ECG signals acquisition, processing and control using a CAN bus real time complex system

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Abstract. *This paper describes a method for acquisition, processing and control hart signals from patients, using a complex system with CAN bus. The proposed system captures and processes the ECG signals, so, it can be successfully used in clinics where more than one patient needs to be investigated or monitoring at the same time. The development and miniaturizing of electronically components had imposed the progress of the medical equipment and the application of new ideas designing. The system does not affect the patients; the signal acquisitions are made in an easy and secure way concerning the patients and the medical stuff.*

Keywords: Controller Area Network (CAN), CAN bus, electrocardiogram, ECG signals, microcontroller.

1. Introduction

As it is known, the classical procedure for the ECG (electrocardiogram) is the following: the electrodes applied on the patient body surface (right leg, right arm, left leg, left arm and chest) collect hart signals. These signals are multiplexed, amplified, converted with a CAD block, processed with a microcontroller and displayed [1], [2].

Figure 1 represents the block scheme for such a system.

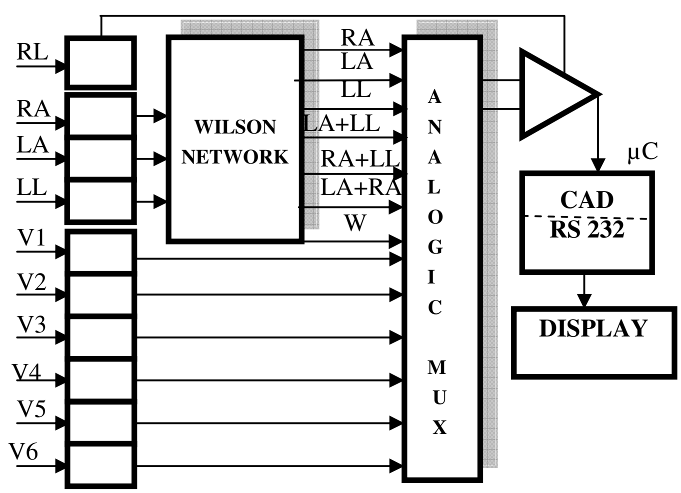

Fig. 1 The block scheme for the classical system

The input signals are RL (right leg), RA (right arm), LA (left arm), LL (left leg) and V_1, …, V_6 (pericardial unipolar derivations). Usually, the electric signal from RL is reference for the instrumentation amplifier IA.

The procedure is easy to be applied for one patient. If more patients need to be investigated or must be observed at the same time, the classical method will be very difficult. In that case, the medical stuff needs more systems for the ECG or the time will be longer in order to complete all the necessary hard work. There must be involved too many persons (doctors, medical assistants, electronic engineers, technicians, etc.). Also, the permanently monitoring of the patients needs a large number of medical devices to satisfy the observing and diagnosing process. So, it is a real problem every time such an event occurs. In the last decades, medicine has made a spectacular progress. The classical blocks have been replaced with electronic devices and the computer make all the hard work.

2. Basic concept

The multiplexed bus complex system proposed in this paper is designed in order to capture the ECG signals from more patients at the same time, isolate, sample, convert and transmit them to the main computer or a microcontroller to be analyzed and to take best medical decisions. The ECG signals are collected from the patients are processed in a separate room and the best decisions will be taken [3].

Figure 2 represents the complex system with CAN bus. The system can do all this hard supervision work and the medical stuff will be called only in special cases, such as: the cardiac pulse decreasing or increasing at high values, wrong cardiac voltage recorded, cardiac stop, etc.

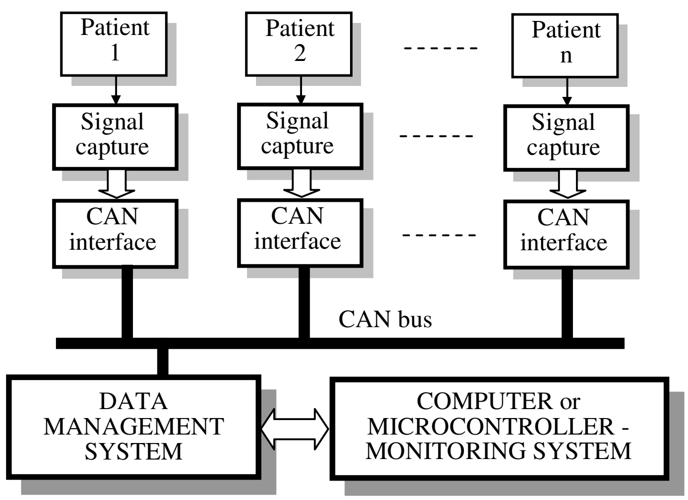

Fig. 2 The block scheme for the proposed system

The ECG signals from each patient are real time transmitted using the CAN bus (Controller Area Network). This is a specialized bus that uses a CAN protocol. The transmission is serial real time type, errors are equal to zero and the bus access is priority type excepting the alarm messages. A specialized operator, through the computer or microcontroller makes the supervision in a single proper designed room.

The method is based on linear programming and the CAN protocol has an insignificant errors ratio, a very high transmitting speed and also is able to avoid the bus congestion. There is a signal capture block for each monitored patient that collects the ECG signals and transmits them to the CAN bus through a CAN interface. The CAN bus transmits the ECG signals to a data system management, regarding the assigned priority. Data management system analyzes each received signal and transmits it to a computer or a microcontroller - monitoring system [3], [4]. Using the CAN protocol method, it is recommended to use a signal capture block and a CAN interface for each patient.

The proposed method improves the medical hard work and reduces the necessary equipment and the number of persons involved. Also, the results are real time obtained, all patients can be quickly diagnosed, the medical treatment is correct. If a hart event occurs, an alarm message will be displayed on the monitor, in the observing room. The operator will be informed about this message and the number of the patient which has the hart sufferance. The method can be successfully used in clinics where there are many patients that need medical care, such as the emergency rooms or post surgical rooms.

3. Signal capture system description

The multiplexed bus complex system proposed in figure 3 shows the block diagram for signal capture system.

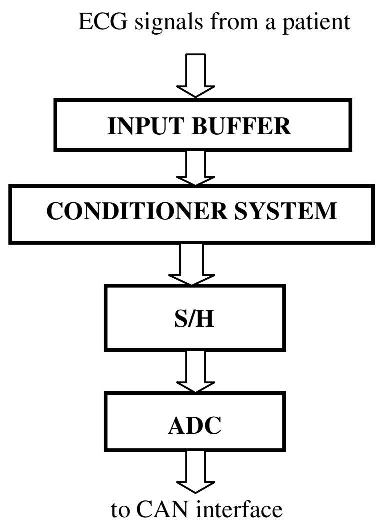

Fig. 3 The diagram for the capture system

Each patient is connected to the medical equipment through an input buffer. The ECG signals acquisition is made with electrodes positioned LA (left arm), RA (right arm), LL (left leg), RL (right leg) and C (chest). The electrodes are connected to differential amplifier inputs through a selective channel variable buffer. The ECG signals obtained from different electrodes pairs have different shapes and amplitudes, so each acquisition channel can give information that are not available on others channels.

The hart electrically axes are seen in six of the standard procedures and it can be diagnosed the type and the place of the hart suffering by examine these different points of view, because the hart suffering anomalies have been correlated with the state of the sickness. The input buffers are operational amplifiers with gain equal to unit and connected as repeater circuits. A necessary condition is a high value for the input impedance and also a good common mode rejection. They have also protection resistors, so the maximum current value through the patient skin is 50 µA [3].

While the cardiac pulses are passing through a patient hart, the electrical currents go in the tissues surrounding hart. Some of these currents arrive at the skin surface. The electrodes are placed on the skin, around the hart (more exactly at the left and the right side), so, the electrical voltages generated by those currents can be recorded and displayed as the ECG (electrocardiogram). The cardiac activity electrical phenomena occur with about 20 ms before the mechanical phenomena take place. Consequently, the recording and tracking of these phenomena bring us vital information regarding the creation, propagation and type of the hart activity.

The electrocardiogram is very important because it represents the map (usually at the body skin surface) of the electrical voltage variations for the main hart vector. As it is known, this vector is the result of the depolarization and polarization of the electrical phenomena in the hart muscles, when a cardiac revolution takes place.

Depending of the electrode positions, the ECG signals acquisition can be done by using a direct method or an indirect method. The direct methods usually need the direct connection between electrodes and the hart tissue, so, they are rarely used in medical practice. The indirect methods use electrodes placed at the body skin surface, so, they are the most used in the medical practice. The patient is not affected and the time is very small comparing with the direct methods. The acquisition system proposed in this paper is used in such an indirect medical procedure. The recorded voltage amplitude depends on the distance between electrodes and the hart and also on the cardiac vector angle with the current deviation [3], [4].

A conditioner system is used in order to establish the input parameters, priorities, etc. The signals must be sampled in S/H block, with a small time constraint so the samples to be very quickly passed to the hold memory. The procedure is adapted in order to operate with the power-line frequency preserving the chosen sampling rate. The output signal from the S/H circuit is converted in digital signal using an ADC with high resolution. The 50Hz noise interference does not affect the system because it modulates the ECG signal gradually from zero through 1 mVp-p with 50 µV/s slope and the residual interference is less than 10 µV (all values related to the output of the amplifier). Digital filters permanently check the signals and if the amplitude of the interference is not acceptable, e. g. exceeding a pre-set noise level, the frequency has to be currently measured by the software. The system also eliminates electrode offset voltages effect. The isolation amplifier used in the system is designed as an optical differential amplifier, with a gain slope –0, 03%/0C and CMR (common mode rejection) > 100 dB [5].

Then, signals are transmitted to the CAN bus, using a CAN interface. Regarding the priorities assigned for each patient, the converted ECG signals arrived to the data management system.

4. CAN bus transmission

CAN is a serial communications protocol that achieves the distributed real time control with a very high security level. Its applications area is extended from the high speed networks to the small multiplexed layers. A very small error ratio and a fast processing mode characterize it. The residual error probability for the undetected perturbed data is smaller then: Error data ratio* 4, $7*10^{-11}$.

For the electronically control systems, single control units can be connected using this protocol. Data transfer speed is approximately 1 Mbit/s.

CAN speed can be different for each system, depending on application or the monitored parameters. Regarding the equipment costs, it is recommended to replace all electrical connections (cables, single wires, etc.) used in-patients monitoring medical equipment with serial multiplexed systems. The serial communications acceptance and introduction to a large number of medical applications has a significant impact for the designers and also for the medical development. A special attention must be given to the compatibility between any two CAN implemented systems. It regards the electrical characteristics and the transmitted data interpretation [3], [6].

In the system, the Controller Area Network has the following main functions:

- CAN guaranties data priority, meaning all received data from the patients will be transmitted in minimum possible time and the alert messages have the highest priority
- CAN minimizes the latency times (the latency time represents the time interval between the moment when data is transmitted on the CAN bus and the time when data is received without errors at the final station, which in this particular case is the computer or the microcontroller). Data is transmitted and also it is corrected on the CAN bus in a minimal possible time, before arriving at the data acquisition system.
- The system configuration is very flexible; more modules (“Patient n” type) can be added or removed without affect the complex system structure. This is a great advantage regarding the permanently variation of the patient’s number in medical clinics.
- Data is multicast received using time synchronization.
- Data integrity is very high level.

- The complex system is designed in a multi-master configuration. So, the transmission access is priority type and permanently controlled.
- All the errors are detected, flashed and corrected in the smaller possible time, during the transmission process, in order to receive the initial form of the signals and take the correct medical decisions.
- Perturbed data is corrected and automatically retransmitted as soon as CAN bus is idle. So, bus congestion is avoided and the transmission time is considerably reduced.
- The described system can make difference between temporally errors and permanently errors from the system nodes and ensures the automatically disconnected of those nodes ("Patient n" type).

Data management system and microcontroller monitoring system in the observing room supervise each patient. ECG signals are processed, analyzed and the medical stuff can take the correct medical decisions regarding the best solutions for the patients. An alarm message will be displayed on the computer if any patient suffers hart damage. Consequently, the operator can detect the affected patient without been in he same room.

The information is transmitted on CAN bus in safe form messages, with different lengths but limited. When bus is free, any connected unit can begin a new message transmission [3], [7].

The flow chart for the system is shown in figure 4.

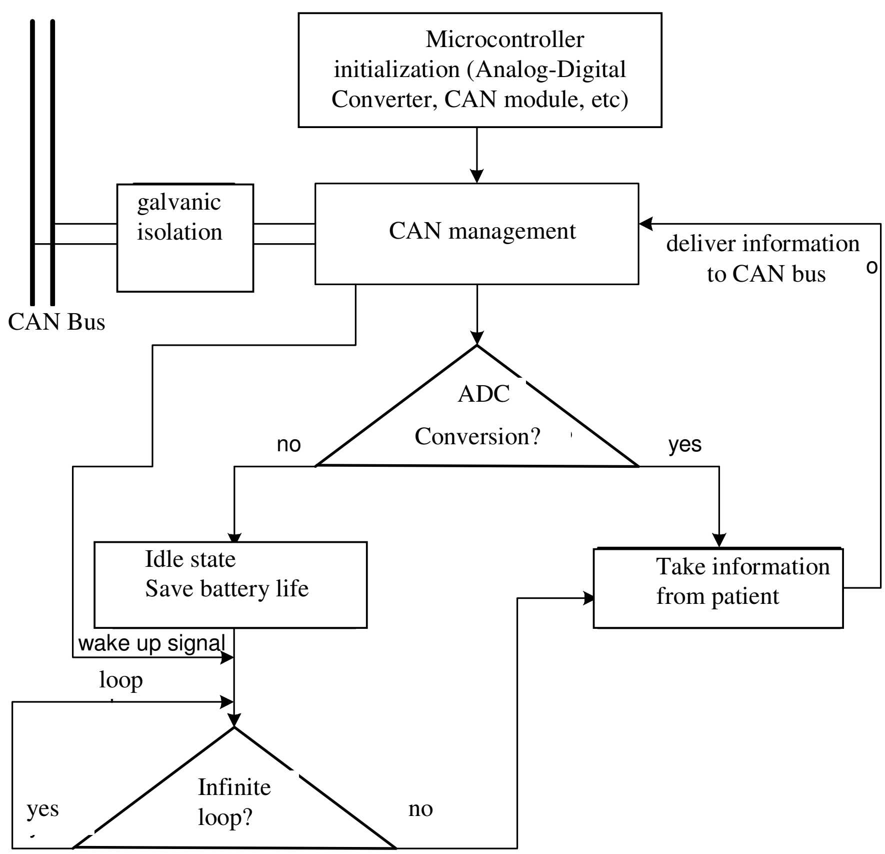

Fig. 4 The flow chart for the proposed system

<u>Microcontroller initialization</u>

The microcontroller manages the flux information in the system. When system is supply ON, all its intern blocks (system clock, PLL, Analog to Digital Converter, CAN module, Ports, etc.) are initialized.

CAN management

CAN communication module is used for data transmitting and reception. The transmission will take place every time the operator asks information from the patient. The command signals are transmitted through CAN bus, to "CAN Management" block. If the microcontroller is in "idle state", then CAN management block will send a „wake-up" signal, to save energy. If the microcontroller is not in "idle state", then CAN management block will sent a command signal for the system and the information from the patient can be processed by the operator.

Idle state

Considering that the microcontroller and sensors supply is assured from the battery, it is very important to save this energy every time when microcontroller and sensors are idle. If the operator wishes to process the information from the five sensors (left arm, right arm, left leg, right leg and chest), then the CAN bus will be no longer in the sleeping mode.

Infinite loop

This is a loop that can be broken every time when „CAN Management" module sends a command signal. In this state the energy will be saved.

Take information from patient

The information from sensors is received and will be transmitted to the operator, through „CAN Management" block.

Galvanic isolation

It is recommended to have a galvanic isolation between CAN bus and microcontroller and the patient, in order to avoid the possible medical devices errors, that would affect the patients lives.

The system is design with alert messages high priority. It is very flexible; consequently, user anytime can add new nodes without making software or hardware modification to the main structure. Also, there is no patients connected number limit. The block scheme for the general system is shown in figure 5.

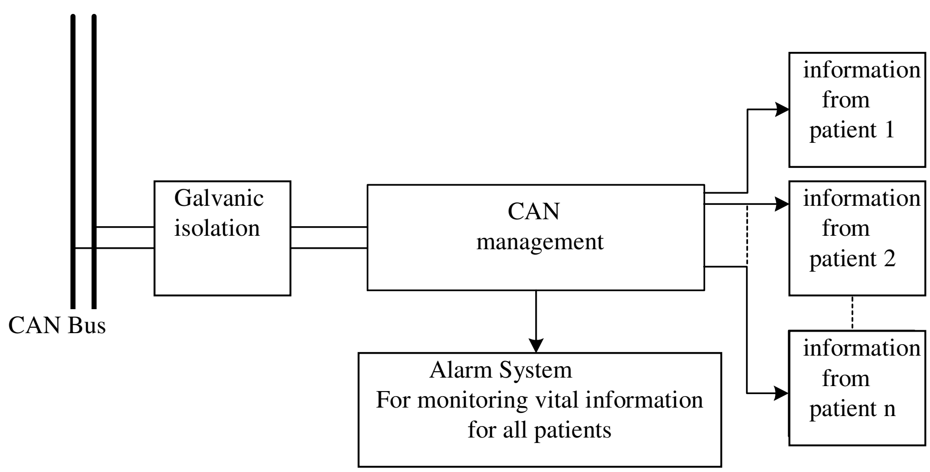

Fig. 5 CAN management system and Alarm System in the observing room

CAN management

CAN communication module is used for data transmitting and reception. Also, it has to take data from more patients (through CAN bus) and to transmit them to the display modules. Every time a reception error occurs, the Alarm System module is enabled.

Alarm system

It is driven by CAN Management and it is useful to diagnose the reception data errors. If the reception data will be correct, then the patient state is critical. If the information is false, then errors must be corrected.

Information from Patient *n*

This represents a display module for the CAN management received information. The display can be electronic or printed on paper.

5. Conclusions

The complex system described in the paper represents a quick method to diagnose and permanently monitored one or more patients with a hart sufferance. he method does not affect the patients or the medical stuff involved in the process. The hart pulses are displayed on a PC so, it is easy to capture, monitoring and processing the ECG signals in order to find the best medical solutions for the patients and to take the correct decisions in real time. The small electrical currents from the skin level are picked, amplified, sampled and processed with medical equipment designed regarding the last electronic technology improvements.

All the patients are monitored observed and there are not undetected cases [8], [9].

The proposed system is very flexible, new patients can be added or removed anytime without making software or hardware modification to the main structure. Also, there is no patients connected number limit.

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