MODELING OF A TIDAL WAVE GENERATING SYSTEM

By

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DISSERTATION

Submitted to the Electrical & Electronics Engineering Programme
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Universiti Teknologi Petronas

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CERTIFICATION OF APPROVAL

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Mohd Tajul Azmi Bin Mohd Noor

ABSTRACT

Basically, tidal wave is the rising of the earth ocean's surface caused by the relative motion of the Earth, Sun and the Moon, which interact via gravitational forces. It arises because the gravitational force exerted on one body by a second body is not constant across its diameter. The side nearest to the second body experiences a greater force, while the opposite side experiences a lesser force. However, tidal wave can also be created artificially using engineering approaches. It can be generated by consistently moving water with a moving pallet, swinging gate, or movable immersed block. This eventually will create disturbance at the water surface and lead to the creation of tidal wave. This project is about designing and modeling a scaled-down model of a tidal wave generating system. A water container, installed with four pressure chamber was designed and fabricated to store water. Vertical pressure is applied inside those chambers using pedals driven by DC motors. The pedals are installed inside the chambers at the water container which are controlled by PLC. The PLC is a control system which takes and processes input from the control panel and send the output to the external relay system. The outputs sent by the PLC to the external relay system will determine forward and reverse movement of the DC motors. By then, artificial tidal wave is created in the water container. The waves formed can be used for structural test and learning tools. Apart from that, the concept can also be applied at water theme parks during the process of making artificial tidal waves.

ACKNOWLEDEGEMENT

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CHAPTER 1
INTRODUCTION

1.1 Background of Study

The tidal wave generating system is defined as a system that will create a few different forms of waves depending on the input that will be chose by user through the control panel. By implementing Bernoulli principle in this project, wave is created by generating pressure at the water surface inside the pressure chambers. Differences of pressure in both sections will cause accelerations of water from the pressure chambers to the water container. In a manner to produce tidal wave that will travel along the water surface, baffle was designated at the floor of the water container to direct the water upwardly displacing it from the pressure chambers to the water container.

The learning and understanding of this tidal wave system is divided into two major scopes which are electrical electronics system and mechanical system. To begin with the design of the system, a building block is constructed to show the general inputs, outputs and their connection with the main system of the tidal wave generator. A water container which acts as a fundamental basis to this project was designed and built with four pressure chambers. Pedaling system, consists of vertical pedals and a set of four DC motors was installed inside the pressure chambers and integrated with the external electronic relay system. The electrical control system is one of the most crucial parts in this project as it will trigger the movement of pedals from the output produced by the PLC. In this part, Programmable Logic Controller (PLC) is used as the control system. In line with that, high understanding and knowledge regarding PLC are required in order to efficiently use the programming software to produce the desired programming code.

To put all in a nutshell, it is crystal clear that with full understanding on the behavior of the system will lead to completion of the project. The expected output of this project is a scaled-down model of tidal wave generating system that can function accurately as desired from the user.

1.2 Problem Statement

In this project, we look into the tidal wave generating system that has been widely implemented in forming artificial tidal waves. But the current situation shows that not many people including engineering student know how the system actually works. In contrary, it is important for the student (especially electrical & electronics engineering students) to know at least the basic understanding of the tidal wave generating system and its mechanism. In working environment, there are possibilities that they are required to encounter tasks involving process control system thus it will be a massive advantage if they have learned the system beforehand. There are some problems that might hinder students from understanding how a tidal wave generating system actually works such as:-

- Lack of detail information such as circuit design, system flowchart, mechanical concept and the programming code for the system.
- The complexity of the circuit design, programming source code and mechanical system might lead the student to consume a lot of time to comprehend.
- The complexity of the practical process of modeling a tidal wave generating system which commonly involves circuit implementation and software programming.

By developing a scaled-down model of the tidal wave generating system, students might be able to understand and experience the application from the tidal wave advantages. Nevertheless, having a specialized purpose or functions implemented in this system will further lead them to appreciate and realize what a tidal wave generating system is capable of doing.

1.3 Objectives

The objective of this project is to design and implement a scaled-down model of a tidal wave generating system with the function to generate four different types of artificial tidal waves. There are several parts of objectives to be achieved in this project, which are:-

- Identify and study the Wave Generator Process Control System in order to create a system that able to meet the projects requirement.
- Study and construct suitable electronics circuits design to be implemented for the system.
- Study and understand the mechanical aspects of the tidal wave generating system.
- Study and use of software to program the Programmable Logic Controller (PLC) to perform the required movements or activities.
- Examine and understand the behavior of the prototype when it is operating in real time after the completion of fabrication.

This tidal wave generating system can be implemented in:

1. Generating artificial tidal waves in swimming pool.
2. Generating surf waves for water theme park.
3. Hydro lab for learning purpose.
4. Structural test such as ship, submarine and tidal wave breaker.

1.4 Scope of Study

The scope of study in this project covers two parts which are electrical electronics system and mechanical system. The electrical electronics system covers four sections which are power distribution system, external electronics relay system, control system (PLC) and control panel. Apart from that, the mechanical system is divided into three sections which are pedaling system and the water container installed with four pressure chambers. The purpose of this part is mainly to create disturbance at the water surface by moving pedaling system vertically inside the pressure chambers. However, the electrical electronics system focuses on processing inputs sent by the control panel to the control system (PLC) and generate outputs that will determine operations on the external relay system. These two parts are vital in order to achieve the objectives of this project. Revisions on previous projects and other related references are necessary to achieve better understanding on the tidal wave generating system.

CHAPTER 2
LITERATURE REVIEW

2.1 Surf Wave Generator

The present invention relates to swimming pool wave-generating apparatus, and in particular swimming pool wave-generating apparatus producing individual surf or tidal waves alone or in sequence. Previous swimming pools having wave-generating apparatus have produced periodic waves or other forms of water motion at short regular intervals which are produced by periodic applications of energy, either through air pressure, water pressure, or other mechanical application. The energy is applied in a periodic fashion to produce the desired periodic waves. In systems incorporating air excitation, the water is displaced by periodic application of air pressure or partial vacuum to an auxiliary water displacement chamber or caisson located adjacent to the swimming pool which receives periodically displaced water, producing the desired wave motion. The periodic waves-generating systems are limited to waves of relatively short periodicity. However, certain water sport activities such as surfing require a large wave with a longer period between each wave. The above-mentioned short-periodic wave generators cannot produce suitable waves for this purpose. [1]

To produce the desired periodic or long-interval surf waves, one approach has been to construct a water reservoir adjacent to and above the water surface of the swimming pool; the release of contained water into the swimming pool produces the desired wave by adding the volume and potential energy of the stored water. This form of wave generator is limited by the volume of water stored and the rate at which the water can be replaced within the above-mentioned reservoir. Also, the valves used to release water from the reservoir into the swimming pool are normally at least partially underwater at all times, reducing the life of such valves. The reservoir itself is expensive to build and to maintain. Moreover, the high profile of the reservoir is visually unattractive to the otherwise normal pool or natural beach surroundings. [1]

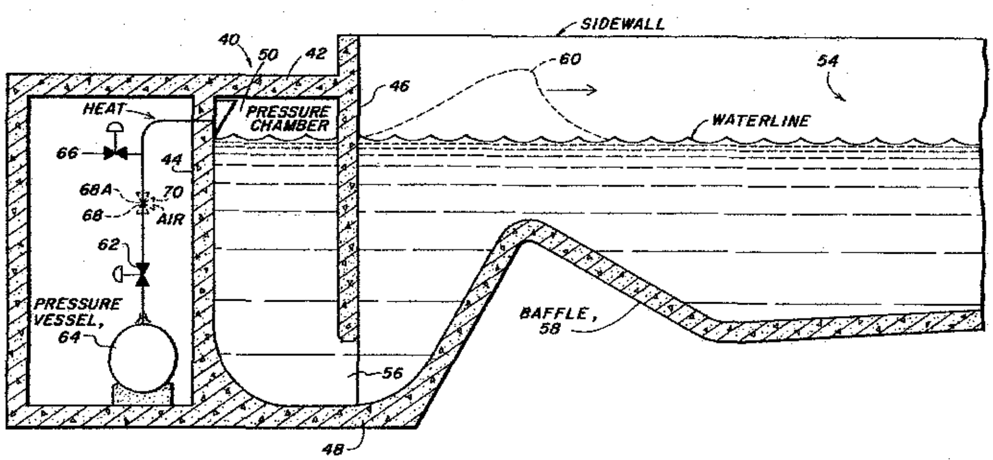


Figure 1: Vertical cross-section of the swimming pool and the caisson structure

Figure 1 shows that the wave generator of the present invention comprises a caisson located adjacent to the swimming pool having subsurface opening through which water may be rapidly moved from the caisson into the swimming pool, hence inducing the desired wave motion. The caisson is rapidly pressurized by a stored charge of pressurized air introduced to the top of the caisson, displacing the caisson water downward through the subsurface opening into the swimming pool. The resulting displaces water is directly received by the swimming pool through an unrestricted opening without mechanical water valves, thereby reducing the problem of wear and maintenance of underwater valves. The pneumatic valves and the plumbing associated with the present invention are substantially removed from the presence of water, thus increasing the lifetime of the system. [1]

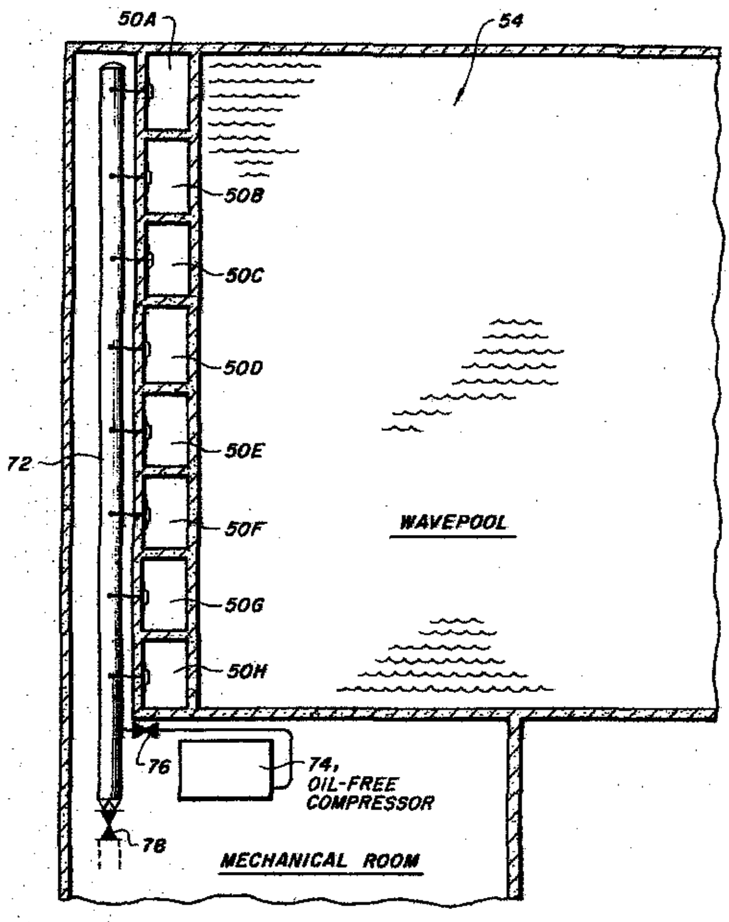


Figure 2: Cross-sectional plan view showing a multiple section caisson implementation

Figure 2 shows that the pressure chamber has a substantially low profile providing no visual obstruction to the surroundings landscape. Moreover, the concrete structure necessary is simplified, reducing the costs associated with construction and maintenance of the pool wave generator. Furthermore, the caisson may be subdivided into smaller sections, allowing for increased structural support. [1]

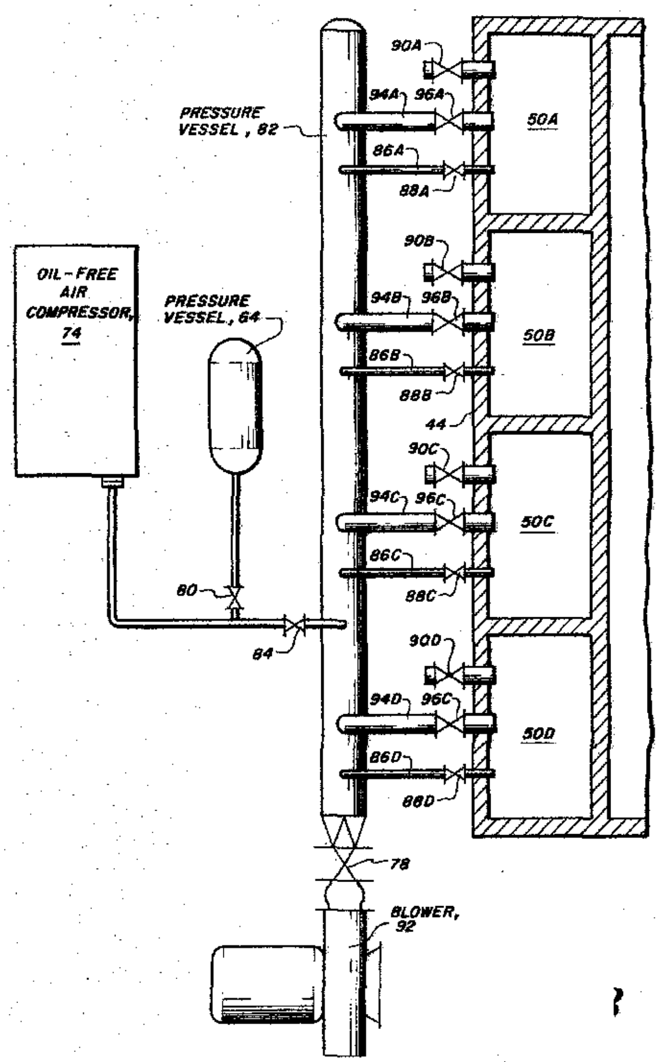


Figure 3: Plan view of the invention partly in section in combination with periodic wave generators

Figure 3 shows that the surf generator of present invention may also implemented in conjunction with other wave generating methods and systems, without any limitation of the effectiveness of their system.[1]

2.2 Method And Apparatus For Wave Formation In Swimming Pools

Normally waves are artificially created in swimming pools by the disturbance of water surface in vertical, inclined, or horizontal direction by directly moving water with a moving pallet, swinging gate, or a movable immersed block. So far only mechanical wave-making machines have been used in wave-activated swim pools. In these cases the disturbance at the water surface has been caused by the immersed movable block, swinging gate or movable piston. These wave-making machines have been driven by electric motor acting through connecting rod and crank and gear reduction mechanism. Since large quantities of water have to be moved, wear and tear on the mechanical parts is heavy and considerable corrosion is a serious problem in which the need for tight water sealing makes even worse. These known installations are large, heavy, and costly to purchase and operate because constant maintenance problem arise.

Another disadvantage of the mechanical wave-making machinery is the complicated and not always accurate formation of the desired waves. The creating of waves across the entire pool width and crossing waves is possible when using several machines which are not moved in synchronism. However, as a general rule of the height of the waves tends to grow higher at the pool rim where one normally wishes a decrease in wave height for safety reasons.

The main object of designed model is to avoid the above-mentioned disadvantages by using a pneumatic wave-making machine. Listed below are the other objects of the invention:

- to provide an air pressure source to contact one or more portions of the water surface so that mechanical wave-making apparatus need to be in contact with water.
- to provide a plurality of wave-forming tanks along one end of the swim pool with air pressure periodically applied to different ones of such wave-forming tanks to move the water in the tanks and in the swim pool.
- to provide a swim pool with diverging sidewalls and a decreasing depth to a beach

area where the waves created by the wave-making apparatus form into breakers on the beach area.

- to provide a wave-activated swim pool with a diverging sidewall leading to a beach area to dissipate the force of the waves and thus create a safe wave and breaker action on the beach area for young children.
- to provide an air pressure source alternately operating into two different wave-forming tanks to move the water in such tanks.
- to provide a wave-activated swim pool with higher waves in the central area than around the rim of the pool.
- to provide a swim pool having a width equal to at least one wavelength of the waves established in the water of the pool and equal to a multiple of half-wavelength.
- to provide force means applied alternately on two different parts of the width of a swim pool with one part having an effective width of one-fourth the water wavelength in order to create a standing wave which travels along the length of the pool.

Another objects and a fuller understanding of the invention may be had by referring to the following description and claims, taken in conjunction with the accompanying drawings.

The invention may be incorporated in the method of forming waves in wave-activated swim pools characterized by the fact that at least part of the water surface is directly brought into contact with an air pressure source. [2]

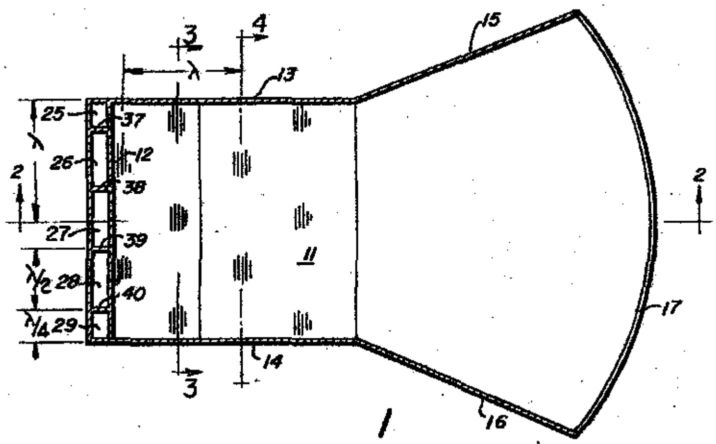


Figure 4: Plan view of line 1 – 1 of Figure 5 of a wave-activated swim pool according to the invention

Figure 4 illustrates that one wavelength is one-half the width dimension of the swim pool 11 and also illustrates that the wave-forming tank 28 as well as tanks 26 and 27 have the width dimension parallel to the width of the pool one-half the wavelength. At the same time the end wave-forming tanks 25 and 2have a width dimension parallel to the width dimension of one-fourth of a wavelength of the water wave. [2]

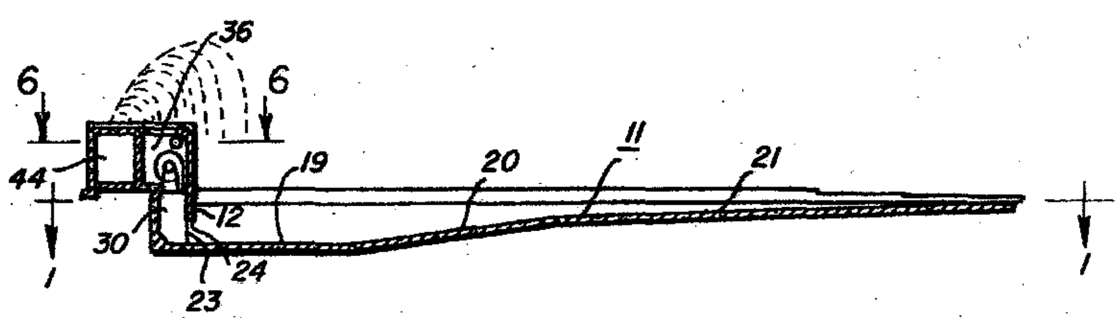


Figure 5: Longitudinal sectional view taken on the line 2 – 2 of figure 4

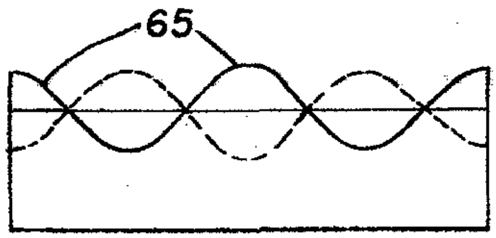


Figure 6: Sectional view of line 3 – 3 of Figure 4

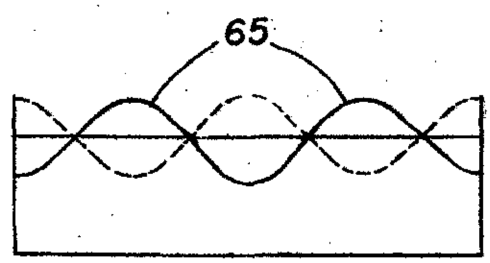


Figure 7: Sectional view of line 4 – 4 of Figure 4

Figure 5, 6, and 7 shows a wave activated swim pool 11 which has a deep end wall 12, sidewalls 13 and 14, diverging sidewall extensions 15 and 16 and a beach area 17. The side wall extensions 15 and 16 diverge to establish the beach area 17 where the water depth goes to zero. The bottom of the swim pool is horizontal at a bottom wall 19, slopes upwardly at a sloping wall 2and has a more gradual upward slope in the beach area bottom wall 21.

The width dimension of the pool is established according to the formula:

$$W = (\lambda/2)(K+1)$$

Where W is the width of the swim pool, λ is the wavelength of the water wave, and K is any positive integer. In previous attempts at wave-making machinery in swim pools, swinging gate has been attempted, for example, swinging alternately and applying force on the water; first on one-half of the width of the pool and then on the other half of the width of the pool. This has undesirable feature from the safety standpoint of creating greater water movement and hence greater water height along the edges of the pool and also establishes that the wave is formed as distinct waves have a wavelength only about one-half the of the pool. In the present design the swim pool has a width at least one wavelength long, or alternatively 3/2, 2, 5/2 etc. of a wavelength depending upon the number of wave-forming tanks across the width of the pool. [2]

2.3 Relay

A relay is an electrically operated switch. Current flowing through the coil of the relay creates a magnetic field which attracts a lever and changes the switch contacts. The coil current can be on or off so relays have two switch positions and they are double throw (changeover) switches.

Relays allow one circuit to switch a second circuit which can be completely separate from the first. For example a low voltage battery circuit can use a relay to switch a 230V AC mains circuit. There is no electrical connection inside the relay between the two circuits, the link is magnetic and mechanical.

The coil of a relay passes a relatively large current, typically 30mA for a 12V relay, but it can be as much as 100mA for relays designed to operate from lower voltages. Most

ICs (chips) cannot provide this current and a transistor is usually used to amplify the small IC current to the larger value required for the relay coil. The maximum output current for the popular 555 timer IC is 200mA so these devices can supply relay coils directly without amplification.

Relays are usually Single Pole Double Throw (SPDT) or Double Pole Double Throw (DPDT) but they can have many more sets of switch contacts, for example relays with 4 sets of changeover contacts are readily available. Most relays are designed for PCB mounting but you can solder wires directly to the pins providing you take care to avoid melting the plastic case of the relay.

2.3.1 SPDT Relay

SPDT (Single Pole Double Throw Relay) is an electromagnetic switch, consist of a coil (terminals 85 86), 1 common terminal (30), 1 normally closed terminal (87a), and one normally open terminal (87).

When the coil of the relay is at rest (not energized), the common terminal (30) and the normally closed terminal (87a) have continuity. When the coil is energized, the common terminal (30) and the normally open terminal (87) have continuity.

The diagram below center shows the relay at rest, with the coil not energized. The diagram below right shows the relay with the coil energized. As you can see the coil is an electromagnet that causes the arm that is always connected to the common (30) to pivot when energized whereby contact is broken from the normally closed terminal (87a) and made with the normally open terminal (87). [3]

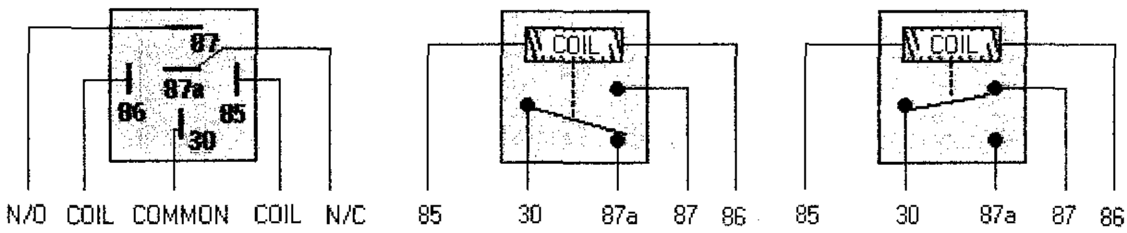


Figure 8: SPDT Relay Connection Diagram

2.3.2 SPST Relay

SPST (Single Pole Single Throw Relay) is an electromagnetic switch, consist of a coil (terminals 85 86), 1 common terminal (30), and one normally open terminal (87). It does not have a normally closed terminal like the SPDT relay, but may be used in place of SPDT relays in all diagrams shown on this site where terminal 87a is not used.

When energizing the coil of a relay, polarity of the coil does not matter unless there is a diode across the coil. If a diode is not present, we may attach positive voltage to either terminal of the coil and negative voltage to the other, otherwise we must connect positive to the side of the coil that the cathode side (side with stripe) of the diode is connected and negative to side of the coil that the anode side of the diode is connected. [3]

2.3.3 Relay Operation

All relays operate using the same basic principle. Shown example will use a commonly used 4 pin relay. Relays have two circuits (shown in GREEN) and a load circuit (shown in RED). The control circuit has a small control coil while the load circuit has a switch. The coil controls the operation of the switch. [4]

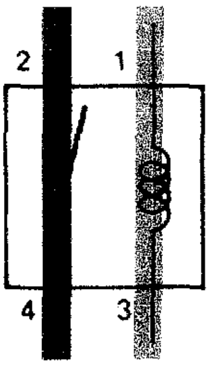


Figure 9: Two circuits in a four pin relay

When no voltage is applied to pin 1, there is no current flow through the coil, hence no magnetic field is developed, and the switch is open. When a voltage is supplied to pin 1, current flow though the coil creates the magnetic field needed to close the switch allowing continuity between pins 2 and 4. [4]

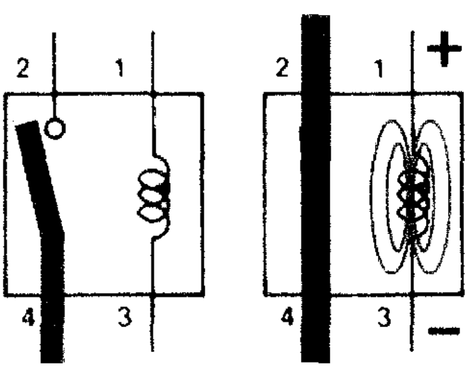


Figure 10: Generated magnetic field in the coil activates the switch

2.3.4 Using Relays To Reverse Polarity

Figure below shown implementation of two 5 pins SPDT relay to reverse polarity for a single motor. [5]

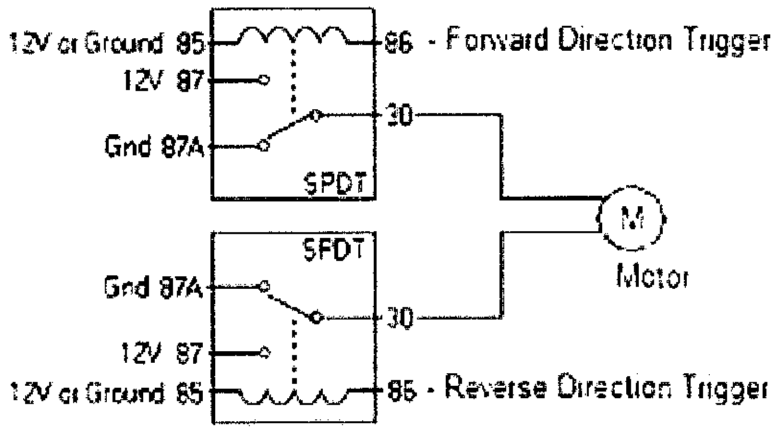


Figure 11: Using relays to reverse polarity for a single motor

2.4 Programmable Logic Controller

In general, a Control System is a collection of electronic devices and equipment which are in place to ensure the stability, accuracy and smooth transition of a process or a manufacturing activity. It takes any form and varies in scale of implementation, from a power plant to a semiconductor machine. As a result of rapid advancement of technology, complicated control tasks accomplished with a highly automated control system, which may be in the form of Programmable Controller (PLC) possibly a host computer, etc. Besides signal interfacing to the field devices (such as operator panel, motors, sensors, switches, solenoid valves and etc.), capabilities in network communication enable a big scale implementation and process coordination besides providing greater flexibility in realizing distributed control system. Every single component in a control system plays an important role regardless of size. [6]

In an automated system, the PLC is commonly regarded as the heart of the control system. With a control application program (stored within the PLC memory) in execution, the PLC constantly monitors the state of the system through the field input devices feedback signal. It will then based on the program logic to determine the course of action to be carried out at the field output devices. The PLC may be used to control a simple and repetitive task, or a few of them may be interconnected together with other host controllers or host computers through a sort of communication network, in order to integrate the control of a complex process.

A PLC consists of a Central Processing Unit (CPU) containing an application program and Input and Output Interface modules, which is directly connected to the I/O devices. The program controls the PLC so that when an input signal from an input device turns ON, the appropriate response is made. The response normally involves turning ON an output signal to some sort of output devices.

2.4.1 Conventional Control Panel and Its Difficulties

In the beginning of the industrial revolution, especially in the 1961970, automated machines were controlled by electromechanical relays. These relays were all hardwired together inside the control panel. In some cases, the control panel was so huge that it could cover the entire wall. Every connection in the relay logic must be connected. Wiring is not always perfect, it takes time to troubleshoot the system. This is a very time consuming affair. On top of that, the relays have limited contacts. If modification is required, the machine has to be stopped, space may not be available and wiring has to be traced to accommodate changes. The control panel can only be used for that particular process. It cannot be changed immediately to a new system. It has to be redone. In terms of maintenance, an electrician must be well trained and skillful in troubleshooting the control system. In shorts, conventional relay control panel are very inflexible. [6]

2.4.2 Advantages of PLC Control Panel

Here are the major advantages that can be distinguishably realized.

- The wiring of the system usually reduces by 80% compared to conventional relay control system.
- The power consumption is greatly reduced as PLC consumes much less power.
- The PLC self diagnostic functions enable easy and fast troubleshooting of the system.
- Modification of control sequence or application can easily be done by programming through console or computer software without changing of I/O wiring, if no additional Input or Output devices are required.
- In the PLC system spare parts for relays and hardware timers are greatly reduced as compared to conventional control panel.
- The machine cycle time is provided tremendously due to the speed of PLC operation is a matter of milliseconds. Thus, productivity increases.
- It cost much less compared to conventional system in situation when the number of I/Os in very large and control functions are complex.
- The reliability of the PLC is higher than the mechanical relays and timers.
- An immediate printout of the PLC program can be done in minutes. Therefore, hardcopy of documentation can be easily maintained.

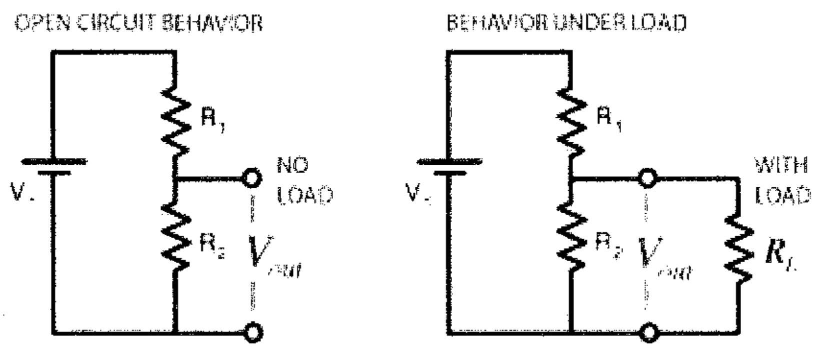
2.5 Types of Motor

Table 1: Types of motors and its features [7]

Types of Motors	Features
1. DC Motor	• Workhorse, high power • Simple to use, two wires • Torque proportional to current, steady state constant-load speed proportional to voltage • Requires gearing • Requires feedback
2. Stepper Motor	• Useful for low-torque applications with no surprises • No feedback required • One step per pulse • More involved driving circuit
3. RC Servo Motor	• High torque, useful for positioning applications • Feedback and gearing built in • Position commanded by persistent pulse train • Limited motion (less than 1 revolution)
4. Solenoid Motor	• For on-off applications • Simple to use • Short stroke • Powered in only one direction; requires external spring for return

2.6 Voltage Divider

The two resistor voltage divider is used often to supply a voltage different from that of an available battery or power supply. In application the output voltage depends upon the resistance of the load it drives. [8]



$$V_{out} = V_1 \frac{IR_2}{I(R_1 + R_2)} = \frac{V_1 R_2}{(R_1 + R_2)}$$

OUTPUT VOLTAGE UNDER "NO LOAD" CONDITION (open circuit)

OUTPUT VOLTAGE UNDER LOAD

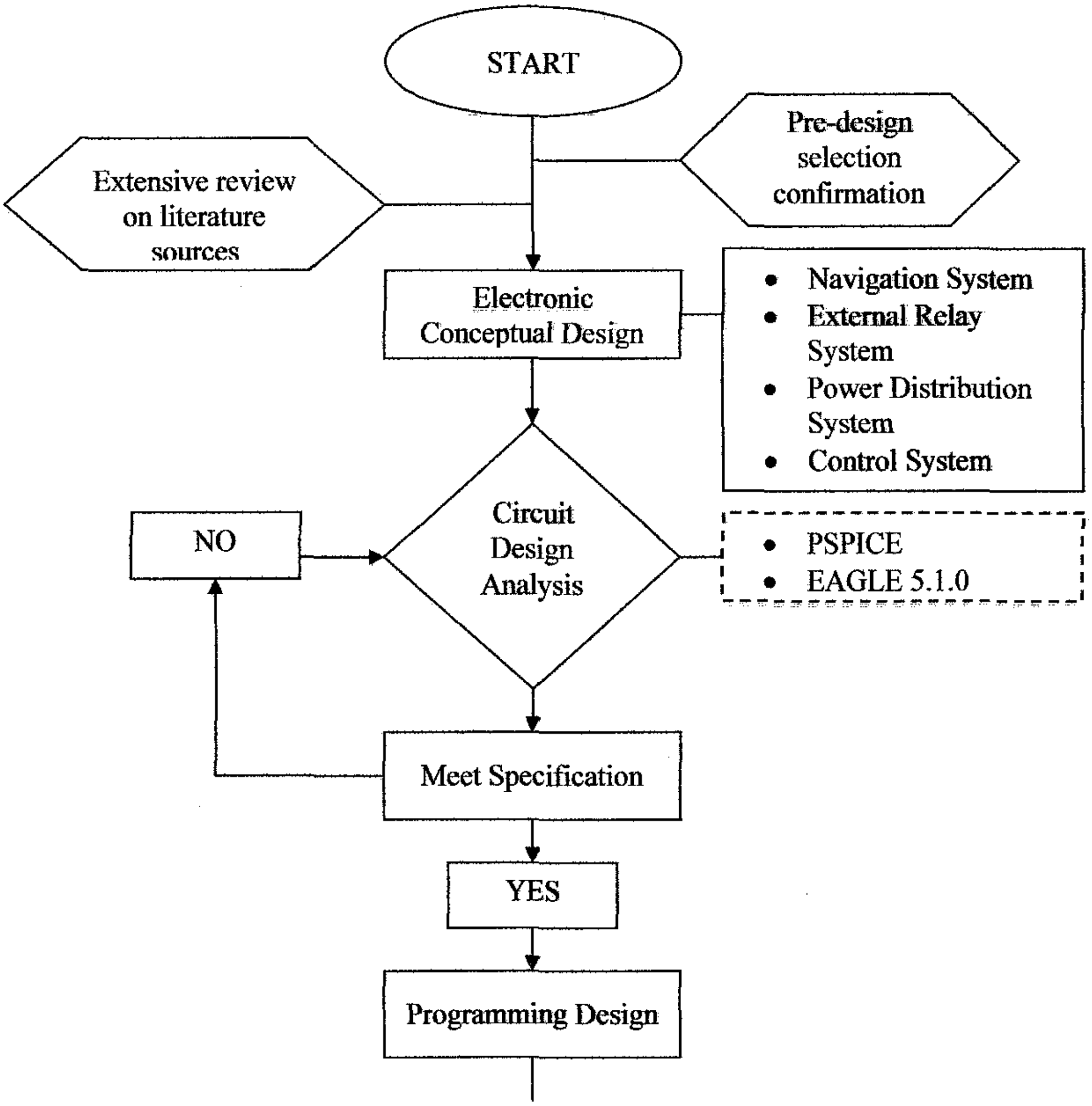
$$V_{out} = V_1 \frac{IR_2}{I(R_1 + R_2)} = \frac{V_1 (R_2 \parallel R_L)}{(R_1 + R_2 \parallel R_L)}$$

Where

$$R_2 \parallel R_L = \frac{R_2 R_L}{R_2 + R_L}$$

CHAPTER 3
METHODOLOGY

3.1 Procedure Identification



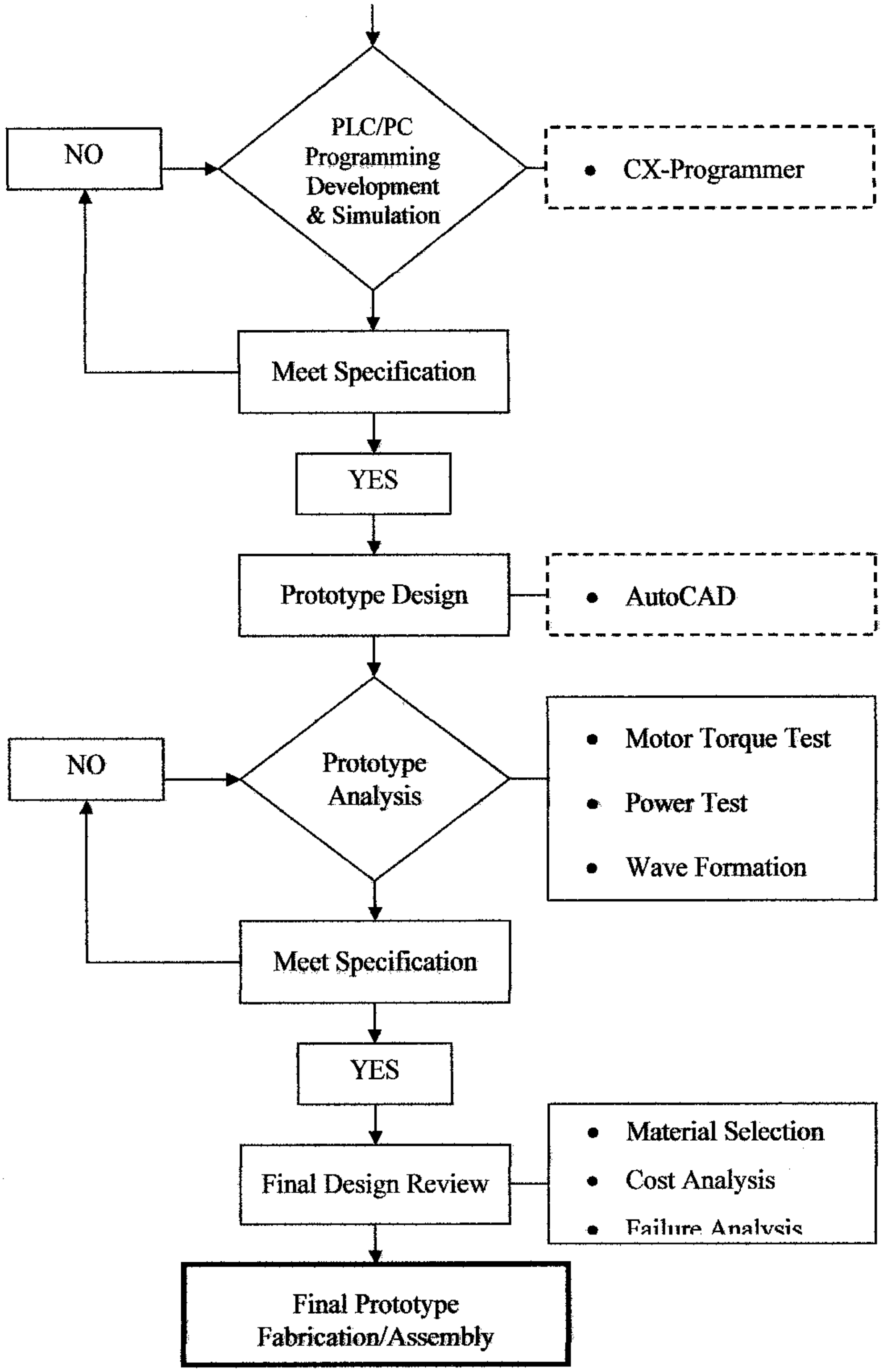


Figure 12: The process flow chart for design and modeling of a tidal wave generating system

3.2 Tools Required

Table 2: Selection of Hardware Software

SUBJECT	HARDWARE	SOFTWARE
Electronics Circuits Design	• Personal Computer	• PSPICE • EAGLE 5.1.0
Programmable Logic Controller (PLC) Programming and Analysis	• Workstation computer connected to PLC OMRON CQM1H 3I/O Training Kit	• CX-Programmer
Prototype Construction	• 12V DC Motors • 8 SPDT 12V Relays • PLC (OMRON CQM1H 3I/O) • Banana Plug Connector • Water Container with 4 Chambers (125x50x30)cm • Perspex, Veroboard • Bolts, Screws, Nat • Voltage Divider • 24VDC Light	• AUTOCAD

	Indicator • 12VDC Light Indicator • 230VAC Light Indicator • 230VAC to 12VDC Converter • Relay PCB Board • 4 Paddles • 80cm Rod with Gear • 4 Fuses • 8 Toggle Switches • 8 Limit Switches • 3 Push Button Switches • 1 Emergency Stop Switch	

3.3 Main Building Block

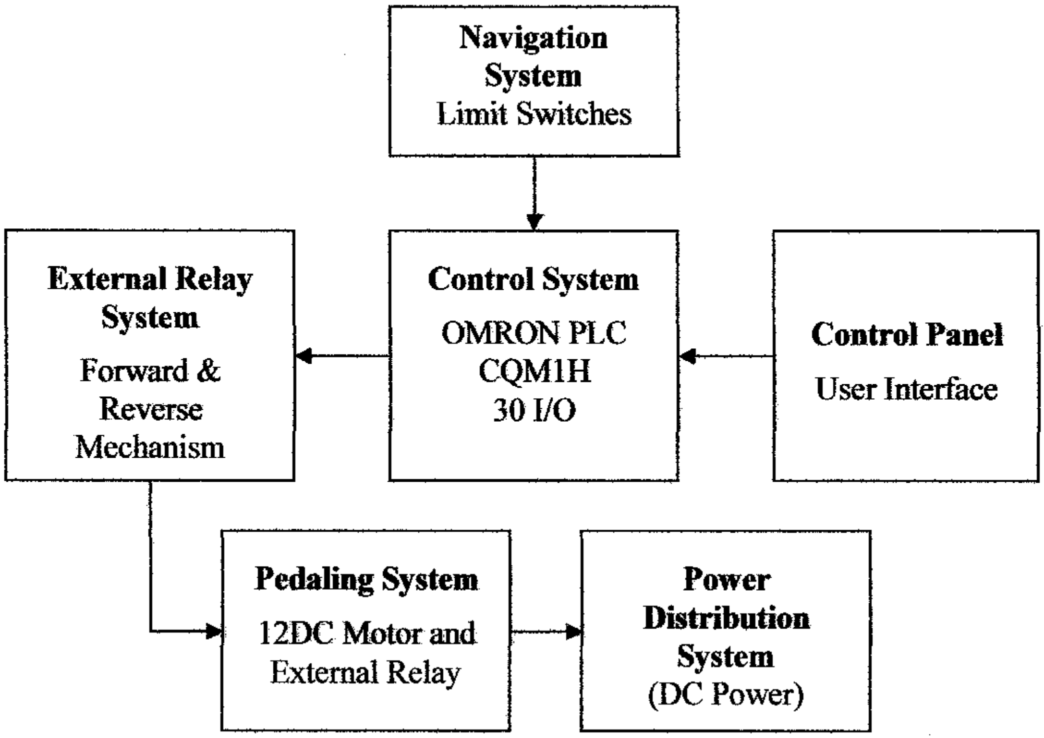


Figure 13: Main Building Block (Main System Design)

3.4 One Cycle Pedaling Sequence

Table 3: One Cycle Pedaling Sequence

		Pedals Move Downwards				**COUNTER**	**Pedals Move Upwards**			
		PEDAL 1	**PEDAL 2**	**PEDAL 3**	**PEDAL 4**		**PEDAL 1**	**PEDAL 2**	**PEDAL 3**	**PEDAL 4**
Mode 1	Start	5s Delay	6s Delay	7s Delay	8s Delay	The Counter will count for 3s whenever all **LS2, LS4, LS6** and **LS8** are activated	Activate R2	Activate R4	Activate R6	Activate R6
	End	LS2 Activated	LS4 Activated	LS6 Activated	LS8 Activated		LS1 Activated	LS3 Activated	LS5 Activated	LS7 Activated
Mode 2	Start	5s Delay	7s Delay	7s Delay	5s Delay		Activate R2	Activate R4	Activate R6	Activate R6
	End	LS2 Activated	LS4 Activated	LS6 Activated	LS8 Activated		LS1 Activated	LS3 Activated	LS5 Activated	LS7 Activated
Mode 3	Start	7s Delay	5s Delay	5s Delay	7s Delay		Activate R2	Activate R4	Activate R6	Activate R6
	End	LS2 Activated	LS4 Activated	LS6 Activated	LS8 Activated		LS1 Activated	LS3 Activated	LS5 Activated	LS7 Activated
Mode 4	Start	5s Delay	5s Delay	5s Delay	5s Delay		Activate R2	Activate R4	Activate R6	Activate R6
	End	LS2 Activated	LS4 Activated	LS6 Activated	LS8 Activated		LS1 Activated	LS3 Activated	LS5 Activated	LS7 Activated

3.4.1 Mode 1 Flow Chart

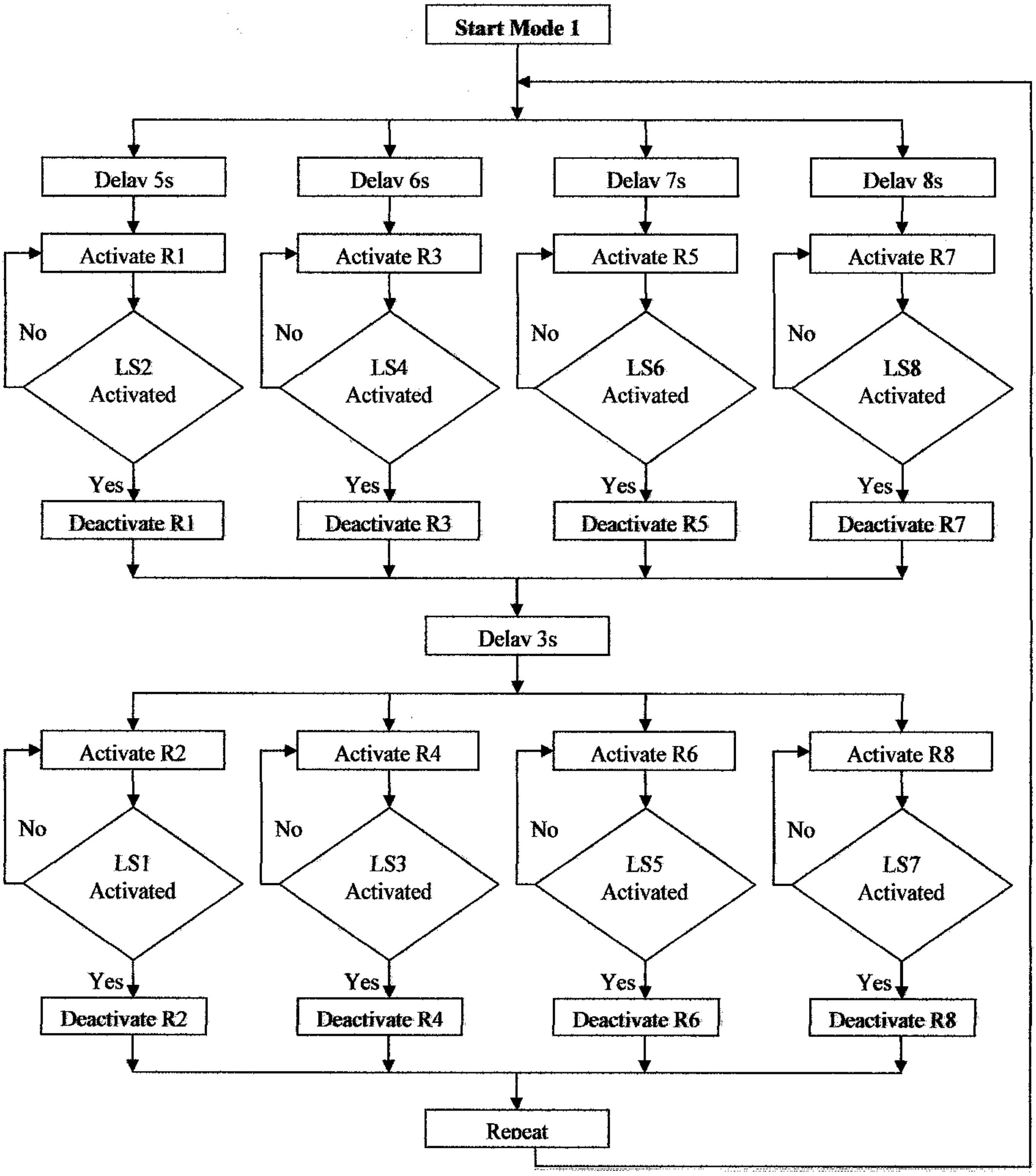


Figure 14: Mode 1 Flow Chart

Mode 1 pedaling sequence will form diagonal waves that travel along the water container.

3.4.2 Mode 2 Flow Chart

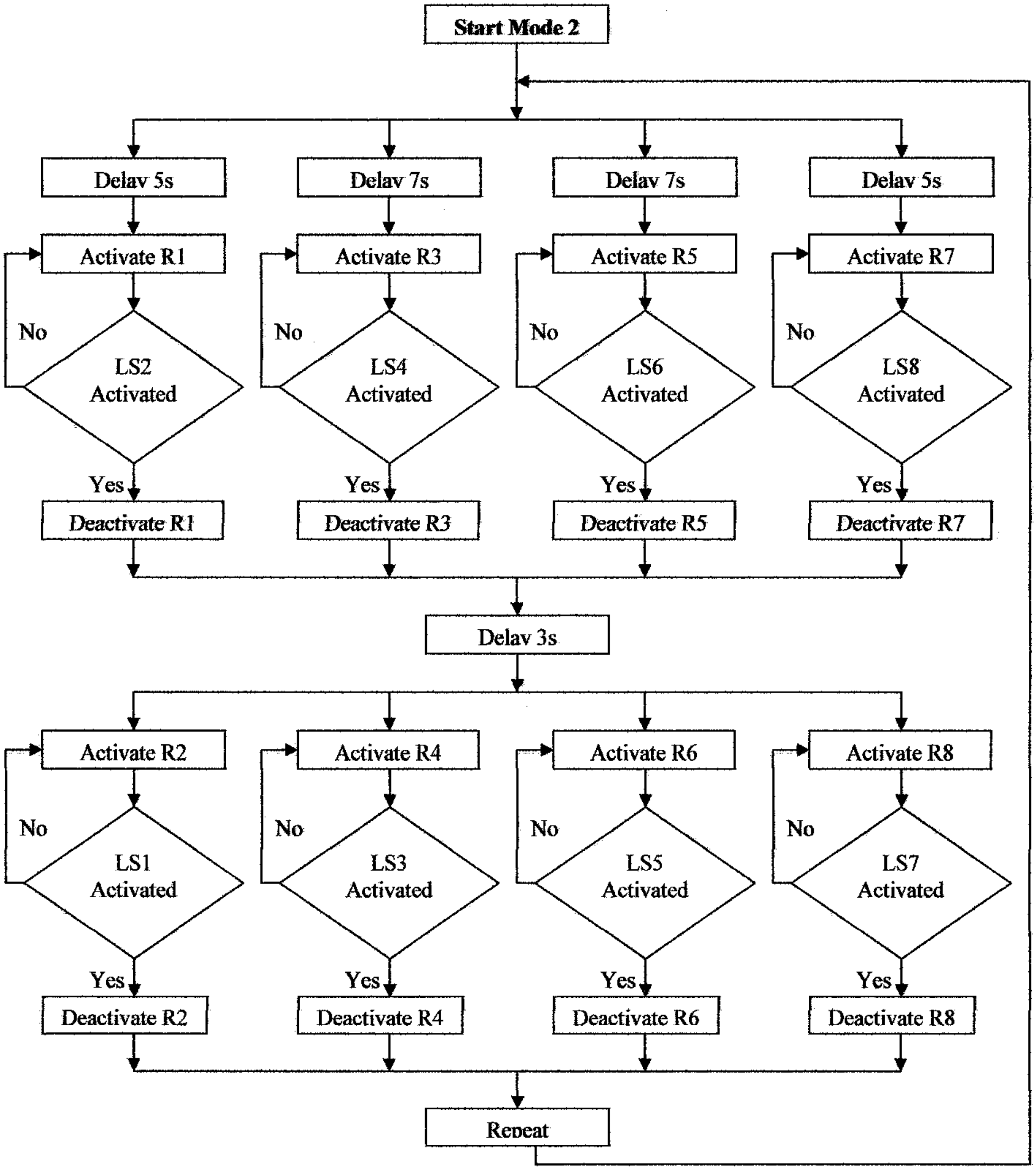


Figure 15: Mode 2 Flow Chart

Mode 2 pedaling sequence will form forward eclipse waves that travel along the water container.

3.4.3 Mode 3 Flow Chart

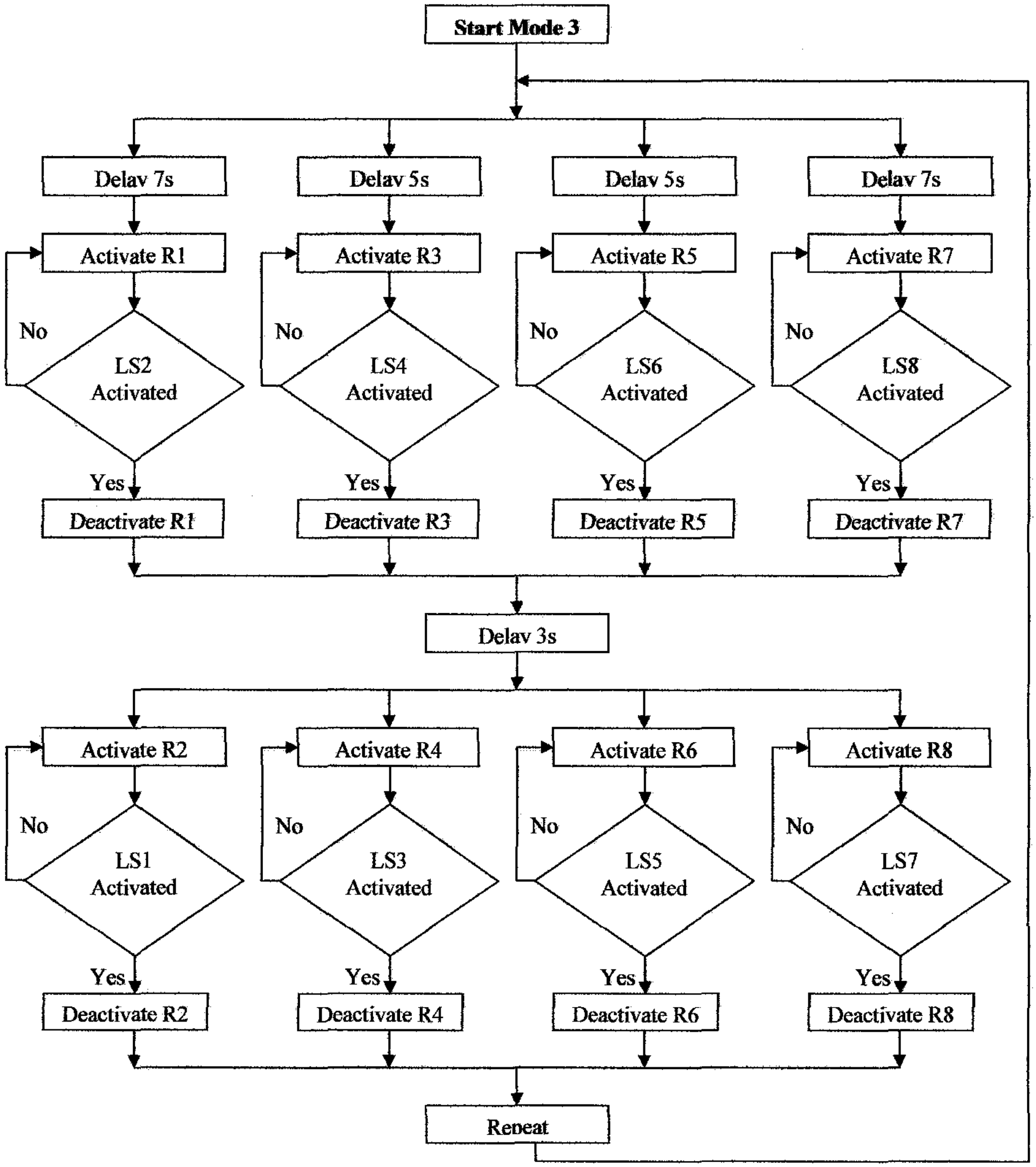


Figure 16: Mode 3 Flow Chart

Mode 3 pedaling sequence will form backward eclipse waves that travel along the water container.

3.4.4 Mode 4 Flow Chart

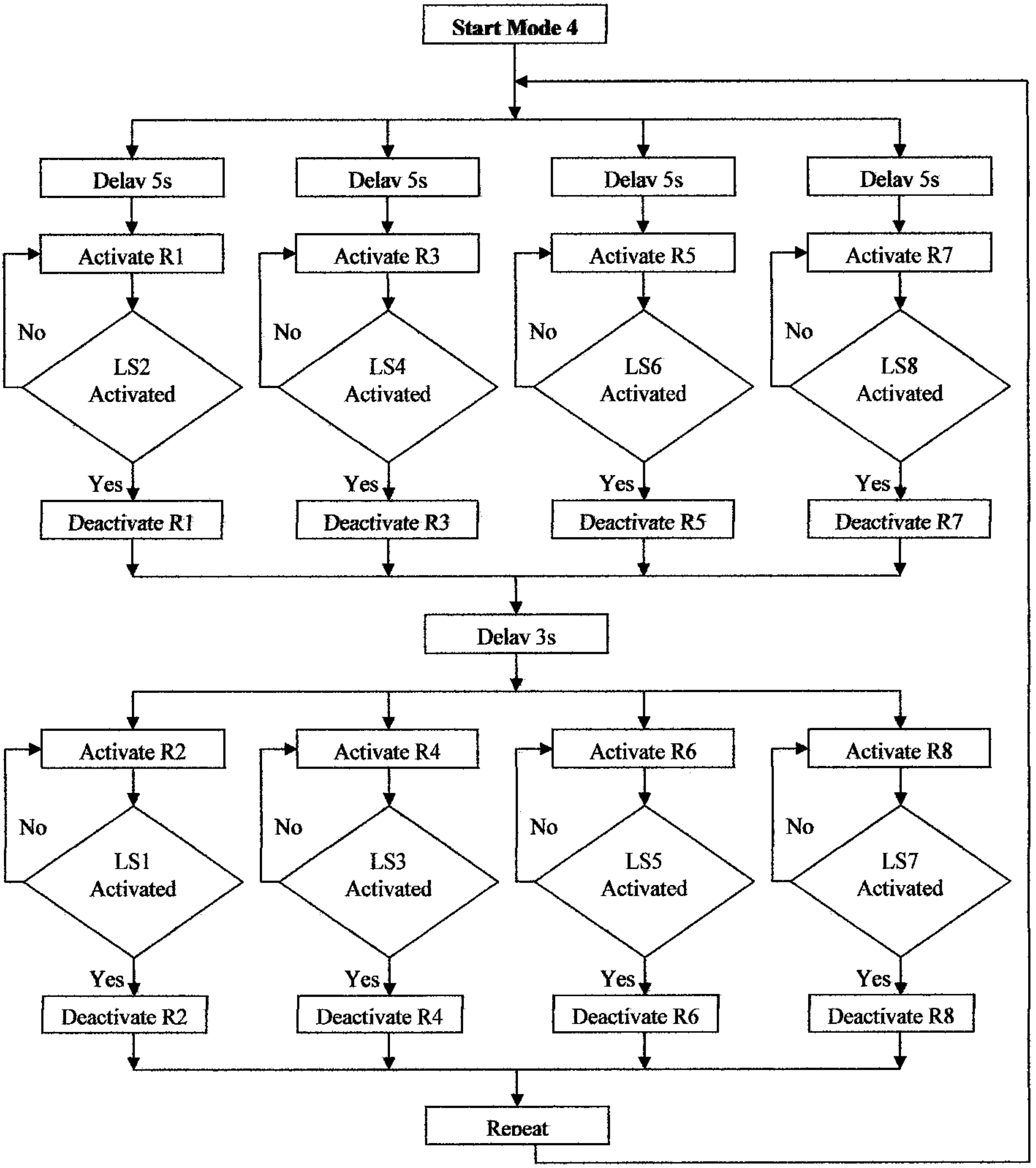


Figure 17: Mode 4 Flow Chart

Mode 4 pedaling sequence will form straight waves that travel along the water container.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Results

4.1.1 Water Container

A water container has been designed and divided into three partitions which are section A, section B and section C. Section A with a dimension of 90cm x 50cm x 30cm, functions as a place where waves will be formed while section B consists of four pressure chambers and separated from section A with a wall. They are connected through a 50cm x 5cm opening at the bottom of the wall. In addition, a baffle was placed at the floor of the water container in section A besides the opening between section A and section B. Furthermore, DC motors was installed on top of section C together with other components such as external relays and control panel which are located in section C.

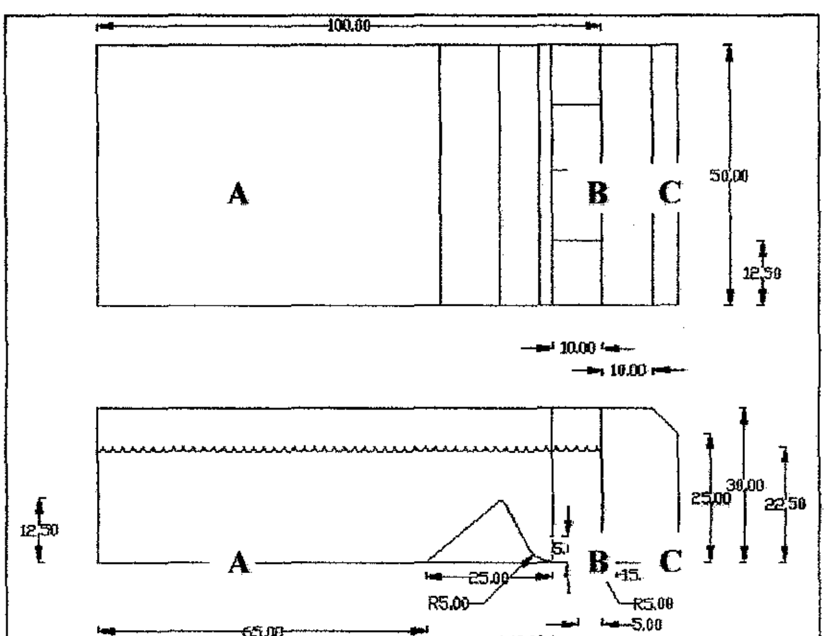


Figure 18: AutoCAD drawing of a water container

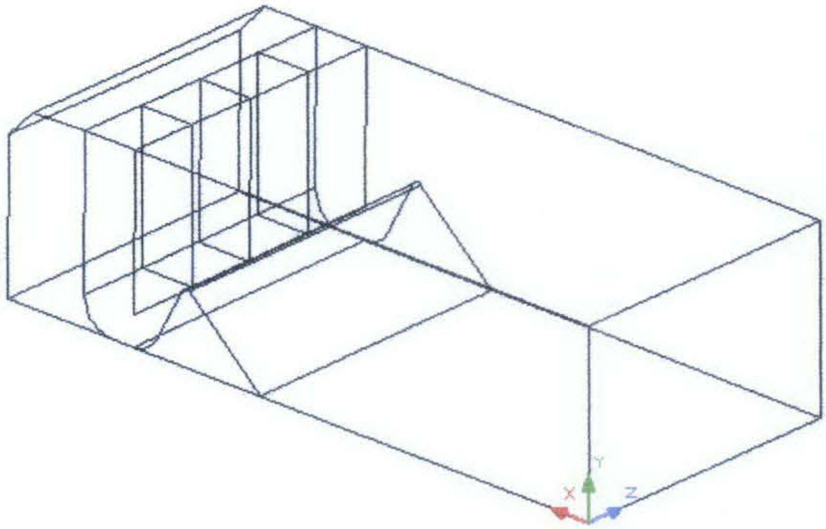


Figure 19: 3 – Dimensional view of the Water Container

Figure 20: Water Container after finished fabrication

The water container in Figure 20 has been fabricated accordingly to dimensions shown in Figure 18. It was built using 5mm Perspex. The material was chosen based on its ability to support 125L amount of water and was see through.

4.1.2 Pedaling System

Pedaling system consists of square pedal, 12VDC motor and steel rod with gear. The pedal was installed inside pressure chamber and attached to the 12VDC motor at the top area. Four sets of pedaling system was built and installed at four pressure chambers which means every pressure chamber was installed with one set of pedaling system.

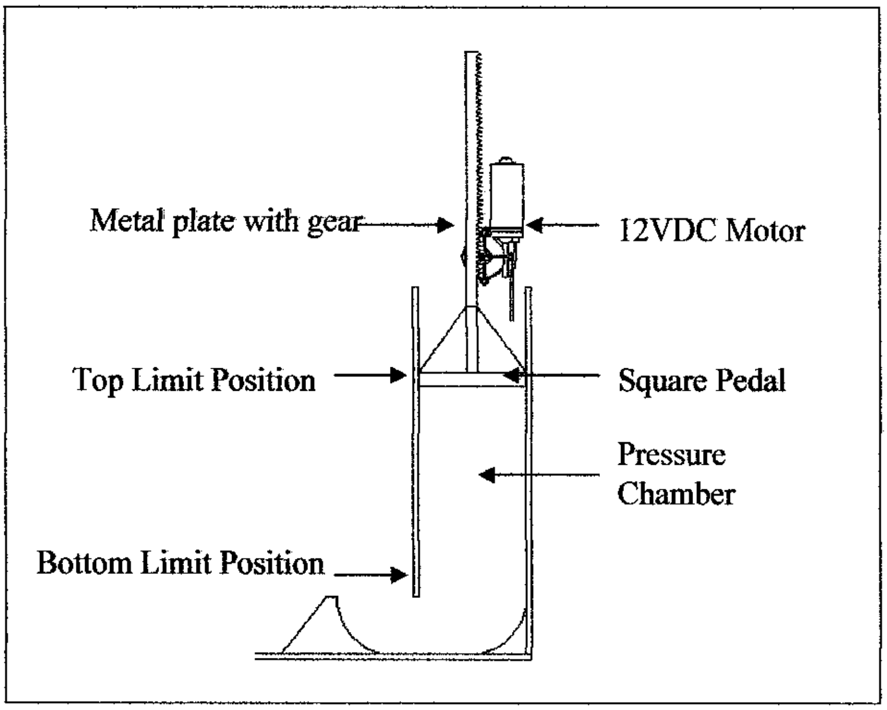


Figure 21: Pedaling system installed at pressure chambers of water container

In addition, the pedals upward and downward movement is driven by the motor while two limit switches was installed to limit their movement. The bottom limit switches was set so that the pedals will stop their downward movement at the bottom limit position which had been set at the beginning of the wall and to prevent the pedal from continuing movement downward.

The top limit switches was set so that the pedals will stop their upward movement at the top limit position which had been set at the water surface level and to prevent the pedal from continuing movement downward.

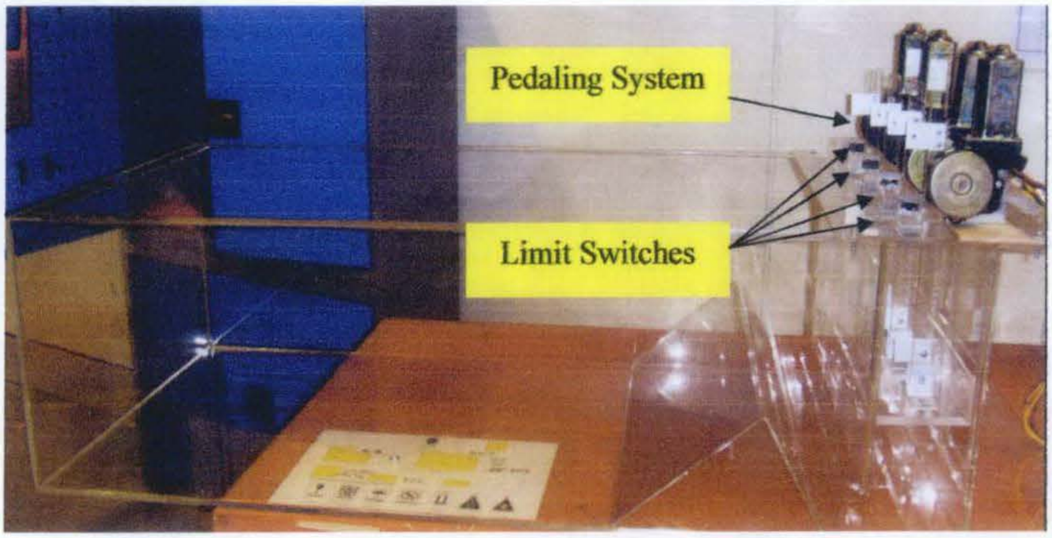


Figure 22: Water Container installed with Pedaling System at pressure chambers

4.1.3 External Relay System

External Relays were used for forward and reverse movement of DC motor. Since two SPDT relays were needed to perform forward and reverse movement of one motor, eight unit of 12VDC SPDT Relays are used for controlling four units of 12VDC Motors.

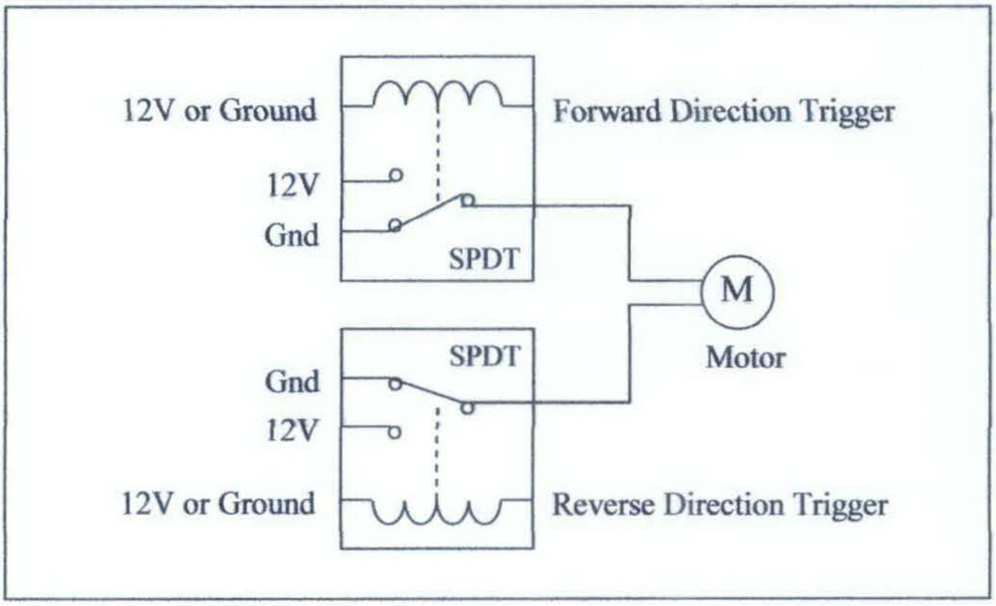


Figure 23: Using relays to reverse polarity for a single motor

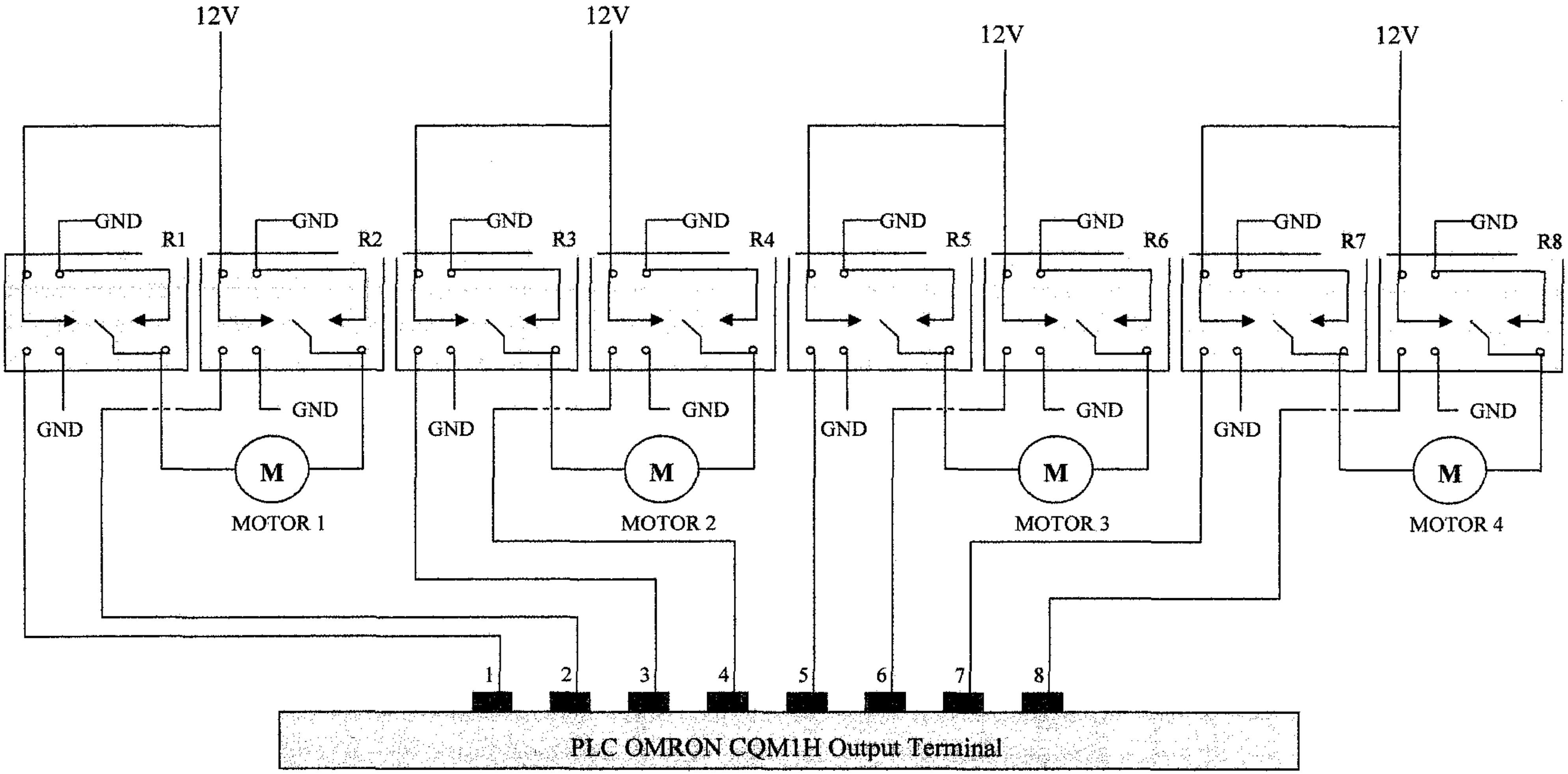


Figure 24: External Relay System Schematic Diagram

Figure 24 shows an External Relay Systems schematic diagram of eight units 12V SPDT relay implemented on a system in order to control four units of DC motors. This schematic diagram then converted into PCB board by using EAGLE 5.1.Software.

Figure 25 shows a schematic diagram of External Relay System. It has been designed by using EAGLE 5.1.Software and measured accurately so that the relays could be mounted on the PCB board.

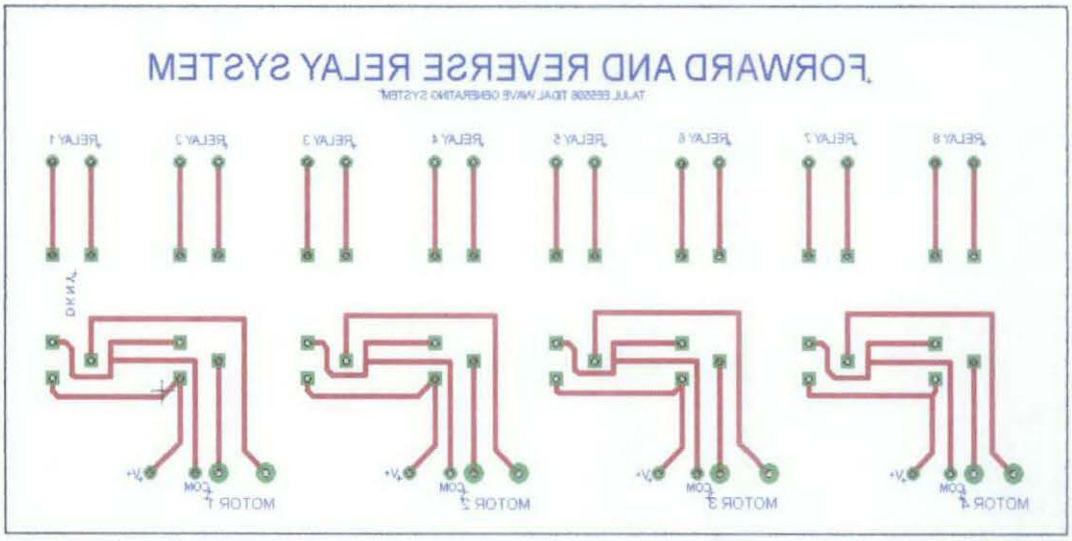


Figure 25: External Relay System designed using EAGLE 5.1.Software

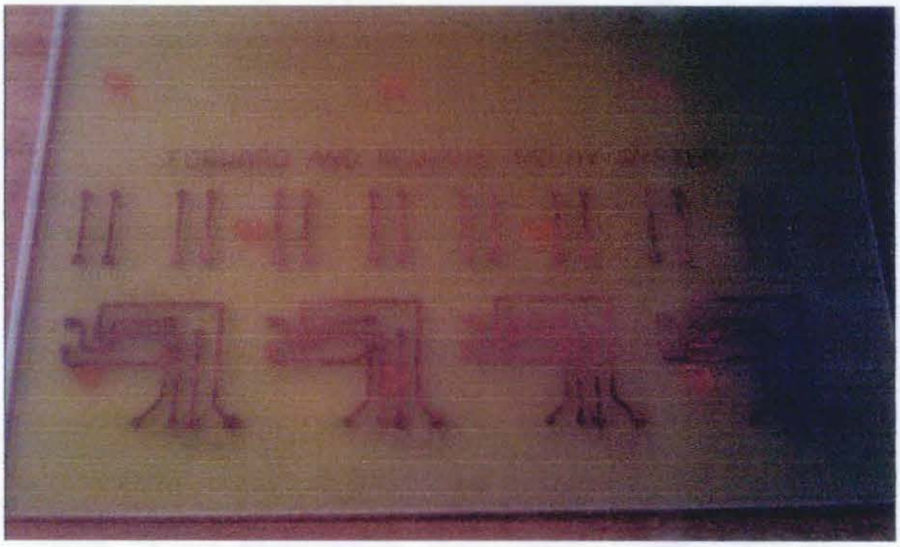


Figure 26: External Relay System printed on PCB board

Figure 27 shows eight 12V SPDT relays and banana plugs that has been mounted on the PCB board. Banana plugs are used to channel inputs from the PLC and Power

Distribution System as well as to channel outputs to the DC Motors. As for the PLC, the inputs are labeled R1, R2, R3, R4, R5, R6, R7 and R8. These input channels are connected to the coil of the relays. PLC will trigger which coil to be activated and thus determine the polarity of DC motors rotation.

In addition, channel M1, M2, M3 and M4 are used for channeling 12VDC voltages from the Power Distribution System. Relays will determine whether the voltages supplied are positive or negative polarity.

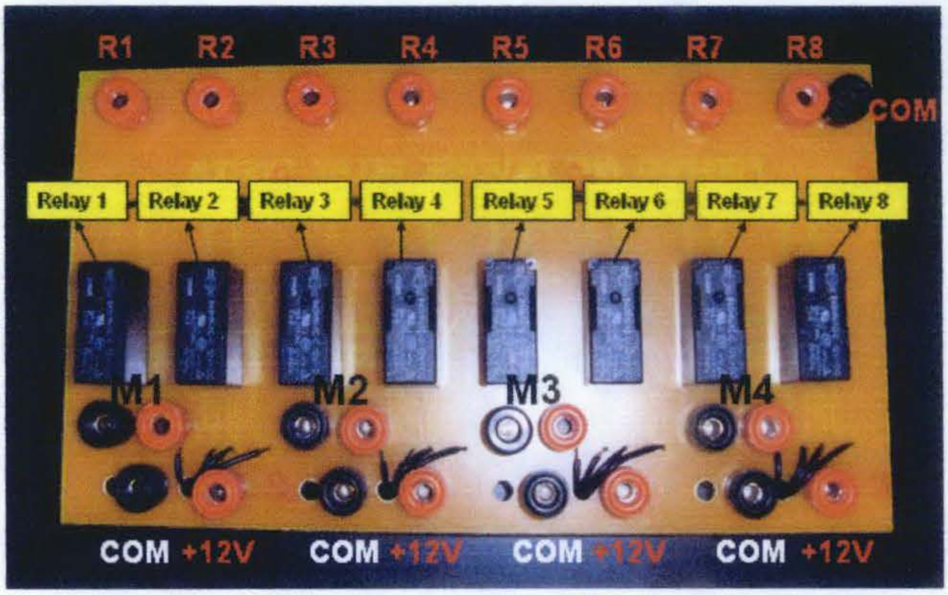


Figure 27: PCB board mounted with relays and banana plugs

4.1.4 Power Distribution System

Power Distribution System is a part of electrical electronics design in developing a scaled-down model of tidal wave generating system. A 240VAC 0.8 to 12VDC 8.5A Converter is used to step down household voltages into 12VDC current. The user interface consists of a main switch, an emergency stop switch, four fuses, indicators, toggle switches and four channels. DC voltages will be channel to DC motors through Channel 1 Channel 4. However, users still need to manually switch on the toggle switches in order for the DC motors to operate. The main purpose of the switches is for users to easily switch on or switch off the motors, for example, during hardware maintenance, hardware failure and troubleshooting.

Figure 28: User Interface of Power Distribution System

4.1.5 Control System

The control system for this scaled-down model is the OMRON SYSMAC CQM1H Programmable Logic Controller (PLC). It has 16 input modules and 16 output modules. Both modules have their own voltage supply of 24V with 0.3A of current. The input and output connected to the PLC are listed in the table below.

Table 4: Input and Output list for the Control System (PLC)

INPUT	OUTPUT
Toggle Switches : • Toggle Switch 1 – Activate Mode 1 • Toggle Switch 2 – Activate Mode 2 • Toggle Switch 3 – Activate Mode 3 • Toggle Switch 4 – Activate Mode 4 Limit Switches : • Top level limit switches: LS1, LS3, LS5 & LS7 • Bottom level limit switches: LS2, LS4, LS6 & LS8	Connect to the external relay system: • Pedals downward movement R1, R3, R5 & R7 • Pedals upward movement R2, R4, R6 & R8

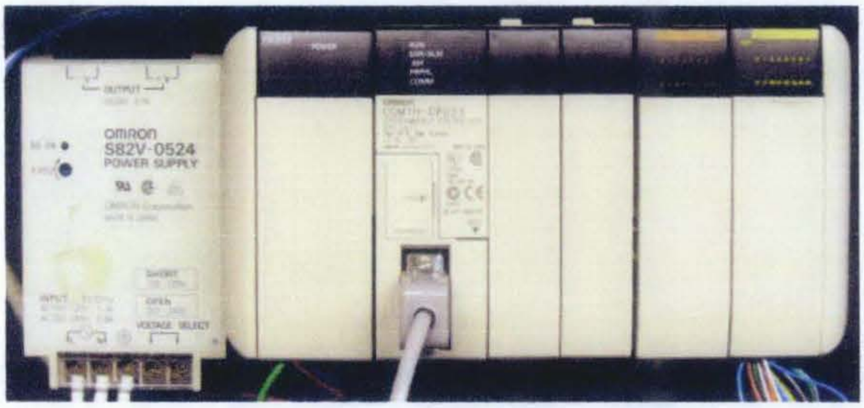


Figure 29: Front view of OMRON CQM1H PLC

4.1.6 PLC Programming & Simulation

The Programmable Logic Controller (PLC) is programmed using CX-Programmer software and simulated using OMRON PLC Training Kit. The programming method used is ladder diagram method. This method is chosen due its simplicity to construct and troubleshoot. According to the one cycle pedaling sequence in Table 3, there are four different types of pedals movement have been setup.

There are four toggle switches where each represents the four destination mode of wave formations. For example, in order for the scaled-down model to be able to perform mode 1, toggle switch 1 should be switched on and the rest of the switches should be turned off. During this operation, PLC will activate R1, R3, R5 and R7 accordingly to their timing sequence. Activations of those relays make the motors driving the pedals downward. The program was set so that those relays will be deactivated whenever their bottom limit switches are triggered.

Whenever all LS2, LS4, LS6 and LS8 are triggered, internal counter will count to three second before all R2, R4, R6 and R8 are activated by the PLC. Activations of those relays make the motors driving the pedals upward. The program was set so that those relays will be deactivated whenever their top limit switches are triggered.

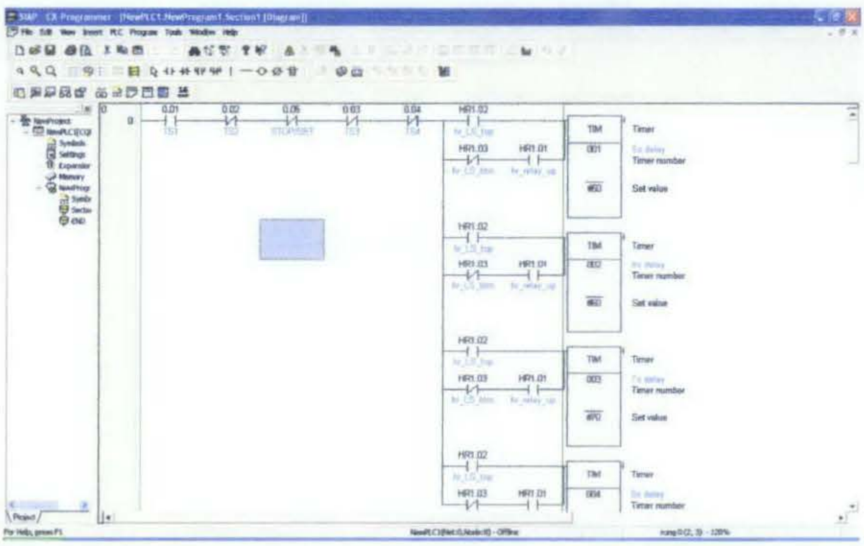


Figure 30: An example of ladder diagram programming using CX-Programmer software

4.1.7 Control Panel

The control panel acts as the user interface in this scaled-down model of tidal wave generating system. It consists of four toggle switch, indicators, one start button, one reset button and one stop/set button. Each of the toggle switch has their own type of wave formation. User can choose the type of wave they preferred by switching on the correct switch. The light indicator will show which mode has been select. The table below shows types of wave can be performed in this scaled-down model.

Table 5: Switches and the type of wave

Switch	Mode	Type of wave
Switch 1	Mode 1	Diagonal waves
Switch 2	Mode 2	Forward Eclipse waves
Switch 3	Mode 3	Backward Eclipse waves
Switch 4	Mode 4	Straight waves

Furthermore, the start button is the main switch of this control panel. The toggle switches and stop/set button are only valid to be used whenever the start button is on. In addition, the stop/set button functions to stop any movement of pedals and restore the pedals to their initial position whenever the mode toggle switch restore to off position.

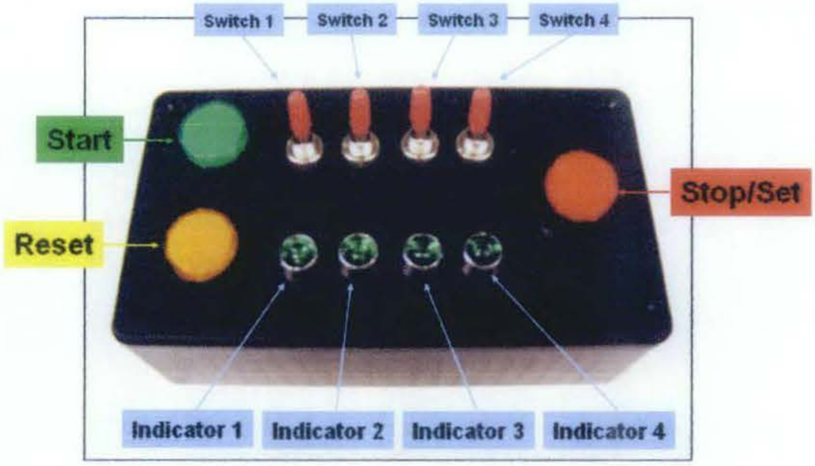


Figure 31: Control Panel

4.1.8 User Instructions

1. Make sure all switch at Control Panel are off.
2. Make sure all switch at Power Distribution System are off.
3. Switch on PLC power supply.
4. Switch on Power Distribution System power supply.
5. Switch on the main switch at power distribution system followed by Motor_S1, Motor S2, Motor S3 and Motor_S4 Switches.
6. Choose waves mode according to table below and switch on their switch.
7. Push Stop/Set button whenever wish to stop pedals movement
8. Reset mode's switch at control panel to reset pedal to their initial position
9. Reset Stop/Set button before switch another mode's switch

Switch	**Mode**	**Type of wave**
Switch 1	Mode 1	Diagonal waves
Switch 2	Mode 2	Forward Eclipse waves
Switch 3	Mode 3	Backward Eclipse waves
Switch 4	Mode 4	Straight waves

* Only one mode switch can be triggered at a time. Misconduct on the mode switches will lead the pedaling system to stop immediately. Push Stop/Set and reset mode switches to reset pedals at their initial position.

CHAPTER 5
CONCLUSIONS

5.1 Conclusions

This project has been developed thoroughly and able to meet the objectives required. Intense reviews on literature works has been done to gain insight knowledge on the tidal wave generating system. The scope of study for this project which are the electrical & electronics, mechanical and programming have contributed to the development of the scaled-down model of the tidal wave generating system. The methodology implemented was also important in providing the guideline for this project. The scaled-down model is able to function as required which is to be able to generate four forms of artificial tidal waves.

5.2 Recommendations

- Instead of using mechanical pedals, they can be replaced by using air pressure to put pressure on the water surface. As a result to that, no motors are needed and it will eventually reduce the power consumed to the system.
- The ladder diagram can be revised and simplified if possible to minimize the complexity of the programming.
- The wires, switches, I/O terminals should be tagged to ease up identification purpose for future troubleshooting.
- The scaled-down model should be continuously examined during operating mode in order to detect real-time problems that possibly occurred.

- A tidal wave breaker can be installed at the end of the water container to reduce bouncy waves.
- The pedaling system should be installed with tight water seal between the pedal and the chamber's wall to reduce lost of pressure at the water surface during downward pedaling.

REFERENCES

[1] http://www.freepatentsonline.com/4522535.html

[2] http://www.freepatentsonline.com/3629877.html

[3] http://www.the12volt.com/relays/relays.asp

[4] http://www.autoshop101.com/forms/hweb2.pdf

[5] http://halloweentinkering.googlepages.com/power&control

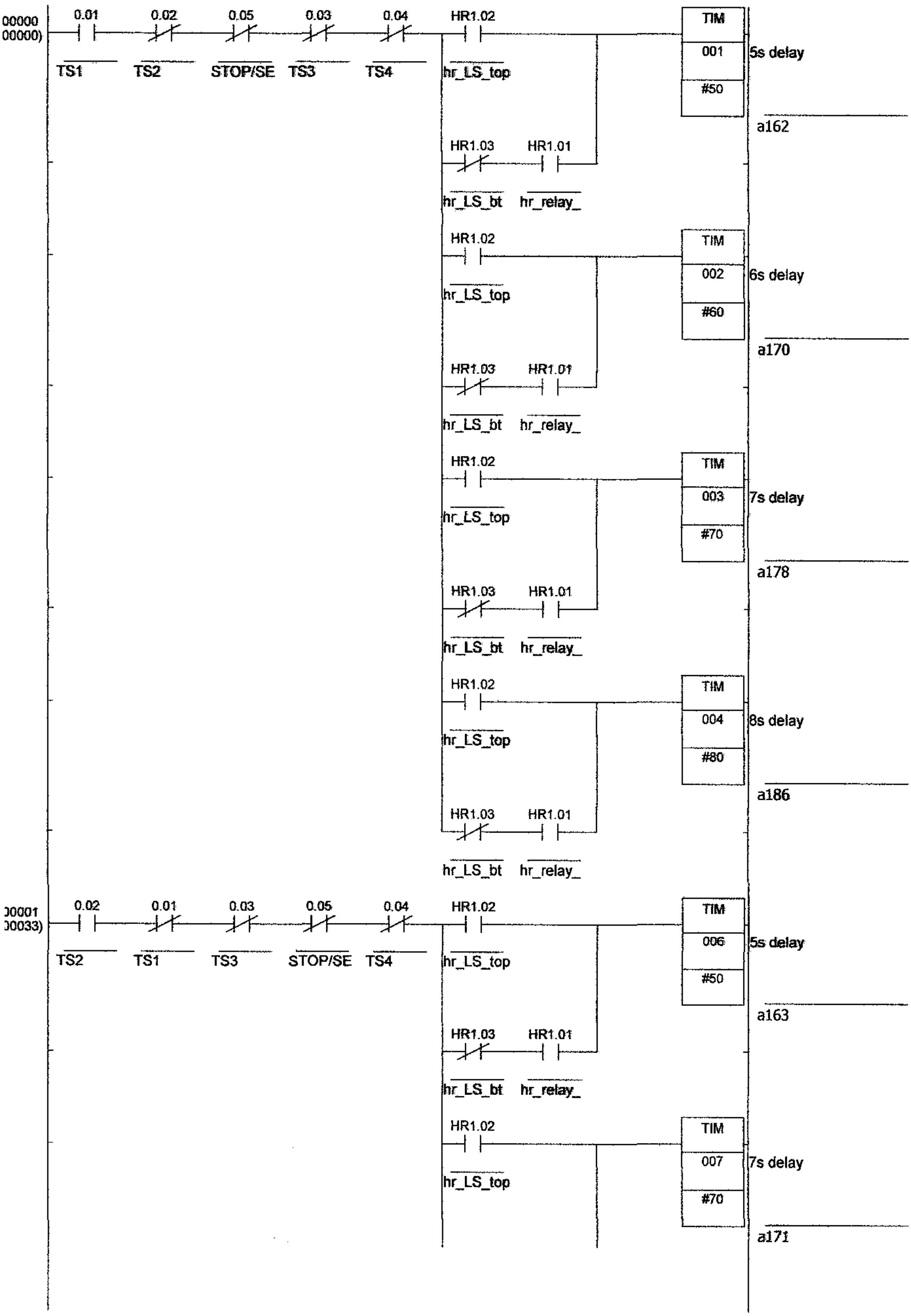
[6] A Beginners Guide to PLC (OMRON)

[7] www.mech.northwestern.edu/hartmann/ME333Files/DCmotortutorial.ppt

[8] http://hyperphysics.phy-astr.gsu.edu/HBASE/electric/voldiv.html

[9] OMRON Programmable Controllers Operation Manual

APPENDICES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0.05
0.03
0.04
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TS2
STOP/SE
TS3
TS4
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TIM
001
#50
5s delay
a162
HR1.03
HR1.01
hr_LS_bt
hr_relay_
HR1.02
hr_LS_top
TIM
002
#60
6s delay
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HR1.03
HR1.01
hr_LS_bt
hr_relay_
HR1.02
hr_LS_top
TIM
003
#70
7s delay
a178
HR1.03
HR1.01
hr_LS_bt
hr_relay_
HR1.02
hr_LS_top
TIM
004
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8s delay
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HR1.01
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0.01
0.03
0.05
0.04
HR1.02
TS2
TS1
TS3
STOP/SE
TS4
hr_LS_top
TIM
006
#50
5s delay
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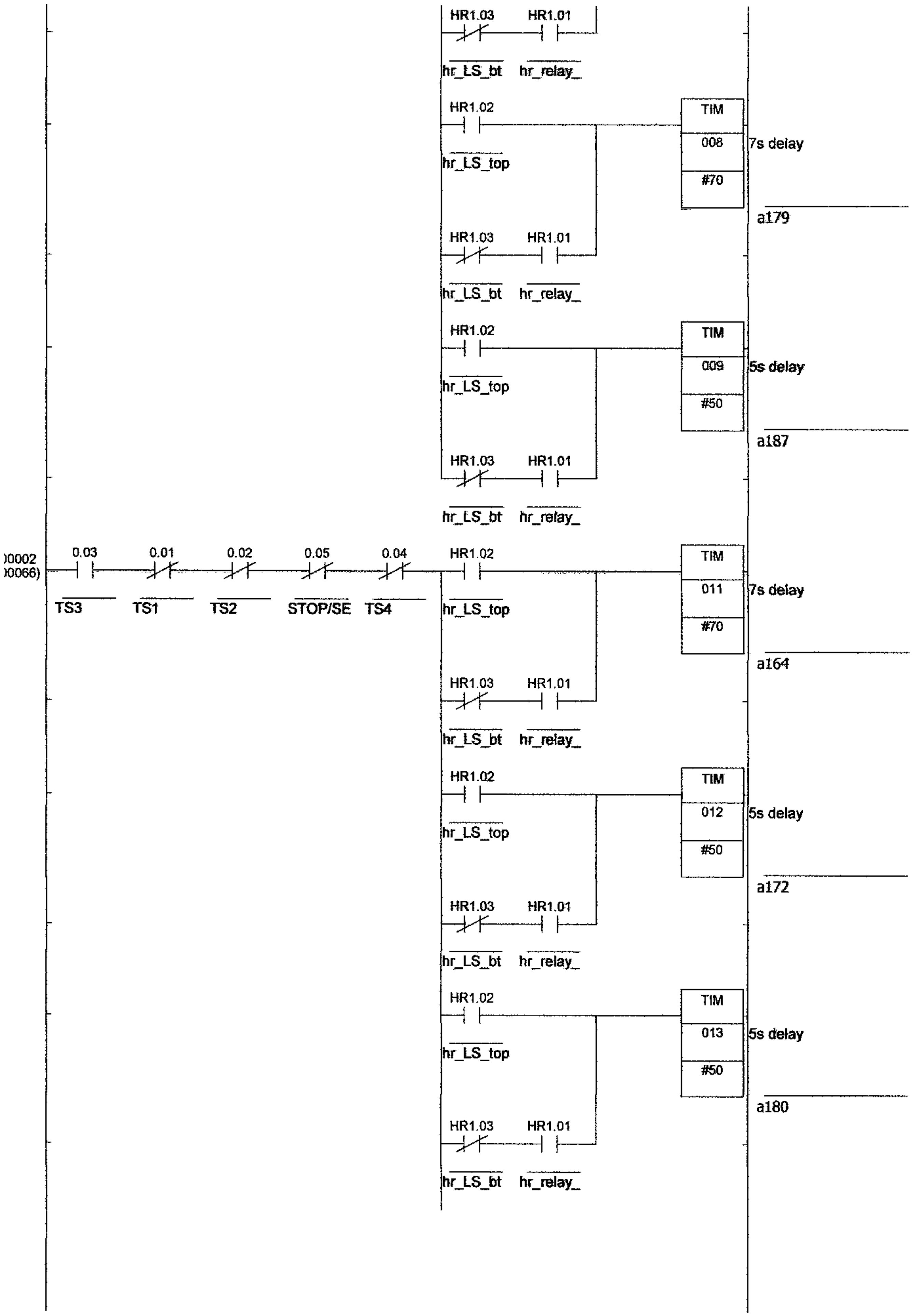
hr_LS_top
TIM
007
#70
7s delay
a171



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HR1.02
hr_LS_top
TIM
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7s delay
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HR1.01
hr_LS_bt
hr_relay_
HR1.02
hr_LS_top
TIM
009
#50
5s delay
a187
HR1.03
HR1.01
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hr_relay_
)0002
)0066)
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0.01
0.02
0.05
0.04
TS3
TS1
TS2
STOP/SE
TS4
HR1.02
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TIM
011
#70
7s delay
a164
HR1.03
HR1.01
hr_LS_bt
hr_relay_
HR1.02
hr_LS_top
TIM
012
#50
5s delay
a172
HR1.03
HR1.01
hr_LS_bt
hr_relay_
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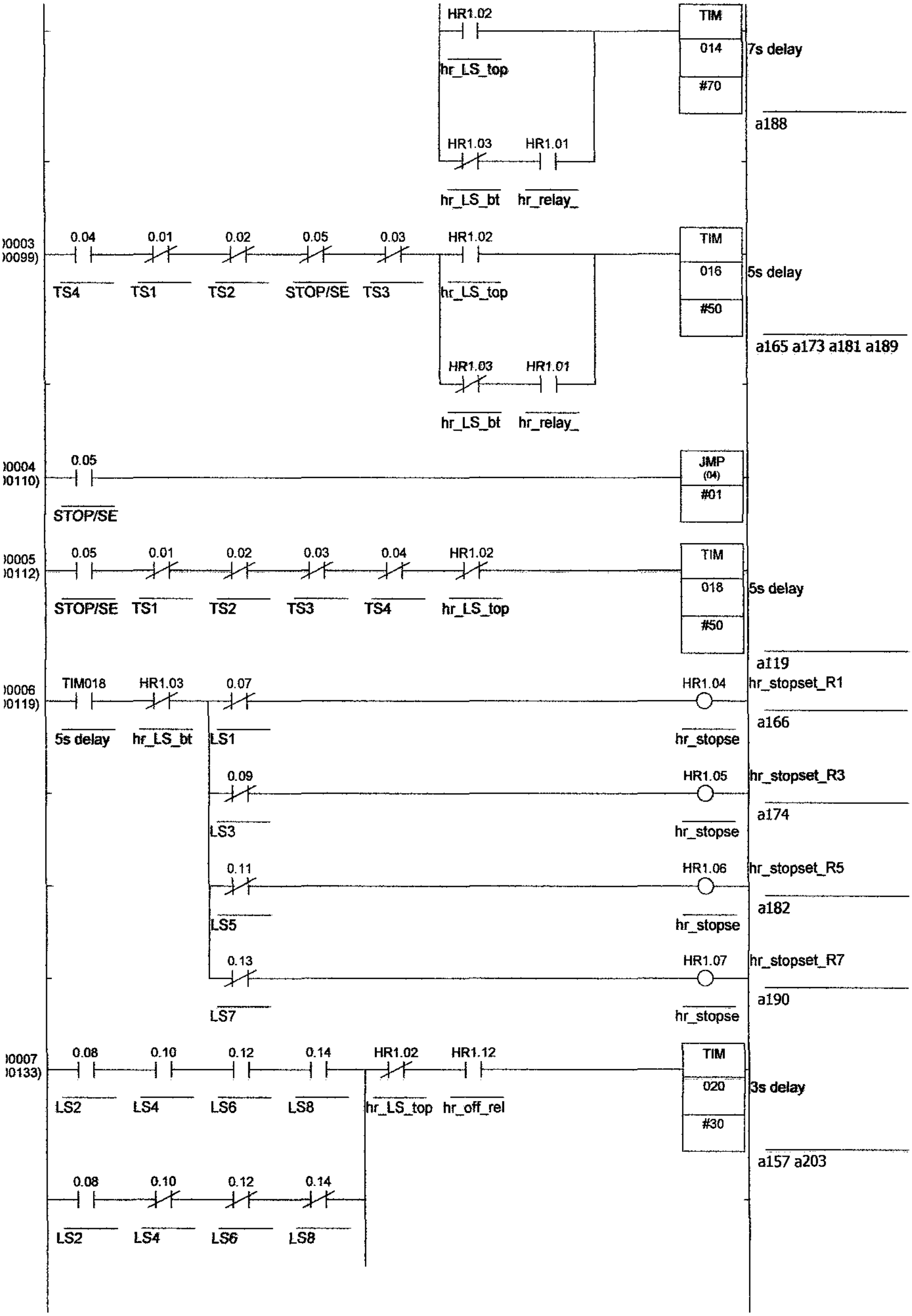
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TS4
TS1
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STOP/SE
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)0005
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0.04
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TS2
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TS4
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TIM
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5s delay
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LS3
HR1.05
hr_stopse
hr_stopset_R3
a174
0.11
LS5
HR1.06
hr_stopse
hr_stopset_R5
a182
0.13
LS7
HR1.07
hr_stopse
hr_stopset_R7
a190
)0007
)0133)
0.08
0.10
0.12
0.14
HR1.02
HR1.12
LS2
LS4
LS6
LS8
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hr_off_rel
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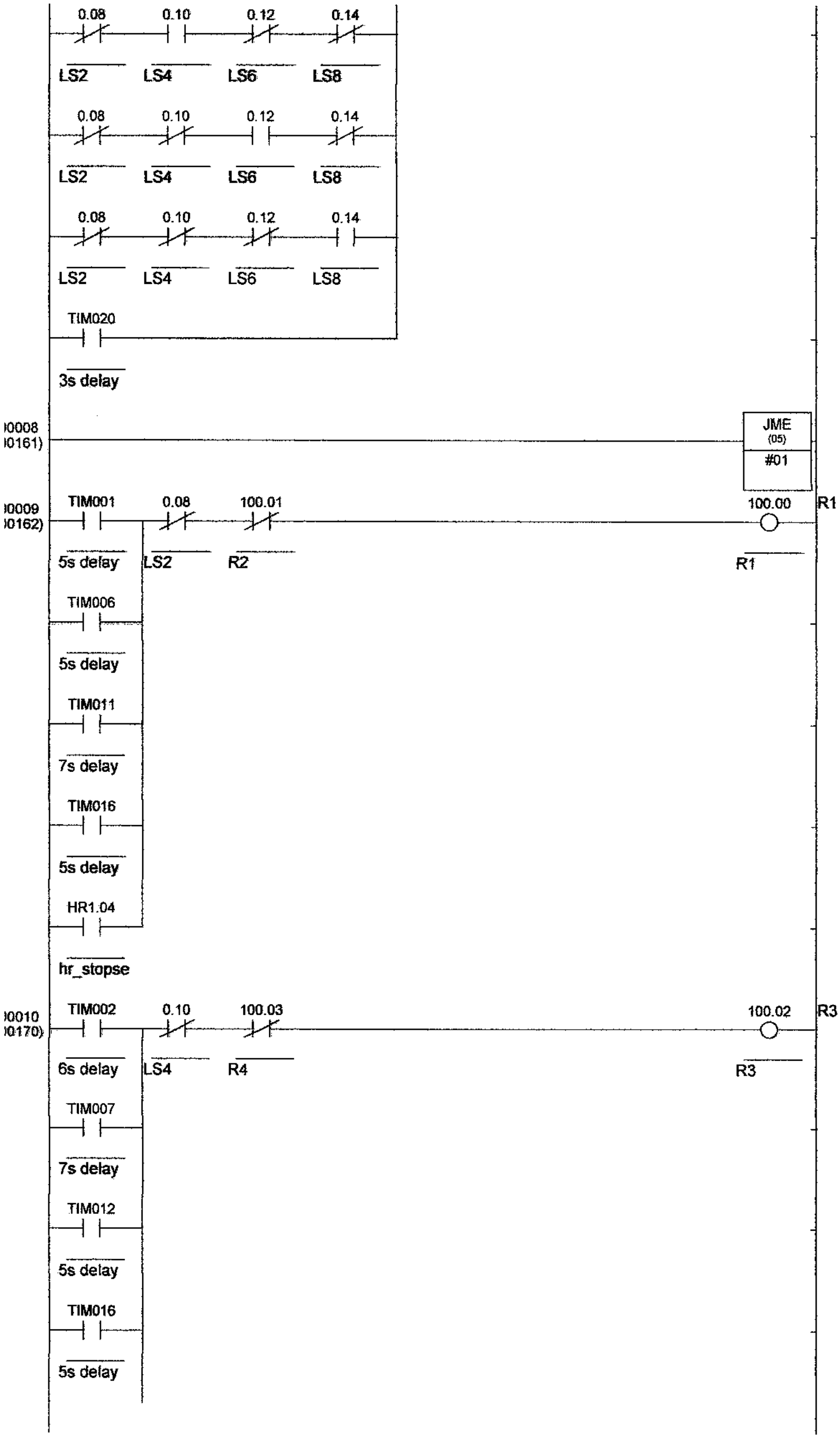
LS2
LS4
LS6
LS8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LS6
LS8
0.08
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0.12
0.14
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LS4
LS6
LS8
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(05)
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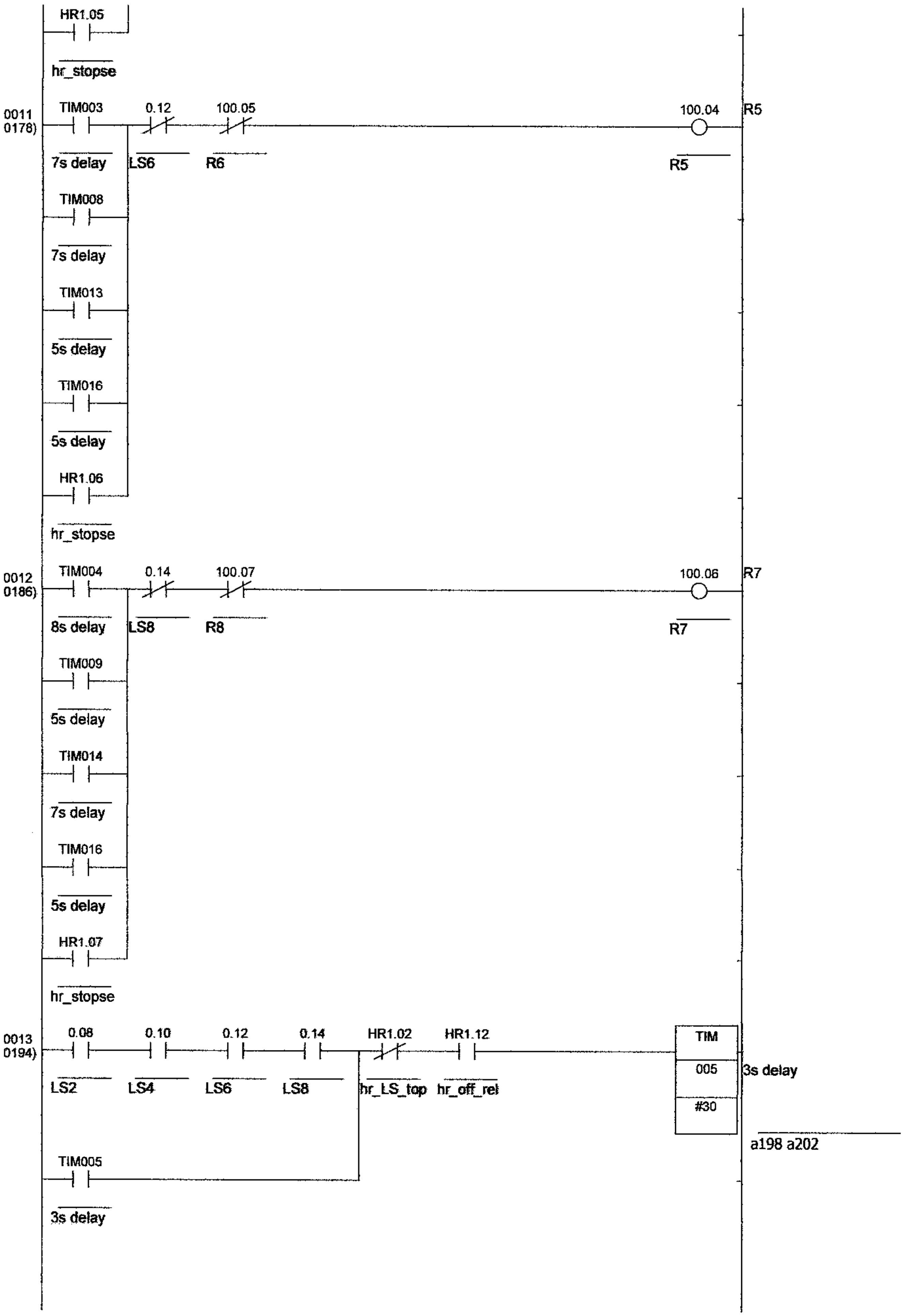
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TIM013
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100.07
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100.06
R7
R7
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TIM014
7s delay
TIM016
5s delay
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hr_stopse
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0194)
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LS2
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LS4
0.12
LS6
0.14
LS8
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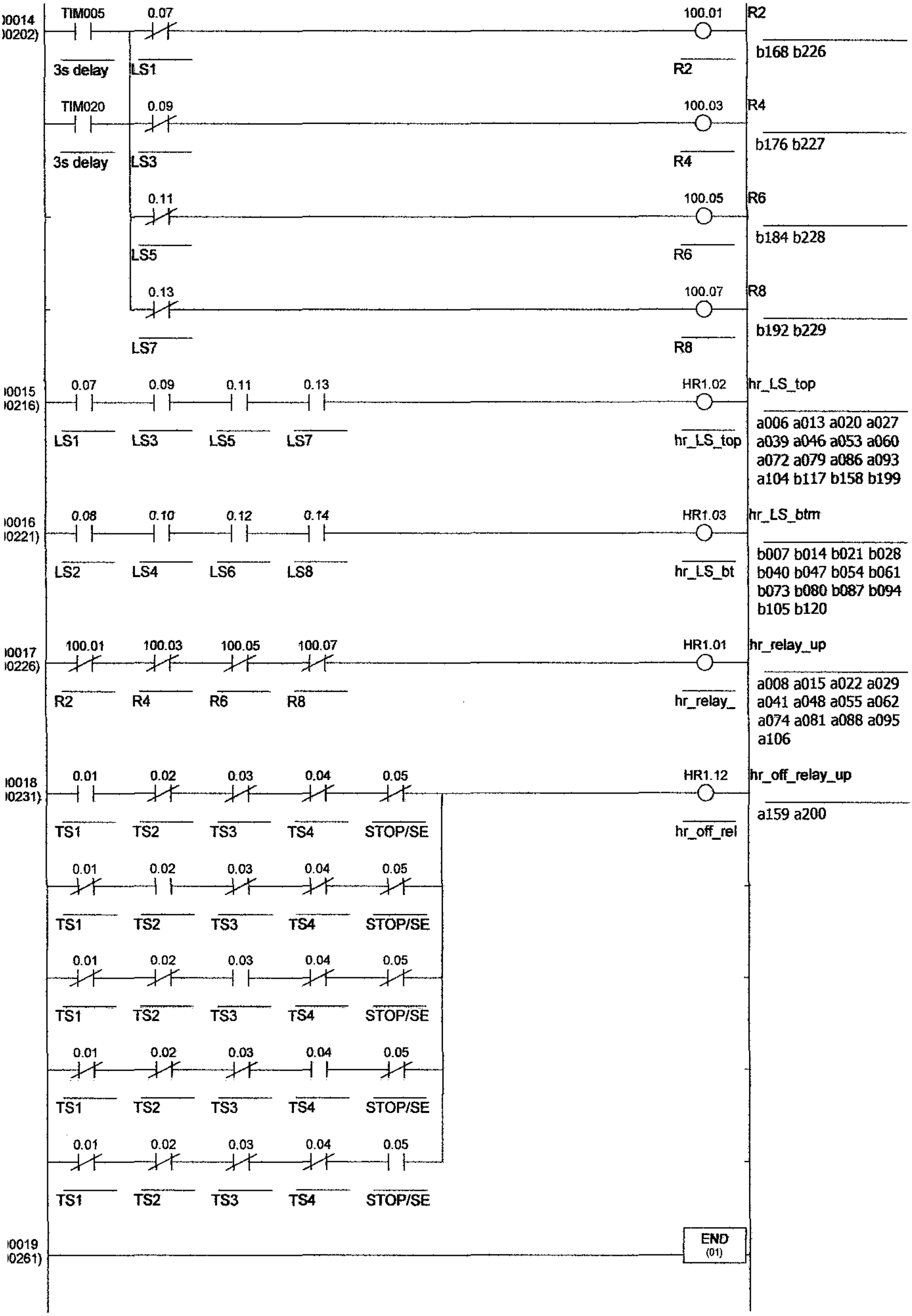
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R2
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100.03
R4
R4
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LS5
100.05
R6
R6
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R8
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LS3
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LS4
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LS6
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LS8
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b040 b047 b054 b061
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R2
100.03
R4
100.05
R6
100.07
R8
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TS3
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TS4
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END
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	BOOL	0.02			TS2
	BOOL	0.03			TS3
	BOOL	0.04			TS4
	BOOL	0.05			STOP/SET
	BOOL	0.07			LS1
	BOOL	0.08			LS2
	BOOL	0.09			LS3
	BOOL	0.10			LS4
	BOOL	0.11			LS5
	BOOL	0.12			LS6
	BOOL	0.13			LS7
	BOOL	0.14			LS8
	BOOL	0.15			RESET
	BOOL	100.00			R1
	BOOL	100.01			R2
	BOOL	100.02			R3
	BOOL	100.03			R4
	BOOL	100.04			R5
	BOOL	100.05			R6
	BOOL	100.06			R7
	BOOL	100.07			R8
	BOOL	HR1.00			hr_repeat
	BOOL	HR1.01			hr_relay_up
	BOOL	HR1.02			hr_LS_top
	BOOL	HR1.03			hr_LS_btm
	BOOL	HR1.04			hr_stopset_R1
	BOOL	HR1.05			hr_stopset_R3
	BOOL	HR1.06			hr_stopset_R5
	BOOL	HR1.07			hr_stopset_R7
	BOOL	HR1.08			hr_stopset_R8
	BOOL	HR1.09			hr_stopset_R6
	BOOL	HR1.10			hr_stopset_R4
	BOOL	HR1.11			hr_stopset_R2
	BOOL	HR1.12			hr_off_relay_up
	BOOL	TIM001			5s delay
	BOOL	TIM002			6s delay
	BOOL	TIM003			7s delay
	BOOL	TIM004			8s delay
	BOOL	TIM005			3s delay

e	Type	Address / ...	Rack Lo...	Usa...	Comment
	BOOL	TIM006			5s delay
	BOOL	TIM007			7s delay
	BOOL	TIM008			7s delay
	BOOL	TIM009			5s delay
	BOOL	TIM011			7s delay
	BOOL	TIM012			5s delay
	BOOL	TIM013			5s delay
	BOOL	TIM014			7s delay
	BOOL	TIM016			5s delay
	BOOL	TIM018			5s delay
	BOOL	TIM019			0.5s delay
	BOOL	TIM020			3s delay
_02s	BOOL	254.01			0.02 second clock pulse ...
_1s	BOOL	255.00			0.1 second clock pulse bit
_2s	BOOL	255.01			0.2 second clock pulse bit
nin	BOOL	254.00			1 minute clock pulse bit
;	BOOL	255.02			1.0 second clock pulse bit
Y	BOOL	255.04			Carry (CY) Flag
ycle_Time_E...	BOOL	253.09			Cycle Time Error Flag
ycle_Time_V...	UINT_B...	AR27			Present Scan Time
Q	BOOL	255.06			Equals (EQ) Flag
R	BOOL	255.03			Instruction Execution Err...
rst_Cycle	BOOL	253.15			First Cycle Flag
T	BOOL	255.05			Greater Than (GT) Flag
our_Date	UINT_B...	AR19			Hours (00-07) Date (08-...
ow_Battery	BOOL	253.08			Low Battery Flag
T	BOOL	255.07			Less Than (LT) Flag
ax_Cycle_Ti...	UINT_B...	AR26			Maximum Cycle Time
lonth_Year	UINT_B...	AR20			Month (00-07) Year (08...
F	BOOL	254.04			Overflow (OF) Flag
ff	BOOL	253.14			Always OFF Flag
n	BOOL	253.13			Always ON Flag
utput_Off_Bit	BOOL	252.15			Output OFF Bit
ec_Min	UINT_B...	AR18			Seconds (00-07) Minute...
tep	BOOL	254.07			Step Flag
F	BOOL	254.05			Underflow (UF) Flag