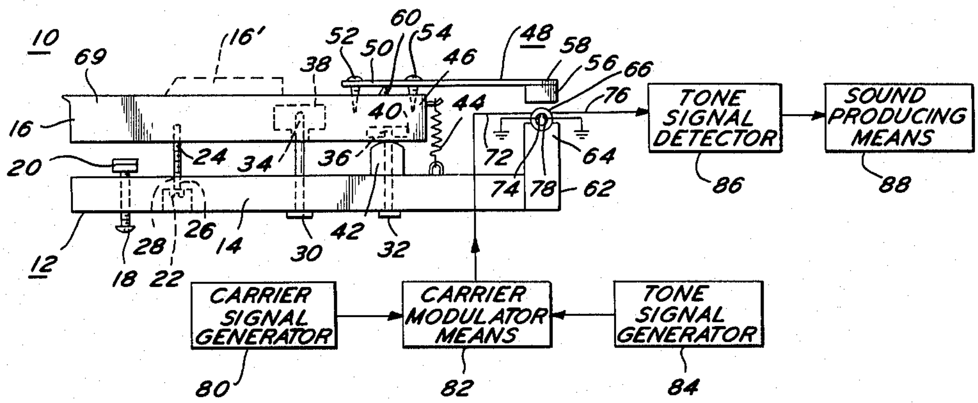
MAGNETIC CONTROL MEANS FOR AN ELECTRONIC MUSICAL INSTRUMENT

Filed Oct. 30, 1963 2 Sheets-Sheet 1

FIG. 1



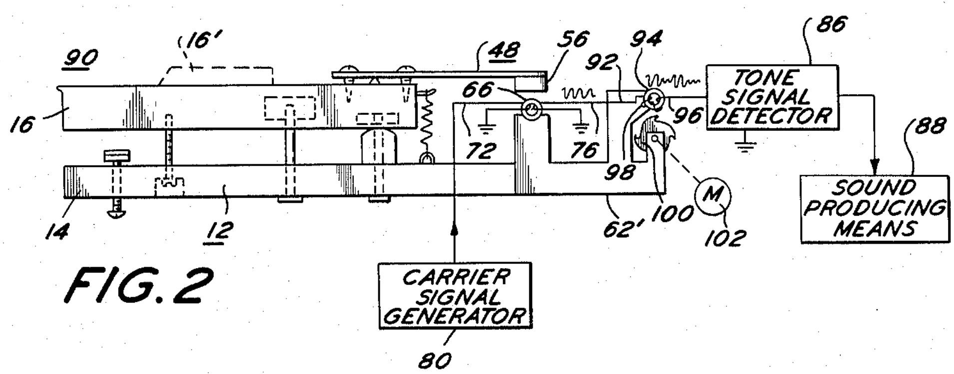


FIG. 2

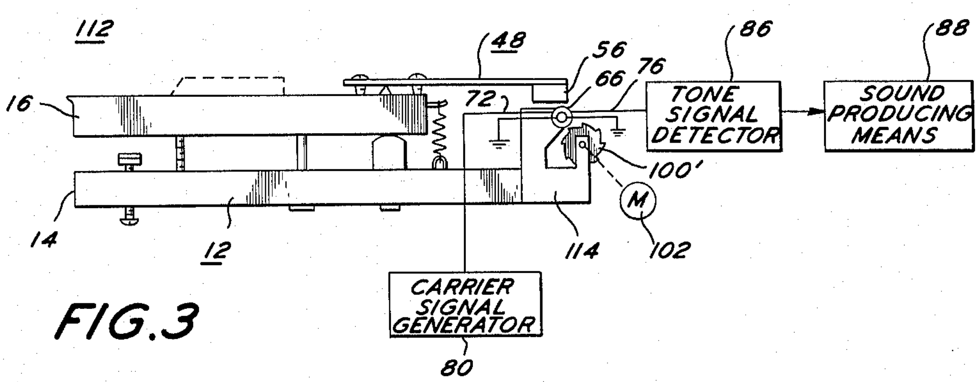


FIG. 3

INVENTOR.
FRANCIS LEE WALKER

BY Jacob Trachtman

ATTORNEY

June 7, 1966 F. L. WALKER 3,255,293

MAGNETIC CONTROL MEANS FOR AN ELECTRONIC MUSICAL INSTRUMENT

Filed Oct. 30, 1963 2 Sheets-Sheet 2

FIG. 4

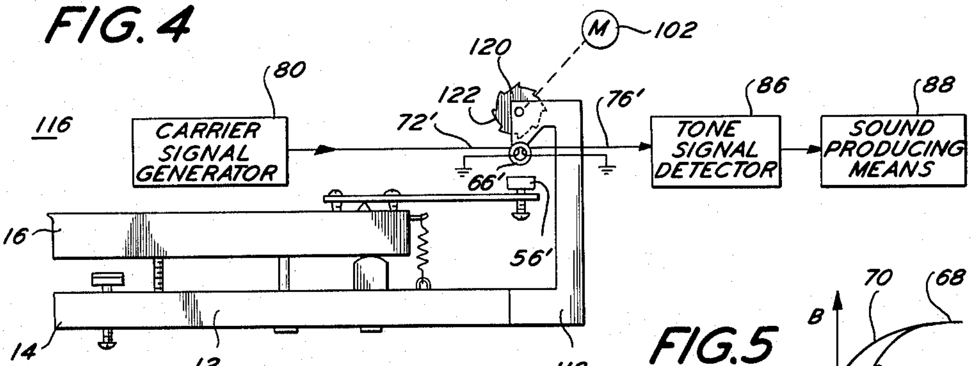


FIG. 5

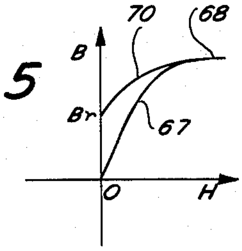


FIG. 6a

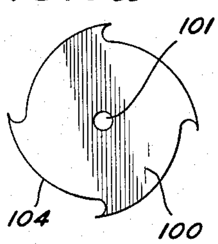


FIG. 6b

FIG. 7a

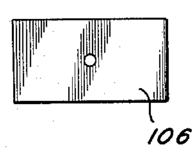


FIG. 7b

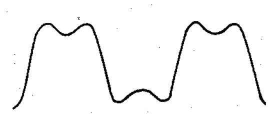


FIG. 8a

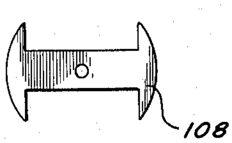


FIG. 8b

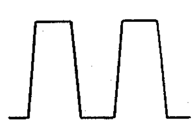


FIG. 9a

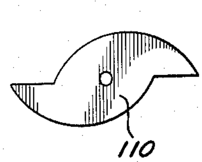


FIG. 9b

INVENTOR.
FRANCIS LEE WALKER

BY Jacob Trachtman

ATTORNEY

United States Patent Office

3,255,293
Patented June 7, 1966

3,255,293
MAGNETIC CONTROL MEANS FOR AN ELECTRONIC MUSICAL INSTRUMENT
Francis Lee Walker, 526 Charles Ave., Barrington, N.J.
Filed Oct. 30, 1963, Ser. No. 320,180
2 Claims. (Cl. 84—1.1)

The invention relates to magnetic control means for an electronic musical instrument, and more particularly to magnetic means for controlling the amplitude and tonal qualities of an electronic musical instrument.

The advantages of the piano over its early competitors, the harpsichord and the clavichord, was in its pianoforte touch, or the ability of the pianist to control the loudness of the notes being produced by the force with which respective keys of the keyboard were struck. While large pipe organs have the greatest compass of all instruments, the organ is still incomplete without the pianoforte touch. A more musically complete instrument than either the piano or organ would be one that combines the compass of the organ and the control of the piano.

It is, therefore, a primary object of the invention to provide a new and improved magnetic control means for an electronic musical instrument allowing the operator to control by touch the loudness of the notes produced.

Another object of the invention is to provide a new and improved magnetic control means for an electronic musical instrument which is highly versatile in producing sounds with predetermined harmonic content.

Another object of the invention is to provide a new and improved magnetic control means for an electronic musical instrument which provides a percussive or transient response in the sound produced controlled by the actuation of the keys of a keyboard.

Another object of the invention is to provide a new and improved magnetic control means for an electronic musical instrument which is highly efficient in operation, rugged in construction and readily maintained in operative condition.

Another object of the invention is to provide a new and improved magnetic control means for an electronic musical instrument allowing the instrument to be played and controlled in a manner similar to the piano.

The above advantages, as well as many other advantages of the invention, are achieved by providing a magnetic control means for an electronic musical instrument with a first magnetically saturable core element having a magnetically coupled signal input lead and a magnetically coupled signal output lead. The first unit produces a space varying magnetic field, and a movable key member controllably positions the unit with respect to the first core element for controlling and varying the degree of saturation of said first core element.

A second magnetically saturable core element is provided having a lead magnetically coupled with the second core element and connected in series with the output lead of the first core element for providing an output signal from the series connected first and second core elements. A rotatable unit driven with a constant angular velocity has a periphery positioned proximate to the second core element and provides a magnetic field varying angularly in space about its periphery.

The key member has a normal position in which said first unit is positioned with its magnetic field saturating the first element so that signals at the input lead are not delivered to the output lead of the first core element. The key member, when actuated from its normal position, moves the first unit to a more distant position with respect to the first core elment, so that the magnetic field of the first unit no longer fully saturates the first core

element and signals at its input lead are delivered at the output lead of the first core element.

A signal generating means delivers a carrier input signal to the series connected first and second core elements and an audio detecting and sound producing means is energized by the output signal derived from the series connected first and second core elements when the key member is actuated from its normal position. The sound producing means provides a sound having percussive or transient qualities and amplitude determined by the actuation of the key member, while the tonal qualities and pitch are related to the modulation of the carrier signal by the second unit.

Several other embodiments and modifications embodying the invention are disclosed hereinbelow.

The foregoing and other objects of the invention will become apparent as the following detailed description of the invention is read in conjunction with the drawings, in which:

FIGURE 1 is a sidee elevational view partially in block form of magnetic control means for an electronic musical instrument embodying the invention,

FIGURES 2, 3 and 4 are side elevational views partly in block form of respective modified forms of the means shown in FIGURE 1,

FIGURE 5 is a hysteresis curve used for disclosing the fully saturated and partially saturated regions of the magnetic core elements described in connection with FIGURES 1 through 4,

FIGURES 6*a*, 7*a*, 8*a* and 9*a* are side elevational views of respective rotatable units having various peripheral configurations producing respective magnetic fields varying angularly in space about their peripheries, while FIGURES 6*b*, 7*b*, 8*b* and 9*b* show in graphic form the periodic modulation signal produced respectively by said magnetic rotatable units.

Like reference numerals designate like parts throughout the several views.

Referring to FIGURE 1, an electronic musical instrument **10** is provided with a keyboard **12** having a bed **14** supporting a plurality of key members **16** in elongated form or key members **16'** of short and raised form shown in dashed lines for producing sharp or flat notes. The keyboard **12** is of conventional construction having a screw element **18** for raising and lowering the key depressing limit pad **20**. A key level adjustment screw element **22** has its end **24** threadedly engaged with the key member **16**, while its head end **26** is movable through an opening **28** in the bed **14**. The bed **14** is also provided with guide pins **30**, **32** which have respective ends **34**, **36** extending into openings **38**, **40** in the key member **16** provided with padding means therein. The guide pin **32** positions a fulcrum block **42** having a rounded top between the bed **14** and the key member **16**. The key member **16** is maintained in a normal level position by a key return spring **44** connected between the bed **14** and the end **46** of the key member **16**.

A lever **48** having an end **50** secured by screw elements **52**, **54** with the end **46** of the key member **16** is provided with a magnetic unit **56** secured at its extending end **58**. A fulcrum **60** secured with the key member **16** between the screw elements **52**, **54**, allows the adjustment of the inclination of the lever **48** by loosening and tightening of the screw elements **52**, **54**.

A supporting block **62** is attached to the end of the key bed **14** mounting at its top **64** a toroidal core element **66** having magnetic properties represented graphically in FIGURE 5.

A typical hysteresis or magnetization curve is shown for the core element **66** with flux density B plotted against magnetizing force H. With the element **66** completely demagnetized, the initial application of a magnetizing force H produces a magnetic flux density B, as shown by the curve **67**. When the magnetizing force is sufficiently large, the curve **66** has a substantially horizontal straight line in portion **68** showing that the core element **66** is fully saturated. The application of further magnetizing force H has no affect upon the flux density B. With the removal of the magnetizing force H, the flux density in the core element **66** is represented by the curve **70** which has an increasing slope, as the magnetizing force H is reduced. When the magnetizing force is zero, a residual flux density remaining in the core element **66** is shown as B_R. If a magnetizing force H is now applied to the core element **66**, the flux density B produced will be represented by the curve **70** and with the increased application of the magnetizing force H, the core element **66** will return to its fully saturated condition illustrated at **68** of FIGURE 5.

The core element **66** is positioned proximate to the magnetic unit **56** with the key member **16** in its normal position shown in FIGURE 1. The magnetic field provided at the core element **66** with the key member **16** in its normal position, saturates the core element **66**, so that same is placed in a condition represented by the substantially horizontal portion **68** of the curve shown in FIGURE 5. The key member **16** is actuated by moving its end **69** downwardly, so that its end **46** pivots upwardly, resulting in the movement of the magnetic unit **56** away from the core element **66**. This reduces the intensity of the magnetic field at the core element **66**, so that the core element is only partially saturated, represented by the curved or knee portion **70** of the curve in FIGURE 5. The intensity of the magnetic field produced at the core element **66** may be adjusted by varying the inclination of the extending lever **48**, by choosing a permanent magnet to produce the desired magnetic field strength, or where an electromagnet is used for the magnetic unit **56**, varying the actuating current to adjust the intensity of the magnetic field produced. By adjusting the key depression limit screw **18**, the maximum reduction of the magnetic field at the core element **66** in the partially saturated region **70** of FIGURE 5, when the key member **16** is actuated, may be limited.

The core element **66**, which may be made of a ferrite material or other material having suitable magnetic properties, represented by the curves in FIGURE 5, has a signal input lead **72** which is magnetically coupled to the core element **66** by a loop or winding **74** which is returned to ground potential, and has a signal output lead **76** which is also magnetically coupled with the core element **66** by a loop or winding **78** which is similarly returned to ground potential.

A signal generator **80** provides a signal with constant amplitude which may, for example, have a frequency in the range of 20 kilocycles to one megacycle. The signal from the generator **80** is delivered to a carrier modulator means **82** which also receives a signal from a tone signal generator **84**. The tone signal generator provides a signal of constant amplitude having a frequency in the audible range which is to be reproduced as a musical sound. The modulator means **82** delivers an output signal to the input lead **72** of the core element **66** comprising the carrier signal modulated by the tone or audio signal.

The signal output lead **76** is connected to the input of a tone signal detector **86** which demodulates the carrier signal and delivers the tone or audio signal to a sound producing means **88**.

In the use of the electronic musical instrument **10**, the operator manipulates the key members **16** of the keyboard **12** by depressing or striking selected ones of the keys **16**, **16'** corresponding to musical notes for producing sounds having the frequency or pitch of the selected musical notes. When a key member **16** is not depressed, the core element **66** of instrument **10** is positioned proximate to the magnetic unit **56** and has its core saturated by magnetic flux. When in this condition, the delivery of the signal to the input winding **74** of the core **66** does not change the flux density within the core **66** due to its saturated condition. Hence, the flux does not vary in the core **66** and a signal voltage is not induced in the winding **78**, so that an output signal is not delivered to the output lead **76** of the core element **66**. Thus, no sound is produced by the means **88** under such conditions. However, when a key member **16** or **16'** is depressed or struck, the magnetic unit **56** is moved away from the core element **66** and the core element **66** is no longer fully saturated, but operates along the portion **70** of the curve shown in FIGURE 5. Under the circumstances, the magnetic field produced by the input winding **74** does have an affect and varies the magnetic flux in the core **66**, so that an output signal is induced in the winding **78** which is delivered to the output lead **76** of the core element **66**. Thus, a signal is delivered to the detector **86** which delivers an audio signal to the sound producing means **88** for providing a sound with the tone or frequency of the signal delivered by the signal generator **84**. It is particularly noted that the degree of saturation of the core element **66** decreases responsive to the amount that the key member **16** is depressed. Also, the slope of the curve in the region **70** increases as the degree of saturation of the core element **66** decreases with the depression of the key member **16**. With the increasing slope of the portion **70** of the saturation curve, the change in flux within the core element **66** responsive to the input signal to the lead **72** correspondingly increases and induces an output signal at the output lead **76** which is correspondingly larger in amplitude. By such means, the amplitude of the sound produced by the means **88** is controlled by the extent that the key member **16** is depressed. In a like manner, the rapidity with which the key members **16** are struck or depressed and released affects the speed with which the core element **66**, which acts as a signal gate, is turned on and off. This controls a percussive or transient quality of the sound being produced by the means **88**.

The magnetic control means of the electronic instrument **10** provides a keyboard having key members **16** and **16'** which allow the production of musical tones at selected times having loudness and precussive or transient qualities determined and instantly controlled by the touch of the operator.

FIGURE 2 illustrates an electronic musical instrument **90** which is a modified form of the instrument **10**. The description provided in connection with the instrument **10** is also applicable thereto, and the differences only, therefore, will be described in detail.

In this embodiment, the carrier signal generator **80** delivers the carrier signal directly to the input lead **72** of the core element **66** and the carrier signal is received by the output lead **76** when the key member **16**, **16'** is actuated from its normal position. The output lead **76** of the core element **66** is connected to the input lead **92** of a core element **94** which may be identical to the core element **66**. The core element **94** is also provided with an output lead **96**. The input and output leads **92**, **96** are magnetically coupled with the core element **94** by being connected to the opposite ends of an inductance winding **98** about the core element **94**. The mounting block **62'** attached with the key bed **14** provides for mounting the core element **66** and supports the core element **94** proximate to a rotatable mounted magnetic unit **100**. The magnetic unit **100** is driven with a constant angular velocity by a motor **102**.

The form of the periphery of the magnetic unit **100** is shown in enlarged form in FIGURE 6*a*. The unit **100** may be made of a permanent magnet material to provide a magnetic field about its periphery **104** which varies in space as an angular function about its central axial opening **101**. Rotation of the magnetic unit **100** about an axial shaft through its opening **101** with its periphery **104** positioned proximate to the core element **94** subjects the core element 94 to a magnetic field which varies periodically with a frequency depending upon the angular velocity of the rotating unit 100.

Referring to FIGURE 5, the magnetizing force provided to the core element 94 by the unit 100 is along the region 70, representing partial saturation of the core element 94. The degree of saturation varies periodically about a point on the region 70 of the magnetizing curve in FIGURE 5 and has the affect of varying the reactance of the winding 98 coupled with the core element 94. The variation in reactance of the winding 98 which is connected in series between the lead 76 of the core element 66 and the input to the tone signal detector 86 has the affect of amplitude modulating the carrier signal delivered to the tone signal detector 86. The modulation signal has a waveform which is determined by the angularly varying space field provided by the rotating element 10 and a frequency determined by the angular velocity of the rotatable unit 100.

FIGURE 6*b* is a graphic illustration of the modulation waveform produced by the rotatable unit 100 shown in FIGURE 6*a*. Similarly, the rotatable unit 106 having a periphery with the rectangular configuration shown in FIGURE 7*a* provides a modulation waveform shown in FIGURE 7*b*, while the rotatable unit 108 of FIGURE 8*a* provides a modulation waveform shown in FIGURE 8*b*, and the rotatable unit 110 of FIGURE 9*a* provides a modulation waveform corresponding to that shown in FIGURE 9*b*. To produce the modulation waveforms shown, the rotatable units 110, 106, 108 and 110 used were magnetically polarized to provide lines of magnetic force within the units having a north-south direction perpendicular to the plane of the figures and parallel to their central axes of rotation, and rotated in the counterclockwise direction.

In the operation of the instrument 90, the actuating of the key members 16, 16′ control the amplitude and the rise time of the carrier signal which is delivered by the output lead 76. However, in this case, an unmodulated carrier signal is controllably delivered through the core element 66 to the winding 98 of the core element 94. The carrier signal which passes through the winding 98 of the core element 94 to the detector 86 has its amplitude further modulated by a periodic waveform having a predetermined frequency and harmonics. This waveform is produced by the periodically varying magnetic field produced by the rotating unit 100. By providing modulation waveforms having different harmonic contents, sounds with different varied tonal qualities may readily be produced by the means 88. Thus, the versatility of the control means of electronic musical instrument 90 is evident for producing many different effects and desired qualities by varying the configurations of the rotating units or otherwise controlling the form of the periodic magnetic force produced at the core element 94 for varying the reactance of its winding.

Referring to FIGURE 3 which discloses a magnetic control means for an instrument 112 which is a modified form of the instrument 10 being provided with a supporting block 114 connected at the end of the key bed 14 providing the rotatable unit 100′ mounted with its periphery proximate to the core element 66. Otherwise, the instrument 112 is substantially similar to the instrument 10, except as explained below. In this connection, it is also noted that the unmodulated carrier signal from the generator 80 is delivered to the input lead 72 of the core element 66.

In operation, when the key member 16 is not actuated, the proximity of the magnetic unit 56 to the core element 66 fully saturates the core element 66, thereby preventing the induction of an output signal for delivery at the output lead 76 of the core element 66. Under conditions of saturation, the varying additional field provided by the rotatable unit 100 has no affect in producing an output signal at the lead 76. This is seen from the curve of FIGURE 5 which shows that there is no variation in magnetic flux linkages in the fully saturated portion 68 due to variations in magnetizing force H.

With the actuation of the key member 16 and the displacement of the magnetic unit 56 from the core element 66, the core element 66 operates in its partially saturated region depicted as the portion 70 of the magnetization curve of FIGURE 5. The periodically varying magnetic field produced by the rotating unit 100′, at this time, is effective for varying the degree of saturation of the core element 66 and periodically varies the amplitude of the induced carrier signal being delivered to the output lead 76 of the core element 66. As explained in connection with the control means 90, a modulation signal will have a predetermined frequency providing the pitch of the sound and a harmonic content giving the tonal qualities for the sound produced by the means 88. The operation of the instrument 112 is similar to the operation of the modified forms of instruments 10 and 90 with the loudness and percussive or transient qualities of notes produced being individually and instantaneously controlled by the touch of the operator upon the key members 16 of the keyboard 12 of the electronic musical instrument 112.

Refer to FIGURE 4 which discloses a magnetic control means for an electronic musical instrument 116 which is a further modified form of the control means of the instrument 112.

The magnetic control means of the instrument 116 differs from that of the instrument 112 by providing a supporting block 118 secured with the key base 14 which supports the core element 66′ above a magnetic unit 56′. The block 118 also rotatably supports a unit 120 over the core element 66′ with its peripheral regions 122 proximate to the core element 66′.

The unit 120 is made of a material having good magnetic flux conducting properties, such as soft iron, which readily loses its magnetism so that it does not provide a permanent magnet with a magnetic field.

The core element 66′ has a signal input lead 72′ and signal output lead 76′ magnetically coupled with the core element 66′ by respective loops or windings. In its normal position, the key member 16 supports the magnetic unit 56′, which may be a permanent magnet or an electromagnet, at a distance from the core element 66′, so that the core element 66′ is not in the partially or fully saturated condition. Under such conditions, the carrier signal delivered to the input lead 72′ of the core 66′ produces a varying magnetic flux which is a function of time, inducing the carrier signal in the winding of the output lead 76′ which is delivered to the tone signal detector 86.

At this time, the rotating unit 120, which rotates at a constant predetermined angular velocity, has no affect on the operating conditions of the magnetic core element 66′ and, therefore, does not affect the amplitude of the carrier signal delivered to the output lead 76′. Since a modulated signal is not delivered to the detector 86, an audio output signal is not produced, so that the means 88 is not energized for producing an output sound.

When the key 16 is depressed, moving the magnetic unit 56′ closer to the core element 66′, its field results in the partial saturation of the core element 66′. At this time, the rotating unit 120, which provides a good magnetic path for the flux induced by the input winding energized by the lead 72′, is effective in periodically varying the degree of saturation of the core element 66′ as it rotates, due to the variation in conductivity of the magnetic flux by the unit 120 by varying the proximity of its periphery 122 to the core element 66′.

As the degree of saturation of the core element 66′ is increased from its fully unsaturated condition, the effect of the rotating unit 120 is increased, thereby increasing the modulation of the carrier signal from the generator 80 which is delivered to the tone signal detector 86. The detector 86 delivers the modulation audio signal to the sound producing means 88 for producing a tone corresponding to the key member 16 which is actuated. As previously explained in connection with the magnetic unit 100, the waveform of the modulation signal in this case is also determined by the form of the periphery 122 of the rotatable unit 120. Thus, by varying the shape of the periphery 122, modulation signals may be produced having different harmonic content, and, therefore, giving different tonal qualities which may be desired. The frequency or pitch of the sound, as determined in connection with the rotatable magnetic unit 100, is a function of the angular velocity of the unit 120 and the number of repetitive forms about the circumference 122 of the unit 120.

The disclosed magnetic control means for electronic musical instruments has versatility and affords control of loudness unavailable in the prior art and provides an instrument with the composite advantages of the piano and pipe organ by including the controls of the piano and the large variation of stops or tonal qualities available in the organ. The control of the electronic instrument by the touch of the performer allows the use of abilities already acquired in connection with the piano, while producing effects which have not been attainable in the musical sound produced by pipe organs.

It will, of course, be understood that the description and drawings, herein contained, are illustrative merely, and that various modifications and changes may be made in the structure disclosed without departing from the spirit of the invention.

What is claimed is:

1. A magnetic control means for an electronic musical instrument comprising a magnetically saturable core element having an input lead and an output lead magnetically coupled therewith; a rotatable magnetically conductive unit having a periphery positioned proximate said core element for periodically varying the degree of saturation upon saturation of said core element; a magnetic field producing device; a movable key member for controllably positioning said device with respect to said core element

for controlling the degree of saturation of said core element; and means for rotating said unit, said key member having a normal position in which said device is positioned so that said core element is unsaturated so that signals at the input lead are delivered to the output lead of said core element, and having an actuated position in which said device saturates said core element and said rotating unit periodically varies the degree of saturation of said core element by varying the conductance of magnetic flux therethrough as a function of time.

2. The means of claim 1 including a signal generating means for delivering a carrier signal to the input lead of said core element for delivery to the output lead of said core element, an audio detecting means deriving unmodulated carrier signals from the output lead of said core element when said key member is in its normal position and deriving carrier signals modulated by a periodic audio signal produced by said rotating unit and delivering an audio output signal when said key is actuated from its normal position, and a sound producing means receiving detected output signals of said detecting means for producing sounds having tone qualities and pitch related to the modulation of said carrier signal.

References Cited by the Examiner

UNITED STATES PATENTS

1,823,716	10/1931	Young	84—1.23
2,142,580	1/1939	Williams.	
2,314,496	6/1939	Hammond	84—1.27 X
2,669,670	2/1954	Eggers	84—1.01 X
2,772,594	12/1956	Rowe	84—1.11
3,133,256	5/1964	Denelsbeck et al.	332—29 X

FOREIGN PATENTS

1,308,996	10/1962	France.
1,008,094	5/1957	Germany.
1,138,995	10/1962	Germany.

ARTHUR GAUSS, *Primary Examiner.*

I. C. EDELL, *Assistant Examiner.*