

# Sam O'Leary Assignment 1

*by* Michael Sam O'Leary

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| FILE           | 2718_MICHAEL_SAM_OLEARY_SAM_OLEARY_ASSIGNMENT_1_58119_1929362020.PDF (1.81M) |                 |       |
| TIME SUBMITTED | 16-NOV-2017 10:52PM (UTC+0000)                                               | WORD COUNT      | 10497 |
| SUBMISSION ID  | 77700436                                                                     | CHARACTER COUNT | 57356 |

2017

# Car Data Acquisition System Design

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## Abstract

Contained in this report is a design of a microcontroller based portable vehicle data acquisition system. The design is based around the PIC18F2458 which is used to measure suspension displacement, engine speed, vehicle speed, engine temperature and g forces. The system is portable and adaptable to any class of vehicle independent of a vehicles existing electrical systems. The design includes sensor selection, circuit schematics and PCB design.

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## 1.0 Introduction

This report contains information on designing a portable vehicle data acquisition system. The design is based around using a microcontroller to measure and log a vehicles suspension movement, Engine speed, vehicle speed, engine temperature and the g forces acting on the vehicle. The data acquisition system is designed to be fitted primarily to a production prototype car in the family saloon market, however the system is also re-usable and adaptable for any class of vehicle. The purpose of designing such a system is to ensure that a vehicles design operates within safe limits but also provides comfortable transport. The system may also be used by race car drivers to improve their track record by knowing how much they can push their vehicle without going out of safe limits. As the system is portable it uses its own battery supply and is completely independent from other electrical sources on the vehicle. Non-volatile storage memory and a USB connection is included which allows the data being stored to be read and analysed by a PC.

Market research has been carried out to gather ideas and to compare costs from other designs currently out on the market. Research into different types of sensors is included with justification on why each type of sensor was chosen. More Research is then carried out on the chosen sensor with a final sensor selection justification taking into account quality, protection ratings, costs etc. Although there is no software included, a structure diagram is shown which helped aid in the selection of the PIC18F2458. Circuit Schematics are included in this report which illustrates step by step how the system is designed and how various sensors connect to the PIC. Appropriate connectors, cable and the systems casing is included and referenced taking into account the harsh environment the system is designed to be installed in. A PCB is designed with 3D images shown. A table is included at the end of this report which details the costs for each component with a total estimated cost of the entire system. Finally, a conclusion is carried out which mainly includes improvements that could be made to the project.

## 2.0 Review of Portable Acquisition Systems

When designing a product it is always good to firstly carry out market research to see what is currently out there. There are many benefits to carrying out market research which includes gaining information about what features customers like to purchase, the aesthetic design of the existing products and to set realistic targets during the design phase such as costs. Below are some data logger systems that are similar to the proposed vehicle data logger design.

### 2.1 Omega Tri-Axial Shock Data Logger

The Tri-Axial Shock Data Logger from Omega is a 3-axis shock recorder which measures and logs shock as the peak acceleration levels which can be user defined. The user defined configurations can be password protected to prevent tampering with the settings. The Omega shock data logger is powered by its own internal battery which makes the design portable and autonomous being independent of other power supplies. Omega claims the battery life can last up to 60 days. The data logger is designed for documenting dynamic levels of shock or acceleration such as moving vehicles, trucks, containers and ships etc. The device can measure up to 349,525 measurements per axis and save the results to a 2GB non-volatile solid state memory. The device includes both a COM and USB port which is used to connect a PC that requires the correct software to operate the data logger. [1] Below is a table showing some of the specifications.



Figure 1 - OM-CP-SHOCK101 Tri-Axial Data Logger [1]

Table 1 – Omega Tri-Axial Data Logger Specifications

|                              |                                                                                                                                                                   |
|------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Channels</b>              | 3 axes (Built-in)                                                                                                                                                 |
| <b>Sampling Rate</b>         | 1.953ms/512Hz                                                                                                                                                     |
| <b>Reading Interval</b>      | 64Hz to 5min                                                                                                                                                      |
| <b>Memory</b>                | 349,525 readings per axis, Total of 1,398,100<br>2GB Solid State Memory                                                                                           |
| <b>Display</b>               | Red LED: Blinks to indicate sleep mode<br>Red & Green LED: Blinks to indicate delay start<br>Green LED: Blinks to indicate taking samples (blinks at sample rate) |
| <b>Power</b>                 | 6 D-Cell alkaline batteries (included)                                                                                                                            |
| <b>Data Format</b>           | Date and time stamped gravities (g and mg)                                                                                                                        |
| <b>Interface</b>             | PC serial or USB; 115,200 baud                                                                                                                                    |
| <b>Operating Environment</b> | -20 to 54°C, (-4 to 129°F) 0 to 95% RH non-condensing                                                                                                             |
| <b>Logging Time</b>          | 60 Days                                                                                                                                                           |
| <b>Dimensions</b>            | 5.5 x 5.4 x 3.2"<br>(140 mm x 137 mm x 80 mm)                                                                                                                     |
| <b>Casing Material</b>       | Anodized aluminium                                                                                                                                                |
| <b>Price</b>                 | £565                                                                                                                                                              |

## 2.2 DL1 Sport Data Logger



Figure 2 - [2]

The DL1 Sport Data Logger is an entry level unit which is designed for new users by making it an easy to use system. It designed to be installed into vehicles for logging data to improve track time and overall race driving quality. The DL1 Sport is an expandable unit meaning the customer can pick and choose their desired sensors (up to 8 analogue sensors) and ECU interfaces, can also be connected to a range of dash boards and video systems. The data logger

comes with PC software which can be used to check lap times, where time was lost/gained and how and where improvements to the driving can be made by the use of a GPS antenna which monitors the vehicles location around the track. There is a start/stop button located on the device which can be used to tell the device when to start or stop logging data to a CF memory card that can support up to 64GB. [2] The main product costs £499.00 however, after adding extras such as 6-axis gyro sensors, rpm sensors etc. the overall costs can be expected to exceed over £2,000. Below is a table showing some of the specifications.

|                              |                                                                     |
|------------------------------|---------------------------------------------------------------------|
| <b>Channels</b>              | 30+ (8 Analogue) Inputs                                             |
| <b>Sampling Rate</b>         | 100Hz                                                               |
| <b>Power Supply</b>          | 9v – 18v                                                            |
| <b>Memory</b>                | Compact Flash Card up to 64GB                                       |
| <b>Display</b>               | Optional DASH2 or DASH4PRO                                          |
| <b>Data Format</b>           | Date, Time and Location Stamp                                       |
| <b>Interface</b>             | ECU, RS232, Removable memory card.                                  |
| <b>Operating Environment</b> | Not temperature rated. Not protected against dust or water ingress. |
| <b>Logging Time</b>          | 24 Hours+                                                           |
| <b>Connectors</b>            | Plastic / spring loaded terminals                                   |
| <b>Casing Material</b>       | ABS                                                                 |
| <b>Price</b>                 | £499 + Extras                                                       |

Table 2 - DL1 Sport Data Logger Specifications

## 2.3 AIM Motorsport MXS Dash Logger

The MXS data logger from AIM Motorsport is a 5" display unit which offer user configurability and is designed for motorsport activities. The unit is designed to log information from an existing ECU system as well as its own built in accelerometer and gyro. A GPS module is included as well as analogue/digital inputs and predefined math channels. The MXS supports up to eight additional expansion modules. The wiring harness and aluminium connectors used are 'military-spec'. There are two digital outputs which can give a 12v 1A supply which are user defined to control external accessories such as lights and cooling fans/pumps etc. The unit has six configurable RGB LED alarms with an accompanying text message. There is also a Wi-Fi chip inside to allow for wireless data stream. [3] Below is a table showing some of the specifications.



Figure 3 – AIM MXS Data Logger [3]

|                              |                                                                                                    |
|------------------------------|----------------------------------------------------------------------------------------------------|
| <b>Channels</b>              | 8 Analogue inputs, 5 Digital Inputs, 2 Digital Outputs                                             |
| <b>Sampling Rate</b>         | 1KHz                                                                                               |
| <b>Memory</b>                | 4GB                                                                                                |
| <b>Display</b>               | Compact 5" TFT High Contrast Display, 6 Configurable RGB Alarm LEDs & 10 RGB LED Shift Light Array |
| <b>Interface</b>             | Wi-Fi, CAN, RS232 or OBDII                                                                         |
| <b>Operating Environment</b> | IP65                                                                                               |
| <b>Dimensions</b>            | 169×97×23 mm                                                                                       |
| <b>Connectors</b>            | 37 pin Aluminium Motorsport Military Specification Connectors                                      |
| <b>Casing</b>                | Anodised Aluminium                                                                                 |
| <b>Price</b>                 | £1890.00                                                                                           |

Table 3 – AIM Motorsport MXS Dash Logger Specifications

### 3.0 Sensor Selection

In order to successfully design a vehicle data acquisition system the sensors used to take the measurements needs to be carefully selected. This chapter contains research on different types of sensors that could be used with a short analysis on each so that the best type of sensor for the project can be selected. After the type of sensor is selected further research is carried out to find multiple products of the same type of sensor and the best one is chosen based on the characteristics shown in the tables. Finally, some calculations are taken for each sensor in order to ensure the correct resolution is selected by the microcontroller and to calculate the required memory allocation for each.

#### 3.1 Suspension Displacement

| <u>Sensor type</u>   | <u>Temperature Range</u> | <u>Voltage Range</u> | <u>Measurement range</u> | <u>Ref</u>           |
|----------------------|--------------------------|----------------------|--------------------------|----------------------|
| Wire Potentiometer   | -40°C to +125°C          | 5v – 30v             | 760mm                    | 2D: SA-WP HQ-000     |
| Linear Potentiometer | -40°C to +85°C           | 5v – 130v            | 350mm                    | 2D: SA-LP350-000 [4] |
| Laser Beam           | 0°C to + 70°C            | 10v – 28v            | 500mm                    | 2D: SA-Dist05b-000   |

*Table 4 – Suspension Displacement Sensors*

Wire Potentiometers are sensors used to measure linear displacement. They consist of a draw wire, a spring-loaded spool and a sensor which can either be an optical encoder or a potentiometer. Wire potentiometers are ideal for wet, dirty or outdoor environments and where the measuring range travels over harsh environments. [5] As the cable extends and retracts it turns a potentiometer back and forth which gives a varying resistance depending on the position of the wire. The wire potentiometer from 2D-datarecording (2D: SA-WP HQ-000) is a sensor designed specifically to measure linear motions in motorsport applications. The sensor comes in various measurement ranges from 76mm up to 760mm. This sensor can be mounted between the lower and upper suspension arms so that as the suspension travels up and down so does the resistance of the potentiometer which gives a varying voltage output.

A linear potentiometer is a displacement sensor similar to that of the wire potentiometer but with a more rigid design. The linear potentiometer from 2D-datarecording is again designed for motorsport and its construction looks similar to that of a linear actuator. The resistance across the terminals changes depending on the position of the shaft. The datasheet specifically states that this sensor is designed for use to 'measure linear motions e.g. front fork, steering, or damper movement' [4]

A laser beam position sensor is a non-contact device that can measure the distance of an object. A laser beam is emitted to the target to be measured and the light is reflected back to the receiver lens. When the targeted object distance changes the angle of the reflected laser beam changes accordingly. [6] The laser beam position sensor from 2D-datarecording comes with a high measurement range from 50mm to 500mm and is designed specifically to measure the distance of a ride height. The sensor has a linear output voltage from 0.25v – 4.75v. The sensor has an IP rating of 67 and is vibration resistance so would be suitable for the environment it is intended to be used for.

Given that the data acquisition system is to be adaptable to different vehicles, the 350mm measurement range of the linear potentiometer is a bit short and therefore has been excluded from the final selection as it doesn't offer much flexibility on a wide variety of vehicles. The laser beam sensor, although has a good measurement range, is likely to add to the complexity of the installation due to requirement that the sensor needs to be

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separately programmed or 'taught' and it is preferable to keep all programmable devices in one package. Also, although the laser beam shown above has been designed for use on vehicles in rough environments, there may be problems with water that may cause light scattering. Therefore, the chosen sensor type for suspension movement is a wire potentiometer. Some other wire potentiometers to consider are shown below;

| <u>Sensor/Reference</u>                                                                                                                    | <u>Temperature Range</u> | <u>Measurement Range</u> | <u>Resistance</u> | <u>Input Voltage</u> | <u>Output Voltage</u> | <u>Power Rating</u> | <u>Protection</u> | <u>Linearity Tolerance</u> | <u>Price</u> |
|--------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|--------------------------|-------------------|----------------------|-----------------------|---------------------|-------------------|----------------------------|--------------|
|  <p>Figure 4 - SA-WP HQ-000 Wire Potentiometer [7]</p>    | -40°C to +125°C          | 760mm                    | 10kΩ              | 5v – 30v             | 0v – 30v              | 90mW                | IP50              | 0.25%                      | £760.76      |
|  <p>Figure 5 - Kubler Linear Measuring Encoder [21]</p>   | 0°C to 50°C              | 1000mm                   | 10kΩ              | 15v – 28v            | 0v – 10v              | 20mA                | IP50              | 0.35%                      | £290.29      |
|  <p>Figure 6 - Miniature wire-actuated encoder [22]</p> | -10°C to 80°C            | 600mm                    | 10kΩ              | 15v – 28v            | 0v – 10v              | 2w                  | IP50              | 0.25%                      | N/A          |
|  <p>Figure 7 - SP1-25-3 Wire Potentiometer [23]</p>     | -40°C to 70°C            | 635mm                    | 10-kΩ             | 30v                  | 0v- 30v               | 2w                  | IP67              | 0.25%                      | £187.04      |

Table 5 – Wire Potentiometers

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As can be seen from the table of various wire potentiometers on the market, most of them have a protection rating of IP50, as this provides no water protection they are not suitable for the environment they are intended to be used in. Therefore, the SP1-25-3 sold at digikey.com has been chosen as the suspension displacement sensor due to its protection rating of IP67. The sensor is essentially a 3-wire potentiometer and therefore has a varying resistance over its measurement range which will give an analogue signal output. The chosen wire potentiometer has a maximum voltage supply rating of 30v AC/DC. In order to simplify the design, a 5v DC supply will be used so that the output can be fed straight into an input of a microcontroller without the need for signal conditioning. As the output signal is analogue it will need to be converted to digital so that it can be read by the microcontroller. Fortunately, most microcontrollers have built-in analogue to digital (ADC) converters. A suitable ADC needs to be chosen so that there is enough resolution for the microcontroller to read at least 1mm increment steps of movement from the wire potentiometer. Given that the wire potentiometer extends up to 635mm and will be supplied by a 5v supply the voltage per 1mm of movement can be calculated as;

$$\frac{5}{365} = 7.874mV$$

As we now know there is a 7.874mV difference per each mm of movement we must now select how many bits the ADC must run at. Given that 10bit has 1024 steps (0-1023) and a supply voltage of 5v is used, a 10bit ADC can read 4mV increments per step, therefore a microcontroller with at least a 10bit ADC must be selected. The memory usage for each sensor needs to be calculated in order to ensure an appropriate storage size is selected. A 10bit reading from four displacement sensors will be taken every 0.5ms for two hours and so the memory allocation required is calculated below;

$$2B * \frac{1}{0.0005} = 4KB/s \text{ per sensor}$$

$$4 * 4KB = 16KB/s$$

$$16KB * 3600 = 57.6KB \text{ per hour}$$

$$57.6KB * 2 = 115.2KB$$

### 3.2 Engine & Vehicle Speed

| Sensor type | Temperature Range | Voltage Range | Ref              |
|-------------|-------------------|---------------|------------------|
| Hall Effect | -40°C - +125°C    | 5v – 24v      | RS: 765-9328     |
| Inductive   | -25°C - +70°C     | 10v – 30v     | Rapid: 78-4138   |
| Optical     | -10°C to +55°C    | 5v – 24v      | Farnell: 1385692 |

Table 6 – Engine & Vehicle Speed Sensors

Hall Effect sensors are also known as magnetic sensors due to their ability to convert magnetically encoded information into electrical signals. Hall Effect sensors are non-contact devices which offers low maintenance, robust design and are immune to vibration, dust and water. Hall Effect sensors are commonly used in automotive systems for the sensing and positioning of the car seats, seat belts, air-bag control and wheel sensing for the anti-lock braking system (ABS) etc. There are two main types of Hall Effect sensors which have either linear (analog) or digital output signals. [8] An NPN Hall Effect sensor from RS (RS No: 765-9328) has an IP rating of IP68, 3 wires and comes in three different dimensions. The shortest sensor (Part No: GS100701) is only 25.4mm long and is designed to be mounted to a gear tooth for speed sensing.

Inductive sensors, also known as proximity sensors are non-contact devices which can detect nearby metal objects. Inductive sensors consists of a coil which is driven by an oscillator which generates a high frequency electromagnetic field. When a metal object comes into contact with the field it consumes some of the power generated by the coil and the signal amplitude decreases. A detector circuit examines the signal and if it has decreased enough it will switch an output. [9] The inductive sensor from rapid (78-4138) has a small design of only 55mm long, has an IP rating of 67 and a sensing distance of 10mm.

Optical sensors are non-contact devices that convert light rays into electrical signals. There are three main types of optical sensors: Through beam, Retro-Reflective and Diffuse reflection. Through beam sensors consists of a transmitter and receiver which are placed opposite each other. The transmitter projects a light beam to the receiver and if the light beam is blocked a signal is generated by the receiver. Retro-Reflective sensors are similar to through beam except the transmitter and receiver are housed in one case and use a reflective material to direct the transmitted light beam back to the receiver. Diffuse reflection sensors are used when the object to be detected is used as the reflective surface. [10] The Omron EE-SPY412 (Farnell: 1385692) is an optical sensor which comes in either the through-beam or reflective type. The operating voltage is 5v – 24vDC which is suitable for the voltage criteria. The reflective type could be used by attaching a reflective tape to the shaft of the engine so that every time the shaft makes a complete revolution a signal is generated. The problem with this sensor is it has an IP rating of IP50 meaning it has no protection against water ingress and would therefore not be suitable for this application.

Although all of the above sensors are non-contact the Hall Effect and inductive sensors require there to be metal in close proximity. These type of sensors in most cases can likely be mounted close to the flywheel to measure engine R.P.M. An inductive sensor could generate a pulse every time one of the teeth on the flywheel pass the sensor, however, as this design is intended for use on any vehicle the design of the flywheel may vary from vehicle to vehicle and there may not be enough room to mount a sensor and therefore the reflective optical type sensor has been chosen for measuring both engine R.P.M and vehicle speed in M.P.H. Below are other optical sensors that could be used;

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| <u>Sensor/Reference</u>                                                                                                                               | <u>Ambient Temperature</u> | <u>Voltage Range</u> | <u>Power Consumption</u> | <u>Measurement Range</u> | <u>Maximum Switching Frequency</u> | <u>Protection</u> | <u>Price</u> |
|-------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|----------------------|--------------------------|--------------------------|------------------------------------|-------------------|--------------|
|  <p>Figure 8 - EE-SPY412 - OPTICAL SENSOR [24]</p>                   | -10°C to +55°C             | 5v – 24v             | 15mA                     | 5mm                      | 100Hz                              | IP50              | £46.04       |
|  <p>Figure 9 - RS Pro Retro-reflective Photoelectric Sensor [25]</p> | -25°C to +55°C             | 10v – 30v            | 30mA                     | 1mm – 100mm              | 1KHz                               | IP67              | £52.85       |
|  <p>Figure 10 - 444-3451 Telemecanique [26]</p>                     | -25°C to +55°C             | 12v – 24v            | 35mA                     | 120mm – 15m              | 500Hz                              | IP67              | £77.98       |
|  <p>Figure 11 - E3S-AD11 Omron [27]</p>                            | -25°C to +55°C             | 10v – 30v            | 30mA                     | 200mm                    | Not specified.                     | IP67              | £165         |

Table 7 – Optical Sensors

The SPY412 has a protection rating of IP50 and is therefore unsuitable. The other three sensors could be used however, the RS pro retro-reflective sensor has been chosen as it offers the best price and also has the highest switching frequency of 1 kHz if so needed.

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To measure mph the optical sensor will be fitted behind one of wheels which will have reflective tape or a mark attached to it. Each time the mark passes the optical sensor a pulse is generated by the sensor. The circumference of a 21" wheel is calculated as;

$$Circumference = \pi \times d = \pi \times 21 = 65.973"$$

Given there are 63360 inches in a mile the number of revolutions a 21" wheel makes per mile can be calculated;

$$Revolutions\ Per\ Mile = \frac{63360}{65.973} = 960.393$$

Given that the vehicles speed needs to be measured from 1mph to 80mph the number of pulses generated from the sensor if one mark is fitted to the wheel can be calculated as;

$$@\ 1mph = \frac{960.393}{3600} = 0.267\ p/s$$

$$@\ 80mph = \frac{960.393 \times 80}{3600} = 21.342\ p/s$$

This means at the lowest speed (1mph) the sensor will only output 0.267 pulses per second which is not enough resolution to accurately measure 1mph. If four markings were added to the wheel this would give four times the amount of pulses and so at 1mph would give 1.068 pulses a second. This is enough resolution to accurately measure 1mph if taking readings every second however, we want the microcontroller to take a reading every 0.5s which means the amount of markings on the wheel needs to double giving eight markings. This results in the sensor giving 2.134 pulses per second or 1.068 pulses per reading. Microcontrollers have counters which will be used to count the number of pulses every 500ms. As the maximum speed of the vehicle is 80mph then the number of pulses read every 500ms will be approximately 85. An 8-bit counter gives 256 possible counts so an 8-bit counter can be used.

When measuring engine speed, for a commercial vehicle, the idle speed is usually no lower than 700rpm and the maximum speed is no higher than 10,000rpm. Below are these speeds converted to revolutions per second;

$$@\ 700rpm = \frac{700}{60} = 11.67\ rps$$

$$@\ 10,000rpm = \frac{10,000}{60} = 166.67\ rps$$

If using one marking on the crank shaft of the engine we will get 11.67 pulses per second or 5.84 pulses per reading (500ms). Therefore, only one marking is required to accurately measure engine speed. Given that at the highest engine speed we will get approximately 83 counts (166/2), an 8-bit counter can also be used to measure engine speed.

As 8bit counters will be used for both rpm and mph with a reading every 0.5s their memory usage can be calculated together;

$$2B \times \frac{1}{0.5} = 4\ B/s$$

$$4B \times 3600 = 14.4\ KB/h$$

$$14.4KB \times 2 = 28.8\ KB$$

### 3.3 Engine Temperature

| <u>Sensor type</u> | <u>Temperature Range</u> | <u>Voltage Range</u> | <u>Contact/Non-contact</u> | <u>Ref</u>             |
|--------------------|--------------------------|----------------------|----------------------------|------------------------|
| Thermocouple (K)   | -75°C - 260°C            | 2.755mV-10.561mV     | Contact                    | RS: 363-0250           |
| Thermistor         | -80°C - 200°C            | N/A                  | Contact                    | Mouser: 527-BR11KA152M |
| Infrared           | -40°C - 1030°C           | 5v -30v              | Non-Contact                | RS: 382-911            |

Table 8 – Engine Temperature Sensors

Thermocouples are contact sensors that are used to measure temperature. They consist of two wires made from different materials. The ends of the wires must be welded together, creating a junction. This junction must be installed where temperature is required to be measured from. The thermocouple generates a voltage which is dependent on the temperature at the junction. There are many types of thermocouples and in order to calculate the temperature the correct reference table must be used for the type of thermocouple.

Thermocouples are common due to their low cost and high operating temperature range. [11]The K type thermocouple from RS (363-0250) is very cheap, has a suitable operating temperature, comes with varying size cables (up to 10m) and comes with a miniature pin plug which could plug straight into the Car Data Acquisition System.

Thermistors are contact sensors which change resistance with change in temperature. Negative Temperature Coefficient (NTC) thermistors decrease resistance when temperature is increased and vice versa for Positive Temperature Coefficient (PTC) thermistors. Thermistors are known to be very precise with long-term stability. [12] The thermistor from mouser (Mouser: 527-BR11KA152M) is encapsulated in glass to protect it from severe environmental conditions and can withstand temperatures up to 315°C although as stated in the datasheet it will lose stability over 200°C. This makes this a hardy component and should not fail even if the engine temperature exceeds safe limits.

Infrared (IR) temperature sensors are non-contact devices used to measure temperature. IR temperature sensors sense electromagnetic waves in the 700nm to 14,000nm range by focusing the IR energy emitted by an object onto one or more photo detectors. The photo detector converts the energy received into electrical signals which is proportional to the IR energy emitted by the object. IR temperature sensors use a 'special' type of plastic on the lens which acts as a filter to filter out unwanted frequencies but also protects the device from dust and dirt. [13] The infrared temperature sensor from RS (RS: 382-911) has a huge operating temperature range from -40°C to 1030°C, response time of 25ms which can be adjusted up to 999s, comes with optional cable lengths from 3m to 15m and various optional mounting brackets. Overall this sensor is very diverse but also has a large cost (£192.12) compared to the other sensor types

Considering the normal operating temperature for a car engine is between 90°C - 105°C [14] and the temperature before the engine is started is not likely to be below -30°C, all of the temperature sensors above are appropriate to be used to measure engine temperature, however, one type of sensor needs to be selected. The infrared type sensor clearly has the best temperature range but is a bit over-kill for the temperatures to be measured. Infrared sensors are also very expensive compared to the other types and unless the non-contact sensing is essential, which for this project it is not, then one of the other contact types seems more appropriate. Comparing both the Thermocouple and Thermistor type sensors, they are similar in that they are both contact devices and have a similar price tag. Looking at the installation the thermistor type sensor

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appears to be easier/quicker to install as it can just be stuck down to the engine whereas the thermocouple type needs to be spot welded to the engine. Therefore, the thermistor has been chosen. A few different thermistor models to consider are shown below;

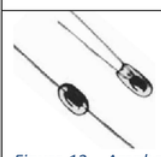
| Sensor/Reference                                                                                                                         | Measuring Temp | Ambient Temp  | Resistance | Power Rating  | Voltage       | Tolerance | Price  |
|------------------------------------------------------------------------------------------------------------------------------------------|----------------|---------------|------------|---------------|---------------|-----------|--------|
| <br>Figure 12 – Amphenol thermistor 527-BR11KA152M [15] | -80°C - 200°C  | -80°C - 600°C | 1.5kΩ      | 7mW           | 0v – 3v       | 20%       | £20.84 |
| <br>Figure 13 - EPCOS Thermistor 769-1892 [16]          | -55°C - 250°C  | -55°C - 250°C | 10kΩ       | 18mW          | 0v – 12v      | 1%        | £2.08  |
| <br>Figure 14 - RS Pro Thermistor 151-237 [17]          | -80°C - 150°C  | -80°C - 150°C | 10kΩ       | 75mW          | 0v – 27v      | 0.9%      | £2.16  |
| <br>Figure 15 - AVX ND03N00103JCC Thermistor [32]     | -55°C - 150°C  | -55°C - 150°C | 10kΩ       | Not specified | Not specified | 3%        | £0.164 |

Table 9 - Thermistors

The Amphenol thermistor appears to be the most robust thermistor but has the least tolerance. The RS Pro thermistor (151-237) has been chosen due to it having the best tolerance. To eliminate the need for signal conditioning the thermistor will be powered by a 5v DC supply so that its output can be connect straight to the microcontroller. Given that the chosen thermistor has a temperature range from -80°C - 150°C, this gives 230 steps per 1°C. As we are required to measure ½°C this give twice as many steps equating to 460 steps. An 8bit ADC only gives 256 steps and therefore a 10bit ADC giving 1024 steps is required. The microcontroller will be measuring the temperature every 30s and so its required memory allocation is calculated below;

$$2B * \frac{1}{30} = 0.067 \text{ B/s}$$

$$0.067B * 3600 = 240B \text{ per hour}$$

$$240B * 2 = 480B$$

### 3.4 G forces

| Sensor type             | Temperature Range | Voltage Range  | Ref                       |
|-------------------------|-------------------|----------------|---------------------------|
| Yaw-Gyro                | -40°C - 100°C     | 4.75v - 5.25v  | 2D: SA-GY-V4-000          |
| Integrated Circuit (IC) | -40°C - 105°C     | 2.375V - 3.46V | Mouser: 410-MPU-6050 [18] |

Table 10 – G force Sensors

Yaw rate gyros are used to measure angular velocity about its vertical axis in degrees or radians per second which can be used to determine a vehicles orientation as it corners or threatens to roll-over. The yaw rate sensor determines how far off-axis a vehicle is tilting using gyroscopes to monitor the angle between the vehicles heading and actual movement direction, known as the slip angle. The yaw rate sensor is usually installed under one of the front seats of the vehicle in order to access the vehicles centre of gravity. [19] The yaw rate gyro from 2D-datarecording is a small compact design with dimensions of 40 x 30 x 16mm, is IP67, has an ideal power supply requirement of 5v and can measure up to 200°/s. If multiple sensors are used mounted in different orientations then they could be used to measure roll, pitch and yaw.

The MPU 6050 found from Mouser (Mouser: 410-MPU-6050) is an integrated circuit that has a 3-axis gyroscope, 3-axis accelerometer and a Digital Motion Processor (DMP) built into one small package measuring 4x4x0.9mm. It includes three 16-bit ADCs for digitising the gyroscope output. The MPU 6050 can be user programmed to measure pitch, roll and yaw from 250°/s up to 2000°/s and is designed to send data over I2C interface. [18] Although the accelerometer is not needed for this project it can still be used for and all-in-one package to measure pitch, roll and yaw. As this is an IC it can be installed on the PCB without the need for external sensors/cables/connectors and is very cheap retailing at mouser for only £5.54 each.

As a yaw gyro sensors can only measure orientation on one axis, three of these sensors will need to be used. Not only would this require 3 extra cables/ connectors but the price for three (for 2D-Datarecording Yaw-Gyro) is £1,915.20 vs. <£10 for an IC that can measure 3-axis in one package. Therefore to measure pitch, roll and yaw a 3-axis integrated circuit sensor will be used. Below are some other 3-axis ICs to consider;

# Electronic System Design – Assignment 1

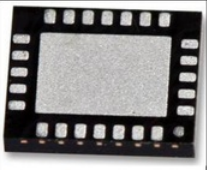
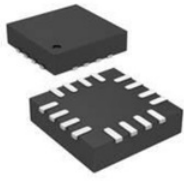
| <u>Sensor/Reference</u>                                                                                                                  | <u>Temperature Range</u> | <u>Voltage Range</u> | <u>Power Consumption</u> | <u>Sensitivity</u> | <u>Output Interface</u> | <u>Output Data Rate</u> | <u>Nº Pins</u> | <u>Price</u> |
|------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|----------------------|--------------------------|--------------------|-------------------------|-------------------------|----------------|--------------|
| <br>Figure 16 - TDK InvenSense MPU-6050 [28]            | -40°C - 105°C            | 2.375V - 3.46V       | 3.9mA                    | 250 - 2000°/s      | I <sup>2</sup> C        | 16-Bit 1KHz             | 24             | £5.54        |
| <br>Figure 17 – NXP FXAS21002CQR1 - MEMS Gyroscope [29] | -40°C - 85°C             | 1.95v – 3.6v         | 2.7mA                    | 250 - 2000°/s      | I <sup>2</sup> C /SPI   | 16-Bit 12.5Hz – 800Hz   | 24             | £3.59        |
| <br>Figure 18 - L3GD20HTR - MEMS Gyroscope [30]       | -40°C - 85°C             | 2.2v – 3.6v          | 5mA                      | 245 - 2000°/s      | I <sup>2</sup> C /SPI   | 16-Bit 11.9Hz - 757.6Hz | 16             | £2.31        |
| <br>Figure 19 - STMicroelectronics I3G4250DTR [31]    | -40°C - 85°C             | 2.4v – 3.6v          | 6.1mA                    | 250 - 2000°/s      | I <sup>2</sup> C /SPI   | 16-Bit 105Hz –          | 16             | £6.03        |

Table 11 – Gyro ICs

## Electronic System Design – Assignment 1

All the gyroscopes shown above are very similar, they can all measure up to 2000°/s and have similar supply voltage requirements. The NXP gyroscope from Farnell.com has been chosen due to it having the lowest power consumption. This gyroscope has a built in 16bit ADC and therefore has a digital output. The measurements from the gyroscope will be read every 0.5ms as so the required memory allocation is calculated below;

$$2B * \frac{1}{0.0005} = 4KB/s$$

$$4KB * 3600 = 14.4MB \text{ per hour}$$

$$14.4MB * 2 = 28.8MB$$

### 4.0 Microcontroller Selection

Now the sensors have been chosen an appropriate microcontroller can be selected. To help aid in the selection of an appropriate microcontroller and to understand how the various sensors, memory storage device, serial output port and status LED indicator all communicate with the microcontroller a structure diagram is shown below;

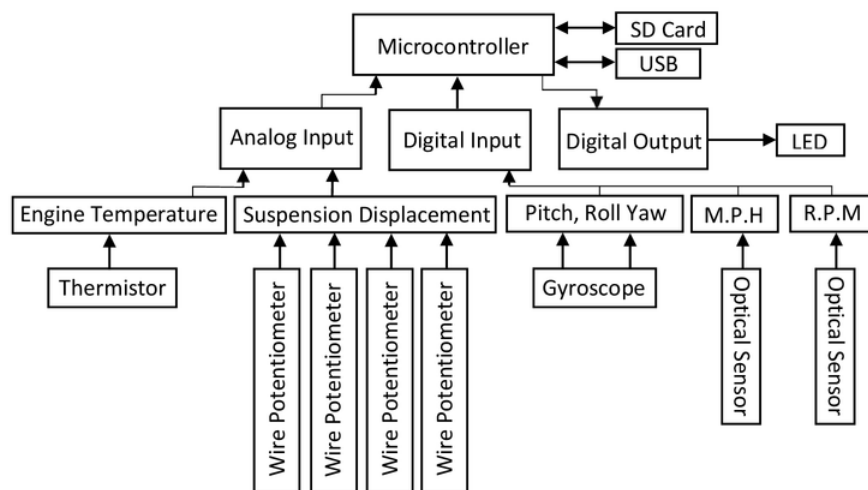


Figure 20 – System Structure Diagram

## Electronic System Design – Assignment 1

To calculate the minimum requirements that the microcontroller must have such as total number of pins, number of Digital/Analog pins, ADC resolution, counter resolution and minimum memory of the SD card a table is shown below;

| Sensor/Interface        | N <sup>o</sup> of I/O | A/D      | Resolution   | Total Memory |
|-------------------------|-----------------------|----------|--------------|--------------|
| Suspension Displacement | 4                     | A        | 10bit ADC    | 115.2KB      |
| Engine Speed            | 1                     | D        | 8bit counter | 14.4KB       |
| Vehicle Speed           | 1                     | D        | 8bit counter | 14.4KB       |
| Engine Temperature      | 1                     | A        | 10bit ADC    | 480B         |
| G-force                 | 2                     | D        | 16bit        | 28.8MB       |
| USB                     |                       | D        | -            | -            |
| SPI                     | 4                     | D        | 8bit         | -            |
| LED                     | 1                     | D        | 1bit         | -            |
| Total                   | 14                    | 5xA, 9xD | 16bit        | 29MB         |

Table 12 – Microcontroller Requirements

The microcontroller requires USB which allows the option to stream the data to a PC, SPI will be used to interface both the gyro sensor and SD card. It should be noted that the total number of I/O pins equating to 14 is not the total required number of pins on the microcontroller as additional pins such as power pins are required. The PIC18F2458 has been selected as it has all the required specifications including enough I/O pins, 10bit ADC, SPI, USB etc. The image below is from microchip.com and shows the main features of the PIC18f2458;

| Parameter Name                    | Value                                                         |
|-----------------------------------|---------------------------------------------------------------|
| Program Memory Type               | Flash                                                         |
| Program Memory (KB)               | 24                                                            |
| CPU Speed (MIPS)                  | 12                                                            |
| RAM Bytes                         | 2,048                                                         |
| Data EEPROM (bytes)               | 256                                                           |
| Digital Communication Peripherals | 1-UART, 1-SPI, 1-I <sup>2</sup> C1-MSSP(SPI/I <sup>2</sup> C) |
| Capture/Compare/PWM Peripherals   | 2 Input Capture, 2 CCP,                                       |
| Timers                            | 1 x 8-bit, 3 x 16-bit                                         |
| ADC                               | 10 ch, 12-bit                                                 |
| Comparators                       | 2                                                             |
| USB (ch, speed, compliance)       | 1, FS Device                                                  |
| Temperature Range (C)             | -40 to 85                                                     |
| Operating Voltage Range (V)       | 2 to 5.5                                                      |
| Pin Count                         | 28                                                            |

Figure 21 – PIC18F2458 Specification [33]

## 5.0 Circuit Design

Now that all the sensors, interfaces and microcontroller has been selected a circuit schematic can be created showing how all the components are connected together. The circuit schematic will also help with the PCB design later on in this report. The software package used to create the following circuit schematic is Proteus.

### 5.1 Engine & Vehicle Speed Circuit

The component which requires the highest voltage level is the RS Pro Optical sensor used for both rpm and mph measurements. The optical sensor has a voltage rating of 10v – 30v but a 12v supply will be used as 12v is a common voltage source. The RS Pro Optical sensor is a 4-wire device that has VDD which will be 12v, ground, and 2 x normally closed (NC) contacts which will be supplied by 5v. The 12v and ground connections are used to power the sensor. A 100R resistor is placed before the VDD input to protect the sensor from the possibility of overcurrent. The reason for using 5v for the switching contacts is so that the output signal is 5v and can be fed into the microcontroller without signal conditioning. A 5.1v Zener Diode is connected between the sensor output and ground to protect the microcontroller from any voltage spikes above 5v that may be induced from interference or short circuits etc. A 1K resistor on the sensor output is used to limit the current into the microcontroller but also with a 100nF capacitor to ground they work together to create a low pass filter. The low pass filter filters out any unwanted high frequencies that are likely to be induced in the cable from other electronic devices installed in the vehicle. A 4k7 resistor is connected between the microcontroller input and to ground so that the input pin is referenced to ground when the output of the sensor is low. This is to prevent unexpected counts from the microcontroller known as ‘floating pin’ when the microcontroller can’t distinguish between logic 0 and logic 1. Below is a screenshot of the completed rpm circuit;

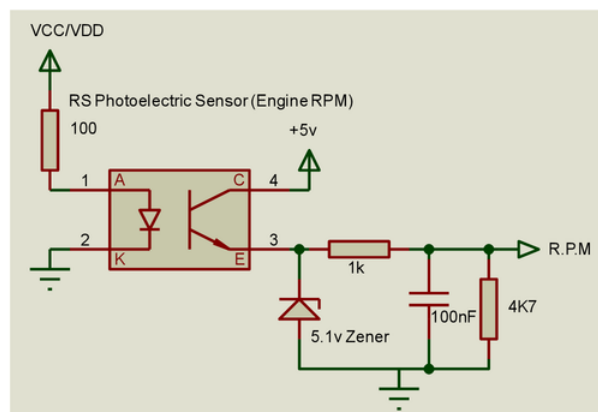


Figure 22 – Engine RPM Schematic

Note: the above schematic is duplicated for mph measurement as they are using the same sensor and the circuit can be identical.

## 5.2 Suspension Displacement Circuit

The SP1-25-3 Wire Potentiometer is a 3 terminal device consisting of +in which will be 5v, ground and +out which will be 0v – 5v. Just like the optical sensor the output has a 5.1v Zener to protect the microcontroller from high voltage spikes, and a low pass filter to filter out high frequencies but also to limit the current into the microcontroller. Below is the schematic for one the suspension displacement sensors;

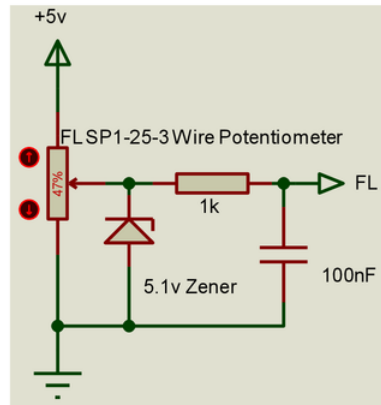


Figure 23 – FL Wire Potentiometer Schematic

Note: As there will be four suspension sensors used the sensor and its corresponding output is labelled FL for 'front left' suspension.

## 5.3 Engine Temperature Circuit

The RS Pro Thermistor is an NTC Coefficient which means its resistance decreases as temperature increases. A thermistor can be used as part of voltage divider with the voltage divider equation given below;

$$V_{out} = V_{in} * \left( \frac{R_2}{R_1 + R_2} \right)$$

We know from the datasheet that the thermistor has a resistance of 10K at 25°C and would expect the voltage output at this temperature to be approximately half of the input voltage. If R1 is the thermistor and R2 is 10K so that Vout is 2.5v at 25°C as the temperature increases, R1 decreases meaning Vout increases. Given that at the lowest temperature (-80°C) the thermistor is likely to be approximately 100R and at the highest temperature (150°C) will be approximately 100k, Vout can be calculated for both high and low temperatures as follows;

$$V_{out} @ -80^{\circ}\text{C} = 5 * \left( \frac{10,000}{100,000 + 10,000} \right) = 0.45\text{v}$$

$$V_{out} @ 150^{\circ}\text{C} = 5 * \left( \frac{10,000}{100 + 10,000} \right) = 4.95\text{v}$$

Figure 24 shows the schematic for the temperature sensor using a voltage divider and using the same protection and filtering techniques;

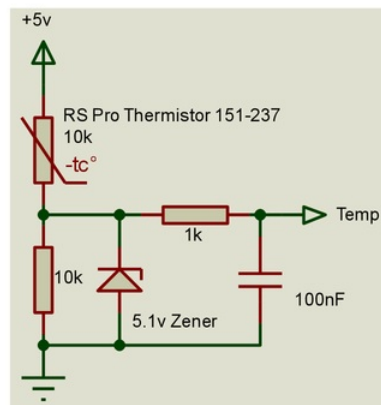


Figure 24 – Engine Temperature Schematic

### 5.4 G-Force Measurement Circuit

The NXP Gyroscope is a 24pin device that has a 16bit output over either I<sup>2</sup>C or SPI. If the gyroscope were to use I<sup>2</sup>C the two pins required for I<sup>2</sup>C on the PIC18F2458 would need to be shared for the SD card SPI interface. This would make programming the PIC unnecessarily complicated by changing the configuration each time a different protocol is required. Therefore, it is decided that SPI will be used for the Gyro so that communications can also be made with the SD card without changing the configuration throughout the program. The datasheet shows how the gyroscope is setup for use in SPI mode and a screenshot is shown below;

#### 1.3.2 Typical Application Circuit—SPI Mode

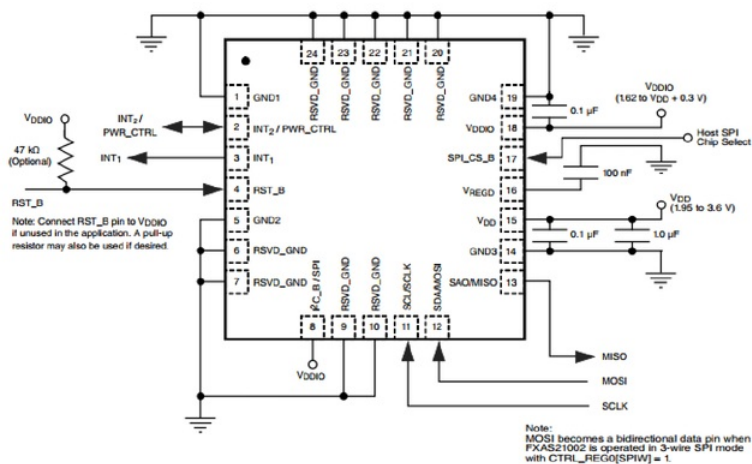


Figure 25 – NXP Gyroscope SPI Mode [34]

## Electronic System Design – Assignment 1

As the gyroscope IC does not exist in the Proteus software a new device has been created with the supply and ground rails omitted for clarity. PWR\_CTRL (Pin 2) allows the IC to switch between standby and active modes. The standby mode is for energy saving and won't be used so is therefore connected to VDD so that the IC stays in active mode. INT1 (pin 3) is an interrupt output that can be programmed to operate when the IC exceeds a programmed threshold. As an interrupt output is not needed it is connected to ground. RST\_B (Pin 4) is a reset pin which is not used so is connected to VDDIO via a 47K resistor as shown in the datasheet. 2C\_B / SPI (pin 8) is the digital interface selection pin and is connected to VDDIO for SPI interface. SCL/SCLK (pin 11) is the SPI clock which is clocked by the PIC. SDA/MOSI (pin 12) and SA0/MISO (pin 13) are the SPI data slave in/slave out connections that allow data transfer between the master and slave. SPI\_CS\_B (pin 17) is the slave select line which the master uses to select which slave can communicate with it. VREGD (pin 16) is the digital voltage regulator output which is connected to ground via 100nf capacitor as specified in the datasheet. VDD is the main power supply while VDDIO is the interface supply, both are connected to a regulated 3.3v supply but are omitted from the schematic. Below is a screenshot of the final gyroscope connections made in Proteus;

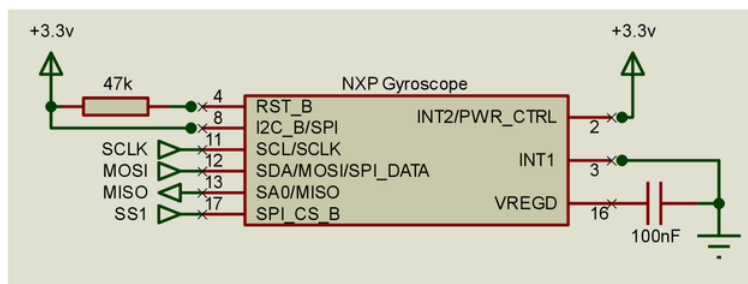


Figure 26 – G Force Measurement Schematic

### 5.5 Power Supply Circuit

As established the minimum voltage required is 10v so a 12v battery is used to power the whole system. A switch is connected to the positive terminal of the battery which allows the user to turn ON/OFF the system. The 12v supply from the battery is labelled VDD/VCC which is directly connected to two voltage regulators and two optical sensors via 100R resistors. The schematic for the power supply circuit is shown below;

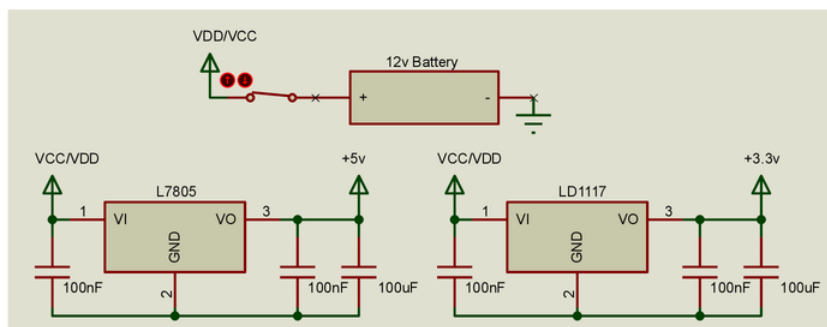


Figure 27 – Power Supply Schematic

## Electronic System Design – Assignment 1

The voltage regulators chosen are L7805 and LD1117 which are +5v and +3.3v regulators respectively. The L7805 was chosen as it's a common regulator with an output current up to 1.5A. The LD1117 is also a common regulator with an output current of up to 800mA which is more than sufficient. The 100nF input capacitors are used to reduce the input impedance and provides a current source if the voltage spikes low on the input. The 100nF and 100uF capacitors on the output are used to stabilise the regulators and give a clean DC output.

### 5.6 Final Circuit

All the above circuits have been connected to PIC18F2458 using labels to minimise connecting lines for clarity. An SD card and USB port has also been included showing how they will interface with the PIC. Below is the final circuit schematic;

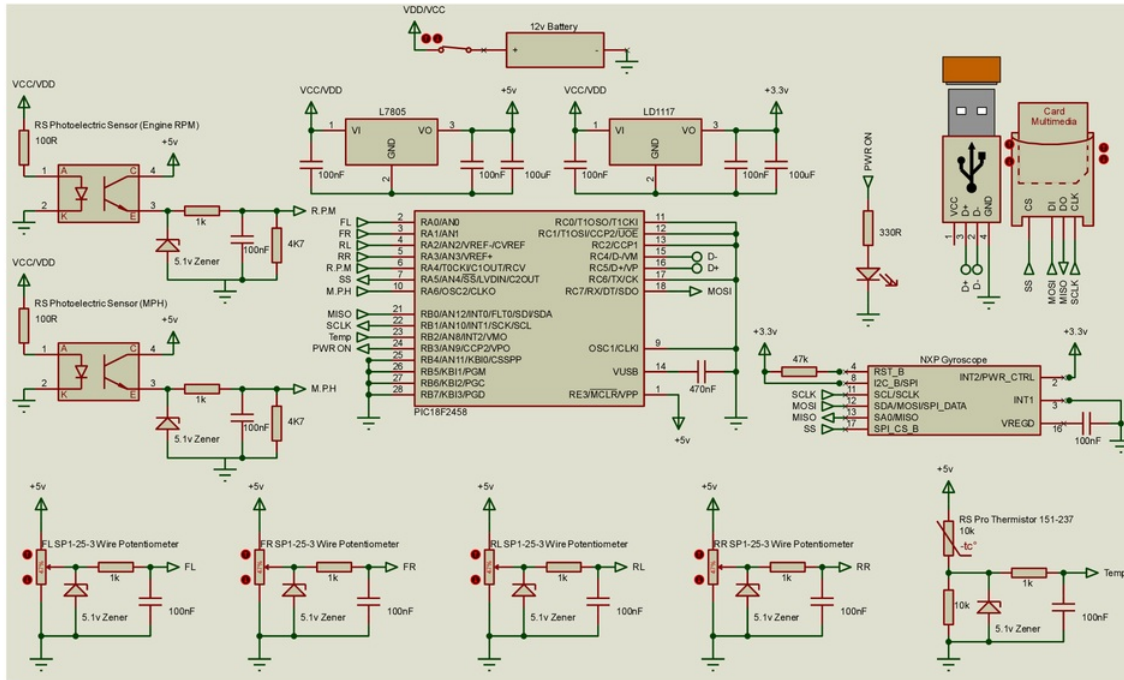


Figure 28 – Final Circuit Schematic

MCLR (pin 1) on the PIC is an active-low reset pin and which is not used so is connected to +5v. VUSB (pin 14) is an internal voltage regulator used for the USB protocol, a 470nF capacitor is connected to ground as recommended by microchip to stabilise the voltage for the USB signal lines. RB3 (Pin24) is used as a digital output to switch on a green LED which shows the user that the unit is powered on and measurements are being read by the PIC. All other pins are not used and are therefore connected to ground.

## 6.0 Connector & Cable Selection

Suitable connectors are to be chosen so that the external sensors can be connected to the circuit. Keeping in mind that the environment the product is to be installed in is a harsh environment and care should be taken when selecting connectors as to their durability and protection ratings. It is useful to select different types of connectors for different sensors so that the customer cannot connect the cables to the wrong sensors. This would prevent any potential accidental damage to the circuit and/or sensors but also if the wrong sensors are connected the readings logged will be false. To help aid in connector selection the number of pins required for each sensor are to be known. Below is table showing the amount of pins required for each sensor;

| Sensor             | Connections            | Nº Of Pins |
|--------------------|------------------------|------------|
| Wire Potentiometer | +V, GND, Output        | 3          |
| Optical Sensor     | +V, GND, Input, Output | 4          |
| Engine Temp        | +V, Output             | 2          |

Table 13 – Connector Pin Count required

Given there are four wire potentiometers which all operate the same way it wouldn't cause harm to plug them in the wrong way around providing that they are not connected to the circuit for a different sensor. This is also true for the optical sensors and if they were connected the wrong way around the data would be reversed but it would be obvious when analysing the data. As each type of sensor has a different number of pin requirements the same connector types can be used but with different number of pins. Murrelektronik connectors have been chosen as they offer a series of durable IP67 connectors that are designed for industrial applications at a reasonable price. For ease of installation it has been decided to have a short cable length with a female trailing socket on each sensor and a female flange socket on the products casing. The sensors will then be connected using a cable with two male connectors on both ends. This way the sensors can easily be connected/reconnected without using screw terminals. The Flange connectors also come prewired. The connectors chosen are shielded which provides mechanical protection and protection against electrical interference. There is a separate terminal to connect the cable shield to. The connectors screw into each other to ensure an IP67 protection rating but also to ensure they do not disconnect while the tester is driving the vehicle. The three images below show the male and female trailing and female flange connectors;



Figure 30 – Female Trailing Connector [35]



Figure 29 – Male Trailing Connector [35]



Figure 31 – Female Flange Connector [35]

## Electronic System Design – Assignment 1

The cable to be used must be shielded to add mechanical and interference protection. Murrelektronik also sell shielded cable with different numbers of cores. 1m of cable will be used at each sensor with 5m of cable between giving a total of 6m cable for each sensor. Below is a table showing the connectors and cables selected from Murrelektronik;

| Murrelektronik Connector/Cable | Murrelektronik Part N° | N° Poles | Price  | QTY | Total Cost |
|--------------------------------|------------------------|----------|--------|-----|------------|
| M12 Female Straight            | 7000-14025-0000000     | 2        | £21.61 | 1   | £21.61     |
| M12 Male Straight              | 7000-14005-0000000     | 2        | £21.61 | 2   | £43.22     |
| M12 Female Flange              | 7000-14171-8410030     | 2        | £15.39 | 1   | £15.39     |
| M12 Female Straight            | 7000-14221-0000000     | 3        | £24.75 | 4   | £99.00     |
| M12 Male Straight              | 7000-14201-0000000     | 3        | £24.75 | 8   | £198.00    |
| M12 Female Flange              | 7000-13613-6000070     | 3        | £14.58 | 4   | £58.32     |
| M12 Female Straight            | 7000-12651-0000000     | 4        | £28.12 | 2   | £56.24     |
| M12 Male Straight              | 7000-12551-0000000     | 4        | £25.27 | 4   | £101.08    |
| M12 Female Flange              | 7000-13611-2010030     | 4        | £14.53 | 2   | £29.06     |
| PUR 1x2xAWG22 shielded         | 7000-C0201-7860000     | 2        | £3.52  | 6m  | £21.12     |
| PUR 3X0.34 shielded            | 7000-C0201-2400000     | 3        | £2.24  | 24m | £53.76     |
| PUR 4X0.34 shielded            | 7000-C0201-2410000     | 4        | £2.36  | 12m | £28.32     |
| Total                          |                        |          |        |     | £725.12    |

Table 14 – Connector Selection

## 7.0 Battery Selection

A 12v battery is needed however, to know what size battery is needed the current consumption of the system needs to be calculated. The worst case scenario will be considered where all components are always using the maximum amount of power. The system is designed for use for a 2 hour track run and therefore the battery must last at least 2 hours. The table below shows the worst case current consumption for each component in the system;

| Component            | Current Consumption | Current Consumption for 2 hours |
|----------------------|---------------------|---------------------------------|
| Displacement Sensors | 0.5mA x 4 = 2mA     | 4mA                             |
| Optical Sensors      | 35mA x 2 = 70mA     | 140mA                           |
| Temperature sensor   | 0.5mA               | 1mA                             |
| Gyroscopic Sensor    | 2.7mA               | 5.4mA                           |
| Microcontroller      | 250mA               | 500mA                           |
| LED                  | 20mA                | 40mA                            |
| Total                |                     | 690.4mA                         |

Table 15 – Power Consumption

The above shows what the maximum current consumption from the sensors and microcontroller are however additional current may be consumed through discrete components and voltage regulators etc. To ensure that the battery will defiantly supply the system for 2 hours the total amount of consumption equating to 650mA can be multiplied by four to give 2760mA and that will be used as the minimum requirement. EL Wire Craft sell Li-ion batteries of various sizes. They sell 2800mAh battery for £20 with dimensions of 6.8cm x 4.7cm x 2.2cm which will be used. [20]

## 8.0 PCB Design

The following screenshots show the PCB design that was created using Easy-PC. The image below shows the front view of the PCB;

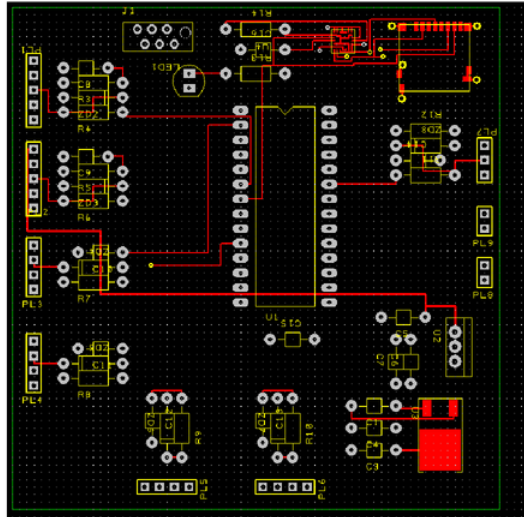


Figure 32 – Front View of PCB

The following image shows the rear view of the PCB;

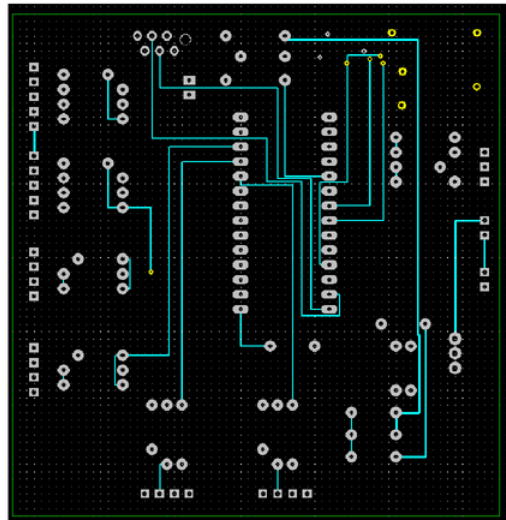


Figure 33 – Rear View of PCB

## Electronic System Design – Assignment 1

The following image shows the composite view of the PCB;

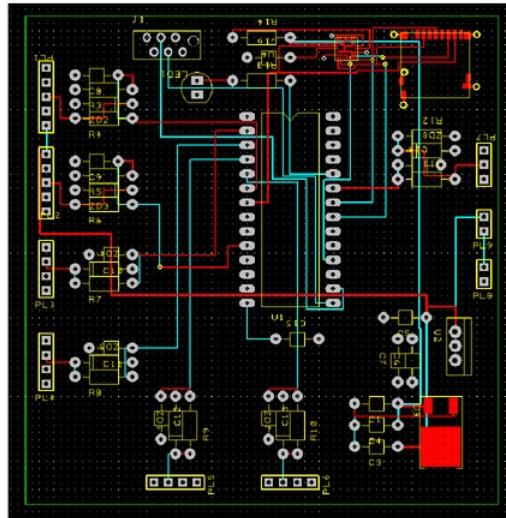


Figure 34 – Composite View of PCB

The following two images show the front and back of the PCB design in 3D;

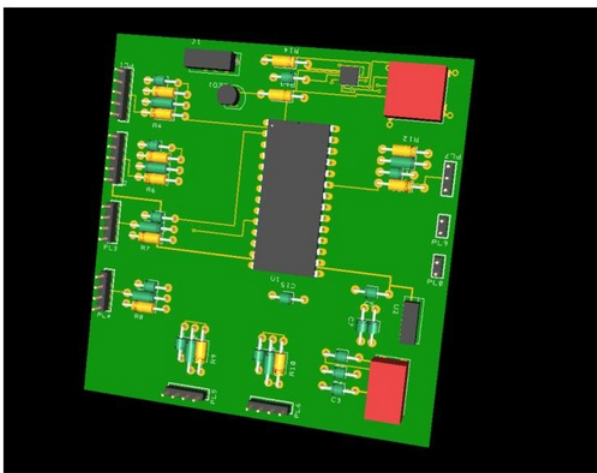


Figure 36 – Front 3D View of PCB

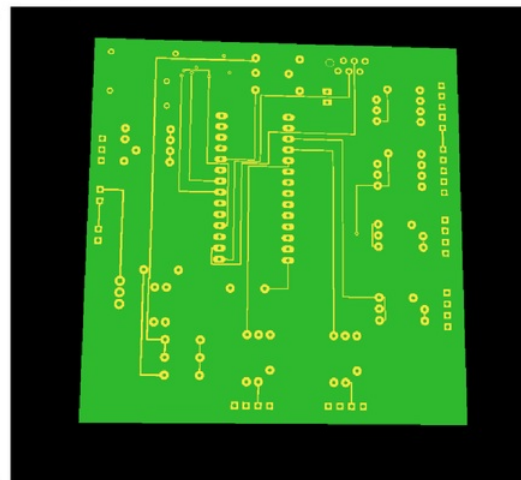


Figure 35 – Back 3D View of PCB

## 9.0 Casing Selection

As the system is intended to be used in a harsh environment and given that the PCB is delicate a Pelicase protector has been chosen as the case selection. The Peli Storm Case iM2075 has been chosen and the PCB will be mounted inside. The case offers mechanical protection to the PCB as well as being waterproof. Below is an image of the Peli Storm Case;



*Figure 37 – Peli Storm Case [36]*

## 10.0 Build Cost

| Component                  | Part N <sup>o</sup>          | Price   | QTY | Price           |
|----------------------------|------------------------------|---------|-----|-----------------|
| Wire Potentiometer         | SP1-25-3                     | £143.20 | 4   | £572.80         |
| Optical Sensor             | RS N <sup>o</sup> : 729-5117 | £52.85  | 2   | £105.70         |
| Thermistor                 | RS N <sup>o</sup> : 151-237  | £2.16   | 1   | £2.16           |
| Gyroscope                  | FXAS21002CQR1                | £3.59   | 1   | £3.59           |
| PIC18F2458 Microcontroller | RS N <sup>o</sup> : 666-8936 | £4.08   | 1   | £4.08           |
| 12v 2800mAh Li-ion Battery | N/A                          | £20.00  | 1   | £20.00          |
| Murrelektronik Connectors  | -                            | -       | 28  | £725.12         |
| Shielded Cable             | -                            | -       | -   | £103.20         |
| L7805 +5v Regulator        | RS N <sup>o</sup> : 918-1971 | £0.27   | 1   | £0.27           |
| LD1117 +3.3v Regulator     | RS N <sup>o</sup> : 686-9767 | £0.24   | 1   | £0.24           |
| 100R Resistor              | RS N <sup>o</sup> : 707-7587 | £0.12   | 2   | £0.24           |
| 1K Resistor                | RS N <sup>o</sup> : 707-7666 | £0.017  | 7   | £0.12           |
| 4K7 Resistor               | RS N <sup>o</sup> : 707-7726 | £0.017  | 2   | £0.03           |
| 10K Resistor               | RS N <sup>o</sup> : 707-7745 | £0.006  | 1   | £0.01           |
| 47K Resistor               | RS N <sup>o</sup> : 707-7805 | £0.115  | 1   | £0.12           |
| 100nF Capacitor            | RS N <sup>o</sup> : 538-1310 | £0.132  | 12  | £1.58           |
| 470nF Capacitor            | RS N <sup>o</sup> : 379-090  | £0.299  | 1   | £0.30           |
| 100uF Capacitor            | RS N <sup>o</sup> : 379-157  | £1.301  | 2   | £2.60           |
| 5.1v Zener Diode           | RS N <sup>o</sup> : 544-3597 | £0.062  | 7   | £0.43           |
| 2 Way Header               | RS N <sup>o</sup> : 483-8461 | £0.099  | 1   | £0.10           |
| 3 Way Header               | RS N <sup>o</sup> : 483-8477 | £0.166  | 1   | £0.17           |
| 4 Way Header               | RS N <sup>o</sup> : 483-8483 | £0.22   | 4   | £0.88           |
| 5 Way Header               | RS N <sup>o</sup> : 670-5243 | £0.311  | 2   | £0.62           |
| 2 Way Crimp Connector      | RS N <sup>o</sup> : 296-4934 | £0.15   | 1   | £0.15           |
| 3 Way Crimp Connector      | RS N <sup>o</sup> : 296-4940 | £0.254  | 1   | £0.25           |
| 4 Way Crimp Connector      | RS N <sup>o</sup> : 296-4956 | £0.302  | 4   | £1.21           |
| 5 Way Crimp Connector      | RS N <sup>o</sup> : 670-5174 | £0.212  | 2   | £0.42           |
| SD Card Socket             | RS N <sup>o</sup> : 487-9327 | £3.54   | 1   | £3.54           |
| 512MB Micro SD Card        | RS N <sup>o</sup> : 146-5580 | £10.82  | 1   | £10.82          |
| USB Socket                 | RS N <sup>o</sup> : 674-1356 | £0.926  | 1   | £0.93           |
| Peli Storm Case            | iM2075                       | £61.56  | 1   | £61.56          |
| <b>Total</b>               |                              |         |     | <b>£1623.24</b> |

Table 16 – Build Cost

## 11.0 Conclusion

This report has demonstrated the design of a portable vehicular acquisition system. Market research was initially carried out to see what is currently out on the market today which helps aid in designing a product that the market demands. It was noticed during this research that most vehicular data acquisition systems have a modular design which allows the user to minimise costs by only purchasing sensors they require. Although the designed data logger is intended for use in a prototype vehicle which the sensors chosen are required to test the prototype for safety and comfort, some of the sensors may not be used if required. In fact the system could be used without any externally sensors and could be used just to measure g-forces like the Omega Tri-Axial Shock Data Logger. It was also noticed that GPS systems are usually integrated into the data loggers to track the position of the vehicle so that the location of an event can be located. Integrating a GPS module could be considered if re-designing the data acquisition system and perhaps a Wi-Fi module to wirelessly stream the logged data similar to the AIM Motorsport MXS. The estimated cost of £1623.24 is not including the cost of the PCB and taking into account other smaller costs that were not included the price could well be estimated at around £2,000. This cost is not bad as it is around the same as the other vehicle data loggers found in the market research however, if this product were to be competitively sold on the market the costs would need to be reduced. The Murrelektronik connectors are quite expensive and perhaps in a future design using a fewer number of connectors could be enough to bring the build costs down.

## 12.0 References

- [ Omega Engineering, "OM-CP-SHOCK101 Series Tri-Axial Shock Data Logger," Omega, [Online].  
1 Available: <https://www.omega.co.uk/pptst/OM-CP-SHOCK101-EB.html>. [Accessed 27 October  
] 2017].
- [ R. Technology, "DL1 SPORT Data Logger," [Online]. Available: [https://www.race-  
2 technology.com/in/racing/products/data-loggers/dl1-sport](https://www.race-technology.com/in/racing/products/data-loggers/dl1-sport). [Accessed 27 October 2017].  
]
- [ A. Motorsport, "AIM MOTORSPORT MXS DASH LOGGER," [Online]. Available:  
3 [https://www.demon-  
4 tweeks.co.uk/Product.do?method=view&n=7170&g=796636&p=1263666&d=124&c=4&l=2&utm  
\\_source=Google&utm\\_medium=Base&utm\\_campaign=Data%20Logging%20Dash%20Loggers%20  
&%20Loggers&gclid=EAlaIqobChMI0vG8oaaR1wIVBp4bCh26YgBzEAKYESABEgJGS\\_D\\_BwE&gclidsrc](https://www.demon-tweeks.co.uk/Product.do?method=view&n=7170&g=796636&p=1263666&d=124&c=4&l=2&utm_source=Google&utm_medium=Base&utm_campaign=Data%20Logging%20Dash%20Loggers%20&%20Loggers&gclid=EAlaIqobChMI0vG8oaaR1wIVBp4bCh26YgBzEAKYESABEgJGS_D_BwE&gclidsrc).  
[Accessed 27 October 2017].
- [ 2d-datarecording, "Linear Potentiometer Datasheet SA-LP250-350-000-DINA4," [Online].  
4 Available: [http://2d-datarecording.com/Downloads/Datasheets/Sensors-length/Pdf/SA-LP250-  
5 350-000-DINA4.pdf](http://2d-datarecording.com/Downloads/Datasheets/Sensors-length/Pdf/SA-LP250-350-000-DINA4.pdf). [Accessed 11 October 2017].
- [ B. Sensors, "Draw Wire Sensors," [Online]. Available: [http://www.beisensors.com/draw-wire-  
6 sensor-transducer.html](http://www.beisensors.com/draw-wire-sensor-transducer.html). [Accessed 11 October 2017].  
]
- [ K. CORPORATION, "Laser location," [Online]. Available:  
6 [http://www.keyence.co.uk/ss/products/sensor/sensorbasics/laser\\_location/info/](http://www.keyence.co.uk/ss/products/sensor/sensorbasics/laser_location/info/). [Accessed 12  
] October 2017].
- [ 2. Datarecording, "Wire Potentiometer Datasheet," [Online]. Available: [http://2d-  
7 datarecording.com/Downloads/Datasheets/Sensors-length/Pdf/SA-WPxxxHQ-000-DINA4.pdf](http://2d-datarecording.com/Downloads/Datasheets/Sensors-length/Pdf/SA-WPxxxHQ-000-DINA4.pdf).  
] [Accessed 22 October 2017].
- [ E. tutorials, "Hall Effect Sensors," [Online]. Available: [http://www.electronics-  
8 tutorials.ws/electromagnetism/hall-effect.html](http://www.electronics-tutorials.ws/electromagnetism/hall-effect.html). [Accessed 12 October 2017].  
]
- [ E. Csanyi, "Purpose and Working Principle of Inductive Sensors," [Online]. Available:  
9 <http://electrical-engineering-portal.com/purpose-and-working-principle-of-inductive-sensors>.  
] [Accessed 12 October 2017].

- [ T. Agarwal, "Optical Sensor Basics and Applications," [Online]. Available:  
1 <https://www.elprocus.com/optical-sensors-types-basics-and-applications/>. [Accessed 12 October  
0 2017].  
]
- [ REOTEMP Instrument Corporation, "Thermocouples," [Online]. Available:  
1 <http://www.thermocoupleinfo.com/>. [Accessed 15 October 2017].  
1  
]
- [ U.S Sensor, "WHAT IS A THERMISTOR?," [Online]. Available: [http://www.ussensor.com/technical-](http://www.ussensor.com/technical-info/what-is-a-thermistor)  
1 [info/what-is-a-thermistor](http://www.ussensor.com/technical-info/what-is-a-thermistor). [Accessed 15 October 2017].  
2  
]
- [ S. C. Inc., "Infrared Temperature Sensors," [Online]. Available:  
1 <http://www.surecontrols.com/infrared-temperature-sensors/>. [Accessed 15 October 2017].  
3  
]
- [ R. Popely, "Should I Worry About How Hot My Engine Is Running?," 1 October 2016. [Online].  
1 Available: [https://www.cars.com/articles/should-i-worry-about-how-hot-my-engine-is-running-](https://www.cars.com/articles/should-i-worry-about-how-hot-my-engine-is-running-1420680334271/)  
4 [1420680334271/](https://www.cars.com/articles/should-i-worry-about-how-hot-my-engine-is-running-1420680334271/). [Accessed 21 October 2017].  
]
- [ R. Components, "Amphenol Thermistor 527-BR11KA152M," [Online]. Available:  
1 [https://www.mouser.co.uk/ProductDetail/Amphenol/BR11KA152M/?qs=%2fha2pyFaduuj%252bU](https://www.mouser.co.uk/ProductDetail/Amphenol/BR11KA152M/?qs=%2fha2pyFaduuj%252bU5N%2fNaakIMxzCtsNG7CBlvqPw9TDIQMFFbqR5yKfbQ%3d%3d)  
5 [N%2fNaakIMxzCtsNG7CBlvqPw9TDIQMFFbqR5yKfbQ%3d%3d](https://www.mouser.co.uk/ProductDetail/Amphenol/BR11KA152M/?qs=%2fha2pyFaduuj%252bU5N%2fNaakIMxzCtsNG7CBlvqPw9TDIQMFFbqR5yKfbQ%3d%3d). [Accessed 15 October 2017].  
]
- [ R. Components, "EPCOS B57540G1103F000 Thermistor," [Online]. Available: [http://uk.rs-](http://uk.rs-online.com/web/p/thermistors/7691892/?searchTerm=769-1892&relevancy-data=636F3D3126696E3D4931384E525353746F636B4E756D626572266C753D656E266D6D3D6D61746368616C6C26706D3D5E285C647B362C377D5B4161426250705D297C285C647B337D5B5C732D2F255C2E2C5D5C647)  
1 [online.com/web/p/thermistors/7691892/?searchTerm=769-1892&relevancy-](http://uk.rs-online.com/web/p/thermistors/7691892/?searchTerm=769-1892&relevancy-data=636F3D3126696E3D4931384E525353746F636B4E756D626572266C753D656E266D6D3D6D61746368616C6C26706D3D5E285C647B362C377D5B4161426250705D297C285C647B337D5B5C732D2F255C2E2C5D5C647)  
6 [data=636F3D3126696E3D4931384E525353746F636B4E756D626572266C753D656E266D6D3D6D](http://uk.rs-online.com/web/p/thermistors/7691892/?searchTerm=769-1892&relevancy-data=636F3D3126696E3D4931384E525353746F636B4E756D626572266C753D656E266D6D3D6D61746368616C6C26706D3D5E285C647B362C377D5B4161426250705D297C285C647B337D5B5C732D2F255C2E2C5D5C647)  
] [61746368616C6C26706D3D5E285C647B362C377D5B4161426250705D297C285C647B337D5B5C](http://uk.rs-online.com/web/p/thermistors/7691892/?searchTerm=769-1892&relevancy-data=636F3D3126696E3D4931384E525353746F636B4E756D626572266C753D656E266D6D3D6D61746368616C6C26706D3D5E285C647B362C377D5B4161426250705D297C285C647B337D5B5C732D2F255C2E2C5D5C647)  
732D2F255C2E2C5D5C647. [Accessed 15 October 2017].
- [ R. Components, "RS Pro Thermistor 151-237," [Online]. Available: [http://uk.rs-](http://uk.rs-online.com/web/p/thermistors/0151237/?searchTerm=151-237&relevancy-data=636F3D3126696E3D4931384E525353746F636B4E756D626572266C753D656E266D6D3D6D61746368616C6C26706D3D5E285C647B362C377D5B4161426250705D297C285C647B337D5B5C732D2F255C2E2C5D5C647B)  
1 [online.com/web/p/thermistors/0151237/?searchTerm=151-237&relevancy-](http://uk.rs-online.com/web/p/thermistors/0151237/?searchTerm=151-237&relevancy-data=636F3D3126696E3D4931384E525353746F636B4E756D626572266C753D656E266D6D3D6D61746368616C6C26706D3D5E285C647B362C377D5B4161426250705D297C285C647B337D5B5C732D2F255C2E2C5D5C647B)  
7 [data=636F3D3126696E3D4931384E525353746F636B4E756D626572266C753D656E266D6D3D6D](http://uk.rs-online.com/web/p/thermistors/0151237/?searchTerm=151-237&relevancy-data=636F3D3126696E3D4931384E525353746F636B4E756D626572266C753D656E266D6D3D6D61746368616C6C26706D3D5E285C647B362C377D5B4161426250705D297C285C647B337D5B5C732D2F255C2E2C5D5C647B)  
] [61746368616C6C26706D3D5E285C647B362C377D5B4161426250705D297C285C647B337D5B5C](http://uk.rs-online.com/web/p/thermistors/0151237/?searchTerm=151-237&relevancy-data=636F3D3126696E3D4931384E525353746F636B4E756D626572266C753D656E266D6D3D6D61746368616C6C26706D3D5E285C647B362C377D5B4161426250705D297C285C647B337D5B5C732D2F255C2E2C5D5C647B)  
732D2F255C2E2C5D5C647B. [Accessed 15 October 2017].
- [ T. InvenSense, "MPU-6000 and MPU 6050 Datasheet," [Online]. Available:  
1 <http://www.mouser.com/ds/2/400/MPU-6000-Datasheet1-1112286.pdf>. [Accessed 15 October  
2017].

8  
]

[ S. Brand, "YAW Rate Sensors," [Online]. Available:  
1 [http://www.standardbrand.com/media/886008/ST10235YAW-FEB14\\_JTF\\_YAW-Rate.pdf](http://www.standardbrand.com/media/886008/ST10235YAW-FEB14_JTF_YAW-Rate.pdf).  
9 [Accessed 15 October 2017].  
]

[ E. W. Craft, "12V Rechargeable Li-ion Battery," [Online]. Available: <http://elwirecraft.co.uk/el-2-products/el-accessories/12v-rechargeable-li-ion-battery-1800mah-2800mah-or-5000mah-for-el-0-driver-led/>. [Accessed 2 November 2017].  
]

[ RS, "447-6192 Kubler Linear Measuring Encoder," Kubler, [Online]. Available: [http://uk.rs-online.com/web/p/products/4476192/?grossPrice=Y&cm\\_mmc=UK-PLA-DS3A-\\_google-\\_1-PLA\\_UK\\_EN\\_Automation\\_And\\_Control\\_Gear\\_-\\_Sensors\\_And\\_Transducers-\\_2-PRODUCT+GROUP&matchtype=&gclid=EAlaIqobChMI0sOznZCE1wIV7RXTCh3nhggsEAYYASABEgLMNPD\\_BwE&gclidsrc=aw.d](http://uk.rs-online.com/web/p/products/4476192/?grossPrice=Y&cm_mmc=UK-PLA-DS3A-_google-_1-PLA_UK_EN_Automation_And_Control_Gear_-_Sensors_And_Transducers-_2-PRODUCT+GROUP&matchtype=&gclid=EAlaIqobChMI0sOznZCE1wIV7RXTCh3nhggsEAYYASABEgLMNPD_BwE&gclidsrc=aw.d). [Accessed 22 October 2017].

[ SIKO, "Wire-actuated encoder SG5," SIKO, [Online]. Available: <https://www.siko-global.com/en-2-gb/products/linearline-wire-actuated-encoders/wire-actuated-encoders/sg5>. [Accessed 22 October 2017].  
]

[ D.-K. Electronics, "223-1662-ND," [Online]. Available: <https://www.digikey.com/product-2-detail/en/te-connectivity-measurement-specialties/SP1-25/223-1662-ND/5277388>. [Accessed 22 October 2017].  
]

[ Farnell, "EE-SPY412 - OPTICAL SENSOR," [Online]. Available: [http://uk.farnell.com/omron-2-industrial-automation/ee-spy412/optical-sensor-switch-4-reflective/dp/1385692?ost=1385692&isrnfonsku=false&ddkey=http%3Aen-1GB%2FElement14\\_United\\_Kingdom%2Fsearch](http://uk.farnell.com/omron-2-industrial-automation/ee-spy412/optical-sensor-switch-4-reflective/dp/1385692?ost=1385692&isrnfonsku=false&ddkey=http%3Aen-1GB%2FElement14_United_Kingdom%2Fsearch). [Accessed 22 October 2017].

[ RS, "729-5117 RS Pro Retro-reflective Photoelectric Sensor," RS, [Online]. Available: <http://uk.rs-online.com/web/p/photoelectric-sensors/7295117/>. [Accessed 22 October 2017].  
5  
]

[ RS, "444-3451 Telemecanique Sensors," Telemecanique Sensors, [Online]. Available: <http://uk.rs-online.com/web/p/photoelectric-sensors/4443451/>. [Accessed 22 October 2017].  
6  
]

- [ Mouser, "E3S-AD11 Omron Automation and Safety," Omron, [Online]. Available:  
2 <https://www.mouser.co.uk/ProductDetail/Omron-Automation-and-Safety/E3S-AD11/?qs=sGAEpiMZZMs50KUSuyRkpiT4xqlZBCldzV4j2E3acGM%3d>. [Accessed 22 October 2017].  
]
- [ Mouser, "TDK InvenSense MPU-6050," TDK InvenSense, [Online]. Available:  
2 <https://www.mouser.co.uk/ProductDetail/TDK/MPU-6050/?qs=%2fha2pyFadugw%252bbjVmg%252b4qgvYTbx8JZcdWsVVStohjxQckhTVnR9zNw%3d%3d>. [Accessed 23 October 2017].  
]
- [ Farnell, "FXAS21002CQR1 - MEMS Gyroscope," NXP, [Online]. Available:  
2 <http://uk.farnell.com/nxp/fxas21002cqr1/gyroscope-3-axis-digital-qfn-24/dp/2474536>. [Accessed 23 October 2017].  
]
- [ Farnell, "L3GD20HTR - MEMS Gyroscope," STMicroelectronics, [Online]. Available:  
3 <http://uk.farnell.com/stmicroelectronics/l3gd20htr/mems-gyroscope-245-500-02000dps/dp/2762758>. [Accessed 23 October 2017].  
]
- [ D.-K. Electronics, "STMicroelectronics I3G4250DTR," STMicroelectronics, [Online]. Available:  
3 <https://www.digikey.co.uk/product-detail/en/stmicroelectronics/I3G4250DTR/497-15699-6-1ND/5267998>. [Accessed 23 October 2017].  
]
- [ R. Components, "AVX ND03N00103JCC Thermistor RS: 697-4465," AVX, [Online]. Available:  
3 <http://uk.rs-online.com/web/p/thermistors/6974465/?searchTerm=697-4465&relevancy-data=636F3D3126696E3D4931384E525353746F636B4E756D626572266C753D656E266D6D3D6D61746368616C6C26706D3D5E285C647B362C377D5B4161426250705D297C285C647B337D5B5C732D2F255C2E2C5D5C647>. [Accessed 15 October 2017].  
]
- [ Microchip, "PIC18F2458," [Online]. Available:  
3 <http://www.microchip.com/wwwproducts/en/PIC18F2458>. [Accessed 28 October 2017].  
3  
]
- [ NXP, "3-Axis Digital Angular Rate Datasheet," May 2015. [Online]. Available:  
3 [http://www.farnell.com/datasheets/2295153.pdf?\\_ga=2.262281993.447185319.1509210308-638430691.1508599379&\\_gac=1.175893014.1509119679.EAlalQobChMlv9Gg8ZSR1wIVSCjTCh32cQB1EAAYASAAEgla6vD\\_BwE](http://www.farnell.com/datasheets/2295153.pdf?_ga=2.262281993.447185319.1509210308-638430691.1508599379&_gac=1.175893014.1509119679.EAlalQobChMlv9Gg8ZSR1wIVSCjTCh32cQB1EAAYASAAEgla6vD_BwE). [Accessed 28 October 2017].  
]
- [ Murrelektronik, "Field Wireable Connectors," [Online]. Available:  
3 <http://shop.murrelektronik.co.uk/en/Connection-Technology/Field-wireable/>. [Accessed 31 October 2017].  
]

## Electronic System Design – Assignment 1

[ W. Cases, "Peli Storm iM2075 Case," [Online]. Available: <https://www.waterproof-cases.co.uk/product/peli-storm-im2075-case/>. [Accessed 9 November 2017].

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# Sam O'Leary Assignment 1

## GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

**Instructor**

61 / 100

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GRADING FORM: SMU GENERIC\_GJ

**MICHAEL SAM O'LEARY**

**60.85**

## RESEARCH-INFORMED LITERATURE



Literature review is reasonable manufacturer information is well presented but it would be improved by following up with a comparison table of relevant information. 58%

**5.8**

## KNOWLEDGE AND UNDERSTANDING



Good overall schematic design but a few problems can be seen. The 7805 is being powered from the VCC/VDD which is a 5 volt rail, although shown as connecting to the +12V from the battery this is an error. The zener diode is shown in almost all cases as being connected directly to the input of the sensor signal, this should be connected via a small resistor to avoid the possibility of damage to the zener via large current in a fault state. Although mentioned in the write up as using separate slave selects, you have used the same selector for both spi devices in the design. 55%

**13.8**

## 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 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%

**22.75**

## PRACTICAL APPLICATION AND DEP.



Costings nicely put forward as a table with price and supplier of component except for the battery. No attempt at future enhancements, this is disappointing, better time management would have made a big difference. 55%

**11.0**

## SKILLS FOR PROFESSIONAL PRAC.



The report is well presented with very well presented tabled data, it could have been improved with a few more illustrations. Very good selection of references. 75%

**7.5**