Research Survey

In the past 30 years there has been a great deal of change in electric motor control. Originally, the only way to control an electric motor was by limiting the current, which was done by using a resistor, or by feeding in a sine wave. With the invention of fast switching mosfets and their low power usage, motor controllers have been revolutionized.

A key part of our project requires measuring the temperature of the motor. For this task we considered a multitude of options. The first option we looked at was a temperature sensor. The main advantage of this type of sensor is that it is very cheap to implement. It measures the current temperature and a reference temperature to create a band gap voltage that can be monitored. This voltage correlates to the temperature of the motor. They are typically made from polymers or ceramics. [1]

Another temperature measuring device we looked at was a thermistor. Thermistors are essentially a resistor that has a changing resistance based on temperature. These are useful in getting precise temperature values, although they have a narrower range of temperature measurements. A thermistor can also be helpful in that it also limits current rushes. There are two types. One that has a decreasing resistance with temperature and another that has an increasing resistance with temperature. For our purposes changing the resistance based on temperature might be impractical. We are looking for a cutoff temperature, rather than slowing down the motor as it heats up. [2]

A similar component to measure temperature is a resistance temperature detector. Typically they have a wider range of temperature detection than thermistors and are made up of metal, like platinum, instead of a polymer or ceramic. They are widely used in industrial applications under 600°C. [3]

A thermocouple sensor can be used for sub-zero temperatures to well over 2000°C.[4] There are many types of thermocouple sensors we can choose from. They differ by what type of metal is used for the positive and negative sections and the temperature range that each type can handle. Also, the accuracy of each type will affect the cost. A thermocouple output is non-linear and will yield a small voltage with a maximum of 0.1 volts.[5] This low voltage will need to be amplified to a value that the microcontroller can read. A plus for the thermocouple is how easy it is to incorporate into a circuit. [6][7]

All four of these methods have their advantages and disadvantages. A thermocouple sensor has a wide range of temperatures it can function at. A resistance temperature detector is one of the most commonly used elements to measure temperature due to its stability. However, they are typically more expensive, less sensitive, and slower reacting than other methods. The thermistor is a good option that has multiple purposes and is probably one of the cheapest methods.[8]

Another key project requirement is a current sensor. Again we have looked at a few options for current sensing. A Hall Effect sensor is a somewhat expensive method that is sometimes used. It measures the magnetic field that is produced by a coil wrapped around a ferromagnetic material. The magnetic field varies based on the current through the coil and is represented by a voltage at the sensor output. It is can be used in motor controllers, although current shunts may be a better choice. [9]

A current shunt resistor (designed specifically for current sensing applications) is a very high precision resistor of a small value. As more current is passed through the resistor, the voltage will increase. This is due to Ohm's law V = I X R. So, a current shunt with a small resistance will have less power lost across it, but the voltage will be very small. These small voltages need to be amplified in order for the microcontroller or analog circuit to read them. The advantage of using shunt resistor is cheap cost and high power to size ratio. Also, we can reuse the current as a renewable energy system based on our circuit. [10][11]

When considering logic control for the circuit we looked at MOSFETs. A MOSFET is a semiconducting transistor that has many applications that can prove helpful to the project. It can act as a switch or an amplifier. [12] They are also typically used in H-bridges to control the state of the motor. They are cheap, effective, and have good reliability. So far we have decided to use at least one as a switch. [13][14]

To control motor power output we have decided to use Pulse width modulation. PWM, as it is often abbreviated, allows for a fundamental frequency to be set. In the case of our controller the frequency will be 20 KHz, which is the audible threshold. PWM changes the percentage of time that the signal is high, which will correspond to what percentage of time that the motor will be on. So, if the voltage to the positive side of the motor is 100Vdc, and the user has set the PWM to 10% the motor will be on for 10% of the time, resulting in an equivalent voltage of 10 volts. [15]

When deciding whether to use an analog or digital (microprocessor) controller, a few advantages and disadvantages arise. An analog controller is cheaper and easier to make. However, it is constrained by a lack of variability and debugging becomes more difficult when compared to a microprocessor. A microprocessor will be a bit more expensive and require coding, but it can be altered quite easily. [16]

Resources:

[1] http://en.wikipedia.org/wiki/Silicon_bandgap_temperature_sensor

[2] http://en.wikipedia.org/wiki/Thermistor

[3] http://en.wikipedia.org/wiki/Brokaw_bandgap_reference

[4] The Watlow educational series book four (Temperature sensors)
http://www.m-r-c.co.il/Media/Doc/TechnicalInformation/Temp_Measuring1.pdf

[5] http://www.temperatures.com/tcs.html

[6] http://www.pyromation.com/Products/Thermocouple.aspx

[7] http://www.hewittindustries.com/

[8] http://content.honeywell.com/sensing/prodinfo/solidstate/technical/chapter2.pdf

[9] http://en.wikipedia.org/wiki/Hall_effect

[10] http://www.rc-electronics-usa.com/current-shunt.html

[11] http://www.reuk.co.uk/What-is-a-Shunt.htm

[12] http://www.techpowerup.com/articles/overclocking/voltmods/21

[13] http://www-g.eng.cam.ac.uk/mmg/teaching/linearcircuits/mosfet.html

[14] http://www.electronics-tutorials.ws/transistor/tran_7.html

[15] http://www.netrino.com/Embedded-Systems/How-To/PWM-Pulse-Width-Modulation

[16] http://en.wikibooks.org/wiki/Control_Systems/Digital_and_Analog