

May 17, 1955

H. M. STRAUBE

2,708,748

CODE CONVERSION

Filed April 13, 1954

2 Sheets-Sheet 1

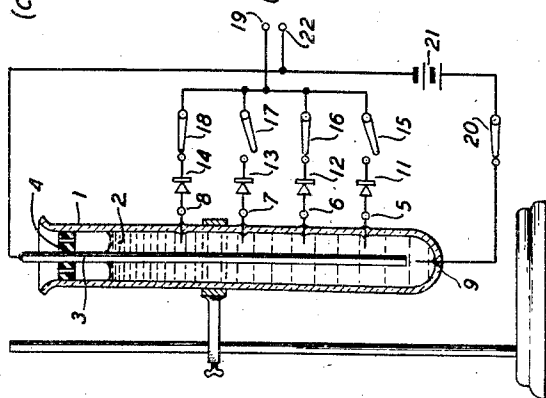
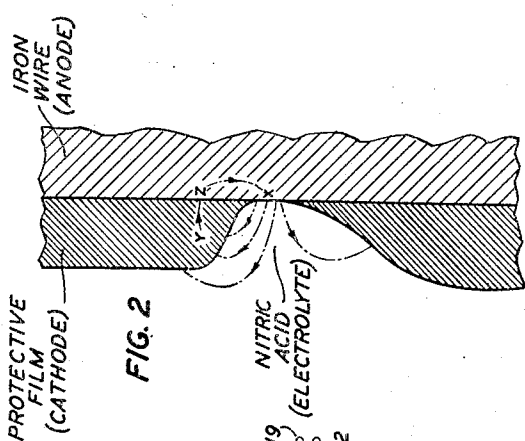
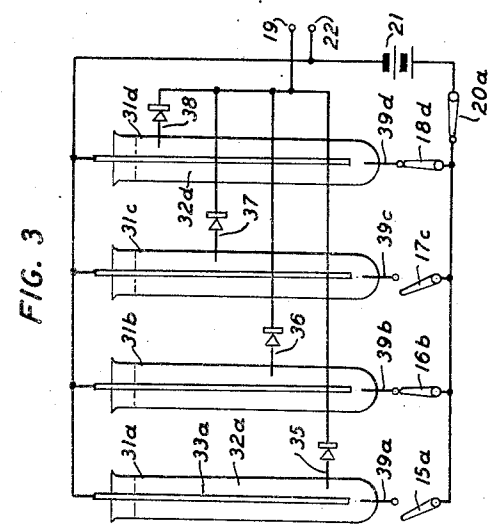
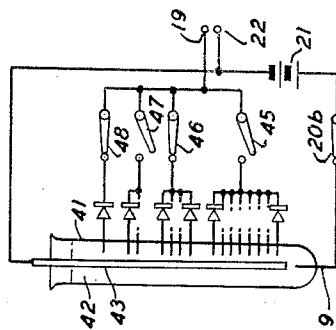
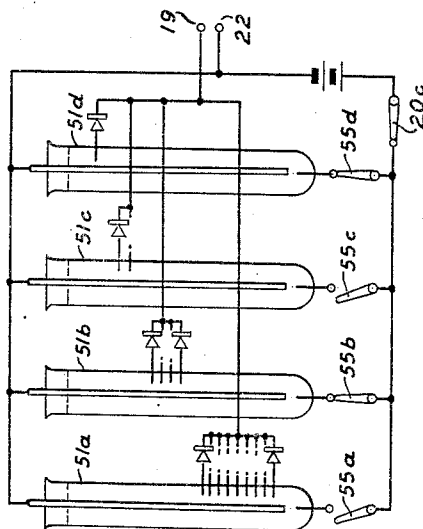


FIG. 5



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

May 17, 1955

H. M. STRAUBE

2,708,748

CODE CONVERSION

Filed April 13, 1954

2 Sheets-Sheet 2

FIG. 7

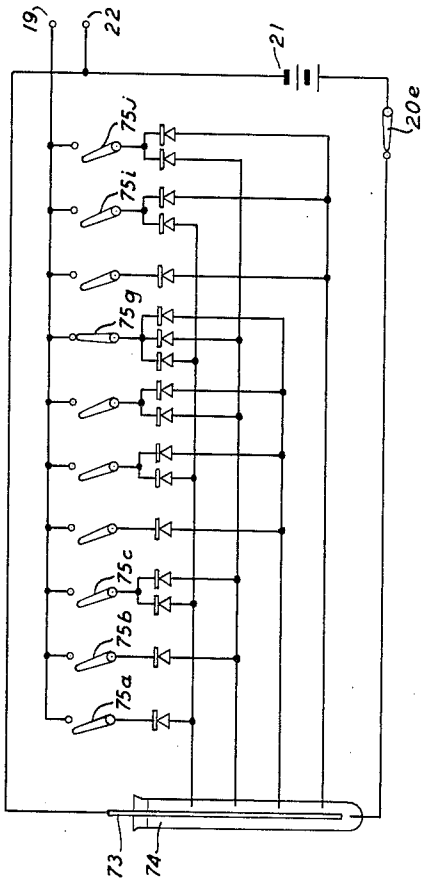


FIG. 8

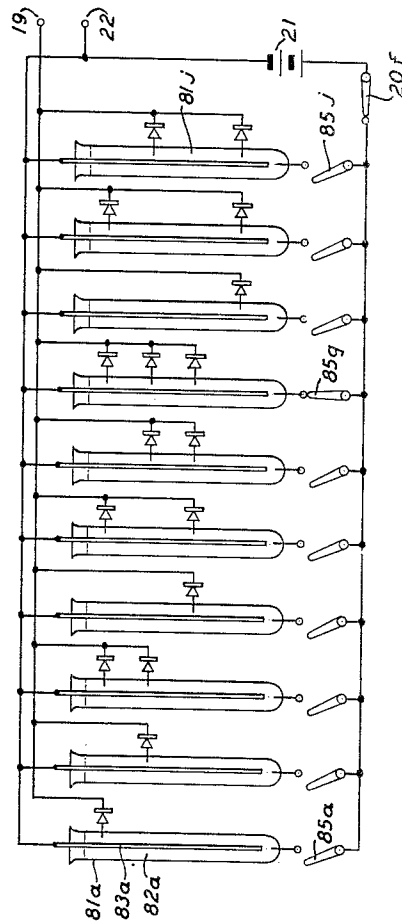
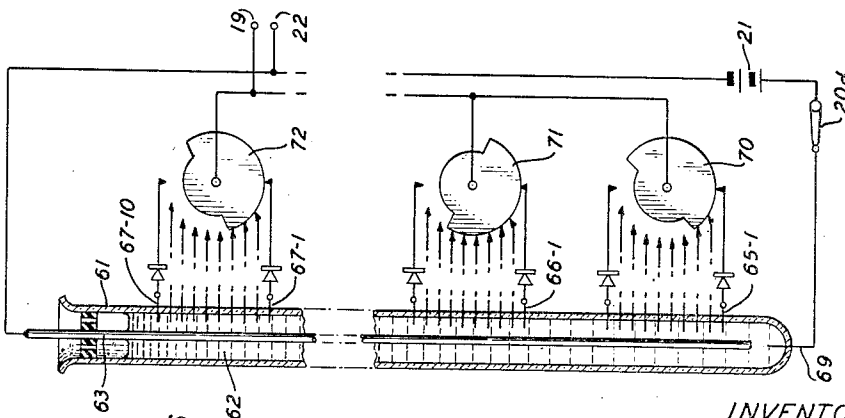


FIG. 6



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

1

2,708,748

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. 422,789

10 Claims. (Cl. 340-354)

This invention relates to code conversion and particularly to the conversion of a space code to a time code. Its general object is to effect such code conversion at such a leisurely rate as to impose no special speed requirements on time code receiving apparatus. A related object is to effect such code conversion, and to generate time-coded output signals which are alike in magnitude, without resort to differential amplification or attenuation of such output signals.

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 code "language," in which case the conversion is analogous to the action of a human being who reads, with his eyes, the words of a printed English text, all of which are present simultaneously, and speaks them one by one with his mouth in the English tongue. But the "conversion" may also include a "translation" from one code language to another, e. g., from the decimal "language" to the binary "language" or vice versa. This is analogous to the action of a bilingual individual who may read with his eyes a printed German text, and speak its English equivalent, translating from German to English as he goes.

An electromagnetic transmission line provided with lateral taps may be employed for space-to-time code conversion. A wave travels from one end of the line to the other, giving rise to an output pulse on each lateral tap as it passes by. These output pulses are then suppressed, amplified or otherwise modified by apparatus connected to the taps, in accordance with a preassigned input space code. The modified pulses are then collected on an output conductor where they appear in succession as a time code.

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 is 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 element

2

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 quasistable 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 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 of components may be caused to follow one another at intervals of 1 second or so with compact apparatus.

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

Fig. 1 shows a simple space-to-time code converter including as one of its elements an electrochemical transmission line;

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

Fig. 3 shows a modification of the converter of Fig. 1;

Fig. 4 illustrates an extension of the principles of Fig. 1 to include translation from one code language to another as well as conversion from space code to time code;

Fig. 5 shows a modification of Fig. 4;

Fig. 6 shows the essentials of a preset telephone dial mechanism embodying the invention;

Fig. 7 shows apparatus for effecting a simultaneous conversion and translation from decimal space code to binary time code; and

Fig. 8 shows an alternative to Fig. 7.

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 2 by a plug 4 which is preferably provided with perforations to permit the egress of gaseous chemical reaction products. The tube is provided with a number of equally spaced taps 5, 6, 7, 8 which pierce its wall and extend through the acid 2 into proximity with the surface of the wire 3. At the lower end of the tube 1 there is provided an additional probe 9 which extends through the acid

3

into close proximity with the lower end of the wire 3. To each of the several probes 5, 6, 7, 8 is connected a rectifier 11, 12, 13, 14 and these rectifiers in turn are connectible by way of switches 15, 16, 17, 18 to an output terminal 19. The probe 9 is connected by way of a start switch 20 and an energizing battery 21 to the upper end of the wire 3 which in turn is connected to a second output terminal 22.

The concentration of the nitric acid 2 is preferably between 50 and 70 per cent. 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 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 $\frac{1}{10}$ 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 electrical disturbance which thus advances along the wire as a wave.

The initial breakdown is preferably initiated at one end of the wire, e. g., at its lower end, as by closure of the start switch 20 which applies the full voltage of the battery 21 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 5, 6, 7, 8, it gives rise to a pulse of similar wave form and of about 0.7 volts magnitude.

In operation a space code, e. g., the code 0101, is set up on the switches 15, 16, 17, 18 by closure of the switches 16 and 18, the switches 15 and 17 being left open. This setup may be accomplished manually and at leisure. By employment of well known apparatus not shown, it may also be accomplished automatically in response to a prescribed stimulus. When the setup is complete, the start switch 20 is briefly closed to initiate the breakdown of the protective film and this disturbance travels from the lower end of the rod 3 to its upper end, passing the taps 5, 6, 7, and 8 in sequence. In the example given above, the resulting output pulse on the probe 5 fails to pass the switch 15 which is open. Later, an output pulse on the probe 6 passes the closed switch 16 to the output terminal 19. Later still, an output pulse on the probe 7 fails to pass the switch 17 which is open. Last, the output pulse on the probe 8 passes the closed switch 18 to reach the output terminal 19. Thus, the code 0101 has been duplicated on the terminals 19, 22 as a sequence of pulses in time.

By well understood techniques a signal which identifies the instant of closure of the starting switch 20 may be

transmitted to a pulse time code receiver, there to identify the time positions in which the pulses occur. Sampling techniques synchronized with the closure of the start switch 20 may then be employed which serve unequivocally to associate the pulses of this group with the second and fourth pulse positions as distinguished from other possibilities.

Fig. 3 shows apparatus which is the same as Fig. 1 except that a plurality of electrochemical transmission lines are employed, each comprising a tube 31, an iron rod or wire 33, and an acid bath 32, in which the wire 33 is immersed. Each of them is provided with a single probe 35, 36, 37, 38 which is connected by way of a rectifier to an output terminal 19 without the interposition of a switch. Instead, switches 15a, 16b, 17c, 18d are connected in tandem with the several input probes 39a, 39b, 39c, 39d and the space code to be converted may be set up in preliminary fashion by closure of selected ones of these switches, leaving the others open. When the setup has been completed, a start switch 20a may be closed which initiates an electrochemical disturbance at the lower ends of selected ones of these several electrochemical devices. Propagation of each disturbance takes place as before, giving rise to output pulses on the lateral probes of the devices thus energized and not on the others. Thus, the apparatus converts the space code set up on the switches 15a, 16b, 17c and 18d into a pulse time code on the output terminals 19, 22.

The arrangement of Fig. 3 permits a reduction in the length of at least some of the propagation devices 31, especially when the initial setup of the input code by the closure of the switches in time sequence is acceptable.

Fig. 4 shows an extension of the apparatus of Fig. 1 in that a group of eight probes, each with its rectifier, are all connected together and, by way of a first switch 45 to the output terminal 19, a group of four probes are all connected by way of a second switch 46 to the output terminal 19, a group of two probes are connected by way of a third switch 47 to the output terminal, while the last probe is connected alone by way of a switch 48 to the output terminal 19. The input code shown by the disposition of the switches 45, 46, 47, 48 is 0101 as before. When the disturbance is initiated as before by closure of the input switch 20b, it passes each of the first eight probes without reaching the output terminals 19, 22. As it passes the next group of four output probes, a sequence of four pulses reaches the output terminals. This group is followed by a pause while the propagated disturbance passes the two probes of the third group and then by a single pulse as it passes the last probe. Thus, a total of five pulses appear at the output terminals of the apparatus in time sequence. It is to be noted that the input code, 0101, is the conventional binary representation of the number 5. Hence, the apparatus has at the same time converted from space code into time code and translated from binary notation into decimal notation. It is easily seen that any other binary number within the compass of the apparatus is likewise correctly translated into its decimal counterpart.

Fig. 5 shows a modification of Fig. 4 in which each of the several groups of probes, all of which are connected by way of rectifiers together, is associated with one of a group of electrochemical propagation devices, 51a, 51b, 51c, 51d. The input switches 55a, 55b, 55c, 55d are connected to the start probes of these several devices and a start switch 20c applies the voltage of a battery 21 to those of the electrochemical propagation devices whose input switches have been closed, as before. Thus, Fig. 4 bears the same relation to Fig. 3 as does Fig. 2 to Fig. 1, and offers the same relative advantages.

Fig. 6 shows a code converter employing an electrochemical wave propagation device comprising a wire 63 in an acid bath 62, supported in a tube 61 having a number of lateral probes 65-1 to 67-10 which are now arranged in groups of ten, any number of adjacent probes

of each single group, starting with the first probe, being selectively connectible together and to an output terminal by way of a manually operable switch 70, 71, 72. By way of illustration, the lowest switch 70 is shown as establishing connections from each of the first three probes of the lowest group 65 to the output terminals 19, 22, the other probes of this group being open; the second switch 71 as establishing similar connections among the first seven probes of the second group 66, and the upper switch 72 as establishing similar connections among the first four probes of the third group 67. The apparatus is broken between the second switch and the upper one, indicating that it may be extended to include a number of such switches in excess of three, each with a group of 10 probes. In the illustrative arrangement of these switches and disregarding the additional switches and probes which are omitted from the drawing, the number 3-7-4 has been established as an input to the apparatus in the form of a decimal space code. This may be done manually and at leisure as, for example, by a telephone subscriber who wishes to transmit a sequence of pulses to a telephone station which shall act at such telephone station to establish a connection with another subscriber whose telephone number is 374. The calling subscriber, having made this setup at his leisure and checked it to his satisfaction, may then operate the start switch 20d to cause an electrochemical disturbance to be propagated from the lower end of the electrochemical transmission line 61 to its upper end. As explained above, this gives rise to an output pulse on each of the probes of each group upon passage thereby. With the switches 70, 71, 72 in the arrangement shown, such output pulses appear as a first group of three followed by a pause, then a group of seven followed by another pause, and finally a group of four, all of these pulses appearing in time sequence on the output terminals of the apparatus where they may be delivered, for example, to an outgoing telephone line.

By proper selection of the diameter of the wire 63, the concentration of the acid 62, and the inside diameter of the vessel 61, and by proper control of the temperature of the apparatus as a whole, the pulses of each group may be caused to follow each other at intervals of about $\frac{1}{10}$ second with pauses of about one second between successive groups, with apparatus which, far from being prohibitively bulky, is reasonably compact. Such pulse rates and interpulse delays are of the correct order of magnitude for the operation of present day commercial telephone switching apparatus.

Fig. 7 shows apparatus for the conversion of a space code represented by the closure of a single one of a plurality of switches into a binary time code representing the same number. As before, an electrochemical delay device, comprising an iron wire 73 in an acid bath 74, is provided with lateral probes and a start probe and the lateral probes are interconnected by way of rectifiers to switches 75a-75j by a matrix of connections of the form shown. It will be apparent to those skilled in the principles and techniques of pulse-code transmission that this matrix may readily be extended without the addition of any further probes to encompass all possibilities for 15 switches. For simplicity of illustration, however, the system is illustrated with only ten switches, designated 75a through 75j. The first switch is connected only to the uppermost probe; the second switch is connected only to the probe next lower; the third switch is connected to each of the two upper probes. The fourth switch is connected only to the third probe, measured from the lower end of the wire 73, and so on. It will be apparent that this pattern of interconnections among switches and probes is in accordance with the binary numeration system. Thus, the seventh switch 75g which stands for the number 7 is connected to the first, the second and the third probes measured from the upper end of the device but not to the lowermost probe. Thus, when the start

switch 20e is closed and the electrochemical disturbance travels upward along the electrochemical transmission line, it delivers at the output terminals the pulse sequence 0111. This code group, as is well known, is the conventional binary number representation of the number 7.

Fig. 8 shows a modification of the apparatus of Fig. 7 employing a number of individual propagation devices 81a-81j equal to the number of input switches 85a-85j. It bears the same relation to Fig. 7 as do Fig. 5 to Fig. 4 and Fig. 3 to Fig. 1, and offers the same advantages as compared with its simpler counterpart.

In each of the foregoing illustrative embodiments, the start pulse which initiates the electrochemical disturbance is shown as being delivered at one end of an elongated conductor whereupon it travels as a wave in only one direction, namely, to the other end of the elongated conductor. Evidently, however, if the start pulse is delivered to the conductor at some point removed from both ends, two disturbances 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.

Some of the foregoing illustrative embodiments of the invention involve translation from one code language to another as well as conversion from space code to time code or vice versa. In such cases, the examples employed were the decimal code and the binary code. It will be readily understood, however, that with appropriate changes of the electrical connections between the lateral probes and the input switches, 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. Code conversion apparatus which comprises an elongated conductor having a chemically active surface, a chemically active medium in contact with said conductor and of a constitution to react with the material of said conductor to form thereon a protective insulating film, a plurality of lateral probes penetrating said medium in proximity with said conductor and spaced along its length, an input probe penetrating said medium in proximity to a first end of said elongated conductor, means including said input probe for applying an electrical start pulse to said first end, to effect 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, an output conductor, and input switch means for selectively connecting said probes to said output conductor in accordance with a preassigned code, whereby output pulses appear on said output conductor in a sequence determined by said code.

2. In combination with apparatus as defined in claim 1, a unidirectionally conducting device connected in series with each of said lateral probes.

3. Apparatus as defined in claim 1 wherein each lateral probe is connected to a single one of said input switch means.

4. Apparatus as defined in claim 1 wherein a number 2^n of said probes are connected to each of said input switch means, where n takes on the integral number values 0, 1, 2, 3 . . .

5. Apparatus as defined in claim 1 wherein said probes are arranged in groups of ten probes each, and wherein each of said input switch means is selectively connectable to all of a subgroup of the probes of one of said groups.

6. Code conversion apparatus which comprises a first elongated medium having a preassigned chemical constitution and a surface, a second elongated medium having

7

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, a plurality of lateral probes penetrating said second medium in proximity with said interface and spaced along its length, an input probe penetrating said second medium in proximity to a first end of said interface, means including said input probe for applying an electrical start pulse to said first end, to effect 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, an output conductor, and input switch means for selectively connecting said probes to said output conductor in accordance with a preassigned code, whereby output pulses appear on said output conductor in a sequence determined by said code.

7. Apparatus as defined in claim 6 wherein said first medium is a metallic conductor.

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

9. Apparatus as defined in claim 6 wherein said first and second media are coaxially disposed, the second medium surrounding the first medium.

8

10. Code conversion apparatus which 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 quasistable condition in the absence of a disturbance applied thereto, a plurality of lateral probes penetrating said second medium in proximity with said interface and spaced along its extent, an input probe penetrating said second medium in proximity to a part of said interface, means including said input probe for applying an electrical start pulse to said part, to effect a local disturbance of said quasistable 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, an output conductor, and input switch means for selectively connecting said probes to said output conductor in accordance with a preassigned code, whereby output pulses appear on said output conductor in a sequence determined by said code.

No references cited.