Chapter 7

AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION

Practical Guide To Railway Engineering

Communications & Signals

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Fred Aubertin

CANAC

Ridgeway, ON. L0S 1N0
faubertin@canac.com

Mark Acosta

Canadian Pacific Rail

Minneapolis, MN 55117
Mark_Acosta@CPR.ca

Chapter 7

Communications and Signals

Types, Theory of Operation and Design Considerations of Train Control and Railway Communications and Signals Systems.

This chapter contains a basic description of the types and theory of operation of Communications and Signals Systems, their application and design considerations. Due to the safety sensitive nature of these systems, the examples and/or sample formulas included should not be incorporated into actual designs. Readers of this chapter are invited to read the AREMA Communications and Signals Manual of Recommended Practices for a comprehensive study of the various elements of signaling, including recommended practices.

7.1 Introduction to Signals

7.1.1 Railway Operation

In the early days of railway operation, there was seldom need for more than one train to operate on a section of track at any given time. As traffic increased, it became necessary to operate trains in both directions over single track.

To permit faster and superior trains to pass and provide for opposing trains to meet, it was necessary to construct sidings. It was then necessary to devise methods to affect opposing and passing movements without disaster and with a minimum of confusion and delay. This was achieved by introducing time schedules so that the meeting and passing of trains could be prearranged. Thus, the "timetable" was born.

7.1.2 Timetable Operation

The timetable was the first system utilized for the spacing of trains. In this system, each train is given definite rights, which have to be respected by all other trains. A schedule is issued where each train crew is notified as to the time of arrival and departure of their train and other trains at specified points.

The chief purpose of this method of operation is to keep trains apart when running, by a period of time. Under the timetable system, all trains are expected to reach meeting points or passing points in ample time for inferior trains to clear for the superior trains. The crew of a given train, when between stations, would have no way of knowing the location of a train ahead except by flagman protection.

The timetable or schedule system of railway operation is a "time-interval system." It incorporates many instructions governing operation of trains over the division to which it applies and it also makes reference to the various methods and rules governing train operation.

As the number of trains and the distance traveled became greater, it was apparent that operation under a prearranged time schedule permitted no flexibility and that delays to traffic would be severe. It was not long before operation by time schedule was augmented by issuance of written train orders, which had the effect of modifying the prearranged time schedule.

The first train order of record was issued on September 22, 1851 by Charles Minot, Superintendent on the Erie Railroad. Superintendent Minot was aboard a westward train, which pulled into a siding at Turner, New York, to meet an eastward train. The eastward train was late. Mr. Minot went to the telegraph office and wired ahead to locate the missing train and learned it was at Goshen, thirteen miles west.

The Superintendent sent a message authorizing the eastward train to be held at Goshen and ordered his waiting westward train to proceed to Goshen for the meet.

The issuance of "train orders" offered a ready means to eliminate many of the deficiencies of the Timetable System of train operation. This procedure gained rapid acceptance and appropriate "operating rules" were formulated for the guidance of employees engaged in the movement of trains.

Under the train order system, the railway is divided into sections and the direction of train movements is under the control of a centrally located train dispatcher. The dispatcher issues orders authorizing train movements by means of telegraph or telephone to operators located at designated stations along the line. The operator then delivers a copy of the train order to the proper members of the train crew. Regular trains run under timetable authority, however, when extra trains are run or special movements are necessary, train orders are issued.

When train movements are controlled entirely by "Timetable" as in the early days, and by "Timetables and Train Orders" only as in later days, train operation is enabled by the "Time Interval" method.

The use of the train order system usually, but not necessarily, requires the use of a signal of some sort, in the form of a semaphore, light or flag to indicate to approaching trains that train orders are to be delivered.

The first railway signals consisted of a variety of simple wayside mechanical devices, usually of fixed location. They were developed because of the danger that station employees, after receiving telegraph instructions to stop a train to deliver orders, might become engaged in other routine station duties and forget to signal the train by hand.

The Ball Signal is a matter of historical interest, one of the earliest methods used in conjunction with timetable operation to convey information as to location and departure of trains. Although primitive in this day and age, considerable ingenuity was required to design, construct and operate such a system. This type of signal was still used in rare instances 100 years later.

The fixed signal could be set to the stop position immediately upon receipt of instructions and thus serve to reduce the possibility of human error. The signal, which the operator used to advise trains that orders were to be picked up, was called a train order signal.

The advantages of fixed signals to prevent collision or accidents at important points such as railway junctions, crossing of other railways or tracks at grade (diamonds) and at movable bridges, soon became apparent. It was not long before railways recognised the importance of developing fixed wayside signals, which were both reliable in operation and uniform in appearance to ensure enginemen properly understood the information conveyed by the signal.

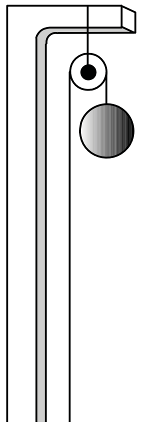

Figure 7-1 It is from this signal that the well-known railway term "highball" was derived.

After a number of experiments, a semaphore type signal was developed. The semaphore signal consisted of a movable arm mounted on a mast situated beside the track over which it governed train movements. The arm was free to pivot to three positions. The common positions were horizontal (0 degrees), an intermediate position (45 degrees) and a vertical position (90 degrees). Standard meanings were given to the various positions assumed by the arm. The horizontal position meant stop. The 45-degree position meant proceed with caution, prepare to stop. The 90-degree vertical position meant proceed.

Lights were used with semaphore signals to provide night indications. The lights were of various colors to correspond with the position of the semaphore arm. With the arm

in the vertical position, a green light was simultaneously displayed. The horizontal position caused the red light to be displayed, and when the semaphore assumed the 45' position, the yellow light was displayed.

These early signals were manually operated, and an oil lamp and the use of colored lenses provided night indications. As technology progressed, electric motors were used to drive the semaphore arm and oil lamps were replaced with electric lamps. In addition to semaphore signals, a system of light signals was devised to provide distinctive visual indications by day and by night. This was accomplished by using lights of different colors or by placing the lights so their positions could be varied, or further, by providing a combination of color/position lights. In general, these light signals conveyed the same indications as those displayed by the semaphore signals.

Figure 7-2 is a close-up of a typical semaphore signal arm mounted on a spectacle casting containing three lenses which would normally be red, yellow and green.

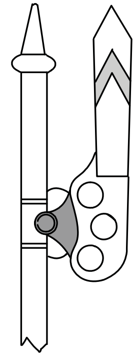

Figure 7-2 Semaphore Signal in the Green Position

The shape and design of the semaphore arm blade was also used to convey certain information according to individual railway practice.

7.1.3 Wayside Signals

There are three general classes of wayside light signals. They are referred to as color light signals, searchlight signals and position light signals. Although the types differ in construction and operation, they all perform the same function, namely to convey operating information to train crews by means of colored light aspects, position of signal and markers on the mast.

7.1.4 Color Light Signal

A popular type of signal is the color light signal. The color light signal has the units arranged vertically as illustrated to the right. Each unit has a lens and lamp. The lenses are colored to give the desired aspect.

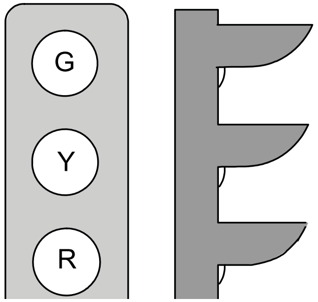

Figure 7-3 Three Aspect Color Light Signal

Signals may consist of one, two or three units, however, the most common is the three-unit signal arranged with the green unit on top, yellow in the center and red on the bottom. Each lens is equipped with a hood, and the signal units are equipped with a dark background.

The hood shields the lens from the sun's rays and the effects of weather. The dark background is provided to accent the effect of the light to achieve maximum visibility. The outer lens is clear glass and is designed to provide various angles of beam deflection. The inner lens is red, yellow or green. Some railways include a lunar (white) aspect.

7.1.5 Signal Terminology

The following is some of the terminology used in describing signals and signal mechanisms

Signal Aspect: Color or color arrangement of a signal.

Signal Indication: The information conveyed by the aspect of a signal.

EB(X) and, EN(X): These are designations given to the wires that light the signal lamp. An x indicates AC lighting and no x indicates DC lighting.

Lens: Collects light from bulb and focuses it into a beam of definite shape; may be clear or colored.

Roundel: A part of a lens or reflector assembly used to deflect or spread or color the projected light beam into a pattern according to its design.

7.1.6 Searchlight Signal

The searchlight type signal differs from the color light signal in that the three aspects are projected through one lens system. This is accomplished by the use of a three-position operating mechanism, which is electrically controlled to position a small roundel (color disc), red, yellow or green in front of the lamp. The light shines through the color disc to produce a colored beam, which is then magnified and projected by the lens system.

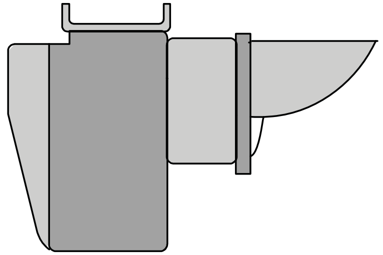
Figure 7-4 Searchlight Signal

7.1.7 Operating Principle

A signal operating mechanism is essentially a three position DC motor type relay having an operating or armature coil and a permanent magnet field structure. The moving element is the armature, which rotates approximately 13.5 degrees each way from the center position. When de-energized, the armature will assume the center position due to a counterweight, and the red roundel will be in front of the lamp.

When current flows through the armature coil in one direction, the armature rotates against a stop bringing the yellow roundel into the light beam. When current passes through the armature coil in the opposite direction, the green roundel is brought into the light beam.

The contacts are operated by the movement of the armature, and are used in external circuits to operate repeater relays.

Note: The contacts do not control the position of the signal mechanism; rather it is the movement of the armature that determines the position of the contacts.

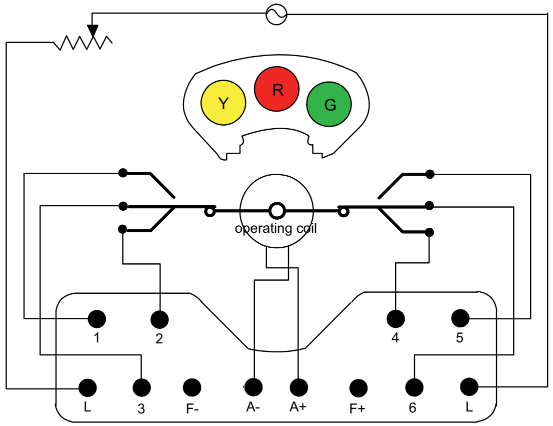

Figure 7-5 Searchlight Signal Mechanism

7.1.8 Automatic Block Signals

With an increase in traffic, a better method for spacing trains other than timetable schedules or train orders had to be found. With the invention of the track circuit, it was possible to control signals and the block system was introduced.

At any given time a train has exclusive possession of a section of track. For example, when a train has the right to occupy the main track under the authority of a track warrant, and a train falls behind for any reason, protection from following trains will be provided by the block signals. This section describes the basic principles and circuits for Automatic Block Signal (ABS) systems.

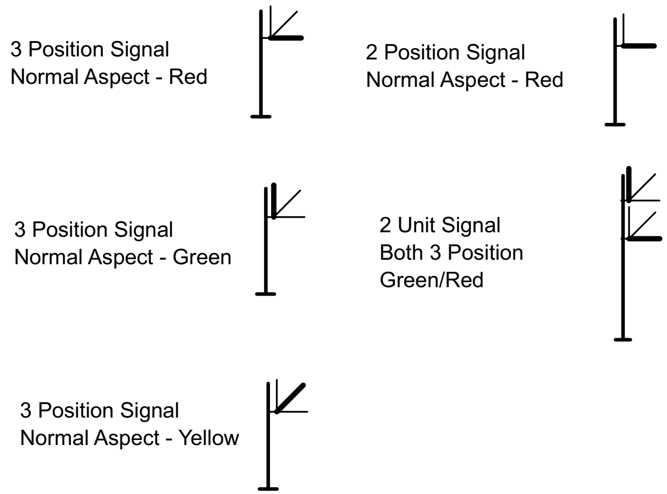

Figure 7-6 Semaphore signals are used as symbols on circuit plans.

The standard symbol used today on signal plans to illustrate the use of fixed signals was derived from the semaphore signal. The symbol, which graphically resembles a miniature semaphore signal, utilizes the different positions of the semaphore arm to convey information about the signal to the person reading the plan. Some examples of signal symbols are illustrated in Figure 7-6. The heavy line indicates the normal position of the signal and the number of lines indicates the number of aspects the signal may display.

7.1.9 Signal Location

The placement of signal symbols on plans indicates other information such as the direction of train movements governed by the signal. For example, signal number 1 governs westward train movements and signal 2 governs eastward movements. Where there are number plates on signals, notice that all odd numbered signals are seen from one direction of travel while the even number signals face the other direction. Refer to the timetable for track orientation.

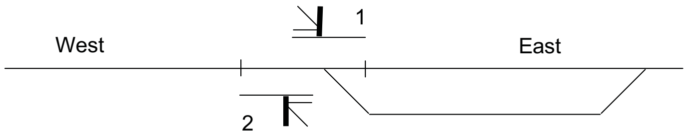

Figure 7-7 Semaphore Symbols Used to Indicate Direction of Travel

7.1.10 Common Terms

Automatic block signal system: A series of consecutive blocks governed by block signals, cab signals or both, actuated by a train, or engine or by certain conditions affecting the use of a block.

Block: A length of track of defined limits, the use of which by trains and engines is governed by block signals, cab signals, or both.

Block signal: A fixed signal at the entrance of a block to govern trains and engines entering and using that block.

Block signal system: A method of governing the movement of trains into or within one or more blocks by block signals or cab signals.

Aspect of a signal: The appearance of a fixed signal conveying an indication as viewed from an approaching train.

Indication of a signal: The information conveyed by the aspect of a signal.

In advance of a signal: A term used in defining the territory beyond a signal as seen from an approaching train.

In approach of a signal: A term used in defining the territory to which a signal indication is conveyed.

Following move: Two or more trains following each other on the same track.

Opposing move: Two trains on the same track in a facing direction.

Conflicting move: Two trains travelling in the same direction, one occupying the side track, and the other, the main track at the siding.

Cab signal: A Cab Signal is a signal located in the engineman's compartment or cab, indicating a condition affecting the movement of a train or engine and used in conjunction with interlocking signals and in conjunction with or instead of block signals.

7.1.11 Automatic Block Signal System

An Automatic Block Signal System (ABS is not a form of train control, it is an additional safety feature that protects a train from a following train. Refer to that railway's timetable to identify the train control method. ABS would have to accompany a form of authority such as a Train Order or a Track Warrant (US) or Occupancy Control System (Canada), i.e., OCS/ABS.

In ABS territory, the track circuit detects the presence of a train, as well as a broken rail or wire. The track circuit provides the automatic feature that changes a signal to red once a train has passed a proceed signal.

In ABS territory signals are normally at green.

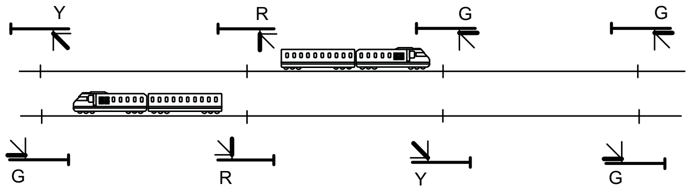

Figure 7-8 Single Direction Automatic Block Signals

The concept of single head automatic block signals is as follows:

- Red signal means the block in advance of it is occupied.
- Yellow signal means the block in advance of it is clear but the next block is occupied.
- Green signal means at least two blocks in advance of it are clear.

Double track, as illustrated above, is sometimes referred to as single direction signalling.

Single track requires signals in both directions. When the block is occupied, the opposing end-of-siding signal is an absolute stop signal (red). Absolute Signals don't have a number plate or are designated by the letter "A" on the mast.

At intermediate signals, the red aspect is considered a permissive signal, meaning stop and proceed at restricted speed. Refer to the railway's operating rules for the proper interpretation of signals.

7.1.12 Centralized Traffic Control (CTC)

Centralized Traffic Control (CTC) is the most efficient system of train control we have today. With the aid of sidings, it permits both following and opposing moves on single track, solely by the indication of block signals. This allows for more than one train to be in a block, in the same direction, at the same time and eliminates the need for train orders and timetable superiority.

CTC is basically a series of controlled switches and signals at wayside (and cab) locations, connected with automatic signalling.

A section of this chapter is dedicated to explaining CTC in greater detail.

7.2 Energy Source

7.2.1 Batteries

In order to discuss track circuits or other signal apparatus, we first need to have an understanding of batteries and charge circuits.

Because the operation of most signal systems depends on electricity, it is imperative that the electrical source be reliable. To ensure this dependability of service, batteries are used. It is a common practice to utilize two power sources. Commercial power supplies energy to the circuits under normal conditions. In addition, batteries are provided as "stand-by" in the event of power failures. Use of commercial power to supply the normal load greatly extends the life of the batteries.

The AREMA revised symbol for the battery uses the long line for the positive terminal. However since most existing circuit plans utilize the older convention, we will utilize the older symbol throughout this section.

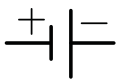

Figure 7-9 AREMA Symbol for a Battery

The railway industry has adopted the conventional theory (hole theory), not electron theory (as you may have learned previously). In railway signal circuits, assume the current flows from positive to negative.

Note: Common usage has made the application of the word "battery" acceptable when applied to one cell or a combination of cells.

There are two general classes of batteries:

- "Primary" which are non-rechargeable.
- "Secondary" (or storage) which are rechargeable.

In most signal applications today, secondary cells are used because of the availability of commercial power.

When a storage (secondary) cell supplies current, a chemical change takes place and it becomes discharged. It then may be restored to its original condition by charging. Charging is accomplished by sending a direct current from an external source through the battery in a direction opposite to that of the discharge current.

The normal external source of current is AC. The AC power must be rectified to DC as a battery can be charged with direct current only.

The two major components of a battery are:

Plates: Various numbers of plates are used per cell. The number, size and composition of plates vary with the current capacity and voltage desired. Some of the plates receive a positive charge and the others a negative charge when placed in the battery solution. The negative plates are of a different metal than the positive.

Electrolyte: The electrolyte is the solution into which the plates are immersed. It may be an acid, salt or alkaline solution, depending on the type of cell.

7.2.2 Battery Charging

Electrical energy supplied to field locations is normally alternating current. However, many signal devices such as switch machines, relays, etc., operate on direct current. DC is also necessary to maintain a charge in storage batteries. Therefore, alternating current must be converted to direct current. This is accomplished through the use of a rectifier.

Charging equipment consists of a transformer and a rectifier combination, referred to as a rectifier. The transformer steps down the AC service from 110 VAC to an AC value required to charge the batteries. Voltage output from the secondary coil of the transformer is adjusted with a magnetic shunt to give exact voltages. This in turn is fed into the rectifier for conversion to direct current (DC).

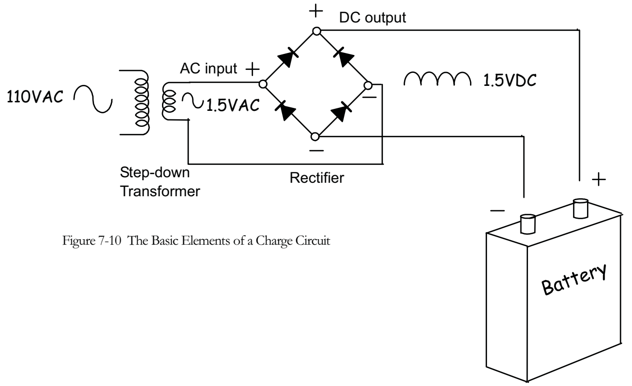

Figure 7-10 The Basic Elements of a Charge Circuit

The rectifier mentioned above is a manual type in which the current must be manually adjusted depending on the state of the batteries. In most of today's new installations, the batteries are maintenance free and a constant voltage type charger is used. With constant voltage rectifiers, the current is automatically adjusted up or down, depending on the condition of the batteries.

Throughout this chapter you will learn about electronic devices that are used in many electrical and electronic applications. The main component of the battery charger is the diode (or rectifier). In simple terms, a diode conducts only when the proper polarity is applied.

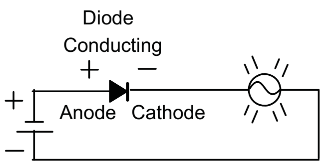

Figure 7-11 Properly Biased Diode in a DC Circuit

In a DC circuit the current is constant. If the diode is reversed, or if the battery is reversed in the simple lighting circuit above, no current flows and the light is extinguished.

In an AC circuit, the current flows only during the positive alternations of the AC sine wave and is considered a pulsing DC current. Notice that in Figure 7-12, the output of the full wave bridge rectifier has positive pulses only. The negative alternations of the AC input have been cut-off.

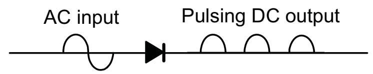

Figure 7-12 Diode in an AC Circuit

7.2.3 Lightning Protection

Lightning results when a difference of potential exists between clouds and the earth. The electrons from the underside of the cloud are carried to the top of the cloud by the rising air currents and moisture. When this occurs, the atoms on the underside, in an attempt to become balanced or whole atoms, attract electrons from the earth, the top of the cloud or from adjacent clouds.

If the lightning strike is between the earth and the cloud, the electrons will take the path of least resistance. The rails of the track and signal line wires provide an excellent conductor, which makes signal equipment very susceptible to lightning damage. Lightning arrestors are used to divert the lightning away from the signal devices and to the earth.

AREMA defines a lightning arrestor as "A device for protecting circuits and apparatus against lightning or other abnormal potential rises of short duration."

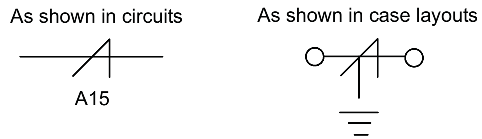

Figure 7-13 The Symbol for a Lightning Arrestor

In an attempt to provide the best possible protection, it has been necessary to try many different types of lightning arrestors in signal systems. Some are in the form of electronic panels and perform two functions. They suppress spikes in the local power supply and protect against lighting strikes.

7.3 Track Circuits

There are many types of track circuits in use today. The types we will cover are:
- DC Track Circuit
- Coded DC Track Circuit
- Style "C" Track Circuit (ring 10)
- Overlay Track Circuit
- AC Track Circuit used in DC Propulsion Territory
- Motion Sensing and Predicting.

7.3.1 DC Track Circuits

Dr. William Robinson invented the conventional DC track circuit in 1872. Although simple in its concept, it remains virtually the same today except for the improved equipment used in its construction.

The introduction of the track circuit made it possible to design the majority of block signal systems in use today. The train provides its own protection by occupying the track circuit, which controls the block signal. Contacts of the track relay are used in circuits for other signal applications and provide a way of indicating the location of a train to the control office.

AREMA defines a Track Circuit as "An electrical circuit of which the rails of the track form a part."

The essential parts of the track circuit are:

- Battery and charger
- Rails
- Resistors
- Bond wires
- Relay
- Insulated joints
- Lightning arrestors and equalisers.

Each track circuit, because it is an electrical circuit, requires a source of energy. Either primary or storage batteries are used to provide the necessary energy to operate the track circuit. Primary batteries are not rechargeable while storage or (secondary) batteries (cells) require a floating charge.

The rails of a track circuit provide the path for the flow of current from the battery. Bond wires are applied to ensure a path of low and uniform resistance between adjoining rails.

Insulated joints define track circuit limits. Track circuits vary in length as required.

AREMA definitions of terms commonly applied to track circuit operation are:

Ballast Leakage: The leakage of current from one rail to the other rail through the ballast, ties, etc.

Ballast Resistance: The resistance offered by the ballast, ties, etc., to the flow of leakage current from one rail of the track to the other rail.

Floating Charge: Maintaining a storage battery in operating condition by a continuous charge at a low rate.

Rail Resistance: The total resistance offered to the current by the rail, bonds and rail connections.

Shunt Circuit: A low resistance connection across the source of supply, between it and the operating units.

Short Circuit: A shunt circuit abnormally applied.

Shunting Sensitivity: The maximum resistance in ohms, which will cause the relay contacts to open when the resistance is placed across the rails at the most adverse, shunting locations.

7.3.2 Track Circuit Operation

A battery is connected to one end of the track circuit, close to the insulated joints, with positive energy applied to the south rail "S" and negative to the north rail "N." The relay is connected at the other end of the track circuit with one lead of the relay coils going to rail "S" and the other to rail "N." With the battery and relay connected, current has a complete path in which to flow, as indicated by the arrows.

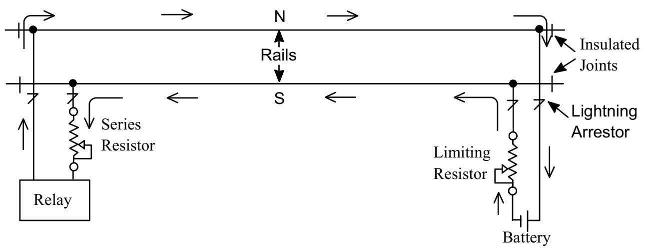

Figure 7-14 Conventional DC Track Circuit Basics

The track circuit is designed as a series circuit, but because of ballast leakage, many high resistance paths exist from rail to rail. When an alternate path for current flow exists from one rail to the other via the ballast, the track circuit becomes a parallel circuit. The current through each ballast resistance and the current through the relay coils adds up to the total current drain from the battery during normal conditions.

When a train enters a track section, the wheels and axles place a shunt (short) on the track circuit. This creates a low resistance current path from one rail to the other and in parallel with the existing ballast resistance and relay coil. When maximum current from the battery is reached because of current flow through the relay coils, ballast resistance and low resistance path created by the train shunt, the relay armature drops. Most of the current flows through the low resistance shunt path. This reduces the current in the relay sufficiently to cause the armature to drop, thereby opening the front contacts. In Figure 7-15, the heavy dark arrows indicate the high current path through the shunt.

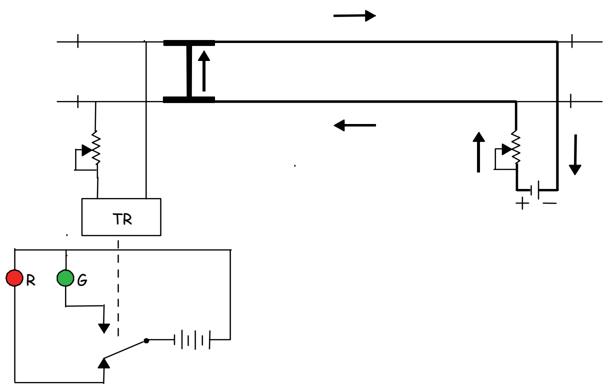

Figure 7-15 Contacts of a DC Track Circuit Relay Controlling a Lighting Circuit

In Figure 7-15, the front contact of the relay is inserted in a signal control circuit to operate a green signal and the back contact to operate the red signal. When a train is present on that section of track, the relay de-energises and the heel contact makes with the back contact lighting the red signal. When the last pair of wheels moves off the track circuit, the current will again flow in the un-shunted track circuit, through the coils of the relay, causing the front contacts to close and light the green signal.

An appreciation of the effect of ballast resistance is necessary to understand track circuit operation. When good ties are supported in good crushed stone and the complete section is dry, the resistance to current flow from one rail to the other rail is very high. This condition is known as maximum ballast resistance and is ideal for good track circuit operation.

When the ballast is wet or contains substances such as salt or minerals that conduct electricity easily, current can flow from one rail to the other rail. This condition is minimum ballast resistance. With minimum ballast resistance, ballast leakage current is high. When the ballast resistance decreases significantly, the relay can be robbed of its current and become de-energized, or fail to pick up after it has been de-energized by a train and the train has left the track circuit. Because the ballast resistance varies between a wet day (minimum ballast resistance) and a dry day (maximum ballast resistance) the flow of current from the battery will vary.

When a train occupies a track circuit, it places a short circuit on the battery. In order to limit the amount of current drawn from the battery during this time, a resistor is placed in series with the battery output to prevent the battery from becoming exhausted. A variable resistor is used in order to set the desired amount of discharge current during the period the track circuit is occupied. This resistor is called the "battery-limiting resistor."

When the battery-limiting resistor is adjusted as specified, higher current will flow through the relay coil on a dry day due to maximum ballast resistance. If this current is too high the relay will be hard to shunt. To overcome this condition a variable resistor is inserted in series with the relay coil at the relay end of the track circuit and is used to adjust the amount of current flowing in the relay coils.

7.3.3 Train Shunting

Relay drop-away time on train shunt is dependent on the following factors:

- The relay current before the shunt is applied
- The effectiveness of the shunt

When a train occupies and shunts a track circuit, the relay will not drop immediately. The magnetic field that built up around the cores when the relay was energized must first collapse. When the field begins to collapse, a counter EMF builds up in the coils, which causes the cores to retain their magnetism for a short period of time. The collapsing field, because of the counter EMF, controls the length of time the armature is held up. If the relay should have a high current flowing in the coil, the magnetic field would be high and complete collapse of the field would take longer, causing the armature drop-away time to increase.

When a train occupies a track circuit, there is not a perfect electrical path between the wheels of the train and the rail. In many cases, the rail is covered with dirt rolled into the surface or with rust from lack of use. A certain amount of voltage is required to break down this surface film. If the voltage between rails (inter-rail potential) is less than that required to break down the film on the rails, no shunting will result. For high shunting sensitivity the track circuit must have high inter-rail potential.

Inter-rail potential can be increased by:

- Using higher voltage batteries.
- Using a small battery feed resistance (battery limiting resistor).
- Keeping ballast in good condition.

Track circuit adjustments: For all types of track circuits, proper adjustments are critical and every effort must be made to ensure that component settings are as close as possible to the values specified in the railway's installation and maintenance standards.

7.3.4 Coded DC Track Circuit

A coded DC track circuit is a circuit in which the battery current flows through the rails in equal on/off cycles. Because the energy is equal on/off cycles, the code does not carry intelligence. The primary function of the coded DC track circuit is the same as the steady energy track circuit; train and broken rail detection.

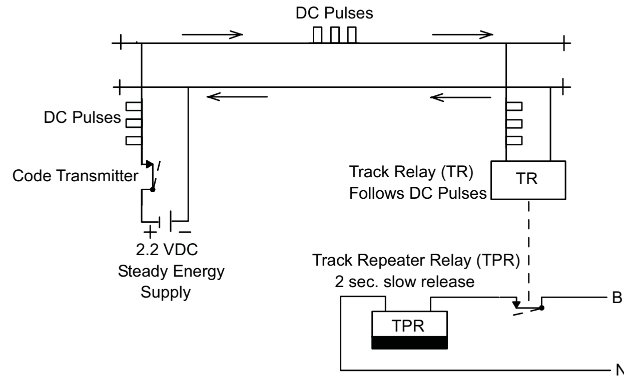

Figure 7-16 The diagram above shows the general components of a coded DC track circuit.

Steady energy is passed through a code transmitter (contacts of an oscillating relay) and is converted to equal on/off DC pulses. Typical code rates are 30, 75, 120 and 180. The DC pulsing voltage energizes and de-energizes a track relay at the other end of the circuit. In a separate circuit, with its own battery source, current flows through the oscillating contact of the TR and energizes the TPR. (See Figure 7-16) The slow release feature of the TPR keeps the relay energized constantly until a train shunt is applied.

The steady energized TPR is used to control other signal circuit applications, including the automatic feature of block signaling.

Coded DC track circuits have several advantages over non-coded DC circuits. Some of those advantages are listed below:

1) **Provides greater shunting sensitivity:** on standard DC track circuits. To de-energize the track relay, the current must be lower than the rated drop-away value of the relay; not so on coded DC track circuits.

   For example: A train applies a poor shunt on the track. The amount of current through the coils of the relay is 50ma. Using the specs listed in Figure 7-17, the current is not low enough to drop the relay in a steady energy circuit, but is in a coded DC track circuit.

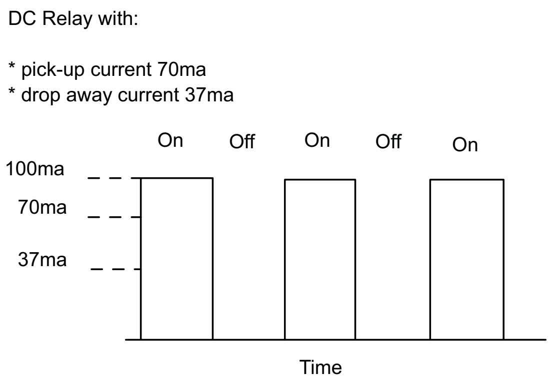

Figure 7- 17 Coded DC track circuit has equal on/off cycles

50ma is higher than the drop-away current in a steady energy track circuit. The current required to drop the relay is less than 37ma.; therefore, the relay remains energized.

In a coded track circuit, during the off cycle, the current is 0. The relay is de-energized and stays down because 50ma is not sufficient to energize the track relay. The relay requires at least 70ma to energize it.

2) **Improved broken rail protection**: For the same reasons listed above, the track relay will not pick up after the off cycle, because a break is a high resistance that keeps the current below the pick-up value.

3) **Inter-rail potential**: Coded DC track circuits have greater inter-rail potential (higher voltage), which helps break down the rail film (rust, dust, grease, etc.) and improves shunting.

4) **Longer track circuits**: Coded DC track circuits can typically be twice longer than the conventional DC track circuits.

5) **Minimize the effect of foreign DC currents**: Excess foreign current will either constantly energize or de-energize the coded track relay. Either way, the track repeater relay will remain de-energized which complies with the fail-safe requirement.

6) **Operate in poor ballast conditions**: Because it has better shunting sensitivity, DC coded track circuits can tolerate lower ballast resistance.

Later, we will see how microprocessor based coded DC track circuits can transmit information in the rails, thereby, eliminating pole line or buried cable.

7.3.5 Style "C" Track Circuit

The Style "C" track circuit, often referred to as a ring 10 circuit because of the type of rectifier used at one end of the circuit, is a DC/AC track circuit. The parts of the circuit are:

- 12VDC battery source and charger.
- Inverter to change DC to AC.
- DC relay.
- Track and relay resistors.
- Diode (or rectifier) at the other end of the track circuit.

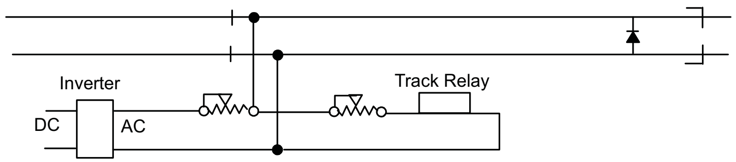

Figure 7-18 Basic Components of a Style "C" Track Circuit

The AC output from the inverter flows through the diode on negative alternations and through the DC track relay on positive alternations, keeping the track relay up. A train shunt on the track would cause all the current to flow through the shunt and back to the source, de-energizing the relay.

Advantages of the Style "C" circuit over the conventional DC track circuit are:

- Better shunting sensitivity, especially in areas with rusty rail.
- Operates well in poor ballast conditions.
- All the equipment and power requirements are in one signal housing (diode between the rails in a water tight box).
- No line wire required to the end feed.

A similar device is the "track driver" which offers a few electronic enhancements to the style "C" circuit and has multiple outputs to feed up to 4 track circuits.

7.3.6 Overlay Track Circuits

The overlay track circuit is a safe and reliable method of detecting a train in either signaled or non-signaled territory. An ideal overlay circuit is the AFO (Audio Frequency Overlay). Another common type of overlay is the AFTAC (Audio Frequency Train Activated Circuit). An overlay can be installed in conjunction with DC track circuits, coded track circuits, other AC track circuits and motion sensor circuits. Audio signals are AC (alternating current).

The basic components of the track circuit are:

- Transmitter
- Receiver
- Receiver relay
- Lightning arrestors and surge suppressors

No insulated joints are required. The distance defines the length of the track circuit between the transmitter and receiver.

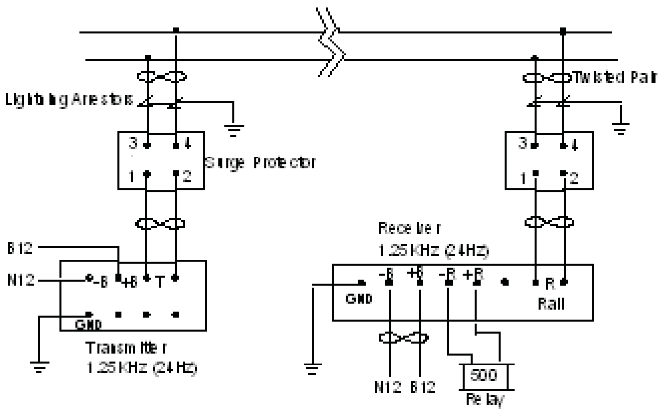

Figure 7-19 Components of a Basic Audio Frequency Overlay (AFO) Circuit

7.3.7 Overlay Track Circuit Operation

The transmitter connected to the rails, emits an audio frequency tone that consists of a carrier frequency and a sub-tone modulation. The transmitter signal is detected by the receiver connected to the rails at the other end of the track circuit.

The receiver functions are to:

- Amplify the incoming signal.
- Check for proper frequency and sub-tone.
- Use the carrier frequency and sub-tone to produce the required DC voltage to energize the relay.

A shunt or open will affect the receiver relay in the same manner as a conventional track circuits. (relay de-energize)

Transmitters and receivers contains filters, which will only pass the AC frequency the transmitter and receiver are designed to operate with, and will block all other AC and DC signals.

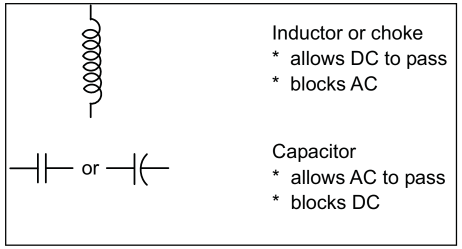

Figure 7-20 How Inductors and Capacitors Behave in a DC and AC Circuit

The overlay circuit does not affect existing track circuits nor does the overlay affect other overlay circuits. Some microprocessor based track circuits are not recommended for use with AFO circuits. Refer to the manufacturer's manual.

Track couplers allow several types of track circuits and frequencies to reside on the same section of track. Below are a few useful electronic devices that will help you understand how couplers work.

7.3.8 Track Coupling Unit

When overlay equipment is installed in conjunction with DC track circuits, and insulated joints are within the same section of track, a coupling unit must be used to pass the AC frequency around the insulated joint. From your new knowledge, what type of electronic device allows the passage of AC while blocking DC? You're right, if you said a capacitor. The track coupler would need to have capacitive characteristics.

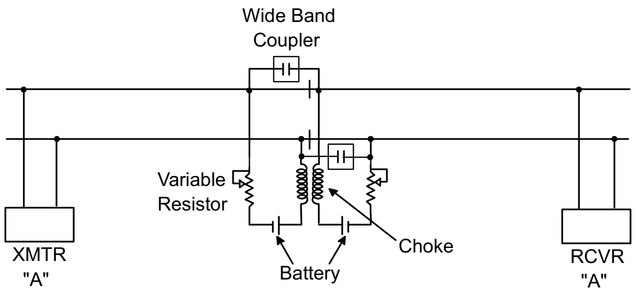

Figure 7-21 Wide band coupler used to pass audio signal (AC) around the insulated joints (blocks DC). The Choke is in series with the battery to keep AC out of the battery and to keep the battery from shunting the AC circuit. (allows DC to pass)

A track battery acts like a capacitor because it has plates similar to a capacitor. A track battery with its track leads plugged into the rail would short an audio or AC signal. It is necessary to place an inductor (or choke) in series, between the track connection and the battery to block the audio or AC signal from passing through the battery and shorting out the overlay circuit.

Couplers could also be tuned to allow only certain frequencies to pass, while blocking all other frequencies. A "wide band" coupler is designed to allow a wide range of frequencies through the coupling unit. A "narrow band" coupler is designed to allow a very small range of frequencies through the coupling unit. To select the appropriate coupler, consider the types of track circuits and the frequencies used.

7.3.9 AC Track Circuits and Relays

Electrified railways, using DC (direct current) propulsion for electric locomotives, necessitated the development of a track relay that could not be operated by propulsion return current in the rails. (See Chapter 9, Railway Electrification)

The first AC vane relay developed was the single-element AC vane relay, but the track circuits were short, which made it inefficient. The demand for longer track circuits required the development of the more efficient two-element AC vane relay.

7.3.10 Apparatus Used with AC Track Circuits

At one end of the track circuit is a track transformer that provides the AC source to the rails. The primary winding is usually powered by 110 volts 60 HZ and the secondary is tapped to provide anywhere from 1 to 18 volts.

The track resistance (load) is considered when determining the transformer output voltage. For example, a longer track circuit would require a higher output voltage from the track transformer. Refer to the manufacturer's specs for output voltages and wiring configuration.

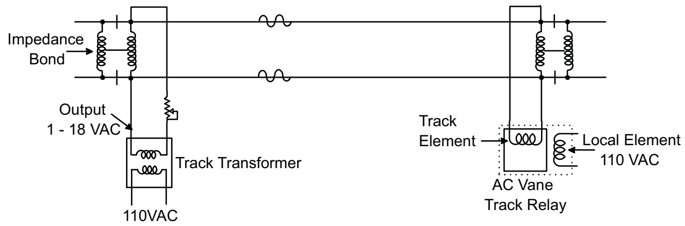

Figure 7-22 Basic Components for an AC Track Circuit in DC Propulsion Territory

An adjustable resistor is placed between the track transformer and the track. The resistor is used to adjust the current to the track and to provide the proper track element to local element phase relationship (as close to 90 degrees as possible).

Non-adjustable resistors are sometimes used with the local element at the relay end to further assist with the phase relationship between the relay and the local element current.

Impedance bonds are connected across the rails at both ends of the track circuit. Impedance bonds are large reactors that permit flow of the DC propulsion current from one track circuit to the next (across the insulated joint), while not shunting the AC to the track relay.

Both rails of a double rail AC track circuit should be equally well bonded because defective bonding in one rail will cause an unbalanced condition of the track circuit due to unequal amounts of return propulsion currents in the two rails.

With DC propulsion return current on the rails and double rail AC track circuits, unbalanced propulsion currents (caused by a difference in rail resistance) may saturate the iron core of the impedance bonds. This may lower the bond impedance to such a point that the AC track relay may be shunted and drop out.

7.4 Track Switches

A railway could not function without track switches. Switches provide the means to establish a route. On single track mainline, switches allow trains to meet and pass by the use of sidings, entry to which is governed by track switches. On double track, they allow trains to cross over between tracks.

Because of their design, track switches demand:

- Careful installation
- Diligent maintenance
- Compliance with FRA rules and railway standards
- Obedience to the railway's operating rules

If maintenance is lacking or rules are not lived up to, serious consequences may result.

Maintenance of hand-operated switches is the responsibility of the track forces. The proper positioning of the switch points is the responsibility of all employees who use switches in the course of their duties. On main tracks, switches must always be left in the normal position and locked. Switch keys are only issued to those with authority to use switches.

There are several types of switches in use today. We will focus on two commonly used switches used on mainline signalled territory, the hand operated switch and the dual control switch machine.

7.4.1 Hand Operated Switch with SCC

In signalled territory, where a proceed signal is the authority for train movements over a hand-operated track switch, additional protection is provided. A device, which provides a check on the position of the switch points before a signal may display a proceed indication, is called a "Switch Circuit Controller" (SCC). The check is accomplished by breaking the signal control circuit through contacts in the controller. A switch circuit rod connected to the switch point positions the contacts of the SCC mechanically. Should the point be in a position making train movements over them unsafe (more than ¼ inch from the stock rail), the contacts will be open and the signal will be put to "stop."

AREMA defines a switch circuit controller as:

"A device for opening and closing electric circuits, operated by a rod connected to a switch, derail or movable point frog."

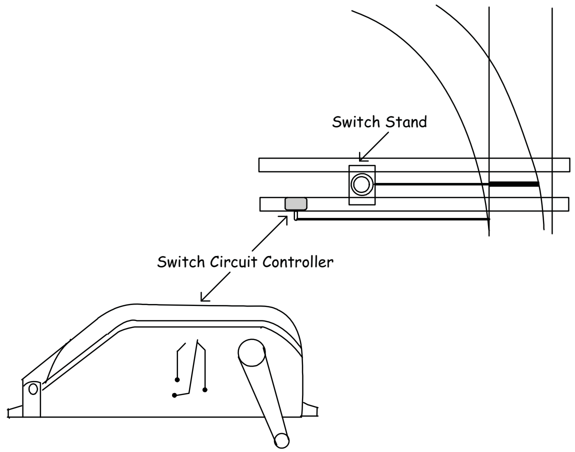

Figure 7-23 Switch Circuit Controller (SCC)

The hand-operated switch moves the switch points to the normal or reverse side. When the switch points are positioned for a straight through move, it is said to be normal and when the switch points are positioned for the diverging route, it is said to be reverse. The switch circuit controller detects the position of the switch points.

Installation, adjustment and maintenance of switch circuit controllers are the responsibility of the Signal Department.

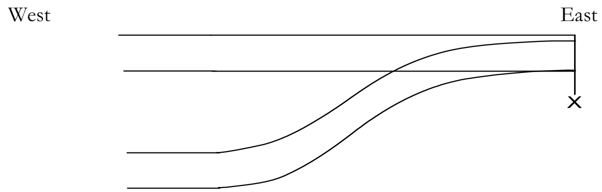

Figure 7-24 The Symbol for a Hand-Operated Switch Equipped with a Switch Circuit Controller

A few common terms used in reference to train movements at a switch are:

Facing Movement: The movement of a train over the points of a switch which face in the direction opposite to that in which the train is moving. A facing movement originates from the main track and into the siding or straight through on the main.

Trailing Movement: The movement of a train over the points of a switch that face in the direction in which the train is moving. A trailing movement could originate from the siding out to the main line or could be a straight through movement on the main.

In Figure 7-24, a facing movement would be from east to west and for a trailing movement the train would be traveling from west to east.

The hand throw switch may be converted to a spring switch with the addition of a spring switch mechanism, which returns the points to their normal position after a train has trailed through the switch.

7.4.2 Electric Switch Lock

An electric switch lock is an electro-mechanical device that provides a means of interlocking a manually operated switch with signal circuits, so that the switch cannot be operated unless traffic conditions permit, or unless a sealed emergency release is operated.

FRA Part 236.314, electric lock for hand-operated switch or derail, states, "Electric lock shall be provided for each hand-operated switch or derail within interlocking limits, except where train movements are not exceeding 20 miles per hour. At manually operated interlockings, it shall be controlled by the operator of the interlocking machine and shall be unlocked only after signals governing movements over such switch or derail display aspects indicating stop. Approach or time locking shall be provided."

The purpose of an electric lock is to prevent unauthorized access onto the main track from a side track. Electric locks improve safety of train operation and reduce train delays.

Instructions, which describe the method of operating electric locks to the train person, are provided inside the compartment door at each lock installation.

AREMA defines an electric lock as: "An electric lock connected with a switch or switch movement to prevent its operation until released." The AREMA symbol for an electric lock is shown in Figure 7-25.

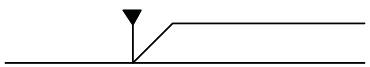

Figure 7-25 Symbol for an Electric Lock

When installing an electric lock, it is important that strict attention be paid to mounting the equipment exactly as shown on the layout plan. Figure 7-26 is just one example of a lock installation.

An additional switch tie or head block is required along with the appropriate switch hardware for fastening the lock rod to the switch points.

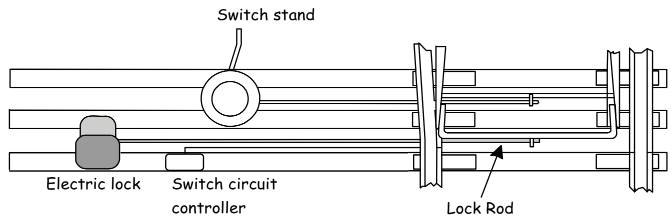

Figure 7-26 Layout with Switch Circuit Controller and Electric Lock

An electric lock has a switch lock relay (WL) located within its housing, which allows use of the hand-operated switch. When all proper signal checks are made, the WL will become energized to allow hand throw switch operation.

Train dispatcher or control operator permission must be obtained to use an electric lock when making a siding to main track move. After receiving permission, the padlock may be removed and an unlock operation will begin, depending on the conditions and the signal circuits at the location. Some railways include a sealed emergency release feature.

A short track circuit in front of the switch points is provided to allow trains to leave the main track as soon as possible. An audio frequency overlay track circuit is most suitable for this type of track circuit.

7.4.3 Dual Controlled Power Switch Machine

The power switch machine is powered by an electric motor of 24 or 110VDC. A dual controlled power switch machine can be electrically operated remotely or manually operated at the switch.

The functions performed by a power switch machine are:

- Unlocking the switch machine.
- Operating – moving the switch points.

- Locking the switch machine.

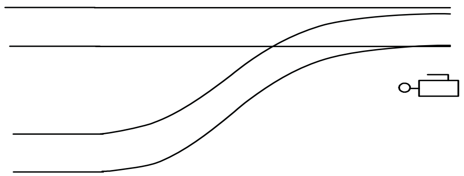

Figure 7-27 Symbol for a Dual Control Power Switch Machine

Power switch machines are designed to have either a right hand or left hand throw. To identify whether a machine is right or left, view it from the motor end. If the rods are connected on the right side, it is a right hand machine. Likewise with the left hand, if the rods are connected to the left side.

At a new switch installation, the first thing to know is whether the turnout is left or right hand. The type of turnout is determined by viewing the turnout from the points. If the turnout section of the switch is on the right, a right hand machine is required, if on the left, a left hand machine is required. Knowing this, it is now possible to select the proper type of switch machine for the installation.

The switch machine is divided into three basic components:
1. Motor compartment.
2. Gear compartment.
3. Contact compartment (electrical).

For a right hand turnout, you will need to install a right hand switch machine. A right hand switch machine has the switch rods on the right side of the machine as viewed from the motor end.

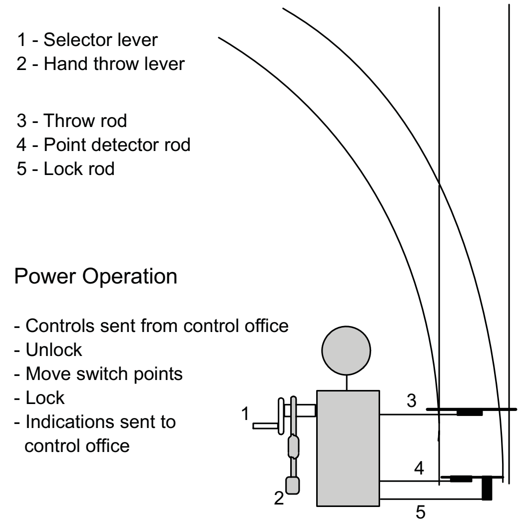

Figure 7-28 Left Hand Dual Control Switch Machine

The switch machine illustrated above is securely bolted to the ties and is connected to the switch points by three rods.

1. Throw Rod: moves the switch points from one position to the other. The throw rod is connected to the No. 1 rod through an apparatus called the "adjustment bracket or basket." The throw of the switch points is adjusted at the basket.

2. Lock Rod: moved by the switch points and is used to lock the points in either the full normal or full reverse position. The lock rod is connected to the front rod, and locks or holds the switch points in the normal or reverse position.

3. Point Detector Rod: moved by the switch points and detects the position of the points. The point detector rod is always connected to the normally closed point. The point detector rod is connected in the same manner as the point detector rod of a switch circuit controller, through a point lug installed on the normally closed point.

The sequence of operation to move the switch points from normal to reverse or vice-versa is as follows:

1. Control operator or dispatcher positions a lever applicable to the switch he wants to throw reverse or normal. The levers are located on a control panel.

2. The positioning of the lever closes a circuit to energize a switch control relay at the desired field location.

3. Contacts of the switch control relay close a circuit to apply DC energy to the switch machine.

4. The machine begins to operate and:
   a) A brake holding the motor stationary is released.
   b) The motor is energized and begins to rotate, and through a gear train, withdraws a locking bar within the switch machine, from a slot in a lock rod connected to the switch points. (The lock bar, when in the lock rod slot, holds the switch points rigidly in place at the completion of the switch machine move.)
   c) Further rotation of the motor turns gears in the machine, which apply pressure to a throw rod connected to the switch points, moving the points to the opposite position.
   d) Upon completion of the switch point movement, the motor continues to rotate until the lock bar is driven into a second slot in the lock rod, securing the switch points in this position.
   e) When the lock bar completes its locking function, contacts in the machine open to de-energize the motor circuit.
   f) Motor holding brake is again applied to hold the motor stationary.

5. Indication contacts in the switch machine close when the switch machine is fully reversed and locked. These contacts complete a circuit to energize a relay, which indicates to the operator or dispatcher, by means of a light, that the switch has completed its move and is locked.

7.5 Highway Crossings

To reduce the danger of collision, it is essential to provide a means of warning of an approaching train to vehicular traffic and pedestrians at a crossing.

Warning at highway grade crossings was first afforded by placing conspicuous signs at the crossing. Use of the locomotive whistle and bell was also required to alert roadway traffic of an approaching train.

Because of increased traffic, both by rail and road, and the opening of more roads, a better type of warning was required. With the advent of the track circuit, automatic

control of crossing warning devices by the train itself eventually became possible. The first automatic protection consisted of a bell at the crossing and was soon followed by an illuminated danger sign, which was controlled by the train when within the limits of the approach track circuit.

The wig-wag was then developed which gave the public a better visual signal by displaying a moving banner by day and a moving or flashing red light by night. The wig-wag has since been replaced by a more modern type of warning with flashing light signals or in combination with automatic gates.

Prior to the installation of new crossing warning devices, the railway company has to submit for approval, to the authority having jurisdiction over the highway, plans showing the location of the crossing in relation to the highway and the railway. When approved by the road authority, the railway company files the plan with the appropriate regulatory body for approval.

To ensure safety and uniformity of crossing warning devices in the United States, the Federal Railroad Administration (FRA) set forth rules and regulations. Refer to **FRA Part 234, Grade Crossing Signal System Safety**.

7.5.1 Crossing Operation

The circuits that control crossing warning devices are designed to activate the crossing when a train is on the approach track and/or the island track. The island track is a short track circuit that spans the roadway. The crossing warning device stops after the train leaves the island track.

Crossing circuits detect the direction of a train in order to stop the warning device after the train clears the island circuit. This is accomplished by relays dropping and picking in a certain sequence.

Figure 7-29 shows the sequence of operations as a train approaches a crossing and until the rear of the train leaves the island track. The example below shows a move in one direction. The operation is the same for trains moving in either direction.

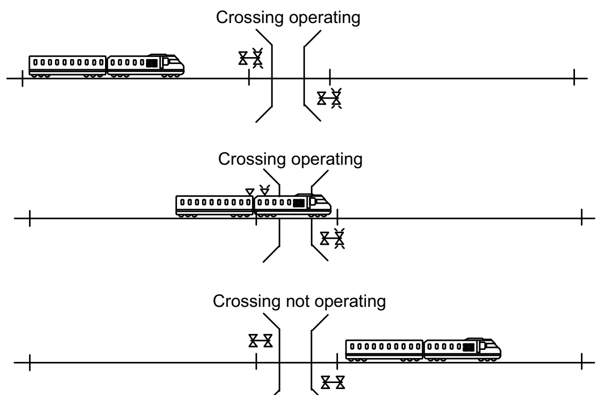

Figure 7-29 Three Track Crossing Operation

In addition to relays, timers should be included in the design to deal with "loss of shunt" and "lockout" conditions. A loss of shunt means that the train wheels lose their electrical contact with the rail. A lockout occurs when a train leaves the trailing track circuit down (i.e., the relay contact does not pick up).

Solid-state crossings are quickly replacing the old relay logic crossings.

7.5.2 Crossing Gates

Where two or more main tracks cross a section of highway or where there is heavy vehicular traffic, gate arms and gate mechanisms are commonly installed to supplement flashing lights.

The main purpose of installing gates at a highway crossing is to discourage vehicular traffic from occupying the crossing after one train passes, if there is another train approaching on the second track.

There are different types of gate mechanisms, but their circuitry and operation are similar. When servicing a crossing warning device with gate mechanisms, always refer to the field plans and the manufacturers' handbook for the particular type of gate used at that installation.

Components: The gate mechanism consists of four basic components. They are:

- Motor
- Gear train
- Hold clear mechanism
- Circuit controller

Counterweights: Counterweights are used in conjunction with various lengths of gate arms for the purpose of off-setting the weight of the gate arm itself, in order that the motor without excessive current draw can raise the gate.

The counterweights are adjustable in two ways to provide a sufficient number of foot-pounds of torque in both the vertical and horizontal positions.

Counterweights are to be installed as per manufacturer's instructions. Gate arms are to be torqued in the vertical and horizontal position according to the manufacturer's handbook, which is included with each mechanism. Settings may vary depending on which type of gate model is used.

Gate Lighting: The light nearest the tip of the gate arm is at the prescribed distance from the tip and burns steadily as per the railway's standards. The other lights are located to suit local conditions and flash alternately in unison with the lights on the gate mast.

When positioning the lights on the gate arm, the rightmost light must be in line with the edge of the roadway and the center light should be placed between the two outer lights.

7.5.3 Crossing Motion Detector/Predictor

On a crossing equipped with a motion detector, the crossing warning device will activate as soon as a train is detected. If the train stops or backs up, the crossing warning device will stop operating. The industry has taken it one step further by converting the motion sensor into a device that can predict the speed of an oncoming train to activate the crossing at a pre-determined time. The automatic warning device is hardware and software driven.

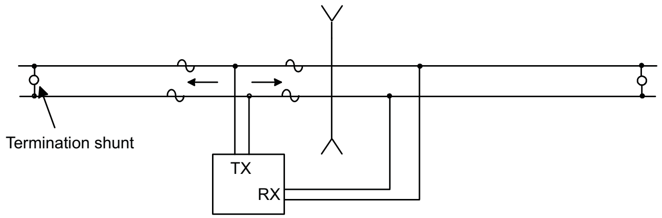

Figure 7-30 Bi-directional - Automatic Crossing Warning Device

There are several configurations to choose from. The above example illustrates a bi-directional configuration.

A key function of the transmitter section is to maintain a constant AC current on the track.

The transmitter wires (TX) send an AC signal:

- Down one rail in both directions (bi-directional)
- Through the termination shunt at the ends of the circuit
- Through the other rail, returning to the AC source

The receiver wires (RX) define the limits of the island circuit and monitor the transmitter signal.

Track impedance, in the form of inductive reactance (resistance to AC), depends on the length of the track circuit, which is defined by the termination shunt and the applied frequency. For this reason, the longer approach circuits should use a low frequency, while the shorter island tracks should use a higher frequency.

With no train on either approach, the electronic box at the crossing creates a 10-volt DC signal (distant voltage). When a train comes onto the crossing approach, the following occurs:

- Lead axle shunts the track.
- Lead axle becomes a moving termination shunt, which shortens the track circuit as it approaches the crossing.
- Track impedance (resistance) decreases as the track circuit shortens.
- As the track impedance decreases, the distant voltage (10 VDC) decreases towards 0 volts at the crossing.

- As the train leaves the crossing, the distant voltage rises again towards 10 VDC.

The rate of voltage drop is dependent on the speed of a train. From this, you can probably see that with a little creative programming, the box can predict the speed of a train and activate the crossing at the appropriate time or stop the crossing operation if the train stops or backs up.

For this configuration (bi-directional), no insulated joints are required. However, if there are insulated joints because of the presence of a DC track circuit, bypass couplers can be used to allow the AC signal around the joints while blocking DC.

Output terminals from the crossing predictor provide 12 volts DC to the crossing control circuits. The crossing control circuits are either relay logic control circuits or solid-state control circuits. Crossing control circuits operate the bell, flashing lights and gate arms.

7.6 Centralized Traffic Control (CTC)

Centralized Traffic Control (CTC) permits both opposing and following moves of trains on the same track by the indication of block signals. CTC allows for more than one train to be in a block, travelling in the same direction at the same time and eliminates the need for train orders and timetable superiority.

Control point circuitry, controlled block signals, dual control power operated switch machines, electric locks in conjunction with switch circuit controllers and advanced communications systems are all integral parts of a CTC system.

Signal indications authorize train movement in CTC. Once a train is allowed into a block by the dispatcher (control signal often referred to as home signal), the train is controlled by automatic block signals (intermediate signals).

Important Note: The sequence of operations described below is a typical model only. For compliance to FRA requirements and regulations refer to Parts 235 and 236.

7.6.1 Operation

Many existing CTC systems are relay based. Modern installations are microprocessor based with solid-state support circuits and advanced communication links. For this discussion, we will consider a relay-based system. A later section of this chapter will introduce solid-state systems.

Control and indication codes rely on step-by-step operation of relays and mechanisms at the field location, working in synchronism with step-by-step operation of relays at the control office.

CTC systems are controlled by a dispatcher with code and carrier systems, which provide communications to the field control points with two line wires and/or by microwave signals, regardless of the number of control points.

Control Codes: To transmit a control, the dispatcher positions the necessary levers and buttons on the control machine. Next, he pushes the appropriate start button that causes a code to be transmitted. All field locations connected to the code line see the control code, but only the one called is selected. At the selected location, the control portion of the code is delivered through field application relays to cause the function relays to operate switches, signals, etc.

Indication Codes: When a field change occurs in the position of a switch, the aspect of a signal, or the condition of a track circuit, an indication code is set up at the field location, which in turn automatically transmits the indication back to the control office. When the indication code is received at the control machine, the appropriate indications light up on the dispatcher's panel to show the conditions existing at the field locations.

Control Point: Control Points may consist of a single switch or a cross-over between tracks, or various combinations of switches and crossovers with associated signals. From the control machine, the dispatcher remotely controls the power switch machines. A network of signals is associated with each power switch to ensure that train movements are made safely. CTC is basically a series of controlled switches and signals at wayside locations, connected with automatic signalling.

Control Office: Each train dispatcher is responsible for the operation of traffic on his/her assigned territory. A dispatcher's duties require that he set up routes and signals for traffic, arrange meets of trains and provide protection for roadway workers.

Railways have implemented computers to assist with train control systems. The computers are equipped with mass storage devices on which train and signal activity are archived for future reference. This information is accessed for purposes ranging from accident investigation to train delay reports.

The dispatching computers are located in a special room. This room contains an air conditioning system to keep the environment at a constant temperature and humidity, and a fire protection system to safeguard against fires in and around the computer room. As well, the system is equipped with an un-interruptible power supply (UPS) to keep it up and running in the event of a commercial power failure. The uninterruptible power supply is made up primarily of storage batteries and a diesel generator. The generator is used to keep the batteries fully charged if the power failure persists.

The computer duplicates all of the interlocking checks performed by the field circuitry, safeguarding against any potentially unsafe requests by any of the system users.

Each dispatcher is equipped with a console, along with a CRT and line printer. The dispatcher's console contains a traffic monitor display and a push-button display. The push-button display is used to send the controls to the different field locations, and the traffic monitor display indicates the status of all signalling equipment. Most push-button functions are duplicated on the dispatcher's CRT in the event that any of the console equipment should fail.

Signal selection is carried out using an entry/exit method. To choose the entrance, the dispatcher selects the signal where the train is going to enter the block by pressing the appropriate signal button. The computer then displays the possible routes where the train can proceed, and the dispatcher chooses the exit he desires by again pressing the appropriate signal button. This procedure has to be performed every time a train enters a different block.

When the dispatcher chooses the "exit" for the train, the computer sends out the controls to the field automatically.

The traffic monitor indicates the location of all the trains in the field. Along with monitoring the movement of trains, many other indications are displayed on the panel to let the dispatcher know about different conditions in the field, as well as the status of conditions in the office.

The dispatcher's CRT consists of a Video Terminal Display (VTD) and a computer keyboard especially configured for this application. The CRT can display OS reports, blocking forms, alarm conditions, and system status.

The dispatcher's line printer is used to provide hard copies of blocking forms and reports concerning the movement of trains.

Communications and Signals maintenance personnel have a compliment of dispatching equipment dedicated solely to them for use in system maintenance, monitoring and altering system operation, and testing both office and field equipment.

The maintenance console can be arranged to duplicate any section of track on any dispatcher's console. It can display several field locations.

The maintenance CRT duplicates all of the functions found on a dispatcher's CRT. In addition, it gives maintenance personnel access to a set of commands that allows them to control every facet of system operation, including manipulation of all signal equipment controlled by any of the dispatchers.

Line-printers provide maintenance personnel with hard copies of blocking forms, train and system activity reports, a log of day-to-day operations and error reports.

Another section of the computer system is used to keep running records of trains. Information about trains is received from the dispatcher, operators and specific indications received from the field locations.

Through the use of remote terminals, the operators can communicate all their information directly to the computer via a modem and telephone line. Previously, this information was transferred from operator to dispatcher by radio, and required that forms be filled out and repeated every time information had to be communicated. With the computer, all parties concerned are relieved of much of this routine paper work. The information gathered aids the dispatcher with the preparation of train sheets, line-ups, train orders and other forms required to perform his duties.

The computer handles information taken from various sources and formats it for storage, retrieval and display. The computer displays OS reports, crew reports, and a time position graph on a graphics CRT. The time position graph replaces the pen graph used with the older machines.

7.6.2 Sequence of Operation

Control points or control locations are field locations, where the dispatcher may request the operation of signals, power operated switch machines or electric locks for the movement of trains. The dispatcher does not control intermediate signals. They respond automatically to the position of the control point signals and track conditions. All signals will go back to their red position automatically as the train passes them.

Before a dispatcher makes a request, the signal system is considered to be at rest. "At rest" means there are no trains in the block and the dispatcher has sent no control request. All signal circuit plans are drawn with the system at rest.

When a dispatcher requests a proceed signal at a control point, several electrical safety checks are made in the field before the request is allowed to be executed.

To line a route, the following sequence occurs between the control office and the control point (field):

1) Control sent.
2) Track circuits and blocks are checked.
3) The route is lined and locked.
4) The signal requested clears.
5) Signal repeater circuits are set.
6) Indications are sent to the control office.

1) **Send Control:** Code transmitted from the control office to the control point (field) is called a "control" and is usually represented by the letter "c." The dispatcher controls only a few relays at a control point. The dispatcher-

controlled relays remain latched in the requested position until the dispatcher reverses their position.

The function relay's task is to set up a relay or a network of relays to:
- Throw a power-operated switch to the normal or reverse position.
- Lock or unlock an electric lock at a hand-operated switch.
- Display a proceed or stop signal.

2) **Perform a Block Check:** The signal system, through the block check circuits, verifies the following:
   - The switches in the route selected are lined and locked.
   - A conflicting signal is not requested.
   - The signal requested returned to red after the last train move.
   - The "OS" track and the track to the next signal are unoccupied.

   Before a signal can clear and display either a green or yellow aspect, it must be determined if the block is clear in advance of the signal and the aspect of the next signal must be known. Line circuits can provide this information. Line circuits are either pole line or underground cable and are usually called HD lines. In new systems, the rails transmit the required information, thereby eliminating line circuits. See the section on microprocessor based track circuits.

3) **Locking:** Locking circuits perform the following functions:
   - Removes battery from all the power operated switches within the route requested (route locking).
   - Ensures that all opposing and conflicting signals are at stop before clearing a signal into that block (time locking).
   - Ensures that once a signal is clear, an opposing or conflicting signal cannot be cleared (time locking or approach locking).

   A pre-set time will run when the dispatcher cancels a proceed signal. No further controls can be sent until the time has expired. Normal train operation does not put time locking into effect.

4) **Signal Control Circuits:** Before a signal can clear, the signal control circuits verify that:
   - The block and route checks in step 2 are still established.
   - The locking functions in step 3 have been completed.

   With all previous checks for the signal still set, a current path in one direction through the operative signal mechanism will light the signal green. Current flowing through the operating coil in the opposite direction will drive the signal to its yellow aspect. Direction of current is determined by the polarity on the HD lines. Signals are usually AC lit with DC power as backup.

5) **Signal Repeater Circuits:** Signal repeater circuits are used to ensure the position of the signal mechanism (searchlight). All control point signals (home signals) are normally at red; therefore all red repeater relays would be energized.

In Figure 7-31, energy on terminals A- and A+ will position a colored roundel (yellow or green) in front of the light bulb, depending on the polarity applied. No energy on terminals A- and A+ will center the mechanism and display the red aspect. The operating coil will position the color roundels and simultaneously rock the operating coil arm.

When the operating coil arm rocks to the yellow position, the yellow repeater relay energizes. A contact of the yellow repeater relay will provide the current path to send an indication back to the control office.

When the operating coil arm rocks to the green position, the green repeater relay energizes. A contact of the green repeater relay will provide the current path to send an indication back to the control office.

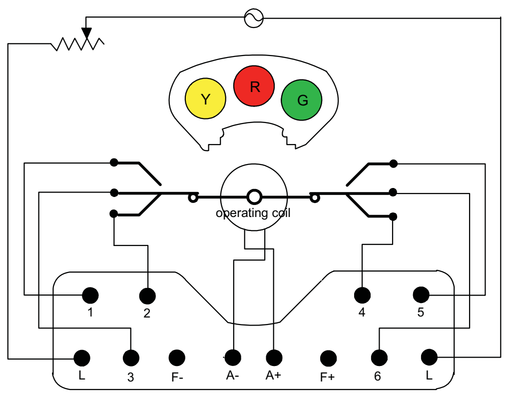

Figure 7-31 Searchlight Type Signal Mechanism

6) **Indication**: Indications are sent from the field to the control office to indicate the status of signals, switches and track circuits. For example, when the dispatcher requests a proceed signal at a specific home signal and the signal

responds with a yellow or green aspect, the proceed indication is transmitted to the control office.

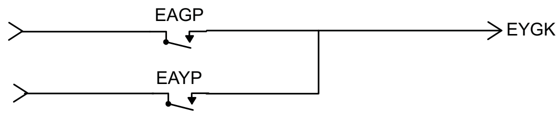

Figure 7- 32 Indication for an eastward signal

EAGP – E east, "A" signal (top head), G green, P repeater
EAYP – E east, "A" signal (top head), Y yellow, P repeater
EYGK – E east, Y yellow, G green, K indication
If the aspect of the top signal head of the eastward signal is either green or yellow, a "Proceed" indication is sent to the control office and is indicated on his/her panel.

7.6.3 Microprocessor Based Coded Track Circuits

In a previous section you learned that DC coded track circuits use a relay code transmitter and code follower to produce an equal on/off DC pulse. The DC coded track circuit is ideal for train and broken rail detection, but because the on/off cycles are equal, no intelligence is conveyed. Hence the birth of the microprocessor based coded track circuit. With the use of synchronization, DC pulse length and pulse grouping (one pulse or two consecutive pulses), information can be transmitted through the rails.

Some of the advantages of microprocessor based coded track circuits are:

- Eliminates the need for line wire (pole line or underground).
- Longer track circuits.
- Monitors the status of track circuits.
- Control of signals.
- Fewer (if any) relays required at signal locations to drive signal mechanisms and lamps.
- With the use of filters, can be used in conjunction with other AC track circuits.

Different units/modules are used for specific applications. These units are designated as follows:

Unit Name	Description
End of Siding (Control Point)	The End of Siding or Control Point Units are used to: • Initiate code transmissions to other signal locations • Decode received pulses • Interface with interlocking relay logic circuits or serial link to solid-state interlocking equipment.
Intermediate	Used at intermediate signal locations to: • Decode signals from the rail • Transmit codes to other units • Drive lamps and various types of signals • Perform all required light out detection One intermediate unit handles both east and west directions. Stick logic for following moves is built in.
Repeater	Repeater units are used to regenerate and repeat codes in both directions. Repeaters are used when the distance between signal locations is too great for one track circuit.
Electric Lock	The electric switch lock unit provides all the functions necessary at a switch lock location and acts as a repeater, which receives and transmits codes east and west if all switch lock conditions are met.
Electrified	The electrified unit is an AC interface used in conjunction with other microprocessor based coded track circuit units in electrified traction territory.

7.6.4 Theory of Coded Track Circuit Operation

No specific type of equipment is intended for this description. The following is a model to explain the basic theory of operation for training purposes only.

Code Repetition: Microprocessor track circuits are bi-directional. A DC pulse is transmitted through the rails to a remote location. The remote location reads the information, then transmits its code back to where it originated. Each transmission takes 1.4 seconds for a total of 2.8 seconds. The process is continuous until the presence of a train interrupts it. When there is no code being received, the signal will display a red aspect.

Codes are grouped into two categories, vital and non-vital codes. In our model, codes 1, 5 and 6 are non-vital codes and codes 2, 3, 4, 7 and 8 are vital codes. A vital code is one that controls the aspect of a signal and is initiated from a control point. Non-vital

codes are single pulses within a 1.4 second window while vital codes are two pulses within a 1.4 second window.

Non Vital Codes		
Code	**Pulse Width**	**Description**
1	115 ms	Status of track circuit
5	225 ms	Status of track circuit plus block check for indications on dispatchers panel. The system sees the first 115 ms and interprets it as a code 1 (track status). Then, as the same pulse continues for another 110 ms, it is also interpreted as a code 5 (block check).
6	600 ms	Status of track circuit plus signal tumbles down. When signals are lined in one direction, the opposing signals will tumble to their most restrictive aspect. A code 6 speeds the process up.

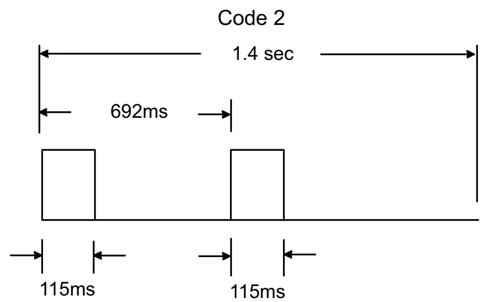

Figure 7-33 "Code 2" Pulse Pair, 692ms Measured from Leading Edge to Leading Edge of Each Pulse

Vital Codes		
Code	**Width of Pulse Pair**	**Aspect**
2	692ms	Yellow
3	488ms	Yellow/Yellow
4	332ms	Flashing Yellow
7	224ms	Green
8	948ms	System at rest – signal aspects and code 8 used for block indication. Direction of traffic per last train movement. Code 8 received at End of Siding indicates clear block to next end of siding.

For indications (interpretation of aspects) in the above table, refer to the railway's operating rules.

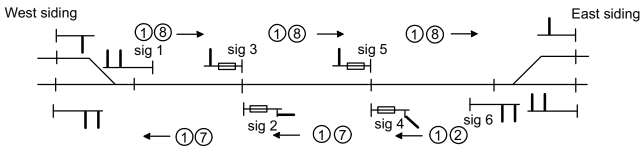

Figure 7-34 CTC System at Rest with Previous Move Being Eastward

In the layout of Figure 7-34, code 5 would also be present on each track circuit to send track status information to the control office.

End of Siding units do not perform interlocking functions. The units decode the pulses received and energize relays to indicate the condition of the block, track circuits or the level of the vital codes. Interlocking functions are vital signal circuits, which are relay based or solid-state. Vital signal circuits control the codes transmitted by the End of Siding unit.

7.6.5 Solid State Interlocking

The Solid State Interlocking (SSI) is an application programmable controller designed to control wayside signals, switches and track circuits at a railway interlocking. With various input/output modules, the SSI is configured to control various signalling applications. SSI replaces most of the relays in older-style control points.

SSI controls and monitors wayside devices and also performs the functions of most conventional code line systems to communicate with the central dispatch office. SSI has the capability of encoding and decoding microprocessor based coded track circuits and generating cab signal outputs.

SSI is chassis mounted containing several vital and non-vital circuit boards. The rack may also contain microprocessor based coded track circuit equipment and a local control panel.

Solid-state interlocking uses standard signalling logic converted to equations that are checked then processed by the microprocessor and related support circuits.

Application logic: Is the site-specific logic that is customized for each location and controls that specific interlocking. Application logic replaces traditional relay logic with Boolean equations that emulate relay circuits.

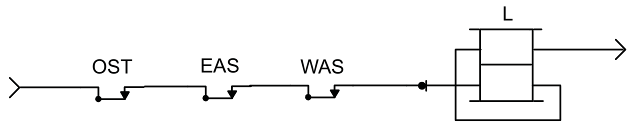

Figure 7-35 Example of a Relay Logic Circuit

In Figure 7-35, the L relay will be energized if the contacts of the OST, and the EAS and the WAS are up. The word "and" is intended to be "logical and."

The Boolean equation, equivalent to the series circuit in Figure 7-36 is:

(OST * EAS * WAS) = L

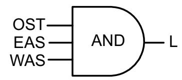

Figure 7-36 Logic AND Gate

The microprocessor driven application software logic has the same inputs and outputs as the equivalent relay logic circuit.

7.7 Defect Detectors

Defect detectors are installed on railways to prevent expensive and dangerous derailments. In the past, people at track-side inspected rolling stock for potential hazards and track inspectors patrolled the track for slides, floods and other signs of danger. New technologies provide an alternative means for defect detection.

The following is an overview of some of the detectors currently in use today.

7.7.1 Hot Box Detector

The Hot Box Detector scans the trains for overheated wheel bearings before they advance to a dangerous state. Undetected, overheated wheel bearings can become molten and cause a wheel/axle separation and a possible derailment.

Scanners, bolted to the outside of each rail, are gated (turned) on as a train approaches them. The scanners look upward to the journal, which houses the bearings, and read the infrared energy emitted by the journal and reference it to two points, the body of the car and the journal on the other end of the axle. If a journal temperature exceeds the assigned threshold, the information is sent to the dispatching office identifying the hot box. Some railways have implemented a talker, which is a synthesised or recorded voice that is broadcast over the radio system, identifying the defect.

7.7.2 Hot Wheel Detector

A Hot Wheel Detector operates on the same principle as the Hot Box Detector. It reads the infrared energy emitted by the web of the wheel.

Sticking brakes usually causes hot wheels. A hot wheel that is allowed to go unchecked could become distempered and eventually break, causing a derailment. A flawed wheel could cause damage to the rail and the roadbed.

One Hot Wheel Detector is mounted on one side of the track, on an angle to see all the wheels that pass through its line of sight. A reference board is placed on the far side of the track to establish a quasi absolute scale. A defective wheel is reported in the same manner as the Hot Box Detector system.

7.7.3 Dragging Equipment Detector

A Dragging Equipment Detector consists of a series of metal paddles on both sides of the rail and between the rails. The paddles are attached to a shaft so that when it is

struck, the shaft rotates and opens a contact, which sends a signal to the electronic equipment, alarming the office and/or the radio system.

Usually the Hot Box Detector, Hot Wheel Detector and the Dragging Equipment Detector are installed at the same location, sharing the same bungalow that houses all the electronic and communication systems.

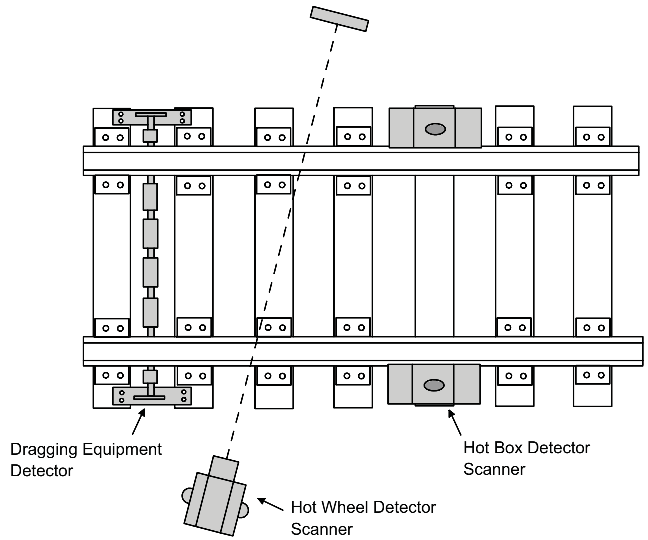

Figure 7-37 A Site with Three Defect Detectors

7.7.4 Wheel Defect Detector

Wheel Defect Detectors effectively measure the degree of impact caused by a flat spot or other wheel defect. Reports are generated by the system and transmitted to the control office and/or the repair shop. Severely damaged wheels will alarm the dispatch office and the car will then be set-out before serious damage occurs to the wheel, rails, ties or roadbed.

The system operates on the principle of measuring small changes in current flowing through strain gauges welded to the web of the rail. As a wheel passes over the rail, it bends downward, distorting the strain gauge and changing its resistive value. The heavier the load, the greater the distortion.

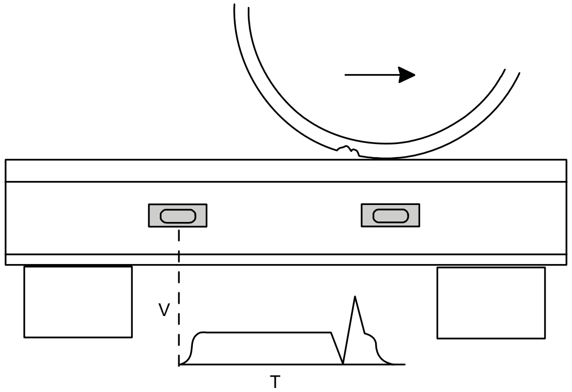

Figure 7-38 Wheel Defect Detector - Volts/Time Graph

The graph in Figure 7-38 shows a signal spike caused by a defective wheel.

Wheel Defect Detectors can be configured to perform the following functions:

- Detect wheel impacts
- Weigh wheel sets (loads) dynamically
- Measure rail stress under different load and climate conditions
- Detect skewed or hunting trucks

7.7.5 Slide Fence

Slide fences are installed in areas where falling rock, rock slides or mud slides are likely to occur. They are most often installed at the approach to tunnels.

Slide fences can be as simple as a network of wires mounted on wooden posts or as elaborate as an array of mercury switches. Broken wires or tripped switches de-energize a relay, which in turn affects the signal system or lights a dedicated signal to prevent trains from running into debris blocking the track.

7.7.6 Flood Detectors

High water on or near the track can saturate or washout the roadbed causing a derailment. This is particularly true where culverts are installed, allowing natural waterways to pass through the tracks.

Two common high water detectors are the grid and float types. The grid type, when submersed in water, lowers the parallel resistance across the coils of a relay causing it to de-energize. The float type has a ball that rises with the water level and opens a contact that de-energizes a relay. The relay controls the signal indication over that area.

7.7.7 Fire Detectors

Fire detectors are usually a fusible wire strung across a wooden trestle or platform. If the trestle catches fire, the wire melts and opens the circuit to a relay. When the relay de-energizes, the governing signals are caused to display a stop indication. A dedicated signal may be installed in dark territory.

7.7.8 High/Wide Load Detectors

High/wide load detectors check for high, wide or shifted loads to ensure that trains on adjacent tracks can safely pass each other and can safely pass through tunnels or where there is a height or width restriction.

One type of high/wide load detector is a frame with a network of wires defining the maximum allowable height and width limits. A broken wire causes a relay to de-energize, thereby affecting the signal system. A more modern type uses laser beams to detect the height and width.