

ENCIT-2018-0830 ACQUISITION OF THERMOCOUPLE DATA BY ARDUINO® MICROCONTROLLERS

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Abstract. *One of the most widely used data acquisition devices for temperature analysis is the CONTEMP a202, which works in conjunction with DAQfactory software, interpreting thermocouple temperature data, with type k being the most used because of its wide measurement range and data accuracy. However, access to this equipment becomes impractical given the license costs of DAQfactory and the CONTEMP acquirer. As a result, was studied the possibility of cheapening the data acquisition process using Arduino® in a diesel generator set WHITE, to compare the data obtained by the two methods and to create a correction parameter that reduces the error between the data recorded by the two acquisitions. The thermocouple generates an electromotive force (emf), which when connected to the board of the Arduino®, makes it possible to read the temperature in a certain environment. With the thermocouple output voltage ranges defined, it was possible to obtain the temperature ranges, and with the aid of the Arduino® programming, an approximate temperature of the medium was determined. In order to improve the obtained data, it was necessary to adjust the curves between both methods.*

Keywords: *Thermocouple, Arduino®, Temperature, Data.*

1. INTRODUCTION

There are different ways to understand technology, such as making work lighter, getting a ride easier, or simply making life more fun and satisfying. And in this context, technology is not something new, but in fact it is something as old as man himself. It is possible to classify the technologies in which they extend the physical force of the man, others that allow to move by the space more quickly and those that amplify the sensorial powers of the man, the last one without doubt is highly relevant for the education (Chaves, 1999). With the popularization of computer science, the need for software followed the same trend. We can describe software as a set of logical components that are required to perform a job, which unlike hardware, makes up the physical components.

Free technology is an ally in teaching practices where it provides ease of use with the public who are unfamiliar with electronics and programming, thereby using free hardware Arduino® is attractive because it has facility in its programming as it is used in the construction of several projects of automation, robotics, among others, and its use is of low operational cost, being thus, the solution proposed for the problem in question besides to use the Arduino® to

carry out the control of the temperature measurements in the locality type, White Motors, it offers a Web application capable of receiving such readings, storing and displaying real-time and historical information.

Data logging systems are usually based on a computer or any processor. These are usually small in size, portable, battery powered and also, they are supplied with a computer processor, sensors and memory required for data storage. These are widely used in obtaining the data in which thermocouples are as sensors, such circumstances where data is needed and where there is a convenience, with all the Arduino® base can also record months of data together at a time, without supervision. This built-in unit can be a single and self-contained device with existing physical sensors that detect available data that fit in the hand or can be a multiplexed channel device provided with many external sensors.

2. MODERN THERMAL SENSORS

Temperature sensors are divided into two distinct groups, based on motion control mechanisms and basic compounds at all stages, capable of generating and / or controlling an electric current flowing between their terminals. Among the various types of temperature sensors, the most common are thermocouples.

Thermocouples are thermal sensors widely used today. Its main attraction is the low cost of production. In addition, its greater limitation is the accuracy, since, errors inferior to 1 °C are difficult to obtain. Due to their simple structure, the thermocouples are robust, in order to work in extreme conditions of temperature, pressure and air conditioning.

The K-type thermocouple produces a 12.2 mV d.d.p. from a temperature of 300 °C. However, to obtain a more accurate measurement, it is necessary to compensate the voltage effect generated by the thermocouple itself using the cold junction compensation technique. The measuring instrument must be able to handle the cold junction compensation as well as the fact that the thermocouple does not present a linear response with the temperature variation. Thus, it is necessary to linearize the polynomial type, by Eq. (1):

$$V = c_0 + c_1T + c_2T^2 + c_3T^3 \quad (1)$$

Where V is voltage, T is temperature and c_n are coefficients, represented by Table 1. used to linearize the voltage results from temperatures between 0 °C and 1372 °C for type K thermocouples. In this way, the following data are obtained by Figure 1 and 2.

Table 1. Linearization Coefficients

c_0	$-1.7600413686 \times 10^{-2}$
c_1	$3.8921204975 \times 10^{-2}$
c_2	$1.8558770032 \times 10^{-5}$
c_3	$-9.9457592874 \times 10^{-8}$
c_4	$3.1840945719 \times 10^{-10}$
c_5	$-5.6072844889 \times 10^{-13}$
c_6	$5.6075059059 \times 10^{-16}$
c_7	$-3.2020720003 \times 10^{-19}$
c_8	$9.7151147152 \times 10^{-23}$
c_9	$-1.2104721275 \times 10^{-26}$

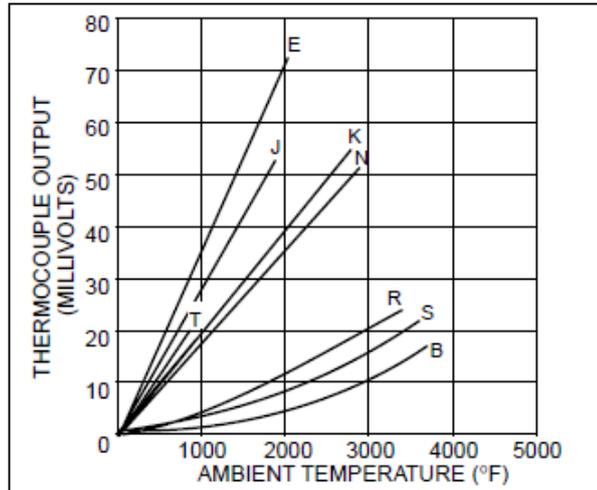


Figure 1. Thermocouple Voltage Output.

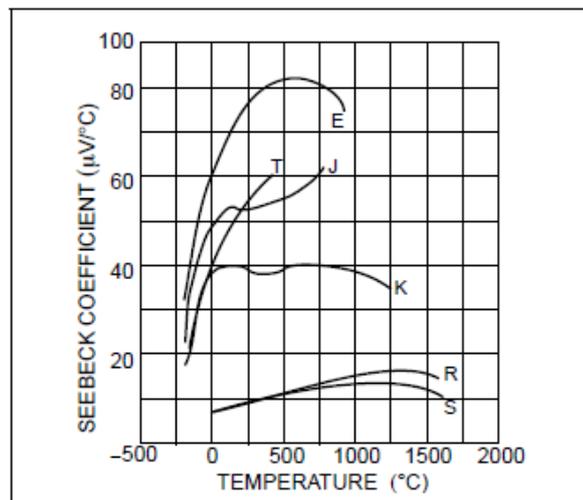


Figure 2. Relation Voltage x Temperature

3. EXPERIMENTAL PROCEDURE

The methodology was executed by compilation of Arduino® Uno, with Java® assistance to create a database. The Figure 3 schematize the system to get data by electrical signals. To build the thermocouple module at Arduino was necessary a protoboard, jumpers, a Nanoshield Thermocouple CI MAX31855 to amplify and convert analogic to digital signals, a Mux Shield II to increase the port numbers of Arduino and were illustrated by Figure 4.

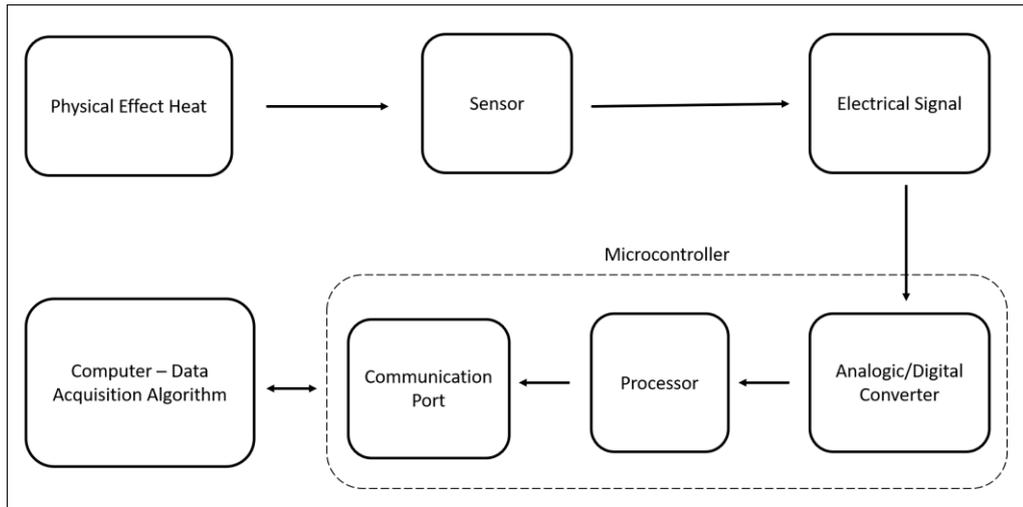


Figure 3. Data Acquisition System.

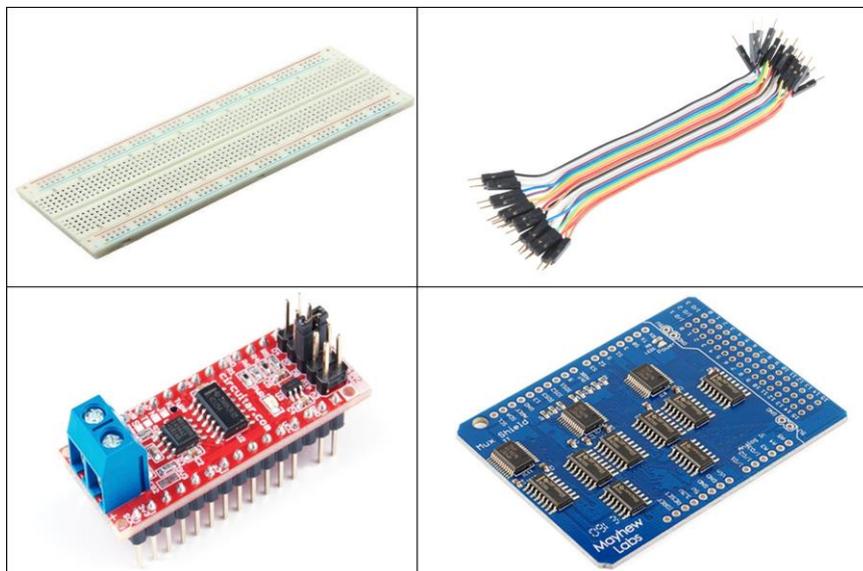


Figure 4. Auxiliary Components

Finally, was connected the K-type thermocouple in Figure 5. After developed the module, this system was installed in a generator set, specified as WHITE BD-6500 CF3E, that was operated by four-strokes single-cylinder engine (there is a low fuel consumption and enables a greater number of tests). And was connected to 50 kW in a resistor bank where changes load at 20%, 40%, 60% and 80% of maximum rated power. The generator set specifications are expressed by Table 2.



Figure 5. K-type Thermocouple

Table 2. Diesel Generator Set Specifications

Parameters	
Manufacturer	White
Model	BD-6500 CF3E
Motor	
Aspiration	Natural
Fuel Injection	Direct
Fuel Injection Angle	16° APMS
Refrigeration	Induced Air
Number of Cylinders	1
Diameter (mm) x Stroke (mm)	86 x 70
Cylinder Capacity (cm ³)	406
Compression Ratio (-)	19:1
Revolution (rpm)	3600
Generator	
Electric Frequency (Hz)	60
Electric Tension (V)	220
Number of phases	2
Efficiency (%)	85,0
Maximum Nominal Power Prime (kW)	4,0
Nominal Standby Power (kW)	4,5

The experiments were developed at Laboratory of Engines (Laboratório de Motores – LabMotor) by Faculty of Mechanical Engineering in Federal University of Pará (UFPA), where the experimental apparatus was installed and instrumented as illustrated by Figure 6 and 7. It was measured the temperature of exhaust gases and was obtained temperature points in each 10 seconds during 10 minutes for each load by Arduino® and CONTEMP a202. Finally, it was compared the results.

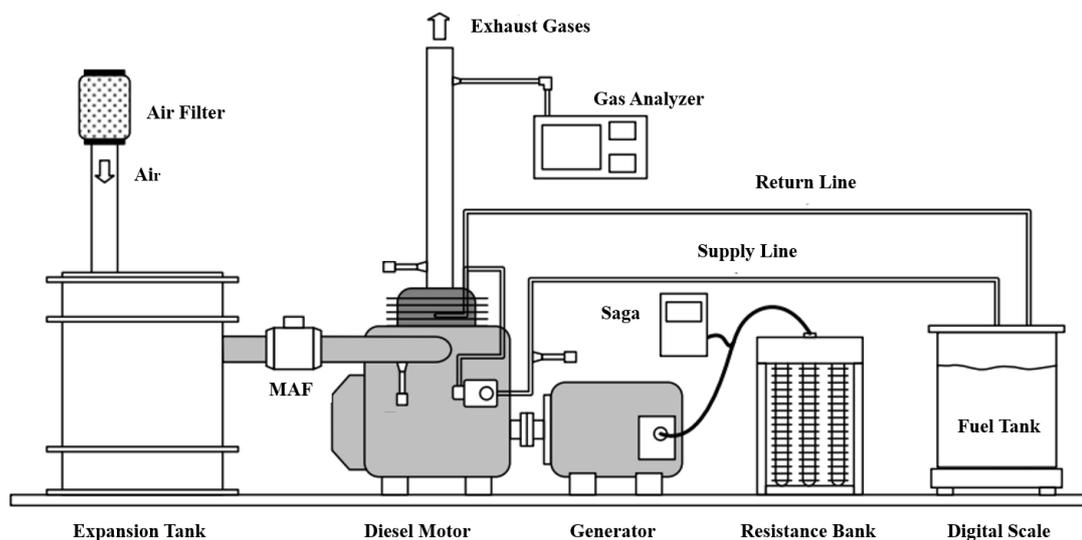


Figure 6. Illustrative System.



Figure 7. Experimental Apparatus.

4. RESULTS AND DISCUSSIONS

The loads chosen to perform the tests in the generator set were 20, 40, 60 and 80%, where they were obtained from a circuit of electrical resistances. The assay was done for both CONTEMP A202 and ARDUINO®, which obtained the following graph in Figure 8.

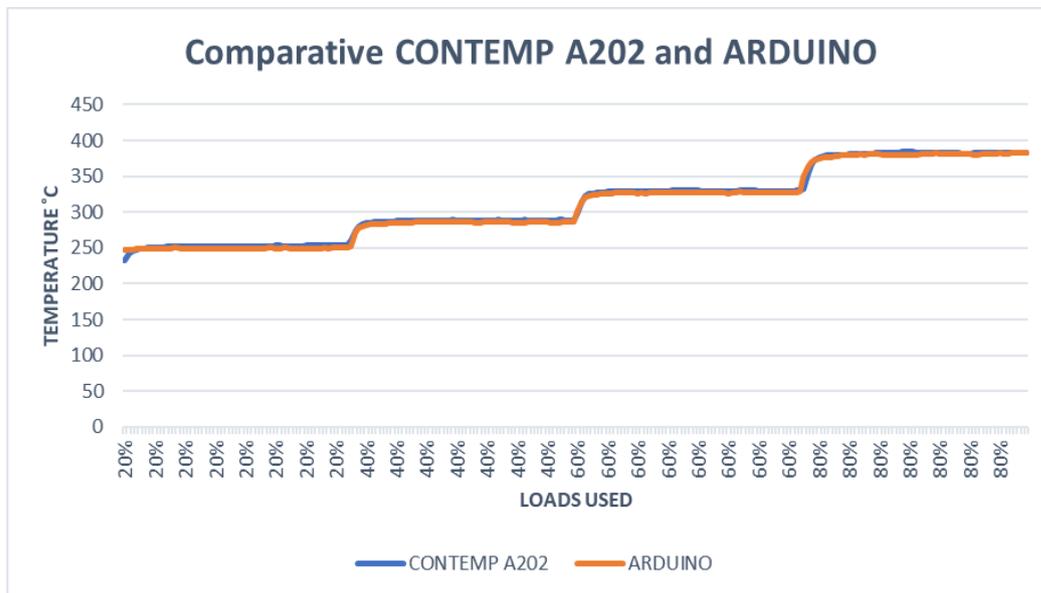


Figure 8. Comparative Acquisition Data.

Below, it was expressed the Table 3, where shows the averages of the temperature values acquired by both Arduino® and CONTEMP A202 for these loads, and the average error found, where a margin of error of two degrees was considered for both higher temperatures and for temperatures inferior.

Loads	CONTEMP A202	Arduino®	Average error
20%	251,56 °C	249,25 °C	0,91%
40%	287,34 °C	284,50 °C	0,98%
60%	328,40 °C	326,20 °C	0,67%

80%	382,48 °C	379,26 °C	0,25%
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The temperature of both the CONTEMP A202 and the Arduino® present in this table are averages of the values acquired. The error used is relative, calculated by the Eq. (2), where T_1 and T_2 are the CONTEMP A202 and the Arduino® temperatures, respectively.

$$ER\% = \frac{|T_1 - T_2|}{T_1} \times 100 \quad (2)$$

The average error is based on the comparative error at each acquired temperature point. During the test, 60 points acquired with both CONTEMP A202 and Arduino® were compared point by point, with a duration of 10 minutes in each load. Based on these values, local errors were taken, and a mean of these local errors was calculated to make the results more accurate.

It was observed that these local errors have increased due to abrupt climatic changes and with respect to the accuracy of the reading of the acquired data, in which the CONTEMP A202 has equal to 0,01 and the Arduino® has equal to 0,25. It is observed that it is more advantageous to acquire data via Arduino®, in view of its low cost and accessible license, as well as its approximation with the results acquired by the CONTEMP A202, which had an extremely acceptable error in the case of engines to combustion.

5. CONCLUSION

Acquisition of data in internal combustion engines is a very recurrent practice in engine laboratories, thus fostering research in trying to make this type of procedure more practical and of fundamental importance for the growth of research in this sector.

It should be noted that the acquisition of data can be expensive, in order to hinder possible advances, so Arduino® becomes an indispensable tool in laboratories, both for its practicality and for its low cost, so that its study enables to students and teachers to find new directions for research and to deepen existing research with the use of a low error data collector.

6. ACKNOWLEDGEMENTS

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