The step-by-step telephone switching system: The selector 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 *selector* switch, which is used in all the "interior" stages 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 and their roles

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.

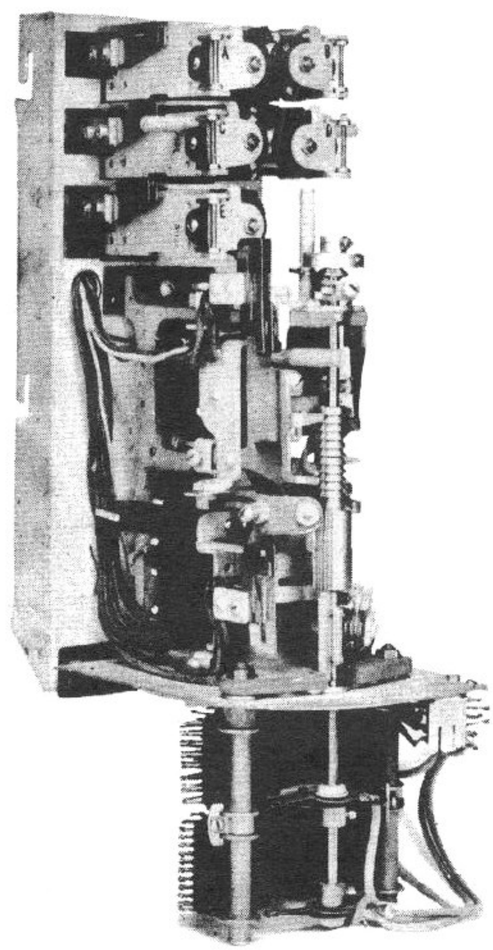

Figure 1. Typical selector switch

2 THE SWITCH ITSELF

Figure 1 shows a typical selector switch, with an unwired bank assembly attached.

Like all the switches we see in this series, this is a two-motion switch. It can make contact with any of 100 terminals arrayed in a curved contact bank in 10 "levels" of 10 terminals each. It reaches a certain terminal by first moving its shaft (which carries the contact making "wiper") up in steps to the appropriate level, and then rotating the shaft in steps to the appropriate terminal on that level.

At the bottom we see the bank, or to be more accurate, banks. Plural? Yes. Three leads (conductors) have to be carried through the switching network, the *ring* and *tip* (which carry the line itself) and the *sleeve*[1], which is used for various control purposes. 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.

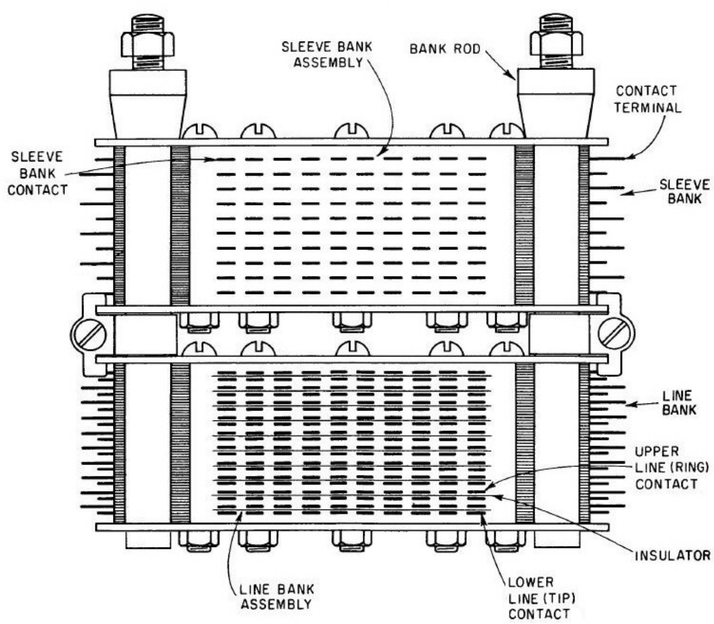

Figure 2. Three-conductor bank assembly

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[1] These names all come from the designations of the three contact members of the plugs used in manual telephone switching systems.

On the lower bank, at each terminal 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 leads. 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 lead.

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.

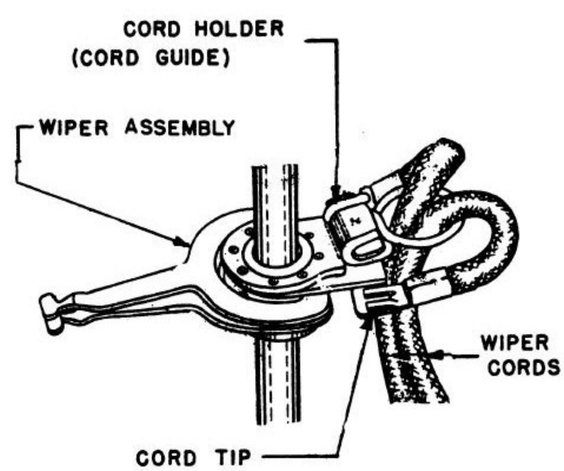

Figure 3. Two-contact wiper

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 “dogs” (retaining pawls) that hold the switch in place after it has stepped up and around, allowing a spring to rotate the shaft back to its home angular position, and then allowing the shaft to drop by gravity to its home position.

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).

For our example, 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.

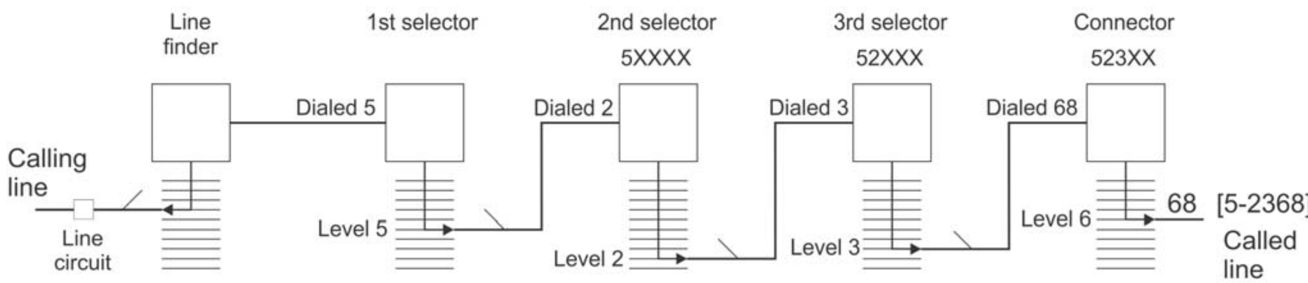

Figure 4. 5-digit switch train

Imagine that now 200 lines are connected through their line circuits to the 100 ("two lines each") terminals of several line finders (all in parallel). The little diagonal line (called a multiple symbol" reminds us of this, even though we only see one line finder.

Each line has associated with it a line circuit, comprising two relays. Battery is fed to the ring of the line through the winding of one, the *line relay*; ground is fed directly to the tip.

When the subscriber lifts the handset to place a call ("requests service", we say), current flows in the line. and that operates the line relay. This causes the next one of the group of line finders that is not already busy on a connection to "start" and, by first stepping vertically and then horizontally, connect to the line. Each line finder is permanently (more or less) connected to a 1st selector.

Once the line finder connects to the line, the second relay in the line circuit (the *cutoff relay*) is operated and it frees the line from the battery and ground applied there. But now the 1st selector feeds battery and ground (through two windings of its battery feed relay) to the line. The presence now of the calling line operates that relay, "awakening" the 1st selector. It now has a "client".

The first digit dialed, 5, is conveyed by the caller's dial interrupting the line current 5 times (at a rate of about 10 "pulses per second"). Each pulse (interruption) is noted by the battery feed relay, and directly activates an electromagnet, 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 layer of contacts on the contact bank (these positions are actually called “levels”). So after the entire digit “5” has arrived, the wipers are at level 5. (If the digit dialed has been “0”, which is conveyed by 10 pulses, the shaft would have gone to the 10th level, which however is spoken of as “level 0”.

Recall that on level 5 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.

Of course, the object of this operation is to extend the connection to a 2nd selector in the group “5XXXX”, moving the connection forward one more stage in its quest to reach the line with number 52368.

But of course there might well be more than one subscriber at this moment interested in reaching a line whose number starts with 5. So we must have more than one selector in the “5XXXX” group (which of course is why I speak of a *group*). To keep it tidy, suppose we have 10 “5XXXX” 2nd selectors (this having been ascertained to be “sufficient” on a statistical basis).[2]

So our selector needs to extend the connection to one of those 10. But which one, and how? As to which one, the answer is, for openers, “one that is not already busy as part of an existing connection”. As to how, links to those 10 “5XXXX” 3rd selectors are connected to the 10 sets of terminals on level 5 of our 1st selector’s contact bank.

While the caller is dialing “5”, a timer (implemented by a relay with a slow release characteristic) observes the time between consecutive pulses. When there has 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. Someplace on level 5 of the bank is where the connection is going to.

At this point, the switch begins, autonomously, to intermittently activate a second electromagnet. Each time this one operates, it steps the wiper shaft in rotation, first to terminal position 1 and then to subsequent positions.

After each step, the switch (with another relay) makes a test on the sleeve contact at the terminal position to determine whether the 2nd

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[2] Typically more than that would be required, but the way this is done is beyond the scope of this discussion.

selector connected to that terminal is already busy (if so, the sleeve lead will be grounded). If so, the switch takes another rotary step and then examines the busy status of **that** 2nd selector.

Suppose at position 4, it is found that this 2nd selector is not busy. A relay in our 1st selector operates which:

- Prevents any further stepping
- Lifts the subscriber's line from the battery feed relay in this selector and transfers it to the wipers, so that it will indeed extend the connection to 5XXXX 2nd selector "number 4".

That 2nd selector has been placing talking battery on its tip and ring through its battery feed relay, so as to welcome any oncoming connection. The flow of current through that battery feed relay awakens the 2nd selector, so it can play essentially this same role with respect to the next digit dialed, which we assume will be "2".

And this process proceeds to a 3rd selector in group 52XXX, perhaps number 4 in that group.

Now let's move ahead to that 3rd selector, which will be the next player in this connection. The result of its work (initiated by the receipt of the 3rd dialed digit, "3") will not be to advance the connection to a "4th selector" (there are no such). Rather, it will advance the connection to a *connector* switch (in the group "523XX"). As mentioned earlier, the connector will, by receipt of the last two dialed digits ("68"), connect to the called line itself at number 5-2368. (When I speak of a specific telephone number, I write it with the customary hyphen after the first digit.)

But, just as for selectors, there of course much be more than one "523XX" connector. And so, the 3rd selector, having been driven to level 3 by that dialed digit, hunts over (perhaps) 10 connectors in the proper group. In fact, a 3rd selector "doesn't even know" that it will be hunting over connectors rather than selectors.

4 THE CIRCUIT SCHEMATIC DRAWING

4.1 Our subject switch

The circuit schematic drawing and associated circuit operation description do not necessarily represent exactly any of the numerous specific selector 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 and operating procedures.

4.2 Basic schematic drawing conventions

The schematic drawing employs a system of notation introduced in the Bell Telephone System in the late 1950s, 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 also 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.

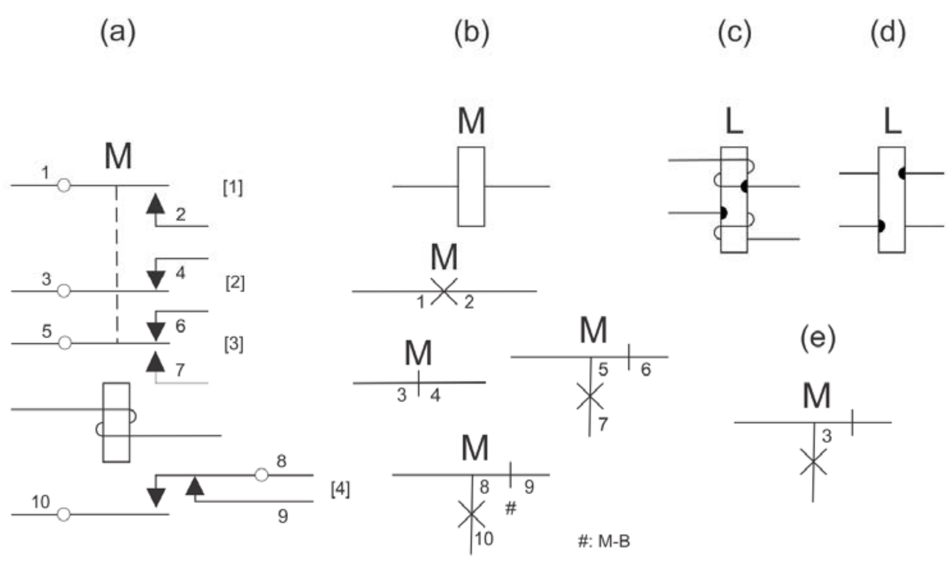

Figure 5. Detached contact schematic symbols—relays

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 contact “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 spring 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.

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 electrical work a “form C” contact) is called a *transfer* contact; It implies a *break-before-make* operation (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. It however implies a *make-before-break* operation. There is never, even momentarily, a path from spring 8 to one of the other springs, 9 or 10. This is often in fact spoken of in other electrical work as a “make before break”, or “form D”, contact. It is sometimes called a *continuity transfer* 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. (In larger drawings, they may well appear on separate sheets.)

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 circuit paths, the two parts may be separated.)

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

In formal Bell Telephone Laboratories drawings, that distinction was provided in a separate “apparatus figure”. But in informal drawings, often some mark was applied, keyed to a note that told this was a make-before-break" contact). 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 relative "polarity" of the windings, so the current through the two windings produces adding, not opposing, magnetic fields (or in some cases, produces opposing 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 connector switch are identified with the designations (the letters A-E) most commonly used in actual practice.[3] For reference in the discussion, the various contacts (not springs) of each relay are identified by fairly-arbitrary numbers; these do not necessarily follow the numbering system that would be found on the formal circuit schematic drawings (which would identify springs).

I will often use a shorthand: to refer to the make aspect of contact number 2 on a relay I will refer to contact 2M, and to refer to a make contact I may refer to contact 3M. Once I get rolling, I might refer to contact 2M on relay K as just "K2M". For a break contact, a typical reference would be "J2B".

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[3] Bell System step by step systems use this convention, inherited directly from the practice in systems made by Automatic Electric. It is based entirely on the physical locations of the relays in the switch. 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".

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 (at the end of the article) is the circuit schematic drawing for the hypothetical selector 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 conductors, both through windings of the A relay (collectively spoken of as “talking battery”). The incoming sleeve conductor is open.

If this is a first selector, dial tone (DT) is supplied (continuously) into the bottom end of the tip winding of the A relay.

5.3 Seizure

When the switch is seized (either by the subscriber line being extended from an earlier selector or, if this is a 1st selector, by the calling line directly, through the attached line finder), the loop current through the calling station operates the A relay. Its contact M1 operates relay B. Relay B contact 1M grounds the sleeve lead, which holds all the earlier switches in their current situations.

If this is a first selector, the calling subscriber will hear dial tone at this point (it coming through the tip-side winding of the A relay).

5.4 Pulsing

When the calling dial creates the first pulse of this digit, a pulse, relay A releases momentarily. But because the B relay is slow release, it does not release. The path though D relay contact M4, A contact B1, and B contact M2, 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 *vertical off normal* (VON) switch operating. It completes a path from the sleeve conductor (already grounded by contact B) through C 1M and VON 2M through relay E to battery. Relay E operates (but this has no effect at this time). Contact E 2M completes a path from the sleeve (grounded) through rotary interrupter (RI) contact 1B and VON contact 2M, which will keep relay E operated after a later event.

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 the digit repeat this process.

At the end of this dialed digit (after its last pulse), relay A remains operated for some while, relay C is de-energized. After perhaps 200 ms, relay C releases. This commences the “rotary hunting” process (the digit that controls this selector having been completed).

5.5 Commencement of rotary hunting

When relay C releases, its contact 1M, through which the E relay had been operated, opens, but the holding path (through E 1M) keeps E operated at this point.

Also, when C releases, ground is extended from the sleeve conductor through C 1B and E 1M and the rotary magnet to battery, operating the rotary magnet. This steps the shaft in the rotary direction to the first contact position.

The rotary magnet armature operates the rotary interrupter (RI) contact. Its contact 1B opens the path to the E relay, which releases. This opens the path to the rotary magnet, which releases. This releases RI, and its contact 1B closes.

Suppose that at the first contact position on the pertinent level the connected selector in the next stage is busy. In that case, the sleeve conductor in the link will be grounded. In that case, ground will pass from the sleeve terminal and the sleeve wiper, through D relay contact 3B, RI contact 1B, and VON contact 3M to the E relay, which operates. Contact E 1M completes the path to the rotary magnet, which operates, stepping the shaft to the next position.

If that position also shows that the associated switch in the next stage is busy, this process repeats, and the shaft is stepped one more position. And so forth.

5.6 A not-busy next stage switch

Now suppose that at after one of these rotary steps, the wipers are on the terminals of a next-stage switch that is not busy. In that case, the sleeve terminal is not grounded but rather is open.

As a result, when the rotary magnet is released, and RI releases, there is a path from the incoming sleeve (grounded) through the coil of relay D, contact 11RS 1B (more about this later), RI 1B. VON 2M, and the coil of relay E to battery.

Relay E has a much lower resistance than relay D, and so expects a much higher current to operate (which it will in fact get if it is connected directly across battery and ground, as we saw happen earlier). But in this case, the lower current that occurs does not operate relay E, but it does operate relay D. This will consummate the work of this selector.

5.7 Cut through

When relay D operates, it:

- Lifts the incoming ring and tip conductors from the A relay (which has been providing “talking battery” to the calling station) and instead puts them on the ring and tip wipers, so they will travel to the next switch. That switch will now (though its A relay) provide the talking battery to the calling station. It will also (by virtue of its B relay) ground the “rearward” sleeve conductor to the sleeve terminal of the bank contacts. Relay A will release. If this is a first selector, the calling subscriber will no longer hear dial tone at this point.

- Through its contact 3M, connects the rearward sleeve to the incoming sleeve lead.

- Via its contact 4B, opens the path through which the A relay controls the stepping of the vertical magnet, so the release of the A relay does not cause such a step.

The release of the A relay causes, in perhaps 200 ms or so, the release of the B relay. This removes the ground (at this selector) on the sleeve (via B 1M). But ground coming rearward over the sleeve lead from the next switch, through D 3M, keeps the incoming sleeve grounded. Now, the next switch has the job of holding the entire connection (up to here) “up”.

The path from the sleeve (grounded) through the coil of the D relay, 11RS 1B, RI 1B, and VON 2M through the coil of the E relay to battery keeps the D relay operated (and, for the reason discussed earlier, the E relay does not operate).

So this selector now is just a “passive conduit” in the connection, passing ring, tip, and sleeve conductors from the previous 2nd selector to the subsequent 4th selector.

But, via its D relay, it watches the state of the sleeve conductor, So long as that remains grounded, the D relay remains operated, and the selector is happy in its role.

5.8 Release

As we saw above, the matter of managing the connection has moved forward as this selector finishes its work, and will eventually propagate to the connector switch (the intervening 4th selector also becoming a passive conduit for the ring, tip, and sleeve conductors. It is in fact the A relay in the connector that furnishes talking battery to the calling station during the actual conversation.

When the calling station hangs up, the A relay in the connector releases, followed (in perhaps 200 ms) by the B relay there. This removes the ground from the “rearward” sleeve lead (it is now “open” at the end of the connection).

At our selector, it is ground on the sleeve is one end of the path that keeps the D relay operated, so the D relay now releases. The path through D 4B, A 1B (A is non-operated), and B 2B (B is non-operated) and through VON 1M 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 clearly is done). VON 2M opens, getting rid of any paths from the incoming sleeve lead.

With D released, talking battery (though the windings of A) is again placed on the incoming ring and tip, and this selector is now ready to be seized by a new call.

5.9 Unequipped switch positions in the next stage

Suppose there are not 10 switches in the next stage group but perhaps only 8. In that case, the sleeve leads for those missing switches are grounded, so that in rotary hunting this selector will pass them by. How does that happen?

If one of the next switches is missing either because that is the plan or because it has been removed, or not yet installed, the contacts by which the switch makes connection with its "shelf" are arranged to ground the rearward sleeve lead when no switch is "plugged in", thus making that "switch" test busy.

5.10 No idle next switch found

Suppose there is no idle next stage switch found after stepping over all 10 positions on the relevant level. The switch will then step to "position 11". There are no bank contacts there.

At this point, a "fin" on the switch shaft operates the 11th step rotary contacts (11SR).

Its contact 1B opens the path through which, otherwise, the D relay would be operated when on a sleeve not-grounded position. (We don't want D to operate and "transfer" the connection to the next stage switch, since there isn't any next stage switch at this bank position).

In addition, 11SR transfer contact 2 takes the bottom of the tip winding of relay A off ground (or, if this is a 1st selector, dial tone) and puts it instead on fast busy tone (FBT)[4]. This is like regular station busy tone except that its cadence is two beeps per second rather than one per second.

This tone cadence implies not that the called line is busy but rather that something has prevented the call from being completed (such as, in our case, a situation in which at this stage of the switching network there is no switch available in the following stage).

5.11 About the tones

I didn't mention this when discussing the application of dial tone at the first selector, but is injecting a tone (DT or FBT) at the bottom of the tip winding of the battery feed relay (A) a really good idea from a transmission standpoint? No. And in fact, in some cases, better ways of doing this have been implemented in the step by step system. But these are beyond the scope of this article, which is predicated on the "classical" circuitry.

6 THE DIGIT ABSORBING SELECTOR

In the master article of this series, we learned of various needs that can be accomplished through the use of digit absorbing selectors. Essentially, such selectors in effect "throw away" one or more digits dialed into them.

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[4] That is not its "official" name, but it has so many official names I thought I would use this self-explanatory name for clarity.

I will not here synopsize these system needs and how digit absorbing selectors meet them. But I will describe here how digit absorbing selectors can operate, and how they do that.

The behavior of a digit absorbing selector after a digit has been dialed into it is, in part, dependent on the digit dialed (which is manifest in the level to which that digit drove the selector). Discrimination on the basis of that level is done through a mechanism that only this kind of selector has, called a *normal post contact assembly*. We see a basic one in figure 6.

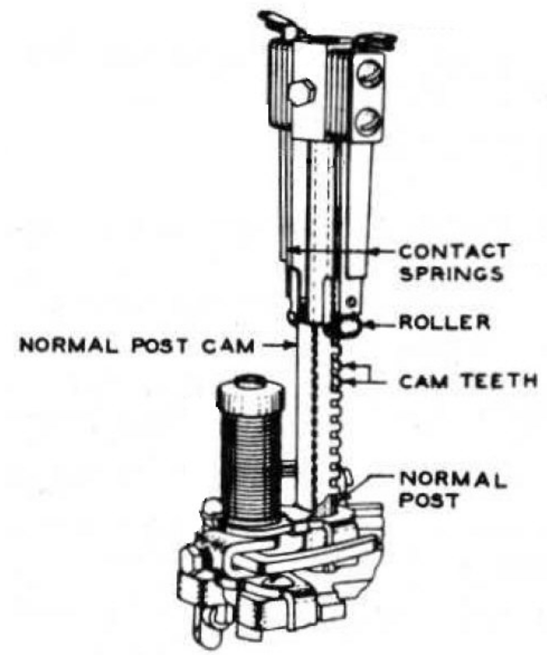


Figure 6. Normal post contact assembly

“Normal post” refers to a post rising from the top of the main switch mechanism casting. An arm pivoting around the top of the switch shaft bears against this post, providing the “fixed end” of the torsion spring that returns the switch shaft to its home angular position. In addition, an arm on the shaft can bear on this post to define that home angular position.

When we have the normal post contact assembly, a channel-shaped sheet metal piece, the normal post cam. fastened by two bent tabs to the non-rotating member that slides on the normal post, surrounds the normal post, and rises and falls with the shaft.

On each side, this cam has 10 little round-ended teeth, any of which can be bent outward (away from the shaft).

Fastened to the top of the normal post is a set of two contact spring assemblies. Each has a small “hard rubber” roller at the tip of its operating spring. These rollers would be moved outward by a bent-out cam tooth for the current switch level.

Thus, with the shaft at any given vertical position, which cam teeth are bent out will establish four different combinations of the states of the two contact assemblies.

The exact logic of a digit absorbing selector varies over various specific switch designs, intended for use in different situations.

For one typical type, possible actions to be taken after a digit has been received, taking the switch to a certain level, for the four possible cam tab settings, are ("R" and "L" refer to the tabs on the right and left side of the cam being bent out):

- (No tabs) Do nothing special; proceed to step in the rotary direction in the usual way; cut though if an idle next stage switch is found. If none is found, return fast busy tone ("a connection cannot be established").

- (L tab) Absorb the digit whether this is the first digit received or not: release the switch and leave it ready to receive the next digit.

- (R+L tab) Absorb the digit only if it the first digit received: release the switch and leave it ready to receive the next digit. If this is a later digit, proceed in the normal way.

- (R tab) Block the level; that is, force the switch to step in the rotary direction all the way (just as if no idle next stage switch had been found), so it will return fast busy tone to the calling line.

In any case, after the first digit has been received, if this is a 1st selector, dial tone is removed.

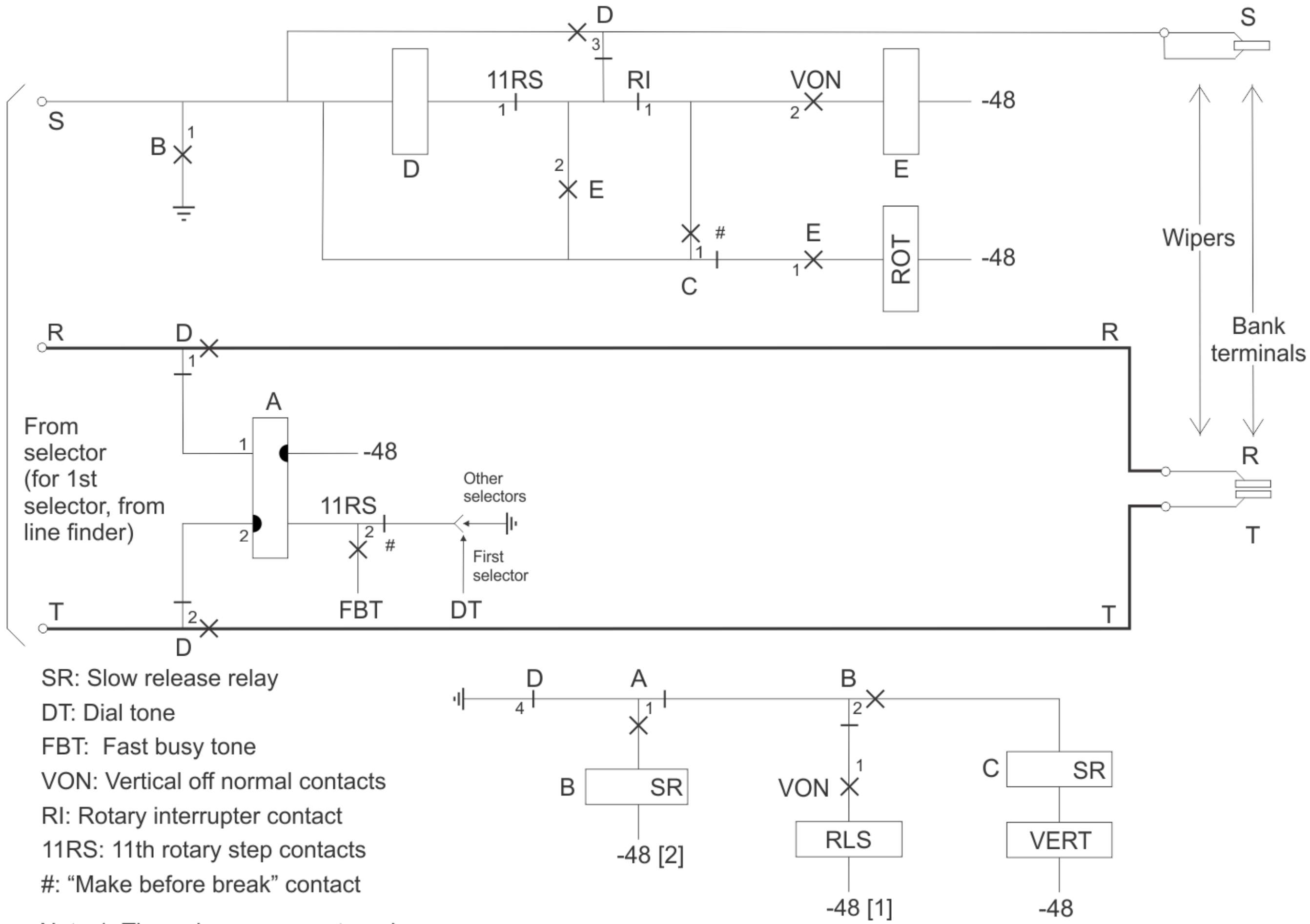
In more complex digit absorbing selectors, there are four separate contact sets on the normal post contact assembly, and the cam has four tabs that can be bent out for each level.

Various more complicated possibilities can be programmed on switches of this class. For example, we can have separate behavior for the first digit, second digit, and subsequent digits. And the behavior can be varied by certain things that happened on earlier digits. Such switches can be utilized in very specialized situations. All this is beyond the scope of this article.

7 ISSUE RECORD

Issue 2 (December 20, 2019) [this issue]: Various editorial revisions. Improved description of detached contact drawing system.

Issue 1 (March 31, 2018): Initial issue.



SR: Slow release relay
DT: Dial tone
FBT: Fast busy tone
VON: Vertical off normal contacts
RI: Rotary interrupter contact
11RS: 11th rotary step contacts
#: “Make before break” contact

Note 1. Through common external relay that detects if any switch has not released properly

Note 2. Through common external relay that detects if any switch has not advanced timely (the subscriber not having dialed a digit as expected).

Figure 7. Illustrative selector circuit