Updated Automatic Bilge Pump Control
By Allan Wing

Recently a club member had asked me to post an article describing an automatic bilge pump controller on our club web site. The controller was designed some years ago and used by combat ship people. That article appears on our web site. When I read the article I found it was a very simple design and would be easy to build. However when I looked closer at the design I felt as an engineer there could be a better design. There were 3 areas of improvement that I thought were possible. First there is a warning in the article that the transistor controlling the pump runs very hot and must have a good heat sink. Second the sensor requires careful spacing and requires nonconductive mounting hardware. Third as soon as the pump pumps a small amount of water out of the hull the pump would shut off. This would mean the sensor would have to be located right at the bottom of the boat and then the pump would continuously cycle. For the combat boats since they shoot holes in each other the leaks tend to become large and once started the pump would probably have to run continuously until it is overwhelmed and the boat sinks.

I looked at each of these concerns and tried to determine how each could be overcome. I looked at sensor design, switching circuits and pumps. First I measured resistance between the sensors to determine what was some of the most important factors affecting the sensor performance. Since we run our boats in the Pacific Northwest the waster is very soft meaning there few minerals in the water so that a sensor will have very high resistance making the transistor either slow to turn on or not turn on completely. This would affect the size and spacing of the sensor plates and also contribute to the heat in the transistor because it does not turn on completely or technically not saturate.

I made up a test to determine the best size and positioning for the brass plates used as a sensor. The original article specified brass or copper strips 1/4 inch wide and 1 1/2 inches long spaced about 1/4 inch apart. I attached two brass strips about 1 inch by 2 inches to wires and conducted a few tests. I found that the resistance would get lower as the strips were moved closer together with the resistance dropping to 5,000 ohms when the strips were almost touching and only going up to about 6,000 ohms when they were about 1 inch apart.

This told me that I needed a more sensitive switch than a Darlington transistor to turn on the pump. This would also assure that the transistor controlling the pump would be fully turned on and this would reduce the overheating problem. It also demonstrated that the two srips of the sensor could be placed farther apart so there would be less dependency on placement and insulating hardware.

I then looked at pumps the original design used an automotive windshield pump. These pumps can draw up to 5 amps which requires that the controlling transistor be fully saturated and then would still require some sort of heat sink. Then my wife got a solar powered bird bath fountain pump. This was the answer, it was low voltage and being solar powered very low power. I found the same type of pump designed to run off of a computer USB port for a desktop

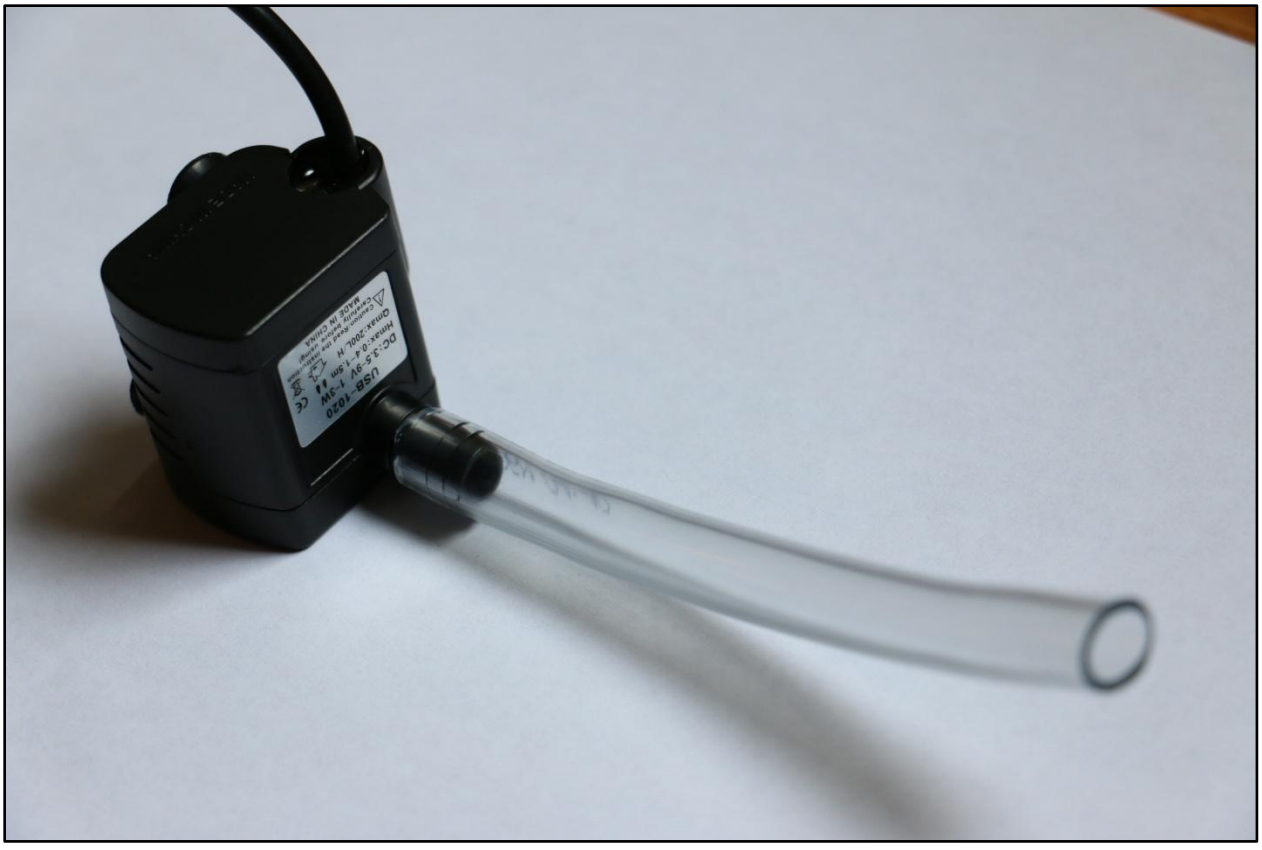
fountain. I ordered one and started testing. It is an excellent solution. The pump is small and works with anywhere from 3.5 to 9 volts. It only draws 200 milliamps at 6 volts. It is low pressure and will provide up to 200 liters per hour to a height of almost 3 feet. This was my choice because we don't need the high pressure of a windshield washer and we only have to raise the water a few inches to get it out of the boat. The pump has a high enough volume so that in most cases only has to run a short time to remove the water from the biggest boats. Also the high volume could save your boat from an extreme leak.

Picture of Pump

Yeeco Part#: Y1300062 710882794378 - Yeeco 200l/h Max1.5m Dc3.5-9v Usb-1020 Water Pump Brushless Dc Mini Submersible Pump

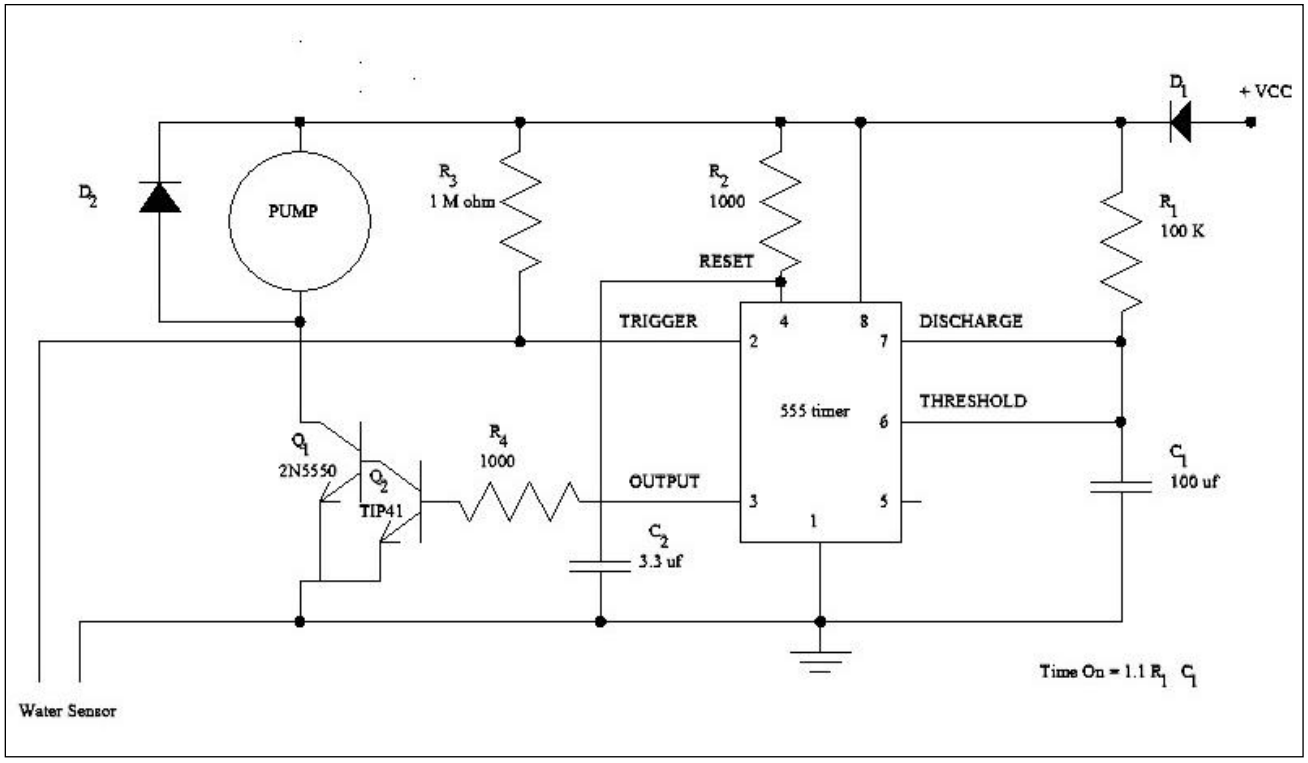
The pump is Less than 1 3/4 inch long and is 2 oz in weight so it will fit in all but the smallest of boats. I recommend that the pump be mounted as shown below this will allow it work in as little as 1/4 inch of water and will pump the water out to less than 1/8 inch. If you place the sensor to trigger at 1/2 to 1 inch this would keep your boat relative dry. The pump can be completely submersed. The pump is not self priming but is mounted as shown will start and pump properly if the water is 1/4 inch or more deep. Also the pump can be allowed to run dry near the end of the on cycle. While running dry is not recommended it would takes hours of dry running to cause any noticeable wear.

Internal parts of the Pump



Suggested mounting Position.

I looked at the third problem of the pump cycling as soon as the sensors were uncovered. Since I needed a sensitive detection circuit to handle our soft water I chose an LM555 circuit to act as the detection device and switch. This allowed a sensitive detection and a method to provide set minimum time for the pump to run when the water level reached the detection point. The circuit I came up with is shown in below.



Detailed Circuit

The circuit consists of a 555 in Monostable operation, which means it is off until triggered by the water sensor and will remain on for the time determined by the selection of R_1 and C_1.

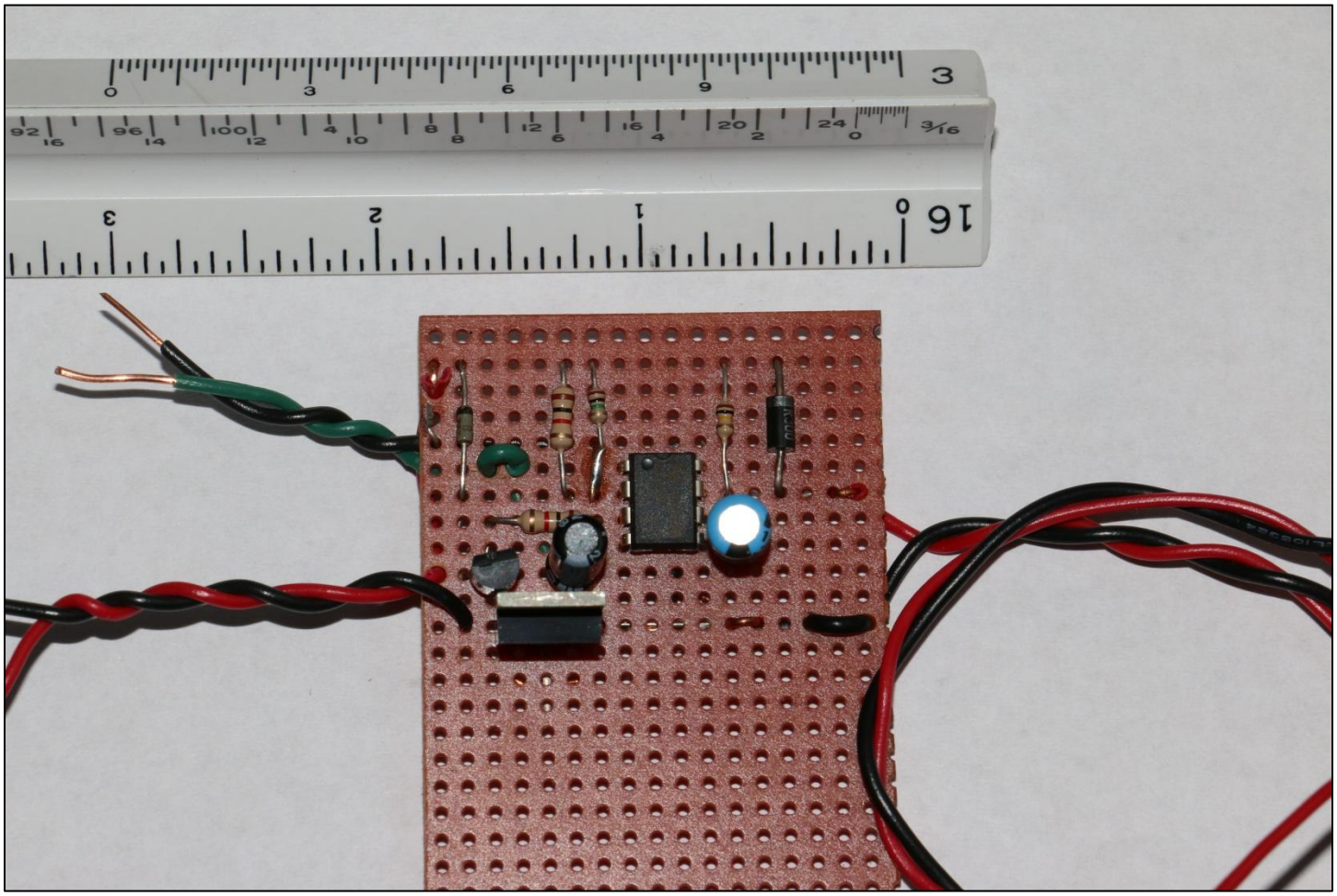
Diode D_1 is optional and is just there so that is the battery is connected backwards there is no damage to the circuit. R_1 and C_1 determine the time the pump will run when the circuit is triggered by the circuit. R_1 is connected to battery and C_1 is connected to ground. Pins 6 and 7 of the 555 are tied together and connected to R_1 and C_1 as shown. The on time is calculated by multiplying 1.1 times R_1 in ohms times C_1 in farads or in this circuit
Time on = 1.1*100,000*0.0001 which equals 11 seconds. For example if C_1 were changed to 200uf the on time would increase to 22 seconds.
R_2 and C_2 are connected to the reset pin and insure the pump is turned off when power is applied. This provides a negative reset pulse when power is initially supplied. the values are not critical so I just chose some parts I had. R_3 reduces the chance of a false trigger so that the pump is only turned on when there is water in contact with the sensor. It must be something higher than 100 K ohms. With the sensitivity of the 555 trigger the sensor can be made of two brass strips only 1/4 inch square and the can be placed anywhere in the boat such that both are in contact with the water when the maximum acceptable level is reached. I would suggest that

one sensor is placed near the bottom of the boat and the other is placed at the level where you want the pump to activate. Either sensor can be placed in either location and they can be several inches apart.

R_4, Q_1 and Q_2 provide the current to run the motor when the 555 is switched on. R_4 is connected to the output pin of the 555. While a 555 can provide the 200 milliamps for the motor I chose it would be working at its limit which is never a good idea. Q_1 and Q_2 form a Darlington pair which provides enough gain to run the motor very easily. Q_1 is a small signal NPN transistor that I had available any similar transistor can work. Q_2 is a TIP 41 power transistor that will switch up to 6 amps. Again any similar transistor will work but the TIP 41is one that I had. With R_4 set at 1000 ohms the circuit will provide at least an amp to drive the motor. If a higher current motor is chosen then R_4 should be reduced to 200 to 300 ohms.

The final element in the circuit is D_2. This is often called a freewheeling diode it protects Q_1 and Q_2 when the motor is turned off. When switching current to a motor or relay coil it is necessary to install such a diode.

Below is a picture of a prototype circuit I made so determine how big it would be and for testing.



Control Circuit

The circuit fits comfortably on a 1 3/4 by 2 inch board. with some refinement it could probably be made a bit smaller. The 2 wires on the right are for power. The 2 wires on the top left go to the sensors. the two wires on the lower left go the pump and are polarity sensitive.

Summary

This circuit and pump should make a reliable automatic bilge pump for almost all of our boats. As designed here the pump will run for 11 seconds and at 6 volts will pump about 2 cups of water. With the pump selected here the combination will work from 4.5 volts to 9 volts. It only draws 7 milliamps in standby and 200 milliamps when pumping so it can be run from your receiver power supply either a battery pack or the ESC supplied power. With 6 volt boats it can be run directly from the battery. With 12 volt boats you either need a 12 volt pump which are available (the control circuit will operate between 4.5 and 15 volts) or you can use any of several linear regulators to provide a voltage of up to 9 volts.