Line Signalling Fundamentals

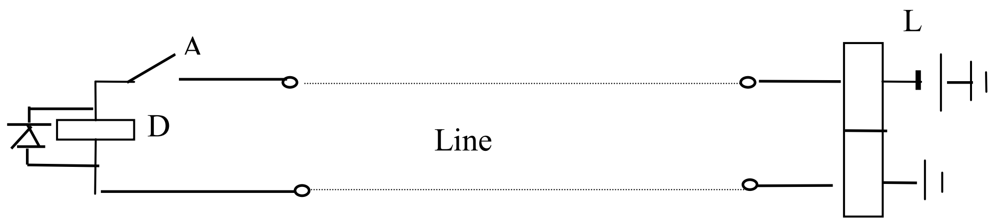
Introduction

This document refers to the types of signalling provided by and large by the PRX in its various forms across the range of delivered systems. Some of the concepts are generic while others are specific to particular administrations.

Loop Signalling

As the name suggests the signalling is carried out over a looped circuit consisting of two signalling wires. In the PRX this type of signalling was referred to as Hook Signalling, i.e. the type of signalling expected from lifting and replacing a telephone receiver. At the terminating end of the circuit there is a battery feed on one wire and an earth connexion on the other. To begin signalling the originating end simply has to form a loop to complete the circuit.

The simple circuit below shows the basic components for a loop signalling device.



Relay A is closed by action elsewhere in the circuit and the line loop is formed from earth from the lower coil of relay L in the terminating set via the line and through the diode short circuiting relay D. Relay L will now operate and the loop is 'seized' Once relay L is operated further processing can take place. Call build-up information can be passed over the circuit either by loop-disconnect signals (rotary dial) or by some other in-band signalling such as MF2. On call answer the line is reversed from the terminal end thus transposing the positions of the earth and battery feed. This back biases the diode on the originating set and allows relay D to operate signalling call answer to the outgoing link. This process is called supervision which relates originally to operator circuits where the operator would be supervising the call progress. Relay D operating will start call charging at the outgoing set.

Additional functionality can be inserted into the two wire loop. The Post Office included some or all of the following features into their trunk and junction circuits at various times:

1. Operator hold
2. Coin and Fee Checking signals
3. Metering Over Junction (MOJ)
4. Backward busy

Operator Hold

This is an inherent feature in all UK systems and stems from the days of manual switching. On emergency calls (999) it has been deemed that the calling subscriber shall remain connected to the manual board until the operator chooses to release the call. This is so that the call could be traced in cases where the identity of the calling number was unknown or unverifiable (through the Trunk Offer circuits for example). This has been variously implemented depending on the other features required simultaneously as follows:

- By providing backward line reversal after forward clear
- Using 48v positive battery signalling over one line wire
- Using 'shifted battery' that is, replacing the -48v feed with -100v and earth by -48v

Coin and Fee Checking (CFC)

The Post Office introduced post-payment coin boxes in 1959 concurrent with the introduction of Subscriber Trunk Dialling (STD). These boxes delivered signals to a special relay set in the local exchange which in turn could be controlled by the operator to open and shut the coin slots allowing insertion and recognition of coins. Signals were repeated over junction circuits from the operator by the use of 48v positive battery signal pulses. These signals were interpreted by the outgoing circuit and repeated to the CFC relay set.

Metering Over Junction (MOJ)

When loop-disconnect signalling was used to connect local exchanges to Register-Translator Centres (RTC's) it was necessary to be able to repeat the metering rate applied at the time of the call to the calling subscriber's meter. These signals used the tried and tested method of line reversal but as such signals might be very frequent (up to 1 a second for international calls) there was an issue of noise being generated in the line due to the spikes formed by the rapid charging and discharging of the line due to the reversals of current flow. This was solved in two ways:

1. By the inclusion of LC filters in the line reversal circuit or
2. By progressively reducing the line current before the line polarity reversal and then increasing it back again on normal polarity restoration

The former method allowed for faster metering rates to be applied and generally was favoured although the second method was cheaper to implement.

Backward busy

On some circuits it was possible to detect backward busy. During the idle time a high resistance relay was applied across the line to check the presence or not of battery and earth from the terminating end. In the event of a line break due to faults or deliberate busying from the far end the relay would release and busy the local relay set.

When all four of the above requirements were implemented in a single relay set then the circuitry became complex indeed.

Further signalling features using such things as ringing currents were used in applications of loop disconnect circuits interfacing with the Post Office rural switches the Unit Automatic eXchange (UAX) systems. Some of these applications were very specific to the UAX world and not in general use in interconnections between director or non-director exchanges. Consequently some of the features outlined above were modified to work under such circumstances.

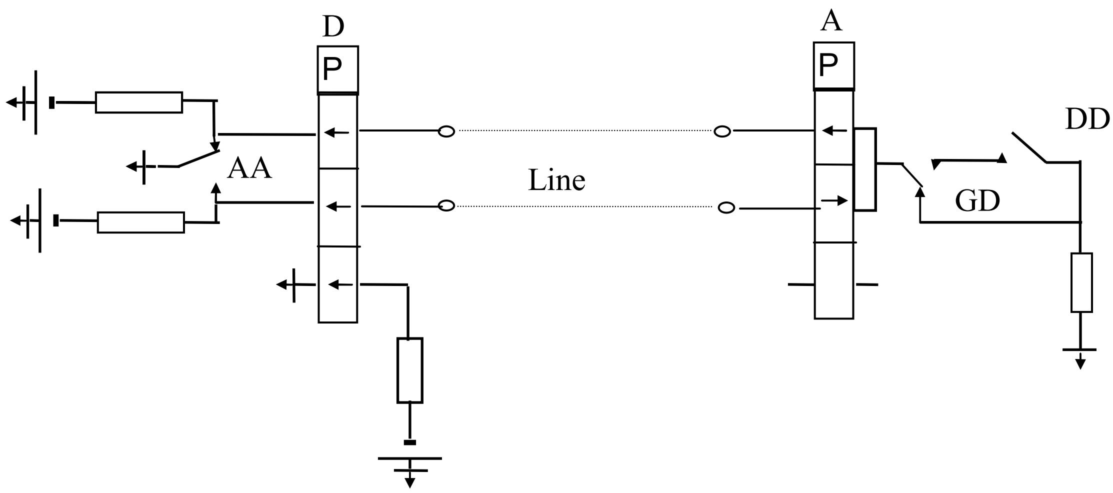
Loop Disconnect Signalling over 4 Wire Circuits (LD4)

Not often implemented in the UK but used around London as connexions to ISC's 4 wire loop disconnect used the same principles as 2 wire MOJ. The signals were passed over the signalling phantoms of the 4 wire circuits.

DC Signalling

DC signalling has its origins way back in telephony. Battery signalling was extensively employed in early manual systems as a method of interconnecting switchboards. It has one great advantage over loop-disconnect in that current feed is applied from both ends of the link thus increasing the distance over which the circuit can be worked.

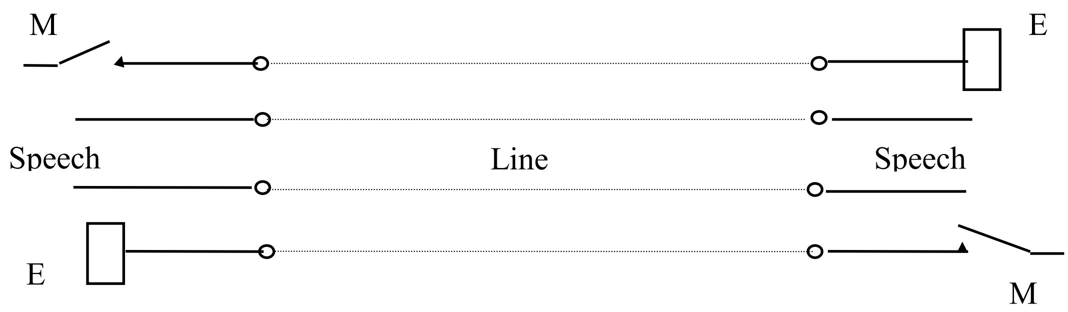
The Post Office formalized the system for automatic working during the 1940's and developed it for use in various applications including MOJ and E&M PBX circuits.



The principle is illustrated in the above drawing. The two line relays are of the polarized Carpenter type, which is a highly sensitive commutating relay used extensively in telegraphy. The arrows within the coils show the normal current flow in the coils which position the relay contacts to what is arbitrarily described as the 'make ' contact. The lower winding of relay D is the bias winding and the current flow is shown as in the idle state. Once the relay set is seized the current flow in the lower winding is dependent on the circuit state. Immediately after seizure the current flow is reversed. Thus if the contact AA changes over with a line seizure signal then D will remain the same while A at the terminal end will change over as the current flow will be opposite to the idle condition. When seizure is recognised then GD operating removes the earth from the windings and the relay is held by the forward battery-earth loop this has the effect of reversing the current flow in the top winding of relay D which will consolidate the relay changeover operation. Relay D now has the current in the upper two windings in opposition thus its operation is now dependent on the lower bias winding and so will change over. Dial pulses will cause AA to release in sympathy with the dial which will again reverse the sense of the two windings forcing relay A back to the idle state for each pulse. When an answer signal is received the operation of relay DD restores the earthed loop to A and relay D will change over again, signalling answer in the outgoing set.

E&M Signalling

E&M signalling, as with many things telephonic, has its origins in North America. Folk lore suggests that it started out in telegraphy with the M lead being the Mouth or sender and the E lead being the Ear or receiver. Whether or not this is true is irrelevant but it is a nice way of describing the lead functions.



In the US the common carrier trunk system, which has always been separate from the local telephone provider, required some degree of standardization between the trunk circuit and the local exchange system. In order to completely divorce the two types of hardware, a standard interface was devised using the E & M leads to provide signalling information and the speech leads provided only AC speech signals. These 4 wires (6 in the case of 4 wire speech bridge circuits originating in the local exchange) were presented to the common carrier to do with what he will. Thus all the DC line signals are removed from the speech circuit by the local exchange and presented instead on separate wires.

E&M comes in two different flavours:

1. Continuous and
2. Discontinuous

Continuous E&M is what it implies. It is relatively simple. The DC signal is continuous from end to end of the link during idle time. This gives circuit security as a broken link will result in local the sensing relay releasing and circuits being busied. On line seizure the continuity is removed from the forward (M) line and responses are received on the local (E) lead from the distant end by disconnection of the backward (M) lead. The forward signalling can be by pulses over the M lead or by inband (R1, R2 or MF2) signalling.

Discontinuous E&M is a little more complex. During idle periods both the E&M leads carry no signals. On forward seizure a timed pulse is sent on the M lead to the distant terminal. The timing of this pulse is critical so as it is interpreted correctly. The distant terminal responds with an acknowledgement signal, again a timed pulse. This is the Proceed-To-Send signal and the reception of this on the E lead enables forward call build-up signalling to start. This can be done using pulses on the M lead or in-band signalling over the speech circuit. Call answer is another timed pulse received on the E lead and then forward clear is again a timed pulse on the M lead followed by backward clear over on the E lead.

The lack of continuous signals on the E&M leads means that one false circuit seizure can take place in the event of a fault condition. But in this case the failure of the Proceed-To-Send response will disable further attempts. Backward busy can of course be sent during idle time and the circuit restored by a following Proceed-To-Send signal while still idle.

This apparent failing has some advantages where circuits are multiplexed over Frequency Division Multiplex (FDM) systems. If continuous E&M were used then there would be forward and backward tones present on all the links while idle. This would increase the overall power consumption of the systems and also have implications for crosstalk and amplifier deterioration and alignment, especially on older valve based technology.

Both flavours of E&M can be used over 4W amplified circuits employing phantom circuits using DC type signalling systems.

Where FDM is employed as a bearer circuit for E&M, then inband conversion of the E&M signals is almost always employed as this saves channel circuits. Thus discontinuous E&M is preferred and the timed pulse signals are converted to tones for transmitting in-band over the speech circuit. The tones are carefully selected so as to fit into a part of the speech band least likely to be interfered with by extraneous speech signals. In the UK 2280Hz is chosen but other frequencies are used elsewhere.

It is at this point that the Post Office AC signalling systems appear. The PO being both local switch provider and common carrier was able to incorporate the E&M inband conversion function directly into their AC signalling system relay sets at the originating exchanges, thus offering pure inband signalling to their repeater stations. This somewhat disguises the true protocol but nevertheless most of their AC signalling systems have their roots in E&M for example AC9 and AC11. Both AC9 and AC11 use discontinuous E&M signals for backward and forward signalling, the major difference between the two systems is their method of call build-up signalling. In order to minimise the possible effects of speech interfering with the signals special guard circuitry is employed. As soon as a tone is detected the near end speech circuit is disabled thus reducing the possible cumulative effects of howl and false tones.

Pulse Code Modulation (PCM) Systems

There are two standards of PCM systems, the North American 24 channel (T1 standard) and the European or ITU (E1 standard) 30 channel system. Although employing basically the same principles they use different philosophies as far as signalling is concerned.

The basic principle of 30 channel PCM is that analogue circuits are sampled at a rate of 8kb/s and the resulting sample is quantized and encoded into an equivalent 8 bit code. This gives an overall signalling rate of 64kb/s which is then sampled at 2.048Mb/s and sent to line. In practice there are 32 channels, 30 channels are dedicated to voice channels, one channel, Time Slot 16, is dedicated to signalling and the remainder to housekeeping and synchronization. In the 24 channel version only 7 bits are used for speech thus giving a sample data rate of 56kb/s and the remaining bit is used for line signalling additionally a framing or synchronization bit is added to the data stream resulting in an overall line rate of 1.544Mb/s.

The Post Office over time has used both systems, experimenting in 1964 with a 24 channel version and then later standardising on their version of the 30 channel system. The 24 channel system used Channel Associated signalling, that is, one of the encoded data bits carried the line signals effectively “inband” while the 30 channel system used a dedicated channel for signalling for all 30 speech channels. This latter philosophy worked better with the CCITT (now ITU) Signalling System No 7 inter-exchange signalling system now universally employed between digital exchanges.

Most countries adopted the E1 system as a standard (with certain country-specific adaptations) leaving the North Americans largely the only users of 24 channel PCM.

The PRX incorporated 30 channel PCM directly into its switch fabric, taking the signalling channel data, passing it to the associated CST and processing it directly. This enabled PRX to coexist with digital exchanges.