



Feb. 9, 1971

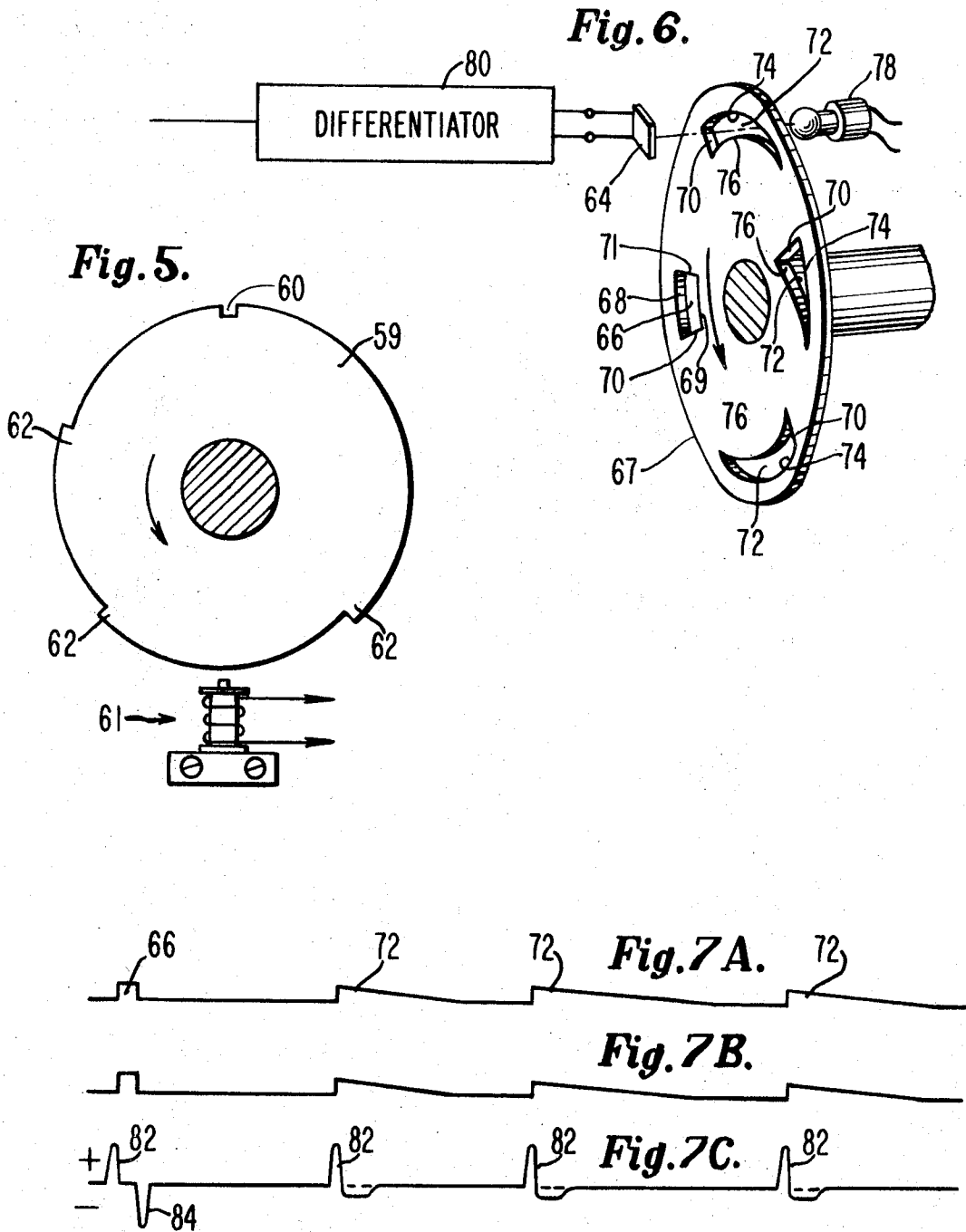
J. C. McEVOY ET AL

3,562,741

ELECTROMAGNETIC PULSE GENERATING SYSTEM

Filed April 5, 1967

2 Sheets-Sheet 2



INVENTORS.

JOHN C. McEVOY.  
PAUL R. HOFFMAN.

BY *Russell C. Wells*  
ATTORNEY.

1

3,562,741

## ELECTROMAGNETIC PULSE GENERATING SYSTEM

John C. McEvoy, Livonia, and Paul R. Hoffman, Farmington, Mich., assignors to Burroughs Corporation, Detroit, Mich., a corporation of Michigan  
Filed Apr. 5, 1967, Ser. No. 628,670

Int. Cl. G08c 9/04

U.S. Cl. 340—347

6 Claims

### ABSTRACT OF THE DISCLOSURE

A system utilizing a single transducer and a mechanically translatable member for generating a plurality of electrical timing signals representing discrete positions of the translatable member including a reference or bench mark signal. The bench mark signal is bipolar and the remaining timing signals are essentially unipolar. The polarity of the signals is dependent upon the shape of projections on the periphery of a rotating disc. The bipolar signal is generated from a substantially rectangular projection, and the unipolar signal is generated from a sawtooth-shaped projection.

### BACKGROUND OF THE INVENTION

#### Field of invention

This invention relates to electromagnetic pulse generating systems utilizing a single reluctance transducer in combination with a movable element which has a plurality of characteristic shapes thereon. Such a pulse generating system may be used as a position encoder developing pulses that are used to control the time of operation of several different mechanisms of a machine such as is found in a card punch machine.

#### Description of the prior art

Prior art pulse generating system devices have included edge coded members which are linearly or rotatably translatable. The coding may be disposed in a series of regular geometric outlines such as slots or projecting teeth of various shapes including a rectilinear, wedge or triangular-shaped configurations. The reference or bench mark is customarily established by means of a special timing relation between certain adjacent coding elements. For example, if the coded element is a disc comprising a plurality of rectangular teeth spaced along the circumference of the disc, the reference or bench mark, could be a pair of adjacent teeth which are more closely spaced than are the rest of the teeth, or in the alternative, the space between a certain pair of adjacent teeth is increased beyond that of the other teeth. If a single reluctance transducer was used, then the associated circuitry contains some form of a separate timing element to indicate the home position in either one of the aforementioned systems.

Other prior art pulse generating systems have used a plurality of coded elements, one of which contains the bench mark reference location. Systems of this type character, however, have employed multiple transducers and additional electronic means to relate the reference or bench mark of the one element with the timing signals of the other elements.

### SUMMARY OF INVENTION

The invention shown herein by the preferred embodiment is a pulse generating system comprising a movable coded element which varies the reluctance of a magnetic circuit and also changes the shape of the magnetic field surrounding the transducer. An adjacently disposed sensing element interpreting both the change in the amount

2

of reluctance and the geometry of the field, provides a voltage signal in response thereto. This signal is then amplified and shaped as required by the machine.

One form of the movable element is a shaped disc mounted on a rotating shaft. Along the periphery of the disc, there are a plurality of projections which are of two characteristic shapes, the first of which is essentially rectangular in shape bounded by a pair of closely spaced apart radially extending edges and the second is essentially sawtooth in shape. The rectangular shaped projection causes a voltage generation from the sensing means which is bipolar while the sawtooth shape projection causes a voltage generation from the sensing means which is essentially unipolar.

The sensing means is a stationary coil wound around a core of an oriented magnetically hard material which is the source of the magnetic flux for the system.

### DESCRIPTION OF DRAWINGS

The invention, both as to its organization and method of operation, will best be understood by reference to the following detailed description taken in connection with the accompanying drawings, in which:

FIG. 1 is a fragmentary perspective view of the preferred embodiment of the invention;

FIG. 2 is a view of the preferred embodiment of the invention;

FIG. 3 is a series of timing diagrams showing the relationship of the tooth periphery in FIG. 3A with the output of the sensor shown in FIG. 3B, and the output of the amplifiers shown in FIGS. 3C and 3D;

FIG. 4 is a block diagram of a circuit used in conjunction with the preferred embodiment of the invention;

FIG. 5 is a plan view of a first modified form of the present invention;

FIG. 6 is a fragmentary perspective view of a second modified form of the invention; and

FIG. 7 is a schematic representation of the second modification with FIG. 7A being a linear representation of the cut outs shown in FIG. 6, FIG. 7B shows the voltage waveforms of the photovoltaic cell and FIG. 7C shows the output voltage waveforms of the differentiator.

### DETAILED DESCRIPTION

Referring to figures and characters of reference and in particular to FIG. 1, there is shown, as a preferred embodiment of the invention, a disc 10 having a plurality of teeth of various shapes on its periphery. The disc 10 is fixedly mounted on a shaft 12 which is journaled in and extends between a spaced apart pair of sideframes 14 and 16 of the machine. The shaft 12 is driven by a belt 18 from a source of power which is not shown. Mounted on the sideframe 14 is a transducer supporting member 20 which is fabricated from a magnetically soft material. The transducer 24 is mounted on the supporting member 20 in such a relationship to the disc 10 as will be hereinafter described.

At least one tooth 26 of the disc 10 is basically rectangular in shape having its edges extending outward in a radial direction from the base or root tooth diameter 28 to the crown tooth or outer disc diameter 30. The crown of the rectangular tooth 26 is essentially a portion of arc extending from one edge 29, called the leading edge, of the tooth to the other edge 31, called the trailing edge, of the tooth. The center of the arc is coincident with the center of rotation of the disc. This tooth 26, which will hereinafter be referred to as a reference tooth, provides a bench mark or home position for relating the position of each succeeding tooth 32 to the reference tooth position.

While the preferred embodiment of the invention shows

3

only one reference tooth 26, it is to be understood that this is not a limitation on the number of reference teeth which would be possible on a given disc. As an example, if the present disc was coupled to a shaft which was controlled by a fractional revolution clutching system, there could well be a reference pulse for each fractional operation of the clutch system.

Referring back to the disc 10, three teeth 32 are shown which have one edge 34 extending radially from the root diameter 28 of tooth to the crown diameter 30. This edge will hereinafter be referred to as the leading edge 34 of the tooth. In distinction to the reference tooth whose second or trailing edge extends radially from the crown diameter to the root diameter, the trailing edge of these teeth return to the root diameter of the tooth along a helical or an arcual path 36 with a radius of curvature which is not coincident with the center of rotation of the disc. Basically, these teeth 32 are essentially sawtooth in shape and will be referred to as timing teeth. Although the preferred embodiment of the invention shows three timing teeth, this number is not a limitation as more or less timing teeth could be provided as required. The angular spacing between the teeth is dependent upon the locations relative to the disc and the shaft at which the timing pulses are to be generated for the system or machine requirements.

The shaft 12 upon which the disc 10 is mounted is driven in a direction indicated by the arrow in the figures. Mounted adjacent to and radially disposed from the periphery of the disc 10 is a transducer 24 for magnetically sensing the teeth 26 and 32 and generating a series of pulses, as shown in FIG. 3B, corresponding to each radially extending tooth edge. The transducer 24 is adjustably mounted on the first side frame 14 so that the distance between the crown diameter 30 of the teeth 26 and 32 and the transducer 24 may be set for optimum pulse generation. This distance or gap has a direct relationship to the amplitude of the output pulses induced in the transducer.

The disc 10 in the preferred embodiment is fabricated from a magnetically "soft" material such as SAE C1010 steel. With the use of such a material, the response of the induced voltage is very sensitive to the change in the flux of the circuit due to the rotation of the disc.

The transducer 24 comprises a multi-turn coil 38 wound around a core 40 of magnetically "hard" material such as Alnico V. The core 40 in the preferred embodiment is magnetically orientated in such a direction that the magnetic "North" pole confronts the disc 10 and the "South" pole is mounted to the supporting member 20. It is to be noted that while in the preferred embodiment, I have positioned the core 40 with the "North" pole confronting the disc 10. This is a mere matter of selection, and the invention is not rendered ineffective if the polarity of the core 40 is reversed.

As the disc 10 rotates past the transducer 24, the magnetic lines of flux emanating from the core 40 are altered by the disc 10 and the projections thereon. In the generation of pulses, the proximity of leading edges 29 and 34 of all the teeth 26 and 32 of the disc 10, and also the trailing edge 31 of the reference tooth 26 to the transducer 24 is the ignition point in the generation of each pulse for the system. The induced electro-motive force (EMF) in the coil is a function of the rate of change of the total number of lines of flux in the circuit. At the radial extending edges of the teeth, this change is the greatest, and the basic equation for induced EMF is applicable.

$$e = \frac{Nd\phi}{dt}$$

The relationship of the tooth shape of FIG. 2 is spread out in linear fashion, as shown in FIG. 3A, with the output of the transducer 24, as shown in FIG. 3B. The abscissa of FIG. 3A represents units of angular displacement, and in FIGS. 3B, 3C and 3D the abscissa represents

4

units of time. The ordinate in FIG. 3A represents units of length while in FIGS. 3B, 3C and 3D, the ordinate represents units of voltage.

The first tooth shown in FIG. 3A represents the rectangular tooth 26 or reference tooth. The corresponding voltage waveform in FIG. 3B is bipolar having essentially equal amplitudes in both the positive and negative directions. The positive pulse 44 is substantially coincident with the leading edge 29, and the negative pulse is substantially coincident with the trailing edge 31. In FIG. 3C, a pulse 56, which is shown in phase with positive pulse 44 in FIG. 3B has fast rise and fall times giving it a square wave appearance, FIGS. 3C and 3D are the outputs of the amplifiers 40 and 42 shown in FIG. 4.

The pulses 56 shown in FIG. 3C are connected to the input 51 of a utilization circuit such as the counter 54 shown in FIG. 4. Each pulse 56 counts the counter so as to provide a discrete output signal therefrom. Each output line 55a, 55b, etc., from the counter 54 produces a unique signal corresponding to the timing of the count signals 56a, 56b, etc. As an example, the embodiment shown has four counting pulses 56a thru 56d, which are generated from the leading edge 29 of the reference tooth 26 and the three leading edges 34 of each timing tooth 32. The unique signal corresponding to pulse 56a is produced on the output line 55a of the counter 54 and is not produced on any other output line of the counter. Each output line of the counter, therefore, corresponds to a predetermined angular position of the disc 10.

The negative pulse 48 is amplified and shaped to a substantially square wave 58, as shown in FIG. 3D by the amplifier 42 shown in the circuit of FIG. 4. Pulse 56 characterized as the resetting pulse for the counter 54 is derived from the negative going signal 48 generated by the movement of the trailing edge 31 past the core 40 and is applied to the reset input 52 of the counter.

In FIG. 3B, I have shown a slightly negative waveshape 45 corresponding to each timing tooth 32. This pulse 45 is due to the slight flux change in the circuit because of the trailing edge 36 of the teeth 32 and is of a very low voltage magnitude. The circuit as shown in FIG. 4, and in particular the amplifier 42, has an input threshold voltage which is greater than the amplitude of the negative pulse 45. Thus, in effect this negative pulse 45 is of such a low signal level that it does not overcome the threshold level of the amplifier 42 to produce an output pulse.

As previously mentioned, FIG. 4 is an example of a circuit which can be used in conjunction with the pulse generating system, as herein described. The circuit shows two separate amplifying and shaping sections 41 and 42. The first section 41 is connected directly to the transducer 24 and amplifies and shapes only the positive going pulses 44 producing the essentially square wave pulse shown in FIG. 3C. The input stage of the amplifier 41 is responsive only to pulses of positive polarity and is not affected by pulses of negative polarity.

The second amplifier 42 is also a pulse shaping amplifier except that it is responsive only to the negative pulses 48 generated by the transducer 24. The diode 46 coupling the second pulse shaping amplifier 42 to the transducer 24 provides a threshold voltage level which is greater in amplitude than the amplitude of the negative pulse 45. The output of the pulse shaping amplifier 42 is supplied to the reset input 52 of the counter for resetting the counter to its "home" position.

FIG. 5 shows a modification that is basically an inversion of the preferred embodiment disc 10 comprising the disc 59 in which the reference tooth is shown as a slot 60 instead of as a projection and the timing teeth 62 are reverse sawtooth shapes. With the transducer configuration remaining the same as hereinbefore described and the disc 59 rotating in the direction indicated in FIG. 5, the output pulses due to the generated EMF in the transducer 61 are opposite that shown in FIG. 3B. That is,

5

where there is shown a positive going pulse in the preferred embodiment, in the modified form the pulse would be negative going and in like manner the negative going pulses of the preferred embodiment are positive going pulses in the modified form. In this modification, the bench mark or home position pulse which resets the counter is a positive pulse instead of a negative pulse, as in the preferred embodiment of FIG. 2.

The circuit configuration, as shown in FIG. 4, for the preferred embodiment of FIG. 2 would have to be altered in such a manner that the count pulses for the counter would come from the negative pulses generated by the transducer 61, and the reset pulse for the counter would come from the positive pulses generated by the transducer 61. The same threshold considerations which were mentioned for the negative signals of the preferred embodiment would have to be made for the positive signals of this embodiment.

FIG. 6 shows another modification of the invention featuring a multi-apertured circular disc 67 and having a photo-voltaic cell 64 as the sensing element. The outline of the apertures are determinative of the output voltage waveforms of the cell. For the reference or bench mark position, the aperture 66 is in the form of a curvilinear rectangle bounded by a first 68 and second 69 spaced apart curvilinear edges and enclosed by a first 70 and second 71 angularly spaced apart radially extending walls or edges. The first radial edge 70 will be referred to as the leading edge of the aperture, and the second radial edge 71 will be the trailing edge of the aperture. The timing marks are shown as slots 72 in the form of curvilinear triangles each of which is bounded by a third 74 and fourth 76 curvilinear edges forming two sides of a triangle, with the third side being a radially extending wall or leading edge 70. In line with the photovoltaic cell 64 and on the opposite side of the timing disc 67 is a suitable light source 78 for activating the cell 64.

In FIG. 7A, I have shown a linear representation of the apertures of FIG. 6 with the abscissa representing units of angular displacement and the ordinate representing units of length. The output voltage waveforms or pulses of the photo-voltaic cell 64 are plotted in FIG. 7B with the ordinate representing units of voltage and the abscissa representing units of time. The waveforms shown in FIG. 7B are then fed into the input of a conventional pulse differentiator circuit 80 which differentiates the waveforms and produces output pulses 82 and 84, as shown in FIG. 7C which shows voltage plotted against time. These output pulses 82 and 84 are not unlike the pulses 44 and 48 in FIG. 3B and, therefore, may be applied to the circuit of FIG. 4 in a similar manner.

In the preferred embodiment of FIG. 1, the disc 10 was fabricated from a soft steel SAE C1010. The transducer 24 comprises 5000 turns of No. 40 AWG wire wound around a core of cast Alnico V. The transducer output, as shown in FIG. 3B, is approximately 5 volts peak to peak.

We claim:

1. A timing pulse generating system comprising:
  - a carrier,
  - a rectangular shaped projection having radially extending leading and trailing edges mounted on the periphery of said carrier for generating a bipolar electrical signal,
  - a sawtooth shaped projection having radially extending leading edge mounted on the periphery of said carrier and spaced from said rectangular shaped projection for generating a unipolar electrical signal, and
  - a transducer spaced from said rectangular and said sawtooth projections and responsive to the radially extending edges of said projections to generate an electrical pulse of one polarity from said leading edge and an electrical pulse of the opposite polarity from said trailing edge.
2. A pulse generating system for indicating the posi-

6

tion of a displaceable member relative to a known reference position said system comprising:

generating means connected to said displaceable member and having a plurality of reference and timing teeth disposed along its periphery, each tooth having a radially extending leading edge and each timing tooth having a uniform trailing edge extending in an arcuate manner from the crown diameter of said timing tooth to the root diameter of the adjacent tooth and each reference tooth having a radially extending trailing edge and a uniform crown diameter extending between said radially extending leading and trailing edges,

sensing means disposed in a spaced relation from said generating means for sensing the radially extending edges of each tooth and providing a pulse of one polarity from each leading edge and a pulse of the opposite polarity from each radially extending trailing edge,

means connected to said sensing means to amplify and shape each of said pulses and to segregate the pulses of one polarity from the pulses of the opposite polarity thereby providing a reference pulse at each of said radially extending trailing edges, and

resettable utilization means connected to said last-named means and having a plurality of discrete outputs representing each and every tooth of said member and each output producing a signal substantially coincident with each of the leading edges of said teeth, said utilization means resettable by said reference pulse.

3. The combination of claim 2 wherein the generating means is a disc carrying said reference and timing teeth.

4. The combination of claim 2 wherein the sensing means is a single reluctance transducer having a multi-turn coil wound around a core of orientated magnetically hard material wherein the core supplies the magnetic flux for the pulse generating system.

5. The combination of claim 4 wherein the core is disposed from the generating means having the magnetic north pole of said core confronting the teeth of said generating means and the signal generated in the sensing means by the radially extending leading edges is positive in polarity and the signal generated in the sensing means by radially extending trailing edge is negative in polarity.

6. The combination of claim 4 wherein the core is disposed from the generating means having the magnetic south pole of said core confronting the teeth of said generating means and the signal generated in the sensing means by the radially extending leading edge is negative in polarity and the signal generated in the sensing means by the radially extending trailing edge is positive in polarity.

#### References Cited

##### UNITED STATES PATENTS

|           |         |                 |           |
|-----------|---------|-----------------|-----------|
| 2,901,170 | 8/1959  | Poole           | 340—347X  |
| 1,868,002 | 7/1932  | Dougass et al.  | 340—359   |
| 2,431,591 | 11/1947 | Snyder et al.   | 340—347X  |
| 2,796,598 | 6/1957  | Cartwright      | 340—347X  |
| 3,004,251 | 10/1961 | Rapacz          | 340—347   |
| 3,131,387 | 4/1964  | Wolff           | 340—347   |
| 3,242,469 | 3/1966  | Anderson et al. | 340—172.5 |
| 3,251,054 | 5/1966  | Simon           | 340—347   |
| 3,265,902 | 8/1966  | Wingate         | 340—347X  |
| 3,418,456 | 12/1968 | Hamisch         | 235—61.11 |
| 1,337,737 | 4/1920  | Van Der Bijl    | 310—169X  |
| 2,719,930 | 10/1955 | Lehde           | 310—111   |
| 3,098,164 | 7/1963  | Inove           | 310—111   |

MAYNARD R. WILBUR, Primary Examiner

G. R. EDWARDS, Assistant Examiner

U.S. Cl. X.R.

310—111, 168