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# TEMPERATURE CONVERTER BASED ON IGBT-BJT STRUCTURE WITH NEGATIVE RESISTANCE

*Abstract. The paper analyses modern development status of temperature converter on the basis of piroelectrics, represents and describes a new temperature converter on the basis of transistor structure with negative resistance, simulates current-voltage and frequency characteristic of this device in the software environment Pspice.*

***Keywords:*** *insulated gate bipolar transistor (IGBT), bipolar junction transistor (BJT), piroelectric, temperature converter, active oscillator, structure with negative resistance, emanation power transducer sensor, Piroelectric detector.*

## Introduction

Piroelectric substances find wide application as touch sensitive devices of different function, detectors and receivers of emanations, thermal sensor instruments. Their key property – any kind of radiation which hits the piroelectric sample, causes modification of its temperature and corresponding alteration of polarisation [1]. The main input influence on piroelectric transducers is a thermal one, with several operations – thermal and mechanical, thermal and electrical and so on. Listed operations irrespective of their physical nature on character of creation of an electrical signal are divided into generating and parametric, in this connection a dual circuit of a piroelectric sensor control is possible to present in the form of parallel (during current measuring) or consecutive (during power measuring) capacitor and oscillator joint (current source or voltage) [2], as is shown in fig. 1.

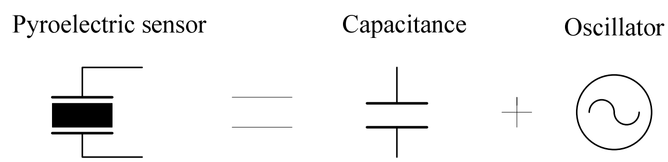


Fig. 1. The equivalent circuit of a piroelectric sensor

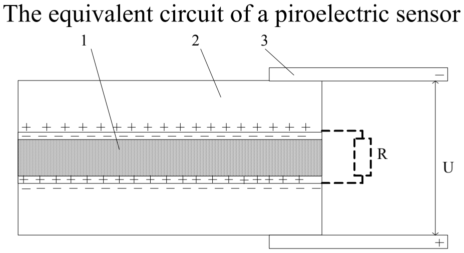


Fig. 2. Switching piroelectric converter in an external circuit

Piroelectric transducer (fig. 2) uses the polar dielectric in the form of a slice 1 coated with metal electrodes 2 to which exterior outputs 3 are connected. As a result of a dielectric flux density in electrodes and exterior outputs, the potential of exterior outputs coincides on the sign with a gain of the bound charge on the appropriate side of piroelectric. Piroelectric is characterised by the volume conductance considered by a load of effusing R [3].

## Theoretical and experimental researches

Let's consider the principle of temperature transformation into the electrical signal. The structure chart of transformation in the sensitive element of the majority of piroelectric devices (fig. 3) consists of three stages [4]:

1. W - $\Delta$T: thermal effect W causes temperature modification $\Delta$T of piroelectric .

2. $\Delta T$ - $\Delta Q$: the change of temperature $\Delta T$ predetermines the appearance of charges $\Delta Q$ on electrodes of Piroelectric .

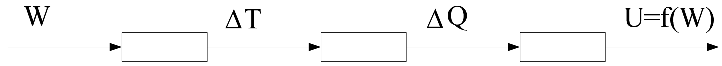


Fig. 3. The structure diagramme of Piroelectric transducers

3. $\Delta Q$ – $\Delta U$: charge $\Delta Q$ on electrodes of Piroelectric creates the difference of potentials $\Delta U$ the value of which depends on own capacity of piroelectric and impedans of loading.

Piroelectric sensors which represent crystals of Piroelectrics with the joint outputs, need the schema of an amplifier of original signal U. To amplify the piroelectric signal for further processing, there are two types of schemas of amplifying: load voltage of Piroelectric (fig. 4a) and amplifying the initial signal of piroelectric on a charge (fig. 4б) [4, 5].

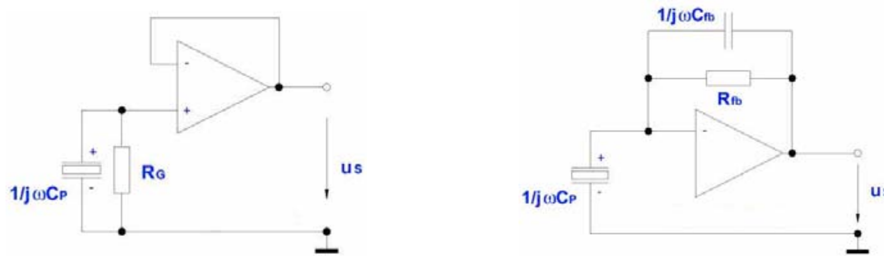


Fig. 4. Schemas of a preamplification of original signal of Piroelectric detectors:
on voltage; on charge

In the simple case the amplifier is generated as the continuer of a source of the field-effect transisor. Undergate resistor and the field-effect transistor are integrated into a sensor control housing. The resistor in a circle of a source of the field-effect transistor is placed outside the housing of a sensor control of radiated power (see fig. 5). The signal high level in relation to noise, as well as ease of schemas is the reason for a wide use of sensor controls [6].

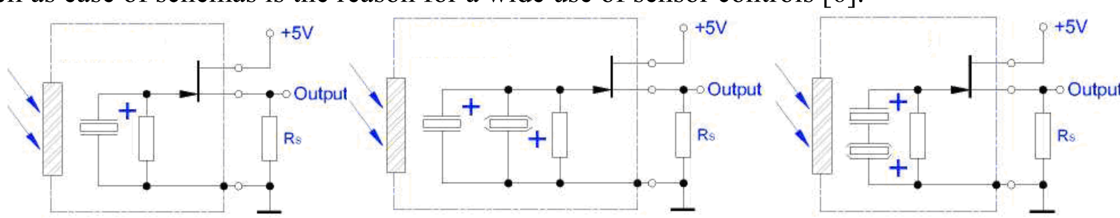


Fig. 5. Basic schemas for a voltage amplification [7]: with the single piroelectric detector; with a parallel combination of piroelectric detectors; with a consecutive combination of piroelectric detectors

Fig. 6 presents the final schema for measuring heat power which contains piroelectric sensor controls of radiated power with amplifying of the initial voltage, and also the schema of processing the initial signal of the sensor controls data [5].

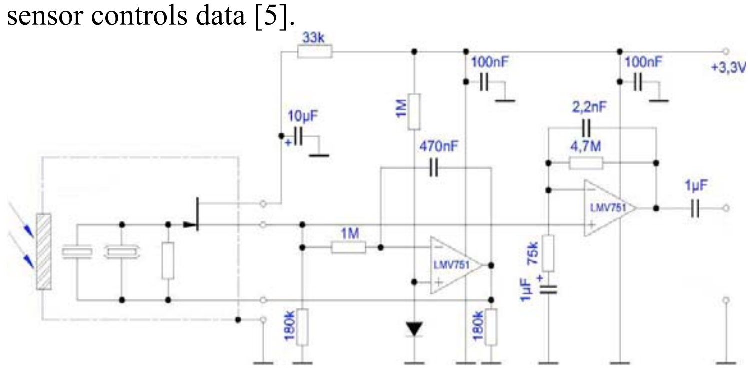


Fig. 6. The schema of Piroelectric sensor controls with schemas of processing of initial signal

As is seen in fig. 6 the devices are complicated by structure, contain many electronic components which influences a measurement accuracy and the cost of metering devices.

The amplification on a charge in schemas with piroelectric units is less popular than a voltage amplification. This is due to the greater complexity, than in schemas on amplification of the initial voltage, schemas of processing the initial signal. Fig. 7 presents four main schemas with the previous amplification on a charge of an original signal of a piroelectric sensor control [6].

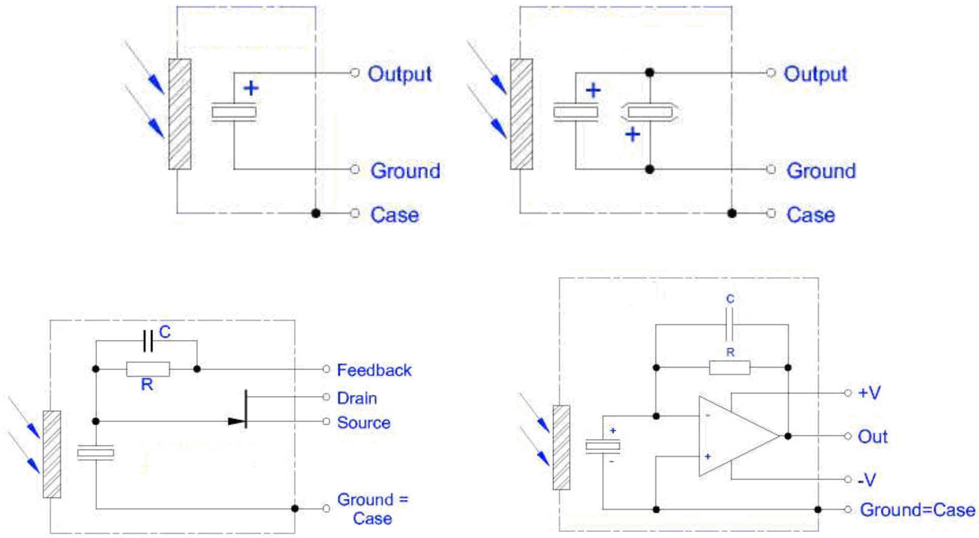


Fig. 7. Piroelectric detectors with an original signal preamplification on a current

Fig. 7a, presents the most simple piroelectric detectors but with the most low level of the initial signal in relation to noises of piroelectric. Fig. 7 б, в present schemas of piroelectric detectors with the negative feedback on a charge. The schema on the basis of an operational amplifier with the feedback circuit (fig. 7в) allows to control its amplification factor. As shown in [4], usage of an operational amplifier results in the considerable reinforcement of sensitivity of a piroelectric sensor control which is restricted by the requirements for a heat insulation and designing parameters of piroelectric detector.

After the amplification the piroelectric signal requires further processing, turning into the form convenient for the analysis. Fig. 8 presents the schemas of further processing of an original signal with preamplification on a current , made by Infratec company [5].

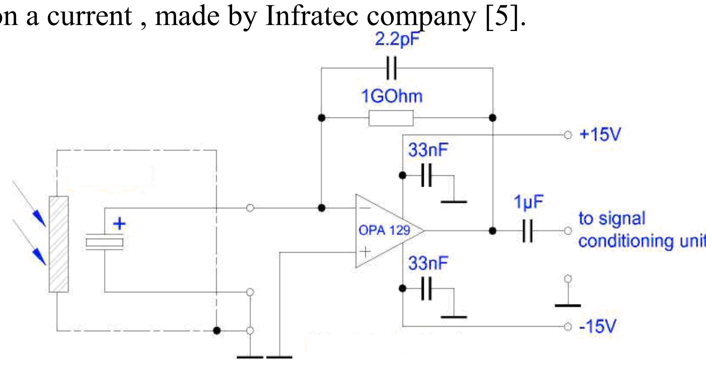


Fig. 8. The schema of amplifying on a charge of piroelectric detectors

On the basis of observing methods of temperature measuring on the basis of piroelectrics, presented in this paper it is possible to make the general conclusion on complexity of measuring. The deep analysis allows to sum up the following:

1) a low measurement accuracy which falls after each link of processing of an original signal (which already is with an error, predetermined by the peculiarity of structure of Piroelectric

materials and additional spurious physical effects, except for Piroelectric effect) since each schema, whether the amplification or processing, has the own error;

2) the low profitability of the device predetermined by presence of schemas of amplification, ADC;

3) low hindrancefirmness;

4) impossibility to deliver information on distance.

In [8] there had been found the solution of the problems and suggested the usage of temperature converter on the basis of transistor structures with a negative resistance. These devices in their structure combine active integral constructions with usage of thin piroelectric films and self-oscillators on the basis of transistor structures with a negative resistance. In this paper we will analyze one of such temperature converters, and simulate its characteristics.

As sensing device from [9] we use the bipolar device with field control (БТПУ or IGBT – insulate gate bipolar transistor) with plotted on baseline a film of Piroelectric Pbtio3 (PTO) and nielloed by gold which is given on fig. 9.

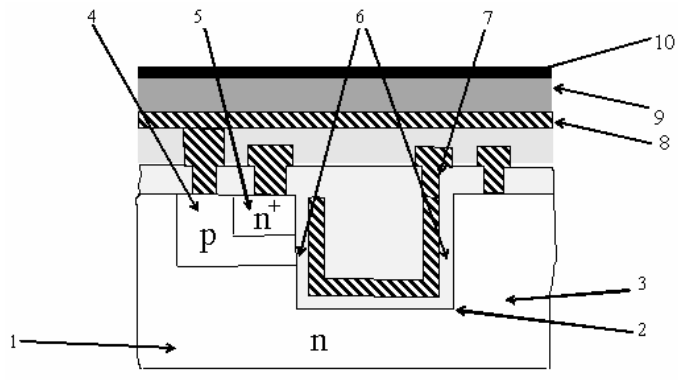


Fig. 9. IGBT structure with a piroelectric thin film

This unit is an emanation power-level detector (EPLD) used as temperature sensor control in system of automated control and monitoring of parameters of the furnace of ИЧ -drying of hardware products of electronics [10]. In the basis of EPLD there is the bipolar transistor with field control (IGBT). Let us conceder the structure and a principle of operation EPLD in details. This IGBT structure contains a sensitive element (SE) – absorber of emanations, which role plays the film of nielloed gold, a control element (CE) – the piroelectric convertert, which role plays the film plotted on baseline Piroelectric $PbTiO_3$ (PTO), and the executive unit (EU), – IGBT. Work EPLD is accompanied by a modification of the initial parameter CE as a result of a modification of potential on the basis of IGBT, electrical connected with piroelectric . Piroelectric heating up takes place due to the transformation of signal capacity in heat with the help of SE [35]. As is seen from fig. 9 [9] the measuring primary transducer contains an undercoat 1, from n-doped silica with orientation (100) on which the isoplanar transistor structure with side $SiO_2$-insulation is fulfilled, in which by means of an anisotropic etch the notch 2 which bottom is located in collector region 3, and fields of baseline 4 and the emitter 5 are restricted by one of notch walls, on notch walls bed $SiO_2$ - 6 and an additional field electrode – a gate 7 is generated. Collector contact 8 is bed with piroelectric layers 9 and metalcarbon composit 10 which realise signal capacity transformation.

We suggest to include this IGBT into the schema with the bipolar device for creating structure with a negative resistance for the purpose to create self-oscillator. The schema of such metering device it is given on fig. 10.

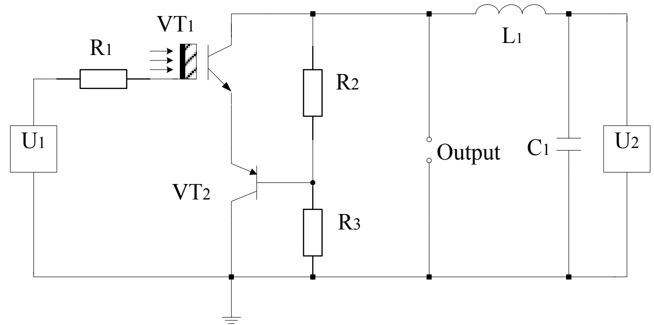


Fig. 10. The converter of temperature on the basis of the IGBT-BJT structure with a negative resistance

As is seen from fig. 10 th e device contains first voltage source $U_1$ that is connected by one pole to the gate IGBT $VT_1$ with raised dust on baseline a film of piroelectric and an absorber of emanations, and the other pole to the collecting channel BJT $VT_2$ which is connected to ground connection, emitter IGBT $VT_1$ is connected to emitter BJT $VT_2$, and collecting channel IGBT $VT_1$ is connected to passive inductance $L_1$, baseline BJT $VT_2$ is connected between the sequentially connected resistors $R_2$ and $R_3$ which are in bridge connected by other poles to IGBT-BJT structure, and also in bridge to transistors $VT_1$ and $VT_2$ passive inductance $L_1$ and capacitor $S_1$ and the second voltage source $U_2$ is connected.

The device works as follows. In the initial time the thermal radiation does not influence the absorber of emanations (SE, a film of nielloed gold). Voltage increase in voltage sources $U_1$ and $U_2$ to the value when on electrodes collecting channel – collecting channel IGBT $VT_1$ and BJT $VT_2$ appears negative resistance which causes the electrical oscillations in the circuit, created by series connection of an resistance with the capacitive character on electrodes a collecting channel – collecting channel IGBT $VT_1$ and bipolar device VT2 and an inductive resistance of passive inductance $L_1$. Capacitor $S_1$ prevents passing alternating current through second voltage source $U_2$. During the following action of thermal radiation it is captured by the absorber of emanations IGBT and pitched to the film evaporated on baseline IGBT of piroelectric $PbTiO_3$ (PTO). The thermal effect of radiated power W causes a temperature change $\Delta\grave{O}$ of piroelectric $(W \to \Delta T)$, the temperature change $\Delta\grave{O}$ predetermines the appearance of charges $\Delta Q$ on electrodes of piroelectric $(\Delta T \to \Delta Q)$, charge $\Delta Q$ on electrodes of piroelectric creates the charge $\Delta Q$ difference of potentials U $(\Delta Q \to U)$ which is added to voltage which exists on electrodes baseline-emitter IGBT $VT_1$ and changes the value of capacitance of oscillatory circuit created by series connection of full resistance with capacitive character on electrodes collecting channel – collecting channel IGBT $VT_1$ and BJT $VT_2$ with an inductive impedance of passive inductance L1, and this causes a change in resonance frequency of a oscillatory circuit which is reflected on the output frequency signal of the device.

Let's simulate self-oscillator of the temperature converter on the basis of IGBT-BJT structure with a negative resistance. For simulation of this device we use software package Orcad Family Release 9.2. As IGBT we will take the transistor of the mark APT25GF100BN, and the bipolar device – BC857A. Fig. 11 presents the window of software environment Orcad Family Release 9.2 with the schema of the researched device.

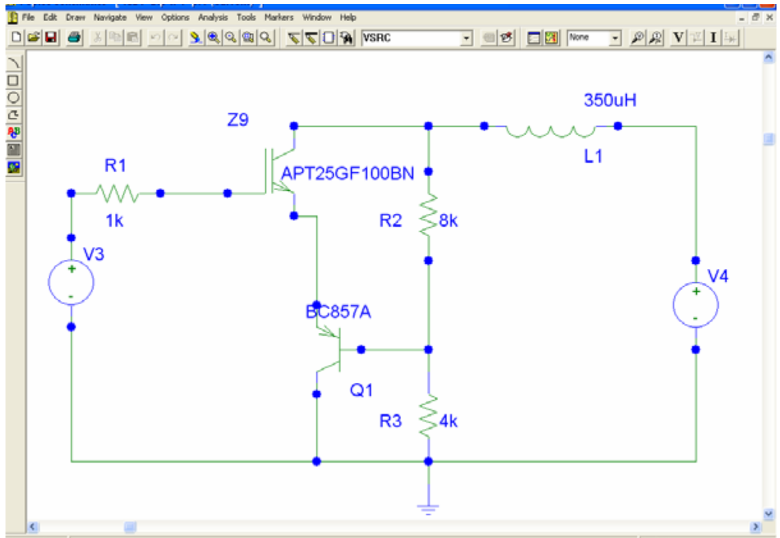


Fig. 11. The schema of the self-oscillator base on the IGBT-BJT structure

Fig. 12 presents the set of volt-ampere characteristics of the researched self-oscillator device, received in the result of simulation in Orcad Family Release 9.2.

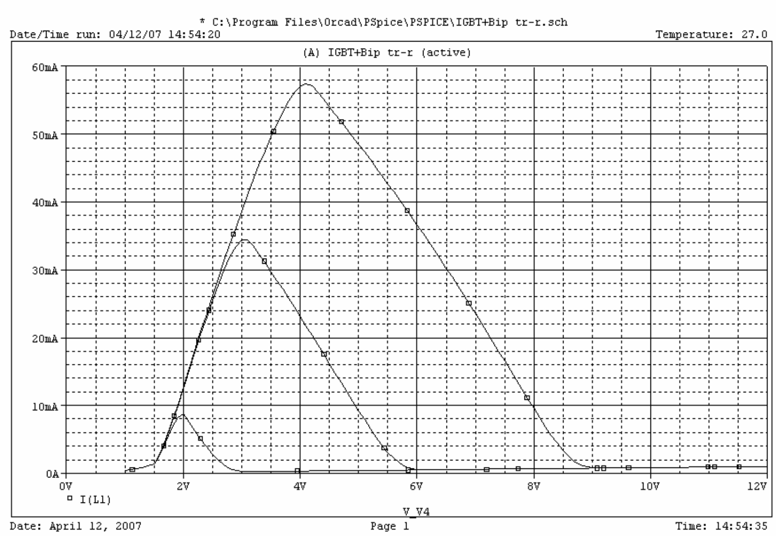


Fig. 12. Voltage-current characteristics of the self-oscillator with different values of controlling voltage

Fig. 13 presents frequency characteristic of the self-oscillator of the researched temperature converter, received in software environment Pspice.

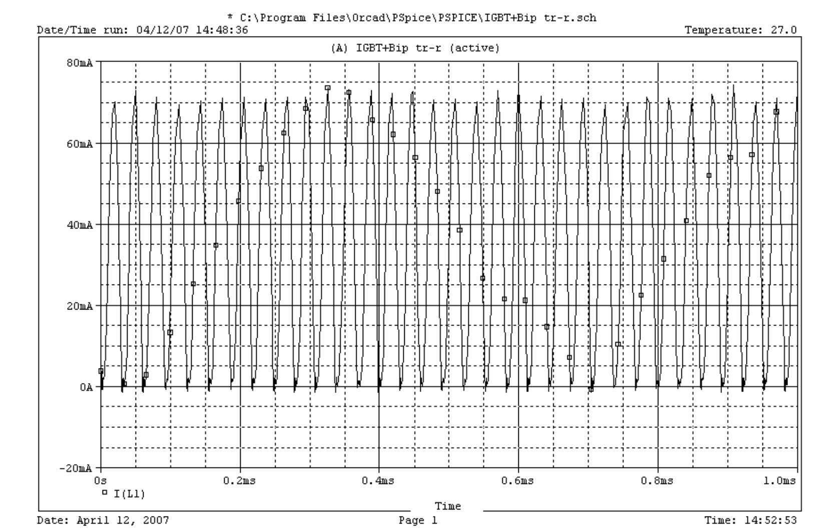


Fig. 13. The frequency characteristic of the self-oscillator received in Pspice

Let's carry out the short analysis of the received outcomes. Thanks to software environment Pspice which is the constituent of software package Orcad Family Release 9.2 there had been simulated the work of the self-oscillator of the temperature converter on the basis of IGBT-BJT structure with negative resistance, in the result of which there had been received the set of volt-ampere characteristics and frequency characteristic of the researched device. The graph of voltage-current characteristics with different values of controlling voltage is given in fig. 12. The analysis of graphs we will make on the main sections of a volt-ampere characteristic. As is seen on fig. 12, on the increasing section the voltage-current characteristics are almost equal, in some sections they merge. It testifies to unessential temperature effect on the converter in this range of voltage (1-3). We will pay attention to peaks or critical sections of voltage-current characteristics. The greatest deviation of graphs is observed in this section. With an increase of temperature the peak sharply rises. It means that the temperature strongly influences the value of a current with which the "fracture" takes place and the descending section which answers the creation of negative resistance in transistor structure will start. It is the most heat-sensitive section. The descending section of voltage-current characteristics represents the greatest interest for development engineers as it determines the range of creation of wave generation in transistor structure with a negative resistance. As is seen from fig. 12 this section is greatly dependent on temperature. If we consider the working point path, it becomes obvious, that with an increase of temperature the working point linearly rises up. The linear relation of working point from temperature influence allows to use this converter for temperature measuring.

## Conclusion

Having analyzed physical basis of piroelectric sensors operation, the existing methods of temperature measuring on the basis of piroelectrics, the authors suggest the new device for measuring temperature on the basis of IGBT-BJT structures with negative resistance. There had also been simulated the operation of this device in software environment Pspice, in the result of which th3ere had been received the voltage-current characteristics and frequency characteristic.

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