EBERLE DESIGN INC.
LOOP DESIGN, INSTALLATION & CONFIGURATION
LOOP PRINCIPLES

• Resonant Circuit - Oscillates between 15KHz and 100KHz depending on loop inductance.

• Loops generate a magnetic field that looks for electrically conductive material, not ferrous material.

• Electrically conductive material lowers inductance. Ferrous material increases inductance.
LOOP SENSITIVITY

• Rule of Thumb - Useable detection height is 2/3 the shortest leg of the loop.

• A loop is most sensitive directly above the loop wire.
LOOP GEOMETRIES

• **Quadrupole** - Incorrectly perceived as a more sensitive loop geometry. Good adjacent lane rejection and noise immunity. More sensitive in the center, but this is not where bicyclist & motorcyclist want to ride.

• **Round** - More sensitive but also more prone to cross-talk. Fewer saw cuts and more pavement friendly.
BICYCLE DETECTION

- Cyclist want to ride in the wheel tracks, not the oil drip line.

- A Quadrupole loop has about half of the sensitivity of a rectangular loop on its edges.

- Leaning the bicycle over just a little bit can increase the strength of a detection by four times.
LOOP INDUCTANCE

• The inductance of a conventional four-sided loop can be estimated using the formula:
  \[ L = \frac{P \times (T_2 + T)}{4} \]

• Where:
  - \( L \) = Loop Inductance in microhenries
  - \( P \) = Loop Perimeter in feet
  - \( T \) = Number of Turns of Wire

• Therefore, a 6ʿ x 6ʿ loop with 3 turns would have an inductance of:
  \[ L = \frac{(6 + 6 + 6 + 6) \times (32 + 3)}{4} \]
  \[ L = 24 \times (9 + 3) / 4 \]
  \[ L = 24 \times 12 / 4 \]
  \[ L = 24 \times 3 \]
  \[ L = 72 \text{ microhenries.} \]
The inductance of a quadrupole loop can be estimated using the formula:

\[
L = \left[ P \times \left( \frac{T^2 + T}{4} \right) \right] + \left[ CL \times \left( \frac{T^2 + T}{4} \right) \right]
\]

Where:
- \( L \) = Loop Inductance in microhenries
- \( P \) = Loop Perimeter in feet
- \( T \) = Number of Turns of Wire
- \( CL \) = Length of Center Leg in feet

Therefore, a 6’ x 6’ loop with 3 turns would have an inductance of:

\[
L = \left[ (6 + 50 + 6 + 50) \times \left( \frac{22 + 2}{4} \right) \right] + \left[ 50 \times \left( \frac{42 + 4}{4} \right) \right]
\]
\[
L = \left[ 112 \times \left( \frac{4 + 2}{4} \right) \right] + \left[ 50 \times \left( \frac{16 + 4}{4} \right) \right]
\]
\[
L = (112 \times 6 / 4) + (50 \times 20 / 4)
\]
\[
L = (112 \times 1.5) + (50 \times 5)
\]
\[
L = 168 + 250
\]
\[
L = 418 \text{ microhenries.}
\]
LEAD-IN INDUCTANCE

- Most Lead-In (home run) cable has approx. 0.22 microhenries per foot.

- Rule of Thumb - Loop inductance should be larger than Lead-In inductance. Preferably by two times.

- Not following this will result in loss of sensitivity as the inductance in the Lead-In can not be affected by the target vehicles.
LONG LEAD-IN LOOPS

• Increase turns in the Loop to keep Loop inductance above Lead-In inductance.

• Increase Lead-In wire gauge to keep total Loop resistance below 5 Ohms.

• Do not exceed 2000 microhenries of total inductance.
SAW CUT LOOP INSTALLATION

- Loops can be damaged during the installation process. This is why Loops should have an insulation test (checked with a megaOhm meter to earth ground) prior to sealing.

- Backer rod or other suitable material should be used to hold the wire at the bottom of the saw cut before sealing. This should be inch long pieces every foot or two, not a continuous piece. The sealant should be allowed to encapsulate the wire and totally fill the saw slot.
SAW CUT LOOP INSTALLATION

• All corners of greater than 45 degrees should be chamfered.

• Only a blunt object should be used to push the wire to the bottom of the saw slot.

• Double jacketed wire should be used whenever the loop will cross expansion joints.

• The sealant used should be suitable for the roadway surface to provide good adhesion to the saw slot and not deteriorate the surface.
A record of the following readings at installation should be kept for future reference:

- Loop/Lead-In Total Inductance
- Insulation Test (megaOhms reading should be greater than 200Meg at install)
- Loop/Lead-In Total Resistance
• Cross-linked Polyethylene (XLPE) is the preferred insulation for Loop wire and Preformed Loops.
• The wire gauge is not critical to proper operation of the loop detector.
• Under similar conditions, XLPE insulation will absorb approximately one percent of the moisture absorbed by PVC. When insulation absorbs moisture, loop drift occurs, which if great enough, can cause false detections. XLPE also has higher resistance to abrasion, heat, oils, and gasoline.
Cross-linked polyethylene has a melting point of 426ºF
LOOP LEAD-IN CABLE

• Cross-linked Polyethylene (XLPE) is the preferred insulation for Loop Lead-In cable.
• In most cases, the wire gauge is not critical to proper operation of the loop detector.
• The currently used Beldon cable has a PVC jacket and is not as good as XLPE for sitting in water filled conduits.
• Direct burial version available for construction zones.
LOOP CONNECTIONS

• Loop to Lead-In splicing should always be soldered then water-proofed.

• Lead-In terminations in the cabinet should be soldered to uninsulated fork (spade) terminals before terminating on a terminal strip.

• Wire nuts should never be used in loop circuits.

• Connectors carrying loop signals, within the signal cabinet, should be gold plated.
LOOP CROSS-TALK

- Cross-talk is when the energy flowing in one Loop influences that of another. This can be magnetic (inductive) coupling or capacitive coupling.
- Magnetic coupling occurs when the magnetic field of one loop exerts influence over that of another.
- Capacitive coupling occurs in cables that lay parallel to each other for long distances or other electrical wiring.
- There are several possible methods of mitigating cross-talk: Phasing, Scanning, Frequency, and physical separation. Each will be discussed shortly.
LOOP PHASING

• When multiple loops are connected to the same detector channel, the phasing of each loop can become important. For a single loop connected to a detector channel, phasing is irrelevant.

• Phasing of a loop is determined by the direction of energy flow around the loop. The actual direction of travel is not relevant, but the direction with respect to the other loops connected to the same detector channel is.

• Loop phasing can be used to deal with cross-talk and external interference (high voltage power lines, etc.)
SCANNING DETECTORS

• These are multi-channel detectors that active a single channel at a time, take a sample, turn off the channel, and advance to the next channel.

• Scanning is a good method of dealing with possible cross-talk issues, by making sure that the two channels are never on at the same time.

• The trade-off for this separation of channel sampling is that the response time of the detector doubles for a two-channel detector, or quadruples for a four channel detector. In some applications, this may be unacceptable.
LEAD-IN SHIELDS

• If you use Lead-In cable that has a shield, this shield should not be connected to anything at either end of the cable. The Lead-In cable has the pair of wires internally twisted to provide noise immunity. Connecting the shields from multiple cables together provides a path for capacitively coupled cross-talk even if connected to earth ground.

• The longer the Lead-In cable, the more capacitive coupling will occur. Many agencies specify that the shields must to all connected to earth ground at the cabinet. This is not a desired connection.
LIGHTENING ARRESTORS

• The detector has on board lightening arrestors consisting of a three terminal gas tube arrestor for each detection channel.
• If additional suppression is desired inside of the cabinet, they should be three terminal gas tube arrestors as well. MOVs (Metal Oxide Varistors) can create undesired affects on the loop circuit once they have actually triggered.
• If experiencing intermittent detector lock-ups with additional suppressors installed, remove them to see if they are the source of the lock-up.
• The center terminal of the gas tube should be connected to earth ground.
WHY PREFORMED LOOPS?

• A PREFORMED LOOP IS STRONGER THAN A STANDARD LOOP
• MANUFACTURED IN A CONTROLLED ENVIRONMENT
• COST EFFECTIVE
• EASY TO HANDLE, SHIP, AND INSTALL
FIVE LAYERS OF INSULATION

1) .035” XLPE Outer Jacket
2) .030” XLPE Middle Jacket
3) Moisture Resistant Mylar Binder
4) Water Block Gel
5) .020” XLPE Conductor Insulation
BENEFITS OF DOUBLE JACKET

• Outer Jacket relieves stress on Inner Jacket and wire

• Minor nicks and cuts in the Outer Jacket will not reflect into the Second Jacket
ELIMINATES SAW CUTS IN A NEW ROAD SURFACE
EASY TO INSTALL

Position loop in proper orientation
EASY TO INSTALL

SECURE LOOP TO ROADWAY
EASY TO INSTALL

FINISH LOOP LAYOUT
EASY TO INSTALL

ROUTE LEAD-IN TO DESIRED LOCATION
EASY TO INSTALL

TEN TO FIFTEEN MINUTES TO POSITION LOOP AND LEAD-IN
COST EFFECTIVE

• No saw cutting expense
• Reduced labor cost
• No replacement cost
• No maintenance cost
PROMOTES LONGER ROADWAY LIFE

- Eliminates loop failures and pavement degradation associated with saw cut loops
- No saw cuts to propagate road surface cracking
- Loop sealant failure eliminated
- Eliminates the possibility of loop and/or lead-in wires becoming exposed
• Loops should never be installed under the rebar.

• It is recommended that the Loop be at least 2 inches above the rebar.

• If the loop can not be installed at least 2 inches above the rebar, then the Loop should be laid out so that none of its edges are directly above a piece of rebar.

• The closer the Loop gets to the rebar, the more it will have its sensitivity effected by it.
MODES OF COUNTING

• Detection Counting
This is counting of the detect output and is typically used with small detection zones (6’ x 6’ or less) with a single loop connected to the detection channel.

• Long Loop Counting
This usually involves some processing of the changes in inductance to determine when each new vehicle enters the detection zone, even if prior vehicles have not exited the detection zone. This configuration is typically used for a single loop 6’ or longer in a lane. This configuration is also used if single loops in each lane are spliced together regardless of their size.

• Multiple Loop Counting
This usually involves processing of the changes in inductance to determine when each new vehicle enters the detection zone, even if the prior vehicles have not exited the detection zone. This configuration is typically used for multiple 6’ x 6’ (or 6’ diameter) loops connected in series in a single lane. The detector allows for the setting of the number of loops in the lane.
DATA COLLECTION

• Traffic Controller Detector Inputs
  – The detector has two outputs per channel. Both are connected to the traffic controller detector inputs, one for detection and one for counting. The count output is a pulse. The detector only outputs the count pulse and has no internal storage of the counts other than a totalizer.

• Data Collection Device
  – The detector can have two outputs per channel or a single output and a COM port. The count is either output to the collection device or available through the COM port. With the COM port, the detector has very limited data storage internally.
DETECTOR RACK IMPACT

• The count detectors are two channel detectors that occupy a four channel slot in the rack.

• This is needed because the count outputs come out of the detectors on the channel 3 and 4 outputs.

• Therefore, a 16 channel TS2 rack with count detectors, can only support 8 channels of detection to leave room for the 8 channels of count outputs.
### STOP BAR LOOP GEOMETRIES

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<th>Adjacent Lane Detection</th>
<th>Crosstalk</th>
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<td>C</td>
<td>A</td>
<td>C</td>
<td>D</td>
<td>C</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Long Quadrupole</td>
<td>C</td>
<td>D</td>
<td>D¹</td>
<td>A</td>
<td>B</td>
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<td>A</td>
</tr>
<tr>
<td>Multiple 6’x6’ Square</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>D</td>
<td>C²</td>
</tr>
<tr>
<td>Multiple 6’ Round</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>B</td>
<td>D²</td>
</tr>
</tbody>
</table>

¹ A Quadrupole is more sensitive in the middle but this is not where most bikes ride.

² Alternating phasing of the loops can significantly improve noise rejection.
RECTANGULAR 6’ X 30’

First vehicle arrives

Second vehicle arrives

Third vehicle arrives and departs

Second vehicle departs

First vehicle departs

Pickup
1.02% ΔL/L

SUV
1.17% ΔL/L

Car
1.95% ΔL/L
QUADRUPOLE 6’ X 30’

First vehicle arrives
Second vehicle arrives
Third vehicle arrives and departs
Fourth vehicle arrives and departs

Pickup 0.22% ΔL/L
SUV 0.48% ΔL/L
Car 1.89% ΔL/L
4 6' X 6' WITH 9' SPACING

First vehicle arrives
Second vehicle arrives
Third vehicle departs
Fourth vehicle arrives and departs
First vehicle departs
Second vehicle departs
Third vehicle arrives

Pickup
0.58% ΔL/L Max
0.28% ΔL/L Min

SUV
0.85% ΔL/L Max
0.16% ΔL/L Min

Car
1.86% ΔL/L Max
0.65% ΔL/L Min
DETECTOR TRAINING

To deal with variations in installations, the detector has a training mode that allows the detector to determine what a typical vehicle looks like to the detector.

The detector uses this information to adjust its counting algorithm and increase its accuracy.
ACCURACY EXPECTATIONS

- **Single Loop per Lane Avg Loops**
  - Long Rectangular +/- 10% +/- 6%
  - Long Quadrupole +/- 10% +/- 5%
  - 6’ Square or Round +/- 5% +/- 2%

- **Multiple Loops per Lane**
  - Two 6’ Square or Round +/- 10% +/- 7%
  - Three 6’ Square or Round +/- 10% +/- 4%
  - Four 6’ Square or Round +/- 10% +/- 5%

- **Single Loop per Lane for Multiple Lanes**
  - Long Rectangular +/- 20% +/- 15%
  - Long Quadrupole +/- 20% +/- 15%
  - 6’ Square or Round +/- 15% +/- 10%
FACTORS AFFECTING ACCURACY

CLIPPING OF LEFT TURN LOOPS

- Vehicles turning left will tend to drive over a portion of L1 when that left turn lane is vacant. The L1 lane thus will have a tendency to have counts higher than that lane’s actual traffic volume.

- This is dealt with in firmware in a multiple loop installation but creates a over counting problem in long loop installations.
FACTORS AFFECTING ACCURACY

MULTIPLE LOOPS

- When multiple loops are to be connected to one detector, all of the loops should be the same size, geometry, number of turns, and connected in series. This will allow all of the loops connected to the detector to all see the same amount of inductance change for the same vehicle. This along with even 9’ spacing will significantly increase the accuracy of detector.

- \( L_1 \) and \( L_2 \) should never be connected to the same channel of detection of \( T_1, T_2, \) and \( T_3 \), only \( T_2 \) can be expected to give accurate counts.

- The signature below shows one of the effects of inconsistent loop geometry.
FACTORS AFFECTING ACCURACY

ADJACENT LANE DETECTION – SAME DIRECTION OF TRAVEL

- If loops L1 and L2 are wider than 6 feet or the lanes are narrow (resulting in 5 foot or less of space between adjacent loops), adjacent lane detection may occur. This can also occur for multi-lane turn lanes if the loops extend beyond the stop bar by a significant distance. Vehicles turning from the outside lane may clip the front of the loop in the adjacent turn lane.
FACTORS AFFECTING ACCURACY

ADJACENT LANE DETECTION - OPPOSITE DIRECTION OF TRAVEL

If a transition occurs through the intersection and the inside left turn lane is unoccupied, the opposing through vehicles may exhibit poor lane control and travel close enough to the left turn loop to be detected and counted.
FACTORS AFFECTING ACCURACY

Crosstalk

Most modern detectors do a very good job at filtering out loop crosstalk issues when the loop is used just for detection. However, loop crosstalk can significantly impact count accuracy causing severe over counting in most cases.
FACTORS AFFECTING ACCURACY

Pavement Surface

A loop to be used for counting should be installed entirely in one type of pavement surface. A loop cut into asphalt and concrete surfaces will most likely exhibit different sensitivities over the two surfaces making it difficult to count with any accuracy.

This is a 6’ x 40’ Rectangular loop with the back 20’ under pavers and the front in asphalt. This vehicle stopped over the pavers and left when the light turned green.
FACTORS AFFECTING ACCURACY

Other Factors

Poor lane control, variations in the percentage mix of vehicles on the street, driver behavior, and the equipment settings used can make the results you achieve better or worse. For instance, a loop may be excellent at counting autos and trucks but poor at counting motorcycles.

Left turning vehicle turns out the side of the loop, barely hitting the front loop.
DETECTOR FEATURES

- Frequency
- Sensitivity
- Delay and Extension
- Max Presence and End Of Green (EOG)
- Loop Inductance Display (Option 1)
- Delta L / L Display (Option 2)
- Buzzer (Option 11)
- L Hi and L Lo Indications
- Prior Loop Fault
THANK YOU