FINAL YEAR PROJECT 2

FINAL PROJECT REPORT

MICROCONTROLLER-BASED AUXILIARY FAN SPEED CONTROLLER FOR AUTOMOTIVE

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CERTIFICATION OF APPROVAL

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Approved by,

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CERTIFICATION OF OIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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(WAN MUHAMAD IZZUDDIN BIN BORHARUDDIN)

ABSTRACT

Designing a prototype that could simulate the idea concept of microcontroller based auxiliary fan for automotive. The fan should work based on the engine’s temperature, engine’s speed and have the ability to be manually control. Arduino Mega which consists of Atmega1280 as the microcontroller was used in this project. This project involves on developing the small scale simulation prototype where the microcontroller were tested to work with the required sensor before transforming it into real working prototype.

ACKNOWLEDGEMENT

First of all, I would like to extend my gratitude to Allah Lord Almighty for giving me the time, health, ideas and opportunity in completing this project. Without His help, I would never be able to overcome the problem I have faced in doing this project. Next, I am forever indebted to my beloved parent, Borharuddin bin Wan Chik and Norhashimah binti Abdul Rahman for their encouragement and financial support which keep me determined in doing this project. I am also indebted with the knowledge and ideas provided by my beloved Project Supervisor, Dr. Mohd Zuki. Last but not least, to all my dearest friends who are willing to sacrifice their dear time in helping me solving any problem I have faced in completing the project.

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CHAPTER 1 : INTRODUCTION

1.1 BACKGROUND

Generally every vehicle has its own cooling system. Radiator fan is one of it. There are two types of radiator fan which is mechanical and electrical fan. Mechanical fan are also called belt-driven fan. The fan speed was adjusted accordingly based on the engine's speed.

The problem with mechanical fan is it rotates slowly when the cars slow down. This could be in the event of car stuck in heavy traffic jam or waiting for the green light where the engine is in idle mode. This can result in engine overheat as there are no proper ventilation system when the car in slow state as the temperature of engine can exceed the optimum temperature in this situation.

Overheated engine can cause a lot of trouble, other than leaving your car in immobile state; it also cost a lot if it were to be repaired. It would be such a heart beating moment where you need to take a good look over the engine temperature meter to ensure that the engine is in its optimum temperature especially when you stop at the traffic light or stuck in a traffic jam where when the engine runs at low rpm, the belt-driven fan would not move in much air to cool down the engine.

Nowadays there are electrical fan which can overcome the mechanical radiator fan problems. Most of the fan works on by using thermostat. Thermostat acts as a switch that open or closed the valve for the coolant to flows into the radiator which then activates the electrical fan. Although this could overcome the problem by mechanical fan, but there are cases where the electrical fan thermostat stuck because of corrosion where it keeps the fan to be turning on all the time draining the car batteries.

So one of the ways to overcome these problems is by using a microcontroller-based fan where it does not use thermostat. On top of that the flexibility of the system increase as the user or driver can set the turn on temperature and also the fan speed.

1.2 PROBLEM STATEMENT

1. *For vehicle with mechanical stock fan, engine can go overheat especially during traffic jam.*
   During traffic jam or when the car slows down, the stock fan also slows down which cause less air to move into the engine part. This reduces the cooling effect and may lead to overheating of the engine.
2. *There are risk in failure of thermostat causing the draining of car batteries*
   For cars with stocked electrical fan that use thermostat, there are risk of thermostat failure for example the thermostat could not closed the valve which allows the coolant to flows into the radiator causing the radiator fan switch to be always on even when the car is off.
3. *The electrical fan is not that users and developers friendly*
   Most of the electrical fan use thermostat as the switch. For car's manufacturer, they need to make some adjustment on the thermostat to set it to works accordingly with the engine's optimum temperature as for the driver or user, they need to go under the hood to make the adjustment.

1.3 OBJECTIVE

The objective of this project is to design, develop and implement a smart device which has the capability to:

- Detect if the car is on or off mode
- Monitor the vehicle speed
- Monitor the engine's temperature
- Control the speed (on and off) of an auxiliary fan which is to be added to the radiator

In general this project aims to improve the vehicle engine's cooling system.

1.4 SCOPE OF STUDY

1. Working principle of car's engine cooling system
   As the project itself aims to improve car cooling system, so I should have the understanding on how the car cooling system works, where are the weak spot of the system, and which part can be improve.
2. Microcontroller and its programming language
   Microcontroller would be the brain of this device; there are several types of microcontroller such as Arduino, Intel 8051, PIC microcontroller and many more. The suitable programming language for this microcontroller might varied from each other there are several programming language that can be used such as C, C++ and assembly language. To do this project I will study on which type of microcontroller would come in handy considering the amount of input and output provided, the programming language used and the ease of compiling the code into the microcontroller.
3. The suitable sensors that can be used to detect speed and temperature
   In this project, there are two main parameters to be considered which is engine's rpm or the car's speed and the engine's temperature. The end product was targeted to be able to react depending on those two parameters. So choosing the right sensors would result in the achieving the objective.

CHAPTER 2 : LITERATURE REVIEW AND THEORY

2.1 HOW CAR’S ENGINE AND ITS COOLING SYSTEM WORK?

Basically the power were produced by engine through conversion of fuel’s chemical energy to heat energy from the process of combustion[1]. Parts of the total heat produces by the combustion were used to drive the piston downwards so that required power were produced[1]. Some of the heats were carried away through the exhaust valve by the exhaust gas. The engine itself absorbed the remaining heat which causes increment in the engine’s temperature.

The coolant plays its role by absorbing the heat from the engine to bring the temperature back to its normal operating range[2]. Usually, a typical automotive engine cooling system contains of fan, radiator, water pump, coolant reservoir, thermostat, heater core, and necessary plumbing for both the radiator and heater core.

As the engine start, the attached water pump will begins to pump the coolant allowing it to flows around the engine cylinder. The flows start from the lower radiator tank and then go into the coolant passages. The coolant starts to flow from the lower tank and head to engine block. After that it will enter the cylinder head and the final destination would be the passage for the radiator[2].

As the coolant travels, it begins to absorb the heat produced by the combustion process and flows towards the radiator inlet. Thermostat was used to block the flow of the coolant to the radiator. Thermostat acts like a switch which only allows the coolant to go to radiator if its temperature is higher than the engine’s normal operating temperature[3].

Heater core can be said to be a mini radiator which play its role by exchanging heat of the coolant with the flowing air inside the car. On the other hand, the thermostat can also be considered as a valve which uses to control the flow of coolant with coolant temperature as the manipulating variable to determine the opening of the valve. It comprises of a cavity occupied with wax and a rod which is constrained counter to it.

As the coolant passing through the thermostat with a temperature which beyond the normal engine’s operating temperature, the coolant will cause the wax inside the thermostat to be liquefied which in turns move the rod to allow the flow of the coolant to the radiator.

The radiator fans will be activated at the moment where the coolant manages to pass through the thermostat to enter the radiator.

If the coolant manages to pass through the thermostat, it will directly enters the radiator hose and flows toward the radiator upper tank. From the upper tank, the coolant will flow downwards in the radiator. As it flows, it will lose its heat to the air that flowing through the space in the middle of the radiator and the flat tubes. Fan attached at the back of the radiator multiply the effect of cooling down the coolant as it increases the air movement.

2.2 WHAT ARE THE WAY AND SUITABLE TIME TO USE AN AUXILIARY FAN?

The suitable time to use an auxiliary electrical fan is when you notice that your car getting a little hot in traffic jam and when you are running slowly. While sitting in traffic or when you're moving slowly, there is little or no air moving through the radiator. This is because; the belt-driven fan could not move much air as the engine is running on low rpm. As a result overheating of engine can occur as there is not enough cool air to absorb the heat.

One of the ways to overcome this problem is by adding an auxiliary electric fan at the front side of the radiator[4]. There is several ways to install and select the auxiliary electrical fan for efficient usage which is reducing heat. Some of the ways are:

- Selecting an auxiliary fan that could cover the core surface of the radiator as much as possible
- Avoid usage of fully-shrouded electrical fan as the installation would be at the front of the radiator, the shroud would block air flow[5]
- If you have an auxiliary transmission cooler in front of the radiator, you may have to move it forward in the vehicle to mount the auxiliary electric fan directly to the radiator core
- For vehicle with transmission cooler located at the front of the radiator, it should be move frontward in the vehicle to support the auxiliary electric fan straight to the radiator core

Auxiliary fan did really come in handy in reducing engine overheating. This also counts in the cases of off-road vehicle which usually moving slow following the trail, towing vehicles which carry a mass of load especially when they are moving on a steep grade, and delivery vehicles which spend most of the time parked and idling[4].

2.3 INTRODUCTION TO MICROCONTROLLER

Microcontroller integrates CPU, memory, input output interfaces and peripherals into a single chip dissimilar to a PC[6]. Some of us might not come to a sense that most of the electronic device or machines around us use microcontrollers as its brain. As an example washing machine and oven were some of the machine that uses microcontroller.

Microcontroller can be said to be a small computer which compressed as a chip. As a computer it should have its own memory, has the ability to receive input and output and it also can be programmed to work in some logic such as doing calculations. The difference between a microcontroller and a PC is that microcontroller combines a CPU, memory, peripherals and input output interfaces attached to a single chip[2].

There are several microcontroller available at the market for example Arduino Uno, Intel 8051, and PIC microcontroller. This microcontroller varies based on their design. They can have different amount of memory, different number of input output, different pin diagram, different voltage input and also different heat resistances.

2.4 HOW CAR'S SPEEDOMETER WORKS?

Speedometer is a device that shows the speed or rpm of the car. Basically there are two types of car's speedometer which is mechanical and electrical. In order to obtain the speed of a car, we must have the capability to measure the rotational speed of either the transmission or the wheels. Usually the speed measurement was done in the transmission with the help of drive cable[7]. By having the information which the speed, we could send it to some kind of gauge.

When a car is moving at some speed, it will moves along its drive shaft and transmissions with the car's travelling speed. As the mandrel of the drive cable were connected to the transmission, moving car will move along the mandrel. As a result the permanent magnet at the drive cable will also rotate.

The spinning magnet causes the creation of rotating magnetic field. The rotating magnetic field will impose force on the speedcup. As the force implied on the speedcup, it result in a small electrical current flows in the cup. The current flow in small eddies, and it is known as eddy currents. As a result, eddy current established a strain torque which works on the speedcup.

The direction of the cup and its stock needle is equal to the direction of the rotating magnetic field with the limit of the hairspring. With the balance between the force establish by the rotating magnet and the force impose on the hairspring, the needle on the speedcup can come to rest[7].

2.5 HOW AUTOMOTIVE TEMPERATURE GAUGES WORK

We depend on temperature gauges to know the situation or condition of the engine's cooling system. There are two types of temperature gauges which are mechanical and electrical. Mechanical gauge operates with something called Bourdon Tube which is a thin metal comprised of easily vaporized fluid.

Mechanical temperature gauge work based on the expansion of the Bourdon Tube. Basically the expansion of Bourdon Tube will push the coiled end of the tube inside the gauge[8]. As the coil wind down it brings along the movement of the temperature gauge needle with it.

Nowadays electrical temperature gauge would be in common use rather than mechanical. Electrical temperature gauge works by reading the value from the coolant temperature sensor which is located in the coolant passages near the engine. To put it simply it just takes the resistance value from the sensor which the resistance value decreases with the increases in coolant temperature and converts it into the form of temperature.

2.6 ENGINE'S COOLANT TEMPERATURE SENSOR

The Coolant Temperature sensor is a sensor which was usually placed at the coolant passage of an engine which commonly at the adjacent of the thermostat. It works by varying its resistance based on the coolant's temperature[9].

Other than reading the engine's temperature, this sensor is vitally needed in Powertrain Control Module function of a car such as ignition timing, transmission shifting, variable valve timing and fuel injection.

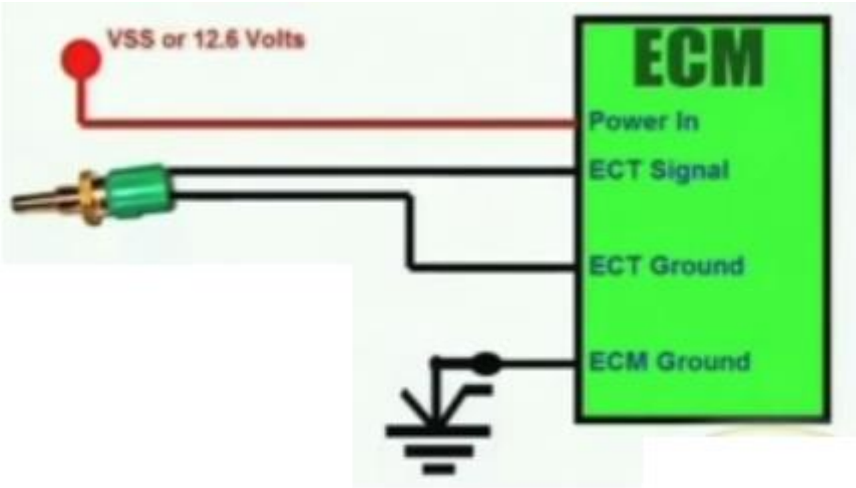

Figure 1: Engine Coolant Sensor Connection Diagram

Engine Coolant Temperature sensors vary based on the type of car. There is no indicator to indicate that which is the best sensor to be used.

2.7 CAR'S COOLING SYSTEM (REAR AND FRONT ENGINE'S PLACEMENT)

Basically there are three types of car engine's placement which is rear engine, mid and front engine[10].The engine of a front-wheel drive cars were usually mounted transversely which result in the output of the engine going through the side of the car. So in this case, the engine could not control the radiator fan directly.

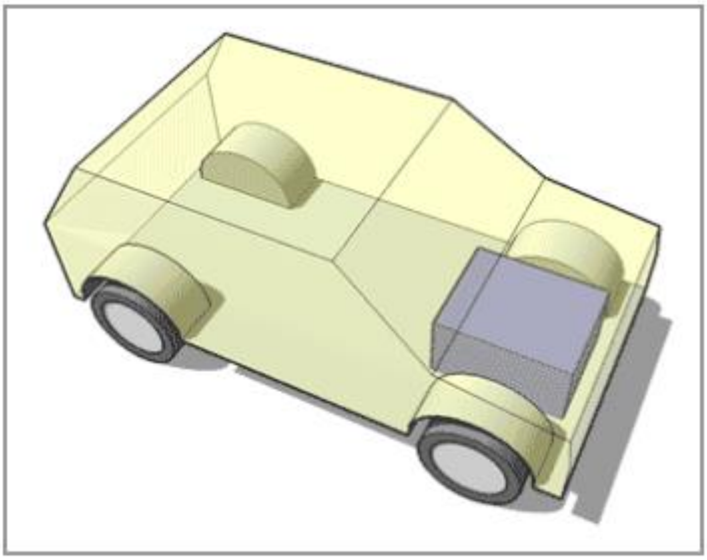

Figure 2: Front Engine's placement

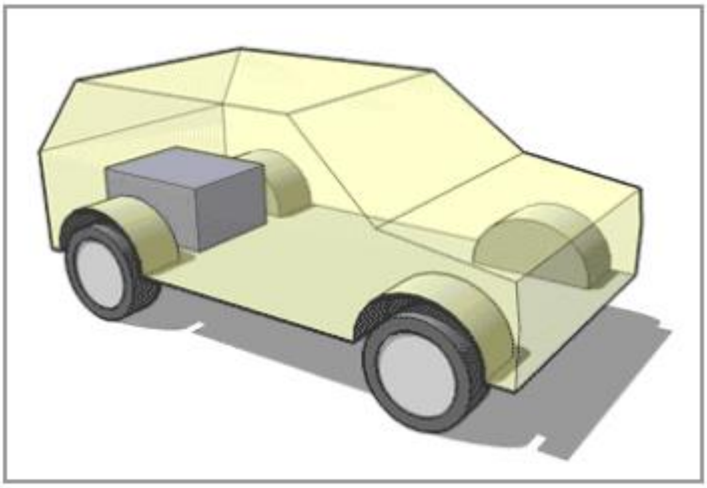

Figure 3: Rear Engine's Placement

As a result for a front - wheel drive car, electric fans were usually mounted rather than mechanical fan. The controls of the fan usually were made via engine's computer system or mostly thermostatic switch. It will be on or off based on the coolant's temperature which if the temperature exceed the engine's normal operating temperature the fan will be switch on and vice-versa.

Unlike front- wheel drive car, rear-wheel drive car comes with longitudinal engines. It can supply its power directly to the radiator fan. Usually a rear-wheel drive car comes with engine-driven cooling fans.

The fan was controlled by a thermostatically viscous clutch which was located at the centre of the fan where air would flow coming through the radiator. Usually this special viscous clutch can be found all-wheel drive cars.

2.8 CAR'S TACHOMETER

A tachometer is a device to measure the engine's rotation or revolution per minute. Wiring tachometer is not that difficult, the black and red wire can be connected to the tachometer and the green wire to the distributor[11]. The setting is simple but not many did understand on the working principle of tachometer. Basically it works by converting the movement into electrical energy so that the driver would know the condition of the engine (the level of RPM), which is quite useful in gear shifting for manual transmission.

Figure 4: Example of car's tachometer

The basic working principle of tachometer is magnetic induction. Magnetic induction happens when you move a magnet in a coil where it results in the creation of electricity or vice versa where you create a magnetic field by allowing electricity to move along the coil that wraps around a magnet. The distributor consists of electrical and magnet sensor which allows the detection of rotor and shaft movement. Increasing the speed of shaft rotation will produce more electrical current as it increase the velocity of the coil.

The electrical current then, will pass through a transistor which actually act as a relay. Hall Effect sensor output both voltage and current in the form of pulses which then recorded by the transistor which result in formation of pre-set burst of current that last around one to three milliseconds. The changes of state (on-off pulse) were important to the tachometer manufacturer as it were used to adjust the inductance coil on the tachometer needle and the return spring that conveys it back.

Initially the current and voltage signal is very weak which it cannot do the work. This where the transistor relay comes in handy which it amplifies the current signal. Basically when the weak signal hit the transistor relay it will closes the main circuit results in the power up of the tachometer needle and induces movement.

CHAPTER 3 : METHODOLOGY

3.1 PROJECT FLOW

The main objectives of this project is to tackle the problem of overheating resulting from inefficiency of mechanical stock fan to work as the car slows down (which can occur in heavy traffic condition or at traffic light) and to increase the reliability of electrical fan by using microcontroller as switch rather than thermostat so the problem of uncontrolled fan's turn on due to thermostat defect can be overcome. To tackle the problem I need to create a device which can detect the speed and temperature of the car and correspondingly give order to the fan to rotate.

To simplify the flow of completing the project, I have divided the project into several stages which is:

1. Stage 1: Creating a microcontroller based fan that works based on temperature
2. Stage 2: Creating a medium for inputting value to control the on/off of the fan
3. Stage 3: Adding LCD display for displaying output and input involved
4. Stage 4: Build or obtain any part or devices that could work the same as car tachometer (signal conversion to a readable value for arduino)

Basically for all the three stages, the project flow chart would be:

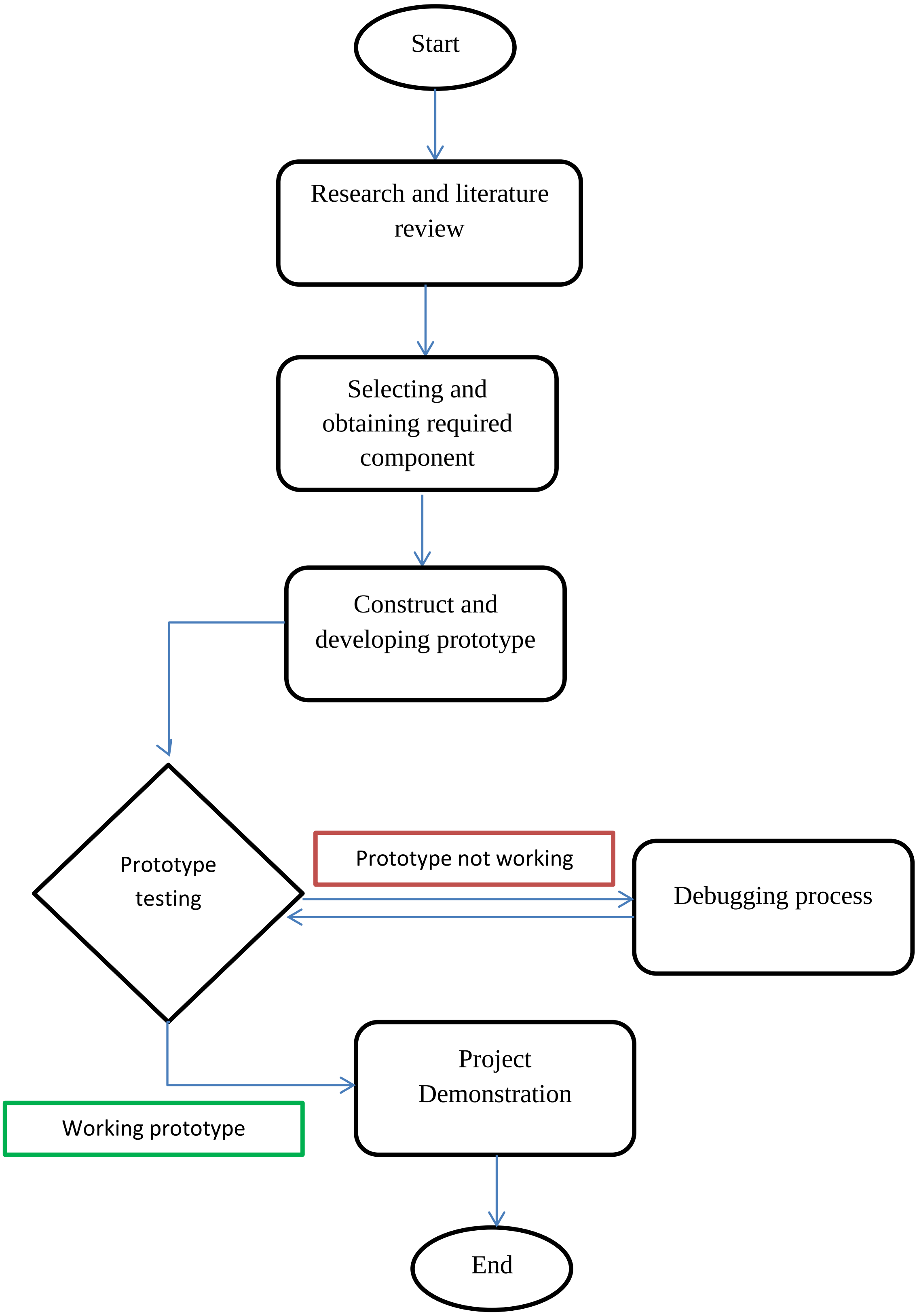

Figure 5: Project stage flow chart

3.2 GANTT CHART AND KEY MILESTONES

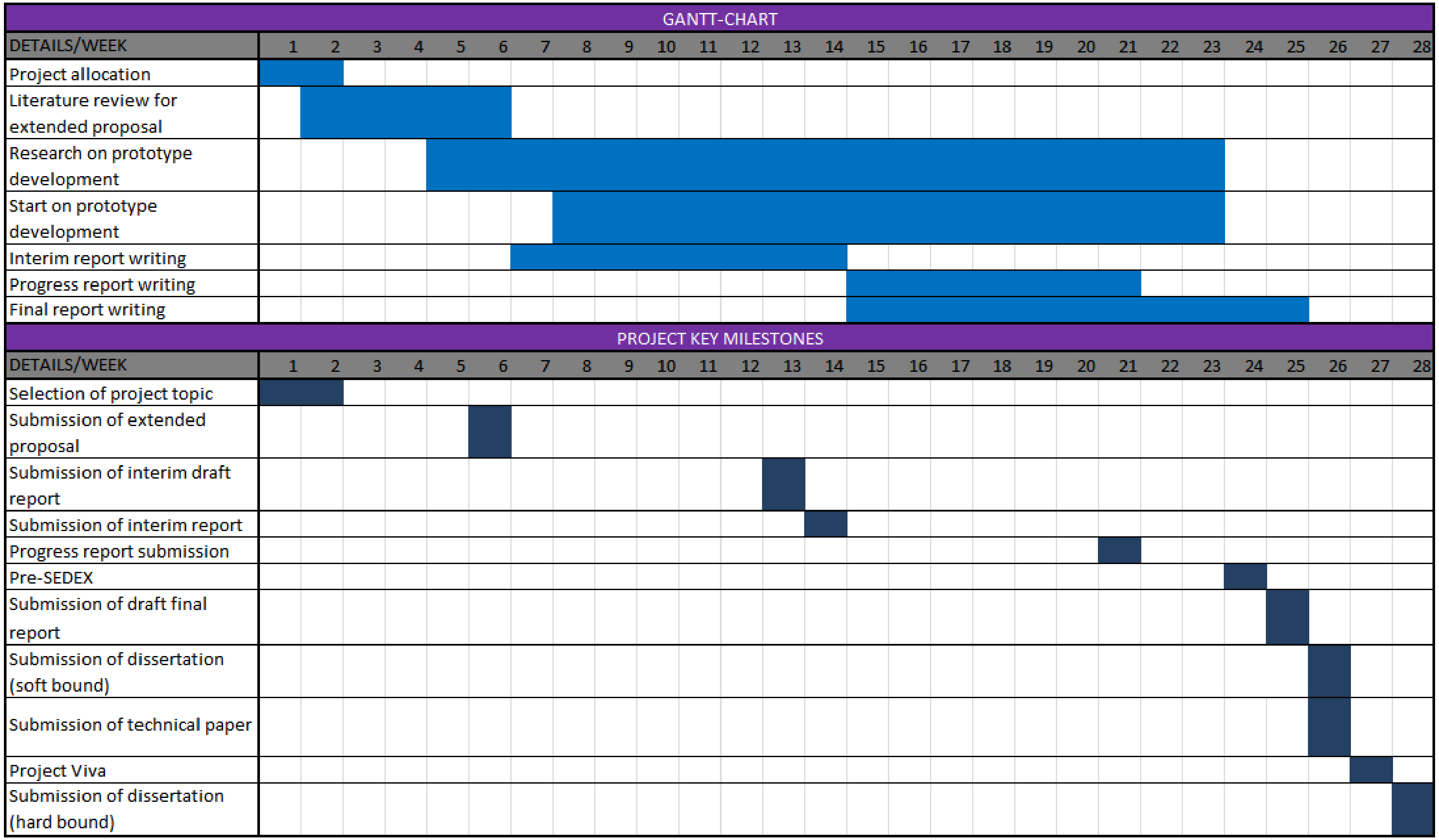

Figure 6: Gantt chart and Project Key Milestones

Based on the above gantt-chart, the “start on the prototype development” section refers to the building of the small-scale concept demonstration prototype. This prototype should have the ability to works based on the suggested concept and it can be transform to a real working prototype with some adjustment.

Basically the small scale concept simulation prototype will consist of this stage:

- Building microcontroller based fan which work with the temperature sensor
- Add the use of keypad to set manually the temperature which initiate the on/off mode of the fan
- Adding feature where the fan work accordingly based on the speed of a small motor

The small scale concept simulation prototype building was initiated as it is cost less, easy to debug, the hazard is not that high as the usage of current is low.

CHAPTER 4 : RESULTS AND DISCUSSION

4.1 MICROCONTROLLER BASED FAN WITH TEMPERATURE SENSOR

As for now I have started on working with the small scale simulation prototype which is the first one :

- Building microcontroller based fan which work with the temperature sensor

For programming code generating and debugging purpose, I have set the fan to be turn on at low temperature which is 29 °C.

The result is as below:

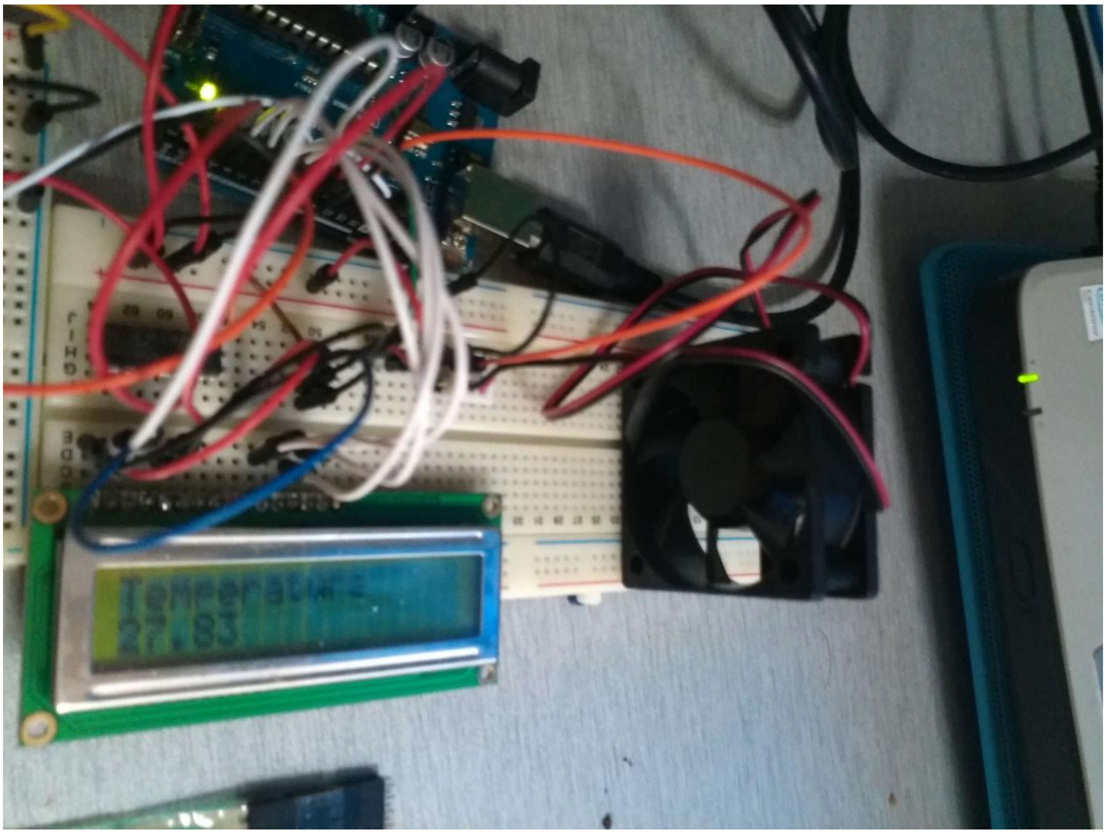

Figure 7: Fan is off when temperature less than 29 °C

From the figure above, we can see that the temperature reading on the LCD is displaying room temperature which is approximately 27°C. We can see from the figure that the fan's blade is held still.

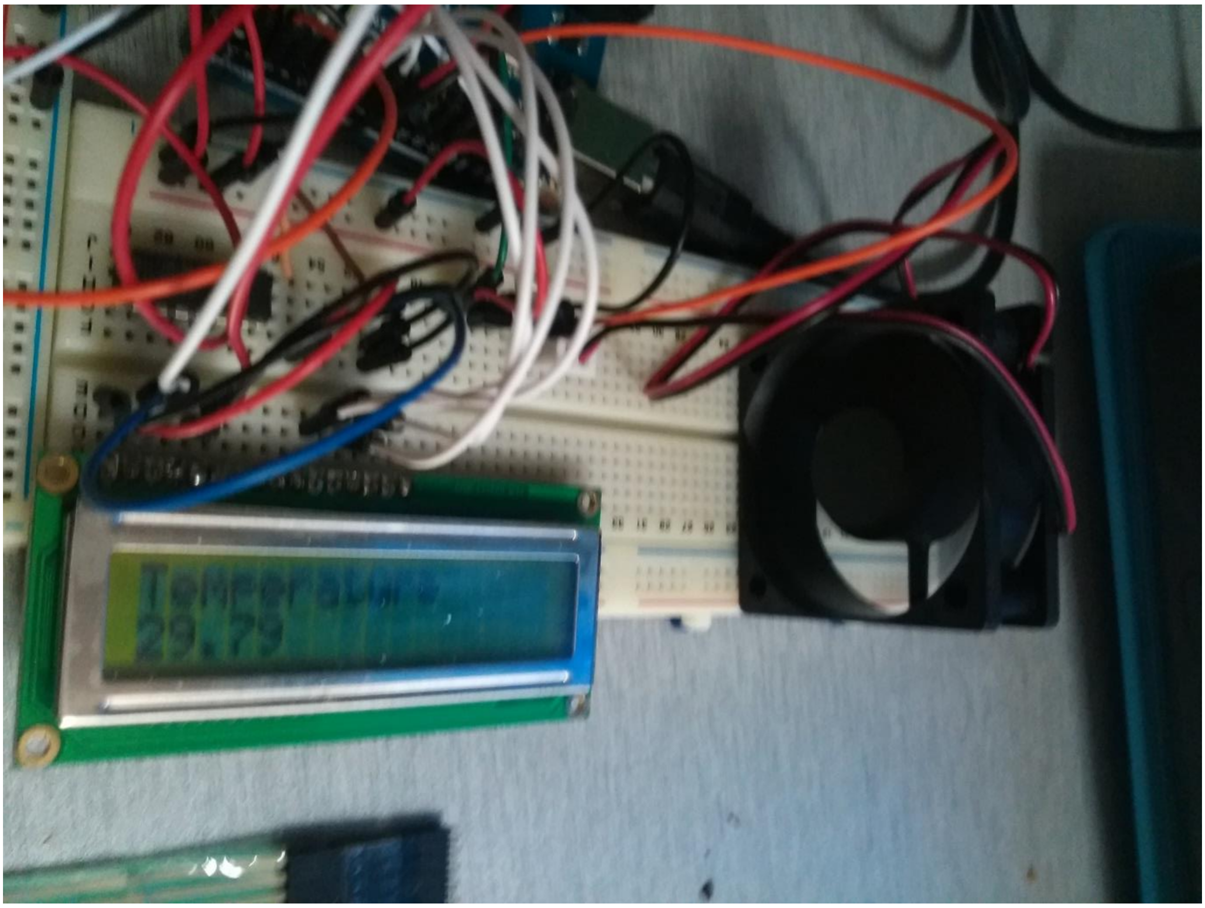

Figure 8: Fan is on when temperature exceed 29 °C

From the figure above, we can see that the temperature reading on the LCD is displaying temperature of 29.79°C. We can see from the figure that the fan's blade is rotating.

The programming was inserted as to direct the microcontroller to take output from the temperature sensor and display it on the LCD. There is also if condition inserted where the microcontroller would turn on the fan if the temperature equal to or exceed 29°C.

From the result, I have should have known that the source code and the components connection are doing fine. The next step would be applying a pulse width modulation as the input of the fan so that the fan speed can be controlled.

Apart from that, I have planned on putting additional features where user can manually set the temperature where they want the fan to be turn on. To do that, I should have added input component such as keypad but unfortunately there are limitation on the I/O port of the microcontroller.

4.2 TURN THE 12VV FAN ON/OFF BY USING TRANSISTOR AS SWITCH

The initial idea was to control the speed of the fan based on the engine's temperature and engine's rpm. Anyhow, it seems that there is no vital need to control the fan speed. So, instead of controlling the speed, we just need to control the state of the fan which is either on or off.

So how can we control the state of a 12V devices using microcontroller which gives out only maximum of 5V output. In other words, we need a 12V voltage source which could not be provided by the Arduino itself. For solving this, I have decided to use outside voltage source combine with the microcontroller which act as switch to control the on or off state of the circuit which is power source to the 12V fan.

To simulate this in a small scale, I have used 12V dc fan and a TIP122 power transistor:

Figure 9:12V DC fan and TIP122 Power Transistor

Circuit configuration:

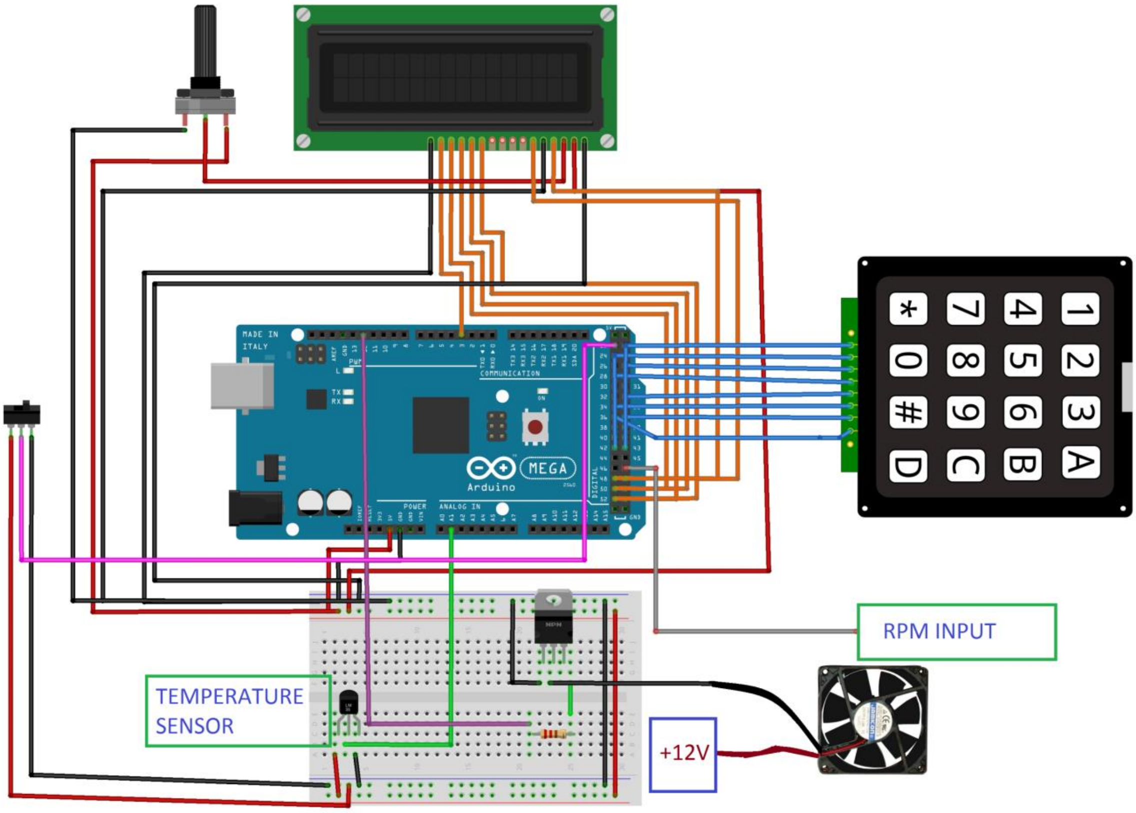

Figure 10: Circuit configuration for 12V external supply

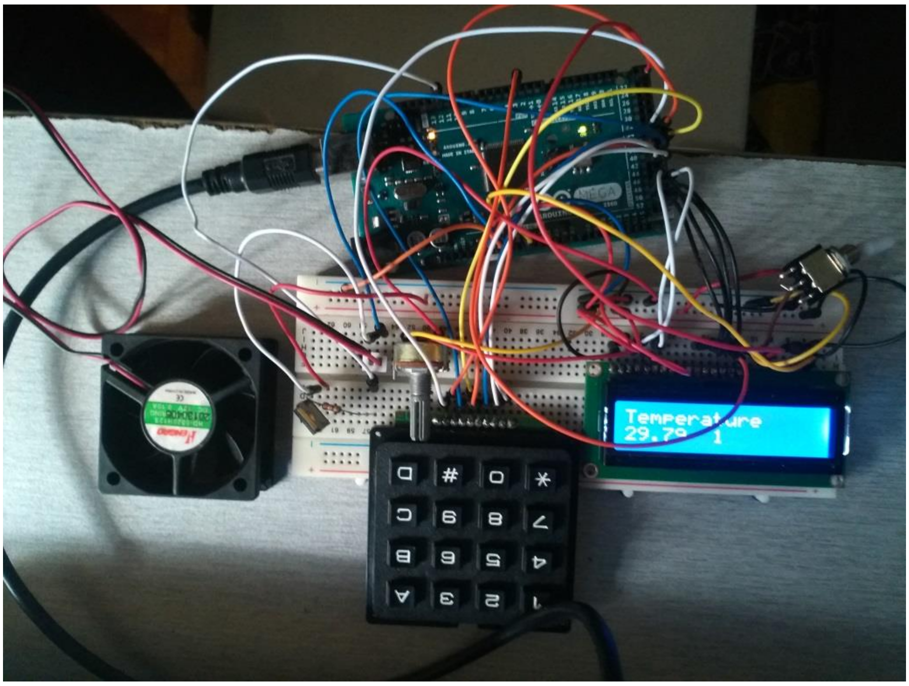

Figure 11: Fan off when temperature less than 30°C

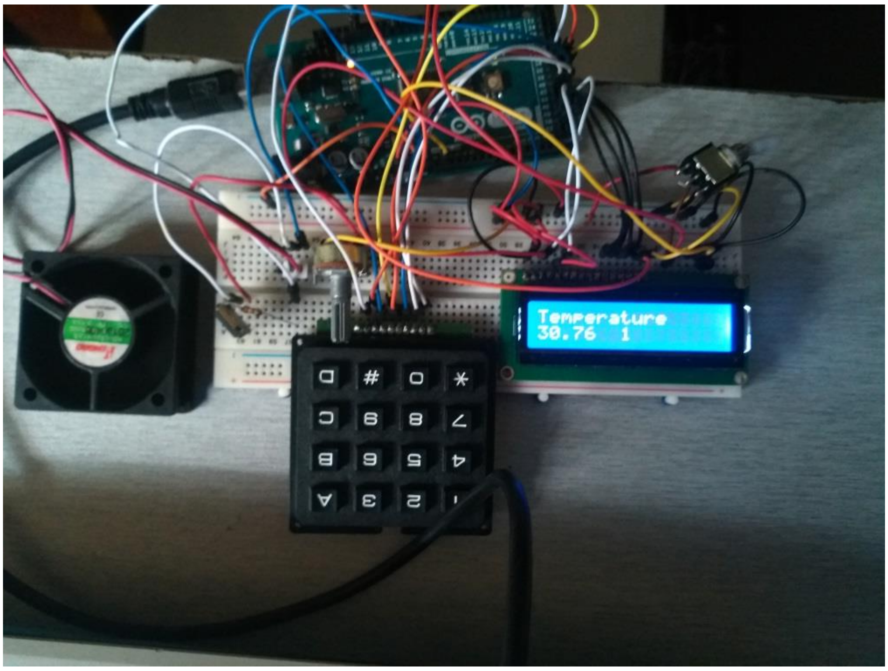

Figure 12: Fan off when temperature more than 30°C

The battery was replaced by Arduino’s Vin pin. The thing’s work well. So for the prototype, the TIP122 power transistor can be replaced with the radiator’s fan relay which basically doing the same job.

4.3 USING KEYPAD AS AN INPUT MEDIUM

Initially the on state temperature of the fan was predetermined in the coding itself as 30°C. One of the things need to be achieved in this project is allowing user to input temperature which determined the on/off state of the fan. To allow this 4x4 keypad was chose as the input medium. In the process of doing this, Arduino Mega 2560 was chose to be used rather than Arduino Uno as Mega contains more input pins to support extra input need for he keypad.

Figure 13: 4x4 keypad use as an input medium to the Arduino

4x4 Keypad was chose as it contains extra letter which is 'A','B','C', and 'D' rather than 3x3. We can set the letter to hold a mode such as 'A' was used to set the on temperature, 'B' was used to set the on engine's rpm, 'C' was used to turn on/off the fan regardless of the condition and 'D' was used to keep the fan works accordingly based on the condition. Meanwhile the '*' button can be used as erase input button and '#' can works as enter input button.

4.4 READING INPUT FROM KEYPAD

I have browsed through a few example of using keypad as an input to Arduino. There are few examples related to Arduino keypad project such as Reading Keypad value and digital code lock. I have found that digital code lock program have this 3 elements which are, read input from keypad, store the inputs and display them. This could come in handy for me in developing the code's to do those three task, which I can just modified from the digital code lock project. This is the flowchart of the read keypad project:

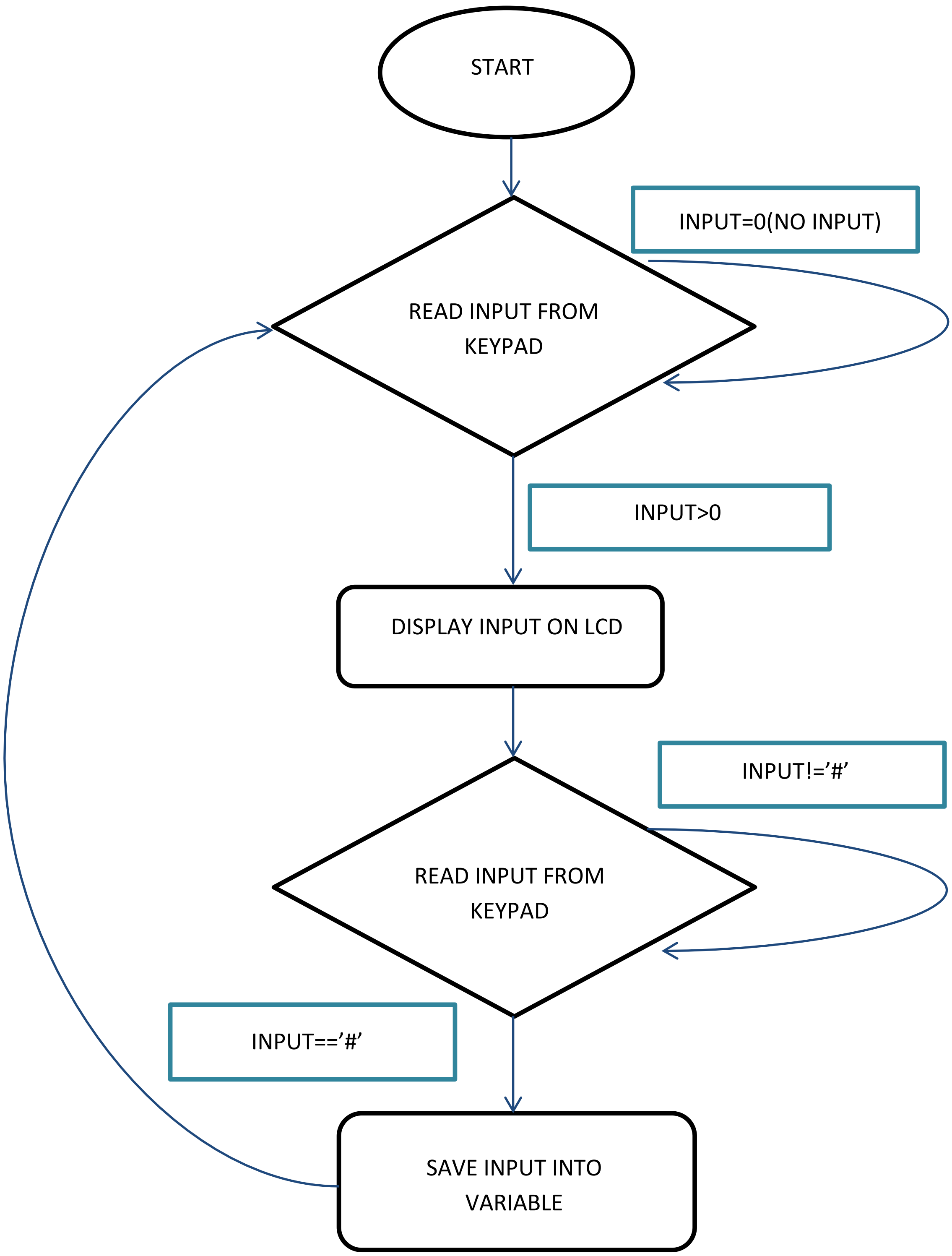

Figure 14: Keypad input flowchart

Figure 15: When '4' then '0' was pressed

Figure 16: When '#' was pressed

4.5 CHANGING LCD MODE

Initially the Liquid Crystal Display (LCD) only displays the temperature which was updated every second. With the addition of keypad input, we need to interrupt the display temperature function to setup mode which is from this:

Figure 17: LCD display temperature every one second

To this:

Figure 18: LCD display goes to setup mode

The problem face in achieving this is, if delay of one second were put to take the temperature reading every one second it will also delay the reading of keypad input receive in one second. In other words, if we push the keypad, it will not eventually go to setup mode unless we hit the keypad on the right time which is approximately one second after the temperature reading. The initial coding was:

```
if (mode==0)
{

   if (key != NO_KEY && key!='#')
  {
   mode=1;
   lcd.clear();
   delay(100);
  }
  else
  {
   showtemp(tempfan(ontemp));
  delay(1000);
  }
```

Figure 19: Part of coding (switch mode initial coding)

As stated above, if it is in 'else' section, it will take that 'delay(1000)' to run before it try to read if there is any button pushed on the keypad. One of the methods in trying to solve this is changing the delay to 0.1 second. But then, comes another problem where the temperature keeps changing every 0.1 second which is not the demanded output.

Currently, I have resorted in a solution where I take direct external input which were not affected by the delay rather than taking internal input which have to go through all the process with delays. Here is part of the modified code:

```
void loop()
{
  mode=digitalRead(inPin);
  tempfan(ontemp);
  if (mode==1)
  {
    showtemp();
    delay(1000);
  }
  else
  {

    readKeypad();
    delay(100);
  }
```

Figure 20: Part of coding (switch mode coding)

From the coding, there is 'mode=digitalRead(inPin)' which the loop will constantly read the value of 'mode' regardless of all the delay in the loop. Toggle switch was used to control the input to the 'inPin' so that it can change value from zero to one or vice versa.

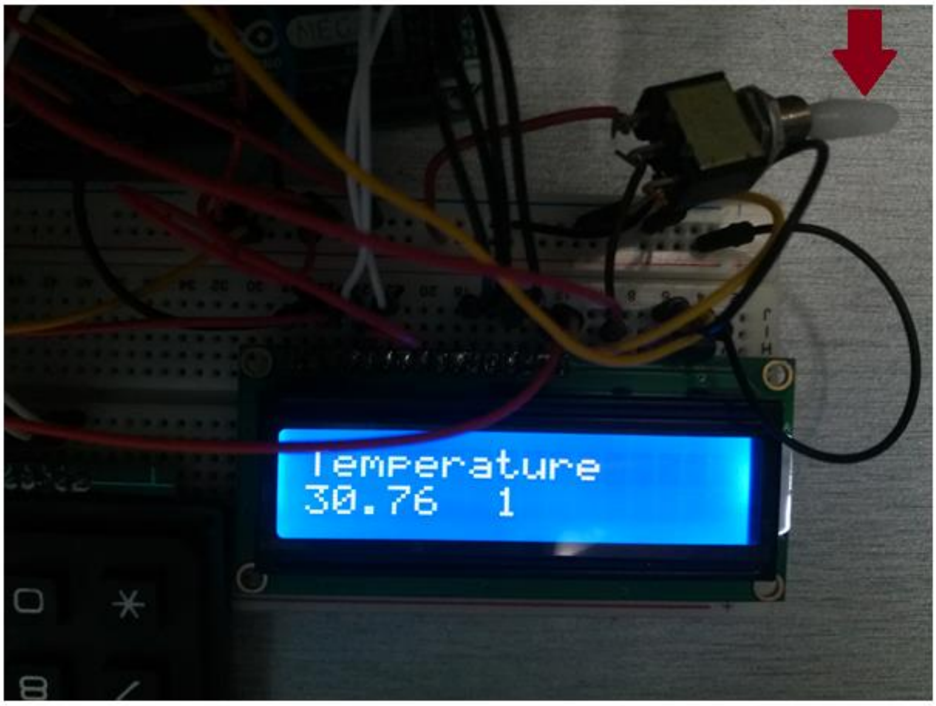

Figure 21: Switch mode using toggle switch (display mode)

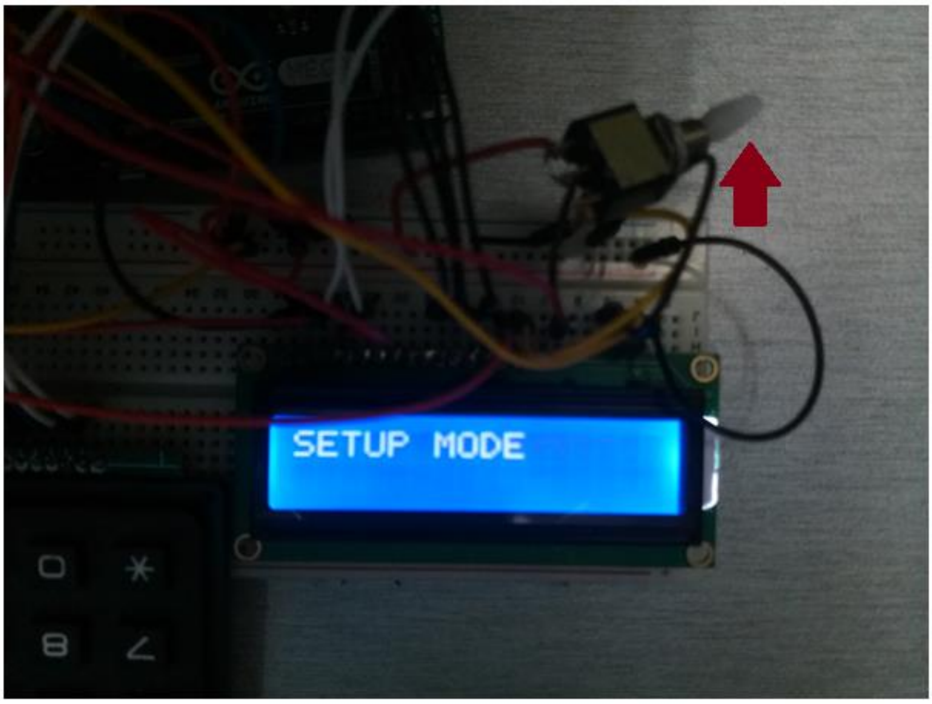

Figure 22: Switch mode using toggle switch (setup mode)

4.6 READING RPM

The input from tachometer is a pulsating voltage with varies value of frequency which determines the engine's speed. Using Arduino Tone() function, the behavior of the pulsating voltage was examined. The method to translate the pulsating voltage into RPM is by using interrupt where the interrupt function will constantly read the value from the pulsating voltage and detect how many changes occur in the state of the voltage either HIGH or LOW which determines the frequency of the voltage. The higher the frequency, the higher the RPM.

Below is the sample of the code to read RPM value using interrupt:

```
int half_revolutions = 0;
int rpm = 0;
unsigned long lastmillis = 0;
void setup()
{
Serial.begin(9600);
 tone(9, 290);//using tone function for testing purpose
 attachInterrupt(0, rpm_fan, FALLING); //enable interrupt
//attachInterrupt(0, rpm_fan, FALLING);
pinMode(12,OUTPUT);
digitalWrite(12,HIGH);
}
void loop(){
if (millis() - lastmillis == 1000){ //Update every one second, this will be equal to reading frecuency (Hz).
detachInterrupt(0);//Disable interrupt when calculating
rpm = half_revolutions * 60; // Convert frecuency to RPM
Serial.print("RPM =\t"); //print the word "RPM" and tab.
Serial.print(rpm); // print the rpm value.
Serial.print("\t Hz=\t"); //print the word "Hz".
Serial.println(half_revolutions); //print revolutions per second or Hz. And print new line or enter.
half_revolutions = 0; // Restart the RPM counter
lastmillis = millis(); // Update lasmillis
attachInterrupt(0, rpm_fan, FALLING); //enable interrupt
 }
}
// this code will be executed every time the interrupt 0 (pin2) gets low.
void rpm_fan(){
 half_revolutions++;
```

Figure 23: Sample code using Arduino Tone function to test for reading pulsating voltage using interrupt

The results are as follows:

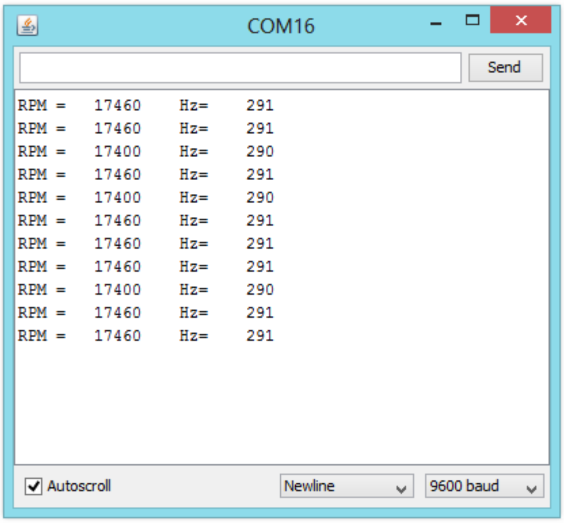

Figure 24: Pulsating voltage with frequency = 290

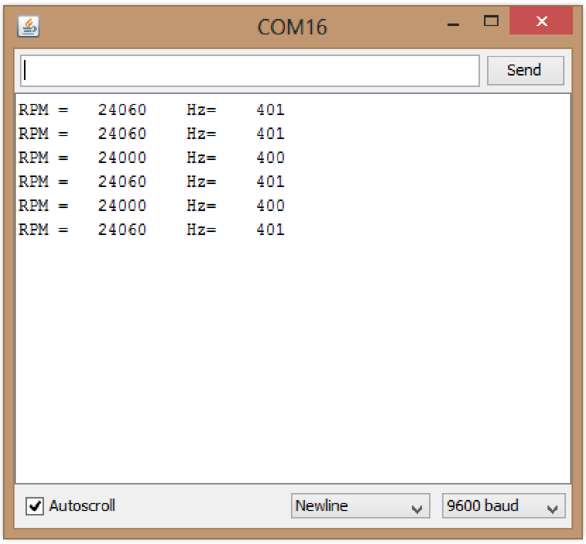

Figure 25: Pulsating voltage with frequency = 400

Based on the result, it can be concluded that the higher the pulsating voltage frequency, the higher the RPM.

4.7 FUNCTIONAL BLOCK DIAGRAM

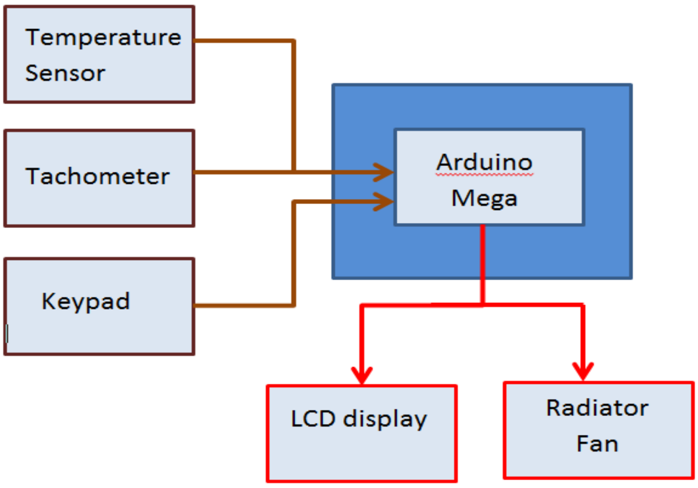

Figure 26: Functional Block Diagram

Based on the above block diagram:

- Temperature sensor and tachometer will constantly give its output as input to Arduino (microcontroller)
- Keypad will only give its output if the device is in “Setup mode”
- Arduino will constantly process the input and send it to the actuator which is the radiator fan and the LCD

4.8 FAN'S STATE TABLE

Engine's RPM	Engine's temperature	Auxiliary Fan state
Lower than idle RPM	Low than optimum temperature	OFF
Lower than idle RPM	Higher or equal to optimum temperature	ON
Higher or equal to idle RPM	Lower than optimum temperature	OFF
Higher or equal to idle RPM	Higher or equal to optimum temperature	ON
Approximately 0	Higher or equal to optimum temperature	OFF
Approximately 0	Lower than optimum temperature	OFF

Figure 27: Fan's state table

Based on the above table, it shows that the main condition that turns the fan on is the temperature. There are also special conditions where the system will be activated only if the rpm is not zero (the car is turn on). The users can also manually setup the fan speed, on temperature and idle RPM by entering setup mode.

CHAPTER 5 : CONCLUSION AND RECOMMENDATION

As a conclusion, the fan turns on/off accordingly based on the temperature and the engine's RPM. User also can adjust the on temperature of the fan by entering the setup mode and then enter the value through the keypad. If the engine's RPM is approximately zero the system would not allow the fan to be turn off as it indicates that the car were not started.

For recommendation, it would be better if the fan were off when the engine is not in idle mode as it indicates that the vehicle were moving in quite a speed which allow a natural surrounding air with intense velocity to flow through the radiator as this could reduce the current draw from the batteries which result in efficient energy usage. Apart from that, the small-scale concept simulation prototype can be turn into real one as for example by replacing the small dc fan with real radiator fan, the LM35 with the coolant temperature's sensor input and make some adjustment on the output signal to suit the input for any part in building the prototype.

The uses of wireless keypad for user input would be highly recommended as it can save space or in other words reducing the size of the prototype which to be attached to the card dashboard and the keypad itself is portable. The cost in building the prototype can also be reduced by using the basic microcontroller's IC rather than Arduino board.

REFERENCES

[1] M. Brain. (2000, June 15). *How Car Engines Work*. Available: http://www.howstuffworks.com/engine.htm

[2] K. Nice. (2000, June 15). *How Car Cooling Systems Work*. Available: http://auto.howstuffworks.com/cooling-system6.htm

[3] (2000, June 17). *How does the thermostat in a car's cooling system work?* Available: http://auto.howstuffworks.com/question248.htm

[4] M. Wright. (June 10). *Figure Out Why Your Car is Overheating*. Available: http://autorepair.about.com/od/enginetroubleshootin1/a/Figure-Out-Why-Your-Car-Is-Overheating.htm

[5] (2012, June 23). *How and When to Use an Auxiliary Electric Fan*. Available: http://www.flex-a-lite-blog.com/2012/03/22/how-and-when-to-use-an-auxiliary-electric-fan/

[6] W. J. M. Gurevich. (June 25). *Microcontrollers*. Available: https://ccrma.stanford.edu/workshops/2006/PID/lectures/ucontrollers.html

[7] W. Harris. (2007, June 25). *How Speedometers Work*. Available: http://auto.howstuffworks.com/car-driving-safety/safety-regulatory-devices/speedometer2.htm

[8] (19th August). *How Automotive Temperature Gauges Work*. Available: http://www.secondchancegarage.com/public/653.cfm

[9] (August 19th). *ECT (Engine Coolant Temperature) Sensor*. Available: http://www.obd-codes.com/faq/ect-sensor.php

[10] (August 19th). *Developing a Track Car*. Available: http://www.drivingfast.net/track/engine-driveline.htm

[11] R. Rowe. (7th November). *How Does a Car Tachometer Work?* Available: http://www.ehow.com/info_12132364_car-tachometer-work.html