# The Automatic Can Crusher

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*ABSTRACT* — **The Automatic Can Crusher not only crushes aluminum cans but also has the technological capacity to distinguish from a water bottle, while not crushing it, disposing properly of its contents into storage. With the added electrical features from based design, the project adds many more sensors for detection, incorporates solenoids, and pneumatic cylinders. The system includes, capacitors, functional controllability via microcontroller, rectifiers, regulators, and switches. The system houses four sensors integrated into its electrical design and incorporated into its seemingly compact mechanical design. With friendly user interface and simplistic yet well thorough purpose, we present the "Automatic Can Crusher".**

## I. Introduction

The Automatic Can Crusher has been modified to accommodate ever-growing expectations with the increase in the demand. Originally it's based design only acted with a single pneumatic cylinder, relay, and was push button. With the conversion from push button to automatic the system houses four sensors, three ultrasonic sensors and one reflective optical sensor integrated into its electrical design. Along with the modification to its electrical design, this system is enclosed, mechanically designed as an additive feature. All sensors are behind Plexiglas, enclosed within a wooden frame. The pneumatic cylinders are also incorporated into the design.

The highlight of the system is the Automatic Can Crusher's ability to sort objects into storage bins. There will be 3 modes. The default mode is signaled by a "yellow" LED, an "operational mode" signaled by a "green" LED and a "stop" mode signaled by a "red" LED. The system will always be in default mode as long as it is turned on. Once an object is detected, the system will go to "operational" mode. There are two set of sensors an object will come into contact with. The object will either be an aluminum can or a water bottle. The two sensors we'll be using are the Ping Ultrasonic sensor and the TCRT5000 Reflective Optical sensor. The purpose of the "Ping Ultrasonic sensor" is to detect whether an object is there. That is its only purpose, only to notify the microcontroller that an object is here. The purpose of the TCRT5000 is to determine whether or not the object is an aluminum can or water bottle. It will do this with the help of an LED. The LED will be connected in a circuit with the TCRT5000, the LED will light up if it is an aluminum can. If it is NOT an aluminum can then it must be a water bottle. (The TCRT5000 has intrinsic properties that will not detect clear objects such as a water bottle). Once the object has been declared a water bottle or an aluminum can it will immediately be sent to where it can be crushed. We will crush both aluminum cans and water bottles. To crush the objects the microcontroller will need to send a signal to a solenoid. The solenoid will then send air to a cylinder that will crush the objects. After the objects have been crushed, the aluminum cans and water bottles will then need to be separated. Then micro-controller will then need to send a signal to another solenoid (separate from the 1$^{st}$ solenoid mentioned earlier) the solenoid will send air to another cylinder (separate from the 1$^{st}$ cylinder mentioned earlier that is connected to a swinging lid. This cylinder will only activate the "swinging lid" when there is a Water bottle that has just been crushed. The solenoid will then send air to the cylinder pushing the "swinging lid" one direction forcing the water bottle to go to its designated storage. The Ultrasonic sensor can also be used as a range finder, meaning it can determine how far away an object is. There will be an Ultrasonic Sensor in each storage bin (for a total of 2). As the pile of aluminum cans and water bottles build up to about 90% the Ultrasonic sensor will need to communicate to the microcontroller that the bin is at 90%. The microcontroller must then signal a "red" LED and STOP all operation until the bin has been emptied. Once the bin has been a "yellow" LED must then be signaled. Once an object has been detected a "green" LED must then be signaled and the process will repeat until the bin is 90% filled.)

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## II. SYSTEM COMPONENTS

The system is comprised of several individual parts collectively working together for a final product. This section provides semi-technical information regarding key parts of the project. Within the sub categories the functionality and purpose of the proposed components will be included, but not limited to, discussion.

Originally a premise, the design of the Automatic Can Crusher has evolved; accomplishing this task via electrical, software and mechanical design. The project incorporated filters, regulators, solenoids, sensors (ultrasonic and Infrared), transistors, diodes, a microcontroller and powered by a transformer. The microcontroller is programmed to systematically respond to an object, first by detecting the object, then by responding to the values resulting from the object to determine whether or not the object is an aluminum can or water bottle. Once the object has been detected by passing through the sensors, the object is then directed to its next station.

### *A. HOPPER*

Is the holding region for the objects. There inside the Hopper are two sensors, the ultrasonic sensor and the IR sensor. Here is where the object will be declared a water bottle or an aluminum can. The hopper is enclosed in a wood framing and shielding by Plexiglass. Limited light enters the hopper. Sensors have been integrated into the wood framing, this allows erroneous results within the circuit analysis of the sensor. The wood framing is built such that typical sizes of water bottles and aluminum cans. The size of the hopper is approximately 16”x 4”x 8”.

### *B. Can Crusher*

This station will crush only aluminum cans. Given power through the solenoids which are relayed a signal via the microcontroller through the transistor. The pneumatic cylinder is operated by an air compressor that will disperse up to 120 psi . The 12 volt solenoid has considerably low current for its use so its power consumption is kept at a minimum. The pneumatic cylinder is a double acting cylinder. Requires air to release and extend its piston. The size of the pneumatic cylinder is approximately 4.5 x 4.5 x 32cm/ 1.8" x 1.8" x 12.6.

### *C. Microcontroller*

The system uses the ATMega328 microcontroller. It operates off 5 volts with a recommended input voltage between 7-12 volts. It has a maximum of 14 digital input/output pins and 6 analog input pins. It requires 40mA and has a memory of 32KB .

### *D. Ultrasonic Sensor*

Detects objects via ultrasonic pulse. Its operating distance is between 2cm- 3m. It is powered by 5 volts and operates off a supply current of 30mA. Its dimensions are 16 x 46 x 22(mm)

### *E. TCRT5000 Reflective Optical Sensor*

Detects objects via infrared light. Operating off of the reflection from the object its peak operating distance is 2.5mm. It is powered by 5 volts and its output current is 1mA.Its dimensions are 10.2 x 5.8 x 7 mm.

### *F. Storage Bins*

There will be two storage bins for the aluminum can and water bottle. Inside the storage bins will be the ultrasonic sensor, which will have two purposes in this project. In this station of the project it will be used as a range finder. Operating on the ultrasonic pulse that it transmits, it waits for the transmission to be received back, depending on the amount of time taken for the transmission to be received it can determine the distance of the object.

### *G. Pneumatic cylinder*

A double-acting cylinder has a two-port on the cylinder, which is located at both ends of the cylinder. With the double-acting cylinder having two airports this would allow the cylinder to move in both extend and retract directions. Basically only one port of the cylinder is pumped with compressed air and the other port is used as an exhausted.

### *H. Solenoid*

The pneumatic cylinder was chosen to be used for the project. Its function would need to be integrated into the design to control not only the direction of the air because of the choice of the pneumatic cylinder but also when the air needs to enter and exit the cylinder.

### *I. Air Compressor*

A portable air compressor bought from Lowes was used for this project. With the purchase of a manifold the air compressor can power each cylinder, filtering enough air through each solenoid to control the pneumatic cylinder. The compressor will be left plugged in during its operation, allowing the tank to continually fill up once its air pressure is too low.

## III. SYSTEM CONCEPT

This section explains the complete system concept with the aid of flowcharts.

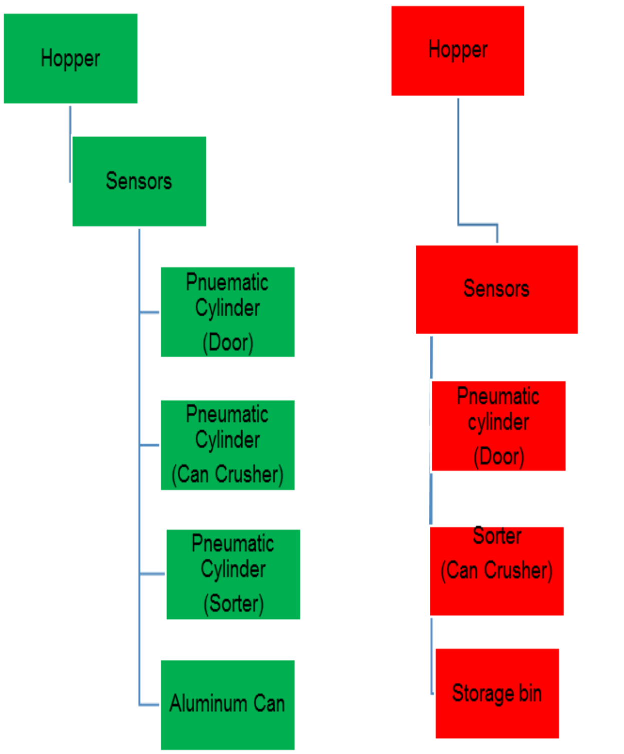



Figure 1. The figure shows the protocol for the Aluminum Cans (Green) and Water bottle (Red), respectively.

## IV. POWER SUPPLY

The power is derived from the plug that's connected to an outlet. Using the "live" and "neutral" wires, connected to the fuse and to the transformer respectively, power is derived.

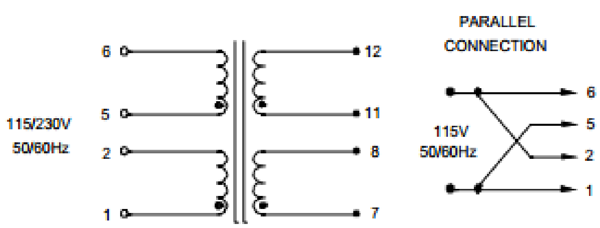



Figure 2. Shows the transformer circuit connected in parallel. The transformer produces 18V and 1.5A.

The pins on the transformer are connected to the wires through female connectors adding for a clean look and hold a solid contact without be soldered. The design allows for the microcontroller to operate on its own.

The microcontroller is not powering any other devices its main purpose is only for the receiving and transmission of information. Diodes were placed across the 7812 regulator to prevent negative feedback from current leakage.

The voltage coming off of the transformers secondary is expected to be approximately 33 volts with no load. In anticipation of this voltage a 35V electrolytic capacitor awaits to filter the voltage into the regulators. The 1.5A transformer connected in parallel is more than enough current to operate a fully running system.

The transformer will not physically be on the board. It will connect to the bridge rectifier which will convert the AC to DC and then run to the rest of the circuit.

The decision to use a fuse connected in series with the live wire was pure safety prevention. In the effect that there is a short we would not damage the rest of the circuit.

There are two power rails in the circuit.

(1) 12 volt power rail
(2) 5 volt power rail

The 12 volt power rail is for the solenoids that power the pneumatic cylinders and the 5 volt power rail, powers all of the other components (LEDs, sensors, and microcontroller)

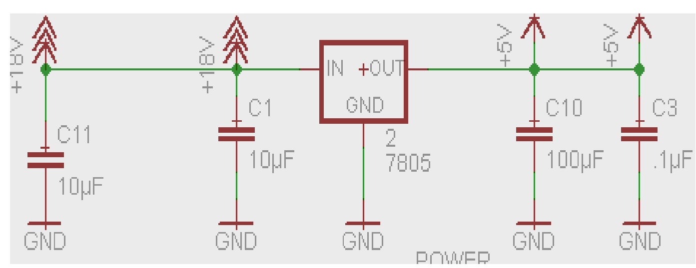



Figure 3. Shows the 18 volts from the transformer passing through the 7805 regulator

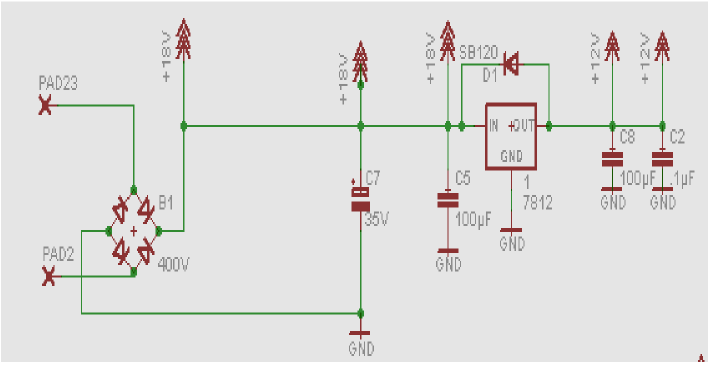



Figure 4. Shows Pad 23 and Pad 2 which will be the leads from the secondary of the transformer connecting to the AC pins of the bridge rectifier. The Positive and negative pins will be connected to the rest of the circuit providing the DC voltage to the regulator

## V. AIR COMPRESSOR

Compressed air is the energy source of choice for doing much of our nation's industrial work. It's an energy source that is relatively easy to store, non-flammable, very powerful, and can generate high speed in a variety of ways. Compressed air can be carried anywhere with an appropriate pressure vessel sometimes called an air hog or air pig. Compressed air is relatively safe because if compressed air was to leak or spill, it doesn't leave a mess and is non-flammable. If the force would be required for an air compressor using appropriately air valves and pneumatic cylinder can generate this project. By choosing an air compressed as are energy source over hydraulics would be a simply choice because compressed air components are less expensive and in are budget. Since using hydraulic energy is more expensive to generate energy to do the work, and the cost of the components to use hydraulic force. We do not need the immense pressures and force that hydraulics would give us; it doesn't make sense to pay for that capability [Bill Wade]. An air compressor would be one of the methods to use, as air compressor is a device in which converts power into kinetic energy by compressing and pressing air into a tank.

## VI. SENSORS

Our idea to distinguish the aluminum bottles and the water bottles is to use an infrared optical sensor and an ultrasonic sensor. We hope that the combination of the two will permit the able to tell if there is aluminum can or a water bottle. The typical water bottle is usually clear except for the label. So for this part we are going to make an assumption. The Reflective Optical sensor (IR) does not sense clear objects. In the models on YouTube the designers have all use white tape and some tape that has a color change, say striped tape. The IR optical sensor will sense the color tape and light up whereas the white tape or clear tape it will not sense and does not light up. Since the water bottles will be horizontal as they come thru the hopper we're assuming that no labels will be in direct sight of the IR optical sensor. So the idea is that if the IR optical sensor does not sense anything then there is a water bottle in its place. We know that there is an object there because of the ultrasonic sensor. The ultrasonic sensor will sense both water bottles and aluminum cans.

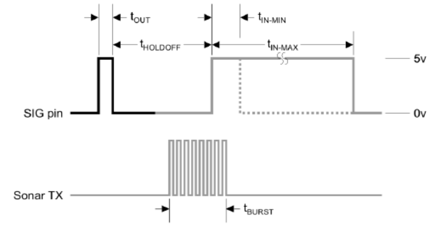
Ultrasonic sensors can also be used for "clear object" detection such as a water bottle in our case. It is up to our group to decide whether we want to use digital or analog. While researching the topic I did want to find out why overwhelmingly people choose digital over analog. During our discussion I was able to look up some ultrasonic sensor demos that suggested that analog output was the easiest. Engineer at Sparkfun, Jim Lindbom illustrates a demo where he discusses the use of ultrasonic sensors at Sparkfun[1]. He mentions that they are composed of a transducer and amplifying circuit and mentions there use of communication, through sound waves, and there applications. An important note to make is that Jim mentions that the sensors have three possible outputs; analog output (voltage), serial signal (RS232) and pulse with modulated output (good for digital pins). Of these possible outputs he says that the analog output is the easiest. In his demo he uses an Arduino. We have not determined what board we will use or if we can even use an Arduino. Jim's statement is solely optional the determination of ease really depends on what we feel most comfortable with. The opinion however does state that sometimes analog can be chosen over digital.

Another alternative is to approach the problem of sensing the water bottle the opposite way. We can use the fact that IR optical sensor will sense colors, so if in fact it does sense a color it will signal that "this is an aluminum can". Again this is another approximation that most aluminum cans will or may have color on them. The ultrasonic sensor will just tell us that there is an object here.

The only task we would need to figure out is the placement of these sensors. In our earlier discussion of using the IR optical sensor's disadvantage to our advantage we were assuming that the water bottle would be in the position as shown in the figure below but the IR would be pointing through the bottle the long way. However, if the aluminum can is facing the same direction as the water bottle than the result would both be the same, the IR sensor wouldn't sense either the water bottle or the aluminum can. Therefore if we use our alternative idea, using the IR sensor on the aluminum cans rather than the water bottle, the aluminum cans pictured below can be place the same direction as the water bottle. If we use our alternative method the IR will point directly into the aluminum can. We do run the risk that since the water bottle is laying in the same direction the IR may directly come into contact with the label on the water bottle. If that is the case the IR will incorrectly tell us that it is aluminum can. Since our technique will not be full proof will we assume that we will have some errors in testing because it is not certain where the label will be on the water bottle.  Some labels may be lower or wider as shown in the figure below.  It will be to ambiguous to determine where the label will be on the bottle because that depends on the brand and we have no way of filtering out what brands will be placed in the trash can

Figure 5. Shows the TCRT5000 Reflective Optical sensor pointing upward towards the hopper. Whichever object enters the Hopper will be directly on top of the TCRT5000, close enough for it to be detected. Adjacent to the TCRT5000 can be seen from the figure is the Ping Ultrasonic Sensor.

Figure 6. Shows the Plexiglass shielding the user from the cans being crushed. Also shows how the sensors have been embedded into the woodframe




| | | | | |
|---|---|---|---|---|
| ▬ (black) | Host Device | Input Trigger Pulse | $t_{OUT}$ | 2 µs (min), 5 µs typical |
| ▬ (gray) | PING))) Sensor | Echo Holdoff | $t_{HOLDOFF}$ | 750 µs |
| | | Burst Frequency | $t_{BURST}$ | 200 µs @ 40 kHz |
| | | Echo Return Pulse Minimum | $t_{IN-MIN}$ | 115 µs |
| | | Echo Return Pulse Maximum | $t_{IN-MAX}$ | 18.5 ms |
| | | Delay before next measurement | | 200 µs |

Figure 7. Shows  the Ping Ultrasonic sensor sending out a pulse signal . It also shows its function acting as a range finder.

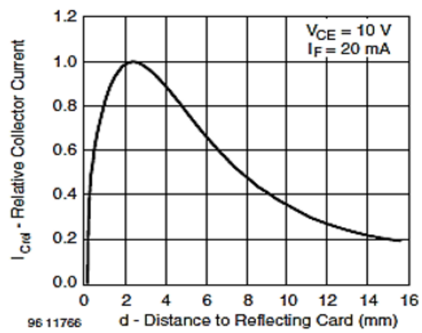



Figure 8. above shows the peak operating distance of the TCRT5000 Reflective Optical Sensor. Peak operating distance is 2.5cm

## VII. SORTER

If we use our alternative method, which we used, theTCRT5000 Reflective Optical sensor will point directly into the aluminum can, as shown in Figure 3. We do run the risk that since the water bottle is laying in the same direction the TCRT5000 may directly come into contact with the label on the water bottle. If that is the case the TCRT5000 will incorrectly tell us that it is aluminum can. Since our technique will not be full proof will we assume that we will have some errors in testing because it is not certain where the label will be on the water bottle.  Some labels may be lower or wider depending on the size and brand of the bottle.  It will be too ambiguous to determine where the label will be on the bottle because that depends on the brand and we have no way of filtering out what brands will be placed in the trash can. A solution for this is to remove the labels completely.

Figure 9. Shows the preconceived idea for the "swinging lid"

The second part portion of our technique is to borrow the idea of lid on a trash can. On some trash cans there is a swinging lid that once pressure is applied to one side, it rotates over its axle and one side becomes available for use. The technique is to use this theory in conjunction with the pneumatic cylinder.

Figure 10. Shows the technique of the "swinging lid". The pneumatic cylinder is connected to a movable plate that will direct which bin the object is stored in

Figure 11. Shows a full view of two storage bins that can be both accessed by the "swinging lid"

Will extend the pneumatic cylinder's piston to one side of the swinging lid and it will close off entrance to the can crusher and route the water bottle into its proper bin. In essence the water bottle will just slide down into its bin. Once an aluminum can is placed into the trash can, the lid will retract allowing for the aluminum can to slip through a designated path with specific dimensions, which is just the appropriate size for a typical aluminum can to fit, and into the Can Crusher where it can be crushed and disposed of into its proper bin.

## VIII. User Interface

Our goal for the LED is to have them light up depending on certain input and outputs readings from the microcontroller and sensors. Figure is the LEDs setup that which will be display on the top of the cabinet to indicate to the user the process that project is in.

- Red (Stop) - Will stop when cabinet door is open to empty the storage bin
- Yellow (in Process) -The machine is either crushing or sorting an item
- Green (Ready) - When the hopper is ready to be loaded
- Flashing Red - Will flash red when either one of storage bins are full

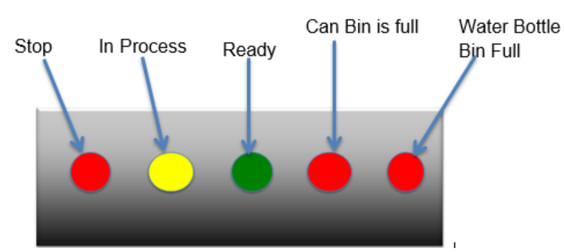
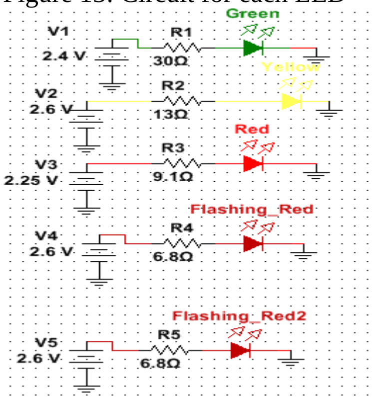



Figure 12: Highlights the LED Display

The four figures that are in figure 10, show the complete circuit of each LED light and resistor that will be needed for this project. All of the LEDs will be built individually, as the circuit shows how much resistance each LED will need to support the voltage and current of the that particular LED. The reason why each LED circuit will be built separately is so that each circuit can be assign to their own output port of the microcontroller. By doing this it will allow the microcontroller to light the LED when a particular response input response comes into the microcontroller.

Figure 13: Circuit for each LED




## VIIII. MICROCONTROLLER

The microcontroller will interact with all phases of the design. Key elements of its function will be dependent upon the feedback of the sensors. Once the microcontroller has received this information it will control the modes of the system, there are three modes (operational, default and stop). The communication between various parts system will be key. The microcontroller protocol is to first receive information from the sensors then trigger the solenoids accordingly. There is a slight time delay to allow the object time to pass to the next station.

Transistors were strategically placed close to the microcontroller to facilitate the communication between the signal sent by the microcontroller and the signal received by the transistor. The transistor placement compared to the solenoid placement was also taking into account so noise wouldn't interfere with the signal.

Decided to develop the software design based from arduino and circumvent all unused portions of the software design that we would not use. This was based on testing of the breadboard circuit. Finding out what pins were dedicated to internal protocols preset by the microcontroller.

The software was designed in the Arduino IDE. The task of the software is to send signals through the microcontroller at various times depending on the condition of the sensors, whether they are operational are not. The first condition in the program is to detect an object in the hopper. The program uses a while loop with an "If"," else- if" statement to check the condition of the sensors and whether they are operational. As the proper conditions are met the program tells the microcontroller to send the signals to activate the solenoid necessary to finish the tasks depending on what object is sensed, in this case a bottle or aluminum can. Thankfully the microcontroller has a built in loop so it is continually "Pinging" the sensors. As listed there are three Ping Ultrasonic sensors and one TCRT5000 Reflective Optical sensor. The Ping sensors convert time into inches and centimeters, the Ping Ultrasonic sensor has the capability converting as far as meters but no objects will be that far away. A stable reading is observed ,as far as measuring centimeters. The TCRT5000 Reflective Optical sensor detects the distortion of light based on the objects reflection, if there is little to no distortion from the object, then the TCRT5000 Reflective Optical sensor will transmit an equivalent reading to the microcontroller signaling that the object detected is a water bottle. And if there is reasonable amount of distortion the TCRT5000 Reflective Optical sensor will transmit to the microcontroller that the object detected is an aluminum can. The purpose of a while loop is to allow the controller to check the sensors while allowing the "while loop" to use the results transmitted from the sensor to complete its task. A condition must be set to first use a while loop. Once the condition is met then and only then will the while loop run and do the assigned tasks. The ATmega328 and courtesy of Arduino built in functions called digitalWrite, analogRead, pinMode, and delay are readily used. These functions control the transmission of signals to designated pins.

For a signal to be sent via the microcontroller a digitalWrite command must be written. In our software a signal is sent when the logic is active high and to stop, it write active low. To read from the analog pin you call the analogRead.

As far as functionality goes you use delays to make the program run smoother.

The pinMode allows you to set pins as input or output as far as reading and writing goes. Once you know these things its just trial and error as far as optimizing the code and making sure that your logic is correct.

```
pinMode(pingPin, OUTPUT);
digitalWrite(pingPin, LOW);
delayMicroseconds(2);
digitalWrite(pingPin, HIGH);
delayMicroseconds(5);
digitalWrite(pingPin, LOW);
```

Figure 14. Shows the Ping Ultrasonic sensor being altered by a high and low pulse for some duration of time

```
int tcrtDetect()
{
 tcrt = analogRead(A0);
 Serial.println(tcrt);
 analogWrite(4, tcrt/4);
 delay(100);
}
```

Figure 15. shows the the code for the TCRT5000 Reflective Optical Sensor connected to analog pin A0

```
inches3 = microsecondsToInches(duration3);
cm3 = microsecondsToCentimeters(duration3);

 Serial.print(inches3);
 Serial.print("in3, ");
 Serial.print(cm3);
 Serial.print("cm3");
 Serial.println();

 delay(100);
```

Figure 16. Shows the serial output of the Ping Sensor converting time into distance

## X. Board Design

The board design was created with the use of Eagle schematic. The board consists of two layers is approximately 9" x 4". It was made with a spacious design to combat any seemingly complicated solder. The board is arranged in groups; capacitors, sensors, LEDs, and solenoids for simple and quick assembly.

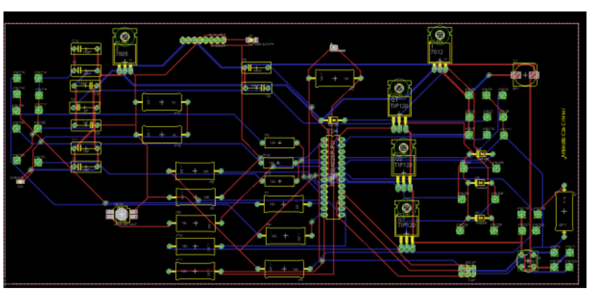
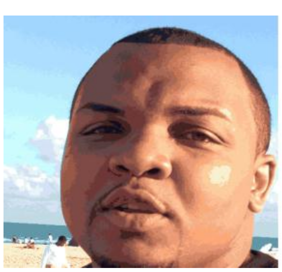


Figure 17. Shows the board file made with Eagle

## XI. The engineers



Stanley Andres is a graduating Electrical Engineer who looks to use his degree upon graduation to go into the marketplace.

Brandon Jefferson will be a graduating Electrical Engineer. He currently has one more semester remaining in his undergraduate academic career.

## XII. Conclusion

The Can Crusher will be able to

- Detect and sort aluminum cans from plastic bottles and glass bottles ( not crushing the non-aluminum cans)
- Have sensors to activate the Can Crusher once a can is placed inside the trash can
- Notify the proper personal that the storage bin is full
- Have LED display, using green and red lights. Green means operational and Red means trash is full and Yellow indicating a standby mode
- Have a storage bin with easy access to empty
- Standby mode


## Acknowledgement

We wish to acknowledge the assistance and support of Dr. Samuel Richie, and countless of Engineering faculty of University of Central Florida. Go Knights!


## References


[1] "Ultrasonic Sensors with Engineer Jim Lindblom." http://www.youtube.com/watch?v=ueqRp_XYau8. n.d 08 June 2010. Web.

31072013. <http://www.makershed.com/product_p/mkpx5.htm>.