

June 14, 1949.

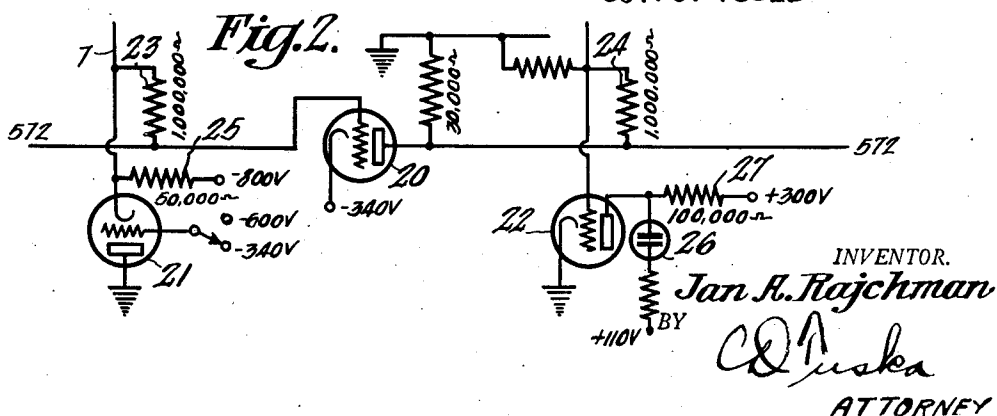
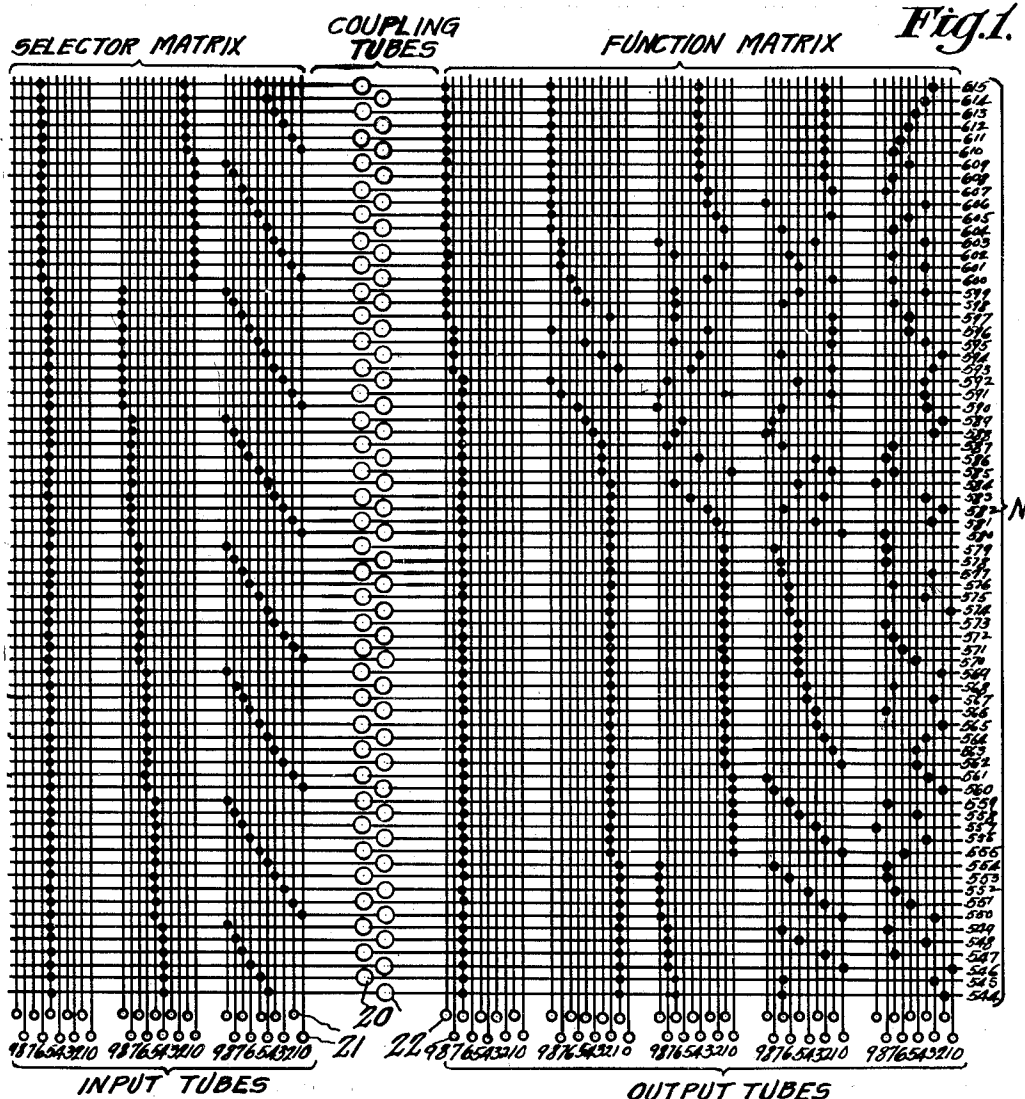
J. A. RAJCHMAN

2,473,444

COMPUTING SYSTEM

Filed Feb. 29, 1944

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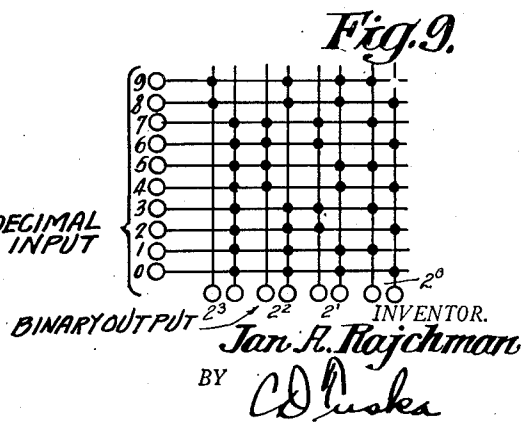
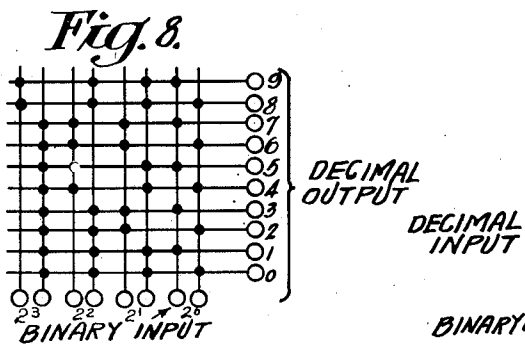
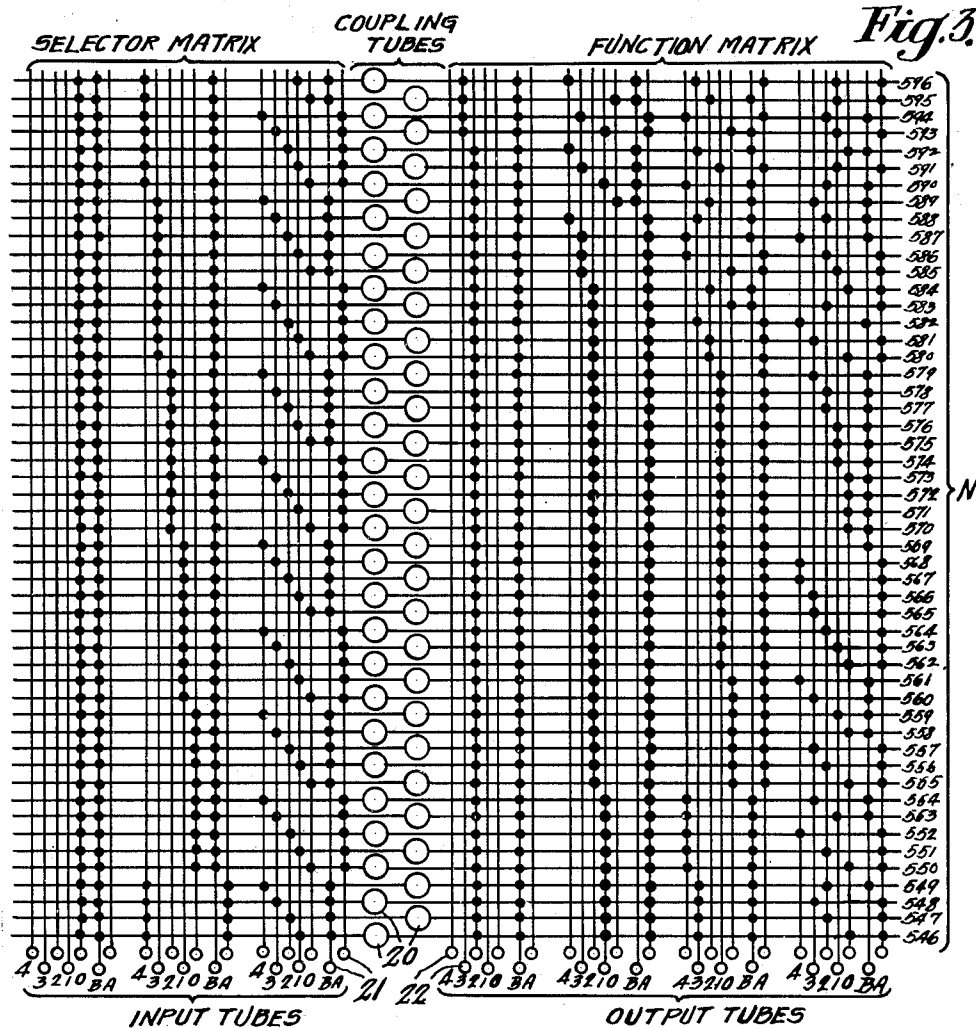
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Fig. 4.

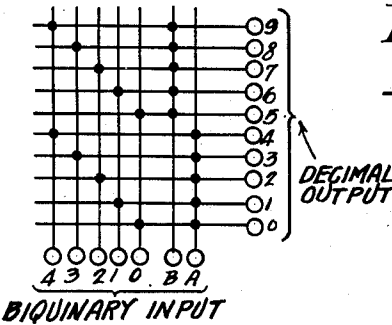


Fig. 6.

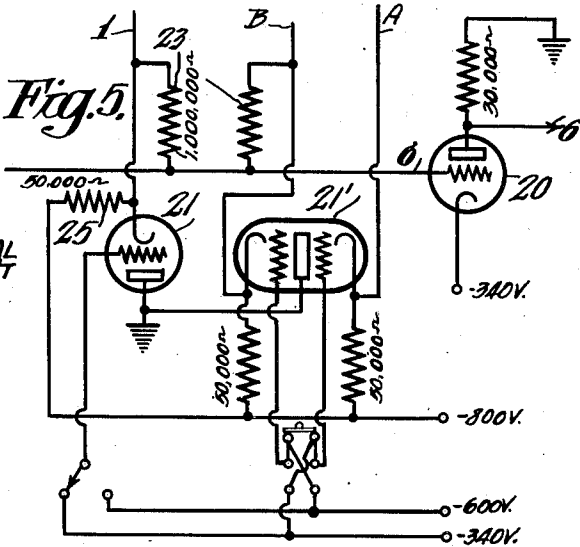
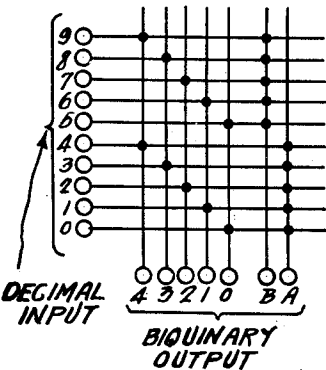
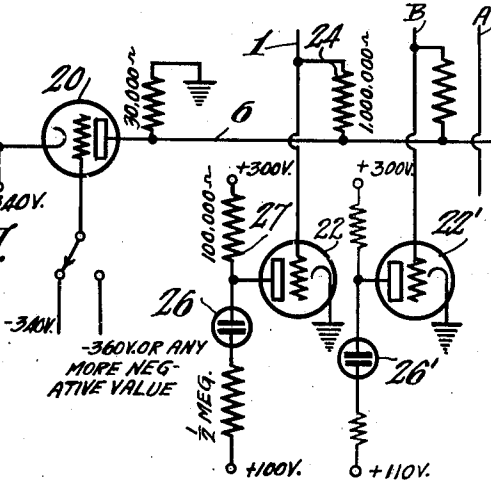


Fig. 7.



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COMPUTING SYSTEM

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2 Claims. (Cl. 235-61)

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This invention relates to computing systems, such as are utilized to convert a value of a variable to the value of a desired function of the variable, and has for its principal object the provision of an improved apparatus and method of operation whereby (1) values of a variable expressed in the decimal system may be converted to values of a function of the variable expressed in the same system, (2) values of a variable expressed in the biquinary system may be converted to values of a function of the variable expressed in the same system or (3) values expressed in one numerical system may be readily converted so as to be expressed in another numerical system.

The present invention is related to that disclosed in a copending application Serial No. 508,343, filed October 30, 1943, now Patent No. 2,428,811, which is directed more particularly to an apparatus for converting values of a variable expressed in the binary system to values of a function of the variable expressed in the same system. This system is satisfactory where potentials representative of the binary values of the function are to be utilized directly in the control of other apparatus. In some cases, however, a direct indication of values expressed in the decimal system is desirable. This is realized by the present invention.

In many computing devices, it is desirable to operate with numbers as opposed to continuously variable physical quantities such as voltage or current. The numbers upon which the computation is made are usually carried on a system of conductors, some of which have one definite potential and some others have another definite potential. To represent numbers in the usual decimal scale, the conductors can be arranged in groups of tens, each group corresponding to a decimal place and each conductor in any one group to one of the ten decimal digits. If such a system is used, one of the ten conductors in any one group will be of the potential V_1 and all others of the potential V_2 .

In such computing devices, it is often desirable to generate one number as a function of one or more others. The functional relationship between the variable and function is often given in terms of a table. An example of such a table for a one variable function $F(X)$ is given in Table I.

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Table I

X	F(X)	X	F(X)
544	717.71	580	722.08
545	717.72	581	722.38
546	718.00	582	723.72
547	718.27	583	725.21
548	718.53	584	727.53
549	718.78	585	730.19
550	719.02	586	734.37
551	719.25	587	739.98
552	719.47	588	748.77
553	719.68	589	757.82
554	719.88	590	769.71
555	720.06	591	781.13
556	720.23	592	798.53
557	720.39	593	815.12
558	720.54	594	834.71
559	720.68	595	857.13
560	720.81	596	883.15
561	720.93	597	927.15
562	721.04	598	957.17
563	721.14	599	967.73
564	721.23	600	973.57
565	721.31	601	981.13
566	721.38	602	987.57
567	721.42	603	989.63
568	721.47	604	991.37
569	721.51	605	992.75
570	721.54	606	993.13
571	721.56	607	993.98
572	721.57	608	994.17
573	721.58	609	994.25
574	721.60	610	994.27
575	721.63	611	994.26
576	721.67	612	994.25
577	721.72	613	994.24
578	721.78	614	994.23
579	721.88	615	994.22

If the various values are expressed in the biquinary system, the converting apparatus is considerably simplified for the reason that ten digits may be represented by seven potentials which are divided into a group of five indicated as 0, 1, 2, 3, 4 and a group of two indicated as A and B. For every digit of the value, one conductor of each group is excited. The relation between the decimal and biquinary systems is indicated by the following Table II:

Decimal	Biquinary
0	0A
1	1A
2	2A
3	3A
4	4A
5	0B
6	1B
7	2B
8	3B
9	4B

It is well known that the ten decimal system digits may be represented by four binary system digits. The relation between the two systems is shown by the following Table III:

Direct Decimal Notation	Decimal in Binary Notation
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001

Whether only one numerical system is involved (as in the conversion of the value of a variable to the value of a function of the variable) or more than one numerical system is involved (as in the conversion of values from the decimal systems to other systems or vice versa), the same type of apparatus is utilized.

This apparatus involves two groups or systems of conductors which, for convenience of expression, may be designated as horizontal and vertical conductors although this particular disposition of the two groups is not at all essential. One or the other of two potentials are applied to the vertical conductors in a manner to represent the successive digits of a number to be converted either to the value of a function or to the same value expressed in another numerical system. In the illustrated forms of the invention, a more positive potential of -340 volts generally is applied to a vertical conductor which is to represent a digit and a more negative potential of -600 volts is applied to a vertical conductor which is to represent the absence of a digit. These voltages are established on the different vertical conductors through input tubes of the cathode follower type by switching their grid potentials to one or the other of the two indicated voltages or their equivalent.

When the number to be converted is expressed in the decimal system, a group of ten vertical conductors, numbered as 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, is provided for each digital position of the number and only one of the conductors of each group is charged to the more positive potential. When the number to be converted is expressed in the biquinary system, two groups of conductors, numbered respectively 0, 1, 2, 3, 4 and A, B, are provided for each digital position of the number and one conductor of each of the two groups is charged to the more positive potential. When the number to be converted is expressed in the binary system, the number of vertical conductors is equal to the number of the digital positions of the largest value to be converted and the vertical conductors corresponding to a digit one of the binary number are charged to the more positive potential while the other vertical conductors are charged to the more negative potential.

The horizontal conductors may be considered as corresponding to the different values of a variable X, e. g. the different numbers represented by potentials established on the vertical conductors as described above. Where the value of a variable is to be converted to the value of a function of the variable, these horizontal conductors are connected through one megohm resistors to the vertical conductors in such a way that the horizontal conductor representing a given value of the vari-

able is charged to the more positive potential when and only when potentials representative of that value are applied to the input terminals of the vertical conductors. Where values expressed in one numerical system are to be converted to the same values expressed in another numerical system, the horizontal conductors are connected through one megohm resistors to the vertical conductors in a manner to make available at the output terminals of the horizontal conductors potentials representative of the converted number as hereinafter explained.

In case the apparatus is to be utilized to convert the values of a variable to the values of a function of the variable, the horizontal conductors discussed above are coupled to a second group of horizontal conductors which are interconnected with a second group of vertical conductors to form a function matrix. Potentials representative of the different values of the function are derived from the output terminals of the second group of vertical conductors and indicated by any suitable means such as neon lamps or the like.

The invention will be better understood from the following description considered in connection with accompanying drawings and its scope is indicated by the appended claims.

Referring to the drawings:

Figure 1 is a wiring diagram of a generator which (1) is actuated by potentials representative of the various digits of a decimal system number expressing a selected value of a variable and (2) delivers at its output terminals potentials representative of the various digits of a decimal system number expressing the value of a function of the variable for such selected value,

Figure 2 is a wiring diagram showing the connections of one set of selector input, function matrix input and function matrix output tubes,

Figure 3 is a wiring diagram similar to that of Fig. 1 with the exception that it is modified to function in connection with decimal scale members having a biquinary notation and somewhat reduces the number of required parts,

Figures 4 and 5 illustrate certain details of an apparatus for converting a biquinary input to a decimal output,

Figures 6 and 7 illustrate an apparatus for converting a decimal input to a biquinary output,

Figure 8 illustrates an apparatus for converting a binary input to a decimal output, and

Figure 9 illustrates an apparatus for converting a decimal input to a binary output.

The function generating apparatus of Fig. 1 includes a function matrix and a selector matrix each having a plurality of horizontal conductors. The horizontal conductors of the two matrices are coupled together through tubes each similar to the tube 20 of Fig. 2. The selector matrix also includes a plurality of vertical conductors which are shown as arranged in groups of ten, there being one of these groups for each digital position of the variable. To the lower or input ends of each of these vertical conductors of the selector matrix is connected an input tube similar to the tube 21 of Fig. 2. The function matrix also includes a plurality of vertical conductors which are shown as arranged in groups of ten, there being one such group for each digital position of the function of the variable. To the lower or output end of each of these vertical conductors of the function matrix is connected an output tube similar to the tube 22 of Fig. 2. These input, coupling and output tubes appear in Fig. 1

as small circles. How they operate is hereinafter explained in detail.

The horizontal and vertical conductors of the selector matrix are interconnected so that successive horizontal conductors represent successive values of the variable. Thus if the lowest value to be assigned to the variable is 544, the lowermost horizontal conductor is connected to conductor 4 of the right hand group, to conductor 4 of the center group and to conductor 5 of the left hand group. These connections (indicated by dots) are made through one megohm resistors similar to the resistor 23 of Fig. 2.

The successive horizontal conductors of the function matrix correspond to successive values of the variable. Each of these horizontal conductors is connected to the vertical conductors of the function matrix so as to make available at the lower ends of the vertical conductors potentials representative of the decimal system number by which the value of the function for that particular value of the variable is expressed. Thus the horizontal conductor representing a value of 544 for the variable is so connected to the vertical conductors as to produce at the output terminals of the function matrix potentials representative of a function having a value of 717.71 (see Table I). These connections (indicated by dots) are each made through a one megohm resistor similar to the resistor 24 of Fig. 2.

The potentials representative of the selected value of the variable X are established on the proper vertical conductors of the selector matrix by means of the input tubes 21 (see Fig. 2) which have their anodes grounded and their cathodes connected to a -800 volt lead through a resistor 25. With these connections, each of these input tubes operates as a cathode follower so that the vertical conductor to which it is connected is at a potential of -600 v. or -340 v. depending on which of these potentials is applied to the control grid of the input tube. When any vertical conductor does not represent a digit of the selected value of the variable X , its potential is established at -600 v. When such conductor does represent a digit of the selected value of the variable X , its potential is established at -340 v. For example, a value of the variable X equal to .572 is established by applying a grid potential of -340 v. to tube 2 of the right hand group of input tubes, to the tube 7 of the center group of input tubes and to the tube 5 of the left hand group of input tubes. The grid potentials of all the other tubes of the three groups are maintained at -600 v. The result is that the horizontal conductor 572 is at a more positive potential than the other horizontal conductors of the selector matrix.

This more positive potential is applied through the vertical conductors, the resistors 23 and the horizontal conductors to the control grids of the coupling tubes 20. For example, a potential of about -340 v. (more positive than -600 v.) is applied to the grid of the tube 20 (see Fig. 2) through the vertical conductor 7 (center group), a resistor 23 and the horizontal conductor 572. The same is true of the vertical conductor 2 of the right hand group and of conductor 5 of the left hand group, which, together with the vertical conductor 7 of the center group, are connected to the horizontal conductor 572. Since the grids of the coupling tubes 20 are each connected to a different horizontal conductor of the selector matrix and their cathodes are main-

tained at -340 v., it follows that the selected one of these coupling tubes will conduct and that all the other coupling tubes will be biased off (since the grids of these tubes are at -600 volts. It is fundamental that if a conductor is connected through equal resistances to three other conductors forcibly maintained at different potentials it assumes the average potential of these conductors. The four possible cases are tabulated below:

(a)	-340, -340, -340	Average	-340
(b)	-340, -340, -600	Average	-427
(c)	-340, -600, -600	Average	-513
(d)	-600, -600, -600	Average	-600

Only case (a) makes the tube (20) conducting since the cathodes are at -340.

All the horizontal conductors 544 to 615 of the function matrix are at zero potential with the exception of the one connected to the coupling tube which is not biased off. The one connected to the coupling tube which is not biased off assumes a potential of about -300 volts. The result is that all the vertical conductors of the function matrix which are connected to this negatively charged horizontal conductor assume a negative potential with respect to all the other vertical wires of the function matrix and the output tubes 22 which have their grids connected to these negatively charged vertical conductors are biased off. This follows from the fact that the cathodes of all the output tubes 22 are grounded. For example, if the horizontal conductor 572 is connected to the coupling tube which is not biased off, the seven tube of the first group (the right hand one), the five tube of the second group, the one tube of the third group, the two tube of the fourth group and the seven tube of the fifth group are all biased off. All the other output tubes 22 are conducting.

For the purpose of indicating the value of the function (in the assumed case equal to 721.57) a neon lamp 26, or the equivalent, is connected between the anode of each tube and a 110 v. terminal. When the tube 22 is conducting, its anode is more negative due to the potential drop of the resistor 27 and the lamp 26 is unlighted. When the tube 22 is not conducting, its potential is at substantially the same potential as the -300 v. lead and the lamp 26 is lighted.

With the selector and function matrices connected as described above, every horizontal conductor is connected to every vertical conductor through many spurious leakage paths. This does not interfere with the operation of the selector matrix because the degenerative drive of the input tubes 21 maintains forcibly the desired potentials of the vertical conductors, nor do these spurious leakage paths or parasitic couplings interfere with the operation of the function matrix because the ratio of the coupling resistance (one megohm) to the driving plate resistance (30,000 ohms) is very high. As suggested in the aforesaid copending application Serial No. 508,343, these parasitic currents may be minimized by (1) phase reversal on vertical conductors having a number of connections greater than $N/2$ or (2) replacing each coupling tube 20 by two tubes arranged to produce a degenerative drive.

Figure 3 illustrates a function generator which is similar to but more simple than that of Figs. 1 and 2 in that it is based on a biquinary notation instead of a direct decimal notation. By means of

this notation, it is possible to express the ten digits by only seven potentials which are divided into one group of five, indicated by 0, 1, 2, 3 and 4, and one group of two, indicated by A and B. For every digit of the value of the variable, one conductor of the group of five and one conductor of the group of two is excited. The pattern of excitation is related to the decimal digits according to "Table II" generally discussed earlier in this disclosure.

The selector and function matrices for the biquinary system are constructed in a manner similar to those of the direct decimal system shown by Figs. 1 and 2. The connections of the various tubes and the values of all the resistances are the same. The proper connections between the horizontal and vertical conductors of the two matrices are indicated in Fig. 3 by dots. The vertical conductors of the selector matrix representing the digits of the selected value of the variable X are made more positive than other vertical conductors of the selector matrix in the same manner as that described above in connection with Figs. 1 and 2. For example, if the selected value of X is 572, the grids of the input tubes 21 connected to the vertical conductors 2 and A of the right hand group, 2 and B of the center group and 0 and B of the left hand group are all connected to the -340 v. terminal. This results in a more positive potential on the grid of the coupling tube 20 connected to the function matrix conductor 572 and biasing off of tubes 0 and B in the first group (right hand), 1 and A in the second group, 2 and A in the third group and 2 and B in the fourth group. Reference to Table II shows that a function having a value 721.5 is indicated. This agrees with Table I to the first decimal place. The values of additional decimal places, of course, may be derived by providing the function matrix with additional groups of vertical conductors properly connected to the horizontal conductors of this matrix.

Certain parts of the apparatus of Figs. 1 and 2 and also those of Fig. 3 may be utilized for purposes other than those heretofore considered. For example, they may be utilized to convert from biquinary to decimal representation (see Figs. 4 and 5), to convert from a decimal representation to a biquinary representation (see Figs. 6 and 7), to convert from a binary representation to a decimal representation (see Fig. 8), or to convert from a decimal representation to a binary representation (see Fig. 9).

It will be noted that Figs. 4 and 5 represent parts of a selector matrix similar to that of Fig. 3. In this case, the more positive potential (-340 v.) and the more negative potential (-600 v.) are applied selectively to the grids of the input tubes 21-21' as previously indicated and potentials representative of the decimal output numbers corresponding to the biquinary input numbers are produced at terminals connected to the anodes of the tubes 20 as indicated by Fig. 5.

Figures 6 and 7 illustrate parts of a function matrix whereby decimal numbers are converted to the corresponding biquinary numbers. In this case, the more negative and more positive potentials are applied to the grids of the tubes 20 and the potentials representative of the biquinary numbers derived through the output tubes 22 and 22' are indicated by the lamps 26 and 26'.

Figures 8 and 9 show miniature matrices suit-

able for converting binary numbers to corresponding decimal numbers and vice versa. As pointed out above in connection with Table III, the ten decimal digits may be represented in four binary orders. Fig. 8 illustrates an apparatus wherein potentials representative of a binary number are applied to the vertical row of potentials, and potentials representative of the corresponding decimal numbers are derived at the horizontal row of terminals all as previously described in connection with the preceding figures. Fig. 9 illustrates a similar apparatus for converting decimal numbers to corresponding binary numbers.

It is apparent that the present invention, like that of the aforesaid copending application Serial No. 508,343, is applicable to the derivation of functions depending on more than one variable such as $F(X_1, X_2, \dots, X_n)$. As explained in that application, all the systems of potentials of the variables X_1, X_2 , etc., are applied to the input terminals of the selector matrix and the function corresponding to each set of values of the variables is established by proper connections between the horizontal and vertical conductors of the function matrix.

The basic features of the present invention are an improved apparatus and method of operation whereby (1) a value of a variable expressed in the decimal system may be converted to a value of a function of the variable expressed in the same system, (2) a value of a variable expressed in the biquinary system may be converted to a value of a function of the variable expressed in the same system, (3) values expressed in the decimal system may be converted to values expressed in the biquinary system or vice versa, and (4) values expressed in the decimal system may be converted to values expressed in the binary system or vice versa.

I claim as my invention:

1. The combination of a first set of conductors arranged in groups each including a number of conductors dependent on the number of digits in a predetermined numerical system, means for establishing on selected conductors of said groups potentials representative of the successive digits of a variable expressed in said numerical system, a second set of conductors, means connected between the conductors of said sets for applying a predetermined potential to a different one of the conductors of said second set in response to potentials representative of each different value of said variable, third and fourth sets of conductors, means interconnecting the conductors of said third and fourth sets in accordance with a predetermined function of said variable, means coupling the conductors of said second set to those of said third set, and means connected to the terminals of said fourth set of conductors for deriving potentials representative of different values of a function of said variable in response to shifting of said predetermined potential from one to another of said second set conductors.

2. The combination of a first set of conductors arranged in groups each including a number of conductors dependent on the number of digits in a predetermined numerical system, means for establishing on selected conductors of said groups potentials representative of the successive digits of a variable expressed in said numerical system, a second set of conductors, means connected between the conductors of said sets for applying a predetermined potential to a different one of the conductors of said second set in response to po-

tentials representative of successive values of said variable, third and fourth sets of conductors, a plurality of electron discharge elements each having a control grid connected to a different one of said second set conductors and an anode connected to a different one of said third set conductors and to a source of potential through a resistor, resistive elements connected between the conductors of said third and fourth sets in accordance with a predetermined function of said variable, and means connected to the terminals of said fourth set conductors for deriving potentials representative of different values of said function in response to shifting of said predetermined potential from one to another of said second set conductors.

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