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Development of Transducer Unit to Transmit Electrical Action Potential of Plants to A Data Acquisition System

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Abstract There is a lot of evidence that plants respond to the alteration of the environmental parameters, particularly with respect to nutrient availability and concomitant changes in partitioning and growth. Extracellular electrical signals that produced from plants have different pattern depending on factors that may cause stress such as water deficiency, nutrient elements shortage, high salinity level in roots environment etc. Due to very low current level of electrical signal of plant's, the transmission of signal must be without distortion. The objective of this work is the development of a transducer unit to transmit electrical action potential of plants to a data acquisition. This transducer could be used to improve the efficiency of data acquisition system, in order to avoid: a) the white Gaussian noise (WGN), (50 Hz power line noise as well as the noise of the operating electrical devices, operating in any commercial greenhouse), and b) the distortion from RF signals. The results show that electrical action potential measurements on plants, obtained with the use of the design transducer unit had a negligible error in contrast to a direct connection of sensors into data acquisition. The measurements are recorded, via a data acquisition system and processed using LabVIEW code.

Keywords Signal Condition, Noise, Plant, Action Potential, Chrysanthemum, Sensor, Transducer, Signal

1. Introduction

There is a lot of evidence that plants respond to the alteration of the environmental parameters, particularly with respect to nutrient availability and concomitant changes in partitioning and growth[1],[2]. Environmental changes caucuses electrical signal which is an essentially critical signal that reflects the responses of a plant to the environmental changes[3] and introduce extracellular electrical phenomena in plants that can be divided in three types: local electrical potential (LEP), action potential (AP) and variation potential (VP). VPs can transmit from the stimulated site to other parts of the plant have been reported in a variety of plant species in response to various stimuli, including light, temperature, humidity, osmotic stress, irrigation, gravistimulation and wounding[4-9]. In accordance a lot of useful information for theoretic and practical applications such as plant's physiological mechanisms, inspection of greenhouse climate and plant's root environment can be derived from the characteristics of that signals and contribute to relative intelligent control. Nowadays, almost of all researches on the plant electrical signal, are focused on the relationship between the electrical signal and generative causes (climate or other parameters) as well as the macroscopical physiological effects[10]. Due to very low current level of plant's electrical signal, the transmission of signal must be without distortion. The aim of this work is the development of a transducer unit to transmit electrical action potential of plants to a data acquisition system reliably without distortion.

2. Materials

The design of development transducer unit includes three subunits (Fig.1):

1) a high sense amplifier
2) a Butterworth filter
3) a voltage to current converter

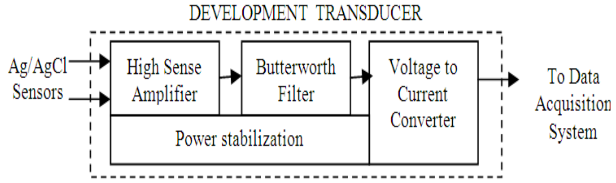

Figure 1. Block diagram of transducer unit

Due to very low current level of plant's electrical signal it was necessary to acquire the signal by an amplifier with high impedance. The amplifier was developed and enclosed in an

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electronic interface with very high impedance in input and high gain coefficient as it shown in Fig 2. Plants electrical signal was detected by Ag/AgCl electrodes which were selected because they are stable in: i) temperature alterations and ii) polarization and erosion[11-12].

In addition Ag/AgCl electrodes have high resistance which is compatible with the input impedance of the preamplifier (>10^{10} Ωhm). The signal of each electrode (reference and measure) was transmitted into a TL081CD which is an integrated circuit operational amplifier that provides very high input impedance, very low input current, and high speed performance. On the second stage of the interface circuit the level of signal was amplified. After amplification, the amplitude range of the electrical signals has a maximum value of 300 mV. This amplification stage includes a high gain operation amplifier in differential mode connection. The gain of amplification of the designed circuit was 40 db. The output of the amplifier was connected to an anti-alias 8^{th} order Butterworth filter. Butterworth filter was designed to have a flat frequency response. The circuit diagram is shown in Fig.3. The pass band frequency of the designed filter was at 5 kHz due to the sample rate of data acquisition system. The rate signal to noise of the designed filter was -72db. For transmission, was designed a high sense Voltage to Current converter. The circuit is shown in Fig. 4 is used so that the signal could be transmitted reliably. The transducer also includes power stabilization circuit for VCC and VEE supplies.

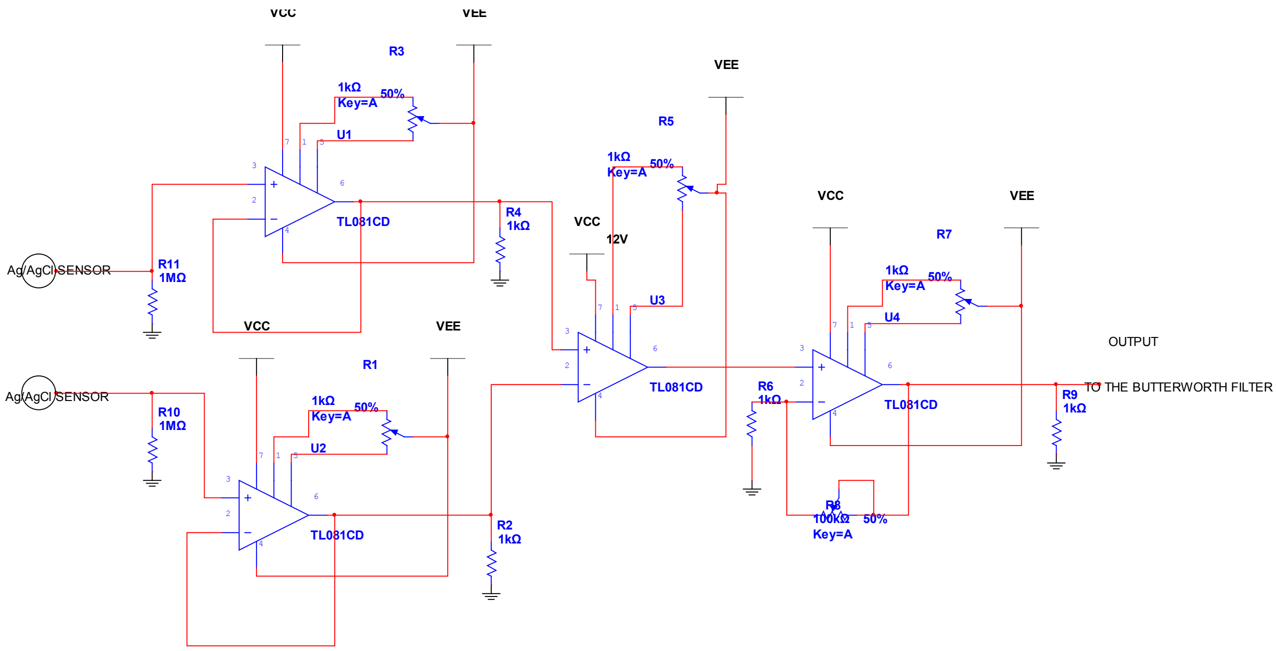

Figure 2. Interface and amplifier circuit of transducer unit

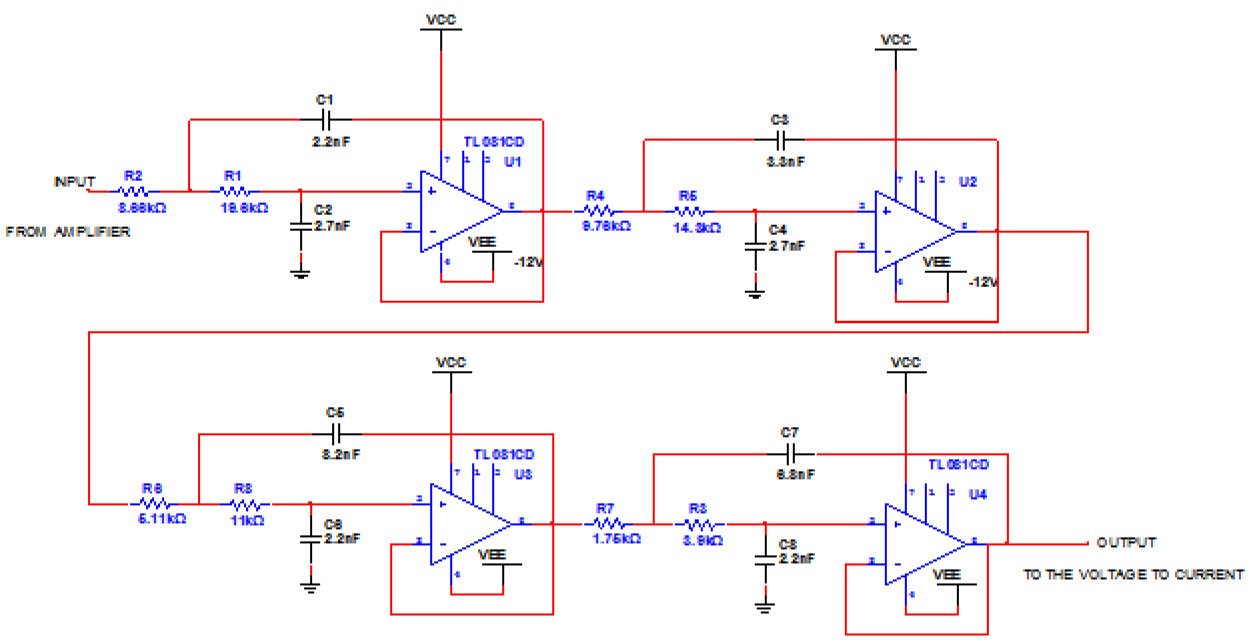

Figure 3. 8^{th} order Butterworth filter of transducer unit

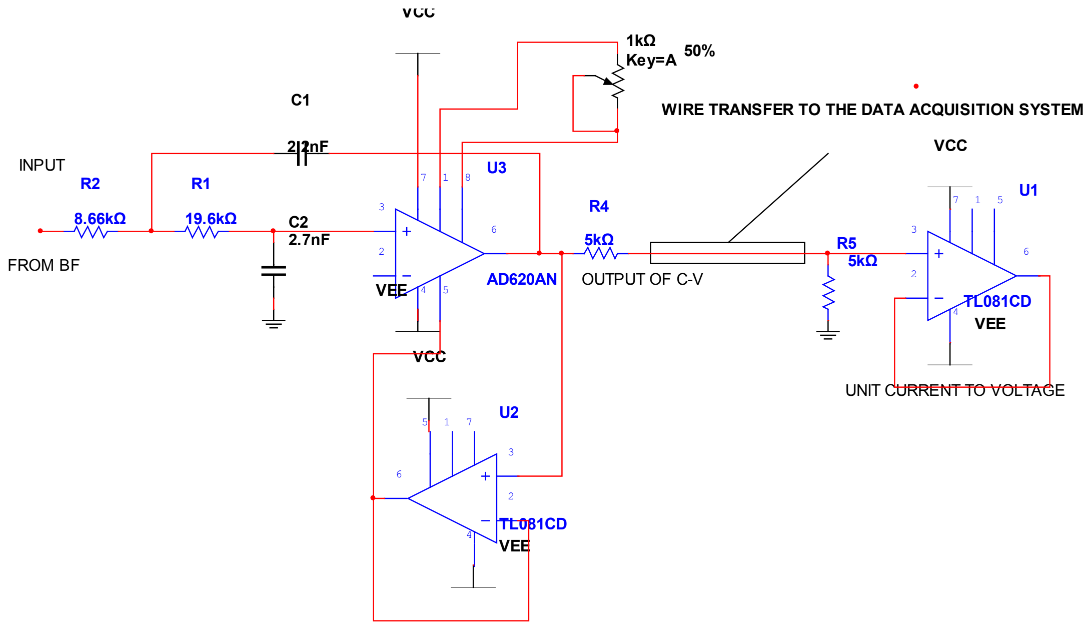

Figure 4. Voltage to current circuit of transducer unit

3. Using Transducer Unit to Transmit Electrical Signals from Plants

The experiment concerned affect environment noise on the designed transducer unit. For electromagnetic interference (EMI) testing an EMI-RF generator device in distance of 30cm away from Faraday's Cage (FC) transmit, three power transmission A, B and C (p=100mW) for each testing frequencies: 0.5, 1.3, 2.3 and 3.3 MHz controlled by labVIEW. The electrical potential in plants was measured and recorded in: a) a data logger placed at a distance of 5 meter away from FC, connected direct with Ag/AgCl sensors via a coaxial wire and b) at a distance of 5 meter away from FC via transducer unit to a data acquisition system. During the experiment, electrical potential was measured in leaves of chrysanthemum plants (*Chrysanthemum moriflorum)* using Ag/AgCl electrodes[12].

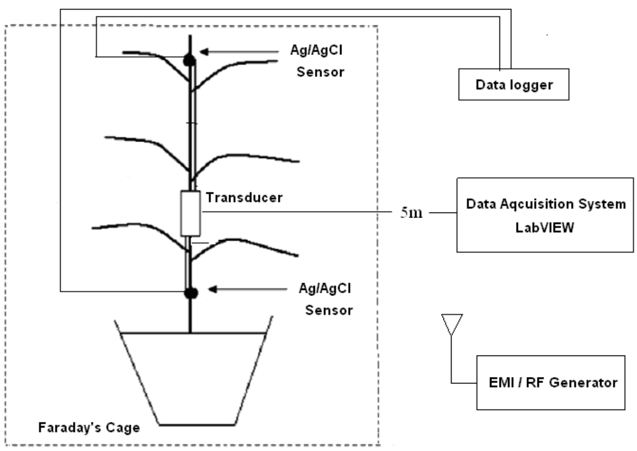

Figure 5. The experimental system for the measurement of plant's signal

Due to the affect of EMI testing the acquired electrical signals via direct connection of sensors into data logger, the transmission showed distortions (Fig.6). Transmission via transducer unit did not affected by the EMI testing. The Fig. 6 shows the distortion of transmitted waves on EMI testing. The magnitude of distortion depended from the wave length of transmitted wave. The EMI-RF transmission in band from 1000 to 2500 Hz affected strongly the acquired biosignal (Fig.7).

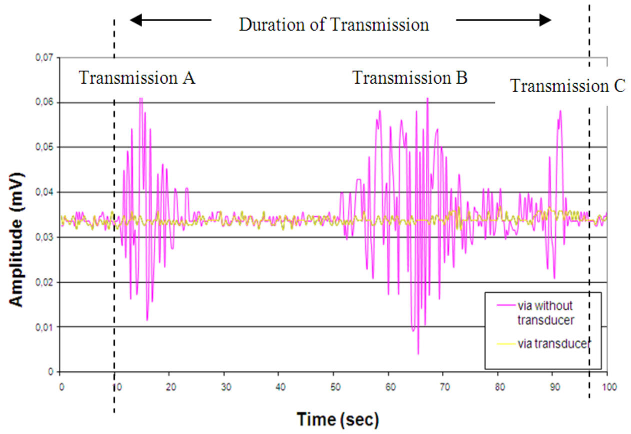

Figure 6. The effect of EMI testing in transmission of signal via direct connection of sensor to data logger (-) and via transducer unit (-)

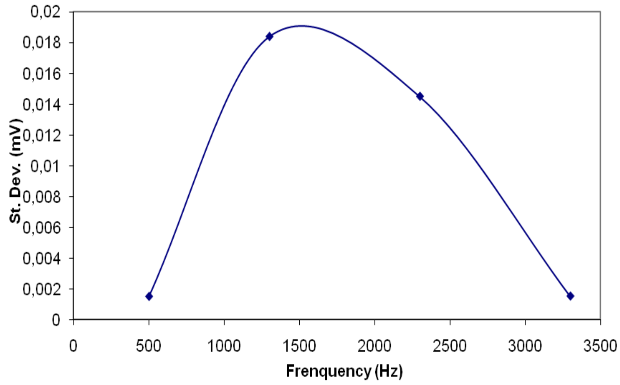

Figure 7. Standard deviation of signals by effect of EMI testing

4. Conclusions

From the above results, we concluded that:

1) The design transducer unit can be used to acquire biosignals of plants in a more effective way than via direct connection of sensors into data acquisition system, since the signal is not affected by the noise of external RF source such as of a typical greenhouse environment, or in an laboratory.

2) By the use of a direct connection of sensors into data acquisition the amplitude of biosignal was affected by about 50% during their acquisition at a distance of 5 m since harmonics distortions caused from the ambient environment resulted to peak voltages signals errors.

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