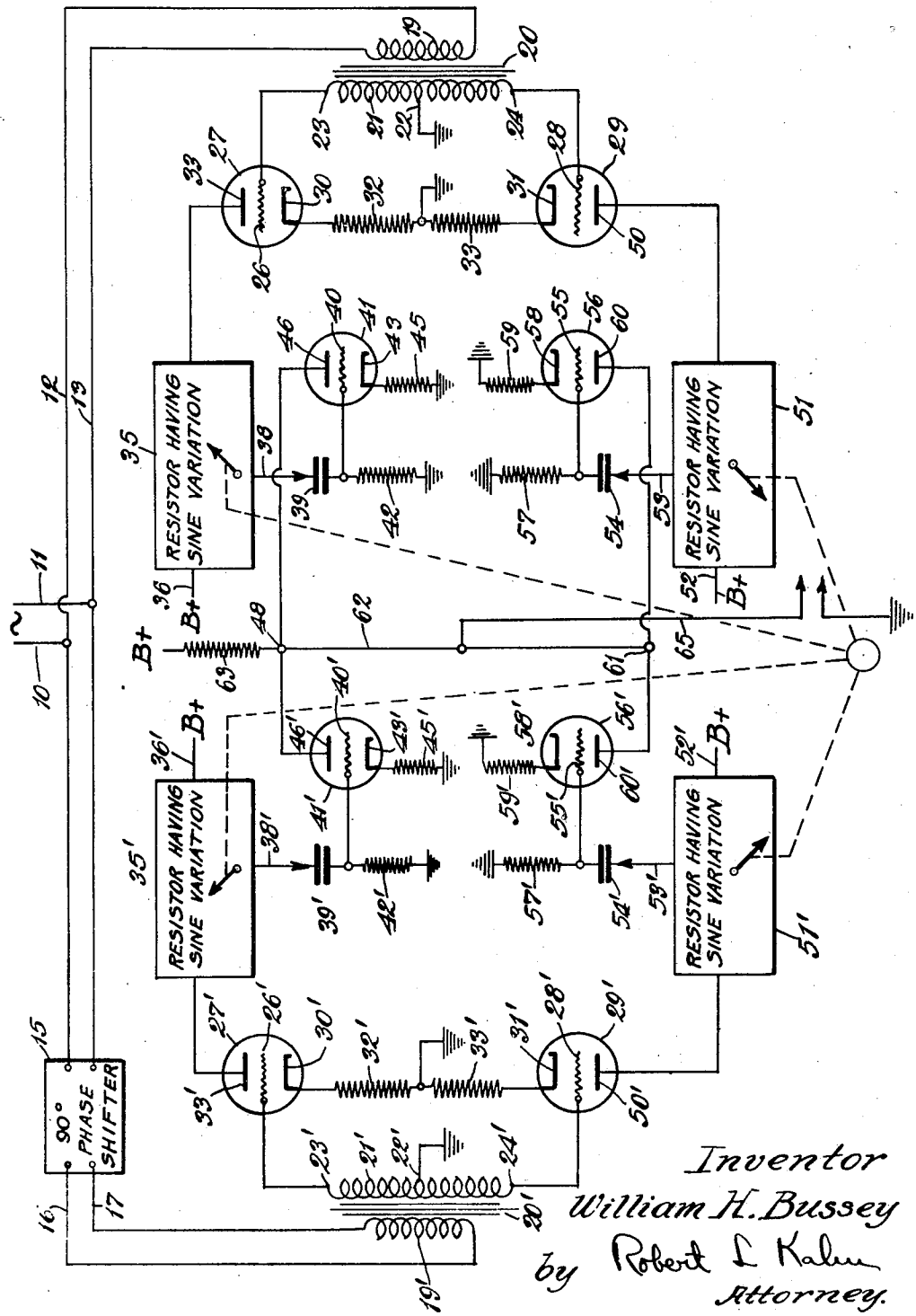
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VARIABLE PHASE SHIFTER

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VARIABLE PHASE SHIFTER

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This invention relates to an electrical apparatus and particularly to a variable phase shifter adapted to vary the phase angle between two currents by any desired value for any desired frequency while maintaining substantially constant amplitude.

Phase shifters for producing a variable phase shift are well known and exist in a variety of forms. However, such shifters as a rule are characterized by relative complexity and variable output and are sensitive to frequency variation. In addition, few shifters are capable of varying the phase angle beyond 90 degrees. This invention provides a system which is relatively simple, economical, dependable, effective over any desired angular range to provide constant amplitude and is substantially independent of frequency. The invention, in general, provides a plurality of variable resistors whose output potentials are combined in a manner so that the resultant potential has any desired phase angle with reference to a fixed phase.

For a more complete understanding of the invention, reference will now be made to the drawing wherein an exemplary embodiment is shown.

Leads 10 and 11 are adapted to be supplied with alternating current at any desired frequency from which another current at a desired phase angle is to be obtained. Leads 10 and 11 are connected to leads 12 and 13 respectively. Leads 12 and 13 are connected to supply ninety degree phase shift means 15, it being understood that the phase shift is fixed. Inasmuch as means for obtaining a ninety degree phase shift are well known in the art, a detailed description thereof is deemed to be unnecessary. In general, such means comprise a combination of capacitance and resistance, although other means are well known. Phase shifter 15 has its output connected to leads 16 and 17.

Leads 12 and 13, on the one hand, and 16 and 17, on the other hand, are connected to supply currents at equal potentials to primaries 19 and 19' of transformers 20 and 20' respectively. The transformers have secondaries 21 and 21', each provided with center taps 22 and 22'. Secondaries 21 and 21' have terminals 23 and 23', on the one hand, and 24 and 24', on the other hand. Terminals 23 and 23' go to control grids 26 and 26' of vacuum tubes 27 and 27' respectively. Similarly, terminals 24 and 24' are connected to control grids 28 and 28' of vacuum tubes 29 and 29' respectively. Tubes 27 and 29 are arranged to form a push-pull amplifier. Similarly, tubes 27' and 29' are arranged for push-pull operation.

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Vacuum tubes 27 and 29 have their cathodes 30 and 31 connected to ground through bias resistors 32 and 33. Center tap 22 is also grounded. Similarly, vacuum tubes 27' and 29' have cathodes 30' and 31' connected through grounded bias resistors 32' and 33'. Center tap 22' is also grounded.

Vacuum tube 27 has anode 33 connected to means 35 for providing an output potential whose relation to an applied potential is a sine function of the angular adjustment. Thus, device 35 may be a potentiometer or rheostat so designed that the output potential is a sinusoidal function of potentiometer or rheostat adjustment. Such potentiometers or rheostats are available in the market in a variety of forms. Thus, in one form, a resistance is tapered so that equal movements of the wiper produce variations of resistance which are sinusoidally related. In another form, a conventional potentiometer may have the wiper operated by a mechanical system which converts a simple mechanical movement into a wiper movement sinusoidally related. There is also the well-known potentiometer wherein a square sheet of insulating material has resistance wire wound thereon, a wiper being pivoted at the center and playing over the resistance.

Examples of such tapered resistors may be found in pages 50 to 52, section 3 of the second edition of "Principles of Radar," published by McGraw-Hill. Certain forms of such tapered resistors require a constant current through the resistance. This constant current may be obtained by disposing a conventional resistor having a high value in comparison to the tapered resistor. As shown in the drawing, such high resistance may be obtained by providing high cathode bias resistors for tubes 27, 27', 29 and 29'. This provides a degenerative action which tends to maintain substantially constant space current through the tube.

Inasmuch as various forms of potentiometers and rheostats are known for providing a sinusoidal output, a detailed description thereof is not given. Device 35 will merely be referred to generally as a tapered resistor.

Tapered resistor 35 has one terminal 36 for connection to a suitable source of potential. This potential is applied through tapered resistor 35 to anode 33 of vacuum tube 27.

The sinusoidal output of device 35 is taken at 38 and applied to the input of an amplifier. Thus, output 38 may be connected through blocking condenser 39 to control grid 40 of vacuum tube 41. Control grid 40 is grounded through high

resistance 42, while cathode 43 is maintained at a suitable potential by grounded bias resistor 45. Vacuum tube 41 has its anode 46 connected to junction point 48.

Vacuum tube 29 has anode 50 connected through the resistance portion of tapered resistor 51 to lead 52 and thence to a suitable source of positive potential. Tapered resistor 51 is similar to 35 and has output 53 connected through blocking condenser 54 to control grid 55 of vacuum tube 56. Control grid 55 is connected to grounded high resistance 57. Tube 56 has cathode 58 biased by resistor 59 going to ground. Tube 56 has anode 60 connected to junction 61. Junctions 48 and 61 are connected together by wire 62, these two junctions being connected through load resistor 63 to any suitable source of positive potential.

Vacuum tubes 27' and 29' are connected in a similar manner, the parts corresponding thereto bearing corresponding primed numbers.

The outputs of the tapered resistors may be combined directly to provide one combined output with respect to ground. However, in order for a tapered resistor to function as such, it is important that each device have a constant load, which may be simply a load having such high impedance that variations of load impedance have no effect on the tapered resistor. In other words, it is important that the wiper of each potentiometer, if a potentiometer system is used, be connected to a circuit having as high an impedance as possible. For this reason, the use of vacuum tubes 41 and 56 and the corresponding primed tubes 41' and 56' is preferred. Also, the grid resistors should be high in comparison to the resistors of the potentiometers. An output 65 for the entire system may be taken from wire 62, output 65 cooperating with ground to provide an alternating potential of substantially constant amplitude whose phase angle with respect to the alternating potential in wires 10 and 11 may be adjusted over any desired range. The adjustment of phase angle is made by tying together controls of the four tapered resistors 35, 51, 35' and 51' to move simultaneously. Devices 35 and 51 are so adjusted, as shown by their controls, to be 180 degrees out of phase. Similarly, devices 35' and 51' are 180 degrees out of phase. The primed and un-primed tapered resistors have a ninety degree phase difference between them. It is understood, of course, that the controls need not be simultaneously moved. However, in order to provide desired operation, the four tapered resistors must be related to each other in the manner indicated. Thus, the amplitude of output in line 65 will be constant over the range of operation.

What is claimed is:

1. A continuously variable phase shifter having a substantially constant amplitude at the output and being substantially independent of frequency, said shifter comprising a pair of push-pull amplifiers, each push-pull amplifier having a pair of vacuum tubes arranged to form a push-pull amplifier and having inputs and outputs, a resistance device for each vacuum tube, said device having manual means for varying the same to provide an output potential sinusoidally related to the manual variation, means for connecting a device in the circuit of a corresponding vacuum tube to control the output thereof, means for combining the outputs of all devices into one system output terminal, all said devices being similar and having their manual controls coupled together for common movement, the controls for the devices for one push-pull amplifier being 180 degrees out of phase with each other with regard to adjustment, the controls for the devices corresponding to the other push-pull amplifier being also 180 degrees out of phase with each other, the controls for the devices for one push-pull amplifier being 90 degrees out of phase with the controls for the other push-pull amplifier, means for supplying alternating potentials to the input of one push-pull amplifier, and means for supplying similar alternating potentials 90 degrees out of phase to the input of the other push-pull amplifier.

2. The system of claim 1 wherein said vacuum tubes have the outputs fed into amplifiers, and wherein the outputs of said amplifiers are combined.

3. The system according to claim 1 wherein said devices are connected in the circuits of said vacuum tubes and wherein said vacuum tube outputs are fed to amplifiers and wherein the outputs of said amplifiers are combined.

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