Mercedes-Benz Oil Level Monitor

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Introduction

The purpose of this project is to develop an engine oil level monitoring system that will replace the current dipstick method during vehicle testing for Mercedes-Benz Research and Development North America, Inc. (MBRDNA). Currently, MBRDNA test drivers check the engine oil level twice a day after two eight hour shifts each day. To measure the oil level, the driver parks on a level surface, waits five minutes for the oil to cool, and then manually checks the oil level with the dipstick. The goal of this project is to have a reliable, physical, working prototype that MBRDNA can use for vehicle testing by spring.

MBRDNA wants a prototype built by the end of this year that is capable of reading oil level without the need of a test driver to measure the oil. It is very easy for a driver to get distracted and forget to check the oil at precisely 5 minutes after the engine has been shut off. This leads to inconsistent results. Drivers are also susceptible to reading the dipstick incorrectly due to the small amount of increments on the end of the dip stick that must be read. Occasionally dipsticks will even break because they are not designed to with stand fatigue loading cycles that are seen during this testing. This leads to an expensive engine tear down to recover broken parts out of the crankcase.

The prototype will consist of the following features: a SICK fiber optic cable connected to a SICK optic sensor, a clamp, a microcontroller, a digital display and a data acquisition.

This project is being continued from the previous senior project group from 2011/2012 academic year.

Background

There are many different types of technologies that can measure fluid level. Some examples of these existing technologies consist of hydrostatic devices, load cells, pressure transducers, magnetic sensors, floats with string potentiometers, capacitance transmitters, ultrasonic level transmitters, laser level transmitters, radar transmitters, etc. A variety of the technologies can be seen in Figure 1 below.

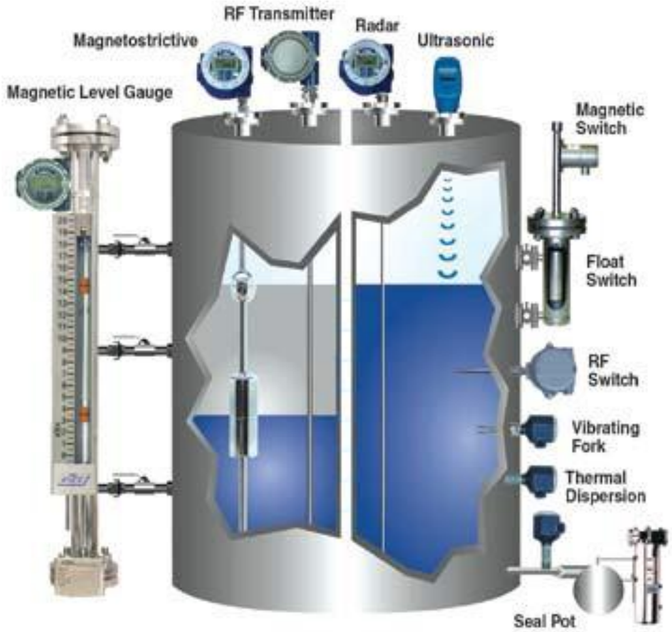

Figure 1. Depiction of various different types of fluid level monitoring systems.

"Hydrostatic Sensors"

Hydrostatic devices measure the difference in pressure of two distinct points. One point is the reference point which is usually exposed to atmospheric pressure. The other point is compared to the reference point and the pressure difference relative to both points can be calibrated to measure height. This application has the potential to work for this application; however, our worries are that size limitations will not allow for a feasible device to be used.

In order for a hydrostatic sensor to be feasible, the fluid needs to be within a certain range for its viscous properties. A hydrostatic sensor for this application would require capillary tubes to be used in order to measure the pressure difference. If the viscosity of the fluid is too high, it is possible that the fluid will not recede down the capillary tube fast enough and allow itself to dry up inside the tube.

"Load Cell Transducer"

Load cells and transducers determine the force load or the pressure load on an existing object such as the wall of a tank or tube. As more fluid is added into the vessel the walls experience more stress which can be calibrated to measure the height of the fluid. The strain or stress change on the wall will be too small to provide a good enough reading making this method inapplicable with this project.

“Magnetic Sensors”

Magnetic sensors are most commonly used with a float to determine the liquid level. A float made with magnetic material is placed inside the float while a stationary magnet is placed outside of the chamber. As the fluid level moves up and down the float is carried along with it. The float gives out a different magnetic field strength depending on its placement on the liquid. This field strength can be calibrated with the height of the fluid. This method is unable to work for this project because the dipstick tube is made of a ferrous material.

“Capacitive Sensors”

Capacitance transmitters operate on the fact that process fluids generally have dielectric constants significantly different from that of air. Oils have dielectric constants, so as the fluid level rises, the overall capacitance rises proportionately. This capacitance can be calibrated to determine the fluid level. This method has potential if the transmitters can withstand operating conditions. From our research we were unable to find any capacitive sensors that would fit in our tight geometry specifications.

“Ultrasonic Sensors”

Ultrasonic level sensors measure the distance between the transducer and the surface using the time required for an ultrasound pulse to travel from a transducer to the fluid surface and back. This time is calibrated to determine which distance which is related to height. This method has potential to work for this project. Research has shown that there are ultrasonic sensors that are small enough to work, but they are not rated for the temperatures that our requirements need.

“Optic Sensors”

Laser level sensors are similar to ultrasonic level sensors except the speed of light is used instead of the speed of sound. This also has potential to work if the light reflects off the oil and back. Optic sensors do not work well off of fluids because of diffraction. Using a solid float may be used to allow for better accuracy. Last year’s senior project used an optic sensor. We tested this sensor and found that the readings are not linear with displacement of the oil level. Last year’s team went to over 50 different manufactures before they were able to find a sensor that would work. We tested the optic sensor by placing it inside a Mercedes dipstick tube, and found that this optic sensor would not fit.

“Sonar Sensor with Microwaves”

Radar systems beam microwaves downward from either a horn or a rod antenna at the top of the vessel towards the fluid. The signal reflects off the fluid surface back to the source and a timing circuit determines overall time and calibrates it to distance. The complexity and variability of all the different shaped dipstick tubes that Mercedes uses would make calibration for every single vehicle difficult. This is one of the requirements, so sonar and microwave sensing are not the best solution for this project.

Objectives

The overall goal of this project is to make a physical, reliable, working prototype by February. The prototype will be either an innovative solution of the previous design or a whole new idea. From the given customer requirements, an engineering specification table was designed below. The compliance column for the table shows how each parameter will be met, either by analysis, testing, research of similar to existing designs, and/or inspection.

Table 1. Customer Specification Requirements Sheet

Spec. #	Parameter Description	Requirement or Target (Units)	Tolerance	Risk	Compliance
1	Reliability	Doesn't break or give false reading	N/A	H	A, T, I
2	Geometry	Doesn't interfere with any other parts	Max	M	A, I
3	Output Signal	-50 – 150%	Min	L	T
4	Accuracy	± 10%	Max	M	T
5	Material	Non-reactive/Non Corrosive	N/A	M	T, S, I
6	Cost	<$1000	Max	L	I
7	Life	450,000 miles	Min	H	T, S
8	Assembly	< 10 minutes	Max	M	T, I
9	Temperature	-10-400°F	Min	M	T, S

Legend: High (H), Medium (M), Low (L), Analysis (A), Test (T), Similarity to Existing Designs (S), Inspection (I)

Design Development

After researching all possible sensors and comparing the sensors to our specification requirements, a decision matrix was formed in order to narrow down the design options. In order to simplify decision making, a scoring system of ±1 and 0 was used.

The decision matrix developed consisted of seven different categories based on the design requirements. Each type of sensor was compared to each other for all of the categories. The weight scale was created to account for each design requirement's impact on the overall design. For example, size and reliability have more of an effect on the design than cost and installation. After discussion, our team decided the most important design constraint was size since the majority of the different sensors researched were eliminated due to its incapability of fitting within the dipstick tube. The decision matrix constructed can be seen in Table 2 below.

Table 2. Decision Matrix during Design Development

Category	Weight	Ultrasonic	Capacitor/Conductive	Photo-electric	Pressure Transducer
Cost	5	1	0	1	0
Compatibility	10	1	1	1	1
Reliability	24	1	0	-1	1
Installation	5	1	0	1	-1
Accuracy	10	1	0	1	1
Size	36	-1	0	1	-1
Operating Temperature	10	-1	1	-1	1
TOTAL	100	8	20	32	13

The bar graph shown in Figure 2 depicts the decision matrix results shown in Table 2.

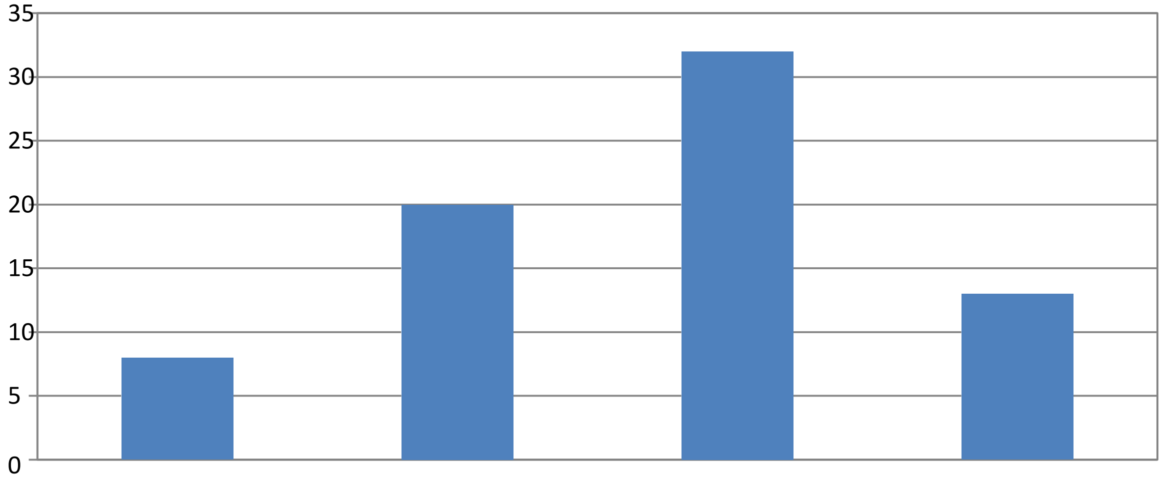

Figure 2. Bar Graph representation of Decision Matrix

The results of the decision matrix showed that the best possible sensors were the capacitance/conductive sensors and optic sensors. As a result, our team decided to continue and improving the fiber optic cable design.

"Fiber Optic Cable: Float Redesign"

To continue with last year's design, our team decided to improve on last year's senior project. The fiber optic cable was going to be reused but now with a different float design. The main problem with the previous float design was that the float which was going to measure the change in oil level height did not float on the oil. Upon further investigation and communicating with last year's team, it was concluded that the reason the float did not work was that the previous team did not take into account the changes in density of the oil due to temperature changes. The designs shown in Figure's 3 and 4 show how this year's team attempted to design an alternative float so that the same fiber optic cable can be used.

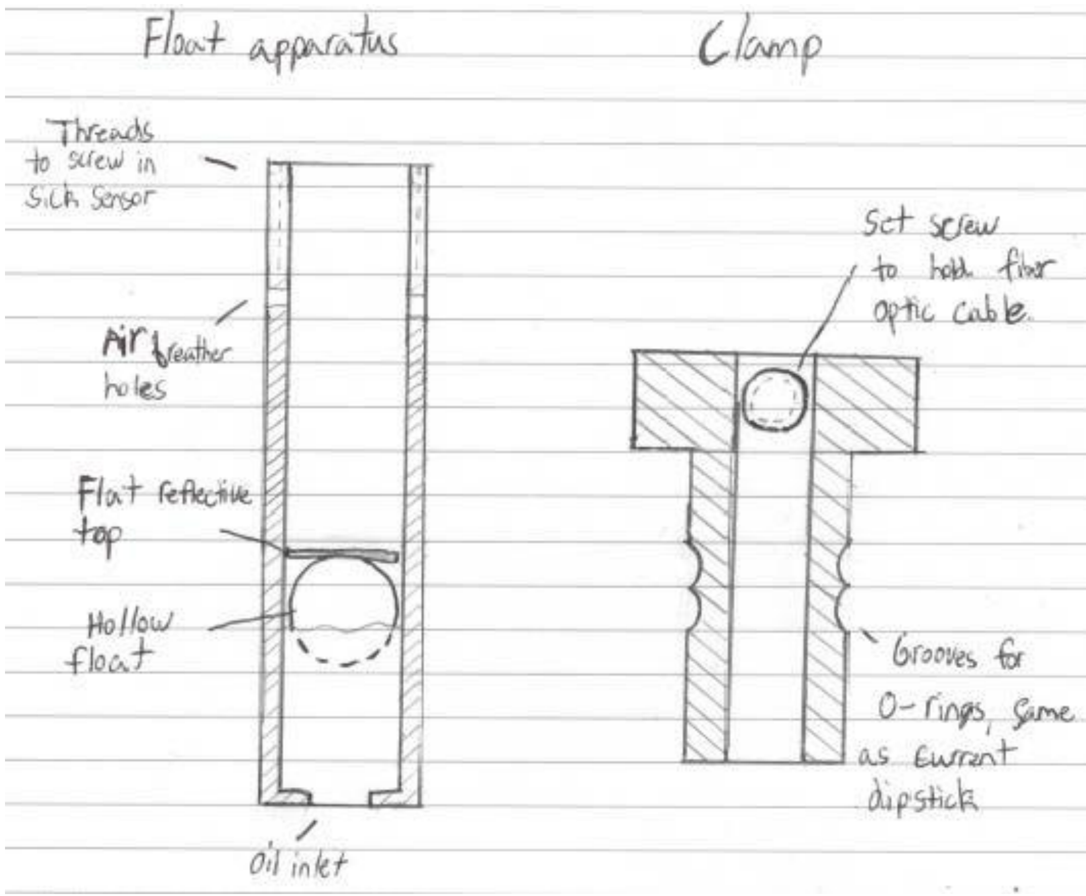

Figure 3. Innovation of Float and Clamp to Previous Design

In the design shown above in Figure 3, the float is being improved to have a spherical hollow shape in order to be evenly displaced in the oil. A flat circular plate is tack welded onto the sphere to keep the oil from going on top of the sphere. The flat surface will be reflective and is needed for the optic sensor to give a stronger reading. The fiber optic cable will measure the

change in distance by using the circular plate to reflect a beam, and the SICK sensor provided from last year's team will record the reading. The float will reside inside an encasement to eliminate the possibility of broken parts falling down into the oil pan and into the crankshaft. The encasement is screwed on at the end of the fiber optic cable. Since the clamp from the previous design was difficult to manufacture and had a complicated design, the clamp is also being improved. An O-ring will be used to seal the dipstick tube and hold the assembly. The fiber optic cable will be clamped with a set screw once the fiber optic cable is routed down the dip stick tube to its required length.

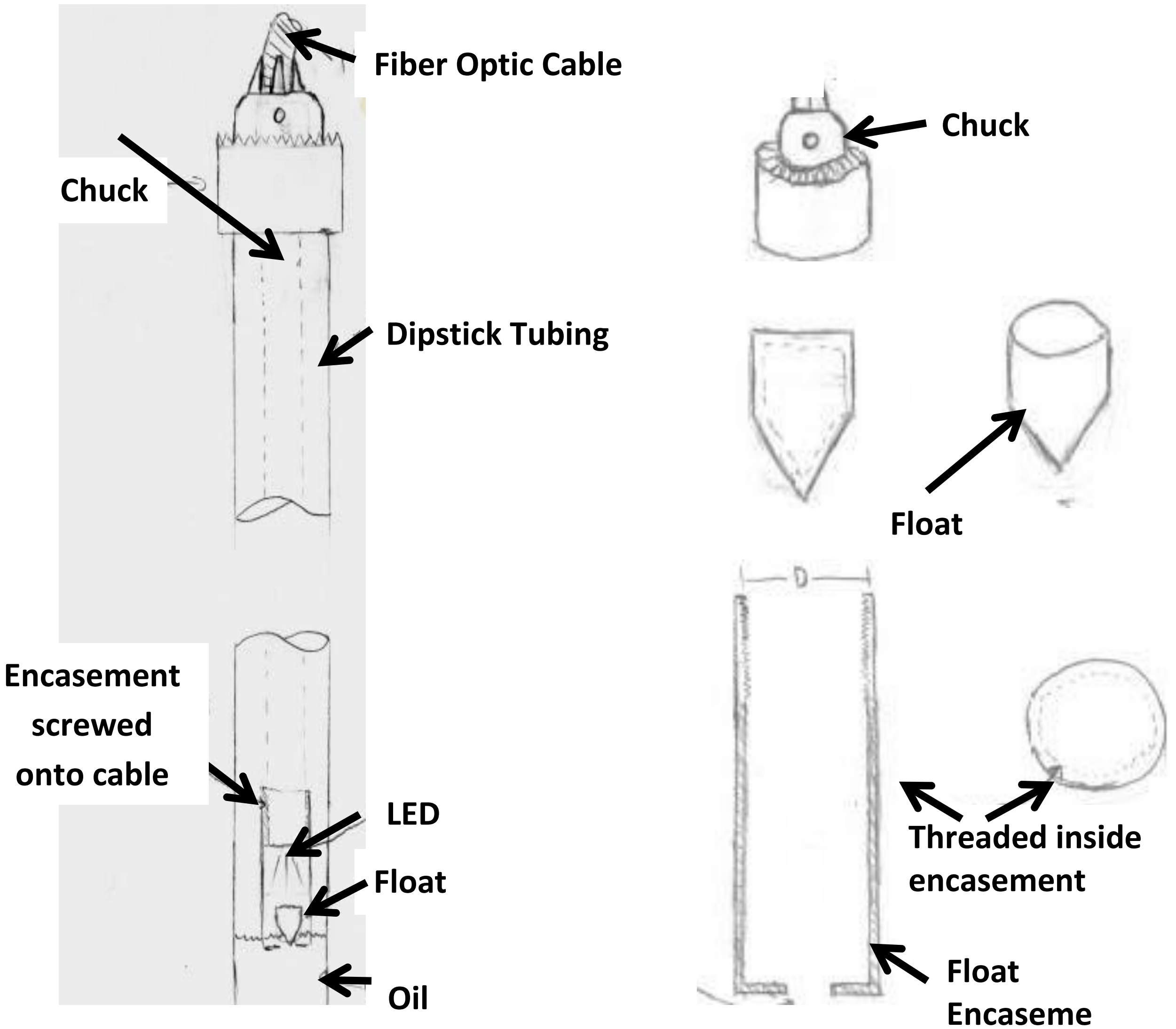

Figure 4. Innovation of Float and Clamp

The design in Figure 4 is very similar to the design in Figure 3 with some changes to the float and to the clamp. The clamp used in this design is a type of chuck design. The three prong chuck will hold the fiber optic cable in place. The chuck will be placed at the top of the dipstick

tube. The float design will be changed to the conical shape shown in Figure 4 above in order to allow the flat surface of the float to be facing upward. The flat end will be the reflective surface and the bottom of the float will be design to be evenly dispersed in the fluid.

With a chosen conceptual design, testing with the fiber optic cable could begin. Before testing with the fiber optic cable, the SICK sensor needed to be programmed. Now that the team had two possible designs, further tests were done with the fiber optic sensor in order to ensure the sensor worked correctly. To do this, we tested the sensor in dry air with different reflective materials and noted how the data read by the SICK sensor changed. From the readings taken, it was concluded that the SICK sensor was not the best choice for this application because the readings were nonlinear. However, we continued to push on with this design using the SICK sensor because our team believed that the 5^{th} order trends seen by the SICK sensor could be calibrated to a linear trend using a control system. After testing the sensor in dry air, another test was done to see how the fiber optic cable would read when exposed to a wet environment. For this test, the previous float needed to be placed in water to see if it floats in water. If it did float, then the fiber optic cable and SICK sensor will be used to take readings while the float is submerged. After testing, the same 5^{th} order trend seen in dry air was seen in a wet test. This concluded that it was possible for the fiber optic cable to take a reading through a clear fluid. The only test now was to test the fiber optic cable and SICK sensor with the actual dip stick tube and oil.

After receiving a pair of dipstick tubes from Mercedes-Benz on December 5^{th}, 2012, we were able to test the optic sensor within the dipstick tube. The size constraints still needed to be tested. During testing, it was discovered that the optic sensor float attachment from last year's team was unable to completely fit down the dipstick tube. To make matters more complicated, this was seen with the simpler of the two dip stick tubes received from Mercedes-Benz. As a result, the team decided that the fiber optic was not going to be the best design for our application. With the optic sensor unable to fit down the dipstick tube to its required length, both designs in Figures 3 and 4 will not be able to work under the specifications of the design. Further idea generation was now needed. To do this, the team now went back to the decision matrix and began to look into other technologies for this application.

"Float and String Potentiometer"

Our team once again had to return to idea generation to move on from the fiber optic cable design. Each member of the group separated and performed individual idea generation which consisted of component brainstorming and full concept designs. After 45 minutes of ideation, the team regrouped and discussed each other's conceptual designs. As each member proposed their designs, the other two members gave constructive criticism. As the pros and cons of each design were discussed, new ideas for a possible design arose from building off of each other's design. Three designs were chosen that seemed to be able to satisfy the design requirements.

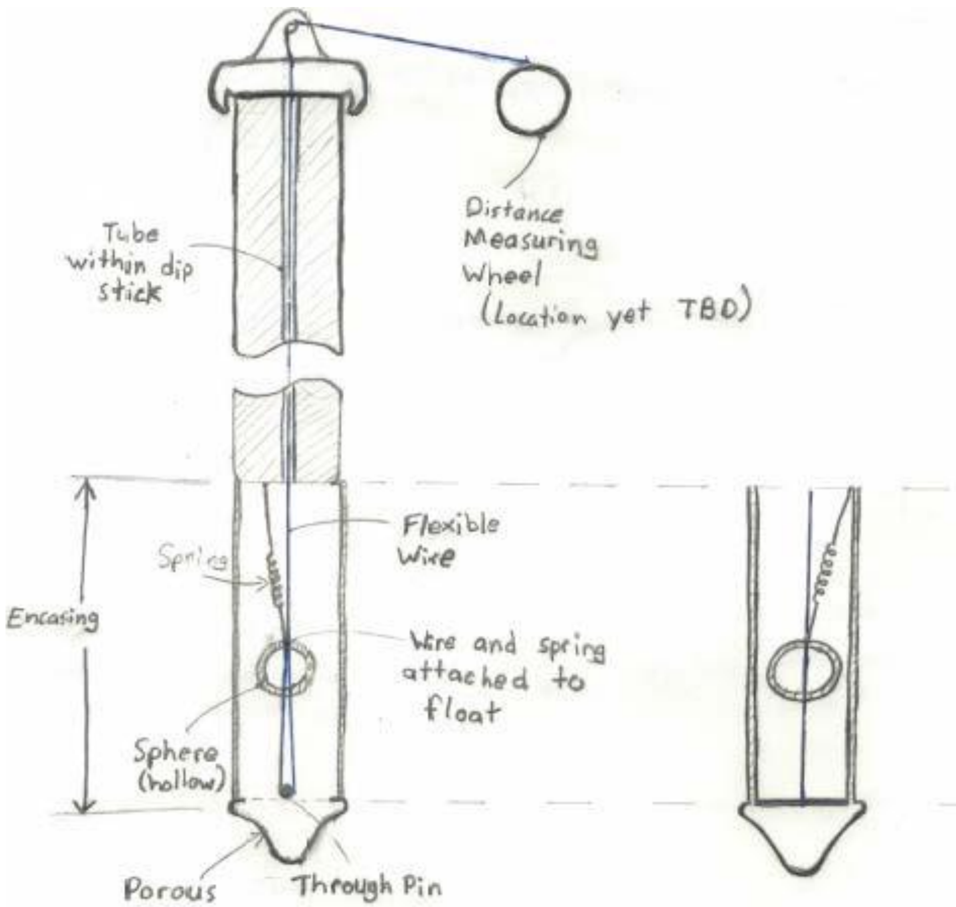

Figure 5. Spring Loaded Float with String Potentiometer

This first design can be seen above in Figure 5. This design satisfied the size requirements needed to fit into the dipstick tube. It consisted of a string potentiometer wire attached to a hollow float. The change in distance from the string potentiometer to the float will determine the height of the oil level. In order to minimize the amount of buoyant force need to cause a change in distance, a spring was added to be attached to the float. A rough buoyancy calculation was done in order to prove the design feasible.

$$F_{bouyant} = \rho_{oil} \times V_{displacement} \times g \qquad \text{[Eqn. 1]}$$

The resulting buoyant force proves this design is not feasible. The average density of Mobil 1 ESP oil is 0.85 g/mL. In order to calculate the buoyant force that can be provided, one must use Eqn. 1, where ρ_{oil} is the density of the Mobil 1 ESP oil, $V_{displaced}$ is the volume of the displaced fluid, and g is the acceleration due to gravity. From this calculation, it was calculated that the expected buoyant force of a completely submerged spherical float is to be 9.4×10^{-4}N. This is much too small of a force to work with. In addition, this design consisted of a bend around a very tight radius, which will cause problems for the slip around the bend. Take this into account, add in the spring, and your resulting design is one with low reliability. At this point, the other designs needed to be considered.

"Capacitive/Conductivity Sensor"

From the first meeting with MBRDNA on October 5th, 2012, it was clear that Mercedes-Benz wanted to stay away from mechanical designs. That is, designs that used mechanical parts in order to measure the oil level. With this in mind, sensors that used fundamentals of electrical circuits, such as resistive, capacitive, or conductive sensors, seemed to be the best choice. This led to our second design after the fiber optic cable.

After reviewing the research done by last year's team, our team found that none of the sensors currently on the market can be used for our application. However, our team believes that the technology behind these sensors is best for our application. These sensors seem to meet all the design specifications except for the size. We believe that because the technology has already been proven to work and already exists, the best design for measuring oil level will be a redesign of current capacitive or conductivity sensors. It is known from research of oil that it is a dielectric material. This will allow us to use the electrical properties to take readings to detect changes in the circuit which can eventually be calibrated to a percentage scale.

The design constructed can be seen on the next page on Figure 6. It utilizes two rigid parallel wires that are securely attached to an encasement nearly identical to the current tip of the dip stick. The reason for this is that the current dip stick tip is known to meet the design specifications for temperature and size. The encasement will resemble a hollow dip stick tip with stripped electrical wires securely fastened using an epoxy or an adhesive. The two wires will maintain a constant distance of separation and must remain parallel during data acquisition. The dielectric properties of the oil and the two parallel wires will create a capacitor. This will allow us to measure the capacitance of the system. As the oil level rises the capacitance will increase.

Our team tested this method during winter break. For this test, we had a pan full of motor oil at room temperature and submerged two wires connected to a power source supplying a constant 12 *V* voltage to the oil. We used a multi-meter to try and detect a change in either voltage, current, or resistance within the oil to find a correlation as the depth of submerged wire increased. Figure 6 below shows a representation of two wires enclosed in a hollow casing. Oil is allowed to go into the casing.

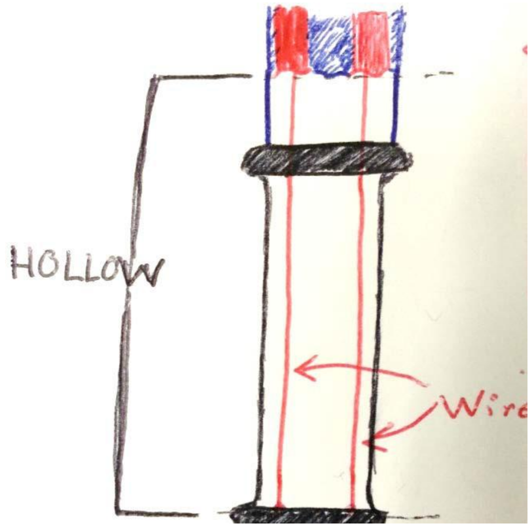

Figure 6. Parallel Conducting Wires

Figure 7 below shows the wiring diagram for the test performed. After testing, we learned that the oil was a complete insulator and no voltage, current, or resistance change was detected. The two wires were at a distance of 1 cm apart.

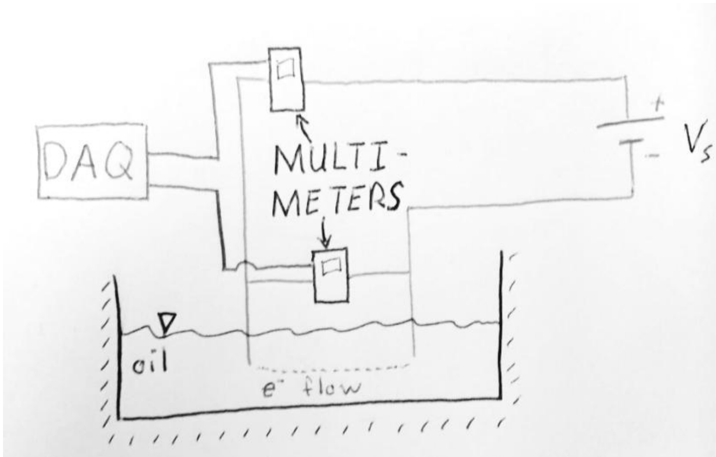

Figure 7. Electrical Circuit for Measuring and Data Acquisition

After learning that the oil insulated the current, the conductive method was not a possible method for this project. We went back to another design for previous ideation.

"Linear Actuator"

Another possible design that our team came up with used a suction method with a linear actuator (similar to a syringe). From Bernoulli's equation we know that there is a linear relationship between the oil level and linear distance traveled by the actuator. This method would allow easier calibration to the percentage readings that Mercedes-Benz has asked for. The design consists of a linear actuator connected to a plunger within a plastic tube (PTFE) which would suck up the oil when the linear actuator is retracted. A sketch of this design can be seen in Figure 8 below.

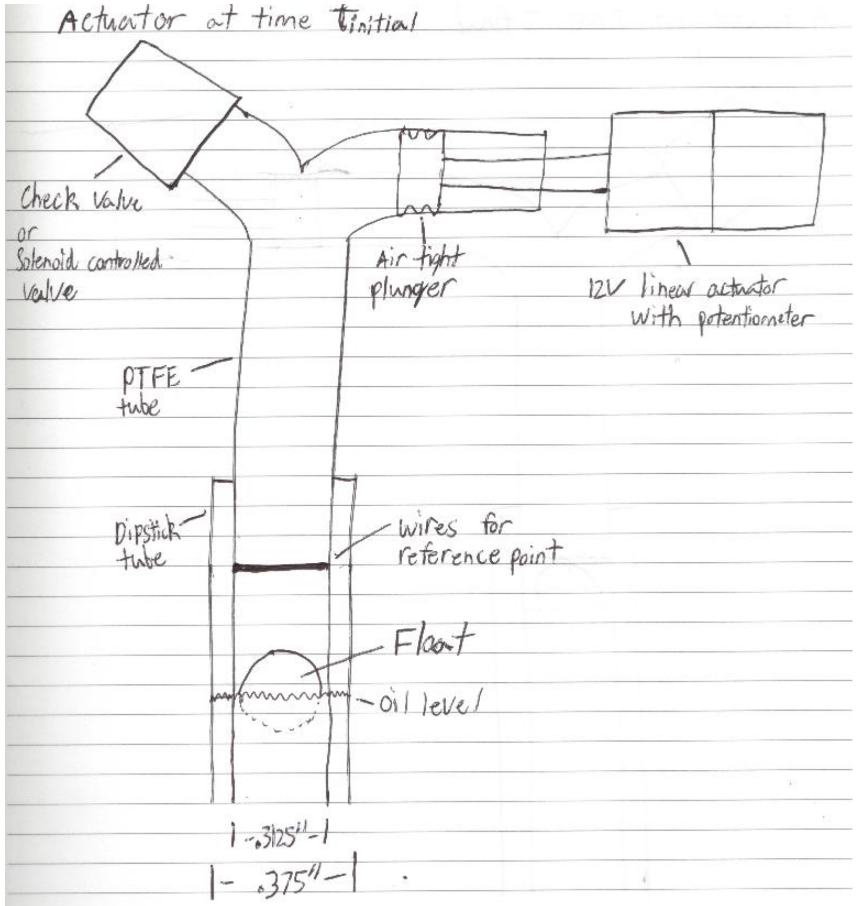

Figure 8. Linear Actuator design for oil monitoring.

The linear actuator creates a negative pressure to lift the level of the oil to a reference point that will be used to give the oil level reading. This reading will be recorded when a float (which raises and lowers with changing oil level) makes contact with the two wires that will be located at the reference point. The float which has conductive properties will short the two wires. This will trigger a circuit that will cause the linear actuator to stop once the float has reached the reference point. The final displacement of the linear actuator will be recorded and used to reference the oil level. Since the oil level will be recorded 5 minutes after the engine has turned off, the properties of the air within the dipstick tube needs to be considered. While the engine is on, the pressure of the air inside the tube increases due to the high temperatures seen within an engine. To account for this pressure differential, a check valve was added in order to release air pressure from the tube. The check valve is such that it allows air to escape but no air could get back into the tube.

A linear actuator for this application was found online made by Progressive Automations. The linear actuator is a PA-14P Linear Actuator with Potentiometer. The actuator rod diameter and the tube inner diameter have a 1:1 ratio giving us a direct relationship between the change in displacement of the actuator and the oil level height. The maximum change in oil level to meet the -50% to 150% would be a change of 50 *mm*. The PA-14P Linear Actuator with potentiometer met the stroke length needed with more room for the actuator to travel if needed.

A test was done to show the direct linear relationship of the oil level and the movement of

the plunger. For this test, transparent plastic tubing representing the dipstick was oriented to match the geometry of the dipstick. A syringe representing the linear actuator was securely fastened to the top end of the tube using a strong adhesive. The apparatus can be seen in Figure 9 below. The plastic tubing was put in a pan filled with oil and the syringe was pulled back to apply negative pressure on the oil. Millimeter tick marks were placed on the tube, as shown in figure 10 below, in order to get a relationship of height of oil within tube and distance syringe plunger was pulled. The data was plotted and showed a linear relationship (Figure 11).

Figure 9. Syringe Test Apparatus

As design development for the linear actuator method was being developed, our team learned that the previous section where our team believed the oil level was read was incorrect. It was discovered that the actual section is before the initial section; therefore our team was able to go back and check feasibility on the fiber optic cable. This time the fiber optic cable had no problem reaching the designated section in the dipstick tube with a float attachment. However, by this time our team had already discovered that it is possible to read the oil level directly without the use of a float. As a result, our team decided to move forward with both designs (fiber optic cable and linear actuator) since both met size requirements.

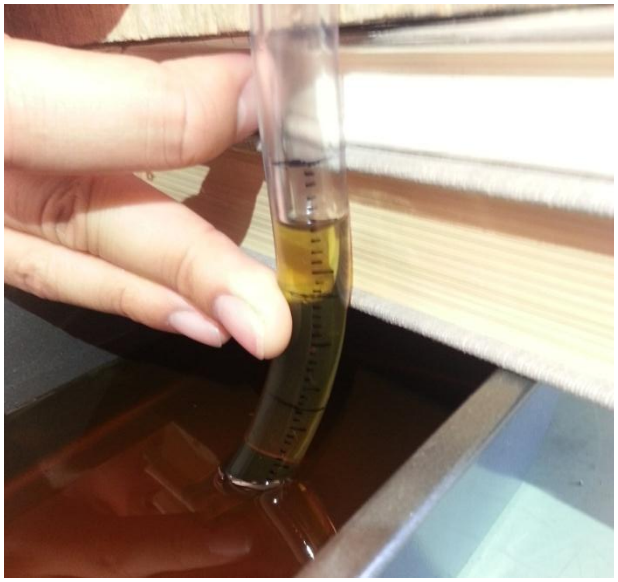

Figure 10. Graduated tick marks in millimeters

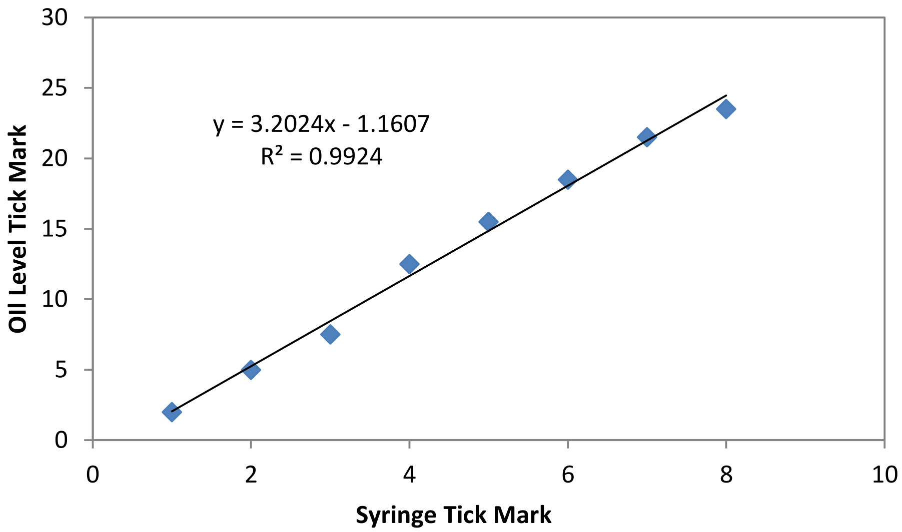

Figure 11. Syringe Test Results

Mercedes-Benz looked over this actuator design and the tests that we did and accepted this design as "plan B" but asked us to continue tests on the optic sensor to see its functionality for more realistic situations. For this, our team did multiple optic sensor tests such as sensing oil level directly (without the use of a float), sensing hot oil, sensing oil after oil splashes on sensor, testing the consistency of the readings after splashing, different fluid property test, testing with used oil, and testing in the actual curved segment of the dipstick tube.

Multiple Optic Sensor Tests

The float from the previous group was unable to remain buoyant on the synthetic oil that Mercedes-Benz vehicles use. Since a system using a float to measure the oil level requires a working float, a test was done to determine if the oil level could be measured directly by the fiber optic cable and sensor.

Oil was placed into a metal pan and the fiber optic cable was oriented such that the incident beam coming out of the fiber optic cable was normal to the oil surface. The optic sensor was placed at different distances from the oil surface and the readings were recorded and plotted on a spreadsheet. This test showed the fiber optic sensor is capable of reading the oil level directly without the use of a float. When the angle of the fiber optic cable was changed slightly, however, the readings greatly changed, meaning that the fiber optic cable is very sensitive when reading at different beam incident angles. Also, our team believed that the reflective bottom surface of the oil pan was affecting the reading. This test needed to be repeated. Our team decided to use a tall container to eliminate the issue of reading the bottom of the container. The repeated test had the same parabolic trend as the previous test. Since both methods of testing showed similar trends without the use of a float attachment, our team concluded that it is possible to read the oil level directly from the oil surface without the use of a float.

The oil level would be measured within the dipstick tube after the engine has been running for 8 hours. The oil being measured would be heated to an operating temperature of around 200 - 250 °F and splashes all around the dipstick tube. The direct oil level reading test was repeated with oil heated to its operating temperature. The test had similar results and showed that the sensor can measure the hot oil directly and the data produced a trend line. We contacted the manufacturer of the optic sensor (SICK Inc.) to see whether the optic sensor will still function when having a thin layer of oil on the fiber optic cable receiver. The manufacturer confirmed that the sensor should function with those parameters and the readings will auto-correct with a bias. The sensor was dipped within the hot oil and the same tests were done with the same parameters. The measured data were not similar to that of the dry sensor due to the thin layer on the receiver affecting the values. The data, however, had a similar trend with only a bias.

After learning that the sensor is capable of measuring oil under the realistic operating conditions, the consistency of the readings was tested in a real vehicle test. The fiber optic cable was placed inside the dipstick tube of James' car and was powered by a portable 12 VDC battery inside the vehicle. Five trials were done and the car was driven on the same route and parked in the same spot after each trial. A reading was taken after the five minute settle period after the engine was shut off. The readings after each trial showed consistency and changed by around 1 or 2 digits. This test proved that the sensor will work in real conditions when oil is splashed on the sensor and still provide consistently accurate readings.

Knowing that the sensor can work in the working conditions for the application that MBRDNA had asked for, we needed to see how the properties of the fluid will affect the sensor. The properties of oil such as density and transparency will change as the oil is cycled through the engine. For this test, we gathered different types of soft drinks with different properties and

transparencies and tested these fluids under the same conditions. During testing of the first fluid, the sensor reading consistently dropped and didn't settle on one number. We changed the fluid, tested it, and noticed that the readings stayed on a number at each level. Both fluids were looked upon and the main difference between them was the carbonation. We noticed that one fluid was carbonated, and it was the carbonation that was affecting the readings of the sensor, causing the readings to drop as carbonation left the fluid solution. This could be a potential problem knowing that the properties of a fluid can skew the readings. This posed concern since very slight changes in a a fluids properties produced large changes in the sensor readings. However, our team ignored the carbonization of the fluid and looked at the magnitudes of the readings since we knew that Mobil 1 ESP is not carbonated. We discussed this problem of transparency with MBRDNA and asked if we could attain used oil at different stages of its life. MBRDNA mentioned that we don't need to worry about this so much since used oil after 20 miles is nearly identical to used oil after 20,000 miles.

The dipstick is currently used to measure the oil level within the dipstick tube. All the dipsticks vary between 100% full tick mark of the dipstick and the distance to the tip of the dipstick. The dipstick that we have been testing measures the oil at a curved location within the dipstick tube. We tested the optic sensor measuring used oil level at the location that the oil would be measured at. The results had a trend showing that the used oil within the slightly curved path could still be measured by the optic sensor. However, if the oil level drops past the curve, then line of sight is lost and the sensor is unable to make consistent readings. If the sensor has to measure the oil level in a curve path, it may be difficult to reach the target range of -50 to 150%.

Clamp Redesign

Before continuing on with the system, our team wanted to spend a couple hours thinking of how to redesign the clamp. The current clamp that was designed by last year's senior project team has a lot of complex geometry that required a CNC (computer numerical control) machining. The result was a very expensive clamp.

The new clamp was designed to take advantage of the groove on the dip stick that uses an O-ring. Also, in order to simplify the design, the top half geometry of last year's clamp design was reused. Rather than use a hinge with two screws to fastened and secure the fiber optic cable, a near symmetrical back plate will be used along with two M4 x 0.7 - 20mm long bolts. The bottom half of the clamp will be placed inside the dipstick tube and will have an O-ring around the outside. The bottom half of the clamp is being design to imitate the current O-ring on the dip sticks seen in Figure 12 below.

Figure 12. Part of the dipstick handle that is being recreated for the clamp design.

The highlighted part in Figure 12 will be recreated for the clamp but will now be made of aluminum. Attached to the bottom half of the clamp will be the previous design from last year's clamp design. The new clamp design can be seen in Figure 13 below.

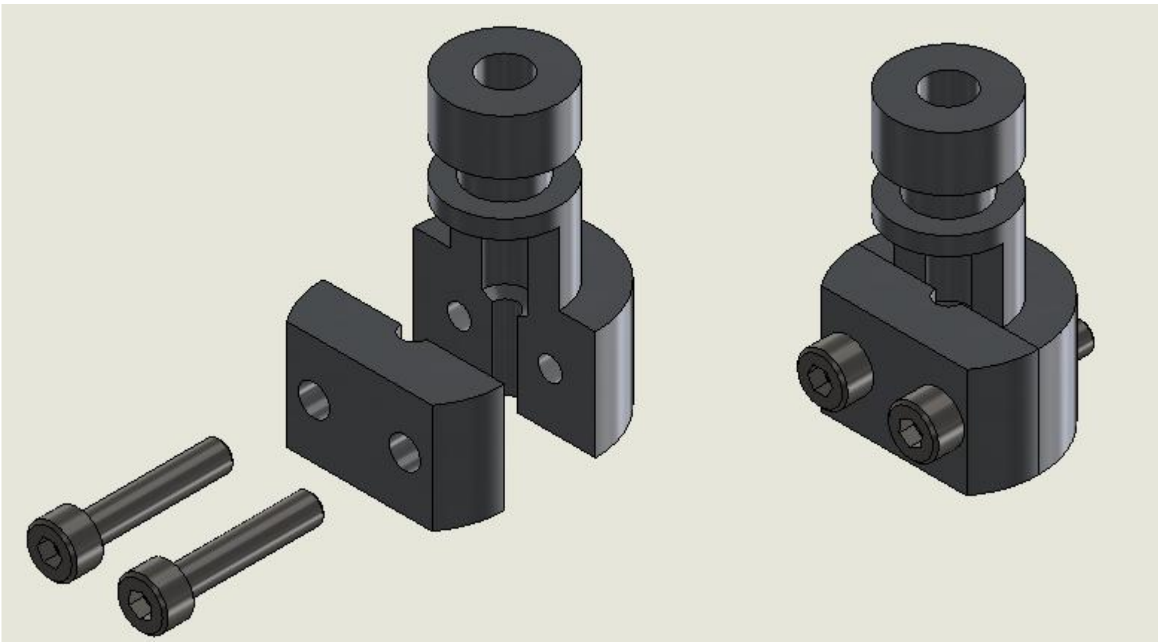

Figure 13. Clamp Redesign

Fixture for Testing

Now that our team felt that the fiber optic cable is the best choice for this application, a fixture needed to be designed for our testing to ensure that all parameters can be controlled, such as orientation of the dipstick tube or the amount of oil within the tube. The fixture will be initially designed such that all testing can be done under a controlled environment for each dipstick tube. The testing can be seen below in Figure 14.

Figure 14. Fixture setup for future testing.

For the testing fixture, tubing that could withstand more than 200°F for our application. Research led us to using 1/2-*in* and 5/8-*in* fuel line hose that can withstand temperature up to 257°F, purchased from Napa Auto Parts. The 1/2-*in* tubing was chosen so that the dipstick tube (OD = 1/2-*in*) can create a tight seal when placed inside the 1/2-*in* hose. Hose clamps were used to tighten seals. The 5/8-*in* fuel line hose was used to connect to the graduated part of a syringe. The graduated part of the syringe was level with the section where oil is being measured. This part was used in order to be able to measure different increments within the dipstick. The 1/2-in and 5/8-*in* were connected using and adapter. A T-adapter was also placed at the bottom of the fixture along the 1/2-*in* hose. This will allow us to drain oil to lower oil levels for testing. The dipstick tube is fastened to square tubing. The square tubing is attached to a double hinge that allows pivoting about the x-axis and y-axis. This allows testing to be at different orientations for different

dipstick tubes.

Initial Testing with Fixture

The test fixture was completed on February 24, 2013. Before any tests were conducted, we needed to test out if the oil level within the graduated cylinder and the dipstick tube showed a linear relationship and are at the same height. The oil level at both ends (the cylinder and dipstick tube) is exposed to atmospheric pressure and has no differential in pressure just like an actual engine. This allows us to know the location of the oil within the dipstick tube. The results of the test are shown in Figure 15 below. This test was performed by using the actual dipstick to locate the oil level within the dipstick tube, and compare it to the graduated cyclinder.

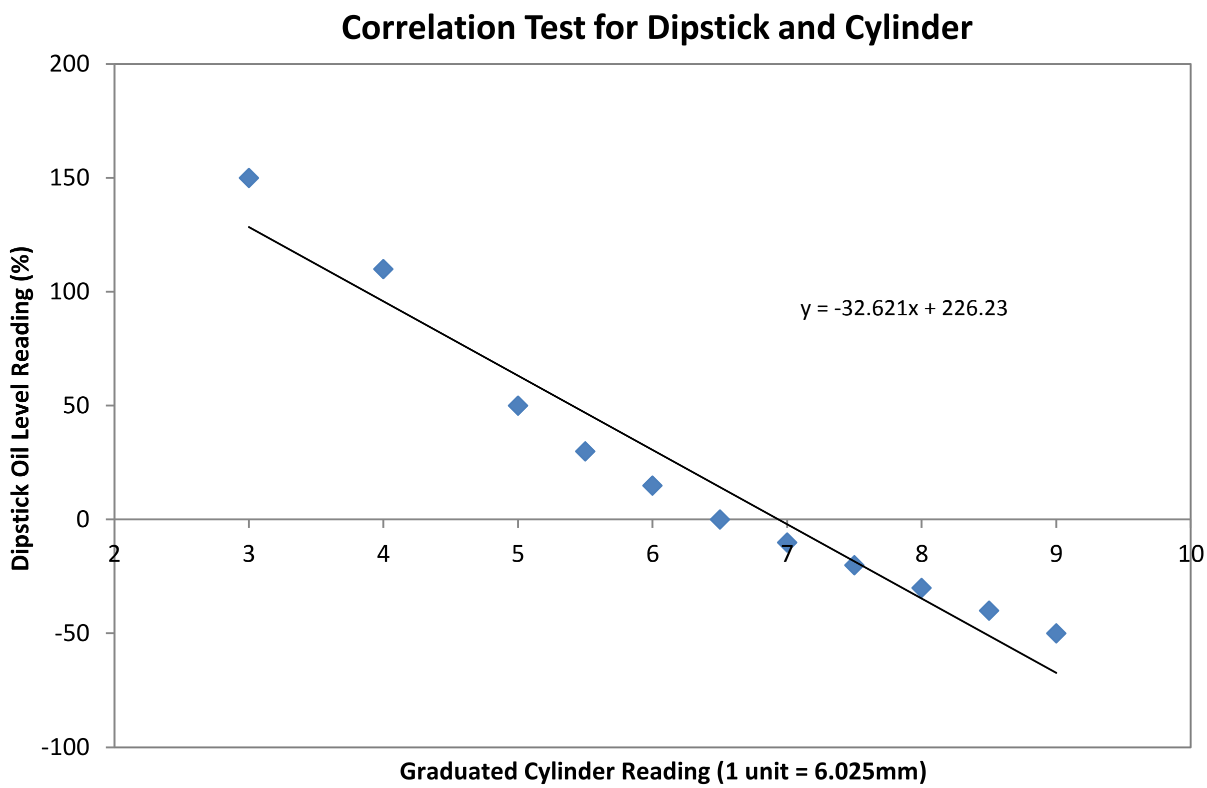

Figure 15. Oil level relationship within cylinder and dipstick tube

The first test with hot oil was performed on the same day. For this test, oil was heated to about 200°F. Oil was poured into the graduated part of the syringe attached to the 5/8-*in* hose until the dipstick tube was full to 150%, which was calibrated by leveling the 3.5 unit on the graduated part to 150% marked on the dipstick tube. The first test consisted of oil on the end of the fiber optic cable. The recorded values gave a constant value. This concluded that perhaps recording oil levels in the curved section of the dipstick tube with hot oil on the end of the fiber optic sensor might not work. The cable was cleaned and the test was repeated without oil on the end of the fiber optic cable. The results can be seen in Figure 15 below.

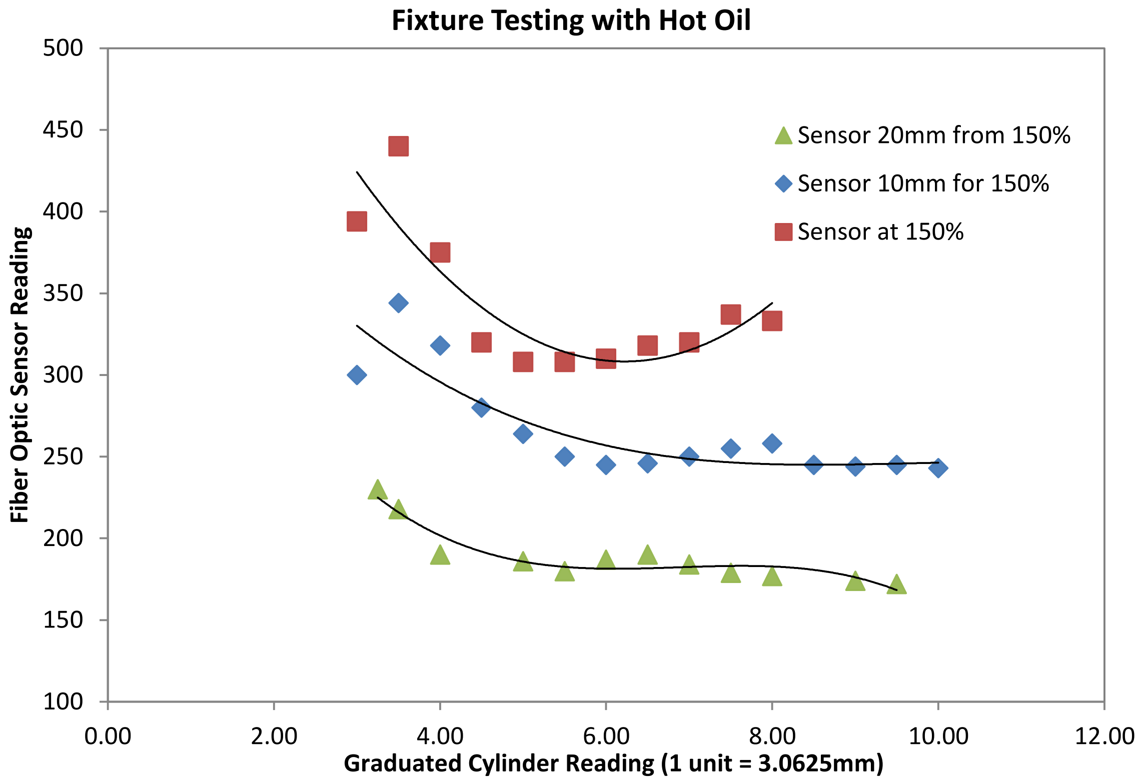

Figure 16. Results for Used Hot Oil Testing at specified distance from 150%.

The results show that the fiber optic cable is not capable of taking linear readings of hot used oil within the curved section of the dipstick tube. For the first run, the fiber optic cable was place at about 20*mm* above 150%. This was measured by placing the fiber optic cable and dipstick tube alongside each other and measuring the position. Runs 2 and 3 were done at 10*mm* from 150% and at 150%, respectively. From the trend lines above, more testing needed to be done to figure out what was causing the skew readings.

In addition, research is being done on a product called Ultra-Ever Dry. The product is a coating that is designed to act as a hydrophobic barrier at the Nano scale. This nanotechnology has the potential to fix the problem with oil getting on the end of the fiber optic cable. Concerns about this technology are that the coating will prevent the sensor from working properly.

Before presenting to MBRDNA, another test was conducted. This test was done with the oil level lying within the straight portion of the dipstick tube. Since this application will be used for a variety of dipstick tubes, testing within the straight portion is necessary since the oil level range will most likely exist in the straight portion of a dipstick tube. The results of the tests are shown below in Figure 17.

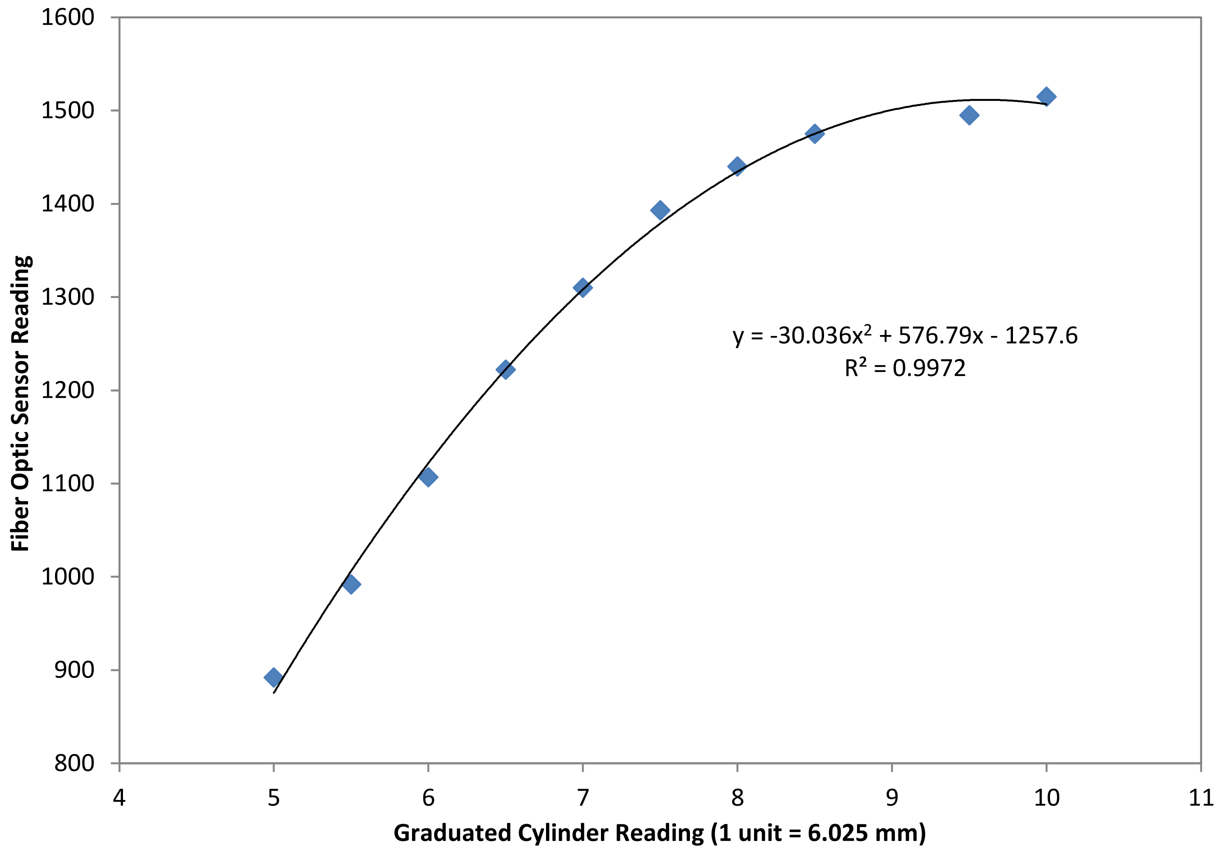

Figure 17. Test done with fixture within straight portion of tube with cold oil

Testing with Constrained Parameters

After presenting to MBRDNA, they suggested that all further tests should be done in the straight portion of the dipstick tube. All further tests should use oil that is heated to the operating temperature of around 200°F.

Due to safety reasons, an alternative method to heating the oil needed to be done. With the help of the Materials Engineering (MATE) department, we were able to find a lab room that would be able to heat up the oil to required temperatures under safe conditions. A flask filled with oil is quenched in heated water and will be heated through convection.

Some adjustments were done to the testing fixture to improve testing. A wooden base plate was added to the bottom of the fixture to provide a non-scratching bottom surface and a more stable base. The wooden base plate has a flat bottom leveling the test fixture. The graduated cylinder was replaced with a tall glass burette allowing for easier pouring. The glass burette has a more precise scale with tick marks measuring tenths of a milliliter (See Figure 18 below).

Figure 18. New fixture with buret attached.

All further tests conducted will have these similar testing procedures. The oil will be heated to around 200°F. Once the oil has reached operating temperature, it will be poured into the burette until the necessary height is reached. The oil level is controlled by draining the oil with the ball valve attached to the fixture (see Figure 18). Data points will be measured at each milliliter increment on the burette.

Previous tests have shown that many variables affect the optic sensor readings. Oil properties such as temperature, life, and opacity play a role in affecting the sensor readings. The orientation of the fiber optic cable and dipstick tube also affects the optic sensor readings. Some variables have a greater effect on the readings than others and these specific variables need to be determined. Before any constrained variable testing will be done, the optic sensor needs to be consistent. With the constrained testing parameters stated previously, four of the same test was repeated. The fiber optic cable remained in the same position within the dipstick. The orientation of the dipstick was directly vertical so the angle of the light emitting from the fiber optic cable was normal to the oil. Figure 19 shown below displays the results of the four runs of the same test.

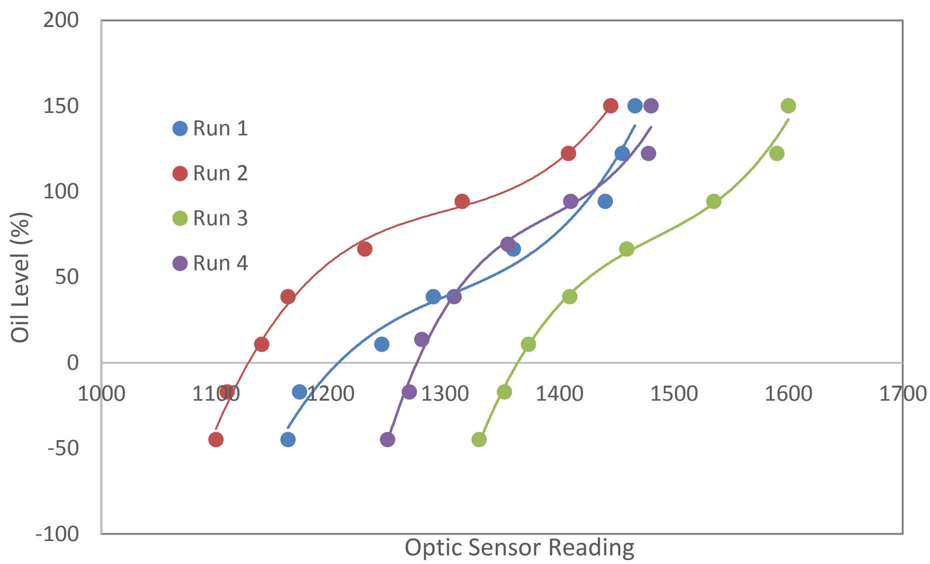

Figure 19. Controlled fixture test with dipstick oriented vertically

After the repeated test, the SICK sensor readings were inconsistent at determining the oil level. This confirmed that there are many variables that need to be checked in order for the sensor to have repeatable measurements. More tests were conducted to determine whether or not the sensor would show any consistencies. The sensor kept proving to be inconsistent.

During some tests, the oil would get onto the end of the fiber optic sensor cable receiver and this would cause an offset depending on the amount of oil on the sensor. The oil would also slowly creep down the walls of the dipstick tube increasing the oil level. As aforementioned, MBRDNA waits five minutes before checking the oil with a dipstick. In order for our tests to match more realistic conditions, we began allowing five minutes for the oil to settle.

More tests were done with this new five minute constraint. A timer is set for five minutes to allow the oil to settle after the hot oil has been poured into the tube. Once the five minutes have passed, the test is conducted and the data points will be measured. The new five minute delay time allows the oil to settle and slightly cool down. Figure 20 shown below displays the results of how the five minute delay affects the oil level sensor readings.

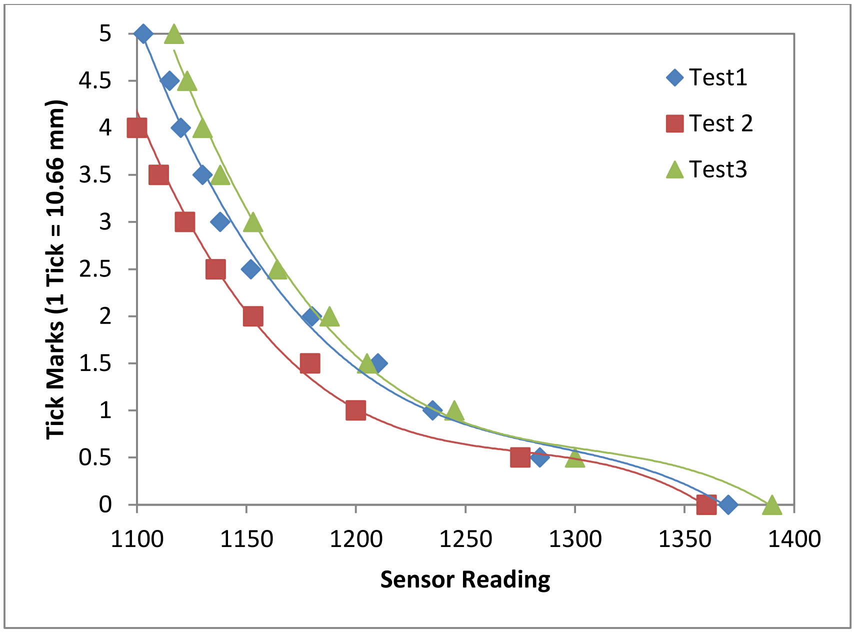

Figure 20. Fixture test with five minute wait time before gathering data points.

The five minute delay increased the consistency of the optic sensor readings. Even though the readings were more consistent, there was an offset that needed to be corrected.

SICK Sensor

From all the tests done, we determined that the sensor itself is very sensitive and many variables can affect the readings. In order to get the most consistent readings, we needed to understand how the sensor works. We have the SICK WLL190T-2P532 optic sensor and a SICK LL3-DW01 fiber optic cable that was selected by last year's team. From reading the manual and specification sheets of both products, as well as contacting SICK, we determined how the SICK optic sensor works. The SICK sensor sends out light from an LED. The light reflects off the surfaces and returns to the receiver of the optic fiber cable. The amount of light received (intensity) is measured and converted into a digital signal displayed on the sensor. Refer to Appendix C.1 for the data sheet of the fiber optic sensor.

Knowing that the optic sensor measures the intensity of received light, we did further research on possible equations that could help us improve the readings and the theory behind it. Cal Poly Professor John Sharpe has a Ph. D in optics and helped us understand how the sensor works. A red light emitting diode (LED) sends light in all directions. In order for the most intensity to be received, the photons from the LED need to reflect back to the receiver. Depending on the medium, some light will pass through, some will reflect back, and some will be absorbed into the matter. Our team came up with an idea of placing the sensor inside a collar or sleeve that will reduce the gap between the sensor and the dipstick tube walls. For the best intensity received, the material would need to reflect the most light back without absorbing much light or allowing light to pass through it. Finding a material that would match the criteria while being rigid enough to fit through the dipstick tube would take a large amount of research. In order to test this concept our

team will use aluminum to quickly prove the concept.

After understanding the most ideal way to receive intensity, we came up with two possible solutions. One idea was to develop a collar that would be attached to the threaded end of the fiber optic cable. This collar would give a tight clearance within the dipstick tube in order to keep the fiber optic cable in the center and so light does not pass behind the receiver. The light would pass behind the receiver but reflect off the surface of the collar, dipstick tube walls, and oil until it is received. The other solution was to create a sleeve that would be threaded on to the end of the fiber optic cable. This sleeve would be long enough to reach the oil at its lowest point measured (which is -50%). The light emitted from the LED would be completely retained within the sleeve and only reflect off the oil and the walls until it reaches the receiver.

Both solutions would improve the results of the optic sensor readings. In comparing the two solutions, the collar is easier to manufacture and the material would not have to be flexible. An aluminum collar was manufactured and used for further testing.

Testing with Collar Attachment

With the collar attached, the consistency of the sensor was tested. Two runs of the same test were done with the collar attached. Figure 21 below shows the results of the collar.

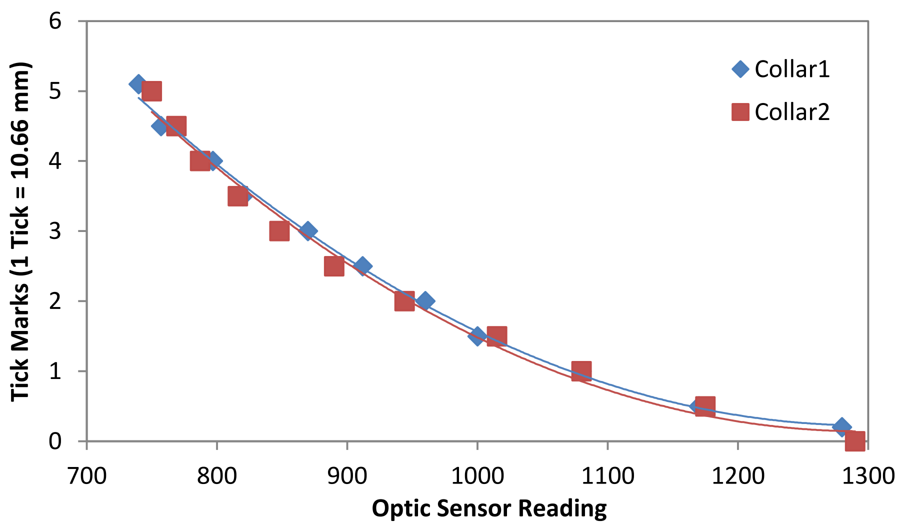

Figure 21. Two runs of same test with collar attached.

The collar greatly improved the optic sensor readings. More tests were done with the same collar to test consistency. The same results were difficult to reproduce and a problem was found in our collar design. When oil goes beyond the collar it remains in the minimal clearance between the dipstick tube wall and the collar. This thin film of oil creates a vacuum seal creating a pressure difference between both ends of our system when we lower the oil level out of the drain valve. Adjustments to the collar needed to be made. The collar was redesigned to have a smaller outer diameter and have grooves along the side for air to pass through and escape to atmospheric pressure. An image showing the isometric view of the collar is shown below in Figure 22. Refer to appendices for CAD drawing.

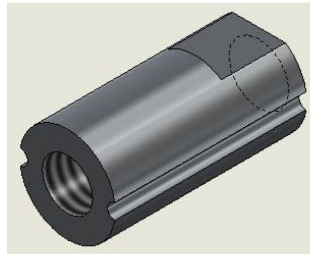

Figure 22. Isometric view of redesigned collar

Many iterations of the collar were created in order for us to test which design gave the best results from the fiber optic sensor. With the new collar design further tests were done for consistency. The threads of the collar need to stop just before going all the way through to the end. This will allow the collar to be tightened with a 5/16inch wrench applied to the flat sides of the collar.

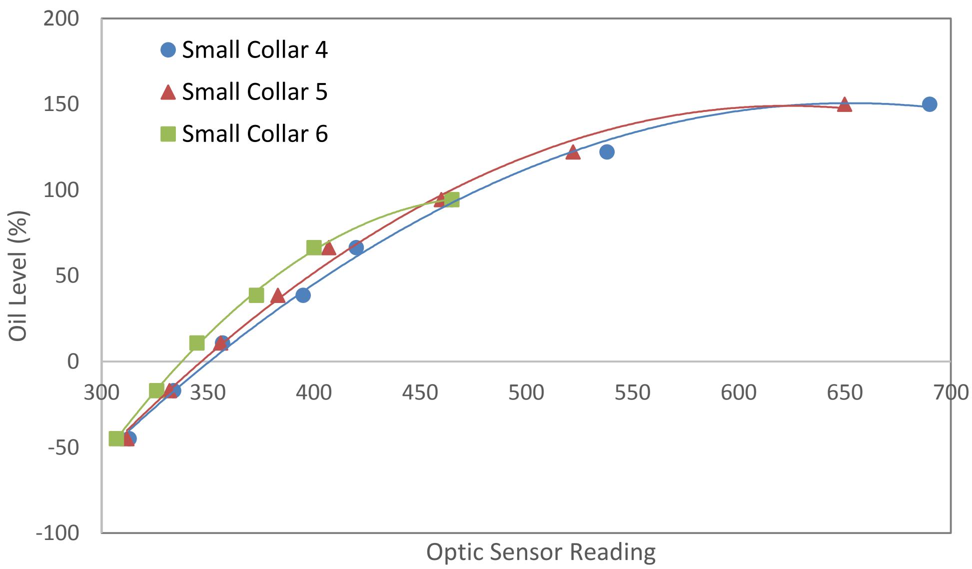

Figure 23. Three runs of same test with redesigned collar

The new collar gave consistent results like the original collar. More tests were done with the collar redesign and proved to remain consistent as seen in Figure 23 above. With the new collar the sensor shows the reliability that MBRDNA is looking for. Now that the sensor is showing consistent readings we are able to test and control specific variables that may affect the optic sensor readings. The size and shape of the collar is still an active research area. The length of the cylinder, diameter, and size of the groves are variables that need to be tested to find the best collar. The length and diameter of the collar play an important role for the ability of the collar to slide down the dipstick tube. However, it is always possible to insert the collar from the bottom of the dipstick tube to bypass the curvature of the tube. This does require partial removal of the dipstick tube from the engine.

The orientation of the fiber optic cable was controlled with the clamp and the collar

attached. The clamp maintains the length of the fiber optic cable within the dipstick tube. The collar keeps the sensor and receiver closer to the center of the dipstick tube. Since the fiber optic orientation is controlled, the other variables such as oil properties and dipstick tube orientation will be looked at.

During vehicle testing, the driver will travel through numerous routes and locations, stop the vehicle, and check the oil. Not all locations will be flat and level so it is necessary to determine how the angle of the oil surface relative to the dipstick tube affects the reading. There are also many different types of dipstick tubes that this system will be used for and the dipstick tube will not always be directly vertical. With these realistic conditions, we determined that the dipstick tube orientation has the most priority on variables needed to be tested.

The same test procedure was done at different angles. We oriented the dipstick tube at 15°, 30°, and 45° from vertical. At each angle, two runs were done and the data was gathered and compared. The range of the oil level (from -50% to 150%) was arbitrary depending on the degree of the angle. We are able to make this assumption since the fiber optic cable could be adjusted and the distance from the oil can be controlled. The most consistent ranges for -50% to 150% were chosen. The results are shown below in Figure 24.

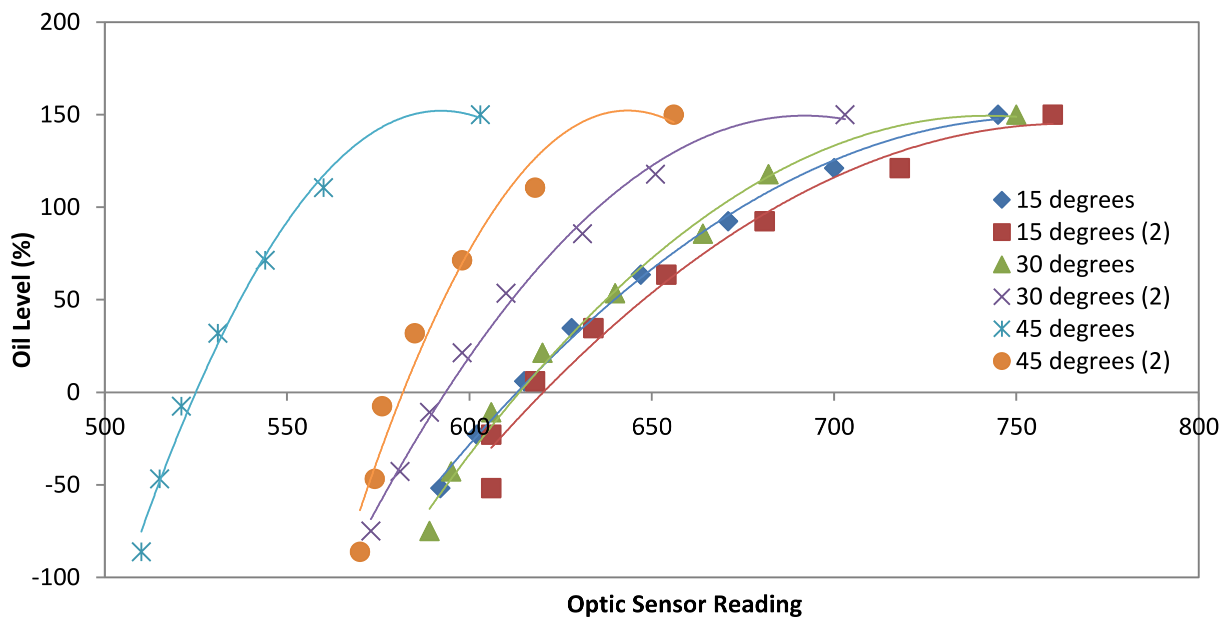

Figure 24. Two runs at each angle.

From the test at different angles, the optic sensor readings remained consistent at 15° from vertical. The 30° orientation gave a slight offset and needs further testing, while the 45° orientation showed no sign of consistency. From the results shown, more tests at angle increments need to be done in order to determine what angle would be too extreme and make the sensor unable to work.

We received used oil from MBRDNA and tested the oil at different life cycles, but we were unable to test with our fixture due to the coloration of the oil. The used oil was too dark and the burette was unable to be read. A few more modifications need to be done on the testing fixture in

order to test the used oil.

Testing Conclusions

The sensor itself cannot be used to determine the oil level. With the attachment of a collar and the time delay of five minutes, the sensor shows consistent measurements and can be used to determine the oil level. The optic sensor can only work at certain angles from vertical, roughly up to a maximum of 30 degrees from vertical. The clamp allows for compatibility with different dipstick tubes by using simpler geometry, resulting in lower manufacturing costs. All tests done were with the testing fixture we created and in order to know whether or not the SICK sensor would work for this application, the sensor needs to be tested inside an engine and under real conditions. The next step is to test the sensor with varying dipstick tubes. The tubes need to be oriented in the same way that they are attached the engine, so orientation and position of the dipstick tubes need to be determined for all engines. The testing fixture will be used to create calibration curves for each dipstick tube. This calibration curve will be used with an onboard computer in order to compute the oil level as a percentage. Actual testing inside of a car will need to be conducted, and verified by a real dipstick to prove the reliability of the sensor. Life testing of the sensor has still yet to be determined.

Control System

Mercedes-Benz has asked our team to record the oil level exactly 5 minutes after the engine has been shut off. The best way to handle this requirement was to design a control system that would record the oil level 5 minutes after the engine is turned off by means of a microcontroller. An Arduino UNO microcontroller will be used, shown in Figure 25 below. Since no member of our team has experience using microcontrollers or programming experience, our team will read over the technical specifications, applications, and instructions for the Arduino.

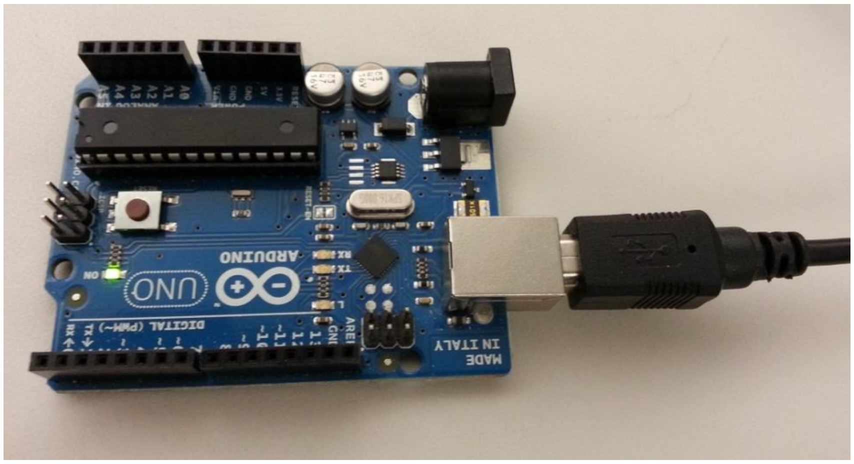

Figure 25. Arduino UNO Microcontroller selected for application.

The team began to research microcontrollers and their applications in order to see if the microcontroller is feasible for our application. From our research it was found that

microcontrollers are very common in timing subsystems. To begin, the microcontroller acts as an open until it is turned on. First, an input signal is received by the microcontroller. This signal triggers a preset counter programmed into the microcontroller. Once the counter has counted the preset number of counters, the output signal is allowed to pass and will “turn on” the overall system. More research is still being conducted with regards to the Arduino UNO.

All hardware involved with this project will be returned to Cal Poly’s Mechanical Engineering department for shipment back to MBRDNA in Long Beach, CA, as per requested by MBRDNA.

Management Plan

In order for the project to be successful, each team member carries a role and responsibility that contributes to the project based on his strengths. In addition, each team member is required to assist and understand all aspects of the project. The separate roles and responsibilities are listed as followed:

Name	Role
Emmanuel Camacho	Main contact, documentation control
Jonathan Manriquez	Project Manager
James Young	Chief Financial Officer

All members of group participated in tests, design, manufacturing, and writing report.

References

Figure 1: http://www.sensorsmag.com/sensors/leak-level/a-dozen-ways-measure-fluid-level-and-how- they-work-1067

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Appendices

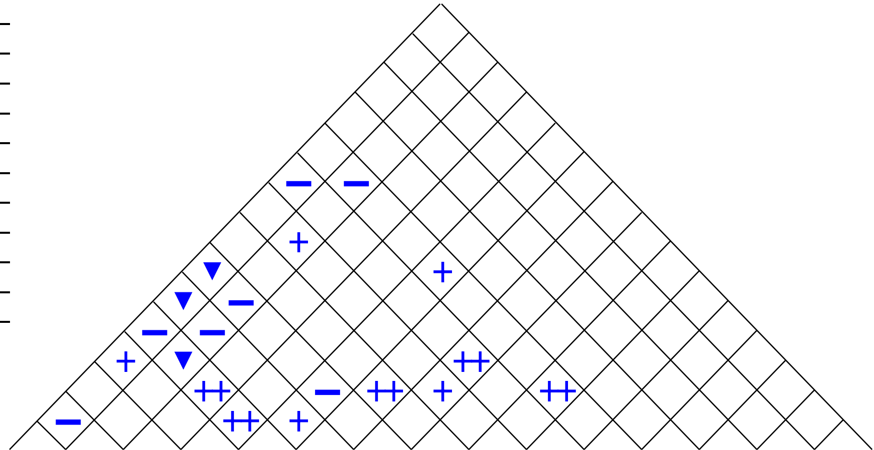
Title: QFD For Oil Level Monitor

Author: Emmanuel Camacho, Jon Manriquez, James Young

Date: 10/9/2012

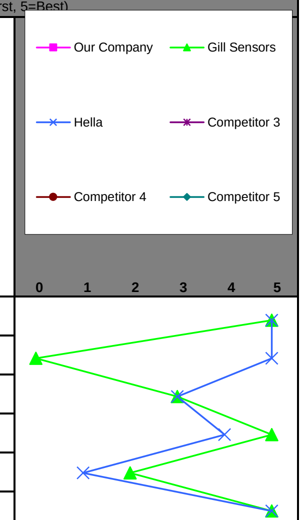
Notes:

Legend		
Θ	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlation	
+	Positive Correlation	
—	Negative Correlation	
▼	Strong Negative Correlation	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
x	Objective Is To Hit Target	



Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Demanded Quality (a.k.a. "Customer Requirements" or "Whats") / Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	1 Adaptable with various dipstick tubes	2 Cost	3 withstand high temperatures	4 Withstand vehicle and engine vibrations	5 Long Product Life	6 High Accuracy	7 Low Weight	8 Readable	9 Environmentally Friendly	10 Doesn't interfere with other parts	11 Non-Corrosive Material	12	13	14	15	Our Company	Gill Sensors	Hella	Competitor 3	Competitor 4	Competitor 5
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)																					
1	9	23.6	30.0	Compatibility with many of all Mercedes Engines	Θ		O	Θ						Θ	Θ						5	5			
2	9	7.9	10.0	Low Cost		Θ	▲	▲	O	Θ	Θ			O							0	5			
3	9	17.3	22.0	Product Life	O	O	Θ	Θ	Θ	Θ			O		O						3	3			
4	9	19.7	25.0	Accurate	O	Θ	O	O	Θ	Θ		Θ			O						5	4			
5	9	11.8	15.0	Quick and Easy Installation	Θ						O			Θ							2	1			
6	9	19.7	25.0	Easy to read sensor output						O		Θ									5	5			
7																									
8																									
9																									
10																									
				Target or Limit Value	All	< $1000	400 F	yes	450,000 miles	5%	< 5 pounds	48 point font	yes	yes	yes										
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	10	8	3	3	5	6	2	1	1	4	4										
				Max Relationship Value in Column	9	9	9	9	9	9	9	9	3	9	9										
				Weight / Importance	429.9	300.0	293.7	435.4	356.7	463.0	106.3	354.3	52.0	342.5	323.6										
				Relative Weight	12.4	8.7	8.5	12.6	10.3	13.4	3.1	10.2	1.5	9.9	9.4										

Competitive Analysis (0=Worst, 5=Best)



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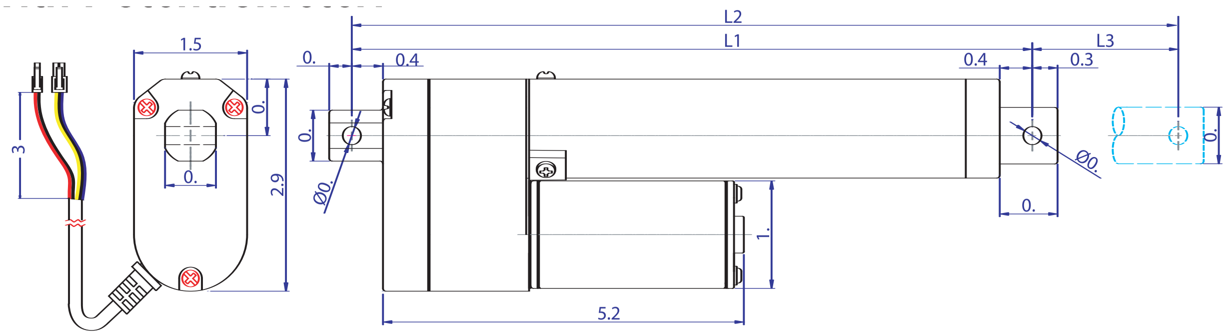
12/07

IMD3 Series Linear Actuators

Part Number	LACT2P	LACT4P	LACT6P	LACT8P	LACT10P	LACT12P
Input Voltage	12 VDC	12 VDC	12 VDC	12 VDC	12 VDC	12 VDC
Load Capacity	110 pounds					
Static Load	550 pounds					
Stroke Length*	2 inches	4 inches	6 inches	8 inches	10 inches	12 inches
Speed @max load	0.50 in/sec					
Retracted Length	7.47 inches	9.45 inches	11.49 inches	13.49 inches	115.50 inches	17.51 inches
Extended Length	9.47 inches	13.48 inches	17.49 inches	21.49 inches	25.50 inches	29.51 inches
Recommended Fuse	10 Amp					
IP Grade	IP 63-total dust protection, water resistant					

*Advertised Stroke Length may not reflect Actual Stroke Length

Other Linear Actuators are available from Creative Werks Inc.. Please call 515-264-8222 to request information.



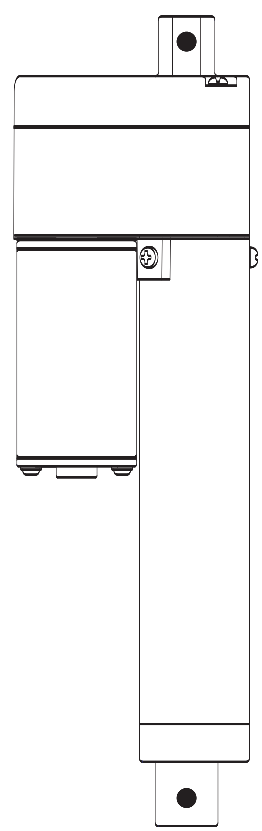
Dimension (inches):

L3 Stroke Length	2	4	6	8	10	12
L1 Stroke Length	7.47	9.48	11.49	13.49	15.50	17.51
L2 Stroke Length	9.47	13.48	17.49	21.49	25.50	29.51

IMD3-SERIES

LINEAR ACTUATORS

WITH POTENTIOMETER



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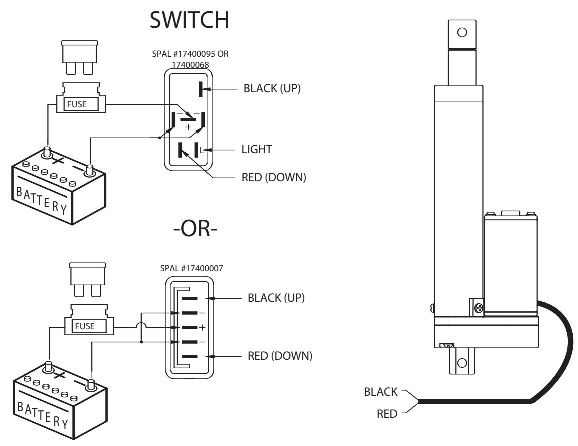
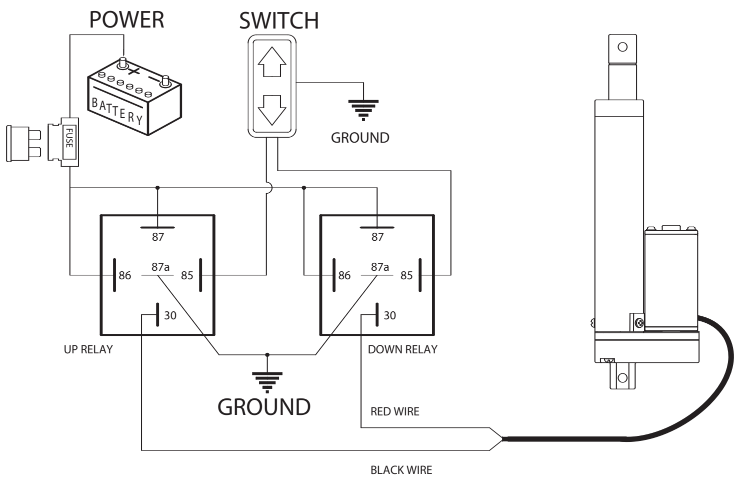
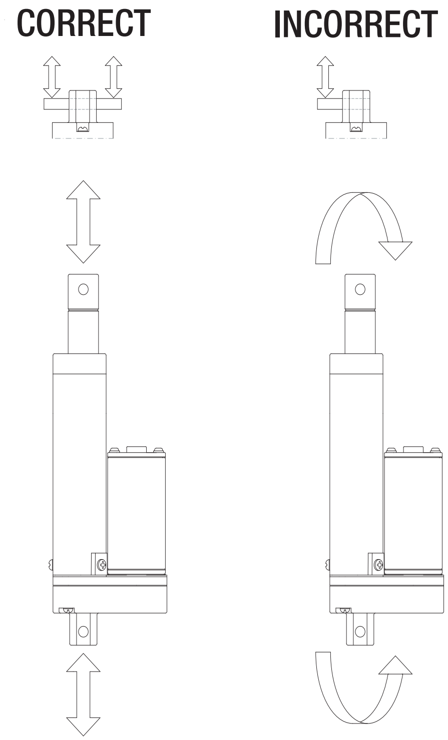


Wiring Installation Instructions:

- If using Creative Werks Inc. switches (such as part #'s 1740.0007, 1740.0068, 1740.0095) the actuator can be connected without relays. (see diagram above)
- Connect the red wire from the actuator to the retraction (down) side of a switch.
- Connect the black wire to the extension (up) side of the switch.
- Place a 10 Amp fuse on the +12VDC wire, no further than 18 inches from the battery.
- One Creative Werks Inc. switch can control up to 2 actuators on a single circuit with a 20 Amp fuse.
- If using other switches, please incorporate two standard automotive relays. (see diagram below)





Mounting Installation Instructions:

(Creative Werks Inc. brackets are available.)

- To prevent premature failure the actuator should be mounted so that the load does not bend or rotate the actuator.
- The load should be centered on the actuator.
- Use only solid pins or bolts that can be fixed on both ends with minimal play on the actuator shaft.

Creative Werks Inc.

LIMITED WARRANTY STATEMENT

Creative Werks Inc. warrants this product to be free from defects in material and workmanship for a period of eighteen (18) months from the date of sale to the original purchaser. Creative Werks Inc. will repair this product free of charge if, in the judgment of Creative Werks Inc., it has been proven defective within the warranty period. The product should be returned, at the customer expense, to the location of original purchase. This warranty does not cover any expenses incurred in the removal and/or reinstallation of the product.

This warranty does not apply to any product damaged by improper installation, accidental misuse, abuse, improper line voltage, fire, flood, lightning, or other acts of God, or a product altered or repaired by anyone other than Creative Werks Inc. This warranty is in lieu of other warranties, expressed or implied, including any implied warranty of merchantability. No person is authorized to assume for Creative Werks Inc. any other liability concerning the sale of this product.

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fibers
LL3, Fibers, proximity system

LL3-DW01

Sensor Intelligence.

fibers
LL3, Fibers, proximity system

Model Name > LL3-DW01
Part No. > 5315234

At a glance

- Heat-resistant plastic and glass fiber-optic cables
- Glass fiber-optic cable with metallic sheath
- Suitable for high-temperature applications up to +350°C

Your benefits

- Very large selection of fiber-optic cables with plastic and glass fibers, giving users more application flexibility
- Resistant to damage caused by mechanical and chemical stress, as well as high temperatures
- Standard and customer-specific types
- Simple installation saves time
- For detection of objects, surfaces, leading edges, and fluid levels

Features

For fiber-optic sensor:	WLL160(T), WLL170-2/WLL170T-2, WLL180T, WLL190T-2
Device type:	Fibers
Housing length:	1 m
Sheath material:	stainless steel
Core material:	Glass
Sleeve material:	Stainless steel
Diameter, connection:	4 mm
Mounting sleeve dimension:	M6
Bend radius, fibre-optic cable:	25 mm
Heat resistance:	200 °C
Ambient temperature, operation:	-40 °C ... 200 °C
Minimal object diameter:	0.02 mm [1)]
Core structure:	Ø 1.6 (mixed 50 µm)
Fiber-optic cable cuttable:	-
Thread sleeve:	
Sleeve:	-
90° offset:	-
Flat housing:	-
High flexible:	-
Long end sleeve:	-
Array:	-
High temperature:	-
Oil/chemical resistent:	-
Lcd/clear material/semiconductor:	-

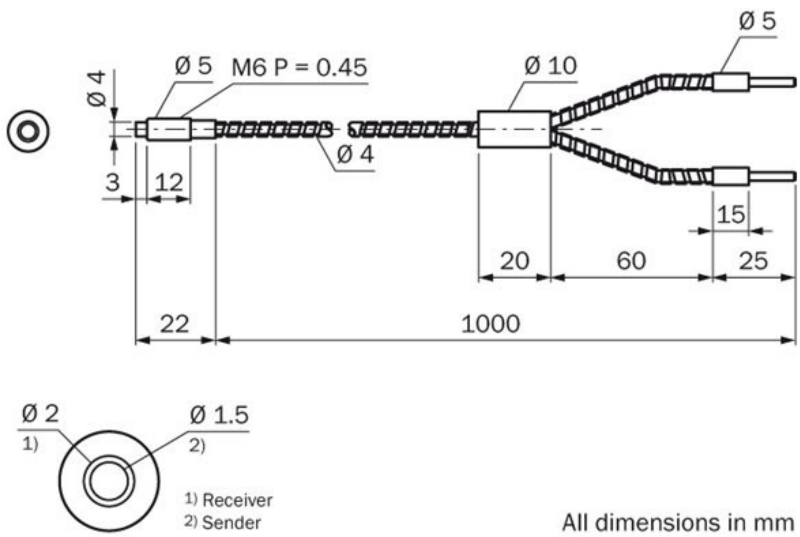
Vacuum:	-
Robotics:	-
Retro-reflective:	-
Liquid level:	
Category fiber-optic cables:	Liquid level, Threaded sleeve, Heat-resistant

1) Minimum detectable object was determined at optimal measuring distance and optimal setting

Sensing range with WLL180T

Operating mode 16 µs:	20 mm
Operating mode 70 µs:	50 mm
Operating mode 250 µs:	95 mm
Operating mode 2 ms:	150 mm
Operating mode 8 ms:	400 mm

Dimensional drawing



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WLL190T-2P532

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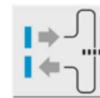
Model Name > WLL190T-2P532
Part No. > 6032557



At a glance

- Scanning range up to 4 m, scanning distance up to 480 mm
- Two separately adjustable channels
- Alarm output
- Optional analog output
- Integrated counter
- Bus-compatible with anti-interference
- 2 x 4-digit display
- Red and green emitter LED

Your benefits

- Two channels can be configured independently of one another
- Simple commissioning and product changeover via external teach input
- No mutual effects from fiber-optic heads mounted in close proximity on account of bus communication
- Easy monitoring of process parameters
- Time delays can be adjusted individually to suit the application
- APC for long-term stable detection
- Alarm output for reliable detection in adverse conditions

Features

Device type:	Stand-alone
Dimensions (W x H x D)::	10.5 mm x 34.8 mm x 76.5 mm
Sensing range max.:	0 m ... 4 m, through-beam system 1)
Sensing range:	0 mm ... 480 mm, proximity system, LL3-DB01 2) 0 ... 2 m, through-beam system, LL3-TB01 3)
Light source:	LED
Type of light:	visible red light
Wave length:	650 nm
Adjustment:	adjustable
Sensitivity adjustment:	adjustable
Adjustment of operating distance:	Teach-Taste Leitung Schrittaste +/- manuell 4)
Teach-in:	Menu-controlled
Time type:	ohne Zeitverzögerung Ausschaltverzögerung Einschaltverzögerung One-Shot

Delay time:	Programmable: 0 ... 9,999 ms
Indication:	Display

With correctly attached fibre-optic cable LL3 and closed protection hood;

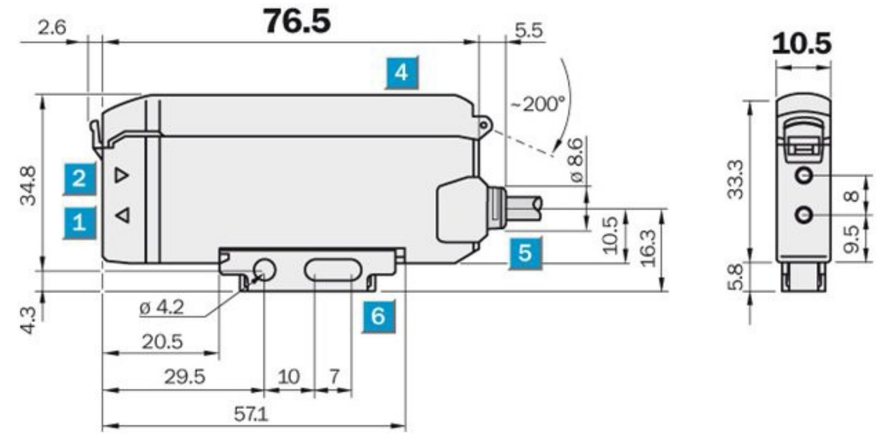
[1] Scanning range at response time 2 ms. Range reduction at shorter response time (see LL3/ WLL190T-2 table) [2) 4)] [3] Average service life 100,000 h at Ta = +25 °C

Mechanics/electronics

Enclosure rating:	IP 66
Supply voltage:	10 V DC ... 24 V DC [1]
Residual ripple:	≤ 10 % [2]
Power consumption:	≤ 50 mA
Switching output:	PNP, Light/Dark-switching, manually selectable, open collector [3]
Output current Imax.:	≤ 100 mA
Response time:	≤ 2 ms ≤ 60 µs ≤ 250 µs
Switching frequency:	8,333 Hz 2,000 Hz 250 Hz
Connection type:	cable, PVC, 2m 2 m [4]
Cable material:	PVC
Number of cores:	4
Conductor cross-section:	0.2 mm²
Protection class:	III
Circuit protection::::	A B C [5) 6) 7) 8)] D
Special device:	0
Housing material:	ABS/PC
Ambient temperature, operation:	-25 °C ... 55 °C
Ambient temperature, storage:	-40 °C ... 70 °C
Weight:	20 g
Output current at an QA2:	4 ... 20 mA

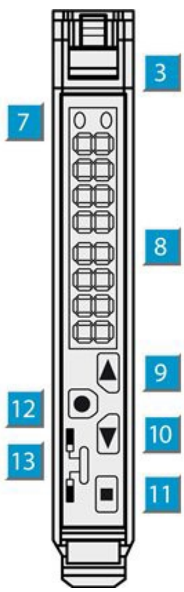
[1] +- 10% [2] May not exceed or fall short of V_S [3] Q1 [4] Do not bend below 0 °C [5] A = VS connections reverse-polarity protected [6] B = inputs and output reverse-polarity protected [7] C = interference suppression [8] D = outputs overcurrent and short-circuit protected

Dimensional drawing



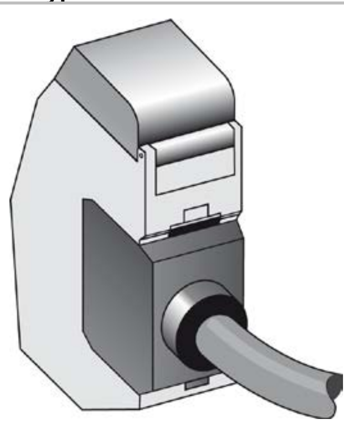
|1| Sender LED, installation of LL3 fibre-optic cable (sender fibre)
|2| Receiver, installation of LL3 fibre optic cable (receiver fibre)
|3| Locking the fiber-optic cables
|4| Protective hood, can be raised at both ends
|5| M8 plugixed or 1-wire cable or 3-wire cable replaceable (cables not included with delivery)
|6| Mounting bracket, included

Adjustment possible

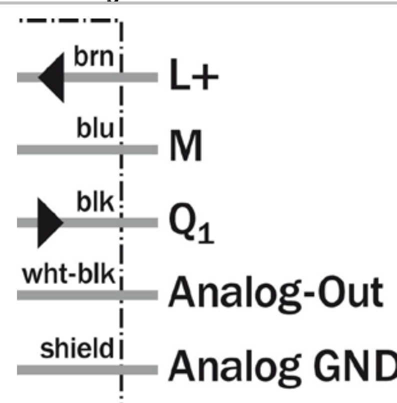


|3| Locking the fiber-optic cables
|7| Status indicator LED, yellow: Output active
|8| Numeric display 3-digit and 4-digit
|9| Step-button> (manual switching threshold: higher; or next function parameter)
|10| Step-button< (manual switching threshold: lower; or previous function parameter)
|11| "Teach-in" push button
|12| Mode/Enter-button

Connection type



Connection diagram



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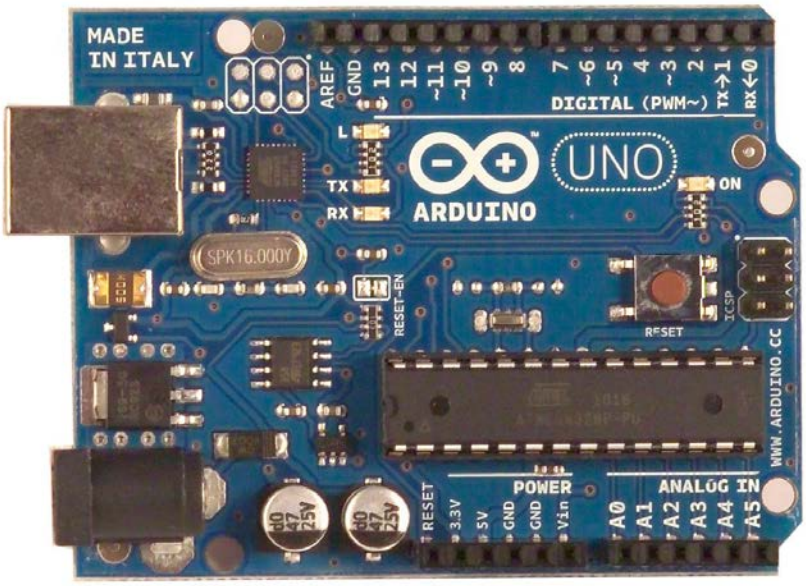
Arduino UNO



Product Overview

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter.

"Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduno, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform; for a comparison with previous versions, see the index of Arduino boards.

Index

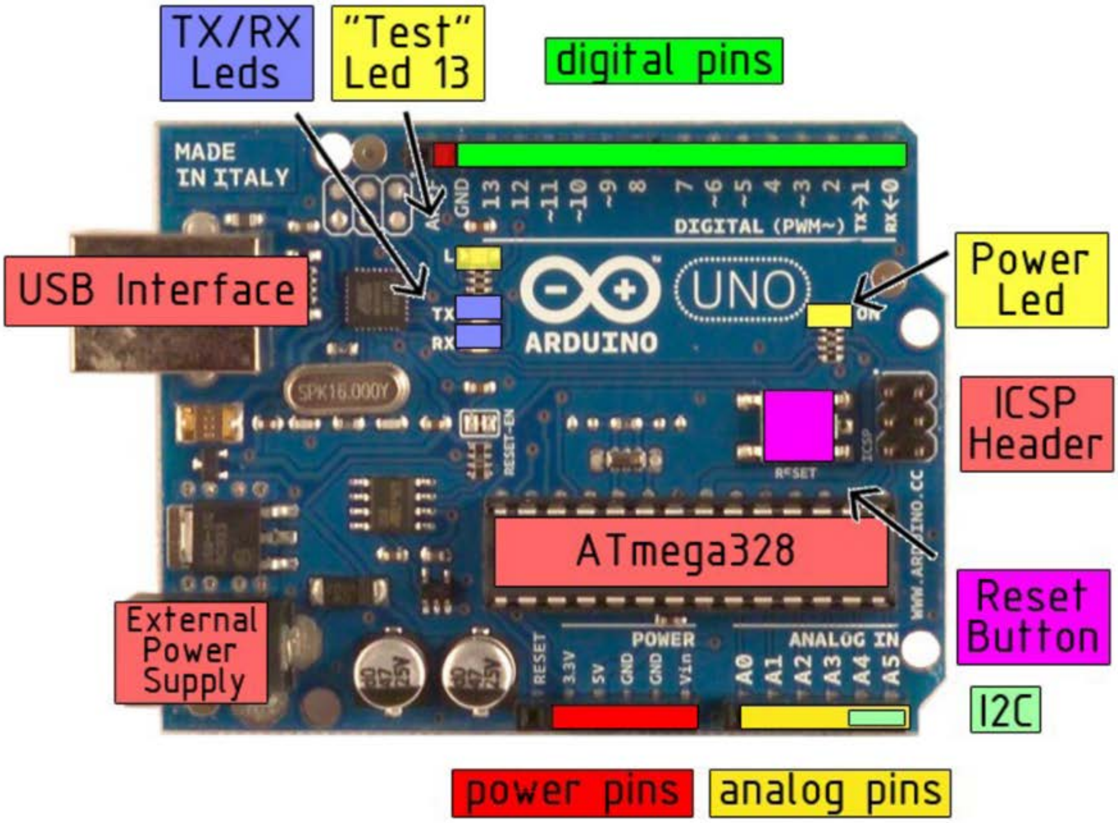
Technical Specification

EAGLE files: arduino-duemilanove-uno-design.zip Schematic: arduino-uno-schematic.pdf

Summary

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB of which 0.5 KB used by bootloader
SRAM	2 KB
EEPROM	1 KB
Clock Speed	16 MHz

the board



Power

The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically.

External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

The power pins are as follows:

VIN. The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
5V. The regulated power supply used to power the microcontroller and other components on the board. This can come either from VIN via an on-board regulator, or be supplied by USB or another regulated 5V supply.
3V3. A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
GND. Ground pins.

Memory

The Atmega328 has 32 KB of flash memory for storing code (of which 0,5 KB is used for the bootloader); It has also 2 KB of SRAM and 1 KB of EEPROM (which can be read and written with the EEPROM library).

Input and Output

Each of the 14 digital pins on the Uno can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:

Serial: 0 (RX) and 1 (TX). Used to receive (RX) and transmit (TX) TTL serial data. TThese pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip .
External Interrupts: 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt() function for details.
PWM: 3, 5, 6, 9, 10, and 11. Provide 8-bit PWM output with the analogWrite() function.
SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). These pins support SPI communication, which, although provided by the underlying hardware, is not currently included in the Arduino language.

LED: 13. There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.

The Uno has 6 analog inputs, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and the analogReference() function. Additionally, some pins have specialized functionality:

I^2C: 4 (SDA) and 5 (SCL). Support I^2C (TWI) communication using the Wire library.

There are a couple of other pins on the board:

AREF. Reference voltage for the analog inputs. Used with analogReference().
Reset. Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

See also the mapping between Arduino pins and Atmega328 ports.

Communication

The Arduino Uno has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An ATmega8U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer. The '8U2 firmware uses the standard USB COM drivers, and no external driver is needed. However, on Windows, an *.inf file is required..

The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the USB-to-serial chip and USB connection to the computer (but not for serial communication on pins 0 and 1).

A SoftwareSerial library allows for serial communication on any of the Uno's digital pins.

The ATmega328 also support I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus; see the documentation for details. To use the SPI communication, please see the ATmega328 datasheet.

Programming

The Arduino Uno can be programmed with the Arduino software (download). Select "Arduino Uno w/ ATmega328" from the **Tools > Board** menu (according to the microcontroller on your board). For details, see the reference and tutorials.

The ATmega328 on the Arduino Uno comes preburned with a bootloader that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol (reference, C header files).

You can also bypass the bootloader and program the microcontroller through the ICSP (In-Circuit Serial Programming) header; see these instructions for details.

The ATmega8U2 firmware source code is available . The ATmega8U2 is loaded with a DFU bootloader, which can be activated by connecting the solder jumper on the back of the board (near the map of Italy) and then resetting the 8U2. You can then use Atmel's FLIP software (Windows) or the DFU programmer (Mac OS X and Linux) to load a new firmware. Or you can use the ISP header with an external programmer (overwriting the DFU bootloader).

Automatic (Software) Reset

Rather than requiring a physical press of the reset button before an upload, the Arduino Uno is designed in a way that allows it to be reset by software running on a connected computer. One of the hardware flow control lines (DTR) of the ATmega8U2 is connected to the reset line of the ATmega328 via a 100 nanofarad capacitor. When this line is asserted (taken low), the reset line drops long enough to reset the chip. The Arduino software uses this capability to allow you to upload code by simply pressing the upload button in the Arduino environment. This means that the bootloader can have a shorter timeout, as the lowering of DTR can be well-coordinated with the start of the upload.

This setup has other implications. When the Uno is connected to either a computer running Mac OS X or Linux, it resets each time a connection is made to it from software (via USB). For the following half-second or so, the bootloader is running on the Uno. While it is programmed to ignore malformed data (i.e. anything besides an upload of new code), it will intercept the first few bytes of data sent to the board after a connection is opened. If a sketch running on the board receives one-time configuration or other data when it first starts, make sure that the software with which it communicates waits a second after opening the connection and before sending this data.

The Uno contains a trace that can be cut to disable the auto-reset. The pads on either side of the trace can be soldered together to re-enable it. It's labeled "RESET-EN". You may also be able to disable the auto-reset by connecting a 110 ohm resistor from 5V to the reset line; see this forum thread for details.

USB Overcurrent Protection

The Arduino Uno has a resettable polyfuse that protects your computer's USB ports from shorts and overcurrent. Although most computers provide their own internal protection, the fuse provides an extra layer of protection. If more than 500 mA is applied to the USB port, the fuse will automatically break the connection until the short or overload is removed.

Physical Characteristics

The maximum length and width of the Uno PCB are 2.7 and 2.1 inches respectively, with the USB connector and power jack extending beyond the former dimension. Three screw holes allow the board to be attached to a surface or case. Note that the distance between digital pins 7 and 8 is 160 mil (0.16"), not an even multiple of the 100 mil spacing of the other pins.

How to use Arduino

Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators. The microcontroller on the board is programmed using the Arduino programming language (based on Wiring) and the Arduino development environment (based on Processing). Arduino projects can be stand-alone or they can communicate with software on running on a computer (e.g. Flash, Processing, MaxMSP).

Arduino is a cross-platoform program. You'll have to follow different instructions for your personal OS. Check on the Arduino site for the latest instructions. *http://arduino.cc/en/Guide/HomePage*

Linux Install **Windows Install** **Mac Install**

Once you have downloaded/unzipped the arduino IDE, you can Plug the Arduino to your PC via USB cable.

Blink led

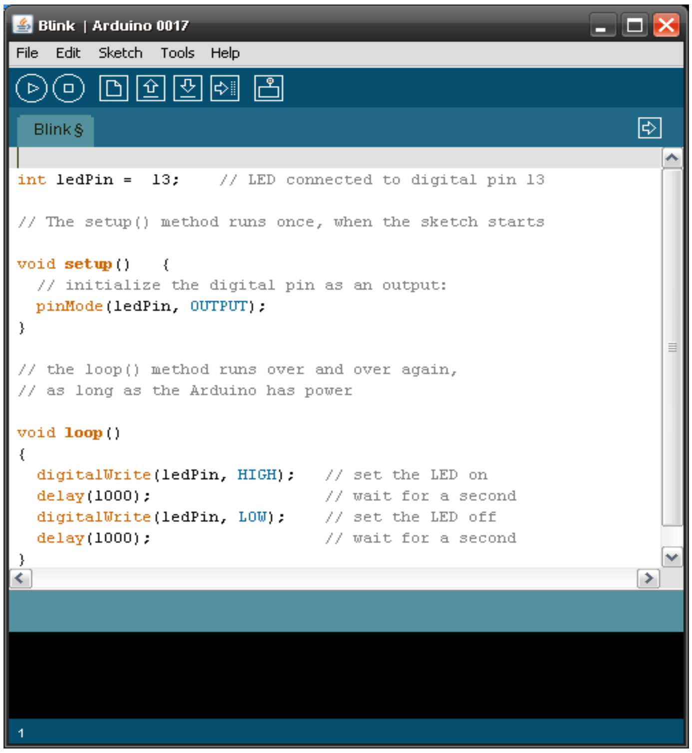
Now you're actually ready to "burn" your first program on the arduino board. To select "blink led", the physical translation of the well known programming "hello world", select

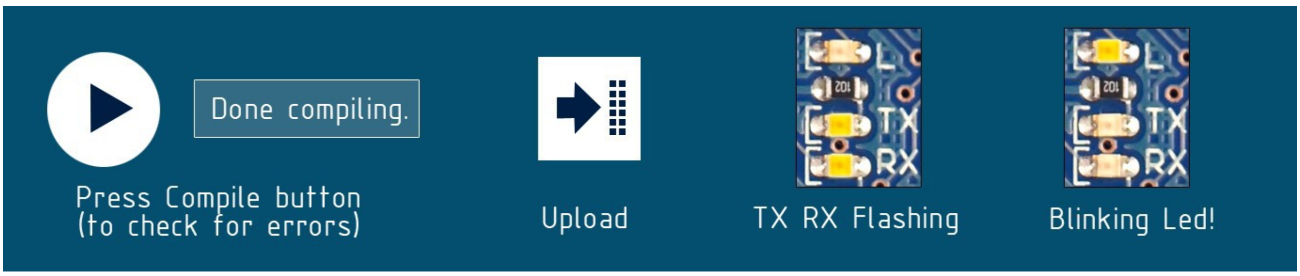
**File>Sketchbook>
Arduino-0017>Examples>
Digital>Blink**

Once you have your skecth you'll see something very close to the screenshot on the right.

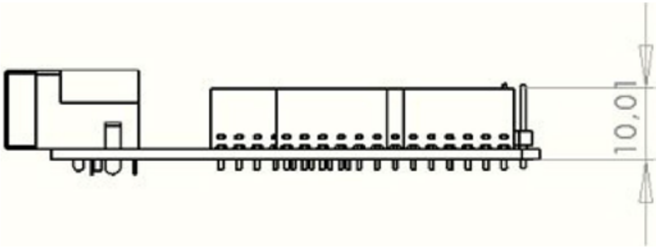
In **Tools>Board** select

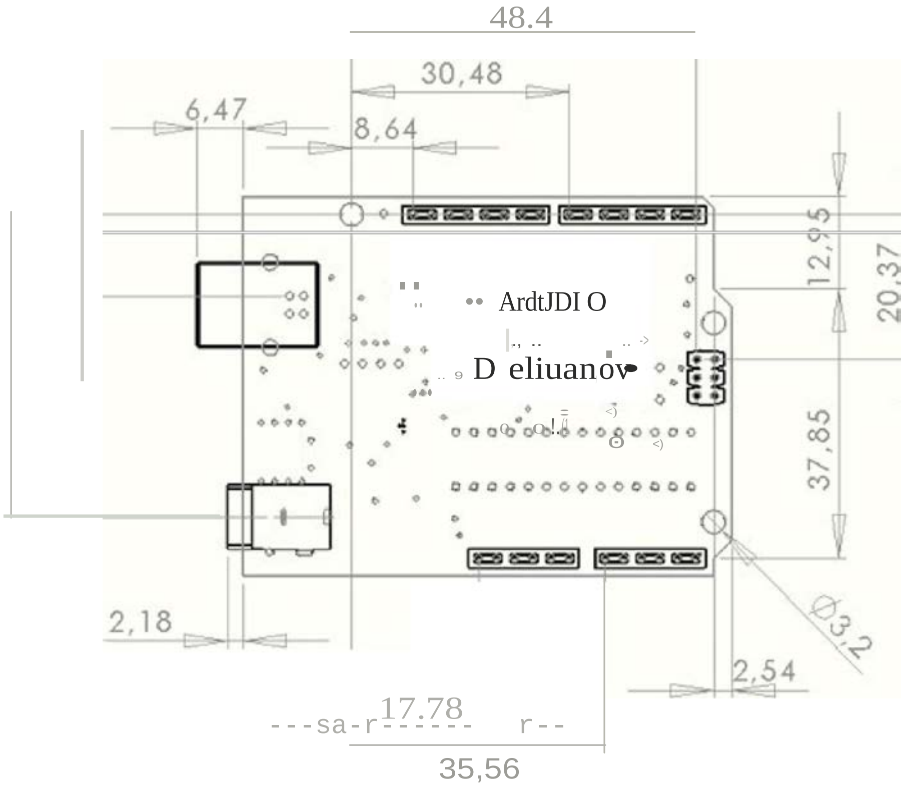
Now you have to go to **Tools>SerialPort** and select the right serial port, the one arduino is attached to.

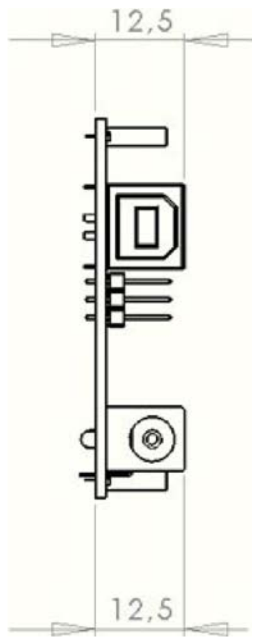


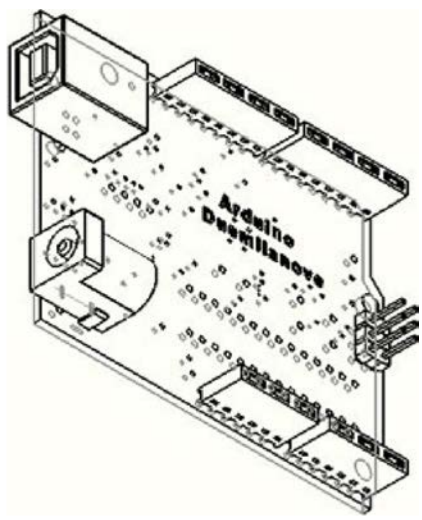


Dimensioned Drawin









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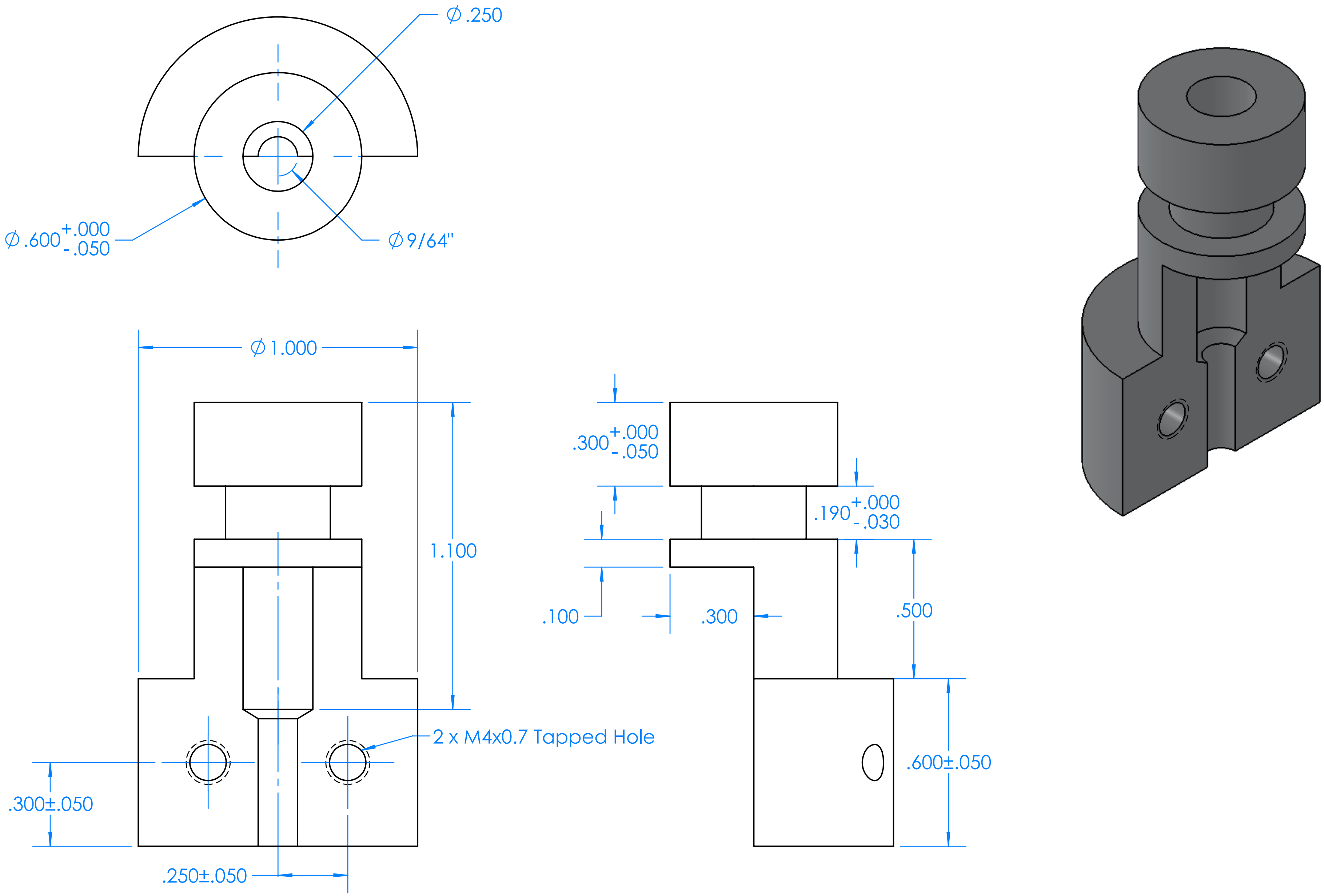
Enviromental Policies

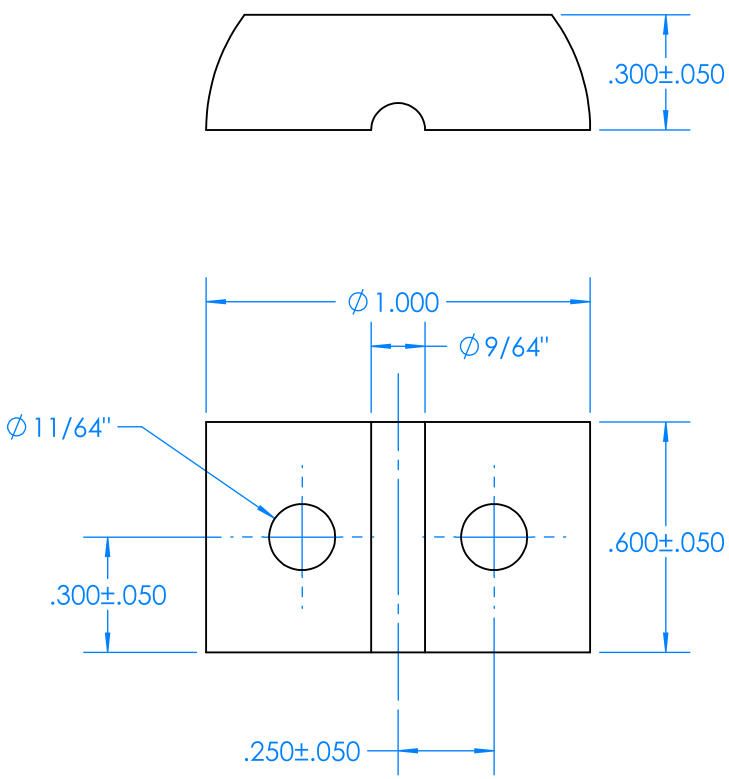
The producer of Arduino has joined the Impatto Zero® policy of LifeGate.it. For each Arduino board produced is created / looked after half squared Km of Costa Rica's forest's.

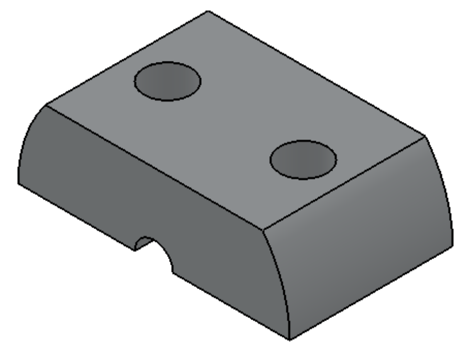


Mechanical Engineering CAL POLY

DRAWN BY: JAMES YOUNG	INIT:	CKD BY: EMMANUEL CAMACHO	INIT:
SCALE: 2:1	TOLERANCE: ± .005	TITLE: CLAMP	
UNITS: INCH	NEXT ASSY: 00003	MATERIAL: 6061 ALUMINUM	
DATE: 2/23/2013	DWG #: 00001	GROUP: PRND	

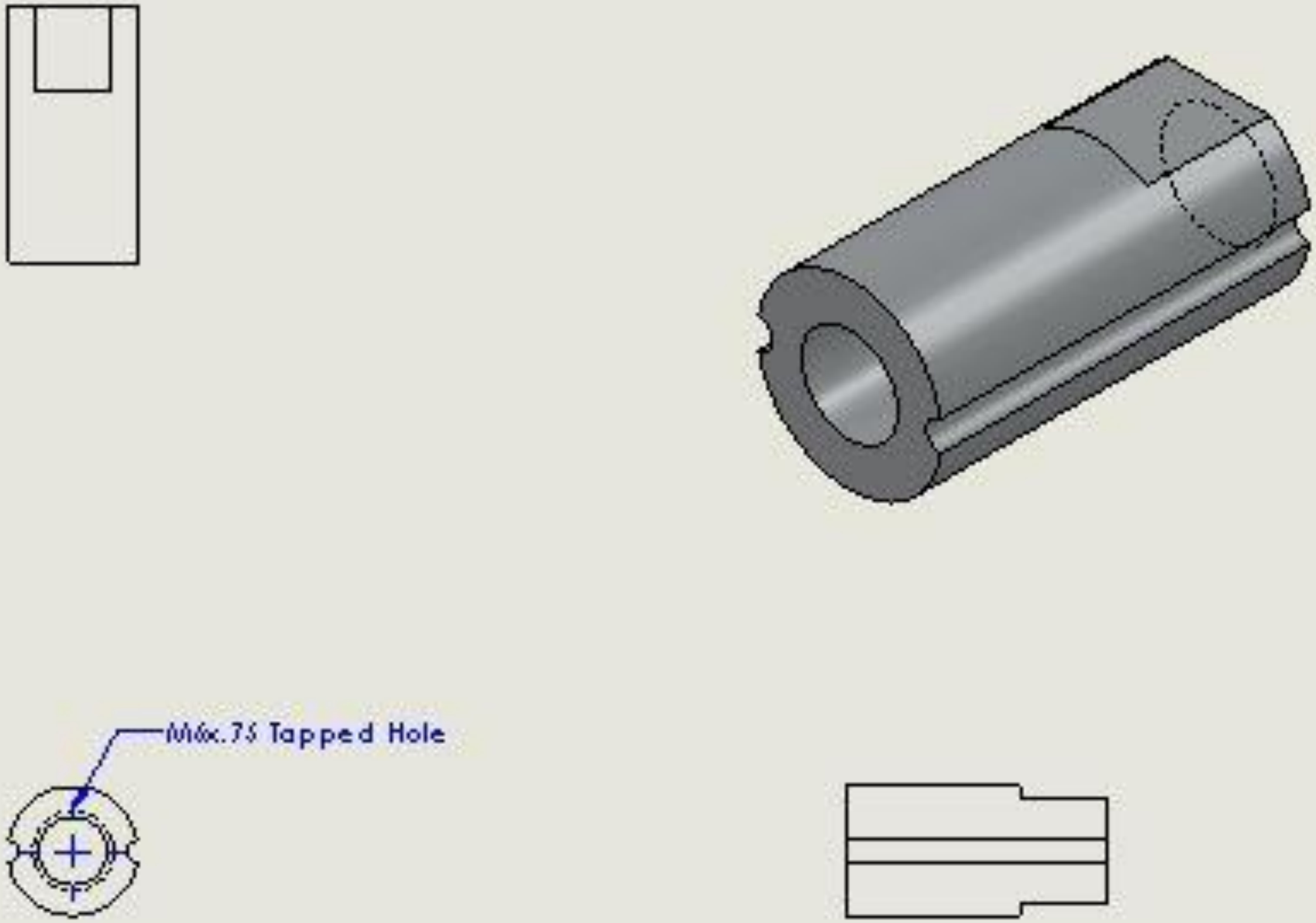
5 4 3 2 1





DRAWN BY: JAMES YOUNG	INIT:	CKD BY: EMMANUEL CAMACHO	INIT:
SCALE: 2:1	TOLERANCE: ± .005	TITLE: CLAMP ATTACHMENT	
UNITS: INCH	NEXT ASSY: 00003	MATERIAL: 6061 ALUMINUM	
DATE: 2/23/2013	DWG #: 00002	GROUP: PRND	

5 4 3 2 1



Cal Poly Mechanical Engineering	Lab Section:	Assignment #:	Title:		Drawn By:
ME 251 - Winter 2013	Dwg. #:	Material:	Date:	Scale:	Chkd. By: