HAND TREMOR MEASUREMENT USING A NON-CONTACT TRANSDUCER

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Abstract A simple and low cost instrument using a non-contact type transducer is proposed which quantifies the hand tremor characteristic of patients having neurological disorders. The transducer has been developed based on the principle of differential capacitance. The subject's hand under tremor, when introduced in between the plates of a parallel plate capacitive arrangement will result in capacitance change. Suitable signal conditioning circuits have been designed to extract the cardinal informations such as intensity and the frequency of the tremor. The experiments performed with the prototype reveal that the measurement is reliable when the observed data are averaged over several samples taken at different instants of time. These data may be acquired into a PC, wherein a built in knowledge base available, will be used for a medical expert system to diagnose the neurological disorders.

Keywords: Hand tremor, Non-contact transducer, CMRR, Amplitude Modulation.

INTRODUCTION

Tremor is a sometimes disabling sign of several neurological disorders such as Parkinson's disease, Essential Tremor (ET), or cerebellar lesions. It is defined as being an involuntary, roughly periodic oscillation of a limb, the head, or any other part of the body. For more than a century, instrumental methods are used to describe and quantify tremor, in order to answer pathophysiological or pharmacological questions or to monitor patient therapy. Conventional contact type of transducers lead to inaccuracy due to damping of tremor. Also current techniques for assessing tremor involve the use of clinical scales, which can be both subjective and unreliable [Duane et al., 1999]. The present work aims to develop a method for quantifying unconstrained tremor using a non-contact type transducer.

MEASUREMENT CONCEPT

The basic arrangement of the measurement is as shown in Fig.1. The transducer consists of a set of parallel plates and the subject's hand is introduced in between, parallel to the plates. This setup forms a differential capacitance [Doeblin, 1987]. The capacitance C_a (between plate 'a' and hand) and C_b (between plate 'b' and hand) are in opposite arms of the bridge as shown. It is obvious that the capacitance C_a and C_b are equal to the value of C if the subject's hand free of tremor is exactly at the middle position between the plates. When there is tremor, the change in capacitance C_a and C_b results in a proportional differential output from the bridge.

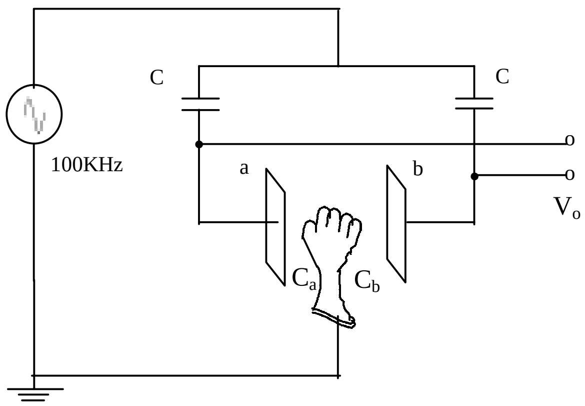

Fig.1 Basic schematic for measurement of hand tremor

If $V_i \sin 2\pi ft$ is the excitation source, then the output voltage V_o is given by

$$V_o = V_i \sin 2\pi ft \left(\frac{C_a}{C+C_a} - \frac{C_b}{C+C_b} \right) \quad (1)$$

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where, V_i is the peak voltage of the sinusoid used for excitation, 'f' is the excitation signal frequency (100KHz) and the capacitance C_a and C_b are calculated from the basic equation of the capacitance as follows.

$$C_a = \frac{\varepsilon_o A_{ph}}{d_a} \quad \text{and} \quad C_b = \frac{\varepsilon_o A_{ph}}{d_b} \qquad (2)$$

where, d_a and d_b are the distances between the hand and plate 'a' and plate 'b' respectively, A_{ph} is the perspective projected area of the hand and ε_o is the permittivity of air. Here, A_{ph} is obtained using the following relation

$$A_{ph} = A_h \sin\theta, \qquad (3)$$

where, A_h is the plane area of the hand and θ is the angle between the area vector of the plate and the plane of the hand .

INSTRUMENT SYSTEM DESIGN

A block diagram of the complete system is shown in Fig. 2 with the various sections identified.The excitation frequency of the capacitance bridge has been chosen to be 100KHz with the consideration that the human tissues act as fairly good conductor at such high frequencies. Instrumentation Amplifiers (IAs) are used in biomedical applications due to several factors: ability to obtain high gain with low resistor values, extremely high input impedance, and superior rejection of common mode signals. In this work, a single chip bipolar input instrumentation amplifier INA 110 has been employed, which offers more than 75 dB common mode rejection ratio (CMRR) at high frequencies and 120 dB rejection of 50Hz noise. It is to be noted that a return path for bias current of IA has to be provided in order to avoid unwanted saturation of the output [Joseph and John, 2001].

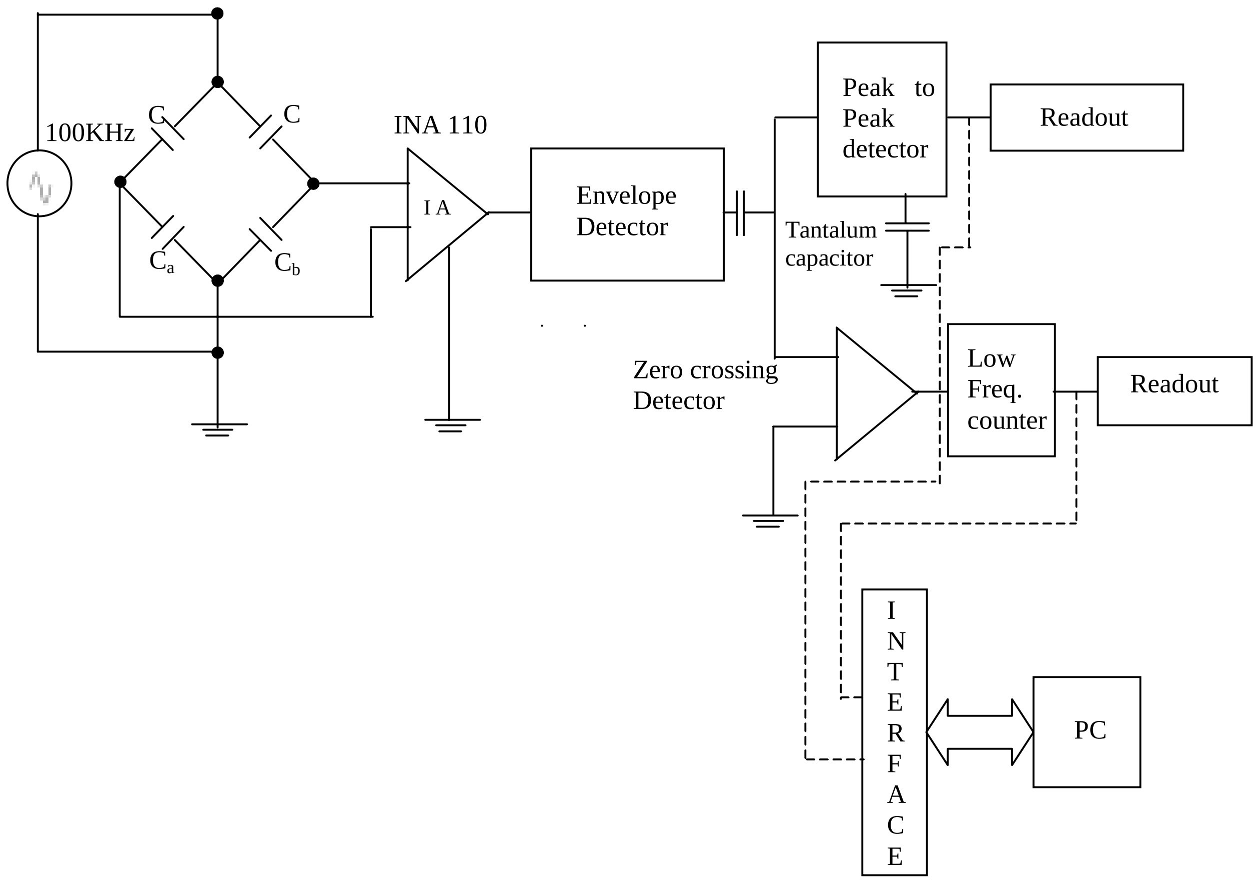

Fig.2 Block diagram of the proposed tremor measurement system

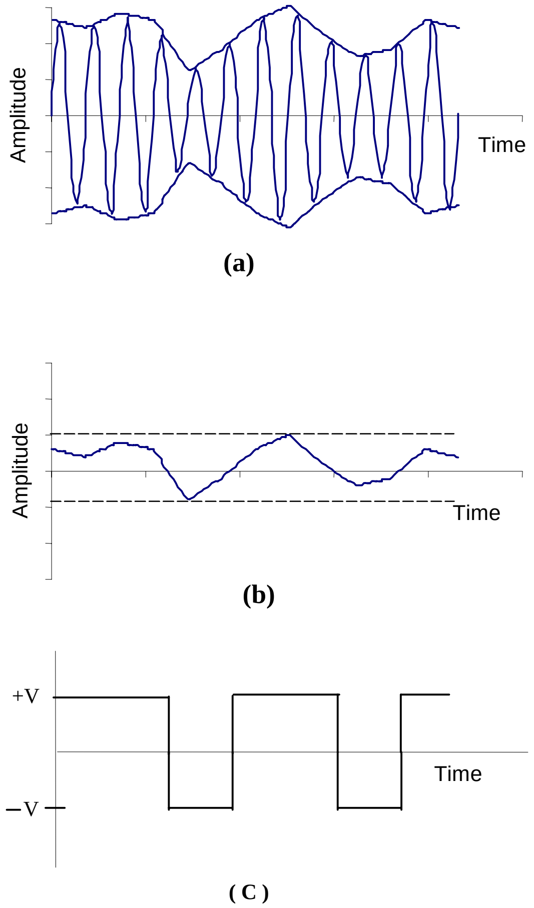

Fig.3. (a) Hand tremor modulated bridge output (b) Envelope with tremor information and (c) Z-C-D output at tremor frequency

It is understood that the frequency of hand tremor is well below 12 Hz [Duane et al., 1999]. This roughly periodic oscillatory motion of the subject's hand changing the value of capacitance C_a and C_b produces amplitude modulated (AM) wave at the output of IA. The cardinal information such as intensity and frequency of the tremor are in the envelope of the AM wave. The low frequency modulating signal is separated using an envelope detector. The Peak -to - Peak detector extracts the intensity information in the detected envelope. Tantalum capacitor is used in the Peak - to - Peak detector, since it offers low leakage. Zero Crossing Detector (Z-C-D) generates a pulse, each time the envelope crosses zero [Coughlin and Driscol, 1987]. These pulses counted over a period of time in a counter provides the tremor frequency information. In this work, an edge triggered low frequency counter has been employed. The signals at various stages of the measurement system are shown in Fig.3.

Shielded coaxial cables are employed in the system to avoid any stray electrical pick-up. Safety precautions have also been incorporated in the instrument system to protect the patient from any unintended electrical hazard [Bouwens, 1997].

The measured intensity and frequency data may also be acquired through an interface into a Personal Computer. With these data and a knowledge base created in the PC, the measurement system can be enhanced into a medical expert system for the diagnosis of neurological diseases.

RESULTS AND DISCUSSION

Experimental studies have been performed with a random sample of 25 healthy and affected persons to assess the performance of the proposed hand tremor measurement system. It is observed that the measurement is reliable when the intensity and frequency values of the tremor are averaged over several measurement cycles carried out at different instants of time. Computational studies have also been done by sweeping a narrow range of angular tilt (θ) of an ideal conductive plate of area A_h kept at various positions in between the capacitor plates. to simulate the output of the complete system.

CONCLUSION

In this proposed work, a non-contact transducer has been employed to measure hand tremor of patients suffering from neurological disorders. This method enhances the measurement accuracy to a great extent when compared to conventional contact type of measurements. The results of the proposed system are mostly in conformity with the clinical assessment. The authors are currently investigating the scope of using an optical type of non-contact transducer for the measurement of unconstrained hand tremor.

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