

EDS Assignment 1

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PROGRAMME

BEng Electrical & Electronic Engineering
Electronic System Design

ASSIGNMENT 1 Motor Vehicle Data Logger

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Introduction

A design is required for a microcontroller based automotive data acquisition system. This design is to be used on a production prototype vehicle, that is targeted at a family saloon. The design must be portable and adaptable to any class of vehicle. From the components that are chosen, they must provide a comfortable means of transport and operate within safe limits. The variable components are;

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

The design must store the collected data on to a non-volatile memory which can be used by an external reader and can be cleared when connected to a computer via a USB. The design must also be battery powered, this means it is separate from the vehicles own power supply. The sensors cannot be connected to the vehicles electronics or signals, this makes the design independent from the vehicle. The design will be required to be portable and adaptable so that it is suitable for operation in its intended environment.

Task 1 - Portable vehicular data acquisition system

A portable data acquisition system or (DAQ, DAS) system that is designed to measure and collect signals of real-world physical conditions. In the example of this report the system will be taking samples of a vehicle, and converting them into digital numeric values that can be shown through a DAQ. The sensors will be mounted at different points around the vehicle depending on what data that will be collected, a DAQ can give real time data that can be compared to other data. When dealing with the installation of a DAQ or DAS, one of the biggest issues comes down to the environment that it is in. A portable system will need to take extra care where it is mounted due to temperature, vibration and moisture conditions.

Comparison

The comparison of the data loggers that can be selected from the open market are displayed below. There is a breakdown of the features and benefits of each model, this is the best way to show quickly how a system would be selected for the best suited data acquisition system. From the table below there are a wide variety of systems and can be used in most applications.

There are a number of different voltages and I/O configurations meaning that most applications can be covered.

Comparison between on the market DAQ's.					
Model	LG-L9-000 Logger 9	2d- datarecording	Sefram DAS 50 Datalogger	OMEGA OMB- DAQ-2408	DT9816-S
Price (£)			3800.00	1841.80	873.00
Portable	Yes	Yes	Yes	Yes	Yes
Input Range	0-5V - 0-20V	0-5V - 0-20V	200 mV to 424 V	±10V	±5V
Supply voltage	9 – 18V DC	9 – 18V DC	±500VDC or 424V	±22V	±10V or ±5V
Counters/ timers	4	5	No	2	1
I/O	32AI / 4DI	16AI / 5DI	16 AI/DI	16AI / 8 DI	9AI / 8DI
External memory	No	No	Yes	Yes	Yes
Internal memory	8GB	128GB	32GB	no	No
Resolution	16 Bit	12 Bit	14 Bit	16 Bit	16 Bit
Sample Rate	10KHz Per channel	800Hz	100KHz	1MHz per channel	
Dimensions	76x90x26mm	80x100x 26mm	210x295x 105mm	127x89.9x 35.6mm	111x90x84
USB	Yes	Yes	Yes	Yes - Micro	Yes

[1] [2] [3] [4] [5]

Task 2 - Microcontroller unit

A microcontroller unit or MCU is at its simplest form of a very small computer. This small computer will have an integrated chip with an integrated circuit. There is mainly two different types of memory that are commonly used with MCU's, non-volatile memory that is used for storing firmware. The other is read-write memory used only for temporary data. The one that we will be focusing on is non-volatile memory. The microcontroller is key to making the system design viable, this mean that we will be looking at certain parameters when determining which MCU to use. A MCU is relatively inexpensive, and come in many shapes and sizes depending on the application. MCU's are used in varying industries. Factors to consider when choosing a microcontroller;

No.	Factors	Description
1.	Power efficiency	when looking at power efficiency, it is a payoff between power consumption and processing performance. The design will be powered by a battery so the processing performance will be limited by the battery life. In this case the battery will need to last at a minimum of two hours for the test drive. This means that the battery will need to last longer than two hours, so power efficiency will be a deciding factor.
2.	Temperature tolerance	With the environment that the system is mounted, the temperature may be high or low. If the design is to be mounted in the engine bay the temperature will be high, if mounted on the external of the vehicle the temperature may swing widely.
3.	Security	With the security of the MCU on this project is not as important due to this being a portable closed system, where you will download the data directly from the design using a USB, with no internet access.
4.	Hardware architecture	With the need of the design to be as small as possible, there are two main types of packages, dual in-line is the most common, or flat no-lead packages. Dual in-line has a smaller footprint than flat no-lead packages, however there is a much better heat diffusion which may be better due to the temperature issues that might occur.
5.	Processing power	The processing power will depend on the application, the more cores you have the faster the processing power will be. This means that the battery will decrease at a faster rate on the more cores the processor will have.
6.	Memory	ROM and RAM is the amount of memory that will be required for the unit to run. The more programs that are running the memory will be required. RAM – random access memory is used for this.
7.	Hardware interface	This is where the type of interface will be required, for this project it is required that a USB interface is required. However there could be an application where WIFI and video could be used.
8.	Cost	When acquiring microcontrollers, in industry they are generally bought in hundreds, meaning the per unit cost is low. In this case buying one could be more expensive as a prototype. Meaning if this went to be adopted the unit cost will fall when buying larger numbers.

[6]



Below is a representation of when each sensor will be taking data on the test run from the data above. For example, the engine temperature has a longer sample window. This is due to the temperature in normal working order will not change, when the engine has reached its operating temperature. Only when there is a fault will the temperature alter. Reducing the sample rates will save on bytes. The sample rate for each sensor are listed below;

- RPM – 500ms
- Engine Temperature – 10s
- Suspension – 10ms
- Pitch, Yaw & Roll – 50ms
- MPH – 50ms

These sample rates were chosen on the basis of how much change would happen between sample points like the example stated above.

Time	Sensor type									
	RPM	Engine Temp	Suspension	Suspension	Suspension	Suspension	Pitch	Yaw	Roll	MPH
0ms	/	/	/	/	/	/	/	/	/	/
↓										
10ms			/	/	/	/				
↓			/	Caption required		/				
50ms			/		/	/	/	/	/	/
↓			/	/	/	/	/	/	/	/
500ms	/		/	/	/	/	/	/	/	/
↓	/		/	/	/	/	/	/	/	/
1s	/		/	/	/	/	/	/	/	/
↓	/		/	/	/	/	/	/	/	/
10s	/	/	/	/	/	/	/	/	/	/

Selection of microcontroller

The following screenshots show how the PIC was chosen and what information was used. The PIC was required to be a 8 Bit with a minimum pin number of 20 as shown in the previous table. There is also a requirement to have a USB and a SD card reader. When searching for the PIC below, the following selections were made;

- 8 Bit
- Pin Count – 14 minimum
- ADC input – 5
- Max ADC resolution – 10
- SPI – 1
- I²C – 1

- No. of UBS modules – 1
- Hardware RTCC / RTC (Real time clock)
- Automotive capable

Parameter Search
☒ Match ALL (AND)
 ☐ Match ANY (OR)
 Collapse

Family

8-bit MCU

Part Family

-All-

CPU Type

-All-

Max CPU Speed (MHz)

-All-

-All-

CPU Speed (MIPS/DMIPS)

-All-

-All-

☐ ARM Neon
☐ FPU

☐ Math Accelerator

☒ 8-bit
☐ 16-bit
☐ 32-bit

--- Product Status ---

☒ Current
☒ Future
☐ Mature

Voltage

Operation Voltage

-All-

-All-

Temperature

Temp Range

-All-

-All-

Packages

Pin Count

20

-All-

Max I/O Pins

18

-All-

Memory Data

Program Memory Size (KB)

-All-

-All-

Program Memory Size (KWords)

-All-

-All-

Auxiliary Flash (KB)

-All-

-All-

SRAM (KB)

-All-

-All-

L1 Cache Memory (Instructions) (KB)

-All-

-All-

L1 Cache Memory (Data) (KB)

-All-

-All-

Data EEPROM/HEF (Bytes)

-All-

-All-

Internal DRAM Amount (MB)

-All-

-All-

DRAM Bus Size (Bits)

-All-

-All-

Boot Memory (KB)

-All-

-All-

Direct Memory Access Channels

-All-

-All-

Number of EBIs

-All-

-All-

ECC Bits on NAND Interface

-All-

-All-

QSPI

-All-

-All-

SDIO/SD-CARD/eMMC

-All-

-All-

Internal DRAM Type

-All-

External Memory Bus Interface

-All-

DRAM Interface

-All-

☐ Multiple Flash Panels

☐ Error Correction Code Program Flash

☐ Emulated EEPROM in Flash

☐ NAND Interface

USB			
Number of USB Modules	1	-All-	
USB Interface	-All-		
☐ USB Active Clock Tuning			
CAN			
Number of CAN Modules	-All-	-All-	
Type of CAN module	-All-		
CAN Transmit Buffers	-All-	-All-	
CAN Receive Buffers	-All-	-All-	
Automotive			
MediaLB	-All-		
Ethernet			
Number of Ethernet Ports	-All-	-All-	
Ethernet	-All-		
Timers			
Max 8-Bit Digital Timers	-All-	-All-	☒ Hardware RTCC/RTC
Max 16-Bit Digital Timers	-All-	-All-	☐ Watch Dog Timer
Max 32-Bit Digital Timers	-All-	-All-	☐ Angular Timer
IC/OC/PWM			
Max PWM Outputs (including complementary)	-All-	-All-	CCP -All- -All-
Number of PWM Time Bases	-All-	-All-	ECCP -All- -All-
PWM Max Resolution (Bits)	-All-	-All-	CWG/COG -All- -All-
PWM Resolution (ns)	-All-	-All-	SCCP -All- -All-
Standalone Output Compare / Standard PWM	-All-	-All-	MCCP -All- -All-
Motor Control PWM Outputs	-All-	-All-	Std PWM -All- -All-
SMPS PWM Outputs	-All-	-All-	NCO -All- -All-
Output Compare Channels	-All-	-All-	PSMC -All- -All-
Input Capture	-All-	-All-	
Data Signal Modulator	-All-	-All-	
Signal Measurement Timer	-All-	-All-	

Hardware Limit Timer	-All-	-All-
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Quadrature Encode/Decode

Quadrature Encoder Interface	-All-	-All-
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Functional Safety

☐ Class B Hardware
☐ CRC

Security

Anti-Tamper Pins	-All-	-All-
☐ Crypto Engine	☐ ARM Trust Zone®	

Display

Segmented LCD	-All-	-All-
☐ Graphics Controller/GPU	☐ Video Decoder	☐ Camera Interface

Audio

Number of PDM Microphone Inputs	-All-	-All-	☐ Audio Fractional PLL
			☐ Class D Amplifier Outputs

Digital

Configurable Logic Cell (CLC/CCL)	-All-	-All-	☐ Peripheral Pin Select / Pin Muxing
Configurable Logic Cell Type	-All-		☐ Peripheral Trigger Generator
Parallel Port	-All-		

Clock

Internal Oscillator	-All-	-All-	☐ Internal Oscillator 1% accuracy
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System

☐ Brown-Out Reset	☐ Low Voltage Detection	☐ Power On Reset
☐ Internal Voltage Reference (Bandgap)		

Tools

☐ Supported in MPLAB Code Configurator

Debug

JTAG Type	-All-
Debug Interface	-All-

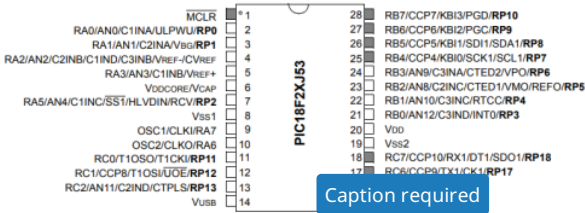
	PIC18F24J50 Microchip delete	PIC18F44J50 Microchip delete	PIC18F26J53 Microchip delete	PIC18F47J53 Microchip delete
Family	8-bit MCU	8-bit MCU	8-bit MCU	8-bit MCU
CPU Type	8-bit PIC MCU	8-bit PIC MCU	8-bit PIC MCU	8-bit PIC MCU
Max CPU Speed (MHz)	48 MHz	48 MHz	48 MHz	48 MHz
FPU				
Operation Voltage	(2V-3.6V)	(2V-3.6V)	(2V-3.6V)	(2V-3.6V)
Temp Range	(-40 to 85)	(-40 to 85)	(-40 to 85)	(-40 to 85)
Pin count	28	44	28	44
Program Memory Size (KB)	16 Flash	16 Flash	64 Flash	128 Flash
Error Correction Code Program Flash				
SRAM	3,710,937.5 KB	3,710,937.5 KB	3,710,937.5 KB	3,710,937.5 KB
Data EEPROM/HEF (Bytes)				
Internal DRAM Type				
Internal DRAM Amount (MB)				
Low Power	Yes	Yes	Yes	Yes
ADC Input	10	13	13	13
Max ADC Resolution (Bits)	10	10	12	12
DAC Outputs				
Number of Op Amps				
Hardware Touch Periphera				
UART	2	2	2	2
SPI	2	2	2	2
I2C	2	2	2	2
I2S				
SSC				
Number of USB Modules	1	1	1	1
USB Interface	FS Device	FS Device	FS Device	FS Device
Number of CAN Modules				
Type of CAN module				
Ethernet				
Max 8-Bit Digital Timers	2	2	4	4
Max 16-Bit Digital Timers	3	3	4	4
Max 32-Bit Digital Timers				
Hardware RTCC/RTC	Yes	Yes	Yes	Yes
Max PWM outputs (including complementary)				
Number of PWM Time Base				
Crypto Engine				
ARM Trust Zone®				
Segmented LCD				
Graphics Controller/GPU				
Video Decoder				

Caption required

	Signal Type	Number of I/O	Number of Pins
Suspension	AI	4	4
Pitch, roll, Yaw	AI	Caption required	3
MPH	DI	1	1
RPM	DI	1	1
Engine temperature	AI	1	1
Start Button	DI	1	1
USB	DI/DO	2	3
LED indication	DO	2	4
SD Card	DI/DO	2	4
Totals		8AI / 9DI	20

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The microcontroller that was chosen was a 28-Pin PIC18F2XJ50 family. This PIC hit all the criteria that was set out by the design. The diagram below shows the basic layout of the PIC.



The price of a PIC18F24J50 is £3.34, this is a competitive price for all the PIC's that would be required. [7]

Task 3 – containment & specifications

Sensor Requirements

Below are examples of sensor, also which ones were picked for the project. They will have details listed such as cost or tolerance. In the table will be advantages and disadvantages. This is to highlight the best and worst of the sensors. When researching for sensors, some key things were a priority.

- Off the shelf sensors.
- Try to keep all the sensors input voltage 12v or under and the output voltage 5v or under.
- To have a low tolerance.
- To be easily removable with simple tools.

The sensor picked is highlighted.

RPM selection

The sensor will be mounted on the flywheel, or on the metal position of the flywheel. With an optical sensor it will be easier for mounting although it is one of the more expensive sensors.

RPM sensors				
Model	SNG-QPLA-000	TACH RPM	SA-AC HQ1-000	SD-V01M8 -000
Type of sensor	Magnetic	Mechanical	Magnetic	Optical
Price (£)	62.47	51.61	Approx – 85.00	Approx – 90.00
Input Signal	4.5V to 26V	9-36V	12V DC	12V
Output Signal	4.5V to 26V	9V	0-5V	12V

Current	12mA -18mA Max	15mA – 20mA	4mA max	20mA
Cable Length	2M	46cm	Made on request	Made on request
Tolerance	± 1%	± 2%	± 0.1%	± 0.1%
Advantages	No contact needed, less expensive than others. Easy to mount.	Not expensive, and reliable.	No contact, low error of linearity, no vibration shock. Easy to mount.	Reliable, mounting is easy.
Disadvantages	Needs additional setting up for best results. Has a wider range of error than others.	Can be damaged easy, not as high vibration protection.	Expensive	Expensive, line of sight could get blocked.

Caption required

[8] [9] [10] [11]

Engine Temperature

The sensor will be mounted on the case of the engine where a suitable point that is easy accessible. This sensor is chosen because it is not intrusive to the engines system and more than one sensor could be used if there was a need for a more accurate reading.

Engine Temperature sensor				
Model	SA-IR V6-000	SA-NTC 5V-000	SA-TK02-000	LM35
Type of sensor	Non-contact - infrared	Contact - thermistor	Contact - Thermocouple	Contact - thermocouple
Price (£)	210.00	50.00	50.60	71.50
Input Signal	5 – 16V	0-5V	12V	4-30V
Output Signal	780-967mV	0-5V	12V	
Current	1mA	10mA		10mV /
Cable Length	1M	Made to order.	2M	2M
Tolerance	± 2%	± 0.5%	± 1%	± 0.4%
Advantages	Non-contact, Infrared has a wide range of up to 20cm. Low cost.	Low power needed and the cheapest type of sensor	Direct contact with a low error. Easy install no tools required.	Depending on the set up is relatively cheap.

Caption required

Disadvantages	Depending on the material can be less accurate.	It has to be mounted directly onto the engine.	It has to be mounted directly onto the engine.	It has to be mounted directly onto the engine.
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[12] [13] [14] [15]

Suspension

The sensor below was chosen because of it's ease of installation, and it's a mechanical part rather than a optical or ultrasonic. This also means that there is no datum point required as it already has a 0 point.

Suspension sensors				
Model	EX-L221	SA-WP HQ-000	DFROBOT SEN0358	UIT504
Type of sensor	Optical	Mechanical – wire potentiometer	Ultrasonic	Ultrasonic
Price (£)	192.84	190.00	95.81	458.04
Input Signal	12-24V	0-30V	7-15V dc	10-30dc
Output Signal	1V	0-5V	7-15V dc	2.2V dc
Tolerance	± 0.1%	± 0.25%	± 0.1%	
Travel range	45-300mm	0-380mm	100-1500mm	350-6000mm
Current	Max. 15mA	1.2mA	350mA	4-20mA
Cable Length	2M	Made to order.	2M	
Advantages	Very accurate in dry conditions. Can be less accurate in the wet. Easy to install.	Easy to install, simple design, very accurate. Easy to install. Requires two forms of contact.	Large travel range. Very accurate. Not expensive.	Large travel range.
Disadvantages	An object can block the line of sight and mess up the results.	Can be expensive	Vibration has more effect on results.	Expensive, The sensor have a blind spot up to 350mm.

[16] [17] [18] [19]

Pitch, Roll & Yaw

The Gyroscope was chosen due to the sensors reliability and accuracy. It is very easy to install, and can be used in most environments.

Pitch, Roll & Yaw Sensors				
Model	SA-AC ST3-000	SA-MAP -000	SA-GY V4-000	4020 accelerometer
Type of sensor	Accelerometer	Accelerometer	Gyroscope	Tri-Axis Accelerometer
Price (£)	Approx 250.00	98.52	~~198.00~~	196.30
Input Signal	12V	5V	4.75 – 5.25V dc	5-30V
Output Signal	0-5V	0-5V	0.5 – 4.5V	2.5V
Current	16mA	10mA	Max. 50mA	4mA
Travel range		±200G	-200°/s –200°/s	±2-6G
Tolerance	1%	±2%	<0.5%	±5%
Cable Length	1.2M	Made to order	80cm	5M
Advantages	Easy to install, and can be installed anywhere.	Very cheap compared to other sensors.	Very accurate, easy to install. Can be used outdoors	Easy to install.
Disadvantages	Getting a datum point can be difficult. Expensive compared to other sensors of the same type.	Getting a datum point can be difficult.	Expensive, Datum set by mounting.	No very accurate compared to the other sensors.

[20] [21] [22] [23]

Miles Per Hour

The optical sensor was chosen due to its reliability and due to the ease of installation. This fits best with the system because of the amount of installation time of the whole system.

MPH sensors				
Model	SNG-QPLA-000	TACH RPM	SA-AC HQ1-000	SD-V01M8 -000
Type of sensor	Magnetic	Mechanical	Magnetic	Optical
Price (£)	62.47	51.61	Approx – 85.00	Approx – 90.00
Input Signal	4.5V to 26V	9-36V	12V DC	12V
Output Signal	4.5V to 26V	9V	0-5V	12V
Current	12mA -18mA Max	15mA – 20mA	4mA max	20mA

Cable Length	2M	46cm	Made on request	Made on request
Tolerance	± 1%	± 2%	± 0.1%	± 0.1%
Advantages	No contact needed, less expensive than others. Easy to mount.	Not expensive, and reliable.	No contact, low error of linearity, no vibration shock. Easy to mount.	Reliable, mounting is easy.
Disadvantages	Needs additional setting up for best results. Has a wider range of error than others.	Can be damaged easy, not as high vibration protection.	Expensive	Expensive

[8] [9] [10] [11]

Accessories

Below are additional equipment required to complete the system.

LED

There will be two LED lights, one green and one red. These will be for indication, letting the user know when the device is active / testing in process.

LED Panel indication			
Model	RS PRO Green, Red panel mount indicators.	Schneider Electric, harmony XB7	LED indicator HE-RED
Price (£)	11.26 	10.10	3.86
Voltage	10.8-13.2Vdc	24V AC/DC	12V
Current	20mA	20-27mA	20mA

[24] [25] [26]

Buttons

The button below was chosen below so it can be mounted on the outside of the container and easily accessible.

Button selection			
Model	RS PRO Push button Switch	EOZ Push button Switch	EAO 82 Series
Price (£)	28.73	40.56	15.72

Voltage	12V	12V	12V
IP Rating	IP67	IP67	IP67

[27] [28]

Cables & leads

The cable selection below will be used for all sensors around the vehicle. The Fischer connectors will be used. The Multicomp cable is used inside the container to connect the connector to the PCB.

Cable			
Type of cable	CY Screened, grey PVC sheath 20 AWG.	CY Screened, grey PVC sheath 20 AWG.	Multicomp Pro 100-30BK
Price (£)	90.03	80.58	15.48
Length	50M	50M	100M
Number of Cores	5	3	1
Cable Size	0.5mm	0.5mm	0.22mm
Maximum current	9 Amp	9 Amp	5 Amp

[29] [30] [31]

Cable fixings

The two methods have been chosen are cable ties and adhesive pads, this is to ensure that the cable is correctly secured throughout the cable run.

Cable Fixings			
Type of fixings	Nylon cable clip, with adhesive pad.	RS PRO Cable clip (P clip)	RS PRO Cable Tie (various sizes)
Price (£)	21.36 per 100	5.00 per 100	14.56 per 100
Advantages	Can be installed quickly and no need for fixings	Can be installed quickly and will be very secure.	Cable be installed quickly and is very secure.
Disadvantages	Can fall off at anytime due to the adhesive. Can be effected by heat.	Will require tools to install, installation will be slower than other types of fixings	Can only be used if there is a secure part to attach to, can be effected by heat.

[32] [33] [34]

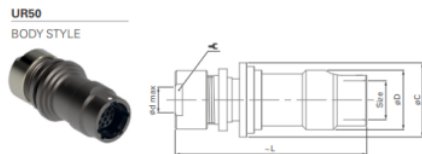
Cable connectors

Fischer ultimate connector was chosen because of the RP rating the locking system and wide arrange sizes.

Cable Connectors			
Model	Amphenol Industrial PT06A 14-12P	Lemo Circular Connector, 2x7 contacts	Fischer UltiMate Series
Price (£)	35.88	32.30	43.20
IP Rating	IP68	IP50	IP68
No. of contacts	16	2x7=14	15
Vibration protection	Yes	Yes	Yes
Current rating	7.5A	7.04A	Up to 26A
Advantages	Most connections per cable terminals. Very versatile. Good IP rating.	Cheapest amongst the competition. Very durable and.	High current rating, excellent IP rating, very durable. Easy to install.
Disadvantages	Expensive, have to by female and males connection separately.	Low IP rating, can be used in less environments.	Expensive compared to competition.

[35] [36] [37]

The female side will be used as the panel mount as seen below;



	003	3	0.9	max ø0.79 mm AWG21 [1] AWG22 [7/30]	-	0.70	0.7	8.2	≤ 250	1.3	1.3	1.8	1.6
	004	4	0.7	max ø0.79 mm AWG21 [1] AWG22 [7/30]	max ø0.62 mm min ø0.38 mm AWG24-28	0.50	0.7	5.5	≤ 200	1.2	1.2	1.7	1.8
	005	5	0.7	max ø0.79 mm AWG21 [1] AWG22 [7/30]	max ø0.62 mm min ø0.38 mm AWG24-28	0.50	0.7	5.2	≤ 160	0.8	1.0	1.3	1.8

[38]

Glands

The female end of the Fischer Ultimate, will be installed to the outside of the container, making the installation quick and easy.

Glands			
Type of glands	Nylon Cable Gland	RS PRO Metallic Nickel plated.	Fischer UltiMate Series
Price (£)	0.28 Each	6.24 Each	43.20
IP Rating	IP68	IP68	IP68
Advantages	Very cheap, good IP rating, Easy to install.	More durable than other glands. Very good IP rating.	High current rating, excellent IP rating, very durable. Easy to install. Will have female connectors.
Disadvantages	Can be over tightened and damaged.	Expensive compared to other glands.	Expensive compared to competition.

[39] [40] [38]

Cable ID

The cables will need to be identified on what cable will be connected to which connector on the Containment. Below is what is selected.

Cable ID	
Price (£)	105.84
Advantages	The cables can be quickly identified, easily to place ID markers on the cables.
Disadvantages	May come off due to damage. Can be brittle when used in outside environment.

[41]

SD card selection & Calculation

To work out the requirements for the microcontroller, a simple table below shows how much will be required for this application. The microcontroller will require, a memory of 7.02MB. There is a breakdown on the table between the sample rates be minutes / hours. This gives an accurate final memory requirements

	Signal Type	Number of I/O	Number of Pins	Sample Rate	Bytes/ Readings	Readings/ minutes	Total Bytes/ 2 hours
Suspension	AI	4	4	10ms	8	6000	576000
Pitch, roll, Yaw	AI	3	3	50ms	6	1200	864000
MPH	DI	1	1	50ms	1	200	24000
RPM	DI	1	1	500ms	1	120	14400
Engine temperature	AI	1	1	10s	2	6	800
Start Button	DI	1	1	n/a	n/a	n/a	n/a
USB	DI/DO	2	3	n/a	n/a	n/a	n/a
LED indication	DO	2	4	n/a	n/a	n/a	n/a
SD Card	DI/DO	2	4	n/a	n/a	n/a	n/a
Totals		8AI / 9DI	20		18	7526	701600

The 2GB SD card is chosen, due to there being very little price difference between a 1GB and 2GB. This will means there will be excess memory if there was requirement to add more sensors or reduce the sample rate.

SD Card		
Price (£)	5.85	5.99
Memory	2GB	1GB
Advantages	Small size, and large enough for the system.	Small size, enough space for the system,
Disadvantages	Can only hold 2GB	Same price as the 2GB SD card

[42] [43]

Battery Selection

To work out the battery selection, the maximum current will need to be worked out first. This is done below.

Sensor	Maximum Current	Number of sensors	Total
RPM	4mA	1	4mA
Engine temperature	10mA	1	10mA
Suspension	1.2mA	4	4.8mA
Roll, Pitch and Yaw	50mA	3	150mA
MPH	4mA	1	4mA
LED	20mA	2	40mA
PCB	1mA		1mA
Total			213.8mA

The total current used using these sensors and LEDs is 212.8mA. The current will be continuous for at least 2 hours. This means it will need to be calculated.

$$212.8 \text{ mA} \times 2 \text{ hr} = 427.6\text{mAh}$$

From below the Yuasa NP2.3-12 battery is chosen. Even though a smaller battery could be chosen, it was opted for a more durable and powerful battery would be chosen.

Battery Selection				
Model	Yuasa NP18-12B VRLA sealed lead acid battery	Gel Lead Acid Battery C 12V-24Ah	Li18-12, 12V 12Ah lithium Iron, LifePO4	Yuasa NP2.3-12
Price (£)	48.75	91.00	97.29	12.95
Voltage	12V	12V	12V	12V
Capacity	18Ah	24Ah	18Ah	2.3Ah
Weight	6.2Kg		2.7Kg	1.2Kg
Dimensions	180x76x167mm	166x175x125mm	180x76x166mm	178x34x64mm
Advantages	Well prices, no maintenance needed. Much larger Ah charge.	No regular maintenance, batteries wont leak. Can work in high temperatures. Much larger Ah charge	No regular maintenance, lighter than other batteries, longer life span, store more energy. Much larger Ah charge.	No maintenance required, cheaper than other batteries, small and compact. Weighs less and can fit into a

				suitable container.
Disadvantages	With not being able to perform maintenance, batteries may not stay at the optimal performance.	Can be easily damaged, slower charging cycles, increased cost over sealed lead acid batteries. Large size compared to other batteries.	Expensive compared to other batteries, used for specialist applications.	With not being able to perform maintenance, batteries may not stay at the optimal performance. Need to be recharged sooner than others.

[44] [45] [46]

Containment selection

The MAX430 will be chosen to because of the excellent IP rating and easy to carry. There is plenty of space inside to mount the equipment in foam. This will increase vibration protection of the equipment when on the test runs. The MAX430 is also very durable and reusable unlike the competitors. The push buttons, LED, USB port and SD card reader will be mounted on the outside of the case. This will mean that mean it can be easily used in all environments.

Container				
Model	MAX Case Max430	ABB Grey Thermoplastic junction box	4 Gang outdoor Multibox connector	ABS wall mounted enclosure
Price (£)	57.40	25.96	40.00 Approx	37.50
IP Rating	IP68	IP65	IP65	IP65
Weight	2.7Kg	900g	1Kg	2Kg Approx
Dimensions	426x290x 159mm	310x240x 110mm	335x220x 107mm	350x250x 150mm
Advantages	Excellent IP rating, easy to carry and install. Easy to install any fixings, and install cable glands. Foam protection against vibration.	Good IP rating, easy to install cable glands. Cheap compared to others.	Good IP rating, the cable install would be very easy due to the connection points.	Good IP rating, easy access to items installed inside. Easy to install fixing points.
Disadvantages	Expensive compared to	Easy to damage/ break.	Might leak if not installed correctly.	Easy to damage or

	others, not many places to install cable glands.			break over time, not very durable.
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[47] [48] [49] [50]

Containment fixing.

The container will be mounted on the roof of the car using the suction cups. There will be four used, to make sure the container doesn't move when driving. This will give easy access to install the cabling around the car to the sensors.

Containment fixings	
Type of fixings	Heavy duty car suction cups
Price (£)	14.98
Advantages	No damage to the car when the container is mounted.
Disadvantages	Couple cause damage if not installed correctly.

[51]

Task 4&5 – PCB design & Prototype software design.

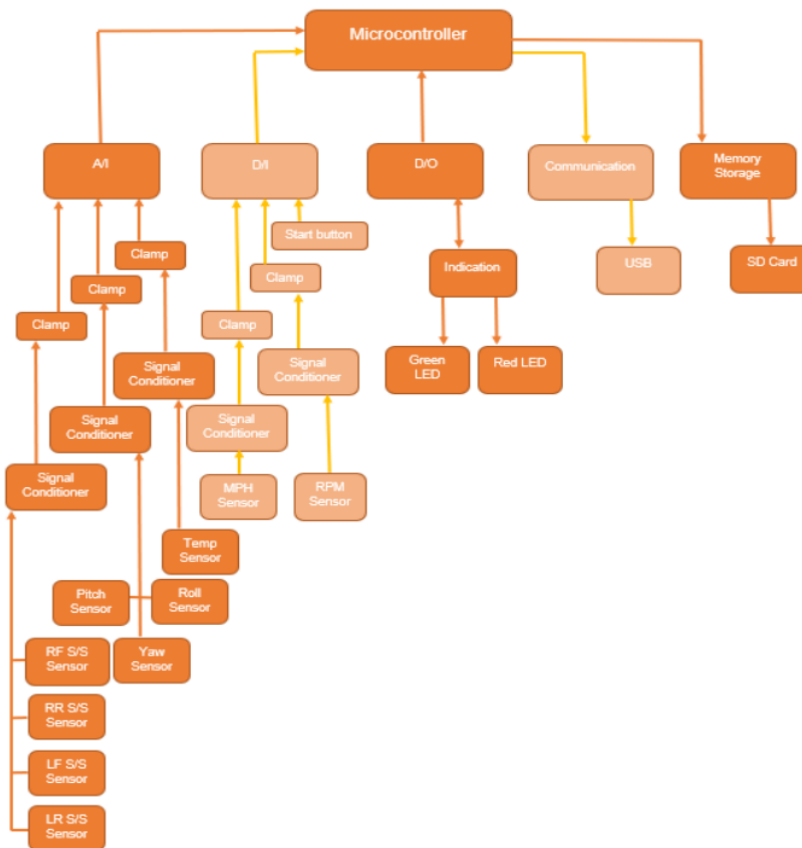
The system was first designed on a program called Proteus, this was used to get the initial design carried out. A program called Easy PC is then used to get the final design of the PCB. On the program the layout of the PCB can be altered for optimum design and can be inspected before manufactured. The following circuit will be broken down due to the different requirements for each.

Sensors	Input voltage	Output voltage
RPM	12	12
MPH	12	12
Temp	5	0-5
Suspension	0-30	0-5
Pitch, Roll & Yaw	4.75 – 5.25	0.5 – 4.5
SD Card	3.3	

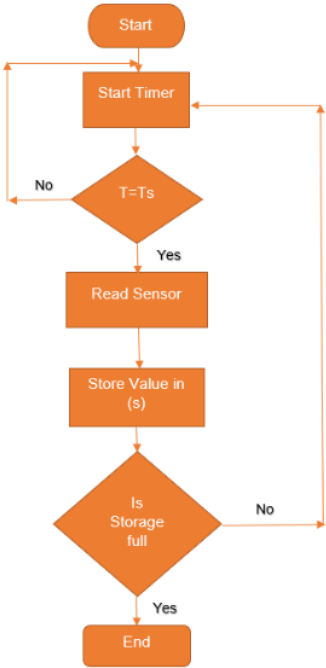
Flow chart & Block diagram

A flowchart is a diagram that is used to show a representation of a system in process. This is broken down into parts that are easily followed. When creating a system, knowing what the process is beforehand can help solve problems before they arise. This will organise the tasks chronologically such as decision, data, process, etc. [52]

A block diagram is used on a high level flow chart that is used in engineering. A block diagram is used like a flow chart; it is used to improve or design new systems. The main difference is that a block diagram shows the relationship between blocks, where a flow chart will show the sequence of steps. On the diagram below, there is the relationship between the microcontroller and the sensors, memory storage, and communication. The arrows show which way the information is traveling, and the boxes represent the components. [53]



From the Block diagram, below is the relationship between the sensor and memory collection which is in a flow chart format. This format would be followed for each sensor. As can be seen there is a constant flow until the memory is full, this means a constant readings depending on the timer.



PCB Components

Below are some of the added components that would be connected to the PCB. The reason for selection of IP rated USB and SD card readers are to make all connections outside the container. This means that's the PCB won't be physically touched in general use. The components will be connected to the pins on the PCB. This gives more security against moisture getting inside the containment and not needing to open the container potentially damaging the sensitive connections / PCB.

			
Component	USB Buccaneer	Micro-SD Card Reader.	JST Crimp Pin Connector
IP Rating	IP68	IP68	N/A
Price (£)	20.46	321.26	8.99
Cable length	3M		

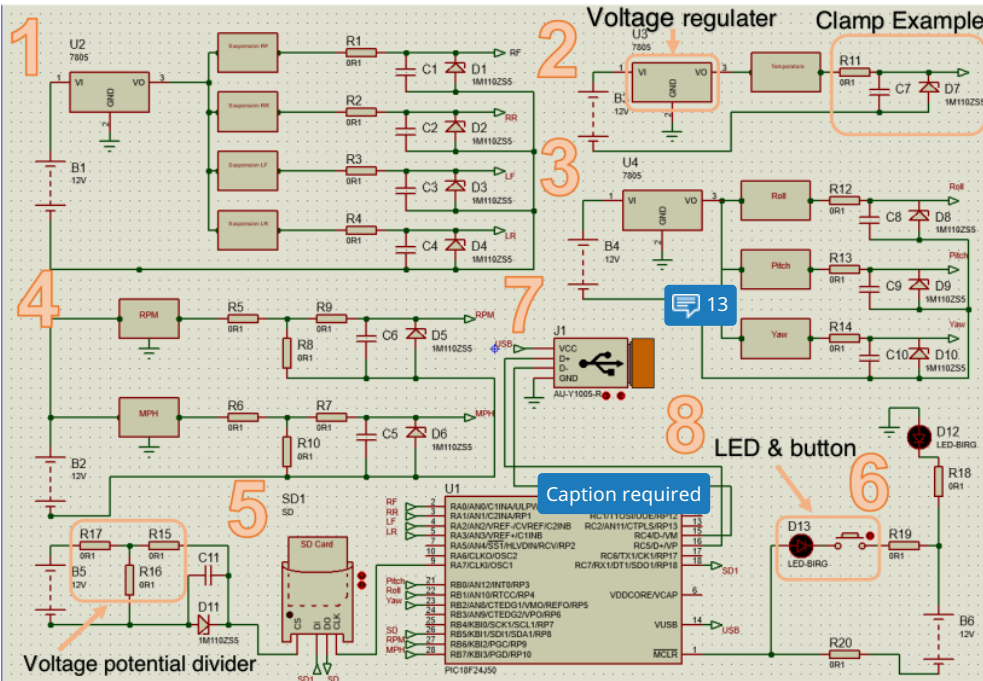
PCB connections	Yes	Yes	Yes
Advantages	Able to be mounted on the exterior of the container.	Able to be mounted on exterior of the container.	Quick and easy to mount components.
Disadvantages	Not board mounted.	Have to run wire inside of containment.	Can be brittle and break.

[54] [55] [56]

Circuit diagram

Proteus

The system was designed using Proteus to give a schematic first.



On the design above, there are highlighted examples of components stating what they are. The Clamp is made up of capacitor, resistor and a Zener diode. To work out the capacitor the formula below is used.

$$C = \frac{1}{2\pi \times 100 \times 5000}$$

The capacitor works out to be 318.3nF with a 100Ω resistor and a 1M110ZS5 (D) Zener diode. The two tables below give details of the corresponding numbers on the Proteus schematic and the values for each resistor, and the calculations.

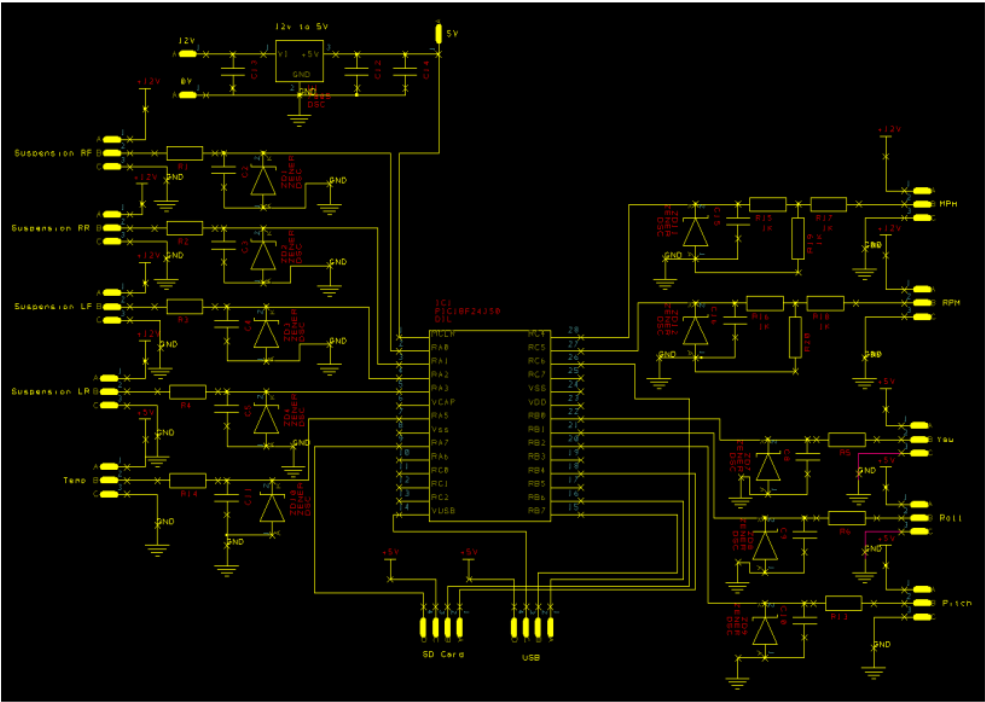
Resistor	Ω value	Resistor	Ω Value
R1-	100Ω	R11-	100Ω
R2-	100Ω	R12-	100Ω
R3-	100Ω	R13-	100Ω
R4-	100Ω	R14-	100Ω
R5-	14KΩ	R15-	100Ω
R6-	14KΩ	R16-	27KΩ
R7-	100Ω	R17-	Caption required
R8-	10KΩ	R18-	Caption required
R9-	100Ω	R19-	100Ω
R10-	10KΩ	R20-	100Ω

No.	Component	Description
1.	Suspension	With a input voltage of 12V and a output voltage of 0-5V the circuit will only require a clamp on each sensor. The clamp will stop any voltage spikes from going to the microcontroller, protecting the PIC.
2.	Engine temperature	The sensor has a input voltage of 0-5V and a output of 0-5V. This means the circuit will require a voltage regulator reducing the voltage from 12V to 5V. A Clamp is also used to protect the PIC from Voltage spikes. Caption required
3.	Pitch, Roll & Yaw	The sensors have an input voltage of 4.75 – 5.25V and a output voltage of 0.5 – 4.5V. This requires a voltage regulator reducing the voltage from 12V to 5V. A clamp is used to protect the PIC.
4.	RPM & MPH	These sensors are part of the same circuit because they are very similar and the same sensors have been used to keep the selection simple. The sensors have an input and output voltage of 12V. this means the systems doesn't require a voltage regulator to supply the sensor, however will require a voltage potential divider circuit because the PIC have a maximum voltage input of 5V. A calculation is done to get the resistors values as seen below RMP - R5 = 14KΩ R8 = 10KΩ & MPH – R6 = 14KΩ R10 = 10KΩ $\frac{V_{out}}{V_{in}} = \frac{R2}{R1 + R2}$ $V_{out} = V_{in} \times \left(\frac{R2}{R1 + R2} \right)$ $12 \times \left(\frac{10K}{14K + 10K} \right) = 5 \text{ volts}$
5.	SD card	The voltage needed to power the SD card is 3.3V. With an input voltage at 12V a voltage potential divider is required for this circuit. The circuit also requires a Clamp to protect the PIC from voltage spikes. As seen in the below calculations the resistors chosen are

		R17 = 10KΩ R16 = 27KΩ. The output voltage is just below the 3.3V required. $\frac{V_{out}}{V_{in}} = \frac{R2}{R1 + R2}$ $V_{out} = V_{in} \times \left(\frac{R2}{R1 + R2} \right)$ $12 \times \left(\frac{10K}{27K + 10K} \right) = 3.25 \text{ volts}$
6.	LED & push button	As can be seen from the diagram above, there are 2 LED lights one green, one red that signal when the battery is connected and when the push button is connected to the circuit. this indicates when the sensors are collecting readings.
7.	USB	The voltage for the  fed directly from the PIC, this is used to export any information gathered by the sensor.
8.	Microcontroller / PIC	PIC18F24J50 is the PIC that is connected to all the sensors, USB, SD card and LED / Buttons.

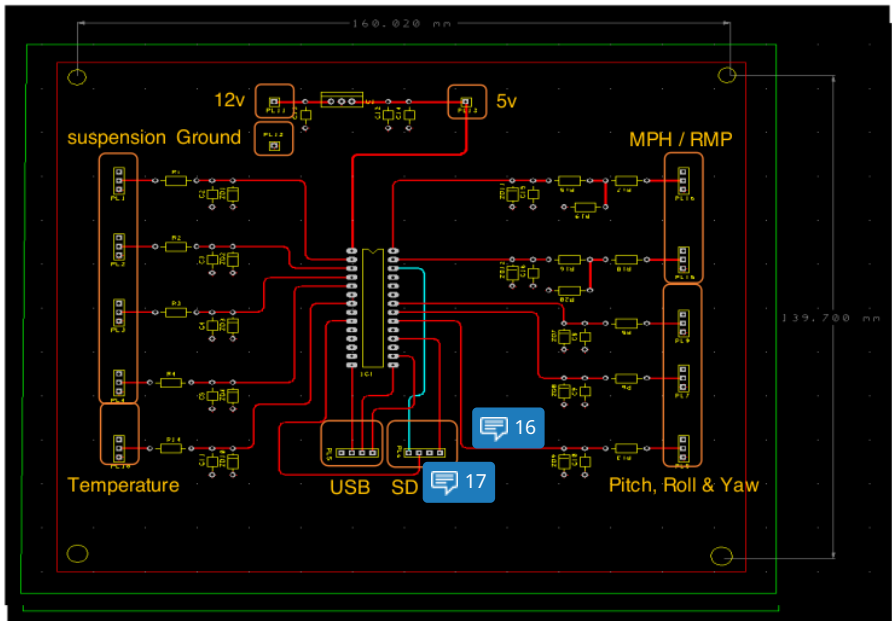
Proteus is used to test out the values that have been chosen and see if the connections match up to the what will be made in easy PC. This is a trail and a good practise to see if the system will or could work in a practical application.

Easy PC



As can be seen above this is a schematic diagram of the PCB on Easy PC. Easy PC is a program that can turn a schematic diagram into a printable, physical PCB. From the schematic diagram I have laid out the pin location in a table below. By using Proteus as a template, I am able to transfer the schematic to Easy-PC and work out the pin layout for the microcontroller. This is table below shows what pins are being used or not used and what sensor is connected.

Pin Number	Sensor / component
1.	Power / LED
2.	Right Front Suspension Senor
3.	Right Rear Suspension Senor
4.	Left Front Suspension Senor
5.	Left Rear Suspension Senor
6.	Not in use
7.	Temperature Sensor
8.	Not in use
9.	SD Card
10.	Not in use
11.	Not in use
12.	Not in use
13.	Not in use
14.	USB VCC
15.	USB D-
16.	USB D+
17.	Not in use
18.	SD Card DO
19.	Not in use
20.	Pitch Sensor
21.	Roll Sensor
22.	Yaw Sensor
23.	Not in use
24.	Not in use
25.	Not in use
26.	SD Card DI
27.	RPM Sensor
28.	MPH Sensor



Above the layout of the PCB. I have used a multilayer PCB to accommodate the different voltages and a ground. The sensor are labelled with the voltage. The sensors, USB & SD card will be connected to the PCB by the pins. The layers are broken down as below. Top copper layer is 12v, inner ground is ground and the Bottom copper layer is 5v.

	Name	Type	Side	Usage	Bias
	Wires	Wire	Top	Wire	None
X	Top Silk	Silk Screen	Top	Non-Electrical	None
X	Top Copper	Electrical	Top	Electrical	Power Plane
	Inner Ground	Electrical	Inner	Electrical	Power Plane
	Bottom Copper	Electrical	Bottom	Electrical	Power Plane
	Bottom Silk	Silk Screen	Bottom	Non-Electrical	None
	Documentation	Documentation	Bottom	Non-Electrical	None
X	Dimensions	Dimensions	Bottom	Non-Electrical	None

Layer Stack Preview

Wires

Top Silk

Top Copper

Inner Ground

Bottom Copper

Bottom Silk

Documentation

Dimensions

[Through Hole]

Print

Close

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When the layers and the PCB layout has been completed a error check is needed to make sure the PCB has no issues when being sent to a manufacturers. Below shows that there is no errors on the PCB.

Summary

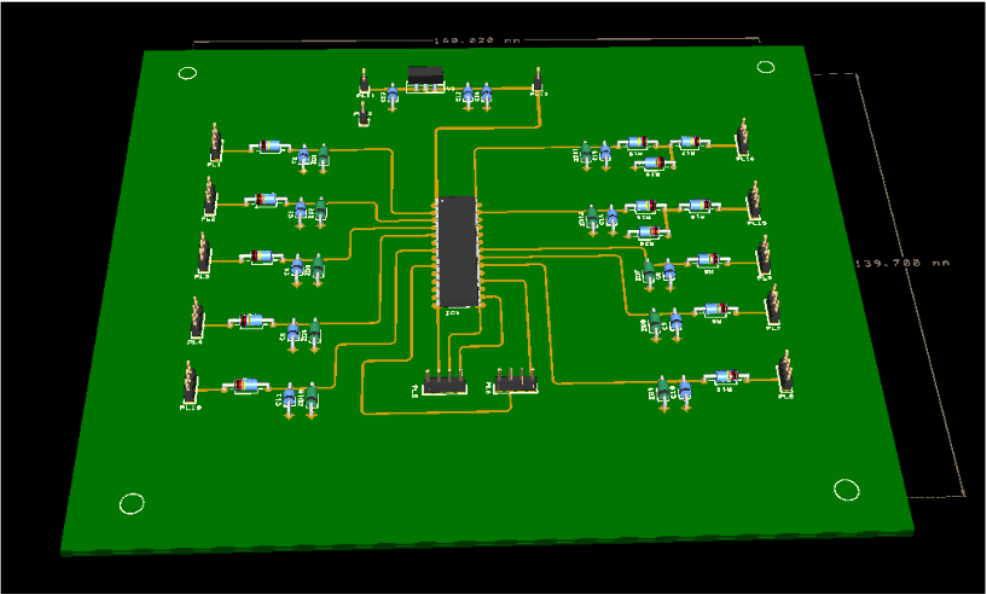
Checked 29 of 29 nets. 0 split nets found. 0 single pin nets found.

Fully connected nets (28)

+5V
+12V
GND
N0000
N0002
N0003
N0004
N0030
N0031
N0032
N0033
N0054
N0055
N0056
N0060
N0061
N0062
N0072
N0075
N0094
N0095
N0096
N0097
N0098
N0099
N0119
N0124
N0126

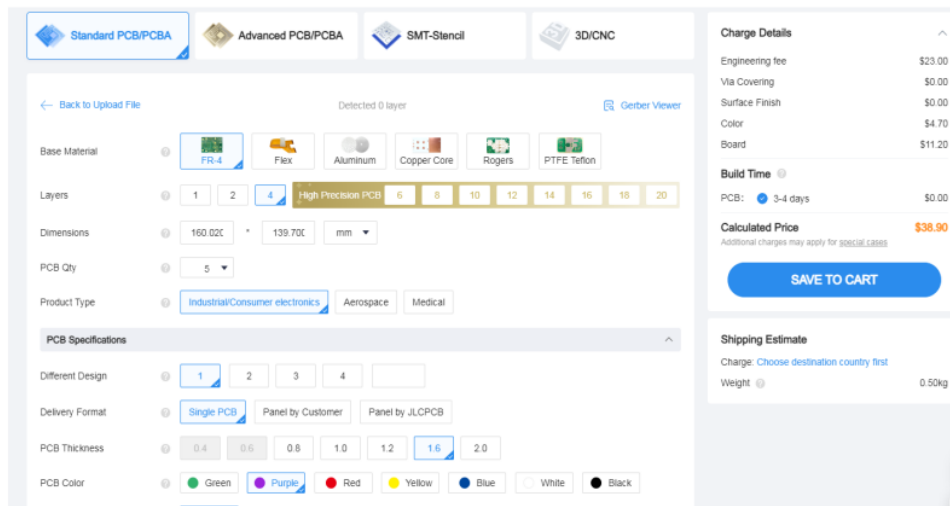
3D PCB design & Price

Below is a 3D model of the PCB that can be sent to a manufacturer to be made. This will give me the final cost of this system. From the 3D model below, this will be the first look of what the PCB will look like. By having as few components of the board as possible the price of the board is reduced  18  ple. One issue that could happen, with all the connections being on the outside of the board, the installation needs to be mindful that all connections need to be tight.



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While using the PCB design in Easy-PC, I can use online PCB manufacturers to build and deliver a new PCB. This will be used as part of my build costs. With any manufacturers, the more that is ordered the bigger the discount will be. This means if this prototype was to be rolled out on a large scale, the price of each PCB will come down. By uploading a zipped file, a price can be given for the manufacturing of one PCB board. The price is given in dollars.



Task 6 - Prototype build costs

Below is the complete breakdown of cost to implement this design.

Components	Units	Costs	Total
PIC	1	3.34	3.34
PCB build	1	1.62	30.31
SD Card	1	5.99	5.99
USB Buccaneer	1	20.46	20.46
Micro-SD Card Reader.	1	321.26	321.26
JST Crimp Pin Connector	1	8.99	8.99
RPM Sensor	1	90.00	90.00
Engine Temp Sensor	1	50.00	50.00
Suspension Sensor	4	190.00	760.00

Pitch, Roll & Yaw sensors	4	198.00	792.00
MPH Sensor	1	90.00	90.00
LED Panel indicator	2	11.26	22.52
Button	1	28.73	28.73
Cable 5 core	1	90.03	90.03
Cable 3 core	1	80.58	80.58
Cable 1 core	1	15.48	15.48
Cable Fixings (Cable ties)	2	21.36	42.72
Cable Fixings (Cable ties)	2	14.56	29.12
Cable Connectors	11	43.20	475.20
Battery	1	12.95	12.95
Cable ID	1	105.84	105.84
Containment Fixings	4	14.98	59.92
Containment box	1	57.40	57.40
Total			£3194.46

With the price of just over three thousand, this makes this a much better option than some of the portable data acquisition system on the market. The price also includes some extra materials that could be used on the next system that was made, bringing the cost down when building a second system. The more systems that are made the cheaper the overall cost will be.

Task 7 – Project improvements

To make the system design more effective I would change some aspects of this design. Below is a table of the items that would be changed to make the system more efficient. Some of the improvements would require an additional cost, so a discussion around the budget and application of the system would need to be done.

Additional temp sensors - Due to the sensor that was chosen, the temp accuracy of the engine may be different depending on how or where it is mounted. This brings into question how the system can be more accurate. Additional sensors could be added at different locations which an average could be used as the final result. This would need to be tested against an internal sensor to make sure that these are accurate enough to be used.

Additional MPH sensors - With the environment of the test, a wet surface could affect the MPH result. Additional sensors on each wheel would indicate if there is any wheel slip or wheel spin. This information can be investigated and the user can get additional information from the test run.

Smaller battery - The battery chosen is a larger battery than is required. This had added weight to the carrier. A smaller battery will require more recharging but will reduce the overall weight. Depending on the sensor selection a lower voltage battery can be chosen reducing the size again.

Add a stop button - An additional button should be added to stop the sensors recording. This could help with any diagnostics that are required. It would also mean that when the test run is complete the tester would not need to rush to stop the system.

Use different connectors - The connectors used for this system are very expensive and add nearly 1/5 of the overall cost. If the project had a budget this could mean that the connectors chosen could not be used.

Add a WIFI / Bluetooth connection - The only way to get any information from the PCB would require a fixed connection. In wet environments this could damage components, also making this an awkward process. If a Bluetooth or WIFI connection was available, then the tester could get the information from a remote location such as in the car or office.

Simplify the sensor design - With the sensors having different voltage inputs/outputs, there is more engineering time to work out what is required. If the inputs/outputs were the same this would mean a simple PCB would be needed, perhaps something that could be bought off the shelf.

GPS - If a GPS was installed, the system would be much more accurate with the test run, also making the test runs more similar. A GPS could also record any pitch, roll or yaw movements



Containment - With the container mounted on the roof of the vehicle, this may effect aerodynamics of the vehicle. This would need to be looked at in more detail to be mounted inside.

PCB Design - I would spend more time making the PCB look more professional. I also would have on board SD card & USB reader instead of off board, Even though it would make it more user friendly the cost would be a factor.

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Scott Thomas - 2315244

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Appendices

Data Sheets

[PIC18F46J50 Family Data Sheet \(rs-online.com\)](#)

[Microsoft Word - SD-V01M8-000.doc \(2d-datarecording.com\)](#)

[SA-NTCxyy_5V-000 \(2d-datarecording.com\)](#)

[Microsoft Word - SA-WPxxxHQ-000.doc \(2d-datarecording.com\)](#)

[Microsoft Word - SA-GYxxV4-000.doc \(2d-datarecording.com\)](#)

[RS Pro 6mm LED Generic \(rs-online.com\)](#)

[A700000008036335.pdf \(rs-online.com\)](#)

[A700000007669680.pdf \(rs-online.com\)](#)

[PowerPoint Presentation \(rs-online.com\)](#)

[A700000007339106.pdf \(rs-online.com\)](#)

[A700000008944186.pdf \(rs-online.com\)](#)

[27 \(cablecraft.co.uk\)](#)

[3110845.pdf \(farnell.com\)](#)

[Yuasa NP18-12B Industrial VRLA Battery \(batterystation.co.uk\)](#)

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[3742526.pdf \(farnell.com\)](#)

[0900766b813eb48e.pdf \(rs-online.com\)](#)

[terrapin_micro-sd_data_sheet_iss2.pdf \(rs-online.com\)](#)

[5600230423_sd.pdf](#)

EDS Assignment 1

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

64/100

PAGE 1

PAGE 2

PAGE 3

PAGE 4



Comment 1

This seems a little high



Caption required

You should always include a caption on figures, equations and tables to allow you to refer to them in your text.

e.g. An illustration of this can be seen in figure 2. The relationship of the variables is shown in equation 2. Table 1 shows the results of the first experiment where the control variable, temperature in degrees celsius is shown in the first column....

PAGE 5



Caption required

You should always include a caption on figures, equations and tables to allow you to refer to them in your text.

e.g. An illustration of this can be seen in figure 2. The relationship of the variables is shown in equation 2. Table 1 shows the results of the first experiment where the control variable, temperature in degrees celsius is shown in the first column....



Comment 2

But which microcontroller did you choose?

PAGE 6



Comment 3

I presume you mean storage space

QM

Caption required

You should always include a caption on figures, equations and tables to allow you to refer to them in your text.

e.g. An illustration of this can be seen in figure 2. The relationship of the variables is shown in equation 2. Table 1 shows the results of the first experiment where the control variable, temperature in degrees celsius is shown in the first column....



Comment 4

This seems a little low

PAGE 7

PAGE 8

PAGE 9

QM

Caption required

You should always include a caption on figures, equations and tables to allow you to refer to them in your text.

e.g. An illustration of this can be seen in figure 2. The relationship of the variables is shown in equation 2. Table 1 shows the results of the first experiment where the control variable, temperature in degrees celsius is shown in the first column....

PAGE 10

QM

Caption required

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QM

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QM

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e.g. An illustration of this can be seen in figure 2. The relationship of the variables is shown in equation 2. Table 1 shows the results of the first experiment where the control variable, temperature in degrees celsius is shown in the first column....



Comment 5

How many are you going to use in this design?

QM

Caption required

You should always include a caption on figures, equations and tables to allow you to refer to them in your text.

e.g. An illustration of this can be seen in figure 2. The relationship of the variables is shown in equation 2. Table 1 shows the results of the first experiment where the control variable, temperature in degrees celsius is shown in the first column....

QM

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QM

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e.g. An illustration of this can be seen in figure 2. The relationship of the variables is shown in equation 2. Table 1 shows the results of the first experiment where the control variable, temperature in degrees celsius is shown in the first column....



Comment 6

Why are you comparing Gyroscopes with Accelerometers? They measure different things. This is like comparing apples and coffee cups.

You should have a table of just gyroscopes and compare those.

PAGE 15



Comment 7

That's an expensive LED. Why did you choose this one?

PAGE 16



Comment 8

CY cable is quite chunky. You may be better off using Def Stan 7-2C cable. This is screened and comes in a range of different cores



Comment 9

Is this for use inside the enclosure, or between the enclosure and the sensors?

PAGE 17

PAGE 18

PAGE 19



Comment 10

I don't think this is a quick enough sample rate - a car doing 70mph will cover about 313mm in 10ms - this is enough to miss most short bumps in the road

PAGE 20



Comment 11

This is a very large battery - you would have been better off looking at something like two lithium 18650 type batteries

PAGE 21

PAGE 22



Comment 12

"could" not "couple"

Is the roof a wise place to mount the box?

PAGE 23

PAGE 24

PAGE 25

QM

Caption required

You should always include a caption on figures, equations and tables to allow you to refer to them in your text.

e.g. An illustration of this can be seen in figure 2. The relationship of the variables is shown in equation 2. Table 1 shows the results of the first experiment where the control variable, temperature in degrees celsius is shown in the first column....



Comment 13

Why do you have so many batteries? You don't need 6 batteries.

QM

Caption required

You should always include a caption on figures, equations and tables to allow you to refer to them in your text.

e.g. An illustration of this can be seen in figure 2. The relationship of the variables is shown in equation 2. Table 1 shows the results of the first experiment where the control variable, temperature in degrees celsius is shown in the first column....



Comment 14

Which capacitor? There are quite a few

QM

Caption required

You should always include a caption on figures, equations and tables to allow you to refer to them in your text.

e.g. An illustration of this can be seen in figure 2. The relationship of the variables is shown in equation 2. Table 1 shows the results of the first experiment where the control variable, temperature in degrees celsius is shown in the first column....

PAGE 26

QM

Caption required

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QM

Caption required

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e.g. An illustration of this can be seen in figure 2. The relationship of the variables is shown in equation 2. Table 1 shows the results of the first experiment where the control variable, temperature in degrees celsius is shown in the first column....

PAGE 27



Comment 15

Should this be USB C?

the device should never power the bus, all voltages on the bus should come from the host (PC) not the device (data logger)

PAGE 28

QM

Use of 1st Person Voice

When writing technical reports, do not use first person voice. Instead, use the third person passive voice.

You should not use words like "I", "you", "we" etc..

PAGE 29



Comment 16

This PCB could be made a lot smaller. PCB real estate is expensive. You could easily have made this a third the size it is



Comment 17

The SD card should have a power connection and a ground connection to it which are not present on this PCB.

Your SD card holder has 9 pins, not 4.



Comment 18

editing mistake?



Comment 19

Why do these numbers not match?



Comment 20

Comparing the build cost of your system to the sale price of other systems is not a fair comparison.

This is the cost to build it, not the selling price. Typically you would add 40% - 50% minimum on to that cost as profit (we don't do things for free!)

The sale price should be what people are willing to pay for it, not what it costs to build.



Comment 21

temperature?



Comment 22

How? GPS only gives global position - longitude, latitude, altitude.

SCOTT THOMAS

64

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty



A comprehensive range of research informed literature embedded in the work. Excellent selection of relevant and credible sources. High-level referencing skills, consistently applied

7

KNOWLEDGE & UNDERSTANDING

Knowledge of the basic underlying concepts and principles of a subject.



Knowledge is extensive. Exhibits understanding of the breadth and depth of established views.

16.25

COGNITIVE & INTELLECTUAL

Evaluate underlying concepts and principles of a subject and interpret qualitative and quantitative data in order to develop lines of argument and make sound judgements.



Sound, logical, analytical thinking; synthesis and evaluation. Ability to devise and sustain persuasive

22.75

arguments, and to review the reliability, validity and significance of evidence. Ability to communicate ideas and evidence accurately and convincingly.
Sound, convincing conclusions / recommendations

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



A good and appropriate application of standard methods, materials, tools and/or techniques.
Good appreciation of the context of the application, with some use of examples, where relevant

11.2

TRANSFERABLE SKILLS

Communicate the results of their study/work accurately and reliably, and with structured and coherent arguments; the qualities needed for employment requiring the exercise of some personal responsibility within a structured and managed environment.



Can communicate well, confidently and consistently in a suitable format.
Work is coherent and fluent and is well structured and organised.

6.8