Communications on Applied Electronics (CAE) – ISSN : 2394-4714
Foundation of Computer Science FCS, New York, USA
Volume 1 – No.6, April 2015 – www.caeaccess.org

Wrist Pulse Acquisition and Recording System

Suket Thakkar
Post Graduate Student,
Embedded Systems, GCET,
V.V.Nagar, Gujarat, India

Bhaskar Thakker
Professor and Head,
EC Department, GCET,
V.V.Nagar, Gujarat, India

ABSTRACT
Wrist pulse signals provide rich amount of information for the health diagnosis. Traditional practitioner following Ayurveda (Ancient Indian Medicine) measures radial pulse signals using three fingers at three distinct radial pulse points identified as Vata, Pitta and Kapha and indentifies the abnormal health status accordingly. This method of diagnosis requires several years of experience. Being subjective in its nature, this approach depends upon the perception of individual practitioner as well. Hence a wrist pulse monitoring and recording system is essential to provide objectivity in measurement and to take the benefits of this ancient approach of diagnosis.

This work focuses on the design and development of a novel wrist pulse acquisition and recording system. In this proposed system, three channel wrist pulse signals are acquired using pressure sensor. Signal conditioning circuit is implemented to amplify and filter the wrist pulse signals. Advance microcontroller having ARM Cortex M4 architecture is used for digitization of signals. These digitized signals are displayed on graphic color LCD for real time monitoring. Touch interface is also included for zoom-out or zoom-in purpose. Recording of the signals is done on micro SD memory card for off line processing and analysis. This system can be used for better understanding of wrist pulse signals and to train Ayurvedic practitioner for the observation of pulse signal.

General Terms
Biomedical Instrument, Pulse Diagnosis, Signal Acquisition, Signal Recording

Keywords
Wrist Pulse Signal, Radial Artery, Ayurveda, Vata, Pitta, Kapha.

1. INTRODUCTION
In arterial system, sudden outcome and transmission of blood results an abrupt expansion of an artery which is called as Pulse. In clinical practice, pulse is examined at radial artery. [1] From ancient time in India, wrist pulse signals have been used for health diagnosis. Science of pulse is called as 'Nadi Vijnana'(Sphygmlogy).

Traditional practitioner following Ayurveda (Ancient Indian Medicine) measures radial pulse signals using three fingers at three distinct radial pulse points identified as Vata, Pitta and Kapha (Distal, Middle & Proximal respectively) and indentifies the abnormal health status accordingly. [2]

These three basic elements; Vata, Pitta and Kapha; and their relative pressure in the body reflect disorder present in the body. The qualities of these three elements are reflected in the form of characteristics of the pulse signals.

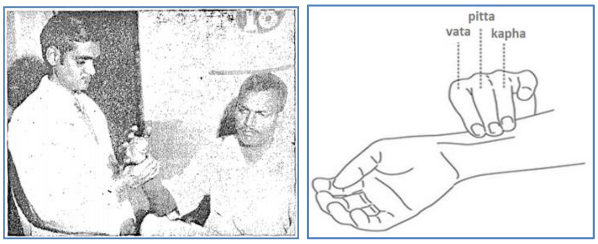

Figure 1: (a) Practitioner examining *nadi* of patient, (b) Traditional Pulse diagnosis method [2]

Traditional method of diagnosis requires several years of experience. Being subjective in its nature, this approach depends upon the perception of individual practitioner as well.

In China, researchers hoped to illustrate the value of the wrist pulses as a diagnostic method and also to aid in standardizing their measurement by devising modern devices for getting an objective pulse form. The result of such a measurement, using devices to detect the pulse, is a printed version, called a sphygmogram. [3] Having mechanical structure in nature, more positioning care was required and it was not much comfortable to use with. [4]

Hence an electronic instrument is to be devised to provide objectivity in measurement and to take the benefits of this ancient approach of diagnosis. [3] In the inspiring paper [5], researchers have used piezoelectric pressure sensors. Spring like mechanism was used to apply pressure. Tiyanyu Fu [6] has developed mobile application named as Dr. Chi which implements heart pulse reading. Admiring work has been carried out by Peng Wang, Wangmeng Zuoand and David Zhang [7] by developing sensor design using SSG (semiconductor strain gauge) sensors for multichannel wrist pulse signals. In this paper, a system is proposed with 32-bit microcontroller for acquiring, monitoring and recording of pulse wave patterns.

2. PROPOSED ARCHITECTURE
Wrist pulse signals are acquired using pressure sensor. Analog and digital filters are applied to remove noise and amplify signals accordingly. The filtered and amplified signals are digitized with the help of 32-bit microcontroller and displayed on LCD having touch interface to monitor them in real time. Signals are stored in micro SD memory card for off line processing that can be done on Personal Computer.

Communications on Applied Electronics (CAE) – ISSN : 2394-4714
Foundation of Computer Science FCS, New York, USA
Volume 1 – No.6, April 2015 – www.caeaccess.org

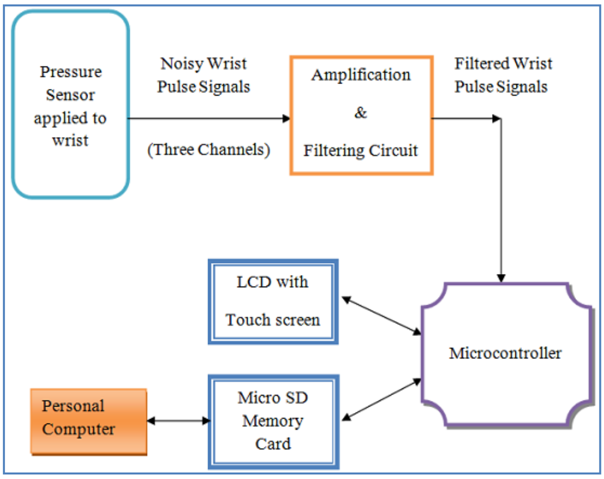

Figure 2: Block Diagram of Proposed System

3. SYSTEM COMPONENTS & DESIGN

System design comprises of wrist pulse sensor mechanism, analog signal conditioning circuit and digital filter implementation using ARM Cortex M4 CMSIS (Cortex Microcontroller Software Interface Standard) library.

3.1 Wrist Pulse Sensor

There are verities of pressure sensors available in the market. Piezo-resistive pressure sensors are highly sensitive and capable of providing DC as well as AC component present in the information signal thereby providing the static as well as dynamic component in the signal. [8]

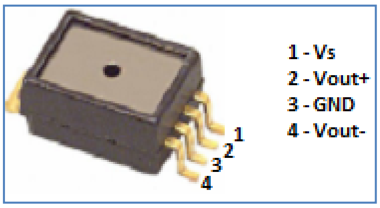

Figure 3: MPXM2053D Peizo-resistive pressure sensor [8]

Among the available peizoresistive pressure sensors, MPXM2053D from Freescale is selected. The physical dimension of the sensor is 9.1mm x 7.1mm in terms of length and width, which is almost similar to the surface area covered by finger tip surface and hence appropriate for the task of wrist pulse acquisition.

Sensor is designed with thin film resistor network integrated on chip and has good linearity and high sensitivity. It provides measurement of pressure signal with full scale pressure range of 50 KPa (375 mmHg) (1 KPa = 7.50061683 mmHg) with 0.8mV/KPa/Volt sensitivity and 0.4% non-linearity.

High Blood Pressure range in adults is 140mmHg to 190 mmHg (systolic) and 90 mmHg to 100mmHg (diastolic). [9] Thus Pressure sensor range of our sensor (350 mmHg) is sufficient to examine patient in various health conditions.

3.2 Pulse Signal Conditioning

Wrist pulse signals are weak in nature and contain noise from outside. Their frequencies are found to be restricted within 20Hz. To remove the noise present in the signal and to amplify and filter the pulse signals, a signal conditioning circuit is essential. Instrumentation amplifier is used for noise removal and amplification, Low pass filter is used to filter signal within 20Hz. Level shifter is designed to add dc offset in the signal so that signal can be given to ADC (A-D Converter) of microcontroller for digital filtering.

FIR (Finite Impulse Response) filter is designed with the help of ARM Cortex M4 CMSIS library. CMSIS supports developers in creating reusable software components for ARM Cortex-M based systems. STM32F4xx series controllers have CMSIS library support and also have built in FPU (Floating Point Unit). FPU is utilized during digital filtering of wrist pulse signals. CMSIS library have FFT (Fast Fourier Transform) algorithm support which can further be utilized in processing the recorded wrist pulse signal for classification of diseases.

3.2.1 Instrumentation Amplifier

The differential input of wrist pulse sensor is given to Instrumentation Amplifier, INA128, with 120 dB CMRR (Common Mode Rejection Ratio). INA128 is having trimmed resistor for achieving high CMRR; which ultimately helps in reducing noise as common mode signal. [10]

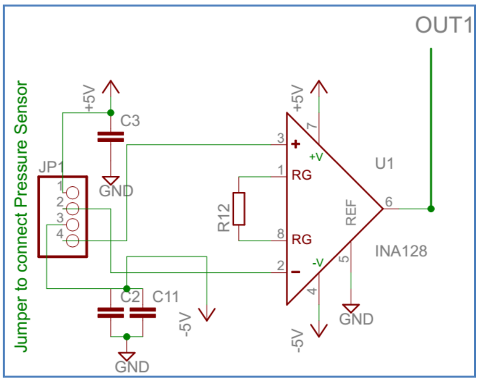

Figure 4: Instrumentation Amplifier Design

Gain is set by using Gain1 = 1 + 50K/R12. Taking R12 = 10K, Gain is achieved as 6.

3.2.2 Low Pass Filter and Level Shifter Design

Wrist pulse signals have low frequencies and not expected to go beyond 20Hz. Thus a second order low pass Butterworth low pass filter has been designed to restrict signal in our band of interest.

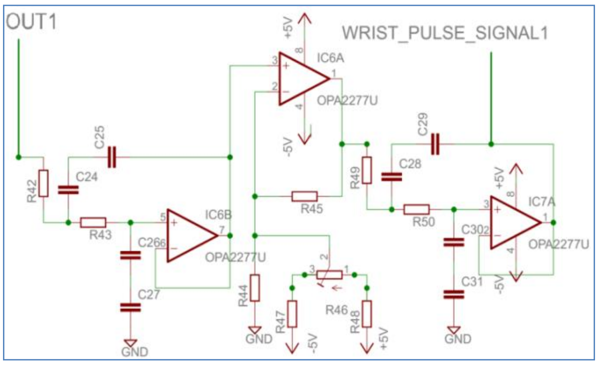

Figure 5: Low Pass Filter and Level Shifter design

The cutoff frequency is given by Equation 1.

$$fc = \frac{1}{2\pi\sqrt{RxRyCxCy}} \quad (1)$$

Where, R_x = R42, R_y=R43, C_x= (C24||C25), and C_y= (C26||C27). Values are adjusted such that f_c becomes 20Hz.

DC offset can be adjusted to remain in boundaries by using level shifter. Thus signal does not acquire negative as well as very low values, which after all help ADC to convert them in digital values. This dc offset is adjusted by variable resistor R46 as shown in Figure 5.

3.2.3 Digital Filter Implementation

Although analog filters are advantageous in terms of the dynamic amplitude and dynamic frequency range, the flatness of signal achievable from analog filters is limited by accuracy of resistors and capacitors used. There remains residue ripple, of perhaps 1%, even if butterworth response is designed. Digital filters are hundreds of times flatter than analog filters. [11] In this context, a digital filter is an effective choice to make the signal smoother after analog filter implementation,. Low pass filter FIR (Finite Impulse Response) filter having cut-off frequency 20Hz is designed using ARM Cortex CMSIS library support. Digital filter is implemented using convolution of signal with coefficients h_m of low-pass FIR filter given by:

$$h_m = 2 * \frac{f_c}{f_s} * \frac{\sin(2\pi m * \frac{f_c}{f_s})}{2\pi m * \frac{f_c}{f_s}} \qquad (2)$$

Where, f_s stands for sampling frequency and f_c stands for corner frequency of the signal. The sharpness of the filter is better for a large number of coefficients. However, a large number of coefficients imply many multiplications in the convolution formula. 64-taps digital low pass FIR filter is designed in our system.

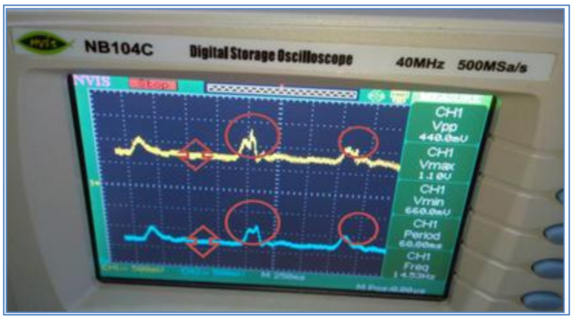

Figure 6: Effect of digital filter on DSO (Digital Storage Oscilloscope)

The first signal shows wrist pulse signal before applying Digital filter. Second signal is the result of applying a digital filter. As shown in Figure 6, unwanted spikes (ripples) have been reduced and noise amplitude has been reduced.

4. EXPERIMENTAL RESULTS

Wrist pulse obtained after signal conditioning is displayed on LCD with touch interface and signals are recorded in micro SD card. Interactive user-friendly design has been designed and VATA, PITTA and KAPHA signals have been acquired.

4.1 Pulse Signal Display on LCD

Wrist pulse signals are displayed on LCD to make system portable. STM32F429 Discovery board is utilized in our system. The choice of this board is made according to the features supported by it to suffice system requirements.

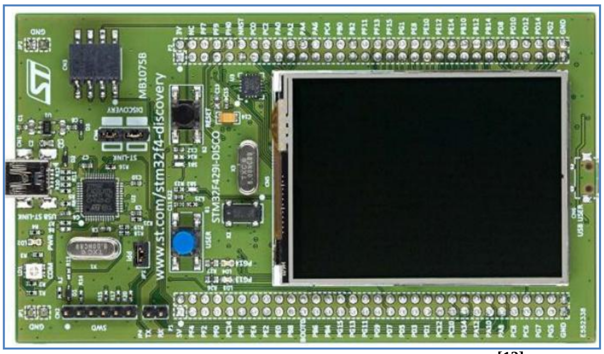

Figure 7: STM32F429I Discovery Board [12]

Features of STM32F429I discovery board:

1) ARM Cortex M4 architecture with CMSIS library support and built in FPU; which helps in digital filtering of signal.
2) 180 MHz High speed clock; which helps in filtering, digitizing and displaying signals in real time.
3) 2.4” color LCD with touch interface; which helps in displaying signal and making system user friendly using touch interface as mentioned in section 4.3.

Wrist pulse signal is applied to one of the ADC (A-D Converter) pins of STM32F429 microcontroller for digitization. The digitized values are mapped to get them displayed on graphic color LCD of STM32F429I Discovery Board.

Figure 8: Examining wrist pulse of colleague

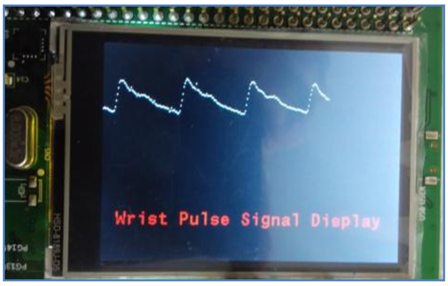

Figure 9: Wrist Pulse Signal of colleague on LCD of STM32F429I Discovery Board

4.2 Signal Data Storage on micro SD card

Offline processing of wrist pulse signals can be done by storing signal values on micro SD memory card. SD card can be interfaced with micro-controller using SDIO (Secure Digital Input Output) and SPI (Serial Peripheral Interface) communication. STM32F4xx has internal SDIO peripheral to work with SD cards. Also, SDIO communication is faster than

Communications on Applied Electronics (CAE) – ISSN : 2394-4714
Foundation of Computer Science FCS, New York, USA
Volume 1 – No.6, April 2015 – www.caeaccess.org

SPI. SDIO can be configured in 4-bit as well as 1-bit mode. SD 1-bit is serial transfer and 4-bit is serial-cum-parallel transfer. Thus 4-bit is faster than 1-bit mode at the cost of three additional pins. Figure 10 shows interfacing of micro SD card with STM32F429 microcontroller.

NR	SDIO INTERFACE			
	NAME	STM32F4XX		DESCRIPTION
		4-BIT	1-BIT	
1	CD/DAT3	PC11	-	Connector data line 3
2	CMD	PD2	PD2	Command/Response line
3	VSS1	GND	GND	GND
4	VDD	3.3V	3.3V	3.3V Power supply
5	CLK	PC12	PC12	Clock
6	VSS2	GND	GND	GND
7	DAT0	PC8	PC8	Connector data line 0
8	DAT1	PC9	-	Connector data line 1
9	DAT2	PC10	-	Connector data line 2

Figure 10: SD Card Pin Out and its connections with STM32F4xx device [13]

Acquired wrist pulse data are stored in micro SD card using 4-bit SDIO (Secure Digital Input Output) mode. Signal data stored in excel file can be visualized as using *Line Chart* functionality in excel as shown in Figure 11. First 200 ADC converted values of signal are displayed. Stored data can be useful in further processing and classification of signal for diseases.

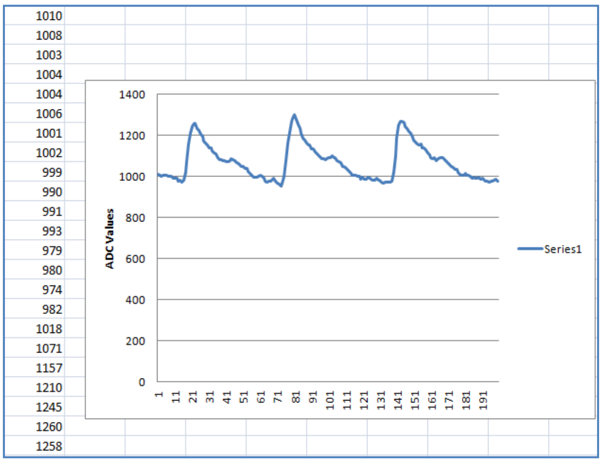

Figure 11: Wrist Pulse Signal data stored in Excel Sheet

4.3 VATA, PITTA and KAPHA Signal: Interactive User-Friendly Design using Touch Screen

Touch Screen is interfaced to make system interactive and easy to use for user. When user touches 'START' symbol, system starts acquiring signals as shown in Figure 13. 'Time Span +' is used to analyze signal for longer duration and 'Time Span -' is used to analyze signal for short period of time. Time is chosen according to the clear view of signal on LCD. Flowchart of the system is shown in Figure 12.

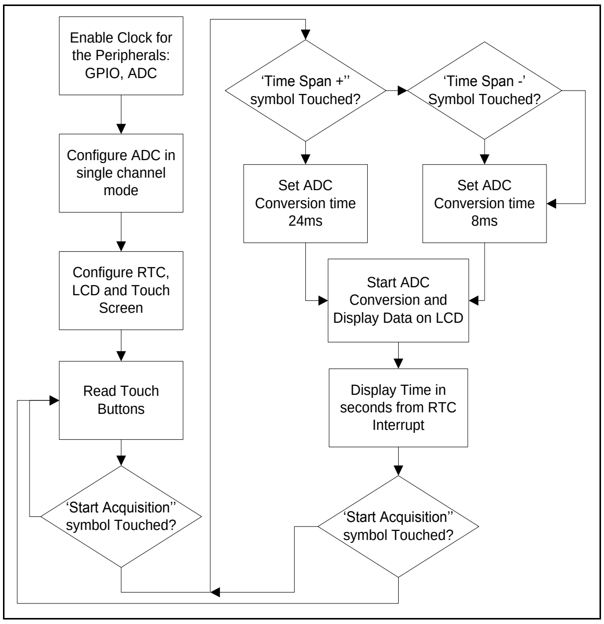

Figure 12: Flowchart of system

As mentioned in [14], VATA pulse is fast, light, feeble and thin. It moves like a cobra and it is best felt under index finger. PITTA pulse is prominent, strong, high amplitude and forceful. It moves like a frog and it is best felt under middle finger. KAPHA pulse is deep, slow, broad, thick and regular. It moves like a swimming swan and it is best felt under ring finger. VATA, PITTA and KAPHA pulses have been observed by examining Vata dominant, Pitta dominant and Kapha dominat persons respectively. The result is shown in Figure 13 (a), (b) and (c).

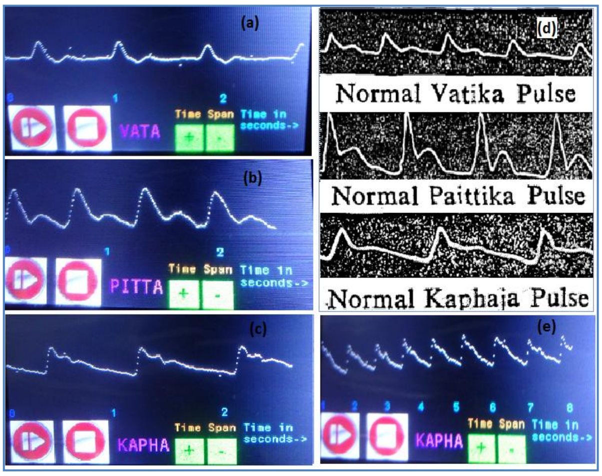

Figure 13: (a) VATA pulse (b) PITTA pulse and (c) KAPHA pulse on LCD (d) Waveforms available in literature [2] (e) Use of Time Span

Obtained result is compared with waveforms available in literature [2] (pp. 171) as shown in Figure 13 (d). Results shows a good match between them. Time Span is used to analyse signal for longer period as shown in Figure 13 (e). Although signal pattern is better observed in shorter time span, the longer time span helps in detecting frequency of signal easily.

5. CONCLUSION AND FUTURE WORK

Wrist pulse signals have been used from ancient time for health diagnosis. This work focuses on the design and development of a novel wrist pulse acquisition and recording system. High speed STM32F429 microcontroller having ARM Cortex M4 architecture, Analog and digital filter implementation, LCD with touch interface, micro SD card for data storage and PC interface for further analysis of signal have been used to make system reliable, fast responsive and user-friendly.

This system can be used for better understanding of wrist pulse signals and to train Ayurvedic practitioner for learning the characteristics aspects of the pulse signals in various health conditions. Future work concentrates on classification of pulses in healthy and unhealthy class. Frequency domain based analysis can be done for further processing.

6. REFERENCES

[1] Medha Sanjeev Dhurandhar, Girish Shrikrishna, “Diagnostic Classifications of Pulse signal waveform data”, United States Patent Application Publication, Pub. No.: US 2012/0184861 A1, Pub. Date: 19, 2012

[2] S. Upadhyaya, “Nadi Vijnana - Ancient Pulse Science”, Chaukhamba Sanskrit Pratishthan

[3] An essay on “Traditional Pulse Diagnosis” by Subhuti Dharmanandana, Director, Institute for Traditional Medicine, Portland http://www.itmonline.org/arts/pulse.htm

[4] J. Bukdon Sandeeson, “Handbook of the Sphygmograph”, Spottiswoode and Co.New Street Square, London

[5] Abhinav, Meghna Sareen, Mahendra Kumar, Jayashree Santhosh, Ashok Salhan, Sneh Anand, “Nadi Yantra : A robust system design to capture the signals from the radial artery for assessment of the autonomic nervous system non-invasively”, J. Biomedical Science and Engineering, July 2009, 2,471-479

[6] Tianyu Fu, “Pulse Reading Mobile Application: Dr. Chi”, Electrical Engineering and Computer Sciences University of California at Berkeley, Technical Report No. UCB/EECS-2012-150, June 1, 2012

[7] Peng Wang, Wangmeng Zuo and David Zhang, “A Compound Pressure Signal Acquisition System for Multichannel Wrist Pulse Signal Analysis”, IEEE Transactions on Instrumentation & Measurement, Vol. 63, No. 6, June 2014

[8] MPXM2053D Datasheet – Freescale Semiconductor

[9] Blood Pressure Chart http://www.bloodpressureuk.org/BloodPressureandyou/Thebasics/Bloodpressurechart

[10] INA128 Datasheet – Texas Instruments

[11] Steven W. Smith, “The Scientist and Engineer's Guide to Digital Signal Processing”, California Technical Publishing

[12] 32F429IDISCOVERY Datasheet – ST Microelectronics

[13] SD Card Interfacing with STM32F4xx http://stm32f4-discovery.com/2014/07/library-21-read-sd-card-fatfs-stm32f4xx-devices/

[14] Vasant Lad, “Secrets of Pulse: The ancient art of Ayurvedic pulse diagnosis”, The Ayurvedic Press, New Mexico