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Interface de Escala Digital Usando I^{2}C

Digital Scale Interface Using I^{2}C

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Resumo: Este documento descreve o desenvolvimento de uma interface digital utilzando sistema embarcado para aquisição de dados de uma balança eletrônica digital comercial. Esta aplicação, desenvolvida no CBPF, tem como objetivo monitorar o peso de uma massa de gás (R134) utilizada nos detectores RPC ("Resistive Plate Chamber") [1] do projeto MARTA (Muon Array for Tagging Air Shower) [2]. O fluxo de gases que circulam pelas câmaras do detector deve ser monitorado porque afeta diretamente o ganho do detector, e este sistema garante que o detector não ficará sem fornecimento de gás. O dispositivo é baseado em sensores de baixo custo e pode ser utilizado em outras aplicações científicas. O trabalho foi desenvolvido pela colaboração entre o Laboratório de Instrumentação de Tecnologia Eletrônica (LITELT) do CBPF, pertencente à Coordenação de Desenvolvimento Tecnológico (COTEC), e o Laboratório de Instrumentação e Física Experimental de Partículas (LIP).

Palavras chave: RPC, strain-gauge, sistemas embarcados, I^2C.

Abstract: This document describes the development of a digital interface using an embedded system to acquire data from a commercial digital electronic scale. This application, developed at CBPF, aims to monitor the weight of a mass of gas (R134) used in the RPC ("Resistive Plate Chamber") [1] detectors of the MARTA (Muon Array for Tagging Air Shower) project [2]. The flow of gases circulating through the detector chambers must be monitored because it directly affects the detector's gain, and this system guarantees that the detector will not run out of gas supply. The device is based on low-cost sensors and can be used in other scientific applications. The work was developed through collaboration between the Electronic Technology Instrumentation Laboratory (LITELT) of the CBPF, belonging to the Technological Development Coordination (COTEC), and the Instrumentation and Experimental Particle Physics Laboratory (LIP).

Keywords: RPC, strain-gauge, embedded systems, I^2C.

I. INTRODUCTION

The use of weight measurements for gas and liquid monitoring is a well-known technique. Calculating the derivative of this parameter allows us to determine the flux. Automating the monitoring process, in addition to reducing operating costs and increasing reliability, is particularly interesting for

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installations with difficult access. This is the case for detectors in cosmic ray monitoring experiments such as MARTA, which is intended to work in deserts and high-altitude locations.

Applying scales based on Strain Gauge type sensors is widely used in industry, medicine, and science due to its cost and versatility. This project explores the linearity and wide working range of this sensor, allowing remote monitoring and recording of acquired data [3].

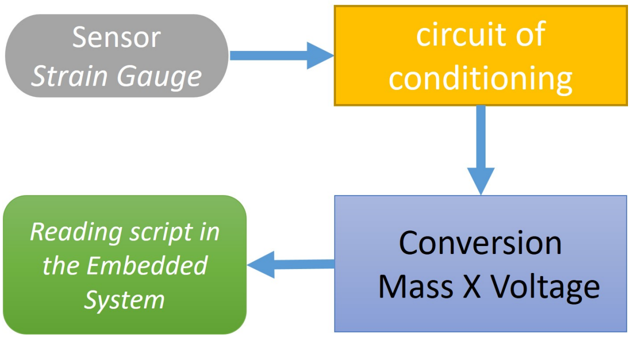

Figure 1. Block diagram of the R134 gas mass measurement system.

The development of this technical note consists of transforming commercial electronic equipment intended to measure mass into a mass measurement system for R134 gas operating under errors and noise acceptable as commercial devices found on the market. Figure 1 shows the reading direction from the sensor to the script made in Python [4] to obtain the weight value transformed into Kilograms.

II. SENSOR CHARACTERIZATION

The "MONDIAL Elegance 150Kg" brand scale was used as a development base where we have four strain gauge sensors as shown in Figure 2.

Once the sensors were identified, it was observed that they were connected in a bridge, that is, connected in *full-bridge strain gauge*, which consists of connecting four sensors in a bridge configuration. As the types of sensors were not known, it was necessary to characterize the bridge sensors to continue the development of the system. The characterization consists of first measuring without weight and measuring which voltage value is read by the multimeter illustrated in Figure 3, which is the voltage versus the mass ratio of the zero kilogram value of the scale. Then, it is measured with a known (calibrated) weight, and with this, it is possible to obtain an equation of the line that passes through two points, which is the transfer function of the proposed system.

$$y = m.x + b,$$

Where:

y = equation of the line.

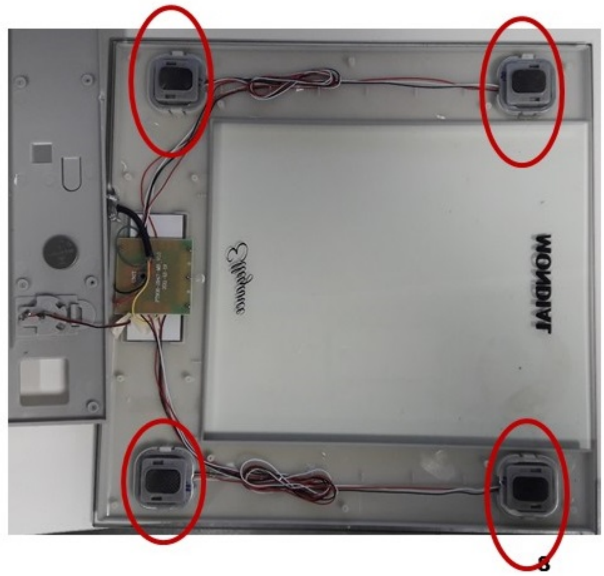

Figure 2. In highlighted red is the sensor strain gauge available at the balance device.

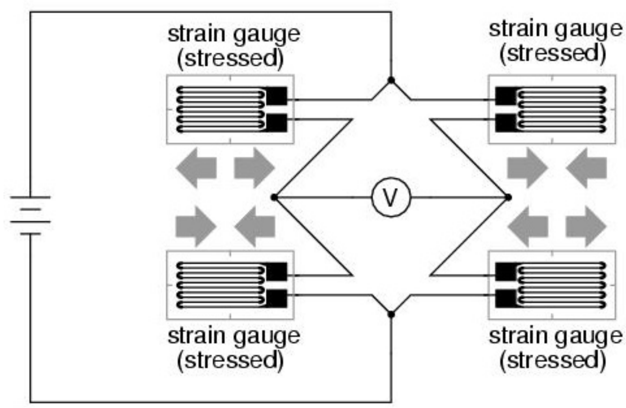

Figure 3. The Circuit used in this project is the bridge scheme with four sensors.

m = slope of the line.
b = point where it intersects the y-axis.
x = point on the line.

From this equation, it becomes necessary to make a compound rule of three to obtain the final relationship finally. This relation as shown in $y_i = V_{output}$.

In this equation, $y_i = V_{output}$, is simply the transfer function of the sensor system in bridge configuration (*full-bridge strain gauge*) where we have:

$$y_i = V_{output} = \left(\frac{(x_i - A) * (E - D)}{B - A} \right)$$

In possession of the function that models this sensor system, obtaining the electrical characteristics within the range of linearity of the sensor's actuation is necessary. The commercial system supports up to 150 Kg; in the proposed system, a factor of twice the weight of the gas mass is used as a design parameter, i.e., 2 x 13.5 Kg $\cong$ 30 kilograms. To certify the linearity of the sensor response, four measurements were made with the known weight value and plotted with MATLAB [5]. Figure 4 shows the linearity response of the strain gauge bridge with four experimental measurement points.

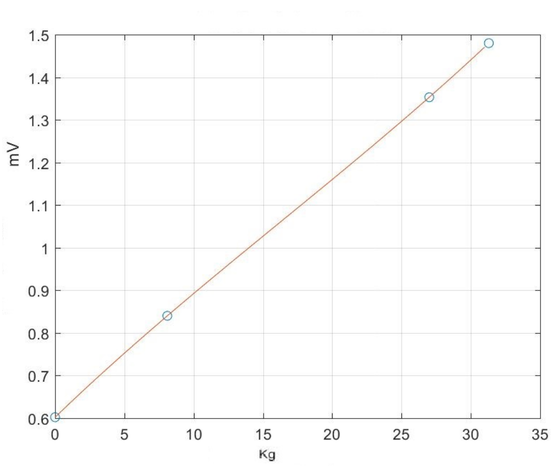

Figure 4. Strain gauge bridge linearity response in MATLAB.

With the certainty that the sensor has a linear response in the projected working range, it is necessary to measure the sensor's sensitivity, precision, and error with the acquired experimental data.

The analysis of this result was critical because it was possible to identify that the analog-digital converter available in the project would not be able to read the decimal places in the order of microvolts. The precision and error measurements will be performed after correctly conditioning the voltage signal collected on the strain gauge bridge.

III. SIGNAL CONDITIONING

Every signal has a magnitude and shape that must be conditioned and treated so connected devices can correctly read the available values. In this project, the signal order of the strain gauge bridge is in the micro-volt range, a characteristic few converters can read properly. That's why it was necessary to connect between the bridge and the ADS1115 [6], a signal amplifier in the order of microvolts to the order of millivolts. Figure 5 shows this connection.

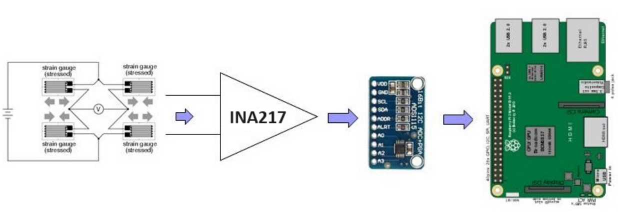

Figure 5. Circuit with the INA217 Instrumentation Amplifier [7].

With the addition of the instrumentation amplifier and the introduction of a gain of 101 at the signal input, the voltage value measured at the bridge, which weighed zero kilograms, was 70 mV. The same procedure to determine if the signal response was still linear was done by measuring with known weights and plotting in MATLAB to see the behavior of the measurements as shown in Figure 6.

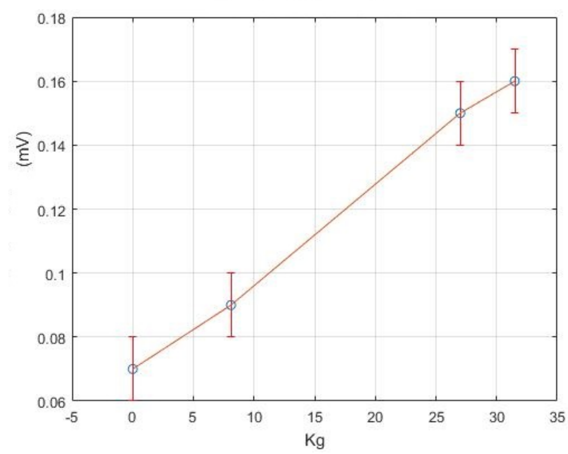

Figure 6. Sensor output with the INA217 Instrumentation Amplifier.

The sensitivity measured after the instrumentation amplifier was:

$$Sensitivity = \frac{Volts}{Weight} = \frac{1,480mV}{31.5Kg} = 46,984mV/Kg$$

In this voltage range, the analog-digital converter can correctly read the voltage value generated by the *strain gauge* bridge. Correct signal conditioning provided adequate conditions for error and precision measurements in this document. Figure 5 shows this connection.

With the addition of the instrumentation amplifier and the introduction of a gain of 101 at the signal input, the voltage value measured at the bridge, which weighed zero kilograms, was 70 mV.

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The sensitivity measured after the instrumentation amplifier was made the acquisition for python code in Listing 1.

Listing 1. Acquisition Python Function.

```
#!/usr/bin/python
import time, signal, sys
import Adafruit_ADS1x15
import csv
def signal_handler(signal, frame):
        print 'You pressed Ctrl+C!'
        sys.exit(0)
signal.signal(signal.SIGINT, signal_handler)
```

```
print 'Press Ctrl+C to exit'
adc = Adafruit_ADS1x15.ADS1115(address=0x49,
    busnum=1)
while True:
        filelog = open('logbal.csv','a')
        print"--------------------"
        #differential reading of channels 0 and 1
        value = adc.read_adc_difference(0, GAIN)
        peso =(value / 32767.0 * 0.256)*10000.0
        dt = time.ctime() #string de data e hora
            do sistema
        filelog.write(str(dt) + '    ' +str(round(
            peso,3))+ '\n')
        filelog.close()
        print"peso=%fKg"%(peso)
        peso=0 #zera vaiavel
        time.sleep(1.0)
```

IV. RESULTS OF DATA ACQUISITION

The output voltage $y_i = V_{output}$, depends on the mass of the scale idealized in Figure 7 so that the scale's weight is transferred in a ratio of Volts/Kg. This value is read by script in Python code developed and written primarily for this transfer function proposed in the project, converting and displaying its value in kilograms as the final result on the terminal screen.

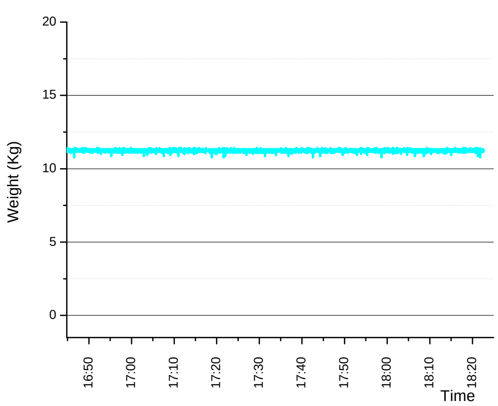

Figure 7. Measurement using a weight pattern test of the full system during one and a half hours.

A data acquisition test was carried out with an initial weight of 11.2349 Kg and was kept the measure to test precision throughout the acquisition. After one hour and a half, the total measurement error was less than 2.29%, and the maximum error was 1.14%, which determined the simple average error in the operation.

Statistics analyses [8] show a Lower 95% confidence interval of Mean of 11.23302 Kg and an Upper 95% confidence

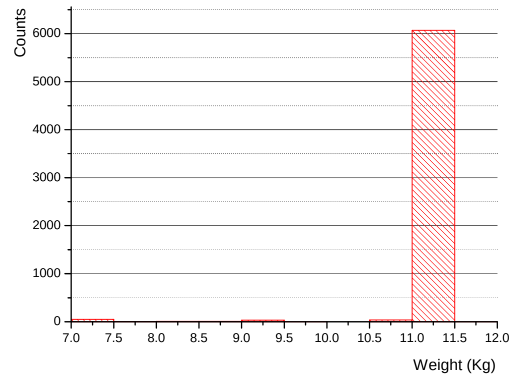

Figure 8. A statistic study using the software OriginLab 8.0 to identify the associated error and range acceptable in measurements per sample numbers.

interval of Mean 11.23679 Kg, for a mean in measurement about of 11.2349 Kg in 6000 samples acquisitions shown in Figure 8. Prolonged testing was not performed, but basic instrumentation and sensor characteristics remained within acceptable limits in this prototype.

V. CONCLUSION

In this work, we present the automation of an electronic scale for monitoring the gas supply for RPC Muon detectors. For the operating range, we can conclude that the maximum total measurement error is equivalent to $\cong 0.1$ measure in Kg.

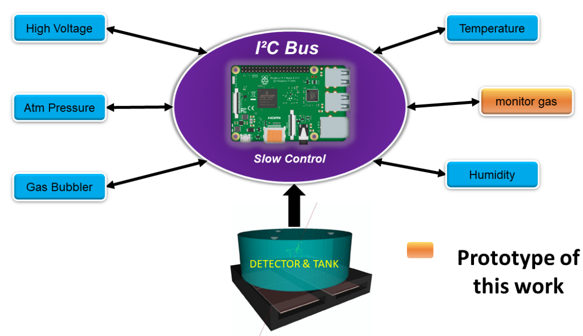

Figure 9. The full Slow Controller system and the circuit operation of the balance are highlighted.

Figure 9 shows a complete illustration part of how the subsystem project circuit works. This characteristic is only possible due to the linearity of the sensor's response, which makes it possible to calculate its output value $y_i = V_{output}$ presenting itself linear at the operating point. Therefore, the instrumentation is suitable for use in the detector system.

Other developments are in progress, like individual subsystems integrated into system control like source high voltage, monitoring atm pressure, monitoring the temperature inside detector RPC, and gas flux.

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