H.A.P.P.I. Systems

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***Abstract* — The purpose of this project is to design and produce a home welcoming system that includes a Central Hub as well as lawn spikes with the support of a mobile application. This project consists of several subsystems that work together to achieve the overall goal. The H.A.P.P.I. (Home Audio Programmable Pathway Illuminations) System will use solar cells for energy as well as batteries in the lawn spikes to power them. During the night the lawn spikes will create a relaxing setting with an LED light show and soothing music as one walks to the entrance of their home.**

***Index Terms* — Bluetooth, LED, Humanoid Detection System, illumination, wireless, home welcoming system, home, audio, programmable, pathway, illuminations, system**

I. Introduction

H.A.P.P.I Systems is a home welcoming system that includes lawn spikes as well as a central hub. This device will greet any person who is walking to the front door of a residence with music as well as a light show. As a person walks toward the front door of a home and is within a certain distance of the solar powered lawn spikes, a motion sensor, will be triggered and sends an alert to the central hub, notifying it to search for a human. Once the central hub detects human presence then it will send a message back to the lawn spikes to play music and start the light show to guide the person to the door of the residence. The H.A.P.P.I. Systems is the perfect product for those who are looking for a bit more curb appeal to their front yard. Our system is lightweight and perfect for any front yard where it will not take away from the landscaping. Although this system is designed, as a home welcoming system it not limited to the front door, this system can be placed throughout the backyard for outside entertainment. As of now, there are no other products on the market that have the ability to do what our H.A.P.P.I. Systems can do. The Cassia Hub is the only product that comes close to what the H.A.P.P.I. Systems can do. The Cassia Hub is not meant for outdoor entertainment nor is it weatherproof. Our future plans for the H.A.P.P.I. Systems is to eventually have the option for it to dual as an outdoor security system, equipped with facial recognition software.

II. Central Hub

This project is made of a two-part system with each part having several subsystems that are best described in their own respective sections. Each of the subsystems has been either been chosen or designed for the appropriate fit to the overall system. Following is each subsystem described from a technical view point.

A. Single Board Computer

The single board computer used in our project will be the Raspberry Pi 2 Model B. This component will handle all the initial communications between the user's android device and handle the wireless audio stream to the lawn spikes. The single board computer chosen has plenty of processing speeds to handle all the communications and subsystem components. We plan on interfacing with the Raspberry Pi 2 Model B, it will include USB interface, camera port interface, and GPIO pin interface. The OS needed to run the Raspberry Pi 2 Model B will be Raspbian. This is a lightweight Debian based OS that will be powerful enough to run the Pi but also not consume too much of the processing power. Raspbian can be placed onto any SD card and be ran directly off of said SD card. We can either interface with the SD card through a port on many laptops or connect the Pi via USB to any computer. The Raspberry Pi 2 Model B contains a 15-pin ribbon cable port, this port will be fully utilized by the camera module selected for the project. The Raspberry Pi Infrared Camera Module (NoIR) is specifically made for our single board computer, this should help eliminate any type of compatibility issues. The camera uses a 5MP native resolution and has the capability for night vision, this is crucial since our systems time to shine is at nighttime. The 40 GPIO pins that the Raspberry Pi 2 Model B comes with will be plenty for the intended purposes of our central hub. These pins will control the input sensor data from the motion sensors and control all LEDs within the device and pins will be utilized for the data output signal from each of the PIR sensors. The two USB ports on the Pi will be fully utilized to hold the Bluetooth dongle and Wi-Fi dongle. This will help alleviate any extra soldering brought on when introducing non-USB modules. The HAPPI system will need to interact with majority of wireless networks, we will utilize the TCP/IP stack protocol, to remove the need for a custom protocol layer. This design makes it very simple for any user to connect the central hub to most wireless networks without any difficulties. The Bluetooth dongle used will utilize the A2DP wireless audio transmission protocols, this helps remove any complexity required in encoding and decoding the audio streams over a Bluetooth network. The Raspberry Pi 2 Model B also is equipped with an auxiliary output port, we will utilize this port to connect a set of speakers too so that the user will be fully immersed in audio no matter what device they are passing. These speakers will require a 5v input which they will be able to receive from the 2nd GPIO pin on the Raspberry Pi and they will be grounded with pin 6. The speakers will have a aux plug on them which we will plug directly into the Pi.

B. Humanoid Detection System

Humanoid detection is a subsystem to our central hub, it will encompass motion sensors and a camera. The motion sensor is important for picking up any type of movement that could be caused by a human. The camera will be the eyes to our project, this will determine whether the motion the sensors picked up are of human origins or just an animal or the wind blowing items around. This design will be used to conserve energy, so that the camera only runs when motion is sensed. The following section will go into further details of the subsystem's components.

Motion Sensing Subsystem

The project will utilize Passive Infrared motion sensors (PIR), these are very unique for they have an extremely wide Field of View (FOV) of 110 degrees. The project will require 3 motion sensors in each device in order to cover as close to 360 degrees as possible. The sensors will be configured into a triangle formation.

This formation will give the sensor the largest FOV without much overlapping signals. Each sensor is created with 3 pins, the outer pins will be used to power and ground each sensor then the middle pins will connect to the Raspberry Pi 2 Model B using the GPIO pins 3,5, and 7. The schematic below will demonstrate our design.

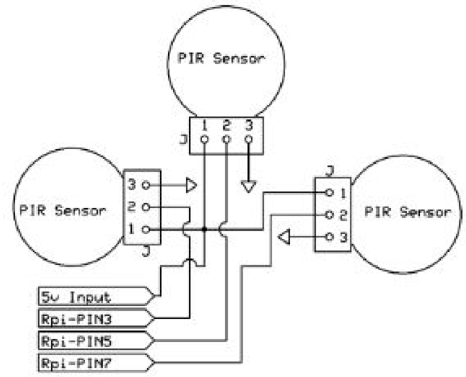


Figure 1: Passive IR Sensor Schematic

Camera

The camera setup for the project will be quite simple, since the Raspberry Pi 2 Model B is equipped with a specific 15-pin port only for a camera module. The camera will communicate with the Pi over the CSI bus, a higher bandwidth link which carries the capture pixels to the processor. The camera will have its own hole bored out of the housing, towards the top of the central hub in order to obtain the best vantage point for image capturing. The camera will only need to capture images. these images should supply a high enough fidelity that will give the image processing a crisp photo to work off of.

C. Power Supply

The power supply will be outlined in the discussion of this section. The sections would range from the power supply from wall outlets and the solar panel sets. The power supply is composed of the Wall outlet, the solar panel, and the battery packs respectfully for the central hub and the solar powered lawn spike**.**

As previously discussed, one of the components to charge the central hub is the wall outlet. The wall outlets provide alternating current which differs from what is needed for the NiMH batteries. All rechargeable batteries need direct current. The need for the DC, the central hub will need an AC/DC adapter and capability to connect to that AC/DC adapter. The AC/DC adapter will not only convert the voltage from AC to DC, it will also provide a step down sequence so that the batteries aren't damaged. The wall outlet output is 120V and DC voltage will need to step down much lower voltage and current. As stated prior as well, NiMH's input has the limitations of so that they do not get damaged. We will be using a 12V adapter to step down the voltage of the wall output.

Silicon diodes approximately a forward a .7 V, causing the loads to have an approximate input voltage of 11.3 V, which would be more than enough voltage to dissipate to each load.

Solar Energy Charging

When charging any battery source, it's important that the source's output voltage matches that of the battery. When constructing the charger circuitry for the battery, the circuit is not as simple as energy from the cells directly into the rechargeable battery. The battery needs to be protected from overcharging and current flowing back to the panel. Schottky diodes are added to the schematic to protect the batteries. The solar cell components generating a power of 1.8 watts with a current of 3.6 amperes, with these measures the time it would take to fully charge the battery unit. With the range of Sun light, the power and energy from the sun varies throughout the day.

Battery Output

The power supply will contain a battery charger and would have the capabilities to charge the battery as well as power the hub and spike. The battery output will have the capabilities to charge from the power supply and send energy to the desired load. As seen below the standard battery charger depicts how a basic battery is charged.

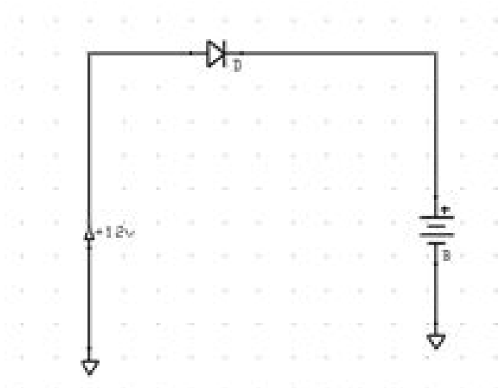


Figure 2: Battery and Schottky diagram

As seen in the prior figure, Schottky diodes are contained in the circuits. The Schottky batteries are set so that the charge from any power supply flows in one direction.

As for the hub and spike will both be using a 6V battery pack which has 2300mAh (milli ampere-hours). For a NiMH battery of those specifications, the usage time before unable to be used without additional charge is dependent upon its discharge rate. For the battery, to fit the requirements of the battery life needing to last at least 2 hours, the discharge rate is at most 1.15 Amperes (A).

Run Time = Current Capacity of Battery / Discharge Current Rate
2 Hours = 2.3 Amp-Hours / At most Discharge Current
Discharge Current = Current Capacity of Battery / Run Tim

III. LAWN SPIKES

Microcontroller

The microcontroller will require the most design for our lawn spike, this is expected since it will be required to control all necessary components. The schematic below goes over our design for the microcontroller, the schematics layout was generated to have all the GPIO pin to be on the right hand side and the other pins will be on the left. The 12MHz crystal only requires a 3.3v input but our group decided to use a faster crystal so we will use the 16MHz crystal which requires 5v input, this input will be outputted from our power supply. We will be utilizing pin 23 for controlling our LED rings, the LED rings will be connected in a fashion that only requires a single input. The motion sensors data output line will be connecting to pins 24-26, we separate each one individual so that we do not overload the microcontroller with a single line that has all three of the signal on, if more than a single motion sensor detects motion then it will send a voltage of 6v and higher which will be too much for the ATmega328p to handle. Finally, the RX and TX terminals, pins 2 and 3 respectively, will be connected to the TX and RX terminals on the Bluetooth transceiver. Finally, the AVCC and VCC pins need to be supplied with a 5v power source, we will utilize the output from our voltage regulator.

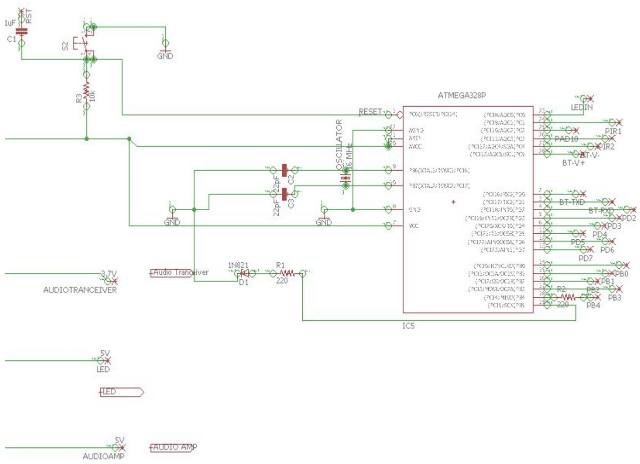


Figure 3: Microcontroller

Bluetooth

The wireless lawn spikes circuitry will require more complexity to it then the simple USB dongle for the central hub. The wireless lawn spikes Bluetooth module will act as the spikes audio receiver to accept the signal from the central hubs Bluetooth transmitter.

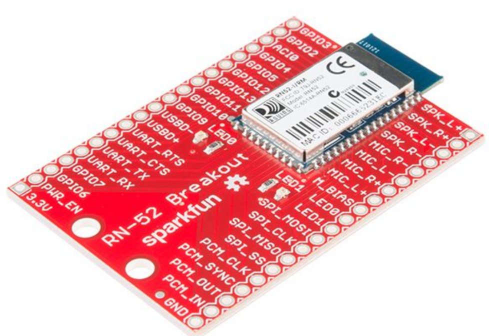


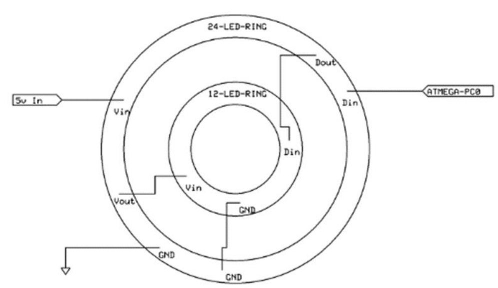
Figure 4: Bluetooth transmitter

The SPK_L- and SPK_R- pin is our stereo differential output negative terminals; this is where our negative wire from our speakers will go. Next is the SPK_L+ and SPK_R+, these pins are for a stereo connection with multiple speakers. The VBAT is our power input terminal and will take the positive lead from our device's power distribution board. The UART_TX and UART_RX terminals will connect straight to our microcontroller; this will allow us to communicate with the central hub via Serial Port Profile. The RX and TX will be connected to the GPIO pins on the microcontroller. The Last terminal to be mentioned are the GNDs these will be connecting to a grounded plate within each device, and in the diagram above we can see which pins will use common grounds though we must be sure separate the common grounds between the audio circuit and the other grounds. The reason for separating the grounds is so we do not get any interference on the audio lines, this would cause our speakers to play a static/white noise which is unfavorable in any audio system. The volume of the device will be controlled through the user's application, the Bluetooth board will be set to max volume, giving the user full control over the level of sound outputted.

Motion Sensing Subsystem

The motion sensors on the lawn spike will act as an extension for the hubs motion sensing. Since the spikes will be further away from the central hub's motion sensing range, the lawn spike will be able to communicate when they detect motion. The sensors will be the same make and model as the ones used in the hub itself. The motion sensors will have the same triangular configuration used in the central hub, since this will supply the largest FOV and conserve the most space. The data output for the motion sensors will utilize their own pin on the microcontroller, pins 24-26.

Lighting Subsystems



The lighting used in the lawn spikes will be two concentric rings, with one ring containing 24 LEDs and the other will have 12 LEDs. The LEDs to be used on the rings will be the same as the central hubs, SMD RGB WS2812. The LEDs on the rings will be in a daisy chain configuration as the schematic provided below. This daisy chain configuration allows for a simple integration into our system. The rings will only require a single data input line, meaning we will only need one pin to connect to on the ATmega328p. The data line will be connected to the PC0 port on the ATmega328p also known as pin 23. The schematic below will show the two concentric rings and their wiring configuration.

Figure 5: Daisy Chain LED rings

Speaker

The solar powered lawn spike has its limitations in size because HAPPI must remain portable. With its limited size, thus sets its limited parts i.e. the speakers. The solar powered lawn spike will have one speaker with the capabilities to produce enough sound. The speaker used for the spike will be an 8 ohm 1-watt speaker. The data will be transmitted from the Bluetooth function to the amplifier then matriculating to the 8 ohm 1-watt speaker. Amplifiers are traditionally built to set and disperse the audio to two speakers (one for the left and one for the right). The amplifier the solar powered spike will contain is a 2.1 W Class D Audio Amplifier and its schematic is similar to most amplifiers. As the speaker needs to set to output to one speaker without losing the effects of another, a passive stereo to mono converter must be used. The conversion can be seen below as well as the convertor being attached to our amplifier.

IV. Software

The design for the software components of HAPPI will primarily encompass human detection, component connectivity and the graphical user interface. Each of which playing an instrumental part in the core functionality of our project. The sections below will unfold the role these components play and how they have been implemented.

Humanoid Detection

The human detection system will utilize the OpenCV library for handling all the image processing. OpenCV is a very robust library and is mainly used for object detection or machine learning applications. We will be using the CascadeClassifier class within OpenCV, this class is used for object detection and allows the computer to visually detect items and object within a 2d image. The method for human detection will be with the person body form. This method will be a bit more tedious and require a lot of training in order for the system to determine if a human is present. In order to train our system, we will be required to subject our program to many different images with humans in them. We must be sure the humans are facing different direction and in different stances in order for the system to accurately determine the motion generated was of human origins. This will be one of the more labor intensive designs for the software aspect of the HAPPI system.

Mobile Application

The phone application in this project will serve as the graphical user interface for controlling the hub. The following will cover the software design of the mobile application that will be incorporated within HAPPI. The software languages included will be primarily Java, XML, and PHP.

Functional Components

The primary aim of mobile application is to make the interaction between the hub as easy and intuitive as possible. Giving the end user a clear detailing of all that can be accomplished with the hub and to provide those functions at the push of a button. Coupled with the accessibility of having it on your phone.
The application will control all functional components of the hub that will in turn repeat functions to the lawn spikes. For this to occur there needs to be a cohesiveness of communication and interrelated functions. There is a preference to have that communication be wireless and remotely controlled.

A. Splash Activity

The mobile application begins with a splash page that welcomes the user to the application and after which directs the user to the login page. This page verifies the credentials of a potential user. They are required to enter in their email address and password. If a new user would like to create a new account this can be done through the register page, where they will be requested to enter their first and last name, email address and password. After being granted access the user can choose from our main components: Google Music Selection, and setting preferences.

B. Google Music

The Google Music Selection page will be used to interface with the Google Play Music API that will be launched from the central hub microcontroller. It will facilitate the viewing of all playlists available to be played. This is achieved by filling a listView element with associated playlists from a database. Each playlist has an associated class that is initiated from the ServerRequest class which is what interacts with the php code associated with the previously mentioned database. When a playlist in the listView is clicked it will send an associated streamID to the microcontroller to initiate the command.

C. Setting Preferences

The settings preference page will include a listView that will contain previously made setting groups. When the group is clicked it will send a command to the microcontroller. There is also an option to create a new settings group that will launch a new page that allows for the creation of a new settings group. On this page a user will configure settings options consisting of: title, Wi-Fi, LED color, speaker volume, playlist selection, and LED power selection.

D. Bluetooth Commands

Communication back and forth between the microcontroller and the application will be sent via Bluetooth. Within every activity's onCreate method the application goes through the process of pairing to the microcontroller and creating a socket to facilitate the sending of information. When the information is sent the application then closes the socket.

Receiving Bluetooth Commands

Data handling as it pertains to HAPPI will be restricted to catching the Bluetooth strings that will be sent from the phone application and appropriately triggering a function to achieve the specified user preference.

A. Bluetooth String Parser

Strings sent from the phone will be given in a format to promote proper decoding by sending the appropriate function or keyword, following will be a corresponding parameter for setting the desired component. This will be fed through a parser that will be responsible for reading the received string and digesting the command into its key components: function call and parameter. In between these two components will be a delimiter, a delimiter is a sequence of one or more characters used to denote the boundary between independent or separate regions in a text. An example of this is LED_ Off where "LED" will be the function call, "_" will be the delimiter and "Off" will be the parameter. Once the delimiter is recognized and separates the keyword from the parameter a command will be used to verify the keyword is the actual word the specified term.

B. Function Hash table

A hash table or hash map as it is sometimes referred to as is a data structure in computer science used to construct an associative array, an arrangement that will map keys to their associated functions or values. Once the text is parsed properly it will be introduced into a hash table where the appropriate keyword will initiate a function to be triggered that will be set with the following parameter. The list of keywords will be located in this hash table and will have the function to call when they are verified as a match.

C. Function Calls

The function calls will be the segment of code that actually accomplishes the desired action of configuring a functional component to the setting specified. There will be 6 function calls for the 6 different setting preferences to be chosen. The function calls will be initiated from the central hub, where they will be sent over to the Lawn Spikes to actually be executed.

VI. Conclusion

The main goals for completing our prototype of the Home Audio Programmable Pathway Illumination (H.A.P.P.I.) System was to create a network of wireless lawn spikes equipped with LEDs, speakers and motion sensors hosted by a single central hub and greet anyone that walks near the speaker devices with music and lights. To accomplish this project, much research was needed in order to read up on the requirements of each component used in the Bluetooth lawn spike and central hub, our main source of information came from the internet. During the researching phase of our project, each of the four group members have shown that they are competent on every component in each of the four group members respective areas of concentrations and or interest, while retaining an overall knowledge of all the areas of the project.

The research phase of the project was the number one important phase. The research that was conducted led many of group members to better components as well as components that are identical, but have a more reasonable in price. The research phase helped us design the structure of the lawn spikes as well as the structure of our central hub.

The most significant result gain from completing this document is the unexpected learning experience of the four individual group members and as well as collectively. At the start of senior design, we were unaware of the task placed before us. During the research and design phase every group member began with doubt in their own ability to contribute to this project. Over time not only did every member reclaim their self-confidence in their own abilities, but was assured that every other member can contribute successfully to the project. This documentation forces our group to manage four different personalities as well as learn how to effectively communicate with each member. If our communication skills were poor, we would have had trouble setting specifications and limitations as well as meeting those specifications and limitations. Our communication skills also allowed us to manipulating of the multiple deadlines, meetings and reports that are all required to be successful in not only Senior Design but as well as working in industry or academia. Testing and troubleshooting real world design issues as a group also creates another invaluable skill set that can be used throughout the group's future career. This project alone will allow us as students to demonstrate our acquired knowledge through our UCF career and build a working device from ground up.

VII. Biographies

A. Sidney Jean-Baptiste

Sidney Jean-Baptiste is a 25-year-old Electrical Engineering student. Currently a senior at the University of Central Florida and will graduate December 2016 with a Bachelor of Science in Electrical Engineering to pursue his interest in power generation. Over the course of Sidney's attendance at the University of Central Florida, Sidney has had various internships with different companies. Thus expanding his mind in the field of engineering and helping him to gain a strong understanding. Sidney has had internships with United Airlines, Power Engineers Inc., and currently Siemens. Those internships specified in avionics, power generation and utilities, and project management Sidney is very interested in circuit design, power, and the aerospace industry.

B. Phillip Bent

Phillip Bent is Computer Engineering student at the University of Central Florida where anticipates graduating at the age of 23 in December of 2016. From here he plans to receive a job from Lockheed Martin, where he has had the pleasure of working for 2 years. Phillip enjoys playing sports such as basketball and football if he is not listening to music and spending time with his friends. Phillip also likes to travel, and has made it a goal to visit each continent with the exception of Antarctica. He one day hopes to procure a job and get married and live happily ever after.

C. Taylor Griffith

Taylor Griffith is a Computer Engineer at the University of Central Florida. Taylor anticipates graduating with his Bachelors of Science in Computer Engineering in December 2016 to pursue a career in simulations. Taylor has worked at Lockheed Martin for his final two and half years at UCF. Taylor worked in the database group as a scriptwriter for simulations. The company he interned with is one of the largest DOD contracted companies nationwide. Other than furthering his career in simulations he also plans on continuing his favorite hobbies; embedded systems, computer repair, and of course PC gaming.

D. Johnnie Alexandria Greene

Johnnie Greene is a 26-year-old who anticipates on graduating as a double major in Physics and Photonics Science and Engineering in May 2017. Johnnie Alex has worked for Dr. Ayman Abouraddy for two and half years as an undergraduate researcher in biophotonics and bio-optics. She is currently working for Dr. M.J. Soileau, who is professor and one of the founding directors of the College of Optics otherwise known as the world renowned C.R.E.O.L. She is now about of the Non-linear Optics Group at C.R.E.O.L. She is very focused on furthering her career in both engineering and physic. She hopes to inspire young Native Americans to take an interest in the STEM fields. Johnnie Alex is very interested and well-rounded in fiber communication, biophotonics and image display and motion detection systems and non-linear optics.

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