April 2, 1940. I. G. WILSON 2,195,439

TESTING FEEDBACK AMPLIFIER

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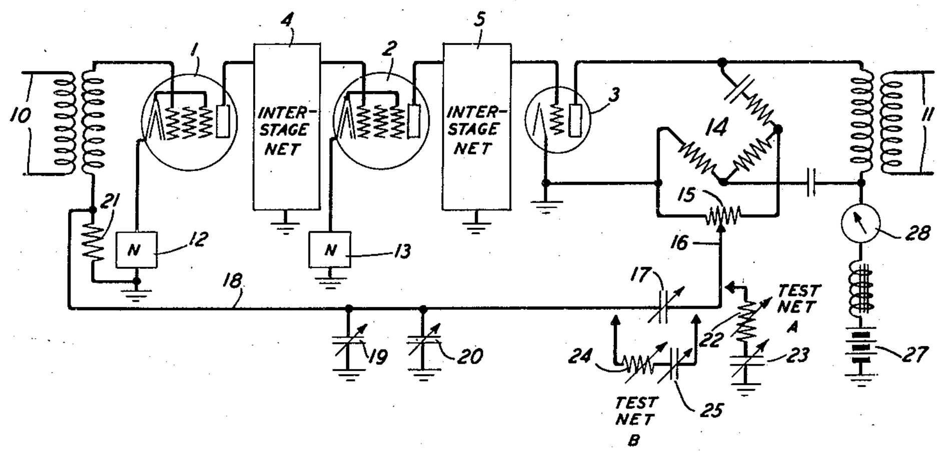
FIG. 1



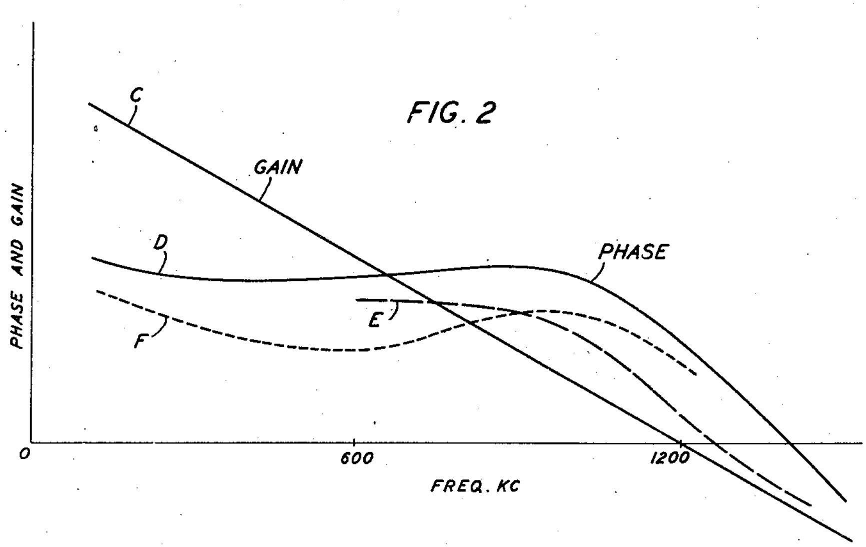


FIG. 2

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TESTING FEEDBACK AMPLIFIERS

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2 Claims. (Cl. 179—171)

The present invention relates to the testing of amplifiers to determine their singing margin.

In the design of amplifiers provided with feedback it is often a difficult matter to design the circuit to have high gain throughout a desired frequency band and at the same time a sufficient margin against self-oscillation or singing. In the manufacture of such amplifiers it is desirable to test them to determine how great a singing margin they possess before putting them out for use.

A criterion for determining whether or not a given amplifier will be stable or unstable as regards singing tendency was devised by H. Nyquist and is disclosed in his Patent No. 1,915,440, granted June 27, 1933. After that criterion was made available, it became customary in the laboratory to make a series of measurements on an amplifier throughout the frequency range of interest in order to determine the characteristic curve proposed by Nyquist and in that way determine whether or not a given amplifier was stable or unstable as regards singing tendency. While this method is suitable for laboratory studies, it would be costly and time-consuming as a manufacturing test.

The present invention provides a simple test which can be made quickly and which gives a quantitative measure of the minimum singing margin of an amplifier. The method and means provided by the invention are suitable for making routine tests of amplifiers in manufacture or for other purposes.

The invention will now be described in greater detail with the aid of the accompanying drawing.

In the drawing, Fig. 1 is a simplified schematic diagram of a typical stabilized feedback amplifier with testing networks in accordance with the invention adapted to be connected to it; and Fig. 2 shows gain and phase curves for the amplifier, to be referred to in the description.

In Fig. 1, there is shown by way of illustration, a three-stage amplifier comprising tubes 1, 2, and 3 connected in tandem with an input circuit at 10 and an output circuit at 11. Interstage networks suitably designed with respect to the frequency range to be transmitted are indicated at 4 and 5. The output of stage 3 is illustrated as containing a bridge 14 of which the feedback diagonal is shown at 15. The feedback connection extends from slider 16 on resistance 15 through gain control condenser 17 and circuit 18 to a terminal of resistance 21 in the grid circuit of stage 1. Resistance 21 should be of sufficiently high value. Variable shunt capacities 19 and 20 are illustrated in connection with the feedback circuit 18 and may be used, for example, for gain control purposes.

The amplifier shown in Fig. 1 is typical of amplifiers used for broad band amplification in multiplex carrier telephone systems where high gain characteristics of predetermined type are required. The amplifier may contain suitable equalizers, for example, in the feedback (not shown) or other means for suitably shaping the waves. Cathode networks 12 and 13 are shown in connection with tubes 1 and 2 for furnishing grid bias and, if desired, for assisting in obtaining the proper phase characteristic. The voltage sources for energizing the amplifier have, for simplicity, been omitted from the drawing except that the space current source 27 is shown for supplying the space current to the tube 3 in series with space current meter 28. A more complete disclosure of this type of amplifier may be found in the copending application of H. S. Black Serial No. 606,871, filed April 22, 1932, Patent No. 2,102,671, granted December 21, 1937. It will be understood as the description proceeds that the invention is not dependent upon the detailed design of the feedback amplifier with which the invention is to be used so that the amplifier shown in Fig. 1 may be considered as merely typical.

If the gain and phase around the amplifier and feedback loop in an amplifier circuit such as that illustrated in Fig. 1 fall within certain values, as more fully disclosed in the Nyquist patent supra, the amplifier will develop self-oscillations or singing. There are certain portions of the frequency range of a broad band amplifier in which the gain and phase around the amplifier feedback loop approach most closely the values corresponding to the singing condition. Consequently, the singing margin of the amplifier can be tested by determining how far the gain and phase at these frequencies are from the values of the gain and phase corresponding to the singing condition.

In accordance with the present invention, the singing margin may be determined by use of either test net A or test net B shown adjacent the amplifier of Fig. 1. When test net A is used, comprising resistance 22 and capacity 23, it is connected between some suitable point of the feedback conductor 18 and ground. This may be done conveniently by clipping the ungrounded terminal of the test net to any available point along the feedback circuit. When the test net

B is used. comprising resistance **24** and condenser **25**, it is connected in shunt with the condenser **17**, as for example by clipping its two terminals to the leads **16** and **18** on opposite sides of condenser **17**. The resistances and condensers in the test nets are shown variable. In general, the effect of varying the capacity is to vary the amount of the insertion phase shift and the effect of varying the resistance is to vary the frequency at which the phase shift takes place. It may be more convenient, however, particularly in making routine or manufacturing tests, to employ one or more test nets with fixed values of resistance and capacity. The manner of use of the test nets may now be described in connection with the curves of Fig. 2.

In Fig. 2 the gain and phase characteristics C and D, respectively, for the amplifier of Fig. 1 are plotted over the portion of the frequency range within which the amplifier has the greatest singing tendency. This is the region in which the gain and phase characteristics approach the asymptotic values and is generally at some frequency high in comparison with the utilized range. For example, if the utilized band is in the neighborhood of 10 to 100 kilocycles, the frequency of greatest singing tendency may be in the neighborhood of 600 to 1200 kilocycles. (This problem is more fully discussed in Robertson Patent 1,994,486, March 19, 1935 to which reference may be made.)

Referring to the curves of Fig. 2, if the phase characteristic D of the amplifier should dip below the zero line at any frequency for which the gain C is positive, singing would result. If the phase curve D is positive at all frequencies for which the gain curve C is positive, the circuit is not in singing condition. However, the phase curve D should not become negative until frequencies are reached considerably higher than the frequency corresponding to the cross-over point of the gain curve. The singing margin may be tested by deliberately degrading the phase by predetermined amounts and noting whether the amplifier sings under these conditions. In practice this may done by providing two test nets similar, for example, to test net B, for degrading the phase by a definite amount at each of two frequencies, such as 1200 kilocycles and 600 kilocycles, at which singing is most likely to occur. Typical curves showing the results of such tests are given at E and F. Curve E shows the position to which the phase curve D was shifted by connecting test net B to the position shown in Fig. 1. Curve F shows the position to which the phase curve D was shifted when test net B was used at the position shown with other values of resistance and capacity. Since the space current meter **28** showed no deflection when either test was applied, it was determined by these tests that the amplifier possessed a singing margin at least as great as that amounting to the phase shift introduced by the testing net. Similar results could have been obtained by use of test nets at position A.

Variations of the test method of the invention will suggest themselves to those skilled in the art. The test networks can be connected to other points of the circuit than those shown, for example, across the cathode network. A test net may be connected to the circuit and its resistance or capacity, or both may be varied to sweep over a range of frequency and phase while noting space current meter **28** or any other suitable indicator to determine whether or not a singing condition develops. The method, however, lends itself readily to a routine test in which one or more networks of predetermined characteristic are clipped on to the circuit and the singing or non-singing condition noted by watching the space current meter. This affords a simple acceptance-rejection test for amplifiers having sufficient or insufficient singing margin.

What is claimed is:

1. The method of testing a feedback amplifier for singing margin comprising arbitrarily varying the phase shift around the feedback loop by a given amount in the direction toward zero phase shift at different portions of the total frequency range which the amplifier is capable of transmitting and determining whether or not the amplifier will sing as a result of such phase variations.

2. The method of quantitatively testing a negative feedback amplifier for singing margin, which method consists in temporarily degrading the phase margin by a predetermined amount at different portions of the total frequency range which the amplifier is capable of transmitting, thereby increasing by a definite amount its singing tendency and determining whether such degradation in phase margin causes the amplifier to sing.

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