BL CLASS 3 SENSORS FOR BICYCLE COUNTING



TE Connectiviy's (TE) RoadTrax BL piezoelectric axle sensors are available in Class 3 forms, specifically intended for bicycle detection (counting, direction and speed) in permanent installations. Class 3 sensors are available in lengths from 1.0 m to suit narrow paths/lanes and with shorter feeder length (10 m). Our optional split-sensor designs allow two riders traveling abreast at just 0.75 m spacing to be detected separately. When mounted in lanes used for mixed traffic, Class 3 sensors can still be used to detect the full range of motor vehicle axles.

Introduction

Many countries are encouraging the general public to use bicycles more regularly as a means of transportation, partly as a way to reduce passenger car usage and also to improve general health and fitness. This can involve setting up dedicated cycle lanes in urban areas and cycle paths across rural landscapes.

Provision of this infrastructure necessarily bear some cost, both in terms of installation and subsequent maintenance, therefore the responsible agencies have increasing interest in monitoring uptake by means of bicycle counting.

There are some key differences between existing road traffic (vehicular) counting/classification methods and the requirements for bicycle counting:

- Detection using inductive loops or magnetometers is difficult, as the area of coverage is not uniform across the full lane width
- Short-range radar detectors may not function well in rain
- Two or more bicycle riders may travel abreast, making transverse-firing optical or passive infra-red (PIR) detection potentially inaccurate
- Cycle lanes tend to be very narrow
- Above-ground detectors (pneumatic tubes, PIR) may be prone to vandalism at rural sites that are concealed from view
- In urban environments, some lanes may alternate between bicycle and vehicular traffic usage at different times of day

The RoadTrax BL piezoelectric axle sensor is well-suited to address these requirements. The BL has a long history of deployment for use in concrete and asphalt pavements, for the purposes of axle counting, vehicle classification, speed measurement and enforcement and high-speed weigh-in-motion. Motorcycles and mopeds already require detection as part of existing motor vehicle classification schemes.

Bicycle wheel detection uses the same principle as other heavier axles: a tire passing over the installed sensor will produce a charge pulse in response, with the amplitude proportional to tire pressure (and therefore axle load), and pulse width proportional to tire footprint length.

Although the load exerted by a bicycle tire is necessarily much lower than typical of motorized vehicles, the piezopolymer sensor at the core of the BL has very high dynamic range, and signals from bicycle crossings should be distinct and clear.

BL Class 3 Sensors

To address the specific requirements for bicycle detection TE expanded the existing **BL product range** of Class 1 and Class 2 sensors.

Class 3 sensors are identical in construction, and differ only in the following ways:

- Class 3 sensors are not passed through our uniformity test after production. We expect these sensors generally to show similar distribution of sensitivity and uniformity as our Class 2 sensors (uniformity < ± 20 % along length)
- Available standard sensor lengths range from 1.0 m to max 5.5 m
- Class 3 sensors are offered with 10 m or 35 m feeder cables. On cycle paths, it is common to have the detection electronics relatively close to the measurement site
- An additional split-sensor configuration has been developed, which offers two separate sensing regions within a single brass length, with very small gap between the active sensors. Each end of the sensor is then terminated to feeder cable, giving a “double-ended” sensor

The recommended installation procedure is also identical for asphalt or concrete pavements.

Use of the RoadTrax BL sensor for bicycle detection offers the following advantages:

- Permanent buried installation, flush with pavement surface – robust and imperceptible to cyclists
- No poles or gantries required
- Speed and direction easy to resolve, with short pulse signals from two transverse sensors
- Simple electronic signal processing required
- Unaffected by rain and other adverse weather conditions
- Very low power requirement (self-generated signals), suitable for battery/solar-powered systems
- Short sensors available to cater for narrow lanes
- Unique split-sensor designs available for improved lane coverage and counting accuracy

Typical Output Signals

Figure 1 shows the charge signal produced from a Class 3 sensor installed full-lane-width in asphalt road open to all traffic. Sensor capacitance (including feeder cable): 5.86 nF, giving open-circuit voltage peaks of 34 mV (front axle) and 65 mV (rear axle). Speed 11.8 km/h. Total weight approx 100 kg. Wheelbase 0.92 m. Air temperature +8 °C.

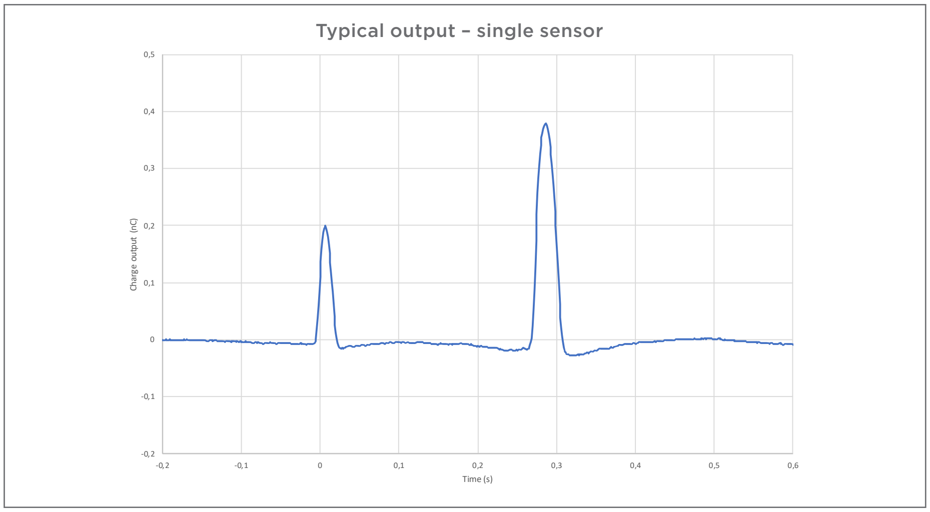


FIGURE 1

Figure 2 displays the same bicycle and rider passing over two similar sensors, spaced 0.35 m apart. Speed and direction are deduced from the time separation between the two waveforms. Wheelbase length can be calculated from time separation between front and rear axles, if speed is known. Tire footprint length can be estimated from pulse width if speed is known.

Note that bicycle tire footprint length will be significantly shorter than typical car tire (or truck) footprint, as illustrated in figure 3.

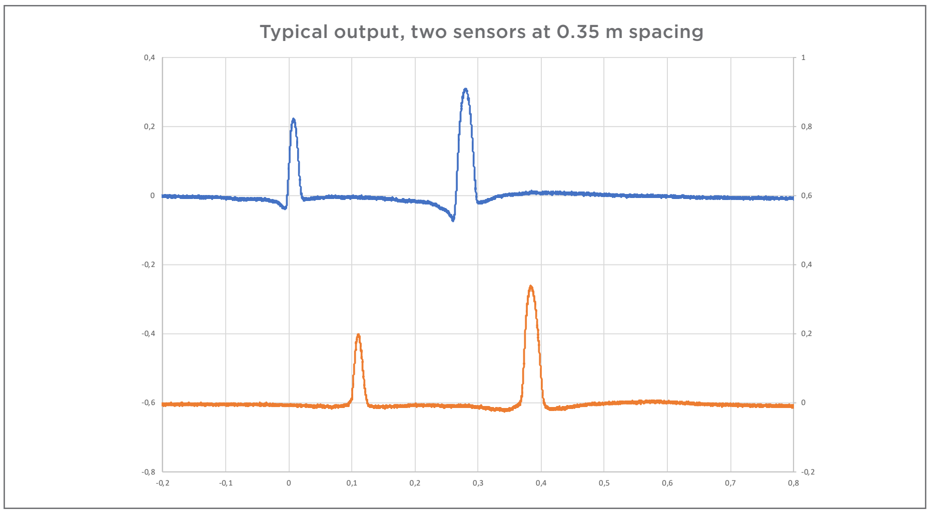


FIGURE 2

Figure 3 is derived from two raw waveforms produced by the same sensor, normalized to same peak amplitude. The blue curve is the front axle of a bicycle. The orange curve is front axle of a 4x4 (SUV). The X-axis has been scaled into units of distance, knowing the speed of each axle crossing. 50 % of peak amplitude points were used to estimate the footprint length (50 mm for bicycle, 128 mm for 4x4).

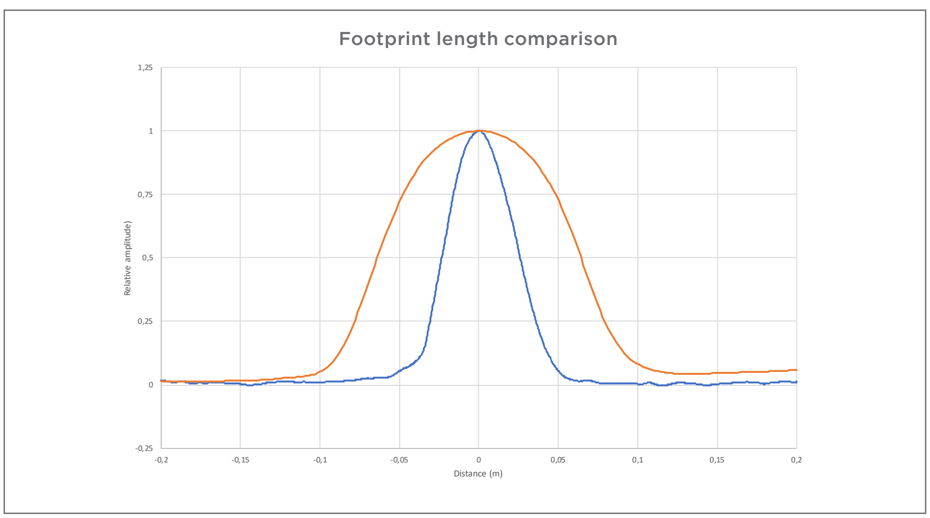


FIGURE 3

Discussion of Output Amplitudes

Although the sensitivity of a BL sensor to compressive force is typically in the range 40-60 pC/N, the apparent sensitivity of a sensor installed in the pavement at normal depth and using typical resin will be much lower, because much of the force exerted by the tire will bypass the sensor itself.

We expect the apparent sensitivity to be below 1 pC/N, and likely around 0.75 pC/N for an installed sensor. A table showing approximate peak charge and voltage output levels for various axle loads is shown below:

	kg	axles	kg/axle	N/axle	nC pk	Voc//10n
STGO Cat 3 limit	16500	1	16500	161865	121	12.1
HGV (max driven)	11500	1	11500	112815	85	8.5
HGV (typ)	6000	1	6000	58860	44	4.4
Van	3000	2	1500	14715	11	1.1
Car (large)	2500	2	1250	12263	9.2	0.92
Car (small)	1200	2	600	5886	4.4	0.44
Motorcycle	300	2	150	1472	1.1	0.11
Bicycle (typ)	100	2	50	491	0.37	0.04
Bicycle (light, child)	40	2	20	196	0.15	0.01

From this table, we predict 0.37 nC peak for each axle of a bicycle/rider with total weight 100 kg. In the measurement data, we saw peaks of 0.2 nC (front) and 0.38 nC (rear), a little lower in total than the expected value but correct in order of magnitude. The absolute output level of a BL sensor is a function of installed depth and of temperature. Waveform data shown above were collected with air temperature around +8°C. At lower temperatures, the hardness of the installation resin increases, and lower peak force is transferred to the sensor element.

Bicycle Counting Accuracy

The accuracy of any bicycle counting system in any specific installation depends not just on the sensor type and performance, but also on the algorithms adopted by the instrumentation, the configuration of the site, and the nature of local traffic.

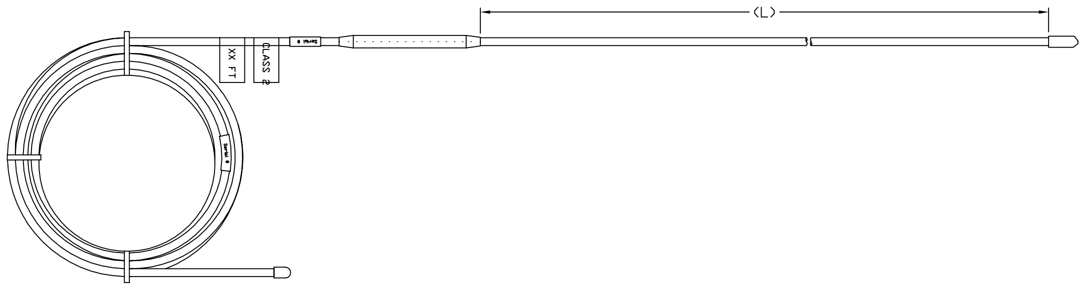
As a producer of the sensor only, TE cannot lay claim to any specific accuracy level. With this said, one system using our BL piezoelectric sensors has achieved accuracy up to 100% (no missed bicycles, no false positives where other vehicles or pedestrians were mis-classified as bicycles) in given circumstances, and 99.0% over a longer time interval (2 apparent missed events, with some question over the reference count accuracy).

In a different multi-technology comparison trial, BL sensors were found to offer overall detection accuracy (measured/actual count) of up to 96.3% (7865/8171) with sensitivity 94.3% and positive prediction value (PPV) 97.2%.

A similar system from another manufacturer also using BL sensors achieved a false positive rate of just 0.4% (PPV 99.6%). The report concluded that systems deploying BL sensors are suitable for off-road paths and separated cycleways and acceptable for on-road monitoring in mixed traffic.

Available Part Numbers

Single-ended sensors



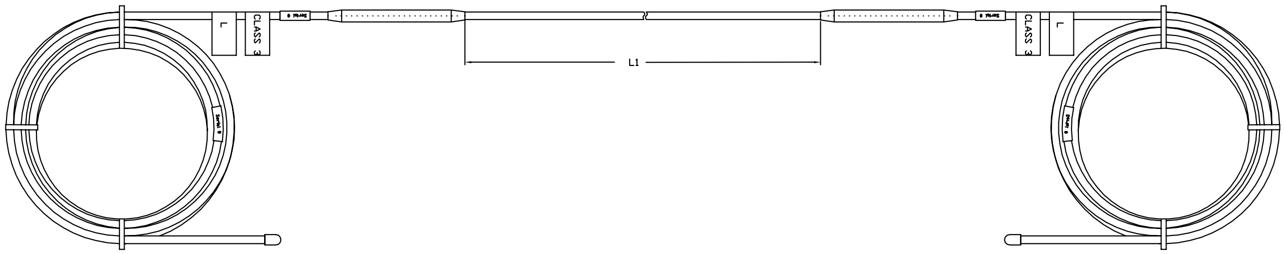
Sensor length in the part description below refers to "visible brass" length (L) as shown above

Part Number	Description
1-1007296-0	BL CL3 1.0M SENSOR/10M CABLE
1-1007296-1	BL CL3 1.1M SENSOR/10M CABLE
1-1007296-2	BL CL3 1.2M SENSOR/10M CABLE
1-1007296-3	BL CL3 1.3M SENSOR/10M CABLE
1-1007296-4	BL CL3 1.4M SENSOR/10M CABLE
1-1007296-5	BL CL3 1.5M SENSOR/10M CABLE
1-1007296-6	BL CL3 1.6M SENSOR/10M CABLE
1-1007296-7	BL CL3 1.7M SENSOR/10M CABLE
1-1007296-8	BL CL3 1.8M SENSOR/10M CABLE
1-1007296-9	BL CL3 1.9M SENSOR/10M CABLE
2-1007296-0	BL CL3 2.0M SENSOR/10M CABLE
2-1007296-1	BL CL3 2.1M SENSOR/10M CABLE
2-1007296-2	BL CL3 2.2M SENSOR/10M CABLE
2-1007296-3	BL CL3 2.3M SENSOR/10M CABLE
2-1007296-4	BL CL3 2.4M SENSOR/10M CABLE
2-1007296-5	BL CL3 2.5M SENSOR/10M CABLE
2-1007296-6	BL CL3 2.6M SENSOR/10M CABLE
2-1007296-7	BL CL3 2.7M SENSOR/10M CABLE
2-1007296-8	BL CL3 2.8M SENSOR/10M CABLE
2-1007296-9	BL CL3 2.9M SENSOR/10M CABLE
3-1007296-0	BL CL3 3.0M SENSOR/10M CABLE
20012269-00	BL CL3 3.25M SENSOR/10M CABLE
20012269-01	BL CL3 3.5M SENSOR/10M CABLE
20012269-02	BL CL3 3.75M SENSOR/10M CABLE
20012269-03	BL CL3 4.0M SENSOR/10M CABLE
20012269-04	BL CL3 4.25M SENSOR/10M CABLE
20012269-05	BL CL3 4.5M SENSOR/10M CABLE
20012269-06	BL CL3 4.75M SENSOR/10M CABLE
20012269-07	BL CL3 5.0M SENSOR/10M CABLE
20012269-08	BL CL3 5.25M SENSOR/10M CABLE
20012269-09	BL CL3 5.5M SENSOR/10M CABLE

Part Number	Description
20012270-00	BL CL3 1.0M SENSOR/35M CABLE
20012270-01	BL CL3 1.1M SENSOR/35M CABLE
20012270-02	BL CL3 1.2M SENSOR/35M CABLE
20012270-03	BL CL3 1.3M SENSOR/35M CABLE
20012270-04	BL CL3 1.4M SENSOR/35M CABLE
20012270-05	BL CL3 1.5M SENSOR/35M CABLE
20012270-06	BL CL3 1.6M SENSOR/35M CABLE
20012270-07	BL CL3 1.7M SENSOR/35M CABLE
20012270-08	BL CL3 1.8M SENSOR/35M CABLE
20012270-09	BL CL3 1.9M SENSOR/35M CABLE
20012270-10	BL CL3 2.0M SENSOR/35M CABLE
20012270-11	BL CL3 2.1M SENSOR/35M CABLE
20012270-12	BL CL3 2.2M SENSOR/35M CABLE
20012270-13	BL CL3 2.3M SENSOR/35M CABLE
20012270-14	BL CL3 2.4M SENSOR/35M CABLE
20012270-15	BL CL3 2.5M SENSOR/35M CABLE
20012270-16	BL CL3 2.6M SENSOR/35M CABLE
20012270-17	BL CL3 2.7M SENSOR/35M CABLE
20012270-18	BL CL3 2.8M SENSOR/35M CABLE
20012270-19	BL CL3 2.9M SENSOR/35M CABLE
20012270-20	BL CL3 3.0M SENSOR/35M CABLE
20012270-21	BL CL3 3.25M SENSOR/35M CABLE
20012270-22	BL CL3 3.5M SENSOR/35M CABLE
20012270-23	BL CL3 3.75M SENSOR/35M CABLE
20012270-24	BL CL3 4.0M SENSOR/35M CABLE
20012270-25	BL CL3 4.25M SENSOR/35M CABLE
20012270-26	BL CL3 4.5M SENSOR/35M CABLE
20012270-27	BL CL3 4.75M SENSOR/35M CABLE
20012270-28	BL CL3 5.0M SENSOR/35M CABLE
20012270-29	BL CL3 5.25M SENSOR/35M CABLE
20012270-30	BL CL3 5.5M SENSOR/35M CABLE

Available Part Numbers

Double-ended (split) sensors



Visible brass length L1 is split into two equal parts.
*For example, part number 1007375-1 has length L1 of 1.50 m, described as 0.75M*2 in the table below.*

Part Number	Description
1007375-1	CLS 3,0.75M*2 SEN/10M CABLE
1007375-3	CLS 3,0.75M*2 SEN/30M CABLE
1-1007375-1	CLS 3,1.0M*2 SEN/10M CABLE
1-1007375-3	CLS 3,1.0M*2 SEN/30M CABLE
2-1007375-1	CLS 3,1.25M*2 SEN/10M CABLE
2-1007375-3	CLS 3,1.25M*2 SEN/30M CABLE
3-1007375-1	CLS 3,1.5M*2 SEN/10M CABLE
3-1007375-3	CLS 3,1.5M*2 SEN/30M CABLE
4-1007375-1	CLS 3,1.75M*2 SEN/10M CABLE
4-1007375-3	CLS 3,1.75M*2 SEN/30M CABLE
4-1007375-5	BL CLS 3,1.75M*2 SEN/50M CABLE

ABOUT TE CONNECTIVITY

TE Connectivity (TE) is a global technology leader, providing sensors and connectivity essential in today's increasingly connected world. We are one of the largest sensor companies in the world with solutions that are vital to the next generation of data-driven technology. TE's portfolio of intelligent, efficient and high performing sensors are used for customers across several industries, from automotive, industrial and commercial transportation and aerospace and defense, to medical solutions and consumer applications.

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11/2020