



ELECTRONIC SYSTEMS DESIGN

Assignment 1

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Introduction

I have been tasked with designing a data acquisition system for a prototype car that will be used for a 2 hour test run on a track. My design must be portable, adaptable and suitable for the environment it will be tested in. The data acquisition system will measure the following:

- Engine RPM
- Engine Temperature
- Front and rear suspension travel
- Pitch, roll and yaw
- Vehicle road speed (MPH)

In this report I will also provide the hardware choices I have made, a block diagram of my software structure and a PCB design.

Task 1

A data acquisition system (DAQ) will process signals that will measure physical conditions from the real world which can then be converted into digital form that can then be processed by a computer and software. A typical DAQ will work with sensors, signal conditioning circuitry which provides the link between the sensors and the A/D converter. After the signal has been converted, it will go to a computer which has the DAQ software.[1]

A vehicular data acquisition system will measure many parameters such as engine temperature, suspension travel, changing tire pressure, oil pressure and fuel level. There are different types of sensors that will allow you to perform these measurements.

To measure the engine temperature a coolant temperature sensor would be used which would be connected to the vehicles ECU and would be constantly monitoring the coolant temperature to ensure the engine is running at an ideal temperature.

A fuel sensor would measure the fuel level this can be achieved using a float on the end of a pivot arm. As the level of fuel increases and decreases the resistance of the fuel gauge will change.

The wheel speed can be measured using an NPN type inductive proximity sensor. This will create a pulse every time the wheel tooth passes the sensor. As the wheel speed

increases so will the number of pulses and as the wheel speed decreases the number of pulses decreases.[2]

Existing systems

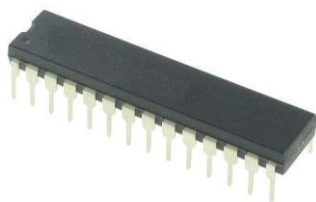
			
Supplier	IMC-TM[3]	NI[4]	RS[5]
Model	Imc CRONOS XT	CompactDAQ	Red lion 5 channel
Features	IP 67 Operating temp ranges from –40 °C to 85 °C Shock and vibration resistant GPS Wide input voltage 10-35VDC	IP 67 Operating temp ranges from –40 °C to 70°C 50g shock rating 5g vibration rating	Operating temp ranges from 0°C to 50°C 24VDC Price £912.12 Extensive built-in driver list allows easy data mapping to PLCs, PCs, and SCADA systems.

Task 2

After my search gave me 10 possible automotive capable microchips, I compared them all and narrowed it down to 4. The side-by-side comparison of these four microchips is shown below:

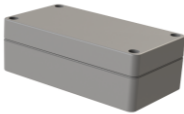
	PIC18F26J53 Microchip delete	PIC18F46J53 Microchip delete	PIC18F27J53 Microchip delete	PIC18F47J53 Microchip delete
Family	8-bit MCU	8-bit MCU	8-bit MCU	8-bit MCU
CPU Type	8-bit PIC MCU	8-bit PIC MCU	8-bit PIC MCU	8-bit PIC MCU
Max CPU Speed (MHz)	48 MHz	48 MHz	48 MHz	48 MHz
FPU				
Operation Voltage	(2V-3.6V)	(2V-3.6V)	(2V-3.6V)	(2V-3.6V)
Temp Range	(-40 to 85)	(-40 to 85)	(-40 to 85)	(-40 to 85)
Pin count	28	44	28	44
Program Memory Size (KB)	64 Flash	64 Flash	128 Flash	128 Flash
Error Correction Code Program Flash				
SRAM	3.7109375 KB	3.7109375 KB	3.7109375 KB	3.7109375 KB
Data EEPROM/HEF (Bytes)				
Internal DRAM Type				
Internal DRAM Amount (MB)				
Low Power	Yes	Yes	Yes	Yes
ADC Input	13	13	10	13
Max ADC Resolution (Bits)	12	12	12	12
DAC Outputs				
Number of Op Amps				
Hardware Touch Peripheral				
UART	2	2	2	2
SPI	2	2	2	2
I2C	2	2	2	2
I2S				
SSC				
Number of USB Modules	1	1	1	1
USB Interface	FS Device	FS Device	FS Device	FS Device
Number of CAN Modules				
Type of CAN module				
Ethernet				
Max 8-Bit Digital Timers	4	4	4	4
Max 16-Bit Digital Timers	4	4	4	4
Max 32-Bit Digital Timers				
Hardware RTCC/RTC	Yes	Yes	Yes	Yes
Max PWM outputs (including complementary)				
Number of PWM Time Bases				
Crypto Engine				
ARM Trust Zone®				
Segmented LCD				
Graphics Controller/GPU				
Video Decoder				
Other Features	This low power and high performance 8-bit MCU with integrated full-Speed USB 2.0, high memory density and peripheral flexibility comes in a small package for cost sensitive application in the PIC18 J-series.	▲ This low power and high performance 8-bit MCU with integrated full-Speed USB 2.0, high memory density and peripheral flexibility comes in a small package for cost sensitive application in the PIC18 J-series. ▼	▲ This low power and high performance 8-bit MCU with integrated full-Speed USB 2.0, high memory density and peripheral flexibility comes in a small package for cost sensitive application in the PIC18 J-series. ▼	▲ This low power and high performance 8-bit MCU with integrated full-Speed USB 2.0, high memory density and peripheral flexibility comes in a small package for cost sensitive application in the PIC18 J-series. ▼

After comparing these four microchips the PIC18F27J53 is the microchip chosen for the DAQ system. This is because it has 28 pins which is more than enough and leaves room for expansion. It also has 128 flash program memory size making these two the best combination for the application I need it for when compared to the other three. The PIC18F27J53 is priced at £5.56 and is shown below: [35]



Task 3

Enclosure

			
Supplier	Licoln binns[6]	RS[7]	RS[8]
Model	Hammond 1554 series	Deltron 486 series	Hammond 1555 series
Price	£9.25 to £38.74	£47.03	£23.57
IP rating	IP 68	IP 68	IP 68

The Deltron 486 will be the enclosure for the DAQ system. The data sheet shows the enclosure comes in the size 125x 125 x 80, this will be a suitable size for the DAQ system. It is also IP 68 rated. The enclosure will be mounted on to the engine using zip ties.

Memory

The size of storage needed.

Parameter	Max value	Resolution	Number of possible Values	Number of bits required	Number of bytes
Engine RPM (Digital)	0 to 8k	10 RPM	800	10	2
Engine temp (Analog)	50 to 150°C	100°C	100	7	1
Suspension travel (Analog)	300 mm	1 mm	300	9 x4 (9 for each wheel)	8 (2 bytes each)
Pitch (I ² C)	-45 to 45°	0.5°	180	8	1
Roll (I ² C)	-45 to 45°	0.5°	180	8	1
Yaw (I ² C)	0 to 360°	1°	360	9	2
Road speed	0 to 255 MPH	1 MPH	256	8	1

The total number of bytes needed adds up to 16 bytes.

We will be sampling 50 times a second.

Therefore,

16 bytes

X 50 samples/sec

X 60 seconds/min

X 60 min/hr.

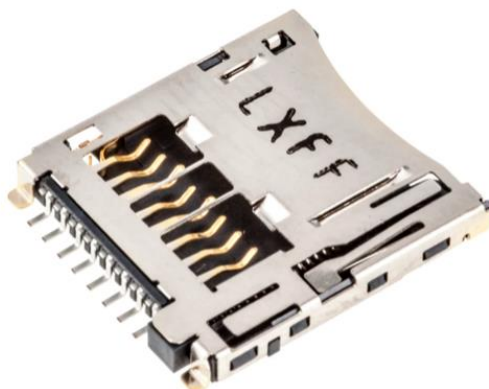
X 2-hour test drive

Total bytes needed = 5,760,00

			
Supplier	RS [9]	RS [10]	RS [11]
Type	SD card	USB flash drive	External hard drive
Model	Integral micro	Kingston kyson	Verbatim store 'n' go
Price	£7.32	£12.36	£80.77
Memory size	32 GB	32 GB	1 TB

Both the SD card and the USB will be chosen. The SD card will be used as a non-volatile option to record the data then the USB will be used to transfer the data from the PCB to the computer. The SD card will be mounted to the PCB and the USB will have a connector from the enclosure to the PCB.

To connect the SD card to the PCB board I will be using this 8 pin Molex connector. It has an operating temperature of -25°C to 85°C and fully shielded stainless steel covers for protection against electromagnetic interference. [12]



Sensors

Engine RPM and MPH

			
Supplier	RS [13]	RS [14]	RS [15]
Type	Encoder	Proximity sensor	Optical sensor
Price	£360.58	£33.72	£15.74
Advantages	Operating temp ranges from 55 °C to 150 °C Self powered operation Simple installation Suitable for measuring engine RPM	IP 67 rated Low cost	Open collector output Supply voltage ranges from 4v to 7v Least expensive option
Disadvantages	Most expensive option	Operating temp ranges from –25 °C to 75 °C Supply voltage ranges from 10v to 30v	Operating temp ranges from 0° C to 70° C

The Honeywell encoder has been chosen to measure the engine RPM although it is the most expensive option when compared to the other two it is the only option which operates in a wide enough temperature range to be near the engine. It is also an open collector output with simple installation.

Engine temperature

			
Supplier	RS [16]	RS [17]	RS [18]
Type	Temperature probe	Infrared	Infrared sensor

		temperature sensor	
Price	£33.73	£784.80	£207.00
Advantages	Operating temp ranges from -50°C to 200°C IP 68 rated Cheapest option	Temperature range: -20°C to 1000°C Fast response time and high stability	Temperature ranges from -40°C to 1030°C Response time: 25 ms Power supply: 5-30 V DC
Disadvantages		IP 65 Operating temp ranges from 0°C to 70°C Supply voltage 12v to 24v	IP 63 Operating temp ranges from -20°C to 80°C Would require extra USB port on pic

The RS PRO PT100 RTD Sensor will be used due to it having the highest IP rating and largest operating temperature range. it is also the cheapest of the three options. To measure the engine temperature, I will be measuring the engine coolant temperature.

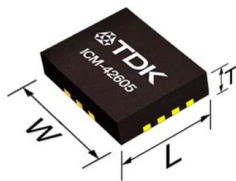
Suspension travel

			
Supplier	RS [19]	RS [20]	RS [21]
Type	Linear potentiometer	Linear potentiometer	Linear potentiometer
Price	£239.23	£379.50	£211.55
Advantages	Operating temperature ranges -30°C to 100°C Maximum supply voltage 60v	IP 65 Maximum supply voltage 60v Operating	Operating temperature -40 to 105°C Cheapest option

		temperature ranges --30°C to 100°C	
Disadvantages	IP 60 rated	Expensive	Unknown IP rating

The Gefran linear transducer will be used although it is the most expensive it has a good operating temperature range and the highest IP rating of IP 65. The linear potentiometers will be mounted to each wheel to measure the suspension travel.

Roll Pitch and Yaw

			
Supplier	RS [22]	RS [23]	Farnell [24]
Type	Gyrosensor	Gyrosensor	Gyroscope
Price	£4.613	£4.28	£1538.40
Advantages	Analog supply voltage: 1.71 V to 3.6 V Operating temp -40°C to 85°C	Analog supply voltage: 1.71 V to 3.6 V Operating temp -40°C to 85°C Cheapest	IP 67 Gyroscope range +/- 450°/s Operating temp ranges from -40°C to 85°C
Disadvantages			Expensive

The invensense gyro sensor will be used to measure the roll, pitch, and yaw. The gyro sensor will be mounted into the PCB. This has been chosen as it is the cheapest of the two PCB mounted gyrosensors.

Battery

			
Supplier	RS [25]	RS [26]	RS [27]
Type	Battery	Battery	Battery
Price	£25.14	£3.539	£80.40
Advantages	Rechargeable Lightweight Small enough to be mounted in enclosure	Lightweight Small enough to be mounted in enclosure 9v 580mAH	12v 12 Ah
Disadvantages	Only 6V Only 300mAh	Not rechargeable	Expensive Too big to be mounted in enclosure

The Varta 9v battery will be used as it has enough voltage and amp hours for what I need. It is also small enough that it can be mounted in the enclosure with the rest of the pcb.

Connectors



These 4 pin M8 connectors have been chosen as they are ideal for automotive purposes and have an IP 67 rating. This IP rating along with the operating temperature range of - 25°C to 75°C fits the environment in which they will be used in. These will connect the sensors to the enclosure in have picked. The female connector is priced at £23.54 each and the male connectors are price at £21.40 each. [28] [29]



The Molex kk connectors and crimps have been chosen to connect from the PCB board to the connector on the enclosure. They are a good choice as they are automotive suitable and have a good operating temperature of 0°C to 75°C. [30] [31]

Switch



This is the switch that will be used to turn on the DAQ system. This switch has been chosen as it is IP 69 rated and has a Wide operating temperature range of -40°C to +70°C. The slow-break contact makes for accurate and reliable response, and it is cheap with a price of £29.17. [32]

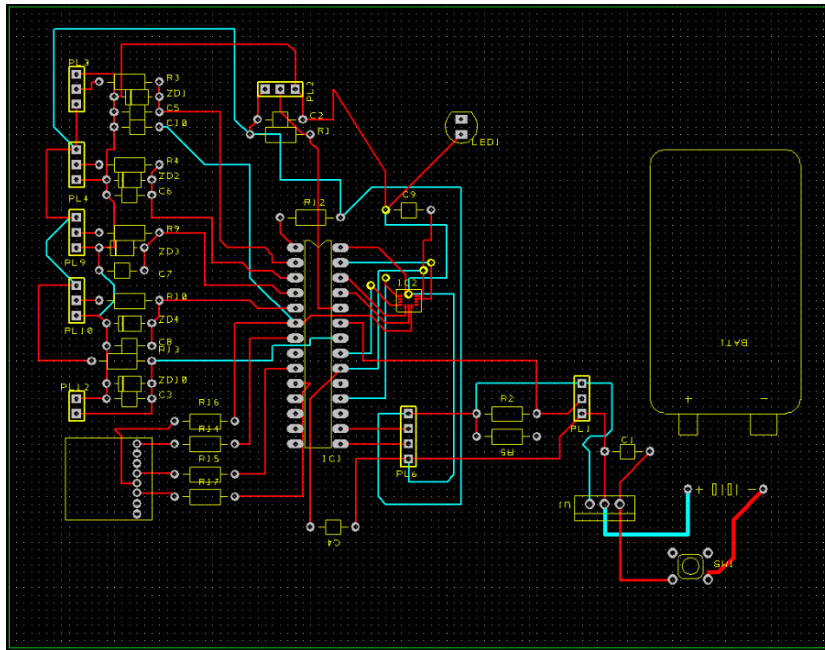
LED



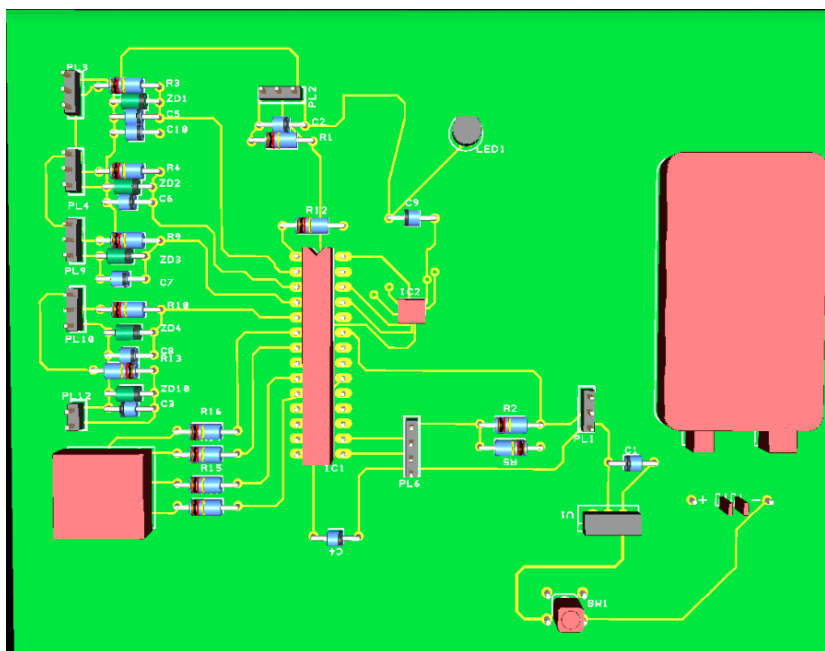
This LED will be used to show my DAQ system is on. This LED has been chosen as it has an operating voltage of 3.5V to 14V so it can be powered straight from the battery. The price of this LED is £4. [33]

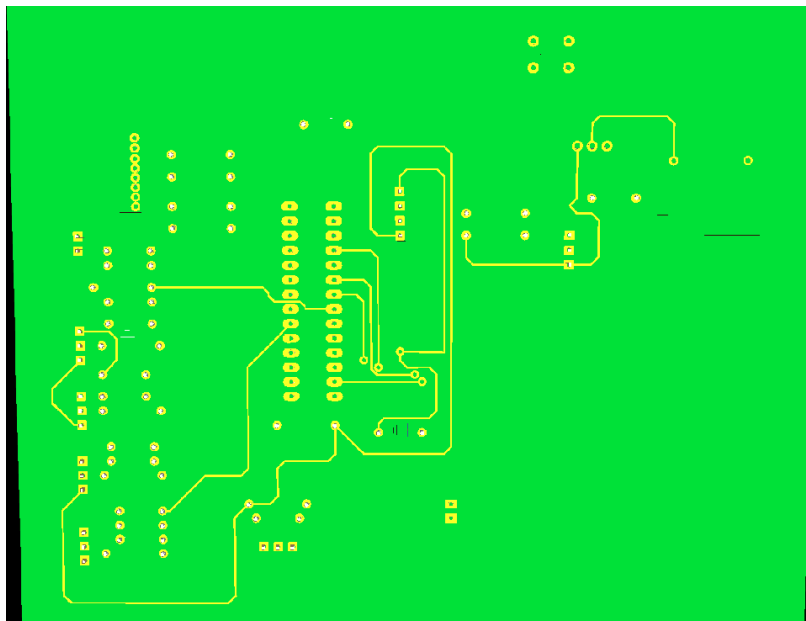
Task 4

The PCB board is design is shown below. The PCB board is 139mm wide and 108mm long meaning my enclosure I will select will have to be suitable to fit this size PCB.



The 3d model of the PCB board is shown below:





A quote for the PCB is shown below. The quote is from JLC PCB, the price of the build costs 9.30 euros when converted to pounds the build of the PCB comes to £8.07.[34]

Charge Details ^	
Engineering fee	\$4.00
Via Covering	\$0.00
Surface Finish	\$0.00
Board	\$5.30

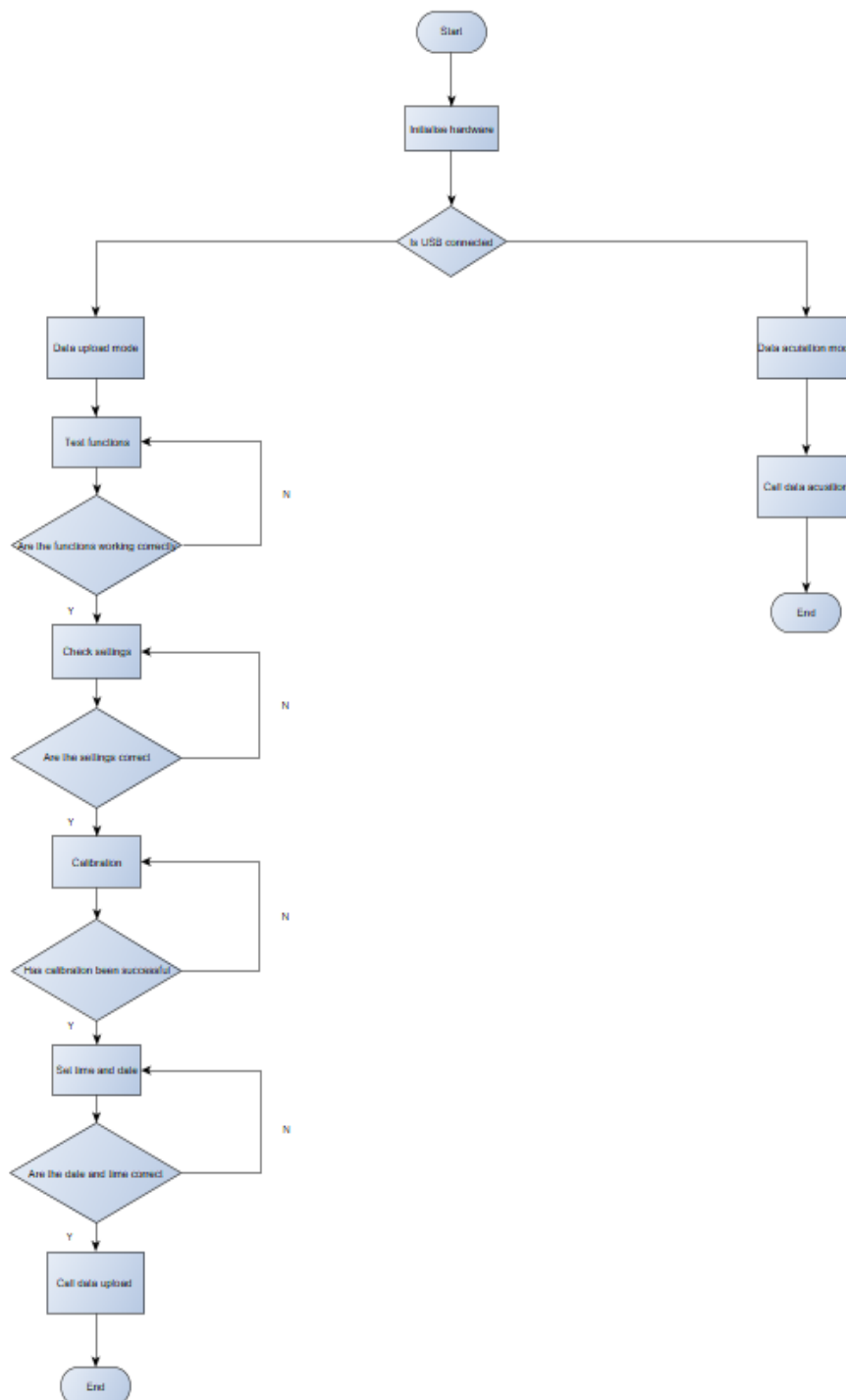
Build Time ?	
PCB: ☐ 3-4 days	\$0.00
☒ 2 days	\$0.00
☐ 24 hours	\$7.10

Calculated Price	\$9.30
Additional charges may apply for special cases	

SAVE TO CART

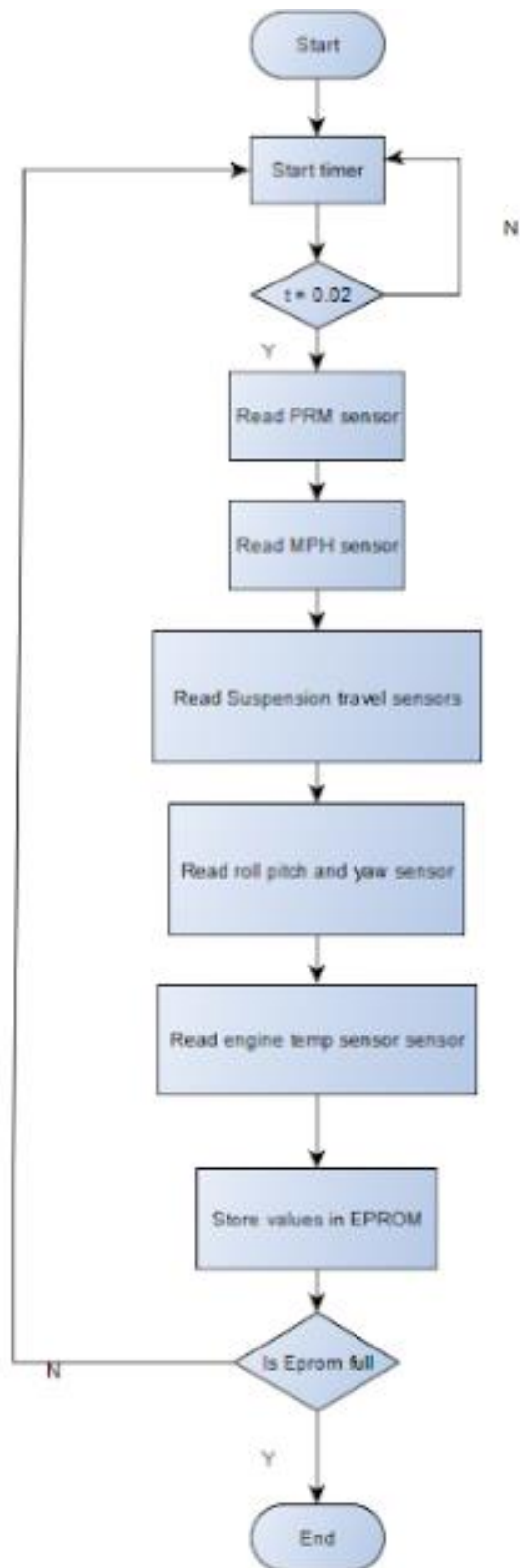
Task 5

The first part of the software structure is shown below. This part of the software will determine whether the DAQ system will be uploading or acquiring data. As shown below whether the USB is connected will determine which mode the DAQ system enters, if the USB is connected it will enter Data upload mode and if the USB is not connected the system will enter data acquisition mode. The software will then call the relevant mode to start.



Data acquisition mode

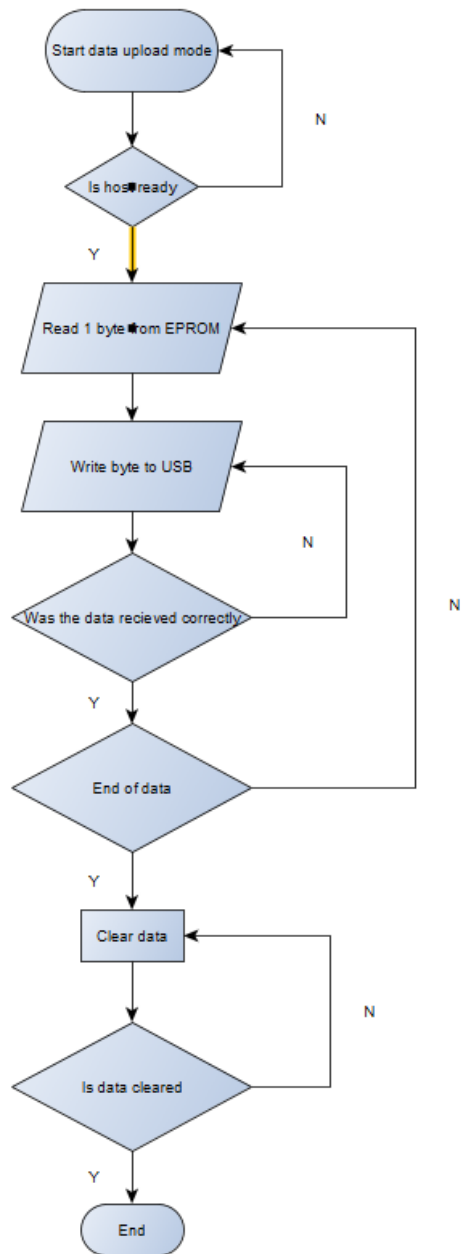
Once the initial software has called for data acquisition mode it begins the program. A timer will start and when the time is equal to the sample time which is 0.02, as we will be sampling 50 times per second, it will get a reading from each of the sensors and store it in the EPROM. The software will continue to repeat this process until the EPROM is full once the EPROM is full it will stop taking reading from the sensors and end the program.



Data upload mode

If the data upload mode has been called the software will begin the process of writing data to the USB. The program will first check if the host is ready if it is then it will continue to read a byte from the EPROM and then write the byte to the USB. The program will then check if the data has been received correctly. If the data has not

been received correctly it will rewrite the byte to the USB. The program will continue this process until all the data has been written on to the USB. It will then clear the data from the EPROM and check that this has been done. If this has been done successfully it will end the program.



Task 6

Components	Purpose	Price	Supplier
Honeywell encoder X2	Engine RPM	£721.36	RS
RS PRO PT100 RTD Sensor	Engine Temperature	£33.73	RS
Gefran Linear Transducer X4	Suspension Travel	£1,518.00	RS
InvenSense 6-Axis Surface Mount Accelerometer & Gyroscope	Roll, pitch & yaw	£4.28	RS
Varta 9V battery	Power	£3.54	RS
RS pro circular male connectors X7	Connectors	£149.80	RS
RS pro circular female connectors X7	Connectors	£164.78	RS
Schneider electric knob switch	Switch	£29.17	RS
Knightbright green LED	LED	£4.00	RS
PCB Build	PCB	£8.07	JLCPCB
Deltron 486 series	Enclosure	£47.03	RS
Integral micro 32GB	SD card	£7.32	RS
Kingston 256GB	USB	£12.36	RS
Molex 8 pin connector	SD card connector	£3.31	RS
Molex female connector housing X10	Connectors	£2.09	RS
Molex crimp connector X10	Connectors	£1.34	RS
PIC18F27J53	Microcontroller	£5.56	Mouser
Total cost		£2,682.01	

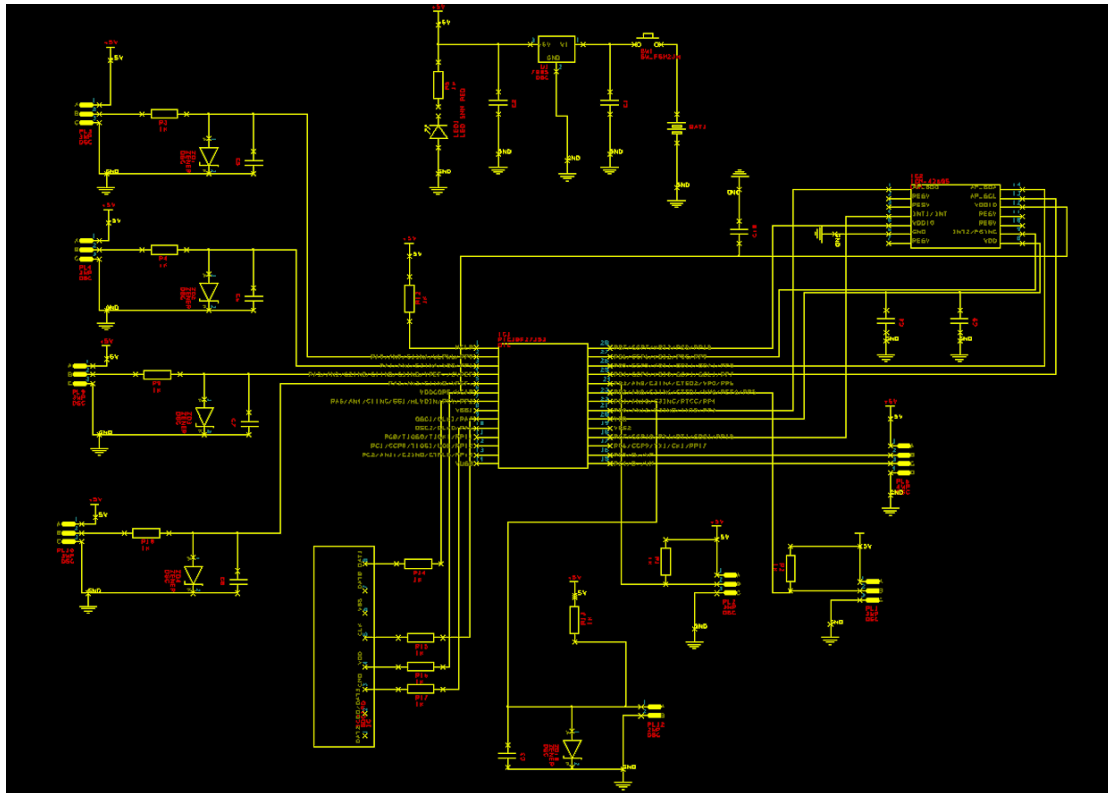
Task 7

To improve the specification for next time the DAQ system would include more parameters to measure. This would include measurements of the fuel level, tire pressure and tire temperature. This is due to these three parameters have an effect on how the car performs therefore would have an impact on my current sensors that are in place. The next iteration would also include some shock and vibration protection for the DAQ system as the current doesn't have any in place and comparing with the DAQ systems from task one this could be an improvement.

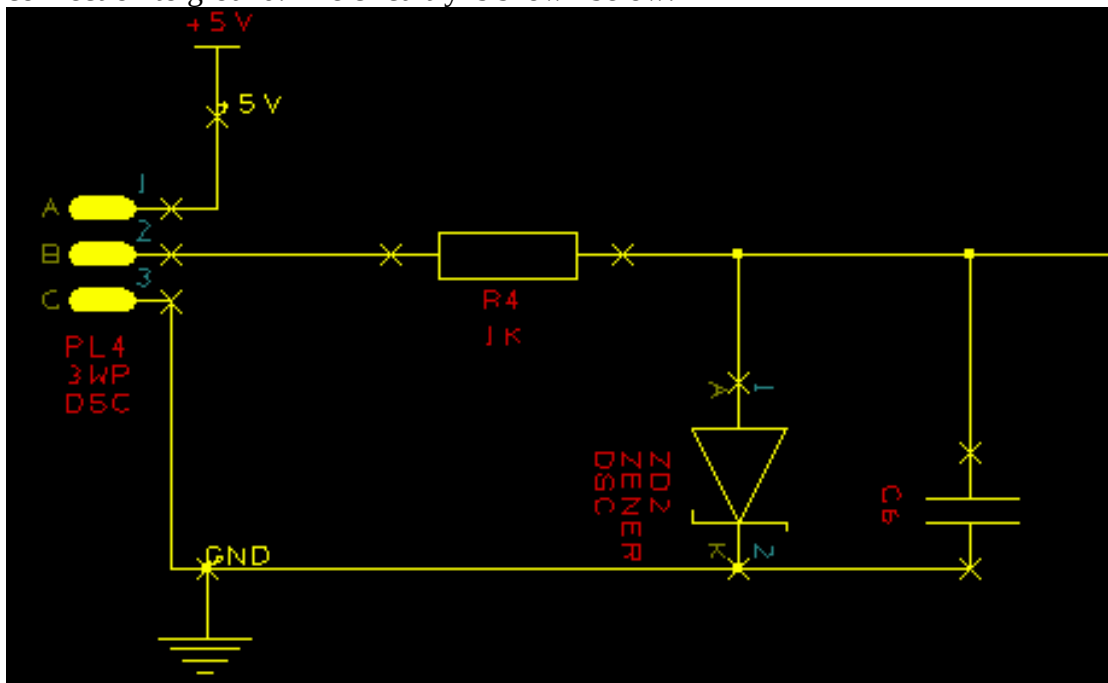
Task 8

Schematic

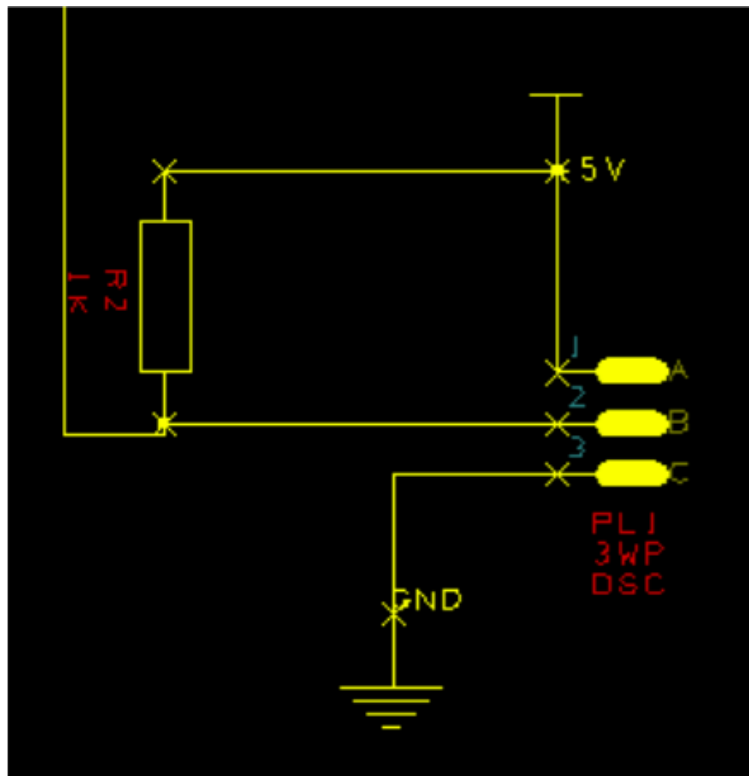
The full circuit schematic is shown below.



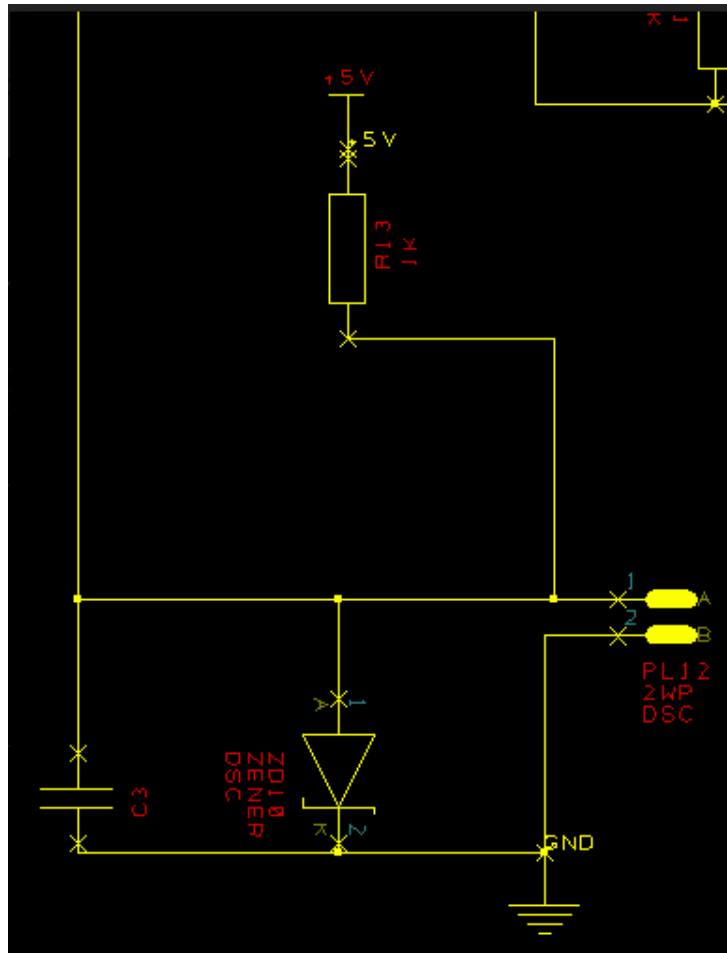
For the linear potentiometers Zener diodes, resistors and capacitors had to be used to get the correct voltage for the microcontroller and to create a low pass filter to combat electrical noise. The linear potentiometers will also require a supply voltage and a connection to ground. The circuitry is shown below.



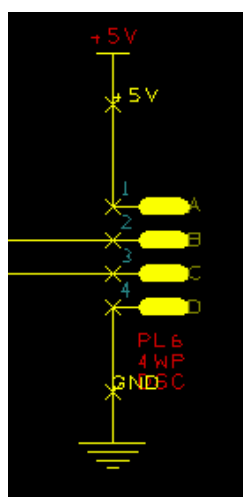
For the encoders measuring the engine RPM and MPH they are open collector sensors meaning they will need a resistor attached to between the voltage supply and signal wire to give a reading. The encoders must also be connected to ground. The circuitry for this is shown below.



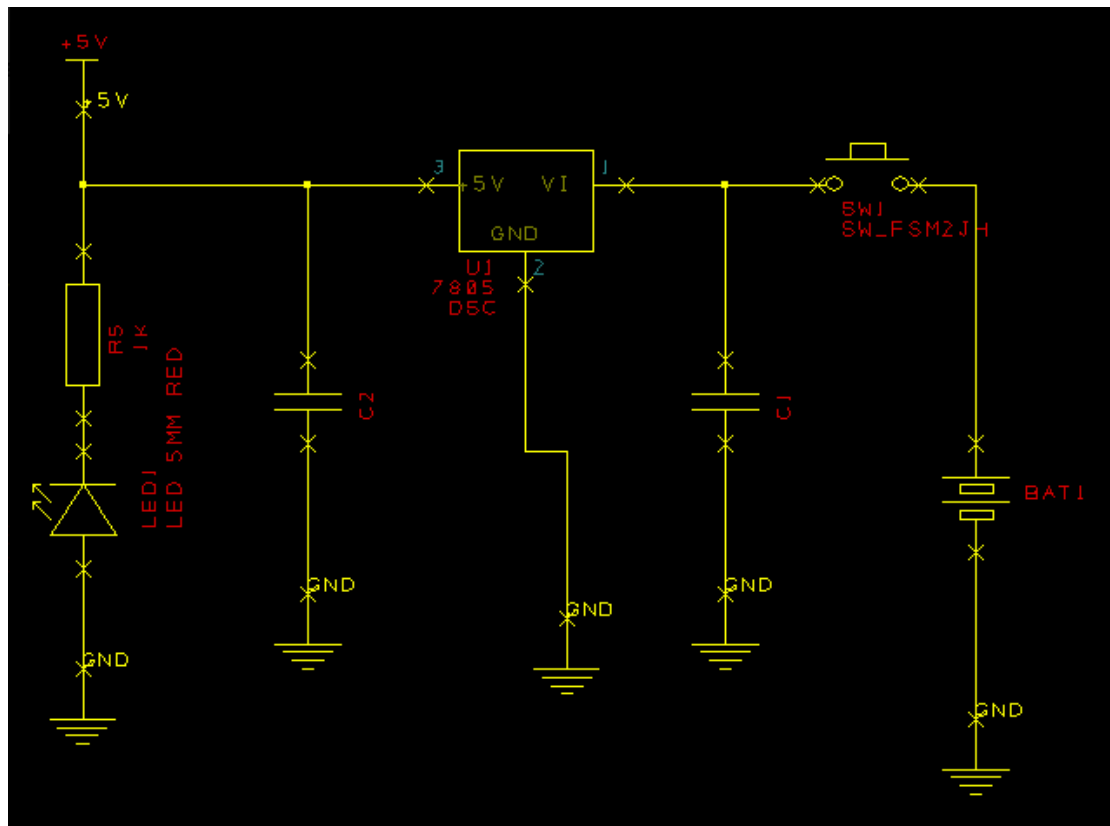
The temperature is a PT100 which is a two-wire sensor. It requires a resistor connected to the supply voltage and a low pass filter to combat electrical noise. It will also be connected to ground. The circuitry is shown below.



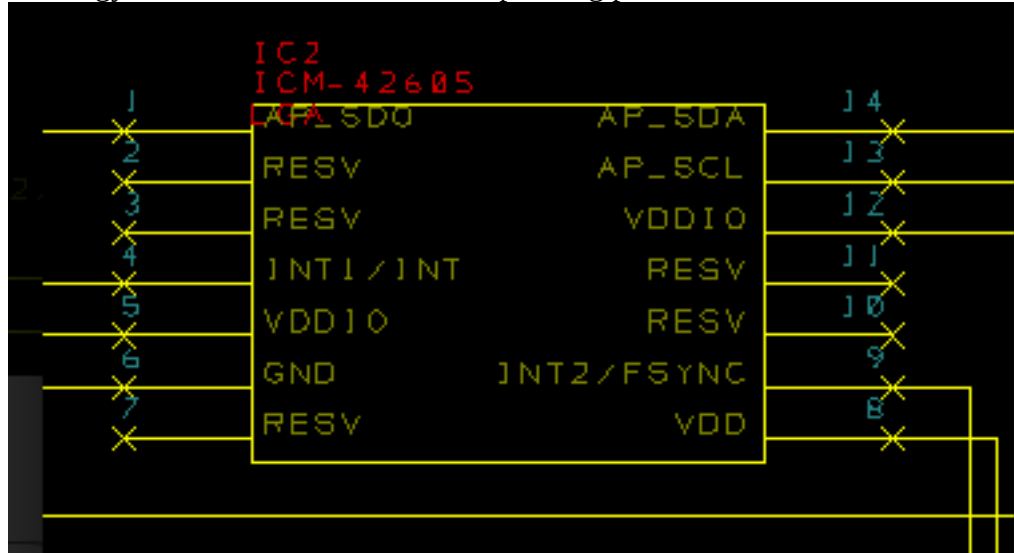
The USB module is shown below it has a connection to the power supply and ground. It is connected to the D+ and D- pins on the microcontroller. The circuitry is shown below:



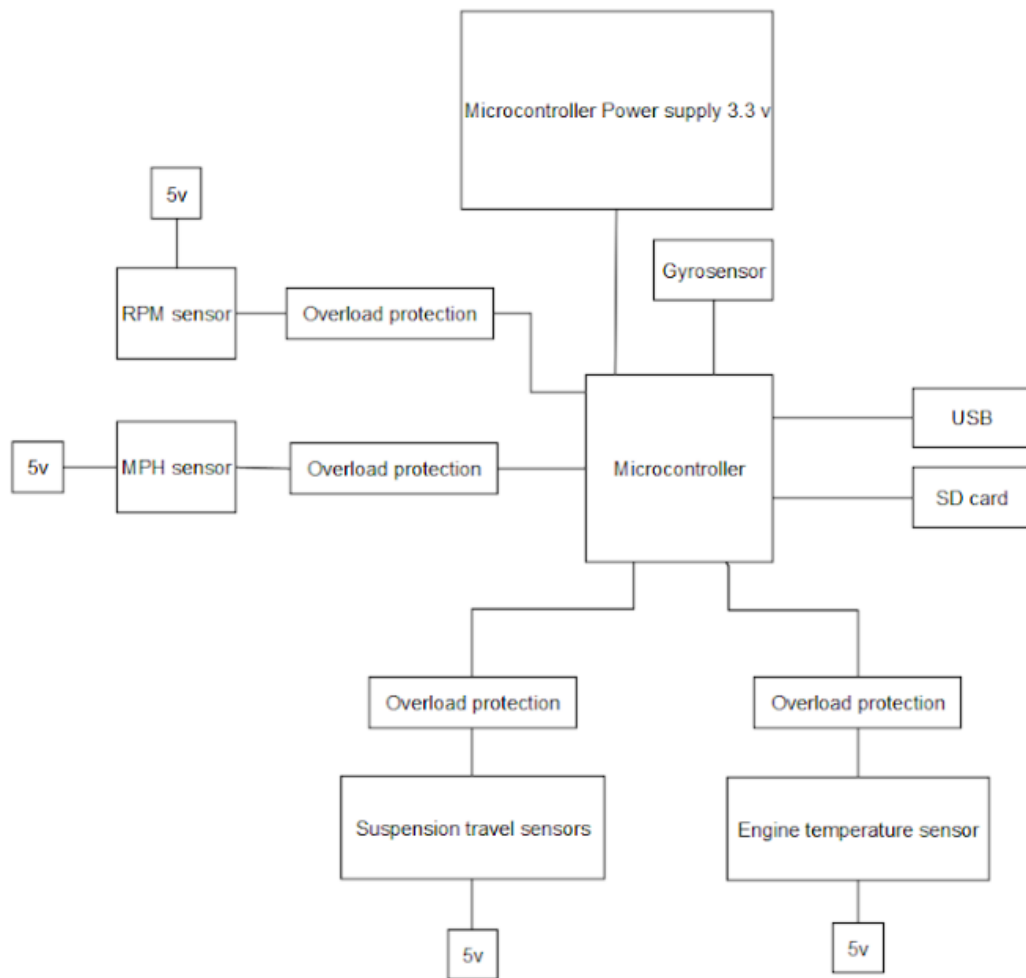
The circuit below shows the power supply to the PCB. There is a battery connected to ground and a switch. When the switch is pressed it allows the 9v battery to pass through the voltage regulator. The voltage regulator then gives out a 5v supply to the rest of the PCB. The circuit also shows the LED that is powered from the 5v supply.



The circuit below shows a gyro sensor, this is directly connected to the PCB. The pins on the gyro sensor link with the corresponding pins on the microcontroller.



Circuit block diagram



References

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