Application of Programmable Unijunction Transistor for Converting the Analog Signal of Semiconductor Sensor in a Frequency-Modulated Pulse Sequence

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***Abstract* — The article describes a circuit in which is used a programmable unijunction transistor for converting an analog signal of the semiconductor sensor in a frequency modulated sequence of pulses.**

***Index Terms* —Unijunction transistor, programmable unijunction transistor, voltage-to-frequency converter, photo receptor, a frequency-modulated signal.**

I. INTRODUCTION

Currently, as an interface between different kinds of sensors and digital information processing systems are used a digital- analog converters. This article suggests another principle: converting an analog signal directly to the frequency-modulated digital signal that can be processed by simple devices such as a frequency counter. The advantages of such solutions are simplicity of circuits, it can be implemented directly in the sensor case; no expensive precision components, as well as an opportunity to correct the non-linearity of the sensor directly at the entrance. Originality of proposed scheme is that it employs programmable unijunction transistor.

II. OVERVIEW UNIJUNCTION TRANSISTOR

Unijunction transistor represents a semiconductor crystal, in which is created a *p-n* junction, called injector (Fig. 1) [1] .

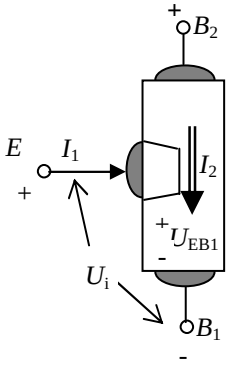

Fig 1. The scheme of unijunction transistor

This semiconductor crystal is divided by *p-n* junction into two base regions. On the injection of carriers, resistivity of volume of the semiconductor base changes. Due to this, on the characteristics of unijunction transistor appears a domain with negative resistance, that is, under certain conditions, the voltage across the transistor can be reduced even with an increase in the output current through the load of transistor (Figure 2). Only the turn off transistor or opening the circuit can remove the input voltage [2].

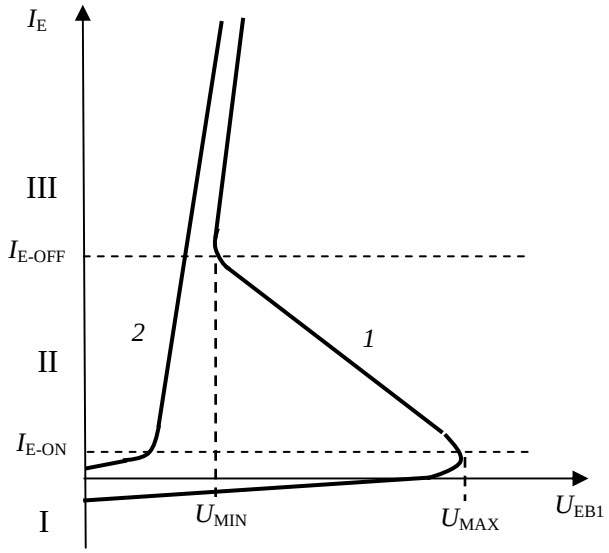

Fig.2. Graph of unijunction transistor characteristic curve, emitter current as a function of emitter-base1 voltage, showing current controlled negative resistance (downward-sloping region)

The area between the bases B_1 and B_2 represents a silicon *n*-type plate and has a linear current-voltage characteristic, i.e. current through this domain is directly proportional to the voltage applied between the bases B_1 and B_2.

In case when is no apply voltage on the emitter (with respect to B_1), the current I_2, passing in the base B_1, inside the crystal creates a voltage drop U_{EB1}, blocking *p-n* junction. When the input voltage is small $Ui \leq U_{EB1}$, the amount of current passing through the junction, rests almost unchanged. When $Vin > U_{EB1}$ the transition became directly polarized and the injection of charge carriers

(holes) in the base starts, leading to a decrease in their resistance. On this decreases the voltage drop U_{EB1}, which leads to avalanche unlocking of transition (part II of characteristic) on the current-voltage characteristic:

Plot III, where the emitter current is limited only by the saturation resistance is called the saturation region. When reducing the emitter voltage to *V*in $<U_{EB1}$ the transition closes. With current of base 2 is zero (i.e., output B_2 is not used) the characteristic (curve 2) represents a characteristic of a ordinary silicon diode.

A version of unijunction transistor is a programmable unijunction transistor – this is four-layer device, whose structure is similar to the structure of the thyristor except that the anode control is used in contrast to cathode control of the thyristor. Unijunction transistor and a programmable unijunction transistor have the same characteristics; however, turn-on voltage of the programmable unijunction transistor can be set using an external voltage divider. Programmable unijunction transistor is more high-speed and sensitive than the unijunction transistor. The equivalent circuit of a programmable unijunction transistor is shown in figure 3.

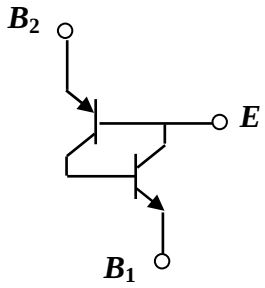

Fig.3. The equivalent circuit of a programmable unijunction transistor

On the basis of this scheme, it can be concluded that the programmable unijunction transistor represents an switched-off tiristor anode operated. When the voltage applied to the gate electrode (emitter) is more negative relative to the anode (base 2), programmable unijunction transistor switches from the cut-off in the connected state. For ensuring functioning of the programmable unijunction transistor in regime of the unijunction transistor is required to maintain an external reference voltage on the operating electrode of the programmable unijunction transistor. The reference voltage is substantially equal to the maximum point. As the reference voltage is determined by the parameters of the external divider, it can be made arbitrarily.

III. PHOTO RECEIVER WITH A VOLTAGE CONVERTER-FREQUENCY BASED ON PROGRAMMABLE ANALOG UNIJUNCTION TRANSISTOR

As a photo receiving device is called the collection of the photosensitive element, which converts the optical radiation into an electrical signal and schemes of preliminary processing of photo signal [3, 4]

The analyze of semiconductor photodetector presented in this paper allowed to create an original photo receptor, advantageously differs from analogues by simplicity, reliability, accuracy, small size, that is powered from a single source. The output signal represents a pulse sequence which may be processed directly by a digital system. The voltage of source of photo receptor device may be selected in the range from 5 to 15 V, which is sufficient for mating with any digital device.

The scheme of a photo reception apparatus is shown in Fig. 4. Semiconductor photosensor based *p-n* junction *VD*1, have as load the resistor *R1*, which is chosen in accordance with the characteristics shown in Fig. 5, so as to achieve a desired accuracy. At the same time *R1* ensures the functioning of transistors *VT1* and *VT2* in a mode of a small signal regime.

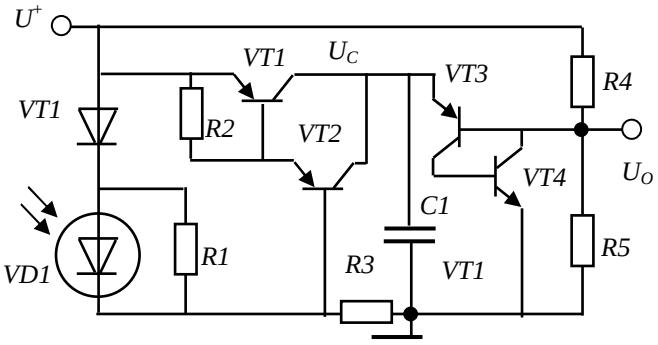

Fig.4. The scheme of converter tension-frequency based on analog of the programmable unijunction transistor, controlled by a light sensor with *p-n* junction

The electrical signal generated by the photocell controls the current generator, assembled on the transistors *VT1*, *VT2*. For the analysis of this part of the scheme, we use the output characteristics of the transistor, operating in a small signal (see Fig. 5). The transistors *VT1* and *VT2* can be considered as one composed transistor with high gain current (so-called Darlington circuit).

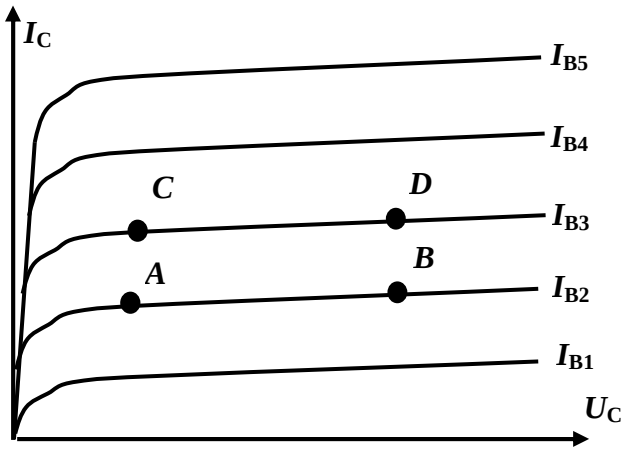

Fig.5. The characteristics of the current generator, managed by photosensor

The resistor R2 principle does not matter and is used to improve the parameters of the device. As follows from the characteristics in the mode of low base current, the collector current is practically independent from the

voltage between the collector and emitter U_{CE} and proportional to the current of base. Typically, for low-power transistors in integrated design, the allowable range of the U_{CE} is approximately 1 – 35 *V* [5]. Stabilization of the base current is carried by diode *VD1*, and the diode is chosen so that, in the absence of a signal from the photosensor, the transistor is almost locked, i.e. $I_C = 0$. When appearing the sensor signal, the transistor *VT1* moves, for example, on the branch corresponding I_{B1}.

Cycle of charge and discharge of the capacitor at a constant level signal from the sensor corresponding to motion in characteristic between points A and B. Increasing the photosensor signal leads to an increase of the base current and a shift to another branch (e. g. corresponding I_{B2}) and commit cycle has between points C and D, etc. With resistor *R1* sensor mode is chosen so that the transistors do not leave the small signal regime, i. e. from where I_C is independent of the U_{CE}. From this it follows that with increasing illumination, the current charging the capacitor *C1*, will increase linearly. With a big gain of transistors *VT1* and *VT2*, charging current capacitor *C1* practically depends only on light photosensor and does not depend on the voltage on *C1* (Figure 4).

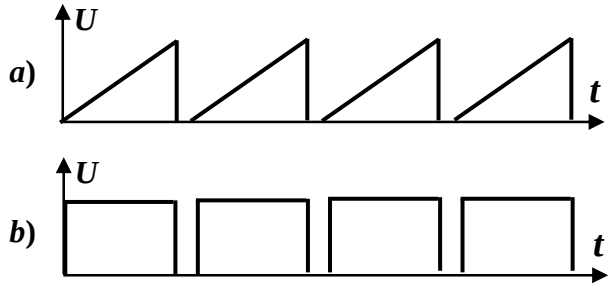

Fig.6. Temporary diagrams of photo receiver

On transistors *VT3*, *VT4* is assembled analog of programmable unijunction transistor [6], which opens when the voltage on the capacitor *C1* achieve certain value U_M. Thus, the capacitor *C1* is discharged and on the output circuit is formed a short pulse.

Voltage U_M is regulated by the selection of *R4* and *R5*. After discharge *C1*, *VT3* and *VT4* are automatically closed and the cycle repeats. Thus, the photo receiving device forms a sequence of short pulses having a frequency proportional to the light intensity (Fig.6).

Thanks to stabilizing the initial base current by diode *VD1*, representing virtually the same *p-n* junction as emitter-base junction transistors, is achieved a good temperature stabilization of the device.

In comparison with a prototype [7], the device comprises a significantly smaller number of components and may be executed in an integral form.

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