

JHeeks ACDA6002 Assignment

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by Jack Heeks

Submission date: 31-Jul-2024 06:55PM (UTC+0100)

Submission ID: 238130505

File name: 32726_Jack_Heeks_JHeeks_ACDA6002_Assignment_1_523682_1367301129.docx (2.93M)

Word count: 5330

Character count: 31113

Electronic Systems Design

Car Data Logger

Embedded Electronic Systems

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Introduction

In this report a microcontroller based automotive data acquisition system will be designed, with the intention of fitting the system to a prototype production car. The brief states the DAQ system will be implemented in the testing of a vehicle being produced for the family saloon market. However, the system must be re-usable, portable and adaptable for any class of vehicle.

Data will be collected over a 2-hour test track run to determine if the vehicle design is able to pass production vehicle safety assessments (such as Euro NCAP) and that the vehicle is able to provide a comfortable means of transport.

Portable Vehicular DAQ Systems

			
GRANITE 10 ^[1]	CANedge3 ^[2]	Multi-Daq K-Box ^[3]	The Validyne VDAS ^[4]
Real-Time Clock Accuracy ± 3 min. per year	The plug & play CAN/LIN logger records timestamped CAN data to an 8 GB SD card	CAN Bus settings, calibration and sampling rates are all easily configurable	Withstands the elements – moisture and temperatures up to 85 °C
Wide range of communications ports and microSD and USB host data storage ports	The compact device uses 3G/4G to securely push data to your own server	Stackable with all other K-series instrumentation modules	Highly accurate using proprietary digital compensation for each channel
8 pulse counters	The device includes GNSS/IMU	Accurate sensor measurement data is transmitted periodically on the CAN Bus	Up to 300 high-density channels of vehicle sensor inputs
Several internet protocols available	Software/APIs are 100% free & open source	Multiple K-Series modules can be connected together to record data	Rugged to take abuse in the field
8 terminals configurable for digital input and output. Terminals are configurable in pairs for 5 V or 3.3 V logic for some functions.	Ideal for telematics, R&D field tests, diagnostics and predictive maintenance	For applications that require a quick set-up and collection of thermocouples, analog, digital and PWM inputs	Low-power consumption – minimal heat generation
4MB battery-backed SRAM for CPU usage and storage	Very low ~ 1 W power consumption	Up to 8 K-type connections at up to 20 Hz sampling rate	Low Power Dissipation – Minimizes Thermal Distortion in Vehicle
Quad core processor running at 1GHz	Reverse and transient voltage protection	8 Analog inputs with variable input sampling rates	1000 V Isolation on all Channels

Table 1 - Table of Commercially Available Vehicle Data Loggers

Component Selection

Measurement sensors

Speed Sensors

Reflective optical sensors will be used to take engine and vehicle speed measurements as this is a non-intrusive method. Using a laser allows for non-contact measurement and utilising a reflective sensor ensures there are no modifications required to the any components, as would be required for a beam break optical sensor to work, a reflective strip can be adhered to the cam wheel or belt and break disk to provide an engine and vehicle speed measurement.^[5]

Optical sensor measurement is preferred to mechanical, inductive, or magnetic. Mechanical sensors were discounted due to the issue of wear during use as this would create the issue of needing replacing and data not being collected when sensor components are excessively worn.

The inductive and magnetic sensors typically require the use of a permanent magnet to interact with and provide a signal as it passes the sensor head. This however requires a magnet to be fixed to a rotating object which poses a risk to the engine should it come loose and may cause the rotor to become unbalanced and pose a greater risk to the engine.^{[6], [7]}

The speed sensor selected is the [GL6G-F2411V](#), this is a red laser retroreflective photoelectric sensor. This sensor was selected for its fast response time of up to 625us, this allows the reflector to be placed on any rotor on the car or engine ensuring that this sensor is versatile as a measurement sensor for all vehicle tests for instance large RPM values expected from motorcycle engines or the high-speed wheel rotations of high-performance cars.

Temperature Sensors

In order to obtain temperature measurements without damaging the engine requires the use of adhesive thermocouples or infrared temperature sensor these will only measure engine casing temperature but are non-intrusive, unlike the typical methods which require alterations to the engine components.

Thermistors are great all round measurement devices but are slower to react than the other devices and have small thermal operating ranges, installing this sensor onto an engine may involve alterations to engine casings and components or leave permanent traces in the engine bay.^{[8], [9]}

Thermocouples and Resistance Temperature Detectors have large ranges and high resolutions, with thermocouples offering faster response times, a smaller surface area and the ability to measure much higher temperatures and RTDs offer increased levels of accuracy, only require one point of measure and are more cost effective to install.^{[10], [11], [12]}

An infrared temperature sensor with inbuilt output buffer has been selected as the sensor of choice. The sensor is described as fast acting and able to correct for ambient temperature, the output buffer provides signal conditioning for driving signals over long distances. The part number is [SA-IR200V6-007](#)

Suspension Travel Sensors

The preferred method of suspension travel measurement is a wire potentiometer, because it is a simple installation and a small package size compared to the linear potentiometer, it will provide accurate and more reliable measurements than laser and ultrasound over the full vehicle speed range and much cheaper than the RF ranging sensor option.^{[13], [14]}

Other measurement options include linear potentiometer and contactless ride height devices. Linear potentiometers measure the change in voltage over the length of the stroke, this means that the potentiometer has to have a stroke length double the distance of the expected suspension travel to ensure that the full travel is measured and not impeded. This means that a linear pot would be bulky and may require involved mounting methods to obtain accurate and useful measurements.^{[15], [16]}

Ride height devices can measure the distance^[17] of a fixed point on a vehicle above a surface, there are three common techniques:

Laser is the most common technique however it can be affected by environmental factors such as water or atmospheric conditions.

Ultrasound is an alternative method however at high vehicle speeds the vibrations will introduce white noise into the measurement system impairing the results.

An RF ranging sensor is a final alternative, but this is complex to implement, will be larger than many of the other sensor options, and this type of sensor is expensive due to the specialist components.

The selected part for this [SG1-120-2](#) a wire potentiometer with a stroke length of 120", this is to enable a universal measurement sensor compatible with all lengths of suspension coil, shock absorber and fork lengths, as well as measuring torsion bar deflection.

Positional Measurement Sensors

The selected positional measurement sensor is a Micro-Electro-Mechanical System Gyroscope^[18] as this sensor can measure all three axis in one rather than needing three separate accelerometers to measure a single axis each. It is also a sensor package as opposed to a surface mount chip which would need to have its own circuit produced or be integrated into the main circuit, a standalone sensor allows it to be mounted freely and easily to any point on a vehicle.

The selected sensor is the [Model 633-050-500-120](#), this sensor is an analog device with the ability to measure 6 degrees of freedom – linear and rotary motion for the roll, pitch, and yaw – using rate sensors and accelerometers to measure the acceleration and angular velocity of the vehicle under test. This ensures that the relevant data can be collected for the briefed testing and for future use cases the system will be able to measure rotational motion of a test vehicle; such as car body roll, motorcycle lean angle or off-road vehicle situational angles.

Memory Requirements

Recording Method	Bytes per Reading	Time per Record	Frequency	Bytes per Record
X pulses per second (RPM)	1	1	1	15
X pulses per second (MPH)	1	1	1	15
Analog (Temp)	2	15	0.066666667	2
Analog (Motion)	6	0.05	20	1,800
Analog (Suspension)	8	0.00005	20,000	2,400,000

Table 2 – Data Recording

Total bytes per record: 2,401,832

Total bytes for 2 hours of data recorded: 1,152,879,360

This suggests the minimum required memory is 1.2GB

Upon researching data storage methods a FLASH memory device was selected as the most appropriate solution. This is because it is a non-volatile memory type ensuring the stored data remains while the device is powered off, this memory type can utilise I2C and SPI communication methods^[19], FLASH memory devices tend to have storage sizes from a few Gigabytes to several Terabytes^[20]. A NAND FLASH memory device is faster to write and erase data than NOR^[21], as such the NAND variety is more suited due necessity to write the recorded data quickly. Flash memory is also widely used in embedded systems as a high-density, low-cost data storage solution^[22], it also has a small footprint so will not require a large amount of space within the system. Based on these parameters an SD card will be used to store the data recorded during testing as this is a small, fast and easy data storage solution.

Microcontroller Selection

Requirements

- 8 analog inputs
- 2 digital inputs
- 4 pins for a microSD card
- 4 pins for power
- 1 pin for a power button
- 1 pin for an LED output
- 2 pins for debugging device
- 4 pins for IO device
- 32MHz operating frequency

- 22 pins minimum
- 1kB RAM minimum
- 32MHz Frequency minimum
- 8 Analog input pins minimum
- USB communication
- SPI communication

Selected Microcontroller

MICROCHIP ADVANCED PART SELECTOR

Parameter Search (Match ALL (AND) / Match ANY (OR))

Family: 8-bit MCU
 Part Family: -All-
 CPU Type: 8-bit PIC MCU
 Max CPU Speed (MHz): 32 MHz / 80 MHz
 CPU Speed (MIPS/DMIPS): -All- / -All-
☐ ARM Neon ☐ FPU
☐ Math Accelerator

Voltage
 Operation Voltage: 5V / -All-
Temperature
 Temp Range: -All- / -All-
Packages
 Pin Count: 24 / 40
 Max I/O Pins: -All- / -All-
Memory Data
 Program Memory Size (KB): 4 / -All-
 Program Memory Size (KWords): -All- / -All-
 Auxiliary Flash (KB): -All- / -All-
 SRAM (KB): -All- / -All-
 L1 Cache Memory (Instructions) (KB): -All- / -All-
 L1 Cache Memory (Data) (KB): -All- / -All-
 Internal DRAM Type: -All-
 External Memory Bus Interface: -All-
 DRAM Interface: -All-
☐ Multiple Flash Panels
☐ Error Correction Code Program Flash
☐ Emulated EEPROM in Flash
☐ NAND Interface

Search Results 11 MCHP parts found

Reset Search
 Sort Results by: Memory Size
 Add PIC18F45K50
 Go to side-by-side

PIC18F45K50 In Production
 Specifications | Dev Tools | Technical Docs | Budgetary Pricing

Family	8-bit MCU
CPU Type	8-bit PIC MCU
Max CPU Speed (MHz)	48 MHz
FPU	
Operation Voltage	(1.8V-5.5V)
Temp Range	(-40 to +125)
Pin Count	40
Program Memory Size (KB)	32
Error Correction Code Program Flash	
SRAM	2 KB
State EEPROM/EEP (Bytes)	256
Internal DRAM Type	
Internal DRAM Amount (MB)	
Low Power	Yes
ADC Input	25
Max ADC Resolution (Bits)	10
DAC Outputs	1
Number of Op Amps	
Hardware Touch Peripheral	
UART	1
SPI	1

Navigation: Analog, Interface, Memory, MCUs & MPUs, Wireless

Not sure of complete part number? Global Part Search

Selection Tools Home
 Have a suggestion? Send Email

More Links
 Select a part in the search results, press one of the buttons below to view.

PIC18F45K50
 MICROCHIP

Figure 1 – Microprocessor Selection Parameters 1

Data EEPROM/EEP (bytes)		AB	AB
Internal DRAM Amount (MB)		AB	AB
DRAM Bus Size (bits)		AB	AB
Boot Memory (KB)		AB	AB
Direct Memory Access Channels		AB	AB
Number of EBIs		AB	AB
ECC Bits on NAND Interface		AB	AB
QSPI		AB	AB
SDIO/SD-CARD/MMC		AB	AB
Low Power			
☐ Low Power ☐ SLP ☐ Vbat/VddIO battery backup			
Analog Peripherals			
ADC Input		8	AB
Max ADC Resolution (bits)		10	AB
DAC Outputs		AB	AB
Number of Op Amps		AB	AB
Number of ADCs		1	AB
Max ADC Sampling Rate (kSps)		AB	AB
Max ADC Sample/hold		AB	AB
DIFF ADC Inputs		AB	AB
Number of DACs		AB	AB
Max DAC Resolution (bits)		AB	AB
Number of Comparators		AB	AB
Comparator max speed (ns)		AB	AB
Programmable Gain Amp		AB	AB
☐ Temp Sensor			
☐ CTMU			
☐ Zero Cross Detect			
I2C		1	
SSC			
Number of USB Modules		1	
USB Interface			FS Device
Type of CAN module			
Number of CAN Modules			
BPM			
Max 8-bit Digital Timers		2	
Max 16-bit Digital Timers		2	
Max 32-bit Digital Timers			
Hardware RTC/RTC			
Max PWM outputs (including complementary)			
Number of PWM Time Bases			
Crypto Engine			
ARM Trust Zone			
Segmented LCD			
Graphics Controller/GPU			
Video Decoder			
Show Other Features			

Figure 2 – Microprocessor Selection Parameters 2

Slope Compensation / Programmable Ramp Generator		AB	AB
Touch			
Hardware Direct Touch Channel Buttons		AB	AB
Hardware Touch Matrix Nodes		AB	AB
Hardware Touch Peripheral		AB	AB
☐ Hardware Cap Voltage Divider			
☐ Touch Library Support			
☐ Resistive Touch Controller			
Communication			
UART		AB	AB
SPI		1	AB
I2C		AB	AB
I2S		AB	AB
SSC		AB	AB
LIN			
☐ LIN			
IDEA			
☐ IDE			
USB			
Number of USB Modules		1	AB
USB Interface		AB	AB
☐ USB Active Clock Tuning			
CAN			
Number of CAN Modules		AB	AB
Type of CAN module		AB	AB
CAN Transmit Buffers		AB	AB
CAN Receive Buffers		AB	AB
Automotive			
ModuLB		AB	AB

Figure 3 – Microprocessor Selection Parameters 3

Based on these parameters the PIC18F family of microcontroller is the most suitable chipset. The PIC18F chips are significantly more powerful than previous PIC series and can be programmed using the C language unlike other PIC series due to larger memories, they are also faster operating. The PIC selected is the PIC18F24K50.

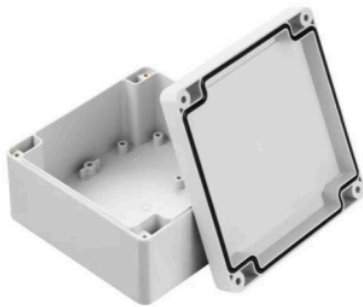
The selection has been determined by the system requirements and the properties as follow. The first digit 2 indicates 28 pins, the second should be greater than 2 to exceed 4kB of chip FLASH memory, the third digit 5 ensures USB compatibility, and the fourth digit ensures it is the more modern PIC type. K in the part number indicates the mid-range type offered as a compromise between the premium PIC18Fxxx and the low-cost PIC18FxxJxx^[23].

Connectors

Deutsch automotive connectors will be used to connect sensors where necessary but most of the sensors are manufactured with cables fitted and an IP67 rating of Ingress Protection. This type of connector was chosen as these are rated for the automotive industry and suited to the conditions expected during driving. An Eaton (Souriau) Free Plug/Cable Mount Motorsport Circular Connector will be used to mate with the connector of the temperature sensor as there is already the male connector built into the sensor package.

Molex PCB header pins will be used on the circuit board, they will be shrouded to ensure they have a lockable mating interface so they are unable to be worked loose through vibrations produced during testing, different series of connectors per sensor will be used where necessary to identify different sensor connections should they have the same number of ports. A microSD holder and USB-C connector will populate the PCB for data communication and storage, these connector types were chosen for the small footprint desired in embedded system applications. Along with the sensor connectors a panel mount USB-A female to USB-A female connector has been included to connect the PIC to the computer when it is time to read the test generated data.

Enclosure



IP67 – Dust tight and Submersion up to depth of 1m (30minutes)

IK07 – protected against 2 joules impact. Equivalent of 0.5kg mass dropped from 400mm above impacted surface

Durable Polycarbonate material

Lightweight

Plastic for electrical isolation for user and microcontroller, this ensures the user cannot receive electric shock and the microcontroller and other ICs cannot be damaged by stray voltages coming into contact with the enclosure.

Circuit Design

Block Diagram

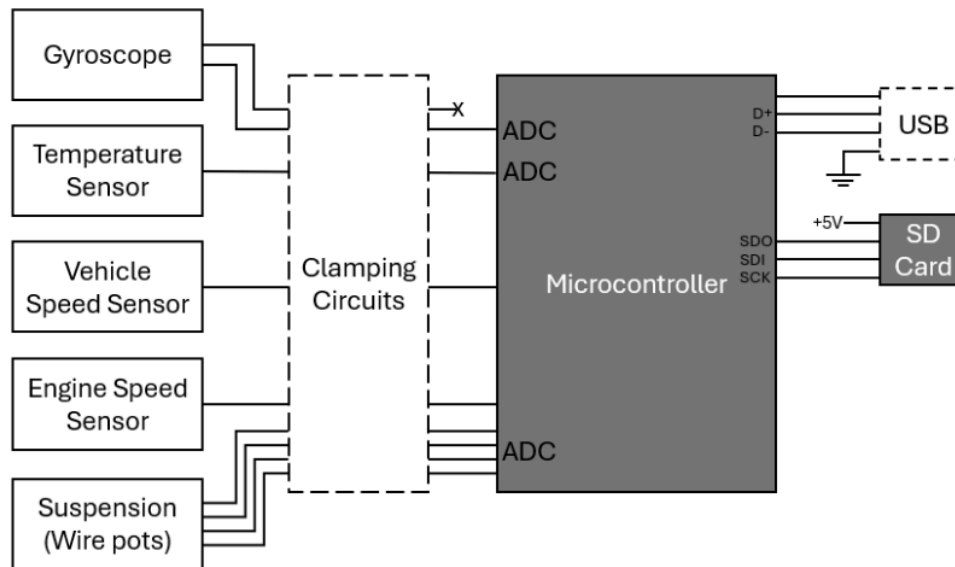


Figure 4 – Circuit Functionality Block Diagram

Schematic

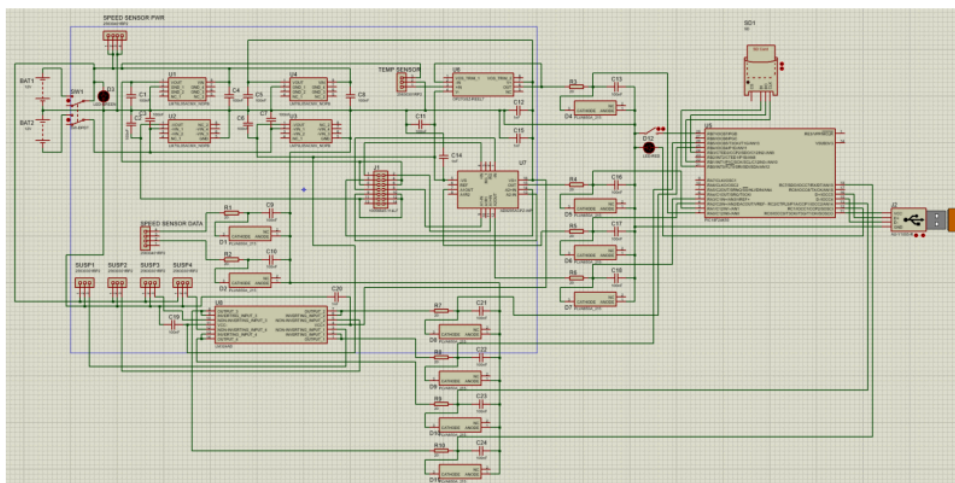


Figure 5 – Proteus Circuit Schematic

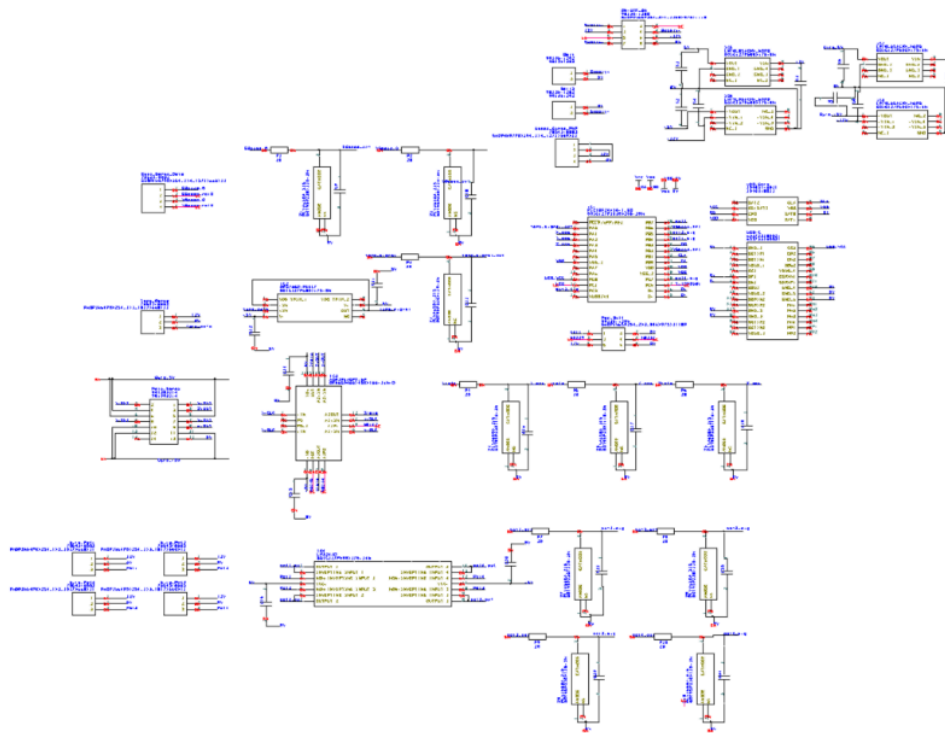


Figure 6 – Easy-PC Circuit Schematic

PCB

The PCB design has been split into power management and signal processing functionality; the power management has been populated on the bottom layer of the board as the components are surface mount and therefore need the tracks to run short distances along the outer layer, header pin connectors have also been populated on this side of the board to ensure no damage to the ICs while connectors are being plugged in during assembly. Then the signal processing is handled on the top layer of the board where all of the surface mount operational amplifier and the PIC chips are populated, the signals are transmitted over very short distances on the top copper tracks and longer distances through the middle two layers denoted signal 1 and 2. ^[24]

All of the copper layers have a 0V copper pour to ensure signal integrity and reduce manufacturing costs and reduce the effects of warping due to thermal expansion. This also acts to shield the signal tracks from electromagnetic interference which could alter signals as they are transmitted across the PCB.

All components are grouped by function and placed for efficient signal flow. Decoupling capacitors are placed as close to ICs as possible and signal clamp components are grouped together to ensure the signal integrity is maintained as it is filtered prior to the PIC reading the data. wherever possible manufacturer power suggestions and application circuits have been adhered to ensure the correct and efficient operation of all components. ^[25]

The operational amplifiers have been selected based on the type of signal and number of incoming signals. The digital speed measurement signals are only conditioned by the clamp as this performs a low pass filtering effect, alongside its intended purpose of changing the DC level of the incoming signal to the desired level. Therefore, any high frequency interference will be negated during this clamping phase. For all analog signals that are being received there is the operational amplifier provides on board signal conditioning, two types of operational amplifier have been selected for this circuit.^[26]

The standard operational amplifier type has been used to condition the signals for the temperature sensor and the wire potentiometers, these have been set up as voltage follower (or buffer) – the intention is that the output signal is used to clean the input signal. Operational amplifiers have good isolation between the input and output signals, as such a buffer style circuit allows the high-impedance input signal to be compared directly with the low-impedance output signal – as this is a unity-gain amplifier circuit – without the electrical load affecting the input signal. The temperature signal has been isolated from the other signals as it has a single channel operational amplifier, whereas the wire potentiometer signals have been grouped and placed onto a single four channel operational amplifier. This has been done in an effort to group signals and reduce the footprint of the board by reducing the number of components needed.^{[27], [28]}

The second type of operational amplifier used is an instrumentation amplifier. This type of amplifier is used for differential signals, so it has been implemented for the differential axis signals produced by the gyroscope sensor. The incoming positive and negative differential signals are fed into the two input channels of the amplifier which are the non-inverting inputs of two separate operational amplifiers the outputs of these amplifiers are then fed into the two inputs of a single operational amplifier to combine them into a single output signal. A three-channel instrumentation amplifier has been selected to host the three differential signals as this reduces the footprint of the PCB by reducing the number of components and tracks.^[29]

Figures 7 through 10 shown below are screen captures of the PCB layers showing the variety of techniques utilised to design the PCB, through hole components for connectorised components for longevity of the board through multiple uses, multiple layers to separate power and signals track as well as components, and the use of vias to route tracks between layers to service surface mount components. A description of the PCBs function has been written onto the top copper to ensure it can be correctly identified and a description of the function of the top and bottom layers has been added in copper to the respective sides of the PCB.

PCB Top Layer

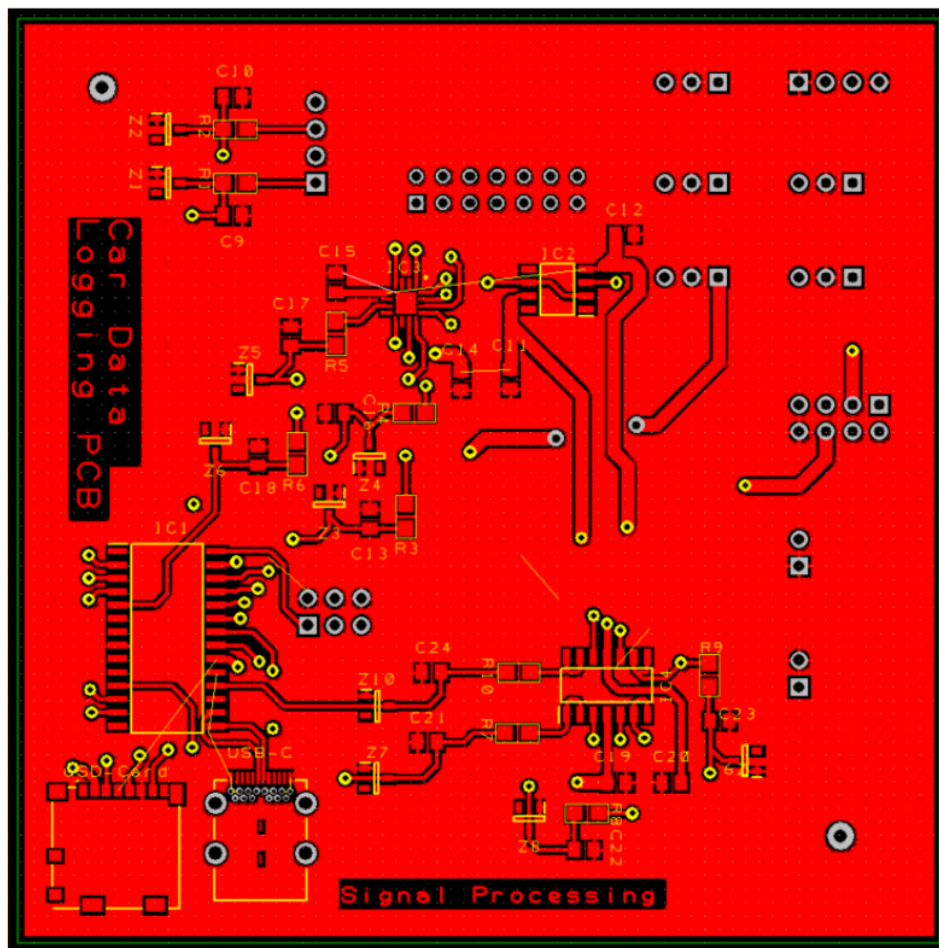


Figure 7 – PCB Top Layer Top Copper

PCB Inner Layers

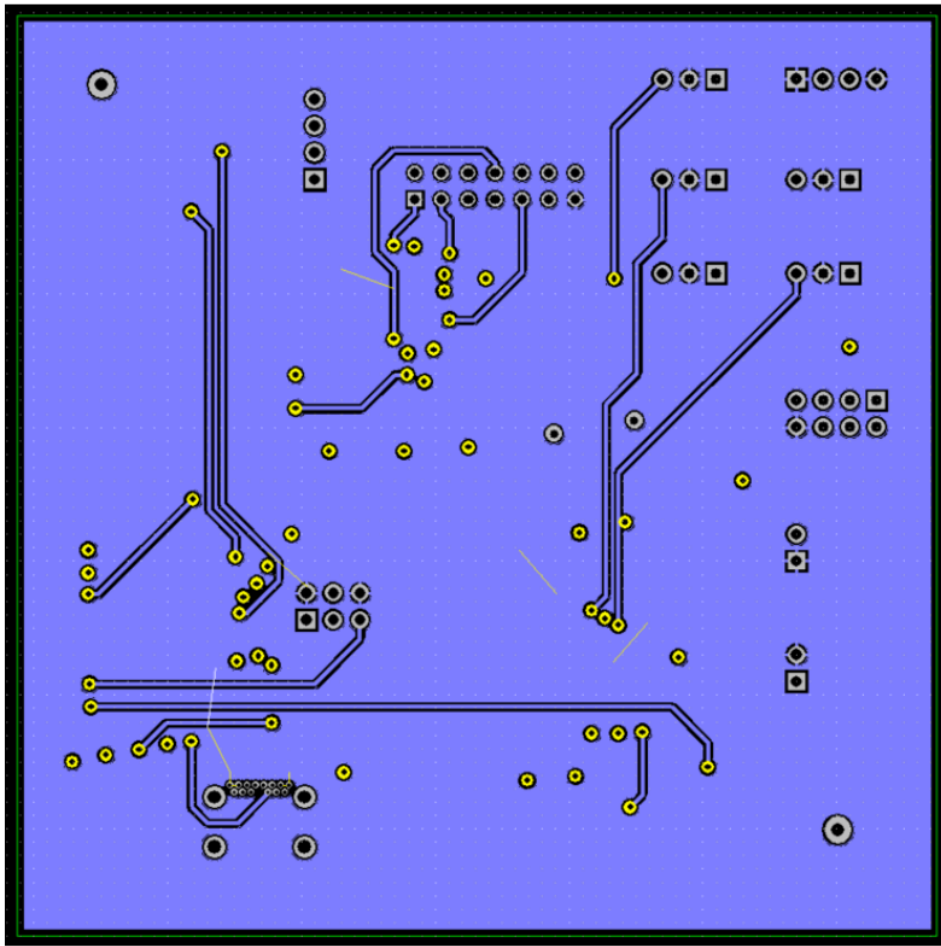


Figure 8 – PCB Inner Layer Signal 1

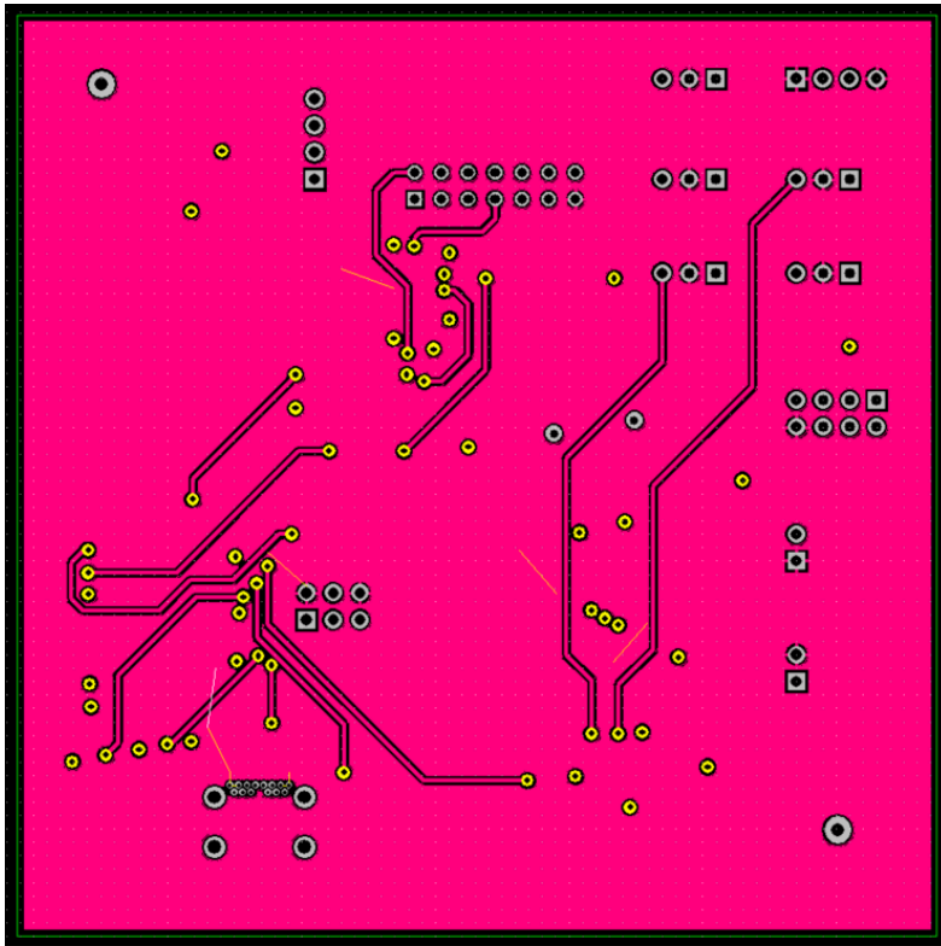


Figure 9 – PCB Inner Layer Signal 2

PCB Bottom Layer

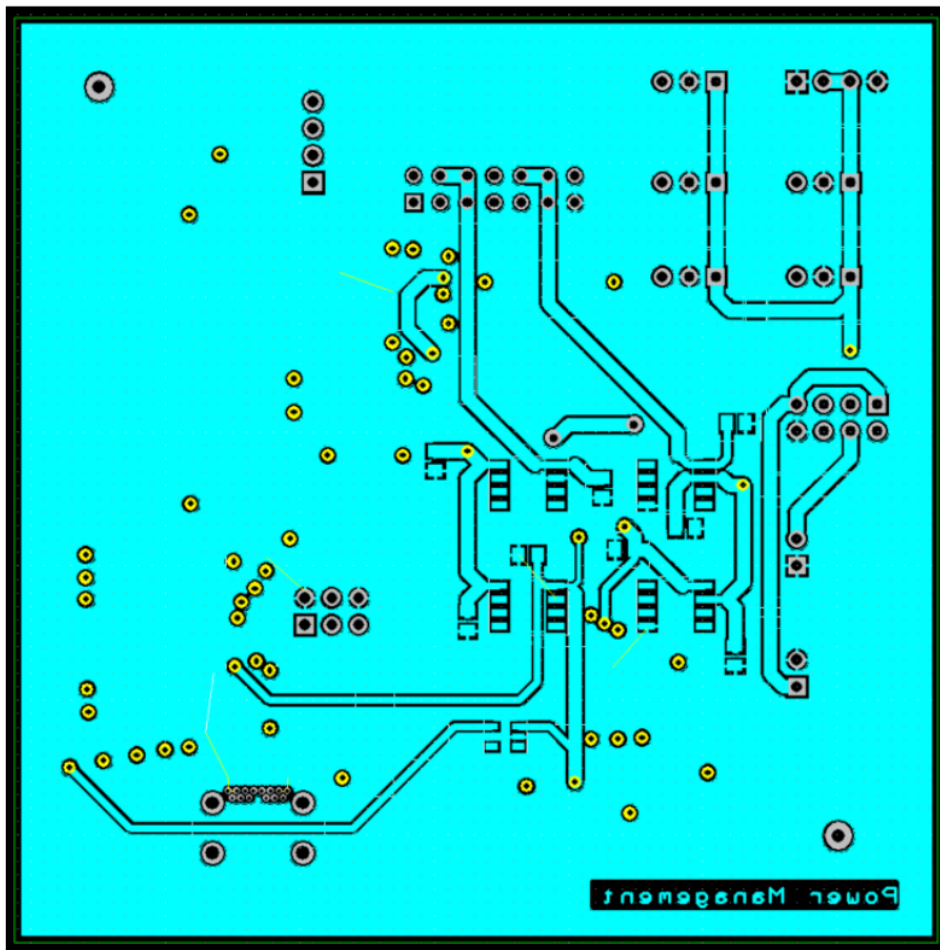


Figure 10 – PCB Bottom Layer Bottom Copper

Software Design and Structure

Software Structure

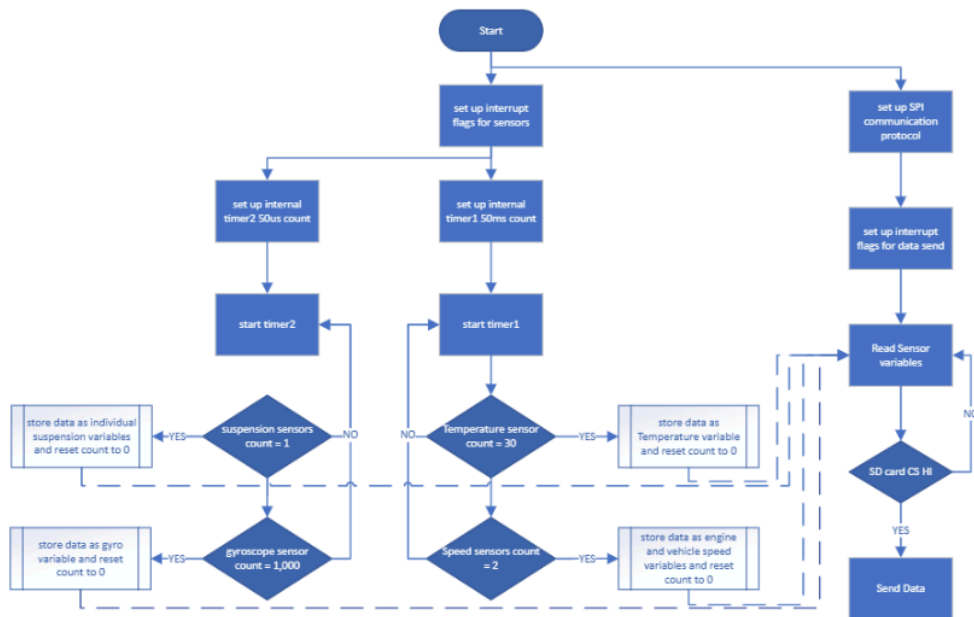


Figure 11 – Code Structure Flowchart

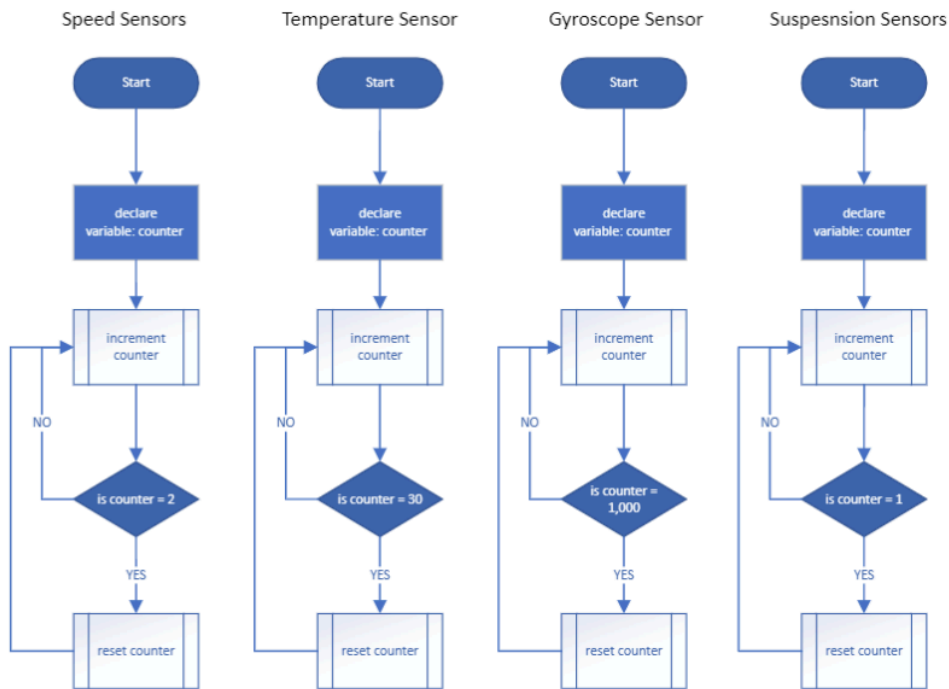


Figure 12 – Counter Flowchart

Data Structure

Suspension								Gyro			Temp	MPH	RFM	Delimiter
Susp1	Susp2	Susp3	Susp4	Pitch	Roll	Yaw		Temp	MPH	RFM				FF
1Byte	1Byte	1Byte	1Byte	1Byte	1Byte	1Byte	1Byte	1Byte	1Byte	1Byte	1Byte	1Byte	1Byte	1Byte
14Bytes														1Byte
15Byte Data Package														

Figure 13 – Data Structure

System Build Costs

Table 3 is a compiled Bill of Materials for the full system build; this includes all the measurement sensors, enclosure and PCB connectors, components, and any ancillary equipment required to setup and operate the system – including USB interconnection cables, data storage microSD card, and any wire, nuts, bolts, and washers required.

Bill of Materials

	Item Description	Quantity	Manufacturer	Manufacturer P/N	Supplier	Supplier P/N	Unit Price	Cost
Sensors	Photoelectric retro-reflective sensor	2	SICK Sensor Intelligence	GL6G-F2411V	RS Components	205-4961	£136.22	£272.44
	Infrared Non-Contact Temperature sensor	1	2D Debus & Diebold Meßsysteme GmbH	SA-IR200V6-007	Dantron Technology	SA-IR200V6-007	£388.08	£388.08
	String Potentiometer	4	TE Connectivity	SG1-120-2	Mouser Electronics	824-SG1-120-2	£435.66	£1,742.64
Enclosure	TE Connectivity 6 DOF SENSOR 633	1	TE Connectivity	633-050-500-120	Mouser Electronics	10203887-00	£3,659.00	£3,659.00
	Eaton (Souriau) Free Plug/Cable Mount Motorsport Circular Connector, Shell Size 02, 3 Way, Female/Socket, Crimp Contacts , Orientation E	1	Eaton Souriau	85TA6-02-35SE	Lane Electronics	85TA60235SE	£46.99	£46.99
	Deutsch DT Automotive Connector Socket 12 Way	2	Deutsch Connectors	DT04-12PA-L012	RS Components	183-9206	£8.39	£16.78
	Deutsch DT Automotive Connector Plug 12 Way	2	Deutsch Connectors	DT06-12SA-C015	RS Components	183-9138	£5.67	£11.34
	Deutsch DT Automotive Connector Plug 3 Way	5	Deutsch Connectors	DT04-3P-CL06	RS Components	425-755	£8.75	£43.75
	Deutsch DT Automotive Connector Socket 3 Way	5	Deutsch Connectors	DT04-3P-P006	RS Components	183-9160	£10.39	£51.95
	Amphenol Socapex Straight, Panel Mount, Socket Type A 2.0 IP68 USB Connector	1	Amphenol Socapex	USBFTV21N	RS Components	536-9281	£64.90	£64.90
	Amphenol Socapex Connector Seal Gasket	1	Amphenol Socapex	JE15	RS Components	536-9354	£5.09	£5.09
	Amphenol Socapex, USBF TV Dust Cap for use with USBFTV Square Flange Receptacles	1	Amphenol Socapex	USBF TVC 2 N	RS Components	536-9297	£40.69	£40.69
	RS PRO USB 2.0 Cable, Male USB A to Male USB A Cable, 1m	1	RS PRO	182-8482	RS Components	182-8482	£3.24	£3.24
PCB Connectors	Molex C-Grid III Series Straight Through Hole PCB Header, 2 Contact(s), 2.54mm Pitch, 1 Row(s), Shrouded	2	Molex	90136-1202	RS Components	360-6601	£1.39	£2.78
	Molex, C-Grid III Female Connector Housing, 2.54mm Pitch, 2 Way, 1 Row	2	Molex	90156-0142	RS Components	360-6077	£0.54	£1.08
	Molex C-Grid III Series Female Crimp Terminal, 24AWG Min, 22AWG Max	32	Molex	90119-0109	RS Components	666-1086	£0.06	£1.92
	Molex SL Series Straight Through Hole PCB Header, 4 Contact(s), 2.54mm Pitch, 1 Row(s), Shrouded	2	Molex	70543-0003	RS Components	679-2471	£1.18	£2.36
	Molex, SL Female Crimp Connector Housing, 2.54mm Pitch, 4 Way, 1 Row	2	Molex	50-57-9404	RS Components	678-3161	£0.25	£0.50
	Molex SL Series Female Crimp Terminal, 24AWG Min, 22AWG Max	8	Molex	16-02-0102	RS Components	679-4742	£0.24	£1.92

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	Molex SL Series Straight Through Hole PCB Header, 3 Contact(s), 2.54mm Pitch, 1 Row(s), Shrouded	5	Molex	70543-0002	RS Components	679-2477	£1.04	£5.20
	Molex, SL Female Connector Housing, 2.54mm Pitch, 3 Way, 1 Row	5	Molex	50-57-9403	RS Components	678-3152	£0.23	£1.15
	Molex SL Series Female Crimp Terminal, 24AWG Min, 22AWG Max	15	Molex	16-02-0102	RS Components	679-4742	£0.12	£1.80
	Molex C-Grid III Series Right Angle Through Hole PCB Header, 14 Contact(s), 2.54mm Pitch, 2 Row(s), Shrouded	1	Molex	90130-3114	RS Components	670-3364	£2.48	£2.48
	Molex, C-Grid III Female Connector Housing, 2.54mm Pitch, 14 Way, 2 Row	1	Molex	90142-0014	RS Components	468-1287	£1.30	£1.30
	Molex C-Grid III Series Straight Through Hole PCB Header, 6 Contact(s), 2.54mm Pitch, 2 Row(s), Shrouded	1	Molex	90130-1206	RS Components	170-7067	£1.00	£1.00
	Molex, C-Grid III Female Connector Housing, 2.54mm Pitch, 6 Way, 2 Row	1	Molex	90142-0006	RS Components	360-6178	£0.73	£0.73
	Molex C-Grid III Series Straight Through Hole PCB Header, 8 Contact(s), 2.54mm Pitch, 2 Row(s), Shrouded	1	Molex	90130-1208	RS Components	189-1411	£1.43	£1.43
	Molex, C-Grid III Female Connector Housing, 2.54mm Pitch, 8 Way, 2 Row	1	Molex	90142-0008	RS Components	360-6235	£1.51	£1.51
	TE Connectivity Illuminated Push Button Switch, Momentary, Panel Mount, 19.2mm Cutout, SPST, Red LED, 250V ac, IP67	1	TE Connectivity	AV1910R312Q04	RS Components	163-9194	£18.93	£18.93
ICs	TE Connectivity Illuminated Push Button Switch, Latching, Panel Mount, 19.2mm Cutout, DPDT, Green LED, 250V ac, IP67	1	TE Connectivity	AV1921P624Q04	RS Components	163-9244	£16.49	£16.49
	8-bit Microcontrollers - MCU 16 KB Flash RAM, 48 MHz Int.	1	Microchip Technology	PIC18F24K50-I/SO	Mouser	579-PIC18F24K50-I/SO	£2.37	£2.37
	Linear Voltage Regulator IC Positive Fixed 1 Output 100mA 8-SOIC	2	Texas Instruments	LM78L05ACMX/NOPB	Digikey	LM78L05ACMX/NOPB-BTR-ND	£0.58	£1.16
	Linear Voltage Regulator IC Negative Fixed 1 Output 100mA 8-SOIC	2	Texas Instruments	LM79L05ACMX/NOPB	Digikey	296-LM79L05ACMX/NOPB-BTR-ND	£0.65	£1.30
	Precision Amplifiers LOW-NOISE PRECISION OP AMP	1	Analog Devices	OP27EPZ	Mouser	584-OP27EPZ	£8.11	£8.11
	Instrumentation Amplifiers Dual Precision InAmp	1	Analog Devices	AD8295ACPZ-WP	Mouser	584-AD8295ACPZ-WP	£7.03	£7.03
	IC OPAMP GP 4 CIRCUIT 14SO	1	STMicroelectronics	LM324AD	Digikey	497-18635-ND	£2.68	£2.68
	Linear Voltage Regulators 300mA LDO 3.3Vout	1	Analog Devices	ADP122AUJZ-3.3-R7	Mouser	584-ADP122AUJZ-3.3R7	£0.99	£0.99
	Zener Diode 5 V 250 mW ±4% Surface Mount TO-236AB	10	Nexperia USA Inc.	PLVA650A,215	Digikey	1727-5167-2-ND	£0.35	£3.50
	10 (8 + 2) Position Card Connector Secure Digital - microSD™ Surface Mount, Right Angle Gold	1	Molex	104031-0811	Digikey	104031-0811	£1.77	£1.77
	USB Connectors WR-COM USB3.1 Type C SuperSpeed+ Rcpt	1	Würth Electronic	6.32723E+11	Mouser	710-632723100021	£2.97	£2.97
	KEMET 100nF Multilayer Ceramic Capacitor MLCC, 16V dc V, ±10%, SMD	22	Kemet	C0805C104K4RACTU	RS Components	170-0304	£0.03	£0.66
	KYOCERA AVX 330nF Multilayer Ceramic Capacitor MLCC, 16V dc V, ±10%, SMD	2	KYOCERA AVX	0805YC334KAT2A	RS Components	124-3304	£0.50	£1.00
	Panasonic 20X, 0805 (2012M) Thick Film SMD Resistor ±1% 0.5W - ERJP06F20R0V	10	Panasonic	ERJP06F20R0V	RS Components	721-7615	£0.17	£1.70
	RS PRO Grey Polycarbonate Enclosure, IP67, IK07, Grey Lid, 119.8 x 119.8 x 60.1mm	1	RS PRO	186-2279	RS Components	186-2279	£25.12	£25.12
	Kingston SDCS2/64GB Canvas Select Plus microSD Card With Adaptor 64GB	1	Kingston	SDCS2/64GB	Rapid Electronics	19-7952	£6.98	£6.98
	RS PRO RS PRO, 12V, 2/3 A, NiCd Rechargeable Battery, 650mAh	2	RS PRO	246-6440	RS Components	246-6440	£53.41	£106.82
	Alpha Wire Multicore Data Cable, 0.35 mm², 3 Cores, 22 AWG, Unscreened, 30m, Grey Sheath	1	Alpha Wire	1173L SL005	RS Components	673-3232	£47.83	£47.83

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2111738

Holo-Krome Black, Self-Colour Steel Hex Socket Cap Screw, DIN 912, M3 x 10mm (box of 100)	1	Holo-Krome	HK76016	RS Components	376-4628	£25.85	£25.85
RS PRO, Bright Zinc Plated Steel Lock Nut, DIN 985, M3 (box of 100)	1	RS Pro	524-281	RS Components	524-281	£5.57	£5.57
A4 316 Stainless Steel Plain Washers, M3, DIN 125A (box of 100)	1	RS Pro	189-620	RS Components	189-620	£5.32	£5.32
RS PRO Standoff, M3 x M3 Thread, 21mm Body, Stainless Steel, Male/Female, 21mm Stud (pack of 10)	1	RS Pro	224-0473	RS Components	224-0473	£2.18	£2.18
Roline USB 3.2 Cable, Male USB A to Male USB C Cable, 110mm	1	Roline	11.02.9014-10	RS Components	266-0497	£10.64	£10.64
Total						£10.64	£6,672.56

Table 3 - Bill of Materials for complete system build

PCB Manufacture

Figure 14 below provides a rough guideline for the expected manufacturing cost of the designed PCB based on the board material, size, use case, and quantity. The costs are produced based on the processes required to deliver the PCB this is because some manufacturing processes will cost more to perform, take longer, or require more materials to complete. As a comparison Figures 15 and 16 show the guide costs of PCB fabrication and stencil production of a different PCB manufacturing firm, this is to show the difference in costs of different PCB manufacturers. Figure 14 shows the PCB manufacturing and delivery costs separately whereas Figure 15 shows the total cost of manufacture and delivery.

Standard PCB/PCBA

Advanced PCB/PCBA

3D Printing/CNC

SMT-Stencil

GBP

Order now

My file

Sign in

0

Back to Upload File

Gerber Viewer

Detected 4 layer board of 87.38x87.25mm(3.44x3.44 inches).

Base Material

FR-4

Flex

Aluminum

Copper Core

Rogers

PTFE Teflon

Layers

124

High Precision PCB

6

8

10

12

14

16

18

20

Dimensions

87.25

*

87.38

mm

PCB Qty

5

Product Type

Industrial/Consumer electronics

Aerospace

Medical

Charge Details

Special Offer£5.45

Via Covering£0.00

Surface Finish£3.82

Stencil£5.45

Build Time

PCB: 3-4 days£0.00

3 daysPCBA Only£0.00

2-3 days£48.99

Calculated Price

Additional charges may apply for special cases

£14.72

SAVE TO CART

Shipping Estimate

DHL Express Worldwide£26.32

2-4 business days

Weight1.09kg

Coupons

Save \$20

Figure 14 - PCB Manufacturing Cost Guide

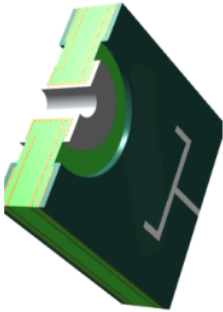
PCB Fabrication

Quantity, Price & Delivery

Quote Information

Data File

Your order details



4 layer FR4 (150 deg C) middle Tg 1.6mm IS Green White

Product Family4 layer

ServiceStandard

Copper WeightMore

35

Quantity1

Update / Reset Price

Supply in panels?No

Show Lot Price

Show Unit Price

W/Days	1	5	10	20	50	100	500
3	£ 251.92	£ 367.95	£ 513.00	£ 716.20	Submit RFQ	Submit RFQ	Submit RFQ
4	£ 199.50	£ 298.95	£ 423.30	£ 597.60	£ 927.00	Submit RFQ	Submit RFQ
5	£ 137.08	£ 219.95	£ 323.60	£ 468.80	£ 743.00	Submit RFQ	Submit RFQ
7	£ 126.12	£ 202.35	£ 297.70	£ 431.20	£ 684.00	Submit RFQ	Submit RFQ
10	£ 109.67	£ 176.00	£ 258.90	£ 375.00	£ 594.50	£ 1064.00	Submit RFQ
15	£ 82.25	£ 132.00	£ 194.20	£ 281.20	£ 446.00	£ 798.00	Submit RFQ
20	£ 76.77	£ 123.20	£ 181.20	£ 262.60	£ 416.00	£ 745.00	£ 2145.00
25	£ 71.28	£ 114.40	£ 168.30	£ 243.80	£ 386.50	£ 692.00	£ 1990.00
30	£ 69.09	£ 110.85	£ 163.10	£ 236.20	£ 374.50	£ 670.00	£ 1930.00
35	£ 66.90	£ 107.35	£ 157.90	£ 228.80	£ 362.50	£ 649.00	£ 1870.00

Figure 15 – PCB Fabrication Cost Guide

PCB Stencil Service

PCB Stencil

Quantity, Price & Delivery

Quote Information

Data File

Your order details

PCB Stencil

Quantity
1

W/Days	Price
1/2	£ 75.65
1	£ 50.43

Back

Next

Note : if a paste layer is supplied then the apertures will be cut 1:1, if not then we will apply our standard 5% reduction to the apertures and modify the edges

Figure 16 – PCB Stencil Cost Guide

System Improvements

Listed below are some areas that should be addressed for a future system redesign as these points would all improve the system functionality and usability.

- Screening / Shielding

Ensuring all cables from the sensors are shielded will help to ensure the integrity of the signals being transmitted as they would not experience interference from external sources, using an RF screens enclosure would also increase the EMI resistance of the system ensuring the PCB and components are isolated and remain unaffected by external interference while being conditioned and processed.

- Variety of Connectors

To ensure sensors cannot be plugged into the wrong connectors a range of different connector types, shapes, and series – this applies to both the enclosure and PCB connectors. By having the different connectors there is only one very clear way of setting up the system as each connector has an obvious one to one connection as there would be no possible other connection options. The would be most applicable to the three pin connectors on the enclosure for the wire potentiometers and the temperature sensor and the speed sensor PCB header pins as these are clear examples of connectors that could be misconnected with the possibility of the speed connector becoming damaged by this misunderstanding.

- Single Supply Voltage

A single supply voltage system would cost less to produce as it would not require two batteries and as such would also be smaller and lighter to mount. By eliminating the need for a negative voltage supply the PCB size and cost can be reduced by removing the negative voltage regulators the design meaning the parts cost and the PCB manufacture cost is cheaper as there are less components necessary to build the system and the manufacturing processes are reduced with the size reduction.

- Operational Amplifier Considerations

Consideration needs to be made to the use of the selected operational amplifiers. For instance, the selected operational amplifiers may not be operating as effectively and efficiently as possible to best condition the signals provided. An increased bandwidth or slew rate may be required to improve the signal conditioning and the multi-channel operational amplifiers may experience cross talk or thermal effects while operating which could degrade the signals. Multi-channel amplifiers also suffer from PCB layout and track spacing concerns due to the number of tracks and components that could be required to perform the signal conditioning.

- Gyroscope

The chosen gyroscope sensor is a rate and acceleration sensor, this combined sensor allows for 6-axis measurement of motion therefore the system could be developed further and greatly improved by utilising this capability – allowing for more data to be gathered during the test. The functionality for the gyroscope is partly designed into the system with the two enclosure connectors for the gyroscope, however the PCB only has one connector for the gyroscope as such a second connector would be added to the board along with a second 3 channel operational amplifier and accompanying clamp circuits. With slight modification the system would then be capable of gathering more data during the test to aid in producing a clearer portrayal of what is happening to the vehicle during the test.

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Appendix I

Data Sheets of selected IC components

[LM78L05ACMX_NOPB](#)

[LM79L05ACMX_NOPB](#)

[ADP122AUJZ-3.3-R7](#)

[OP27GSZ-REEL7](#)

[AD8295ACPZ-WP](#)

[LM324AD](#)

[PIC18F24K50-I_SO](#)

Data Sheets of selected measurement sensors

[GL6G-F2411V](#)

[SA-IR200V6-0077](#)

[SG1-120-2](#)

[Model 633-050-500-120](#)

Appendix II

All other measurement sensor data sheets

Speed Sensors

[GL6-P4211](#)

[SD-VOP02-000](#)

[MiniVLS 111](#)

Temperature Sensors

[SA-TK02-000-DINA4](#)

[SA-WPxxxxHQ-000](#)

[SA-WP0038HQ-000](#)

[SP2-50](#)

[SG1-80-2](#)

Gyroscope

[ADXL354/ADXL355](#)

[XV- 8100CB](#)

JHeeks ACDA6002 Assignment 1

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

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GRADING FORM: SMU GENERIC_GJ

JACK HEEKS

74

RESEARCH-INFORMED LITERATURE



Good literature review of available systems with a fairly good comparison table of relevant information.67%

6.7

KNOWLEDGE AND UNDERSTANDING



Your schematic diagram is good but there are a couple of issues. The 7805 regulators need a tank capacitor of about 10uf in addition to the 100nf caps you have. Your PCB has been routed but there are many errors, you need to use the PCB checking tools.. A very good attempt 78%

19.5

ANALYSIS



Good selection of microcontroller, questionable selection of the enclosure as there does not appear to be sufficient room for the battery and no protected place for the bulkhead connectors. Good selection of sensors and given the nature of suspension reading and the high likelihood of wet an IP rating of 67 is sufficient. A 100nf cap should be placed between the power lines as close to the microcontroller as possible. Your connectors are reasonable .70%

24.5

PRACTICAL APPLICATION AND DEP.



your costings are nicely tabulated and carry supplier and part numbers. Good attempt at future enhancements. 78%

15.6

SKILLS FOR PROFESSIONAL PRAC.



The report is well presented with some good explanations of choices and images. Excellent selection of references. 77%

7.7