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ABSTRACT

This paper discusses the use of the Nuvistor triode in two- and three stage if amplifiers and places particular emphasis on neutralization. Theoretical stable-gain limits are also discussed and the results of practical designs are presented.

The development of television tuners using the 6CW4 Nuvistor triode has suggested the possibility that the high-figure-of-merit characteristics of the Nuvistor could also be used to advantage in if systems. The basic question is one of cost for a specified performance; triodes are inherently cheaper and more reliable than tetrodes and pentodes. On the other hand, because of high grid-to-plate capacitance, triodes are more difficult to stabilize at high gains than tetrodes and pentodes and, therefore, require more careful and expensive neutralization techniques. However, the relatively uniform characteristics of the Nuvistor triode greatly simplify neutralization problems.

NEUTRALIZATION

If triodes are to be used in an if amplifier, neutralization must be simple, stable with changing conditions and component variation, and inexpensive. A number of circuits could be used to effect neutralization, but all have some drawbacks. Considerable attention has been given to the selection of a good workable and inexpensive neutralization system.

All neutralization circuits involve the balancing of a bridge having either the input or the output of the tube as one branch. With triodes, the resistive component of the bridge branches makes it necessary to compensate for the loading effects of both the plate resistance and the plate dropping resistance. The grid side is less resistive and, therefore, a more satisfactory operating point.

The tapped-coil arrangement shown in Fig.1 (known as the Rice System of neutralization) is the best basic neutralization method for triodes because of its simplicity and its use of the grid circuit as the point of application. As the coefficient of magnetic coupling between L_1 and L_2 approaches unity, the bridge approaches perfect balance. However, the coefficient of coupling in practical systems is usually less than one-half, and more complete balancing may require the addition of an RC network in parallel with L_2.

An equivalent system that is easier to apply and uses fewer components is shown in Fig.2. This arrangement, which uses tapped-capacitor neutralization of the grid circuit, removes the inductive elements from the bridge branches so that tuning of the band pass has little effect on neutralization and facilitates alignment. Unfortunately, this circuit causes an unavoidable 3-db gain reduction. Using a similar tapped-coil arrangement in the plate circuit eliminates the loss in gain, but introduces bridge-balance problems that make the system undesirable.

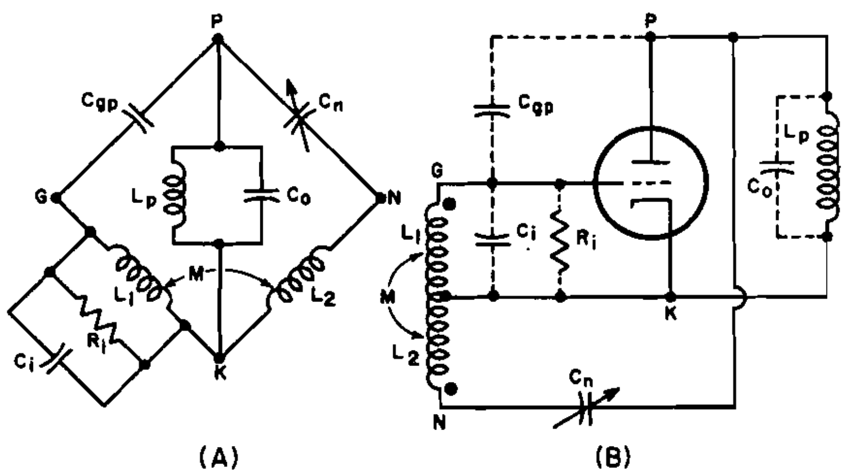

Fig.1 - Basic tapped-coil arrangement for triode neutralization (Rice system of neutralization).

STABILITY

In practice, no system can have perfect balance; over-neutralization or under-neutralization must necessarily exist in any practical system. Either condition reflects a negative resistance into the grid tank and instability results if the stage gain is sufficiently high. A stability analysis of the tapped-capacitor circuit shown in Fig.2 defines the admittance determinant, Δ, the characteristic equation of a single-loop feedback amplifier.

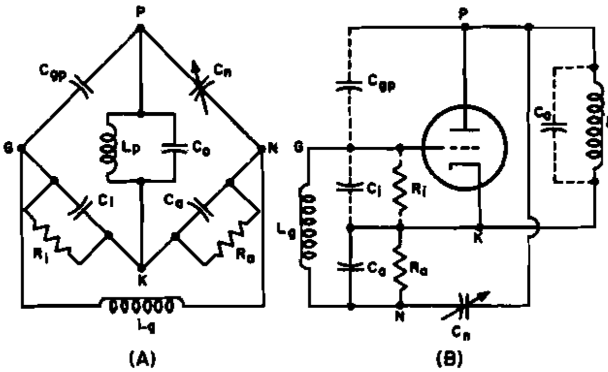

Fig.2 - Tapped-capacitor neutralization of a grid circuit.

The application of Routh-Hurwitz criterion indicates system stability, and several applications using various values of x, y, and z show the effect of parameter changes on the gain margin. This analysis shows that the system is marginally stable at a transconductance of 12,000 micromhos if the only bridge imbalance is a 20 per cent increase or decrease in one of the grid-circuit resistive components. An imbalance of about 20 per cent or less in any bridge impedance is approximately equivalent to reducing the gain margin by that percentage.

When this information is used in the design of a single stage in which the components have a value tolerance of ± 5 per cent, the anticipated variation in parameters can be compensated for by gain reduction. For a ± 5-per-cent variation in grid-to-plate capacitance and a ± 5-per-cent variation in neutralizing capacitor, the gain must be reduced by 20 per cent. The same variation in both capacitors across the grid tank requires another 20-per-cent gain reduction which makes the usable transconductance 60 per cent of 12,000 micromhos, or 7200 micromhos for a well-balanced circuit. If the resistive element of the tank is not balanced (that is, removed entirely from one branch), the transconductance must be further reduced to 3600 micromhos. In practice, it is not necessary to consider the change in the input resistance of a gain-controlled stage because the reduction in transconductance is sufficient to retain stability.

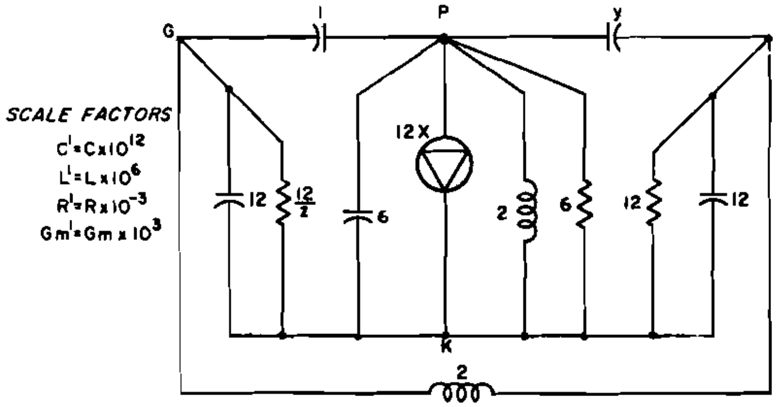

Fig.3 - Tapped-capacitor neutralization circuit having typical Nuvistor impedance values.

$$\Delta = \begin{vmatrix} \left[13s + \frac{z}{12} + \frac{1}{s}\right] & [-s] & \left[-\frac{1}{s}\right] \\ [12x - s] & \left[(7+y)s + \frac{1}{6} + \frac{1}{2s}\right] & [-ys] \\ \left[-\frac{1}{s}\right] & [-ys] & \left[(12+y)s + \frac{1}{12} + \frac{1}{s}\right] \end{vmatrix}$$

stability requirements specifically for the Nuvistor triode. This circuit is redrawn in Fig.3 with impedance values typical of the Nuvistor when appropriate scale factors are applied. S is the Laplace-transform variable, and x, y, and z are variation factors of the associated admittance (that is, if x, y, and z are unity, the bridge is perfectly balanced and at maximum gain). By varying x, y, and z, the degree of imbalance which the circuit can tolerate may be determined. Fig.3 also shows

For a television receiver having automatic gain control (agc), the variation in if response can be minimized by using the short-circuit input-loading data shown in Fig.4. These curves indicate that an unbypassed resistor of approximately 47 ohms minimizes loading variations in the agc-controlled stage.

EXPERIMENTAL TWO- AND THREE-STAGE AMPLIFIERS

Because stability analysis of the mutually coupled Rice Neutralization circuit is difficult, experimental circuits were built to determine whether practical coefficients of coupling were large enough to provide usable gains without the use of the more expensive tapped-capacitor circuit. The resulting two-stage amplifier, shown in Fig.5, is a conventional synchronously double-tuned amplifier using a conventional 6EA8 mixer. More than 56 db of gain was obtained with good stability. A normal range of Nuvistors can be substituted without causing excessive tilt or oscillations. The agc control provides more than 40 db of control. The first stage uses the developmental remote-cutoff Nuvistor triode and the output stage uses the 6CW4.

The strip has a 3.5-megacycle bandwidth and a 4700-ohm detector load. Because proper bandwidth is obtained by loading of the plate resistance and input loading of the tube, no additional loading is necessary. Bandwidth narrowing with agc gain reduction resulting from increased plate resistance is not severe because of the accompanying increase in coupling. The result was a small drop in the center of the response with only a slight decrease in bandwidth. An unbypassed 47-ohm resistor was used in the first stage to minimize variations in input capacitance with agc control.

The three-stage amplifier shown in Fig.6 is similar to the two-stage counterpart and has two identical gain-controlled stages and a 3900-ohm detector load. This amplifier also uses the conventional 6EA8 mixer shown in Fig.5. Much greater care is necessary with layout and wiring than with the two-stage amplifier. However, without resistive and capacitive balancing of the neutralizing bridges, a stable gain of only 68 db is possible. The agc line provides 80 db of control. More gain may be obtained using the more complete balancing shown in Fig.7. A stable voltage gain of 30.5 db per stage for the first two stages and 12.3 db for the output stage can be obtained. Although the resultant three-stage gain should be 11,400 or 81.14 db, a 3-db loss per stage from the voltage division of the tank capacitors results in a maximum stable gain for the Nuvistor triode three-stage if amplifier of 72 db.

The design shown in Fig.7 uses the capacitor-tapping ratio of approximately 1:1 because this con-

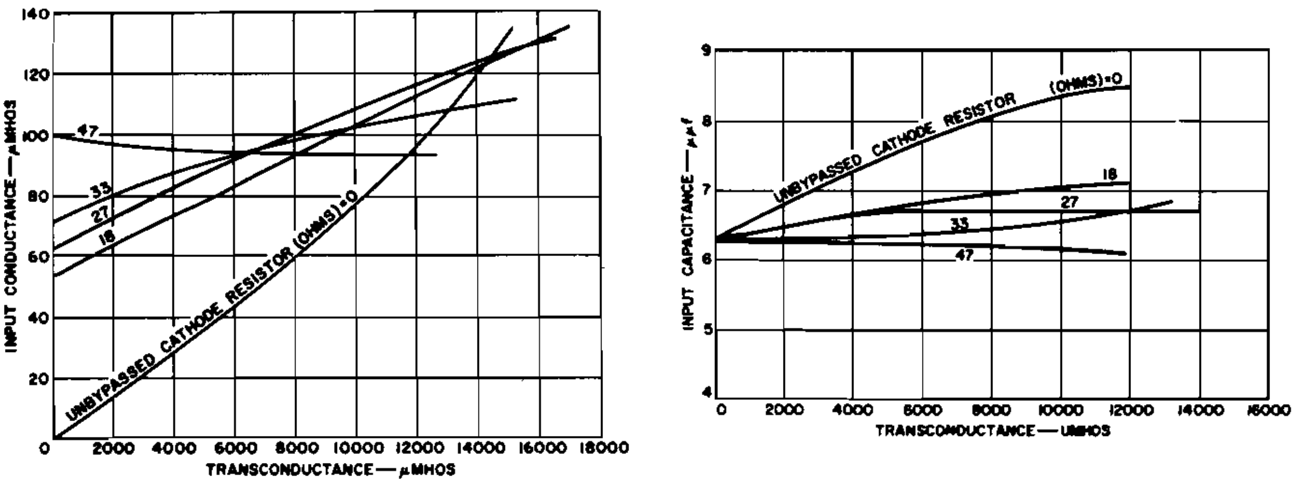

Fig.4 - Short-circuit input-loading data for Nuvistor triode.

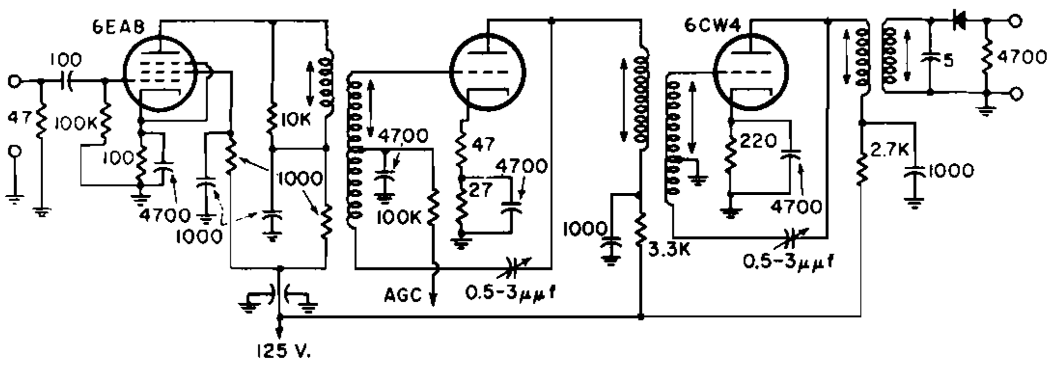

Fig.5 - A two-stage synchronously double-tuned amplifier using a conventional 6EA8 mixer.

dition minimizes input and output capacitances. In addition, the stage gain is 3 db less than the equivalent ideal Rice neutralized system having unity coefficient of magnetic coupling. A slight improvement in gain can be effected by using a tap ratio that produces a slightly higher grid voltage. Unfortunately, the improvement is small because the input and output capacitances are also increased. The optimum tap ratio for this circuit of approximately 1:1.5 provides 0.4-db improvement over the 1:1 case. Greater ratios result in less gain; beyond a ratio of 1:3 the gain is less than in the 1:1 case.

has been aligned, the neutralizing capacitors can be set at ± 5 per cent values.

CONCLUSION

Two- and three-stage synchronously double-tuned if amplifiers are feasible when the Nuvistor triode is used with simple Rice neutralization and with no additional bridge balancing. This system makes possible a gain of 56 db with a 4700-ohm detector load for the two-stage strip and 68 db with a 3900-ohm load for the three-stage strip. Substitution of tubes within the Nuvistor specification limits

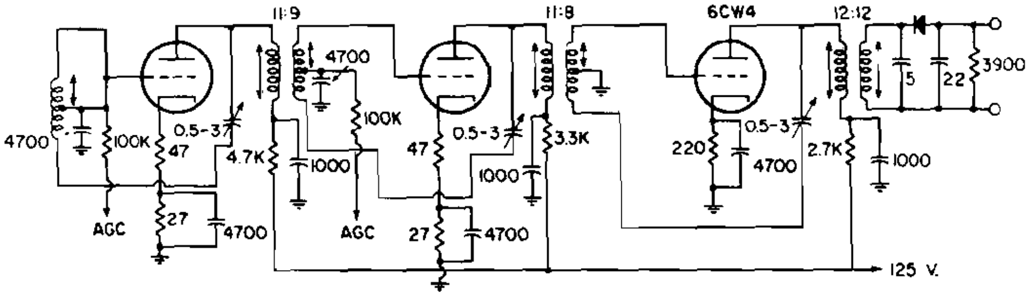

Fig.6 - Three-stage amplifier having two identical gain-controlled stages and a 3900-ohm detector load.

ALIGNMENT

In the alignment procedure, the gain control is set for minimum gain. The neutralizing capacitors of the gain-controlled stages are adjusted for minimum feedthrough, and the output stage is adjusted for minimum tilt. Band-pass adjustment is made in the normal way: the gain is increased by a small

does not cause oscillator or excessive tilt. The practical maximum gain possible from the Nuvistor three-stage amplifier is 72 db when ± 5-per-cent-tolerance components are used and a 20-per-cent imbalance in the resistive component of the neutralization bridge and ± 15-per-cent spread in Nuvistor and stray capacitances are assumed.

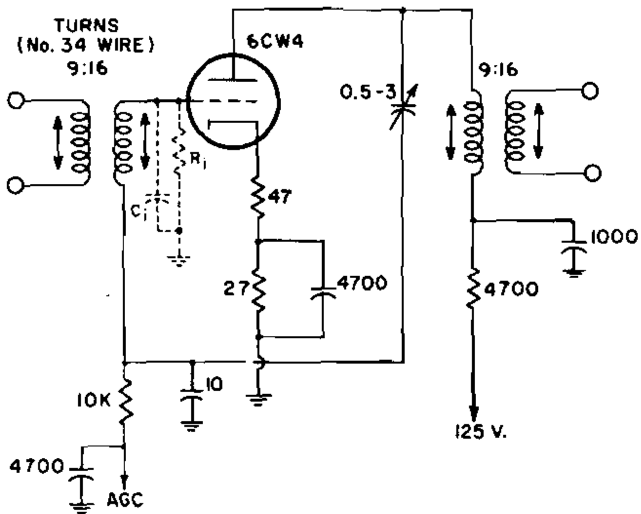

Fig.7 - Neutralization circuit using a 1:1 capacitor-tapping ratio.

amount and the gain-controlled stages are re-neutralized and then cut off to permit adjustment of the output-stage neutralization for minimum tilt. This process is continued until full agc control can be applied without causing tilt or oscillation from maximum to minimum gain. When a given layout

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