

CF ESD Assignment

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Electronics Systems Design
Assignment – Cameron Paul Fitze
2111737

Implementing a Car Data Logger

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Course Number:

Course Name: BEng Embedded Electronic Systems



Abstract

This report details the process of creating a data acquisition system (DAQ) for a family saloon. A variety of sensors are identified and used to obtain various parameters of the car.

Once the hardware is identified, the design is complete using EasyPC to create a schematic and then a PCB. The PCB will be used to create a gerber file, which is sent onto a manufacturer to build the PCB.

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1. Introduction

1.1 Aim

The aim of this assignment is to design a data acquisition (DAQ) logging system for a family saloon, controlled by a microcontroller.

A DAQ is a system that collects data from a network of sensors around the car in order to inform the driver of various live measurements from around the car including the following:

- Engine Revolutions Per Minute (RPM)
- Speed (Miles Per Hour (MPH))
- Engine Temperature (°C)
- Pitch, Roll and Yaw (PRY)
- Suspension Travel (")

This assignment will comprise of the following steps:

1. Enclosure design (casing selection) – Task 2 (see section 3)
2. Microcontroller selection (from the 8bit PIC range) – Task 2 (see section 3)
3. Memory sizing with justification (non-volatile data storage memory) – Task 3 (see section 4)
4. Sensor selection and specification – Task 3 (see section 4)
5. Connector specification – Task 3 (see section 4)
6. Circuit diagrams – Task 4 (see section 5)
7. PCB design (only Easy-PC files will be accepted) – Task 4 (see section 5)
8. Software structure (block diagram form) – Task 5 (see section 6)
9. A structure showing how the data is aligned in non-volatile memory – Task 5 (see section 6)

1.1 Report Layout

This report details the process of assessing and procuring a range of sensors for a data acquisition (DAQ) system for a typical family saloon car.

The sections are as follows:

1. Background Research (see section 2)
2. Microcontroller Considerations (see section 3)
3. Hardware Considerations (see section 4)
4. Circuit and PCB Designs (see section 5)
5. Prototype software, design, and structure (see section 6)
6. Prototype build costs (see section 7)
7. Suggested improvements of specifications based on literature review (see section **Error! Reference source not found.**)

8. Conclusions (see section 8)
9. Recommendations (see section 9)

2. Task 1 – Background Research (Literature Review)

A DAQ system collects measurements from various parameters of a car to inform either the driver or the car's central processing unit (CPU) of the car's current health and performance.

DAQ systems for a car collect the following data:

- Vehicle performance (speed, fuel efficiency, engine temperature, amongst other)
- Driver performance (acceleration delta, braking, and steering G)

The above data can be collected and stored in maintenance logs, which can be accessed as and when required to assist with vehicle development and inform vehicle maintenance procedures.

Sensors are used to collect the data that the DAQ system processes. The type of sensors depends upon the nature of the data being collected. Referring to the list above, the sensors typically seen in a DAQ system include [1]:

- Accelerometer
- Wheel speed sensor
- Suspension travel sensor
- Steering angle sensor
- Gear position sensor
- Fuel level sensor
- Coolant temperature sensor

The method of measuring data varies across the sensors. These methods include, but are not limited to:

- Reflective
- Non-contact
- Gyroscopic
- Wire pot

A reflective sensor comprises of a sensing element and the target. The sensor detects when the target passes through the light beam by detecting a change in light quantity. This is used for measuring RPM and MPH.

A non-contact sensor does not experience any physical contact. An example of this is an infrared sensor. This has applications in temperature sensing – which will be used within this project.

A Gyroscopic sensor measures a targets position change in the x, y, and z axis. This has applications in measuring pitch, roll, and yaw.

A wire-pot sensor measures the linear or rotational displacement of an object. This has applications in measuring suspension travel.

3. Task 2 – Microcontroller Selection Considerations

This project requires a microcontroller to control this circuit. The minimum specifications of the microcontroller were as follows:

- RAM = >16KB
- Clock speed = >32MB
- Pin count = 28
- ADC input = >2
- Communications – UART, SPI, I2C
- USB interfaces = 1

A parametric search tool was used to identify a range of chips what would be suitable for the project based on pre-determined parameters filled in at the beginning of the search. These parameters included those mentioned above.

Once the specifications are filled in, the search returns a range of PICS that meet those specifications.

Search Results
3 MCHP parts found

PIC18F45K50
PIC18F25K50
PIC18F24K50

Reset Search

Sort Results by
Memory Size

To add MCHP part to side-by-side:

Add PIC18F24K50
Go to side-by-side

Automotive Capable:
☐

PIC18F24K50
In Production

Specifications
Dev Tools
Technical Docs
Budgetary Pricing

Family	8-bit MCU
CPU Type	8-bit PIC MCU
Max CPU Speed (MHz)	48 MHz
FPU	
Operation Voltage	(1.8V-5.5V)
Temp Range	(-40 to +125)
Pin Count	28
Program Memory Size (KB)	16
Error Correction Code Program Flash	
SRAM	2 KB
Data EEPROM/HEF (Bytes)	256
Internal DRAM Type	
Internal DRAM Amount (MB)	
Low Power	Yes
ADC Input	14
Max ADC Resolution (Bits)	10
DAC Outputs	1
Number of Op Amps	
Hardware Touch Peripheral	
UART	1
SPI	1
I2C	1
I2S	
SSC	
Number of USB Modules	1
USB Interface	FS Device
Number of CAN Modules	
Type of CAN module	
Ethernet	
Max 8-Bit Digital Timers	2
Max 16-Bit Digital Timers	2
Max 32-Bit Digital Timers	
Hardware RTCC/RTC	
Max PWM outputs (including complementary)	
Number of PWM Time Bases	
Crypto Engine	
ARM Trust Zone	
Segmented LCD	
Graphics Controller/GPU	
Video Decoder	

Show Other Features

Figure 1 - Microcontroller Selection using Parametric Search

Figure 1 - Microcontroller Selection using Parametric Search
Figure 1 shows the specifications of the selected PIC from the results of the parametric search conducted for this microcontroller selection. This PIC meets the minimum requirements set out for this project. One point to note is that this PIC has a differential serial data signal set split signal to D+ and D- lines. This creates two signals, which get received, then changed back into a single series data set. This is required for a USB interface, which this PIC features.

4. Task 3 – Hardware Considerations

This section will describe the various hardware considerations for the DAQ system.

4.1 A suitable package (casing) for the system that is both portable and suitable for the environment

The casing for the DAQ circuit board should be of sufficient size to host the circuit board, sensors and all of the connectors, whilst being a suitable size of its intended application. It should also have external access for a variety of interfaces to successfully connect whilst the case is closed.

Background research was conducted online to identify casing that is used in current DAQ systems. For this project, the following was deemed suitable:

- Case (see Figure 2) – National Instruments SCC-68 – data sheet - <https://www.ni.com/docs/en-US/bundle/scc-68-seri/resource/374748b.pdf>

This casing was deemed appropriate as it has historically been used for DAQ systems and features holes for mounting it within the car, various ports for connecting the sensors to the DAQ system, and screw terminals to affix the PCB to.



[2]

Figure 2 - SCC-68 Enclosure for DAQ System

4.2 The size of the storage (non-volatile) memory needed

The storage required depended on the amount of data all of the sensors were collecting over a two-hour period. The vehicle the sensors are fitted to is a family saloon travelling at 85mph.

The steps for each sensor were as follows:

1. Identify the bytes per reading
2. Identify the rep time
3. Calculate the readings per second
4. Calculate the total bytes per second

Total Bytes per Second = Bytes per Reading x Number of Readings per second

5. Calculate total bytes per 15 seconds – 15 seconds being a record, therefore total bytes per record
6. Total bytes per minute
7. Total bytes per 2 hours
8. Total Storage = Total Bytes per 2 Hours

Sensor Type	Bytes per reading	Readings per second	Total Bytes per second	Total bytes per 15 seconds (per record)
Reflective	1	1	1	15
Reflective	1	120	120	1800
Non-contact	2	2000	4000	600000
Gyroscopic	6	15	90	1350
Wire Pot	8			
Total bytes per 15s				601815
Total bytes per min				2407260
Total bytes per 2 hours				288871200
Total bits per 2 hours				2310969600

Table 1 - Sensor Data Consumption

Table 1 shows the total data consumption across all of the sensors over a two-hour period. The total bytes per 2 hours equated to 288MB. So now the requirements of the SD card, to provide the storage, were identified.

SD card selection of course depends upon the total storage, but also the price. There is no need to procure a 16GB SD card for this application as the minimum requirements are 288MB, so there will be extra cost for no reason. Therefore, a 1GB SD card should be sufficient. As this is a live data-gathering application, the SD card should also have a relatively speed read/write capability, but it does not need to be too high, which will add significant cost to the project. The total bytes per second for all sensors is 40121 or 40KB/s. SD cards range from 10B/S to >1MB/s, so an SD card toward the middle of the range should be sufficient.

Therefore, the following SD card has been selected:

- Hama SD card 2GB 10mb/s https://www.amazon.co.uk/Hama-High-Speed-Secure-Digital/dp/B000BGFJIG/ref=sr_1_4?crid=K0AFYDI4ZL6X&dib=eyJ2ljojMSJ9.tkL3wdIGUrnV40k9vcC1oDc0jnAQGfslabidZK2RsivtSxZW7qYM3tfKC9hu9Z6nBMEuN8yb7DszD4yy7eJYtw1OXqshOWncPqFygGlqmKzc5oKlsrSBK5ZKUxPe00sQB1dV-gL7GKnxjq_qmTaPQjkywlgFaAHokvyszGd0xcyseZNT3l76lJ-p4XkpPXB0i-BOK61xETjzP7l_c_tZGhKf1JCQLYRudAqg0eylNE.DcTqN4QWVdnXV4bARWO-MKDOAU30bnvApt7_YgWPH4w&dib_tag=se&keywords=1gb%2Bsd%2Bcard%2Bfor%2BDAQ&qid=1722510699&srefix=1gb%2Bsd%2Bcard%2Bfor%2Bdaq%2Caps%2C263&sr=8-4&th=1

4.3 Required sensors

The sensors required for this project were discussed in section 2. This section describes the specifications of each sensor that has been deemed suitable, on the back of internet research.

See Table 2 for sensor information.

Sensor Type	QTY	Temperature Range	Displacement (inches)	Current Draw (mA)	Voltage Required	Analogue/Digital	Clamp Required?	Signal Condition Required?
Reflective MPH and RPM	1	N/A	N/A	50	5	A	Y	Y
Non Contact	1	0-200c	N/A	1	5	D	Y	N
Gyroscopic	4	N/A	N/A	3	6	D	Y	N
Wire Pot	4	N/A	25	2	3.6	D	Y	N
Total	10	0-200c	25	106	6	N/A	5	2

Table 2 - Sensor Specifications

Table 2 shows the sensors required for this project. The application for this is a family saloon travelling at 85mph. So the MPH and RPM can be sensed with one sensor placed at the wheels. The temperature sensor will be placed within the engine to measure engine temperature. The gyroscopic and wire pot sensors will be placed at each wheel, so quantity of 4 per sensor.

4.4 Connector specification

Once the sensors are selected, the connectors that connect the sensors to the DAQ system need obtaining. Within the circuit design, see section 5, the connectors that were used were 2WP. Within the circuit this connects the sensor directly to either the Clamp or the Signal Conditioner (if required).

The connector should be water/dust proof as the sensors will be external may be subject to wet weather and spray from the car as it moves along.

The 2WP connector identified as suitable for this project is the following:

- Evonic WEIPU SA20 2 Pin Waterproof Connector <https://www.amazon.co.uk/Eonvic-Waterproof-Connector-Aviation-Electrical/dp/B0BKL9WVNC>

5. Task 4 – Circuit PCB Design

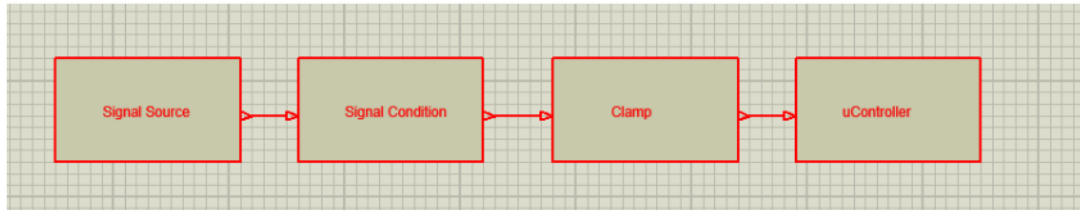


Figure 3 – Circuit Block Diagram - Flow

The circuit comprises of four main stages, which are described in the following subsections.

5.1 Signal Source

The **Signal Source** is provided from each of the sensors outputs.

5.2 Signal Conditioning

The **Signal Conditioner** manipulates the signal to prepare it for the next stage. Sensors that collect mechanical data may incur corruption to their signal due to the mechanical forces exerted on the sensor as part of the data acquisition process.

Analogue signals especially require signal conditioning because analogue signals experience instability that can prove difficult for the DAQ system to process. This can result in erroneous readings for the DAQ system, which will erode its validity. Additionally, analogue signals experience a varying voltage range. Therefore, if signal conditioning is not done before the analogue-to-digital converter (ADC), this can essentially result in a mismatch in voltage between the sensor and the ADC.

Signal conditioning often employs a filter (low pass, high pass, band pass) to block any frequencies outside of the ADC's sampling range.

Not all of the sensor circuits will require signal conditioning. This is because some of their output voltages fall below 5V – with the >5V signal sources, the signal conditioner reduces that voltage.

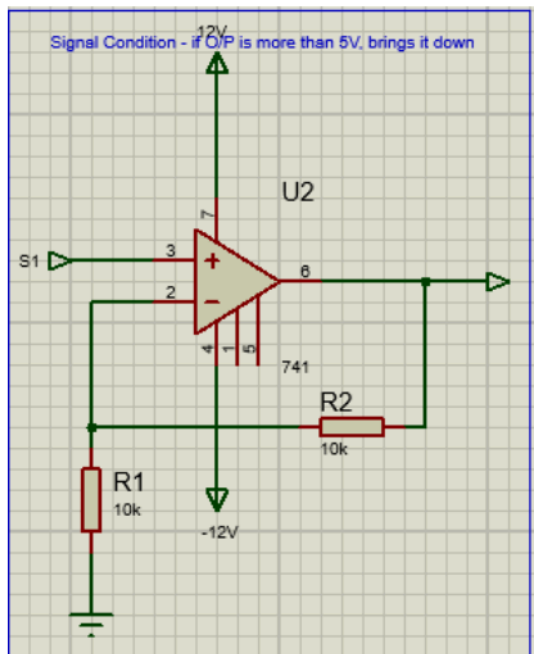


Figure 4 - Signal Conditioning Circuit

Figure 4 shows the signal conditioning circuit design on Proteus. The main component is the LM741 Op Amp, which takes the input signal and amplifies its power, producing an output signal with a voltage differing to that of the input signal voltage. The operating voltage of the 741 is up to 22V [3]. This is sufficient to facilitate the highest input voltage from the sensors, which is 6V from the gyroscope (see section 4.3 for full details).

5.3 Signal Clamping

The **Clamp** provides protection to the PIC against a high voltage input from the sensors. All sensor-to-IC circuits require a clamp.

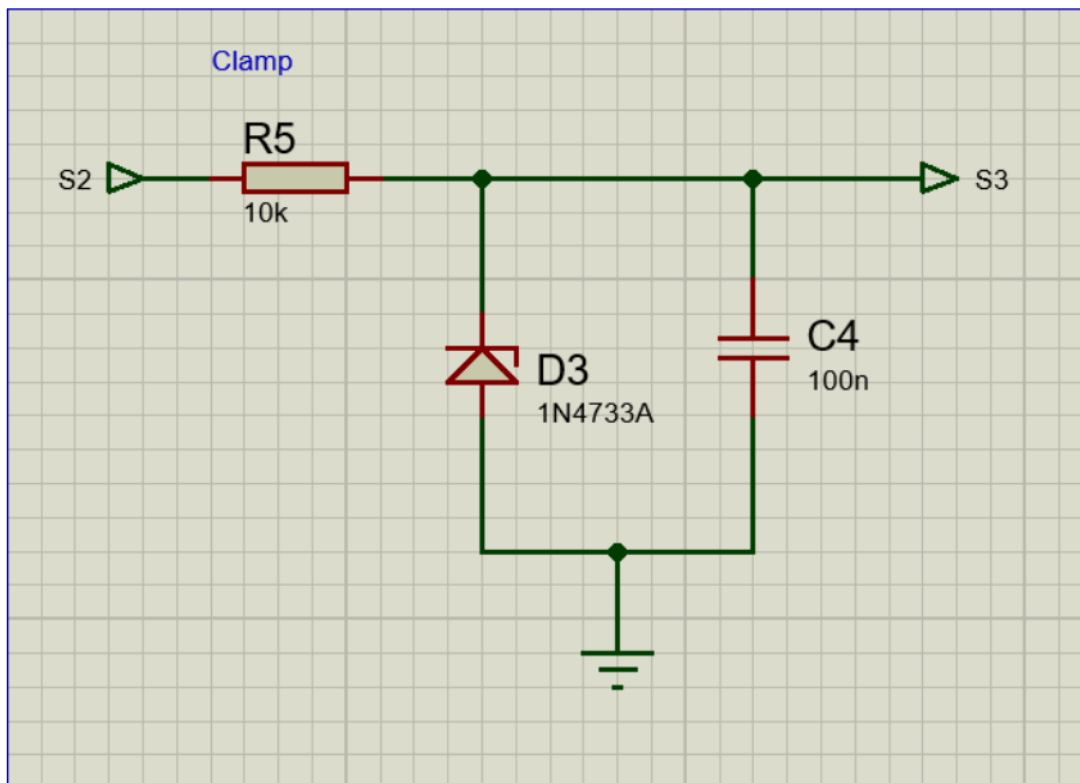


Figure 5 - Clamping Circuit

Alternatively, a Clamping Circuit integrated circuit (IC) can be used. These ICs, like the circuit above, protect the PIC from high voltage power spikes from the signal sources (sensors).

5.4 Controller

The **uController** is the PIC18F24K50 chip. This is described in section 3.

5.5 Complete Design

The circuit design consists of the following stages:

- Produce a schematic on Proteus
- Extrapolate that design on EasyPC
 - Produce circuit schematic
 - Produce PCB design

6. Task 5 – Prototype software, design and structure

The prototype was produced using EasyPC. EasyPC is a software for producing electronic circuit schematics and PCB designs.

6.1 Schematic

The first stage was to produce the circuit schematic within EasyPC.

Once a new project was set up, the component libraries had to be imported. These were sourced from the university's Moodle resources section for this module. Once these are downloaded, they are then added to the library via the design technology tab. To download any components that were not included within the provided component library, an application called *Library Loader* was used. This enabled the ability to search for a component on the Library Loader website and download its EasyPC file. This is then added to the project. This was done for the PIC18F24K50.

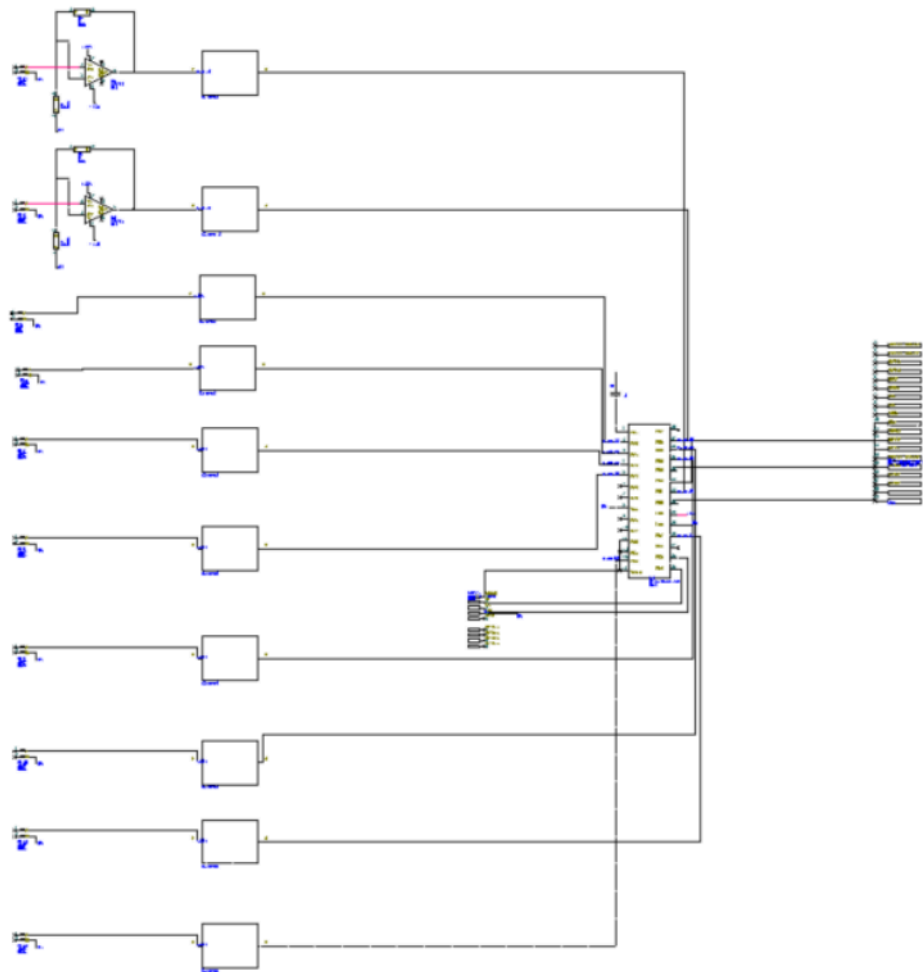


Figure 6 - EasyPC Circuit Schematic

Figure 6 shows the circuit schematic within EasyPC. This consists of, starting from the left, the signal source connectors, the signal conditioner circuit (if required), the clamps (within blocks), and then the PIC. USB and SD components are also seen on the design.

The reason the block is used for the clamps is to enable seamless medication to the clamp circuits in isolation from the rest of the circuit. Once a modification is done, that block can then be copy and pasted as an where, without the need to modify the main design.

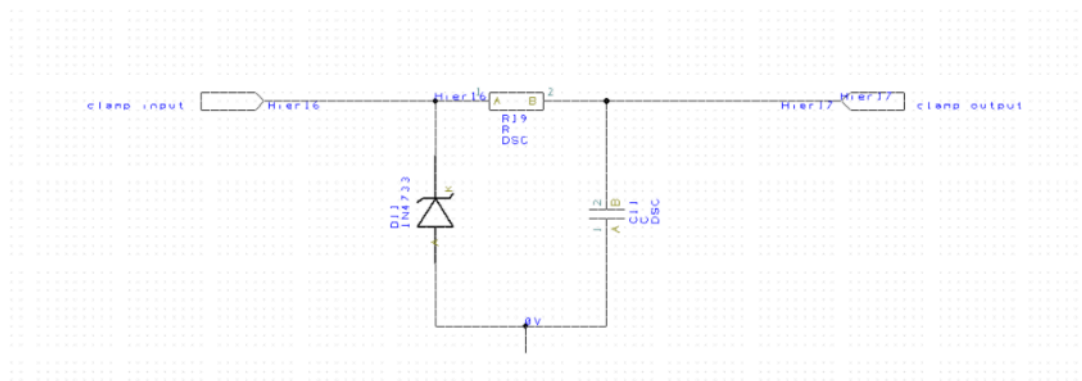


Figure 7 - EasyPC Clamp Schematic

Figure 7 shows the Clamp schematic within EasyPC. This is the circuit that was produced within a block, as mentioned previously. The clamp consists of the input, a resistor, capacitor, diode, and the output.

6.2 PCB Designer

Once the schematics is complete, they can then be used to create the PCB. This is achieved by first doing a Design Rule Check, see below:

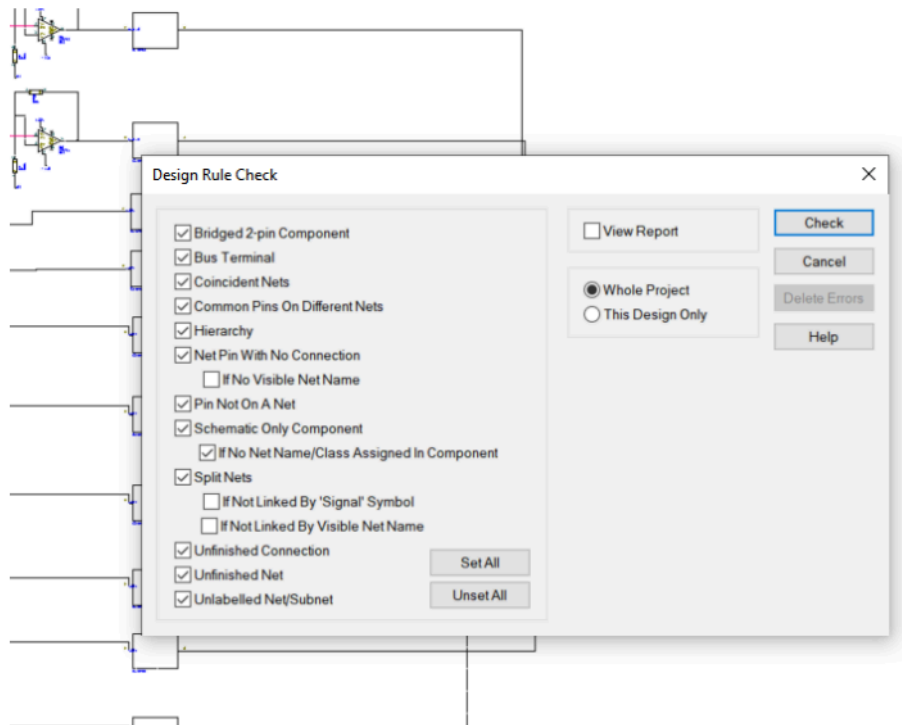


Figure 8 - Design Rule Check

Once a satisfactory Design Rule check is complete, the schematic can then be translated to PCB. This process opens up the PCB design in another window within the project, with the component list on the side. The components are placed onto the design using a drag-and-drop method. Care is taken to ensure that the components are placed neatly and as tightly packed as is possible, thus ensuring the physical footprint of the PCB is kept to a minimum.

Once the PCB components have been suitably placed onto the design, the next step is to add the 0V and 5V layers through the *Design Technology* tab, as shown in Figure 9.

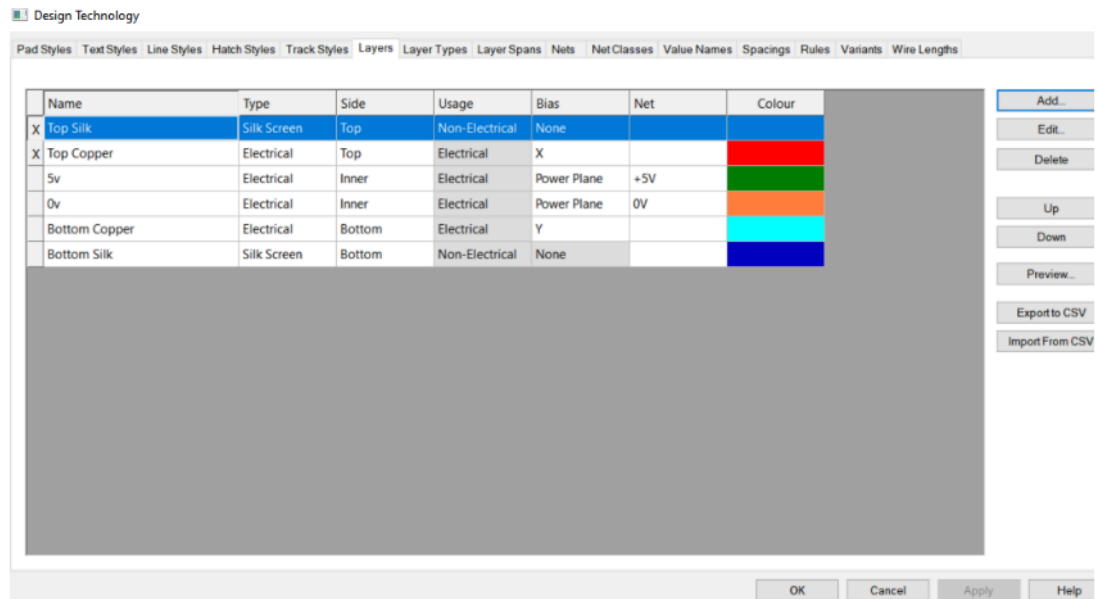


Figure 9 - Design Technology Layers Specification

Figure 10 shows the PCB design on EasyPC.

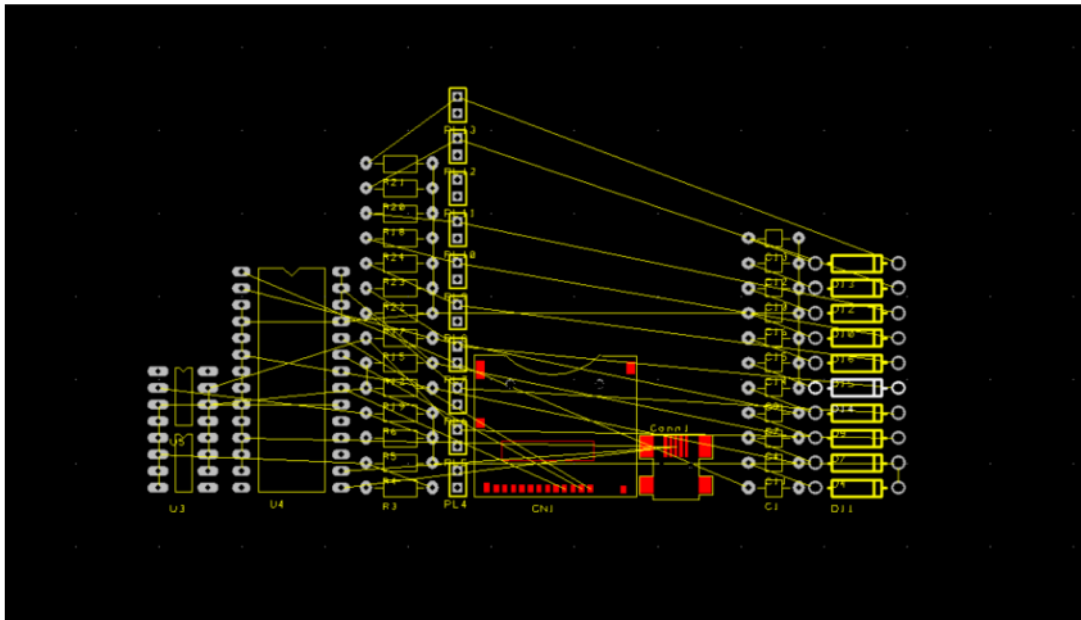


Figure 10 - PCB design

Once the components are all placed, and the layers have been added, the next stage is to conduct another Design Rule Check, in order to certify that all connections, Nets, etc. are all correct. This will be required before the final stage, which is to pour the copper. This is done per layer, and within EasyPC is done by highlighting each net, then simply pouring copper.

Once this is done, the Gerber files can now be generated. These are used to upload to a PCB manufacturer's website, which will provide a cost estimate for the manufacturer of the PCB.

7. Task 6 – Prototype build costs

The costs for this project can be observed in the Bill of Materials (BOM) in table 3

Item	Quantity	Cost (£)	Total Cost (£)	URL
Reflective sensor	1	16.42	16.42	https://uk.rs-online.com/web/p/reflective-optical-sensors/0414197
Non-contact sensor	1	POA	POA	https://www.datrontechnology.co.uk/infra-red-non-contact/
Gyroscopic sensor	4	25.91	103.64	https://uk.rs-online.com/web/p/sensor-development-tools/2475720
Wire Pot sensor	4	430.04	1720.16	https://uk.farnell.com/multicomp-pro/sp1-25/transducer-linear-cable-25-inch/dp/2146295?MER=sy-me-pd-mi-acce
DAQ Case	1			
SD Card	1	6.95	6.95	Amazon
Connector	10	23.69	236.90	https://www.amazon.co.uk/Eonvic-Waterproof-Connector-Aviation-Electrical/dp/B0BKL9WVNC
PCB	1			

Table 3 - BOM

8. Conclusions

There were various approaches to the design for this sensor circuit. The requirement to have signal conditioning depended on the sensor that was being used, and so the complexity of the circuit could have been reduced. However, the affect this has on the accuracy of the data the sensors collect is not known and could be explored in future iterations of this project.

9. Recommendations

Various recommendations can be made based on the work conducted for this task.

- Reduce design complexities by using a different sensor to measure speed and RPM that would not require signal conditioning. This would save component costs, but this would have to be balanced out by any potential increases in sensor prices
- Design
 - The blocks have input and output connections to the rest of the circuit, which have to be associated with their respective blocks. This caused various errors within the circuit due to block port errors. This caused confusion, and hindered the ability to translate to PCB. The Next time, blocks should either not be used, or need to be set up properly in order to avoid these errors.
- Resolve issues with copper pouring in order to be able to generate the gerber files.

References

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- [3 National Semiconductor Corp., "LM741 Operational Amplifier," 2000.
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- [6 S. Rise, "Ring Modulator," The Synthesiser Academy, [Online]. Available:
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- [7 M. Steer, "Analog Modulation," LibreTexts Engineering, [Online]. Available:
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CF ESD Assignment

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

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GRADING FORM: SMU GENERIC_GJ

CAMERON FITZE

32.75

RESEARCH-INFORMED LITERATURE



The literature review is very limited and would be improved by adding devices, a review of each device and followed up with a comparison table of pros and cons as you see them. This was a practical assignment so just talking about what such a device can do is insufficient 35%

3.5

KNOWLEDGE AND UNDERSTANDING



The circuit diagram is incomplete with no signal conditioning shown except one amplifier which has a -12v power line but no -12V is available in the design. A 100nf cap should be placed between the power lines as close to the microcontroller as possible to try to contain noise. 25%

6.25

ANALYSIS



Good selection of microcontroller, but where did the numbers come from, ram, clock speed etc. The casing is not suitable as there is no room for a battery and insufficient space for bulkhead connectors. You have not selected any sensors other than to say they must have certain attributes, Why would the gyroscopic sensors be placed at the wheels?? The connectors are reasonable but only suitable for 2 pin devices. 40%

14

PRACTICAL APPLICATION AND DEP.



The costings, are not related to actual components and are therefore meaningless guesstimates. 20%

4

SKILLS FOR PROFESSIONAL PRAC.



The report is poorly presented but contains some tabled data and a few images/illustrations . A poor array of references were included. More care and understanding of the assignment including better time management would have seen a huge improvement in the quality of this submission which is unexpectedly disappointing. 50%