Abridgment

Inductive Loop Vehicle Detector: Installation Acceptance Criteria and Maintenance Techniques

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The field of vehicle detection is filled with design pitfalls and maintenance frustrations. This paper represents only one step toward relieving the pressures on the technician and the traffic engineer. Emphasis is on enabling the traffic engineer to predict during the design phase whether the system will work with available loop detector amplifiers. Emphasis is also on outlining an exact method of evaluating the sensitivity of a loop and lead-in system before the loop detector amplifier is attached to the system.

INSTALLATION DESIGN CRITERIA

When critical, sensitivity may be calculated for loop and lead-in systems during the design phase to verify that the loop and lead-in system will function with available amplifiers.

Procedure

The percentage of change in inductance for the worst case vehicle is calculated for the system in question. This is compared to the sensitivity threshold of the amplifier selected or specified.

Example

According to Table 1 and Figure 1, the percentage of change in inductance $\%\Delta L$ due to the passage of a Honda 100 motorcycle over the center of a 4-series-parallel connected-loop system with 183 m (600 ft) of lead-in is 0.06 percent and the loop inductance is 80 μH. The lead-in inductance is about 130 μH [0.72 μH/m $\times$ 183 m (0.22 μH/ft $\times$ 600 ft)]. If we use the information on lead-ins from Table 1,

$$\%\Delta L = 0.06 \times [80/(80+130)] = 0.023 \qquad (1)$$

Because the loop has been installed within 2.5 cm (1 in) of the road surface, no reduction in sensitivity need be accounted for. Because the loop amplifiers purchased in California are tested for a 0.03 percent ΔL high sensitivity threshold, the 0.023 percent ΔL may well not result in an output from brand X or Y amplifier. Brand Z may advertise a high sensitivity threshold of 0.02 percent or less, and it may work, but a better approach might be to split the four loops into two sets of two and provide a second lead-in and amplifier. If we use the same tables and procedures, the $\%\Delta L$ for each of the two systems (two 1.83-m-square (6-ft-square) series connected loops with 183 m (600 ft) of lead-in) is found to be 0.046. This is a comfortable margin of sensitivity.

INSTALLATION ACCEPTANCE CRITERIA

Because it was not practical for every jurisdiction to use the same vehicle as a standard for the acceptance of new loop detector installations, choosing an easily fabricated and conveniently carried device that might closely model a vehicle seemed desirable. Such a device might well model the worst case vehicle (that vehicle most difficult for the system to detect, such as a small motorcycle). One such device is a shorted loop of wire mounted around the edges of a 0.61-m-square (2-ft-square) piece of plyboard. Although this device may well be used to test the operation of a loop detector system (system equals loop + lead-in + amplifier), testing the sensitivity of the loop and lead-in portion of the system separately from the amplifier may be more desirable. A second device is required, one that will measure the loop and lead-in sensitivity to the vehicle model. This device, when attached to the loop and lead-in, would measure $\%\Delta L$ due to the presence of the vehicle model. Installation acceptance testing, which includes the measurement of loop resistance, insulation resistance, and inductance, should also include a test for the sensitivity of the loop and lead-in system to a "standard" vehicle or vehicle model.

Procedure

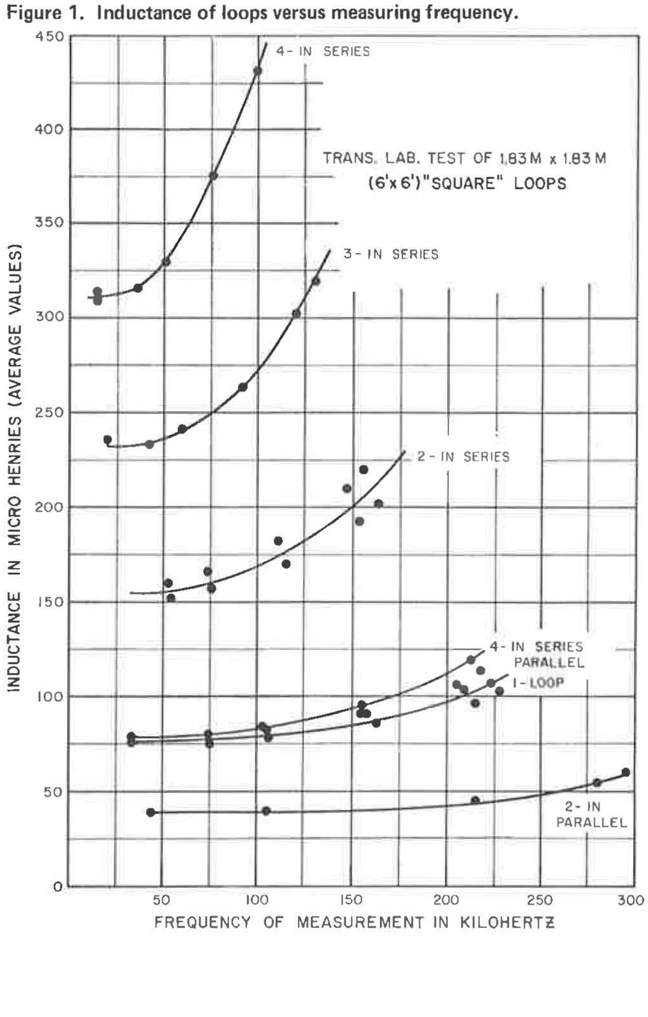
With the loop detector amplifier disconnected, the test device (if equipped with a standard amplifier connector) may be plugged directly into the harness. If the inductance change measuring device is a loop oscillator-frequency counter, the frequency of oscillation (f_1) is recorded. With the vehicle model placed in the center of the loop [±15 cm (6 in)], the new frequency (f_2) is recorded. The percentage of change in frequency $\%\Delta f$ is then calculated according to the formula $100\ [(f_2 - f_1)/f_1]$. It can be shown that $\%\Delta L$ is approximately equal to 2 times $\%\Delta f$. This is a good approximation for ΔL up to 10 percent and for loops where Q, the quality factor, is greater than 5. $\%\Delta L$ is then calculated by multiplying the results by 2. The result is then compared with the data in Table 1.

Table 1. Expected values of change in inductance due to a Honda 100 or the vehicle model.

Expected Inductance (μH)	Valid Range of Measuring Frequency (kHz)	Expected Change in Frequency (%)	Change in Inductance (%)	Loop Configuration
79	34 to 100	0.12	0.12	1 loop
158	24 to 75	0.06	0.12	2 in series
40	47 to 150	0.06	0.12	2 in parallel
235	19 to 50	0.04	0.08	3 in series
80	34 to 100	0.03	0.06	4 in series parallel connected
312	10 to 30	0.03	0.06	4 in series

Notes: All values may vary by +10 percent.
All loops are 1.83 by 1.83-m square (6 by 6-ft) 3-turn loops made with 20 metric gauge (12 AWG) wire and less than 4.6 m (15 ft) of lead-in.
Lead-in inductance is generally 0.72 μH/m (0.22 μH/ft). Adding lead-in will reduce the percentage of change by the ratio of loop inductance to loop plus lead-in inductance. Thus the table values for percentage of change in inductance or frequency must be multiplied by this factor when lead-in lengths exceed 4.6 m (15 ft). A further reduction of about 2.4%/cm (6%/in) results in a burial depth greater than 2.5 cm (1 in). Thus a loop buried at a depth of 7.5 cm (3 in) below the surface will have an 18% reduction in both frequency and inductance change values.

Figure 1. Inductance of loops versus measuring frequency.



Example

A new detector installation, consisting of four 1.83-m-square (6-ft-square) series-parallel connected three-turn loops and 76 m (250 ft) of lead-in, is being tested for acceptance. The following measurements are taken:

1. Frequency of loop oscillator with no vehicle on the loop (f_1 = 57 994 H_z) and
2. Frequency of loop oscillator with vehicle model in center of loop (f_2 = 58 005 H_z).

$\%\Delta L$ is calculated

$$100[(f_2 - f_1)/f_1] = 11/57\ 994 = 0.019 \text{ percent } \Delta f \quad (2)$$

Then

$$\%\Delta L = 2 \times \%\Delta f = 2 \times 0.019 \text{ percent} = 0.036 \text{ percent } \Delta L \quad (3)$$

Table 1 predicts the following: for the four series-parallel connected loops, $\%\Delta L = 0.06$. The reduction due to 76 m (250 ft) of lead-in is calculated according to the notes in Table 1:

$$\%\Delta L = 0.06[80/(80 + 55)] = 0.36 \quad (4)$$

The measured value is 5 percent higher than the table predicted; the sensitivity of this loop is acceptable.

MAINTENANCE TECHNIQUES

The loop-oscillator, frequency-counter test device will enhance maintenance capability.

More detailed information on maintenance techniques is available elsewhere (1) and describes a loop-oscillator, frequency-counter test device and gives procedures and data so that the device can be used to isolate problems with loop detector systems. These procedures would enable the signal technician to

1. Evaluate the condition of a loop detector system at any point in its life cycle (preventative maintenance);
2. Predict the failure of a system before it fails;
3. Isolate failures to the loop, lead-in, amplifier, or splices;
4. Eliminate crosstalk problems; and
5. Determine the cause of intermittent behavior.

REFERENCE

1. J. W. Ingram. The Inductive Loop Vehicle Detector Installation Acceptance Criteria and Maintenance Techniques. Division of Construction and Research, California Department of Transportation, Sacramento, Jan. 1976.