WIDE BAND ACTIVE TRANSFORMER

By

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Features of the traditionally terminated transformer will be shown at first in order to draw a comparison between its properties and those of the active transformer. The simplest generally used input transformer can be seen in Fig. 1.

The equivalent circuits of the transformer (including the terminations) at low and at high frequency is shown in Fig. 2.a. and Fig. 2.b.

Considering the equivalent circuits it is easy to prove that the main properties of the input transformer seen in Fig. 1 are as follows:

— the input impedance is determined by the parameters of the transformer and by the secondary termination;

— the low and high corner frequencies depend even on the generator impedance;

— the realizable relative bandwidth covers about 3 decades (the ratio of frequencies belonging to the 3 dB attenuation);

— assuring the high main inductance of the audio-frequency transformer its dimension becomes too large compared with other up-to date circuit elements;

— the signal balance ratio is determined only by the spurious capacitances which are not included in the equivalent circuit.

These features are completely modified in case of the transformer terminated by a short circuit. The secondary short circuit is converted into primary one by the transformer. It is easy to understand that primary and secondary current transfer function of the transformer is more favourable relating to the voltage transfer function of the circuit shown in Fig. 1.

The circuit diagram of the active transformer is shown in Fig. 3.

Applying an active current-voltage converter the advantageous current transfer function of the transformer can be utilized, so the active transformer as a name is correct.

The active transformer can not be treated by the equivalent networks in Fig. 2, because the ohmic resistances of the coils are not negligible. The

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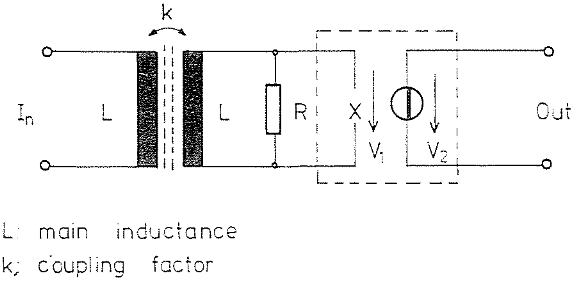

Fig. 1. One-to-one input transformer

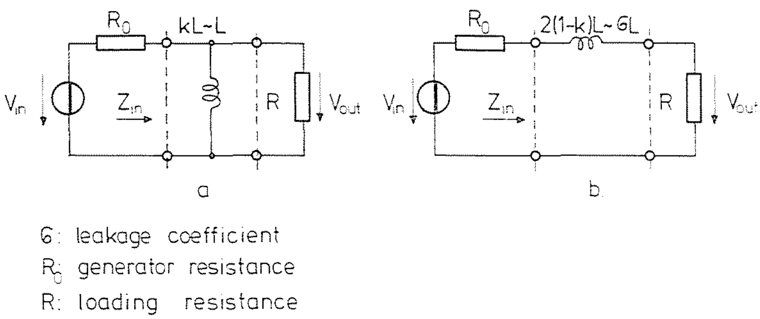

Fig. 2. The equivalent networks at low and at high frequency

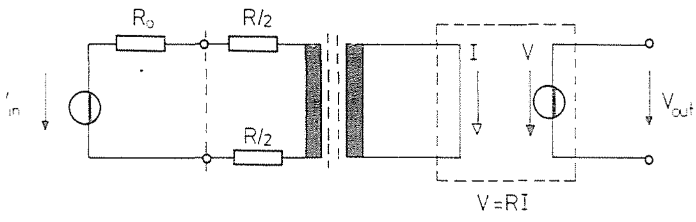

Fig. 3. The circuit diagram of the active transformer

complemented equivalent circuit is given in Fig. 4, where r marks the copper loss of the coils.

As generally $r \ll R_0 \leqq R$, and applying these conditions and the equivalent network at the low frequencies, a good approximative form of the transfer function of the active transformer is obtained:

$$T(s)=\frac{r(R_0+R)}{R}\,\frac{1+s\dfrac{L}{r}}{sL}\,. \tag{1}$$

At low and medium frequencies the input impedance is:

$$Z_{in}=R\,. \tag{2}$$

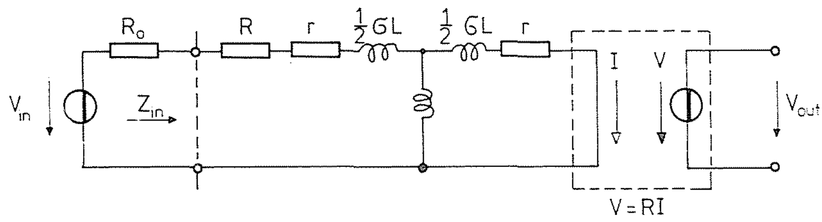

Fig. 4. The equivalent circuit of the active transformer

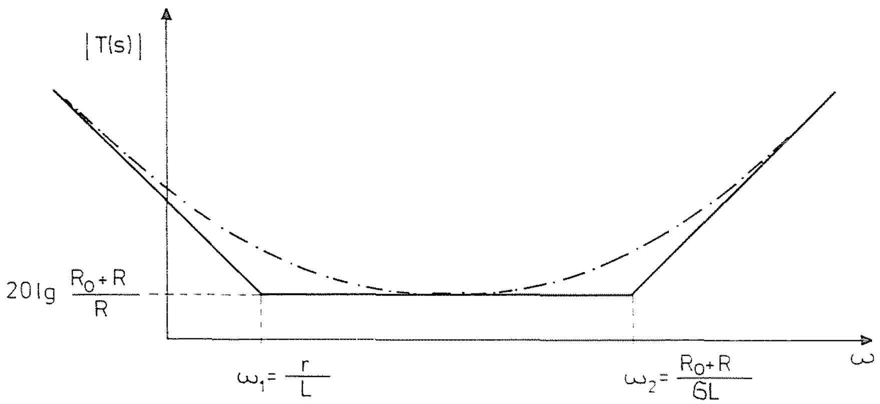

Fig. 5. The complete frequency response of the active transformer

Considering the equivalent circuit shown in Fig. 4 the approximate transfer function at high frequencies can be expressed:

$$T(s)=\frac{R_0+R}{R}\left(1+\frac{s\sigma L}{R_0+R}\right). \tag{3}$$

At high frequencies the input impedance is:

$$Z_{in}=R+s\sigma L. \tag{4}$$

Consequently the frequency response given by equations (1) and (3) are shown in Fig. 5 (Bode diagram).

On the basis of the diagram the relative bandwidth of the active transformer can be given as:

$$\frac{\omega_2}{\omega_1}=\frac{R_0+R}{\sigma r}. \tag{5}$$

If $R=R_0$, then

$$\frac{\omega_2}{\omega_1}=\frac{2R}{\sigma r}. \tag{6}$$

As the value of r is considerably lower than that of R, the bandwidth of the active transformer can cover 5—6 decades.

It is worth-while to note that ω_1 is independent of the generator impedance (R_0) and the input impedance is approximately an ohmic resistance having value R. The active transformer shows further advantages, as the effect of spurious capacitance is reduced and the signal balance ratio is improved as well.

On the basis of the above-treated theory active transformers have been realized in the hybrid integrated technique. The circuit diagram is shown in Fig. 6 and the photo of the type HLT 03 hybrid circuit can be seen in Fig. 7. The applied operational amplifier is a TBA 221 D type.

The value of the ohmic resistance of the secondary coil is important because the D. C. gain of the op. amp. is determined by it and by R_f.

Some other solutions are developed to adjust the D. C. gain, but in our case there is no need to apply them, as the offset voltage does not disturb the operation. The circuit is protected from the high voltage impulses by D_1 and D_2 diodes.

Some quick reference data of the hybrid circuit are as follower:

Type:	HLT 03
Breakdown voltage:	1 kV
Voltage gain (at 1 kHz):	0 ± 1 dB
Input impedance:	600 Ohm $\pm$ 1% $\|$ 2 pF
Signal balance ratio at 10 kHz:	80 dB
at 100 kHz:	60 dB
Loading impedance:	$R_L \geqq 5$ kOhm
Output voltage (up to 5 kHz):	7.75 V (+20 dB)
Corner frequencies:	$\omega_1 \leqq 20$ Hz
	$\omega_2 \geqq 500$ kHz
Noise (with psophometric weighting filter):	$\leqq -100$ dB

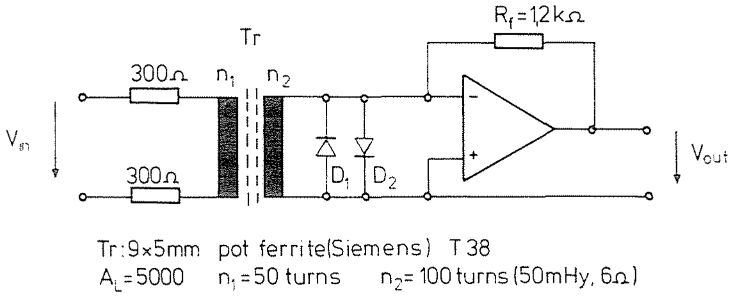

Fig. 6. The circuit diagram of the realized active transformer

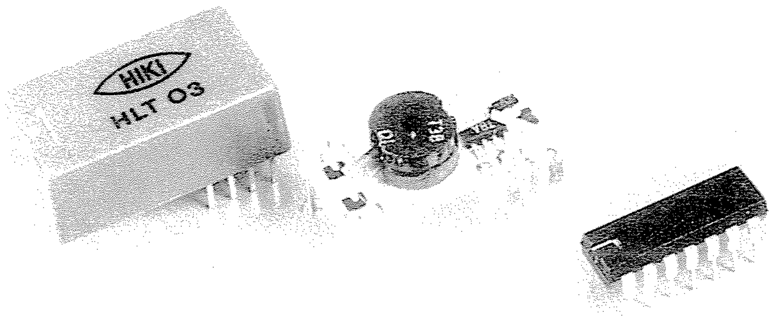

Fig. 7. The photo of the type HLT 03 hybrid integrated active transformer

Summary

The potential separation of input stages can be carried out with relatively large geometrical dimensions by means of classically terminated transformers. The transmission properties of extremely terminated transformers are favourable that is why they can be used advantageously in separating stages. Finally, a potential transformer is shown realized by using hybrid integrated technique.

References

1. Hungarian Patent, No 173735
Belgian Patent, No 852410
Swedish Patent, No 7702848 of Industrial Research Institute for Electronics "HIKI" Budapest, Hungary
Contrivers: R. FÖLDVÁRI, F. SZILÁGYI, G. DÁLNOKI, A. SONKOLY
2. GÉHER, K.: Lineáris hálózatok (Linear networks), Műszaki Könyvkiadó, Budapest, 1975.
3. IZSÁK, M.: Vezetékes távközlő berendezések, Tankönyvkiadó, Budapest, 1966.
4. GOENNING, F.: Fortschritte in der Technik der Gruppenlaufzeitmessung. NTZ 1965, Vol. 18. p. 503.

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