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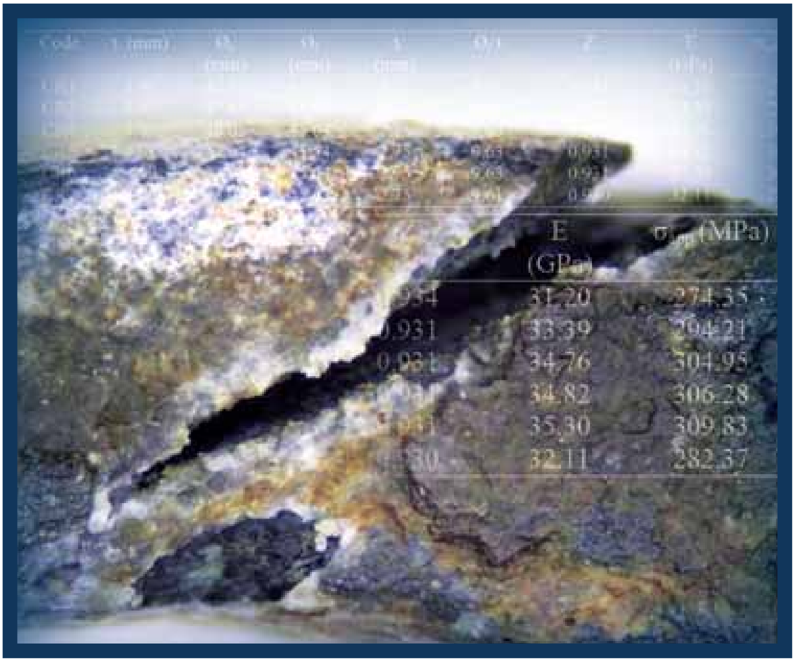

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Design and Development of Universal Data Logger for Testing Vehicle Performance

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ABSTRACT

Monitoring car performance in terms of fuel consumption, velocity and other important parameters is crucial in order to ascertain whether a car is operating optimally. The purpose of this research is to design and develop a new data logger to monitor general car performance. Data has been collected via a wireless device attached to the car, which transmits information to the base station. The data logger (data acquisition processor) was developed based on an 8-bit Single-Chip Microcontroller. Speed, revs, fuel levels and temperature probes placed in the experimental car provided the required information. The information was then processed by the data acquisition processor before being transmitted to a computer via an RLM3000-Radio Link Modem. Laboratory results of the data logger for different speeds, revs and fuel levels are presented and discussed herein.

***Keywords**: Data logger, Speed, Revolution, Fuel, Temperature, Car Performance*

Introduction

A data logger is an electronic device that records data over time or spatially using either built-in instrumentation, sensors or via external instruments

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and sensors. The design of data loggers are based upon digital processors. Data loggers are small, battery powered and portable, hence making them highly versatile; applications may be as general purpose measurement devices or as highly specific devices for measuring a particular parameter in a specified environment. It is common that general purpose loggers are programmable and many are static with a limited number of changeable parameters. Due to the versatility of electronic data loggers they have replaced chart recorders in many applications [1]. This research focuses on the development of a data logger development capable of presenting and enabling the analysis of car performance related data. The data logger developed has been designed to essentially provide real-time information thus elucidating not readily apparent details of car performance.

The data collected by the data logger can be used to address several vehicle performance issues. The most basic use of the data is the creation of a vehicle usage log, which enables evaluation of the degree to which the vehicle is utilized and to determine when, or how often, maintenance is required. Data regarding distances and journey times can be used to optimize the routes taken for regular delivery runs. Input such as the peak engine speed, engine low oil pressure and engine temperature could be used to verify the abuse of a vehicle or conversely, to validate vehicle warranty. The monitoring of battery voltage can be used to detect when problems occur in the vehicle electrical system; hypothetical battery failure or alternator problems could be detected earlier and rectified prior to failure, thus reducing unnecessary vehicle down time [2].

System Design (Hardware Design)

The data logger prototype measures $16 \times 9 \times 4$ mm (Figure 1) and can be readily miniaturized using SMT techniques. Figure 2 presents the system architecture of the data logger.

The 8-bit Single-Chip Microcontroller has been used as the central control unit for data flow coordination. The decision to use this microcontroller is based on its capability to drive a stepping motor, for external meter control, or cross coil. As a result the data logger design will be simpler, less time consuming to fabricate and more cost effective. The design process is initiated by first constructing the overall system specifications outlined in [3]. The data logger is composed of a number of components: a12V voltage supply which regulates a dc supply for the

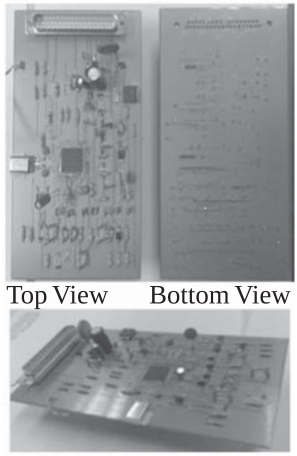

Figure 1: Data Logger Prototype

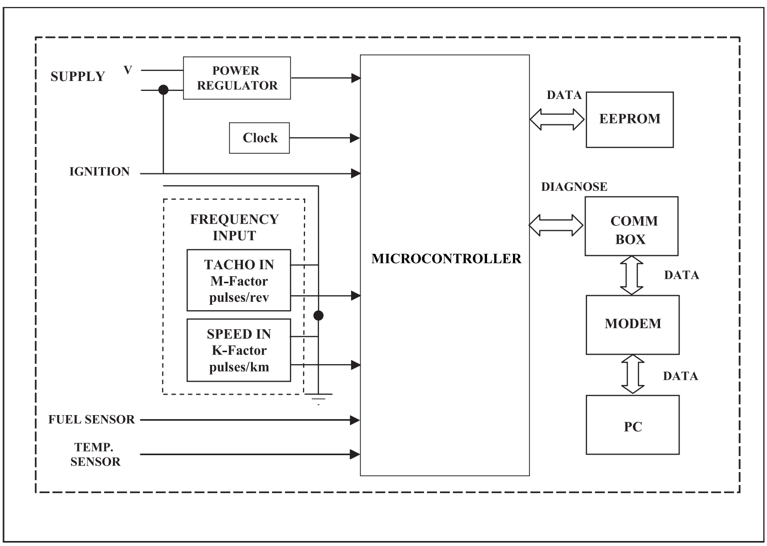

Figure 2: System Architecture of the Data Logger

microcontroller, a clock which generates an 8.00 MHz frequency to the Microcontroller and the four inputs from the different sensors, namely Speed, Tacho, Fuel and Temperature. All sensors used have been made available in the target vehicle. The speed and tacho sensors will supply a fussy frequency that represents the speed of the vehicle and the revolutions per minutes (r.p.m). The fuel and temperature sensors will be used to evaluate the resistance values that indicate the current value of fuel left in the fuel tank and the engine temperature.

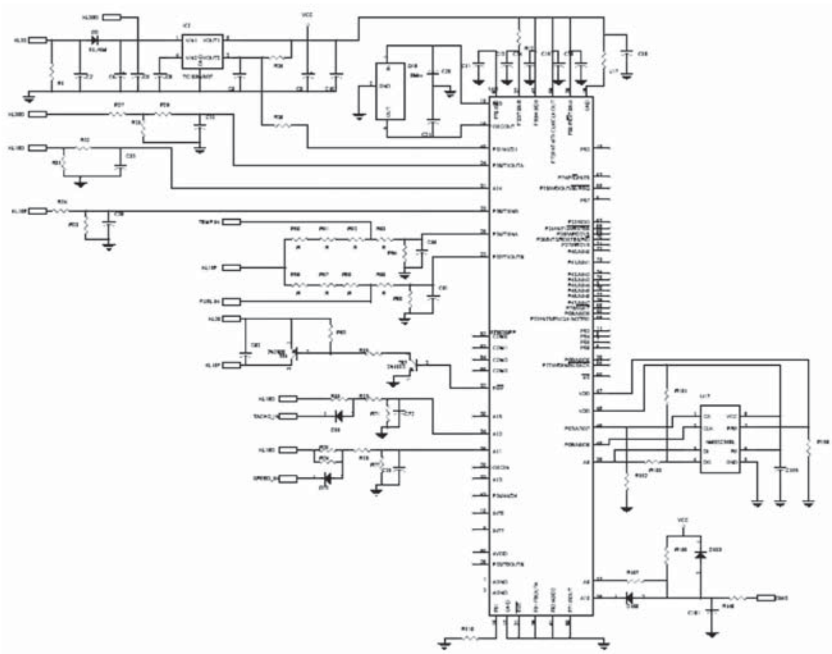

Figure 3: Circuit Diagram Design of the Data Logger

The circuit diagram of the data logger is presented in Figure 3 and shows that the microcontroller uses a memory bank comprising of 8 SPI EEPROMs for storing data. As part of the circuit design, a communication box (COMM BOX) has been developed to enable communication between the microcontroller and a personal computer. The COMM BOX enables the data logger to receive and transmit data from external sources using RS-232 and **RLM3000-Radio Link Modem** communication protocol [4-5]. The next section will explicate the algorithm used in the software development.

Software Design

Data logger operation is controlled by the microcontroller software code residing in the microcontroller. The following section describes in detail the connection between the vehicle and the data logger. The algorithms used to calculate the speed, revolution, fuel and temperature are also presented.

Speedometer Gauge

The connection of the hall sensor with speed input is shown in Figure 4. The microcontroller measures the frequency of the pulses received as input and drives the stepper motor to a position which is dependent on the frequency. There should not be any visible ‘step’ movement of the

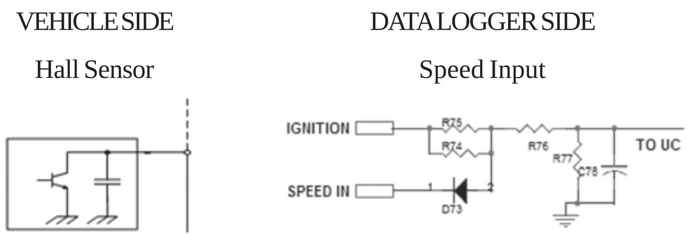

Figure 4: Speedometer Connection Diagram

speedometer gauge. The speed input is received from an open collector hall sensor. The input signal is calibrated by means of the pulses/km number [k-factor] programmed into the EEPROM. The k-factor is stored in the EEPROM with a resolution of 1 pulse/km. K-factor storage is limited to values between 2000 and 8000, where the speed is calculated according to:

$$\text{Speed} = \frac{f \times 3600}{\text{k-factor}} \tag{1}$$

where the k-factor = $2548 \frac{\text{pulse}}{\text{km}}$ and f = Input frequency (Hz).

The measurement of speed with the k-factor of 2548 pulse/km is tabulated in the Table 1. This table compares the laboratory results obtained during the data logger troubleshooting sessions.

Table 1: Speedometer Gauge Characteristics- km/h Scale

Input frequency (Hz)	0	14.16	28.31	42.47	56.62	70.78	84.93	99.09	113.28	127.44
Measured Speed (km/h)	0	20	40	60	80	100	120	140	160	180

Tacho Gauge (Revolution)

The connection of the tacho and tacho input to data logger is presented in Figure 5. The microcontroller measures the frequency of the pulses received by the input and drives the stepper motor to a position dependent

VEHICLE SIDE DATA LOGGER SIDE

Tacho Tacho Digital Input

Signal = square wave with 50 % duty cycle

Figure 5: Tacho Connection Diagram

on the frequency. There should be no visible 'step' movement of the Tacho gauge. The tacho is calculated according to:

$$\text{Speed} = \frac{f \times 3600}{\text{k-factor}} \tag{2}$$

where m-factor = engine factor, f = input frequency (Hz) and r.p.m = revolutions per minute.

The gauge response specifications are based on the frequency input signal versus the m-factor of an 8000 r.p.m. engine (2 pulses per revolution) and are presented in Table 2. This table has been used to evaluate the laboratory results during the data logger troubleshooting sessions.

Table 2: Tacho Gauge Characteristics

Input frequency (Hz)	0	25	50	75	100	125	150	175	200
Measured Revolution (r.p.m)	0	1000	2000	3000	4000	5000	6000	7000	8000

Fuel

A resistive sender provides the fuel tank level and the microprocessor measures the analogue input for the resultant voltage. The fuel sender connection to the data logger is presented in Figure 6. Any increment of fuel level will not be displayed during ignition on (normal condition), the

VEHICLE SIDE — DATA LOGGER SIDE

Fuel Sender — Fuel Sender Input

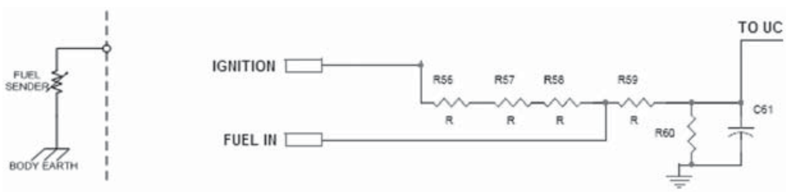

Figure 6: Fuel Sender Connection Diagram

increment of fuel will only be displayed during ignition off to on. The fuel-input value (Table 3) is damped by the microprocessor software.

Table 3: Fuel Level Characteristics

Fuel(Litre)	5	8	12.5	25	37.5	45
Resistance (Ohm)	304	284	252	188	124	77

Temperature of Engine Coolant

The engine coolant temperature input is provided by a resistive sender and the microprocessor measures the analogue input for the resultant voltage. The temperature sender circuit and connection circuit to the data logger are presented in Figure 7. The input and output characteristics shown in Table 4 are calculated by the EEPROM.

VEHICLE SIDE DATA LOGGER SIDE

Temperature Sender Temperature Sender Input

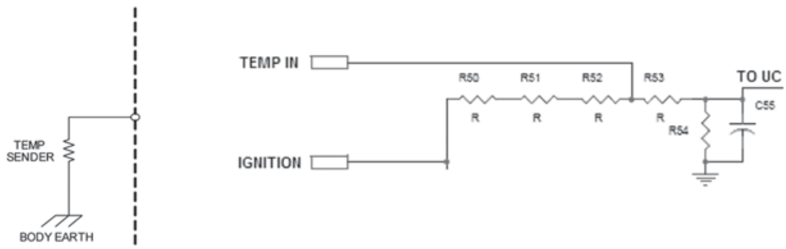

Figure 7: Temperature Sender Connection Diagram

Table 4: Sender Value of Input and Output Characteristics of Temperature

Temperature (Celsius)	45 °C	50 °C	112 °C	117 °C
Resistance (Ohm)	222.3 Ω	181.1 Ω	23.6 Ω	20.6 Ω

Results and Discussion

The designed data logger was prototyped using a commercial-off-the-shelf (COTS) component and a surface mounted device (SMD) component and packaged in a 17 × 10 × 5 mm housing. The total weight of the data logger is approximately 200 g. A Nassi-Shneiderman diagram (or NSD) was used to represent the algorithm for determining the speed, tacho, fuel and temperature. The data logger software was developed using C++.

The system has not yet been deployed inside a vehicle for the purposes of on the road testing, but it has performed well under laboratory conditions. Using a signal generator as its analog input, the system was able to record and analyze data exactly as designed. The algorithm was applied to the data and three different frequencies from the speed sensor were detected. The corresponding speeds, which matched those expected, were calculated and are presented in Figures 8-10.

The expected corresponding results for the tacho meter sensor, fuel sender and temperature sensor are also presented in Figures 8-10. The

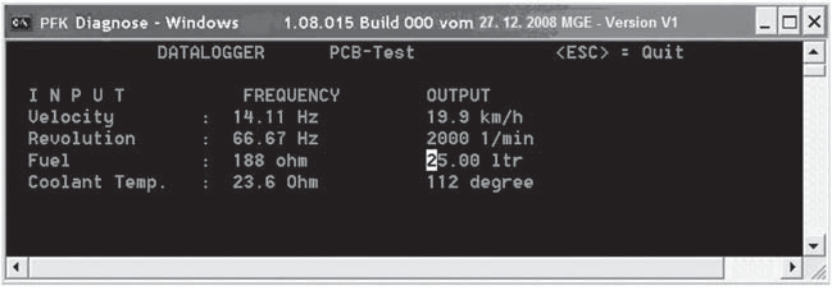

Figure 8: F_{speed} = 14.11 Hz, F_{rpm} = 66.67 Hz, R_{fuel} = 188 Ω, R_{temp} = 23.6 Ω

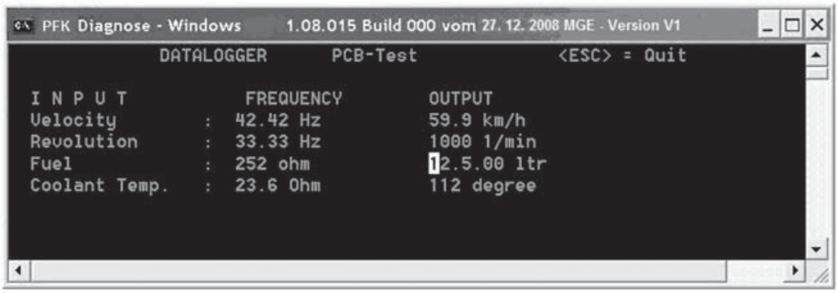

Figure 9: F_{speed} = 42.42 Hz, F_{rpm} = 33.33 Hz, R_{fuel} = 252 Ω, R_{temp} = 23.6 Ω

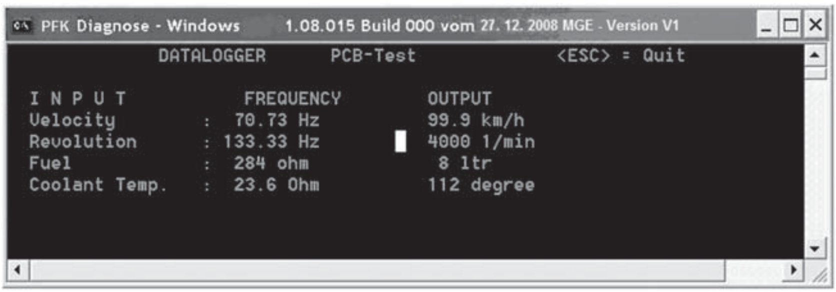

Figure 10: F_{speed} = 70.73 Hz, F_{rpm} = 133.33 Hz, R_{fuel} = 284 Ω, R_{temp} = 23.6 Ω

system was tested over a period of three continuous working days and all four sensors performed well and returned the expected values. This data logger system could be readily adapted and applied to other vehicle types by changing the k-factor, m-factor, resistance range of the fuel sender and the temperature sensor defined in the data logger software.

Conclusions

A systematic design approach for designing a data logger for universal vehicle has been presented. This paper highlights the hardware design and the laboratory testing of a car performance data logging system. The data logger system met the needs of the vehicle data logging process and potentially could be adapted to suit other vehicular forms. The findings of this research indicate that the implementation of a data logger for a universal vehicle is economically viable and furthermore this system could be used as a standalone data logger with a small modification.

Acknowledgement

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