

## **Spiking Neuron Devices Consisting of Single-Flux-Quantum Circuits**

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Single-flux-quantum (SFQ) circuits can be used for making spiking neuron devices, which are useful processing elements for constructing intelligent, brain-like computers. The device we propose is based on the integrate-and-fire neuron model and uses a SFQ pulse as an impulse signal or a spike of neurons. It can operate at a short processing delay of 100 ps or less and is probably the highest-speed neuron device ever reported.

Our neuron device consists of three parts, i.e., input connections, a leaky integrator, and an output connection, which roughly correspond to the dendrites, the soma, and the axon of biological neurons. The input connections collect SFQ pulses from other neuron devices and transmit the pulses to the leaky integrator. The leaky integrator performs a nonlinear, threshold processing; it produces an output SFQ pulse if the total input exceeds a certain threshold. The output pulse is taken over by the output connection and delivered to other neuron devices.

The key component of the device is the leaky integrator, consisting of Josephson memory loops connected with a damping resistor. It accepts SFQ pulses and stores the flux quanta in its loops; the stored flux quanta fade away with a certain time constant because of the damping resistor. If many SFQ pulses arrive in a short time, the number of the stored flux quanta reaches the threshold, and the leaky integrator produces an output SFQ pulse. Immediately after the output, the integrator extinguishes all the stored flux quanta to initialize its state. This way our device can imitate the operation of neurons.