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PHOTODETECTORS WITH FREQUENCY OUTPUT ON THE BASIS OF UNIJUNCTION AND FIELD-EFFECT PHOTOTRANSISTORS

The construction of photodetector representing the pulsing oscillator designed which frequency depends on quantity of light stream, as the sensing device of generator — the silicon chip — consisting of unijunction and field-effect phototransistors is used.

The sensor with frequency output represents the generator of variable voltage, which frequency is the function of measured action (temperature, pressure, light etc.). The signal from such detector may immediately be handled by computer and also by any chip-pulse counting device. Such sensors on the basis of unijunction and field-effect phototransistors are discussed in this paper.

The unijunction transistor (UJT) consists of semiconductor rod with two ohmic base contacts (B_1, B_2) on testing faces and emitter p—n-junction (e) between them (fig. 1). Its input current-voltage characteristics falls into S-type, that allows to create the generator by prime hook up of capacity to input circuit (e—B_1). The condenser C is charged up to potential of basis opposite to the emitter V_1 after insert of the power supply E. The emitter p—n-junction is switched on in a forward direction and the condenser is fast discharged through the bottom of basis. Then the process is iterated. The oscillations of voltage on emitter have a saw tooth view, and their amplitude is equal to the difference between the switch on voltage and residual voltage at current-voltage characteristics:

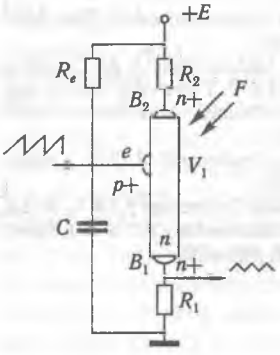

Fig. 1. The unijunction transistor

$$V_a = V_b - V_0. \quad (1)$$

The period of oscillations is defined [1] as

$$T = R_e C \ln \frac{E - V_0}{E - V_b}. \quad (2)$$

The current pulses on the resistance of basis R_1 is possible to use as output signal also.

The UJT can work as the photodetector at irradiating basis. The irradiation increases the concentration of charge carriers in basis, that gives the decrease V_b and T, so also the growth of oscillation frequency $f = 1/T$ with increase of light stream F. However, the essential deficiency of such photodetector is nonlinear dependence $f(F)$, that follows from [2]. The photo-FET which is included into the scheme as the two-pole (the gate makes with transistor source) instead of resistor R_e to derive linear relation $f(F)$ is offered to use by us [2]. At such insert FET works as current generator, that is charging current for the condenser I_c and does not depend on voltage, that simplifies the formula (2) to a view [3]

$$T = \frac{I_c}{C} V_b - V_0. \quad (3)$$

The charging current develops of FET-photocurrent and photocurrent of UJT emitter p—n-junction. They are linearly depend on F, that gives the linearity of dependence $f(F)$.

Both of these transistors may be manufactured in one chip of semiconductor as microcircuit. The example of such structure is shown by fig. 2. In the initial base n-semiconductor, there are two n^+-fields being base contacts UJT (B_1, B_2), and between them the p-region of the emitter is firmware, on which surface the n-channel of MOS-type FET places. One extremity of the channel (drain) is connected through the basis to contact B_2, and the second (source) — with the emitter. The dielectric on channel surface is deposited. Behind it semitransparent layer of metal being gate of the FET and jointed with source is superimposed. The light stream falls on FET channel (through transparent metal and dielectric) and on the upper part of the basis UJT. Experimental samples of chips with FET and UJT, manufactured on the basis of epitaxial n-silicon by planar diffusion technology, have shown, that their photosensitivity is higher by not less than order of magnitude than responsibility of the separate UJT.

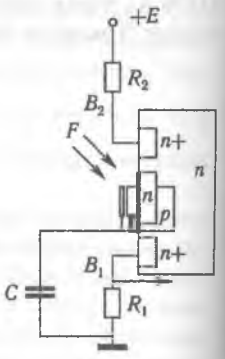

Fig. 2. UJT and FET as a chip

The further magnification of photosensitivity can be received by usage in microcircuit of the FET with

longitudinal p—n—...—p—n-structure as a gate (fig. 3). There is photo-voltage V_F under irradiation

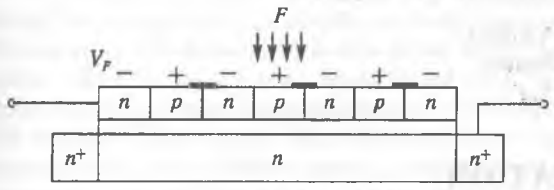

Fig. 3. Microcircuit of the FET with longitudinal p—n—...—p—n-structure as a gate

of such structure in each of the p—n-junctions. However, in the series located p—n-junctions V_F have opposite sings and cancel each other. If to make all even p—n-junctions by opaque metal film, only V_F will stay on odd p—n-junctions, which in a current circuit developed each other. Therefore, potential of the last area for a drain is equal $V_g = kV_F$, where k — the quantity of odd p—n-junctions. This summary photo-voltage is drived a current through FET channel as well as usual voltage on a gate. In this case FET channel works in a mode of the charge carriers enhancement. If, on the contrary, to bring up all the odd p-n-junctions (and even to unlock), the channel will operate in a mode of a depletion. Experimental samples of the MOS-photo-transistors on the basis of silicon epitaxial films covered with silicon dioxide, on which the polycrystalline silicon film of a gate representing six-layer longitudinal p—n—...—p—n-structure was superimposed have shown a photosensitivity being by tens-hundreds fold greater, than responsibility of usual FET with semitransparent metal gate. Accordingly, using such FET in photosensing chip (fig. 2) in during long time its responsibility is incremented also. The frequency output of photodetector allows considerably to simplify its jointing with computer and to make microminiaturisation of the construction for the measuring device. So, for example, the scheme of the measurer for illumination intensity is implemented as follows. During one measurement the generator UJT feeds one current pulse by duration $t_p = 0{,}1$ *s*. Circuit elements of relaxation oscillator are selected so that in absence of light in time t_p UJT generated 100 impulses. The frequency of the generator grows at irradiating. The responsibility of photodetector can be installed so, that magnification of illumination intensity at 1 unity there will corresponds to growth of frequency 1 *Hz*. Then 200 impulses corresponds 100 units, to 300 impulses — 200 units etc. The impulses from generator move on pulse counting devices, including digital indicators, where the value of illumination intensity is highlighted. The scheme together with the power supply is agglomerated in a housing by the size about usual pen with a photodetector on the face.

Photosensitive chip (UJT and FET) and chip — pulse counting device are made on sample technology silicon microscheme and can be integrated in one chip.

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