

Assignment 1 - Jordan Randel

by Jordan Mark Randel

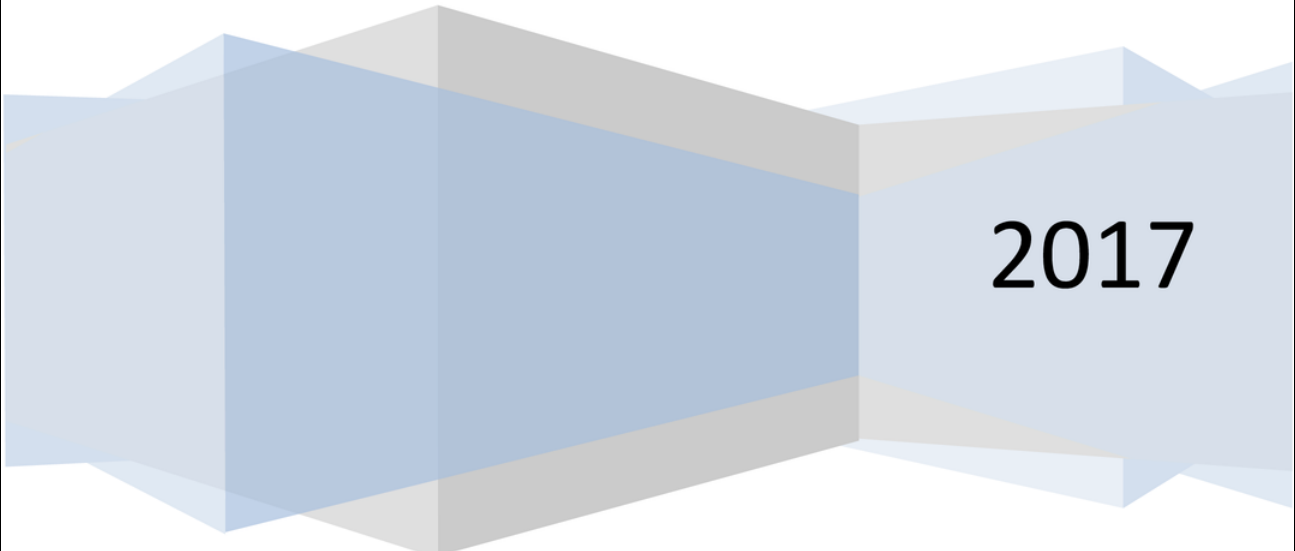
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Dr Gary Jones

Assignment 1

Vehicle Data Acquisition System

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2017

Abstract

Vehicle data acquisition systems are more widely used now than they ever have been. Electric data logging systems are used to record data and store the data through sensors that may be attached to a vehicle. The system at hand is a microcontroller based vehicle acquisition system. Relevant sensors, connectors, housing, memory size have been selected to help measure the different variables of a vehicles performance. A full working circuit design has been achieved using Proteus and a ready to manufacture PCB has been design on EasyPC. Although the system has been a success it isn't perfect. Improvements to the system can be made by adding Bluetooth, Wi-Fi, GPS and others. Another improvement to the cost of the system would have been to use surface mount electronic components on the PCB instead of through hole to save costs.

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1. Introduction

This report undertakes the task of designing a microcontroller based vehicle acquisition system. The report will compare different existing vehicle acquisition systems. The report will contain a comparison of a range of sensors that could be used to measure a vehicles performance which includes its RPM, engine surface temperature, suspension movement, etc. The relevant connectors will need to be selected to accommodate the sensors selected. An appropriate microcontroller will be selected after completed a series of calculations to help justify the selection. A full circuit design on Proteus will need to be completed with a PCB design on EasyPC. The report will include a build cost for a prototype, this would include the casing and battery as well as all other components. Finally, a review will be carried out on the project with a list of improvements to the specification and design for the next iteration.

2. Literature Review

2.1. Background Research

Data acquisition is measuring of real time measurements such as temperature to create data that a computer can control. The desired information is processed from signals and waveforms.

A data logger can be manually performed by a constant human observation. However, electronic data loggers are more accurate, effective and reliable for periodic readings, an electronic system that records data and stores that data [1]. The stored data can then be called upon and transferred to a computer for analysis. Data loggers allow one or more sensor inputs to be connected to it. They will log the data received at a pre-set frequency which can be as fast as hundreds readings per second [2].

2.2. Existing Systems

The portable VBox 3i is a powerful data logger that logs data at 100 times per second with high accuracy. It is used to measure a vehicles brake testing, handling & dynamics, performance testing and more. It has an LCD screen to show real time readings and even a USB and RS232 port. Pitch, Roll and Yaw can be measured by adding the RACELOGIC Inertial Measurement Unit [3]. This VBox 3i with the Pitch, roll and yaw add on is £11,145 + £15 Carriage + VAT.



Figure 1 - VBox 3i Vehicle Data Logger [3]



Figure 2 - DASH2 PRO Data Logger [4]

The Rebel LT data logger from Influx Technology is a small compact data logger that Influx Technology claim is very easy to use. It even has GPS and 3G. Its sample rate is a massive 1 KHz. It is used to as a vehicle tester, data acquisition, customer vehicle investigations and other data logging applications. It has an option for a screen to show real time readings and has a USB port. Pitch, Roll and Yaw can be measured by adding an accelerometer as an extra [5]. This price of this data logger with the pitch, roll and yaw add on is unknown as the supplier did not get back with a price.



Figure 3 - Rebel LT Data Logger [5]



Figure 4 - Aim EVO5 Data Logger [6]

The Aim EVO5 is a car racing data logger, it is a compact design with an aluminium IP65 enclosure. They claim to have a simple and immediate software configuration. This data logger comes with a GPS module. The logger has a 3 axis $\pm 5G$ accelerometer and 3 axis gyroscope. This data logger cost £1350 [6].

Data Logger	Input Voltage	Logging Time	Data Download	CAN Bus	Memory	Inputs/ Outputs	Sample Rate	Features
VBOX 3i	7-30VDC	Power Supply Dependant	USB/ Bluetooth/ RS232	Yes	32GB	Inputs – 4 Analog, Brake/Event Trigger, Log Switch Outputs – 2 Analog, 2 Digital	100Hz	Can measure velocity, time, Position, Radius of turn, acceleration and brake test time, brake stop accuracy, lap timing, absolute positioning.
DASH2 PRO	10-23V	24 Hours+	USB	Yes	8GB	Inputs - 1 Freq, 1 RPM, 4 Analog Outputs – 2 5V Ref, 4 Drivers, 4 PWM	100Hz	IP64, accelerometer, measure lap times, time slip, wheel speed, RPM
Rebel LT	4.7-36VDC	Power Supply Dependant	USB	Yes	64GB	Inputs – 4 Analog, 4 Digital IO Outputs – 4 Digital IO	1000Hz	Extras include; GPS, accelerometer, Wi-Fi, 3G
Aim EVO5	9-15V	Power Supply Dependant	RS232	Yes	4GB internal, SD up to 128GB	Inputs – 8 Analog, 2 Digital, 1 RPM Outputs – 2 Digital		Expandable IO, GPS, gyroscope, accelerometer, supports video integration, WiFi.

3. Product Details

3.1. Sensor Selection

3.1.1. Suspension Movement

A number of different types of sensors have been compared in the table below to help identify the best sensor to measure suspension movement.

Sensor Type	Accuracy	Typical Range	Ruggedness	Life Span and Repeatability	Relative Cost
Optical	High	Low	Low	Medium	Medium
Ultrasonic	Low	High	Medium	High	High
LVDT	High	Low	High	High	High
Wire Potentiometer	Medium	Medium	Medium	Medium	Low

A wire potentiometer has been chosen out of the sensors to measure suspension movement. One of the reasons was because wire potentiometers are unaffected by the conditions it's in but may require more lubrication and maintenance. Wire potentiometers also seemed to be easier to be able to fit than the other sensors. This is important as the system will be getting moved around a lot. LVDT sensors do not have the flexibility of wire potentiometers, they require a vertical movement but suspension movements can curve slightly. Optical sensors would have problems with dirt and water spraying up as the light would scatter or get restricted by water or dirt. Ultrasonic would have problems at high speeds, the wind at high speeds could affect the ultrasonic sound. Wire potentiometer also tend to be a lower cost compared to other types of sensors.

A selection of wire potentiometers specifications have been compared in the table below to aid in selecting the most relevant sensor for the system.

Manufacturer	Part Number	Input Voltage	Power Consumption	Output Signal	Range	Material	IP Rating	Accuracy	Price
UniMeasure	FX-HM-15-N1S	4.9-30VDC	30mA	0-10V	375mm	Thermoplastic Body	IP65		
TE Connectivity	SP2-25	30VDC Max	2W	Voltage	635mm	Polycarbonate	IP50	0.25-1%	£172.40
SICK	BCG05-L1KM01PP	19-33VDC	2W	0-10V	1.25m	Plastic, Noryl	IP65		£418.81
BEI Sensors	CD050-0750-R01K-L25-L4-IP67	5V	2W	1K Ohm	0-750mm	Aluminium	IP67	High	£395

The sensor from BEI Sensors proved to be the best option out of all the sensors listed above. This sensor has been adapted for the harshest of conditions which is critical as the sensor will have plenty of water and dirt sprayed. As the IP rating is crucial, this rules out the sensor from TE connectivity. Also, the sensor will be moved from vehicle to vehicle so it will have to robust, preferably made from metal. This rules out the sensor from UniMeasure and SICK. The supply voltage for the wire potentiometer from SICK could also be a problem. This sensor is adapted for the harshest of environments which means it would be perfect for the application.



Figure 5 - BEI Wire Potentiometer [9]

3.1.1.2. Engine Surface Temperature

A number of different types of sensors have been compared in the table below to help identify the best sensor to measure the surface temperature of a vehicles engine.

Sensor Type	Accuracy	Typical Range	Ruggedness	Life Span and Reliability	Relative Cost
Optical (Infrared)	High	High	High	High	High
Thermocouple	Medium	High	High	Low	Medium
RTD	High	Medium	Low	High	Medium
Thermistor	Dependent on calibration	Low	Medium	Medium	Low

Engine temperature could be measured using a thermistor, thermocouple, RTD or infrared sensors. Infrared sensors have proven to be the better method of the ones that were looked at for measuring temperature as there is no physical contact or damage to the sensor, hence the operating life is greater. RTDs are susceptible to damage when vibration occurs which would make them a bad choice for this application. Thermocouples require cold-junction compensation which can increase costs.

A selection of infrared sensor specifications have been compared in the table below to aid in selecting the most relevant sensor for the system.

Manufacturer	Part Number	Input Voltage	Power Consumption	Output Signal	Range	Material	IP Rating	Accuracy	Price
FLIR	FLIR AX8	10.8-30VDC	2W		-10°C to 150°C		IP67	±2%	£834
Omega	OS136-1-V1	12-24VDC	50mA	0-5VDC	-18°C to 204°C	Stainless Steel	IP65	3%	£172.80
Omron	ES1C-A40	12-24VDC	70mA	0-20mA	0-400°C	SUS Body	IP67	±2°C	£483.90
Semitec	NC-F16	5VDC			-10°C to 150°C	(Metal)		±3°C	£48.48

The sensor from Omega proved to be the best option out of all the sensors listed above. All the sensors are fairly similar in terms of robustness as they are all metal. They all have good IP ratings and operate within a reasonable input voltage range and similar accuracy. However, the Omega sensor has the lowest power consumption. The output signal is more desirable as microcontrollers tend to operate up to 5VDC which means no signal conditioning will be needed to bring the output voltage down. The Omega sensor is also a reasonable price. A mounting bracket will need to be either manufactured or purchased.



Figure 6 - Omega Temp Sensor [10]

3.1.3. G Forces

A number of different types of sensors have been compared in the table below to help identify the best sensor to measure the G Forces (Pitch, Roll, and Yaw).

Sensor Type	Accuracy	Typical Range	Ruggedness	Life Span and Reliability	Relative Cost
Gyroscope	High	High	High	High	High
Accelerometer	Medium	High	Medium	High	Medium
Magnetometer	Low	High	High	High	Medium

A gyroscope was chosen to be the best approach to measuring G forces because it is not influenced by gravity and it has a higher dynamic range. Accelerometers are influenced by gravity. So, without a gyroscope it is impossible to conclude if a measured acceleration is due to motion or gravity. A magnetometer measures magnetic fields and as the earth has a magnetic field it can be used to determine orientation. However, if being used for orientation or fast movement the accuracy is poor on a magnetometer. Unlike a gyroscope which reacts quickly and is accurate to changes.

Manufacturer	Part Number	Input Voltage	Power Consumption	Output Signal	Range	Material	IP Rating	Accuracy	Price
3DM	3DM-GX5-25	4-36VDC	500mW		±300°/s	Aluminium			£1375
Texense	GYRN3-S-XC-YC-ZC	5-16VDC	16mA	0-5V	±150°/s	Aluminium	IP66	2% FS	£1460
Seiko Epson	XV-9300D	5V	6.7mA	Analog Voltage	±300°/s				
Texense	GYRN3-S-X-Y-Z	5-16VDC	16mA	0-5V	±300°/s	Aluminium	IP66	2% FS	£1460

Sensor GYRN3-S-X-Y-Z from Texense proved to be the best option out of all the sensors listed above. Most of the sensors above were suitable for the application as a normal family saloon car would not rotate more than 300°/s. The sensor GYRN3-S-XC-YC-ZC from Texense fit perfectly but the range was not great enough. After emailing the supplier it was found that another sensor very similar was available for the same price and the desired range. The reason the 3DM and Seiko Epson sensor wasn't chosen was because of the lack of information such as the IP rating even after multiple emails from the supplier.



Figure 7 - Texense Gyroscope [12]

3.1.4. RPM & MPH

A number of different types of sensors have been compared in the table below to help identify the best sensor to measure a vehicles RPM and MPH. As these measurements will be measured in the same way it would make sense to use the same type of sensor for both RPM and MPH.

Sensor Type	Accuracy	Typical Range (mm)	Ruggedness	Life Span and Reliability	Relative Cost
Magnetic (Reed)	Medium	Low	Low	High	Medium
Magnetic (Hall)	Medium	Low	Medium	High	Medium
Optical (Reflective)	High	Medium	Medium	High	Medium
Optical (Beam Break)	High	Medium	Medium	High	Medium

RPM and MPH can be measured in many different ways, a few are listed above and compared. Optical reflective was chosen over other types because optical sensors are typically more accurate than magnetic which is crucial as a change in RPM or MPH can occur very quickly. A reflective type of optical sensor was chosen purely for ease of installation. The idea is to have reflective tape on the wheel, if beam break was used it would be more awkward to fit this type of sensor and move from vehicle to vehicle.

Manufacturer	Part Number	Input Voltage	Power Consumption	Output Signal	Speed Range	Material	IP Rating	Operating Range	Price
Monarch Instrument	MON-6180-057-ROS-P	6-24VDC	40mA	TTL	1-50K RPM	Stainless Steel		61cm	£114.67
Emerson	A0430L3	5-7.2VDC		±2.5V	2-120K RPM			9m	
Compact Instruments	Mini VLS 111	5VDC	30mA	5V (Digital Pulse)	0.1-250K RPM	Stainless Steel	IP67	100-2000mm	£285+£25
Pruftechnik	VIB 6.631	5V		5V (TTL)	0.1-600K RPM		IP65	0.05-2m	

The most suitable sensor out of the listed sensors above is the Compact Instruments sensor, the price listed also includes reflective tape. However, it does say in the manual that a white can be painted on a non-reflective object, it would be wise to purchase the reflective tape just in case. This sensor is perfect for the job in every way, stainless steel housing with a great IP rating, and low input voltage and power consumption. A strong magnetic base can be purchased to fit the sensor to for £65. It also had a thread on the body of the sensor so that it can be secured into a bracket. The sensor from monarch instrument may not have a large enough speed range if the vehicle is travelling at high speeds. Other sensors were ruled out due to the lack of information gathered on them.



Figure 8 - Compact Instruments Speed Sensor [11]

3.2. Connector Selection

All connectors to have gold plated contacts as gold plated contacts won't corrode or tarnish over time and in this scenario it would be beneficial. The connectors will also need to have an adequate IP rating for the application it will be used for, at least IP65.

3.2.1. Suspension Movement



Figure 10 - RS PRO 3 Pole Panel Mount Connector [14]

The wire potentiometer chosen needs a connector with at least 3 pins. A pin for its supply voltage, a ground and an output signal. This 3 pole connector was chosen because it has gold plated contacts, a strong metal housing and an IP rating of IP67. As there are 4 sets of connectors needed for the suspension movement the connectors will be colour coded to ensure the correct pair are connected together. If someone was to connect them up wrongly by accident it would not cause any damage.



Figure 9 - RS PRO 3 Pole Cable Connector [14]

3.2.2. Engine Surface Temperature



Figure 12 - Brad Harrison 6 Pole Panel Mount Connector [15]

The infrared sensor chosen needs a connector with at least 5 pins. As for the input, it needs a pin for the positive, a pin for the negative and a pin for the ground. The output also needs a positive pin and a negative pin. This 6 pole connector has gold plated contacts, it has an IP rating of IP67. It is also small in size for mounting on the box.



Figure 11 - Brad Harrison 6 Pole Cable Connector [15]

3.2.3. G Forces



Figure 13 - Brad Harrison 8 Pole Panel Mount Connector [15]

The gyroscope chosen needs a connector with at least 5 pins. A pin for the supply voltage, a pin for the 0V, and also a pin for each pitch, roll and yaw. A generic photo has been used on the Brad Harrison website for these connectors. This 8 pole connector has the same characteristics as the 6 pole. This ensures that the connectors cannot incorrectly connected.



Figure 14 - Brad Harrison 8 Pole Cable Connector [15]

3.2.4. RPM & MPH

The optical sensor chosen needs a connector with at least 3 pins. A pin for the supply voltage, a pin for the ground and a pin for the output signal.



Figure 16 - Hirose 4 Pole Panel Mount Connector [16]

The connector chosen for RPM is a 4 pole connector with gold plated contacts, its IP rating is IP68 and is made from metal.



Figure 15 - Hirose 4 Pole Cable Connector [16]



Figure 18 - Hirose 3 Pole Panel Mount Connector [16]

The connector chosen for MPH is the same type as the one chosen for RPM but this one is a 3 pole connector instead so the user would not be able to connect to the RPM connector.



Figure 17 - Hirose 3 Pole Cable Connector [16]

3.3. Battery Sizing

To determine a battery size that would be adequate all of the sensors, LEDs, and other components must be considered.

Component	Power Consumption	Quantity	Total Power Consumption
Temperature Sensor	50mA	1	50mA
Gyroscope	16mA	1	16mA
RPM & MPH Sensor	30mA	2	60mA
Suspension Sensor	5mA	4	20mA
LEDs	25mA	2	50mA

The total for all the components total power consumption is 196mA. This is then multiplied by 2 hours for the amount of time it is needed to be online for. Then it is multiplied by 4 to allow enough extra capacity in the battery. This totals around 1.6Ah, so anything above this would be sufficient.

3.4. Casing

This Peli case is waterproof with an IP rating of IP67. The case is fitted with foam which will protect the PCB and other components from moving around or coming into contact each other. Peli have claimed the case is “virtually indestructible” [7]. The external dimensions are 196mm H x 300mm W x 249mm D and the internal dimensions are 184mm H x 241mm W x 190mm D. This case will be big enough to all the components in and fit the connectors to the case.



Figure 19 - Peli iM2075 Case [14]

4. Microcontroller Selection

4.1. A/D Bit Resolution

This needs to be worked out as all the analog signals will be going through the multiplexer. This being said, the maximum A/D bit resolution needs to be known.

4.1.1. Suspension Movement

Suspension movement is needed to be measured every 1mm. The vehicle will sit at 380mm and will move up or down by 150mm, giving a range of 300mm. The range of the sensor chosen is 0-750mm and the output is up to 5V. To work out the voltage at 380mm the following calculation is done;

$$\frac{5}{750} * 380 = 2.53V$$

Likewise, to work out the voltage at the upper limit of 530mm and the lower limit of 230mm, the following calculations are completed;

$$\frac{5}{750} * 530 = 3.53V$$

$$\frac{5}{750} * 230 = 1.53V$$

The span in voltage is 2V and in mm is 300mm. Next is to work out the voltage change per mm.

$$\frac{2}{300} = 0.0066V$$

Therefore, to work out the A/D bit resolution the first thing to know is how many different levels an 8 bit, 10 bit, and 12 bit has. An 8 bit has 256, 10 bit has 1023 and 12 bit has 4095. With this in mind, the following calculation is done;

$$\frac{5}{1023} = 0.0048V$$

For suspension movement a 10 bit is adequate as only 0.0066V is needed per mm but with a 10 bit we will get 0.0048V.

4.1.2. Engine Surface Temperature

Engine surface temperature must be able to be detected when there are changes of 0.5°C. The temperature of a vehicles engine will range from -10 °C to 120 °C, giving a range of 130 °C. The range of the sensor chosen is -18°C to 204°C, so 222°C and the output is up to 5V. To work out the A/D bit resolution, the following calculation is done;

$$\frac{222}{0.5} = 444$$

As there needs to be 444 readings, 8 bit is 256, 10 bit is 1024, which will have to be used.

4.1.3. G Forces

Pitch, roll and yaw must be able to be detected when there are changes of 1°/s. Pitch will not change at more than ±60°/s, roll ±30°/s, and yaw ±260°/s. The range of the sensor chosen can measure ±300°/s, so 600°/s and the output is up to 5V. The voltage at 0°/s will be 2.5V. The three for pitch roll and yaw will be the same, so there is no need in working out for each of them.

To work out the voltage at the limits for roll of ±60°/s, the following calculations are completed;

$$\frac{5}{600} * 360 = 3V$$

$$\frac{5}{600} * 240 = 2V$$

The span in voltage is 1V. Next, is to work out the voltage change per °/s.

$$\frac{1}{120} = 0.0083V$$

Therefore, to work out the A/D bit resolution at say 10 bit, the following calculation is done;

$$\frac{5}{1023} = 0.0048V$$

For pitch a 10 bit is adequate as only 0.0083V per °/s is needed.

4.2. Digital Counter Bit Resolution

4.2.1. RPM

RPM will need to be measured every 50 revs. The range on an Audi A4 is between 0 and 8000 revs. To work out the bit resolution, the following calculation is done;

$$\frac{8000}{50} = 160$$

Therefore, 8 bit would be sufficient as there is 256 levels to an 8 bit counter.

4.2.2. MPH

An Audi A4 has been chosen for a family saloon vehicle, its wheel size is 18" in diameter. To work out how far the wheel will travel in 1 revolution this formula will be used;

$$Circumference = \pi d$$

Equation 1 - Circumference of a circle

$$\pi * 18 \cong 56"$$

There are 1760 yards in a mile, there are 3 feet in a yard and 12 inches in a foot. Which means there are 63360 inches in a mile. To work out how many revolutions in a mile the vehicle will travel this calculation is done;

$$\frac{63360}{56} = 1131 \text{ revs/mile}$$

There are 3600 seconds in an hour. So, to work out how many pulses per second that is needed the following calculation is done;

$$\frac{1131}{3600} = 0.26 \text{ pulse/second}$$

As it is not possible to have 0.26 pulses per second on the wheel it will need to have 4 bits of reflective tape to be able to work. This would make 1.06 pulse/second. The top speed we will set to be measured at is going to be 90mph. So to work out how many measurements we will take per second at 90 mph is the following;

$$90 * 1.06 = 95.4$$

Therefore, 8 bit would be sufficient as there is 256 levels to an 8 bit counter.

4.3. System Memory

4.3.1. Suspension movement

An Audi A4 has been chosen for a family saloon vehicle, its wheel size is 18" in diameter. To work out how far the wheel will travel in 1 revolution equation 1 is used;

$$\pi * 18 \cong 56"$$

There are 1760 yards in a mile, there are 3 feet in a yard and 12 inches in a foot. Which means there are 63360 inches in a mile. To work out how many revolutions in a mile the vehicle will travel this calculation is done;

$$\frac{63360}{56} = 1131 \text{ revs/mile}$$

If the vehicle is travelling at 60mph, to work out how many revolutions per second the vehicle is travelling the following calculation is done;

$$\frac{1131}{60} = 16 \text{ revs/second}$$

To work out how far the vehicle will travel in a second at 60mph the following calculation is done;

$$\text{Vehicle Distance Travelled} = 56 * 16 = 896" \text{ per/second}$$

The suspension sensor must be able to detect objects as little as half an inch. Therefore, the vehicle could run over 1792 of those half inches in a second. To work out how often readings must be taken the next calculation is done;

$$\frac{1}{1792} \cong 0.5 \text{ milliseconds}$$

The frequency at which measurements are taken is 0.5 milliseconds. To work out the memory, firstly the following formula will be used;

$$\text{Frequency} = \frac{1}{\text{Periodic Time}}$$

Equation 2 - Frequency

$$\frac{1}{0.5 \times 10^{-3}} = 2000$$

There are 4 wheels so there will be 4 readings taken every 0.5ms of 2 bytes each so the 2000 is multiplied by 4 readings to make 8000 and by the 2 bytes to make 16KB per second.

4.3.2. Engine Temperature

As engine temperature is slow changing a reading every 30 seconds would be sufficient.

The frequency at which measurements are needed to be taken is 30 seconds. To work out the memory, firstly 'equation 2' will be used;

$$\frac{1}{30} = 0.033$$

Regardless of its size if it's under 2B it would have to be 2B because the A/D resolution is over 8 bits.

4.3.3. G Forces

The frequency at which measurements are needed to be taken is 5 milliseconds. To work out the memory, firstly 'equation 2' will be used;

$$\frac{1}{5 \times 10^{-3}} = 200$$

There are 3 axis to measure (pitch, roll and yaw), so there will be 3 readings taken every 5ms of 2 bytes each so the 200 is multiplied by 3 readings to make 600 and by the 2 bytes to make 1.2KB per second.

4.3.4. RPM & MPH

The frequency at which measurements are needed to be taken is 0.5 seconds. To work out the memory, firstly 'equation 2' will be used;

$$\frac{1}{0.5} = 2$$

As the RPM & MPH there only needs an 8 bit counter, the frequency will be multiplied by the 1 byte to give 2B per second.

4.3.5. Total Memory

As the MPH, RPM and temperature are all very small amounts they can be ignored when working out the total memory per second. This adds up to a total of 17.2KB per second. To find this out per hour the 17.2KB per second is multiplied by 3600 to get roughly 62MB per hour. However, the system specification requires this to be able to last for two hours, this is achieved by then multiply by 2 to get a total memory required of 124MB.

After searching a 512MB micro SD card was chosen as it was cheaper than a 128MB SD card.

4.4. Pin Count

One of the specifications needed for selecting a microcontroller is how many pins is needed. The amount of analog and digital signals that are needed depend on the sensors chosen. The sensors for measuring suspension movement, engine temperature, and G forces (pitch, roll and yaw) are analog signals. Pins wise, this means there is 8 analog signals, 4 for suspension movement, 1 for engine temperature and 1 for G forces. There are 2 digital signals that are needed which is for RPM and MPH. The PIC will also need to accommodate for its supply, USB is that the data can be uploaded to a PC after the recording are taken, RS232 is so that the data can be seen, SPI is so the PIC can talk to the SD card, an LED and a start pushbutton. Again, pins wise there is 2/4 for the supply, 2 for RS232, 3 for SPI, 1 for an LED and 1 for a start pushbutton. This adds up to a minimum of 21 pins, PICs pin counts standards around this amount are 20, 28, 40. So, a pin count of 28 would be sufficient.

4.5. Internal Oscillator

For an example, if a 4MHz internal oscillator was chosen it would have 1 million instruction in a microsecond. This is because PICs are designed with quadrature architecture this means they need 4 clock cycles per instruction.

- 3 instructions to select a channel
- 30 microseconds delay to settle
- 5 instructions to start the conversion
- 6 microseconds delay for the conversion
- 4 instructions to read the analog to digital conversion
- 30 instructions to store the data

This then adds up to a total of 78 microseconds per channel for 1 analog reading and storage. The worst case of readings at the same time would be 78 microseconds multiplied by 8 analog signals gives 624 microseconds. The delays add up to 36 microseconds, multiply this by 8 analog signals gives 288 microseconds, this can't be helped. However, if we were to subtract 288 by 624 this equals 336 microseconds. The amount of time for loops needs to be considered so the actual amount of time per reading can be doubled. This being said, 336 microseconds would need to be divided by around 150, which calculates to more than 2. So, 4MHz is not great enough and as it's multiplied by over 2 then at least 16MHz is required for the internal oscillator.

4.6. Microcontroller Selection

When selecting a microcontroller, the website Microchip was used to help determine what PIC to select. The following minimum required data was entered into the website to narrow down the choices for a PIC:

- 28 pins as 20 pins would be too little
- 8 A/D channels
- 10 bits of A/D resolution
- 1 UART
- 1 SPI
- 1 USB
- 16MHz Internal oscillator

As shown below there were quite a few selections left. All PICs shown met the criteria above and also the program memory, CPU speed and RAM requirements. So, at this point the cheapest PIC was chosen which was PIC18F24K50.

Parameter Name	Value
Program Memory Type	Flash
Program Memory (KB)	16
CPU Speed (MIPS)	12
RAM Bytes	2,048
Data EEPROM (bytes)	256
Digital Communication Peripherals	1-UART, 1-SPI, 1-I2C1-MSSP(SPI/I2C)
Capture/Compare/PWM Peripherals	2 Input Capture, 1 CCP, 1 ECCP,
Timers	2 x 8-bit, 2 x 16-bit
ADC	14 ch, 10-bit
Comparators	2
USB (ch, speed, compliance)	1, FS Device
Temperature Range (C)	-40 to 125
Operating Voltage Range (V)	1.8 to 5.5
Pin Count	28
Low Power	Yes
Cap Touch Channels	14

Figure 20 - PIC18F24K50 Spec [13]

To SORT a column click the column header. Use CTRL key to select multiple values.

Product	Buy	Status	Documents	SK Pricing	Program Memory Size (Kbytes)	RAM (bytes)	EEPROM / HEF	Pin count	Max. CPU Speed MHz	Peripheral Pin Select (PPS)	Internal Oscillator	# of Comparators	Operational Amplifier
Reset PIC18F24K50 PIC18F25K50 PIC18F26K50 PIC18F27K50 PIC18F28K50 PIC18F29K50 PIC18F44K50 PIC18F45K50 PIC18F46K50 PIC18F47K50 PIC18F48K50 PIC18F49K50 PIC18F50K50 PIC18F51K50 PIC18F52K50 PIC18F53K50 PIC18F54K50 PIC18F55K50 PIC18F56K50 PIC18F57K50 PIC18F58K50 PIC18F59K50 PIC18F60K50 PIC18F61K50 PIC18F62K50 PIC18F63K50 PIC18F64K50 PIC18F65K50 PIC18F66K50 PIC18F67K50 PIC18F68K50 PIC18F69K50 PIC18F70K50 PIC18F71K50 PIC18F72K50 PIC18F73K50 PIC18F74K50 PIC18F75K50 PIC18F76K50 PIC18F77K50 PIC18F78K50 PIC18F79K50 PIC18F80K50 PIC18F81K50 PIC18F82K50 PIC18F83K50 PIC18F84K50 PIC18F85K50 PIC18F86K50 PIC18F87K50 PIC18F88K50 PIC18F89K50 PIC18F90K50 PIC18F91K50 PIC18F92K50 PIC18F93K50 PIC18F94K50 PIC18F95K50 PIC18F96K50 PIC18F97K50 PIC18F98K50 PIC18F99K50 PIC18F100K50 PIC18F101K50 PIC18F102K50 PIC18F103K50 PIC18F104K50 PIC18F105K50 PIC18F106K50 PIC18F107K50 PIC18F108K50 PIC18F109K50 PIC18F110K50 PIC18F111K50 PIC18F112K50 PIC18F113K50 PIC18F114K50 PIC18F115K50 PIC18F116K50 PIC18F117K50 PIC18F118K50 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5. Design

5.1. Schematic Design

Below is the finished circuit for the vehicle data acquisition system. The circuit was designed on Proteus.

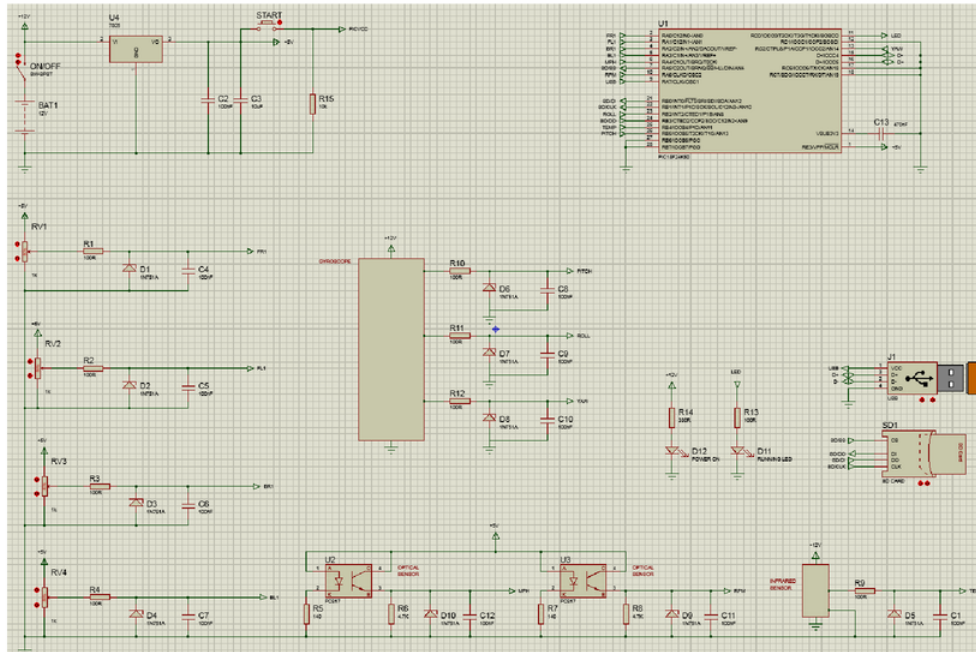


Figure 22 - Full Schematic Design

This below circuit is the power for the system. It has a 12V battery fitted, when turned on it will supply any sensors that require 12V. It also supplies a voltage regulator, this regulator requires a 7-35V input and a ground, and it will output a regulated 5V. Capacitor C2 is a filter and capacitor C3 is a tank capacitor that will store some voltage if power is lost. There is a 5V output for when it is switched on there will be a constant supply for all sensors that require a 5V supply. A start button has been fitted so that a 5V pulse is sent to the PIC to tell it to come online. R15 is a pull down resistor so that the signal doesn't float.

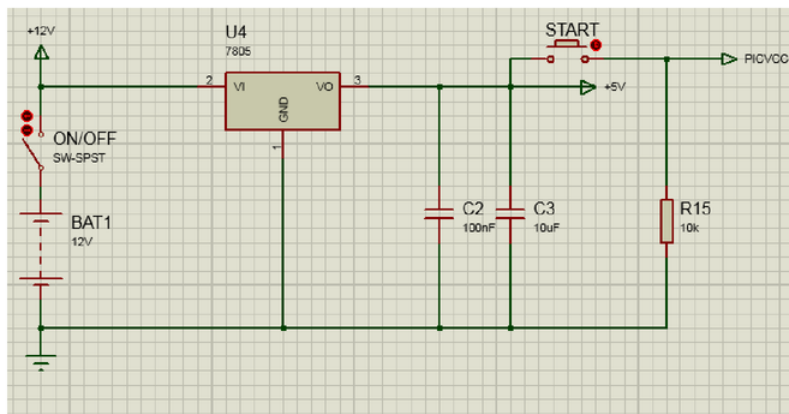


Figure 23 - Power Distribution

Here is the circuit for all of the 4 wire potentiometers. FR1 is the front right tyre, FL1 is the front left tyre and so on. The potentiometer is the sensor, it has a 5V supply and a ground. On the output there is a resistor and capacitor which act as a low pass filter. The Zener diode is added to clamp from over voltage.

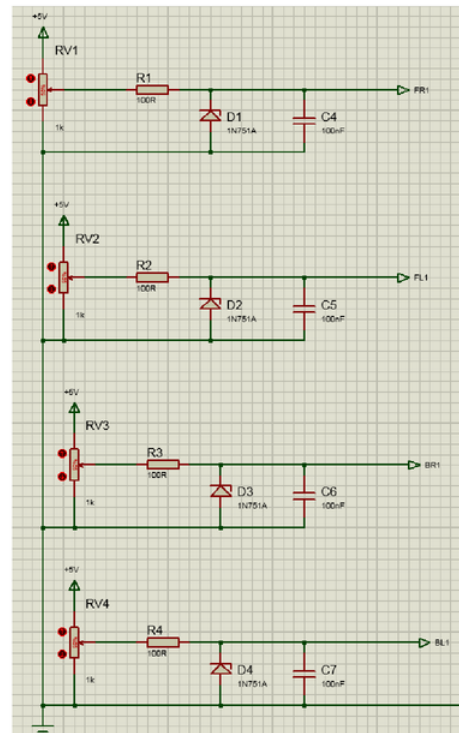


Figure 24 - Suspension Movement Circuit

Here is the circuit for the engine surface temperature. The block drawn is the sensor, it has a 12V supply and a ground. The sensor outputs 0/5VDC so again on the output there is a low pass filter and Zener diode to clamp from over voltage.

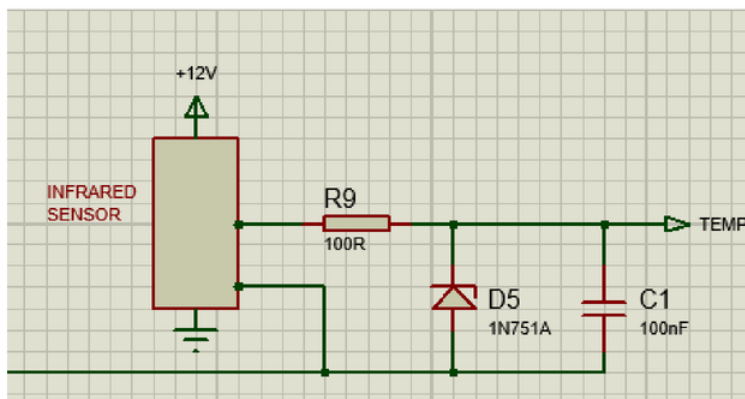


Figure 25 - Temperature Sensor Circuit

Here is the circuit for the gyroscope. The block drawn is the sensor, it required a 12V supply and a ground. It also needed a separate core for each of the signals. The gyroscope also output a 0/5V signal so again on the outputs there is a low pass filter and Zener diode to clamp from over voltage.

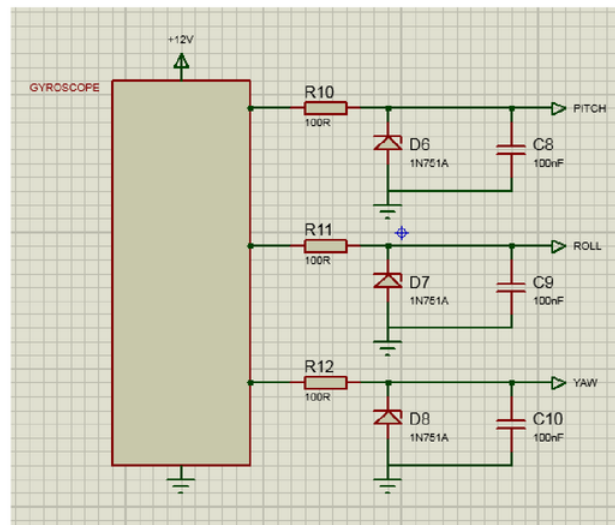


Figure 26 - Gyroscope Circuit

Here is the circuit for the RPM & MPH sensors as they are using the same type of sensor. The sensor is a photo electric sensor. It has a 5V supply and a ground. The datasheet specifies that the pull up resistor must be 4.7K. Again, on the output there is a low pass filter and Zener diode to clamp from over voltage.

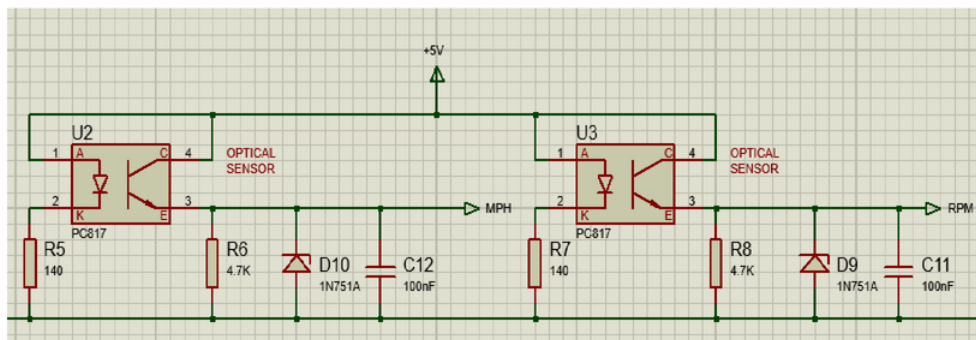


Figure 27 - RPM & MPH Circuits

The specification states that USB is needed to connect to a computer. A USB is a bi-directional device but it also needs a ground and the VCC will come from the computer when plugged in.

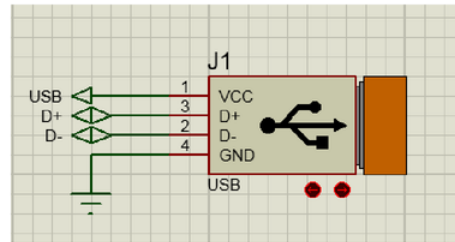


Figure 28 - USB Configuration

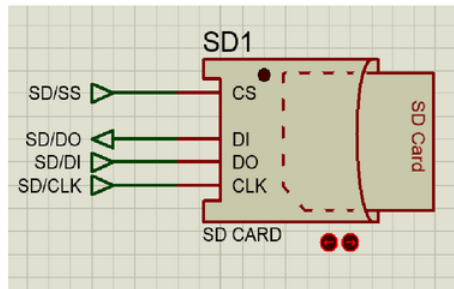


Figure 29 - SD Card Configuration

The specification states that the system must store collected data to a non-volatile memory. An SD card is used. The SD card needs a digital input from the PIC and also a separate digital signal to output to the PIC. It needs a SPI clock rate to be sent from the PIC to synchronise and also a chip select which is a reference signal so the PIC can begin to write to it.

There is two LEDs for the system. The first is fed from the 12V power signal after the switch to indicate that the power is on. The second is to indicate that the PIC is running. The resistor calculations is as follows:

$$R14 = \frac{12 - 2.5}{0.25 \times 10^{-3}} = 380\Omega$$

$$R13 = \frac{5 - 2.5}{0.25 \times 10^{-3}} = 100\Omega$$

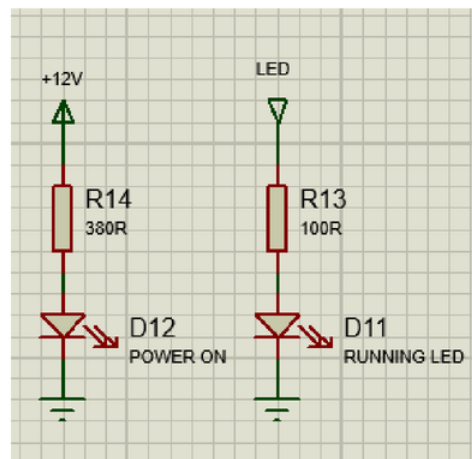


Figure 30 - LEDs

The PIC needs the 470nF on pin VSUB3V3 to stabilise the voltage regulator output voltage for the USB. A capacitor of 0.1uF is added between VDD and VSS.

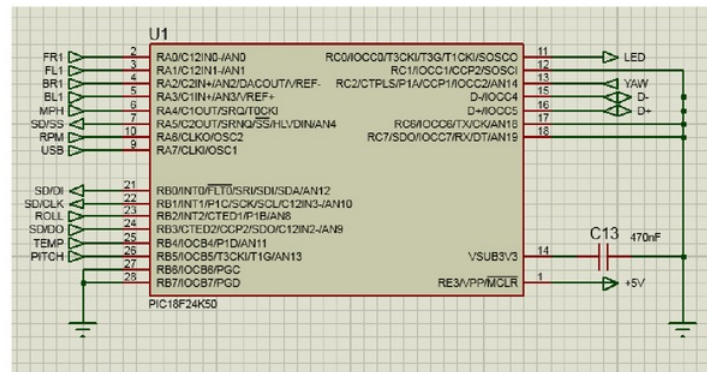


Figure 31 - Microcontroller

5.2. PCB Design

The schematic design that was completed in Proteus was transferred onto EasyPC so that the PCB design could be completed. Below is an image of the finished schematics on EasyPC.

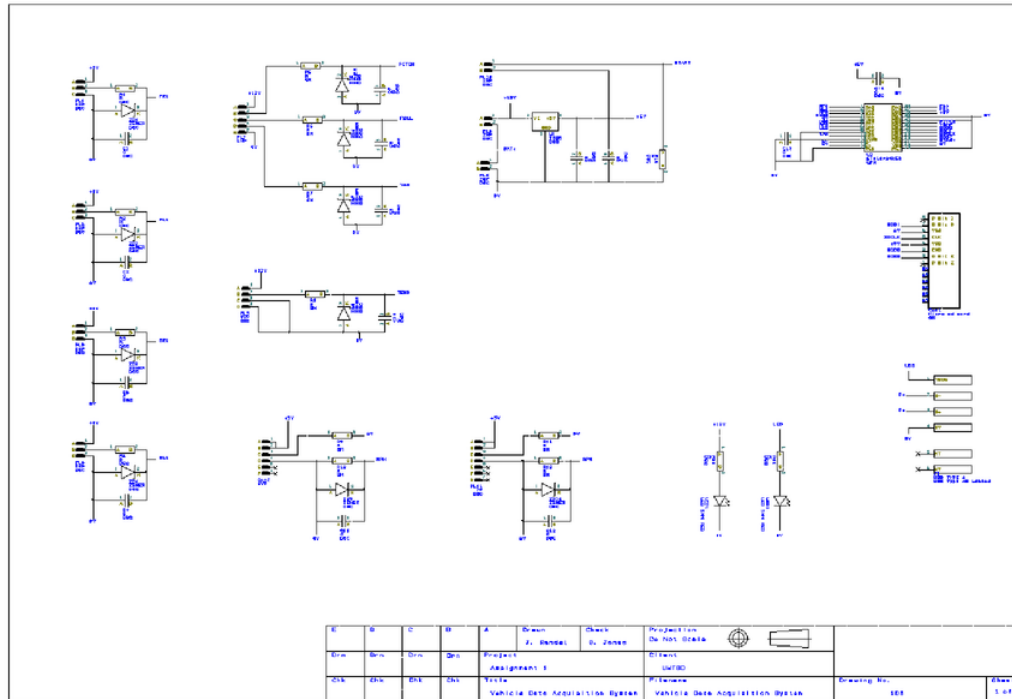


Figure 32 - EasyPC Schematics

Below is the finished PCB design for the system. The first image is to show that there are now no errors in the design after running a design rule check.

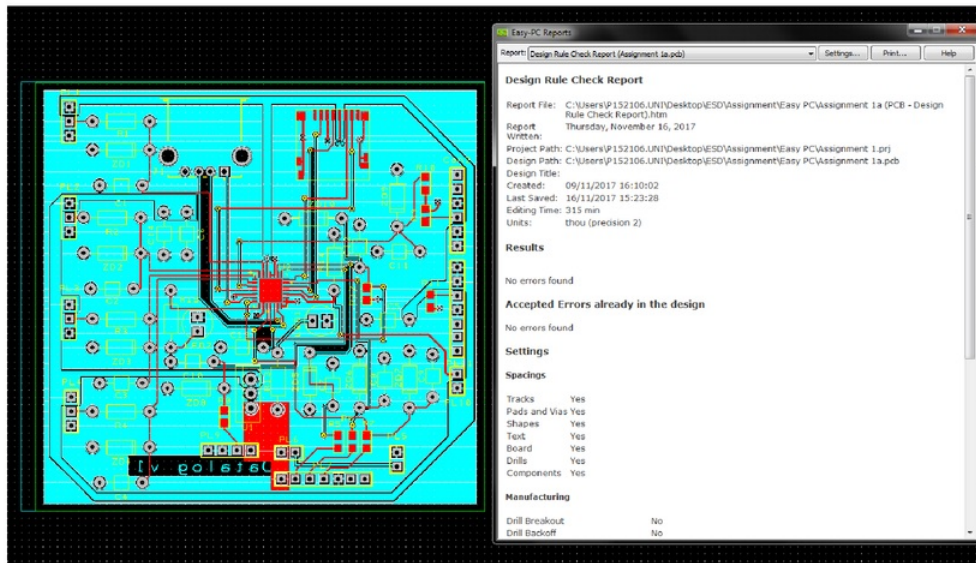


Figure 33 - No errors in PCB Design

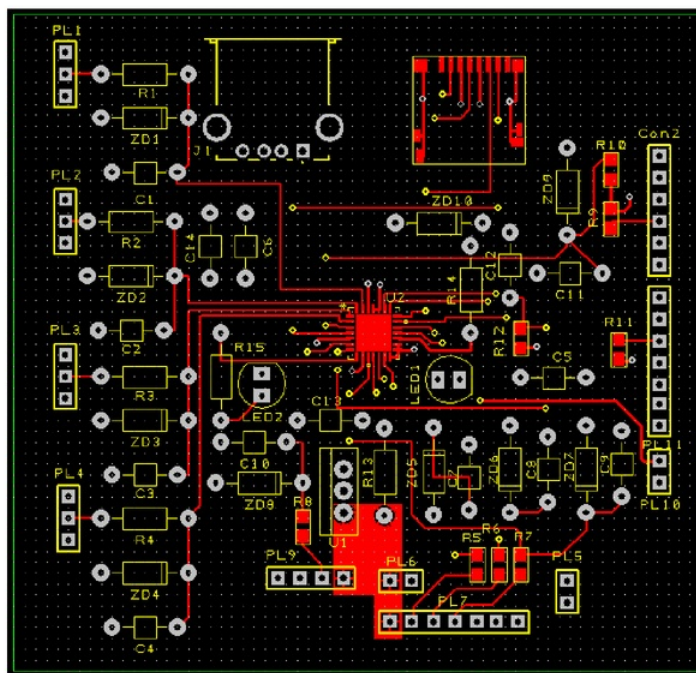


Figure 34 - PCB Top Layer View

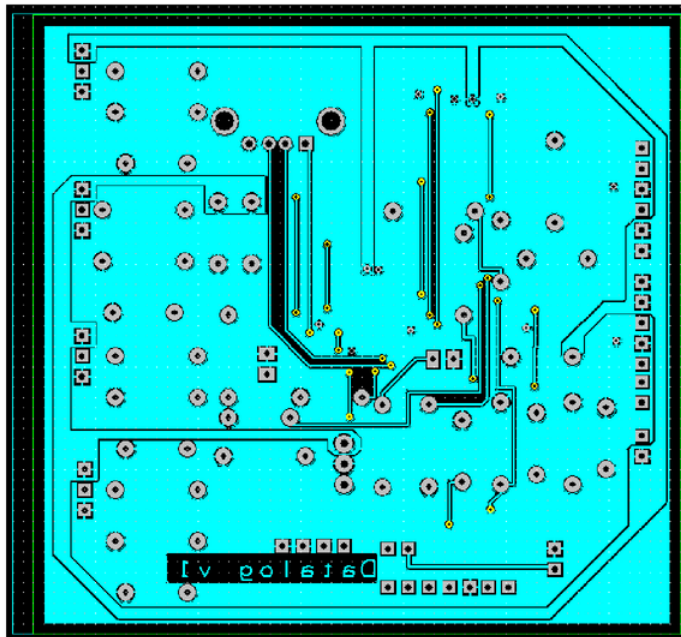


Figure 35 - PCB Bottom Layer View

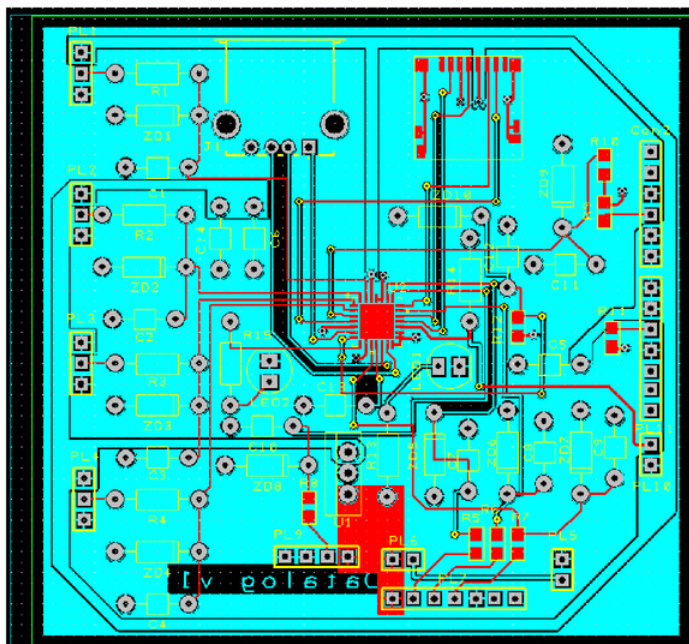


Figure 36 - PCB Composite View

It's easily noticeable that the PCB does not have drill holes to be able to fix the PCB inside the box. This is because the PCB will be mounted using sticky pads. The connectors were kept to the outside of the PCB to avoid disrupting anything on the PCB. The USB and microSD ports are on the outside of the PCB to allow for easy access.

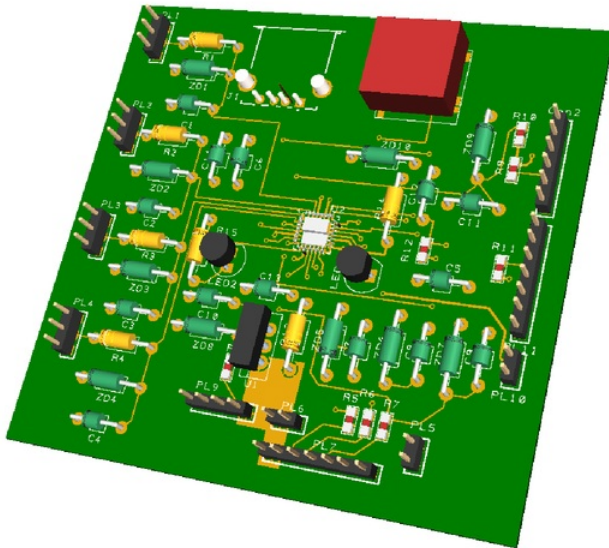


Figure 38 - PCB 3D Top Layer View

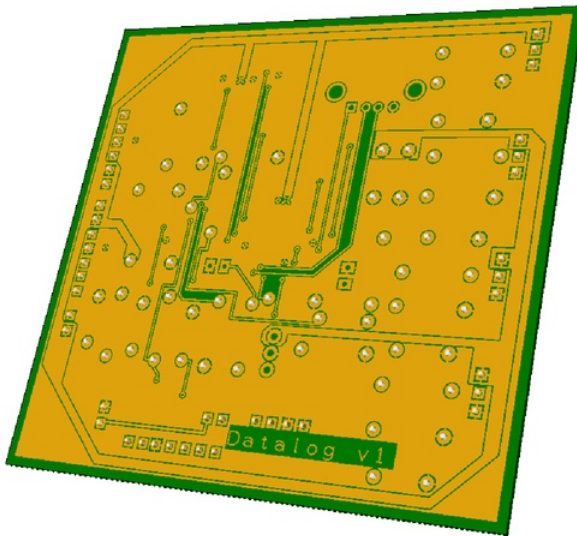
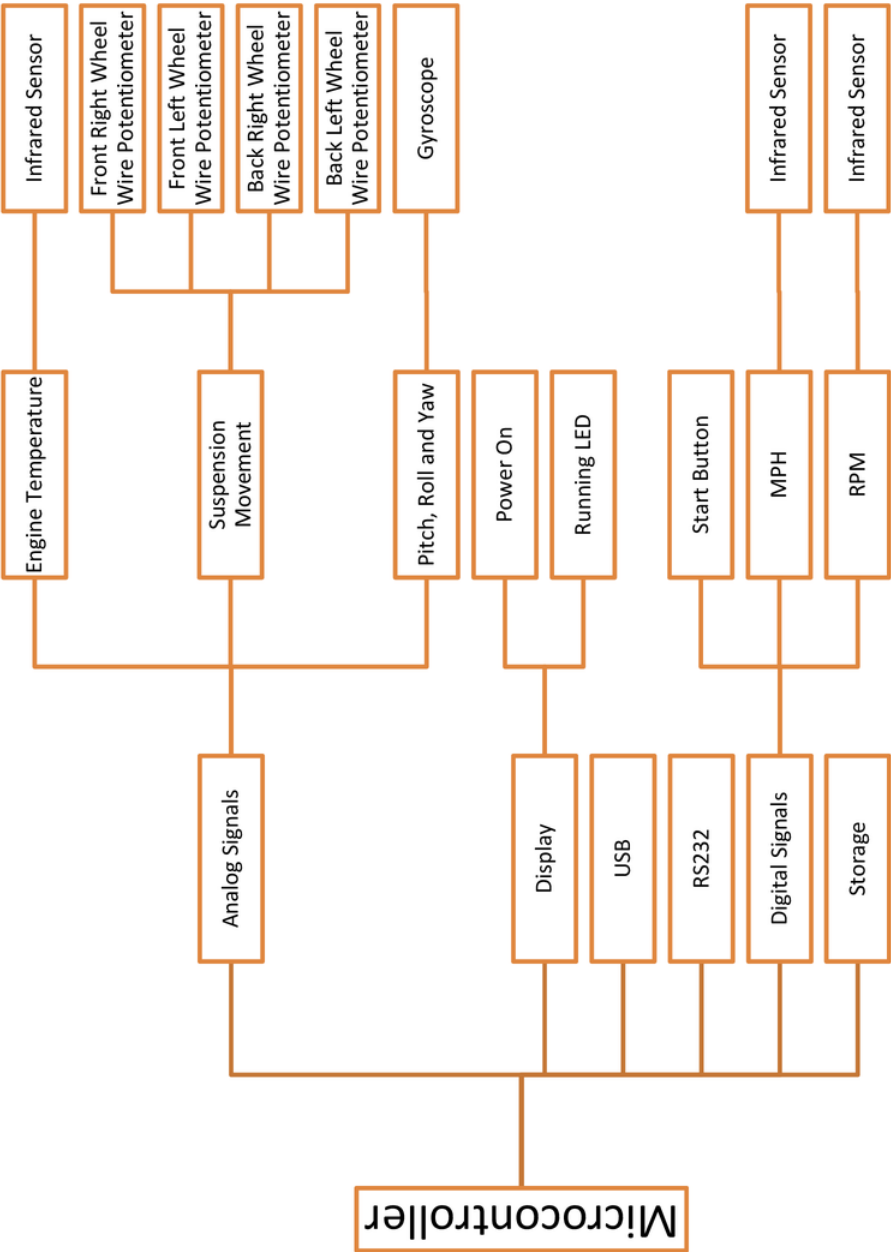


Figure 37 - PCB 3D Bottom Layer View

6. Structure Diagram



7. Design Flow Chart

The design flow chart indicates that when the system has starting it will log for 2 hours. If it has not logged for 2 hours it must start logging every 0.5 milliseconds for suspension movements. Once it has done that 5 milliseconds then a reading for pitch, roll and yaw must be taken every 5 milliseconds alongside the suspension movement readings. Next, readings must be taken for RPM & MPH every 0.5 seconds and then temperature readings every 30 seconds. All these readings are constantly being taken until the system has been running for 2 hours. The system is then finished after it has taken 2 hours' worth of readings.

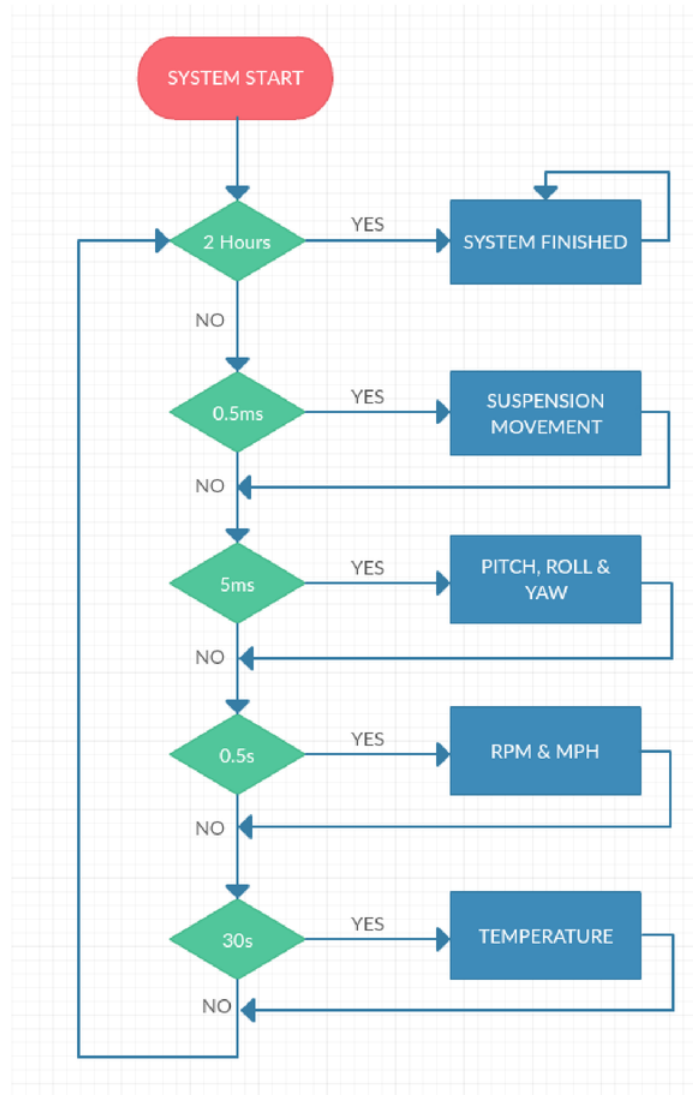


Figure 39 - Design Flow Chart

8. Prototype Build Cost

Below is the list of components used and cost of each component.

Component	Manufacturer	Part Number/Component ID	Quantity	Price per unit	Total Cost
Wire Potentiometer	BEI Sensor	CD50-0750-R01K-L25-L4-IP67	4	£395	£1580
Temperature Sensor	Omega	OS136-1-V1	1	£172.80	£172.80
Gyroscope	Texense	GYRN3-S-X-Y-Z	1	£1460	£1460
Speed Sensor	Compact Instruments	Mini VLS 111	2	£285	£570
Reflective Tape	Compact Instruments	RT5	1	£25	£25
Suspension Movement Panel Mount Connector	RS Pro	124-6706	4	£8.13	£32.52
Suspension Movement Cable Connector	RS Pro	124-6740	4	£13	£52
Engine Temp Panel Mount Connector	Brad Harrison	120234-0001	1	£20.09	£20.09
Engine Temp Cable Connector	Brad Harrison	120233-0017	1	£18.67	£18.67
Gyroscope Panel Mount Connector	Brad Harrison	120234-0003	1	£19.89	£19.89
Gyroscope Cable Connector	Brad Harrison	120233-0021	1	£20.03	£20.03
MPH Panel Mount Connector	Hirose	LF07WBR-3P	1	£5.54	£5.54
MPH Cable Connector	Hirose	LF07WBJ-3S	1	£6.32	£6.32
RPM Panel Mount Connector	Hirose	LF10WBRB-4P	1	£7.08	£7.08
RPM Cable Connector	Hirose	LF10WBPD-4S	1	£13.22	£13.22
Case	Peli	IM2075-01001	1	£68.39	£68.39
Battery 5.2Ah	Battery Space	BL-4PL896474-FPC	1	£119.30	£119.30
PIC	Microchip	PIC18F24K50	1	£1.25	£1.25
Green LED	Kingbright	L-813GD	1	£0.10	£0.10
Red LED	Kingbright	L-813SRD-C	1	£0.20	£0.20
Toggle Switch	RS Pro	734-7154	1	£1.32	£1.32

Momentary Pushbutton	Grayhill	30-3	1	£2.32	£2.32
100Ω Resistor	RS Pro	707-8827	9	£0.035	£0.315
10KΩ Resistor	RS Pro	739-7130	1	£0.021	£0.021
4.7KΩ Resistor	RS Pro	739-7121	2	£0.021	£0.042
140Ω Resistor	Vishay	MRS25000C1400FCT00	2	£0.063	£0.126
383Ω Resistor	Vishay	MRS25000C3830FCT00	1	£0.06	£0.06
470nF Capacitor	RS Pro	711-1110	1	£0.083	£0.083
100nF Capacitor	RS Pro	711-1396	11	£0.018	£0.198
10uF Capacitor	RS Pro	711-1425	1	£0.029	£0.029
Zener Diode	Taiwan Semiconductor	1N4751A R0	10	£0.045	£0.45
5V Voltage Regulator	Texas Instruments	LM4040DIZ-5.0/NOPB	1	£0.57	£0.57
2 Pin PCB Connector	JST	S2B-ZR (LF)(SN)	3	£0.36	£1.08
2 Pin Female Connector	JST	ZHR-2	3	£0.046	£0.138
3 Pin PCB Connector	JST	S3B-ZR (LF)(SN)	4	£0.27	£1.08
3 Pin Female Connector	JST	ZHR-3	4	£0.032	£0.128
4 Pin PCB Connector	JST	S4B-ZR (LF)(SN)	1	£0.29	£0.29
4 Pin Female Connector	JST	ZHR-4	1	£0.039	£0.039
5 Pin PCB Connector	JST	S5B-ZR (LF)(SN)	1	£0.13	£0.13
5 Pin Female Connector	JST	ZHR-5	1	£0.066	£0.066
6 Pin PCB Connector	JST	S6B-ZR (LF)(SN)	1	£0.16	£0.16
6 Pin Female Connector	JST	ZHR-6	1	£0.069	£0.069
7 Pin PCB Connector	JST	S7B-ZR (LF)(SN)	1	£0.17	£0.17
7 Pin Female Connector	JST	ZHR-7	1	£0.11	£0.11
Crimps	JST	SZH-003T-P0.5	1 Pack of 50	£1.20	£1.20
USB PCB Mount	TE Connectivity	292303-7	1	£1.94	£1.94

USB Panel Mount	RS Pro	124-6392	1	£4	£4
USB A to B Cable	RS Pro	815-8466	1	£1.25	£1.25
Micro SD Card PCB Mount	Molex	503398-0891	1	£1.05	£1.05
Micro SD Card 512MB	ATP	AF512UDI-ZADXM	1	£10.82	£10.82

The total cost for the prototype would be £4220.44.

9. Improvements

This report has covered the task of designing a microcontroller based vehicle acquisition system. The research completed at the beginning of the report shown information gathered on other systems. Other systems used Bluetooth and Wi-Fi to allow for easy access to your data as it's a wireless technology. This can be used to transmit the data of the test, sending the data online and for configuration.

Another improvement could be to add GPS to the system. The use of GPS in automotive testing is now very common. GPS is used to measure different variables such as speed which leads to incredibly accurate speed measurements.

Some systems use a LCD Screen to display real time results; this could be something that's looked into net time instead of only using two LEDs to indicate power on and running.

All of the existing systems were small compact housed systems that were made specifically for that systems. An improvement would be to design a housing to fit the system that has been created instead of selecting an enclosure to modify.

Most of the components on the PCB design are through hole, if the project was re-done then it would be beneficial to use surface mount components instead. This would allow the PCB to be manipulated further to be smaller in size. If the board was mass produced this would save a lot of time for manufacturers to design and assemble boards for the fraction of the cost of through hole as holes need to be drilled for through hole components [8].

If the task was to make a system that was very cost effective then the system costs could be decreased massively by sensor selection as the sensors were the most expensive part of the system. A comparison was completed that outlined the best type of sensors for the application but a cheaper option could have been satisfactory. For example, a MEMs gyroscope or accelerometer could have been used instead or a thermistor for engine temperature to save on hardware costs.

On the whole the project has been a success as it has done what it was set out to do although if the same task was to be completed again the above improvements would be considered.

Bibliography

- [1] D. Ibrahim, "Design of a GPS data logger device with street-level map interface," *Advances in Engineering Software*, vol. 41, no. 6, pp. 859-864, June 2010.
- [2] Omega, "Omega," [Online]. Available: <https://www.omega.co.uk/prodinfo/dataloggers.html>. [Accessed 1 November 2017].
- [3] VBOX Automotive, "VBOX Automotive," [Online]. Available: <https://www.vboxautomotive.co.uk/index.php/en/products/data-loggers#features-2> . [Accessed 24 September 2017].
- [4] Race Technology, "Race-Technology," [Online]. Available: https://www.race-technology.com/in/racing/products/display-products/dash2-pro/dash2-pro_enhancement-options#6g_accel. [Accessed 29 September 2017].
- [5] Influx Technology, "Influx Technology," 2016. [Online]. Available: <http://www.influxtechnology.com/products/can-data-loggers/rebel-lt/>. [Accessed 15 September 2017].
- [6] AiM Tech, "Aim-Sportline," [Online]. Available: http://www.aim-sportline.com/download/doc/eng/evo5/EVO5_102_eng.pdf. [Accessed 16 October 2017].
- [7] Peli, "Peli," [Online]. Available: <http://docs-europe.electrocomponents.com/webdocs/12ed/0900766b812ed97f.pdf>. [Accessed 13 November 2017].
- [8] M. Turpin, "Contract Electronics Manufacturing and PCB Assembly Blog," *Who Comes Out On Top Between SMT vs. Through-Hole Mounting*, 24 July 2014.
- [9] BEI Sensors, "BEI Sensors," [Online]. Available: http://www.beisensors.com/pdfs/cdb_draw-wire-sensor_potentiometer_bei.pdf. [Accessed 21 Septemeber 2017].
- [10] Omega, "Omega," 2013. [Online]. Available: <https://www.omega.com/manuals/manualpdf/MQS3946.pdf>. [Accessed 29 September 2017].
- [11] Compact Instruments, "Compact Instruments," [Online]. Available:

<http://compactinstruments.co.uk/product/minivls-111-speed-sensor-threaded-housing-5vdc/>.

[Accessed 1 October 2017].

[12] Texense, "Texense," [Online]. Available: <https://www.texense.com/images/documents/40.pdf>.

[Accessed 2 October 2017].

[13] Microchip, "Microchip," [Online]. Available: <http://www.microchip.com>. [Accessed 19 October 2017].

[14] RS, "RS," [Online]. Available: <http://uk.rs-online.com>. [Accessed 23 October 2017].

[15] Brad Harrison, "Brad Harrison," [Online]. Available: <http://www.bradharrisononline.com/>.

[Accessed 23 October 2017].

[16] Hirose Electric, "Hirose," 1 October 2017. [Online]. Available: <http://www.hirose-connectors.com>. [Accessed 26 October 2017].

Assignment 1 - Jordan Randel

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RESEARCH-INFORMED LITERATURE



Literature review is reasonable, manufacturer information is well presented with a good comparison table of relevant information. A little more information from the manufacturer would be an improvement. 62%

6.2

KNOWLEDGE AND UNDERSTANDING



Good overall schematic design but a few problems can be seen. The pic requires constant power once powered up, the circuit shows the pic being powered via a push button- the pic will power down when the button is released. All inputs share a common design of voltage clamp except for the optical sensors. The zener diode should be connected via a small resistor to avoid the possibility of damage to the zener via a large current in a fault state. When switching an Led from a pic it is good practise to have the pic sink the current rather than source it, a pic may provide 20ma per pin but it can sink 25ma. 58%

14.5

ANALYSIS



Good selection of microcontroller. Good selection of sensors showing calcs for each one with a very nicely laid out table showing the selection of sensors to be chosen from. Good case selection

22.75

but there is no discussion or reflection of other cases. Good selection of connectors but again there is no discussion or reflection of other connectors 65%

PRACTICAL APPLICATION AND DEP.



Costings nicely put forward as a table with price and supplier of component. Good attempt at future enhancements, better time management would have made for a better result.65%

13

SKILLS FOR PROFESSIONAL PRAC.



The report is well presented with very well presented tabled data and structure diagrams. A good selection of references. 80%

8