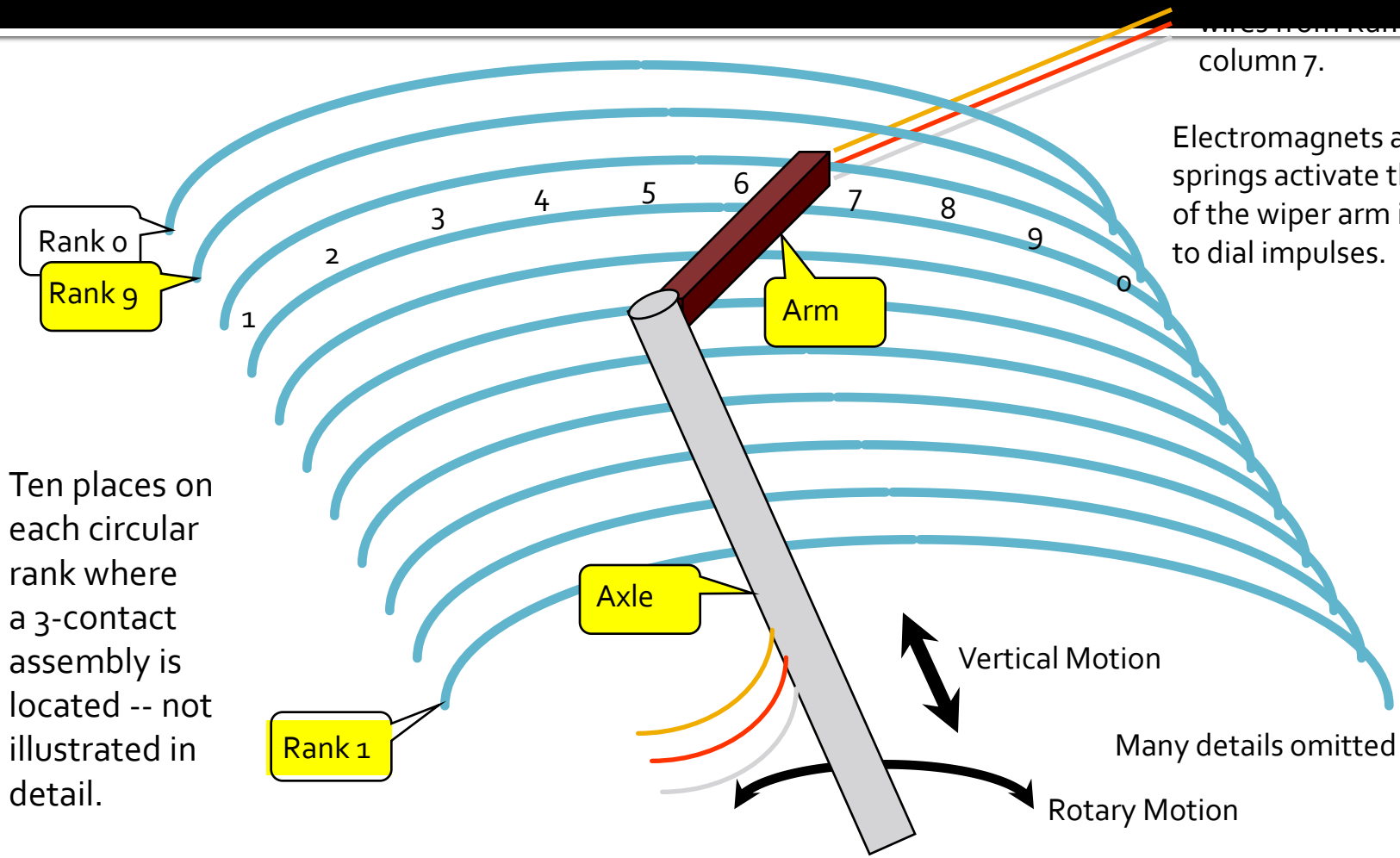
TSN: Lecture 13
Stepper Diagram for Switch

Topics Covered

- Schematic Stepper Diagram
- Stepper Switching
- Selector Switches
- Significant Properties of Stepper Switches
- Undesirable Stepper Properties
- Common Control
- Electronic Switches

Schematic Stepper Diagram



column 7.

Electromagnets and springs activate the motions of the wiper arm in response to dial impulses.

Ten places on each circular rank where a 3-contact assembly is located -- not illustrated in detail.

Stepper Switching

- Strowger switches evolved into an assembly with a movable wiper switch "inlet" and 100 "outlets" (wire pairs with "sleeve" wire)
  - 10 contact pairs arranged in a horizontal arc, selected by rotating the wiper switch arm. (Also a third "sleeve" wire in addition)
  - 10 such horizontal arc sub-assemblies stacked and selected via vertical motion of the axle (actually the first motion is vertical)
  - Single-motion (rotation only) switch assemblies were also used
- "Line Finder" switch (mostly single motion) acts as input concentrator ("inverse" of selector action)
  - Wiper arm contacts act as the single outlet
  - Line finder single-motion stepper typically wired to 10 subscriber lines, selects a line when that line goes off-hook
    - Stepper starts stepping from line to line when any of the 10 lines go off hook, then stops when correct "off-hook" line is "found"
  - analogous to operator responding to buzzer and light
  - Multiple line finders wired in parallel to the same 10 telephone sets analogous to multiple operator stations with each having access to the same subscriber sockets.
    - Number of simultaneous originating conversations limited to the number of line finder switches connected to those lines. Ten line finders wired to ten subscribers is "non-blocking" with regard to line finders. (Overall system may still block at later stages…)

Selector Switches

- Line finder outlet goes through a transformer "cord circuit"
  - Connected to dial-tone generator until the first dialed digit.
  - Then the circuit is switched through a chain of two-motion selector stepper switches, with a "motion" for each digit. Each burst of impulses (dialed digit) produces a rotary or vertical motion constituting the next stage of the wiper arm selection process
  - Dial pulses from rotary dial (typically 10 impulses per second, each one approximately 60 millisec current OFF and 40 ms current ON) are passed *around* the cord circuit by special electro-mechanical relays
    - A relay employs magnetically operated switch contacts, so that current ON/OFF status in the contacts mimics the current ON/OFF status in the wire coil causing the magnetic action.
  - Special "slow release" relays hold the line finder so the 60 ms OFF intervals do not cause a disconnection
- After turning and releasing the telephone set rotary dial from an angle labeled with a specific number, the returning rotation of the dial to its normal position produces 1 to 10 current impulses
  - Simultaneously, an "Off-normal" switch contact in the telephone set temporarily short-circuits earphone so clicking is not heard
    - Following a stage of selection motion, a slow release relay is automatically connected into that line to prevent further disturbance of that particular selection due to the succeeding bursts of dialing impulses

Incidental Information

- Rotary dial label "0" represents 10 impulses everywhere in the world (except Sweden, where the dial is labeled 0, 1, 2…9)
  - However, touch-tone dials in Sweden use the same digit labels for DTMF tones as the world standard.
  - Impulsive signaling must be converted at international boundaries to Swedish telephone system. But symbolic signaling (binary digit codes used in CCS7, etc.) is the same everywhere.
- Alphabetic dial labels (2="ABC", 3="DEF", etc.) were introduced in New York City in ~1923 when subscribers complained about "long" 5 digit directory numbers.
  - Alphabetic dial labels were introduced in US, Canada, UK, France, Scandinavia and USSR (three cities only) but not all the same:
    - Examples: Q on French dial, Russian (Cyrillic А В… Г …Ф) letters in Moscow, Leningrad, Odessa,
  - Considered an obstacle to direct international dialing, alphabetic exchange names were purged from telephone directories in 1960s by international agreement.
    - The "anti-digit dialing league" and other grass roots groups in the US opposed all-digit directories in the 1960s.
  - Letter labels still appear on the dial in most of these named countries. Business users highly value so-called "Anagram" numbers such as 1-800-FLOWERS, or 1-800-NORSTAR, 1-800-AMERICAn, etc.

Significant Properties of Stepper Switches

- To add more traffic capacity, install more line finders and more selector switches
  - This increases parallel path (traffic) capacity through the switch, since multiple last stage selectors lead to the same destination lines.
    - Only one last stage selector can connect at a given time. The sleeve wire is also connected to each corresponding position on the selectors and is used to divert the call to a busy signal generator if the sleeve voltage is ON for that destination line and a call is attempted while destination line is busy.
    - A non-blocking Strowger step switch assembly would require 100 last stage selector switches connected to 100 destination telephone lines, and similar replication of parallel paths all the way to the originating lines (line finders, earlier stepper stages, etc.).
- This automatically increases the call processing capacity (BHCA) of the switch as well
  - Each selector is both a traffic path and a part of the digit processing hardware
  - When there is a traffic path available to the destination, there is also the hardware to respond to the succeeding dialed digits.
    - A stepper switch assembly "automatically" has enough call processing capability if it has adequate traffic path capacity

Stepper Properties

- Stepper switches are extremely reliable overall
  - Because of parallel path capability through a large stepper switch, the failure rate of these switches (when properly maintained) is very good
    - Failures affecting only *one user* amount to only about 1 hour cumulative in 20 years
    - Failure of the *entire* switch is only 1 or 2 minutes in 20 years, and when this occurs it is mostly due to power supply or other aspects of the system
- Steppers can be adapted to many improvements
  - Touch-tone dialing (by means of a tone-to-pulse converter)
  - Computer control has been adapted to steppers to make advanced features available (such as call waiting, 3-way conference, etc.)
  - Unfortunately, basic reliability, power consumption and size not improved!
- Inter-switch signaling between stepper switches requires electrical transmission of dialing impulses
  - conversion between modern digital signaling (common channel 7) and impulse switching is feasible, but slow acting
    - European version of SS7 signaling allows transmission of one dialed digit at a time, but North American (ANSI) version does not send dialed number onward until the "last" digit is dialed.
  - several earlier "electronic" but non-digital switching systems still used electromechanical switching (small relays) and analog transmission (example: No. 1 ESS), but digital computer central control or stored program control

Undesirable Stepper Properties

- High maintenance
  - '"Gross Motion" or "Large Motion" wiping contacts
    - Require lubrication, cleaning, adjustment, etc.
  - Susceptible to corrosion from sparking, air pollution (such as SO_2 in the air, etc.)
- Slow mechanical operation
  - Even when tone-to-pulse converters support Touch-tone dialing
- Slow signaling
  - Can't take full advantage of CCS7 and other electronic signaling systems
- Big and bulky
  - Digital switches use ~1/50th the floor space of steppers; ~1/10th the floor space of crossbar switches.

Some Other Historical Electro-Mechanical Switches

- Panel
  - A huge mechanical "monster" switch using continuously running electric motors and electrically operated clutches to move wipers vertically and horizontally on a rectangular wall panel of contacts. A high maintenance problem.
- Crossbar
  - An assembly of rocking contacts attached to vertical and horizontal rotating actuator axles. Because of relatively small motion and compact size, this was the heir apparent to the stepper switch in both North America and Europe until electronic switching appeared.
- X-Y
  - A horizontally platform with rows and columns of contacts with wipers actuated by magnetic coils. Gross motion problems, but more compact than Strowger design.
- Rotary
  - Similar to X-Y switch, but platforms had contacts arranged in semi-circles of increasing radius. More compact than Stepper, but same gross motion problems.
- Multi-relay
  - Rocking contact motion, but still rather complex and difficult to maintain.

The last 3 were mainly used by "independent" telcos in North America. All here except Crossbar and Multi-relay were "gross motion" switches.

Common Control

- Many of these electro-mechanical designs had separate relay assemblies to count ("decode") the dial impulses, completely separate from the switching portion of the system. These so-called "common control" portions were analogous to the computer control in a digital switch.
- Once the desired destination directory number was decoded, it was "translated" by special purpose wired logic devices
  - One method for this was to use magnetic core memory of a special wired type (not addressable RAM like modern computer memory)
  - The equipment numbers resulting from the translation were used to select a path through the switching part of the system.
- The result of the "translation" was a code designating the proper bay, shelf, and switch outlet wire for the internal destination calls, or the proper outgoing trunk group for outgoing (other switch) calls. The first non-busy channel in a trunk group was selected by an appropriate special outgoing trunk switch.
- These systems first demonstrated the need for provisioning separately both sufficient call processing capacity (BHCA) and also sufficient switching capacity (Erlangs)

Electronic Switches

- ESS No. 1: Electronic but not Digital!
  - Computer control/stored program control (SPC)
  - Analog Relay switching, using sealed contact reed switches
- Most of the design problems for high reliability were addressed in this design.
  - Duplicated processors, etc.
- ESS No. 4: Fully Digital but Trunks Only
  - When designed (1960s-70s) the cost of A/D conversion (CODECs) on each subscriber line was seen as prohibitive
  - Depended on T-1 channel banks at distant ends of trunk groups for A/D (analog/digital) conversion
  - 4 ESS is a transit or tandem switch, not a central office or end office
    - 4 ESS has only T-1 links at its ports (no telephone sets except for a few test telephones)
- Above are all Lucent (then AT&T) products. Competitors had similar designs shortly after or almost contemporaneously. In that era Western Electric (manufacturing division of AT&T) only sold products to the Bell System operating companies, and was required to license all its patents as one result of an earlier anti-trust settlement.