Portable System for High Resolution ECG Mapping

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Abstract

In the paper a high resolution ECG mapping system based on personal computer or notebook equipped with fast IEEE 1284 parallel port working in ECP mode is introduced. Concept of the device enables high-resolution multi-channel ECG mapping using up to 256 ECG leads. Concept of the device and description of electrical and mechanical solution of portable 134-channel system is given.

1. Introduction

Body surface potential mapping (BSPM) is a non-invasive electrocardiographic method enabling more precise diagnostics of cardiac diseases. However, results obtained from maps constructed from 24 to 32 leads showed that the information contents is not substantially greater than that of standard 12-lead ECG. It is hoped that maps constructed from more leads measured with better accuracy could improve the diagnostic information in BSPM. ProCardio 7 system described in this paper is designed for recording of ECG signals from limb leads and up to 134 chest leads. It enables high resolution BSPM using several electrode sets.

2. Method and Results

Concept of the mapping system

ProCardio 7 mapping system is designed as a specialized portable or mobile configuration of a multi-channel measuring subsystem placed in patient terminal box PT134 connected to a personal computer through fast parallel port IEEE 1284 working in ECP mode. The patient terminal is powered by an isolated power supply placed in separate shielded box. Block scheme of the system is shown in Fig.1.

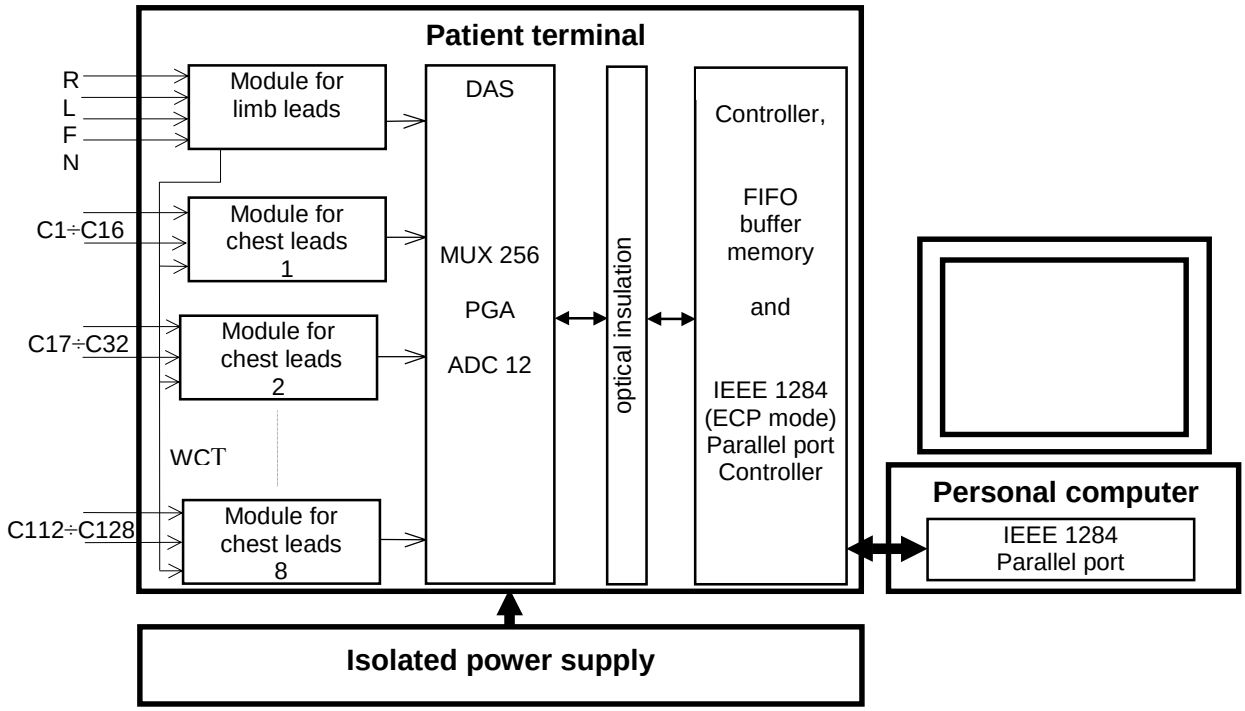

Fig.1. Block scheme of the mapping system with patient terminal PT134.

This concept enables independent design and selection of basic parts of the mapping system and setting of an optimal configuration corresponding to the user's requirements to number of channels, portability of the system, signal processing speed, and the system price. Structure of the patient terminal unit enables to build a measuring system respecting regulations for medical electrical equipment of type BF or CF using commercial personal computer or notebook.
From the user's point of view, measuring system has following important features:

- standard PC or notebook with the fast parallel port is used; no hardware intervention into the PC unit is needed during system installation or service,
- optical isolation of the measured object enables measurement of signals for body surface potential mapping and also acquisition of patient's heart electrograms (with CF-type unit),
- contact of measuring electrodes and integrity of measured leads is continuously checked and faulty leads are reported on computer screen during the test phase of the measurement process,
- upper cut-off frequency of measuring channels can be set under program control depending on the measured signals and the actual sampling frequency,
- individually programmable gain of each measuring channel enables optimal resolution of signals even with very different amplitudes,
- all standard bipolar and unipolar ECG signals are generated by the hardware of the measuring channels and no additional computations of combined signals are required during recording.

Patient terminal unit

Patient terminal PT134 represents a specialized data acquisition system (DAS) for use in biology and biomedicine. It consists of three basic sections:

- amplifying section,
- measuring section containing DAS and optoelectronic insulation,
- interface section with microcontroller and fast parallel port driver.

Internal structure of the amplifying section is shown in Fig. 2. Its task is to amplify ECG signals measured on the body surface or on epi- and endocardium and optimize their amplitudes for connection to the DAS inputs. The amplifying unit fulfills safety requirements for ECG measuring equipment [1]. Arrangement of the measured leads conforms to demands for ECG lead standards [2, chap.3.2.2.]. Disposable adhesive pre-gelled Ag-AgCl electrodes for ECG recording are used because of their low differences of the polarizing potential.

Signals from limb electrodes R, L, F are processed in one limb lead module LL6A, signals from chest electrodes C1, C2, … are processed in up to eight 16-channel unipolar chest lead modules CL16A. Full configuration of the PT134 patient terminal contains 6 measuring channels for standard limb leads and 128 measuring channels for unipolar chest leads.

Neutral electrode N on the patient's left leg is connected to the output of a neutralization amplifier placed in the limb lead module. It supplies to the measured object (patient) an amplified and inverted signal of the common mode voltage derived from the R electrode. By this active neutralization level of disturbing common mode voltage on the measured patient caused by the presence of mains in the examination rooms is reduced. Common mode interference caused by currents induced into lead cables by capacitive coupling with mains is minimized by shielding of the lead cables. To reduce the influence of high parasitic capacity of cable shielding on the stability of the active neutralization loop, shielding of all cables is also driven by the common mode voltage signal derived from the R electrode.

Signals from R, L and F electrodes are preamplified in the limb lead module and connected to the standard Wilson/Golberger resistor network. Signals from its nodes are processed in 6 differential amplifiers and signals of Einthoven's bipolar limb leads I, II, III and Golberger's augemented limb leads aVR, aVL, aVF are available on their outputs. Wilson's central terminal potential (WCT) obtained in the Wilson/Golberger resistor network is used as the reference potential for all unipolar leads and is fed to the inverting inputs of all differential amplifiers in the chest lead modules CL16A.

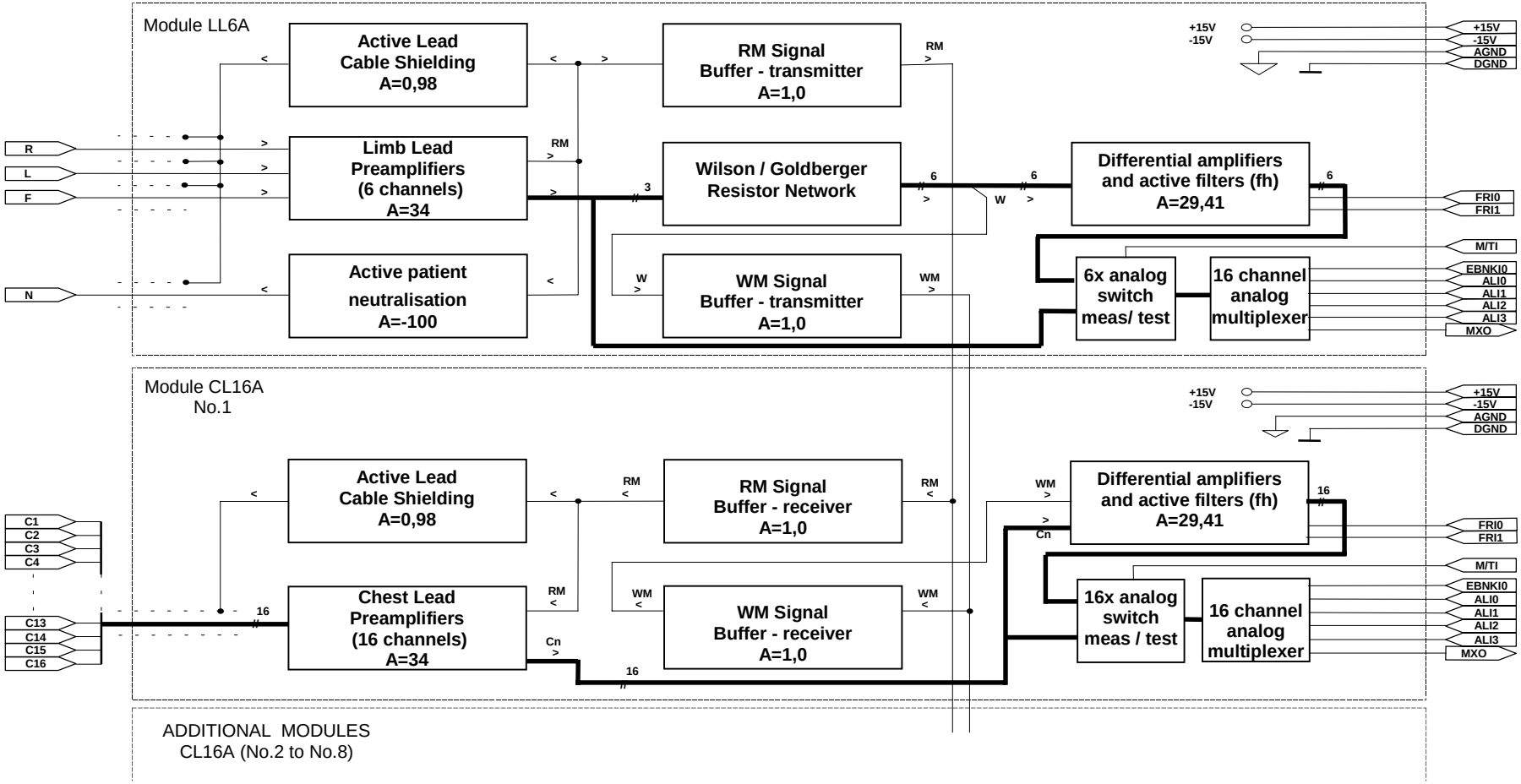

Fig.2. Block scheme of the amplifying section of the patient terminal PT134

Signals from chest electrodes C1, C2, ….C128 and WCT signal are led to the inputs of differential amplifiers in the chest lead modules CL16A and unipolar chest lead signals V1, V2, … V128 are generated. ECG signals from outputs of differential amplifiers in LL6A and CL16A modules are fed into active band-pass filters where the upper cut-off frequency of the measuring channels can be set to 100, 250, 500 or 1000Hz under program control.

Each filtered ECG signal is led to input of one CMOS single-pole-double-throw (SPDT) switch. Output of corresponding ECG preamplifier is connected to the second SPDT input. During the lead test phase all SPDTs are switched-over to preamplifier outputs and error signals from preamplifiers can be transmitted to the channel outputs. In this way, contacts of measuring electrodes and integrity of measured leads are checked and faulty leads reported on the computer screen.

Outputs of SPDT switches are finally connected to a first-stage 16-channel analog multiplexer that forms one output of each LL6A or CL16A module. Outputs of these multiplexers are fed to inputs of a second-stage 16-channel analog multiplexer in the measuring section.

Measuring section of the patient terminal shown in Fig. 1 consists of a DAS and an optoelectronic insulation interface placed on the motherboard. The DAS circuitry consists of a second-stage 16-channel analog multiplexer, a programmable gain amplifier (PGA) and a 12-bit A/D converter. The optoelectronic insulation interface is created by set of 27 high-speed 4kV optocouplers for transmission of control and data signals over an insulation barrier between the measuring section and interface section.

Interface section of the patient terminal contains a microcontroller (89C2051) with supporting logic (Lattice programmable array), 16 KB FIFO memory (CY7C4851) for data buffering during fast data acquisition and an IEEE1284 parallel port controller (CL-CD1283) for interfacing to the PC. The whole measuring procedure is pre-programmed through the parallel port in a 256-channel sequencer and the port controller. The sequence of channels, gains for all channels, sampling frequency and cut-off frequencies for ECG filters are stored in the sequencer memory. After the measurement is started, all operations are performed autonomously and data are transferred through the parallel port into the PC in DMA mode.

Mechanical design

In the mobile configuration of the ProCardio 7 mapping system, computer and patient terminal are placed on a special carriage easily transportable by 1 person. Its dimensions permit to pass through standard doors, passages and lifts and to use the system as a bed-side unit. The patient terminal box is detachable from the carriage and its remote operation is possible.

Application software

Complete set of application programs enabling data acquisition, ECG signal processing and maps computation presentation was developed for the mapping system. Currently it is experimentally used in clinics.

3. Conclusions

First experience with the systems shows that despite complexity of the measurement process due to increased number of measured ECG leads the system may supply more detailed and diagnostically interesting data about the human cardioelectric field.

Acknowledgment

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References

[1] Medical electrical equipment. Part 1: General requirements for safety, Standard STN EN 60601-1. (Bratislava), SÚTN, 1995.
[2] Diagnostic Electrocardiographic Devices. ANSI/AMMI 1991. Am. National Standard.