

ESD_1

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1 Introduction

This assignment explores the design and specification of a car data logger that cannot interact with the on-board electronics of the vehicle it is measuring. There are both advantages and disadvantages to this requirement. The primary advantage is the portability of this system to other vehicles. While this has been designed specifically for a family saloon, the parts used make it compatible with smaller vehicles up to SUV-class vehicles. One difficulty of this is that some measurements may not be as accurate as the car itself would be able to record, such as the internal RPM of the engine. This assignment explores some of the solutions and suggests further improvements to make in future versions of a data recorder.

2 Literature review

2.1 OBD2 Data Logger [1]

However, this connects to the cars on board sensors, which is not appropriate for this assignment so another solution is required. This data logger also uses WiFi functionality to add the ability to automatically upload the data that has been recorded to a dedicated web service, or use an SD card to record and transfer data with. To keep this design simple, an SD card has also been used as a lot of additional overhead is required for a WiFi design, either a processor that has built in WiFi or an external WiFi module would be required in order to communicate wirelessly. This could be a consideration for a future improvement, but is outside the scope of this assignment.

This specific data logger uses the OBD2 [1], an interface which presents data on request, within a car to log data. As the data recorder that is being designed for this assignment may not touch the cars internal electronics, this is not an option that can be carried through to this design.

3 Component and sensor selection

3.1 Status LEDs

There are two status LEDs located next to each other on the exterior of the enclosure. The first, a power on LED, is to indicate power is applied to the board and the second, an activity LED, is to indicate that data is being recorded. This activity LED will light up each time the PIC MCU writes data to the SD card.

Resistor values of 330Ω have been selected as the datasheet for the LED [2] specifies a

$$V = IR$$

Equation 1: Ohms law

$$V = 5$$

$$I = 15mA$$

$$R = \frac{V}{I}$$

$$R = \frac{5}{0.015}$$

$$R = 333.33\Omega$$

Figure 1: The power and status LEDs displayed in the Proteus schematic

3.2 Voltage Regulators – LM78

Two different voltage regulators have been selected in order to satisfy the input voltage ratings of different sensors. The LM7805 and LM7809 have been selected to provide an on-board voltage of +5VDC and +9VDC respectively.

3.3 Suspension – CD50 Draw Wire sensor [3]

$$\begin{aligned} \text{speed} &= 80\text{mph} = \frac{35\text{m}}{\text{s}} \\ \text{wheel circumference} &= 17\text{in} * 0.0254 * \pi \\ &= 1.35\text{m} \end{aligned}$$

At 80mph, the wheel completes 26 revolutions per second, so in order to detect running over an object 3.5cm in height, the suspension must be read out at a twice rate, or for an object with a height of 1.75cm. Travelling over an object 1.75cm in height and width at 35m/s would produce a reading for only 50µs.

$$\frac{0.00175\text{m}}{35\text{m/s}} = 0.00005\text{s}$$

The suspension is to be read back to the PIC MCU at a rate of 20KHz, or once every 50µs. This is to allow for running over a solid object 1.75cm in height at 80mph to be detected. The distance the

suspension can travel is estimated to be 1 foot, so a part that can travel further, at 500mm has been selected.

3.4 Temperature probe [4]

A K-type [5] thermocouple that can be secured to the outside of the engine with a heat resistant temporary adhesive, such as polyimide film has been selected.

3.5 Optical RPM / vehicle speed sensor [6]

One possible approach to reading the RPM of the engine would be through the use of a microphone and passing the output through a fast Fourier transform and extracting the peak frequency. An issue with this approach is the increased signal processing requirement and operation inside a noisy environment.

A piece of reflective tape can be placed on the engine in order to record the RPM using an optical sensor instead of using internal busses to communicate with the cars on board electronics. This same approach can be used to measure the speed of the car, by placing a different piece of reflective tape on a wheel and monitoring the rate at which pulses are received by the PIC MCU through the use of an interrupt on a particular port.

This optical RPM sensor uses a class II laser, which will be operating inside of an enclosure away from direct line of sight, but when it needs to be started / stopped there could be a short period of exposure. A short period of exposure to a class II laser shouldn't put the user at risk, however it is cautioned that "prolonged viewing may be dangerous" [7].

3.6 Gyroscope – L3GD20H [8]

The gyroscope chosen for this is an I2C device. Data can be read back in a single transmission by specifying that 6 bytes should be returned, as each of the pitch, roll, and yaw axis hold 2-byte values [8]. As this single device has 3 separate axes for pitch, roll and yaw, only a single device over I2C is required.

3.7 Storage – 2GB SD Card [9]

The SD card is a class 10 SDHC which has a minimum write speed of 10MB/s or 10485760 bytes per second [10]. To meet the timing requirements of this assignment, 50us due to the suspension being read out at 20KHz. over a period of 50us, a total of 524 bytes could be written to the SD card. The greatest number of sequential bytes that would be written to the SD card in this example is 8 from all four suspension recordings.

3.8 Microcontroller - PIC18F24K50 [11]

For this assignment, a PIC18F24K50 was chosen as it was one of the three MCUs that met the specification following a search through Microchip's Advanced Processor Search [12]. This processor operates at 5V, which allows for the operation of most of the other components, such as the accelerometer detailed further below, without additional voltage regulators.

At most, approximately 400 instructions would need to be executed in total over a period of 50us in order for the PIC MCU to read data from all of the sensors and send it to non-volatile storage on the SD card. These instructions are a ballpark for: Reading each of the 10 (including duplicate) peripherals outlined above, formatting data, performing checks and writing to the SD card. 400

instructions in 50us would require 8,000,000 (8MHz) instruction cycles, as an instruction cycle is 4 clock cycles for PIC MCUs, this requires a processor that runs with a frequency of at least 32MHz.

Each instruction is 16 bits, as detailed by section 26 in the PIC18F24K50 Data Sheet [11]. For the main loop estimated at 400 instructions, 800 bytes of internal memory would be required. Additionally, start-up code which configures peripherals and then USB functionality to allow for the device to send data back to a host PC from the SD card.

A minimal amount of RAM is required as very little data will be buffered on this device.

MICROCHIP ADVANCED PART SELECTOR

The screenshot displays the Microchip Advanced Part Selector web application. The 'Parameter Search' section on the left includes filters for Family (8-bit MCU), Part Family (8-bit PIC MCU), CPU Type (8-bit PIC MCU), Max CPU Speed (32 MHz), CPU Speed (MIPS/KMIPS), CPU Pin, and Math Accelerator. The 'Voltage' section shows Operation Voltage (5V) and Temp Range (-40 to +125). The 'Temperature' section shows Pin Count (24) and Max I/O Pins (40). The 'Memory Data' section includes Program Memory Size (4K), Program Memory Size (On-chip), Auxiliary Flash (0), SRAM (0), L1 Cache Memory (Instructions) (0), L1 Cache Memory (Data) (0), Data RETENTION (0), Internal DRAM Amount (0), DRAM Bus Size (0), Boot Memory (0), Direct Memory Access Channels (0), Number of EBCs (0), ECC Bits on NAND Interface (0), and QSPI (0). The 'Search Results' section on the right shows 3 MCHP parts found, with PIC18F4450 selected. The 'PIC18F4450' section on the right provides detailed specifications for the selected part, including Family (8-bit MCU), CPU Type (8-bit PIC MCU), Max CPU Speed (32 MHz), CPU Pin (40), Operation Voltage (2V-5.5V), Temp Range (-40 to +125), Pin Count (144), Program Memory Size (16K), SRAM (3584 Bytes), Internal DRAM Type (0), Internal DRAM Amount (0), Low Power (0), ADC Input (10), Max ADC Resolution (10), DAC Outputs (0), Number of Op Amps (0), Variable Touch Peripheral (0), UART (1), SPI (0), I2C (0), Number of USB Modules (0), USB Interface (0), Number of CAN Modules (0), Type of CAN module (0), Ethernet (0), Max 16-bit Digital Timers (1), Max 16-bit Digital Timers (0), Max 16-bit Digital Timers (0), Max PWM outputs (including complementary) (0), Number of PWM Time Bases (0), Crypto Engine (0), and ARM TrustZone (0).

Figure 2: Microchip's Advanced Part Selector

4 12V Battery - PC1.2-12F1

A 12V battery has been selected to power this device as it holds enough power to supply the pic MCU and peripherals for a duration of at least 4 hours, and has a voltage compatible with the on-board voltage regulators.

4.1 Enclosure – Peli-case [13]

An enclosure large enough to fit both the 12V battery, and the PCB has been selected for the car data logger. It measures 188 x 125 x 84 mm on its interior.

4.2 Printed Circuit Board (PCB)

The minimum order quantity for PCBs from jlcpcb.com, a PCB prototype and production manufacturer, is 5. For small quantities, there is a fixed cost of 2USD / 1.57GBP for 5 PCBs. The total cost of the order comes to £16.51. To remain compliant with regulations surrounding the restriction of hazardous substances (RoHS) [14], a hot air surface level with free solder was selected.

Charge Details



Special Offer	£ 1.57
Via Covering	£ 0.00
Surface Finish	£ 1.02

Build Time

PCB: ☒ 2 days	£ 0.00
☐ 24 hours	£ 5.63
☐ 24 hours PCBA Only	£ 0.00

Calculated Price

£ 2.58

Additional charges may apply for [special cases](#)

SAVE TO CART

Shipping Estimate

£ 13.93

✓ DHL Express Worldwide 2-4 business days

Weight  0.29kg

Figure 3: Cost with separate shipping, of 5 PCBs from jlcpcb.com

5 Final component cost

The total cost of the car data logger is shown below

Table 1: The cost of each component selected for this build

Optical speed sensor x 2	£355.00
Reflective tape	£30.00
Temperature Probe	£7.88
Wire strip potentiometers x 4	£432.25
TELL LED = 20mA	£0.00
Battery	£6.81
Enclosure	£39.25
Gyros	£9.86
SD Card	£6.94
PCB	£16.51
Total	£2572.59

6 Data structure

Due to SD cards having no moving integral parts, the seek time to write to different locations is significantly reduces when compared with a hard disk. This is advantageous because it allows for fast writes to arbitrary memory locations. To signify the beginning and ends of each of the sections, they are marked with the following ASCII encoded headers/footers:

- "ERPM" for Engine RPM;
- "EMPH" for Vehicle speed;
- "TEMP" for Engine temperature;
- "SUFL", "SUFR", "SUBL", "SUBR" for the four suspension distances;
- "GYRP", "GYRR", "GYRY" for the gyroscopic pitch roll and yaw values.

A fictitious example is shown below where the engine starts at 0 degrees Celsius and rises in temperature to 23°C after a total of 6 minutes, or 18 readings spaced at regular intervals of 15 seconds:

Address	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F	ASCII
00000000:	54	45	4D	50	00	01	02	03	04	05	06	07	08	09	0A	0B	TEMP.....
00000010:	0C	0D	0E	0F	10	11	12	13	14	15	16	17	54	45	4D	50	TEMP

Figure 4: An example of the format data is stored in created in a hex editor ImHex

Table 2: Structure of data stored on the SD card

Memory Address Range			Description	Size (bytes)
0	to	3	Engine temperature header	4
4	to	963	Engine temperature readings	960
964	to	967	Engine temperature footer	4
968	to	971	Engine RPM header	4
972	to	8171	Engine RPM readings	7200
8172	to	8175	Engine RPM footer	4
8176	to	8179	Vehicle speed header	4
8180	to	15379	Vehicle speed readings	7200
15380	to	15383	Vehicle speed footer	4
15384	to	15387	Gyroscope pitch header	4
15388	to	303387	Gyroscope pitch readings	288000
303388	to	303391	Gyroscope pitch footer	4
303392	to	303395	Gyroscope roll header	4
303396	to	591395	Gyroscope roll readings	288000
591396	to	591399	Gyroscope roll footer	4
591400	to	591403	Gyroscope yaw header	4
591404	to	879403	Gyroscope yaw readings	288000
879404	to	879407	Gyroscope yaw footer	4
879408	to	879411	Suspension front-right header	4
879412	to	288879411	Suspension front-right readings	288000000
288879412	to	288879415	Suspension front-right footer	4
288879416	to	288879419	Suspension front-right header	4
288879420	to	576879419	Suspension front-right readings	288000000
576879420	to	576879423	Suspension front-right footer	4
576879424	to	576879427	Suspension front-right header	4
576879428	to	864879427	Suspension front-right readings	288000000
864879428	to	864879431	Suspension front-right footer	4
864879432	to	864879435	Suspension front-right header	4
864879436	to	1152879435	Suspension front-right readings	288000000
1152879436	to	1152879439	Suspension front-right footer	4

7 Software flowchart

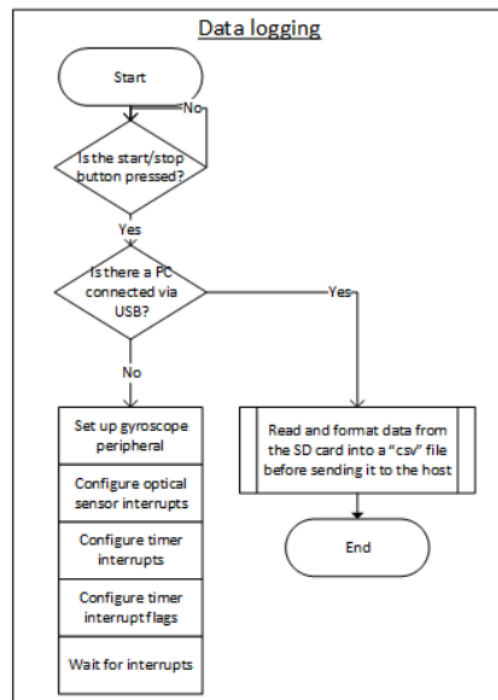


Figure 5: A software flowchart of the PIC MCU's start-up behaviour

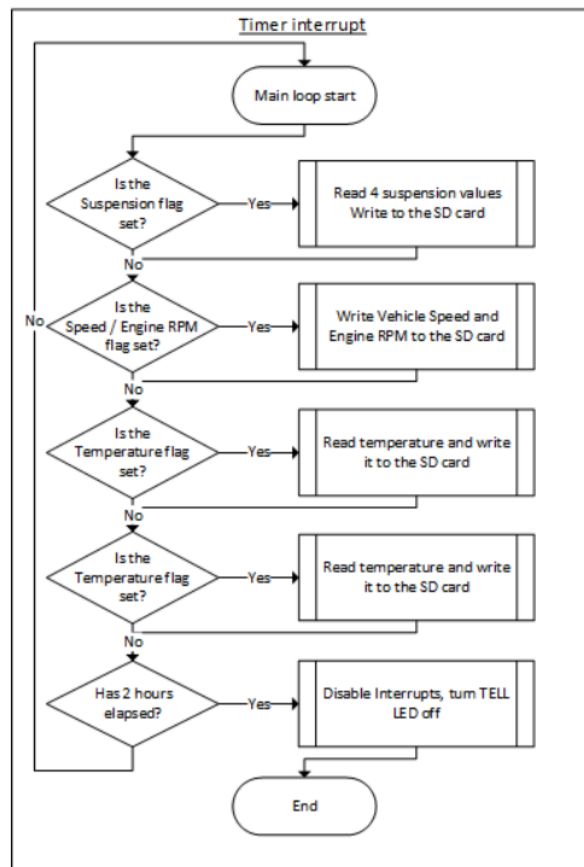


Figure 6: A software flowchart of the PIC MCU's main program loop

8 Conclusion

This car data logger operates with a PIC MCU running at 32MHz

9 Future Improvements

A class II laser is used inside the car, in line with [REFERENCE] safety goggles should be used when working around this. An additional button to detect when the bonnet is open could disable this laser when the bonnet is opened so that a class II laser is not in operation while a person is present.

A microcontroller with (DMA) Direct Memory Access would enable the MCU to hand off the movement of data from one point to another to a dedicated on-chip peripheral, a DMA controller, to allow for the MCU to process data instead of waiting for lengthy conversions to take place.

Direct Memory Access [15] would also allow for the processor to enter a low power state [ref] so when there is no data to be processed, the power consumption can decrease allowing for either greater battery life or a smaller battery to be used.

DMA allows for processors to enter a low power state or spend extra cycles processing data instead of retrieving and moving it internally. An example of where DMA may come in handy is arbitrary

signal generation [15]. The CPU can instead spend time processing data in order to generate a lookup table, and once the table has been generated, the DMA engine can transfer the data to an external peripheral, such as an analogue pin or digital-to-analogue converter.

For our example, the main loop would be free to handle the formatting of data and writing to the SD card. With the additional time saved, it is also possible for digital filters to be implemented within the microcontroller, these could be simple moving average filters to get rid of some noise in measurements [16], or slightly more advanced filter such as a Kalman filter, which would be able to make use of both a gyroscope and accelerometer in order to account for gyroscope drift [17] over time [18].

A further improvement that could be made which would all for the design of the PCB to be simplified is a reduction in component count and by using shielded cables running from the sensors to the board, instead of implementing signal clamps once each of the signals have passed through their respective signal conditioners. Each clamp for an off-board sensor currently uses 3 components, with a total of seven off board, connectors, this comes to a total of 21 components that could be eliminated through the use of different cabling throughout the rest of the system. In production, this would save cost as the only use of the diodes in this circuit is to prevent a spurious signal from damaging the PIC MCU, and each unique component added to a PCB increases the cost of production.

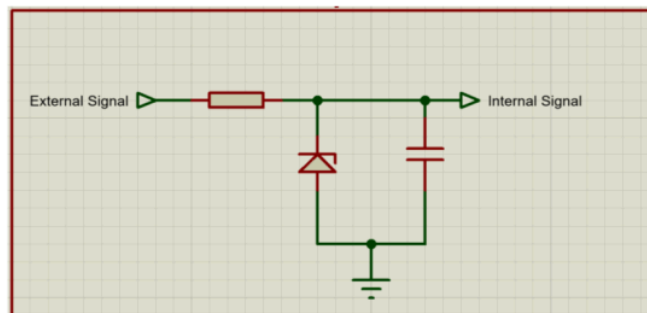


Figure 7: A clamp designed in Proteus Professional 8, using 3 passive components

Finally, the connectors to external peripherals that have been used could be changed from header pins to unique connectors that are only used for each type of sensor. Colour-coding could also be used on the outside of the peli-case and on the cable to indicate which connector should be plugged into which receptacle.

10 Bibliography

- [1] CSS Electronics, "OBD2 Data Logger - Easily Record & Visualize Your Car Data," CSS Electronics, [Online]. Available: <https://www.csselectronics.com/pages/obd2-data-logger-sd-memory-convert>. [Accessed 1 August 2024].
- [2] RS Pro, "Cone Bezel or Prominent Bezel Indicator," [Online]. Available: <https://docs.rs-online.com/0f8f/A700000008260555.pdf>. [Accessed 1 August 2024].
- [3] Strainsense, "CD50 Draw Wire Sensor 0-1250mm," Strainsense, [Online]. Available: <https://strainsense.store/product/draw-wire-sensor-0-1250mm/>. [Accessed 1 August 2024].
- [4] Digilent, "Thermocouple Wire, 1 meter," Digilent, 24 August 2015. [Online]. Available: https://mm.digikey.com/Volume0/opasdata/d220001/medias/docus/1178/240-080_Web.pdf. [Accessed 1 August 2024].
- [5] Omega, "What is a type K Thermocouple," Omega, [Online]. Available: <https://www.omega.com/en-us/resources/k-type-thermocouples>. [Accessed 1 August 2024].
- [6] Compact Instruments, "VLS-DA1-LSR-Optical-Speed-Sensor," Compact Instruments, [Online]. Available: <https://compactinstruments.co.uk/wp-content/uploads/2016/09/VLS-DA1-LSR-Optical-Speed-Sensor-Laser-7.5-15vdc-6v-Output-Instruction-Manual.pdf>. [Accessed 1 August 2024].
- [7] C. Flores, "Laser Classification Explanation," Lawrence Berkeley National Laboratory, Environment, Health & Safety, 4 June 2018. [Online]. Available: <https://ehs.lbl.gov/resource/documents/radiation-protection/laser-safety/laser-classification-explanation/>. [Accessed 1 August 2024].
- [8] DigiKey, "1032 Adafruit Industries LLC," [Online]. Available: <https://www.digikey.co.uk/en/products/detail/adafruit-industries-llc/1032/4990761>. [Accessed 1 August 2024].
- [9] Integral, "SDHC Card Class 10 (20MB/s*)," Integral, [Online]. Available: <https://docs.rs-online.com/016a/0900766b81686dd3.pdf>. [Accessed 1 August 2024].
- [10] Kingston, "A guide to speed classes for SD and microSD Cards," December 2020. [Online]. Available: <https://www.kingston.com/unitedkingdom/en/blog/personal-storage/memory-card-speed-classes>. [Accessed 1 August 2024].
- [11] Microchip, "PIC18F2455/2550/4455/4550 Data Sheet," Microchip, August 2009. [Online]. Available: <https://ww1.microchip.com/downloads/en/devicedoc/39632e.pdf>. [Accessed 1 August 2024].
- [12] Microchip, "MICROCHIP ADVANCED PART SELECTOR," [Online]. Available: <https://www.microchip.com/maps/microcontroller.aspx>. [Accessed 1 August 2024].

- [13] Peliproducs, "1120 Protector Case," [Online]. Available: <https://peliproducs.co.uk/collections/cases/products/1120-protector-case>. [Accessed 1 August 2024].
- [14] Office for Product Safety and Standards, Department for Business and Trade and Department for Environment, Food & Rural Affairs, "Guidance Regulations: restriction of hazardous substances (RoHS)," UK Government, 22 April 2024. [Online]. Available: <https://www.gov.uk/guidance/rohs-compliance-and-guidance>. [Accessed 1 August 2024].
- [15] Microchip, "Direct Memory Access on PIC® Microcontrollers," Microchip, [Online]. Available: <https://www.microchip.com/en-us/products/microcontrollers-and-microprocessors/8-bit-mcus/core-independent-and-analog-peripherals/system-flexibility/direct-memory-access>. [Accessed 1 August 2024].
- [16] Analog Devices, "Moving Average Filters, The Scientist and Engineer's Guide to Digital Signal Processing," [Online]. Available: https://www.analog.com/media/en/technical-documentation/dsp-book/dsp_book_Ch15.pdf. [Accessed 1 August 2024].
- [17] D. & L. H. Wang, "A new MEMS gyroscope drift suppression method for the low-cost untwisting spin platform," *IEEJ Transactions on Electrical and Electronic Engineering*, vol. 12, no. 2, p. 262–268, 2017.
- [18] B. Baker, "Apply Sensor Fusion to Accelerometers and Gyroscopes," DigiKey, 30 January 2018. [Online]. Available: <https://www.digikey.com/en/articles/apply-sensor-fusion-to-accelerometers-and-gyroscopes>. [Accessed 1 August 2024].

FINAL GRADE

GENERAL COMMENTS

23/100

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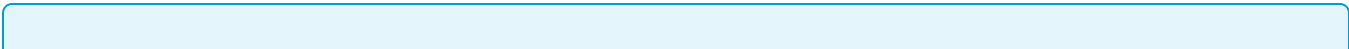
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RESEARCH-INFORMED LITERATURE

 Your literature review is limited to a fictitious obd2 logger. The literature review is very limited and would be improved by adding more devices, a review of each device and followed up with a comparison table of pros and cons as you see them. 30%

3.5

KNOWLEDGE AND UNDERSTANDING

 No Schematic design has been handed in and as such no marks can be given for it. 0%

0

ANALYSIS

 Good selection of microcontroller, but the rest of the sensor have not been defined,. The sd card seems appropriately defined but does not have a defined part number and therefore cannot be confirmed as correct for SPI operation. Good selection of casing. No connectors specified. No Pcb design put forward. 30%

10.5

PRACTICAL APPLICATION AND DEP.



The costings, although put forward in a suitable manner, are not selected to any components and are therefore meaningless. 20%

4

SKILLS FOR PROFESSIONAL PRAC.



The report is poorly presented but contains some tabled data but no images/illustrations and few diagrams except the operational flow charts which appear to have been rushed which is why they have mistakes. A reasonable array of references were included but all were stated as being accessed on 1 August 2024. More care and better time management would have seen a huge improvement in the quality of this submission which is unexpectedly disappointing. 50%

5