Feb. 15, 1966 E. M. JONES 3,235,878

DEVICE AND METHOD FOR PRODUCING CODE MEMBERS

Filed June 18, 1962 7 Sheets-Sheet 1

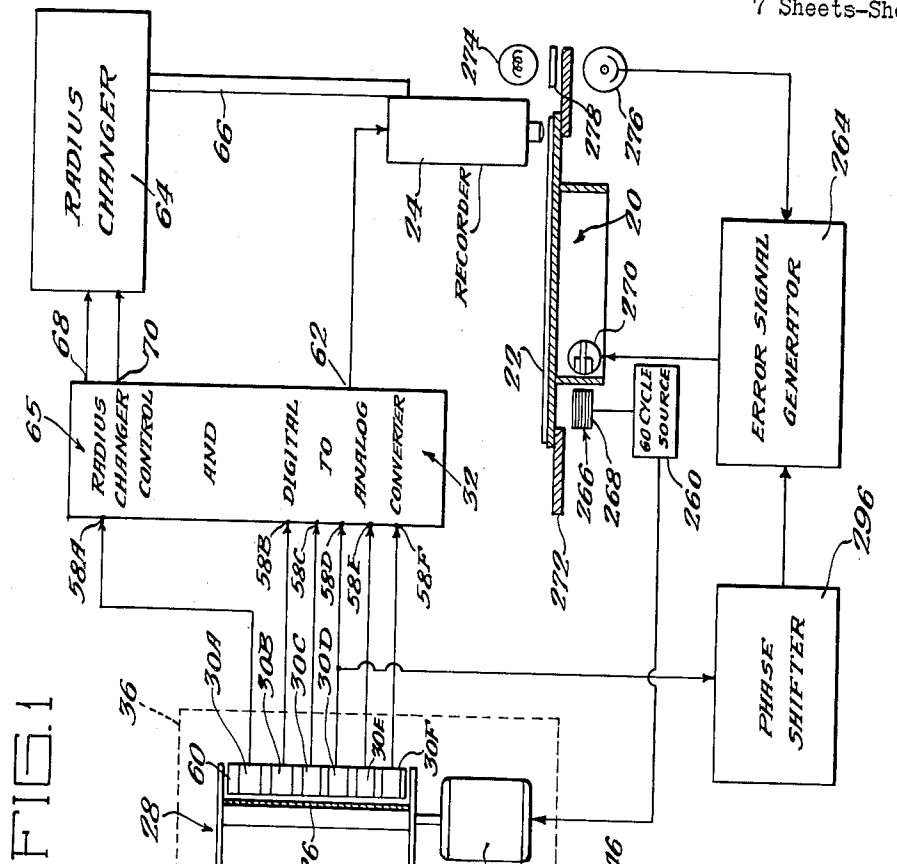


FIG. 1

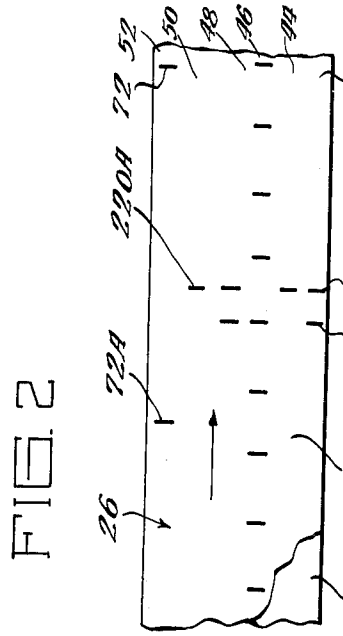


FIG. 2

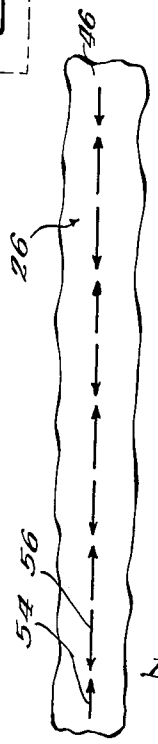


FIG. 3

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Feb. 15, 1966 E. M. JONES 3,235,878

DEVICE AND METHOD FOR PRODUCING CODE MEMBERS

Filed June 18, 1962 7 Sheets-Sheet 2

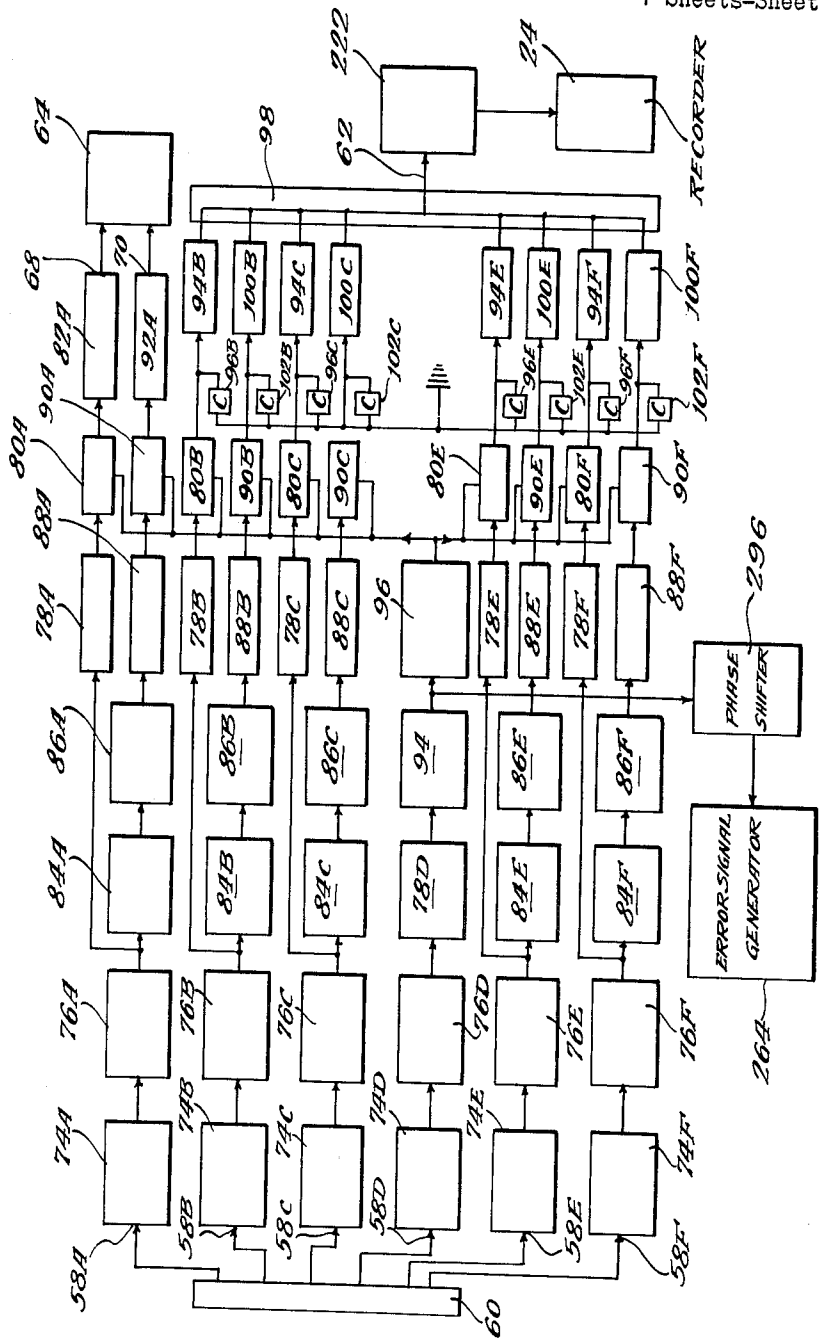


FIG. 4

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DEVICE AND METHOD FOR PRODUCING CODE MEMBERS

Filed June 18, 1962 7 Sheets-Sheet 3

FIG. 5

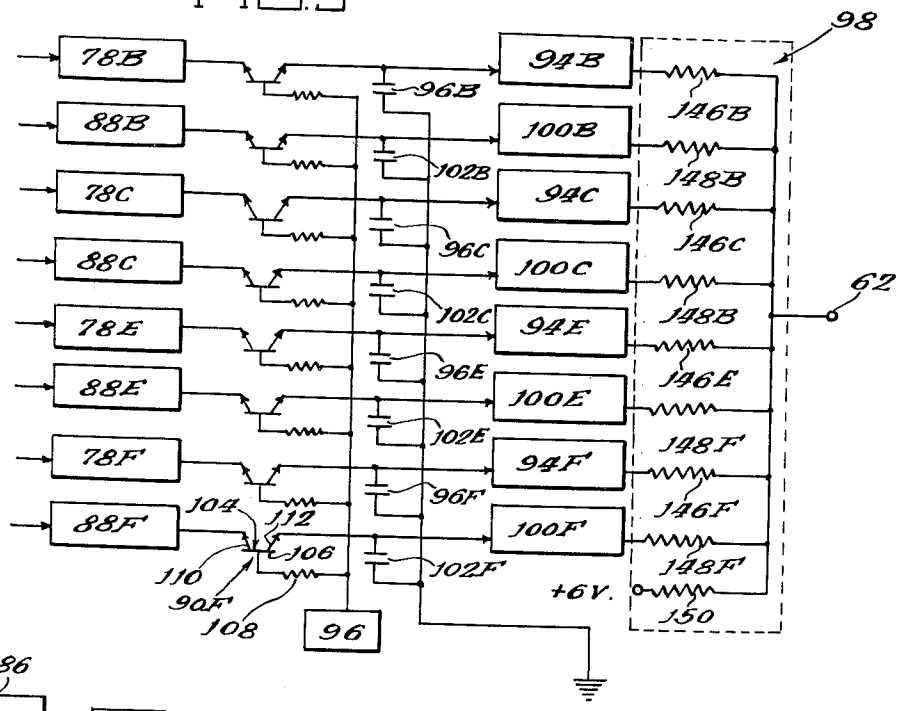
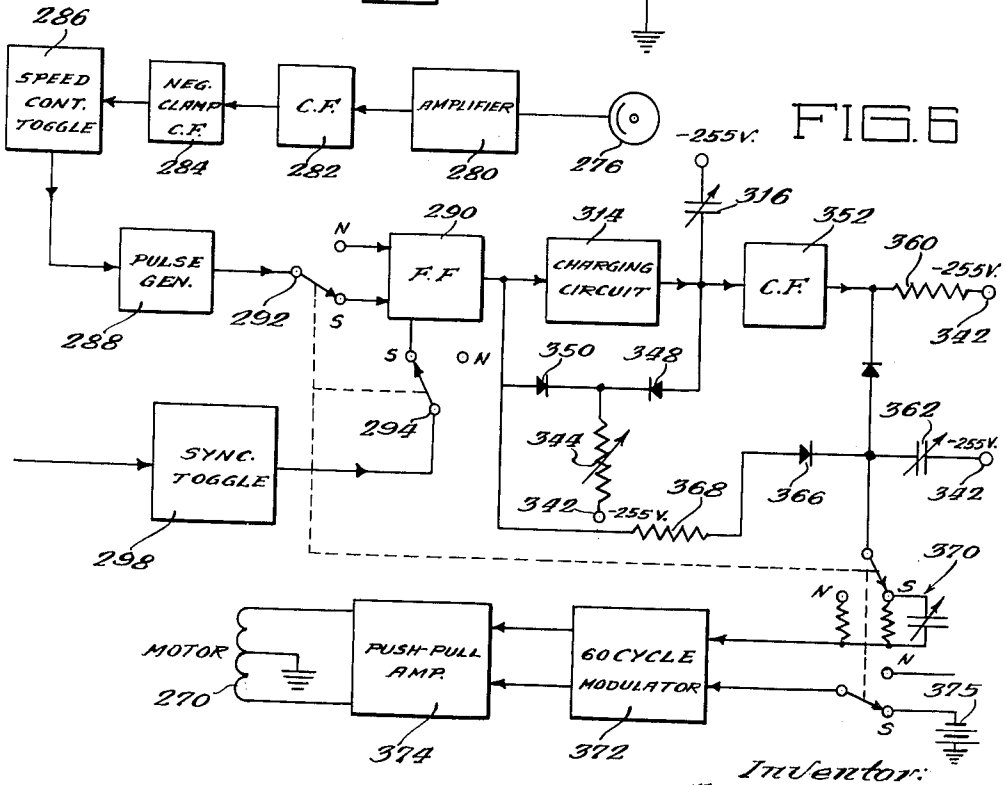


FIG. 6



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DEVICE AND METHOD FOR PRODUCING CODE MEMBERS

Filed June 18, 1962 7 Sheets-Sheet 4

FIG. 5a

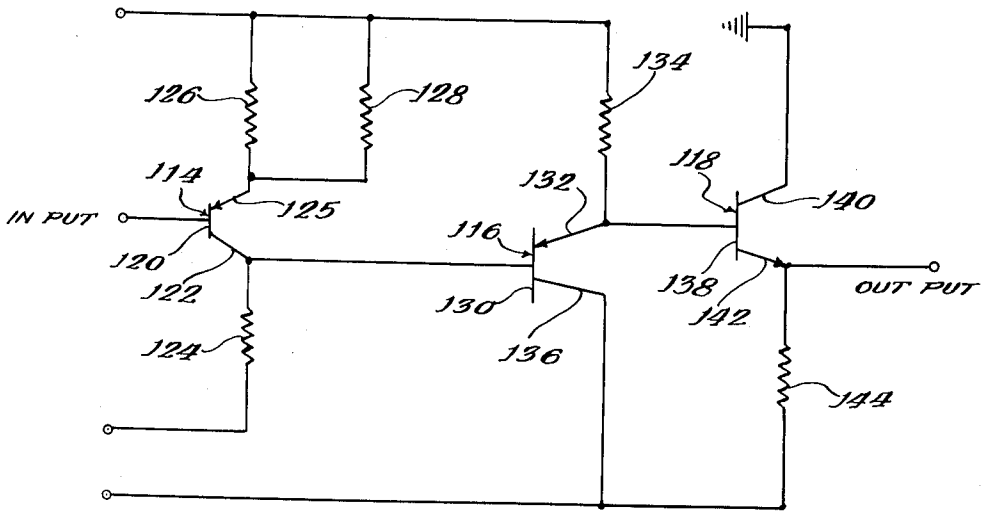
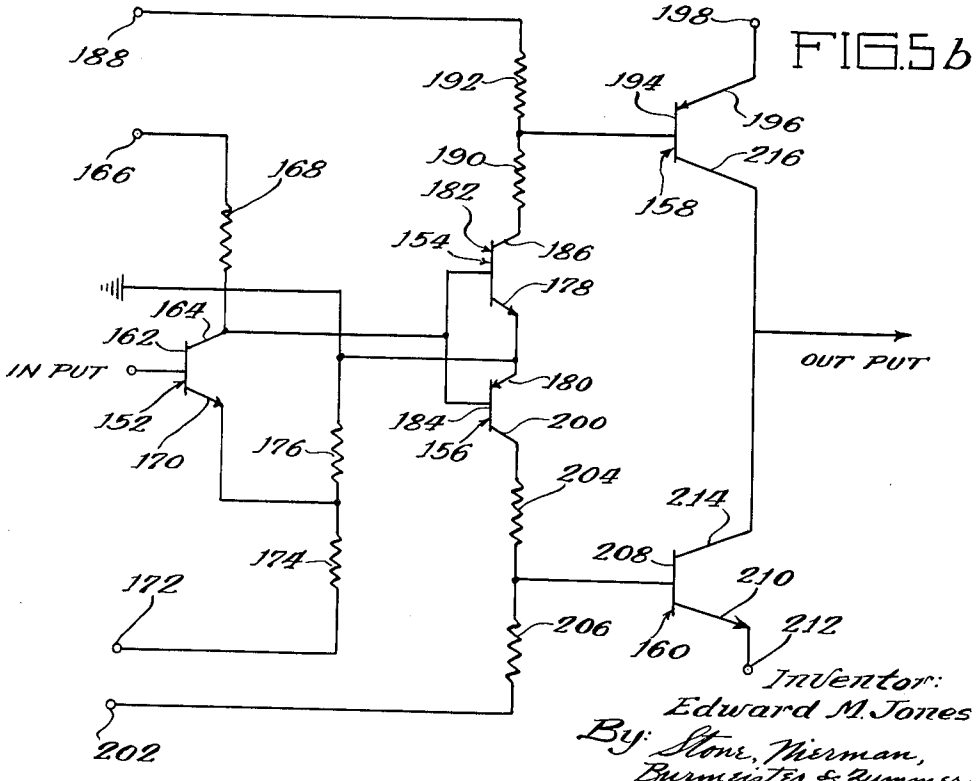


FIG. 5b



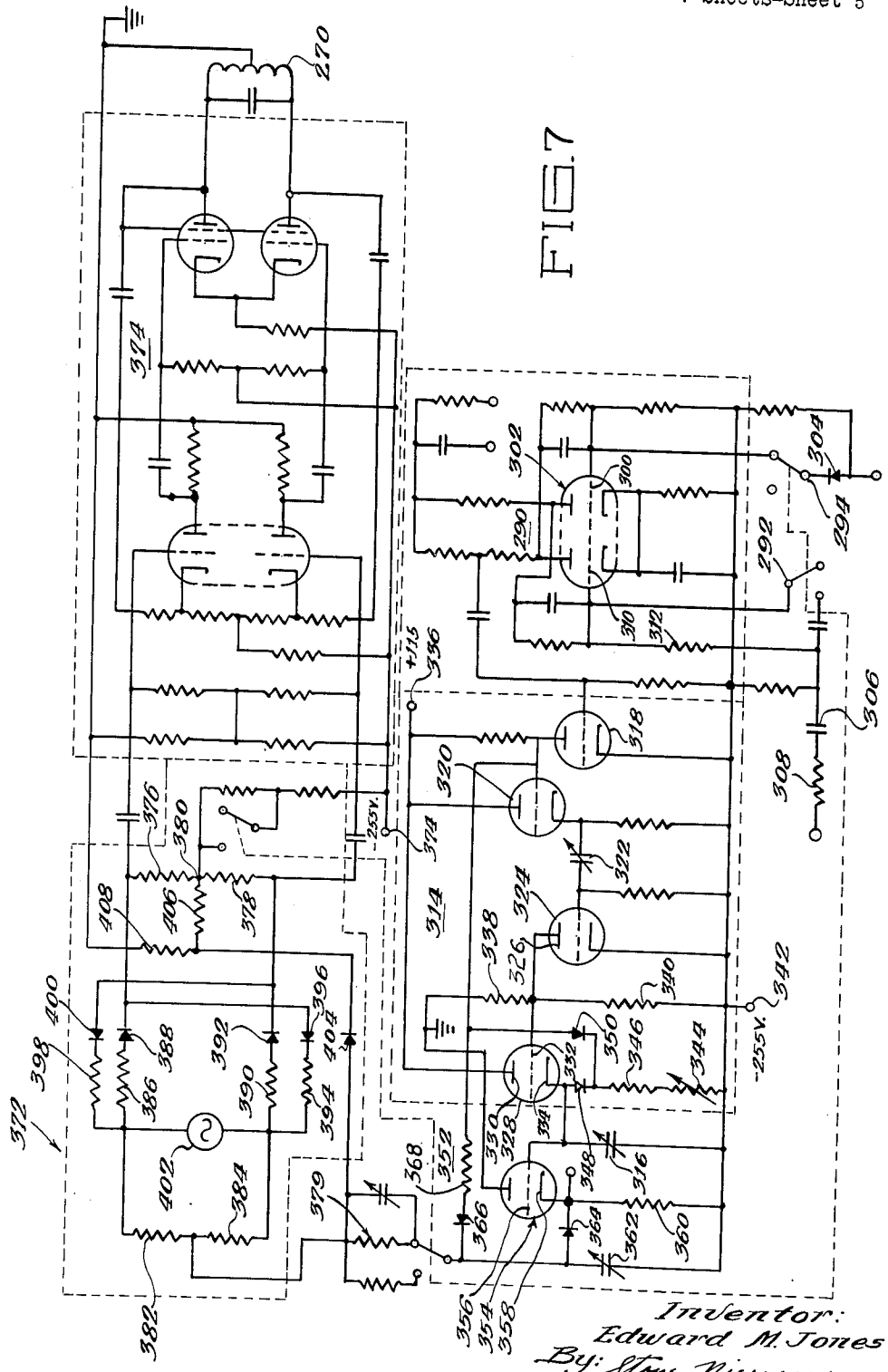
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DEVICE AND METHOD FOR PRODUCING CODE MEMBERS

Filed June 18, 1962 7 Sheets-Sheet 5

FIG. 7



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DEVICE AND METHOD FOR PRODUCING CODE MEMBERS

Filed June 18, 1962 7 Sheets-Sheet 6

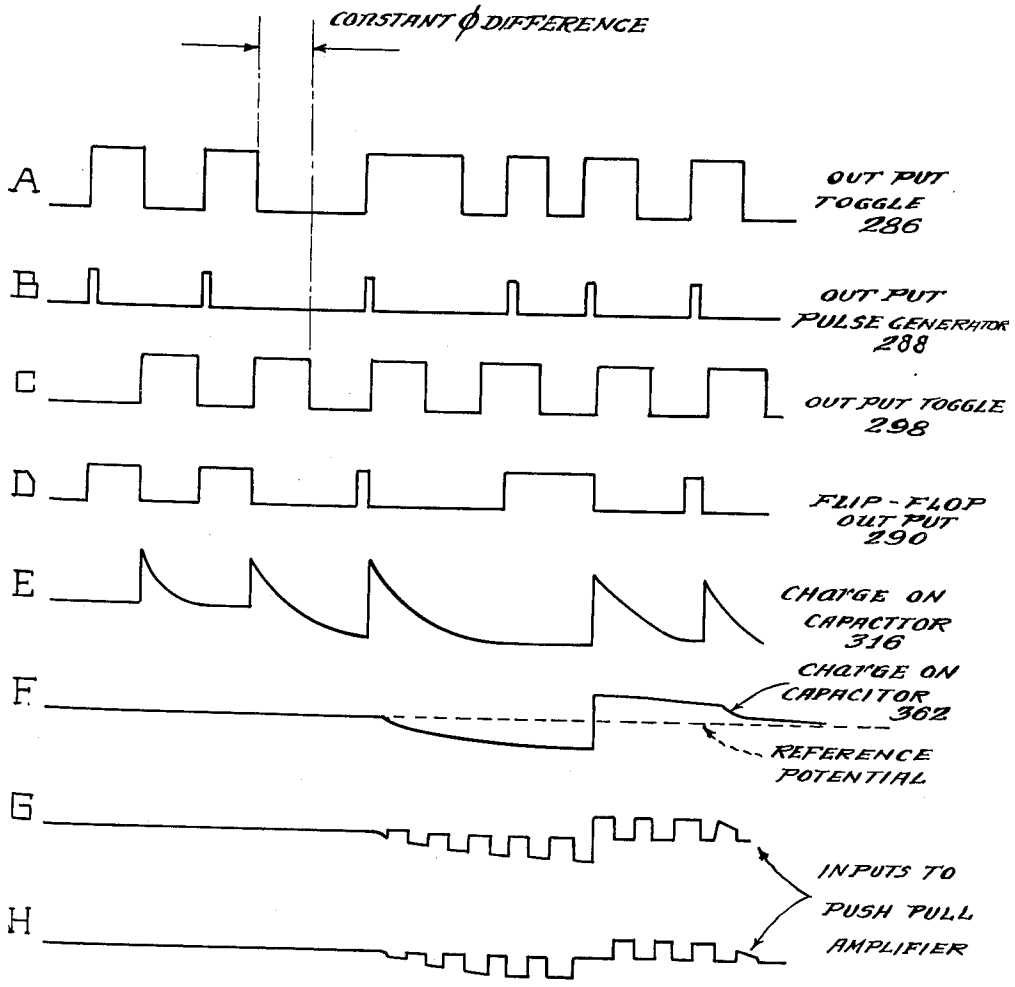


FIG. 8

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Feb. 15, 1966 E. M. JONES 3,235,878

DEVICE AND METHOD FOR PRODUCING CODE MEMBERS

Filed June 18, 1962 7 Sheets-Sheet 7

FIG. 9

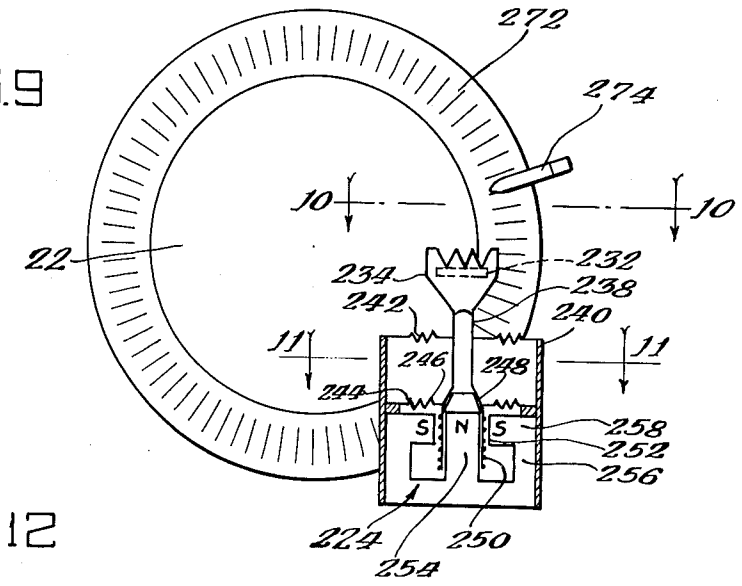


FIG 12

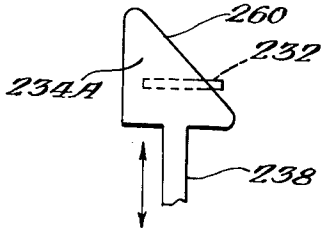


FIG. 10

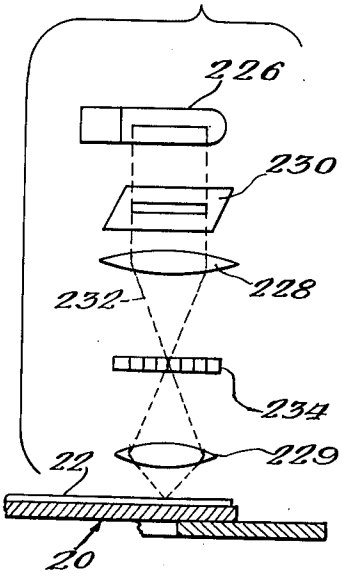
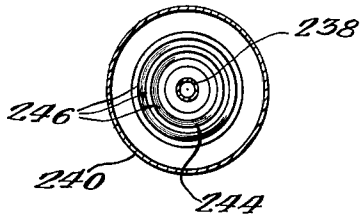


FIG. 11



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United States Patent Office 3,235,878 Patented Feb. 15, 1966

3,235,878

DEVICE AND METHOD FOR PRODUCING CODE MEMBERS

Edward M. Jones, Cincinnati, Ohio, assignor to D. H. Baldwin Company, Cincinnati, Ohio, a corporation of Ohio

Filed June 18, 1962, Ser. No. 203,354
29 Claims. (Cl. 346—33)

The present invention relates to devices for producing code members for use in electrical generators. More specifically, the present invention relates to devices and methods for producing pitch discs and voice discs for electrical organs and code discs for analog to digital encoders.

Code discs are well known for encoding analog information into binary digits. Such code discs have a plurality of annular tracks of opaque and transparent sectors coaxially disposed about the center of the code disc. An analog to digital encoder employing such a disc has a light source disposed adjacent to one side of the code disc, and a light responsive cell confronting each of the tracks of the code disc on the other side of the code disc. The code disc is mounted on a shaft, and the angular position of the shaft may be read in digital form by periodically sampling the response of the light responsive cells. Patent No. 3,023,406 entitled, "Optical Encoder," issued February 27, 1962, of the present inventor illustrates such an optical encoder.

Pitch and voice discs for use in generating tones of a photoelectric organ are of similar construction to the code discs of an optical encoder, except that the transparent areas of voice discs are either varied as to opacity, or varied in area. The present inventor's Patent No. 3,023,657, dated March 6, 1962, entitled, "Photoelectric Musical Instruments and the Like," discloses a photoelectric organ employing such a pitch disc and voice disc. Both the pitch disc and the voice disc may be produced according to the present invention.

Voice discs, pitch discs and code discs have been produced in accordance with the teachings of Patent No. 2,924,138 of the present inventor, dated February 9, 1960, and entitled, "Electronic Synchronizing System for Producing Pitch Discs and the Like." In accordance with the teachings of this patent, a photosensitive layer is rotated on the surface of a turntable rotating at a rate synchronized with a pulse generator, and the pulse generator is utilized to periodically flash a lamp focused on a small area of the turntable. In this manner, a plurality of tracks may be exposed on the photosensitive surface containing exposed areas which are a multiple of the number of pulses of the pulse generator for each rotation of the turntable. Code discs for analog to digital converters and pitch discs for electric organs may be directly produced by this equipment. Voice discs for electric organs, however, require a means to vary the intensity of light impinging upon the photosensitive surface during the period of a light flash in accordance with the desired wave form to be impressed upon the photosensitive surface. For the production of voice discs, a harmonic synthesizer is used to generate the desired wave forms and to control the intensity of the light falling on the photosensitive surface during each pulse of the pulse generator.

The method of producing code discs and voice discs disclosed in Patent No. 2,924,138, has three principal disadvantages. First, the number of light pulses per revolution of the turntable is limited to a multiple of the pulses from the synchronizing pulse generator. As a result, it has proven difficult to produce code discs for analog to digital encoders which directly read in terms of trigonometric functions, since the spacing between the

transparent sectors of such discs varies in accordance with the trigonometric function used in encoding the angular position of the disc. Second, the harmonic synthesizer must itself generate the wave forms being impressed upon voice discs for musical instruments, and the tones which may be generated by such voice discs are therefore limited by the ability of the harmonic synthesizer to generate these tones. Third, the output of the harmonic synthesizer is utilized to vary the intensity of the light source, and hence produce a variable intensity photographic disc. Photoelectric sound systems operating on variable density recordings have not proven to be as satisfactory as variable area recordings.

Patent No. 2,760,404 to King discloses a device for exposing sectors of a photosensitive surface on a turntable in which a tape transport mechanism is operated in synchronism with the turntable and indicia on tape carried by the transport mechanism are utilized to control the exposure of these sectors. By synchronizing a tape transport mechanism with the turntable, the indicia on the tape may be arranged to provide any spacing desired between light flashes focused on sectors of the photosensitive film. It is difficult, however, to synchronize the motion of the turntable with the translation of the tape transport mechanism with the accuracy required for the production of code discs, voice discs and pitch discs, and it is an object of the present invention to provide a device for producing such discs in which a light source is controlled by a tape with an improved means for synchronizing the movement of the member carrying the photosensitive film and the tape transport mechanism.

It is also an object of the present invention to provide a machine for recording wave forms on code members, such as voice discs, in which electrical signals generated from a tape represent the wave forms to be recorded and are utilized for control of the recorder. More specifically, it is an object of the present invention to provide a machine for recording wave forms on members, such as voice discs, in which a plurality of electrical signals are generated from a tape representing digitally the magnitude of the wave form, and these digital signals are converted into an analog signal for controlling the recording of the member.

It is a further object of the present invention to provide a machine for producing variable area photoelectric voice discs.

It is a further object of the present invention to provide a method for recording information on members generated from tape carrying digital indicia.

These and further objects of the present invention will become readily apparent to those skilled in the art from the following specification, particularly when viewed in the light of the drawings, in which:

FIGURE 1 is a schematic electrical diagram illustrating a device for recording indicia on a member from digital electrical signals derived from a tape;

FIGURE 2 is a fragmentary schematic view of a magnetic tape for use in the machine of FIGURE 1 illustrating the location of recorded indicia thereon;

FIGURE 3 is a schematic diagram illustrating the polarization vectors in a portion of the tape of FIGURE 2.

FIGURE 4 is a block schematic diagram of the digital to analog computer illustrated in FIGURE 1;

FIGURE 5 is a schematic electrical circuit diagram of the digital to analog converter illustrated in FIGURE 1, FIGURES 5*a* and 5*b* illustrating details thereof;

FIGURE 6 is a block schematic diagram of the error signal generator illustrated in the machine of FIGURE 1;

FIGURE 7 is a schematic electrical circuit diagram of a portion of the error signal generator illustrated in block diagram in FIGURE 6;

FIGURE 8 contains a plurality of graphs illustrating the shape of electrical waves at various locations in the circuit illustrated in FIGURE 7;

FIGURE 9 is a fragmentary view illustrating a photoelectric machine for recording variable area indicia on a photographic member;

FIGURE 10 is a sectional view of the machine illustrated in FIGURE 9 taken along the line **10**—**10** thereof;

FIGURE 11 is a fragmentary sectional view taken along the line **11**—**11** of FIGURE 9; and

FIGURE 12 is a fragmentary view illustrating a different form of shutter for use in the machine of FIGURE 9.

FIGURE 1 illustrates a turntable **20** which carries centrally thereof a disc **22** upon which indicia are to be recorded to form a code disc or a pitch disc or a voice disc. A recorder **24** confronts a portion of the disc **22** and is adapted to alter a characteristic of the disc in order to inscribe or place thereon the necessary indicia. The disc **22** may be a photographic sensitive film, and the recorder **24** may be the combination of a light source focused on the photosensitive film and a shutter for interrupting or varying the light falling upon the disc **22**. The disc **22** may also be a magnetically polarizable plate, and the recorder **24** a recording head capable of aligning polarization vectors along desired axes, as is conventional in magnetic recording.

The recorder **24** is controlled by a plurality of electrical signals generated from a tape **26** mounted on a tape transport mechanism **28**. In the embodiment of FIGURE 1, the tape **26** is a magnetic tape, and a plurality of magnetic reproducing heads **30A**, **30B**, **30C**, **30D**, **30E** and **30F** confront the tape **26** along an axis normal to the longitudinal axis of the tape **26** and in close adjacency. Each of the recording heads is separately connected to a digital to analog converter **32** which converts the electrical signals separately generated by the reproducing heads to a single electrical signal appearing at the output of the digital to analog converter **32**, and this output is electrically connected to the recorder **24**.

The tape transport mechanism **28** is driven by a synchronous electrical motor **34**, and the tape **26**, tape transport mechanism **28**, reproducing heads **30A**, **30B**, **30C**, **30D**, **30E** and **30F**, and the motor **34**, comprises a means for generating electrical signals representing digital values of a particular function to be recorded on the disc **22**, this generating means being enclosed within the dashed lines designated **36** in FIGURE 1.

A fragment of the magnetic tape **26** is illustrated in FIGURE 2, and this tape is of the type which is conventionally used with computer equipment. It is first determined that the shape of the recorded indicia on the disc **22** shall assume the form of a mathematical function, generally indicated as $f(x)$. A plurality of values for the function $f(x)$ may be calculated for exposing a plurality of sectors of a coaxial track on the turntable, and the number of values which may be used is determined by the mechanical accuracy of the equipment including the accuracy with which the tape transport mechanism **28** is synchronized with the turntable **20**.

FIGURES 2 and 3 illustrate a fragmentary portion of the tape **26** in detail. The tape **26** has an elongated strip base **38** of nonmagnetic electrically insulating material, such as paper or polyethylene plastic, and a coating **40** of ferromagnetic material is disposed on the base **38**. The coating **40** is capable of maintaining magnetic polarization, and a plurality of tracks designated **42**, **44**, **46**, **48**, **50** and **52** are disposed upon the tape **26** along parallel paths parallel to the axis of elongation of the tape. Each of the tracks represents the area confronting a single reproducing head **30** for reproducing a signal from that track of the tape when the entire tape passes the playback head assembly **60**.

Each track of the tape **26** contains a series of alternating indicia of two types, the indicia being the transitions of magnetic polarizations is opposite directions in the case of the magnetic tape **26**. FIGURE 3 shows the polarizations for the track **46**. The arrows **54** are polarized parallel to the track **46** in one direction, and the arrows **56** disposed between the arrows **54** are polarized in the opposite direction. In this manner, the reproducing head **30D** produces an electrical signal of one polarity for a transition after the arrows **54** and a signal of the opposite polarity for a transition after the arrows **56**. It is apparent that all of the other tracks of the tape **26** are also polarized in the same manner, except the length of the arrows are different between the transitions.

The magnetic tape **26** may be magnetically polarized as indicated, or in any other manner which is subject to calculation, directly from the output of an electronic computer. Most such computers directly produce its output in the form of a magnetic tape which can be used as the tape **26**. Thus, the calculated output of an electronic computer is directly useable with the equipment of FIGURE 1.

The digital to analog computer **32** is illustrated as having input terminals **58B**, **58C**, **58D**, **58E** and **58F**. These terminals are connected to the reproducing heads **30B**, **30C**, **30D**, **30E** and **30F**, respectively, which are mounted in a common housing to form a playback head assembly **60**. The digital to analog converter **32** has an output terminal **62** on which an analog signal voltage is produced which is proportional to the digital value of the signals appearing on the input terminals. FIGURE 4 illustrates in block diagram the circuit for the digital to analog converter **32**.

It will be noted in FIGURE 1 that a radius changer **64** is indicated electrically connected to the output of a radius changer control **65** which is included in an assembly with the digital to analog converter **32** and mechanically connected by an arm **66** to the recorder. It is the function of the radius changer **64** to move the recorder toward or away from the axis of the disc **22** in accordance with programming information appearing in the output of the radius changer control **65**, and two output terminals **68** and **70** are provided for that purpose. Track **52** of the tape **26** carries instructions for the radius changer **64**, and the pickup head **30A** detects the presence of an instruction signal, indicated at **72** in FIGURE 2, on the tape **26** and transmits it to the input of a preamplifier **74A**, illustrated in FIGURE 4. The output of the preamplifier **74A** is connected to the input of an undelayed signal amplifier **76A**, and the output of the undelayed amplifier **76A** is directly connected to a fullwave rectifier **78A**. The output of the fullwave rectifier **78A** is electrically connected through a gate circuit **80A** and an "in pulse" amplifier **82A** to the output terminal **68**. The output of the undelayed signal amplifier **76A** is also connected through a delay line **84A**, a delayed signal amplifier **86A**, a fullwave rectifier **88A**, a gate **90A** and an "out pulse" amplifier **92A** to the output terminal **70**. As stated above the output terminals **68** and **70** are electrically connected to the radius changer **64** and control its position.

The gates **80A** and **90A** are controlled by signals from the pickup head **30D**. The pickup head **30D** is connected to a preamplifier **74D** through the input terminal **58D**, and the output of the preamplifier **74D** is connected to the input of the undelayed amplifier **76D**. The output of the undelayed amplifier **76D** is connected to the input of a fullwave rectifier **78D**, and the output of the rectifier is connected to a resonator **94**. The output of the resonator **94** is connected to a toggle and sampling pulse generator **96**, and the output of the sampling pulse generator **96** is connected to the control input of both gates **80A** and **90A**.

The pickup head **30D** is aligned with the track **46** of the tape **26**, and each of the marks of this track, which correspond to the mark **72** of track **52**, generate an electrical pulse in the pickup head **30D** of opposite polarity to that generated between the marks, as indicated in connection with the description of FIGURE 3. The pulses of

both polarities are amplified by the preamplifier 74D and the undelayed signal amplifier 76D and impressed upon the input of the fullwave rectifier 78D. The rectifier 78D inverts the positive pulses generated by the pickup head 30D, and passes the negative pulses on to the resonator 94 substantially unchanged. The resonator 94 has the resonant frequency of 375 cycles per second, and the pulses of the track 46 of the tape 26 are spaced to generate 375 cycles per second at the rate of transportation of the tape transport mechanism 28. As a result, small errors in the position of a single mark or the omission of a single mark of the track 46 will not appreciably affect the rate of the signal impressed upon the input of the toggle and sampling pulse generator 96.

If the mark 72 of the track 52 is aligned on an axis normal to the axis of the tape 26 with a mark of the track 46, which is the synchronizing track, then a pulse will be delivered from the rectifier 78A to the gate 80A simultaneously with a pulse from the toggle and sampling pulse generator 96 impressed on the control input of the gate 80A. The gate 80A is a coincidence circuit, and will deliver a pulse to the "in pulse" amplifier 82A under these conditions, but will not deliver a pulse to the "in pulse" amplifier unless the two inputs of the gate circuit 80A receive pulses at approximately the same time.

FIGURE 2 shows the marks 72 representing magnetic polarization in the proper direction aligned with a mark on the track 46, and the result is that the "in pulse" amplifier 82A will receive a pulse when this portion of the tape confronts the playback head assembly 60. It is also to be noted that a pulse 72A is illustrated in FIGURE 2 which is located between pulses of the synchronizing track 46. Under these circumstances, the gate 80A will not pass a pulse to the "in pulse" amplifier 82A. However, the delay line 84A will delay the pulse generated by the mark 72A generated by the playback head assembly 60, and the delayed pulse will be amplified by the delayed pulse amplifier 86A and rectified by the fullwave rectifier 88A. As a result, pulses will appear on the control input terminal of the gate 90A simultaneously with the pulse impressed on the input of the gate 90A from the fullwave rectifier 88A, thus resulting in a pulse in the output of the gate 90A which is impressed upon the "out pulse" amplifier 92A. The output from the "out pulse" amplifier appears on the terminal 70, and this pulse results in the radius changer 64 moving the arm 66 in the direction to move the recorder 24 outwardly from the center of the disc 22. When a pulse appears in the output of the "in pulse" amplifier 82A, the resulting pulse impressed upon the radius changer 64 causes the arm 66 to move the recorder 24 in a direction toward the axis of the disc 22.

The radius changer 64 is diagrammatically illustrated in FIGURE 1 and is an electromechanical device for positioning the arm 66. For example, the arm 66 may be the pivotal arm of a stepping relay which is driven one step in a first direction by each pulse from the "in pulse" amplifier 82A and is driven one step in the reverse direction by each pulse from the "out pulse" amplifier 92A. Since stepping relays and stepping motors suitable for performing this low speed function are well known in the art, as indicated by Section 5.39 of "Control Engineer's Handbook," John G. Truxal, Editor, McGraw-Hill Book Co., Inc., 1958, the radius changer structure will not be described in detail.

It is to be noted that the fullwave rectifiers 78A, 78D and 88A invert positive pulses impressed thereon but transmit the negative pulses impressed thereon without substantial alteration. As a result, negative pulses are in all cases impressed upon the input of the gate circuits 80A and 90A, and these gate circuits will have an output only if coincidence exists between the pulse on the gate circuit input and on the control input of the gate circuit.

The resonator 94 has a Q which is sufficiently high to produce an output even if one of the marks of the synchronizing track 46 of the tape 26 is missing, or fails to generate a signal, but the Q of this circuit is not sufficiently high to cause appreciable phase shift due to spacing variation of the marks on the track 46 of the tape 26 which may be the result of variations of the rate of transport of the tape 26 during its recording operation.

The track 50 of the tape 26 produced electrical signals on the input 58B of the digital to analog converter 32. Input 58B is electrically connected to a preamplifier 74B, and the output of the preamplifier 74B is electrically connected to an undelayed signal amplifier 76B. The output of the undelayed signal amplifier 76B is electrically connected to the input of a fullwave rectifier 78B and the output of the fullwave rectifier 78B is electrically connected to the input terminal of a gate 80B.

The output of the undelayed signal amplifier 76B is also connected to the input of a delay line 84B, and the output of the delay line 84B is electrically connected to a delayed signal amplifier 86B. The output of the delayed signal amplifier 86B is electrically connected to a fullwave rectifier 88B, and the output of the fullwave rectifier 88B is electrically connected to the input terminal of a gate 90B. The gate 80B and the gate 90B have control input terminals which are electrically connected to the output of the toggle and sampling pulse generator 96.

In like manner, the track 48 of the tape 26 generates an electrical signal on the input terminal 58C of the digital to analog converter 32. A preamplifier 74C is electrically connected to the input terminal 58C, and the output of the preamplifier 74C is electrically connected to an undelayed signal amplifier 76C. The output of the undelayed signal amplifier 76C is connected electrically to the input of a fullwave rectifier 78C and the output of the fullwave rectifier 78C is connected to the input terminal of a gate 80C. The output of the undelayed amplifier 76C is also connected to the input of a delay line 84C, and the output of the delay line 84C is connected to the input of a delayed signal amplifier 86C. The output of the delayed signal amplifier 86C is connected to the input of a fullwave rectifier 88C, and the output of the fullwave rectifier 88C is connected to the input terminal of a gate 90C.

In like manner, track 44 of the tape 26 generates electrical pulses on the input terminal 58E of the digital to analog converter 32. The terminal 58E is electrically connected through a preamplifier 74E, and undelayed signal amplifier 76E, a fullwave rectifier 78E, to the input terminal of a gate 80E. Also, the output of the undelayed signal amplifier 76E is electrically connected to a delay line 84E, a delayed signal amplifier 86E, a fullwave rectifier 88E, to the input terminal of a gate 90E. The gates 80E and 90E also have control input terminals which are connected to the output of the toggle and sampling pulse generator 96.

Further, the track 42 of the tape 26 generates electrical signals on the input terminal 58F of the digital to analog converter 32. A preamplifier 74F, undelayed signal amplifier 76F, fullwave rectifier 78F, and gate 80F are connected to the input terminal 58F. A delay line 84F is also connected to the output of the undelayed signal amplifier 76F, and a delayed signal amplifier 86F and fullwave rectifier 88F are connected between the delay line 84F and a gate 90F. The control input of the gate 90F is also connected to the output of the toggle and sampling pulse generator 96.

The electrical signals impressed upon the input terminals 58B, 58C, 58E and 58F contain the digital input which is to be converted to an analog electrical signal. The output of the gate 80B is connected to the input of a D.C. amplifier 94B, and a capacitor 96B is connected from the input of the D.C. amplifier 94B to ground. The output of the amplifier 94B is connected to a resistor network 98.

In like manner, the output of the gate 90B is connected to the input of a D.C. amplifier 100B, and a capacitor

102B is connected from the input of this amplifier to ground.

The output of the gate 80C is connected to the input of a D.C. amplifier 94C, and a capacitor 96C is connected between the input of the amplifier 94C and ground. The output of the gate 90C is connected to the input of an amplifier 100C, and the input of the amplifier 100C is connected by a capacitor 102C to ground.

The output of the gate 80E is connected to the input of a D.C. amplifier 94E, and the input of the amplifier 94E is connected to ground through a capacitor 96E. In like manner, the output of the gate 90E is connected to the input of a D.C. amplifier 100E, and the input of the amplifier 100E is connected to ground through a capacitor 102E.

The output of the gate 80F is connected to the input of a D.C. amplifier 94F, and the input of the amplifier 94F is connected to ground through a capacitor 96F. Also, the output of the gate 90F is connected to the input of a D.C. amplifier 100F and a capacitor 102F is connected between the input of the D.C. amplifier 100F and ground. The output of the D.C. amplifiers 94B, 100B, 94C, 100C, 94E, 100E, 94F and 100F are connected to the resistor network 98.

FIGURE 5 illustrates in greater detail the electrical circuit of a portion of the digital to analog converter circuit illustrated in FIGURE 4 by block diagram including the resistor network 98, the fullwave rectifiers 78B, 88B, 78C, 88C, 78E, 88E, 78F and 88F, and the intervening circuits, including the electrical circuit diagram for each of the gates 80B, 90B, 80C, 90C, 90E, 80F and 90F. Also, FIGURE 5*a* illustrates the circuit diagram for one of the full-wave rectifiers 88F. FIGURE 5*b* illustrates the circuit for one of the D.C. amplifiers 100F.

It will be noted that each of the gate circuits utilizes a transistor 104 with a base 106 electrically connected through a resistor 108 to the toggle and sampling pulse generator 96. The input element 110 of the transistor 104 is electrically connected to the output terminal of the fullwave rectifier 88F, and the output terminal 112 is electrically connected to input of the D.C. amplifier 100F. The transistor 104 is a symmetrical transistor, which means that it will conduct equally well in both directions. As a result, the negative pulse appearing at the output of the fullwave rectifier 88 will charge the capacitor 102F to the instantaneous negative potential of the pulse during the period in which a pulse is received from the toggle and sampling pulse generator 96, or discharge the capacitor to this value. The other gate circuits designated 80A, 90A, 80B, 90B, 80C, 90C, 80E, 90E, and 80F operate in the same manner.

FIGURE 5*a* also illustrates one of the full wave rectifiers 88F, although it is to be understood that the other full wave rectifiers 78A, 88A, 78B, 88B, 78C, 88C, 78E, 88E, and 78F may be of identical construction. The purpose of the full wave rectifiers is to invert positive pulses to negative pulses while transmitting the negative pulses substantially unaltered. In this manner, the positive and negative pulses from the tape 26 may both be utilized.

The full wave rectifier 88F employs three transistors 114, 116, and 118. The base 120 of the transistor 114 forms the input of the rectifier, and the collector 122 of the transistor 114 is connected to the negative terminal of a power source through a resistor 124. The emitter is connected to the positive terminal of a power source through a resistor 126. A balancing resistor 128 is connected in parallel with the resistor 126. The collector 122 of the transistor 114 is electrically connected to the base 130 of the transistor 116. The emitter 132 of the transistor 116 is also connected to the positive terminal of a power source through a resistor 134, and the collector 136 is connected to a negative terminal of the power source.

The emitter 132 of transistor 116 is electrically connected to the base 138 of the transistor 118, and the collector 140 of this transistor is connected to ground. The emitter 142 of the transistor 118 is connected to the same negative terminal of the power source as the collector 136 of transistor 116 through a resistor 144. The output of the full wave rectifier 88F is taken from the emitter 142 of the transistor 118 which is directly connected to the emitter 110 of the gate circuit 90F.

In the particular construction described, the positive terminal of the power source is at a potential of plus 6 volts relative to the collector 140, or ground terminal, and the collector 122 of transistor 114 is electrically connected to a terminal of the power source having a potential of minus 6 volts. The collector 136 of transistor 116 is connected to a terminal of the power source of minus 10 volts. Transistors 114 and 116 are a type 2N368, and transistor 118 is of a type 2N312.

The output of the gate 90F charges the capacitor 102F to the instantaneous value of the output of the gate 90F at the moment of a pulse from the toggle and sampling pulse generator 96. In practice, outputs from the tape 26 representing "1" always charges the condenser 102F to a potential of known value, and in the particular construction described, this potential is minus 1.4 volts. For the "0," the condenser will be discharged and in the particular construction described, this potential is approximately minus 0.4 volt or less. This mode of operation is also true for the other gate circuits in the digital to analog converter 32.

The signal from the storage capacitor 96B is fed through the D.C. amplifier 94B to a precision resistor 146B. In like manner, the charge on the capacitor 102B is conducted through the D.C. amplifier 100B to a precision resistor 148B. Also, the charge in the capacitors 96C, 102C, 96L, 102E, 96F, and 102F are conducted through the D.C. amplifiers 94C, 100C, 94E, 100E, 94F, and 100F to precision resistors 146C, 148C, 146E, 148E, 146F and 148F. The one-terminal of the resistors are all interconnected and connected to a resistor 150 which is connected to the plus terminal of a 6 volt source of direct current. Also, the interconnected resistors are connected to the output terminal 62 of the digital to analog converter 32.

The amplifiers 94B, 100B, 94C, 100C, 94E, 100E, 94F, and 100F are direct current amplifiers which have the property of saturating very accurately in both the positive and the negative directions. The output of each of these amplifiers is either a fixed positive value or a fixed negative value with very small deviations.

One of the D.C. amplifiers, 100F, is also illustrated in FIGURE 5*b*, and the other D.C. amplifiers are of identical construction. This D.C. amplifier 100F utilizes five transistors, 152, 154, 156, 158, and 160. The base 162 of transistor 152 forms the input for the amplifier 100F, and the collector 164 of the transistor 152 is connected to a positive terminal 166 of a power source through a resistor 168. The emitter 170 of transistor 152 is connected to a negative terminal 172 of the power source through a resistor 174, and a second resistor 176 connected to the emitter 170 is connected to ground. The emitter 178 of transistor 154 and the emitter 180 of transistor 156 are also connected to ground, and the base 182 of transistor 154 is connected to the collector 164 of transistor 152, as is also the base 184 of transistor 156. The collector 186 of transistor 154 is connected to the positive terminal 188 of the power source through resistors 190 and 192. The junction of the resistors 190 and 192 is connected to the base 194 of transistor 158, and the emitter 196 of transistor 158 is connected to a positive terminal 198 of the power source.

The collector 200 of transistor 156 is connected to a negative terminal 202 of a power source through two resistors 204 and 206. The junction between the resistors 204 and 206 is connected to the base 208 of transistor 160. The emitter 210 of transistor 160 is connected to a negative terminal 212 of the power source, and the col-

lector 214 of transistor 160 is connected to the collector 216 of transistor 158. The collectors 214 and 216 form the output of the D.C. amplifier 100F.

In the particular construction described, transistor 152, transistor 154, and transistor 160 are type 2N312. Transistor 156 is a type 2N369 and transistor 158 is a type 2N315A. Terminal 188 is at a potential of plus 10 volts, terminal 166 is at a potential of plus 6 volts, terminal 172 is at a potential of minus 6 volts, terminal 202 is at a potential of minus 10 volts. Terminal 198 is at a potential of plus 6 volts and terminal 212 is at a potential of minus 6 volts. With this particular amplifier, an input potential of minus 0.78 volt applied to the base 162 of transistor 152 results in an output potential of minus 6 volts, which is the output potential applied to terminal 212. When the input potential applied to the base 162 falls to minus 1.08 volts, the output potential is plus 6 volts as seen at the collectors 214 and 216. As a result, a "1" can always be expected to produce plus 6 volts at the output of the D.C. amplifier and a "0" will always produce a minus 6 volts at the output of the D.C. amplifier.

Tracks 42, 44, 48 and 50 produce all of the digital information needed from the tape 26 which is used for controlling the recorder 24. These four tracks on the tape 26 contain eight bits of information which is enough to control the variable area modulator with an accuracy of one part in 256. To achieve this, the four tracks of the tape 26 carry the information of an 8-digit binary number having values between 0 and 255. If a mark or a "1," such as the mark 218 in FIGURE 2, occurs simultaneously with a clock count, that is a mark on the track 46, the mark represents one of the least significant digits, and hence the four least significant digits of each value encoded on the tape 26 occur on axes which are normal to the axis of elongation of the tape 26 and traverse marks of the track 46 which carry the synchronizing marks. In order of increasing value, the least significant digits occur on tracks 42, 44, 48 and 50, and therefore, the output of the D.C. amplifier 94F contributes $\frac{1}{256}$ of the total voltage on the output terminal 62, the output of the amplifier 94E contributes $\frac{2}{256}$, the output of the amplifier 94C contributes $\frac{4}{256}$, and the output of the amplifier 94B contributes $\frac{8}{256}$ of the potential appearing on output terminal 62. In order to achieve this, the resistors of the resistor network 98 are selected to have the same ratios.

The most significant digits of the code impressed upon the tape 26 occur slightly ahead of the clock counts of the track 46, and in FIGURE 2, the most significant digit of track 42 is indicated by the mark 220. An electrical pulse generated by the mark 220 is delayed by the delay line 84F to occur simultaneously with an electrical pulse generated by the mark 218 of track 42. Also, the more significant digits of the tracks 44, 48, and 50 are likewise delayed to occur simultaneously with the less significant digits. The most significant digit of the tape occurs in the track 50 and is indicated by the mark 220A in FIGURE 2. The tracks 48, 44 and 42 contain decreasingly significant digits preceding the clock count. Hence, the resistor 148B is $\frac{1}{128}$ of the resistor 146F, and the resistor 146C is $\frac{1}{64}$ of that resistor. In like manner, resistors 148E and 148F are $\frac{1}{32}$ and $\frac{1}{16}$, respectively, of the value of resistor 146F.

In the particular construction described in this application, resistor 146F has a value of 160,000 ohms, and the output of the terminal 62 when all "1's," or marks, confront the playback head assembly 60, a potential of 6 volts is attained. When all "0's" confront the playback head 60 on the tape 26, the potential obtained is minus 3.13 volts. For other combinations of digits between these values, the voltage obtained is a function of the digital value of the marks or "1's" on the tape 26.

As indicated in FIGURE 4, the output from the resistor network 98 which appears on a terminal 62 is impressed upon the input of a direct current power amplifier 222. The output of the direct current power amplifier 222 is impressed upon the recorder 24. In the particular construction described in this application, the recorder 24 is in the form of a variable area light modulator, and this variable area light modulator, designated 224, is illustrated in FIGURES 9 through 11.

As illustrated in FIGURE 10, the variable area light source employs a lamp 226 which is focused on the turntable 20 by means of a lens 228, a member 230 defining a slit, and a second lens 229. The light emitted from the lamp 226 is in the form of a narrow elongated beam which falls upon the disc 22 on the turntable 20 along a radius of the disc. The image of the light from the lamp 226 falling upon the turntable 20 is indicated by the dotted line designated 232 in FIGURE 9. Lens 228 forms an intermediate image of slit 230 onto a variable area shutter 234, which, in turn, is focused on disc 22 on the turntable 20 by means of lens 229. The variable area shutter 234 is in the form of a flat plate with a plurality of indentations 236 at one edge, FIGURE 10 illustrating three such indentations. The indentations have straight edges to form teeth, and a shaft 238 extends from the opposite edge of the plate forming the shutter 234. The shaft 238 is mounted coaxially within a cylindrical housing 240, by means of a pair of compliant discs, 242 and 244, mounted on the housing 240. The discs 242 and 244 have a plurality of coaxial rings 246 which increase the compliance of the discs 242 and 244 to translation of the shaft 238 along its axis, but the discs 242 and 244 restrain motion of the shaft 238 to its axis.

The end of the shaft 238 opposite the shutter 234 has a cup shaped electrically insulating member 248 which terminates in a cylindrical portion carrying thereon a coil 250. The coil 250 is electrically connected to the output of the direct current power amplifier 222 illustrated in FIGURE 4.

The coil 250 is disposed within an annular gap 252 in a magnetic structure formed by a central pole piece 254, a yoke 256, and a plate 258. The central pole piece 254 is disposed on the axis of the coil 250 and therein, and the plate 258 has a central aperture surrounding the coil 250. The plate 258 is connected to the central pole piece 254 by the yoke 256, and the magnetic structure is magnetized to have an opposite magnetic pole confronting the coil from the central pole piece 254 from that confronting the coil from the plate 258, as illustrated.

It is to be noted that the beam of light illustrated by the dotted line 232 falling upon the shutter 234 is illustrated as totally disposed upon the shutter and blocked from impinging upon the disc 22 on the turntable 20. This represents the position of the shutter 234 for minimum output from the resistance network 98 as it appears on the terminal 62. As the marks or "1's" on the tape 26 generate signals in the playback head assembly 60, the output from the resistance network 98 will increase in accordance with the numerical value of the digital number represented by the marks, and a resulting flow of current through the coil 250 will force the shutter to move in a direction inwardly of the housing 240. As a result, the beam of light represented by the dotted line 232 will begin to pass through the teeth 236 of the shutter 234 and fall upon the photosensitive surface of the disc 22. Since the disc 22 is rotating, tracks of exposed areas on the disc 22 of varying widths will occur. As illustrated, three parallel regions representing a single track will be produced by motion of the shutter 234 relative to the beam of light.

FIGURE 12 illustrates an alternate construction for the shutter 234 illustrated in FIGURES 9 and 10. In the construction of FIGURE 12, the shaft 238 of the variable area modulator is connected to a plate shaped shutter 234A which has an edge 260 disposed at an angle to the axis of the shaft 238. The edge 260 is illustrated as partially covering the image of the beam of light as illustrated by the dashed line 232, and it is to be noted that a portion of the beam of light extends beyond the edge 260 to im-

pinge upon the disc 22 on the turntable 20. The shaft 238 is translatable in the direction of the arrow of FIGURE 12, in exactly the same manner as described in connection with FIGURE 9, thereby varying the area of the light beam 232 which is permitted to impinge upon the disc 22 on the turntable 20.

As previously stated, the motor 34 for the transport mechanism must be synchronized to the turntable 20 in order for the coaxial tracks of variable area exposure to assume the proper radial positions. As illustrated in FIGURE 1, the motor 34 is driven from an alternating current source 262 and is a synchronous motor, but the motor 34 cannot be expected to transport the tape 26 at an absolutely constant rate. For this reason, the pulses generated by the track 46 of the tape 26 are conducted to an error signal generator 264 which generates an error voltage for controlling the motor 266 which drives the turntable 20. The motor 266 is a two-phase alternating current synchronous motor and has one coil 268 connected to the alternating current source 260 and a second coil 270 or control coil connected to the output of the error signal generator.

A comparison signal for the error signal generator is generated by means of a disc 272 affixed about the periphery of the turntable 20 and carrying a coaxial track with the turntable 20 of alternate opaque and transparent sectors of equal length. A lamp 274 is disposed on one side of the track of alternate opaque and transparent sectors of the disc 272, and a photocell 276 confronts the opposite side of the track. A slit member 278 is disposed between the lamp 274 and the disc 272, so that the photocell generates an electrical signal for each transparent sector of the disc 272. This construction has been substantially described in the present inventor's Patent No. 2,924,138. The photocell 276 is connected to the error signal generator 266, and phase differences between the signals generated from the track 46 of the tape 26 and the position of the disc 272 affixed on the turntable 20 are used to control acceleration and deceleration of the turntable 20 to maintain it in synchronism with the tape 26.

FIGURE 6 illustrates the error signal generator 264 in block diagram. The photocell 276 is illustrated connected to the input of an amplifier 280, and the output of the amplifier 280 is connected to a cathode follower 282. The output of the cathode follower 282 is connected to a negative clamp cathode follower 284, and the output of this cathode follower 284 is connected to a toggle circuit 286.

The purpose of the amplifier 280 and cathode followers 282 and 284 is to amplify the output of the photocell which has essentially sine wave form. The toggle 286 converts this sine wave into a square wave, and the output of the toggle circuit 286 is impressed upon a pulse generator, or multivibrator 288.

The ouput of this pulse generator 288 is connected to one of two input terminals of a flip flop 290 through a switch 292. The flip flop 290 also has two control input terminals, and a switch 294 selects which of the control terminals is also utilized. The output of the resonator 94 which is connected to the reproducing head 30D, FIGURE 4 is electrically connected through a phase shifter 296 and a toggle circuit 298 to the pole terminal of the switch 294. As stated above, the photocell 276 generates an essentially sinusoidal wave from the movement of the disc 272 affixed at the periphery of the turntable 20, and this sinusoidal wave is impressed upon the toggle circuit 286. Essentially square wave pulses are produced by the toggle circuit, and these trigger the pulse generator 288 to produce positive short pulses of fixed amplitude.

The essentially sinusoidal waves generated by the resonator 94 are also impressed upon the toggle 298 to produce square waves.

The electrical circuit diagram of the flip flop 290 is illustrated in FIGURE 7, and the flip flop 290 is of conventional circuit design. It is to be noted that the output of the toggle 298 is connected through the switch 294 to one grid 300 of the vacuum tube 302 which is utilized in the flip flop 290, and that a diode 304 is connected in series with this circuit. Also, the output of the pulse generator 288, or multivibrator, is in the form of positive pulses, and these are fed to the grid 310 of a second triode section of the vacuum tube 302. As a result, the flip flop 290 is triggered by the positive going edge of the pulses from the pulse generator 288 in one direction, and the positive going edge of the pulse on the toggle 298 flips the flip flop 290 in the opposite direction.

FIGURE 8 shows synchrograms for the voltages at various points in the circuit illustrating operation of the error signal generator. In curve A of FIGURE 8, the rectangular pulses impressed upon the input of the multivibrator or pulse generator 288 are illustrated, and it is to be noted that the differences in the width of these square wave pulses indicate variations in speed of the turntable 20. Curve B of FIGURE 8 illustrates the narrow pulses generated by the multivibrator or pulse generator 288 which are impressed upon the input of the flip flop 290. Curve C illustrates the output from the toggle 298 which represents the clock pulses generated from the tape 26, and it is to be noted that these pulses do not vary in length in the same manner that the pulses showed in curve A. Curve D illustrates the output of the flip flop 290, and it is to be noted that the leading edge of each pulse of curve D corresponds to the positive edge of a pulse of curve A, while the trailing edge of each pulse of curve D corresponds to a positive going edge of a pulse of curve C. Also, it is to be noted that the width of the pulses vary greatly depending upon the phase relation of the pulses indicated in curves A and C.

The output of the flip flop 290, after being amplified by tube 318, is impressed upon the input of a charging circuit 314 which charges a capacitor 316. As indicated in FIGURE 7, the charging circuit 314 has an amplifier employing vacuum tube 320, and is differentiated by a capacitor 322 connected in the input of an amplifier which includes vacuum tube 324. The output of vacuum tube 324 is taken from a plate, 326, is used to trigger a saw-toothed generator which employs vacuum tube 328. Vacuum tube 328 has a plate 330, grid 332, and cathode 334. The plate 330 of vacuum tube 328 is directly connected to the positive terminal 336 of a direct current source, the negative terminal of the source being connected to ground. A grid resistor 338 is connected between the grid 332 and ground. The grid 332 is maintained at a negative potential by a resistor 340 connected to a negative terminal 342 of the direct current power source, and this negative terminal 342 is also connected to the cathode 334 through serially connected resistors 344 and 346 and a diode 348. A second diode 350 is connected between the junction between the diode 348 and the resistor 346 and the plate of vacuum tube 318 of the amplifier.

The charging circuit 314 produces a series of saw-toothed waves as indicated in curve E of FIGURE 8, and these saw-toothed waves are of different lengths. The depth of the saw-toothed waves is determined by the width of the negative going pulse of the curve D of FIGURE 8. The saw-toothed waves appear on the cathode 334 of vacuum tube 338.

A cathode follower 352 having a vacuum tube 354 is connected to the output of the charging circuit. Vacuum tube 354 has a grid 356 which is connected to the cathode 334 of vacuum tube 328. The cathode 358 of vacuum tube 354 is connected to the negative terminal 342 through a resistor 360, and a capacitor 362 is connected in parallel with the resistor 360 through a diode 364. The capacitor 362 is also connected through a diode 366 and resistor 368 to the flip-flop output D.

The saw-toothed generator utilizes the capacitor 316 and the resistors 344 and 346 to produce saw-toothed

waves. The saw-tooth waves then pass through the cathode follower 352 and are impressed upon the storage capacitor 362. The storage capacitor 362 is charged through resistor 368 and diode 366 from the plate of vacuum tube 318 as a result of the square wave pulses appearing at this point in the circuit but only to the voltage at the bottom of the saw-tooth wave. The diode 366 prevents the capacitor 362 from discharging after the charging pulse terminates. The capacitor 362 discharges through the diode 364 and the resistor 360, but only to the value of the voltage at the bottom of the saw-tooth waves. FIGURE 8 indicates the manner in which the charge on the capacitor 362 varies.

The charge on the capacitor 362 is the input to the 60 cycle modulator 372 and passes through a damping circuit 370 to the input of the 60 cycle modulator 372. The 60 cycle modulator produces two outputs indicated in FIGURE 8 by the curves G and H, and these are impressed on the input of the push-pull amplifier 374. The output of the push-pull amplifier 374 is connected to the control winding 270 of the motor 266.

The 60 cycle modulator 372 compares the signals appearing at the output of the damping circuit 370 with a fixed reference potential indicated by the battery 375 in FIGURE 6 but is actually the voltage divider terminal 380 in FIGURE 7. This fixed reference potential is applied to the junction of two resistors 376 and 378. The resistors 376 and 378 are a part of a bridge circuit, and resistors 382 and 384 are also a part of the bridge and form a junction which is connected to the output of the damping circuit 370. A resistor 386 and a diode 388 connect the resistors 382 and 376, and a resistor 390 and a diode 392 connect the resistors 378 and 384. Also, a resistor 394 and a diode 396 are connected in series between the resistor 384 and the resistor 376, and a resistor 398 and a diode 400 are connected in series between the resistors 382 and the resistor 378. An alternating current potential source 402 is connected in parallel with the resistors 382 and 384. Also, the junction between the resistors 382 and 384 is connected to the junction 380 between the resistors 376 and 378 by a diode 404 and a resistor 406, and the junction between this diode and resistor is connected to ground through a resistor 408.

The modulator 372 is a balanced bridge circuit, when the voltage at the junction between the resistors 382 and 384 is the same as at the junction 380. The resistor 390 and diode 392 are effective to connect positive pulses appearing from the A.C. source 402 between the resistor 390 and the resistor 384 to one of the inputs of the push-pull amplifier 374, and the resistor 394 and diode 396 are effective to conduct negative charges appearing at that point to the other input of the amplifier 374. In like manner, the diode 388 and resistor 386 are effective to conduct positive charges which appear between the resistor 386 and the resistor 382 to the other input of the push-pull amplifier 374, while the resistor 398 and diode 400 conduct negative charges from this point to the first input of the push-pull amplifier 374. In this manner, the unbalanced voltages from the bridge circuit are conducted to the inputs of the push-pull amplifier 374 at the rate of the alternating current source 402, which is 60 cycles in the illustrated construction.

There will be no input to the push-pull amplifier 374 if the output of the damping circuit 370 equals the reference potential of the junction 380. FIGURE 8G and FIGURE 8H illustrate the two inputs to the push-pull amplifier 374. It is to be noted that the 60 cycle modulator impresses on the input of the push-pull amplifier 374 pulses at a rate of 60 cycles per second which have amplitudes corresponding to the phase difference between the turntable 20 and the tape transport mechanism 28, as shown by the curve F of FIGURE 8.

It should also be recognized that the output of the tape 26 may be recorded on the disc 22 by conducting the output of an individual playback head 30 directly to the recorder in order to produce transparent and opaque sectors on the disc 22. In this case, the analog to digital converter 32 would not be required, and only the output from the playback head, for example 30F, would be conducted to the recorder 24 to produce sectors from a given track of the tape 26, such as the track 42 in this illustration.

It should also be recognized that the tape 26 may be replaced by a photographic film. The marks indicating "1's," designated in FIGURE 3 by the reference numeral 72, 218, 220 and 72A, are replaced by transparent sectors, and a light source and photocells replace the reproducing heads 30 of the digital signal generating means 36. In this manner, outputs may also be generated which are suitable for controling the digital to analog converter 32.

Those skilled in the art will devise many further embodiments of the present invention, and will also devise many modifications of the structure hereinbefore set forth and the methods described. It is therefore intended that the scope of the present invention be not limited by the foregoing disclosure, but rather only by the appended claims.

The invention claimed is:

1. A device for transforming a physical characteristic of a member comprising, in combination, means for mounting the member for movement, drive means mechanically coupled to the mounting means for moving the member, an energy source mounted on the mounting means for conveying energy to a portion of the member, the physical characteristic of said portion of the member being transformed from one state to another by the presence of energy from said source, and said source including means responsive to an electrical signal for modulating a characteristic of the energy conveyed from the source to the member throughout a range, means for generating electrical signals representing digital values of a function to be recorded on the member, means electrically connected to the means for generating digital values for converting the digital values into an analog electrical signal, said converting means being electrically connected to the electrically responsive means of the energy source and the magnitude of the change and physical characteristic of the member being determined by the magnitude of the change in characteristic of the energy from the source.

2. A device for transforming a physical characteristic of a member comprising, in combination, means for mounting the member for movement, drive means mechanically coupled to the mounting means for moving the member, an energy source mounted on the mounting means for emitting energy toward the member, the physical characteristic of said member being transformed from one state to another by the presence of energy from said source, and said source including means responsive to an electrical signal for modulating within a range a characteristic of the energy directed from the source on the member, means for generating electrical signals representing digital values of a function to be recorded on the member, means electrically connected to the means for generating digital values for converting the digital values into an analog electrical signal, said converting means being electrically connected to the electrically responsive means of the energy source, the magnitude of the change in physical characteristic of the member being determined by the magnitude of the change in characteristic of the energy from the source, and means for synchronizing the drive means for the member with the means for generating digital values.

3. A device for transforming a physical characteristic comprising the elements of claim 2 wherein the member comprises a disc.

4. A device for transforming a physical characteristic of a member comprising, in combination, means for mounting the member for movement, drive means me-

chanically coupled to the mounting means for moving the member, an energy source mounted on the mounting means for emitting energy toward the member, the physical characteristic of said member being transformed from one state to another by the presence of energy from said source, and said source including means responsive to an electrical signal for modulating a characteristic of the energy directed from the source on the member, means for generating electrical signals representing digital values of a function to be recorded on the member, means electrically connected to the means for generating digital values for converting the digital values into an analog electrical signal, including a plurality of gate circuits, each gate circuit having an input electrically coupled to the means for generating electrical signals representing digital values of a function, each of said electrical signals being coupled to a different gate circuit, a storage capacitor electrically connected across the output of each gate circuit, each gate circuit passing charges of the electrical signal for charging the capacitor connected thereto and discharging said capacitor in the absence of said charges, a separate means having an input connected across each capacitor for generating an output potential having a first value for charges on said capacitor greater than a threshold value and a second value for charges on said capacitor less than a threshold value, and a plurality of resistors having values in the same ratios as the numerical values of the electrical signals of the generating means, the output of each potential generating means having one terminal of a resistor connected thereto, and the other terminals of said resistors being electrically interconnected, a resistance element having one terminal electrically connected to the interconnected terminals of the resistors, and a fixed potential source connected to the other terminal of the resistance element, said converting means being electrically connected to the electrically responsive means of the energy source.

5. A device for transforming a physical characteristic of a member comprising the elements of claim 4 wherein each gate circuit includes a control input, said gate circuit conducting in either direction during periods in which a potential is impressed on said control input, in combination with a pulse generator having an output terminal electrically connected to the control input of the gate circuits.

6. A device for transforming a physical characteristic of a member comprising the elements of claim 4 wherein the means for generating an output potential having a first and a second value comprise direct current amplifiers, each amplifier having a first pnp transistor and a first npn transistor with the emitters of these transistors interconnected, a first potential source having a positive and a negative terminal and a central tap electrically connected to the emitters, a first and a second resistor electrically connected in series between the positive terminal of the power source and the collector of the npn transistor, a third and a fourth resistor connected in series between the negative terminal of the power source and the collector of the pnp transistor, a second pnp transistor and a second npn transistor, the base of the second pnp transistor being connected to the junction of the first and second resistor and the base of the npn transistor being connected to the junction between the third and fourth resistors, the collectors of said third and fourth transistors being interconnected and forming an output terminal, and a second direct current power source having a positive terminal connected to the emitter of the second pnp transistor and a negative terminal electrically connected to the emitter of the npn transistor, said second power source having a center tap electrically connected to the emitters of the first pnp and npn transistors.

7. A device for exposing the photosensitive surface of a member comprising, in combination, means for mounting the member for movement, drive means mechanically coupled to the mounting means for moving the member, a light source mounted on the mounting means directed toward the photosensitive surface of the member, said light source including means responsive to an electrical signal for modulating within a range the intensity of the light impinging on the photosensitive surface, means for generating electrical signals representing digital values of a function to be recorded on the member, means electrically connected to the means for generating electrical digital values for converting the digital values into an analogue electrical signal, said converting means being electrically connected to the electrically responsive means of the light source, the magnitude of the exposure of the photosensitive surface being determined by the intensity of light emitted by the light source, and means for synchronizing the drive means for the member with the means for generating digital values, said synchronizing means limiting movement of the member to a fixed distance for each digital value generated by the means for generating digital values.

8. A device for magnetizing a ferromagnetic member comprising the combination of claim 1 wherein the energy source includes a magnetic recording head mounted on the mounting means confronting a small portion of the ferromagnetic member, and electrically connected to the means for converting the digital values to an analogue electrical signal.

9. A device for transforming a physical characteristic of a member comprising the elements of claim 1 wherein the means for generating electrical signals representing digital values of a function to be recorded on the member comprises a tape transport mechanism, an elongated tape mounted on the tape transport mechanism, said tape having a plurality of paths parallel to the longitudinal axis of the tape containing a first segment and a second segment of different physical characteristics, the first segments being disposed between second segments, and a transducing means confronting each of said paths for generating an electrical signal responsive to the presence of first segments in said path.

10. A device for transforming a physical characteristic of a member comprising the elements of claim 9 wherein the tape has a layer of magnetically polarizable material and only the first sectors in each of said paths have polarization axes oriented in a given direction relative to the direction of motion of the tape, and each transducer comprises an electromagnetic reproducing head.

11. A device for exposing the photosensitive surface of a member comprising, in combination, means for mounting the member for movement, drive means mechanically coupled to the mounting means for moving the member, a light source mounted on the mounting means directed toward the photosensitive surface of the member, said light source including means responsive to an electrical signal for modulating within a range the intensity of the light impinging on the photosensitive surface, means for generating electrical signals representing digital values of a function to be recorded on the member, and means electrically connected to the means for generating electrical digital values for converting the digital values into an analogue electrical signal, said converting means being electrically connected to the electrically responsive means of the light source and the magnitude of the exposure of the photosensitive source being determined by the intensity of the light emitted by the light source.

12. Means for synchronizing the translation of an elongated tape on a tape transport mechanism with a turntable comprising a synchronous electric motor mechanically coupled to the tape transport mechanism and electrically connected to an alternating current source of relatively constant frequency, a transducer mounted adjacent to the path of the tape for generating an electrical signal responsive to the passing of a portion of the tape having

a particular physical characteristic adjacent thereto, said tape having a track along its length with areas with said particular characteristic spaced at equal intervals by areas of a different physical characteristic, whereby the transducer generates a plurality of pulses as the tape is translated along its path, a two phase electrical motor mechanically coupled to the turntable having two coils, one of said coils being electrically connected to the alternating current source, said turntable having a coaxial track thereon of a plurality of equally spaced areas of a first physical characteristic separated by areas of a second physical characteristic, a second transducer mounted adjacent to the turntable confronting the track for generating an electrical signal each time an area of the first characteristic passes the transducer, and an error signal generator having a first input electrically connected to the first transducer and a second input electrically connected to the second transducer, said error signal generator having an output electrically connected to the second coil of the second motor and the electrical signal of said output being a function of the difference in phase between the signals from the first and second transducers.

13. Means for synchronizing the translation of an elongated tape on a tape transport mechanism with a turntable comprising the elements of claim **12** in combination with a phase shifter electrically connected between one of the transducers and the error signal generator.

14. Means for synchronizing the translation of an elongated tape on a tape transport mechanism with a turntable comprising the elements of claim **12** wherein the first transducer comprises a magnetic pickup head, and the first areas on the tape are areas of magnetic polarization different than the second areas thereof.

15. Means for synchronizing the translation of an elongated tape on a tape transport mechanism with a turntable comprising the elements of claim **12** wherein the coaxial track on the turntable comprises a disc mounted about the periphery of the turntable having a coaxial track of equally spaced transparent sectors spaced by opaque sectors, and the second transducer comprises a light source mounted on one side of the disc confronting the track and a light responsive cell mounted on the other side of the disc confronting the light source.

16. Means for synchronizing the translation of an elongated tape on a tape transport mechanism with a turntable comprising the elements of claim **12** wherein the error signal generator comprises a first means for transforming the output of the first transducer to pulses, a second means for transforming the output of the second transducer to pulses, a flip flop having a first input electrically connected to the first means and a second input electrically connected to the second means, said flip flop being triggered one way by the output of the first means changing polarity in a particular direction and said flip flop being triggered the other way by the output of the second means changing polarity in the same direction, whereby the length of the pulses produced by the flip flop are a function of the difference in phase between the signals of the first and second transducers, and means connected between the flip flop and the second coil of the two phase electrical motor for generating a control current for said motor from the pulses at the output of the flip flop.

17. Means for synchronizing the translation of an elongated tape on a tape transport mechanism with a turntable comprising the elements of claim **16** wherein the means for generating a control current for the two phase electrical motor comprises a saw-tooth generator electrically connected to the flip flop, said saw-tooth generator being triggered by the leading edge of pulses from the flip flop and including a capacitor charging circuit with a capacitor connected in parallel with a resistor and a first diode connected in series, the capacitor discharging through the first diode to produce the saw-tooth wave, a second diode connected between the output of the flip flop and the junction between the first diode and resistor for passing charges in the opposite direction from the first diode, direct current bias means electrically connected to the junction between the capacitor and resistor for biasing said junction oppositely from the pulses in the output of the flip flop, whereby the trailing edge of the pulses of the flip flop terminates the period of discharge of the capacitor following each pulse of the flip flop, a storage capacitor and storage capacitor charging circuit including in series a first diode electrically connected to the output of the flip flop for passing pulses of the polarity of said output, the storage capacitor, and a direct current bias source connected to bias the terminal of the capacitor opposite the flip flop oppositely to the pulses therefrom, a discharge circuit for said storage capacitor including a resistor and a second diode connected in series across the storage capacitor, said second diode being connected to pass charges from the capacitor and the junction of said second diode and resistor being coupled to the output of the saw-tooth generator, a source of alternating current electrically coupled to the second coil of the two phase motor, and means electrically coupled to the storage capacitor for amplitude modulating the current from said alternating current source responsive to the potential of said storage capacitor.

18. A device for transforming a physical characteristic of a disc comprising, in combination, a turntable including a support means for mounting the disc on the turntable for rotation therewith, an energy source mounted on the turntable support confronting a portion of the turntable for emitting energy toward the disc, the physical characteristics of the disc being transformed from one state to another by energy from said source, and said source including means responsive to an electrical signal for modulating a characteristic of the energy directed from the source on the member, a tape transport mechanism, a tape carried by the tape transport mechanism having a plurality of spaced areas disposed in a track along the longitudinal axis of the tape of a different physical characteristic than other areas of said tape, and means for rotating the turntable in synchronism with translation of the tape on the tape transport mechanism comprising the elements of claim **12**.

19. A device for transforming a physical characteristic of a disc comprising the elements of claim **18** in combination with a phase shifter electrically connected between one of the transducers and the error signal generator.

20. A device for transforming a physical characteristic of a disc comprising the elements of claim **18** wherein the first transducer comprises a magnetic pickup head, and the first areas on the tape are areas of magnetic polarization different than the second areas thereof.

21. A device for transforming a physical characteristic of a disc comprising the elements of claim **18** wherein the coaxial track on the turntable comprises a disc mounted about the periphery of the turntable having a coaxial track of equally spaced transparent sectors spaced by opaque sectors, and the second transducer comprises a light source mounted on one side of the disc confronting the track and a light responsive cell mounted on the other side of the disc confronting the light source.

22. A device for transforming a physical characteristic of a disc comprising the elements of claim **18** wherein the error signal generator comprises a first means for transforming the output of the first transducer to pulses, a second means for transforming the output of the second transducer to pulses, a flip flop having a first input electrically connected to the first means and a second input electrically connected to the second means, said flip flop being triggered one way by the output of the first means changing polarity in a particular direction and said flip flop being triggered the other way by the output of the second means changing polarity in the same direction, whereby the length of the pulses produced by the

flip flop are a function of the difference in phase between the signals of the first and second transducers, and means connected between the flip flop and the second coil of the two phase electrical motor for generating a control current for said motor from the pulses at the output of the flip flop.

23. A device for exposing the photosensitive surface of a member comprising in combination, means for mounting the member for movement, drive means mechanically coupled to the mounting means for moving the member, a light source mounted on the mounting means directed toward the photosensitive surface of the member including a light shutter having a flat plate with an edge disposed on an axis normal to the direction of motion of said surface, a plurality of spaced indentations extending into said plate from said edge, each indentation having a surface disposed at an angle less than a right angle to said edge, means for mounting the plate for translation parallel to the direction of motion of the member, an electromechanical driver mechanically coupled to the plate for reciprocating said plate parallel to the direction of motion of the member, means for collimating the light of the source into a straight elongated beam impinging on the plate parallel to the edge thereof, and means for focusing the transmitted light onto the photosensitive surface, means for generating electrical signals representing digital values of a function to be recorded on the member, and means electrically connected to the means for generating electrical digital values for converting the digital values into an analog electrical signal, said converting means being electrically connected to the electromechanical driver of the light source.

24. A device for exposing the photosensitive surface of a member comprising the elements of claim 23 wherein the electromechanical driver comprises a shaft mounted on the plate of the shutter and extending therefrom normal to the edge of the shutter, a coil mounted on the shaft on an axis parallel to the surface of the member and normal to the edge of the plate, said coil being electrically connected to the means for converting the digital values to an analog electrical signal, and a magnetic circuit including a magnet and a magnetic gap, the coil being disposed within the magnetic gap.

25. An intensity modulated light source comprising a light generator, a light shutter disposed adjacent to the light generator and having a flat plate provided with a plurality of spaced indentations extending into said plate from an edge thereof, each indentation having a surface disposed at an angle less than a right angle to said edge, means for mounting the plate for translation normal to the edge of the plate, an electromechanical driver mechanically coupled to the plate for reciprocating said plate normal to the edge thereof, means for collimating the light of the source into a straight elongated beam impinging on the plate parallel to the edge thereof, means for generating electrical signals representing digital values of a function for modulating the light of said source, and means electrically connected to the means for generating electrical digital values for converting the digital values into an analog electrical signal, said converting means being electrically connected to the electromechanical driver.

26. A modulated light source comprising the combination of claim 25 wherein the electromechanical driver comprises a shaft mounted on the plate of the shutter and extending therefrom normal to the edge of the shutter, a coil mounted on the shaft on an axis parallel to the surface of the member and normal to the edge of the plate, said coil being electrically connected to the means for converting the digital values to an analog electrical signal, and a magnetic circuit including a magnet and a magnetic gap, the coil being disposed within the magnetic gap.

27. An intensity modulated light source comprising a light generator, a light shutter disposed adjacent to the light generator and having a flat plate provided with a plurality of spaced indentations extending into said plate from an edge thereof, each indentation having a surface disposed at an angle less than a right angle to said edge, means for mounting the plate for translation normal to the edge of the plate, an electromechanical driver mechanically coupled to the plate for reciprocating said plate normal to the edge thereof responsive to an electrical signal, and means for collimating the light of the source into a straight elongated beam impinging on the plate parallel to the edge thereof.

28. A modulated light source comprising the combination of claim 27, wherein the electromechanical driver comprises a shaft mounted on the plate of the shutter and extending therefrom normal to the edge of the shutter, a coil mounted on the shaft on an axis parallel to the surface of the member and normal to the edge of the plate, said coil being electrically connected to the means for converting the digital values to an analog electrical signal, and a magnetic circuit including a magnet and a magnetic gap, the coil being disposed within the magnetic gap.

29. Means for synchronizing the translation of an elongated tape on a tape transport mechanism with a turntable comprising a motor mechanically coupled to the tape transport mechanism, a transducer mounted adjacent to the path of the tape for generating an electrical signal responsive to the passing of a portion of the tape having a particular physical characteristic adjacent thereto, said tape having a track along its length with areas with said particular characteristic, whereby the transducer generates a plurality of pulses as the tape is translated along its path, a second motor mechanically coupled to the turntable, said second motor having an electrical input terminal and rotating at a rate responsive to an electrical signal applied on said input terminal, said turntable having a coaxial track thereon of a plurality of equally spaced areas of a first physical characteristic separated by areas of a second physical characteristic, a second transducer mounted adjacent to the turntable confronting the track for generating an electrical signal each time an area of the first characteristic passes the transducer, and an error signal generator having a first input electrically connected to the first transducer and a second input electrically connected to the second transducer, said error signal generator having an output electrically connected to the input terminal of the second motor, and the electrical signal of said output being a function of the difference in phase between the signals from the first and second transducers.

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