Robofan

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***Abstract* — Robofan is a ceiling mounted fan that can point anywhere in the space it is in and tracks the user with a PixyCam. The tracking will be based on color identification through the PixyCam. We use a Printed Circuit Board (PCB) as the centerpiece to connect our microchip, camera, temperature sensor, motors and Bluetooth module. Robofan also has a companion application for android that communicates with the MCU via Bluetooth to give the user specific control over it. The range of motion for the Robofan is dictated by two motors and will allow continuous rotation.**

***Index Terms* — Android App, Bluetooth Communication, Color Identification Tracking, Embedded Systems, Motor Control, Real Time Programming**

I. Introduction

Workshops can get extremely hot, especially if airflow is sub-par. Even worse, you could be working out of a garage in Florida! This team is comprised of four young Floridians who are striving to combat every Floridian's two greatest enemies the heat and humidity. Many members of this team have had to work in environments where airflow was less than optimal. The air pushing apparatus at our disposal, did not meet our satisfaction. Hence the passion. Large fans may not always fit in a personal workspace, and if you are moving around you will get limited effect from a stationary fan or oscillating fan. We are going to design a fan that does not fall into these same pitfalls. We are introducing the Robofan. It is a ceiling mounted fan armed with sensors that can track a user around a room. This will be accomplished by equipping the Robofan with mechanisms to allow it to tilt and rotate. What separates this from a standard oscillating fan is that it will not be limited by a 180-degree operating threshold, instead the Robofan will have the capability to continuously rotate. With this ability, just a single Robofan can cover an entire room, never letting a user escape its cooling gaze. An accompanying smart phone application will allow users to control the Robofan remotely. Manually pointing the fan, controlling the speed of the fan, and tracking the user are among the actions that can be taken with the smart phone application.

The Robofan's main components will be the mechanism that controls its tilting motion, the mechanism that controls its panning motion, a sensing technology to track the user, wireless communication technology, and a microcontroller to tie it all together. The selection of components is crucial. Therefore, this document will detail the technology made selected to create the Robofan. This project is self-funded, so great consideration is taken to make sure the components, software, and tools are the best for our price range. The Robofan must be able to keep up with the speed of the target/user at a reasonable walking pace to simulate its primary use for a potential consumer.

To achieve this functionality a specially designed firmware is implemented to communicate with the specifically chosen hardware as well as the communication module, used to connect with the Android application for the optimal consumer experience. To gain the most from our modest hardware, due to our financial constraints, clever implementation of firmware has been used to gain the optimum output from each individual piece of hardware.

II. System Components

This project can be broken down into three distinct types of components: movement, sensing, and communications. The operation of these components is coordinated by the microcontroller to provide the functionality of the Robofan. This section will discuss each type of component starting with the MCU.

A. Microcontroller

The ATmega328p is a microcontroller developed by Atmel. This is the chip that is found at the heart of the popular Arduino test boards. The Atmel chip is based on an 8-bit architecture. The processing speed of 16 MHz is suitable for the Robofan's needs, since it only needs to send signals to the two motors whenever the user is out of the PixyCam's view. There are 26 available input/output pins, which meets the number needed for the Robofan. The ATmega328p has a storage ROM of 32 kilobytes and SRAM of 32 kilobytes. The operating range of the ATmega328 is between -55 degrees Celsius and 125 degrees Celsius. These temperature ranges are important since the device will be used in hot indoor areas.

B. Servo Motor

For the purposes of the Robofan, a servo motor will be used to control the joint within the tilting arm of the device. A servo motor was chosen for this function over a stepper motor due to the fact that servos are less complex than stepper motors in general. A servo motor, in a general sense, has more torque than what is required than a stepper motor provides. Choosing a servo motor also conserves energy when compared to a stepper motor which would be better suited for the panning motion of the Robofan. Stepper motors would require more space than a servo due to the necessary gear box attached. Another advantage of utilizing a servo motor is that you can run it on DC power from the PCB with the use of a controller.

The specific servo motor purchased is a Lewansoul LD-27MG full metal standard gear digital servo. This motor is a type of positional rotation servo that comes with a servo horn kit to allow the motor to attach directly to the joint of the tilting arm. The outer housing of the servo motor is fabricated out of aluminum to allow for fast and effective heat dissipation to protect the motor from thermal damage.

C. Stepper Motor

The NEMA 17 stepper motor was selected for the panning motor. The specifications are all suitable for the needs of the Robofan's panning motion. The step angle of 1.8 degrees allows for highly accurate and controllable movement. Its small size is very suitable for the Robofan panning motor. The holding torque is listed as 83.6 oz·in., which is much less than the servo's torque rating. Since it only needs to move a gear as opposed to lifting something this torque rating will not pose a problem.

To operate a stepper, it must be connected to a motor driver integrated circuit. This is because stepper motors are rated for higher voltages and currents than what microcontrollers can handle. For this project the stepper motor will be connected to a DRV8825 driver. The driver is set at a current limit of 2.0 amps to ensure that the stepper motor is not damaged by a large influx of power.

D. Slip Ring

With this component the Robofan can continuously rotate in any direction for as much as it needs while eliminating the possibility of wires disconnecting or getting tangled. The programming of the Robofan's behavior is greatly simplified with the addition of this component. Since it can continuously rotate in any direction, the Robofan only needs to keep track of whether the user has moved left or right and proceed to turn in that direction. This solution is also much easier on the panning motor since it will not have to reorient itself to prevent wires from breaking. It follows that power usage will be reduced since motor usage will be reduced. The slip ring chosen for the Robofan is provided by Spark Fun. It has 3 wires and is rated for 380 volts AC and 10 amps. For our project the slip ring will supply 120 volts AC to the fan's motor as well as the 12-volt power supply.

E. PixyCam

For the sensor of the Robofan, a PixyCam will be utilized to track the desired target/user. The PixyCam is useful because it has a thorough premade API. The PixyCam is very small, (1.5 x 2.25 x 2.25 in) so it will easily fit on the front of our fan.

The PixyCam can detect colors by a detection software. Colors, and color patterns can be programmed in as a recognized object by utilizing this detection feature. We are going to use this feature to teach it color sets that are easily identifiable from a range, as well as in an environment that may have many things going on. The camera itself has a manually adjusted focus. This is used to set the range at which the camera gets the best view of its targets. The focus is adjusted by rotating the lens at its attachment point on the camera. The lens is attached by a screw system, and as such has a very wide range of distances it can focus to.

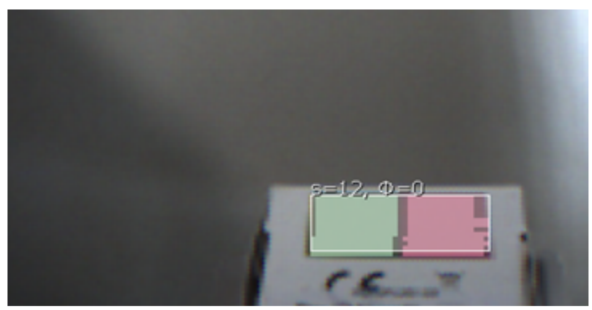

Fig. 1. PixyCam view with detection

F. Bluetooth Module

The Robofan will be using Bluetooth to communicate wirelessly with the mobile phone app. The particular model we are going to use is the HC-05 Bluetooth module. For the Robofan, the fan's Bluetooth module will be set to slave mode, and the phone will be set to master mode. This retains the phone's ability to be connected to Bluetooth devices at the same time as the fan, such as wireless headphones or a phone headset. The Bluetooth module comes with UART (Universal Asynchronous Receiver-Transmitter) compatibility, which is an asynchronous way of passing messages between two devices, either through wires, or in this case, wireless.

The Bluetooth module will utilize UART to receive commands from the phone to change modes, position data for the manual mode, and pattern data for the pattern mode.

III. Hardware Design

This section discusses how every component will be connected. All hardware will be detailed in this section. This includes hardware not related to the motion, sensing, or communication as well.

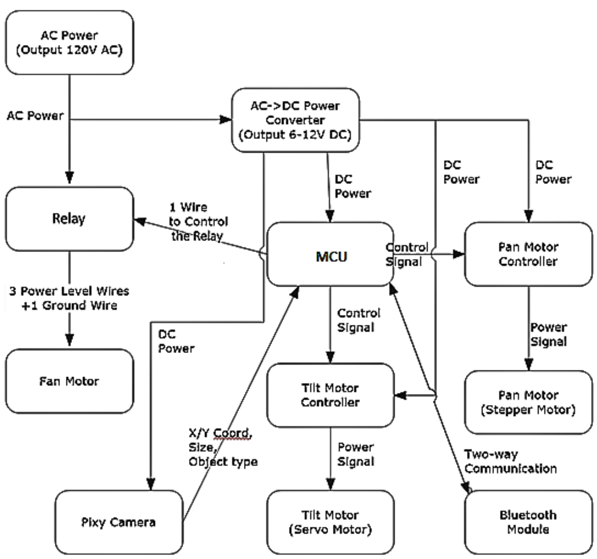

Fig. 2. Wiring Diagram

Figure 2 begins at "AC Power" however there are a few components that function before this. Starting with a plug in a standard wall outlet will be a fuse. This fuse is rated at 5 amps and will prevent the Robofan from getting damaged should there be any power surges. After the fuse, the cord will have an in-wire switch. This allows the user to turn the fan on or off without having to use the mobile app. Next the cord will be attached to the slip ring via soldering. Now the Robofan will be able to rotate continuously without wires breaking. The amount of voltage provided to the fan motor directly will be 120 volts AC.

The fan that is being used for this project is a Lakewood Oscillating Table Fan. It has a 12-inch diameter. The fan has three different operating speeds. The total weight of the fan is 4 lbs. However, the entire fan will not be used. For the purposes of this project the fan cage, blades and motor will be used. The total weight of these parts is 2 lbs. This reduces the amount of torque the servo needs to oppose.

Connected to the fan is a 3-channel relay. This allows the MCU to send signals to turn the AC device, in this case the fan, on or off. This particular relay is equipped with an Optocoupler IC. This feature will isolate the AC power from the MCU and the rest of the DC powered components. Three channels are needed to be able to turn the fan on/off as well as switch between the three different speed settings wirelessly. To accomplish this, the wires corresponding to low, medium, and high are connected to the normally open terminal of three different relays. The positive or negative wire will then be attached to the common terminal of all three relays.

The rest of the Robofan's components use DC power. A 12-volt power supply will convert the 120 AC voltage coming from the slip ring to DC voltage. The 12 volts will then be used by the DRV8825 stepper driver as a supply voltage.

The remaining components operate using 5 volts. To get this value a 5-volt regulator will be used. For this project a switching regulator will be used. This type of regulator is more efficient than a standard linear regulator. The datasheet for this specific switching regulator lists the efficiency to be in the range of 85% to 95%. It is rated at 2.5 amps. This is enough since the servo needs 1 amp and the rest of the components need less than 1 amp combined.

The frame and tilting arm of the Robofan is constructed out of oak wood. This type of wood is sturdy while being light enough to stay well within the 227.6 oz·in torque rating constraint of the servo motor. The length of the tilting arm is also kept as short as possible to reduce the torque applied to the servo motor. In order to perform the panning motion, the stepper motor will be used in conjunction with a two-gear system and a ball bearing.

IV. Firmware

The firmware will have several different modes that determine what the fan will do. The device boots into sleep mode, where it takes no actions until given input. The main functionality of the device is in Searching/Tracking Mode. In this mode, the code's objective will be to keep the user in the center of the frame, thereby keeping the column of air produced by the fan centered on the user. The coordinates from the pixy camera will be used to adjust the motors. As long as the user is still in view and the Bluetooth command is set to tracking mode, the device will keep tracking the user. If the fan cannot find the user, then the mode will switch to searching mode. In this mode the fan will rotate in an attempt to locate the user, and if the user is located, it will go back to tracking mode.

If the Bluetooth module receives a command from the phone app to change between modes, the firmware will change modes as soon as possible and do whatever that mode entails. The two modes mentioned previously are the default modes, and the device will try those first if there is no Bluetooth connection. The other two modes, manual and pattern, are only accessible from the application.

The pattern mode will perform a specific pattern and not use any input from the camera. Example patterns would be to rotate continuously at a specific speed and height. Another pattern would be to slowly change height while continuously rotating around the room. The manual mode locks the fan in place and allows the user to set its position. This would be useful if the user wants airflow in a specific spot where they may or may not be standing, or if they need airflow on something they are working on. This mode doesn't involve very much moving, so it will be a bit more power efficient than the tracking and pattern modes. The code is fairly simple for this mode, as the motors will just be moving to the values given by the phone application through the Bluetooth connection. The flowchart for the modes can be found below in Figure 3. This chart shows the different modes along with the cases in which the code will switch between them, as discussed in this section.

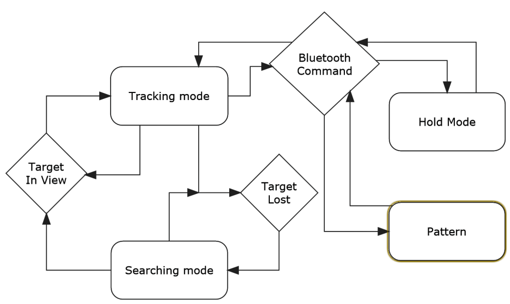

Fig. 3. Mode Flowchart

A. Motor Control

The directional functions for motor control are written as simply as possible. The servo motor is controlled by telling it what position it should be placed at. The position is chosen based on several components of the tracking algorithms data. Because the overall goal is to produce smooth movement, the motors will primarily choose how to move based on the speed of the target being tracked. The servo motor's new position is calculated based on the current position, and the ratio of how long it will take to get to the targets new location versus how fast the motor can move. The simple implementation of the servo motor controller is shown in Figure 4.

Since the camera is updating at a certain frame rate and the processor can cycle at 16 MHz, the motors will not try to move the entire distance at once. Rather, they will attempt to move a certain percentage of the total distance every so often. If the motors' previous tracking command was within a ten percent of what a new command would be, such that any difference in movement is minor, the new command should be ignored. This will further add to the perceived smoothness of motion, as it allows the device to "rest" in certain areas. The Stepper motor is controlled in steps in a given direction. It is possible to produce one method for both directions that attempts to do a certain number of steps. The tracking algorithm will determine how many steps are required to stay tracked on the target horizontally.

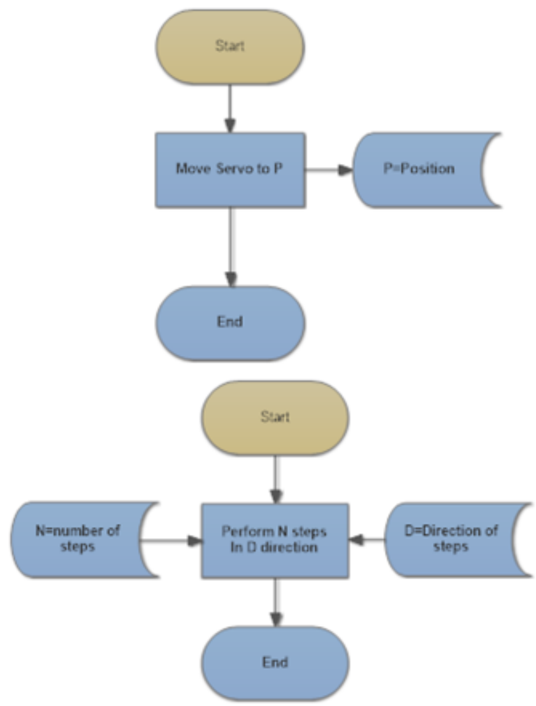

Fig. 4. Servo and Stepper Motor Flowchart

B. Robofan Modes

Searching mode is the default mode for the device turning on. The fan will not be active during searching mode by default, but can be enabled by the application. It will rotate the device continuously at a slow speed until it finds a target to track. When it finds a target matching a pattern it knows, it will enter tracking mode. If it does not find a target within 2 rotations, it will begin to add a delay to the searching movements. It will add a 1-minute delay every time it fails to find a person, up to a maximum of 5 minutes. This is done to conserve power.

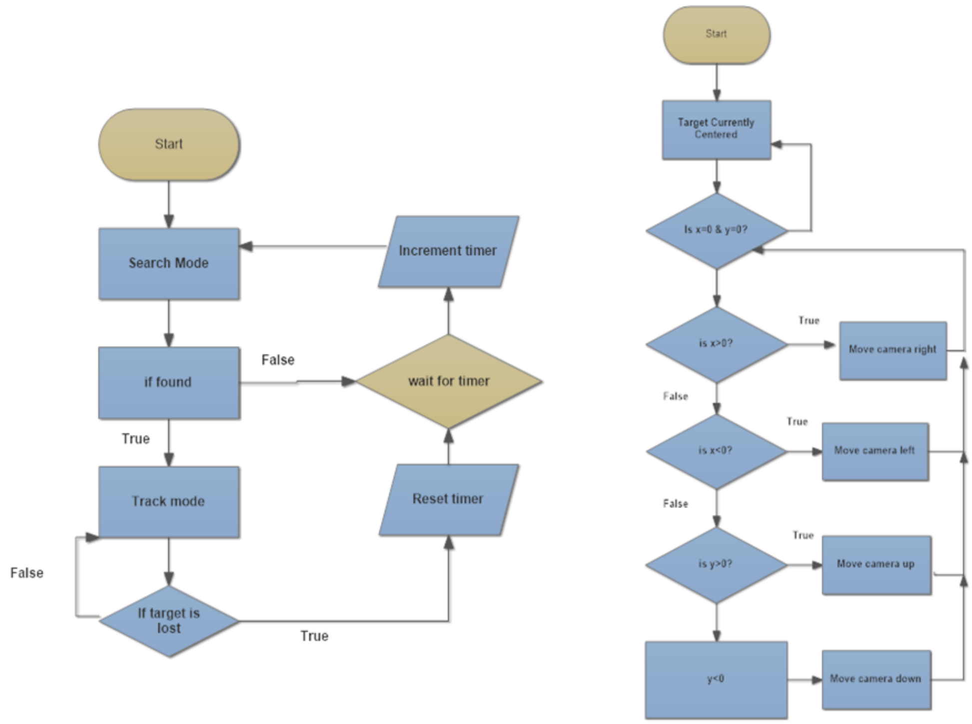

Fig. 5. Searching and Tracking Mode Flowcharts

When the device enters tracking mode, it changes behavior. First it turns the fan portion active, and second it focuses on the target it has located. While in tracking mode its primary goal is to keep the target in the center of the camera. It does this by sending signals to the fan motors based on the changing XY coordinates of the target. Additionally, the tracking mode can utilize the temperature and humidity sensor to determine how comfortable or uncomfortable the room is. It can use this information to automatically adjust the fan power output, to provide a relatively constant amount of air to a target. This feature can be overridden on the application to set a constant airflow. A basic flowchart showing tracking algorithm is shown above to the right.

The third mode is for manual control via the phone. While in manual mode the mobile app will present a page that will have controls for the fan. It will be able to set power, and manually move the fan in its 4 directions. This manual control will not allow the user to move the fan below its maximum depth as limited by the hardware. The same applies for upwards elevation. At a maximum elevation or depression, the command from the relevant button will be effectively ignored.

V. Software

The application is designed for android devices. Android was chosen because it was what the developer owns, and is thusly easily testable and usable. The goal of the application is to have a mobile platform that will control the device from a nearby position via a Bluetooth connection. The application should be easily usable, with self-explanatory controls. The application is lightweight due to its small scope. This is useful as requiring less memory to install, and fewer resources to run. This leads to easier running on the phone. It will not consume much battery power, leading to a prolonged activity time. The application will be necessary to utilize the fan, because all functionality will be controlled via signals sent from the application to the device.

The application is designed using MIT AppInventor. This is used due to ease of modification and learning time. The current design was for proof of concept and testing purposes due to time constraints. The application utilizing Java and Android Studio is not currently in use.

The android app is programmed utilizing the IDE Android Studio. This was chosen because it is the official IDE recommended by Google for Android devices. This will utilize the Java language, which must be separately installed on the development system. An additional benefit of this IDE, is that it allows emulation of an android device. This provides an easy method for testing of the application in development without the hassle of constantly uploading it to a device manually.

The application connects to the device via a Bluetooth module. The Bluetooth module has a limited range which acts as a layer of security. Additionally, no video is transmitted via Bluetooth, and the data that is transmitted is only about sizes and identification codes of colors found, and is not compromising information. Further, the fan cannot be controlled without knowing the exact format of code it is expecting as a final security measure.

The goal of the user interface for the phone application is to be simple to use and easily convey information. The user interface starts with a welcome screen on launch of the app. This transitions to a menu which allows the user to select the desired mode for the Robofan.

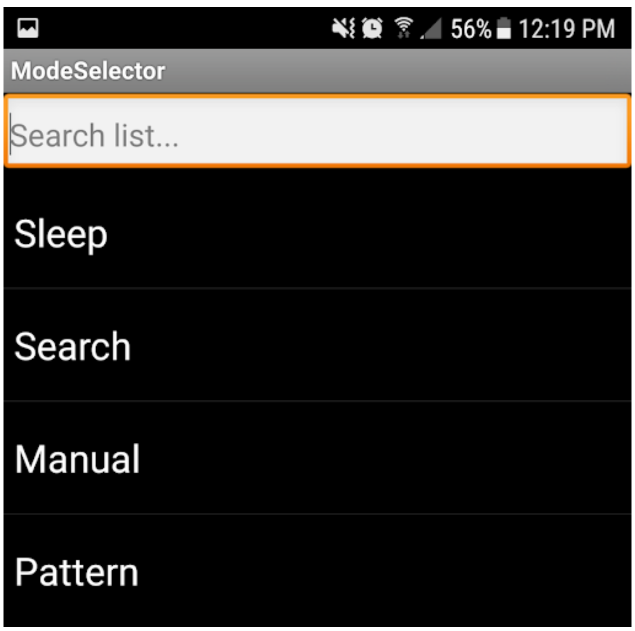

Fig. 6. Mode Select Screen

Sleep mode will turn off the fan motor as well as the motors dedicated to movement, selecting this will not move to a different menu. The search button sends the Robofan into the mode that utilizes the PixyCam to track a user around a room. The pattern mode button takes users to a screen which lists the available patterns, such as continuous spinning mode. The third button is the more interesting one as it will take users to a screen that allows them to control the fan manually. In this screen the left and right arrows will control the stepper allowing the Robofan to perform preset steps in the desired direction. The up and down arrows correspond to the servo motor controls. This allows users to set the Robofan at the desired angle. The last button, found in the center of the arrow, controls the speed of the fan. The first press sets the fan to high, the second press sets it to medium and a third press sets the fan to low. A fourth press will send the fan speed to automatic mode. This means that the speed of the fan will change based on what the incorporated temperature and humidity sensor is reading. Higher temperatures will switch the corresponding relays to set the fan at the highest speed. While lower temperatures will do the opposite. This setting is great for lowering power usage without having users think about it.

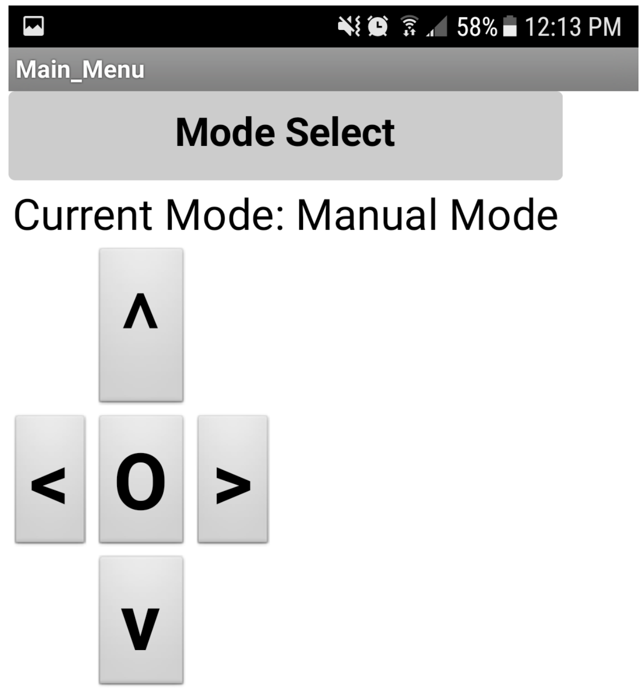

Fig. 7. Manual Mode Screen

VI. PCB Design

The very first board was completed and ordered using Autodesk Eagle. It was important for the two EE majors to have working experience with a professional circuit design tool used in the industry. From then on, the browser based EasyEda was used to create each new revision of the PCB. EasyEda proved to be a much more intuitive tool and boasted a comprehensive library of components.

A. Schematic

The schematic for the Robofan has the ATmega328p at the center. The upper part of the schematic deals with the power. The 12-volts needed for the DRV8825 stepper driver is provided by a 12-volt power supply connected to the PCB via a standard barrel power jack. A 100 uF capacitor is used to filter any high-frequency noise that may appear in this power signal. To the right of that is the switching voltage regulator, which will provide 5 volts for the rest of the components. Once again, a decoupling capacitor is used for this power signal as well.

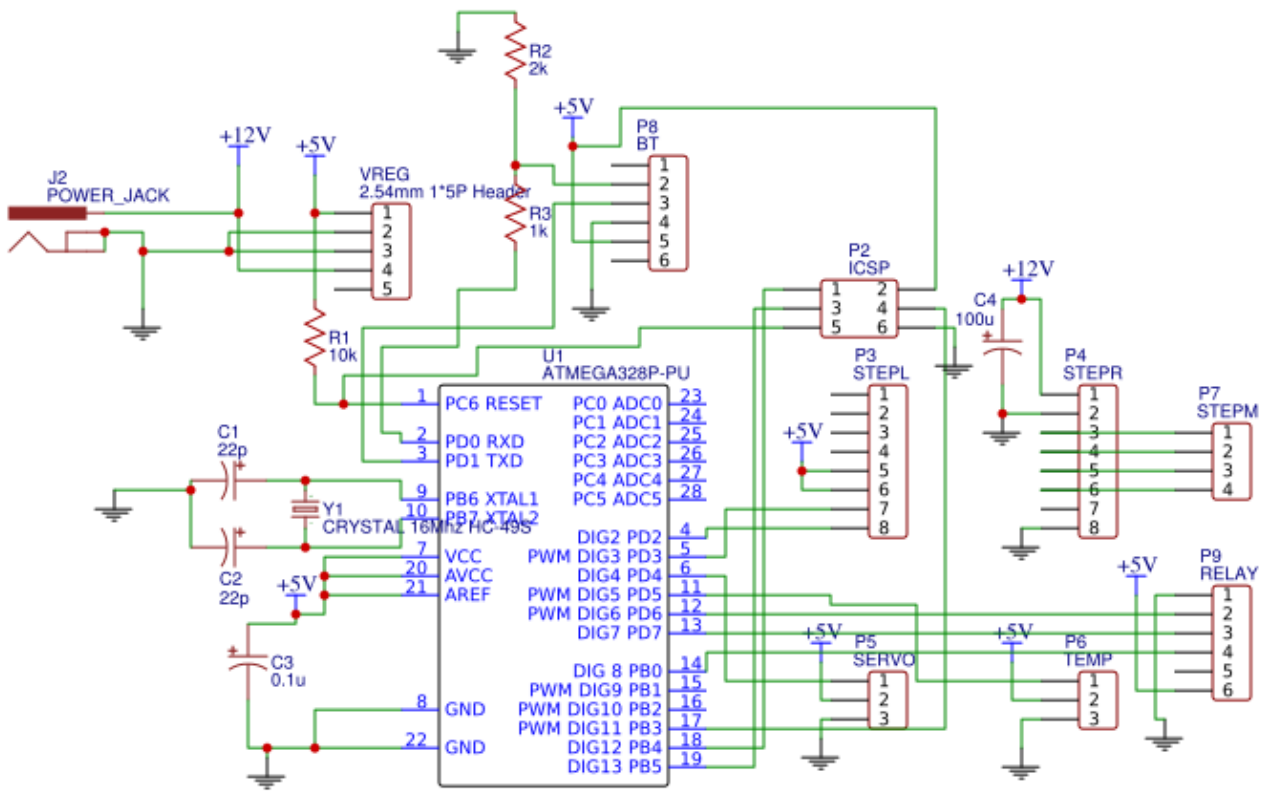

Fig. 8. Robofan Schematic

The left side contains all the components that the microcontroller will interact with. This includes the stepper motor and driver, the servo motor, the temperature sensor, the relays, and the Bluetooth module. There is also a set of pins for the ICSP connection which will allow the PixyCam to be easily plugged in. It is worth noting that the Bluetooth RX line uses a voltage divider comprised of a 1k ohm resistor and 2k ohm resistor. Signals going to the Bluetooth module must be at 3.3 volts. If it is left at 5 volts than it could damage the components or at least lessen its lifespan. This is a rather crude solution, but it is cheap and easy to implement. More importantly though, signals will be going to the microcontroller from the Bluetooth module in most situations. A better solution would be needed if the situation was reversed.

B. Board Layout

The board ended up having a dimension of 2.67 x 3.18 in. Size was not a major constraint in this project. It just needed to fit in the back compartment of the fan. This meant that the board's size was based on making sure it wouldn't be difficult to solder the components.

The trace widths used for the circuit board was determined using a trace width calculator tool. Three different width sizes were used. The 12-volt power line used 1.300 mm trace widths so the necessary 2.00 amps could be provided to the stepper driver. The 5-volt power line used a trace width of 0.800 mm. The remaining traces used a width of 0.500 mm.

For the early versions of the PCB, designs used through-hole components. We wanted to be able to test all our components on a breadboard. Nothing was to be left up to chance. The through-hole components also allowed us to troubleshoot quicker. We already had the tools needed to solder through-hole components in our possession. We could do all the soldering at home, without having to go to the senior design lab. This meant that we could quickly assemble the circuit boards as soon as they arrived. After having a working design hooked up on a breadboard the next step would be transferring it to a schematic and board layout. All in all, it took four revisions of the through-hole style boards to get it working perfectly. Unfortunately, fixing a mistake on the PCB is costly, since it must be ordered, fabricated, and shipped each time. Each revision put a strain on our budget, as well as taking at least a week of time since we had to wait for the boards to arrive.

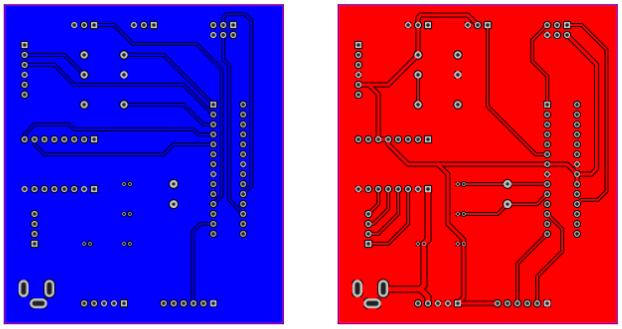

Fig. 9. Bottom and top layer of PCB

VI. Conclusion

The Robofan is a device made up of several different components coordinated by an MCU. There is an accompanying mobile application. The device utilizes AC power, DC power, and a custom printed circuit board. With all these things to consider, it's clear that this unique group of students, comprised of a computer science major, a computer engineering major, and two electrical engineering majors were well suited for this project.

This senior design project was a valuable learning experience beyond getting a chance to apply all the knowledge we have gained throughout our time at UCF. It has provided us with opportunities to create professional documentation and presentations. For many of us this has been the first time we have worked on one team for an extended period of time. Coordinating conflicting schedules and making sure a working project could be delivered by the end of the semester was a great challenge that was ultimately met.

Acknowledgement

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The Engineers

William Terry is a Computer Engineering senior at the University of Central Florida. He is graduating at the end of the summer 2018 semester with his bachelor's of science in computer engineering. He is interested in embedded systems and software development, and is seeking a job in the Orlando area.

Ryan Rossbach is in his senior year for a Computer Science bachelor's degree at the University of Central Florida and he graduates at the end of Fall 2018 semester. He is very excited to be done with this portion of his education, and move into the professional world.

Ivan Sarmiento is currently a senior at the University of Central Florida. He will be graduating in summer 2018 with a bachelor's of science in electrical engineering. He is currently seeking a job and is highly interested in working for the USPTO as a patent examiner.

Floyd Thormodson is a senior electrical engineering student at the University of Central Florida. He is graduating at the end of the summer 2018 semester with a bachelor's of science in electrical engineering. His interests are in the power distribution industry.

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