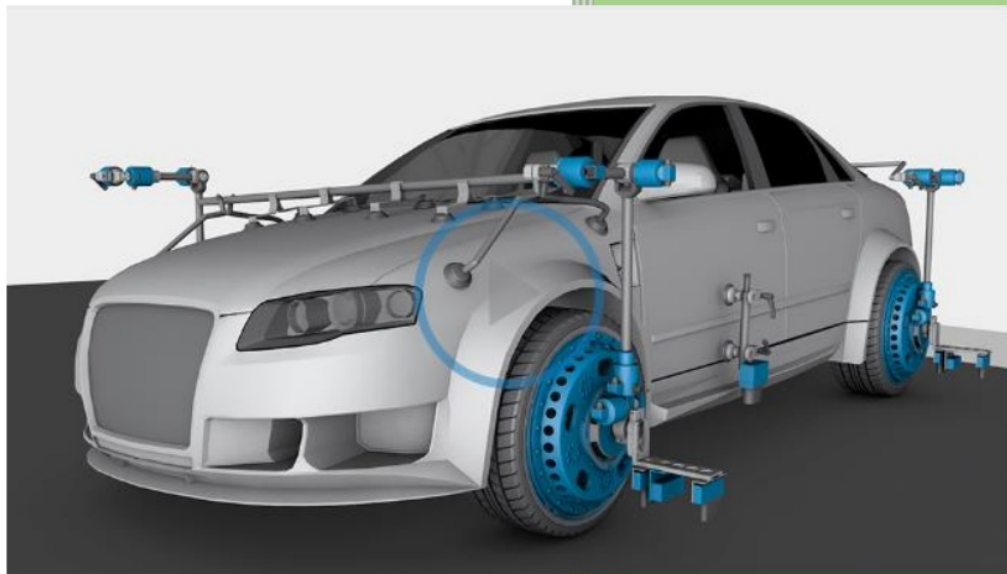


ESD Data Aquisition System _ C Stonelake

by Christopher Stonelake

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Data Acquisition Technologies & Design



Stonelake, Christopher

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Introduction

In this document I will be looking at a vehicle dynamic testing system, these systems are used extensively in the automotive industries to validate car performances without relying on the car/manufacture internal monitoring systems.

The main objective is to research / design and specify a vehicle data logging system to capture key vehicle dynamic performances during a 2hr test drive on a private track, during this test the following areas of information will be tracked and recorded.

- RPM (Revolutions Per Minute)
- MPH (Miles Per Hour)
- Suspension travel
- Pitch, roll, yaw
- Engine Temperature

The design specification will require individual sensors to measure each point for performance monitoring, the sensors will be connected back to one central control unit, and information values processed via a microcontroller and stored on local memory.

The unit will have connection ports such as USB for extraction of information obtained from test runs, the unit must be mobile and portable in this it must be self-powered for the duration of the test period and initial set up and down load so a battery life of 3hrs minimum would be required.

Section 1 - (TASK 1)

Existing market vehicle data monitoring systems

Vehicle dynamic data monitoring systems are a vital part of the automotive industry's whether this is in the line of improvements in safety features for a car, improved performances to obtain the competitive edge in professional racing such as WRC/Formula 1 or E etc or to the more extreme case such as the VW emissions scandal where VW's cars were tested against independent vehicle data acquisition systems in real world road test, which highlighted the serious findings that what the car output significantly higher CO₂ levels than that stated by the manufacture.

There are a number of established manufactures/suppliers of data acquisition loggers available on the market today, below we will have a look at four of these suppliers and evaluate the pros and cons of each to establish which is more suitable.

Manufacture 1

Dewetron Systems

<https://www.dewetron.com/products/data-acquisition-hardware-chassis/all-in-one-chassis/dewe2a4/>

Dewetron systems have a leading and robust reputation within the automotive testing industry [1] Our equipment ensures the high precision and comprehensive measurement data necessary for objective decisions in vehicle development, during acceptance tests and maintenance.

Measurement systems by DEWETRON comply with the standards of EURO NCAP and NHTSA for assessment programs. [1]



Figure 1 – DEWE2-A4

Portable measurement system DEWE2-A4 for mobile applications.

[2] The DEWE2-A4, portable measurement system, is the most convenient system for mobile applications. With the plug'n'play TRION™ modules, the hardware can be re-configured for different tests within one minute. [2]

Other benefits and features;

- Sync-clock (synchronizes all signal sources)
- GPS
- Multi-sensor inputs (voltage, acceleration, strain etc)
- Real-time mathematics
- Export files to different formats
- Input signals (GPS position, velocities, pitch, roll, yaw, optical velocity sensors, wheel vector, brake force, pedal travel)

Manufacture 2

Kistler

<https://www.kistler.com/?type=669&fid=88296&model=document&callee=frontend>

Kistler another performance market data acquisition manufacture who are at the fore front of data acquisition, below are their portable flag ship option.

[3] The DTI-logger type 5343B is a powerful data acquisition for the applications of vehicle dynamics, fatigue strength and tire based on the standard DTI bus (digital transducer interface) [3]



Figure 2 – DTI- Logger Type 5343B

- 8 DTI ports connection of upto 96 sensors
- Data transfer, synchronization, configuration and power supply via one cable
- Crosslinking of up to three DTI loggers via sync switch type 5614a

Manufacture 3

Dewesoft

<https://dewesoft.com/products/daq-systems/r4>

Dewesoft offer an extremely versatile all-round data acquisition system;

[4] R4 is a compact data acquisition system built around 'Sirius DAQ technology' Systems feature dual core ADC analog inputs with 160dB dynamic range and acquisition speeds of 200KHz per channel or optional high-speed amplifiers with speeds up to 1Mhz per channel.

R4 chassis can hold upto SIRIUS DAQ slices with a total of 64 analog channels, 32 counter/encoder channel, 96 digital channels and up to 4 high sped CAN bus prots. An array of different amplifiers is available to acquire signals from virtually any sensor. [4]

- High end signal conditioning
- Powerful & reliable computer
- Upto 64 analog inputs
- Upto 32 counter/encoder inputs
- Upto 4 isolated can ports
- Ethernet master port
- 100Hz GPS with RTK
- Softwear included with free lifetime upgrades



Figure 3 – R4 DAQ Data Logger

Manufacture 4

V-box Automotive –

<https://www.vboxautomotive.co.uk/index.php/en/products/data-loggers/vbox-3i#features>

[5] A great many aspects of vehicle testing can be conducted using a VBOX data logger, from simple performance evaluation through to complex development of the latest ADAS applications. GPS log rates range from 10 Hz to 100 Hz, and there are options for single and dual antenna systems - ideal for vehicle dynamics testing. Differential GPS and RTK solutions allow for high positional accuracy, and inertial measurement integration increases the testing scope further.

VBOX GPS data logging solutions vary from the 10 Hz VBOX Mini, an easy to use but highly capable unit perfect for simple testing and lap timing; through the SX range which brings together survey-grade GPS engines and CAN Bus logging; to the VBOX 3i which logs at a true 100 Hz and forms the basis of the VBOX ADAS testing packages.

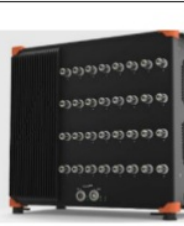
VBOX systems are employed in many types of testing: automotive, open-cast mining, motorsport, aviation, and collision forensics. Every major vehicle and tyre manufacturer in the world uses VBOX products. [5]



Figure 4 – Vbox ADAS

- 100 Hz logging to CF memory card
- High brake stop accuracy up to ± 1.8 cm
- Very low latency: 8.5 ± 1.5 mS
- Oversampled brake/event trigger input (25 nS)
- 4x analogue inputs
- 1x default CAN Bus port for input module expansion
- 1x configurable CAN Bus for vehicle CAN interface or VBOX data output
- Easy to fit and transport
- Real-time result display via serial, USB or Bluetooth
- User configurable logging conditions
- IMU integration
- Wide 7 V to 30 V operating range
- Low current consumption
- Audio voice tagging

Data Logger's Comparison Table

Data Logger Image				
Data Logger Name	Dewetron Systems	Kistler	Dewesort	V Box
Logging Rate	90 Mb/s	40 bytes/ms	1MHz Per Chan	182Mb per Hours
Supply Voltage	10-36 V DC	10-28 V DC	10-33 V DC	7-30 V DC
Inputs	Digital & Analogue	Digital (must use Kistler sensors)	Digital & Analogue	Digital & Analogue
Out Puts	-SD Card -USB -RS232	-Ethernet TCP/IP	-USB -HDMI -LAN	-USB -CF Card -RS232
Portability	Very Portable	Very Portable	Very Portable	Very Portable
Negative against the other makes	Les input range from rest of the range	Can only use sensors from manufacture	No visual interface	No visual interface and can only use sensors from manufacture

Task 2 – Microcontroller specification & Selection

Within task 2 the selection of the microcontroller will need to be chosen with specific care and attention to system data acquisition demands, these can be items such as; bit size, logging rate, number of pins, range and accuracy.

In the table below gives an over view of the specification required, from these points below it should be a minimum in which the microcontroller is selected on.

Sensor	Signal	Pins	Logging Rate	Bits
Suspension	Analogue	4	0.25ms	10
Engine Temperature	Analogue	1	10s	10
Pitch	Analogue	1	1s	10
Roll	Analogue	1	100ms	10
Yaw	Analogue	1	1ms	10
MPH	Analogue	1	1s	8
RPM	Analogue	1	1s	8
RS232	digital	2		
SD Card	digital	3		
USB	digital	2		
SPI		1		

Microcontroller Specification

- 10 Analogue Signals
- 7 Digital Signals
- 10Kb Programming
- 2048 SRAM
- USB Module
- 1 SPI

Using microchip.com (<https://www.microchip.com>) for the selection of my unit, I was able to use the selection tool interface to narrow down my selection for the right choice of chip.

While putting my individual requirements as above, the final selection only resulted in x1 selection fo chip from microchip.com, the selection page is as seen in the below image (xxx)



TABLE 1: PIC18(L)F2X/45K50 PIN SUMMARY

IO	28-Pin PDIP/SOP/SSOP	28-Pin QFN	40-Pin PDIP	40-Pin QFN	44-Pin TQFP	Analog	Comparator	CTMU	SR Latch	Reference	USB	(E)CCP	EUSART	MSSP	Timers	Interrupts	Pull-up	Basic	ICD
RA0	2	27	2	17	19	AN0	C12IN0-	—	—	—	—	—	—	—	—	—	—	—	—
RA1	3	28	3	18	20	AN1	C12IN1-	CTCMP	—	—	—	—	—	—	—	—	—	—	—
RA2	4	1	4	19	21	AN2	C2IN+	—	—	Vref-, DACOUT	—	—	—	—	—	—	—	—	—
RA3	5	2	5	20	22	AN3	C1IN+	—	—	Vref+	—	—	—	—	—	—	—	—	—
RA4	6	3	6	21	23	—	C1OUT	—	SRQ	—	—	—	—	—	T0CKI	—	—	—	—
RA5	7	4	7	22	24	AN4	C2OUT	—	SRNQ	HLVDIN	—	—	—	SS	—	—	—	—	—
RA6	10	7	14	29	31	—	—	—	—	—	—	—	—	—	—	—	—	OSC2 CLK0	—
RA7	9	6	13	28	30	—	—	—	—	—	—	—	—	—	—	—	—	OSC1 CLK1	—
RB0	21	18	33	8	8	AN12	—	—	SRI	—	—	FLT0	—	SDI SDA	—	INT0	Y	—	—
RB1	22	19	34	9	9	AN10	C12IN3-	—	—	—	—	P1C ⁽⁶⁾	—	SCK SCL	—	INT1	Y	—	—
RB2	23	20	35	10	10	AN8	—	CTED1	—	—	—	P1B ⁽⁶⁾	—	—	—	INT2	Y	—	—
RB3	24	21	36	11	11	AN9	C12IN2-	CTED2	—	—	—	CCP2 ⁽¹⁾	—	SDO	—	—	—	—	—
RB4	25	22	37	12	14	AN11	—	—	—	—	—	P1D ⁽⁶⁾	—	—	—	—	IOCB4	Y	—
RB5	26	23	38	13	15	AN13	—	—	—	—	—	—	—	—	T1G T3CKJ ⁽²⁾	—	—	—	—
RB6	27	24	39	14	16	—	—	—	—	—	—	—	—	—	—	IOCB6	Y	PGC	—

Note 1: Alternate CCP2 pin location based on Configuration bit.
2: Alternate T3CKJ pin location based on Configuration bits.
3: Pins are enabled when ICPRT = 1, otherwise, they are disabled.
4: Location on 40/44-Pin parts (PIC18(L)F45K50). Function not on this pin on 28-Pin parts (PIC18(L)F2XK50).
5: Location on 28-Pin parts (PIC18(L)F2XK50). Function not on this pin on 40/44-Pin parts (PIC18(L)F45K50).
6: Alternate SDO pin location based on Configuration bits.
7: RE3 can be used for digital input only (no output functionality).

PIC18(L)F2X/45K50

Figure 5 – Microchip

PIC Data sheet - http://ww1.microchip.com/downloads/en/DeviceDoc/PIC18F2X_45K50-30000684B.pdf

due to the overall set criteria in which I was choosing the final results were in one device selection as above, the PIC18F25K50

Given that the research into the devices and specific criteria has yielded one offering I am happy to continue with this selection as the selection tool from microchip.com

Task 3

In task 3 sensors for data acquisition during the car 2hr task will be made by specific sensors for each measuring application one of the main features for all the sensors shall be to be as non-invasive as possible.

Below are tables which show this detailed review;

Engine Temperature Measurement

Technology Name >	Thermocouple	Infrared	RTD (Resistance Temperature Detectors)
Pro's	• Cheap to buy • Simple construction • Durable in extreme temperatures • High IP rating	• Non-invasive measuring • Very accurate • Ease of installation • Good IP rating	• High accuracy levels • Good durability
Con's	• Requires invasive connection • Cost of compensating cable	• Expensive • Dust/dirt build up on lenses	• Requires invasive connection

From the above quick pro's/con's table I will be moving forward with the detailed review based on the infrared temperature measuring technology.

Engine Temperature Sensor's Technical Over View

Technology sensor name	Thermocouple	Infrared Sensor	RTD
Picture			
Cost per Unit	£48.94	£278.00	
Durability	Very Good	Very Good	Very Good
Portability	Very Good	Very Good	Very Good
Power Supply	N/A	12 – 24 V DC	N/A
Power supply connection Plug	N/A	Pre wired flex	N/A
Data Connection	N/A	Pre wired flex 5c	N/A
Data Connection Plug	N/A	Pre wired flex 5c	N/A
Power Consumption	N/a	70mA	N/A
Data Out Put (Digital / Analog)	Analog 4-20mA	Analog 0-5v DC	Analog 4-20mA
Manufacture Web Link			
Data Sheet Web Link		https://raytec.com	
Brief over view how the technology works	A thermocouple is made with two wires of different metals, joined to gather at one end to form a junction, as the temperature changes, the two dissimilar metals begin to deform, causing a change in resistance.	sensors work by focusing the infrared energy emitted by an object onto one or more photodetectors, these photodetectors convert that energy into an electrical signal, which is proportional to the infrared energy emitted by the object.	RTD sensor measures temp using the principle that the resistance of metal changes with temperature. In practice an electrical current is transmitted through a piece of metal (RTD element) locally to the area where temp is to be measured.

From the above technical sensor over view, I have highlighted the chosen sensor I will be using for my design/system.

Below is the sensors manufacture data sheet.



« Go to Raytek Compact CI Infrared Pyrometer Series

Raytek RAYCI3A Infrared Temperature Sensor, 0-5VDC Output, 0 to 115°C (32 to 240°F)

Model: RAYCI3A

The CI sensor provides the advantages of infrared temperature measurement in a compact, low cost sensor and can easily replace traditional contact probes with a J-type or K-type thermocouple output, or with a 0-5V output, when integrated into a standard 4-wire system.

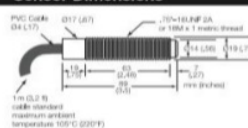
Electrical Specifications

Output:	User selectable thermocouple output (model specific, either J or K) or voltage output 0 to 5VDC
Cable Length:	1 m (3.2 ft) standard, longer cables optional
Output Impedance:	50 ohms
Minimum Load Impedance:	50K ohms
Power Supply:	12-24 VDC (+/- 2.5% ripple) @ 20 mA

Sensor Specifications

Environmental Rating:	IP 65 (NEMA 4)
Ambient Temperature Range:	0°C to 70°C (32°F to 160°F)
With air cooling:	0°C to 90°C (32°F to 200°F)
With water cooling:	0°C to 260°C (32°F to 500°F)
Storage Temperature:	-30°C to 85°C (-22°F to 185°F)
Relative Humidity:	10 to 95%, non-condensing
Shock:	8 G 60-2,000 Hz, STD 8100C
Vibration:	8 G 60-2,000 Hz, STD 8100C
Weight:	130 g (4.5 oz)

Sensor Dimensions



Accessories Options

Each CI sensor includes two mounting nuts, 1m (3.2ft) of cable, and an operator's manual. Longer cables up to 15m (50ft) maximum are available and must be specified at the time of order.



Figure 6 - Raytec data sheet

RPM Measurement

Technology Name >	Magnetic Induction Sensor	Optical (with reflective strip)	
Pro's	- Cheap to buy - Simple construction - Durable rough conditions - High IP rating	- High accuracy levels - Ease of installation and set up	- Hight accuracy levels - Very portable
Con's	- Installation Time - Requires Secure & precise fixing - Fixing and securing of magnet	- Expensive - Requires reflective strip	Only suitable for in garage applications, due to the main sensor is a hand-held device

RPM Sensor's Technical Over View

Technology sensor name	Magnetic Induction Sensor	Optical (with reflective strip) VLS5/T	Hall Effect Sensor
Picture			
Cost per Unit	£89.45	£188.00	£278.43
Durability	Very Good	Very good	Good
Portability	Very Good	Very good	Very Good
Power Supply	12 V DC	5 V 30V DC	12V DC
Power supply connection Plug	Pre wired sensor	Pre wired sensor with 4c cable	Pre wired sensor
Data Connection	Pre wired sensor	Pre wired sensor 4c cable	Pre wired sensor
Data Connection Plug	Pre wired sensor	Pre wired sensor	Pre wired sensor
Power Consumption	45Ma	120Ma	30Ma
Data Out Put (Digital / Analogue)	4-24 Mv	Analogue 5VDC (VLS/DA1 only)	4-24 Mv

Sample Rate		0-250,000 RPM	
Manufacture Web Link		www.raytek-direct.com	
Brief over view how the technology works	Magnetic inductive sensor uses electromagnetic induction to detect or measure objects, the inductor develops a magnetic field when this field is broken the sensor will pass current.	Optical sensor gives a continues light beam output when a reflective of sudden change in the measure surface occurs this reflects back and the sensor gives an out put	Hall effect sensor consist of a thin piece of semiconductor which has a continuous current passing through it, when a magnetic object is in close proximity it changes the semiconductor to different resistance and voltage change.

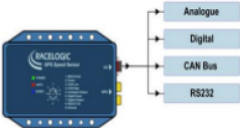
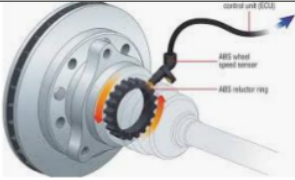
From the above technical sensor over view, I have highlighted the chosen sensor I will be using for my design/system.

Below is the sensors manufacture data sheet.

MPH Measurement

Technology Name >	GPS	Hall Effect Sensors	ABS wheel sensors
Pro's	- Cheap to buy - Simple construction - Easy installation accurate	- Non-invasive measuring - Very accurate	- High accuracy levels - Good durability
Con's	Interfacing with our design in being able to receive and read the data	- Expensive - Difficulty in installation	Requires a high invasive installation to sensor to work correctly.

MPH Sensor's Technical Over View

Technology sensor name	GPS	Optical VLS5/T with speed adaptor	ABS wheel sensors
Picture			
Cost per Unit	£349.87	£188 + £45 for speed sensor	£278.99
Durability	Good	Very good	Very Good
Portability	Very Good	Very Good	Very Good
Power Supply	24v	5 V DC	12V DC
Power supply connection Plug	RS232	Pre-wired sensor 4 c cable	Pre-wired sensor
Data Connection	N/A	N/A	N/A
Data Connection Plug	N/A	Pre-wired flex	N/A
Power Consumption	230mA	120Ma	235Ma
Data Out Put (Digital / Analogue)	Rj11 Comms	Analogue 5VDC (VLS/DA1 only)	Analogue 4-20ma
Out Put Signal Conditioner required			
Sample Rate			
Manufacture Web Link		http://compactinstruments.co.uk	
Brief over view how the technology works	GPS tracking uses a network of satellites to determine the location of a device in a process known as trilateration to determine is physical location	Optical sensor gives a continues light beam output when a reflective of sudden change in the measure surface occurs this reflects back and the sensor gives an out put	ABS sensors work on a similar principle to hall effect sensors and monitor wheel rotation, when the sensors pick up a difference in wheel rotations this triggers the ABS to activate.

From the above technical

sensor over view, I have highlighted the chosen sensor I will be using for my design/system.

Below is the sensors manufacture data sheet.

VLS Series Optical Speed Sensors VLS5/J

VLS Series Optical Speed Sensors - Standard Models

The VLS series of Visible Light Optical Sensors is primarily designed for speed related use. Ideal for use with our range of Digital Tachometers, including hand held, panel mounted and bench style instruments. A range of mounting devices is available for hands free applications.

Condition monitoring applications

There are 2 versions with on/off switch fitted so that battery power is conserved when used with battery powered equipment.

Mains/battery pack

A suitable mains adaptor/battery pack is available for use with all 5vdc VLS versions.

Optical ranges

Up to 1 metre for visible light versions and up to 2 metres with the Laser light types (with reflective tape).

High speed applications

A clip on prefocussed adaptor lens (LN1) is available which can allow operation without reflective tape in certain controlled conditions.

Power options

These sensors are available in 5vdc and 7.5-40vdc powered options, normally provided by the associated instrument from our range.

Contact Adaptor

The contact adaptor converts the optical function into direct shaft contactor for both RPM and linear speed measurement. This bayonet fitting device operates via a Hall Effect magnetic sensor built into the Sensor housing which picks up from a magnet in the VLS sensor.

Optional Accessories

A range of mounting devices is available for use with these sensors, brackets, clamps, fixed focus lens for high speed and small shafts.

General Specification

Optical range	50mm - 2 metre (1 metre Visible light version)
Overall speed	0-250,000 rpm (with lens range adaptor at high speed)
Optical angle	Up to +/- 80 deg (45 deg visible light version)
Ext. Power input	9-12vdc @ 300mA (ext. Adpt.)
Lens	Double lens reflex
Light sources	Visible light 5vdc minilamp - typical 2,000hrs Visible Laser 635nm CLASS II
Power requirements	VLS5/versions = 120mA@ 5vdc (Laser max. 85mA)
Operating temp.	-10 to +70 deg C (45 deg C Laser type)
Dimensions	L 130mm x D 34mm
Connections	Various cable & connector options
Output Pulse	NPN
Analogue	5v dc (VLS/DA1 only)

VLS/DA1 Optical Speed Sensor with Analogue output

The new VLS/DA1 Optical Sensor with integral Digital/ Analogue convertor, is designed for datalogging applications and where general speed monitoring of machines is required. It is particularly useful for monitoring & recording speed data.

The VLS/DA1 is designed for use with Datalogging and Condition monitoring equipment.

Figure 7 – VLS5 Data Sheet

MPH Adaptor for Sensor =

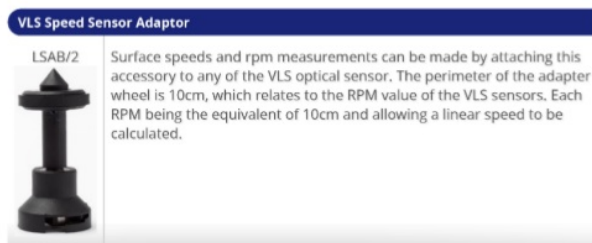


Figure 8 – MPH Speed Adaptor

On the adaption sensor for every 1 rotation equates to 10cm travelled.

Pitch, Roll & Yaw Measurement

Technology Name >	Inclinometer	Combined Pitch, Roll, Yaw sensor	Yaw rate sensor
Pro's	• High accuracy • Simple construction • Robust • Ease of installation	• High accuracy • Simple construction • Robust • Ease of installation • Multiple variants measured	• High accuracy • Simple construction • Robust Ease of installation
Con's	• One directional measurement would require multiple sensors	• Expensive	• One directional measurement would require multiple sensors

Pitch, Roll & Yaw Sensor's Technical Over View

Technology sensor name	Inclinometer	Combined Pitch, Roll, Yaw sensor	Yaw rate sensor
Picture			
Cost per Unit	£48.67	£198.49	£23.45
Durability	Very Good	Very Good	Very Good
Portability	Very Good	Very Good	Very Good
Power Supply	12V DC	4.75 – 5.25 V DC	12 VDC
Power supply connection Plug	Hard wired direct to sensor	Pre wired flex	4 pin connector
Data Connection	Wired flex	Pre wired Flex	4 pin connector

Power Consumption	65mA	50mA	30mA
Sample Rate		28Bit	
Manufacturer Web Link		https://www.microstrain.com/inertial/3dm	
Brief overview how the technology works	Inclinometer compares the angle of the object to the gyroscope and displays the result on an electronic readout	The 3 – in 1 combined sensor uses the same technologies designed in the yaw rate and inclinometer so it will have a yaw rate sensor and 2 x inclinometer at different directs, but within this sensor all 3 measuring devices are conveniently combined into the one housing.	Yaw rate sensor is a gyroscopic device that measures a vehicles angular velocity around its vertical axis. The angle between the vehicles heading and vicinal actual movement direction is called slip angle, which is related to yaw rate

From the above technical sensor over view, I have highlighted the chosen sensor I will be using for my design/system below is the sensors manufacture data sheet.

2D 2D Design & Develop Mfg Systems GmbH, 40549 Krefeld, Germany
Tel.: +49(0)2124 405-0 Fax: +49(0)2124 405-25

SA-GYxxxV4-000 Yaw-rate-sensor (gyro)

Functions

- To measure pitch, roll and yaw speed
- To measure turning angle speed of a bike
- To calculate the inclination of the bike (the required function is included in the software)

Notice

- ⚠ The sensor should be mounted vertically to the bike.
- ⚠ Avoid strong vibrations of the sensor!



Technical specifications

Electrical characteristics	Mechanical characteristics
Power supply 4.75 - 5.25 VDC	Dimensions 40 x 30 x 16 mm
Operating current max. 50 mA	Weight (inc. cables) 22 g
Range	Housing material aluminium
SA-GY200V4-000 -300°/s @ 0.1V / 300°/s @ 4.0V	Cable
SA-GY500V4-000 -577°/s @ 0.1V / 577°/s @ 4.0V	type PUL cable
Sensitivity	wire cross section 3 x AWG 28
SA-GY200V4-000 ± 200 °/s	length 300 mm
SA-GY500V4-000 ± 577 °/s	
Resolution 0.1 °/s	Environmental data
Linearity < 0.5% FS	Ambient operating range -40° to +100 °C
	Humidity 5 to 95 %
	Sealing class IP 67
Calibration	Ordering information
Use the formulas on 2 nd page to calculate the physical values	Art. No. SA-GY200V4-000
	Gyro ± 200°/s SA-GY500V4-000
	Gyro ± 500°/s

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2D Design & Develop Mfg Systems GmbH
20.09.2009 / 1.01

Figure 9 – 2D Gyro Data Sheet

Suspension Travel Measurement

Technology Name >	Laser Distance Sensor	Inductive Measuring Sensor	Draw wire position Sensor
Pro's	• Accurate • Variety of measurement ranges • Shape of target object is irrelevant	• Cheap • Extremely robust • Deals with vibration extremely well	• Easy mounting • High operational safety • Good for difficult installation locations
Con's	• High cost • Lenses surface potentially subset -ble to dirt	• May not give us the detail level of measurement we would require	• High cost • Could be easily damaged if not installed correctly

Suspension Travel Sensor's Technical Over View

Technology sensor name	Laser Distance Sensor	Inductive Measuring Sensor	Draw wire position Sensor Sendix M5861
Picture			
Cost per Unit	£678.34	£59.76	£278.00
Durability	Fair	Very Good	Very Good
Portability	Good	Very Good	Excellent
Power Supply	30 V DC	5-30 V DC	12 -30 V DC
Data Connection	4-20Ma	4-20Ma	4 pin M12 Connector – f

Data Connection Plug	Pre-wired flex	Pre-wired flex	4 pin M12 Connector
Power Consumption	280mA	30mA	50mA
Data Output (Digital / Analogue)	4-24 mA	4-24 mA	Analogue / 0 v – 5 v DC
Sample Rate			
Data Sheet Web Link			https://docs.rs-online.com/6309/0900766b8168238b.pdf
Brief overview how the technology works	A laser distance sensor works by measuring the time it takes a pulse of laser light to be reflected of a target and returned to the sender, known as time of flight' principle.	A inductive measuring sensor uses the principle of electromagnetic induction for detect or measure objects, so the sensor will give a pulse output when the inductive field is broken.	Core components of a draw wire sensor as a precision measuring wire and a sensor element (potentiometer or encoder), which convert the path change into a proportional electrical signal.

From the above technical sensor overview, I have highlighted the chosen sensor I will be using for my design/system.

Below is the sensors manufacture data sheet.

Draw wire mechanics with encoder or analog sensor **Draw wire encoder B80** **Measuring length max. 3 m**
Traverse speed max. 10 m/s



The draw wire mechanics B80 can be used up to a measuring length of 3 meters.

These draw wire mechanics may be combined with the proven Kührer Sendix encoders with incremental or absolute interface, as well as with analog sensors.

SSI **PROFIBUS** **ETHERCAT**
Analog **CANopen** **EtherNet/IP**

Robust

- The titanium-anodized aluminum housing and the stainless steel wires allow for using the mechanics even in harsh conditions.
- Wear-free wire exit thanks to special plain bearing guide.
- Various wire types and wire fastenings.

Versatile

- High traverse speed, up to 10 m/s.
- High acceleration, up to 140 m/s².
- Quick fastening by means of 2 screws.
- Various connection possibilities available.
- Interchangeable encoders (interchangeable installation).

Order code with encoder (incremental, absolute) **D8.XB1.XXXX.XXIX.XXXX** **Standard variants are represented bold underlined**

① Mechanics
2 = interchangeable installation ¹⁾
4 = fixed installation ²⁾

② Encoder used
01 = Sendix 8080, incremental
M2 = Sendix M280, absolute
F3 = Sendix F380, absolute
63 = Sendix 580, absolute
M6 = Sendix M680, absolute
F4 = Sendix F480, absolute
60 = Sendix 580, absolute

③ Output circuit
depends on the encoder used

④ Type of connection
depends on the encoder used

⑤ Resolution / Protocol / Options
depends on the encoder used

Optional on request
- Other measuring ranges
- Cable diameter 1 mm
- Epoxi or M6 wire fastening instead of wire clip
- Modified cable and/or connector installation
- Sensor protection level IP67
- Improved linearity (0.02 %)

Standard resolutions for draw wire with incremental encoder Sendix 8080

Draw circumference (mm)	200	250	280
Pulses / revolution (ppr)	200	200	400
Pulses / mm	1	10	20
Resolution (mm)	1	0.1	0.05

Standard resolutions for draw wire with absolute encoder Sendix M280 (12 bit ST) or M680 (13 bit ST, programmable via bus)

Draw circumference (mm)	200
Pulses / revolution (ppr)	4096
Pulses / mm	20.5
Resolution (mm)	0.05

Figure 10 – Sendix data sheet

Task 3.2

Housing Container



Figure 11 – Carry Case

Image xx - <https://i.ebayimg.com/images/g/1u4AAOSwnKdbXuxF/s-l300.jpg>

The above storage box is made from aluminium which will provide low weight for ease of transportation and also a strong protection for the internal sensitive instruments.

For the internal mounting the instruments will be mounted on (type of board pictured below) this will secure in the components in place.

Output connectors for field devices will have connection points on the case external side wall to allow for ease of installation.

LED Start/Stop visual indicators

LED type:	3501 Standard LED Red 3mm
	Get LED details
LED brightness (at typical current):	275 mCd
LED forward voltage:	2.1 V
Max LED current:	25 mA
Typical LED current:	20 mA
Battery voltage:	5 V
Number of parallel LEDs:	1
	Calculate resistor
Calculated resistance:	145 Ohms
Preferred value:	150 Ohms
Resistor colour bands:	Brown, Green, Brown



<https://uk.rs-online.com/web/p/leds/8609696/>

From the selector for the led above, I can work out my resistor size for the LED as follows;

$$I_f = 25\text{Ma}$$

$$V_f = 2\text{V}$$

$$V_{res} = 5 - 2 = 3\text{V}$$

$$R = 3 / 20 \times 10^{-3} = 150\text{ohm}$$

Task 3.3

Non-Volatile Memory Storage

For the overall system data logging storage, we need a memory to safely store the acquired data from the 2hr track test.

On the table below shows a quick overview of the required memory storage for the acquisition system can operate.

Measurement	Signal Type	Bytes	Logging Rate	Total Bytes
MPH	Digital	1	1s	1
RPM	Digital	1	1s	1
Suspension	Analogue	8	100us	80000
Pitch, Roll, Yaw	Analogue	6	1ms	6000
Temperature	Analogue	2	10s	20

From the above table this is the data acquired during a 2hr track testing data acquisition, the total number of bytes is 86,022 Bytes, which totals 86KB.

Total memory for the 2hrs track period is 700MB, how I came to this value is shown in the below calculation;

Calculated Values rounded to the nearest 100.

- $86\text{KB/s} \times 60 = 5.16\text{MB/min}$
- $5.16\text{MB} \times 60 = 309.6\text{MB/hour}$
- $309.6\text{MB} \times 2 = 619.2\text{MB}$ but round to nearest 100 = 700MB / 2hrs

For the removable SD card, any size from 1GB and up will have sufficient memory for the application.

Due to the low cost of the SD cards I have selected the below, SD card which is 64GB well over specified but at £12 per unit its well within allocated budget cost.



SanDisk Ultra UHS-I, Class 10, SDXC Card, up to 80MB/s Read Speed, 64GB

£12.24

Free standard delivery over £50
[View delivery options](#)

★★★★★ (2 reviews)

[View product description](#)

Figure 12 – Sandisk SD card

Power Supply (Rechargeable 12V Battery)

On the below table is the power requirements for the data logging system;

Sensor	Max Current mA
Suspension 1	50mA
Suspension 2	50mA
Suspension 3	50mA
Suspension 4	50mA
Pitch, Roll, Yaw (combined sensor)	50mA
RPM	120mA
MPH	120mA
Engine Temperature	70mA

Total mA Current	560mA
------------------	-------

From the above table the total maximum current is calculated at 560mA, from this we can work out the battery requirement as follows;

- Capacity (Amp Hour) = Total Current (Amps) x Time (Hours)
- Capacity = 0.560 (Amps) x 2 (Hours)
- Capacity = 1.12 mAh @ 12 V DC

From the research my selection came to (RS PRO NiMH Battery pack) @ 12 V DC 1.3Ah.

From the above it was mentioned to keep the battery at around 1.12Ma as so not to deplete the battery beyond 50%, the RS PRO battery will allow us to deplete the battery down to 75% at low drain rates and can surpass equivalent alkaline batteries on high draw rates.

These battery's will also come with a 5yr warranty, at a cost of £11.85 it's a very economical deal.



Attribute	Value
Chemistry	NiMH
Nominal Voltage	12V
Number of Cells	10
Capacity	1.3Ah
Terminal Type	Tags
Size	AA
Operating Temperature Range	-10 → +60°C

Figure 13 – RS 12V Battery

As the final battery is 12v, the supply power circuit will require a voltage regulator.

Proteus Design

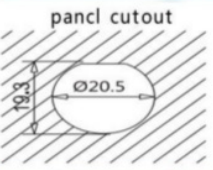
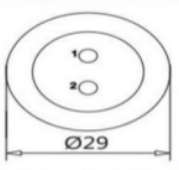
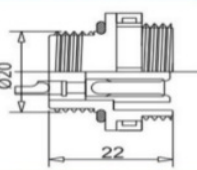
Connector Selection

Connector	SD 16, 5pin	Hi-rose connector	XLR Connectors	CDI connectors
Image				
Cost	£3.49	£10.40	£18.56	£2.34
Durability	Very Good	Very Good	Good	Poor
Product Range (pins/sizes etc)	High Product Range Available in good variety of pin configure ranges	High product range available in good variety.	High product range available in good variety	Limited range
Positives	High IP rating and good pin selection, Economical cost	Good build quality and durable	Product range	Cheap
Negatives	None	Low IP rating higher cost	High cost value	Poor build quality, limited on connector sizes

For the connector selection I have gone with the SD range of connectors they were second cheapest on my review table and overall best quality and value for money.

Below figure shows the available product range and different pin connectors, this is extremely important where we may have different voltages or currents operating using different connects will emitting the errors in wrong connects and potentially damaging equipment.

Figure 14 – Multi Pin Connector

Rear-mounted socket							
  							
SD20	02	03	04	05	07	09	12
male contact face view							
contact diaamette	Ø2.8×2	Ø2.8×3	Ø2.8×4	Ø2.8×5	Ø1.8×7	Ø1×9	Ø1×12
Current Rating	25A	25A	25A	25A	10A	5A	5A
Rated voltage(AC.V)	250V	250V	250V	250V	250V	250V	250V
Test voltage(AC.V)	1500V	1500V	1500V	1500V	1500V	1500V	1500V
Contact resistance MΩ	1	1	1	1	2	5	5
Insulation resistanceMΩ	2000	2000	2000	2000	2000	2000	2000

Cost Break Down

Part Description	Cost £	Quantity	Total
Cary Case	£29.99	1	£29.99
Suspension 5pin Connectors M&F pair	£3.79	4	£13.96
RPM/MPH 4pin Connectors M&F pair	£3.49	2	£6.98
Temperature 6pin Connectors M&F pair	£4.05	1	£4.05
Gyro 8pin Connectors M&F pair	£4.67	1	£4.67
Battery	£11.85	1	£11.85
5core Flex (0.5mm2)	£0.34 per Mtr	32Mtrs	£10.88
Suspension sensor bracket	£0.67 per bracket	4	£2.68
RPM/MPH sensor bracket	£0.67 per bracket	2	£1.34
Temp sensor bracket	£0.67 per bracket	1	£0.67
Gyro mounting bracket	£39.76	1	£39.76
LED's	£0.78 per LED	2	£1.56
PCB	£67.55	1	£67.55
SD Card	£12.00	1	£12.00
USB cable	£14.99	1	£14.99
Suspension Sensor	£287.00	4	£1,112.00
Temp Sensor	£278.00	1	£278.00
RPM & MPH Sensor	£188.00	2	£376.00
Gyro Sensor	£198.48	1	£198.48

Total initial cost for our prototype built.....£2,187.14 Ex VAT

PCB Cost

\$85.77

Quantity:

1

Tooling Cost

\$59.03

(one time cost, reorder free)

Unit Price:

\$26.74

Lead time:

in 6 days

Total

\$85.77

Add To Cart

Price Matrix

Print Quote

When you're ready to order, click ADD TO CART button to proceed. Shipping cost will be added on Order Confirmation before checkout. A Step-by-Step Guide

67.55 Pound Sterling =

87.00 US Dollar

Last updated - 25 November, 17:13 GMT

GBP £ - Pound Sterling

↔

USD \$ - US Dollar

67.55

87.00

Day

Week

Month

Year

5 Year

Max

Suspension

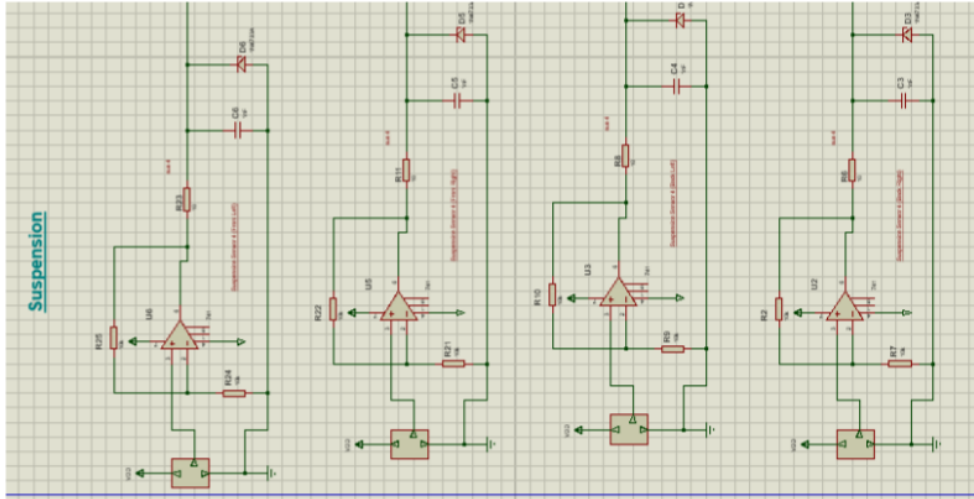


Figure 15 – Proteus Sus Set Up

For the suspension movement tracking a draw wire position potentiometer sensor is being used, for the set up as example from the draw wire mounting position to the wheel centre mounting position the draw wire will approximately stretched out 50% at around 250mm of its 500mm total length.

From this once the sensor and measuring point are connected/positioned, we will ensure that the mid-point voltage level is set at 2.5 V DC respectively.

For each 1mm travelled would equate to a 0.4 V DC +/- dependant on cost.

The voltage clamp arrangement in the above circuit, will limit of max V DC input to the pic at

5.1 V DC, this ensures protection for the individual circuit and the pic.

Engine Temperature

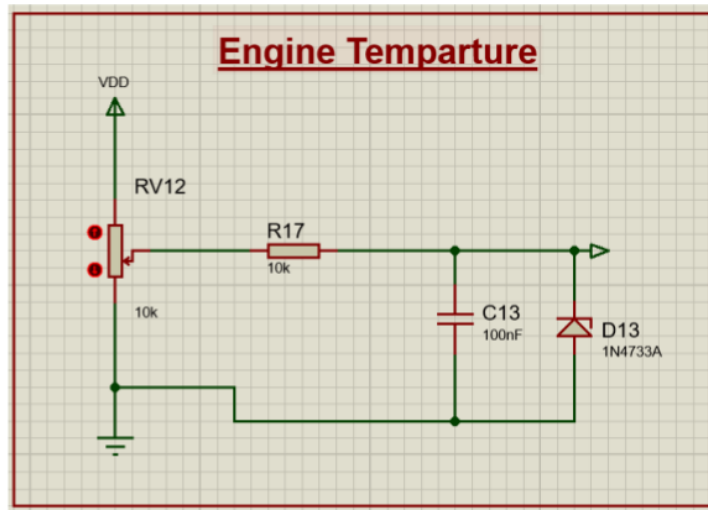


Figure 16 – Proteus Engine Temp

For the engine temperature a infra-red temperature sensor is to be used, for the voltage setting at 0-deg this will be set at an output value of 0.5 VDC.

Ideally, we would like to ensure engine temperature monitoring capabilities of up to 200-deg so from 0.5 V DC (0-Deg) every 0.0225 V DC increase will represent 1-Deg rise in engine temperature. For every 0.225 V DC decrees from 0.5 V DC will show temperature running into the negative ranges respectively.

RPM

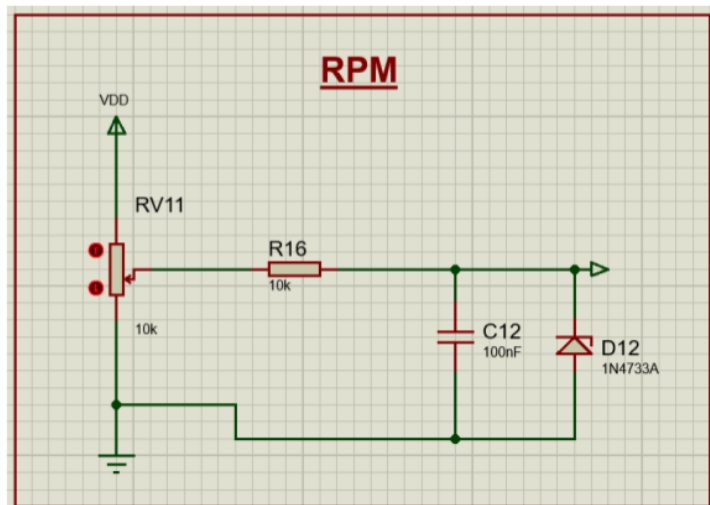


Figure 17 – Proteus RPM Sensor

The sensor for RPM measurement is based on the same principle as the hall effect sensor in which a reflective stick is attached to the fly wheel at the front of the engine and the sensor positioned in front, each RPM of the fly wheel the sensor when it picks us the reflective strip

will give a out put pulse of 5 V DC each RPM rotation, the number of rotations per minute gives the overall RPM value.

MPH

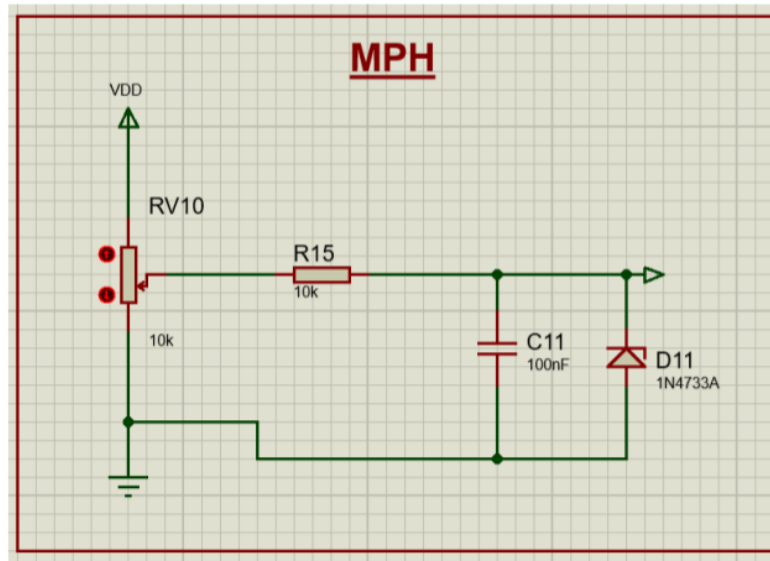


Figure 18 – Proteus MPH sensor

Mph sensor is the same sensor in principle as the one used to measure RPM, with the significant difference is the additional attached required, this attachment can be mounted onto the drive shaft/car wheel which will give us a calculated value for every 1 x RPM of the attachment wheel equates to 10cm of travel.

USB

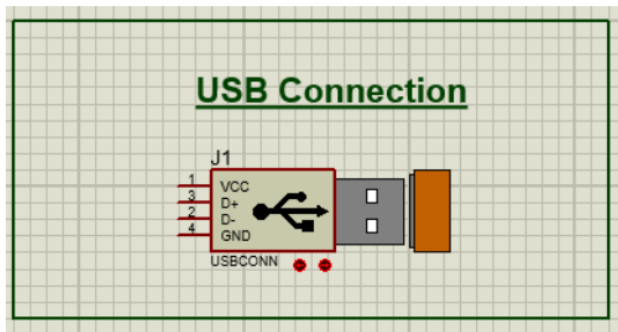


Figure 19 – Proteus USB Connector

USB connectivity is quite essential for modern IT equipment, with in the application the USB port can be used to connect to laptop for setting up the test values and potentially seeing live data. It can also be used as another way to potentially down load memory and other information.

SD Card

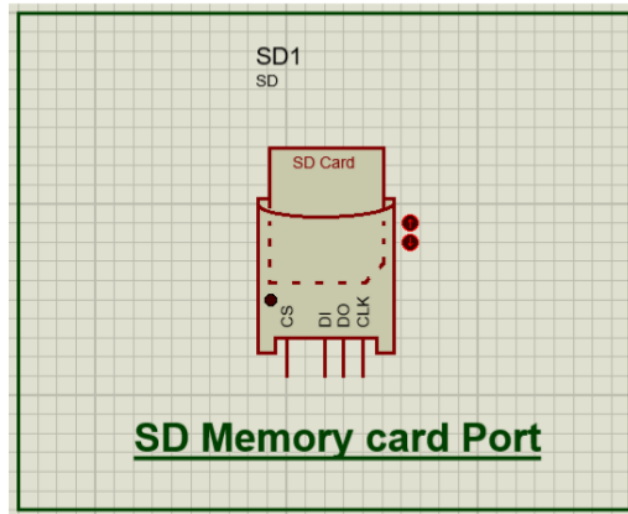
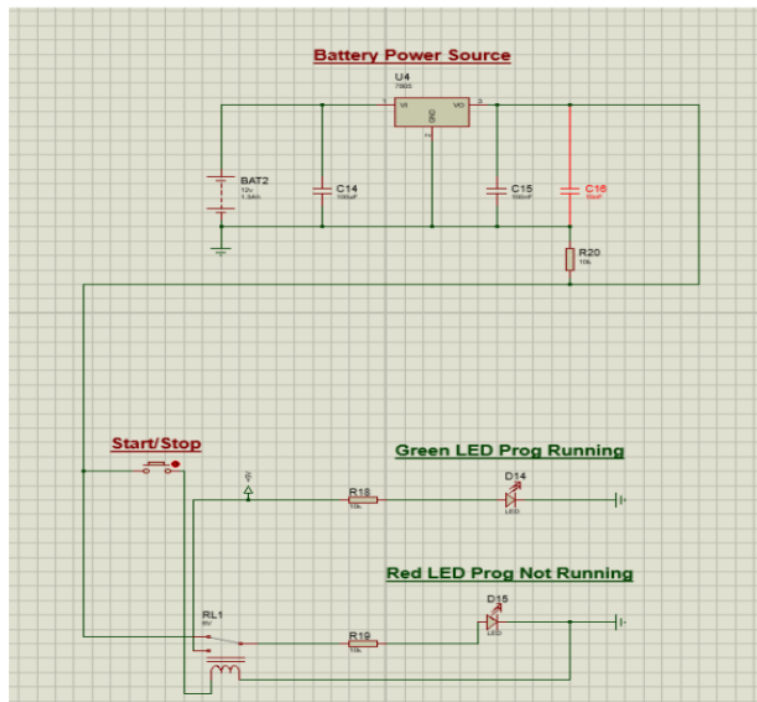


Figure 20 – Proteus SD Memory Card

For the initial stored memory implementation of a solid-state SD memory card will be used, so our design has incorporated a SD card port.

Battery



the battery pack delivers a voltage of 6 V DC, this is +1 VDC to high for our PIC input so, I have run the battery supply through a voltage regulator so that we end up with a constant supply voltage

at + 5 V DC, capacitors are also added to in circuit in parallel this will even out the supply voltage and ensure a constant voltage should any devices require an initial surge in power before operation.

LED

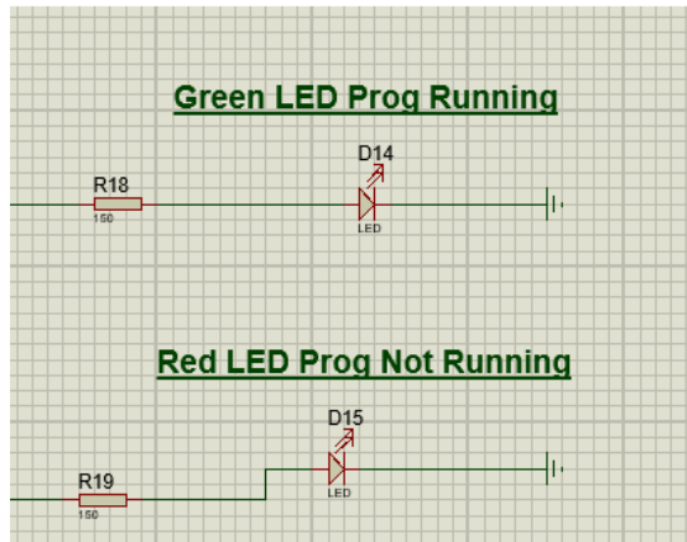
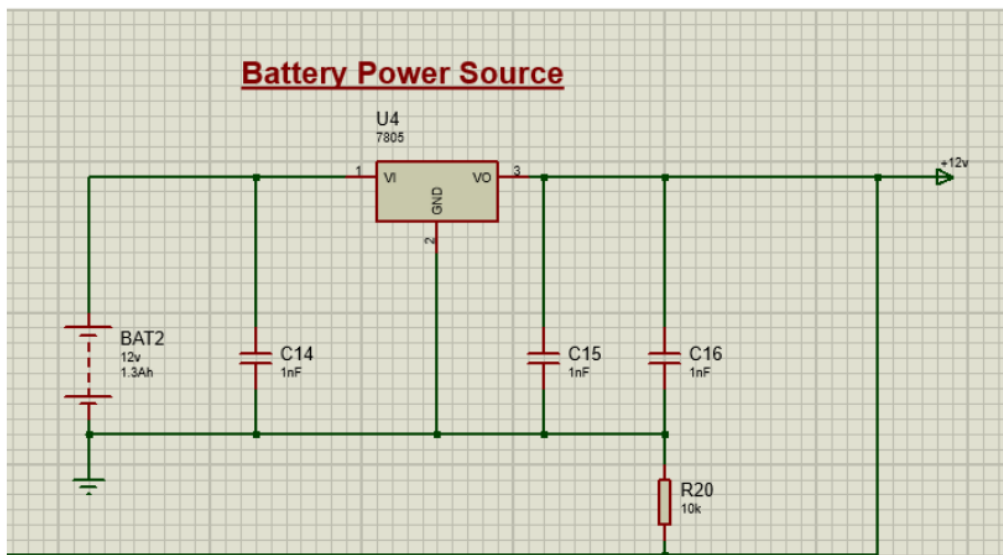


**Figure 21 –
Proteus LED**

The LED addition to the circuit allows for the users to know when the system is running which will be indicated by the 'green' LED, the red LED is connected before the start button but is also controlled via a contact coil so when the start button is operated this will energise the coil and open the circuit supplying the red LED, the red led can also signal that there is an operational battery connected to the circuit.

Figure 22 – Proteus Battery



Over All Circuit on Proteous (with lines shown)

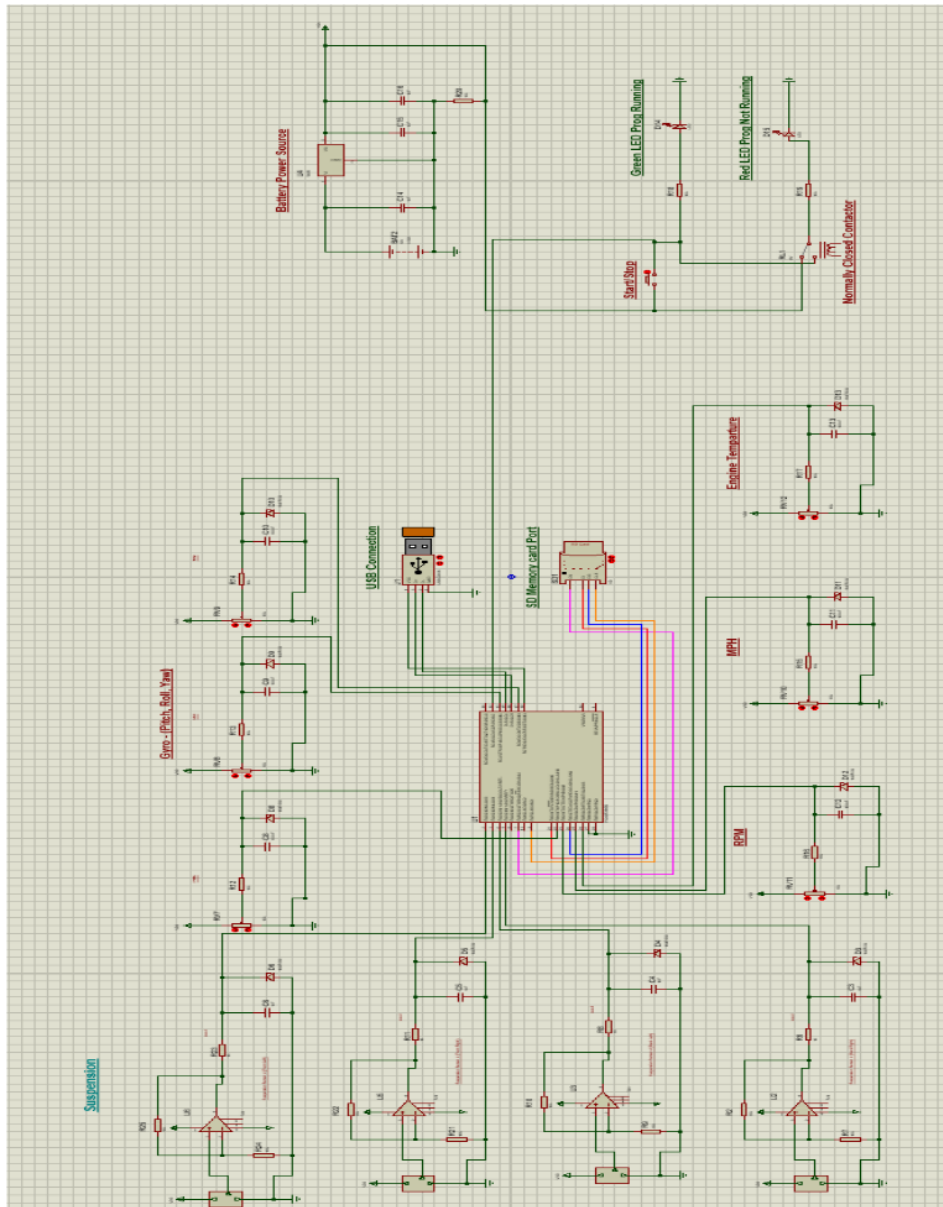


Figure 23 – Proteus Full Schematic with Lines

The above overall proteuous layout shows all connections with physical wire representation.

Over View Circuit on Proteus (with short cut lines)

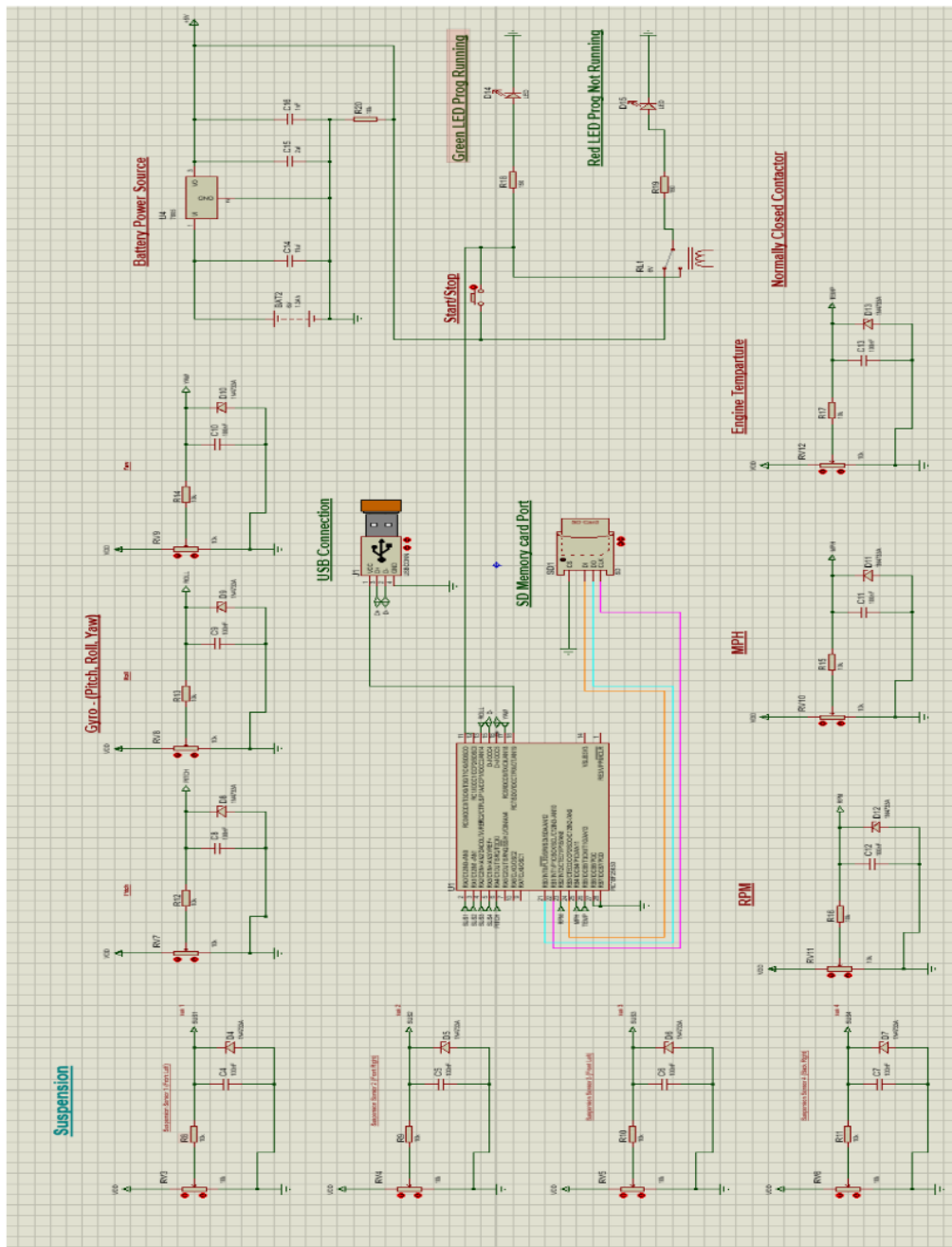


Figure 24 – Proteus Full Schematic Reduced Lines

In the above I have cleaned up the overall layout with removing the physical cable links and opting for the input/outputs to clear up the clutter looking physical cables.

Easy PC Schematic

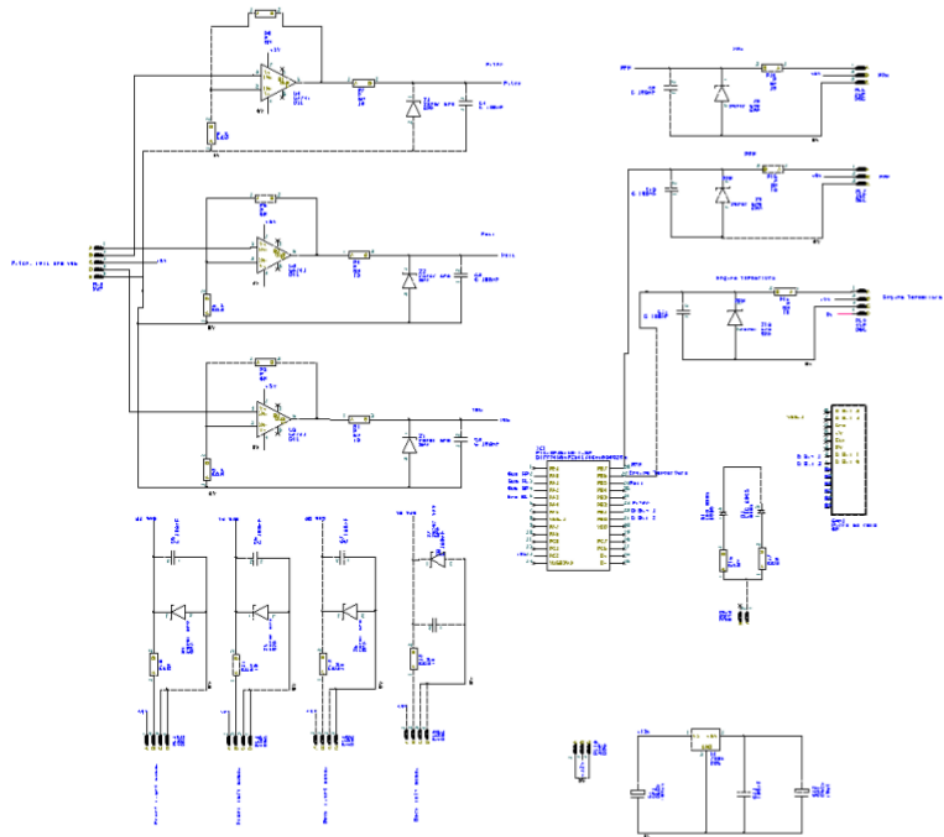


Figure 25 – Easy PC Full Schematic

The above image from easy PC shows the first step in the easy pc process and developing steps to the final PCB design.

Easy PC PCB

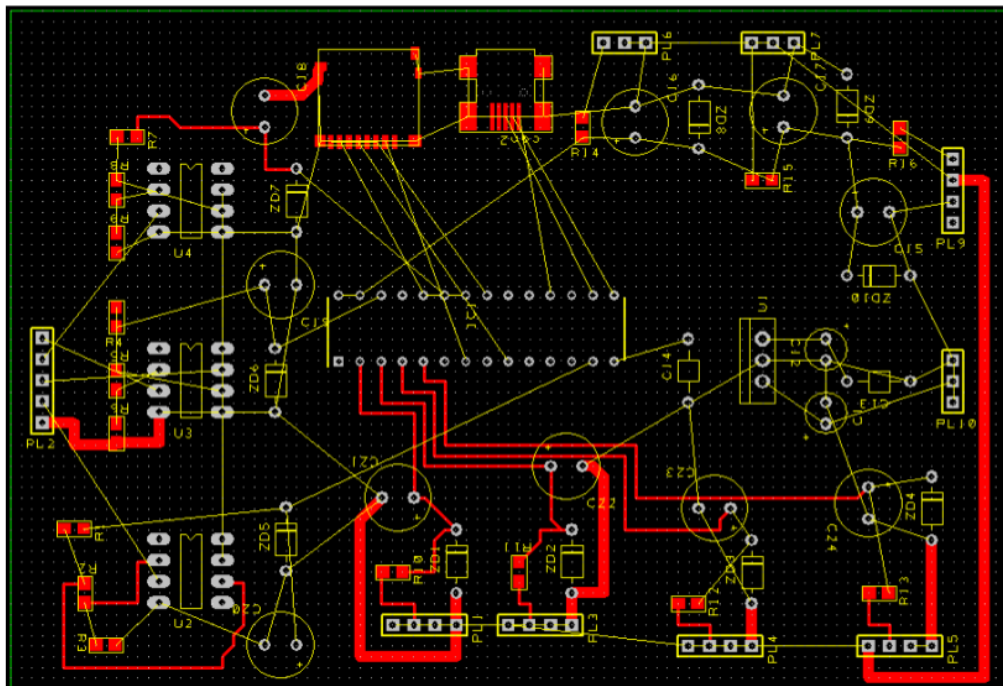


Figure 26 – Easy PCB design 1

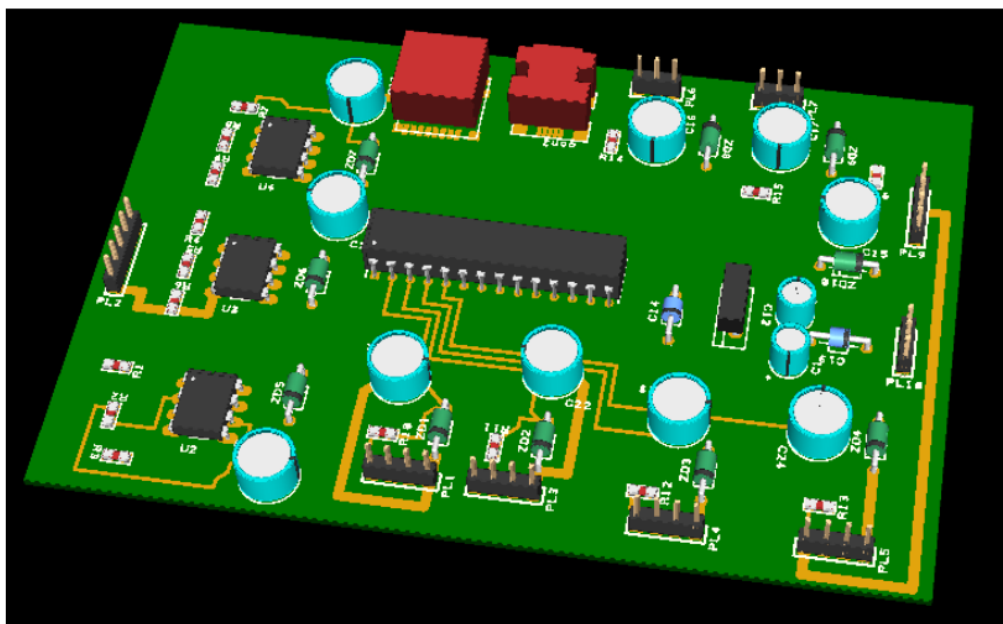


Figure 27 – Easy PC Design 3D View

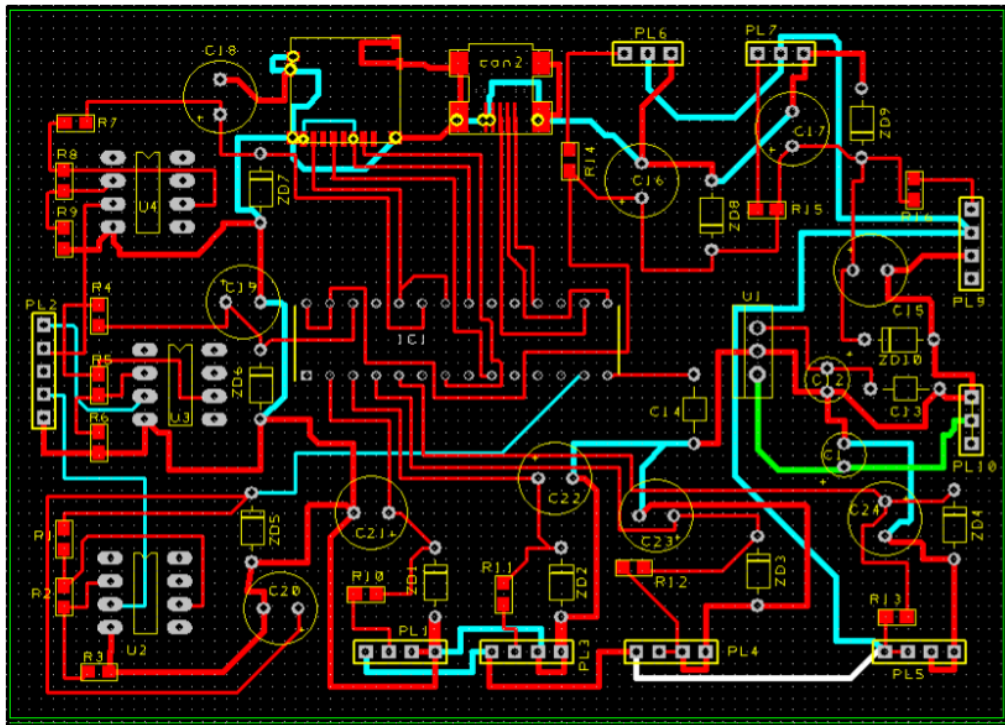


Figure 28 – Easy PC further developing Circuit design

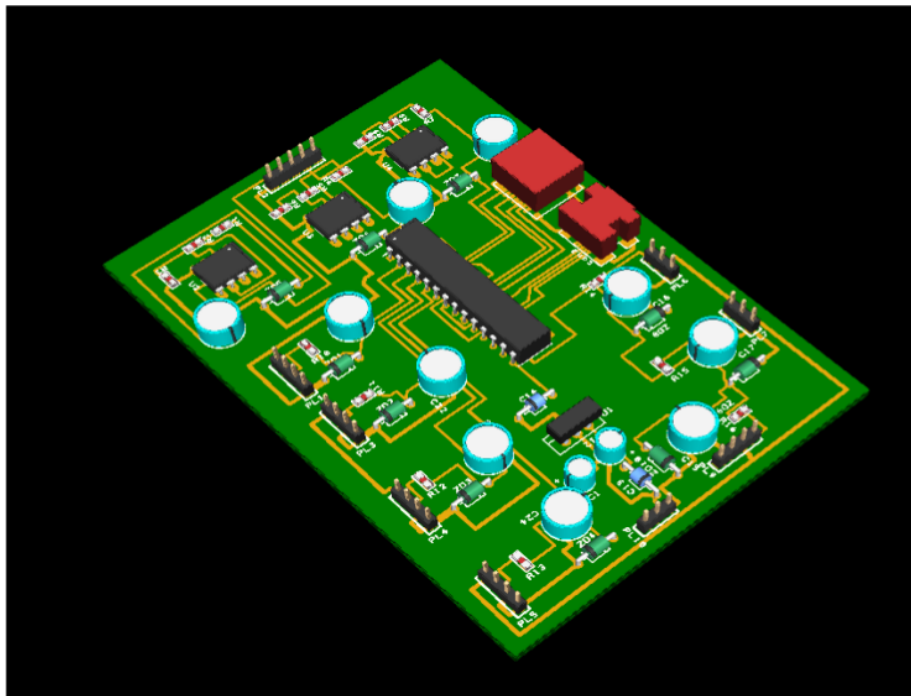


Figure 29 – Easy PC 3D View from figure 27

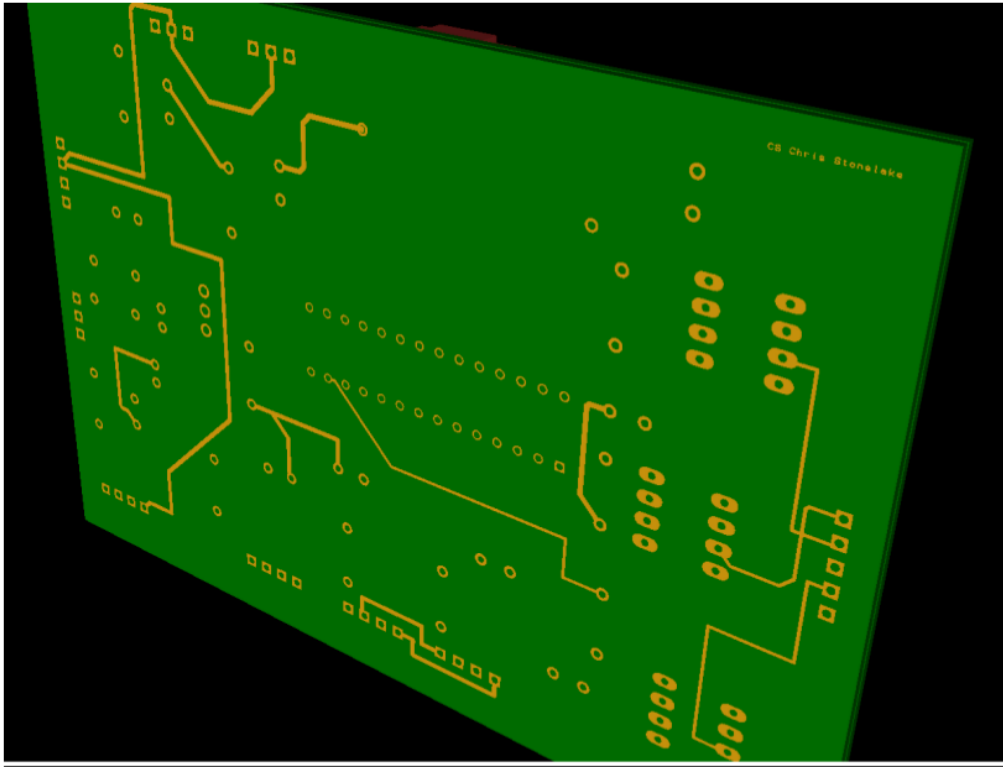


Figure 30 – PCB back View

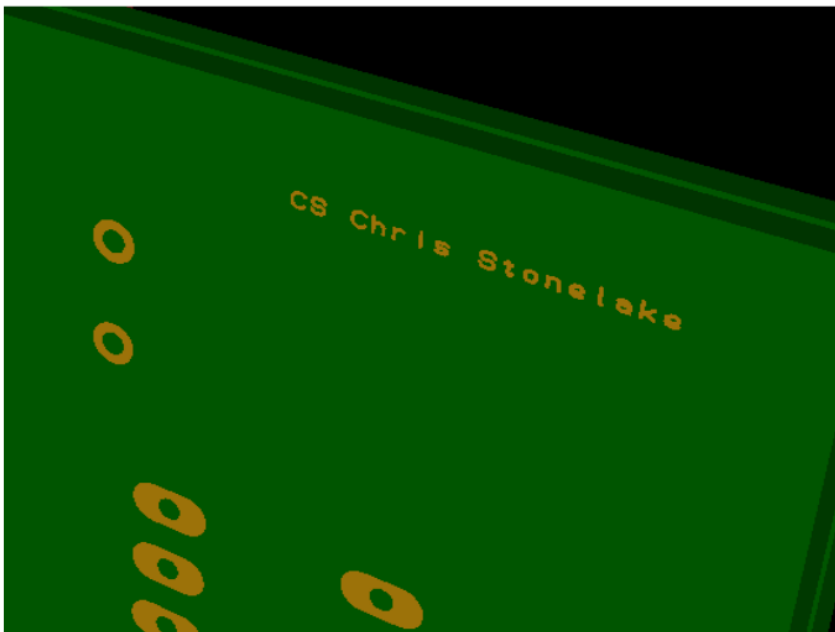


Figure 31 – PCB Back View With Name

Structure Diagram



Conclusion

Within this project the aim was to design and build a data acquisition system in which we can accurately and effectively record data vales from various sensors to monitor/measure car performances.

The below review topic has been considered in the most concise and precise format as possible,

Given what was asked to deliver in the brief on of the initial areas for improvement would be the mounting of the sensors to include the MPH vales, these can be achieved much more easily with on the market components such as the hub connection unit which will monitor MPH/Acceleration etc.

The second biggest improvement would be the suspension travel measurements, for this design the use of tape tensiometers was utilised, looking further and with the right rigging equipment the use of laser measurement would be a much more suitable option, installation time would be greatly reduced.

The utilisation of and LED screen would also be an advantage to so the test driver some real time information, this would also potentially open the use of monitoring MPH with GPS tracking, the other advantages of the driver been able to see the real time information is that during the test there may be a requirement to hit a certain RPM for example and the driver not aware until end of the test trail and review of the data would relies that the required values were not meet, would cause a great deal of lost time during testing.

Going forward and reviewing existing systems on the market, in which there is a high quality of suppliers, more effort should be made into the mounting of the sensors and the supporting systems for these, what was found during research that the most popular systems had a big entthesis on ease of installation and set, with that said it should also be noted that the popular systems also had some kind of screen interaction which made ease of the set up and data available to the testers while setting up the car and during testing operations.

References

- [1] - <https://www.dewetron.com/products/data-acquisition-hardware-chassis/all-in-one-chassis/dewe2a4/>
- [2] - <https://www.kistler.com/?type=669&fid=88296&model=document&callee=frontend>
- [3] - <https://www.kistler.com/?type=669&fid=88296&model=document&callee=frontend>
- [4] - <https://dewesoft.com/products/daq-systems/r4>
- [5] - <https://www.vboxautomotive.co.uk/index.php/en/products/data-loggers/vbox-3i#features>

ESD Data Aquisition System _ C Stonelake

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

71 /100

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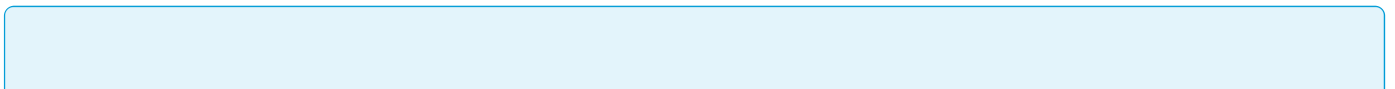
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GRADING FORM: SMU GENERIC_GJ



CHRISTOPHER STONELAKE 71.15

RESEARCH-INFORMED LITERATURE

 Good literature review of available systems with a good comparison table of relevant information. 75% **7.5**

KNOWLEDGE AND UNDERSTANDING

 Good overall schematic design but a few things to be kept in mind. When designing a complex board it is beneficial from a understanding point of view to limit the number of lines travelling around and instead use net names which you have done. The suspension sensors have an output of 0-5V so they do not need amplification. Sdi and Sdo should be cross connected on the SD card. Your pcb shows a +6V net where this does not exist in the schematic. This is a 4 layer board. There are a few short circuits on the board and there are pads with vias in them. 65% **16.25**

ANALYSIS

 Good selection of microcontroller. Good selection of sensors with comparison table showing the other devices that were researched. Good case selection. Good selection of connectors with images but and comparison table. 76% **26.6**

PRACTICAL APPLICATION AND DEP.



Costings nicely put forward as a table with price but did not include manufacturer part numbers or supplier of component. Good and insightful future enhancements. 68%

13.6

SKILLS FOR PROFESSIONAL PRAC.



The report is well presented with very well presented tabled data and structure diagrams. A limited number of references. 72%

7.2