Telephones and POTS Signalling

This lecture describes the subscriber signaling on the PSTN: the signalling between the telephone and the CO.
After this lecture you should be able to describe and recognize the waveform or impedance changes used in telephone signalling for: line seizure, pulse and DTMF dialing, ringing, and basic call-progress tones (dial tone, ringback, busy).

Regulations

Unlike many other areas of telecommunications, governments have set technical standards for telephony equipment.

In the US, CFR 47 (FCC Regulations) Part 68, also published as TIA-968, specifies terminal equipment (telephones, modems, etc.) interoperability requirements such as connectors, impedances, signal levels and frequencies to ensure telephones and other devices from different manufacturers can be connected to the PSTN.

In Canada, Industry Canada sets similar standards in regulation CS-03, which is based in large part on TIA-968.

Telephone Schematic

The diagram below shows a simplified diagram of a telephone set.

Exercise 1: Draw the diagram of the telephone set described below.

When the phone is on-hook the ringer is connected across the line through a capacitor. Thus the phone appears as an open circuit at DC but AC current can flow through the ringer to ring the phone.

When the phone is taken off-hook, the "hook switch" allows current to flow through the transmitter and receiver. The varying resistance of the transmitter (microphone) causes the current to vary at the audio frequency. This time-varying current causes the corresponding sound the be reproduced at both the near and far ends of the loop.

In an actual phone there is a network called a hybrid that provides isolation between the transmitter and receiver.

The hook switch may also disconnect the ringer to avoid loading the voice circuit and to avoid "tinkle" due to dial pulses.

Some phones use pulse dialing to transmit the called number to the CO. The dialer breaks the loop current to encode the number as described below. The dialer also shorts out the transmitter and receiver to avoid distorting the pulses or causing annoying 'clicks' to be heard in the receiver.

Telephone Signalling

Signalling between the subscriber and CO can use four techniques:

- the subscriber can switch the loop current off or on to indicate that the receiver is on- or off-hook;
- the subscriber can interrupt the loop momentarily to dial a number
- the CO can place a low-frequency (20 Hz), high-voltage (80 VAC) ringing signal across the pair
- the CO can put audio-frequency (1-2 kHz) low-voltage (-9 dBm) tones on the loop current to report the state of the call

Current Signalling

The CO supplies a loop voltage of -48 VDC from lead-acid battery (nominally (4x6) cells x2 volts). The voltage on the tip lead is 0V and on the ring is -48V relative to ground.

The phone line is "seized" by completing the tip and ring circuit. This is called "loop start".

There are current-limiting resistors in the CO of 400 to 800 ohms (can be set depending on the loop length). The phone itself has a resistance of 100 to 400 ohms.

The loop current when the phone goes off-hook will depend on the resistance of the loop and the phone. Typical off-hook currents are 20-120 mA. The CO has minimum threshold for detecting off-hook current, on the order of 6 to 25 mA.

Exercise 2: Assuming a zero-length loop and CO current-limiting resistors of 400 ohms and phone resistance of 200 ohms, what is the loop current? What are the voltages relative

to ground assuming the CO resistance is split into two 200 ohm resistors?

Exercise 3: If the battery voltage is 48V and the loop current is 48 μA, what is the loop resistance? Is the phone on-hook or off-hook? What if the loop current is 48 mA?

The DC resistance of a 24-gauge loop is about 52 ohms per kft but will vary with the gauge.

Exercise 4: Assume the CO and telephone in the above example are now operating over a 15kft (about 5km) 24-gauge loop. What is the loop current?

Pulse Dialing

To dial a number using pulses, the loop current is interrupted at a rate of 10 pulses per second with a minimum gap between digits of 400–900ms. The open/close ratio is 60 to 66%. A pause of several seconds before the called number is finished causes the call to be released.

The timing of the pulses was designed to drive electromechanical switches and is enforced by a mechanical clutch mechanism that controls the speed at which the dial can turn (in both directions).

DTMF Dialing

For DTMF signalling, two tones are transmitted, one at a lower frequency (697, 770, 852 or 941 Hz) and one at a higher frequency between (1209, 1339, 1447 or 1633 Hz). The frequency tolerance is $\pm$1.5%. The minimum tone duration is 50 ms with a 50 ms pause between digits.

Exercise 5: What is the maximum number of DTMF digits that could be sent in the time it takes to dial a '5' and wait until the start of the next digit?

The high-frequency tones are sent at a level of -4 to -9 dBm. The lower-frequency tones are sent at a level about 2 dB lower.

Signal levels on telephone circuits are often given in dBm under the assumption that the impedance level is 600 ohms (although it often isn't).

Exercise 6: What is the amplitude of a -6 dBm tone?

Ringing

In North America the ringing waveform is 20Hz at approximately 86 V (voltage depends on loop length) with a 2 s on, 4 s off cadence.

The ringer is capacitively coupled so it does not draw current at DC. The AC ringing voltage causes the ringer to sound, but the DC (average) current is zero.

When the phone goes off-hook, the line is connected in series with the transmitter/receiver and the CO detects the unbalanced current flow.

The ringer also has to be disconnected when the phone is off-hook so that it does not distort speech and it has to be disconnected when pulse dialing so that the ringer doesn't "tinkle".

DTMF signalling has various advantages: faster dialing, lower signalling voltages, and the digits can be transmitted end-to-end.

Call Progress Tones

The CO generates tones that the subscriber can hear and interpret as indicating the state of the call. The following definitions are taken verbatim from the Wikipedia articles:

- dial tone is a continuous tone having frequencies of 350 and 440 Hz at a level of −13 dBm
- ringback tone is defined as comprising frequencies of 440 and 480 Hz at a level of −19 dBm and a cadence of 2 seconds ON and 4 seconds OFF
- busy tone is defined as having frequency components of 480 and 620 Hz at a level of −24 dBm and a cadence of half a second ON and half a second OFF
- reorder tone, also called "fast busy" tone, contains the same frequency components as busy tone at a similar level but with a cadence of 0.25 of a second on and 0.25 of a second off;