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DEVELOPMENT AND RESEARCH OF AN INVERTER BASED ON INJECTION – VOLTAIC ELEMENTS

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Abstract

The article explores the possibility of using the injection-voltaic mode of operation of a bipolar transistor to create electronic switching cells (electronic keys) – the basis of digital electronic elements operating at a supply voltage of the order of the contact potential difference.

Keywords: *photo-voltaic effect, injection-voltaic effect, bipolar transistor, microelectronics, integrated circuit, inverter*

Introduction

Microelectronics is one of the fastest growing areas of science and technology. The technical characteristics of microelectronic products – integrated circuits (ICs) – are constantly being improved and the functionality expanded. Improvements in microcircuits are achieved through advances in technology, circuit design, and system organization of integrated circuits.

ICs are the elemental base of radio engineering devices. Research and practical implementation of technological ideas to reduce its dimensions, weight, energy consumption, material consumption, and cost, increase the volume of functions performed, etc. continue at a tremendous pace.

The design process for ultra-large ICs can be divided into electrical and physical design. Electrical design includes functional design, logic design, circuit design, and semiconductor design. Physical design includes the topology of ultra-large ICs, i.e. placement of semiconductor devices, routing, etc.

However, the basis for both electrical and physical design of ultra-large ICs is semiconductor device design. Since the design of semiconductor devices is carried out in conjunction with the development of corresponding technological processes, this means that the design of semiconductor devices is the basis of ultra-large ICs machine design.

Since the main element of the IC are bipolar transistors, on their basis it is possible

to create a number of traditional functional devices that are widely used in practice.

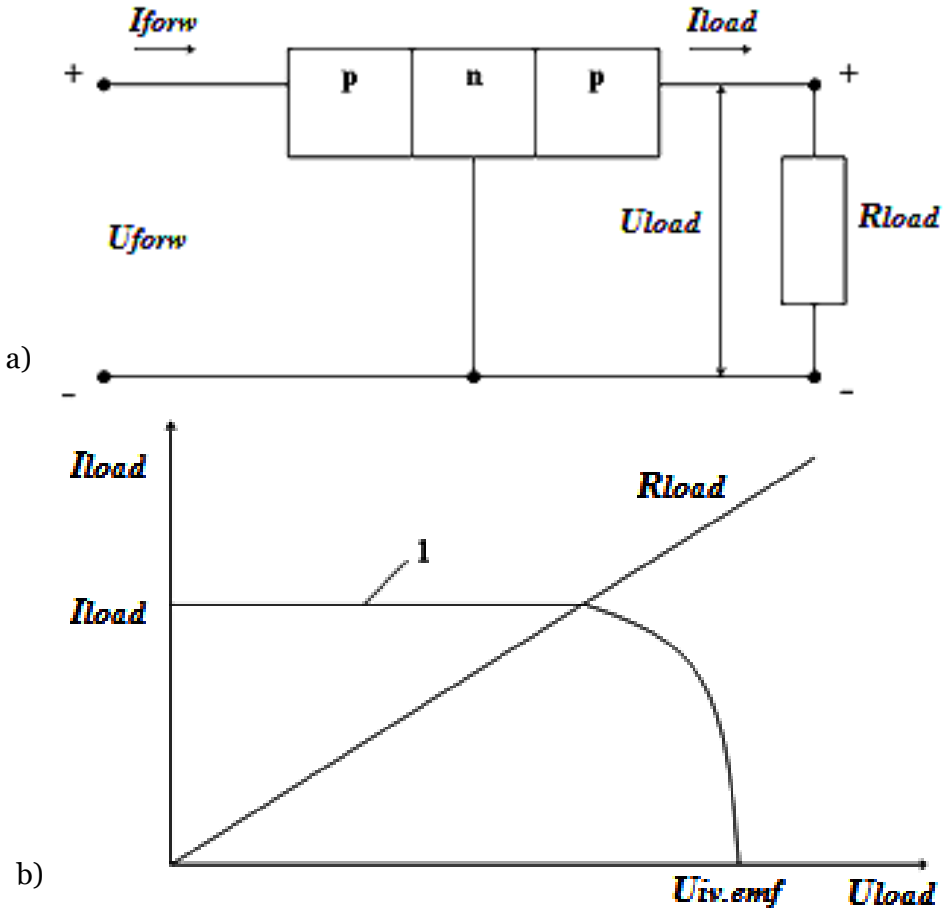
Solution

In recent years, studies have been carried out on the photovoltaic effect of solar radiation electrical conversion devices (Alimova, N. B., 2008). Some aspects of the operation of diodes, transistors and other devices as nonlinear elements were also studied. However, the area of research where both of these aspects are taken into account in the interrelation is practically unexplored in their mutual influence, although one should expect the manifestation of physical phenomena that determine new properties of semiconductor devices developed on the basis of this approach.

The injection-voltaic effect in bipolar transistors and thyristor structures was theoretically predicted and experimentally discovered. The injection-voltaic effect is observed in transistor and thyristor structures with p-n junctions upon injection of current carriers from one forward-biased p-n junction to another and consists in generating voltage in it (Fig. 1. a). The magnitude of the injection-voltaic voltage and current depends on the value of the load resistance Rload. By varying the values of the load resistance Rload from zero to infinity, it is possible to obtain the load characteristic of the structure in the injection-voltaic mode (Fig. 1. b).

At $R_{load} = 0$ voltage $U_{load} = 0$ and $I_{load} =$ Iing. As R_{load} increases to certain values, the p-n junction current will remain practically constant (Fig. 1.b, curve 1), and the forward voltage at the collector junction will increase. At a sufficiently large value of R_{load} ($R_{load}=\infty$), the injection current of the collector junction will be equal to zero (Fig. 1.b). At this value $U_{load} = U_{iv.emf}$ and it approximately corresponds to the value of U_{st}. In this case, the voltage between the emitter and collector is zero. And the transistor can be considered as a closed electronic switch with a dynamic resistance of the order of zero.

Figure 1. *Injection-voltaic effect in transistor structures (a) and its current-voltage characteristic (CVC) (b)*



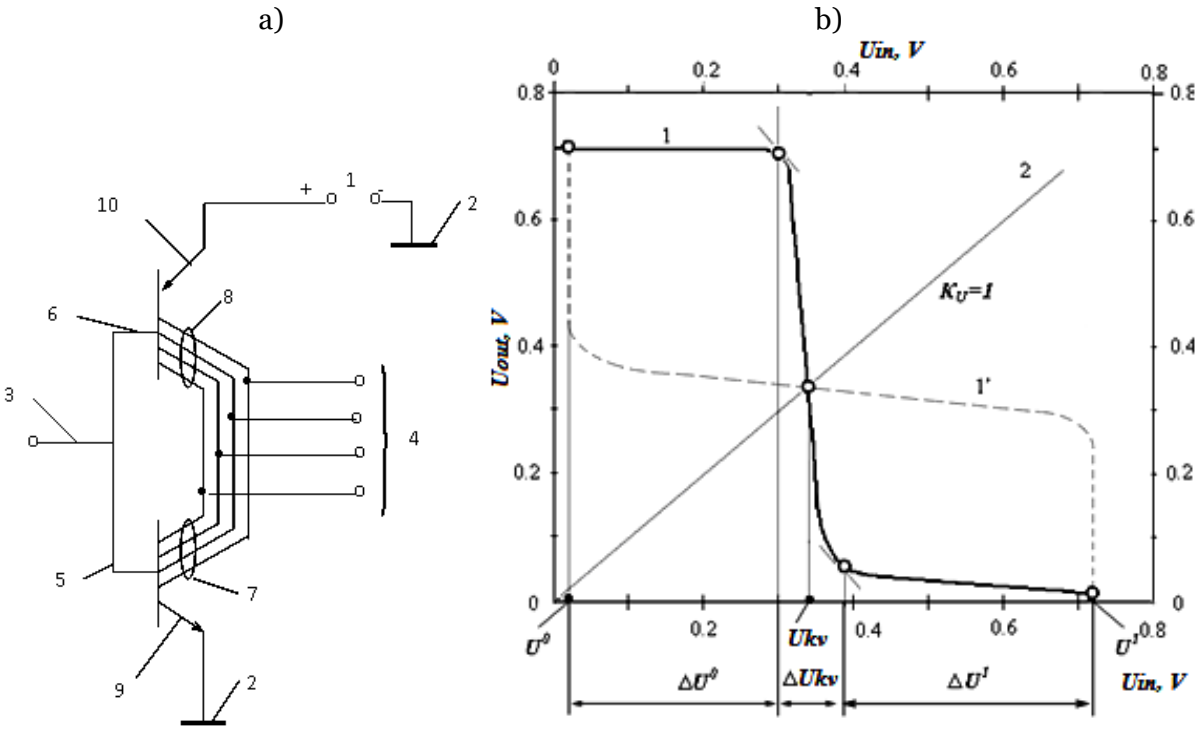
These properties can be used in the synthesis of inverters based on bipolar transistors operating at a supply voltage value of the order of the contact potential difference (Aripov, K.K., Alimova, N.B., Bustanov, Kh. Kh., Ob'edkov, E.V. and Toshmatov, Sh.T., 2009; Alimova, N.B., 2009; Aripov, Kh.K., Alimova, N.B., 2013; Alimova, N.B., 2019). An inverter based on complementary bipolar transistors (CBT) can be used in discrete and integrated circuit technology, information and telecommunication systems.

Inverters based on bipolar transistors are known. The main disadvantages of inverters are low speed, bulkiness, high power consumption during switching and high supply voltage. In addition, the inverter contains a high-resistance resistor, which is difficult to implement technologically in an IC. The complexity of implementing high-resistance resistors forces a separate resistor to be placed next to the IC, disrupts the temperature conditions of the IC, and reduces the degree of integration of the IC.

You can reduce the power consumption during switching and reduce the supply voltage.The proposed connection of two different types of multicollector transistors makes it possible to reduce the current consumption and the supply voltage due to the simultaneous use of cutoff and saturation modes in bipolar transistors.

If a signal corresponding to logical "1" is supplied to the input of the inverter CBT, equal in value to the voltage of the power supple (+V), then the emitter-base voltage of the n-p-n multi-collector transistor is equal to the value of V, and the emitter-base voltage of the p-n-p transistor is zero. In this case, the n-p-n transistor operates in saturation mode, and the p-n-p transistor operates in cut-off mode. In cut-off mode, the resistance between the collector-emitter electrodes is very high (practically determined by the leakage current of the collector junction), and the collector-emitter voltage of the n-p-n transistor is close to zero.

Figure 2. *Electrical circuit of the CBT inverter (a), transfer amplitude characteristic of the CBT inverter (b)*



In (Fig. 2, a) the electrical circuit of the CBT inverter is shown. Multicollector n-p-n and p-n-p transistors are designated VT1 and VT2, respectively. The numbers indicate: 1-power supply V; 2-common bus; 3-inverter input; 4-inverter output; 5,6-base, 7,8-collector, 9,10-emitter electrodes of transistors.

In (Fig. 2, b) shows the transfer characteristic of the inverter on the CBT. The CBT inverter has a transfer characteristic

symmetrical with respect to *V*, quantization voltage $U_{kv} = V/2$, practically the same noise immunity for logical states, and a sharp transition front from one stable state to another stable state.

The CBT inverter is a basic cell for synthesizing AND-NOT, NOR-NOT logic elements with an arbitrary set of inputs and outputs, and other digital devices. In addition, the inverter can be widely used in telemetry systems, automation, industrial and automotive electronics.

Conclusion

The injection-voltaic effect in multilayer semiconductor structures was discovered and studied.

A new basic cell of digital ICs has been proposed in terms of circuit design – an inverter based on complementary bipolar transistors (CBTs), operating at supply voltages (*V*) limited by the natural limit of the *V* on the order of the contact potential difference in the p-n junction. Thus, *V* ~ 1.2 *V* for BT made from GaAs, *V* ~ 0.8 *V* for BT made from Si, and V ~ 0.4 V for BT made from Ge. The proposed inverter based on the KBT using the injection-voltaic effect has been studied from the theoretical and experimental sides. The inverter was made on the basis of bipolar transistors of the KT315 and KT361 types. It has been established that the inverter has a symmetrical transfer characteristic with the parameters: $U_{=}^{1}$ = 0.710 V, $U_{=}^{0}$ = 0.02 V, U_{kv}= 0.34 V, $\triangle U_{=}^{1}$ = 0.32 B, $\triangle U_{=}^{0}$ = 0.28 V for V = 0.71 V.

The CBT inverter based on bipolar transistors can be used in digital ICs and large ICs, as well as in digital technology as the basic elements of “NOT”, “OR-NOT”, “AND-NOT” circuits, etc.

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