A simple impedance convertor

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internal report by

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abstract : In the following a device is given , which converts an impedance into its dual . It can be used to simulate grounded inductances .

Introduction .

As far as we know, up till now every active device with gyrator properties consisted of at least two differential amplifiers [1] , or four operational amplifiers [2] , or contained two negative impedance convertors [3] , all these circuits requiring a lot of components for proper action .

Recently W. Jost [4] has realised a gyrator with only two operational amplifiers in connection with a resistance network , in which tolerances of the resistance-values must be kept very small to guarantee good operation .

In some aspects, the circuit given here borrows from the various circuits of the references mentioned above .
It basically consists of only one negative resistance convertor and one emitter follower .

Theory of operation.

Consider the T - circuit of figure 1. After transforming it into its equivalent delta-network, the circuit of fig. 2 is obtained.

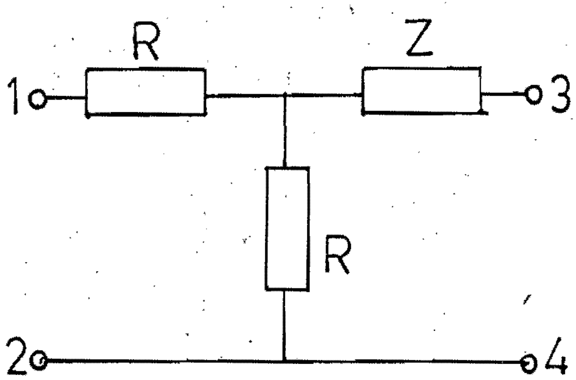

fig. 1

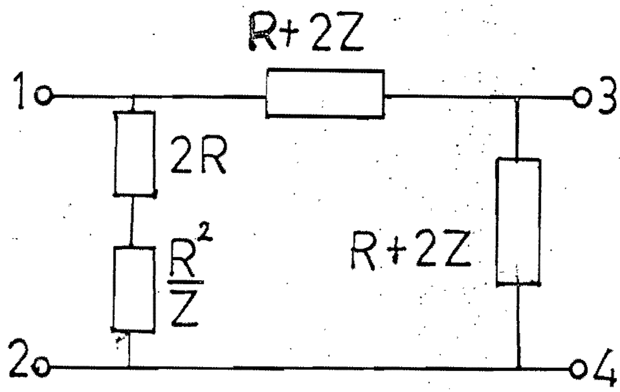

fig. 2

If now an ideal emitter follower is placed between points 1 and 3, these two points will achieve the same potential, and therefore, in the equivalent configuration of fig.2, obviuusly no current will flow from point 1 to point 3.

Thus, looking into the circuit between points 1 and 2 of fig.2, what remain will be the impedance $2R + (R^2/Z)$.

Finally, by adding a negative resistance $-2R$ in series with the impedance between 1-2, to compensate the $+2R$, only R^2/Z will be left, which is precisely the dual of the original impedance Z.

The complete circuit is depicted in figure 3 .

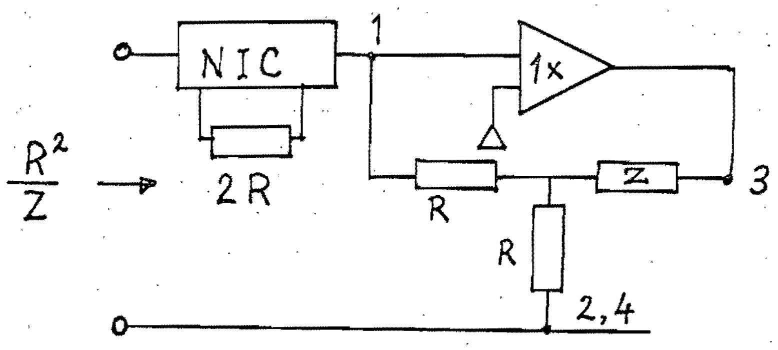

fig. 3

This circuit has the advantage, that apart from the negative resistance, it can easily be build in integrated - circuit form , because stability is evident and furthermore, element tolerance cannot disturb proper action .

The negative resistance has to be constructed in such a way, that it can be controlled from the outside . The overall circuit is stable, if the absolute value of the negative resistance is smaller than 2 R .

If Z of fig.3 is taken to be a capacitor, the input impedance will be an inductance in series with a small amount of resistance, which can be compensated with the negative resistance . In this way, inductor values from 5 millihenry to 1 henry with quality factors of 800 and more has been obtained in the range from zero to a few hundred kilocs./sec. at stable circuit operation.

Practical realisation .

The practical circuit is shown in fig. 4 .

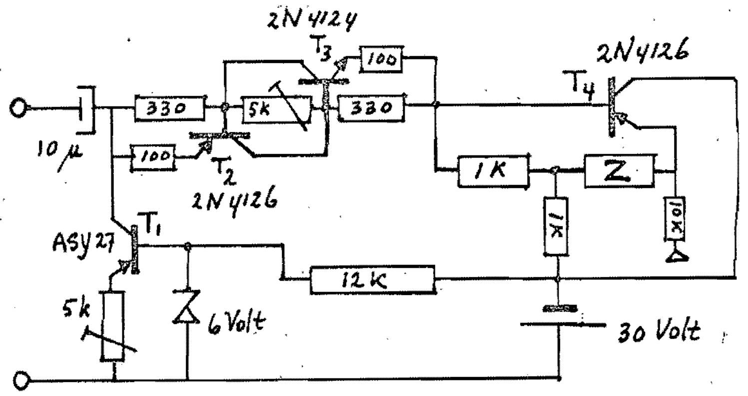

fig. 4

The transistor T_1 is used as a current-source to bias the negative impedance convertor formed by T_2 and T_3 . Transistor T_4 is the emitter follower . The circuit can be improved by replacing T_4 with a darlington-connection, a field-effect transistor or a combination of both ; but for almost every practical application one transistor T_4 will prove sufficient .

For verification, we have constructed a first-order Tchebycheff-filter, first with a conventional wire-wound inductor with quality-factor 200 at the pole frequency and then replacing the inductor with the above simulator circuit .

The lastmentioned case gave equal or even better characteristics, especially at the pole frequency, due to the higher Q (about 900) of the simulated inductance .

Conclusions .

An active device is given to generate dual impedances , for instance to convert a capacitive impedance into an inductive impedance with high Q - factor ; with few components needed , thus facilitating future integrated-circuit realisation.

Moreover , if we consider the emitter-follower and the negative resistance of fig.4 to be ideal ; then a simple proof, as privately communicated to us by Prof.A.Fettweis, shows, that the circuit of fig.4 indeed represents an ideal gyrator with gyration-resistance R (here R = 1 k.) and loaded at the output by the arbitrary impedance Z .

At the moment, work is in progress on a modified form of the above gyrator , which we hope will be more suitable as simulation for the ungrounded inductance . For this we have in mind a balanced-bridge configuration , in which the balancing is again maintained by an emitter-follower , similar to the one we used here .

References .

[1] R.H.S.Riordan : Simulated Inductors using Differential Amplifiers . ("Electronics Letters", 1967,no.2,pp.50-51)

[2] A.S.Morse and L.P.Huelsman : A Gyrator Realisation using Operational Amplifiers . ("Trans.I.E.E.E. 1964, CT-11, pp.277-278.)

[3] H.J.Carlin : Synthesis of non-reciprocal networks . (Proc. of the Symp. on Modern Network Synthesis, Polytechnic Institute of Brooklyn, 1955 .)

[4] W. Jost : Die Realisierung des idealen Gyrators mit zwei Operations - verstärkern . ("Arch.El.Ubertr.", 1967, Heft 3, pp.152-157.)

The negative resistance realisation as used in fig.4 , is due to "Western Electric" . (Dutch Patent pending , no.6608228 , Dec.15, 1966.)

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