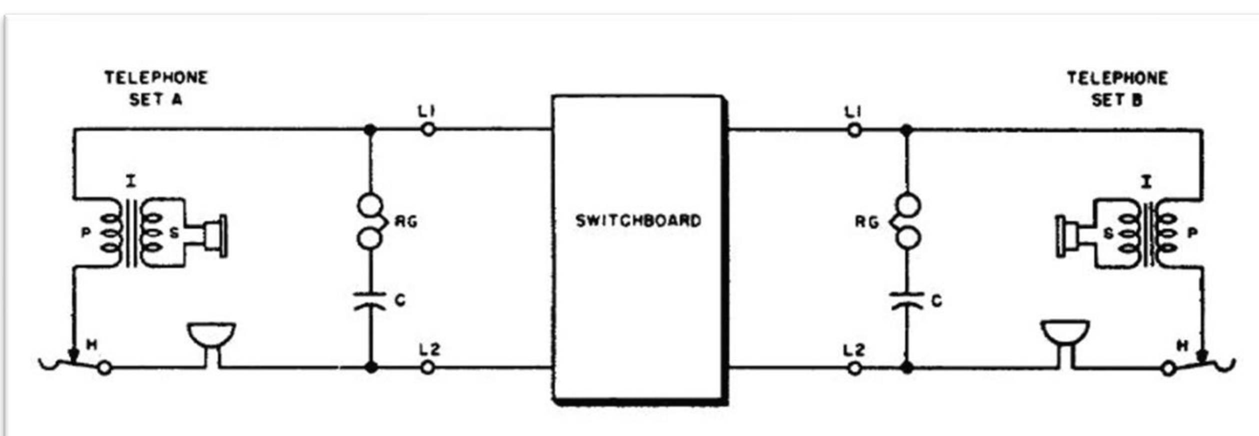
October 22, 2021

This particular blog entry is both a stream-of-consciousness and an exercise in pseudocode. My youngest tells me that I think in a patois of BASIC, C++, HyperCard, and FORTRAN with a little Assembly Language thrown in for good measure. There is no intent to deceive or confuse, just a modicum of confusion and perhaps some early-onset senility at work.

Loop Start and Some Early Thoughts on Automation for the Switchboard:

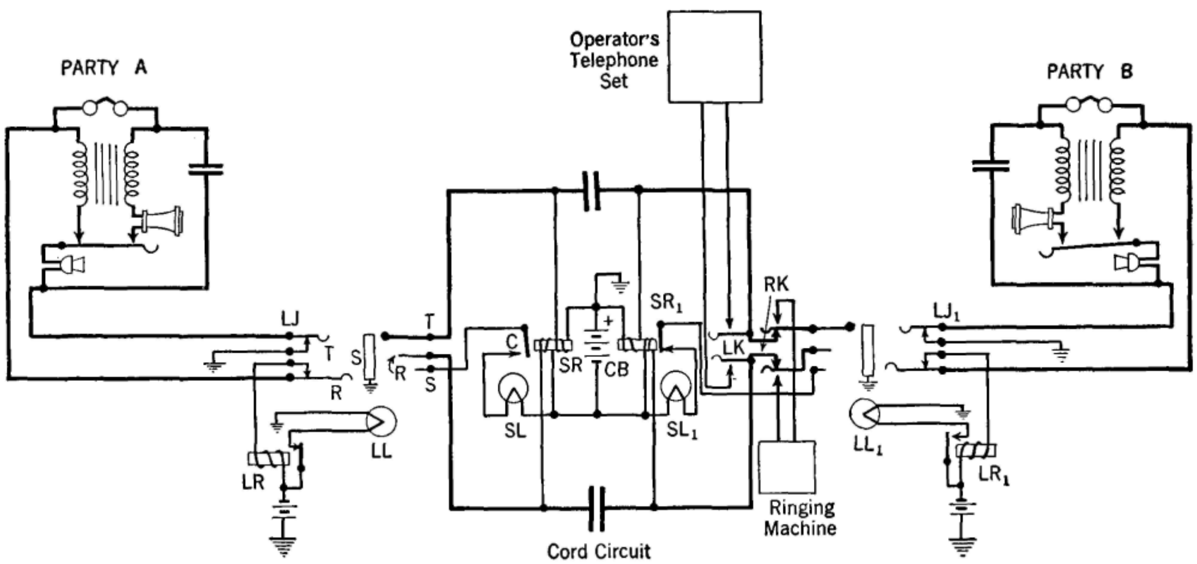
For our basic common-battery telephone circuit, the idle condition (on hook) is established by a lack of DC continuity on the local loop. As shown in the following diagram, the capacitor (C) prevents DC current through the ringer. When the hook switch (H) is open, there's no current path through either the receiver or the induction coil connected to the transmitter.

For an incoming call, the switchboard signals the telephone ringer by placing AC current on the line at a frequency of 20-30 Hz and a nominal voltage of around 100 volts (96 if using the typical Western Electric dynamo or motor-generator circuits.) Answering the call closes the hook switch (H), completing the DC circuit and operating a line relay in the switchboard. Operating the line relay serves two critical functions – first, it disconnects the line from the source of ringing current (preventing potential damage to the speech circuit from the ringing voltage), and second it provides some indication that the line is in-use for the switchboard operator.



In the case of an outgoing call, the line relay closes when the hook switch is closed and a lamp on the switchboard illuminates to indicate that the line is requesting service. Optionally, a buzzer may also sound to get the operator's attention. At this point, the operator selects a cord circuit and plugs it into the jack for the line requesting service.

This is where the cord circuit on a telephone switchboard differs from a patch cord in most other applications. Rather than simply provide a metallic pathway from connection A to connection B, the cord circuit is the heart and soul of the switchboard, allowing interaction with the operator (or, as the Bell System manuals insist, the "Attendant."), control of ringing, line supervision, and even a bypass function for night service.



When the operator plugs the cord circuit into the jack of a line that has just gone off-hook, the tip of the plug breaks an internal connection in the jack. This extinguishes the lamp and allows the line relay (LR) to open, silencing the buzzer on the switchboard. Loop current is applied to the coil of the supervision relay (NC) ensuring that the lamp at SL remains extinguished until the calling party (Party A) hangs up the telephone. The operator manually operates the contacts at LK (listening key) to connect her telephone set to the calling party. "Number Please?" was the normal interrogative used to determine what connection the calling party required. Assuming that the called party is not busy, the operator plugs the opposite side of the cord circuit into the jack of the called party and signals an incoming call using contacts (RK) that connect the AC output of the ringing machine to the line of the called party. When the called party answers, the operator drops out of the conversation by opening contacts LK. She occasionally checks the status of lamps SL and SL1 as they will illuminate when the respective party hangs up. If either party requires additional operator intervention, they may "flash" the hook switch on their telephone to likewise cause a blinking indication on the supervisory lights (SL or SL1.) Circumstances where additional operator intervention might be required include adding additional parties to the conversation, making notification to some third party, or setting up things like conference calls or a long-distance connection.

A third set of contacts (not shown on the diagram) allow the operator to establish "night service" to a particular set of telephones. This takes the bulk of the cord circuit out of the equation and also bypasses the local batteries, allowing direct connection to a CO line and outgoing calls when the switchboard is unattended.

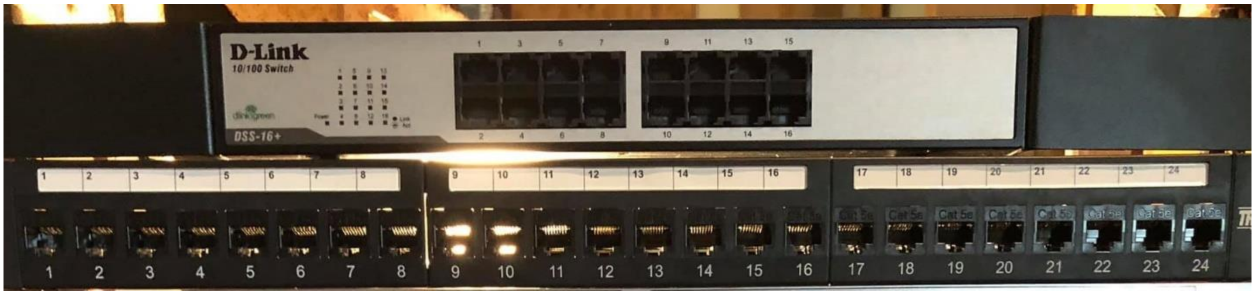
So that's how the system is supposed to work, given the original design and specifications for the switchboard. That was great for 1927 when Western Electric first marketed this switchboard, but I need to do things a little bit differently.

Updating the Switchboard for A Modern Workflow:

The first big difference between the typical use case in 1927 and today is that MANY of the connections made by this switchboard are not humans talking to other humans. Instead, at least in terms of total traffic, most of the connections are actually machines talking to other machines.

We'll start with the ADSL internet connection. This requires a full-time connection to the CO line and bandwidth protection for the uplink and downlink. The hardware elements here are the modem/router and the DSL filters that need to be installed between "regular" telephone equipment and the telephone line. From this point, our communication lines are divided between these "regular" telephone circuits and our 100-Base-T Ethernet Connections that utilize the digital subscriber line. Since the DSL modem handles things like DHCP, internet routing, a firewall, and port forwarding; we can connect most of our network devices directly to the ethernet. The modem/router only has three ports, so we need to add an un-managed ethernet switch to the mix. A patch panel allows for manual re-configuration of the network on an as-needed basis, and this will take up two "rack units" or approximately 3.5 inches of the 13 inches of vertical space on the switchboard frame.

At the moment, several devices can be connected to the Ethernet patch bay and thence to the Ethernet switch for seamless network connectivity.



First, we need a port to connect the DSL modem/router to the rest of the system. Second, we're also using a VOIP appliance to connect the switchboard to Google Voice. This gives us a second "landline," independent of the local telephone company, and a bit more flexible in the event we drop the local dial-tone service and go with "Fiber to the Premises" in the near future. Network printers have always been a luxury I enjoy – particularly when I'm able to print from devices other than the desktop computer; like my iPad and iPhone. Some of my older "Vintage" PC's can also easily connect themselves to the internet using a simple ethernet connection. These include my Macintosh LC-475, Macintosh SE, DEC 3000 Server, Vax 6000, and Vaxstation. Since several of these machines are located in a remote workshop / storage container, it's simpler just to run an ethernet connection using a "short haul" modem.

In a previous post, I've also alluded to the audio patch pays that have replaced the OEM patch panels from 1927. While I admire both the form and function of the originals, they've suffered from internal corrosion and simple wear over the years. Since I'm adapting the nominal 12" rack spacing of the original switchboard to a 19" rackmount spacing for the Ethernet gear, I can also easily upgrade the patch bays with modern audio gear. These particular patch panels have switch-selectable normalization, which will come in handy as I put other switching mechanisms in place. "Normalized" patch bays allow a standard configuration to exist without the use of any patch cables, but re-configuring the system "on the fly" is possible by sampling patching in a new connection.

In the "Normalized" condition, the circuit connected (at the rear) to the top jack is automatically patched to the circuit connected (at the rear) to the bottom jack. In this way, the "Normal" state of connectivity is achieved without using any patch cords. By plugging in a patch cord to the "A" (top) jack, you can divert that signal to another location or device, using a simple patch cable. By plugging in a patch cord to the “B” jack, you can send the signal along two parallel pathways, both to the “standard” destination and two a separate destination. In this case, the patch panel acts as a signal splitter. For instance, if I plug a patch cable into the B (lower) jack and connect that patch cable to a tape recorder, I maintain the “normalized” connection to the output device but also connect the tape recorder in parallel.

With this in mind, I can set a number of “default” connections through the switchboard that do not require any patch cables to function. This applies to the “top” patch-bay

Patch Bay Circuit No:	Source Circuit:	Normalized Connection:	Normalized Partner:
1	CO Line	15	Desk Phone
2	VOIP	16	Cordless Phone
3	DC Loop 1A	--	--
4	DC Loop 1B	--	--
5	DC Loop 2A	--	--
6	DC Loop 2B	--	--
7	Ringdown 1A	17	Bat-Phone
8	Ringdown 1B	18	Workshop
9	Ringdown 2A	19	Linux Machine
10	Ringdown 2B	20	Silent 700 TTY
11	Metallic Pair 1A	--	--
12	Metallic Pair 1B	--	--
13	Metallic Pair 2A	--	--
14	Metallic Pair 2B	--	--
15	Desk Phone	--	--
16	Cordless Phone	--	--
17	Bat-Phone	--	--
18	Workshop	--	--
19	Linux Machine	--	--
20	Silent 700 TTY	--	--
21	Macintosh	--	--
22	Dec 3000	--	--
23	Windows	--	--
24	Fax Machine	--	--

The careful reader will note that this particular configuration is somewhat different than the one presented on October 15 when I started wiring the jack field. I expect this to evolve even more as I complete additional circuits and start putting more equipment online. In particular, I'd like to add more vintage computer hardware and some amateur radio equipment. My ultimate goal is also to have a few working cord circuits for manual switching, and at least a few circuits that allow for automatic (or perhaps semiautomatic) switching. The second patch panel will hopefully accommodate this expansion.

Automatic Switching and Operation of the PABX:

Although the earliest automatic telephone exchanges used a "Strowger" or step-by-step switching fabric that used stepper relays, I'm thinking that a slightly older matrix-switch technology might be simpler to wire and implement, given the amount of time remaining in this year's Retrochallenge and the hardware resources at my disposal.

The telephone company referred to this as a "crossbar" switch, and it was the third type of telephone exchange implemented in North America following the "Step-by-Step" and "Panel Offices." The Connections Museum in Seattle has several examples of switching equipment (including all of the above types) and has produced a series of YouTube videos demonstrating their theories of operation.

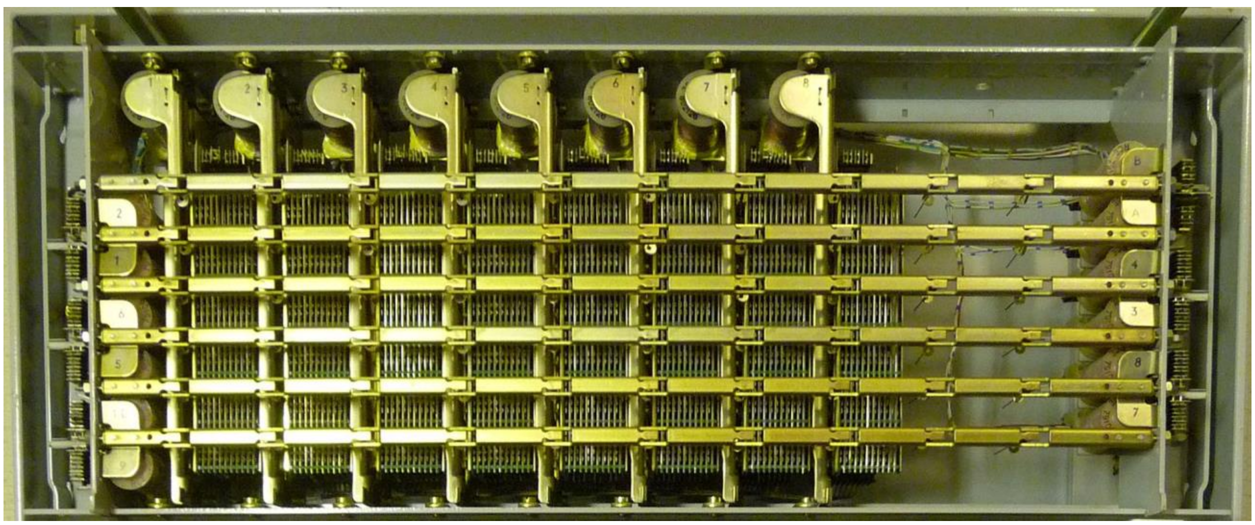
The current URL for the Connections Museum is: Connections Museum Seattle | The Telecommunications History Group, Inc (telcomhistory.org)

Their YouTube channel can be found at: Connections Museum - YouTube

Crossbar switches were actually used in telegraph exchanges long before the invention of the telephone. The switch consisted of horizontal and vertical bus-bars made of brass with holes drilled at each potential intersection. To complete a connection, a brass pin was inserted at the point where the desired input intersected with the desired output.

The example switch shown at the bottom of the last page is a five row by four column (5 x 4) matrix switch with 20 possible switching points. Unlike a conventional Strowger or panel switch, a crossbar switch can connect any input to any output, and can also accommodate one-to-many connections.

Whereas the original telegraphic crossbar switches were purely manual in operation and could accommodate a limited number of conductors in a given circuit, the matrix switches used by the Bell System were magnetically operated and could easily accommodate 2, 4, or 6 wire circuits used in local, long-distance, and special-purpose (videophone, broadcast networks, radio control links, etc.) circuits.



The above example of a mechanical crossbar switch (used in a small PBX) implements a 6 x 8 matrix switch using a series of vertical and horizontal selector magnets to open or close up to 48 switching points of four-wire circuits.

One of my YouTube heroes, Hicken65, has produced the definitive video explanation of how these crossbar switches worked, and this video can be found at:

https://youtu.be/myqHoVcHkkA

The crossbar switch that I would like to implement for this Retrochallenge can be a good deal simpler than those used by the Bell System – especially since I don't care too much about line supervision, tolls, or the connection to other telephone exchanges. I can simplify my switching fabric, and using one of my vintage microcomputers, provide a common-control system with much less complexity than those used by the telephone company back in the bad-old-days.

Since most of the telephone circuits implemented in this telephone circuits are basic two-wire circuits, I can use relatively inexpensive reed-relays for the switching elements. Each DPST reed-relay is controlled by a single S/R flipflop based on two TTL outputs from the microprocessor. If I construct a 12 x 12 matrix switch, I only need 288 bits (36 bytes) of output to manage any number of simultaneous connections within the switch.

I guess the first step will be sitting down with LogiSim to lay-out my circuit and develop the software needed to handle routine switching tasks.

-- *Paleoferrosaurus*