

Electronic systems desgin EES (acdA6002)Robbie Young

211907

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Electronic Systems Design (ACDA6002)

Car Data Logger

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Introduction/ Brief

With the aid of market research, a car data logger is to be designed with certain criteria. The car data logger must be able to read the RPM of the car, engine Temperature, suspension travel on both the rear and the front tyres of the car, get the pitch, roll and yaw and know the speed of the vehicle. The car data logger must be able to achieve this without any of the sensors being allowed to be attach to the car, this way it is portable and can be swapped

between any car model. Other features of the data logger are, it must be able to plug into a computer or laptop via USB and be able to store the data within the system for analysis later.

Sensor Choices

RPM

Table

RPM	How Viable is this method
Microphone	A microphone would pick up the RPM of a motor by listening to how much noise it was making, however there are a few problems with using this method. One problem would be an electric car, as there would be little to no noise created by the electric motor, an electric car would just produce a constant whine. Another problem would be tuning and calibration, as a microphone would not just pick up the engine noise but also pick up adjacent cars or birds or other random noises depending on the scenario. Over the two-hour test period it is very plausible that this would happen. The two problems with a microphone make it hard to implement making it a bad choice when trying to determine the RPM.
Laser Tachometers	A Laser Tachometer works by using a laser on the end of the Tachometer, there are two different ways of reading the laser on the end of the Tachometer, the first is via an optical reader next to the laser which works due to reflections, the second method is by putting an optical reader on the other side of the object that you are trying to read. Both methods work well and make Laser Tachometers very effective at reading RPM's of different objects. For the use in a car engine to determine its RPM, the engine's fan can be used as the object thus making this method of reading the RPM very good.
Optical	Optical works in a similar way as the laser would, however instead of a laser sensor it uses a light sensor, it has the same use case and setup as a laser Tachometer. However, the output would be an analogue signal, as light would always be present. Being able to read the change in light would give the RPM. Using the fan from the engine, the fan blades would cover the sensor, giving a change in light. To get the RPM you would have to divide the number of times a fan blade has passed the sensor by time. This method is just as viable as using a Laser Tachometer, however, requires more set up as calibration of light levels needs to be done in software.
Contact tachometers	Contact tachometers require contact with a rotating object to obtain the RPM of the device. They work by contacting a magnetic or a driven shaft to the object, the shaft will rotate with the object and determine its RPM as it goes round. Contact tachometers will either use magnetic or an optical encoder to determine the RPM [1]. A contact tachometer isn't a viable option for the car data logger as the shaft would make contact with the car breaking the rule.

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Best Choice

A custom version of an optical Tachometers would be used to read the RPM of the car. Instead of buying a prebuild one a custom one can be made far cheaper and would allow for better flexibility when changing between cars, as the amount of room is undefined and would change depending on the car.

Engine Temperature

Table

Engine Temperature	How Viable is this method
Temperature sensors	A temperature sensor or a simple thermistor would be affected enough for a car data logger. A thermistor can reliably change resistance with temperature, using a voltage divider a voltage can be changed, as heat rises or cools, which can be converted to degrees. This method would work reliably and is simple to install, making it a good pick for being able to read the temperature of the engine.
IR Camera	An IR camera could also be used to read the engine temperature. However, there are a few problems with this method. The first problem being room inside the engine bay, the second is that the camera would only be able to read the plastic covers over the engine and not the ambient air temperature produced from the engine. The last problem is reading the camera, as the processing power and storage needed for this to be a viable option would be large and expensive. In trying to make a car data logger as cheap and as simple to set up and use using, a IR camera is over the top and would be very time and cost consuming making it a bad option of the data logger.

Best Choice

A simple set up of using a thermistor and voltage divider is going to be the best setup for a data logger, this is because it is simple and cheap to do and can be moved around and put in different cars making it effective at read engine temperature.

Suspension Travel

Table

Suspension travel	How Viable is this method
Strain Gauge	A strain gauge can be used to predictably read force applied to an object, it is possible to use one of these in the car data logger, however, to mount this correctly without interfering with the car's suspension isn't possible. So, although it would be a cheap and easy

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	solution to determining the cars suspension travel it isn't practical and would break the rule of not changing anything on the car.
linear potentiometer	linear potentiometer would work by attaching to the suspension, but not directly changing the characteristics of the car, which would be the perfect way for the data logger to read the suspension travel.
Microphone	It is possible to use a microphone to determine the suspension travel, however it isn't practical at all for the purpose, to make a microphone work, a lot of signal processing would have to be done. It is possible to use a microphone by listening to the tyres, as every bump will make a slight noise change for the tyres. However, to implement this would be impractical making its use case limited for the design.
Camera	A camera could be used to watch the suspension, however it would be limited due to the immense amount of processing needed for all four tyres, also the amount of storage for the data would be very large making it impractical.

Best Choice

linear potentiometer is the best option to uses for the data logger, as it can be put on any car with ease and be calibrated, giving the best results when reading the suspension travel.

Pitch, Roll and Yaw

Table

Engine Temperature	How Viable is this method
Gyroscope and accelerometer	When using a gyroscope and accelerometer it is possible to get the pitch roll and yaw of the car by placing the sensors inside on a level part of the car, using a gyroscope along with an accelerometer would work well and is the best way to get roll, pitch and yaw.
Spirit level and Camera	A very unviable method of measuring all three at the same time, is some version of digital spirit level, like a laser level with a camera watching it. Feeding back the data would require a lot of storage and processing time as well as being hard to set up making it unviable.

Best Choice

Although using an electronic spirit level along with a camera would be tricky it would work. To setup it would be complex and cost far too much to get it working, which is why using a gyroscope and accelerometer will work best, as it is cheaper and have more functions.

MPH/ Vehicle speed

Engine Temperature	How Viable is this method
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GPS	A GPS could track the car, take the distance travelled every second then workout the speed of the car. This is a very viable method to get the MPH of the car, the reason a GPS is useful for a aftermarket car data logger, is because there is no modification to the car, another reason is it can be fitted to any car model, the last reason is it is a reliable way that can be cost effective.
mechanical	Reading the MPH is similar to reading the RPM however, instead of having the mechanical shaft connected to the fan, you would connect it the axial/ tyre, thus reading the MPH. The reason it won't be used for this design, is because it has to be attached to the car making it a modification
laser	Again, similar to RPM the laser system would work in the same way, just over a wheel. A laser would be the most viable setup again for determining the MPH
light	A light sensor is also a good choice, it just comes with problems with calibration and outside light factors, which could make the sensor believe the car is going faster.

Best Choice

A laser will be used, as again like the RPM it will be the most cheapest and effective method of getting the cars MPH.

Sensors selected

Signal conditioning

To try and limit the amount of signal conditioning and connectors required along with PCB space, by assuming that there is limited noise on the cables. This is possible to assume if the cables that go between the PCB and the Sensors are twisted pairs and have shielding around them, these factors would limit the amount of noise and cross contamination. Another way is to have set points, this would also make so noise is a limited factor.

RPM

To get the PRM of the car, a Infrared proximity sensor [2] with a price of £1.39 and an IR LED [3] with a price of £2.54 . This would work by putting the LED on side of the fan and the sensor the other, this would allow for the PRM to be read, as every time the fan spins around the light for the LED would be blocked briefly, allowing for the sensor to change its output voltage, thus allowing the system to count the change and then divide by time, giving the RPM of the system. Doing it this way makes sure that the design is as cheap as possible saving costs and potentially allowing for mass production.

Engine Temperature

To read the engine temperature a simple set up with a thermistor [4] at £9.97 (which can read up to 110 degrees) and a potentiometer in a voltage divider, this would allow for the voltage to change as the temperature does. Choosing this one made the most sense as it can go up to a cars maximum operating temperature and is cheap to buy.

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Suspension Travel

The most expensive part of the data logger is going to be four linear potentiometers [5], as each one with 100mm of travel cost £247, that makes the total of for 4, £988 before VAT. The linear potentiometer would work by attaching to the suspension and change the output voltage depending on how the piston moves. This was the cheapest option that was found.

Pitch, Roll and Yaw

To get the roll yaw and pitch of the car a 3-axis gyroscope can be used [6] it cost just £22.75 and can use I²C to communicate between the master chip and itself, making it ideal for a car data logger.

MPH/ Vehicle speed

The same set up as RPM is going to be used to gather the MPH of the car just used over the wheel rather than the engine fan. This makes the total £3.93 to get the car MPH.

Microcontroller

Table/ data

Data	Bytes size	Bytes per second	total
PRM	To accurately read the RPM of the car, 1 byte of data should suffice, as it just has to count upon triggering.	To accurately collect data a minimum of double the sample rate. To know the sample rate, an assumption on the car needs to happen. For the example, the car will have a max RPM of 7000. Giving $(7000 \times 60 \times 2)$ to get a sample rate of 840,000 bytes a second.	The total amount of processing time every second will need to be around 1MB/s to correctly collect the car RPM. The total data stored across two hours of driving will be 7200MB
Engine temperature	After converting the analogue signal, one byte should be efficient to store the data.	Given that temperature doesn't change that quickly and will slowly rise taking an engine temperature reading every ten seconds should be enough to accurately read the temperature across a two-hour period.	Doing a 1-byte sample reading every ten minutes won't require any extra processing time, as it can be incorporated into the PRM clock cycle. The data store requirements are less than 1KB across the two hours, so also too small to bother with extra storage space.
Suspension travel	4 bytes as one byte of for each tyre will be precise.	Given a car going 80MPH, a reading should be done every 1mm, 80MPH is 36 meters a	Having a processor speed of 1.5MB/s should cover the

		second, 36000 readings must be done per second, times four for each tyre, 144000 per second is the total number of bytes a second.	processing time needed to work out the suspension travel. Given 144000 bytes a second times by $60 \times 60 \times 2$ will convert to the total storage space needed for 2 hours 1,036,800,000 bytes is the total, which is just under 1GB of storage needed.
Roll, pitch, yaw	Looking at the data sheet it uses 2 bytes as its outputted data	As the car shouldn't be rolling pitch or yawing very much a sample rate of every 0.05 seconds should cover the cars movement. 2 bytes at 0.05 seconds is 40 bytes a second.	40 bytes a second is small enough that the processing time can be done in the excess processing time for other tasks. The storage requirements for two hours is 300KBs
MPH	As it is the same set up as RPM 1 bytes will suffice to collect the data.	If the car is traveling at 80MPH that is 36 meters a second, given the average tyre will do two spins before it reaches a meter on the road a sample rate of 100 will be able to determine the cars speed.	At a sample rate of 100 bytes a second the processing power doesn't need to be that high and can be incorporated into other processing time. For the storage capacity 100 bytes a second is $(100 \times 60 \times 60 \times 2)$ less than 1MB which can be incorporated into other storage.

Selection

After using Microchip part selector [7] and putting in these parameters: 8 analogue pins, 10 Digital IO pins and 1 IO device along with 32Mhz processing speed the chip selected that can cope with the demand of the car data logger is a PIC18F24K50. The chip selected has plenty of extra processing power and has plenty of analogue pins and could allow for higher sample rates if required.

Data storage

After calculating the total data storage needed for two hours of travel it is around 2GBs making [8] the best option for SD, card as it is cheap and has plenty of extra storage allowing for around 16 hours of driving.

PCB

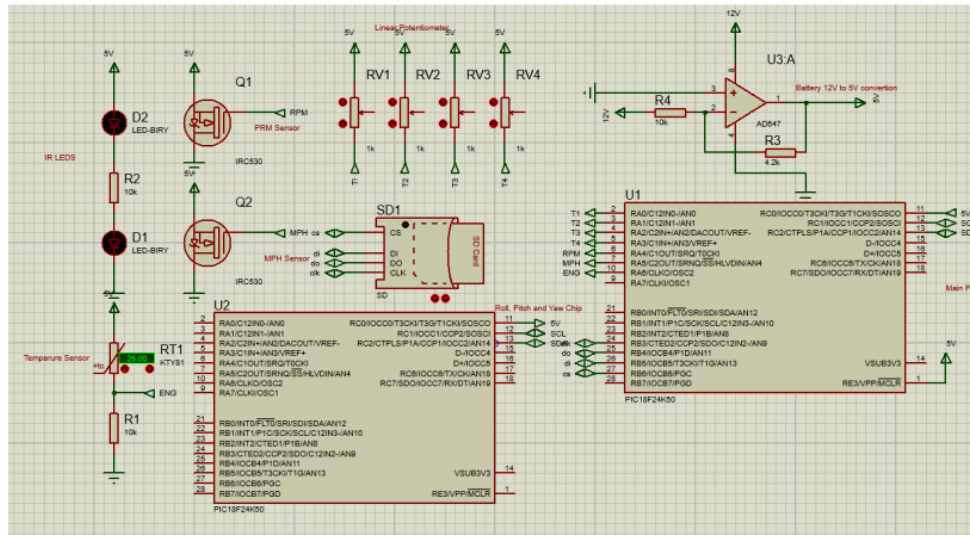
Battery

To prevent using a large battery the power supply for the master board and other sensors will all come off the car's battery saving money on a large battery.

Power supply

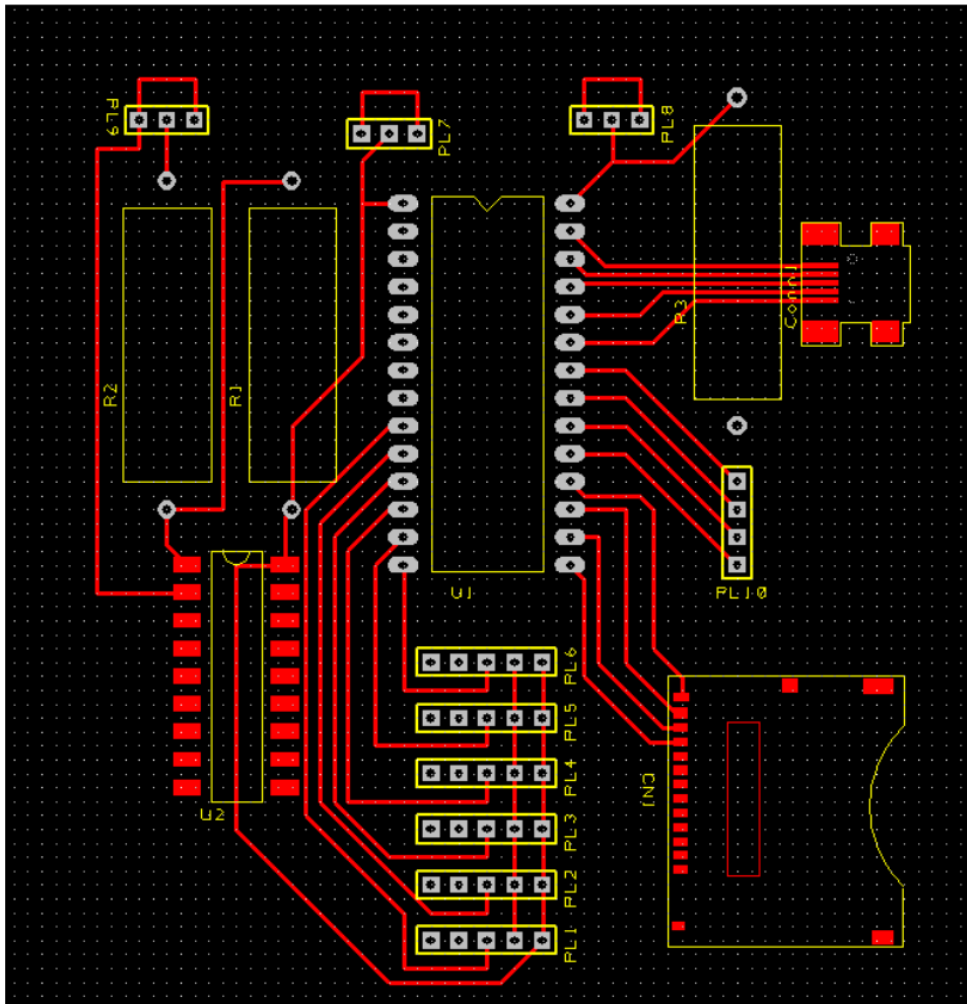
Having looked at the data sheets, all the sensors that would be used can run off 5V or less making them ideal, as no power amplification needs to happen.

Protus



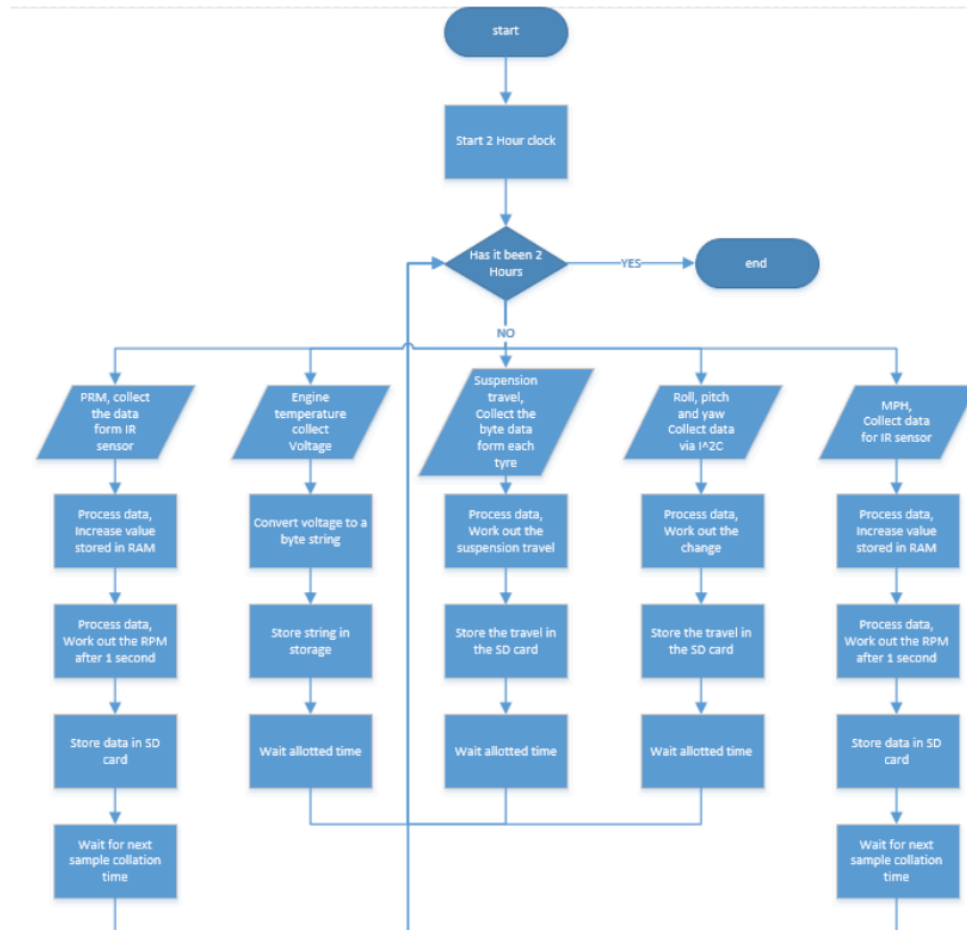
Top left of the image is the IR LEDs they are best operated in series as it saves adding more connectors. The 10K resistor isn't needed in this configuration. Next to the LEDs would sit the IR sensors which would feed back to the chip. Bottom Left is the temperature set up, the thermistor would change depending on temperature, whilst R1 should be a pot to calibrate the temperature. The top middle is the four linear pots that would connect to the suspension. To right is an op amp that converts the 12 volts for the battery to 5 volts, that will run all the circuits. Last up is the Roll pitch and yaw sensor represented by another PIC as this best represented the set up. Finding the correct parts (including USB port) wasn't possible so close representatives were chosen.

Easy PC



The SD card and USB C port would be mounted to the side of the board. The easiest way to make this board would be 3 layers, bottom would be ground, top would have 5v patches and the middle layer would be copper connections running through the board. PL9 is power coming into the board. PL7 output to LED. PL8 Input/output to thermistor. PL10 to gyro Board. PL1 to PL 4 suspension. PL5, 6 to IR sensors.

Structured Diagram



The structured diagram is a simple flow chart of how the car data logger would be programmed. For both RPM and MPH, RAM would store the data over a second then determine the value of each one before sending the data to storage, for engine temperature, the voltage has to be converted before it is passed to storage, this is the same for the suspension travel. For roll pitch and yaw it works a little differently, as they are on their own custom board, which means that the main mother board would have to communicate via I²C before the data can then be logged into the SD card.

Costings

Costings for buying all the sensors is £1028.58 this is rather cheap making the design fit for purpose. The £1028.58 doesn't include the opamp or resistors and the PCB however, these

will be rather cheap so won't add much to the total price. The most important price would be labour costs which would trump the overall price point.

Improvements

An improvement for the above Roll, pitch and yaw is the sampling rate as it is slow and would most likely miss some of the car's movements, by increasing the sample rate with the spare space on the microcontroller and storage capacity, it would be very simple to increase it. These could be applied to other sensors as well.

Another factor is by using a simple voltage divider to get the temperature the second resistor that is mounted to the PCB will have a heat tolerance, which means when it gets slightly hot the resistance will change a small amount, this will change the voltage slightly and give an inaccurate reading on the engine temperature.

Appendix

- [1] <https://uk.rs-online.com/web/content/discovery/ideas-and-advice/tachometers-guide>
- [2] https://uk.rs-online.com/web/p/proximity-sensor-ics/2444821?cm_mmc=UK-PLA-DS3A--google--CSS_UK_EN_ePMax_Prio3--2444821&matchtype=&&gad_source=1&gclid=EAlaIqobChMluYPP5I3jhwMVRI9QBh3xMSIKEAQYBSABEgLF6_D_BwE&gclidsrc=aw.ds
- [3] <https://uk.rs-online.com/web/p/ir-leds/7531567>
- [4] <https://uk.rs-online.com/web/p/thermistors/2500158>
- [5] <https://www.racedatasystems.com/products/motec-linear-potentiometers>
- [6] <https://uk.rs-online.com/web/p/sensor-development-tools/7813033>
- [7] <https://www.microchip.com/maps/microcontroller.aspx>
- [8] <https://uk.rs-online.com/web/p/sd-cards/1805811?gb=s>

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GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

45/100

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GRADING FORM: SMU GENERIC_GJ

ROBBIE YOUNG

44.95

RESEARCH-INFORMED LITERATURE



No literature research. 0%

0

KNOWLEDGE AND UNDERSTANDING



Your schematic diagrams are incomplete, do, di, clk and cs pins for the sd card are available on the device called SDI,SDO,SCK and /SS respectively a quick read of the data sheet for the micro would have given you this information. Some of your analog inputs have been taken to unsuitable pins only capable of digital input. 45%

11.25

ANALYSIS



Good selection of microcontroller, and of the enclosure. Reasonable selection of sensors with some images and short spec. A 100nf cap should be placed between the power lines as close to the microcontroller as possible. Your connectors are good. 50%

17.5

PRACTICAL APPLICATION AND DEP.



your costings are missing, although there is a guestimate for the final cost.. Poor attempt at future enhancements. 38%

12.4

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 good. A limited array of references were included. More care and better time management would have seen a huge improvement in the quality of this submission which is unexpectedly disappointing. 50%

3.8