Reprinted from ELECTRONIC ENGINEERING, *December 1966*

A Transistor RC Oscillator Using Negative Impedances

By S. Pasupathy*

A generalized form of RC oscillator circuit using negative impedances, of which the Wien bridge type of oscillators are shown to be special cases, is described. A direct synthesis of this network with a negative impedance convertor results in a novel transistor oscillator. The oscillator circuit, its two primary modes of operation and some special features are discussed.

THIS article is concerned with a new type of transistor oscillator circuit, developed from the concept of negative impedance. This circuit has certain similarities with some existing bridge types of *RC* oscillators, but has the advantages of using fewer components, having the common point of the tuning capacitor at ground potential and of achieving very low frequencies of oscillation.

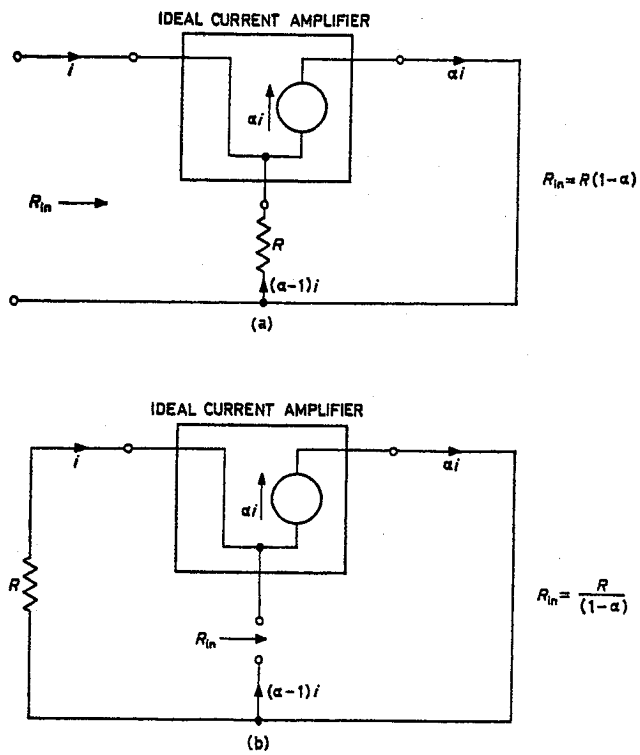

Fig. 1. Ideal current amplifier connected to produce
(a) Open circuit stable negative input resistance
(b) Short circuit stable negative input resistance
(current gain α is assumed to be greater than unity)

Generalized Form of RC Oscillator Circuit

It is general practice to analyse *RC* oscillators from the view-point of feedback.. However, in many circuits, positive feedback produces the effects of negative impedance; for example, Fig. 1 shows how positive feedback using an ideal current amplifier produces open-circuit stable and short-circuit stable negative input resistances. Hence *RC* oscillators can also be analysed using the concept of negative impedance.

The current derived *RC* oscillator[1], shown in a simplified form in Fig. 2(a), can be taken as an example. It is known that the output and input currents, i_1 and i_2, are in phase at a frequency:

$$f = 1/2\pi RC \quad \text{.................} \quad (1)$$

* *Indian Institute of Technology, Madras.*

and:

$$i_1/i_2 = 3 \quad \text{..................} \quad (2)$$

at this frequency. Therefore, for a simplified analysis, the two-stage transistor amplifier with negative feedback can be replaced by an ideal current amplifier having a gain of 3 and with no phase shift between input and output; the oscillator circuit, thus modified, can be drawn as shown in Fig. 2(b). A comparison with Fig. 1 shows that each

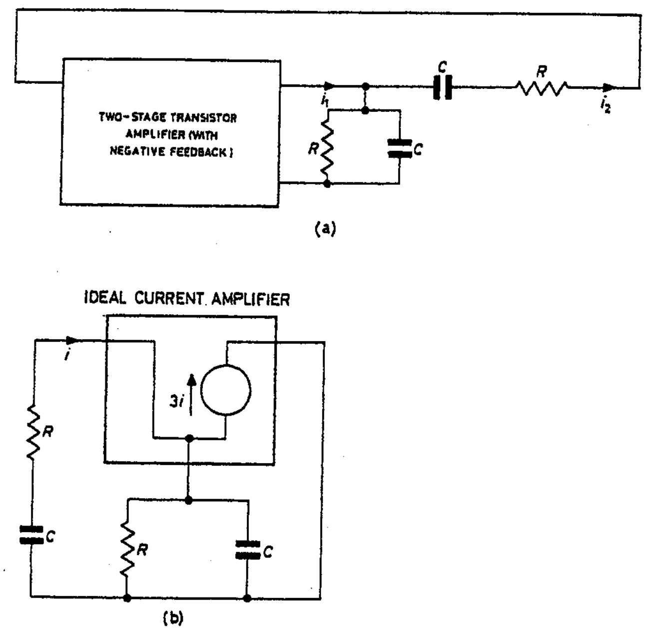

Fig. 2.
(a) Current derived RC oscillator
(b) Modified form of the current derived RC oscillator

RC pair in Fig. 2(b) is reflected across the other as a pair of negative impedances. Thus a generalized form of *RC* oscillator circuit, as shown in Fig. 3, can be evolved, with the negative sign being affixed to any impedance pair without loss of generality.

For sustained sinusoidal oscillations, the loop impedance of the network in Fig. 3 should have zeros on the imaginary axis of the complex frequency plane. The loop impedance:

$$Z(s) = \frac{1 + s(R_1C_1 + R_2C_2 - R_2C_1) + s^2R_1R_2C_1C_2}{sC_1(1 + sR_2C_2)} \quad \text{....} \quad (3)$$

From equation (3), the condition of oscillation is:

$$R_1/R_2 + C_2/C_1 = 1 \quad \text{.............} \quad (4)$$

and frequency of oscillation:

$$f = \frac{1}{2\pi\sqrt{(R_1R_2C_1C_2)}} \quad \text{............} \quad (5)$$

The current derived *RC* oscillator which is the current-derived version of the Wien bridge oscillator, can now be seen to be a special case of this generalized circuit. From consideration of Figs. 1 and 2, it can be seen that the parallel *RC* combination is reflected across the series *RC* branch as $-2R$ in parallel with $-C/2$, thus satisfying the condition of oscillation given by equation (4). Similarly by considering the two-stage valve amplifier in the Wien bridge oscillator circuit as an ideal voltage amplifier having a gain of 3, the Wien bridge oscillator also can be reduced to the generalized form shown in Fig. 3.

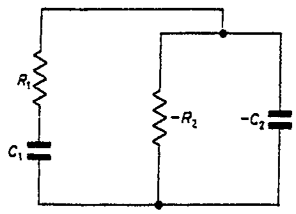

Fig. 3 (right). Generalized form of RC oscillator circuit

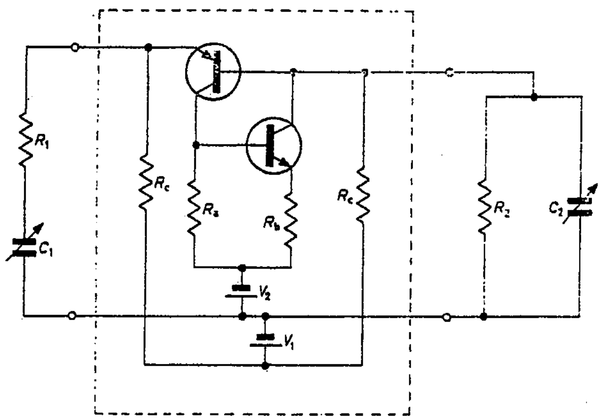

Fig. 4 (below). Transistor RC oscillator using negative impedance convertor
(The negative impedance convertor circuit is shown inside dotted lines)

RC Oscillator Using Negative Impedance Convertor

The generalized oscillator network of Fig. 3 can be directly synthesized with a well-known negative impedance convertor[2]. The resulting oscillator circuit, shown in Fig. 4, can be operated in two primary modes depending upon the ratio of (R_a/R_b) (Refer to Fig. 4).

Mode 1

$R_a = R_b$. This is the usual negative impedance convertor[2] circuit and assuming ideal convertor action, R_2 and C_2 will be reflected as $-R_2$ and $-C_2$ at the input of the convertor. In this mode of operation, the condition of oscillation given by equation (4) can be satisfied by keeping:

$$R_1/R_2 = C_2/C_1 = 1/2 \qquad (6)$$

The frequency of oscillation becomes:

$$f = \frac{1}{2\pi R_1 C_2} = \frac{1}{2\pi R_2 C_2} \qquad (7)$$

The frequency of oscillation can be varied by keeping R_1 and R_2 constant and by using a three-gang tuning such that two sections are in the series arm and the third section in the parallel arm. It is to be noted here that the input port of the convertor is open-circuit stable and the output port short-circuit stable, the *RC* branches cannot be interchanged.

Mode 2

$R_a = 2R_b$. In this case, assuming ideal convertor action, it can be shown that R_2 and C_2 are reflected as $-2R_2$ and $-C_2/2$ at the input. The circuit is similar to the circuit in Fig. 2(b). The condition of oscillation is now satisfied by keeping:

$$R_1/R_2 = C_2/C_1 = 1 \qquad (8)$$

Results and Conclusions

In the experimental oscillator circuit, the entire audio frequency range of 20c/s to 20kc/s could be covered by keeping the resistances constant and varying the capacitances. The output taken at the collector of the pnp transistor was stable and maintained purity of waveform through the frequency range. By using capacitances of large values, it was found possible to achieve as low a frequency as 0·1c/s. Improvement in the oscillator performance and extension of the frequency range can be expected by using Darlington's compound connexions and by using transistors with high α-cut-off frequencies.

This oscillator scheme has all the advantages of *RC* oscillators as well as some additional merits. Its chief advantage is that the common point of the tuning can be grounded, unlike in the bridge type of oscillator where it has to be kept above ground potential. Moreover, due to the direct coupling between transistors and absence of a separate negative feedback network, this circuit uses fewer components. The circuit also achieves very low frequencies of oscillation due to direct coupling. Hence, this circuit can very well form the basis for a cheap and compact laboratory oscillator.

REFERENCES

1. Hooper, D. E., Jackets, H. H. Current Derived Resistance Capacitance Oscillator Using Transistors. *Electronic Engng. 28*, 333 (1956).
2. Joyce, M. V., Clarke, K. K. Transistor Circuit Analysis, p. 402. (Addison-Wesley Publishing Co. Inc., Reading, Mass., 1963).

Printed in England by The Press at Coombelands Ltd., Addlestone, Surrey.