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Wave filtering and firing modes in a light-sensitive neural circuit

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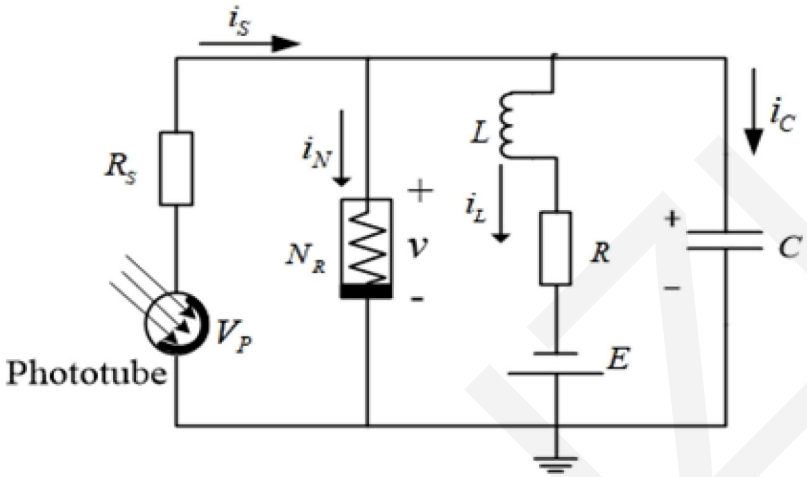
Main contents

1, Light-sensitive circuit and neuron
2, Field energy and Hamilton energy
3, Criterion for wave filtering
4, Signal source in wide band frequency
5, Some results
6, Conclusion

Function neural circuit

Scheme: Phototube is incorporated into a RLC circuit, and photocurrent is induced to regulate the dynamics of the neuron.



$$\begin{cases} C\dfrac{dV}{dt} = i_S - i_L - i_{NR}; \\ L\dfrac{di_L}{dt} = V - Ri_L + E; \end{cases} \quad (1)$$

$$i_{NR} = -\frac{1}{\rho}(V - \frac{1}{3}\frac{V^3}{V_0^2}); \quad (2)$$

$$\begin{cases} \dfrac{dx}{d\tau} = x(1-\xi) - \dfrac{1}{3}x^3 - y + u_s; \\ \dfrac{dy}{d\tau} = c(x + a - by); \end{cases} \quad (3)$$

Field and Hamilton energy

$$W = \frac{1}{2}CV^2 + \frac{1}{2}Li_L^2 = CV_0^2(\frac{1}{2}x^2 + \frac{1}{2c}y^2) = CV_0^2 H; \qquad (4)$$

$$H = \frac{1}{2}x^2 + \frac{1}{2c}y^2; \qquad (5)$$

The field energy can be kept and pumped in/from the capacitor with electric field energy and induction coil with magnetic field energy. By applying scale transformation for the field energy, and then Hamilton energy H is obtained to regulate the firing modes in neural activities.

Criterion for wave filtering

$$u_s = A(\omega)\cos(2\pi\omega\tau); \qquad (6a)$$

$$A(\omega) = \begin{cases} A_0 \exp(-\tau/\lambda), & \omega \geq \omega_{\max}; \\ A_0 \quad , & \omega_{\min} < \omega < \omega_{\max}; \\ A_0 \exp(-\tau/\lambda), & \omega \leq \omega_{\min} \end{cases} \qquad (6b)$$

$$u_s = A(\omega)\cos 2\pi\omega\tau = [H(\omega-\omega_{\max})+H(\omega_{\min}-\omega)]A_0 \exp(-\tau/\lambda)\cos 2\pi\omega\tau$$
$$+[H(\omega_{\max}-\omega)H(\omega-\omega_{\min})]A_0 \cos 2\pi\omega\tau; \qquad (7)$$

Heaviside function can be used to realize the signal filtering in experiment.

Signal source

Chaotic series have wide frequency band, and the output voltage from the chaotic Chua Circuit is used as signal source. The output signals from Chua system (8) are filtered under the criterion in Eq.(6), and then they are used to excite the neuron for generating appropriate firing modes in electrical activities.

$$\begin{cases} \dfrac{dx'}{d\tau} = y' - \delta z'; \\ \dfrac{dy'}{d\tau} = -x' + 2\gamma y' + \alpha z' + \beta; \\ \dfrac{dz'}{d\tau} = \mu(x' + z' - z'^3); \end{cases} \quad (8)$$

Some results

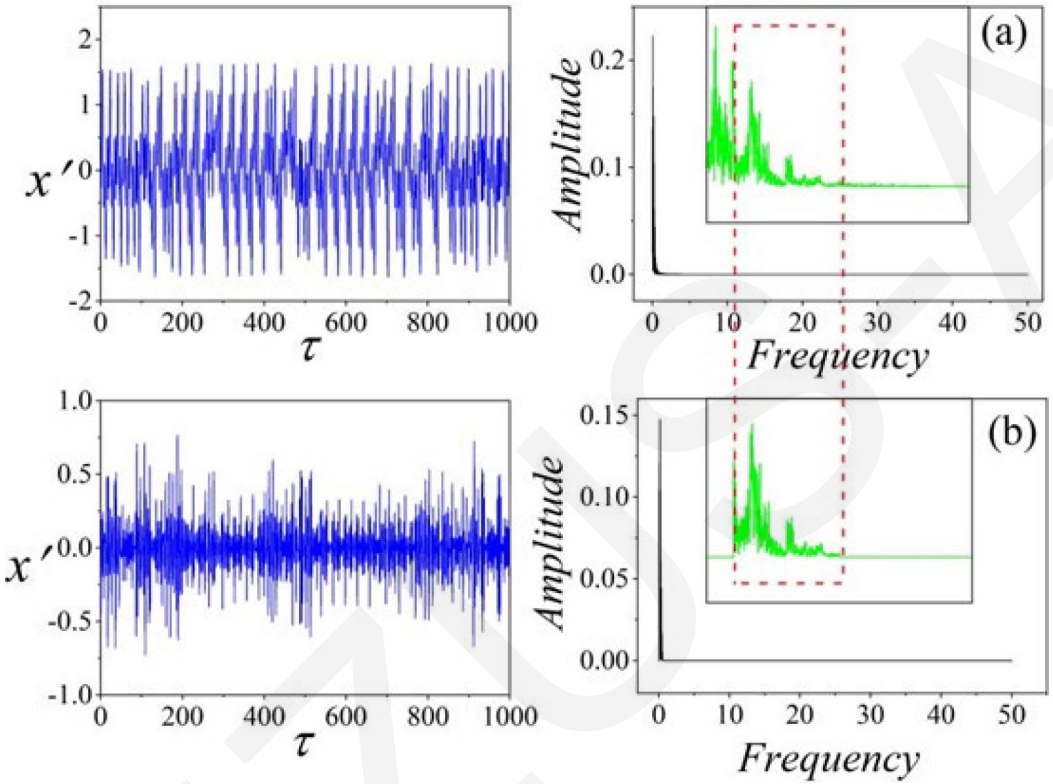


Fig.2 Wave filtering and the power spectrum for the chaotic signals and filtered signals. For (*a*) original chaotic series and the power spectrum via FFT (fast Fourier transform); (b) the filtered signal source and power spectrum. The thresholds for frequency selection and parameters are fixed at ω_{min}=0.1, ω_{max}=0.5, a=0.7, b=0.8, c=0.1, ξ=0.175, λ=5. The inserted subfigure is an enlarged version and the frequency region is within [0.0, 1.0].

Some results

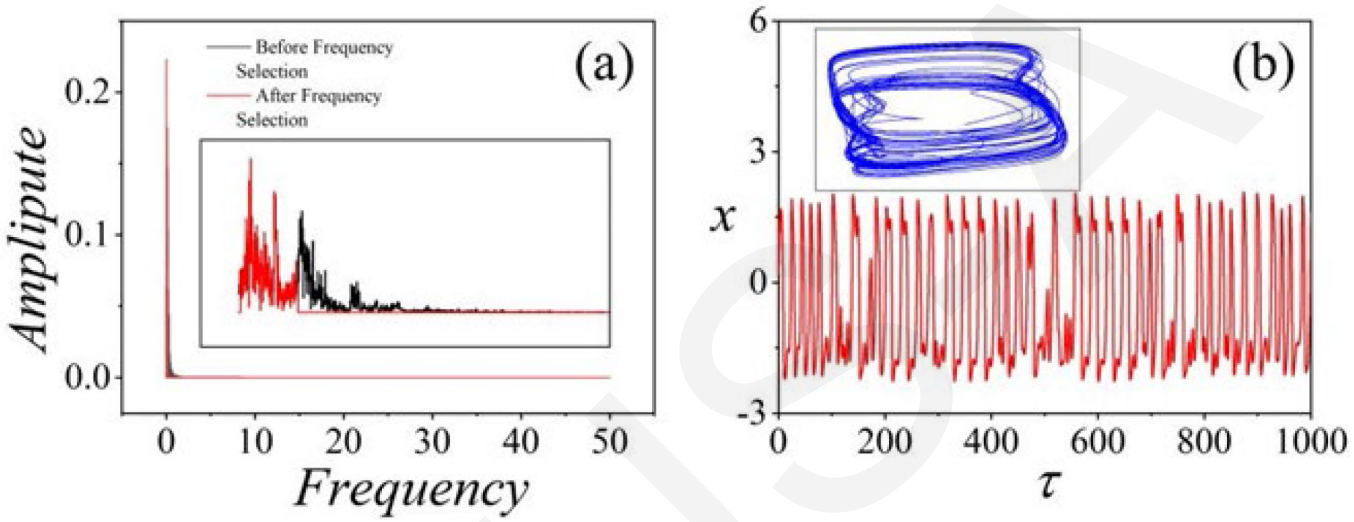


Fig.4 Frequency domain for exciting signals and phase portraits for neuron. Frequency domain (*a*) for voltage source with and without wave filtering, and (b) phase portraits and firing patterns with wave filtering at ω_{min}=0.005, ω_{max}=0.16. The parameters are fixed at a=0.7, b=0.8, c=0.1, ξ=0.175, λ=5.

Conclusions

1, Light-sensitive neuron can discern external illumination and lights within certain frequency band.

2, Realistic lights can be filtered by the phototube and even the preposed filter, and then photocurrent is induced to excite the neuron for presenting right firing modes and patterns.

3, It provides suggestions to know the potential mechanism for signal identification in neuron and building artificial eyes and sensor to lights.