The step-by-step telephone switching system: The connector switch

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ABSTRACT AND INTRODUCTION

The step-by-step telephone switching system (as it is known in the Bell Telephone System; the "Strowger" system elsewhere) was the earliest "mechanized" telephone switching system to receive broad acceptance, and it remained important for many decades. This is one of a series of articles on this system, and it describes the *connector* switch, which is used in the final stage of the switching network. The basic functions of the switch are summarized, and an illustrative schematic drawing is used as the basis for a detailed description of its operation.

1 GENERAL

1.1 The series of articles

This article is one of a series. The "master" article, "The step-by-step telephone switching system: Overview", by the same author, gives background on the historical development of the system, and then describes its overall architecture, scheme of operation, and the technical details of the unique type of switch used in the system. It also gives background on such telephone concepts as battery and ground; tip, ring, and sleeve; and the like. The other articles (including this one) describe in detail (including at the circuit level) the different switches used in the step by step system.

In some cases, information given in the master article is repeated here for continuity.

All the articles are indexed on, and available at, my site, The Pumpkin:

`http://dougkerr.net/pumpkin`

1.2 Types of switches

The step by step switching system in its most widely-used form uses three kinds of switch, all with essentially the same base mechanism but varying substantially in their complement of relays, function, and operation. The three types are the *line finder*, the *selector*, and the *connector*. The line finder serves to provide a connection from a subscriber line requesting service (the user lifts the handset) into the switching network itself, in the person of a selector switch (this one being a so-called *first selector*). The selectors serve to advance the concretion stage by stage through the "interior" of the switching network, each one in response to a successive digit of the dialed number, not including the last two.

The connectors constitute the final stage of the overall switching network. After all but the last two digits are dialed, the connection has been extended to a connector switch, one which can access 100 line, including of course the one whose number has been dictated by the earlier dialed digits.

The last two dialed digits move the connector to the corresponding line. The connector tests the line to determine if it is busy (on an existing connection). If not, a connection is made to the line and the ringing signal applied. When the called station answers, the ringing signal is removed and a transmission path is completed between the calling station and the called station.

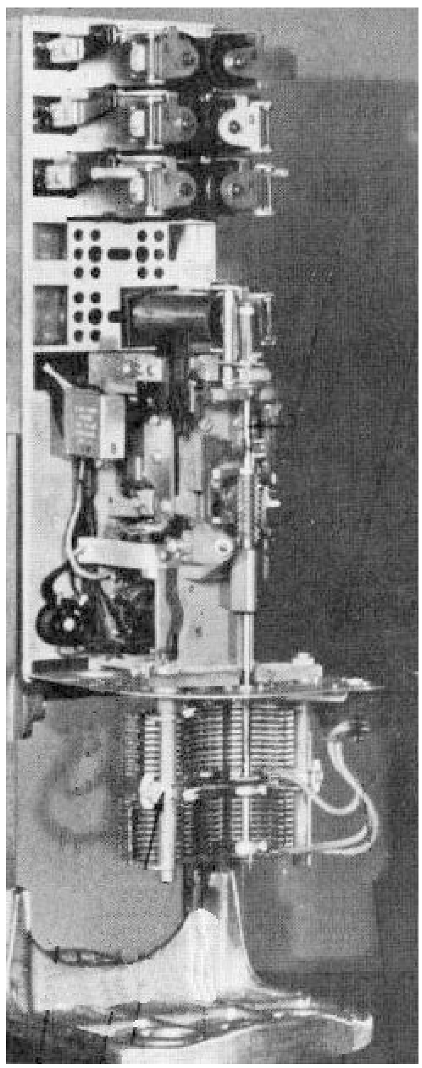

Figure 1. Typical connector switch

2 THE SWITCH ITSELF

Figure **Error! Reference source not found.** shows a typical connector switch, with an unwired bank assembly attached, in a test stand, used to hold the switch while it is being adjusted or tested.

At the bottom we see the banks. Plural? Yes. When I introduced the concept of the Strowger bank and wiper system, I was intentionally vague about the nature of the bank "terminals". It would be easy to assume that each "terminal" of the bank had three contacts (for tip, ring and sleeve) and that the wiper had three contact-making members to connect to them.

But in reality, we can only readily have two contacts at a bank position. So in fact the "bank" of the switch is actually an assembly of two banks, as we see in some detail in figure 2.

On the lower bank, at each position are two contacts, rather thin, lying opposite one another on a thin insulating phenolic sheet. At each position, these contact pairs carry the ring and tip of the circuit. There is a thicker phenolic sheet, not shown in the drawing, between these "sandwiches" at the various levels.

On the upper bank, at each position, a single contact, a bit thicker than the contacts on the lower bank, projects out from between two thick phenolic sheets. At each position, this contact carries the sleeve of the circuit.

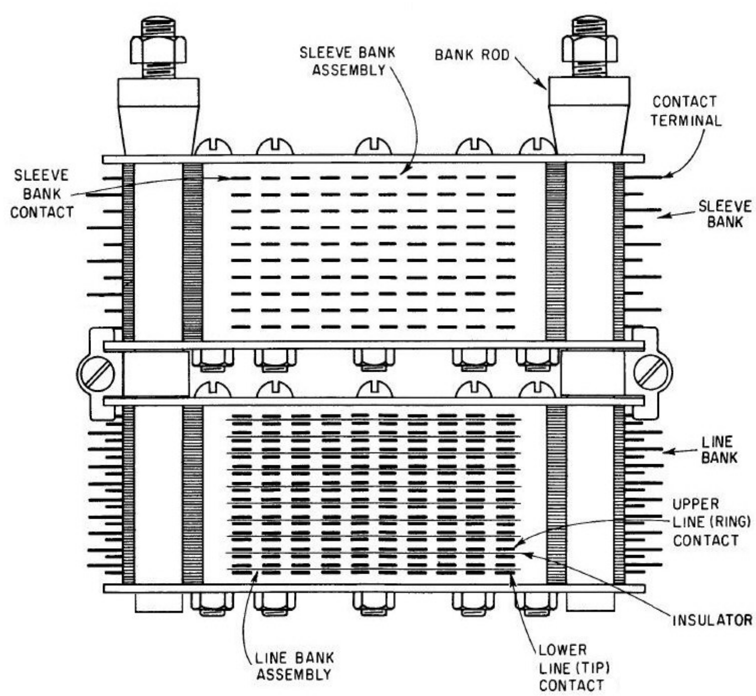

Figure 2. Three-conductor bank assembly

For either bank, the entire stack of phenolic sheets and metal contacts, for all ten levels, is clamped together between steel pates at the top and bottom by long screws extending from top to bottom.

What we have thought of as “the wiper” of the switch is actually two wipers, one running on the lower bank and one on the upper bank. Each wiper has an upper and lower contact “leaf”. On the bottom wiper, the two contact leaves are insulated from one another (since they will touch separate contacts, for the tip and ring leads). On the top wiper, the two leaves are electrically connected together, since they will be touching the top and bottom of a single contact, for the sleeve.

The bank assembly is fastened to the switch, in rather precise alignment, by way of the threaded studs seen at the tips of the bank rods (with the nuts seen there).

In figure 3 we see a “two-contact” wiper.

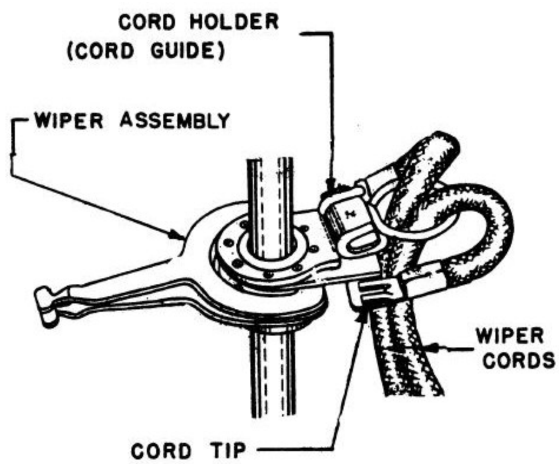

Figure 3. Two-contact wiper

As we see, the wiper (which of course moves around quite a bit) is connected to the switch circuitry with two very flexible cords. Their actual conductors use what is called “tinsel” construction. A very thin ribbon of conducting material is wound around a small fabric core, this whole thing then covered by a durable but flexible woven cover. This style of cord is able to withstand literally millions of cycles of flexure and twisting as the switch goes through its motions.

Toward the top of the switch “chassis” we see five relays. The different kinds of switch (line finder, selector, and connector, whose roles will be described shortly) have different numbers of relays, and their functions vary between the type of switch.

These relays are of a basic design long associated with the step by step system. Although, for example, the switching systems designed by the Bell System and made by Western Electric used, from the outset, new types of relay, more compact and less costly to manufacture, step by step switches made by Western electric (as well as those made by Automatic Electric) continued to use the relay design we see here.

Just above the bank assembly is the switch mechanism. Its heart is three electromagnets (generally just called “magnets”). One steps the switch in the vertical direction, one steps the switch in the rotary direction, and the third releases the pawls that hold the switch in place (after it has stepped up and around) and allows a spring to rotate the shaft back to it home angular position, and allows the shaft to then drop by gravity to its home position. There are several pawls, latches, and the line involved in this operation.

There are also various contact assemblies that do things like detect if the switch is at its home position or not. These play various roles in the logic executed by the relays in controlling the switch movement and otherwise managing the emerging connection.

In use, the switches (not including the banks and wipers) are each covered by the iconic “mailbox-shaped” sheet metal cover.

3 SWITCHING NETWORK ARCHITECTURE AND OPERATION

In these articles, “switching network” means the portion of a switching system through which the connection is extended inside the switching system from the calling line to the called line (as distinguished from the use of the term to mean a number of interconnected switching systems).

We will consider a city in which there are several central offices, and in which a 5-digit numbering plan is used. The first digit identifies the central office in which the line with that number is served.

We will imagine a call to number 5-2368. The digit “5” tells us that the line with that number is served by the “5” central office. And we assume that we are in fact looking at the “5” office, and that the calling line is also served by the “5” office (so this is an *intraoffice* call). The hyphen is of no technical significance, but is just used to help the subscriber in dealing with the number. I will omit it in some places in this discussion.

For context, figure 4 shows the entire “train” through which the call is handled from one end to another. We see a line finder, three selectors (in successive stages), and a connector.

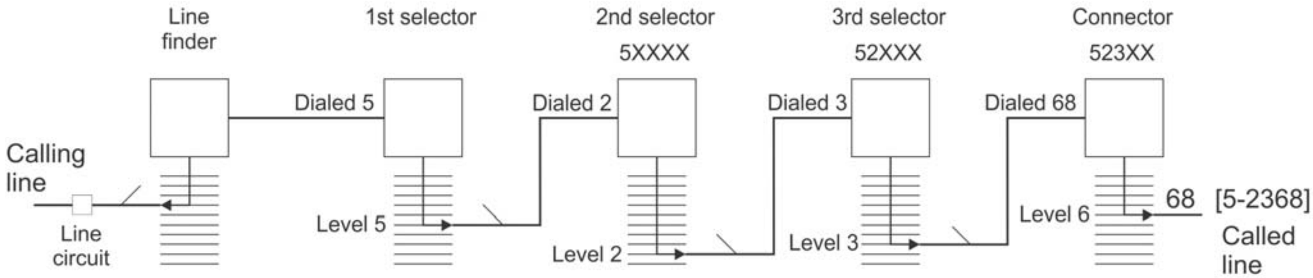

Figure 4. 5-digit switch train

Each consecutive digit dialed controls the operation of a selector in a consecutive stage of the switching network.

Suppose we join the action after the subscriber has lifted the handset, the line has been found by a line finder, the subscriber has gotten dial tone from the associated 1st selector, and has so far dialed “523”. This call has ended up in a connector, in particular a connector we can describe as being in the 523XX group.

That means that it is only ever involved in calls to lines whose telephone numbers start with 523. And thus it is only ever reached by a caller starting his dialing with 523.

Our connector is the source of DC voltage on the calling subscriber’s line (back through all the selectors in the train up to the line finder and through it to the calling line), and the current that results is noticed by a battery feed relay in our connector. This “wakes up” the connector, which, among other things, grounds the sleeve lead going back through the network, holding all the intervening switches (line finder, several selectors) “up”.

The next digit dialed, 6, of course is conveyed by the caller’s dial interrupting the line current 6 times (at a rate of about 10 “pulses per second”). Each pulse (interruption) is perceived by the battery feed relay, and directly activates an electromagnet in the connector, causing the wiper shaft of the switch mechanism to rise by one “vertical step”. Each vertical step causes the contact wipers on the shaft to align with one further level of contacts on the contact bank. So after the entire digit “6” has arrived, the wipers are at level 6. If “0” is dialed, with 10 pulses, the shaft rises to level 10, which is of course called “level 0”.

Note that on this level of the contact bank there are 10 sets of terminals, arranged in an arc, so the wipers on the shaft could, if the shaft were to rotate, contact any one of them. These lead to the lines whose telephone numbers are 5-2361 through 5-2369 and finally 5-2360 (because movement over this arc of terminals will be directly caused by stepping by the pulses of the last digit, and of course as we noted dialed “0” is represented by 10 pulses).

While the caller was dialing “6”, a timer (implemented by a relay with a “slow release” characteristic) observes the time between consecutive pulses. When there had been no pulse for, perhaps, 200 ms, the relay releases, in effect declaring, “I think there are going to be no more pulses for this digit”. So the vertical journey of this switch is complete. Level 6 of the bank is where the connection is going to.

And so, when the next digit (8) begins, each pulse causes the shaft to step in the rotary direction by one step. During the receipt of the pulses of the second digit, another slow release relay observes the between consecutive pulses. When there had been no pulse for, perhaps, 200 ms, this relay releases, in effect declaring, “I think there are going to be no more pulses for **this** digit”

And in fact, at this time, the switch wipers are on the terminal (contact set) in the contact bank leading to the line whose number is 5-2368.

At this point, the busy/idle status of the line is tested. If the line is busy, its sleeve conductor is grounded (a result of another connection to it). If it is not busy, the sleeve conductor goes to battery through the winding of a relay in the lines line circuit.

If the sleeve shows ground, a relay is operated that sends busy tone back over the connection to the calling subscriber.

If the sleeve does not show ground, but shows battery, a relay operates that causes ringing voltage to be applied to the line. This is done through the coil a “ringing trip” relay that does not respond to the AC current flowing in the line through the station ringer, but does operate when the subscriber there answers and DC current flows in the line.

When the “\ringing trip relay operates, it disconnects the called line from the ringing voltage and connects it to a second “battery feed” relay. A pair of capacitors provides for the propagation of voice frequency signals (“audio”) between the two lines during the conversation.

I’ll leave discussion of the further adventures of the connector for the detailed circuit description.

4 The schematic drawing

4.1 Our subject switch

The schematic drawing and associated circuit operation description do not necessarily represent exactly any of the numerous specific connector switch designs found in the wide range of step by step switching systems. All of them, however, follow almost identical principles, and the hypothetical one we will discuss uses representative circuitry.

4.2 Basic schematic drawing conventions

The schematic drawing employs a system of notation introduced in the Bell Telephone System in the early 1960s, called *detached contact* notation. In it, the relay contacts are not shown in a form evocative of actual physical contacts, with all the contacts on a certain relay all adjacent on the drawing, much as they are in real life.

Rather, in this system, simple (easily drawn!) geometric symbols are used for the basic contact elements, what would be called in other contexts a “normally open” or “normally closed contact”.

The contacts on a certain relay are not gathered together on the drawing, but rather are placed so as to allow the most clear portrayal of the circuit paths. The possibly many contacts of a relay, and its activating coil, are related by each being marked with the same symbol (which, by the way, in real equipment would likely be marked on the relay itself).

In this context, the two basic kinds of contact mentioned above are not called by the names I mentioned there. Rather, the contact type that in other contexts would be called “normally open” is called a *make* contact; the type that in other contexts would be called “normally closed” is called a *break* contact.

Figure 5 shows the principles of this convention.

In panel (a) we see a relay, M, under the older *attached contact* convention. This relay has a coil with a single winding and four “spring sets”, each of a different type. Each “spring” is identified by a number (from 1-10).

The dashed line we see between the three spring sets shown above the coil emphasizes that the “moving springs” of all these springs sets move together. Of course, spring 10 on the spring set shown below the coil moves at the same time, but we are expected to know that.

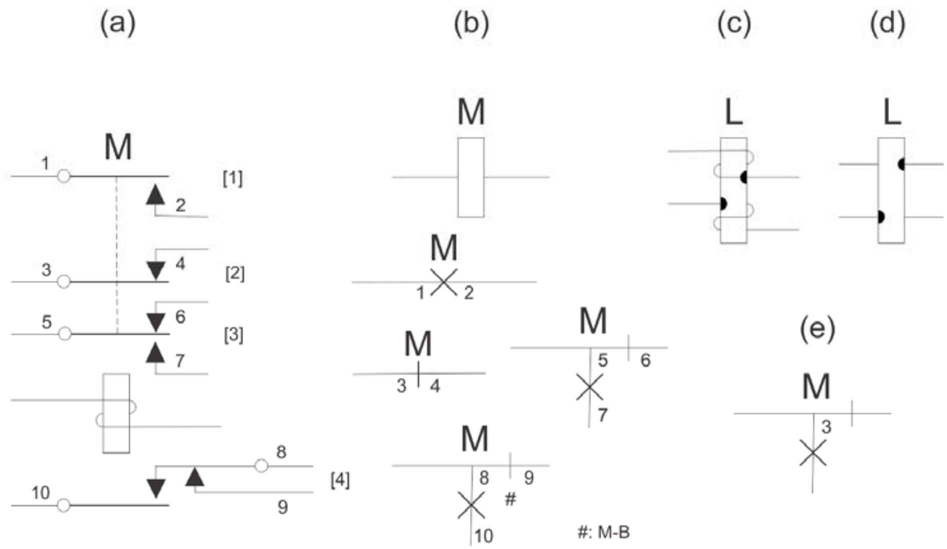

Figure 5. Detached contact schematic symbols—relays

Spring set 1-2 is a *make* contact (what would be called in other electrical work a “normally open” or “form A” contact). Spring set 3-4 is a *break* contact (a “normally closed” or “form B” contact).

Spring set 5-6-7 (what would be called in other contexts a “form C” contact) is called a *transfer* contact, but is also called a *break-make* contact. This latter name makes it clear that the break occurs before the make (so there is never, even momentarily, a path from spring 6 to spring 7.

Spring set 5-6-7 is also called a *transfer* contact, but is also called a *make-break* contact. This latter name makes it clear that the make occurs before the break (so there is never, even momentarily, no path from spring 8 to one of the other springs, 9 or 10). This is often spoken of in other contexts as a “make before break” contact.

In panel (b) we see this same relay portrayed under the detached contact convention. There I have purposely shown the spring sets “scattered” to remind us that they would not ordinarily be shown adjacent to the relay coil but would be placed on the drawing wherever the circuit paths through them would be easiest to follow.

We see that the coil has a simpler symbol, one not graphically evocative of its winding.

As we see for contact 1-2, the symbol for a *make* contact is a simple cross, centered in the line representing the circuit path. For contact 3-4 we see the symbol for a *break* contact, a simple line across the circuit path.

For the basic transfer contact (*break-make*) (5-6-7), we use a combination of those two symbols, usually adjacent, as we see here. (But if needed for clarity of the drawing, the two parts may be separated.)

For the *make-break* contact (8-9-10), the portrayal is the same as for the *break-make* spring set. There is nothing in the graphic representation that distinguishes the *break-make* and *make-break* forms of a transfer contact.

In formal Bell Telephone Laboratories drawings, that distinction was provided in a table that listed each relay and its many properties. But in informal drawings, often some mark was applied to a break-make keyed to a note that told this was a *break-make* contact (the note might even say "make before break"). I do that using the symbol "#".

In some cases, there are two (in rare cases even more) windings on the coil. We must generally be aware of the "polarity" of the windings, so the current through the two windings produce adding, not opposing, magnetic fields.

In panel (c) we see a two-winding relay coil shown under the attached contact convention. In panel (d) we see that same coil under the detached contact convention. In both cases, the little half-moon marks show "corresponding" ends of the two windings. (But those were not always shown under the attached-contact convention.)

Especially in the case of more modern relays whose physical construction is not that suggested by the symbol shown in panel (a), the contacts (rather than individual springs) are identified by number. In panel (a),I have shown these contact designations in brackets. In panel (e), we see the contact whose springs would be numbered 6-7-8, but as a contact would be numbered 3, identified by the contact number.

4.3 Identification

In the schematic drawing in this article, the relays in the selector switch are identified with the designations (the letters A-G and K) most commonly used in actual practice.[1] For reference in the discussion, the various contacts of each relay are identified by

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[1] Bell System step by step systems use this convention, inherited directly from the practice in systems made by Automatic Electric. Other systems, originally designed in the Bell System would typically use mnemonically-based relay designations, perhaps "BF" for the battery feed relay rather than "A".

fairly-arbitrary numbers; these do not necessarily follow the numbering system that would be found on the formal circuit schematic drawings.

I will often use a shorthand: to refer to the make aspect of contact number 2 on a relay (maybe there is only a make aspect) I will refer to contact 2M. Once I get rolling, I might refer to contact 2M on relay B as just “B 2M”.

4.4 Simplifications

A very few simplifications have been adopted in the drawing. For one thing, it omits various R-C networks used to limit the amplitude of the voltage spikes that occur when the circuit to a serious electromagnet is interrupted. Also eliminated (or in some cases simplified) are some circuit paths devoted to the monitoring of switch behavior by external circuitry.

5 CIRCUIT DESCRIPTION

5.1 The circuit schematic drawing

Figure 7 is the circuit schematic drawing for the hypothetical connector switch being discussed.

5.2 Initial conditions

With the switch idle, all relays, electromagnets, and contacts are released. The switch wiper shaft is in the idle (full down) position.

Battery (-48 V DC) is standing on the tip conductor of the incoming circuit and ground on the tip conductor, both through windings of the A relay. The incoming sleeve conductor is open.

5.3 Seizure

When the switch is seized (by the subscriber line being extended through the prior switches in the train), the loop current through the calling station operates the A relay. Its contact 1M operates relay B. Relay B contact 2M grounds the incoming sleeve lead, which holds all the earlier switches “up”.

5.4 The first digit

When the calling dial creates the first pulse of the first digit handled by the connector (the next-to-last digit of the called number), relay A releases momentarily. But because the B relay is slow release, it does not release. The path though A contact 1B, B contact 1M, and the *vertical off normal* (VON) switch contact 2B through the coils of relay C and the vertical magnet, to battery, is completed, Both relay C and the vertical magnet operate. The vertical magnet steps the switch shaft up one level.

This results in the VON switch operating. It reroutes the path to the C relay and rotary magnet coils to now pass through C 1M (workable since C is now operate.

At the end of the pulse, relay A re-operates, breaking the path to relay C and the vertical magnet. The vertical magnet releases, but relay C does not, it being slow release.

Subsequent pulses for this digit repeat this process.

At the end of this dialed digit (after its last pulse), relay A remains operated for some while, and relay C is de-energized for that period. After perhaps 200 ms, relay C releases. Its contact 1, combined with VON being operated, reroutes the pulse path to go to the coil of relay E and, through some other contacts, through the rotary magnet, to battery.

At this point, using our example of the dialed number being 2368, the switch shaft is at level 6 of the bank.

5.5 The second digit

Much as we saw for the first digit, the first pulse of the second digit (the last digit of the called number) results in A being momentarily released. The path though A contact 1B, relay B contact 1M, and the VON contact 2M, then through the coils of relay C, then some other B contacts, and the vertical magnet, to battery, is completed, Both relay E and the rotary magnet operate. The rotary magnet steps the switch around by one position. Each subsequent pulse steps the shaft around one father position.

Relay C, being slow release, returns operated until perhaps 200 ms after the end of the last pulse of this digit.

5.6 Busy test—called line busy

As mentioned earlier, for a line that is busy (as a result of another connection. its sleeve lead is grounded. If the line is not busy, the sleeve shows battery in series with a relay in the line's *line circuit*.

When the shaft has made its final rotational step, the sleeve wiper contacts the sleeve contact on the line's position on the bank.

Let us assume that the line of interest is in fact busy. Because the E relay is operated through the entire train of second digit pulses (and a bit after), the ground on the sleeve (S″) passes through E 1M and K 4B to the coil of relay G, which operates. A locking path for G is provided via K4B, E 2aB, and G3 to the incoming sleeve (S), which has since seizure been grounded by B 2M.

G relay contact 1M connects busy tone (BT) to lead R', from which it passes through capacitor C1 to the ring of the incoming line (R), and thence to the calling subscriber.

5.7 Line idle

If the line is not busy, relay G is not operated when the wipers have landed on the called line terminals. Shortly, relay E releases. Now the sleeve wiper will go though E2B and J2B (relay G not being operated) to winding 1 of relay, and through it to the incoming sleeve (S), which is grounded. Relay K operates. A holding path for K is established through K 5M to the sleeve (grounded).

K makes a "connection" to the called line, through K 1M and K 2M. But this connection is at this point committed to applying ringing voltage to that line.

Additionally, through K 3M, the sleeve wiper is grounded. In the station's line circuit, this operates a relay that removes from the line the *line relay*, which, when the line is idle, detects of the station is taken off-hook in order to place a call. And of course that ground on the sleeve "marks" the line as busy, for the information of other connectors that may later aspire to make a connection to it.

Before I proceed with the story, let me digress and talk about ringing and ringing voltage.

5.8 Ringing and ringing voltage

The basic signal used to operate telephone ringers is an AC signal at perhaps 75-90 V RMS at perhaps 20 Hz, to which is added a DC voltage of perhaps -48 volts.

At the station, the coil of the ringer "motor" (which is a bit like a polarity-sensitive relay) is connected across the tip and ring of the line through a capacitor. The main purpose of the capacitor is to prevent the flow of (DC) current through the ringer coil. This could falsely indicate to the central office that an idle station was "off-hook" and thus wanted to make a call. It would also "steal" some of the line current when the station was on a call, and we want all of it conserved to operate the station transmitter (microphone).

Why the DC component of the ringing signal? When ringing is applied to the line, although there is a DC component to the applied voltage, because of the capacitor in series with the ringer coil, there is no DC component to the current that flows.

But when the subscriber answers, the telephone set circuit proper is placed across the line. It of course has DC continuity, and so now there is a DC component to the current that flows (from the DC component of the ringing voltage).

At the central office, when a line is rung, the ringing voltage is applied through a winding of a special kind of relay. It is very insensitive to the AC component of the current through it, but is sensitive to any DC component.

Thus, with ringing voltage applied to the line, this relay does not operate until the station answers. Typically, the operation of this relay causes ringing voltage to be removed and the final "connection" to be made to the line (and we will see just that here). This action is called "tripping the ringing", and from that, the special relay is called a *ring tripping* (or just *ring trip*) relay.

Of course, normally, the ringing signal is applied in repeated "bursts", typically 2 seconds long separated by 4 seconds of no ringing voltage. But during these "silent" intervals, there is still voltage applied to the line, this time just -48 V DC.

The result is that if the station is answered during the quiet interval, the ring trip relay still operates (from the DC current from the "silent interval" DC voltage), and ringing is tripped promptly in that case.

Going back to manual switching days, the matter of mechanically generating the repetitive "cadence" of ringing (rather than having the operator pull the ringing key intermittently), and to have the ringing automatically ended by a trip relay, was overall called *machine ringing*. And from that usage, the ringing voltage, with the DC component, and interrupted to form ringing and silent intervals, is spoken of as machine ringing (MR).

5.9 Ringing the called line

After the K relay has operated, the line having been found to be idle, a connection has been made to the line, but at this point only specifically for ringing the line.

The ringing voltage (MR) is applied to the ring wiper (and thus to the ring of the called line) through relay contact K 6M and winding 1 of relay F (the ring trip relay), through F relay contact 1B, and through contact K 1M. The "ground side" of the ringing voltage source (RG[2]) is connected to the tip of the line through F 2B, K2, and the tip wiper. Thus the tip is grounded during ringing.

When the called station is answered, as I discussed above, relay F (the ring trip relay) operates. F relay transfer contacts 1 and 2 transfer the wipers from the ringing voltage source to what will be their permanent home in the completed connection. There, battery is applied to the tip, and ground on the ring, through the windings of relay D[3]. This of course provides "talking battery" to the called station.

The flow of current through called station operates the D relay. One result is that, via D relay contacts 1 and 2, the polarity of the battery fed to the calling station is reversed. The purpose of this is beyond the scope of this article.

5.10 Audible ringing

A bit of the ringing voltage (on the called station ring lead, R″) is fed to the R′ lead through capacitor C3, and travels to the ring of the calling line through capacitor C1. This allows the calling subscriber to hear that the called line is being rung. This is called *audible ringing* (but sometimes *ringing induction*).

But wait—the frequency of the ringing voltage proper is typically 20 Hz. At that frequency, the response of the telephone set is almost nil, and this is at the bottom limit of human hearing response as well.

In the earlier days of telephone switching, AC ringing voltage was often generated in a number of ways that hardly generated a sine wave (normally a desirable property of an alternator). Thus the ringing voltage itself was high in harmonics, and these were readily heard.

When motor-drive alternators were used to generate the ringing voltage, they would typically develop a fairly-sinusoidal waveform, and thus audible ringing performance was problematical. So ways were found to change the design of these alternators to intentional generate a less-perfectly-sinusoidal waveform.

5.11 Release—calling party hangs up first.

If, at the end of the conversation, the calling party hangs up first (as suggested in the "good old days" by etiquette authorities), opening the

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[2] RG: ringing generator ground.

[3] Yes, this is opposite the "polarity" normally used; the reasons are esoteric and beyond the scope of this article.

DC path at the station, and ceasing the flow of DC in the line, the A relay releases, which through A 1M de-energizes the B relay. In a short while, the B relay releases.

Contact B 2M opens and removes the ground from the sleeve of incoming line. This causes all the previous switches to release, destroying the “calling line” portion of the connection.

In addition, the holding paths for relays K and F, which were completed to that sleeve, are now disabled. Those relays release, “turning loose” of the called line, ring, tip, and sleeve.

Then, the path from ground through A 1B, B1 B, K 5B, and VON 1M and through the release magnet to battery operates the release magnet. This allows the switch shaft to rotate back to its “zero” rotational position, and then to drop to the “fully home” position.

That releases the VON contact set. Its contact 1M opens, de-energizing the release magnet (whose work is done).

5.12 But . . .

If in fact when the calling station hangs up, the called station has not yet done so, what happens to the called station line when the connector “turns loose” of it? When ground is removed from the sleeve lead, the cutoff relay in the called line’s line circuit is released. The line relay is put back in place.

Since the called station is still off-hook, the line relay is operated, just as if the subscriber had picked up the handset to place a call. A line finder is started and, when it “finds” the line, connects it to a first selector (each line finder is connected permanently to one). The called line receives dial tone.

Unless indeed the next thing the called subscriber planned to do was to make another call, this is of no use, and he hangs up, abandoning this fruitless partial connection.

So, doesn’t this result in useless wear on the switches and some consumption of their traffic capacity? Yes. So why does it work that way? The reasons aren’t fully clear, and what I know about this is beyond the scope of this article.

Nevertheless, in Appendix A I describe a cinematic convention (I hate it) that arose from this situation and another from a situation I will describe shortly.

5.13 Called party hangs up first

Suppose that (contrary to the etiquette experts' advice), at the end of the conversation, the called party hangs up first, and for some reason, the calling party doesn't promptly follow suit.

When the calling party hangs up, the D relay releases (immediately). Via its transfer contacts 1 and 2, the polarity of the battery fed to the calling line is restored to "normal".

That's all? Yes, that's all. The connection is not released? No.

In Appendix A, I describe a second part of the cinematic convention I mentioned before that results from this situation.

And in Appendix B I relate a common prank that used to be played in cities served by the step by step system, based on this situation.

5.14 Back to the busy test

There is an interesting wrinkle to the matter of testing the called line to see it is busy. I did not mention it earlier so as not to derail the point of the story. But it is interesting.

Suppose that the first digit has been dialed and, after a brief pause, the second (and final) digit is being dialed.

During this process, relay E is operated (it operates soon during the first dial pulse) and remain operated until a while after the dialing of this digit is done.

So the entire time the second digit is being dialed, the sleeve wiper goes, through contacts E 2M and K 4B, through the coil of relay G to battery.

Thus, as the wipers, heading toward the desired line terminals, pass over any line that is busy at the time, relay G will momentarily operate and, depending on where we are at the time in the "cadence" of the busy tone, might cause busy tone to be briefly retired toward the calling station.

Won't that sound—well—odd to the calling subscriber? Well, this happens while a digit is being dialed. During that time, the receiver muting contact on the station dial mutes the receiver (to prevent the subscriber from hearing a loud series of clicks from the interruption of the line current to send the pulses forming the digits. So the calling subscriber won't hear these anomalous bursts of busy tone at all.

This odd (but evidently harmless) phenomenon could be averted by waiting until the release of the E relay (when the second digit is seen to be completed) before testing the sleeve for ground with the G relay. But then we would need to wait an additional interval (presumably timed by a new slow release relay) before concluding the that G relay had not operated and giving the K relay a chance to operate.

This added delay, albeit short, will delay the completion of every successful call, extending by that amount to the "holding time" of the switches in the connection. And, considered over the many millions of calls completed by step by step equipment across the entire North American telephone network in whatever period of time, it would contribute in a measurable way to the overall number of selectors and connectors that needed to be provided to attain a certain call completion probability, and so on and so forth.

6 HUNTING CONNECTORS

6.1 The rotary hunting connector

Suppose a small law office has three telephone lines, but of course wants callers to dial a dingle directory number, which will result in the call being completed to one of the lines that is idle.

This is the job of the *rotary hunting connector*. Its bank has four terminal contacts, T, R, S, and H. For our hypothetical law office, the three lines have consecutive numbers, with all digits the same but the last, as for example (and from here on I will only speak of the last four digits) 4572, 4573, and 4574.

The number listed in the directory, sometimes called the *guide number*, is 4572. On the connector bank, on the terminals for all but the last line, the H contact is connected to the S contact; for the last line, the H contact is open.

Suppose the first line (4572) is busy, and a caller dials 4572. When the connector lands on terminal 72, and the E relay releases to indicated that this digit is completed, an added relay H[4], tests to see if the H terminal is grounded. It is, since the line being busy results in the S terminal being grounded and the H contact is connected to it.

The operation of this relay causes the connector mechanism to make an additional rotary step, landing on terminal 73. Again, the added relay tests for a ground on the H terminal. This line is idle, so the S terminal is at battery (through the cutoff relay) and so the H terminal

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[4] The only relay in a step by step switch that has a mnemonic designation (hunt?), but that is mostly good luck, as a relay in its physical position in the selector would ha called "H" anyway.

is likewise at battery. The result is that the K relay operates, in the usual way, and ringing begins on line 4573.

Suppose that all three lines were busy. The process we described just above causes the switch to eventually step to terminal 74. Here, S is grounded, but not H. The result is that the switch does not step further, but relay G operates and the caller is sent busy tone.

This scheme can accommodate up to 10 lines, in which case of course it is mandatory that the number of the first line (and thus the guide number) end with "1".

6.2 The level hunting connector

But suppose that we have a department store with 35 lines (which actually go to a PBX at the store). But again, we want callers to be able to dial a guide number and end up connected to an idle one of the 30 lines. Providing for this is the job of the level hunting connector.

Imagine that the guide number is 8611. The digits "11" go into the connector as usual, and as usual, the switch wipers end up on terminal 11. The process proceeds as described just above for the rotary hunting connector, and if an idle line is found on this level, the call is completed to it.

But here, the H contact is connected to the S contact at terminal 10 (since this is not in fact the last line of the group). So if that line is busy, the switch steps to rotary position 11 (where there is of course no terminal). A "fin" on the switch shaft operates a set of contacts, called the "11th step rotary contacts" (11SR). This sets off a scenario in which first the switch is released, and then, autonomously steps in the vertical direction to level 2.

But:

a. how does it know that at this point it should step to level 2, and

b. how does it know when it gets there?

With regard to (a), there is in the connector a small single-motion, resettable stepping switch (called the *register* switch). During the first "round" of this adventure, that switch was stepped once, and thus stood at its position "1". That meant that when the next round begins, the main switch needs to step to level 2.

With regard to (b), this type of connector has little vertical strip of 10 terminals, called a *commutator*, against which a special wiper runs as the switch autonomously steps vertically. We see this arrangement in figure 6.

When the *register* switch stands at its position 1, it puts ground on terminal 2 of the commutator. As the main switch autonomously steps in the vertical direction, a relay connected to the commutator wiper looks for that ground on a commutator contact. When it finds it, the vertical stepping is discontinued, and the rotary magnet is pulsed once, to move the wipers to (at this point) terminal 21. Then the register is stepped once (to its position 2)

The process continues on level 2 as described earlier when the wipers first landed on terminal 11.

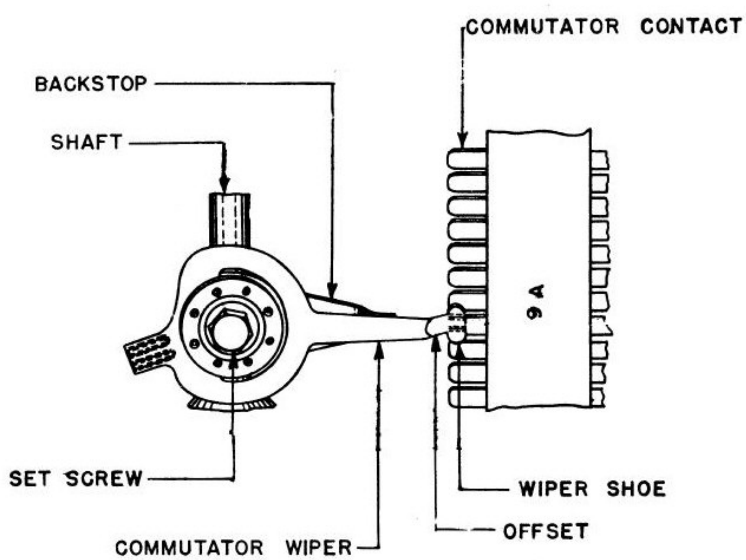

Figure 6. Vertical commutator and its wiper

If no idle line is found on level 2, the 11SR contact again operates, the switch releases and then begins stepping vertically, this time looking for a ground on commutator terminal 3. And so forth.

If all 35 lines (with numbers 8611 through 8635) are busy, after the wipers land on terminal 35, the S lead there will be grounded but not the H terminal. So the switch does not advance by one more rotary step, but rather stays where it is and returns busy tone to the calling line.

By varying from the obvious relationship between the positions of the register switch and the commutator terminal that is grounded (perhaps using a different pattern for each shelf of connectors in the 586XX group) we can reduce the average amount of vertical stepping by selectors as the overall busy-ness of the lines in the group increases.

6.3 Implications on telephone numbers

If a large subscriber has perhaps 65 lines, an entire XXnn number block might be allocated to it (so that there is a group of connectors that only serves that subscriber). It makes sense in such a case to have the guide number be XX11. This would allow the number of lines to be expanded toward 100 without changing the guide number (which of course would be unthinkable to the subscriber).

The result is that, in cities served by step by step systems, large businesses almost invariably had a guide number of the form XX11.

On the other hand, in the Bell Telephone System, in the larger cities, the *panel dial* system was the system first used to mechanize telephone switching. By virtue of the architecture of the switching network in that system, it was best for subscribers with a large number of lines to have a guide number of the form XX00 (stating only the last four digits).

6.4 And for me

I'll close this part of the article with a personal anecdote, In 1973, I was preparing to move from northern New Jersey to Dallas, Texas. I had called the Southwestern Bell business office in Dallas to arrange for my service there. And I wanted to negotiate a "nice" telephone number.

I knew that Dallas had for many years been served by step by step systems, although in recent years they had been superseded by more modern systems, more suited for the large city that Dallas had become.

And, for the reason I described just above, the large department stores and such in Dallas itself (all having been in existence for many decades) all had guide numbers of the form) XX11.[5] And the corollary was that XX00 numbers were not unusually in demand.

Of course, in a larger city never really served by step by step equipment (think Cleveland), the XX00 numbers not already assigned were in effect "reserved" for service to new large businesses. These businesses would like an XX00 number, which was recognized by the public in those cities as the mark of a large business, and the telephone company was eager to accommodate that.

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[5] Still today, the iconic Nieman Marcus department store in downtown Dallas has the number 214-741-6911, and its long time branch at the NorthPark Center shopping center has the number 214-363-8311.

But to the long-time citizens of Dallas, an XX11 telephone number was the mark of a large business. So even though, in the actual modern systems, groups of lines could be arranged to have any sort of guide number, new large businesses generally did not seek to have an XX00 telephone number, but more likely an XX11 number. The bottom line was that there were probably in Dallas many XX00 numbers not assigned, nor reserved. So I asked for one. And got it.

Later, when I opened my own (one man) consulting engineering practice, I repurposed that line to it and got a new line, with a "random" telephone number, for personal use. And colleagues and clients would ask, "Wow! How did you get that telephone number?"

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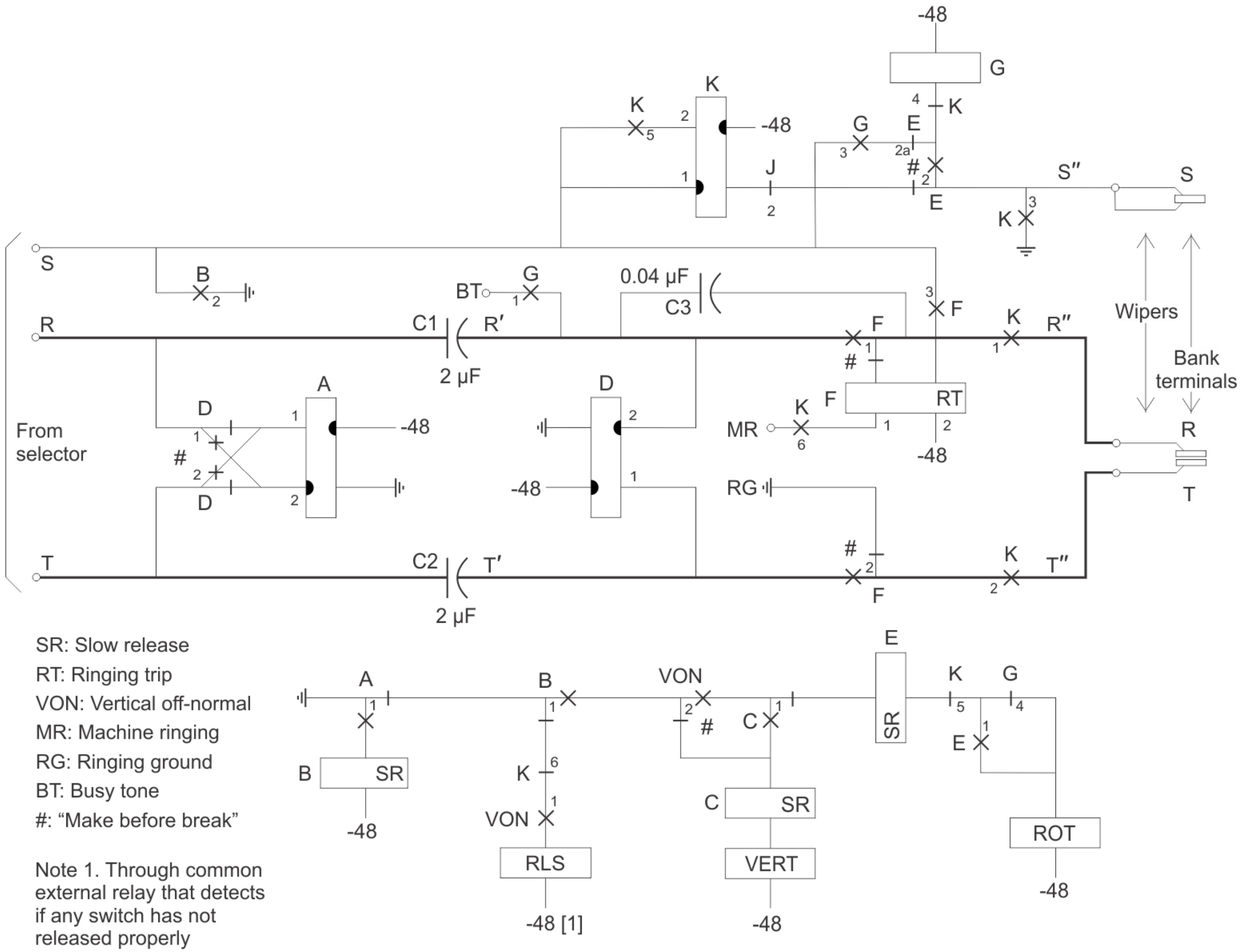

Figure 7. Illustrative connector circuit

Appendix A
A cinematic device

A.1 Hollywood

In most of the larger metropolitan areas of the United states, local telephone service was given by the appropriate Bell Operating Company, and this usually extended through the first one or even two “rings” of suburbs. But often the further suburbs were served by a non-Bell telephone company.

In part because of the way that the Greater Los Angeles area itself evolved, Los Angeles proper was served by the Bell company, but many of the other communities of the area were served by non-Bell companies. most of which used step by step equipment. In fact, in the earlier days, even Los Angeles proper was served by step by step equipment

As a result, almost all the people involved with the writing and production of motion pictures lived in areas served by step-by step systems. And so their personal experiences with telephone systems were usually in that context.

A.2 “More sophisticated” switching systems

In “more sophisticated” switching systems than the step by step system (*e.g.*, the panel dial system, No. 1 and No. 5 crossbar systems, and so forth), when the calling subscriber hangs up, the overall connection is released, but (one way or another) the called line is kept on a “vestige” of the connection until the called station hangs up. This vestigial connection keeps the cutoff relay in the line’s line circuit operated (just as when that line was on the “real” connection). Thus the line relay in the line circuit is disconnected, and the calling line being off-hook is not treated as a request for service for a new call.

A.3 Step by step

In the step by step system, as we saw in the detailed circuit description, when the calling station hangs up, the entire connection is released, and the called line is just “turned loose”. With its sleeve conductor no longer grounded, the cutoff relay in the line circuit is released and the line relay put back in place (just as when the line is idle). But the line is still off-hook. Thus the line relay is operated, which the system takes as a request for service.

As a result, a line finder is started. When it finds the line, the line is extended to the 1st selector with which that line finder is permanently paired. And the line receives dial tone from that 1st selector.

Of course, assuming that the subscriber there isn’t really interested in placing a new call, he hangs up, and the partial connection is released.

The point here is that subscribers served by a step by step system were used to hearing dial tone when they had been called by someone and that subscriber hung up first.

A.4 So, in the movies

Now, suppose we were making a film about events in New York City (which had always, since the onset of "dial" service, been served by the "more sophisticated" switching systems I referred to above), and we had a scene in which one person had been called by another, and the other person hung up first. To "be accurate" we would not have the called person receive dial tone until he hung up.

But at first the people planning the movie thought that was how telephone systems worked, so. "to be accurate", when the caller hung up, the called subscriber got dial tone.

Now I imagine it was not too long in which these people learned that this was not the way telephone systems worked in New York, or Chicago, or Boston, of Cleveland. But by that time, they had learned that this was a wonderful cinematic "device". Getting dial tone was a clear indication that the caller had hung up. And so when that had some dramatic significance ("Joanie just hung up on me"), the dial tone was a wonderful "sign".

And so to this day, even for films set in any city you can think of, when the caller hangs up first, and this is of dramatic significance, the called party gets dial tone.

A.5 But it gets worse

Now, having hit on a good thing, the movie makers extended this "cinematic device" to another situation. Suppose our character had called Buggsy (perhaps to plead for more time to pay off a gambling debt), and Buggsy has said "no", and hung up. Again, "Buggsy just hung up on me."

Of course, when Buggsy (at the called end) hung up, nothing would have (at least immediately) happened, even in the step by step offices the movie makers were used to. Still, the convention was adopted that, in the scenario I just described, when Buggsy hung up (at the called end, remember), our poor hero (the calling party) got dial tone, so the audience was very aware that "Buggsy had hung up".

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