Detecting Bicycles and Motor Vehicles Using the Same Loop Detector

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Active area of research since at least 1982

- George Palm (3M/Canoga) issued bicycle application notes
- Lawsuit against ITE over specification of vehicle detectors (loop sensors)
- Glenn Grigg started experimenting in Cupertino in early 1980's
- Knowledgeable cyclists knew how to trip detectors if they could see the loops
- 25 years later, bicyclists are still having trouble, especially if they cannot see the loops
Efforts need to be made to ensure that signal detection devices are capable of detecting a bicycle.
AB 1581, Fuller

- Signed by Governor Schwarzenegger on October 8, 2007
- Bicyclists and motorcyclists are legitimate users of roadways in California
- Will require all new and replaced traffic signals to detect bicycle or motorcycle traffic
- Will take effect when Caltrans adopts uniform standards, specifications, and guidelines for the detection of bicycle and motorcycle traffic and related signal timing
- Incremental costs of installing sensor wiring subject to State Mandates provisions
Bicycle Detection and Operational Concept at Signalized Intersections

- Caltrans has contracted with California Partners for Advanced Transit and Highways (PATH)
- Research into advanced methods of detecting bicyclists and differentiating them from motor vehicles
- Purpose: providing longer minimum green times for bicyclists
- This research will not be investigating loops
- Video detection, radar, infrared, transponders
- Most people agree that for the foreseeable future, loops will continue to be the detection method of choice for most jurisdictions in the state
Detecting bicycles with loops involves six steps:

1. Loop configuration
2. Loop location
3. Selection of loop sealant
4. Method of connecting multiple loops
5. Selection of loop detector sensor unit
6. Number of sensor units assigned to a lane
7. Method of setting the sensor unit’s sensitivity level
Inductive loops have two major requirements

• They must detect motor vehicles and bicycles
• They must reject vehicles in adjacent lanes
Type A loops

- Dipole
- Will detect a bicycle, but only if the rider knows where on the loop to stop
- A bicycle is vertical, so the best place to stop is on top of one of the sawcuts parallel to the direction of travel
How loops detect bicycles

- Magnetic field in a wire is in a circle around the wire
- Left-right horizontal magnetic field intersects the wheels and frame of the bicycle at a right angle
- Magnetic field then induces eddy currents in metal wheels and frame, which in turn create a magnetic field in the opposite direction
- Loop sensor senses the reduced magnetic field and detects the bicycle
When loops cannot detect bicycles

- Worst place for a bicyclist to stop over a Type A loop is in the center
- All horizontal magnetic field from the wires on the left is cancelled by the magnetic field in the opposite direction from the wires on the right
- No eddy currents are induced in the bicycle’s wheels or frame
- Loop sensor cannot detect the bicycle
- No loop can detect a bicycle with non-metal wheels or frame (carbon-fiber or plastic)
Rejecting vehicles in adjacent lanes

• Type A loops do not do a good job of rejecting vehicles in adjacent lanes because they have a long length of wire parallel to the direction of travel

• Type A loops need to be installed at least 3' from the adjacent lane

• This plus the standard lane width of 12' is apparently what led to the wide deployment of 6' loops centered in the lane

• Bicyclists often stop in the 3' between the loop and the lane line
What if the bicyclist cannot see the loop?

- A bicycle that is just a short distance from the sawcut is not detected.
- Standard Specification 86-5.01A(5) states, “If asphalt concrete surfacing is to be placed, the loop conductors shall be installed prior to placing the uppermost layer of asphalt concrete.”
- Bicycle Detector Symbol (Standard Plan A24C) located over a sawcut shows the bicyclist where to stop.
- For practical, financial and institutional reasons, deployment of Bicycle Detector Symbols is relatively rare.
Type B and Type E loops

- Best place for a bicycle to be detected is along one edge of the loop
- Worst place is in the center
- Bicycle is harder to detect with Type B and E loops because not as much loop wire is parallel to the bicycle
- Type B and E loops are better at rejecting vehicles in adjacent lanes than Type A loops because they have less wire parallel to the lane line, allowing sensitivity to be set higher
Type Q loops

- Quadrupole
- Best place for a bicycle to be detected is on top of one of the sawcuits
- Major advantage of the Type Q loop is that it is excellent at rejecting vehicles to the sides of the loop because the magnetic field from the center wires partially cancels the magnetic field from the outside wires
- Allows the sensitivity of the loop sensor to be set higher without detecting vehicles in an adjacent lane
- But bicyclist just off loop cannot be detected
Type Q loops (cont’d)

• George Palm taught that a quadrupole loop will reject vehicles more than 15" from its edge
• Why not make it wider than 6'?
• Wider loop would put the right-hand sawcut in a location where bicyclists are more likely to stop
• But a bicycle stopped about a third of the way towards the center will not be detected
• If a Type Q loop is not visible to the cyclist, then the loop still needs a Bicycle Detector Symbol
Type D loops

• Diagonal quadrupole

• Can detect bicycles across its width because it has some horizontal magnetic field everywhere within the loop

• Like a Type Q loop, it does an excellent job of rejecting vehicles in adjacent lanes

• If a Type D loop is built larger than 6’ and located close to the lane line then bicyclists are more likely to stop over it

• A large Type D loop would not need a Bicycle Detector Symbol
Problems with Type D loops

• Not widely adopted
• Type D loop has four acute angles, which need to be rounded off to prevent damage to the conductors
• Acute angles cause premature pavement failure and are to be avoided
• The Type D loop is more complex and thus more expensive to install than the Type A, B or E loop
• Division of Research and Innovation (DRI) says, “Currently, wherever applicable, bicycle detection is installed using the Type D inductive loop. The Type D loop is very expensive to install and hard to maintain”
Other diagonal quadrupoles

- Add diagonal sawcut to Type A, B or E loops
- Type E with diagonal sawcut is called a “quadracircle” (or “quadrocircle”)
- Quadracircle being used in Palo Alto, Cupertino and Monterey
- Quadracircle mentioned in “Implementing Bicycle Improvements at the Local Level,” FHWA-98-105, 1988
- Quadracircle has similar characteristics to Type D, but is cheaper to install and has no acute angles
Large quadrupole loops

• Any quadrupole loop can be built larger and still reject vehicles in the adjacent lane

• If a diagonal quadrupole loop is built larger, then a bicyclist is more likely to stop over it, so a Bicycle Detector Symbol would not be needed
Other attempts at “bicycle loops”

- George Palm proposed a loop with 3 diagonal slots and 8 poles
- Not responsive to trucks because of small areas enclosed within sawcuts
- Robert Duemmel proposed “Angular Design Detection”
  - Detects bicycles because of angles
  - Detects trucks because of large area enclosed within sawcuts
- Unknown whether ADD loop is good at rejecting vehicles in adjacent lane
Locating loops where bicyclists are expected to stop

- At a signalized intersection, a bicyclist may use left turn lanes to turn left and through lanes to continue straight
- Figure 4D-111(CA) from the 2006 California MUTCD shows bicycle loops centered in each travel lane as well as the bike lane, but bicycle loops in travel lanes are too narrow

NOTES:
1. Bike/Push Button for Green Light (R62C (CA)) Sign or a Type D Loop Detector may be used to activate a traffic signal. A push button should be located so it is convenient to use by bicyclists.
2. Typical Type D Loop Detector locations.
3. Typical Loop Detector locations. See Section 4D.105 (CA).
Loops in left turn lanes

• An experienced bicyclist turning left will usually stop either in the center or toward the right side of the left turn lane

• An inexperienced bicyclist turning left will usually stop toward the left side of the left turn lane

• A bicyclist making a U-turn will usually stop toward the left side of the left turn lane

• The head loop in a left turn lane needs to detect bicyclists across almost the full width of the lane

• A wide diagonal quadrupole loop does the job well
Loops in through lanes

- In the absence of other traffic, an experienced bicyclist continuing straight will usually stop in the middle of the through lane
- An inexperienced bicyclist will usually stop toward the right side of the through lane
- If there is a right turn lane, a diagonal quadrupole needs to extend to within about a foot of the lane line, similar to a left turn lane
- If there is no right turn lane, the loop needs to extend to within about a foot of the curb or the edge of pavement at the stop line
Loops in right turn lanes

- If right turn on red is allowed, then no loop is needed
- If right turn on red is not allowed, then the loop needs to extend to within about a foot of curb or edge of pavement at the stop line
Loop sealant

• A loop’s ability to detect bicycles deteriorates far faster than its ability to detect motor vehicles

• Loop sealant failure is a major cause of loop failure
Loop sealant properties

• Flexibility
• Encapsulation of the conductors
• Good insulating properties
• Strength
Caltrans specifies 4 types of loop sealant

- Elastomeric
- Asphaltic emulsion
- Hot-melt rubberized asphalt
- Epoxy
Asphalt emulsion and epoxy

- I have personally seen loops fail in asphalt pavement that were sealed with asphalt emulsion sealant and with epoxy sealant
- The wires in loops sealed with asphalt emulsion sealant had been squeezed up out of the slots and exposed to the passage of traffic
- The asphalt pavement around cured epoxy sealant lost its asphalt binder and simply fell apart, allowing the epoxy and wires to move with the passage of traffic
Elastomeric sealant and hot-melt rubberized asphalt

• I have used 3M elastomeric sealant, and it appears to have all the required properties

• I have no experience with hot-melt rubberized asphalt, but others report that it also appears to have the required properties
Connecting loops in series

- George Palm taught always to connect loops in series
- Caltrans Standard Plan ES-5A shows loops in a 4 loop array wired in series-parallel, same as NEMA TS-1
- Modern sensor units can handle a much larger input inductance than when TS-1 was prepared, so it is no longer necessary to connect loops in series-parallel
- Connecting loops in parallel reduces the change in inductance from a bicycle by about half, making it harder to detect
- Loops should always be connected in series
Selection of loop detector sensor units

- George Palm taught that loop sensors should detect based on inductance change ($\Delta L$), not percent of inductance change ($\Delta L/L$)
- Bicycle makes a certain change in inductance, $\Delta L$
- If using $\Delta L$ loop sensor, then sensitivity setting does not change with number of loops or length of detector lead-in cable
- If using $\Delta L/L$ loop sensor, then sensitivity setting does change with number of loops and length of detector lead-in cable
- Determination of the correct sensitivity setting is difficult on $\Delta L/L$ sensor unit
Connecting loops in multiple lanes to one $ΔL/L$ sensor unit

- The more loops connected to one sensor unit, the higher the sensitivity needs to be in order to detect a fixed $ΔL$

- Problematical whether a suitable sensitivity setting can be found when connecting loops in multiple lanes to one $ΔL/L$ sensor unit
Number of sensor units assigned to a lane

- Hooking up a bicycle loop to its own sensor unit allows the sensitivity to be set such that bicycles are detected but vehicles in the adjacent lane are not

- Also allows Type A, B or E loops to be connected to a second sensor unit, the output of which is connected in parallel to the output of the bicycle loop’s sensor unit

- Connecting quadrupole loops and Type A loops to the same sensor unit is not recommended because Type A loops are more subject to detecting vehicles in the adjacent lane

- If only one DLC is installed, then head loop should be bicycle loop, others Type Q or diagonal quadrupole
Setting the sensitivity level

• Typical signal technician usually starts with the sensitivity at the lowest level and turns it up until cars and trucks are reliably detected

• Easy and only requires one person

• But unless the sensitivity is adjusted specifically for bicycles, they will not be detected

• Better to start at the highest sensitivity level and reduce it until vehicles in the adjacent lane are no longer detected but bicycles are detected

• Requires a second person driving a vehicle in adjacent lane and moving a metal bicycle or bicycle rim over the loop during the setting of the sensitivity
Conclusion

1. Configure the head loop as a diagonal quadrupole
2. Locate the loop where bicyclists are expected to stop, but if this is not possible, use a Bicycle Detector Symbol
3. Use elastomeric loop sealant (or perhaps hot-melt rubberized sealant)
4. Connect the loops in series
5. $\Delta L$ sensor units preferable over $\Delta L/L$ sensor units
6. Best to use a separate sensor unit for bicycle loop, but if this is not possible, add only quadrupole loops
7. Set the sensitivity of the sensor unit at the highest setting that will detect bicycles and still reject vehicles in adjacent lanes