April 4, 1944. E. B. FERRELL 2,345,925

PULSE-COUNTING CIRCUIT

Filed Oct. 31, 1941 2 Sheets-Sheet 1

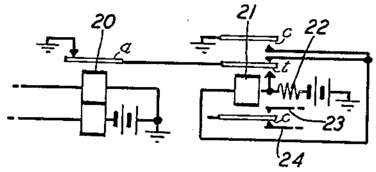


FIG. 1

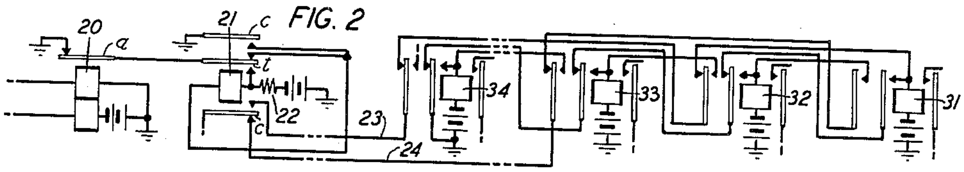


FIG. 2

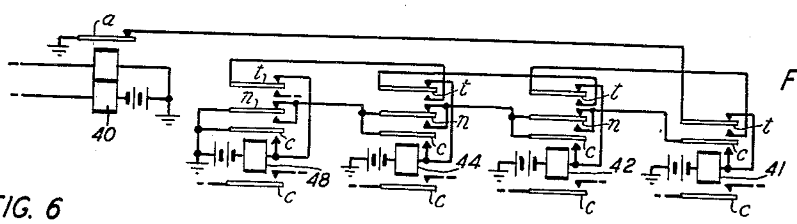


FIG. 3

FIG. 6

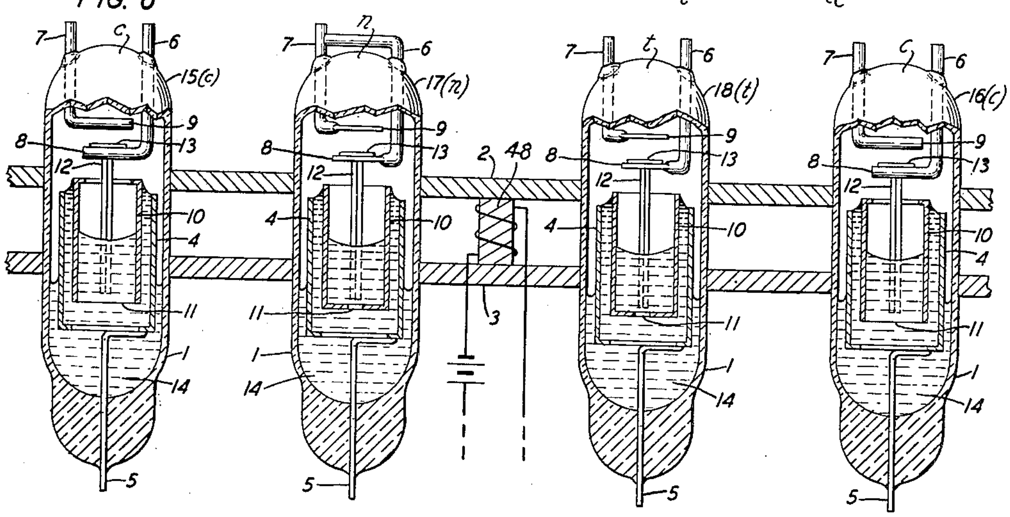


FIG. 7

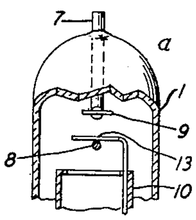


FIG. 8A

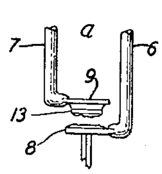


FIG. 8B

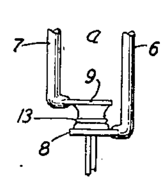
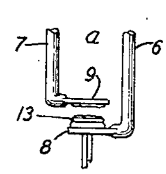


FIG. 8C



INVENTOR
E. B. FERRELL
BY
P. C. Smith
ATTORNEY

PULSE-COUNTING CIRCUIT

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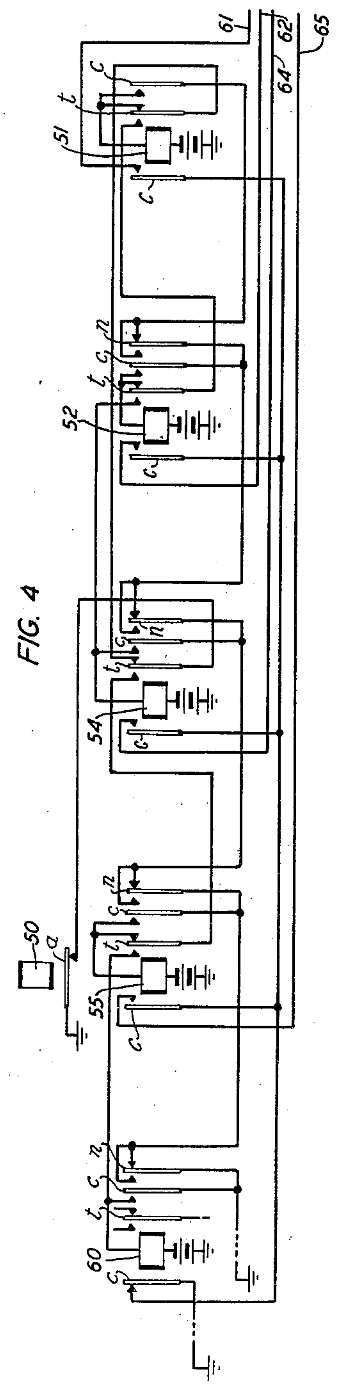

FIG. 4

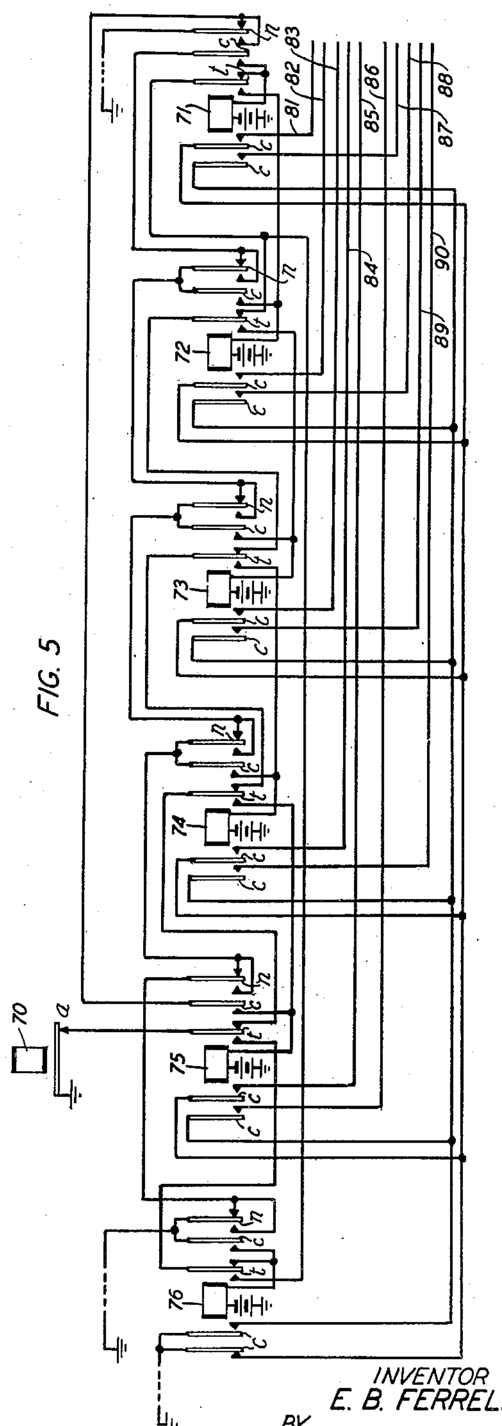

FIG. 5

INVENTOR
E. B. FERRELL
BY
P. C. Smith
ATTORNEY

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PULSE-COUNTING CIRCUIT

Enoch B. Ferrell, Chatham, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application October 31, 1941, Serial No. 417,322

5 Claims. (Cl. 175—320)

This invention relates to telephone systems and has for its object to provide improved pulsing equipment for such systems.

In automatic telephone systems, the directive operation of the switching devices is generally controlled by series of pulses. Two types of pulse are most commonly used, namely, interruptions of a previously closed circuit or ground pulses in shunt of the battery supplied to the pulsing circuit. In either case the pulse relay closes a back contact at each pulse.

For the purpose of controlling the switching operations, in some systems the pulse relay acts directly on the switch magnets, while in other systems the number of pulses is counted by a series of relays, known as counting relays.

The most widely employed counting relay arrangement requires two relays for each pulse to be recorded. Another arrangement employs six pairs of relays for counting ten pulses while a still more economical arrangement is enabled to employ six single relays for counting pulses by interposing a pulse halver, made up of three relays, between the pulse relay and the counting relays.

In accordance with the present invention a still further saving in number of relays is attained by the use of accurately timed mercury contact relays.

More specifically, a single relay is enabled to act as a pulse halver by the use of accurately timed pulses and a transfer contact on the pulse halver which closes its alternate contact subsequent to the termination of the actuating pulse.

Alternatively, the pulse halver may be omitted by using as counting relays a chain of single relays each having timed contacts.

Switching elements of the type suitable for use in producing the accurately timed pulses of the present invention are disclosed in United States Patent No. 2,295,602, granted to C. E. Pollard, Jr., September 15, 1942.

The invention will be more clearly understood from a consideration of the following description in connection with the drawings in which:

Fig. 1 shows the pulse halver;

Fig. 2 shows the pulse halver in connection with a chain of simple relays;

Fig. 3 shows the timed contact relay as a binary counter;

Fig. 4 shows the timed contact relay in one form of register;

Fig. 5 shows the timed contact relay in another form of register;

Fig. 6 shows the contact arrangements used in the circuits of Figs. 3 to 5; and

Figs. 7, 8A, 8B and 8C show the form of contact used for pulsing.

Referring first to Fig. 6, a brief description will be given of the type of switch element especially serviceable for the purpose of the invention. These switch elements 15 to 18 are very similar and each comprises a glass envelope 1, positioned in the aligned openings of the pole-pieces 2 and 3 of a magnetic circuit including an energizing coil 48 schematically shown.

Positioned within the envelope is a cylindrical guide sleeve 4, entirely open at its upper end and partially closed at its lower end, and supported on and secured to the upper end of terminal wire 5. The guide sleeve 4 is made of a non-magnetic material which is wettable by mercury. Sealed through the upper end wall of the envelope are two parallelly disposed contact members 6 and 7, having their ends which extend into the envelope bent at right angles toward each other to form two stationary contact portions 8 and 9.

Movable within the guide sleeve 4 is a cylindrical tubular armature 10, the upper end of which in elements 17 and 18 is entirely open and the lower end of which is closed except for the small opening 41 therein. In switch elements 15 and 16 the bottom of armature 10 is entirely open and the top has a narrow collar to strengthen it. The armature is made of magnetic material but its surfaces are so treated that they are readily wetted by mercury. Secured to the inner surface of the armature is a contact member 12 which may be formed by doubling a length of wire, bending the looped end at right angles and flattening the same to provide a widened contact portion 13 for engagement with the contact portions 8 and 9 of the contact members 6 and 7. A contact member of this type has the property of conducting mercury to the surface of the contacts with which it cooperates.

To complete the switch element, a measured amount of mercury 14 is deposited in the bottom of the envelope, the envelope is evacuated and refilled with a gas at the proper pressure. Due to the wettable character of the guide 4 and the armature 10, the mercury rises to the positions shown in Fig. 6. The surface tension of the mercury acting between the armature 10 and the guide 4 holds the contact portion 13 firmly against the contact 8 when coil 48 is not energized. A film of mercury also lies between these contact members. In the switch elements 17 and 18, contact portions 8 and 9 are flattened to increase the surface tension between them and contact 13. These switch elements are therefore designed to consume definite time intervals between the energization of the operating magnet 68, the opening of the lower, or normal contact and the closure of the upper, or alternate contact. By varying the size of the contact elements and the size of the aperture 11 in the armature 10, these time intervals may be regulated as desired. The reverse movement following deenergization of the relay magnet 68 is similarly controlled.

In the case of switch elements 15 and 16, since quick action is required, the bottom wall of the armature 10 is omitted as above mentioned. In addition, the contact members 8 and 9 are unflattened, as shown, to give a linear contacting surface with contact 13 which is easily disrupted.

By placing contact members 8 and 9 closer together, a continuity closure may be obtained as shown in Figs. 7, 8A, 8B and 8C. Fig. 8A shows the position of the contact members 8, 9 and 13, when the relay coil is energized. When the coil is deenergized in response to a pulse the armature moves downward under the force of the surface tension and contact member 13 draws out the film of mercury connecting it with member 9, as shown in Fig. 8B. Contact member 8 is near enough so that member 13 makes contact therewith through the mercury films on their faces before the upper film breaks, thereby connecting contact members 8 and 9. When the member 13 is drawn against member 8 the mercury film breaks down and the contact is opened as shown in Fig. 8C. These switch elements and their function are described in greater detail in the above-identified Pollard patent.

Relays may be designed having one or more switch elements like those shown in Figs. 6 and 7. A possible arrangement of the operating magnet and the switch elements is shown in United States Patent 2,247,493 to H. C. Harrison et al., July 1, 1941.

In the circuits shown in Figs. 1 to 5, relays 20, 40, 50 and 70 employ one switch element *a* which is of the type shown in Fig. 7 and which functions as described in connection with Figs. 8A, 8B and 8C to make one timed closure between contacts 8 and 9 in response to each opening of the circuit of the operating magnet.

Other relays, such as relays 42, 44 and 48 employ four switch elements as shown in Fig. 6, that is, one timed transfer contact *t* (element 18), one timed transfer contact *n* which has its two fixed contacts connected together (element 17), and two quick operating contacts *c* (elements 15 and 16).

Relays like relays 21, 41, 51 employ only three switch elements, namely, one element *t* and two elements *c*, while the relays of Fig. 5 employ five switch elements, the four elements of Fig. 6 with an additional element *c*.

With no current flowing in the magnet winding the contacts take up the positions shown in Figs. 6 and 7, the movable member 13 being held in normal contact with the contact member 8 under the force of the surface tension as stated hereinbefore. Whenever an energizing circuit for the operating magnet of one of these relays is closed, a magnetic flux is set up between the pole-pieces, such as pole-pieces 2 and 3, and each of the armatures 10 rises, carrying with it contact member 13. In the case of switch element *c* the normal contact between member 13 and member 8 is immediately broken, followed at once by the closure of the alternate contact between member 13 and member 9. In the case of switch elements *t* and *n*, a time interval elapses between the opening of the normal contact and the closure of the alternate contact.

It is obvious that, although switch elements *c* and *t* are shown as transfer switches, the wiring may be varied to use only the make or the break function.

In Figs. 1 to 5 the relays are shown with conventional armatures and contacts but, with the exception of relays 31 to 36, each armature with its associated contacts represents one of the switch elements, each armature being lettered to indicate the type of switch element represented thereby. In each case the armature corresponds to the movable member 13, the back contact corresponds to member 8 and the front contact to member 9.

Referring now to Figs. 1 and 2, relay 20 is a pulsing relay normally operated over the dial contact and responding to dial pulses to close a contact at each interruption of its circuit by the dial. This relay as pointed out above is equipped with a switch element of the type described in connection with Figs. 7, 8A, 8B and 8C. No connection is made to the armature contact 13, whereby a contact of measured duration takes place between the contact elements 8 and 9 at each interruption of the line current. Contact member 8 being cylindrical in form, when relay 20 is reenergized the surface tension is insufficient to make a closure. For convenience, all contacts of this type have been indicated by the letter *a* as they appear in the circuits.

Relay 21 is provided with two or more quick acting contact switch elements *c*, such as shown at 15 and 16 in Fig. 6, together with a switch element, shown at *t*, like element 18 of Fig. 6. Contacts *t* and *a* are adjusted so that contact *t* closes its alternate contact after the termination of the closure by contact *a*.

Fig. 1, therefore, functions as follows. At the interruption of its circuit, relay 20 makes a measured closure at its contact *a*. Ground over this contact completes a circuit extending over the contact *t* in normal position of relay 21, through the winding of relay 21 to battery through resistance 22. Relay 21 immediately closes its quick acting contacts *c*, locking to ground over the upper contact. After a measured interval, greater than the closed time of contact *a*, contact *t* closes its alternate contact. At the next closure of contact *a*, ground is connected over this alternate contact of contact 21*t* to resistance 22, so that the winding of relay 21 is short-circuited and the contacts *c* fall back, followed after a measured interval by contact *t*. Relay 21, therefore, acts as a pulse halver, closing a circuit over conductor 23 at each odd-numbered pulse and over conductor 24 at each even-numbered pulse.

In Fig. 2 the pulse halver relay 21 is shown controlling a set of conventional counting relays. Ground connected to conductor 23 in response to the first pulse operates relay 31 over back contacts of even-numbered relays 34 and 32. Relay 31 locks over a chain circuit including back contacts of all of the higher numbered relays, and prepares the circuit of relay 32. The second pulse, which causes relay 21 to ground conductor 24, operates relay 32 over contacts of odd-numbered relays 33 and 31. Relay 32 locks over the chain circuit, opens the locking circuit of relay 31 and prepares the operating circuit for relay 33.

While only four relays have been shown, any desired number may be employed.

In Figs. 3, 4 and 5, relays of the type of relay **21** are formed into chains for counting and registering series of pulses.

Relays **42**, **44** and **48** of Fig. 3 have contact assemblies such as shown in Fig. 6. That is, each relay has two or more quick acting switch elements *c*, such as contacts **15** and **16**, in which no circuit connection is made to contact member **6**, one transfer contact *t* like switch element **18** and one contact *n* like switch element **17**. In the case of element **17** contact members **6** and **7** are connected together so that contact **13** closes the same circuit when in contact with either element but in moving from contact **8** to contact **9** causes a measured interruption of the circuit. Relays **52**, **54**, and **55** of Fig. 4 and relays **71** to **76** of Fig. 5 are similarly equipped. Relays **41** and **51** lack contact *n* while on relay **60** contact *t* is not wired.

In Fig. 3 counting is binary in character and the arrangement is particularly adapted for timing operations. Fig. 4 shows a chain of relays suitable for acting as a sender register of the type which transfers the designation by code to a decoder or marker, while Fig. 5 shows a chain of relays suitable for direct counting, for example, under the control of revertive pulses.

More specifically, in Fig. 3, when contact *a* of relay **40** closes, ground is connected over the normal contact of contact **41***t* to the winding of relay **41** and battery. Relay **41** locks over upper contact **41***c* and contacts **42***n*, **44***n*, **48***n*, etc., to ground. After contact **40***a* reopens, contact **41***t* closes its front contact. The second closure of contact **40***a* operates relay **42** which locks over contacts **42***c*, **44***n* and **48***n*. When relay **42** operates, contact **42***n* opens, releasing relay **41** and then recloses. Therefore the third pulse operates relay **41**, and since relay **42** is locked operated, the fourth pulse operates relay **44**. Contact **44***n* releases relays **41** and **42**. Relays **41** and **42** recycle so that the eighth pulse operates relay **48**. Contact **48***n* releases relays **44**, **42** and **41**. Additional relays similarly wired would require **16**, **32**, etc., pulses to operate, thus providing means for measuring long time intervals at the expense of a comparatively few relays.

In Fig. 4, pulsing relay **50** responds to incoming pulses such as dial pulses to close contact **50***a*. At the first closure, relay **51** operates in a circuit over the normal contacts of contacts **51***t* and **54***t*. Relay **51** locks over contacts **51***c*, **52***n*, **54***n*, **55***n* and **60***n*. Contact **51***t* closes its front contact after contact **50***a* opens. The second pulse operates relay **52** which locks over contacts **52***c*, **54***n*, **55***n* and **60***n* and releases relay **51**. With relay **51** released, the third pulse reoperates relay **51** which locks as above, relay **52** having reclosed contact **52***n*. With both relays **51** and **52** operated, the fourth pulse operates relay **54**, which locks over contacts **54***c*, **55***n* and **60***n* and releases relays **51** and **52**. The fifth pulse operates relay **55**, which locks over contacts **55***c* and **60***n* and releases relay **54**.

With relay **54** released, relays **51**, **52** and **54** are reoperated as above described by the sixth, seventh, eighth and ninth pulses. When relay **54** operates in response to the ninth pulse, with relay **55** held operated, the tenth pulse is directed to relay **60** which locks and releases relays **54** and **55**.

Relays **51**, **52**, **54** and **55** ground conductors **61**, **62**, **64** and **65**, respectively, when operated. From the above description it will be apparent that the conductors will be grounded in accordance with a code such that the sum of the units digits of the conductor numbers grounded at the end of any pulse will correspond to the number of the pulse. Since this is the code used in transferring designations from the crossbar sender to the marker, it is apparent that such an arrangement as that of Fig. 4 would find use in the crossbar system.

The circuit of Fig. 5 is arranged to ground one of ten conductors to indicate the number of pulses received and might be useful to count revertive pulses in a crossbar sender.

The pulsing circuit controlled by relay **70** at the beginning of pulsing extends over normal contacts **75***t*, **74***t*, **73***t*, **72***t* and **71***t* to the winding of relay **71**. At each pulse the corresponding relay operates its *t* contact to extend the pulsing circuit to the next relay. Each relay locks over the *n* contacts of higher numbered relays and opens its own *n* contact to release the lower numbered relay. Relay **75**, however, locks over the contact **71***n*, so that it remains operated after relay **76** operates in response to the sixth pulse. With relays **75** and **76** operated a branch of the pulsing circuit is extended to the winding of relay **71** over contacts **75***t* and **76***t* so that relay **71** responds to the seventh pulse. The operation of relay **71** releases relay **75** restoring the pulsing circuit to operate relays **72**, **73** and **74** in response to the eighth, ninth and tenth pulses. The inner armatures of relays **71** to **75** receive ground over a normal contact of relay **76** and when operated extend ground to conductors **81** to **85**, respectively. The outer armatures of relays **71** to **75** receive ground over an alternate contact of relay **76**. Relay **75** is held operated after relay **76** operates from the sixth pulse and together they ground conductor **86**, while relays **71** to **74**, operated with relay **76**, ground conductors **87** to **90**, respectively.

What is claimed is:

1. In combination, a source of pulses of fixed predetermined duration and a relay for receiving said pulses, said relay having a locking contact and a timed transfer contact, the time of travel of said transfer contact adjusted to overlap an operating pulse and cause the closure of the alternate contact after the termination of said operating pulse.

2. In combination, a source of pulses of fixed predetermined duration and a set of relays for receiving said pulses, each of said relays having a locking contact and a timed transfer contact, the time of travel of said transfer contact adjusted to overlap an operating pulse and cause the closure of the alternate contact after the termination of said operating pulse to prepare a circuit for operating the next relay in said set in response to the next pulse.

3. In combination, a source of pulses of predetermined duration and a set of relays for receiving said pulses, each of said relays having a locking contact and a transfer contact, said transfer contact adjusted to close its alternate contact after the termination of an operating pulse to prepare a circuit for operating the next relay in said set in response to the next pulse, all but the first of said relays having a normally closed contact over which extend the locking circuits of relays earlier in the set, said normally closed contacts being opened momentarily during the operation of the corresponding relay to re-

lease all earlier relays and to permit them to reoperate in response to subsequent pulses.

4. In combination, a pulse halving arrangement employing a pulsing relay having a contact which closes for a measured interval at each incoming pulse irrespective of the length of said pulse, and an auxiliary relay having a transfer contact timed to consume more than said measured interval in moving from one contact to the other, said transfer contact alternately closing a circuit to operate said auxiliary relay and a circuit to short-circuit said auxiliary relay.

5. In combination, a pulsing relay having a contact which closes for a measured interval at each incoming pulse irrespective of the length of said pulse, and a relay operated over said contact having a transfer contact timed to consume more than said measured interval in moving from one contact to the other.

ENOCH B. FERRELL.