

Data Acquisition Systems

by Glen Joseph Henley

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DESIGN OF A DATA ACQUISTION SYTEM



Glen Henley (P148252)

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Introduction

This report will demonstrate the procedures taken into designing a data acquisition system. The System is to be fitted to a production prototype family saloon car, this system must also be portable re-usable and adaptable to any vehicle. The system requirements are to measure:

- RPM
- Engine Temperature
- Front and rear suspension
- Pitch, roll and yaw
- Vehicle speed

Connectors will also be researched to pair the sensors with the microcontroller.

The system must record this data over a 2 hour period to non-volatile memory which can be externally read and cleared when connected to a computer via USB and to be battery powered.

The sensors recording the data is not allowed to interfere with the car electronics or signals or in other words the car is not allowed to be modified in any way.

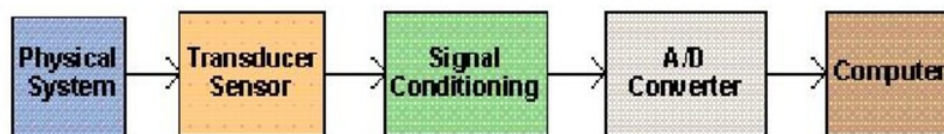
Included will be research of existing vehicle acquisition systems to gain information on what features they possess and parameters that top manufacturing companies use.

The thought process of the selection of each sensor is included paying fine detail to the parameters in order to meet the report specification, other parameters have been considered for easy installation/interpretation of sensor signals.

The design itself will be created on easy PC providing PCB layouts, a schematic diagrams will be created using Proteus.

Data Acquisition System Literature

Data acquisition systems aka DAQ/DAS measures an electrical or physical phenomenon such as voltage, frequency, temperature, position and many more. These phenomenon are signals (analogue or digital) that are sent to a device and recorded. Input signals from the sensors (phenomenon) may need signal conditioning or conversion, this is important as some signals may damage the device if connected directly, conversion is important as the MCU requires a specific data input signal to process it. This data can then be accessed via a bus (USB) to be read from a computer and then analysed. [1]



[2]



To gain more knowledge on these system, research is going to be made to see what is available on the market and to see what features they have to offer.

CRX1000x



Benefits and Features

- Operational in extreme environments with a standard operating range of -40°C to $+70^{\circ}\text{C}$ and an extended operating range of -55°C to $+85^{\circ}\text{C}$
- Connects directly to a computer's USB port
- Captures quickly changing data values with fast analogue measurement capabilities (300+ Hz)
- Differentiates even slight changes in data values with higher resolutions measurements (24 bit Adc)
- Includes two non-isolated current input channels for directly connecting sensors with 0-to-20 mA or 4-to-20 mA current outputs
- Contains an on-board CPI port for hosting Campbell high-speed sensors and distributed modules (CDM)
- Directly connects to Ethernet
- Includes microSD card drive for extended memory requirements
- Provides simple serial sensor integration and measurement with SDI-12, RS-232, and/or RS-485
- Supports full PakBus networking
- IP communication via Ethernet port or optional NL241 Wi-Fi module
- Includes embedded web page for direct connection via web browser [3]

CR310



Benefits and Features

- Set up easily with PC software and USB connectivity
- Measure with confidence analog and digital sensors
- Internet ready—email, FTP, HTTP/web, TCP—with required add-ons
- Trust in the Campbell Scientific quality, including integral surge and ESD protection
- Save money and space using the integrated Ethernet port
- Network wirelessly to another node or Internet gateway with integrated radio option
- CR310-WIFI ideal for short-range, wireless IP communication
- Wiring made easy through removable terminal block
- Communicate from anywhere when using cellular or satellite peripheral
- Charge batteries using the integrated 12 V battery solar charge regulator
- Measure smart sensors using RS-232 or SDI-12
- Connect with PakBus, Modbus, DNP3, GOES, and other standard communication protocols
- Analyze and control with programmability and multiple general purpose I/O
- Notify with event-driven communications and physical outputs [4]

SLICE IP68



Benefits and Features

- Meets IP68 for dust and water ingress
 - MIL-STD-810G for temp, altitude, shock & vibration
 - Ultra-small, embeds on or in test article
- High Performance
- High shock rated
 - Record for milliseconds to hours; stored in 16GB flash
- Expandable
- 3-channel units, up to 24 channels per stack
 - Daisy-chain stacks for large channel counts
 - Supports a variety of sensors, including: bridge, IEPE, MEMS, strain, load, voltage, **temperature**
- Software that's fast and easy
- Amplifiers and filters auto-configure
 - Real-time, logging, viewing and exporting
- [5]

Results

All of the above DAS offer channels that allow sensors to be installed, signal conditioning such as amplifiers/filters, buses such as USB, Ethernet and Micro SD.

Sensor Selection

RPM & Speed

When measuring RPM the device used is referred to as a tachometer.

- Tachometers can be classified on the basis of data acquisition (contact/contactless), data type (analogue/digital) or the basis of power (mechanical/electrical). [6] [7]

When considering these classifications referring back to the design specification/brief will help narrow down the selection of sensors that are acceptable.

“be battery power so that it is independent of the subject of vehicles power supply, none of the sensors is allowed to be connected to the vehicles electronics or signal”. [7]

Sensor	Data Acquisition	Data Type	Power Basis
Push Switch	Contact	Digital	Mechanical
Reed Switch	Contact + Non Contact	Digital	Mechanical
Hall Effect	Non Contactless	Both	Electrical
Photo-Electric	Non Contactless	Both	Electrical
Inductive	Non Contactless	Both	Electrical
Capacitive	Non Contactless	Both	Electrical

Looking back at the classification a contactless electrical tachometer with a digital output is required. A digital output is required as the data needs to be stored. All mechanical, contact and sensors with an analogue output shall be excluded when considering sensors to measure RPM. This includes proximity sensors such as:-

- Photoelectric
- Inductive/Hall effect
- Capacitive

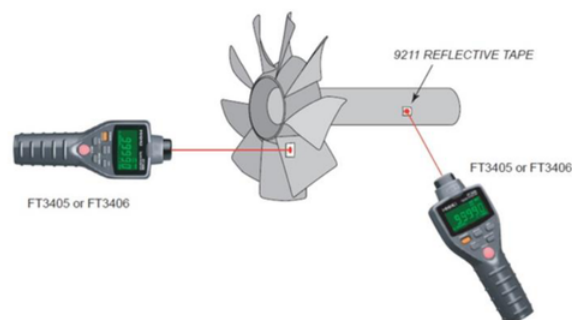
Capacitive sensors are avoided in the automotive environment when measuring RPM due the installation difficulty, vulnerability to environment conditions and as the gear of the car is metallic the inductive sensor is more effective. Hall Effect sensors require a magnet to be attached to the shaft of the engine, this goes against the assignment brief as modifying the car is not applicable however there are available products where this can be avoided. [6] [7]

The sensors left to consider when measuring RPM of an automobile is the photoelectric and the inductive sensors. These both are widely used within the automotive industry.

- Photoelectric

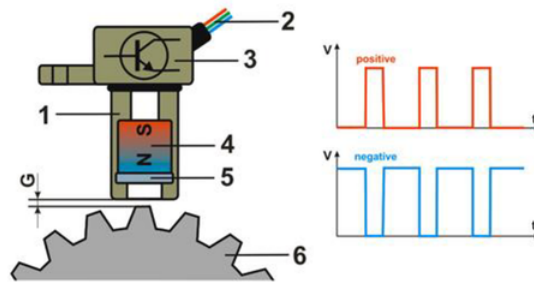
One method of using a photoelectric sensor to measure RPM is a use of a retro reflective sensor.

With the use of reflective tape gives the user flexibility as they can select the amount of pulses per revolution just by adding more reflective tape to the rotating object. Emitted is a beam of light (sensor dependant) and when the beam comes into contact with this reflective surface it reflects the beam back to the receiver of the sensor.



- Inductive

1. Sensor housing
2. Output wires (+Vcc, -Vcc and signal)
3. Integrated electronics
4. Permanent magnet
5. Hall Effect device
6. Trigger wheel
- G. Air gap [8]



Whilst the photoelectric sensor uses reflective tape for the amount of pulses read per revolution, when using an Inductive sensor the pulses are determined by the amount of teeth that are located on the crank. The output pulses are generated when the teeth of the crank are in range of the sensor giving a digital output of either VCC or 0v. The sensor range has minimal range as shown in figure 2 usually having a sensing range of a few millimetres, this might cause some difficulty when mounting the device. [8]

As mentioned before both sensors are acceptable when measuring RPM in an automotive vehicle but for the authors particular design photoelectric sensor is going to be used as the PPR (pulses per revolution) is more flexible allowing you to select the amount PPR determining the resolution and accuracy of output. Another reason choosing the photoelectric sensor over the inductive/hall effect

Parameter/Product Number	<u>729-5117</u>	<u>444-3619</u>	<u>289-2491</u>	<u>444-3451</u>
Detection Range (m)	0.05 → 7	1.3 , 2 , 11 , 40	2.4	0.12 , 0.3 , 2 , 15
Response Time (ms)	<=0.5	<25	<=0.5	<2
Cost (£)	52.85	127.47	89.82	77.98

is that

photoelectric sensors have more range once again giving more flexibility for positioning of the sensor.

Out of the photoelectric sensors parameters such as detection range, response time, cost, mount type and connectors have been taken into consideration.

- **Detection range**
Detection range is a parameter to ensure installation is a quick and easy process, with a larger detection range it allows the user to have more flexibility on where to install the sensor.
- **Response time**
Response time is an important factor to know how fast the readings are being recorded, it allows the designer to understand and process the information being recorded when selecting a microcontroller.
- **Cost** is the final parameter, cost determines the selection of sensors selected have the same parameters, if it does the same thing the cheaper option is always optimal.

The selection chosen to measure RPM is the 727-5117 as it has a 0.5ms response time, with a flexible detection range. This sensor is fast, flexible and allows easy installation.

Engine Temperature

Engine temperature is important as it provides the user information to ensure there is no problems with the car being tested, such as its radiator, pumps or any other problems that might arise. Engine temperatures operate in the range of 195 – 220 degrees Fahrenheit (87-105 degrees Celsius), this will be one of the important parameters when selecting a sensor. [9]

Referring back to the specification, the temperature sensor needs to be contactless. The only type of contactless temperature sensor on the market for measuring a surfaces temperature uses infrared technology. The final parameter to consider is the output signal the particular sensor has, it either being thermocouple or voltage. Thermocouples output signal are non-linear therefor making it harder to read compared to a voltage output or a MA output however these require additional circuitry for amplification.

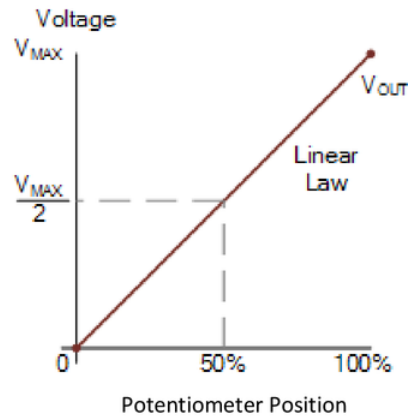
Sensor/Parameters	<u>553-321</u>	<u>553-337</u>	<u>553-343</u>	OS136-1-MA
Temp Range °C	0-250	0-250	0-250	-18-202
Response Time (ms)	240	240	240	150
Sensor Type Output	MA Output Signal	Type K Thermocouple	MA Output Signal	MA/thermocouple /voltage
Cost (£)	180.83	167.43	167.43	144.00

All sensors selected meet the temperature range requirement and the specification. The final sensor to be used to measure engine temperature is the OS136-1-MA as it has a quicker response time and configurable outputs for designers, it offers a voltage output in the range of 1-5v making the output requiring little conditioning. It's also the cheapest out of all sensors considered.

Suspension

When measuring suspension we are referring to the compression or extension of the spring. This movement in a standard salon family car is of a lateral movement varying in a few millimetres (mm).

There are a few sensors that capable of such application that are commonly called displacement sensors. "A displacement sensor is used to measure travel range between where and object is and its reference position. Using the cars resting position we can refer to this as the reference position.



Types of sensors to consider:

- Photoelectric
Photoelectric sensors such as laser sensors are high accuracy, great response time and are reliable in normal environment conditions. As the sensors is in a high vibration, dust and potentially a lot of dirt this could affect the sensors accuracy greatly.
- Ultrasonic
Ultrasonic is going to be ruled out immediately as it has a slow response time. When measuring suspension a high response time is mandatory as it needs to be read very quickly.
- Inductive
Inductive placements sensors are brilliant in accuracy, fast and resilient to all environments (excluding high electromagnetic interference) however it requires an AC power source. The specification asks for a portable data acquisition system therefor DC battery powered is required.
- Potentiometer
A potentiometer displacement sensor runs off DC, its output is mv/V depending on the VSS and has a direct linear proportional relationship to its position. However these produce electrical noise as it's a mechanical device which will also result in a short life span.

As environment is an important parameter when choosing a sensor relating to the specification, photoelectric, ultrasonic and inductive are ruled out as they are not applicable due to the brief or environmental factors. [10]

The parameters chosen are stroke, supply voltage, linearity and cost.

- Stroke

Stroke range is important because if the stroke range is not large enough it could cause damage to the sensor.

- Supply Voltage
As selecting a battery is part of the specification, having a reasonable supply voltage is key to ensure the battery for the system is a decent size and a suitable voltage range.
- Cost is the final parameter, cost determines the selection of sensors selected have the same parameters, if it does the same thing the cheaper option is always optimal.

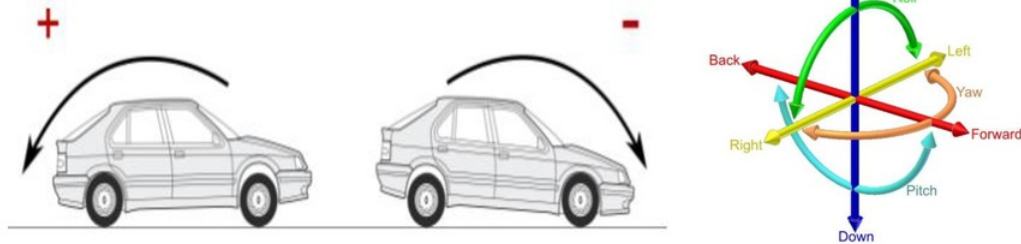
Sensor/Parameters	B 261 209 534-01	SE04-150	Linear290
Stroke (mm)	0-150	0-150	0-290
Supply Voltage (v)	5	5	5
Linearity (%)	0.15	0.15	0.5
Cost (£)	180.83	167.43	167.43

The final sensor chosen to measure the suspension is the linear290 because it offers a larger stroke therefore being more applicable for a wider range of cars, this however comes at a cost of accuracy (linearity) of 0.35%.

Pitch, Roll and Yaw

Best to describe pitch roll and yaw is to look at figure "n". Each aspect displays the position of the vehicles body.

Pitch is measured on the lateral axis measuring the rotation from the centre of the car and side to side. Variation of pitch occurs when either tail/nose of the car elevates or drops from its reference position, this occurs when going up/down a hill or acceleration/braking is applied. [11] [12]

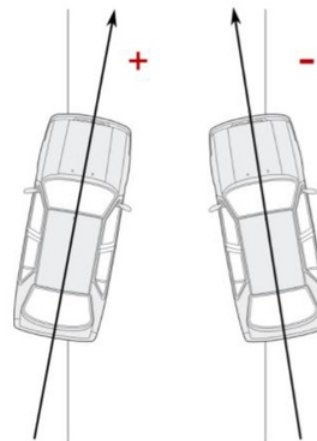


Roll is measured on the longitude axis measuring the rotation of the vehicle from nose to tail, this occurs when the vehicle turns a corner resulting in the suspension compression on one side of the car and extension on the opposite. [11] [12]



Yaw is the rotation around the vertical axis, it is described as side to side movement of the nose or tail, this occurs when the car over/under steers.

The measurement units used to measure all of these parameters are degrees per second, the sensors available on the market to do such a task are accelerometers and gyroscopes.



- Gyroscope
Gyroscopes is a device that measure rotation using the earths gravitational pull as its reference, gyroscopes are more than capable is measuring pitch, roll and yaw.
- Accelerometer
"An accelerometer is a device that measures the vibration, or acceleration of motion of a structure. The force caused by vibration or a change in motion (acceleration) causes the mass to "squeeze" the piezoelectric material which produces an electrical charge that is proportional to the force exerted upon it. Since the charge is proportional to the force, and the mass is a constant, then the charge is also proportional to the acceleration." [13]

Out of these two sensors the gyroscope is going to be used as it is more accurate in measuring pitch, roll and yaw.

The chosen sensor will be the SA-GYxxV4-500.

Electrical characteristics

Power supply.....	4.75 - 5.25 V DC
Operating current.....	max. 50 mA
Range:	
SA-GY200V4-000.....	-200°/s@0.5V 200°/s@4.5V
SA-GY500V4-000.....	-573°/s@0.5V 573°/s@4.5V
Sensitivity:	
SA-GY200V4-000.....	± 200 ° / s
SA-GY500V4-000.....	± 573 ° / s
Resolution.....	0.1 ° / s
Linearity.....	< 0.5% FS

The sensor has been chosen due to its high range, low input voltage and low output voltage. It requires no extra circuitry or signal conditioning. [14]

Selection of PIC

Considering a PIC can be difficult as there are many parameters, however looking at the specification we already have knowledge of necessary parameters. Theses parameters are:

- USB
- Minimum of 9 A/D channels (Based on sensor selection)
- UART (MicroSD compatibility)
- 8bit Microcontroller

Program memory and internal oscillation have also been inserted. Programmed memory that has been estimated at 4k, to be sure this number has been multiplied by 4 to be safe. Internal oscillation has also been selected to allow more space for the PCB when designing and also results in less additional circuitry.

After all these parameters have been inputted the selection tool has left me with 4 options as shown.

The screenshot shows a selection tool interface with five adjustable parameters, each with a dropdown menu and a slider bar:

- Total # of A/D channels:** The dropdown menu shows options from 0 to 14. The slider bar is set to 9.
- UART:** The dropdown menu shows options [Reset], 0, 1, 2, 3, 5. The slider bar is set to 1.
- CPU:** The dropdown menu shows options [Reset], 8-bit AVR, 8-bit PIC, 8-bit PIC MCU. The slider bar is set to 8-bit PIC MCU.
- Number of USB Modules:** The dropdown menu shows options [Reset], 0, 1. The slider bar is set to 1.
- Program Memory Size (Kbytes):** The dropdown menu shows options from 1.75 to 28. The slider bar is set to 14.

Product	Channels	Program Memory (kbytes)	UART	USB	RAM
PIC16F1459	9	14	1	1	1024
PIC18F13k50	9	8	1	1	512
PIC18F4k50	9	16	1	1	768
PIC18F24K50	14	16	1	1	2048

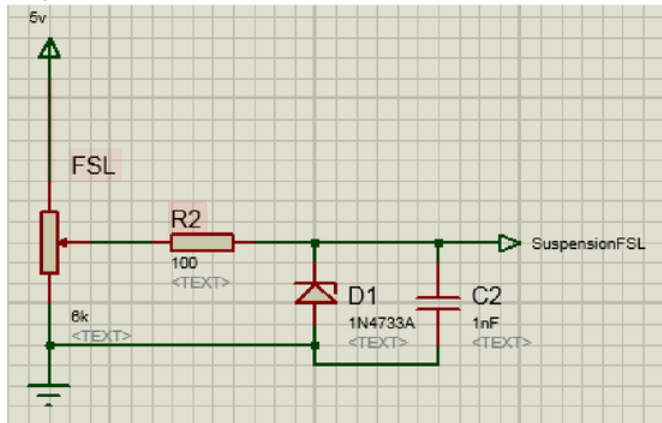
Selection of the PIC18F24K50 has been selected as it meets all of the specifications, the only other PIC to meet all desired parameters is the PIC16F4K50 how this hasn't been selected as it has less ram and only 9 A/D channels (14 allows more room for improvement and error).

Data Acquisition Design

To design the system Proteus will be used:

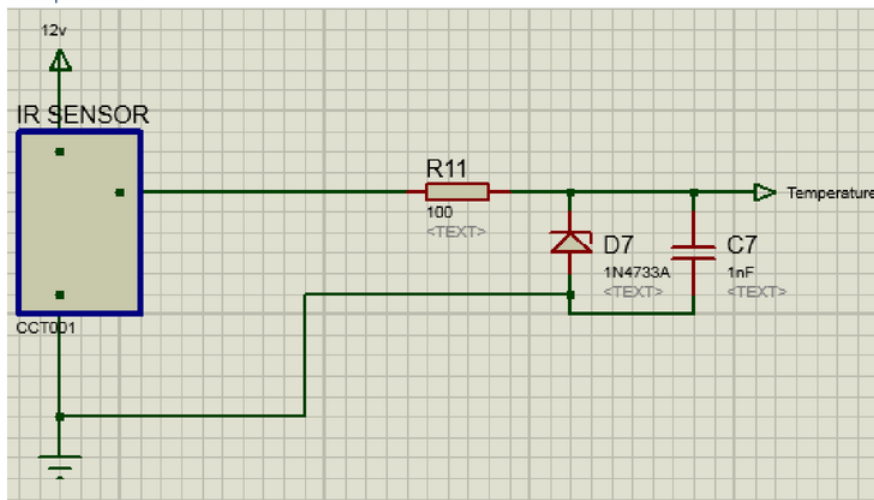
Proteus Designs

Suspension



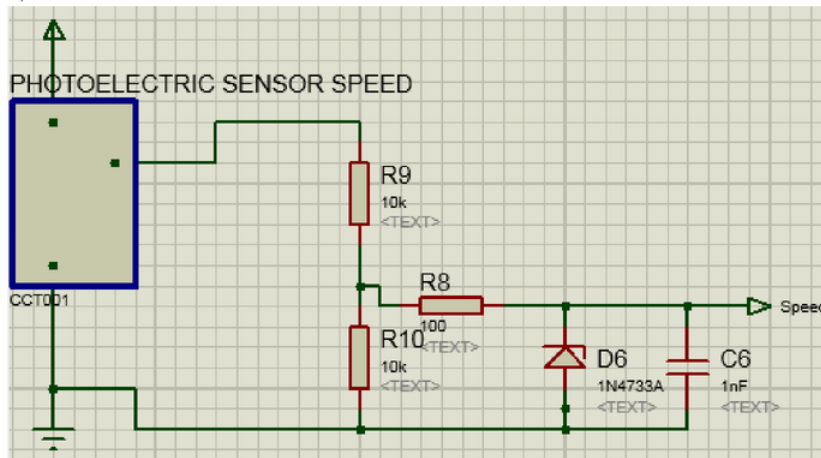
This image is displaying the design of the suspension sensor. The sensor used is a potentiometer with a supply voltage of 5v. This particular diagram shows the wiring diagram for the front left suspension (FSL). This configuration has been duplicated for front right suspension (FSR), rear right suspension (RSR) and rear left suspension (RSL).

Temperature



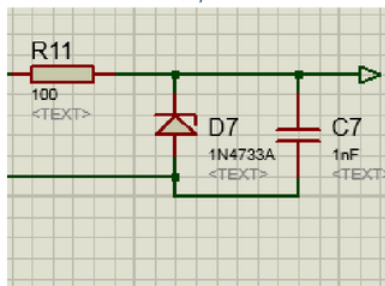
This image is displaying the design of the temperature sensor. The sensor used is Infrared with a supply voltage of 12v.

Speed and RPM



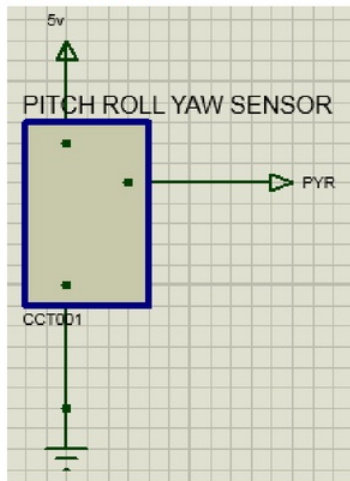
This image is displaying the design of the RPM/Speed sensor. The sensor used is a reflective Infrared with a supply voltage of 12v. The potentiometer provides a 5v output so that I doesn't damage the IC. This sensor*2 is used to measure speed and RPM.

Additional Circuitry



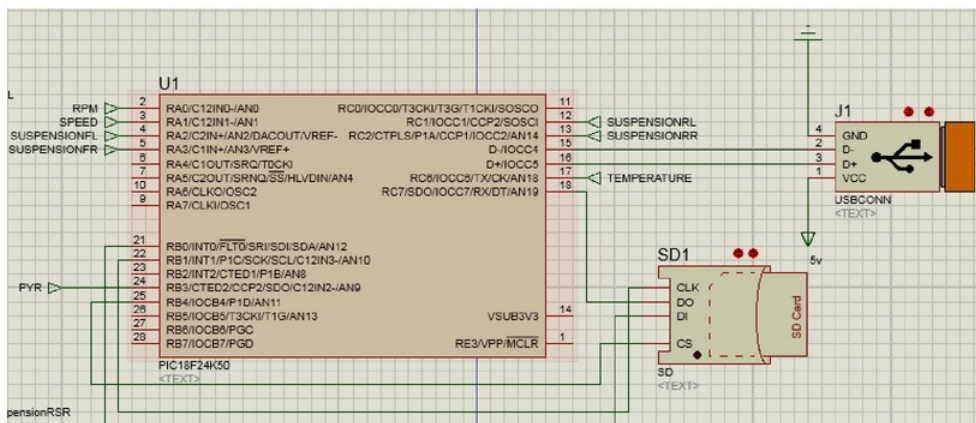
This additional circuitry is signal condition the outputs of the above sensors to provide a low current, stable voltage to satisfy the PIC operation requirements and provides protection for the PIC. It also reduces any noise that the sensors may emit.

Pitch Roll Yaw



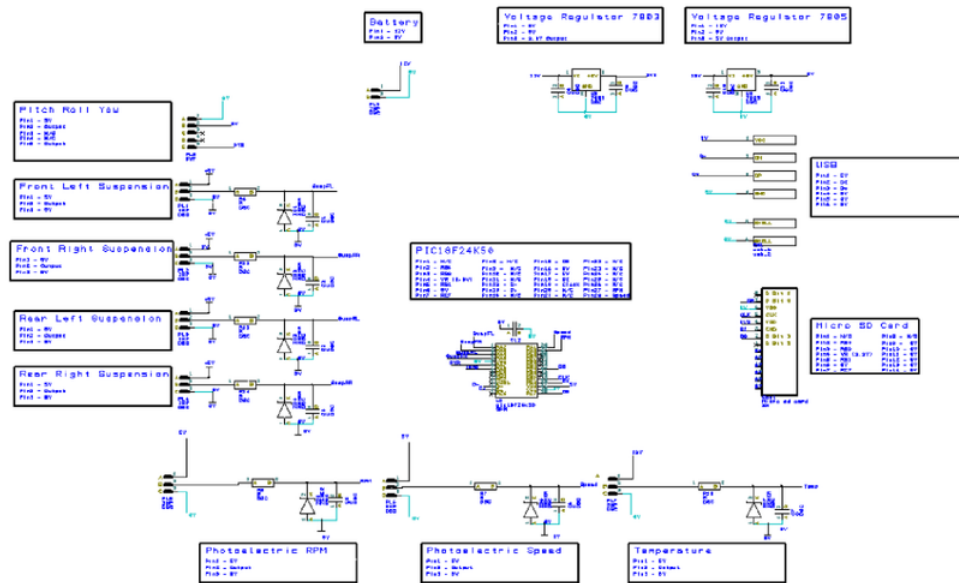
The sensor measuring pitch, roll and yaw is a gyroscope with an input of 5v.

PIC18F24K50



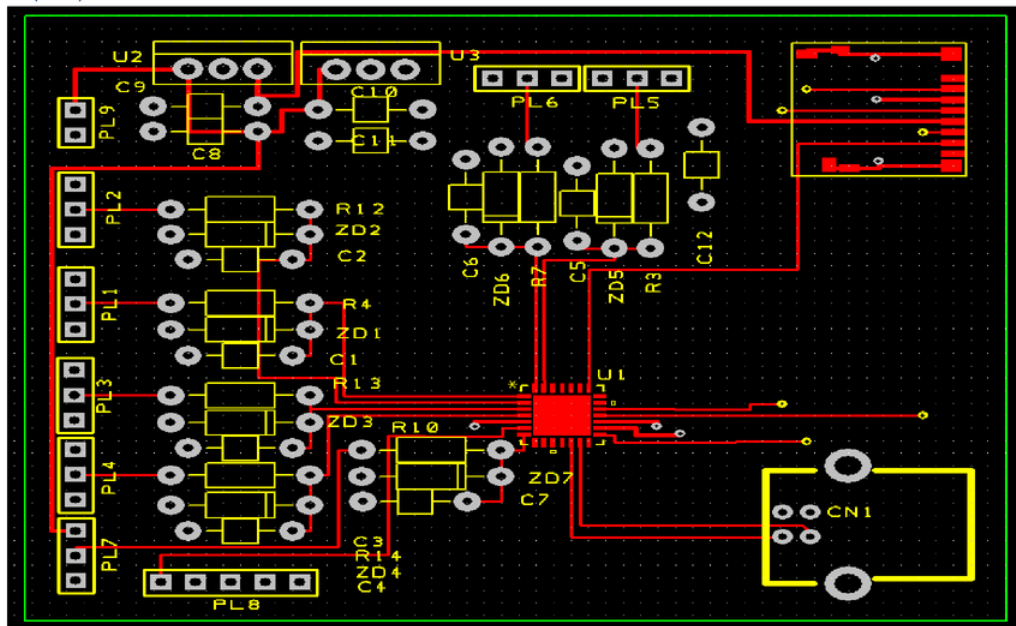
Here shown is the PIC connected to all the other sensors on the suitable pins along with the SD card and the USB that was asked in the specification.

Easy PC Design



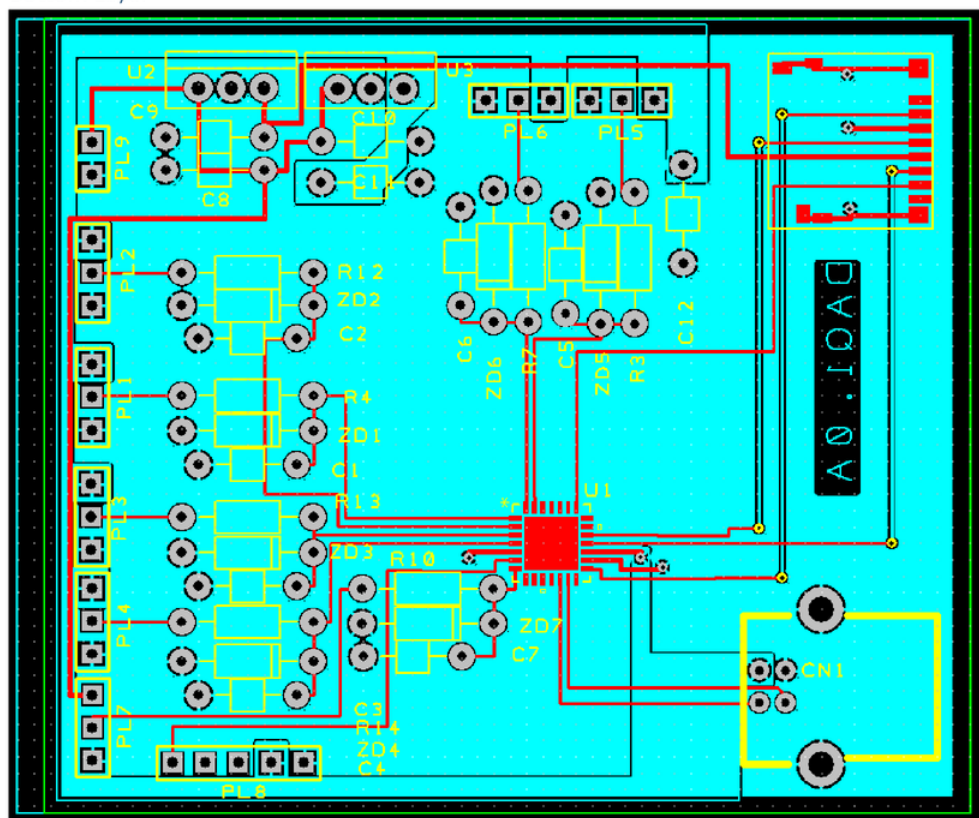
Translating the Proteus design the Easy PC, this allows the data acquisition system to be translated to PCB. Two voltage regulators (5V,3.3v) have been added along with a 12V battery to supply specific sensor with their required input voltages.

Top Layer

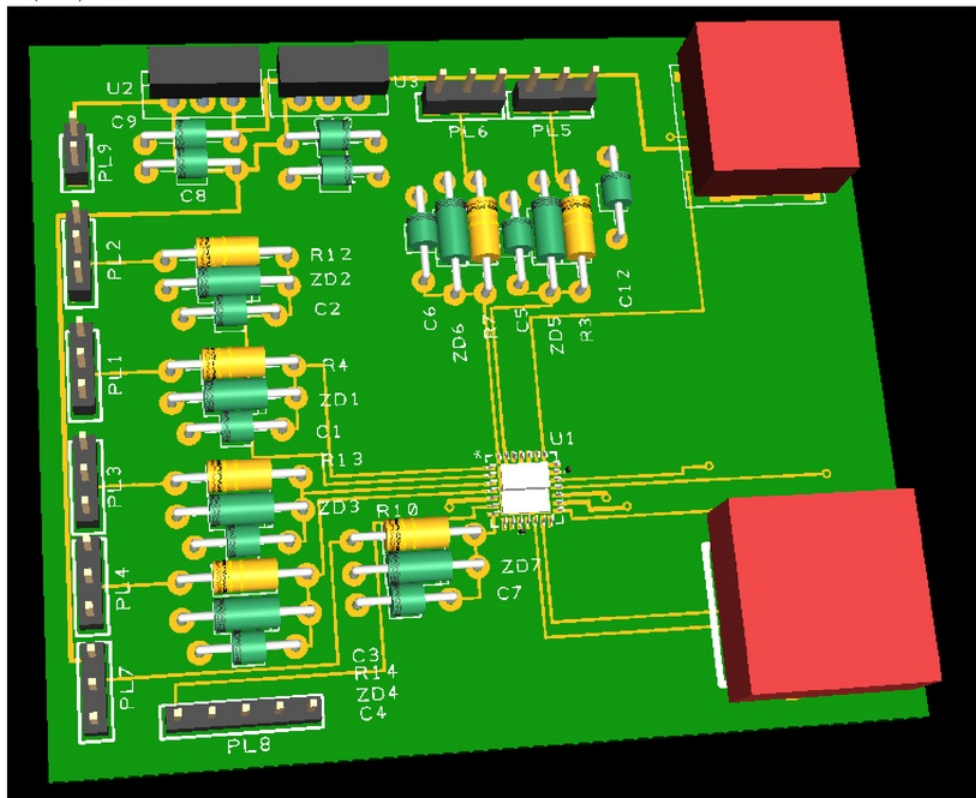


PL1	Suspension
PL2	Suspension
PL3	Suspension
PL4	Suspension
PL5	RPM
PL6	Speed
PL7	Temperature
PL8	Pitch, Roll and Yaw
PL9	12V Battery
U1	PIC
U2	5v Voltage Regulator
U3	3.3v Voltage Regulator
CN1	USB
Micro	Micro SD

Bottom Layer



Top Layer 3D



[9]Bottom Layer 3D

References

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Data Acquisition Systems

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

47 /100

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GLEN JOSEPH HENLEY

47.05

RESEARCH-INFORMED LITERATURE



Literature revue is reasonable manufacturer information is well presented but it would be improved by following up with a comparison table of relevent information. 58%

5.8

KNOWLEDGE AND UNDERSTANDING



Good overall schematic design but a few problems can be seen. The PRY sensor only has 1 5V signal coming out to the Pic, this would indicate either a multiplexed signal (but there does not appear to be any control signal) or that a mistake has been made in it's implementation. The connections between the sdcard and the Pic show MIDO connected on both sides as data input whilst the MODI is connected to both data outputs. 58%

14.5

ANALYSIS



Good selection of microcontroller. Reasonable selection of sensors, a table showing the selection of sensors to be chosen with an image or illustration of each would have been an improvement. There is no case selection or discussion. There is no connector selection or discussion. 45%

15.75

PRACTICAL APPLICATION AND DEP.

- | | | |
|---|---|----------|
|  | No costings table put forward but some sensor costs are included in the text. No attempt at future enhancements.30% | 6 |
|---|---|----------|

SKILLS FOR PROFESSIONAL PRAC.

- | | | |
|---|---|----------|
|  | The report is reasonably presented with some good explanations of concepts which could have been improved with more images/illustrations and diagrams. Reasonable selection of references. More care and better time management would have seen a vast improvement in the quality of this submission. 50% | 5 |
|---|---|----------|