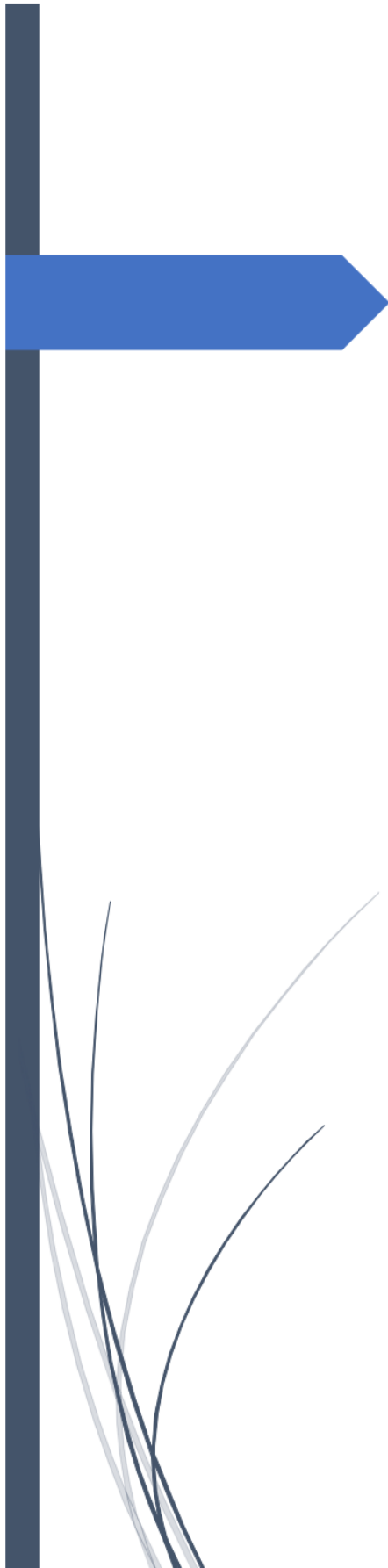


jack solomon - ESD assignment 1

by Jack Solomon

FILE	18279_JACK_SOLOMON_JACK_SOLOMON_- _ESD_ASSIGNMENT_1_58119_2042975978.DOCX (10.02M)		
TIME SUBMITTED	25-NOV-2019 06:13PM (UTC+0000)	WORD COUNT	5599
SUBMISSION ID	114329761	CHARACTER COUNT	33767



Electronic System Design

M6X01095

Jack Solomon

1503512

Assignment 1

Dr. Gary L Jones

25/11/19

UNIVERSITY OF WALES TRINITY
SAINT DAVID

Contents

Introduction	3
Current Vehicle Acquisition Systems	3
VBOX 3i	4
Aim EVO5	4
Datataker DT80	5
GL240 Data Logger	5
Microcontroller Specification	6
Microcontroller Selection	7
Non-Volatile Memory Required	7
SD card Selection	8
Logging Rates	8
Block Diagram	9
Sensor Selection.....	9
MPH & RPM	9
Optical Sensor	11
Engine Temperature	12
Pitch, Roll and Yaw Gyro's.....	13
Suspension	15
Connector Selection.....	17
MPH & RPM Connectors	17
Temperature Connector	17
Suspension Connectors.....	17
Gyroscope connector	18
Battery Selection.....	18
Casing Selection	20
LED Selection.....	21
PCB Prototype Quote	21
Total Costs.....	22
Proteus Design	22
Signal Conditioning	23
RPM & MPH	24
Temperature	24
Suspension	25
Gyroscope	26
Battery.....	26
SD Card.....	27

USB.....	27
Start/Stop Button & LED	27
Microprocessor Connections	28
Full Proteus Design	28
Easy-PC Design - Schematic Diagram	29
Without Copper Pour	30
With Copper Pour	31
3D View – front	32
3D View – back.....	33
Suggested Improvements	34
Bibliography	35

Introduction

The aim of this assignment is to design a microcontroller based automotive data acquisition system. The microcontroller will be designed to be fitted onto a family saloon prototype car, while it is subjected to a two-hour test track run. The following components will be tested;

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

Each component will have its own sensor. The sensor will send the acquired data to a microcontroller to be stored in non-volatile memory, which can be externally read and cleared when connected to a computer via USB. A battery will be used to power the whole system so none of the components will be reliant on the cars power supply.

Current Vehicle Acquisition Systems

The data acquisition systems are very helpful as they can be used to improve a cars performance and safety. The purpose of vehicle acquisition systems is to: -

- Determine if a car meets its specification.
- Establish if a car will drive safely.
- Identify if a car complies with all road going regulations and laws.
- Pin point outstanding issues within a car.

There are many types of data acquisition system available in the current market. They all have different specifications to be able to meet a variety of different purposes. Below are current data acquisition systems which are available to purchase on today's market. The table below highlights the key difference between the selected four data acquisition systems.

Image				
Data Logger Description	VBOX 3i	Aim EVO5	Datataker DT80	GL240 Data Logger
Sample Rate	Up to 100Hz	Up to 1000Hz	Up to 40Hz	Up to 50HZ
Inputs	• 4 analogues • 2 can bus • Brake trigger • Voice tapping • Log Switch • Power Supply	• 8 analogues • 4 Digital • 1 RPM • Built in Gyro	• 5-15 analogue • Up to 10 isolated inputs • 8 digital input/outputs • 2 serial 'smart ports'	• 10 analogues • Up to 4 Logic/pulse signal input channels

Outputs	• Can bus • RS232 • USB • Bluetooth • 2 digitals • 2 analogues • CF card	• CAN output • RS232 • K line • 2 digitals • Wi-Fi • SD port • USB	• 8 digital input/ outputs • USB • RS232 • Ethernet	• USB • WLAN • 2 SD ports • Alarm output
Operating voltage	7-30V	9-15V	Mains power, 10-30Vdc external supply or battery	100 -230V AC, 8.5 – 24Vdc or battery
Dimensions	170 x 121 x 41mm	114 x 47 x 59mm	180 x 137 x 65mm	188 x 117 x 42mm
Weight	900 grams	300 grams	1.5Kg	500 grams
Internal Memory	No information	4GB	Up to 10 million data points	4GB
Display Screen	N	N	Y	Y - 4.3" LCD
GPS	Y	Y	Y	
Price	n/a	£1500	£2750	£1095

Table1; Demonstrates four types of vehicle acquisition systems. [1] [2] [3] [4]

VBOX 3i

The VBOX 3i is a highly accurate data logger. It has multiple input and output types available which give the user many options to choose from. The 7-30V supply gives it flexibility when powering the device, making it convenient. This system is quite large and heavy which will impair the portability. [1]



Figure 1; Illustrates a VBOX 3i.

Aim EVO5

Along with the built in Wi-Fi, second CAN bus, gyroscope, high sample rate and the vast amount of input/outputs makes the Aim EVO5 a top contender. The EVO5 is light in weight and is small in stature which makes portability easier. It is also quite expensive. [2]



Figure 2; Shows a photo of an Aim EVO5.

Datataker DT80

This product has a wide range of supply voltages which give the users multiple options. The Datataker DT80 is the heaviest and largest of the above systems which may affect portability. It also is very expensive, which may negatively influence the decision if other systems have a more advance or equal running system but come up cheaper than Datataker DT80. [3]



Figure 3; Illustrates a Datataker DT80 Series 4.

GL240 Data Logger

The main features of the GL240 are the 4.3" LCD screen and the wireless connectivity option which is unlike the other systems above. This would make it easier to read data throughout the tests. It also has multiple analogue inputs, dual SD ports, 4GB internal memory and is compact in size. [4]



Figure 4; Shows a photo of a GL240 Data Logger.

Microcontroller Specification

A specification list must be created to outline what is required from the PIC. It is important to do this because if a pic is selected that doesn't meet the criteria, then it could cause problems later along the line.

Count Speed	Name	Pins	A or D	Bits
0.1ms	Suspension	4	A	10bit
0.1s	Pitch	1	A	10bit
0.1s	Roll	1	A	10bit
0.1s	Yaw	1	A	10bit
1s	MPH	1	D	Counter 8bit
1s	RPM	1	D	Counter 8bit
15s	Temperature	1	A	10bit
	SD card	3	D	
	Start button	1	D	
	Tell	1	D	
	USB	2	D+/D-	
	RS232	2	D	

	Bits
Digital signal pins (plus interrupt)	11
Analogue signal pins	8 (10bit)
USB	2
SPI	3
Total	22 pins + power

Total pins required in pic	28
----------------------------	----

Table 2; Shows the specification created for this assignment.

Memory, RAM and clock speed will also need to be taken into consideration while selecting a microcontroller.

Pins required	28+
Memory	16K+
RAM	500bytes+
Clock speed	16MHZ+

Table 3; Shows the requirements for the microcontroller.

It is good practice to select a microcontroller with spare pins, the reason being is to allow spare pins in case they are required during development. The decision was made to select a device with a minimum of 28 pins.

Microcontroller Selection

The website '**Microchip.com**' was used to find the correct microcontroller to meet the specifications. Figure 5 shows the results given after specification had been entered in to the website. Three of the microcontrollers met the specification. It would be unnecessary to use a microcontroller which has too many pins, therefore PIC18F45K50 is out of contention. This leave the selection is between PIC18F24K50 and PIC18F25K50. Between the two remaining microcontrollers there are many similarities and limited differences. However, the decision was made to use microcontroller model PIC18F25K50 due to its larger memory size.

Product	Buy	Status	Documents	SK Pricing	CPU Type	Architecture	Family	Program Memory Size (KB)	Program Memory Size (KWords)	Bootload capable	SRAM (Bytes)	Emulated EEPROM in Flash	DMA Channels	Max I/O Pins	Pin count
PIC18F24K50	Buy	In Production	Documents	\$1.65	8-bit PIC MCU	8	8-bit MCU	16	8	Yes	2048	256 / HEF	0	25	28
PIC18F25K50	Buy	In Production	Documents	\$1.76	8-bit PIC MCU	8	8-bit MCU	32	16	Yes	2048	256 / HEF	0	25	28
PIC18F45K50	Buy	In Production	Documents	\$1.99	8-bit PIC MCU	8	8-bit MCU	32	16	No	2048	256	0	36	40

Figure 5; shows the PIC selection on microchip.com. [5]

Non-Volatile Memory Required

Non-volatile memory is needed for the designed system.

Measurement	Signal Type	Bytes	Logging rate	Total bytes
RPM	Digital	1	1s	1
MPH	Digital	1	1s	1
Engine Temp	Analogue	2	15s	30
Pitch, Roll, Yaw	Analogue	6	1ms	6,000
Suspension	Analogue	8	100us	80,000
Total bytes				86,632

Table 4; shows the calculations for the non-volatile memory.

Referring to table 4 the total number of bytes is 86,632 or 86.6KB's. The vehicle acquisition test is completed over a 2-hour period. The calculation below is to find out how much memory is needed to complete the test.

$86.6\text{KB/s} \times 60 = 5.2\text{MB/min}$
 $5.2\text{MB/min} \times 60 = 312\text{MB/hour}$
 $312\text{MB} \times 2 = 624\text{MB} / 2 \text{ hours}$

A total of 623Mb of memory is required for the 2-hour test drive. For the SD card selection, anything greater than 1GB will be sufficient.

SD card Selection

The Cloudisk SD card was selected it has 4GB memory at a cost of £3.45. A combination of the memory size along with the cost of the Cloudisk SD Card is the reason why it was selected to complete the test. [6]



Figure 6; Shows the selected SD card.

Logging Rates

Below demonstrates which logging rates are going to be taken by each of the sensors.

		Data Log Times			
0s	Suspension	P,R,Y	RPM	MPH	Temp
100us	Suspension				
200us	Suspension				
↓	Suspension				
900us	Suspension				
1ms	Suspension	P,R,Y			
1s	Suspension	P,R,Y	RPM	MPH	
15s	Suspension	P,R,Y	RPM	MPH	Temp

Table 5; Shows the data logging rates.

Block Diagram

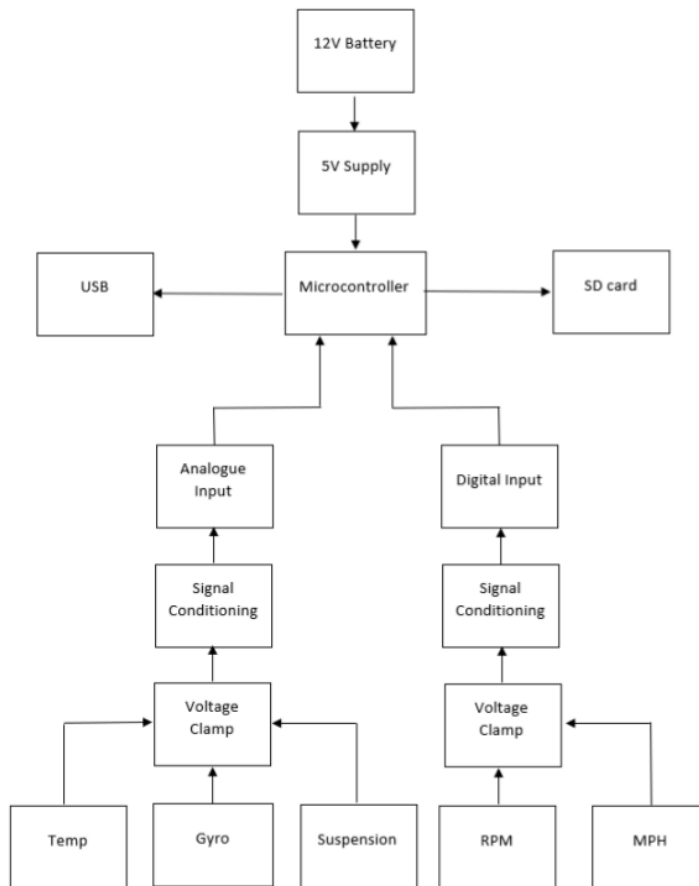


Figure 7; Shows the structure diagram for the designed system.

Sensor Selection

It is important that correct sensors are used for each of the tasks in hand. Various tables are shown in the following sections to outline the features of each types of sensors along with their advantages and disadvantages. This will help make the decision on which type of sensor to use easier. Additionally, an explanation will be given to why the type of sensor was chosen.

MPH & RPM

MPH and RPM are both measurements of a rotating part. It seems suitable to choose and use the same sensor for both applications.

Sensor Type	Hall Effect	Optical	Inductive
Image			
Description	SS466A - latching	Monarch 6180-056	AK1/AP-1H
Voltage supply	3.8 - 30Vdc	3 – 15Vdc	10 – 30Vdc
Output	0.4V, 20mA	Negative pulse input voltage (+V) to 0 40mA	PNP – max 200mA
Sensor range		1 metre	5 mm
Connection	3 pins	4 pins	4 pins
Dimensions	4.06 x 3 x 1.57mm	74 x 16mm	64 x 18mm
Protection			IP67
Price	£2.00	£240	£16.56
Operation	Measures magnet opposed to sensor	Measures light beam reflected from target	Measures a change in magnetic field
Positives	• Non-contact • Accurate • Cheap	• Non-contact • Accurate	• Cheap • Simple • Durable
Negatives	• Subjected to environment (dirt on sensor lens) • Requires magnet on rotating component – issues may occur with attachment • Vulnerable to other magnetic fields	• Subjected to environment (dirt on sensor lens) • Requires strip/mark on rotating component – could become dirty/rub off • Expensive	• Distance limitations due to metallic target • Voltage outputs unknown until tested • Can only detect metallic targets

Table 6; Highlights the key differences between sensor types. [7] [8] [9]

The chosen sensor to measure MPH and RPM is the Optical sensor. The Optical sensor was chosen over the Hall Effect sensor because of magnet attachment issues. A magnet is required on the rotating element in order for the sensor to operate. It was also chosen over the Inductive sensor because of the limited sensor range in comparison. Some cars may require the sensor mounted further away.

Optical Sensor

Image			
Description	VLS/DA1	LIPS P112	Monarch 6180-056
Voltage Supply	7.5-15VDC	5V DC	3 – 15Vdc
Voltage Output	0 – 6Vdc	0.5 to 4.5 V dc	Negative pulse input voltage (+V) to 0 40mA
Sensor range	50 - 2,000mm	10-50mm	1 metre
Price	£427.50	£412.50	£240
Connection	5 core	4 pins	4 wires
Dimensions	130 x 34	205 x 59mm	74 x 16mm
Protection		IP67	
Positives	• Good size	• Durable • Output & input voltage in range	• Good size
Negatives	• Output & input voltages out of range	• Short measurement range • Large in size	• Output & input voltages out of range

Table 7; Illustrates the features of the Optical sensor. [10] [11] [8]

The chosen sensor is the Monarch 6180-056, the reason is that it has a good measurement range, and compatible input & output voltages, which can be seen in table 7.

With regards to the RPM measurement, the sensor would need to be mounted in front of the flywheel, with a white strip to be clearly marked so the sensor can read it.

The MPH sensor is going to be measuring how many times the tires rotated to give mph reading. The white strip is required on the tyre to make sure that the strip is read correctly it will be outlined with white paint to be accurate. The sensor must be mounted in a secure place in clear view of the white strip.

Both the RPM and MPH sensors come with a mounting bracket and screws which makes attachment easy.

Engine Temperature

A sensor will be needed to monitor the engine temperature throughout the test, below are three different types of sensors which could be used.

Sensor Type	Thermocouple	Thermistor	Infer-red sensor
Image			
Description	RS PRO 2 wire PT100	LM335Z/NOPB	Optris CS LT
Voltage Supply	0 – 5V	5V	5-30Vdc
Temp Range	-50°C - +500°C	-40 - 100°C	-40 - 350°C
Operating Distance	Direct contact	Direct contact	n/a
Response Time	0.1s		25ms
Accuracy	Class B	0°C to +1°C	1.5 %
Connection Type	4 pin	3 pins	5 wires
Output	PT100	10 mV/°K	0-10 V or 0-5 V
Price	£1.89	80p	£160.93
Operation	• Peltier effect	• Resistance depends upon the temperature.	• Detects & measures infrared radiation
Positives	• Can be robust • Cheap • Can be very accurate	• Can be robust • Cheap • Simple usage • Fairly accurate	• Non-contact • Accurate • Can be robust
Negatives	• Contact issues • Needs to be close to the engine so has to be insulated • Costly cables • Small signal • Signal conditioning	• Contact issues • Needs to be close to the engine so has to be insulated	• Expensive • Lens is subjected to environment (dirt)

Table 8; Shows the difference between three different types temperature sensors. [12] [13] [14]

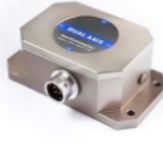
The decision was made to use an infer-red sensor. This because it requires no direct contact with the engine, so the sensor can be mounted away from the engine whereas thermocouples and thermistors both require contact. Although IR sensors are expensive, they are very accurate and can be robust making them the most appropriate sensor for the testing.

Image			
Description	Omega OS136A-1-MA	Calex PC21MT	Optris CS LT
Voltage Supply	12 to 24 Vdc	24Vdc	5-30Vdc
Temp Range	-18 - 202°C	0 - 250°C	-40 - 350°C
Operating Distance	Up to 9.1 m	n/a	n/a
Dimensions	19 OD x 89 mm L	18 mm OD x 103 mm L	M12 OD x 85 mm L
Response Time	150ms	250ms	25ms
Accuracy	3% of rdg	1%	1.5 %
Connection Type	4 wires	4 wires	5 wires
Output	0-5 V or 0-10 V	4-20 mA	0-10 V or 0-5 V, 50mA
Price	£170	£162.60	£160.93
Positives	• Durable • Accurate • Output voltage in range	• Accurate	• Supply & output voltage in range • Durable IP65 • Accurate • Smallest out of the 3
Negatives	• Input Voltage out of range • Expensive	• Expensive • Temp range doesn't go below 0°C	• Expensive

Table 9; Highlights a comparison of three types of infra-red sensors. [15] [16] [14]

The decision was to use the Optris CS LT, this is because it has a high temperature range, good response time and compatible input and output voltages. It also has a threaded diameter which makes mounting easy. The temperature sensor needs to point directly at the engine for the most accurate results.

Pitch, Roll and Yaw Gyro's

Sensor Type	Yaw rate sensor	Gyroscope	Inclinometer
Image			
Description	VEX Yaw Rate Sensor	WIT MPU6050	XHA1 dual axis
Voltage Supply	2.7 V to 3.6 V	4 – 36Vdc	9-36Vdc

DPS	1000°/s	2000°/s	0.05
Response	140Hz	100Hz	18Hz
Connection Type	10 pin	4 pins	4 pin
Output	2.6V	0-5V	0 to 5V
Price	£35.99	£24.17	£381.70
Operation	Measures a vehicle's angular velocity around its vertical axis	Measures orientation and angular velocity	A device for measuring the angle of inclination
Positives	Cheap	- Measures 3 pitch roll & yaw - Wide range online - Cheap	- Measures 3 pitch roll & yaw - Wide range online
Negatives	- High pin count - Voltage out of range		- Expensive - Input voltage out of range

Table 10; Shows three types of sensors to measure pitch, roll and yaw. [17] [18] [19]

The decision was made to use the Gyroscope. The reason being is that there is a wide range to choose from online which will perform well. The majority of them have the ability to measure pitch roll and yaw.

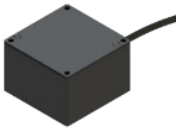
Image			
Description	BC-3Axx_3Gyyyy-000	KG Angular Rate Gyro	WIT MPU6050
Voltage Supply	8 – 18 VDC	5V	4 – 36Vdc
Bandwidth	5 to 250 Hz	10Hz	100Hz
DPS	2000°/s	2000°/s.	± 2000°/s.
Connection Type	5 pin	5 pins	4 pins
Price	n/a	n/a	£24.17
Output	40 mA	0.5V to 4.5V (Offset 2.5V)	0-5v
Positives	- IP67 – durable - High bandwidth - High DPS	- Supply voltage in range 3 axis	- Input voltage in range - Cheap - High DPS - Option of gyro + accelerometer
Negatives	Price not given	- Output voltage out of range - Price not given	

Table 11; Shows three types of Gyroscope sensors. [20] [21] [18]

The decision was to use the WIT MPU6050. This because it has a compatible input/output with the PIC, its cheap, it has a high DPS in comparison to the other two systems. Another reason is that it will measure pitch roll and yaw.

The mounting for the gyro is important in order to receive the correct data outputs, to be able to;

- Measure pitch, the sensor is required to be facing the front of the car, on its side axis of 90°.
- Measure roll, the sensor needs to be mounted facing the side of the car door and on its side axis of 90°.
- Measure yaw, the sensor needs to be facing the front of the car and flat on its axis at 0°.

Suspension

Sensor Type	Draw wire	Laser distance	Linear Potentiometer
Image			
Description	Kuebler C100	OADM 20I6592	Aim Motorcycle Potentiometer Pop End Fitting
Supply voltage	5V	12 ... 28 VDC	Max 40Vdc
Count Speed	1m/s	2.5ms	10m/s
Output Voltage	0.5-4.5V	4 ... 20 mA / 0 ... 10 VDC	0.5 – 4.5V
Range	Up to 5M	100 - 600 mm	0 – 150mm
Dimensions	109 x 98 x 80	65 x 20.6 x 50mm	132mm
Connection Type	5 pins	8 pin	4 pin
Protection	IP67	IP67	IP65
Price	£357.00	\$3,199.00	
Operation	• Contact measuring - measure the change in position of objects	• Sends a pulse of laser light to the target and measures the time it takes for the reflection to return	• Measures the change in position of objects
Positives	• Simple • Accurate • Mounting screws & brackets included when purchasing • Most are well protected	• Non-contact • Accurate if aligned properly • Long range measurement • Quick response time	• Accurate • Simple design – but complex to use in this aspect • Well protected
Negatives	• Mounting issues • Measurement length restricted to length of wire	• Target & alignment issues • Debris issues cause inaccuracy • Expensive	• Contact required • Tight spaces under the wheel arch may cause issues • Expensive

	Response time not as good as laser distance	Damage may occur if space under the wheel arch is too small
--	---	---

Table 12; Shows the differences between three types of suspension sensor types. [22] [23] [24]

The decision was made to use the draw wire sensor. The reasons are that alignment may be an issue with the laser distance sensor and the linear potentiometer, whereas it is very simple with the draw wire sensor. Additionally, poor weather conditions won't affect the draw wire sensor but may cause some accuracy and durability concerns of the laser sensor. Furthermore, the linear potentiometer may struggle with cars which have a small space under the wheel arch so may cause damage to the sensor.

Image			
Description	Sick BCG05-L1KM01PP	CALT 1000mm	Kubler C100
Supply voltage	19 - 33 V	12 – 24Vdc	5V
Signal output	Potentiometer	Potentiometer	Potentiometer
Count Speed	4m/s	1m/s	
Output voltage	0-10V	0 – 5V, 4 – 20mA	0.5-4.5V
Range	Up to 1.5 m	1000mm	Up to 5M
Dimensions	72 x 55 x 52mm	100 x 80 x 50mm	109 x 98 x 80mm
Connection Type	4 pins	3 pins	5 pins
Protection	IP65	IP65	IP67
Price	£453.47	£88	£357.00
Positives	Durable	Output voltage in range	- Durable 5-volt input & output
Negatives	- Output & supply voltages out of range - Expensive	Input voltage out of range	Expensive

Table 13; Shows three types of draw wire sensors. [25] [26] [22]

The decision was made to use the CALT 1000mm from analysing the data provided in table 13. The reasons being is that it has a high measurement range, durable and an in-range output voltage.

The sensor needs to mount under the wheel arch and the wire must be attached to the lower end of the strut.

Connector Selection

A big design concern is users inserting the wrong sensors into the wrong places on the PCB. To solve this issue, all the sensors will have different connectors & colours to make connecting the sensors correctly.

MPH & RPM Connectors

	MPH	RPM
Image		
Description	Pin 4A 20AWG - black	Pin 4A 20AWG white
Pins	4 pins	4 pins
Colour	Black	White
Price	£1.90	£1.90

Table 14; Shows data of MPH and RPM connectors. [27]

These products were chosen as they can be purchased easily and are very cheap. They are waterproof and robust which makes it fit for purpose. They also have a twist lock which makes the connection more secure.

Temperature Connector

Image	
Description	HP20
Pins	5 pins
Colour	Black
Price	£13.24

Table 15; Shows the information of the chosen temperature connector. [28]

This connector was chosen as it is designed to be used with automotive purposes. It is robust which is what is required for this sensor. Another positive is that it's not too expensive.

Suspension Connectors

Four suspension connectors are required for the four sensors. Unlike the other sensors, it does not matter if these sensors get mixed up as they are all the same. Colour coded cable ties can be attached to each male/female pair to prevent inconvenience.

Image	
Description	TEEPLUG
Pins	3 pins
Colour	Black
Price	£15.49 x 4 = £61.96

Table 16; Shows the specifications of the suspension connector selected. [29]

These connectors were chosen because they are relatively cheap, also because they have an IP68 rating which makes it very durable.

Gyroscope connector

Image	
Description	M14-4
Pins	4 pins
Colour	Black
Price	£6.24

Table 17; Shows the specifications of the selected Gyroscope connector. [30]

This connector was chosen because it is very cheap, waterproof and with an IP68 rating making it highly durable.

Battery Selection

Before the battery is selected, the maximum current output for each sensor must be used to calculate the battery capacity required. This can be seen in table 14 below.

Sensor	Max Current
RPM	40mA
MPH	40mA
Suspension	20mA x 4
Temperature	50mA
Pitch	15mA
Roll	15mA
Yaw	15mA
LED	20mA
Total	275mA

Table 18; Highlights the total current output.

To calculate the battery capacity required, the following calculations were used.

Capacity (amp hour) = Total current (A) x Time (hours)

Capacity = 0.275Ah x 2 (hours)

Capacity = 0.550Ah (550mA) (for 2 hours)

A comparison must be made into which type of battery would be best for the task in hand.

Battery	Lithium-ion (Li-ion)	Nickel-Cadmium NiCd	Nickel-Metal Hydride (Ni-MH)
Image			
Description	Safari Drives 12V	NiCd Rechargeable Battery 120mAh	GTL 9v Rechargeable Battery 900mAh
Voltage	12v	9V	9V
Capacity	4800mAh	120mAh x 5	900mAh
Price	£22.99	\$3.65	£8.50 (for 2)
Positives	• High energy density • Not subjected to the 'memory effect' • Wide range of sizes and capacity • Good performance to weight ratio • Rechargeable	• Good at maintaining voltage and holding charge when not in use • Delivers their full rated capacity at high discharge rates • Rechargeable	• Possess 2-3 times the capacity of a nickel-cadmium battery of the same size • Isn't subjected to the 'memory effect' • Rechargeable
Negatives	• Can be expensive	• Subjected to 'memory effect'. When a partially charged battery is recharged, it lowers the future capacity of the battery • Lack of selection online -above battery doesn't meet the capacity required, would need to meet spec.	• High self-discharge

Table 19; Shows a comparison of three battery types. [31] [32] [33]

The decision was made to select the Lithium-ion battery. The reason for this decision was because it doesn't possess 'memory loss'. It also seems like the better battery to use compared to the others. A 12v battery will be used as the highest input voltage from the sensors will be 12v. A battery with an excess of 12v would not be required.

Image			
Description	Safari Drives 12V	TalentCell Rechargeable	12V DC Rechargeable
Voltage	12v	12v	12v
Capacity	4800mAh	6000mAh	6800mAh
Price	£22.99	£45.55	£32.99
Dimensions	11 x 6.5 x 2.5cm	13 x 2.5 x 7.6 cm	11.5 x 6 x 2cm
Weight	163g	349g	210 g
Positives	• Light • Large capacity • Cheaper than the other 2	• Very large capacity	• Very large capacity
Negatives	• Heavy • Large size	• Expensive • Large size • Very Heavy	• Expensive • Large size • Heavy

Table 20; Shows three types of Lithium-ion batteries. [31] [34] [35]

Using the data in table 16 the Safari Drives 12v battery will be used. The decision was made to use the safari drives as it is cheaper and lighter in weight in comparison.

Casing Selection

A suitable casing is required to safely transport the PCB, sensors and battery.

Image		
Description	ROC	Case 10
Dimensions	L310xW240xH130mm	345 x 266 x 165mm
Protection	n/a	IP65
Price	£16.82	£45.97
Positives	• Cheap • Foam interior	• Good protection • Foam interior
Negatives	• IP rating not given	• Expensive

Table 21; Shows two case comparisons. [36] [37]

From analysing the cases in table 17, Case 10 will be used due to it being robust and better size for what is needed.

LED Selection

Figure 6 shows the LED which will be used in the project. A resistor will have to be in series with the LED.

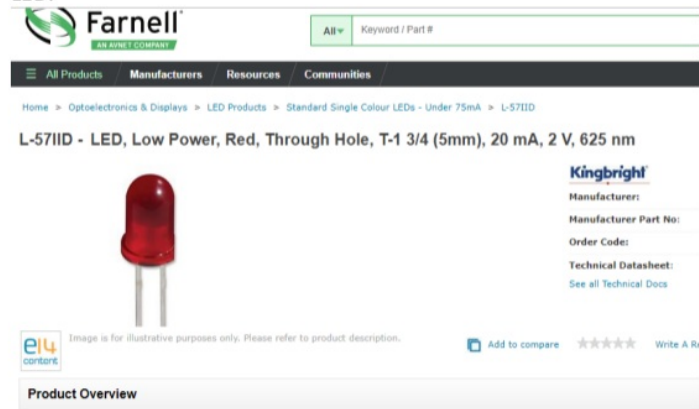


Figure 8; Shows details of the LED selected. [38]

The calculation of the resistor is as follows;

$$I_f = 20\text{mA}$$

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

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

$$R = 3/20\text{mA} = 150\Omega$$

PCB Prototype Quote

PCB proto

- 1, 2 or 5 PCBs in 2 or 3 working days
- 2 and 4 layers: 150µm technology

Price summary

Service	PCB proto	
Delivery term	7 working days	
Estimated shipment date	04-12-2019	
Quantity	1 PCBs	
Board surface / Order surface	0.44 dm² / 0.44 dm²	
Prices	Net	Gross*
Single PCB	€ 40.52	€ 49.03
Total boards	€ 40.52	€ 49.03
Express transport	€ 1.98	€ 2.40
Total	€ 42.50	€ 51.43

* The gross prices include 21.0% VAT.

Proceed

Figure 9; shows the price for the PCB to be produced. [39]

Total Costs

Component	Quantity	Price	Total Price
MPH sensor	1	£240.00	£240.00
MPH connector	1	£1.90	£1.90
RPM sensor	1	£240.00	£240.00
RPM connector	1	£1.90	£1.90
Gyro sensor	1	£24.17	£24.17
Gyro connector	1	£6.24	£6.24
Suspension sensor	4	£88.00	£352.00
Suspension connector	4	£15.59	£62.36
Temperature sensor	1	£160.93	£160.93
Temperature connector	1	£13.24	£13.24
Battery	1	£22.99	£22.99
LED	1	£0.295	£0.295
Case	1	£45.97	£45.97
PCB	1	£43.94	£43.94
Total Cost			£1,215.94

Table 22; Shows the total cost of the design.

Proteus Design

Before the schematic diagram is created in proteus, pin selection needs to be planned out. The microprocessor (PIC18F25K50) which is being used has specific analogue, digital, SPI and USB pins. Even though there are multiple analogue and digital pins available to use, the SPI and USB can only be connected a certain way. This information can be found on the datasheet.

© 2015-2014 Microchip Technology Inc. DS 30000448A-page 5

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

IO	28-Pin PDIP/SOC-SOP	28-Pin QFN	40-Pin PDIP	40-Pin UQFN	44-Pin TQFP	Analog	Comparator	CTMU	SR Latch	Reference	USB	EEPROM	USART	MASSP	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-	—	—	—	—	—	—	—	—	—
RA3	5	2	5	20	22	AN3	C1IN+	—	—	VREF+	—	—	—	—	—	—	—	—	—
RA4	6	3	6	21	23	—	C1OUT	—	SRQ	—	—	—	—	—	TOCK0	—	—	—	—
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	—	—	FLY0	—	SDI SDA	—	INT0	Y	—	—
RB1	22	19	34	9	9	AN10	C12IN3-	—	—	—	—	P1C ^(R)	—	SCK SCL	—	INT1	Y	—	—
RB2	23	20	35	10	10	AN8	—	CTED1	—	—	—	P1B ^(R)	—	—	—	INT2	Y	—	—
RB3	24	21	36	11	11	AN9	C12IN2-	CTED2	—	—	—	CCP2 ^(R)	—	SDO	—	—	—	—	—
RB4	25	22	37	12	14	AN11	—	—	—	—	—	P1D ^(R)	—	—	—	—	—	—	—
RB5	26	23	38	13	15	AN13	—	—	—	—	—	—	—	—	—	—	—	—	—
RB6	27	24	39	14	16	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Note 1: Alternate CCP2 pin location based on Configuration bit.
2: Alternate T3CKI pin location based on Configuration bits.
3: Pins are enabled when ICPR1 = 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)F25K50).
5: Location on 28-Pin parts (PIC18(L)F25K50). 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

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

IO	28-Pin PDIP	28-Pin QFN	40-Pin PDIP	40-Pin UQFN	44-Pin QFP	Analog	Comparator	CTMU	SR Latch	Reference	USB	(E)CCP	EUSART	MSDP	Timers	Interrupts	Pull-up	Basic	IO
RB7	28	25	40	15	17	—	—	—	—	—	—	—	—	—	—	IOCB7	Y	PGD	—
RC0	11	8	15	30	32	—	—	—	—	—	—	—	—	—	—	IOCC0	—	—	—
RC1	12	9	16	31	35	—	—	—	—	—	—	CCP2	—	—	—	IOCC1	—	—	—
RC2	13	10	17	32	36	—	—	CTPLS	—	—	—	CCP1 P1A	—	—	—	IOCC2	—	—	—
—	14	11	18	33	37	—	—	—	—	—	VUSBV3	—	—	—	—	—	—	VDDCORE	—
—	15	12	23	38	42	—	—	—	—	—	D-	—	—	—	—	—	—	—	—
—	16	13	24	39	43	—	—	—	—	—	D+	—	—	—	—	—	—	—	—
RC6	17	14	25	40	44	AN18	—	—	—	—	—	—	TX CK	—	—	—	—	—	—
RC7	18	15	26	1	1	AN19	—	—	—	—	—	—	RK DT	SDO ⁽⁷⁾	—	—	—	—	—
RD0	—	19	34	38	AN20	—	—	—	—	—	—	—	—	—	—	—	—	—	—
RD1	—	20	35	39	AN21	—	—	—	—	—	—	—	—	—	—	—	—	—	—
RD2	—	21	36	40	AN22	—	—	—	—	—	—	—	—	—	—	—	—	—	—
RD3	—	22	37	41	AN23	—	—	—	—	—	—	—	—	—	—	—	—	—	—
RD4	—	27	2	2	AN24	—	—	—	—	—	—	—	—	—	—	—	—	—	—
RD5	—	28	3	3	AN25	—	—	—	—	—	—	P1B ⁽⁴⁾	—	—	—	—	—	—	—
RD6	—	29	4	4	AN26	—	—	—	—	—	—	P1C ⁽⁴⁾	—	—	—	—	—	—	—
RD7	—	30	5	5	AN27	—	—	—	—	—	—	P1D ⁽⁴⁾	—	—	—	—	—	—	—

Note 1: Alternate CCP2 pin location based on Configuration bit.
 2: Alternate T3CKI pin location based on Configuration bit.
 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 bit.
 7: RE3 can be used for digital input only (no output functionality).

PIC18(L)F2X/45K50

Figure 10; Demonstrates the data sheet for the PIC. [39]

From the datasheets shown in figure 9, it is now possible to plan out the connections. SPI can only be connected in RA5, RB0, RB1 and RB3. USB can only be connected to IOCC4 and IOCC5. All the analogue pins are shown as 'AN..' and all the digital pins are shown as 'IOC'.

Signal Conditioning

The microprocessor has a +5V supply. To prevent any damage occurring, a clamp must be present on all of the sensors to limit the voltage into the PIC to +5V. A clamp consists of a capacitor, resistor and a Zener diode, which can be seen in figure 8 below.

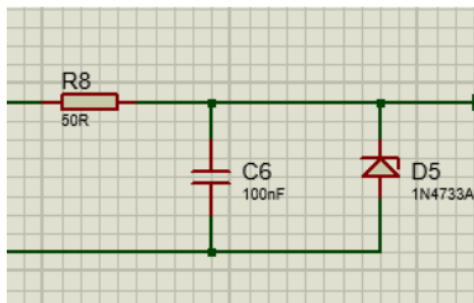


Figure 11; Shows the clamp in Proteus.

RPM & MPH

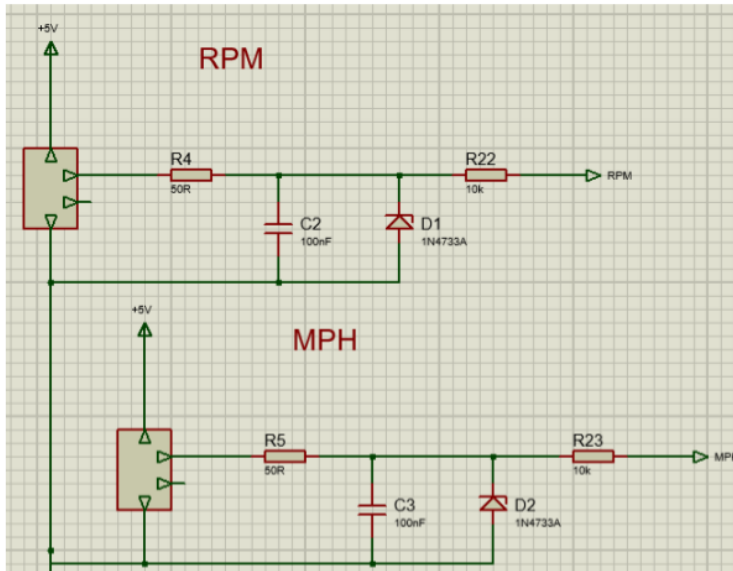


Figure 12; Show the RPM and MPH Sensors.

The output signal of these sensors is a negative pulse. For the sensor to operate correctly then a resistors R22 for RPM and R23 for MPH are needed to bring the pulse down from +5V. A clamp is needed to limit the voltage to the pic to 5V for signal conditioning.

Temperature

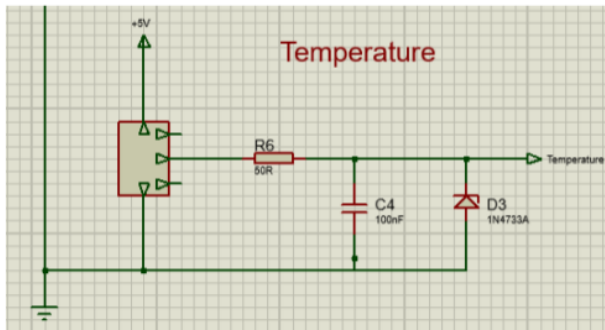


Figure 13; Shows the temperature sensor.

This sensor has a 0 – 5V output which is compatible with the microprocessor, so no action is needed. A clamp is needed to limit the voltage to the pic to +5V for signal conditioning.

Suspension

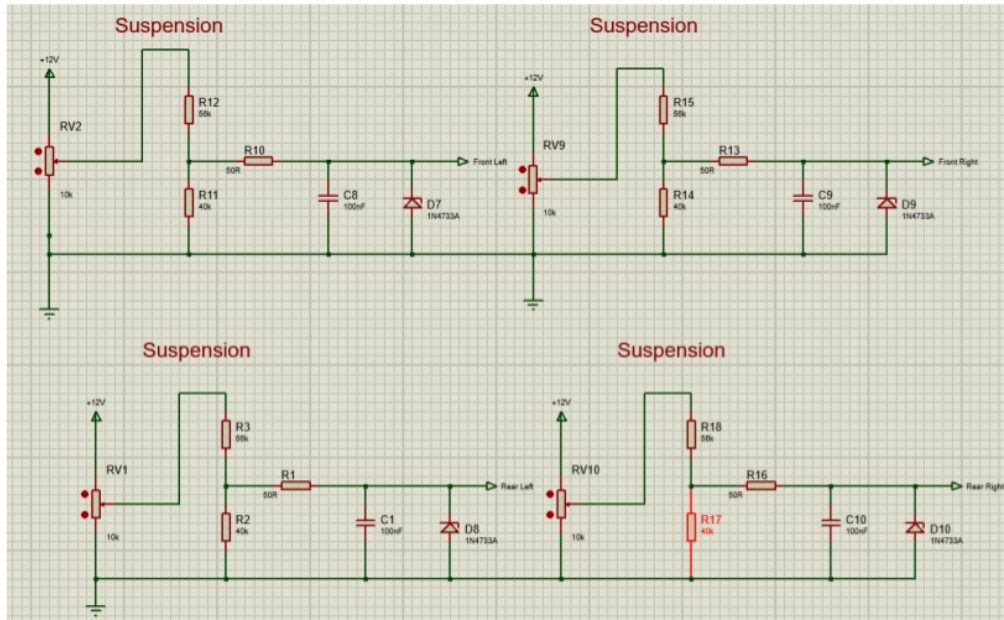


Figure 14; Shows the suspension sensors.

The suspension sensors have a +12V supply so a potential divider is needed to reduce the voltage down to +5V. The resistances for the potential divider have been calculated by using the following equation;

$$V_{out} = V_{in} \times \frac{R2}{R1 + R2}$$

$$12V \times \frac{40}{56 + 40} = 5V$$

The output of these sensors is 0 – 5V which is compatible with the microprocessor, so no action is needed. A clamp is needed to limit the voltage to the pic to 5V for signal conditioning.

Gyroscope

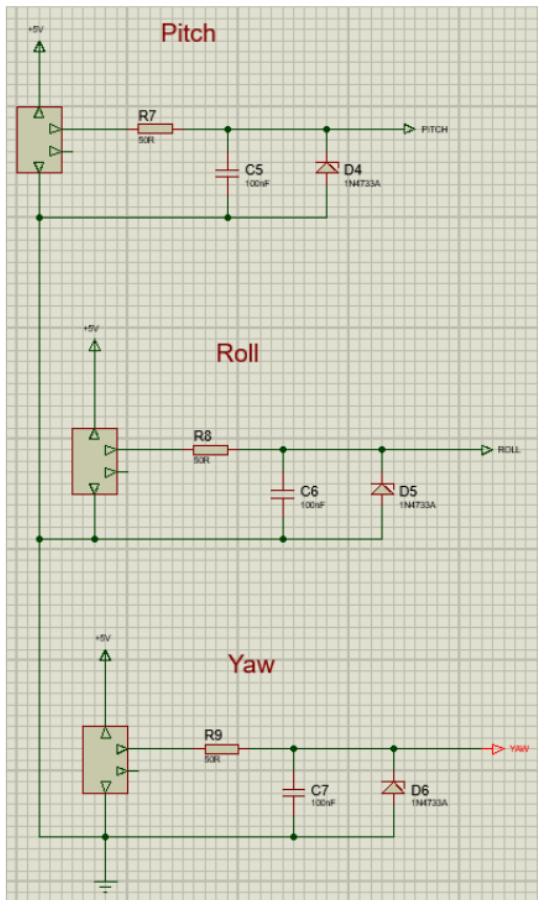


Figure 15; Shows the gyroscope

This sensor has a 0 – 5V output which is compatible with the microprocessor, so no action is needed. A clamp is needed to limit the voltage to the pic to +5V for signal conditioning.

Battery

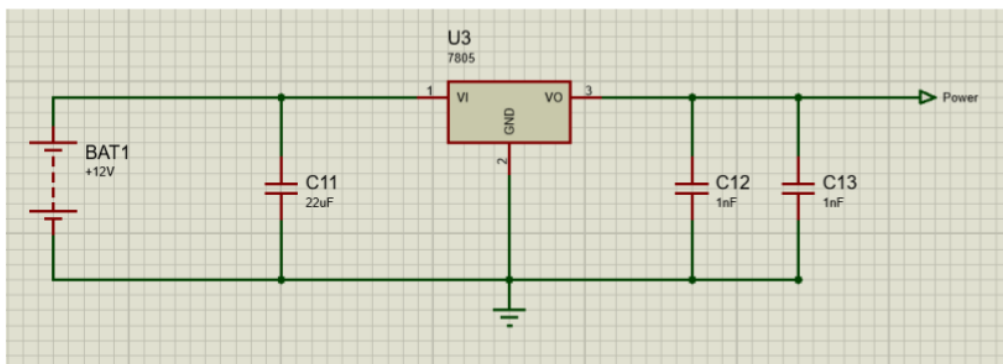


Figure 16; Shows the selected battery.

The battery has a +12V supply so a '7805' voltage regulator is required to reduce the voltage down to +5V, which is the voltage required for the PIC. A series of capacitors are used to stabilise the 7805. A heat sink for the 7805 is not required as the max current output is quite low.

SD Card

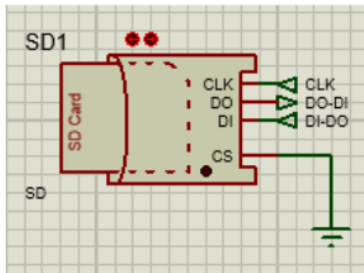


Figure 17; Shows how the SD card connects to the PIC.

The SD will be used to collect the data which the system produces. Once the data has been collected and stored, the SD card can then be removed and installed into a PC for data analysis and storage. The CS port on the SD card is not needed so it is grounded to earth.

USB

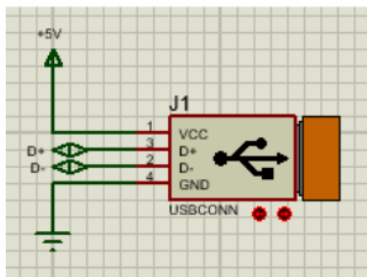


Figure 18; Shows which pins the USB uses to connect to the PIC.

It is the USB port which is used in the system for communication purposes. It could be used for the configuration of the sensors or to access data.

Start/Stop Button & LED

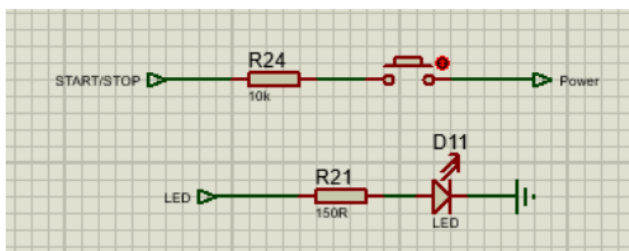


Figure 19; Shows how the stop/start buttons are connected to the PIC.

Microprocessor Connections

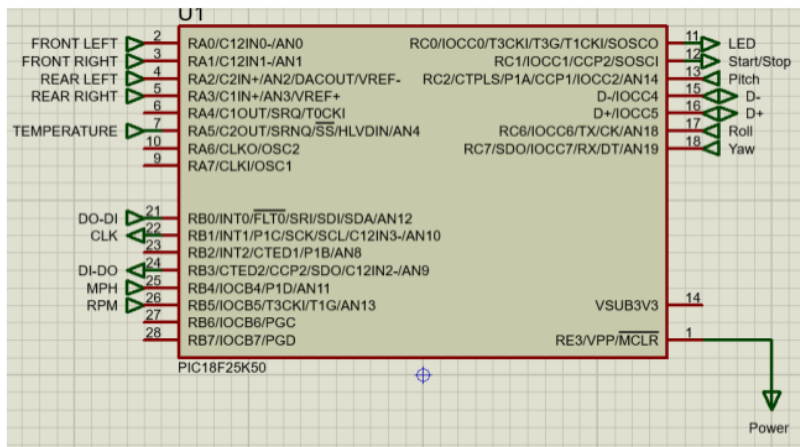


Figure 20; Shows all the connection on the microprocessor.

Full Proteus Design

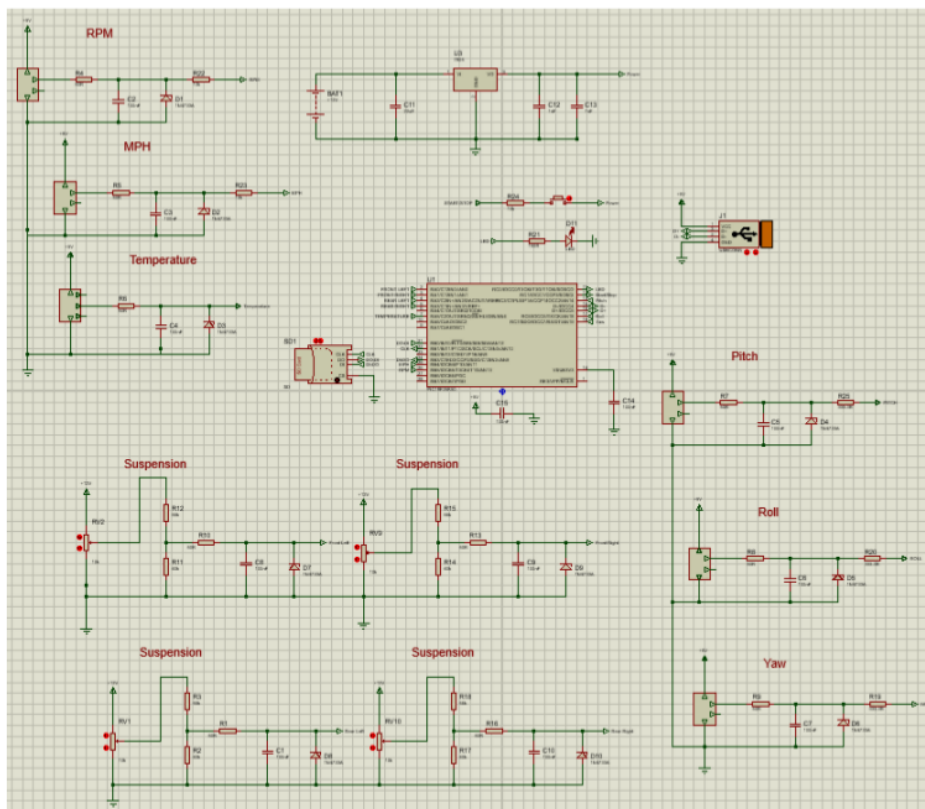


Figure 21; Shows the full proteus design.

Easy-PC Design - Schematic Diagram

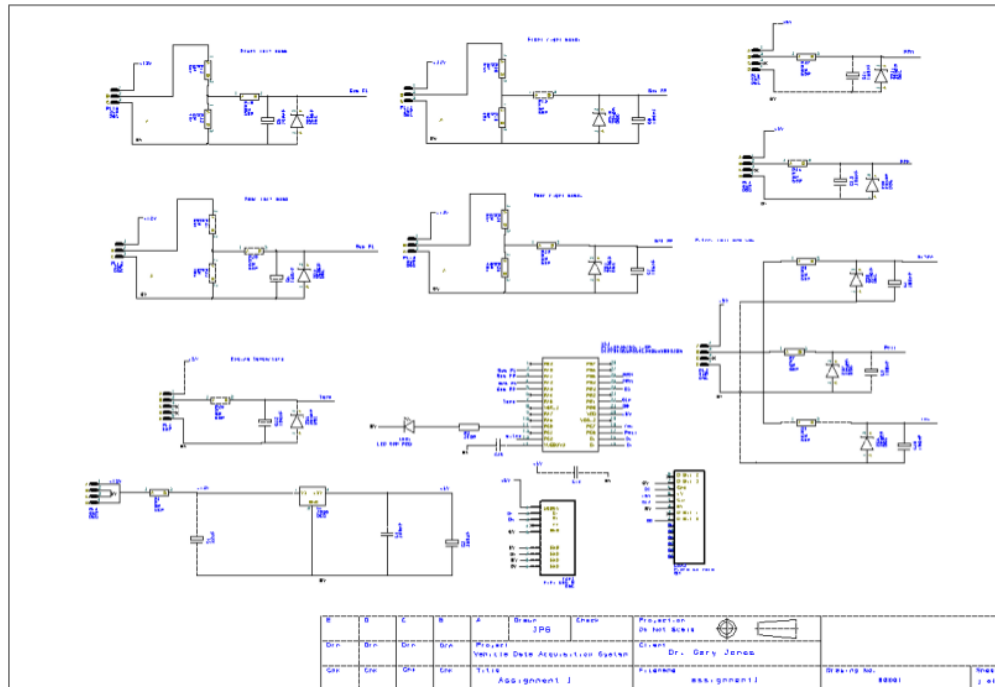


Figure 22; Shows the full Easy-PC schematic diagram

Without Copper Pour

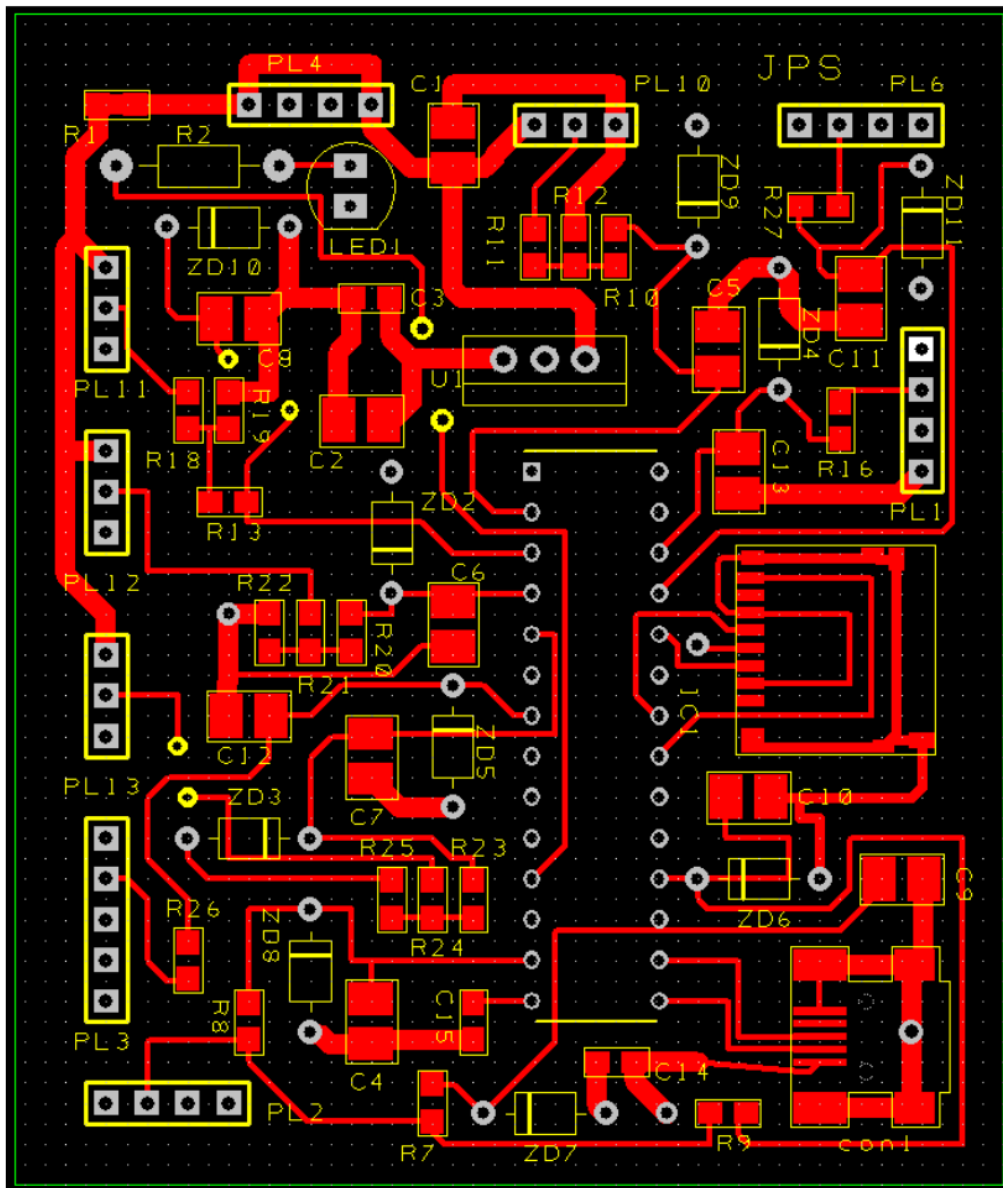


Figure 23; Shows Easy-PC PCB design pre copper-pour.

With Copper Pour

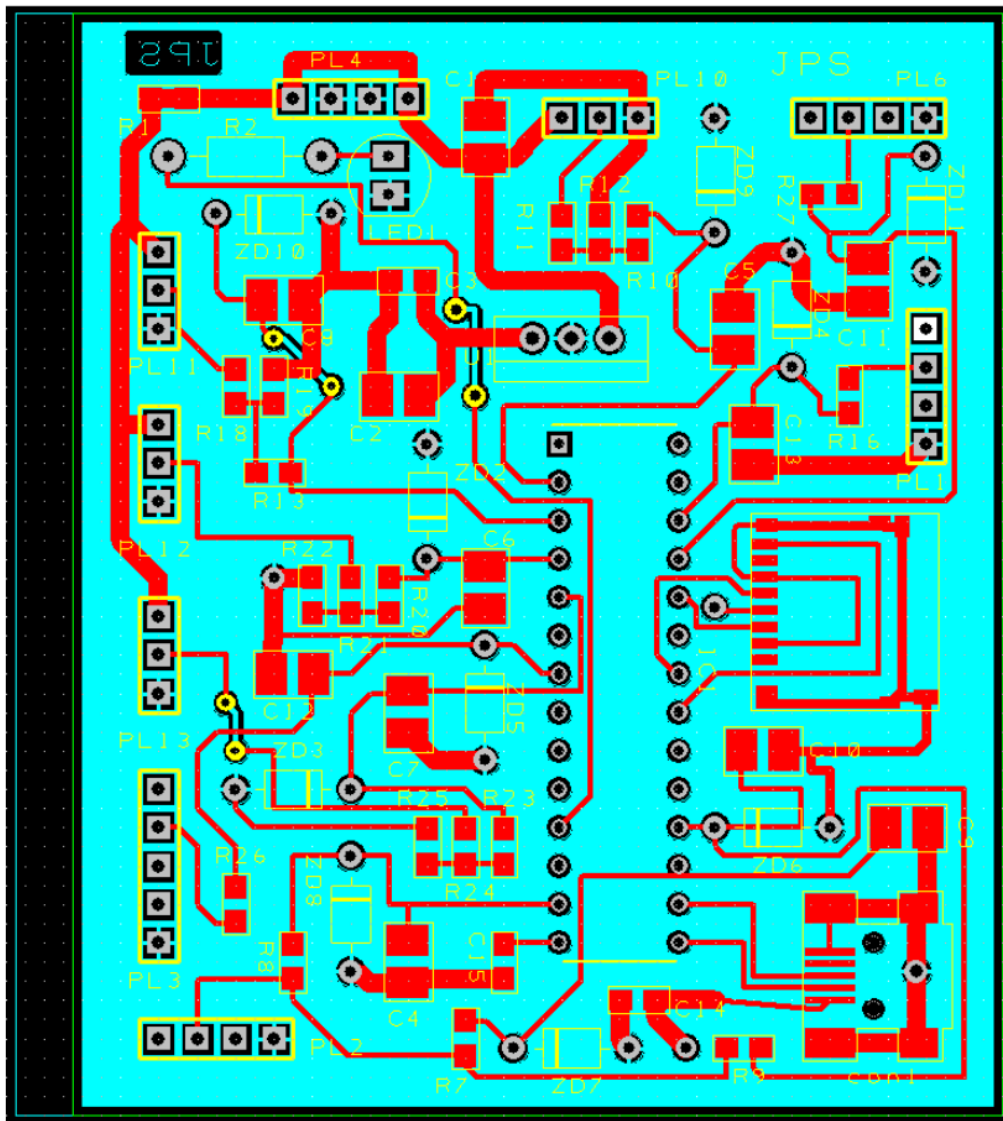


Figure 24; Shows the Easy-PC PCB design post copper-pour.

3D View – front

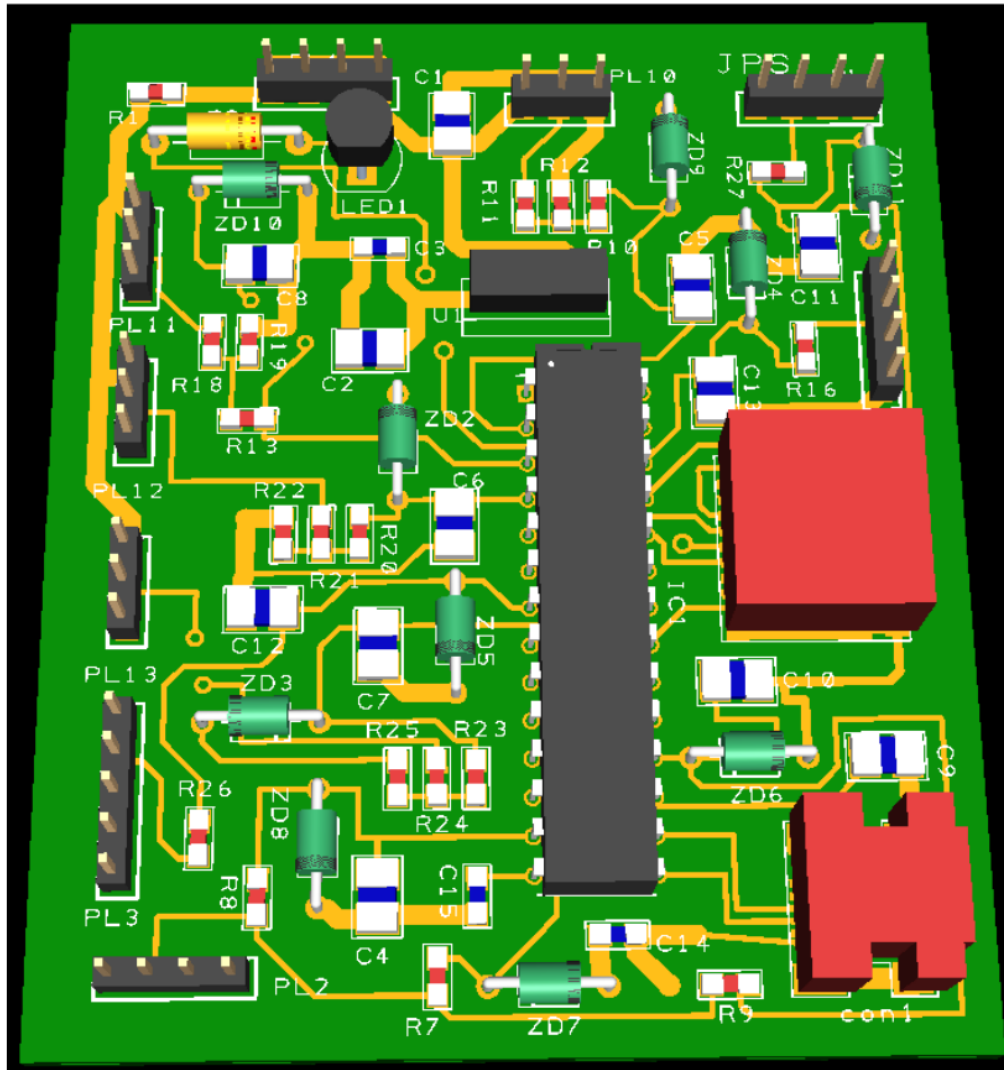


Figure 25; Shows the top view of the 3D Easy-PC PCB design.

3D View – back

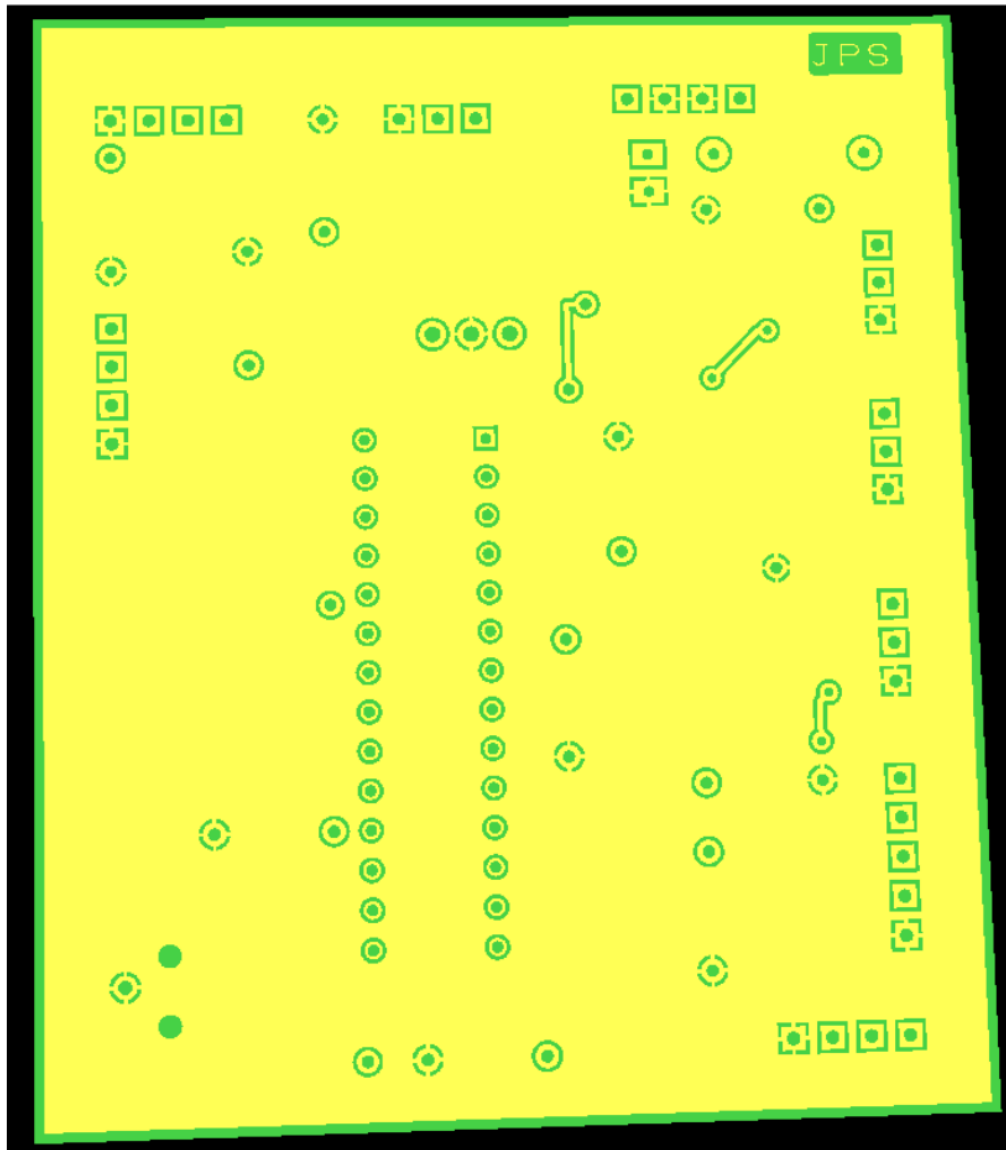


Figure 26; Shows the 3D bottom view of the Easy-PC PCB design.

Suggested Improvements

After completing this data acquisition system, there are several ways in which it could be improved. First improvement would be a built-in screen. It would be beneficial to monitor a cars performance during a 2-hour car test. Although this would make the system more practical, it would make it more complex. Careful and thoughtful PCB design and planning would be required to make this possible.

Another feature could be Bluetooth connection. This could also be used to view and monitor a cars performance on test runs. This would be beneficial as changes to the system can be easily made on the in the middle of test runs.

Additionally, the use of a GPS tracker could be used to aid the measurement of speed. It could also be used to measure new parameters, including acceleration and distance covered. The disadvantages of GPS are that it cannot give accurate readings when the car travels on an incline/decline. GPS trackers can also lose signal.

Bibliography

- [1 "vbox automotive," 20 11 2019. [Online]. Available:
] <https://www.vboxautomotive.co.uk/index.php/en/products/data-loggers/vbox-3i>.
- [2 "demon-tweeks.com," 19 11 2019. [Online]. Available: <https://www.demon-tweeks.com/aim-motorsport-evo5-data-logger-2003462/?sku=AlMEVO5-CR4&istCompanyId=a2904180-3a7d-4e56-b876-cf81c9512180&istFeedId=6fbc4b04-fd28-4ce1-8513-835c8f118690&istItemId=writaawaa&istBid=t&gclid=Cj0KCQIAk7TuBRDQARIsAMRrfUa2zsaEZuxla>. [Accessed 20 11 2019].
- [3 "omniinstruments.co.uk," 20 11 2019. [Online]. Available:
] https://www.omniinstruments.co.uk/data-logger-multi-channel-programmable/datataker-data-logger-range/datataker-dt80-data-logger.html?gclid=Cj0KCQIAk7TuBRDQARIsAMRrfUYm4cmDaJaxDrnor-Ll-x5FptaotcfyD6fpteadbnz6s6gPPyY8WYaAqLDEALw_wcB. [Accessed 20 11 2019].
- [4 "omniinstruments.co.uk," 20 11 2019. [Online]. Available:
] https://www.omniinstruments.co.uk/data-logger-multi-channel-programmable/graphtec-data-logger-range/gl240-data-logger.html?gclid=Cj0KCQIAk7TuBRDQARIsAMRrfUY4UOP6J3aH6H70e2hrYeOjwXZq1YWS5ZpJglmr_sFELCOmdMgnuqYaAtZpEALw_wcB. [Accessed 20 11 2019].
- [5 "microchip.com," 15 11 2019. [Online]. Available:
] <https://www.microchip.com/ParamChartSearch/Chart.aspx?branchID=1004>. [Accessed 15 11 2019].
- [6 "amazon.co.uk," 22 11 2019. [Online]. Available: https://www.amazon.co.uk/Cloudisk-Card-Flash-Memory-Class4-4GB/dp/B07RTHHVBj/ref=sr_1_9?adgrpid=50758209102&gclid=CjwKCAiA8ejuBRAaEiwAn-iJ3qEueUS3CrQh9MudQhOg5c4vWy21OhFm5-3lePOh_UqeD8aGlf03BoCs6sQAvD_BwE&hvadid=259064359843&hvdev=c&hvlocphy=9045405&hvne. [Accessed 22 11 2019].
- [7 "RSonline.com," 15 11 2019. [Online]. Available: <https://uk.rs-online.com/web/p/hall-effect-sensors/7659325/>. [Accessed 15 11 2019].
- [8 "coleparmer.co.uk," 15 11 2019. [Online]. Available: https://www.coleparmer.co.uk/i/monarch-6180-056-optical-sensor-for-up-to-3-feet-range-from-1-to-250-000-rpm/0821253?PubID=UY&persist=true&ip=no&keyword=&gclid=EA1alQobChMlg-zghefi5QIVC_IRCh2tpQYQEAQYAiABEgLnxD_BwE. [Accessed 15 11 2019].
- [9 "automation.co.uk," 15 11 2019. [Online]. Available:
] https://www.automation24.co.uk/inductive-sensor-m-d-micro-detectors-ak1-ap-1h?previewPriceListId=1&refId=adwords_shopping_UK&gclid=Cj0KCQIAk7TuBRDQARIsAMRrfUZuFD_yavNmghTE9qkT8Y-kWT5eexWr1NMeyfye2gy-H4wNSzGgRIaAuqCEALw_wcB. [Accessed 15 11 2019].
- [1 "omniinstruments.co.uk," 15 11 2019. [Online]. Available:
0] <https://www.omniinstruments.co.uk/vls-optical-speed-sensor-with-analogue-output.html>. [Accessed 15 11 2019].
- [1 "omniinstruments.co.uk," 15 11 2019. [Online]. Available:
1] <https://www.omniinstruments.co.uk/lips-p112-gauge-head-position-sensor.html#upsell-product-div>. [Accessed 15 11 2019].
- [1 "uk.rs-online.com," 15 11 2019. [Online]. Available: https://uk.rs-online.com/web/p/products/3629840?cm_mmc=UK-PLA-DS3A-_-google-_-CSS_UK_EN_Automation_And_Control_Gear-_-

- Sensors_And_Transducers%7CPlatinum_Resistance_Temperature_Sensors_-
PRODUCT_GROUP&matchtype=&pla-432216837506&gclid=Cj0KCQiAtrnuBRDXARIsA. [Accessed 15 11 2019].
- [1 "farnell.co.uk," 15 11 2019. [Online]. Available: https://uk.farnell.com/texas-instruments/lm335z-nopb/ic-temp-sensor-precision-to-92/dp/1564652?gclid=Cj0KCQiAtrnuBRDXARIsABiN-7AbzximHKK5BcJwypeDdqJ-IQQBiID7pixQhCdIGEVyXQg578MCGraAkPREALw_wcB&gross_price=true&mckv=73kNSYYh_dc|pcrid|78108290469|&CMP=KNC-. [Accessed 15 11 2019].
- [1 "uk.rs-online.com," 15 11 2019. [Online]. Available: https://uk.rs-online.com/web/p/products/382911?cm_mmc=UK-PPC-DS3A-_-google-_-3_Migrated_OldAccount_BMM-_-Migrated-_-%2Boptris+%2Bcs&matchtype=b&kwd-362418118480&s_kwid=AL17457131246282058680!b!g!%2Boptris%20%2Bcs&gclid=EAlaQobChMlx9f33fv. [Accessed 15 11 2019].
- [1 "www.omega.co.uk," 16 11 2019. [Online]. Available: <https://www.omega.co.uk/pptst/OS136A.html>. [Accessed 16 11 2019].
- [1 "uk.rs-online.com," 16 11 2019. [Online]. Available: <https://uk.rs-online.com/web/p/ir-infrared-temperature-sensors/0553349/>. [Accessed 16 11 2019].
- [1 "rapidonline.com," 16 11 2019. [Online]. Available: <https://www.rapidonline.com/VEX-Yaw-Rate-Gyroscope-Sensor-V1-0-70-6360?IncVat=1&pdg=pla-294357559827:kwd-294357559827:cmp-757438067:adg-44804851896:crv-207912323492:pid-70-6360:dev-c&gclid=Cj0KCQiAtrnuBRDXARIsABiN-7AFM25HpEHCEBxGmVBR28lqANmTV-BWtTLPLDLHRX>. [Accessed 16 11 2019].
- [1 "uk.banggood.com," 16 11 2019. [Online]. Available: https://uk.banggood.com/WIT-MPU6050-3-Axis-Bluetooth-Digital-Accelerometer-6-Axis-Gyro-Gyroscope-AHRS-Transducer-Sensor-p-1387406.html?gmcCountry=GB¤cy=GBP&createTmp=1&utm_source=googleshopping&utm_medium=cpc_bgcs&utm_content=zouzou&utm_campaign=ssc. [Accessed 16 11 2019].
- [1 "www.omniinstruments.co.uk," 16 11 2019. [Online]. Available: https://www.omniinstruments.co.uk/gyros-accelerometers-imu-s-tilt-sensors/inclinometers-tilt-sensors/xhai-dual-axis-high-accuracy-inclinometer.html?gclid=Cj0KCQiAtrnuBRDXARIsABiN-7CvzlvzboIThYNqHnRVmsDmlN_NJTVe5pi237NNTFsWdAiH0cQr6h0aAr3HEALw_wcB#upsell-p. [Accessed 16 11 2019].
- [2 "omniinstruments.co.uk," [Online]. Available: <https://www.omniinstruments.co.uk/lca310t-0-series-single-axis-inclinometer.html>.
- [2 ".kasensors.com," 16 11 2019. [Online]. Available: <https://www.kasensors.com/en/products/gyro>. [Accessed 16 11 2019].
- [2 "kuebler.com," 16 11 2019. [Online]. Available: <https://www.kuebler.com/en/products/measurement/linear-measuring-systems/product-finder/product-details/C100>. [Accessed 16 11 2019].
- [2 "wolfautomation.com," 16 11 2019. [Online]. Available: <https://www.wolfautomation.com/laser-distance-sensor-44400/>. [Accessed 16 11 2019].
- [2 www.aimshop.com, 16 11 2019. [Online]. Available: <https://www.aimshop.com/products/aim-4-motorcycle-potentiometer-pop-end-fitting>. [Accessed 16 11 2019].
- [2 "seltec.co.uk," 16 11 2019. [Online]. Available: <https://www.seltec.co.uk/products/details/12445.html?aditem=12445&gref=51322696450&gdev=c&gloc=9045405>. [Accessed 16 11 2019].
- [2 "amazon.co.uk," 16 11 2019. [Online]. Available: <https://www.amazon.co.uk/CALT-1000mm-Measure-Analog-Displacement/dp/B01E9ZHGY>. [Accessed 16 11 2019].

- [2] "banggood.com," 16 11 2019. [Online]. Available: [https://uk.banggood.com/Big-Size-4-Pin-4A-7\) 20AWG-Waterproof-Female-And-Male-Connector-Cable-Wire-for-RGB-LED-Strip-Light-p-1456544.html?gmcCountry=GB¤cy=GBP&createTmp=1&utm_source=googleshopping&utm_medium=cpc_bgcs&utm_content=zouzou&utm_campaign=ss](https://uk.banggood.com/Big-Size-4-Pin-4A-7) 20AWG-Waterproof-Female-And-Male-Connector-Cable-Wire-for-RGB-LED-Strip-Light-p-1456544.html?gmcCountry=GB¤cy=GBP&createTmp=1&utm_source=googleshopping&utm_medium=cpc_bgcs&utm_content=zouzou&utm_campaign=ss). [Accessed 16 11 2019].
- [2] "chmelaeon.com," 16 11 2019. [Online]. Available: <https://www.chmelaeon.com/products/hp20-5-pin-automotive-electrical-wire-connectors-car-charging-connector-wire-connectors-male-and-female-connectors-5-pin>. [Accessed 16 11 2019].
- [2] "screwfix.com," 16 11 2019. [Online]. Available: [https://www.screwfix.com/p/teeplug-ip68-17-9\) 5a-plug-socket/38456](https://www.screwfix.com/p/teeplug-ip68-17-9) 5a-plug-socket/38456). [Accessed 16 11 2019].
- [3] "agouk.com," 17 11 2019. [Online]. Available: [https://agouk.com/index.php/m14-4-ip68-15a-4-0\) pin-waterproof-connector-locking-cable-plug-socket-butt-type.html](https://agouk.com/index.php/m14-4-ip68-15a-4-0) pin-waterproof-connector-locking-cable-plug-socket-butt-type.html). [Accessed 17 11 2019].
- [3] "amazon.co.uk," 17 11 2019. [Online]. Available: [https://www.amazon.co.uk/650mAh-Battery-1\) Rechargeable-KeyBoard-Microphone-White/dp/B07HYSMD51/ref=asc_df_B07HYSMD51/?tag=googshopuk-21&linkCode=df0&hvadid=311075391090&hvpos=1o6&hvnetw=g&hvrnd=10346599358221032770&hvpone=&hvptwo=&hvmmt=&hvdev=c&hvdvcmdl=&](https://www.amazon.co.uk/650mAh-Battery-1) Rechargeable-KeyBoard-Microphone-White/dp/B07HYSMD51/ref=asc_df_B07HYSMD51/?tag=googshopuk-21&linkCode=df0&hvadid=311075391090&hvpos=1o6&hvnetw=g&hvrnd=10346599358221032770&hvpone=&hvptwo=&hvmmt=&hvdev=c&hvdvcmdl=&). [Accessed 17 11 2019].
- [3] "batteryspace.com," 17 11 2019. [Online]. Available: <https://www.batteryspace.com/nicdrechargeablebattery9v120mah1pcs.aspx>. [Accessed 17 11 2019].
- [3] "ebay.co.uk," 17 11 2019. [Online]. Available: <https://www.ebay.co.uk/i/383175769556?chn=ps&norover=1&mkevt=1&mkrid=710-134428-41853-0&mkcid=2&itemid=383175769556&targetid=594652162240&device=c&mktype=pla&googleloc=9045405&poi=&campaignid=6619151966&mkgroupid=84510980808&rlsatarget=aud-381667280803:pl>. [Accessed 17 11 2019].
- [3] "amazon.co.uk," 17 11 2019. [Online]. Available: [https://www.amazon.co.uk/TalentCell-4\) Rechargeable-6000mAh-12000mAh-Lithium/dp/B0713T4XT9/ref=sr_1_6?crid=29YZUTWCB8WBU&keywords=12v+rechargeable+battery&qid=1574359007&s=electronics&prefix=12v+rech%2Celetronics%2C142&sr=1-6](https://www.amazon.co.uk/TalentCell-4) Rechargeable-6000mAh-12000mAh-Lithium/dp/B0713T4XT9/ref=sr_1_6?crid=29YZUTWCB8WBU&keywords=12v+rechargeable+battery&qid=1574359007&s=electronics&prefix=12v+rech%2Celetronics%2C142&sr=1-6). [Accessed 17 11 2019].
- [3] "amazon.co.uk," 17 11 2019. [Online]. Available: [https://www.amazon.co.uk/Rechargeable-Li-5\) ion-Battery-6800mAh-Charger/dp/B00BWW9WRM/ref=sr_1_7?crid=29YZUTWCB8WBU&keywords=12v+rechargeable+battery&qid=1574359007&s=electronics&prefix=12v+rech%2Celetronics%2C142&sr=1-7](https://www.amazon.co.uk/Rechargeable-Li-5) ion-Battery-6800mAh-Charger/dp/B00BWW9WRM/ref=sr_1_7?crid=29YZUTWCB8WBU&keywords=12v+rechargeable+battery&qid=1574359007&s=electronics&prefix=12v+rech%2Celetronics%2C142&sr=1-7). [Accessed 17 11 2019].
- [3] "amazon.co.uk," 17 11 2019. [Online]. Available: [https://www.amazon.co.uk/Max-6\) MAX235H105S-Waterproof-Watertight-Photography/dp/B00PUL6AVM/ref=pd_bxgy_60_img_2/262-4595967-8497035?_encoding=UTF8&pd_rd_i=B00PUL6AVM&pd_rd_r=7e37f323-a43f-4406-9a33-ffc7f8899624&pd_rd_w=VDryN&pd_rd_wg=fDiSI&pf_rd_p=6f720012-](https://www.amazon.co.uk/Max-6) MAX235H105S-Waterproof-Watertight-Photography/dp/B00PUL6AVM/ref=pd_bxgy_60_img_2/262-4595967-8497035?_encoding=UTF8&pd_rd_i=B00PUL6AVM&pd_rd_r=7e37f323-a43f-4406-9a33-ffc7f8899624&pd_rd_w=VDryN&pd_rd_wg=fDiSI&pf_rd_p=6f720012-). [Accessed 17 11 2019].
- [3] "stagedepot.co.uk," 17 11 2019. [Online]. Available: [https://www.stagedepot.co.uk/rigging-7\) install-staging/tools/storage/dap-audio-daily-case?sku=HI-D7160&gclid=CjwKCAiA8ejuBRAAEiwAn-iJ3pA5P2NQM3UYWlzcQgt3OeP0KkBkIaNCfqUA1dC08pbBYZAiqafGrhoC3CIQAvD_BwE#horizontalTab3](https://www.stagedepot.co.uk/rigging-7) install-staging/tools/storage/dap-audio-daily-case?sku=HI-D7160&gclid=CjwKCAiA8ejuBRAAEiwAn-iJ3pA5P2NQM3UYWlzcQgt3OeP0KkBkIaNCfqUA1dC08pbBYZAiqafGrhoC3CIQAvD_BwE#horizontalTab3). [Accessed 17 11 2019].
- [3] "farnell.co.uk," 17 11 2019. [Online]. Available: [https://uk.farnell.com/kingbright/l-57iid/led-bi-8\) polar-5mm-red/dp/2217953](https://uk.farnell.com/kingbright/l-57iid/led-bi-8) polar-5mm-red/dp/2217953). [Accessed 17 11 2019].
- [3] "microchip.com," 15 11 2019. [Online]. Available: <https://www.microchip.com/wwwproducts/en/PIC18F25K50>. [Accessed 15 11 2019].

[4 "coleparmer.co.uk," 15 11 2019. [Online]. Available: [https://www.coleparmer.co.uk/i/monarch-0\] 6180-056-optical-sensor-for-up-to-3-feet-range-from-1-to-250-000-rpm/0821253?PubID=UY&persist=true&ip=no&keyword=&gclsrc=aw.ds&&gclid=EAlaQobChMlg-zghefi5QIVC_IRCh2tpQYQEAQYAiABEgLnxD_BwE](https://www.coleparmer.co.uk/i/monarch-0] 6180-056-optical-sensor-for-up-to-3-feet-range-from-1-to-250-000-rpm/0821253?PubID=UY&persist=true&ip=no&keyword=&gclsrc=aw.ds&&gclid=EAlaQobChMlg-zghefi5QIVC_IRCh2tpQYQEAQYAiABEgLnxD_BwE). [Accessed 15 11 2019].

jack solomon - ESD assignment 1

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

73/100

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10

PAGE 11

PAGE 12

PAGE 13

PAGE 14

PAGE 15

PAGE 16

PAGE 17

PAGE 18

PAGE 19

PAGE 20

PAGE 21

PAGE 22

PAGE 23

PAGE 24

PAGE 25

PAGE 26

PAGE 27

PAGE 28

PAGE 29

PAGE 30

PAGE 31

PAGE 32

PAGE 33

PAGE 34

PAGE 35

PAGE 36

PAGE 37

PAGE 38

PAGE 39

GRADING FORM: SMU GENERIC_GJ

JACK SOLOMON

72.85

RESEARCH-INFORMED LITERATURE



Good literature review of available systems with a good comparison table of relevant information. 70%

7

KNOWLEDGE AND UNDERSTANDING



Very good circuit diagram. The PCB design is very good the only issue is the dummy layers have been left in making it a 4 layer board. 75%

18.75

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 no comparison table. 73%

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. Reasonable attempt at future enhancements. 65%

13

SKILLS FOR PROFESSIONAL PRAC.



The report is well presented with very well presented tabled data and structure diagrams. A good selection of references. 75%

7.5