Memory Devices with the Possibility of Adding on Optoelectronic Devices

Mykhailo Semenyuk and Andriy Semenyuk

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Mykhailo Semenyuk[a], Andriy Semenyuk[b]

[a] *Naukovo-Doslidnyy Instytut Reabilitatsiyi Osib z Invalidnistyu, 104. vul. Khmelnitsky highway, Vinnytsia, 21000, Ukraine*
[b] *Vasyl' Stus Donetsk National University,21. vul. 600-richchia, Vinnytsia, 21021, Ukraine*

Abstract
The article deals with optoelectronic devices, which utilize quantum memory chips. These devices can be used for creation of optical computers based on signal processing in the decimal calculation format, with direct indication of the data being processed.

Keywords 1
Optoelectronics, quatron, decimal calculation system, memory, adders, computing devices.

1. Introduction

All the specter of the popular electronic computing devices that were and are now produced utilize bit-logic components. This approach has been taken due to the fact that electronic memory devices have only two stable conditions characterized either by presence or by absence of the potential ("07" 1"). The optimum dialog between man and any data processing device, however, is possible only in the data representation system that the man has got used to, with the use of decimal digital system.

The first computing devices were created in accordance with this rule. To represent the digits, those devices utilized such memory units as [1]:

- Mechanical elements on the basis of counting wheels (arithmometers, computing machine by Howard Getway Iken known as MARK-1 machine)
- Decade relay devices (machines by K Zuse, George Stibitz).

The same principle is used nowadays in various mechanical counters (for water, gas and electricity consumption metering). In the course of time such mechanical devices have been replaced by electronic and electric devices. First such devices utilized the former scheme of design of computing systems, by analogy to their prototypes. The ENIAC computer by John V. Mouchley and Presper D. Eckert consisted of a number of triggers on electronic valves linked in a ring of 10 elements. This ring acted as the counting wheel in a mechanical calculating machine.

This approach to the design of computing systems, however, was not rational, as their elements were not used to their best. New hardware required both new calculating system design and new methods of data storage and processing. As a result of collaboration of D. von Neumann, G. Goldstein and A. Burks, a new concept of computer design was put forward, and the new system of data representation - binary digital system (proposed independently by two scholars, D. Atanasov and K. Zuse) [2] was proved to be indispensable.

In the course of time, electronic valves were replaced by semiconductor devices, which in their turn, were followed by chips of different levels of integration; the calculation speed and the number of bits constantly increased, whereas the scheme of data storage and processing by computers remained the same, as proposed by the three ideologists of the binary digit theory.

Its predominance was caused by a number of its merits and demerits.

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EMAIL: ours13temp@gmail.com (A. 1); sam12122003@gmail.com (A. 2)
ORCID: 0000-0003-4774-7606 (A. 1); 0000-0003-2910-6258 (A. 2)

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The binary system allowed to easily solve the problem of storage and encoding of data and computer operation management programs. It also showed some advantages in performance of arithmetic and logical operations, in design of ALU's and in increasing of the computer bit range. The disadvantage of the new electronic components, arising from the fact that triggers could be only in two stable conditions, also led to the introduction of the binary number system. However, the binary number system is not the best choice for computer design.

A number of research works conducted at various periods of time proved the correctness of John Atanasov's conclusions that he arrived at when designing his calculating machine. According to Atanasov's conclusions, the optimum digital system for computers is the digital system with irrational base of "e=2,71828..." number.

However, it appears that the design of hardware components that could be based on such number system is not possible, as only integer can constitute the basis for any number system.

The closest integer to e-number is number "3". The ternary number system is more economical from the point of view of power consumption. This number system was utilized during creation of SETUN Soviet computer. However, production of electronic components with three stable conditions is a very complex task, thus such systems did not find wide application.

Nonetheless, the work on implementation of other number systems went on. A number of research works were devoted to another irrational number "p=l,618033..." being used as the base, on which Fibonacci codes and "Golden" Ration Codes are grounded [3]. For design of the systems using such a base, binary components are used with the only difference in the bit weight. The systems that utilize Fibonacci codes and "Golden" Ration Codes are well protected against noise on account of their redundancy, but this redundancy leads to the increase of the number of components used. Besides, arithmetic operations require transformation of operands into minimum form and this requires the performance of code fold and unfold operations.

2. Optoelectronic decimal memory devices

2.1. Serial Optoelectronic Registers

Each of the data representation systems discussed has both merits and demerits, but all of them have a common disadvantage, as they require first transformation of data for their processing in a computer and then another transformation for their subsequent display.

The components currently used in the design of computers are electronic devices whose production technology is coming to its limit. To further increase the speed of computers, we have to resort to hardware and algorithmic paralleling of operations which would lead to an increase of the total number of components several times.

Therefore, we can draw a conclusion that to ensure further development of computing systems, a new revolutionary approach is required. In should incorporate both the development of new structures for data processing and display and the development of new computer system composition technologies (as it was at the time of transition to electronic devices and to the binary number system).

For such systems, the devices based on optoelectronic (and further purely electronic) components can be used. These components use optical radiation as the data carrier, and allow performing arithmetical operations within the decimal number system.

Having developed a coil of the spiral in its development, the computing systems have come back to their incipient stage - to the decimal number system although at a quite new level.

Now, for data storage it is proposed to use optical memory devices, the so-called quantrons [4]. The distinctive feature of these components is the combination of several functions within one component: information reception, its saving and display (Figure 1). Therefore, to display data no additional devices are thus no additional transformations are required.

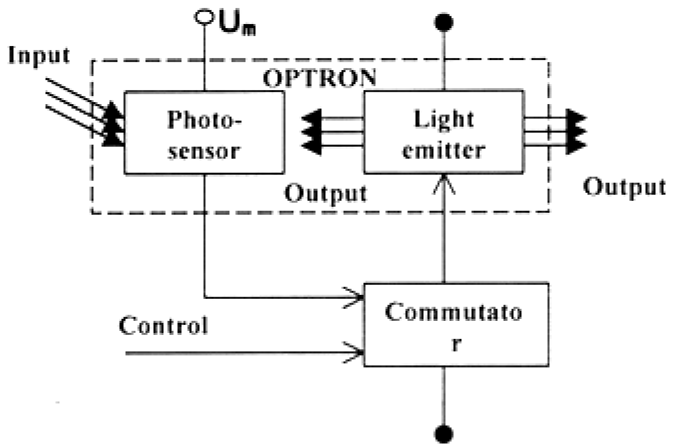


Figure 1: Quantron

A qauntron as a singular component is not very effective because, as its predecessor, the trigger, it must be either on or off. Its main advantage that it can be in several stable conditions comes to the surface when it is used in combination with several other quantrons - within a quantron array. [4].

Figure 2 shows the structural diagram of one decimal bit of the memory register. The optoelectronic couples are (options) are distributed in such a sequence that the flow coming from the emitter of the preceding couple can influence the photo-sensor of the next couple. During the data recording session (when the flow of light reaches the input of the photo¬sensor of the first optron and when at the input "Um" there is activation voltage Ua) the optron array sequentially goes on.

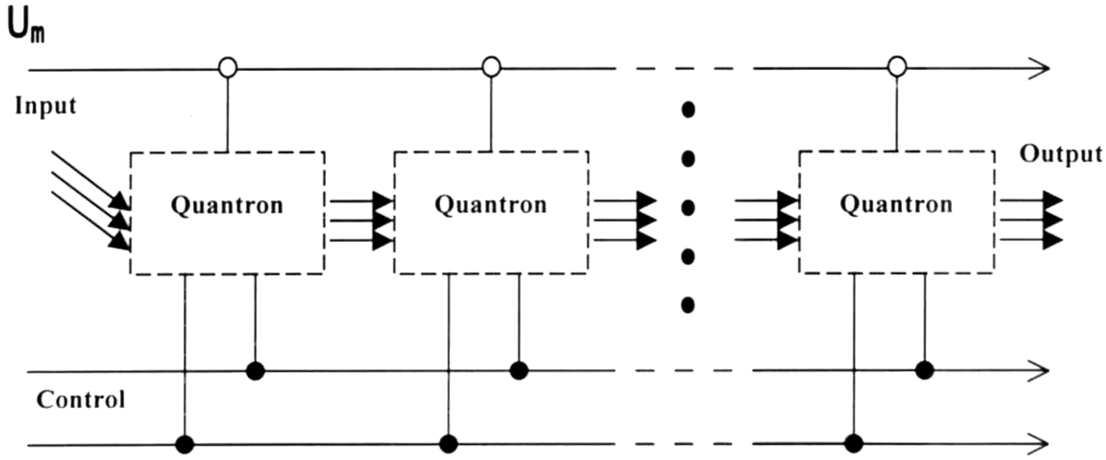


Figure 2: Serial Optoelectronic Register

After the cessation of the light flow, or after the voltage TJm has come down to the level of the storage voltage Us, its operation in the activation mode is not possible any longer, and thus the device goes into the data storage mode. The number of active quantrons (the switching time of each of the quantrons is x) allows us to determine the duration (value) of the light flow, nxx. In case of the overflow of the decimal bit (quantron array), the data are transferred to the next decimal bit (the first photo-sensor of the next decimal bit is exposed to radiation) and the reset signal for the quantrons belonging to the overflow bit is generated. So we have the opportunity to have the result measured and displayed directly without any cumulative errors.

The disadvantage of this structure, as with any other serial structure, is that the time of processing is greatly influenced by the number of bits to be processed. Coding of data through variations in the duration of the signal requires a complex system of data synchronization during their recording and arithmetical operations on them.

2.2. Parallel Optoelectronic Registers

As it is seen from the quantron design (Figure 1), the quantron storage mode can be controlled in two ways:

1. by reducing the control voltage Um;
2. by removing the input signal.

Each of these actions leads to the reduction of the value of the current passing through the photo-sensor down to the level that is not sufficient for the commutator operation. Still, the optical radiation is characterized not only by the duration but also by the intensity of the light flow and by the spectral composition of the radiation. If we have the functions of the photo-sensors of quantrons, viz.:

- the input data reception;
- maintenance of quantron in active condition

distributed between two photo-sensors, then (upon the introduction of an additional photo-sensor into the quantron design) it will be possible to control each quantron through the intensity (or through the spectral composition) of the light radiation.

Figure 3 shows the structural model of a memory register used to store data in the decimal number format in case of parallel data storage.

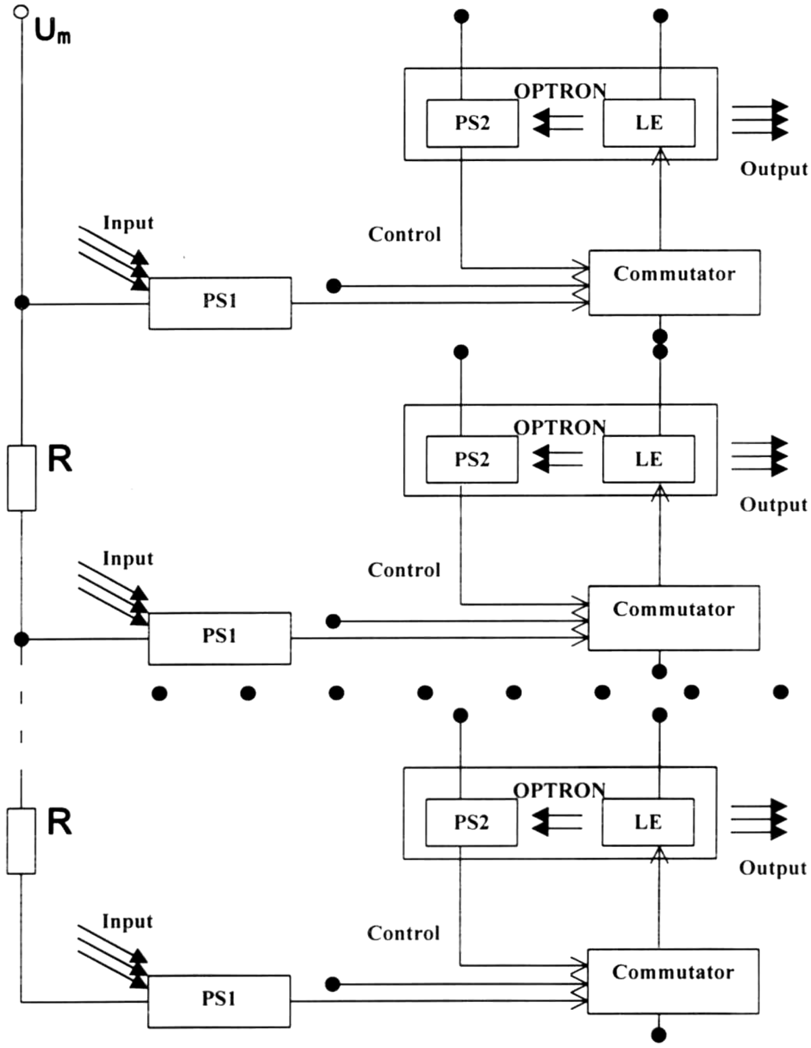


Figure 3: Parallel optoelectronic registers

The "PS1 "auxiliary photo-sensor serves for the creation of the commutator activition current. The voltage divider is assembled from "R" resistors and allows to switch on individual optrons depending on the intensity of the input light radiation. The function of the optron remains the same: one portion of the light radiation is used for the bit value display, while the other is used for maintaining of the quantron in the active condition.

Unlike the serial storage registers, these registers store data, with their function being separated into:

- determination of the decimal bits that will keep the data;
- determination of the decimal bit active elements (bit value).

In case of encoding through the radiation specter, each decimal bit is defined by the length of the optical radiation waveform, while the value of the bit is defined by the intensity of the radiation within the given range. The separation of the range (bit) is done with the use of filters, prism or by other methods.

In case of encoding through the radiation intensity there are two methods of separation into decimal bits.

The first method is based on the use of an additional quantron per each bit (overflow flag). The moment it is

activated, a signal is being generated that activates an additional resistance for the current bit and for the preceding ones, thus compensating the excess of radiation for these bits.

The other method is based on initial generation of the most significant bit and then on reduction of the "sensitivity" of the preceding bit by the weight of the current bit, and so on.

At the second phase, which is the same both for the operation based on the radiation intensity encoding principle and for the one based on spectral encoding principle, the following things take place.

The input value of "Um" changes from TJa in the data saving mode to Us in the storage (display) mode. The activation voltage and the values of "R" registers are chosen on the basis of the following:

1. the level of the current on the lower element must correspond to the minimum value of the light radiation;
2. the value of Ua must be sufficient to activate the upper element;
3. the values of Ua and Us,must provide for the protection against erroneous switching on of the elements;
4. the switching on of the elements must correspond to the system discretization.

As a result of serial switching of resistors with the nominal value of R, the level of the voltage applied to the input of first photo sensors changes from the maximum value on the first element to the minimum value on the last one. All quantrons incorporate the same commutators and therefore, the current that is necessary to their opening should be the same. To achieve this, it is necessary to compensate the insufficient current value at the expense of the photocurrent coming from photo-sensors, i.e. at the expense of the intensity of the light radiation.

When the activation voltage is present at the input of "Um", and the light radiation is applied to the data input with the intensity sufficient to excite the quantrons, the elements where the current coming to the input of the commutator is sufficient for its opening, switch on simultaneously. As the commutator is open, the light emitter of the optron is on. A portion of the optron's light radiation is used for data display, and another portion of the radiation is used for excitation of the photo receiver of the same optron in order to generate the current sufficient to maintain the quantron in its active condition (still some other portion of the energy may be used for other purposes, for instance, for performance of arithmetic operations).

Upon cessation of the input signal or when the device gets into the data storage mode, the active (switched on) elements sustain themselves in the active condition through feedback. The quantrons are switched off by the RESET signal.

Depending on the actions to be performed, the optoelectronic decimal register may be designed to incorporate instead of additional photo receivers only one additional photo-sensor for the whole bit, with a voltage divider included after it.

The diagram of switching of the quantrons shown at Figure 3, unlike the systems with serial switching, saves data to all elements of the register during the T period, i.e. the ignition time of one quantron.

3. Optoelectronic decimal adders

An adder is a basic element which can be used to build any arithmetic devices. The generalized view of the adder may be represented as follows:

- 1 -st item register;
- 2-nd item register;
- result register;
- calculation unit;
- clock and control unit.

Depending on the peculiarities of the design, some units may be omitted (for instance, the data registers in case of direct reading of input and output data, or when there are external storage devices) or combined together (item registers with the result register; the calculation unit with the control unit).

Let us first consider the adder that incorporates all basic elements. The data are recorded into operand registers either simultaneously (if there are independent input data channels or when there is a signal phase shift, etc.), or serially (if there is only one data channel).

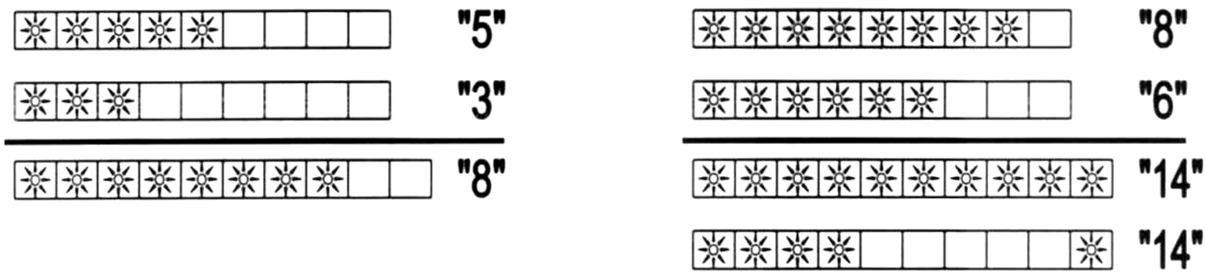
A portion of the light radiation coming from the optrons belonging to the first and the second operands, is gathered into one beam (for example, by an opto-fiber element) and is further fed to the optical input of the result register. Upon arrival of a signal from the control unit, the summed-up data are stored in this register and displayed.

Unlike the operand registers, the result register contains an additional quantron used to generate the overflow signal (emulation of the number "10") [5]. When this signal is available, the "RESET" signal is applied to the significant elements of this register, which entails lowering of the quantron activation threshold down to the level corresponding to the bit weight and recording of the modified value. Figure 4 shows examples of the summing operation for two decimal numbers:

a) - when there is no data transfer;

b) - with data transfer.

The "one" transferred from the preceding bit is sent to the data input of the result register simultaneously with the signal coming from the operand registers.



a) b)

Figure 4: An example of the summing operation:

a) in case of transfer to the nest bit;

b) when there is no transfer to the next bit

The summing operation is performed in all adder bits at the same time. In order to reduce the time required for obtaining of the modified result, a fast overflow signal transfer scheme is used.

If the result register and the first operand register are combined within one unit, summing operations are performed at the expense of the feedback between the optical output of the first register and its input.

When the data are supplied serially, it is possible to use a adder consisting of a single register. In this case there also exists feedback between the light emitters and the optical input of additional photo sensors. In the event of such configuration, the input data are accumulated until the "RESET" signal is sent.

The use of a single register for storage of the result is also possible when there are independent data inputs channels. The data input channels must hold the data during a certain time required for the store operations into the result registers to be completed. The summing operation in this case is performed as a result of a joint impact of the light radiation from the first and the second operands on the optic receivers, as well as of a transfer of the overflow signal from the lower bit.

4. Conclusion

The use of quantrons will allow computers to utilize optic radiation as the data media, whereas their computing and storage components will be used to process these optical data. Thus, the data processing speed will approach the maximum possible speed known so far.

Besides, the use of quantrons will allow to improve such a parameter as the speed of signal propagation which greatly influences the computer efficiency. This improved parameter can entirely "nullify" the advantages of high-speed processing units and memory chips, as, despite the high level of integration of the integrated circuits, the time required for a signal to pass the distance between individual gates is several times greater that the time of gate activation. Moreover, the time needed for a signal to pass between individual chips still far greater affects the efficiency of the whole of a computer.

Encoding by the method of radiation specter allows to perform simultaneous data saving to all elements, but requires additional optical signal dispersion. In case of encoding by the signal intensity method, only optoelectronic elements are used, although in this case the data saving process is slower. Both encoding systems allow to increase the number of bits per operation without modification of data transmission paths but solely on the basis of replacement of the active components, thus providing for upgrading of computers without the need of their design modification.

In addition, a system featuring the parallel principle of data recording is protected against the noise, the duration of which is less than a quantron activation period.

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