

ESD Assignment - LC

by Louise Caygill

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Designing a Car Data Logger System

Electronic Systems Design ACDA6002

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[Date]

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Introduction

This report documents the proposed design of an automated car data logger. It is designed to monitor the RPM and temperature of the engine, as well vehicle speed, pitch, roll and yaw, and front and rear suspension travel. The system will acquire data over a 2-hour test track run, during which the data acquired will be sent to non-volatile memory on board the PCB. This data will then be able to be read and cleared when connected to a PC through the USB-C port.

Sections include a literature review, microcontroller and data specification, hardware, circuit design, prototype design, prototype build costs, potential future improvements and a conclusion.

Literature Review

A vehicle data acquisition system is used to test various features or forces on a car, such as acceleration, velocity, body roll and vibration [1]. They may also be used for insurance purposes through the use of a "black box" recording system [2].

For this assignment, four systems will be compared, the SIRIUS R1DB from DEWESoft, Figure 1 [3] below, the RT3000 v4 from OxTS (Oxford Technical Solutions), also Figure 1 below [4], ARGUSfit from imc, Figure 2 below [5], and the Granite 10 from Campbell Scientific, also Figure 2 below [6].



Figure 1: DEWESoft SIRIUS, left and RT3000 v4, right

The DEWESoft SIRIUS, may be connected to up to 16 analogue, 8 counter or encoder, 24 digital or 9 CAN bus inputs. It also has an inbuilt screen and can run on batteries to be a fully portable unit.

The RT3000 v4 can measure altitude, velocity, roll and pitch, true heading and slip angle as well as global positioning through. It is a smaller system than the others listed, making it more portable.

The ARGUSfit from imc, Figure 2 below, is entirely modular, instead of being one unit, it has different units that connect to make the whole system, building from one base unit. The sensors that the user wants are then connected to measure the characteristics under test. The system comprises of a base model unit, alongside two additional test units. Each test unit is



Figure 2: ARGUSfit, left and Granite 10, right

sold separately, with the base model only having two connections for sensors, and power, microSD and LAN slots.

Lastly is the Granite 10 Campbell Scientific. It is an all-digital base unit, designed to connect to multiple external sources including the sensors. It is able to wirelessly communicate to a controlling PC.

UNIT	Modular	wireless	Screen	GPS	Add units	Able to work standalone	Assignment parameters			
							RPM/Speed	TEMP	Suspension	PRY/Gyroscope
DEWESoft SIRIUS R1DB	Y	Y	Y	Y	Y	Y	N	Y	N	N
RT3000 v4	N	N	N	Y	Y	N	Y	N	N	Y
ARGUSFit	Y	Y	N	Y	Y	Y	N	N	N	N
Granite 10	Y	Y	N	N	Y	N	N	N	N	N

Figure 3: DAQ Systems Comparison Table

The table in Figure 3 above shows a comparison of the 4 units. It can be seen that all systems are able to have extra units added on, whilst only two of the units, the Sirius and the ARGUSFit, are able to work without the addition of other units. All of the units bar the RT3000 are capable of wireless and all bar the Granite 10 have inbuilt GPS. From the table the DEWESoft Sirius unit is the most complete and capable system by itself.

Microcontroller and Data

For the purposes of this assignment a total of 22 pins were needed; 8 analogue pins for connections to the sensors, 4 pins to connect to the USB, 2 digital, 2 pins for debugging and 1 pin each for power and indication (indication here meaning that the system is powered on and running). The clock speed needed to be fast enough to be able to fulfil the needs of the various sensors and the tasks, which returned a minimum of 32MHz.

The chosen microcontroller needed to have the following parameters:

- 8-Bit family
- 22 I/O pins
 - 2 digital
 - 8 analogue
 - 4 micro-SD/USB connections
 - 1 power
 - 1 indicator
 - 2 debug
- 32MHz clock speed
- 1 UART
- 1 USB
- SPI comms (for SD card)

From this the MicroChip Advanced Part Selector was used, and the above parameters entered. This returned the PIC18F24K50 [7] among others. The PIC18F24K50 was chosen due to familiarity with it compared to the alternatives presented.

The data is to be sent in packets of 70 bytes every 250uS, which translates to 2.016GB of data over the two-hour test run, resulting in a 4GB SD card being required to run the system at a suitable speed. The data packets are structured as below in Figure 4. This number is found through the fact that the suspension sensors are checking and producing data every 0.00005s, due to the speed of the vehicle and the rate at which bumps can be experienced. Therefore, the data needed to be sent at a rate that would not overwhelm the memory and PIC. It was thus decided to use 70 bytes at a time to ease congestion. As seen in Figure 4 below in the proposed data packet structure there are two bytes for each suspension sensor sent in each packet.

0	TMP	MPH	RPM	P	R	Y	S1	S1	S2	S2	S3	S3	S4	S4
1	TMP	MPH	RPM	P	R	Y	S1	S1	S2	S2	S3	S3	S4	S4
2	TMP	MPH	RPM	P	R	Y	S1	S1	S2	S2	S3	S3	S4	S4
3	TMP	MPH	RPM	P	R	Y	S1	S1	S2	S2	S3	S3	S4	S4
4	TMP	MPH	RPM	P	R	Y	S1	S1	S2	S2	S3	S3	S4	S4
70 BYTES														

Figure 4: Structure of Data Packets in Memory

Hardware

Enclosure

The enclosure is made of ABS and flanged so that it is able to be mounted to the vehicle or a mounting plate that will sit in the vehicle to make it more stable if needs be. Plastic was selected to reduce the risk of a short across any connections on the PCB or wires, it is also tall enough so that the wires within the box will have space and reduce the likelihood of kinks being made in the wires leading to damage. As it will be inside the vehicle the enclosure doesn't need to be IP rated or water/dust resistant. The PCB will be affixed to the flanged half of the box using screws specified in the build costs table. This will give the connectors and the wires plenty of space to sit in the taller part of the box, with the sensors connected through panel mount connectors around the sides of the box.



Figure 5: Image of Selected Enclosure

Sensor Selection

As mentioned previously, the system would acquire the following data:

- RPM and temperature of engine
- Vehicle speed (MPH)
- Suspension travel
- Pitch roll and yaw (PRY)

Therefore, the following sensors were chosen.

RPM and MPH

The speed of the vehicle and the RPM of the engine will make use of the same type of optical sensor from Optek. An OPB720B-06Z optical Speed Sensor [8]. The sensor is non-contact and will count edges crossing its threshold to monitor the RPM and speed. In the case of this assignment, one will be placed so that it may read the revolutions of the cam belt for the engine RPM, and the other the tyre revolutions for the vehicle MPH. The sensor requires a supply voltage of 4-7V, and has a working ambient temperature range of 0°C to 70°C.



Figure 6: Calex PyroCouple Temperature Sensor

Temperature

An infrared sensor was required for temperature in order to remain contactless, and a Calex PyroCouple General Purpose Infrared Temperature Sensor was selected, seen in Figure 6 above [9]. This sensor is infrared (IR) meaning that it is able to monitor the temperature without having to be attached to the item being monitored. It also has a supply voltage of 6-28V DC, meaning that it is able to be powered from the selected battery. Finally, it has an IP65 rating, with a working temperature range of -0°C to 250°C, it is protected from dust and water ingress and covers the expected range of the engine temperature [10].

Suspension travel

The best type of sensor for this data was decided as a wire or string potentiometer. As such the SP2 Compact String Pot from Measurement Specialties was chosen [11]. It is relatively small, ruggedised and has a stroke range of 50 inches, which can more than accommodate the travel of the suspension. As the length of the arm extends, the resistance of the potentiometer is increased, reducing the voltage seen at the output. The supply voltage is a maximum of 30V, meaning it is able to be powered by the same central supply. It is IP50 rated and has an operating temperature of -18°C to 71°C. The temperature range will cover the expected conditions, but the IP50 rating could be improved, as it only prevents dust ingress, not liquids. However, it is able to withstand vibrations of up to 2KHz, and will be suitable for the purposes of the assignment where the vehicle will be based on a test track rather than public roads.

PRY

It was decided to use a gyroscope to monitor the PRY of the vehicle. The Analog Devices ADXL335 [12] was therefore chosen due to its 5V power supply, ability to withstand high levels of shock or vibration, its small size allowing it to sit on top of the control PCB, plus low cost. As it will sit atop the PCB, it will use an 8-pin header rather than the connectors identified later in the section. This sensor also comes on an evaluation board, meaning that the connections

to and from the gyroscope are much simpler, and it is able to provide its own supply voltage regulation when given a 5V supply. The evaluation board may be seen in Figure 8 below [13].

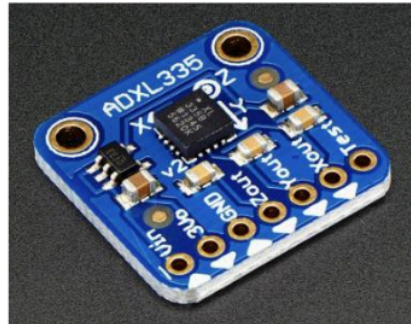


Figure 7: ADXL335 from Analog Devices

Battery Supply

All of the sensors will work comfortably at 5V, bar the temperature sensor which requires 6V. The current needed by the system is in the milli amps. Factoring in redundancy and the multiples of sensors, the power supply should be capable of producing around 2A, meaning a 6V, 4Ah battery will be beneficial. As such, the 6N4-2A-4 Numax Motorcycle Battery from GO Batteries was selected, seen in Figure 7 below [14]. The 6N4-2A-4 is a motorcycle battery and as such will be able to withstand the vibrations and forces created by a motor vehicle. Additionally, it is relatively small, being 71x71x96mm, meaning it will not be ungainly or take up too much space in the vehicle.



Figure 8: GO Batteries 6V 4Ah Motorcycle Battery

Choosing 6V for the battery negates the need for multiple voltage regulators. The 5V components simply require a single step-down regulator. As the step down from 6V to 5V is so small, a low drop out voltage regulator was required. For this reason, a TSRN 1-2450 from Tracopower [15] was selected. By choosing 5V for the majority of the sensors, the resultant

outputs will not have to go through signal conditioning, bar the output from the gyroscopes, reducing the size and cost of the PCB, as well as potential sources of interference to the lines.

Connectors

Lastly, the Molex Mini-Lock series of connectors were chosen for the design, Figure 9 overleaf [16]. These come in 2-10 pin configurations and have a tab on the plug and header that not only stops the connector from being put in the wrong way round, but also holds the connection firmly in place, meaning it shouldn't be knocked out due to vibrations. They also have a

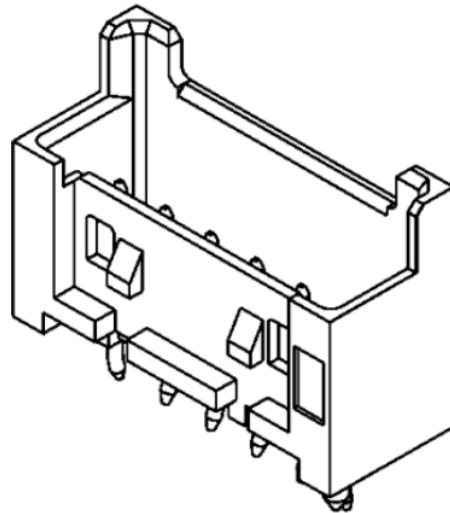


Figure 10: Molex Mini-Lock PCB Header

standard pitch of 2.5mm, which will fit the headers used in the PCB design. The board makes use of 2, and 3-pin connectors. Using the same type of header will reduce the costs associated with purchasing crimps and crimp tools, but means that the board the box will need to be clearly labelled.



Figure 9: RS Pro Circular Connectors

To connect to the sensors outside of the box, the RS Pro range of circular connectors was selected, examples of which are seen above in Figure 10. These are threaded connectors

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which will not come undone during the stresses exerted during the test run and have a current rating of 1A and a voltage rating of 48V. More than ample for the proposed system.

Circuit Design

Initially, the circuit was designed using Proteus 8 Professional [17], which may be seen overleaf in Figure 13. The block diagram of the circuit may be seen below in Figure 11, as demonstrated the sensors create the signal sources, which then enter the clamp circuits, with the gyro first going through signal conditioning before entering the clamp. The signal then enters the PIC which writes to the SD card.

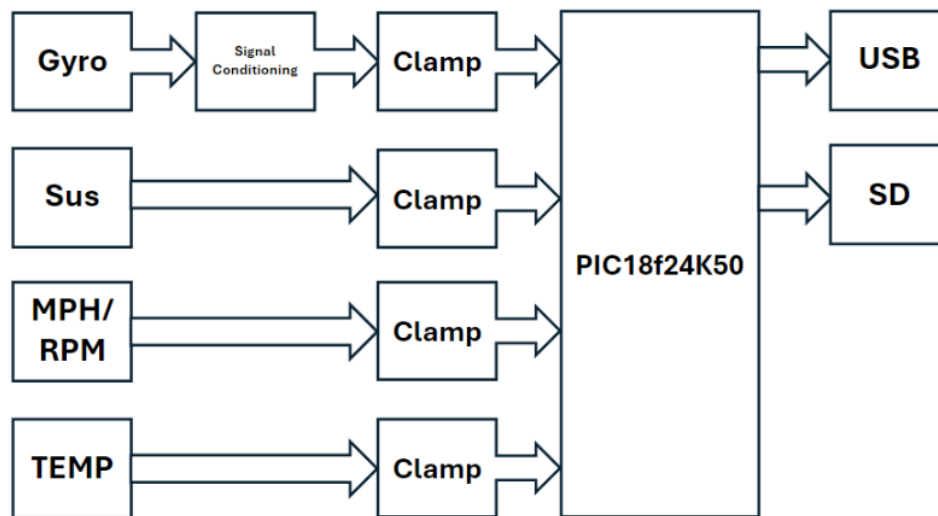


Figure 11: Schematic Block Diagram

The circuit diagram and associated PCB design were both created using the Easy-PC software package [18]. The design of the circuit works thusly, the sensor input enters the board through one of the Molex connectors, and if it is above 5V, such as the gyroscope outputs, the signal enters a signal conditioning circuit and then a clamp. This protects the PIC from any over-voltage that may be sent from a sensor. As most of the sensors can work at 5V, the same as the PIC, not many of these additional circuits are needed. The circuit schematic diagram may be seen rotated 90° overleaf in Figure 12 (a larger image may be found in Appendix 1). The top row is the power in, +5V linear regulator, button connector, RxTx/debug header and the header for the gyroscope. Underneath in the first two columns are the various sensor inputs and their clamps, which will protect the microcontroller from any erroneous signals that may result from the sensors in over voltage, causing the PIC damage. In the next column is the PIC itself, with the LED circuit and the USB and SD connectors. Finally, to the right of the PIC are two dual op amp TLC252CP [19] from Texas Instruments that are used to condition the signals from the gyroscope. These prepare the analogue signals for the next stage of processing, so that they may be accurately read by the PIC [20].

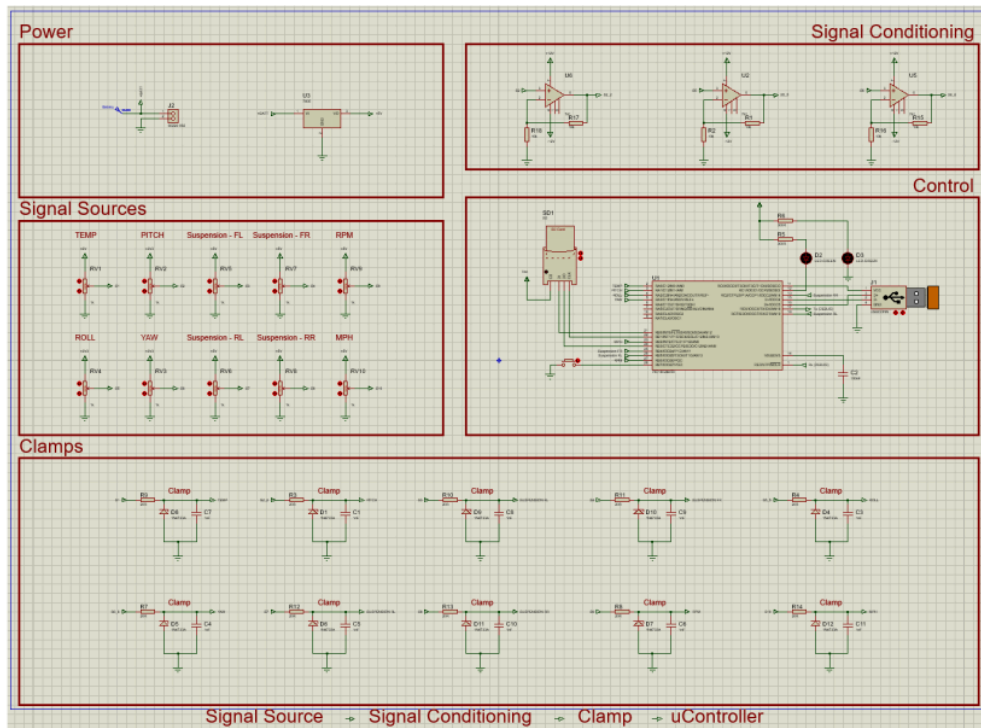


Figure 13: Proteus Circuit Schematic

All of the sensors have been designed to be off board.

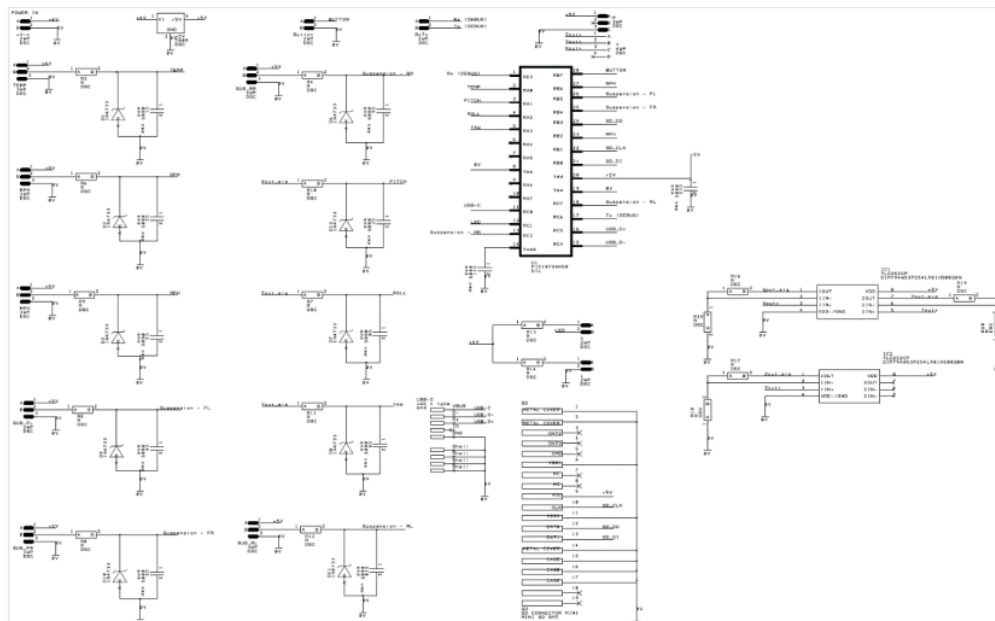


Figure 12: Circuit Schematic Diagram

PCB Design

It was decided to layout the PCB around the PIC, as it was the largest single component and made connections on either side. The layout may be seen in Figure 14 below (a larger image of which can be found in Appendix 2). As stated, the PIC is in the middle of the board, with the clamp circuits for the sensor connections surrounding, and the connectors for the sensors themselves placed around the edge of the board for ease of access. At the bottom of the board sits the SD card slot and USB-C connector. They are placed separately from the other components so that they can sit on the edge of the board, enabling to user to easily plug and un-plug the USB-C cable, and remove or insert the SD card into the reader. Surface mount components were used for the resistors and capacitors to increase the usable space on the board design, as well as produce a more uniform and professional finish.

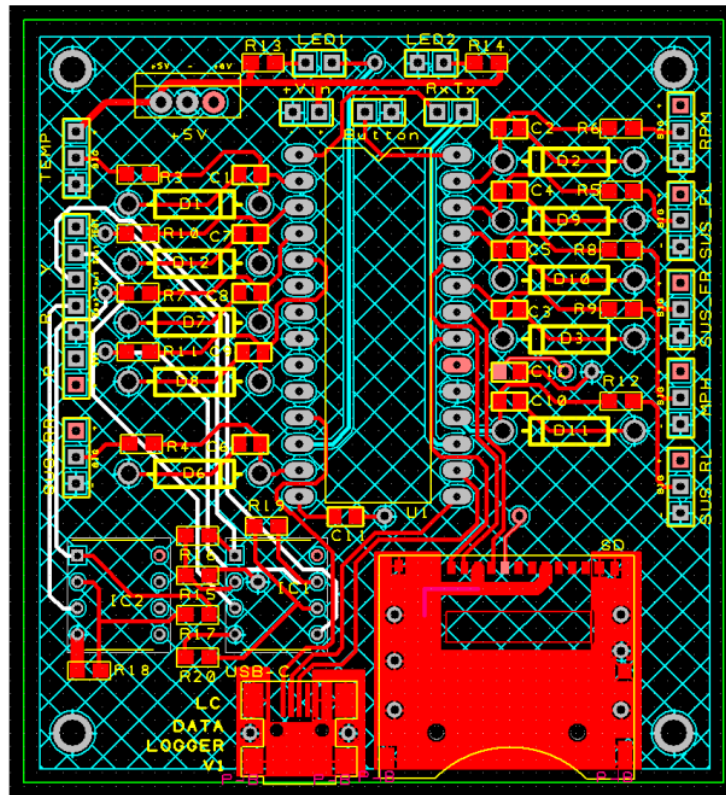


Figure 14: PCB Design

The board is comprised of four layers. It was possible to complete the design in two layers, however, for ease of track routing, it was decided to create middle layers to distribute the 5V around the board for the sensors and external connections, and to add the connections for the signal conditioning op amps, rather than having to route each individually. Similarly, on the bottom layer is a ground pour to connect the grounds in the design together, reducing the number of tracks needed on the board and saving space. The +6V lines are given a wider track width to reduce any chance of overheating.

Lastly, everything on the board is labelled, not only with the designators so that the components are able to be identified during production, but also so that the user is able to identify where sensors connect, with a plus and a minus simple to designate power and ground. The connectors themselves will only plug in one way due to a clip that keeps a secure connection, so this step wasn't necessary, however, it signifies where voltages and signals are present around the board, which may help to identify test points more easily for the user during fault finding.

The finished PCB was then uploaded to JLC PCB for a quote. As can be seen in Figure 15 below the total cost for the manufacture of 5 boards is \$11.90 (£9.25) with a lead time of 3-4 days, not including shipping.

The screenshot displays the JLC PCB configuration interface. At the top, there are tabs for 'Standard PCB/PCBA', 'Advanced PCB/PCBA' (selected), 'SMT-Stencil', and '3D Printing/CNC'. Below the tabs, two PCB layout images are shown. The main configuration area includes:

- Back to Upload File** and **Gerber Viewer** links.
- Detected 3 layer board of 74.8x68.77mm(2.94x2.71 inches)**.
- Base Material**: FR-4 (selected), Flex, Aluminum, Copper Core, Rogers, PTFE Teflon.
- Layers**: 1, 2, 4 (selected), High Precision PCB, 8, 10, 12, 14, 16, 18, 20.
- Dimensions**: 68.77 * 74.8.
- PCB Qty**: 5.
- Product Type**: Industrial/Consumer electronics (selected), Aerospace, Medical.

 On the right side, the **Charge Details** section shows:

- Special Offer**: \$7.00
- Via Covering**: \$0.00
- Surface Finish**: \$4.90
- Build Time**:
 - PCB: 3-4 days (selected) \$0.00
 - 3 days PCB Only \$0.00
 - 2-3 days \$62.90
- Calculated Price**: **\$11.90** (Additional charges may apply for special cases).
- SAVE TO CART** button.
- Shipping Estimate**:
 - DHL Express Worldwide: \$20.80
 - 2-4 business days
 - Weight: 0.21kg
- Coupons**: Save \$20 >

Figure 15: PCB Manufacture Costs

Software Design

The software will run as seen in Figure 16 below. The system will run a count and at certain intervals will perform a reading and raise a flag. Once a certain amount of time has elapsed the counter and flags will be reset. Another counter will be running to time when two hours have passed. Upon 2 hours elapsing the system will stop, ceasing all readings. The user will then be able to connect to the system using the USB port and may choose to clear the

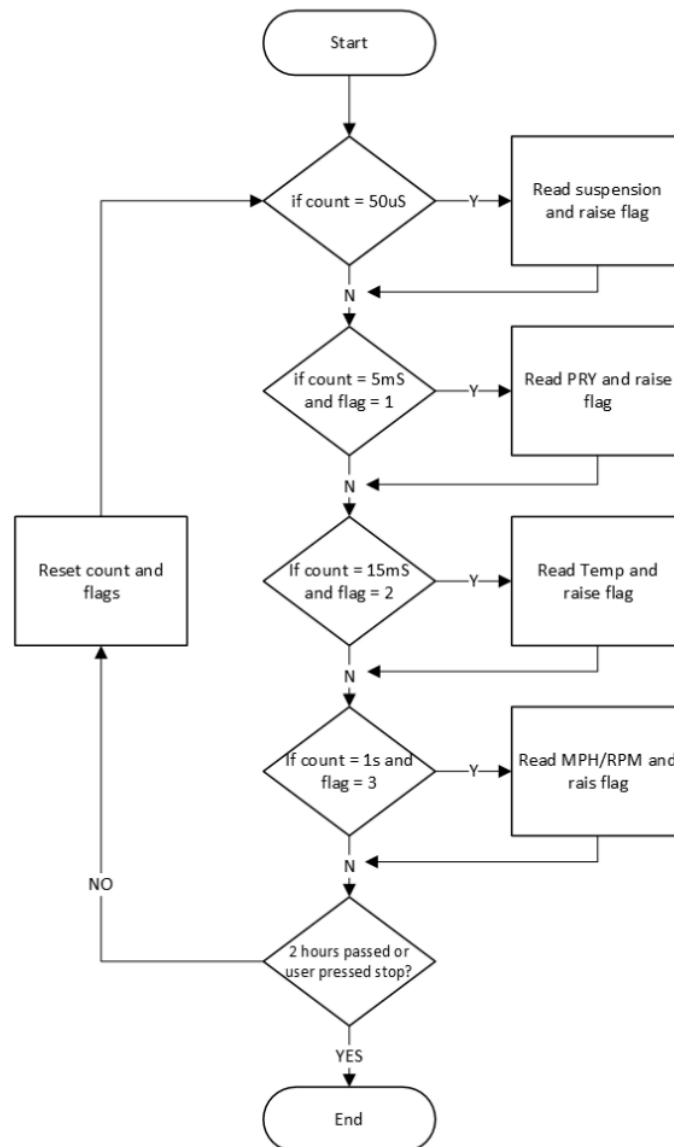


Figure 16: Software Operation Flowchart

readings. The user may also decide to remove the SD card from the slot to plug it into a PC to read and clear.

Prototype Build Costs

The total cost for the prototype build totalled just over £2000. The majority of this cost was the sensors themselves, as seen in Figure 17 below.

	Item	cost (£)	qty	total	supplier/link	Section Total
POWER	Battery	16.99	1	16.99	battery-6v-4ah/	62.12
	5V Regulator	7.78	1	11.66	https://uk.rs-online.com/web/p	
	TLC252CP	2	6.2	12.4	https://uk.rs-online.com/web/p	
	Resistor 20ohm (0805)	0.049	100	4.9	https://uk.rs-online.com/web/p	
	Resistor 330ohm (0805)	0.02	50	1	https://uk.rs-online.com/web/p	
	Resistor 10kohm (0805)	0.475	10	4.75	https://uk.rs-online.com/web/p	
	Capacitor 100nF (0805)	0.047	25	1.175	https://uk.rs-online.com/web/p	
	Capacitor 1nF (0805)	0.07	50	3.5	https://uk.rs-online.com/web/p	
	Diode 1N4733	0.147	20	2.94	https://www.mouser.co.uk/Prod	
	LED - Red (0805)	0.362	5	1.81	https://uk.rs-online.com/web/p	
	LED - Green (0805)	0.199	5	0.995	https://uk.rs-online.com/web/p	
	PIC18F24K50	2.73	2	5.46	https://www.mouser.co.uk/Prod	
CONTROL	USB Port	3.122	5	15.61	https://uk.rs-online.com/web/p	58.22
	SD Card Port	4.76	1	4.76	https://uk.rs-online.com/web/p	
	SD Card	14.69	1	14.69	https://uk.rs-online.com/web/p	
	Button	17.7	1	17.7	https://uk.rs-online.com/web/p	
SENSORS	Gyroscope	14.1	1	14.1	https://thepihut.com/products/	1831.94
	Wire pots	385.05	4	1540.2	https://uk.rs-online.com/web/p	
	Temperature	244.8	1	244.8	https://uk.rs-online.com/web/p	
	RPM/MPH	16.42	2	32.84	https://uk.rs-online.com/web/p	
HARDWARE	Enclosure	6.55	1	6.55	https://uk.rs-online.com/web/p	84.7
	PCB Mounting screws	8.77	1	8.77	https://uk.rs-online.com/web/p	
	Nuts	12.71	1	12.71	https://uk.rs-online.com/web/p	
	LED Mounts	1.591	5	7.955	https://uk.rs-online.com/web/p	
	2 pin plug	0.056	10	0.56	https://uk.rs-online.com/web/p	
	3 pin plug	0.187	10	1.87	https://uk.rs-online.com/web/p	
	8 pin plug	0.07	10	0.7	https://uk.rs-online.com/web/p	
	2 pin header	0.281	10	2.81	https://uk.rs-online.com/web/p	
	3 pin connector	0.196	10	1.96	https://uk.rs-online.com/web/p	
	8 pin connector	0.542	10	5.42	https://uk.rs-online.com/web/p	
	Crimps	0.078	100	7.8	https://uk.rs-online.com/web/p	
	Panel mount 2 pin	3.61	1	3.61	https://uk.rs-online.com/web/p	
	Panel mount 3 pin	5.34	1	5.34	https://uk.rs-online.com/web/p	
	Cable mount 2 pin	5.34	1	5.34	https://uk.rs-online.com/web/p	
	Cable mount 3 pin	5.62	1	5.62	https://uk.rs-online.com/web/p	
	8 pin header	1.537	5	7.685	https://uk.rs-online.com/web/p	
Build Total				2036.98		

Figure 17: Bill of Materials Spreadsheet

Added to the BOM are the mounting screws and mounts for the LEDs to sit flush to the enclosure. Additionally, there are the passive components such as resistors and capacitors that make up the basis of the circuit. Not included in the BOM is any cabling, as these will be sourced from lab supplies.

Future Improvements

In the future to improve the PCB design, as the USB-C port and SD card slot are surface mount components with two drill holes each to position, they may be placed on the rear of the board to further compact the design and achieve a sleeker finish.

It may also be prudent to change all components that are able to surface mount to reduce the overall size of the board and allow for a more compact finish. This would also mean that both sides of the boards are able to be utilised effectively.

Additionally, the system could be designed to receive more sensor inputs for different parameters, such as acceleration, humidity, g-force etc. With a screen as with the DEWESoft Sirius unit, and inbuilt software in order to be a fully portable, self-contained unit.

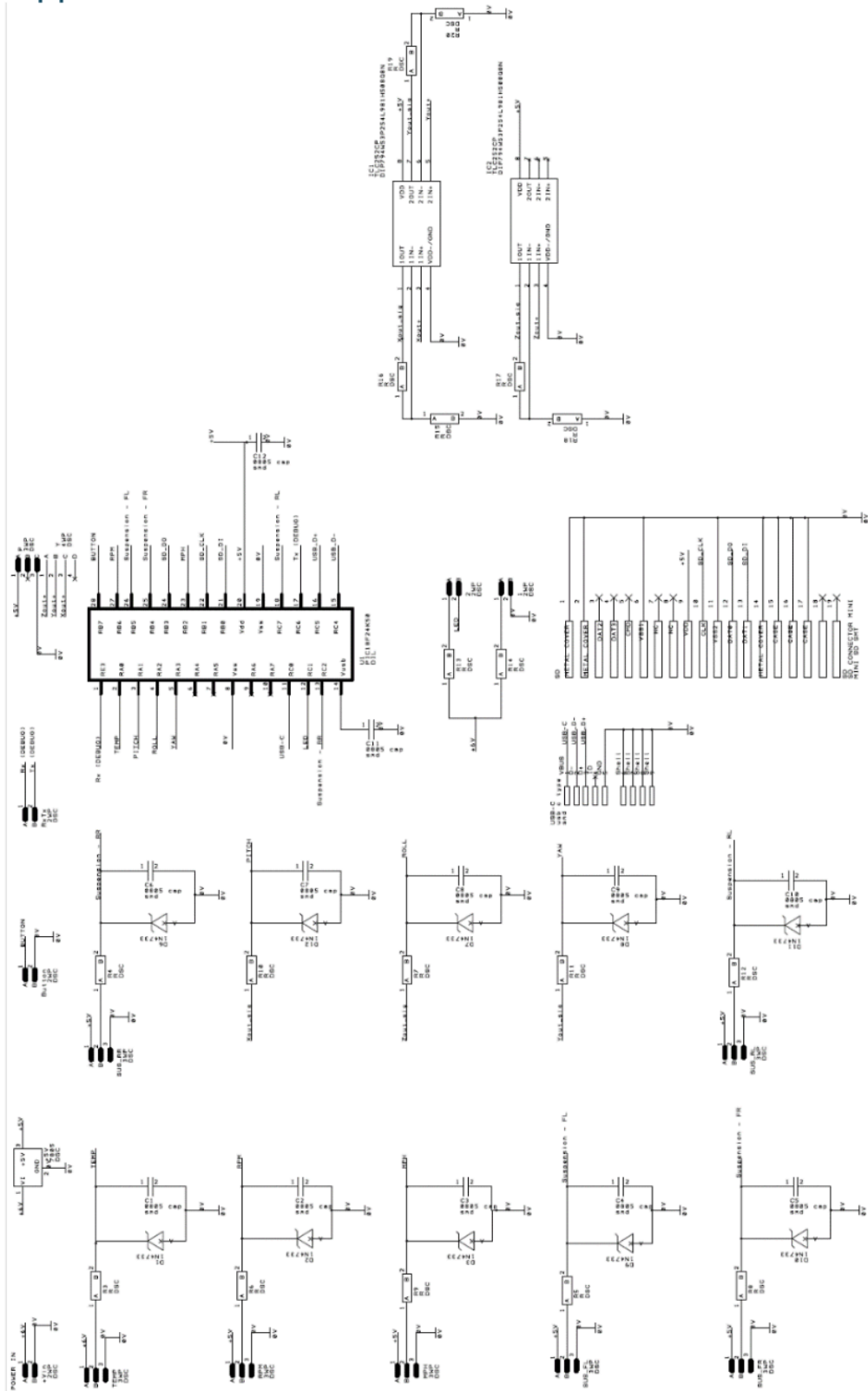
Alternatively, the unit could be made to be wireless and communicate with a PC system in real time instead of storing the data. This will also mean that the user is able to see if there are any issues with the system, such as it not functioning properly, in quicker time and may end the test early, saving time.

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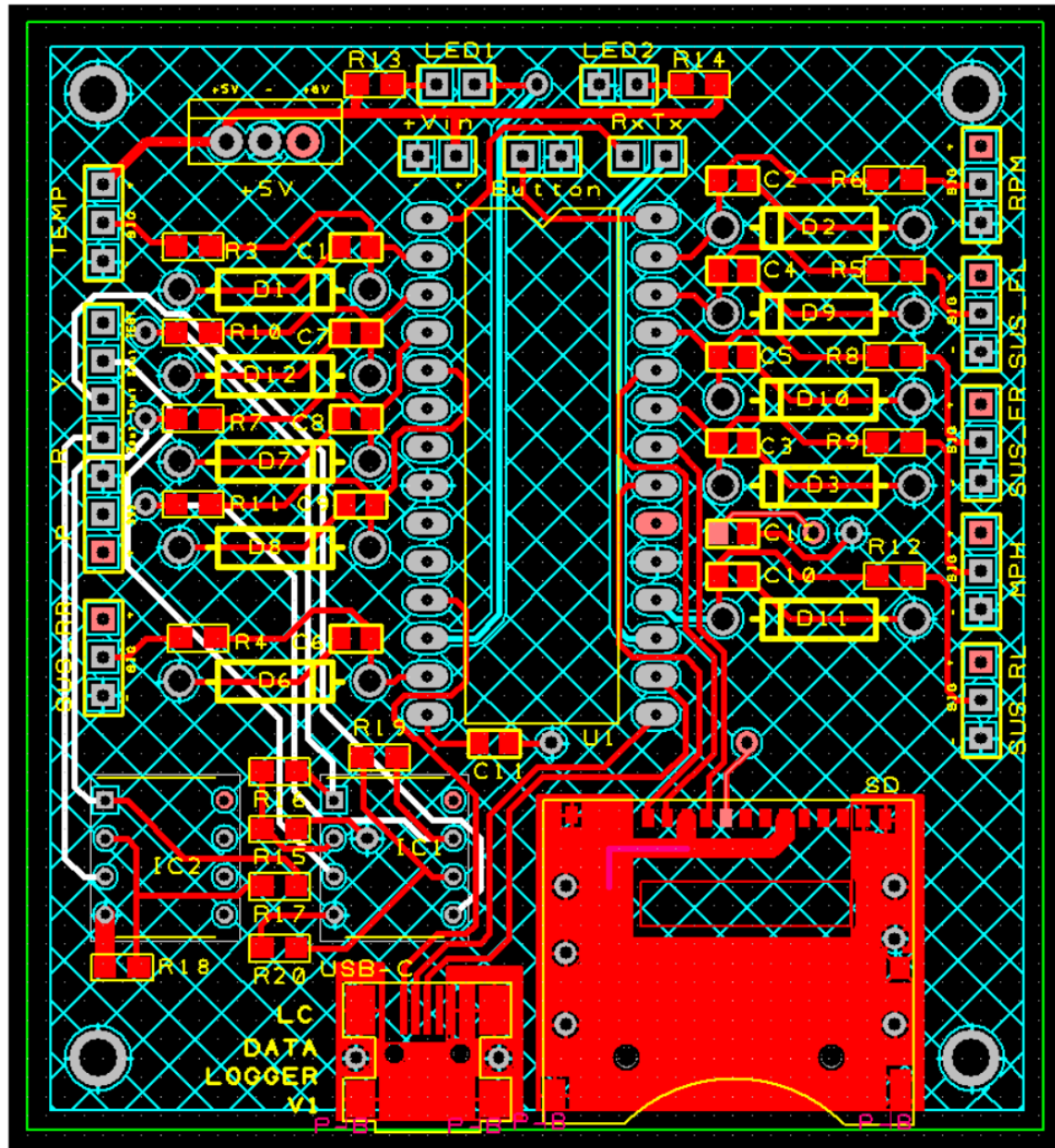
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Appendix 1



Appendix 2



ESD Assignment - LC

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

73/100

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GRADING FORM: SMU GENERIC_GJ

LOUISE CAYGILL

73.25

RESEARCH-INFORMED LITERATURE



Good literature review of available systems with a fairly good comparison table of relevant information.67%

6.7

KNOWLEDGE AND UNDERSTANDING



Your schematic diagram is good but there are a couple of issues, there is a -12V going to the amplifiers, although there is no -12v source, the 7805(U3) should have a tank capacitor before it and a smoothing pair of caps after it, and all of the capacitors in the clamps should have been 100nF

18.75

or 0.1uF. Your chosen regulator needs 6.5V min not 6V to operate. A very good attempt 75%

ANALYSIS



Good selection of microcontroller, questionable selection of casing as there does not appear to be sufficient room for the battery and no protected place for the bulkhead connectors. Good selection of sensors although given the nature of suspension reading and the high likelihood of wet conditions as you state an IP rating of 50 is insufficient. A 100nf cap should be placed between the power lines as close to the microcontroller as possible. Your connectors are good but they really should have gold contacts to minimise resistive losses. 70%

24.5

PRACTICAL APPLICATION AND DEP.



your costings are nicely tabulated and carry supplier and part numbers. Good attempt at future enhancements. 78%

15.6

SKILLS FOR PROFESSIONAL PRAC.



The report is well presented with some good explanations of choices and images. Excellent selection of references. 77%

7.7