Traffic 101 Training

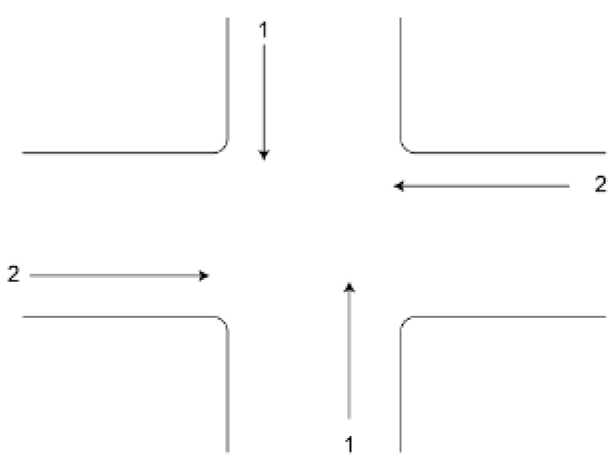
History of how far traffic signals since the early 1900s

The history of traffic congestion goes back to horses and buggys at junctures of two roads. There was such a problem with buggys that towns needed to find a way to regulate the management of the buggys. The idea of a traffic signal came from the railroad. The railroad had warning signals for the trains. From this idea, the traffic signal was born (red first).

Fixed Time

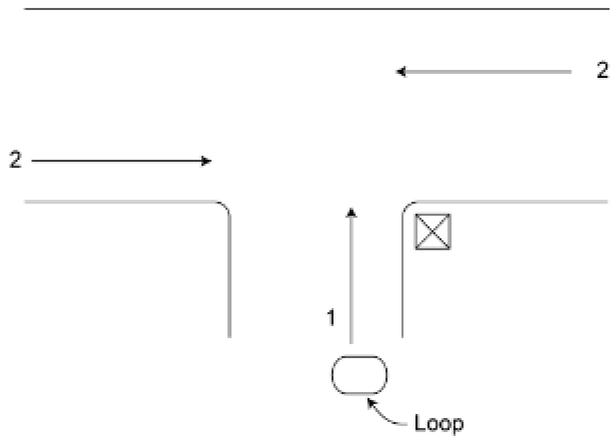
The first intersections ran on Fixed Time where there were two phases and each ran a defined amount of time (e.g., main street given 30 seconds of green and side streets given 20 seconds of green) without knowing whether or not vehicles were waiting. Fixed time is ideally suited to closely spaced intersections where traffic volumes and patterns are consistent on a daily or day-of-week basis.

The first controllers on the market, electro-mechanicial controllers, ran fixed time plans. Many old signalized intersections still use electro-mechanical signal controllers, and signals that are controlled by them are effective in one way grids where it is often possible to coordinate the signals to the posted speed limit. They are however disadvantageous when the signal timing of an intersection would benefit from being adapted to the dominant flows changing over the time of the day.



Semi-Actuated Intersections

The need soon arose for semi-actuated intersections in which detectors, such as loop wires, were placed on minor movements at an intersection to indicate vehicle presence. The controller is programmed to stay on the phase that does not contain detection, thereby maintaining a green light for the highest flow movements (normally the major street through movement). Minor movement phases are serviced only when a detection is received.



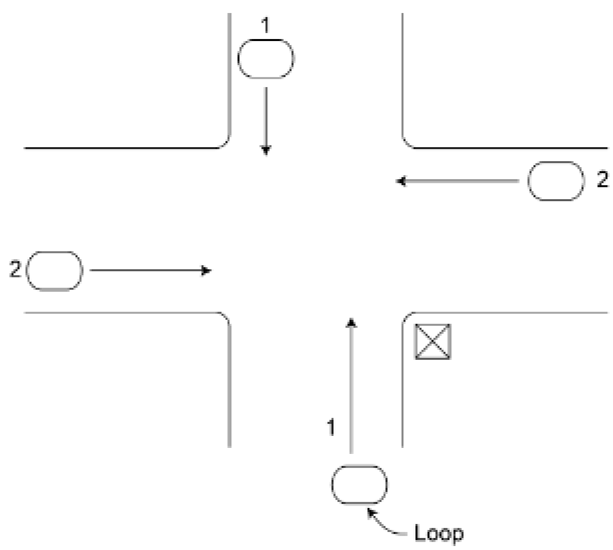
How do loops work?

Loops are two wraps of #14 wire buried in the roadway, and connected to an electronic circuit, causing a magnetic field in the loop area. The loop resonates at a constant frequency that the detector monitors. A base frequency is established when there is no vehicle over the loop. When a large metal object, such as a vehicle, moves over the loop, the resonate frequency increases. This increase in frequency is sensed and, depending on the design of the detector, forces a normally open relay to close. The relay will remain closed until the vehicle leaves the loop and the frequency returns to the base level.

For more information, see Inductive Loop Writeup.

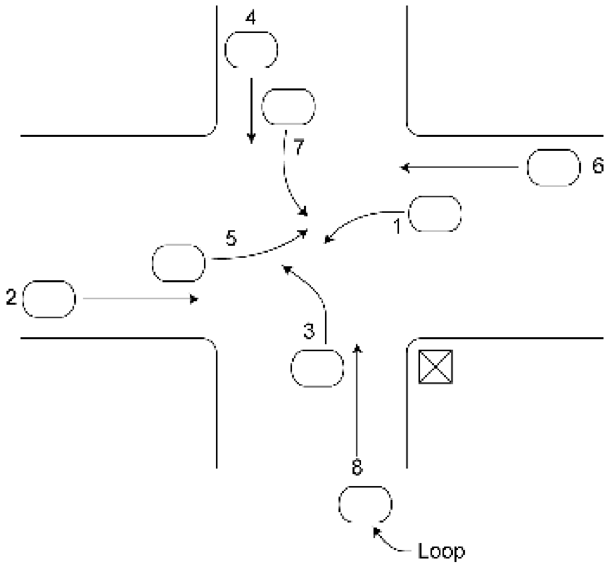
Fully Actuated

Fixed timing was intended for grid network roadways systems, which worked well because of the predictability of speeds and distance between intersections.This method, however, did not work well for intersections are at irregular distances. Fully actuated intersections are ideally suited to isolated intersections where the traffic demands and patterns vary widely during the course of the day.



Adding in Left Turns

As things got more complicated, dedicated phases needed to be assigned to left turn lanes. Eight-phase intersections were introduced shortly after introducing fully actuated intersections. Eight phase intersections have four straight thrus (even numbered phases) and 4 left turns (odd numbered phases). The numbering (odd for lefts, even for thrus) is consistent in the industry. Normally phases 2 and 6 are considered the main street; however, sometimes 4 and 8 can be the main street. This is not always consistent.



Introducing an eight-phase, fully actuated intersection brought up a dilemma: what phases can be up at the same time. The answer is to define permissive phases (phases that can run at the same time).

For the above example, the following phases can run at the same time (also known as Permissive Phases):

- Phases 1 and 5
- Phases 1 and 6
- Phases 2 and 5
- Phases 2 and 6
- Phases 3 and 7
- Phases 3 and 8
- Phases 4 and 7
- Phases 4 and 8

Non-permissive phases are phase that cannot be served at the same time.

Regulating the Industry

The MUTCD (Manual on Uniform Traffic Control Devices) defines standards used by engineers nationwide to install and maintain traffic control devices. Although the Federal Highway Administration specifies standards and guidelines through the MUTCD which apply to the usage of traffic control equipment, individual state and local agencies often provide additions or slight variations to these standards. Agencies can never do less than what the MUTCD requires. The MUTCD requires that there be barriers in the controllers so that conflicting phases are not served at the same time. The purpose of barriers is to define which phases are permissive (set up on one side of the barrier).

Timings

As intersection timing advanced, the amount of information that governs the intersection became more advanced. The following standard information is now required of all controllers:

Straight Thrus

- **Min (originally called Initial) Green:** (15 sec.) The minimum amount of green time that must be serviced for a phase
- **Passage (originally called Extension) Time:** (7 sec.) Amount of time that is added on to the Min Green time if a vehicle triggers a detection; this times concurrently with the minimum green time.
- **Max 1:** (50 sec.) Maximum amount of time that can be serviced for a phase.
- **Max 2:** (75 sec.) For special times of the day, you can apply a different maximum amount of time for servicing a phase.
- **Yellow (aka Amber):** (4.5 sec.) The amount of time that Yellow displays for a phase. Normally this is 4.5 seconds, but it depends on the width of the intersection and speed of traffic.
- **Red (also known as the all-red interval):** (1.5 sec.) This is the amount of time following the yellow interval of each phase in which all lights at an intersection display red. It must expire before the next phase in sequence can begin.
- **VR (vehicle recall):** Recall causes the controller to place a call for a specified phase each time the controller is servicing a conflicting phase, regardless of the presence of any detector-actuated calls for the phase. This is used for when a detector is not working. This can be max recall, min recall or soft recall.
- **PR (ped recall):** Places a call on a pedestrian phase for the situation when a push button has gone bad. This forces a ped phase to be served every time the corresponding vehicle phase is served.

*Ped phase number follow the vehicle phases.

Bad vehicle detectors can take time to be fixed; they end up going on a list to be eventually fixed. Bad ped buttons get replaced immediately since buttons are easier to replace and bad ped buttons pose a higher safety risk.

Left Turn Timings

If left turns have dedicated assigned phases, the timings for those phases are typically:

- **Min (originally called Initial) Green:** 3 sec.
- **Passage (originally called Extension) Time:** 3 sec.
- **Max 1:** 15 sec.
- **Max 2:** 20 sec.
- **Yellow (aka Amber):** 3 sec.
- **Red (also known as the all-red interval):** 0 sec.

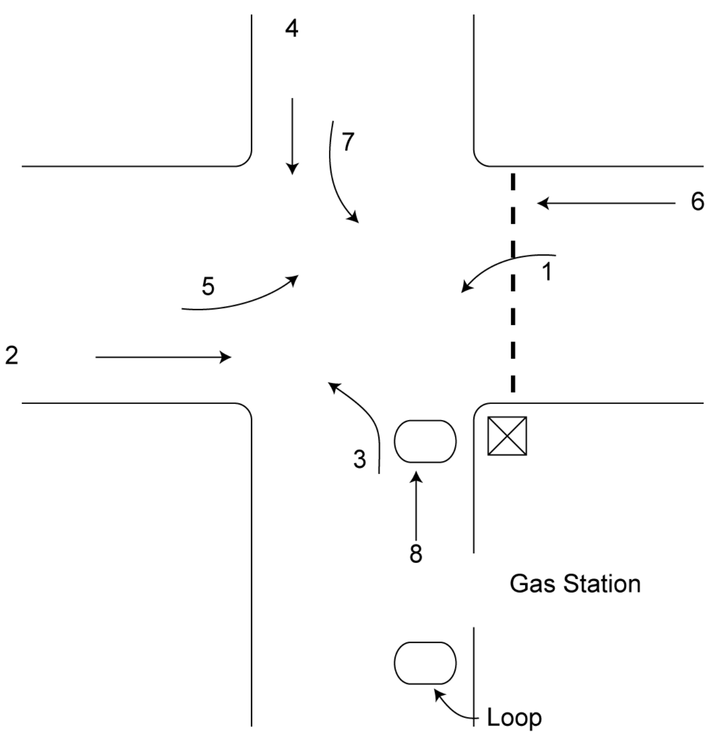
How Pedestrian Movements Can Disrupt Timing

Consider the following timings and situation for a standard 8-phase intersection:

- Min:10 s
- Passage: 4 s
- Max: 20 s
- Walk: 10 s
- Pedestrian Clear (FDW - flashing Don't Walk): 22 s.

In this case, there is a side street with loop detection at the front of the approach and another loop behind a exit/entrance of a gas station, meaning that the loop located the furthest from the approach is sometimes worthless. The main street (phases 2 and 6) is wide, so the walk time/ped clear needs to be long (10/22). When a car pulls up on the sidestreet loop from the gas station, the main street terminates and the side street gets a green. For one car, the side street is served with 10 seconds (min green time).

For the next cycle, there is again someone pulling out of the gas station, but also there is a ped call. The controller starts timing the min of 10 seconds. After 10 seconds, it must remain green because the Ped Clear has not finished timing. It must remain green for another 22 seconds until it can go back to serving the main street. This throws off coordination.



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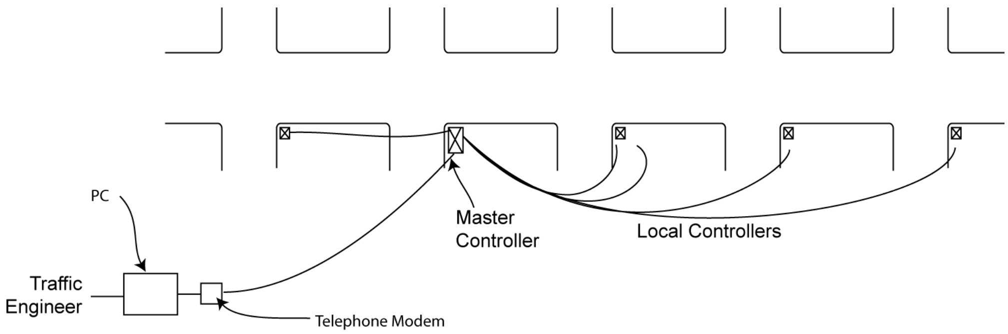
Traffic Management Systems

There are a couple of different ways in which traffic engineers can control traffic signals:

- Closed Loop System
- Traffic Management Center

Closed Loop System

Closed loop systems are popular, but are beginning to be phased out in favor of TMC (Traffic Management Center)-based systems. These type of systems require a master controller and local controllers.



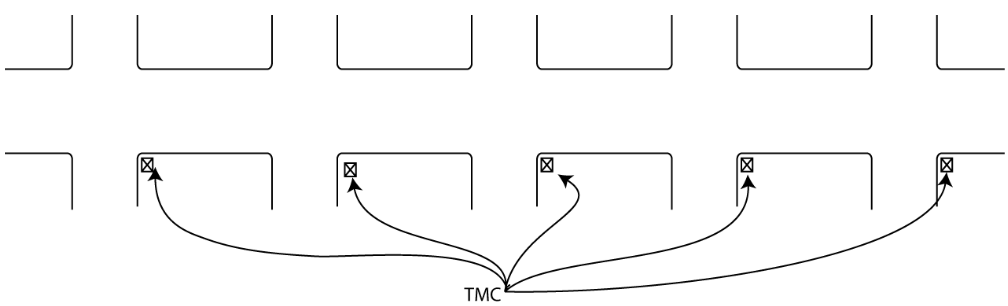
In a closed loop system, all the controllers are connected to each other using fiber optic cable. The Master Controller is connected back to the office. There are also sampling detectors on both ends and in the middle of the closed loop system. These are in addition to the inductive loop detectors used for the local controller. Multi-mode wire is run between intersections. Multi-mode wire is great for short runs.

In this system, an engineer in the office can call up the master controller. The master controller then regulates the closed loop system and controls the local controllers.

When the master controller fails, the locals fall back to fixed timings. Fixed time plans tend to generate more customer complaints, which is a strong indication that a master controller is offline.

Closed loop systems can run traffic responsive.

Traffic Management Center (TMC)



In recent years, TMC-controlled controllers have become more popular. In these systems, each controller reports back to the office, which is running traffic management software. This software can adjust timing plans based on detections, but it does not do the adjustment in real-time (as it is happening). That is, it will adjust timings for future cycles but not for the current cycle. InlSync is revolutionary in its adjustment of the current cycle/demand.

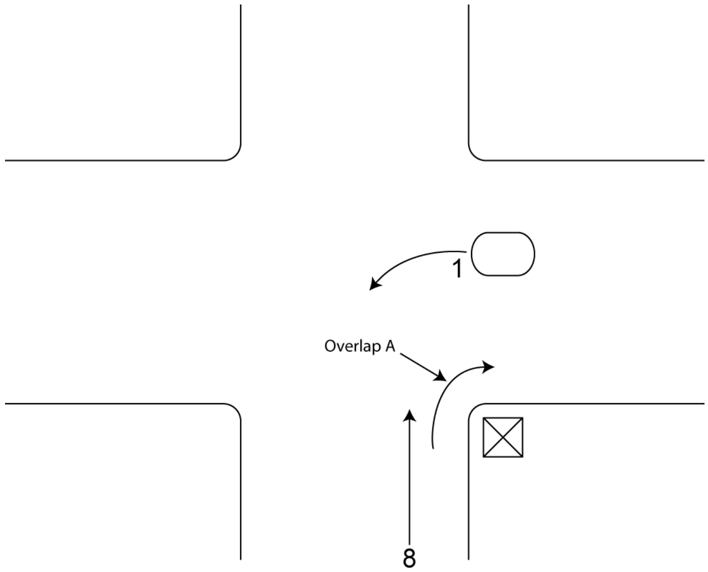
However, it must be noted that re-timing of intersections has fallen into the hands of service technicians, who are tasked to go out to an intersection and troubleshoot issues. In reality, traffic engineers spend most of their time creating budgets, ordering equipment, planning improvements, fielding complaints and meeting with prospective vendors.

Moving Beyond Eight Vehicle Phases

As roadways evolved, so did the complexity of intersections. This created a need for more phases. One instance is the need for Overlaps. Overlaps is a non-conflicting movement of traffic that is made up of one or more phases.We drive through intersections with overlaps every day.

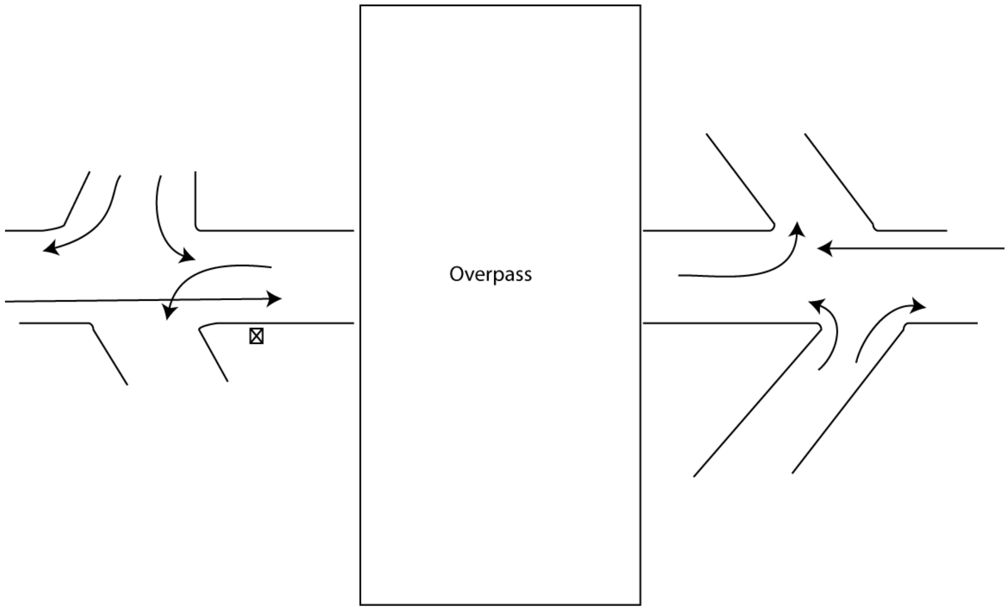
Overlaps exist in situations where you get a lot of heavy left turn movement on phase 1 and a lot of heavy right turn movement on phase 8. To solve this problem, two options are to move the traffic through phase 8 by increasing the green timing for phase 8 or phase 1.

Another option is to bring up a **right turn arrow** while phase 1 is timing. This would be called overlap A. Overlap A comes up when running phase 1. It is not an actuated movement, while phases are actuated movements. This option makes sense if you have a lot of left turning traffic.



You can also have Overlap A up running when phase 8 is not green (i.e., when phase 8 is yellow and red).

So, most of today's controllers now handle 16 vehicles phase, 16 pedestrian phases and 16 overlaps available to be programmed. There was a time where you had to interlock two controllers together to handle bigger intersections. A case in point would be an intersection like Metcalf Ave. and 435



Controller and Cabinet Technology

How an electromechanical controller works

The earliest controllers were electromechanical (prior to 1970s). In general, electro-mechanical signal controllers use three dial timers that have fixed, signalized intersection time plans. This type of controller uses synchronous motors and an electrical magnetic coil to energize and de-energize a solenoid, which in turn, advances rows of preset cams and contacts (one for each lamp) to mechanically change the signal lamps. For details on how electromechanical controllers work, see http://streets.mn/2015/06/20/all-about-traffic-signal-controllers-part-one/

First Electronic Controllers and Cabinets

From 1963-69, the microprocessor came into existence as a byproduct of the space program. This opened the door to numerous improvements.

NEMA

Early in the 1970s the NEMA organization decided to standardize on the connectors to a controller. They instituted the A, B, and C waterproof connector, but did not standardize the D connector. All manufacturers had to use the A, B, C connectors. The manufacturers created their own D connectors. NEMA also carried it forward more by defining minimal requirements on a cabinet. Prior to NEMA, cabinets had to be custom made for an intersection. NEMA developed the standard TS1 cabinet.

CalTrans

The State of California did not like the NEMA standard and decided to develop their own standard 170 controller and standard 332 cabinet. New York partnered with California and installed these types of controllers/cabinets in their locations. Other smaller pockets around the country also adopted this standard; however, most of the country adopted the NEMA standard.

Today's Controllers/Cabinets

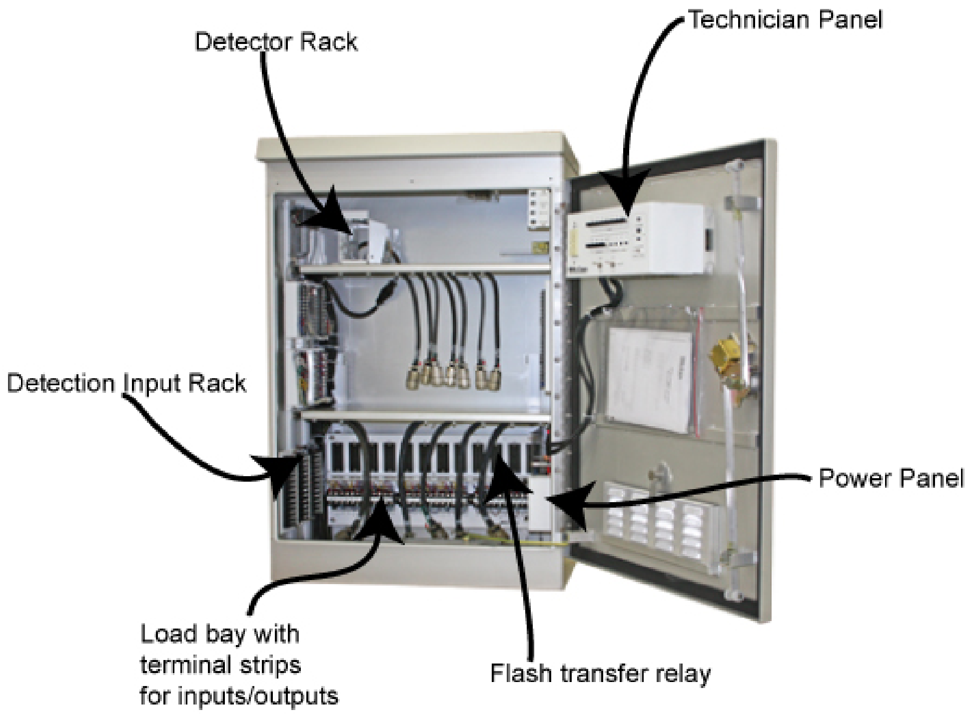
In 1992, NEMA upgraded to the TS2, Type 1 controller, which was a digital state machine. The TS 2 Type 1 controller is unique in the sense that is uses an RS-232/SDLC data link connection to the peripheral devices, with a separate power connector (5). In 1998, the TS 2 Type 2 was developed. It provides the same connectors as the TS 1 but also includes the data link connector. This allows the TS 2 Type 2 controller to be installed in TS 1 cabinets, reducing the upgrade costs.

The Type 170 controller standard differed from NEMA standards in that it was a hardware standard only. Software to run the controller can be supplied by independent vendors and designed to perform specific applications. In 1986, the NYS DOT developed the Model 179 controller standard, and in the early 1990's, Caltrans developed the Model 170E controller standard. Both were enhancements to the Model 170 standard to meet current needs, and increased processing power, improved user display capabilities, provided larger memory storage, and enhanced communications capabilities. Only a few years later, in 1995, the rapid advances in computer technology led Caltrans to develop yet another standard, titled the Model 2070.

Standard Cabinet Components

Standard NEMA TS1 controllers contain the following:

- Detector Rack
- Load Bay with terminal strips for inputs/outputs and load switch sockets
- Technician's panel
- Police door with signal on/off and auto/flash switches (located on the front of the cabinet
- Flash transfer relay sockets
- Power panel with surge protector and filter
- Detector input rack (where field detection comes in)
- Mercury contactor switch
- Flasher



Inductive loop detections plug into the detector rack at the top of the controller. When you order a cabinet, you don't get the loop detectors, you just get the rack.

The power supply is located on the left side of the rack to power the detector rack. It also plugs right into the detection rack.

The CMU ties to the field wires, which tie on to the output of the load switch. It monitors the ambers, peds, greens and every single signal (AC side) that comes out of the traffic cabinet. When it sees something that it doesn't like, it throws the intersection into red flash (all approaches flash red signals). It also monitors all the voltages. If the voltages seems abnormal, it will also put the intersection into flash. MMUs (TS2, Type 2 cabinets) have additional logging abilities. It can report back anything wrong that happens during a crash. It is basically the "black box" of the traffic industry.

Flash Transfer relays have contacts that when touching, energize and activate a light. The red light on a traffic light is the only light that has two functions: flash red when the police, a tech or the CMU/MMU sets it to flash and solid red for regular operation. The reds are split with the flash transfer relays. When the intersection is flashing, contacts move to touch another contact to energize. Flash transfer relays do this on a phase basis, so four relays will handle 8 phases. Flash transfer relays are driven directly from load switches.

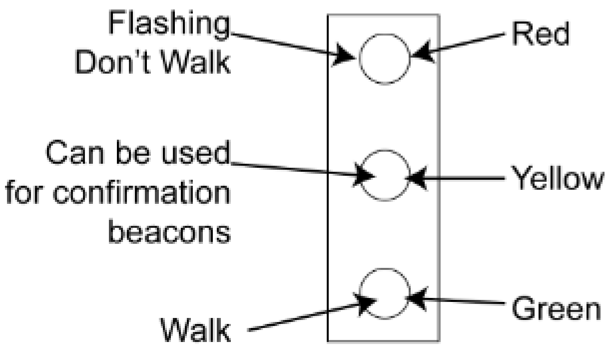
A tech panel is on the inside of a cabinet door. It is for emergency use by a tech when an intersection is experiencing issues. There are four switches on the tech panel: Flash/Auto, Signals On/Off (shuts off the field signals completely), Controller On/Off, and Stop Time On/Off (keeps a certain sequence indefinitely). There is also a police panel on the reverse side of the tech panel (on the outside of the cabinet). There is a skeleton key given to police that allows a police officer to open up the police panel. There are two switches available to the police for controlling traffic: Flash/Auto, Signals On/Off, and Stop Time On/Off.

The flashers are a two-circuit flasher that generates the flash.

The load switches are a universal device between NEMA and CalTrans. It has three lights on them and they are interchangeable. Because the load bay is low voltage DC and so is the controller, everything runs on the following voltages:

- Send green light to the field: sends out logic common/ground
- Shut green light off: shoot back to 24V

The whole load bay, in fact everything, is 24 DC except where the power comes in. A load switch is basically a TRIAC. A TRIAC functions as a bi-directional switch to pass the current in both directions once a gate is triggered. For more information on how TRIACS work, see https://en.wikipedia.org/wiki/TRIAC.



Most intersections now use LED traffic lights. LED traffic signals require significantly less power (24 amps down to 3-4 amps). Because of these LED lights, they were able to put in battery backups at the cabinets. These battery backups can run an intersection for 2-6 hours. Battery backups are for running intersections when power is cut, and for cleaning up the incoming power (makes high power lower and low power higher) that is coming into the cabinet.

There is a mercury tilt switch on both the cabinets and the battery backups. When a cabinet or battery backup is knocked over, the mercury level flows the other way and opens up a switch, which then kills the power, thereby eliminating the risk of electrical shock to a service technician.

Pluggables that go into the cabinet include:

- Controller
- Flash Transfer Relays
- Load Switches
- Flasher
- Harnesses
- Detector Cards
- Power supply for detector rack
- CMU (Conflict Monitor Unit)

For more information on cabinet hardware, see Cabinets and Controllers.ppt.

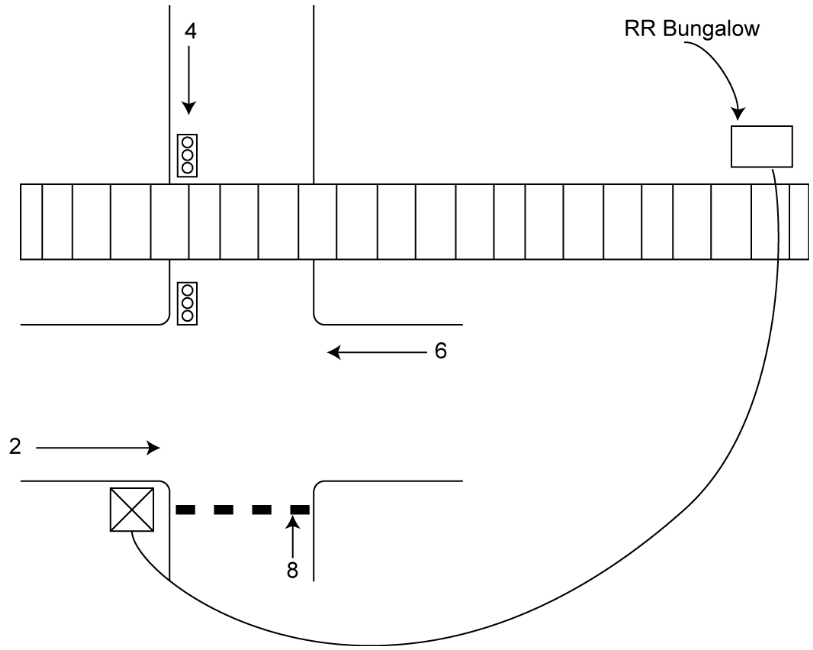
Preemption

Most controllers have six preempts. Preempts 1 and 2 are typically tied to railroad preemption. Preempts 3, 4, 5 and 6 are tied to emergency vehicle preemption (EVP). Preempts are prioritized according to the number; that is, a call coming in on Preempt 3 will be serviced before a call coming in at the exact same time as Preempt 5.

Serving Railroad Preemption without Pedestrian Traffic

Consider the following timings and the intersection geometry below:

- Min: 15 s
- Max: 50 s
- Passage: 7 s
- Yellow: 4.5 s
- All Red: 1.5 s
- Walk: 8 s
- FDW: 16 s
- The time it takes for a train to travel from the RR Bungalow to the intersection is 30 seconds.



In the following scenario, phases 2 and 6 have just received a green light and no peds are active. What happens when a RR call is received:

- The 115 V line breaks to indicate that a train is coming
- Green is terminated immediately on phases 2 and 6
- 4.5 seconds is given to yellow on phases 2 and 6
- 1.5 seconds is given to all red on phases 2 and 6
- Track clearance time, yellow time, and all red time is given to phases 4 and 8 (perpendicular phases) to clear any vehicles off the railroad tracks
- Go back to serving phases 2 and 6 while RR is passing by.

Serving RR Preemption with Pedestrian Traffic

Using the same timing parameters above, does the following scenario work for an active ped button using the normal timing rules (serving ped times before switching over to serving a conflicting phase)? No, it does not. Serving the ped in this scenario takes 24 seconds (8 walk time and 16 flashing don't walk time). Add to this yellow time (4.5 seconds) and all red (1.5 seconds). This would add up to 30 seconds for serving parallel traffic, meaning that there would be no time to clear the perpendicular approaches (train reaches the intersection in 30 seconds).

This led to a change in how pedestrian traffic is served at railroad intersections. For intersections that have both railroad preemption and pedestrian phases:

- The 115V line breaks to indicate that a train is coming
- Walk is terminated immediately on phases 2 and 6
- Flashing Don't Walk runs and is timed concurrently with vehicle green, yellow, and all red (for 16 sec. of Flashing Don't walk, green is served for 10 seconds, yellow is timed for 4.5 seconds, all red is timed for 1.5 seconds.
- Track clearance time, yellow time, and all red time is given to phases 4 and 8 (perpendicular phases) to clear any vehicles off the railroad tracks
- Go back to serving phases 2 and 6 while RR is passing by.

Signs warning pedestrians of shortened walk times have been placed at intersections containing railroad crossings.