ME 3484
Final Project Report

DETACHABLE POTHOLE DETECTION AND WARNING SYSTEM

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1. ABSTRACT

This project focused on building an easily detachable and user-friendly device that specializes in detecting potholes besides doing close range obstacle detection. The device comprised of two systems, one that is mounted on the front of a vehicle such as baby strollers, carts etc and the other is worn by the user maneuvering the vehicle . The first system looks for an obstacle and sends a signal to the other system wirelessly when detecting an obstacle and the second system warns the user of the obstacle by vibrating and blinking LEDs. Obstacles are detected using two non-contact ultrasonic sensors and the device is run by two BASIC Stamp modules.

2.INTRODUCTION

Obstacle detection has been the topic of much research in the past and new ways for avoiding various types of obstacles in various surroundings have been experimented upon . But the focus has been mostly on obstacle avoidance by autonomous agents and that too was mostly limited to extruding obstacles. These tended to make the detection mechanism very system-specific and not much suitable for general purposes.

The fact that a device is not fully autonomous does not mean that it can extract no advantage from an obstacle detection system . In fact , even if the user has adequate control over a device , he/she may still benefit from such a detection mechanism . Firstly , a human user, such as a person pushing a baby stroller or a grocery cart may not always be attentive enough to detect every obstacle on the way and risk the trouble of waking a sleeping baby , or scattering the grocery items all over the place. Also, users who use wheelchairs may need such a system especially if they face difficulty moving their head and keep an eye out for low or depressed obstacles manually. The system can also be helpful to manual goods transformation carts in large stores etc where a large amount of good**s** piled up for quick displacement does not go through the hassle of intricate fastening , thus run the risk of falling if the wheel of the cart is jolted by a pothole or the like.

Now though much work has been done for detecting various sorts of protruding obstacles , depressed obstacle detection has been somewhat neglected since it is naturally less straightforward. Methods that have been tried out were mostly mechanical (projected parts from the vehicle that detects potholes only after it touches them/falls in them) or based on image processing . These either add up to the cost or make the physical device unnecessary bulky and awkward.

This project was thus geared to meet the needs of the users who has maneuvering control over their vehicles but still may find it highly convenient to have a simple obstacle, and especially potholes , detection device. With that in mind , research was conducted to find the exact extent of needs of the users. It was found that all wheelchair chairs users were strongly against autonomous avoidance by their vehicle. This finding was generalized to users pushing baby strollers as, by common sense also, the potential threat to safety is too high if such vehicles are provided with autonomous control . Based in this research, it was decided to incorporate into the device a simple warning system instead of automatic avoidance.

The project's ultimate aim thus finalized as one to build a general, easy-to-use, detachable and versatile system that detect potholes, besides close objects , and give warning to the user accordingly.

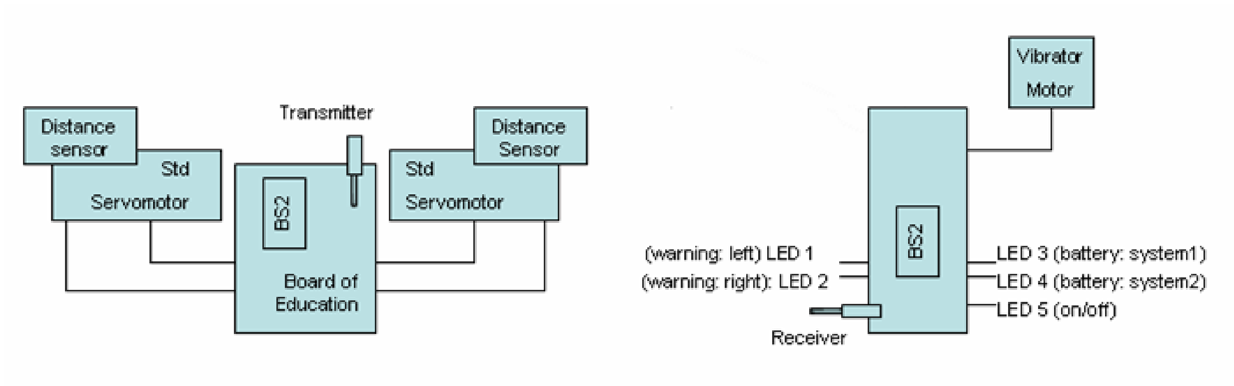
3. DEVICE DESCRIPTION

3.1 THEORY

The device is a collaboration of two systems. Both of them are run by a separate BS2. The first one uses a BASIC Stamp Board of Education while the second one only uses the BASIC Stamp 2 microcontroller. The systems will be referred to as System A and System B respectively throughout the rest of the report. The general object on which the device is mounted will be referred to as the 'vehicle' henceforth .

System A is the sensing part of the device. It is meant to be mounted on the lower front part of the vehicle and consists of two distance sensors on servomotors and is powered by a single BS2 module on a Board of Education . The servomotors are there to allow the sensor align themselves towards their critical angles. Once either of the sensors detects an object , a signal is sent wirelessly through a transmitter to System B which receives it using the wireless receiver of the pair.

System B is meant to be worn on the wrist of the user - the person maneuvering the vehicle . It has a vibration motor that starts vibrating once a signal of pothole detection is received and two LEDs that light up based which sensors sensed the obstacle (left or right) . There are also three other LEDs , one to display the status of the whole system (on/off) , the other two are basically the outputs of a battery meter - each represent the battery of one system and lights up when the battery is running low, indicating that the user should change the battery . This part has two switches that the user can use - one to shut down the whole system and the other to only turn off the vibrator if the user wishes to .



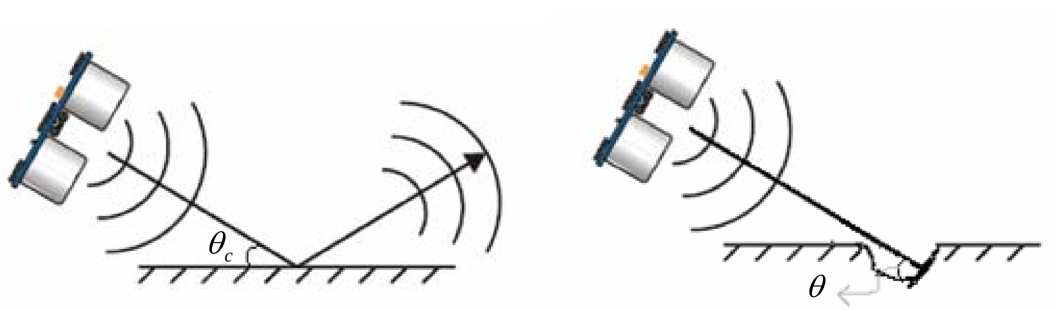
(a) (b)

Figure 1 : Block Diagram of the device : (a) System A (b) System B

Each component of the diagram is described in more details below -

<u>Ultrasonic Distance Sensor:</u> This sensor consists of a transmitter and a receiver . The transmitter sends an ultrasonic signal of 40 Hz which, if it hits an object which reflects it back, returns and is received by the receiver. The sensor provides the total time of flight of the sound and the distance can be calculated from it. Normally, solid obstacles in the path can be detected the following way: sensor would face the path and continue giving highest value of time (nothing close enough to reflect the signal) until the sensor experiences an obstacle and provides a shorter time value. But this way is good enough only for solid obstacles that stick out in an otherwise plain path ; not for depressed obstacles , like a pothole or staircase etc .

To detect the latter type of obstacles, the device uses the sensors in a somewhat different way. Once the sensors are mounted on the vehicle, they align themselves towards the path in such a way that , the signal they emit bounces of the ground right at its critical angle . This results in the signal never coming back to the receiver , thus the sensor provides the highest value of time . Now if a pothole is there on the way , the signal travels a bit farther and almost always hit the ground (the side of the pothole) at a bigger angle than the critical angle and thus reflects back to the sensor which outputs a much lower value of time, and thus , 'detects' the pothole .



(a) plain ground (b) pothole

Figure 2 : Ultrasonic burst hitting ground at (a) critical angle θ_c *(b)* $\theta > \theta_c$

As the ultrasonic sensor only provides the time of flight of the burst, calculations are made as follows to find the conversion value to get the distance in centimeters .
If the speed of sound in air is denoted as V_{air} m/s and the time of flight of the ultrasonic burst is T s, then the distance traveled by the pulse before it hit the obstacle is given by :

$$D = \frac{V_{air} \times T}{2}$$

But V_{air} at room temperature 72 °F (22.2 °C) is 344.8 m/s. So the distance in cm is given by

$$D = 0.03448T$$

For the PBasic code , this constant is converted to 2260 to be used with the ** operator .

Because the datasheet for this sensor mentions that measurement that the sensor gives is dependent on the surrounding temperature, initially a temperature sensor was used keep track of the temperature and adjust the distance values accordingly. But it was found that the difference in the distance measurements caused by temperature is only that of a few millimeters whereas the project deals with distances in terms of several centimeters. So the temperature sensor was taken off to reduce cost.

The reason why this sensor was chosen was that other sensors are either very sensitive and will detect the slightest obstruction (like the laser sensor)or they are very costly.

<u>Standard Servomotors:</u> The distance sensors are glued to the horn of the servos. The servos are used to help the sensors position themselves at the correct critical angle with respect to the ground. Because there is wide range of possible places in the vehicles where the user can mount the sensors, the sensors have to realign themselves each time the user decided to change their place. The sensors starts by facing vertically downwards , the left sensor then slowly rotates along an axis parallel to the ground until it finds the point where it reads infinity, i.e., it is at its critical angle and the sound that it emits never comes back . It positions itself there and the second sensors follow suit .

<u>Receiver and Transmitter :</u> The transmitter in system A transmits 3 binary bits serially : the first one for cart battery, the second one for obstacle detection from the right sensor , the third one for obstacle detection from left sensor.

<u>Vibrator Motor:</u> The vibrator was made by using a standing DC motor with a non symmetric load to use inertia to our advantage,

<u>Battery Meter:</u> The batteries used in both systems are having ratings of 9 Volts each. To make the meter, a voltage divider was used with a 100 KΩ and 33KΩ resistor. Divided voltage goes into P2, once the voltage goes below 1.4V pin state will change detecting

low battery. If the voltage across the battery goes lower than 5.64 volts P2 will become low

7805 5V voltage regulator
TIP NPN transistor

A switch is provided in System B that instantaneously shuts down the system and effectively the whole device (as System A doesn't have any actuating part that can prove harmful or show visible and inconvenient malfunction) . Another switch is provided to shut off the vibrating motor only , as the user might wish to only be warned of pothole and/or obstacles by the LEDs, but not the vibrator.

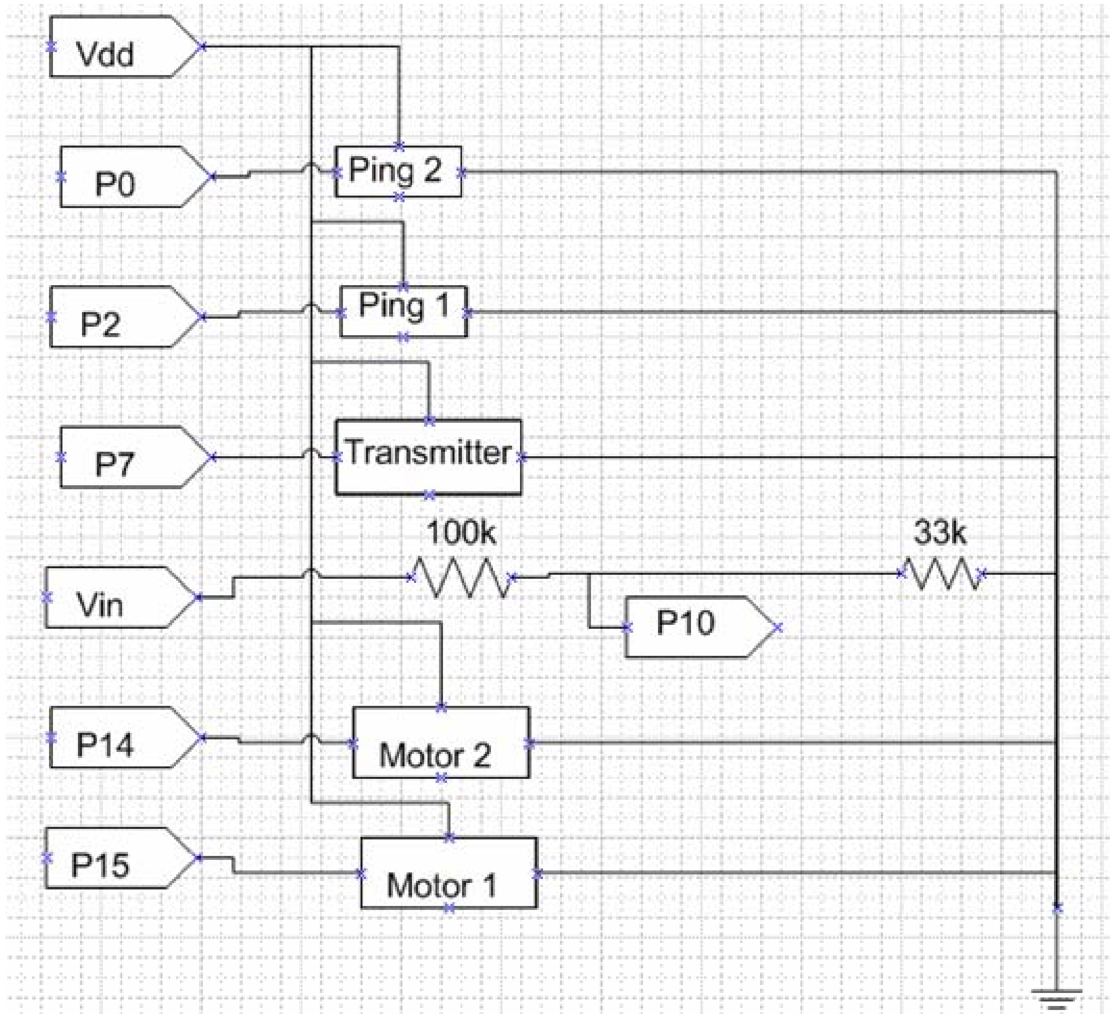
3.2 MECHANICAL DESIGN

In System A , to make the device more versatile , each servomotor , on which the distance sensor is mounted , is itself mounted on a slider made of aluminum rod and stuffed with rubber . This given the user a horizontal range of around 4 centimeters to position the sensor even after it is mounted . Once slid to a desired position , the sensor-servo pair can be fastened with a small screw.
This slider is stuck to a metal plate which itself is attached to the rotating interior end of a 2" C-clamp . The whole sensor-servo-slider-plate combination can be thus instantly attached anywhere in the front structure of a vehicle . Because the metal plate is attached to the rotating end of the clamp , the clamp can be easily fastened onto bars that are horizontal , vertical or tilted at any angle. The size of the clamp was also chosen so that it caters to a variety of bar thickness in a typical vehicle structure .

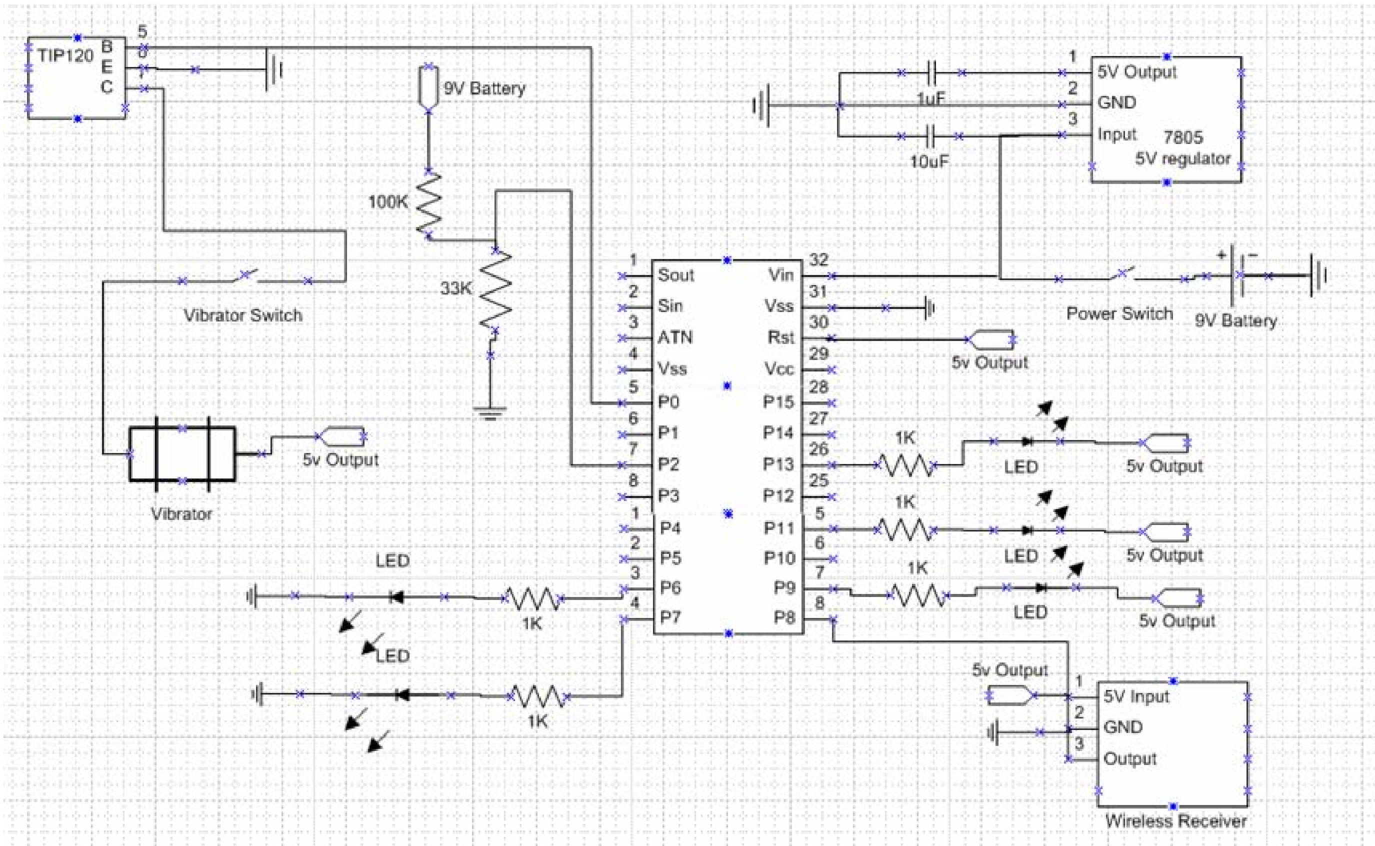
System B required an extensive amount to mechanical work not only to build a circuit from scratch on a strip board but also to build a safety case for it made of Plexiglas. System B thus has all its circuitry in a box that can be attached to a user's wrist using Velcro straps . The vibrator motor is situated spiritedly outside the box so that it can be closer to the skin .

3.3 ELECTRONIC CIRCUITS

The circuitry for System A is placed on the Board of Education and reproduced below:



The circuitry for System B is soldered onto strip board and is slightly more involved as it has to pack a lot of materials in container to be worn around the wrist . It is as follows:



4. DISCUSSION

4.1 COST ISSUES

The total cost of the prototype was around $366 .
The bill of prototype is produced below :

Serial No.	Item Name	Quantity	Price per item ($)	Total cost ($)
1	BASIC Stamp 2 Module	2	49	98
2	BS2 Board of Education	1	69.95	69.95
3	PING))) Ultrasonic Distance Sensor	2	29.95	59.9
4	Standard Servo (#900-00005)	2	12.95	25.9
5	DC Vibration Motor	1	2	2
6	Parallax 433.92 MHz RF Transmitter (#27980)	1	39.95	39.95
7	Parallax 433.92 MHz RF Receiver (#27981)	1	39.95	39.95
8	Velcro	1	4	4
9	C-Clamp	2	4	8
10	Connection cables/wires	2	3	6
11	Plexiglas	1	5	5
12	NPN BJT TIP120	1	0.40	.40

13	7805 Voltage Regulator	1	1	1
	GRAND TOTAL			360.055

If mass produces the cost will go down much lower . With all the electronic parts and parallax parts that has reduced priced when bought in bulk , it is estimated that for mass producing 100 products , the cost of each product will come down to as follows :

Serial No.	**Item Name**	**Quantity**	**Price per item ($)**	**Total cost ($)**
1	PIC micro controller	2	2.50	3
2	Custom Ultrasonic Distance Sensor w/ Circuitry	2	7	14
3	Standard Servo (#900-00005)	2	5	10
4	DC Vibration Motor	1	2	2
5	Custom RF Transmitter	1	5	5
6	Custom RF Receiver	1	5	5
7	Velcro	1	0.20	0.20
8	C-Clamp	2	1	2
9	Switches	2	0.10	0.10
10	Plastic Cover	1	1	1
11	NPN BJT TIP120	1	0.05	.05
12	7805 Voltage Regulator	1	.05	0.05
	GRAND TOTAL			40.40

4.2 ADVANTAGES AND DISADVANTAGES

The advantage of the system is that it can detect potholes and object in the way. It is user friendly and can fit on multiple vehicles. The only disadvantage is that it cannot detect cliffs.

5. CONCLUSION

The pothole detection system proved to be quite a handy device to be used at will on any manually driven slow vehicle . Its maintenance is easy and easily replaceable parts guarantee a long life. Possible future work may focus on making the distance at which potholes are detected greater and making the part that is worn by the user lighter and smaller .

6. REFERENCES

1. Smart Sensors and Applications , Student Guide. Version 1.0. Parallax Inc.
2. What's a Microcontroller , Student Guide. Version 2.2 . Parallax Inc
3. PING)))™ Ultrasonic Distance Sensor (#28015), Data sheet , Parallax Inc.
4. . The parallax official website : www.parallax.com

7. APPENDICES

7.1 APPENDIX A: PBasic Code

System A

```
' {$STAMP BS2}
' {$PBASIC 2.5}

'name the variables
initialdistance1 VAR Word
initialdistance2 VAR Word
distance1 VAR Word
distance2 VAR Word
counter VAR Byte
motorAngle1 VAR Byte
motorAngle2 VAR Byte
warning VAR Byte

'assign the pins
ping1 PIN  2
ping2 PIN  0
motor1 PIN 15
motor2 PIN 14
battery PIN 10

'initialize parameters
motorAngle1 = 50
motorAngle2 = 100
DIR10 = 0                          'make battery pin an input

' Make the sensors face downwards
FOR counter = 1 TO 25
  PULSOUT motor1, motorAngle1*10
  PULSOUT motor2, motorAngle2*10
  PAUSE 20
NEXT

'---------Search for critical angle -------------'

getCriticalAngle:

GOSUB getDistance
```

```
IF 2260**distance1 < 300 THEN              'finding critical angle 1
  motorAngle1 = motorAngle1 + 1
    FOR counter = 1 TO 10
      PULSOUT motor1, motorAngle1*10
      PAUSE 20
    NEXT
  GOTO getCriticalAngle
ELSEIF  2260**distance2 < 300 THEN          'finding critical angle 2
 motorAngle2 = motorAngle2 - 1
    FOR counter = 1 TO 10
      PULSOUT motor2, motorAngle2*10
      PAUSE 20
    NEXT
  GOTO getCriticalAngle
ELSE
  motorAngle1 = motorAngle1 - 1
  motorAngle2 = motorAngle2 + 1
    FOR counter = 1 TO 10
      PULSOUT motor1, motorAngle1*10
      PULSOUT motor2, motorAngle2*10
      PAUSE 20
    NEXT
  GOSUB getDistance
  initialdistance1 = 2260**distance1        'get initial distance 1
  initialdistance2 = 2260**distance2        'get initial distance 2
  motorAngle1 = motorAngle1 + 1
  motorAngle2 = motorAngle2 - 1
    FOR counter = 1 TO 10
      PULSOUT motor1, motorAngle1*10
      PULSOUT motor2, motorAngle2*10
      PAUSE 20
    NEXT
  GOTO detectPothole
ENDIF

'---------- Detect Pothole----------------------'
detectPothole:

DO

  GOSUB getDistance

    IF 2260**distance1 > (initialdistance1 + 5) AND 2260**distance1 < 100 THEN
'right
      warning = 2
```

```
    ENDIF

    IF 2260**distance2 > (initialdistance2 + 5) AND 2260**distance2 < 100 THEN    'left
      warning = 4 + warning
    ENDIF

    IF battery = 0 THEN
      warning = 1 + warning
    ENDIF

  PULSOUT 7, 1200
  SEROUT 7, 16468, [ "!", warning]
  PAUSE 10
  warning = 0

LOOP

END

'----------- Get Distance --------------------'

getDistance:

PULSOUT ping1,5
PULSIN  ping1,1, distance1
PULSOUT ping2,5
PULSIN  ping2,1, distance2

DEBUG CLS, DEC5 2260**distance1, "      ", DEC motorAngle1*10, "        ", DEC
initialdistance1
DEBUG CR, DEC5 2260**distance2, "      ", DEC motorAngle2*10  , "        ", DEC
initialdistance2
DEBUG CR, DEC battery
PAUSE 100
RETURN
```

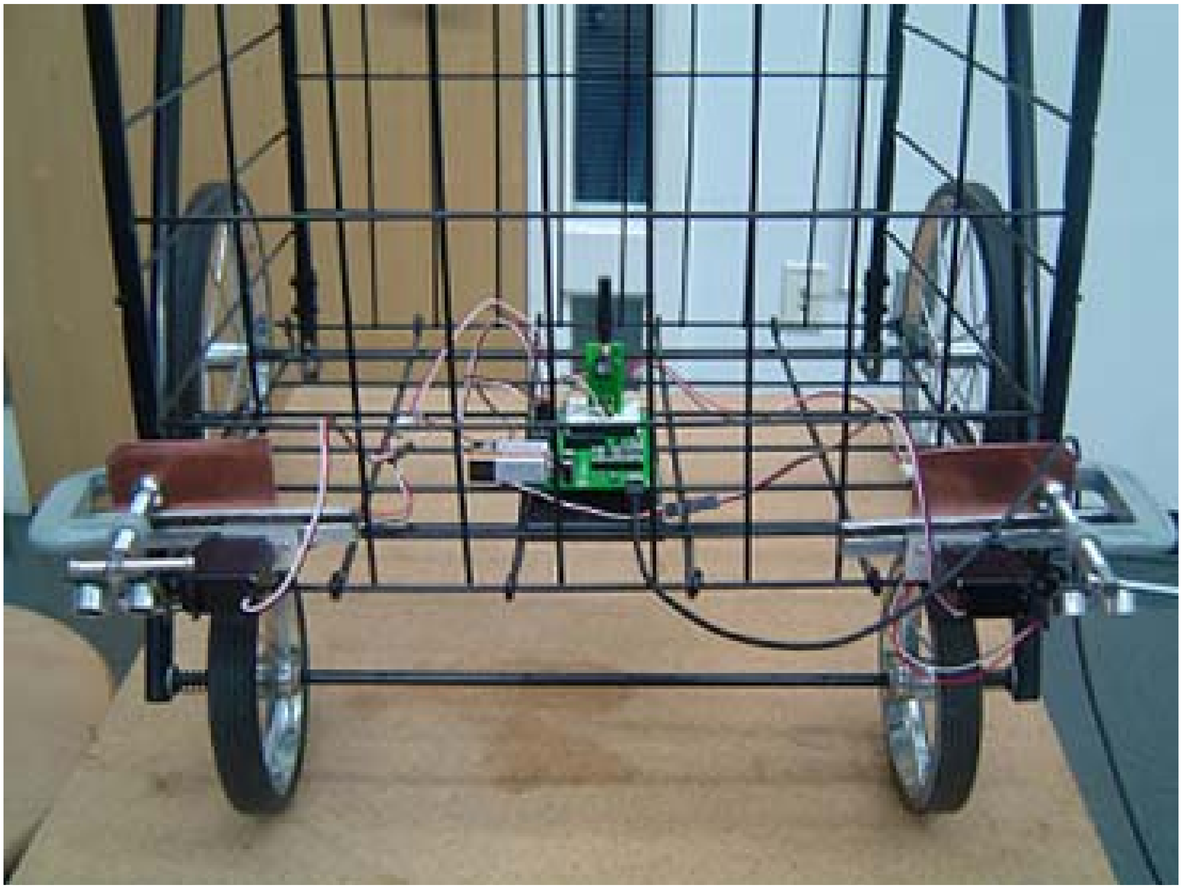
System B

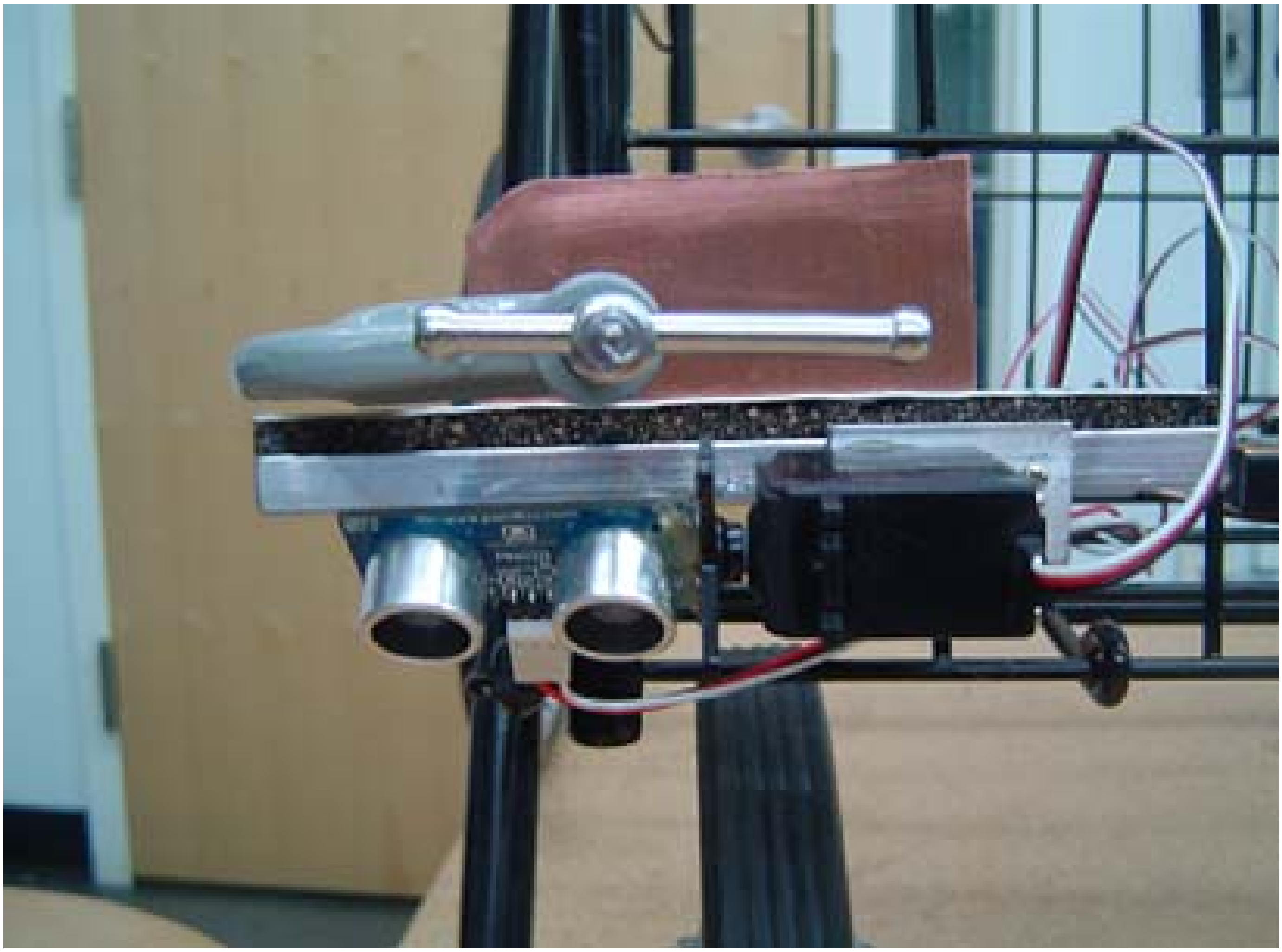
```
' {$STAMP BS2}
' {$PBASIC 2.5}
```

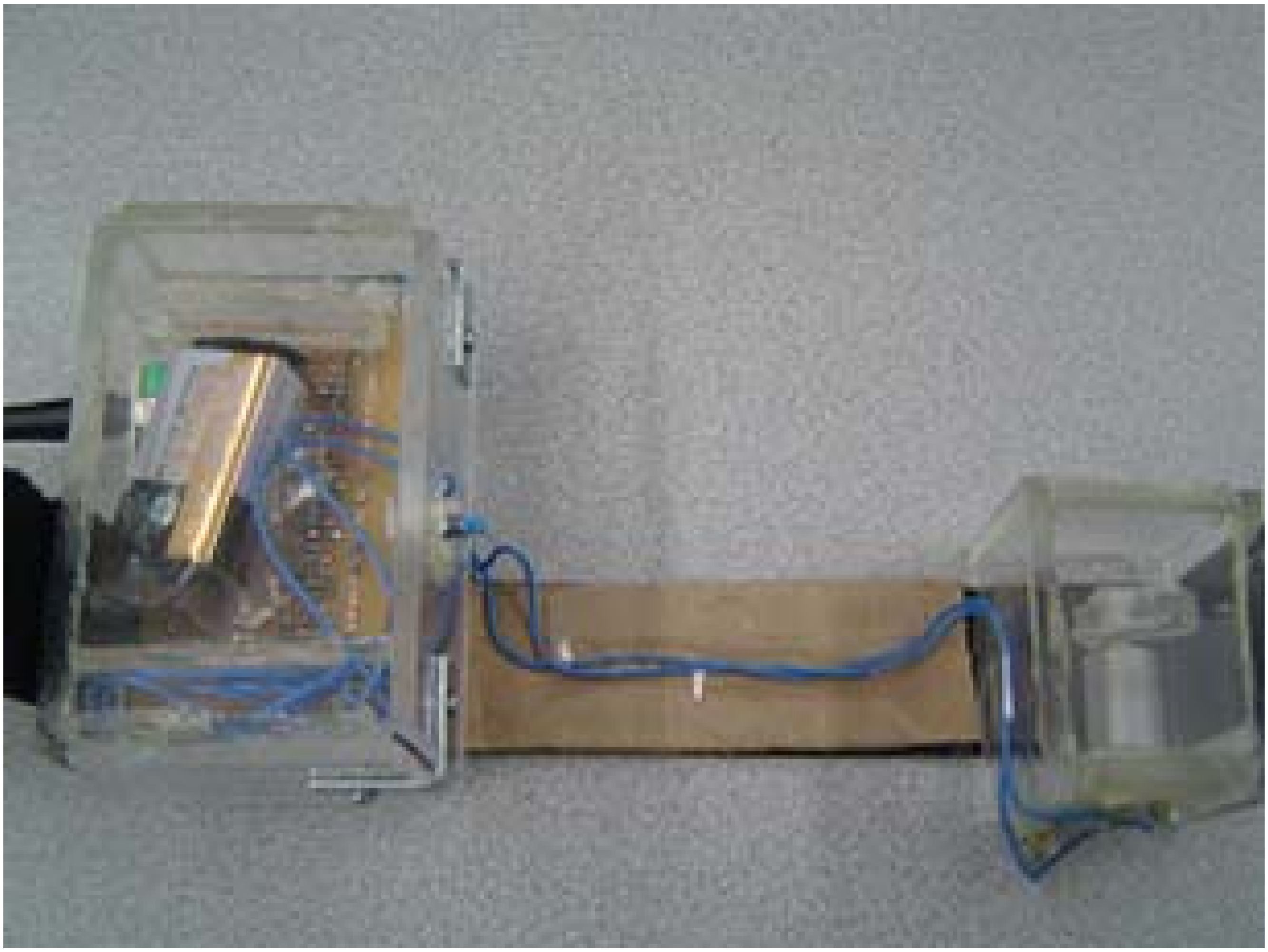
```
' pin 7 left
' pin 6 right
' pin 8 reciver
' pin 9 ON/OFF
' pin 11 hand held battery
' pin 13 cart battery
' pin 2 battery meter
' pin 0 motor control


control VAR Byte
'control
'LSB down TO msn
'0  cart battery active high
'1  right
'2  left



DIR9 = 1
DIR2 = 0
DIR13 = 1
DIR6  = 1
DIR7  = 1
DIR0 = 1


LOW 9  'power
HIGH 13

DO

OUT11 = IN2 ' handheld battery

SERIN 8, 16468, [WAIT("!"), control]

IF control < 7 THEN

OUT13  = ~control.BIT0
OUT6   =  control.BIT1
OUT7   = control.BIT2

   IF control >= 2 THEN
     OUT0 = 1
     PAUSE 500
     OUT0 = 0
```

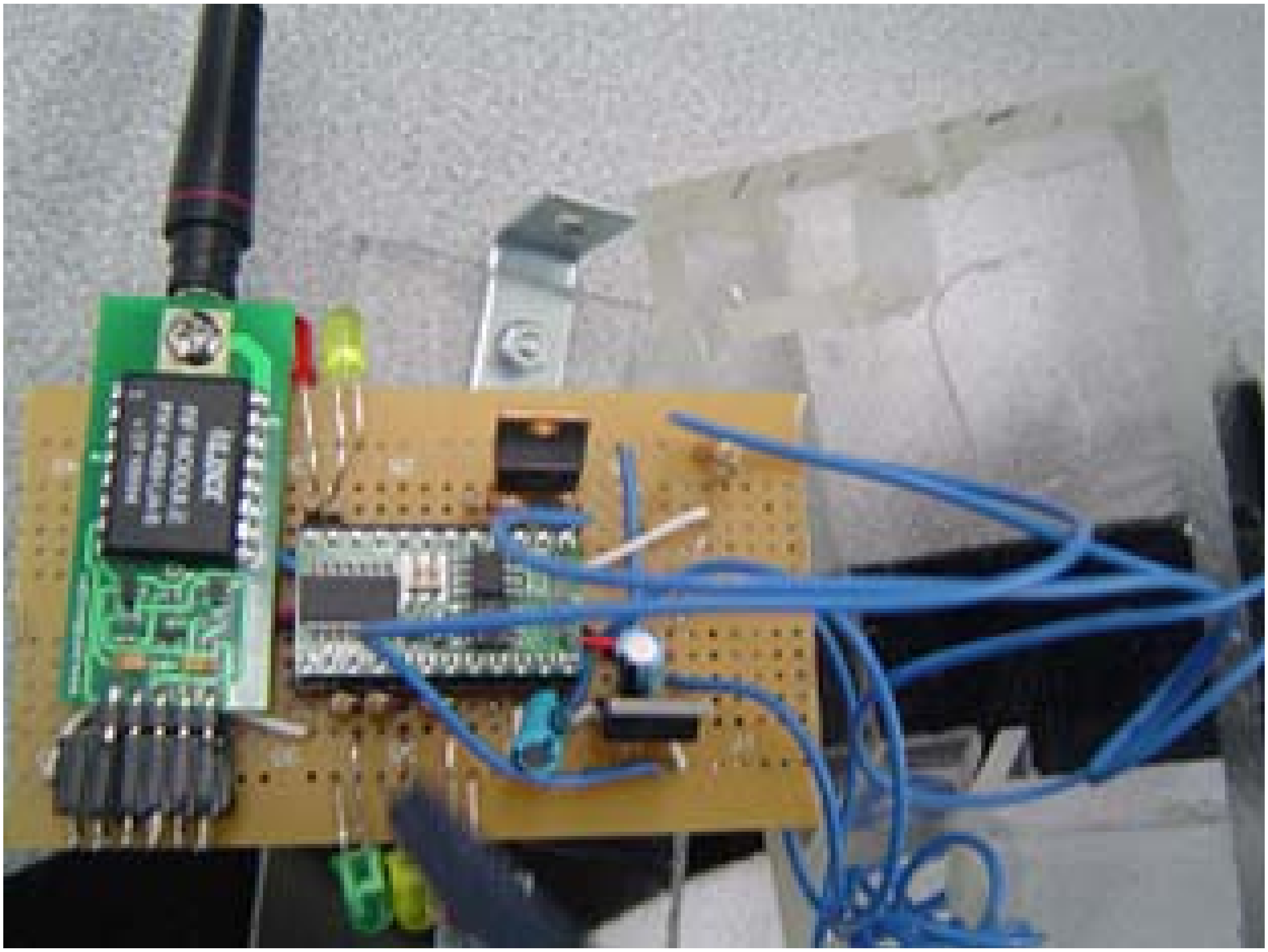
```
    ENDIF
ENDIF
LOOP
```

7.2 APPENDIX B : Pictures









7.3 APPENDIX C : Minimum Requirement Checklist

	Requirement as provided by instructor	How the project meets them
a	Your device will be controlled by BS2.	Both systems of the device are controlled by BS2 modules .
b	You must incorporate and document hardware and software features to prevent damage to the BS2 IC and other components on your device. In addition, you must provide guidelines for safe operation of your device. Include a provision for instantaneous shutdown of your device in case of incorrect/unsafe operation.	Proper safety resistors and transistors are used in the circuits . System B is enclosed in a box of Plexiglas . Guideline of safe operation in provided in the user manual . An easy to reach switch is in System B (which is worn on the user) that shuts down the whole system r
c	Your project must include some form of a user interface so that a human user can monitor and control your device (excluding b above).	The battery meter : User can motor battery status. When battery condition is poor , user can see it and replace the battery .
d	Your project must utilize at least one actuator (excluding b, c above).	2 servomotors and 1 DC motor are used
e	Your project must utilize at least one analog and one digital sensor (excluding b, c above).	analogue : the ultrasonic distance sensors digital : the switch to turn off only the vibrator motor
f	Your actuator must be controlled using sensory feedback. You can use any primitive to advance control design methodology for this purpose.	The servomotors moves based on what the distance sensors see, until the sensor detects their critical angle.