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(54) APPARATUS FOR DISPLAYING A VARYING VOLTAGE

(7 1) We, S I E M E N S
 AKTIENGESELLSCHAFT, a German
 company of Berlin and Munich, Germany,
 do hereby declare the invention, for which
 we pray that a patent may be granted to us,
 and the method by which it is to be
 performed, to be particularly described in
 and by the following statement:-
 This invention relates to apparatus for
 displaying a varying voltage.
 One aspect of this invention relates to
 apparatus for displaying a varying voltage,
 for example an ECG, on the screen of a
 cathode-ray tube, in which successive values
 of the varying voltage are read in the same
 order as a function of time into an image
 repetition store from which they are subse-
 quently read out in cyclic repetition onto the
 signal deflection system of the tube.
 In known apparatus of this type (*c.f.*, for
 example, German Auslegeschrift No.
 2,013,620), circulating shift registers for
 digital measured values of the unknown
 quantity are used as image repetition stores.
 To this end, the varying voltage is digitalised
 by means of analogue-digital converters, the
 digital measured values thus obtained being
 cyclically read into the shift register and
 cyclically read out again therefrom. The
 measured values read out cyclically are
 converted back in a digital-analogue conver-
 ter into corresponding analogue measured
 values which, finally, are delivered to the
 signal deflection system of the cathode ray
 tube for image synthesis. The latest appar-
 atus of this type require from 7 to 10 shift
 registers, each having a storage capacity of
 1024 bits, in order to obtain suitable delay
 times for the required resolution. However,
 the relatively large number of shift registers
 required, together with the associated anal-
 ogue-digital and digital-analogue conver-
 ters, increases the cost of the apparatus as a
 whole.
 According to this invention there is pro-

vided apparatus for displaying a varying
 voltage on the screen of a cathode ray
 tube, the apparatus including an image
 repetition store into which, in use, succes-
 sive values of the voltage are fed as a
 function of time and from which store they
 can be cyclically read out to the signal
 deflection system of such a cathode ray
 tube, in which apparatus the image repeti-
 tion store comprises a signal-regenerative,
 variable-gain, "bucket-brigade" store, for
 storing values of the voltage in analogue
 form, and a voltage comparator connected
 with an input and output of the bucket-
 brigade store for comparing the value of a
 reference voltage after passage through the
 bucket-brigade store with the actual value of
 that reference voltage stored in advance
 and, in the event of deviations between
 these two values, for adjusting the gain of
 the bucket-brigade store such that equal
 reference voltage values occur at the input
 and output of the bucket-brigade store.
 The bucket brigade store could be of the
 type described, for example, in "Philips
 Technische Rundschau", Vol. 31, 1970/71,
 No. 4, pages 97 to 111. A bucket brigade
 store of this type, which consists of a
 plurality of successive storage capacitors
 with intermediate switches for relaying the
 analogue data, is comparable in price with a
 single shift register having the same number
 of storage positions. In addition, the even
 more expensive analogue-digital and digital-
 analogue converters are no longer neces-
 sary, which considerably reduces the overall
 costs involved. However, the use of a
 bucket-brigade store involves the following
 problem: the gain of the bucket-brigade
 store is not exactly ONE, in other words,
 during circulation of the varying voltage (or
 "measuring voltage"), a slight drop in level
 would result in the information read in
 approaching zero. By contrast, a gain of
 greater than ONE leads to undesirable

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oscillation of the circuit. However, the invention solves this problem by simultaneously delivering a reference voltage value U_{ref} with the measuring voltage, for example an ECG, to the bucket-brigade store. Although this reference voltage value circulates together with the analog measured values of the measuring voltage, the reference voltage is cyclically sought out at the output end of the bucket-brigade store and is compared with the reference voltage originally fed in. The deviation is delivered from the comparator as an AGC voltage to an AGC amplifier which ensures that equal reference voltage values always occur at the input and output ends of the bucket-brigade store. The latter case is reached when the gain of the bucket-brigade store is exactly ONE. This in turn means that the amplitude trend of information read in is kept constant and avoids the danger of the circuit beginning to oscillate. In a preferred embodiment of the apparatus according to the invention, the reference voltage value may be obtained either from the measuring voltage or through an external reference voltage generator. In the latter case, U_{ref} should be faded out from the image so that it is not visible therein. In the former case, fade-out is not necessary because U_{ref} forms part of the signal to be displayed. However, for the possible comparison of U_{ref} at the output end with U_{ref} at the input end of the bucket-brigade store, an additional store should be present for storing the momentary value of the measuring voltage which is scanned at certain intervals and used as the reference voltage U_{ref} . Another important factor is the necessary opportune selection of the reference value at the output end of the bucket-brigade store in the accumulation cycle of the high-frequency store circulation. A sample-and-hold circuit with a scanning switch is used for this purpose, the scanning switch directing the circulating signal to a storage capacitor of the sample-and-hold circuit at a predeterminable reduction frequency of the circulating shift clock frequency of the bucket-brigade store. By correspondingly synchronising the divider frequencies with the input clock frequencies for the reference voltage values in the bucket-brigade store through further input frequency dividers in addition to a flip-flop stage, it is possible to ensure that those voltage values which accumulate exactly with the directing clock of the scanning switch at the output end of the bucket-brigade store are also always exactly identical with reference voltage values fed in previously and now in circulation. Accordingly, reference voltage values which have just passed through the bucket-brigade store beforehand are always present at the storage capacitor of the sample-and-hold circuit and, hence, also at the actual-value input of the voltage comparator. The clock of new storage operations corresponds to the accumulation clock of the reference voltage values at the output end of the bucket-brigade store.

The invention will now be described by way of example with reference to the accompanying drawing.

The Figure shows a basic circuit diagram of one example of apparatus in accordance with the invention. Referring to the Figure, the reference numeral 1 denotes an input for a measuring voltage, i.e. in this example for an ECG, and the reference numeral 2 denotes a reference voltage generator (a d.c. voltage source) for supplying a reference voltage U_{ref} . These voltages, i.e. both the measuring voltage and the reference voltage U_{ref} , can be switched to a signal input of a so-called bucket-brigade store (comprising storage capacitors with intermediate switches for relaying analog data) at preselectable times by means of switches 3 and 4. The principle according to which this bucket-brigade store functions is that voltage value data delivered at its input are relayed as analog voltage values from storage capacitor to storage capacitor until, finally, they reappear at the output of the store after a certain storage time, which time is dependent both upon the number of storage capacitors and upon the shift clock frequency of the bucket-brigade store. The bucket-brigade store 5, which preferably comprises 1024 individual storage elements, acts as an image repetition store. Accordingly, it comprises a feedback line 6 in which a signal amplifier 7 is incorporated for amplifying feedback signals. The feedback output signal of the bucket-brigade store 5 is supplied by the feedback line 6 to the non-inverting input of the amplifier 7 which comprises an operational amplifier. The inverting input of this amplifier 7 is coupled to its output via a feedback resistance 8. A field-effect transistor 9, which is also connected with the inverting input of the operational amplifier 7, acts as control means for adjusting the gain of the amplifier 7. This adjustment is effected by changes in resistance at the transistor 9 in dependence upon an output signal of a voltage comparator 10. This voltage comparator 10 is used for comparing the reference voltage value after passage through the bucket-brigade store 5 with the reference voltage value which was originally fed into the store 5 by scanning of the reference voltage U_{ref} supplied by the reference voltage generator 2. Scanning of the reference voltage value at the output of the bucket-brigade store 5 is effected according to the sample-and-hold principle by means of a scanning switch 11 in conjunction with a storage capacitor 12 at an

actual-value input of the comparator 10. A desired-value input of the comparator 10 is connected with the reference voltage U_{ref} supplied by the reference voltage generator 2.

The circulating shift clock frequency of the bucket-brigade store 5 is determined by a central clock generator 12' which operates, for example, at a clock frequency of approximately 420 kHz. Frequency division of this shift clock frequency in a ratio of 1:1025 by means of a first frequency divider 13 provides a clock frequency for the switch 4, i.e. the input clocking frequency of new analog information into the bucket-brigade store 5. Further division of this input clocking frequency in a ratio of 1:64, by means of a second frequency divider 14, ultimately provides a reference voltage supply clocking frequency for feeding the reference voltage U_{ref} via the switch 3 to the bucket-brigade store 5. Accordingly, on the basis of the divider ratios selected, every 64th scanned voltage value (which is newly fed into and circulates in the bucket-brigade store 5) is a reference voltage value U_{ref} . Intermediate scanned voltage values represent analog values of the measuring voltage, i.e. of the ECG. A switching control circuit comprising third and fourth frequency dividers (15 and 16 respectively) is used for selecting reference voltage values U_{ref} at the correct times, at the output of the bucket-brigade store 5 during high-frequency circulation of analog data in the store 5, by means of the scanning switch 11 of the sample-and-hold circuit. The third frequency divider 15 directly divides the circulating shift clock frequency supplied by the clock generator 12' in a ratio of 1:64, whereas the fourth frequency divider 16 divides the clock frequency in a ratio of 1:1024. The fourth frequency divider 16 is set at the beginning of counting (zero) by a flip-flop stage 17 when the second frequency divider 14 controlling the reference voltage supply clocking frequency produces an input pulse for the reference voltage U_{ref} . When at least the first 1024th pulse of the circulating shift clock frequency is obtained, the fourth frequency divider 16 sets the third frequency divider 15 to commence counting. In addition, when every 1024th pulse is obtained, the flip-flop stage 17 is also set to its original state by the fourth frequency divider 16. Accordingly, the effect of the described switching control circuit is that, after 1024 + 64 voltage values supplied at the output of the bucket-brigade store 5, the first reference voltage value accumulating and subsequently, for every 64th voltage value, every other reference voltage value accumulating is picked up and supplied to the storage capacitor 12, and hence to the actual-value input of the comparator 10 by means of the

scanning switch 11 which is energised at that instant. The actual value of the reference voltage thus obtained is compared by the comparator 10 with the original reference voltage value U_{ref} . In the event of differences between these values, the gain of the amplifier 7 is adjusted by the amplifier 9 in dependence upon the output signal of the comparator 10. This adjustment continues until the output signal of the comparator 10 disappears, i.e. until U_{ref} at the input of the bucket-brigade store 5 and U_{ref} at the output of the bucket-brigade store 5 are equal in value.

If, as in the arrangement described above, an external reference voltage generator 2 is provided for supplying the reference voltage value U_{ref} , it should be possible to blank-out this reference voltage value from the measuring voltage as soon as it appears at the output of the bucket-brigade store 5. The scanning switch 11 is used for blanking-out the reference voltage value by interrupting the signal path to indicating means, on accumulation of the reference voltage value. The signal path comprises a storage capacitor 18 and a vertical amplifier 19 connected with a vertical deflection coil 20 of a cathode ray tube 21 and indicating means. When the signal path is interrupted by the scanning switch 11, the storage capacitor 18 holds the particular analog value of the measuring signal which has previously accumulated. Blanking intervals in a display of the signal are thus avoided. The cathode ray tube 21 also comprises, in the usual way, a horizontal deflection amplifier 22 connected with a horizontal deflection coil 23. The electron beam of the cathode ray tube 21 is horizontally deflected by means of a control line 24 at the synchronous clock frequency of the clock pulses produced by the clock generator 12'.

WHAT WE CLAIM IS:-

1. Apparatus for displaying a varying voltage on the screen of a cathode ray tube, the apparatus including an image repetition store into which, in use, successive values of the voltage are fed as a function of time and from which store they can be cyclically read out to the signal deflection system of such a cathode ray tube, in which apparatus the image repetition store comprises a signal-regenerative, variable-gain, "bucket-brigade" store, for storing values of the voltage in analogue form, and a voltage comparator connected with an input and output of the bucket-brigade store for comparing the value of a reference voltage after passage through the bucket-brigade store with the actual value of that reference voltage stored in advance and, in the event of deviations between these two values, for adjusting the gain of the bucket-brigade store such that equal reference voltage

values occur at the input and output of the bucket-brigade store.

2. Apparatus according to claim 1, wherein, in use of the apparatus, the reference voltage is derived either from the varying voltage or from an external reference voltage generator.

3. Apparatus according to claim 1 or 2, wherein, in use of the apparatus, the reference voltage is produced at predeterminable time intervals and supplied to the bucket-brigade store.

4. Apparatus according to claim 3, wherein, in use, the said time intervals are determined by a reference voltage supply clocking frequency which is equivalent to a fraction of the input clocking frequency of new analogue information supplied to the bucket-brigade store.

5. Apparatus according to claim 4, provided with two frequency dividers connected in series, for determining such a reference voltage supply clocking frequency, the first frequency divider being arranged to divide a circulating shift clock frequency supplied to the bucket-brigade store by a first factor and the second frequency divider being arranged to divide the divided signal supplied by the first frequency divider by a second factor to give the reference voltage supply clocking frequency.

6. Apparatus according to claim 5, wherein the said first factor is $n + 1$, where n is the total number of storage positions of the bucket-brigade store.

7. Apparatus according to claim 5 or 6, provided with a sample-and-hold circuit, a switching control circuit, and a flip-flop stage, for selecting, at correct times during the high-frequency circulation of analogue data in the bucket-brigade store in use, reference voltage values from an output of the bucket-brigade store, wherein the sample-and-hold circuit comprises a scanning switch and the switching control circuit comprises third and fourth frequency dividers, the third frequency divider being arranged to divide the circulating shift clock frequency by the said second factor and to clock the scanning switch, and the fourth frequency divider being arranged to divide the circulating shift clock frequency by n , and wherein the flip-flop stage is arranged to set the fourth frequency divider to start counting when the second frequency divider produces a reference voltage supply clocking pulse, and to set the third frequency divider to start counting when at least the first n th pulse of the circulating shift clock frequency is obtained.

8. Apparatus according to claim 7, wherein the fourth frequency divider returns the flip-flop stage to its original state when the n th pulse is obtained.

9. Apparatus according to any preceding claim, provided with a feedback circuit connected with an input and an output of the bucket-brigade store, for adjusting the gain of the bucket-brigade store, the feedback circuit comprising an AGC-amplifier and a control device for the AGC-amplifier, the control device being arranged to vary the gain of the AGC-amplifier in use, in dependence upon an output signal of the comparator, such that reference voltage values at an input and an output of the bucket-brigade store are equal.

10. Apparatus according to claim 9, wherein the control device is a field effect transistor.

11. Apparatus according to any preceding claim, wherein, where an external reference voltage generator is provided, the reference voltage can be blanked-out from the voltage including the varying voltage as soon as it appears at an output of the bucket-brigade store.

12. Apparatus according to claim 11, wherein the scanning switch may be used for blanking-out the reference voltage by interrupting a signal path, for the varying voltage, to a cathode ray tube used for displaying the varying voltage, on accumulation of a reference voltage value.

13. Apparatus according to claim 12, wherein a storage capacitor is provided after the scanning switch, along the signal path to such a cathode ray tube in use of the apparatus, which capacitor holds a previously-accumulated analogue value of the varying voltage when the signal path is interrupted by the scanning switch.

14. Apparatus according to claim 7 or any of claims 8 to 13 as dependent on claim 7, wherein the said first factor is 1025 and the said second factor is 64.

15. Apparatus for displaying a varying voltage substantially in accordance with any example herein described with reference to the accompanying drawing.

16. Apparatus according to any preceding claim, in combination with a cathode ray tube, the image repetition store being connected with the signal deflection system of the cathode ray tube.

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