

12-LEAD ECG MODULATOR AND DEMODULATOR EQUIPMENT FOR TELEPHONY TRANSMISSION

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ABSTRACT

This paper describes a teleassistance system that consists of a modulator equipment for the acquisition, storage and FM transmission of the typical 12 lead ECG signals and a demodulator equipment for recovering the original signals in a medical center. Switched telephone network and GSM network can be used to transmit the audio frequency modulated signal carrying ECG information. This project has been developed in collaboration with Teleasistencia Cardiotest, S.L.

1. INTRODUCTION

Consumers are demanding more access to health information and more convenient health care service. Particularly, people living in rural or remote areas lack the access on urgent and special medical care. In these cases, health insurance companies must provide a medical assistance within a minimum distance. Besides, consumer satisfaction in all telemedicine program evaluations has been very high. Given the choice between convenience of telemedicine and traveling to see the consultant in person, they overwhelmingly choose telemedicine.

In this paper, we propose a modulator and demodulator equipment for ECG transmission. The link between the patient and the specialist is established using a frequency modulated audio signal transmitted by the telephone network. Figure 1 shows the basic flow of information. The remote point (a patient, a non specialist doctor) can connect with a medical center to transmit the previously stored ECG signal using the ECG modulator. The ECG demodulator of the host center can recover the original ECG signal and then a specialist can diagnose any heart disfunction.

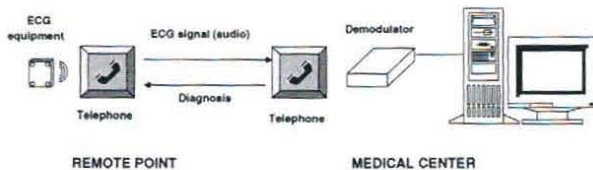


Figure 1: Block diagram of ECG system

The 12-lead ECG equipment is actually an expansion module for the basic equipment described in [1]. In next

two sections, we explain the hardware and software of the ECG modulator and demodulator. Section III shows the final prototype and some results, and finally conclusions will be pointed out in section IV.

2. 12-LEAD MODULATOR

The 12 lead modulator equipment must optimize several restrictions: area, power consumption and simultaneous acquisition.

It must be taken into account that ECG signals must be sensed and amplified by a factor of 1000. Electrocardiographic signals may be corrupted by various kind of noise [2]. Typical examples are:

- Power line Interference. It is the main source of noise, because of the cables attached to the 10 electrodes.
- Electrode contact noise. It is a transient interference cause by the loss of contact between the electrode and the skin.
- Motion artifacts. It consists of transient baseline changes caused by changes in the electrode-skin impedance because of movements of the patient.
- Other noise sources. There are several other noise sources due to muscle contraction, respiration or radio frequency interferences.

To record an ECG an electric circuit between the heart and the electrocardiograph must be completed. For this purpose, electrodes are placed on different parts of the body surface. Ten electrodes are connected to the modulator equipment by means of cables: nine of them are "exploring" electrodes while the last one is the reference placed on the right leg. Depending on the position of electrodes and the measured vectors, we can distinguish three groups of ECG signals [3].

- Bipolar standard leads. Electrodes placed on the right arm (RA), left arm (LA) and left leg (LL) are used to pick up the potential variations on these extremities. Bipolar leads named dI, dII and dIII are obtained by recording respectively the potential differences between LA and RA, LL and RA, and LL and LA.
- Unipolar extremity leads. Unipolar extremity leads are obtained by recording the differences between

RA, LA and LL and a point named Wilson's central terminal. This point is given by the sum of the potentials from RA, LA and LL. These leads are known as aVR, aVL and aVF.

- **Unipolar precordial leads.** The unipolar precordial ECG is obtained by placing the exploring electrode on the classical six locations of the anterior and left portions of the chest. Unipolar precordial leads are obtained as the difference between these six positions and the Wilson's central terminal. They are prefixed by the letter "V" followed by numbers 1 through 6, which indicate the corresponding chest sites.

The acquisition stage is performed by a low power instrumentation amplifier with a programmable gain factor. ECG interferences are treated in the following way: power line interferences are attenuated thanks to common mode rejection ratio (CMRR) of the amplifier; besides, a 50 Hz notch filter is digitally implemented in the microprocessor chip. Input signals are high pass filtered to eliminate baseline changes. Finally, electrodes consists of patches with a conductor gel that guarantees a good contact with the body surface. It is a requirement of the project that the 12 leads must be acquired simultaneously in ten seconds. That means that the input signals must be multiplexed for the 8-bit analog to digital converter of the micro-controller.

Figure 2 shows a block diagram of the modulator equipment. Using the typical 10 electrodes, the 12-lead ECG signals are acquired in parallel and them multiplexed for the analog to digital conversion. Sampling frequency is 100 Hz. The micro-controller (MC68L11 from Motorola [4]) stores the ECG signals using the analog to digital converter (10 seconds for each lead) in the REC position of the equipment and sends the modulated ECG signals to the speaker in the PLAY position, showing the corresponding ECG lead in a four digits alphanumeric display.

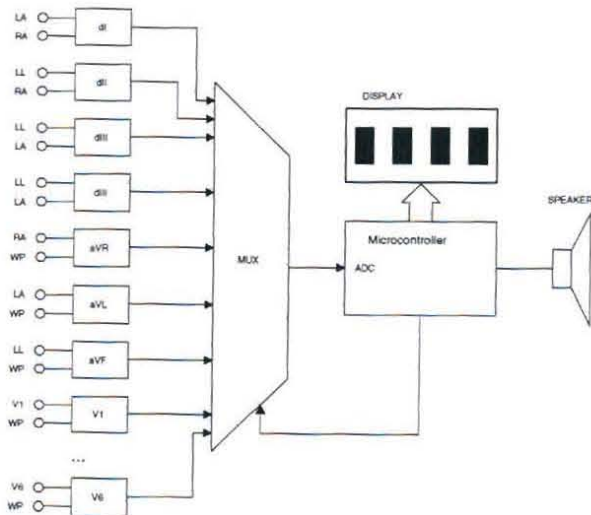


Figure 2: Block diagram of the 12-lead ECG modulator

3. DEMODULATOR

Figure 3 is a block diagram of the demodulator equipment. The audio signal is acquired and preamplified.

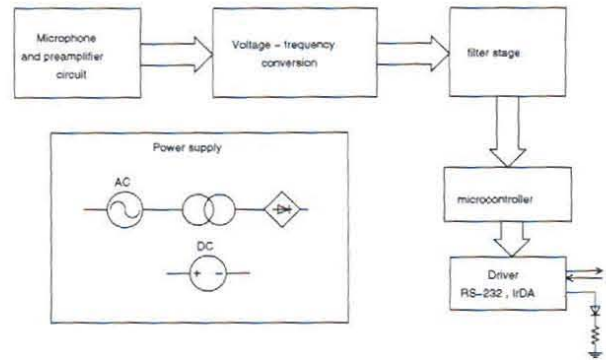


Figure 3: Block diagram of the ECG demodulator

Then a frequency-voltage converter recover the original signal. After a filter stage, the ECG signal is digitally converted using the analog to digital converter of the micro-controller circuit. Finally, the digital signal is transmitted to a host PC using a serial RS-232 link or a infrared link (IrDA). The equipment can work with batteries or a DC power supply.

4. PROTOTYPE AND RESULTS

The modulator equipment has been divided in an analog board and a digital board. Figure 4 is a picture of the analog board (top view). It includes the acquisition of the 12-lead signals. SMT components allow to achieve size restrictions. There is a potentiometer for each signal to set the zero value.

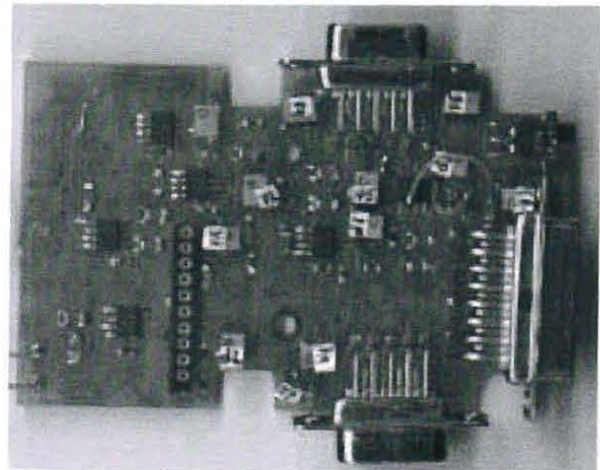


Figure 4: Modulator: analog board

Figure 5 shows the digital board. It is based on the micro-controller circuit that controls the analog multi-

plexers, the four digit alphanumeric display and a low battery circuit detector.

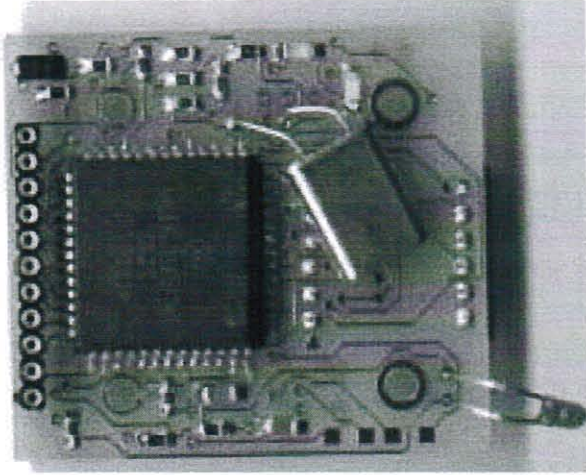


Figure 5: Modulator: digital board

Finally, figure 6 is a picture of the demodulator equipment. The board includes a DC power supply (on the right bottom part of the picture) the preamplifier and the frequency to voltage converter (on the left bottom) and the serial connector and the IrDA led on the top of the picture. The micro-controller and the driver for the serial link are placed on the other layer of the board.

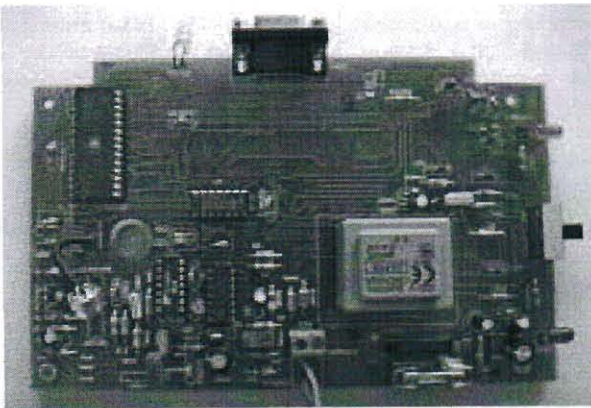


Figure 6: Demodulator board

An example of the demodulated signals are shown in figures 7 and 8. Particularly, fig. 7 shows the bipolar and unipolar extremities leads, and fig. 8 shows unipolar pre-cordial leads. Vertical axis is the captured digital value transmitted to the PC.

5. CONCLUSIONS

A teleassistance system for ECG signals has been developed in collaboration with a medical center. The system consists of a portable 12 lead modulator equipment, used

by the patient or a non specialist doctor, and a demodulator located in this medical center. The main restrictions are related with the modulator because it will be used by the patient. It must be of reduced size, with the maximum autonomy and user friendly.

This equipment can be useful in remote areas without a cardiology specialist and in mandatory medical revisions in factories where hundreds of ECG must be done. Simultaneous acquisition of the 12 lead allows a record time of ten seconds for each revision.

6. REFERENCES

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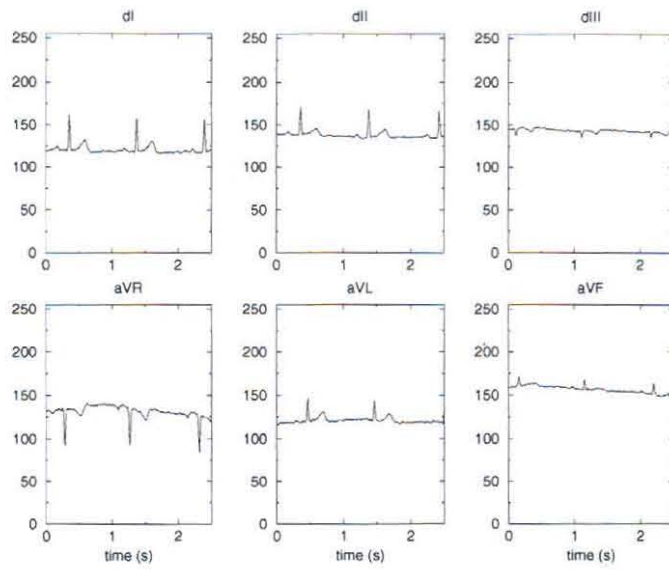


Figure 7: 12 lead ECG: bipolar and unipolar extremities leads

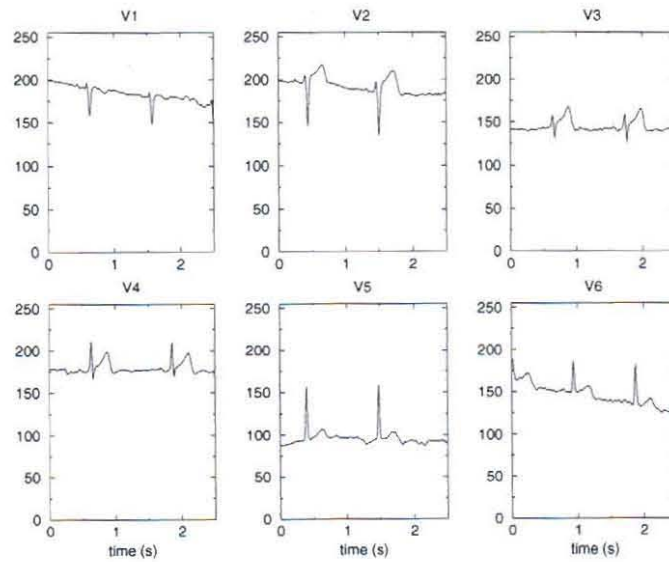


Figure 8: 12 lead ECG: unipolar precordial leads