

Nov. 29, 1949

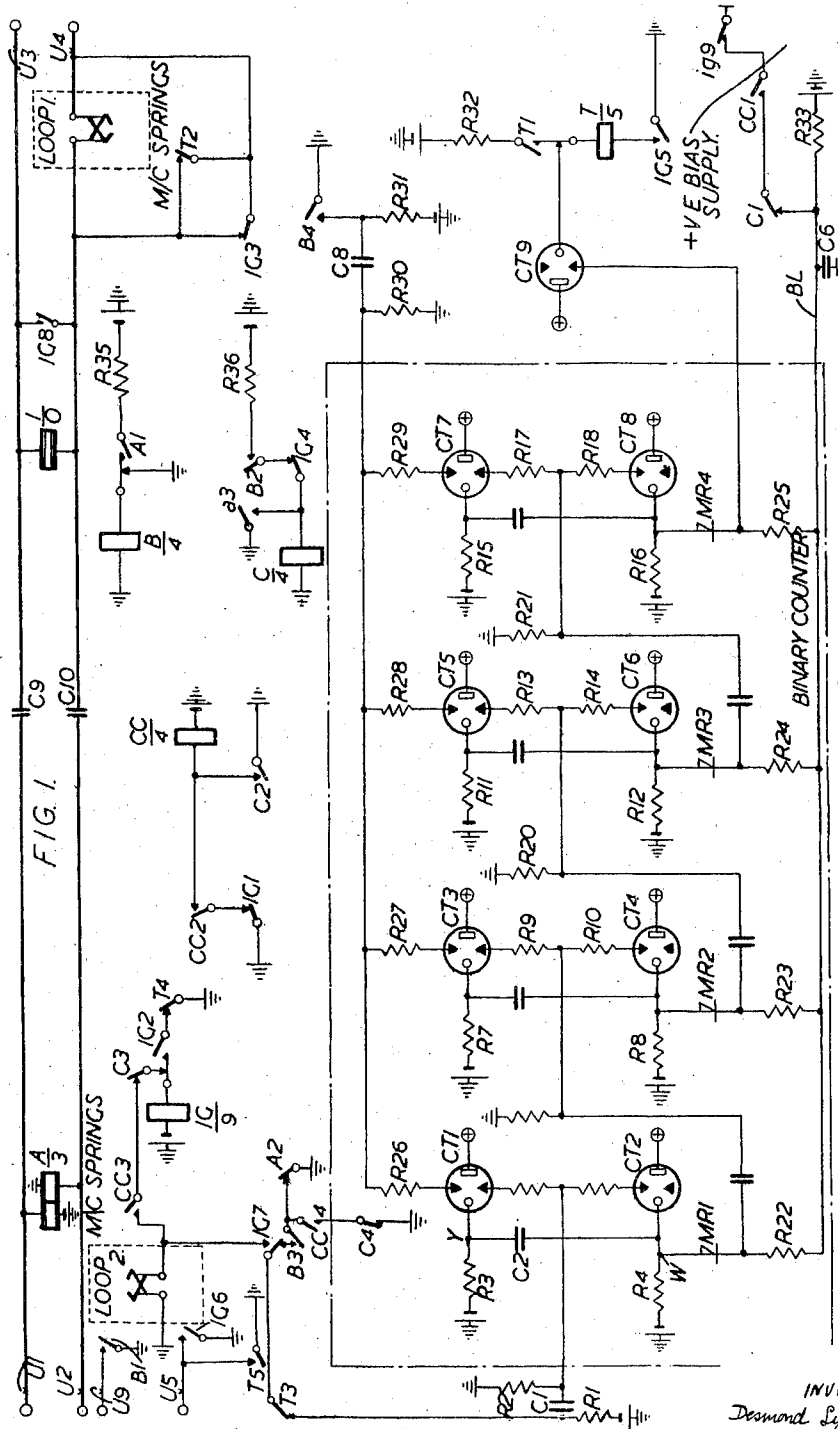
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ELECTRICAL STORAGE OF INFORMATION

Filed Oct. 25, 1947

3 Sheets-Sheet 1



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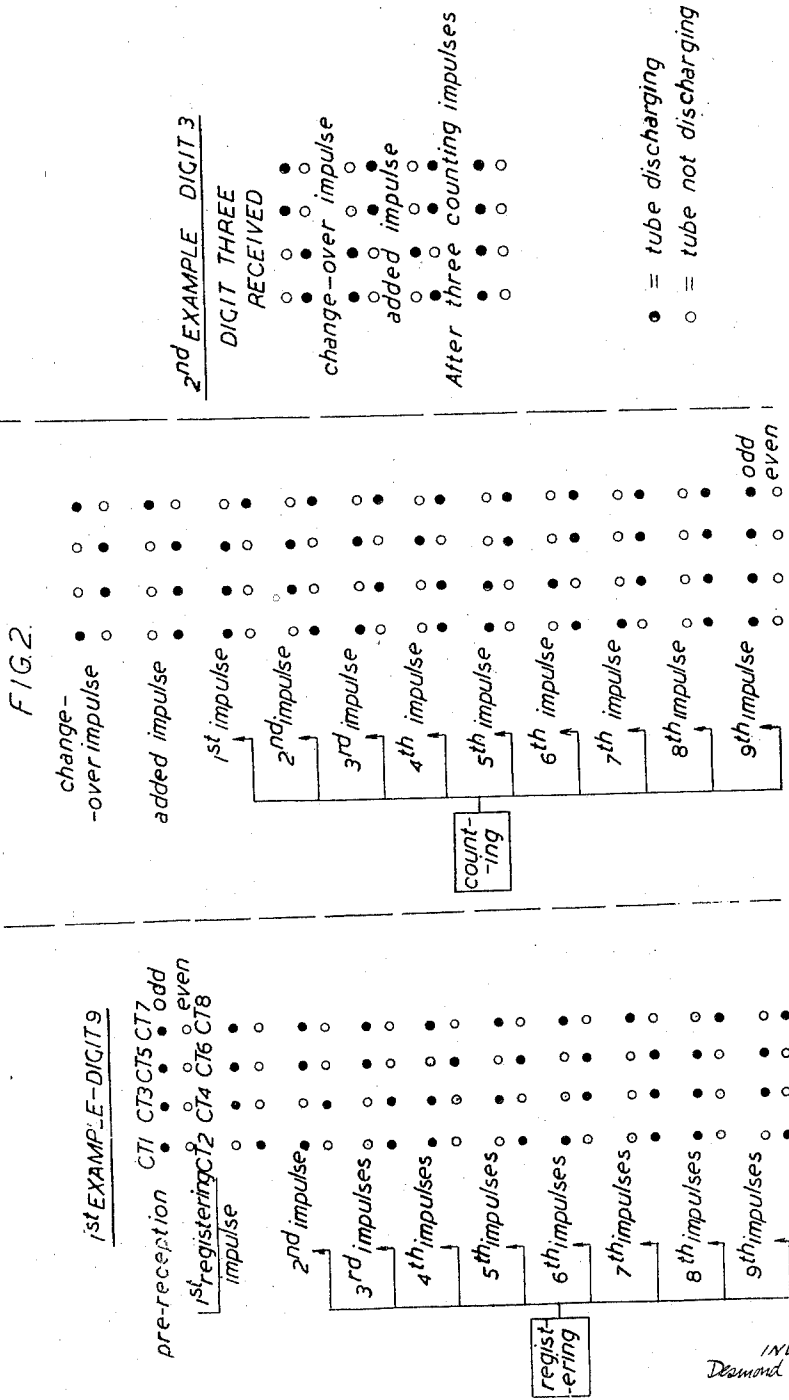
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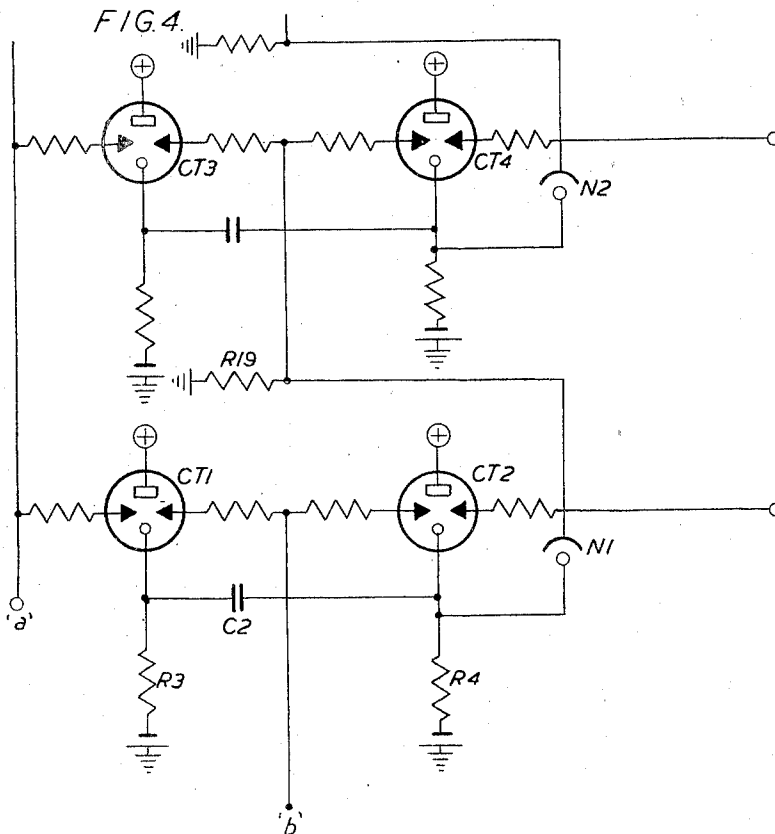
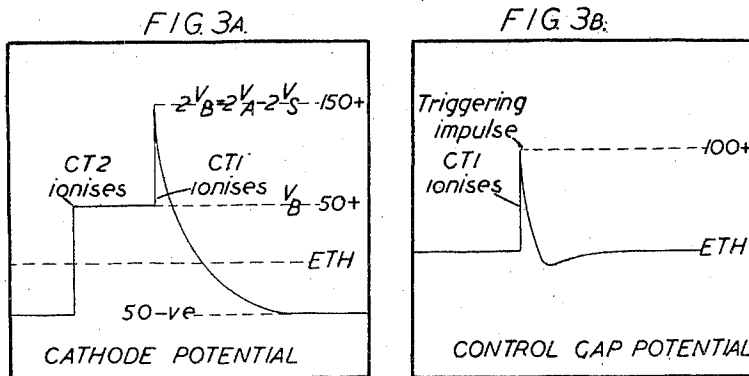
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3 Sheets-Sheet 3



INVENTOR
 Desmond Sydney Ridler
 By Robert Handberg
 ATTORNEY

UNITED STATES PATENT OFFICE

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ELECTRICAL STORAGE OF INFORMATION

Desmond Sydney Ridler, London, England, assignor to International Standard Electric Corporation, New York, N. Y., a corporation of Delaware

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This invention relates to impulse registering arrangements using discharge tubes and has for its objects the provision of improved arrangements of that type.

The main feature of the invention comprises interconnected set of discharge tubes adapted to respond to a train of impulses and register it on a binary basis.

The invention will be clearly understood from the following description of certain embodiments thereof shown in the accompanying drawings in which:

Fig. 1 is a schematic circuit diagram of a regenerative impulse repeater for use, for instance in automatic telephone exchange systems and adapted to receive a digit or a series of digits and to transmit or control locally originated impulse trains equal in number to the digit or digits received.

Fig. 2 shows the sequence of operations of the discharge tubes forming part of Fig. 1 during impulse registration and impulse counting.

Fig. 3, A or B show the potential values occurring in the triggering circuits of and between the pairs of tubes during impulsing.

Fig. 4 shows a modified form of interconnection between the pairs of discharge tubes of Fig. 1.

The form of counter described comprises two parallel sets of cold-cathode gas discharge tubes each having two auxiliary electrodes either of which can be used for triggering the tube.

Corresponding tubes of the two sets are interconnected in pairs and the pairs are interconnected in series, so arranged that the tubes of one set can be initially triggered into discharging conditions, after which impulses applied to the first pair of tubes each cause the non-discharging tube to discharge and the discharging tube to be quenched, while change-over from the originally non-discharging tube to the discharging tube causes a triggering impulse to be given to the next pair of tubes to cause a change-over of condition. The transmission of triggering impulses between pairs of tubes consequent on a change-over from the originally non-discharging tube to the originally quenched tube operates between each pair so that an impulse applied to the first pair may affect one, two, three, —, or all pairs according to their setting.

If after a train of impulses had been applied to the set of tubes, further impulses are applied to the set to complete its cycle of change-overs from one set of tubes, one per pair, being all operated to the other set of tubes all operated,

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the number of impulses required is the complement of the number originally registered with respect to the capacity of the complete set of tubes on a binary basis. With four pairs of tubes the capacity is $1 + 2 + 4 + 8 = 15$.

By transposing the condition of the two sets of four tubes, one per pair each, or by changing the triggering arrangements between pairs the set can be made to count out in response to the original number of impulses received instead of its complement. It is convenient to return the tubes to their original setting at the end of a cycle that is to work with a cycle of 16 instead of 15, so that at the end of the cycle the originally discharging set of tubes is again discharging, this can be achieved by inserting an additional impulse.

Referring now to Fig. 2, the black circles indicate tubes under discharge while the white circles indicate non-discharging or quiescent tubes. The upper four circles of the sets of eight indicate the odd-numbered tubes CT13, 5, 7 of Fig. 1 while the lower four circles represent the even-numbered tubes. The odd-numbered tubes are initially triggered as indicated by the pre-reception indication in the first example. The changes and condition consequent on successive impulses are then shown in the groups marked "1st registering impulse"—"9th registering impulse." The next group indicates the result of the change-over between the upper and lower sets of tubes, the following group the insertion of an additional impulse to take care of the return of the tubes to the pre-reception condition at the end of counting while the remaining groups indicating the counting of nine impulses equal in number to those registered.

Fig. 2 shows also the reception change-over and counting out of the tubes for digit 3.

The detailed operation of the regenerative repeater shown in Fig. 1 will now be described.

The repeater is seized by a loop extending from the impulsing springs at the distant station to relay A which operates and removes a short circuit from relay B which operates from battery through R35 and a1. Contact b1 busy the repeater. Contacts b2 prepare the circuit for relay C which, for the moment short-circuited at a3. Contacts b3 prepare the impulsing circuit for the cold cathode counting train which is open at a2. Contacts b4 trigger the odd-numbered cold cathode tubes in the counting train preparatory storage by discharging condenser C8 which is normally charged via R30, 31.

If now a series of impulses representing say,

the digit 9 are transmitted to the regenerator from the distant impulse springs, relay A will release and re-operate nine times. Contact *a2* pulses this digit to the counter by means of the condenser resistance network *R1*, *C1*, and *R2*. *C1* being discharged by each impulse. The first pulse instantaneously raises the potential across *R2* and consequently triggers cold cathode tube *CT2*. The potential drop across *R4* reverses the charge on condenser *C2* and therefore reduces the potential across the main gap of cold cathode tube *CT1*, which is therefore extinguished. The first impulse has changed the glow from *CT1* to *CT2*. The second impulse changes the glow back from *CT2* to *CT1*, but passes a further impulse to the next pair of tubes by means of the biased rectifier *MR1*, which conducts when the cathode potential rises above the bias potential as described below. The glow therefore changes from *CT3* to *CT4*. Further impulses up to the seventh operate the binary counter in a similar way, an impulse being passed on the succeeding pair of tubes each time an even-numbered tube is triggered. The pattern on the counter after the ninth impulse can be seen from Fig. 2. Relay C is operated during the first release of relay A and remains operated during impulsing since the short circuiting contact *a3* produces a slow to release effect. Relay C operates relay CC which locks, via *cc2*, *ig1*.

The counter makes use of the four-electrode cold cathode tube, which is similar to the conventional three electrode tube in principle, but has two control electrodes so that the tube may be triggered from two independent sources. This additional facility is used in the binary counters for preparing or pre-setting the counters according to the desired pattern.

The counter is initially triggered by applying a potential from condenser *C8* to ionise the upper four cold cathode tubes *CT1*, 3, 5, 7. Positive counting impulses are then applied to the first pair of tubes from condenser *C1*. A pulse is passed to the next pair of tubes (*CT3* and 4) only when the glow changes from *CT1* to *CT2*.

Consider the changes in potential across the resistance *R4*. The first impulse, ionises tube *CT2* and *CT1* is deionised. Since the charge on the cathode coupling condenser *C2* is reversed, instantaneously reducing the potential across *CT1*. The cathode potential Fig. 3A across *R4* therefore rises to a value determined by the difference between the applied volts *V_A* and the sustaining volts *V_s* for the tube. If this potential is *V_B*, then $V_B = V_A - V_s$. The next impulse triggers tube *CT1* and the instantaneous potential across *R2* is then $2(V_A - V_s)$ and the potential across the tube *CT1* is reduced to

$$V_A - 2(V_A - V_s) = V_A - 2V_B$$

The positive bias potential is made equal to $V_B = V_A - V_s$ so that until the potential across *R4* rises above *V_B* no potential drop occurs across *R22* since the rectifier *MR1* is non-conductive. When the potential rises to $2(V_A - V_s) = 2V_B$, however, a potential drop $= (V_A - V_s)$ occurs across *R22* since the rectifier is conductive. A pulse of amplitude $= (V_A - V_s)$ indicated in Fig. 3B triggers the second pair of tubes *CT3* and 4 as a result. This pulse is produced only after each alternate pulse applied to the first pair of tubes.

The digit nine has now been transmitted and stored. Relay C releases after impulsing and changes the bias applied to rectifiers *MR1*, *MR2*,

MR3, *MR4* by connecting earth via *cc1* *c1*, to the connection between *C6* and *R33*. At the next closure of machine operated loop springs 1, 2 the impulse guard relay *IG* operates over *C3* and *CC3* and locks via *ig2*, *t4*. Contacts *ig1* pulse the second pair of tubes in the counter once over *C4* and *CC4* by discharging *C1*, *CT4* operates and the change-over of glow in the second pair of tubes sends a pulse to the third pair and so on and the pattern on the second, third and fourth pairs of tubes is therefore reversed since change of glow to either side will now send a pulse forward because the bias has been changed. The operation of relay *IG* releases relay *CC* which is slightly slow to release to allow the reversals to be effected. Contacts *CC1* restore the original bias to the counter. Contacts *ig3* now remove a short-circuit from impulse spring 1, 2 which transmit regenerated impulses over *U3* and *U4*. At each successive impulse springs 2 pulse the counting train once until the end of the seventh loop, when the glow will be changing from all the even to all the odd cold cathode counting tubes; position 15, Fig. 2. A pulse is then passed to the "end of sending" cold cathode tube *CT9* which ionises. The cathode relay *T* operates and locks.

The release of relay C connects earth via *ig9* back, *cc1* front, *c1* back, to the bias lead *BL* for the rectifiers *MR1* . . . 4, to change the bias on the tubes. Earth via *c4* back, *cc4*, front, *b3* front, *ig1* back, *t3* back causes *C1* to impulse the counting train. Due to the change in bias the rectifiers become conductive in response to *V_B* and 2*V_B*, instead 2*V_B* only as the other electrodes are now earthed, and triggering potential is passed to the next pair of tubes at each change-over between a pair of tubes.

The impulse to the counting train therefore causes a change-over in condition of every pair of tubes in turn, as indicated in Fig. 2.

Release of C closes a circuit from relay *IG* via *ig2*, *c3* back, *cc3* front to loop springs 2 so that on the next closure of springs 2, *IG* operates and locks via *ig2* front, *t4* back. Contacts *c2* being open, the opening of contacts *ig1* releases *CC*.

Contacts *ig3* open a short-circuit on impulsing springs which are machine operated in synchronism with springs 2. Contacts *ig4* open the circuits of relay C. Contacts *ig5* prepare a circuit for relay *T* in the main discharge circuit of tube *CT9*. Contacts *ig6* earth lead *U5* to the preceding circuit. Contacts *ig7* connect the impulsing circuit of tubes *CT1*, 2 to springs 2. Contacts *ig8* close an impulsing loop on the outgoing leads *U3*, *U4*, while contacts *ig9* open to restore positive bias to the tubes. The change-over of the tubes takes a very short time and will happen before *IG* operates and restores the bias: if desired, *IG* may be slightly slow to operate to give a factor of safety on this operation.

The connection of springs 2 to condenser *C1* via *ig1* takes place while the closure of springs 2 which operates *IG* is still operative so that an impulse is transmitted by *C1* to tubes *CT1*, 2 before springs 2 open. This is the additional impulse the result of which is indicated in Fig. 2.

The opening of springs 1, 2 sends an impulse via springs 1 to line and the subsequent closure of springs 2 sends an impulse to the tubes *CT1*, 2. Nine successive impulses are sent in turn to line and to the tubes which change condition, in response thereto as indicated in Fig. 2.

In response to the ninth impulse to the tubes, a changeover from *CT8* to *CT7* takes place for the first time since *IG* operated and as a result

a triggering impulse is sent via MR4 to tube CT9 which discharges via relay T which in turn operates and locks via *t1*, R32. Contacts *t1* also disconnect CT9 and contacts *t2* short circuit the sending springs 1 so that no further impulses are sent to line. Contacts *t3* disconnect the counting train which is now at normal. Contacts *t4* disconnect relay IG and contacts *ig5* in turn disconnect relay T. Earth indication that sending was in progress is removed from U5 by the break of *t5* and *ig6*. The circuit is now free to receive and transmit any further digits in a similar measure.

An advantage of such a semi-electronic regenerator is that the incoming signal may have any make or break ratio providing the relay A will release and reoperate. This can be so since only transient impulses are required to operate the tubes and can have a mean duration of the order of one millisecond or less. The frequency of the incoming impulses is also only limited by the incoming relay since thermionic or gas-filled counters will count at comparatively high speed. If counting pulses are derived from a third winding on the A relay by transformer effect, very high receiving speeds are possible.

The advantage of the "reversal" effect is that additional apparatus is not required to deal with the complement which would otherwise be obtained. The same effect could be obtained by switching over the bias connections for each pair of tubes from the even tube to the odd tube, e. g. from point W to point X, the changeover persisting until the train of outgoing impulses has been counted out. This gives the same result as transferring the setting of the odd tubes to the even tubes and vice-versa.

Referring now to Fig. 4, a small neon tube replaces the rectifier network used in the counter of Fig. 2. This arrangement has the advantage of simplicity but may not be so flexible as the rectifier network.

As in the case of Fig. 2, the counter is prepared by triggering the left hand tubes from the point *a*. Counting pulses are then applied to point *b*. The potential changes are the same as before. The positive peak potential which occurs when tube CT2 is de-ionised is used to trigger the next pair of tubes. The level of potential across R4 is too high, and the neon N1 is arranged in series so that the potential drop across its discharge gap when the triggering pulse occurs reduces the potential to the required value.

The potential which occurs when tube CT1 is de-ionised is insufficient to produce a triggering impulse across the neon.

Any other device giving a constant potential drop could be used.

What I claim is:

1. An impulse register comprising a set of discharge tubes interconnected in pairs, means for interconnecting several pairs of tubes in series, means for pre-setting the register by placing certain of said tubes in discharging condition while maintaining one tube of each pair in non-discharging condition, means for applying registering impulses to a first pair of said tubes to cause the one of said tubes that is in non-discharging condition to be placed in discharging condition, means responsive to the creation of a discharge in said tube last mentioned to place the other tube in that pair in non-discharging condition, means responsive to a change-over of discharge from one tube of a pair to the other in one direction only to send a triggering impulse to change over the

next pair whereby a train of impulses imposed on the first pair of tubes is registered on a binary basis.

2. Interconnected set of discharge tubes as claimed in claim 1 comprising means for changing the triggering arrangements between pairs so that a triggering impulse is sent from one pair to the next consequent on a change-over between tubes of the former pair in either direction.

3. Interconnected set of discharge tubes as claimed in claim 2 so arranged that after registration of a train of impulses, the triggering arrangements are changed, an impulse is given to the first pair of tubes to change-over each pair of tubes in turn, and the triggering arrangements thereupon restored to normal, whereby the set of tubes is conditioned to count a further number of impulses applied to the first pair of tubes which is equal to that received.

4. Interconnected set of discharge tubes as claimed in claim 1, adapted to register a number on a binary basis, and thereafter to change its condition so that it adds further impulses received to the complement of said number in respect of the capacity of the set on a binary basis.

5. Interconnected set of discharge tubes as claimed in claim 1 comprising means for changing the triggering arrangements between pairs so that a triggering impulse is sent from one pair to the next consequent on a change-over between the tubes of the former pair in the direction opposite to that normally initiating such a triggering impulse.

6. Interconnected set of discharge tubes as claimed in claim 5 adapted to register a number on a binary basis, and thereafter to change the inter-pair triggering arrangements in the manner claimed in claim 5 so that it adds further impulses received to the complement of said number in respect of the capacity of the set on a binary basis.

7. Interconnected set of discharge tubes as claimed in claim 1 and in which the triggering connections between the pairs of tubes include a biased rectifier network.

8. Interconnected set of discharge tubes as claimed in claim 1 and in which the triggering connections between pairs of tubes include constant potential-drop devices.

9. Interconnected set of discharge tubes as claimed in claim 1 and in which the triggering connections between pairs of tubes include neon tubes.

10. Interconnected set of discharge tubes as claimed in claim 1 so arranged that after registering a train of impulses on a binary basis it automatically changes its condition so that it adds further impulses received to the complement of the number of impulses received in respect of the capacity of the set on a binary basis.

11. An impulse register comprising a set of discharge tubes interconnected in pairs, means for interconnecting several pairs of tubes in series, means for pre-setting the register by placing certain of said tubes in discharging condition while maintaining one tube of each pair in non-discharging condition, means for applying an initial registering pulse to one of said tubes that is in non-discharging condition to place it in discharging condition, and means responsive to the creation of a discharge in said tube last mentioned to place the other tube in that pair in non-discharging condition.

12. A register in accordance with claim 11 comprising means responsive to the application of a second registering pulse to said other of said tubes to apply a pulse to a second pair of said tubes and to cause the non-discharging tube of that pair to be placed in discharging condition.

13. A register according to claim 11 wherein each of said discharge tubes has a pair of main electrodes and a control electrode, one main electrode of each tube is connected to ground through a biasing resistance, the two main electrodes just mentioned are interconnected by a condenser, the two control electrodes are interconnected by a resistance and the registering pulses are applied to an intermediate point of said resistance through a condenser both sides of which are connected to ground through additional resistors one of which has a source of potential in series therewith.

14. A register in accordance with claim 13 wherein one of the tubes of each pair has a second auxiliary electrode and means for applying a change of potential to said electrode to place said tube in discharging condition, a source of biasing potential is applied through a resistance and a rectifier to the first main electrode of the other tube and a connection including a condenser is made from a point between said resistance last mentioned and said rectifier to the mid-point of a resistance interconnecting the auxiliary electrodes of a second pair of discharge tubes which also have their first main electrodes interconnected by a condenser and separately grounded through resistances, the one tube of said pair last mentioned which corresponds to said one of said tubes of the pair first mentioned likewise being provided with an auxiliary electrode and means to apply a potential to said electrode to place said tube in discharging condition, whereby when a registering impulse is applied to said first pair of tubes the one which has been in non-discharging condition is placed in discharging condition and the one which is in discharging condition is placed in non-discharging condition.

15. An impulse register comprising a set of electron discharge tubes connected in pairs consisting of a first tube and a second tube, each tube having a pair of main discharge electrodes and an auxiliary electrode, means for setting the register for operation by causing the first tube of each pair to be placed in discharging condition, means for applying registering impulses to the auxiliary electrodes of the first pair of tubes, means responsive to the application of the first impulse to cause the second tube of said first pair of tubes to be placed in discharging condition and the first tube to be placed in non-discharging condition, and means responsive to the application of the second impulse to the auxiliary electrodes of said first pair of tubes to cause the first tube of said pair to be placed in discharging condition, the second tube of said pair to be placed in non-discharging condition and the second tube of a second pair to be placed in discharging condition and the first tube of said second pair to be placed in non-discharging condition.

16. An impulse register comprising a plurality of pairs of electron discharge tubes, each pair consisting of a first tube and a second tube, means for applying a series of registering impulses to a first pair of tubes, means responsive to the application of the first registering impulse to cause one of said first pair of tubes to be placed in discharging condition and the other tube to be placed in non-discharging condition and responsive to the application of a second registering impulse to cause the process to be reversed, and means interconnecting several pairs of such tubes for causing the second tube of a second pair to be placed in discharging condition and the first tube of said second pair to be placed in non-discharging condition only responsive to even numbered pulses applied to said first pair of tubes.

DESMOND SYDNEY RIDLER.

No references cited.