

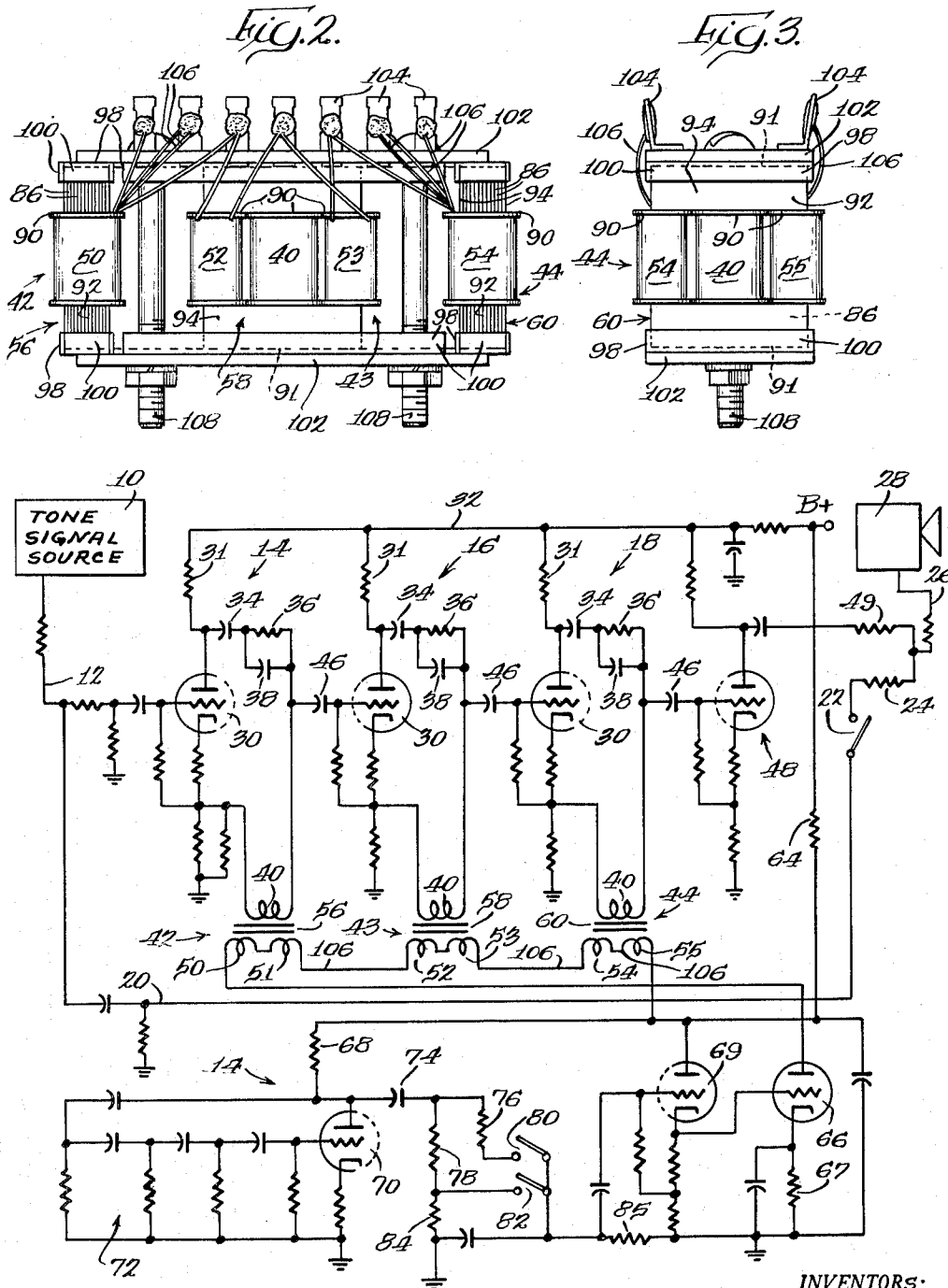
June 14, 1966

H. E. MEINEMA ET AL
 CASCADED PHASE SHIFT CORE REACTOR ARRANGEMENT FOR
 SECURING VIBRATO IN AN ORGAN

3,256,380

Filed June 26, 1962

2 Sheets-Sheet 1



INVENTORS:
 Herbert E. Meinema
 Hans Laube
 By *Whipper, Grudolph & Love*

June 14, 1966

H. E. MEINEMA ETAL
 CASCADED PHASE SHIFT CORE REACTOR ARRANGEMENT FOR
 SECURING VIBRATO IN AN ORGAN

3,256,380

Filed June 26, 1962

2 Sheets-Sheet 2

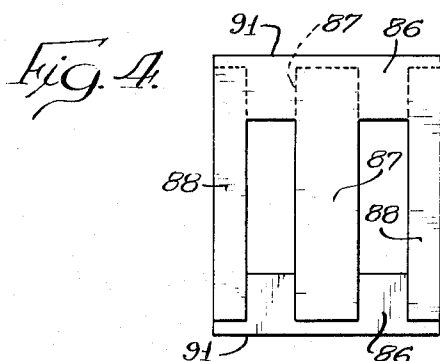
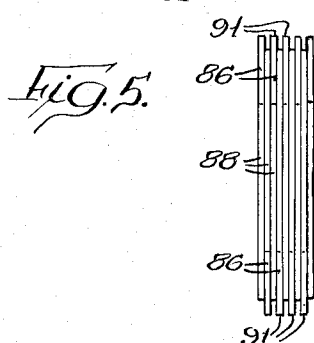
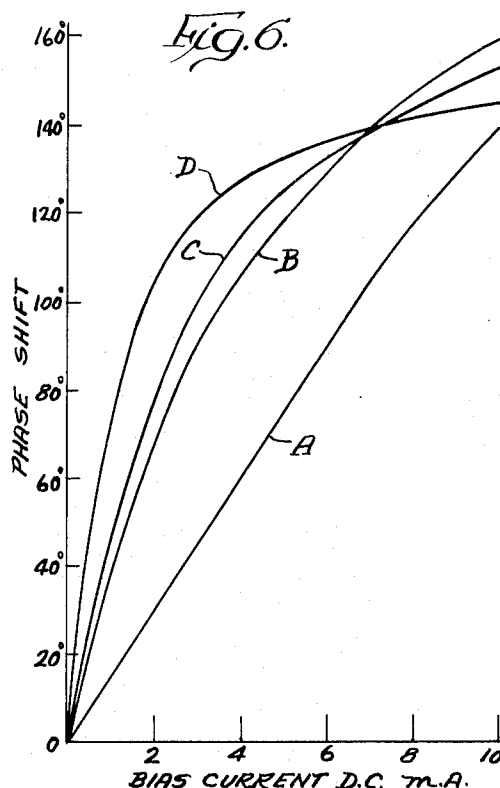
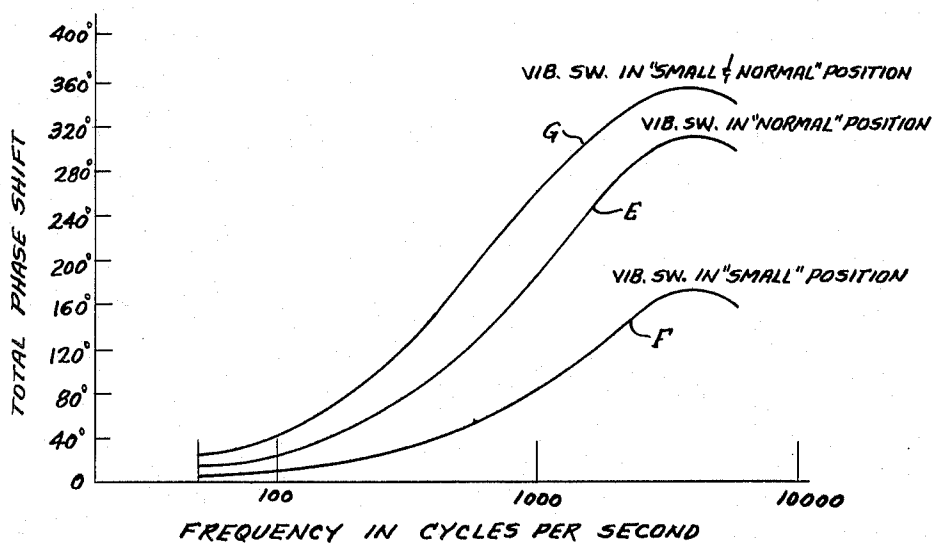


Fig. 7.

INVENTORS:

Herbert E. Meinema
 Hans Laube

By

Wagner, Bradolph & Love
 Attys

1

3,256,380

CASCADED PHASE SHIFT CORE REACTOR ARRANGEMENT FOR SECURING VIBRATO IN AN ORGAN

Herbert E. Meinema, Lake Forest, and Hans Laube, Chicago, Ill., assignors to Hammond Organ Company, Chicago, Ill., a corporation of Delaware

Filed June 26, 1962, Ser. No. 205,287

8 Claims. (Cl. 84-1.25)

This invention relates in general to an arrangement for phase shifting an input signal by means of a saturable core whose saturation is continuously varied and more particularly to a saturable core construction used for shifting the phase in each of a plurality of cascaded stages to secure an improved vibrato effect in an organ.

An object of the invention is therefore to provide an improved phase shift arrangement utilizing a saturable core whose saturation is varied at a desired rate.

Another object of the present invention is to provide an improved phase shift arrangement for securing a vibrato effect in a musical instrument.

Another object of the present invention is to provide an improved core construction and a mounting arrangement for a plurality of saturable cores within a comparatively small space and with a minimum of interaction therebetween.

Still another object of the present invention is to utilize the advantages of a magnetic arrangement for securing a tone signal phase shift in each of a plurality of cascaded stages in order to achieve economies of construction and operation together with an improved vibrator effect.

The above and other objects of the present invention will become apparent on examination of the following specification and claims together with the drawings wherein:

FIG. 1 illustrates the pertinent portions of an electronic organ circuit together with the arrangement for driving a plurality of saturable cores each associated with a respective phase shift stage in order to secure a vibrato effect;

FIG. 2 is a front elevational view of the saturable core assembly used in the present invention;

FIG. 3 is a side elevational view of the assembly shown in FIG. 2;

FIGS. 4 and 5 illustrate the manner in which the laminations of the cores are stacked;

FIG. 6 illustrates the phase shift secured for various signal frequencies and bias levels of the cores; and

FIG. 7 illustrates the phase shift effect secured by varying the amplitude of the vibrato frequency signal driving the cores.

Referring now to FIG. 1, there will be seen a tone signal source indicated by the block 10 which may be selectively keyed to provide tone signals of different frequency over an output lead 12. The output lead 12 is connected to the first stage of a plurality of cascaded phase shift stages 14, 16 and 18 which provide the vibrato. The lead 12 is also connected over a lead 20 to a switch 22. The switch 22 may be operated to connect a tone signal on leads 12 and 20 over resistor 24 and a lead 26 directly to an output system indicated by the block 28 for the purpose of providing a vibrato chorus effect.

The phase shift stages 14, 16 and 18 each comprise a respective tube 30 having a plate, cathode and grid circuit. The plates are each connected to a source of B+ through a resistor 31 and over a lead 32, and each plate is also connected to its respective cathode through a phase shift circuit comprising a coupling capacitor 34, a resistor 36 having a high frequency compensating capacitor 38 in shunt therewith and a respective coil or winding 40.

2

Each winding 40 comprises the secondary winding of a respective saturable core structure 42, 43 and 44.

The grid of tube 30 of the first stage 14 is fed by the tone signal output on lead 12, and this tone signal may actually comprise one or more signals of respective frequencies. The signal output of tube 30 in turn is derived from the junction of resistor 36 and winding 40 and fed to the grid of the tube 30 in the succeeding stage 16 through a capacitor 46. The output of the second stage 16 is similarly applied from the junction of the respective resistor 36 and respective winding 40 to the grid of tube 30 in stage 18 and the output of stage 18 is applied in a similar fashion to the grid of an amplifier 48. The amplifier 48 in turn feeds the output system 28 through a resistor 49 and the lead 26 with a continuously phase shifted tone output for creating a vibrato effect, as will be explained. If switch 22 is closed, a portion of the original tone signal is also connected directly to the output system 28 to create a vibrato chorus effect.

Each saturable core structure 42, 43 and 44 has a pair of primary windings or coils 50 and 51, 52 and 53, and 54 and 55 respectively together with a respective core structure 56, 58 and 60 respectively. The primary windings 50-55 are all connected in series with each pair connected so as to provide series aiding fields therebetween. The winding 55 is thus connected at one end to winding 54 and at the other end is connected through a voltage dropping resistor 64 to the B+ supply. The winding 50 is connected at one end to the winding 51 and at its other end to the plate of a tube 66 whose cathode is connected to ground through a resistor 67. Thus, the serially connected windings 50-55 are provided with a D.C. bias current for introducing a desired saturation level in the cores dependent on the value of the resistor 67. The saturation level is controlled so that the cores do not become fully saturated.

The B+ source extended through resistor 64 is also connected to the plate of a cathode follower tube 69 and through a voltage dropping resistor 68 to the plate circuit of a tube 70. A ladder network 72 associated with tube 70 enables the tube to function as an oscillator for generating a vibrato frequency signal of six or seven cycles per second, for example. The plate of tube 70 is connected through a capacitor 74 and respective resistors 76 and 78 of about 3.9 meg. and 6.8 meg. respectively to switches 80 and 82 respectively. Resistor 78 is connected through another resistor 84 of about 2.2 meg. to ground, and switches 80 and 82 are each connected to the grid of tube 69 and to ground through a .39 meg. resistor 85. If switch 82 is closed, the output of the vibrato oscillator 70 is connected through capacitor 74 and the high value resistor 78 to the grid of tube 69 for providing a signal of smaller amplitude than when switch 80 is closed. When switch 80 is closed, the output of the oscillator 70 is connected through resistor 76 to the grid of tube 69 to provide a comparatively high amplitude signal, and if both switches 80 and 82 are closed, the amplitude of the signal is higher than that of either switch alone.

The cathode of tube 69 is connected to the grid of tube 66 so that current passing through tube 66 fluctuates at a vibrato frequency about an average value determined by resistor 67 and with the amplitude of the fluctuations dependent on the amplitude of the signal provided to tube 69. The current passing through the coils 50-55 fluctuates accordingly to vary the saturation level of the respective cores accordingly and therefore the effective impedance of the respective secondary 40. The fields of the primaries of course serve to prevent the six cycle vibrato frequency component from affecting the secondary windings 40 since any voltage induced by one primary in the center leg of the core, upon which the secondary

is wound, serves to oppose and cancel the effect created by the other primary.

Since each secondary winding 40 is connected between the plate and cathode of the respective tube 30 in series with the resistor 36, a signal voltage as an out of phase voltage is impressed across the winding 40 and the resistor 36. The instantaneous voltage at the junction of resistor 36 and winding 40 varies in accordance with the relative impedance of the winding and resistor and follows the input voltage, with a phase displacement that varies as the impedance of winding 40 is varied. The signal phase at the junction of each winding 40 and the respective resistor 36 therefore reflects the impedance level of the winding 40 to the particular frequency of the signal applied thereto with the total change in phase across the three stages being additive so that the phase shifts continuously to provide a vibrato effect.

Referring to FIG. 6, there will be seen a graph whose horizontal axis represents the bias current in milliamperes passing through the coils 50-55 to control the average saturation level of the cores. The vertical axis represents the phase shift in degrees per stage and the respective curves A-D represent a 4 kilocycle, 2 kilocycle, 1 kilocycle and 500 cycle input tone signals. It will be seen that for curve A the slope is comparatively constant for bias values between .5 and 9 milliamperes and that the slope of the curves B, C and D is also comparatively constant but of progressively greater slope over a range of bias currents from about .5 milliampere to about 4 milliamperes whereafter the slope becomes as small as or smaller than the curve A. Thus by choosing a bias current value in the neighborhood of 7 milliamperes, the rate of change in phase for curves B, C, and D becomes progressively smaller so that a fairly constant percentage of vibrato can be provided since the amount of phase shift corresponds to the frequency with the greater shift taking place at the higher frequencies in the range above 7 milliamperes.

In FIG. 7 there will be seen a graph in which the horizontal axis represents the frequency of the tone signals on a log scale and the total phase shift is indicated on the vertical axis. A series of curves E, F and G illustrate the respective range of phase shifts with switch 80 closed, with switch 82 closed and with both switches 80 and 82 closed. Thus it will be noted that when a vibrato frequency signal of comparatively large amplitude is used, the saturation level of the cores varies over a greater range to provide a greater phase shift than when a low amplitude signal is applied to tube 66 and this is indicated by the slope of the curves E and F each being progressively shallower than the slope of curve G. In addition, it will be noted that the slope of each curve is comparatively linear with the percentage of shift, for example at 1000 cycles, approaching the percentage of shift at 400 cycles on each of the curves and with the most constant percentage of shift being indicated for curve E covering the normal vibrato.

The core structures 56, 58 and 60 are each constructed of respective E-shaped magnetic laminations 86. The laminations 86 are preferably of high permeability nickel alloy and are seen in FIGS. 4 and 5 without the coils to better illustrate their stacking. The center leg 87 of each lamination is inserted through a respective center coil 40 with adjacent laminations being inserted through the coil from opposite sides thereof. The end legs 88 of the laminations are inserted through the respective primaries 50-55 with the legs of adjacent laminations also extending in opposite directions. The dimension of the bobbins 90 seen in FIG. 3 for carrying the respective coils is chosen so that the ends of the legs 87 and 88 are spaced slightly from the back 91 of the adjacent laminations to thereby provide a slight air gap between alternate laminations as illustrated in FIG. 5. This controls the relationship between the saturation level and the bias cur-

rent to provide a gradual change in saturation level for changes in bias current.

The opposite sides of the lamination stacks 92 are provided with a retaining wall 94, and a bracket 98 of brass or similar non-magnetic material having side and end walls 100 is arranged over the opposite ends of each stack for the purpose of holding the components in close proximity. The brackets 98 are affixed to a respective one of a common pair of phenolic plates 102 so that the core constructions 42, 43 and 44 are sandwiched between the plates 102. Terminals 104 are provided on the upper plate 102 to permit the windings to be facily connected by the leads 106 and a pair of bolts 108 are extended through the plates and a central pair of brackets 98 to fasten the assembly.

The core construction 42 is arranged along one edge of the plates 102 and the core construction 44 is arranged along the opposite edge of the plates, while the core construction 43 is arranged along the central axis of the plates and transverse to the core constructions 42 and 44. This minimizes magnetic interaction as any coupling of the field occurs equally in the primaries and therefore is canceled, while wiring is considerably facilitated.

Thus having described one embodiment of our invention, but believing it capable of considerable modification without departing from the inventive concept, there is appended hereto a series of claims which are believed to set forth the invention.

We claim:

1. An arrangement for controlling a tone signal to secure a vibrato effect when applied to a first one of a plurality of cascaded phase shift circuits and derived from a last one of said circuits for application to an output system, the improvement comprising, a secondary winding in each of said phase shift circuits, a saturable magnetic core for each winding, a primary winding for each of said secondary windings with all of said primary windings being arranged in series, and means for placing a vibrato signal across said primaries.

2. The arrangement claimed in claim 1 in which each primary winding comprises a plurality of windings connected so as to generate currents of opposing polarity in the respective secondary.

3. A phase shift arrangement for use in progressively shifting the phase of an input tone signal at a predetermined rate, the improvement comprising, a plurality of windings each having a respective impedance element serially connected thereto and arranged so that a signal having opposing phases applied across one winding and the respective impedance element is derived as an output signal at the junction of the winding and impedance element for application across a succeeding winding and impedance element in opposing phases, a group of serially connected windings with each of said latter windings being associated with a respective one of the former windings, a respective saturable core for each of said former and latter associated windings, means for passing a bias current of predetermined value through said serially connected latter windings for controlling the reactance of each associated winding, and means for varying the bias current at a predetermined rate.

4. An arrangement for controlling a tone signal to secure a vibrato effect when applied to a first one of a plurality of cascaded phase shift circuits and derived from a last one of said circuits for application to an output system, a secondary winding in each of said phase shift circuits, a saturable magnetic core for each winding, a primary winding for each of said secondary windings, each of said primary windings being comprised of a pair of elements, and means connecting a vibrato signal across each of said primary windings in opposition in the respective primary pairs so that the current induced in the secondaries by the respective pairs of primary elements are of opposite polarity and substantially cancel.

5. An arrangement for controlling a tone signal to

5

apply a cyclically variable pitch shift thereto at a sub-audible frequency when the signal is applied to a first one of a plurality of cascaded phase shift circuits and derived from a last one of said circuits for application to an output system, the improvement comprising a winding in each of said phase shift circuits the reactance of which establishes the degree of phase shift of the circuit, means providing a pair of closed magnetic circuit loops comprised each of a plurality of legs, said pair of magnetic circuit loops having a mutually common leg, said winding embracing said common leg, means for cyclically varying the level of magnetic saturation at a subaudible rate in the legs of said magnetic circuits other than said common leg in balanced relationship relative to said common leg such that the level of magnetic saturation in said common leg remains substantially constant regardless of the level of magnetic saturation in the remaining legs, whereby the level of magnetic saturation of a portion of the magnetic circuit for said winding varies at said sub-audible rate without inducing a current in said winding at said subaudible rate.

6. An arrangement for controlling a tone signal to apply a subaudible cyclically variable pitch shift thereto when the signal is applied to a first one of a plurality of cascaded phase shift circuits and derived from a last one of said circuits for application to an output system, the improvement comprising a winding in each of said phase shift circuits the reactance of which establishes the degree of phase shift of the circuit, a saturable magnetic circuit for each winding the level of magnetic saturation of which establishes the reactance of its winding, means for cyclically varying the level of magnetic saturation of each magnetic circuit at said subaudible rate to vary the reactance of the respective windings cyclically at said subaudible rate, said means for cyclically varying the level of magnetic saturation comprising a pair of coils for each magnetic circuit, means providing a cyclically varying subaudible current, and means connecting the last said means to each pair of coils, such that the magnetic fields induced in said windings by said coils at said subaudible frequency mutually substantially cancel.

6

7. A phase shift arrangement for a tone signal animator comprising a pair of impedance elements connected to form an array having a pair of ends and a midpoint, means for applying a tone signal to one end of said array, means for applying the same tone signal but of substantially opposite phase to the other end of said array, means for taking off a signal from the midpoint of said array such that the phase of the signal take off depends upon the relative impedance of the impedance elements in said pair, one of said impedance elements comprising a winding, means providing a magnetic circuit of magnetically saturable material for said winding such that the impedance of said winding depends upon the degree of magnetic saturation of said magnetic circuit, and means for varying the degree of magnetic saturation of said magnetic circuit cyclically at a subaudible rate.

8. The arrangement called for in claim 7 in which the means for cyclically varying the degree of magnetic saturation comprises a coil for said magnetic circuit and means connected for applying a subaudible frequency alternating current to said coil.

References Cited by the Examiner

UNITED STATES PATENTS

2,043,828	6/1936	Coupleux	84—1.25 X
2,382,413	8/1945	Hanert	84—1.25 X
2,581,202	1/1952	Post	323—89 X
2,598,432	5/1952	Price	323—122
2,598,433	5/1952	Mittag	323—122
2,933,697	4/1960	Oncley	84—1.25 X
2,985,854	5/1961	Brosch	336—30
2,999,234	9/1961	Creusere	323—89 X
3,039,069	6/1962	Shipes	336—30
3,160,695	12/1964	Bonham	84—1.25
3,178,502	4/1965	Clark	84—1.24

LLOYD McCOLLUM, *Primary Examiner*.

D. L. RAE, W. E. RAY, *Assistant Examiners*.