Wheel detection and axle counting as key elements of level crossing protection systems

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There are approximately 500,000 level crossing protection installations throughout the world. In many respects, new construction, expansion, optimisation and on-going renewal offer potential for innovation and further technological development within this market segment of railway signalling technology (Fig. 1). The range of types and variants of technical designs for level crossing protection systems is extremely widespread. The main reasons for this are country-specific design and safety requirements as well as approval regulations. In addition, providers of level crossing protection systems who generally operate on a local or regional basis work to different standards and offer various technical solutions. As a flexible, scalable and integrated component of level crossing protection systems, wheel detection and axle counting technologies offer many advantages, yet they must satisfy a series of specific requirements and framework conditions. (Fig. 2). This article looks at these requirements and at the current trends, and describes a very wide range of configuration solutions for controlling level crossing protection systems.

Figure 1: Technical protection systems for level crossings are growing in importance

Figure 2: Trend towards wheel detection and axle counting based level crossing protection systems

1 Requirements and trends

The requirements on their integrated components are every bit as diverse as the implementation possibilities for level crossing protection systems. The following will highlight some of the resulting core requirements for wheel detection and axle counting systems, and will deduce trends and future developments without claiming to be complete.

1.1 A very wide range of configuration variants

Switching on and off and triggering of a level crossing protection system can be carried out in many different ways. A separate section of this article deals with this issue (see 2. configuration variants).

1.2 Existing cable systems

When renovations and optimisations are carried out (e. g. replacement of track circuits and loops), the aim is generally to reuse the existing cabling as far as possible. Electromagnetic interference and poor cable quality must be controlled.

1.3 Environmental conditions

Components of level crossing protection systems are generally installed on a stand-alone basis or as a closed group in the open country. An extended ambient temperature range from −40°C to +85°C for both outdoor and indoor system components may be required.

1.4 Interface between wheel detection/axle counting and control logic

Manufacturers of level crossing protection systems often use widely differing interfaces to the integrative components. The range extends from optocoupler and relay interfaces to vital Ethernet-based software interfaces [1].

Further to the physical interface technology, the actual function and the time response itself is of great importance.

System pulses (information regarding the detection of axles) and information on the direction of traversing in various timing variants, from milliseconds to seconds, may be required [1].

Depending on the design of the level crossing protection system, axle counting systems must be able to offer and realise a wide range of different basic settings. The range varies from direct/indirect reset, automatic reset, clearing of track, etc. to complex combinations of individual variants [2].

1.5 Low power consumption

Level crossing protection systems generally operate as closed systems, i. e. independently from interlockings and without a central power supply. For example, solar cells may be used, with a focus on low power consumption for the complete system.

1.6 Low LCC, maintenance and remote diagnostics

The procurement costs for level crossing protection systems are increasingly compared with the costs over the system's life cycle. The life cycle costs of wheel detection and axle counting systems are significantly lower than those of comparable technologies. In addition, the possibilities for remote diagnostics using UMTS or network technologies offer further advantages.

A high availability of the sub-systems and of the complete system is expected or stipulated respectively as a prerequisite.

1.7 Radio transmission

One emerging trend in the further development and optimisation of level crossing protection systems is the use of modern radio technology. It shall be possible to transmit the wheel detection system information by radio to the switching points which may be installed at up to 3 km from the actual level crossing protection system. This innovative communication technology allows to significantly reduce investment in cabling.

1.8 Speed relation

In order to optimise the switching times of a level crossing protection system, the traversing speed can be established by a wheel detection system. Fast-moving trains may request immediate switching while slower trains may need delayed switching.

It is therefore necessary to determine the traversing speed at the point of switching, i. e. from the wheel detection components [3].

Figure 3: Variants with detection points

2 Configuration variants

The central elements of a level crossing protection system are the systems for switching on and off, respectively releasing. The following section looks at some variants that have been implemented or discussed from the point of view of the manufacturer of wheel detection and axle counting systems. As there is no limit on the diversity of variants in this field, there is no claim for completeness.

2.1 Variants with detection points

Figure 3 shows two configuration variants with exclusive use of wheel detection systems. Apart from the actual axle detection, these systems are also able to output additional information such as the direction of traversing. Here, different variants of the direction pulses can be used: direction pulse at the start of traversing (1-edge direction pulse) or at the end of traversing (4-edge direction pulse) [1] (Fig. 3).

When a train approaches from direction A, a 1-edge direction pulse is emitted when the wheel sensor DP 1 (detection point 1) is traversed. This pulse triggers the closure of the barriers and/or the warning lights. As the vehicle continues travelling in direction A, a 1-edge direction pulse is also emitted at DP 2. If the level crossing protection system has not already been secured, this occurs at this point and no later. A fail-safe 4-edge direction pulse is emitted when DP 3 is passed. The level crossing protection system may now be unsecured again.

The second variant shown in figure 3 uses only three detection points instead of four. However, this can also be sufficient or reach the purpose from an operational point of view.

2.2 Variants with clear track sections

Figure 4 shows multiple variants with clear track sections (FMA) that are formed using axle counting components.

The simplest option here is monitoring using a clear track section that is formed by the counting heads ZP 1 and ZP 2. If this section is occupied by a train traversing at ZP 1 or ZP 2, the barriers close and/or the level crossing protection system's light signals are activated. When track section 1 becomes clear, the barriers are opened again with the lights deactivated.

This track section can be extended by an additional section. In the variant depicted in figure 4, counting heads ZP 1 to ZP 3 form two track sections, FMA 1 and FMA 2. When a train approaches from direction A, the occupied status is emitted by track section FMA 1 when counting head ZP 1 is traversed. This occupied status triggers the closure of the barriers and/or the activation of the warning lights. Once the train has completely left the track section FMA 1, the clear status revokes the secured status. This also applies in the same way for a train approaching from direction B.

It is also possible to control a level crossing protection system with three track sections with a similar function as explained above.

The track sections must not always be arranged adjacent to each other. For conceptional and operational reasons, an overlapping arrangement may also make

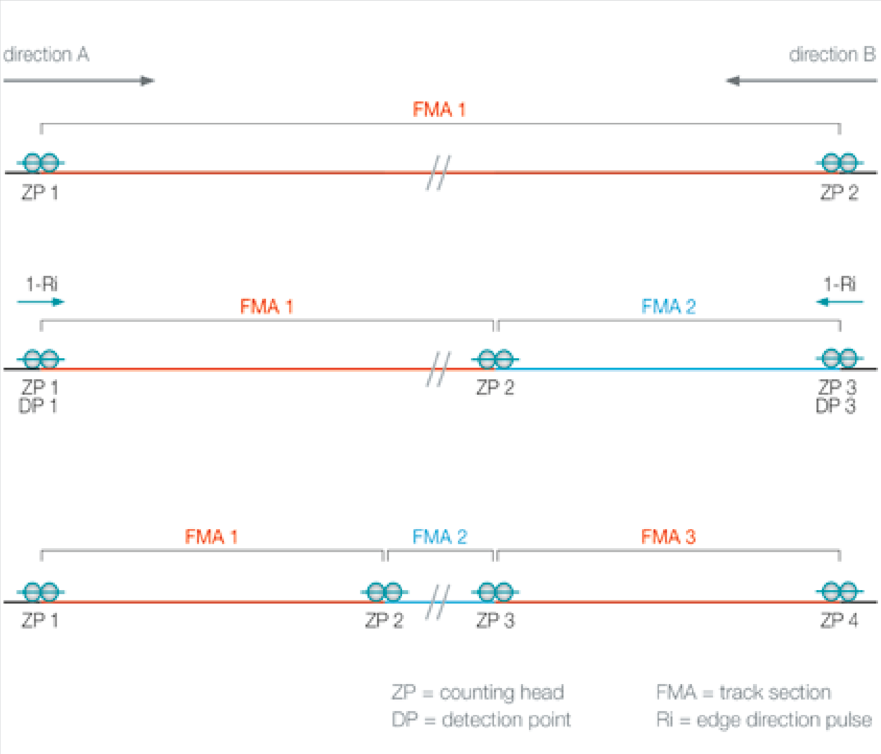

Figure 4: Variants with track sections

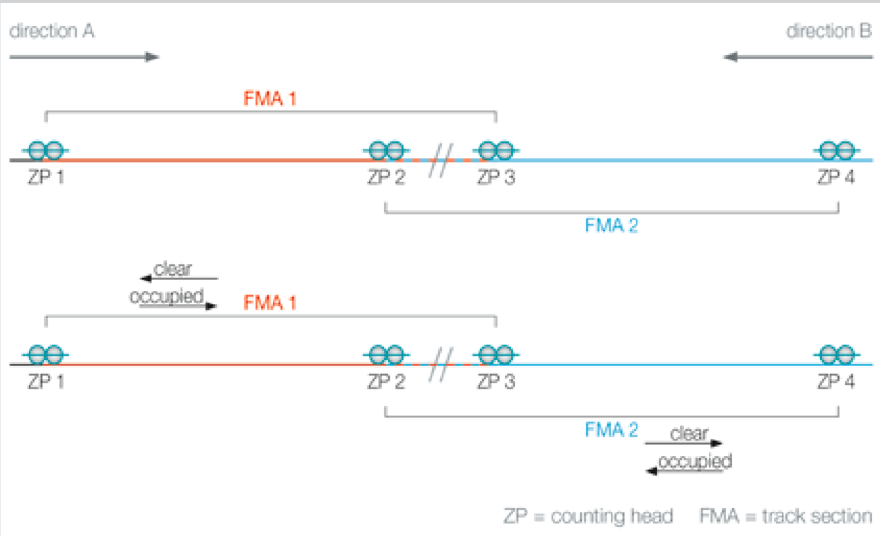

Figure 5: Variants with overlapping track sections

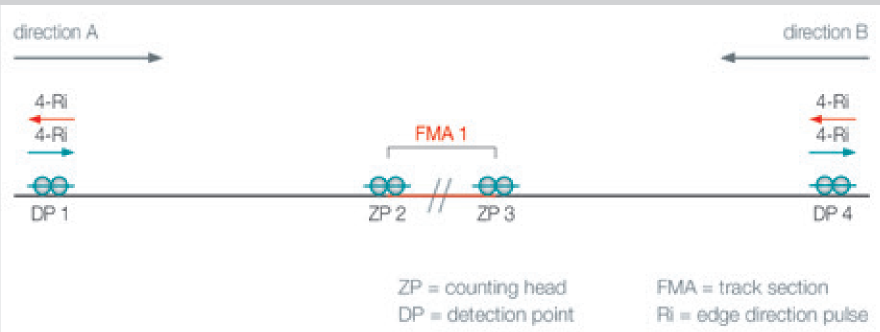

Figure 6: Variants with detection points and track sections

sense. Figure 5 shows two variants with overlapping track sections.

In this configuration, the counting heads ZP 1 and ZP 3 make up the track section FMA 1. Track section FMA 2 is formed by ZP 2 and ZP 4 (Fig. 5).

If a train now approaches from direction A, the occupation of track section FMA 1 is detected, leading to the closing of the barriers and/or the activation of the light signals.

Subsequently, track section FMA 2 is occupied and the level crossing remains closed. The higher-level logic of the level crossing protection system must now evaluate whether the train has arrived from direction A and will in this case suppress the occupied status of track section FMA 2 from further evaluation. Once FMA 1 emits a clear status when the train travels onwards or leaves the track section, the barriers can be opened and the signals can be deactivated. The same applies in analogy for trains traversing from direction B.

The variants described above share the fact that in each case the level crossing protection system's higher-level logic must evaluate from which direction the train has approached. Based on this information, the system evaluates the clear or occupied statuses of the relevant track sections.

However, modern axle counting systems offer the option of carrying out this function. When a train from direction A passes track section FMA 1, this section indicates that it is "occupied". However, if the train comes from direction B, track section FMA 1 does not emit any occupied status. This function is known as the direction-dependent occupied status and reduces the logic outlay in the level crossing protection system's higher-level control system.

2.3 Variants with detection points and track sections

In practice, the variants with detection points and track sections are often combined. To represent the many combination possibilities, figure 6 shows a frequently used representative example.

The detection points DP 1 and DP 4 act as wheel detectors. The counting heads ZP 2 and ZP 3 form the track section FMA 1. When a train approaches from direction A, a 1-edge direction pulse is emitted when wheel sensor D 1 is traversed. This pulse triggers the closure of the barriers and/or the activation of the warning lights. The train continues in direction A and occupies the track section FMA 1, which is laid over the actual level crossing. Once the train has completely passed FMA 1, i.e. the entire train has left the level crossing, FMA 1 indicates that it is "clear". This clear status means that the secured status can be revoked.

As it continues to travel in direction A, the train passes detection point DP 4, which is, at the same time, also the switching point for direction B. DP 4 emits a 4-edge direction pulse and thereby indicates that the train is travelling away from the level crossing. The level crossing can therefore remain open and the level crossing protection system can also stay in its open state.

2.4 Variants with speed-dependent switching

A clearly emerging trend in planning and design of level crossing protection systems is speed-dependent switching with an assessment aiming at adapting the closure time of the barrier system and/or the activation of the light signals to the train speed. For slowly travelling trains, the level crossing protection system can be activated significantly later than with trains travelling at high speed.

This principle reduces the interference that the level crossing protection system causes for crossing traffic to a minimum. Figure 7 shows two possible variants.

The length of the clear track sections FMA 4 and FMA 5 is precisely defined. When a train traverses over ZP 1, the sections FMA 1 and FMA 4 are occupied. Once FMA 4 is cleared, the higher-level logic of the level crossing protection system can calculate an average speed based on the time the section is occupied and its defined length, using the formula speed equals distance divided by time. On the basis of the calculated speed, the barrier and/or warning lights can therefore be controlled in a speed-dependent manner.

Moreover, modern wheel detection systems are already capable of independently determining the speed, using just one detection point. This is shown in the second variant in figure 6. The advantages are clear when it comes to cutting down the number of components and reducing the logical outlay within the level crossing protection system's higher-level control system. [3]

2.5 Evaluation of the different variants

The extremely different design approaches and possible solutions for level crossing protection systems make it very difficult to undertake a universal evaluation and comparison of the individual variants. In any case it is only possible to carry out

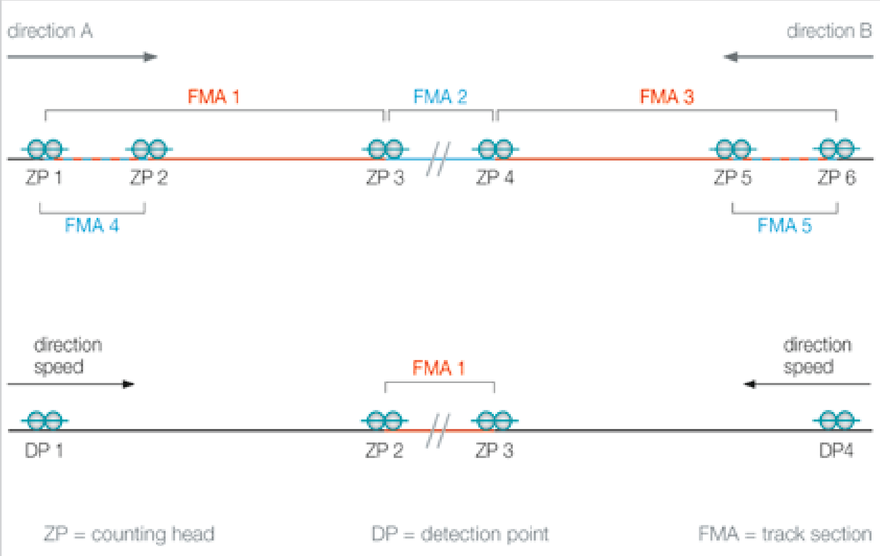

Figure 7: Variants with speed-dependent switching

an individual assessment, or one which takes into account the overall context of level crossing protection systems, not imperatively in the field of wheel detection or axle counting. The following section attempts to highlight some possible criteria and/or topics from the perspective of wheel detection/axle counting. Advantages/disadvantages may be derived from these criteria on a case-by-case basis.

– Interface
Control systems for level crossing protection systems are increasingly realised using industry controls (PLC, controller, etc.). The criterion here may be the number of required inputs and outputs to integrative components. Wheel detection and axle counting systems offer an extremely wide range of options here, from optocoupler and relay interfaces to software interfaces.

– Functionality
As explained in the above sections, wheel detection and axle counting systems can provide significantly more information than the mere detection/occupied status. The generation of information on the direction of traversing, traversing speed, etc. may significantly influence and simplify the distribution of the control logic and the design of the complete system.

– Number of components
Cost-effectiveness in terms of investment and operating costs is often an important criterion. Where components can be reduced or functionalities resolved in a compact manner, concepts based on wheel detection/axle counting increase in importance.

– Safety level
Depending on the requirements of the operator or end customer respectively, level crossing protection systems have to match a very wide range of safety levels (SIL0 to SIL4). In this respect, the system integrator must consider the complete system, i.e. the higher-level control system including the wheel detection/axle counting system. A high degree of functionality in the wheel detection and axle counting systems, and existing expert reports, support and facilitate appropriate implementation.

3 Wheel detection and axle counting systems

This section provides an overview of the wheel detection and axle counting platforms offered by Frauscher Sensortechnik GmbH for level crossing protection systems application. For further information please refer to the two articles "Die Herausforderungen an Raddetektion und Achszählung in der Zukunft" [The demands on wheel detection and axle counting in the future], published in the specialist journal Signal+Draht in 2011 [2], [4].

3.1 Wheel detection system RSR180/RSR123

The aim and task of the wheel detection systems RSR180/RSR123 is to provide digital pulses that are either fail-safe or non-fail-safe depending on requirements, and which indicate the presence, speed or the traversing direction of an axle. Requirements for the interface to the cus-

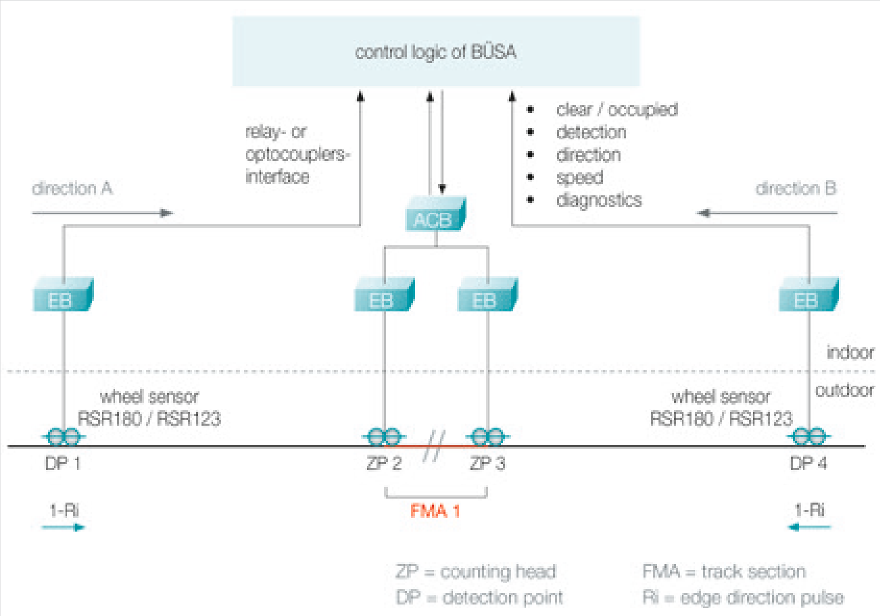

Figure 8: ACS2000 – simple customer-specific configuration (hardware configuration)

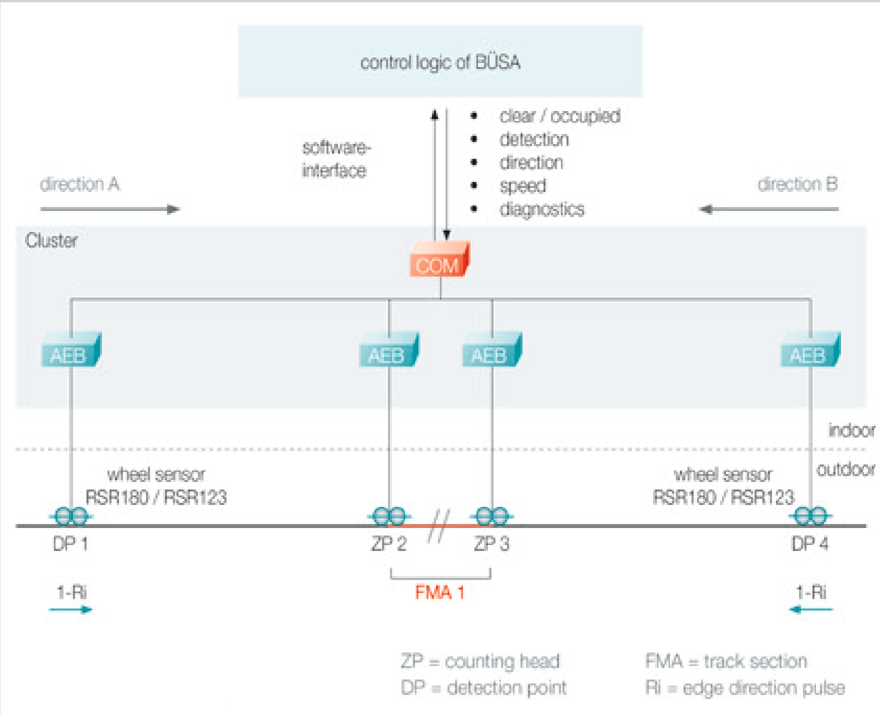

Figure 9: FAdC – optimal integration via various interface standards (e. g. software)

tomer application can be met by providing electronic switching contacts (optocouplers), relay contacts (voltage-free) or in software-based form (serial data protocol).

During traversing, the wheel flange of the axle dampens the wheel sensor RSR which is attached to the wheel flange side of the rail by a rail claw. Either the wheel sensor RSR180 or the RSR123 can be used here, depending on individual requirements.

This wheel sensor, which is made up of two independent systems, is based on inductive processes and generates the analogue signal aspect. This is proportional to the dampening and is transmitted to the evaluation board EB as a direct current signal. The relevant evaluation board EB is responsible for evaluating these signals and making the appropriate digital switching patterns available at the interface, in accordance with the customer application. Standardised output characteristics in accordance with CENELEC are available at all levels (SIL0 to SIL4) (Fig. 8).

3.2 Axle counting system ASC2000

The system architecture of the Frauscher axle counting system ACS2000 is of a very simple design, with each counting head and each track section assigned to a fail-safe board. (Fig. 8)

As the individual boards are pre-configured during manufacture, application-specific configuration takes place exclusively via the hardware (DIP-switches and/or solder bridges). This means that no specific knowledge or software tools are required. All that is necessary is to plug the boards into the board racks or to replace them as appropriate in the event of changes. In addition, this concept guarantees a very high level of availability, as only one section is affected if there is an error in a board.

Using open and universal interfaces such as optocouplers and relay outputs, the ACS2000 can be simply and reliably integrated into level crossing protection systems. Customer-specific requirements can be implemented in a very individual and flexible way thanks to the availability of a large selection of pre-configured boards.

3.4 Axle counting system FAdC/FAdCi

The Frauscher Advanced Counter (FAdC/FAdCi) constitutes the latest generation of axle counting systems using an Ethernet-based software interface (a relay interface is also available as an option). This open communication structure enables the FAdC/FAdCi to be integrated into level crossing protection systems in an optimised way with only a small number of components needed.

The FAdC/FAdCi system therefore offers a range of benefits with regard to functionality, required space and investment/operating costs.

The connection can be established either by developing a customer-specific interface or via the Frauscher protocol (FSE). In any event, the higher-level application has access to all the functional and diagnostic information from the system for further processing (Fig. 9).

4 Summary

Level crossing protection systems are subject to a wide range of diverse safety and approval regulations that are predominantly country-specific. This is one of the reasons why many medium-sized, local and regional providers offering specific solutions have established themselves over the years.

As an independent components supplier, Frauscher serves a number of these manufacturers and has therefore already realised an etraorinarily wide range of different configuration variants. Thanks to the broad product portfolio of wheel sensor types, evaluation platforms and interfaces, the best conditions for customer-specific adaptations, simple integration and consideration of future requirements can be offered.

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ZUSAMMENFASSUNG

Raddetektion und Achszählung als wesentliche Elemente zur Steuerung von BÜSA

Die Formen und Varianten der technischen Ausführung von Bahnübergangssicherungsanlagen (BÜSA) sind sehr vielfältig. Gründe hierfür sind vorwiegend national geprägte Ausführungs-, Sicherheits- und Zulassungsvorschriften. Hinzu kommen die unterschiedlichen Standards und technischen Lösungen der meist lokalen und regionalen Anbieter von BÜSA.
Die Technologien Raddetektion und Achszählung bieten als flexibler, skalierbarer und integrativer Bestandteil von BÜSA viele Vorteile, müssen aber eine Reihe spezifischer Rahmenbedingungen erfüllen. Dieser Beitrag beschäftigt sich mit diesen Anforderungen sowie mit aktuellen Trends und stellt verschiedenste Konfigurationslösungen zur Steuerung von BÜSA dar. Als unabhängiger Komponentenlieferant bedient Frauscher eine Reihe dieser Hersteller und hat daher schon die verschiedensten Konfigurationsvarianten realisiert. Das breite Produktportfolio hinsichtlich Radsensortypen, Auswerteplattformen und Schnittstellen bietet hier beste Voraussetzungen für eine kundenspezifische Anpassung, einfache Integration und die Berücksichtigung zukünftiger Anforderungen.