

Personal Digital Exercise Trainer for Managing, Monitoring and Recording the Exercise

Praveen Kumar Diwakar*, Young Keun Oh*, Seung-Hun Park*, Young-Ro Yoon**
Dept. of Biomedical Eng., School of Electronics and Information, Kyung Hee University*, Korea
Dept. of Biomedical Eng. Health Science College, Yonsei University** Wonju, Korea
E-mail: diwakar150@rediffmail.com, parksh@khu.ac.kr

Abstract— We developed a portable digital exercise trainer device which manages, monitors and records the user's physical status and workout during exercise session. It guides the user in doing efficient exercise to reach specific fitness goals. It keeps the full exercise program i.e. exercises start date and time, duration, mode, control parameter, intensity in its memory which helps the user in managing his exercise. Exercise program can be downloaded from the internet. During exercise it continuously monitors the user's physiological parameters: heart rate, number of steps walked, and energy consumed. If these parameters do not range within prescribed target zone, the device will alarm the user as a feedback to control exercise. The device displays these parameters on graphic LCD. During exercise it continuously records the heart rate and number of steps walked every 10 seconds along with exercise date and time. This stored information can be used as treatment for the user by an exercise expert. Real-time ECG monitoring can be viewed wirelessly on a remote PC.

Keywords- ECG, Exercise, Heart Rate, Session, Steps, Wirelessly

I. INTRODUCTION

Exercise is essential for maintaining health and fitness of the body. But exercise without guidance can have harmful effects therefore people prefer a personal trainer. They hire personal trainers for a variety of reasons: to teach them how to use exercise equipment properly, to help them design programs to reach specific fitness goals and to give them the incentive to work out regularly. A trainer designs a personalized program that includes strength training, cardiovascular work, and flexibility exercises [1]. But these personal trainers are not affordable to all due to the high cost. This restricts them to higher income group only.

We developed a digital personal trainer which functions the same way as human personal trainer, is affordable to the mass and provides exhaustive information which will make exercising an informative experience. For instance they will get informed about physiological parameters: ECG, energy wasted which is directly linked to their health and fitness.

There exists number of devices like heart rate monitor, pedometer, speedometer etc. which helps the personal trainer in monitoring exercises. But the main feature which these devices lack is exercise management with proper

feedback. In our research we have tried to solve this exercise management problem so that we can probably replace personal trainer. It is an all in one device which not only keeps track of the heart rate and number of steps but also manages the user's exercise schedule perfectly just like a personal trainer

To sum up the essential requirements which the user needs in a personal trainer are: managing the exercise, monitoring the heart rate, steps walked, recording the exercise data, wireless display of exercise parameters and user friendly interface. The system specification must meet the above mentioned requirements.

II. SYSTEM SPECIFICATION

To meet the user requirement mentioned above the system should have following functions:-

- Continuously monitors heart rate, number of steps walked, and distance.
- Wireless interface for transmitting ECG signal wirelessly on remote PC. Maximum range is 10 meters.
- USB2.0 communication to download and upload exercise program and data respectively. Maximum speed is 12 Mbps.
- Graphic LCD 128*64 pixel with backlight to display exercise information.
- Real time clock which displays current date and time on LCD.
- 64 kb memory for storage of exercise prescription, data.
- Receiver for receiving wireless data having capability to detect multi device and can display their data simultaneously on computer.
- Low power consumption as device goes into sleep mode when not in use.
- Buzzer for giving alarm as feedback.

III. SYSTEM DESIGN

There are few terms which we need to know in order to understand system design:-

Session:-Session is the full exercise procedure which user will do at a time. Each session has its own time schedule [1].

Exercise Phase: Each session is divided into 3 phases (stages): Warm-Up phase, Endurance phase and Cool-Down Phase [1].

Exercise Mode Unit (EMU): Each phase is divided into various types of exercise unit: stretching, running on treadmill etc. Each exercise unit is commonly called as EMU.

Exercise Program: It is the exercise information which includes each session: start date and time, exercise mode (treadmill, health bike, stretching etc.), exercise duration, control parameters, target heart rate zone. This information is stored in memory.

Fig. 1 shows the overall hardware architecture. It contains heart rate monitor, pedometer, clock, RF module, graphic LCD, USB, alarm and memory. Microcontroller (MCU) controls the operation of all these functional blocks.

Firmware always polls the start date and time for each session. If polling matches then it will indicate the user to start the exercise session using audio alarm. User attaches our device on waist and put ECG electrodes on his chest and performs the exercise. Heart rate monitor and pedometer continuously monitors the heart rate and steps respectively and stores the information every 10 seconds in memory. This device will then guide the user in doing proper exercise according to the preloaded exercise program. If heart rate falls outside the target heart rate zone then it will alarm the user as feedback to control his exercise process. Exercise parameters are displayed on graphic display. RF module continuously transmits ECG signals wirelessly which can be displayed on computer [3]. Fig. 2 shows the flowchart of device functioning.

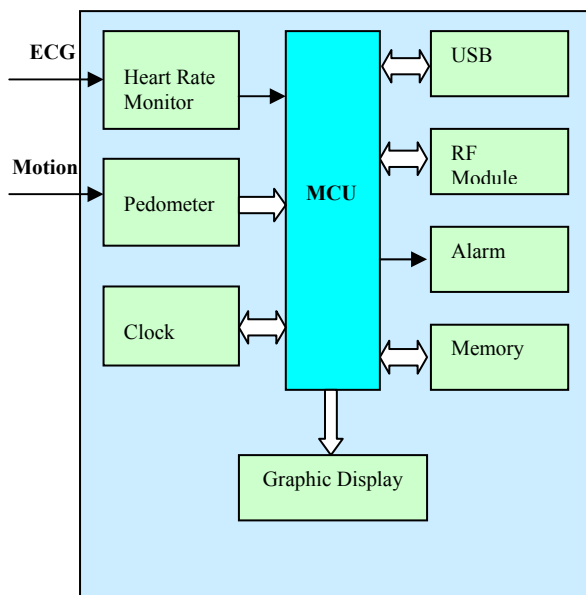


Fig. 1. Block Diagram of system Architecture

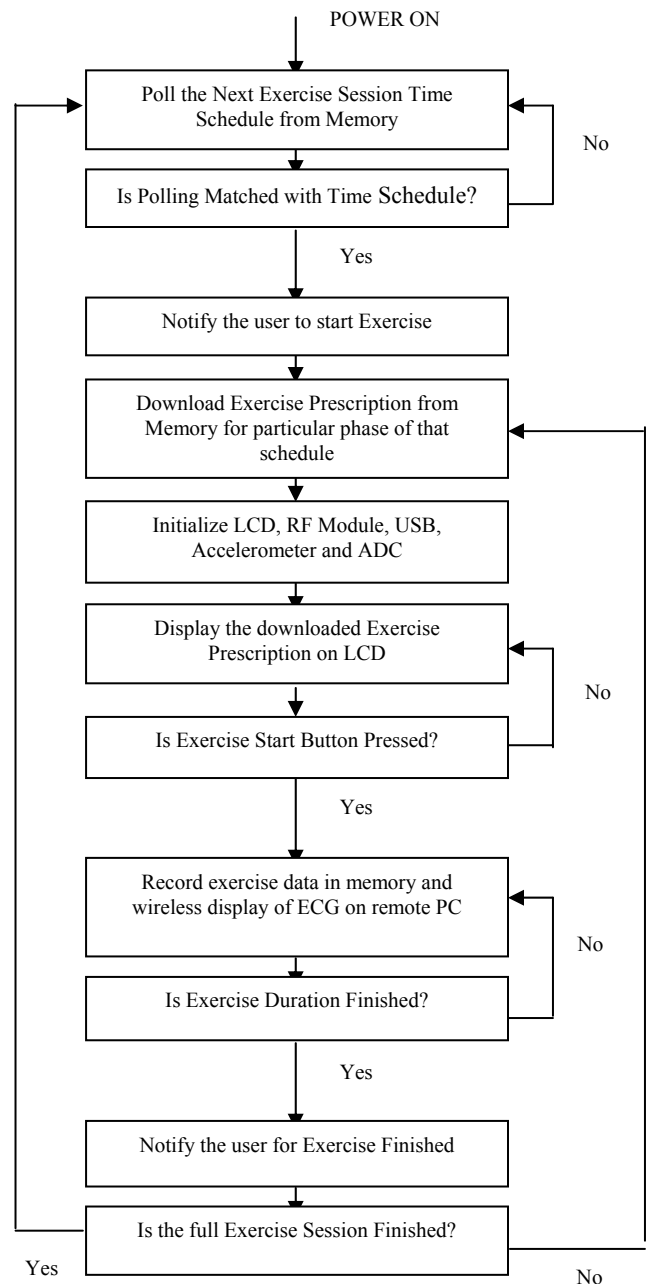


Fig. 2. Flowchart explaining the system functioning

IV. SYSTEM IMPLEMENTATION

This part shows the system overview. Implementation of each functional block is given as follows:

A. RF Module

We have used Nordic nrf2401 chip for this part [3]. It enables the device to communicate wirelessly. It is a single chip radio transceiver for the 2.4GHz ISM band. It is programmable with 3 wire serial interface to microcontroller.

The microcontroller samples the ECG data every 2.77ms. This sampled data is then added with 4 bytes of receiver address and transferred to nrf2401 for air transmission. Nrf2401 buffers all the data in its FIFO buffer at the rate of 2kbps and then transmits in the air at 250kbps. Fig. 3 shows wireless data transmission principle of our device. On remote PC side the receiver will check the first four bytes of address. If it matches with correct receiver address then it will accept the ECG data and display it to computer.

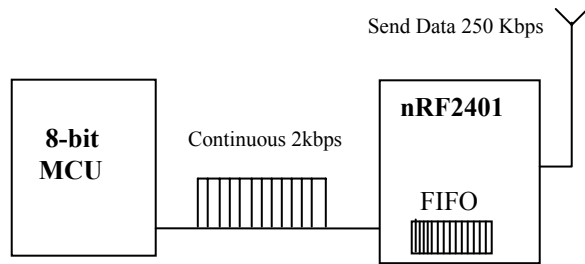


Fig. 3. RF module data transmission diagram

B. Heart Rate Monitor

This block contains the circuit which gets the ECG signal from human body through the 3 electrodes and then filters and amplifies that signal compatible to microcontroller. ECG signal is in mili volt range. Therefore circuit contains the pre-amplifier which requires a gain of 1000. Then there is low pass filter (LPF), high pass filter (HPF), notch filter to eliminate the 60Hz noise [2][4]. Fig. 4 shows the block diagram of ECG amplifier.

Cutoff frequency of Low Pass filter = 160Hz
Cutoff frequency of High Pass filter = 10Hz

The amplified ECG signal from the circuit is then sampled by microcontroller at the rate of 2.77ms (300Hz). ADC resolution microcontroller is of 8 bit. The heart rate detection algorithm inside the microcontroller calculates *heart rate* from this sampled ECG signal

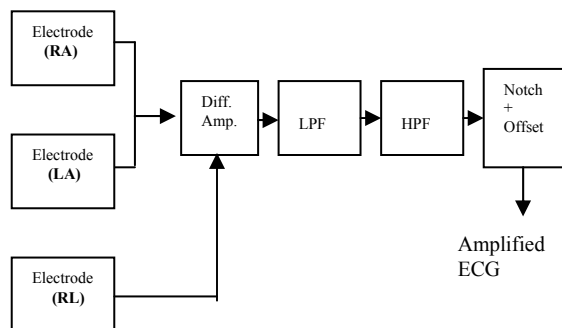


Fig. 4. Block Diagram of ECG amplifier

C. Pedometer

Pedometers uses accelerometer which senses the motion of the body and then transmit the pulse width modulation (PWM) output proportional to the movement of the body. We have used MXD2125ML for this part. It can measure the two dimensional (x and y) movement of the body.

It has two pin output. One pin gives x direction PWM output and other gives y direction PWM output. The PWM output is given in Fig. 5. By knowing the values T1 and T2, acceleration can be calculated as explained in Fig. 5 [5]. Device firmware continuously monitors this acceleration which helps in calculating steps.

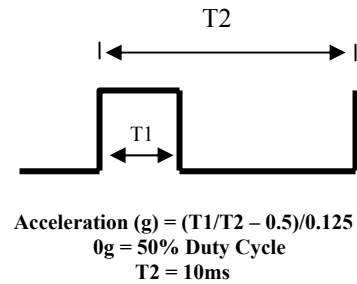


Fig. 5. Typical Duty Cycle output of Accelerometer

D. USB

We have used CP2101 chip for the USB communication. This chip is USB to UART bridge with USB specification 2.0 compliant, full speed (12 Mbps). It converts the serial data from microcontroller to USB compatible data. This chip can be interfaced to microcontroller with minimal parts.

E. Other functional blocks

Other functional blocks are microcontroller, graphic display, Memory, Clock. Microcontroller is PIC16Lf877A. We chose this microcontroller because it is cheap, works in low power mode (3.0 volt), readily available, and contains additional features. Graphic display is 128*64 pixels graphic LCD and is used for displaying date, time and other useful information. Memory 24lc512 is of 64kb with Inter IC Communication (I2C). NJU63556 is used as a real time clock.

V. RESULT

Fig. 6 and Fig. 7 show the top and bottom view of PCB design of our device respectively. PCB main board dimensions (mm) are: L90xW40xT1. PCB for RF module is designed separately. It is attached to main PCB with the help of socket. All components are surface mounted. Fig. 8 shows the complete device with case. Fig. 9 shows the software for uploading and downloading exercise data and prescription respectively. User can attach the device to computer's USB port and click the "Upload" button of software to upload the prescribed exercise program to device. Fig. 10 shows the wireless ECG display on computer send by our device. This signal was recorded

when user was walking and the device was attached to his waist. ECG signal output range is from 0-3 volt

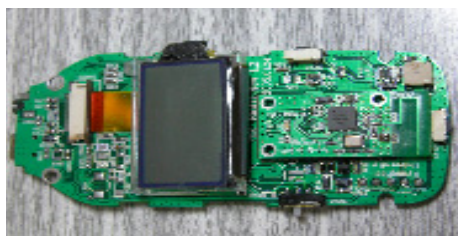


Fig.. 6. Top View of system PCB

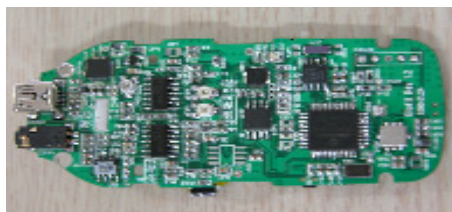


Fig. 7. Bottom View of system PCB



Fig. 8. Complete Device with case

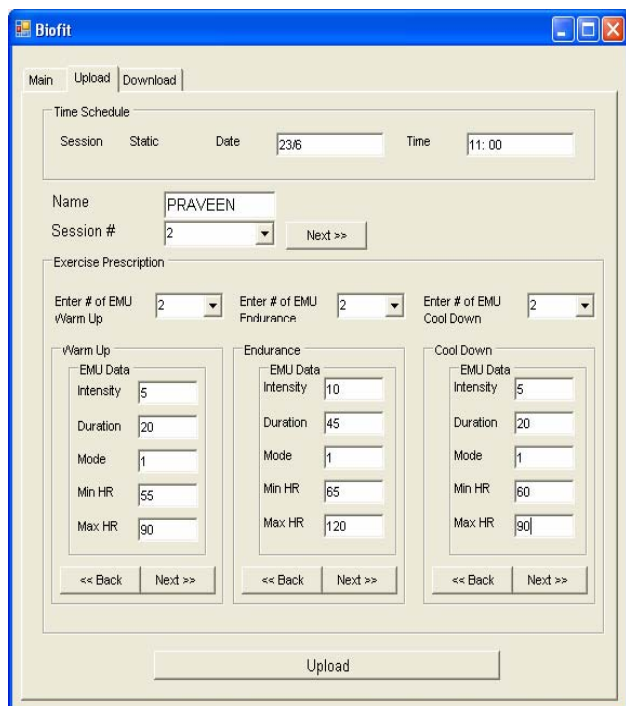


Fig. 9. Software for uploading and downloading exercise data and exercise prescription respectively

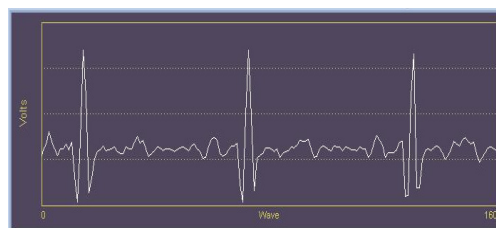


Fig. 10. Wireless ECG display on computer

VI. DISCUSSION

We have used all the surface mount components to make the device compact and to reduce noise interference. But ECG amplifier circuit faces noise problem due to ECG electrode wire movement during exercise. Using wireless electrodes will solve this problem to great extent. In future research we are planning to develop smart electrodes which will transmit digital ECG signals to our device wirelessly. Making this device more portable and compact will help in embedding it in other devices such as mobile phones, PDA etc.

VII. CONCLUSION

This paper describes the portable digital exercise trainer device which helps in managing, monitoring and recording exercise. It guides the user in doing efficient exercise with proper feedback. It stores the full exercise time schedule and exercise prescription in its memory which helps in guiding the user during exercise. It also helps in easy monitoring and controlling health by knowing certain physiological parameters (heart rate, number of steps) provided by the device. It can be called as a "Training Assistant" type instrument since it trains the user for doing proper exercise thereby helping him in improving his health.

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