THE TIME RESOLUTION OF THE BALANCED COMPARATORS ON THE TUNNEL JOSEPHSON JUNCTIONS FED BY THE SLOW-GROWING RATE STROBE PULSES

I.N. ASKERZADE
Institute of Physics, Academy of Science of Azerbaijan,
370143 Baku, H. Javid pr. 33
(Received 01.03.96)

The time resolution of the balanced comparators on the tunnel Josephson junctions fed by slow-growing rate strobe pulses is calculated.

The replacement of the semiconductor elements in the impulse comparators by the tunnel Josephson junctions allows to improve not only the resolution but also the sensitivity of samplers. The time resolution $\delta t=2ps$ and sensitivity $\delta I=1\ mkA/Hz^{1/2}$ are obtained in [1]. The scheme of the balanced comparator with the tunnel Josephson junctions which gives the chance to approach to the fundamental limit value of the sensitivity is proposed in [2]. In this paper the numerical modelling of the process to the so-called R-state of the such comparators fed by the different growing rates of the strobe pulses is carried out.

In the present paper the time resolution magnitude of the comparator, proposed in [2], is analysed in the slow-growing strobe pulses case.

The equivalent scheme of balanced comparators on the tunnel Josephson junctions is shown in Fig. 1. The comparator is pair of identical Josephson J_1 and J_2 (shunted by the resistor R_s), connected with the strobe pulse generator by the L_1R_1-circuit. The strobe pulse is the form step wise of potential drop. I_1 -is the sum of the measured and feedback currents. The average value the $V_{1,2}$ -voltage is output signal of the comparator. Under the influence of the strobe pulse of the stepwise form, the comparator is switched over to the one of the possible R-states. The switching regions of such Goto pairs are presented in [2].

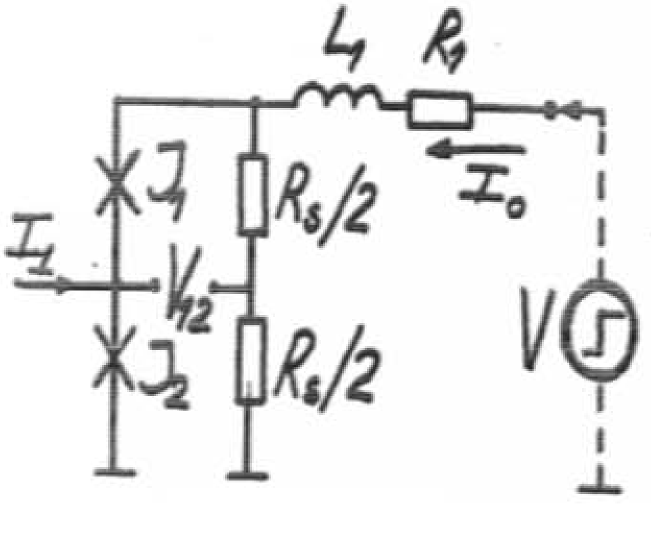

Fig.1. The equivalent scheme of the balanced comparator.

The time resolution δt of these samplers can be determined by means of the transitional characteristic $H(\tau)$, representing output signal of samplers V_{out} under the input signal to comparators of the small stepwise form of the current $I_s=I_0\delta(t)$. The time resolution δt is the time of growing of the $H(\tau)$ from the level of 0.1 H up to level of 0.9 H [3], where τ - the time of delay (outstrip) of the strobe pulses with respect of moment of the beginning of the stepwise input signal feeding the comparator. For the values of the phases of the Josephson junctions J_1 and J_2 we have the following set of equations:

$$\begin{aligned} \beta\ddot{\varphi}_1+\dot{\varphi}_1+\sin\varphi_1 &= i_0 \\ \beta\ddot{\varphi}_2+\dot{\varphi}_2+\sin\varphi_2 &= i_0+i_1 \end{aligned}, \qquad (1)$$

where the following dimensionless parameters are introduced : i - the current in units of I_c, I_c - the critical current for the Josephson junctions; τ - the time in units of $\Phi_0/2\pi I_cR_N$; Φ_0 - the quantum of the magnetic flux, R_N - the resistivity of the Josephson junctions; $\beta=2\pi I_cR_N^2C$ - the so-called McCumber parameter, C - the capacity of the junctions. For the small magnitude of the signal with respect of strobe pulses, and also for the small difference of phases $\tilde{\varphi}=\varphi_1-\varphi_2$ the following relationships holds true:

$$\begin{aligned} \beta\ddot{\tilde{\varphi}}+\dot{\tilde{\varphi}}+\cos\frac{\varphi_+}{2}\cdot\tilde{\varphi} &= i_1 \\ \beta\frac{\ddot{\varphi}_+}{2}+\frac{\dot{\varphi}_+}{2}+\sin\frac{\varphi_+}{2} &= i_0 \end{aligned} \qquad (2)$$

where $\varphi_+=\varphi_1+\varphi_2$. Let the $i_s=1(t-\tau)$ is an input signal at the moment $t=\tau$. Under this condition the solution of the equation (2) has the form:

$$\tilde{\varphi}(t)=\int_{-\infty}^{t}K(t,\xi)[1(\xi-\tau)+i_{f.b.}(\tau)]d\xi \qquad (3)$$

The structure of the kernel of the equation (3) in the case strobe pulses with linear-growing rate $i_o = \alpha\tau$ (where $\alpha = (dI/dt)\Phi_o/2\pi I_c R_N$ is dimensionless growing rate of the current via junction), on condition that $\alpha\beta << 1$, has the following form [4]:

$$K(t,\xi) = \pi A_i(G\xi) B_i(Gt) \quad (4)$$

where $A_i(...)$, $B_i(...)$ are Airy functions, and $G = 1.14^{1/3}\alpha^{1/5}\beta^{-2/5}$. The transitional characteristic $H(\tau)$ for the arbitrary values of τ in the case of the non-growing solutions of the (4) while $t \to \infty$ may be written as follows

$$H(\tau) = -i_{t.b.}(\tau) = H_0^{-1}\int_{\tau}^{\infty} A_i(G\xi)\, d\xi \quad (5)$$

where $H_o = \int_{-\infty}^{+\infty} A_i(Gt)\, dt$.

As it is shown in fig.2, the transitional characteristic $H(\tau)$ for $\tau<0$ has a oscillatory behaviour. Such a behaviour is due to the presence of the full set of the reactive elements in the equivalent circuit of the junction [5]. For the time resolution from fig.2 we obtained:

$$\delta t = 2.3\beta^{2/5}\cdot\alpha^{-1/5} \quad (6)$$

It can be seen from this formula, δt is determined mainly by the capacity of junction; δt is highly sensitive to the changing of capacity of junction,rather than to the magnitude of the growing rate of the current through junctions. Now let us estimate the time resolution of the balanced comparators in the regime of slow-growing rate of strobe pulse, for $\alpha\beta << \delta i$; here δi - the value of the fluctuation range of the critical current of the junctions. It is know [5], that at the helium temperatures for the values of the δi is highly reasonable $\delta i = 0.3mkA/i_c$, where the critical current of the tunnel junctions changes from 10 mkA to 1 mA. The estimations based upon the formula (6) show that the time resolution of the balanced comparators can reach the values of ten ps.

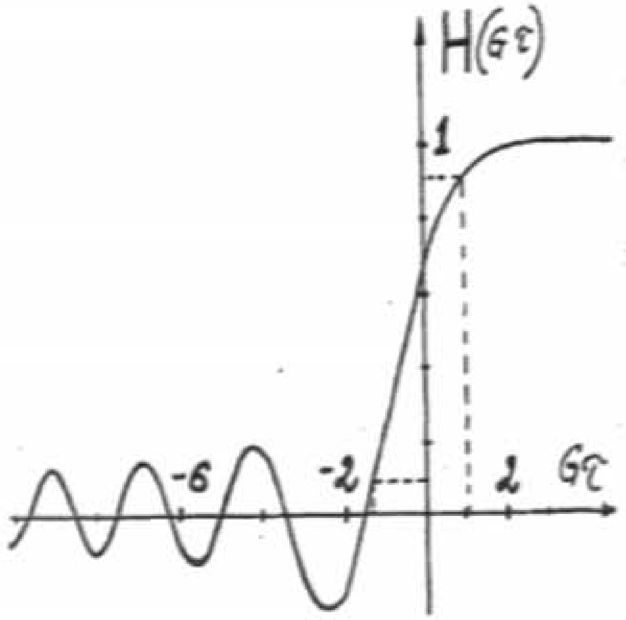

Fig.2. The transient characteristic of the balanced comparator

Thus, the quantitative analysis shows that the growing rate of the strobe pulses exerts an insignificant influence on time resolution of the Josephson junctions balanced comparators. In addition, the possibility of the obtaining of the highest values for the time resolution within the schemes under consideration is underlined.

---

[1] *P. Wolf, B.J Van Zeghbroeck., U. Deutsch.* IEEE Trans.1985. V MAG-21, n.3, p.226.

[2] *I.N. Askerzade, V.K. Kornev.* Radiotekhnika i electronika,1994. v.39, n.5, p.869.

[3] *E.Ch. Khermanis, V.G. Karklinsh.* Dvystoronnie preobrazovateli signalov. Riga. Zinatne.1980.

[4] *O.V. Snigirov.* Radiotekhnika i electronika,1984, v.29, n.11, p.2216.

[5] *K.K. Likharev.* Vvedenie v dinamiky Josephsonovskikh perekhodov. M. Nauka. 1985.

İ.N. Əsgarzadə

TUNNEL COZEFSON KEÇİDLƏRİNDƏN İBARƏT BALANS KOMPARATORUNUN KİÇİK SÜR'ƏTLƏ ARTAN STROB İMPULS REJİMİNDƏ ZAMANA GÖRƏ AYIRDETMƏ GABİLİYYƏTİ

Tunnel Cozefson keçidlərindən ibarət balans komparatorunun kiçik sür'ətlə artan strob impuls rejimində zamana görə ayırdetmə gabiliyyəti hesablanmışdır.

И.Н. Аскерзаде

ВРЕМЕННОЕ РАЗРЕШЕНИЕ БАЛАНСНЫХ КОМПАРАТОРОВ НА ТУННЕЛЬНЫХ ДЖОЗЕФСОНОВСКИХ ПЕРЕХОДАХ ПРИ СТРОБИРОВАНИИ МЕДЛЕННО-НАРАСТАЮЩИМИ ИМПУЛЬСАМИ

Вычислено временное разрешение импульсного балансного компаратора на туннельных джозефсоновсктх переходах в случае медленно-нарастающего стробирующего импульса.

Редактор: Р.Р. Гусейнов