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Integrated Variable Capacitors for Large Capacitance Variations

Although capacitors are readily available in integrated circuits [1, pp. 161, 185], still their values are somewhat limited (between 10–1000 pF) due to the small surface areas usually available. Likewise, the actual capacitance values are generally fixed due to the unavailability of moving plates, etc. Here we describe, by the use of a variable gyrator [2], how rather large and electronically variable capacitance values can be obtained.

Even though a generalized gyrator [2] with an impedance matrix given by

$$Z = \begin{bmatrix} 0 & -R_b \\ R_a & 0 \end{bmatrix} \tag{1}$$

is not necessarily passive, a cascade connection of two such gyrators as shown in Fig. 1 has the very useful property of impedance transformation and, as a consequence, such a cascade can be used to transform capacitor values.

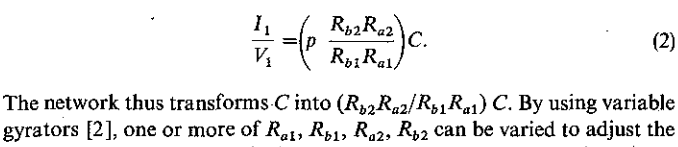

Fig. 1. Transformation of a capacitor.

With a capacitor C connected to the output terminals at the right, as shown in Fig. 1, the input admittance looking into the network at the left, with all "gyration resistances" fixed, is given by

$$\frac{I_1}{V_1} = \left(p\ \frac{R_{b2}R_{a2}}{R_{b1}R_{a1}}\right)C. \tag{2}$$

The network thus transforms C into $(R_{b2}R_{a2}/R_{b1}R_{a1})\,C$. By using variable gyrators [2], one or more of R_{a1}, R_{b1}, R_{a2}, R_{b2} can be varied to adjust the capacitance value seen at the input of the network. In a typical setup we may fix R_{a2} and R_{a1} and change R_{b2} and/or R_{b1} to obtain a wide range of effective capacitance values from a capacitance value that is most easily obtained for use in an integrated circuit. It can be seen that the same cascade arrangement can be used to adjust the value of a resistor or inductor.

It should be observed that the input capacitance of the input "gyrator" places a lower limit on the capacitance obtained. Nevertheless, cascading of more transforming sections allows almost arbitrarily large capacitors to be obtained, and these can be "varied" over an equally wide range by variation of the gyration resistances. Consequently, such circuits could, for example, be used to implement the tuning capacitors for ordinary radio receivers in integrated form.

Because of the original blocking capacitors [1] it is more convenient to realize the cascade connection by using the more recent direct coupled variable gyrator circuits [3], [4].

The size of resistors that can ordinarily be achieved in integrated circuits is limited inherently by the range of ohms per square of the available materials. The use of gyrators however permits resistors outside the usual range to be obtained; to obtain a large resistor, one need only terminate a gyrator in a small resistor, and vice versa. Alternatively, of course, two gyrators may be used to simulate a transformer.

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