

**CSC Piggy Back Group**  
**MEE 487**  
**Midterm Report**

Submitted to Professor Mick Peterson  
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## I. Objective

The object of the Piggyback group is to continue to reverse engineer the existing stock engine control unit (ECU) on a 2003 Arctic Cat four stroke 660 cc snowmobile engine to improve upon last years results. This reverse engineering will allow improved control of emissions after the addition of a catalyst. Particularly, hydrocarbon (HC) and nitrogen oxides (NO<sub>x</sub>) emissions will be monitored for optimum performance in the SAE Clean Snowmobile Challenge (CSC). Since HC and NO<sub>x</sub> emissions are the most important to control in an engine, the CSC has based the emissions part of the competition on measurement of HC and NO<sub>x</sub> in each of teams' sleds. One of the goals in this project is to minimize the HC and NO<sub>x</sub> emissions for a total minimum percentage of emissions required for the greatest amount of design points. (CO emissions are also considered in the test, but are weighted less than the HC and NO<sub>x</sub> emissions levels). Table 1 lists the operating conditions of engine emissions testing, and scoring for the emissions event is listed in Equation 1 and Equation 2.

**Table 1: Operating Conditions for Emissions Testing**

Mode	1	2	3	4	5
Speed, %	100	85	75	65	Idle
Torque, %	100	51	33	19	0
Wt. Factor, %	12	27	25	31	5

**Equation 1: Sled Emissions Number, must be greater then 100**

Sled Emission Number "E" =

$$\left[ 1 - \frac{(HC + NO_x) - 15}{150} \right] * 100 + \left[ 1 - \frac{CO}{400} \right] * 100 \geq 100$$

Table 1 and Equation 1 courtesy of SAE CSC 2006Rules

**Equation 2: Scoring for CSC Emissions Test**

$$YourScore = 100 + 200 * \left\{ \frac{\left[ \frac{E_{min}}{E_{your}} \right]^2 - 1}{\left[ \frac{E_{min}}{E_{max}} \right]^2 - 1} \right\}$$

Last year's group used a "piggyback" or override for the existing ECU to control the emissions from the sled. The idea behind the piggyback is to allow a separate control unit or computer programmed microcontroller to bypass the existing engine control unit when certain operating conditions are met by the engine. This year we continued to work on the piggyback controller and have targeted improving on the sleds idle condition since this is where the team performed badly at competition last year. To fix this problem at idle we are going to add the throttle position as an input to the microcontroller. In order to do this an engine map will have to be created to understand what is happening in the engine.

## **II. Engine Map**

### 1. Overview

The purpose in doing an engine map is to have a better understanding of what is happening in the engine at all times. For our purposes the engine map must contain the throttle position, RPM, Speed, and AIT (air inlet temperature). This way we will know the AIT (variable we are trying to control) as a function of the RPM, and Speed. We will also use this map to find out how the throttle position vary with theses same parameters. To aid us in creating an engine map an R-500 data logging unit was purchased from PLX devices. This unit can handle up to 6 analog inputs and also can display the air fuel ratio and the exhaust gas temperature (EGT).

### 2. Inputs

The R-500 unit has a direct set up for inputs. All that has to be done is to attach the wire you want to look at to the wire leading to the logger. This is possible because the logger has a built in ground wire so no input needs to be grounded. The logger can handle any 0-5 volt analog input and will reduce any input up to 25 volts to a 0-5 volt scale without damage to the unit. With this feature any sensor on the engine can be tapped into directly and all that has to be done is to use a volt meter to make sure the wire you are tapping into is not the ground or the supply, but the third variable wire. For the throttle position, the AIT, and the tachometer (RPM) the above process was all that had to be done to add the inputs to the data logger.

In order to get the input from the Speedometer into the data logger we needed to find a way to convert from a cable driven speedometer to one that would output a voltage signal. By looking on line we found a device to do just that. It will take the cable from one end and then attach directly to the speedometer.

**Figure 1: speedometer cable to voltage converter**



### 3. Problems with engine map

While trying to obtain an engine map for the end of this semester we ran into a few problems and that is why there are not graphs and charts of the engine map present in this section of the report. One problem we encountered was that the device we ordered to convert from the cable driven speedometer to a voltage signal, didn't have the right connects to fit the sled. So to fix this problem we will have to fabricate our own connection. We also damaged the USB port on the data logger and had to send that back to PLX to get fixed so we could map the engine but we could not get the map off the logger and on to a computer.

## III. Piggyback and Basic Stamp

### 1. Development

The original plan for the semester was to try and reuse last years piggyback. This ended up not being an option since the piggyback was potted making it impossible to add more inputs into it. So a very important part of this semesters work was learning what the inputs / outputs to the piggyback were and also learning how to properly wire the circuits.

**Figure 2: I / O Diagram for the piggyback digital potentiometer**

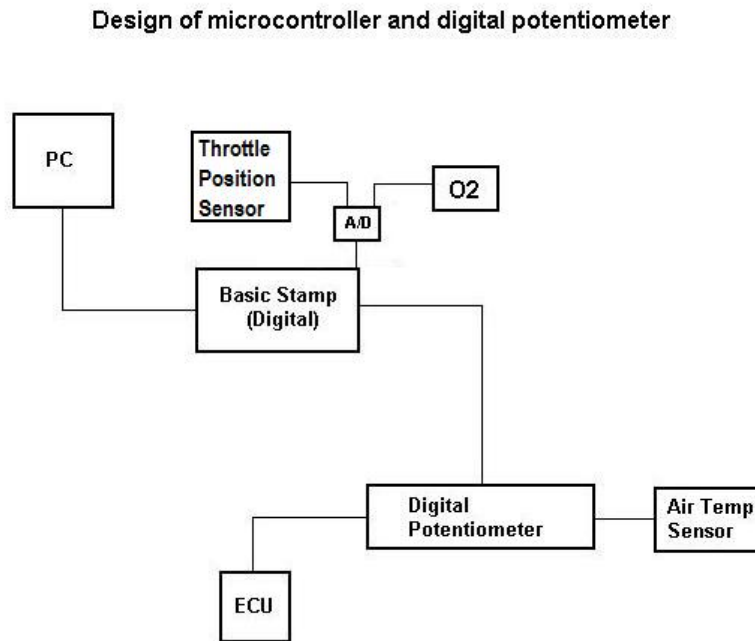


Figure 2 will allow us to change the A/F ratio on the snowmobile by using a microcontroller. The following is a description of the parts:

- PC – A computer used to program the basic stamp
- Basic Stamp – A microcontroller
- A/D – Analog to digital converter
- Digital Potentiometer – Changes the resistance
- ECU – Main computer which operates the snowmobile
- Air Temp Sensor – Measures inlet air temperature on the snowmobile
- O<sub>2</sub> Sensor – Measures the amount of oxygen in the exhaust system
- Throttle position sensor – measure the position of the throttle

## 2. Theory and Control of the Microcontroller

The basic stamp is a microcontroller developed by Parallax, model BS2P24IC. It can easily be programmed using a form of the BASIC programming language, called Stamp. After the program is written, the microcontroller connects to a computer through a serial cable, and the program downloads into the basic stamp's memory (EEPROM).

This year there will be two inputs to the microcontroller, a Bosch LSU4.2 wideband O<sub>2</sub> sensor, and an input from the throttle position sensor. The O<sub>2</sub> sensor will be mounted before the catalytic converter in the exhaust system to monitor the gas mixture. A program will be written and sent to the microcontroller based on the relationship between the O<sub>2</sub> sensor and the air inlet temperature sensor and the throttle position. Notice in

Figure 2, an analog to digital converter is used since the outputs of the O<sub>2</sub> sensor and throttle position sensor are analog and the microcontroller is digital.

A digital potentiometer will be wired in series between the ECU and air inlet temperature sensor. A catalytic converter was installed on the snowmobile, since the A/F ratio has been lean. Using a digital potentiometer to change the resistance of the air temperature sensor the A/F ratio can be changed. Changing the resistance tricks the ECU, and will allow the fuel mixture run a little richer. Since last years team had trouble with emissions at idle the throttle position sensor was added to be able to adjust the A/F ratio at this special condition.

### 3. Next Semester's work

For next semester a non test version of the piggyback will have to be created and soldered to a breadboard. A casing will have to be fabricated and then mounted on the sled and the program will have to be adjusted until exhaust gases are minimized.

## IV. Problems with Fall Emission Testing

### 1. Exhaust Gas Analyzer (EGA)

The EGA was used by last year's emission team to test the exhaust produced from the sled before they went to competition. Although the EGA is a very useful device that allows us to determine how accurate the piggyback is performing we had several problems getting the machine working properly. The first was the lab's supply of calibration gas. This had been exhausted from the previous year's crew. Without the proper gas to calibrate the O<sub>2</sub> sensor in the EGA, the measurements taken would be inaccurate. This pushed back our initial goal of testing last years piggyback.

Once the proper gas, BAR 90, had been found and ordered through [www.emissionsupply.net](http://www.emissionsupply.net). We tried again to test the sleds emissions and compare these to what the team received last year. Again we had trouble getting the machine to calibrate. Either through the computer or manual controlling the EGA we were unable to capture a gas sample for calibration. After consulting with people from the help line, it was determined that the exterior filter was the likely cause. This would have to be changed out along with the interior filter for maintenance issues. The filters were ordered and should arrive sometime during break. Once they are installed the EGA unit should be able to be calibrated.

### 2. Track Dyno

During tests we have tried to use the Track Dyno to hold the sled at the constant RPM range that is needed. We have found that it is possible to hold the sled at constant Speed however the sled will not hold at a constant RPM. The team from last year did not use the software of the Track Dyno. Instead the simply held the throttle in place at the needed RPM generally these were, 3000, 4000, 5000, 6000 and idle. Although the Track Dyno

has not been able hold the sled at a constant RPM we have continued to test the sled using the same method as the previous year.

### 3. Datalogger

While we were setting up for an emissions test run an accident occurred damaging the USB output of the Datalogger. The Datalogger is still full functional and will allow us to map the engine. However in its present state we are unable to transfer the collected information to a computer to place into excel for graphing. We do know that with the Datalogger we were able to determine that our newest input, Throttle Position Sensor, has a variable voltage of .21 V at idle and 3.8 V at full throttle. We were not able to determine more variation then this without being able to graph the data.

After contacting the PLX help line, concerning the condition of the Datalogger, it was concluded that it would need to be sent back to the company to replace the USB Port. This unit was sent back on December 15<sup>th</sup>. Meg Smith will contact our group once it has been sent back to her office.