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1. Executive Summary

Automated honey extractors along with many other automated equipment necessary for the honey extraction processes are popular among big honey extraction industries. In fact, no big industry will be able to exist without automated equipment in order to extract big amounts of honey in a short period of time. Among beekeepers who do not own big businesses or industries, automated honey extraction equipment is not so popular due to high costs.

The main idea of this honey extractor is to make it automated and available (in terms of cost) to the beekeepers who practice beekeeping not necessary for business purposes. Once the start button is pushed, the honey extractor shall spin the motor and calculate the optimal time when to stop the motor (which is at a point of time when the honeycomb frames do not lose mass anymore). Besides just being an automated extractor it will have many other useful and unique features to enhance its usefulness.

The main feature of the automated honey extractor is that it will have a controllable electric motor which spins the honeycomb frames with honey inside of a container and extracts the honey to the walls of the barrel (the same principle is used in a centrifuge). The honey then flows down the walls to the valve where it will be collected.

Once the beekeeper gets the honeycomb frames ready or prepared for the extraction process through a process of uncapping, they are ready to be loaded into the automated honey extractor (this extractor will have a capacity of at least eight frames). Once the frames are loaded into the apparatus, the beekeeper or the operator of the machine will be presented with two ways of controlling the machine. One option is the on board analog buttons and knobs, the other option is wirelessly through an android device. The convenience of operating the machine wirelessly through an android device comes with an additional advantage such as on screen statistical information about the extraction process, for example, the current temperature inside the apparatus, the humidity level, the time left for the process to finish and many more.

As already may be assumed from the information of the above paragraph, the automated honey extractor will come with three sensors on board, these are – a temperature sensor, a humidity sensor, and a weight or force sensor. Each of the sensors will provide a valuable piece of information to the beekeeper or the person who will operate the machine.

The temperature sensor is used for the heating mechanism built into the extractor and for the user who chooses the temperature he or she wants the extraction process to be at. The purpose of the heating mechanism is to speed up the whole extraction process. The more the honey is heated the less viscous it becomes which speeds up the flow of the honey out of the container down through the valve. Also, in order not to damage the honey, the temperature cannot exceed certain value for certain types of honey. Thus, giving the option to the user to set a certain temperature limit and be able to monitor the temperature is a neat and useful feature which helps speed up the process.

The humidity sensor will be used to provide a valuable information to the user about the humidity levels. During the extraction period, the humidity levels directly affect the water content in honey. As a general rule of thumb for beekeepers, the more there is water content in the honey the worse its quality is considered to be. In order not to exceed a certain percentage of water content in the product, the beekeeper must know the humidity levels of the surrounding environment.

The weight sensor will be used for two purposes as well. As the honeycomb frames inside the frame holders spin and lose mass, the weight sensor will be used to detect the loss of this mass and based on this information, the automated controller will calculate the optimal time when to stop the motor. The sensor will also be used to provide the user with information about the amount of honey extracted at the end of the process and optionally the rate of the honey being extracted in real time if the group will manage to implement the weight sensor in a way which will allow for this feature to be accomplished.

Summarizing all the points and features of this equipment, the automated honey extractor is an extractor, first of all, with low cost, which makes it available to small honey extraction industries and, most importantly, to nonprofit seeking beekeepers. Second of all, it is automated and requires minimal input form the user – the loading of the frames and pushing the start button. Finally, the extractor provides the user with a handful of features such as indirect temperature control and monitoring, humidity monitoring, wireless and on board control over the motor and real-time feedback on the android device.

2. Project Description

2.1. Motivation

Although honeybees are worth billions of dollars to farmers just in the United States, very few people other than them realize the importance of the beekeepers and their bees. The reason why they are so important is because the bees in the process of making honey have to collect nectar from trees and flowers. While collecting nectar, the bees also cross-pollinate the plants that they collect from, which in turn produce fruits and seeds. For this very reason farmers even rent bees from beekeepers. However, regardless of the importance of beekeeping, it is becoming less and less popular, especially in the United States.

There are several reasons why the number of beekeepers started to dwindle. It is no secret that beekeeping has never been easy, however with the arrival of tracheal mites in the 1980s and varroa mites and small hive beetles in the 1990s (all of which are pests that invade hives and hinder beekeepers) keeping bees has become much more challenging for beekeepers. However these pests were not the only thing that the beekeepers had to face. Another thing that the beekeepers had to face was high prices for the machinery that they needed in order to operate their business. With these problems the number of beekeepers stated to slowly become smaller and smaller, until the only people that still kept bees are the ones that were ready to invest large amounts of money into their business or the ones that were ready to spend enormous amounts of time tending to their bees.

Our senior design group decided to address this problem, and as engineers we cannot help with reducing the pests since we lack the proper education, but what we could do in order to make the work of the beekeepers easier, is build a device that will somehow aid their struggle. After doing some research, the most useful device that we could build is a honey extractor since extracting honey is probably the most troublesome part in the honey production, and for this reason over the years beekeepers came up with numerous methods of extracting honey from the wax frames, starting with the aged method of just letting gravity do its work of draining the honey from the frame, to the more modern methods which involve fairly expensive machinery. And as in any other industry, the more advanced the machinery, the more money it costs. However as most people cannot afford a device that costs several thousand dollars, the market is in need of a device that will do the same thing but costs at most several hundred dollars.

Therefore our senior design group decided to build a honey extractor that will have the functions of a high-end commercial extractor and maybe even some new functions that have never been seen before in a honey extractor, and yet be at the price of the lower-end extractors. We hope that with the introduction of this device, the number of hobbyist beekeepers will rise, and beekeeping will become a little more popular.

2.2. Goal & Objectives

The goal of this senior design project is to create a as low-cost as possible automated honey extractor that is fast and easy to use, which should help beekeepers to extract honey without too much trouble. The purpose of creating such a device is because it would help decrease the costs of maintaining a bee farm and at the same time increase the profits of the beekeepers and ultimately increase the number of hobbyist beekeepers and small-scale beekeeping.

The objective of the Automated Honey Extractor in its simplest form is to extract the honey from the wax frames. However the entire process, other than the loading of the frames into the device and then removing them after the process is complete, should be autonomous. After the frames are loaded into the honey extractor and the start sequence is activated, the honey extractor should do the rest of the work automatically. It should use the centrifugal force to remove the honey from the wax frames with minimal damage done to the frames. This should decrease the effort put in by the beekeepers in the honey extraction process and give them time for other things that need to be taken care of in their business.

2.3. Requirements & Specifications

In this section all of the project's requirements and specifications will be listed. To simplify this section, the project requirements and specifications will be split into several categories. The categories are: General Requirements (Table 2.3.1), Mechanical Requirements (Table 2.3.2), Heating System Requirements (Table 2.3.3) and Wireless Communication Requirements (Table 2.3.4).

2.3.1. General Requirements

Requirement	Description
AHE-GR01	The extractor shall extract honey
AHE-GR02	The extractor shall have a heating system.
AHE-GR03	The extractor shall have an onboard controller
AHE-GR04	The extractor shall be able to be operated wirelessly
AHE-GR05	The extractor shall be powered by a standard wall outlet(s)
AHE-GR06	The extractor shall be "User Friendly"
AHE-GR07	The extractor shall have a stainless steel vat
AHE-GR08	The extractor shall have a humidity sensor
AHE-GR09	The extractor shall not damage the wax frames too much
AHE-GR10	The extractor shall cost no more than $1000
AHE-GR11*	The extractor shall have a weight sensor

Table 2.3.1: General Requirements

*Optional, Not Required

2.3.2. Mechanical Requirements

Requirement	Description
AHE-MR01	The extractor shall support at least eight (8) frames
AHE-MR02	The extractor shall have a vat of at least ten (10) gallons
AHE-MR03	The extractor shall be driven by an electric motor
AHE-MR04	The extractor shall have a radial design
AHE-MR05	The extractor shall have a valve
AHE-MR06	The extractor shall use centrifugal force to extract honey
AHE-MR07	The extractor shall have a emergency stop button
AHE-MR08*	The extractor shall have a basic filter for the honey

Table 2.3.2: Mechanical Requirements

*Optional, Not Required

2.3.3. Heating System Requirements

Requirement	Description
AHE-HSR01	The heating system shall heat up the honey to no more than forty (40) degrees Celsius
AHE-HSR02	The heating system shall have a temperature sensor
AHE-HSR03	The system shall adjust the temperature based on data from sensor
AHE-HSR04	The temperature will be displayed on the android device in real time
AHE-HSR05	The heating system shall not use more than 500W of power to heat up the heating element
AHE-HSR06	The temperature sensor will have the range of at least twenty degrees Celsius to fifty degrees Celsius

Table 2.3.3: Heating System Requirements

2.3.4. Wireless Communication Requirements

Requirement	Description
AHE-WCR01	The extractor shall be able to be operated wirelessly from a distance of at least five (5) feet
AHE-WCR02	The extractor shall use Bluetooth.
AHE-WCR03	The extractor shall be able to be operated using an android device wirelessly
AHE-WCR04	Data from the humidity sensor shall be displayed on the android device

Table 2.3.4: Wireless Communication Requirements

3. Research

3.1. Existing Similar Projects and Products

3.1.1. Other Extractors

From the countless senior design projects we could not even find one project that tried to build a similar device. However even though there were no similar projects, there are many different extractors on the market that in principle are the same. In general there are two types of extractors that dominate the market, the tangential type (see figure 3.1.1.1), and the radial type (see figure 3.1.1.2). And since we did not want to “reinvent the wheel” we were going to stick with one of them.

3.1.1.1. Tangential Extractors

What makes an extractor "tangential" is the positioning of the frames inside the extractor. If the frames are organized similarly to what we see in the figure below, it is considered to be a tangential extractor since the frames are "tangent" to the circular shape of the centrifuge. Due to the positioning of the frames in such a manner, a problem occurs, that problem is the fact that the frames need to be flipped in order to get all of the honey from the frame. While this type of extractor is fairly common and effective in the amateur beekeeping world, it is very impractical when the number of frames that need to be extracted exceeds four-six at a time. When we were designing our extractor our initial idea was to make it tangential, however after some research we decided that a radial extractor is more suited for our objectives.

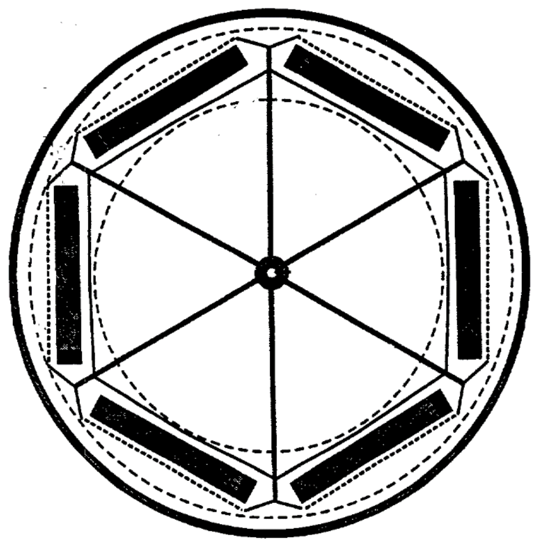


Figure 3.1.1.1 Tangential Extractor Top view

3.1.1.2. Radial Extractors

The second major type of extractors is the radial extractor. In the radial extractor, unlike the tangential extractor, the frames are positioned "radially" which means that one edge of the frame is facing the center of the centrifuge, while the second edge is facing the edge of the circle, just like the radius of the circle. At first glance this type of positioning does not make sense because one would assume that it would be difficult for the honey to be extracted, however what makes this type of extractor work is the natural shape of the honeycomb in the frames. The honeycomb because of gravity is tilted. This design uses that tilt to the fullest. By placing the frame with the honeycomb tilt facing the outer edge ensures the easy extraction of the honey from that frame, without much damage to the honeycomb. And due to that placement of the frames, the frames do not need to be flipped in order to extract the honey, which saves a lot of time, especially if this is done on a commercial scale where the number of frame extracted exceeds hundreds. Another advantage that this frame placement has is that it takes up much less space compared to the tangential type, which makes it even more appealing to the beekeepers that have a large quantity of frames. For this very reason, our group decided that this type of extractor is more suited for our goals. However event though our extractor's basic layout will be the same, our extractor will have numerous features that other extractors do not.

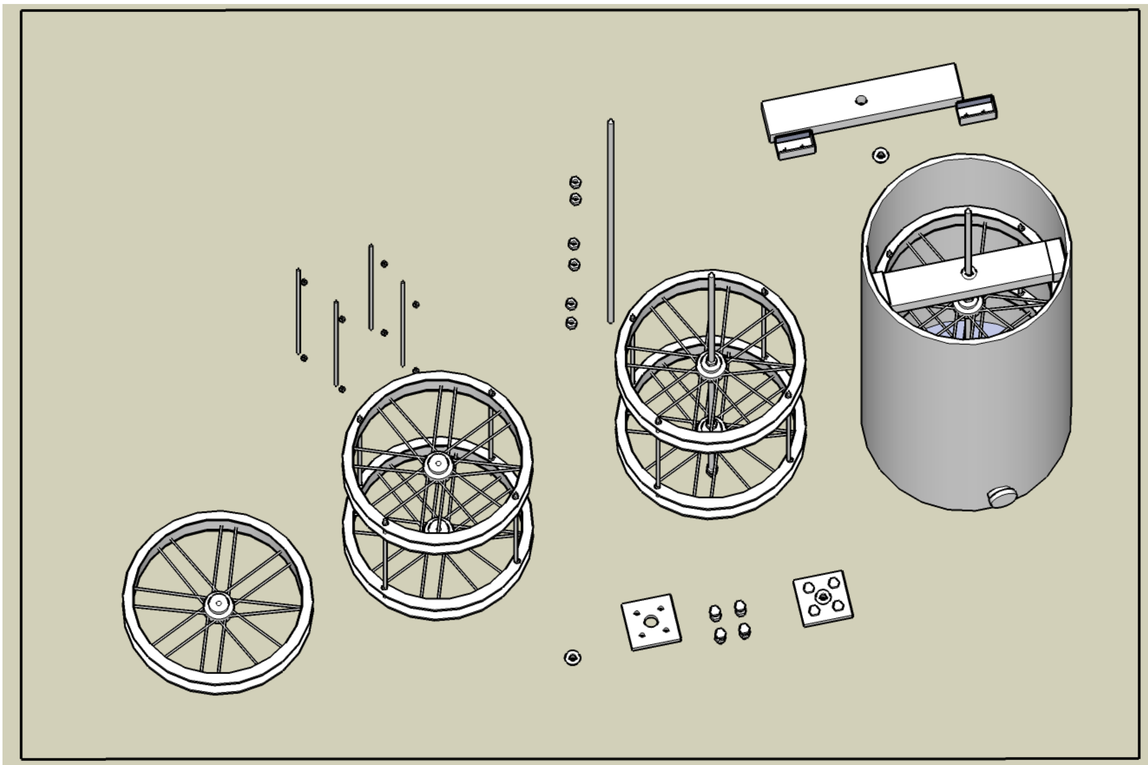


Figure 3.1.1.2 Basic Radial Extractor

3.1.1.3. Other Extractor Features

Since our extractor is almost identical in its core with other extractors, our extractor needs to have something that will set it apart from the rest. But to do that we needed to first find out what the others had. Extractors exceeding the price tag of one thousand dollars usually have the following features:

- They are motor driven
- Can hold anywhere from eight to twenty frames
- Made of stainless steel
- Some have speed control

Anything beyond that is very rare. Our extractor will have all of these features, as well as many other ones. A schematic of a lower end honey extractor can be found below.

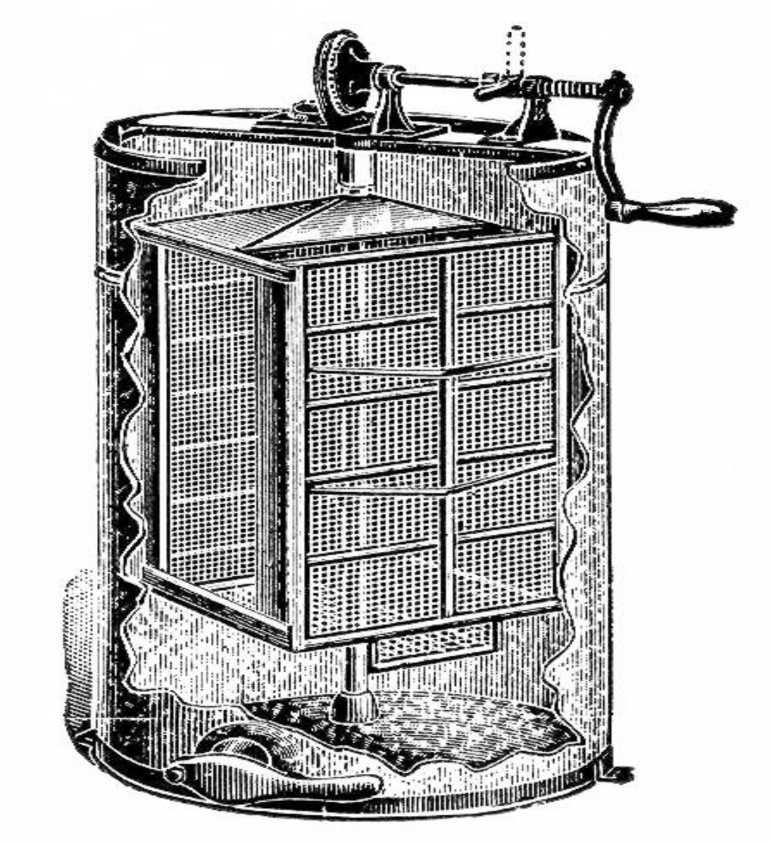


Figure 3.1.1.3.1: Figure of Lower End Honey Extractor

3.2. Relevant Technologies

3.2.1. Temperature/Humidity Sensors

Monitoring temperature and humidity is essential for the quality of honey the honey extractor will produce. Controlling the temperature and measuring it throughout the process of extracting honey will contribute to a better flow of the honey from the walls or the frame of the extractor down to the valve where it will be collected in special containers. Overall, controlling the temperature will contribute to the efficiency of the apparatus. Temperature sensor will provide essential data to the heating mechanism. The heating mechanism cannot exceed a set temperature as that will have a negative effect on the quality of the honey. Overheating will result in quality loss of the honey (this includes caramelization, fresh flavor loss etc.) [3].

Enzyme destruction occurs when honey is overheated. Overheating the honey is practiced by many manufacturers because it makes the honey stay clear instead of cloudy, and it also prevents it from caramelization. Some industries go for cosmetic looks instead of quality. Many of the good properties are lost with overheating, this is why a temperature sensor is so important in this project since quality is our priority concern. Fermented honey is often also reclaimed by heating it to 150 degrees Fahrenheit. This process may destroy enzymes as well. In the table 3.2.1.1 below the safe temperatures and heating time is outlined [3].

Temperature F	**Heating Time (Minutes)**
128	470
130	170
135	60
140	42
145	7.5
150	2.8
155	1.0
160	0.4

Table 3.2.1.1: Honey Pasteurization Treatments

Humidity is another key factor that determines the quality of the honey. Honey has a tendency to absorb water from the air. The higher the humidity during the extraction process the more water content the honey will contain. Honey with high amount of water content negatively affects the quality, as it allows for the fermentation to occur. The water content in honey ranges anywhere from thirteen (13) to twenty five (25) percent. Honey with over nineteen (19) percent water will ferment and with seventeen (17) percent and less will not ferment if kept in proper temperature [3]. The humidity sensor will provide the operator essential data which will determine whether it is “safe” to begin extraction or not. In a case with high humidity which will result in water content of over nineteen (19) percent the extraction process should be delayed until the humidity drops into safe levels or the humidity should be forcefully lowered by using a dehumidifier.

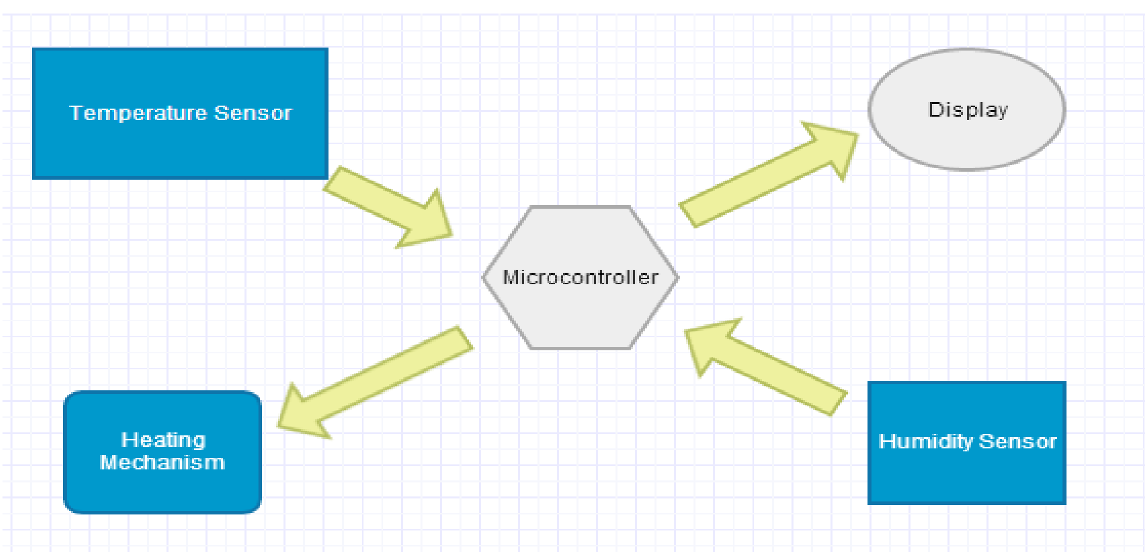


Figure 3.2.1.1 - Temperature/Humidity Sensor diagram

3.2.1.1 Temperature Sensor

The infrared temperature sensor comes with a handful of other useful features that make it easier to integrate into our design from an electrical perspective; the pins of the sensor are shown in figure 3.2.1.1.1.

The following table shows some of the features of the infrared temperature sensor that stand out the most, one should note that even with features such as these, the sensor does not exceed the price range allowed by our sponsor:

Features and Benefits
❑ Small size, low cost ❑ Easy to integrate ❑ Factory calibrated in wide temperature range: -40…+125˚C for sensor temperature and -70…+380˚C for object temperature. ❑ High accuracy of 0.5°C over wide temperature range (0…+50°C for both Ta and To) ❑ High (medical) accuracy calibration ❑ Measurement resolution of 0.02°C ❑ Single and dual zone versions ❑ SMBus compatible digital interface ❑ Customizable PWM output for continuous reading ❑ Available in 3V and 5V versions ❑ Simple adaptation for 8…16V applications ❑ Sleep mode for reduced power consumption ❑ Different package options for applications and measurements versatility ❑ Automotive grade

Table 3.2.1.1.1: IR Temperature Sensor Advantages

Permission granted from Melexis

Despite all other advantages discussed before, this sensor has many other features. The only disadvantage over the other sensors is that the spinning frame holders might hinder its accuracy.

Out of the three options we consider the latter two, first we will try the infrared sensor if that gives us complications and does not perform as expected we will implement the second option.

Product Number	Manufacturer	Temp Range/Accuracy	Cost
TMP100	TI	-55~125C/+-2C	$0.75
TMP101	TI	-55~125C/+-2C	$0.75
480-3161-ND	Honeywell Sensing and Control	-60~150C/+-1.3%	$4.74
DS18S20	Maxim Integrated	-55~100C/+-0.5C	$4.00
LM335	TI	-40~100°C/+-6C	$1.35

Table 3.2.1.1.2 - Temperature Sensor Comparison

There are many types of temperature sensors that could be implemented in our project. For the purposes of the honey extractor, the temperature sensor does not need to be a high performance and very accurate sensor, in fact, all of the sensors in the comparison table have a very good accuracy and satisfy the requirements. As seen from table 3.2.1.1.2 above, all of those sensors have satisfactory specifications. The cost is not an issue since we do not need many sensors for the project. The ease of communication between the sensor and the microcontroller unit will be the key factor in choosing which sensor to go with if the decision is made to avoid the infrared temperature sensor.

The 192-302LET-A01 is actually a thermistor, but using it as a temperature sensor is very common. This sensor has only two outputs or pins which is an advantage over the other sensors. The complicated part about this sensor is translating the output to the measured temperature. But since it is a very common sensor and is easily integrated with the microcontroller, many resources are available on how to do this part.

LM335, TMP100 and TMP101 all come with wide temperature ranges, satisfactory accuracy, voltage inputs and costs. All of them are analog and will require an analog to digital converter part if it is not supported by the microcontroller. They all will have to be sealed to avoid contact with the honey which will eventually destroy the sensor. They are all good options with good functionality, specifications and options.

If the infrared sensor will not meet our expectations we will go for the 192-302LET-A01 thermistor, which is very cheap and very small, has only two pins which is very beneficial in our project design. The infrared sensor still remains as our first option.

Product	Input Voltage	Temp Range	Response Time	Cost
IRTEMP	3 to 5V	15~35C	1 second	$34.95
MLX90614	8 to 16 V	-40~85C	-----	$12.49
OS211	6 to 24 V	-20~500C	240ms	$196.00

Table 3.2.1.1.2: Infrared Temperature Sensor Comparison

Research and comparison led to a conclusion to choose the MLX90614 infrared temperature sensor as a first option. Below in the **figure 3.2.1.1.1** are the pins of the sensor. **Table 3.2.1.1.3** describes the function of each pin. This table along with the figure will be very helpful later on in the testing section of the temperature sensor.

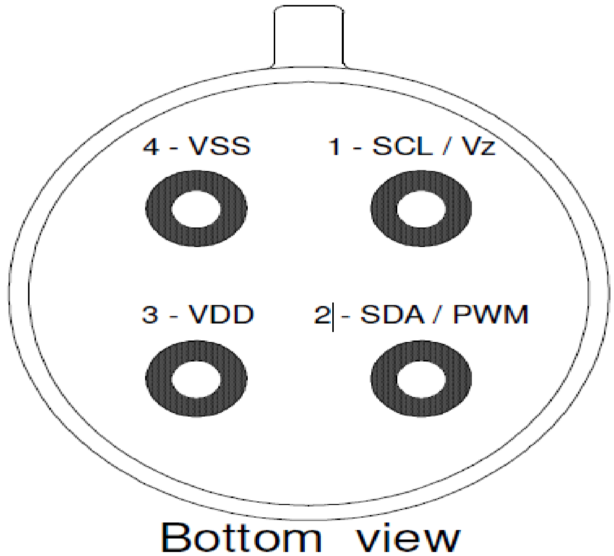


Figure 3.2.1.1.1 – IR Temperature Sensor Pins

Permission granted from Melexis

Pin Name	Description
SCL / Vz	Serial clock input for 2 wire communications protocol. 5.7V zener is available at this pin for connection of external bipolar transistor to MLX90614Axx to supply the device from external 8 …16V source.
SDA / PWM	Digital input / output. In normal mode the measured object temperature is available at this pin Pulse Width Modulated. In SMBus compatible mode the pin is automatically configured as open drain NMOS.
VDD	External supply voltage.
VSS	Ground. The metal can is also connected to this pin.

Table 3.2.1.1.3 – Pin Description

Permission granted from Melexis

Below is a table 3.2.1.1.4 of absolute maximum ratings of the MLX infrared temperature sensor. This table shows the voltage supply and current ratings, temperature at which the sensor operates etc. The table will come handy when testing the sensor.

Parameter	MLX90614ESF-Axx	MLX90614ESF-Bxx MLX90614ESF-Dxx	MLX90614KSF-Axx
Supply Voltage, V_{DD} (over voltage)	7V	5V	7V
Supply Voltage, V_{DD} (operating)	5.5 V	3.6V	5.5V
Reverse Voltage	0.4 V		
Operating Temperature Range, T_A	-40…+85°C		-40…+125°C
Storage Temperature Range, T_S	-40…+125°C		-40…+125°C
ESD Sensitivity (AEC Q100 002)	2kV		
DC current into SCL / Vz (Vz mode)	2 mA		
DC sink current, SDA / PWM pin	25 mA		
DC source current, SDA / PWM pin	25 mA		
DC clamp current, SDA / PWM pin	25 mA		
DC clamp current, SCL pin	25 mA		

Table 3.2.1.1.4: MLX IR Sensor Maximum Ratings

Permission granted from Melexis

3.2.1.2. Humidity Sensor

Humidity sensor implementation is not as difficult as the temperature sensor implementation because humidity does not necessarily have to be measured inside the container. Anywhere close to the container will be accurate enough for the purposes of this project.

There are a variety of sensors that come with a humidity sensor and a temperature sensor as one part. If the infrared temperature sensor will not be satisfactory in our project we will consider humidity/temperature sensors that come as a one part to avoid extra complication.

SHT1x is the part number of a temperature/humidity sensor manufactured by DF Robot. It comes as a very small unit which is an advantage for our needs. Another advantage of this sensor is that it has a digital instead of an analog output. It is also very low power. For part specifications refer to table 3.2.1.2.1 and part dimensions refer to figure 3.2.1.2.1.

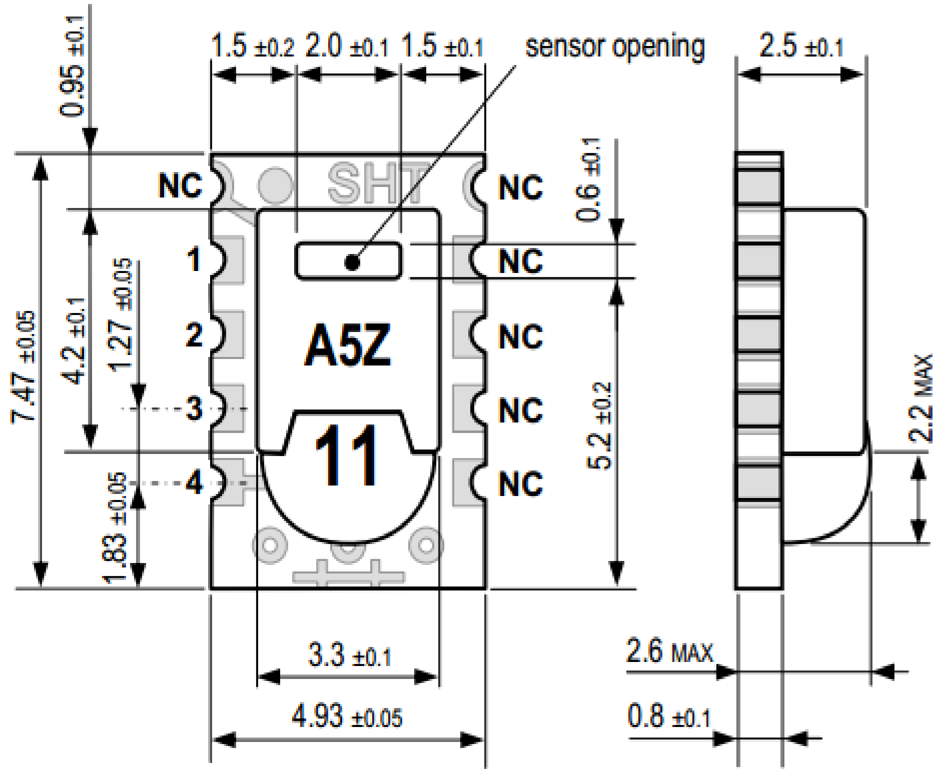


Figure 3.2.1.2.1: – SHT1x Sensor Dimensions

Permission granted from Sensirion

The table below shows the specifications of the the SHT1x sensor. With its resolution, accuracy and repeatability values, this sensor will be a good choice for the project.

SHT110 Sensor	Accuracy	Operating Range	Response Time	Cost
Temperature	+-0.5C	-40 to 123.8C	5 to 30 seconds	$24.00
Humidity	+-2% RH	0 to 100% RH	8 seconds	-------------

Table 3.2.1.2.2: – Temperature/Humidity Sensor

Parameter	Condition	min	typ	max	Units
Resolution [1]		0.4	0.05	0.05	%RH
		8	12	12	bit
Accuracy [2] SHT10	typical		±4.5		%RH
	maximal	see Figure 2			
Accuracy [2] SHT11	typical		±3.0		%RH
	maximal	see Figure 2			
Accuracy [2] SHT15	typical		±2.0		%RH
	maximal	see Figure 2			
Repeatability			±0.1		%RH
Hysteresis			±1		%RH
Non-linearity	linearized		<<1		%RH
Response time [3]	τ (63%)		8		s
Operating Range		0		100	%RH
Long term drift [4]	normal		< 0.5		%RH/yr

Table 3.2.1.2.1 – SHT1x Specifications

Permission granted from Sensirion

Table 3.2.1.2.3 below describes a humidity sensor that will be our first choice humidity sensor. It is much cheaper than the humidity/temperature sensors and unnecessary redundancy is avoided. This sensor operates by changing its capacitance as the humidity changes. The sensor has a low temperature dependence, has an increased resistance against contamination which suits our needs perfectly.

Part Number	Operating frequency range	Operating Range	Response Time	Cost
HCH-1000-002	1 – 100 kHz	10 %RH to 95 %RH	15 seconds	$4.32
HH10D	5 – 10kHz	0 to 100 RH	8 seconds	$9.95

Table 3.2.1.2.3: Humidity Sensor

The response time of the SHT11x temperature sensor is minimum 5 seconds and maximum 30 seconds. This is a slow response time compared to previous standalone temperature sensors, and this is the only disadvantage. If the infrared sensor will meet our expectations there will be no need of a humidity/temperature sensor.

The following table gives the power consumption of the humidity sensor. These power consumption information will be used to roughly calculate the power consumption of the whole electronics part of the project.

Electrical and General Items

Parameter	Condition	min	typ	max	Units
Source Voltage		2.4	3.3	5.5	V
Power Consumption [5]	sleep		2	5	µW
	measuring		3		mW
	average		90		µW
Communication	digital 2-wire interface, see Communication				
Storage	10 – 50°C (0 – 125°C peak), 20 – 60%RH				

Table 3.2.1.2.4: SHT11x Power Consumption

Permission granted from Sensirion

Another alternative humidity sensor listed in table 3.2.1.2.3 – the HH10D model is an interesting alternative. The HH10D sensor module comes with a capacitive type of technology. Due to this technology, the sensor responds to humidity changes very quickly. This specific sensor comes with the following special features according to sparkfun datasheet:

- Two point calibrated with capacitor type sensor
- Frequency output type, can be easily integrated
- Very low power consumption
- No extra components needed

Below is the circuit diagram of the HH10D sensor module.

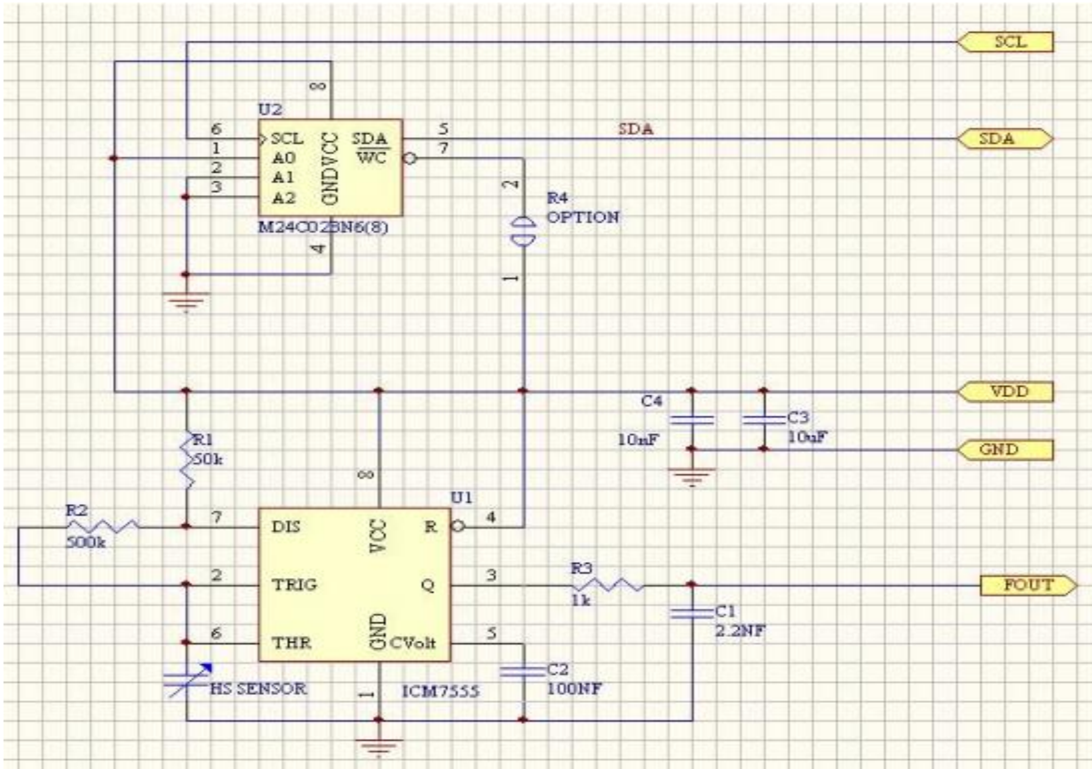


Figure 3.2.1.2.2: Circuit Diagram of HH10D Module

According to hoperf datasheet, in order to read out the correct humidity, 4 calibration factors need to be read out from the EEPROM at address of 10 and 11, 12 and 13 for sensitivity, offset. Once the frequency output from the sensor is measured, then the correct humidity value can be calculated in the following method:

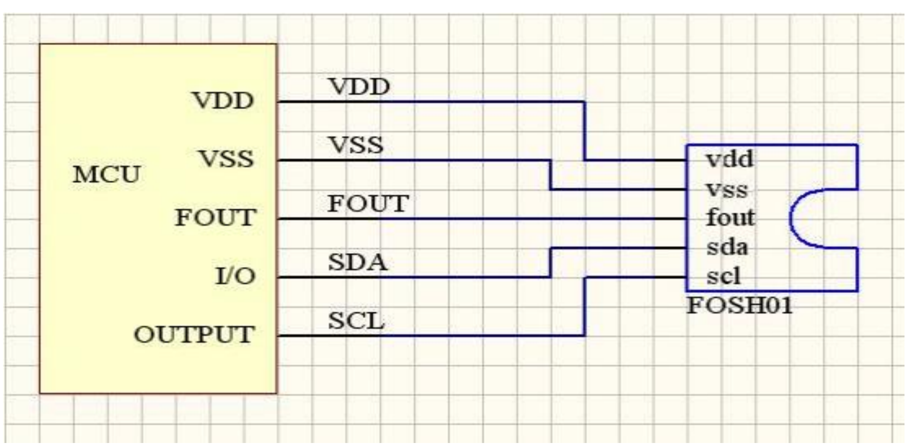


Figure 3.2.1.2.3: Application Circuit

3.2.2. Weight Sensor

The weight sensor will be used to calculate the amount of honey being extracted from the frames. The user will be receiving a feedback on a LCD screen and/or android device. The weight sensor will not only calculate the weight of the honey extracted at the end of the process, but will also be used to calculate the weight being extracted in real time of the process. This means that the user will receive a feedback on the screen with either a counter or a graph plot of real time weight extracted from the honeycombs in desired units of weight measurement. Measuring weight in real time instead of just the weight difference of the honey extractor at the end of the process allows us to calculate the optimal time when to stop the extraction process, for example, if the honeycomb frames do not lose weight this means the motor should be slowing down. Also it allows us to create many statistical calculations for the user if one desires to know at what point of time or at how many revolutions per minute is the honey extracting the fastest or the slowest and so on.

Part Number	Retailer	Range	Accuracy	Price
S-20-1000-FS15	Trossenrobotics	1 to 100N	+/- 6%	$7.95
SEN-09376	Sparkfun	0.1 to 10kg	+/- 15%	$7.95
SEN-08685	Sparkfun	1 to 100lb	+/- 3%	$19.95
S-20-1000-FS5	Trossenrobotics	1 – 100N	+/- 6%	$6.60

Table 3.2.2.1 – Thin and Flexible Force Sensors

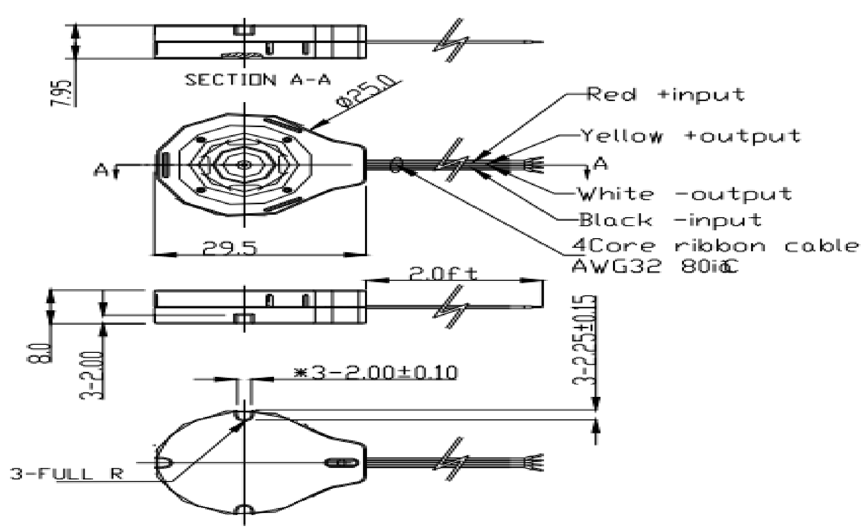


Figure 3.2.2.1: FX1901 Dimensions

Permission granted from Meas-spec

All of the sensors in the table 3.2.2.1 are thin and flexible type of force sensors, the sensors in Table 3.2.2.2 are heavy duty force sensors with mechanical parts. The SEN-10245 is a load sensor used in regular electronic scales. All of the sensors from table 3.2.2.1 are based on a principle where the more pressure or weight is applied to the sensor the less the resistivity becomes. The change in the resistivity can be converted into a voltage change using a Wheatstone bridge. Figure 3.2.2.4 shows the diagram of a Wheatstone bridge.

Measuring the voltage changes and converting them using the given formulas in the datasheets of the sensors will give us the weight of an object applied on the sensor. The SEN-10245 sensor will most likely be used in our project. It has a few advantages over the other sensors, though has its own disadvantage as well. It is more accurate and has a wider range while staying relatively cheap. The sensor that comes closest to that range from the flexible type is the SEN-08685, which has a 100lb limit, though comes with a higher price tag. Another disadvantage of the SEN-10245 is its size and mechanical parts which will add to the implementation difficulty in our project.

Another advantage of the flexiforce sensors is that they come with a detailed user manual and formulas that explain how to use the sensor and how to connect it to the microcontroller and measure the actual weight. Below in the figure 3.2.2.4 is an example of how SEN-08685 is hooked up and operates.

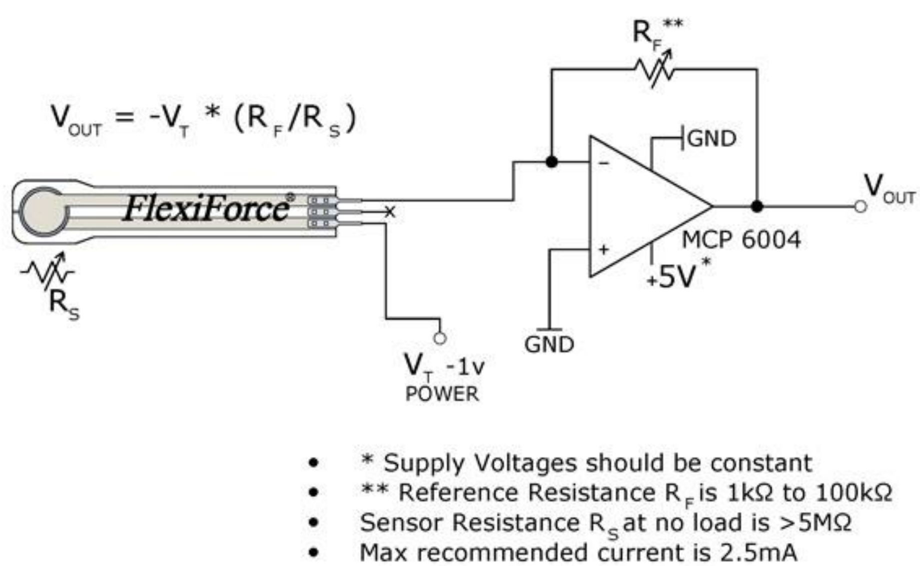


Figure 3.2.2.2: Force Sensor Excitation Circuit

Permission granted from FlexiForce

The heavy duty sensors below in Table 3.2.2.2 are complete package sensors, it means they are ready to be hooked up straight to the microcontroller. They are factory calibrated, robust, sturdy and very reliable.

For our project the heavy duty sensors are preferable at this point of time. When all of the eight honeycomb frames will be added into the frame holders, the weight will be approximately 35 pounds not counting the weight of the frame holder. The frame holder is constructed from metal so it will add by approximation another 10 to 20 pounds, therefore we have a total weight of 55 pounds or so. From this approximation the sensor should be, preferably, with at least 100lb maximum force range.

Part Number	**Retailer**	**Range**	**Accuracy**	**Price**
SEN-10245	Sparkfun	1 to 110lb	+/- 0.03%	$9.95
FN2570-6	-------------	40 to 500lb	+/- 2.5% F.S.	$120.00
FMT6	-------------	20 to 4000lb	1 - 5% F.S.	~ $400
FX1901	Future Electronics	10 to 100lb	+/- 1%	$22.41
FC2231-0100-L	Digi-Key	10 – 100lb	+/- 1% Span	$62.87
FC2311-1000-L	Digi-Key	50 – 2000lb	+/- 1% Span	$119.43

Table 3.2.2.2: Heavy Duty Force Sensors

Most of the sensors come with two outputs where the voltage difference can be measured straight from those outputs. If the sensor comes with four outputs, the two of the outputs are for the excite voltage – the positive and negative nodes as shown in Figure 3.2.2.4. The other two outputs are from the Rx resistor. When there is a slight change in the resistance, the voltage difference can as well be easily detected. The voltage differences are usually very small and an amplifier will be used to amplify that difference if not implemented in the microcontroller.

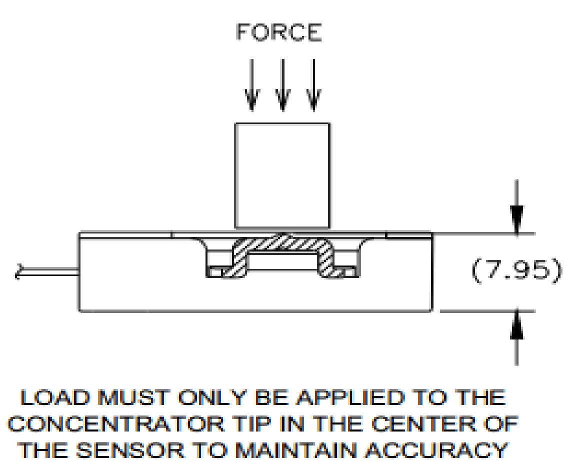


Figure 3.2.2.3: Force Application on FX1901 Sensor

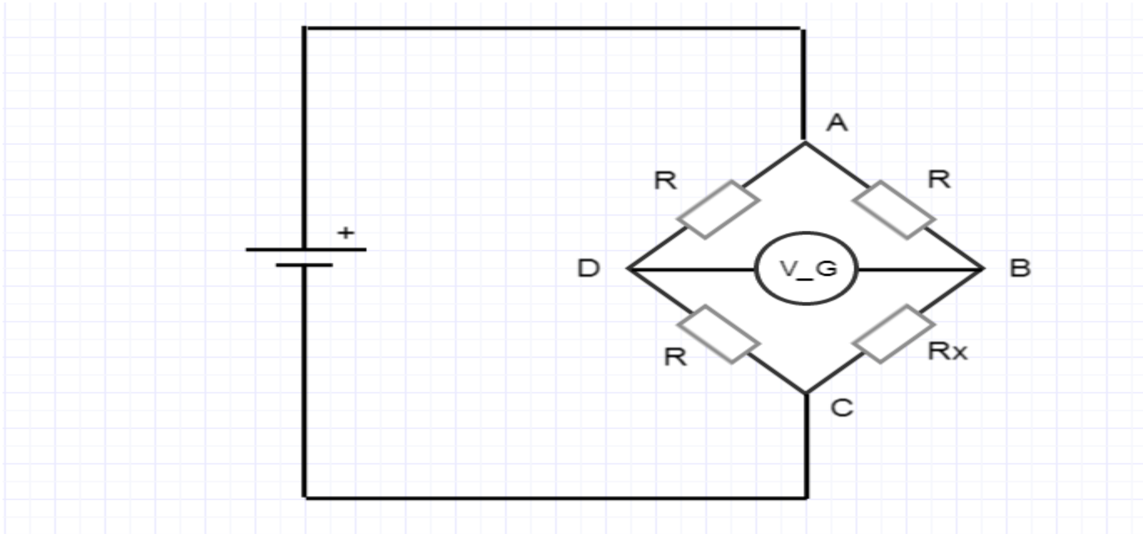


Figure 3.2.2.4: Wheatstone Bridge

The FMT6 sensor is considered only because of its design. Although it comes with a high price point it will be probably easier integrated in the extractor due to its shape. Figure 3.2.2.5 below shows the construction of the FMT weight sensor. This is a donut shaped sensor that will make it easy to implement in our design.

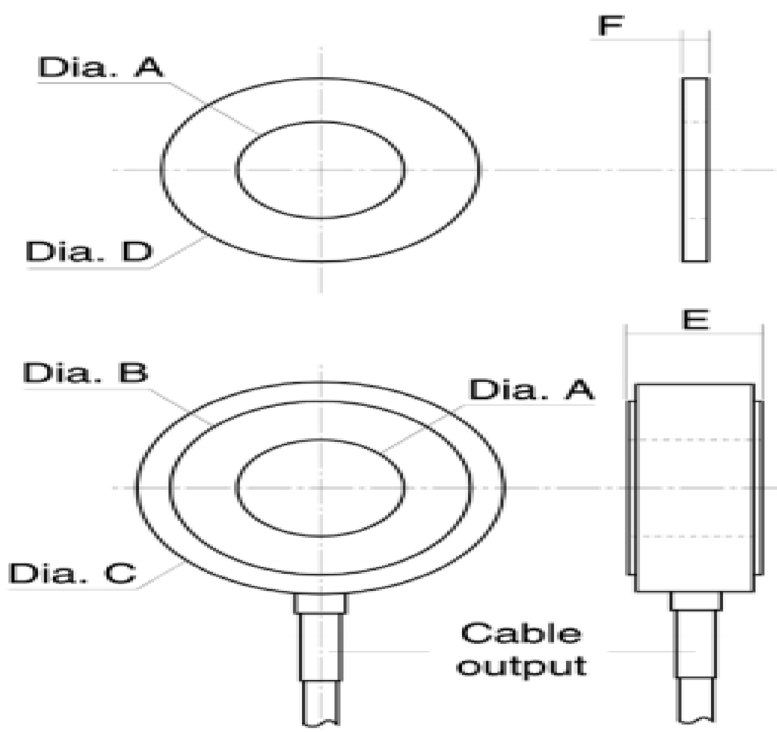


Figure 3.2.2.5: Donut Shaped Weight Sensor

The Figure 3.2.2.6 below shows how the sensor is implemented in a screw. This is very similar to frame holder's axle.

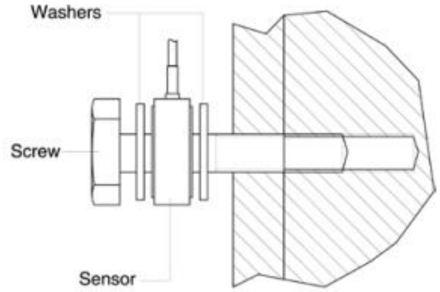


Figure 3.2.2.6: Implementation of Donut-Shaped Weight Sensor

Permission granted from Meas-Spec

As already was mentioned before, the donut-shaped load cell weight sensor will be the easiest to implement in our project. The only concern is the price. The team will have to decide whether to buy this sensor or not depending on budget information. Below are the specifications of the sensor in Table 3.2.2.3.

PARAMETERS	
Operating Temperature Range (OTR)	-20 to 80° C [-4 to 176° F]
Compensated Temperature Range (CTR)	0 to 60° C [32 to 140° F]
Zero Shift in CTR	<0.5% F.S. / 50° C [/100° F]
Sensitivity Shift in CTR	<1% of reading / 50° C [/100° F]
Range (F.S.)	0-20 to 320 kN [4 to 64 klbf]
Over-Range	
Without Damage	1.5 x F.S.
Without Destruction	3 x F.S.
Accuracy	
Combined Non-Linearity & Hysteresis	From 1-5% F.S.

Electrical Characteristics

Model	**FMT**
Supply Voltage	10Vdc
F.S. Output	1.5mV/V
Zero Offset	±5% F.S.
Input Impedance	700Ω
Output Impedance	700Ω
Insulation under 50Vdc	≥100MΩ

Table 3.2.2.2: Parameters of the Donut-Shaped Weight Sensor

3.2.3 Valve

The valve in the honey extractor is another important part of the entire project. Without the use of a valve, there would be no honey flow control. The idea of the valve is to open it once the honey is configured, filtered through a screening filter and is collected at the bottom of the vat.

Looking at a variety of valves available on the market, a conclusion has been made to use a knife gate type of valve (Figure 3.2.3.1) or a specially designed valve for honey flow. The construction of these knifes allows for fast flow of viscous fluids such as honey. A regular valve used for water and less viscous fluids will not be a good choice because it will greatly reduce the rate of honey flow and also may get clogged over time. Both, the knife gate type valve and the specially designed valve for honey should perform the same.

Initially we had the idea to implement an electronic valve (typical in water flow applications) to be controlled using the on board buttons or wirelessly with an android device, but electronic valves have many disadvantages and will most likely not be used in the project. The disadvantages are:

- Small diameters
- Easily clogged by viscous fluids
- Unreliable operation with honey

There are electric knife gate type of valves on the market as well. Predictably, they will operate much better than the valves discussed above. But they have their own disadvantages and do not meet our project goals. These disadvantages are:

- Very expensive
- Large sized
- Hard to acquire

Analyzing all of the options discussed above, unless an inexpensive knife gate valve is found, a decision has been made to use a mechanical knife gate valve or honey designed valve. Both valves are very similar and are operated similarly.

Product	**Retailer**	**Diameter**	**Price**
Honey Gate Valve	Shop.meghowe.com	4.00 cm	$13.50
GV2-2 Gate Valve	Aquiticeco.com	3.81 cm	$11.85
M005792 Plastic Scissors Gate	Dadant.com	3.81cm	$10.99

Table 3.2.3.1 – Mechanical Valve Gates

From table 3.2.3.1 the first valve seems to be a better choice due to higher diameter which translates to a faster flow.

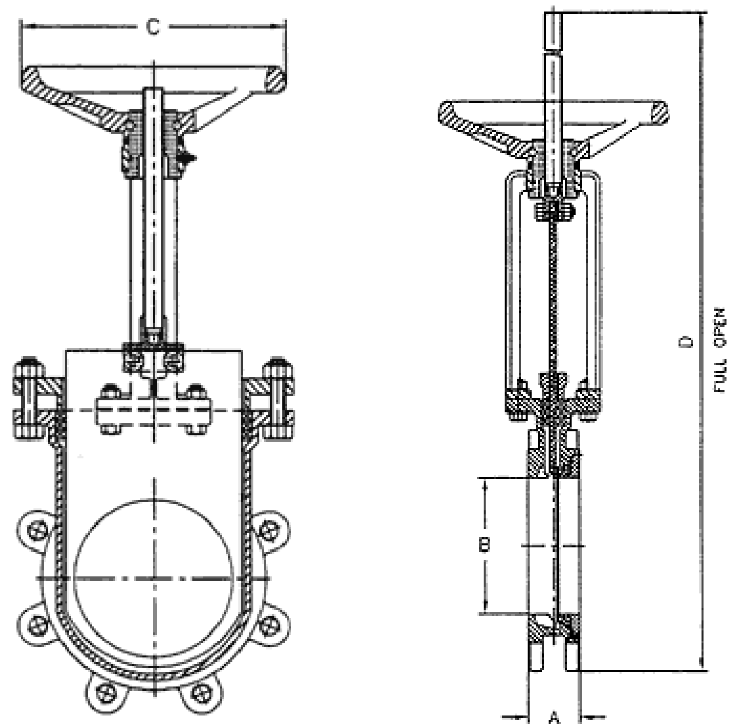


Figure 3.2.3.1 – Knife Gate Valve

Permission granted from Boilersupplies

3.2.4 Wireless Communication Technologies

The automated honey extractor will have an on-board control unit and the emergency button. However, the team has requested that the device should also be controlled remotely via an android phone. It should be pointed out that this feature is beyond our customer requirements.

The question at hand is how to make a phone control the automated honey collector. To answer this question it's important to consider several android phone capabilities. One of the capabilities currently available in the android phone is Bluetooth connectivity. Bluetooth technology is a wireless communications system that intended to replace the cables that used to be used to connect many different types of devices. Bluetooth is now commonly integrated in mobile phones, headsets, and a wide variety of electronic equipment. Bluetooth is a short-range wireless technology. The connection would have to be established with a Bluetooth module on the printed circuit board (PCB) of the automated honey collector and the phone within a distance range of 100 meters, so that devices can exchange information seamlessly.

Here are some advantages and disadvantages of using Bluetooth technology:

Advantages:

- Bluetooth is inexpensive technology
- Bluetooth is low energy consumption technology. Maximum permitted power 100 mW for the range of 100 meters
- Since the technology uses radio waves the devices don't have to be in a clear line of each other.
- Low latency rate. Small amount of data being send more quickly
- Simplicity of use

Disadvantages:

- Data transfer rate between two devices has maximum speed of 1 MB per second
- Lacks security. Easy to hack into

Another wireless communication technology that is integrated in the android phone and can potentially be used for this project is Wi-Fi technology. Wi-Fi technology uses radio waves to provide high-speed Internet and network connection which allows electronic devices to exchange data. Here are some advantages and disadvantages of using Wi-Fi technology:

Advantages:

- Wi-Fi offers high speed connection
- Wi-Fi has high throughput

Disadvantages:

- Communication is not possible without cell phone service provider or a hotspot service provider
- Wi-Fi is a high energy consumption technology

Table 3.2.4.1 summarizes both technologies features that are critical to our project.

Technology	Simplicity of use	Hotspot requirement	High Speed	Penetration through metal
Wi-Fi	✓	✓	✓	
Bluetooth	✓			✓

Table 3.2.4.1 Communication Technology Comparison

Since the automated honey collector is going to be used in the field, a barn, or in an area without access to a cellphone tower, customer's cell phone provider services, or a hotspot, may not be reachable to his location. In this situation Wi-Fi communication will not be possible. Also, the radio waves should be able to penetrate through the metal walls of the honey collector in order to communicate with the microcontroller. With Wi-Fi technology this will not be possible. These two major aspects will play crucial role in selecting between the two technologies. Since there is no security concerns present and no large amounts of data will be transmitted via established communication link between the two devices, the Bluetooth technology appears to be the most suitable technology for this project.

3.2.5 Bluetooth Module

There are three classes of Bluetooth modules. Each class has a different effective range of coverage and power consumption. The differences between the three Bluetooth classes are represented in Table 3.2.5.1.

Bluetooth Power Class	Maximum Output Power	Operating Range (m)
Class I	100 mW (20dBm)	100
Class II	2.5 mW (4dBm)	10
Class III	1 mW (0dBm)	1

Table 3.2.5.1 Bluetooth Transmitter Power Classes

Since the distance between an android and the automated honey collector may be up to 15 meters it would be better to choose Class 1 Bluetooth module for seamless data exchange between devices. The market has great variety of Bluetooth modules with great range of specifications and features. We are going to closely examine a few of them. Here is the list of features that the Bluetooth module should possess in order to be considered for our project: good operating temperature range, onboard embedded Bluetooth stack, should support Bluetooth data link to an android device, high data rate, low power consumption, on-board antenna.

One of the Bluetooth modules we are going to examine is RN41SM-I/RM designed by Roving Networks. This is fully certified Class 1 Bluetooth 2.1 + EDR module consumes low power and provides fast data rates up to 3 Mbps baud rate speed, over air data rate of 721kbps to 2.0Mbps, high power amplifier with on board ceramic RF chip antenna, universal asynchronous receiver/transmitter (UART) local and over-the-air RF configuration, and 128 bit encryption for secure communication. Bluetooth version 2.0, 2.1+EDR will have pairing compatibility with Android version 2.2 and later.

Another Bluetooth module to consider for this project is RN25S-I/RM. This module consumes low power, has status LEDs, on-board embedded Bluetooth stack, external SMA jack or ceramic on-board antenna. Other features include auto-connect, connect-on RX data, transfer data up to 100M, error correction for guarantied packet delivery, UART (SPP or HCI) data connection hardware interfaces. This Bluetooth version will also be compatible with Android version 2.2 and later. The RN-25 module also accepts a wide range of unregulated DC power 4Vdc to 24Vdc. Technical specifications for the Bluetooth RN25S-I/RM module described in Table 3.2.5.3.

Bluetooth	RN41S-I/RM	RN25S-I/RM
Bluetooth Version	2.1 + EDR, 2.0, 1.2, 1.1	Bluetooth 2.1/2.0/1.2/1.1 and v2.0+EDR
Frequency band	2.412-2.484 GHz	2.402 to 2.480 GHz
Operating temperature	-40C to + 85C	-40C to +85C
Data rate	Onboard stack 300Kbps HCI mode: 1.5Mbps sustained, 3Mbps burst	Up to 300Kbps
Supplied voltage	3 V ~ 3.6 V	5 V
Power - Output	16dBm	12dBm
Sensitivity	-80dBm	-80dBm
Current - Receiving	35mA	35mA
Current - Transmitting	65mA	65mA
Data Interface	Pads for Pins	PCB, Through Hole
Antenna	On-Board	On- Board
Price	$45	$99

Table 3.2.5.3: Bluetooth RN41SM-I/RM and RN25S-I/RM

Specifications Summary

After close examination of all specifications and features of both of these modules they both could be great candidates for our project. The RN25S-I/RM with all its features appears to be the most desirable module to use in the project, but because of its high price (around $99 per unit) consideration will be given to RN41SM-I/RM module around($45 per unit).

3.2.6 Display

Several display technologies were considered to be used. The requirements were that it must display information from the sensors. That means that the unit must have at least ASCII output and room for at least 16 digits and 2 rows. One row will be used for displaying the type of information measured, and another row will be used to display the value of the measured sensor. More functionality will increase costs of the project, and is unnecessary for the display of basic information. Other technologies that were considered included Touch screen displays and Graphics LCD displays.

Touch screen displays appeared desirable at first because of the functionality including both display and human interface. After extensive testing and serious thought, the conclusion agreed upon was that this is not the choice for this project. Reasons for this decision include honey interfering with the capacitance of the screen and producing false inputs, high cost, and high level of difficulty in interfacing the device with the microcontroller.

Graphics LCD displays were another viable option. These displays included functionality to produce bar graphs and other complex display types. The extra functionality initially appeared desirable, but further examination of the purpose proved this functionality unnecessary.

3.2.7. Micro controller Decision

The microcontroller we decide to choose must interface with several components. These components include a screen on the unit its self, a Bluetooth unit to the android device, several sensor interfaces and a motor controller. In order to meet these requirements, the microcontroller must have at least 2 duplex serial lines, and at least 7 analog to digital converters. In order to meet the specifications, an array of micro controllers was selected.

The microcontroller we decide to choose must interface with several components. These components include a screen on the unit its self, the Bluetooth unit to the android device as well as sensor interface. In order to meet these requirements, the microcontroller must have at least 2 duplex serial lines, and at least 7 analog to digital converters. In order to meet the specifications, an array of micro controllers was selected.

3.2.7.1. PSoC Discussion

The first microcontroller chosen for evaluation is the Cypress Semiconductor PSoC (Programmable socket on chip) family. These devices have three separate memory blocks, SRAM for data, Flash memory for instructions and fixed data, and I/O registers. This selection includes small FPGA capabilities, as well as several integrated libraries to incorporate other systems to the Module. The pros of this system are high functionality. The cons of this choice are high cost and a steep learning curve.

Some interesting features of the PSoC include a vast array drop in modules. The board also has a large amount of analog devices. This allows for an ease of design using very little off chip components. The only components that must be off board are passive components such as resistors, capacitors and inductors. This allows for a super modular design. Components such as the specified load cell will be easily implemented. Figure 16 shows how to implement an instrumentation amplifier in Cypress PSoC Creator 2.2. The resistors will be off board, and will consist of surface mount devices. On the output of the instrumentation amplifier there will be an Analog to digital converter to convert the analog signal to a digital signal. The signal will then be read by the microcontroller and processed to display the temperature. Other modules can be easily implemented into the PSoC. Another example of this is the LED driver. The driver is simply dragged and dropped into the Top Design section of the PSoC programmer. The wires are then connected to the appropriate pin as shown previously/

Another interesting feature that could be used is the PSoC’s CapSense module. This module is meant to interface with capacitive touch buttons. It has built in capacitive measuring capabilities, and the idea is that it will interface with the humidity sensor.

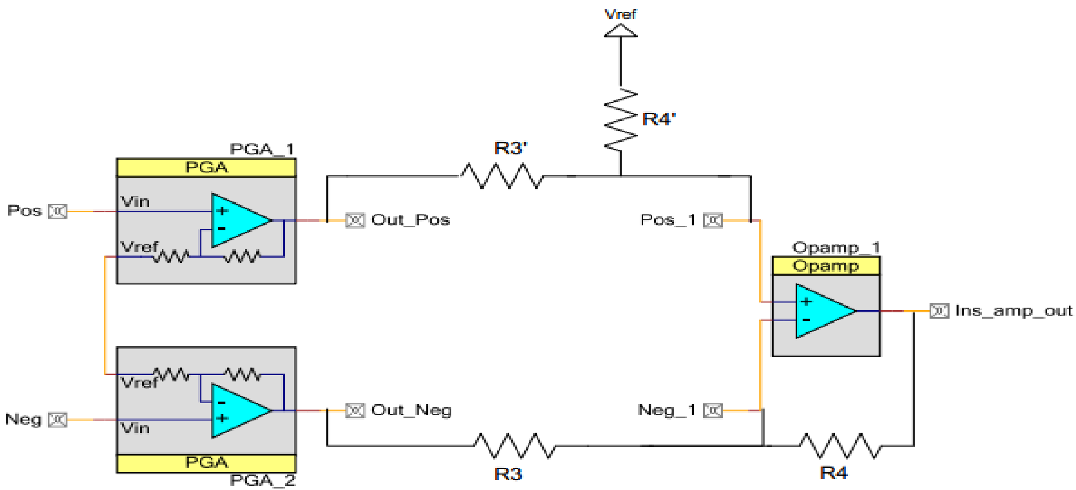


Figure 3.2.7.1.1: Implementation of an Instrumentation in a PSoC 3 chip.

3.2.7.2 Raspberry Pi Discussion

Another choice for a microcontroller is the Raspberry Pi. This choice is good because a board is already laid out, and standard connectors are used (UBS connectors, RJ-45 Ethernet port, HDMI port). Also A Linux build can be incorporated into the project, and my allow for a smooth interface to an android device. Pros for this choice include ease of connection and assembly due to the standard connectors. Cons include the GPIO pins operating at 3.3V, so a level converter may be required, and an operating system will need to be incorporated.

3.2.7.3. Arduino Discussion

The third choice would be the Arduino platform. This platform is widely used in the hobbyist marketplace. There are a plethora of devices that Arduino produces, as well as devices that are produced by non Arduino companies that interface to the Arduino programing environment, such as PRJC's Teensy line. Arduino also has all open source hardware, so the schematics are available online and they can be easily modified in Eagle CAD. The Pros for this choice are ease of use, extensive hobbyist background and relatively low cost. The Cons are some-what limited hard ware capabilities and interfacing with the android device may be difficult.

3.2.7.4. MSP 430 Discussion

Another microcontroller option is the Texas Instrument's MSP 430 microcontroller. This micro controller is a generic device that can be programed in assembly level language or C language. An advantage about this device is that most students have experience with this device due to taking Embedded Systems at UCF. Serial communication and push button interfaces have been mastered in class. This microcontroller does not have the large tutorial set that the Arduino has, or the advanced functionality of the PSoC, so it may not be the best choice for this project.

3.2.7.5. IOIO board Discussion

The fifth and final choice for micro controllers would be the IOIO board. The IOIO board is based off of a Microchip PIC 24 microcontroller. It has firmware built in to it specifically designed for interface with an android device. This product is also open source and containing a large hobbyist background. Pros for this device are ease of integration into the Android environment. Cons include having to use Java to program the Microcontroller.

The PIC 24 class of micro controller also has some drop in capabilities added to it. It has a module to facilitate the capacitive touch sensing interface, so it will also be able to integrate the humidity sensor. Other built in features include an I2C interface and built in Analog to digital converters.

Implementation of this device will first consist of testing with the IOIO board, and once a final design has been developed, the design will be copied and integrated into a custom built PCB.

Figure 3.2.7.5.1: Micro Controller Decision Reasoning

After some debate about which product to use, the Arduino environment is the best choice. Reasons for this choice are ease of documentation for programing the units, and low cost. The honey extraction project does not require a fancy connection to a monitor or other devices, and FPGA style device is not necessary, and programming entirely in the android environment is not practical.

The Arduino Mega 2560 is a good choice because it has 3 built in hardware serial lines. This will provide more than enough capabilities to interface with the android device as well as other serial devices. It also includes 16 analog in pins and 54 digital I/O pins. This should be more than enough functionality for our project. Also a development board can be purchased and tested on before a board is made from the schematic.

MCU	Part number (chip)	Digital pins	Analog pins	Serial communication	Other	Price
PSoC 3	CY8C3244PVI-133	25	25	25 pins, I2C, SPI, UART	Routable pins	$5.41
Arduino Mega	ATMEGA1280-16AU	54	16	4UART, ICSP, 1 SPI, 1 I2C	Easy to use	$16.13
MSP 430	MSP430F5659IPZ	74	12	SPI, UART, USB	Used in class	$11.86
IOIO	PIC24FJ256GB206-I/MR	52	24	4 UART, 3 SPI, 3 I2C, USB	Android board	$7.81
Raspberry Pi	Broadcom BCM2835	17	0	I2C, SPI, USB, Ethernet	Linux	$35

Table 3.2.7.5.1: Various Microcontroller Options

3.3 Operation of Classical Honey Extractor

The operation of a classical honey extractor is a long and tedious process. First the honeycombs must be extracted from the beehives. Figure 3.3.1 shows this process. The process includes first introducing a harmless smoke into the beehive to coerce the bees out of the hive. Once the bees are removed from the hive the honey combs can be extracted. This is a dangerous process due to the close interaction with the bees and the smoke causing temporary loss of vision. To combat these dangers, beekeepers wear protective bee suits so that they do not come in contact with the bees directly.

Figure 3.3.1: Extracting honey combs from beehives

The next step is to uncap the honey combs. Throughout the years a standard honey comb size has been developed and is constructed from wood. The wooden frames allow the bees to create honey combs from their natural wax. The reason why bees create honeycombs is to allow for food storage for young bees during fruitless months. The bees create caps on the honey combs to seal in the honey for use later. During the extraction process, these caps must be removed to allow the honey to escape. This process called uncapping is shown in figure 3.3.2. A knife is used to scrape off the sealing units for the honey combs and the honey is exposed.

Figure 3.3.2: Uncapping honey

After the honey is uncapped, it is put into an old fashioned honey extractor. The old style honey extractor uses a hand crank connected to the frame holders to spin the honey out of the frames. The frames are spun until the operator feels that they are empty. He then removes the frames and puts them back into the bee hives so that the bees can fill them with honey again.

3.3.1 Operation of Our Honey Extractor

The operation of the honey extractor will be a very simplified process. The Same extraction process is used with the extraction of the honey combs and the uncapping, but the actual extraction method will be much more simplified. The frames are simply inserted into the unit and the start button is pressed. The unit will automatically start spinning and honey will be extracted so that the honey combs will be perfectly empty. After the unit has stopped spinning, the emergency stop switch will be activated. This will insure that the system is ready for the frames to be removed. After the frames are removed, they are put off to the side. The extracted honey is run though a filter to remove impurities. The frames are then returned to their respective hives. Our process will show an improvement over older styles by increased honey extraction percent and speed.

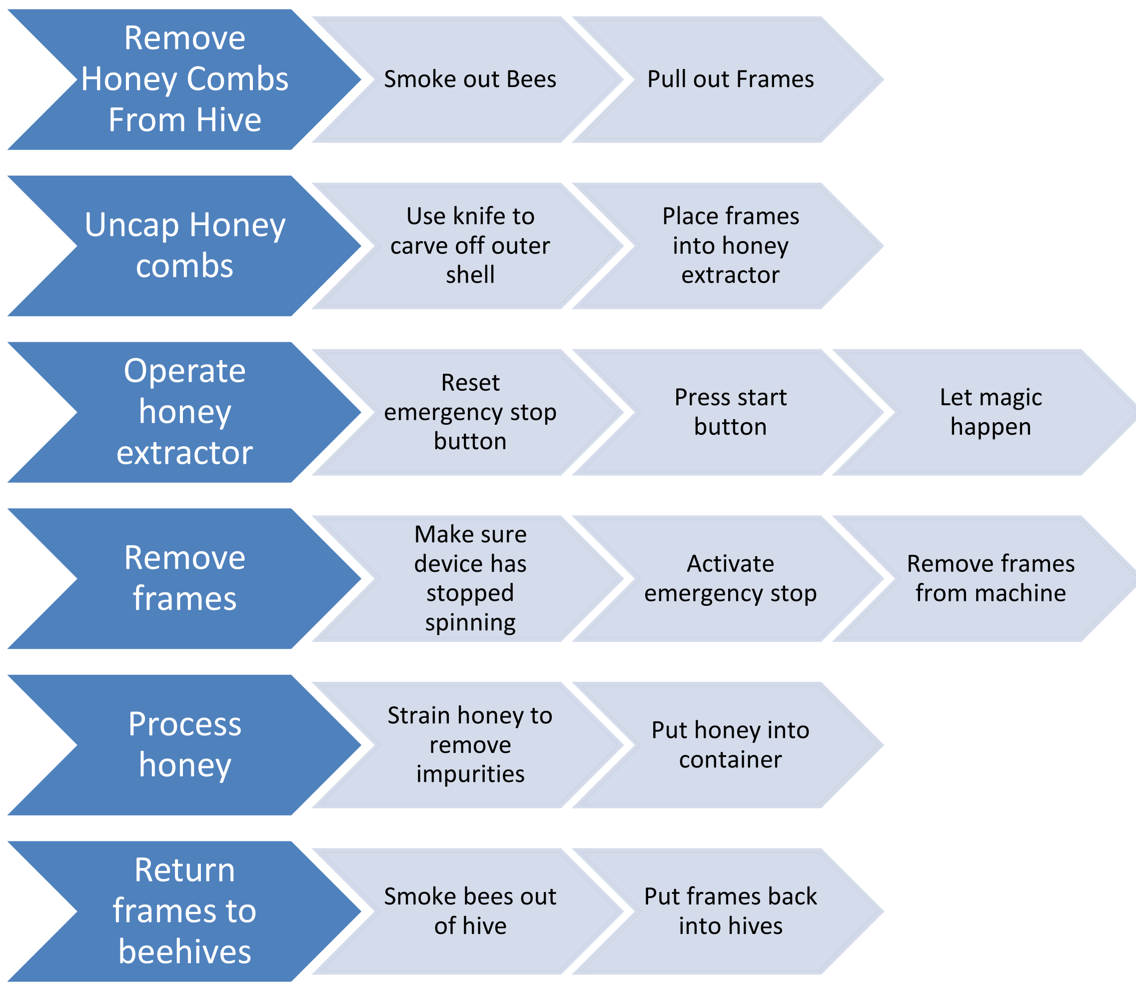


Figure 3.3.1: Flow Chart for Operation of Honey Extractor

3.3.2 Dangers of Honey Extraction

One of the many dangers of honey extraction is the contact between the operator and the bees. Bees have stingers which contain an apitoxin. The apitoxin is mostly comprised to melittin and other histamines. Some humans may be allergic to these histamines and may develop an allergic reaction requiring immediate medical attention. If treatment is not carried out soon enough an anaphylactic shock may occur. If this happens, the best way to seek treatment is through the injection of an EpiPen. Honey bees contain barbs on their stingers so the stinger may remain in contact with the skin even after the bee has flown away 3.3.2.1. Usually if this happens the bee will die shortly after. When the bee dies it releases a pheromone that will attract more bees. These bees have entered a heightened "hive mentality" and will sting anything they see as a threat. The best way to escape these bees is simply to run in one direction until the bees become too far from their hive. The bees are aware of where their hive is at all times and will not leave the vicinity of their hive. Once you are outside the hive's zone of control, you will be safe.

Figure 2.3.2.1: Stinger Stuck in the Skin after a Bee Sting

Another Risk of honey extraction will be with the honey extractor itself. The honey extractor will have a half horsepower alternating current motor attached to it. The motor is dangerous not only because of the mechanical power it is producing, but also because of the electrical power it is using. Honey contains many electrolytes and will conduct electricity similarly to how salt water does. During construction of the extractor extreme care will be taken into the routing of the AC power lines. They will be well insulated and placed out of the way so that accidental contact is not made. The mechanical power that the honey extractor produces will also be a safety concern. All loose articles of clothing will be removed or tucked away prior to operation. This is to prevent accidental snags and keep people outside of the dangerous spinning device. An example of clothing getting caught is shown in Figure 3.3.2.2.

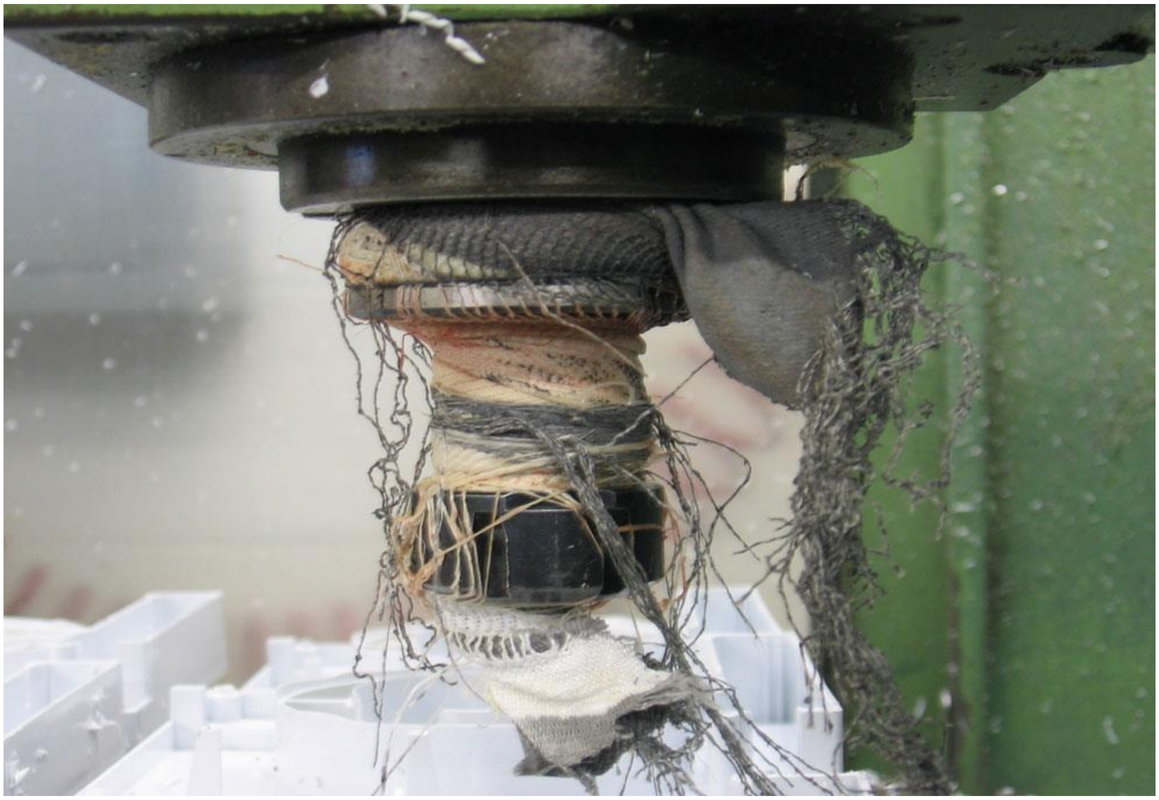


Figure 3.3.2.2: Example of clothing caught in machinery.

Another concern for safety will be the extractor itself falling over and possibly pinning someone to the ground. The spinning of the honey extractor may cause excessive vibration in the unit and create an unstable mounting position. To alleviate the worry caused by this scenario the honey extractor will only be operated by the buddy system, meaning that no less than two people are allowed to operate the machine at a time. If all of these safety precautions are taken into account then no injuries should occur during operation of the honey extractor

4. Project Hardware and Software Design

4.1 Hardware Block Diagram

Before the system can be built it is important to identify what modules the system will include, how they are going to be interacting with each other, how they are going to be powered and connected. For software development is to identify user needs and design flexible and easy to use custom user interface.

Figure 4.1.1 depicts major blocks of the automated honey collector.

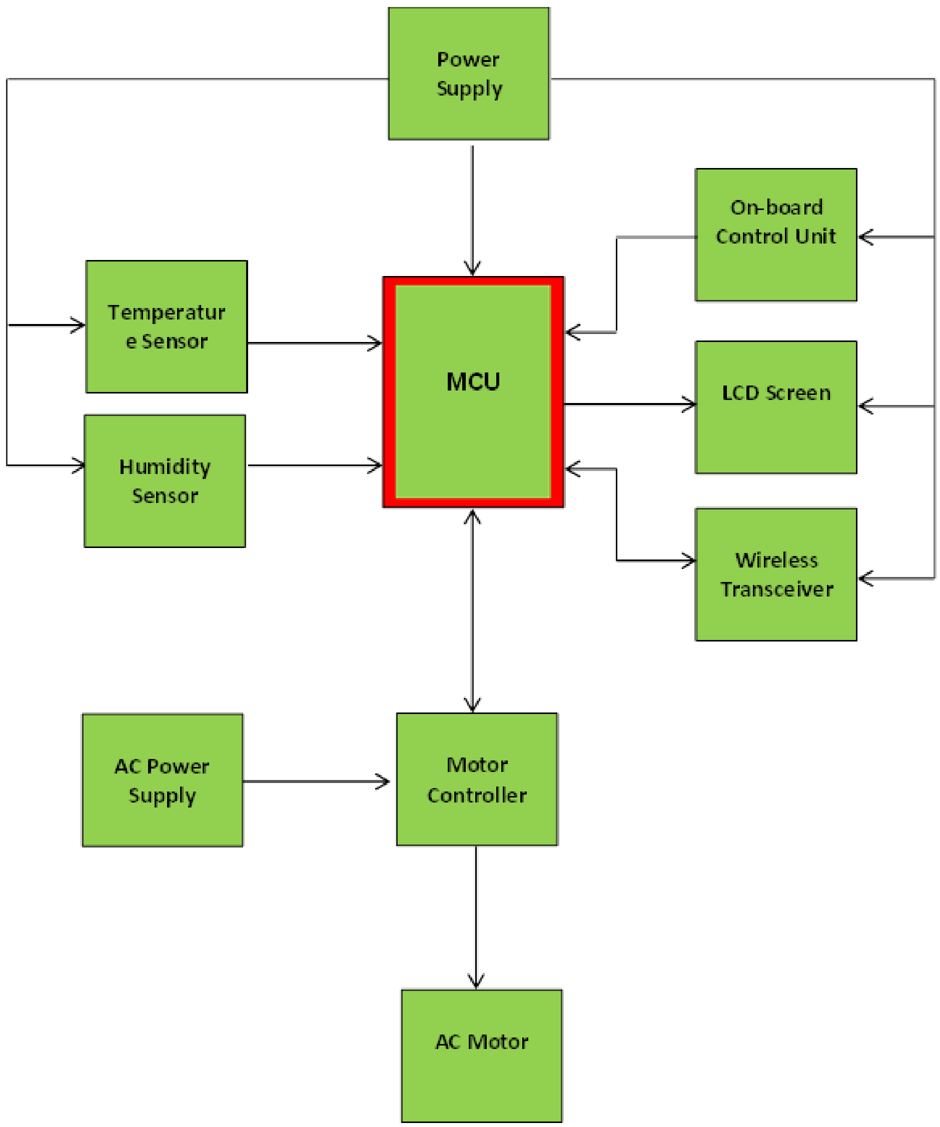


Figure 4.1.1: Honey Extractor Main Unit Block Diagram

4.2 Software Activity Diagram

In order to give an alternative to honey collector's an on-board control unit the system can be controlled by a custom Android application with user friendly custom graphical user interface. The application will be compatible with Android running devices operating system version 2.2 or later. Graphical user interface will be displaying data received from the Bluetooth which in its turn will receive sensors' data from the microcontroller. Sensor data will include: temperature data in numerical form, humidity data in numerical form, and weight sensor data (weight data will not be shown, but will be processed in order to find the correct time to spot the motor). Custom control selections will be also available to the user in the GUI. The user will be able to press the Start button to start spinning the honey collector. The Stop button will also be included so that the user could stop the spin at any time (something similar to the manual emergency stop button).

Figure 4.2.1 portrays the application's entire activity diagram.

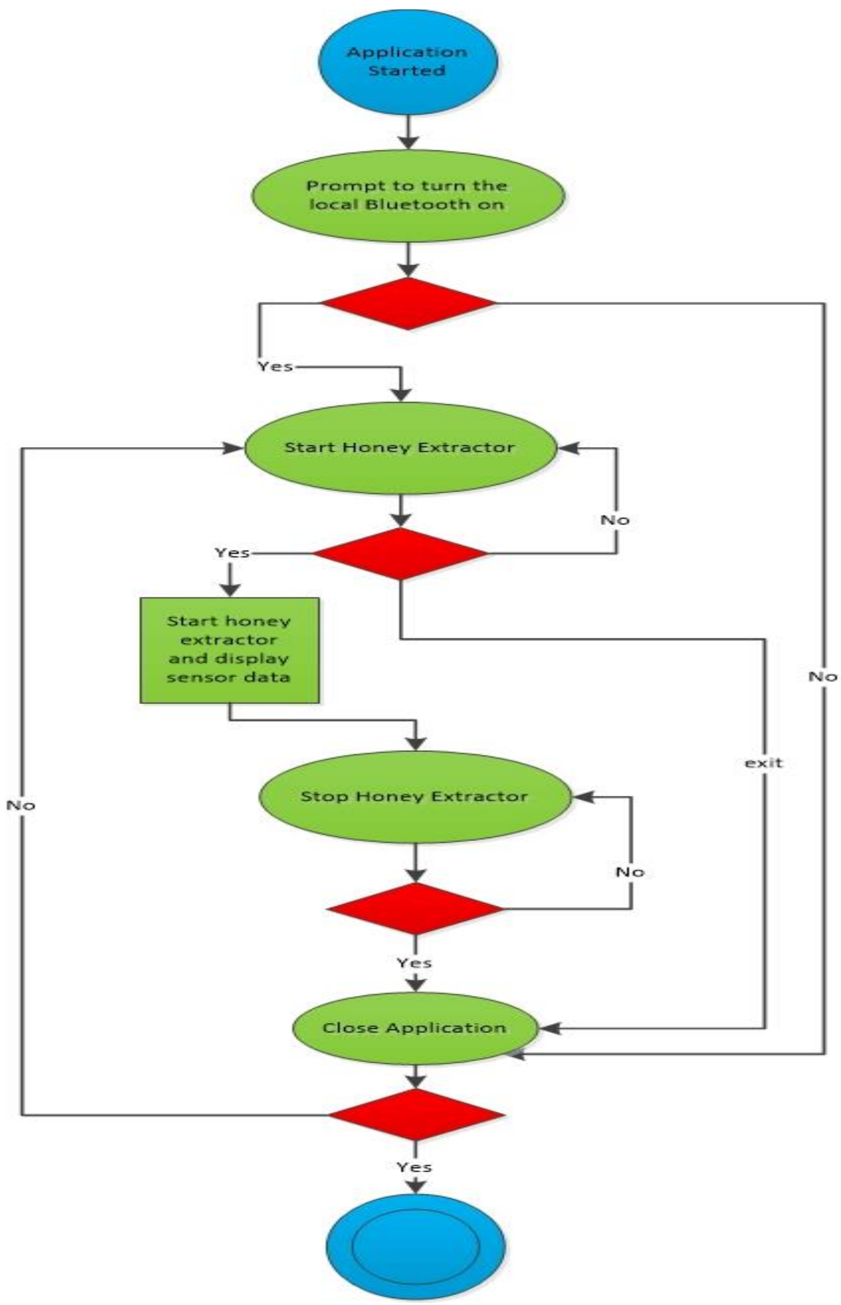


Figure 4.2.1 Android Software Activity Diagram

4.2.1 Software Development Tools

There are a lot of free extensible build tools that are available to the developers today for the android application development. One of these tools is the Android software development kit (SDK). The Android SDK provides developers with the application programming interface (API) libraries, debugger, a handset emulator, documentation, and sample code. All these tools aim the developers to build, test, and debug great applications for Android. The Android SDK is free, open source, and runs on major operating systems platforms. Eclipse integrated development environment (IDE) is used hand in hand with the Android SDK. Java is the primary android development language, but other languages might be used for the development as well. Since Java is mature and well documented programming language it will be given preference.

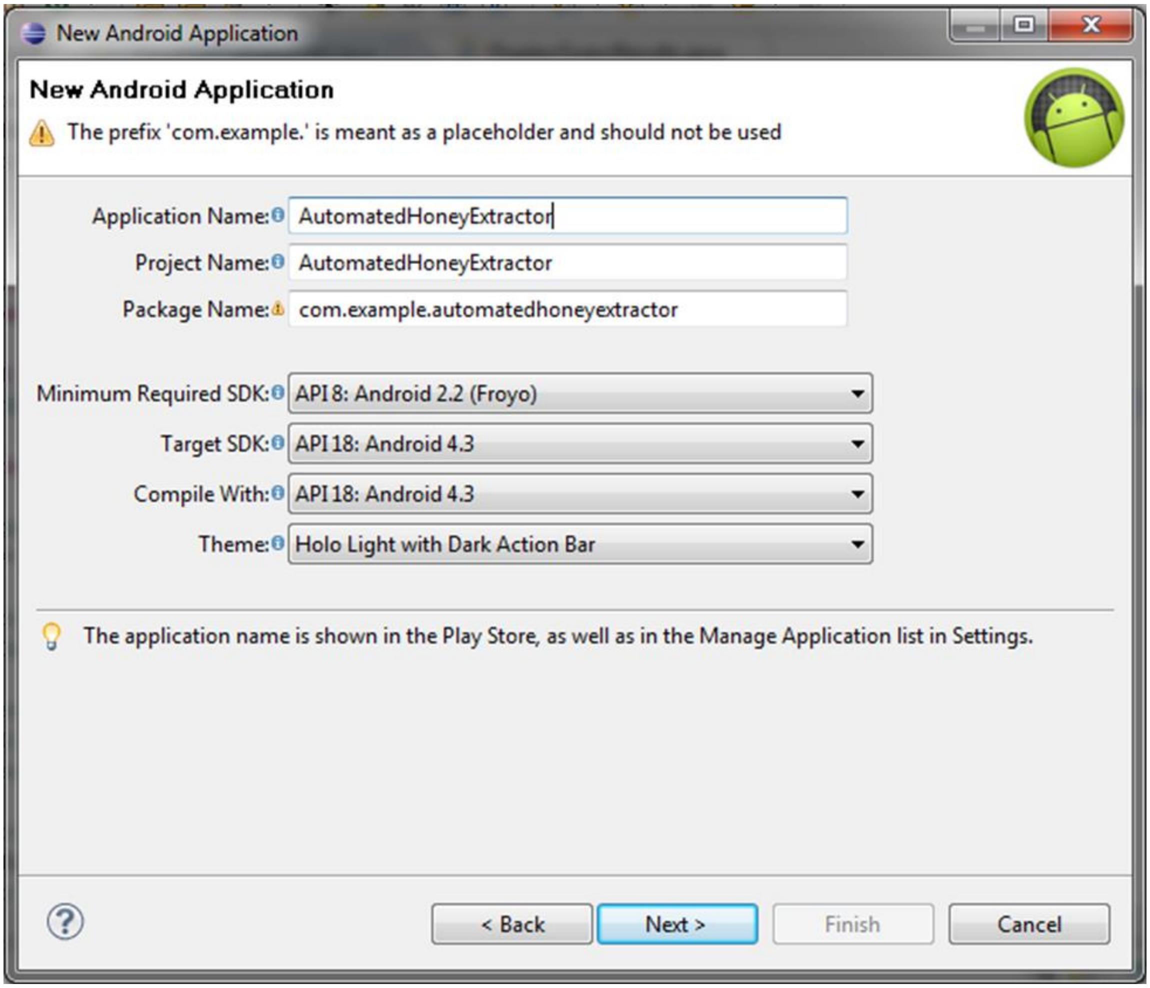
4.2.2 Software System Requirements

Over the past decade, Android has matured and evolved into an extremely reliable Linux-based embedded operating system platform. One of the greatest advantages choosing developing an Android application is that Java and Eclipse IDE are free tools and are available in both 32-bit and 64-bit versions on the three primary operation systems in use today. In this project the automated honey collector will not only be controlled by an on-board control panel, but also by a custom Android application. The application will be developed on a machine running Windows 7 64-bit version operating system, utilizing Eclipse IDE 3.6.2 Helios, and programming language Java.

4.2.3 Android Application Development

The application will be developed for a smartphone running Android operating system. The lowest version of Android operating system that our application will support is Android 2.2. By setting our application development to be the minimum required Android SDK to Android 2.2 (SDK 8) we will ensure that our application will support as many devices as possible. The target SDK for with we will be developing is Android 4.3 which is the latest version available as of today. The latest version will include all of the new features. With these setting we will be able to provide enhanced user experience through modern user interface and make the application available and compatible with older versions.

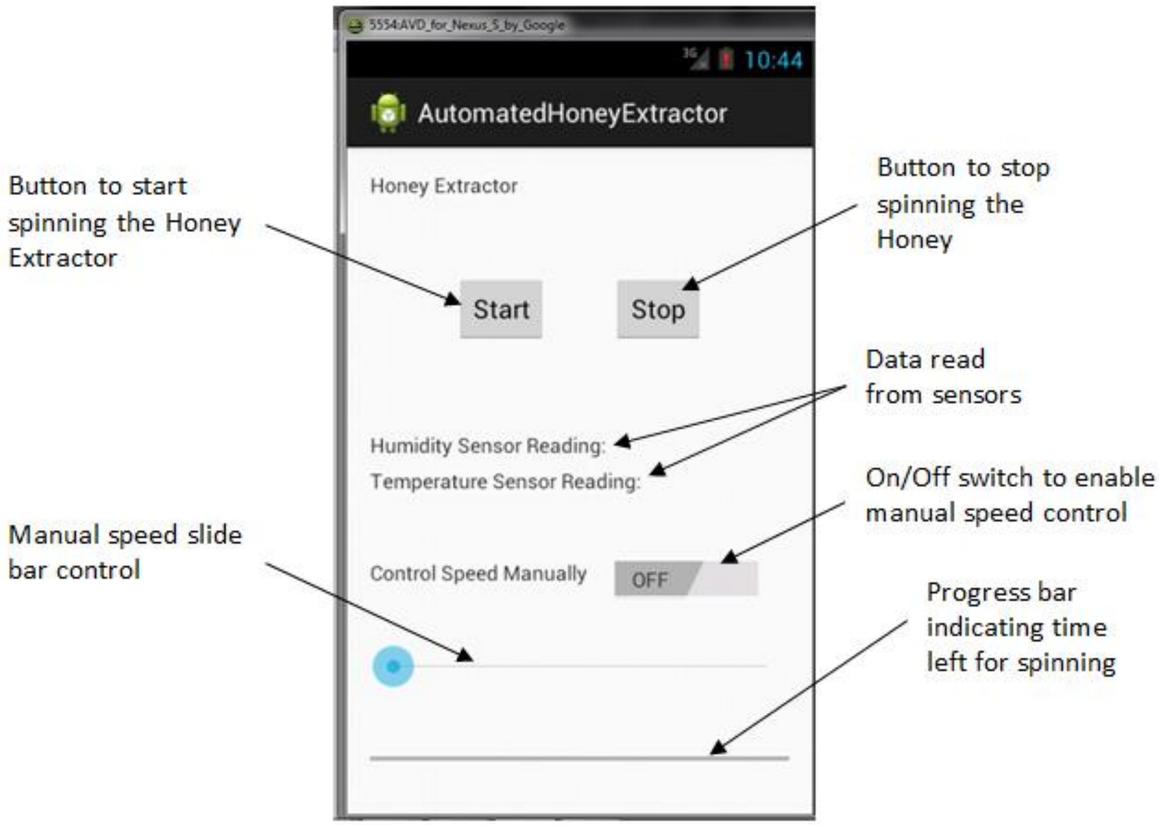
Figure 4.2.3.1 depicts the new android application project setup in Eclipse IDE.



4.2.3.1 The New Android Application Project

One of the greatest features that Android platform includes is support for the Bluetooth network stack. This feature will allow our Android phone wirelessly communicate with the RN41 Bluetooth module. The application will use the Android APIs to access local Bluetooth. By using Bluetooth API in our remote control application we will enable it to scan for Bluetooth devices and query the local Bluetooth for a paired Bluetooth device, establish point-to-point wireless connection without leaving the application and transfer data to and from local Bluetooth [5].

Figure 4.2.3.2 depicts preliminary graphical user interface developed in Eclipse and run of the emulator. This is only a prototype. Some design features may be changed, removed, or added as project progresses. The user will be able to start the honey collector by pressing the Start button. If no speed was specified on the GUI then the device will start spinning at default speed. The Stop button will also be included, so that the user could stop the device at any time. If user chooses not to press the Stop button, then the honey collector will stop after default period of time. The graphical user interface will also allow the user to set custom spinning speed. This can be done by the slider after the Control Speed Manually was set to ON. The progress bar will indicate time left for the honey collector to spin. The application will also display data being read from temperature, humidity and, perhaps, weight sensors. The data will be received from the Bluetooth which in turn will receive sensors' data from microcontroller.



4.2.3.2 Graphical User Interface Sample

4.3. Configuring and Pairing the Bluetooth

Pairing the Bluetooth module with the smartphone is a very straight forward process. The Bluetooth comes with dipswitches that set the module in various configurations.

The Bluetooth is considered to be a slave and smartphone is the master. Before proceeding to pairing we will need to power up the Bluetooth. This can be done by connecting the Bluetooth with two wires to a LiPO battery. The procedure can be described in tree steps.

1. On the Bluetooth set the dipswitch to be in slave mode. Automatic discovery is available only in salve mode. The Bluetooth will be set in slave mode by setting switches as shown in Figure 4.3.1. In this phase the module will broadcast its name, profile, support and unique MAC address.
2. In this step the Android phone (master) discovers the Bluetooth (slave). Select the Bluetooth name on the screen. When prompted, enter pin on the phone code 1234. If the pin code was entered correctly and validates successfully the Bluetooth and Android exchange security keys. The Android phone stores Bluetooth's credentials and connects to the Bluetooth. The two devises should be now paired and Bluetooth's light emitting diode (LED) should be on solid.
3. Next, switch the dipswitch on the Bluetooth to off so that the two devices do not try to re-pair each time power is cycled. The configuration of the dipswitches shown in Figure 4.3.2 [4].

Usually, the devices need to be paired only once. Once paired, when the two devices in the range of each other, they will be able to connect.

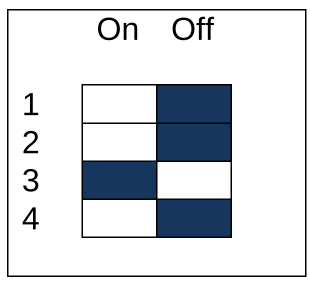


Figure 4.3.1 Dipswitch Configuration for Slave Made

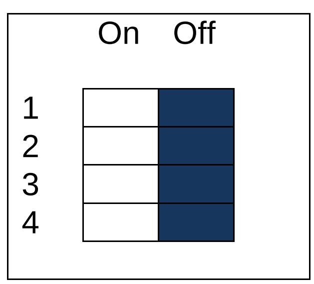


Figure 4.3.2 Dipswitch Configuration for Deployment

Since the remote control application will be using the Bluetooth as a pipe to transmit data to the microcontroller, without paired and properly configured Bluetooth module an android phone and a microcontroller will not be able to exchange data.

There are two ways to configure the RN41 Bluetooth module: via Bluetooth and using computer's serial port. The procedure is simple and relatively straight forward for setting up and configuring the RN41 family Bluetooth modules. We will be configuring our Bluetooth module with the microcontroller over local configuration. Since the RN41 Bluetooth module has UART port, it can easily be configured over this port.

The module will be connected to the computer via the RS-232 DB9 port. With the Bluetooth module powered up and connected to the computer we will be able to put it into command mode by launching a terminal emulator then specify the module's serial port default settings. Finally, to enter the command mode we will type $$$ in the terminal. The command mode has to be entered within the period of 60 seconds. In command mode the Bluetooth accepts ASCII bytes as commands. On the emulator we will be able simply type a command from a set of available commands to configure the module. The serial port default settings such as baud rate, parity bit, 1 stop bit, data bits, and hardware flow control will be set at this point.

The system shall be rebooting after configuration so that the settings take the effect. After reboot all the settings will take the effect and will persist on the module until we will reconfigure or reset the module. Figure 4.3.1 demonstrates data and command modes of the RN41 Bluetooth module [4].

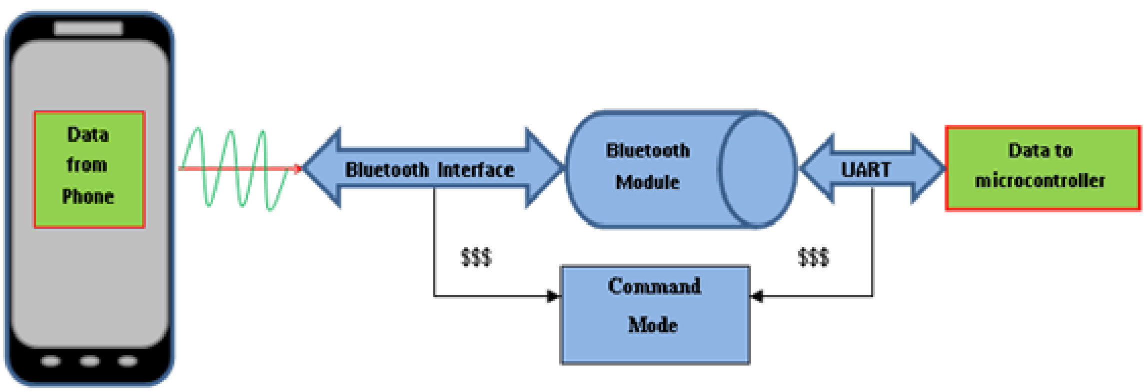
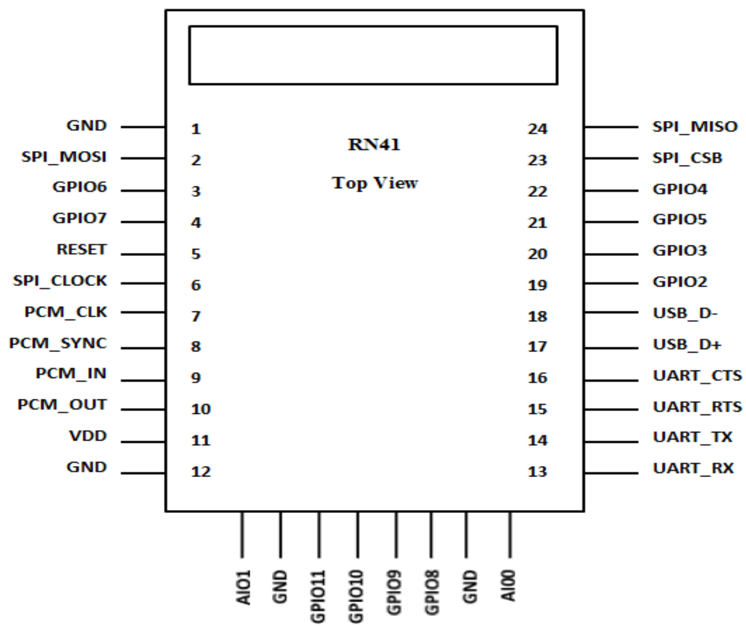


Figure 4.3.1 Data and Command Modes of the Bluetooth Module

4.3.1 Integrating the Bluetooth into Circuit

The Bluetooth will be powered up by 3.3V or 5V regulated power input VDD (pin 11), GND pins and will be grounded (pins 1 and 11). In order to avoid noise caused by other circuit elements a decoupling capacitor will be placed in the circuit.

The Bluetooth module will be connected to pin 10 of the microcontroller through UART_TX transmit line (pin 14). The receive line UART_RX (pin 13) of the Bluetooth will be connected to the microcontroller's pin 11. The module has hardware flow control and it is set to enable as a default factory setting. This feature is controlled by request to send (RTS) and clear to send (CTS) protocols. When the hardware flow control is set to enable on the Bluetooth module, it will refrain from sending packets to the microcontroller until the microcontroller send CTS signal back to the module. This configuration will resolve hidden node problem and provide protection against packet collisions. The CTS will hold the medium while the RTS accessing the medium thus preventing others from sending data. RTS/CTS protocol increases network performance. However, there is a tradeoff. RTS/CTS also introduce an increase in overhead, thus decrease in throughput which is undesirable tradeoff in our project. Moreover, our network will have no other nodes trying to access the medium and we are not going to transmit large amounts of data over the medium that will have to be broken up into chunks. Thus, in order to avoid the overhead that comes with enabled hardware flow control, pins UART_CTS (pin 16) and UART_RTS (pin 15) will be shortened. The schematic of the RN41 Bluetooth module is shown in Figure 4.3.1.1.



4.3.1.1 Bluetooth RN41 Schematic

4.4. Heating System

One of our requirements for this honey extractor was to have a heating system that will heat the vat of the extractor in order to increase the flow of the honey, thus decrease the extraction time. In order to satisfy this objective we could use several heating methods. Deciding which particular method to use was one of the most challenging tasks, while considering cost, heating ability and ease of use.

The heating system will include a temperature sensor (see Temperature Sensor section for more details), and heating elements. The temperature sensor and the heating elements will be both connected to the MCU. The temperature sensor will measure the temperature of the honey and then send the data to the MCU, and based on the readings from the temperature sensor, the MCU will automatically adjust how much heat the heating elements will produce by controlling the amount of current that will go to them. If the temperature of the honey is higher than what it should be, the current will be decreased. On the other hand if the temperature is too low, the current will be increased. Also, the temperature reading of the temperature sensor will also be available for system monitoring, meaning they will be displayed on the GUI for the user to see. However there are no plans of giving direct control of the temperature to the user as of this moment. A general block diagram of the heating system can be found below.

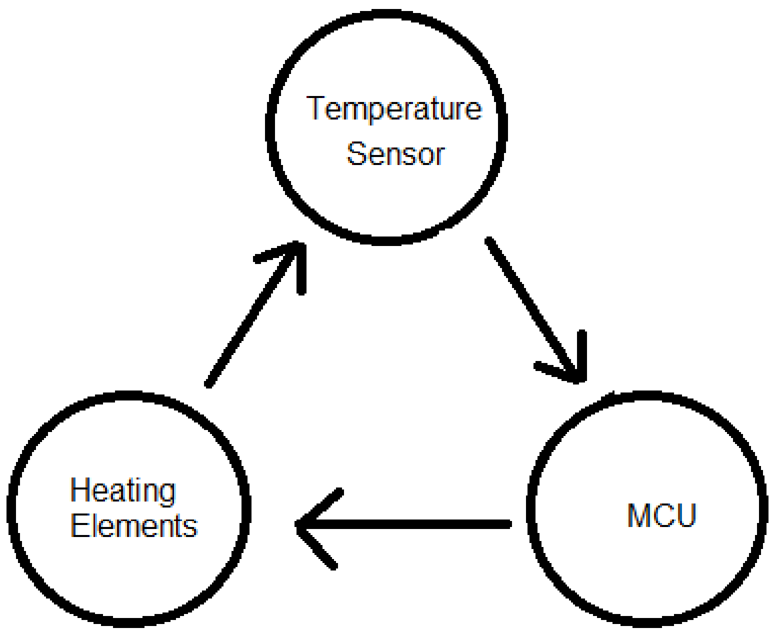


Figure 4.4.1 Heating System Block Diagram

4.4.1. Coil Heating & Heating Plates

One method of heating that was considered is using a coil or a heating plate to heat the vat that will be holding all of the extracted honey. The coil or the heating plate would be installed at the bottom of the vat, and this way the vat would be heated, essentially it would be like installing a stove under the vat (see figure 2). This method is probably the most cost efficient in regard to the actual element cost (not power consumption) since coils and plates are well spread.

However the major problem would be actually installing the coil or the plate as well as the fact that it would take some time for the vat to heat up from bottom to top, thus slowing the whole extraction process. The problem with installing the coil or the heating plate under the vat consists in that, on the bottom of the vat we need to have a draining valve as well as the scale which leaves little room for the heating element. Therefore either we come up with a way to install the coil or the heating plate without getting in the way of the scale and the valve and find a way to increase the heating time or we should use another method to heat the vat.

Figure 4.4.1.1: Coil or Heating Plate Diagram

4.4.2. Flexible Heating Elements

The second method of heating the vet that was considered for our project was using flexible heating elements such as flexible coils or silicon rubber heaters. This method is probably the most convenient method to heat up the vat since the vat would be “wrapped” with the flexible heating element, thus increasing the rate at which the vat would heat up (see figure 3) also because it is fairly easy to find space around the vat to install the heating element. By installing drum heaters around the vat, the vat would be fairly quickly heated up and ready for use, while the bottom of the vat is still available for other parts to be added there.

However, because of its convenience and easy use, the price of a flexible heating element rises exponentially. While using a hot plate or a coil as that of a stove or range, the cost would be around thirty dollars for components, using a flexible heating element would cost over one hundred dollars. Overall this method of heating is more advantageous compared to other methods, the only problem that occurs is the cost of the element.

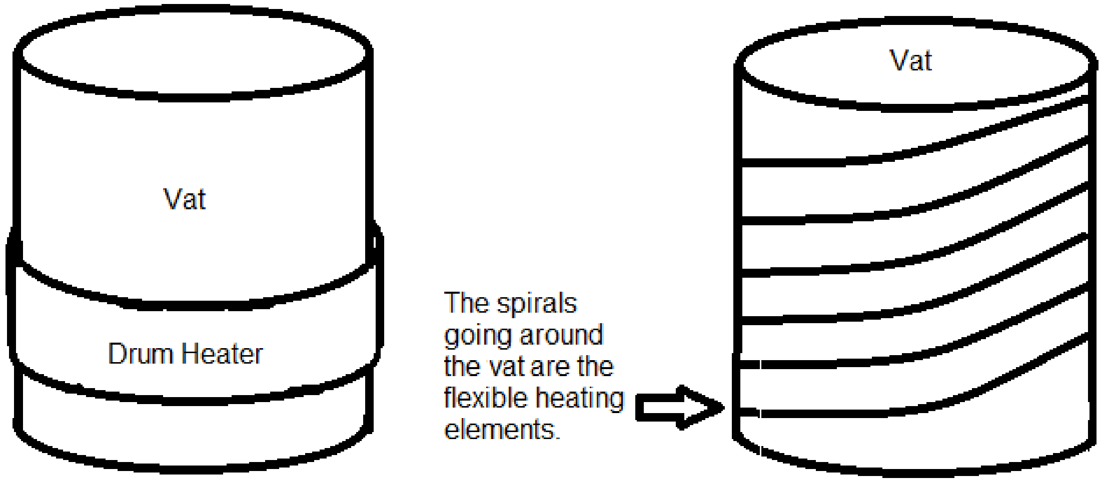


Figure 4.4.2.1: Heating Vat using Flexible Heating Elements

However even after deciding that we want to use a flexible heating element in our project, deciding which particular one is a challenge on its own; our choices were either, a drum heater, a silicon rubber heater or apecolator heating element. After some research, an alternative for the more expensive flexible heating elements was also found—Nichrome Resistive Wires. If we are able to effectively use the Nichrome wires as a flexible heating element, we should be able to reduce the cost considerably. When choosing the right part, the temperature range, the physical proportions, and the cost were considered. A general table of the parts considered can be found below.

Name	Volts	Power	Price / Each
Briskheat DHCS15 Drum Heater	120	1200 W	$155
Silicon Rubber Heater (12” by 24”)	120	1440 W	$109.21
Nichrome Resistive Wire	?	? W	$8-$20
Stove/Oven/Range 6" Heating Element - 2391B	120	1250 W	$26.40
Frigidaire 5308011964 - P1-8 Coil Element	120	2100 W	$49
Frigidaire 316442300 Range Surface Coil Element NEW OEM	120	?	$13

Table 4.4.2.1: Heating Elements

4.4.3. Implementing the Temperature Sensor

Implementing the temperature sensor on the drum (which spins to create a centrifugal force and fly the honey out of the honeycomb) or on the interior side of the container or the vat is essential in our design because of the heating mechanism which will be integrated in the apparatus. The temperature inside the container, therefore, will be different from the surrounding environment of the extractor which is the reason why it is so important to read the temperature inside of the container. Implementing the temperature sensor on the spinning drum would require a wireless communication of the sensor and the microcontroller which brings redundancy, ineffective and costly decision to the project. Implementing the sensor on the walls of the container where it will get in contact with the honey itself is more practical to do.

Another option would be to use an infrared temperature sensor, which does not have to be placed inside the container in order to read the temperature of the inside environment. The latter option is the easiest in terms of implementation and that is the biggest advantage of it comparing to other options, but comes with its own cons too.

Thorough and detailed analysis of the three options of implementation of the temperature sensor is required in order to decide which will be the best option in our project.

4.4.3.1 Implementation Options

Implementing the temperature sensor on the spinning drum comes with one advantage over the implementation on the container, i.e. it will not come into contact with the honey. The disadvantages are: it will be always in motion, it will require wireless connection to the microcontroller. Since the microcontroller will be outside of the container, a wireless connection with the temperature sensor must be established, this brings many challenges and complications and, therefore, this option is omitted.

Implementing the sensor on the walls of the container, as shown in figure 4.4.3.1, is again more practical to do. The advantages are: it will be stationary and a wired communication with the microcontroller can be easily established. The disadvantages are: it will be in contact with honey, a special sensor will have to be acquired that will be “honey proof”. To avoid the possible costly feature of a temperature sensor which will be “honey proof” meaning it can withstand certain acidity levels, (of the honey in our case) the sensor can be sealed in a metal or plastic material. Wires will also get in contact with the honey, which brings another con to this option. To see some of the temperature sensors we have considered using in this option refer to table 3.2.1.1.1 for comparison.

Infrared temperature sensor is the easiest to implement among the three options from a mechanical perspective. The advantages over the two options are: it will be stationary, it will be wired to the microcontroller unit, and it will not be inside the container and will not be in contact with the honey. To see some of the infrared temperature sensors we have considered using in this option refer to table 3.2.1.1.2.

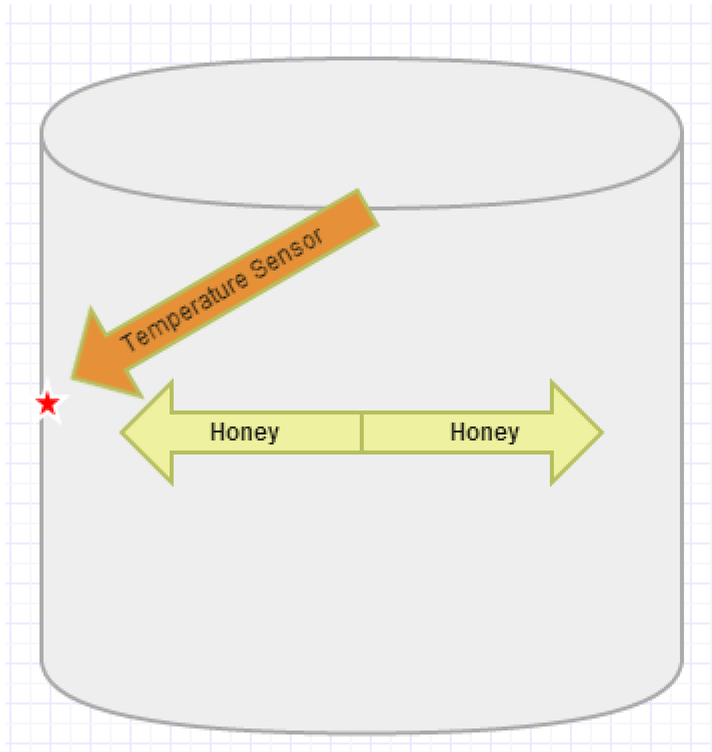


Figure 4.4.3.1 - Temperature Sensor inside the Barrel

4.4.4. Powering the Heating System

The heating system, in our project will be one of the most power-demanding systems other than the motor. To power the system we will implement DC voltage. We will purchase an AC to twelve-twenty four volt DC invertor. The AC side will directly be plugged into a standard wall outlet, while the DC side of the invertor will be connected to the heating elements.

The other parts of the heating system, such as the temperature sensor and the MCU will be powered using another AC to five volt DC inverter. A simple diagram of the way the heating system powering can be found below, note that only general items are shown in this diagram. However, if we find that by combining the power source of the MCU and the Sensors with the Heating Element will not decrease the stability and reliability of the system, we will combine them together.

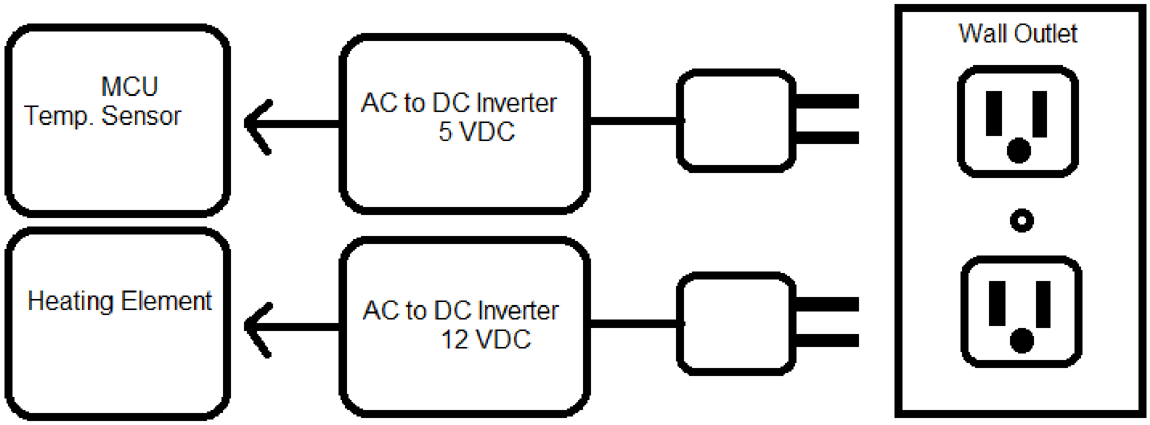


Figure 4.4.4.1: Powering the Heating System

4.5. Designing the Mechanical Components

A good amount of our project consists of mechanical parts such as the vat and the frame holder, and designing those mechanical parts was also one of this group's responsibilities.

4.5.1. Designing the Frame Holder

When we were designing the frame holder, we had a few requirements that needed to be met.

- The frame holder has to be made of stainless steel or other non-corroding material
- The frame holder has to fit at least eight frames at the same time
- The frame holder has to utilize frames of the dimensions 17.75" by 9.125"
- The frame holder has to be as light weight as possible
- The frame holder has to be able to support the weight of eight frames full with honey (approximately thirty-forty pounds)

Having these requirements in mind we first considered a tangential design for the frame holder, and we even came up with a flipping mechanism to solve one of the main problems with that design. The flipping mechanism incorporated hinges on each individual frame support and depended on the centripetal forces made by the motor to do the flipping. A figure of what we came up with can be found below.

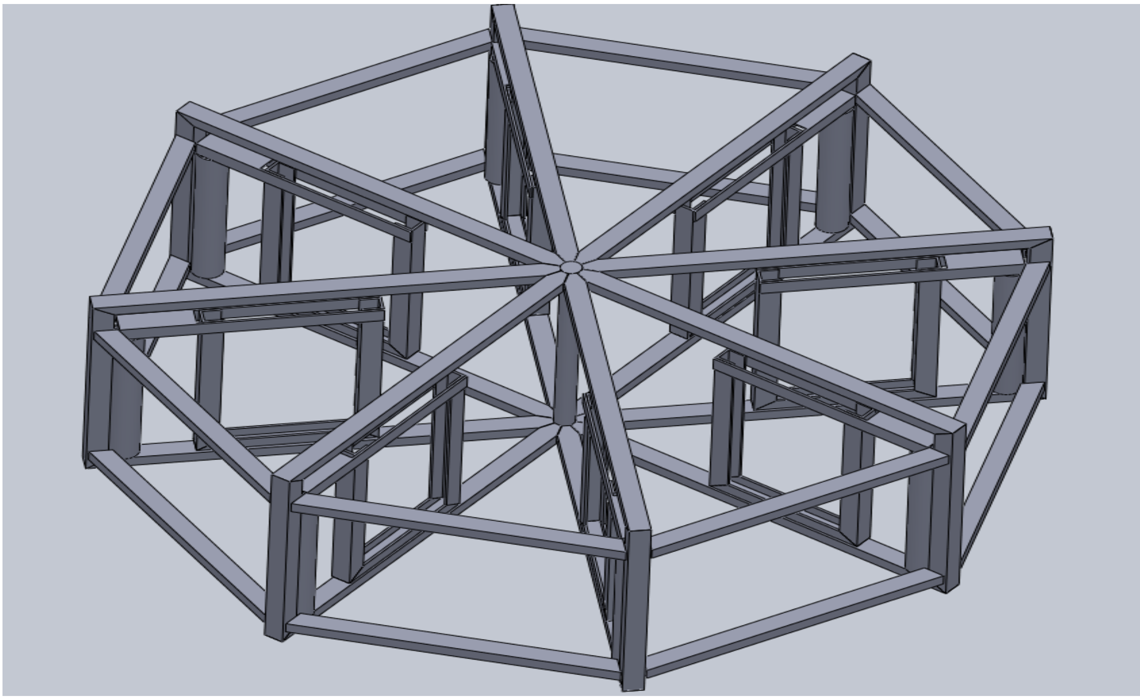


Figure 4.5.1.1: Tangential Frame Holder

The figure below shows a closer look on each of the individual frame holders. And as it is seen in the diagram above, we had eight of them on the frame holder. Each one of the wax frames would be placed in one of these things, and then spun around to extract the honey from one side, then spun in the opposite direction, which due to the rotational force would flip the individual frame holder and that way the honey would be extracted from the other side of the wax frame.

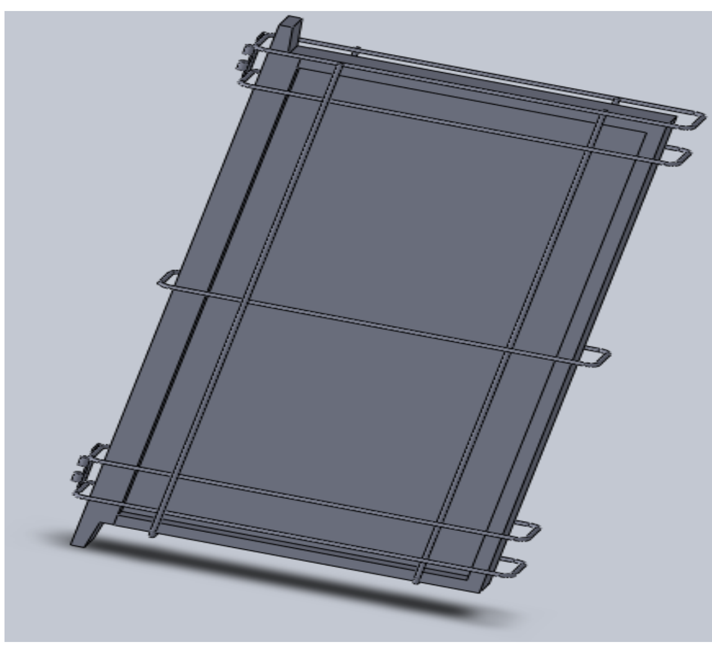


Figure 4.5.1.2: Individual Frame Holder

However after looking at what we have achieved, we realized that using a tangential design for the frame holder is just too inconvenient. To utilize eight frames at the same time, the size of the frame holder becomes too bulky and heavy with the dimensions of the wax frames being seventeen inches and three quarters (17.75”) by nine inches and an eighth (9.125”). So we decided to start from scratch and design a frame holder that utilizes the radial design instead of the tangential in order to save up some space and also decrease the weight of the entire extractor. And as a result also save some money on materials.

As you can see by comparing the figures above with the figures below, the amount of materials being used in the one below is much less, which makes the frame holder a lot lighter in mass. Also even though it looks “simple” it completes all of the requirements and if the future owned of the device decides that he needs to fit two times more wax frames into the extractor, it could be done with a minor modification to this existing frame holder. In addition it uses fewer components and is more “solid” since there are no moving parts in the holder, unlike the previous version of the frame holder that we designed.

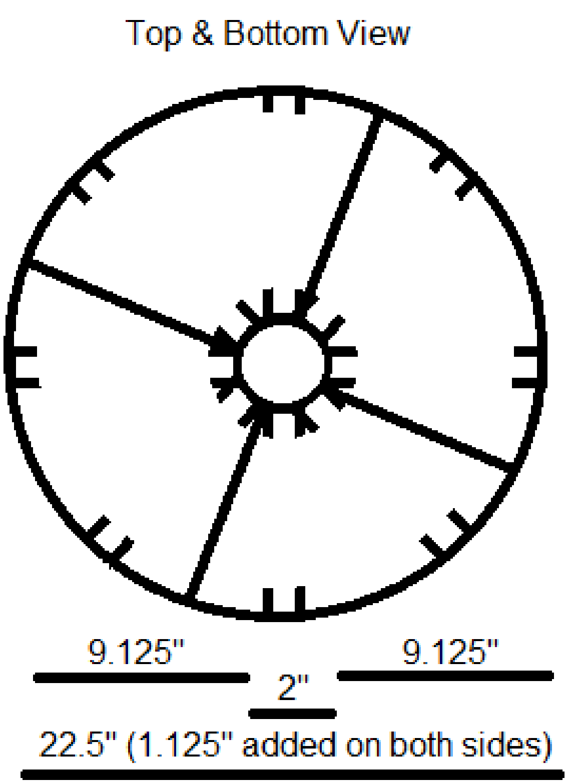


Figure 4.5.1.3: Frame Holder Top & Bottom & Side View

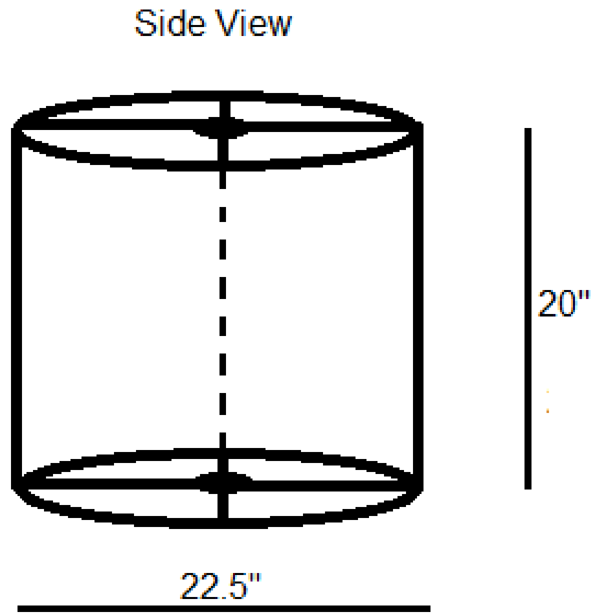


Figure 4.5.1.4: Frame Holder Top & Bottom & Side View

4.5.2. Designing the Vat

Although designing the vat may sound "simple" there were actually not that few things that had to be considered. Also, there were some requirements that needed to be met as well.

- The vat must be made of stainless steel, or any other non-corroding material
- The vat must be able to fit the frame holder and have five (5) inches of free space between its outer rim and the frame holder on all sides.
- The vat must have at least five (5) inches of free space below the frame holder
- The vat must have at least five (5) inches of free space above the frame holder

In order to satisfy these requirements we are going to use a cylindrical shaped vat made of stainless steel. The dimensions of the cylinder being: a diameter of thirty two and a half inches (32.5") and a height of forty five inches (45"). Using these proportions we accounted for the size of the frame holder, the required space around the holder as well as above and below. We also added a filtering netting into the vat. Doing that makes sure that the valve that Is below will not get clogged up with wax from the frames, as well as the honey will be ready to be filled directly into the containers without the need of much more filtering, thus saving time in the whole process of the honey production. A diagram of the vat can be found directly below (not to scale).

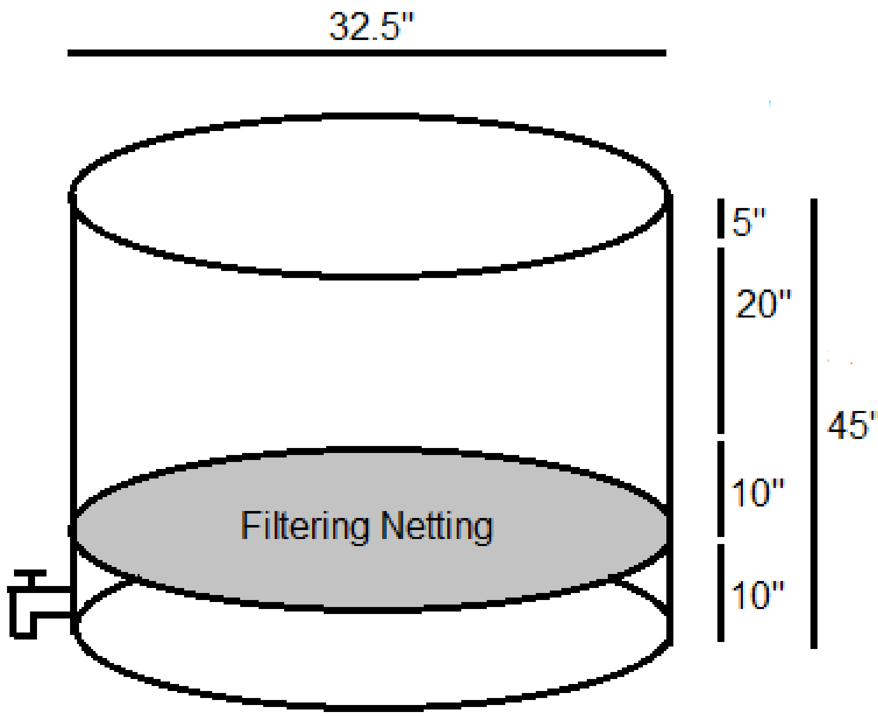


Figure 4.5.2.1: Side View of Vat

4.6. Sensor / Driver Interface

A variety of sensors will be necessary in order to meet the project's requirements. Some sensors may have a serial interface, while other sensors will have an analog interface instead. The micro controller must be able to sample each of these sensors on a separate pin, so that external switches or multiplexers aren't required.

The types of sensors required for this project Include temperature sensors, humidity sensors, weight sensors and possibly speed sensors. Each of these sensor types contains several technologies in order to obtain measurement. For example, temperature sensors require either an analog voltage signal or an infrared readout type signal.

4.6.1. Temperature sensor interface

Thermocouples were first considered because of their wide usage in industry. Thermocouples will produce a voltage on a junction of two dissimilar metals as seen in the figure 4.6.1.1 below. This is due to the thermoelectric effect or Seebeck effect, a figure of which can be found below as well (figure 4.6.1.2). According to the equation it is clear that certain details such as the conductors' size and the length of the conductor do not matter. However, thermocouples must maintain direct contact with the material being measured, so caked on material will prove difficult to measure due to insulation properties.

$$V_{A-B} = \int_{T_c}^{T_h} \left(S_A(T) - S_B(T) \right) dT,$$

Figure 4.6.1.1: Seebeck effect

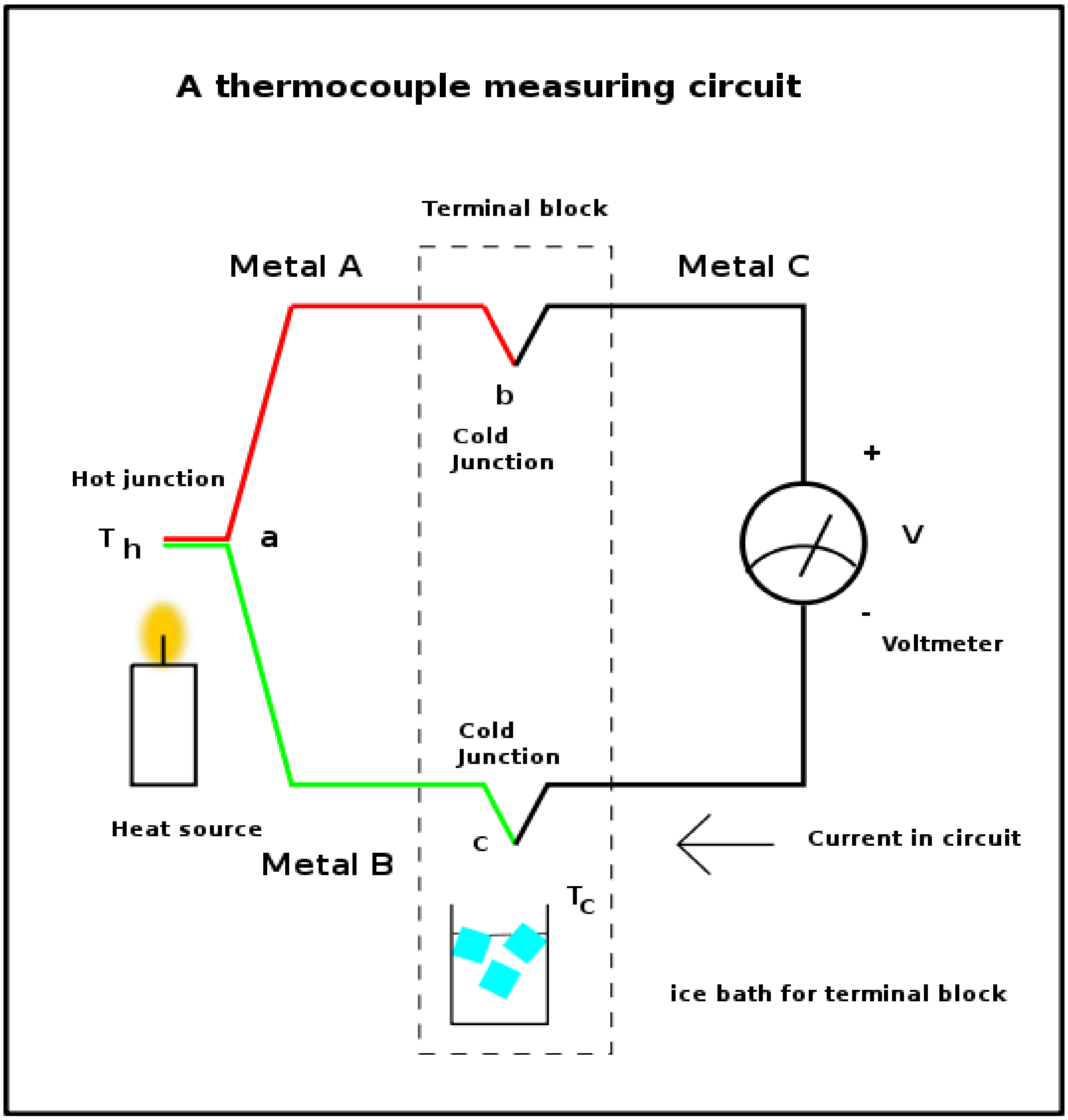


Figure 4.6.1.1: High level thermocouple diagram

Infrared sensors seamed most desirable due to the remote nature of the device. Caked on material will not affect the accuracy of the sensor. These sensors have a less standard interface when compared to thermocouples. The infrared sensor we decided to use is the Melexis . The connection of the MLX90614 can be seen in figure 4.6.1.2. The connection required is simply a PWM interface in order to communicate with the module. The SCL pin is used to program the device, however the device comes out of the box outputting a 10-bit PWM signal in the temperature range of -20°C to 120°C. This range provides an output resolution of .14°C, and will satisfy the problem of temperature measurement.

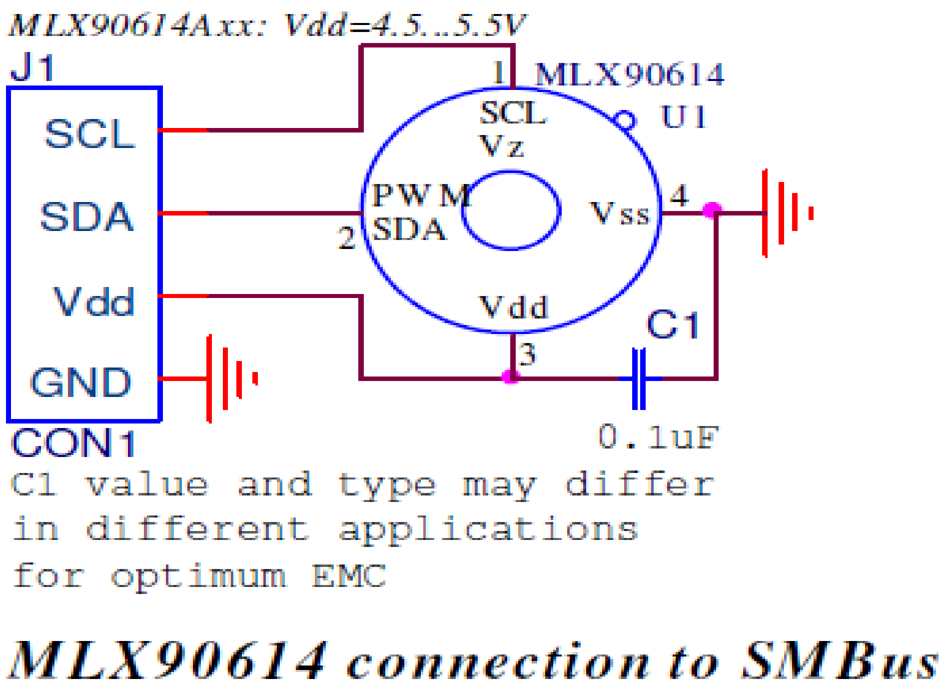


Figure 4.6.1.3: connection of the MLX90614 (courtesy of Melexis)

4.6.2. Humidity sensor interface:

As described earlier, humidity is another factor that determines how honey is extracted. Measuring humidity is common in electronics, as humidity is also I great factor in determining how well electronics function. Some microcontrollers may even have an integrated humidity sensor, so that an external sensor is not required. There are many types of humidity sensors that have different output types. Some humidity sensors output an analog voltage, where others have a more passive sensing approach. One sensor that seamed interesting to interface with was a capacitive temperature sensor. A sensor from Honeywell stuck out as a good match for the project. A sensitivity chart is shown in figure 4.6.2.1. Many of the micro controllers that were looked at included built in capacitive touch sensing functionality. These modules usually functioned through pulsing the capacitor at a certain frequency and measuring the response via the drop off time in an RC circuit. This functionality is shown in figure 4.6.2.2.

CapSense Sigma-Delta

Capacitive sensing using a sigma delta modulator (CSD) provides CapSense® functionality using a switched capacitor technique with a sigma-delta modulator to convert the sensing switched capacitor current to digital code.

Figure 1. CSD Application Diagram

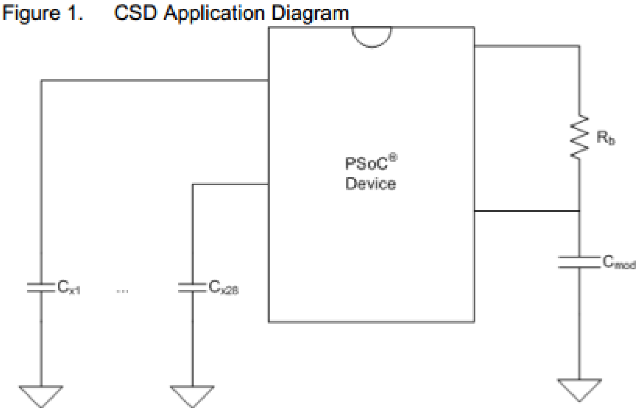


Figure 4.6.2.1: Cypress PSoC cap sense module (embedded in PSoC 3 units and PSoC 5 LP units)

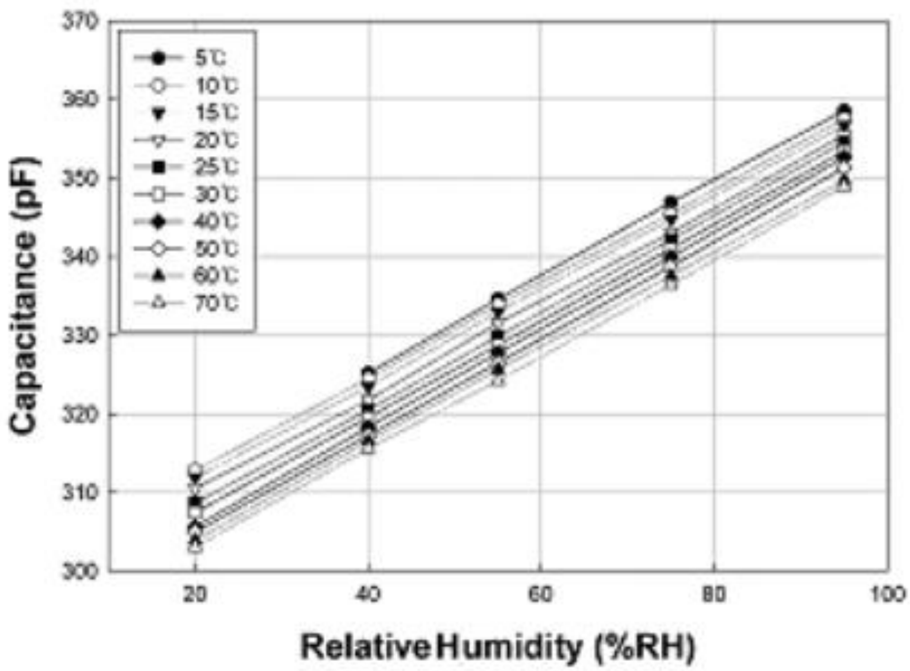


Figure 4.6.2.2: humidity sensor response

4.6.3. Weight Sensor Interface

Another functionality required by the system is an interface to a weight sensor. Technologies that were researched include Load cells (figure 4.6.3.1) and pressure sensors (figure 4.6.3.2). Pressure sensors that were researched generally included totally integrated designs. Therefore these sensors used a high level digital interface to communicate. Because of the high level of integration, pressure sensors were also considerably more costly. A decision was quickly made to use load cells to measure weight.

From a high level understanding, load cells measure resistance to produce a weight measurement. Most load cells consist of an array of four resistors connected together in a Wheatstone bridge. When a force is applied on the load cell, the resistors incorporated are designed to flex and change with weight. The response of the load cell generally requires an instrumentation amplifier in order to operate.

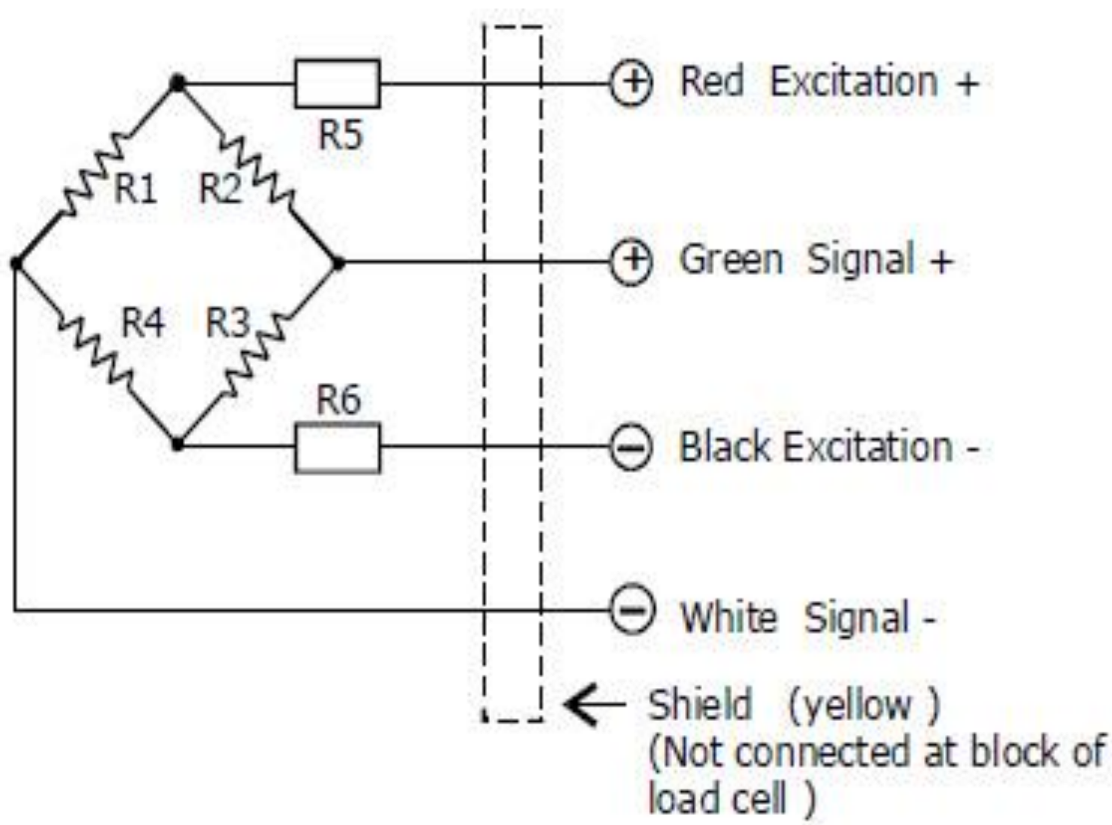


Figure 4.6.3.1: load cell generic schematic (Wheatstone bridge)

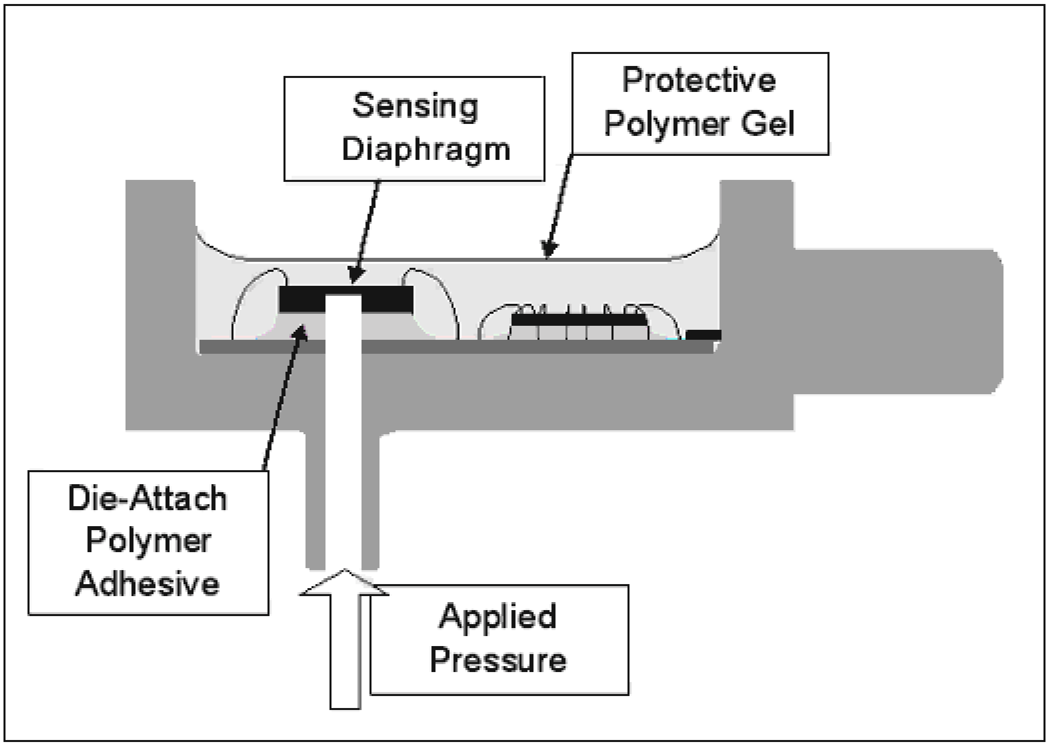


Figure 4.6.3.2: pressure sensor generic diagram

Instrumentation amplifiers are a type of differential amplifier. This means that they have input buffers in order to eliminate the need for impedance matching. Instrumentation amplifiers also have very low DC offset, low drift, low noise, very high open-loop gain, very high common-mode rejection ratio. This means that very small signals can be accurately measured, such as those produced by a load cell.

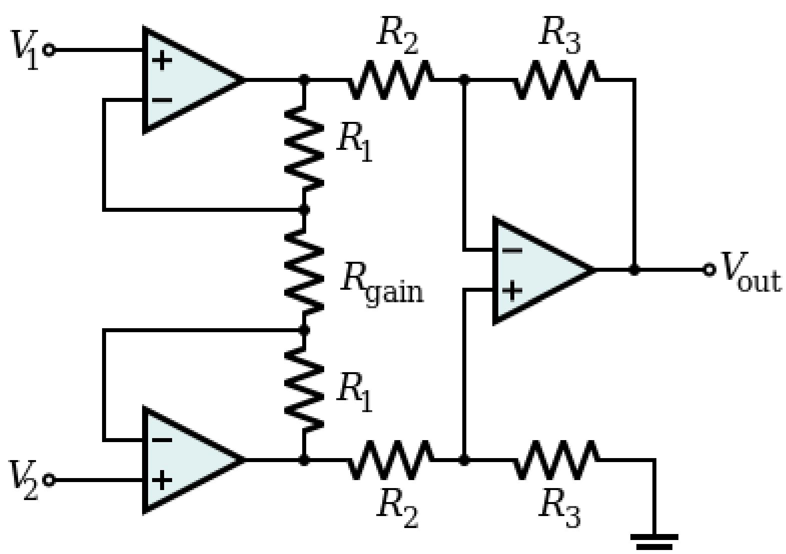


Figure 4.6.3.3: Instrumentation amplifier generic schematic

$$\frac{V_{\text{out}}}{V_2 - V_1} = \left(1 + \frac{2R_1}{R_{\text{gain}}}\right)\frac{R_3}{R_2}$$

Figure 4.6.3.4: Equation for Generic Instrument Amplifier

4.6.4. Bluetooth Interface (Android Interface)

Android devices are revolutionizing the way people think about computers and engineering. Bluetooth is a wireless communication protocol that allows various devices to connect to one another through thin air! Most android devices contain built in Bluetooth modules, allowing for seamless integration to devices such as wireless headsets.

For this project a Roving Networks RN41 Class 1 Bluetooth module was selected to create an android interface. Details on this module were discussed earlier in the paper. This module communicates to the micro controller via an integrated UART (Universal Asynchronous Receiver / Transmitter). This creates and easy interface system and should easily connect to any microcontroller. This module allows for data rates of up 240Kbits per second for slave mode and 300kbits per second of master mode.

Connection from the Bluetooth module the micro controller will happen via RS232 protocol. The connections will be made coincident figure 4.6.4.1. The custom built circuit board will facilitate the connections and contain the module.

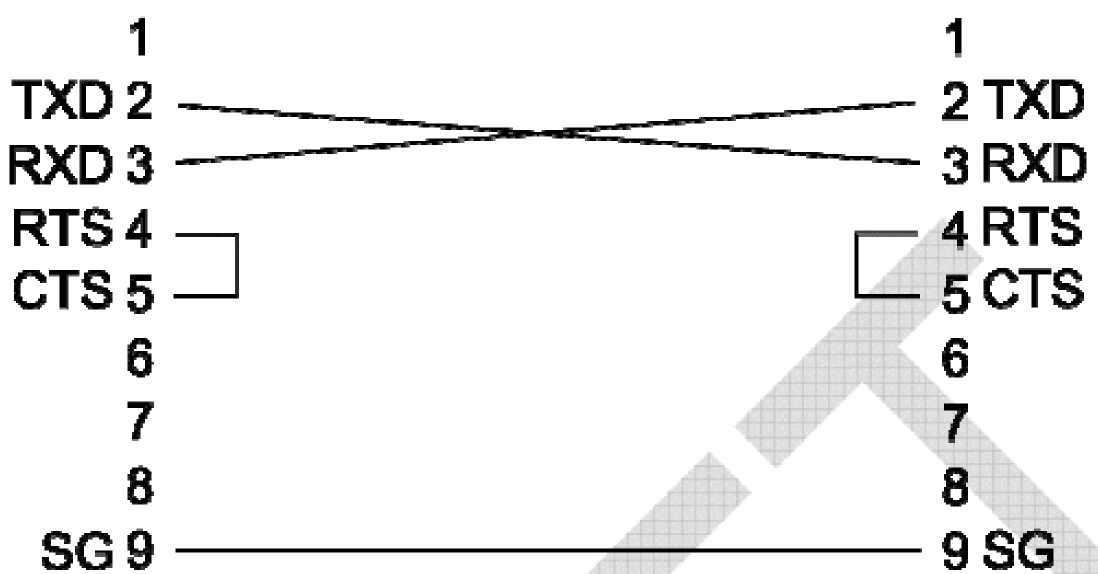


Figure 4.6.4.1: RS232 Connection

4.6.5. Display Interface

In case a Bluetooth device is not connected to the module, a Liquid Crystal Display screen will be used. The Liquid Crystal Display that is to be used was described earlier. The display will have an integrated Hitachi HD44780 display controller. This controller requires a parallel communication interface, meaning that more than one signal is sent to the display at a time. This requires for 7 pins to be connected to the microcontroller. The connection is shown in figure 4.6.5.1.

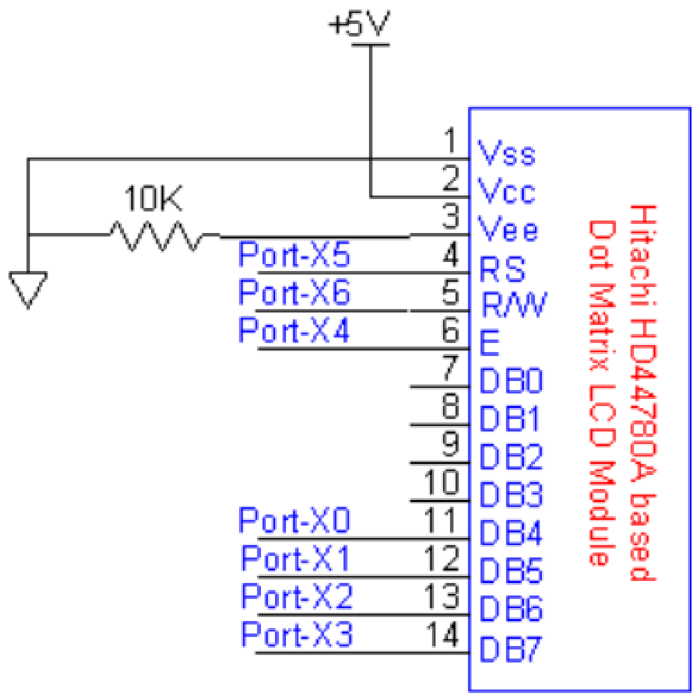


Figure 4.6.5.1: Hitachi HD44780 LCD Controller interface

Pin 1 is a common ground Pin. Pin 2 is the voltage in pin used to power up the Module. Pin 3 normally contains a potentiometer used for contrast adjustment. In the application that the LCD is used for, variable contrast is not required. Because of this, a 10K Ohm resistor ties the pin to ground. This will keep the LCD at full brightness. Pin 4 is a register select pin. This pin selects which register is to be used. The Hitachi HD 44780 controller has two data registers; Command Register select = 0, and Data, Register select = 1. Pin 5 is the Read / Write pin. When Read Write = 0, the protocol is waiting for data to be written to it. Then the Read Write pin = 1, the protocol will send data via the data pins. Pin 6 contains the clock pin. The clock is falling edge triggered, meaning the on transitions from 1 to 0, the protocol will read the input pins and preform operations based on the inputs. The rest of the pins on the module are used for data transmission. Pins 7, 8, 9, and 10 are unused, because the data transmitted across will be in a 4 bit format. The rest of the pins; 11, 12, 13, and 14 are 4 bits used to send data to the module via a parallel interface.

4.6.6. Human Interface Device

Also contained in the display module will be a human interface device. This device will be simply a couple of touch buttons. The buttons will be connected to the micro controller via pull up or pull down resistors (figure 4.6.7.1). More complex circuitry is not necessary. The functionality of the human interface device will be limited to only button presses. These buttons will select which sensor will be displayed, as well as cycle through values for motor speed and temperature sensing

4.6.7. Motor Controller Interfacing

An alternating current motor is going to be used to spin the honey combs in order to extract honey. As discussed earlier in the paper, a Variable frequency drive motor controller will be used to control the motor. This motor controller acts as a way to control the motor by varying the frequency of the alternating current connected to it. According to figure 4.6.7.1., first 3-phase power enters the controller and is converted to a direct current by means of a rectifier diode bridge. The direct current bridge is then switched using high power transistors to mimic an Alternating current. Because these transistors are going to be controller using some kind of microcontroller, it is possible to vary the frequency of the alternating current entering the motor. Figure 4.6.7.1 is shown as a 3-phase system, but a single phase system will be used in this project.

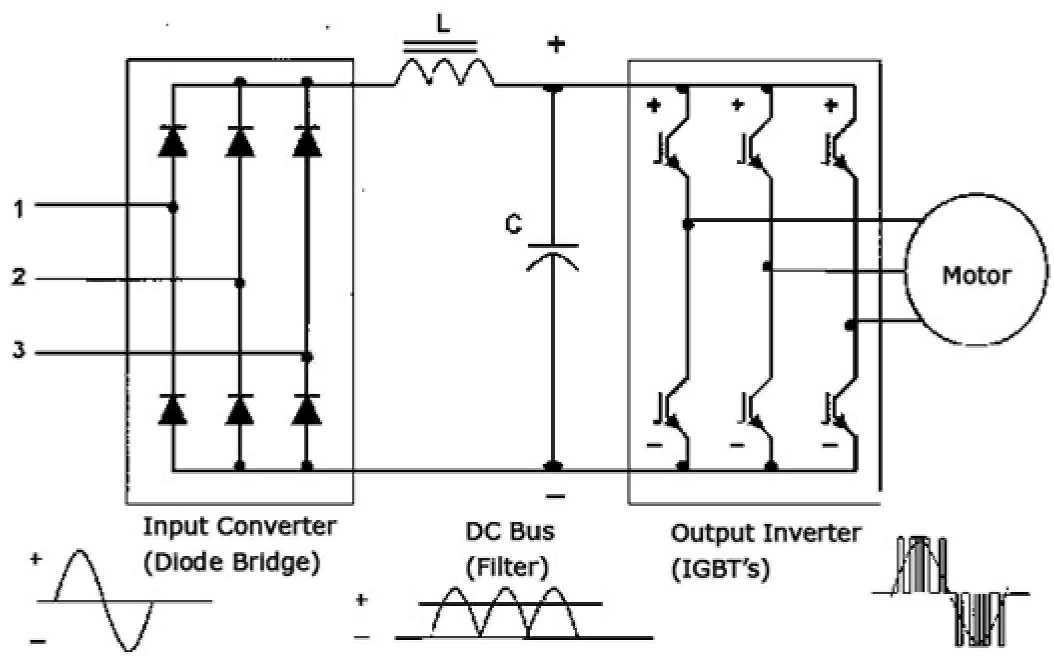


Figure 4.6.7.1: High level Variable Frequency Drive Motor Controller Diagram

The microcontroller interface to the motor controller will possibly be another rs232 connection, or possibly a direct connect for the H-bridge used to modulate the signal. This connection will consist of a pin to select the direction of rotation of the motor, and another pin to select the frequency of the motor connection.

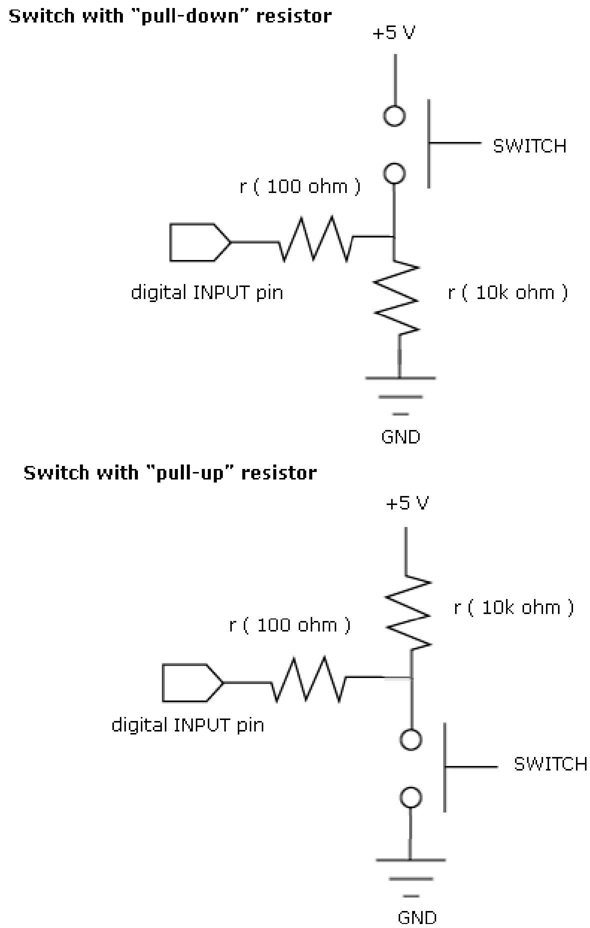


Figure 4.6.7.2: pull up or pull down

4.7 The Motor

One of our project's requirements is to have an electric motor that will create the centrifugal force in order to extract the honey from the wax frames. However not just any motor will work in this situation. The motor we need is a motor with enough torque to rotate at least eight frames full with honey, and on top of that the metal assembly that will be holding the wax frames, which by our estimations may add up to forty-fifty pounds at about 300RPM. Also, as mention by our requirements, the motor should be electrical and be powered by a regular wall outlet of 110-120 volts. With these two main requirements, our choices became very limited. However most motors that meet these requirements are very expensive, over $150 but since it is also a requirement for our project to make this device as low cost as possible, none of them fit the bill. For that reason we had to “dig deeper” and find a motor that could be used for our purposes and that is fairly cheap compared to the other ones. And we found such a motor—“O002 1/4 HP, 1800 RPM MARATHON SURPLUS ELECTRIC MOTOR.” With the quarter of a Horse Power the problem with the torque is taken care of. Also the voltage that it uses is 115 Volts, so that makes it possible for it to be powered by a regular wall outlet. And finally the price tag of $50 sold us in this particular motor. A picture of the motor can be found below.

4.7.1 Mounting the Motor

The placement of the motor in the honey extractor plays a big part. We need to place the motor in a place that will be the most convenient. There are two possible positions where we can place the motor at. The first position is to mount it above the extractor, and directly connect the motor to the wax frame holders. A diagram can be found below.

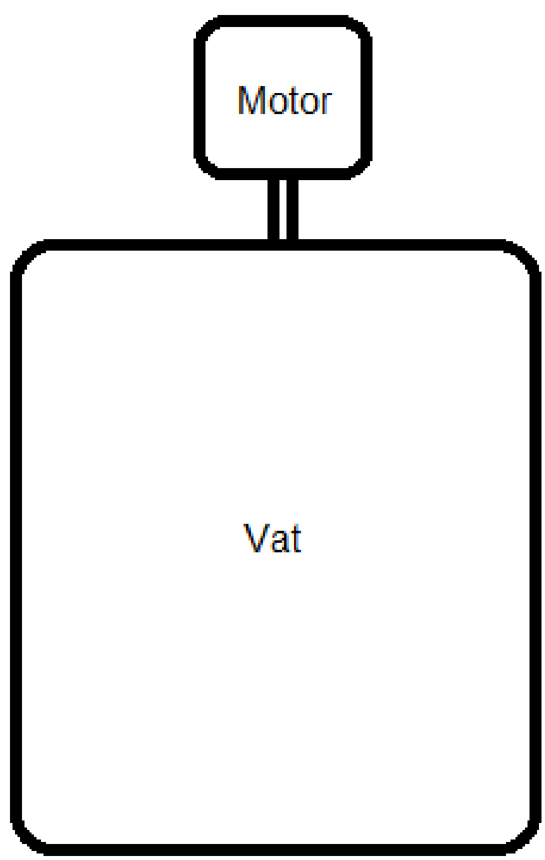


Figure 4.7.1: Motor Positioned above the Vat

The problem with positioning the motor in this manner is that it takes up the space above the extractor, which makes the loading of the frames into the extractor a little inconvenient, however it reduces the number of parts used to connect the motor.

The second possible way of mounting the motor is by placing the motor adjacent to the vat and having a rubber belt that will connect the motor and the frame holder. So as the motor spins, the belt will rotate as well and spin the frame holder. However connecting the motor in this manner adds more components to the project as well as makes the extractor a little unstable due to the weight being on one side on the vat unlike how it was in the center in the previous method. A diagram can be found below.

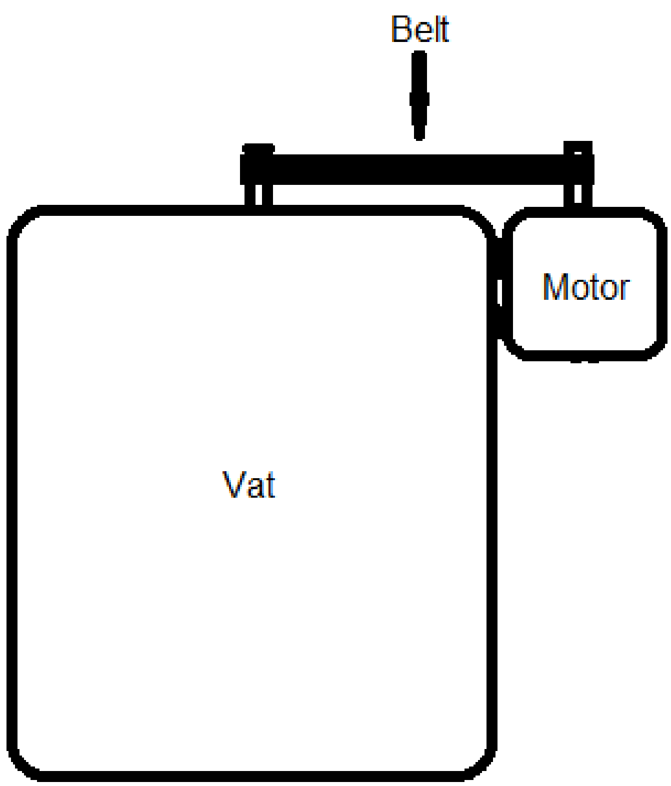


Figure 4.7.2: Motor Positioned Adjacent to Vat

All in all, choosing either method would create some problems, however we decided to first go with the second method and place the motor adjacent to the vat we will see how that turns out, and if the extractor becomes too unstable, we will reconnect the motor using the first method of positioning the motor above the frame holder and directly connecting it without the use of a belt or other connecting components, and deal with the problem of loading the frames some other way.

4.8. Weight Sensor Implementation Options

In order to achieve the goal of real time measurement without delays, (which is essential for calculating the optimal time when to stop the motor) the weight sensor cannot be placed where it will measure the whole weight of the honey extracting apparatus because the viscous honey takes time to flow out of the container. Instead, the weight sensor must measure only the weight of the honeycomb frames, and in order to achieve this, we must place the weight sensor on the bottom of the frame holder along with its axis, in other words, we have to measure the weight of the spinning part separately from the other parts. Refer to figure 4.8.1 and figure 4.8.2 for clarification.

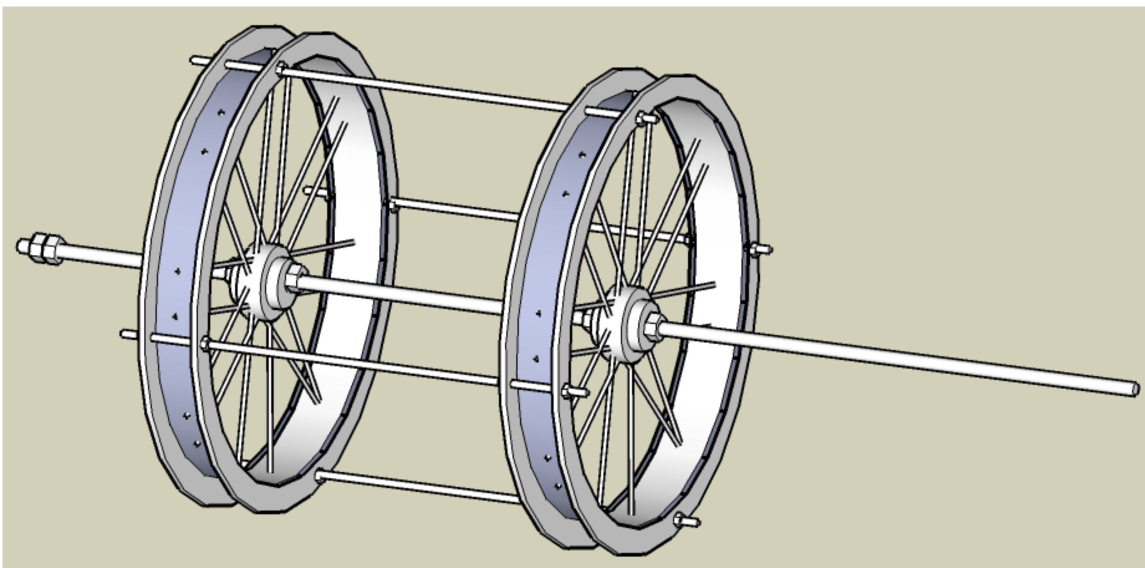


Figure 4.8.1: The Spinning Frame Holder Alone

Another approach would be placing the sensor on the top as shown in figure 4.8.2. In this approach, the bottom of the axis must not be supported by the container or the vat, in order for the weight differential to be detected by the sensor when the honeycomb frames are placed inside the holder.

The above two approaches are fairly difficult to achieve from a mechanical point of view and as a backup plan we must consider weighing the whole apparatus approach, which will not be as desirable as the above two approaches, but is easier to achieve and which is why this approach is our back up plan.

Currently there are many types of force and weight sensors available in the market that can be used in our project. Through the process of elimination and research we have come up with a list of sensors that fit our needs. Table 3.2.2.1

outlines and compares the main characteristics of chosen sensors in the above section.

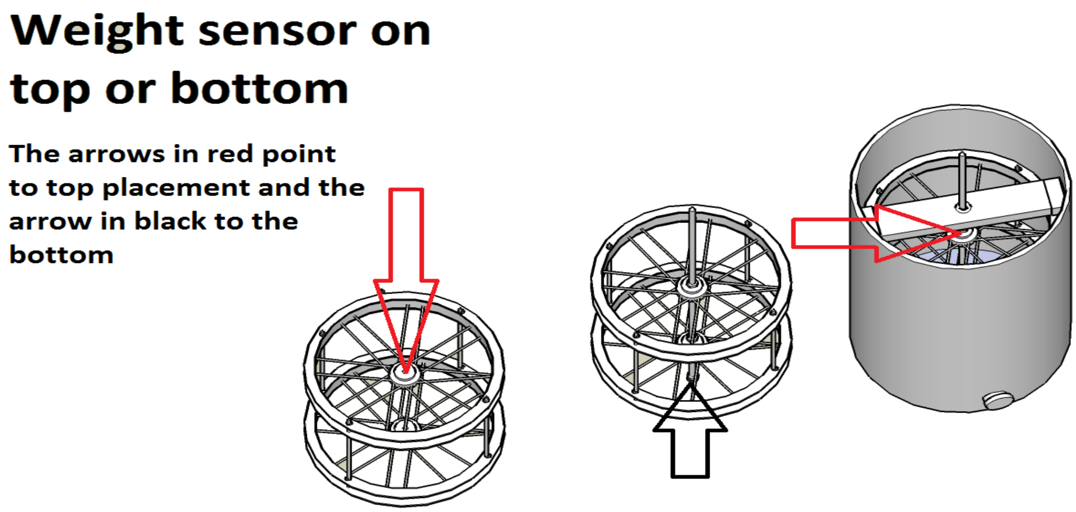


Figure 4.8.2: Top or Bottom Placement of the Weight Sensor

4.9. Printed Circuit board (PCB)

According to the requirements for the course, a printed circuit board is to be created. Printed circuit boards are used to connect electrical components together. Most circuit boards are made of copper laid on top of a fiberglass material. Usually this material is FR4.

4.9.1. Circuit Board Design

The design of the printed circuit board is going to be created in CadSoft's Eagle. This program allows for electrical components to be created or imported and placed in a circuit schematic. The schematic is then converted to a net list, which describes how the components are connected. These connections are then physically laid out on a computer generated model of the printed circuit board. An example of how this project is put together is shown in figure 4.9.1.1. The colors represent different layers of the circuit board. Some circuit boards may contain up to 16 layers!

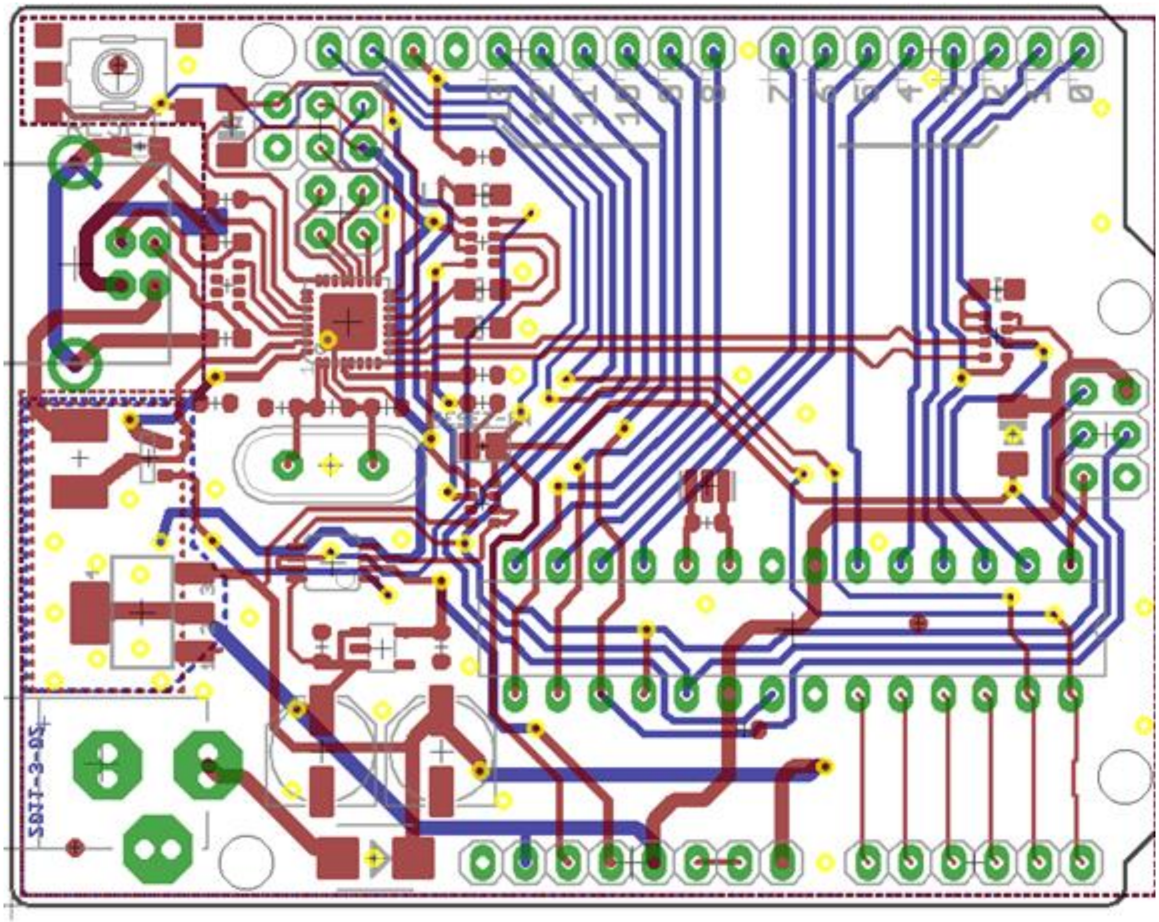


Figure 4.9.1.1 Example of circuit board design in CadSoft's Eagle program

According to 4.9.1.1, there are 4 layers; top layer, bottom layer, drill holes and vias. The top layer is shown in red and containing information describing where the copper is located on one side of the board. The bottom layer is shown in blue. It contains the information related to the traces on the other side of the board. The green layer is showing where the through hole pads are going to be placed. Holes are drilled through the circuit board, then connected together by means of conductive material. The yellow layer contains information related to the placement of vias. Vias are junctions between the top layer and the bottom layer.

4.9.2. Fabrication

Fabrication of the printed Circuit board will be done by an out of house manufacturing process. Board manufacturing can be done primarily in two ways. One way consists of using a sheet of copper clad FR4. This process is called etching. These boards are cheap and easy to make in small quantities, but once the quantities become larger this process becomes difficult. Problems with design process include the difficulty of placing vias, the lack of solder mask and the inability to produce a silk screen. This adds difficulty in the board assembly process. As you can see in figure 17, all circuitry is on the top side of the board. This is not a coincidence. Unless through hole components are placed at angles that expose the top and bottom of the pad, they must be soldered only on one side.

Another widely used printed circuit board manufacturing technique is chemical etching. Etching creates circuit boards by chemically removing material in specific spots. This is done by creating mask of material that is not removed. This process allows for many additional layers to be created. A silk screen layer and a solder mask layer is possible with this technique. A silk screen allows for information to be displayed showing assembly instructions. A solder mask allows solder to flow only to the pads. Without solder mask, solder is able to flow anywhere there is copper present on the board.

4.10 Powering the Extractor

Almost every part of our project will need to be supplied with power, starting with the motor, the MCU, the sensors and ending with the heating system. For this purpose we will need to implement both AC and DC.

Our motor will use a regular 115 Volt outlet as a power source and it will be connected into the wall outlet directly, without the use of an inverter or a transformer of any kind. However, we will need to implement an AC to DC inverter for our other electrical parts that need to be supplied with power. The heating elements will use an AC to twelve volts DC inverter as a power supply, and the MCU along with all of the sensors such as the humidity sensor and the temperature sensors will use an AC to five volts DC inverter.

However if it will prove not difficult to accomplish, all of the DC components will be merged and will use a single AC to DC inverter, thus reducing the number of outlets needed to run the whole machine.

All high power components are operating at 110 volt alternating current (AC). This power device is used to limit the current flowing through the system. 110 volt AC allows for the unit to simply plug into a standard wall outlet. The subsystems fed by the 110V system are the 12 volt power supply, the Variable frequency drive and the Dimmer Switch. The 12 volt Power supply is a modified 12 volt wall wart. It is a self-contained unit that takes in 110 volt alternating current and rectifies and steps it down to produce 12 volts DC source. This 12 volt source is used to power the relays, lights and the microcontroller board.

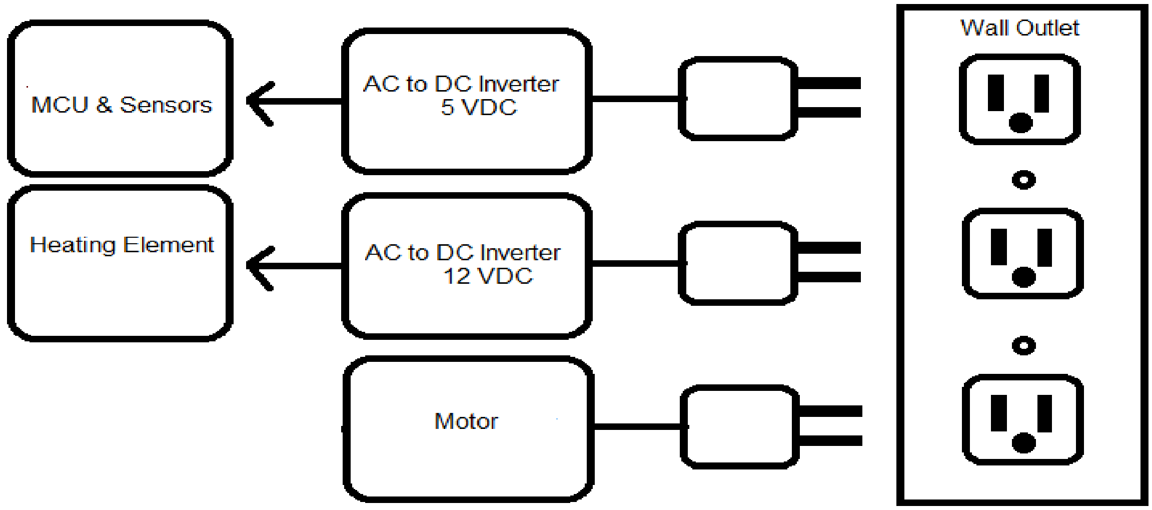


Figure 4.10.1: Power Supply Using Three Outlets.

4.11. Emergency Stop Design

An important part of the design is safety. In case of failure, a purely electric and mechanical system must be in place to safely stop the unit. The emergency stop must be separate from the microcontroller, to ensure robustness. when systems fail, the smaller low voltage components tend to be destroyed.

The emergency stop will consist of a double single pole double throw relay and two switches as shown in figure 4.11.1. One of the relay's switches will be connected to the power feeding the motor. The other switch will be used to reset the unit once an emergency stop has been triggered. The circuit will also consist of a normally closed "emergency stop" switch and a normally open "power on" switch.

When the normally closed emergency stop switch is activated, power to the relay's coil is cut off. The relay will collapse and break the circuit feeding the motor power. To turn back on the relay, the power on switch will be pressed. The switch will reenergize the coil so that both the switch feeding the relay and the switch feeding the motor will be closed, allowing current to flow to the devices.

If the switch feeding the motor is shown to be too low current rated, then a larger relay or contactor will be added so that the coil is energized by the "power out" node. This may be necessary because relays with more than one switching circuit generally tend to cost more and be lower power than single switch relays.

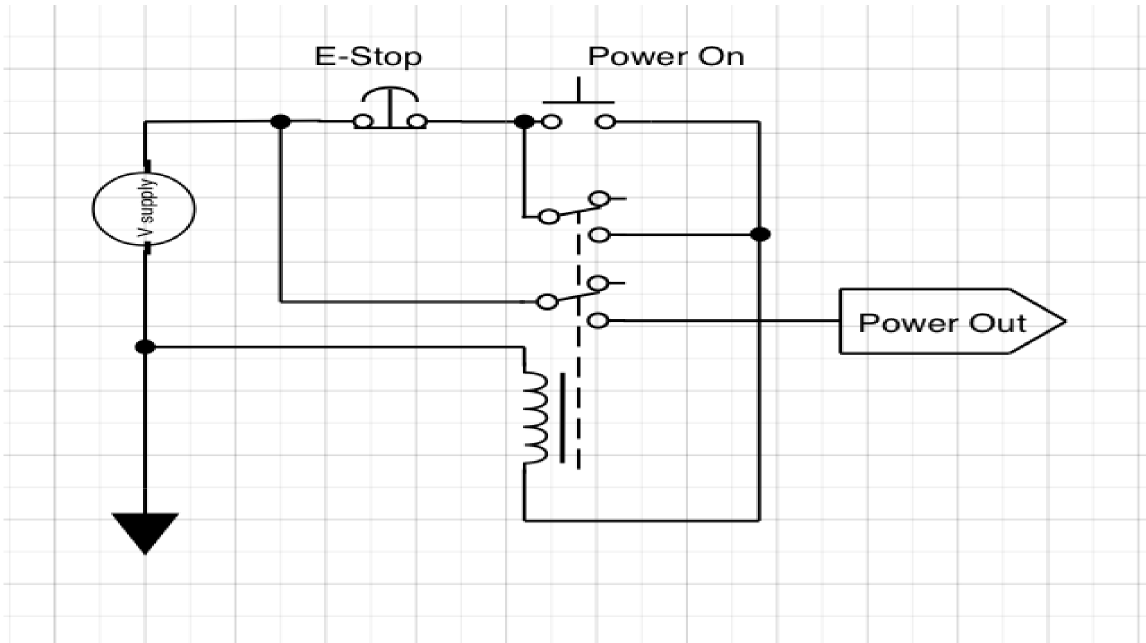


Figure 4.11.1: Emergency Stop Schematic

4.12. Procedure for Presentation

Our first presentation is going to be a great milestone in our project. If we stick to the design calendar, the requirements should be met well before this date. The time in between these dates will give us plenty of time to practice our presentation. Mandatory requirements to be met before this time include integrating the Human Interface Device, the Liquid Crystal Display Screen, the temperature sensor, humidity sensor, the motor and the android device interface.

First thing that will be done during the presentation will be to plug in our power for our devices. Light emitting diodes will be turned on to show that various systems will be enabled. Once all of the devices are tested, a motor test will start. The motor will slowly power on and spin until full speed is reached. The motor will run for a little while, then the emergency stop button will be pressed. Once the motor has powered down, the reset circuit will be tested. The motor should power back on. This will complete the testing phase of our device.

Next test will be to connect the android device to the unit. The Android device will be powered on and connected to the device. Sensor input will be verified to make sure the connection is made. The Android device will be given to one of the members of the review committee so the sensor information can be read remotely.

Next we will load the unit with the honeycomb frames. The frames will be removed from sealed containers over the extractor as not to spill honey on the floor during the presentation. Once the frames are inserted, the device will be closed and the start button will be pressed. The device should start spinning and honey should start coming out of the units. The vat should heat up so that it will flow easier to the straining device. The vat will then open and the honey will be poured into a cup. The cup full of honey will be presented to the review committee.

The final step will be to ask the review committee if there are any questions, and answer them as appropriate. Once all of the questions are answered and our group is dismissed, we will pack up our equipment and examine the room for any honey that may have escaped. The Android device will be collected. Any messes will be cleaned up, and the group will leave the room in an orderly fashion.

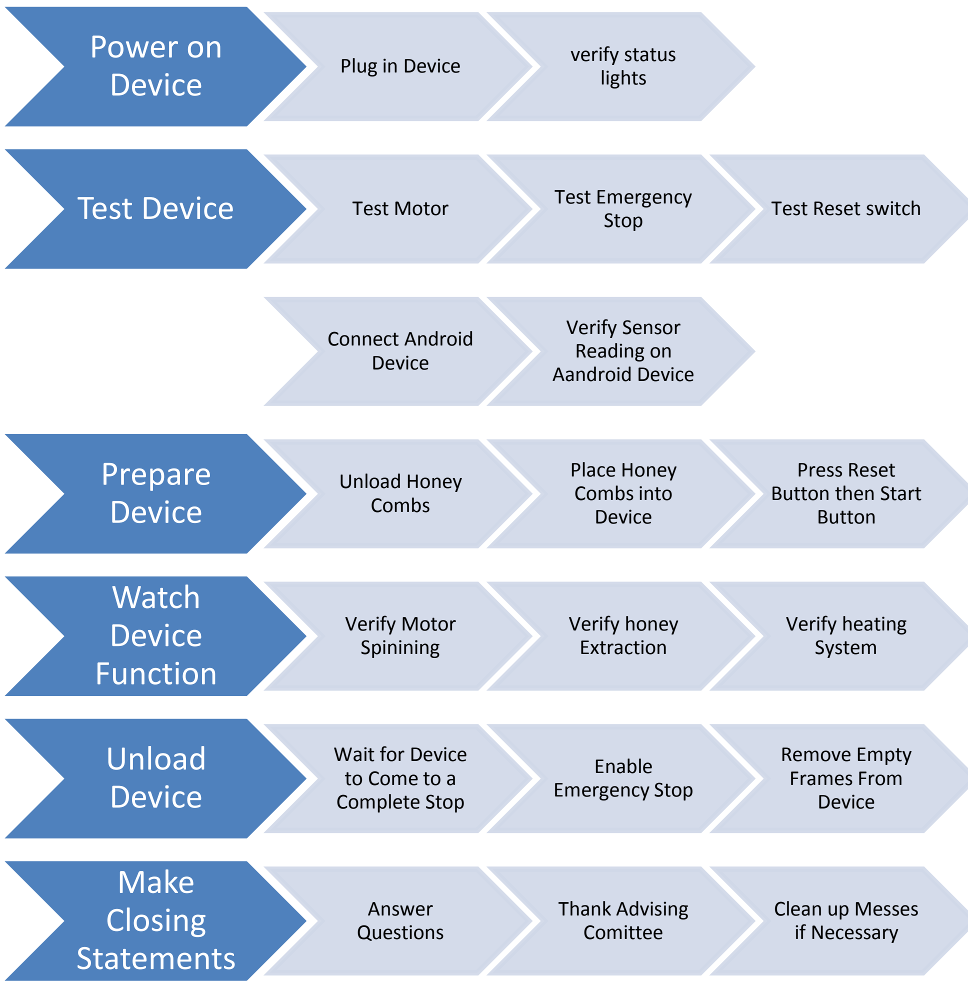
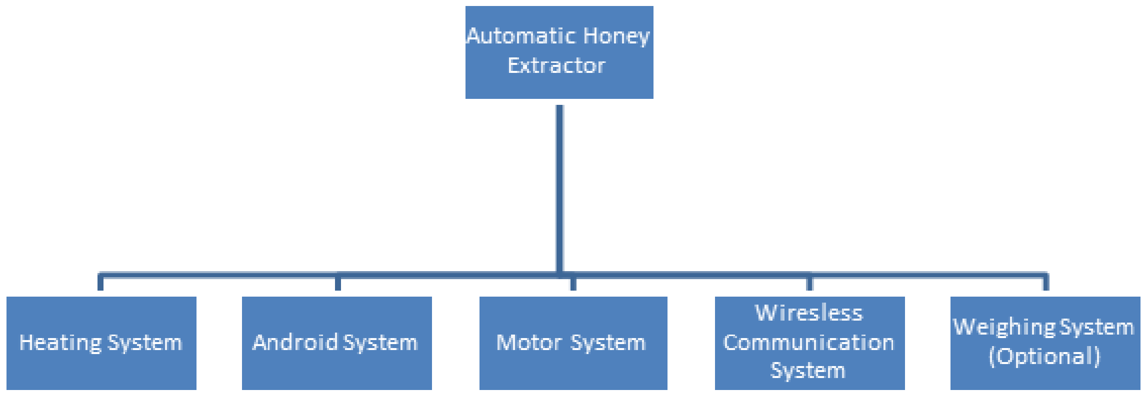


Figure 4.12.1: Presentation Procedure

5. Design Summary

The Automated Honey Extractor design is composed of several detailed subsystems. The main subsystems are the motor system, the heating system, the wireless communication system, the android system and the optional weighing system as seen in the figure below.



5.1 Automatic Honey Extractor Systems

5.1. The Motor System

The motor system will include a motor, a motor controller and a power supply. All of these components will be connected to the microcontroller unit. The motor controller will be controlled by the user both directly using the onboard controlls and with an android device using the wireless communicatoiin system as a medium. The figure below shows how the motor system is set up, which parts communicate with what.

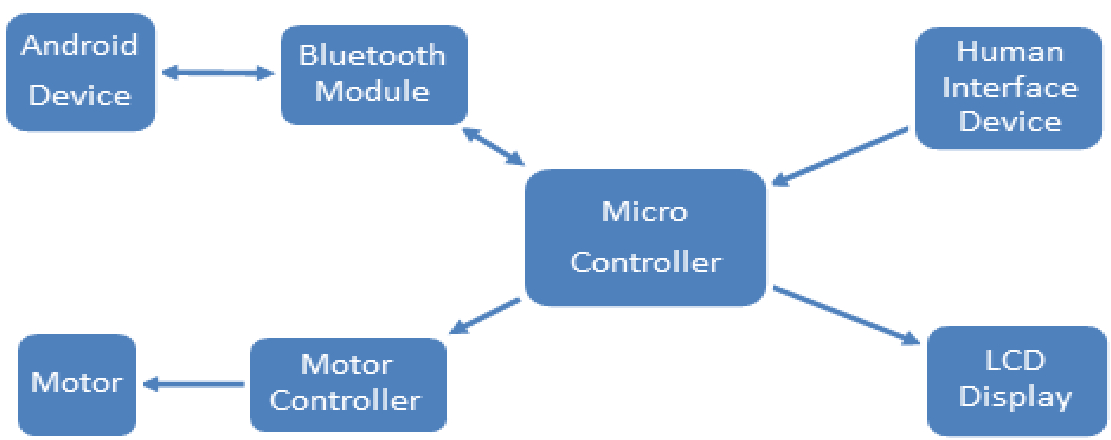


Figure 5.1.1: The Motor System

5.2. The Heating System

The heating system will include flexible heating elements such as the Nichrome wires, a power supply and a temperature sensor. The temperature sensor will constantly read the temperature of the extracted honey and feed the data to the MCU, which in turn will transfer the data to the android for viewing, as well as make decisions to either increase the temperature of the vat or decrese the temperature. The figure below shows the control loop of the heating system.

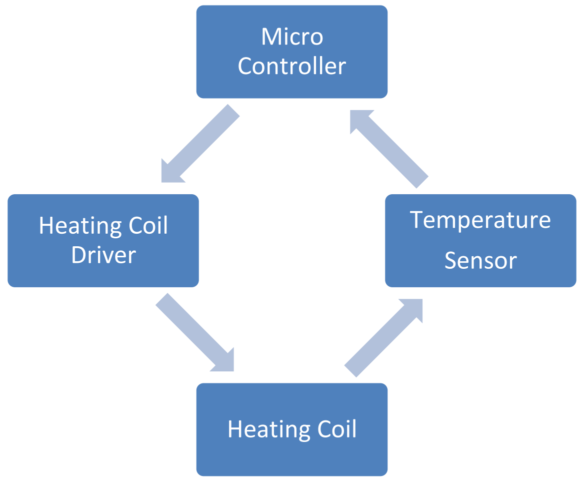


Figure 5.2.1:Heating System Control Loop

5.3. The Wireless Communication System

The wireless communication will be basically consist of two bluetooth trancievers. One tranceiver will be installed on the adroid device and the second will be installed on the MCU. The wireless communication system will be used to send both data and commands to and from the android device. It will be used to control the motor system, the heating system and the weighing system. All in all it will be the bridge from the adroid system to all of the other systems as seen in the figure below.

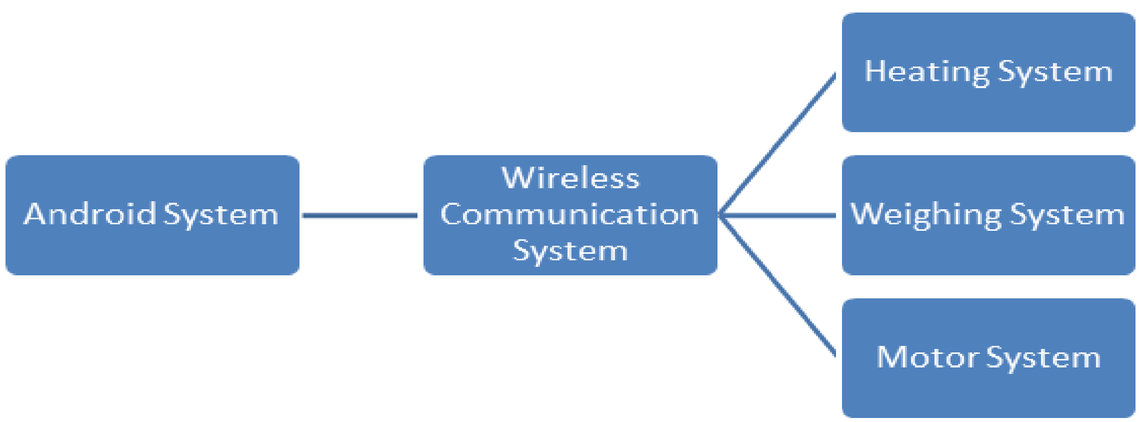


Figure 5.3.1: Wireless Communication System Hiararchy

5.4. The Android System

The andoid sytem is composed of basically an android phone. However what makes this a system is the software that will be installed on the android device.

The application written for the adroid device will have a GUI that will show the temperature and the humidity data in real time. Also through the application, the user will be able to fully control the honey extractor. The user will be able to turn the motor on and off, as well as start an automatic extraction proccess.

5.5. The Weighing System (Optional)

The weighing system will consist of a wheatstone bridge force sensor and an instrumintation amplifier, the instrumintation amplifier will be integrated into the microcontroller chip. The wheatstone bridge will change resistance based on the force applied by the weight of the honey onto the axle of the honey extractor. The instrumincation amplifier will be tuned to detect minute changes in weight. The data will be processed by the microcontroller into an appropriate form and decisions will be made to either continue spinning the motor or stop.
The Figure below shows the control loop of the weighing system.

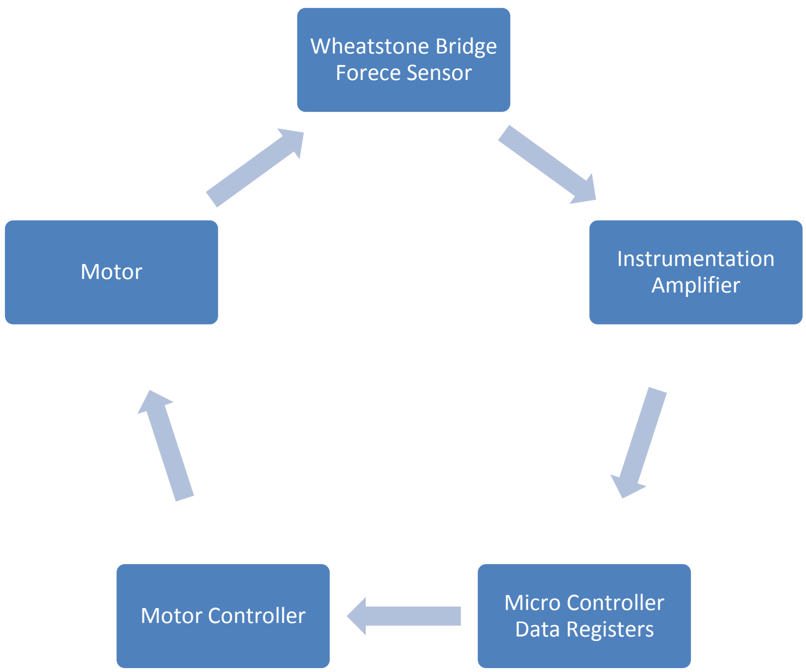


Figure 5.5.1: Weighing System Control Loop

6. Construction Process

The figure below shows the full construction process of the automated honey extractor.

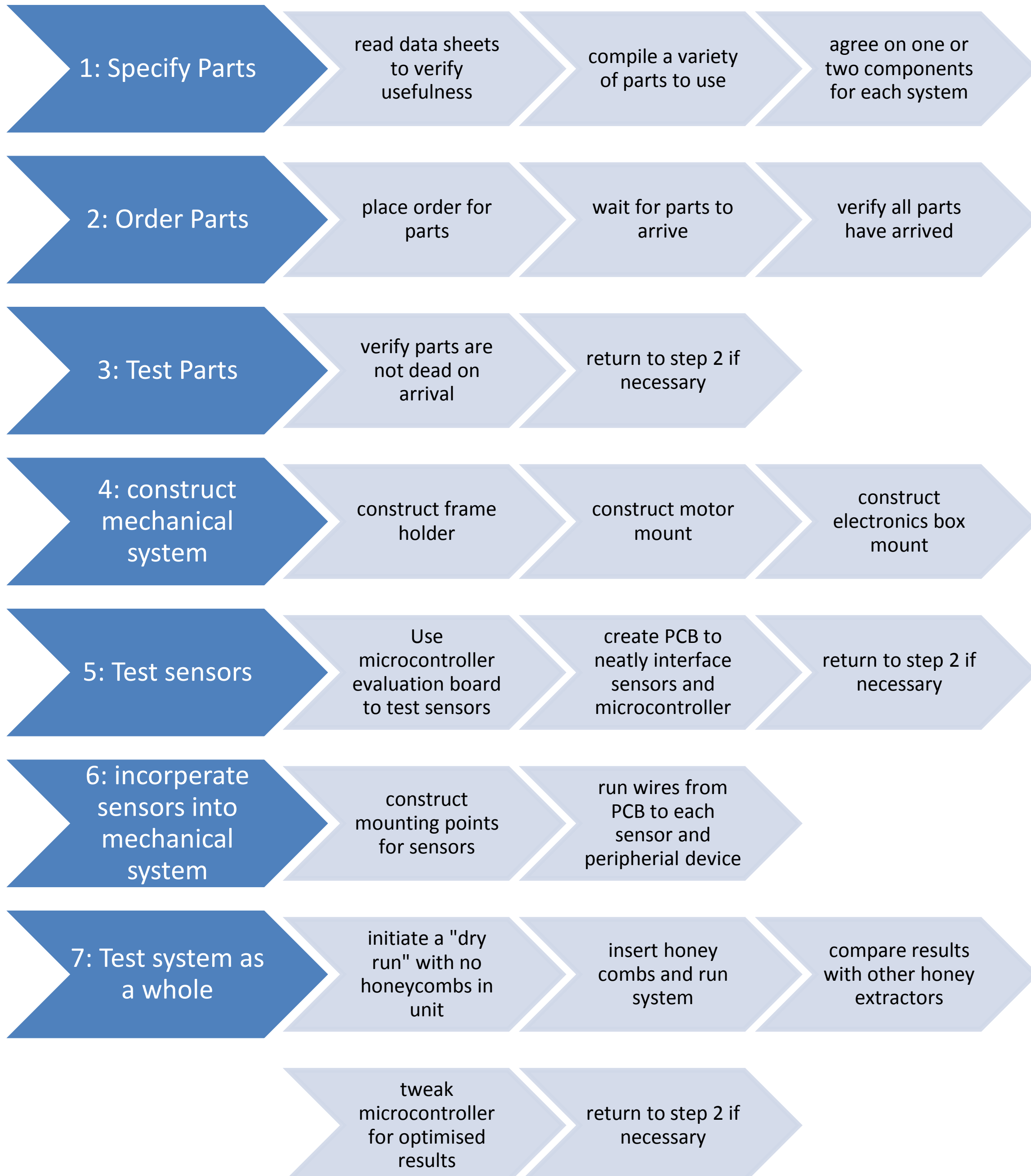


Figure 6.1 Construction Process Diagram

7. Project Prototype Testing

7.1. Hardware Test Environment

Before we built the complete system each component of the future system needs to be tested. To send and receive serial data over Bluetooth, we will need terminal program and a Bluetooth serial adapter. There are many free applications today on the market designed to test data transmission over a Bluetooth. One of the most popular and reliable applications is BlueTerm. BlueTerm can be downloaded from Google's application play store. This application is terminal emulator for communicating with a serial device using a Bluetooth serial adapter. The RFCOMM/SPP protocol emulates serial communication over Bluetooth. The way it works is as follows: the data sent from the phone will be pushed to the UART_TX pin, then, since UART_TX and UART-RX pins will be shorted, it will be transferred to the UART_RX pin, and finally the data will be sent back to the phone and will appear on the screen. The application requires Android Version 2.1 or later which will be compatible with the version on our testing phone. The application will be installed on the smartphone before testing.

7.2.1 Bluetooth Data Transfer to Android

7.2.1.1. Phone Preliminary Testing

To check data transfer between RN-41 Bluetooth module and Android phone start BlueTerm on the phone. Pins UART_CTS (pin 16) and UART_RTS (pin 15) will be shortened for reasons described in section 4.3.3 "Integrating the Bluetooth into Circuit". Power up the Bluetooth by connecting the Bluetooth with two wires to a LiPO battery. Next, wirelessly connect the phone and RN-41 and start typing on the application's emulator. If the Bluetooth works correctly, characters typed on the emulator will appear on the screen.

Test No.	Requirement	Procedure	Expected Result
1.	The Bluetooth shall be able to transfer data to Android within the distance of 1 meter.	Type characters on the emulator.	Characters typed on the emulator appear on the screen.
2.	The Bluetooth shall be able to transfer data to Android within the distance of 15 meters.	Type characters on the emulator.	Characters typed on the emulator appear on the screen.

Table 7.2.1.1.1 Software Functional Requirements Test Procedures

7.2.1.1. Bluetooth Troubleshooting

If the testing data transfer over the Bluetooth fails then the device will be troubleshot.

First we need to make sure that the powered on Bluetooth is discoverable. If the module is not appearing on the screen then polarity will be checked by making sure that GND pin is connected to batteries' negative terminal and VDD is connected to the positive batteries' terminal. If the connection appeared to be correct, the supplied voltage will be checked with a multimeter to make sure that the correct voltage is supplied to the device. If the voltage within required specification and no pairing occurs the last thing to check is if the voltage supplied is supplied to correct pins. This can be verified with the datasheet for the RN41 Bluetooth module. If all of the configurations were checked and appeared to be correct and no pairing still occurs then the module will be replaced.

In case if the device is able to pair, but is unable to transfer characters to the screen we will check the loopback pins connection and whether the correct pins were shorted.

7.2.2 Data Transfer between Android and Development Board over Bluetooth Preliminary Testing

If the data transfer testing over Android and Bluetooth was successful, we can continue by connecting the microcontroller unit and test the Bluetooth on the development board. To test data transfer between from the microcontroller to Android we are going to transmit temperature sensor data. The temperature sensor will be connected to the development board and tested before we begin microcontroller data transfer to Android over the Bluetooth testing. To test data transfer from Android to the microcontroller we are going to connect an LCD display to the microcontroller that will display the data received on the UART_RX pin of the microcontroller.

Test No.	Requirement	Procedure	Expected Result
1.	The Bluetooth shall be able to transfer data to Android within the distance of 1 meter.	Type characters on the emulator.	Characters typed on the emulator appear on the screen.
2.	The Bluetooth shall be able to transfer data to	Type characters on	Characters typed on the emulator appear

	Android within the distance of 15 meters.	the emulator.	on the screen.
3.	Make sure that the transmitted data is being transmitted over the correct Bluetooth module.	Disconnect the Bluetooth from the power supply. Type characters on the emulator.	No characters appear on the screen.

Table 7.2.2.1: Data Transfer Testing

7.3 Android Application Software Testing

The graphical user interface (GUI) software will have two types of requirements to meet: functional requirements and non-functional requirements. Variety and large amount of tests can help finding the weak parts of the system and optimize them to reduce the risk of system failure. To ensure that all of the requirements are met, tests will be conducted by all of the group members on their android phone. This will ensure that software correctly operates across variety of android versions.

Test procedures will be written and provided in this documentation. When the whole system is built and ready to be tested, the software testing will be conducted according to these instructions. Functional requirements will describe software required behavior in terms of specific activities. Non-functional requirements, in other words quality performance, will describe some quality attributes that our software should possess. After performing software tests and comparing outcomes with expected results, we will be able to verify whether we built the right system that specifies user needs or not.

Before the user can start testing the system, the automated honey extractor should be loaded with frames and powered up. The user could establish connection between the smartphone and the Bluetooth before starting the application. Initial pairing of the two devices is not part of the software requirement and will not be discussed in this testing procedure.

Testing procedures for system’s functional performance and expected results are described in Table 7.3.1.

Test No.	Requirement	Procedure	Expected Result
1.	User shall be able to start the application.	Select the application.	The application is opened.
2.	The system shall be able to automatically discover the Bluetooth.	Start the application.	The system automatically detects the Bluetooth device and prompts the user for permission to turn it on.
3.	The system shall be able to connect to a Bluetooth module.	Start the application. When prompted to connect to a Bluetooth device select the 'Yes' button.	The phone and the RN41 Bluetooth are now connected.
4.	User shall be able to start the automated honey extractor.	Start the system by pressing the Start button on the graphical user interface of the software.	Automated honey extractor's inner part started spinning at default speed.
5.	User shall be able to manually increase/decrease rotational speed of the center part of the honey collector.	Adjust spinning speed setting on the graphical user interface.	Rotational speed increased/decreased.
6.	User shall be able to view data collected from honey collector sensors.	The data from the sensors will appear at the startup of the application.	The data is displayed on the screen.
7.	User shall be able to stop the automated honey extractor.	Press the Stop button on the graphical user interface of the software.	Automated honey extractor's inner part stopped spinning.

Table 7.3.1 Software Functional Requirements Test Procedures

The testing procedures for the system's non-functional requirements such as the graphical user interface operation verification, good system availability and performance, compatibility with at least one version of Android OS and operational longevity are described in Table 7.3.2, as well as the expected results to each testing.

Test No.	Requirement	Procedure	Expected Result
1.	Graphical user interface operation verification.	Make sure all the GUI features function properly by navigating around the application.	No misleading buttons, user control selections applied in the application.
2.	Good system availability and performance	Perform steps listed in Table 7.4.2	At any point of run-time system's responses shall take no longer than 10 seconds
3.	Compatibility with at least one version of Android Operating System (OS) version 4.0.3 or later	Download the application on a device running Android version 4.0.3 OS or later	The system is up and on the device
4.	Operational longevity	Have the system up and running for at least 6 hours.	The system controls shall be functional during operational time. The system shall not crash, or shut itself down abruptly at any time.

Table 7.3.2 Software Non-Functional Requirements Test Procedures

7.4. Testing the Motor

7.4.1 Initial Testing

After the purchase of the motor, the motor will be first tested for basic functionality. It will be plugged into a regular wall outlet to see if it turns on. If it does work, it will then be connected to other parts of the project. If it does not work it will be replaced and this test will be done again with the new motor.

7.4.2 Intermediate Testing

After the motor has passed the initial testing, it will be connected to the Speed Control Unit, and to the MCU, however it will not be mounted onto the extractor yet. This testing include a:

- Check connection between motor and power supply.
- Check connection between MCU and motor
- Check if the Manual Speed Control Unit is able to control the speed of motor
- Check if the motor can be controlled wirelessly.
- Check lowest RPM of motor
- Check highest “safe” RPM of motor
- Check the autonomous motor controlling sequence

The motor will not be mounted onto the extractor until all these checks produce positive results.

7.4.3 Final Testing

After passing both the initial and the intermediate testing, the motor will be mounted onto the extractor adjacent to the vat, and after testing all systems that involve the motor we will observe how the extractor behaves, we will decide if the motor will stay in that position or it will be mounted above the vat depending on how stable the extractor will be. (Refer to “Mounting the Motor” section for more details.) Also after deciding the exact positioning of the motor, we will assemble the entire extractor and test at which motor speed the honey will be extracted the most efficiently and for how long the motor should be spinning in order to extract the honey. The obtained data will go into improving the autonomous motor controlling sequence.

7.5. Testing the Heating System

7.5.1 Testing the Heating Element

7.5.1.1 Initial Testing

After the purchase of the heating element it will undergo a basic functionality test, to check its basic heating functionality. It will be connected to a twelve volt DC power supply and checked if the elements work as advertised. If the elements appear to be heating up the way they are designed to do, they will then be connected to other parts of the project such as the temperature sensor and the microcontroller. (For further testing information check “Testing the Entire Heating System” section)

7.5.2 Testing the Entire Heating System

7.5.2.1 Initial Testing

Each individual part of the heating system will undergo its testing first (refer to each section for detailed testing plan for each part). After each individual part is tested and confirmed to be functioning, the testing of the heating system will go to the next stage.

7.5.2.2 Intermediate Testing

After connecting the heating elements to other parts of the project, these are the tests that will be conducted:

- Check if there is a connection between the power supply unit and the heating elements
- Check if there is a connection between the temperature sensor and the MCU
- Check if the MCU is able to control the temperature of the heating elements based on the readings received from the temperature sensors
- Check minimum temperature
- Check maximum "safe" temperature
- Check if the heating system can work autonomously

7.5.2.3 Final Testing

After passing both the initial testing and the intermediate testing, the heating system will be installed onto the extractor. After it installation, the heating system will be rechecked and observations will be made. After the entire extractor is assembled, the extractor will be loaded with honey frames and all systems will be checked. During this stage of testing, the optimal temperature in order to increase the honey flow will be recorded and programmed into the automatic extraction sequence.

7.6. Testing the Sensors

7.6.1. General Sensor Testing Ideology

Before the sensors will be implemented into the design, each sensor will be tested through a series of tests to verify their functionality according to the specifications. First of all, every sensor will have to be checked if it works properly. Then, the sensors will be verified if they work according to the datasheet graphs and other data. For example, to verify whether the temperature sensor works, an environment of fluctuating temperature should be created and the output of the sensor should be read for any differences.

If the temperature sensor is a thermistor, for example, the output resistivity will be according to the temperature changes. The resistivity can be simply measured by a resistance meter. The rest of the sensors will be tested in a similar fashion.

Before any tests all sensors have to be verified for functionality through monitoring output changes in either voltage, resistance, or current according to a specific sensor. A diagram of the general sensor testing ideology can be found below.

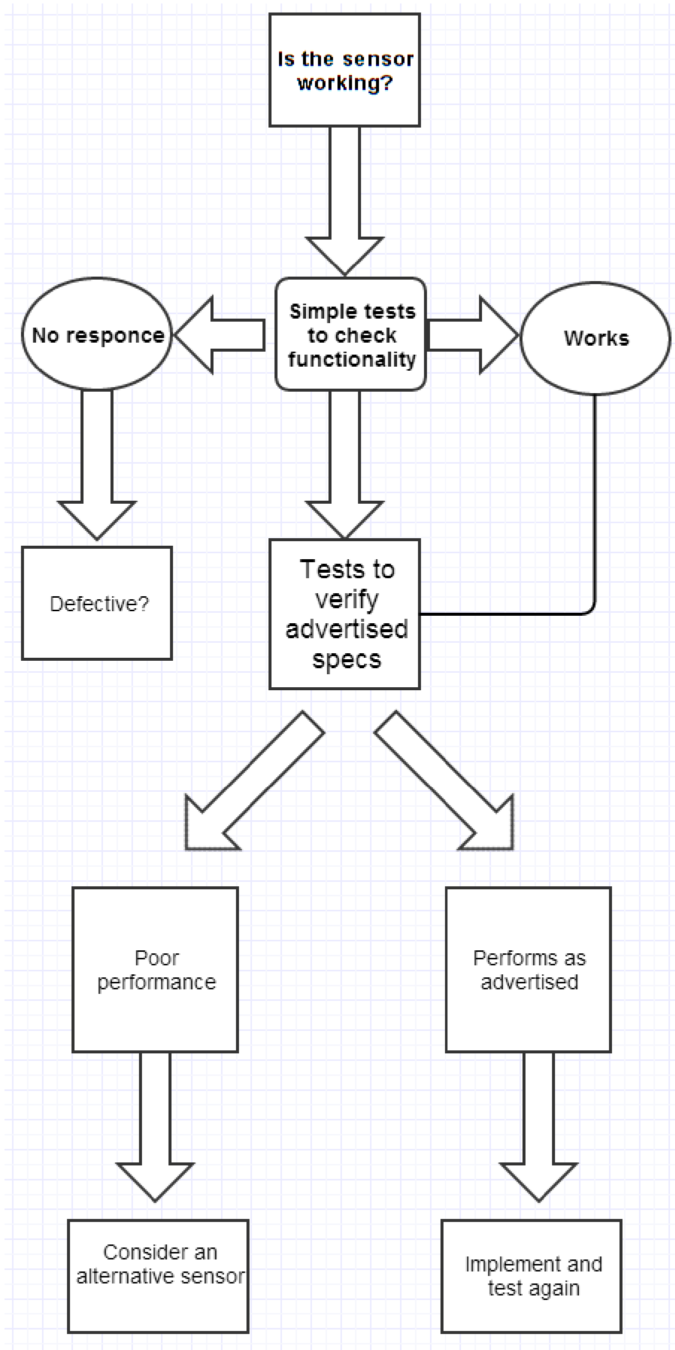


Figure 7.6.1.1: General Sensor Testing Ideology

7.6.2. Weight Sensor Test

Before the weight sensor is implemented into the entire design, first, it will have to pass a series of standalone tests as described in the general sensor testing ideology section.

Before going through serious tests, first, the weigh sensor will have to pass a simple test which checks if the sensor is functional or not. The idea of this test is as follows:

1. Connect the sensor outputs to a voltage amplifier
2. Connect a voltage meter from the voltage amplifier
3. Apply some weight to the weight sensor
4. The resistance should decrease as more weight is applied or voltage should change accordingly

If the sensor passes the above third step, most likely, the unit is functional and is not a defective one.

If the FMT donut shaped weight sensor will be acquired, the connections are shown below in Figure 7.6.2.1.

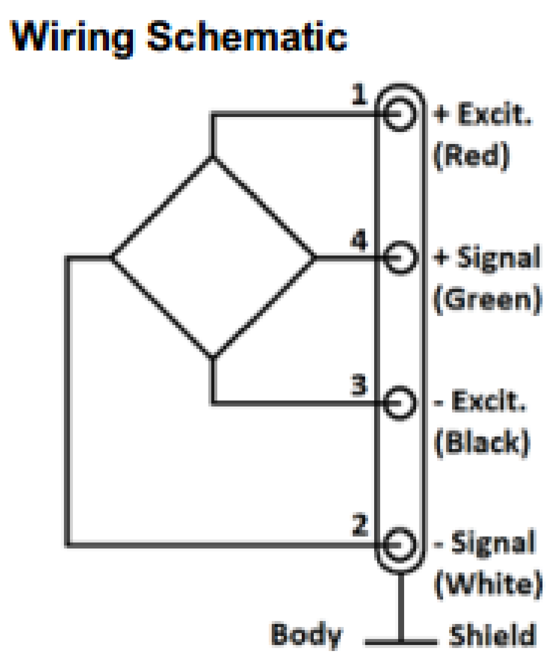


Figure 7.6.2.1 – Wiring Schematic of FMT Sensor

Permission granted from Meas-spec

As can be observed from the above figure, the FMT sensor operates using the Wheatstone bridge principle. The wires numbered 4 and 2 (figure 7.6.2.1) – the signal wires are the ones that will be connected to the microcontroller. Wires 1 and 2 are just excitation inputs necessary for the signal voltage differences to occur when weight is applied or removed from the sensor.

The idea of the second test is to perform a precise test – verify the measured values correspondence with the actual weight within a degree of error according to the sensor's specifications. This test will be performed according to the following procedure:

1. Connect the outputs of the sensor to the breadboard
2. Feed the outputs through a voltage amplifier
3. From the voltage amplifier connect the wires to the microcontroller analog inputs
4. Write a code that will convert the voltage into actual weight using the formulas in the datasheet
5. Write necessary code for establishing a wireless connection between the android device and the microcontroller
6. Use the android device as a monitoring device for the current test to read the weight applied to the sensor values
7. Compare the reported values from the sensor with the actual weight applied to it

Once the weight sensor passed all the tests and showed positive results, the next and most important test is to integrate it into the system and test it again. Once the weight sensor is mounted into the honey extractor it should be connected to the development breadboard and then to the microcontroller, the microcontroller will communicate with an android device and report the measured data from the sensor. The weight sensor is an analog weight sensor. The output of the weight sensor should be amplified on the breadboard and then connected to the microcontroller's analog input.

Test Description	Outcome	Comments
The weight sensor is mounted or implemented into the system. The honeycomb frames full of honey are weighed before they are inserted into the extractor. The weight is read from the sensor through an android device.	Does the weight of the frames match?	If the weight does not match, was the frame holder weighed correctly before inserting it to the extractor? Does the frame holder have support from the body of the extractor that directly affects its weight measured by the sensor?
The extractor is on, the frames are spinning.	Does the weight sensor register the weight loss? Could the weight loss ratio be calculated or	Is the system stable while it is spinning? The jumps from the steady decreasing values could

	does the sensor report false values, i.e. jumps from the steady decreasing values?	be caused by system instability. Work on system stability and balance should be done if that is the case.
Before the sensor is completely tested, the system cannot rely on sensor's information when to stop the process. Once the frames are rotated for a long enough time, in order to verify that all of the honey is out of the frames, the system is stopped.	Is the value reported by the sensor at its lowest throughout the entire process?	The weight reported by the sensor at this point of time should be at its lowest. If that is not the case, the sensor's calibration could be off and needs recalibration, or the above suggested problems could be still present in the system.
The weight of the empty frames along with the frame holders is measured and recorded through the weight sensor. The frame holders' mass is subtracted from that value. Then the frames are pulled out of the system to be weighed on a different scale	Do these values match?	If the values matched for previous tests, the weight sensors calibration might be off. Possible solution – recalibrate the sensor.
Repeat the process with different sent of honeycomb frames.	Is this test similar to the previous one? Do the values match within a degree of error from the sensor and from the standalone scale?	The tests should be repeatable within a degree of error that could be calculated from the sensors accuracy specification from table 7.6.2.1

Table 7.6.2.1– Weight Sensor Final Test Steps

7.6.3. Temperature Sensor Test

The MLX90614 infrared temperature sensor is factory calibrated with a digital PWM and SMBus (System Management Bus) output. This makes it easy to test and also ready for testing.

The temperature sensor as well as the weight sensor, should be tested before it is implemented in the system. According to the general sensor testing ideology section, the temperature sensor has to pass a series of standalone tests. Before going through those tests, a simple test to check sensor's functionality should be performed. The steps of this test are as follows:

1. Connect the sensor to the breadboard
2. Connect a voltage meter to the corresponding pins (refer to figure 3.2.1.1.1 and table 3.2.1.1.3 for pin description)
3. Change the temperature of the sensor
4. Monitor voltage differences as the temperature of the sensor is changed

If the sensor passes the above third step, most likely, the unit is functional and is not a defective one.

The idea of the second test is to perform a precise test – verify the measured values correspondence with the actual weight within a degree of error according to the sensor's specifications. This test will be performed according to the following procedure:

1. Connect the outputs of the sensor to the breadboard
2. Feed the outputs through a voltage amplifier
3. From the voltage amplifier connect the wires to the microcontroller analog inputs
4. Write a code that will convert the voltage into actual weight using the formulas in the datasheet for the microcontroller
5. Write a necessary code for establishing a wireless connection between the android device and the microcontroller
6. Use the android device as a monitoring device for the current test to read the weight applied to the sensor values
7. Compare the reported values from the sensor with the actual weight applied to it

Once the temperature sensor passed all of the tests above and showed positive results, the next and most important test is to integrate it into the system and test it again. Once the temperature sensor is mounted to the honey extractor it should be connected to the development breadboard and then to the microcontroller, the microcontroller will communicate with an android device and report the measured data from the sensor. The temperature sensor is an analog temperature sensor. The output of the temperature sensor should be amplified on the breadboard and then connected to the microcontroller's analog input.

Test Description	Outcome	Comments
The temperature sensor is mounted or implemented to the system. The heater should be functional at this point, but not yet controlled using the temperature sensor. Temperature is measured using a regular thermometer not used in the design for verification purposes. The temperature is read from the sensor through an android device.	Do the temperatures match read from both sensors?	The infrared temperature sensor might be off due to the spinning of the frame holders.
The extractor is on, the frames are spinning. Measure temperature using both sensors, the infrared sensor and a regular thermometer for verification purposes.	Compare the temperatures reported by both sensors.	Make sure the infrared temperature sensor does not point to the spinning part of the extractor.
Before the sensor is completely tested, the heater control cannot rely on sensor's information. Control the heater by manually increasing the current. Heat the system to the maximum temperature point and measure the temperature again by both sensors. Thermometer is used for verification purposes again.	Compare the temperatures reported by the infrared temperature sensor and the thermometer.	The temperature accuracy of the infrared sensor should remain throughout a wide range temperature change. Make sure the sensor is not pointed directly to the heating element.
Repeat the test again after a while to make sure the sensor remains calibrated.	Make sure the results are repeatable compared to the initial test.	Temperature differences should not exceed the marginal error for stable and reliable system performance.

Table 7.6.3.1: Temperature Sensor Final Testing Procedure

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Supplies						
External supply	V_{DD}		4.5	5	5.5	V
Supply current	I_{DD}	No load		1.3	2	mA
Supply current (programming)	I_{DDpr}	No load, erase/write EEPROM operations		1.5	2.5	mA
Zener voltage	Vz	Iz = 75…1000µA (Ta=room)	5.5	5.7	5.9	V
Zener voltage	Vz(Ta)	Iz = 70…1000µA, full temperature range	5.15	5.7	6.24	V
Power On Reset						
POR level	V_{POR_up}	Power-up (full temp range)	1.4	1.75	1.95	V
POR level	V_{POR_down}	Power –down (full temp range)	1.3	1.7	1.9	V
POR hysteresis	V_{POR_hys}	Full temp range	0.08	0.1	1.15	V
V_{DD} rise time (10% to 90% of specified supply voltage)	T_{POR}	Ensure POR signal			20	ms
Output valid (result in RAM)	Tvalid	After POR		0.25		s
Pulse width modulation[1]						
PWM resolution	PWMres	Data band		10		bit
PWM output period	$PWM_{T,def}$	Factory default, internal oscillator factory calibrated		1.024		ms
PWM period stability	$dPWM_T$	Internal oscillator factory calibrated, over the entire operation range and supply voltage	-10		+10	%
Output high Level	PWM_{HI}	I_{source} = 2 mA	V_{DD}-0.2			V
Output low Level	PWM_{LO}	I_{sink} = 2 mA			V_{SS}+0.2	V
Output drive current	$Idrive_{PWM}$	Vout,H = V_{DD} - 0.8V		7		mA
Output sink current	$Isink_{PWM}$	Vout,L = 0.8V		13.5		mA

Table 7.6.3.2: IR Temperature Sensor Electrical Specifications

Permission granted from Melexis

7.6.4. Humidity Sensor Test

The humidity sensor as well as the weight and temperature sensors, should be tested before it is implemented in the system. According to the general sensor testing ideology section, the humidity sensor has to pass a series of standalone tests. Before going through those tests, a simple test to check sensor's functionality should be performed. The general testing procedure steps of this test are as follows (note: refer to figure 7.6.4.2 and explanations of the capacitance-to-frequency circuit):

1. Connect the humidity sensor to the breadboard
2. Connect the voltage pin to a 5 volt power supply
3. Connect the data pin to a voltage amplifier if necessary
4. Connect the data pin to the voltmeter
5. Connect the ground pin to the second node of the voltmeter
6. Read the voltage as the humidity environment changes

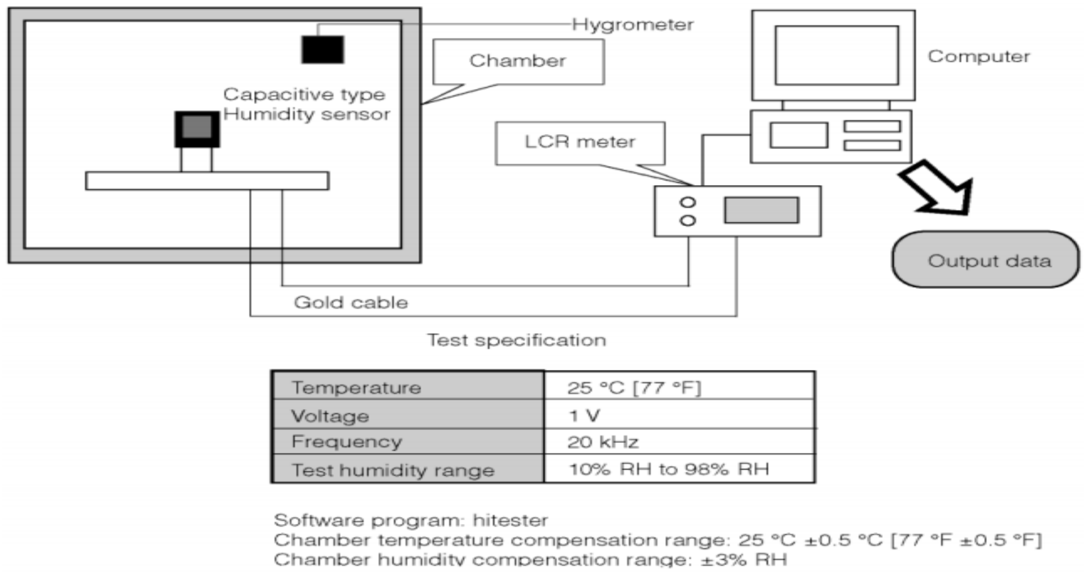


Figure 7.6.4.1: Humidity Sensor Environmental Test System Diagram

Permission granted from Honeywell

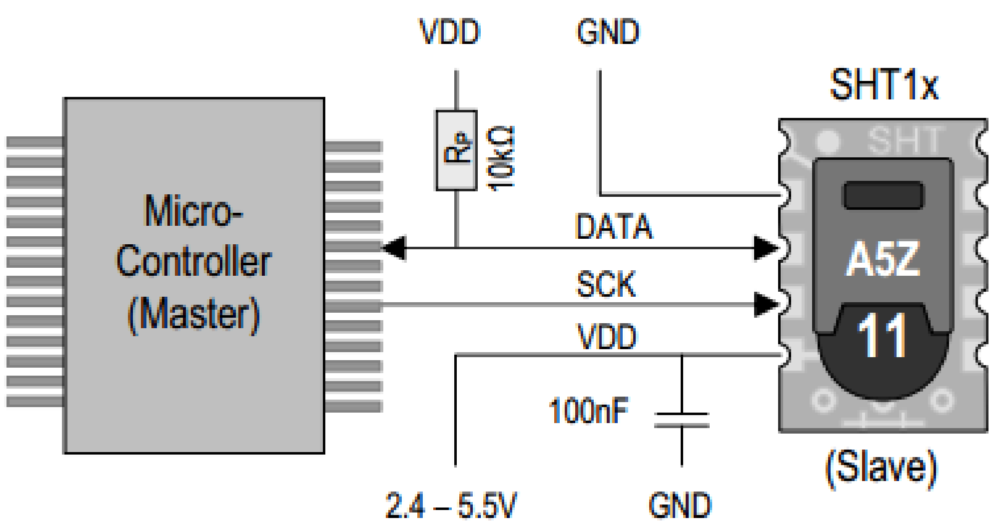


Figure 7.6.4.2: Connecting Humidity Sensor to the Microcontroller

Permission granted from Sensirion

Since the HCH-1000-002 humidity sensor is capacitance type sensor, step five above of the general testing steps procedure cannot be applied without special circuitry.

There are two common circuitry additions used in order to be able to convert the capacitance changes to the actual humidity changes [2].

The first one is called a capacitance-to-frequency conversion circuit as shown in Figure 7.6.4.2 below:

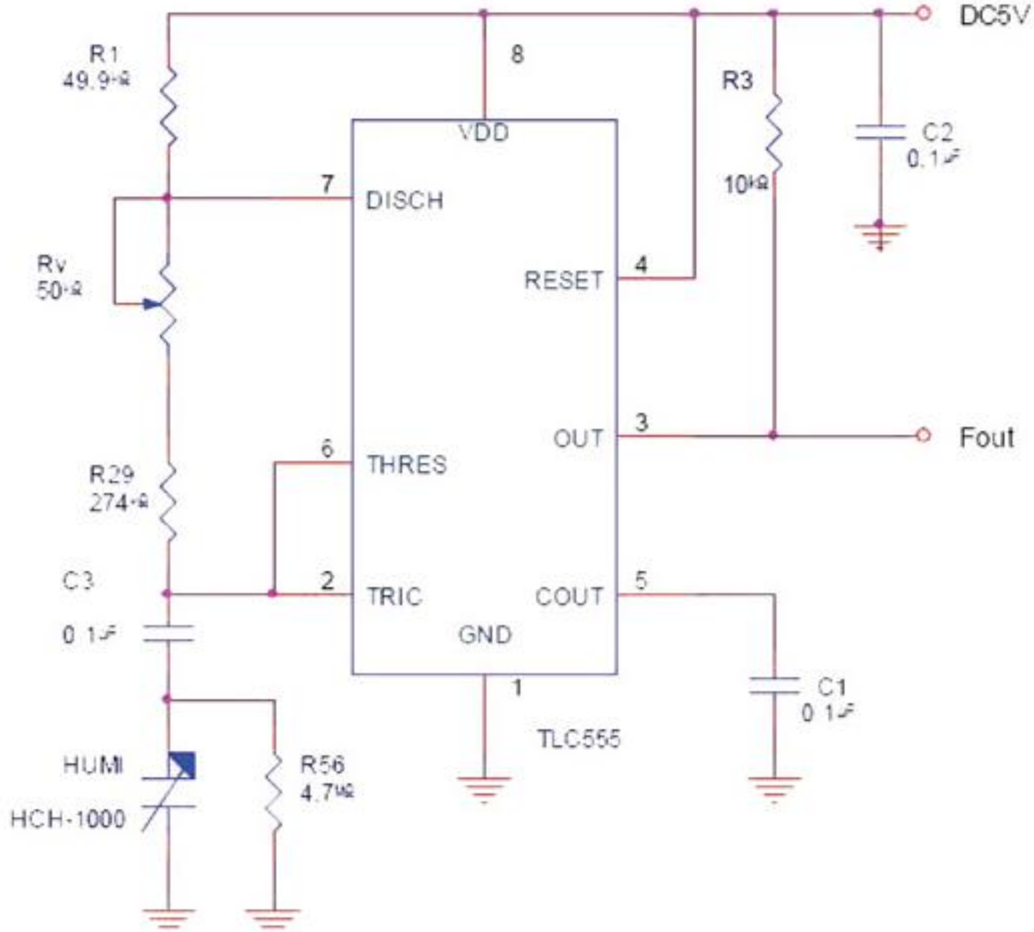


Figure 7.6.4.2 – Capacitance to Frequency Circuit

Permission granted from Digi-Key

For the above capacitance to frequency circuit, a 555 timer could be used. It is a simple integrated circuit device and is very small in size (source). Once this circuit is applied, a small program for the microcontroller will be written to count the frequency changes and output the relative humidity percentage measured by the sensor.

The second method to derive the relative humidity measurements is to convert the capacitance changes from the sensor to voltage differences. This is generated by two 555 timers (source).

If the sensor passes the third step, most likely, the unit is functional and is not a defective one.

The idea of the second test is to perform a precise test – verify the measured values correspondence with the actual humidity levels within a degree of error according to the sensor's specifications. This test will be performed according to the following procedure:

1. Connect voltage pin to the 5 volt output of the microcontroller
2. Use the 555 timer chip to convert capacitance to frequency/voltage
3. Connect the data pin to the analog input of the microcontroller
4. Connect the ground pin to the ground of the microcontroller
5. Before proceeding to step 6 read how to calibrate the sensor section
6. Write the necessary code for the microcontroller to count and convert the frequency changes outputted by the sensor to actual humidity levels using the calibration technique provided in the humidity sensor calibration section.
7. At this point the wireless link between the microcontroller and the android device should be established
8. Necessary code written for the android device to receive data from the microcontroller about the humidity levels should be functional at this point
9. Compare the results with a different complete humidity meter device.

Once the humidity sensor passed all of the tests above and showed positive results, the next and most important test is to integrate it into the system and test it again. Once the humidity sensor is mounted to the honey extractor it should be connected to the development breadboard and then to the microcontroller, the microcontroller will communicate with an android device and report the measured data from the sensor. The humidity sensor is an analog humidity sensor. The output of the humidity sensor should be amplified on the breadboard and then connected to the microcontroller's analog input if an amplifier is necessary.

Test Description	Outcome	Comments
Mount the humidity sensor to the honey extractor. Connect it similarly as described in the previous test. Read the values from the android device. Measure the humidity sensor with a different humidity meter.	Do the humidity levels match?	Testing the humidity inside the system should be any different from as testing it alone. Make sure the sensor maintains its accuracy throughout a long period of time.

Table 7.6.4.1: Humidity Sensor Final Testing Procedure

Once all the steps of the testing are done the sensor should be compared to the following graph below (Figure: 7.6.4.4).

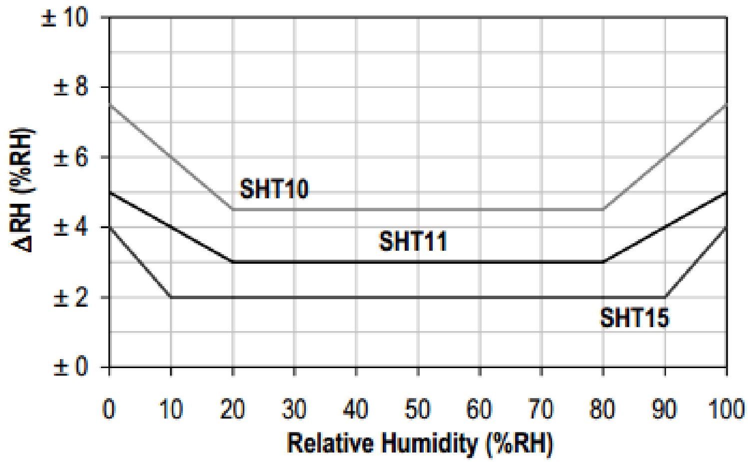


Figure: 7.6.4.5: Humidity Sensor Performance

Permission granted from Sensirion

Pin	Name	Comment
1	GND	Ground
2	DATA	Serial Data, bidirectional
3	SCK	Serial Clock, input only
4	VDD	Source Voltage
NC	NC	Must be left unconnected

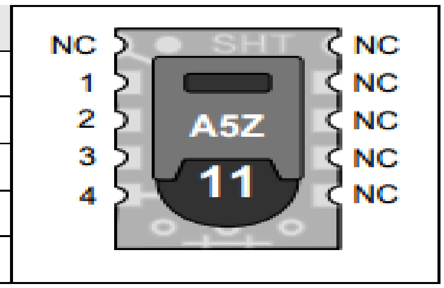


Figure: 7.6.4.6: Pins of the Humidity Sensor

Permission granted from Sensirion

7.6.4.1. Calibrating the Humidity Sensor

Tricks can be done to reach near 0% and 100% humidity at home or lab environment [1].

To do this, the following things will be needed:

- Paper towels
- Robber band
- Plastic bag

To reach 0% humidity, put the paper towel in an oven for an hour. This will dissipate all the moisture from the paper. Then, put the paper towel together with the sensor in the plastic bag. Wait for the sensor to reach the lowest value and record this value. Remember to refer to the datasheet of the humidity sensor for the operation range specification. For example, the HCH-1000-002 sensor's operation range is about from 10% RH to 95% RH.

To reach near 100% humidity, pour boiling water on the paper towel and put it in the bag along with the sensor. Make sure the terminals do not contact the moisture of the paper towel. Record the highest value read by the sensor.

7.7. Circuit board testing

Once the circuit board has been assembled, it will need to be tested in order to confirm functionality. Testing of circuit boards will first consist of an optical inspection. The optical inspection consists of simply looking at the solder joints through a magnified lens. Things to check for during this process include raised pads on the solder joint, shorted pad knees, and shorted pads. 7.7.1 shows an example of a bad solder joint. A connection may be possible on this joint, but it may break in the event of a shifted chip of other mechanical disturbance. Other tests that will be done during the optical inspection is inspection of proper placement of the parts.

After an optical inspection is done, an electrical inspection will be required. A digital multi meter will be used to check for shorts, and make sure that there are open circuits where appropriate and closed circuits where appropriate. Once this test is passed, the board will be powered on with a current limited supply. The supply will slowly be cranked up to allow for more current to be let into the system. Once the voltage level has stabilized to operating voltage the power supply on the board will be assumed functional. The next step is to test the functionality of the microcontroller.

7.8. Micro Controller Testing

Once all of the components are in hand, they must be tested on the microcontroller unit. The testing will be done on a development board, more specifically the FreeSoC. As you can see from the figure, all of the pins are broken out so that they can easily be connected to using male headers. This will allow for an ease of implementation of our sensors and other interface devices.

7.9. Human Interface Device Testing

The human Interface device will be the first peripheral unit to be tested. With the functionality of this unit verified, interface to other devices would be possible. The LCD screen will display information from the sensors, and the touch buttons will allow the user to interface with the peripheral devices. The testing will be done using the FreeSoC board. The seven pins required to interface to the LCD will be plugged in, and the buttons with their pull up or pull down resistors will be connected. The first test will be to verify the screen is outputting characters. This will be done by a project written for the PSoC that scrolls text across each pixel in the LCD. The second test will be to verify the functionality of all of the buttons. This will be done by writing a simple project that will show which button is pressed. After the human interface device is tested, then other parts of the system will be ready to test.

7.9.1 Temperature Interface Test and Calibration

The temperature sensor's interface will be a more difficult sensor to test. The connections to the MLX90614 will be made as shown in a figure previously and the appropriate signals will be sent across the connections. An oscilloscope will measure the signal coming off of the sensor. An example of how to measure the temperature along with the equation to compute temperature is shown in figure 7.9.1.1. The calculated temperature will be compared with a measurement taken from a hand held infrared temperature sensor.

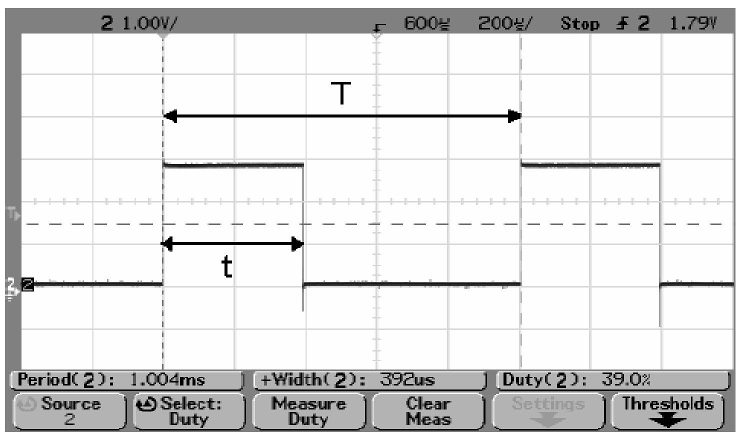


Figure 15: PWM example single mode

$$T_{O\_MIN} = 0°C \rightarrow T_{O\_MIN}(EEPROM, 0x01) = 100 \times (T_{O\_MIN} + 273.15) = 27315d = 0x6AB3$$

$$T_{O\_MAX} = 50°C \rightarrow T_{O\_MAX}(EEPROM, 0x00) = 100 \times (T_{O\_MAX} + 273.15) = 32315d = 0x7E3B$$

Captured PWM period is T = 1004µs
Captured high duration is t = 392 µs
Calculated duty cycle is:

$$D = \frac{t}{T} = \frac{392}{1004} = 0.3904 \text{ or } 39.04\%$$

The temperature is calculated as follows:

$$T_O = 2 \times (0.3904 - 0.125) \times (50 - 0) + 0 = 2 \times 0.2654 \times 50 = 26.54°C$$

Figure 7.9.1.1: Example of Temperature Sensor Reading Using the Melexis MLX 90614.

7.9.2 Humidity Interface Test and Calibration

The humidity sensor will also present a challenge to test. The sensor that was chosen is a passive capacitive response sensor. This means that its capacitance changes with humidity and temperature. There are two possible options to measure this feedback. The first is to use the PSoC's Cap Touch module. The built in module will simply be placed into a test project and the analog response (capacitance) will be displayed on the LCD. The values measured will then be compared to actual values measured for another humidity sensor.

The second way to test the capacitance will be to set up a simple RC circuit. A pulse will load the capacitor, and then be removed. The time that the capacitor drains will determine the capacitance due to the formula shown in figure 7.9.2.1. These values will also be compared to values obtained from form another humidity sensor.

$$V(t) = V_0 e^{-\frac{t}{RC}}$$

Figure 7.9.2.1: Ideal equation for capacitive decay.

R is resistance in units of Ohms, C is capacitance in units of Farads, t is time in units of seconds, and V is voltage in units of volts

7.9.3 Weight Sensor Interface Testing

The weight sensor chosen consists of a Wheatstone bridge. The best way to test resistivity on the Wheatstone bridge is to use an instrumentation amplifier. The instrumentation amplifier is preferred over other amplifiers because of the high input impedance. This high impedance measurement will insure that the measuring device doesn't interfere with the resistive Wheatstone bridge.

The Wheatstone bridge will be implemented using the PSoC's integrated Operational Amplifiers. Off chip resistors will be used to tune the amplifiers to a reasonable gain. The signal will then be sent to a high resolution analog to digital converter, where the signal is digitized. The signal will then be read and calibrated using measured values for actual weight and measured response values. These values will be fit to a linear model of the sensor's response

7.9.4. Motor Controller Interface Testing

The motor controller will be a variable frequency drive motor controller. This motor controller is only for alternating current motors because it uses digital signals to recreate an alternating current operating at different frequencies based on motor speed. The motor controller will use a serial communication protocol. To test the controller, commands will be sent to the unit while an Alternating current is connected to the input of the device. An oscilloscope will be connected to the output via a high voltage probe. A high voltage probe will be used so the oscilloscope will not be damaged. The output signal will be measured and verified for each different motor controller command. The LCD screen will display the motor power and theoretical frequency. The input buttons will be used to select the different operating frequencies.

After the commands appear to correlate to frequencies correctly, the AC motor its self will be connected to the motor controller. The motor will also cycle through the frequencies to test if it is capable to move. The motor will then be subjected to a “burn in” period. This means that the motor will be run at full power for an hour. This time will allow the motor to warm up and verify the motor is not dead on arrival. After the burn in a load test will be performed. A mechanical load will be placed on the motor so that higher current will be run through the motor. The motor will be then subjected through a sweep through the various operating frequencies so that each motor power will be tested under load. After the motor passes all of these tests, then the functionality will be confirmed.

7.9.5. Bluetooth Interface Testing

The Bluetooth interface will be the most difficult part of the project to test. The interface to the microcontroller will be a simple RS232 serial link. The link will be created with the PSoC’s serial module.

To test the communication between the units, a hand shaking packet will be sent. Upon powering on the Bluetooth on the Android device, a packet will be sent to the Bluetooth module to verify connection. The microcontroller will be waiting for the packet, and when it receives it, a handshake packet will be sent back through the Bluetooth module back to the phone to verify the connection.

The LCD display will display which state the microcontroller is in; awaiting connection, or connected. Once connection is established, the microcontroller will send packets containing the sensor information to the android device. The packets will be processed by the Android device and decoded so that the information can be viewed on the screen.

The microcontroller will be awaiting an emergency stop command from the android device in case the motor or the heater needs to stop functioning. The functionality of this feature will also be tested.

A summary of the entire micro controller and human interface testing can be seen in the figure below. The main components which are the LCD display, the Human Interface Device, the temperature sensor, the humidity sensor, the weight sensor, the motor controller and the android interface are divided into separate rows (as seen in the figure). Each one of the have a specific testing procedure.

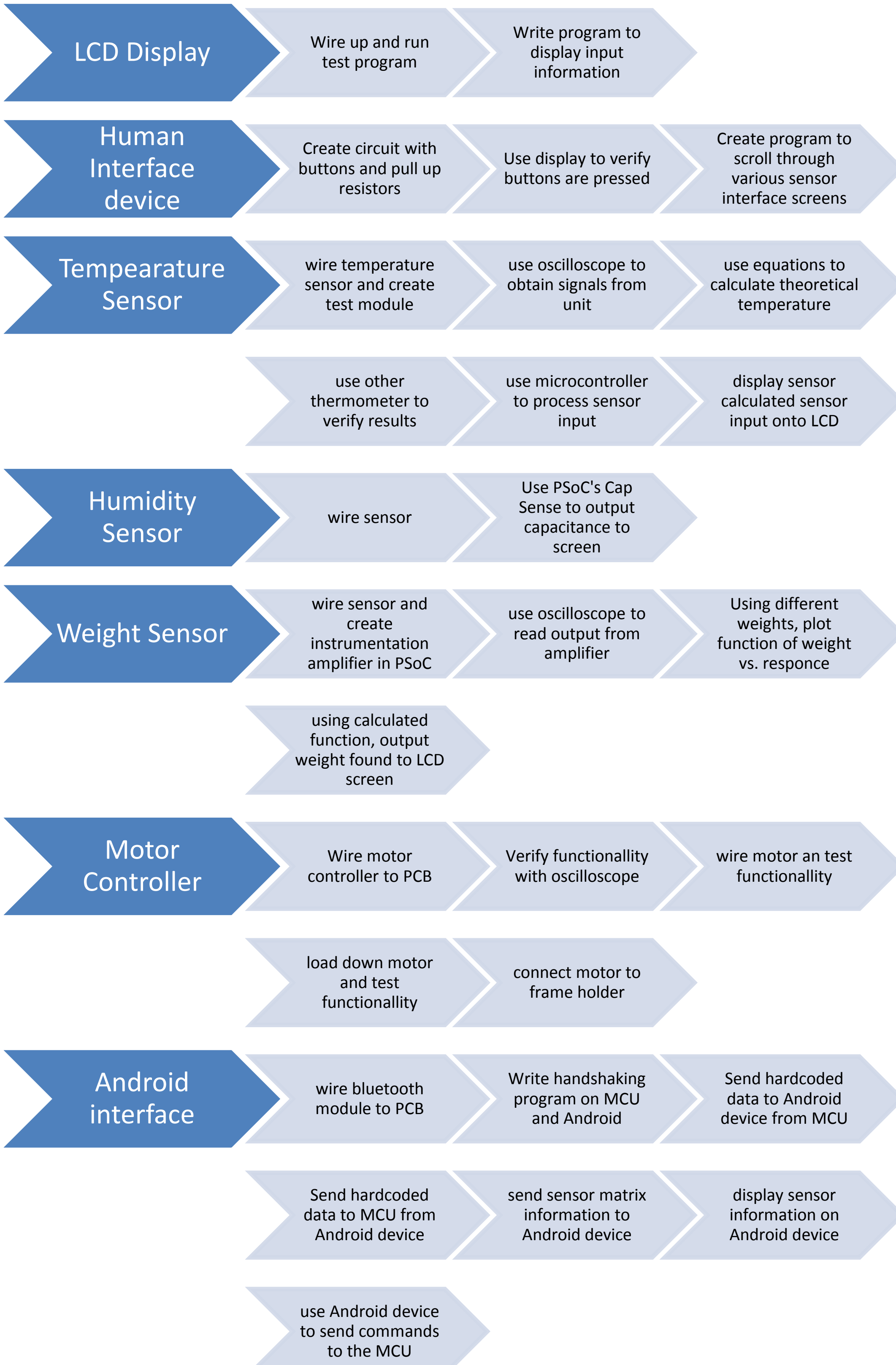


Figure 7.9.1: Testing Summary

7.10. Emergency STOP Testing

Another feature that must be tested is the emergency stop circuit. This circuit is essential to the system as it adds a level of safety to the unit. Without this circuit, the system will be unsafe to use. Testing of this circuit will be simple. First the motor will be powered on. Then the emergency stop switch will be pressed to stop the motor. If the motor comes to a complete stop, then the next phase will be performed. The next phase will be to test the reset switch. Once the motor has safely come to a stop, then the reset switch will be pressed. If the motor returns to power, then the emergency stop circuit can be verified as functioning.

8. Administrative Content

The team will have two semesters to complete the project successfully. During the first semester the team members will split responsibilities and work on their research. Project's design and development will progress through weekly meetings and discussions. The main focus will be given to projects design and documentation.

Good project management is a major factor in success of any project. In order to successfully build an automated honey extractor, allocated timeframe will be broken down into milestones. Every milestone will include an extra allocated time in case if problems arise during development process. If no problems arise during previous phase then the team will start working on the next task and will have more time to complete it.

8.1 Project Milestones

Generally, during the first twelve weeks team members will collaborate with each other on high level design of the project, software and its libraries, what parts and part numbers will be best to use based on specifications and their cost, identifying possible problems during design phase and their solutions, and parts and complete system testing. Research will take large amount of time.

On the software side the research will include the identification of the most suitable platform for wireless communication with the honey extractor. Once the platform is selected the class structure, libraries research and algorithm and GUI design will begin. On the hardware side the research will include research about components, components' specifications and related software for hardware design.

During the second semester the team will be working on building system's working prototype. Ordering parts is the most critical milestone. Without major parts the team will not be able to work on preliminary testing to ensure they work properly. Ordering parts is the very first milestone and will have to be done promptly. Once all parts received preliminary testing will begin. In this phase we need to make sure of functionality of every component of the system before it can be put in the system. Once all the parts were tested the team will be working on putting the system together and testing. By that time the software development will be finished and the system can proceed to testing. Testing is crucial part of system development. During that period of time problems may arise. Some parts may require reorder and replacement. With that in mind 7 weeks were allocated to this milestone.

Table 8.1.1 depicts critical milestones of the project and allocated timeframe for their completion during the first semester. Table 8.1.2 depicts critical milestones and allocated time for their completion during the second semester.

		Senior Design I Summer 2013								
		Jun-03	Jun-13	Jun-17	Jun-24	Jul-01	Jul-08	Jul-15	Jul-22	Jul-29
Research	Bluetooth									
	Temperature sensor									
	Humidity Sensor									
	Motor									
	Weight sensor									
	LCD display									
	Eagle software									
	Android development									
	Solid Works									
	System design									
	System design in Solid Works									
	On-board control panel									
	Microcontroller									
	DC Power Supply									
	AC Power supply									
	Software for bluetooth testing									
	Motor Controller									
	Driver Modules									
Preliminary Testing	Analog-Digital converter									
	Microcontroller									
	LCD display									

Table 8.1.1: Senior Design I Milestones

		Senior Design II Fall 2013													
		Aug-27	Sep-03	Sep-10	Sep-17	Sep-24	Oct-01	Oct-08	Oct-15	Oct-22	Oct-29	Nov-05	Nov-12	Nov-19	Nov-26
Order Parts	Bluetooth	■	■	■											
	Temperature sensor	■	■	■											
	Humidity Sensor	■	■	■											
	Motor	■	■	■											
	Weight sensor	■	■	■											
	LCD display	■	■	■											
	On-board control panel	■	■	■											
	Microcontroller	■	■	■											
	DC Power Supply	■	■	■											
	AC Power supply	■	■	■											
	Motor Controller	■	■	■											
	Driver Modules	■	■	■											
	PCB					■	■	■							
	Honey Extractor Barel	■	■	■											
	Honey Extractor Frames Holder	■	■	■											
Preliminary Testing	Bluetooth				■										
	Temperature sensor				■										
	Humidity Sensor				■										
	Motor				■										
	Weight sensor				■										
	LCD display				■										
	On-board control panel				■										
	Microcontroller				■										
	DC Power Supply				■										
	AC Power supply				■										
	Motor Controller				■										
	Driver Modules				■										
Software	Microcontroller Code	■	■	■	■	■	■	■							
	Android Development	■	■	■	■	■	■	■							
Prototype Testing	Putting together and								■	■	■	■	■	■	■
	Testing Complete System								■	■	■	■	■	■	■

Table 8.1.2: Senior Design II Milestones

8.2 Budget & Financing

8.2.1. Expected Costs

The table below shows the list of parts that will be purchased and their respective prices. The team is prepared for the net total to change due to possible changes in parts, replacement parts due to malfunctioning or incompatibility with the project. During the testing stage the team might look for the alternative parts described throughout the paper. In theory everything works out perfectly, but in practice something might not work and the budget should be flexible enough to allow changes in parts.

Function	Part Number	Cost Each	Quantity	Total
IR temperature sensor	MLX90614ESF-AAA-000-TU	$ 9.56	2	$ 19.12
Microcontroller	CY8C3244PVI-133	$ 5.41	3	$ 16.23
Humidity sensor	HCH-1000-002	$ 4.32	2	$ 8.64
LCD display	NHD-0216BZ-RN-YBW	$ 8.75	2	$ 17.50
Bluetooth (socket module)	RN41SM-I/RM?	$ 45.34	1	$ 45.34
Honey valve		$ 45.70	1	$ 45.70
Valve and strainer		$ 39.99	1	$ 39.99
Weight sensor		$ 62.87	1	$ 62.87
Motor	048S17S25	$ 50.00	1	$ 50.00
Nichrome Wire 14 Gauge 30ft		$ 21.00	1	$ 21.00
Power Supply		$ 15.00	2	$ 30.00
1/2 HP AC Motor		$ 50.00	1	$ 50.00
VFD Motor Controller		$ 100.00	1	$100.00
			Net Total	$506.39

Table 8.2.1.1: Bill of Materials

8.2.2 Financing

Financing for this project will be provided the the Boychev family. The Boychev family will cover costs up to one thousand dollars ($1000), anything over that will not be covered by the Boychev family. If the production of the Automated Honey Extractor will cost more than what the Boychev family is financing, the remainder will be covered by the senior design group, since they did not manage to complete one of the requirements set by the Boychev family. However if the money spent over budget will produce a significantly better product, the Boychev family will cover all of the costs if they deem reasonable.

The device produced by the senior design group, after completion will belong to the Boychev family. If students used their own parts in order to build the device, they may be compensated.

8.3 Advisors

Throughout the process of planning the project our team received advice from a few individuals who have experience from either an electrical background and/or mechanical field background. We value the opinions and the advices from these individuals and we try to give credit for their assistance in this project by mentioning their names and areas we have received advices in or will be receiving in the process of constructing the project in this section of the paper.

Assistance from our advisors is not limited to only the thinking process. Some assistance will be received in the actual construction process. Things like welding the parts together will be done by certified welders who are, in fact, part of the entire group of the advisors.

- Dr. Richie: general advice received about the project. Dr. Richie guides the team in the right direction by giving his opinion on what things or options should be added or left out in the project, which things are practical for the team and which things are not feasible.

- Peter B.: advice received in the mechanical area. Also willing to assist in welding and other mechanical related construction process.

- Dmitry B.: another advisor who assisted the team throughout the thinking process in the mechanical construction area. Also is willing to assist the team in welding and other mechanical related process of construction.

- Dr. Gary Stein: Doctorate in Computer Engineering. Willing to assist in microcontroller programming and Android interface. Previous experience in construction of robotic platforms, as well as sensor interface from various types of sensors

- Jonathan Mohlenhoff: MS in Electrical Engineering. Expert in microcontroller programming. Well versed in several micro controllers including Cypress' programmable system in chip family.

- The Robotics Club

As a team, we appreciate all the assistance provided and that will be provided in the process of construction by the above mentioned advisors and anyone who will contribute to the development of the project. This section of the paper is devoted to them as a way of expressing our appreciation for the time spent assisting the team.

8.4 Facilities and Equipment

Building and assembling the honey extractor will require special facilities and equipment as well as qualified personnel for some parts of the construction process. Open spaced facilities with appropriate ventilation and safety requirements will be used. Some of the most important pieces of equipment that will be used in the project construction are

- Portable welding station along with the welding materials
- Welding mask
- Grinder
- Machines designed for bending metals
- Machine designed for cutting metals.

The welding station will be mainly used to weld the rods to the axle and for other mechanical parts such as the frame holder and the vat. Most of the welding and other mechanical work will be done in privately owned facility with privately owned equipment. Welding work will be done by several certified welders who are also going to assist the team and give advice. Another facility owned by Microflex Inc. might be used for mechanical construction related work if needed.

Another facility that is available for the group to use is the Robotics Club at the University of Central Florida's lab. This lab contains a wide variety of electrical test equipment including but not limited to:

- Soldering stations
- Power supplies
- Oscilloscopes
- Various electronic components.

This facility also contains several machines to aid in the mechanical construction of the honey extractor. The machines include but are not limited to:

- Band saw
- Drill press
- 3-D printer
- Computer numerically controlled mill

Appendix A: References

A-1. Works Cited

[1] Markal. "Discovering Arduino and Fascinating World of Electronics." *Starter Kit RSS*. Starter Kit, 11 Oct. 2010. Web. 27 July 2013.

[2] Taranovich, Steve. "Humidity Sensors and Signal Conditioning Choices." *Digi-Key*. Digi-Key Corporation, n.d. Web. 27 July 2013. <http://www.digikey.com/us/en/techzone/sensors/resources/articles/humidity-sensors-and-signal-conditioning-choices.html>.

[3] White, and Landis W. Doner. "Honey Composition and Properties." – *Beesource Beekeeping*. Bee Source, n.d. Web. 27 July 2013. <http://www.beesource.com/resources/usda/honey-composition-and-properties/>.

[4] Roving Networks. "Bluetooth Data Module Command Reference & Advanced Information User's Guide".[Online]. Available: www.rovingnetworks.com/files/resources

[5] Android.com. "Bluetooth" [Online]. Available: http://developer.android.com/guide/topics/connectivity/bluetooth.html

A-2. Email Requests

Von: dima [mailto:dima@knights.ucf.edu]
Gesendet: Mittwoch, 17. Juli 2013 07:52
An: Info
Betreff: Datasheet SHT1x Permission

Hello,

My name is Dmytro Boichev, I am an electrical engineering student at the University of Central Florida. I am writing a paper for my senior design project and was wondering if I could use your figures of the Datasheet SHT1x humidity and temperature sensor. Here is the link of this datasheet:

http://www.sensirion.com/fileadmin/user_upload/customers/sensirion/Dokumente/Humidity/Sensirion_Humidity_SHT1x_Datasheet_V5.pdf

Thank you.

To: pfg.cs.amer@meas-spec.com;

Cc:

Subject: Datasheet use permission request

Calibri 12

Hello,

My name is Dmytro Boichev, I am an electrical engineering student at the University of Central Florida. I am writing a paper for my senior design project and was wondering if I could use your figures of the **FMT Load Washer Cell and FX1901 Compression Load Cell** in the paper. The source will be specified in the paper. Here are the links to the datasheets:

http://www.meas-spec.com/downloads/FX1901.pdf

http://www.meas-spec.com/downloads/FMT.pdf

Thank you.

Name*:	Dmytro Boichev
Company Name:	
Email Address*:	*** You Must Enter a Valid Email Address for us to reply*** dima@knights.ucf.edu
Phone Number*:	[redacted]
Fax Number:	
Subject:	Cutsheet or Datasheet Request
Request:	Hello, My name is Dmytro Boichev, I am an electrical engineering student at the University of Central Florida. I am writing a paper for my senior design project and was wondering if I could use your figures of the knife gate valve datasheet for the paper. The source will be specified in the paper. Here is the link of this datasheet: http://www.boilersupplies.com/knifegate/model-61.html Thank you.

XZLY6
Enter web form code

XZLY6
reload image

Submit Reset

To: sales_usa@melexis.com;

Hello,

My name is Dmytro Boichev, I am an electrical engineering student at the University of Central Florida. I am writing a paper for my senior design project and was wondering if I could use your figures of the infrared temperature sensor MLX90614 in the paper. The source will be specified in the paper. Here is the link to the datasheet:

http://www.melexis.com/Assets/IR-sensor-thermometer-MLX90614-Datasheet-5152.aspx

Thank you.

dima
Tue 7/30/2013 1:09 PM

mark as unread

To: info.sc@honeywell.com;

Hello,

My name is Dmytro Boichev, I am an electrical engineering student at the University of Central Florida. I am writing a paper for my senior design project and was wondering if I could use your figures of the Datasheet HCH-1000-002 humidity sensor. Here is the link of this datasheet:

http://sensing.honeywell.com/honeywell-sensing-hch1000%20series-product-sheet-000699-2-en.pdf

Thank you.
P.S. The source will be attached to the paper in a professional format.

* Email dima@knights.ucf.edu

Phone

Please select your Industry: Please Select

* Please describe your application and needs in as much detail as possible.

Hello,

My name is Dmytro Boichev, I am an electrical engineering student at the University of Central Florida. I am writing a paper for my senior design project and my team is planning on using your product, so I was wondering if I could use your figures from the user manual of the flexiforce pressure sensor for the paper. Here is the link of this user manual:

http://www.tekscan.com/pdf/FlexiForce-Sensors-Manual.pdf

Thank You.

How did you hear about Tekscan?

- (•) Search Engine
- ( ) Advertising
- ( ) Globalspec.com
- ( ) Trade Show
- ( ) Article
- ( ) Other (please specify):

submit reset

7/26/13 Gmail - RE: School project using your display

> http://www.newhavendisplay.com/specs/NHD-0216BZ-RN-YBW.pdf
>
> Let me know if it would be possible for me to use information from this datasheet in my report.
>
> -Thanks, Brandon Parmeter

A-3. Email Permissions:

John LeDuc <John.LeDuc@digikey.com>

Mon 7/29/2013 11:13 AM

mark as unread

To: dima@knights.ucf.edu;

Bing Maps | + Get more apps

Hi Dmytro,

Yes you can use the information requested below in your paper as long as you credit & reference Digi-Key, The Authors name and company.

Good luck with your senor design project and make sure to give us a call if you need assistance – 800-338-4105

Best Regards,

John LeDuc

John LeDuc
Manager, Technical Content
DIGI-KEY CORPORATION
701 Brooks Ave South
Thief River Falls, MN 56701 USA
john.leduc@digikey.com
800.338.4105 Ext 1173

To: dima@knights.ucf.edu;

- To help protect your privacy, some content in this message has been blocked. To re-enable the blocke
- To always show content from this sender, click here.
- Flag for follow up. Start by Thursday, July 25, 2013. Due by Thursday, July 25, 2013.

Action Items

Dear Dmytro Boichev

Thank you for your interest in our *FlexiForce®* products. In response to your inquiry:

"so I was wondering if I could use your figures from the user manual of the flexiforce pressure sensor for the paper."

We do allow referencing and use of the manual's figures and numbers for educational purposes. Please try to reference back to source.

Please feel free to contact me if you have any questions or need additional information.

Best Regards,

Steve Tran
FlexiForce ® Inside Sales and Technical Support
(617) 464-4500 x337

To: dima@knights.ucf.edu;

Yes

Sent from my iPhone

On Jul 28, 2013, at 12:23 AM, dima@knights.ucf.edu wrote:

>
> Name = Dmytro Boichev
> Company_Name =
> Email_Address = dima@knights.ucf.edu
> Phone_Number = 407-900-5742
> Fax_Number =
> Subject = Cutsheet or Datasheet Request
> Request = Hello,
>
> My name is Dmytro Boichev, I am an electrical engineering student at the University of Central Florida. I am writing a paper for my senior design project and was wondering if I could use your figures of the knife gate valve datasheet for the paper. The source will be specified in the paper. Here is the link of this datasheet:
>
> http://www.boilersupplies.com/knifegate/model-61.html

From: Reto Kleiner <Reto.Kleiner@sensirion.com>
Sent: Wednesday, July 17, 2013 5:32 AM
To: 'dima'
Subject: AW: Datasheet SHT1x Permission, University of Central Florida, US

Dear Mr. Boichev,

Thank you for your e-mail. As long as you mention the source of the data fell free to use the information provided in the datasheet.

Best regards

Reto Kleiner

____

Reto Kleiner
Technical Customer Support

SENSIRION AG
Laubisruetistrasse 50
CH-8712 Staefa ZH
Switzerland

phone: +41 44 306 40 00
direct: +41 44 927 11 44
fax: +41 44 306 40 30
mailto:reto.kleiner@sensirion.com
www.sensirion.com

To: dima@knights.ucf.edu;

Yes

Sent from my iPhone

On Jul 28, 2013, at 12:23 AM, dima@knights.ucf.edu wrote:

>
> Name = Dmytro Boichev
> Company_Name =
> Email_Address = dima@knights.ucf.edu
> Phone_Number = 407-900-5742
> Fax_Number =
> Subject = Cutsheet or Datasheet Request
> Request = Hello,
>
> My name is Dmytro Boichev, I am an electrical engineering student at the University of Central Florida. I am writing a paper for my senior design project and was wondering if I could use your figures of the knife gate valve datasheet for the paper. The source will be specified in the paper. Here is the link of this datasheet:
>
> http://www.boilersupplies.com/knifegate/model-61.html

Peter Riendeau <pre@melexis.com>

Thu 7/25/2013 3:28 PM

mark as unread

To: dima@knights.ucf.edu;

Bing Maps | Get more apps

Permission is granted to use the figures from Melexis datasheet in your paper. Thank you for citing the source of those figures and good luck with your studies.

Sincerely,

Peter Riendeau
Marketing Communications
15 Trafalgar Sq. Suite 100
Nashua, NH 03063
603-204-2907
pre@melexis.com
Website: www.melexis.com

Dan Slavik
Office Phone/Fax +1 973-347-3756
dan.slavik@meas-spec.com

From: Slavik, Dan
Sent: Monday, July 29, 2013 11:29 AM
To: dima@knights.ucf.ed
Subject: RE: Datasheet use permission request

Hello Dmytro,

Thank you for contacting us regarding your request. You can use our specification sheets in your paper as long as the figures are correct as represented and the source is specified as you have indicated.

Best regards,

Dan

Gmail by Google

Brandon Parmeter <brandonleeparmeter@gmail.com>

RE: School project using your display

Brandon Parmeter <brandonleeparmeter@gmail.com> Fri, Jul 26, 2013 at 10:10 AM
Draft To: mlavine@newhavendisplay.com

uOn Jul 26, 2013 9:49 AM, "Michael LaVine" <mlavine@newhavendisplay.com> wrote:

Hello Brandon,

Yes you can use the information from the datasheet.

Good luck with your project!

Regards,

Michael LaVine | Engineering

Newhaven Display International, Inc.

2511 Technology Drive, Suite 101

Elgin, IL 60124

Phone: 847-844-8795, Fax: 847-844-8796

www.newhavendisplay.com

From: Brandon Parmeter [mailto:brandonleeparmeter@gmail.com]
Sent: Thursday, July 25, 2013 9:26 PM
To: nhtech@newhavendisplay.com
Subject: School project using your display

Hello,

I am a student from the University of Central Florida. I am in the process of selecting items items for my senior design project. I am particuarly interested in your LCD display:

Brandon Parmeter <brandonleeparmeter@gmail.com>

School project using your micro controller

2 messages

Brandon Parmeter <brandonleeparmeter@gmail.com> Thu, Jul 25, 2013 at 10:30 PM
To: customercare@cypress.com

Hello,

I am a student from the University of Central Florida. I am in the process of selecting items items for my senior design project. I am particularly interested in your Micro controller:

http://www.cypress.com/?docID=42780

Let me know if it would be possible for me to use information from this datasheet in my report.

-Thanks, Brandon Parmeter

Qin Liu <qliu@cypress.com> Thu, Jul 25, 2013 at 10:37 PM
To: Brandon Parmeter <brandonleeparmeter@gmail.com>, Patrick Kane <pkx@cypress.com>
Cc: customercare <customercare@cypress.com>

Hi Brandon,

Thanks for contacting Cypress Semiconductor.

I copied Patrick Kane who is our University Alliance program director and he may assist you in this inquiry.

Hi Patrick,

Please help below question. Thanks.

Best Regards,

Zinna Liu

From: Brandon Parmeter [mailto:brandonleeparmeter@gmail.com]
Sent: Friday, July 26, 2013 10:30 AM
To: customercare
Subject: School project using your micro controller

[Quoted text hidden]
This message and any attachments may contain Cypress (or its subsidiaries) confidential information. If it has been received in error, please advise the sender and immediately delete this message.

To: sales@hoperf.com;

Cc:

Subject:

Hello,

My name is Dmytro Boichev, I am an electrical engineering student at the University of Central Florida. I am writing a paper for my senior design project and was wondering if I could use your figures of the HH10D datasheet in the paper. The source will be specified in the paper. Here is the link for the datasheet

https://www.sparkfun.com/datasheets/Sensors/Temperature/HH10D.pdf

Thank you.