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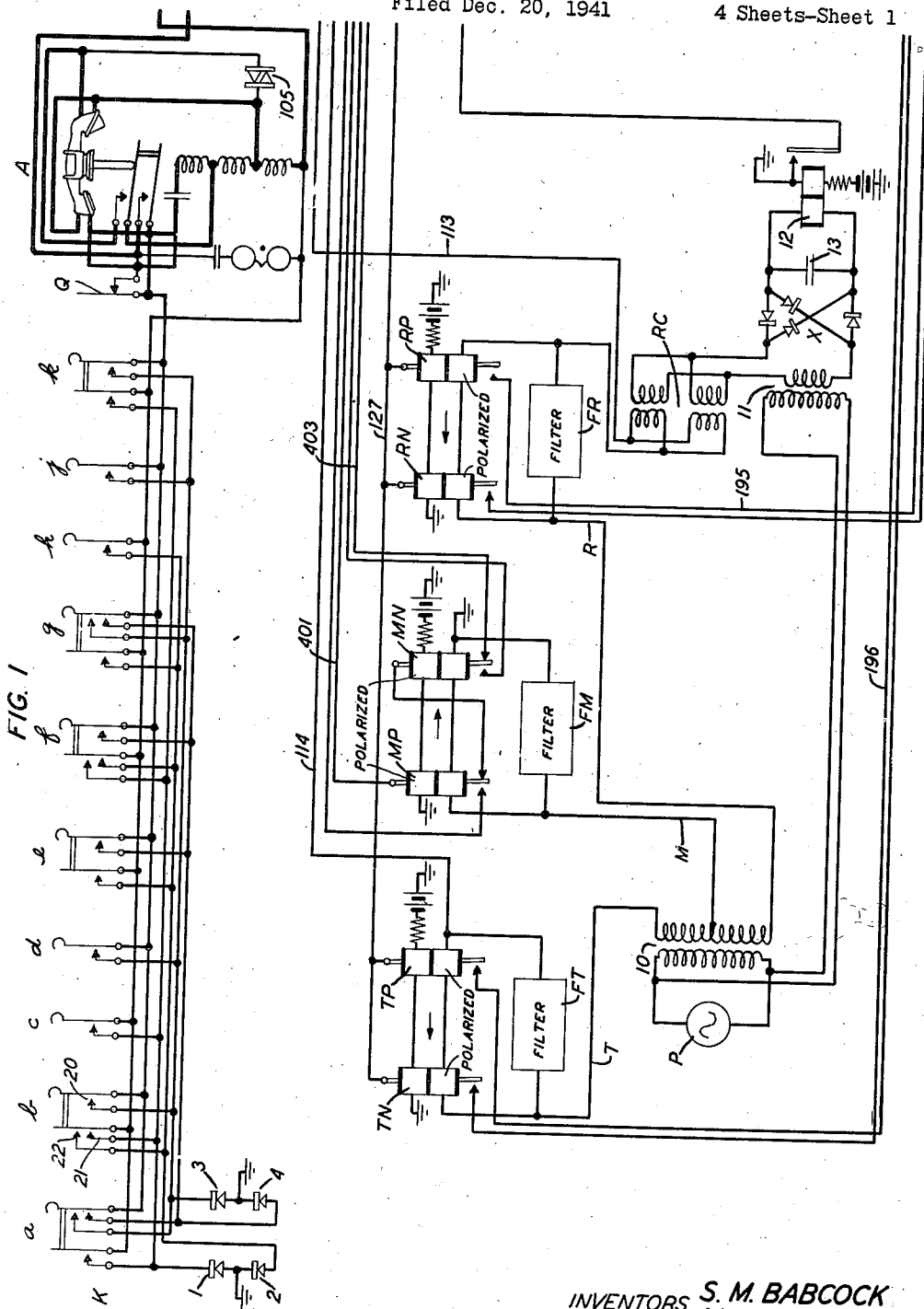
S. M. BABCOCK ET AL

2,308,637

TELEPHONE SYSTEM

Filed Dec. 20, 1941

4 Sheets-Sheet 1



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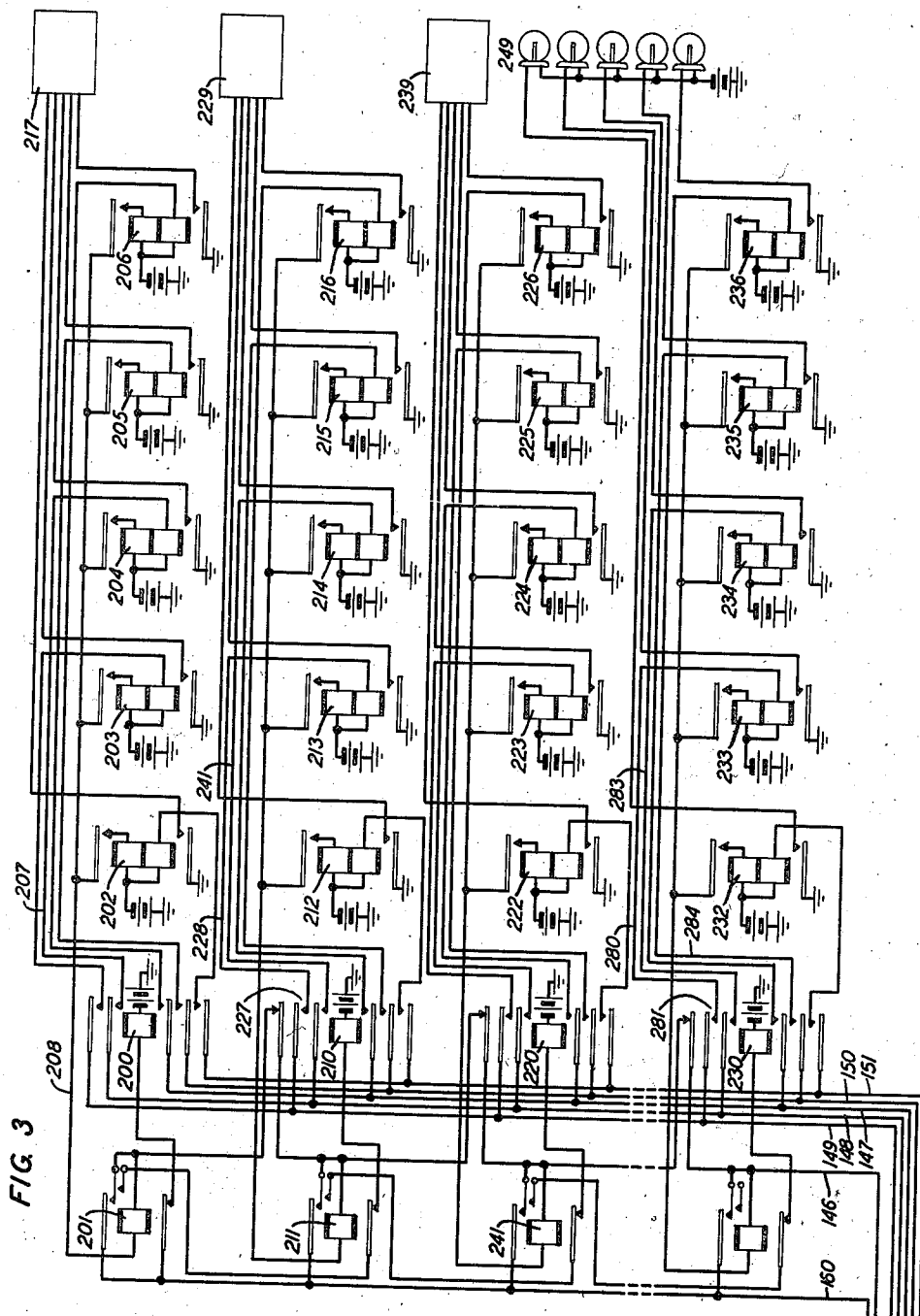
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TELEPHONE SYSTEM

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4 Sheets-Sheet 3



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TELEPHONE SYSTEM

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4 Sheets-Sheet 4

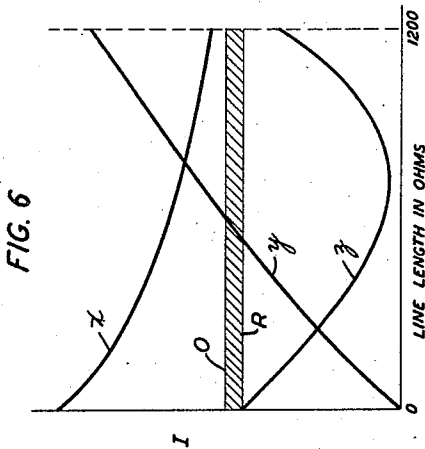


FIG. 4

FIG. 1	FIG. 2	FIG. 3
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FIG. 5

DIGIT	KEY ACTUATED	RECTIFIERS CONNECTED				CODE RELAYS OPERATED			
		1	2	3	4	MP	TP	RN	RP
1	a								
2 ABC	b	1	2	3		MP	TN	RP	
3 DEF	c	1				MP	TP		
4 GHI	d			3		MP		RP	
5 JKL	e		2		4	MN	TN	RN	
6 MNO	f	1	2		4	MN	TP	RN	
7 PRS	g			2	3	MN	TN	RP	
8 TUV	h			2		MN	TN		
9 WXY	i				4	MN		RN	
0 OPERATOR	j	1		3		MP	TP	RP	

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2,308,637

TELEPHONE SYSTEM

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Application December 20, 1941, Serial No. 423,812

15 Claims. (Cl. 179—18)

This invention relates to signaling and communication systems and particularly to telephone systems of the type in which connections between calling and called stations are completed by means, such as automatic switches, controlled from the calling station.

Telephone communication systems have been proposed heretofore, in which the telephone designations assigned to telephone lines or trunk circuits are transmitted from one point to another by means of direct current impulses of different polarities, which singly or in combination serve to characterize the different numerals, or symbols of which the designations are composed. A particular system of this character is disclosed in a copending application, Serial No. 412,402, filed Sept. 26, 1941. This system contemplates the use of a rectifier or varistor type of key sender at the subscriber's station, a three-phase alternating current supply at the central office, and a signal receiving network or circuit comprising a plurality of differently poled polarized code relays arranged in either delta or Y connections. The code relays, two of which are included in each of the three legs of the delta or Y termination, are operated in various combinations in accordance with the actuation of the various keys of the varistor type key sender, to characterize the several digits, or symbols of the telephone designation. The code relays, through the medium of a translator circuit, control the operation of register relays in a decoder register circuit in which the transmitted designations are registered and stored for subsequent use in controlling the operation of automatic switches. The automatic switches, so controlled, function, in a well-known manner, to extend the connection from the call originating station to the called station.

It is the object of this invention to simplify and improve telephone designation transmission systems of the type disclosed in the above-identified copending application.

This object is attained in accordance with a feature of the invention by utilizing a source of single-phase alternating current of relatively high frequency at the central office in place of the 60 cycle, three-phase supply used in the prior system. This feature results in a simplification and a reduction in cost of the apparatus required, and effects a system having improved capabilities.

Another feature of the invention contemplates terminating the tip and ring conductors of the code receiving circuit at opposite terminals of a transformer secondary, through which the single-phase alternating current is supplied to the tele-

phone line, and in utilizing, as a third leg, a branch circuit extending between ground and a center tap on the transformer secondary. In each of the tip and ring leads of the code receiving circuit, and in the said branch circuit there is included a pair of oppositely poled polarized relays, which operate in various combinations to characterize the digits or symbols of a telephone designation.

A further feature of the invention resides in a novel keying arrangement whereby the digit characterizing codes are obtainable in a simplified manner, and which permits the use of the third, or branch circuit of the code receiving circuit mentioned above. In accordance with this feature, certain of the digit characterizing codes are obtained by connecting a single varistor from the tip or ring conductor of the line to ground and effectively short-circuiting the other conductor to ground. By virtue of this arrangement, the direct current produced by the single varistor is caused to flow over the conductor to which it is connected, and to divide and flow over the other, now grounded, conductor, and also over the third or branch leg of the code receiving circuit. In this manner a code relay in each of the three leads, tip, ring, and third branch, of the code receiving circuit is operated on current whose direction is determined by a single varistor. The term "varistor" is used in this specification to characterize a dry rectifier of the copper-oxide type, or similar device.

A still further feature of the invention resides in a novel type of supervisory circuit. Any alternating current supervisory scheme encounters the difficulty that the loop capacitance causes a charging current to flow, and this current, to which the supervisory relay is subject, obscures the change of impedance over the loop when the switchhook at a subscriber's station is operated, upon which impedance change the supervisory relay depends for its operation or release. This difficulty is minimized, in accordance with this particular feature of the invention, by normally subjecting the supervisory relay to a current of such phase and magnitude as to cancel out a portion of the current due to maximum loop capacitance. When the handset telephone is not removed from its cradle support, this current is such that, when combined with the current produced by the loop capacitance which increases with increasing length of subscriber's line, the resulting current in the supervisory relay is reduced when the subscriber's telephone set is disconnected from a maximum length line, and is

increased on a zero length line to a value about the same as the new value obtaining on a maximum length line.

These and other features of the invention will be readily understood from the following detailed description taken in connection with the accompanying drawings, in which:

Fig. 1 shows the varistor type key sender located at a calling subscriber's station, and also the code signal receiving circuit located at a central office;

Fig. 2 is a circuit diagram showing the automatic switches which serve to extend a connection from a calling subscriber's station to a called subscriber's station, and also the translator circuit which is controlled by the code signal receiving circuit of Fig. 1;

Fig. 3 is a circuit diagram illustrating the decoder register circuit and associated apparatus which is controlled by the translator circuit of Fig. 2, and which registers and stores the telephone designations transmitted from the calling station of Fig. 1;

Fig. 4 is a block diagram showing the manner in which Figs. 1, 2 and 3 are to be assembled to effect a complete system;

Fig. 5 is a table showing the varistor combinations resulting from the actuation of each of the ten keys of the key sender, and the corresponding combination of code relays which respond to each key actuation; and

Fig. 6 is a graphical representation of the several currents which are involved in the supervisory feature of the invention.

It will be observed that the translator circuit of Fig. 2 and the decoder register circuit of Fig. 3 are substantially identical to the translator and decoder register circuits shown in Figs. 4 and 3, respectively, of the above-identified copending application. The only material change made in these figures is that involving the identification of certain of the multicontact translator relays. Relays MP2, MN2, TP2 and TN2 of the prior application disclosure are identified in the present disclosure as relays TP2, TN2, MP2 and MN2, respectively. In view of the fact that the translator and decoder register circuits have been fully described in the above-referred-to copending application, the preliminary brief description of this equipment is omitted from this application. This equipment, however, will be fully described in the description of the operation of the system to be made presently.

The key sender K at the subscriber's station A comprises ten keys *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, *j*, and *k*. In practice, each key would be equipped with a cap or similar character-bearing device which displays a set of designation symbols corresponding to those appearing on the number-plate of the conventional telephone dial. Key *a* would bear the symbol "1," key *b*, the symbols 2ABC; key *c*, the symbols 3DEF; key *d*, the symbols 4GHI; key *e*, the symbols 5JKL; key *f*, the symbols 6MNO; key *g*, the symbols 7PRS; key *h*, the symbols 8TUV; key *j*, the symbols 9WXYZ; and key *k*, the symbols 0.OPERATOR. Some of the keys, such as keys *c*, *d*, *h* and *j* control a single contact whereas others control a plurality of contacts. At the lower left of the key sender K there are shown four dry rectifiers, or varistors 1, 2, 3 and 4. The varistors 1 and 2 are adapted to be connected to the tip side of the line through the operation of the keys, while the varistors 3 and 4 are adapted to be similarly connected to the ring side of the line. Varistors 1 and 3 func-

tion to effect the transmission of positive direct current pulses over the tip and ring sides, respectively, whereas varistors 2 and 4 function to effect the transmission of negative direct current pulses over the tip and ring sides, respectively.

At the central office there is located a single-phase source, P, of alternating current which supplies current to the leads T, R and M through the medium of transformer 10. The frequency of this source is preferably 100 cycles. The lead M is known as the ground lead and extends from the center tap of the secondary winding of transformer 10 to ground by way of the operating windings of code relays MP and MN. The leads T and R extend from opposite end terminals of the transformer secondary and include the operating windings of code relays TN and TP and RN and RP, respectively. These leads, as will appear from a later description, connect with corresponding leads of the line L when a call is initiated at station A. Relays TN, TP, MP, MN, RN and RP are referred to as code relays since they operate in different combinations of two or three at a time in accordance with the code set up by the keys of the key-type sender K. A 100 cycle elimination filter FT, FR, FM, is bridged across each pair of code relays to prevent them from buzzing on alternating current of the fundamental frequency of source P. Because these relays do not operate except when direct current is present, there is no release current requirement imposed on them due to the alternating current drawn by the loop capacitance or leakage.

The supervisory circuit is shown at the lower right of Fig. 1. It comprises a repeating coil RC, a step-down transformer 11, a full-wave rectifier indicated at X, a supervisory relay 12 and an electrolytic condenser 13. The repeating coil RC is connected in the ring lead R at the central office and the impedance looking into it is low enough so as to have very little effect on the currents in the code relays. The resistance of relay 12 is relatively low so that very little direct current potential drop occurs across it. Condenser 13, shunted across the relay 12 provides a low impedance shunt for the alternating current components, thus smoothing the current that flows in the relay and helping to hold down the impedance looking into the repeating coil RC. As will be described more fully hereinafter, the voltage introduced by the step-down transformer 11 is of such phase and magnitude as to cancel out a portion of the voltage due to loop capacitance, thereby insuring the proper operation of relay 12 in response to receiver switchhook operations.

The table in Fig. 5 illustrates how the varistors 1, 2, 3 and 4 may be connected in ten different combinations to pass ten different signals to the central office. It is to be understood that the possible varistor combinations are not limited to ten. Only ten have been indicated, since this number is adequate to provide a comprehensive understanding of the arrangement when used in the telephone designation transmission system disclosed in the drawings. As a matter of fact, the table of Fig. 5 shows a particular assignment of only ten of the codes to the ten digits or characters from which a telephone designation is constructed. The arrangement suggested by Fig. 5 is one which lends itself to the relatively simple translator circuit shown in Fig. 2, for translating the operation of the code relays of Fig. 1 into signals receivable by the decoder register circuit of Fig. 3.

The ten different codes used in the description

of the system disclosed are obtained as follows: Four codes are obtained by connecting one rectifier at a time. These codes, as shown in the table of Fig. 5 characterize the designation characters 3DEF, 4GHI, 8TUV and 9WXY. These codes each bring up two code relays at the central office as indicated in the table. Two more codes are obtained by connecting two rectifiers at a time. These codes, as shown in the table, characterize the designation characters 5JKL, and 0. The last four codes are obtained by connecting three rectifiers at a time. These codes, as shown in the table, characterize the designation characters 1, 2ABC, 6MNO and 7PRS. The code relays which operate for each combination of varistors connected are indicated in Fig. 5.

The first four codes mentioned above cause the operation of two code relays. In the case of the rectifier combinations 2—4 and 1—3, corresponding to the designations 5JKL and 0, respectively, three code relays at the central office are operated. The currents in the tip and ring relays TN, TP and RN, RP are the same as if single rectifiers were connected, and the current in the ground relays MN and MP is double since the currents due to the two rectifiers add together in the ground lead.

The rectifier combinations 1—3—4, 2—3—4, 1—2—3, and 1—2—4 (designation characters 1, 2ABC, 6MNO, and 7PRS, respectively) are equivalent to connecting a rectifier from one side of the loop to ground and short-circuiting the other side of the loop to ground. With the combination 1—3—4, for example, the direct current is produced by rectifier 1, while the others merely serve to short the ring lead to ground. Because of the ring-to-ground short, the direct current which would flow only in the ground lead if No. 1 rectifier were connected alone, is made to divide and flow partly in the ring lead R which is paralleled with it; the result is that three central office code relays (MP, TP and RN) are operated.

The foregoing discussion explains how it is possible to obtain the ten codes used in the designation transmission system disclosed, with only single phase alternating current.

A detailed description of the operation of the system disclosed in the drawings (Figs. 1, 2 and 3) will now be made and for this purpose it will be assumed that the subscriber at station A desires a connection with the subscriber's station B (Fig. 2), the telephone designation of which, for descriptive purposes, will be assumed to be "AD4—5678." The subscriber at station A accordingly lifts the handset from its support and actuates keys *b*, *c*, *d*, *e*, *f*, *g*, and *h* in that order.

When the handset at station A is removed from its support, the line circuit is closed, and the line finder F operates, in a well-known manner, to seize the calling subscriber's line L. At the same time the sender selector S—1 becomes effective to extend the calling line through to an idle sender. When these operations have been completed, a circuit is closed from the alternating current source P at the central office over the closed subscriber's loop at station A by way of the leads T and R, conductors 114 and 113, brushes 101 and 100 of switch S—1, sequence switch contacts 102 and 103, tip and ring brushes and corresponding terminals of line finder F, and the tip and ring conductors of line L extending to the called station A. The polar-

ized code relays TP and TN, included in the lead T, relays RP and RN, included in the R lead, and relays MP and MN, included in the M lead do not operate on this current because filters FT, FR, and FM eliminate this current from these relays.

Repeating coil RC is included in the ring conductor of the circuit just traced and it introduces the metallic alternating line current into the full-wave rectifier X in series with the small out-of-phase voltage from transformer 11 causing the operation of relay 12, its operating current being rectified by means of the full-wave rectifier X.

Relay 12, operated, establishes an obvious circuit for the off-normal slow-to-release relay 400. Relay 400, at its upper armature and front contact, connects off-normal ground to the armature of "signal present" relay 402 by way of conductor 401. Relay 402 now operates in a circuit extending from grounded battery, upper winding of relay 402, conductor 403, right-hand contacts and armatures of code relays MN and MP, conductor 401, to ground by way of the front contact and upper armature of relay 400.

Relay 402, operated, establishes an obvious operating circuit for "enabler" relay 404, which, in operating, causes the "signal recorded" relay 406 to operate in a circuit which may be traced from grounded battery, lower armature and front contact of relay 400, conductor 405, armature and left-hand contact of relay 404, to ground by way of the operating winding of relay 406. With relays 400, 402, 404 and 406 operated, the translator circuit is prepared to receive the telephone designation digits, or symbols, characterized by the particular code relays that operate.

Upon the actuation of key *b* at station A in accordance with the first character "A" of the desired, or assumed, telephone designation, contact Q operates, as it does when each key of the key sender K is actuated. The operation of contact Q insures the opening of one of the leads to the subset so that there is no low resistance path from tip to ring while the signal is being passed. Whenever the off-normal switch Q is closed, the subscriber will hear an audible tone in the receiver due to the alternating current voltage being impressed on the line from the source P. A varistor 105 is connected across the receiver at station A to reduce the receiver noise caused by the operation of switch Q.

When key *b* is actuated at station A, it will be observed that the right-hand spring, which is connected to the ring conductor of the line by way of the switchhook contacts, closes on contact 20 which connects with varistor 3, while the left-hand spring, which is connected to the tip conductor of the line, closes simultaneously on contacts 21 and 22 which connect respectively to varistors 1 and 2. The closure of contacts 21 and 22 results in an effective short-circuiting of the tip conductor to ground. Therefore, the varistor 3 alone functions to transmit the controlling direct current impulse over the line. The circuit for this current may be traced from ground, positively poled varistor 3, closed contacts 20 of key *b*, switchhook contacts at station A, ring conductor of the line L, ring terminal and corresponding brush of finder switch F, sequence switch contacts 103, brush 100 and associated contact of switch S—1, conductor 113, left-hand windings of repeating coil RC, operating windings of code relays RP and RN, lead R, lower half of the secondary winding of trans-

former 10 to the center tap thereof, and thence in parallel over two paths, one extending from the said center tap and including lead M and the lower windings of code relays MP and MN, to ground, and the other extending from the said center tap and including the upper half of the secondary of transformer 10, lead T, lower windings of code relays TN and TP, conductor 114, to ground, it being understood that conductor 114 is connected to the tip conductor of line L which, as above indicated, is now effectively shorted to ground at the calling station A. The currents in the circuits just traced are in such direction as to cause the operation of polarized code relays MP, TN and RP.

Relay MP, operated, opens the operating circuit for relay 402. Relay 402, released, starts the slow-to-release relay 404 to release; connects the ground on conductor 401 to the armature of relay 406, which ground operates "timing" relay 408 in a circuit extending from grounded battery, upper winding of relay 408, back contacts and middle upper armatures of relays TP2, TN2, RN2 and RP2, back contacts and outer upper armatures of relays MP2 and MN2, conductor 409, left contact and armature of relay 406, left contact and armature of relay 402, conductor 401, to ground at the front contact and armature of relay 400. By way of conductor 127, which is a continuation of conductor 409, ground is connected to the armatures of code relays RP, RN, TP and TN (Fig. 1).

Since there is no battery voltage connected to any of multicontact translator relays TP2, TN2, RN2, RP2, MP2 and MN2 at this time, none of these relays operates due to the operation of the code relays MP, TN and RP. When relay 408 operated, it removed ground from the "lock and transfer" lead 146 extending to the decoder register circuit (Fig. 3), and applied locking ground to the multicontact translator relays and to the "battery hold" relay 410, none of which relays is yet operated.

When the maximum transient operation time of the code relays TP, TN, RP and RN has elapsed, the "enabler" relay 404 releases. These four relays are the only code relays which are subject to extended transient operation. Relays MP and MN always have operate current and are not as subject to transient operation. Relay 404, released, starts relay 406 to release and connects battery, at the lower armature and front contact of relay 400, to the operating windings of all the multicontact translator relays, so that they are prepared to operate in accordance with the combination of code relays operated. Relay 410 also operates as a consequence of the release of relay 404 and locks in an obvious circuit. Relay 410 maintains battery on the multicontact relays even if the "enabler" relay 404 should be reoperated due to a short key closure.

With code relays MP, TN and RP operated as a consequence of the operation of key b at station A, translator relays MP2, TN2 and RP2 now operate. Relay MP2 operates in a circuit extending from grounded battery, lower armature and front contact of relay 400, conductor 495, armature and right contact of relay 404, upper winding of relay MP2, back contact and outer lower armature of relay MN2, and upper armature and back contact of "long closure" relay 412, left contact and armature of code relay MP, conductor 401, to ground at the front contact and upper armature of relay 400. Relay TN2 operates in a circuit extending from grounded battery,

lower armature and front contact of relay 400, conductor 495, armature and right contact of relay 404, upper winding of relay TN2, conductor 196, contact and armature of code relay TN, conductors 127 and 409, left contact and armature of relay 406 (before this relay releases), left contact and armature of relay 402, conductor 401, to ground by way of the front contact and upper armature of relay 400. Relay RP2 operates in a circuit extending from grounded battery, lower armature and front contact of relay 400, conductor 495, armature and right contact of relay 404, upper winding of relay RP2, conductor 195, contact and armature of code relay RP, conductors 127 and 409 and thence to ground at the front contact and upper armature of relay 400 as described in connection with the operation of relay TN2.

Relays MP2, TN2 and RP2, operated, lock to ground on the armature and left contact of relay 408 by way of their innermost lower armatures and front contacts. The ground on the armature of relay 408 also acts as a locking ground for relay 410. The operation of relays MP2, TN2 and RP2 opens the operating circuit to slow-to-release relay 408.

When relay 408 operated, it established an obvious operating circuit for relay 200 (Fig. 3), by way of the lower armature and back contact of relay 201 and conductor 160. Relay 200 operates in this circuit and connects the leads 147 to 151, inclusive, to the windings of register relays 202 to 206, inclusive, respectively, which constitute the first group of register relays.

With translator relays MP2, TN2 and RP2 and relay 200 of the decoder register circuit operated, a circuit is established for the operation of register relay 204. This circuit may be traced from grounded battery, lower winding of relay 204, conductor 207, front contact and inner upper armature of relay 200, conductor 148, front contact and outer lower armature of relay TN2, front contact and outer lower armature of relay RP2, inner upper armature and front contact of relay MP2, conductor 401, front contact and upper armature of relay 400, to ground.

Register relay 204, operated, locks in a circuit extending from grounded battery, upper winding of relay 204, front contact and upper armature of relay 204, conductor 208, winding of relay 201, back contacts and outer upper armatures of relays 210, 220 and 230, conductor 146, to ground by way of the right contact and armature of relay 408. At its lower armature and front contact, relay 204 establishes an obvious circuit for the energization of a lamp signal at 217. Thus the character "A" of the telephone designation AD4-5678 is stored in the register for future use in controlling the automatic switches S, S-2 and S-3, which function to extend the call to the called station B.

When relay 408 released, it opened the locking circuit for the multicontact translator relays whereupon relays MP2, TN2 and RP2 release.

When relay 406 released, as hereinbefore described, it removed the ground connection to the armatures of relays RP, RN, TN and TP to prevent false operation of any multicontact translator relay due to an ending transient, and reconnected ground to the winding of relay 400 to hold this relay operated should the supervisory relay 12 release during reception of a digit. This ground is not applied until the expiration of a predetermined interval of time after a digit is received, but the minimum release time of relay

400 is considerably in excess of this time. The contact of relay 406 operates the "long closure" relay 412 to disconnect the code relays MP and MN from their associated multicontact translator relays MP2 and MN2.

The translator circuit performs exactly in the same manner as does the translator circuit shown in Fig. 4 of the above-identified copending application. The several characteristic features of this circuit are set forth in detail in the copending application and do not require repetition here.

When relay 204 in the decoder register circuit operated as described above, its locking circuit was traced through the winding of relay 201, so that relay 201 operated and locked to ground at the armature and front contact of relay 400 by way of conductor 160, and the uppermost front contact and armature of relay 201. The ground is also carried through to the winding of relay 210 by way of the upper armature and two front contacts of relay 201 and the lower armature and back contact of relay 211. Relay 210 operates and connects the leads 147 to 151, inclusive, to the second group of register relays 212 to 216, inclusive. At its lower armature relay 201 opens the circuit to relay 200 which relay releases its armatures.

The translator circuit has now been restored to its initial condition and the character "A" has been registered in the decoder register circuit, and the register has been prepared for the receipt of the next designation character "D".

The subscriber at station A next actuates key *c* which in practice would be characterized by the symbols "3DEF." The operation of key *c* connects varistor 1 to the tip conductor of the line L so that direct current of positive polarity traverses a path extending from ground, varistor 1, closed contact of key *c*, tip conductor of the line to the corresponding brush and terminal of line finder F, sequence switch contacts 102, brush 101 and corresponding terminal of switch S—1, tip conductor 114, lower windings of code relays TP and TN, lead T, upper half of the secondary winding of transformer 10, lead M, lower windings of code relays MP and MN to ground. It will be observed that the circuit involving the lower half of the secondary winding of transformer 10, lead R, lower windings of code relays RN and RP is open in so far as having a varistor connected thereto. Current traversing the closed circuit traced above is in a direction such as to cause the operation of code relays MP and TP.

Code relay MP functions to prepare the translator circuit for operation in the same manner as it did when it operated in response to the actuation of key *b* at station A. It is believed unnecessary to repeat the detailed description of the operation of the translator circuit for each actuation of a key at the calling station.

With code relays MP and TP and register relay 210 operated, certain register relays will be operated to store the character "D" of the designation and the manner in which these relays operate will now be described.

Translator relay MP2 operates in a circuit extending from grounded battery, lower armature and front contact of relay 400, conductor 405, armature and right contact of relay 404, upper winding of relay MP2, back contact and lower armature of relay MN2, upper armature and back contact of relay 412, left contact and armature of code relay MP, conductor 401, to ground by way of the front contact and upper armature of relay 400. Translator relay TP2 operates in a

circuit extending from grounded battery, lower armature and front contact of relay 400, conductor 405, armature and back contact of relay 404, upper winding of relay TP2, conductor 199, left contact and armature of code relay TP, conductors 127 and 409, left contact and armature of relay 406 (not yet released), left contact and armature of relay 402, conductor 401, to ground by way of the front contact and upper armature of relay 400.

Relays MP2 and TP2, operated, lock under control of relay 408. Register relay 213 now operates in a circuit extending from grounded battery, lower winding of relay 213, conductor 228, contact 227 and its working spring of relay 210, conductor 149, back contact and innermost upper armature of relay RN2, back contact and innermost upper contact of relay RP2, outermost upper armature and front contact of relay TP2, to ground at the front contact and upper armature of relay 400. Register relay 214 also operates in a circuit extending from grounded battery, lower winding of relay 214, conductor 241, front contact and innermost upper armature of relay 210, conductor 148, back contact and outermost lower armature of relay RN2, back contact and innermost upper armature of relay RP2, inner upper armature and front contact of relay MP2, conductor 401, to ground by way of the front contact and upper armature of relay 400.

Register relays 213 and 214, at their lower armatures establish obvious circuits for lamp signals at 229. Relays 213 and 214 lock in the same manner as did relay 204, previously described, and in the locking circuit therefor, relay 211 operates to cause relay 220 to operate, and to release relay 210. Relay 220, operated, connects the leads 146 to 151, inclusive, to the windings of relays 222 to 226, inclusive, respectively, of the third group of register relays, whose function it is to register and store the digit "4" of the telephone designation AD4—5678.

The equipment which functioned as a consequence of the operation of key *c* at substation A restores when the key *c* is released, in a manner similar to that described after the registration of the designation character "A" by the register relay 204. The telephone designation characters "A" and "D" are now stored in the decoder register and the equipment is prepared to register the digit "4" in response to the actuation of key *d* at the substation A.

When key *d* is actuated to cause the transmission to and registration at the central office of the third character "4" of the desired telephone designation, the varistor 3 is connected to the ring conductor of the line whereupon positive direct current impulses traverse a circuit which may be traced from ground, varistor 3, closed contact of key *d*, ring conductor of the line L, corresponding terminal and brush of line finder F, sequence switch contacts 103, brush 100 and terminals of switch S—1, ring lead 113, left-hand windings of repeating coil RC, operating windings of code relays RP and RN, lead R, lower half of the secondary winding of transformer 10, lead M, operating windings of code relays MP and MN to ground. The direction of the direct current in this circuit is such as to cause relays MP and RP to operate.

When the translator relays 402, 404 and 406 function, in the manner previously described, in response to the operation of relay MP, the multicontact translator relays MP2 and RP2, corresponding to the code relays MP and RP, operate.

Relay MP2 operates over the same circuit traced previously in connection with the actuation of keys *b* and *c* at station A. Relay RP2 operates in a circuit extending from grounded battery, lower armature and front contact of relay 403, conductor 405, armature and right contact of relay 404 (released), upper winding of relay RP2, conductor 195, contact and armature of code relay RP, conductors 127 and 409, left contact and armature of relay 406 (not yet released), left contact and armature of relay 402 (released), conductor 401, to ground by way of the front contact and upper armature of relay 400. Relays MP2 and RP2 lock to ground at the left contact and armature of relay 408.

Register relay 225 now operates in a circuit which may be traced from grounded battery, lower winding of relay 225, front contact and innermost lower armature of relay 220, conductor 147, back contacts and innermost upper armatures of code relays TP2 and TN2, outermost upper armature of relay RP2 in parallel with the inner upper armature and front contact of relay MP2 and their respective front contacts, conductor 401, to ground by way of the front contact and upper armature of relay 400. Relay 225, by way of its lower armature and front contact, establishes an obvious circuit for the operation of a lamp signal at 239. At its upper armature and front contact, register relay 225 locks in a circuit which includes the winding of relay 241. Relay 241 operates in this circuit causing the release of relay 220 and the operation of a relay, corresponding to relays 200, 210 and 220, associated with the next group of register relays.

The decoder register circuit shows in detail only those groups of register relays which function to store the first three and the last characters of a telephone designation. It is to be understood that at least three, and possibly five similar groups of register relays are interposed between the third and fourth groups illustrated. The broken lines to the left of Fig. 3 indicate the omission of the other groups of register relays of the decoder register circuit. The groups of register relays, not shown, function in the present case, in response to the successive actuations of keys *e*, *f*, and *g* to store the telephone designation digits "5", "6" and "7."

Key *h* at the subscriber's station A is actuated for the transmission of the last digit, "8," of the desired designation whereupon a circuit is established which may be traced from ground, negatively poled varistor 2, closed contacts of key *h*, tip conductor of line L, corresponding terminal and brush of line finder F, sequence switch contacts 102, brush 101 and associated terminal of switch S—1, conductor 114, lower windings of code relays TP and TN, lead T, upper half of the secondary winding of transformer 10, lead M, lower windings of code relays MP and MN to ground. Code relays MN and TN operate in this circuit.

Relay MN performs the same functions as does relay MP previously described. That is, it opens the operating circuit for relay 402 causing this relay to release. Relays 402, 404 and 406 then function in the manner previously described. Relay MN, operated, causes multicontact translator relay MN2 to operate while code relay TN causes translator relay TN2 to operate. The operating circuits for these relays need not be traced since they are substantially identical to the operating circuits for translator relays previously operated.

With relays MN2 and TN2 operated, decoder register relays 233, 234 and 236 operate.

Relay 233 operates in a circuit extending from grounded battery, lower winding of relay 233, conductor 280, contacts 281 of relay 230, conductor 149, back contact and innermost upper armature of relay RN2, back contact and innermost upper armature of relay RP2, outermost upper armature and front contact of relay TN2, to ground by way of the front contact and upper armature of relay 400.

Relay 234 operates in a circuit extending from grounded battery, lower winding of relay 234, conductor 283, front contact and innermost upper armature of relay 230, conductor 148, back contact and outermost lower armature of relay RN2, back contact and innermost upper armature of relay RP2, outermost upper armature and front contact of relay TN2, to ground by way of the front contact and upper armature of relay 400.

Relay 236 operates in a circuit extending from grounded battery, lower winding of relay 236, conductor 284, front contact and middle lower armature of relay 230, conductor 150, inner upper armature and front contact of relay MN2, outermost upper armature and front contact of relay TN2, to ground by way of the front contact and upper armature of relay 400.

At their lower armatures and front contacts, register relays 233, 234 and 236 establish obvious circuits for three of the lamp signals at 249. At their upper armatures, relays 233, 234 and 236 lock to ground on conductor 146. Thus the last telephone designation digit "8" is stored in the register. The release of key *h* at the subscriber's station A restores the equipment to normal in a manner already described in connection with the release of key *b*.

The telephone designation AD4—5678 is now registered and stored in the decoder register circuit for use in controlling the operation of switches S, S—2, and S—3 which extend the call, originated at station A, to the station B.

The supervisory circuit and its operation will now be described.

Supervisory schemes in general require that the supervisory relay respond to switchhook operations at the subscribers' stations. The relay is required to operate when the subset is on the line, that is, when the handset is removed from its switchhook or cradle support, and to release when the subset is disconnected from the line. In the present case, supervisory relay 12 (Fig. 1) is normally released. It receives operating current from the right-hand windings of repeating coil RC whose left-hand windings are included in the ring conductor 113. When the subscriber at station A, initiated the call to station B, alternating current from the source P traversed the T, R and M leads of the code relay circuit over the closed loop at station A. The current traversing the lead R (Fig. 1) obviously traverses the left-hand windings of repeating coil RC with the result that the current induced in the secondary windings of coil RC causes relay 12 to operate and to perform the functions heretofore ascribed to it, such as the operation of relay 400.

In any alternating current supervisory scheme there is introduced the difficulty caused by the flow of a charging current produced by the loop capacity. In Fig. 2, the line L extending from the central office to the subscriber's station A, Fig. 1, is shown to include two capacities C_E to ground, and a "metallic" capacity C_m which ap-

pears between the two conductors of the line L. These capacities are inherent in the line L and are effective in causing the charging current from the source P to flow when the subset at station A is disconnected from the line L during signaling. This charging current obviously traverse the primary or left-hand winding of the repeating coil RC to whose right-hand winding the rectifier X and the operating winding of the supervisory relay 12 are connected. Therefore, the operating winding of the relay 12 is subjected not only to alternating current from the source P when the line loop is closed, but also to a charging current caused by the loop capacitance when the line loop is open. It has been discovered that with a long enough loop this charging current obscures the change in impedance when the switchhook at the calling station A is operated and that the current in the supervisory relay is actually lower when the subset is on the line than when it is off the line. What is required is that the current in the supervisory relay be larger when the subset is on, all lengths of line loop considered, than when the subset is off, all lengths of loop considered. Furthermore, the margin must be sufficient for a commercial relay adjustment. In the present invention this has been accomplished by utilizing a balancing voltage, which, in effect, cancels the voltage due to the average loop capacitance so that substantially no current flows in the supervisory relay when the subset is off the line.

This balancing voltage, in accordance with the present invention is supplied by means of the step-down transformer 11, which is supplied directly from the alternating current source P. The current due to this voltage lags the voltage of P because of the inductance of repeating coil RC and therefore is 180 degrees out of phase with the charging current and is of such magnitude that the resultant current which flows in the supervisory relay, when the subset at station A is disconnected from the line L, is substantially zero for an average length of line loop and which, throughout the entire range of loop lengths, up to the maximum, never exceeds that value of current below which the supervisory relay is adjusted to release.

Fig. 6 illustrates, graphically, the effect of introducing a balancing voltage in the supervisory circuit of this invention. The horizontal straight lines O and R represent the operate and release current values, respectively, to which the supervisory relay 12 is adjusted. For example, the line O indicates a current value above which the relay is adjusted to operate, while the line R indicates a current value below which the relay is adjusted to release. Obviously, the conditions of the line with which the relay is associated must be such that, when the substation A is disconnected from the line by the opening of the switchhook contacts thereat, the current which traverses the operating winding of the supervisory relay must not exceed the release current value represented by the line R in Fig. 6, otherwise the relay would fail to release.

When the subset at station A is connected to the line L by the closure of the switchhook contacts, an operate current is caused to flow over the line which functions to operate the supervisory relay 12. This current is illustrated, graphically, by the downwardly sloping line x of Fig. 6. This current varies from a maximum at zero loop to a minimum at the maximum length of loop, and for the maximum length of

loop this current obviously must exceed the operate current value to which the relay is adjusted, and which is represented by the line O.

The charging current produced by the loop capacity is represented by the upwardly sloping line y of Fig. 6. This current varies from zero, at zero loop, to a maximum at maximum loop length. This current, as hereinbefore indicated, is present in the loop when the subset at station A is off the line due to a disconnect. It will be observed that for certain lengths of line, the current due to the line capacity is greater in value than the operate current x so that the current in the relay 12 would be greater when the subset at station A was off the line than when it was on the line. As hereinbefore indicated, the converse is desired.

It will also be observed that for certain lengths of line, the current due to line capacitance exceeds the release current value R to which the relay 12 is adjusted to release. The supervisory relay, therefore, would fail to release under these circumstances and would remain operated regardless of whether or not the line was closed at the substation A.

Balancing out the voltage due to the line capacitance and which produces the current y shown in Fig. 6, results in an open circuit (subset disconnected) current whose graph is shown at z in Fig. 6. It will be noted that this current graph is always below the release current line R, indicating that the open circuit current to which the supervisory relay is subject never exceeds the current value below which the relay is adjusted to release.

The currents due to the loop capacitance voltage and to the voltage supplied by transformer 11 are rectified at X and impressed upon the operating winding of relay 12. Under the condition in which the subset at station A is off the line, that is, due to a disconnect, the supervisory relay 12 is subject to current produced by the voltage caused by the line capacitance and also to current produced by the voltage supplied by transformer 11, and since, by design, these currents are in phase opposition, they effectively tend to cancel out, and the net current flowing in the relay winding, due to these two sources is minimized. During signaling, when the off-normal contact Q is opened, the relay 12 may or may not release depending on the digit key depressed and on the length of loop, but the slow release relay 400, operated by relay 12 between digits, is kept operated by relay 406 as already described.

What is claimed is:

1. In a telephone system, a calling station, a central office, a source of single-phase alternating current at said central office, a transformer, a two-wire code receiving circuit terminating in the secondary winding of said transformer, said source of current being connected to the primary winding of said transformer, means responsive to the initiation of a call at said station for extending said code receiving circuit to said station, means at said station for translating the current from said source into direct current impulses and causing them to be transmitted to said code receiving circuit, and means selectively responsive to the transmitted impulses comprising a pair of oppositely poled polarized relays in each wire of said code receiving circuit and in a branch circuit extending from a center tap on the secondary winding of said transformer to ground.

2. In a code signaling system, a sending sta-

tion, a central office, a source of single-phase alternating current at said central office, a code receiving circuit at said central office comprising a pair of conductors connected to the line conductors of said sending station, a transformer having its primary winding connected to said source of alternating current and a secondary winding connected across the conductors of said code receiving circuit, a branch circuit extending from a center tap of the transformer secondary winding, and a pair of polarized relays serially included in each of the conductors of said code receiving circuit and in the said branch circuit, a plurality of current rectifying devices at said sending station, and means at said sending station for connecting said rectifying devices in various combinations to the line conductors of said station to cause rectified current impulses to be transmitted over the conductors of said code receiving circuit to selectively operate one of each of said pairs of polarized relays.

3. In a code signaling system, a sending station, a central office, a source of single-phase alternating current at said central office, a two-wire code receiving circuit connected to the line conductors of said sending station, a transformer connecting said source of current to said code receiving circuit, a pair of polarized relays serially included in one wire of said code receiving circuit, a pair of polarized relays serially included in the other wire of said code receiving circuit, a branch circuit extending from a center tap on the secondary winding of said transformer to ground, a pair of polarized relays in said branch circuit, a plurality of varistors at said sending station having normally grounded and ungrounded terminals, and switching means at said station for selectively connecting the ungrounded terminals of certain of said varistors to the line conductors of said sending station in such a manner, that current from said source is rectified by one only of said varistors and caused to flow over both wires of said code receiving circuit and over said branch circuit to cause the operation of a relay of each of said pairs of polarized relays.

4. In a code signaling system, a sending station, a source of single-phase alternating current, a two-wire code receiving circuit, a transformer coupling said source of current to said code receiving circuit, a branch circuit extending from a center tap on the secondary winding of said transformer to ground, signaling devices included in each wire of said code receiving circuit and in said branch circuit, and switching means at said sending station for connecting either of the wires of said code receiving circuit to ground through a varistor and for simultaneously shorting the other wire of said code receiving circuit to ground, whereby direct current is caused to flow over one wire of said code receiving circuit and in parallel over the other wire and said branch circuit to cause certain of said signaling devices to operate.

5. In a code signaling system, a sending station, a source of single-phase alternating current, a two-wire code receiving circuit connected to the line wires of said sending station, a transformer having its primary winding connected across said source of current and a secondary winding terminating the wires of said code receiving circuit, direct current responsive devices included in each wire of said code receiving circuit, a branch circuit extending from a center tap on the secondary of said transformer to ground, direct current

responsive devices included in said branch circuit, two pairs of varistors at said sending station, the varistors of each pair having an opposite terminal connected to ground, and switching means at said sending station for connecting the ungrounded terminal of a varistor of the first of said pairs to one line wire of the sending station and the ungrounded terminals of both varistors of the second of said pairs to the other line wire, whereby direct current of a polarity determined by the connected varistor of the first pair traverses both wires of said code receiving circuit and said branch circuit to cause the operation of a certain combination of said direct current responsive devices.

6. In a code signaling system, a sending station, a receiving station, a single-phase source of power at said receiving station, a transformer at said receiving station, a two-wire code receiving circuit terminating in the secondary of said transformer whose primary is connected across said source of power, a branch circuit extending between a center tap on the secondary of said transformer and ground, signaling devices included in each wire of said code receiving circuit and in said branch circuit, a plurality of oppositely poled varistors at said sending station each having one terminal grounded, and switching means at said sending station for connecting the ungrounded terminal of one of said varistors to one wire of said code receiving circuit and simultaneously connecting the ungrounded terminals of two oppositely poled varistors to the other wire of said code receiving circuit, whereby the said other wire of said code receiving circuit is effectively grounded at said sending station and direct current of a polarity determined by the varistor connected to the said one wire of said code receiving circuit is caused to traverse each of the two wires of said code receiving circuit and said branch circuit, to effect the selective operation of signaling devices included therein.

7. In a telephone system, a calling station, a central office, a source of alternating current at said central office, a line connection interconnecting said station and said central office and supplied with current from said source, a supervisory relay, means for inductively connecting the winding of said relay to said line connection, and other means for connecting the winding of said relay directly to said source of alternating current.

8. In a telephone system, a calling station, a central office, a source of alternating current at said central office, a line connection interconnecting said station and said central office and supplied with current from said source, a repeating coil having a primary winding included in said line connection, a transformer having a primary winding connected to said source, and a series connection including the secondary windings of said repeating coil and said transformer and the winding of said supervisory relay.

9. In a telephone system, a subscriber's station, a central office, a source of alternating current at said central office, a line connection interconnecting said station and said central office and supplied with current from said source, a supervisory relay, and separate means for connecting said supervisory relay to said line connection and to said source of current comprising a repeating coil and a transformer having their secondary windings included in series with the operating winding of said relay.

10. In a telephone system, a subscriber's sta-

tion, a central office, a two-wire circuit interconnecting said station and said central office, a source of alternating current connected to said two-wire circuit, a supervisory relay, a repeating coil having its primary winding included in one wire of said two-wire circuit, and a step-down transformer having its primary winding supplied directly from said source and its secondary winding included in a series circuit including the secondary winding of said repeating coil and the operating winding of said relay.

11. In a telephone system, a subscriber's station, a central office, a line loop interconnecting said station and said central office, a source of alternating current connected to said line loop, a supervisory relay, means for connecting said relay to said line loop so as to subject it to a voltage produced by current caused to flow in said loop when the subset at said station is connected to said loop, and auxiliary means for subjecting said relay to a voltage other than the voltage produced by the flow of current in said loop.

12. In a telephone system, a subscriber's station, a central office, a loop circuit extending from said station to said central office, a source of alternating current, said loop circuit having an inherent capacitance characteristic whereby current from said source due to the loop capacitance is caused to flow in said loop circuit, a supervisory relay, means connecting said relay to said loop circuit so as to subject said relay to a voltage commensurate with the current in said loop caused by the capacitance thereof, and means for subjecting said relay to a voltage of such magnitude and phase with respect to the voltage produced by the loop capacitance current that the two voltages substantially cancel each other.

13. In a telephone system, a subscriber's line, a station thereon, a two-wire supply circuit connected to said line and having a source of alternating current connected thereto, said line constituting a loop circuit having an inherent capacitance characteristic which causes a charging current to flow in said loop from said source, a repeating coil having its primary winding in-

cluded in said loop so as to be traversed by the charging current, a supervisory relay having its operating winding connected to the secondary winding of said repeating coil so as to be subject to the voltage set up therein by the flow of charging current in the primary thereof, and means for superimposing on said relay a voltage which, for average loop length is substantially equal in magnitude and in phase opposition to the voltage produced by the charging current flowing in the primary winding of said repeating coil.

14. In a telephone supervisory signaling system, a telephone line, a two-wire circuit adapted to be connected to said telephone line, a source of alternating current connected to said two-wire circuit, said telephone line having an inherent capacitance characteristic such as to cause a charging current to flow therein from said source, a supervisory relay having its operating winding inductively connected to said two-wire circuit and therefore subject to the charging current flowing in said line, and means for balancing the effect of the charging current on said supervisory relay comprising transformer means for connecting the operating winding of said supervisory relay directly to said source of alternating current.

15. In a telephone signaling system, a subscriber's station, a loop circuit having an inherent capacity characteristic, extending from said station to a central office, a source of alternating current associated with said loop circuit, said loop circuit being normally subjected to a charging current produced by the inherent capacity characteristic thereof and its association with said source of alternating current, a supervisory relay included in said loop circuit, and means for subjecting said relay to a current of such phase and magnitude with respect to the charging current of said loop as to substantially cancel it whereby the current in said relay when said station is disconnected from said loop is substantially zero.

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