Introduction to Railway Signalling

1. Why do Railways have a Signalling System

There are two fundamental physical reasons why railway signalling systems exist:

1. Trains are guided by the track and hence have to be routed in such a way as to avoid collisions with one another
2. Trains cannot stop within the distance that the driver can see – they need to have prior warning of the need to slow down and stop ahead

2. Signalling System Basics

2.1 Basic Principles

The basis principle underpinning all UK signalling systems is the Block System.

Each line is divided into Block Sections, and except in particular circumstances only one train is permitted to be in each block section at any one time.

A signal is provided at the start and end of each block section to allow the train to enter and exit the block.

2.2 Functions of a Signalling System

Based upon this simple principle, signalling systems have evolved to provide the following key functions:

Safety Functions:

• To prevent trains taking conflicting routes
• To maintain a safe separation distance between trains
• To protect trains from driver malfunction (incapacity / inattention / misjudgement)
• To ensure trains do not exceed their permitted speed

Non Safety Functions:

• To maximise the use of the track
• To route trains automatically and regulate their flow
• To provide data on train running for passenger information purposes

Not all functions are provided at all locations

3. Generations of Signalling Systems

Within the UK there are three generations of signalling system in use or planned:

• Mechanical Signalling - is basically 1860’s technology, but there is much of it still in use especially on regional lines
• Multiple Aspect Signalling – is the predominant generation of signalling in use, and covers virtually all main lines in the UK. Its use began in the 1930’s and after a pause for World War 2 was rolled out over much of the network in the 1960s, 70s and 80’s. It is still being installed, albeit with more modern technology.
• Cab Signalling – Signals are dispensed with and instructions to the driver are displayed in his cab. This is the next generation of signalling based on ETCS.

Hybrid systems also exist.

In the case of mechanical and multiple aspect signalling, the driver is required to “know” the route he is travelling and therefore the speed restrictions (including at junctions), and the signal aspects provide him with specific routing information.

4. Mechanical Signalling

Mechanical signalling developed in the mid 1800’s. The signalman operates large mechanical levers in a small wayside signalbox to change the state of individual points and signals. The lever frame in which the levers are mounted incorporates mechanical interlocking, such that individual levers can only be operated when other levers are in the correct position. The levers are connected to the signals and points by means of mechanical connections of rods or wires.

Signals are of the semaphore type, and consist of two key types:

Stop signals – the driver has to stop at these if the signal arm is horizontal (at danger). If it is raised (or sometimes lowered) by approx 60 degrees, then this gives the driver permission to proceed beyond the signal (into the next block section).

Distant signals – if the arm of these is horizontal, it advises the driver that the next stop signal is at danger, and he must slow to stop at it. If it is raised (or sometimes lowered) by approx 60 degrees, then it advises the driver that all the stop signals ahead controlled from this signalbox are clear, and that he can proceed at the speed of the line. Distant signals are positioned at least braking distance from the next stop signal.

A typical mechanically signalled layout is illustrated below:

At diverging junctions, indications of route to the driver are provided by mounting multiple stop arms on a single post.
5. Multiple Aspect Signalling

Multiple aspect signalling was a development designed both to increase the train carrying capacity of the track and to enable a single signaller to control a much larger geographical area, since he is not restricted by mechanical rods and wires to be in close proximity to the signals and points.

The functional of mechanical stop and distant signals are combined into a single colour light signal with three or four aspects.

- A red light requires the driver to stop
- A single yellow advises him that the next signal is at red, and therefore to slow appropriately
- A double yellow advises him that the next signal is at yellow, and hence the one beyond that is at red, and therefore to slow appropriately
- A green advises him to proceed at linespeed

A typical sequence of aspects as trains proceed along the line is illustrated below:

At diverging junctions, indications of route to the driver are provided by adding junction indicators above the signal, which is lit in addition to the main aspect when a diverging route is set.
6. Components of a Signalling System

The following section highlights the key elements of the signalling system.

6.1 Train detection

The function of a train detection sub system is to determine if a particular section of track is occupied by a train.

6.1.1 Manual Detection

With the original mechanical signalling systems the only form of train detection was manual observation by the signaller looking out of the signalbox window.

6.1.2 Track Circuits

To protect against human error, track circuits were developed, which use insulated sections of the rails as an electrical circuit, which the wheels of a train shunts as it enters the section.

Conceptually a track circuit is represented thus:

In the simplest form the transmitter is a battery and the detector is an electro-mechanical relay.

Many much more sophisticated types exist using coded audio signals and frequency shift keying (FSK), which were developed to provide immunity from EMI generated by electric trains.

The track circuit illustrates the key principle of “Fail Safe” applied to all traditional signalling equipment, in that any break in the circuit between the transmitter and the receiver has the same functional effect as a train shunting the rails, and hence the system fails to a safe state.

In Multiple Aspect Signalling installations, large numbers of individual track circuits cover the entire track layout to provide complete train detection.
6.1.3 Axle Counters

Axle counters were developed to avoid the need to electrically insulate sections of rail (as required for track circuits) and to provide a greater degree of EMI immunity from electric trains.

They operate simply by counting the axles of a train entering and leaving a section of track. If the section is initially clear, then any net number of axles in the section implies that the track section is occupied.

Axle counters are becoming the preferred means of train detection. A typical counting head is illustrated.

6.2 Point operating mechanisms

Point operating mechanisms provide 3 key functions:
- To move a particular set of points (switches in civil engineering terms) from one position to another
- To physically lock them in that position, to provide security for the passage of trains
- To detect that they are both in the correct position and locked.

6.2.1 Mechanical Points

In mechanical signalling, points were operated and locked by means of galvanised steel rodding attached to the levers of a mechanical signalbox, such that the signaler provides the motive power for the movement.

Detection was also provided by mechanical means with arrangements of rods and sliders.

6.2.2 Point Machines

A large number of different types of point machine exist, but they all combine the functions of control, locking and detection. Usually the motive power is electrical, but occasionally piped compressed air.

A typical point machine is illustrated.

6.3 Signals

Signals fall into 2 key types, semaphore and colour light, as discussed in sections 4 and 5. There are many further sub types, conveying particular messages to the driver.

Colour light signals have until recently been based upon incandescent bulbs and lens systems, however these are rapidly giving way to arrays of LEDs
6.4 **Interlocking**

The functions of the interlocking are:

- To maintain a current record of the position of every train in the control area
- To maintain a current record of the status of all signalling outputs (position of points / aspects displayed by signals etc)
- To process the signaller’s input requests to set a particular route or swing a set of points etc, and to determine if these requests are safe given the current situation. If so to control signalling outputs in accord with the signaller’s request.

6.4.1 **Mechanical Interlocking**

Mechanical interlocking in a mechanical signalbox consists of a series of steel bars and tappets connected to the levers, which prevent unsafe combinations of levers being pulled by the signaller. These are still common on rural lines, but rely for some of their safety integrity on the signaller.

6.4.2 **Relay based Interlocking**

These were developed from the 1930’s onwards, and reached their peak of development in the 1960’s / 70’s. Here the interlocking functions are provided by very large numbers of electro-mechanical relays, drawn from a range of relays specifically designed to operate in a highly reliable fail safe nature.

The required functionality at a particular location is literally hard wired between the relays.

6.4.3 **Computer based Interlocking**

There are a number of types in operation in the UK, but the most widely used is known as SSI (Solid State Interlocking) and was developed by BR in the 1980’s. It is based upon an 8 bit microprocessor, and achieves its safety integrity by operating 3 processors in parallel, of which at least 2 have to agree on a change of output before it is put into effect.

The interlocking communicates with individual points and signals by means of a duplicated serial data link, with complex data coding, which interfaces with a TFM (Trackside Functional Module) to provide parallel input and outputs at an appropriate power level for individual signal and points.

The required functionality at a particular location is entered as configuration data, and is produced in a bespoke language and then compiled.

Other computer based interlockings are in use, including:

- Interlockings developed in mainland Europe and customised for UK application
- Successor interlockings to SSI which operate in a very similar manner but on a more modern hardware platform

6.5 **AWS**

Automatic Warning System was developed in the 1950’s to provide the driver with warning of a signal which was not at green. It consists of a pair of magnets (1 permanent and 1 electro) mounted between the rails about 200m before each signal.

If the signal is green, the electro magnet is energised, and the driver receives a bell sound in the cab. In all other cases, the
permanent magnet causes a horn to sound in the cab, and the brakes to be applied if the driver does not acknowledge it within a certain time.

The AWS track mounted equipment is illustrated.

6.6 TPWS

Train Protection Warning System was developed and installed across the network in the early 2000’s in response to a number of high profile accidents, notably at Ladbroke Grove in 1999. It is designed to largely mitigate risks associated with drivers inadvertently passing signals at danger.

It operates by means of pairs of antenna (loops) mounted in the track, which when the signal is at danger are energised with a pair of frequencies in the 65kHz range.

One pair of loops is mounted together just past the signal. The first loop frequency arms a timing circuit on the passing train, and if within a preset time the second frequency is detected, the system triggers a brake application and the train is stopped. Thus with the two loops together a train passing the signal is stopped. This pair of loops is known as the “Train Stop”.

A second pair of loops are located a few hundred metres on the approach to the signal, and are separated by a pre determined distance. A train passing over these loops above a preset speed (determined by their separation) will also be triggered and bought to a stand. This pair of loops is known at the “Overspeed Trap” The speed setting is designed to be above that which a train should be travelling to safely stop at the signal.

The photograph shows a single TPWS loop.

6.7 Signalbox control and display systems

There are two key types of signalbox display systems, ignoring mechanical signalling, where the display system is broadly to look out of the window!

6.7.1 Panels

These consist of a mimic of the track layout, usually etched onto small metal tiles. The signaller can control the signals / points etc by means of individual buttons and switches, and is provided with information on the state of the system by means of illuminated displays within the panel.

There are many panel signalboxes in use in the UK covering hundreds of route miles each.

6.7.2 VDU based displays

These are a logical extension of panels, but utilise VDU technology to provide the same and sometimes enhanced information. The signallers control interface is via a keyboard and mouse. This is the predominant form of control and display system for new signalling systems.

6.8 Ancillary items

The key components of the traditional signalling system have been dealt with above; the following are a small subset of the remainder.
6.8.1 Location Cases

These are lineside steel cases containing the power supplies and control equipment for signals, points, axle counters, track circuits etc. The photograph shows a location case under test.

6.8.2 Train describers

These are non safety critical computer systems which display to the signalman with a unique alpha numeric description of each individual train to assist the signaler with routing decisions.

They obtain the train location and movement information from the signalling interlocking.

In turn the train describer can port train movement data onto a large range of further systems:

- Automatic route setting systems to take away some of the signaler's workload in setting individual train routes, and enable signalers to supervise more train movements
- Passenger information systems to drive station displays and internet updates on train running
- Train performance monitoring systems

6.8.3 Level Crossing protection equipment

A more specialised signalling sub system deals with the management and control of conflicts between road and rail vehicles at level crossings. Equipment includes road lights, barriers, CCTV monitoring systems.

A typical installation is illustrated.

7. Cab Signalling

This is the next generation of signalling systems which seeks to abolish lineside signals and provide comprehensive displays in the driver’s cab to indicate the speed he may travel at and the limit of his authority to move. They ultimately aim to also replace infrastructure based train detection, by enabling the train to know its precise position and report it to the signalling system via a secure high reliability radio link.

The key system is ERTMS – European Rail Traffic Management System.