

ESD_Assignment

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Electronic Systems Design Report



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L6 – Electronic Systems Design
(ACDA6002)

Embedded Electronics Degree Apprenticeship

Abstract

This report details the design process and costings of this system. The system will need to be able to measure the RPM, engine temperature, front and rear suspension, pitch/roll/yaw and the vehicle speed. The system will need to be able to sample the sensors at 4 different sensors at given rates and be capable of storing that information into an SD card for the user to analyse. The device will need to be water resistant and portable and therefore will require it to be powered by a battery.

The choice of sensors will be determined by how capable and accurate they are. For this system all the sensors are specified to have at least an IP65 rating and an output voltage of 5V maximum to ensure they are compatible with the PIC series microcontrollers.

The enclosure selected must be capable of fitting the final PCB design, a battery and the external connectors need to be mountable. Having external connectors ensures that the electronics inside the Pelicase remain protected when using the system in the car.

The microcontroller must have enough pins to accommodate all the sensors and external outputs. It must also have enough RAM to temporarily store the data before being transferred to the SD card. The clock speed of the microcontroller also needs to be considered as it will determine whether it can sample the sensors at the desired rate. Calculations to determine this will be detailed in the report justifying the reason for choice of storage and sensor.

The schematic of the system will be designed and created on a PCB to determine the size and cost which will be detailed in the report as well. The costings for all the sensors, components and manufacture will be listed in the report giving an overview of the price for this prototype.

Suggested improvements and considerations will be detailed at the end of the report for possible future upgrades and improvements. This includes developing a GUI for the user, configurable external ports, additional built in sensors and support for CAN bus.

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Literature Review

Data Logger	Race Technology DL1	CAS Dataloggers Influx Rebel LT	AIM Technologies EVO4s
Features	Logging to SD Card 12 external sensors Timing GPS USB Connection for live monitoring Compatible with CAN Bus Built in accelerometers Built in ECU serial interface	2 x CAN Bus ports 1 x K-Line 4 x Digital/Analog Inputs SD Card logging Supports module analyser Internal GPS	Supports CAN, RS232, K-Line Internal accelerometers and gyro Internal GPS 5 Configurable Channels RPM Speed ECU USB
Benefits	All in one package with support for external sensors Supports CAN Bus Small package size Ruggedised Waterproofed Live data feed	All in one Package Supports External sensors Supports CAN bus Ruggedised Live data capture and viewing Compatible with Module Analyser	Supports a wide variety of inputs Support for external sensors Uses the same connections Has optional expansion slots Ruggedised

Table 1 - Comparison Table

From research online these vehicle data loggers, shown in Table [1], give a good overview of the range of devices that you can currently buy to meet the assignment brief. All these data loggers come with very similar capabilities and designs but differ with what additional features are included depending on the price.

All the dataloggers come in a ruggedised and sometimes waterproof case and offer their own companion software to view and monitor the live data stream via USB. This feature allows the users to configure the setup on the go through a laptop. They also come with standard connectors which can be configured for analogue or digital data inputs. They also provide SD card storage and GPS/accelerometers for precise tracking whilst the vehicle is in motion.

The main differences between these systems are down to the number of external sensors they support as well as what other serial communication they can interact with. K-Line and RS232 are two examples of this as some systems don't support them by default and require additional money spent on expansions or firmware upgrades. But having the option to upgrade is still a possibility with these devices as the external ports can be configured how the user wants.

The Race Technology DL1 [1], according to the datasheet, comes with 12 additional ports for external sensors which are all configurable but ultimately result in a higher price to get this. This is a common trend between all the data logging devices found online as the more features packed into the system the higher the premium. This price cannot be directly compared with the cost of the prototype designed in this report as these devices are mass manufactured which will overall reduce the cost.

Selection of Microcontroller

To meet the assignment brief it is required that the data logging system's microcontroller is chosen from the 8-bit PIC range. To appropriately select a microcontroller a few considerations, need to be taken into account. Firstly, the PIC needs to have enough pins to support all the sensors and external connections. After choosing the sensors, the number of pins can be determined which means that, as a minimum, it needs 2 digital pins, 8 analogue pins, 4 pins for micro-SD card, 4 for Power, 1 for start/stop button, 1 for LED tell and 2 for USB C data. This amounts to 22 pins minimum.

Secondly, the clock speed of the PIC needs to be fast enough to meet the sampling data rates required when outlining the design. The fastest sample time required for this system is 0.05 milliseconds and therefore the PIC needs to support that.

Sensor	Rep time (sec)	Bytes per reading	Total Bytes	Reading/sec	Bytes/15s
Temp	15	2	2	0	2
Gyro *3	0.05	2	6	120	1800
Suspension *4	0.00005	2	8	20000	2400000
RPM	1	1	1	1	15
MPH	1	1	1	1	15
Total bytes per sec		20122	per 15 sec	1	2401832
Total bits per sec		160976	per min	4	9607328
			per 2 hrs	120	1152879360

Table 2 - Calculations for number of bytes

Table [2] shows the calculations used to work out the number of bytes per second required for all the sensors which equals approximately 160000 bits per second. Therefore, a clock speed of 32MHz will be more than enough to accommodate this as well as any extra connections that are required.

Thirdly, the amount of RAM needs to be considered as the PIC also needs to accommodate enough temporary storage for all the sensors before saving it onto the SD card. This will be based on the calculations seen in Table [2] as the sensors will use at least 20122 Bytes of RAM per second. If the sensor data only needs to be held in the RAM temporarily and will be transferred to the SD card every second, then any PIC with at least 20136 bytes will be sufficient.

Finally, any extra features and serial communication interfaces that it supports need to be considered. The PIC will need to support SPI to write to the SD card, A/D conversions to read the sensors and will need to support USB to allow the user to view the data being stored.

After working out the minimum requirements, these parameters can be entered into a microcontroller filtering service which will narrow down the choice of PIC that complies with all the requirements. This tool identified the PIC18F24K50 as a suitable choice of microcontroller that covers all the baseline requirements.

Selection of Case, Storage, Sensors and Connectors

Case:



Figure 1 – Pelicase [2]

The selection of enclosure/case will be a watertight case from Pelicase. All the cases offered by Pelicase are waterproof to a high enough specification for this application and provide great optional extras that allow external connectors to be mounted. The chosen case is the 1300 protector from Pelicase with the dimensions of this case are 270 x 246 x 174 mm [2].

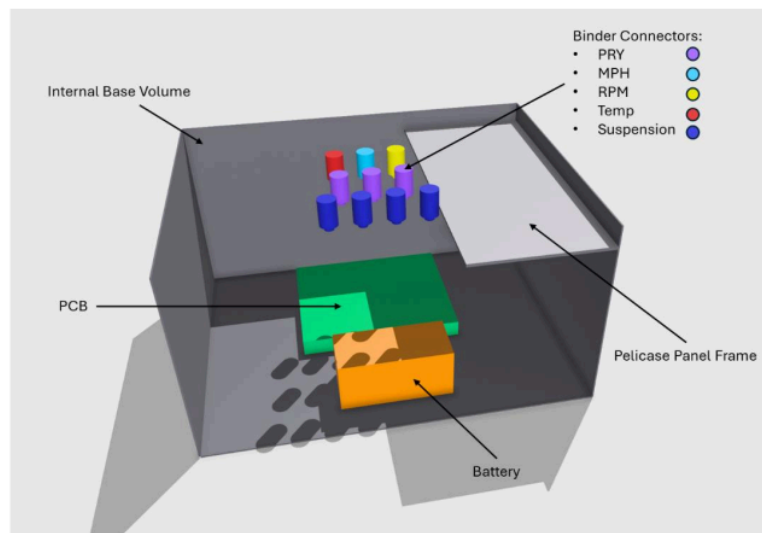


Figure 2 - Internal Case Layout

The Figure [2] shows the cross-sectional internal area of the lower part of the case which demonstrates that this choice of case has plenty of room to fit the components required. Both the PCB and Battery will be mounted to the bottom of the case with shock and vibrational dampers to reduce the risk of damage during testing. The Binder connectors will be mounted on a separate panel attached to a frame at the top of the case allowing the user to open the lid and still retain the waterproof rating of the case. This optional extra offered by Pelicase allows the user to access these external connections without having to drill holes to the side of the case. The panel can be swapped out with different layouts depending on where the system will be used, and the lid can be shut completely once the system is no longer in use.

Storage:

The data being collected by these sensors need to be stored in non-volatile memory which means that when the device is turned off the any data stored in the RAM will be lost. This can be achieved by using an external SD card, but it must be able to support SPI mode as that is how it will communicate with the microcontroller.

Sensor	Rep time (sec)	Bytes per reading	Total Bytes	Reading/sec	Bytes/15s
Temp	15	2	2	0	2
Gyro *3	0.05	2	6	120	1800
Suspension *4	0.00005	2	8	20000	2400000
RPM	1	1	1	1	15
MPH	1	1	1	1	15
			per 15 sec	1	2401832
			per min	4	9607328
			per 2 hrs	120	1152879360

Table 3 - Calculations for storage

To calculate an appropriate amount of storage the number of bytes per second needs to be worked out which will then need to be converted to bytes per 2 hours (the max amount of time for testing). As seen above in Table [3] these are calculations to achieve this which result in approximately 1.15GB of data per 2 hours. Therefore, a suitable choice of storage would be a 2 GB MiniSD card.

Sensors:

From the brief the selection of sensors needs to be able to measure RPM, engine temperature, front and rear suspension travel, pitch, roll, yaw and vehicle speed (MPH). To reduce the size and complexity of the PCB all the sensors have a maximum 5V signal output, so they are directly compatible with the PIC and do not require signal conditioning to reduce the voltage.



Figure 3 - Optical Sensor [3]

The choice of sensor for RPM and MPH is an optical sensor from 2D data recordings. This sensor works by detecting a reflective marker and counting how many times it passes over a period. For RPM it will measure the cam belt revolutions and for MPH it will measure the wheels revolutions. It has an input voltage of 10-30V and has a detection range of 120mm. The device has a response time of 0.8ms and therefore can handle the sample rate of 1 second. The output voltage on the signal pin is 5V and therefore is compatible with the PIC microcontroller [3].



Figure 4 - Infrared Sensor [4]

The choice of sensors for temperature is a laser infrared sensor from RS electronics. This sensor will be mounted in the engine bay and will record engine temperature. This sensor is capable of measuring from 0-1000 degrees and can be configured to use USB or measuring the voltage on the signal line. This sensor has a response time of 250ms and is therefore can handle a sample rate of 15 seconds. The sensor needs a minimum voltage input of 5V and has analogue output of 5V, so it is compatible with the PIC microcontroller. The sensor is also IP65 rated and therefore is suitable for the systems application [4].

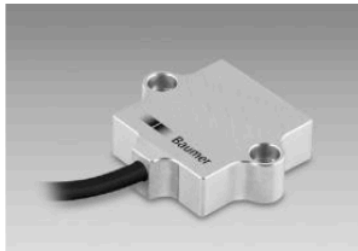


Figure 5 - 1 axis Gyroscope [5]

The choice of sensors for Pitch, Roll and Yaw will be 3 separate 1 axis gyroscopes from Baumer. These sensors will be mounted on 3 different axis and calibrated by the “teach” pin. This sensor has a voltage range of 8-30V with an output voltage on the signal wire of 0.5-4.5V meaning that it is compatible with the PIC microcontroller. The sensor is capable of measuring from 0-360 degrees but can be configured to measure any chosen range with an accuracy of 0.4 degrees. The sensor is also IP67 rated and therefore is suitable for the systems application [5].



Figure 6 - Wire Potentiometer [6]

The choice of sensors for suspension will be 4 wire potentiometers for each corner of the car from 2D data recordings. They will be mounted to the frame of the car and the wire pot will be connected to the brace connected to the wheel. This sensor is capable of measuring up to 760mm of travel but for this application 380mm will be good enough. The sensor supports a voltage range of 4-30V and an accuracy of 0.25 [6].

Connectors:

As most of the sensors will be exposed to harsh conditions it is important that the IP rating chosen reflects the amount of protection needed. Therefore, the connectors are all rated to IP67 which provide sufficient protection against dust and water for this application [7].



Figure 7 - Binder Connectors [7]

The connectors themselves are all from the Binder 620 series but will differ with the number of contacts needed for each sensor. The existing connectors from the selection of sensor do not all support a sufficient IP rating and will therefore need to be replaced with the Binder 620 series snap in connectors. Both male and female connectors have been included in the build costs as the enclosure will need to be waterproof as well. The male connectors will be mounted on a watertight panel that will sit under the lid of the Pelicase to keep all the electronics safe and for easy access when operating the device.

Battery:



Figure 8 – Battery [8]

Total Current	302.5mA
Min for 2 hours	605 mAh
min for 4 hours	1210 mAh

Table 4 - Current consumption calculations

To determine a suitable battery the average current draw of each sensor needs to be calculated. These values can be found detailed on the sensor's datasheets and the total current draw and then you can work out the minimum average power consumption per hour. As seen in Table [4] the total consumption for 2 hours is 605 mAh and to compensate for the PCB components it is doubled again, and a battery is selected from that value. As the require input voltage needs to be above 10V a 14.8V LiPo battery with a capacity of at least 1210 mAh is required. Therefore, the overlander 13.8V 1300mAh battery was chosen to power the system as it meets all the requirements.

Circuit Schematic and PCB Design

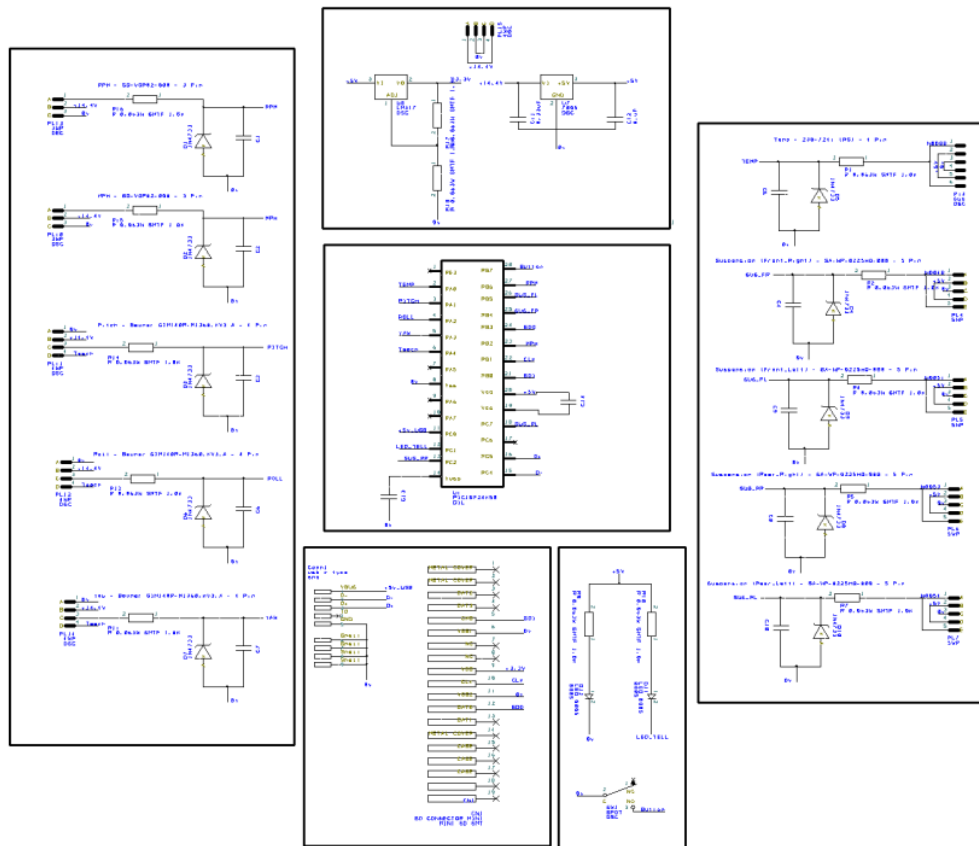


Figure 9 - System Schematic

Shown above in Figure [8] is the schematic for the data logger system with each section outlined and separated. The two boxes on the left and right side of the microcontroller are the connections to the external sensors for this system. As all the sensors output a maximum of 5V on the data line, signal conditioning is not required to reduce the incoming signal voltage and therefore a clamp is only used between the sensors and microcontroller which is used to protect the PIC from any spikes in voltage if the sensor malfunctions. Each type of sensor uses a different number of pins to reduce the chance of an incorrect connection. Some of the 5 and 6 pin headers have also been designed to be reversible to further reduce the chance of incorrect connections.

The lowest voltage required by some of the components is 10V and can support up to 30V. Therefore, the choice of input voltage for this system is a 14.8V from a LiPo battery. However, some of the components will not be able to take an input voltage of 14.8V and will be required to be stepped down to 5 or 3.3V as required by the microcontroller and the SD card. To do this a voltage regulator is required as it provides a stable output at the correct voltage which preferred over a potential divider as it offers protection against voltage spikes and thermal issues. For this design two voltage regulators are used, 1 is used to step down the 14.8V to 5V and the other is used to reduce the 5V to 3.3V which will cover all the voltage requirements for the selection of components.

The bottom left box shows the connections for a surface mounted min SD card as well as a surface mounted USB C port. Both these interfaces are needed for storing and accessing the data collected from this system. The bottom right box shows the connections for two LED tells. The first shows whether the board has power and the second shows if the microcontroller has power. It also includes a button to start and stop the recording.

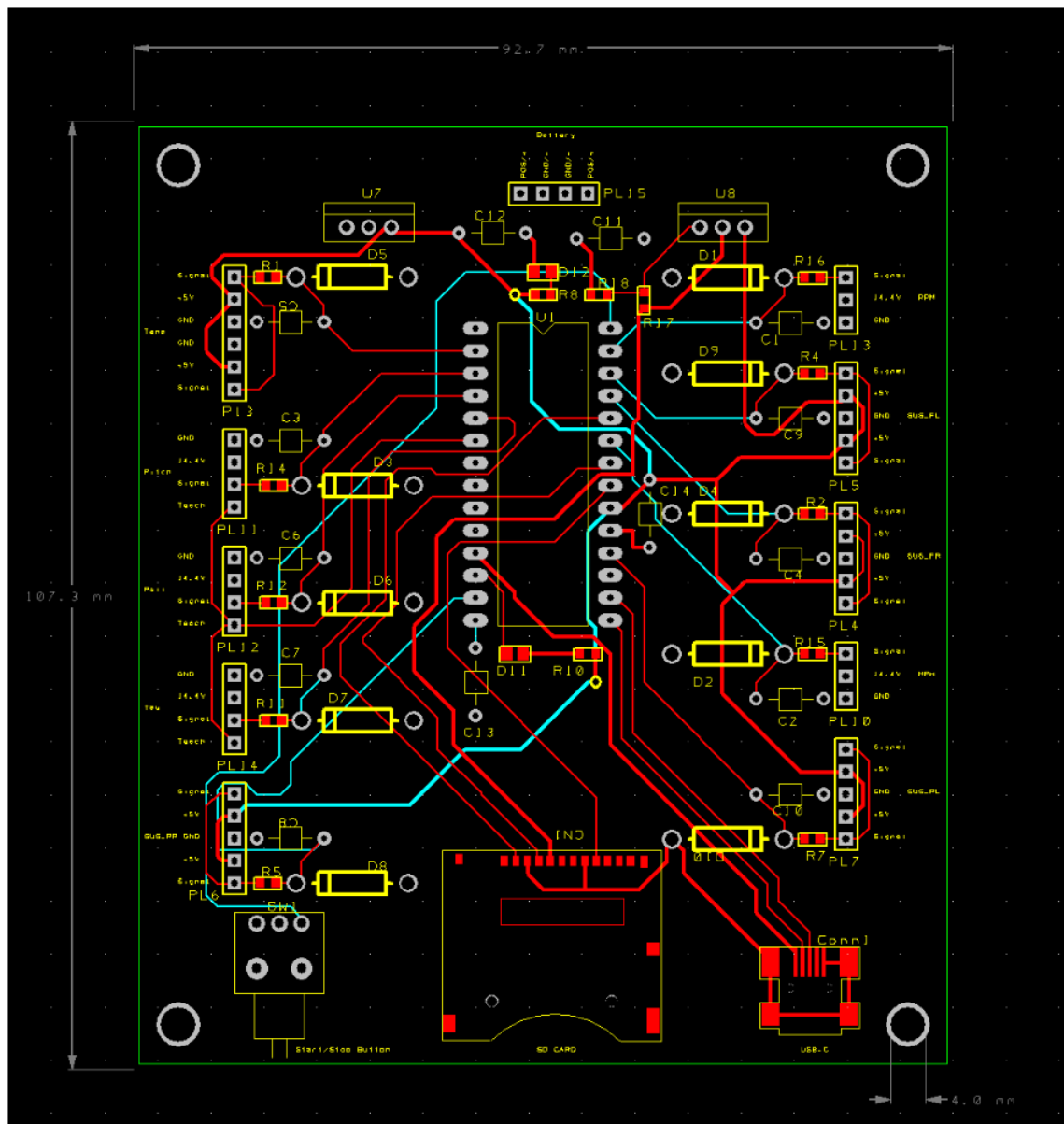


Figure 10 - PCB Design

Figure [9] shows the PCB design for this system which includes 10 separate pin headers on the side of the PCB, Power management integrated components on the top and the SD card storage and USB connection at the bottom. The PCB consists of 6 Layers that include: The top silk, top copper layer, ground copper pour, 14.8V power copper pour, bottom copper layer and bottom silk. Having multiple layers and copper pours mean that there are less tracks to connect which reduces the complexity of the top and bottom copper but will increase the price. The holes on the 4 corners of the PCB will be used as mounting points when fitting it into the case which have a 4mm hole to be used with M4 screws.

The software used to design this PCB has built in design rule check to ensure that the spacing, size of tracks and components are within specification to avoid complications when being used.



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Software Flowchart

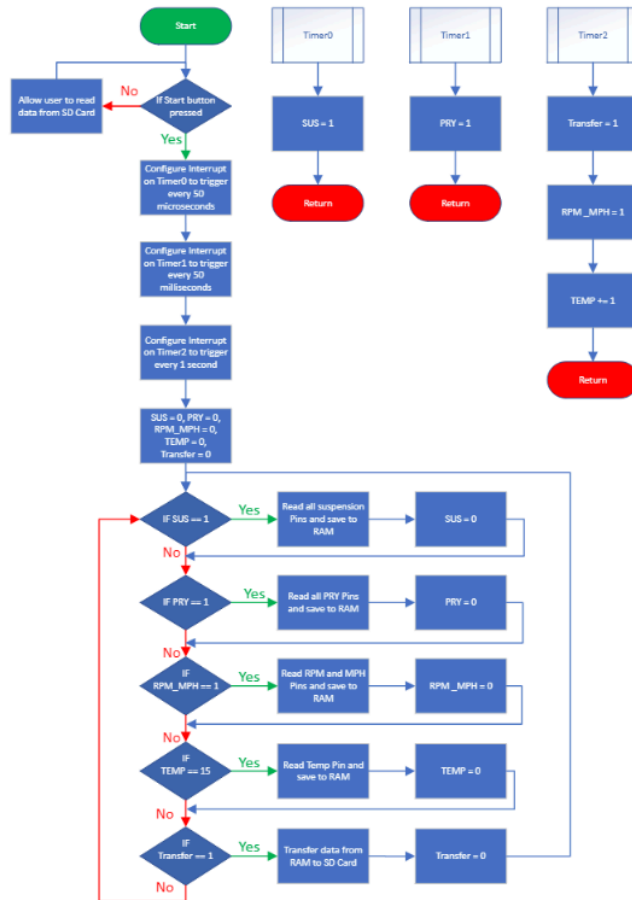


Figure 12 - Software Flowchart

The Figure [11] shows the software flowchart of this system which utilises interrupts to trigger when a sample needs to be taken. The timings of the interrupts are configured to trigger according to the requirements outlined before designing the system. The first interrupt is to be triggered every 0.05 milliseconds, the second interrupt will be triggered every 50 milliseconds, and the final interrupt will be triggered every second. Using interrupts over delays is a better way to trigger the sampling as the PIC will interrupt the code every time the timer reaches its specific value.

The main code consists of two parts the first if statements check the status of the start button and won't begin sampling the sensors until that is pressed. Whilst the code is in this cycle it will allow the user to read and extract any data stored on the SD card. Once the program has started the access to the SD card through the USB will be restricted to prevent the chances of corruption when reading and writing to the storage.

Once the start button is pressed the PIC will configure the interrupts and timers to sample the sensors at the correct time. It will then run through multiple IF statements that determine when and what is sampled before transferring the data in the RAM to the SD card every second. The flags for each sensor are then set back to zero until the interrupts trigger them again. The transfer function is the last operation to happen in the flowchart as all the data, from the sensors, that is stored in the RAM will be moved over at once. This data will contain the time of the sample taken, an identifier to match the data to the sensor as well as the data itself. The output format of the data on the SD card will be a .CSV file which stands for comma separated values as this format can be used in excel and other software for data analysis/representation.

Build Costings

Part	Component	Price per unit	Amount	Total Price
RPM	SD-VOP02-000	£215.00	1	£215.00
MPH	SD-VOP02-000	£215.00	1	£215.00
Temp	238-7241 (RS)	£180.60	1	£180.60
PRY	Baumer GIM140R-M1360.KV3.A - 1 axis	£192.00	3	£576.00
Suspension	SA-WP-0225HQ-000	£219.07	4	£876.28
Connector	Binder snap in series 620 Male	£6.59	3	£19.77
Connector	Binder snap in series 620 Female	£22.10	3	£66.30
Connector	Binder snap in series 620 Male	£7.99	2	£15.98
Connector	Binder snap in series 620 Female	£24.05	2	£48.10
Cable	PRT-10364	0.99	3	£2.97
Cable	PRT-10366	£1.05	1	£1.05
Cable	PRT-10375	£1.85	4	£7.40
Cable	PRT-10363	£1.05	2	£2.10
PCB		£53.36	1	£53.36
Case	1300 PROTECTOR CASE	£98.76	1	£98.76
Peli Panel Frame	1300 Panel Frame	£30.05	1	£30.05
mini SD Card	MiniSD Card 2GB	£5.94	1	£5.94
Battery	14.8V 1300 mAh LiPo	£25.92	1	£25.92
MCU	Pic18f24k50	£1.49	1	£1.49
Voltage Regulator	LM7805	£0.68	1	£0.68
Voltage Regulator	LM317	£0.72	1	£0.72
SMD Capacitor	Capacitor	£0.34	14	£4.76
Diode	Diodes	£0.27	10	£2.70
SMD LED	LED	£0.30	2	£0.60
Pin Header	3WP	£0.18	2	£0.36
Pin Header	4WP	£0.25	4	£1.00
Pin Header	5WP	£0.24	4	£0.96
Pin Header	6WP	£0.31	1	£0.31
USB Connector	USB Type C	£0.77	1	£0.77
SMD Resistor	Resistor	£0.10	14	£1.40
SD Connector	SD MINI	£1.76	1	£1.76
Button	Push Button	£0.48	1	£0.48
			92	£2,458.57

Table 5 - Build costings

The costings for this system were priced from various websites such as 2D-Data-Recording, RS, Farnell, Pelicase, JLCPCB and Digikey. The items highlighted in green are the chosen sensors, the items highlighted in blue are the extra parts required to build the system and the items in orange are the components used on the PCB. As seen in Table [5] shows the price per unit, the amount needed and the total price which is £2,458.57.

Suggested Improvements

Based on the evidence gathered in Task 1 here is a list of suggested improvements for the next iteration of the device:

- Create a GUI for the user to interact with that can configure the sensors on the go and viewing the live data streams.
 - The current design of the device only allows the user to view the data in a CSV file format which can get extremely cluttered when lots of data is being saved to the list. Therefore, having the option to view this data in a GUI with graphs and figures will make this device more appealing to operate as well as reducing the analysis time for the user. This will likely require the user to have an external computer to aid in the processing of the data.
- Include built in sensors such as GPS and accelerometers to provide the user with more information and tracking capabilities.
 - Most of the devices found online come with these features as standard and provide more information to the user for analysis later.
- Include support for CAN and K-Line buses.
 - Vehicles are already fitted with these buses to share information to the ECUs throughout the car and will monitor parameters that are currently being monitored by external sensors. A good example of this is RPM, Speed and engine temperature. Utilising these existing technologies within the car will free up ports that can be used for other sensors. OBD dataloggers already exist on the market and are quite inexpensive for the data it can acquire.

References

- [1] Race Technology, "DL1 CLUB - Our most popular data logger," [Online]. Available: <https://www.race-technology.com/gb/racing/data-logging/dl1-club>.
- [2] Pelicase, "1300 Protector Case," [Online]. Available: <https://peliproducs.co.uk/collections/cases/products/1300-protector-case>.
- [3] 2D-Daterecordings, "SD-VOP02-000 Optical speed sensor," [Online]. Available: <https://2d-daterecording.com/Downloads/Datasheets/Sensors-digital/Pdf/SD-VOP02-000.pdf>. [Accessed 20 07 2024].
- [4] RS Electronics, "Infrared Temperature Sensor with Voltage Output and UART," [Online]. Available: <https://docs.rs-online.com/5904/A700000009210826.pdf>. [Accessed 20 07 2024].
- [5] Baumer, "GIM140R - 1-dimensional, analog," [Online]. Available: <https://docs.rs-online.com/7f80/A700000007226262.pdf>.
- [6] 2D-Daterecordings, "SA-WPxxxxHQ-000 Wire potentiometer," [Online]. Available: <https://2d-daterecording.com/Downloads/Datasheets/Sensors-length/Pdf/SA-WPxxxxHQ-000-DINA4.pdf>. [Accessed 20 07 2024].
- [7] Binder, "Snap-In IP67 female cable connector, Contacts: 4, 3.0 - 5.0 mm, solder, IP67," [Online]. Available: <https://docs.rs-online.com/19fc/0900766b80bb8dd5.pdf>.
- [8] Overlander, "1300mAh 14.8V 4S 100C FPV LiPo Battery," [Online]. Available: <https://www.overlander.co.uk/lipo-batteries/14-8v-4s/1300mah-14-8v-4s-100c-fpv-lipo-battery.html>.
- [9] Microchip, "PIC18(L)F24/25K40," [Online]. Available: <https://docs.rs-online.com/8063/0900766b81559b9b.pdf>. [Accessed 20 07 2024].
- [10] RS Electronics, "Binder Subminiature Connectors Case Mount," [Online]. Available: <https://docs.rs-online.com/f8bd/0900766b80fc16f3.pdf>.
- [11] CAS Dataloggers, "Influx Rebel LT," [Online]. Available: <https://dataloggerinc.com/product/rebel-lt-vehicle-data-logger/>.
- [12] AIM TECHNOLOGIES, "AIM EVO4s," [Online]. Available: <https://www.aimtechnologies.com/aim-evo4s/>.

ESD_Assignment

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

67 /100

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GRADING FORM: SMU GENERIC_GJ

THEO ROSE

66.80

RESEARCH-INFORMED LITERATURE

Good literature review of available systems with a fairly good comparison table of relevant information but would have been better with some images.65%

6.5

KNOWLEDGE AND UNDERSTANDING

Your schematic diagram is good and very clear but there are a couple of issues. You are showing a 741 amplifier being used with a single sided supply, are you sure it works correctly like this. Your PCB images look good. Your PCB has been routed well, although this cannot be checked as the pcb files were not included. I wold like to see the PCB and Proteus file. A good attempt 60%

15

ANALYSIS

Good selection of microcontroller, and of the enclosure. Reasonable selection of sensors with

an image and short spec. A 100nf cap should be placed between the power lines as close to the micro-controller as possible. Your connectors are good. 70%

24.5

PRACTICAL APPLICATION AND DEP.



your costings are nicely tabulated and carry manufacturer and part numbers. Reasonable attempt at future enhancements. 68%

13.6

SKILLS FOR PROFESSIONAL PRAC.



The report is well presented with a good number of images. Good selection of references. 72%

7.2