

Electronics Systems Design

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Level 6

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1. Abstract

Vehicle data acquisition systems have become increasingly popular due to advancements in technology. These systems use electric data logging and sensor technology to record and store data from vehicles. The specific system mentioned here is a microcontroller-based vehicle acquisition system. It incorporates relevant sensors, connectors, housing, and memory size to accurately measure various performance variables of a vehicle.

To develop this system, a complete circuit design was achieved using Proteus software, and a PCB design suitable for manufacturing was created using EasyPC. While the system has been successful, there is room for improvement. One possible improvement is the addition of Bluetooth, Wi-Fi, GPS, and other connectivity features to enable easy data transfer and remote monitoring.

Furthermore, cost optimization could be achieved by using surface mount electronic components on the PCB instead of through-hole components. This approach can help reduce manufacturing costs without failing the system's functionality.

Overall, the use of vehicle data acquisition systems has significantly expanded, and ongoing improvements in technology and design continue to grow.

2. Introduction

This report aims to design a microcontroller based vehicle acquisition system based. It will involve comparing various existing vehicle acquisition systems and comparing their suitability. The report focuses on comparing different sensors that can be used to measure various performance parameters of a vehicle, such as RPM, engine surface temperature, suspension movement, and more. The selection of appropriate connectors will be crucial to the chosen sensors.

To justify the selection of a microcontroller, a number of calculations will be conducted. This analysis will help determine the most suitable microcontroller for the system, also a comprehensive circuit design using Proteus software and a corresponding PCB design using EasyPC will be completed.

The report will also include a build cost estimation, which will include the casing, battery, and all other necessary components. Finally, a project review will be completed, highlighting areas for improvement in both the specification and design for future designs.

Overall, this report will provide a detailed analysis and design plan for a microcontroller-based vehicle acquisition system, along with recommendations for enhancing its performance and functionality.

3. Literature Review

The table below demonstrates existing data vehicle acquisition systems that are available on the market.

		
[1] Link VMAX M4000	[2]Granite 10	[3] SIRIUS R8D8
• Modules can be added as test needs evolve • Modules can be shared between systems • Data and video synchronization • Designed to aid the driver in successful test execution • Driver prompts • Configurable heads-up display • Commenting interface • Customizable target bars with ramp rate functionality • Channel saturation warnings	• Traditional network connections via Ethernet port • EPI port switch for high-speed connection to all GRANITE™ measurement modules • Onboard storage of streaming data with 2 GB of DDR3 SDRAM and a 128 GB solid-state hard drive (SSD) • Built-in GPS for network synchronization • General-purpose CAN channel	• High End Signal Conditioning • All in one instrument • 64 Counter channels • Up to 27 isolated CAN Ports • EtherCAT Expansion port • Connectivity interfaces • 100Hz GPS with RTK • Software included • Dual Core ADC Technology

Table 1

4. Hardware Specification

4.1 Sensor Selection

4.1.1 Engine RPM & Vehicle Road Speed (MPH)

The table below illustrates many types of sensors that could potentially be used to measure the engines RPM by comparing different aspects of the sensors that will play a part in the functionality and practicality of the data acquisition system.

<u>Type of Sensor</u>	<u>Durability</u>	<u>Life Expectancy</u>	<u>Accuracy</u>	<u>Range</u>	<u>Credibility</u>	<u>Cost</u>
Optical (Beam Break)	MEDIUM	HIGH	HIGH	MEDIUM	HIGH	MEDIUM
Magnetic (Hall)	MEDIUM	HIGH	MEDIUM	LOW	HIGH	MEDIUM
Optical (Reflective)	MEDIUM	HIGH	HIGH	MEDIUM	HIGH	MEDIUM

Table 2

RPM and MPH can be measured using various methods, and a few of them have been mentioned and compared above. Among these methods, optical reflective sensors were chosen as the preferred option over other types. This choice is based on the fact that optical sensors, in general, tend to offer higher accuracy compared to magnetic sensors. This accuracy is crucial, especially considering that changes in RPM or MPH can occur rapidly. The specific choice of a reflective type of optical sensor was made primarily for the ease of installation. By using reflective tape on the flywheel, the installation process becomes simpler. In regards to a beam break sensor, if this type of sensor was used, it would be more awkward to fit and transfer it between different vehicles.

<u>Supplier</u>	<u>Reference</u>	<u>Part Number</u>	<u>Material</u>	<u>IP Rating</u>	<u>Input Voltage</u>	<u>Output Signal</u>	<u>Power Consumption (mA)</u>	<u>Range</u>	<u>Price (Inc VAT)</u>
KA Sensors	[9]	SP Series	SS	IP67	5 to 24 VDC	NPN	25		
Ahlborn	[10]	FUA 919-3	Brass, nickel plated	IP67	5VDC		32	Up to 30000 RPM	
Compact Instruments	[11]	VLS211	SS	IP67	5VDC	NPN	30	Up to 25000 RPM	£345

Table 3

To conclude the table above, the sensor that would be more beneficial to the design is the compact sensor. The compact sensor has an IP67 rating which will be perfect for the environment it will be used in, it has a 5VDC supply and a very low power consumption, the other sensors chosen did not give enough information on their products to identify if their product will be more compatible or not. The Compact sensor will be mounted with Zip ties to the car frame.



Figure 4 [11]

4.1.2 Engine Temperature Sensors

The table below illustrates many types of sensors that could potentially be used to measure the engines temperature by comparing different aspects of the sensors that will play a part in the functionality and practicality of the data acquisition system.

<u>Type of Sensor</u>	<u>Durability</u>	<u>Life Expectancy</u>	<u>Accuracy</u>	<u>Temperature Range</u>	<u>Credibility</u>	<u>Cost</u>
<u>RTD</u>	LOW	MEDIUM	MEDIUM	MEDIUM	HIGH	MEDIUM
<u>Thermocouple</u>	HIGH	HIGH	HIGH	HIGH	LOW	MEDIUM
<u>Infrared</u>	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
<u>Thermistor</u>	MEDIUM	LOW	Calibration Dependant	LOW	MEDIUM	LOW

Table 4

In conclusion of the comparison table, the type of sensor that is chosen is the Infrared sensor. The infrared sensor proves to have the best capabilities in comparison to the other types of sensors. The infrared sensor can measure temperature while coping with an environment that is impacted by vibration, this is proven by a high life expectancy and durability level, while the RTD sensor is vulnerable to vibrations which could be damaged very easily when implemented into this design resulting in receiving unreliable data. The RTD sensor could arise more issues in measuring the engine temperature due to the sensor needing to be in full contact with the engine to receive a true value, as this design will be for a temporary test this could cause some issues with positioning the sensor into the engine. Thermistor and thermocouple sensors would not be as compatible as the infrared sensor due to the durability and life expectancy rates. The thermocouple would also need a cold junction implemented which is also cost effective. The Thermistor would also need frequent calibration to ensure true data is received.

The table below compares a selection of infrared sensors that could be potentially used.

<u>Supplier</u>	<u>Reference</u>	<u>Part Number</u>	<u>Material</u>	<u>IP Rating</u>	<u>Accuracy</u>	<u>Input Voltage</u>	<u>Output Signal</u>	<u>Power Consumption (mA)</u>	<u>Range</u>	<u>Price (Inc VAT) (£)</u>
<u>RS</u>	[3]	PC151LT-0	SS	IP65	+/- 1% or +/- 1°	24VDC	4-20mA		-20°C to 500°C	210.24
<u>Farnell /Optris</u>	[4]	OPTCSLT15SFCB1	SS	IP63	+/- 1.5% or +/- 1.5°	5-30VDC	Analogue 0-5V	10	-50°C to 1030°C	127.02
<u>Micro Epsilon</u>	[5]	ThermoMETER CSmicro	SS	IP65	+/- 0.5% or +/- 0.5 °	5-24VDC	0-5VDC	9	-20°C to 100°C	275.90

Table 5

The Micro Epsilon sensor has been determined to be the most suitable choice among the aforementioned sensors. While all the sensors share similarities in terms of their robustness and metal construction, they also possess good IP ratings, operate within a reasonable input voltage range, and offer similar accuracy. However, the Micro Epsilon sensor stands out with its lower power consumption. Additionally, its output signal is advantageous as it aligns with the operating voltage range of microcontrollers, eliminating the need for signal conditioning to adjust the output voltage. Furthermore, the Omega sensor is reasonably priced. It is worth noting that a mounting bracket will need to be either manufactured or purchased.



Figure 5 [5]

4.1.3 Front and rear suspension travel Sensors

The table below illustrates many types of sensors that could potentially be used to measure the vehicles front and rear suspension travel sensors by comparing different aspects of the sensors that will play a part in the functionality and practicality of the data acquisition system.

<u>Type of Sensor</u>	<u>Durability</u>	<u>Life Expectancy</u>	<u>Accuracy</u>	<u>Range</u>	<u>Credibility</u>	<u>Cost</u>
<u>Ultrasonic</u>	MEDIUM	HIGH	LOW	HIGH	HIGH	HIGH
<u>Wire Potentiometer</u>	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW
<u>Linear Variable Differential Transformer (LVDT)</u>	HIGH	HIGH	HIGH	LOW	HIGH	HIGH
<u>Optical</u>	LOW	MEDIUM	HIGH	LOW	MEDIUM	MEDIUM

Table 6

A wire potentiometer has been selected as the preferred sensor for measuring suspension movement due to several reasons. Firstly, wire potentiometers are known for their resilience to various environmental conditions. Additionally, wire potentiometers offer ease of installation compared to other sensors, which is crucial considering the frequent movement of the system.

In Comparison , LVDT sensors lack the flexibility required for suspension movements, as they need vertical motion while suspension movements can exhibit slight curves. Optical sensors would face challenges with dirt and water by scattering or obstructing the light used by the sensors. Similarly, ultrasonic sensors would encounter difficulties at high speeds, as the wind could interfere with the transmission of ultrasonic sound.

Furthermore, wire potentiometers tend to be more cost-effective compared to alternative sensor types. This makes them a favourable choice from a financial view.

<u>Supplier</u>	<u>Reference</u>	<u>Part Number</u>	<u>Material</u>	<u>IP Rating</u>	<u>Accuracy</u>	<u>Input Voltage</u>	<u>Output Signal</u>	<u>Power Consumption (mA)</u>	<u>Range</u>	<u>Price (Inc VAT)</u>
<u>LIKA</u>	[12]	SFPS1	Aluminium	IP64	+/- 0.15mm	10 to 30VDC	4-20 mA	2	300 to 2000mm	
<u>Applied Measurements</u>	[13]	WPS-1500-MK60	plastic, PBT GF20	IP65	+/- 0.005%	14 to 27 VDC	0 to 10 VDC	30	1500mm	£376
<u>Digital Advanced Sensors</u>	[14]	DWS Mini	Plastic	IP65	≤10mm	5VDC	0.5V to 3.25VDC	10	1200mm	£164

Table 7

In conclusion of the compared wire potentiometer sensors, the Digital advanced sensor proved to be the most suitable choice. It has been specifically designed to withstand extreme conditions with an IP rating of IP65, making it ideal especially as it will be exposed to water and dirt consistently. The sensor from LIKA is not as suitable due to its IP rating. The wire potentiometers from LIKA and Applied Measurements may also pose

an issue due to the minimum supply voltage being higher than 5VDC while the Digital advanced sensor operates at 5VDC. The Digital advanced sensor was also at a reasonable price.



Figure 6 [14]

4.1.5 Pitch, Roll and Yaw

The table below illustrates many types of sensors that could potentially be used to measure the vehicles pitch, roll and yaw by comparing different aspects of the sensors that will play a part in the functionality and practicality of the data acquisition system.

<u>Type of Sensor</u>	<u>Durability</u>	<u>Life Expectancy</u>	<u>Accuracy</u>	<u>Range</u>	<u>Credibility</u>	<u>Cost</u>
<u>Accelerometer</u>	MEDIUM	HIGH	MEDIUM	HIGH	HIGH	MEDIUM
<u>Magnetometer</u>	HIGH	HIGH	LOW	HIGH	HIGH	MEDIUM
<u>Gyroscope</u>	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH

Table 8

The gyroscope has been chosen as the preferred method for measuring Pitch, Roll and Yaw is based on its reliable performance. Unlike accelerometers, which are influenced by gravity, a gyroscope stays unaffected by gravity and offers a higher dynamic range. This allows for accurate measurement of acceleration, distinguishing between motion and the influence of gravity. On the other hand, a magnetometer measures magnetic fields, including the Earth's magnetic field, which can be utilized for determining orientation. However, when used for orientation or fast movement, the accuracy of a magnetometer is relatively poor compared to a gyroscope. A gyroscope, with its quick reaction time and accuracy in detecting changes, is a more reliable choice for this application.

<u>Supplier</u>	<u>Reference</u>	<u>Part Number</u>	<u>Material</u>	<u>IP Rating</u>	<u>Accuracy</u>	<u>Input Voltage</u>	<u>Output Signal</u>	<u>Power Consumption (mA)</u>	<u>Range</u>	<u>Price (Inc VAT) £</u>
TE	[6]	11206AC-3099	Aluminium	IP65	+/- 0.5%	8.5 to 36VDC		10	+/- 50°/s to +/- 180°/s	
Epson	[7]	M-G552PJ7	Metallic	IP67		9 to 32 VDC		32	+/- 450°/s	
Sens 4 Pro	[8]	GYRN3-S	Alluminium	IP66	+/-2%	5 to 16VDC	0-5VDC	16	+/- 300°/s	1880

Table 9

The Gyroscope that is chosen for the system is from Sens 4 Pro. Sens 4 Pro states that the gyroscope has been designed specifically towards the automotive industry. This aids the design in terms durability and robustness in comparison to the TE and Epson gyroscope. The GYRN3-S also advantages over the other gyroscopes by having a minimum supply voltage of 5VDC which will be more practical when designing the circuitry as the other sensors chosen also have a 5VDC supply.

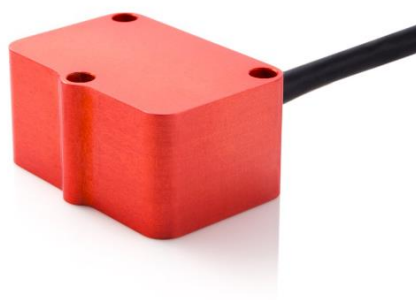


Figure 7 [8]

4.2 Battery Specifications

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

<u>Component</u>	<u>Power Consumption</u>	<u>Quantity</u>	<u>Total Power Consumption</u>
<u>Suspension Sensor</u>	10mA	4	40mA
<u>RPM & MPH Sensor</u>	30mA	2	60mA
<u>Gyroscope</u>	16mA	1	16mA
<u>Temperature Sensor</u>	9mA	1	9mA
<u>LEDs</u>	25mA	2	50mA

Table 10

The total for all the components power consumption is 155mA. The specification specifies the test has to collect data for two hours so, 255mA is multiplied by 2 which will give a total power consumption of 310mA over a two hour period. To ensure that the battery have enough power to capacitate for a for two test runs before re charging the battery, 310mA will be multiplied by 4. This totals around 1.24Ah, so anything above this would be sufficient. The chosen battery pack was the BAK TECHNOLOGY 18650CA-2S-3J it consists of Lithium-ion cells with a 2.25 Ah output. The battery pack is rechargeable which is an advantage to the design as it can be taken away recharged and used again. The current output is considerably more than has been calculated which will also give a positive impact to the final product.



Figure 8 [15]

The voltage output is 7.4V this will require a step down of voltage to ensure the components do not become damaged. A voltage regulator will ensure this does not happen, the voltage regulator shown below is compatible for the design.

4.3 Connector Specifications

The figures below demonstrate the type of connectors that each sensor will be terminating into, the male connectors can easily be taken on and off for each test without entering the enclosure, the female connectors are panel mounted which can be drilled and mounted around the box, while still keeping the IP65 integrity of the enclosure since the connectors are IP67 rated.

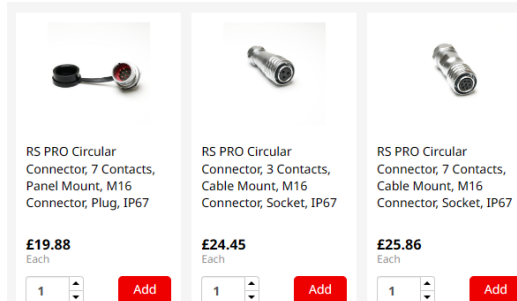


Figure 9 [29]



Figure 10 [29]

The figure below illustrates the type of connectors that will be used on the PCB board.



Figure 11 [17]

4.4 Enclosure

The enclosure that has been chosen for the design is from Eterna, this enclosure has an IP65 rating which will ensure that no water or dirt will be able to enter inside the enclosure and damage the components inside. The dimensions are 200mm X 160mm x 80mm, this will be ideal for the intended application since it will be mounted under a car bonnet which will make it easier to find space to cable tie to the car frame. The size will also allow for all components including connectors to be easily fixed to the enclosure. Since the switches are IP65 rated they will be easily drilled and fixed to the external cover. This will make the design more user friendly as the user can switch the power on and initiate the measurements to start without entering the enclosure.



Figure 12 [28]

5. Microcontroller Selection

5.1 Digital Bit Resolution

5.1.1 Vehicle MPH

The system is aimed for the family saloon vehicle type, according to [22] Haynes the average wheel size is around 14" to 21", within reason an 18" wheel diameter is a more realistic size for a family saloon car, using the measurement of 18", we can calculate the distance the wheel will travel in one revolution using the following formula.

$$\text{Circumference} = \pi d \text{ (where } d \text{ is the diameter).}$$

Applying this formula, the circumference is approximately 56 inches.

To determine the number of revolutions the vehicle will travel in one mile, we take into consideration that there are 1760 yards in a mile, 3 feet in a yard, and 12 inches in a foot. This results in 63360 inches in a mile. Dividing 63360 by 56 results in approximately 1131 revolutions per mile.

Since there are 3600 seconds in an hour, we can calculate the required pulses per second. Dividing 1131 by 3600 yields approximately 0.31 pulses per second, it is not possible to have fractional pulses, so 4 pieces of reflective tape positioned on the wheel, would result in 1.25 pulses per second.

Considering a top speed of 100 mph, the number of measurements per second. Multiplying 100 by 1.25 results in approximately 125 measurements per second. Based on these calculations, an 8-bit counter with 256 levels would be sufficient for this application.

5.1.2 Engine RPM

To accurately measure RPM on an engine, measurements will need to be taken every 10 revolutions within the range of 0 to 8000 revs. To determine the appropriate bit resolution for this purpose, a calculation is performed by dividing 8000 by 10 results in 800. Therefore, an 10-bit counter with 1024 bytes would be sufficient for this application.

5.2 Analogue/Digital Bit Resolution

5.2.1 Suspension Movement

In order to accurately measure suspension movement, a resolution of 1mm is required. The vehicle's initial position is set at 380mm, with a potential range of movement of 150mm +/-, resulting in a total range of 300mm. The selected sensor has a range of 0-1500mm and provides an output of 0.5 to 3.25V.

Firstly the actual voltage output will need to be calculated:

$$3.25 - 0.5 = 2.75V$$

To determine the voltage output at the 380mm position, the following calculation is performed:

$$\frac{2.75}{1500} \times 380 = 0.7V.$$

Similarly, for the upper limit of 530mm and the lower limit of 230mm, the calculations are as follows:

$$\text{Upper Limit} = \frac{2.75}{1500} \times 530 = 0.97V$$

$$\text{Lower Limit} = \frac{2.75}{1500} \times 230 = 0.42V$$

The voltage span is 0.55V to a range of 300mm. To calculate the voltage change per millimetre, 0.55V is divided by the range of 300mm, resulting in 0.0018V per mm.

An 8-bit resolution provides 256 bytes, a 9-bit resolution offers 512 bytes, a 10-bit resolution offers 1023 bytes, and a 12-bit resolution provides 4095 bytes. Using this information it seems that a 10-bit resolution could suit this application. To confirm the calculation is performed as follows:

$$\frac{2.75}{1023} = 0.0027V.$$

Given that suspension movement requires only 0.0018V per mm, the 10-bit resolution will be sufficient enough due to the wire potentiometer having a bigger range than needed, and highly likely never going to maximise out to 1500mm. This being said a 10-Bit resolution is chosen for the wire potentiometers.

5.2.2 Engine Surface Temperature

To ensure accurate detection of engine surface temperature changes of 1°C. The temperature of a vehicle's engine can vary from -10°C to 120°C, resulting in a total range of 130°C. The chosen sensor has a range of -40°C to 1030°C, providing a much wider range of 1070°C. Additionally, the sensor outputs a voltage signal of up to 5V.

To determine the appropriate analogue-to-digital (A/D) bit resolution for the sensor, the following calculation is performed by dividing the total range of 1070°C by the desired temperature change of 1°C which results in a value of 1070. This indicates that there should be 1070 readings to accurately capture the temperature changes.

Considering the available options for A/D bit resolution, a 10-bit resolution offers 1024 bytes while a 12-bit resolution offers 4095 bytes. In this case, the 10-bit resolution is suitable for achieving the required temperature measurements since the temperature of a car should not be going above 120 °C resulting in the maximum temperature of 1070 °C never being met.

5.2.3. G Forces

The detection of pitch, roll, and yaw will need to be measured at a rate of $1^\circ/\text{s}$. The maximum rate of change for pitch is $\pm 45^\circ/\text{s}$, for roll it is $\pm 45^\circ/\text{s}$, and for yaw it is $\pm 360^\circ/\text{s}$. The selected sensor has a range of $\pm 300^\circ/\text{s}$. The output voltage of the sensor ranges from 0V to 5V, with 2.5V representing $0^\circ/\text{s}$.

Since the voltage range for pitch, roll, and yaw is the same, there is no need to calculate it separately for each. To determine the voltage at the limits of roll & pitch which is $\pm 45^\circ/\text{s}$, the following calculations are performed:

$$\frac{5}{450} * 360 = 4V \text{ and } \frac{5}{450} * 240 = 2.6V.$$

This results in a voltage span of 1.4V. Next, we calculate the voltage change per $^\circ/\text{s}$:

$$\frac{1.4}{120} = 0.0117V.$$

Therefore, for a 9-bit analogue-to-digital (A/D) resolution, the calculation is as follows:

$$\frac{5}{512} = 0.0098V.$$

This resolution is sufficient for pitch, as it only requires 0.0117V per $^\circ/\text{s}$.

4.3 Memory

4.3.1 Engine RPM & Vehicle MPH

In order to determine the required memory for taking measurements at a frequency of 0.5 seconds, we can use the following calculation.

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

Since the RPM and MPH measurements only require an 8-bit counter, the frequency can be multiplied by the size of 1 byte, resulting in 2 bytes per second.

4.3.1 Engine Temperature

To monitor the slow-changing engine temperature, it is determined that a reading every 30 seconds would be appropriate. To calculate the required memory, we can calculate as follows,

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

Considering the A/D resolution is over 10 bits, the memory size required would need to be at least 2 bytes (2B) regardless of its actual size.

4.3.3 Front and Rear Suspension Travel

The family saloon vehicle with 18" wheel diameter, we can calculate the distance the wheel will travel in one revolution using the following calculation :

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

To determine the number of revolutions the vehicle will travel in one mile, we know that there are 63360 inches in a mile, dividing 63360 by 56, results in 1131 revs/mile.

If the vehicle is traveling at 80mph, we can calculate the number of revolutions per second using the equation $1131/70 = 16 \text{ revs/second}$.

To determine the distance the vehicle will travel in one second at 70mph, we multiply 56 by 16, resulting in 896" per second.

Considering the suspension sensor's capability to detect objects as small as half an inch, the vehicle could potentially travel over 1792 of those half inches in one second.

To determine the frequency at which readings must be taken, we calculate $1/1792$, which is approximately 0.5 milliseconds, using the following calculation we find that the frequency is 2000.

$$\text{Frequency} = 1/(\text{Periodic Time}),$$

Since there are 4 wheels and 4 readings taken every 0.5ms, with each reading occupying 2 bytes, we multiply 2000 by 4 readings to obtain 8000 then by 2 bytes, resulting in 16KB per second of memory required.

4.3.4 Roll, Pitch & Yaw

The memory capacity needs to be calculated. To calculate the memory requirement, for the measurements to be taken every 10 milliseconds, the following equation can be used, which proves that the frequency is equal to the reciprocal of the time interval.

$$\frac{1}{10} = 100 \text{ measurements per second}$$

Considering that there are three axis to measure (pitch, roll, and yaw), and each measurement will be taken every 10 milliseconds of 2 bytes of memory, multiplying the frequency of 100 by the 3 readings gives us 300 readings per second. Multiplying this by the 2 bytes per reading results in a memory requirement of 600 bytes per second.

4.3.5 Memory Total

The Table below illustrates the total memory needed for the data acquisition system.

<u>Measurement</u>	<u>Memory Per Measurement</u>	<u>Memory Per Hour</u>	<u>Total Memory Per Test (2Hr)</u>
<u>MPH</u>	2B	86.4kB	1.73MB
<u>RPM</u>	2B	86.4kB	1.73MB
<u>Suspension Movement</u>	16kB	11.5MB	23MB
<u>Engine Temperature</u>	2B	14.4kB	28kB
<u>Roll, Pitch & Yaw</u>	600 Bytes	2.2MB	4.4MB

Table 11

The total memory needed for the full test cycle is 31.14 MB.

4.5 Pin Count

The table below illustrates the total pin count that will be needed for the data acquisition system.

<u>Pin</u>	<u>Pin Count</u>	<u>Application</u>
<u>Suspension</u>	4	Sensor
<u>Temperature</u>	1	Sensor
<u>MPH</u>	1	Sensor
<u>RPM</u>	1	Sensor
<u>Roll, Pitch & Yaw</u>	3	Sensor
<u>USB</u>	3	Data Read
<u>SD Card</u>	4	Data read
<u>LED</u>	1	Indication
<u>Start Button</u>	1	Start Test
<u>Supply</u>	1	-
<u>GND</u>	1	GND

Table 12

The minimum total number of pins needed for the microcontroller is 21, the standard pin counts that PIC's are available in are 20, 28 & 40, a 28 pin PIC would be a reasonable amount for the design.

4.6 Selected Microcontroller

The Microcontroller chosen for the system is from microchip PIC18F2550. The Reasoning for this choice is that it is suitable for the application in many different areas, when researching to find the most suitable PIC the minimum criteria was as follows:

- 28 pin
- Automotive capable
- SPI
- I2C
- 10 bits ADC resolution
- Operation 5VDC
- USB compatible
- Internal Oscillator
- 8 A/D Channels

The microchip website tool was used to help finalise the choice of the microcontroller, many results were suitable for the design. The PIC18F2550 was chosen due to the cost and compatibility to criteria that needed to be met.

Parametrics	
Program Memory Size (KB)	32
RAM (bytes)	2048
Data EEPROM (bytes)	256
Pin Count	28
Operation Voltage Max.(V)	5.5
Operation Voltage Min.(V)	2
Timers	1 x 8-bit - 3 x 16-bit
Max ADC Resolution (bits)	10
ADC Channels	10
Zero Cross Detect	No
Number of Comparators	2
SPI	1 -SPI
I2C	1 -I2C
Stand alone PWM	0
Low Power	No
Numerically Controlled Oscillator (NCO)	0
Data Signal Modulator (DSM)	0

Figure 13 [20]

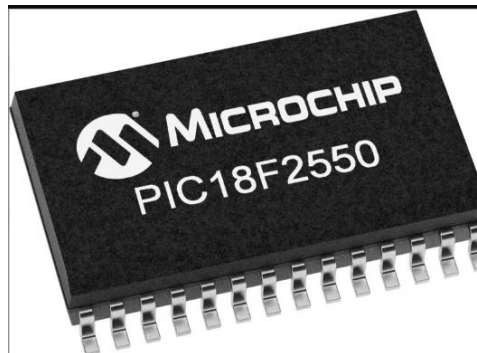


Figure 14 [20]

5. Design

5.1 Schematic Design

The images below illustrate the finalised schematic design of the vehicle data acquisition system which was designed on proteus figure [14] and Easy PC figure [15].

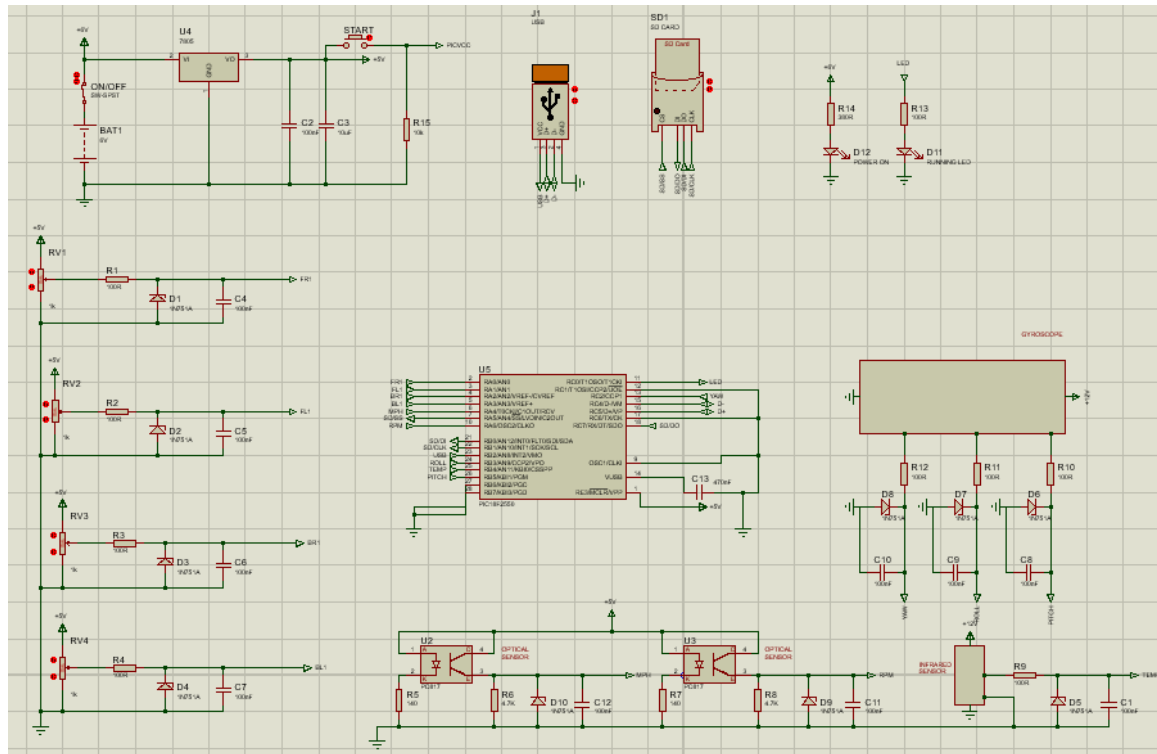


Figure 14

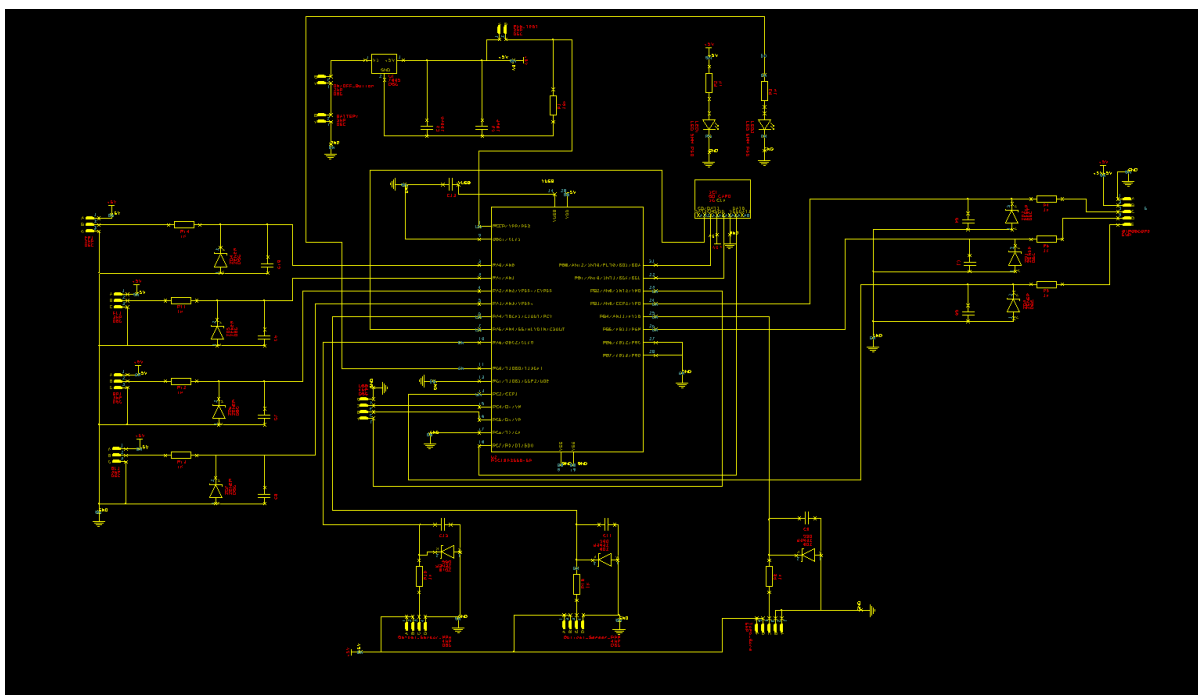


Figure 15

The figures below illustrate the supply circuit for the system. It consists of a 7.4V 2.2Ah battery pack which is connected to a switch that will be mounted to the external side of the IP65 casing. When turned on the supply will feed into a voltage regulator. The voltage regulator will regulate the voltage down to a steady 5V which will align with all of the circuitry components. The capacitors immediately after the voltage regulator are used for filtering and the other for storing voltage in case the power is lost to ensure the data is saved. The supply will then immediately feed into 'LED1' to state that the circuitry has voltage, then feeding into the sensors and microcontroller giving them a constant supply. The second switch is used to initiate the start of a test when the user is ready, when the user initiates the test the program will run, 'LED2' will light up and measurements will start to be taken.

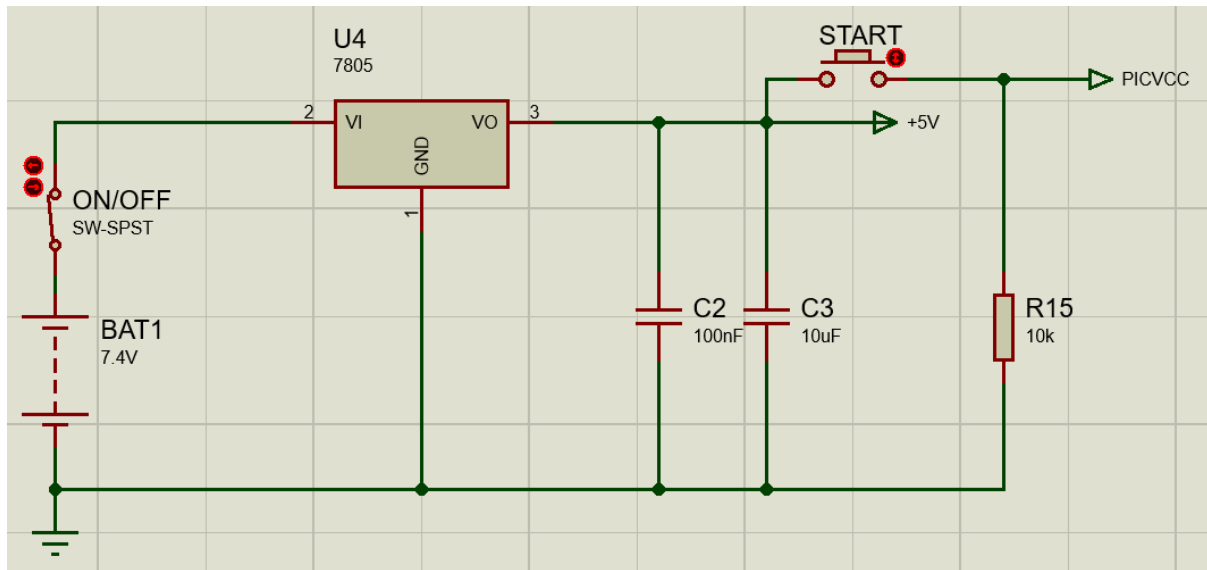


Figure 16

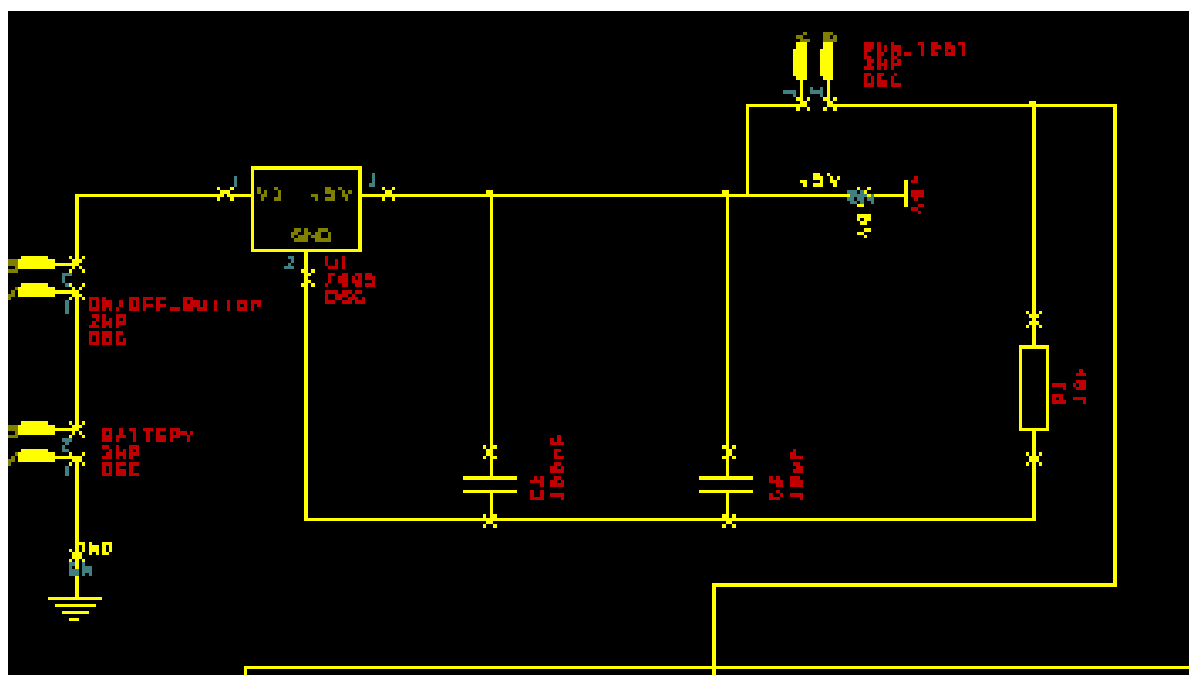


Figure 17

The next two figures demonstrate the gyroscope circuitry. The gyroscope requires a +5V supply, GND and three output signal pins, on each output there is a Zener diode for voltage clamping for a worst case scenario if a voltage spike is induced onto output, the Zener diodes breakdown voltage would then activate and take the excessive voltage to ground and save the PIC from being overloaded. The resistor and capacitor on each output act as a low pass filter, this filters the signal cutting out any unwanted high frequencies.

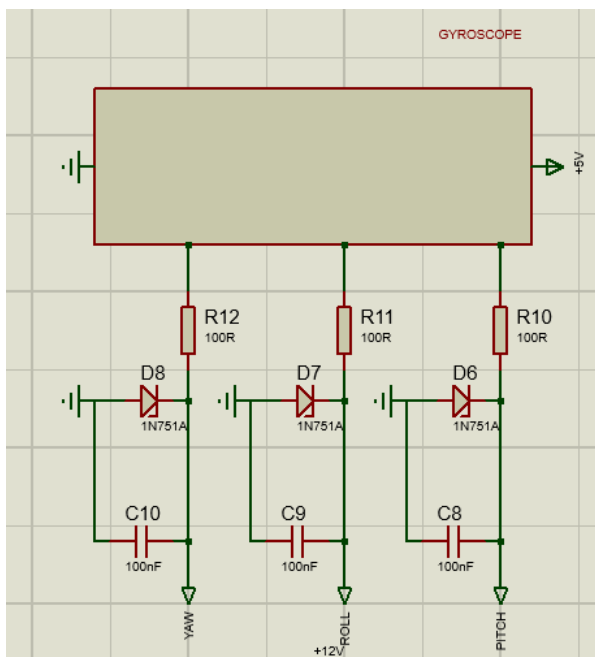


Figure 18

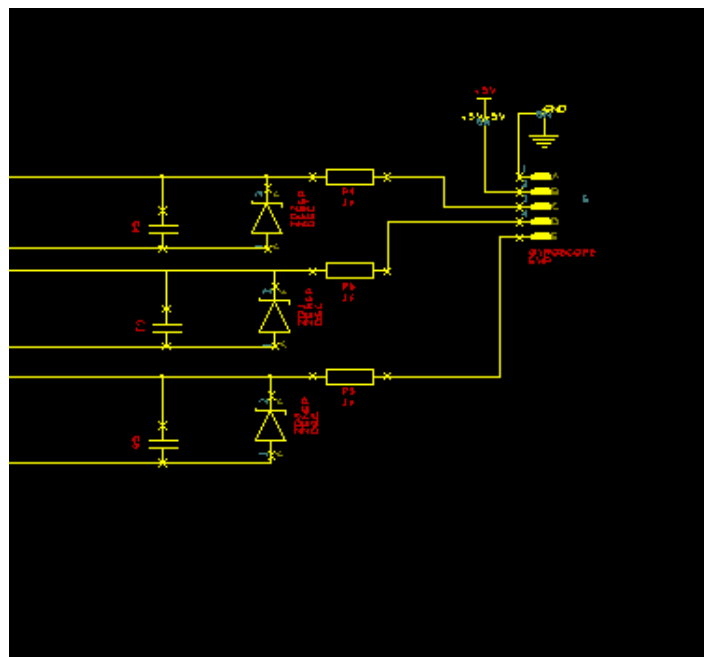


Figure 19

The two figures below illustrate the engine temperature sensor circuit. The infrared sensor requires a voltage source, shield, ground, and an output. The output signal is an analogue signal that again has a Zener diode for voltage clamping and a Low pass filter containing a resistor and capacitor.

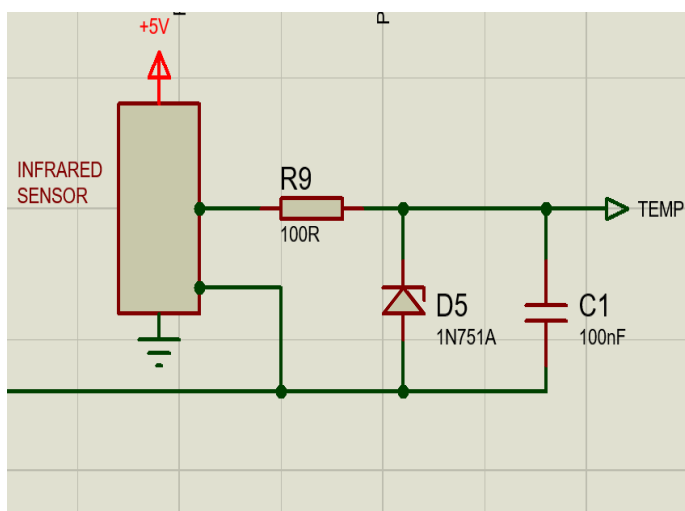


Figure 20

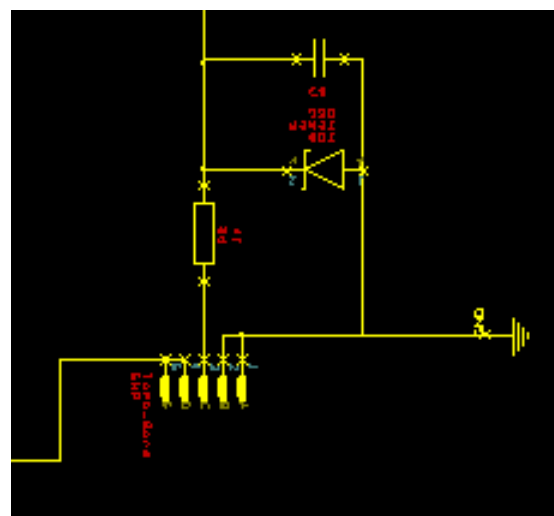


Figure 21

The next two figures demonstrate the suspension movement circuitry. This circuit consists of four wire potentiometers. The wire potentiometers require a +5V input, ground and an output for an analogue signal. the output signal has a Zener diode for voltage clamping and an low pass filter also to filter any unwanted signal from the sensor.

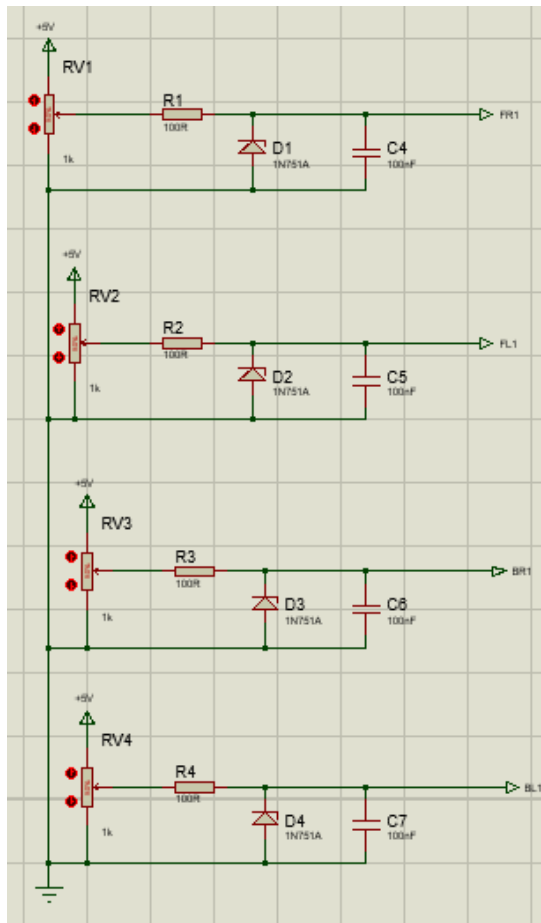


Figure 22

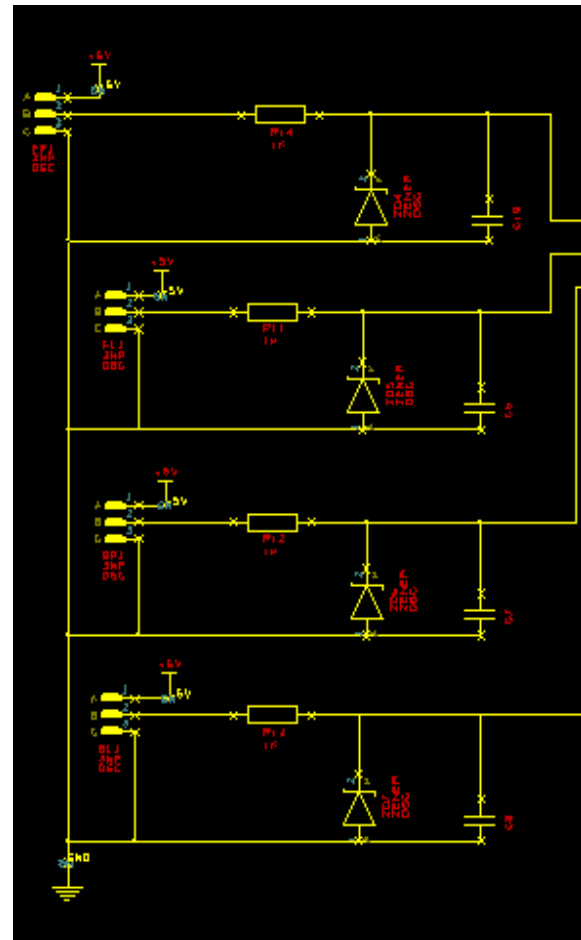


Figure 23

The following figures demonstrate the vehicle road speed and engine RPM circuitry, since these are the same sensors they have the same circuitry. The sensors require a +5V supply, ground, a +5V supply for the input of the sensor which when activated will pass through to the output. The datasheet states that a 4.7K pull down resistor will be needed on the output of the supply. The output also has a Zener diode for voltage clamping and a low pass filter.

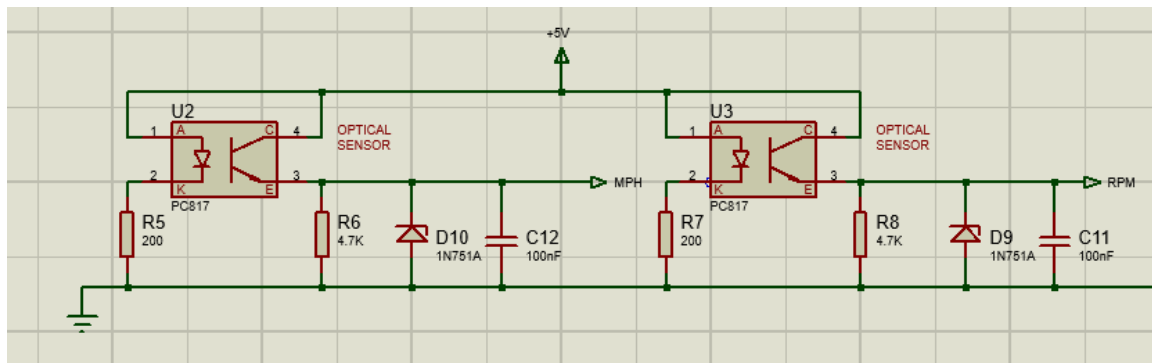


Figure 24

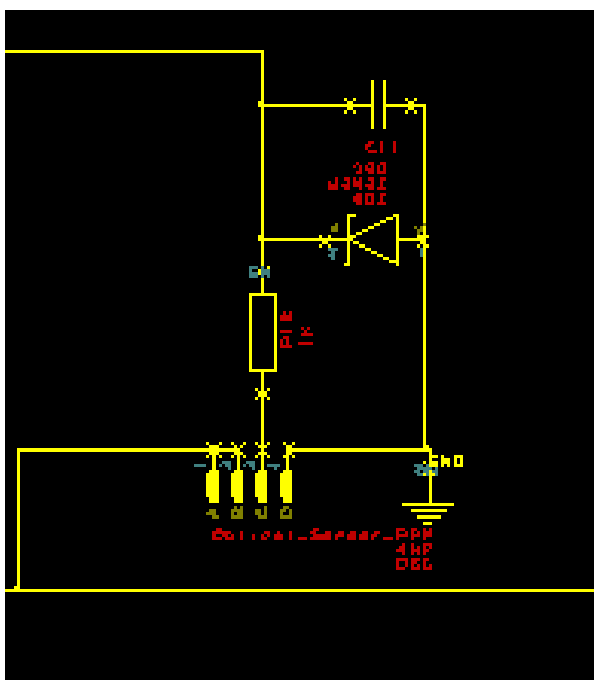


Figure 25

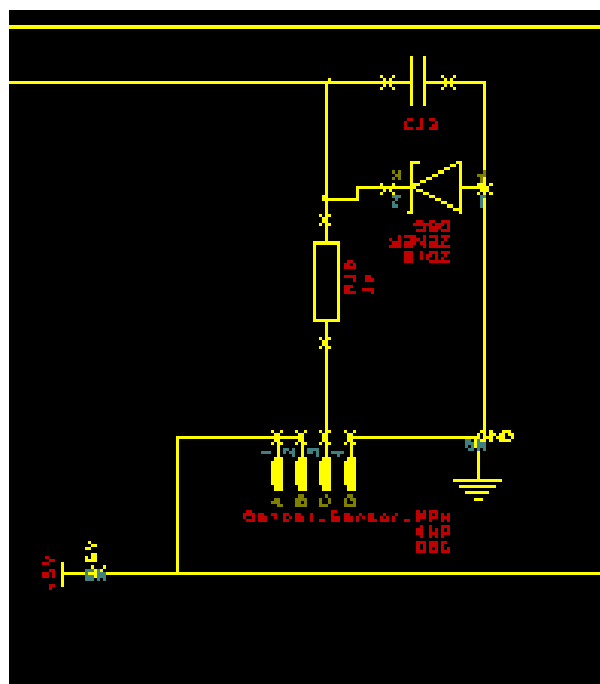


Figure 26

The following figures illustrates the SD Card connector and a USB module. The specification states that the data must be stored to a non-volatile memory, this being said an SD card is to be included. The SD Card requires a digital input pin, digital output pin, SPI clock to enable the PIC and SD card to synchronise and also a chip select to initiate the PIC to start writing. The USB will require a ground, VCC which will be supplied form the PC/Laptop when inserted and bidirectional pins for the data to be written or read.

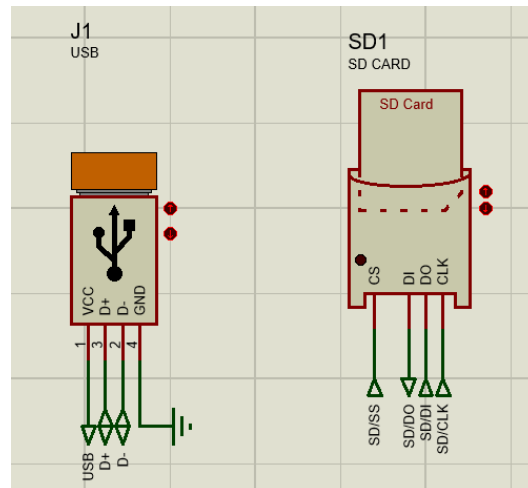


Figure 28



Figure 29

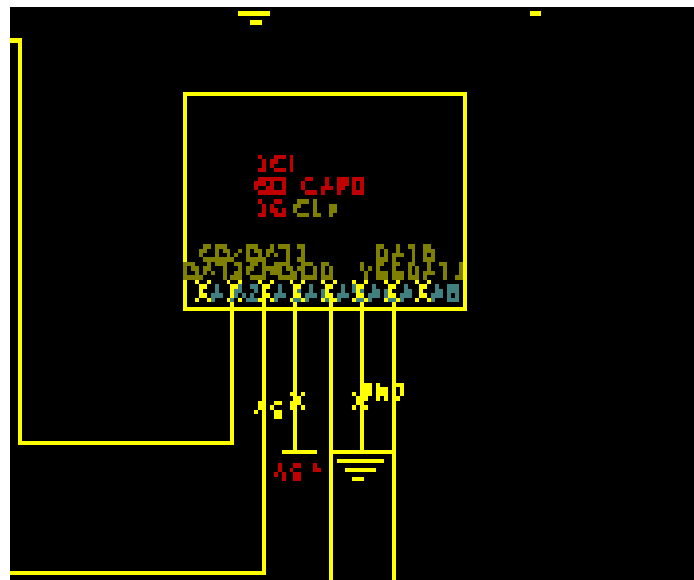


Figure 30

The Final two images demonstrate the two LEDs in the circuitry, as explained above one LED is to indicate the voltage has been applied to the circuitry and the second LED is to indicate the test is running. The following calculations for the resistors are as follows.

$$\frac{5 - 2.2}{0.3 \times 10^{-3}} = 9333\Omega$$

The calculation confirms the LED resistors will need to be 9333 ohms. The closest available resistor to this would be a 10k ohm resistor.

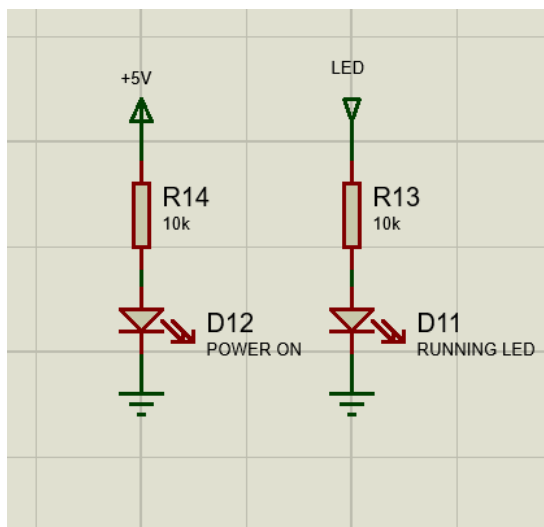


Figure 31

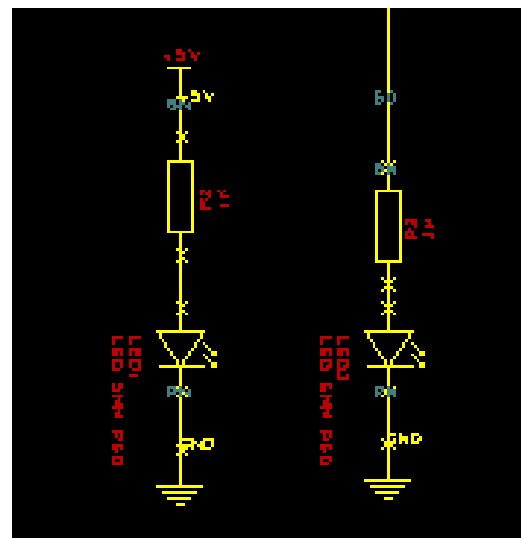


Figure 32

6.2 PCB Design

The figure below demonstrates the PCB design proving there are no design errors after using the design check tool.

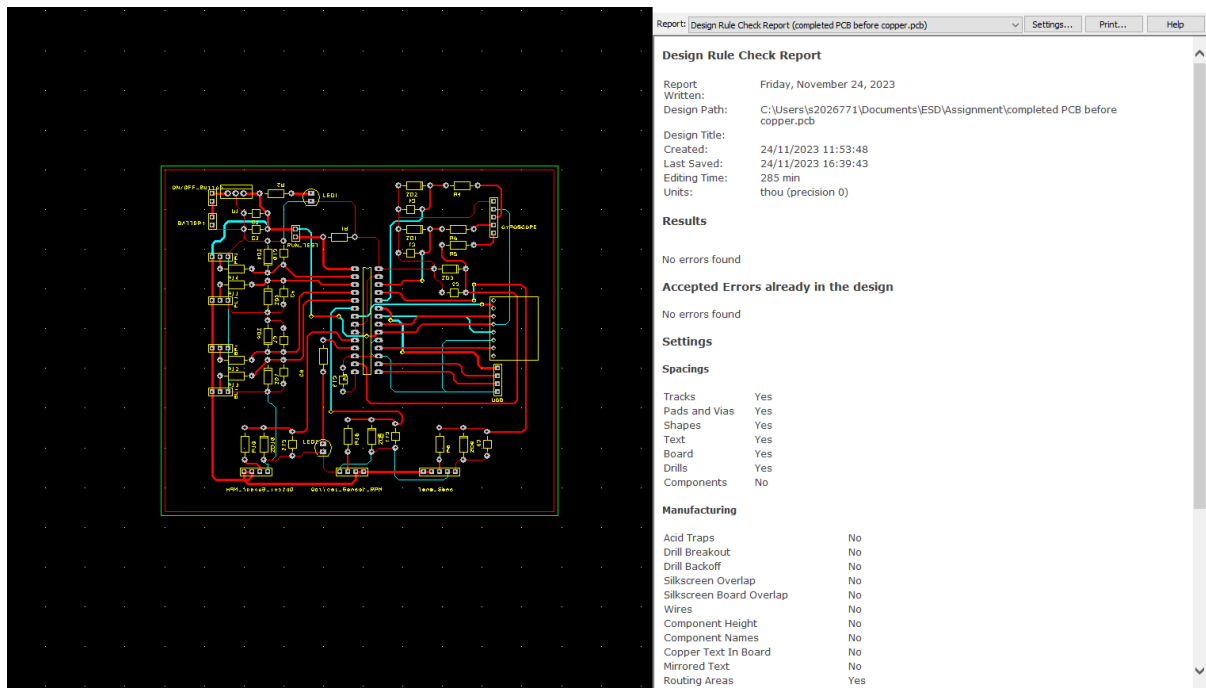


Figure 33

The following figure illustrates the top layer view of the PCB.

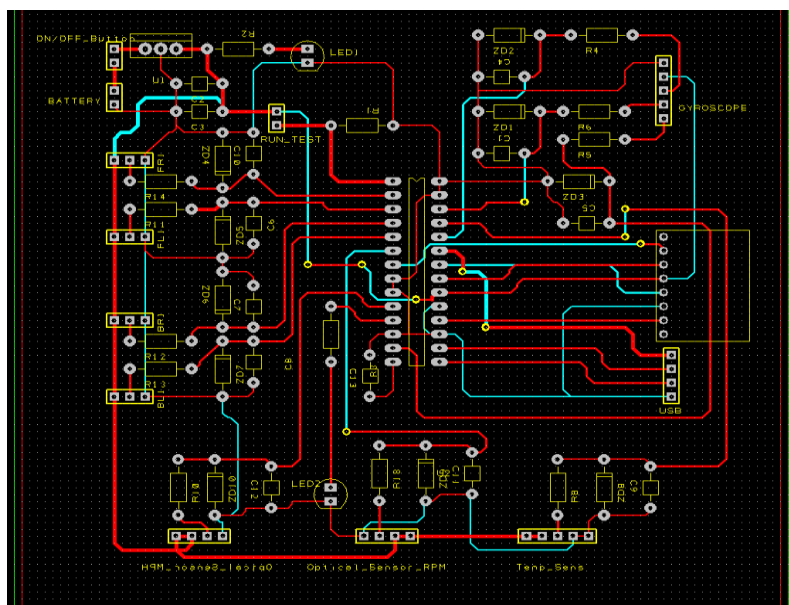


Figure 34

The following figure illustrates the copper pour of the PCB.

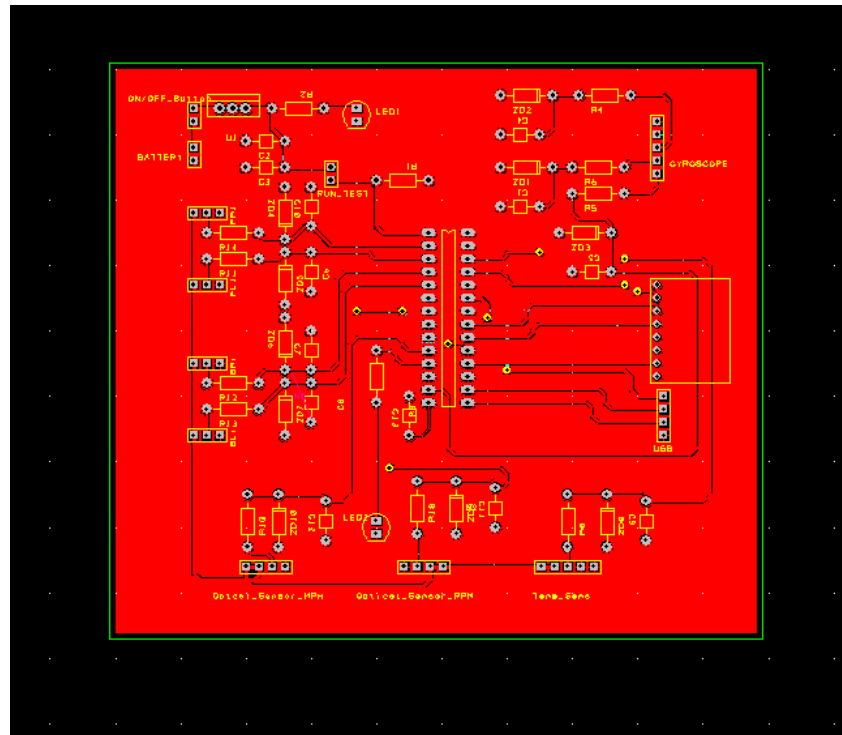


Figure 35

The figure below demonstrates the 3D model of the PCB.

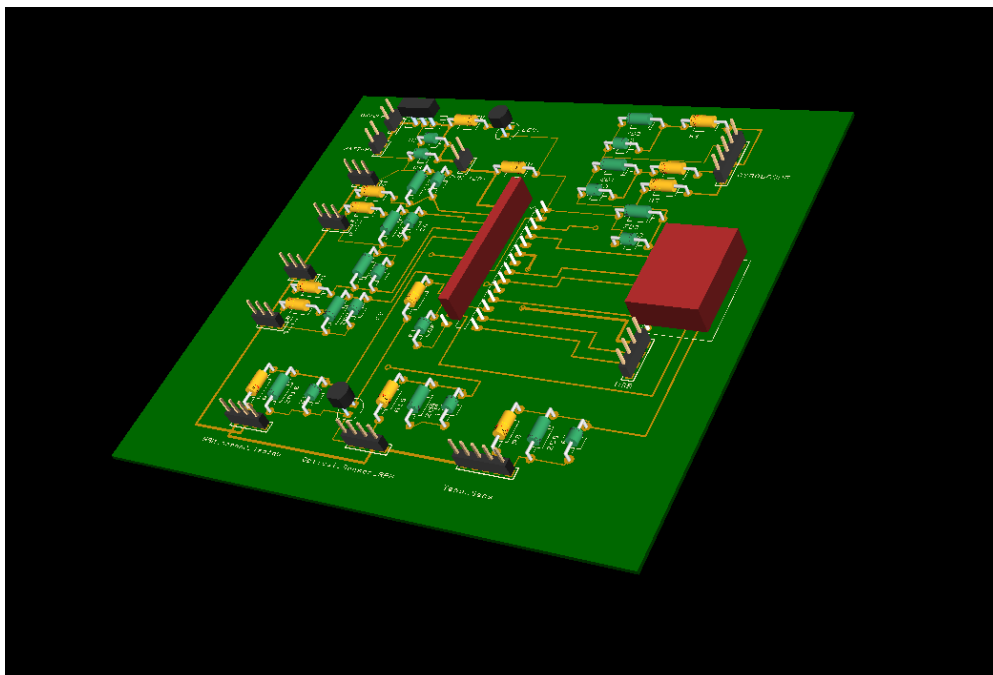


Figure 36

The figure below illustrates the bottom layer of the PCB.

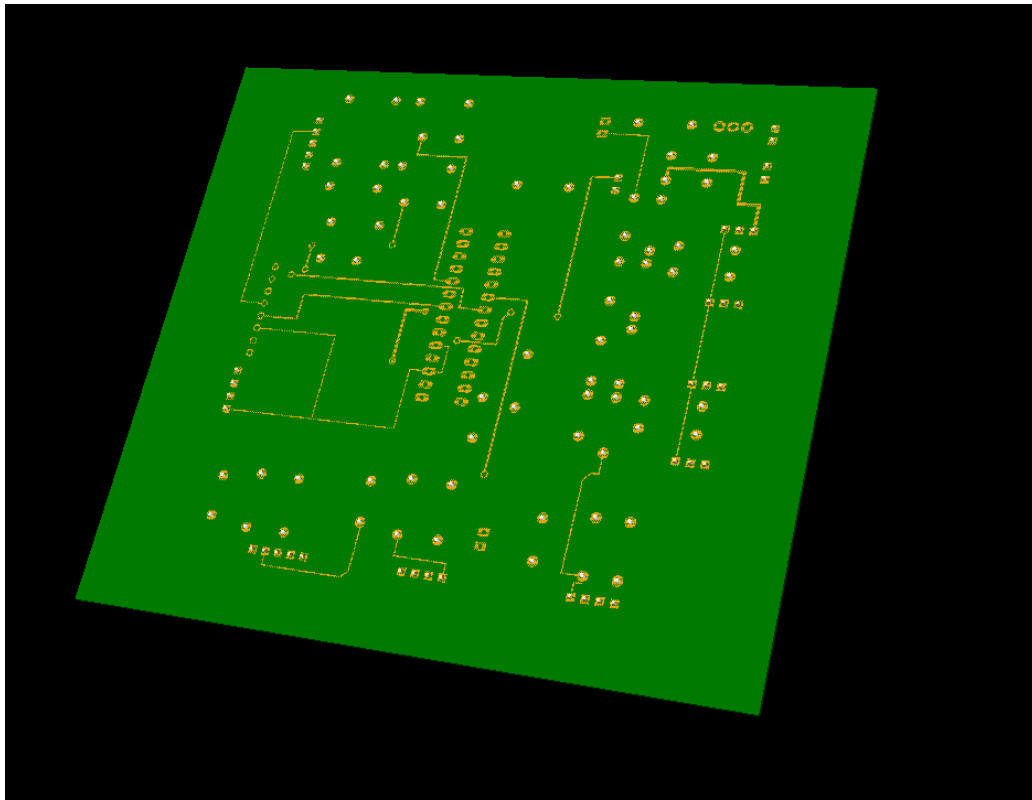


Figure 37

6. Software Design

8.1 Structure Diagram

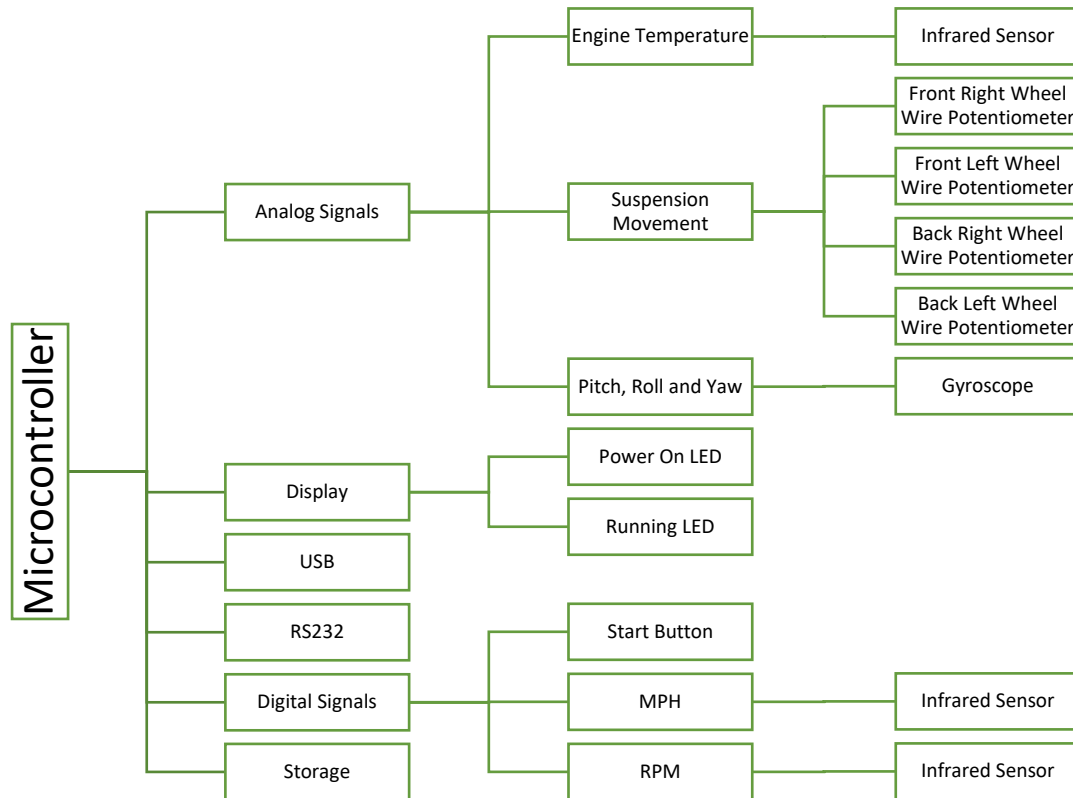


Figure 38

7. Costs

The Table below illustrates an estimated cost list for the design.

Component	Unit No.	Unit Price (£)	Price (£)
PIC	1	4.93	4.93
PCB Manufacture	1	7.22	7.22
Speed Sensor	2	345	690
Gyroscope	1	1880	1880
Temperature sensor	1	275.9	275.9
Wire potentiometer	1	164	164
IP65 Connector	8	22.84	182.72
IP65 Casing	1	9.02	9.02
Battery	1	34.152	34.152
LED	2	8.01	16.02
IP65 Switch	1	4.16	4.16
IP65 Button	1	7.99	7.99
Resistor	15	1.26	18.9
Capacitor	13	3.38	43.94
Zener Diode	12	0.27	3.24
Voltage Regulator	1	1.548	1.548
USB Connector	1	4.15	4.15
SD Card Connector	1	3.59	3.59
Molex Connectors	8	0.236	1.89

Table 13

The total estimated cost for the design equals a total of £3353.37

The image below is from the manufacturer who quoted the manufacture cost of the PCB.

Standard PCB/PCBA Advanced PCB/PCBA SMT-Stencil 3D/CNC

← Back to Upload File Detected 2 layer board of 109.35x124.59mm(4.31x4.91 inches) Gerber Viewer

Base Material: FR-4, Flex, Aluminum, Copper Core, Rogers, PTFE Teflon

Layers: 1, 2, 4, High Precision PCB, 6, 8, 10, 12, 14, 16, 18, 20

Dimensions: 124.59 * 109.35 mm

PCB Qty: 5

Product Type: Industrial/Consumer electronics, Aerospace, Medical

Charge Details

- Engineering fee: \$4.00
- Via Covering: \$0.00
- Surface Finish: \$0.00
- Board: \$5.10

Build Time

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

Calculated Price \$9.10
Additional charges may apply for special cases

Shipping Estimate
Charge: Choose destination country first
Weight: 0.36kg

SAVE TO CART

Figure 39

8. Suggested Improvements

This report have covered the task of designing a data acquisition system. The design was based around using a microcontroller breaking down the design in different aspects to do with the theoretical, and practicality of the design to ensure it would meet the specifications that were given. The design met the specification but there could have been improvements in all areas of the design.

In regards to the cost of the installation, the sensors were the most expensive components in comparison to the others, this could have been avoided by using more available products such as accelerometers instead of gyroscopes and thermistors instead of infrared temperature sensors.

In regards to improving the practicality of the design, a display screen could have been added which would state the real time measurements or a Bluetooth module which could link with an app on a hand held device to aid with real time monitoring of the system.

The PCB board could of also had improvements made to it such as mounting holes in the design which would ensure no damage to the PCB was caused while the test was running. Another improvement could be that the sensors could have had magnetic brackets which would save the time of installing the sensors.

To conclude the report, the design was a success it met the specification, although there is room for improvement on the next design

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