

Sept. 30, 1958

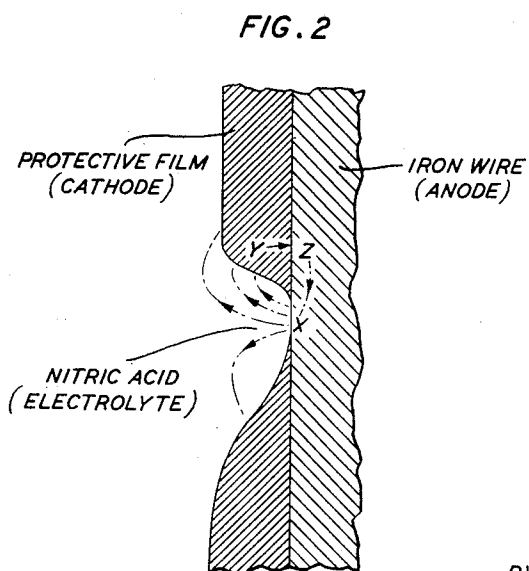
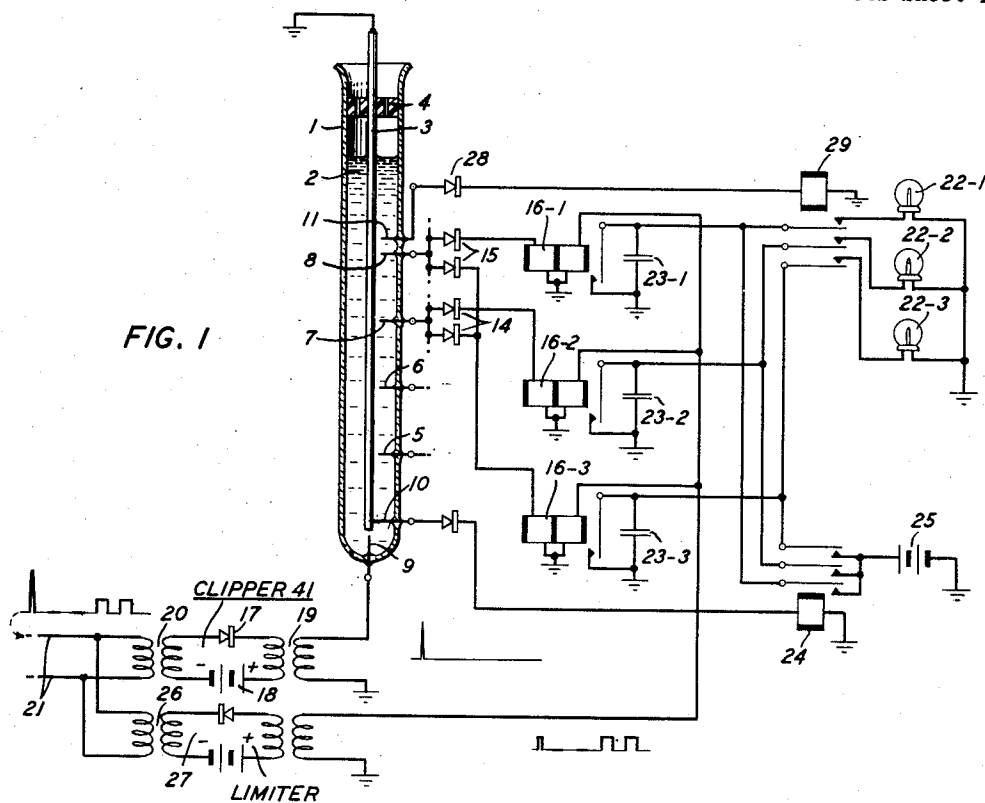
H. M. STRAUBE

2,854,657

CODE CONVERSION

Filed April 13, 1954

2 Sheets-Sheet 1



INVENTOR
H. M. STRAUBE
BY *Harry C. Hart*
ATTORNEY

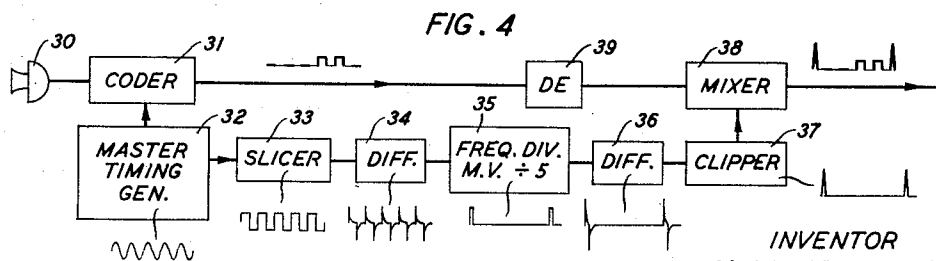
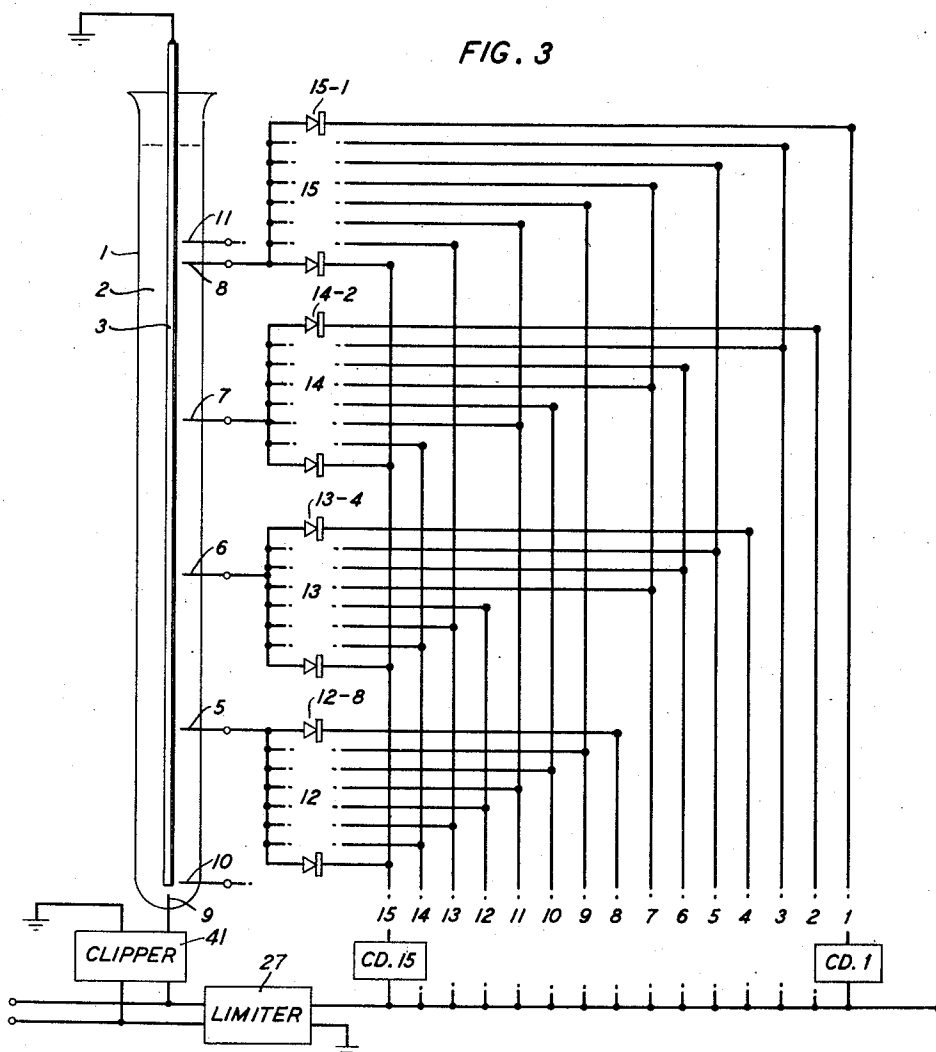
Sept. 30, 1958

H. M. STRAUBE
CODE CONVERSION

2,854,657

Filed April 13, 1954

2 Sheets-Sheet 2



INVENTOR
H. M. STRAUBE
BY
Harry C. Hart
ATTORNEY

1

2,854,657

CODE CONVERSION

Harold M. Straube, Mendham, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application April 13, 1954, Serial No. 422,835

11 Claims. (Cl. 340—347)

This invention relates to code conversion and especially to the conversion of a time code to a space code. Its general object is to effect such code conversion at such a leisurely rate as to impose no special high speed requirements on the associated registering apparatus. A related object is to effect such code conversion, and to generate unequivocal space code registration, without resort to differential amplification or attenuation of intermediate signals which appear in the apparatus.

By "time code" a sequence of pulses which follow one another in time, e. g., on a common conductor, is intended. By "space code" there is intended a distribution of energization conditions which may be simultaneous, e. g., among a plurality of different conductors. The codes may be in the same "language" in which case the conversion is analogous to the action of a stenotypist, who hears with her ears the words of an English sentence as they are spoken one by one, and types the printed text equivalent. But the "conversion" may also include a "translation" from one code language to another, e. g., from the binary "language" to the decimal "language," or vice versa. This is analogous to the action of a bilingual stenotypist who may hear with her ears a sentence spoken in German and type its printed text equivalent in English, translating from German to English as she goes.

An electromagnetic transmission line provided with lateral taps may be employed for time-to-space code conversion. For each of a sequence of time-coded input pulses a wave may be caused to travel from one end of the line to the other giving rise to an output pulse on each lateral tap as it passes by. The distribution of the various simultaneous output pulses as between the several lateral taps constitutes the space code. Translation from one code language to another may be accomplished by interconnections among the taps in accordance with a prescribed code translation pattern.

Electromagnetic transmission lines are characterized by very high velocities of propagation. In circumstances where delays of the order of a microsecond or less are required, this is of great advantage. But in some circumstances the delays required lie in the range from $\frac{1}{100}$ second to a second or more. To achieve such delays with a conventional electromagnetic transmission line would necessitate a line of enormous length. Such a line is out of the question as a practical matter, both because of the excessive space requirements which it imposes and because any wave is greatly attenuated in the course of its propagation from one end of such a long line to the other end, with the result that the pulses derived at the successive output taps are successively diminished in amplitude, necessitating a large amount of differential amplification.

What is needed in such a situation is some extended element along which a disturbance of suitable character may be propagated slowly and without attenuation, and a particular object of the present invention is to provide one. The invention is based on the realization that, with proper attention to design features, an electrochemical

2

element may be endowed with these properties. In particular, the interface between a solid of one chemical constitution such as a metal and liquid electrolyte of another constitution, such as an acid of suitable proportions, constitutes an extended medium which is quasi-stable in the sense that, upon immersion of the metal in the acid, a protective film at first forms on the metal which, however, may be broken down by administering an electrical pulse to it. The breakdown proceeds to travel along the interface away from the point at which it was initiated. Thus, if the breakdown is initiated at one end of a rod or wire, the breakdown is propagated as an electrochemical disturbance toward and ultimately to the other end. As the disturbance proceeds, the protective film is continually reformed immediately behind the disturbance. A good example of such a device comprises a rod or wire of iron immersed in a bath of nitric acid of moderate concentration, the wire and the acid being together supported in a vertical position by a glass tube. The propagation speed of an electrochemical disturbance initiated at the lower end of the wire is of the order of $\frac{1}{10}$ to 10 meters per second, its exact value being determined by the concentration of the acid, the outside diameter of the wire, the inside diameter of the supporting vessel, the temperature of the apparatus and the thickness of the protective film, which in turn depends in part on the time which may have elapsed since the last disturbance. As the disturbance passes each of a succession of taps which may be inserted through the wall of the glass tube, it gives rise to an output pulse on that tap. It is a feature of the invention that the amplitude of an output pulse derived at any tap depends only on conditions in the neighborhood of that tap and is to a large extent an electrochemical constant. It is entirely unrelated to the distance which separates the tap from the point of origin of the disturbance, i. e., the input end of the device. Consequently, with like constructions for the several taps, the amplitudes of all the output pulses are identical, and with proper selection and spacing of components may be caused to follow one another at intervals of 1 second or so with compact apparatus.

The comparatively long recovery time required by the electrochemical transmission line serves to ensure against the propagation of a spurious wave originating in an unintended initiating pulse due to noise or an image of a desired pulse. On the other hand, it introduces a delay between successive operations of the apparatus which might be objectionable in a system of the prior art. To obviate such objections, the invention provides a novel approach to the code conversion operation in that only a marker pulse is propagated over the transmission line, to give outputs at the several taps and, by way of a code-conversion matrix, at the several output points of the apparatus. Such outputs are thus always the same, independent of the pulse group to be converted. The pulse group itself is then balanced against such output point indications as to give an unequivocal indication of that one of the group of output points at which the balance is complete.

The invention will be fully apprehended from the following detailed description of a preferred illustrative embodiment thereof, taken in connection with the appended schematic diagrams in which:

Fig. 1 shows a time-to-space code converter including, as one of its elements, an electrochemical transmission line, but omitting the details of a matrix which interconnects the lateral taps of the line with the output points of the apparatus;

Fig. 2 explains the mechanism by which an electrochemical wave advances;

Fig. 3 shows the same apparatus as Fig. 1 and pro-

vides the details of the matrix omitted from Fig. 1 but omits others; and

Fig. 4 is a block schematic diagram showing a combination of apparatus components which may be employed to insert a marker pulse of a particular form between successive time code pulse groups to be converted.

Referring now to the drawings, Fig. 1 shows a glass vessel or test tube 1 containing a liquid solution 2 of nitric acid in which a rod or wire 3 of iron is immersed. The rod 3 may be centrally supported within the tube 1 by a plug 4 which is preferably provided with perforations to permit the escape of gaseous chemical reaction products. The tube is provided with a number of equally spaced lateral probes 5, 6, 7, 8 which pierce its wall and extend through the acid 2 into proximity with the wire 3. At the lower end of the tube 1 there are provided two additional probes 9, 10 of the same construction as the probes 5, 6, 7, 8 which extend through the acid into close proximity with the lower end of the wire 3. Adjacent to that part of the wire 3 which lies above the uppermost one of the equally spaced probes 5, 6, 7, 8 is another auxiliary probe 11, likewise of the same construction. Preferably, it is spaced from the probe 8 less widely than are the probes 5, 6, 7, 8 among themselves. The auxiliary probe 9 serves to initiate an electrochemical disturbance. The auxiliary probe 10 serves to preset the apparatus for its code conversion operations just before the commencement of each code pulse group. The auxiliary probe 11 initiates the operation of reading out the converted code.

Each of the several probes 5, 6, 7, 8 is connected to the anodes of all the members of a group of rectifiers 12, 13, 14, 15 (Fig. 3) and these rectifiers in turn are connected by way of a matrix to coincidence detectors CD1 to CD15 of Fig. 3, each of which may include a relay 16 of Fig. 1. The probe 9 is connected by way of a clipper 41 comprising a rectifier 17 and a battery 18 and one or more pulse transformers 19, 20 and a source of incoming pulses 21 to ground. The upper end of the wire 3 is connected directly to ground.

The concentration of the nitric acid 2 is preferably between 50 and 70 percent. In other words, its specific gravity lies in the range 1.3 to 1.4. When acid of specific gravity below this range is employed, it readily dissolves the iron wire. When acid of specific gravity 1.3 or more is employed, a protective film commences to form on the wire immediately upon immersion of the wire in the acid and very soon reaches such a thickness that substantially no further corrosion of the iron takes place. When acid of a concentration above the recommended range is employed, this film is highly stable and the initiation of a disturbance is difficult. When, however, the concentration of the acid lies within the recommended range the film may be readily broken down by application of an electrical pulse of a few volts magnitude and enduring for $\frac{1}{100}$ second or so.

Once the local breakdown has taken place, the acid makes contact with the iron and a voltaic cell is formed in which the iron wire provides the anode, the nitric acid the electrolyte and the protective film the cathode. With this arrangement of the materials, depicted in Fig. 2, an electrical circuit is completed at the interface between the protective film and the iron below it, thus short-circuiting the local voltaic cell. Local galvanic currents then flow primarily in the path X—Y—Z. In the vicinity of the point Y the direction of current flow is such as to cause the protective film to be removed by cathodic reduction. At the region X of Fig. 2 the iron (anode) is again oxidized by a series of chemical reactions that ultimately generate a new protective film. As a result of this process the unprotected part of the iron wire advances steadily in the direction of the protective film, carrying the local voltaic cell with it. The local voltaic cell currents which thus travel along the wire constitute an elec-

trical disturbance which thus advances along the wire as a wave.

The initial breakdown is preferably initiated at one end of the wire 3, e. g., at its lower end, as by application of a pulse of electric potential, whose amplitude exceeds a preassigned threshold determined by the clipper 41, across the film at the lower end of the wire. This breakdown then travels as a propagated wave of sharply defined boundaries and with a minimum of distortion or change of form to the upper free surface of the acid 2 where it disappears. In passing each of the probes 10, 5, 6, 7, 8, 11, it gives rise to a pulse of similar wave form and of about 0.7 volt magnitude.

The remaining features and details of the apparatus will be described by reference to Figs. 1 and 3 taken together, of which Fig. 3 shows the details of the code conversion matrix by way of which the several lateral pickup probes 5, 6, 7, 8 are connected to the several coincidence detectors CD1 to CD15. One construction for such coincidence detectors is shown, together with the interconnections among its components, in greater detail in Fig. 1 as comprising similarly numbered relays 16, capacitors 23, and lamps 22.

In the example shown, the apparatus is constructed for conversion from four-place binary time code into numerical space code. That is to say, in operation, one and only one of the coincidence detectors CD is actuated for each possible permutation of the pulses of an incoming time code pulse group. In such a case the transmission line 1, 2, 3 is provided with four probes 5, 6, 7, 8, one for each binary place, and each of these is connected to all of the anodes of one of four groups of eight rectifiers 12, 13, 14 and 15, respectively whose cathodes are in turn multiplied in the fashion shown in Fig. 3 to the coincidence detectors CD. Evidently the system could be extended to higher numbers. For example, to convert from numbers in the five-place binary code, five lateral probes would be provided and each of these would be connected to the anodes of a group of sixteen rectifiers whose cathodes would in turn be multiplied by way of a matrix of the same general pattern as that of Fig. 3 to 31 load devices.

The operation will be illustrated in connection with the conversion of the four-place code pulse group 0011 which in the conventional binary notation stands for the number "three." This code pulse group is shown alongside of Fig. 1 preceded by a marker pulse whose amplitude is two or three times as great as that of the code pulses and which is preferably of very short duration. It is therefore illustrated as a sharp narrow spike. Such a sharp narrow spike may easily be caused to precede each code pulse group by apparatus which may be located at a transmitter station and which may, for example, be as indicated in Fig. 4. Here a signal, for example a voice wave originating in a telephone transmitter 30, is converted into a code pulse group by a coder 31 whose operation is controlled by a master timing generator 32. The latter may generate a wave of sinusoidal form as indicated below the generator 32. This is converted substantially into a square wave by a slicer 33 whose output is in turn converted into a sequence of sharp positive and negative spikes by a differentiator 34. A frequency dividing multivibrator 35 is then provided which responds, for example, to every fifth positive spike, being insensitive to the negative spikes. It therefore delivers pulses of one sign at a rate $\frac{1}{5}$ of that of the timing wave generator 32. Such pulses are differentiated, 36, to sharpen them, the negative excursions being then removed by a clipper 37 to leave a sequence of sharp spikes of one sign. These are inserted in the outgoing pulse train by a mixer 38 and are precisely located on the time scale with respect thereto by the inclusion of a delay equalizer 39.

Assume that the code pulse group to be converted is of the form 0011 and preceded by the sharp positive-

5

going marker pulse as shown in Fig. 1. The clipper 41 is adjusted by selection of the magnitude of the battery 18 to pass only voltages in excess of the code pulse amplitudes. It therefore passes a pulse each time a marker pulse arrives but blocks the code pulses. This marker pulse, applied by way of the input probe 9, originates a disturbance which travels in the fashion described above from the lower end of the wire 3 to its upper end giving rise to an output pulse on each of the lateral pickup probes in turn. As it passes by the first lateral probe 10, which is auxiliary in the sense that it does not form a part of the binary numbering system, it gives rise to an output pulse on the probe 10. This pulse energizes the winding of a multicontact relay 24 and the closure of its contacts applies the voltage of a battery 25 simultaneously to all of a group of condensers 23, thus charging them to the battery voltage. This may be termed a presetting operation which prepares the remainder of the system to receive and recognize an incoming code pulse group.

The output pulse from the first binary probe 5 reaches all of the coincidence detectors CD8 through CD15 and no others. The output pulse from the second probe 6 reaches the coincidence detectors CD4, CD5, CD6, CD7, CD12, CD13, CD14, CD15 and no others. The output pulse from the third probe 7 reaches the coincidence detectors CD2, CD3, CD6, CD7, CD10, CD11, CD14, CD15 and no others. The output pulse from the last probe 8 reaches the coincidence detectors CD1, CD3, CD5, CD7, CD9, CD11, CD13, CD15 and no others. Referring again to Fig. 1, each of the coincidence detectors CD may be a two-winding relay 16 of which the center point is grounded. By adjustment of the tension of the contact spring and the ampere turns of the winding, the sensitivity may be so adjusted that a pulse through one of these windings suffices to close the relay contacts, thus discharging the condenser 23 which is connected across these contacts. When, however, pulses of the same polarity are applied to both the windings of any such relay at the same time, the contacts remain open and the condenser 23 remains charged.

The incoming code pulse group also passes by way of a transformer 26 and a limiter 27 to the second windings of all of the several relays 16 in parallel. The limiter 27 serves to reduce the amplitude of the marker pulse to that of the code pulses. As explained above, its duration is very short compared with the duration of any code pulse. When its amplitude has been thus limited, therefore, its energy is small compared with that of any code pulse. The relay windings 16 are proportioned in such a way that they are sensitive to the energy of a code pulse but not to the lesser energy of the limited marker pulse.

With this arrangement it is evident that the second windings of the relays 16 remain unenergized during the first pulse interval and the second but are energized during the third pulse interval and the fourth. From the interconnections of the matrix of Fig. 3 it will be apparent that every relay 16 of the group is energized at one time or another during the course of progress of the electrochemical disturbance from one end of the transmission line to the other with the single exception of the one identified as 16-3. This one receives energy on its first winding from the electrochemical disturbance as it passes the third probe 7. At the same instant it receives energy from the third code pulse on its second winding, and the magnetic pulls of the two windings are balanced so that the contacts remain open. Similarly, at the fourth pulse interval the same relay 16-3 receives energy from the propagated electrochemical disturbance as it passes the fourth lateral probe 8 and, by way of the transformer 26, from the fourth code pulse. The two resulting magnetic pulls are again balanced, and the contacts continue to remain open. Inasmuch as the third relay 16-3 is not connected to the first probe 5 or to the second 6 at all, and inasmuch, further, as the second winding of this

6

relay receives no energy from the incoming pulse group at the first pulse interval or at the second, it remains completely unenergized throughout the entire code pulse group, and it is the only one of the group which does so. Consequently the condenser 23-3 is the only one of the group 23 which remains charged throughout the code pulse group.

As the electrochemical disturbance proceeds beyond the last output probe, it passes the read-out probe 11 and a pulse passes by way of a rectifier 28 to the winding of the read-out relay 29. The pull of this relay closes all of the associated contacts, shown in Fig. 1 as three in number but in fact, in four-place binary apparatus, fifteen in number. Each of these contacts interconnects the ungrounded terminal of one of the condensers 23 through one of the lamps 22 to ground. In the particular example under consideration, connection of the third condenser 23-3 to the third lamp 22-3 discharges the condenser through the lamp and causes it to flash. This lamp may be provided in well known fashion with an opaque mask through which is cut an aperture of the form of the Arabic numeral 3. Closure of the other contacts of the relay 29 likewise establishes connections from the ungrounded terminals of the other condensers 23 to their correspondingly numbered lamps 22. However, as explained above, each of these condensers 23, with the sole exception of the third one 23-3, has already been discharged either by the energization of the first relay winding through the action of the propagated pulse or by the energization of the second relay winding through the action of the code pulse. Hence, one and only one of the lamps 22 of the bank is caused to flash and so makes known its identity and therefore the translated value or meaning of the incoming binary time code pulse group.

In the foregoing illustrative embodiment, the start pulse which initiates the electrochemical disturbance is shown as being delivered at one end of an elongated conductor whereupon it travel as a wave in only one direction, namely, to the other end of the elongated conductor. Evidently, however, if the start pulse were to be delivered to the conductor at some point removed from both ends, two disturbances would travel in opposite directions toward the respective ends of the elongated conductor. If desired, each of these disturbances may be individually turned to account by application of the principles and techniques described hereinabove.

The foregoing illustrative embodiment of the invention involves translation from one code language to another as well as conversion from time code to space code, and the examples employed were the binary code and the decimal code. It will be readily understood, however, that with appropriate changes of the electrical connections between the lateral probes and the output load devices, any one of a number of other codes may serve as the code language to be translated or as the translated code language. Examples of such other code languages are the reflected binary code and the well known two-out-of-five code. Since the necessary circuit changes are entirely straightforward, no further detailed description of such translators is called for.

What is claimed is:

1. Apparatus for converting an incoming group of pulses which are arranged sequentially in time to represent a number in accordance with a preassigned permutation code and are preceded by a distinguishable marker pulse into a unique designation of said number, which comprises a pulse propagation line having an input point and a first plurality of uniformly spaced lateral output taps, a second plurality of conductors connected to each of said lateral taps, a third plurality of coincidence detectors each having first and second input terminals, for indicating, by simultaneous energization of both of said terminals, balance of signals applied to said first and second terminals, respectively, a matrix of cross connections interconnecting the first terminals of said detectors

with said conductors in accordance with a preassigned code, means for applying said marker pulse to said input point as a start pulse, whereupon said start pulse is propagated as a wave along said line from said input point, giving rise to an output pulse on each of said lateral taps in its passage thereby, means for applying the pulses of said code group to the second terminals of all of said detectors, and means responsive to such balance, in any one of said detectors at every pulse position of said code group, for indicating the identity of said one detector.

2. In combination with apparatus as defined in claim 1, a rectifier connected in series with each of said conductors.

3. Apparatus as defined in claim 1 wherein said pulse propagation line comprises an elongated conductor having a chemically active surface, a chemically active medium surrounding said conductor and of a constitution to react with the material of said conductor to form thereon a protective insulating film, wherein each of said lateral taps comprises a probe penetrating said medium in proximity with said conductor and spaced along its length, wherein said input point comprises a probe penetrating said medium in proximity to a first end of said elongated conductor, and wherein the application of said start pulse to said input probe effects a local breakdown of that part of said film which protects said first end, whereupon said breakdown travels as an electrochemical disturbance along said elongated conductor and to the other end thereof, giving rise to an output pulse on each of said lateral probes in its passage thereby.

4. Apparatus as defined in claim 1 wherein said pulse propagation line comprises a first elongated medium having a preassigned chemical constitution and a surface, a second elongated medium having a chemical constitution such as to react with the first medium, disposed in contact with the first medium in a fashion to provide an interface between said media, said interface having formed thereon, due to chemical reaction between said media, a protective insulating film, wherein each of said lateral taps comprises a probe penetrating said second medium in proximity with said interface and spaced along its length, wherein said input point comprises an input probe penetrating said second medium in proximity to a first end of said interface, wherein the application of said start pulse to said input probe effects a local breakdown of that part of said film which protects said first end, whereupon said breakdown travels as an electrochemical disturbance along said interface and to the other end thereof, giving rise to an output pulse on each of said lateral probes in its passage thereby.

5. Apparatus as defined in claim 4 wherein said first medium is a metallic conductor.

6. Apparatus as defined in claim 4 wherein said second medium is an acidic liquid.

7. Apparatus as defined in claim 4 wherein said first and second media are coaxially disposed, the second medium surrounding the first medium.

8. Apparatus as defined in claim 1 wherein said pulse propagation line comprises a first extended medium having a preassigned chemical constitution and a surface, a second extended medium having a chemical constitution such as to react with the first medium, disposed in contact with the first medium in a fashion to provide an interface between said media, said interface being characterized by a quasi-stable condition in the absence of a disturbance applied thereto, wherein each of said lateral taps comprises a probe penetrating said second medium in proximity with said interface and spaced along its extent, wherein said input point comprises an input probe penetrating said second medium in proximity to a part of said interface, and wherein the application of said start pulse to said input probe effects a local disturbance of said quasi-stable condition, whereupon

said disturbance travels as an electrochemical wave along said interface and to other parts thereof, giving rise to an output pulse on each of said lateral probes in its passage thereby.

9. Apparatus for converting an incoming group of binary pulses which are arranged sequentially in time and are preceded by a distinguishable marker pulse into a unique designation of the number represented in the binary numeration system by said pulses which comprises a pulse propagation line having an input point and number n of uniformly spaced lateral output taps, a number $m=2^{n-1}$ of conductors connected to each of said lateral taps, a number $N=2^{n-1}$ of coincidence detectors, a matrix of cross connections interconnecting said detectors with said conductors in accordance with a preassigned code, means for applying said marker pulse to said input point as a start pulse, whereupon said start pulse is propagated as a wave along said line from said input point, giving rise to an output pulse on each of said lateral taps in its passage thereby, means for applying the pulses of said code group to all of said detectors in opposite phase, and means responsive to balance, at each pulse position of said code group, of the energies applied to any one of said detectors for indicating the identity of said last-named detector.

10. Apparatus for converting an incoming group of binary pulses which are arranged sequentially in time to represent a number in accordance with a preassigned permutation code and are preceded by a distinguishable marker pulse into a unique designation of said number, which comprises a pulse propagation line having an input point and a first plurality of uniformly spaced lateral output taps, a second plurality of conductors connected to each of said lateral taps, a third plurality of condensers, means for charging all of said condensers, a relay associated with each of said condensers for discharging it, a matrix of cross connections interconnecting said relays with said conductors in accordance with said preassigned code, means for applying said marker pulse to said input point as a start pulse, whereupon said start pulse is propagated as a wave along said line from said input point, giving rise to an output pulse on each of said lateral taps in its passage thereby and so energizing selected ones of said relays in one phase, means for applying the pulses of said code group to all of said relays in opposite phase, and means responsive to balance, at each pulse position of said code group, of the energies applied to any one of said relays for indicating the identity of a condenser which remains charged throughout said code pulse group.

11. Apparatus for converting a time coded pulse group into a space coded signal which comprises means for applying a distinguishable marker pulse preceding said time coded pulse group to an input point, a pulse propagation line connected to said input point, a first plurality of lateral taps spaced along said pulse propagation line, a second plurality of means, each having two independent input terminals, for passively indicating, by simultaneous energization of both of said terminals, chronological balance of signals applied to said terminals respectively, connections from one terminal of each of said indicating means to distinctive combinations of said lateral taps and means for applying said time coded pulse group to the alternate terminal of each of said indicating means, whereby said time coded pulse group is converted to a distinctive combination of those of said individual indicating means which are thus simultaneously energized.

References Cited in the file of this patent

UNITED STATES PATENTS

2,006,582	Callahan et al. -----	July 2, 1935
2,403,561	Smith -----	July 9, 1946
2,616,965	Hoepfner -----	Nov. 4, 1952