Evento: XXVI Seminário de Iniciação Científica

DESIGN AND CONSTRUCTION OF A DIFFERENTIAL AMPLIFIER CIRCUIT FOR EDUCATIONAL PURPOSES[1]

PROJETO E CONSTRUÇÃO DE UM CIRCUITO AMPLIFICADOR DIFERENCIAL PARA FINS EDUCACIONAIS

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INTRODUCTION

In the past few years a term has been popular inside the industry, especially because of the current need for qualified workforce, the high demand for personalized products, the need for reducing the energy consumption and the high number of occupational accidents. This term is "Industry 4.0", this designation originally from Germany represents the connection between real and virtual world in order to increase the production allowing it to be more flexible and providing an effective relationship between man and machine. The Advanced Manufacturing consists of collecting data from sensors, processing and then convert them into actions previously programmed. In this new industry age, the sensors play a crucial role getting the information, to further help the system to make the most suitable decision based on its database. However, the sensors generally emit small-signal and in a small range, those which need to be amplified and processed before their use in control systems, so that improving their reliability. Based on this, a cheap and simple signal amplifier circuit was designed and developed aiming to be used to supply the needs of the NIMASS, from Portuguese "Núcleo de Inovação em Máquinas Automáticas e Servo-Sistemas" located in Panambi town, and also for educational purposes in the University’s electronic classes.

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METHODOLOGY

The methodology utilized in this paper consists in a bibliography review, a study of the software called Labcenter Proteus Design Suite, by which the circuits were designed and simulated.
The most suitable power supply and operational amplifier circuits were chosen based on Malvino and Bates (2016) and Agarwal and Lang (2005), and the circuits' elements sized based on their availability, software simulations and their datasheet. As result, a prototype was developed and tested. For the test a Berman load cell model BSPL-C was used along with standard calibration masses. Once the load cell is characterized for this circuit a large application field can be covered, as force control, force measurement, strain and mass measurement.

RESULTS AND DISCUSSION

The circuit was divided in three parts according to their purpose, the voltage transformer, the dual regulated power supply and the differential amplifier circuit.

Voltage transformer: The voltage transformer is defined by Agarwal and Lang (2005, p.478) as "a two-port device made by winding a second coil around the inductor", and it is used for transferring electrical energy through electromagnetic induction from one circuit to another. For this design a 220V-to-12V transformer was used due to the use of the transistors LM7805 and LM7905 in this circuit, whose input voltage, according to Malvino and Bates (2016, p.980), needs to be at least 2V or 3V higher than the output voltage.

Dual regulated power supply: A dual regulated power supply is a device whose purpose is to convert alternated current into direct current. For this design the following electrical elements were used: four diodes 1N4004, two 1000µF capacitors, four 104 Capacitors and a voltage regulator transistor LM7805 together with LM7905, this last for the feedback voltage. The reason for the use of these transistor was that the circuit was developed to match the microcontroller Arduino Uno's input voltage which is 5 volts. The diodes mentioned before were used to build a Full-wave diode bridge, this configuration is used in order to achieve a smoother and steadier direct current. According to Malvino and Bates (2016, p.981) capacitors should be used in series connection with the voltage regulator transistors in order to avoid oscillations when they are placed before the transistor, and to improve the transient response when placed after it. Based on this, the circuit was designed and simulated in Proteus software as shown in Figure 01.

Figure 01 – Dual Regulated Power Supply.

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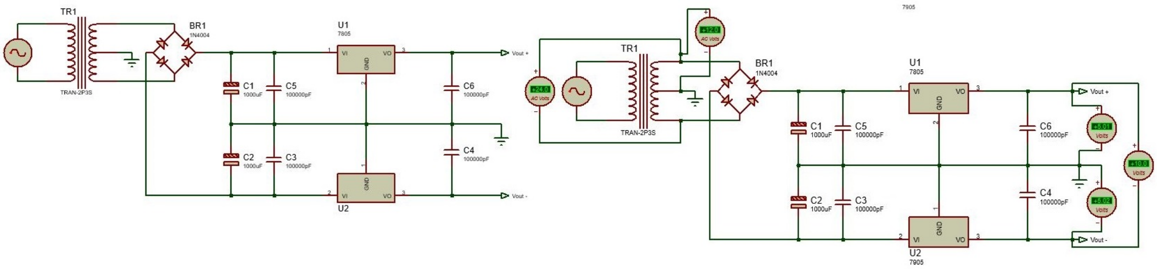


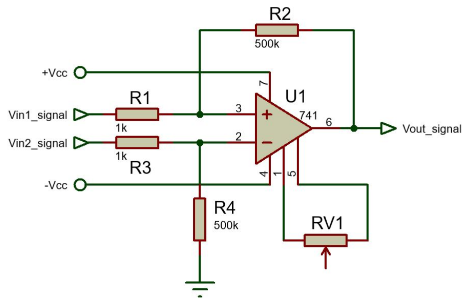
Source: Author.

Differential amplifier circuit: Typical Operational amplifier uses only two electronic elements, resistors and operational amplifier, although a potentiometer intended to provide a fine tuning was added in the configuration presented on this paper, this configuration is pictured in figure 02. The Differential Amplifier, also known as Subtractor are used when it is necessary to amplify the difference between two signals. According to Agarwal and Lang (2005, p.859) for the circuit pictured in figure 02 the total voltage output can be obtained using the equation 01 provided that R1=R3 and R2=R4, where the gain of the amplifier is represented by the ratio between R2 and R1, for this circuit the gain is 500 times.

$$v_{out\_signal} = \frac{R_2}{R_1}(v_{in2\_signal} - v_{in1\_signal})$$

Equation 01

Figure 02 – Differential amplifier.



Source: Author.

As result, the three circuits were set together inside a polymer box in the following order, the transformer 220V-to-12V, the dual regulated power supply and the differential amplifier circuit. As precaution one power switch button and an LED were added to indicate when the circuit is switched on.

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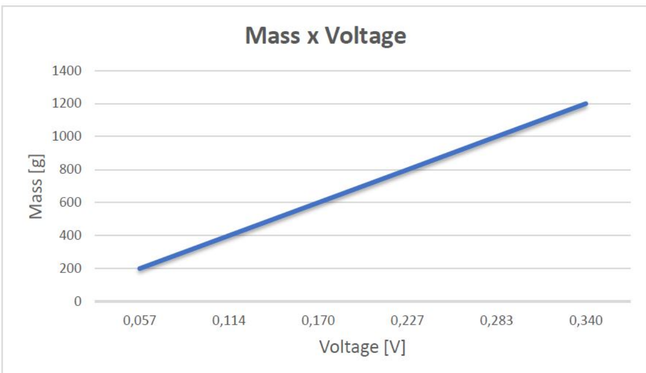
Example of Application: The calibration of a Berman load cell model BSPL-C was chosen as application example. A load cell is a sensor used for measuring forces, the model used in this paper consists of a strain gage load cell, strain gage is an electronic device whose resistance changes proportionally to the strain undergone by the material. In strain gage load cells, the sensor is attached to relatively stiff materials designed with specific geometries in order to have longer life-cycles in application and to measure precisely the applied force. For this test, the load cell was securely attached to a structure, the load cell signal output was connected to the developed device's input signal, then six different masses were placed on the load cell. For each mass a distinct voltage value was attained as shown in table 01. Each of the six masses were divided by their related voltage signal, so the average values were computed in order to obtain the gradient of the line for this load cell, which is 17,22g/unit for Arduino microcontroller's range and 3522g/V for unprocessed signal. The plot mass x voltage for this system can be observed in figure 03. The voltages also were converted to the usual microcontroller's reading range in case of future use.

Table 01 – Circuit characteristics.

N	Mass (g)	Voltage (V)	Voltage converted to microcontroller's range (digital 0 to 1023)	Gradient of the line (microcontroller's range)	Gradient of the line (signal in Volts)
1	200	0,057	11,65644172	17,16	3509
2	400	0,114	23,31288344	17,16	3509
3	600	0,170	34,76482618	17,26	3529
4	800	0,227	46,42126789	17,23	3524
5	1000	0,283	57,87321063	17,28	3534
6	1200	0,340	69,52965235	17,26	3529
	Average Gradient of the line			**17,22**	**3522**

Source: Author.

Figure 03 – Mass x voltage characterization.



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Source: Author.

FINAL CONSIDERATIONS

Despite simple and cheap, this circuit offers a large application field and plays an important role in automation systems, such as in temperature control, force control and ambient light control.
As the results show, the power supply offers steady and suitable voltage to the differential amplifier, by which one can obtain the difference between two distinct voltages from a sensor for further process in automation systems. This paper also presents a practical example of a load cell characterizing for further use in force and load control in the University's Masters Program in Mathematical Modeling.

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