SIGNAL CONDITIONING SYSTEM TO ENABLE USING A LVDT IN PRECISION AGRICULTURE

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Abstract: *The need of recording data and collect measurements taken by sensors is common to many applications and aims to facilitate the registration and monitoring of the development of events in various areas such as health, industry, meteorology, precision agriculture and others. However the electrical signals provided by sensors are not always directly capable of being manipulated which implies the need for adequacy of these signals so that they can be used in monitoring systems (data logger). In precision agriculture or phytomonitoring one of the sensors used for studies is designated as LVDT (Linear Variable Differential Transformer), which due to its characteristics require a signal processing system to facilitate its use. Thus this study aimed to demonstrate the development of an adequacy system of electrical signal to be used connected to a LVDT and to a data logger and thus provide the monitoring of crop development. The results showed that the system deals properly the signals representing the characteristics of the linear sensor reliably and conditioning the voltage level of the signal in order to connect it to the data logger adequately showing low level of residual noise.*

Keywords*: Signal conditioning, LVDT, Phytomonitoring.*

1. INTRODUCTION

Precision agriculture, also known as localized management or variable application of production factors, is a fairly old idea but it was resumed recently due to advances in technology such as electronic and digital communications. Developments in these fields provided to this philosophy to create means of understanding and controlling factors of crop development. Thus, intrinsic to philosophy of precision agriculture there is the phytomonitoring involving the use of physiological parameters of plants and soils to evaluate the crop development. This behavioral verification of the culture occurs through sensory systems that are composed of transducers that convert the body's evaluated reaction to electrical signals proportional to its variation. [1], [2]

Among the sensors used in phytomonitoring stands out the LVDT (linear variable differential transformer) sensor used in checking the stem dynamic to determine the water status of the plant. For this the sensor is connected to the culture so that the variation of the stem derived of matric state is measured. This analysis is possible due to the oscillatory motion of contraction and dilation of the stem that runs these variations according to the matric potential (soil moisture content). Once the soil with low humidity the stem tends to contract, in contrast, with high content of moisture in the soil the stem tends to dilate. Thus, the LVDT is connected to the culture to monitoring the dilation and contraction movements. [3]

This device operates by magnetic principle of mutual inductance, where the magnetic interaction of the sensor comes from the constructive and operative characteristics thereof, which has two concentric and coaxial coils designated respectively as the transmitter magnetic circuit (usually placed at the center of the sensor) and receiver magnetic circuit (juxtaposed on both sides of the transmitter coil and phase shift of 180° between its windings). These constructional characteristics of the sensor involve directly the signal phase shift coming from the core displacement between the coils. [4]

Therefore as exposed by Alhais 2008, the signal intrinsic gap in this type of sensor leads to the need for development of a signal conditioning system, so that the sensor can be used in an evaluation system. Thereby, this work demonstrates the development of a signal conditioning system that meets the conditions of low noise and linearity required for LVDT sensors, providing the connection of this sensor to a data logger for sensing the dynamics of crops, characterized as phytomonitoring.

2. SIGNAL CONDITIONING SYSTEMS IN PRECISION AGRICULTURE

The Precision Agriculture or phytomonitoring may represent the management of the different attributes that influence agricultural development. However in order to reach concise monitoring of crops and thus obtain pertinent variables to their evolution, it is of fundamental importance the use of systems that are able to detect the most important factors in its development. Thus, for the analysis of crop management be performed efficiently, providing results that demonstrate effectively the evolution or development of a particular culture, it is necessary to create sensory systems with quality in the supply and collection of signals to thereby assign the feasibility to the evaluation system.

One of the philosophies of reliability in detecting important factors in agricultural development occurs through phytomonitoring, which uses sensors able to measure and store data from several variables, such as expansion of stem, moisture content of soil and fruit development. This mode of agricultural monitoring through sensors requires reliability in signal provided by the electronic sensory system and it is directly linked to the treatment carried out on the representative signal of the measured magnitude, [6]. Therefore, for accurate data, the providing systems of signals must go through a conditioning that inhibits the mitigations that distort the measurement provided by the sensor. [7]

There are innumerable evaluative ways of essential parameters in a culture, among these is irrigation management, for example, where it happens the monitoring of the water content variation in the soil. Currently there are three sensors capable of performing this assessment: the tensiometer, FDR (Frequency Domain Sensor) and TDR (Time Domain Reflectometer) [8]. What characterizes this diversity in methods of agricultural control is the evolution of electronic devices, programming languages. With this more sophisticated systems are being developed, such as the work of TEIXEIRA & COELHO (2005), who used pressure and temperature transducers in an automatic data acquisition system, in order to evaluate the effect of temperature on reading tensiometers.

The agriculture performed through accurate data analyses provided by the technological evaluation systems as sensors, positioning systems, transducers and data loggers, used by the philosophy of precision agriculture or phytomonitoring, which use the electronic sensing technology, provides producers the opportunity for a more reliable and detailed analysis of crop development [10]. This leads to diagnostics and more reliable strategy controls such as strategies to choose the best time to start or stop the irrigation of a particular culture, or strategies to control the concentration of fertilizers over the planting area. So these agricultural treatment philosophies seek the proper management of crop targeting quality productivity and economy in the field [11].

This way, through concise data - provided by evaluation technological systems using electronic sensory technology - farmers have the opportunity of a more reliable and detailed analysis of crop development, what provides more reliable diagnostic and measures control in agricultural management.

3. MATERIALS AND METHODS

The experiment was installed and conducted in the electromechanical technology department, Federal Technological University of Paraná, Medianeira Campus. The signal suitability system was developed under various settings of operational amplifiers, because circuits with operational amplifiers can perform numerous operations with algebraic signs, extremely necessary feature needed in signal conditioning. However, for the analysis of signal conditioning system, it was subdivided into three steps: "connection and amplification" of signal, "rectification, filtering and subtraction" of signal, and finally, "offset, amplification, and filtering" of signal [5].

The first step corresponds to the connection and amplification of the conditioner modeling of signal, which is necessary to match the impedances of the systems and amplify the signal. The configuration of transmitter follower used is characterized by obtain gain 1, this peculiarity leads to the same values of input and output signal, directly influencing the quality of the signal coming from the sensor to the conditioning system. This way we it was used an operational amplifier LM324 in configuration follower block diagram U1: A and U1: B, which are displayed in Figure 1.

As observed in Figure 1, the LVDT signal comes from the connector J1, from this point the amplifiers in transmitter follower configuration operate in each measuring device polarity, coupling the impedances between the sensor and the circuit, thereby minimizing attenuation that could happen in case both systems present divergence in their impedances.

Upon completing the connection system, it was made the non-inverting amplifier configuration. This electronic modeling performs the multiplication of the difference between the inputs, thereby providing at its output a signal of greater intensity, which is controlled by the feedback loop that in Figure 1 corresponds to RV1 and RV2. It was this system due to the low voltage level emitted by the sensor, so, according to the configuration in Figure 1 block diagram U1: C and U1: D configured as a non-inverting amplifier increases the intensity of the signal according to necessity without any phase shift.

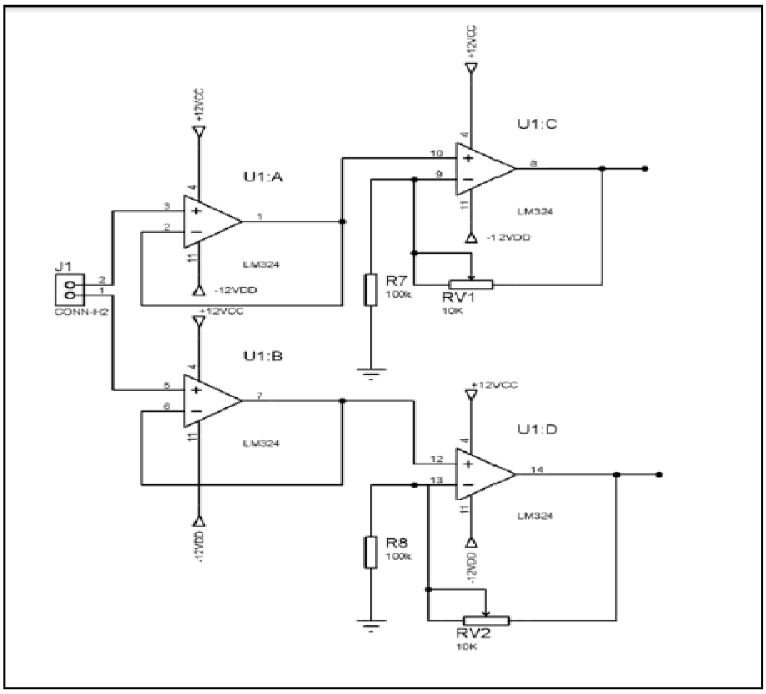

Figure 1. Connection and amplification circuit of the signal conditioning system.

The next developed step consistent with the correction required for the signal processing. On this step was carried out the rectification of the waveform emitted by the sensor, in this procedure the diode turns the AC signal of high frequency into pulsed signal. This way there will be the appearance of two images originated from the sensor due to its constructive characteristics, where in the sensor LVDT in each core positioning its output signal will be outdated of 180°. Figure 2 shows the characteristic of the signal during conditioning. [5]

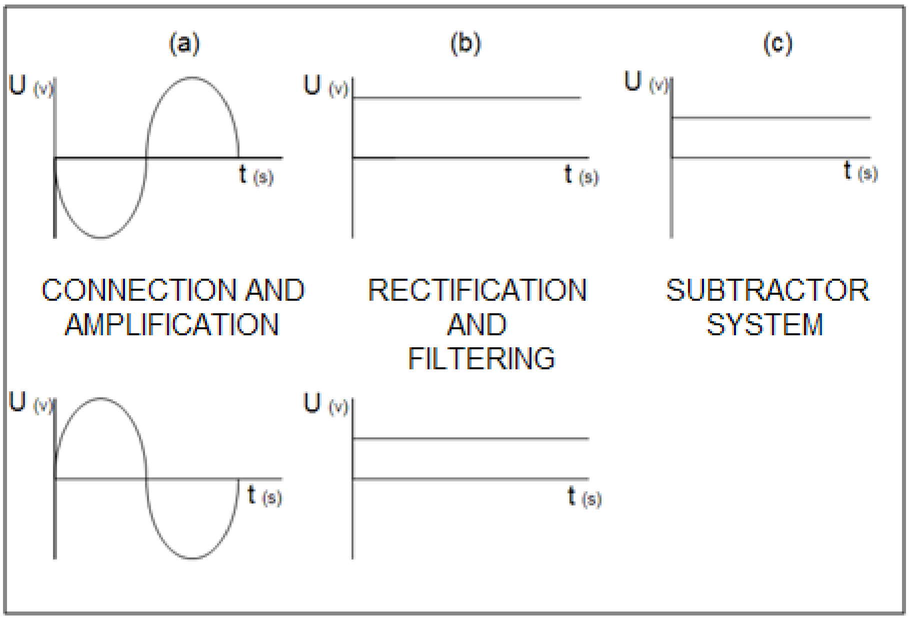

Figure 2. Illustration of the waveforms during the signal conditioning.

In Figure 2 it is observed the behavior of the signal LVDT under the suitability system. The outputs of the sensor secondary are shown in the two graphs in Figure 2 (a), which have a winding signal with phase shift of 180º. However, as already discussed this signal is amplified and then rectified, as shown in Figure 2 (b), and therefore, it is used the subtraction circuit to convert the two signals into one.

To perform the processing of the two signal images it was used an operational amplifier in subtractor configuration, according to Figure 3, this used in the signal processing, it consists in a typical assembly of a non-inverting subtractor. The subtractor amplifier consists in a configuration which allows obtaining at the output a voltage signal equal to the difference between the applied signals. [5]

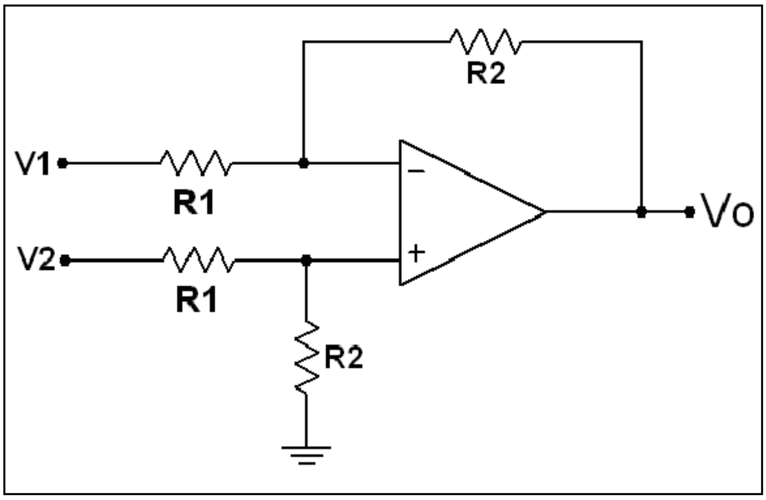

Figure 3. Circuit in subtractor configuration used in the development of signal suitability system.

This way the output result of a circuit in subtractor configuration has feature according to the equation 1 exposed by WEDLING (2010), where the voltage Vo depends on the ratio between R1 and R2 integrated to a product of the signal difference added to the positive and negative terminals of the operational amplifier. [13]

$$V_O = \frac{R_2}{R_1}\left(V_2 - V_1\right) \tag{1}$$

Equation 1. Output ratio of an operational amplifier in subtractor configuration.

From the subtractive configuration it is obtained the graph (c) of Figure 2, where the stresses that formed two images are subtracted into a single signal that oscillates only in the positive cycle based on the offset that will be detailed below.

The offset phase performed in the signal processing system making is necessary due to the subtraction results in a negative signal to one half of the displacement, and with the implementation of this circuit it can be performed the correction of the signal, i.e., adjusting the signal for its variation is only positive. Figure 4 demonstrates the offset and amplification configuration, which has been necessary due to the result the subtraction provides a low amplitude signal which prevents its use in an acquisition system. [12]

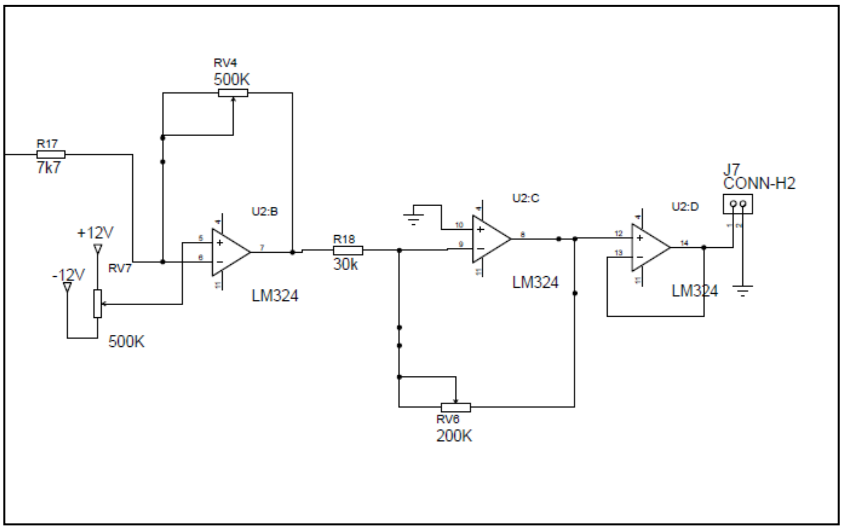

Figure 4. Circuit used in the offset, amplification, and connection system in the signal conditioning

In the previous illustration, from the resistor of 7.7 kΩ (kilo-ohms) considered as subtractor output occurs the signal input in the offset and amplification stage. The offset phase in the circuit is represented by LM324 U2: B.

The signal transmitted by the subtractor is connected to the negative terminal of the offset, and from the references of signals, with the trimpot it is made the correction of the signal. The use of the offset was necessary due to the microcontrollers do not accept negative characteristic signals.

However, the circuit complement matches the amplification, necessary due to the result the subtraction provides a low amplitude signal which prevents its use in an acquisition system

4. RESULTS AND DEBATES

With the completion of the signal adequacy system project, this showed the as characteristic the output voltage level from 0 to 3.3 mV (millivolts), scaled voltage to avoid possible damage by peaks to input of the microcontroller. Another characteristic achieved in the development of the system was the signal linearization with very low noise levels providing the utilization of the signal to an acquisition system. Figure 5 presents the suitability system connected to a sensor LVDT and to an oscilloscope to check the behavior of the signal processing system in operation.

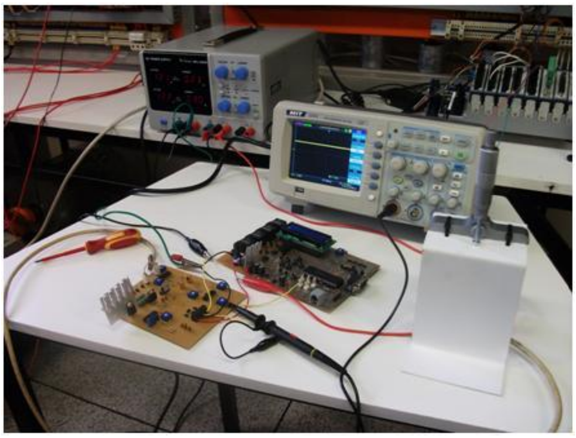

Figure 5. Verification of the signal suitability system under operating conditions.

The signal behavior after processing and under the operating conditions was satisfactory, because the residual noise of the conditioning was inhibited by the acquisition system providing reliability to measurements performed by the sensor, thus enabling integration of the system to the sensor and data logger to be used as evaluation system in the development of culture.

5. CONCLUSIONS AND RECOMMENDATIONS

Regarding to the signal conditioning system, this gives care in the treatment of noises, because according to the performed project, if there is the use of filters with range of operation off-design it will occur a delay of signal response when there is variation in the sensor, and so it is essential to use dimensioned filters appropriately according to the project.

However it is possible to conclude that the conditioning signal was satisfactory when used connected to the sensor, since the signal emitted after rectification, amplification and subtraction, necessary procedures that will enable the signal emitted by the conditioning system present themselves without any interference, as high amplitude noise which preclude the use of the signal together with a data logger, because they provide measurement errors.

Thus, with the stability of the signal emitted by the developed circuit and appropriate levels of the response voltage it was possible to use the signal connected to a data acquisition system, enabling the study of the hydro dynamic behavior of plants through the contraction and expansion effects of stem occurred by the matric state of soil.

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