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Electronic System Design

ACDA6002

Non-Invasive Implementation of Monitoring Equipment for Automotive Platforms

2112087

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Abstract

The report herein explores the potential application of a PIC microcontroller as a basis for the development of a non-invasive measurement solution for logging various data points regarding the function and properties of a vehicle in transit. The details within include a specification of a non exhaustive list of literature, a template for design, diagrams illustrating the processes within the design, a summary of components to be utilized in production and a discussion of potential improvements and shortfalls of the design. This system is notably restrained on words and some editorial decisions were made to reduce its word count in the removal of sections. Considering these restraints, the report seeks to provide as good of an insight into the development of the system as possible.

Introduction

Herein, this report shall investigate the best methods to implement non-invasive test and measurement capabilities onto an automotive platform. In this case, using the LADA Riva as a stand-in for a basic platform. This additional module shall seek to accurately monitor several properties. These being the Revolutions Per Minute (RPM), Temperature of the Engine block, Front and rear suspension travel, Vehicular speed and the relevant gyroscopic values of pitch, roll and Yaw. The nature of the design is to be somewhat modular, as to allow relatively easy retrofitting to different models of vehicle.

This report will seek to illustrate these properties as accurately as possible while also including the factors necessary for a safe and continued function of the device, namely including the design of the system, casing and component specification as to allow for the best theoretical operation. It is of note that this system will not transition into production or physical tests, so this report shall seek to investigate the function as accurately as possible theoretically, making use of simulation software where possible and best applied.

Relevant Literature

The relevant literature can largely be separated into two separate, distinct categories, these being specification documentation, relevant to the components selected. The second comprises testing standards and reports.

Literature Review

The following table shows a brief review of literature examined in the pre-design phase of this report, in the interest of brevity it will only be represented as this table.

Subject or Title	Boones	Banes
Real time vehicle monitoring and tracking system based on embedded Linux board and android application [1]	High level solution to long range data transfer Monitors temperature of engine	Much higher level application than in this case Does not measure all aspects required Functions more as a monitoring system and safety mechanism than logging system. Little compatible insight

Vehicle and Driver Monitoring System Using On-Board and Remote Sensors [[2]	Functions with generic sensors Uses non-invasive monitoring methods	Utilises onboard car technologies unavailable to this report Focuses more on efficiency and pollution rather than data of properties regarding car operation
An Embedded Data Logger Based Vehicle Trajectory Monitoring System[3]	Embedded system Tracks trajectory, which links intrinsically to speed Discusses Calibration, a hereto unthought of aspect of design	Uses GPS, and unlikely system to be utilised herein Utilises alternative processors to those intended I this report
An Embedded Data Logger for In-Vehicle Testing[4]	Embedded system Tracks some aspects that might be useful as well as considerations regarding data and the software step Provides a template for component explanation	Uses a different microcontroller than intended Focuses more on the software aspect than the embedded electronics required herein. Sources are questionable

Summary

Ultimately, these reports provide some valuable insights into the testing and requirements of various systems, although oftentimes these systems differ dramatically in some form or another to that required from the specification here. Some of these did, nonetheless, provide valuable insight into aspects not limited to testing protocols, design methodology and implementation in a physical and software space. This does all culminate in a series of reinforceable and tested approximate methods to work with. These methods, when modified slightly for the purposes required for this task, will give a solid springboard for operational design.

Component justification

RPM Measurement

The RPM measurement is difficult to measure without bending the definition of invasive as measuring it accurately requires access to the engine block and thus, some direct installation and fixing into position that would likely require alteration of the block, although the method chosen to measure would be a large influence on this, with a switch system requiring installation onto both the block and crankshaft, which could also need replacing[5]. While the alternative most likely to be employed herein, a reflective method, would comprise mostly of affixing a laser mechanism to the block which should require minimal replacement short of direct damage. It is in large part due to this reliability that this is chosen.

The RPM measurement system can be simple to complex, either the count of the revolutions could be stored in a small local counter, which is then shared with the central controller after a fixed period or capacity or have it directly sent to a microcontroller – however, this might occupy too much of the chip at high frequencies. Assuming a maximum RPM of 4000[(Or 67 RPs) – the counter and laser would need to be capable of reading 67 samples a second, though these samples would only be a single bit until the counter sends its quantity, which would likely be a 16-bit sequence, which would store 16 minutes at maximum revolutions or 128bits of data over two hours for the aggregate revs per 2 hour period. The item chosen to best fit the specification give an RS Pro photoelectric sensor, [seen here](#).

Temperature Measurement

Surface level analysis for temperature measurement simples simple compared to other aspects due to be measured, as it will unequivocally require a thermometer of some description. However, the exact

specification of thermometer is subject to debate. It was determined that the most accurate method may derive from a thermistor or, alternatively an IR thermometer could be used and would likely be the most reliable option, due to the lack of contact required for both installation and for measurement, resulting in a system with minimal points of failure.

The memory requirement for a temperature measurement should be required infrequently enough as to only result in a minimal burden, assuming a measurement approximately every minute, which, due to the latent heat capacity of steel components, should be plenty to measure change. Assuming a digital output, a 10 bit binary output should be plenty to accommodate an upper band temperature range (Even accounting for floating point). Assuming the heating rate is no faster than half of that as a blow torch[6], one minute per sample should be enough to detect significant shifts within a reasonable time. This would result in 2560 bits per 2 hour period.

The model of IR device selected is Calex PMO-151-HT-C Infrared Temperature Senso, [seen here](#).

Gyroscopic Measurement

Gyroscopic measurement is one that is defined much less by the equipment and much more by the parameters, while methods such as accelerometers or magnetic systems can provide alternatives, gyroscopic devices are by far and away the most efficient[7], compact and durable of the solutions. The far greater challenge comes with approximating the degrees of Pitch, Roll and yaw required for a typical measurement. Foremost amongst these is that of Yaw, which would easily be anticipated as 400 gradians and would likely be employed as such, though greater than 200 gradians would be unnecessary in most applications. The far greater restriction comes when considering pitch, which, particularly in compact models, limits the selection of components dramatically. While it is arguable if more than 60 gradians would every be reasonably required, since most roads are limited to around 50 at a maximum, even in Gwynedd[8]. Using the digital cooperative gyroscope as specified, the measurement dimensions should encompass reasonable use of a car and should transmit via SPI, operating at an output of 16bits. Thus it can be assumed that, if a measurement is taken every 25 seconds (Thus taking a measurement approximately every 100m travelled at 45 Miles per hour, an approximate average speed of the commuter in transit[9] when taken as a high proportional median average). This would then result in 4608bits of data over a 2-hour period.

The selected component to meet this specification laid out above is the 3-axis digital gyroscope produced by ST, [as seen here](#).

Speed Measurement

Speed can be measured in a multitude of ways, the two main categories of which are that of rotary and stationary calculation. With a rotary method, one could use a reflective strip or beam to measure the rotations of a wheel and, given the quantity of rotation compared to the size of the tire, ascertain the distance travelled and the speed at which travel is taken. Alternatively, a stationary method would utilise an accelerometer to calculate the acceleration and thus approximate the speed of locomotion. This report has elected to use this stationary accelerometer method as it would first, not require installation on the exterior of the car and thus would limit its risk of being damaged and secondly, would avoid complications that may arise because of steering altering the reflection or detracting of light from the wheel. Thus, in keeping with the design methodology of this equipment, a high degree of reliability is

retained. This reliability is also demonstrated in how often they are employed in car subsystems already[10].

The model chosen for implementation is the ADAFRUIT INDUSTRIES 3-Axis sensor, as [seen here](#).

As this component would utilise I2C for communication, the pin breadth of the component is not at issue, instead the data rate would equate to 14 bits every time a measurement is taken. In order to conserve data efficiency, readings only being taken when acceleration changes by more than 2.5% would be adequate, though this would not reduce the load on the processor.

Suspension Measurement

The suspension mechanism can be approached from multiple aspects, using lasers to measure distance between the axle and body of the vehicle. However, the most viable of all of these systems likely results from using a draw-potentiometer with a form of wire or string pulley, which would produce resistance proportional to the distance, thus allowing a measurement to be ascertained, equally in this instance, due to holding the same merits as using a string potentiometer, this report has elected to use a draw wire position sensor due to ease of data processing, with the model selected to be the Strainsense CD120L, [seen here](#). Though it is worth noting that this is just a precision potentiometer with a small amount of onboard processing.

The balancing of data volume compared to accuracy is a particularly prudent issue to address in this instance due to the presence of four measurement nodes and the potentially infinite data throughput of each one of these. To best balance these properties, this report has elected to take suspension measurements a system of averages to reduce the overall data load requirement. This ends up creating a software-based solution ultimately but will be formatted in such a way that every 0.25 seconds (Approximately every 5m at 45mph, established earlier as standard assumed average speed) The software on the microcontroller would aggregate the results periodically as to reduce the total requirement for storage by a logarithmic factor. This simple form of data compression should increase the efficiency of this, the most data intensive metric on the device.

This report calculates that, though a 8bit resolution of input from an ADC in four locations, aggregated every 15 minutes, instead of requiring 921600 bits be stored, it would instead reduce the stored value to that of only a 15 bit variable, if then aggregated another 7 times for the total two hour period, this would result in a 22bit variable with a temporary requirement for 28800 bits in this window, reducing the data requirement from 921600 to 115222 bits. This could be applied to further increase data rates should the sample time provided for prove ineffective in testing, despite assumptions, and would still greatly reduce data requirements.

Microcontroller

The issue of the microcontroller is a simple one, largely due to the limited selection of suitable fits for the specification. This being the requirement for; A USB compatible pin arrangement, SPI compatibility and a relatively high operating frequency with a comparatively similar quantity of pins as to allow for greater modularity. The basic requirements being a relatively high clock cycle, adequate communication protocols for the hardware and a USB module for interfacing with components and devices, such as a laptop to analyse the recordings or, in this particular case, and SD card reader.

The selected microcontroller is that of the PIC18F66J50, [seen here](#), which is designed with the intention of being used on monitoring equipment that interfaces with a laptop or computer[11], with more than enough RAM memory and storage to allow for seamless functionality with plenty of space for expansion of data throughput or scale, while it does lack non-volatile memory, this was not stated to be an issue in the specification.

Commented [JB1]: [PIC18F66J50](#) | [Microchip Technology](#)

Miscellaneous aspects

These parts are largely arbitrary or require little in the way of consideration due to the wide compatibility of a large number of components with the system.

This includes the SD card, connectors, board details and components such as buttons. With the SD coming in to about 22GBP for the reader and 11GBP for the card.

The selected connector type is opted to be copper on the board, due to the high level of adoption and its position as a defacto standard for PCB design[12]. While the respective connections external to the board would likely mostly use copper based wires, albeit with insulated cores.

The casing unit for the internal and external components depends largely on the environment of use, while it is possible and feasible to over protect compared to the risk, but the devised solution will account for 95% of reasonable risk, as to fit for the typical standard of design[13].

The battery unit would need to sustain enough charge for use of the system over an approximately two hour time period. The approximate milliamperage of the system comes to approximately 254mA, as such the amp-hour requirement for it is quite low (approx 0.5Ah). This report has elected to use any form of D battery to fulfil this with plenty of excess if a miscalculation has been made or the battery is not changed for an extended period.

As such, it is elected that a Pelicase should suffice, with the Micro likely fitting the board in fairly comfortably – a smaller unit could be used for more board specific dimensions but it is likely that with a Pelicase, there would be little need for further casing short of for organisational or more short-scale transit. This particular model would come to about 34.65GBP.

Aggregated Cost

The sum of parts are estimated to be as follows:

PCB and PCB components: ~21.01GBP

Casing unit: 34.65GBP

Battery Unit: 3.20GBP

Suspension subsystem: ~160.00GBP

Speed subsystem: 5.00GBP

Gyroscope subsystem: 17.34GBP

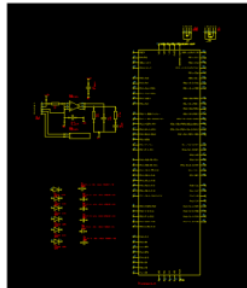
Thermometer subsystem: 241.20GBP

Total cost: 515.56GBP

As observable in figure [x], the structure of the circuit is largely defined. One issue that first appears is that the system lacks the correct components in the diagram. As previously outlined, it was desired that a PIC18F66J50 be used in the system and, indeed, that is the intended device even despite the diagram. Due to library limitations, this particular and similar models appeared to be absent from the version of proteus employed by the author. As such, a pic with the same number of pins was selected and used to represent the PIC18F66J50. The interfacing with the chip is largely controlled by clamping and conditioning at least for those components that operate largely off resistance based comprehension. This doesn't explicitly need to be the case when considering direct digital interfacing that is present on some measurement devices.

Above, Figure 1, Proteus design of the system

In figure 1 we can observe the PCB design schematic. While this one does have a PIC from the same family as the desired PIC, it is still notably absent from the libraries present in the particular installation that the author had access to. The system designed does largely conform with standards, however the operation of such a system is hard to demonstrate exclusively using design software. As a large portion of the solution to the given problem is intended to be that comprising a software component, without employing a physical demonstration, a theoretical examination is all that could be presently tested.

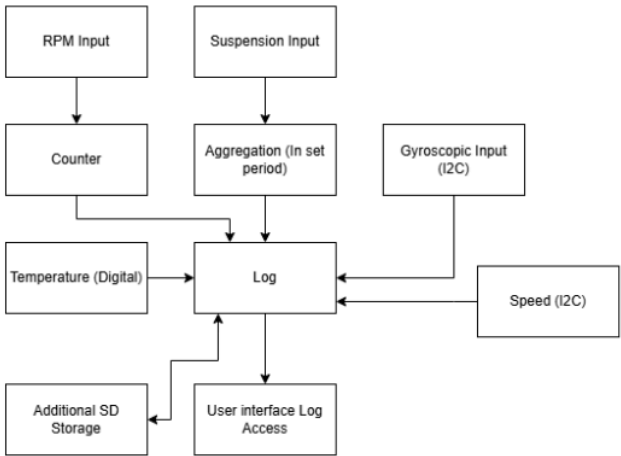


Above, Figure 2, EasyPC schematic

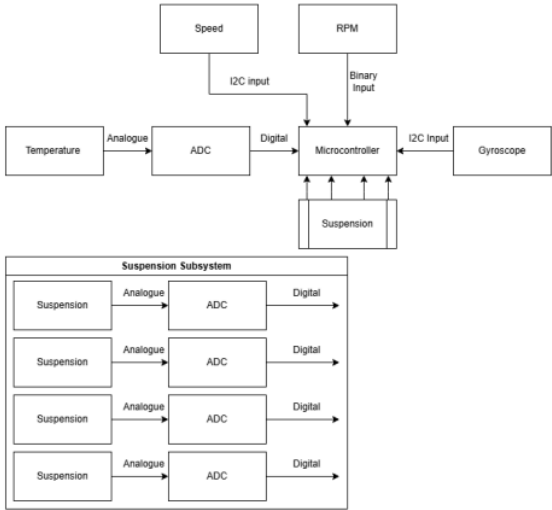
Following the prior point, figure 3 shows an approximate diagram as to the flow of data in the system, with figure 4 showing the connection of components. Each of these augments their select subsystems, with the software largely holding responsibility for processing and compression as outlined in the previous section, the image in figure 4 shows the function of the entire system in a logical sense, in lieu of some aspects absent in the alternative diagrams above.

The software aspect of design is likely to be an incredibly critical part of the design to ensure functionality of, due to it acting as both the interface and processing mechanism, without even considering its role in compression, this would lend to a requirement to ensure interoperability with some form of control software and allowance for the SD card memory to be utilized either as a means to draw code from or, more likely, to store data that would be inviable to store within the chip itself.

Ultimately, despite the inherent complexities, the above is feasible and by no means impossible to implement, though it is also of critical note that, while design shortfalls may exist, the theoretical operation of the system is sound.



Above, Figure 3, Software setup for logging of data



Above, Figure 4, Diagram of connections and interface requirements

Conclusion

It is undeniable that there are some shortfalls in the design, though it is true that in every effort, this report tried to make a system that fits into various systems due to a focus on reliability and replicability, with a sub focus on modularity. While drawing a complete success from this model might be short of that which it is truly deserved of, the consideration given to adaptability and particularly with consideration to data management, should mean that this report can at least be considered a partial success. Future models could benefit from further research into interfacing between the chip, greater research into the software structure and use of the modularity to develop one that might be more functional for the specific use case intended, but short of this, the report has demonstrated the basic feasibility of this project and design and, with the aforementioned research, could develop into a fully functional model sustaining all the intended functionality required.

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FINAL GRADE

GENERAL COMMENTS

33/100

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GRADING FORM: SMU GENERIC_GJ

JACOB BROWN

32.95

RESEARCH-INFORMED LITERATURE



The literature review is very limited and would be improved by adding more devices, a review of each device and followed up with a comparison table of pros and cons as you see them. 35%

3.5

KNOWLEDGE AND UNDERSTANDING



Your schematic is somewhat complete but a number of issues are visible :- SCK2 is not taken to the correct pin, it is on rd3 not rd6; you have put signal conditioning blocks on the suspension, temp and rpm inputs, what are the signal conditioning circuits, this is supposed to be a completed circuit and not a guess the component game; You have incorrectly named the clamp and an amplifier circuit and applied +12V and -12V without reference from whence they came; You have parallel connected your gyro and speed input in such a way that neither can speak as there is no selector on either. You have not transferred the schematic to easy-pc and therefore have not attempted to design a pcb. You have also connected analog inputs to pins that are not meant for analog inputs . Your input for RPM is correctly taken to a interrupt input. 25%

6.25

ANALYSIS



A reasonable selection of micro controller, the selected sensors are reasonable but you have not

14.7

included any images or comparative tables showing the types of sensors you could have chosen from. Good case selection. No selection of connectors. 42%

PRACTICAL APPLICATION AND DEP.



The costings, are not related to actual components and are therefore meaningless guesstimates. 20%

4

SKILLS FOR PROFESSIONAL PRAC.



The report is poorly presented but contains some tabled data but no images/illustrations and few diagrams except the operational flow charts. A reasonable array of references were included. You appear to have been more intent on trying to minimise the amount of data storage used, rather than following the specification you were given to design to.

A specification is given to you as a blue print for what your customer requires, it is not given to you so that you can ignore it and continue with your own blue print. More care and better time management would have seen a huge improvement in the quality of this submission which is unexpectedly disappointing. 45%

4.5