KODAIKANAL OBSERVATORY REPRINT No. 43

Reprinted from the *Indian Journal of Pure & Applied Physics*, 1968, Vol. 6, No. 11, pp. 647-648

Dual Input Null Networks Utilizing RC Ladders

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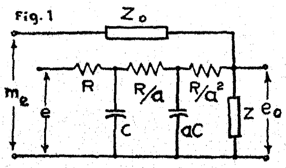
Manuscript received 12 *July* 1968

Two RC ladder networks are presented each of which, with an auxiliary input channel, shows transmission zero at a frequency that can be varied simply and widely by varying the ratio of the two inputs.

RECENTLY there has been some interest in dual input null networks[1-3] because of the simplicity with which the notch frequency can be controlled. Efforts have been made to work out the dual input versions of the common RC networks like the bridged-T[1] and the twin-T[2] circuits. The bridged-T circuit requires a lossy inductor and hence is unsuitable for many purposes, e.g. integrated circuit, etc. This note reports the circuits of two dual input null networks employing RC ladders and using resistance and capacitance only. It will be noted that these networks use two T-networks in tandem and thus are, in a way, generalization of the bridged-T networks without Ganguly's[1] requirement of a lossy inductor.

The first network is presented in Fig. 1. Assuming negligible source impedance, nodal analysis shows that

$$e_0 = \frac{D}{\Delta} \qquad \ldots(1)$$



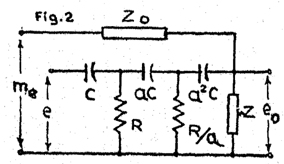


Fig. 1 — Circuit diagram of network I

Fig. 2 — Circuit diagram of network II

(In Figs. 1 and 2, m and a are positive real quantities)

where

$$D = \frac{me}{Z_0} a(g^2+y^2+a^2g^2+2agy+2gy+2ag^2) - \frac{me}{Z_0} a^2g^2+a^3g^3e \qquad \ldots(2)$$

$$\Delta = a(g+y+ag)^2\left(a^2g+\frac{1}{Z}+\frac{1}{Z_0}\right)-a^4g^2(g+y+ag) -a^2g^2\left(a^2g+\frac{1}{Z}+\frac{1}{Z_0}\right) \qquad \ldots(3)$$

$$g = \frac{1}{R} \qquad y = j\omega C$$

For null transmission, $D = 0$ or

$$m\left[\omega_0^2C^2-\frac{1}{R^2}(1+a+a^2)\right]-j\frac{2m\omega_0 C}{R}(1+a) = \frac{a^2}{R^3}Z_0 \qquad \ldots(4)$$

where ω_0 is the null frequency. Let Z_0 be a series combination of resistance R_0 and capacitance C_0, so that

$$Z_0 = R_0 - \frac{j}{\omega C_0} \qquad \ldots(5)$$

Equating real and imaginary parts,

$$\omega_0^2 = \frac{a^2R_0}{C^2R^3m}+\frac{1}{R^2C^2}(1+a+a^2) \qquad \ldots(6)$$

and

$$\omega_0^2 = \frac{a^2}{R^2CC_0}\frac{1}{2m(1+a)} \qquad \ldots(7)$$

If

$$\frac{a^2R_0}{C^2R^3m} \gg \frac{1}{R^2C^2}(1+a+a^2) \qquad \ldots(8)$$

i.e.

$$\frac{R_0}{R} \gg m\left(1+\frac{1}{a}+\frac{1}{a^2}\right)$$

then Eq. (6) reduces to

$$\omega_0^2 = \frac{a^2R_0}{C^2R^3m} \qquad \ldots(9)$$

For Eqs. (7) and (9) to be simultaneously satisfied,

$$RC = 2(1+a)R_0C_0 \quad \ldots(10)$$

giving the null condition. It will be seen that the null condition does not depend on Z that includes load impedance as well. But Z will affect the selectivity and transmission symmetry about null.

The second circuit is shown in Fig. 2. Similar analysis [or by interchanging g and y in Eq. (2)] shows that

$$D = \frac{mea}{Z_0}(y^2+g^2+a^2y^2+2gy+2ay^2+2agy)$$

$$-\frac{me}{Z_0}a^2y^2+a^3y^3e = 0 \text{ for null transmission} \quad \ldots(11)$$

Putting

$$Z_0 = R_0 - \frac{j}{\omega C_0}$$

and equating real and imaginary parts to zero,

$$\omega_0^2 = \frac{m}{R^2C^2\left[m(1+a+a^2)+a^2\frac{C}{C_0}\right]} \quad \ldots(12)$$

and

$$\omega_0^2 = \frac{2m(1+a)}{a^2C^2RR_0} \quad \ldots(13)$$

If

$$\frac{C}{C_0} \gg m\left(1+\frac{1}{a}+\frac{1}{a^2}\right) \quad \ldots(14)$$

Eq. (12) reduces to

$$\omega_0^2 = \frac{C_0m}{a^2R^2C^3} \quad \ldots(15)$$

From Eqs. (13) and (15),

$$R_0C_0 = 2(1+a)RC \quad \ldots(16)$$

Conditions of Eqs. (8) and (14) are easily attained for $a \gg 1$ and $m \ll 1$. However, if they are not adequately satisfied, exact zero transmission is obtained at one value of m only. This is similar to the case of a bridged-T or a twin-T network with appreciable source impedance[3].

It will be seen that the variation of m changes the notch frequency in opposite directions in the two cases. In Fig. 1, if $R_0 = 0$, and in Fig. 2, if $C_0 = \infty$, null is still obtainable for one value of m only.

References

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