Multichannel Measurement of Human Intestinal Tract Electrical Activity

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Abstract
This paper presents concept of a PC based multi-channel measuring system for measurement, processing and displaying of signals of gastric electrical activity in humans. It is designed for non-invasive measurements in clinical research and practice.

1. Introduction

Signals of gastric electrical activity can be obtained either by invasive methods or by noninvasive methods from the body surface. From clinical point of view, parameters of electrogastrographic (EGG) signals can be used to indicate some abnormalities of the gastric motility. Since many diseases are related to gastric motility, EGG can be used as a tool to state the diagnosis. The system described in this paper is designed for noninvasive EGG measurements.

2. Methods and results

The system for measurement of human intestinal tract activity is designed for recording of 4 or 8 EGG signals measured relatively to one reference electrode. Block diagram of the measuring system is shown in Fig. 1.

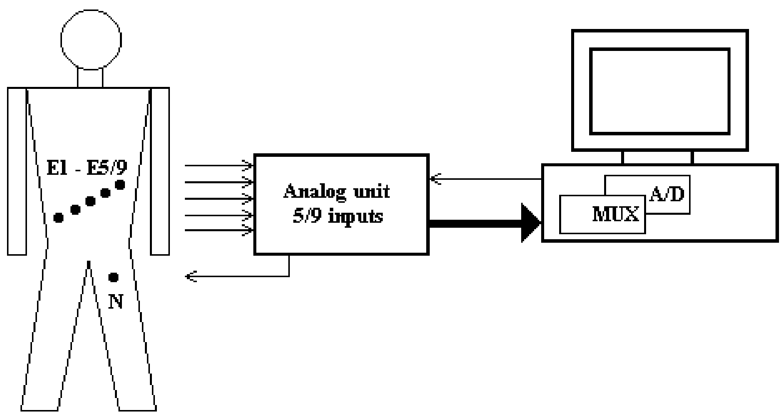

Fig.1. Block diagram of the EGG measuring system

Signals are sensed by a set of 5 or 9 electrodes (E1 to E5, or E1 to E9) placed in commonly used positions in the abdominal region. From independent combinations of input signals, system derives differential bipolar EGG signals. For 5 channel system they are:

EGG1 = E1 – E2
EGG2 = E1 – E3
EGG3 = E1 – E4
EGG4 = E1 – E5

Another EGG signal combinations used in medical practice, which present linear combinations of the measured input signals are derived by the computer software:

E2 – E3 = EGG2 – EGG1
E2 – E4 = EGG3 – EGG1
E3 – E4 = EGG3 – EGG2
E4 – E5 = EGG4 – EGG3

Presented EGG measuring system consist of following main blocks:

- analog unit,
- measuring unit,
- notebook personal computer with docking station.

A. Analog unit

Analog unit consists of 4 (or 8) amplifiers with appropriate band-pass filters and a block of control registers. One more input amplifier is added for deriving independent EGG signals. Power supply for the unit is taken from the docking station of the notebook computer. Block diagram of one measuring channel of the analog unit is shown in Fig.2.

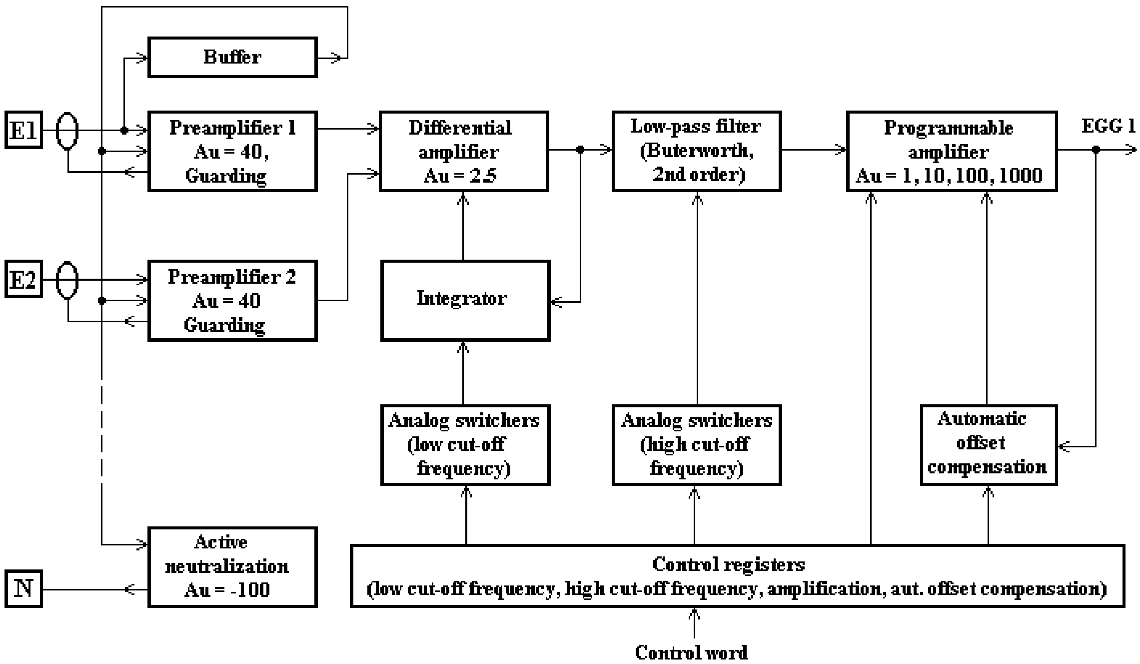

Figure 2. Block diagram of one channel of Analog unit

Each measuring channel consists of:

- two preamplifiers,
- circuit for active patient neutralization,
- circuit for lead cable guarding,
- differential amplifier with digitally controlled frequency dependent negative feedback (high-pass filter),
- digitally controlled low-pass filter,
- cascade of two amplifiers with programmable gains,
- automated offset compensation circuit.

Inputs of all preamplifiers are protected by an over-voltage protection and include radio-frequency filters. The preamplifiers are designed as differential stages. Signal from the measuring electrode is connected to the first input of each preamplifier, buffered signal from the reference electrode is connected to the second input. Thus the disturbing signal, which is supposed to be common for both inputs is only carried over the preamplifier but not amplified. The common mode rejection ratio is therefore equal to Au.

For reduction of common disturbing signals, especially of the power supply voltage with frequency 50 Hz that is usually present on the patient body, several circuits are implemented.

Circuit for patient active neutralization is driven by buffered signal from the reference input channel. It amplifies and inverts common disturbing signal from the patient. Patient body is then driven with this signal through electrode N. If amplification of the circuit is –100, then suppression of the common disturbing signal on the patient body is 40 dB.

Coaxial cables are used to protect the sensitive signal inputs against capacity currents flowing from mains through parasitic capacities. To keep the input impedance of the preamplifiers high, shields of these cables are driven by guarding circuits. Each input cable has its own guarding circuit driven by buffered signal from the reference electrode (E1).

Signals from all electrodes are amplified in preamplifiers by Au=40. For the used power supply voltage, this value of amplification is a compromise between the best signal to noise ratio and an admissible difference between polarization voltages of measuring electrodes. The upper cut-off frequency of the preamplifiers is high above the highest frequency component to be processed in the EGG signals.

Each EGG signal is formed in a differential amplifier with a gain of 2.5. To its inputs pre-amplified signals from one measuring electrode and from the reference electrode (E1 in Fig. 2) are connected. To eliminate DC component of the EGG signal and DC offset of all previous circuits, integrator in a feedback loop is used. Its cut-off frequency defines the lower cut-off frequency of the channel. This frequency is optional and is adjustable by digitally controlled analog switches. For quick compensation of the DC component, DEBLOCK function can be used. Suppression of the DC component on the output of the differential amplifier is about 80 dB. The resultant common-mode rejection ratio of each channel is then more than 90 dB.

Upper cut-off frequencies of the channel are adjustable by low-pass filters digitally controlled by analog switches and additional amplification (1, 10, 100 or 1000) is provided by programmable amplifier with automatic offset compensation.

Considering the parameters of input signals measured in the abdominal region of a human body, analog unit has these parameters:

- accepted range of input signal: 0.01 – 0.5 mV
- voltage amplification in each channel: 10^2 , 10^3, 10^4, 10^5
- low cut-off frequency: 0.015 Hz, 0.029 Hz, 0.5 Hz, 1.6 Hz
- high cut-off frequency: 0.1 Hz, 0.5 Hz, 2 Hz, 3.4 Hz
- number of measured channels: 4 or 8

Additional signal amplification is provided by a programmable gain amplifier in the measuring unit. That amplification can be set to 1, 2, 4 or 8, thus the resulting amplification of all measuring channels is variable from 100 to $8x10^5$.

B. Measuring unit

Measuring unit of the device consists of two main modules:

- analog multiplexer,
- analog to digital converter.

Both modules are placed in a docking station of the controlling notebook computer and connected to 2 ISA slots. Power supply for modules in the measuring unit is derived from power supply voltages in the docking station.

Module of analog multiplexers switches selected EGG signal to the input of the A/D converter module. This module includes 1 16-channel multiplexer and a block of DC/DC converter to provide supply voltage from the computer Bus.

Analog to digital converter module (A/D) is designed as a 4-channel conversion unit with programmable amplifier (gain 1, 2, 4 or 8). Block diagram of the module is in Fig. 3.

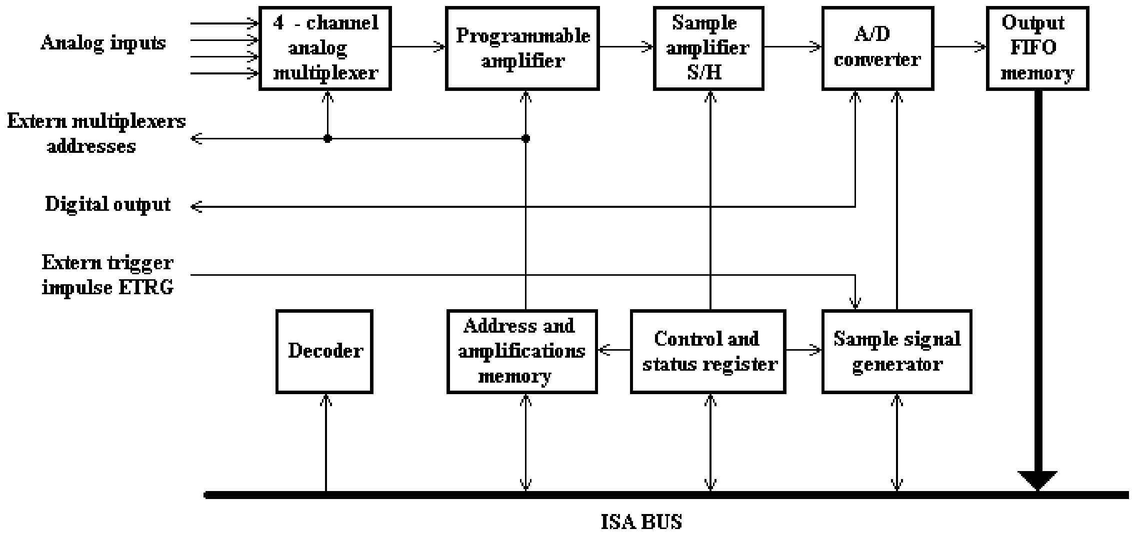

Figure 3. Block diagram of the A/D converter module

This module provides selection of input channel, adjustment of the amplification in the programmable amplifier, A/D conversion and writing data to output FIFO register. Its digital output signals control also the amplifiers, filters and DEBLOCK function in the analog unit. Input range of the A/D converter is – 10 to + 10 V, conversion time is 30 μs for 12 bit data. Digital data are transferred in DMA mode to the notebook computer and processed by devoted application software.

3. Conclusions

Experimental measurements using the system proved that the system works well and the obtained data are suitable for use in clinical research. To bring the device further to clinical practice, device with improved measuring unit based on ADuC812 micro-converter and connected to serial port of the notebook computer is being developed.

Acknowledgement

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