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.

©2003 AREMA®

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.

©2003 AREMA®

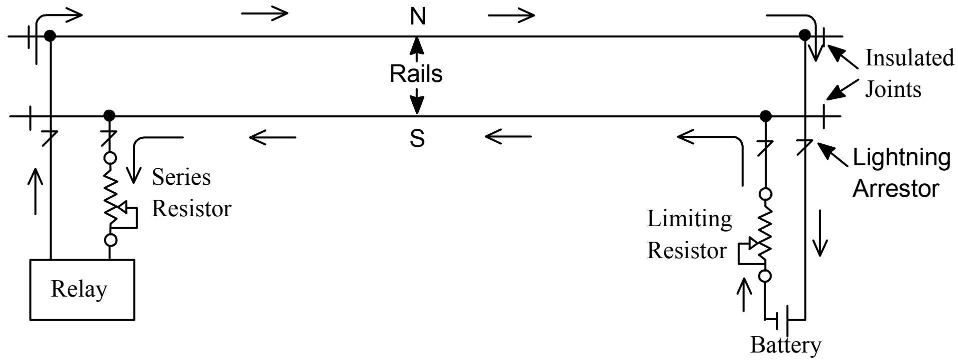

Figure 7-14 Conventional DC Track Circuit Basics

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.

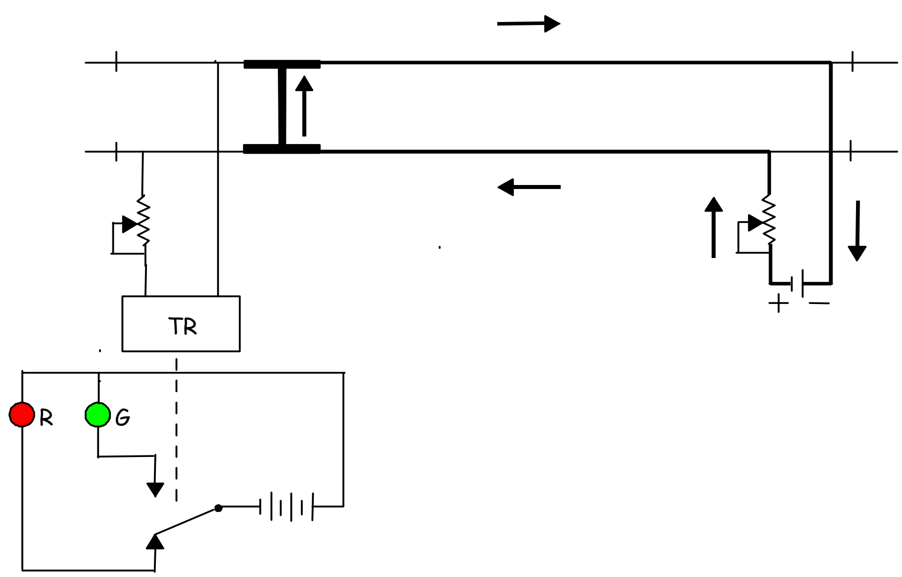

Figure 7-15 Contacts of a DC Track Circuit Relay Controlling a Lighting Circuit

©2003 AREMA®

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

©2003 AREMA®

- 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.

©2003 AREMA®

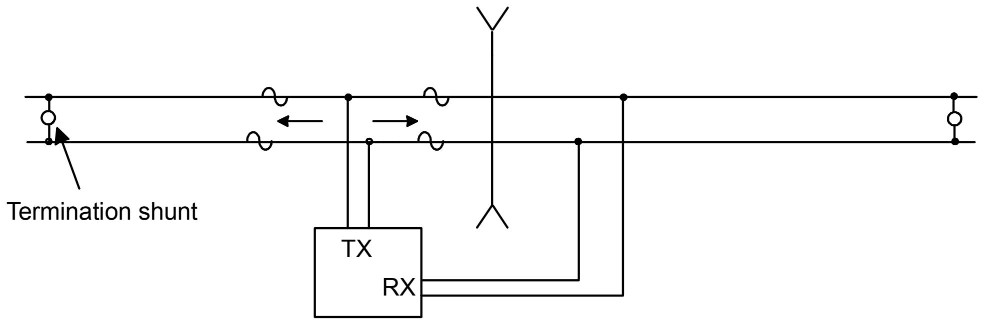

Figure 7-30 Bi-directional - Automatic Crossing Warning Device

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.

©2003 AREMA®

- 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.

©2003 AREMA®

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.

©2003 AREMA®