Chapter 8
Designing a Microcontroller-Based Portable MMC/SD Card Recorder:
Time and Frequency Domain Analysis of HRV Using Sequential Interbeat Times

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ABSTRACT

In this chapter the authors described a microcontroller-based MMC/SD card recorder design. It can be used as a reference model to build portable data logging systems. In this case the authors used this design to get the 500 Hz rated samples of Electrocardiography (ECG) signal, and evaluate them for R-wave peak detections by using an on-line procedure. The system measures the interbeat times between the consequtive peaks, and records them into a file in the recording media. Heart Rate Variability (HRV) of the two recordings, each has 12-hours length from a healthy and a cardiac disordered man, have been analysed in MATLAB environment. Further analysis has been completed by using the time series of Instantaneous Heart Rates (IHRs) obtained from 48-sets of ECG recordings in the Physionet database. The results support the fact that some of the time and frequency domain parameters reflecting the variability of heart rate can be used as early predictors for some of the heart disorders.

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DESIGNING A MICROCONTROLLER-BASED PORTABLE MMC/SD CARD RECORDER; TIME AND FREQUENCY DOMAIN ANALYSIS OF HRV USING SEQUENTIAL INTERBEAT TIMES

Providing healthcare in highly populated rural and remote areas is driving the need for remote patient monitoring and telemedicine. In this context, **data logging** has a critical importance to make the patient's health history available to the health care provider. In implementing such patient treatment and monitoring equipments, researchers can design power-full medical devices with embedded processors that are easier to use, accessible and affordable.

Implementation begins with the physiological interface to collect the signals from the human body. Using required front-end solutions for essential signal conditioning, processor can perform further digital signal processing, measurements, recordings and analysis to monitor patient condition. As well as short-term measurements long-term measurements can be recorded in massive **data storage** and they can be transfered to a computer workstation for advanced analysis.

Over the last two decades, researchers have studied on developing some portable physiological **data logging** systems consisting of various analog signal conditioning and digital data processing solutions with different **data** recording capacities. These systems have been used generally in Electrocardiography (ECG) studies to detect infrequent cardiac arrhythmias or transitory cardiac function abnormalities (Segura-Juárez, Cuesta-Frau, Samblas-Pena, & Aboy, 2004). Several system designs have been described in this context (Jovanov, Gelabert, Adhami, Wheelock, & Adams, 1999; Tenedero, Raya, & Sison, 2002). Some of them achieved the performance of commercial Holter recorders, the systems that are named after an ECG recorder developed by N.J.Holter (1961), regarding the portability and nonvolatile **data storage** capacity.

Such a system may utilize sampling frequency range from 100 Hz to 1 KHz, depending on the ECG analysis to be performed. However, a value around 250 Hz is sufficient for long-term recordings (Segura-Juárez, Cuesta-Frau, Samblas-Pena, & Aboy, 2004). The computational power of a simple microcontroller is sufficient for this aim, since the most complex and time-consuming tasks are usually carried out off-line in a computer workstation. As a result of the developments in solid-state technology, researchers presently can implement such systems in a small and light structure with huge capacity of **data storage**. For instance, they can record the samples of physiologic signals in a flash memory card, Multi Media Memory Card (MMC) or Secure Digital Memory (SD) card. They can easily transfer the recorded data to a computer workstation for advanced signal analysis.

In this chapter we described such a microcontroller-based **recorder** design. It can be used as a reference model to build portable **data logging** systems. The design is powered by a NiMH battery. It integrates a microcontroller and its interfaces including a front-end unit for bio-signal conditioning. It provides recording capacity up to 1 GB and sampling rate up to 1 kHz. Thus, it can be used for **logging** the **data** related to the various bio-signals. It includes off-the shelf components and can be easily built with inexpensive components including an embedded microcontroller, PIC18F452, from Microchip family. In this case, we used it to get the 500 Hz rated samples of ECG signal and evaluate them for R-wave peak detection in QRS complexes, by using an on-line procedure. The system measures the interbeat times between the consequtive peaks, and records them into a file in the **MMC/SD card** recording media.

We also described some **time** and **frequency** domain **analysis** of **Heart Rate Variability** (**HRV**) in this chapter. They have been completed in MATLAB (2008) environment. In this context we have used the two recordings obtained by the designed system, each has 12-hours length from