# ECE 445 – SENIOR PROJECT (TEAM 31)
# Fall - 2012

# Smart automatic recycling trash basket

## Design Review

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# 1.0 Introduction

## 1.1 Overview

Our project is to design a smart automatic recycling trash basket. We selected this project because it is an interesting solution to an everyday inconvenience, and we are looking forward to its completion because of its practical uses. We hope that the convenience of a recycling trash basket that helps its user sort materials will encourage more people to recycle.

## 1.2.1 Goal

The goal of this project is to essentially create a recycling bin that is just as convenient to use as the small desk-side trash cans that students and office workers use. We hope to promote recycling by making it as easy to recycle something, as it is to simply throw it away. In addition to this, we will make our product as affordable as possible to achieve widespread use.

## 1.2.2 Advantage

The trash basket must be convenient as it is intended for practical use in everyday life. Some of these conveniences include:

- Being able to sort recyclables automatically
- Automatic lid for ease of use
- Warning light indicating when a basket is nearly full

## 1.2.3 Features

These will be accomplished through the use of the following features:

- Motor-operated lid that opens when it detects a nearby object
- Motor-operated tilting plate that closes off one bin to ensure proper disposal
- Internal infrared sensors that detect when either bin is getting too full
- Lid-mounted LED display that indicates when one or both baskets are full

# 2.0 Design

The block diagram on the following page describes the various components of the automatic recycling trash basket and their relationships to each other. Three separate sensors detect if an object is present, the type of object to be recycled, and whether or not the basket is full. The capacity check circuitry will activate the LED display when full.

As for the functionality of the basket itself, the basket lid and the tilting plate are operated by motors, and as such are only activated when their control circuitry indicates to do so. The interaction between the two control circuits allows for a set amount of time that the basket lid is open.

## 2.1Block Diagrams

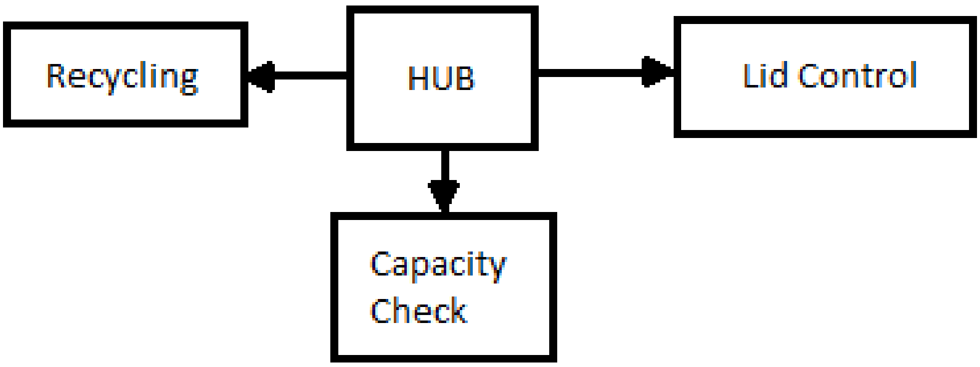



Fig 1: Overall System Setup Block Diagram

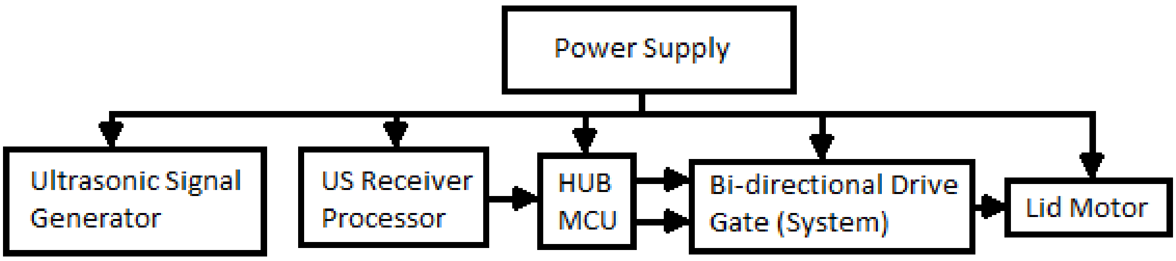



Fig 2: Lid Control Diagram

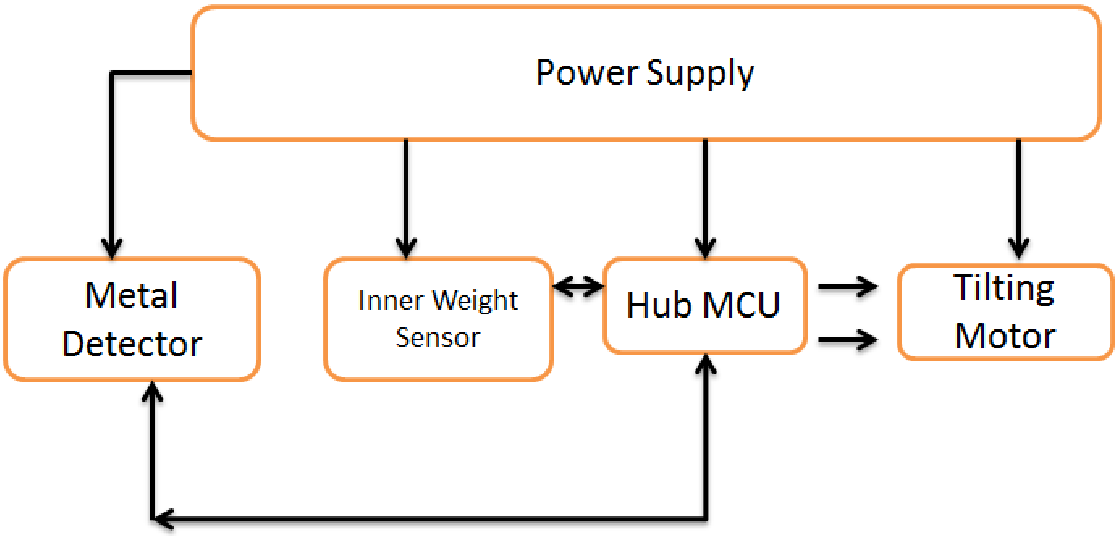



Fig 3: Recycling Block Diagram

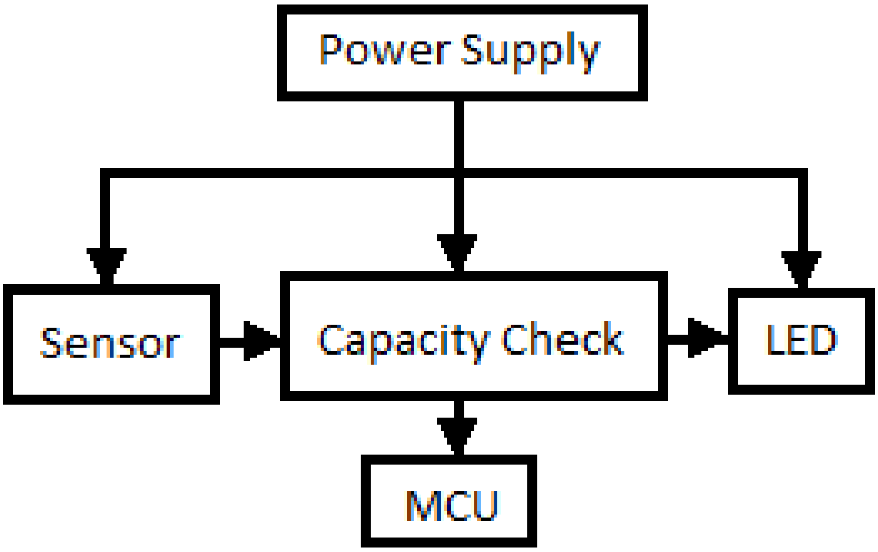



Fig 4: Capacity Check Block Diagram

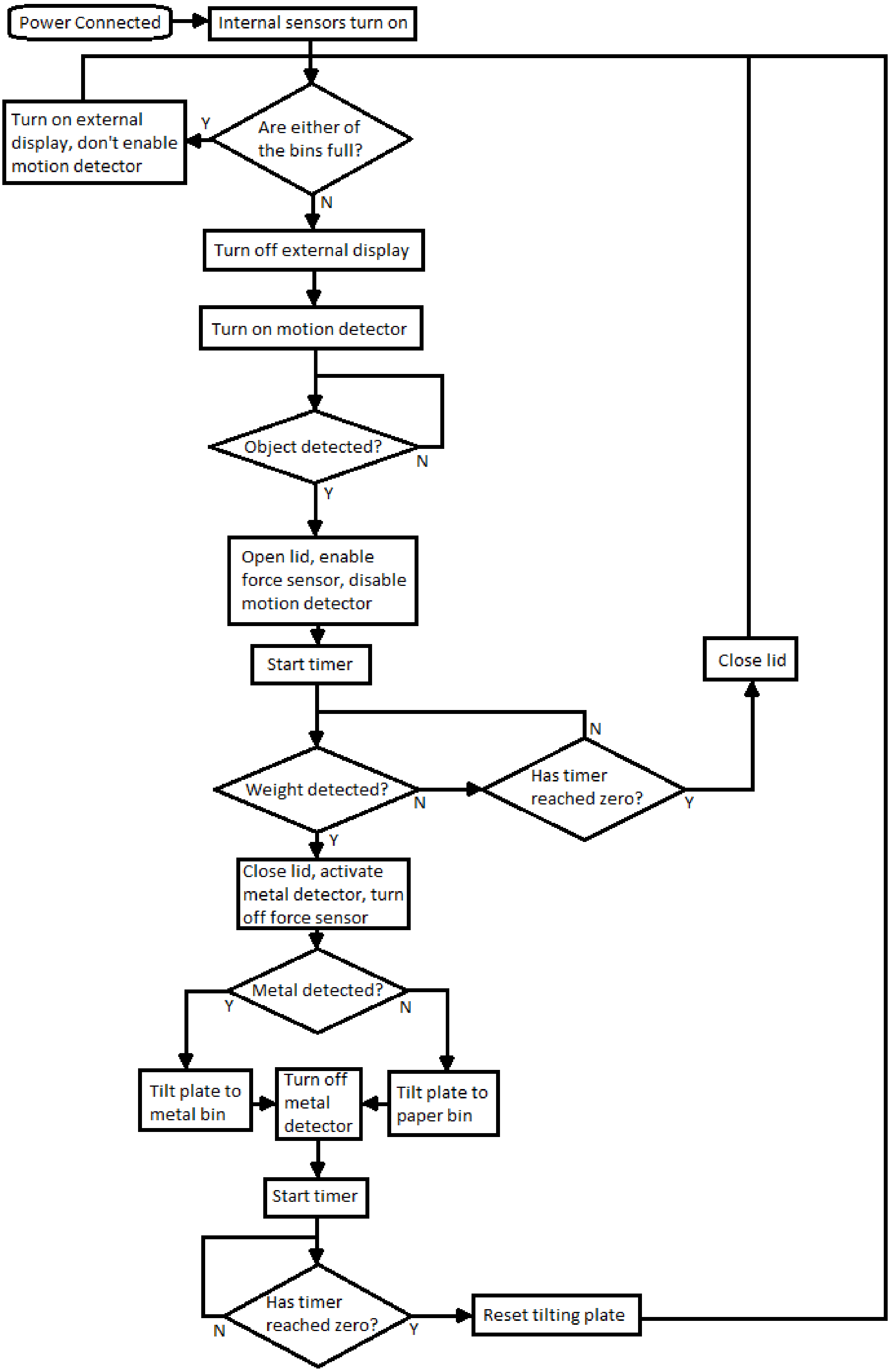



Fig 5. Algorithm Flow Chart

# 2.2 Block Description

## 2.2.1.1 Front Detection Sensor

The following schematic-level description of the Obstacle detection sensor circuit are divided into **two** function parts as Ultrasonic Generator and Receiver with processer:

**Sensor Generator**

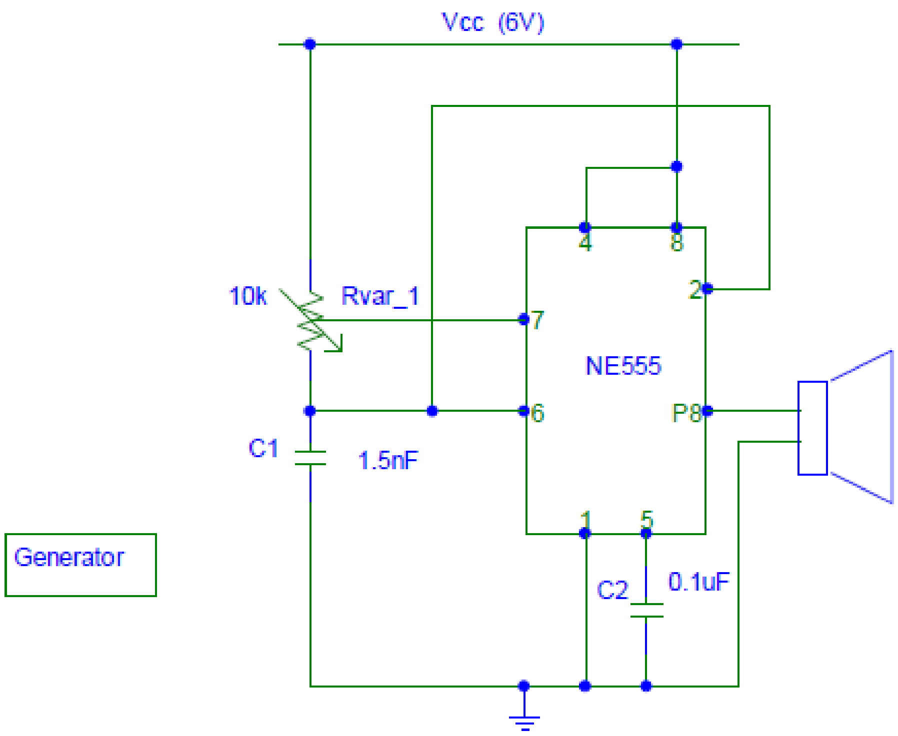



Fig 6. Ultrasnoic Generator

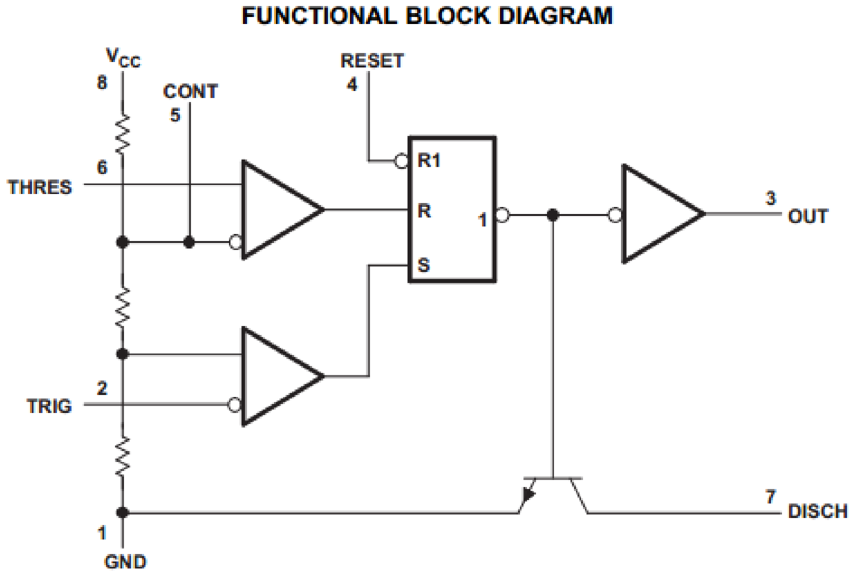



Fig7. Inner Structure of TIMER 555[1]

The generator part based on the 555 IC timer with variable resistor to control the output signal to change the generating distance of the Transducer, at 40KHz frequency (determined by $R_{var\_1}$ and $C_1$).

The purpose of the generator is to keep sending the detecting signal to the front area of the smart trash basket. If any significant object(human body) stand ahead, the signal will be reflect back and received by the Receiver. We use the 555 timer in astable mod as the timer can operate as an oscillator. It puts out a continuous stream of rectangular pulses having a specified frequency(40KHz). Resistor $R_1$ (verified by $V_{var\_1}$)is connected between $V_{CC}$ and the discharge pin (pin 7) and another resistor (10K of $R_{var\_1}$) is connected between the discharge pin (pin 7), and the trigger (pin 2) and threshold (pin 6) pins that share a common node. Hence the capacitor is charged through $R_1$ and $R_2$, and discharged only through $R_2$, since pin 7 has low impedance to ground during output low intervals of the cycle, therefore discharging the capacitor. Ctrl Node(pin 5) will not be used in the performance and is connect through 0.1uF $C_2$ to the GND.

Under this operation, the frequency of the pulse stream depends on the values of $R_1$, $R_2$ and C:

$$f = \frac{1}{\ln(2) \cdot C_1 \cdot (R_{var_1} + 10\text{K}\Omega)}$$

The high time from each pulse is given by:

$$T_{high} = \ln(2) \cdot (R_{var_1} + 10\text{K}\Omega) \cdot C_1$$

and the low time from each pulse is given by:

$$T_{low} = \ln(2) \cdot 10K\Omega \cdot C_1$$

**Signal Receiver:**

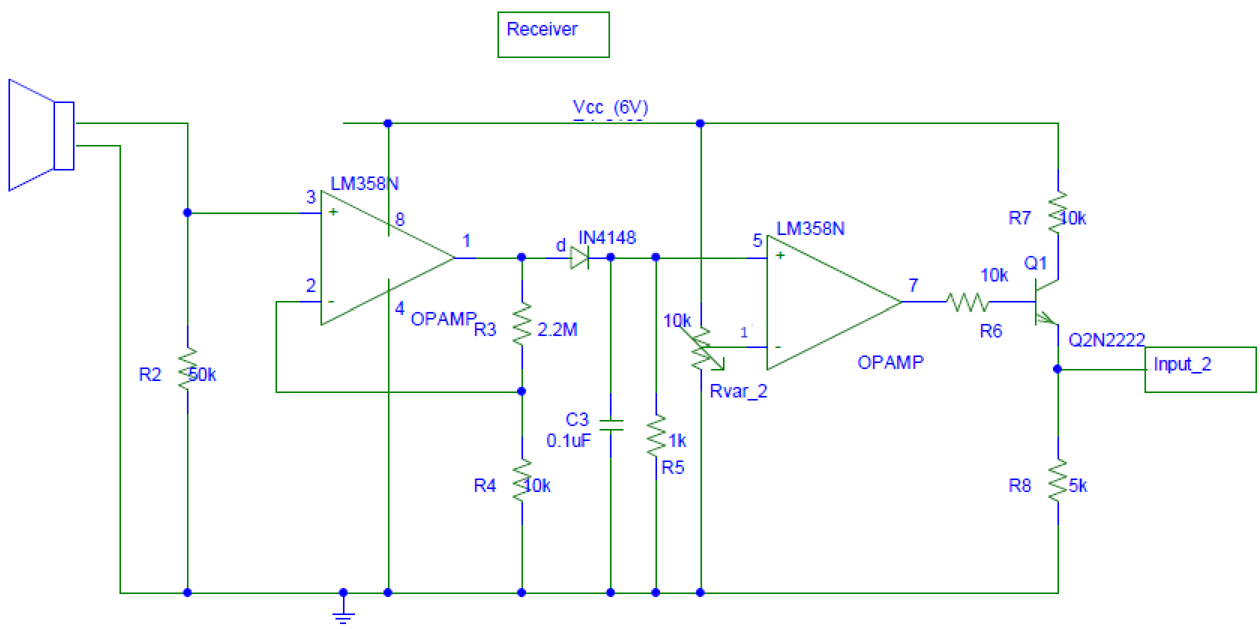



Fig 8. Ultrasonic Sensor (Receiver)

As the untrasonic detection signal hit the Obstacle back, iff any change happened in the feedback of sound, the transducer(UTR2) will provide a signal (a change in voltage) to the amplifer U1 by pin 3. This feedback voltage is varies based on the distance of the block object caused the reflecting ultrasonic signal. The pin2 is used as $V_{ref}$ /221 from the output by voltage regulator($R_3$ & $R_4$). The change voltage signal made by UTR to the pin3 will output a Changing signal to U2. Pin1 the set up through another variable resistor and the adjust value is the determination of the max detection distance of sensor system.

$$Vout\ (Pin\ 7) = (V5 - V1) * Gain$$

Once Vout > Vgate of bipolar transistor, the input_2 siganl will be on and send into HUB MCU.

## 2.2.1.2 Bi-directional driving system

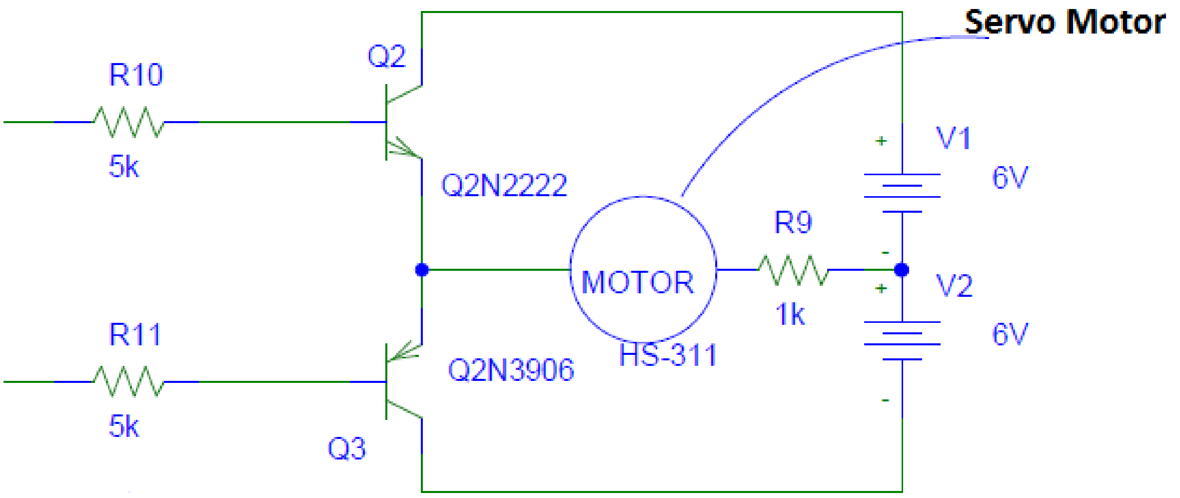



Fig9. Bi-directional Gate and Drive Circuit

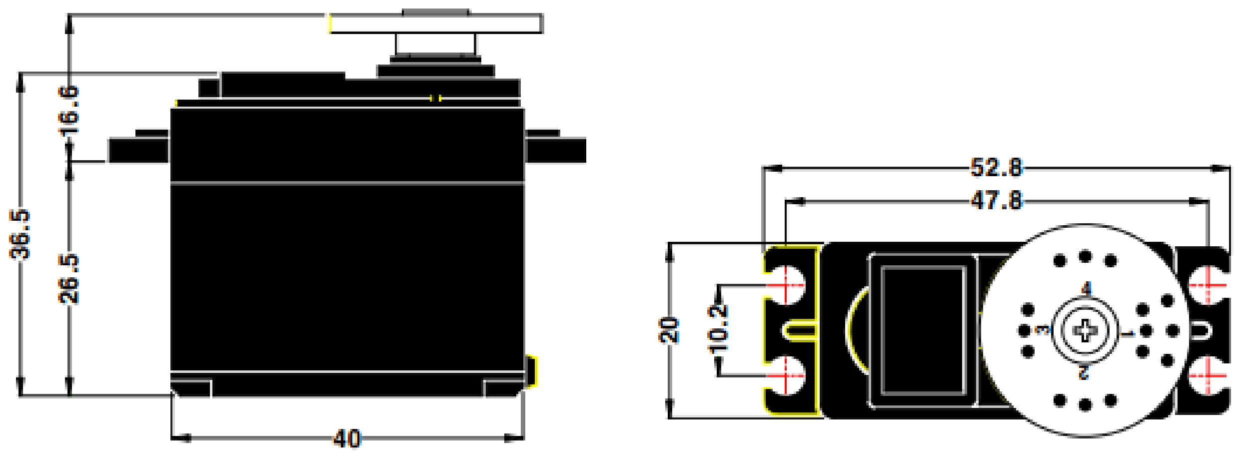



Fig10.Motor Feature Diagram[2]

Two (NPN and PNP) transistors are used to achieve the bi-direction of the servo moter as it used to drive the Lid and Tilting plate. And its two inputs is control by MCU, to determine the responding action(Open or Close):

| Q2(NPN) | Q3(PNP) | Current Direction | Motions(Lid/Tilting Plate) |
|---|---|---|---|
| ON | OFF | Forward | OPEN/Clockwise |
| Off | ON | Backward | CLOSE/Anticlock wise |

Motor Needs two power supply at 6v to run at 0.15sec/60$^o$ AT NO LOAD with 180mA. In case with load, we set R9 = 1KΩ and so $I_{load} < 600mA$.

### 2.2.2.1 Metal Detector

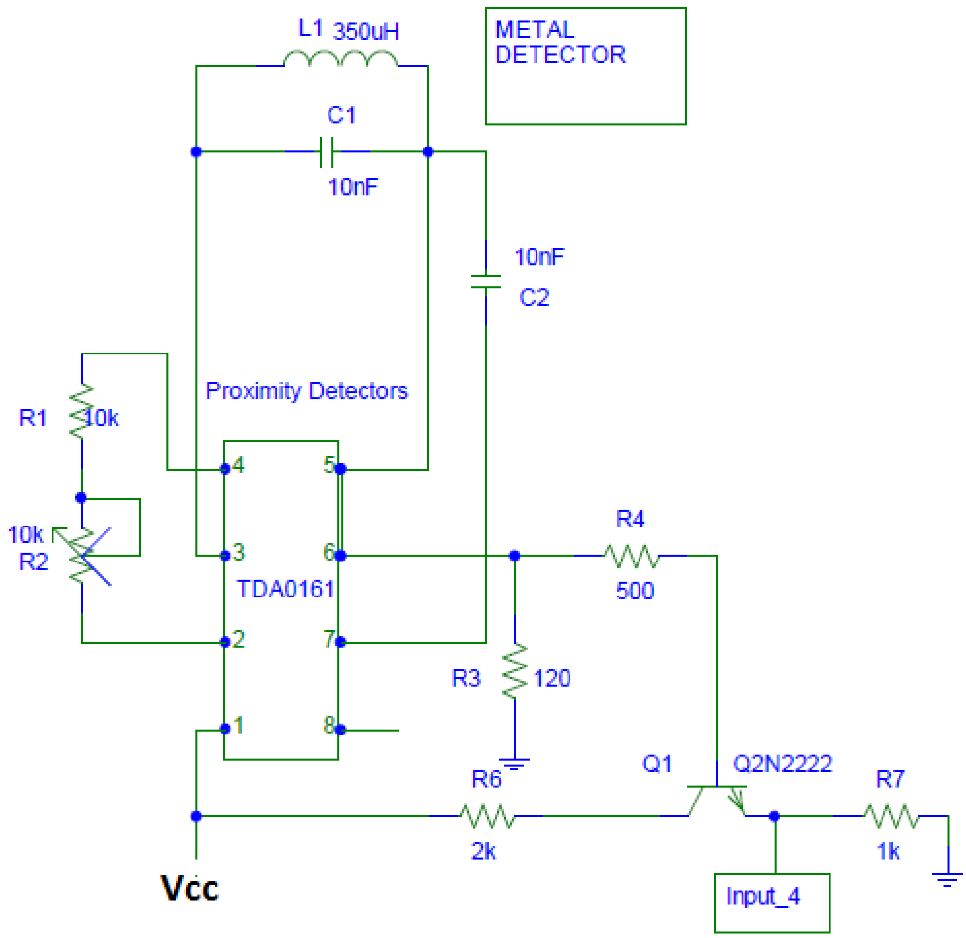



Fig11. Metal Detector

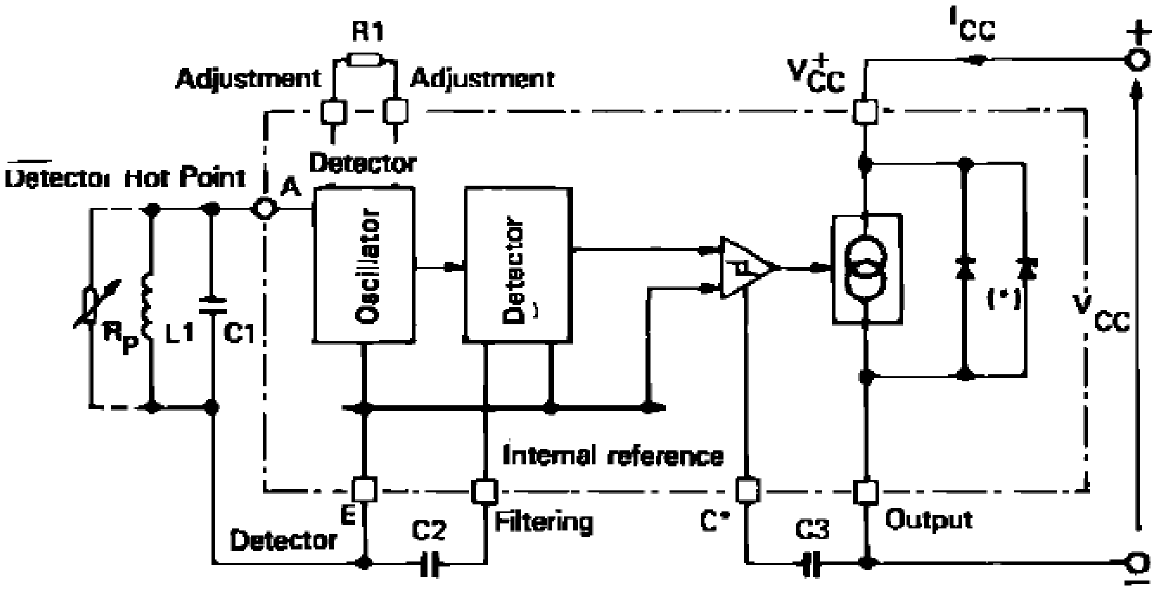
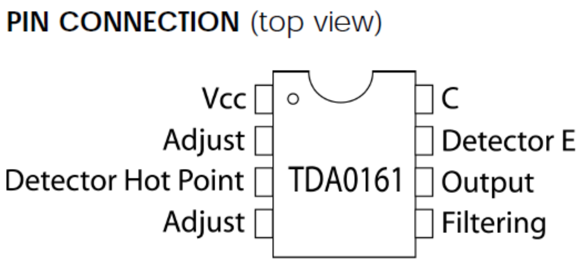



Fig12. TA0161 Schematic Diagram[3]

Figure 10 shows the complete schematic diagram of METAL DETECTOR. $L_1$ the searching coil connected with $C_1$ to generate the signal. Changing in $L_1$ $C_1$ and $R_2$ can result changing in sensitivity and range of the detection. The heart of this sensor module is the TDA0161 chip from ST microelectronics.TA0161 are designed for metallic body detection by detecting the variations in high frequency Eddy current losses. With an external tuned circuit they act as oscillators.




- Output current : 10mA.
- Oscillator frequency : 10 MHz.
- Supply voltage : + 4 to + 35 V

Fig13. TDA0161 Pin Connection & Rating[4]

Output signal level is altered by an approaching metallic object. Output signal is determined by supply current changes. Independent of supply voltage, this current is high or low according to the presence or the absence of a close metallic object. Input_4 is the output of the circuit to MCU show if a metallic stuff inside the basket(1/0 signal). We can use LEDs to test circuit provide an visual indication of presence or absence at a metals around the coil. To adjust the circuit you need to make sure there is no metal near the coil and then set the fine adjustment to a "Mid position". After that you need to adjust the course adjustment to turn on the LED and , adjust the fine adjustment to turn off the LED. This detector electronic circuit operates over a wide range input voltage of 4 -35 volts(specified in datasheet), we apply 6V output as uniform power support in all equipment.

## 2.2.2.2 Tilting Motor

The servo motor use for tilting plate is the same one used for Lid with same driving gate. It turns in one direction when it receives positive current, and turns in the opposite direction when it receives negative current. This is achieved through the two control signals located at P4 and P5, which are connected to an NPN and a PNP BJT respectively. Only one signal is high at a time, allowing for control of the direction of current flow.

## 2.2.2.3 Weight Sensor

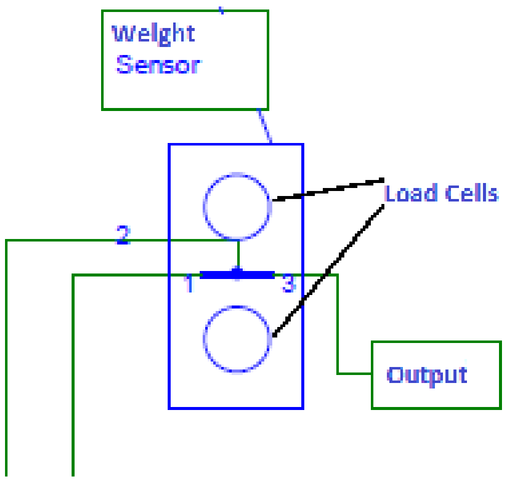



Fig 14. Weight Sensor

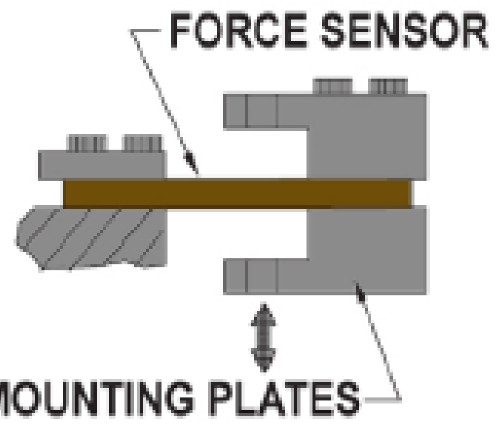



Fig 15. Sensor Cross Section

Sensor consist of two load cell is working like a transducer that is used to convert a force into electrical signal.This conversion is indirect and happens in two stages. Piezoelectric load cells are applied in this sensor, every load cell is subject to "ringing" when subjected to abrupt load changes , then will affect the output voltage of the cell. The electrical signal output is typically in the order of a few millivolts and requires amplification by an instrumentation amplifier before it can be used. A voltage difference with $V_{ref}$ (reference voltage will set up with previous measure result before load change) will occur and output signal “1” to the MCU.

## 2.2.3 Capacity Checking Block

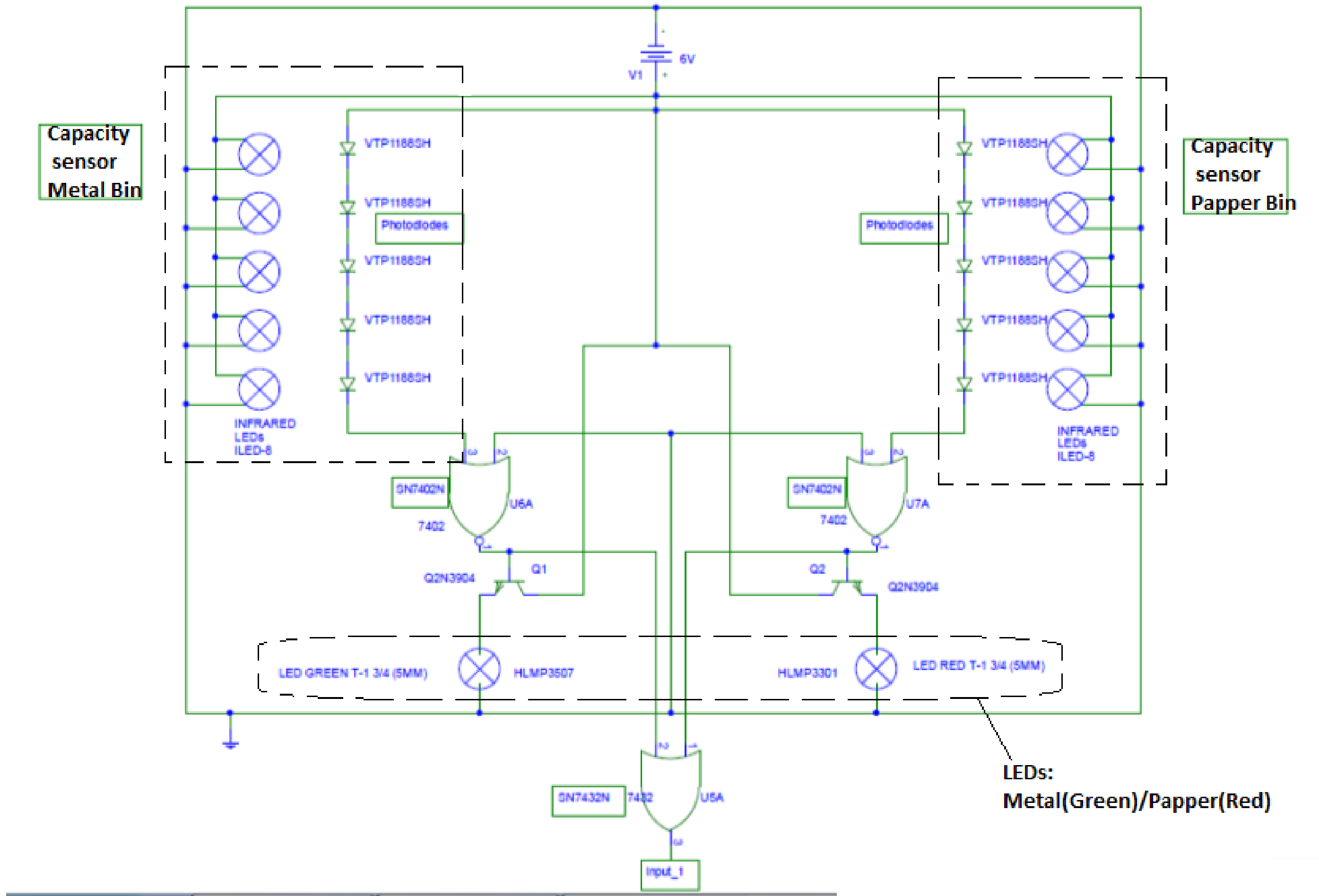



Fig 16. Capacity Checking system (schematic)

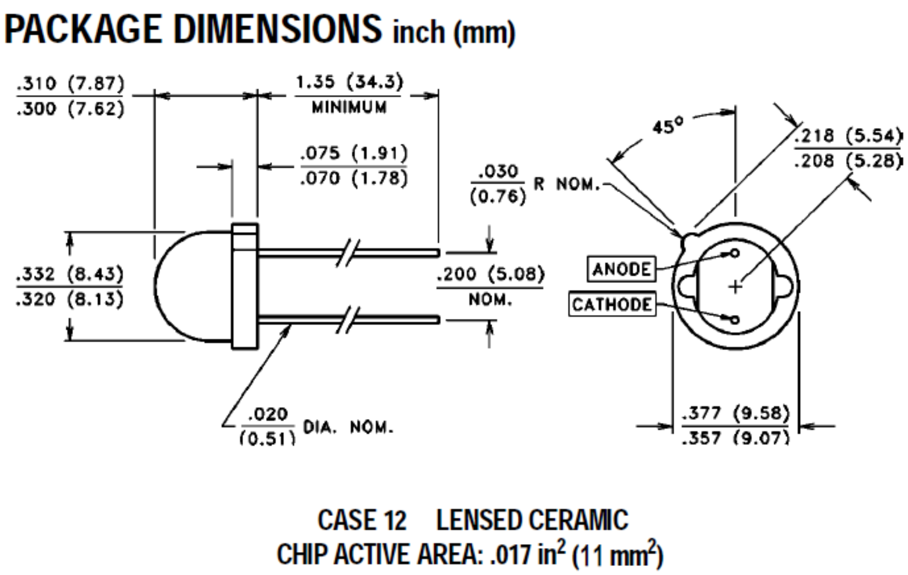



Fig 17. VTP 1188SH Package Dimensions[5]

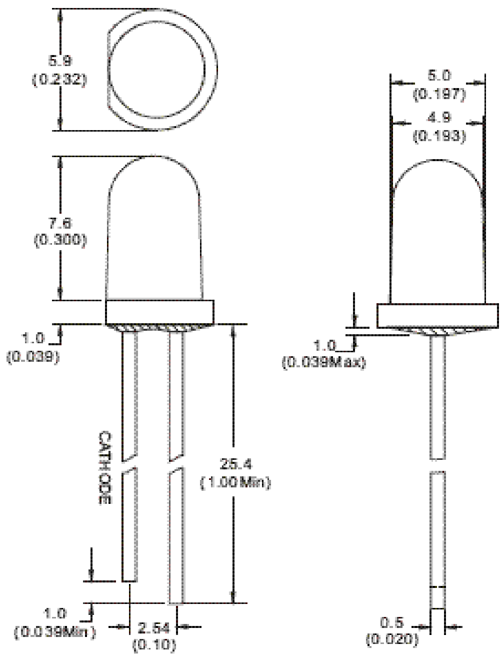



Fig 18. Infrared LED 940nm 5mm Round[6]

The sensors working in the capacity checking are two lines of infrared LEDS relates to two lines of photodiodes. Each line of LED (5 LEDs) is work in pair with 1 line of (5)photodiodes, every photodiode is going to detect one of the infrared LED in horizontal. If bins reach the horizontal "FULL" level and start block the light, and any one of the diode is off, it turned the NOR Gate ON to light up the corresponding LED and also sent the FULL signal back to MCU.

### 2.2.4 Hub Micro Control Unit

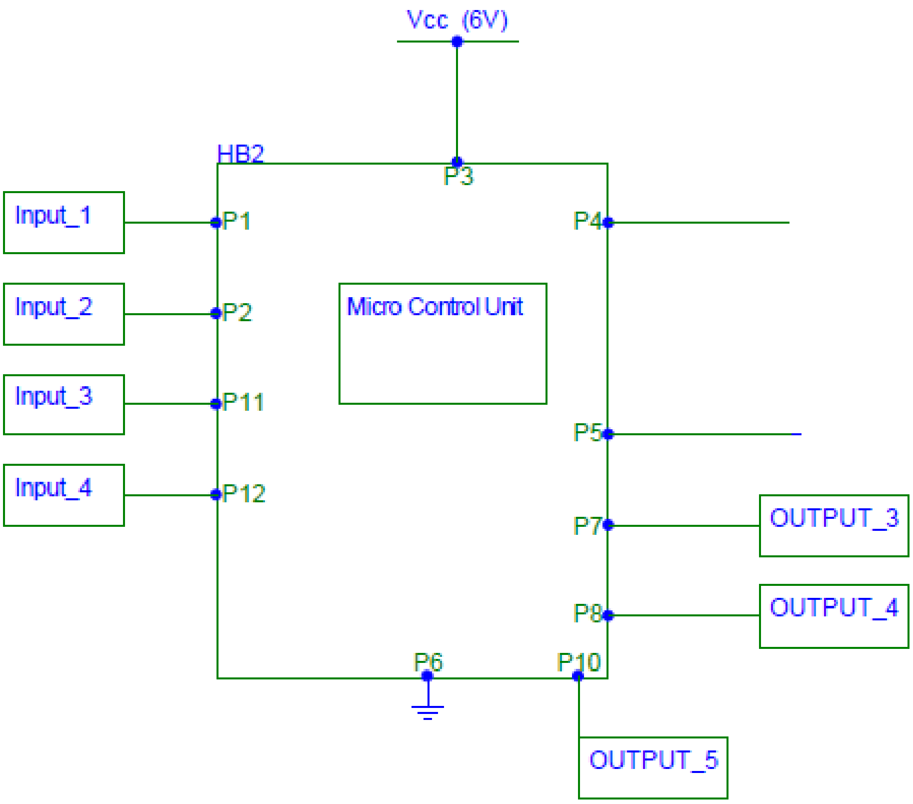



Fig 19. MCU Schematic

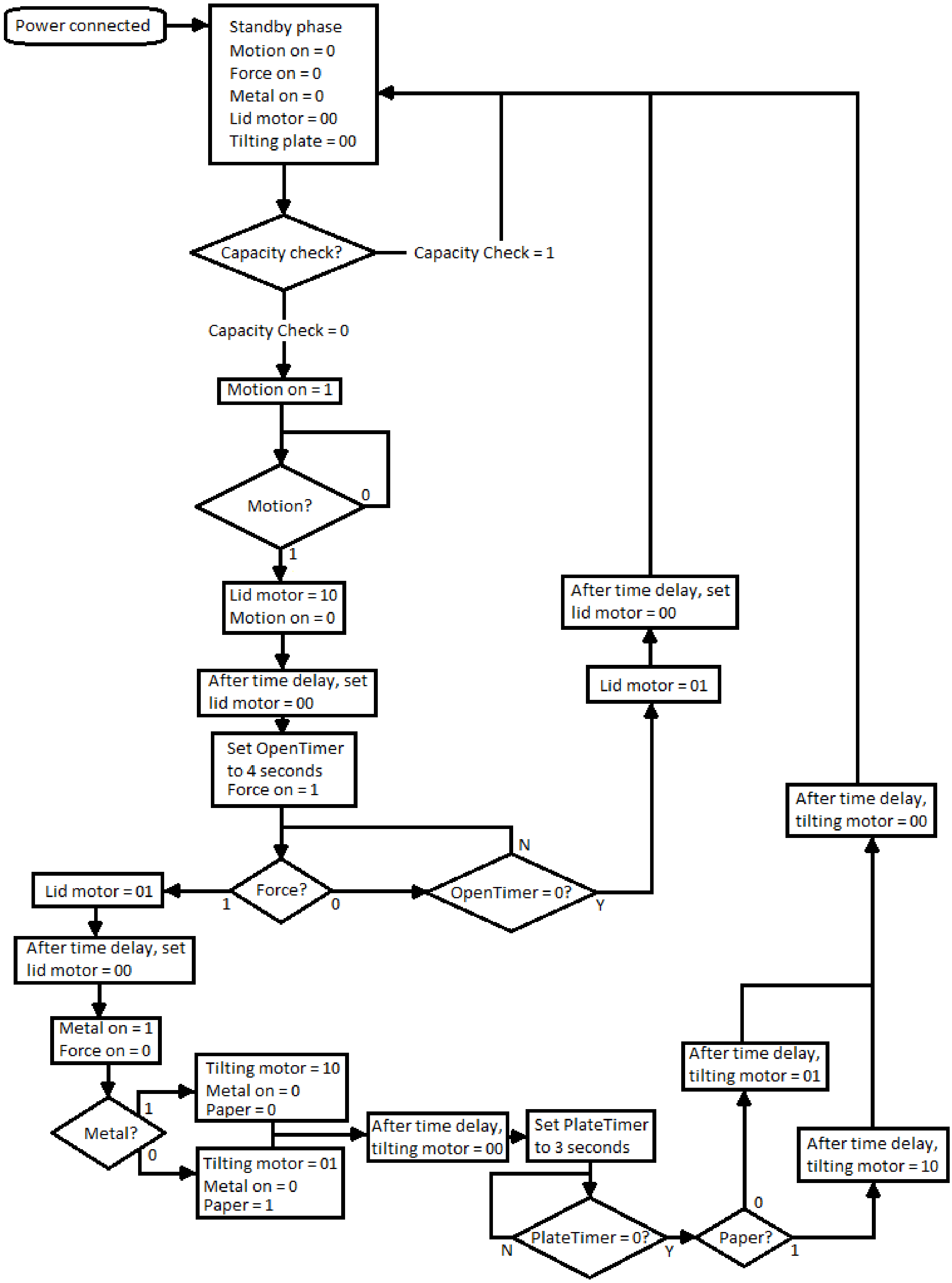



Fig 20. MCU Logic Flow Chart

The microcontroller unit relays signals between the various parts of the waste basket and determines when each sensor and motor is turned on based on the current state. When the waste basket is initially powered on, the microcontroller sets all of its outputs to zero and sits in a standby state. From this state, it checks the current capacity of the two bins. If either bin is full, the microcontroller remains in the standby state until one or both bins are emptied. The microcontroller does not turn on the external LED display. That is handled by the internal sensor circuitry.

However, if the capacity check reveals that the bins aren't full, the microcontroller instead turns on the motion sensor. This sensor continually scans the area in front of it for an object until it finds one. Once it does, it relays this to the microcontroller, which sets OUTPUT_1 to 1, opening the lid in the process. After a set time delay, OUTPUT_1 is zeroed out, halting the motion of the lid. A timer within the microcontroller is then started and OUTPUT_3 is set to 1, which grants a window of time during which an object may be placed in the waste basket. If an object is not placed in the waste basket within this time period, OUTPUT_2 is set to 1 to close the lid and is zeroed out after it is closed. The microcontroller then returns to its standby state.

If the force sensor detects weight in excess of the minimum tolerance on the tilting plate, it will close the lid and read the output of the metal detector to determine the composition of the material. Note that while "metal on" and "force on" are listed as separate signals, they are merely used as internal signals in the microcontroller for the sake of keeping track of states. OUTPUT_3 is the only physical signal that corresponds to these two signals.

After determining if the material is metal or paper, the microcontroller sets the tilting motor to turn the plate in the appropriate direction while turning off the metal detector. As the "metal" signal is a product of the metal detector, a dummy variable known as "paper" is used to simplify the states in the upcoming process. Regardless of the material, the motor is stopped after a brief delay, and then held at its tilted angle for three seconds to allow for the material to fall into the bin. After this delay, the microcontroller uses the Paper signal to correctly tilt the plate back to its original position, where it then stops moving. This returns the microcontroller to its standby state, and the process repeats.

# 3 Requirement & Verification

| Block | Requirement | Verification |
|---|---|---|
| **Microcontroller Unit** | | |
| Lid & Motion Detection Control | 1. Receive the sensor signal by programmable chip and transfer command signal to Motor to start mechanical motion(Open)<br>2. Stop proceed action signal to motor for certain seconds<br>3. Send second command to motor to achieve the CLOSE action<br>4. Proceed another signal to active Detection Controller<br>5. Wait until receive feedback signal from detection controller to start new cycle again.<br>6. If there is a signal from capacity monitor, turn to STOP status and let the lid closing until the signal is disappears | Test the coded chip with standard inputs(1/0) to different pins and measure the corresponding out pins result by oscillator equipment in school lab Use stop watch to check the waiting periods Set opening time to 3s<br>That T(open) = Tm+Tw = 3s;<br>Tm = time motor takes to complete the action on lid, set Tm ⩽ 0.75s by control the speed of motor<br><br>Tw = time the controller wait for the trash to be thrown in.<br><br>While T(close) = Tm |
| Recycling Control | 1. Start a operation cycle after the signal from Lid controller<br>2. Actions depends on the sensor inside the basket, if nothing has detected, call END signal back to Lid controller; if anything detected, active metal detector.<br>3. Detector find metal, proceed to motor to open | Test the chip with 1/0 inputs to pins to simulate all the state situations and check the correctness of responded outputs.<br>Check certain waiting period between two states with stopwatch.<br>T(open) = Tm<br>T(close) = Tm<br>Set Tm ⩽ 0.75s by |

| | | |
|---|---|---|
| | metal bin(tilt the plate to metal side)<br>4. Detector didn't find, proceed to motor to open paper bin(tilt the plate to paper side)<br>5. Wait certain seconds(T[open]) to let OPEN action done<br>6. Call motor to close the bin, and send END signal back to Lid controller when the bin closed. | control the speed of motor<br><br>Plate is fixed in horizontal before motor start by controller. It need to be strong enough to hold heavy metal trash. Test with maximum load of 5kg to decide the materials & structure of the plate and its holder.<br><br>Plate should tilts over $60^0$ to open big enough and let larger pieces drop in bins |
| **Motor** | | |
| Plate motor | 1. Able to receive two different signals from controller and response in opposite movement<br>2. Need to be drive by DC source like batteries. | Motor Condition synchronous servo motor<br>Vdc = 1.5-4.5V(drived by 1-3 batteries)<br>Higher Efficiency: Higher speed to reduce Tm with less power consumed |
| Lid motor | 1. Able to receive two different signals from controller and response in opposite movement<br>2. Need to be drive by DC source like batteries. | Motor Condition synchronous servo motor<br>Vdc = 1.5-4.5V(drived by 1-3 batteries)<br>Higher Efficiency: Higher speed to reduce Tm with less power consumed |
| **Sensor** | | |
| Front Sensor | 1. It need to detect presence of objects in front of the wastebasket within 50 cm. | Sensor Condition: Ultrasonic<br>Stable operation and |

| | | |
|---|---|---|
| | | lower failure rate, tests form in different testing distance and content sizes<br>Less Reaction time: T ≤ 0.5s |
| Inner Sensor | 1. Need higher sensitivity then others in this project to detect mini size of trash | Sensor:<br>Higher detect resolution: test the sensor with min object's weight at 1g |
| Capacity Sensors | 1. 2 detector should focus on the available capacity in each sub-basket, and give a signal back to the circuit if they are full. | Use one like lid sensor but has less detection distance within 2cm<br>Place the sensor on top of the bins and detect anything pile up to the top |
| **Metal Detector** | | |
| Oscillator | 1. Be able to generate alternating current into coil from dc current supply by DC power supply | Current need to be operates in a certain level that the magnetic field would be affected by any existing metal inside the bin at the bottom |
| Coils | 1. One coil used to generate magnetic field with oscillating current<br>2. One coil for measuring the electric field as a magnetometer, the change in the magnetic field due to the metallic object can be detected | Fixed the coil size to keep the measuring range around the area above the tilt-able plate |
| **Power Supply** | 1 Aim on one supply to support all the electrical device in this project with different needs of voltage and current values. | Using a series of voltage dividers to approach multi operation voltages on each device |

# 4 .Test Procedure

**Ultrasonic Transducer Pair**

Once the circuit is wired correctly, we will adjust the varistors listed in the schematic to achieve the desired signal quality and gain.

**Internal Infrared LED Array**

Primary testing will revolve around signal speed for various LEDs and lining up the arrays properly.

**Tilting Plate**

Testing will require multiple benchmarks to be reached. Our desired turning angle is 70 degrees, which must be accounted for in the placement of objects beneath the plates. Our force sensor should be able to detect 1g on the plate. The metal detector's range must cover the tilting plate but must not receive interference from outside sources.

**Tilting Motor**

Testing will revolve around adjusting turning speed and overall time to match the angle set in the tilting plate requirements. This will be tested along with the tilting plate.

**Control Unit**

Testing will primarily concern minimizing signal propagation delay and adjusting intentional delays between signal transmission to match the desired time delays (i.e. between detecting an object and activating the metal detector).

# 5. Ethical Consideration

## 5.1 Engineering Ethics

## (IEEE codes for electrical engineering)

Ethics is a set of moral principles or values to govern the conduct of an individual belonging to a group or profession on the basis of honesty, fairness, and justice. (IEEE) Electrical engineers must take caution in releasing new products to the public as well as in the technology that they themselves use, in order to ensure that no one will be hurt by the use of this technology. So, we added several codes of ethic that are needed when we make our project.

**7.8 IEEE Code of Ethics** **http://www.ieee.org/about/corporate/governance/p7-8.html**[7]

1. To accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment;

-> As we stated in the introduction, the goal of this project is to make a smart automatic recycling trash basket. As it is intended for commercial use, the price is an important factor. To account for that, we are going to find parts that are inexpensive as well as efficient. Also, since we are going to use batteries for power, the batteries also need to be safe, efficient, and have a long lifetime. This can be aided by implementing a standby time when the trash basket is not in use.

5. To improve the understanding of technology; its appropriate application, and potential consequences;

-> Our project utilizes several complex parts, which will require rigorous testing to successfully implement. The design combines electrical and mechanical parts to accomplish a task that could not be done as easily by only using one or the other.

7. To seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others;

-> We fulfill this requirement of the IEEE code by getting feedback and criticism through the peer review and design review and presentations. We need to mention any used information to give proper credit. Also, team members will give each other constructive criticism along the way to ultimately improve the finished product.

# 6. Costs and Schedule

## 6.1. Cost Analysis

### 6.1.1 Labor:

| Name | Analysis | Costs |
|---|---|---|
| Suwon Shin | ($15/hour) x 2.5 x 160hours | $ 6,000 |
| Scott Mattews | ($15/hour) x 2.5 x 160hours | $ 6,000 |
| Kaiyuan Fan | ($15/hour) x 2.5 x 160hours | $ 6,000 |
| Total | | $ 18,000 |

### 6.1.2 Parts:

| Part # | Manufacturer | Description | Use Purpose | Price | Qty | Total |
|---|---|---|---|---|---|---|
| NE556N | FAIRCHILD | General purpose dual Bipolar timer | Sensor / Inner lid control | $0.20 | 2 | $0.40 |
| Resistors | 10K(7), 1K(7), 5K(5) 120(1), 2.2M(1), 500(1) | Sensor / Inner control unit | | $0.05 | 22 | $1.10 |
| LM358 | NATIONAL | Low power op-amplifier | Sensor | $0.32 | 2 | $0.64 |
| XDR-24 | All Electronics | Ultrasonic Transducer | Sensor | $1.25 | 2 | $2.50 |
| Capacitor | 1.5nF, 0.1uF(2), 10nF(2) | | | $0.05 | 5 | $0.25 |
| Trash Basket | Janibell | Trash Basket | Body | $43.00 | 1 | $43.00 |
| Tilt-able Plate | Self-Made | Tilt-able Plate(Plastic) | Recycling Motion | $5.00 | 1 | $5.00 |
| HS-311 | BPHOBBIES.COM | Servo Motor | Drive systems | $7.55 | 2 | $15.10 |
| 2N2222A | STMICROELECTRONICS | NPN BIPOLAR | Motor, LED part | $0.15 | 3 | $0.45 |
| 2N2905A | MULTICOMP | PNP BIPOLAR | Motor, LED part | $0.58 | 3 | $1.74 |

| | | | | | | |
|---|---|---|---|---|---|---|
| VTP1188 SH | EG&G | Silicon photo Diode | Capacity Sensor | $2.14 | 10 | $21.4 |
| ILED-8 | All Electronics Corp | Infra LEDS | Capacity Sensor | $0.26 | 10 | $2.6 |
| HLMP3301 | AVAGO TECHNOLOGIES | LED RED T-1 ¾ | Capacity warning | $0.15 | 1 | $0.15 |
| HLMP3507 | AVAGO TECHNOLOGIES | LED GREEN T-1 3/4 | Capacity warning | $0.15 | 1 | $0.15 |
| SN74AHCT02N | TEXAS INSTRUMENTS | NOR GATE | Capacity warning | $0.50 | 2 | $1.00 |
| Miscellaneous | | Cables, Wires. Etc | Support equipment | $30 | | $30 |
| Total | | | | | | $125.48 |

### 6.1.3 Grand Total

Labor + Parts = $18,000 (Labor) + $125.48 (Parts) = **$ 18,125.48**

## 6.2 Schedule

| Week | Suwon | Scott | Kaiyuan |
|---|---|---|---|
| 10/ 1 | Design Review Finalization | Design Review Finalization | Design Review Finalization |
| 10/ 8 | Begin initial testing of motors and start working on bi-directional drive gate | Research proper operation of the microcontroller circuitry and its instruction set | Build up circuit of Motion Detector |
| 10 / 15 | Continue working on bi-directional drive gate, finalize motor timings | Begin writing simple code for motors and time delays | Finalize motion detector design, test for operation |
| 10 / 22 | Finalize bi-directional drive gate design | Finalize motor code and test on motors, begin working on sensor code | Begin designing force sensor circuitry |
| 10 / 29 | Begin tilting plate calibrations | Finalize sensor code, test on actual sensors | Finalize force sensor design, test for minimum tolerance |

| | | | |
|---|---|---|---|
| **11 / 5** | Design physical tilting plate, finalize angle calculations | Refine state transitions for microcontroller | Begin designing metal detector circuitry |
| **11 / 12** | Begin working on internal LED display | Test completed microcontroller, software debugging | Finalize metal detector design, test in with all mechanical parts |
| **11 / 19** | Thanksgiving Break | | |
| **11 / 26** | Finalize LED display, mechanical debugging | Final round of software debugging | General sensor debugging |
| **12 / 3** | Project Demo | Project Demo | Project Demo |
| **12 / 10** | Final Design Presentation / Graduation | Final Design Presentation | Final Design Presentation |
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# 7.0 Reference

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