Excel Technology Co Pty Ltd

Vehicle Detector Error & Performance

Analysis

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Document:L100.7Rev C Vehicle Detector Error & Analysis

Error Analysis

The XL Detector uses multiple speed and length measurements for each vehicle, to increase the probability of more accurate results. Combined with the high scan rate, the detector gives consistently low error results. However, the loop spacing and loop length parameters also influence the accuracy of the speed and length calculations. The error analysis in the following sections investigates the impact of each factor. It is calculated using metric units.

1.1 Speed

1.1.1 Scan rate

The speed of a vehicle is calculated using the time taken to travel from the leading loop to the lagging loop and the loop spacing, using the following formula:

Speed (s) = Loop Spacing (d) / Time Between Loops (t)

The ETG detector uses four time measurements (two time periods) to calculate time between loops:

- Activation of loop 1 (t_{i1}) to activation of loop 2 (t_{i2})
- Clearing of loop 1 (t_{o1}) to clearing of loop 2 (t_{o2})

These measurements are then averaged to find the time between loops.

Therefore $t = [(t_{i2} - t_{i1}) + (t_{o2} - t_{o1})] / 2$

Assuming a worse case scenario, the scan rate for the loops is ~2.5ms. The detector measures time with 1ms precision. Therefore there is an error in each time measurement of 0 to 3 milliseconds. This error can be modelled as a uniform random variable e where e is an element of [0,3].

Therefore:

$$t = \{[(t_{i2} - e_{i2}) - (t_{i1} - e_{i1})] + [(t_{o2} - e_{o2}) - (t_{o1} - e_{o1})]\} / 2$$
$$t = [(t_{i2} - t_{i1}) + (e_{i1} - e_{i2}) + (t_{o2} - t_{o1}) + (e_{o1} - e_{o2})] / 2$$
$$t = [(t_{i2} - t_{i1}) + (t_{o2} - t_{o1})] / 2 + E; \text{ where } E = (e_{i1} - e_{i2} + e_{o1} - e_{o2}) / 2$$

Figure 10a on the following page shows the probability density function (p.d.f.) for E when the typical one set of measurements is used (left graph); compared to the p.d.f. for E when the ETG two measurement method is used. It can be seen that the two measurement method gives a higher probability of an accurate result.

Since Measured Speed (s') = Loop Spacing (d) / Measured Time (t')
And t' = Actual Time (t) + E
Then s' = d / (t' + E)

Thus the percentage error in speed (e_s) is:

$$e_s = 1 - s'/s \times 100\%$$
$$e_s = 1 - \{[d / (t' + E)] / [d / t]\} \times 100\%$$
$$e_s = 1 - [t / (t' + E)] \times 100\%$$

A car travelling at 100km/h takes 180ms to travel 5m. If loops are spaced 5m apart, then the maximum speed error due to scan rate will be 1.67%. However the probability of this error is low and we can therefore assume that the majority of readings will be within 1% of the actual speed.

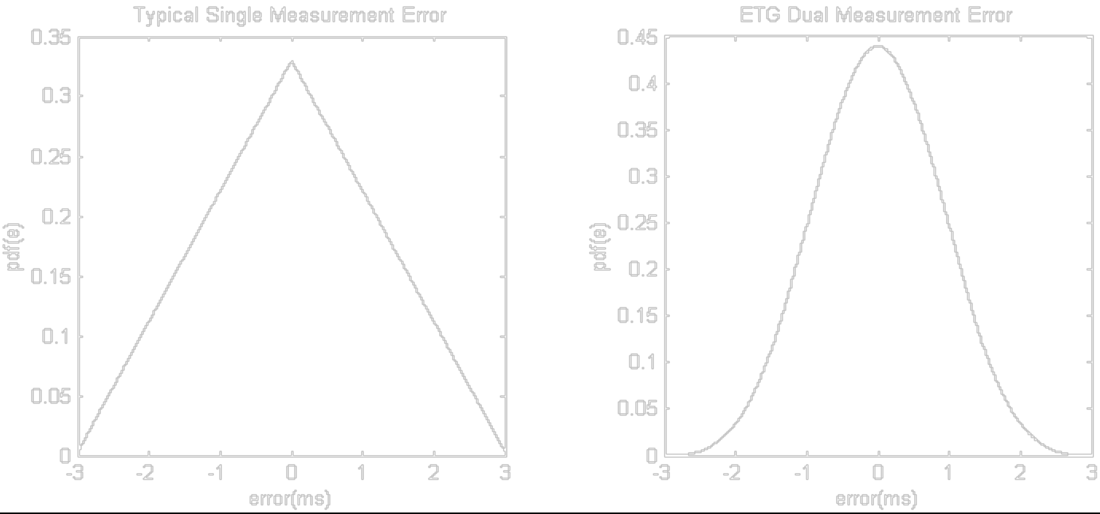


Figure 10a: Single Measurement Error

Averaging the speed measurements decreases the error probability. Figure 10b shows the average speed error p.d.f. for 100 cars travelling at 100km/h measured over a 5m spaced loop pair:

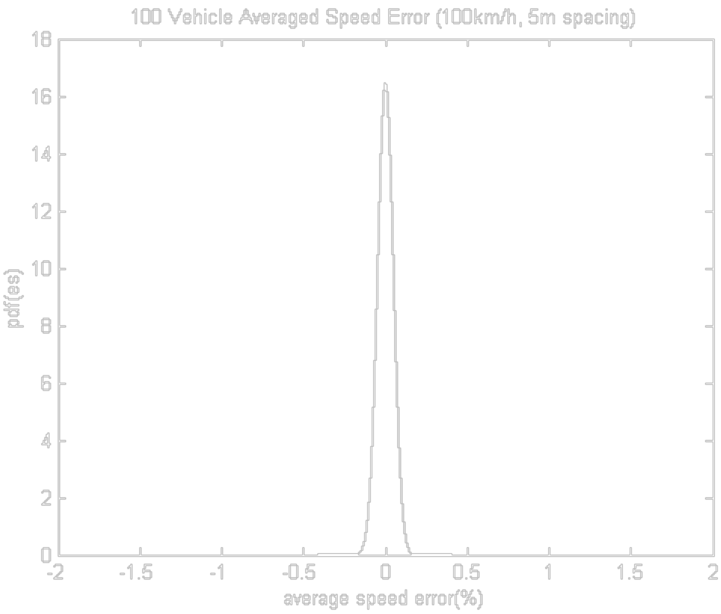


Figure 10b: 100 Vehicle Average Measurement Error

1.1.2 Loop Spacing

The speed error due to loop spacing is proportional to the error in the loop spacing.

Measured Speed (s') = {Loop Spacing (d) ± Loop Spacing Error (e_d)} / Time Between Loops (t)

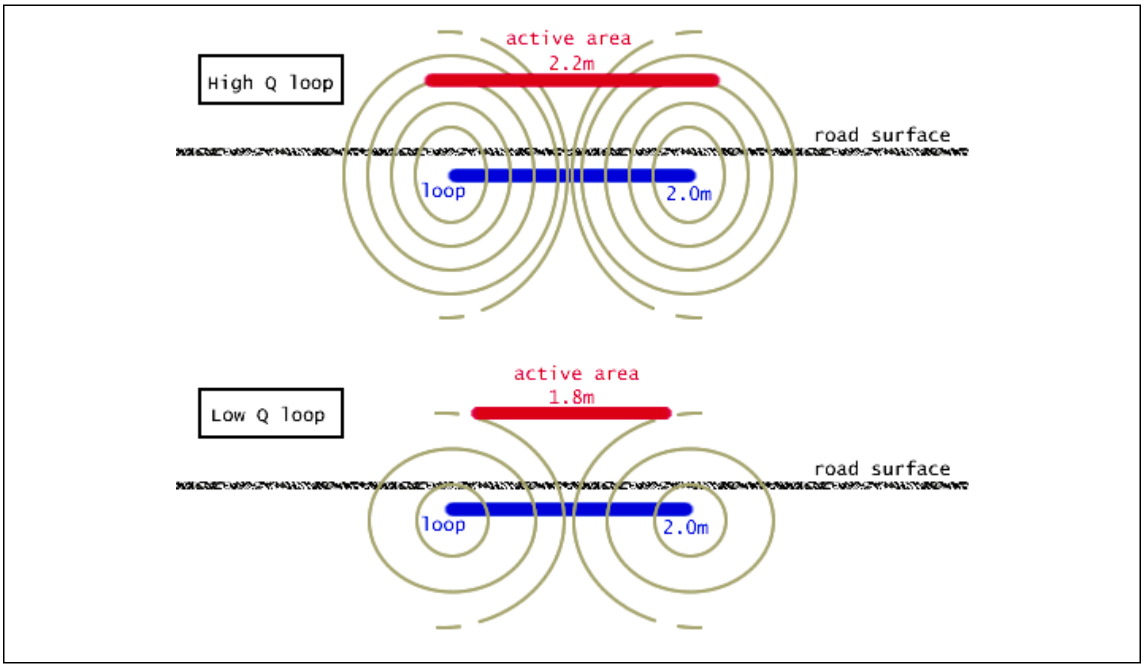
Therefore percentage speed error (e_s) = $1 - s' / s \times 100\%$

$$e_s = 1 - \{[(d \pm e_d) / t] / [d / t]\} \times 100\%$$
$$e_s = 1 - (d \pm e_d / d) \times 100\%$$
$$e_s = \pm e_d / d \times 100\%$$

Thus a ±10cm loop spacing error on a loop pair of proper length 5m will result in a speed error of ±2%. To avoid this error care should be taken to make sure the loop spacing is correct. This error does not diminish with averaging.

1.1.3 Loop Length

Loop length is the length of the active area of the loop in the direction of travel. The active area is size of the loop electromagnetic field in which a vehicle will change the inductance of the loop above the detection threshold. The size of the active area is determined by the sensitivity of the loop (Q), the depth of the loop, and the sensitivity of the detector.



For loops installed according to the specifications given referred to in the product manual (typically 2mt x 2 mt with 4 turns), the active area of the loop should be close to the physical loop size. For existing loops with low Q the active area may be diminished.   LOW ‘Q’ LOOPS or LOOPS with varying numbers of turns will impact on ‘ACTIVE AREA’ and therefore effect loop length.

The error in the loop length directly affects the error in the vehicle length. For example if there is an error in the loop length of -0.4m then vehicles will be reported as being 0.4m shorter than they actually are. This error can be minimised by following these steps:

1. Set the detectors to the most sensitive setting possible without crosstalk (crosstalk can only occur between cards)
2. Using the debug mode in the console, observe the lengths of 5 or more Holden or Ford sedans. These cars have a typical length of 4.9m
3. Average the results and subtract 4.9m.
4. The result is the amount by which the loop length value should be modified.
5. For example: 5 vehicles are measured at 4.1m, 4.3m, 4.0m, 4.0m 4.1m. The average is 4.1m. Subtracting 4.9 gives – 0.8m. Therefore the loop length should be decreased by 0.8m.

1.2 Consequences of varying measurements

1.2.1 Vehicle Length an compounding error

The length of a vehicle is calculated using the speed of the vehicle, the loop length and the average occupied time of both loops:

Length (l) = Speed (s) × Occupied Time (t) – Loop Length (d_l)

The ETG detector uses four time measurements (two time periods) to calculate the loop occupancy:

- Activation of loop 1 (t_{i1}) to clearing of loop 1 (t_{o1})
- Activation of loop 2 (t_{i1}) to clearing of loop 2 (t_{o2})

These measurements are then averaged to find the average occupancy.

Therefore $t = [(t_{o1} - t_{i1}) + (t_{o2} - t_{i2})] / 2$

As in Section 1.1.1 we can express the total error of this measurement as the summation of four uniform random variables, E, where $E = (e_{o1} - e_{i1} + e_{o2} - e_{i2}) / 2$. The p.d.f. for E is therefore the same as shown in Figure 10a.

To calculate the overall length error p.d.f. is complicated as it is related to the speed error, and is beyond the scope of this manual. A worst case analysis will give a rough idea of the error however.

Assume a 5m long vehicle travelling at 100km/h (27.78m/s) drives over a 2m loops spaced 5m apart. From Section 1.1.1 we know the speed error is ± 1.67 km/h (0.46m/s); and simple maths tells us that the time over each loop should be (2m + 5m) / 27.78m/s = 0.252s.

Therefore: Length (l) = Speed (s) × Occupied Time (t) – Loop Length (d_l)

$l = (27.78\text{m/s} \pm 0.46\text{m/s}) \times (0.252\text{s} \pm 0.003\text{s}) - 2\text{m}$

$l = 7.00\text{m} \pm 0.12\text{m} \pm 0.08\text{m} - 2\text{m}$

$l = 5\text{m} \quad \pm 0.2\text{m}$

Thus the length error is ± 0.2m.