

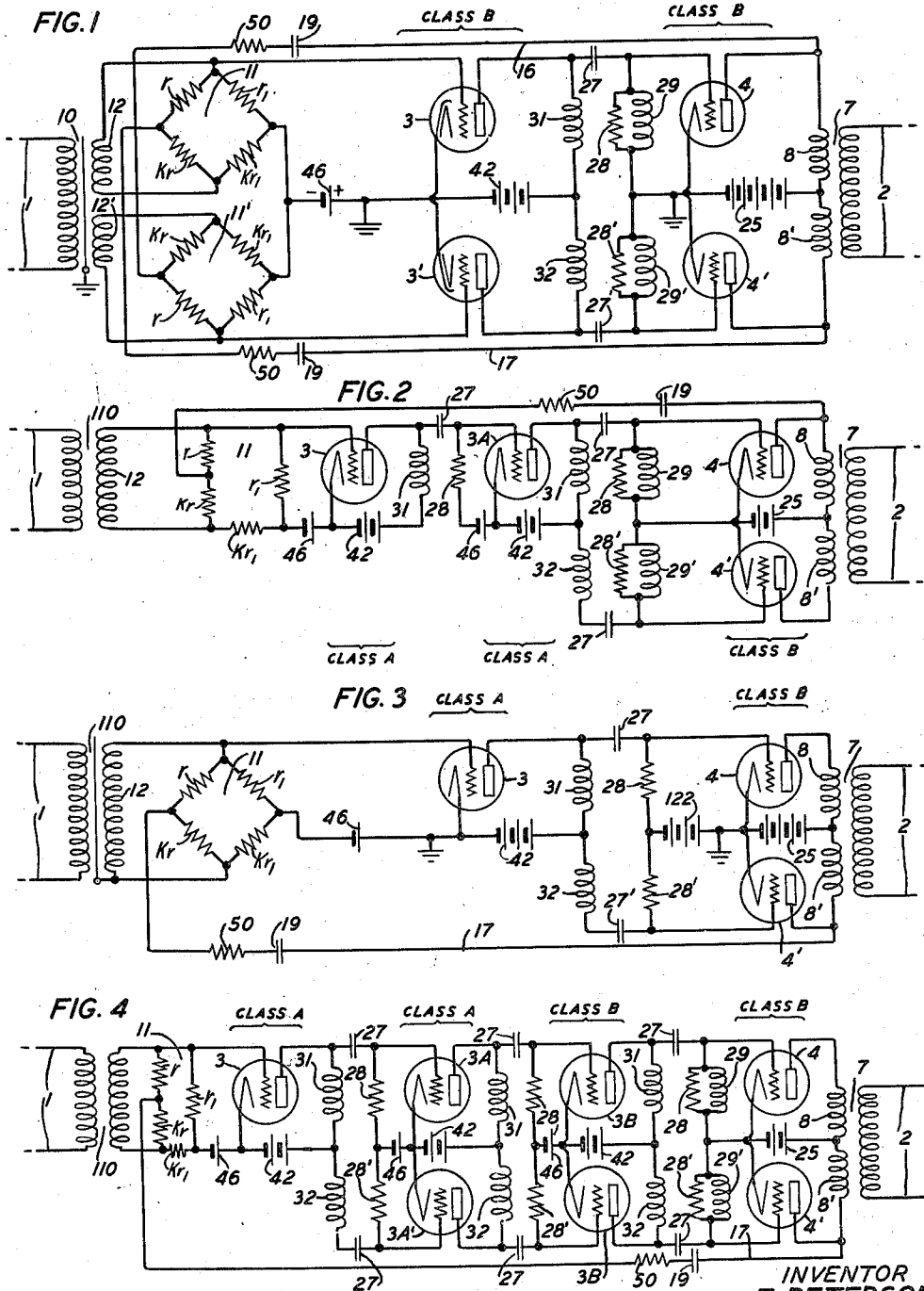
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AMPLIFIER CIRCUIT

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AMPLIFIER CIRCUIT

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This invention relates to wave translating systems, as for example systems involving vacuum tubes or wave amplifying devices.

An object of the invention is to control transmission properties of such systems, as for example, to control transmission efficiency, plate power efficiency or modulation or distortion in such systems.

It is also an object of the invention to facilitate application of feedback in such systems.

Pronounced difficulty has been encountered in cascade operation of vacuum tubes whose grids are driven down to or below the plate current extinction point, due to marked increase of gain of the circuit with load or input level, an effect which for convenience will be referred to as gasping effect; and it has been found that the gasping effect can be reduced or eliminated by proper feedback in the circuit.

A specific feature of the invention is an amplifier having cascaded tubes operated with space current interruptions, and having connections for feeding waves back in the amplifier in gain-reducing phase and in magnitude sufficient to render the gasping effect less than without feedback. The tubes may be operated, for example, in accordance with so-called class B operation, in which the steady grid potential without alternating current input is such that the space current without feedback would be extinguished for the order of half the period of the waves to be amplified. The amplifier stages may be, for example, of the balanced or push-pull type, with the potentials of the control grids of the output stage maintained always positive during operation of the amplifier and the potentials of the control grids of the preceding tubes maintained always negative during operation of the amplifier. Maintaining the grid potential for the output stage always positive serves to avoid change of sign of the grid potential that might change the input impedance of the stage sufficiently to cause objectionable change in its amplification. Maintaining the grids of the preceding stages negative facilitates driving them with stages of relatively low power capacity.

In one specific aspect the invention relates to a cascade amplifier including a push-pull stage and a preceding single-sided stage, a feature of the invention being a reverse feedback from the push-pull stage to the single-sided stage of waves derived from the combined outputs of the two sides of the push-pull stage, as for example, by a connection from one side of the balanced primary winding of an output transformer of the push-pull stage to the grid of the single-sided stage. The push-pull stage may be, for example, a class B stage; and the cascade amplifier may be formed of two single-sided amplifiers with the feedback connection crossed from the output

of one to the input of the other, in the case, for example, of an even number of stages in the feedback loop, or with the feedback connection linking the output and input of one of the single-sided amplifiers in the case, for example, of an odd number of stages in the feedback loop. Each of these simple types of feedback connections have been found effective in providing reverse feedback rendering linearity and gain stability of the amplifier greater than without feedback, with the push-pull stage either a class A stage or a stage operated with space current interruptions, as for instance, a class B stage.

Other objects and aspects of the invention will be apparent from the following description and claims.

Figs. 1, 2, 3 and 4 are circuit diagrams of four forms of the invention.

Fig. 1 shows a two-stage push-pull amplifier for amplifying waves received from circuit 1 and transmitting the amplified waves to circuit 2. The waves may be, for example, speech waves or a broad band of carrier waves transmitting a number of speech messages by multiplex carrier telephony. The first stage of the amplifier comprises two similar vacuum tubes 3 and 3', shown by way of example as triodes. The second stage may be a power stage. It comprises two tubes 4 and 4' which are also alike and which are also shown, by way of example, as triodes. The tubes 4 and 4' are connected to the outgoing circuit 2 through output transformer 7 having closely coupled primary windings 8 and 8'.

The incoming circuit 1 is connected to the tubes 3 and 3' through input transformer 10 and bridge networks 11 and 11'. The transformer has secondary windings 12 and 12'. The winding 12 forms one diagonal of bridge 11; and the winding 12' forms one diagonal of bridge 11'. The four ratio arms of bridge 11 comprise resistances r_1 , kr_1 , kr , and r , respectively, the grid and cathode of tube 3 being connected to receive the voltage across arm r_1 . The four ratio arms of bridge 11' likewise comprise four resistances r_1 , kr_1 , kr and r , the grid and cathode of tube 3' being connected to receive the voltage across this resistance r_1 .

A plate current supply source 25 is shown for tubes 4 and 4'. The tubes may be operated in accordance with so-called class B operation, in which the grid potential in the absence of alternating current input is in the neighborhood of the value required to reduce the space current substantially to zero. For example, the grids of tubes 4 and 4' are shown connected to the cathodes through high resistances 28 and 28', respectively, shunted by choke coils 29 and 29' of low impedance for direct current.

The plate of tube 3 is connected to the grid of tube 4 through a stopping condenser 27; and

the plate of tube 3' is connected to the grid of tube 4' through a stopping condenser 27'.

A plate current supply source 42 supplies direct space current for the tubes 3 and 3' through choke coils 31 and 32, respectively, which are closely coupled. (Sources 42 and 25 may be common if desired.)

Negative grid bias for the tubes 3 and 3' is supplied by a voltage source 46 which may condition the tubes for class B operation and maintain their grids always negative during operation of the amplifier.

As indicated above, pronounced difficulty has been encountered in class B operation of cascaded stages as in Fig. 1, due to gasping effect, but this effect can be reduced or eliminated by negative feedback. The proper feedback is provided in Fig. 1 by a feedback path comprising two feedback connections 16 and 17, each including a stopping condenser 19.

The alternating current potentials of the plate of tube 4 and the grid of tube 3' are approximately opposite in phase; and the alternating current potentials of the plate of tube 4' and the grid of tube 3 are approximately opposite in phase.

With the two-stage balanced amplifier, the feedback is obtained in the desired phase by reversing the feedback leads 16 and 17, i. e., crossing them over from one side of the push-pull circuit to the other side, as disclosed in my Patent 1,955,827, April 24, 1934. Thus, lead 16 is connected from the plate of tube 4 (which is in the upper side of the push-pull circuit) to the bridge circuit 11' in the input circuit of tube 3' (which is in the lower side of the push-pull circuit); and lead 17 is similarly connected between the plate of tube 4' (which is in the lower side of the balanced circuit) to the input bridge circuit 11 of tube 3 (which is in the upper side of the balanced circuit). The bridge circuits 11 and 11' render the feedback path comprising connections 16 and 17 conjugate to windings 12 and 12' and circuit 1 at balance of the bridges, as pointed out in my above-mentioned patent, for example. The gain-reduction effected by the feedback may be large. The gain of the amplifier without feedback should then correspondingly exceed the gain desired with feedback. For instance, the gain without feedback may be of the order of forty decibels and the feedback may reduce the gain to, say, a value of the order of twenty decibels. Feedback resistors 50 are shown in leads 16 and 17 for controlling the amount of feedback.

The close coupling of coils 31 and 32, and likewise the close coupling of coils 8 and 8', reduces parallel-singing tendency of the amplifier as pointed out in my above-mentioned patent.

Fig. 2 shows an amplifier circuit somewhat similar to that of Fig. 1. However, in Fig. 2 the first stage is a single-sided stage which may be a class A operated tube 3, and a stage shown as a single-sided stage comprising a tube 3A which may also be a class A stage, is interposed between tube 3 and the output stage, which may be like the output stage of Fig. 1. Moreover, negative feedback, which may serve to increase linearity and gain stability of the amplifier, is provided by a feedback connection extending through condenser 19 and resistor 50 and linking the plate of tube 4 and the grid of tube 3. The tube 3 is connected to circuit 1 by an input transformer 110 which has a secondary winding 12 associated with input bridge 11 as in Fig. 1. If desired, the stage

driving the output stage may be a push-pull class B stage of the type shown as the first stage of Fig. 1.

Fig. 3 shows an amplifier circuit somewhat similar to that of Fig. 2 with the second stage of Fig. 2 omitted. However, in Fig. 3 the class B push-pull output stage has a grid biasing battery 122 which may maintain the grids always negative during operation of the amplifier; and in Fig. 3, negative feedback, which may reduce the amplifier gain several times ten decibels and serve to increase linearity and gain stability of the amplifier, is provided by a feedback connection 17 linking the plate of tube 4' and the grid of tube 3.

Fig. 4 shows an amplifier circuit somewhat like that of Fig. 3, but with the last stage having its grids always positive, as in the case of the last stage of Fig. 1, and with two stages interposed between the first stage and the output stage. The first of these interposed stages may be a class A stage. It may be either a single-sided stage such as that shown as the second stage of Fig. 2, or a push-pull stage, and is shown by way of example as a push-pull stage comprising tubes 3A and 3A'. The second of these interposed stages, i. e., the third stage of the amplifier, comprises tubes 3B and 3B' and is a push-pull, class B stage with its grids maintained always negative as in the case of the first stage of Fig. 1. Negative feedback is provided by feedback connection 17. This feedback may reduce the gain of the amplifier several times ten decibels, for example, and serve to reduce or eliminate gasping effect due to the cascaded class B stages of the amplifier.

What is claimed is:

1. In combination, an amplifier having cascaded stages, each of said stages comprising space discharge devices in push-pull relation operated in accordance with so-called class B operation, in which the steady control-grid potential of each of the devices is such that the space current of the device is interrupted for the order of half the period of the waves to be amplified, said class B operation of said cascaded stages producing an objectionable gasping effect consisting of increase of gain of said amplifier with increase of load, and means for improving operation of the amplifier comprising connections for feeding back to the first of said cascaded stages a portion of the output waves of the amplifier in gain-reducing phase and in amount sufficient to suppress said gasping effect below the value without feedback.

2. In combination, an amplifier having cascaded stages, each of said stages comprising space discharge devices in push-pull relation operated in accordance with so-called class B operation, in which the steady control-grid potential of each of the devices is such that the space current of the device is interrupted for the order of half the period of the waves to be amplified, the last of said stages having means for maintaining its control grids always positive during operation of the amplifier and the preceding stage having means for maintaining its control grids always negative during operation of the amplifier, and means for improving operation of the amplifier comprising connections for feeding back to the first of said cascaded stages a portion of the output waves of the amplifier in gain-reducing phase and in amount sufficient to reduce the distortion below the distortion level without feedback.

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