PORTABLE MICROPROCESSOR SYSTEM FOR TREMOR SIGNAL RECORDING IN EXTRAPYRAMIDAL DISEASE

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Abstract - Tremor constitutes one of the most important symptoms of neurological disorders. However, its objective assessment is very difficult. The methods used for objectivisation require application of such devices as piezoelectric detectors or kymographs. The best results are achieved with the use of spectral analysis. A simple measuring set consisting of accelerometer transducers and multichannel A/D converter plugged in the ISA slot of a computer has been designed in the Institute of Fundamental Electronics of Military University of Technology, Warsaw, Poland. The equipment has been created to meet the requirement of objective tremor measurement. The set includes specialised software.

1. Introduction

Tremor is a rhythmic involuntary oscillatory movement of body parts, with a relatively fixed frequency and amplitude. It can be observed in healthy subjects as well as in patients with various diseases. Tremor constitutes one of the most important symptoms of neurological disorders. Among the pathological cases, essential and parkinsonian tremor are the most often observed types. The proposed system for acquisition and processing of tremor signals can be used as an aid in both – medical diagnosing and observing the progress of treatment. The developed, easy to use and portable tremor data logger is essential for continuous monitoring of patients. It could be used at home in everyday actions as well. The main task of the logger is then to acquire the outputs of acceleration transducers in predefined periods of time as well as to store and to transmit them to a computer for further processing. Any kind of more sophisticated analysis can be applied in the later. Practical requirements concerning the logger have been assumed as follows:

- 4 channel tremor recording;
- sampling rate - minimum 100Hz;
- the possibility of continuous recordin during 24 h.
- write data to digital memory;
- battery powered, low power consumption;
- low cost, small dimensions and weight;
- cooperation with master computer via interface RS 232;
- possibilities software selectable configuration parameters from master computer;
- simplicity service, high automation of measurements

2. Project Realization

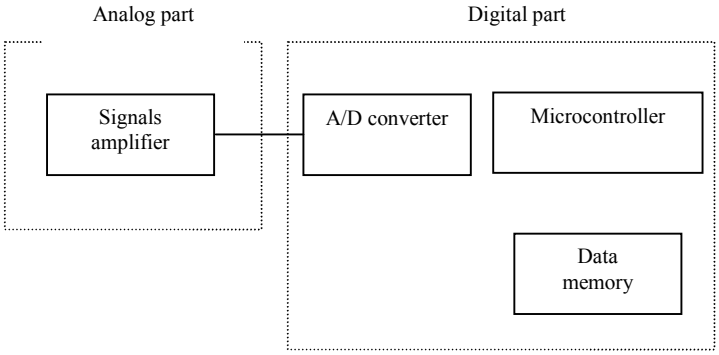

Fig. 1. Recorder block diagram.

The practical realization and the option of the applied elements resulted of the conditions imposed by the assumptions accepted in the recorder project. Basic requirement is battery powered circuits (±3V) in continuous time working 24 hours. This term can be performed by low power and low voltage all elements (as digital as analog) applying. This term connection with remaining assumptions was considered in particular project. Fig. 1. is presented recorder block diagram.

The designed system is characterized by the high degree of the integration, compact and possibly simple design at simultaneous high level automation process measurement and limiting interference user. It is possible in he single out part analogue containing amplifier measurement signals and part digital containing converter A/D , adapter microprocessor and constant data memory.

3. Amplifier

Basic role of amplifier is amplification and filter measurement signal so as to adjust low level output signal from sensor to range of analog input signal A/D conversion and at the same time limitation signal bandwidth and elimination disturbances outside bandwith.

Measurement signal parameters on amplifier input are depend on type transducers and range of measured physical quantity. Because system will be basic application to tremor signal recording, then basic physical quantity will be acceleration and signal source will be piezoelectric transducers. Tremor signal bandwidth is 30Hz (0÷30) Hz. On the basis of tentatively investigation was determined then basic kind of transducers will be accelerometer type B&K 4375. They possess charge sensitivity 0,316 pC/ms^{-2} and voltage sensitivity 0,48 mV/ms^{-2}. Output signal from accelerometer is bipolar signal. For measurement assumption of acceleration (0,1÷20) ms^{-2} voltage sensitivity determine range of transducers voltage output signal to (±0,05÷±10)mV.

For recorder system is accepted assumption its universal, that is on use recorder to measurement also other biological signals. Therefore is taken into consideration possibility cooperation with other signal sources beside accelerometers e.g. while recording ECG signal. That's why input amplifier should be made on base voltage amplifier with high input impedance. If will be applied input charge amplifiers than recorder application is delimited only to cooperation with accelerometers. This is excluded its universal application. As expected max. amount of signal measurement from sensors (4) is forced four channel amplifier realization. Input signal from accelerometer is bipolar signal, however for the sake of universal application, amplifier should be enable to cooperation with unipolar signal.

Depicted assumption is taken considerations high automation recorder is leaded to rise up detailed project of amplifier in recorder system. Amplifier functional diagram is presented on Fig. 2.

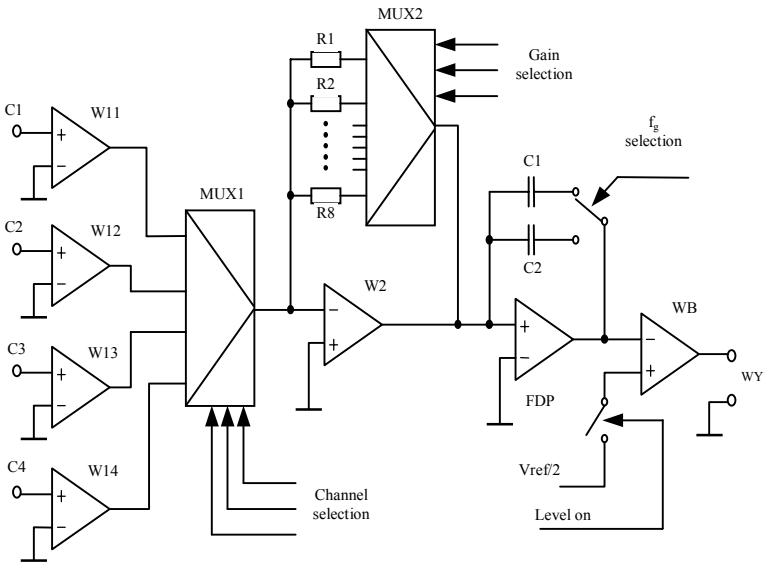

Fig. 2. Amplifier functional diagram.

In amplifier there are:
- four input voltage amplifier with equal constant gain;
- analog multiplexer to switch measurement channels;
- amplifier with digital adjusted gain (8 measurement range);
- active low pass filter with selectable limit frequency;
- output buffer with switch on reference label measurement signal control system.

Amplifier control: channel selection, filter limit frequency selection, on/off reference label measurement signal control system is executed programmable and completely automatically without direct user (patient). Amplifier is cooperated with analog/digital converter which range input analog voltage signal equal (0÷2,5)V for unipolar signals or ±1,25V for bipolar signals. For input signal task is selected values of system gain so as to with nominal input voltage obtained full range transducers analog voltage. Amplifier possessed eight ranges which choose is made automatically in measurement process.

There are access following input measurement signal ranges: 0,1/±0,05mV, 0,25/±0,125mV, 0,5/±0,25mV, 1/±0,5mV, 2,5/±1,25mV, 5/±2,5mV, 10/±5mV, 25/±12,5mV. Choose input measurement range is made by change system gain. Gain four input amplifier stage is constant and equal 100V/V. Gain second amplifier stage is adjusted depend on range and equal: 250V/V, 100V/V, 50V/V, 25V/V, 10V/V, 5V/V, 2,5V/V, 1V/V. Low pass filter application in measurement circuit has two software programmable limit frequency: 30Hz and 100Hz. Frequency 30Hz is selected to tremor signal measurements. Frequency 100Hz is selected to other biological signal measurements.

4. Digital Part

Digital part task is control the measurement system, analog/digital signal conversion and its recording. Digital part functional diagram is shown on Fig 3.

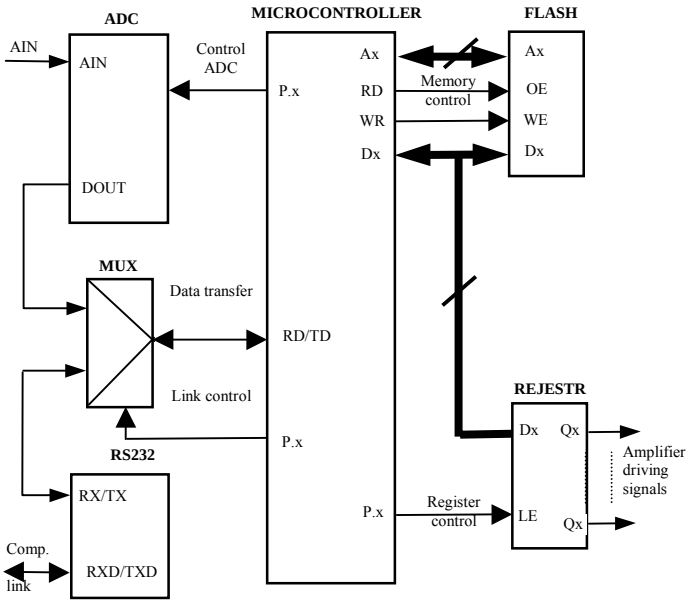

Fig. 3. Digital part.

The main tasks of analog/digital converter is conversion analog input signal to numerical signal in binary form and its preparation to read by control microprocessor. Realized analog/digital converter should be according to global assumption operate with low voltage power supply and charakterize low power consumption. From respect on simplicity design and admitted assuming on purpose is applying monolithic integrated analog/digital converter. It is necessary assure 12-bit resolution and required speed processing. If take into account than maximum frequency band of signal measurement is 100Hz (for biological signals), than sampling rate in each channel should be equal minimum 200Hz. With four measurement channels there is minimal processing frequency 800 Hz. Therefore transducer should be possessed possibility programmable service and serial data output. This condition is limited number of use microprocessor line. Take on base this assumptions is selected to realization integrated circuit (analog/digital converter) Analog Devices AD7853L. Selected integrated circuit is made up almost complete analog/digital converter module to meet project assumptions. Its required only outside sync signal from quartz oscillator. Than converter unit included integrated circuit AD7853L and quartz oscillator with frequency equal 1,8MHz. Its realized on logical gate. Converter is cooperated with master computer via serial interface. Microcontroller is the main part of system, which basic tasks consist of control and conducted measurement process.

Realization of controller basis on 8-bit microcontroller Amtel AT89LV52 which is compatible as regards list of commands and pins with microcontroller 80C51/80C52. System is characterized low power consumption especially connections with available mode of power saving. Its additionally advantage is possession in internal structure memory type flash (8 Kbytes). Memory is electrical programmable and erasable. This solution has two principal advantages: simplifies the structure of the driver by the elimination of the external EPROM memory and provides easy programming as many times as need. Data memory module is designed for measurement data recording of subsequent cycles during the day profile of tremor. The data memory should be nonvolatile and independent on the voltage supply of the whole system. The required memory space is determined by number of data bytes recorded in the unit of time (seconds) as well as by general time of recording. For specific maximal processing frequency of signal (here 100Hz) – amount of data bytes accumulating on second from four channel measurement is equal 800Hz, because:

$$2 \text{ bytes from one conversion} \times 100 \text{ conv./sec.} \times 4 \text{ channels} = 800 \text{ bytes/sec.}$$

The proposed recording per day includes time series of 20 seconds in length acquired with 30 minutes gaps. The resulting time equals then 960 records per day. This the required memory space must include:

$$960 \text{ sec.} \times 800 \text{ bytes/sec.} = 768\,000 \text{ bytes}$$

On this base is applied assumption of realization memory area 1 Mbytes. Memory unit is made on integrated circuit AM29LV008BB. Microcontroller is possessed 16-bit address bus. This allowed to address 65536 bytes. Because required memory is about 1 Mbytes, it needs 20 address lines. Therefore is made use buffer latch for widen standard address bus (additionally 4 lines). In control module is possible beside microcontroller and memory, serial interface module realizing choice setup

cooperation (analog/digital converter, master computer) and matching signals to standard RS232; setup space adress decoder; control signals buffer for analogue part recorder.

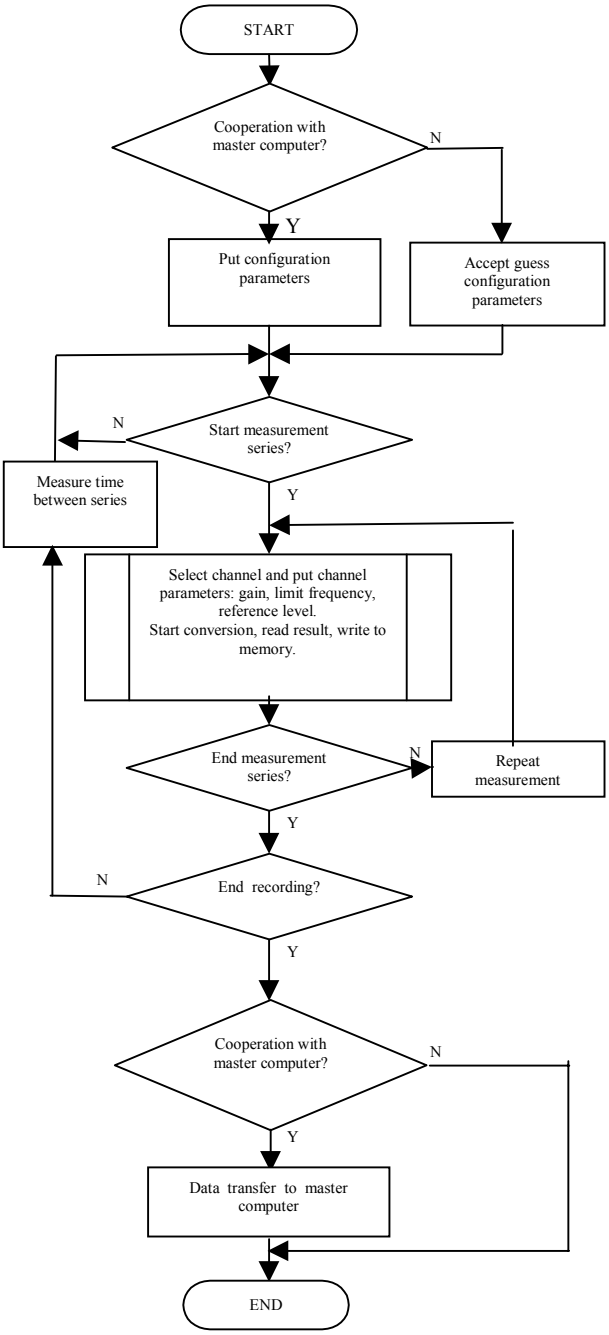

Fig. 4. Functions algorithm.

5. Functions Algorithm

The setup is accepting the basic, default configuration parameters after switching on the power. Change parameters configuration possible is in process preparing setup to work from master computer label by interface RS232. To configuration parameters belong:

- number of measurement channels (1÷4);
- sampling rate in each channels is selected (100Hz or 200Hz) on the basis of what kind of signal is chosen;
- low pass filters limit frequency for signal in each channel, automatically selected on sampling rate base;
- duration of one measurement series: 1÷30 sec.
- idle time between measurement series: 1÷60 min.
- current date of measurements.

After putting parameters configuration recorder is ready to independent work. Idle time between measurement series is started. After idle time, recorder is signalled availability to start next measurement series. Recorder is waited for patient readiness for perform measurements. After confirmation availability (button READY) is realized measurements on the imposed duration one series measurement. System is chosen measurement channel, set up gain in this channel, low pass limit frequency and on/off moved reference label signal. Start analog/digital converter is followed. After conversion processing result is received via microcomputer serial interface and written to flash memory. Next system is operated another channel. Measurement frequency in each channel is fixed in system configuration parameters. Service channel is repeated to end of measurement cycle. Next system go down to measure break between cycles.

Process is repeated as long as recorder data memory is filled or end of 24-hours recording cycle. The recorded data is kept in the memory till the moment of cooperation with master computer. Then particular measurement results are transmitted with the use of serial port. The reset of flash memory is conducted and whole algorithm is repeated. Functions algorithm is shown on Fig. 4.

References

[1] AMD, Flash memory products, 1998, (435-470)
[2] ATMEL, 8bit flash microcontrollers data book, (193-249)
[3] Texas Instruments, Mixed-signal and analog products, 1999, CD-ROM
[4] Kwiatos K., Bobrowicz R., Chwaleba A., Jakubowski J.: *„Tremor Measurement in Extrapyramidal Disease”* 2-nd International Conference on Measurement "MEASUREMENT'99" Bratysława 1999