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A module based hybrid analyzer of biological signals

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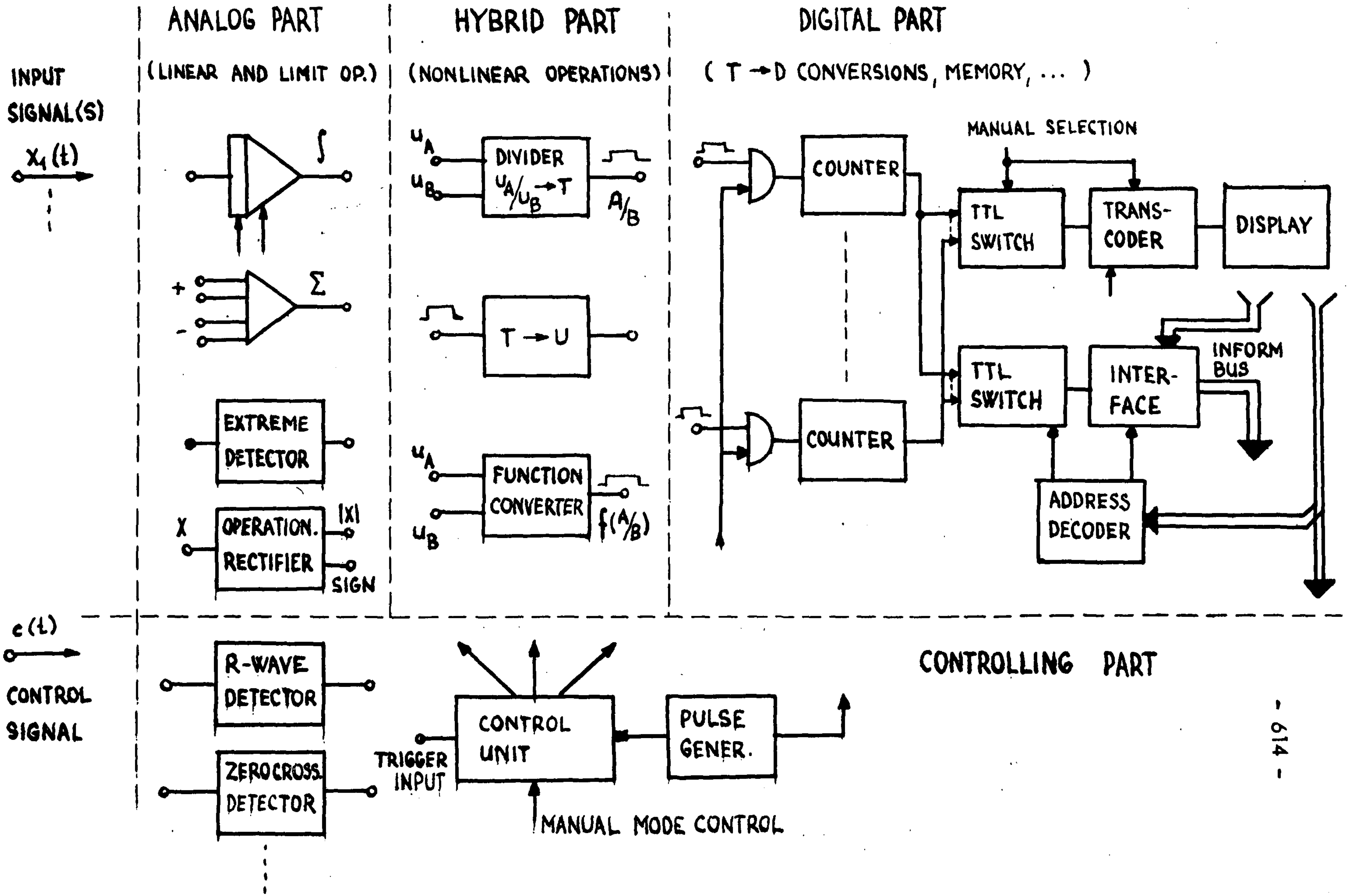
1. Introduction

The analyzer presented here is in fact a kit which enables to hangle different signals for various purposes. It consists of three basic parts: an analog part, a hybrid part and a digital one. All the operations performed by analog and hybrid circuits can, of course, be done digitally with many advantages, but we have not any access to the necessary semiconductor LSI devices to construct the equipment economically. On the other hand, the reason why to exploit digital technique (even only partly) is the need to display results in digital form and in some cases to connect the analyzer and possibly many other similar apparatuses to a controlling computer without any further interface. Also the function of time-unlimited memory is practicable only in this form.

2. System description

The basic elements of the analyzer can be seen in Fig. 1. The analog modules based on integrated operational amplifiers are: integrators with an electronically controlled integration constant and zero setting, extreme detectors with controlled hold function, operational rectifiers giving the absolute value and the sign of the input voltage and summators-subtractors. This analog hardware can be utilized in many ways - practically any linearly derived parameter of input signals can be obtained in this part by properly connected elements. We have used it to determine the definite integral of the signal

$$\int_0^T x(t)\, dt$$



ANALOG PART
(LINEAR AND LIMIT OP.)
HYBRID PART
(NONLINEAR OPERATIONS)
DIGITAL PART
(T → D CONVERSIONS, MEMORY, ...)
INPUT SIGNAL(S)
x1(t)
EXTREME DETECTOR
OPERATION. RECTIFIER
|x|
SIGN
DIVIDER uA/uB → T
A/B
T → U
FUNCTION CONVERTER
f(A/B)
MANUAL SELECTION
COUNTER
COUNTER
TTL SWITCH
TTL SWITCH
TRANS-CODER
DISPLAY
INTER-FACE
INFORM BUS
ADDRESS DECODER
c(t)
CONTROL SIGNAL
R-WAVE DETECTOR
ZEROCROSS DETECTOR
TRIGGER INPUT
CONTROL UNIT
PULSE GENER.
MANUAL MODE CONTROL
CONTROLLING PART

Fig. 1.

for some time interval T, to measure the time intervals by integrating a constant voltage, to get the maximum and minimum values (MAX, MIN) of the signal in the interval T and to calculate the difference between the last two values. Because following hybrid dividers can handle only one polarity voltages the operational rectifiers are included in branches where the voltage can be of both polarities and the sign of the value is treated separately in digital form.

The hybrid part of the analyzer includes two basic types of blocks: first of them dividers which convert the fraction u_A/u_B into a corresponding time interval. The second type consists of fast time interval to voltage converters. Modified version of dividers can provide time intervals proportional to square roots or logarithms of the ratio of input values. These blocks based also on common ICs are able to make all the basic nonlinear operations which are usually thought of as difficult to a hardware realization. In addition to the mentioned operations the multiplication is available if a chain of a divider, T/U converter and another divider is connected and properly timed (in fact, the expression of the type A.B/C or A/BC can be calculated by means of the chain). It is substantial that all the operations are executed theoretically perfectly, there are no approximations. We have verified experimentaly that inaccuracies due to nonideal operational amplifiers are negligible so that the total errors of nonlinear operations are less then 1 % which is quite acceptable. In the application for hemodynamic signals the following parameters are being calculated: the mean value

$$M = \frac{1}{T} \int_0^T x(t)\, dt,$$

the beat frequency $f = 1/T$,

and the pulsatility index

$$PI = \frac{(MAX-MIN).\,T}{\int_0^T x(t)\, dt} .$$

To keep the number of module types as low as possible, the dividers are also used to convert voltages to time intervals even if no nonlinear calculation is needed, as in the case of extreme values. At the first look it seems to be not very economic like in the case of the mentioned multiplication chain, but thanks to the simplicity of the respective modules it is a very acceptable solution.

The outputs of the hybrid part are time intervals proportional to calculated parameters which can easily be digitized by counting impulses of a train with a constant rate during the intervals. This is the first task of the gated binary counters, the second being the memory function mentioned above. Every counter keeps one desired signal parameter, normaly up to 8 or even up to 16 parameters (especially in the case of cross analysis of more signals) can be stored. All the binary values are normalized into the extent $\pm (2^7 - 1)$ regardless of the practical meaning of the value, in this way the minimum redundancy is achieved. If used by a computer the values are multiplied by suitable constants known to the programme, but for visual evaluation by doctors and nurses it is necessary to convert every number into a new scale so that the parameters are expressed in common units. This is the purpose of a simple transcoder which also converts the number from binary into BCD code for display. The scale is automatically selected together with manual selection of the displayed parameter. An identical TTL switch chooses the parameter to be send to computer, which parameter is taken depens on 3 or 4 lowest bits of the address transmitted from the computer. The correspondence between the computer and the analyzer realizes only if the 8 most significant bits of the address represents the internally coded number of the respective analyzer. This enables that up to 255 such peripheries can be connected to a computer. The analyzer is matched to the data bus by means of a standard interface card.

The timing of all the parts is made by the control unit which is supplied by necessary pulses from the pulse generator providing also the pulses for counters and the transcoder. Manual control is limited to the selection of working mode which may be either normal or slow. The normal mode means that all the values are computed from the last period of the signal (e.g. last R-R interval), the slow mode uses the last four periods that needs among others the integration constants to be four times greater than in normal mode. The control unit is triggered by the signal being analyzed (e.g. by means of a zero crossing or extreme detector) or by another correlated signal (e.g. by R-waves of the ECG signal).

3. Applications

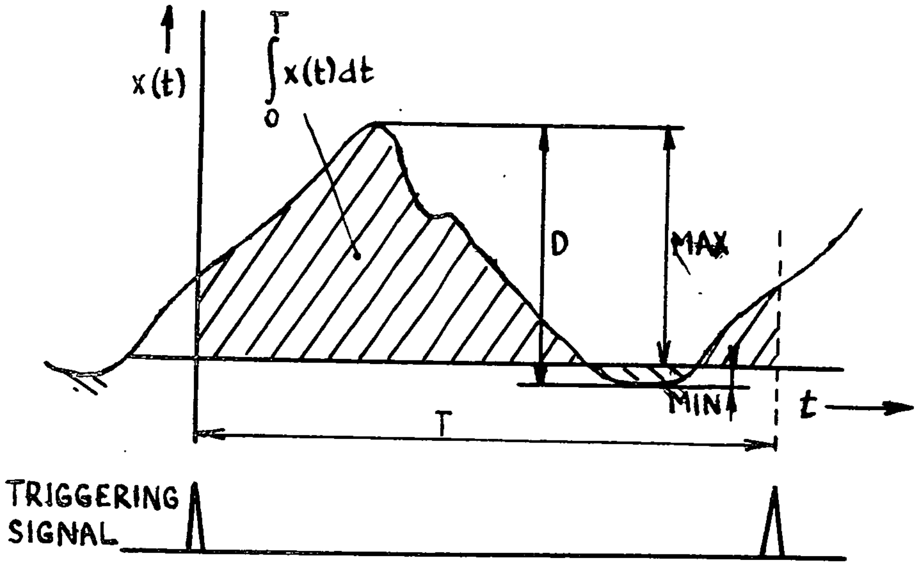
Fig. 2 shows the meaning of the parameters calculated by a realized example of the proposed analyzer system, marked HYDRA, for evaluation of hemodynamic signals.

The analyzer has been clinicaly examined in two different situations. The first one was a direct use with visual reading of the parameters in a surgery of a specialist in hemodynamics. The analyzed signal reprezenting the blood flow was picked up by a Doppler ultrasound flowmeter. The use of the analyzer removed the tedious work with evaluation of recorded curves and sped up the diagnosis.

The other application was made at a modern intensive care unit for seriously hurt patients equipped with a computer of the type M 6000, that served for automatic monitoring. The philosophy of such a use is as follows: It is practically impossible to convert all the monitored signals into digital form and to process them in a central computer as it would lead to enormous demands on the memory size and computing speed, Because every such signal is in fact described by only a few main parameters that are taken into account in monitoring process, it is more economic to preprocess the signals in specialized processors (analog or digital) and to load the computer only with the parameters. The interface of the analyzer is so designed that it enables to build systems like in Fig. 3 where every new apparatus can be simply connected to an already existing system without any need for hardware changes in the system. In simpler systems a computer can be substituted by an electric typewriter with a control logic so that at least printed records of monitored parameteres are available.

4. Principle of some modules

Finally let us show the principle of two seemingly complicated modules, i.e. dividers and transcoders, which are in fact very simple. Both principles are subjects of CS patents.



DISPLAYED VALUES

MAX,

MIN,

$$\text{MEAN} = \frac{1}{T}\int_0^T x(t)\,dt\,,$$

$$D = \text{MAX} - \text{MIN}\,,$$

$$PI = \frac{T \cdot D}{\int_0^T x(t)\,dt}\,,$$

$$F = \frac{1}{T}\,.$$

Fig. 2

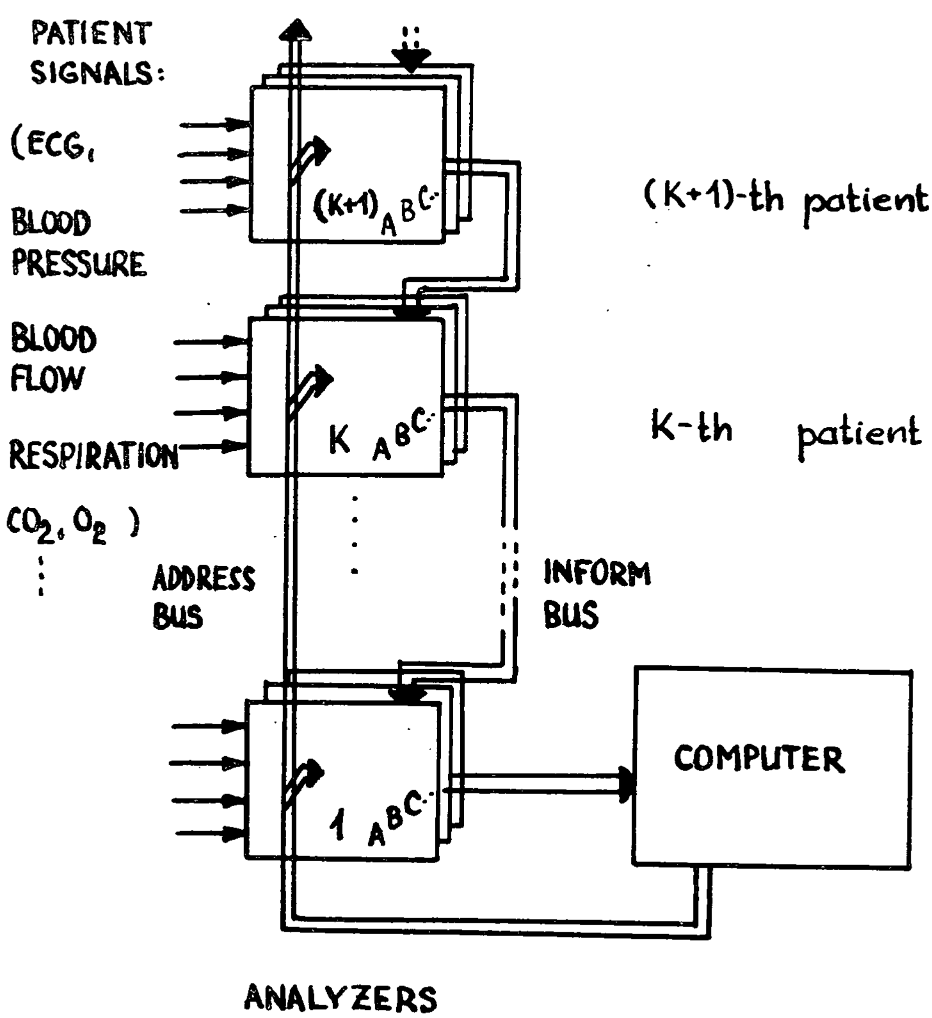


Fig. 3

Fig. 4 shows the principle of the conversion of a fraction u_A/u_B into a time interval $\triangle t$. It is obvious that

$$u_C = K \int_0^t u_B \, dt = u_B \, t \, K$$

(where K is an integration constant). The output impulse which starts at $t_o = 0$ ends at the time t_1 when $u_A = u_C$ so that

$$\triangle t = t_1 = \frac{1}{K} \frac{u_A}{u_B} .$$

The transcoder should convert the number from an input code, say A, into another code B and at the same time multiply the number by a suitable coefficient. As this operation for finite word lengths is a finite alphabetic operator it could principal 24 be realized as an inertialess combining circuit, but this form would be very complicated when numbers with more than one decimal place are to be converted. The change of the coefficient is practically unrealizable in this way. Another common, but in the given case apparently impractical, prossibility is to use a microprogramme executed either on a computer or on a microprocessor with ROMs. Much simpler is a circuit drawn in Fig. 5 which works in principle as follows: When the input number changes so that it differs from the content of the counter A, both of the counters are set to zero by means of a control logic, and the output of the comparator is set to 1 which opens the gates. The pulses of the rate f_1 and f_2 are counted in the counters A and B respectively until the content of the counter A is not again equal to the input word when the gates close. The content of the counter B is then obviously equal to A (f_2/f_1) and is expressed in the desired code according to the code of the counter B. To change the coefficient only to simply switch the rates of the counted pulses is needed. A special measure in the logic arranges such a synchronization that the result is correctly rounded in cases when f_2/f_1 is not an integer.

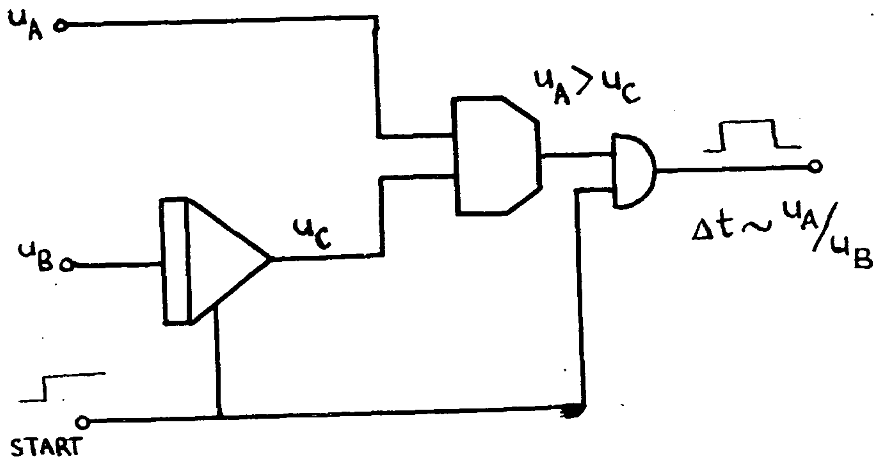


Fig. 4

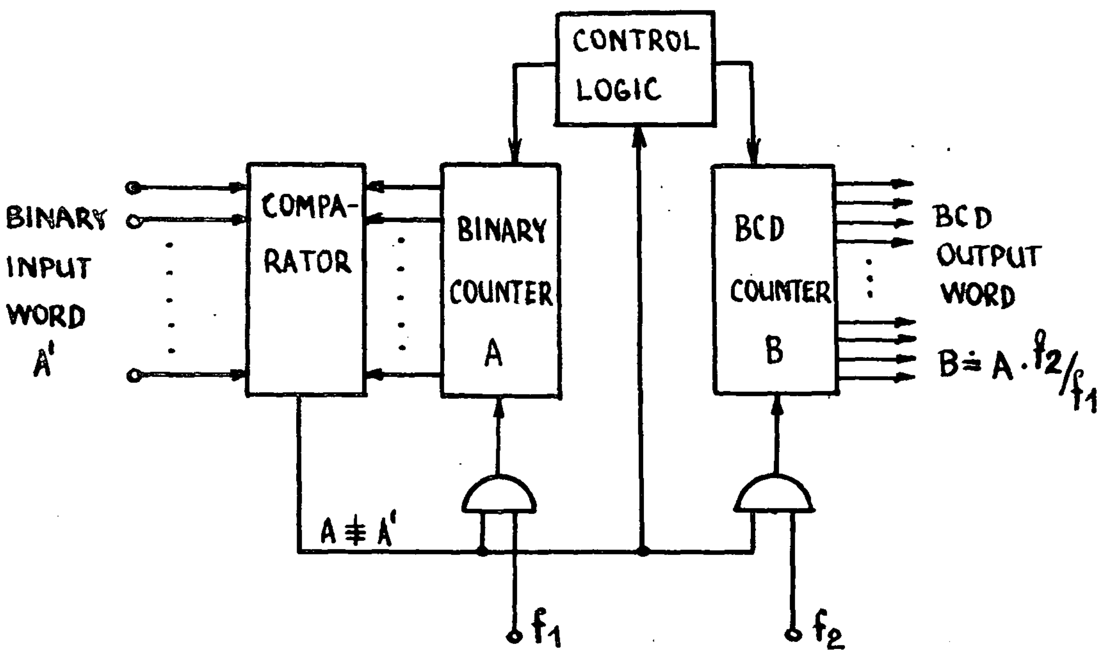


Fig. 5

5. Conclusion

The basic ideas of a possible approach to preprocessing of biological signals for the needs of immediate use by medical staff or of monitoring systems have been shown. There is a hope that the analyzer modules will be industrially produced and consequently relatively widely used which would examine whether the ideas are reasonable.

References

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