Defence Science Journal, Vol. 57, No. 1, January 2007, pp. 109-114

SHORT COMMUNICATION

Piezoelectric Sensor for Human Pulse Detection

A.E. Kalange and S.A. Gangal
University of Pune, Pune-411 007

ABSTRACT

Diagnosis according to *Ayurveda* is to find the root cause of a disease. Out of eight different kinds of examinations, *nadi-pariksha* is very important. By checking the pulse, the *Ayurvedic* physician finds the predominant *dosha* out of the three - *vata*, *pitta* and *kapha*. *Nadi-pariksha* is done at the root of the thumb by examining the radial artery. Presently, this technique is subjective and the accuracy of the diagnosis depends upon the expertise of the *Ayurvedic* physician. As a first step towards making the diagnosis by *nadi-pariksha* objective, human pulse detection and processing system has been developed.

Piezoelectric sensor was used for human pulse detection. The pulse signals obtained from the piezoelectric sensor were processed through signal processing circuitry. The signal provessing circuit consists of signal amplifier, filters, and noise-reduction circuit. The signal processing circuit has been designed, built, and tested. The performance of the developed system was evaluated by recording the pulses of people (subject) having different *doshas*. Pulse shapes, repetition rate, amplitude were found to be different for people having different *doshas*. Performance of the signal processing circuit and the pulse waveforms obtained have been presented and analysed.

Keywords: Human pulse, *nadi pariksha*, piezoelectric sensor, *doshas*, *vata*, *kapha*, *pitta*, piezoresistive sensors, human pulse detection

1. INTRODUCTION

Ayurveda[1] is a Sanskrit word that translates into knowledge (*veda*) of life (*ayur*). Ether, air, fire, water, and earth, the five basic elements, manifest in the human body as three basic principles, or humors, known as the *tridosha* called *vata*, *pitta* and *kapha*. As per the *Ayurvedic* system, from the ether and air elements, the bodily air principle called *vata* is manifested. The fire and water elements manifest together in the body as the fire principle called *pitta*, and the earth and water elements manifest as the bodily water humor known as *kapha*. These act as basic constituents and protective barriers for the human body in its normal physiological condition; when out of balance, these cause the disease.

Diagnosis according to *Ayurveda* is to find the root cause of a disease. Out of the eight different kinds of examinations *nadi-pariksha* (pulse examination) is important. By examining the pulse, an *Ayurvedic* physician finds the predominant *dosha* out of the three - *vata*, *pitta*, and *kapha*. So, once it is known which *dosha* is aggravated or out of balance, it is easy to bring it under control or balance using different kinds of therapies. *Nadi-pariksha* is done at the root of the thumb by

Revised 16 September 2006

examining the radial artery using three fingers. Presently, this technique is subjective and the accuracy of the diagnosis depends upon the expertise of the *Ayurvedic* physician. An expert *Nadi-Vaidya* diagnoses the disease quite accurately. It was felt that the method be converted to the objective one. As a first step towards the diagnosis by *Nadi-Vaidya*, an objective human pulse detection system has been developed.

Different types of pressure sensors are used for human pulse detection. Two types of sensors– piezoresistive and piezoelectric were tried for humanpulse detection. While using strain gauge transducer, waveform was noisy and there was dc shift due to the holding pressure and the shift varied as the holding pressure changed. Secondly, the strain gauge requires a power source for its operation. Piezoelectric transducer has good dynamic response, it does not show dc shift because of holding pressure and is an active transducer. Therefore, piezoelectric transducer was used for human pulse detection and the detected human pulse was processed through signal processing circuit. The pulse data obtained from people (subjects) having different *doshas*- *vata*, *pitta*, and *kapha*, have been compared with the standard pulse data in the literature, consulted with the *Nadi-Vaidya*, and discussed.

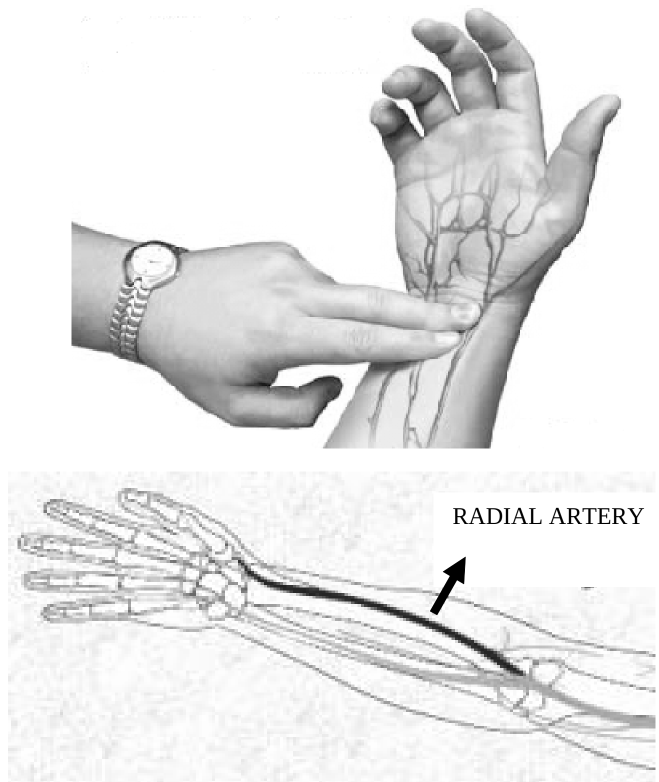


Figure 1. Pulse examination.

2. EXPERIMENTAL METHODS

The details of experimental methods used for detecting the human pulse and the circuits used for signal conditioning, have been given.

2.1 Human Pulse Detectors

Human pulse is detected on the radial artery at a position shown in Fig.1. Piezoelectric transducer is used for detecting the human pulse. This sensor has the advantage that it detects the dynamic pulse pressure and rejects the static pulse pressure operating on it, when it is pressed against the wrist. The piezoelectric transducer is placed on the skin surface over a palpable pulse. The pulse signals obtained from the piezoelectric sensor are passed through a signal processing circuitry. Since the sensor output is in mV, it is amplified so that it is appropriate for input into the data acquisition system. The noise is removed using filters. The circuit consists of buffer amplifier, low-pass filter, signal amplifier, and noise-reduction circuit. Position of the sensor on the wrist is to be adjusted to obtain appropriate pulse signal. A digital storage oscilloscope (Agilent 54621A model) is used to observe pulse waveform.

2.2 Signal Conditioning

Figure 2 shows the block diagram of the pulse processing circuit. The function and design of each block has been described as follows:

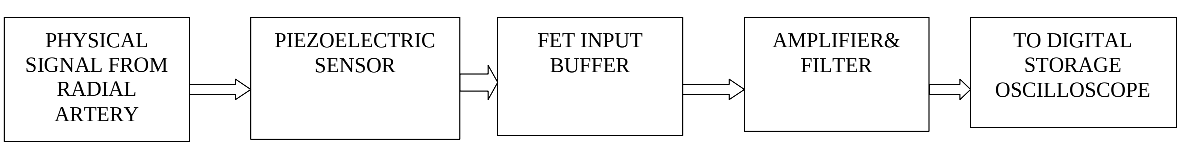


Figure 2. Block diagram of pulse detection system using digital storage oscilloscope.

- *Pulse sensor*: The piezoelectric sensor (lead zirconate titanate) was used for human pulse detection because it has good dynamic response. The piezoelectric elements act in the thickness compression mode and transforms changes in skin contact stress into an electric charge.

- *FET input buffer*: Piezoelectric sensor is modelled electrically as a capacitor and charge generator. A 10 MΩ resistance parallel to the sensor (Fig. 3) was chosen to reduce the cutoff frequency to below 1 Hz. When a high load resistance

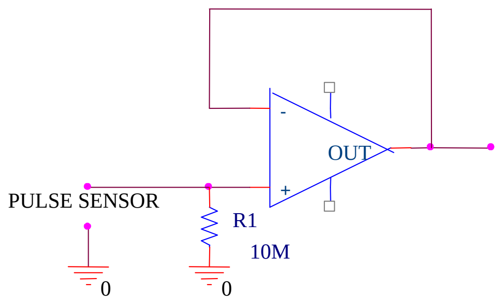


Figure 3. FET input buffer amplifier.

is selected, a low-leakage, high-impedance buffer is necessary. The FET input buffer circuit converts the high impedance of piezo film element into low impedance.

- *Low-pass filter and amplifier*: The output of the buffer is connected to low-pass filter[2,3] (Fig. 4) to filter out unwanted frequencies present in the pulse waveform. The low-pass filter is designed at the cutoff frequency of 100 Hz. The cutoff frequency is calculated by the following equation

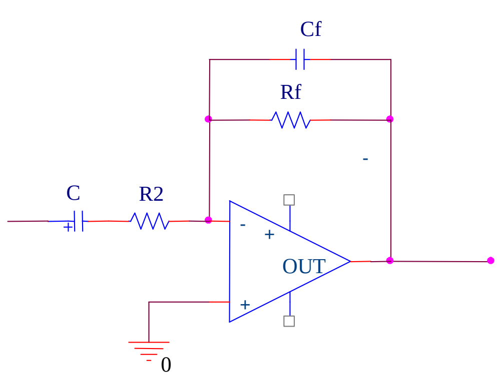


Figure 4. Low-pass filter/amplifier.

$$f_c = \frac{1}{2\pi R_f C_f}$$

and has a gain R_f/R_2.

- *Notch filter*: The signals received[2,3] are weak and therefore are susceptible to various noise sources. The information content in the pulse signal is approximately within the 0.1 Hz to 100 Hz frequency band. In this band, the most dominating disturbance is effect of the main ac power supply. The frequency of the ac power supply was 50 Hz (60 Hz within the US). Hence, a narrow-band suppress filter was used to suppress the 50 Hz frequency. This could be achieved using an R-C network followed by a 741 buffer (Fig. 5).

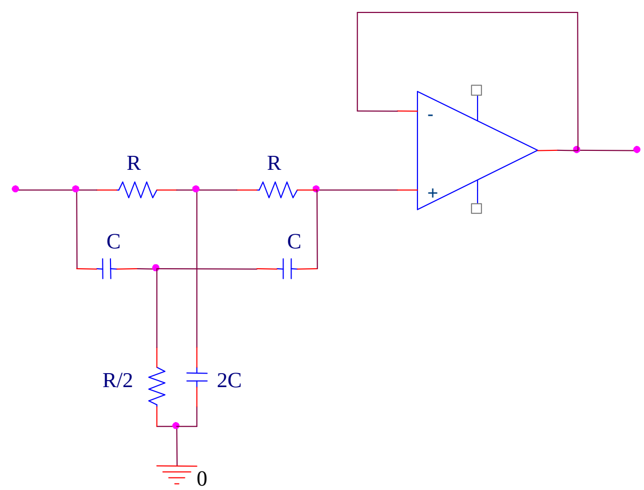


Figure 5. Notch filter.

2.3 Observing the Output Pulse Waveforms

The transducer is placed on the skin surface over a palpable pulse. A small size sphygmomanometer cuff is wrapped around the wrist and used to produce the holding. The cuff is first inflated to a pressure at which the pulse wave starts to appear on the monitor screen. The optimum pressure is applied to cuff to get a large, clear pulse of sufficient amplitude. Position adjustments are made to obtain appropriate signal.

A digital storage oscilloscope (Agilent 54621A model) is used to observe the pulse waveform. Pulse signal measurements were taken on different subjects (people). Each subject was asked to relax and sit on the chair and rest the forearm on the lab table to help the entire hand keep steady.

3. RESULTS AND DISCUSSION

Large number of human pulse samples was collected using the selected sensor and the developed signal conditioning circuit. The results obtained are analysed and discussed.

3.1 Signal Conditioning Circuit

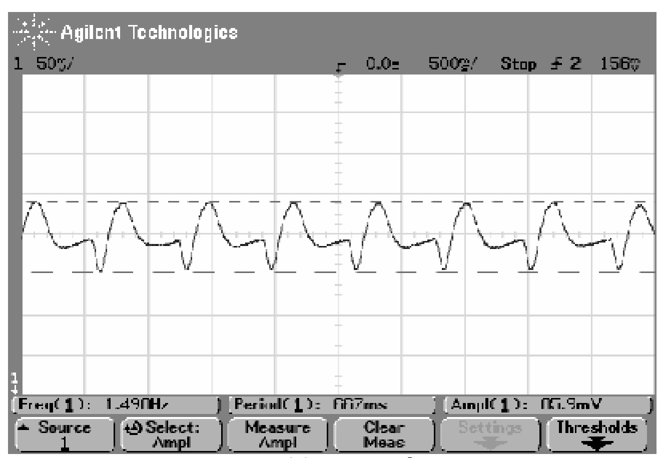
To develop the human pulse detection circuit, selection of the sensor is important. Two different types of sensors were tried. While using strain gauge transducer, it was observed that pulse waveform was noisy and there was a dc shift. The dc shift was because of the finger pressure on the sensor while holding. The dc shift varied as the holding pressure changed, and therefore, difficult to eliminate. Secondly, the strain gauge required a power source for its operation.

Therefore, piezoelectric transducer was used for human pulse detection. To interface piezoelectric sensor, high input impedance amplifier was necessary, therefore buffer amplifier was used. The circuit has very high input impedance. Applications notes from Measurement Specialties, Inc report that the low-end frequency response of the piezo film could be lowered from 5-6 Hz to 0.7 Hz using a 10 MΩ or higher input impedance. The same was therefore connected. The gain of buffer amplifier was unity. The filter/amplifier circuit was designed for cutoff frequency of 100 Hz and had a gain of 10. The filter/amplifier circuit filters out high frequencies (above 100 Hz) and amplifies input signal. The output pulse waveform contains more noise due to power line frequency interference. It is removed using narrow-band filter (notch filter) designed for 50 Hz. Since the frequency of pulse is very low, therefore digital storage oscilloscope was used for observing the human pulse. Applying averaging method using digital storage oscilloscope reduces the noise in pulse waveform. The output pulse waveforms observed were clear and sharp.

3.2 Recorded Pulse Waveform

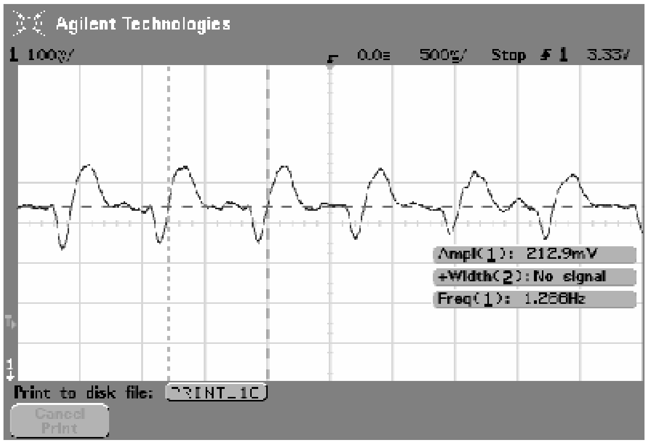
The pulse waveforms recorded with digital storage oscilloscope (Agilent model 54621A) on representative three different subjects are shown in Figs. 6(a) to 6(c). As can be seen from the figure, the pulse waveforms taken on different subjects had different shapes. It was also observed that the pulse repetition rate (frequency) was different. The pulse repetition rates were calculated on three different subjects were 1.498 Hz for subject a, 1.266 Hz for subject b, and 0.980 Hz for subject c. The subjects were also examined by the *Nadi-Vaidya*. Accordingly subject a was found to be *vata* dominant, subject b was found to be *pitta* dominant, and subject c was found to be *kapha* dominant. Pulse data on other subjects Vata, pitta. kapha dominated subjects was taken. The pulse repetition frequency for vata dominated was found to be in the range 1.35 Hz to 1.58 Hzthat for pitta dominated was found to be 1.16 Hz to 1.33 Hz & for kapha dominated was found to be0.833 Hz to 1.2 Hz.

The obtained human pulses were compared with the standard pulse data available in the literature. Pulses observed using Dudgeon's Sphymograph[5] are shown in Figs 6 (d) to 6(f) for comparison. The pulses shown in Figs 6 (d), 6(e), and 6(f) were reported to be diagnosing *vata*, *pitta*, and *kapha*, respectively. The pulses observed in the present work and identified by *Nadi-Vaidya* as *vata*, *pitta*, and *kapha* are shown by the side of the reported ones. The repetition rate calculated for reported data[5] are 1.37 Hz for *vata* pulse, 1.23 Hz for *pitta* pulse and 1.06 Hz for *kapha* pulse. *Vata* pulse is

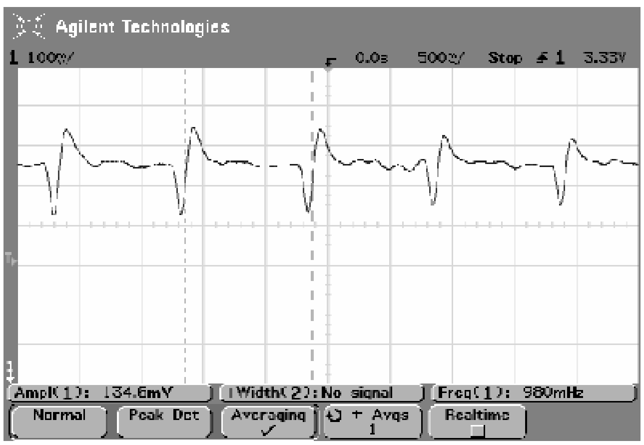


(a) *Vata* pulse

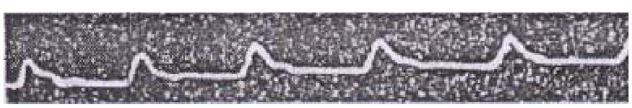
Figure 6. Comparison of observed waveform with pulse waveform obtained using Dudgeon's sphymograph.



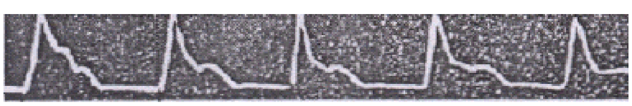
(b) *Pitta* pulse



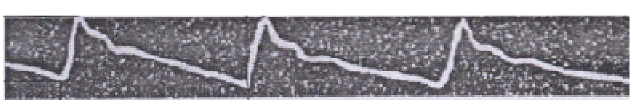
(c) *Kapha* pulse



(d) *Vata* pulse



(e) *Pitta* pulse



(f) *Kapha* pulse

Figure 6. Comparison of observed waveform with pulse waveform obtained using Dudgeon's sphymograph.

having more pulse repetition rate than the *pitta* pulse, and *pitta* pulse is having more pulse repetition rate than the *kapha* pulse. A similar trend was also observed in the case of observed pulses in the present study. It shows the feasibility of identifying dominant pulse type for the subjects.

4. CONCLUSION

A system to detect human pulse is successfully developed and pulse waveforms are recorded for different subjects. The recorded pulse waveforms are compared with standard pulse waveforms and also confirmed by *Nadi-Vaidya*. From the observed waveforms, pulse repetition rate (frequency), and conformation by *Nadi-Vaidya*, it can be concluded that it is possible to identify *vata*, *pitta*, and *kapha*-dominant subjects analysing pulse waveforms.

ACKNOWLEDGEMENTS

Mr Kalange is thankful to the Anekant Education Society, Tuljaram Chaturchand College, Baramati, and University Grant Commission (UGC) for providing Teacher Research Fellowship (TRF) to carryout this study.

REFERENCES

1. Lad, Vasant. Ayurveda–Secrets of the pulse; Lotus Press, Motilal Banarasi dass Publishers, Delhi, 2005, pp.10-14.

2. Clayton, George & Winder, Steve. *In* Operational amplifier, Ed. 5. Elsevier Publication, 2003, pp. 241-42.

3. Gayakwad, Ramakant. Op-amps and linear integrated circuits, Ed. 3. PHI Publication, 1998. pp. 315-16.

4. McNeill, McLaughlin; Braun, B. & McCormack, P.D. Piezoelectric sensor determination of arterial pulse wave velocity. *J. Physiol. Meas.*, **24**, 693-02.

5. Upadhya, Sarva Deva. *In Nadi Vignanam*. Chowkhamba Series, Varanasi, 1986. pp.169- 74.

Contributors

Mr A.E. Kalange was working as a Lecturer in the Dept of Physics at the Tuljaram Chaturchand College, Baramati. Presently, he is working as Teacher Research Fellow in the Dept of Electronics, University of Pune. His area of interest are: Biomedical instrumentation, biophysics, sensors.

Dr (Ms) S.A. Gangal is Professor and Head, Dept of Electronics, University of Pune. Her areas of interest are: Sensors, microelectroics, micromachining, electron beam lithography and resists, thin and thick films physics and technology, microwave microstrip-line circuits.