THE TIME RESOLUTION OF THE BALANCED COMPARATORS ON THE OVERDAMPED JOSEPHSON JUNCTION

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The time resolution of the balanced comparators on the overdamped Josephson junction (JJ) fed by the single quantum pulses is calculated. It is shown that subpicosecond resolution can be achieved.

The replacement of the Esaki tunnel diodes by the JJ allows improving characteristics of samplers. The time resolution δt =2 ps and sensitivity δI =1mkA/Hz$^{1/2}$ are obtained in [1]. The scheme of the balanced comparators with overdamped JJ fed by single flux quantum pulses and used as a dc comparator is proposed in [2,3]. The current resolution of the sampler is estimated to be as low as 40 pA/Hz$^{1/2}$. The time resolution of balanced comparator is calculated numerically in [3]. After discovery high temperature superconductivity (HTSC) Josephson sampler with time resolution δt =3.5 ps on YBaCuO compounds have been suggested and experimentally tested [4]. The measurements of the I-V curve of HTSC JJ shows, that this type junctions are nonhysterestics and we can use approach of overdamped junctions.

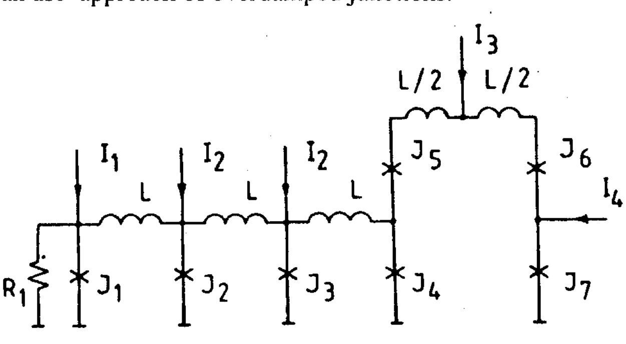

Fig. Equivalent circuit of the experimental device ref. [2].

In the present paper the time resolution magnitude of the comparator ,proposed in [2], is analysed in general case. Figure shows an equivalent circuit of the comparator. The circuit contained a generator of the single flux quanta (SFQ) using the junction J_1;frequency of the pulses can be controlled by the dc bias current $I_1 > I_{C_1}$. The quanta are fed into the discrete Josephson transmission line J_2-J_3-J_4, which plays the role of a buffer stage making the generator insensitivity to processes in further parts of the circuit. From the output of the transmission line the SFQs are passed to the balanced comparator formed by junctions J_6 and J_7,through an additional junction J_5. The typical regimes of operation of circuit are presented in [3] in detail.

The time resolution of this 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 $I_S=I_0 1(\tau)$. The time resolution δt is the time the growing of the $H(\tau)$ from the level 0.1H up to the 0.9 H [5],where τ-is 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 φ_6, φ_7 of the JJ J_6 and J_7, we have following equations:

$$\begin{cases} \dot{\varphi}_6 + \sin\varphi_6 = i_0 \\ \dot{\varphi}_7 + \sin\varphi_7 = i_0 + i_1 \end{cases}, \qquad (1)$$

where the following dimensionless parameters are introduced: i_o - the current in units of I_c , i_o is the sum of the current I_3 and strobe pulse current, I_c - the critical current of the JJ, t - time in units of $\Phi_o/2\pi I_c R_N$, Φ_o - the quantum of the magnetic flux, R_N - the resistivity of the JJ; $i_1' = i_4$ is the sum of the measurement signal i_S and feedback current $i_{f.b.}$. For the small magnitude of the signal with respect of the strobe pulses, and also for the small difference of phases $\tilde{\varphi} = \varphi_6 - \varphi_7$ the following relationships holds true:

$$\begin{cases} \dot{\tilde{\varphi}} + \cos\dfrac{\varphi_+}{2}\tilde{\varphi} = i_1' \\ \dfrac{\dot{\varphi}_+}{2} + \sin\dfrac{\varphi_+}{2} = i_0 \end{cases}, \qquad (2)$$

where $\varphi_+=\varphi_6+\varphi_7$. In order to find the time resolution we linearise equations in (2).Let the $i_S=1(t-\tau)$ is the input signal at the moment $t=\tau$.

Under this conditions solution of the equation (2) has the form:

$$\tilde{\varphi}(t) = \int_{-\infty}^{t} e^{-\int_{\xi}^{t} \varphi_{+}(x)dx} \left(i_{f.b.} + 1(t - \tau)\right) d\xi \quad (3)$$

Asymptotic solutions to second equation in (2) for the case of linearly growing current $i_o=\alpha\tau$ (where $\alpha=dI/dt\Phi_o/2\pi I_c R_N$ is the dimensionless rate of the current increase via JJ) are presented in [6]:

$$\tilde{\varphi}_{+}= \begin{cases} -(-2\alpha\tau)^{1/2} & \text{at } \tilde{\varphi}_{+} \to -\infty \quad \text{(a)} \\ c_1\alpha^{2/3}(\tilde{\tau}- c_2\alpha^{-1/3}) & \text{at } \tilde{\varphi}_{+}\cong 0 \quad \text{(b)} \\ \left(2/(c_3\alpha^{-1/3}- \tilde{\tau})\right)^{1/3} & \text{at } \tilde{\varphi}_{+}\to \infty \quad \text{(c)} \end{cases} , \quad (4)$$

where $\tilde{\tau}=\tau-\alpha^{-1}$; $\tilde{\varphi}_{+}=\varphi_{+}-\pi/2$; C_1=1.25; C_2=1.21; C_3=2.9. Using the solution in the stage of inertial motion (4b) in the (3) and after integration, we have the following formula for the transient characteristic:

$$H(\tau) = 1 - erf\left(\left(\frac{c_1}{2}\right)^{1/2} \alpha^{1/3}(\tau - \tau_0)\right) , \quad (5)$$

where $erf(x)$ - error function Finally, using table data for the function $erf(z)$ and definition of the time resolution , we obtained the following formula:

$$\delta t = 0{,}56 C_1^{-1/2}\alpha^{-1/3} \quad (6)$$

The estimation of the value δt we will carried out by the formula for the single flux quantum pulses:

$$\int V dt=2\pi\Phi_o \quad (7)$$

Consider that single flux quantum pulses has a form of triangles , we can calculated:

$$\alpha= 2/\pi \quad (8)$$

Finally, we can derived for the time resolution in usual units:

$$\delta t = \frac{0.56\Phi_o}{2\pi I_c R_N} \quad (9)$$

Thus, in this paper a quantitative analysis of the time resolution of overdamped JJ samplers has been carried out. For the realistic values of the product $I_c R_N$ for the low temperature superconductors we have time resolution about 0.1 ps.

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BÖYÜK SÖNMƏYƏ MALİK COZEFSON KEÇİDLƏRİNDƏN İBARƏT BALANS KOMPARATORUNUN ZAMANA GÖRƏ AYİRDETMƏ QABİLİYYƏTİ

Böyük sönməyə malik Cozefson keçidlərindən ibarət balans komparatorunun zamana görə ayirdetmə gabiliyyəti hesablanmışdır. Subpikosaniyə tərtibində ayirdetmənin mümkünlüyü göstərilmişdir.

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ВРЕМЕННОЕ РАЗРЕШЕНИЕ БАЛАНСНОГО КОМПАРАТОРА НА ДЖОЗЕФСОНОВСКИХ ПЕРЕХОДАХ С БОЛЬШИМ ЗАТУХАНИЕМ

Вычислена величина временного разрешения балансного компаратора из джозефсоновских переходов с большим затуханием при стробировании одноквантовыми импульсами. Показано, что можно достичь субпикосекундного разрешения.

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