Microcontroller Based ECG Arrhythmia bio-Simulator for Testing ECG Machines

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Abstract

This paper the design and development of Micro-controller based ECG simulator intended to use in testing, calibration and maintenance of ECG machines and to support biomedical engineering student's education. It generates all 12lead ECG signals of varying heart rate, amplitude and different noise contamination in a manner which reflects true noninvasive conditions. Since standard commercially available electronic components were used to construct the prototype simulator, the proposed design was also relatively inexpensive to produce. It is portable battery operated instrument with alphanumeric LCD display and keyboard for waveform selection. The operator can control the amplitudes of various signals and the name of selected signal will appear on 16X2 LCD display.

The aim of the ECG tester is to produce the typical ECG waveforms of different leads combinations and as many arrhythmias as possible. The ECG simulator enables us to analyze and study normal and abnormal ECG waveforms without actually connecting it patients. During testing of ECG machines it is not possible to connect it to patient hence this instrument facilitates to the task. This can also used as teaching aid for Engineering and medical college laboratories for cardiac signal study and testing [3].

Keywords- *simulator, ECG arrhythmia, electrocardiograph monitoring, patient cable, ECG pad, secure digital card.*

I. INTRODUCTION

ECG is an electrical activity of the heart whende polarization and depolarization occur of the a trial and ventricular chambers of the heart [1]. The ECG electrical manifestation of the contractile activity of the heart can be recorded easily with the surface electrodes on the limbs or chest. It is the most commonly recognized biomedical signal[2]. The rhythm of heart in terms of beats per minute may easily estimated. Abnormal heart rhythms (arrhythmias) are caused by problems in the electrical system that regulates the steady, rhythmic beat of the heart. The heartbeat may be too slow or too fast; it may remain steady or became chaotic. Some arrhythmias are dangerous and cause sudden cardiac death, while others may be bothersome but are not life threatening [11].Before testing ECG on monitor sing patient, it is wise to have an electronic simulator with which it can be tested. This is important for a couple of reasons. First, it is important in the, building and debugging, in order to have a test signal with which to test each new component. Second, it is important in the final safety testing stage, in order to make sure the full system is working satisfactory and safe to use on a human subject before making any electrical connections to a living being [4].Using standard signals of ECG simulator one can test ECG monitors for base line drifting, 50 Hz noise interference, no offset present, accurate display of the standard signals, checking for various standard arrhythmia signals.

II. DATA BASE COLLECTION

ECG Data is collected from cardiac department of few reputed hospitals in Pune. The collected data is stored in the secure digital card of simulator. The secure digital card is interfaced with microcontroller in serial peripheral interface mode. The standard square wave, sine wave also stored in the SD card for calibration. The selected data is interfaced with12-bit DAC which outputs 9lead ECG waveform. The output of DAC is connected to the ECG connector pad and the selected waveform is observed on the monitor using patient cable.

To introduction to various ECG waveforms is given as below.

A. *Electrocardiogram*

The body fluids and the tissues of the human body conduct electrical current. Consequently, the electrical changes that result from the depolarization and depolarization of the myocardium (the second layer of the heart) are spread to the body surface, from where the changes are recorded [1]. Figure1 shows a PQRST waveform. The P wave is caused by the contraction of the atria heart chambers. Since the mass of the ventricular chambers is large compared to the mass of the atria chambers, it causes a large deflection when the ventricles contract. This deflection is called the 'QRS' waveform. The 'T'wave of the ECG is caused by the return of this ventricular mass to the resting electrical state (depolarization).P wave amplitude = 0.2mV, QRS complex = 1.6mV, T wave= 0.1 to 0.5 mV, R-R interval = 0.6 to1.2 sec, Q-R-S interval= 80 to 120msec, P wave = 80 msec, P-R =120 to 200 msec,

A. S-T wave interval = 80 to 120 msec, T =160 msec [10].

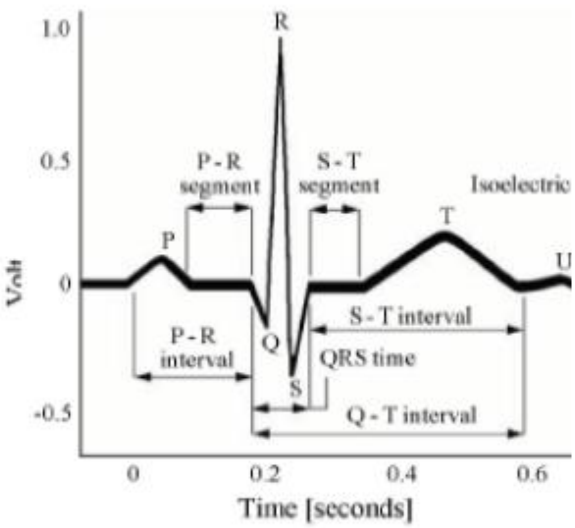

Fig. 1 A standard ECG signal

B. Causes & Types of arrhythmia mentioned as below

1) AV node blockage
2) SA node blockage
3) Improper working of valves
4) Obstacles in the transfer path of electrical stimuli from top to bottom of heart [11].

Types of arrhythmias
Arrhythmias that originate in the heart's upper chambers, the
atria
1) Sinus bradycardia
2) Sinus tachycardia
3) Atrial flutter
4) Atrial fibrillation
Arrhythmias that originate in the heart's lower chambers, the
ventricles
1) Ventricular tachycardia
2) Ventricular fibrillation
Other
1) Premature Contractions
2) Long QT Syndrome (LQTS) [11].

C. Sinus bradycardia

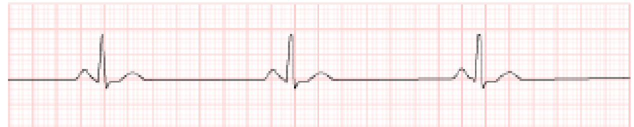

Fig. 2 ECG bradycardia

The heart rate less than 60 beats per minute is known asbradycardia. Sinus bradycardia is not a changed rhythm, it issimply normal sinus rhythm slowed down.

D. Sinus Tachycardia

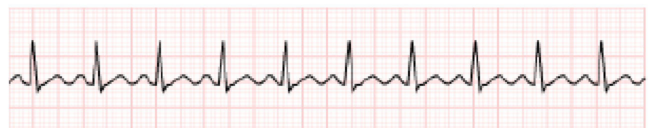

Fig. 3 ECG tachycardia.

During exercise, it is common for a person's heart rate togo above 100bpm. This is known as Tachycardia and, ifthe rhythm is sinus, it is known as Sinus Tachycardia.Sinus tachycardia is not a different rhythm; it is simplysinus rhythm going faster than 100 bpm.

E. Atrial flutter

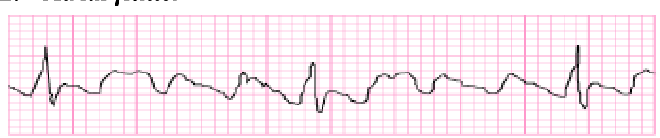

Fig. 4 Atrial Flutter (with 4:1 block)

AFL is caused by a single electrical wave that circulatesvery rapidly in the atrium, about 300 times a minute,leading to a very fast, steady heartbeat.

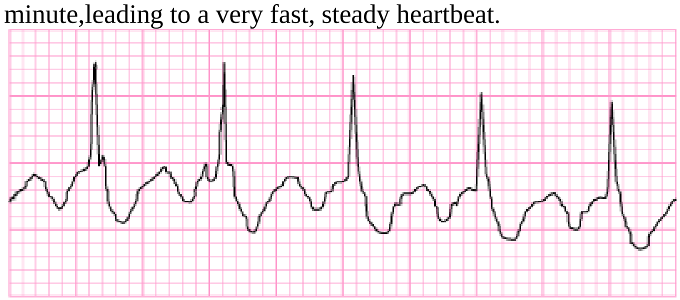

Fig. 5 Atrial Flutter (with 2:1 block)

F. Supra-Ventricular Tachycardia

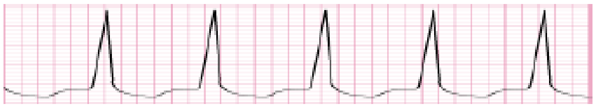

Fig. 6 Ventricular tachycardia

In this case ventricles beat with very fast rate above 400
beats per minute.

III. TECHNICAL SPECIFICATION OF SIMULATOR

The required technical specification of the proposedsimulator is given below

A. Input Specification

· Power: Mains Input: 230VAC, 50Hz,1Phase
· DC Output: 18Vdc & 1.2A
· Battery: 12V/ 0.8AH rechargeable.
· LED indication
• Mains on - Green LED.
• Battery on - Yellow LED.
• Battery low—Red LED.
· Dimensions: 211LX161WX 88 H mm approximately.
· Weight: 1.5 kg. (With Battery) approximately
· Operating temperature -5 degree to +45 Degree C
· Gain selection facility provided
• Display: 16 X 2 alphanumeric blue LCD display withbacklit
• Keyboard interfacing for proper waveform selection: Up & down Keys

B. Design

The dsPIC33F device family employs a powerful 16-bit architecture that seamlessly integrates the control features of a Microcontroller (MCU) with the computational capabilities of a Digital Signal Processor (DSP). Theresulting functionality is ideal for applications that rely on high-speed, repetitive computations, as well as control [4].

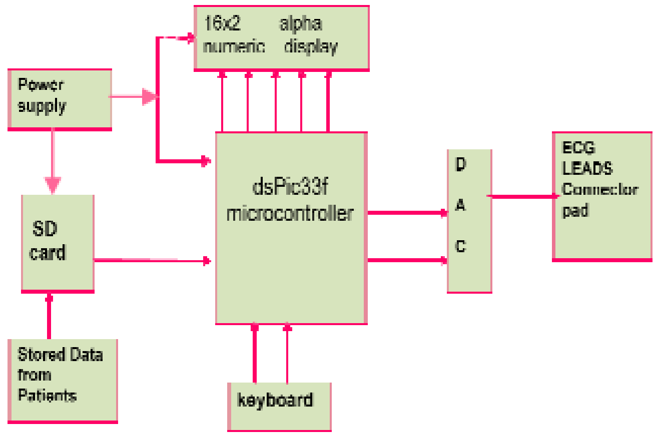

Fig. 7 Block diagram of ECG simulator

Data collected from various patients stored in SD card of2GB transferred to DAC through microcontroller interfacing programming. SD card and DAC is interfaced with microcontroller in SPI mode[6]. AS per key selection name of the waveform will display on 16 x 2 LCD and selected waveform transfer to DAC with 12 bit resolution. The waveform will available on 12 lead press button ECG pad This ECG waveform can be used for testing ECG machines by connecting patient cable to the ECG pad.

1) Hardware Design

1) Microcontroller: Microcontroller dsPicFJ128GP306From microchip commands several actions in thecommunication and DAC interfacing.The assignments of Port pins RG2 to RG9 are used SD cardconnection.
RG3 - SD card power on
RG6 - SD clock
RG7 - SD output
RG8 - SD Input
RG9 - SD chip select

2) DAC interfacing

IC TLV 5630 with 8 channels used as DAC1 for 8 leadconnection and single channel from IC TLV 5638 DAC2 thus9 lead ECG will be available on ECG pad.

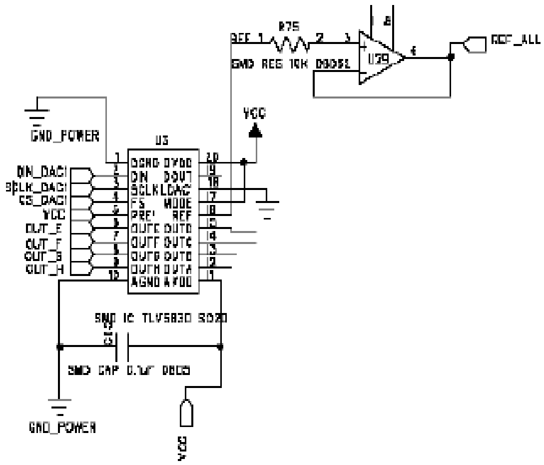

Fig. 8 DAC TLV 5630

Microcontroller port pins RB15 acts as DAC input, RB14 is used for clock, RB13 is used for chip select pin for DACinterfacing.

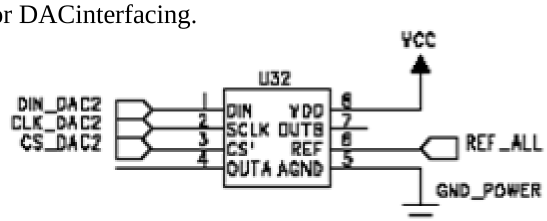

Fig. 9 DAC TLV 5638

Microcontroller port pins RB12 acts as DAC2 input, RB11 acts as clock and RB10 acts as chip select.

3) Op-amps interfacing

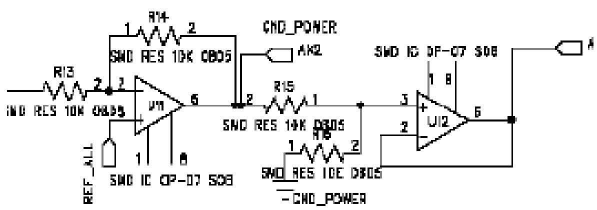

Fig. 10 Amplification of Signal at Stage I and Stage II

Output of each op amp is given to analog multiplexer andswitch is connected for gain selection 1mV or 1V. Further it isconnected to ECG pad which can be connected to ECGmachine using patient cable.

4) LCD interface
Microcontroller port pins RC13 & RC 14 pins are used forLCD

5) Keyboard interface
Microcontroller port pins RB4 &RB5 are used for key boardinterfacing

6) Secure Digital card (SD card)
The Secure Digital Card is a flash-based memory card that isspecifically designed to meet the security, capacity,performance and environmental requirements inherent innewly emerging audio and video consumer electronic. The SDCard interface allows for easy integration into any design, regardless of microprocessor used. For compatibility withexisting controllers, the SanDisk SD Card offers, in additionto the SD Card interface, an alternate communicationprotocol, which is based on the SPI standard [6].

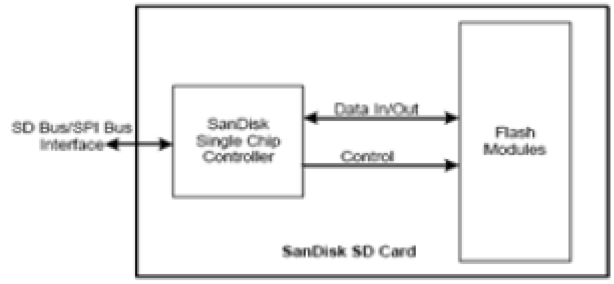

Fig. 11 SD Card Block Diagram

7) Power supply design

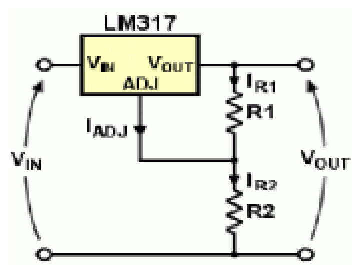

Fig. 12 IC LM317 Voltage Regulator

LM 317 develops a nominal 1.25 v reference voltage between the output and adjustment terminal. Vin =18V.
Vout = Vref (1+ R2/R1) +IadjR2
R2=1.5K_, R1=145_ sets output voltage equals to 14.2Vrequire for charging battery.

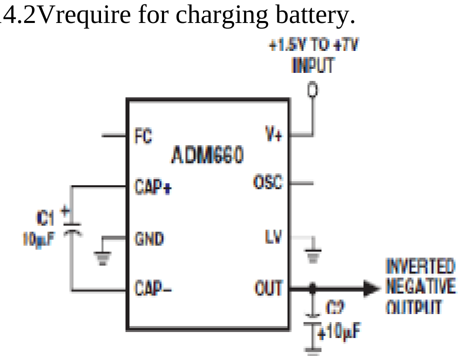

Fig. 13 IC ADM660

ADM660 configured to generate a negative output voltage.The MAX1614 drives high-side, N-channel power MOSFETsto provide battery power-switching functions in portableequipment. The LM2650 is a step-down DC/DC converter.

2) Software Design

The program resident in the microcontroller was written in compilersoftware using MPLAB IDEV8.10.This program controls data transfer between SD card and microcontroller and between microcontroller and DAC using SPI interfacing mode. The serial peripheral interface (SPI) is a synchronous serial interface useful for communicating with other peripheral or microcontroller devices. Each SPI module consists of a 16-bit shift register, SPIxSR,used for shifting data in and out, and a buffer register,SPIxBUF. A control register, SPIxCON, configures themodule. Additionally, a status register, SPIxSTAT, indicates various status conditions.

The serial interface consists of 4pins: SDIx (serial data input), SDOx (serial data output),SCKx (shift clock input or output) and SSx (active low slaveselect). In Master mode operation, SCK is a clock output butin Slave mode, it is a clock input. A series of sixteen (16)clock pulses shift out bits from the SPIxSR to SDOx pin and simultaneously shift in data from SDIx pin. An interrupt is generated when the transfer is complete and the corresponding interrupt flag bit SPI2IF is set. This interrupt can be disabled through an interrupt enable bit SPI2IE [5].
The receive operation is double-buffered.

When a completebyte is received, it is transferred from SPIxSR to SPIxBUF. Ifthe receive buffer is full when new data is being transferred fromSPIxSR to SPIxBUF, the module will set the SPIROVbit indicating an overflow condition. The transfer of the data fromSPIxSR to SPIxBUF will not be completed and the newdata will be lost. The module will not respond to SCLtransitions while SPIROV is '1', effectively disabling themodule until SPIxBUF is read by user software [5].

Transmit writes are also double-buffered. The user writes to SPIxBUF. When the master or slave transfer is completed, thecontents of the shift register (SPIxSR) are moved to thereceive buffer. If any transmit data has been written to thebuffer register, the contents of the transmit buffer are movedto SPIxSR. The received data is thus placed in SPIxBUFandthe transmit data in SPIxSR is ready for the next transfer.

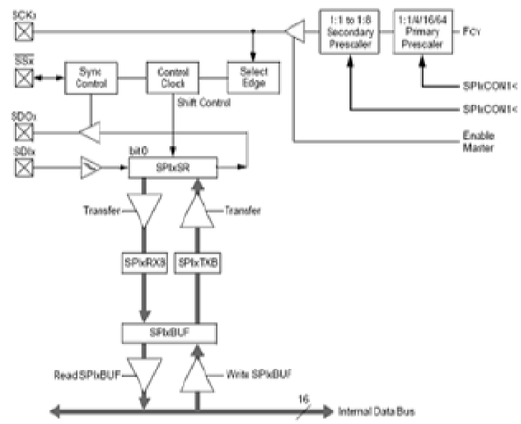

Fig. 14 SPI Module Block Diagram

In Master mode, the system clock is prescaled and then usedas the serial clock. The prescaling is based on the settings inthe Primary Prescale bits (PPRE<1:0>) in SPIx ControlRegister 2 and the Secondary Prescale bits (SPRE<2:0>) inSPIxCON2. The serial clock is output via the SCKx pin toslave devices. The clock pulses are only generated when thereis data to be transmitted. The CKP and CKE bits determinethe edge of the clock pulse on which data transmission occurs.Both data to be transmitted and data received are respectivelywritten into, or read from the SPIxBUF register [5].

IV. CONCLUSIONS

The aim of ECG tester is to produce the typical ECGwaveform of different leads and as many arrhythmias aspossible. The simulator has many advantages in the teachingand training field. The ECG machines can be tested andcalibrated with standard recognized signals from simulator soas to improve production quality.

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