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Equivalence of LC and RC oscillators

S. PASUPATHY

Department of Electrical Engineering,
University of Toronto, Toronto 181, Canada

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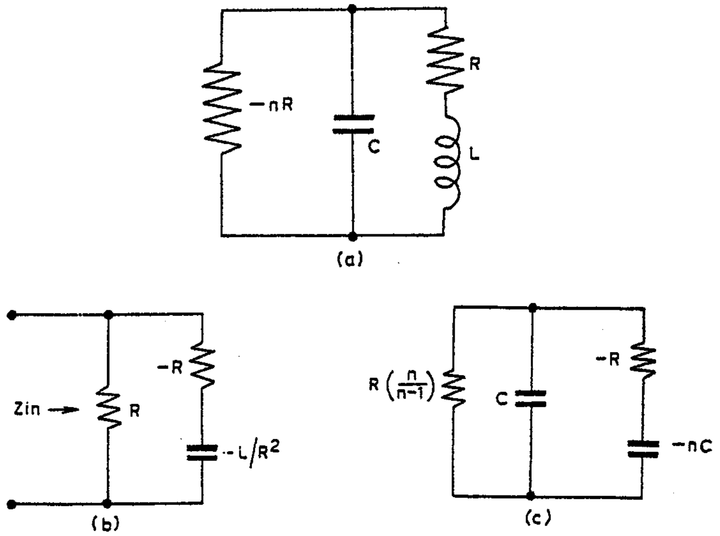
A general *RC* oscillator circuit using positive and negative *RC* elements is derived from a well-known *LC* oscillator circuit. The active *RC* network, thus obtained, is shown to represent the equivalent circuits of many existing *RC* oscillators, such as twin *T* and Wienbridge oscillators.

1. Introduction

The concept of synthesizing oscillators using devices or circuits exhibiting negative resistance seems to have been generally associated with *LC* oscillators only and the analysis and synthesis of *RC* oscillators as networks having positive and negative *RC* elements do not seem to have attracted much attention in scientific literature. This paper considers the synthesis of *RC* oscillator as an inductorless synthesis of a *LC* oscillator and points out the unifying role of negative impedances in the equivalent circuits of the two types of oscillators. An active *RC* network is derived by a transformation of a basic *LC* oscillator and it is shown that many existing *RC* oscillators can be identified as special cases of this generalized *RC* oscillator network.

Fig. 1



(*a*) A basic *LC* oscillator. (*b*) An active network, equivalent to a lossy inductance ($Z_{\text{in}} = R + sL$). (*c*) A general *RC* oscillator.

2. Equivalence of LC and RC oscillators

The circuit shown in fig. 1 (*a*) can be considered as the basic equivalent circuit of many LC oscillators. The condition for sinusoidal oscillation for this circuit is

$$n=\frac{L}{R^2C} \quad (n>1) \tag{1}$$

and the frequency of oscillation is

$$f=\frac{1}{2\pi}\left(\frac{n-1}{nLC}\right)^{1/2} \tag{2}$$

When the impedance of the lossy inductance, $R+sL$, in fig. 1 (*a*) is replaced by the equivalent active RC network of fig. 1 (*b*) a basic RC oscillator circuit results and is shown in fig. 1 (*c*). The value of the negative capacitance in fig. 1 (*c*) has been chosen so that the condition for oscillation given by eqn. (1) is satisfied. The frequency of oscillation of the RC circuit is

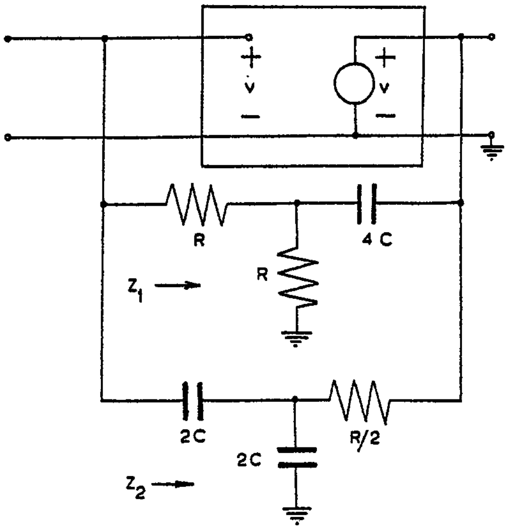
$$f=\frac{1}{2\pi}\frac{(n-1)^{1/2}}{nRC}. \tag{3}$$

The positive and negative signs in fig. 1 (*c*) can be interchanged without affecting the general nature of the network.

3. Twin T and Wienbridge oscillators

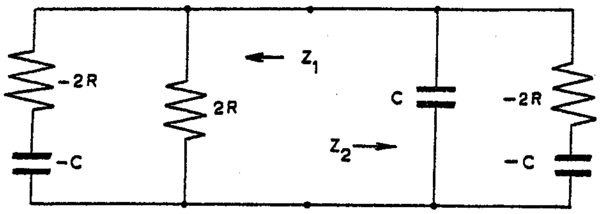
We shall now show that the equivalent circuits of many RC oscillators can be represented by this network. An ideal RC oscillator using a unity gain amplifier and a twin T network is shown in fig. 2 (*a*) (in practice an emitter follower can replace the unity gain amplifier). By considering the two T networks one by one (Su 1965), we can easily derive the equivalent

Fig. 2



(a)

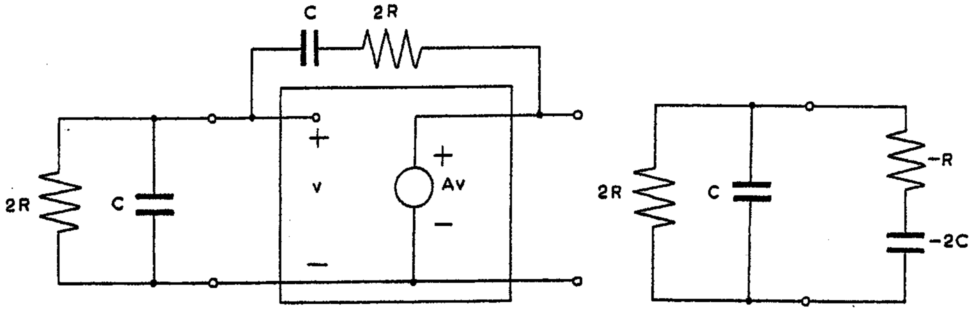
Fig. 2. *(cont.)*



(b)

(*a*) An ideal twin *T RC* oscillator using a unity gain amplifer. (*b*) Equivalent circuit of twin *T* oscillator.

Fig. 3



(a) (b)

(*a*) An ideal Wienbridge oscillator ($A=3$). (*b*) Equivalent circuit of Wienbridge oscillator.

circuit shown in fig. 2 (*b*). It is evident that the circuit reduces to that of fig. 1 (*c*) with $n=2$.

An ideal Wienbridge oscillator is shown in fig. 3 (*a*). Since the voltage gain of the amplifer, $A=3$ for oscillation, the equivalent circuit easily follows as shown in fig. 3 (*b*) and can once again be identified with the general oscillating network of fig. 1 (*c*). Similarly some other *RC* oscillators, such as the Wienbridge-type oscillator using current amplifier (Hooper and Jackets 1956) and *RC* oscillators using negative impedance converters (Patranabis and Sen 1971, Pasupathy 1966) can also be easily shown to reduce to the equivalent circuit of fig. 1 (*c*).

4. Conclusion

Apart from the insight that the basic *RC* oscillator circuit of fig. 1 (*c*) offers about the equivalence of *LC* and *RC* oscillators, a direct synthesis of the circuit with different active networks or devices simulating the negative impedances would give rise to many novel *RC* oscillators suitable for low frequency and integrated circuit applications.

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