June 6, 1967 W. BARWICZ ET AL. 3,324,345

APPARATUS FOR CONVERTING ANALOG QUANTITIES INTO NUMERICAL QUANTITIES

Filed Aug. 19, 1963 3 Sheets-Sheet 1

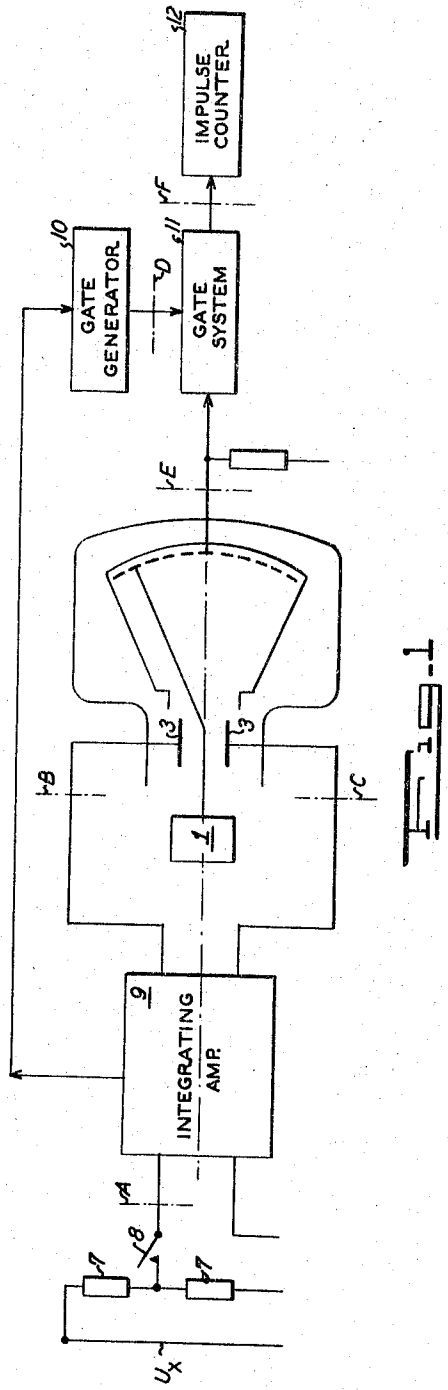

Fig. 1

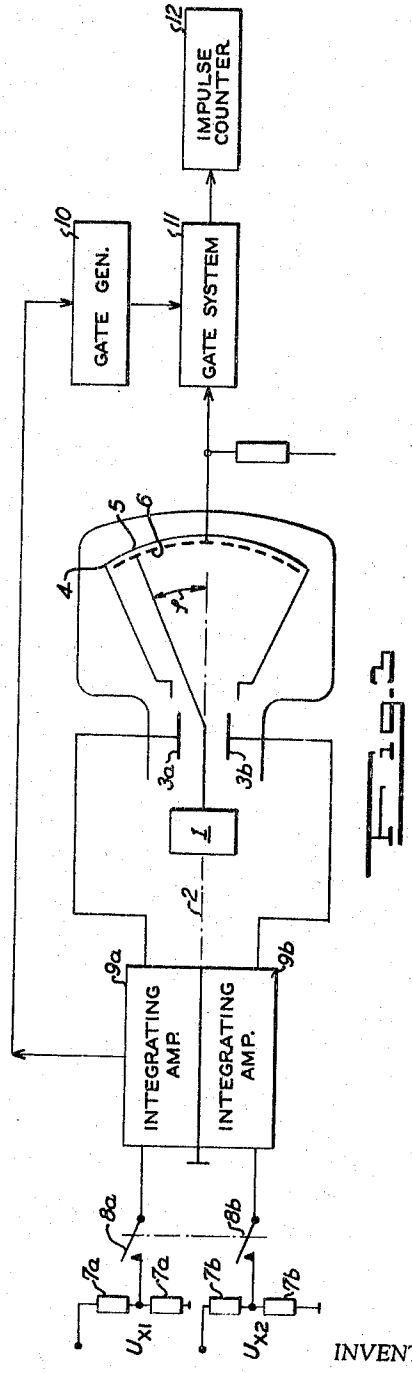

Fig. 2

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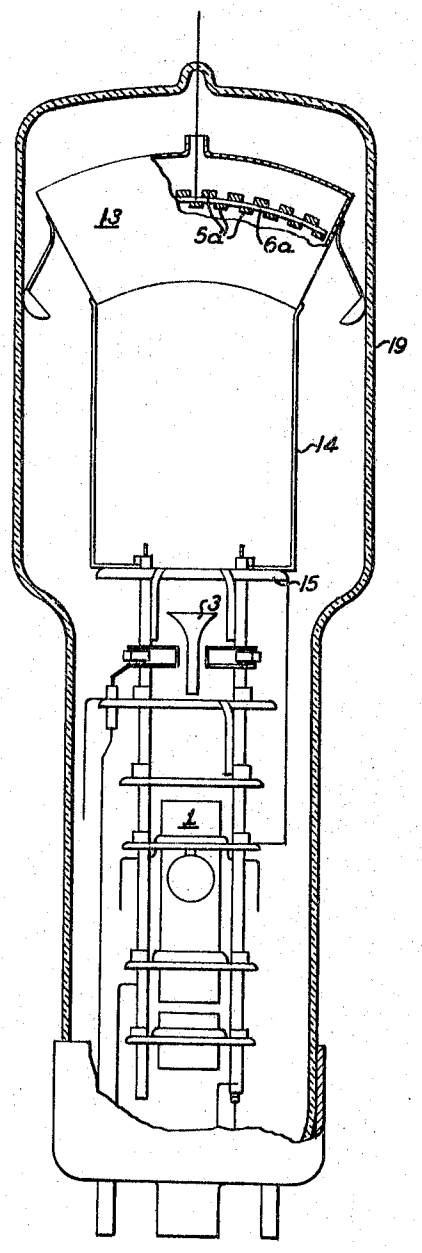

Fig. 4

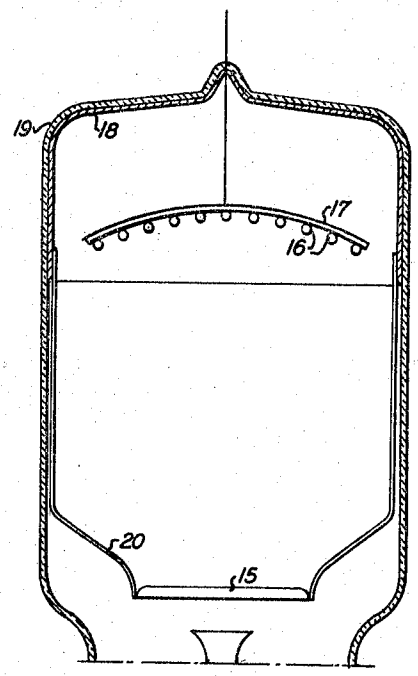

Fig. 5

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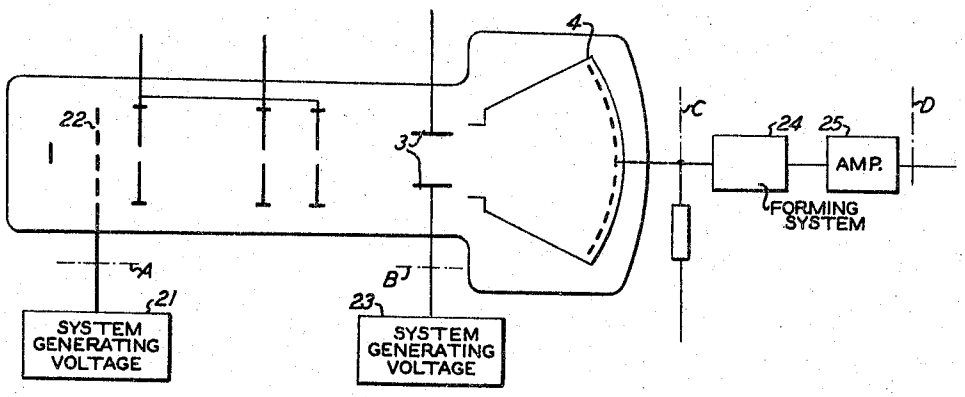

Fig. 6

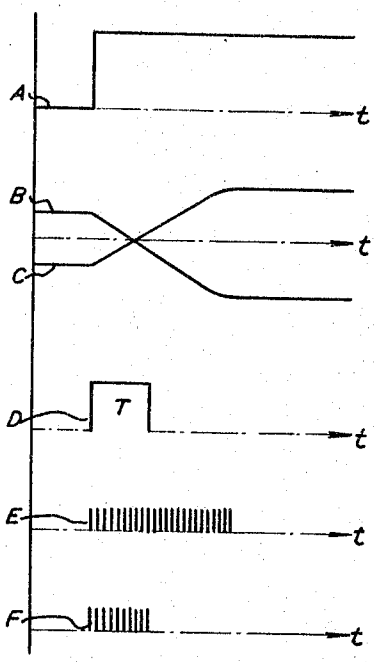

Fig. 2

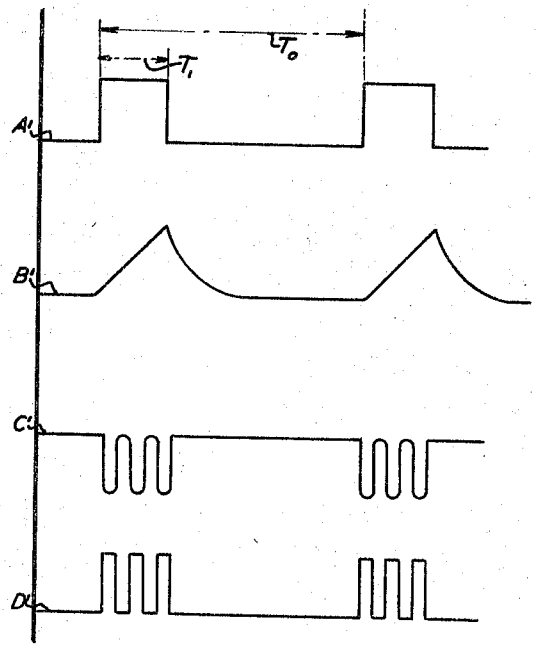

Fig. 7

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APPARATUS FOR CONVERTING ANALOG QUANTITIES INTO NUMERICAL QUANTITIES

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5 Claims. (Cl. 315—8.5)

This invention relates to arrangements for changing quantities, expressed as voltages proportional to said impulses expressing any of the said quantities in numerical form.

It is one object of the invention to provide improved apparatus for converting analog information to digital form.

Another object is to provide a simplified but more accurate system than heretofore available.

Still another object is to provide a device of improved reliability.

By way of brief description and according to the invention, apparatus is provided comprising a cathode ray tube having alternately located elements of different secondary emission capabilities, the tube's electron ray being deflected by means of a deflecting voltage such that there is produced an electric current of impulse characteristics, the number of impulses being proportional to the value of the deflecting voltage. Due to the above, there has been eliminated the previously used unreliable mechanical-electrical and electronic optical systems, and also there has been obtained a substantial simplification and increase of accuracy. Besides, for amplification of the analog quantities amplifiers can be employed which are considerably simpler and cheaper than those hitherto used.

The invention is disclosed in more detail in the accompanying drawing in which:

FIG. 1 diagrammatically shows an arrangement for changing an analog quantity into pulses;

FIG. 2 shows the pulse forms for FIG. 1;

FIG. 3 shows a variation of the arrangement of FIG. 1 for changing a sum or a difference of two analog quantities into numerical quantities;

FIG. 4 shows a cross-section of an electronic tube which forms a vital part of the arrangement of the invention;

FIG. 5 shows another form of electronic tube;

FIG. 6 shows another application of an electronic tube for generating of groups of impulses; and

FIG. 7 shows the voltages in the arrangement of FIG. 6.

The basic element of the arrangement according to the invention is a cathode ray tube provided with a conventional electron gun **1** emitting an electron ray **2** deflected by means of deflecting plates **3** and also provided with an electrode **4** consisting of the alternately placed elements **5** and **6** having different values of secondary emission factors. The electron beam hitting the electrode **4** strikes consecutively the elements **5** and **6** which are included within the deflection angle 2φ while in the secondary current collected from the said electrode **4** there appear impulses caused by the difference of the secondary emission of the said elements **5** and **6**. Moreover the number of the produced impulses is equal to the number of the elements struck by the electron beam, which means that this number is strictly dependent on the deflection angle 2φ, and because of that depends on the amplitude of the deflecting voltage.

The arrangement for changing analog quantities into numerical quantities, the scheme of which is shown in FIG. 1, consists of a potential divider **7**, a change-over switch **8**, an integrating amplifier **9** the output of which is connected with the deflecting plates **3** of the cathode ray

tube, a gate generator **10**, a gate system **11** and an electronic impulse counter **12**.

The following is the operation of the above described arrangement.

An analog quantity converted into a voltage is applied to the input of the potential divider **7** and then—by closing of the change-over switch **8**—it is applied to the input of the integrating amplifier **9**. At the input of the said amplifier appears an increasing or decreasing linear variable voltage, the speed of this variation be proportional to the value of the analog voltage. When the variations of voltage in the integrating amplifier are applied to the deflecting plates **3** of the cathode ray tube, they cause shifting of the electron ray with a speed proportional to the analog quantity.

The electron beam **2** moving across the electrode selects consecutive and alternately elements **5** and **6** included within the angle 2φ and because of that—as a result of the different values of the secondary emission factor—in the electrode **4** circuit there flows a pulsed current wherein the number of pulses is proportional to the value of the deflecting voltage. Next the said impulses are passed to the input of the gate system **11**, while the gate generator **10**, opening the system, generates a pulse of constant duration T. During the period of time when it is opened, the gate system **11** passes to the electronic counter **12** the number of impulses which is proportional to the analog quantity, and the said electronic counter counts those pulses and gives the result in numerical form.

The measurement may be carried out once or it can be repeated periodically, measuring each voltage in one channel or else in various channels by switching the required channel to the input of the integrating amplifier **9** by means of the change-over switch **8**.

In FIG. 2, there are shown characteristics of the voltages at points A, B, C, D, E, F in the arrangement of FIG. 1.

Another arrangement according to the invention is shown in FIG. 3 and is used for converting a sum or a difference of two analog quantities into numerical quantities. This form is different from the above described form in that it is provided with two potential dividers *7a* and *7b* each of which is connected by means of change-over switches *8a* and *8b* with the integrating amplifiers *9a* and *9b*, while the output of one of these amplifiers *9a* is applied to one of the deflecting plates *3a* and the output of the second amplifier *9b* is applied to the second deflecting plate *3b* of the impulse tube.

The analogue quantities converted into the voltages U_{x1} and U_{x2} are applied to the potential dividers *7a* and *7b*, and next by means of the change-over switches *8a* and *8b* they are passed to the input of the two integrating amplifiers *9a* and *9b*. At the output of these integrating amplifiers *9a* and *9b* there are obtained two voltages increasing or decreasing in linear manner, which voltages are next applied to the deflecting plates **3** of the cathode ray tube for shifting the electron ray the speed of which shifting is proportional to the sum or to the difference of the analog quantities. The pulses produced by the cathode ray tube are then converted in the above described way into numerical readings by the electronic counter **12**.

In FIG. 4 there is shown an electronic tube used for producing pulses according to the invention.

This electronic tube comprises the known system consisting of the electron gun **1** emitting an electron ray **2** and the deflecting plates **3** to which there is applied the deflecting voltage from an outer electronic system. It also comprises an electrode in the form of a bent plate *6a* made of a metal of a small secondary emission factor. The metal may be, for example, an alloy of nickel and chromium. On plate *6a* there is wound a band *5a* made

of a material of relatively larger value of secondary emission factor. This material, for example, can be beryllium bronze. The plate 6*a* has moreover the shape of an arc drawn from the center of deflection of the electron ray 2 and is placed inside the electron collector 13 having the form of a box made of a metal of small secondary emission factor. The box is fastened by means of a bracket 14 to the plate 15 forming an electro-static screen separating the space in which is located the electrode from the space in which are placed the deflecting plates 3. Operation of this electronic tube is the same as described above.

Another form of electronic tube shown in FIG. 5 comprises an electrode forming a ladder consisting of small bars 16 made of metal of large secondary emission factor, the metal being, for example, beryllium bronze. The ladder is fitted in frame 17 within an electron collector having the form of a layer 18 of metal of small secondary emission factor for example, aluminum covering the inner surface of the tube bulb 19. Operation of this form of the electronic tube differs from the operation of the system shown in FIG. 1 in that the deflected electron beam falls consecutively on the small bars 16 of the electrode or on the layer 18 of the metal covering the inner surface of the bulb and having the smaller secondary emission factor as a result of which it produces impulses in the current collected from the electrode. The screening plate 15 is in this case connected by means of springs 20 contacting the electron collector 13.

FIG. 6 shows another arrangement according to the invention, in which the above described electronic tube is used for generating groups of pulses.

The latter arrangement consists of an electronic system 21 generating a voltage of rectangular shape and connected to the grid 22 of the electronic tube, a system 23 generating a voltage increasing linearly and passed to the deflecting plates 3 of the electronic tube, forming system 24, and amplifying system 25, which latter are connected to the electrode 4 of the electronic tube.

The rectangularly shaped voltage, of duration T_1 (FIG. 7) and of repetition period T_o, which is applied to the grid 22 and the linear voltage from system 23, which is applied to the deflecting plates 3 of the electronic tube, causes pulses in the circuit of the electrode which are passed on the output of the arrangement by the forming system 24 and the system described above relative to FIG. 1. The deflected electron beam falls consecutively on the small bars 16 of the electrode or on the metal layer 13 covering the inner surface of the bulb and having the smaller secondary emission factor. As a result, pulses of current are obtained from the electrode. The screening plate 15 is in this case connected by means of contacting springs 20 with the electron collector 18.

The FIG. 3 shows another example of application of the arrangement according to the invention, in which the above described electronic tube is used for generating groups of impulses.

The adjustment of the width of the said group of pulses obtained by suitable adjustment of the time T_1 of pulses in the system 21 and the repetition period T_o of these groups is adjusted by adjusting the repetition period of the pulses sent by the system 21, while the number of impulses in each group is adjusted by adjusting the amplitude of the voltage passed by the system 23 to the deflecting plates 3. All the above three values can be of course adjusted either incrementally or in continuous manner.

The arrangement according to the invention can be applied particularly to changing analog quantities into digital and then perhaps numerical quantities but it can also be used for measuring direct-current voltage or alternating-current voltage or else other physical quantities which can be expressed by voltages.

What is claimed is:

1. Apparatus for the conversion of an analog signal; said apparatus comprising a cathode ray tube including a gun adapted for generating an electron beam, deflection plates for deflecting said beam, and a target and collector system including alternating elements of different secondary emission characteristics and adapted for being swept by said beam; integrating amplifier means for receiving an input analog voltage and generating a linearly varying output voltage the rate of change of which is proportional to said analog voltage, gating means coupled to the target and collector system to collect pulses generated in said system when swept by the beam, and means coupled to said electron tube to control said beam in proportion to the analog voltage to generate a number of pulses corresponding to the analog voltage.

2. Apparatus for the conversion of an analog signal; said apparatus comprising a cathode ray tube including a gun adapted for generating an electron beam, deflection plates for deflecting said beam, and a target and collector system including alternating elements of different secondary emission characteristics and adapted for being swept by said beam; integrating amplifier means for receiving an input analog voltage and generating a linearly varying output voltage the rate of change of which is proportional to said analog voltage, gating means coupled to the target and collector system to collect pulses generated in said system when swept by the beam, the pulses being generated at a rate proportional to the analog voltage, and gating control means coupled to the integrating amplifier means and applying to the gating means a gating signal of duration proportional to the analog voltage whereby there is gated a number of pulses representative of the analog voltage.

3. Apparatus as claimed in claim 2, comprising a pulse counter coupled to the gating means to count the pulses.

4. Apparatus as claimed in claim 2, wherein the alternating elements are all parts of said target.

5. Apparatus as claimed in claim 2, wherein the alternating elements are respectively parts of the target and collector.

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