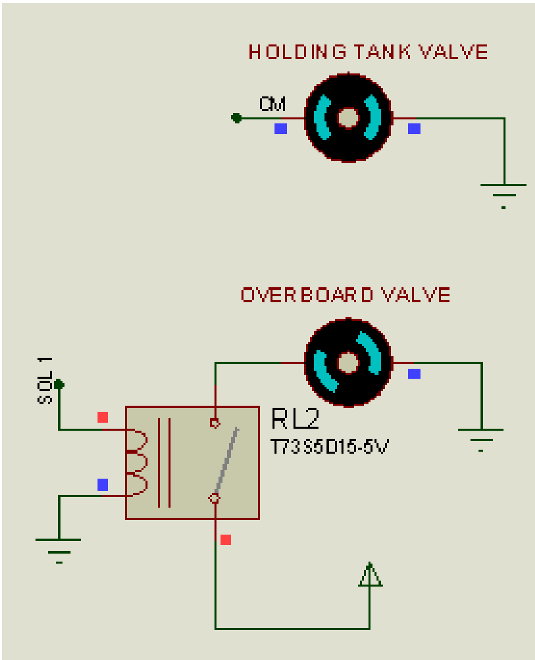


Figure 5: Sewage Holding Tank and Overboard Valve

The second part of the output for the primary MCU is for the LED indicators, which provide the user with a visual and simple identification of the vessel's position from the nearest shoreline. Four different LEDs are used; Red (Less than 3 N.M.), Yellow (3 to 12 N.M.), Green (More than 12 N.M.), and Blue (Manual Operation). These outputs are commonly supplied for all LEDs located at the Local (Figure 6) and Remote side (Figure 7).

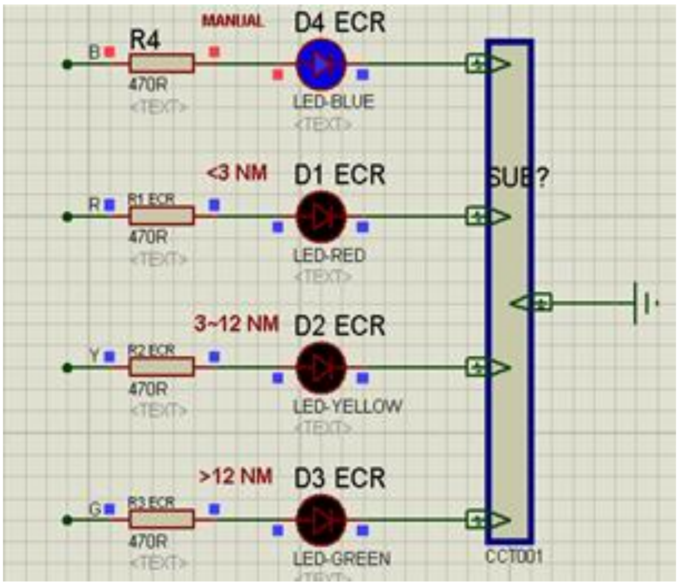


Figure 6: Light Indicator at STP local

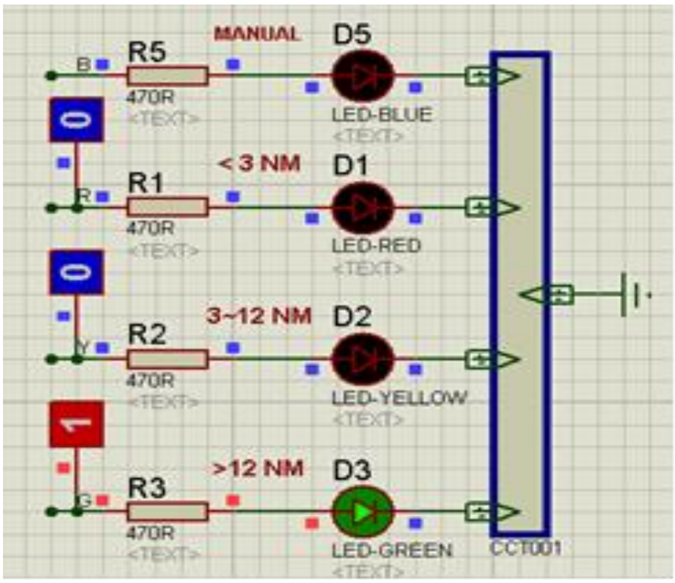


Figure 7: Light Indicator at ECR

A secondary MCU is used to program and power up the LCDs (both local and remote side) to indicate the Discharge Valve status and the distance range of the vessel from the nearest shoreline (Refer to Figures 8, 9, and 10).

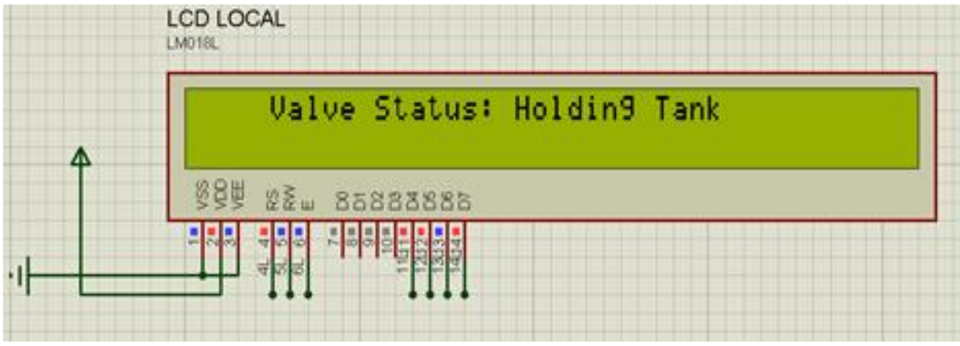


Figure 8: LCD at STP Local

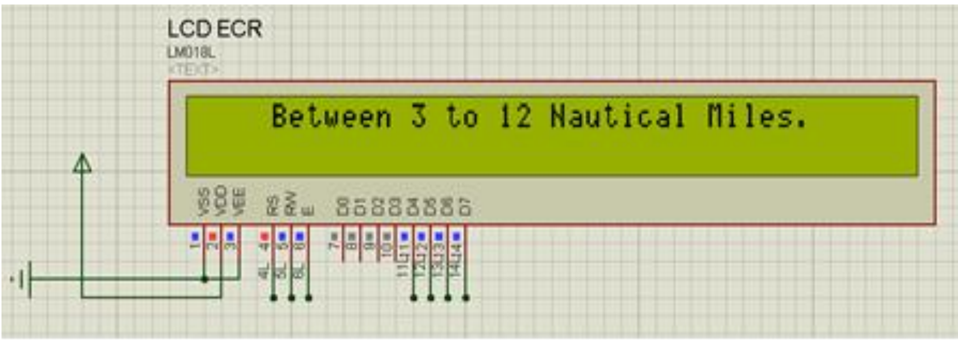


Figure 9: LCD in ECR

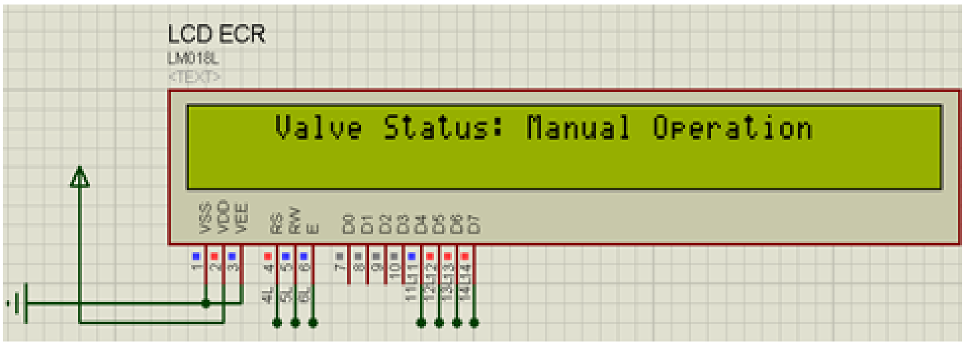


Figure 10: LCD in ECR Local

## 3.0 CIRCUIT DESIGN SIMULATION

This electronic circuit (Figure 11) was created using PROTEUS 7 Professional software and programmed using the PIC C Compiler. PROTEUS 7 Professional has almost all the components required to stimulate and visualise the actual project being created. Using this software has enabled us, the designers and creators of this project, to further understand the behaviour, flow, and operation of the actual circuit. Multiple trials have been carried out after designing and programming the MCU, and the outcome shows good performance and results. A 3-way ROT Switch was used to stimulate the different distance range picked up from the vessel's navigation system, which is then interpreted by the MCU to give out the right output and change over the discharge valve accordingly. In addition to that, usage of the LCD Module, which enables us to display the relevant data, makes it more user-friendly, especially in both Local and Remote locations. Overall performance, accuracy, and outcome of the digital circuit are good.

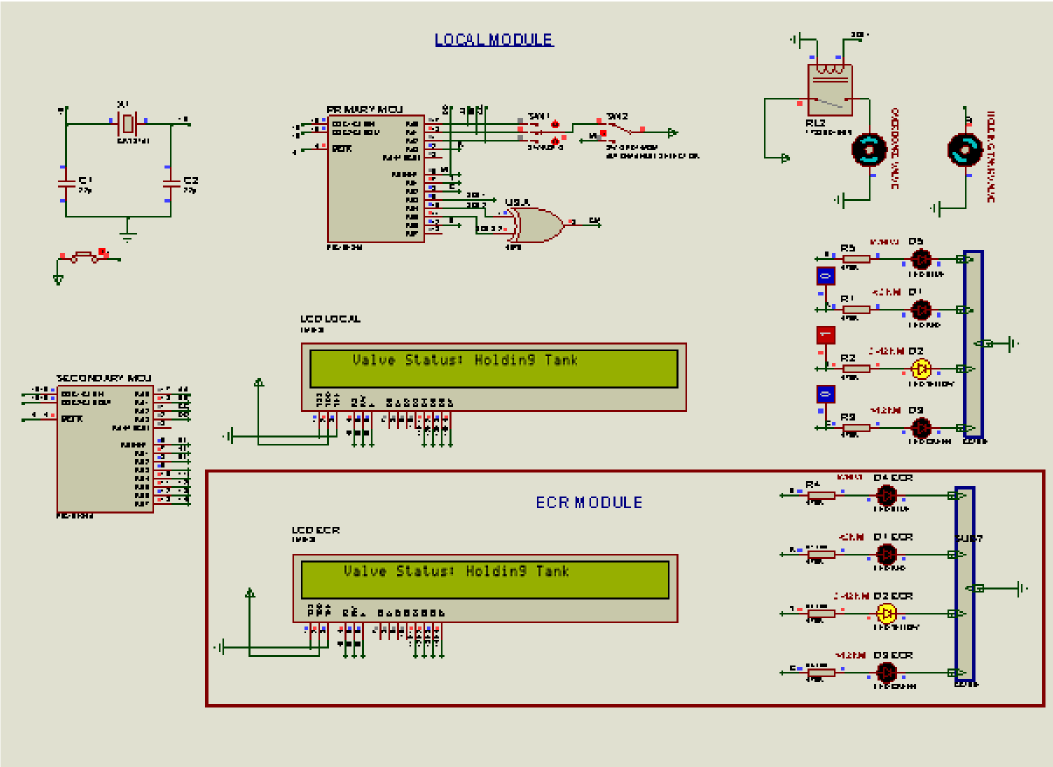


Figure 11: Circuit Design Simulation

## 4.0 RECOMMENDATIONS

Based on the results achieved from the digital circuit simulation, and as to relate to the purpose of this project, the authors would like to suggest that besides having such a system installed onboard ships to ease the operation, ship crew shall always be vigilant and up to date with the regulations updated by MARPOL with regards to MARPOL Annex IV as certain Special areas can be outside the 12 nautical miles mark and would require the system to be switched to Manual Operation. The best would be to make this compulsory for all ships to install the system; then, it will be much easier to consult with MARPOL itself to update the existing program whenever there is a change in regulation. This way, all ships would be complying with an automatic system.

## 5.0 CONCLUSION

Most of the designs on the vessel focus primarily on technological advancements in their sewage treatment plant, but the existing valve systems onboard remain unchanged. The international community is concerned about marine oil pollution because it has had significant negative impacts on the ecological environment, human security, and economic development. With increasingly stringent environmental protection laws and standards, vessels must exercise greater caution when dealing with MARPOL law-breaking. The authors believe that this system will undoubtedly shift toward efficiency and environmental protection in the future.

## 6.0 ACKNOWLEDGEMENTS

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