November 5, 2012

Dr. Andrew Rawicz

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V5A 1S6

Re: ENSC 440W Design Specification: Human Chasing Robot by Auto Tech

Dear Dr. Rawicz,

Please find the attached enclosed design specification for the Human Chasing Robot from Auto Tech. It is a tracking robot that follows and monitors patients which can be widely used in hospitals, mental institutions, and nursing homes to track patients.

The design specification presents a set of high-level requirements for the system's functionality for different phases of development. This document will be used as a guide to ensure all the specified designs of the product are implemented.

Auto Tech consists of five brilliant students with backgrounds in Electronic Engineering and Computer Engineering: Johnny Leung, Michael Leung, Eric Zhao, Alex Jiang, and Ken Nam. For further inquires about our company and proposal please feel free to contact via our team email: ensc440-groupn@sfu.ca, or by phone at 778-855-2480.

Sincerely,

Johnny LEUNG

Chief Executive Officer

Auto Tech

Enclosure: Design Specification for Human Chasing Robot

TRACKER BY DESIGN

DESIGN SPECIFICATION FOR HUMAN CHASING ROBOT

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Submitted to

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November 5, 2012

EXECTIVE SUMMARY

The design specification for the Human Chasing Robot presented by Auto Tech contains a detailed description of the design and development of our proof-of-concept model and final product. So, in this document we will only discuss design considerations pertaining to the functional requirements marked I or II, as given in the document Functional Specification for the Human Chasing Robot **[1]**.

This document outlines the detailed design of our Human Chasing Robot and also provides detailed justification for our choices. Furthermore, this document contains our design improvements and alternative solution for future releases of the system. A test plan is provided to ensure that all of the functionality requirements have been met.

As given in the document Functional Specification for Human Chasing Robot, our Human Chasing Robot consists of two independent systems: the imaging system, a robot that follows a target **[1]**. The camera on the robot captures video, the video through the microprocessor are transmitted to a computer by using Wi-Fi. Then video is finally displayed on the computer screen. The beacon that is hold by target, also known as the transmitter, produces a signal that can be received by our receivers. The two ultrasonic sensors are our receivers, are programmed to search for the target. The receivers tell the microprocessor that the location of the target. In this document we also discussed our alternative solution that using three receivers. In addition, In order to achieve that our robot could make turns, two motors are placed in our robot. Two microprocessors are used in our Human Chasing Robot system. One is used in imaging system and the other one is used in robot movement system. All microprocessors will read inputs and apply control algorithm.

This document also includes a detailed description of the resources required to complete the project. A general system process flowchart with integrated hardware and software programs are also provided.

According to our process, we spent too much time on building wireless communication circuit. We changed our sensor and redesigned our circuit. We will try to do the integrated system test as soon as possible. So the completion of the proof-of-concept device is expected at the early of December 2012.

Table of Contents

List of Figures

List of Tables

1. INTRODUCTION

The Human-Chasing Robot is a tracking robot that can follow the patients and monitor their activities. This product is made up of an imaging system and a movement system. The imaging system is responsible for capturing the images of the patients and then to be recognized by the microcontroller for the commanding usage. The movement system would control the movement of the robot by indicating the direction of the motion. By combining the two systems, the tracking robot would work perfectly in any desirable environment. The detailed functional requirements for this Human-Chasing Robot are described in this document.

1.1 Scope

The objective of this document is to outline the design requirements that must be met by a functioning Human Chasing Robot and explains how the design meets the functional requirements as described in the Functional Specification for the Human Chasing Robot. **[1]** This document will also outline the implementation methods required to achieve the level of specification.

1.2 Intended Audience

The functional specification is intended to act as a reference for all members of Auto Tech. Engineers from different departments should refer to the listed requirements as the overall design goals throughout the implementation. Engineers shall refer to this document for test plan criteria and make sure all the requirements are satisfied.

2. SYSTEM OVERVIEW

The human-chasing robot is composed of two independent units: the video streaming unit and the robot. The imaging system is responsible for capturing video and streaming it in real time. The main components of the imaging system are the camera, the microcontroller, and the computer. The microcontroller transmits the video captured by the camera to the computer via Wi-Fi. The robot is made up of the wireless communication circuit, the action control circuit, and a microprocessor. The wireless communication uses one ultrasonic transmitter as a beacon, and an array of ultrasonic receivers mounted on the robot to determine location of the target. The outputs of the receivers are processed by the microprocessor. The action control circuit reads the signals from the microprocessor and turns the differential motors appropriately. All components on the robot draw power from the centralized power management circuit, while the ultrasonic transmitter operates on an individual 9V battery. Figure 1 is a block diagram summarizing the overall structure of the Human-Chasing Robot.

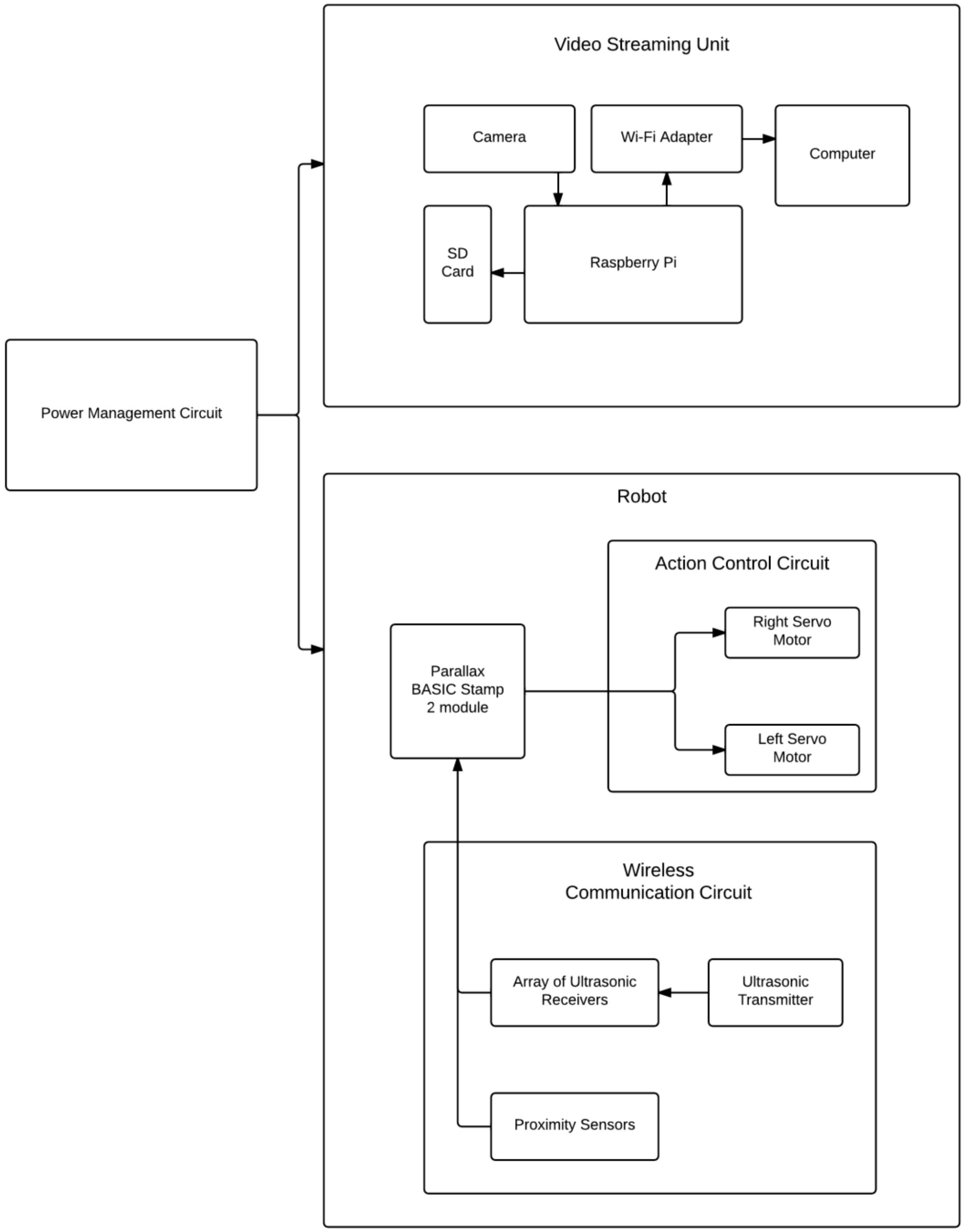

Figure 1 System overview block diagram

3. Robot

The robot is mainly responsible for movement control. It takes the information from the wireless communication circuit and controls of the servo motors. This unit is the physical body of the project. Both the wireless communication circuit and video streaming unit are mounted on the robot.

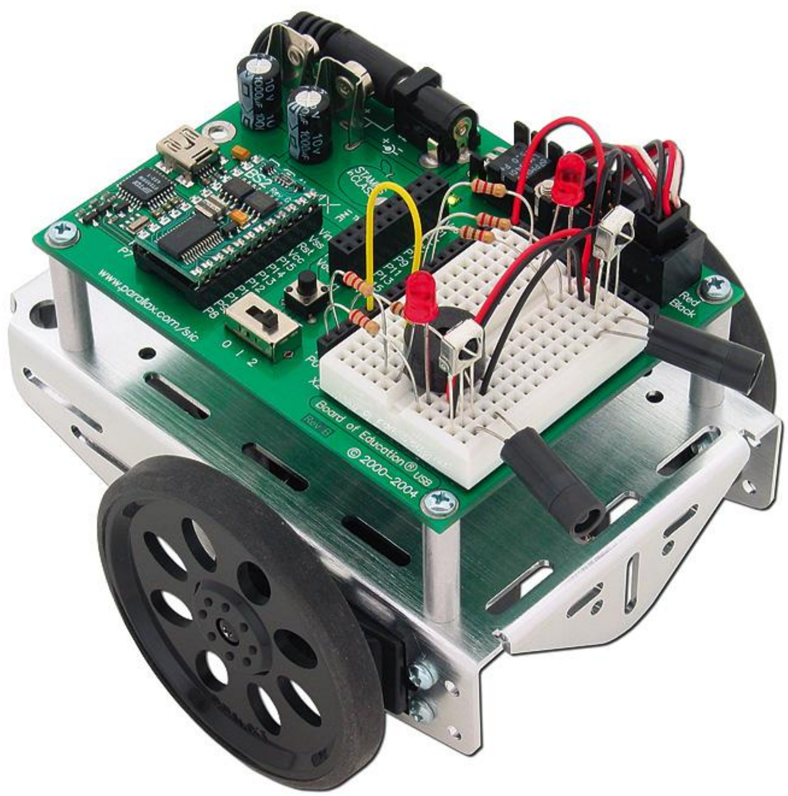

Figure 2 Boe-Bot Kit [2]

3.1 Hardware Components

The robot used in this project is the Board-of-Education robot kit by Parallax, Inc. The Boe-Bot robot kit is designed for introducing students to robotics, and it includes the BASIC Stamp 2 programmable microcontroller, a Boe development board, two continuous rotation servos with wheels and a metal frame.

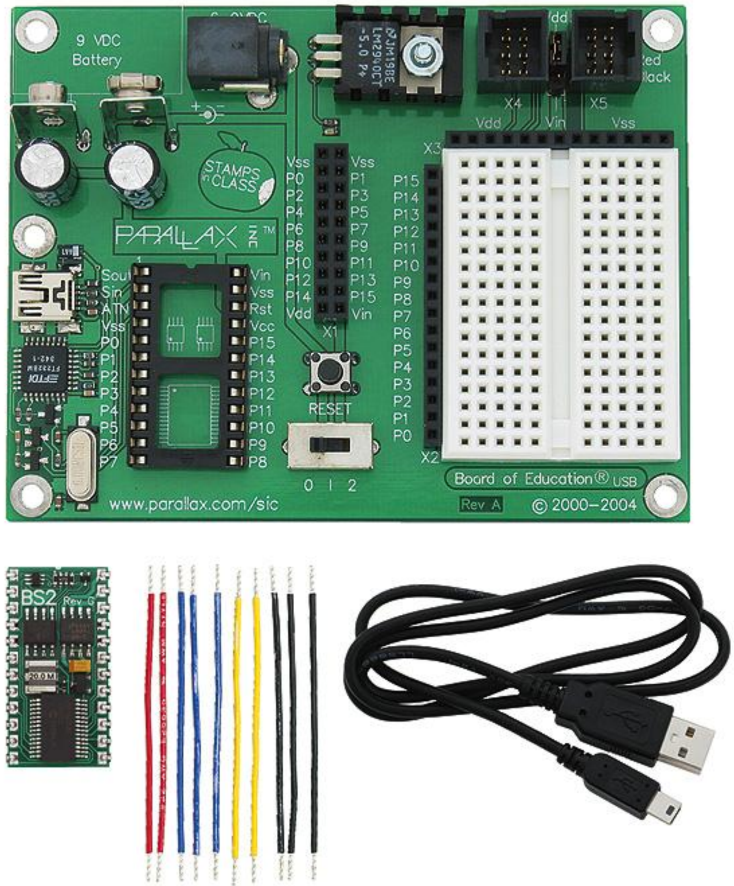

Figure 3 BASIC Stamp 2 microcontroller and Boe development board with USB interface[3]

3.1.1 BASIC Stamp 2

The BASIC Stamp is a microcontroller invented and manufactured by Parallax Inc. It has its own programming language called PBASIC. Parallax provides its own software named BASIC Stamp Editor for programming the microcontroller. There are 16 I/O pins on the BASIC Stamp, which it can use for reading signals from peripheral sensors, and generating output signals to control motors and/or speaker.

Table 1 Product information of the BASIC Stamp 2 Module [4]

Released Products	BS2-IC
Package	24-pin DIP
Package Size (L x W x H)	1.2"x0.6"x0.4"
Environment	-40 to +185 °F (-40 to +85 °C) **
Processor Speed	20 MHz
Program Execution Speed	~4,000 instructions/sec.
RAM Size	32 Bytes (6 I/O, 26 Variable)
Scratch Pad RAM	N/A
EEPROM (Program) **Size**	2K Bytes, ~500 instructions
Number of I/O pins	16 +2 Dedicated Serial
Voltage Requirements	5 - 15 vdc
Current Draw @ 5V	3 mA Run / 50 µA Sleep
Source / Sink Current per I/O	20 mA / 25 mA
Source / Sink Current per unit	40 mA / 50 mA per 8 I/O pins
PBASIC Commands	42
PC Programming Interface	Serial Port (9600 baud)
Windows Text Editor	Stampw.exe (v1.04 and up)

3.1.2 Boe Development board

The Boe development board provides various interfaces between the BASIC Stamp microcontroller and peripheral. There is a small breadboard for building circuit with external sensors and speaker. The development board also provides interface for connecting the servos to specific I/O pins of the BASIC Stamp. The Board of Education can be powered by a 6V battery pack, a 9V battery, or an AC powered DC supply.

3.1.3 Continuous rotation servos

The two servos included in the Boe-Bot kit are designed for continues rotation and ideal for controlling wheels and pulleys. While standard servos are designed hold certain positions, these continuous rotation servos turn at certain speeds and directions. The servos need to be centered by tuning the potentiometer inside the servos. Centering ensures the servos rotate at accurate speed.

Figure 4 Parallax Continuous rotation servo [5]

1.1.4 Metal frame

The metal frame that came with the Boe-Bot kit is large enough to house the development board, servos and a battery pack. However, for our project we need to include the ultrasonic receivers and video streaming unit. These components will be added to another layer on top of the robot frame.

1.2 Software Design

The BASIC Stamp Editor is the custom software designed by Parallax Inc. to be used with the Boe-Bot kit. The programming language used is PBASIC, which stands for Parallax Beginners All-purpose Symbolic Instruction Code **[6]**. This programming language is designed for beginners who do not have much programming experience. It is meant for handling simple logic loops and also controlling signals of the I/O pins.

1.2.1 Servo control

The BASIC Stamp controls the motions of the continuous rotation servo but sending a pulse signal via its I/O pins. The pulse width of the signal determines the direction and speed of servos. For example, a pulse train show in the Figure 5 would turn the servo clockwise at full speed.

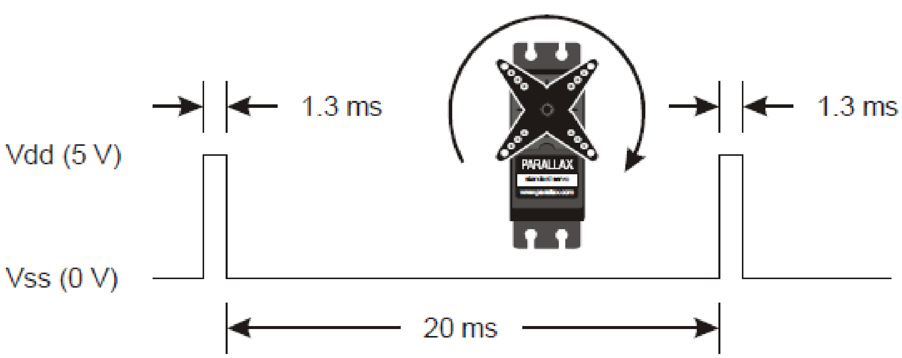

Figure 5 1.3 ms pulse train signal for turning servo full speed clockwise [7]

1.2.2 Movement control algorithm

The following flow diagram summarizes the algorithm of how the human-chasing robot controls its movement. Based on the inputs from the ultrasonic receivers, it will determine the direction and distance from its target. The robot then decides the direction to move if it is not facing its target. The robot turns left or right until it is facing its target. If the robot is facing its target, then it checks the distance from its target. The robot moves forward if it is not within a certain distance from its target, otherwise the robot does nothing. Depending on the desired movement direction, different pulse trains will be sent to the servos. The robot's movement speed was initially designed to depend on distance away from its target **[1]**. The pulse width of the signals sent to the servos will change depending on distance from the target.

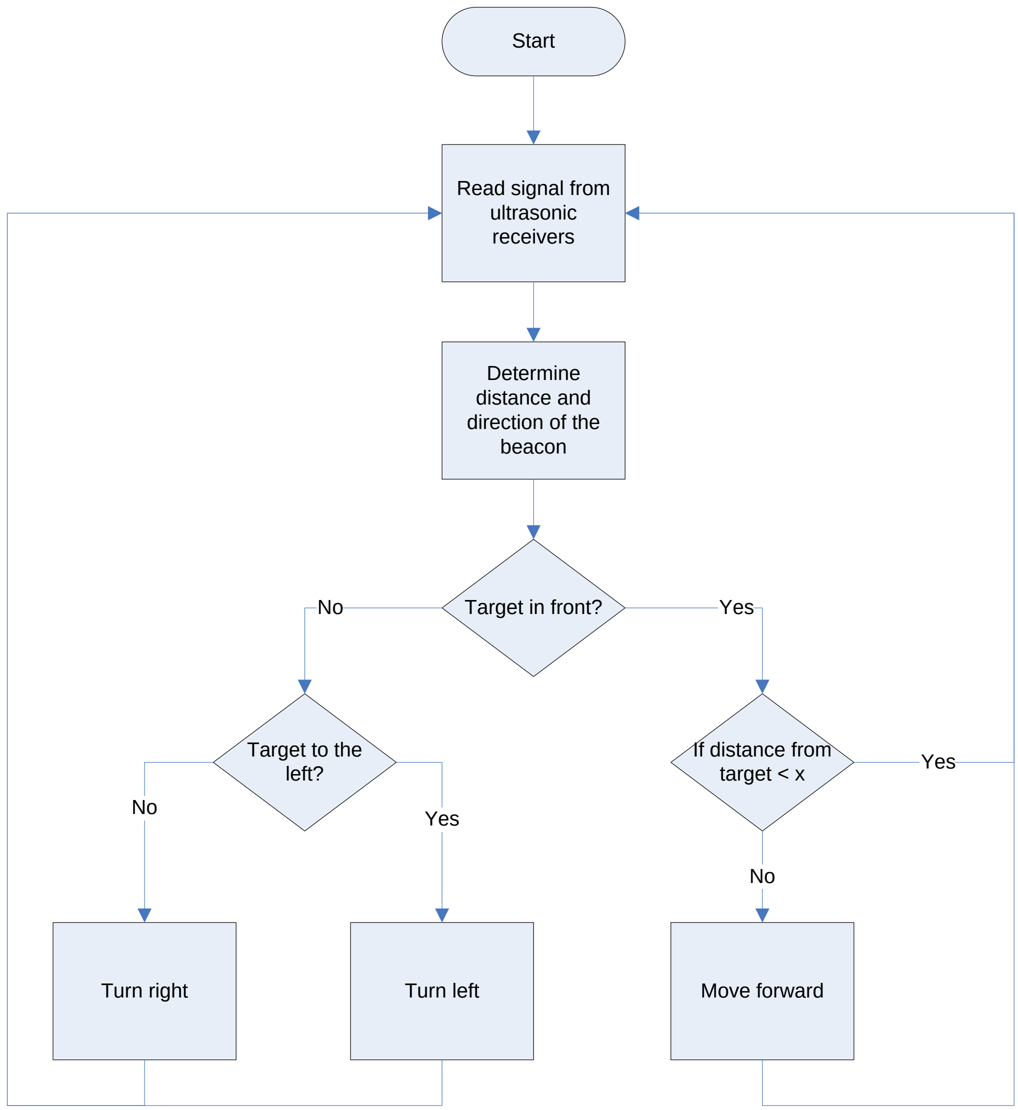

Figure 6 Flow chart of robot's movement control

4. Ultrasonic Sensor Tracking Unit

The Ultrasonic sensor tracking unit is used to detect the object and send the data to microcontroller. We chose ultrasonic 40kHz transducer (SONIC40) to be our transducer and receiver.

4.1 Ultrasonic Sensor transducer

The circuit diagram of the transducer is shown in Figure 7. The 555 timer is in astable mode, and is creating a frequency of roughly 40 kHz. We have an on/off switch connected to pin#4 and the VCC line. When we press the on/off switch, VCC will be applied to pin#4, then activates the output of the 555 timer. In other words, when we press the button, we are transmitting. When the on/off switch is not being pushed, the unit is in idle mode, and is not transmitting.

One of the two transducer pins is connected to a voltage divider circuit (R_1/R_2). The second pin is connected to R_3, which is also connected to the V_{CC} line. The second pin of the transducer is also connected to the collector of a low-power NPN transistor (2N2222). The emitter is connected to the ground line. The resistor between the 555 timer output (R_4), which is pin#3 **[9]**.

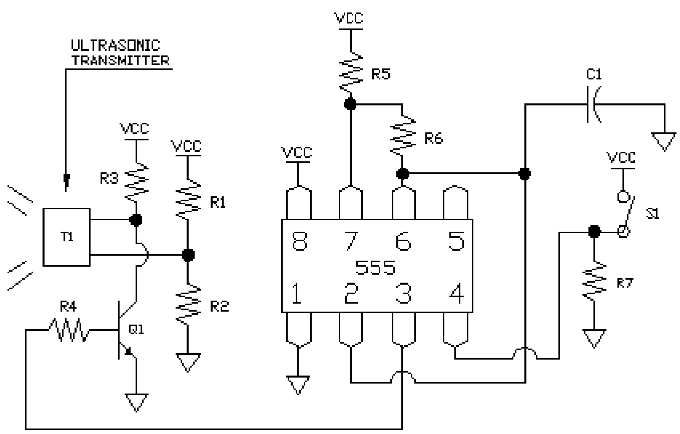

Figure 7 Schematic of the Transmitter Circuit

4.1.1 Table of Components

Table 2 lists the components in the ultrasonic Sensor transducer circuit. All parts were purchased from local electronic stores.

Table 2 Components in the ultrasonic Sensor transducer circuit

Component	Part#
Transducer (SONIC40)	T1
NPN transistor (2N2222)	Q1
Lm555 Timer	555
Capacitor (0.01uF)	C1
Resistors (220R)	R1
Resistors (220R)	R2
Resistors (470R)	R3
Resistors (5k6)	R4
Resistors (1k8)	R5
Resistors (1k8)	R6
Resistors (10k)	R7

4.1.2 LM555 Timer Pin Assignments

The LM555 is a highly stable device for generating accurate time delays or oscillation. It acts as an oscillator in our design by using astable operation. The pin assignment is shown as Table 3.

Table 3 LM555 Pin Assignment

Pin	Description
1	GND
2	Trigger
3	Output
4	Reset
5	Control Voltage
6	Threshold
7	Discharge
8	+Vcc

4.2 Ultrasonic Sensor Receiver

As shown in Figure 8, ultrasonic sensor receiver is a three-stage passive amplifier circuit. In order to get rid of the DC component, we connect a capacitor between each stage. Finally, the signal gets into the positive input of a comparator (LM386). The output of the circuit is a square wave TTL when a ultrasonic signal is being received. In LM386, we connect Pin#1 and Pin#8 in orders to maximums the gain of the comparator to 200.

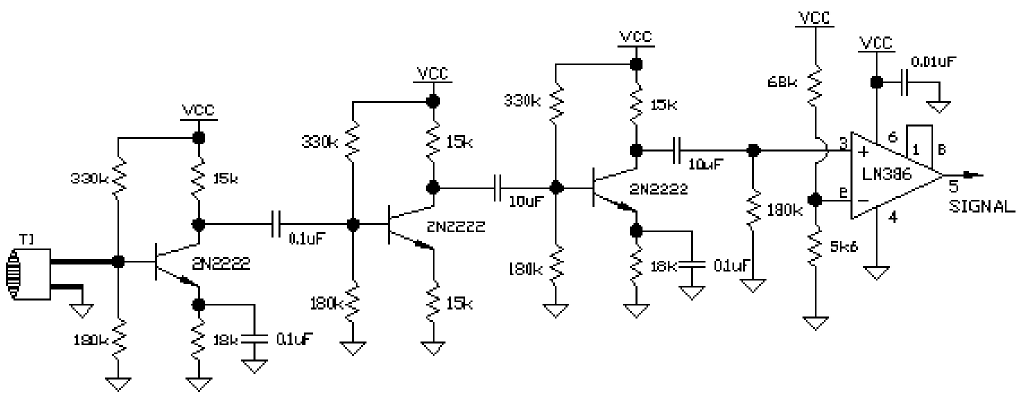

Figure 8 Schematic of the Ultrasonic Sensor Receiver circuit

4.2.1 LM386 Timer Pin Assignments

LM386 is a power amplifier, which is used in low voltage consumer applications. The gain is internally set to 20 **[10]**, but the addition of an external resistor or capacitor between pins 1 and 8 will increase the gain from 20 to 200. The pin assignment is shown as Table 4.

Table 4 LM386 Pin Assignment

Pin	Description
1	Gain
2	-Input
3	+Input
4	GND
5	Vout
6	Vs
7	Bypass
8	Gain

4.3 Power Management Unit

4.3.1 Transmitter Circuit

In the transmitter circuit we are using 9V battery instead of other AC power sources because we need the circuit to be mobile and using battery will not affect the performance.

4.3.2 Receiver Circuit

In the receiver circuit, we are also using a 9V battery as the power sources. However, we need to step down the voltage form 9V to 5V by using a voltage regulator circuit. The reason of stepping down the voltage is protecting the TTL component. The voltage regulator circuit is shown as Figure 9**[11]**.

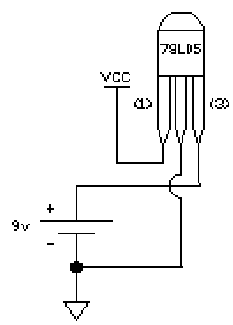

Figure 9 Voltage Regulator Circuit

4.3.2.1 78L05 Positive Voltage Regulator Pin Assignments

The 78L05 is a three-terminal positive voltage regulator. It can deliver 100 mA current and 5v voltage. The pin assignment is shown as Table 5.

Table 5 78L05 Pin Assignment

Pin	Description
1	Input
2	GND
3	Output

5. Video Streaming Unit

The video streaming unit is the system that captures video using a camera, and streams the video through wireless network. This unit is integrated to the robot so it can feed the live video of the chasing object or human.

5.1 Hardware Components

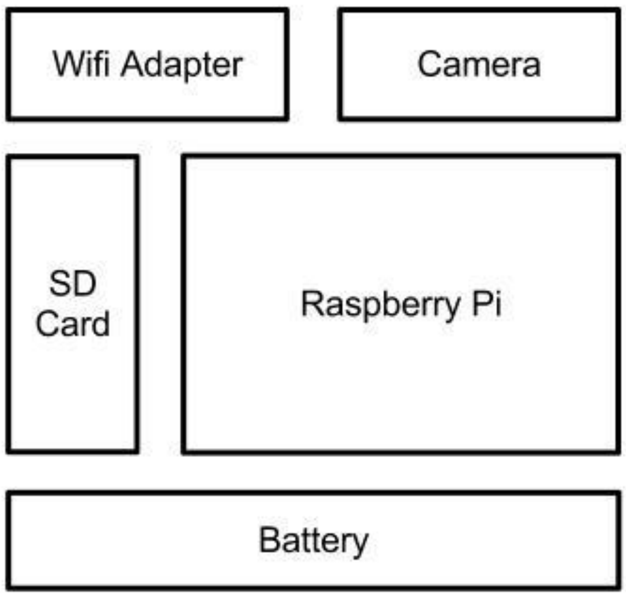

Figure 10 Video streaming unit design diagram

As shown in the Figure 10, the video streaming unit is consisted of five different hardware components: a Raspberry Pi as the main processor, a SD card as the main memory, a Wi-Fi adapter for wireless communication, a camera for capturing video and a battery as the power supply for the system. To view the streaming, the user needs to connect to this system using a computer through Wi-Fi.

5.1.1 Raspberry Pi

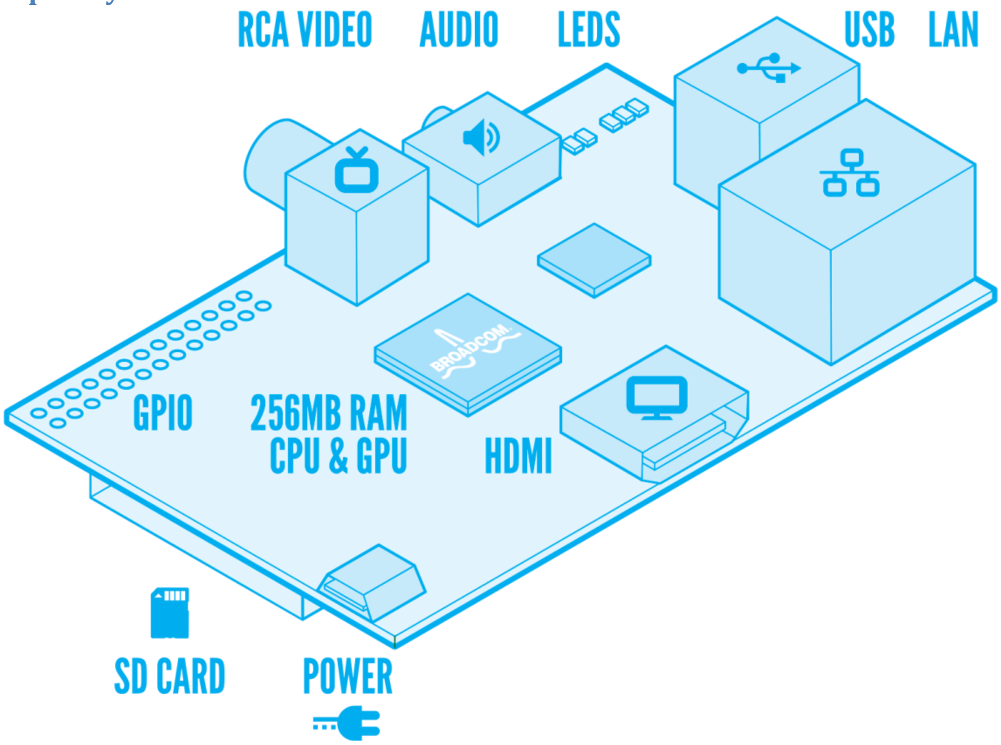

Figure 11 Raspberry Pi design diagram [8]

Raspberry Pi is an ARM GNU/Linux box that is capable of doing many different services [12]. In our design, it is the main processor part that does all the required processing for streaming video. Figure 11 is the simplified diagram of the board. It has a SD card slot, two USB ports, an Ethernet port, an audio port, an RCA port, a HDMI port and a micro USB port. Only the SD card slot, micro USB and two USB ports are used for the system.

5.1.2 4GB Class 4 SD Card

For the proof-of-concept model, a 4GB Class 4 SD card is used. A higher-class SD card can improve the performance but class 4 is sufficient for the required performance. Higher capacity memory is not necessary as only half of the 4GB is used by the system.

5.1.3 AirStation N150 Wireless USB Adapter

Figure 12 An image of the Wireless USB Adapter [13]

The wireless adapter we used for the proof-of-concept model is AirStation N150. As displayed in the figure 12, it is a very compact sized adapter weighing only 0.0087lbs, which suits to our system well. It is capable of running in an access point mode, and able to use WPA2, WPA-PSK and 128/640-bit WEP as the security option. Maximum communication speed is 150 Mbps, which is enough for our system requirement [14].

5.1.4 Logitech Webcam C200

Figure 13 An image of the Webcam [15]

The webcam we used for the proof-of-concept model is Logitech C200. It has 0.3 million effective pixels and able to capture 30 frames per second with a maximum resolution of 640 x 480 **[16]**. This is enough for showing the following object or human clearly.

5.1.5 Battery

For the proof-of-concept model, HAME P6 mobile battery is used. It is a very high capacity battery with 10400mAh and has an output capacity of 1A/2.1A **[17]**. The weight of the battery is 4.409lb.

5.2 Software Design

To begin with, Raspbian, which is an operating system based on Debian optimized for Raspberry Pi hardware, is installed on the Raspberry Pi [18]. Since Raspbian is a Linux distribution, the system can run any of the available Linux applications. In our system, we are running hostapd, dnsmasq and MJPG-Streamer to service the video streaming.

5.2.1 Hostapd

Hostapd is a daemon that lets the system to be able to behave as a Wi-Fi access point [19]. Because we have only one robot for the proof-of-concept model, we converted the video streaming unit as a Wi-Fi access point. This way, any devices with Wi-Fi capability can connect to the unit and view the video. The Wi-Fi network name is set to RpiNetwork and the password is set to rpitestpass with WPA2 as the security option.

5.2.2 Dnsmasq

Dnsmasq is a daemon that provides DNS and DHCP services to a small network [20]. It is used to let the Raspberry Pi to be able to assign IP addresses to the clients connected to the Raspberry Pi. The Raspbeery Pi is given a static IP address 10.0.0.1. Any devices connecting to the Raspberry Pi will be given IP address from 10.0.0.2 to 10.0.0.5.

5.2.3 MJPG-Streamer

MJPG-Streamer is an application that can take images from webcams and stream them as M-JPEEG via HTTP [21]. This is the core program running on the Raspberry Pi that does the video streaming service. The video is viewable from a web browser on the client side.

5.2.4 Python script

To simplify the steps for starting up the software system, a python script is written. The script can be run from the client side to start all the necessary software on the Raspberry Pi remotely.

6. Test Plan

The three distinct parts of the system will be tested separately first to make sure each component works. Then, five test cases will be run to verify the system behaves as expected.

6.1 Unit Test Plan

6.1.1 Robot

Steps	Execute	Expected Behavior
1	Power on the Boe-Bot.	Light on the development turn on.
2	Connect to PC via USB.	BASIC Stamp Editor detects the Boe-Bot.
3	Run “CenterServo“ program.	Both servos do no move. Otherwise, calibrate the potentiometers on the servos until servos stop moving.
4	Run “TurnServo” program.	Both servos rotate, and the Boe-Bot turns 360 in left and then right.
5	Run “ForwardServo” program.	Boe-Bot moves forward in a straight line for a fixed distance.

6.1.2 Sensor

6.1.2.1 Transmitter Circuit Test Scenario

Steps	Execute	Expected Behavior
1	Power on the circuit.	Heard stridence noise from transducer.
2	Probe Pin#3 of the Lm555 timer by using oscilloscope.	Square wave frame should appear on the oscilloscope screen.
3	Probe the pin of transducer, which the pin connected to the voltage divider.	Square wave frame should appear on the oscilloscope screen.
4	Prober another pin of transducer.	Square wave frame should appear on the oscilloscope screen.

6.1.2.2 Receiver Circuit Test Scenario

Steps	Execute	Expected Behavior
1	Place the transmitter and receiver face to face.	
2	Power on the transmitter.	Heard stridence noise from transducer.
3	Probe the pin#5 of Lm386.	Square wave frame should appear on the oscilloscope screen.
4	Move the transmitter far away the receiver.	Pulse width of the square wave should become larger.
5	Move the transmitter close to the receiver.	Pulse width of the square wave should become smaller.
6	Move the transmitter to 45 degree right of the receiver.	Pulse width of the square wave should become larger.
7	Move the transmitter back to face to face the receiver.	Pulse width of the square wave should become smaller.
8	Move the transmitter to 45 degree left of the receiver.	Pulse width of the square wave should become larger.

6.1.2.3 Power Management Circuit Test Scenario

Steps	Execute	Expected Behavior
1	Power on the circuit.	
2	Probe the Vcc and GND by using multi-meter.	5V should be displayed on the multi-meter.

6.1.3 Video Streaming Unit

Steps	Execute	Expected Behavior
1	Connect the SD card, the wireless USB adapter, the webcam and the battery to the Raspberry Pi.	The Raspberry Pi's power LED is turned on. A Wi-Fi network named RpiNetwork is created.
2	Connect to the RpiNetwork using a computer.	Wi-Fi connection is established.
3	Run the python script from the client computer. Open a web browser and enter 10.0.0.1:8080 on the URL panel.	A webpage that streams a video is accessed.

6.2 System Test Plan

6.2.1 Test Scenario 1: Powering on the system.

Prerequisites: None.

Steps	Execute	Expected Behavior
1	Power on the system.	All the units must be started. Check if the Wi-Fi network is created and connectable. Check if the video streaming is started and viewable from a web browser.

6.2.2 Test Scenario 2: Following the human going forward.

Prerequisite: The system is powered on.
The person to be followed is holding the signal transmitter.

Steps	Execute	Expected Behavior
1	The person to be followed walks forward.	The robot must move forward. The person followed must be shown in the video streaming.

6.2.3 Test Scenario 3: Following the human going right

Prerequisite: The system is powered on.
The person to be followed is holding the signal transmitter.

Steps	Execute	Expected Behavior
1	The person to be followed walks forward.	The robot must move forward. The person followed must be shown in the video streaming.
2	The person to be followed turns right and walks forward.	The robot must turn right and move forward. The person must be still visible in the video streaming.

6.2.4 Test Scenario 4: Following the human going left

Prerequisite: The system is powered on.
The person to be followed is holding the signal transmitter.

Steps	Execute	Expected Behavior
1	The person to be followed walks forward.	The robot must move forward. The person followed must be shown in the video streaming.
2	The person to be followed turns left and walks forward.	The robot must turn left and move forward. The person must be still visible in the video streaming.

6.2.5 Test Scenario 5: Following the human going backward

Prerequisite: The system is powered on.
The person to be followed is holding the signal transmitter.

Steps	Execute	Expected Behavior
1	The person to be followed walks backward.	The robot must move backward. The person followed must be shown in the video streaming.

7. Environmental Considerations

The prototype model will basically be a combination of a RC car, microcontrollers, and some electronic components.

The electronic components used on the robot can all be reused and the environmental impact is reduced to minimal.

The microcontrollers can be either reused for other projects or sent to the recycling facilities which handle the recycling of discarded electronic components.

8. Safety Considerations

The speed of the robot is too slow to cause injuries on collisions, so the robot does not pose any physical threat to its surroundings. The ultrasonic transmitter generates signals at 40 kHz, which is out of the human audible range and does not cause any issues with human hearing. However, 40 kHz is within audible range of dogs and cats. The signal coming from the tracking beacon might cause confusions for household pets. For this reason, we advise the Human Chasing Robot not to be used near pets.

9. Conclusion

In this document, we have outlined our design specification for the Human Chasing Robot. All the specifications will meet the functional requirements for the proof-of-concept device that was described in the document, Functional Specification for Human Chasing Robot **[1]**. Most of the design solutions presented in this document will be able to be used in the design specifications for the final product. Some clear test plans are provided in this document to ensure that the proposed functional requirements meet.

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