

May 8, 1956

A. E. CANFORA ET AL

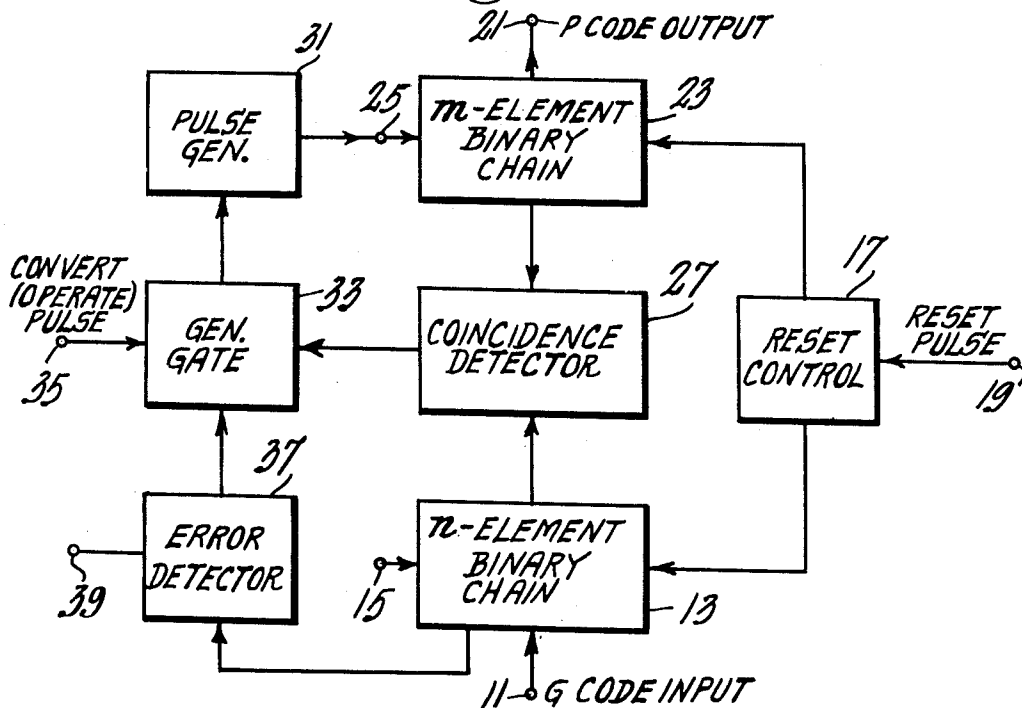
2,744,955

REVERSIBLE ELECTRONIC CODE TRANSLATORS

Filed Aug. 24, 1953

5 Sheets-Sheet 1

Fig. 1.



KEY TO FIG. 2

a	b	c	d
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5 Sheets-Sheet 2

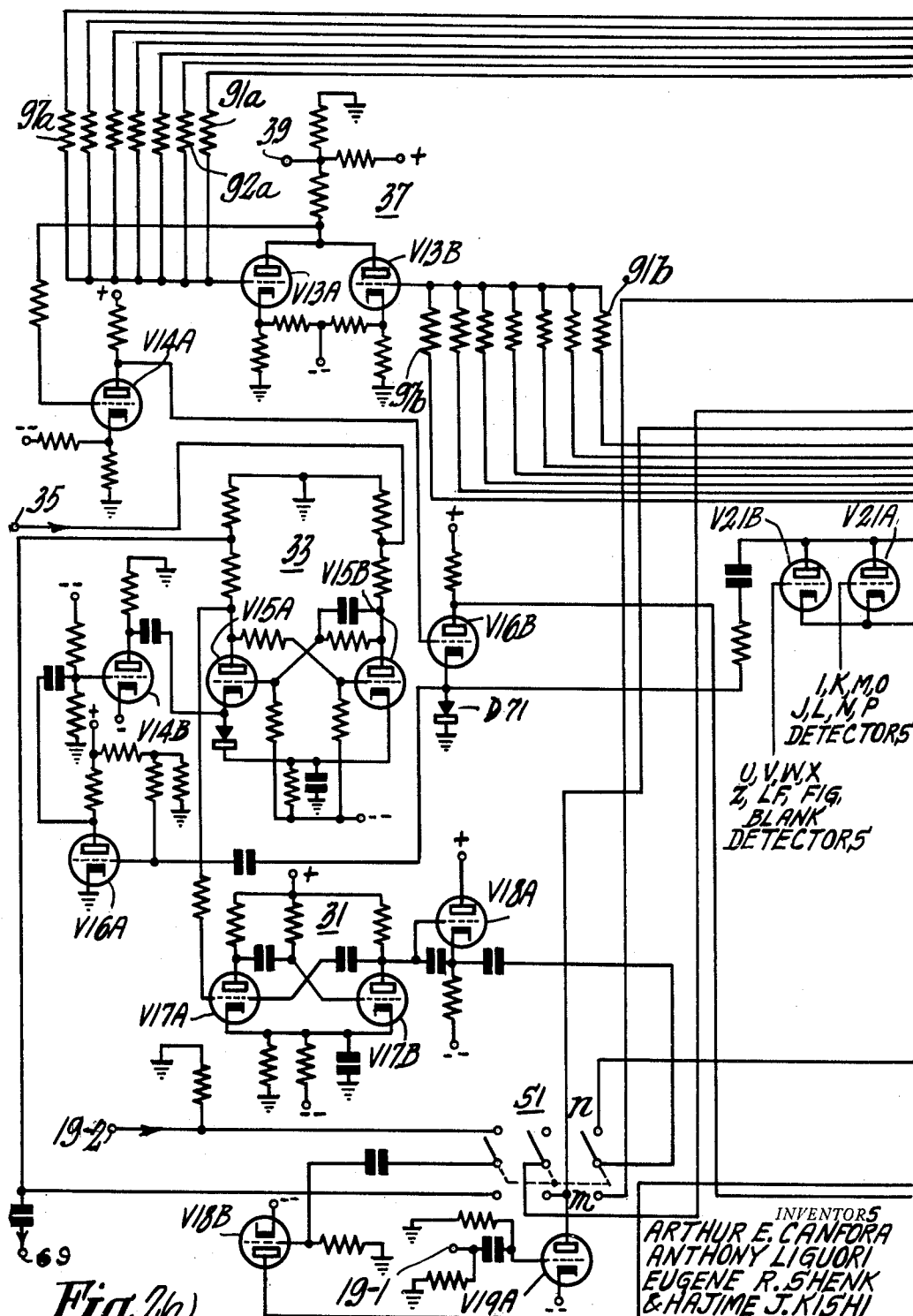


Fig. 2a.

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5 Sheets-Sheet 3

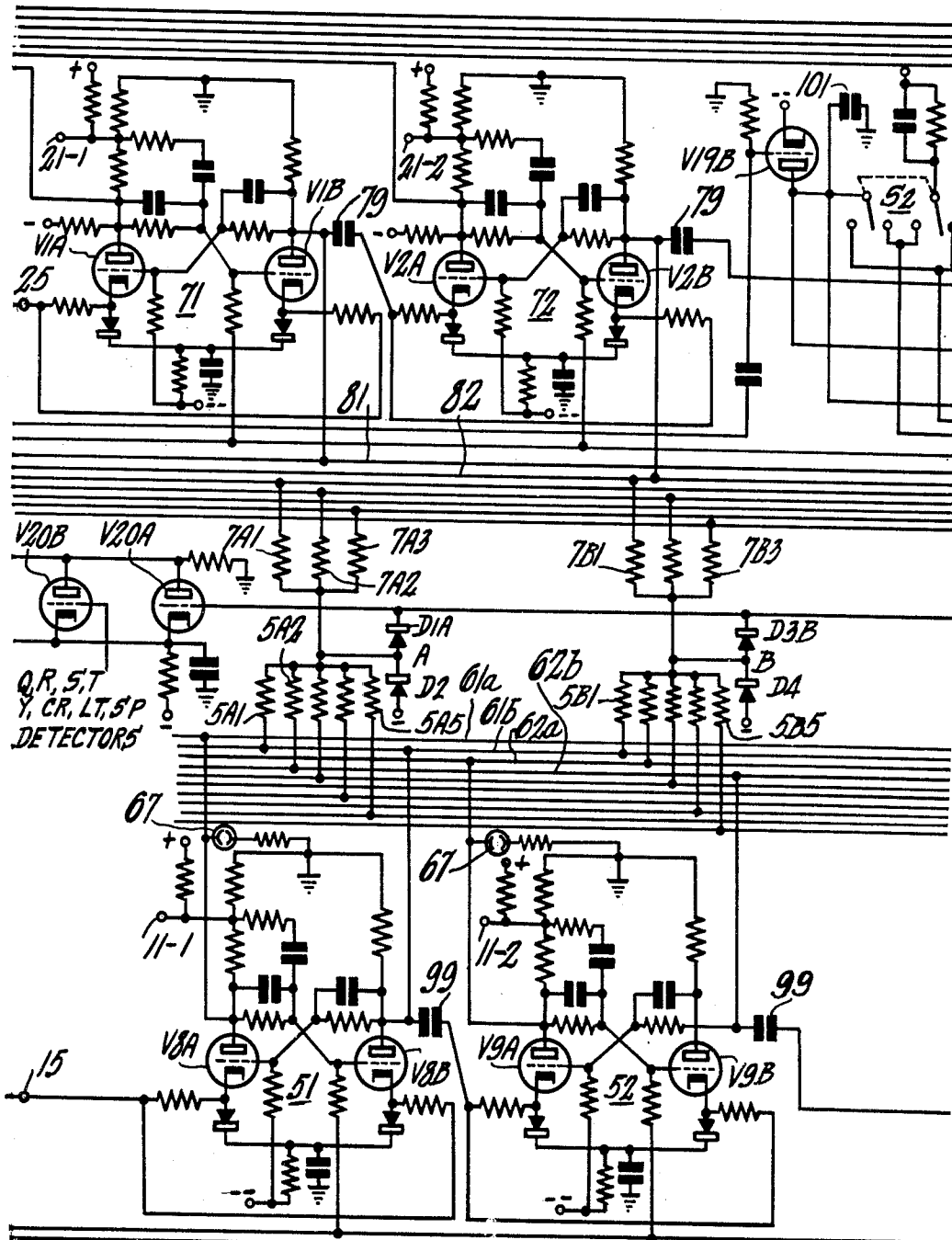


Fig. 2(b).

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5 Sheets-Sheet 4

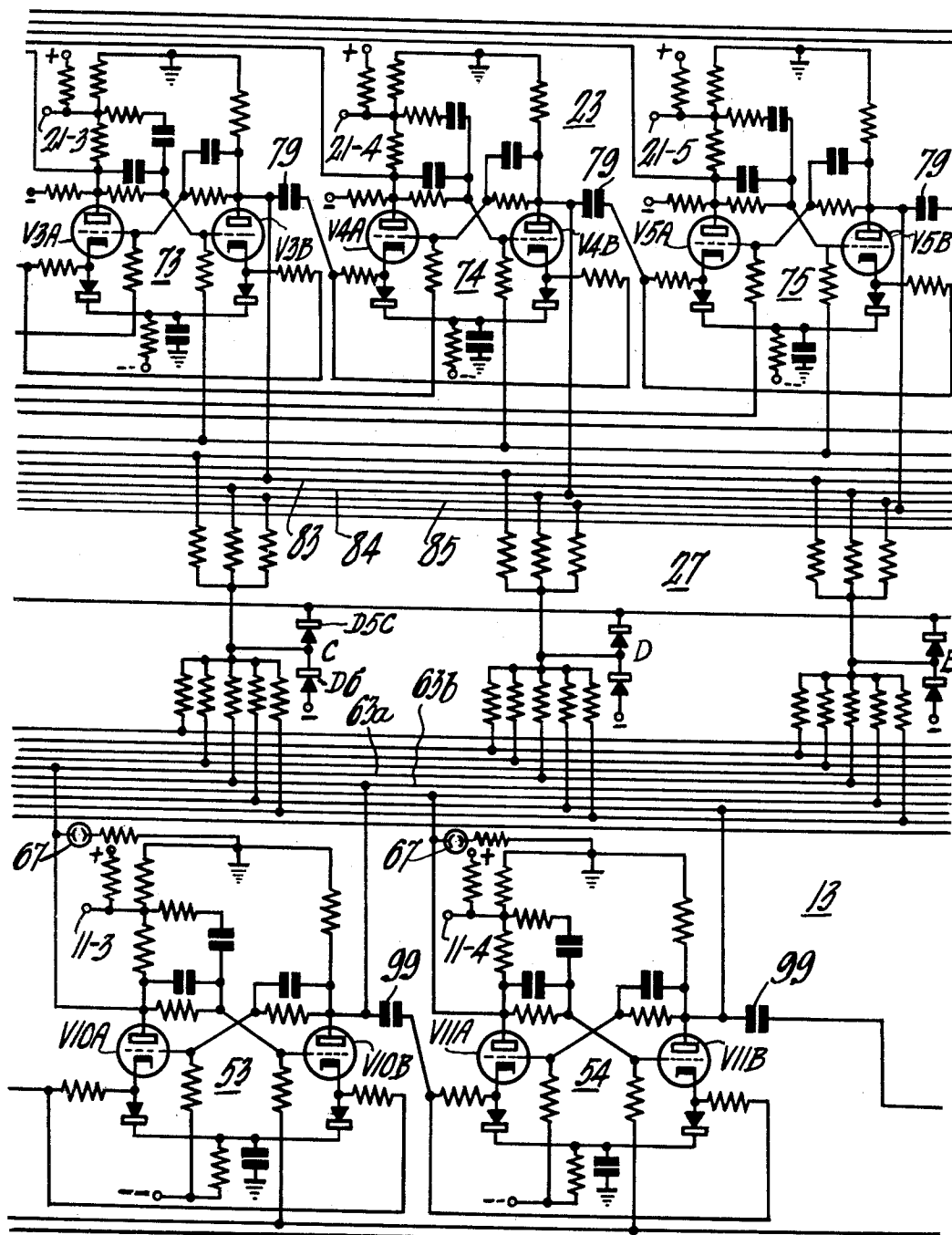


Fig. 2(c).

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5 Sheets-Sheet 5

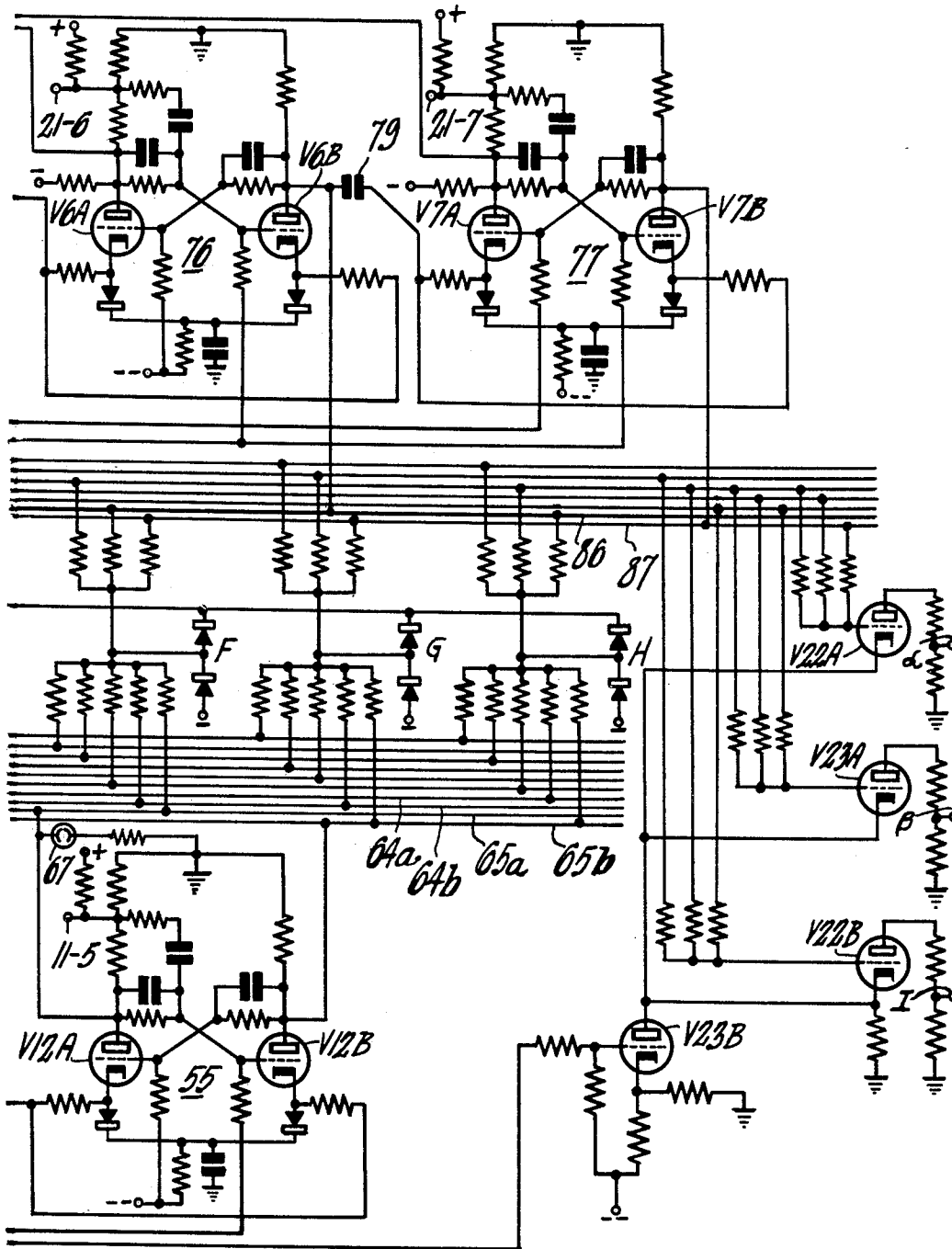


Fig. 2(a).

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REVERSIBLE ELECTRONIC CODE TRANSLATORS

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Application August 24, 1953, Serial No. 375,995

16 Claims. (Cl. 178—23)

The invention relates to code signalling systems and the like. It particularly pertains to a reversible electronic code translator for translating from one fixed-length telegraph code to another fixed-length telegraph code.

The prior art printing telegraph equipment makes use of a fixed-length code, in which a predetermined number of units of time are allotted to each transmitted character, exclusive of start and stop pulses. Each time unit will be referred to hereinafter as a signal element or as a baud element or "baudel." A specific character will be designated, depending on whether these baud elements contain "tone" corresponding to mark or "no tone" corresponding to space. For example, in the conventional 5-unit printer code the letter "A" is composed of baud elements 1 and 2 marking and baud elements 3, 4 and 5 spacing. One or all of the baud elements may be marking, depending on the character being transmitted.

As stated above, a character expressed in the 5-unit code could contain from zero to five marking elements. In transmission, particularly over radio circuits, some marking elements may be deleted and some spacing elements may be filled in by noise. The result is the recording of a false character, which can be serious in coded-word transmissions. A safety or "protected" code has been devised which requires the transmission of a predetermined number of baud elements for each character, a fixed number of which are marking. The reception of seven elements or "baudels" containing more or less than three marking elements can be made to prevent an error misselection from being processed as a legitimate character, either by printing a misselection symbol in place of the mutilated character or, preferably, requesting a repeat of the transmission. For this reason such a "protected code" is often called an "error detecting code" and is sometimes referred to as a "safety code."

Because of the extensive use of 5-unit equipment throughout the world, it is more economical, if not an absolute necessity as well, to use this type of terminal equipment, and at the same time retain the error indicating features of the 7-unit "protected" code for transmission over radio circuits. Previous methods of code translation, in the main, have utilized either multi-contact relays or other mechanical means. These methods indirectly bring about serious disadvantages in slowness of operation and excessive maintenance of contacts which must be kept in working order at appreciable expense and difficulty. Electronic code translators have been suggested for both telegraph and accounting systems. An excellent discussion of such prior art arrangements is given in chapter 12 of the "The Design of Switching Circuits" by Keister and others of Bell Laboratories 1950 and in several copending U. S. patent applications. Examples of such U. S. patent applications are Serial No. 272,825, filed February 21, 1952, on behalf of Arthur

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E. Canfora for an Electronic Code Converter, now abandoned and Serial No. 361,979, filed June 16, 1953, for a Code Converter System, now patent No. 2,724,739, issued November 22, 1955, Serial No. 364,074, filed June 25, 1953, for a Code Converter, now U. S. Patent No. 2,716,156 dated August 23, 1955, Serial No. 368,973, filed July 20, 1953 for a Validity Checker, now U. S. Patent No. 2,688,050 dated August 31, 1954, on behalf of James S. Harris. For the most part these prior art arrangements are not sufficiently flexible for application to a number of systems without extensive revision and are limited to translation in one direction only.

An object of the invention, therefore, is to translate code characters as expressed in a given fixed-length code to the corresponding characters as expressed in any other fixed-length code by improved electronic means.

A more specific object of the invention is to provide a simplified electronic code translator which can be reversed to translate from a given code to a predetermined code or conversely by manipulation of a single switching element.

A further object of the invention is to provide a reversible code translator which can accommodate any two fixed-length codes by interchanging a small portion of the circuitry as an integral unit.

It is a feature of the invention that characters expressed in any fixed-unit code may be translated into any other existing fixed-unit code.

The objects of the invention are attained by means of an electronic circuit arrangement comprising a plurality of storage elements, preferably bistable reciproconductive circuits, one for each signal element of a character as expressed in the code to be translated, having input circuits coupled to a signal input means to which signal elements of each character under consideration are individually applied to energize the storage elements according to the nature of the signal element assigned.

A further plurality of bistable reciproconductive circuits, one for each signal element of a character as expressed in the outgoing code are interconnected as a binary counting chain, and coupled to an astable reciproconductive circuit or other form of pulse generator. The storage elements and the binary counting chain are coupled by a plurality of resistive elements connected to the output terminals of each of the storage elements and bistable reciproconductive circuits in such permutations as to establish a plurality of coincidence voltage points, there being one such coincidence voltage point established for each character to be translated. The coincidence voltage points are individually coupled to the input electrodes of a number of unilateral impedance coincidence detector devices, such as vacuum tubes, transistors or germanium diodes. The output electrodes of the coincidence detector devices are all connected to a gating circuit which, in turn, is coupled to the pulse generator.

After the storage means are reset to the initial condition and the input signal elements for the character under consideration are established in the storage elements, an operate pulse is applied to the pulse generator to start the conversion process. The train of pulses produced by the pulse generator is applied to the counting input of the binary counting chain, which operates in the conventional binary or scale-of-two counting chain fashion with the tubes of each reciproconductive circuit conducting or blocking in accordance with the number of successive pulses that have been applied at any given time. As soon as the tubes in the binary counting chain are conducting in accordance with the elements of the character under consideration, as expressed in the translation corresponding to the signal elements of the character un-

der consideration, as set up in the storage elements, a unidirectional potential will be set up at one of the coincidence voltage points, which is opposite in polarity to all of the potentials at every other coincidence point. Preferably this potential will be positive and will cause the corresponding coincidence detector device to conduct or otherwise change the mode of operation. Only one of these coincidence devices is operated for any one coded character, there being separate devices for each character. The operated coincidence device changes conductivity of the gating circuit to block the pulse generator. The reciproconductive circuits in the binary counting chain are now left conducting in accordance with the signal elements of the character under consideration, as expressed in the code as translated, and are applied to any suitable utilization means. After each character is translated, a reset pulse is applied to the storage elements, restoring them to the initial condition. This reset function, of course, is performed automatically where the signal elements are of actively opposing nature, but is required where one nature is represented by an active current flow and the other by absence of such current flow.

A translator according to the invention may be arranged to handle any two fixed-length codes by changing the coincidence connections. One suggested arrangement is that of a plugin type mounting for the isolating resistors and the coincidence detectors having one set of terminals for connection to one counting chain, another set of terminals for connection to the other counting chain, and a further set of terminals for connection to the pulse generator control gate.

According to the invention a reversible code translator is realized by using bistable reciproconductive circuits for the storage elements with interconnections to form another binary counting chain and interchanging the connections between the pulse generator and the binary counting chains, together with the reset circuitry, so that when the input signal elements are applied to the first mentioned binary counting chain, the second chain is advanced through the various permutations by the oscillator to establish coincidence for the character under consideration, exactly as described before with reference to the first mentioned binary counting chain. A simple multi-pole double-throw switch is sufficient to switch the circuits for translation in one direction or the other.

Further, in accordance with one aspect of the invention, the reset circuit arrangement is used to set up one or more prearranged code characters in the outgoing binary counting chain as required for operational signals in certain automatic telegraph code signalling systems. More particularly this resetting is accomplished by means of a reset circuit arrangement wherein the leading edge of a reset pulse is employed to trigger the reset circuit to place all of the electron discharge devices affected in the initial states of conduction and the trailing edge of the same reset pulse is utilized to trigger those electron discharge devices to the opposite state of conduction necessary to establish the prearranged code character desired in the storage bank.

Where a protected code is used, one or more further coincidence points are established by resistive isolation means as described above in such permutations that the points change polarity with respect to a predetermined circuit point, as the proper ratio of spacing-to-marking signal elements present in each character of the protected code is established in a binary counting chain. A vacuum tube or other controlled electron flow path device is coupled between this further validity coincidence point and the gating circuit, to control the output train from the pulse generator in response to the output of the validity detector device.

In an alternate embodiment of the invention the validity detector is used in conjunction with the coin-

cidence detector to resolve ambiguities arising from the omission of certain component parts of the basic arrangement of the invention.

In order that the invention may be more clearly understood and readily put to practical use, a circuit arrangement embodying the invention is hereinafter described, by way of example only, with reference to the accompanying drawing in which:

Fig. 1 is a functional diagram of a basic electronic code translating circuit arrangement according to the invention; and

Fig. 2 (sections *a*, *b*, *c* and *d* being taken together) is a schematic diagram of an embodiment of a reversible electronic code translating circuit arrangement, according to the invention.

Referring to Fig. 1, there is shown a functional diagram of the electronic code translator according to the invention. A character as expressed in a given code is applied to the coding terminals 11 of a plurality of storage elements, preferably n stages of bistable reciproconductive circuits interconnected as an n -element binary counting chain 13. As employed herein, the term "reciproconductive circuit" is construed to include all two-tube regenerative devices, in which conduction alternates in one or the other tube in response to applied triggering potential. The term "multivibrator" is frequently applied to this circuit and the term "locking circuit" is sometimes applied to a bistable reciproconductive circuit, which is one in which two triggers are required to switch from one stable state to the other and return. The bistable reciproconductive circuits may be further distinguished as binary reciproconductive circuits which have a single input terminal and reverse the state of conduction each time a trigger is applied and as lock-in reciproconductive circuits which have two input terminals and require alternate input triggering in order to reverse the state of conduction. According to the invention either type of bistable reciproconductive circuit may be used in the counting chains, although for reasons later given the lock-in type is preferred. In the counting chain 13, there is actually a separate coding terminal for each reciproconductive circuit stage, as well as the single conventional counting input terminal 15 for the cascade of stages. The reciproconductive circuits of the counting chain 13 may be reset to a prearranged state of conduction under the influence of a reset control circuit 17 acting in response to a reset pulse applied to the terminal 19. The character under consideration as expressed in a predetermined code is read out at the coding terminals 21 of an m -element binary counting chain 23 having m stages of bistable reciproconductive circuits also connected in the conventional binary or scale-of-two counting chain circuit. Again there is a separate coding terminal for each reciproconductive circuit stage, as well as the conventional counting terminal 25. According to the invention m and n may be any integers and may, if desired, even be the same integer. The reset control circuit 17 may also be used, if desired, to reset the m -element chain 23 to a prearranged state of conduction.

Two leads, one from each of the reciproconductive stages of the binary counting chains 13 and 23, are connected to a coincidence detector circuit 27 arranged to establish a predetermined current relationship, when the conduction of the stages of the n -element chain 13 correspond to the conduction of the stages of the m -element chain 23. A pulse generating circuit 31, controlled by a generator gating circuit 33, is coupled to the m -element binary counting chain 23 at the counting terminal 25. An operating or "convert" pulse is applied to the generator gate circuit 33 at an input terminal 35 to start the pulse generator 31. The coincidence detector 27 is coupled to the generator gate 33 to turn the pulse generator off in response to coincidence as indicated by the predetermined current relationship.

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The circuit arrangement, as thus far described, may be reversed to translate a character expressed in the predetermined code into the given code by switching the pulse generator 31 from the counting terminal 25 to the counting terminal 15 and applying the signal elements of the predetermined code to the coding terminals 21. Upon coincidence being established, as described above, the signal elements of the character under consideration can be read out in the given code at the coding terminals 11.

Where a protected code is in use, a further coincidence circuit or error detector 37 is coupled to the binary counting chain 13, as shown in Fig. 1, for the protected code. This detector 37 is arranged to determine the coincidence of the proper ratio of marking signal elements to spacing signal elements. When such coincidence is established, the gate 33 is arranged to stop the pulse generator 31 in response to the operation of the coincidence detector 37. When an invalid signal element combination is scanned, the gate 33 is held open under the influence of the error detector 37 and the pulse generator 31 continues to step the protected code chain 13 until a valid constant ratio code character is determined. At the receiving end of a telegraph signalling system incorporating a code translator according to the foregoing description, an indication of mutilation of the received character signals is set up in the error detector 37, at the error output terminal 39, which is used, either to print an error symbol or to hold up the translating process and call for a repetition of the character by the source as desired in some automatic telegraph signalling systems.

Referring to Fig. 2 there is shown a reversible circuit arrangement specifically designed for translating from the five unit printer code to a seven unit protected code and conversely. Obviously, conversion of any fixed unit code to any other fixed unit code will be possible in accordance with the basic principles of the invention as set forth hereinafter.

Referring particularly to sections *b*, *c* and *d* of Fig. 2 there are shown five coding terminals 11—1 through 11—5 connected to individual storage elements, shown here as bistable reciproconductive circuits 51—55. While capacitors or magnetic structures or other simple devices may be used for the storage elements according to the invention, some form of triggered electronic storage element is preferably used, and for reasons which will become obvious later, the reciproconductive circuit is preferred. Initially, the storage elements in the form of reciproconductive circuits 51—55 are set to the initial condition wherein the A tubes of each of the circuits are blocked and the B tubes are conducting. If the code character elements to be stored were in the form of energy of different nature or level, such as a positive potential for mark and a negative potential for space, this would not be necessary. The circuit arrangement of Fig. 2 is designed for the application of energy for elements of one nature and the absence of energy for elements of the other nature. In this case potentials corresponding to the marking signal elements of a code character are applied individually to the coding terminals 11—1 through 11—5. The respective reciproconductive circuits 51—55 are then triggered and remain energized in accordance with the nature of the signal elements assigned to each reciproconductive circuit. Until reset these reciproconductive circuits 51—55 serve to store the character under consideration as indicated by the state of conduction of each of the reciproconductive circuits.

The anodes of the tubes V8A through V12B are individually connected to a plurality of busses 61a through 65b respectively. Since the code in use is a binary code the number of busses necessary will be equal to twice the number of elements or $2n$ in this case $2 \times 5 = 10$. It is desired to transform the signal character elements applied to the coding terminals 11—1 through 11—5 into other signal character elements at the further coding ter-

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minals 21—1 through 21—7. The signal elements established at the further coding terminals 21—1 through 21—7 are intended to remain for a time period long enough to enable the associated apparatus to read out the intelligence and perhaps also to perform other functions. For this reason, it is desired that some type of storage element be used, and, therefore, a plurality of bistable reciproconductive circuits 71 through 77 are individually connected to the further coding terminals 21—1 through 21—7. The reciproconductive circuits 71—77 are shown as being identical in design and circuit components to the first mentioned reciproconductive circuits 51—55, though this need not necessarily be so in order to practice the invention. The reciproconductive circuits 71—77 are interconnected in cascade by means of capacitors 79 to form a binary counting chain. The outputs of the individual reciproconductive stages 71—77 are connected to a plurality of busses 81—87. According to the basic principles of the invention, 14 busses would be required as explained in connection with reciproconductive stages 51—55 and the busses 61a through 65b. However, due to a further aspect of the invention only seven busses are required for use with the protected seven-unit code. The seven busses 81—87 are interconnected to the five-unit busses 61a through 65b by means of resistors 5A1 through 5A5, 5B1 through 5B5 and so on, and resistors 7A1 through 7A3, 7B1 through 7B3, and so on in such permutations as to form one coincidence point at the common junctions of each group of resistors for each character to be translated from one code into the other. According to the basic principles of the invention, n -resistors are required for the n -element code and m -resistors are required for the m -element code. In the example shown there are five resistors for the five-unit code, but instead of seven resistors for the seven-unit code, only three resistors are required because the latter code is of the protected variety. The resistors actually used are those connected to those busses which represent the signal elements of a given nature, in this instance marking elements, and the ambiguities inherent in such a short-circuit arrangement are resolved in conjunction with the operation of the error detector 37 as later explained. The potentials applied to the reciproconductive circuits and those subsequently applied to the busses are chosen so that if any one of these busses coupled by resistors to the coincidence point contributes a negative voltage, the coincidence point will not go positive. Thus, the seven-unit arrangement as shown involves fewer resistors and provides larger steps of voltage at the coincidence points. Only one coincidence point is established for each of the characters involved. In the example shown eight such coincidence points A through H corresponding to the respective letters of the alphabet are established. According to the invention, each coincidence point is connected to the input electrode of a coincidence detector device. A triode vacuum tube, connected either as shown for the tube V20A or the tube V22A, makes an excellent coincidence detecting device and a high vacuum diode device could also be used to advantage. In the circuit arrangement shown, however, 35 such triodes or diodes would be required to handle the total number of characters to be translated. Considerable savings in filament power is effected by utilizing cold cathode triode or diode elements, such as gaseous discharge devices, transistors or germanium diodes. In the circuit arrangement of Fig. 2 germanium diodes are shown for the detection devices D1A, D3B and so forth. Further, clamping diode elements D2, D4 and D6 and so forth are connected from the input electrode of the coincidence detecting diodes D1A, D3B and so on, to a point of negative potential as indicated by the minus sign. These clamping diodes are used to prevent the large negative voltages, that would appear at the coincidence points in the absence of the clamping diodes, from appearing across the coinci-

dence detecting diodes and consequently nullifying the one positive voltage which should appear on the common output lead. These clamping diodes are necessary where the detection devices are germanium diodes, or the like, having finite back resistance components. The need for such clamping diodes is obviated, if the coincidence detection devices are vacuum tube diodes or triodes with practically infinite back resistance components. Only eight coincidence circuits are shown in Fig. 2, sections *b*, *c* and *d*. The output electrodes of the coincidence detector diodes D1A, D3B, and so on, as previously mentioned, are connected in common to the grid of an isolating triode tube V20A. Twenty-four of the remaining coincidence points are divided among three additional triode vacuum tubes V20B, V21A and V21B. These vacuum tubes are used to separate the coincidence circuits into groups whereby larger differential voltages may be used in order to obtain the desired coincidence selection. If vacuum tube coincidence detectors were used, the tubes V20A through V21B would not be used as isolating tubes. Instead these tubes and others would be connected in parallel as shown except that the grids would be individually connected to the coincidence voltage points, A, B, C, and so on. Dividing the load presented by the coincidence devices into groups will reduce the impedance presented across the subsequent input circuit.

The cathode and anode elements of tubes V20A through V21B are connected in parallel and the tubes are coupled to the grid of an inverter-amplifier triode vacuum tube V16A. A similar inverter-amplifier triode vacuum tube V14B is coupled to the output of vacuum tube V16A. The output of vacuum tube V14B is coupled to a gating lock-in reciproconductive circuit 33 comprising vacuum tubes V15A and V15B crosscoupled in a conventional bistable lock-in reciproconductive circuit configuration. The reciproconductive circuit 33 is in effect a gating circuit for the pulse generator 31 according to the invention which is shown as an astable reciproconductive circuit comprising the tubes V17A, V17B. A convert pulse or an operate pulse applied to the convert pulse input terminal 35 is injected in the anode circuit of the vacuum tube V15B to open the generator gate 33 and the output of the tube V14B is applied to the cathode of the vacuum tube V15A to close the generator gate 33. Opening and closing of the gate 33 turns the astable reciproconductive circuit 31 on and off to produce a train of pulses which are applied to the cathode follower and impedance transforming tube V18A. The pulses obtained from the cathode follower tube V18A are applied by means of a switch S1 to the counting input terminal 25 of the *m*-element binary chain comprising the reciproconductive circuits 71—77. The application of a convert pulse to the generator gate 33 will start the pulse generator 31 to produce a train of pulses which when applied to the counting input terminal 25 will advance the binary counting chain 23 in the normal counting mode.

When the first pulse is applied at the counting terminal 25, the state of conduction of the tube V1A of the reciproconductive circuit 71 is reversed and the tube V1B is likewise reversed in response to the reversal of the former tube; the remainder of the tubes in the circuit remaining in the initial condition. The second pulse from the generator 31 will restore the reciproconductive circuit 71 to the initial condition and trigger the reciproconductive circuit 72 to the opposite stable state condition; the remainder of the tubes in the chain remaining in the initial condition and so on. As the stages of the counting chain 23 are advanced in the conventional counting chain mode varying potentials will be applied to the *m*-element busses 81—87. Some of the groups of resistors 7A1—7A3, 7B1—7B3, and so forth will have at least one resistor contributing a negative potential to the coincidence point. All of the resistors in the re-

maining groups will have positive potentials thereacross rendering the coincidence points positive insofar as the *m*-element busses are concerned.

When the elements of a five-unit character are presented for conversion at terminals 11—1 through 11—5, one group of resistors will contribute five increments of positive voltage to the coincidence point corresponding to the character under consideration. Application of the convert pulse to the convert input terminal 35 will open the gate 33 and cause the pulse generator 31 to produce a train of pulses which are applied to the counting terminal 25 to advance the reciproconductive circuits 71—77 through the permuted states of conduction until the three resistors of one set each contribute a positive voltage to the coincidence point associated therewith. Assuming that the proper set of resistors is selected, coincidence will be established and the positive potential will be applied through the diode coincidence detector device to the generator control gate 33. This will close the gate 33 and stop the pulse generator 31 from applying pulses to the counting chain 23. The bistable reciproconductive circuits 71—77 are then left in individual conduction conditions representative of the respective elements of the character under consideration as expressed in the code into which translation is desired. This character will be stored for a time sufficient to enable any utilization device to read out the character.

More detailed explanations of the operation of the coincidence circuit are to be found in copending U. S. patent applications Serial No. 272,825 for Electronic Code Converters filed February 21, 1952, on behalf of Arthur E. Canfora, now abandoned, and Serial No. 279,432 for Electronic Duplex Transmitting Distributors, filed March 29, 1952, now U. S. Patent No. 2,682,574, dated June 29, 1954 on behalf of Arthur E. Canfora and Eugene R. Shenk.

It is not necessary to reset the counting chain 23 when counting to 7-unit code because the scanning process will step the counting chain 23 through all of the conditions of conduction of the reciproconductive circuits until coincidence is established. Because it is preferable to have the reciproconductive circuits 71—77 indicative of spacing signal elements when idling, reset is accomplished by means of a reset pulse obtained from a suitable source and applied to the reset pulse input terminal 19—1. The grids of all of the B tubes in the reciproconductive stages 71—75 are connected by resistors through the reset control tube V19A to negative potential biasing the B tubes of the reciproconductive stages. When the reset pulse is applied, the normally conducting reset tube V19A is blocked and the grids of all of the B tubes are allowed to go positive with respect to the associated cathodes thereby rendering the tubes conducting to establish the initial state of conduction of the entire counting chain with all of the A tubes blocked and all of the B tubes conducting. Neon glow lamps can be connected to the anodes of the A tubes to provide a visual indication of idling condition if desired.

When converting from five unit to seven unit code, the five unit reciproconductive circuits 51—55 need be reset only if one nature of the applied signal elements is the absence of energy. Since the arrangement of Fig. 2 is designed for positive marking and zero spacing voltages, a reset pulse is obtained from the anode of the generator gate tube V15A and applied through the switch S1 and the reset tube V13B to the grids of the B tubes of the counting chain 13. This reset circuit functions exactly as that described for the seven-unit reciproconductive circuits. This reset pulse is made available at the terminal 69 for use in other apparatus.

It is further desirable that in some instances the seven-unit protected code storage elements or reciproconductive circuits 71—77 be left with a definite or prearranged character established therein. For example, when converting from a five-unit code to seven-unit code for trans-

mission over a radio relay path, it is highly desirable that the character α or the character β be set up in the counting chain 23 between the message text characters in order to indicate in what service the circuit is being operated. That is, to indicate to the operator whether tolls are being computed, or the like. The circuit arrangement comprising the reset triodes V19A, V19B and the switch S-2, shown in Fig. 2b, is utilized for this purpose. All of the tubes of the m -element counting chain 23 are first reset to the initial condition in response to the leading edge of a negative-going reset pulse applied to the terminals 19-1 as described above. The grids of the tubes V3A and V4A are connected to the anode of the service character reset tube V19B to place the voltage at the anode of tube V19B on the grids of tubes V3A and V4A. The control-signal selecting switch S2 also selects either the grid of the tube V5A or the tube V7A for connection to the anode of the reset tube V19B and places the usual negative voltage on the grid of the other tube V7A or V5A respectively. This selection determines whether or not the character α or β is placed in storage; the difference between the two characters being only in the time occurrence of the last element. A relatively large capacitor 101 is connected between the anode of the tube V19B and ground. The reset pulse causes this capacitor to be charged so that when the trailing edge of the reset pulse appears, a sharp pulse is applied to the grids of tubes V3A, V4A and either of the tubes V5A or V7A. The negative-going reset pulse applied to the grid of tube V19A causes a positive going pulse to be applied from its anode, thru switch S1, and thru a capacitor-resistor differentiating circuit to the grid of normally conducting tube V19B. The negative spike from the differentiating circuit occurring at the trailing edge of the reset pulse causes the tube V19B to be momentarily cut off with the result that a positive trigger is applied to the grids of tubes V3A, V4A and either of the tubes V5A or V7A. The reciproconductive stages 73, 74 and either 75 or 77 are thereupon triggered to the opposite condition thereby establishing the desired character in storage until cleared out for the next message text character.

When converting from seven-unit into five-unit code another reset pulse is applied at terminal 19-2 to reset the n -element counting chain 13 to the initial condition only in order to extinguish the neon glow lamps 67. If such reset were not made, the last character set up in the counting chain 13 would be indicated. When idling it is preferable to show all elements spacing, hence the reset circuit is preferably included in the circuit arrangement.

With the arrangement set up as shown for converting into a protected code, it is possible to have more than one group of resistors satisfying the coincidence condition during this scanning process because it is possible to have more than three of the bi-stable reciproconductive circuits in the counting chain 23 in a marking condition and contributing positive voltages to the respective coincidence resistors. Once the coincidence condition is satisfied, the binary counting chain advance will be stopped and consequently there will be presented at the output terminals 21-1 through 21-7 an erroneous seven-unit code character consisting of more than three marking elements. To prevent this, an error detector circuit 37 is used. It should be noted that while the detector 37 was shown connected to the counting chain 13 in Fig. 1, it is shown connected to the counting chain 23 in Fig. 2 since the latter chain is the only one in which the protected code is set up. It should be clearly understood that such an error detector can be connected to either chain if arranged for protected code. The error detector 37 comprises two normally blocked triode tubes V13A and V13B having interconnected anodes and individually biased cathodes. The grid of the tube V13A is connected to the anodes of each of the A tubes in the reciproconductive circuits 71-77. The bias on the tube V13A is set so that this tube is blocked when the voltages on the resistors 91a,

92a . . . 97a are indicative of three marks or three marking elements, that is, four of these resistors are contributing positive voltage. The grid of vacuum tube V13B is likewise connected to the reciproconductive circuits 71-77 except that the resistors 91b, 92b . . . 97b are connected to the B tubes by way of the busses 81-87. The bias is set on tube V13B so that the tube V13B is also blocked if three of the resistors 91b, 92b, 97b, are producing positive voltage. Since the voltages applied to the grids from the reciproconductive circuits are in effect out of phase, it can be seen that tube V13A is conducting (indicating an erroneous combination) as long as the voltages applied to the grid indicate that there are zero, one or two marking elements, that is, less than three marking elements, and the tube V13B is conducting when there are four or more marking elements. Conduction of either tube V13A or V13B serves to prevent the generator gate 33 from being closed. Since no valid combination has less than two marking elements, the functioning of the tube V13A is not important here and its application will be further discussed hereinafter. The tube V13B when conducting maintains the pulse generator 31 in operation until a valid coincidence point is established. With the use of the error detector circuit as shown, a large number of coincidence point connecting resistors are eliminated and better operation is obtained because wider voltage differences are available for energizing the busses from a given power supply. The pulse voltage developed by the error detector 37 is purposely made to shunt out the pulse derived from the coincidence detector isolating tubes V20A through V21B so that in the event that an erroneous selection is made the coincidence detector cannot control the gate 33 to stop the pulse generator 31.

The circuit arrangement in Fig. 2 is arranged for use with the five-unit printer code, which has a possible total of 32 distinct combinations for assignment to intelligence values, and a protected code of seven units, three of which are always marking or spacing. This protected seven-unit code, which is the most efficacious protected code for use with the printer code, from the standpoint of simplicity of apparatus, provides a total of 35 distinct combinations. The three extra combinations may be used to provide an indication of misselection or nonuse, but in many instances these extra combinations are used to effect some change in the operating circuit without affecting any of the five-unit equipment. In the arrangement shown in Fig. 2, three separate coincidence detectors comprising three triode tubes V22A, V23A and V22B are used to detect combinations which are not converted into five-unit code. These combinations are used to establish currents at the terminals α , β and I. The currents developed at these terminals are then applied to apparatus controlling the operation of associated circuitry. The tube V23B is coupled between the cathodes of all of the extra combination detectors V22A, V23A and V22B and the error detector amplifier tube V14A by way of an amplifier triode V16B. An error output voltage applied to the grid of the tube V16B causes the tube V16B to pass current through the diode D71 to shunt any coincidence pulse that may be presented across the diode D71, thereby preventing any such pulse from closing the gate 33 and locking the oscillator 31. The anode of the tube V16B goes low at the same time to cut off the tube V23B. This renders the cathodes of the tubes V22A, V22B and V23A high, tends to cut these tubes off, thereby preventing these tubes from developing any output current.

According to the invention, the circuit arrangement shown in Fig. 2 is reversible. To reverse the circuit the elements of the seven-unit code characters to be translated are applied to the further coding terminals 21-1 through 21-7 and the switch S-1 is thrown to connect the pulse generator 31 to the counting terminal 15, and also to make certain desired changes in the reset circuitry after which the elements of the character under consideration will be represented in the code into which translation is desired

at the coding terminals 11—1 through 11—5. The storage elements of the n -element binary chain 13, which are the reciproconductive circuits 51—55, are interconnected by means of capacitors 99 to form a binary counting chain of the same configuration as that of the binary counting chain 23. Thus the counting chain 13 is advanced stage by stage by operation of the pulse generator 31 until coincidence is established and the pulse generator 31 is blocked. The outgoing code is then set up at the coding terminals 11—1 through 11—5 of the n -element chain 13.

In accordance with a further aspect of the invention, the circuit arrangement of Fig. 2 is constructed with the coincidence circuitry assembled on a plug-in sub-chassis. A socket is provided on the main chassis having contacts connected to the anodes of the tubes V1B, V2B, V3B, . . . V7B, other contacts connected to the anodes of the tubes V8A through V12B and further contacts connected to the grids of the tubes V20A through V23A. The busses 61a through 65b and 81—87 are connected to prongs on a plug corresponding to the socket. The diodes D1A, D2, D3B, D4, D5C, D6 and so forth, the resistors 5A1—5A5, 5B1—5B5 and so on and the resistors 7A1—7A3, 7B1—7B3 and so on are mounted on the busses in the proper permutated connections for the codes involved.

Thus such chassis can be wired so that any seven-unit code can be translated into any five-unit code and conversely, simply by changing the plug-in sub-chassis. Obviously any code having fewer elements can be accommodated merely by wiring the "extra" combinations to a circuit which will prevent misselection, should coincidence be established first for such "extra" combinations.

It is also suggested that the code translating circuit arrangement hereinbefore described is not limited to code signalling systems for communication, but can be readily applied by one skilled in the art to many types of telemetering systems and commercial computing or accounting systems.

The invention claimed is:

1. A reversible code translating circuit arrangement, including a plurality of storage circuits in the form of input bistable reciproconductive circuits connected as a binary chain, there being one such reciproconductive circuit for each element of a character as expressed in the code to be translated, means responsive to code signals expressed in the code to be translated, to trigger said reciproconductive circuits in accordance with the nature of the signal elements of the character to be translated, a number of output bistable reciproconductive circuits, there being one such reciproconductive circuit for each element of a character as expressed in another code, an astable reciproconductive circuit, a gating lock-in reciproconductive circuit coupled to said astable reciproconductive circuit, normally holding the latter inoperative by an applied holding bias voltage, a source of operate or convert pulses synchronized with the utilization apparatus, means to apply said operate or convert pulses to said gating reciproconductive circuit to remove said bias voltage and permit said astable reciproconductive circuit to run freely, a plurality of coincidence points, a plurality of resistive elements connected to coincidence points, a plurality of plural electrode electron flow path devices connecting said coincidence points to said astable reciproconductive circuit, means to apply the output of said astable reciproconductive circuit to said output bistable reciproconductive circuits connected as a binary chain, said output reciproconductive circuits producing voltages whereby a single one of said coincidence points will receive a potential above a predetermined value, means to apply said voltage transition to said gating lock-in reciproconductive circuit to block said astable reciproconductive circuit, thereby leaving the output reciproconductive circuits with the proper binary code combination for the character to be translated as expressed in said other code, a switching element interposed between said astable recip-

roconductive circuit and the counting chain comprising said plurality of bistable reciproconductive circuits and counting chain comprising said number of bistable reciproconductive circuits to apply the output pulses of the astable reciproconductive circuit selectively to said chains, means to reset said input reciproconductive circuits to the initial condition, said means including further means connected to said gating lock-in reciproconductive circuit to reset said output reciproconductive circuits to a predetermined condition, a validity checking circuit comprising input and output terminals, a connection from the input terminal of said validity checking circuit to each of said plurality of reciproconductive circuits, means biasing said validity circuit to produce current at said output terminal upon the state of conduction of said reciproconductive circuits, failure to represent a valid character combination, and means to apply said current to said lock-in reciproconductive circuit to control the operation of said astable reciproconductive circuit.

2. A reversible code translating circuit arrangement, including a plurality of storage circuits, there being one such circuit for each element of a character as expressed in the code to be translated, means responsive to code signals expressed in the code to be translated, to trigger said circuits in accordance with the nature of the signal elements of the character to be translated, a number of bistable reciproconductive circuits, there being one such reciproconductive circuit for each element of a character as expressed in another code, an astable reciproconductive circuit, a gating lock-in reciproconductive circuit coupled to said stable reciproconductive circuit, normally holding the latter inoperative by an applied holding voltage, a source of operate or convert pulses synchronized with the utilization apparatus, means to apply said operate or convert pulses to said gating reciproconductive circuit to remove said holding voltage and permit said astable reciproconductive circuit to run freely, a plurality of coincidence points, a plurality of resistive elements connected to coincidence points, a plurality of plural electrode electron flow path devices connecting said coincidence points to said astable reciproconductive circuit, means to apply the output of said astable reciproconductive circuit to said bistable reciproconductive circuits connected as a binary chain, said reciproconductive circuits producing voltages whereby a single one of said coincidence points will receive a potential above a predetermined value, means to apply said voltage transition to said gating lock-in reciproconductive circuit to block said astable reciproconductive circuit, thereby leaving the reciproconductive circuits with the proper binary code combination for the character to be translated as expressed in said other code, means to reset said storage circuits to the initial condition, said means including further means connected to said gating lock-in reciproconductive circuit to reset said reciproconductive circuits to a predetermined condition, a validity checking circuit comprising input and output terminals, a connection from the input terminal of said validity checking circuit to each of said plurality of reciproconductive circuits, means biasing said validity circuit to produce current at said output terminal upon the state of conduction of said reciproconductive circuits, failure to represent a valid character combination, and means to apply said current to said gating reciproconductive circuit to control the operation of said astable reciproconductive circuit.

3. An electronic code translating circuit arrangement, including a plurality of storage devices one for each signal element of a character as expressed in a given code arranged to be energized in one of two conditions in accordance with the nature of the signal element of the character under consideration assigned to the storage element under consideration, a plurality of bistable reciproconductive circuits one for each signal element of a character as expressed in a predetermined code, said bistable reciproconductive circuits being connected in cas-

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cade to form a binary counting chain having a counting input, a generator arranged to produce a continuous train of pulses and being coupled to the counting input of said binary counting chain, an electronic gating circuit coupled to said generator to control the starting and stopping of the same, a plurality of resistive elements interconnected between said storage devices and said bistable reciprocal circuits in permutations at which a number of junction points are established equal to the maximum number of characters possible to express in either of said codes, a plural electrode controlled electron flow path device for each of said junction points, each of said plural electrode devices having one electrode connected to the associated junction point, means coupling other electrodes of all of said controlled electron flow path devices to said electronic gating circuit, means to apply an operate pulse to said electronic gating circuit to start said pulse generator and step said counting chain through the cycle of conduction changes until coincidence current at one of said junction points is applied through the associated controlled electron flow path device to said gating circuit to stop said pulse generator, thereby leaving said counting chain in a condition representative of the code character under consideration as expressed in said predetermined code.

4. An electronic code translating circuit arrangement, including a plurality of storage devices one for each signal element of a character as expressed in a given code arranged to be energized in one of two conditions in accordance with the nature of the signal element of the character under consideration assigned to the storage element under consideration, a plurality of bistable reciprocal circuits one for each signal element of a character as expressed in a predetermined code, said bistable reciprocal circuits being connected in cascade to form a binary counting chain having a counting input, a generator arranged to produce a continuous train of pulses and being coupled to the counting input of said binary counting chain, an electronic gating circuit coupled to said generator to control the starting and stopping of the same, a plurality of resistive elements interconnected between said storage devices and said bistable reciprocal circuits in permutations at which a number of junction points are established equal to the number of characters desired to be translated between said codes, a plural electrode controlled electron flow path device for each of said junction points, each of said plural electrode devices having one electrode connected to the associated junction point, means coupling other electrodes of all of said controlled electron flow path devices to said electronic gating circuit, means to apply an operate pulse to said electronic gating circuit to start said pulse generator and step said counting chain through the cycle of conduction changes until coincidence current at one of said junction points is applied through the associated controlled electron flow path device to said gating circuit to stop said pulse generator, thereby leaving said counting chain in a condition representative of the code character under consideration as expressed in said predetermined code.

5. An electronic code translating circuit arrangement as defined in claim 4 and wherein said storage devices comprise further bistable reciprocal circuits.

6. An electronic code translating circuit arrangement as defined in claim 5 and wherein said further bistable reciprocal circuits are connected in cascade to form a further binary counting chain having a counting input and there are means provided to switch said pulse generator from the first said counting chain to said further counting chain to translate characters between said codes in opposite directions.

7. An electronic code translating circuit arrangement, including a plurality of storage devices one for each signal element of a character as expressed in a given code arranged to be energized in one of two conditions in

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accordance with the nature of the signal element of the character under consideration, a plurality of bistable reciprocal circuits one for each signal element of a character as expressed in a predetermined code, said bistable reciprocal circuits being connected in cascade to form a binary counting chain having a counting input, a generator arranged to produce a continuous train of pulses and being coupled to the counting input of said binary counting chain, an electronic gating circuit coupled to said generator to control the starting and stopping of the same, a plurality of resistors interconnected between said storage devices and said bistable reciprocal circuits in permutations at which a number of junction points are established equal to the number of characters desired to be expressed in either of said codes, a plurality of diode devices—one for each of said junction points and having one electrode connected thereto, means coupling the other electrodes of all of said diode devices to said electronic gating circuit, means to apply an operate pulse to said electronic gating circuit to start said pulse generator and step said counting chain through the cycle of conduction changes until coincidence current at one of said junction points is applied through the associated diode device to said gating circuit to stop said pulse generator, thereby leaving said counting chain in a condition representative of the code character under consideration as expressed in said predetermined code.

8. In a code translating circuit arrangement for translating a protected code having a predetermined ratio of signal elements of one nature to signal elements of another nature, a pair of electron discharge devices each having cathode, control and anode electrodes, a plurality of current limiting elements connecting the control electrode of one of said electron discharge devices to each of a plurality of circuit points arranged to be energized in correspondence with said signal elements of one nature, another plurality of current limiting elements connecting the control electrode of the other of said electron discharge devices to another plurality of circuit points arranged to be energized in correspondence with said signal elements of another nature, means biasing said electron discharge devices to cut-off when said circuit points are energized in correspondence with said predetermined ratio of said signal elements, one of said electron discharge devices being further biased to conduct when said circuit points are energized in correspondence with a smaller ratio of signal elements, and the other discharge device being biased to conduct when said circuit points are energized in correspondence with a larger ratio of signal elements, and an output circuit connected between the anode electrodes and the cathode electrodes of said electron discharge devices.

9. In a code translating circuit arrangement for translating a protected code having a predetermined number of signal elements of one nature, a pair of electron discharge devices each having cathode, control and anode electrodes, a plurality of resistors connecting the control electrode of one of said electron discharge devices to each of a plurality of circuit points arranged to be energized in correspondence with said signal elements of said one nature, another plurality of resistors connecting the control electrode of the other of said electron discharge devices to another plurality of circuit points arranged to be energized in correspondence with said signal elements of another nature, means biasing said electron discharge devices to cut-off when said circuit points are energized in correspondence with said predetermined number of signal elements of one nature, one of said electron discharge devices being further biased to conduct when said circuit points are energized in correspondence with a lesser number of signal elements of said one nature, and the other discharge device being further biased to conduct when said circuit points are energized in correspondence with a greater number of signal elements of said one

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nature, and an output circuit connected to the anode electrodes of said electron discharge devices.

10. In a code translating circuit arrangement for translating a protected code having a predetermined ratio of marking elements to spacing elements, a pair of electron discharge devices each having cathode, control and anode electrodes, a plurality of resistors connecting the control electrode of one of said electron discharge devices to each of a plurality of circuit points arranged to be energized in correspondence with marking signal elements, another plurality of resistors connecting the control electrode of the other of said electron discharge devices to another plurality of circuit points arranged to be energized in correspondence with spacing signal elements, means biasing said electron discharge devices to cut-off when said circuit points are energized in correspondence with said predetermined number ratio of marking to spacing elements, one of said electron discharge devices being further biased to conduct when said circuit points are energized in correspondence with a smaller ratio of marking to spacing elements, and the other discharge device being further biased to conduct when said circuit points are energized in correspondence with a larger ratio of marking to spacing elements, and an electronic output gating circuit connected to the anode electrodes to be energized in the absence of said predetermined ratio of marking to spacing signal elements.

11. In a code translating circuit arrangement, including a plurality of bistable reciproconductive circuits, there being one such reciproconductive circuit for each element of a character as expressed in the translated code, means responsive to the leading edge of a reset pulse signal to trigger said reciproconductive circuits to the initial condition of conduction, said means including further means responsive to the trailing edge of said reset pulse signal to reset certain ones of said reciproconductive circuits to a predetermined condition of conduction other than said initial condition.

12. In a code translating circuit arrangement as defined in claim 11 and wherein said bistable reciproconductive circuits each comprise a pair of cross-coupled electron discharge devices having cathodes and grids with individual grid resistors and wherein said means to reset said reciproconductive circuits comprise a normally conducting electron discharge structure having cathode, control, and anode electrodes, a further normally conducting electron discharge structure having cathode, control, and anode electrodes, all of said grid resistors of one electron discharge device of each reciproconductive circuit being connected to the anode of the first electron discharge structure and the grid resistors of the other electron discharge device of a portion of said reciproconductive circuits being connected to the anode of said further electron discharge structure, and a capacitor connected across said further electron discharge structure, thereby to render all of said grids positive with respect to the respective cathodes in response to the lead-

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ing edge of the reset pulse applied to said grid electrodes of said electron discharge structures to establish said initial condition and to render said other grids positive with respect to the associated cathode to reverse the corresponding reciproconductive circuit and establish a given character in said circuits in response to the trailing edge of said reset pulse.

13. A code translating circuit arrangement including a plurality of signal element storage devices having input coding terminals, a number of signal element storage circuits having output coding terminals, means to apply signal elements of a code character to be translated to the coding terminals of said signal element storage devices to energize the same individually in accordance with the nature of the signal element assigned, means to cyclically energize said signal element storage circuits in all possible combinations and permutations of the nature of signal elements assignable, detector circuitry connected between said storage devices and said storage circuits to determine coincidence between the character under consideration as established in said storage devices and as established in said storage circuits and means coupled from said detector circuitry to said cyclically energizing means to stop said cyclically energizing means upon determination of coincidence by said detector circuitry.

14. A code translating circuit arrangement as defined in claim 13 and incorporating means in conjunction with said cyclically energizing means to energize said storage devices and said storage circuits selectively whereby signal elements of a character established at the coding terminals of said storage devices in one code correspond to the signal character elements established at the coding terminals of said storage circuits and conversely.

15. A code translating circuit arrangement as defined in claim 13 and wherein said storage circuits comprise reciproconductive circuits interconnected as a binary counting chain.

16. A reversible code translating circuit arrangement as defined in claim 13 and wherein said storage devices and said storage circuits comprise reciproconductive circuits interconnected as a binary counting chain, said cyclically energizing means comprises an astable reciproconductive circuit and said control circuitry comprises a lock-in reciproconductive circuit.

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