Dec. 15, 1970 R. E. DAYTON 3,548,397

UNIT-DISTANCE ENCODER

Filed July 27, 1967

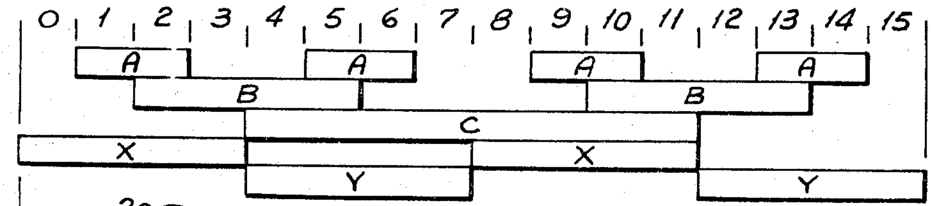


Fig 1a

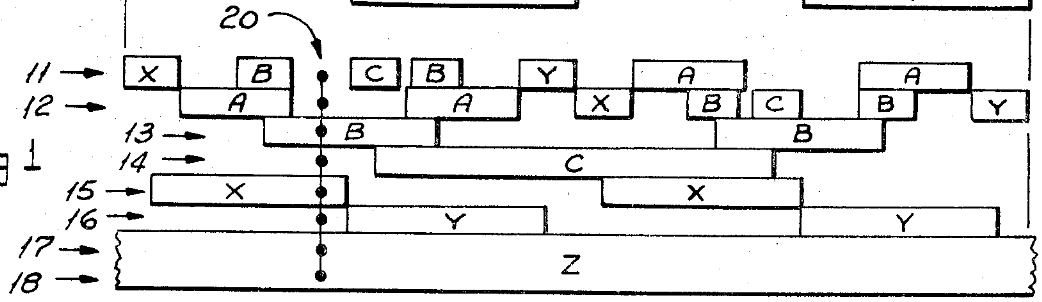


Fig 1

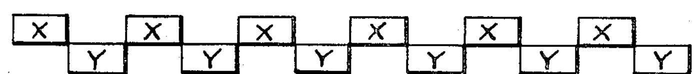


Fig 2a

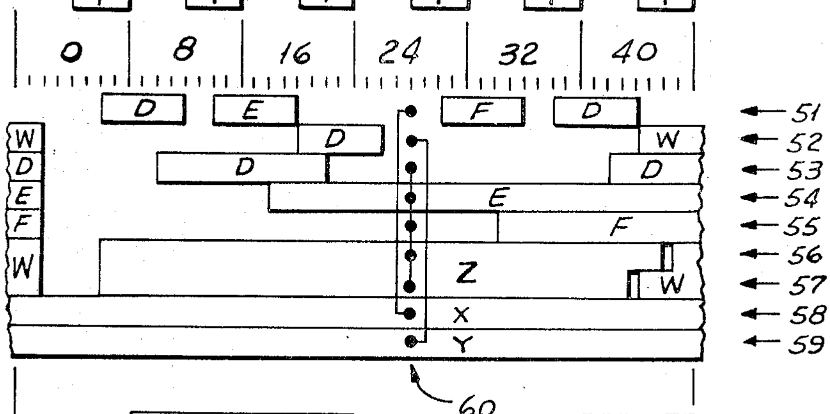


Fig 2

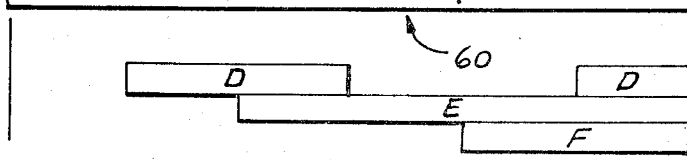


Fig 2b

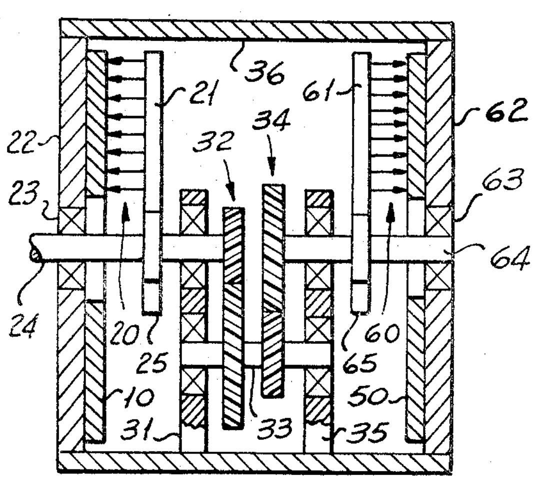
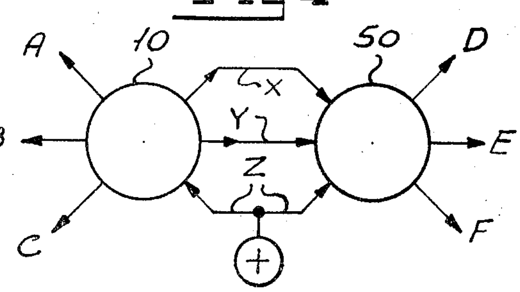


Fig 3

Fig 4



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3,548,397

UNIT-DISTANCE ENCODER

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U.S. Cl. 340—347 8 Claims

ABSTRACT OF THE DISCLOSURE

A unit-distance encoder in which all transfer points between counts are controlled by segments mounted on the two outermost tracks of greatest diameter and circumferential length.

SUMMARY OF THE INVENTION

One object of my invention is to provide a unit-distance encoder of high accuracy.

Another object of my invention is to provide a unit-distance encoder in which transfer points for all counts are controlled on the two outermost tracks of greatest diameter.

A further object of my invention is to provide a multiple-pattern unit-distance encoder of simple construction which eliminates inaccuracies due to backlash in reduction gearing without requiring auxiliary electronic components.

A still fu**r**ther object of my invention is to provide a multiple-pattern unit-distance encoder of truncated count wherein a plurality of digits may change polarity simultaneously at the recycling transfer point.

Other and further objects of my invention will appear from the following description.

DESCRIPTION OF THE DRAWINGS

In the accompanying drawings which form part of the instant specification and are to be read in conjunction therewith and in which like reference numerals are used to indicate like parts in the various views:

FIG. 1 is a developed schematic view showing the pattern and brush arrangement for the high-speed disc.

FIG. *1a* is a diagrammatic view showing the outputs provided by the high-speed pattern of FIG. 1.

FIG. 2 is a developed schematic view showing the pattern and brush interconnections for the truncated low-speed disc.

FIG. *2a* is a diagrammatic view to be read in conjunction with FIG. 2 showing the X and Y outputs of the high-speed disc of FIG. 1.

FIG. *2b* is a diagrammatic view showing the outputs provided by the low-speed pattern of FIG. 2.

FIG. 3 is a sectional elevation of my two-speed encoder.

FIG. 4 is a schematic view showing the interconnections between the high-speed and low-speed pattern discs.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. *1a* of the drawings, the high-speed pattern provides sixteen counts ranging from 0 through 15 in the Gray code. Three digits are generated.

The least significant digit is provided by the segments A; the digit of intermediate significance, by the segments B; and the most significant digit, by the segment C. It is desired to provide an A output during the **1** and **2** intervals, the **5** and **6** intervals, the **9** and **10** intervals, and the **13** and **14** intervals. It is desired to provide a B output during the **2** through **5** intervals and the **10** through **13** intervals. It is desired to provide a C output during

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the **4** through **11** intervals. It is also desired to provide X and Y outputs for eliminating ambiguities in the low-speed pattern. An X output is provided during the **0** through **3** and the **8** through **11** intervals; and a Y output is provided during the **4** through **7** and **12** through **15** intervals.

Referring now to FIG. 1, the high-speed pattern is shown broken at the **15–0** transfer point and developed. The high-speed disc **10** comprises eight circles of segments indicated generally by the reference numerals **11** through **18**. The two outermost circles or tracks comprise **11** and **12**. In track **11**, an X segment subtends the **0** interval; a B segment, the **2** interval; a C segment, the **4** interval; a B segment, the **5** interval; a Y segment, the **7** interval; and A segments subtend the **9** and **10** and **13** and **14** intervals. In track **12**, A segments subtend the **1** and **2** and the **5** and **6** intervals; an X segment subtends the **8** interval; a B segment, the **10** interval; a C segment, the **11** interval; a B segment, the **13** interval; and a Y segment, the **15** interval. In track **11**, the C and B segments adjacent the **4–5** transfer point are provided with a somewhat enlarged insulating space; and in track **12** the B and C segments adjacent the **10–11** transfer point are similarly provided with an enlarged insulating space. The purpose of this is to prevent shortcircuiting between the B and C segments due to deposition in the insulating gap of minute particles occasioned by brush wear.

Track **13** comprises B segments extending from the midpoint of the **2** interval to the midpoint of the **5** interval and from the midpoint of the **10** interval to the midpoint of the **13** interval. Track **14** comprises a C segment extending from the midpoint of the **4** interval to the midpoint of the **11** interval. Track **15** comprises X segments extending from the midpoint of the **0** interval to the **3–4** transfer point and from the midpoint of the **8** interval to the **11–12** transfer point. Track **16** comprises Y segments extending from the **3–4** transfer point to the midpoint of the **7** interval and from the **11–12** transfer point to the midpoint of the **15** interval. Tracks **17** and **18** comprise a double-width continuous Z slip ring which affords a common connection for the application of input excitation voltage. The high-speed disc comprises a multiplicity of layers. The pattern at the surface is shown in FIG. 1. All segments of the same type are electrically connected through risers which extend from the underlying layers to the surface segments shown. The remaining portion of the surface comprises electrical insulation.

A column of eight aligned brushes is indicated generally by the reference numeral **20**; and one brush engages each track. Two brushes engage the double-width Z slip ring in tracks **17** and **18** in order to reduce electrical wear by decreasing the current flow. All eight brushes **20** are shorted together.

The encoder is shown at the midpoint of the **3** interval. As the brushes move to the right relative to the stationary pattern, the **3–4** transfer point is created by the brush of track **11** contacting a C segment. At the midpoint of the **4** interval, the brush of track **14** contacts a C segment, thus insuring the continued existence of a C output. Slightly before the **4–5** transfer point, the brush of track **11** disengages a C segment; but a C output is produced because the brush of track **14** is well in engagement with a C segment. At the **4–5** transfer point, the brush of track **12** engages an A segment, thus providing the desired A output. Slightly after the **4–5** transfer point, the brush of track **11** engages a B segment, thus insuring the presence of a B output produced by the engagement of the brush of track **13** with a B segment. At the midpoint of the **5** interval, the brush of track **13** disengages a B segment; however, a B output is still produced from track **11**. At the **5–6** transfer point, the brush of track **11** disengages its B segment. At the **6–7** transfer point, the brush of track **12** disengages its A segment. Also adjacent the **6–7** transfer point, the brush of track **11** engages a Y segment, thus insuring the presence of a Y output produced by the engagement of the brush of track **16** with a Y segment. At the midpoint of the **7** interval, the brush of track **16** disengages its Y segment; however, a Y output is still produced by track **11**. At the **7–8** transfer point, the brush of track **11** disengages its Y segment; and the brush of track **12** engages its X segment.

At the midpoint of the **8** interval, the brush of track **15** engages an X segment, thus insuring the presence of an X output. At the **8–9** transfer point, the brush of track **11** engages an A segment. Also adjacent the **8–9** transfer point, the brush of track **12** disengages its X segment; however, an X output is still produced since the brush of track **15** is well in engagement with its X segment.

It will be noted that a B output is provided by track **12** in the first half of the **10** interval, by both tracks **12** and **13** during the last half of the **10** interval, by track **13** during the **11** and **12** intervals, by both tracks **12** and **13** during the first half of the **13** interval, and by track **12** during the last half of the **13** interval. Thus track **12** is effectively in control of the origination of a B output at the **9–10** transfer point and of the termination of a B output at the **13–14** transfer point. Track **11** is in control of the origination of a B output at the **1–2** transfer point and of the termination of a B output at the **5–6** transfer point. Track **11** controls the origination of a C output at the **3–4** transfer point; and track **12** controls the termination of a C output at the **11–12** transfer point.

As previously indicated, the X and Y outputs are used for controlling the low-speed pattern in order to eliminate amibigities. Only the ends of the X and Y segments adjacent the **15–0** and **7–8** transfer points are critical. Accordingly, the X and Y segments of tracks **15** and **16** are shortened adjacent these transfer points and then effectively lengthened by the overlapping X and Y segments of tracks **11** and **12**. Since the X and Y segments are not critical adjacent the **3–4** and **11–12** transfer points, the segments of tracks **15** and **16** are made substantially to coincide with these points.

Referring now to FIG. 2*a*, there is shown the region of X and Y outputs of the high-speed pattern of FIG. 1 for a multiple-pattern encoder having a maximum count of forty-eight ranging from 0 through 47, wherein the low-speed pattern revolves through one revolution while the high-speed pattern rotates through three revolutions.

Referring now to FIG. 2*b*, the low-speed pattern provides six counts in increments of eight comprising 0, 8, 16, 24, 32, and 40. Three digits are generated. The least significant digit is provided by the segments D, the digit of intermediate significance by the segment E, and the most significant digit by the segment F. It is desired to provide a D output during the **8** through **23** intervals and the **40** through **47** intervals. It is desired to provide an E output during the **16** through **47** intervals; and an F output during the **32** through **47** intervals. It will be noted that the count of the low-speed pattern is truncated, since it is not an integral power of the number "2." Accordingly the D, E, and F outputs all change polarity at the **47–0** recycling transfer point.

Referring now to FIG. 2, the low-speed pattern is shown broken at the **47–0** recycling transfer point and developed. The low-speed disc **50** comprises nine circles of segments indicated generally by the reference numerals **51** through **59**. The two outermost circles or tracks comprise **51** and **52**. In track **51**, a D segment subtends the **6** through **11** intervals; and E segment, the **14** through **19** intervals; and F segment, the **30** through **35** intervals; and a D segment, the **38** through **43** intervals. In track **52**, a D segment subtends the **20** through **25** intervals; and a W segment, the **44** through **1** intervals.

Track **53** comprises D segments subtending the **10** through **21** intervals and the **42** through **1** intervals. Track **54** comprises an E segment subtending the **18** through **1** intervals; and track **55** comprises an F segment subtending the **34** through **1** intervals. Track **56** comprises a Z segment subtending the **6** through **45** intervals and a W segment extending approximately from the midpoint of the **46** interval to the **1–2** transfer point. Track **57** comprises a Z segment extending from the **5–6** transfer point to approximately the midpoint of the **43** interval and a W segment subtending the **44** through **1** intervals. The somewhat enlarged insulating spaces of track **56** adjacent the **45–46** transfer point and of track **57** adjacent the **43–44** transfer point are provided to prevent short-circuiting between the Z and W segments due to deposition in the insulating material of minute particles occasioned by brush wear. Track **58** comprises a continuous X slip ring, and track **59** comprises a continuous Y slip ring. The low-speed disc comprises a multiplicity of layers. The surface pattern is shown in FIG. 2. Similar segments are connected by risers which extend from underlying layers to the surface segments.

A colum of nine brushes is indicated generally by the reference numeral **60**, one brush being associated with each track. The brush of track **58** is connected to the brush of track **51**; the brush of track **59** is connected to the brush of track **52**; and the brushes of tracks **53** through **57** are shorted together.

The composite encoder is shown at the midpoint of the **27** interval. As the brushes **60** move to the right relative to the stationary pattern, the brush of track **51** engages an F segment at the **29–30** transfer point. However, no F output is produced since the brushes of tracks **51** and **58** receive no excitation from the X slip ring. At the **31–32** transfer point, the X slip ring of track **58** receives excitation from the high-speed pattern; and the low-speed pattern now provides an F output, since the brush of track **51** is well in engagement with its F segment. At the **33–34** transfer point, the brush of track **55** engages the F segment, thus insuring the continued existence of an F output. Adjacent the **35–36** transfer point, the brush of track **51** disengages its F segment, and the excitation of the X slip ring **58** is removed; however, an F output is produced because the brush of track **55** is well in engagement with the F segment. The D output is similarly initiated in track **51** at the **39–40** transfer point and reinforced in track **53** at the **41–42** transfer point.

Slightly before the **43–44** transfer point or approximately at the midpoint of the **43** interval, the brush of track **57** disengages its Z segment and enters the somewhat extended insulating space. However, the brush of track **56** is still in engagement with its Z segment, so that the brushes of tracks **53** through **55** continue to receive input excitation voltage. At the **32–44** transfer point, the brushes of tracks **52** and **57** enagge their W segments; and the brush of track **52** is excited by Y slip ring **59**. Accordingly, the brush of track **57** again receives input excitation voltage reinforcing that supplied from the brush of track **56**. The brush of track **56** disengages its Z segment at the **45–46** transfer point. But the brush of track **57** supplies excitation to the brushes of tracks **53** through **55**. At the midpoint of the **46** interval, the brush of track **56** engages its W segment, thus reinforcing that supplied from the brush of track **57**.

At the **47–0** recycling transfer point, the Y output of the high-speed pattern is terminated; and no excitation is applied to Y slip ring **59**. This removes the excitation of the W segments of tracks **52**, **56**, and **57**. Since the brushes of both tracks **56** and **57** are in engagement with W segments, the excitation of the brushes of tracks **53**, **54**, and **55** is similarly removed. Thus the D, E, and F outputs are terminated simultaneously.

At the **1–2** transfer point, the brushes of tracks **52** through **57** disengage their associated segments. At the 5–6 transfer point, the brush of track **51** engages a D segment and the brushes of tracks **56** and **57** engage Z segments; however, no D output is produced, since the X slip ring of track **58** receives no excitation. The D output is initiated at the **7–8** transfer point when the X slip ring is excited. This D output is reinforced in track **53** at the **9–10** transfer point, since the brushes of tracks **56** and **57** are well in engagement with the Z segments.

An E output is similarly initiated in track **51** at the **15–16** transfer point and reinforced in track **54** at the **17–18** transfer point.

At the **19–20** transfer point, the brush of track **52** engages a D segment; and the Y slip ring is excited, thus reinforcing the D output provided by track **53**. At the **21–22** transfer point, the brush of track **53** disengages its D segment. However a D output is still produced, because the brush of track **52** engages a D segment and receives excitation from the Y slip ring **59**. At the **23–24** transfer point, the excitation of the Y slip ring is removed, and the D output is terminated.

It will be noted that the leading edges of the D, E, and F outputs are created by segments in track **51**; and the trailing edges thereof are generated by the segments in track **52**. The W segment of track **52** generates the simultaneous trailing edges of the D, E, and F outputs at the recycling transfer point.

For the high-speed pattern of FIG. 1, the tolerances in positioning the ends of the segments of the non-critical tracks **13, 14, 15,** and **16** are approximately $\pm\frac{1}{2}$ interval. For the low-speed pattern of FIG. 2, the tolerance in positioning the segments of tracks **51** through **57** is approximately ± 2 intervals including backlash in the gear trains connecting the high-speed and low-speed brush assemblies **20** and **60**. All transfer points for the low-speed pattern are controlled by the segments mounted on the two outermost tracks **51** and **52**, the brushes of which are controlled by the X and Y outputs of the high-speed pattern of FIG. 1.

Referring now to FIG. 3, the eight high-speed brushes **20** are secured to a brush holder **21** which is mounted on a high-speed input shaft **24**. Input shaft **24** is journalled in a bearing **23** mounted in an end wall **22** and in another bearing which is mounted in a hanger **31**. The high-speed brush assembly is statically and dynamically balanced by a counterweight **25**. The high-speed shaft **24** drives a countershaft **33** through a gear reduction indicated generally by the reference numeral **32** which comprises a pinion mounted on shaft **24** and a gear mounted on countershaft **33**. Countershaft **33** is supported in bearings mounted in hanger **31** and in another hanger **35**. Countershaft **33** drives the low-speed shaft **64** through reduction gearing indicated generally by the reference numeral **34** and comprising a pinion mounted on countershaft **33** and a gear mounted on low-speed shaft **64**. The speed reduction provided by **32** is 2:1; and the speed reduction provided by **34** is 1.5:1. Thus the overall speed reduction between the high-speed and low-speed shafts **24** and **64** is 3:1. The low-speed shaft **64** is journalled in a bearing **63** mounted in a second end wall **62** and in a bearing mounted in hanger **35**. The nine low-speed brushes **60** are secured to a brush holder **61** which is mounted on low-speed shaft **64** and provided with a balancing counterweight **65**. End walls **22** and **62** are secured to a cylindrical housing **36** which encloses the encoder. The high-speed pattern **10** is secured to end wall **22**, and the low-speed pattern **50** is secured to end wall **62**.

Referring now to FIG. 4, a source of input excitation voltage, which is shown as being positive, is coupled to the Z segments of patterns **10** and **50**. The X and Y output segments of the high-speed pattern **10** are connected to the respective X and Y input segments of the low-speed pattern **50**. Pattern **10** provides A, B, and C outputs from its corresponding segments; and pattern **50** provides D, E, and F outputs from its corresponding segments. The W segments of the low-speed pattern are provided only with internal connections and are not used externally.

It will be seen that I have accomplished the objects of

my invention. All transfer points are generated by segments mounted on the two outermost tracks of the high-speed disc. My unit-distance encoder accordingly has a high accuracy, since the two outermost tracks have the greatest circumferential length. The transfer points for the low-speed pattern are controlled by segments mounted on the two outermost tracks. This also affords an increase in the permissible tolerances. I have provided a multiple-pattern encoder of truncated count, wherein a plurality of digits change polarity at the recycling transfer point by utilizing auxiliary internally-connected segments which interrupt the input excitation voltage at the recycling transfer point.

It will be understood that certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and is within the scope of my claims. It is further obvious that various changes may be made in details within the scope of my claims without departing from the spirit of my invention. It is, therefore, to be understood that my invention is not to be limited to the specific details shown and described.

Having thus described my invention, what I claim is:

1. A unit-distance encoder of truncated count having a recycling transfer point at which a plurality of digits change polarity including in combination a plurality of concentric circles of segments providing a plurality of output digits, a further concentric circle having a substantially continuous slip ring which is interrupted for a short interval adjacent the recycling transfer point, and means including the further circle for exciting at least two circles of the plurality.

2. An encoder as in claim **1** in which the plurality of circles comprises a pair of outermost circles and at least two additional circles, in which the exciting means further includes a first short segment occupying a portion of the interrupted interval of the slip ring and a second short segment mounted on one of the pair of outermost circles and positioned adjacent the recycling transfer point, and in which the exciting means excites the additional circles.

3. A multiple-pattern unit-distance encoder including in combination on a high-speed pattern providing a pair of substantially complementary signals which change polarity at substantially 90° intervals, a low-speed pattern comprising at least three concentric circles of segments providing at least two output digits, means responsive to the pair of complementary signals for exciting the two outermost circles of the low-speed pattern, means comprising a first segment of one of the excited circles for initiating a first output digit, means comprising a second segment of said one of the excited circles for initiating a second output digit, means comprising a third segment of the other of the excited circles for terminating the first output digit, means comprising a fourth segment of said other of the excited circles for terminating the second output digit, means comprising a fifth segment of the third circle of the low-speed pattern for continuing the first output digit subsequent to initiation and prior to termination, means comprising a sixth segment of a circle of the low-speed pattern other than the two outermost for continuing the second output digit subsequent to initiation and prior to termination, means directly connecting the first and third and fifth segments, and means directly connecting the second and fourth and sixth segments.

4. A unit-distance encoder including in combination at least three concentric circles of segments providing at least three output digits, means comprising first segments of at least one of the two outermost circles for generating a first output digit of highest periodicity, means comprising second segments of at least one of the two outermost circles for initiating and terminating a second output digit of lower periodicity, means comprising third segments of at least one of the two outermost circles for initiating and terminating a third output digit of lower periodicity, means comprising a fourth segment of the third circle for continuing the second output digit subsequent to initiation and prior to termination, means comprising a fifth segment of a circle other than the two outermost for continuing the third output digit subsequent to initiation and prior to termination, means directly connecting the fourth segment and the second segments, and means directly connecting the fifth segment and the third segments.

5. An encoder as in claim **4** in which each initiating and terminating segment overlaps its associated continuation segment by not appreciably less than one-half the interval of one count.

6. An encoder as in claim **4** wherein the circles of segments are mounted on a stationary multiple-layer disc having a surface which is contacted by rotating brushes.

7. An encoder as in claim **3** in which each initiating

and terminating segment overlaps its associated continuation segment by an amount which corresponds to approximately 45° of the high-speed pattern.

8. An encoder as in claim **3** wherein the circles of segments are mounted on a stationary multiple-layer disc having a surface which is contacted by rotating brushes.

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