

The Panel Dial Telephone Switching System— Interoperation with Manual Switching Systems

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ABSTRACT AND INTRODUCTION

The *panel dial* system was a very complex telephone switching system developed by American Telephone and Telegraph company in the 1910s. It came to be the mainstay of the Bell Telephone's System's massive program, from the 1920s on, of mechanizing telephone service in many of the largest cities in the United States. Prior to mechanization these cities were served by switching systems using large manually-operated switchboards.

During the conversion process in a given city, which might take a decade or more, elaborate provisions were emplaced to allow the seamless interoperation of the new mechanized ("dial") systems with the existing manual systems, allowing subscribers served by either kind of system to reach subscribers served by the other kind in a straightforward way.

This article discusses the most widely used of such arrangements in some technical detail. Included is a detailed discussion of a telephone signaling system (the "PCI pulsing system") that was developed to support these interoperation arrangements but which then went on to have a life of its own elsewhere in the telephone network.

1 COMPANION ARTICLES

This article revolves around the complex interaction between two complex telephone switching systems, the manual switchboard system and the panel dial system. Sections 2 and 3 give, as background, a description of these two systems in moderate detail, hopefully sufficient to make this article self-contained.

However, those readers who would like further insight into the intricacies of these two systems may be interested in two companion articles, by the same author, probably available where you got this, "Manual Telephone Switching" and "The Panel Dial Telephone Switching system".

2 MANUAL TELEPHONE SWITCHING

2.1 Introduction

Prior to the 1910s, telephone service was almost universally conducted by way of manual switching systems, generally using switchboards of a certain general construction and using certain principles of operation. Although it is tempting to think of these as primitive, they were anything but. Their physical construction, circuitry, electrical and mechanical components, and method of operation were very sophisticated, and they were operated in a very sophisticated scheme of protocols.

Just for context, figure 1. shows part of a modest sized metropolitan area manual switchboard lineup (Ames, Iowa, perhaps ca. 1950s).



Figure 1. Typical manual switchboard lineup

2.2 Central offices

In a city of any appreciable size, telephone switching systems (whether manual or "dial") are located in multiple facilities known as *central offices*. Any subscriber's line is connected to the switching system in one of those central offices (typically the closest one). For the moment, considering manual switching, these different central offices have names, which are used to distinguish the telephone lines served by them.

Often, as a small town grew from having a single central office (which was “nameless”) to having a few more, the original one was given the name “Main” and the others might be named in geographic terms, such as “East” or “West”. But in larger cities, it became the custom to give many central offices names of localities, trees, or former presidents, and the like (just as is often done for the names of streets).

2.3 Caveat

There are many subtle but important differences over the range of manual switchboards. In order that the important points emerge clearly, I will ignore many of these, not always scrupulously saying “in the most common case” or “in the earlier versions” or the like, and using for illustration one arbitrarily-chosen arrangement.

2.4 The multiple jack concept

A metropolitan manual switchboard will have many positions (operators’ “workstations”), as required for handling the overall flow of calls.

Any one of these operators may be called upon to “deliver” a call to a certain line (which we for the moment will consider as equivalent to a certain telephone number). Thus each line is connected (electrically in parallel) to a number of jacks—let’s at first think of one in front of each operator.

Not surprisingly, this is said to be a *multiple jack* arrangement. And, by extension, this whole collection of jacks, one in front of each position for every line in the central office, is said to be the *line multiple*. Yes, that is very many jacks altogether, and just think of the wiring, behind the jack panel, connecting them all together (there being three leads involved here for each line).

However, in reality, we do not have each line appear on a jack in front of every position. Rather, the spacing of the multiple jacks for any given line is typically about twice times the width of a position. Thus, when an operator needs to plug into the jack for line 2368, that jack will either be in front of her position, or in front of the position to the left, or in front of the position to the right. Thus the operators will often exercise their “boarding house reach” in completing a call.

2.5 The cord circuit

At each operator’s position, there are, on the shelf in front of her, a number of *cord circuits* (it is common for there to be 17 of them). Each has two plug ended cords, one behind the other. Each cord passes (underneath the shelf) through a weighted pulley, whose purpose is to keep there from being any slack in the cord and to help

the cords, when the plugs are no longer plugged into anything, to pull their plugs smartly into their little resting “wells”.

But these cord pairs are not just “patch cords”. Rather the cords go to the two sides of a *transmission circuit*. That feeds DC current to the two lines, provides a low-loss transmission path for speech signals between the cords, and observes whether there is current flow in one cord or the other (so as to know whether that line is “off hook” or not, needed for such reasons as so the operator can tell when the called party has answered or when either or both parties have “hung up” at the end of the conversation).

There are (usually) two lever-type keys in front of the two cords of each cord circuit. When one, the talking key (a locking key), is operated, it connects the operator’s telephone set to that cord circuit for speech signals. When the second one (momentary) is operated in one direction or the other, it applies the ringing signal to one cord or the other (although in the more sophisticated systems this key is not needed under ordinary circumstances).

We can follow the action on figure 2.

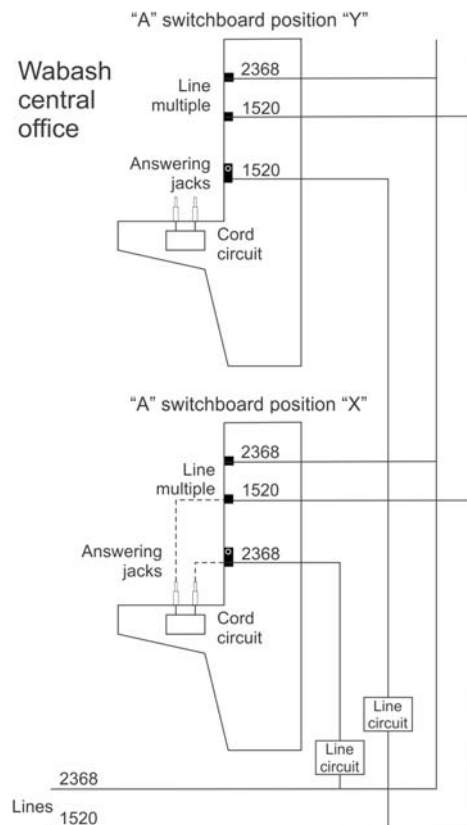


Figure 2. “A” switchboard positions

Here we see, in block diagram form, two “A” switchboard positions in the “Wabash” office. “A” positions are responsible for initially handling

new calls, and in many installations, if the call is to a line in the same central office, for “completing” the call to the called line as well (and here we will assume that arrangement).

We see two lines, with numbers 1520 and 2368. We note that each is connected to a *multiple jack* appearing in front of both of the positions shown. As described earlier, for every line, one jack in the multiple is within the reach of the operator at every position on the switch board.

2.6 The answering jack

Each line, in addition to being connected to many jacks in the line multiple, also appears in a jack in the lower portion of the jack field in front of one position¹. This jack differs from the jacks in the line multiple in that it has a lamp just below it. We see the answering jack for line 2368 on position “X” and the answering jack for line 1520 on position “Y”.

Suppose that line 2368 is not in use at the moment. The line’s *line circuit* provides 24 V DC across the line through the winding of the *line relay* in the line circuit. With the station set “on hook” there is no DC continuity at the station, so no current flows in the line, and the line relay is not operated.

2.7 Intra-office call

Now that subscriber (at Wabash 2368) wishes to place a call to the subscriber at Wabash 1520, He lifts his receiver or handset (I will say “handset” from here on). This closes a contact in the telephone set, providing DC continuity across the line, so that current flows, which operates the line’s line relay. This lights the lamp above the line’s answering jack, which is this case at position “X”.

The operator at that position, seeing the answering jack lamp, takes the *back cord* (farthest from the operator) of an idle cord circuit, plugs it into the answering jack, and operates the talk key on that cord circuit (which connects the operator’s telephone set to the cord circuit, so that she is now in communication with the calling subscriber).

She says, “number please”. The subscriber says, “Wabash 1520”. The operator locates the jack for number 1520 (this is the Wabash office; thus this is an *intra-office* call), checks to see if the line is busy

¹ The line might in fact appear on answering jacks in front of two positions or even three, but certainly not on as many jacks as that line will appear on in the line multiple.

(I will not discuss here how that is done) and if not, plugs the *front cord* of that same cord circuit (the one nearest the operator) into the 1520 jack. Ringing signal is automatically applied to that cord and thus to the line.

I won't discuss the remainder of the operation right here.

2.8 Inter-office call

But suppose the calling subscriber, at "number please", said, "Melrose 5730". That is a line in a different central office, "Melrose". To follow the action here, we will look at figure 2.

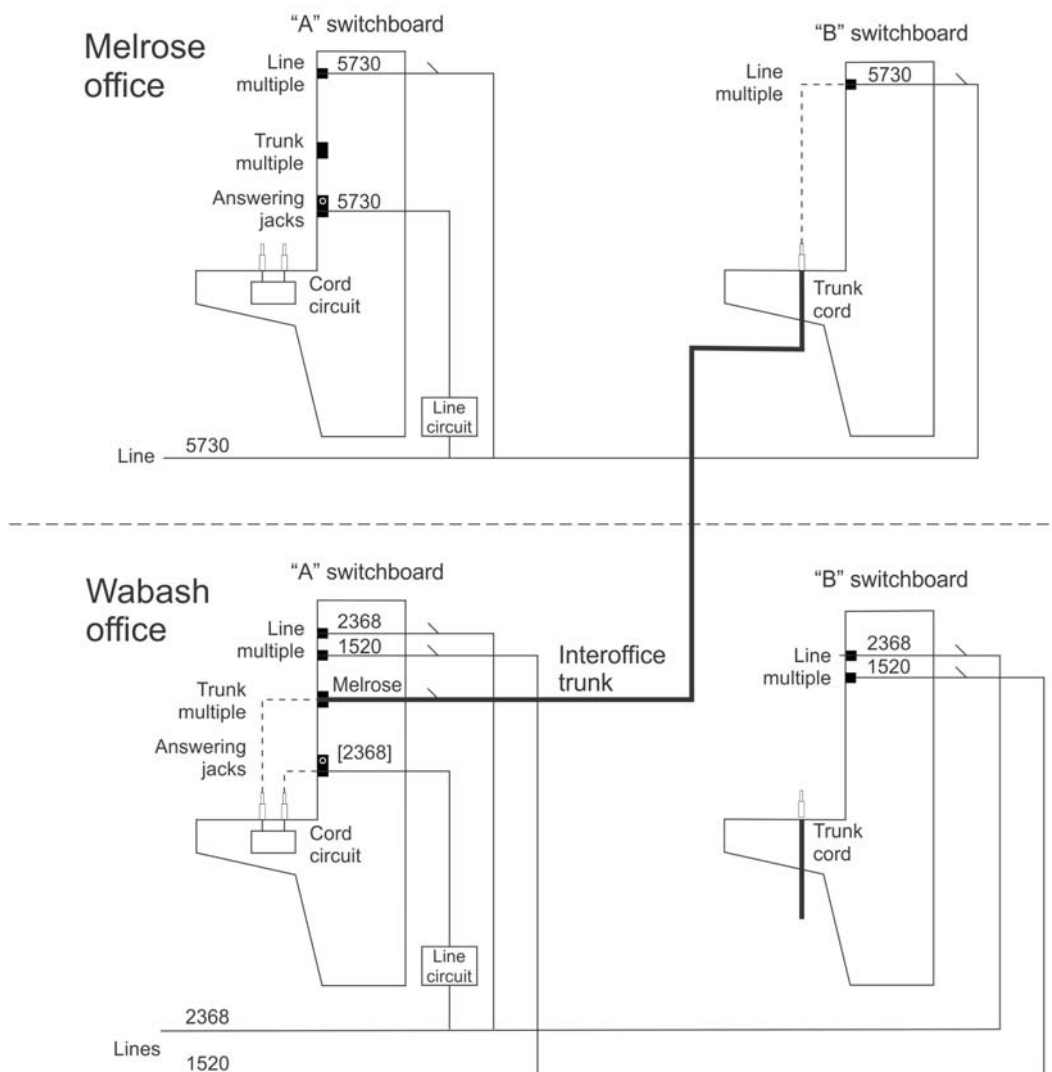


Figure 3. "A" and "B" switchboard positions

We see here the Wabash office and the Melrose office. At each we see a position of the "A" switchboard and a position of the "B" switchboard. The job of the "B" switchboard is to "complete" calls that originated at other central offices.

We note that at each office the lines are not only connected to jacks on the line multiple at the "A" switchboard positions but also to a similar line multiple at the "B" switchboard positions. But there are no answering jacks at the "B" switchboard positions (they would play no role in its "charter").

The "A" operator at Wabash, having heard that the wanted line is in the Melrose office, looks at another section of her board face, above the answering jacks but beneath the line multiple jacks. This is the *trunk multiple* area. Its jacks go to trunks to all the other central offices in town. There will generally be quite a few to each office in front of each position. But any given trunk will appear on jacks in front of many positions, so this is again a "multiple jack" arrangement (this whole array of jacks being called the *trunk multiple*).

Here, at each trunk jack there is a lamp. For the group of trunks to a certain central office (and those groups are labeled), one of the currently idle ones (the one that is "next up") will have its lamp lit.

Our operator looks for the trunk in the group to the Melrose office that has its lamp lit, and plugs her front cord into that jack. She has now made a connection to a trunk to the Melrose office.

Each trunk arriving at the Melrose office (and they will of course come from all the other central offices, not just Wabash) ends up permanently at a cord on a Melrose "B" board position. This is not one of a cord pair, as in the cord circuits at the "A" position. It is a single cord, functionally rather like the front cord of a cord circuit, ready to be connected to the called subscriber.

When the trunk to Melrose has been "seized" by the Wabash "A" operator, current flows in the trunk conductors, operating a relay at the trunk circuit at the Melrose office associated with the trunk and its permanently-associated cord, lighting a lamp next to the cord. This shows that a call is trying to arrive over that trunk.

The Melrose operator takes that cord in hand and operates a momentary key next to the lamp to have her telephone set be connected to the trunk. She need not prompt the operator at the calling end for the desired number; as soon as she operates the key, a quick sequence of two beeps ("order tone"²) is automatically sent back over the trunk as a prompt.

² Often colloquially called "zip tone", as to someone it sounded like "zip zip".

The Wabash operator, hearing this order tone, says, "5730". She doesn't need to say, "**Melrose** 5730"; this trunk goes to the Melrose office, and all the numbers there are "Melrose" numbers.

The Melrose "B" operator checks to be certain the line is not busy, and if not, plugs the trunk cord into that line jack. The trunk cord circuit automatically begins applying ringing signal to the called line.

Again, I will not here discuss the rest of the scenario.

3 The panel dial system

3.1 Introduction

Of course, "our" player in the various scenarios of interoperation is the *panel dial* switching system. Here I review its architecture and method of operation.

3.2 Historical context

The system was developed by American Telephone and Telegraph company (the portion that later would become part of Bell Telephone Laboratories) in the 1910s. It was the centerpiece of the Bell Telephone System's program of converting large metropolitan areas' telephone service from manual switching to machine switching (*i.e.*, "dial") operation. It was extraordinarily complicated and sophisticated.

3.3 The panel selectors

3.3.1 Introduction

The panel system revolves around a unique type of motor-driven selector. Each selector's moving part (the *selector rod*, sometimes called an "elevator rod") moves only along one axis, vertically. The terminals to which it can make contact are made in large unitary "panels" (hence the name of the system), which in most cases can be accessed by up to 30 selectors on one face and 30 more on the other face.

3.3.2 The banks

In most of the selectors, there are 500 terminals that can be accessed. But these are arranged in five separate "banks" (each a unitary "panel") with 100 terminals (at each selector rod's position) each. The travel of the selector rod is only over 100 positions.

We see one bank (and its method of construction) in figure 4.

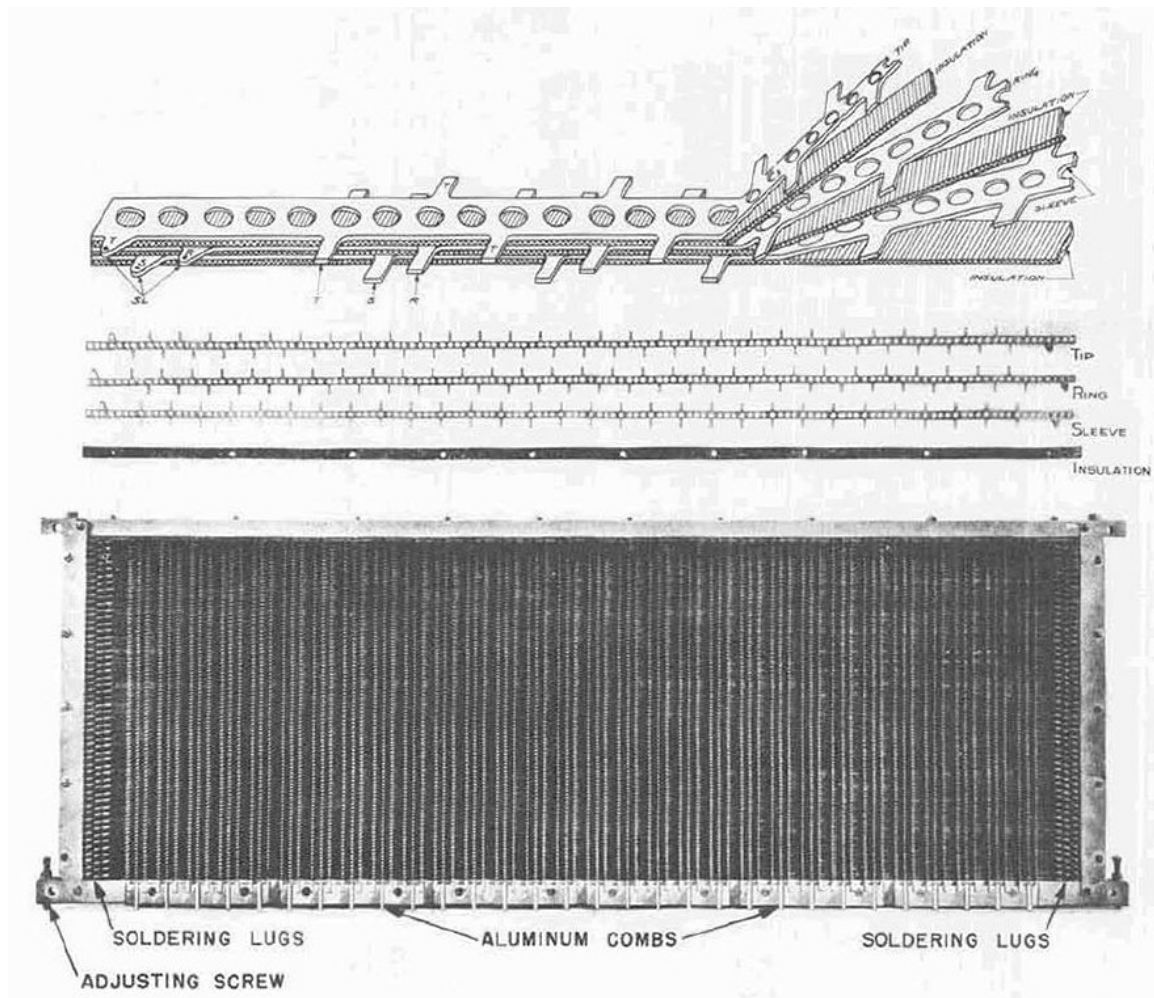


Figure 4. Typical panel bank

The little tabs extending (in both directions) are the “terminal contacts” to which the selector brushes (for selectors on both faces of the frame) make contact. For this bank, there are three contacts at each terminal position one for each of three leads.

3.3.3 *The selector drive*

The rod is raised (and later, lowered) by means of an electromagnetically-operated “pinch roller” pressing a flat strip of spring brass extending from the bottom of the rod against one of two motor-driven, continuously-rotating rollers, faced with a cork friction surface. Figure 5 shows the principle.

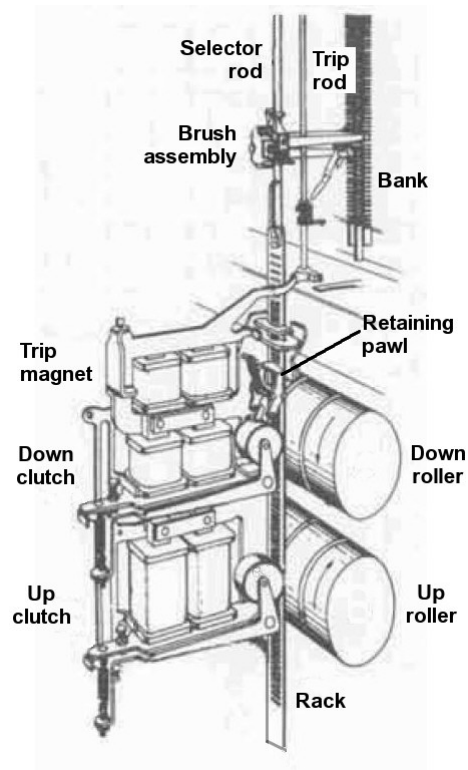


Figure 5. Selector drive system

3.3.4 *Brush assemblies*

Each rod is equipped with five *brush assemblies*. These carry the brushes (wipers) that make contact with the terminal contacts. (There are usually three, but in some cases four, contacts at each terminal position, carrying three or four leads of the circuit.) One brush assembly travels over each bank.

On any given active selector rod, all but one of these brush assemblies have their contact brushes retracted so they do not make contact with the terminal contacts. All five in fact are initially retracted.

Thus, for a terminal to access one of the 500 terminals, the brush assembly for the bank in which that terminal exists is "tripped" so its brushes can make contact with the terminal contacts. Then the rod is moved to the proper one of its 100 possible contacting positions. The result is that contact is made with the contacts of the proper terminal out of 500 possibilities.

The desired brush is tripped by first moving the selector rod to one of five positions, all of them before the actual bank terminals could be contacted. Then a *trip rod*, behind the selector rod, is rotated by a magnet on the clutch magnet assembly.

There is a finger assembly on the trip rod for every brush assembly. These are staggered vertically, so that for any one of the five preliminary selector rod positions, as the trip rod rotates, one of them

will engage a *trip lever* on the brush assembly, while the other four will swing past, above or below “their” brush assembly’s trip lever, having missed “catching” it. Then the selector rod is started again on its upward motion. The trip lever that was caught by a trip finger will be “pulled down” (relative to the brush assembly), and that will drop the brushes on that brush assembly (only) so they will make contact with the terminal contacts on its bank.

3.4 The commutator

One need here is for a path from the brushes on the movable selector rod back to the circuitry on *terra firma*. This is done by a component called the *commutator*, which is mounted on the frame at the top just above each selector rod. We see an example in figure 6.

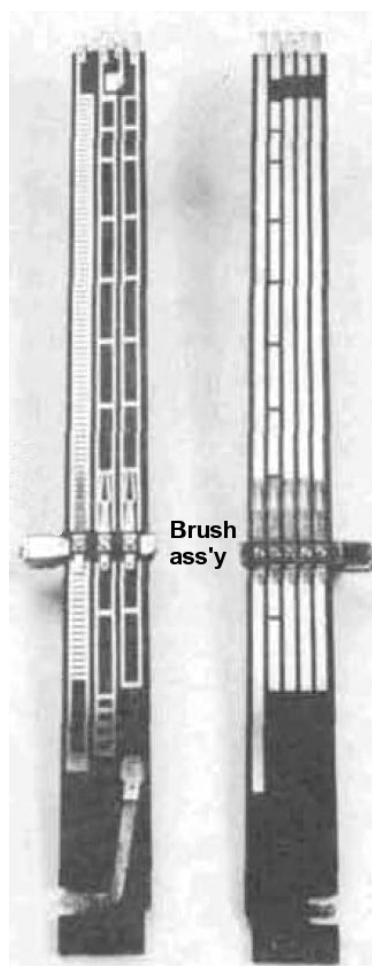


Figure 6. Commutator and commutator brush assembly

We can think of one aspect of this as being like a set of “slip rings”, except of course they are straight. Each lead from the brush assemblies (all five assemblies in parallel) goes to a contact brush on a *commutator brush assembly* mounted at almost the very top of the selector rod. (Recall that the selector rod is in fact a tube, so those

leads travel inside it, coming out at each brush assembly, their ends coming out the open top and connecting to the commutator brushes.)

These brushes ride on conducting tracks in the commutator that run essentially the entire length of travel of the brush assembly. These carry the brush leads electrically to the selector circuit in "*terra firma*".

In the figure, the brush assembly is shown where it would be with the selector rod about 20% of its way "to the top".

But the commutator performs another kind of function. In addition to the tracks carrying the brush leads, there are other conductive tracks on the commutator that have various conducting patterns on them. Brushes on the commutator brush assembly, not connected to anything moving but just to each other, ride on these tracks. The result is that electrical conductivity is provided between these tracks or not depending on the position of the selector rod and the patterns of the tracks. The roles these play in system operation will be discussed later.

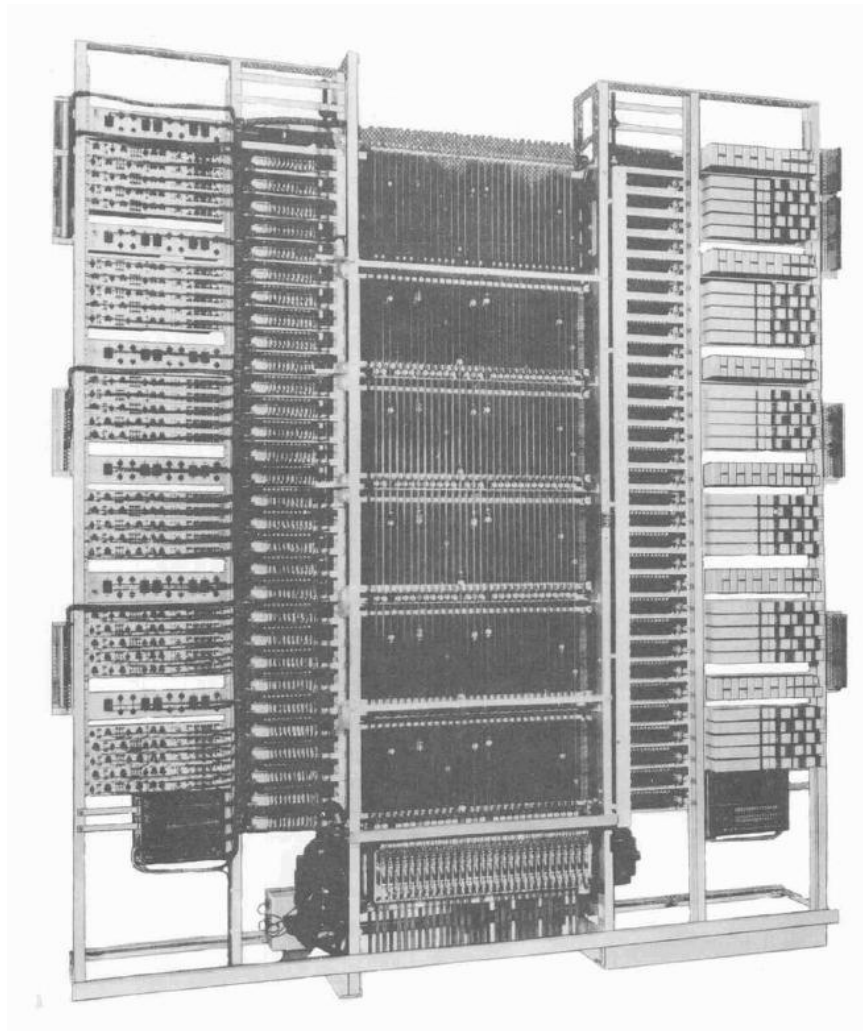


Figure 7. Typical panel dial system selector frame

3.4.1 *Typical selector frame*

In figure 7, we see a typical panel dial system selector frame.

In the center is the selector portion proper. At the bottom we see the clutch assemblies. In this example all 30 selector positions (on each side) are populated. Above, we see the five banks. At the top, we see the commutators.

To the right of the selector area we see a series of *sequence switches*, one for each selector. These are power-driven rotary switches that sequentially establish the complex circuit paths for the many "states" of a selector as it does its job.

Further to the right we see relays and transmission apparatus associated with the 30 selectors on this side.

To the left we can see the wiring on the back of the sequence switches and the relays and other circuit apparatus for the 30 selectors that run on the other side of the banks; the frame is wholly symmetrical.

3.5 The common control concept

The step by step (Strowger) telephone switching system, very widely used outside the Bell Telephone System, and widely used in the Bell system in smaller cities, is classified as a *direct progressive* system. "Direct" means that the switches, which are stepping switches, are directly moved by the pulses sent by the subscriber's dial. So when the subscriber dials "3" as a digit of the wanted telephone number, each of the three pulses sent by the dial to convey that digit's value steps the switch up by one "notch", and it finds itself on "level 3".

"Progressive" means that each digit of the dialed number moves a successive switch in the buildup of the entire connection (the exception being that the last two digits set the last switch in the connection). So if the subscriber dials 5212368, the "5" moves a switch in the first stage of the network to its 5th level, which extends the connection to an appropriate switch in the next stage of the network. The pulses for the next digit, "2", go to that switch, and move it to its 2nd level. And so forth.

In contrast, the panel system is classified as a *common control* system. There, the entire dialed number is received and recorded by an equipment unit that is not part of any of the switches, and in fact is taken from a "pool" of them just long enough for it to attend to the establishment of one connection.

That unit then sends, to the various switches along the connection as it is built up, stage by stage, the instructions for setting each of them

to the desired position, using a coding system that is entirely different in concept from the trains of pulses, coming from the subscriber's dial, that set the switches in the step by step system.

3.6 Switching machine architecture

Figure 8 shows the overall architecture of a typical panel switching machine:

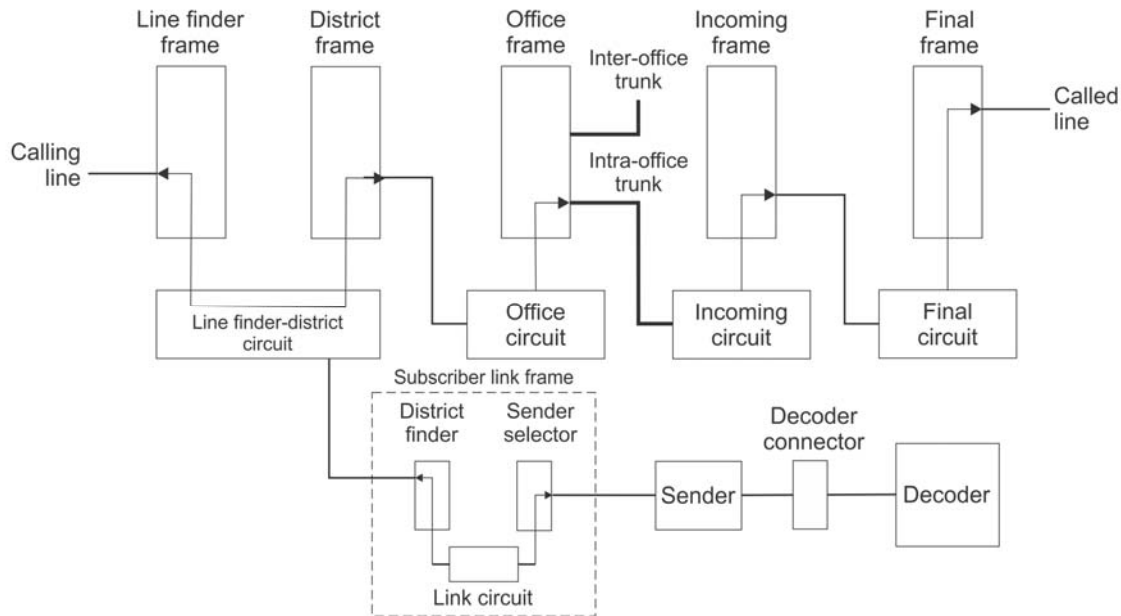


Figure 8. Typical panel system architecture

The actual switch train comprises the five frames shown at the top. The items at the bottom are "common control" equipment.

3.7 Basics of call setup

The first stage of the switch network consists of essentially permanently paired *line finders* and *district selectors*. The task of the line finder (implemented with panel selectors) is to give a calling line access to the switching network, in the person of a district selector.

Suppose that a subscriber takes his station off hook to place a call. Just as in the manual system, the *line relay* in the line's *line circuit* (not shown in the figure) detects this. Through some complex control circuitry, an idle line finder-district selector pair is chosen for this call and the line finder connects to the line.

Also, an idle *sender* (more about its name in a minute) is chosen and, through a little double-ended switching network using panel selectors, it is connected to our line finder-district circuit. It is the sender that gives the calling subscriber dial tone, and all the digits dialed by the subscriber are received by and stored in the sender. (Makes you

wonder about its name, doesn't it. But be patient.) There are typically over 100 senders in an office.

Now, after an exceedingly important operation that I will ignore for now, the sender sends forward (aha!) the numerical instructions for setting the district selector mated to "our" line finder. The result is now that the nascent connection is extended to a certain *office selector*.

Then the sender sends, through the connection as it so far exists, to that office selector, the numerical instructions for setting that selector. The result is that the nascent connection is then extended to a certain *incoming selector*. Then the sender sends to that incoming selector the numerical instructions for setting it. The result is that the nascent connection is now extended to the appropriate final selector. Now the sender sends, over the connection as it is so far built up, to the final selector, the numerical instructions for setting it.

The result is that the connection has been extended to the desired called line. The ringing signal is applied (don't worry just now about who does that) and we are on the way.

Note that I have identified the path from an office selector to an incoming selector as an intra-office trunk, and I have also shown an inter-office trunk leaving from the office selector. At the distant end, that trunk terminates on an incoming selector, just as we see for the intra-office selector at this office.

We can now see the rationale for the names of the *office* and *incoming* frames. The *district frame's* name was apparently coined since a "district" sounds like a place where there might be a number of central offices. But there is no relationship between a certain district frame and any geographical area of the city, or administrative region of the telephone company. Its name is metaphorical.

3.8 Translation of the office code

The up to 10,000 telephone lines/numbers that can be reached through a fully fleshed out panel office are placed on the final frames in a logical way such that the numerical instructions for setting the incoming frame and then the final frame can be derived via a fixed algorithm from the four digits of the "station number", and that algorithm is "hard wired" into every sender.

But the trunks to various central offices (including our own) are not placed on the office frames in a way that is directly relatable to the 3 digits of the dialed office code (in a large city; 2 digits in a smaller city for many years). That situation allows great and very beneficial advantages in configuring the resources of a panel office to best meet

the requirements for handling the expected traffic over the various paths.

But to get that benefit, each sender must have access to what amounts to a gigantic lookup table, entered with the dialed central office code as the “address”, the “return” from which is a set of all the numerical parameters needed to set the district and office selectors in the connection to reach that central office.

That “table lookup” process, from the 1928 vintage of the panel system onward, was done by common control equipment units called *decoders*. It only took one of these about 300 ms to do the translation for one call, and any sender could access any decoder that was not now in use (and there was a sophisticated queuing system), so in fact even a rather busy central office might only need 3 decoders altogether (and the system design imposed a limit of 6).

We see this arrangement toward the bottom of the figure. The decoder connector is a little switching network, made up wholly of relays, through which a sender, with the dialed office code digits in hand, could connect to any of the decoders that was available at the time (or wait for one) to get that translated into a slate of selector setting parameters.

A total of 50 leads is carried between the sender and the decoder, over which the “input” office code and all the “returns” are carried in parallel form. To this end, the relays that make up the decoder connectors are a multi-contact type initially developed just for this and related purposes in the panel system. No, decoder connectors are not quiet. They go steadily bang-bang-bang during times of heavy traffic. And the decoders themselves do likewise.

The “lookup table” proper, a full copy of which is in each decoder, is “populated” by way of cross-connections on a large terminal field in the decoder frame.

3.9 Revertive pulsing

3.9.1 Introduction

So far I have dodged discussion of in what fashion does the sender send forward the numerical parameters that define how each selector along the trail should be sent. It is a rather unique system, called *revertive pulsing*.

The concept can best be explained with a parable. Alice wants to direct Bob to climb up a ladder to a certain point, 4 rungs up from the ground, where she knows he will have to be to do something she wants done (perhaps put in a nail on which to hang a picture).

She says "start". Bob starts climbing, and each time he gets to a new rung he says "mark". After Alice has heard "mark" four times, she says "stop". Bob stops, and is on rung 4, just as Alice desired

So the actual numeric parameter of Bob's climb, "4", is conveyed in the **reverse** direction (by four consecutive cries of "mark"). His utterances have "reverted" to the "commanding" end of the communication channel.

3.9.2 The fundamental circuit

Fundamental circuit refers to a two-wire path (tip and ring leads) that starts at the sender, passes through the sender link to the district circuit, and from there grows forward, one stage at a time, as each switch in the train is set. It is over this circuit, out to the switch to which it has so far been "assembled", over which the sender sets that switch.

After all switches have been set, the part of it from the district circuit forward metamorphoses into the actual "connection".

3.9.3 Principle of operation

Now let's see, in figure 9, how this really happens, electromechanically.

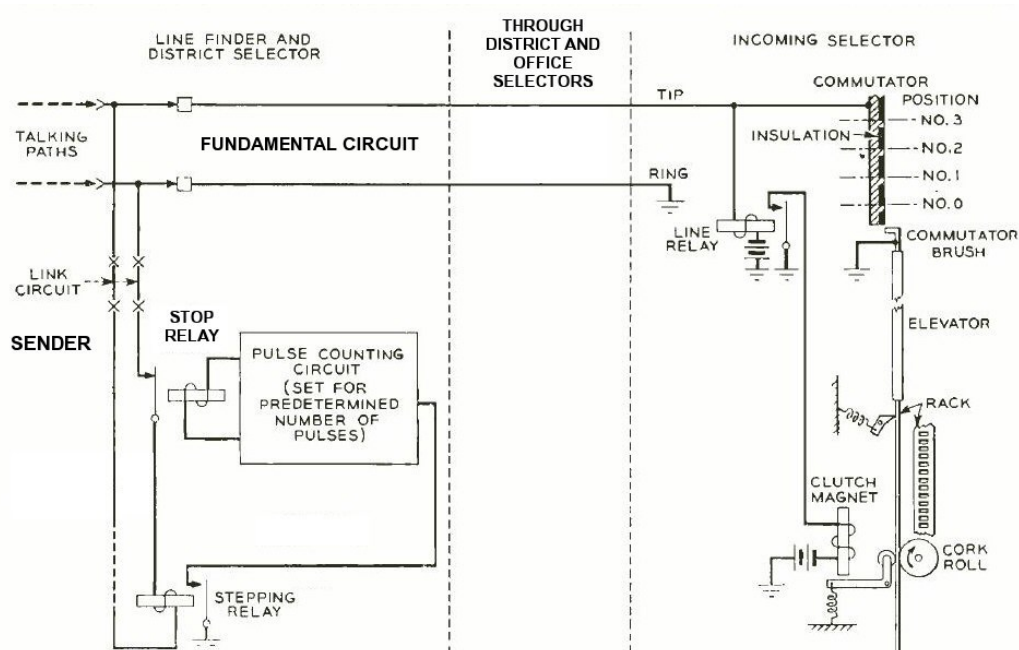


Figure 9. Revertive pulsing

On the left toward the top we see the line finder-district selector circuit. On the lower left we see the sender, attached (for the duration of its work) to the line finder-district selector circuit through the link circuit. On the right we see the incoming selector being controlled.

The fundamental circuit has been extended to it through our district selector and an office selector (both having already been "set" as required, using the very scheme we are about to see for the incoming selector).

We will assume that we are in the first stage of control of the incoming selector, needing to move it to one of five positions so that the proper brush can be tripped.

The incoming selector, when idle, maintains ground on its incoming ring lead and battery through the winding of its line relay on the tip lead.

When the connection has been made through the district and office selectors to this incoming selector, there is continuity from tip to ring in the sender (through the coil of the stepping relay in the sender).

The current that flows operates the stepping relay in the sender and the line relay in the incoming selector. At the sender, this tells the sender circuitry that indeed it is now connected to a selector (which it presumes to be an incoming selector, owing to where the sender is in its overall scenario). At the incoming selector, the line relay operates the up clutch magnet, and the selector rod begins to rise.

As it does, a grounded brush on the commutator wiper assembly travels over a region of the commutator in which there are periodic narrow contacts, separated by insulating regions. When the selector rod reaches its first step position (called "position 0") the wiper makes contact with the first of these conducting places on the commutator, which grounds the tip conductor of the incoming circuit.

That causes no change at the incoming selector end; the line relay remains operated (in fact, the current through it increases). But to the sender, the fundamental circuit is "short circuited", and current flow through the stepping relay ceases. That causes the counting circuit (composed of a bunch of relays) to say, in effect, "that's one". Then the brush moves off the first conducting place, the ground on the tip is removed, and there is again current through the fundamental circuit to the stepping relay ("and-a").

This process repeats until the counting circuit says, when the count reaches the target location of the distant selector, "that's it", which it does by operating the stop relay.

Now, when the brush moves beyond this conducting place, removing the ground from the tip, there now no longer a path through the fundamental circuit and the sender, and so the line relay at the incoming selector releases, releasing the up clutch magnet, and stopping the motion of the selector. The selector drive rack settles

back on the retaining pawl, and this stage of the movement of the selector rod is done.

We will see a little later what is the overall sequence of "instructions" issued by the sender in this way to set all the selectors in the connection path.

3.9.4 *Pulse rate*

The rate of the pulses in one reverive pulsing train varies with the specific "setting" command that is being conveyed. The fastest rate is about 30 pulses per second.

4 NUMBERING PLAN MATTERS

4.1 Basic number range

A widely-used configuration of the most common Bell System manual switchboard could provide up to 9600 jack strings in the line multiple. This corresponds to 9600 telephone numbers, which are ordinarily in the range 0000-9599.

4.2 Numbers over 9999

However, a later alternate design could accommodate up to 10,500 jacks in the line multiple (and still required less "reach" by the operators).

In an office with this capability, for station numbers not over 9999, the numbers are always expressed in four digits: 0075, 2368, 9995, etc. Numbers over 9999 (they are never over 10499) are expressed in five digits: 10050, 10498.

4.3 Four party line party letters

In multi-party line (known to civilians as "party lines"), the stations of two or more subscribers (the separate "parties") are connected to the central office over a single pair of conductors. The objective is to share the cost of that pair (and to some extent the per-line cost of the central office equipment) over the multiple subscribers, thus leading to a lower charge for service.

Two types of *multi-party lines* were commonly used by the Bell System: the two-party line and the four-party line. In the most desirable systems, these were both *full selective*; that is, when there was a call to one of the stations on the line, the ringer at only that station would sound. This of course depended on the use of two (or four) distinct electrical signals that could be applied to the line.

Under manual switching, most commonly (in a metropolitan area system), for a two-party line, each party had its own number. The two

numbers did not need to be related in any way. When completing a call to such a number, the operator just plugged the front cord (or trunk cord) into the jack for that number and rang in the usual way. A clever wiring trick resulted in the proper electrical condition being presented to the line so as to ring the ringer for the station of the party with that number and not the ringer at the station of the other party. This operating plan was known as "jack per station" operation.

Commonly, for a four-party line, with manual switching, all four parties had telephone numbers with a common numerical part (in a metropolitan area, four digits) followed by a letter. The numerical part identified the line, and the letter the party. Commonly, the letter was from the set W, R, J, and M. Each letter denoted one of the four distinct electrical ringing signals used on a four party line. At any station, the ringer would only respond to one of those four signals.

Under this scheme, the operator would plug into the jack labeled with the numerical part of the number (which identified the line as such) and then used one of four ringing keys on the cord circuit (based on the letter suffix of the number as given by the calling subscriber) to apply the proper ringing signal for that particular station on that line. This operating plan was known as "jack per line" operation.

4.4 Central office names and codes

When mechanization of telephone service was instituted (with panel dial switching systems) in large metropolitan areas, in the existing network of manual offices, each central office had a name, usually chosen from the names of localities, trees, former presidents, etc (Lakeside, Mulberry, Garfield, etc.)

Under manual operation, the name of the destination office was spoken by the calling subscriber. Of course, with panel switching, a sequence of digits at the beginning of the overall telephone number (the *central office code*) would identify the destination central office. In the largest cities (*e.g.*, New York, Chicago), there were so many central offices that a three-digit central office code was needed. In smaller cities, with fewer central offices, a two-digit central office code was used.

It was decided that in the converted-to-panel dial parts of the network, the familiar central office names would be preserved, and additional panel dial offices would be given names in that same vein. This was made workable by an invention by W. G. Blauvelt of the American Telephone and Telegraph company. Letters would be put adjacent to the digits 2-9 on the dial, in the now very familiar pattern (there was originally no "Z" on the digit zero).

So if (in a city with three-digit central office codes) the call were to a line in a panel office with the office name "Mulberry", the caller would dial the digits near which on the dial appeared the first three letters of the central office name: M-U-L (which of course would be the digits 685, the central office code for the Mulberry central office). And to facilitate this, numbers were presented in the directory this way:

MUL berry 2368 (dialed as 6852368)

and subscribers were "encouraged" to do the same on business cards, newspaper advertisements, and the like.³

In smaller cities, with two-digit central office codes, that worked this way:

ME Irose 5569 (635569)⁴

4.5 Five digit station numbers

As we will see, in a metropolitan area having both manual central offices and panel dial offices (and that situation might endure for a decade or so), a subscriber served by a panel office could dial any telephone number in the city, regardless of the type of office involved.

The basic station number in a metropolitan manual system, or a panel dial system, was four digits long. But in a manual office with numbers over 9999, for those numbers the station number was five digits long. And in a manual office with four-party lines, a number for a station on such a line would be five digits long. (For a call to such a station dialed by a panel office dial subscriber, the party letter was dialed based on the digit on the dial that was accompanied by that letter.)

What if the number was over 9999 and a party letter was involved? Well, that was never done; four-party lines were never given numbers over 9999.

But now, when the calling subscriber was dialing, and the sender was receiving and storing the dialed digits, there was an uncertainty: would the caller dial 7 digits altogether (we continue to assume 3-digit central office codes) or 8?

Ordinarily, after 7 digits had been dialed, the sender would proceed to establish the connection. But after three digits were dialed (the office

³ But later, that became presented as: MULberry 5-2368 (still dialed as 6852368)

⁴ But in the late 50s all numbers became 7 digits, so that this one probably became ME Irose 1-5569 (6215569) (in this context there was no motive to make the third digit match the third letter of the name, and smaller digits were quicker to dial).

code), the sender consulted a decoder to learn how to “route” the connection through the district and office selectors. And two further pieces of information also came back from the decoder (part of the “class of service” indication) that are pivotal here:

- Is the central office implied by the dialed office code another panel office or a manual office? If the latter, the call will have to be handled in a special way, which is one of the main topics of this article.
- If the central office is a manual one, does it ever use either (a) numbers over 9999 or (b) party letters? If so, after 7 dialed digits have been received, the sender will wait a certain period of time (perhaps 4 seconds) for the subscriber to dial an 8th digit (which may or may not happen). If that doesn’t happen within the allotted time, the sender assumes that only 7 digits are involved, and proceeds to establish the connection.

Again, to summarize, in a call placed in a panel office to the Wabash office, a manual office that could have numbers over 9999 or party letters (although never both in the same number) the caller might dial:

WAB-4982 (9224982) (7 digits)

WAB-10361 (92210361) (8 digits)

WAB-5872J (92258725) (8 digits)

5 CALLS FROM A MANUAL OFFICE TO A PANEL DIAL OFFICE

5.1 Introduction

There are about five different schemes for handling calls from a subscriber served by a manual office to a number served by a panel dial office. I will describe here only two, the ones that were the most important over the breadth of panel office deployment and over the history of the conversion from manual to dial operation.

As elsewhere, there are a plethora of details, some great and some small, that I will not be mentioning.

5.2 The panel cordless “B” board

This is the most basic method of handing manual-to-panel calls.

Recall that in a manual system, for an inter-office call to another manual office, the “A” operator plugs the front cord into a trunk jack for an idle trunk to the destination office (a lamp at that jack being lit to show that the trunk is idle, and in fact is the one the operator should choose).

At the destination office, that trunk terminates in a cord at a "B" position, where a lamp for the cord lights to tell the operator that there is an incoming call on that trunk. The operator presses a key for that cord, connecting her telephone set to that cord and sending *order tone* back to the calling office.

The "A" operator says the desired station number. The "B" operator, using the plug on the cord, tests the line (on the nearest multiple jack for that number) for busy, and if it is not busy, plugs the cord into the jack. The incoming trunk circuit (which is also a special kind of cord circuit) rings the called line.

Now, if the number asked for by the calling subscriber is in another office but it is a panel dial office, the "A" operator proceeds in exactly the same way, plugging the front cord into a jack for the preferred trunk to the panel office. There the trunk terminates in two things:

- A selector on an incoming frame (just as if it had been a trunk from another panel office).
- A "trunk strip" (my term) on a *panel cordless "B" switchboard* at the panel office.

The cordless "B" switchboard is not a switchboard in the usual sense. It has no jack panel, and it has no cords (hence the name). It is more like a "desk", and had it been developed at a later era would probably have been called a "desk". Figure 10 shows a typical installation.

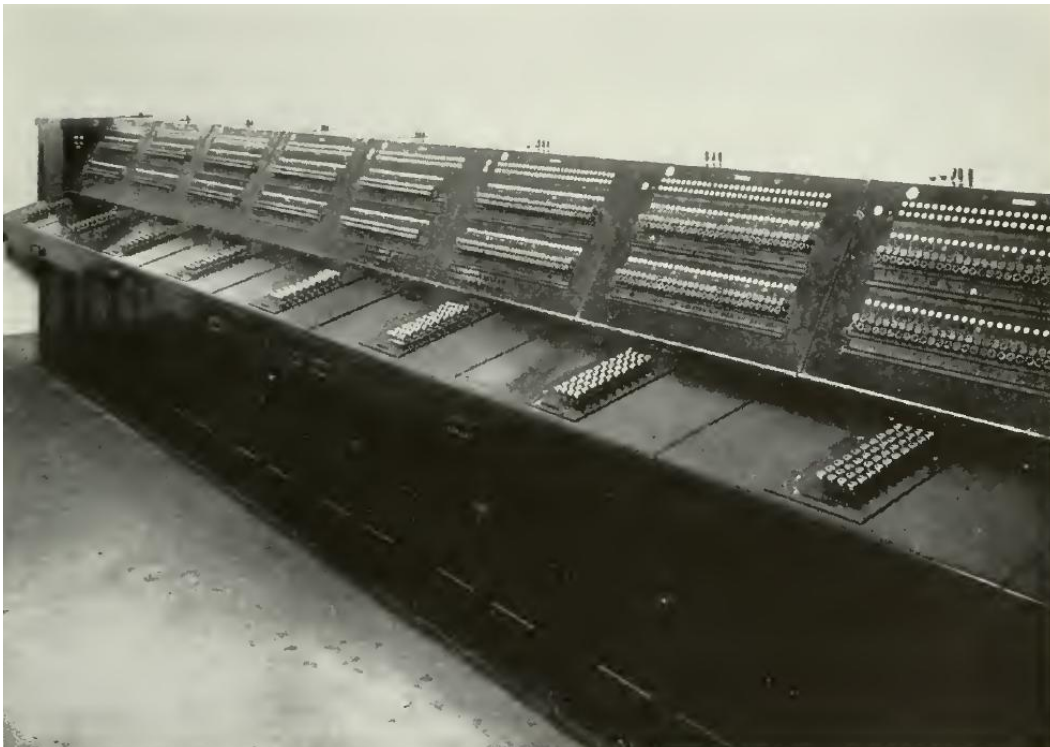


Figure 10. Panel system cordless "B" board

We see its critical operational features in figure 11.

The lower portion is a nearly horizontal work surface, essentially replacing the key shelf and cord shelf positions of a conventional (cord) "B board. The upper portion slopes mildly upward, and consists of a number of modules I call "trunk strips".

While a manual "B" switchboard position might have had up to 50 cords (each terminating an incoming trunk), all in a row from left to right, the panel cordless "B" switchboard position can have up to 60 "trunk strips", in two rows of up to 30. Thus this position can be rather more narrow than a manual "B" position, while still potentially providing for a greater number of trunks.

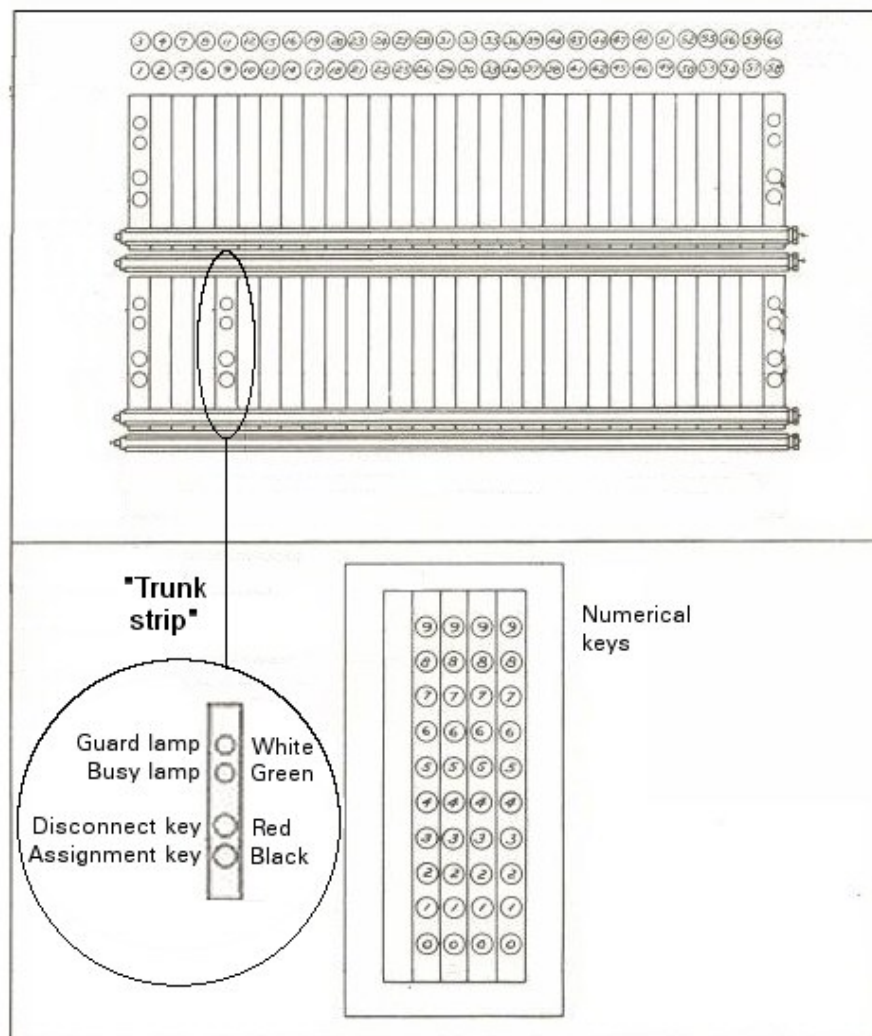


Figure 11. Panel cordless "B" position

It is now time to look at a block diagram of this system (figure 12).

We see the incoming trunk from the manual office terminating both on an incoming selector and on a "trunk strip" on the cordless "B" position. But it goes to a third place, a "B" sender link frame. This

consists of a number of "double-ended" links, implemented at both ends on panel selectors of a special type, one link for each cordless "B" position.

When the trunk is "seized" by the manual "A" operator plugging into its jack, the link for this "B" position has its trunk finder end find and connect to the incoming trunk, and its sender selector end find and connect to a "B" sender.

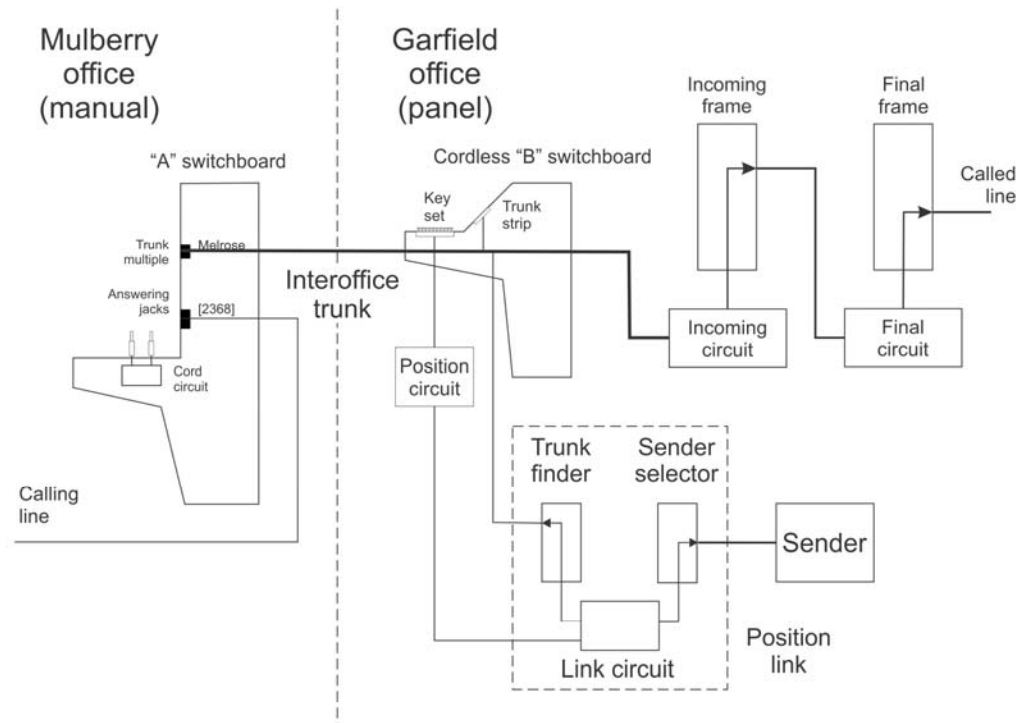


Figure 12. Panel cordless "B" switchboard system

The seizure of the trunk also causes the *guard lamp* (white) to light on the trunk strip. The "B" operator as soon as she can presses the *assignment* key on that trunk strip. This connects the "B" operator's telephone set to the trunk, and sends order tone back over the trunk to the originating office.

The "A" operator says the desired station number. The "B" operator enters the number (always four digits) on a set of keys. These are not in "keypad" form (that being a later development) but rather in "cash register" form, one strip of ten keys for each digit. Figure 13 shows the layout.

The depressed key in each digit strip remains locked down until all four digits have been entered and their settings sent to the sender, after which an electromagnet releases all the keys.

The four digits go directly to the position's sender link and through its sender selector end into the chosen sender. The sender then, using reverive pulsing in the usual way, sets the incoming and final

selectors to connect to the wanted line. The rest of the process proceeds in essentially the same way as for a call wholly in or between panel offices.

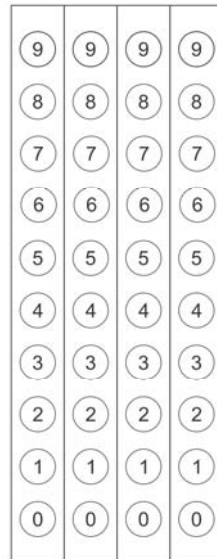


Figure 13. Cordless "B" board key set

The "B" operator's telephone set is disconnected from the trunk, both ends of the position's sender link go to their idle positions, and the sender is dismissed and retires to the "sender pool". The guard lamp (white) on the trunk strip goes out, and the busy lamp (green) lights.

If the call ends in the usual manner, with both parties hanging up, the "A" operator pulls down the cord circuit (thus releasing the trunk). No further attention is needed by the "B" operator. The incoming selector goes to its idle position, and the busy lamp on the trunk strip goes out.

Note that to the manual system "A" operator the operation is essentially indistinguishable from a call to another manual office.

5.3 The call distributing "B" switchboard

5.3.1 *A disadvantage of the cordless "B" switchboard system*

A disadvantage of the panel cordless "B" switchboard scheme (and the classical manual "B" switchboard system had always had this as well) is that a given interoffice trunk could only be handled by the specific "B" position where it appeared. Thus, the incoming traffic could not be spread over several or even all of the occupied "B" positions.

5.3.2 *The call distributing "B" switchboard system*

In the *call distributing "B" switchboard system*, this situation was greatly alleviated. We see it in block diagram form in figure 14.

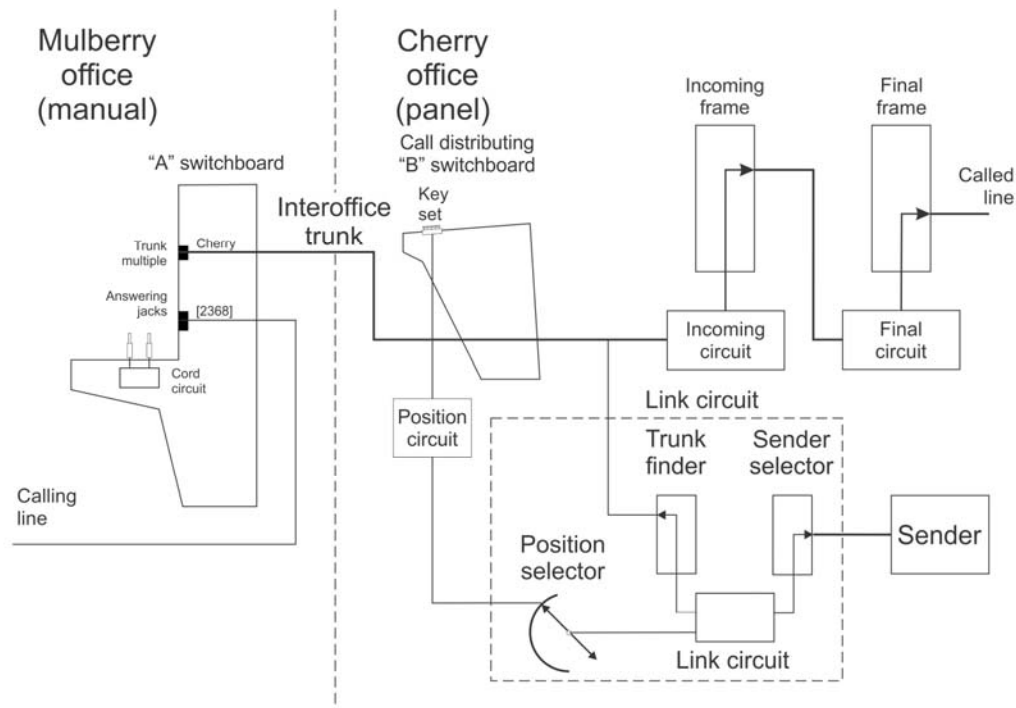


Figure 14. Call distributing "B" board system

Note that now the incoming trunk goes to an incoming selector and to a link circuit, but not to a "trunk strip" on the "B" position. There are no "per trunk" creatures on the switchboard.

Now the link circuit has a third "end", the position selector. This does not use a panel selector but rather a rotary stepping switch (often spoken of as a "200-type" or "206-type" selector). Its task is to bring into the picture, when a call arrives over an incoming trunk, a "B" position.

5.3.3 The call distributing "B" switchboard position

This position (again "desk-like" in configuration) is much simpler than the cordless "B" position we saw before, mainly in that it does not have any trunk strips. We see in figure 15 a little over two positions of a typical installation.



Figure 15. Panel system call distributing "B" board

The position has just a few lamps and some control keys that are rarely needed. Its central feature is a 10-key numerical entry *key set*, what we today might call a "key pad". But its layout is not what became familiar on "10-key" adding machines, or on "push button dialing" telephone sets (and those two were of course not the same). We see its layout on figure 16.



Figure 16. Call distributing "B" board key set

This key set layout was for many years used on the numeric input facilities (called, in fact, "dials") on many kinds of telephone switchboards and "desks". A great deal of human factors study went into the choice of this layout.

The overall pattern was meant to imply a squared-up “semicircle”, along which the operator’s eye could scan looking for the desired digit. The “0” was of course at the beginning, where it belonged. The designers avoided putting it at the end, a convention that would only have recognized the “illogical” situation on the rotary dial, where it had to be that way owing to the coding used in dial pulse sending of numbers.

The overall rectangular form factor facilitated integrating such a key set into, for example, the key shelves of various types of switchboard.

5.3.4 *Method of operation*

The overall concept of operation very much parallels that we saw for the panel cordless “B” board system.

As before, after the “B” position is brought into the connection, order tone is sent to the originating office and the “B” operator hears it as well, which alerts her that she will be hearing the “order” from the originating “A” operator (the four digits of the station number). After she hears the number, she keys it into her key set. Since the number of digits is always the same (4), after she has keyed the last digit her position is automatically disconnected from this connection and is now free to be assigned to a new incoming connection.

5.3.5 *DC key pulsing*

The transmission of the digits from the key set to the sender uses a signaling scheme with heavy and light current pulses over three conductors. This came to be known as *DC key pulsing* signaling. This concise circuitry facilitated the transmission of the digits through the position selector and sender selector to the sender.

The term has roots in the fact that, when digits were sent, especially by an operator, using a rotary dial (just as used at a station set), because the transmission was in the form of *pulses*, the operation came to be known as “pulsing”. As a result, any entry of digits in dial pulse form by an operator (or even their transmission over a trunk) came to be spoken of as “pulsing”. By extension, that term came to be applied to any entry of digits by an operator (or their transmission over a trunk), whether or not any “pulses” were really involved.

So in the cordless “B” board, where the operator enters digits with a key set, and the digits were sent using combinations of DC current values, the signaling scheme used eventually came to be known as *DC key pulsing*.

Another form of transmission of digits from a key set used only two conductors. There, DC currents of two values and two polarities were used on those conductors. This came to be widely used in long

distance switchboards working through collocated switching machines.

Nor surprisingly, the scheme used in the call distributing "B" switchboard came to be known as *3W DCKP* (3-wire DC key pulsing), while that used in long distance switchboards and the like came to be known as *2W DCKP* (2-wire DC key pulsing).

5.3.6 *A wonderful job*

Can you imagine what it must have been like to be an operator at a call distributing "B" board, where the entire job consisted of, every few seconds, hearing four digits spoken by a disembodied voice and keying them into a 10-key key set?

6 CALLS FROM A PANEL DIAL OFFICE TO A MANUAL OFFICE

6.1 Introduction

In this section we will learn how a call from a subscriber in a panel dial office is actually completed to a number in a manual office.

We learned earlier that when a city was being converted from manual operation to "dial" operation (with the panel dial system), there were provisions for the "name" of the destination office (whether dial or manual) to be dialed by a subscriber in a dial office, and also for the party letter (when used) to be included.

6.2 The panel call indicator (PCI) system

6.2.1 Introduction

The most widely used system of handling a call originated in a panel dial office for a number in a manual office was the *panel call indicator* (PCI) system.

6.2.2 The call indicator

This system required a number of "B" positions in each participating manual office to be modified. The most visible feature was the adding to the cord shelf of the "B" position a numerical display panel, called a *call indicator*. We see this in place in figure 17.



Figure 17. Panel call indicator at manual "B" position

This could display the basic numerical part of the destination number (4 digits; "4259" in the figure)); the "ten thousands" digit, used with numbers over 9999 in offices using switchboards that could accommodate up to 10,500 numbers (that leading digit would always be "1"); or (where used) the party letter, W, R, J, or M (that field is dark in the figure, as there was no party letter).

If there was neither a leading "1" nor a party letter, "0" was shown at the left (as we see in the picture) to make clear that there is no party letter that should be shown but might not be seen because of a lamp failure. (At one point in time, a "star" was shown rather than "0".)

Figure 18 shows the layout of the call indicator panel. All the digit markings are shown. In operation, only the applicable digits light up, as we saw in figure 17.

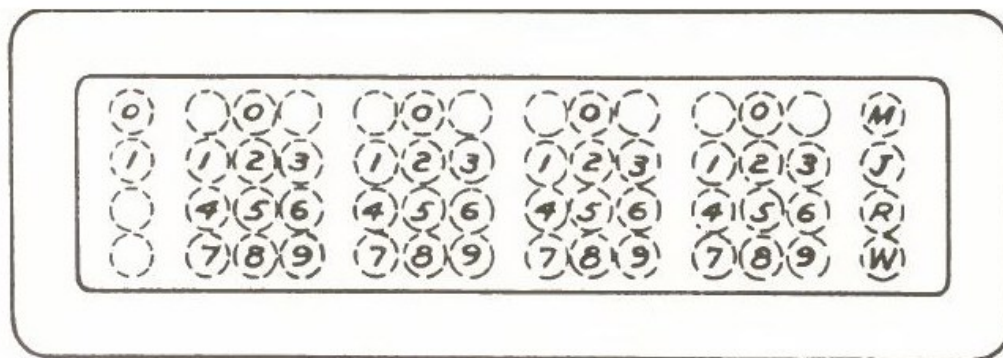


Figure 18. Call indicator panel

6.2.3 System architecture

Figure 19 shows in block diagram form the architecture of a call using this system.

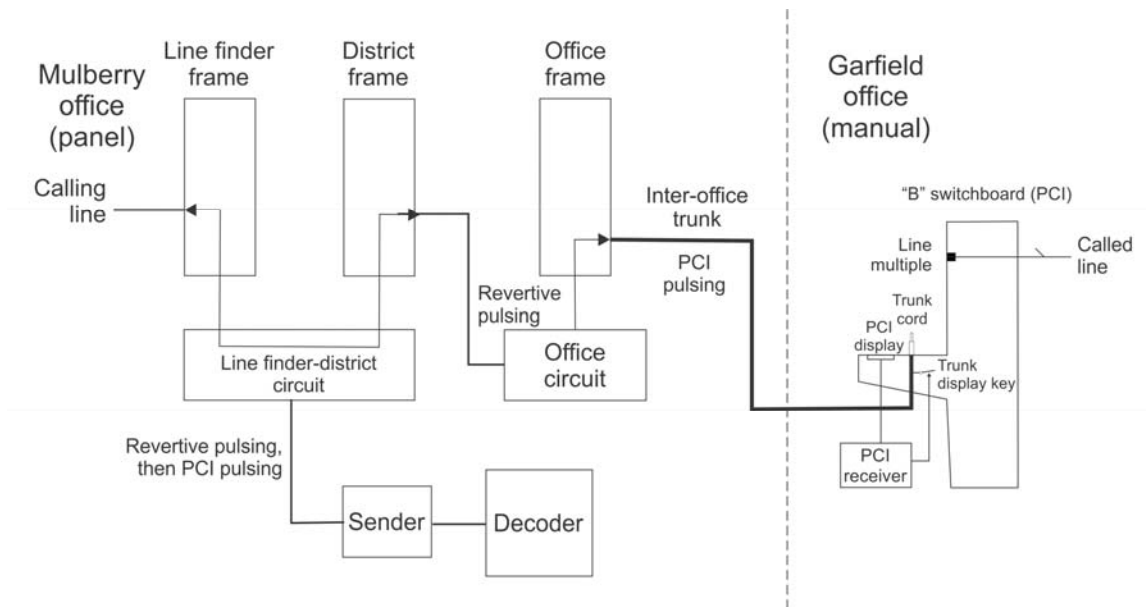


Figure 19. Panel-manual call via PCI

At the panel office, the sender receives and stores the digits dialed by the calling subscriber in the usual way. After the office code digits (2 or 3, depending on the numbering plan used in the city), the sender consults a decoder to find how to set the district and office selectors to reach a trunk to that office. In our case, that is a manual office, and the sender returns to the decoder, in addition to the setting information for the district and office selectors, an indication that the destination office is a manual one, to which we connect using the PCI system.

The trunk, just as in wholly-manual operation, goes to a trunk cord at a "B" position at the destination manual office.

In this situation, after the sender has sent the setting information for the district and office selectors, it sends the digits of the "station number" forward to the manual office, not using the revertive pulsing scheme used to send setting information for panel selectors, but in a wholly different "forward acting" signaling system, called *panel call indicator pulsing* (PCI pulsing). It will be described at length in section 7.

When the trunk is "seized" (when the office selector has connected to it), at the manual "B" board the *assigned* lamp for the trunk lights. The operator operates the *display* key for the trunk. This connects her position's PCI receiving circuitry to the trunk (the process is actually

rather complicated), and returns an indication to the sender at the originating office that it may send the station number by PCI pulsing.

When the entire string of digits has been received, the number is displayed on the PCI panel. The operator uses the trunk cord's plug to test the wanted line for busy (using the nearest multiple jack for that number) and if the line is not busy, plugs the trunk cord into the line jack. The rest of the story proceeds in the by now familiar way.

7 THE PCI SIGNALING SYSTEM

7.1 Introduction

When the concept of the call indicator manual "B" board for operation with panel systems was first introduced, the "obvious" approach to signaling as to use revertive pulsing just as used to control all of the selectors in a "fully mechanical" panel connection.

Of course, the revertive pulsing system is very much a creature of the panel selector design itself, and to use it to convey the station number to something that was not a panel selector would require this new kind of destination to mimic the operation of a panel selector.

In the original call indicator system, power-driven rotary sequence switches in the "call indicator receivers" at the manual "B" switchboard played this game. But the equipment was cumbersome, especially in a context where there were not motor drive arrangements for any other part of the central office equipment.

Additionally, the timing of the revertive pulsing system was based on the speed capabilities of panel selectors, but where there were not such creatures to be operated, conceptually a much faster signaling system could be used.

Accordingly, the designers of the panel system soon created a wholly different, forward-acting system for conveying the called station number from a panel office to the call indicator at a manual "B" board. The whole arrangement was initially called the *relay call indicator* (RCI) system, because one of its earmarks was the use of relays, rather than sequence-switch based panel selector emulators, to receive the digits.

Shortly, however, the fascination with the relay implementation faded, and the whole scheme came to be known as the *panel call indicator* (PCI) system. That moniker was also applied to its unique signaling system.

7.2 Principles

7.2.1 *The transmission*

In the context we are considering, the entire “transmission” consists of 5 digits. The five digits in the transmission are designated TH, H, T, U, and STA. Those designations represent “thousands”, “hundreds”, “tens”, “units”, and “station”, respectively. In certain cases they in fact carry the corresponding digit of the station number, but in some cases not. More on that shortly.

Each digit is sent as a sequence of four bit intervals (“pulses”). The bit values are drawn from an alphabet of four “symbols”, named in terms of the physical current through the fundamental circuit: *Open* (no current), *light positive*, *light negative*, and *heavy negative*. (A 5th symbol, *heavy positive*, is used only in a “trailer” to indicate the end of the entire transmission.) These names are fairly self-explanatory.

Only two symbols are possible in each pulse position, one set of two (open and light positive) in pulse positions 1 and 2, and a second set of two (light negative and heavy negative) in pulse positions 2 and 4. Thus the receiving end can readily keep track of where it is in the sequence of pulses. The four pulses for one digit follow immediately after the four pulses for the prior digit. The overall transmission proper comprises 20 contiguous pulses.

The nominal pulse length is 6.875 ms, so each digit takes about 0.275 s to send. The entire message proper lasts 1.375 s, but there is sometimes a “trailer” comprising one pulse of open and one of heavy positive, making the overall time a little over 1.5 s.

For all digits but TH, the four bits have weights (in the order of transmission) of 1, 2, 4, and 5, a special binary coding widely used in the panel system for the storage of decimal digits on relays. For the TH digit, the four bits normally have weights (in the order of transmission) of 2, 4, 8, and 1.

Figure 20 shows this binary encoding, and as well shows the possible symbol values, for each kind of pulse position, to represent binary “0” and “1”.

	Bit pulse position			
	1	2	3	4
	Bit weighting			
TH digit	2	4	8	1
Other digits	1	2	4	5
Bit values	Bit line coding*			
0	O	-	O	-
1	+	=	+	=

- * Notation mine (but much like that often seen).
- O Open (no current)
- + Light positive
- Light negative
- = Heavy negative (symbol evocative of "minus minus")

Figure 20. PCI digit encoding

We note that in pulse positions 2 and 4 (of every digit), the line state (symbol) will always be negative (light or heavy); in pulse positions 1 and 3 (of every digit), the line state (symbol) will never be negative. It is this that allows the receiving end to easily know where we are in the transmission without requiring any "time consciousness"..

The designations "positive" and "negative" are defined in terms of the voltage on the ring compared to the tip. No "positive" voltage (with respect to ground) is actually used, only a negative voltage (-48 V with respect to ground). To produce a "negative" pulse, that negative voltage is placed on the ring, through an appropriate resistance, and the tip is grounded. To produce a "positive" pulse, that negative voltage is placed on the tip, through an appropriate resistance, and the ring is grounded.

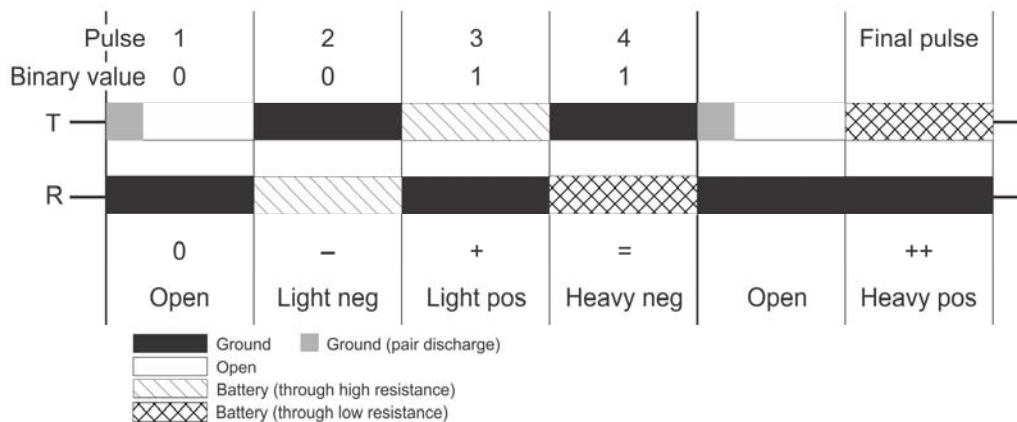


Figure 21. PCI pulsing—the physical reality

Figure 21 shows this physical reality.

The example is the digit whose binary representation is 0011 (for most digits representing "9").

Also seen here is the singular symbol, *heavy positive*. It is sent (with one pulse period of no current before it) to mark the end of the entire transmission. Actually, the PCI receiver does not need this, as the transmission proper always comprises the same number of pulses (20). But it is sometimes needed in another part of the system.

We note that when moving to a pulse period in which the symbol sent is *open*, for which the ring is grounded and the tip open, for about the first 1/4 of the pulse period the tip is grounded as well. This is to discharge the charge on the capacitance of the fundamental circuit pair from the prior symbol. That charge could inappropriately keep the receiving relays (see section 7.2.2) operated when in fact for the open symbol all should be released.

7.2.2 Reception

At the PCI receiver, a set of three relays is typically used to interpret the electrical conditions on the fundamental circuit. One, a "polar" (polarity-sensitive) relay, determines whether the current through the circuit is positive or negative. (If it is "none", this relay retains its prior position, but in that event its state is not significant.) A second relay ("sensitive") will operate if there is any current in the circuit, whether positive or negative, light or heavy. A third relay ("marginal") has a carefully adjusted operating current, and will only operate for a heavy current (positive or negative). Of the eight possible states of these three relays, five of them are mapped to the symbols used in the PCI code.

One might wonder, for a transmission in which the first pulse of the first digit is "open" (binary 0), which of itself is "invisible", how does the receiver know that the transmission has even begun? The answer is that the second pulse will be "visible" (being either light negative or heavy negative), so the receiver will note its value and, as an aside, conclude that the first pulse, which was not "seen", must have been "open", and record it as such.

7.3 Different dialed digit cases

The use of the PCI encoding system we are discussing here only carries the "station number" portion of the called telephone number, the part that follows the central office code. The central office code is not included in the PCI transmission since the transmission is over a trunk that already leads to the relevant destination central office.

But there can be three different situations with regard to the dialed station number. And the format of the PCI transmission varies among them.

- Case 1. The station number has only 4 digits. STA is sent first, followed by TH, H, T, and U.
- Case 2. The station number has four base digits and a “party letter” (5 digits dialed). STA is sent first, followed by TH, H, T, and U.
- Case 3. The station number is over 9999 (5 digits dialed). TH is sent first, followed by H, T, U, and STA. (In this case, the TH digit carries the ten-thousands digit of the number, the H digit the thousands digit, and so forth.)

How does the sender know which case it is dealing with?

If:

- five digits were dialed, and
- the first digit is “1”, and
- the second digit is “0”, and
- the third digit is less than 5

then case 3 is presumed (valid number over 9999, meaning not over 10499) In that case, STA is sent last, and there is a special consideration with regard to TH (which carries the first digit), which we will learn of shortly. STA carries the last digit dialed, and is encoded in the “normal” way.

Otherwise,

- if four digits were dialed, case 1 is assumed, or
- if five digits were dialed, case 2 is assumed.

In either of these cases, STA is sent first. If we have case 1, then the encoded value of STA is “0” (nothing was dialed into the corresponding register of the sender, and 0 is essentially the default, and is encoded as found).

If we have case 2, and the dialed value is 5, 6, 7, or 9 (representing the party letters J, M, R, and W, respectively), then the STA digit is encoded as 4, 5, 2, or 3 respectively (representing the respective party letters in the PCI encoding). Any other dialed value is encoded as “0”.

In figure 22, we see the implications of this for valid dialed numbers of each case.

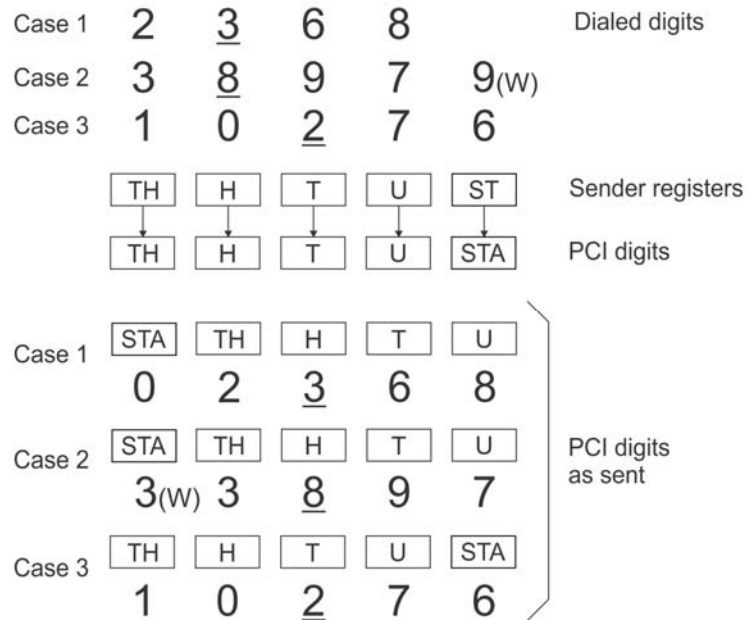


Figure 22. The travel of the dialed digits

Note that in case 1, no dialed digit reaches the sender ST register, so that register contains its initialized value, 0.

We see that each PCI digit is invariably created from the content of its similarly-named sender register.

I have underlined the hundreds digit of each dialed number for ease in keeping track of them as a landmark for the “alignment” of the entire number. And we see that this digit does not end up in a consistent place in the sender registers (and thus in the PCI digits). In cases 1 and 2 the hundreds digit ends up in the H (hundreds) register/PCI digit. But in case 3, the hundreds digit ends up in the T (tens) register/PCI digit.

This portends a challenge for the PCI receiver, where we would like the digits of the dialed number to appear consistently in the various fields of the display panel.

Of course, the receiver could do this, but it would mean some kind of shifting of the received digits in one case, not easily done with the relay technology used. It can't do this “on the fly”, since the receiver would have to be able to first be able to discern what case was in force, which would require it to examine the TH, H, and STA digits.

So we deal with this matter at the sender. As we see in the lower portion of the figure, for cases 1 and 3 we send the STA digit first, and for case 3 we send it last.

The result is that, with respect to the string of digits seen by the receiver, the digits of the numeric part of the station number are in consistent locations. We can note this in particular for the hundreds digits, still seen underlined, which always travels in the third digit transmitted.

7.4 The complete encoding table

With this background of the three cases in hand we can now understand some of the subtleties on the complete PCI code table, seen in figure 23.

TH		STA			H, T, U	Line code			
Sent 2nd	Sent 1st	4- digit ¹	Party letter ¹	Over 9999 ²		Pulse 1	Pulse 2	Pulse 3	Pulse 4
0		0		0	0	0	-	0	-
2				1	1	+	-	0	-
4			W	2	2	0	=	0	-
6			R	3	3	+	=	0	-
8			J	4	4	0	-	+	-
1			M	5	5	0	-	0	=
3	1			6	6	+	-	0	=
5				7	7	0	=	0	=
7				8	8	+	=	0	=
9				9	9	0	-	+	=

Notes:

1. STA sent first (before TH) Invalid value for this case
2. STA sent last (after U); TH is thus sent first.

Figure 23. PCI code table

We note that the encoding of the TH digit (when sent in its “normal” position, as the 2nd digit) is different from the other numeric digits. (I alluded to this earlier.) No, I don’t know why.

Then, when TH is sent 1st (in case 3, with a dialed station number over 9999) it has a different encoding yet. We will see the purpose of this shortly.⁵

⁵ I have never seen this mentioned, much less discussed, in any of the today-available documents on this system., I only discovered it through tedious reverse engineering from circuit drawings in various extensive training documents.

7.5 At the receiver

Now we will look at the receiver. The notation here is a bit complicated. We will start, in figure 24, with case 1 (where only 4 digits of the station number have been dialed).

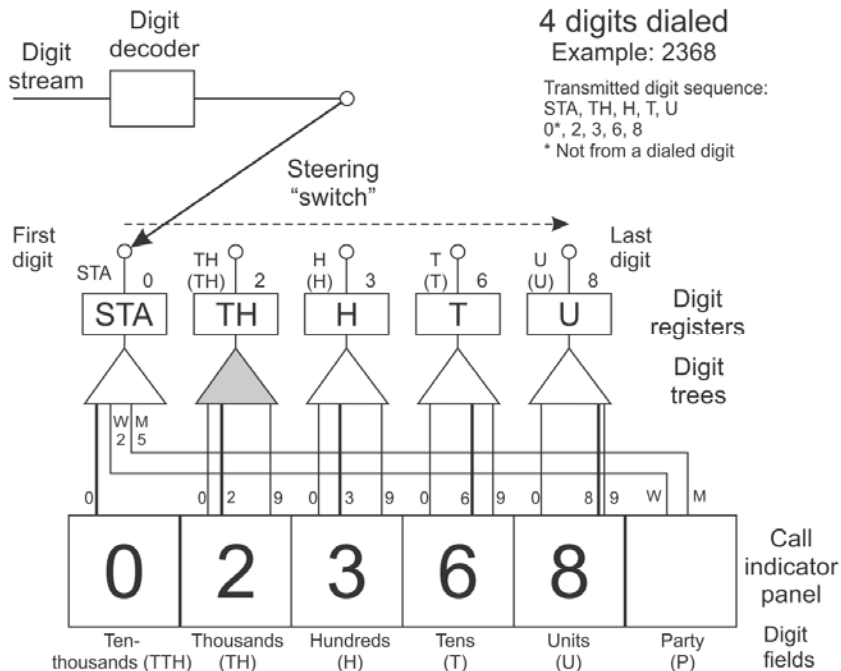


Figure 24. PCI receiver—case 1

Here I use the symbol for a rotary switch (but with the contacts in a straight line, for graphic convenience) as a metaphor for the relay "steering" chain that delivers the incoming PCI digits (after they have been decoded from the "line code") into five digit registers, always in the sequence the digits are received (and there will always be five digits in the PCI message).

But we saw earlier that the PCI digits are sent in two different sequences, and each one does not always carry the same dialed digit. So above each register (to the left) we have (for the applicable case) the designation of the PCI digit that ends up in that register and (in parentheses) the identifier of the dialed digit that digit carries. Above the register to the right we see the actual numeric value (for this example) that ends up in that register.

Each register feeds a "tree" that grounds one of a number of leads going to indicator lamps in the appropriate field of the call indicator panel. The light lines show the range of leads that can be grounded (always 0 through 9); the heavy line shows the lead grounded in this example.

We saw above that the TH digits has a different encoding than the other numeric digits. Thus the decoder for that digit is different from

those for the other numeric digits. The TH tree is lightly shaded to remind us that it is different.

We see that the dialed digits (“2368”) show up where they should. The STA digit carries the value that is in the sender’s ST register, but since only four digits are dialed in this case, no digit reaches that register, and so that register holds its default value, 0, which is carried by the PCI STA digit and into the STA register of the PCI receiver. The STA tree, not surprisingly, grounds its 0 lead, so the 0 lamp is lit in the leftmost field of the call indicator panel. That tells the “B” operator that there is neither a party letter nor a ten-thousands digit for this number.

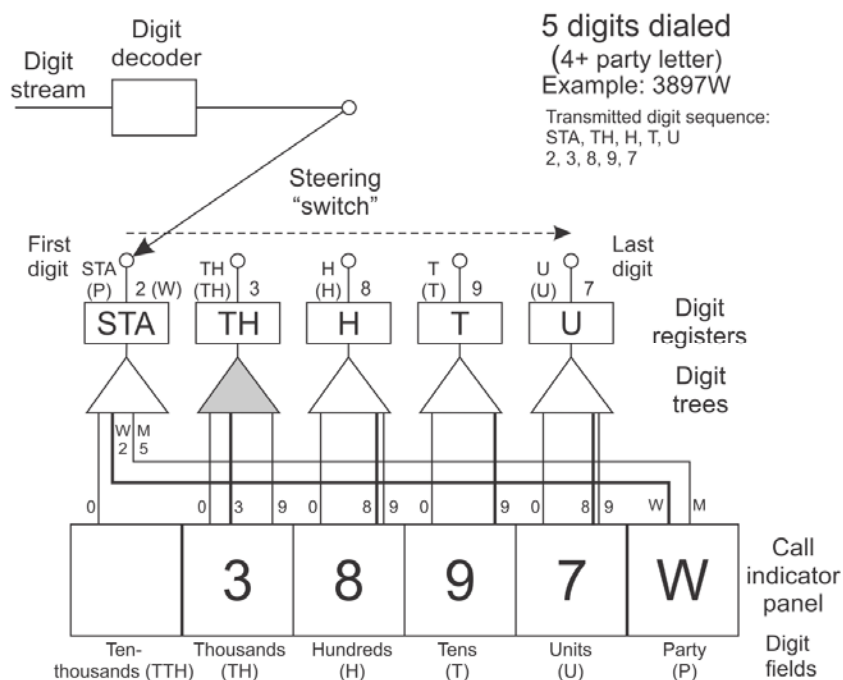


Figure 25. PCI receiver—case 2

In figure 25, we see this same presentation for case 2, in which five digits are dialed, four numeric digits and a party letter.

The story here is much like that for case 1, except that here a fifth digit (representing the party letter) was dialed, ending up in the sender ST register, from which it goes to the PCI STA digit and into the STA register of the receiver. In this case, that digit was 2, representing the party letter “W”, and we see that this lead from the tree goes over to the Party field, where it lights the “W” lamp.

Now, in figure 26, we see the action for case 3, where a number over 9999 was dialed (again, five digits).

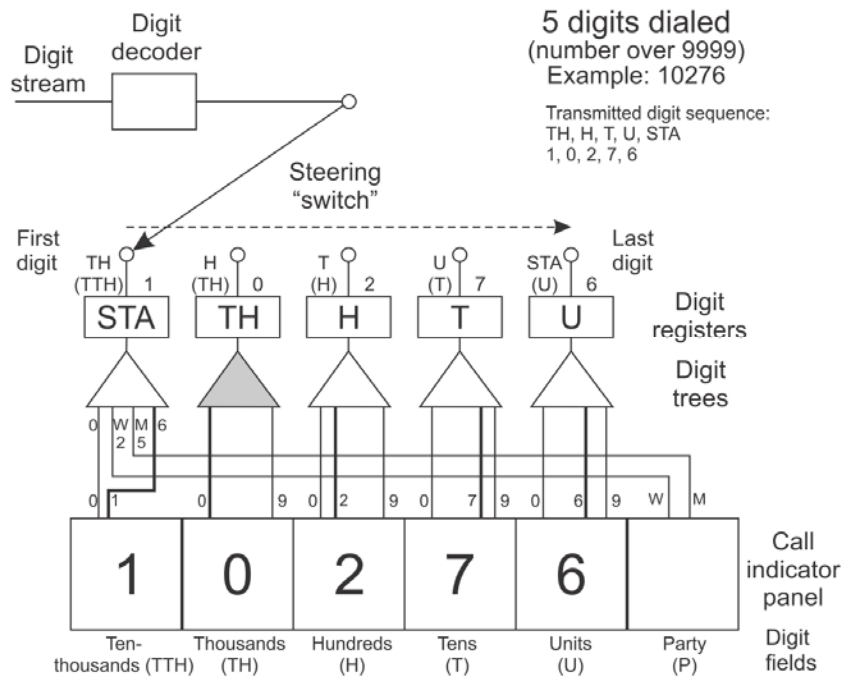


Figure 26. PCI receiver—case 3

Here the STA digit is not sent first, so the TH digit is first, but in this case it actually carries the ten-thousands digit of the dialed station number. In case 3, that digit is always 1. But there is a problem.

The TH digit uses a special encoding, but the STA portion of the receiver uses a "normal" digit tree. So the encoding that 1 would have in the TH digit, 0001, would be interpreted by that tree as "5". But 5 would be a valid station letter ("M"), and so would end up lighting the "M" lamp on the party field.

But here is where that really odd alternate encoding of the TH digit, used when that digit is sent first (as in this case), comes in. Under that encoding, the code for the value "1" is 1001. The STA tree would interpret that as "6", which of course is not a valid station letter. But the "6" output of the STA tree is actually "bent back" and connected to the "1" lamp of the ten-thousands field. So that digit displays correctly.

There is another potential problem to be averted. Here, because the STA digit is not sent before the TH digit, the receiver TH register holds the PCI H digit, which carries the dialed thousands digit. A problem would seem to be that the tree on the TH register is set up for the special TH digit encoding, but it now holds the H digit, which uses the "normal" encoding. So it would seem as if this digit would be incorrectly decoded on its way to the thousands lamp field.

But that isn't really a problem. In case 3, the value of the dialed thousands digit is always 0, and both encodings are the same for that

value! So the output of the TH tree in this case is always the "0" lead, which goes to the "0" lamp in the thousands field of the display panel, which is always correct.

I could not make this up!

7.6 The end of transmission "tag"

After all four digits are sent (20 pulses altogether) there is one pulse period of *open* and then one *heavy positive* pulse (a symbol used nowhere else).

The PCI receiving circuit does not need this, as the number of pulses in the entire transmission is fixed. But (in certain call handling scenarios) the office selector needs to know when PCI pulsing is finished so it can go into the proper state to participate in the completed connection, and it would be complex for it to keep track of the series of pulses in the PCI transmission. It can very simply recognize the heavy positive pulse with a single special relay (*polar marginal* type).

8 PCI SIGNALING—LIFE BEYOND THE CALL INDICATOR

In 1937 the Bell Telephone System introduced into actual service a new switching system based on a dramatically new switching element, the crossbar switch. This machine was called the Crossbar Switching System (later the Number 1 Crossbar Switching System). It expanded the concept of "common control" such that the element higher in the hierarchy than the sender (the *marker*) actually made the connections within the office. The system had greater "intelligence" than the panel system, and could make decisions as to alternate routing of calls, make second attempts when a first attempt to establish a connection had failed, and so forth.

It was of course natural that working from a crossbar office to a panel office would use revertive pulsing for the numerical signaling. And in fact operation from a panel office to a crossbar office used revertive signaling (which required the incoming senders at the crossbar office to emulate the behavior of panel selectors).

Shortly there was introduced a new *tandem switching system* (an intermediate switching office) using the crossbar principle (known just as the Crossbar Tandem switching system). For working from a No. 1 Crossbar office to a Crossbar Tandem office, it was decided to

normally use PCI pulsing, which was faster than revertive and fact required a "less fussy" arrangement at the receiving end.⁶

Thus the PCI signaling system, whose original "correspondents" (manual offices) had mostly passed into history, got a new life. And over the years, PCI signaling found many new applications

Although the transmission of numerical information between central offices eventually came to be done by a tone coding system known as *multifrequency pulsing*, the PCI system had a long and respected life for that task.

9 THE CALL ANNOUNCER SYSTEM

A second approach to the handling of traffic from a subscriber served by a panel office to a number in a manual office was called the *call announcer* system. Here, no modification (*e.g.*, the addition of call indicator equipment) was needed at the "'B" positions of the manual offices, a really attractive feature.

Rather, at the point when, in basic manual operation, the "A" operator would speak the station number to the "B" operator over the trunk, now the panel sender "speaks" the station number to the "B" operator over the fundamental circuit and the trunk.

This digit speaking capability of the senders had its heart in a machine that provided repeated recitations of all ten possible digits and the four party letters. For each such utterance there was a metal drum, in a continuously-rotating shaft) that had clamped around its rim a strip of 35-mm sound-format motion picture film, with the sound track hanging over the edge of the drum. In one revolution of the shaft, the utterance was repeated four times on the sound track. (Actually, each drum had two strips of film, one projecting over each edge.)

For each of these film strips (two per drum) there was a sound head (conceptually identical to that used in a sound motion picture projector⁷), with an associated amplifier chain (the first part of the needed gain was provide by an amplifier in this machine itself, and the latter part in the supporting equipment in a relay rack).⁸

⁶ In fact, this modus operandi was earlier used for a panel office working to a manual office through a manual tandem office or through a panel sender tandem office.

⁷ We note that this form of sound recording was principally developed, in its original context of "sound movies", by a predecessor of Bell Telephone Laboratories.

⁸ The whole machine was very parallel to the one developed to provide on a mechanized basis the "time" service once provided by most telephone companies.

In figure 27, we see a portion of the drum array, four of the eight drums (the eighth drum was for "expansion"), with their covers removed.

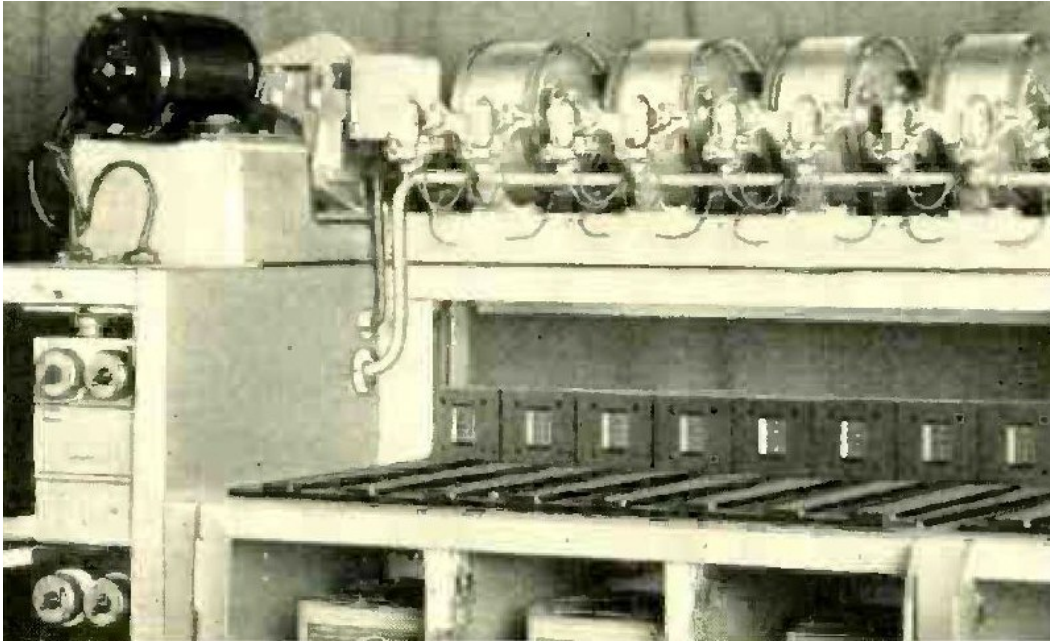


Figure 27. Call announcer (four drums seen, covers off)

The 14 streams of repeated utterances, with an associated timing signal, were distributed over a "bus" system to all of the panel senders.

If the decoder reported to the sender that the office code was for an office over which call announcer operation was used, the sender would then, at the appropriate point in time, and when the "B" operator was ready (indicated by an electrical signal over the trunk—the sender did not have to "listen" for order tone), the sender would pick up the needed sequence of four utterances, one every 0.35 second, except that between the hundred and tens digit one interval was skipped, producing the pause in stating the number that all telephone operators were taught to use (and many other telephone folk, as well as those involved in other telecommunication activities, picked up as well).⁹

One might have thought that the call announcer scheme would have displaced the call indicator scheme, removing the costly and complex

⁹ Any of those who have spoken to me over the telephone and had me give you the telephone number of some person or office will have heard that: "The number there is five-zero-five, (pause) nine-two-one, (pause) two-three (pause) six-eight."

need to make extensive modifications at many "B" positions at every manual office when dial switching was being introduced in a city.

But countering this was that the call announcer equipment itself was costly and "fussy", and it would have had to be included in every new panel office installed so long as working to manual offices was still in the picture. As the "dial" conversion progressed, there would be fewer manual offices in operation, and more panel offices, so the economic advantages of the call announcer approach would shift in the wrong direction over time.

The result was that call announcer equipment was, for all practical purposes, only installed in tandem offices (intermediate switching offices¹⁰), where there would be a greater "bang for the buck". On a call from a panel office to a manual office, when the route was through an intermediate panel tandem office, the originating office would send the entire number (destination central office code and all) to the tandem office by PCI pulsing¹¹, and then the station number (and party letter, if applicable) would be generated as speech by the sender, working from by the call announcer equipment, and sent to the destination "B" board (which was of the conventional type).

Then, calls that might otherwise have been routed over direct trunks to the destination manual office could instead be "artificially" routed through the tandem office to take advantage of the call announcer mode of operation.

The call announcer system could only be installed in the more-elaborate of two types of panel tandem office, called a *panel sender tandem office*, and in fact only a few of those were every installed, only in a few very large cities.

In any case, the call announcer system was not a "permanent hit", and its use declined over the years. By 1960, it had essentially fallen completely out of use.

¹⁰ The name comes from the fact that, to reach a certain destination office, the call was switched twice, once at the originating office (to the intermediate office) and then again at the intermediate office (to the destination office). This was spoken of (reasonably) as *tandem switching*, and as a result, the intermediate switching offices became classified as *tandem offices*.

¹¹ The provisions for including the central office code in the PCI transmission are straightforward, but were not discussed in the section on the PCI system.

10 ISSUE RECORD

Issue 4 (this issue), June 18, 2018. Added additional information about PCI encoding.

Issue 3, June 15, 2018. Extensive revisions.

Issue 2, June 9, 2018. Extensive revisions.

Issue 1, May 12, 2018. Initial released issue

11 ACKNOWLEDGEMENTS

Special thanks go to R.E. Hersey of Bell Telephone Laboratories, whose monumental tutorial on the Panel Dial System (done in 1928-1929 as the "course notes" for a BTL "out of hours" training course) was a major reference for me as I prepared this article.

Also valuable is a scan of what appears to be "C. Ryan's" copy of an extensive training course book on the panel dial system of the "BCO" type (dated February, 1955), complete with extensive annotations. And the same for a comparable book on the "GCO" type of panel office.

And thanks to "neverether" for uploading these scans and many other valuable documents from the collection of the Connections Museum, Seattle, to the Internet Archive.

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