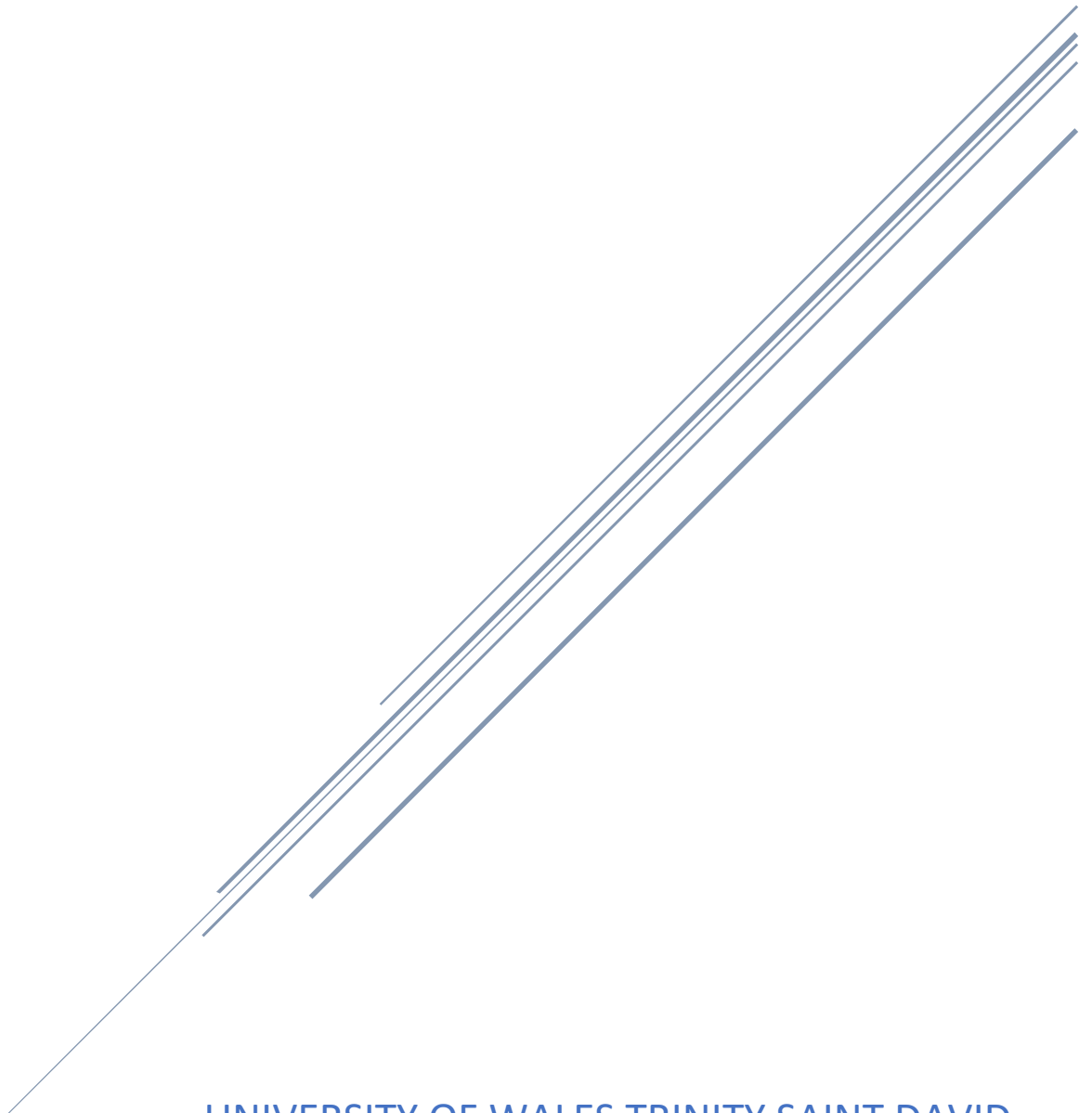


MOTOR VEHICLE DATA LOGGER

ASSIGNMENT 1

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ELECTRONIC SYSTEM DESIGN – ACDA6002

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1 ABSTRACT

This report shows the process taken to design a custom data acquisition system required for gathering metrics during a 2-hour saloon car test drive. Research into relevant technologies is shown and a full system is described in the report as well as supplementary documents. A PCB design was also completed as part of the design.

2 DESIGN BRIEF

The design brief is as follows:

“design a microcontroller based automotive data acquisition system.”

“The data acquisition system is intended to be fitted to a production prototype car. In this case, the vehicle is targeted for the family saloon market, however the system must be re-usable, portable and adaptable for any class of vehicle.

The data will be gathered to establish that the vehicle design both operates within safe limits and provides a comfortable means of transport. The following data will be acquired during a 2 hour test track run:

- *Engine RPM*
- *Engine Temperature*
- *Front and rear suspension travel*
- *Pitch, roll and yaw*
- *Vehicle road speed (MPH)*

The system must:

- *Store the collected data to non-volatile memory which can be externally read and cleared when connected to a computer via USB*
- *Be battery powered so that it is independent of the subject vehicle’s power supply. None of the sensors are allowed to be connected to the vehicle’s electronics or signals.*

Ensure that your design is portable, adaptable, and suitable for operation in its intended environment.

You must ensure that adequately sized variables are used for each parameter measured.”

3 RESEARCH

3.1 DATA ACQUISITION SYSTEMS

Data acquisition systems (DAS) for motor cars provide a way for developers to log and analyze important data over time related to sensors within a system. In motor car DAS systems, this could be suspension displacement readings for example. The developer could use the data to review how their car is performing and identify and potential issues.

A DAS system is comprised of some common parts. Firstly, there is the logging unit, which contains the main control circuit that all sensors are connected to. This will be housed within an enclosure that can be fitted within the car. It must also be robust enough to survive the cars environment (high IP rating for example). The sensors within the DAS are another key part and are responsible for taking measurements. Another common feature within DAS systems are displays, which allow users to easily get feedback from the device [1].

3.2 EXISTING DAS SYSTEMS

The table below shows 2 existing car DAS systems that are currently available.

PRODUCT NAME	LG-L9-000	GRANITE 10
IMAGE		
KEY FEATURES	4 CAN LINES, 1 USB, 1 RS232, GPS INPUT, ETHERNET, CAN DAIST CHAIN WITH SAME MODULE TO INCREASE ADC CHANNELS	CAN FD, CAN, ETHERNET, USB MICRO B, USB HOST, CS I/O, 0 to 5 V serial, SDI-12, RS-485, RS-422, CPI/RS-232, EPI
ANALOG INPUT	32 CHANNELS	0, ANALOG INPUT MODULES CAN BE ADDED TO SYSTEM, SUCH AS THE CDM-A108 [2].
DIGITAL I/O	4	8
IP	67	EXTERNAL CASE REQUIRED
MEMORY	8GB ON BOARD	MICRO SD SOCKET
REFERENCE	[3]	[4]

Table 1 – EXISTING DAS SYSTEMS

3.3 ENGINE RPM AND SPEED MEASUREMENT

To determine the range of engine RPM that would be required for the project, some example saloon cars were reviewed.

CAR NAME	Audi A6 (2018) manual	Mercedes-Benz S-Class (2012) manual	Skoda Octavia (2014) manual
IMAGE			
MIN SPEEDOMETER MEASUREMENT	0	0	0
MAX SPEEDOMETER MEASUREMENT	180	160	240
MIN TACHOMETER MEASUREMENT	0	0	0
MAX TACHOMETER MEASUREMENT	8000	7000	8000
REFERENCE	[5]	[6]	[7]

Table 2 – SALOON CAR ENGINE RPM AND SPEED REVIEW

The values shown in Table 2 will be used to determine the suitability of speed and RPM sensors to be used in the project.

Both the RPM and speed of the car are measurements that can be determined by the rotational speed of specific parts of the car (wheels for example). Each will require a sensor mounted within the car to determine to rotational speed of the wheel (speed) and the rotation of components within the engine.

One of the most common ways to measure rotational speed it to use a tachometer. Most tachometers will generate 1 voltage pulse for a single revolution of the shaft being measured. The frequency of pulses can be used to determine the speed of the shaft being measured [8].

PRODUCT NAME	DIGITEN 4	MP780522	MM-0024
IMAGE			
MEASURE TYPE	MAGNETIC	PHOTOELECTRIC	PHOTOELECTRIC
UPPER RPM	9999	99999	20000
COST	£16.99	£39.94	NOT AVAILABLE
REFERENCE	[9]	[10]	[11]

Table 3 – TACHOMETER COMPARISON TABLE

All products shown would be capable of measuring the required RPMs of the car however some are more suitable than others. The MP780522 was deemed unsuitable due to the inability to connect it to external hardware. The MM-0024 was selected for the project as it could be mounted a distance away from the rotating parts. It also has good documentation on how to use it. A reflective strip will need to be installed on the rotating part for it to work.

3.4 ENGINE TEMPERATURE MEASUREMENT

Correct engine operating temperature is usually defined between 90 -105°C [12]. The sensor for the project must be able to detect temperatures within this range. Some potential sensors can be seen in Table 4.

PRODUCT NAME	101020993	TSMAGK00002M0AA7	RS PRO PT100 RTD Sensor
IMAGE			
MEASURE TYPE	IR ARRAY	THERMOCOUPLE – TYPE K – CLASS 1	RTD
MEASURE RANGE	-20 - 300°C	0 - 1100°C	-50 - 150°C
ACCURACY	±1°C	±1.5°C	±1.3°C AT 200°C,
COST	£32.64	£51	£54.92
REFERENCE	[13]	[14] [15]	[16]

Table 4 – TEMPERATURES SENSOR COMPARISON TABLE

The TSMAGK00002M0AA7 was selected as the temperature sensor for this project as it can take readings within the required range. It also has a convenient mount which allows it to be places on chassis of the engine easily.

3.5 SUSPENSION DISPLACEMENT MEASUREMENT

A cars suspension will deflect when the wheels encounter a raised obstacle. Some examples recordings show the displacement reached 40mm on the front suspension. This can be seen in Figure 1, which shows the displacement when a test car drove over a speed bump at 15km/h [17].

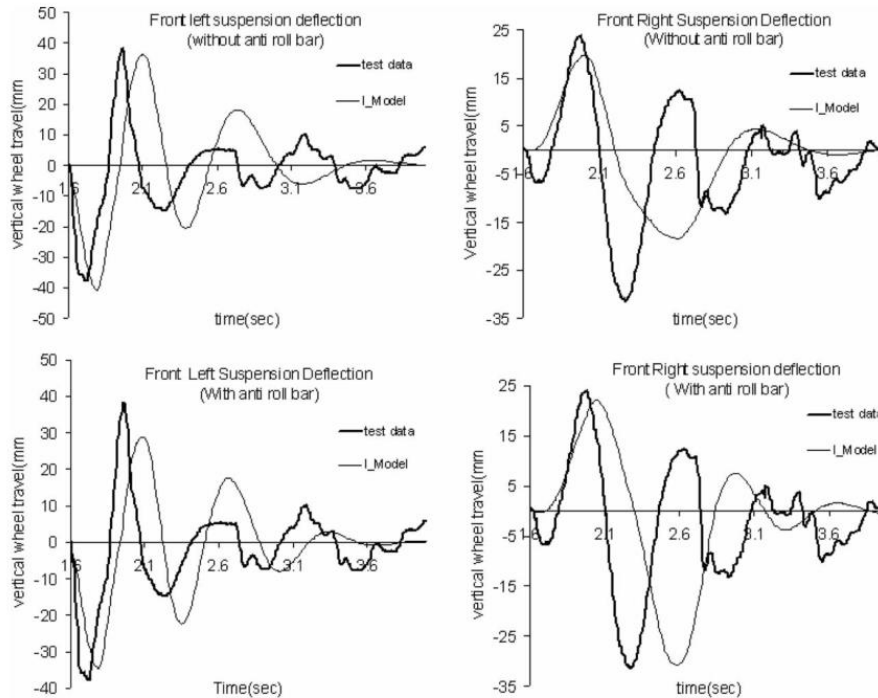


Figure 1 – EXAMPLE SUSPENSION DEFLECTION [17]

The measurement devices for the test car must therefore be capable of detecting deflections near these values. However, the displacement in the test car may potentially be greater as the speed will be higher and therefore the force of any impact.

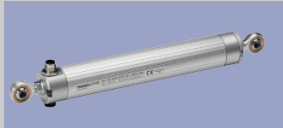
	PRODUCT NAME	LWX-0300-003-101	AML/SGDA	optoNCDT
IMAGE				
MEASURE TYPE		VARIABLE RESISTANCE	LVDT	LASER REFLECTION
MAX DISPLACEMENT		300mm	100mm	500mm
MEASUREMENT				
IP RATING		67	54	65
COST		£958.80	532	NOT AVAILABLE
REFERENCE		[18]	[19]	[20]

Table 5 – LINEAR DISPLACEMENT SENSOR COMPARISON

3.5.1 PITCH ROLL AND YAW MEASUREMENT

Pitch roll and yaw are the rotation in the x, y and z axis with its origin as the center of gravity. This is shown in Figure 2 [21].

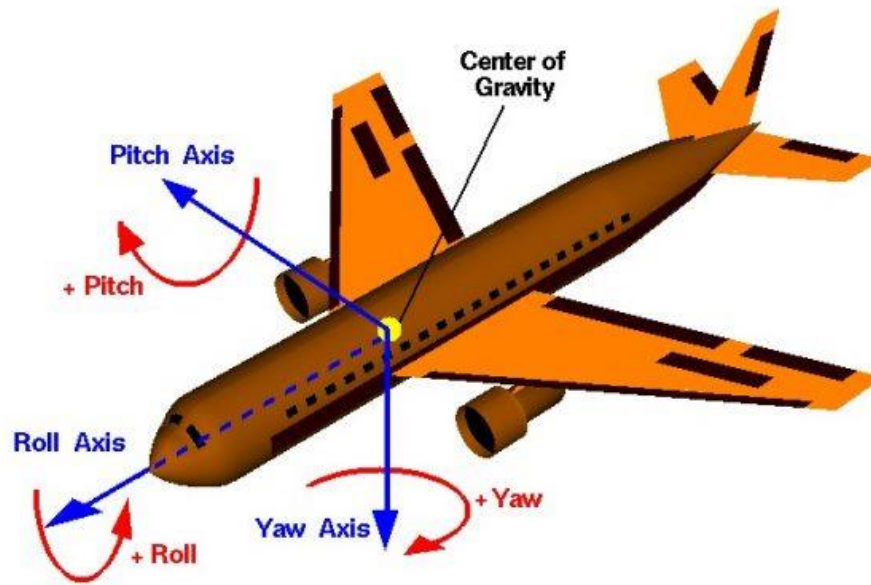


Figure 2 – Pitch, roll and yaw example [21]

To measure the pitch, roll and yaw of the saloon car during the test, a combination of accelerometers and gyroscopes can be used, one for each of the x axis.

An accelerometer is used to measure the acceleration in a specific direction. A gyroscope measures the angular velocity of an axis [22]. Each gyroscope and accelerometer value can be used to detect the change in pitch, roll and yaw.

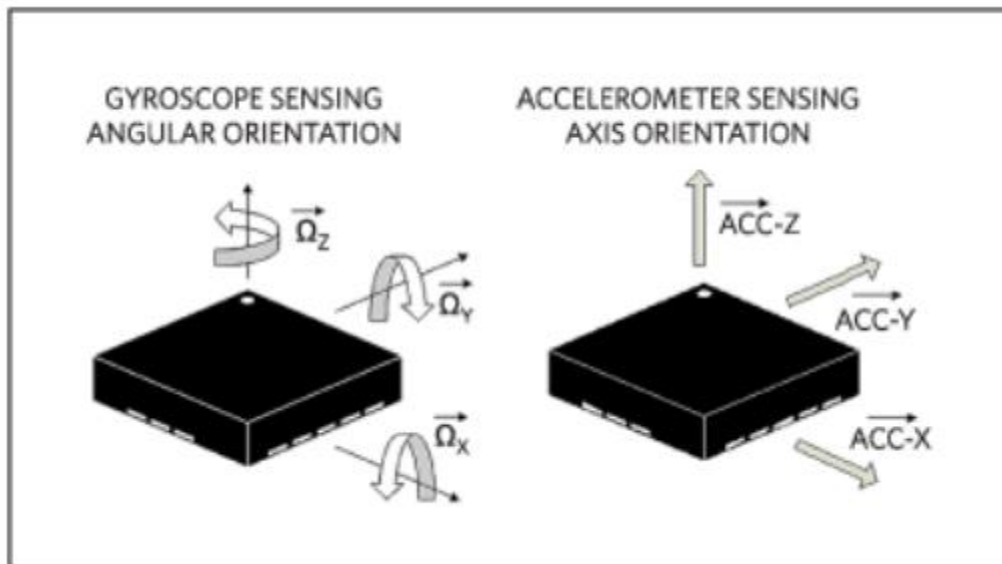


Figure 3 - Angular versus linear motion [22]

PRODUCT NAME	ICM-42688-P	MPU-6050 MODULE	ADIS16364BMLZ
IMAGE			
MEASURE TYPE	MEMS	MEMS	MEMS
FEATURES	3 AXIS ACCELEROMETER, 3 AXIS GYROSCOPE	3 AXIS ACCELEROMETER, 3 AXIS GYROSCOPE	3 AXIS ACCELEROMETER, 3 AXIS GYROSCOPE, 2000 G SHOCK SURVIVABILITY,
COMMUNICATION INTERFACE	I2C	I2C	SPI
COST	£5.50	£8.59	£509.06
REFERENCE	[23]	[24]	[25] [26]

Table 6 - PITCH ROLL AND YAW SENSOR COMPARISON

The ICM-42688-P was selected as sensor used to determine the pitch, roll and yaw of the car during the test.

4 LOG DATA REQUIREMENTS REVIEW

Table 7 shows the required measurement ranges of all sensors and data for the test drive. This data can then be used to determine a suitable PIC microcontroller. It can also be used to calculate the required memory size to store all readings. A 100Hz sample rate selected for the project.

Measurement	Type of signal	Minimum Value	Maximum Value	Resolution	Number of possible values	No of bits required	No of bytes	sample rate
Engine Temperature	Analog	50	150	1 degree	200	8	1	100 Hz
Suspension Travel (Front Left)	Analog	0	300mm (+/- 150mm)	1mm	300	9	2	100 Hz
Suspension Travel (Front Right)	Analog	0	300mm (+/- 150mm)	1mm	300	9	2	100 Hz
Suspension Travel (Rear Left)	Analog	0	300mm (+/- 150mm)	1mm	300	9	2	100 Hz
Suspension Travel (Rear Right)	Analog	0	300mm (+/- 150mm)	1mm	300	9	2	100 Hz
Engine RPM	Digital	0	10000	10 revolutions	1000	10	2	100 Hz
Pitch	Digital (i2c)	-45	45	1 degree	90	32 bits (length of measured word of selected gyro and accelerometer reading, 16 bits each)	2	100 Hz
Roll	Digital (i2c)	-45	45	1 degree	90	32	4	100 Hz
Yaw	Digital (i2c)	0	360	1 degree	360	32	4	100 Hz
Vehicle road speed	Digital	0	300	1mph	300	9	2	100 Hz
Timestamp	from PIC*	na	na	na		16 (from datasheet)	2	100 Hz

Table 7 – LOG DATA SPECIFICATION

*timestamp data was added after pic selection

From the data in the table above, it would require 18Mb non-volatile memory to store all readings over 2 hours*. One potential implementation could be the use of a mico SD card for the data logger. They can easily store data of this size for relatively cheap [27].

*calculation in appendices section 11.1.

5 MICROCONTROLLER SELECTION

Table 8 shows a comparison between 3 8-bit microcontrollers that are available to purchase. The PIC10F220 is unsuitable for this project as it does not have a USB interface.

The PIC18F46J50 was selected as it met all analog and digital input requirements. It also has built-in real-time clock which can be very useful as it can be used to timestamp all sensor readings during the test drive. It also has 2 channels for SPI and I2C, which increases the types of ICs that can be connected at once. The PIC18F2553 has SPI and I2C options however they share the same pins, so it is not possible to have both interfaces without additional hardware.

Chip Name	PIC18F2553	PIC18F46J50	PIC10F220
Family	8-bit MCU	8-bit MCU	8-bit MCU
CPU Type	8-bit PIC MCU	8-bit PIC MCU	8-bit PIC MCU
Max CPU Speed (MHz)	48 MHz	48 MHz	8 MHz
FPU			
Operation Voltage	(2V-5.5V)	(2V-3.6V)	(2V-5.5V)
Temp Range	(-40 to +85)	(-40 to +85)	(-40 to +125)
Pin Count	28	44	6
Program Memory Size (KB)	32	64	0.375
Error Correction Code Program Flash			
SRAM	2 KB	3.7109375 KB	16 Bytes
Data EEPROM/HEF (Bytes)	256		
Internal DRAM Type			
Internal DRAM Amount (MB)			
Low Power		Yes	
ADC Input	10	13	2
Max ADC Resolution (Bits)	12	10	8
DAC Outputs			
Number of Op Amps			
Hardware Touch Peripheral			
UART	1	2	
SPI	1	2	
I2C	1	2	
I2S			
SSC			
Number of USB Modules	1	1	
USB Interface	FS Device	FS Device	None

Number of CAN Modules			
Type of CAN module			
Ethernet			
Max 8-Bit Digital Timers	1	2	1
Max 16-Bit Digital Timers	3	3	
Max 32-Bit Digital Timers			
Hardware RTCC/RTC		RTCC	
Max PWM outputs (including complementary)			
Number of PWM Time Bases			
Crypto Engine			
ARM Trust Zone			
Segmented LCD			
Graphics Controller/GPU			
Video Decoder			

Table 8 - PIC MICROCONTROLLER COMPARISON TABLE

6 HARDWARE REQUIREMENTS

6.1 CONNECTOR SPECIFICATION

The connectors that are use on this project require the following:

- Enough pins to satisfy the connection requirements.
- Locking capability. As the car will generate vibrations during the 2 hour test drive, it is possible that a non-locking connector could come loose. This would be a critical failure for the test as all data from that connection would be lost during the test drive. This would be required for connections internal to the enclosure and any external ones as well.
- High IP ratings are desirable if the housing box is to be stored on the outside of the car and exposed to the environment.

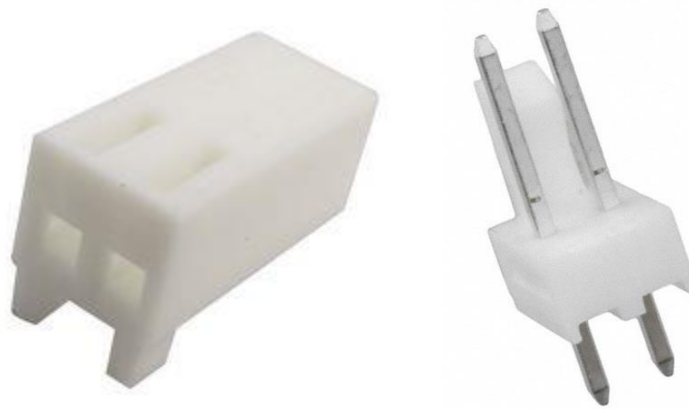


Figure 4 - Molex KK254

The moles KK series of connectors and crimp housings have been selected as a suitable solution for any connection to the PCB. This is because they have friction lock which makes them perfect for high vibration environments. They also have a polarizing back wall which will prevent and reversed connections from cables to the PCB [29].

The 772-E SERIES D-sub connectors have been selected for connections interfacing with the external sensors of the device as they have locking options available. They also have seals which are available and will provide the connection with an IP67 rating. They can be seen in Figure 5.



Figure 5 - 772-E SERIES D SUB CONNECTOR [44] , SF67 SERIES PANEL SEAL [43], 967 SERIES IP67 BACKSHELLS [45]

6.2 BATTERY

The specification for the battery is as follows:

- Must have enough capacity to power the circuit for 2 hours
- Rechargeable batteries are desirable.
- Small form factor.
- Minimum weight to reduce affect on car performance.

The battery that was selected for the project is the Lithium 2,600mAh 18650. Two will be used in series for the project. The reason for this selection is that they can supply the required voltage the circuit and will have enough capacity to last for the 2-hour test drive, or longer if required. They are also rechargeable and therefore will prevent any consumable battery usage for the datalogger.



Figure 6 – DUAL LITHIUM 18650 BATTERY [30]

6.3 PROJECT ENCLOSURE

The specification for the project enclosure is as follows:

- Large enough to house all electronics.
- Have enough room on side for any connectors required.
- IP rating is desirable as the case enclosure could be exposed to the elements in installed under the car.

The method used to select a suitable case is as follows. After the schematic was completed, all components were placed on the PCB design. A rough measurement was taken of how much space was required for the board. A suitably sized enclosure was then selected.

The selected enclosure is the starCASE SC 110. It has enough room for all the electronics and space on the edge for any required connectors. It also has raised mounting points for installing the PCB inside. The case has an IP rating of 66.



Figure 7 - starCASE SC 110 3F view [31]

7 DATA LOGGER BLOCK DIAGRAM

Figure 8 shows a block diagram of the data logger system. The system will be powered using batteries, which will be monitored using some kind of battery protection circuit. Any battery faults will trigger an electronic fuse to shut off power to the circuit.

The electronic fuse will also trigger during any overcurrent events or high temperature events.

After the fuse section is the voltage regulation. Firstly, the battery voltage is regulated into 5V. The 5V is then regulated into 3V3 in a second stage. These voltages are then used to power all components within the circuit.

The microcontroller has USB, I2C and SPI interfaces connected. USB for external connection to a PC to retrieve logs or program the PIC during initial bring-up. The SPI interface is used to communicate to the SD card which is the non-volatile memory for the system. I2C is used to communicate to the accelerometer/gyroscope module and a unique EEPROM IC. The EEPROM IC is used to uniquely identify the system and the value will be used as a prefix to the log file. You will therefore know what device has made the recording if there are multiple.

The system has an input button which is used to start the logging sequence and an LED indicator to display the state of the system i.e. logging mode or idle mode.

Each tachometer has a separate BNT connector on the enclosure, as the devices are supplied with BNT connectors. All linear potentiometer connections go to a 15-way D type connector. The thermocouple has a separate 9-way d type connector.

Wires will be soldered to the internal side of all connectors and then crimped and connected to the Molex connectors described previously. The relevant signals will then go through their respective circuits and into the PIC inputs.

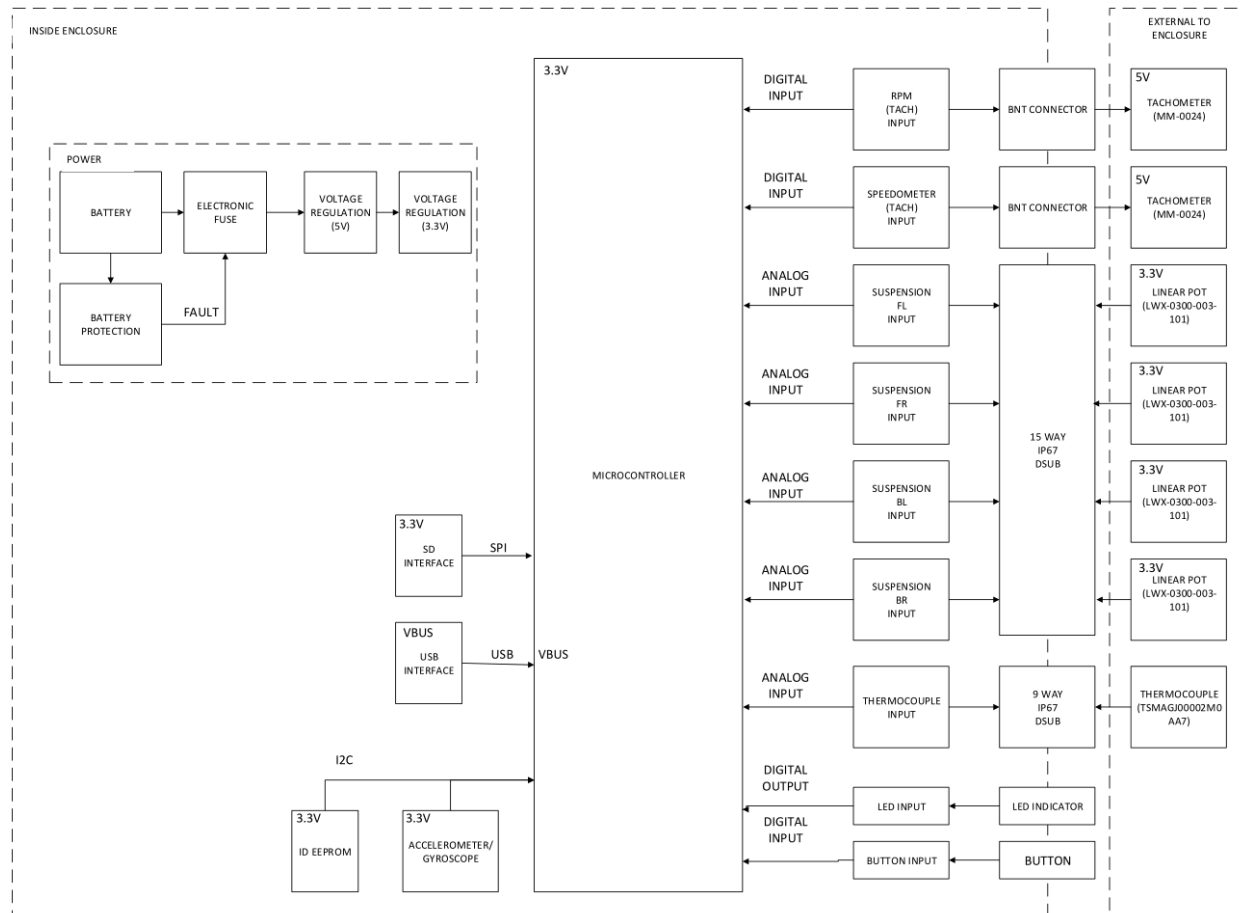


Figure 8 – DATA LOGGER DESIGN BLOCK DIAGRAM

8 PCB DESIGN

8.1 SCHEMATIC OVERVIEW

This section will detail the function of each section of the car data acquisition circuit.

8.1.1 BATTERY

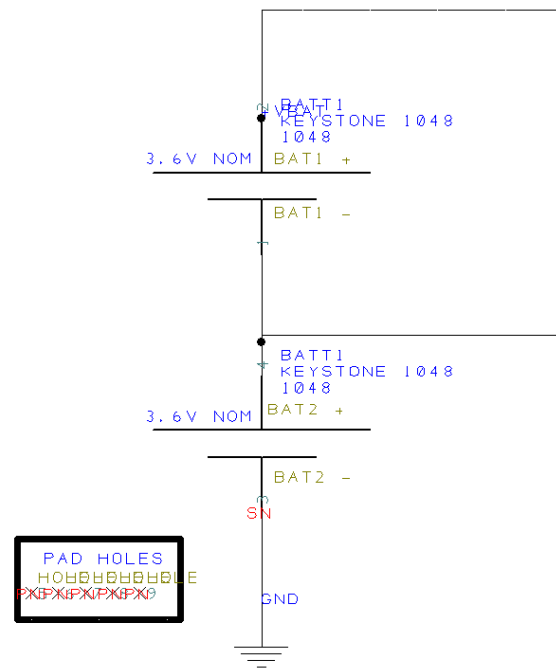


Figure 9 - BATTERY SCHEMATIC EXTRACT

The circuit above shows the two 18650 batteries in series. They should produce a nominal voltage of 6.2V. There are 2 connections to the battery monitoring circuit. A keystone 1048 part was used so that the batteries could be fitted directly onto the board.

8.1.2 BATTERY PROTECTION

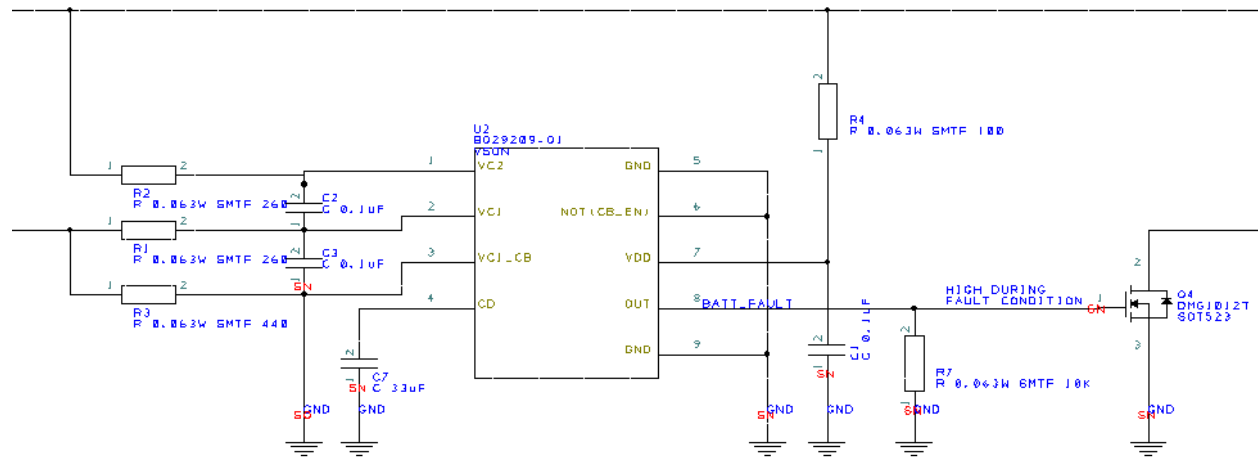


Figure 10 - BATTERY MONITORING SCHEMATIC EXTRACT

The battery monitoring circuit utilizes a BQ29209-Q1, which contains overvoltage protection with a threshold of 4.3V for each cell and automatic cell balancing. It is designed for two li-ion cells in series.

If a fault is detected, the out pin will go high and activate the N-channel MOSFET, pulling the enable line of the electronic fuse low, disabling power to the rest of the circuit. This line has a 10k pull down resistor to prevent any floating states. Fault conditions will also illuminate an LED.

The circuit is an implementation of the reference design shown in the BQ29209-Q1 datasheet [32].

8.1.3 ELECTRONIC FUSE

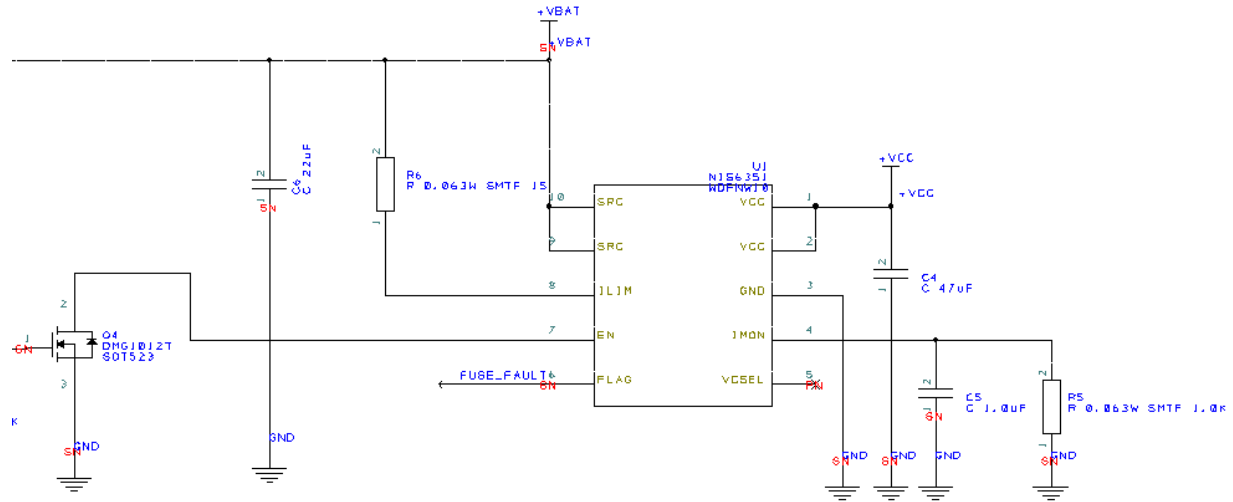


Figure 11 - ELECTRONIC FUSE CIRCUIT EXTRACT

The NIS6351 is an electronic fuse that is used to protect the PIC circuit from any overcurrent events. The device is also used to disable power in case of a battery fault as the enable line will be pulled low.

The circuit shown is an implementation of the typical application circuit shown in the NIS6351 datasheet [33].

8.1.4 VOLTAGE REGULATORS

8.1.4.1 5V

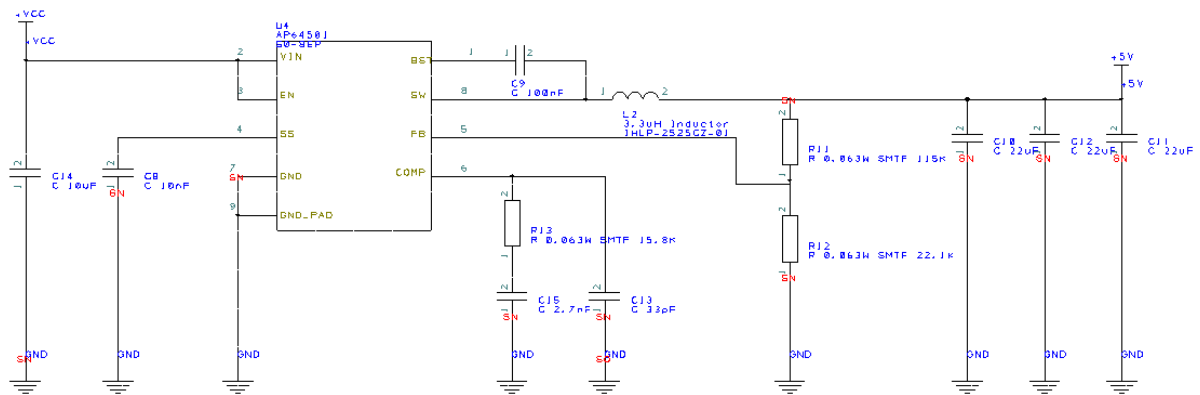


Figure 12 - 5V REGULATOR SCHEMATIC EXTRACT

Switch mode voltage regulators were selected for this project due to the high efficiency when compared to linear ones such as 7805s. The AP64501 has an efficiency of 85% at light loads and it increases with the load. This can be seen in Figure 13. The circuit AP64501 has a wide voltage input and will regulate voltages between 3.8-40V. It has also been designed to reduce EMI emissions with its design features. The AP64501 IC also has build in overvoltage protection, current limits, and thermal shutdown. Fault conditions will illuminate an LED.

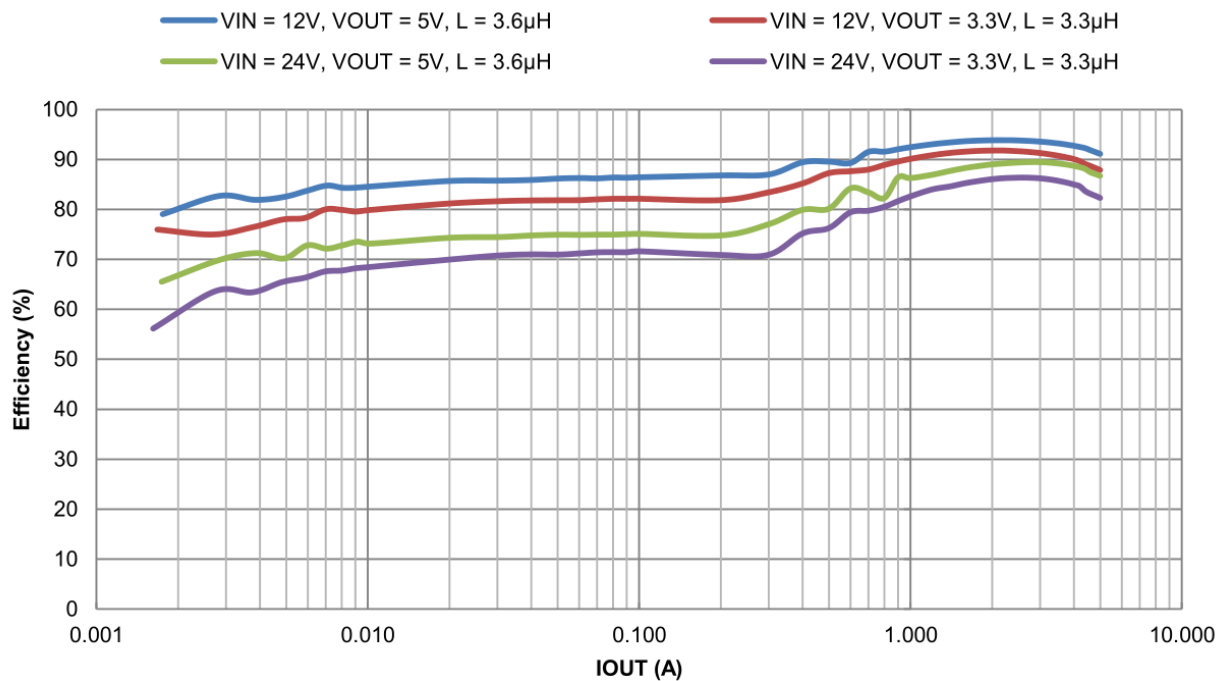


Figure 13 – EFFICIENCY VS OUTPUT CURRENT OF AP64501 [34]

The circuit shown is an implementation of the reference circuit shown in the AP64501 datasheet [34].

8.1.4.2 3V3

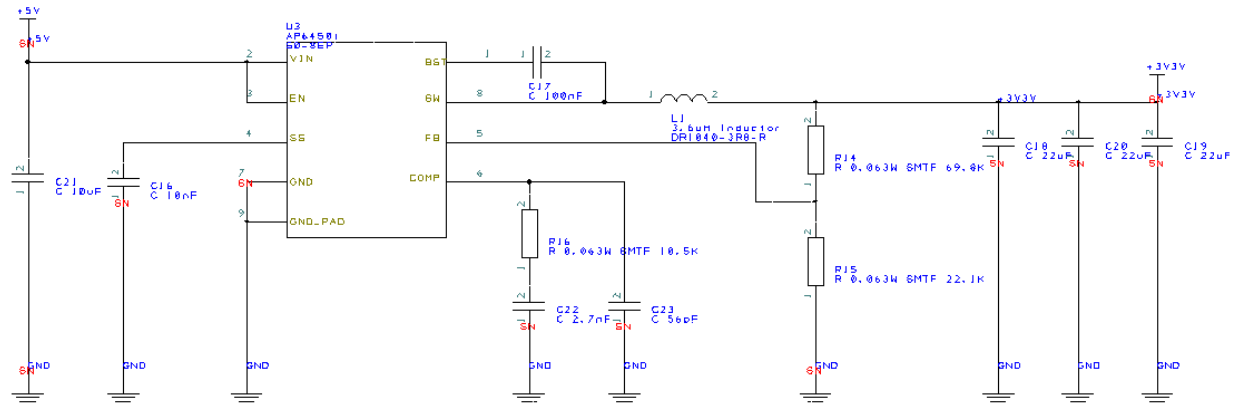


Figure 14 - 3V3 REGULATOR SCHEMATIC EXTRACT

The circuit in Figure 14 is very similar to the reference circuit shown in the datasheet, however the output voltage has been adjusted to 3V3 by changing the feedback resistors R14 and R15, inductor L1 and R16 as described in the datasheet recommended component selection table shown in Table 9.

AP64501										
Output Voltage (V)	R1 (kΩ)	R2 (kΩ)	L (μH)	C1 (μF)	C2 (μF)	C3 (nF)	C4 (pF)	R5 (kΩ)	C5 (nF)	C6 (pF) (Optional)
1.2	11.0	22.1	1.5	10	3 x 22	100	OPEN	3.74	2.7	150
1.5	19.6	22.1	2.2	10	3 x 22	100	OPEN	4.75	2.7	120
1.8	27.4	22.1	2.2	10	3 x 22	100	OPEN	5.62	2.7	100
2.5	47.5	22.1	3.3	10	3 x 22	100	OPEN	7.87	2.7	68
3.3	69.8	22.1	3.3	10	3 x 22	100	OPEN	10.50	2.7	56
5.0	115.8	22.1	3.6	10	3 x 22	100	OPEN	15.80	2.7	33
12.0	309.0	22.1	10.0	10	3 x 22	100	OPEN	37.40	2.7	15

Table 9 - AP64501 RECCOMENDED COMPONENTS SELECTION TABLE [34]

8.1.5 PIC18F46J50

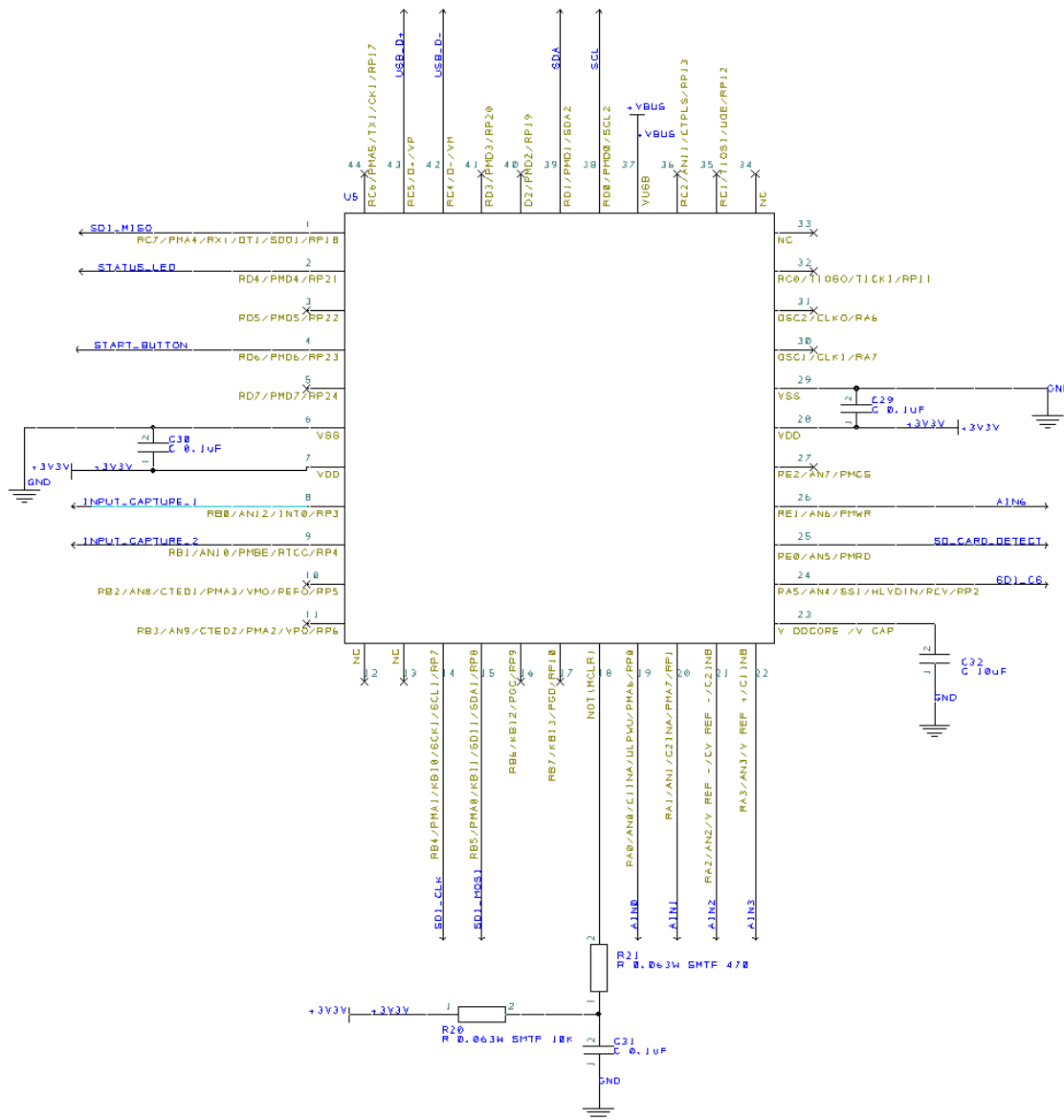


Figure 15 - PIC SCHEMATIC EXTRACT

The circuit shown in Figure 15 is an implementation of the recommended minimum connection circuit shown in the PIC18F46J50 datasheet. C29 and C38 are decoupling capacitors reducing and noise to the PIC. The R21,R20 ,C31 network are used for device reset and device programming and debugging. Recommended values from the datasheet were used [35].

All interfaces described previously have been connected, USB, I2C and SPI. Pins 8 and 9 are configurable inputs that have been set to digital input capture pins. This type of pin is used to detect the time interval between two peaks and will be used in the calculation to determine the rotational speed of the wheel and of the engine [36].

8.1.6 TACHOMETER INPUTS

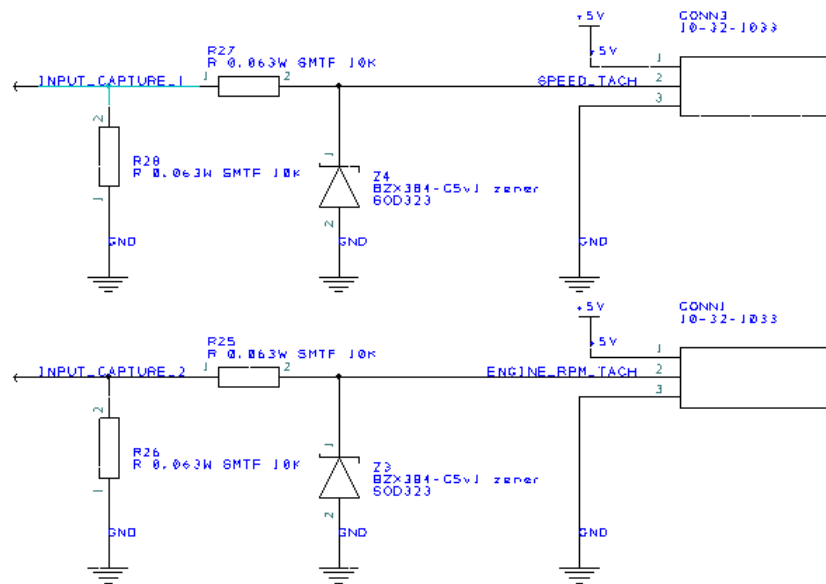


Figure 16 - TACHOMETER INPUTS SCHEMATIC EXTRACT

Each tachometer input is connected to a 3-pin locking Molex connector. Overvoltage protection is provided to the input using a 5.1V Zener diode. Any voltage above 5.1V will enable the diode in reverse bias mode, providing a path for the high current event to go down without damaging the PIC input. Each input has a voltage divider to half the input voltage. This will meet the threshold voltage for a high state (V_{ih}) which is 0.8V on the selected pins [35]. The PIC inputs are 5V tolerant however this is an additional precaution.

8.1.7 LINEAR VARIABLE RESISTOR INPUTS

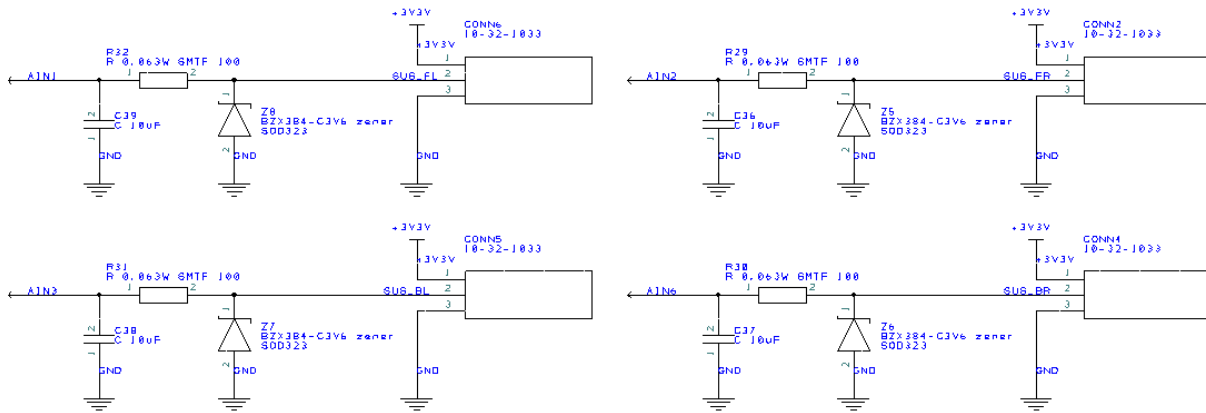


Figure 17 - LINEAR RESISTOR INPUTS SCHEMATIC EXTRACT

Each linear variable resistor input has a Zener diode as overvoltage protection. Any voltage above 3.6V will enable reverse bias mode and provide a safe path the dissipate the current.

A low pass filter has been added to each input to prevent any high frequency noise from reaching the PIC inputs. The cutoff frequency was calculated at 159Hz.

8.1.8 GYROSCOPE / ACCELEROMETER IC

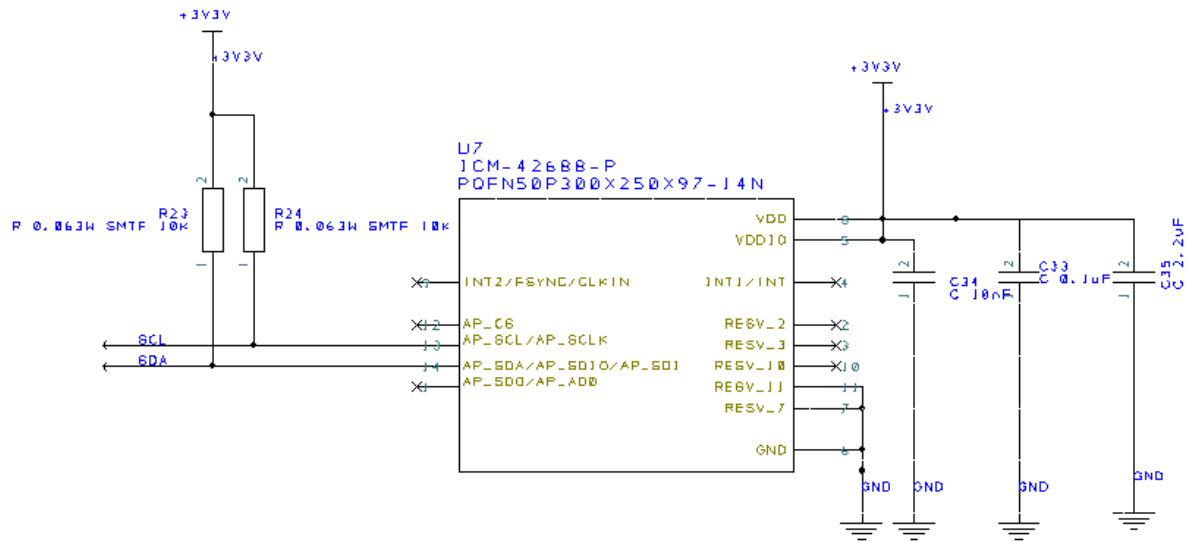


Figure 18 - GYROSCOPE / ACCELEROMETER IC SCHEMATIC EXTRACT

The pullups for the I2C clock and data lines are done using R23 and R24. The circuit shown above is a recommended implementation shown in the ICM-42688-P Datasheet [37].

8.1.9 THERMOCOUPLE CIRCUIT

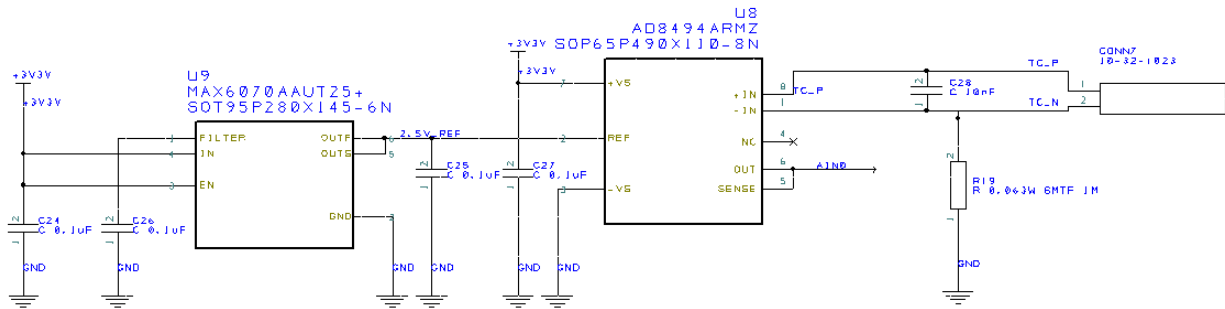


Figure 19 - THERMOCOUPLE CIRCUIT SCHEMATIC EXTRACT

The shown in Figure 19 is an implementation of a thermocouple project found on Altium's website. It contains an instrumentation amplifier with a cold junction compensation. The thermocouple connected to CONN7 is generating a voltage across its terminals depending on the temperature at the probe. Due to the different metals within its probe, it can affect the thermocouple reading as there is another metal junction. Connecting it to the circuit requires some compensation as you are introducing different metals into the system. U8 is the dedicated IC used for this compensation (cold junction compensation). Without which, errors in the reading would occur. U9 provides an accurate reference voltage for U8 [38].

The temperature of the thermocouple junction can be calculate using the following equation:

$$\text{Thermocouple Junction Temperature} = (V_{out} - V_{ref}) / (5\text{mv}/^{\circ}\text{C}) \quad [39]$$

8.1.10 USB INTERFACE

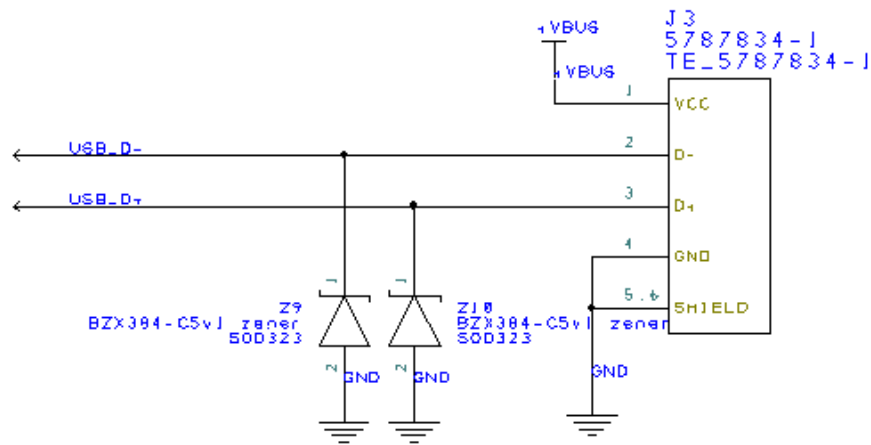


Figure 20 - USB INTERFACE SCHEMATIC EXTRACT

The USB circuit is very simple and only has 2 Zener diodes for overvoltage protection on the differential pair data lines. A USB type B connector was used as it is large and robust.

8.1.11 SD INTERFACE

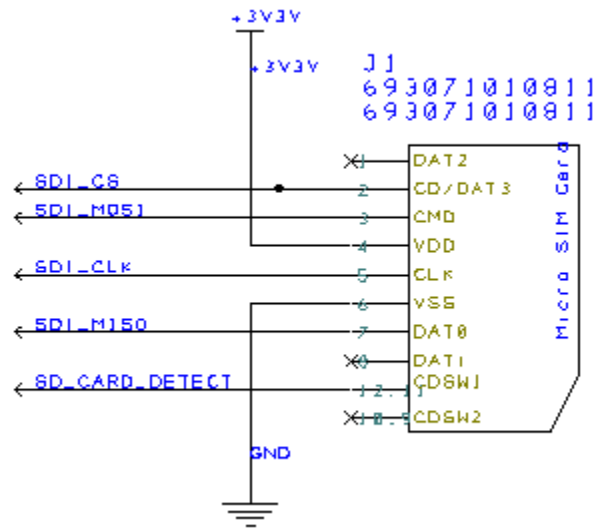


Figure 21 - SD INTERFACE SCHEMATIC EXTRACT

The SD card socket is connected using the SPI interface.

8.1.12 UNIQUE EEPROM IC

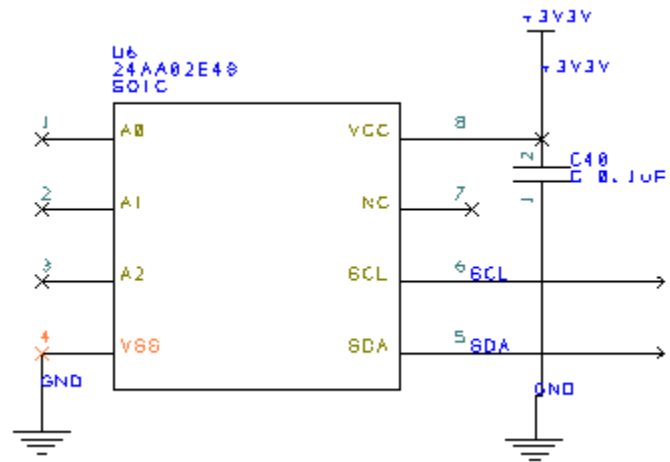


Figure 22 - UNIQUE EEPROM IC SCHEMATIC EXTRACT

The unique ID EEPROM is connected to the I2C bus and has a decoupling capacitor on its input. Pins 1-3 are not used by the IC and can be left floating [40].

8.1.13 LEDS

8.1.13.1 FAULT LEDS

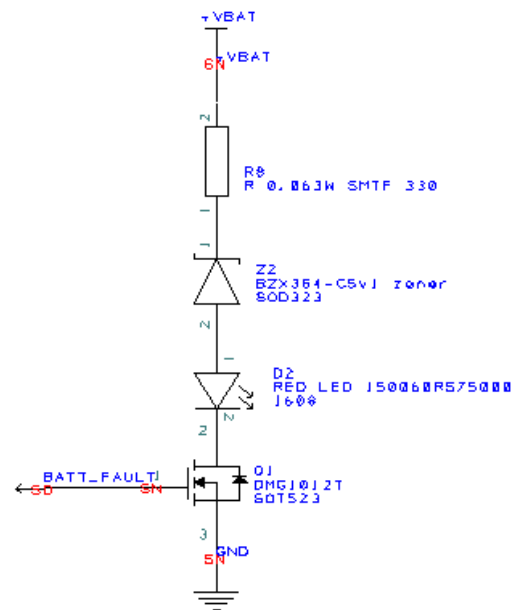


Figure 23 - BATTERY FAULT INDICATOR SCHEMATIC EXTRACT

When a battery fault is detected, the gate of the MOSFET Q1 will go high and pull D2 to ground, turning it on.

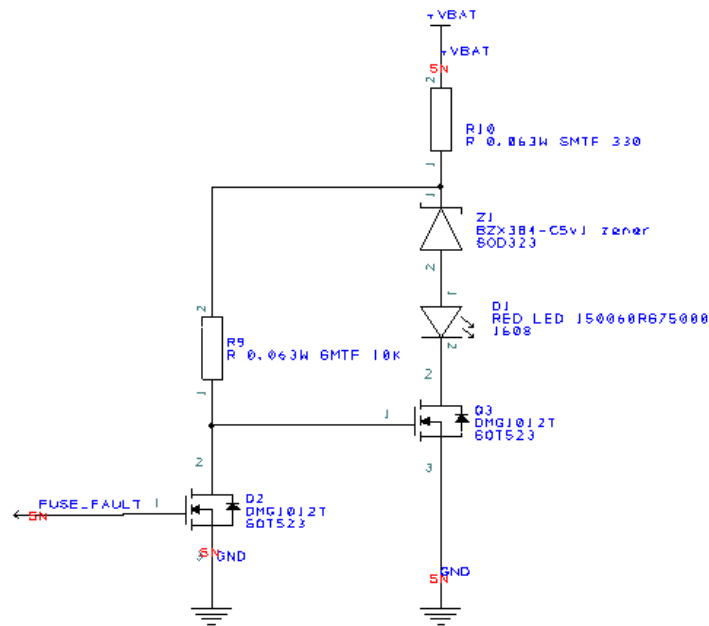


Figure 24 - FUSE FAULT INDICATOR SCHEMATIC EXTRACT

When a fuse fault is present, the fuse_fault net will go low. To trigger the LED only in the fault condition, two MOSFETS have been used. In correct working conditions, fuse_fault is high, indicating no error. In this state, Q2 is open and the gate of Q3 is pulled low, preventing D1 from illuminating.

In a fault condition, the gate of Q2 will be low and this will cause Q3 to go high, due to the R9 pullup resistor. Q3 gate will activate and pull D3 to ground, illuminating the led.

8.1.13.2 VOLTAGE INDICATORS

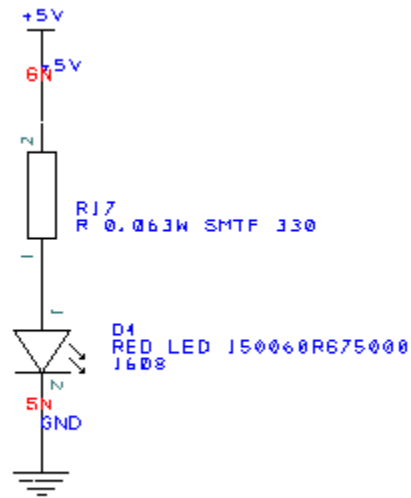


Figure 25 - 5V INDICATOR SCHEMATIC EXTRACT

There is an indicator on the PCB for 5V.

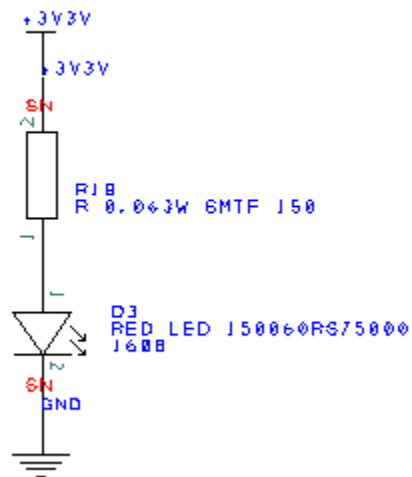


Figure 26 - 3V3 INDICATOR SCHEMATIC EXTRACT

There is an indicator on the PCB for 3V3.

8.1.13.3 SD ACTIVE LED

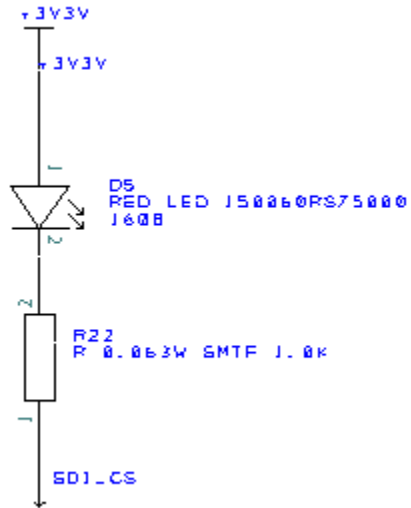


Figure 27 - SD INTERFACE ACTIVE LED SCHEMATIC EXTRACT

An LED will flicker when there is data being sent to the SD card. SDI_CS will turn the LED on when it goes low.

8.1.13.4 EXTERNAL LED AND BUTTON

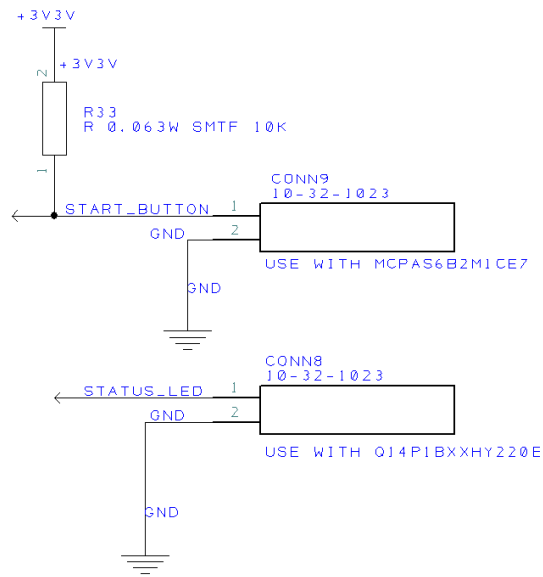


Figure 28 - EXTERNAL LED AND BUTTON SCHEMATIC EXTRACT

The circuit in Figure 28, shows the connections for the button and LED indicator on the top of the box. The button has a pull up resistor R33 to ensure there are no floating states.

The LED connection does not have any current limiting resistors as per the datasheet [41].

8.2 PCB OVERVIEW

8.2.1 BOARD SIZE

Figure 29 shows the outline of the PCB required in order to fit within the selected case.

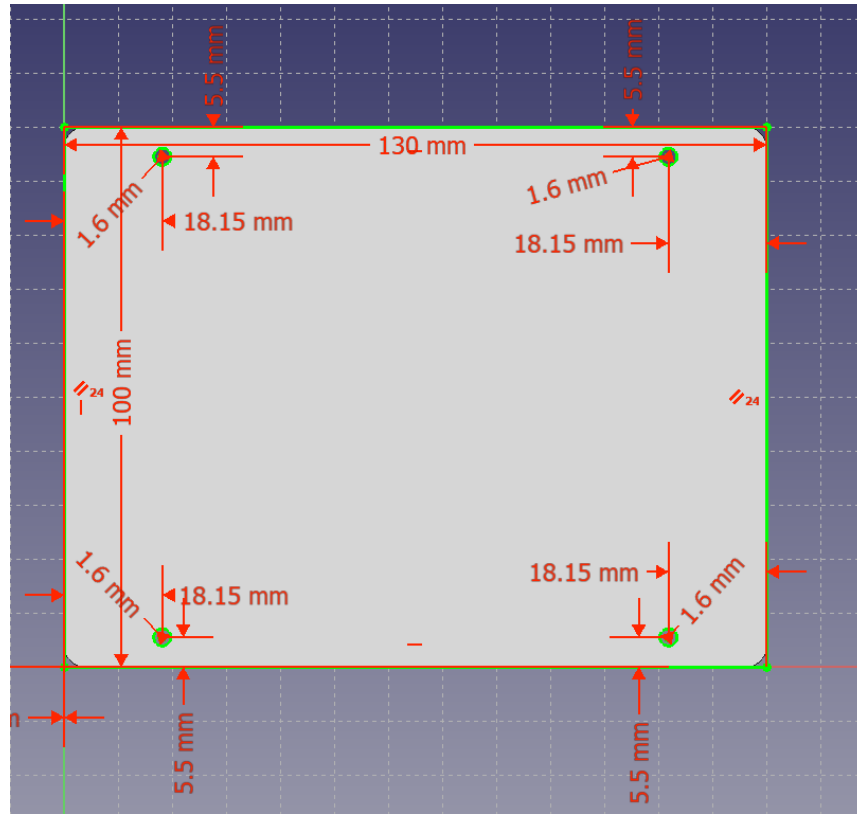


Figure 29 - PCB OUTLINE SKETCH

8.3 STACKUP

The PCB that was designed for this project was a 4-layer board with 2 signal layers, a ground layer and a power layer. The reason for this choice was it simplifies the wiring of all ground and power signals and reduces routing. Any ground or power connection simply requires a via to the plane of the same net below.

8.4 POWER DISTRIBUTION

8.4.1 SPLIT POWER PLANE

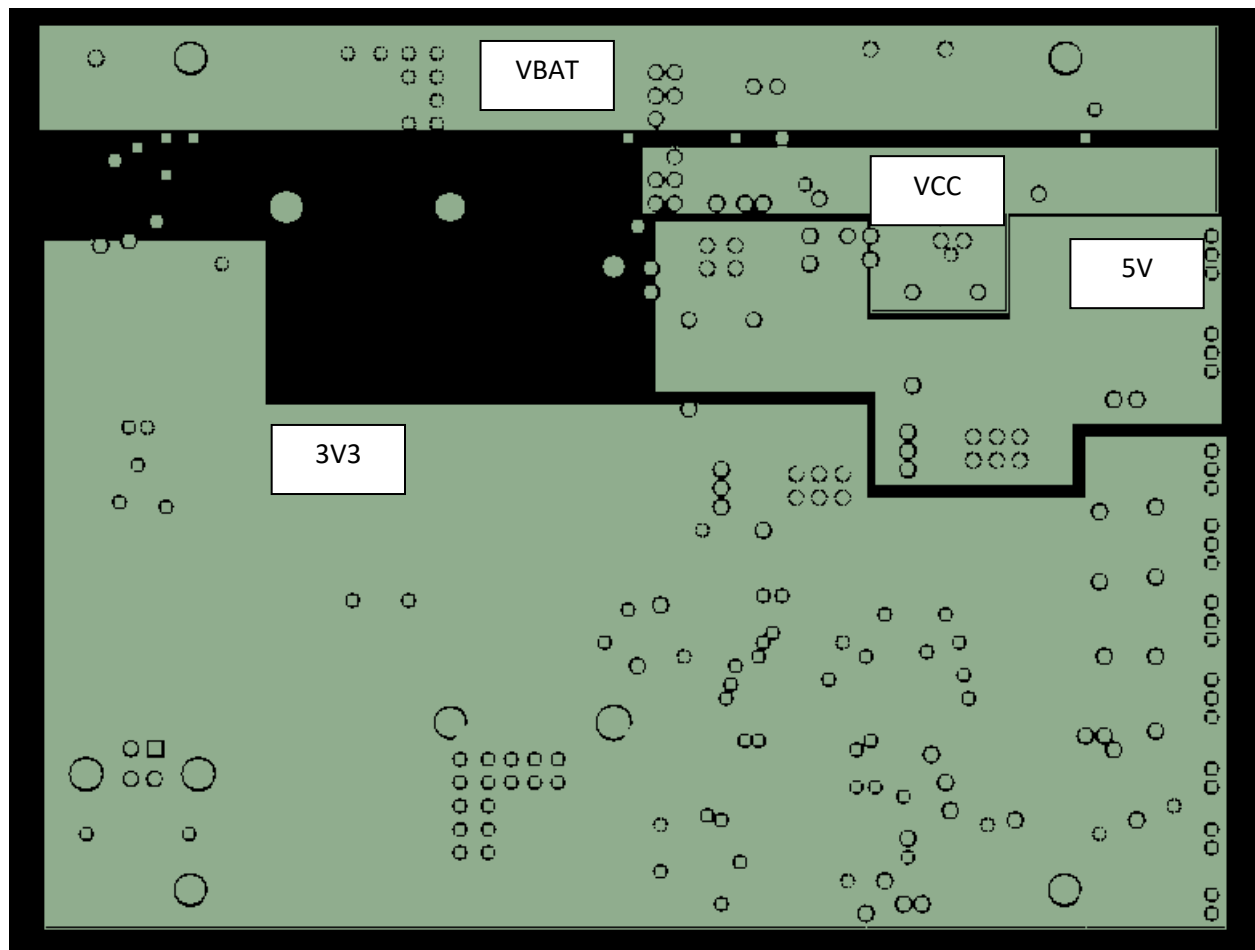


Figure 30 - SPLIT POWER PLANE

Figure 30 shows the positive power setup on the PCB. There are 4 copper polygons on the power plane, each for a different power net used within the circuit. Components have been placed in such a way that their respective power net is below them, allowing for simple power connections.

8.4.2 GND PLANE

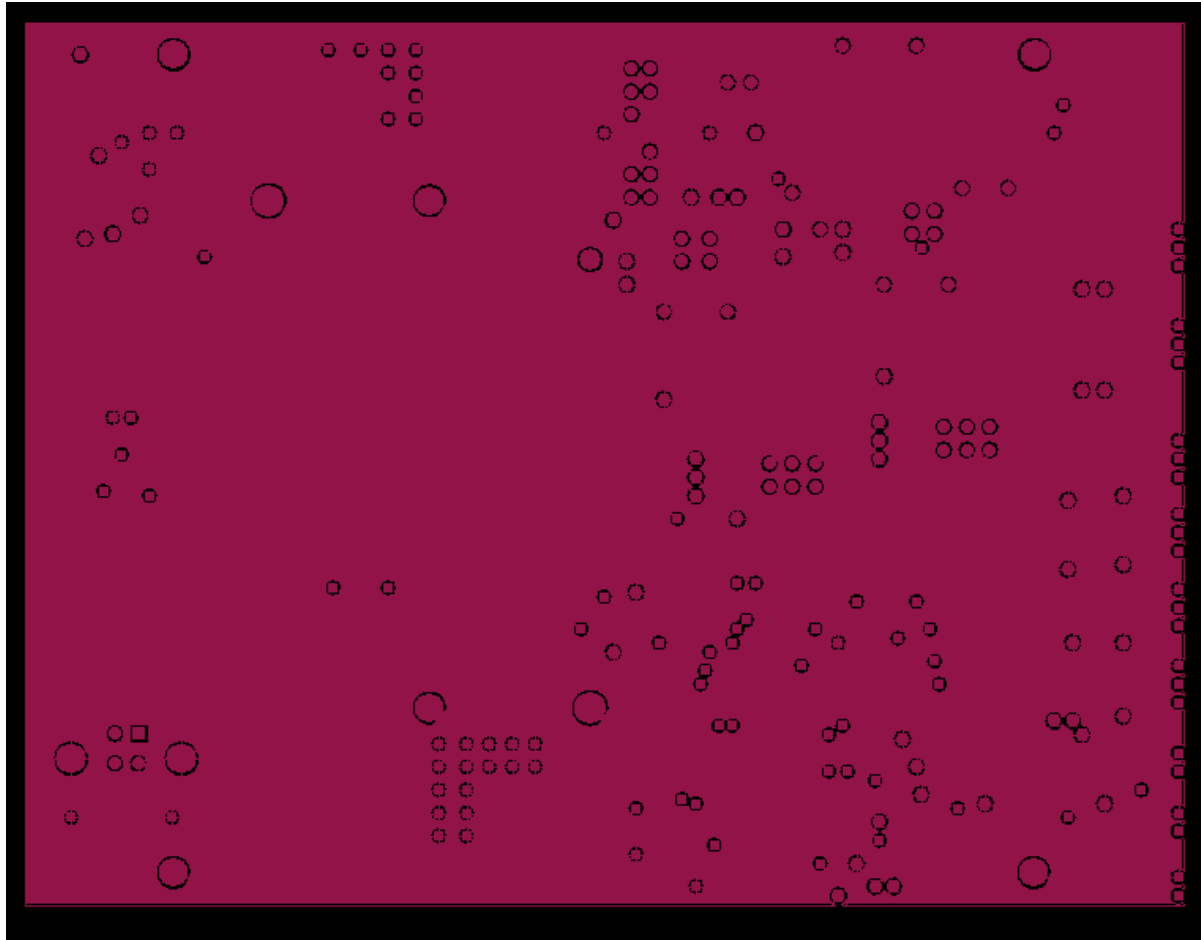


Figure 31 - GROUND PLANE

The ground plane covers most of the board, with a small gap around the edges. This allows for simple connections to ground and ensures a good return path for all ground connections. No signals have been routed on this later as splitting the ground plane can cause unwanted noise within the system [42].

8.4.3 DESIGN RULE CHECK

After the design was completed, a design rule check was run. All nets were confirmed to be wired correctly. Any further warnings were reviewed and deemed acceptable.

8.4.4 SPECIAL CONSIDERATIONS

8.4.4.1 FILTER CAPS

Decoupling capacitors were placed as close to their respective ICs as possible and should be connected to ground through a via to a ground plane to minimize inductance [43]. The purpose is to try and remove as much high frequency noise away from the chip.

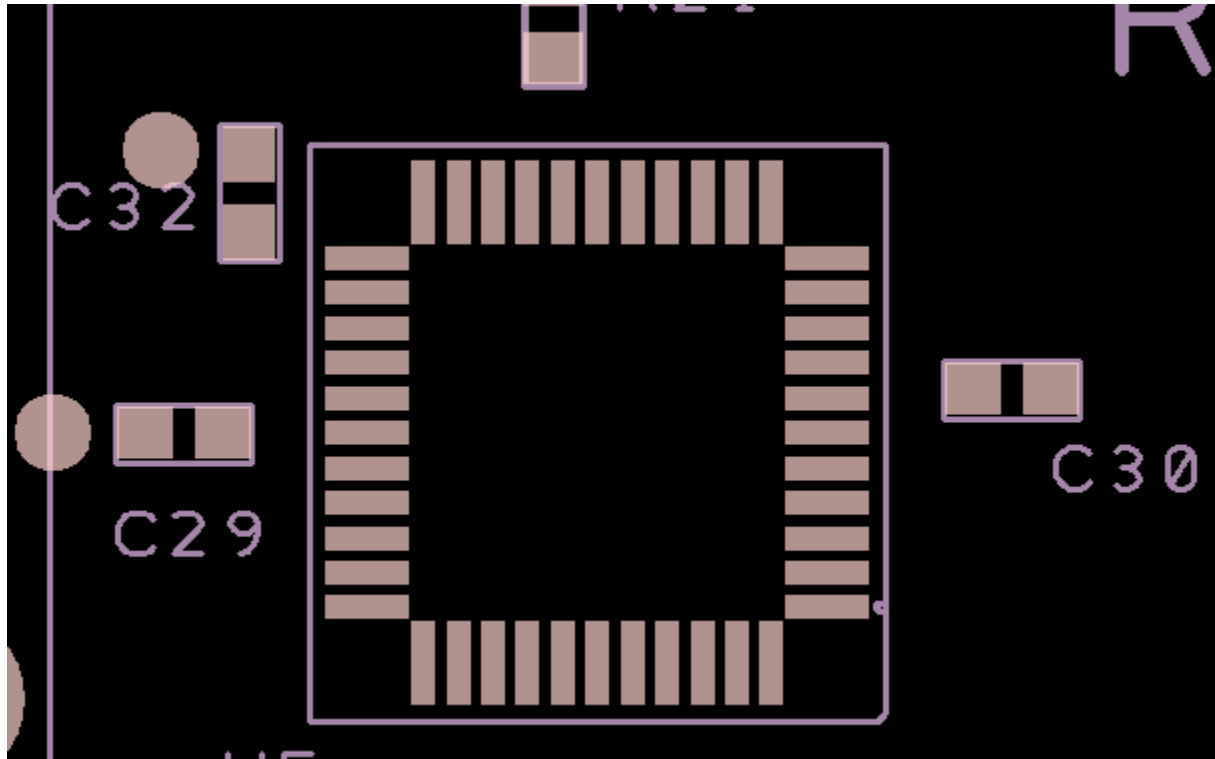


Figure 32 - DECOUPLING CAPACITORS C29 AND C30 EXAMPLE

8.5 PCB 3D VIEW

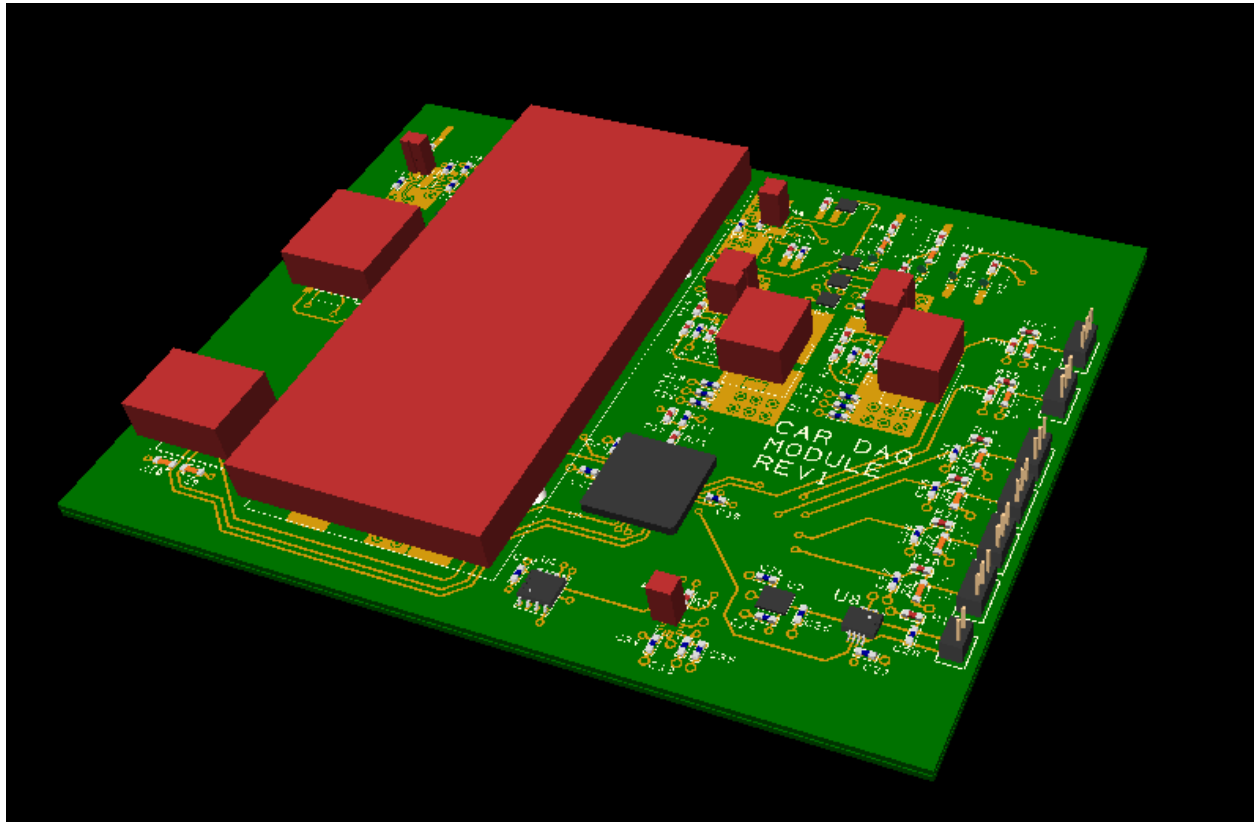


Figure 33 - PCB 3D VIEW

Figure 33 shows the 3D view generated by easy-pc.

8.6 COST BREAKDOWN

ITEM	QTY	COST	REFERENCE
PCB BOM PARTS	1	£57.04	See 11.5
PCB COST	1	(\$46) ~£36.79	See 11.6
18650 BATTERY (2)	1	£9.95	link
starCASE SC 110	1	Price not available (similar product link £35.88)	link
IP67 D SUB CONNECTOR (15 POS) MALE	1	Price not available	link
IP67 D SUB CONNECTOR (9 POS) MALE	1	Price not available	link
IP67 D SUB CONNECTOR (15 POS) FEMALE	1	Price not available	link
IP67 D SUB CONNECTOR (9 POS) FEMALE	1	Price not available	link
SFP6715 (D SUB PANEL SEAL)	2	Price not available	link
SFP6709 (D SUB PANEL SEAL)	1	Price not available	link
LWX-0300-003-101	4	(£958.80 each) £3835.2	link
MM-0024	2	Price not available	link
PHOTOELECTRIC PROBE BNT SOCKET CONNECTOR	2	£79.44	link
THERMOCOUPLE TYPE K	1	£51	link
EXTERNAL BUTTON (MCPAS6B2M1CE7)	1	£2.94	link
EXTERNAL LED (Q14P1BXXHY220E)	1	£5.964	link
3-Way, 2.54mm Pitch Housing, KK 254 - 22-01-3037	6	(£1.08 each) £6.48	link
2-Way, 2.54mm Pitch Housing, KK 254 - 22-01-3027	1	£0.9	link
Crimp Terminals, 22-30 AWG - 08-50- 0032	20	0.492	link
SD CARD (32GB)	1	£7.29	[27]

*wiring costs not included

The known cost is for the project is £4,128.874, however there are many unknown costs which could significantly increase the price. Additional quotes would be required in order to get a fully accurate costing of the project.

A full PCB BOM can be found in the appendices (11.5).

A download link to the full flow chart can be found in the appendices(11.4).





Figure 34 - OPERATIONAL FLOW CHART

10 SUGGESTED IMPROVEMENTS

Some potential improvements to the circuit are listed below:

- An additional battery charging circuit would allow users to recharge the batteries without having to remove the lid of the enclosure.
- A USB connector on the external part of the enclosure would prevent anyone from removing the lid to get the data.
- Test points on the PCB would allow for easier debugging if there are issues.
- Fiducial marks could be added to the PCB to make it easier for fabrication houses to do pick and place programs for the PCB. However this could easily be added to a panelized version of the design.
- An OLED screen would be a good way to get more information out of the device. Currently only 1 LED is exposed to the outside of the enclosure. Feedback is limited to anyone using the device.
- More external LEDs. Currently fault indication LEDs are only visible when the lid is off. This is a design flaw.

11 APPENDICES

11.1 MINIMUM MEMORY REQUIREMENT CALCULATION

100Hz = 100 readings every second

25bytes * 100 = 2,500bytes per second

2,500 * 60 = 150,000 bytes per minute

150,000 * 60 = 9,000,000 bytes per hour

9,000,000 * 2 = 18,000,000 bytes per 2 hours

11.2 FULL SCHEMATIC PDF LINKS

11.2.1 SHEET 1 – BATTERY AND PROTECTION

https://www.dropbox.com/scl/fi/3tqum7d93zk07h5zfldmt/car_daq_system_battery_and_protection-Schematic.pdf?rlkey=5vnu38nw7zoep68h9tt9us86h&dl=0

11.2.2 SHEET 2 – VOLTAGE REGS

https://www.dropbox.com/scl/fi/des6zi2hlrgt6ypq0eo1a/car_daq_system_voltage_regs-Schematic.pdf?rlkey=w8y6913g1ua4g8zzkcaik8sil&dl=0

11.2.3 SHEET 3 – MICROCONTROLLER AND OTHER

https://www.dropbox.com/scl/fi/3mj12i0qlviwymiouuw/car_daq_system_microcontroller_IO_ADC_OTHER-Schematic.pdf?rlkey=cayw7gx2m014aut79hh1zps37&dl=0

11.3 GERBER DOWNLOAD LINK

<https://www.dropbox.com/scl/fi/vh5p6hkeh5a6ra2k7bhd1/Plots.zip?rlkey=3sxsjhkivugofnnqp3kw7ime&dl=0>

11.4 OPERATIONAL FLOW CHART DOWNLOAD LINK

<https://www.dropbox.com/scl/fi/pd8a8iqd61okydgpmw814/car-DAQ-SYSTEM-OPERATIONAL-FLOW-CHART.pdf?rlkey=ev3aph03uia7jcu69kwch9zfb&dl=0>

11.5 FULL BOM

Component	Names	Quantity	Manufacturer Part Number	Supplier	Cost (£)	Total Cost (£)
24AA02E48	U6	1	24AA02E48T-E/OT	Digikey	0.31	0.31
AD8494ARMZ	U8	1	AD8494ARMZ	Digikey	6.35	6.35
AP64501	U3-4	2	AP64501SP-13	Digikey	1.9	3.8
BQ29209-Q1	U2	1	BQ29209DRBR	Digikey	0.76	0.76
ICM-42688-P	U7	1	ICM-42688-P	Digikey	5.77	5.77
MAX6070AAUT25+	U9	1	MAX6070AAUT25+T	Digikey	3.61	3.61
NIS6351	U1	1	NIS6351MT1TXG	Digikey	2.18	2.18
PIC18F46J50	U5	1	PIC18F46J50-I/PT	Digikey	4.15	4.15
C 0.1uF	C1-3, C24-27, C29-31, C33, C40	12	CL10B104KB8NNWC	Digikey	0.08	0.96
C 1.0uF	C5	1	CL10A105KA8NNNC	Digikey	0.08	0.08
C 2.2uF	C35	1	CL10A225KO8NNNC	Digikey	0.08	0.08
C 2.7nF	C15, C22	2	2211Y4K00272KXT	Digikey	1.4	2.8
C 10nF	C8, C16, C28, C34	4	C0603C103K4REC7867	Digikey	0.09	0.36
C 10uF	C14, C21, C32, C36-39	7	CL10A106MQ8NNNC	Digikey	0.09	0.63
C 22uF	C6, C10-12, C18-20	7	GRM188R60G226MEA0D	Digikey	0.15	1.05
C 33pF	C13	1	C0603C330J5GAC7867	Digikey	0.12	0.12
C 33uF	C7	1			0	0
C 47uF	C4	1	GRM188R60J476ME15J	Digikey	0.42	0.42
C 56pF	C23	1	600S560FT250XT	Digikey	1.54	1.54
C 100nF	C9, C17	2	CL10B104KB8NNWC	Digikey	0.08	0.16
RED LED 150060RS75000	D1-5	5	150060RS75000	Digikey	0.12	0.6
10-32-1023	CONN7	1	22232021	Digikey	0.17	0.17
10-32-1033	CONN1-6	6	22232031	Digikey	0.22	1.32
5787834-1	J3	1	5787834-1	Digikey	2.58	2.58
693071010811	J1	1	693071010811	Digikey	2.57	2.57
R 0.063W SMTF 1.0K	R5, R22	2	RMCF0603FT1K00	Digikey	0.08	0.16
R 0.063W SMTF 1M	R19	1	ERJ-3EKF1004V	Digikey	0.08	0.08
R 0.063W SMTF 10K	R7, R9, R20, R23-28, R33	10	RMCF0603FT10K0	Digikey	0.08	0.80
R 0.063W SMTF 10.5K	R16	1	RMCF0603FT10K5	Digikey	0.08	0.08
R 0.063W SMTF 15	R6	1	WR06X15R0FTL	Digikey	0.08	0.08

R 0.063W SMTF 15.8K	R13	1	RMCF0603FT15K8	Digikey	0.08	0.08
R 0.063W SMTF 22.1K	R12, R15	2	RMCF0603FT22K1	Digikey	0.08	0.16
R 0.063W SMTF 69.8K	R14	1	RMCF0603FT69K8	Digikey	0.08	0.08
R 0.063W SMTF 100	R4, R29-32	5	RMCF0603FT100R	Digikey	0.08	0.4
R 0.063W SMTF 115K	R11	1	RMCF0603FT115K	Digikey	0.08	0.08
R 0.063W SMTF 150	R18	1	RC0603FR-07150RL	Digikey	0.08	0.08
R 0.063W SMTF 260	R1-2	2	Y1636260R000T9W	Digikey	0.08	0.16
R 0.063W SMTF 330	R8, R10, R17	3	CR0603-JW-331ELF	Digikey	0.08	0.24
R 0.063W SMTF 470	R21	1	ERA-3AEB471V	Digikey	0.26	0.26
DMG1012T	Q1-4	4	DMG1012T-7	Digikey	0.26	1.04
3.3uH Inductor	L2	1	IHLP2525CZER3R3M01	Digikey	0.9	0.9
3.6uH Inductor	L1	1	DR1040-3R8-R	Mouser	0.76	0.76
BZX384-C3V6 zener	Z5-8	4	BZX384-C3V6,115	Digikey	0.17	0.68
BZX384-C5v1 zener	Z1-4, Z9-10	6	BZX384-C5V1,115	Digikey	0.17	1.02
KEystone 1048	BATT1	1	1048	Digikey	7.53	7.53

11.6 JLC PCB FULL QUOTE

[USDShip to](#)
[Order now](#)
[My file](#)
[Sign in](#)

Standard PCB/PCBA

Advanced PCB/PCBA

SMT-Stencil

3D/CNC

[← Back to Upload File](#)
Detected 6 layer board of 100x130mm(3.94x5.12 inches) .
[Gerber Viewer](#)

Base Material

FR-4

Flex

Aluminum

Copper Core

Rogers

PTFE Teflon

Layers

1

2

4

Dimensions

X

*

Y

Size

PCB Qty

5

Product Type

Industrial/Consumer electronics

Aerospace

Medical

PCB Specifications

Different Design

1

2

3

4

Delivery Format

Single PCB

Panel by Customer

Panel by JLCPCB

PCB Thickness

0.4

0.6

0.8

1.0

1.2

1.6

2.0

PCB Color

Green

Purple

Red

Yellow

Blue

White

Black

Silkscreen

White

Material Type

FR4-Standard TG 135-140

FR-4 TG155

FR-4 TG170

Surface Finish

HASL(with lead)

LeadFree HASL

ENIG

High-spec Options

Outer Copper Weight

1 oz

2 oz

Inner Copper Weight

0.5 oz

1 oz

2 oz

Specify Layer Sequence

No

Yes

Impedance Control

No

Yes

Impedance calculator >

Via Covering

Tented

Untented

Plugged

Epoxy Filled & Capped

Copper paste Filled & Capped

Min via hole size/diameter

0.3mm(0.4/0.45mm)

0.25mm(0.35/0.4mm)

0.2mm(0.3/0.35mm)

0.15mm(0.25/0.3mm)

Board Outline Tolerance

±0.2mm(Regular)

±0.1mm(Precision)

Confirm Production file

No

Yes

Remove Order Number

No

Yes

Specify a location

Flying Probe Test

Fully Test

Gold Fingers

No

Yes

Castellated Holes

No

Yes

Edge Plating

No

Yes

Advanced Options

Cookie Notice

Our website uses essential cookies to help us ensure that it is working as expected, and uses optional analytics cookies to offer you a better browsing experience. To find out more, read our [Cookie Notice](#)

Accept only essential cookies

Accept all cookies

Charge Details

Engineering fee

\$23.00

Via Covering

\$16.50

Surface Finish

\$0.00

Board

\$6.50

Build Time

PCB:

3-4 days

\$0.00

2-3 days

\$62.00

Calculated Price

\$46.00

Additional charges may apply for special cases

SAVE TO CART

Shipping Estimate

Charge: Choose destination country first

Weight

0.35kg

Welcome back, may I help you?

Write a message..

Figure 35 – FULL JLC PCB QUOTE

12 REFERENCES

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