Genius Challenge: Signal Overview

Train Control Systems

The objective of any train control system is to detect train presence to provide safe train separation and to maintain the required headway throughput, allowing for the appropriate timing between successive train movements in the same direction on a particular route. The main train control systems utilized on NYCT properties are Fixed Block Wayside Signaling and Communication Base Train Control (CBTC).

Fixed Block System

In fixed block systems, track sections are divided into blocks separated by Insulated Joints (IJ) that are installed in the rails. The blocks are incorporated into the rail system using electrical circuits detect the presence of trains in the blocks. Signals are placed at the entering end of a block as needed. Signals are composed of colored lights with associated automatic train stops. Each signal is assigned a control line that consists of a minimum of two blocks to provide safe separation of trains.

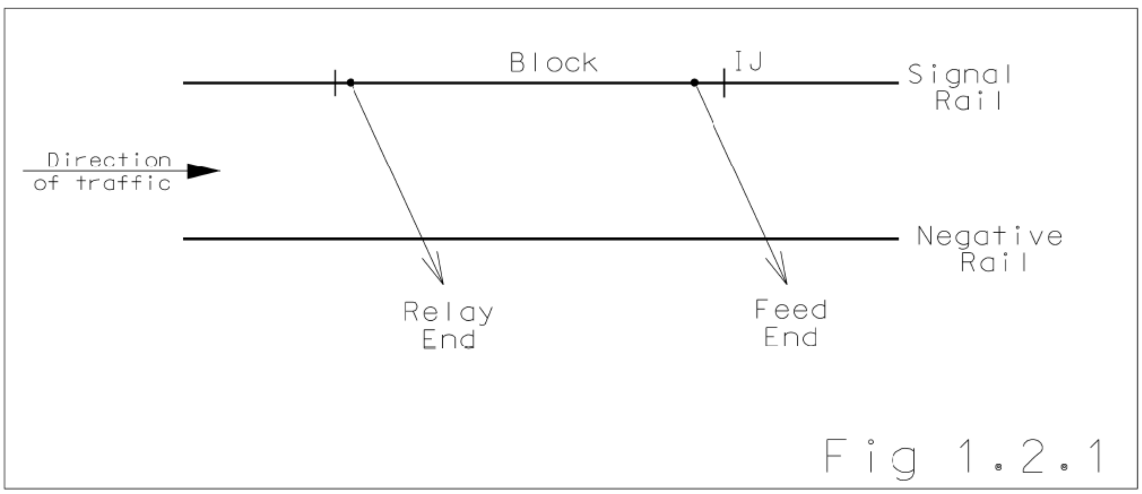


Figure1.2.1: Single Rail Track Circuit

Once the fixed block signal system is commissioned, no change can be made without evaluation. Changing any of the design parameters such as car performance, track profile, point of switches, signal locations or headway requirements will impact the safety or headway of the signal system. For that reason, when and if changes need to be made, safety and headway calculations have to be redone to validate the required change before implementation.

CBTC System

This system is based on two-way communication between the train and the wayside equipment. The area under design is divided into zones that are governed by zone controllers. Each zone controller communicates and exchanges information with adjacent zone controllers and with trains in their zones of coverage. Passive Transponders are located between rails at specific fixed points (stationing). When train “A” passes over a transponder, it reads the transponder’s location and updates its own location. Trains continuously transmit their locations to the zone controller. The zone controller, which knows the location of a preceding train and the status of Home Signals and Switches at Interlockings up ahead, assign a Movement Authority Limit (MAL) to train "A", via radio communication. The train cab has a microprocessor (CBTC Carborne Controller) that is installed in the car and is connected to and can control train acceleration and braking systems. The Carborne Controller equipment of train "A" generates an appropriate speed profile which will safely stop the train within a short distance of an obstacle ahead. A limited number of Track circuits are used for train detection for failed or unequipped trains (e.g.: Work Trains) and as an important part of the safety sequence for entry into CBTC areas and for system initialization if a restart of the Zone Controller is required.

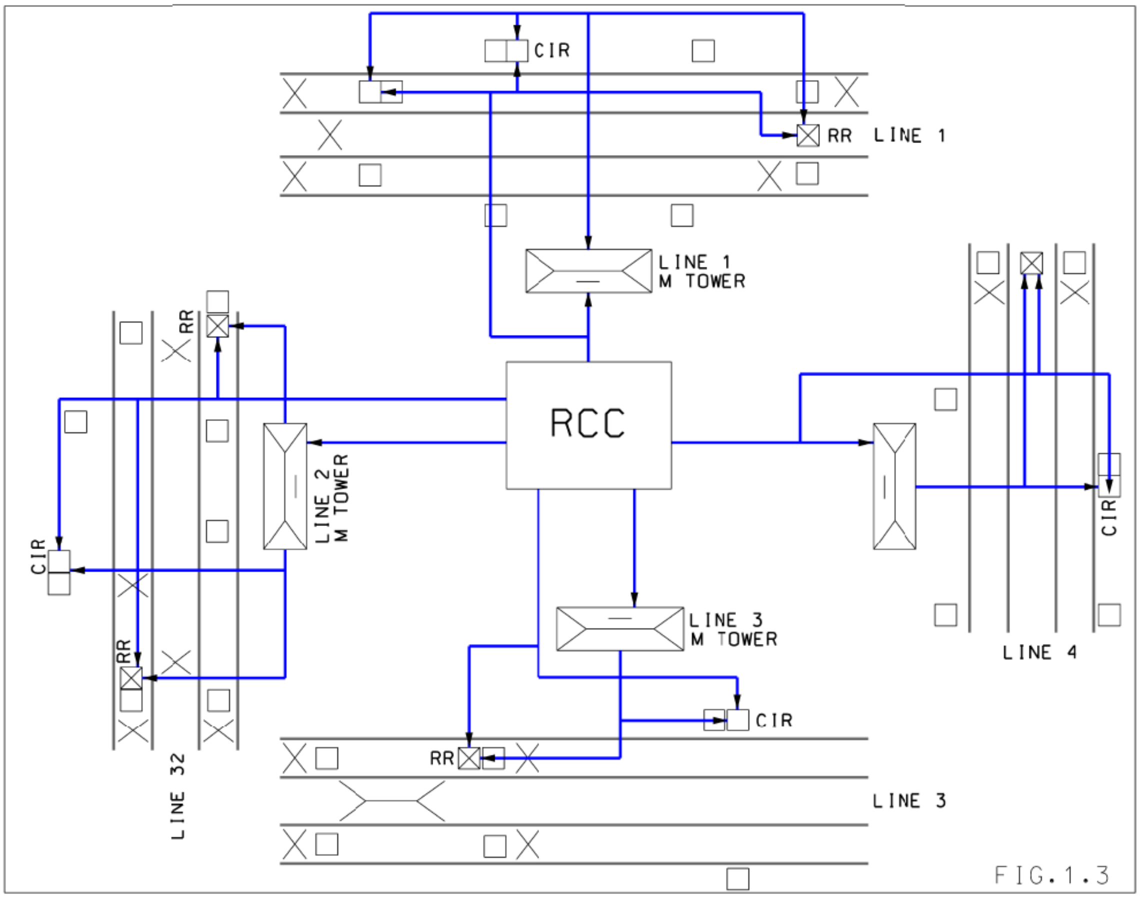
NYC Transit Rail System

New York City is one of the largest rapid systems in the world. It operates in two Divisions: Division A (IRT) and Division B (IND & BMT). The main difference between the two divisions is the car width. Division A cars are narrower than Division B cars. For this reason, Division B cars cannot operate on the Division A mainline. The system has a few spots that run Division A cars on Division B mainline to provide access to yards with car shops. Both Divisions include 708 track miles of mainline track and 114 miles of yard storage track. There are 472 passenger stations and fleet over 6000 subway cars.

In addition to being large, the NYC Transit network is the most complex in the world in terms of the multiple services using common tracks. The network includes over 200 interlockings, which consist of one or more crossovers to permit train movement from one track to an adjacent track or transfer from one line to another line.

The control system includes electrical machines with push buttons entrances-exits (NX) to establish route and control the interlocking, an arrangement of switch and signal appliances interconnected in such a way that their movements must succeed each other in a predetermined order.The electric machine facilitates control of the interlocking locally and remotely from longer distances at a Master Tower. The Master Tower provides visibility of one or more service lines and controls all the interlockings within that limit of visibility. The interlocking logic and signal equipment is housed in a Relay Room (RR) adjacent to the interlocking. Block control signals (BSC) or automatic signals logic equipment is housed in Central Instrument Room (CIR).

Currently, all Division A is controlled from Rail Control Center (RCC) in addition to Master and Local Towers, under the Automatic Train Supervision (ATS) project (see fig. 1.3 for illustration). The BMT portion of Division B is completely controlled locally and from Master Towers.Portions of Division B (IND only) are still only controlled locally by mechanical lever machines. Efforts are ongoing to modernize the remaining IND interlockings, to bring both Divisions to RCC for control of NYC Transit network. The following schematic illustrates the control of NYC Transit signal system.



NYC Transit Signal Equipment

Track Circuit

The track circuit is the foundation of the signal system. A track circuit is an electrical circuit whose rails form a part of the circuit. The primary purpose of the track circuit is to detect the presence of a train on a specified section of track. It also serves as a check of the continuity of the rails to detect broken rails. (Please refer to Fig 1.2.1 "Single rail track circuit diagram.") From the diagram, the track circuit track relay will be energized under normal conditions. As the wheels of the train roll over the rail (or if there is a broken rail), shunting across the source of energy causes the track relay to drop, indicating the track ahead is unsafe or occupied. This arrangement is called "fail safe design." The maximum length of a track circuit is 1400ft and the minimum length is 50ft. The maximum (length, which is limited by the interference from the return current with harmonics of new AC motor cars, is more than the distance between car axles to prevent fluctuation of the track relay as the train goes by that track circuit.

Insulated Joint

Insulated Joint (IJ) is insulator placed in rails between adjacent sections of track circuits to insulate one from the other. This is a piece of insulating material inserted at rail joints that has the same cross section as rails. The track circuit between two insulated joints is called a block.

Automatic Train Stop

Except for some cases such as repeater signals (where no stop is required), storage yard signals (no stop required in most cases) and bumper post (fixed trip is utilized), every signal is provided with an automatic stop mechanism to ensure proper observance of STOP indications by the signal. This device prohibits the unauthorized movement of a train past a restrictive signal. It is a mechanism located along the right of way. It has a stop arm, when actuated would be on the tripping position, so as to mechanically engage an air release device on any car attempting to pass the signal, thus applying the emergency braking system of the train. Therefore, the train is brought to a safe stop under emergency condition short of the occupied track without any action on the part of the train operator.

Interlocking

Interlocking plants are installed at all terminal, junction points and at other locations where it is necessary to route trains from one track to another. As mentioned, an interlocking is an arrangement of signals and signal appliances so interconnected that their movement must succeed each other in proper sequence and for which interlocking rules are in effect. The interlocking rules are governed by the Table of interlocking routes, which is based on the final signal design.

Switch Machine

Switch machine is installed next to the rail switch point. Switch machines are controlled from the relay room’s control panel. In establishing a route, the route logic has to be satisfied in order to activate the switch machine and move the rail switch point to the required track and clear the associated signals.

Interlocking Panel

The interlocking panel is an assemblage of levers locally or remotely operated to control the interlocking signals and switches in order to prevent any conflict while establishing the required route, locking the switches and clearing the signals designated for this route. Lever numbers are assigned by circuits group for interlocking signals switches and traffic.

Signals

All types of signals used in NYC Transit System are of the color light type. The indications are displayed by illuminating LED modules behind a colored lens, which may be red, yellow or green. The signals in NYC Transit system are categorized into two categories depending on how they are used in the system. They are the automatic signals and interlocking signals.

CANARSIE LINE CBTC OVERVIEW

Background

The New York City Transit (NYCT) subway system is one of the largest and most complex in the world. It consists of approximately 809 track miles, and provides service to 472 stations in four counties (boroughs). Its 25 subway lines are interconnected with free transfers between lines permitted at more than 50 locations. Many lines also feature express and local service with across-the-platform transfers. Some lines provide "skip-stop" service. Intervals between trains range from 1.5 to 5 minutes (peak), 6 to 15 minutes (off peak) to 20 minutes (between midnight and 5 am). The system operates 24 hours per day, presently running some 6,500 scheduled trains each weekday and moving in excess of 5.5 million riders daily. Peak period service presently includes approximately 540 trains. The system has approximately 16,000 signals, 220 substations, and over 6,000 revenue and non-revenue rail vehicles.

Almost a third of the existing signal system is more than 80 years old. As part of its ongoing modernization program, NYCT plans to modernize its signal system from fixed block, wayside signals/trip stop technology to state-of-the-art communications-based train control (CBTC) technology, utilizing two-way digital RF communications between intelligent trains, and a network of distributed zone controllers. The primary characteristics of CBTC include:

- High resolution train location determination by carborne equipment, independent of track circuits.
- Communication of this information and other train status data to wayside zone controllers over the RF train-to-wayside data communications link
- Determination of movement authority limit information for each CBTC-equipped train by wayside zone controllers, based on train derived location information and inputs from wayside interlockings
- Communication of this authority limit information and other train control dat, to the appropriate train over the RF wayside-to train data communications link
- Determination and enforcement of the safe speed/distance profile by the carborne CBTC equipment
- Communication of required CBTC commands from the wayside zone controllers to interlockings to support CBTC operations

The new CBTC system is intended to provide shorter headways, lower maintenance costs (due to less field equipment), greater operational flexibility, enhanced safety (due to continuous over speed protection), smoother and more predictable operation, and improved reliability and availability.

The Canarsie Line is the Pilot and first location at NYCT to be equipped with CBTC technology. It is one of only two lines in the NYCT system that is essentially self-contained with a dedicated right-of-way. The previous signal system, along the line's 23 track miles, was a traditional fixed block system with wayside equipment. The original equipment was installed in 1926 and was 20 years past its useful life.

The CBTC system has been in service since 2006.