design document for

Water Detector

submitted to:

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EXECUTIVE SUMMARY

One of the severe real world problems of aquatic engines is the existence of water in the lower unit chamber. Water invades the lower unit with relative ease, since the engine extends below the water line so that the propeller can be located below the surface of the water. The gears, shafts, and support bearings are also still contained in the lower unit chamber of the engine.

Manufacturers have tried to deter the contamination of water in the lower unit by sealing the chamber. However the main cause of water intrusion is the deterioration of the seals. These seals can be broken many different ways, however, the entanglement of fishing line in the propeller shaft is the leading cause of their destruction. Once a seal is broken, it creates a path for oil to escape and water to enter the system.

Once there is enough water in the lower unit it mixes with the oil and forms the possibility of damage to the unit and even failure to the engine. This damage can include rust or deterioration of the chamber. The most overwhelming element of this problem is the cost of engine repair due to the loss of oil and water. These costs can exceed $1800 on the eventual replacement of the boat's engine.

Our project goal is to design a device that will detect the presence of water in the housing of the lower unit. This design will consist of a capacitance sensors located in the chamber's casing. Upon the detection of capacitance changes, the frequency levels will shift. These changes are consistent with that of water mixed with oil, a warning light will be displayed to the occupant of the vessel. This will allow the said occupant to shut down the engine before critical damage can occur.

There are several criteria that must be recognized in our design specifications. The most vital information for our design is determining the amount of water intake needed to eventually cause damage to the engine.

Our sensor is designed to read the frequency due to the capacitance of the oil during pulses. Our sensor will be wired directly into the oscillating circuit. Once, the frequency of the oscillating circuit drops below a minimum value, a LED will alert the user of excess water intake in the lower unit.

This process is made possible via our micro controller, and the 555 timer or oscillating circuit. Once the micro controller is programmed to our specific parameters, it will be able to determine when the frequency of the circuit is lower than what is allowed - which in reality means too much water has entered the lower unit - to maintain an operational engine.

Currently, there is no such device on the market to detect the amount of water intake in the lower unit. Since this is definitely a real world problem, our product should meet the interest of many boat owners looking to save time and money.

1. PROBLEM

The original design of the outboard motor dates back to 1881, when Gustave Trouve introduced his "Motor and Screw" at the Paris Exposition. Trouve's design consisted of an electric motor positioned directly over a rudder. Within the rudder's frame was a three bladed screw, or propeller, that was driven by sprocket, cogwheel, and chain [1]. In the original design, the gears that drove the "screw" were exposed to the elements. However, in 1885, Samuel H. Jones, revised Trouve's design by creating an underwater casing that projected the propeller and housed the gears of the unit.

Today in outboard motors a portion of the engine's housing still extends below the water line so that the propeller can be located below the surface of the water. The power head of the engine delivers power to a drive shaft that is geared to turn the propeller shaft, thus delivering thrust to propel the boat. Additionally, the gears, shafts, and supporting bearings are still contained in a lightweight housing or gear-case to protect them from the surrounding elements of the engine [2]. This casing, often referred to as the "lower unit", is sealed and filled with oil that provides lubrication to its gears.

One problem that is associated with this type of engine is the intrusion of water into the lower unit's chamber. This water intake is mainly caused by the degeneration of seals that protect the encasing from its surrounding environment. These seals can be broken many different ways, however, the entanglement of fishing line in the propeller shaft is the leading cause of their destruction. Once a seal is broken, it creates an avenue for oil to escape and water to enter the system.

Water mixed with oil in the lower unit's chamber forms the possibility of damage to the unit. This damage can include rust or deterioration of the chamber. Also, lack of sufficient lubrication to the gears of the lower unit can cause excessive heat in the casing. If these problems are undetected, engine failure may occur. And depending on the location of the craft, loss of propeller motion can cause a great inconvenience to those on the vessel. Additionally, the costs of engine repair due to the loss of oil and water intake are expensive.

The objective of this project design is to create a sensor system that will detect the presence of water in the housing of the lower unit. This design will consist of a capacitance sensor located in the chamber's casing. Upon the detection of different capacitance levels, the oscillator will either increase or decrease the frequency due to the variation in capacitance. Capacitance levels change due to the dielectric. Ideally, the dielectric will be pure lower unit oil until contamination occurs. These changes will be consistent with that of water mixed with oil, and a warning light will be displayed to alert the occupant of the vessel. This will allow the said occupant to shut down the engine before critical damage can occur.

Upon initial review of techniques suitable for measurement of the water entering the lower unit, we concentrated our research on the following characteristics of the oil: temperature, density, conductivity, and capacitance. After careful evaluation we concluded that the measurement of capacitance would benefit our design the most.

Since the addition of water will make the capacitance of oil increase, specific limits of how high the capacitance of the oil can reach will be designated in order to accurately alert the users of water contamination.

Currently, there is no such device on the market to detect a breech in the lower unit. Significant repair cost can be greatly reduced if water is detected early enough. Upon the completion of building the detection device, it will be compatible with many different types of outboard motors from various manufacturers. Therefore, interest in a finished product should be noteworthy.

2. OBJECTIVES

The water detector will have a significant impact on boating among marine enthusiasts everywhere. Our product is a sensor system for detecting the presence of water in a sealed oil chamber of a marine engine, and also serves as a warning signal to the boat operator. The main objectives for our design include:

1) Finding a limitation on the amount of water that is allowed to mix with the oil.
2) Designing a system that will have a fast and accurate response time in order to warn the users of the potential damage of too much water contaminating the lower unit.

The sensor assembly will be mounted in the lower unit of the marine outboard. On the lower unit of any marine outboard there are two screws. The lower screw's function is to drain the oil and the upper is used as an air breather. Our product will be mounted in the lower part of the lower unit for the detection of water. In order for our product to be successful, we've come up with the following constraints:

1. **Cost:** Our estimated product cost should not exceed $200.

2. **Weight:** The weight of our measuring device and circuit board is expected to be less than 3 lbs.

3. **Compatibility/Packaging:** Our measuring device will be approximately 2" in circumference, and our board will measure about 6" wide, 4" high, and 4" deep.

4. **Readability:** The signal processed to the user should be easily read allowing the user to interpret the seriousness on the amount of water contaminating the lower unit.

5. **Durability:** An important factor our group must consider is the durability of the product within its working environment. The Water Detector will be exposed to constant vibration in the lower unit.
6. **Power Requirement:** A voltage regulator will be used due to the inconsistency of the voltage source caused by the charging from an alternator.

7. **Electromagnetic Interference (EMI):** Our product will be designed to not be affected or cause interference to other electronic devices in the boat in accordance

to the Federal Communication Commission's (FCC) regulation on induced voltage in watts per meter.

8. **LED user interpretation:** One of our major objectives of the design, the LED's will determine how much water has contaminated the lower unit.

9. **Output Latency:** The response time of our board will vary from 1 to 5 seconds. This will also designate the importance of proper reaction from the users.

10. **Capacitance:** In order to measure the amounts of water entering the lower unit, our device will be designed to constantly measure the capacitance of the oil that in return affects the frequency of the oscillating circuit.

Since this is a totally new product, our specifications will change during research. The ability to recognize the constraints of the product will determine its success. One major concern we will face during the implementation of our design will be coming up with an effective way to detect the water in the oil. In order for our team to succeed with this water detector additional research will be necessary.

2.1 Cost

Since one of our main goals is to guard against the expensive route of interchanging lower units due to water contamination, we will try to minimize the cost of our product. Our initial target price of $200 should not be difficult to maintain.

2.2 Weight

Another feature of the Water Detector is that it is designed to be light and compact. The weight of our measuring device and circuit board is expected to be less than 3 lbs. This will provide easy installation and it will not interfere with other lower unit devices.

2.3 Compatibility/Packaging

Due to the measurements of our device, compatibility will be a key factor of our product. The compatibility of our product will enable it to adapt to various motors ranging from different sizes (5-225hp) and types (Yamaha, Mercury, Evinrude). The installation process of the measuring device will vary from motor to motor due to the different size lower units; however, the installation of the circuit board will remain the same. As a result of time and cost constraints, we will feature our device using only one engine.

2.4 Readability

Another key feature of our product is that it is designed to be user friendly. The signal processed to the user should be easily read allowing the user to interpret the seriousness on the amount of water contaminating the lower unit. One key deterrent to our product will be too much sunlight not allowing the brightness of the LED's to be visible. We will be forced to counter issues like sunlight in order to make our product as readable as possible.

2.5 Durability

Due to the continuous vibration of the motor in boats, our product must be durable enough to perform accurately within its surroundings. A huge task that our group will deal with is implementing a conductivity sensor that will be able to properly adapt to the environment.

2.6 Power Requirement

Since a 12-V battery powers most boats, our product does not need additional sources of power. However due to the inconsistency of the voltage source caused by the charging from an alternator, a voltage regulator will be used to keep the power supplying our device, constant at 12-V.

2.7 Electromagnetic Interference (EMI)

One aspect of our product that we are concerned about is Electromagnetic Interference. In some cases electronic devices that operate within short distances of each other cause interference in the operation of one another. The Water-Detector should be designed to operate around other electronic devices such as a cell phone, radio, laptop computers, etc. Some causes of EMI include high clock rate timing pulses used in these devices, and their harmonics.

2.8 LED User Interpretation

One of our major objectives of the design, the LED's will determine how much water has contaminated the lower unit. Ranging from a simple warning to serious water contamination, the LED's will allow the user to always have knowledge about the amount of water entering the lower unit. Through extensive research, our group will determine the different acceptability levels of water in the lower unit.

2.9 Output Latency

One of the ultimate responsibilities of our product is to alert the user of water entering the lower unit of the boat. Our group has estimated that a respectable response time for the sensor to alert the users is in the range of 1 to 5 seconds. As a group, we must find a sensor that achieves our ultimate goal of alerting the users.

2.10 Capacitance/Frequency

One huge aspect of our research is determining how to measure the water entering the lower unit. After preliminary research we have chosen to constantly measure the conductivity of the oil contained in the lower unit. Due to the polarization, and various inconsistencies of water, this approach was a failure. The only feasible approach is measuring the capacitance of the oil. Since the addition of water will make the capacitance of oil increase, we will designate specific limits of how low the frequency of the oil can reach before the sensor alerts the users. These specific limits will be determined with more accurate research and testing.

3 APPROACH

3.1 Hardware

The following sections will give a detailed explaination of the hardware components of our system.

3.1.1 Sensor

Our sensor was constructed to measure the capacitance of oil, water, or a dielectric. Also, our sensor will be wired directly into our oscillating circuit to produce a certain frequency due to the dielectric within the capacitor. In its simplest form, a capacitor consists of two conducting plates separated by an insulating material called the dielectric. The capacitance is directly proportional to the surface areas of the plates, and is inversely proportional to the separation between the plates. Capacitance also depends on the dielectric constant of the substance separating the plates. The sensor system of this project is the equivalent of a capacitor. This sensor was constructed and tested by using the fundamental principle of a RC circuit. This RC circuit is shown below in Figure 3.1.1.1.

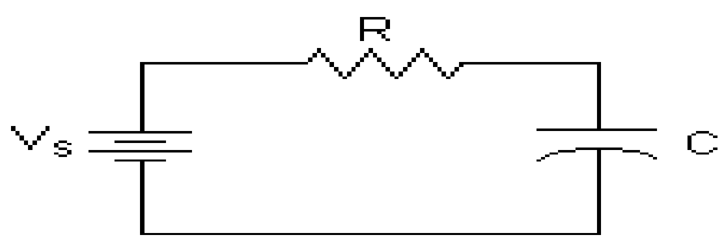

Figure 3.1.1.1

The construction of the sensor consists of one ½ inch copper tubing, two copper male adapters, two plastic female adapters, one rubber washer, one washer, one .625 inch copper tubing, one .123 inch copper tubing, two solid conductor #14 wire, and one copper fitting.

In order to construct the sensor, 4 inches of ½ in. copper tubing was heated and the two copper male adapters were placed on each end of the tubing. The copper had to be cleaned at both ends, and then flux was brushed on both ends. After the flux was applied, both male adapters were placed and soldered.

Next, the copper fitting had to be mounted within the plastic female adapter. The plastic adapter had to be sanded on the inside to accommodate the larger diameter washer. This washer was placed in the plastic adapter and epoxy was applied. Once the epoxy dried, it formed a mounting section for the copper fitting. The plastic adapter was then screwed on the ½ in. copper tubing with the rubber washer separating them. The copper fitting was then mounted to the washer. This would allow the .625 in. copper tubing to be secured by the copper fitting within the ½ in. copper tubing. Once the copper fitting was tight, stability of the inner conducting core was complete. Once centered, the #14 solid conducting wire is inserted in the .625 in. copper tubing until it reaches the desired length. The desired length would be attributed to the length of the ½ in. copper tubing. Our sensor contains a 3 inch #14 solid conducting wire. After inserting the #14 solid conducting wire, we soldered the end to ensure no fluids would begin to leak from our sensor.

Finally, we soldered another #14 solid conducting wire to the side of ½ copper tubing. Thus giving us a ground for our circuit. This capacitor is shown below in Figure 3.1.1.2.

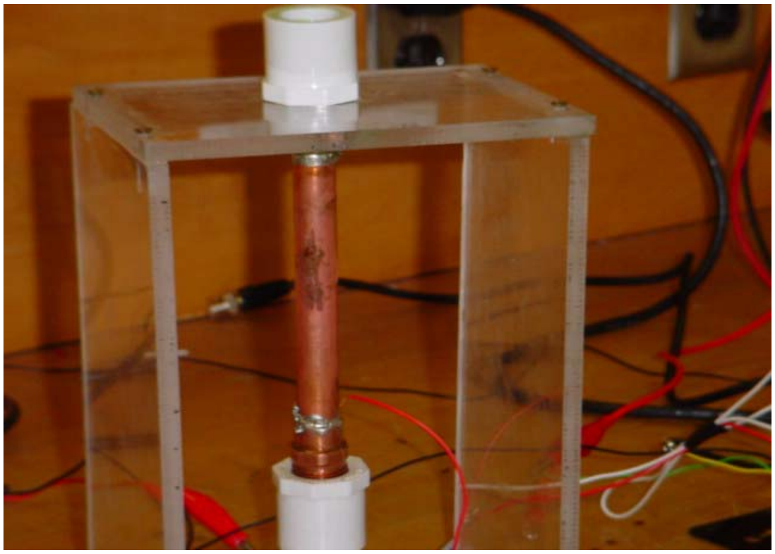

Figure 3.1.1.2 Picture of the Sensor

After construction was complete, the testing phase began. Testing began by using the RC circuit mentioned in Figure 1. We connected a 100 kHz frequency with the amplitude of 2 volts to our sensor in series with a resistance box. This would give us a charging curve to calculate the capacitance of our constructed sensor. In Figure 3.1.1.3 below, it shows you the charging of the capacitor. During each time constant, the capacitor charges 63.2 % of the remaining distance to the maximum voltage level. Our maximum voltage level was measured at 2 volts, thus giving us a 1.26 voltage level. After measuring a 1.26 voltage level, we were able to use a time constant equation. This equation is noted as:

$$T=RC \tag{1}$$

Thus, measuring the time from the oscilloscope, and using a resistance box, we were able to solve for the capacitance.

T= 4us

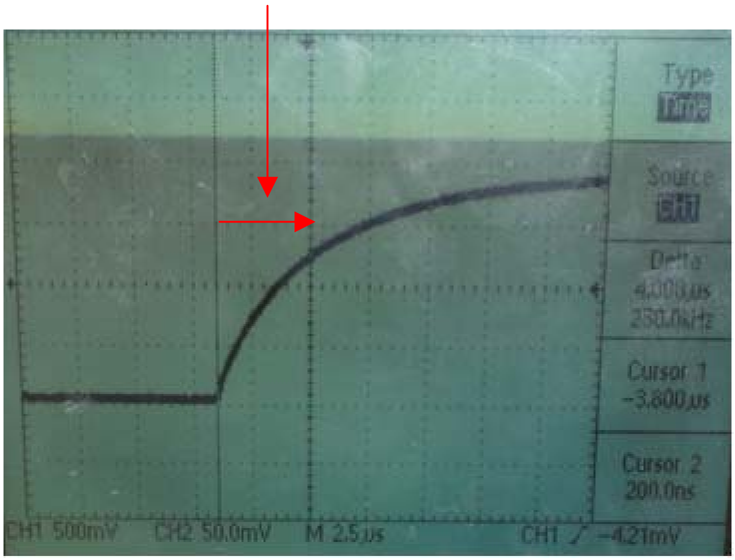

Figure 3.1.1.3 Example of Charging Curve

To ensure consistent values, we were able to simulate the capacitance curve in P-spice. The output should be consistent with that of Figure 3.1.1.3. In Figure 3.1.1.4, you see that the output did match that of the oscilloscope.

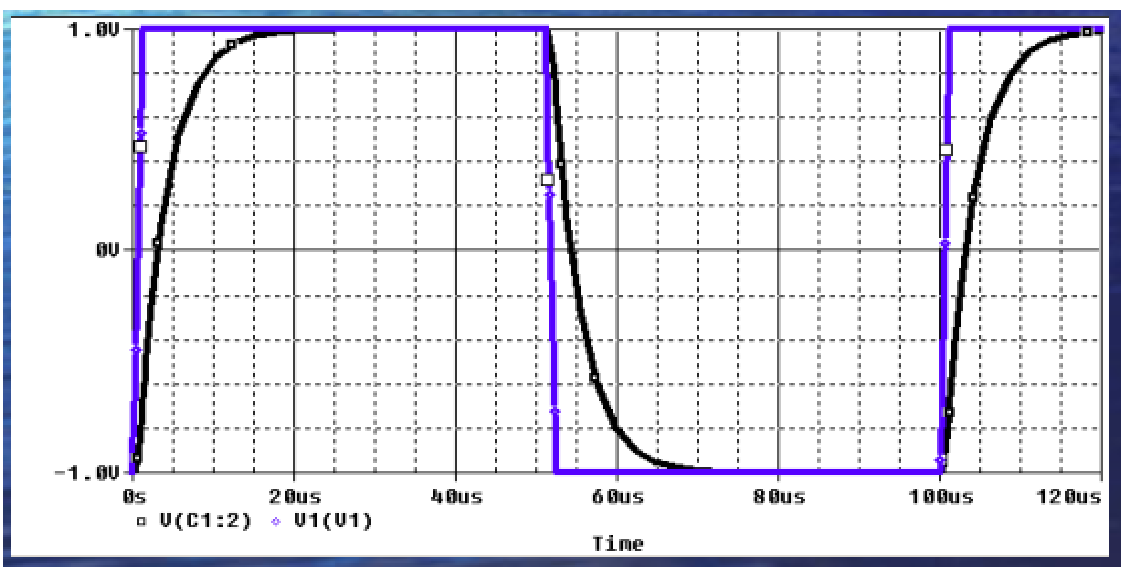

Figure 3.1.1.4

One more way to ensure accuracy would be the theoretical approach. By using the equation 1.1 below, capacitance can also be calculated by knowing the permittivity of free space, permittivity of the dielectric, and also the diameter of the inside and outside conductor. As mentioned before the outside conductor measured .625 inches, while the inside conductor measured .123 inches. Having this information, we were able to calculate the following values in Table 1:

Types of Dielectrics	ε_0	ε_r	Capacitance Values
Air	8.854×10^{-12}	1	34.39pF
Oil	8.854×10^{-12}	2	68.79pF
Water	8.854×10^{-12}	80	2.75nF

Table 3.1.1.1 Theoretical Capacitance Calculations.

Once these values were obtained we were able to compare them. Although the values were slightly different, we were able to justify them due to the internal capacitance of the oscilloscope.

3.1.2. Oscillating Circuit / 555 Timer

The 555 Timer used in the oscillating circuit has applications that include precision timing, pulse generation, sequential timing, time delay generation and pulse width modulation (PWM). These are functions that are essential in the design.

Another desired ability of the 555 Timer is the capability of transforming analogue signals to digital values. By using a 555 chip it is possible to add this desired A/D capability in the circuits with a big resolution, as long as the delay of the A/D conversion is not crucial, as it is the case in most custom circuits. The basic pin connections for the 555 Timer are shown in the figure below.

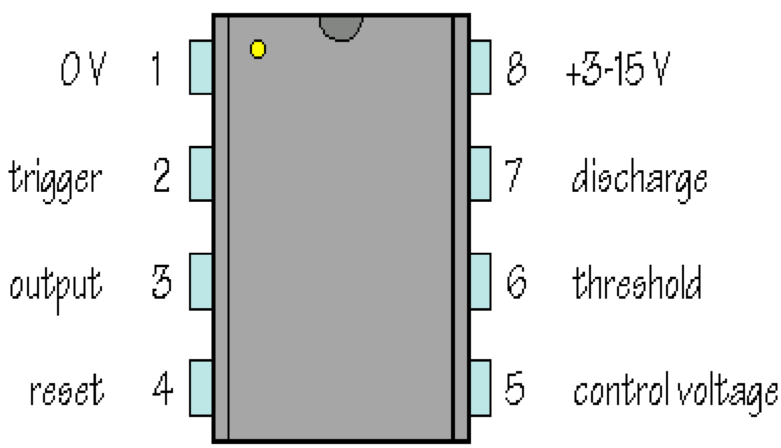

Figure 3.1.2.1 555 Timer

Pin 1 (Ground): The ground pin is the most-negative supply potential of the device, which is normally connected to ground when operated from positive supply voltages.

Pin 2 (Trigger): This pin is the input to the lower comparator and is used to set the latch, which causes the output to go high. Triggering is accomplished by taking the pin from above to below a voltage level of 1/3 V+ (or one-half the voltage appearing at pin 5). The action of the trigger input is level sensitive, allowing slow rate-of-change waveforms, as well as pulses, to be used as trigger sources.

Pin 3 (Output): The output can be returned to a low state by causing the threshold to go from a lower to a higher level, which resets the latch. The output can also be made to go low by taking the reset to a low state near ground.

Pin 4 (Reset): This pin is also used to reset the latch and return the output to a low state. The reset voltage threshold level is 0.7 volts, and a sink current of 0.1mA from this pin is required to reset the device. Delay time from reset to output is typically around 0.5 μS, and the minimum reset pulse width is 0.5 μS.

Pin 5 (Control Voltage): This pin allows direct access to the 2/3 V+ voltage-divider point, the reference level for the upper comparator. It also allows indirect access to the lower comparator, as there is a 2:1 divider to the lower-comparator reference input.

Pin 6 (Threshold): Pin 6 is one input to the upper and is used to reset the latch, which causes the output to go low. The action of the threshold pin is level sensitive, allowing slow rate-of-change waveforms. The voltage range that can safely be applied to the threshold pin is between V+ and ground. A dc current, termed the threshold current, must also flow into this terminal from the external circuit

Pin 7 (Discharge): Usually the timing capacitor is connected between pin 7 and ground and is discharged when the transistor turns "on". The conduction state of this transistor is identical in timing to that of the output stage. It is "on" (low resistance to ground) when the output is low and "off" (high resistance to ground) when the output is high.

Pin 8 (V +): The V+ pin is the positive supply voltage terminal of the 555 timer. Supply-voltage operating range for the 555 is + 4.5 volts to +16 volts, and it is specified for operation between +5 volts and + 15 volts. The device will operate essentially the same over this range of voltages without change in timing period.

In the figure below the basic principle of the PWM circuit is shown. The CPU triggers the 555 (with a negative pulse), this sets the flip-flop, resulting in turning the discharging transistor off. The capacitor Ct is then charged until the voltage on Ct becomes equal to the input voltage Vin.

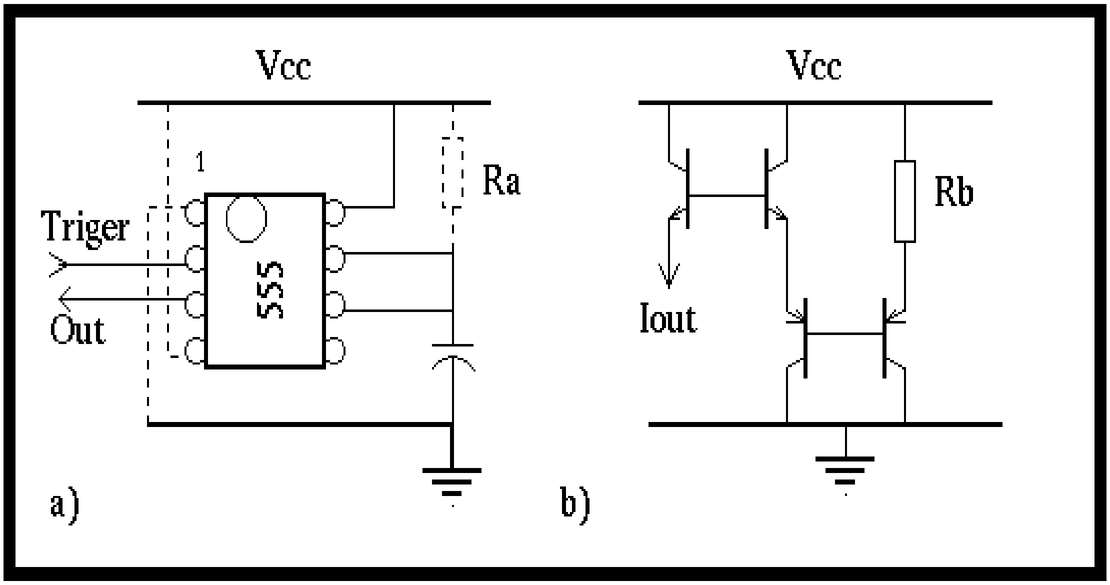

Figure 3.1.2.2 PWM circuit

The voltage on the capacitor is an exponential function in T. It would be desired for the charging to be linear in time, so that the duration of the pulse would be proportional to Vin. The duration of the output pulse is given by the following equation:

$$\text{Vin} = \frac{1}{Ct}\int idt \Leftrightarrow \text{Vin} = \frac{\Delta T}{Ct} \qquad (2)$$

The timer in the design is set to count the pulses generated by the oscillator circuit. These pulses are directly correlated to the frequency, which in fact, is the measuring unit for the user to determine the amount of water intake in the lower unit of the boat. In other words, water intake causes the reduction of both the frequency and the pulse count.

After we have successfully found the direct correlation between the pulse counts and the frequency with the amount of water intake, the 555 Timer output is connected to the input of the PIC 16F876. The PIC will then set the threshold levels for the specific counts for the pulses that influence the LED signals to the user.

The design formula for the frequency of the pulses is:

$$\text{f} = \frac{1.44}{(\text{R1} + 2\text{R2}) * \text{C}} \qquad (3)$$

* Note that the sensor built for this designed is portrayed by the capacitor labeled C2.

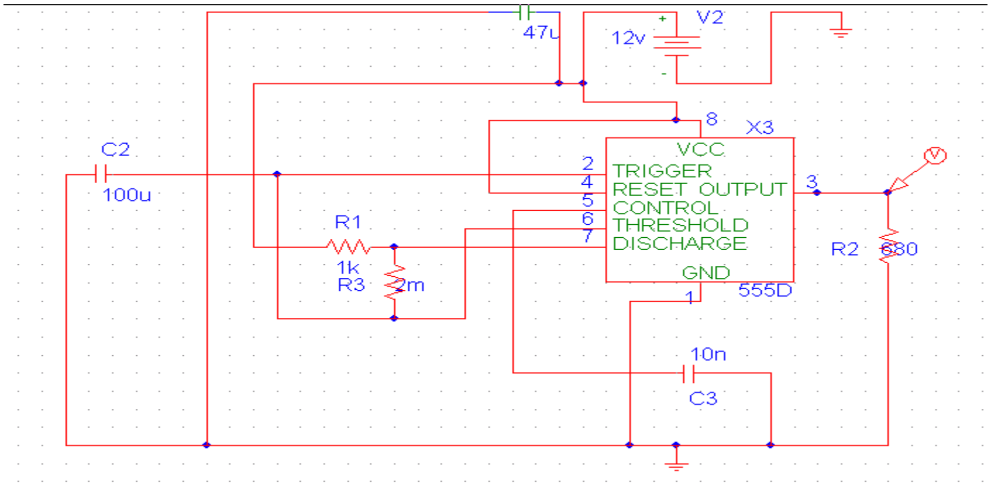

Figure 3.1.2.3 A P-Spice Schematic of the Oscillating Circuit

3.1.3 Microprocessor Board

The microprocessor board is a useful tool for experimentation with microcontroller applications. It acts as the embedded system for the water detector. In general, an embedded system is a special purpose computer device, which is designed to control an operation, given some specific firmware. The microprocessor board is composed of various components, which help compel the design process. The microprocessor contains the circuitry required to operate: 5-volt power supply, 5 volt regulator, 3 LEDs, a potentiometer that acts like a pseudosensor, an RC servo connector and an RS-232 serial port interface. A small prototyping area is included on the microprocessor for the eventual insertion of the oscillator circuit. The microprocessor is versatile and is able to run programs written in assembly, PicC and PicBasic. It also includes in-circuit programming connectors, so the PIC can be reprogrammed with a flash device, and some EPIC Programmer software. All of the PIC I/O pins are joined to a header socket at the bottom edge of the microprocessor board, which allows the oscillator circuit to be connected via the breadboard. All of the pins on the microprocessor board are wired to a 28 pin PIC, which is used to complete the prototype circuitry.

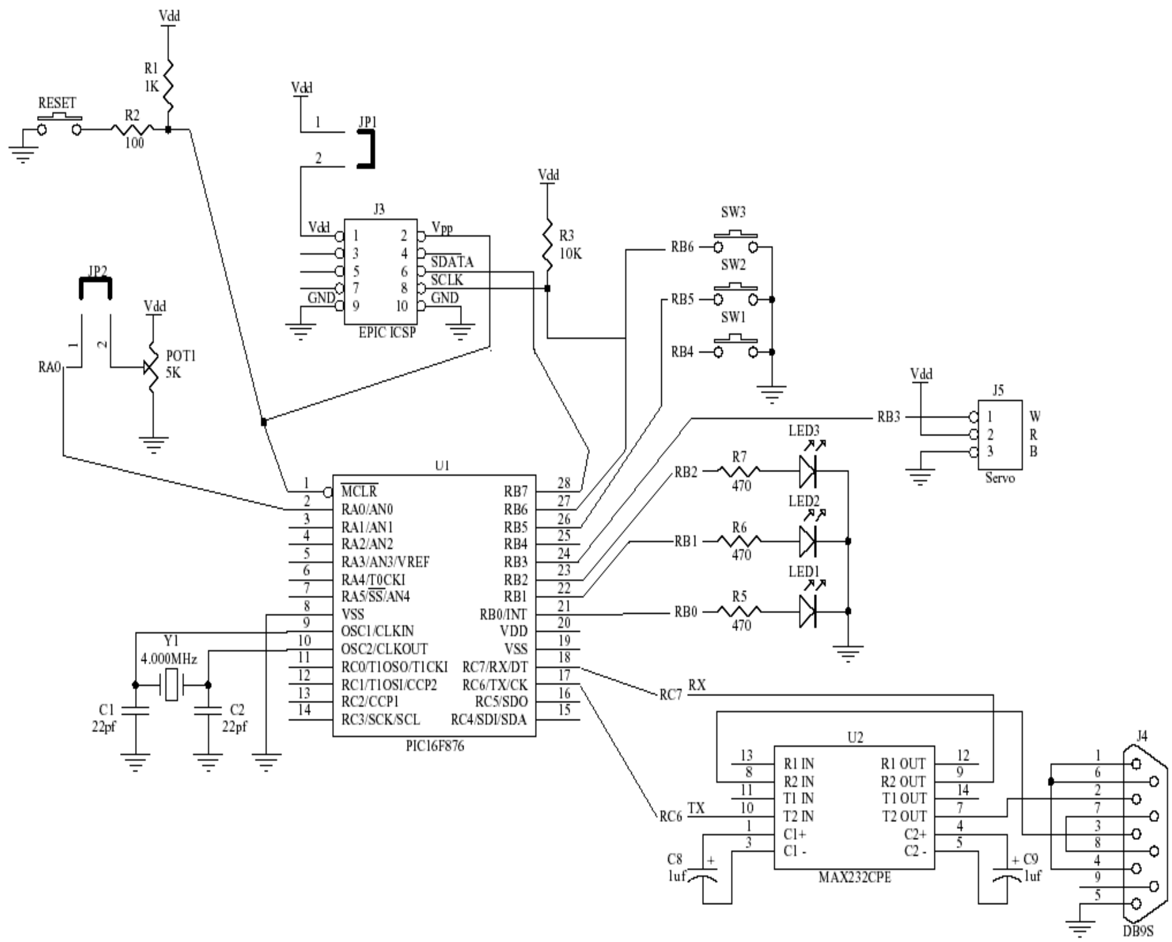

Figure 3.1.3.1

Figure 3.1.3.1 shows a schematic of the microprocessor and its components. The power supply provides regulated +5 volts DC for use by the components. An AC adapter helps to ensure that the recommended DC voltage of 7.5 to 16 volts is provided to the board via the DC power connector (J2). The three programmable LEDs are connected to ports RB0-RB2. There is also 1 power LED that is always on when power is applied to the microprocessor. Resistors R4 - R7 are the current limit series resistors for the LEDs. Three push button switches are connected to pins port RB4 - RB6 on the PIC. A closed switch will show a 0 and an open switch will show a 1. These schematics can be seen below in figure 3.1.3.2

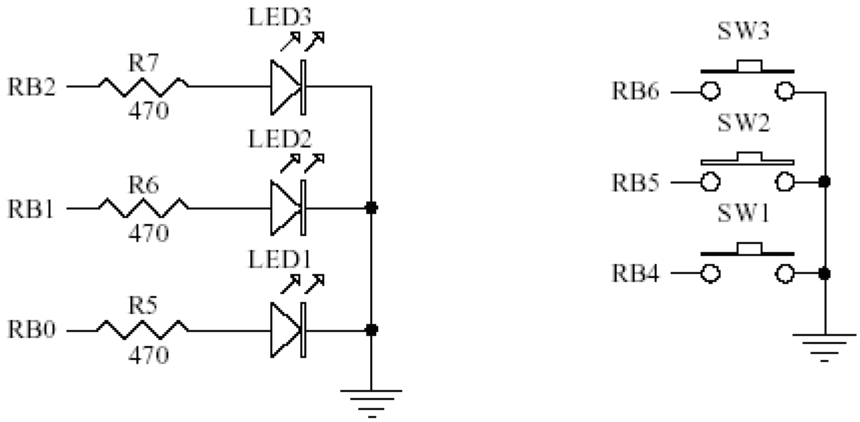

Figure 3.1.3.2

The microprocessor board includes a potentiometer connected to port RA0 of the PIC. Jumper JP2 allows the potentiometer to be disconnected from the PIC pin when the pin is used for other purposes. The potentiometer may also be used as a switch by setting the input pin to digital mode and moving the pot wheel all the way to either the 5-volt or ground position, which ultimately provides either a high or low on the input. The three-pin header (J5), shown in figure 3.1.3.3 is used to connect the RC servo to the microprocessor board. Pin 1 is the servo pulse input, which is connected to port RB3. Pin 2 is the 5 volts coming from the source to the servo, and Pin 3 is the ground. Most RC servos are operated by sending a 1ms to 2ms pulse 50 to 60 times a second. The pulse width determines the servo position.

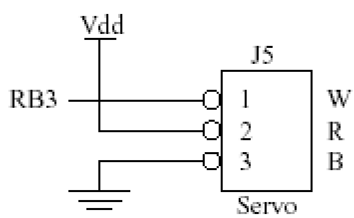

Figure 3.1.3.3

The microprocessor includes an RS232 interface to connector DB9S female right angle connector (J4) shown below in figure 3.1.3.4. This allows asynchronous serial communication with other devices, including PCs. A MAX232 IC in socket U2, along with several capacitors, generates the required RS232 voltages. The serial TX line (pin 2 on J4) is connected to port RC6 through the MAX232. The serial RX line (pin 3 on J4) is connected to port RC7 through the MAX232. RTS is connected to CTS (pin 7 to pin 8) on J4. DTR is connected to DCD and DSR (pin 1 to 4 to 6) on J4. These jumped connections make most common programs think the microprocessor board is online and ready to communicate.

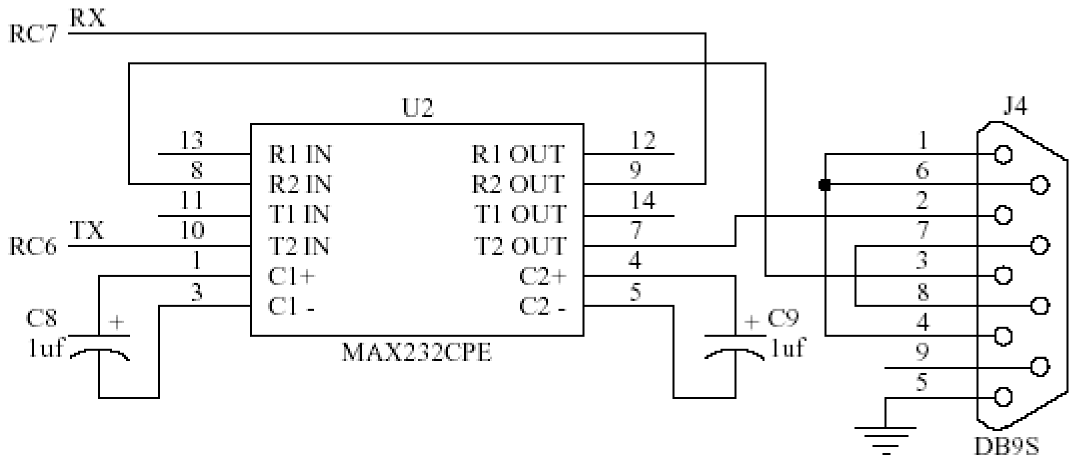

Figure 3.1.3.4

The microcontroller board utilizes a high-performance FLASH PIC16F876 shown below in figure 3.1.3.5, which provides the design team with the highest design flexibility possible. It has the capability to be programmed and erased in blocks rather than bytes by using the EPIC Programmer software. This PIC has 8096x14 words of FLASH programmable memory as well as 256 data memory bytes, and 368 bytes of user RAM. It features an integrated 5-channel 10-bit Analog-to-Digital converter, which converts analog input voltage to a ratio metric digital equivalent value, and it also consist of 22 I/O pins. Peripherals include two 8-bit timers, one 16-bit timer, a Watchdog timer, and a Brown-Out-Reset (BOR), which will force the device to the RESET state if the power supply voltage falls below the specified voltage level. This PIC also allows for in circuit-serial programming to occur as opposed to creating an external circuit much like other devices. The Universal Asynchronous Receiver Transmitter (UART) is a module that can operate as a full duplex asynchronous communications port. By operating in the asynchronous mode, the UART can be interfaced to the PC serial port for multi-drop data acquisition applications, and I2C or SPI communications capability for peripheral expansion.

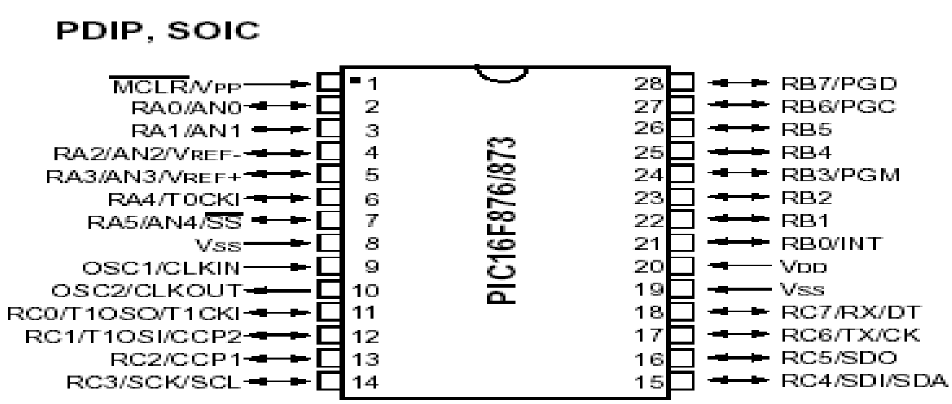

Figure 3.1.3.5

Precision timing interfaces are accommodated through two CCP modules, that can be configured to operate as an input capture, or a timer compare. An in-circuit debugging feature allows the designer to “emulate” the PIC16F876 device without an in-circuit emulator since the microprocessor board itself acts like an emulator. The various applications of the PIC16F876 range from body controllers, programmable machine controls, network maintenance, and diverse sensory conditions. In the case of the water detector, we recognized the functionality of the microprocessor board. We also recognized the opportunity the board would provide for parallel development of the firmware and the sensor, as well as avoid having to “reinvent the wheel”. Ultimately, this board increased productivity and helped make the design team more efficient as we work toward building a successful prototype.

3.2. Software Approach

The main portion of the software involved in the water detection system deals with the counting of pulses of the function that is generated by the oscillator circuit. Code will be written for the PIC16F876 that will enable one of its input pins to take in the output of the oscillator circuit and count each time it reads a change in the signal. One-way to do this is to count the number of interrupts that occur at the desired input pin. Once the pulses are counted we will be able to set threshold values. If the number of pulses counted is below a certain limit, code will be written to turn on one of the LEDs to warn the boat occupant that water has been detected in the lower unit.

There will be a minimum amount of user interaction with the actual system. The only interaction that will actually take place will be when a warning led is turned on letting the user know that water has been detected in the lower unit.

3.2.1 PIN Selection

We selected to use pin RB4 as the input for the systems interaction with the oscillator circuit. This pin was arbitrarily selected and can be changed if it is deemed necessary. The location of RB4 is denoted in Figure 3.1.3.5.

Therefore, counting the pulses generated by the system over a set period of time, we will be able to denote a difference when water has been mixed with the oil. Once the capacitance of the structure goes up due to the presence of water, the overall frequency of the function generated by the oscillator circuit goes down.

Therefore, counting the pulses generated by the system over a set period of time, we will be able to tell if there has been a change in the overall frequency of the system. Figure 3.2.2.1 shows the flow diagram for the software that will be needed to count the pulse generated by the oscillator circuit.

The first constraint here will to be to make sure that all counting is done at the same length of time. One way to do this would be to set a timer. Code will be written that will have one of the LEDs of the micro controller board turn on for about 1 second. Each time the LED is on, the system is allowed to count the interrupts that occur at pin B4. Once the LED goes off, the counting stops, the value is printed to the screen, and the pulse count is cleared.

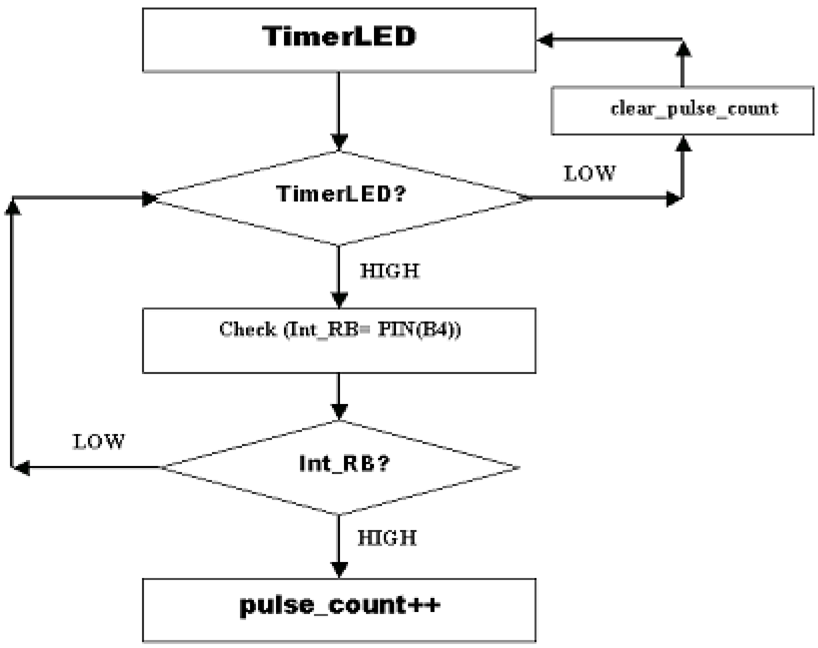

Figure 3.2.2.1 The Flow Diagram for the Pulse Counting.

3.2.3 Threshold Frequency Flow Diagram

Once a pulse count is collected by the PIC, and before it is cleared, the value will be compared to threshold values that will be set by the programmer. These threshold values will correspond to frequencies and pulse counts of mixtures of oil that are deemed to be detrimental to the well being of the lower unit.

Since the frequency of our system falls when there are higher amounts of water present in the oil, our system will check if the counted pulses has fallen below the threshold limit. If the value has fallen below the threshold, then a LED will be turned on. This LED will warn the occupant that there is water present in the oil. Furthermore, if the pulse count falls below the next threshold, another LED will be activated and an alarm will sound. The flow diagram for these comparisons is shown by Figure 3.2.3.1.

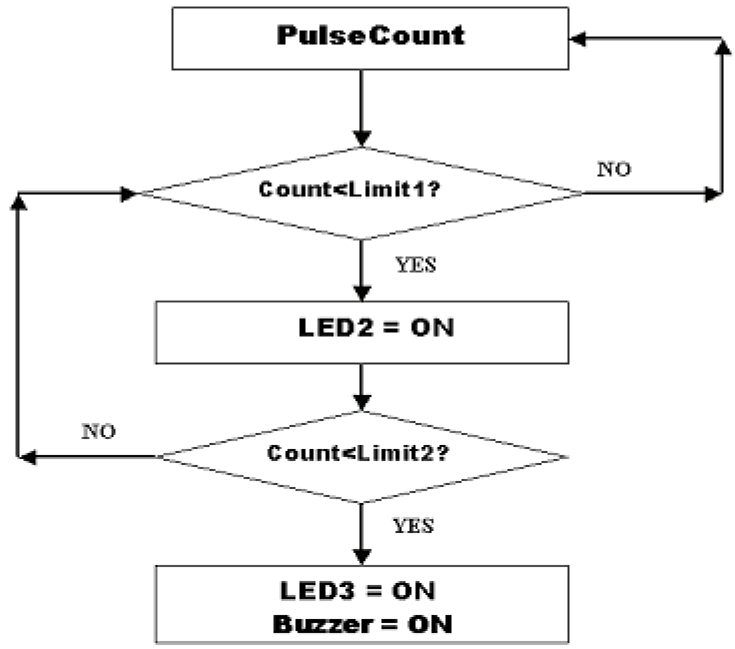

Figure 3.2.3.1 The Flow Diagram for Pulse Count Compare.

4. TEST SPECIFICATIONS

Requirements	Pspice	Digital Multimeter	Oscilloscope	Performance Testing	Conductivity Meter
Input Voltage		•			
Capacitance/ Frequency	•	•	•		
Conductivity					•
Output Latency	•				
Endurance				•	

Table 4.1

4.1 P-Spice

In the process of building the prototype it will be important to know the levels of voltage associated with our system. To regulate this voltage we will simulate our circuit design using p-spice. To ensure accuracy, voltage will be measured using a digital multi-meter. The main voltage to be tested will be supplied by the 12-volt battery once the ignition switch is turned. P-spice will also be used to determine output latency.

4.2 Digital Multi-meter

A digital multi-meter will be used to test the voltage being supplied to our circuitry from the 12-volt battery located on the marine craft. Since the alternator is constantly charging the battery, the voltage supplied can fluctuate anywhere from 12-15 volts. As well as measuring voltage, the multi-meter will be used to measure current, and resistance throughout our circuit design.

4.3 Ocilloscope

Oscilloscope measurements will be made throughout the testing period. This will allow us to calculate the capacitance of our circuit. Once the capacitance of the circuit is measured, we will be able to compare it to P-spice, and any theoretical values calculated. Another benefit of the oscilloscope is determining the frequency of the oscillator. This measurement will be directly attributed to the threshold level that will determine when a led is turned on.

4.4 Performance Testing

Performance testing will be made throughout different stages of the design in order to guarantee the reliability and endurance of our product. The performance testing will include durability and accuracy during the operation of the marine craft. These items will fluctuate due to temperature, humidity, and location.

4.5 Conductivity Meter

A conductivity meter measures conductivity based on the total number of ions in a liquid. The meter will be used to test the conductivity of the oil in the lower unit based on the number of water molecules in the lower unit. This test proved to be the wrong approach.

5 Test Certification

5.1 P-SPICE

One of our main objectives was to verify that the sensor we built was consistent with any other comparable capacitors as far as charging times goes. The simplest way to test this was to construct a RC circuit in P-spice. After an initial analysis of our capacitance sensor, we were able to obtain that the capacitance of the structure itself was about 20pF, however, combined in parallel with the oscilloscope, the capacitance was about 120pF. Therefore, we took a snapshot of the charging curve that was generated from the sensor and the oscilloscope and compared it to the charging curve that was simulated in PSPICE. Figure 5.1.1 denotes the circuit that was used in PSPICE and Figure 5.1.2 denotes the curve generated in PSPICE. Additionally Figure 5.1.3 shows the snapshot of the charging curve from the sensor and the oscilloscope.

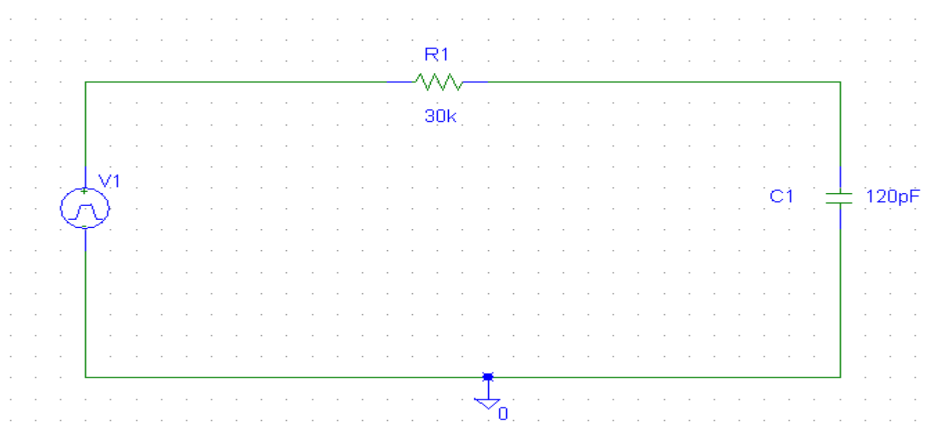

Figure 5.1.1 RC Circuit in PSPICE

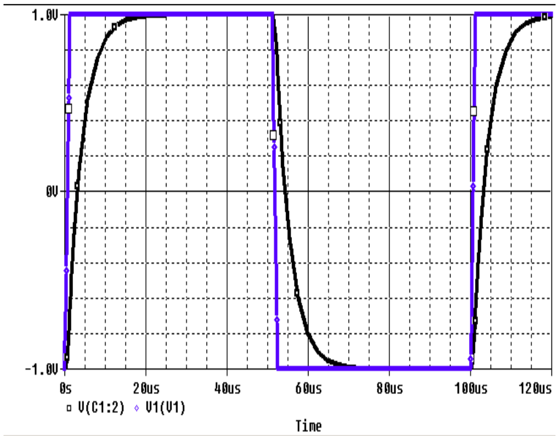

Figure 5.1.2 PSPICE Charging Curve

Figure 5.1.3 Actual Charging Curve

The curves turned out to be very similar; therefore we were certain that the capacitance we derived by doing an analysis of the charging curve were correct. This allowed us to move on to the next stage of testing.

The PSPICE Simulation tool was also used in the initial analysis of the oscillator circuit that was built using the 555 timer. We were very interested seeing the response of the circuit to varying capacitance values. Figure 5.1.4 shows the oscillator circuit schematic used in PSPICE.

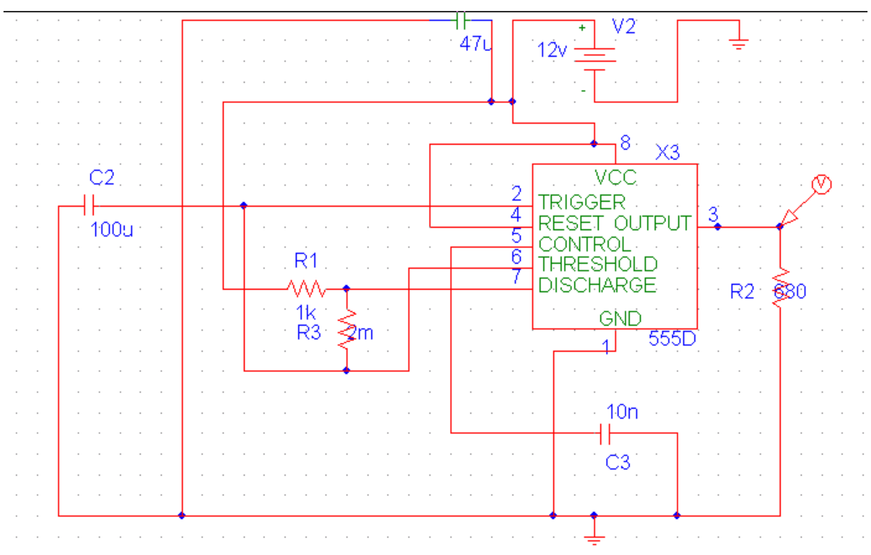

Figure 5.1.4 Oscillator Circuit Schematic.

We weren't able to find the exact 555 Timer that we used in our circuitry, however the 555D that we found was gave us a pretty good representation of what occurred in our system. As we increased the capacitance that is denoted by C2, the frequency of the simulation decreased. Here is an example output of the oscillator circuit.

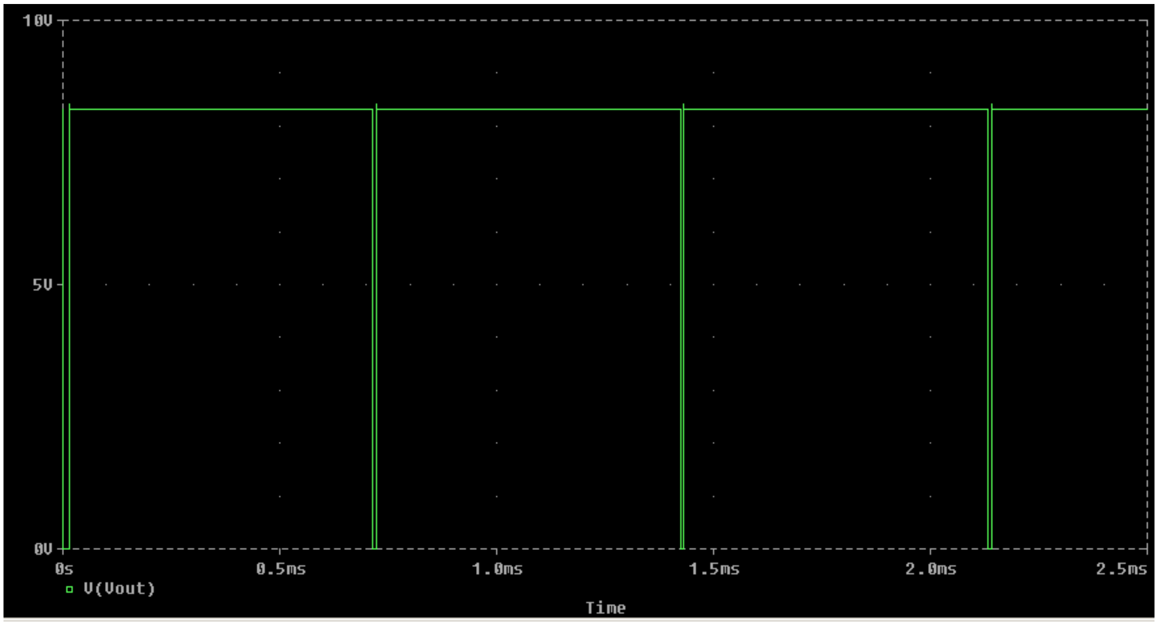

Figure 5.1.5

5.2 Conductivity Measurements

The first objective of this project was to decide how to detect water in the lower unit of a marine outboard. Measuring the conductivity of the oil/water content was an option. By using a conductivity meter, we took measurements ranging from 5% to 80%. As you will note below the measurements were very unstable. To ensure the accuracy of our measurements, we took two trial samples. The results are listed in Table 4.

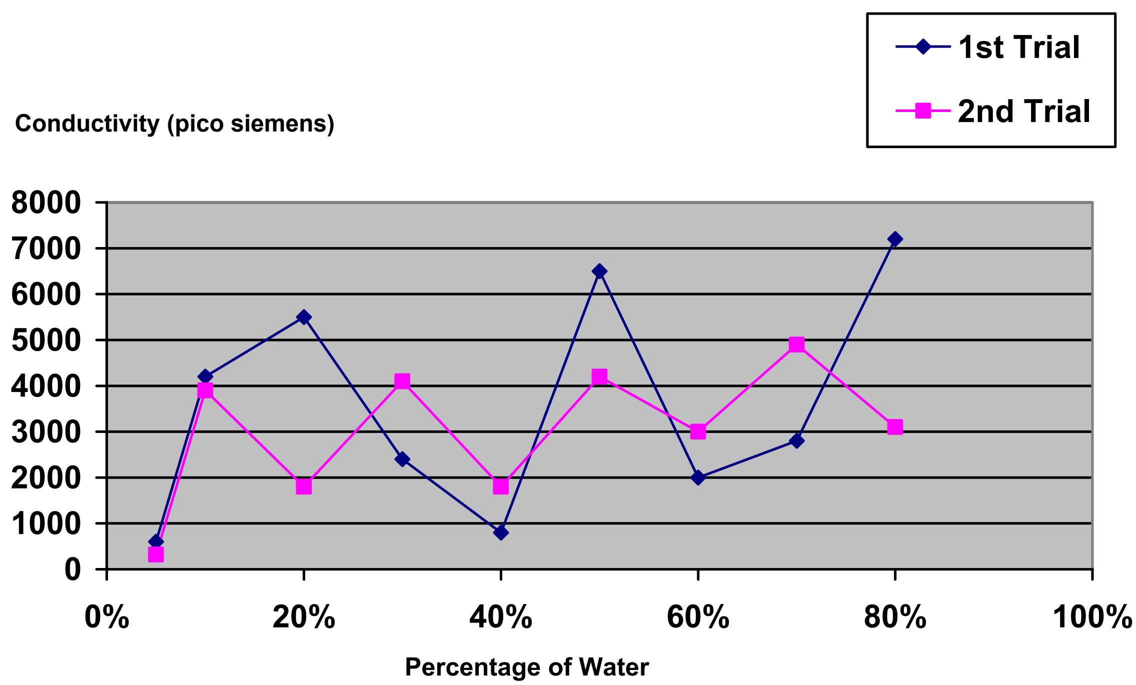

Figure 5.2.1

The results concluded that the conductivity path was not an option due to its sporadic behavior.

5.3 Capacitance Measurements

The next big approach consisted of a capacitance measurement. This measurement would be taking with the same concept as before. Two trials samples would be taken with the different percentages of water. After taking these measurements, we noticed very consistent values at different percentages of water. These results can be best described by the graph below.

Water Concentration	Capacitance (pF) 1st Trial	Capacitance (pF) 2nd Trial
0%	120	124
10%	135	130
20%	143	140
30%	149	145
40%	185	175
50%	273	250
60%	596	667

Figure 5.3.1

After noticing these consistent values, we begin integrating our sensor into our oscillating board and measured the frequency. These values seem to be inversely proportional. As the capacitance increased, the frequency decreased. This is shown in the graph below.

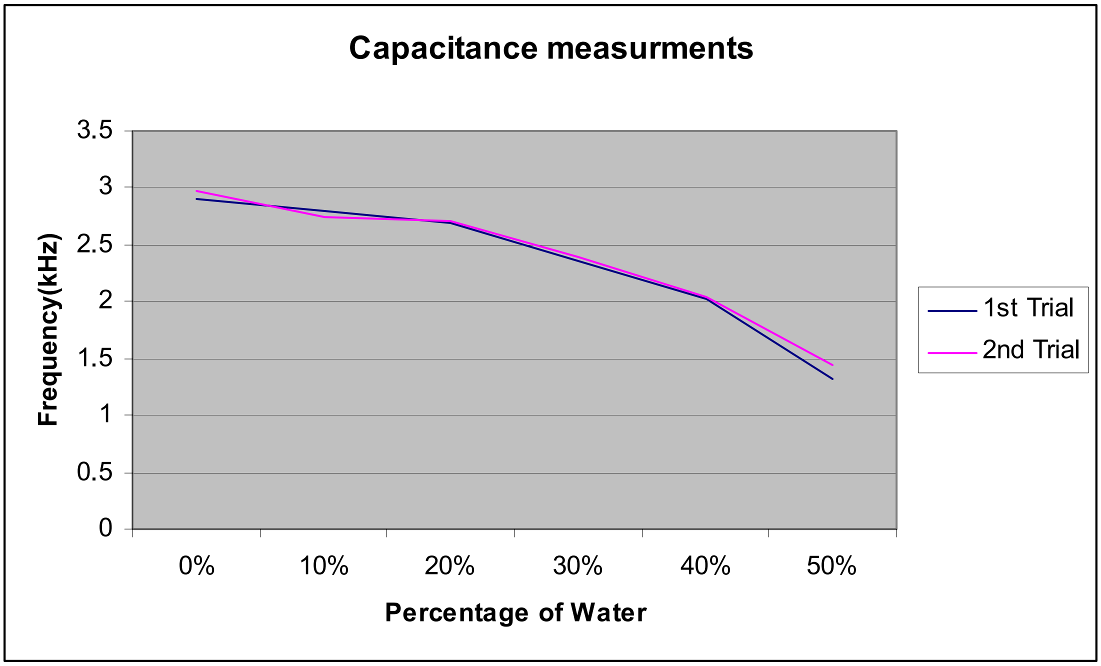

Figure 5.3.2

5.4 Digital Multimeter

This piece of equipment was used to verify the voltage, and also used to verify the frequency. The frequency measurements from the multimeter will be used to determine our threshold frequency. After analyzing the data, we will be able to set limits to light up LED's to warn the occupant of the severity of danger associated with lower unit.

5.5 Ocilloscope

The oscilloscope was used to verify, and calculate the capacitance of the sensor. These measurements would change due to the dielectric of the capacitor. The dielectric is directly associated with the ratio of oil to water.

5.6 Performance Testing

This testing was done at the Mississippi State University chemical engineering laboratory. All oil testing was done with highly accurate measuring devices that were calibrated in November. These test were also done twice for accuracy purposes. All oil samples were measured and mixed according to their weight. For example, 10% water had 27 grams of oil and 3 grams of water. According to Dr. Hossein Toghiani, a MSU professor, this is the most accurate way to measure percentages.

6 Summary and Future Work

Our team met a huge challenge in determining a feasible approach in determining water contamination in the lower unit. Initial options included building sensors that measured:

- Conductance/Resistance
- Optical
- Absorption

After spending a large portion of the semester trying to figure out methods of measuring the conductance and resistance of oil with different water mixtures, we finally concluded that there was no definite trend in the values with increasing water concentration.

Since so much of the semester was taken up by erroneous results due to the persistence of trying to get the conductance or resistance sensor to work, we quickly fumbled through some other options.

We came across the idea of designing an optical sensor that actually detected the change in color of the oil as water concentration increased. Even though the oil actually did turn into a milky white color with the addition of water, the change was not drastic enough for us to be able to measure the water intake accurately.

Next, we came upon the idea of absorption. A general overview of this method dealt with actually heating the oil to figure the energy transmitted. This was quickly overturned once expense and difficulty were evaluated.

Finally we came upon measuring the capacitance. Our sensor received consistent measurements after multiple testing of the oil with different water percentages. The oil went through testing from water percentages ranging from 10% - 70%. We even tested pure oil and saw the capacitance change as water was manually inserted into the oil.

Due to the use of an oscillating circuit, our design was also set to measure the frequency and the pulse count of the oil. This actually proved to be the determining factor of water detection in the oil. We quickly realized that pure oil has a set frequency of about 2.9 kHz and with an increase in water; both the frequency and the pulse count steadily decrease.

Along with packaging of our design, this sets our team up for much work in the future. In order to portray the seriousness of water contamination, we have to determine the amount of water it takes to cause damage to the lower unit and to program our PIC at these certain thresholds of the pulse count, so that once those limits have been exceeded, the users will be alerted with the buzzer and the LED board.

7. ACKNOWLEDGEMENTS

We would like to acknowledge all of the following people who have made considerate contributions to our design and its implementation: Steven Laboe – MS Power Company, Alan Xie – MSU Chemical Engineering, Dr. Hossein Toghiani – MSU Chemical Engineering, and Bill Buchanan – Senior Engineer Advisor. Without the help of these individuals our design would not have been possible.

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