Oscillators, Modulators, and Mixers Suitable for Integrated Circuit Realization

Abstract—**It is shown how the variable grounded gyrators now becoming available in integrated-circuit form can be used in conjunction with transistors and capacitors to obtain oscillators, modulators, and mixers.**

Recent work [1], [2] has outlined proposed realizations in integrated form of adjustable grounded gyrators. With such gyrators on hand, one can readily obtain single and coupled tuned circuits [3] which are adjustable in center frequency and coefficient of coupling. Likewise, microminiature delay lines [4] and integrated circuit filters [5] become available. In fact, with the use of capacitors and gyrators almost any circuit operation can be performed, except that care must be exercised to obtain the grounding required. Here we show how standard circuits can be modified for incorporation of gyrators to obtain oscillators, modulators, and mixers.

The basic gyrator has the port description

$$v_1 = -R_b i_2 \tag{1a}$$

$$v_2 = R_a i_1 \tag{1b}$$

where the two resistance parameters R_a and R_b are electronically adjustable. Using these relationships, the equivalence of Fig. 1, which is a special case of that in [3], is readily shown. We have, in fact, for Fig. 1,

$$L\begin{bmatrix} T^2 & T \\ T & 1 \end{bmatrix} = C\begin{bmatrix} R_{a_1}R_{b_1} & R_{b_1}R_{b_2} \\ R_{a_1}R_{a_2} & R_{a_2}R_{b_2} \end{bmatrix} \tag{2}$$

which determines the gyrator parameters when L, C, and the (ideal) transformer turns ratio T are given. Note that if port two is ignored (open-circuited), then at port one an inductor of inductance $CR_{a_1}R_{b_1} = LT^2$ is seen.

Using Fig. 1, and its special cases when port two is ignored, Fig. 2 shows some proposed oscillator circuits in which a common feature is that it is always possible to ground the gyrators. In all cases of Fig. 2, standard circuits [6, p. 308], [7, p. 14–4], [8] were used with gyrator-capacitor replacements of inductors via the equivalence of Fig. 1. Consequently, standard design procedures [6, p. 316] can be used, with (2) giving the gyrator parameters.

Voltage-controlled oscillators are immediately available by observing that the inductance values in the preceding circuitry are all dependent on the gyrator parameters, while the latter are electronically variable. For example, when port two of Fig. 1 is open-circuited, the describing equation is

$$v_1 = R_{b_1} \frac{dR_{a_1}C i_1}{dt} \tag{3}$$

in which case the equivalent inductance can be varied by varying R_{b_1}, with R_{a_1} (and C) held fixed. Thus, variations in oscillation frequency can be obtained by electronically adjusting the equivalent inductance through gyration resistance variation. Considerations for the coupled-coil case are in principle the same.

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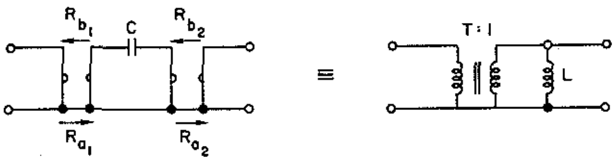

Fig. 1. Coupled coil realization.

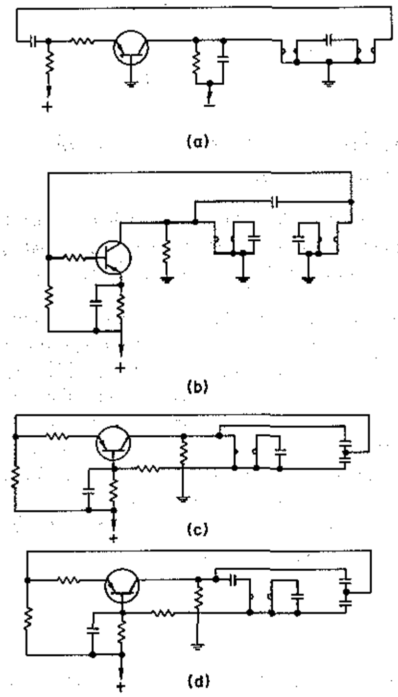

Fig. 2. Oscillator circuits. (a) Hartley-transformer feedback. (b) Hartley. (c) Colpitts. (d) Clapp.

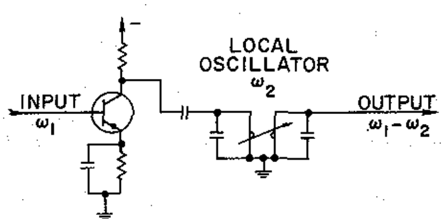

Fig. 3. Mixing circuit.

For frequency modulation we can vary an equivalent inductance through a gyration resistance which varies directly with a modulating voltage. Thus, any of the oscillator circuits of Fig. 1 can be appropriately designed to obtain a frequency modulator through suitable gyrator variation. From (3) we note that the variation can be made linear by varying only R_b, but that it also can be quadratic if R_a is also varied (though, of course, slowly with respect to variations in the current).

As with frequency modulators, we can avoid using nonlinearities of active devices in mixing circuitry. Such a mixing circuit is shown in Fig. 3, where a frequency of ω_1 is the input to the transistor, and a signal of frequency ω_2 is used to modulate a gyrator parameter or parameters. By choosing the two capacitors on each side of the gyrator so that the resulting circuit is resonant when there is no modulating signal at, say, $\omega_1 - \omega_2$, a suitable mixing circuit results. The selection of the relevant frequencies is governed by precisely the same set of considerations as for any other mixer. If desired, the simple tuned circuit of the figure can be replaced by a double tuned circuit of the type described in [3].

It should be pointed out that the idea presented here for obtaining oscillators is but one among many suitable for integrated circuit techniques. For example, one can use operational amplifiers [9] or bistable circuits [10]. However, the circuits described here should have the advantage of being easily adjusted and varied as desired.

Although lumped oscillators and frequency modulators have been constructed and satisfactorily operated using the philosophy of this letter, continued theoretical and experimental investigations are currently in progress.

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