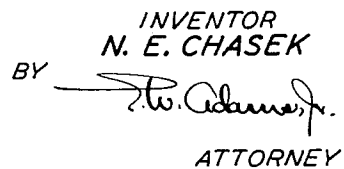


N. E. CHASEK  
ELECTRON BEAM ENCODER

Filed Dec. 28, 1959

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Nov. 12, 1963

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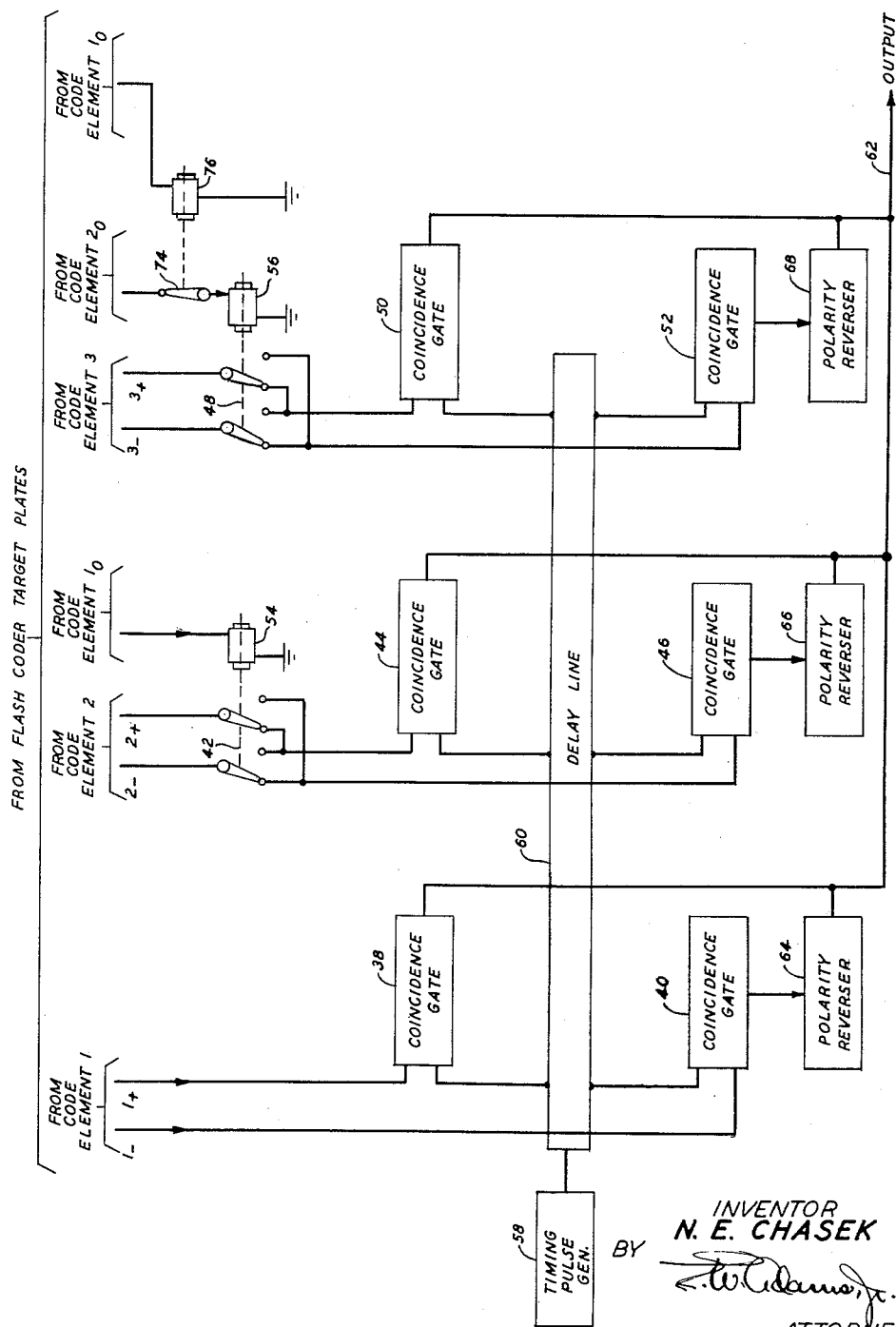
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ELECTRON BEAM ENCODER

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FIG. 3



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## ELECTRON BEAM ENCODER

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10 Claims. (Cl. 315-3.5)

This invention relates to electron beam encoders and more particularly to electron beam encoders for use in the generation of pulse code modulation signals, the code elements of which may have any of at least three different values.

Pulse code modulation has become well known as an efficient method of transmitting baseband or video information over broadband transmission facilities. This method of transmission is well known for its high degree of protection against background noise in the transmission medium, particularly when the so-called binary code is employed. Such discrimination against noise, however, is obtained at the cost of an increased bandwidth requirement and as a result pulse codes having more complicated structures are of interest. Here, the high degree of discrimination against noise is sacrificed to a limited extent in favor of the reduction of bandwidth. A typical code of this variety is the so-called ternary code in which each of the end elements of a code group may have any of three values, usually or conveniently represented by plus, zero, or minus signals.

Ternary codes, like binary codes, may be produced in response to the amplitudes of applied signal samples by a wide variety of coding devices. One of the most popular of these devices is the electron beam coding tube such as the so-called "flash coder" which forms the subject matter of Patent 2,616,060 to W. M. Goodall, October 28, 1952, and which is disclosed in its application for encoding signal samples in binary code. An encoder of the same general type for use in encoding ternary signals is disclosed in Patent 2,602,158 to R. L. Carbrej, July 1, 1952.

Such coding devices rely upon the accurate positioning of a ribbon beam of electrons with respect to a mask or target array which furnishes for each code element individual output circuits which may be completed by the beam, depending upon the position at which it strikes the target array. Misalignment, such as tilting of the beam, may cause improper translation of a signal amplitude into the code group required by the code for which the coder was designed and various proposals have been made for the reduction of ambiguities which may thus occur. Patent 2,632,058 to F. Gray, March 17, 1953, illustrates one approach to this problem in accordance with which the pattern of the targets is adjusted in such a way that ambiguities are reduced. Application of the principles disclosed in the Gray patent to known electron beam encoders for ternary and more complicated pulse codes has not as yet been accomplished.

It is the object of the present invention to minimize the occurrence of errors in electron beam encoders for the production of code elements according to codes requiring multiple values for each code element.

In accordance with the above object, the electron beam encoder of the invention is arranged for the production of ternary code signals having possible values of zero, plus, or minus for each element of the code. A ribbon beam is directed toward a target array and is deflected to a discrete position in accordance with the amplitude of a signal sample to be encoded. The target array comprises separate shadow plates for each code element value located in the path of the beam to be intercepted in order thereby. Aligned columns of the several shadow plates

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correspond to individual elements of the code and each succeeding shadow plate in the order in which it intercepts the beam is provided with openings for each discrete position of deflection for which, according to the code, one of the remaining code element values is required. External circuits completed by impingement of the beam upon the individual shadow-masked columns of the several target plates collect contributions to form a code group representing the deflection position of the beam.

According to another feature of the invention, the resulting code groups are converted from the form in which the nonambiguous coder produces them to the so-called straight ternary form which is susceptible of decoding by relatively simple circuit arrangements.

The above and other features of the invention will be considered in further detail in the following specification taken in connection with the drawings in which:

FIG. 1 is a perspective view illustrating the essential details of an encoding tube according to the invention;

FIG. 2 illustrates the layout of target areas of the several target plates appearing in the coding tube of FIG. 1; and

FIG. 3 is a schematic circuit diagram in block form of a code converter arranged to translate the nonambiguous ternary code produced by the coding tube of FIG. 1 into a conventional ternary code.

The general arrangement of the coder, according to the invention, is illustrated in FIG. 1 of the drawings. As in the so-called flash coder referred to above, the coder comprises an electron gun system 10, mounted in an evacuated envelope 12, and arranged to project a ribbon beam of electrons toward a target array 14, which is arranged to present various target areas upon which the beam of electrons may impinge. These target areas constitute elements of circuits, completed by the beam and extending exteriorly of the envelope 12, in which currents may flow in accordance with a preassigned code.

In the electron gun, the usual cathode 16 emits electrons, the intensity of which is adjusted by a grid 18, and this stream of electrons is passed through accelerating electrodes 20 and 22 which serve both to increase the velocity of the electrons and to form them into a so-called ribbon beam. The section of this beam as it travels along the evacuated tube is a thin line extending horizontally across the tube. Deflection plates 24 and 26 are provided to center the ribbon beam, while vertical deflection plates 28 and 30 serve to deflect the beam in a direction normal to its wider cross section. The various external circuits necessary to supply operating potentials for the electron gun structure and for the deflection plates are conventional and are not shown in FIG. 1. It will be understood that vertical deflection plates 28 and 30, which serve to sweep the ribbon beam in a direction normal to its greatest cross-sectional dimension, receive samples of the signals which are to be encoded. Conveniently, the signals applied to deflection plates 28 and 30 are quantized and represent successive samples of the amplitude of a complex wave which is to be encoded in pulse form according to a particular code. By virtue of such quantization, the possible different deflection positions which may be occupied by the beam are limited to a number that conveniently corresponds to the total number of different amplitudes which are capable of representation by the selected code.

The target structure 14 is illustrated in FIG. 1 as it would be arranged for use in the generation of ternary pulse code groups having three code elements, each of which may have any of the values plus, minus, or zero. As is well understood, such a code is capable of uniquely representing any one of twenty-seven different input quantities. Accordingly, it is assumed that the quantized in-

put signals applied to deflection plates 28 and 30 may have any of twenty-seven different amplitudes and will serve to deflect the ribbon beam from electron gun 10 to unique positions along the vertical dimension of target array 14.

The basic arrangement upon which the target array is designed involves the use of a separate shadow plate for each possible value of the elements of the code. Each of these shadow plates as, for example, plates 32, 34, and 36 of FIG. 1 is subdivided into columns which are conducted and are insulated from one another and each column has openings formed therein corresponding to a particular value of the code element required, according to the code, for representation of the amplitude to which the respective deflection position corresponds. In accordance with this general arrangement, the first of the shadow plates 32 to intercept the electron beam is provided with openings in each of the columns corresponding to the various elements of the code for all values required by the code other than the zero value. When a zero value is required for the code group representing this particular position of deflection, the electron beam impinges upon the corresponding column of plate 32. For other code values the beam passes through the openings in plate 32 and travels toward plates 34 and 36. The second target or shadow plate 34 is provided with corresponding openings for those locations which require a positive value in the corresponding code element. The third plate 36 of the array has no openings at all and serves merely to intercept those portions of the beam which have passed successfully through the openings in the first and second target plates.

The detailed arrangement of openings in the target plates 32, 34, and 36 of FIG. 1 are shown in FIG. 2 of the drawings. Here, the target plate 32 is identified as the "zero" plate since it is provided with openings according to the code such that the beam does not intercept the plate for any position except those in which the code requires a value of zero. Wherever a value of plus or minus is required by the code, zero plate 32 has an opening appropriately positioned so that the beam will pass unimpeded through the plate and progress to the second plate of the target array.

The second plate 34 is identified in FIG. 2 as the "negative" plate and is designed according to the same general principle outlined above in connection with the zero plate. Here, it is required that the beam be intercepted by the shadow plate wherever the code requires the production of a negative pulse and otherwise be allowed to pass unhindered in the direction of the third shadow plate of the target array.

The third shadow plate 36 is identified in FIG. 2 as the "positive" plate and is of extremely simple design. As soon as all portions of the beam corresponding to zero or negative values for a particular position of deflection have been intercepted by shadow plates 32 or 34, only those portions of the beam corresponding to positive values of the code ever reach target plate 36. No special provision is therefore required and it is necessary only that the portions of the beam corresponding to the individual code elements be separately intercepted. Accordingly, the positive plate comprises only three conducting columns corresponding to the three elements of the code chosen herein for purposes of illustration.

As shown in FIG. 1 of the drawings, each of shadow plates 32, 34, and 36 is provided with a separate output lead for each of the columns corresponding to the elements of the code. External circuitry, not shown, completes the path from the cathode 16 of the electron gun to each of the output leads from each of the target plates so that impingement of a portion of the electron beam upon a particular column area completes the circuit through which current may flow externally to the coding tube. These currents, of course, constitute outputs which may be detected and transmitted as required.

It may be noted from an examination of FIG. 2 of the drawings that the target array does not follow a pattern which corresponds to the conventional ternary code system. In Table I, shown below, the right-hand column for each code element indicates the value by which that code element should be represented according to the conventional ternary code. It will be understood that the three element codes shown in Table I permit unique representation of twenty-seven different values. The coding pattern upon which the target array shown in FIG. 2 of the drawings is based is illustrated by the left-hand column appearing for each code element of Table I. It will be observed that no change is made in code element I, which is the element of the code carrying the greatest significance. The remaining code elements, however, are evaluated in accordance with a modified plane. The principle upon which such modification is based is that the electron beam should not, for any position of deflection, be required to discriminate between different code element values in more than one column at a time. Thus, in the second column corresponding to code element II, the arrangement of plus and minus values is modified in a symmetrical manner about the center of the pattern represented by Table I. Zero values remain unchanged but the positive and negative values required are modified so that in no case is there a transfer required between a positive and negative value as the beam travels between successive positions of deflection. This same arrangement is repeated for the third element of the code and the overall approach obviously can be carried to codes having a larger number of elements.

Table I

|    | Code Element I | Code Element II | Code Element III |
|----|----------------|-----------------|------------------|
| 1  | +              | +               | +                |
| 2  | +              | +               | 0                |
| 3  | +              | +               | -                |
| 4  | +              | 0               | +                |
| 5  | +              | 0               | 0                |
| 6  | +              | 0               | -                |
| 7  | +              | -               | +                |
| 8  | +              | -               | 0                |
| 9  | +              | -               | -                |
| 10 | 0              | -               | +                |
| 11 | 0              | -               | 0                |
| 12 | 0              | -               | -                |
| 13 | 0              | 0               | +                |
| 14 | 0              | 0               | 0                |
| 15 | 0              | 0               | -                |
| 16 | 0              | +               | +                |
| 17 | 0              | +               | 0                |
| 18 | 0              | +               | -                |
| 19 | -              | +               | +                |
| 20 | -              | +               | 0                |
| 21 | -              | +               | -                |
| 22 | -              | 0               | +                |
| 23 | -              | 0               | 0                |
| 24 | -              | 0               | -                |
| 25 | -              | -               | +                |
| 26 | -              | -               | 0                |
| 27 | -              | -               | -                |

It will be recognized that the flash coding principle results in the simultaneous production of output signals corresponding to all of the elements of the code group which represents a particular position of beam deflection. It may be, and ordinarily is, desirable to translate this parallel occurrence of code element signals into serial occurrence so that the code element pulses corresponding to a particular code group may be translated in tandem over a single communication channel. This is usually accomplished through the use of timing circuits or delay line devices by which the individual output circuits for the several columns of the target array are connected to the transmitting channel. This general principle is followed in the system shown in the drawings but at the same time the specialized ternary code employed in the design of the shadow plates to reduce ambiguity in coding is translated to standard or conventional ternary code form. Circuitry for accomplishing this is illustrated in FIG. 3 of the drawings.

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Inputs to the translating circuit of FIG. 3 are shown as being derived from the various output leads of the shadow plates of target array 14. In general, the signal contributions corresponding to positive or negative values of the code for each element are applied to switching circuitry while inputs corresponding to the zero values of at least some of the code elements are employed to operate the switches.

As will be observed from Table I above, translation from the special ternary code to standard ternary code may proceed according to the following criteria: If the value of the first element of the code is either positive or negative, the value of the second element of the code is correct as it stands, according to conventional ternary code. If, on the other hand, the value of the first element of the code is zero, the polarity of the value of the second element must be reversed; that is, change from plus to minus, or vice versa. Likewise, if the value of the second element of the code is either plus or minus, the third element already constitutes a correct representation of the code element value in conventional ternary code. Here, too, if the value of the second code element is zero, the third element must be reversed in sign unless the value of the first code element is also zero. Obviously, where the value of the succeeding element in the code is already zero, reversal of sign is meaningless and need not be performed.

Stated generally for codes of any number of elements, the polarity or value of any code element save the first must be reversed whenever the values of the preceding element (in order of decreasing significance) include an odd number of zeros. When the number of such zero-valued elements is even, no reversal is required.

One circuit for carrying out the operations required by the above criteria for a three element code is shown in FIG. 3. The positive and negative output leads of the target plates for the first code element are applied respectively to the inputs of coincidence gates 38 and 40. In similar fashion, the positive and negative output leads corresponding to code element II are applied to coincidence gates 44 and 46. In this case, however, these leads are connected through a transfer switch 42 in such fashion that they may be interchangeably connected to the inputs of coincidence gates 44 and 46. Likewise, the positive and negative outputs corresponding to the third code element are connected through a transfer switch 43 to the inputs of coincidence gates 50 and 52.

Transfer switches 42 and 43 are shown schematically as double-pole, double-throw switches and are shown as being actuated by solenoids 54 and 56, respectively, which are, in turn, driven by signals from the code element output leads corresponding to zero value of the first and second code elements. Obviously electronic switching circuitry may be substituted for the mechanical devices shown in the drawings for ease of explanation. Thus, whenever a zero occurs in the first code element, the plus and minus leads for the second code element output are interchanged. Likewise, when the value of the second code element is zero, the plus and minus output leads for the third code element are interchanged. In addition, a normally closed switch 74 is interposed in the lead to solenoid 56. An additional solenoid 76, controlled by the zero value output lead for the first code element serves to open this switch, thus preventing interchange of the connections to gates 50 and 52 when both the first and second code elements have the zero value.

Second inputs for coincidence gates 38, 40, 44, 46, 50 and 52 are provided from the outputs of a timing pulse generator 53, the repetition rate of which is that desired for the individual code element pulses of the code group. The output of this generator is applied to a delay line 60, the constants of which are so chosen that the three pairs of coincidence gates 38 and 40, 44 and 46, and 50 and 52 are enabled, in turn, at the desired code element rate.

The outputs of coincidence gates 38, 44, and 50 are

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connected together and applied directly to an output lead 62. On the other hand, the outputs of coincidence gates 40, 46, and 52 are connected respectively to polarity reversers 64, 66, and 68. These polarity reversers may constitute any convenient circuit arrangement capable of reversing the polarity of an applied pulse signal. This may be accomplished, for example, for a simple single amplifier stage. Other more sophisticated polarity-reversing circuits may also be employed. The outputs of the three polarity-reversing circuits are connected together and are also connected to output lead 62.

The arrangement shown in FIG. 3 and described above is employed by way of example since a wide variety of logic circuits may be devised to perform the necessary operations on the coding tube output to convert the special code produced thereby to conventional ternary form. All such circuits, however, regardless of the number of code elements involved, must be designed according to the criteria set forth above.

What is claimed is:

1. A coder for representing signal amplitudes by code groups of  $m$  elements, each of which may have any of  $n$  values comprising, an electric beam tube, means for forming a ribbon beam of electrons therein, means for deflecting said beam to any of  $m^n$  different positions, each corresponding to a different signal amplitude, a target structure comprising a shadow plate for each possible value of said code elements, each plate having a column aligned in the direction of beam travel for each element of said code, each successive shadow plate in the path of said beam having openings therein for each position of deflection of the beam requiring one of the values of said elements other than that represented by said plate and any preceding plate in the succession of plates in the direction of beam travel for representation of that signal amplitude according to the code, and separate circuits completed by said beam for each column of each shadow plate.

2. A coder for representing signal amplitudes by code groups of  $m$  elements, each of which may have any of  $n$  values, comprising an electron beam tube, means for forming a ribbon beam of electrons therein, means for deflecting said beam to any of  $m^n$  different positions, each corresponding to a different signal amplitude, a target structure comprising a shadow plate for each possible value of said code elements, each plate having a column aligned in the direction of beam travel for each element of said code, each successive shadow plate in the path of said beam having openings therein for each position of deflection of the beam requiring one of the values of said elements other than that represented by said plate and any preceding plate in the succession of plates in the direction of beam travel for representation of that signal amplitude according to the code, an output lead, separate circuits for each column of each shadow plate and completed by said beam, and means interconnecting said separate circuits and said output lead for the production of a code group of signals representative of the input signal amplitude.

3. A coder for representing signal amplitudes by code groups of  $m$  elements, each of which may have any of three values, comprising an electron beam tube, means for forming a ribbon beam of electrons therein, means for deflecting said beam to any of  $m^n$  different positions, each corresponding to a different signal amplitude, a target structure comprising a shadow plate for each possible value of said code elements, each plate having a column aligned in the direction of beam travel for each element of said code, each successive shadow plate in the path of said beam having openings therein for each position of deflection of the beam requiring one of the values of said code elements other than that represented by said plate and any preceding plate in the succession of plates in the direction of beam travel for representation of that signal amplitude according to the code, the

pattern of openings in the first of said shadow plates to intercept said beam being symmetrical about the center position of the possible positions of deflection of said beam and such that transitions in any column between the two extreme code element values can occur only by way of the intermediate value for that element.

4. A coder for representing signal amplitudes by  $m$  code elements, each of which may have any of three values, one of which is zero, comprising an electron beam tube, means for forming a ribbon beam of electrons therein, means for deflecting said beam to any of  $m^3$  different positions, each corresponding to a different signal amplitude, a target structure comprising three shadow plates, each having  $m$  columns aligned in the direction of beam travel, a first and second of said plates in the path of said beam having openings therein for each position of deflection of the beam requiring, respectively, a zero or a first one of the remaining values according to said code, said third plate having aligned collector targets for each of said code element columns and separate external circuits connected to each of the columns of each of said plates and completed by the beam.

5. A coder for representing signal amplitudes of code groups of  $m$  elements, each of which may have any of three values, comprising an electron beam tube, means for forming a ribbon beam of electrons therein, means for deflecting said beam of any of  $m^3$  different positions, each corresponding to a different signal amplitude, a target structure comprising a shadow plate for each of the three values of said code elements, each plate having a column aligned in the direction of beam travel for each element of said code, the first and second successive shadow plates in the path of said beam having openings therein for each position of deflection of the beam requiring one of the values of said elements other than that represented by said plate and any preceding plate in the succession of plates in the direction of beam travel for representation of that signal amplitude according to the code, and circuits for each column of each shadow plate completed by the beam.

6. A coder for representing signal amplitudes by ternary code groups of  $m$  elements, each of which may have any of the values zero, plus, or minus, comprising an electron beam tube, means for forming a ribbon beam of electrons therein, means for deflecting said beam to any of  $m^3$  different positions, each corresponding to a different signal amplitude, a target structure comprising three shadow plates disposed successively in the path of travel of said beam, each plate having a column aligned in the direction of beam travel for each of the  $m$  elements of said code, openings in the first of said shadow plates for each position of deflection of said beam requiring a plus or minus value according to said code for representation of that signal amplitude, openings in the second plate for each position of deflection requiring a minus value according to said code, and targets on said third plate for intercepting all portions of said beam reaching said third plate through the openings in said first and second plates.

7. A coder for representing signal amplitudes by ternary code groups of  $m$  elements, each of which may have any of the values zero, plus, or minus, comprising an electron beam tube, means for forming a ribbon beam of electrons therein, means for deflecting said beam to any of  $m^3$  different positions, each corresponding to a different signal amplitude, a target structure comprising three shadow plates disposed successively in the path of travel of said beam, each plate having a column aligned in the direction of beam travel for each of the  $m$  elements of said code, openings in the first of said shadow plates for each position of deflection of said beam requiring a plus or minus value according to said code for representation of that signal amplitude, openings in the second plate for each position of deflection requiring a minus value according to said code, the pattern of openings in said first plate being symmetrical in each column about the center posi-

tion of deflection of said beam, and the value significance of an opening in one half of the column and that for the corresponding opening in the lower half of the column being interchanged and targets on said third plate for intercepting all portions of said beam reaching said third plate through the openings in said first and second plates.

8. A coder for representing signal amplitudes of code groups of  $m$  elements, each of which may have any of three values, comprising an electron beam tube, means for forming a ribbon beam of electrons therein, means for deflecting said beam to any of  $m^3$  different positions, each corresponding to a different signal amplitude, a target structure comprising a shadow plate for each of the three values of said code elements, each plate having a column aligned in the direction of beam travel for each element of said code, the first and second successive shadow plates in the path of said beam having openings therein for each position of deflection of the beam requiring one of the values of said elements other than that represented by said plate and any preceding plate in the succession of plates in the direction of beam travel for representation of that signal amplitude according to the code, circuits for each column of each shadow plate completed by the beam, external circuit means for determining the value of each code element produced by said beam for a particular position of deflection thereof, and means for interchanging between the values other than zero the value of each code element when the values of the preceding code elements include an odd number of zero values.

9. A coder for representing signal amplitudes by ternary code groups of  $m$  elements, each of which may have any of the values zero, plus, or minus, comprising an electron beam tube, means for forming a ribbon beam of electrons therein, means for deflecting said beam to any of  $m^3$  different positions, each corresponding to a different signal amplitude, a target structure comprising three shadow plates disposed successively in the path of travel of said beam, each plate having a column aligned in the direction of beam travel for each of the  $m$  elements of said code, openings in the first of said shadow plates for each position of deflection of said beam requiring a plus or minus value according to said code for representation of that signal amplitude, openings in the second plate for each position of deflection requiring a minus value according to said code, targets on said third plate for intercepting all portions of said beam reaching said third plate through the openings in said first and second plates, external circuit means for determining the value of each code element produced by said beam for a particular position of deflection thereof, and means for reversing the polarity of each code element when the values of the preceding code elements include an odd number of zero values.

10. A coder for representing signal amplitudes by code groups of  $m$  elements, each of which may have any of three values, comprising an electron beam tube, means for forming a ribbon beam of electrons therein, means for deflecting said beam to any of  $m^3$  different positions, each corresponding to a different signal amplitude, a target structure comprising a shadow plate for each possible value of said code elements, each plate having a column aligned in the direction of beam travel for each element of said code, each successive shadow plate in the path of said beam having openings therein for each position of deflection of the beam requiring one of the values of said elements other than that represented by said plate and any preceding plate in the succession of plates in the direction of beam travel for representation of that signal amplitude according to the code, separate circuits for each column of each shadow plate and completed by said beam, a pair of coincidence gates for each of said code elements, means for enabling said gates to accept said code elements in a predetermined order, means for normally connecting the output circuit for the first and third

values of said code respectively to the inputs of said coincidence gates, means for each code element save the first for interchanging the connections between said output circuits and said coincidence gates whenever the number of column inputs from the plates corresponding to the second value of said code is an odd integer, means for reversing the polarity of the outputs from gates normally associated with the second value of said code elements, and means for combining the outputs of said first coincidence gates and said reversing means to yield a code group of pulses.

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