

Electronic System Design



Level 6 Assignment
Submitted By
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Abstract

When designing prototype vehicles, it is important to analyse how they perform over a designated testing period. To obtain this data, data acquisition systems are used. This report will detail how one such system could be designed.

This paper will highlight how each section of this design was undertaken from microcontroller and transducer selection through to printed circuit board (PCB) and enclosure design.

Basic design software is also considered with operational flowcharts being created for the different mode accessible when using this product.

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Introduction

Data acquisition systems are systems designed to sample and process information from a variety of real-world applications. They are created using various transducers, integrated circuitry, and some form of software capable of processing this information [1].

For this project, it has been requested that a portable data acquisition system is to be designed for use on a prototype car. This system will be required to measure suspension travel, engine temperature, chassis position as well as engine and road speed.

This report will detail the design process from initial project research to components selection and finally PCB board design.

Project Research

There are many portable data acquisition systems currently on the market for use in the automotive industry. Depending on the application, these systems are designed with different features. A brief overview of three such systems can be seen below.

1. MCC USB-2404-UI [2]

This is a general-purpose device marketed for use in basic sensing applications such as temperature, voltage and current. It is a 24-bit, analogue system that is designed for use in low power, high resolution testing (400k s/sec).

Signal conditioning is built into each input of the device protecting against overvoltage and noise interference.

No internal battery or memory storage is provided within this product meaning physical connections to an external device is required for operation.

This product is marketed at £1200.



Figure 1 - MCC USB-2404-UI [2]

2. NI-9219 [3]

The NI-9219 is another 24-bit analogue system designed for low power applications. It provides a moderate sampling rate of 250k s/sec with a maximum signal voltage of 5V.

Again, this device is able to monitor basic analogue signals such as voltage and current, although at a reduced capacity to the MCC USB-2404-UI. Signal conditioning is provided for overvoltage protection and noise reduction.

For outside applications, this product has been designed with an Ingress Protection (IP) rating of 54. An operational temperature range of -40°C to 70°C is also specified for this purpose.

An external device is again required for operation due to a lack of battery or memory storage. This product is marketed at £615.



Figure 2 - NI-9219 [3]

3. DNA-PPCx [4]

This is a 32-bit device supplied with both analogue and digital inputs. Due to the digital inputs, this device can be used for a wider range of sensing applications such as GPS, pressure, and motion.

The analogue inputs for this device are capable of detecting signals up to 150V significantly larger than the other two devices. This is an independent system, provided with both an internal battery pack and an SD memory card. This ensures the device is portable and usable in a larger market. These higher specifications do however, greatly increases the required size of the device.

The drive is IP20 rated meaning that it should only operate in clean, dry, and low humidity environments.

It is available for £1500.



Figure 3 - DNA-PPCx [4]

A comparison table for each of the research devices can be seen below in Table 1.

	<u>MCC USB-2404-UI [2]</u>	<u>NI-9219 [3]</u>	<u>DNA-PPCx [4]</u>
Analogue Inputs	4	4	6
Digital Inputs	0	0	3
Device Bitrate	24	24	32
Operating Voltage	0.15 to 10 VDC	0.20 to 5VDC	1.5 to 150V
Battery	×	×	✓
Internal Memory	Flash Only	Flash Only	128MB
Maximum Sampling Rate	400k (s/sec)	250k (s/sec)	100k (s/sec)
Operating Temperature	0°C to 60°C	-40°C to 70°C	-40°C to 85°C
Ingress Protection (IP) Rating	Not Specified	IP54	IP20
Measurable Inputs	• Voltage • Current • Thermocouple • Resistance • Bridge-based	• Voltage • Current • Thermocouple • Resistance • Bridge-based	• Voltage • Current • Thermocouple • Resistance • Bridge-based • Digital Sensors
Price	£1200	£615	£1500

Table 1 - Data Acquisition Systems Comparison

Component Selection

Suspension Travel:

To measure suspension travel within this system, four RS PRO 842-7217 Linear Transducers [5] will be used.

These are linear potentiometers that change their resistance based on the position of a central tap located on the extension staff. A voltage proportional to this resistance and the total voltage applied will then be fed back to the PIC microcontroller as the output signal. Program software can then be used to convert this signal to a proportional distance value.

The largest benefit to using potentiometers for this application is that they have an incredible linear response ensuring highly reliable, and accurate signals are produced.



Figure 4 - RS Pro Linear Transducer [5]

Specifications [6]:

- 300mm total travel. Will provide +/- 150mm if positioned centrally.
- 0 to 10V operating range – Similar to a standard PIC.
- -40 to 105°C temperature range.
- Analogue output.
- Three leads – V_{DD}, Ground and Signal

These sensors will be directly bolted across the suspension of the vehicle.

Engine Temperature:

Through research, it was found that engine temperature is typically measured via its coolant fluid [7]. As temperature dissipates through materials, measuring the external case of an engine block, will not provide an accurate measurement of internal temperature. Instead, threaded coolant sensors are more commonly used.

These sensors have temperature probes that protrude into the coolant fluid via a threaded hole drilled directly into the coolant system. These threaded holes are present on almost all modern vehicle, although varied in size and thread pitch. To ensure this system design remains universal, thread reducers can be used.

For this project the Amphenol GE-2096 will be used [8].



Figure 5 - Amphenol GE-2096 Temperature Transducer [8]

Specifications [8]:

- -40 to 160°C temperature range.
- 5V operation – Similar to a standard PIC.
- Analogue output.
- Three leads – V_{DD} , Ground and Signal

Vehicle Pitch, Roll and Yaw:

To measure pitch, roll and yaw of the vehicle, the Parallax 3-axis Gyroscope Sensor Module will be used [9].

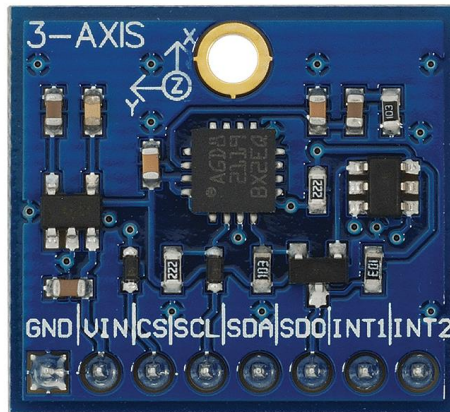


Figure 6 - Parallax 3-Axis Digital Gyroscope [9]

This is an integrated circuit (IC) build around a L3G4200D accelerometer that measures angular velocity of the device. It communicates via I²C that requires two digital input pins on the PIC. One for designated I²C communication whilst the other is connected directly to a clock input.

Specifications [9]:

- 2.7 to 6.5V operation.
- Digital output.
- Communication: I²C up to 400kHz.
- -40 to +85°C operating temperature.
- Four Leads - V_{DD}, Ground, I²C Signal and I²C Clock.

Engine and Road Speed:

Initially, a small, inferred tachometer was going to be used to measure engine and road speed, however, research indicated that temperature, vibration, and other environmental conditions such as dust and dirt, can significantly affect the accuracy of these meters [10].

As a result, additional sensing methods were researched, and variable reluctance speed (VRS) sensors were found.

VRS sensors operate based on the principle of electromagnetic induction. They contain small permanent magnets that when placed near ferrous materials, move within a coil of copper wire. This in turn, induces an output voltage proportional to the rate at which the magnet moves.

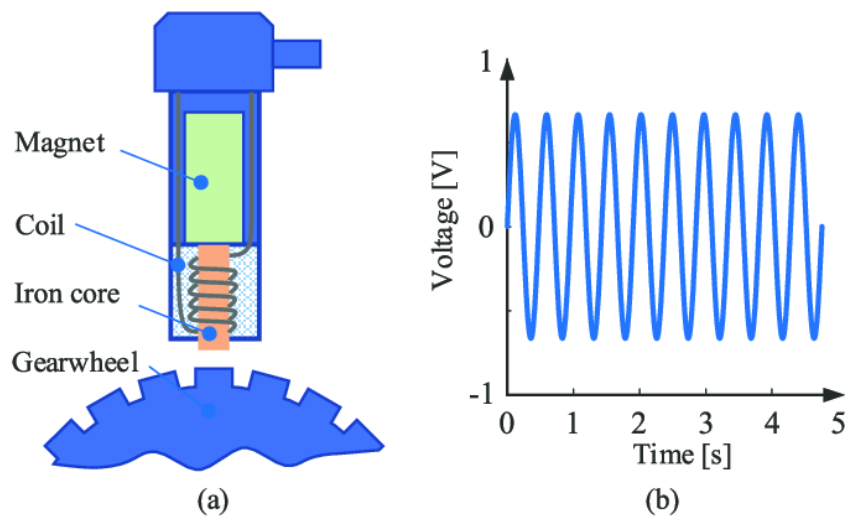


Figure 7 - VRS Sensor Operation [40]

For this project, a VRS sensor will be directly mounted above one of the pistons to measure engine speed, via the crankshaft, and to the drive axle to measure road speed.

Whilst the piston will act as the ferrous material required to measure engine speed, a small ferrous material will have to be tied to the drive axle for road speed measurement. This can be secured using a strong jubilee clip ensuring it can be universally used on different vehicles.

The sensor chosen for this application is the Honeywell MA3055S10 VRS speed sensor [11].



Figure 8 - Honeywell MA3055S10 Transducers [11]

As these sensors self-induce their output signal, no input supply is required for them to operate. They are provided with two leads, one a signal cable fed directly to the PIC, and the other to be connected to ground.

The Honeywell MA3055S10 produces an output signal between 2.5 – 12V DC. As the signal back to the PIC cannot exceed 5V, overvoltage protection will have to be included within the signalling circuit. Engine speed calculation will then be programmed proportionally for output signals between 2.5 – 5V.

Battery:

For this project, a rechargeable battery will be required to power the selected microcontroller and sensors, all of which will operate utilising 5VDC or less. For this application the RS Pro 7.4V Lithium-Ion rechargeable battery pack (144-9410) will be used [12].



Figure 9 - RS Pro 7.4V Li-Ion Battery [12]

Specifications [12]:

- Supply of 7.4 to 5.5V.
- Battery life of 2.6Ah.
- -20°C to 75°C operating temperature.
- Two Leads – V_{DD} and V_{SS} .

Power distribution will be closer examined within the Circuit Design section of this paper.

USB:

In order to recharge the battery pack and transfer data between devices, a USB connection is required. For this, the Amphenol SMT Type B USB Connector will be used [13].



Figure 10 - Amphenol Typer B USB Connector [13]

Specifications [13]:

- Micro USB 2.0 connection.
- 5V operation.
- -55°C to 85°C temperature range.
- Four pin connection – VDD, Vss, D+ and D-.

PIC Selection

Using the Microchip Selection Tool [14], thousands of PIC microcontrollers can be filtered based on desired parameters.

Using the data gathered during component selection and by analysing the project specification, the following PIC parameters have been identified:

- 8-Bit MCU.
- Minimum pin count of 22.
- A programable flash memory of 8kB to allow for future program expansion.
- Seven analogue inputs.
- Ten digital inputs.
- Two 8-Bit Timers.
- I²C compatibility.
- USB compatibility.
- Automotive compatibility.

Using these parameters, the selection tool found a total of 22 compatible microcontrollers. As any of these controllers would be appropriate for application, the remaining microcontrollers were sorted by pin count to minimise PCB space. From this, three micro controllers were selected for further analysis:

1. PIC16F1459
2. PIC18F26J53
3. PIC18F25J50

The specifications for these microcontrollers can be seen in Figure 11.

	PIC18F26J53 Microchip delete	PIC16F1459 Microchip delete	PIC18F25J50 Microchip delete
Family	8-bit MCU	8-bit MCU	8-bit MCU
CPU Type	8-bit PIC MCU	8-bit PIC MCU	8-bit PIC MCU
Max CPU Speed (MHz)	48 MHz	48 MHz	48 MHz
FPU			
Operation Voltage	(2V-3.6V)	(1.8V-5.5V)	(2V-3.6V)
Temp Range	(-40 to 85)	(-40 to 125)	(-40 to 85)
Pin count	28	20	28
Program Memory Size (KB)	64 Flash	14 Flash	32 Flash
Error Correction Code Program Flash			
SRAM	3.7109375 KB	1024 Bytes	3.7109375 KB
Data EEPROM/HEF (Bytes)			
Internal DRAM Type			
Internal DRAM Amount (MB)			
Low Power	Yes	Yes	Yes
ADC Input	13	9	10
Max ADC Resolution (Bits)	12	10	10
DAC Outputs		1	
Number of Op Amps			
Hardware Touch Peripheral			
UART	2	1	2
SPI	2	1	2
I2C	2	1	2
I2S			
SSC			
Number of USB Modules	1	1	1
USB Interface	FS Device	FS Device	FS Device
Number of CAN Modules			
Type of CAN module			
Ethernet			
Max 8-Bit Digital Timers	4	2	2
Max 16-Bit Digital Timers	4	1	3
Max 32-Bit Digital Timers			
Hardware RTCC/RTC	Yes		Yes
Max PWM outputs (including complementary)		3	
Number of PWM Time Bases			
Crypto Engine			

Figure 11 - Microcontroller Comparison [14]

Of the three microcontrollers, the PIC18F26J53 provides the highest performance when looking at programable flash memory, analogue to digital converters, I²C modules and the timers provided, both 8 and 16 bits. The PIC18F256J53 also matches the other microcontrollers in every other aspect.

Whilst these additional specifications may not be required, they will provide the user with a far greater range of operations should future project expansion be required without compromising PCB space.

For these reasons, the PIC18F26J53 [15] has been selected for this project.

Memory Requirements

Parameter	I/O	Measurement Range	Resolution	No. of Possible Values	No. of Bits / Sample	No. of Bytes / Sample
Engine RPM	Analogue	0 – 6000 RPM	10 RPM	600	10	2
Engine Temperature	Analogue	50 – 150°C	1°C	100	7	1
Suspension Front Left	Analogue	± 150 mm	1mm	300	9	2
Suspension: Front Right	Analogue	± 150 mm	1mm	300	9	2
Suspension: Rear Left	Analogue	± 150 mm	1mm	300	9	2
Suspension: Rear Right	Analogue	± 150 mm	1mm	300	9	2
Vehicle Pitch	Digital	± 30°	0.5°	120	7	1
Vehicle Roll	Digital	± 30°	0.5°	120	7	1
Vehicle Yaw	Digital	± 360°	1°	360	9	2
Road Speed	Analogue	0 – 300 MPH	1 MPH	301	9	2

Table 2 - Memory Requirements per Sample

Parameter	Sample Frequency	Bytes / Second (x B / Sample)	Bytes / Minute (x60)	Bytes / Hour (x60)	Bytes / Test (x2)
Engine RPM	50Hz	100	6000	360kB	720kB
Engine Temperature	1Hz	1	60	3.6kB	7.2kB
Suspension Front Left	100Hz	200	12000	720kB	1.44MB
Suspension: Front Right	100Hz	200	12000	720kB	1.44MB
Suspension: Rear Left	100Hz	200	12000	720kB	1.44MB
Suspension: Rear Right	100Hz	200	12000	720kB	1.44MB
Vehicle Pitch	100Hz	100	6000	360kB	720kB
Vehicle Roll	100Hz	100	6000	360kB	720kB
Vehicle Yaw	100Hz	200	12000	720kB	1.44MB
Road Speed	50Hz	100	6000	360kB	720kB
Total Memory Required: 10.09MB					

Table 3 - Total Memory Requirement per Test Period

To determine memory requirement for this system, Table 2 was created showing the number of bytes required to store information for each sensor per sample. By choosing a sample rate for each sensor, a total memory requirement was then calculated for a two-hour test period as seen in Table 3.

SD Card:

To store the 10MB of data required for the test period, a micro-SD card will be used. This will require a SD card holder to be integrated onto the PCB. A Molex 104031 micro-SD card holder will be used for this purpose [16].

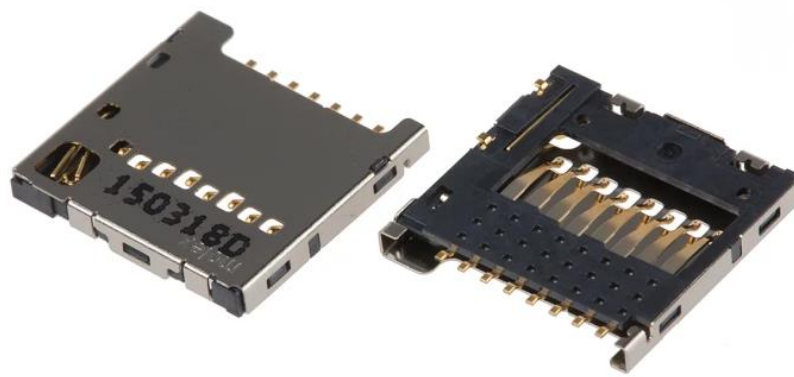


Figure 12 - Molex Micro-SD Card Holder [16]

Data Alignment:

Within this system, each data sample will be stored in independent bytes. Whilst not the most efficient method of storing data, an appropriately size SD card can eliminate any downside to this process.

The benefit to storing data in this way is that it allows quick and easy access to memory during operation. If stored within the same byte as other data, unwanted information has to be read by a computer before desired information can be accessed. This slows system speed and would increase download and communication times.

Connectors

For this project two types of connectors will be required. The first will connect sensor leads to the chosen enclosure, the second will be required for wire to board connections.

Due to the environment these connectors will be operating in, they must meet the following specifications:

- IP65 rated or higher.
- Thermal protection – Assumed engine bay temperature of up to 80°C.
- Anti-vibration – Must provide some form of latching mechanism.

Sensor to Container Connection:

For this project, Deutsch automotive connectors will be used [17] [18]. These are specially designed, environmentally sealed (IP66) connectors specifically designed for use in harsh environments.

Each connector is made from a thermoplastic housing, encapsulating rubber pin retainers and copper alloy contact pins, all of which can operate within a temperature range of -55°C to 125°C. The male and female connectors also have latching mechanisms to prevent self-loosening.

To conserve space on the device containment, a single 12 pin connector will be used for the suspension sensors. Likewise, a four-pin connector will be used for both speeds sensors with the temperature sensor being connected through a single two pin connector.

The connectors selected for this application can be seen in Table 4.

<u>Deutsch Product</u>	<u>Sensor Connector</u>	<u>Component</u>
DT0412PA-CL06 12 Pin Surface Mounted Socket Connector [19]	Suspension	
DT0612SA-CE10 12 Pin Plug Connector [20]	Suspension	
DT043P-CL06 3 Pin Surface Mounted Socket Connector [21]	Engine Temperature	
DT063S-CE06 3 Pin Plug Connector [22]	Engine Temperature	
DT044P-CL06 4 Pin Surface Mounted Socket Connector [23]	Engine RPM Road Speed	

DT064S-CE06 4 Pin Plug Connector [24]	Engine RPM Road Speed	
0462-209-16141 Crimp Terminals [25]	Required for all connectors.	

Table 4 - Sensor to Enclosure Connector Selection

Wire to Board Connection:

The wire to board connectors will require similar specification to the Deutsch connectors excluding the IP rating as they will be housing within a sealed enclosure.

For this project, Molex wire to board connectors will be used [26].

Molex connectors are small, nylon connectors designed for use in electronic circuit. They are available in both male and female types that latch together when connected. Molex also offer specific connectors that can be directly soldered onto PCBs' during manufacturing.

This design will utilise a single Molex connector for each sensor to allow for easier fault finding should it be required.

The Molex connectors selected for this project can be seen in Table 5.

<u>Molex Product</u>	<u>Connector</u>	<u>Component</u>
22-05-7028 2 Pin Male Connector [27]	Engine RPM Road Speed Battery	
679-5363 2 Pin Female Housing [28]	Engine RPM Road Speed Battery	
22-27-2031 3 Pin Male Connector [29]	Suspension Engine Temperature	
22-01-3037 3 Pin Female Housing [30]	Suspension Engine Temperature	
22-27-2051 4 Pin Male Connector [31]	Gyroscope	

22-01-2041 4 Pin Female Housing [32]	Gyroscope	
08-50-0032 Crimps Terminals [33]	All Connectors	

Table 5 - Wire to Board Connector Selection

Circuit Design

Power Distribution:

Within this circuit, three separate voltage levels will be present 7.4V, 5V and 3.3V.

As the chosen lithium-ion battery supplies 7.4V, a 7805-voltage regulator [34] will be used to provide the stable 5V output to power each of the sensor components. Per the datasheet, two smoothing capacitors will be used to provide a stable, noise free output voltage as shown in Figure 13.

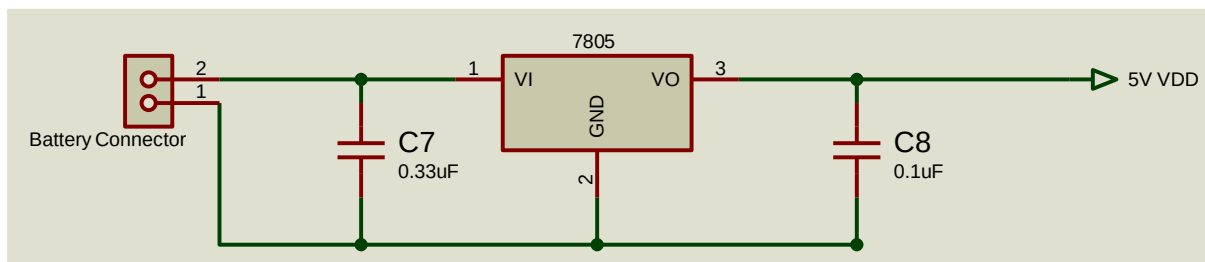


Figure 13 - 7.4V to 5V Power Distribution

The PIC18F26J53 requires a supply voltage of 3.3V. To achieve this, a 3.3V Zener diode will be connected between the supply pin and ground. If a voltage greater than 3.3V is present, the Zener diode will act in reverse bias and drop excess voltage across a connected resistor as shown in Figure 14.

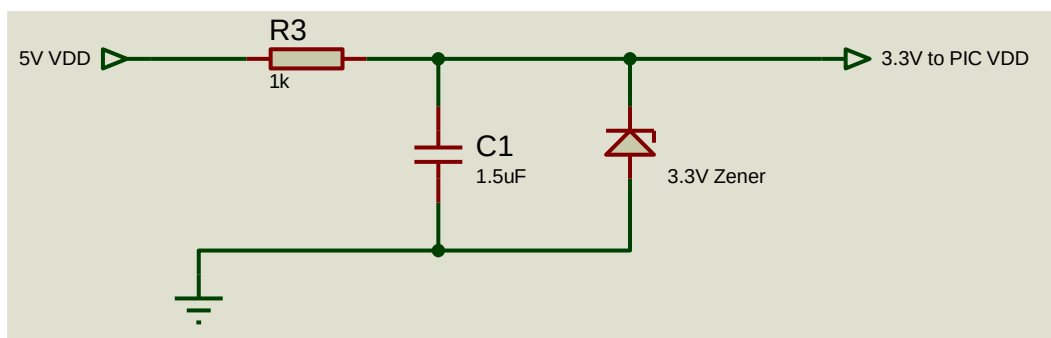


Figure 14 - 5V to 3.3V Step Down for PIC

A 1.5uF capacitor will also be connected across the Zener diode to create a low pass filter (LPF) with the 1kΩ resistor. This will remove any high frequency noise from the output and was designed with a cut off frequency of 100Hz. The following calculation were used to determine component values.

$$\text{Cutoff Frequency (Fc)} = \frac{1}{2\pi \times \text{Resistance (R)} \times \text{Capacitance (C)}}$$

$$\text{Capacitance (C)} = \frac{1}{2\pi \times \text{Resistance (R)} \times \text{Cutoff Frequency (Fc)}}$$

Let R = 1kΩ and Fc = 100Hz

$$\text{Capacitance (C)} = \frac{1}{2\pi \times 1000\Omega \times 100\text{Hz}} = 1.59\mu\text{F} = \textbf{Standard Size of 1.5}\mu\text{F}$$

Sensor Signal Conditioning:

The output signal from each of the sensors will be susceptible to high frequency noise within this system. This interference may also affect the signal magnitude. Due to this, a LPF and voltage protection similar to that shown in Figure 14, will be required for each sensor.

For this project, each sensor will have its output signal limited between 0 to 5V. Program software will then be used to interpret a proportional reading base on this output range.

The overvoltage protection will be provided by a 5.1V Zener diode whilst the LPF will be designed based on the sample rate outlined in Table 3.

Suspension and Gyroscope:

Both the suspension and gyroscope circuits have been designed with a sample rate of 100Hz. The following calculation were used to design their signal conditioning circuits shown in Figures 15 and 16.

$$\text{Capacitance (C)} = \frac{1}{2\pi \times \text{Resistance (R)} \times \text{Cutoff Frequency (Fc)}}$$

Let R = 1kΩ and Fc = 100Hz

$$\text{Capacitance (C)} = \frac{1}{2\pi \times 1000\Omega \times 100\text{Hz}} = 1.59\mu\text{F} = \textbf{Standard Size of 1.5}\mu\text{F}$$

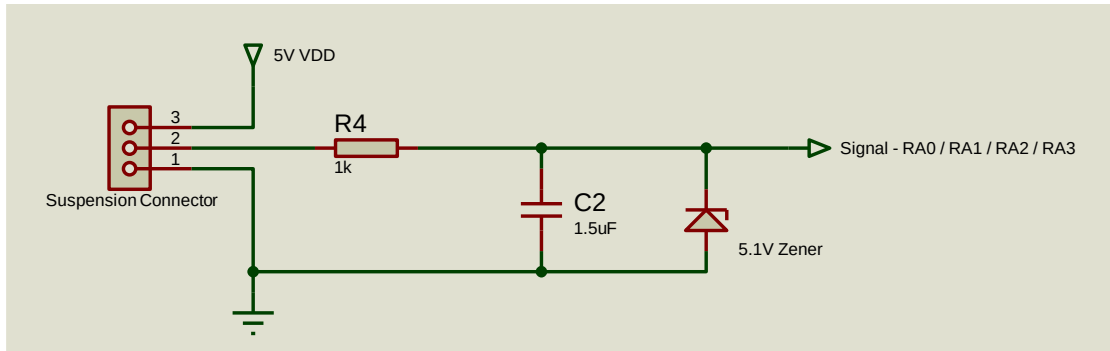


Figure 16 - Suspension Signal Conditioning Circuit

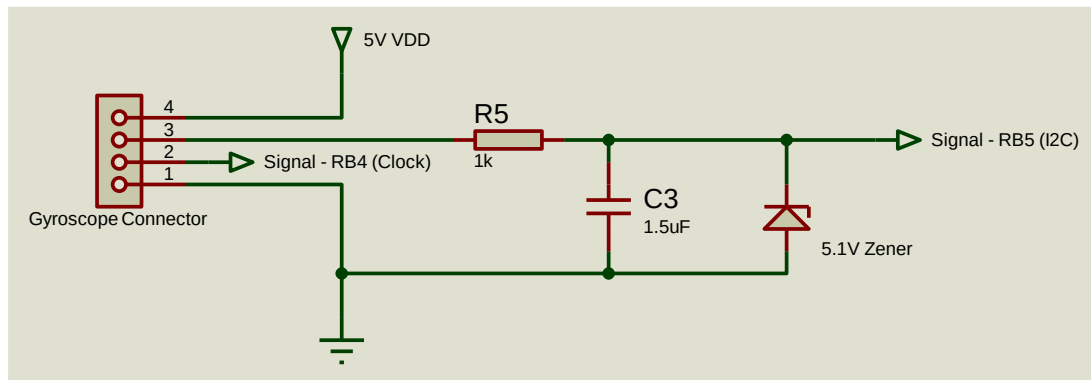


Figure 15 - Gyroscope Signal Conditioning Circuit

Whilst suspension signals can be connected to any analogue input available on the PIC, the gyroscope signal has to be connected via the I²C inputs. Per the datasheet [15], the I²C communication and clock inputs are available on RB5 and RB4 respectively.

Engine Temperature:

As engine temperature will change slowly over time, a sample rate of once per second (1Hz) was chosen. This requires the signal conditioning circuit shown in Figure 17.

$$Capacitance (C) = \frac{1}{2\pi \times Resistance (R) \times Cutoff Frequency (Fc)}$$

Let R = 1kΩ and Fc = 1Hz

$$Capacitance (C) = \frac{1}{2\pi \times 1000\Omega \times 1Hz} = 159\mu F = \textbf{Standard Size of 150}\mu F$$

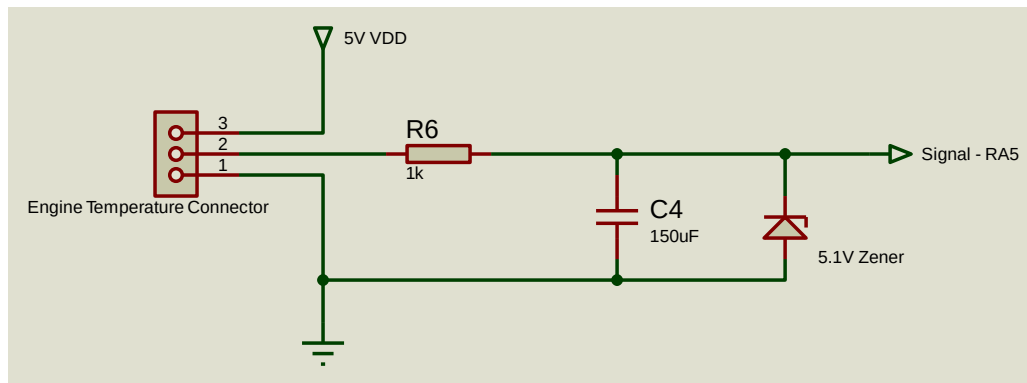


Figure 17 - Engine Temperature Signal Conditioning Circuit

This sensor produces an analogue output and will be connected to analogue input RA5.

Road and Engine Speed:

The road and engine speed sensors will be sampled at a frequency of 50Hz. For this, the signal conditioning circuit shown in Figure 18 will be used.

$$Capacitance (C) = \frac{1}{2\pi \times Resistance (R) \times Cutoff Frequency (Fc)}$$

Let $R = 1k\Omega$ and $Fc = 50Hz$

$$Capacitance (C) = \frac{1}{2\pi \times 1000\Omega \times 50Hz} = 3.18\mu F = \textbf{Standard Size of } 3.3\mu F$$

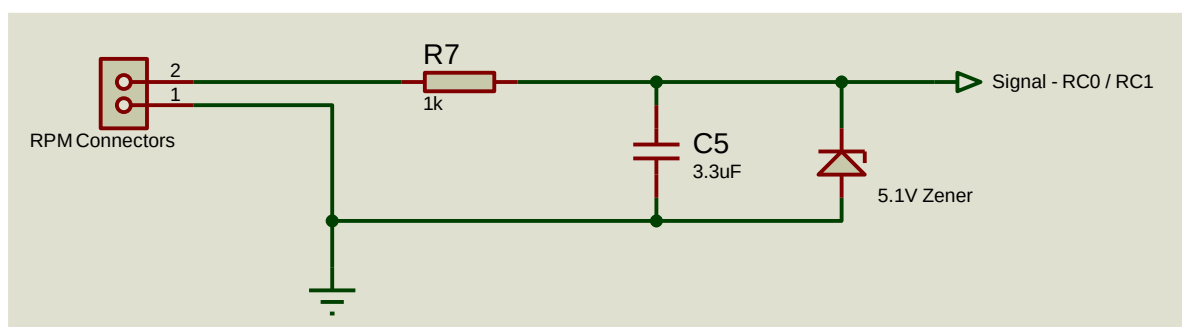


Figure 18 - VRS Transducer Signal Conditioning Circuit

The signals for engine RPM and road speed will be connected to analogue inputs RC0 and RC1 respectively.

Circuit Schematic:

Using Easy-PC software the following schematic diagrams were created for this circuit.

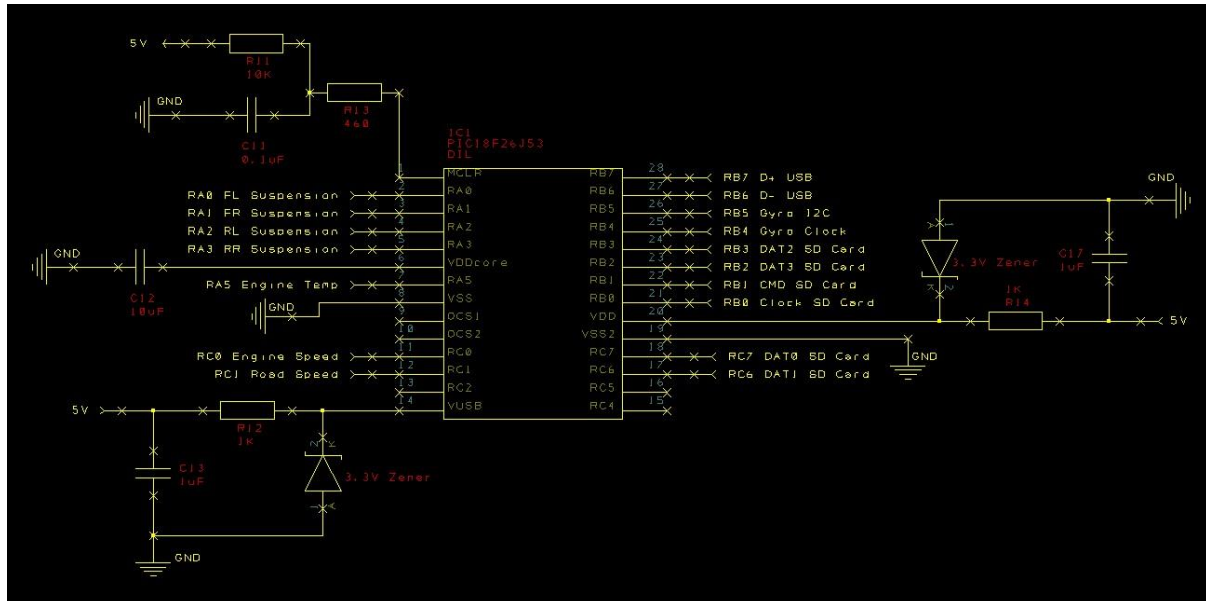


Figure 19 - Schematic of Microcontroller Connections

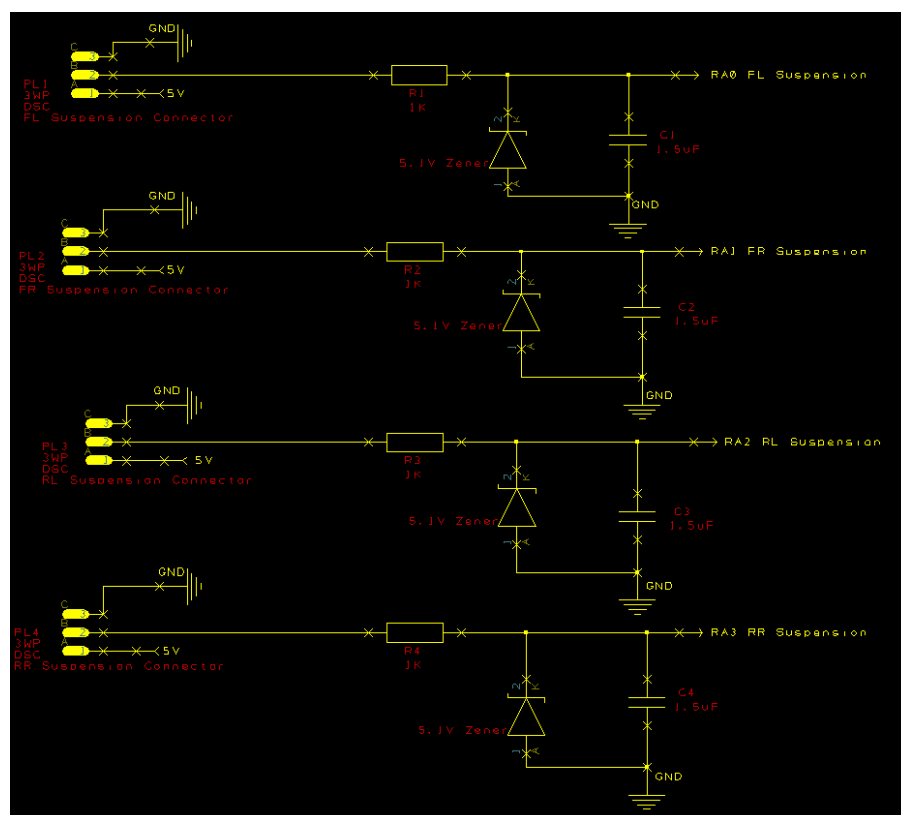


Figure 20 - Schematic of Suspension Sensors

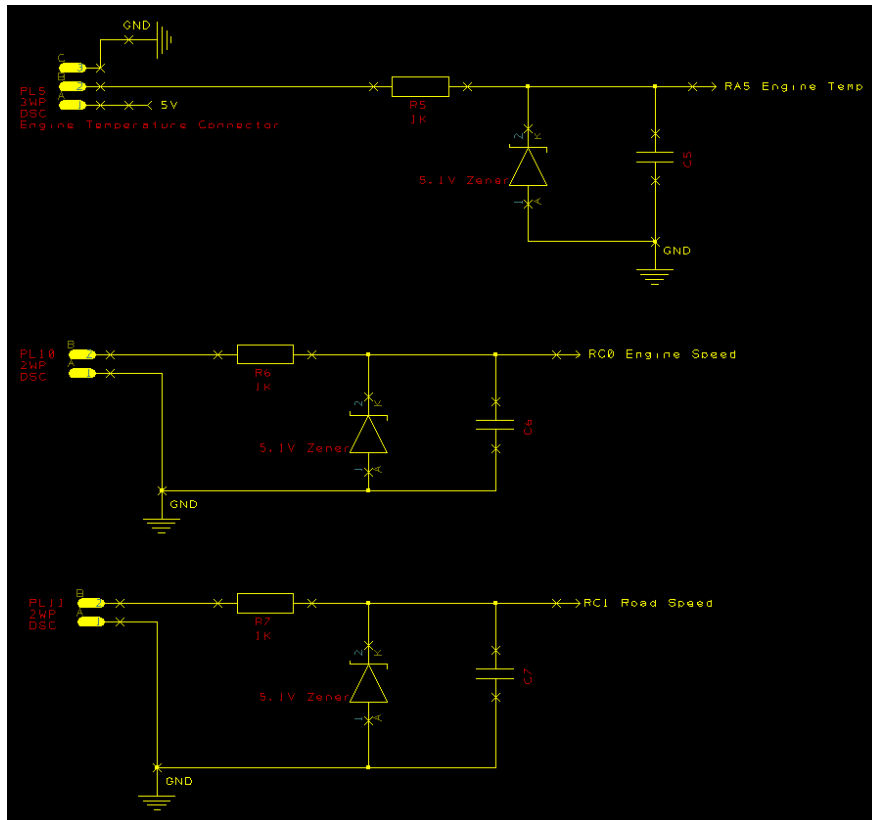


Figure 21 - Schematic of Speed and Temperature Sensors

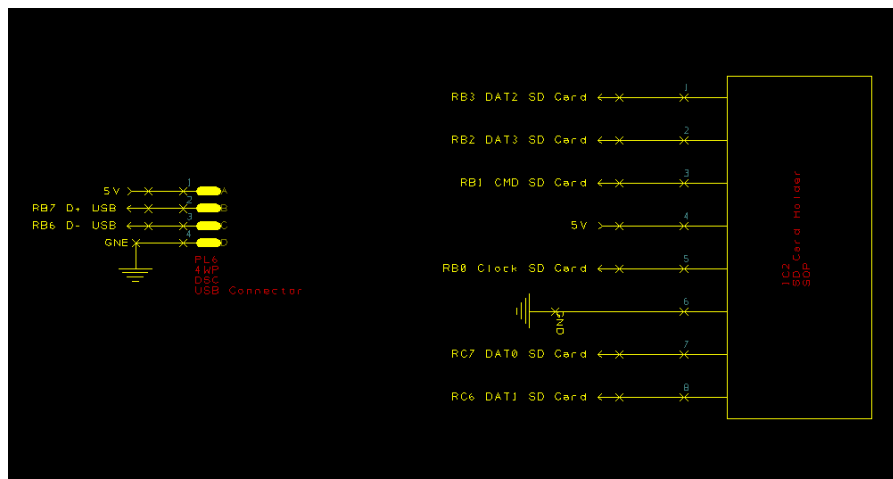


Figure 22 - Schematic of SD Card and USB Connections

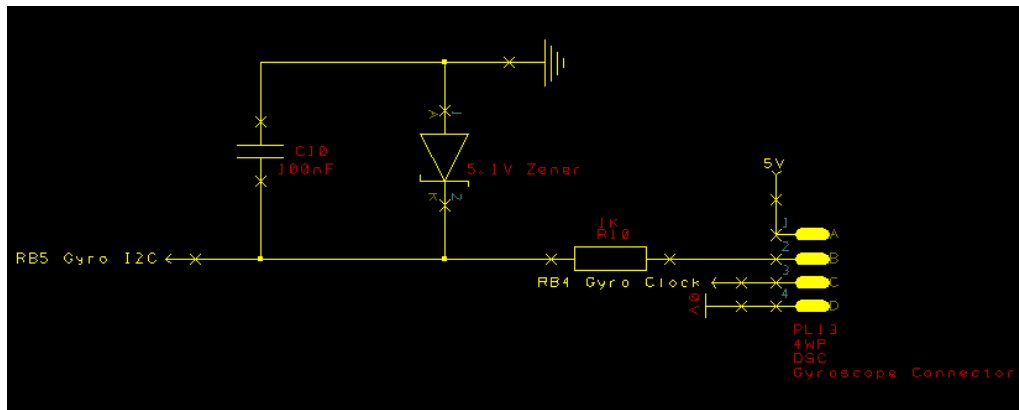


Figure 23 - Schematic of Gyroscope Connections

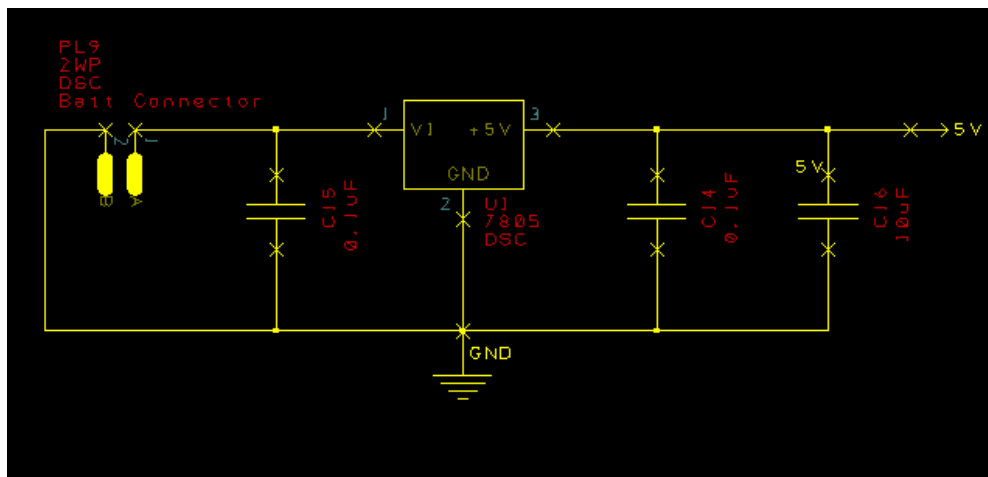


Figure 24 - Schematic of 7.4V to 5V Power Distribution

PCB Design:

Utilizing the same software, a PCB design was created. From this design, a 3D image of the PCB was generated and final dimensions were established.

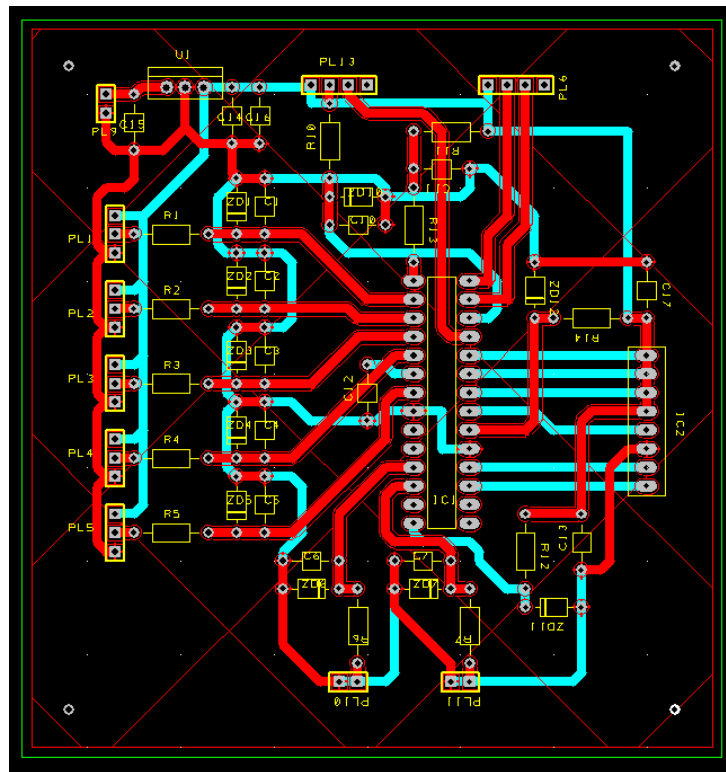


Figure 25 - PCB Circuit Design

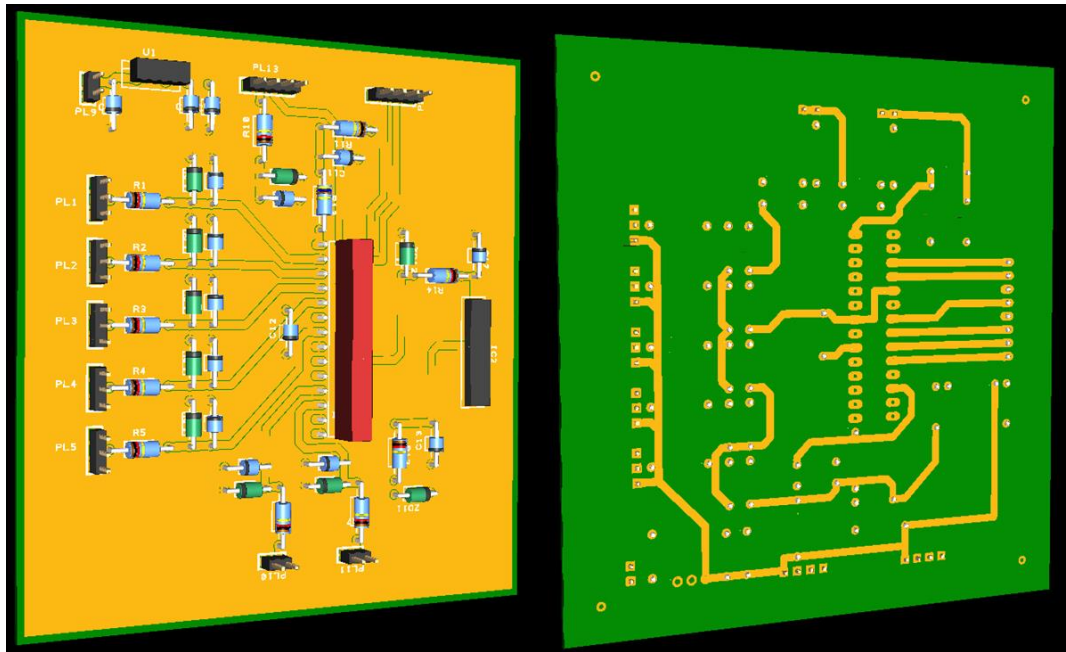


Figure 26 - 3D Model of PCB Design

PCB Cost:

The final PCB measured 95.25mm x 100.33mm. Using the design files created within Easy-PC, JLCPCB [35] could be used to price the PCB design. When a standard, two-layer FR-4 board was chosen, JLCPCB quoted a fabrication cost of £2.55 per board.

Figure 27 - JLCPCB Quotation

Enclosure

With the circuit design complete and component dimensions finalised, an enclosure to house all of the device's circuitries can now be selected. To protect the circuitry from the environment within an engine bay, the enclosure will be required to be IP65 rated and act as a thermal insulator to heightened temperatures.

Due to poor thermal insulation and its tendencies to create noise within electronic circuit, a metal enclosure will not be suitable for this application. Instead, a small thermoplastic junction box will be used.

ABB Thermoplastic Junction Box 00846 M008460000 [36]:



Figure 28 - IP65 ABB Junction Box

This ABB junction box measures 100 x 100 x 50mm and is IP65 rated for applications up to 75°C. It is made from an insulative, thermoplastic material and has flat, 2.5mm thick walls that will provide excellent mounting for then chosen connectors.

The lid is secured through four plastic screws that are supplied with small O-rings to prevent self-loosening and maintain IP rating.

Within the container, adhesive PCB mounting pins will be used secure the PCB. The enclosure itself, will be fitted within the engine bay of a vehicle and secured using stainless steel banding.

Project Costing

Components	Source	Quantity	Cost (inc. VAT)
RS PRO 842-7217 Linear Transducer	RS Components	4	£844
Amphenol GE-2096	Farnell	1	£60.20
Parallax 3-axis Gyroscope	Parallax	1	£7.50
Honeywell MA3055S10 VRS	Farnell	2	£900
RS Pro 7.4V Lithium- Ion Battery	RS Components	1	£23.54
PIC18F26J53	Mouser	1	£3.52
Deutsch DT0412PA- CL06	RS Components	1	£19.68
Deutsch DT0612SA- CE10	RS Components	1	£5.46
Deutsch DT043P-CL06	RS Components	1	£8.75
Deutsch DT063S-CE06	RS Components	1	£1.54
Deutsch DT044P-CL06	RS Components	1	£14.62
Deutsch DT064S-CE06	RS Components	1	£2.38
Deutsch 0462-16141	RS Components	38	£3.96
Molex 22-05-7028	RS Components	3	£1.39
Molex 22-01-3027	RS Components	3	£1.05
Molex 22-27-2031	RS Components	5	£1.19
Molex 22-01-3037	RS Components	5	£1.13
Molex 22-27-2051	RS Components	1	£0.37
Molex 22-01-2041	RS Components	1	£0.15
Molex 08-50-0032	RS Components	25	£2.75
ABB Junction Box	RS Components	1	£4.45
7805 Voltage Regulator	Farnell	1	£0.56
PCB	JLCPBC	1	£2.55
1kΩ Resistor	RS Components	9	£1.75
460Ω Resistor	RS Components	1	£0.19
10kΩ Resistor	RS Components	1	£0.14

0.1µF Capacitor	Farnell	5	£0.35
1µF Capacitor	Farnell	3	£0.81
1.5µF Capacitor	Farnell	5	£1.15
3.3µF Capacitor	Farnell	1	£0.18
10µF Capacitor	Farnell	1	£0.22
150µF Capacitor	Farnell	1	£0.15
5.1V Zener Diode	Farnell	8	£1.28
3.3V Zener Diode	Farnell	2	£0.52
Total Component Cost - £1917.48			

Table 6 - Component Costs

Software Structure

Mode Selection:

To outline the desired operation of this device's software, several flowcharts have been created. The first flowchart shown in Figure 29 shows the basic mode selection for the program.

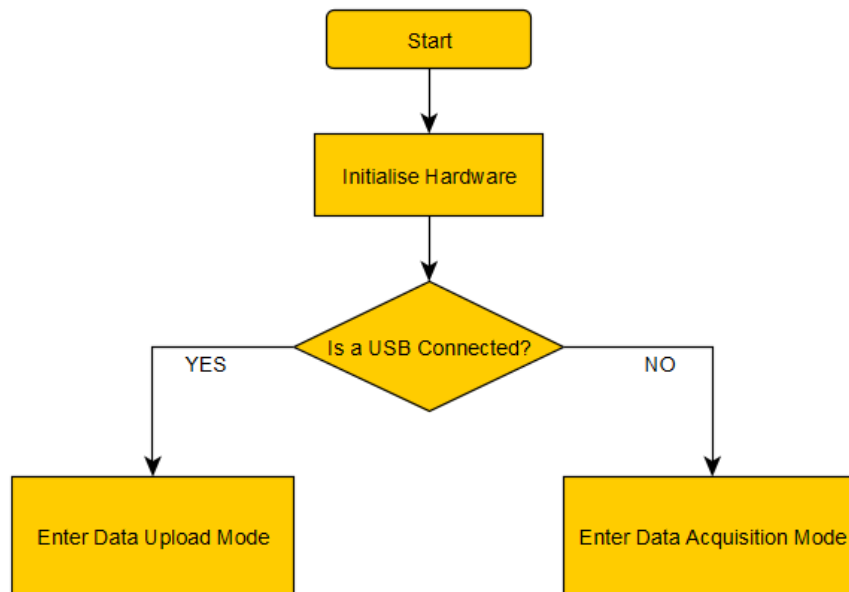


Figure 29 - Mode Selection Software Structure

This is a simple process and will simply enter either “Data Upload” or “Data Acquisition” mode based on whether or not a USB is connected.

Data Upload Mode:

Data upload mode will be selected when a USB is connected and test data is required to be transferred to an external device. The user will also be able to access system settings in this mode to change test parameters, calibrate sensors or reset the system. Figure 30 outlines the data upload operation.

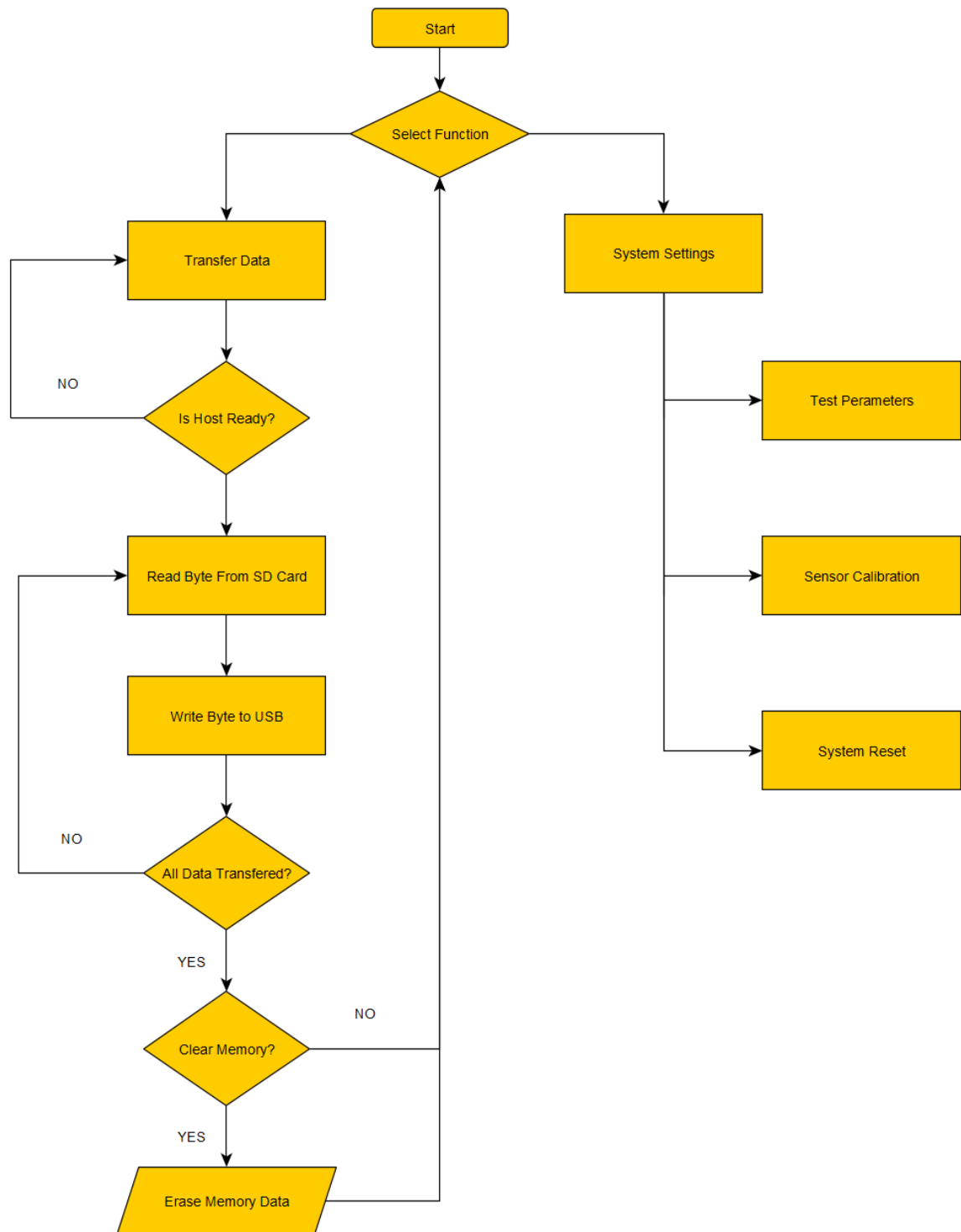


Figure 30 - Data Upload Software Structure

Data Acquisition Mode:

If no USB is connected to the device, the system will initiate testing via the data acquisition mode.

The flowchart shown in Figure 31 outlines the basic program operation required for each sensor during testing. Depending on the sample rate of each sensor, the “Sample Time” value will change for each component.

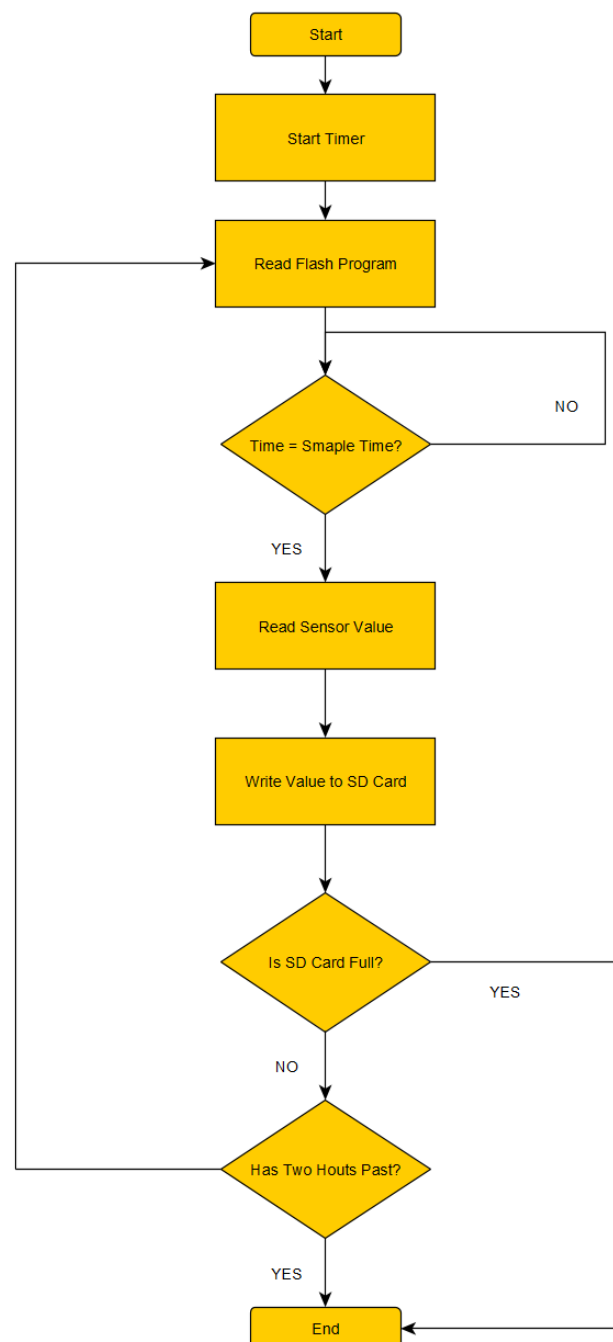


Figure 31 - Data Acquisition Software Structure

Design Improvements

With additional time and research, there are several design improvements that could be made:

1. Sensor Selection - Cost:

Whilst the sensor chosen for this project meets all design specifications, it is likely that far cheaper alternatives are available. The Honeywell VRS transducers by themselves totalled £900 of this project's total costs.

This pricing would not be sustainable if looking to mass produce this product.

2. Gyroscope Module:

The gyroscope selected for this project was purchased as a pre-built module on its own PCB. This takes up significant space within the enclosure increasing product size, and therefore cost.

Accelerometers are available as single chip devices that could be integrated directly onto the system PCB design.

3. Enclosure Design

With modern 3D printing technology, a custom designed thermoplastic enclosure could have been produced for this project. This would have allowed all dimensions to be specified as well as for PCB and connector mounting to be integrated into the housing.

This would have reduced product size, shortened assembly times, and provided a more secure method of housing the PCB. Production costs would also be significantly cheaper.

Conclusion

Throughout this project, it has been shown how, through the use of basic electronic components and sensing devices, a portable data acquisition system can be designed.

Each of the chosen components meet project specification and have been integrated into the PCB design per datasheet instructions. With correct software programming, it is believed that this data acquisition system will function as intended.

The PCB itself, is efficiently laid out and fits onto a compact 95.25mm x 100.33mm board. Utilising a two-layer design, all components have been correctly connected without interference. Through the use of a copper pour, all ground components have been connected without additional tracks having to be created, whilst also providing noise reduction within this circuit.

Several improvements have been outlined within the report that would benefit the overall design and production of this product. Whilst this initial design will be sufficient for prototype testing, prior to marketing the product, it is recommended that these changes be made.

The next stage of this process would be to write and upload program software to this device. A testing phase will then be required before customer applications could be offered.

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