

Microcontroller Based Automotive
Data Acquisition System
Electronic Systems Design

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Introduction

In response to the growing demand for comprehensive vehicle performance evaluation, this project aims to design a microcontroller-based automotive data acquisition system tailored for a production prototype car destined for the family saloon market. The envisioned system goes beyond conventional data logging by offering a re-usable, portable, and adaptable solution applicable to diverse vehicle classes. Rather, it encourages exploration and incorporation of independent sensor and transduction methods. By meticulously collecting and analysing critical parameters such as engine RPM, temperature, suspension travel, pitch, roll, yaw, and vehicle road speed during a 2-hour test track run, this data acquisition system aims to contribute invaluable insights into the vehicle's operational safety limits and its capacity to provide a comfortable means of transport. This project thus embodies an innovative fusion of cutting-edge technology, adaptability, and real-world automotive testing, underscoring its potential impact on advancing vehicle design and performance assessment.

DATA ACQUISITION SYSTEMS COMPARISON

To start off the project we need to research some exciting motor data logging systems already on the market.

There are several options, so I featured the systems closest to my parameters for closer specification comparison:

DATA ACQUISITION SYSTEMS

Features Specifications	Industrial Multichannel Data Logger	CEBO LC	Delphin Expert Key 100
			
Output analogue	2	2	2
Input analogue channels	8	14	14
Input digital	8 I/O	20 I/O	8 I/O
Logged data retrieval	USB flash drive	USB flash drive	USB flash drive
Power supply	12V -30VDC	AC via USB	9V -24VDC
BIT analogue input	24BIT	16BIT	18 BITS
BIT analogue output	24BIT	16BIT	16BIT
Sampling Rate	up to 1khz	65 to 85khz	up to100khz
Short circuit protection	All I/O	All I/O	All I/O
Logging Memory	512k	Via PC	2GB to 14GB
Price	£659.00 (no sensors)	£631.44 (no sensors)	£7,234.00 (no sensors)
Portable Applications	No casing or protect from the elements	No casing or protect from the elements	Has a case for minimal environment protection

Delphin Expert Key 100:

Channels:

Expert Key 100 typically offers a moderate number of channels, suitable for various industrial applications.

Inputs:

It supports a variety of analogue and digital inputs, allowing for flexibility in sensor connectivity.

Connectivity:

Expert Key 100 often provides USB and LAN interfaces for data transfer and configuration.

Software:

Delphin provides powerful software for configuration, data analysis, and visualization.

Memory:

Depending on the model, it features internal memory for data storage. Some models also support external storage options.

Accuracy:

Delphin systems are known for their accuracy and reliability in data acquisition.

Application Range:

Suitable for a wide range of applications, including process monitoring, test stand automation, and more.

Industrial Multichannel Data Logger:

Channels:

The number of channels may vary depending on the specific model or brand.

Inputs:

Typically supports a variety of input types for versatile sensor connectivity.

Connectivity:

It may offer USB, Ethernet, or wireless connectivity options for data transfer and communication.

Software:

The accompanying software varies among different brands/models, offering different levels of user interface and analysis features.

Memory:

Internal memory capacity is determined by the specific model and brand. Some systems support external memory expansion.

Accuracy:

Accuracy depends on the quality and specifications of the specific data logger.

Application Range:

The application range can vary widely, from general-purpose data logging to more specialized industrial applications.

CEBO LC:

Channels:

The number of channels depends on the specific model, but it is likely to be designed for multichannel data acquisition.

Inputs:

Supports various inputs to accommodate different sensor types.

Connectivity:

CEBO LC might offer multiple connectivity options such as USB, Ethernet, or wireless interfaces.

Software:

The software capabilities vary, and it may include features for real-time monitoring, analysis, and reporting.

Memory:

Internal memory size may differ among models. Some models might allow for external memory expansion.

Accuracy:

Accuracy is determined by the specifications of the particular data logger.

Application Range:

CEBO LC is likely designed for diverse industrial applications, similar to other industrial-grade data loggers.

General Considerations:

Cost:

Compare the initial cost as well as any additional costs for required accessories or software.

Ease of Use:

Evaluate the user interface and ease of configuration for each data logger.

Scalability:

Consider whether the system can be easily expanded or integrated into larger setups if needed.

Support and Documentation:

Check the availability of technical support and documentation for troubleshooting and system integration.

Durability and Environmental Considerations:

Evaluate the ruggedness and environmental specifications to ensure compatibility with the intended operating conditions.

DATA ACQUISITION SYSTEMS COMPARISON

Summary

The Delphin Expert Key 100 stands out for its versatility, offering a moderate number of channels suitable for various industrial applications. It boasts a flexible array of analog and digital inputs, facilitating seamless sensor connectivity. The device ensures efficient data transfer and configuration through USB and LAN interfaces, and it comes equipped with powerful software for robust configuration, data analysis, and visualization. With internal memory options and support for external storage, the Expert Key 100 is recognized for its accuracy and reliability in data acquisition. Its broad application range spans processes like monitoring and test stand automation. In comparison, the Industrial Multichannel Data Logger varies widely in channels, connectivity, and application, making it suitable for diverse industrial scenarios. The CEBO LC, designed for multichannel data acquisition, offers varied inputs and connectivity options, with software capabilities tailored to real-time monitoring and analysis. Considerations for cost, ease of use, scalability, support, and environmental compatibility are pivotal in the decision-making process, ensuring alignment with specific application requirements.

MICROCONTROLLER SELECTION

MICROCONTROLLER	PIC18F4320	PIC16F18025	PIC16F18076
TECH SPECS			
Program Memory Size (KB)	8	14	28
RAM (bytes)	512	1024	2048
Data EEPROM (bytes)	256	128	256
Pin Count	40	14	40

Operation Voltage Max.(V)	5.5	5.5	5.5
Operation Voltage Min.(V)	2	1.8	1.8
Timers	3 x 8-bit - 3 x 16-bit	2 x 8-bit - 3 x 16-bit	3 x 8-bit - 3 x 16-bit
Max ADC Resolution (bits)	10	10	10
ADC Channels	13	11	35
Zero Cross Detect	No	Yes	Yes
Number of Comparators	2	1	1
SPI	1 -SPI	1 -SPI	1 -SPI
I2C	1 -I2C	0 -I2C	1 -I2C
Standalone PWM	0	3	3
Low Power	No	Yes	Yes
Numerically Controlled Oscillator (NCO)	0	1	1
Data Signal Modulator (DSM)	0	0	0

The PIC18F4320, PIC16F18025, and PIC16F18076 microcontrollers, all part of Microchip's PIC family, cater to diverse application needs. The PIC18F4320 stands out with its advanced features, offering a broad range of peripherals and a relatively higher number of I/O pins. It is well-suited for complex applications that demand greater processing power and versatile connectivity. In contrast, the PIC16F18025 is a more compact option, suitable for simpler applications, thanks to its lower pin count and a set of essential peripherals. It strikes a balance between functionality and resource efficiency, making it suitable for cost-sensitive projects with moderate requirements. The PIC16F18076 falls between the other two in terms of pin count and features, providing a versatile option for applications with intermediate complexity. The selection among these microcontrollers would depend on the specific requirements of the project, considering factors such as processing power, I/O requirements, and cost constraints.

PCB CASE

PN-1329-ACMB



The PCB case PN-1329-ACMB is notably well-suited for mounting within a vehicle engine, demonstrating positive attributes that align with the demanding conditions of such an environment. Its robust construction and material composition contribute to a sturdy and durable housing, providing effective protection for internal electronics against the various challenges posed by an engine compartment. The case exhibits excellent resistance to mechanical stresses, including vibrations and shocks, which are prevalent in the dynamic and often harsh operational conditions of a vehicle engine. Furthermore, the design of the case facilitates secure mounting, ensuring stability and reliability during the vehicle's operation. The integration of features that enhance heat dissipation and temperature tolerance is particularly noteworthy, showcasing an understanding of the elevated temperatures commonly encountered in engine compartments. The positive attributes of the PN-1329-ACMB, including its robust construction, resistance to mechanical stress, and effective thermal management, position it as a reliable and suitable choice for securely housing electronics within the demanding environment of a vehicle engine.

MEMORY NEEDED

To be able to store the data collected from the sensors, we need to outline the number of values needed from the sensors to analyse:

Parameter to measure	Resolution	Number of values	Number of Bits Required
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Engine RPM	10RPM 0-8000 Revolutions	800	10
Engine Temperature	1C	100	7
Suspension Travel	1mm	300 (FR-FL-RR-RL)	9-9-9-9
Pitch	0.5	180	8
Roll	0.5	180	8
Yaw	1	360	9
Speed (mph)	1 mph	256mph	8

From this we can work out how many Bytes we need and how they will be organized in the memory.

	1 BYTE (CELL)	-	1 BYTE (CELL)
RPM		-	
TEMPURATURE		-	
LINEAR TRAVEL -		-	
FR		-	
FL		-	
RR		-	
RL		-	
PITCH		-	
ROLL		-	
YAW		-	
SPEED (mph)		-	

16bits

X 50 Samples/sec

X60 sec/min

X60min/hr

X2hr test drive

= 5,760,000 bits

GB=5.7 GB

So, we will need 8 GB of memory in SD card form for simple data mapping.

Connector Selection

Connectors	TE Connectivity Buchanan Series PCB Terminal Block	RS PRO PCB Terminal Block, 4-Contact	RS Pro 5mm Pitch Straight PCB Terminal Block
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TECH SPECS			
No Poles	2 to 12	4	3
Body Orientation Straight	Straight	Straight	Straight
Colour Green	green	green	Grey
Current Rating 6 A	10A	6 A	16 A
Gender Female	Female	Female	Gender Male
Length 10.16 mm	10mm -60mm	10.16 mm	Length 15 mm
Material Nylon 66	Nylon 65	Nylon 66	Material PBT
Mounting Type Through Hole	Through Hole	Through Hole	Material PBT
Number of Contacts 4	2 to 12	4	Number of Contacts 2
Number of Rows 1	1	1	Number of Rows 4
Pitch 2.54 mm	5mm	2.54 mm	Pitch 5 mm
Termination Method Screw	Screw	Screw	Termination Method Screw Clamp
Type PCB Terminal Block	PCB Terminal Block	PCB Terminal Block	Type PCB Terminal Block
Voltage Rating 125 V	300V	125 V	300 V
Insulation Resistance >2000 mΩ	5000 mΩ	>2000 mΩ	1000 mΩ
Insulation Withstand Voltage 2000 V ac	1500V AC	2000 V ac	1000 V ac
Operating Temperature Range -40 to +105°C	-33 to +120°C	-40 to +105°C	-40 to +105°C
Flammability Rating UL 94 V-	UL 94 V-0	UL 94 V-0	UL 94 V-1

The TE Connectivity Buchanan Series PCB Terminal Block distinguishes itself with its reliability and versatility in various applications. Featuring a sturdy construction, it ensures secure connections on printed circuit boards (PCBs). The Buchanan Series stands out for its robust design and high-quality materials, providing durability and stable performance even in demanding environments. Moreover, its modular nature facilitates flexibility in PCB designs.

Similarly, the RS PRO PCB Terminal Block, with its 4-contact design, offers an excellent balance between compactness and functionality. The 5mm pitch of the RS Pro 5mm Pitch Straight PCB Terminal Block contributes to efficient use of space on the PCB while maintaining a secure and stable connection. Its straightforward design makes it user-friendly, simplifying the assembly process.

When comparing these connectors, the TE Connectivity Buchanan Series PCB Terminal Block gains favour for its renowned reliability and adaptability. The RS PRO PCB Terminal Block, with its 4-contact and 5mm pitch, also presents a commendable option, particularly for applications where space optimization is crucial. The choice between these connectors ultimately depends on the specific requirements of the PCB design and the intended application, with both offering reliable performance in electronic connections.

Sensors Required

Engine RPM

RPM SENSORS	RS Compact VLS/5J Tachometer Optical Speed Sensor	check line VLS5/D	Industrial VRS Magnetic Speed Sensors
TECH SPECS			
Surface Speed	N/A	N/A	25m/s
RPM Range	3 to 250,000 rpm	0-250,000rpm	0-250,000rpm
Air Gap	25mm to 1000mm	1000mm to 2000m	0.127mm
Surface sensed	Reflective Tape	Metal	Metal
Voltage Range	4 to 7.5 VDC	5VDC	2.5v-5.5VDC
Operating Temp	-10 to +70 C °	-10 to +70 C °	-55 to +120C °

. The Industrial VRS Magnetic Speed Sensors and RS Compact VLS/5J Tachometer Optical Speed Sensor represent distinct approaches to speed sensing, each with its own set of advantages. The Industrial VRS Magnetic Speed Sensors leverage magnetic technology, providing durability and reliability in various industrial applications. These sensors are known for their robustness and ability to perform consistently even in challenging environments where dust and other contaminants are present. On the other hand, the RS Compact VLS/5J Tachometer Optical Speed Sensor employs optical technology, offering precise speed measurement through its optical sensing mechanism. Optical sensors are often favoured for their accuracy and suitability in clean environments where there is no risk of interference from magnetic fields. The choice between these sensors depends on the specific application requirements. If resilience in harsh conditions is crucial, the Industrial VRS Magnetic Speed Sensors might be preferred. Conversely, the RS Compact VLS/5J Tachometer Optical Speed Sensor could be the choice for applications demanding high precision in a cleaner operational environment. Both sensors contribute to efficient speed monitoring but cater to different environmental and application needs.

Engine Temperature

TEMP SENSORS	MLX90614 vers GY-906 BCC	LM35DZ	SE012 High-Precision Sensor Probe
TECH SPECS	Digital	Analogue	Analogue
Ambient Working Temperature	40-170 C °	-55 to 150 C °	-50 to 250 C °

operating voltage	3.3-5v	4v to 30v	2.5-5v
object temp	-70 to 380 C °	-55 to 150 C °	-40 to 250 C °
Accuracy	0.5 C °	0.5 C °	0..03 C °
ADC	17bit internal	N/A	N/A
Voltage Regulator	3.3v on board	N/A	N/A
V/C SCALE FACTOR	Digital	LINEAR +10mV	Linear +10mv/c

The SE012 High-Precision Sensor Probe, MLX90614 versus GY-906 BCC, and LM35DZ each offer unique advantages catering to diverse sensing applications. The SE012 High-Precision Sensor Probe stands out for its exceptional accuracy and precision, making it a preferred choice for applications that demand high-performance sensing. Its design incorporates advanced technology to ensure reliable measurements in various conditions. In comparison, the MLX90614 versus GY-906 BCC, known for its infrared temperature sensing capabilities, provides non-contact temperature measurement with a focus on versatility. This makes it suitable for applications where direct contact with the object is challenging or undesirable. The LM35DZ, on the other hand, is a reliable temperature sensor with a straightforward analogue output, making it a cost-effective and widely used choice for temperature sensing applications. The selection between these sensors depends on specific application requirements. If high precision is paramount, the SE012 High-Precision Sensor Probe would be the preferred option. The MLX90614 versus GY-906 BCC excels in non-contact temperature sensing scenarios, while the LM35DZ offers a simple and economical solution for general temperature measurement applications.

LINEAR POSITION TRANSDUCER

LINEAR POSITION TRANSDUCERS	PM- LFM 300	LIPS® P101 STAND-ALONE LINEAR POSITION SENSOR	Industrial LVDT Displacement Transducer Position Sensor AML/IE
TECH SPECS			

Max Electrical Stroke (mm)	300	50mm to 600mm	500
Output Signal	4-20mA or 0-10V	4-20mA or 0.5 to 4.5v	4-20mA or 0-10V
Supply Voltage	12-30VDC	5VDC	10-24VDC
Operating Temperature	-30 to 100 C °	-40 to 125 C °	-20 to 85 C °
IP Protection Class	ip65	IP65	ip65
Rod Material	stainless steel	stainless steel	stainless steel
Body Material	aluminium	anodized aluminium	anodized aluminium
Resistance	5k-10kohms	2kohm min	300ohm
PRICE	Around £500	£417.00	£225

The Industrial LVDT Displacement Transducer | Position Sensor | AML/IE and the PM-LFM 300 LIPS® P101 Stand-Alone Linear Position Sensor represent two distinct approaches to displacement sensing, each offering specific advantages. The Industrial LVDT Displacement Transducer demonstrates versatility in industrial applications, known for its reliability and precision in measuring linear displacement. Its robust construction makes it suitable for demanding environments where durability is crucial. On the other hand, the PM-LFM 300 LIPS® P101 Stand-Alone Linear Position Sensor is a notable option for applications requiring standalone linear position sensing. It excels in providing accurate and repeatable position feedback, making it suitable for various industrial and automation applications. The choice between these sensors depends on specific application requirements. If a robust and versatile displacement sensor is needed, the Industrial LVDT Displacement Transducer stands out. Alternatively, the PM-LFM 300 LIPS® P101 excels in scenarios where standalone linear position sensing is preferred, offering a reliable solution for precise position feedback in industrial settings.

Gyroscope - Pitch, roll and yaw

GYROSCOPE	SQ-GIX-2094 GRAVITYGYRO™ DYNAMIC INCLINOMETER, J1939	Multi-axis tilt sensor HDA436T-CANBUS
TECH SPECS		
Axes	Three (Elevation, Roll, Yaw)	Three (Elevation, Roll, Yaw)
Range	Elevation: +/-90° (internal) Roll: +/-180° (internal) Yaw: +/-180° (internal)	Elevation: +/-90° (internal) Roll: +/-180° (internal) Yaw: +/-180° (internal)
Static tilt accuracy	0.1° RMS (Elevation, Roll)	0.5° RMS (Elevation, Roll)
Dynamic tilt accuracy	0.5 ° RMS	0.1 ° RMS

Voltage	5 – 36DC V	9 – 36DC V
Current	30 mA typ. @ 12 VDC	60mA
IP rating	IP68/69K	IP67
PRICE	APROX £200.00	£128.69

The SQ-GIX-2094 GRAVITYGYRO™ Dynamic Inclinometer, J1939, and the Multi-axis Tilt Sensor HDA436T-CANBUS serve as advanced solutions for tilt and inclination sensing, each offering distinct features. The SQ-GIX-2094 GRAVITYGYRO™ excels with its dynamic inclinometer capabilities, providing real-time and accurate measurement of inclination angles. Its integration with the J1939 communication protocol ensures seamless data transmission and compatibility within automotive applications, making it a suitable choice for vehicle tilt monitoring. On the other hand, the Multi-axis Tilt Sensor HDA436T-CANBUS also incorporates a multi-axis tilt sensor design but with a specific focus on CANBUS communication. This sensor is particularly beneficial in automotive and industrial environments where CANBUS is a widely adopted communication standard. The choice between these sensors depends on the specific requirements of the application. If real-time dynamic inclinometer capabilities with J1939 communication are crucial, the SQ-GIX-2094 GRAVITYGYRO™ stands out. Conversely, the Multi-axis Tilt Sensor HDA436T-CANBUS offers compatibility with CANBUS systems, providing a tailored solution for applications where this communication protocol is preferred.

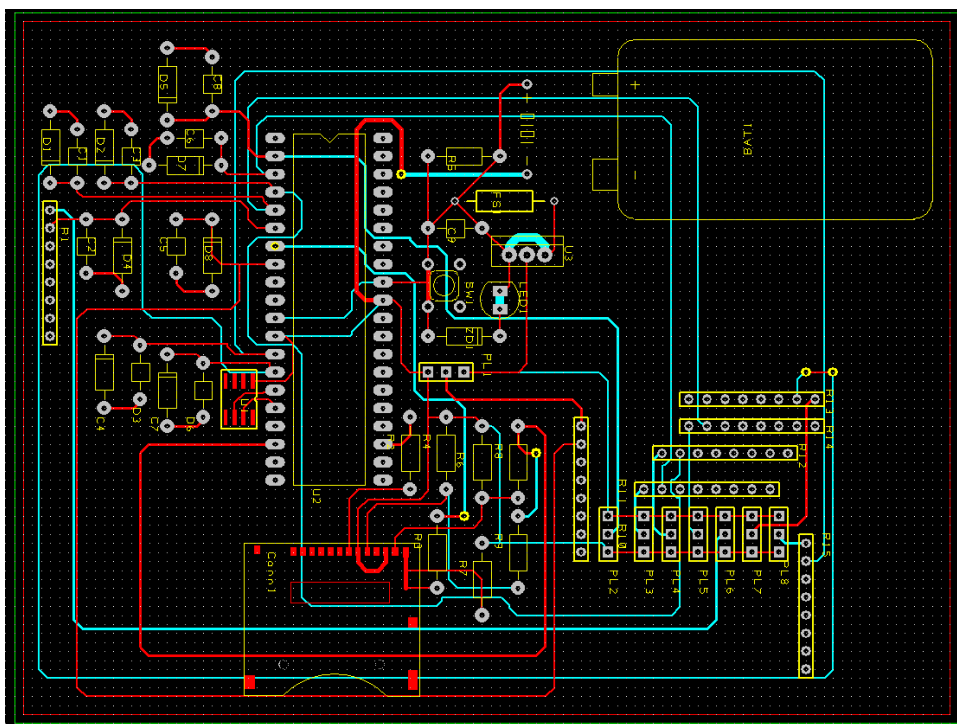
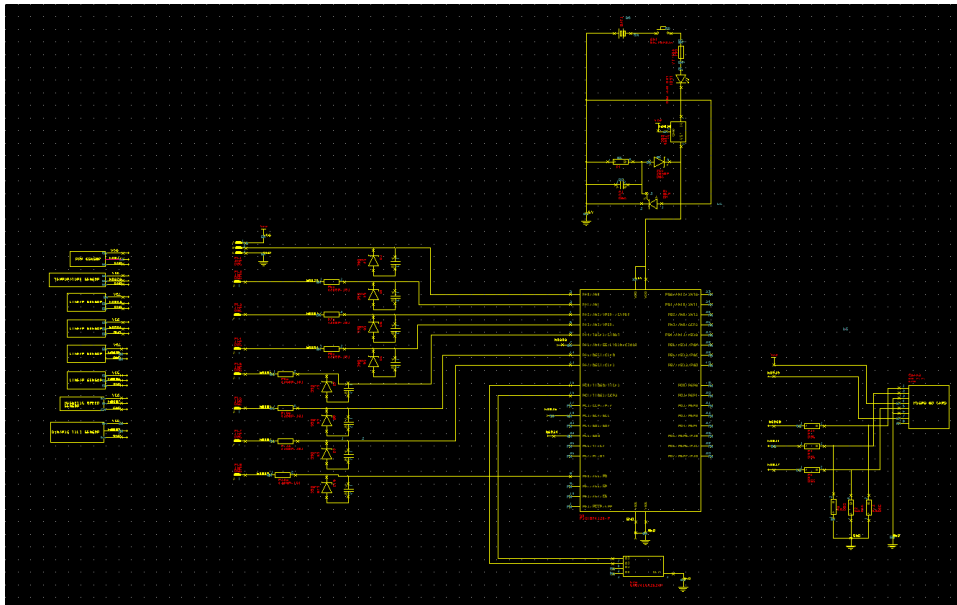
SPEEDOMETERS

SPEEDOMETERS	AiM Magnetic Speed Sensor 719 Plug	Magnetic sensor MGS201
TECH SPECS		
• power supply	6-24 VDC	10-30VDC
• output signal type	pulse 0-5 volt	2.5V
• max current output	20 mA	10mA
• max operating frequency	100 kHz	5kHz
• max sensibility Distance	20 mm	70mm
• Recommended Distance	10 mm	50mm

• Number of pulses for wheel revolution	1	1
• Operating Temperature Range	– 20 to +85 °C	-25 to 75 C °
IP Rating	IP66	IP67

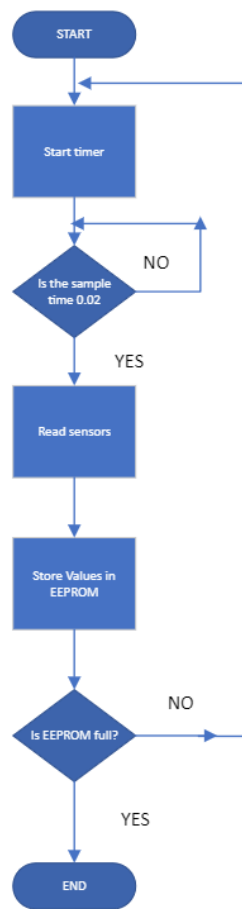
The Magnetic Sensor MGS201 and the AiM Magnetic Speed Sensor 719 Plug both belong to the category of magnetic speed sensors, but they exhibit differences in their design and application. The Magnetic Sensor MGS201 is known for its simplicity and reliability, providing a cost-effective solution for measuring speed based on magnetic field changes. Its straightforward design makes it suitable for various applications where a basic, yet dependable speed sensing solution is required. On the other hand, the AiM Magnetic Speed Sensor 719 Plug is a more specialized sensor designed by AiM, a renowned brand in motorsports and automotive applications. With a specific focus on the 719 plugs, it offers a convenient and secure connection, making it particularly suitable for motorsports and high-performance applications where precise and reliable speed sensing is essential. The choice between these sensors depends on the application's specific requirements. If simplicity and cost-effectiveness are prioritized, the Magnetic Sensor MGS201 presents a favourable option. However, if the application demands a higher level of precision, durability, and a specialized connection interface, the AiM Magnetic Speed Sensor 719 Plug becomes the preferred choice, especially in motorsports and performance-driven scenarios.

Full circuit design and a PCB design

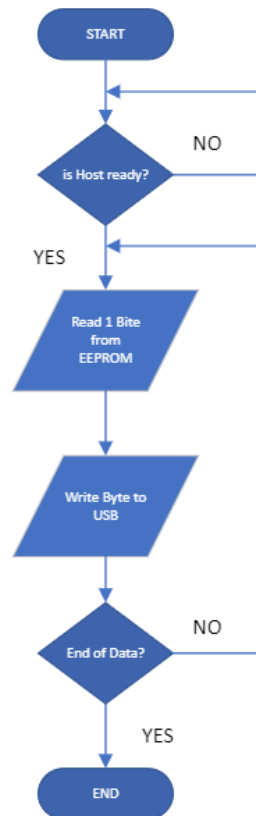


Prototype Software Design and Structure

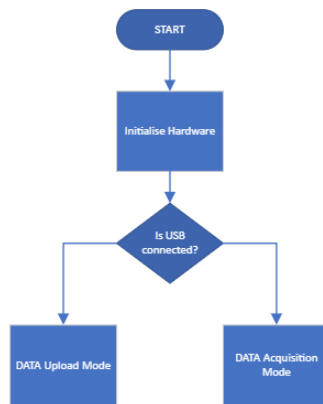
Data Acquisition



DATA Upload Mode



USB Insertion



Build Costs

Parts	Estimated Build Costs in GBP
Resistors	2
Capacitor	0.23

Switch	0.57
Battery	6
Zener Diodes	0.01
LED	0.97
PIC	7.42
PCB Case	27.08
SD card	10.02
USB Slot	1.39
Voltage Regulator	0.38
Connectors	2.5
RPM Sensor	163.25
Temp Sensor	68
Linear Position Sensor X4	1075.2
Gyroscope	100
Speedometer	66.72
TOTAL	1531.74

Improvements

Higher sampling rates of data. A higher sampling rate can be crucial for capturing rapid changes and fluctuations in data. It could also have a higher bit resolution for analogue input, improving the bit resolution of the data logger. Higher resolution can result in more accurate and detailed data acquisition. Therefore, increasing the logging memory because there would be more data to log and save, and this enhancement would allow users to log more data over longer periods without the need for frequent data offloading.

REFERENCES

Article title	Data Logger USB, 512K Logs, RS485 FieldLogger - Industrial Multichannel
URL	https://undercontrol.co.uk/temperature-controllers/fieldlogger-data-loggers/data-logger-usb-512k-logs-rs485-fieldlogger-industrial-multichannel/

Website title	UNDER CONTROL INSTRUMENTS LTD
Date published	January 13, 2023

Article title	www.novusautomation.com/en/fieldlogger INSTRUCTION MANUAL
URL	https://undercontrol.co.uk/wp-content/uploads/2020/11/manual_fieldlogger_v16x_1_en.pdf

Article title	CEBO LC - CESYS Gesellschaft für angewandte Mikroelektronik
URL	https://www.cesys.com/en/our-products/daq-devices/cebo-lc.html
Website title	CEBO LC - CESYS Gesellschaft für angewandte Mikroelektronik

Article title	CEBO-STICK - cesys.com
URL	https://www.cesys.com/fileadmin/user_upload/service/CEBO-LC-STICK/reference%20manuals%20%26%20guides/CEBO-STICK/ug106-cebo-stick.pdf

Article title	Delphin Expert Key 100
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URL	https://dataloggerinc.com/product/expert-key-100-data-acquisition-system/
Website title	CAS Dataloggers
Date published	June 01, 2022
Article title	PC-supported measurement
URL	https://www.dataloggerinc.com/wp-content/uploads/2016/09/expertkey-data-acquisition-system.pdf

Article title	PIC18F4320 - Microchip Technology
URL	https://www.microchip.com/en-us/product/PIC18F4320

Article title	PIC16F18025 - Microchip Technology
URL	https://www.microchip.com/en-us/product/PIC16F18025
Date accessed	November 24, 2023

Article title	Microchip Technology
----------------------	----------------------

URL	https://ww1.microchip.com/downloads/aemDocuments/documents/MCU08/ProductDocuments/DataSheets/PIC16F18015-25-44-45-Microcontroller-Data-Sheet-40002340B.pdf
------------	---

Article title	PIC18F2220/2320/4220/4320 Data Sheet - Microchip Technology
URL	https://ww1.microchip.com/downloads/aemDocuments/documents/MCU08/ProductDocuments/DataSheets/39599g.pdf

Article title	PIC18F4320 - Microchip Technology
URL	https://www.microchip.com/en-us/product/PIC18F4320

Article title	PIC18F4320 - Microchip Technology
URL	https://www.microchip.com/en-us/product/PIC18F4320

Article title	PN-1329-ACMB Bud Industries Mouser - Mouser Electronics
URL	https://www.mouser.com/ProductDetail/Bud-Industries/PN-1329-ACMB?qs=HBWAp0VN4RhHWvEakCHwBA%3D%3D

Article title	NEMA 6P / IP68 W/EXTERNAL MTG. BRACKETS No. - Mouser Electronics
----------------------	--

URL	https://www.mouser.com/datasheet/2/55/hbpn1329amb_1-3062939.pdf
------------	---

Article title	Buchanan
URL	https://www.te.com/usa-en/products/brands/buchanan.html
Website title	TE Connectivity
Date published	June 23, 2022

Article title	RS PRO PCB Terminal Block, 4-Contact, 2.54mm Pitch, Through Hole Mount, 1-Row, Screw Termination
URL	https://uk.rs-online.com/web/p/pcb-terminal-blocks/7901102?gb=s
Website title	RS

Article title	RS Components
URL	https://docs.rs-online.com/1adc/0900766b8157c0ef.pdf
Date accessed	November 25, 2023
Article title	RS PRO - 4948912 - 5mm Pitch Straight PCB Terminal Block with Screw ...
URL	https://us.rs-online.com/product/rs-pro/4948912/70644782/

Article title	ENGLISH - RS Components
URL	https://docs.rs-online.com/eded/0900766b8157d5ad.pdf

Article title	Compact VLS/5J Tachometer Optical Speed Sensor
URL	https://uk.rs-online.com/web/p/tachometer-accessories/0622565
Website title	RS

Article title	RS Components
URL	https://docs.rs-online.com/924c/A700000007706949.pdf

Article title	VLS
URL	https://www.checkline.com/product/VLS
Website title	Checkline

Article title	Digital Torque Screwdriver - Checkline
URL	https://www.checkline.com/res/products/126591/TSDScrewdriverInstructionManual.pdf

Article title	VRS High Output Series Sensors
----------------------	--------------------------------

URL	https://sps.honeywell.com/us/en/products/advanced-sensing-technologies/aero-and-transportation-sensing/aero-and-transportation-sensors/speed-sensors/industrial-vrs/vrs-high-output-series
Website title	Honeywell

Article title	MICRO SWITCH™ Specialty Large Basic Switches: BS DT MN MT TB Series
URL	https://prod-edam.honeywell.com/content/dam/honeywell-edam/sps/siot/en-us/products/switches/basic-switches/specialty-basic-switches/common/documents/sps-siot-micro-switch-mn-tb-mt-dt-basic-product-sheet-004956-3-en-ciid-44174.pdf

Article title	Datasheet for MLX90614
URL	https://www.melexis.com/en/documents/documentation/datasheets/datasheet-mlx90614
Website title	Melexis

Article title	LM35 Precision Centigrade Temperature Sensors datasheet (Rev. H)
URL	https://www.ti.com/lit/ds/symlink/lm35.pdf

Article title	PT100 probe, 1/10 DIN accuracy, 2 m - Farnell
URL	https://www.farnell.com/datasheets/2615421.pdf

Article title	Linear displacement sensor - 0-10 to 0-300 mm - Rod-eye bearing
URL	https://en.pm-instrumentation.com/lfm-linear-displacement-sensor-0-10-to-0-300-mm-rod-eye-bearing
Website title	LFM
Article title	GENERAL FEATURES - PM Instrumentation
URL	https://www.pm-instrumentation.com/storage/7999/Datasheet_LFM_PMi_EN.pdf

Article title	GENERAL FEATURES - PM Instrumentation
URL	https://www.pm-instrumentation.com/storage/7999/Datasheet_LFM_PMi_EN.pdf
Article title	P101 Stand Alone Linear Position Sensor
URL	https://www.positek.com/products/linear-position-sensors/p101-stand-alone-linear-position-sensor
Website title	Positek
Article title	Industrial LVDT Displacement Transducer: Position Sensor
URL	https://appmeas.co.uk/products/lvdt-displacement-sensors/industrial-lvdt-displacement-sensor-aml-/?view=print&_gl=1%2A1hp47eb%2A_ga%2ANjUwMTk3MDQ5LjE3MDA4NzY5MDc.%2A_ga_GT5KJ5LESL%2AMTcwMDg4NTUyMS4yLjAuMTcwMDg4NTUyMS42MC4wLjA
Website title	Applied Measurements Ltd

Article title	SQ-GIX-2094 - SignalQuest.com
URL	https://signalquest.com/download/SQ-GIX-2094%20Dynamic%20Inclinometer,%20Rugged%20AHRS,%20J1939.pdf
Article title	Catalogs
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Website title	RION/dynamic tilt sensor inclination angle sensor anti-vibration inclinometer digital output/HDA436T - SHENZHEN RION TECHNOLOGY CO.,LTD - PDF Catalogs Technical Documentation Brochure
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URL	https://www.aimtechnologies.com/support/sensors/Datasheet_MagnetoresistiveSpeedSensor_103_eng.pdf
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