

## Getting AS-Interface ready for the long distance

### *New possibilities by using the 'Advanced Repeater'*

It was common to hear and read that AS-Interface was limited to a network length of 100 meter. This statement dates back a long time ago and is now outdated. With Double Master, Repeater, Bus Terminator, Tuner, and the recently developed 'Advanced Repeater' Bihl+Wiedemann now offers several options to implement extensive linear as well as two-dimensional networks. This article discusses the various possibilities for network extensions and describes the important criteria to develop the 'right' configuration.

### *The classical 100 m network*

In general, the shorter a network the more stable it will operate. A short network minimizes its susceptibility to errors. It may sound trivial but is still correct: Since the mechanisms of AS-Interface and its components have been primarily constructed for 100 m networks, this is the configuration where the network is easiest to implement

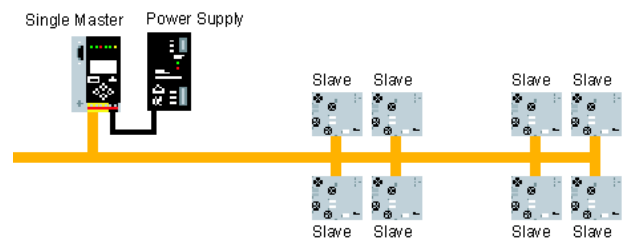


Fig. 1: Standard network with a length of 100 m

and works with the fewest flaws possible; assuming components in perfect working order are used. Hence, every time the 100 m limit is surpassed the danger increases that (initially) single telegrams are not immediately recognized by master or slave and thus have to be repeated, or that the communication with an individual slave is temporary or permanently interrupted. A crash such as this usually occurs quite abruptly when exceeding a relatively exactly defined length limit that depends on the particular configuration. In general, this is not a concern for a network length under 100 m and it is the reason why the classical 100 m network is so successful (see 'Theory', 4).

### *Several 100 m networks*

One option to operate larger AS-Interface networks is to divide an extended network into several sub-networks, each with a length of less than 100 m, and to operate each sub-network with its own master and power supply or to use a Double Master for two neighboring 100 m networks.

This solution has become a de-facto standard. It has all the advantages of a 100 m network and represents a fast route to a robust, functional layout. An additional advantage is that resistive cable related losses slaves with high current consumption are kept small. Furthermore, sub-networks fully support the modular configuration of many machines, as found for instance in material handling systems with long conveyor distances and they also simplify system layout and startup.

### Theory: Classical 100 m network versus controlled long distance

In five steps it is possible to understand how to extend networks beyond the 100 m limit:

1. *Transmission mechanism:* AS-Interface uses  $\sin^2$ -shaped positive and negative voltage pulses for data transmissions. Receivers in master and slaves are designed explicitly to recognize these voltage pulses. This kind of coding is extremely safe because of its lack of higher harmonics. Additionally, the receiver inspects the correctness of every single telegram on the basis of several criteria. This is the root of the exceptional operational safety of AS-Interface even in difficult environments.
2. *Limits:* Yet, the laws of physics remain valid for AS-Interface also: Device and cable impedances as well as reflections on the cable ends deform the voltage pulses on the cable, such that – as soon as the deformations are too excessive – they cannot be clearly identified by the receivers in the devices and, thus, cannot be distinguished from interferences. Consequently, this leads to an increasing number of 'requests' through the system in form of repeated telegram transmissions and ultimately to failure of a single or several components. This is exactly where every cable extension design needs to start.
3. *Repetitions and errors:* As always when talking about AS-Interface it is necessary to clearly differentiate between 'repeats' and 'errors'. If the receiver in a master or slave has difficulties recognizing a telegram because of deformed signals due to impedances effects or external noise, it does NOT mean that faulty data can get to the control system – AS-Interface is too well protected for this to occur. Instead, single telegrams are repeated (prolonging the individual cycle by only 150  $\mu$ s each). When occurring infrequently these repetitions are absolutely normal and harmless for the system. If several repetitions are unsuccessful the respective slave will be removed from the configuration until the master can resume communications with this slave. The master is required to report an error message at this point.
4. *100 m networks:* One of the sacred cows of AS-Interface is the demand for complete interoperability between all devices in the network. Regardless of its position in the network, the manufacturer of the counterpart, the number of devices in the network, and the network length, the receiver in each device must be able to clearly recognize even distorted voltage pulses in each telegram. This can only be guaranteed when strict requirements for device and network impedances are specified. For a device these requirements are enforced via the certification process. For the network this is accomplished by limiting the length to 100 m. Goal of these requirements is to guarantee the uninterrupted operation of each system according to its guidelines and thus assure the reliability of AS-Interface for the user. Hence, the classical 100 m network has proven to be successful in tens of thousands of installations.
5. *Control:* In many networks the rigid requirements for the system impedance lead to inherent reserves; reserves in the form of "under-utilized" repetitions. Today these reserves can be measured with simple accessories like Analyzers and Tuners. The innovative new aspect is that the frequency of repetitions is measured and evaluated. Thus, it is possible to carefully approach the actual limits of a system and to deal in a controlled way with deviations from the theoretical objective: a system free of repetitions. This is the foundation of network extension by 'tuning' the network impedance: 'controlled long distance'.

This solution cannot be used in the following two cases:

- Data of individual master (gateways) must be transmitted to the control system: Usually this is done by employing an upper level bus. In systems without an upper level bus or if the upper level bus cannot be used, this does not work. Examples for these systems are controller applications or applications without an upper level bus.
- Safety at Work applications are easiest to implement when the Safety Monitor and the AS-Interface safety slaves are on the same AS-Interface network. However, workarounds are possible.

### **Signal refreshing: The classical Repeater**

Another option is refreshing the network signals, provided that a receiver can recognize them. A Repeater is placed within the 100 m limit. It divides the network into two galvanic isolated segments, refreshes the data received at one segment, boosts them to the specified signal shape, and transmits the data on the second segment. An additional Repeater can be used at the end of the second segment to extend the network by another standard length of 100 m for a total of 300 m. The galvanic isolation into segments minimizes cable loss and achieves exceptional stability under conditions of extreme electromagnetic noise even in critical environments. (Even though AS-Interface has excellent noise immunity, there are limits! See 'Theory', 3)

Since each master expects the reply of the called slave during a specified time frame ( $T_{out}$ ) a combination of two daisy-chained Repeaters and a network length of 300 m present the operational limit for the classic Repeater. If the master does not receive a reply the communication is considered corrupted. Each Repeater delays the transmission of the master telegram and the slave reply by a certain small amount of time. Thus, daisy-chaining more than two classic Repeaters would exceed the allowed timeout  $T_{out}$ . However, it is permitted to use several parallel operating Repeaters configured in a star shape. This allows two-dimensional – not linear! – networks of over 300 m length.

Network extension using Repeaters leads to the situation where telegrams of all 31 (or 62, respectively) slaves are read by one master that therefore processes the data image of all inputs and outputs. In this case the use of a controller to pre-process data and control the process is possible. Safety at Work networks extending over several segments are also permitted.

### **Advanced Repeater**

The Advanced Repeater is the newest development in network extensions. The following two features differentiate the Advanced Repeater from the classic Repeater: Firstly, transmitter and receiver are further optimized and tuned to each other enabling the clear transmission and recognition of signals even in difficult situations. Secondly and most importantly is the minimization of the delay time of the signals when passing through the Repeater. While the classical Repeater delays each pair of telegrams by slightly less than 14  $\mu$ s, the Advanced Repeater only causes delays of 9  $\mu$ s. This seemingly small difference facilitated through a new concept enables the design of larger networks (see below).

(Detail: The classic Repeater uses approximately one positive voltage pulse to interpret a signal as an AS-Interface telegram and to transmit it to the next segment. The Advanced Repeater starts this process considerably earlier. Initially, this introduces the risk to misidentify noise as the beginning of a telegram. But the Advanced Repeater instantly uses the error detection mechanisms of AS-Interface to differentiate between telegrams and noise interference. If interference occurred, the transmission is interrupted immediately, enabling the next



*Fig. 2: By using the Advanced Repeater a total network length of up to 3 \* 300 m and 2 daisy-chained Repeaters can be realized.*

receiver to clearly recognize the transmitted pulses as defective. This way the accurate transmission of telegrams is guaranteed.)

**The alternative: Signal corrections**

The alternative to signal refreshing are corrections on the system impedance and thus on the signal shape. The rigid requirements for the system impedance (see 'Theory', 5) lead to reserves in most networks. Violations against the 100 m rule frequently happened consciously or unconsciously, without causing problems in individual cases. This action can be compared to 'blindly' crossing a border that was consciously set earlier. Since Analyzers and Tuners are available as simple diagnostic devices to monitor the communication quality of the network, these reserves can be used and the network can be 'tuned.' Consciously changing the system impedance and automatically controlling the result without compromising the safe operation of the system can achieve larger networks.

**Bus Terminator**

The Bus Terminator is a fixed impedance, primarily used to reduce reflections along the cable. Hence, the Bus Terminator is installed far away from the power supply. In many cases it is possible to expand the network to about 200 m if a Bus Terminator is employed.

**Tuner and Diagnostic Tuner**

When using the Tuner<sup>1</sup> the network impedance is individually optimized. In a learning phase the Tuner automatically varies its internal impedance over a large range while measuring which slaves can be reached at all and how many errors they produce. At the end of the learning phase the impedance value resulting in the lowest number of telegram repetitions is held. This value can be permanently saved for future reference. Additionally, testing results are displayed by using a 'traffic light' similar to the one used for the Analyzer: the red, yellow, and green LEDs signal the actual tolerance range of the system. Since the Tuner is usually installed permanently in the network, the monitoring process is active all the time. With the Tuner a controlled network extension of up to 300 m is possible.



Fig. 3: Diagnostic Tuner.

Any possible concerns by the user that the system could become unstable when the remaining reserves have been exhausted are addressed by the LEDs. Instead, the system becomes even safer because of the optimization of the impedance and the qualified monitoring of the communication.

The Diagnostic Tuner<sup>2</sup> automates monitoring even further: it is used as a slave sending the results of the continuous monitoring process to the master and control system. Here the application program can automatically react with countermeasures or requesting preventive maintenance.

1. AS-i XXL with the AS-i Tuner [http://www.bihl-wiedemann.de/englisch/press/articles/tuner\\_e.html](http://www.bihl-wiedemann.de/englisch/press/articles/tuner_e.html)  
 2. Tuner and diagnosis in one device. SPS Magazin, issue12, December 2005, p. 30-31

### Large networks: Alternatives

By using the devices described above a greater variety of techniques for large networks extensions, in addition to dividing the network into sub-networks as explained in the beginning, is available. In many cases network extensions using these components have economical and technical advantages, as long as the following two requirements are observed:

- Generally, in critical environments short networks are less prone to interferences than longer networks. This holds true for AS-Interface also, but is rarely of any consequence because of its low susceptibility to interferences. Dividing the network into galvanically isolated sub-networks or segments (utilizing Repeaters) usually are of theoretical advantage only, but should still be considered.
- If a system has a cable length of over 100 m the safe range as described in the original specifications is exceeded. In general, using the tools described above makes this possible without endangering the system. But this should be verified since this control action represents the key to all network extensions (possibly with the exception of pure Repeater networks). Hence, it is strongly recommended to either continuously monitor the system with a Tuner or to selectively examine the system with an Analyser<sup>3</sup> during its installation. Both control techniques prevent 'surprises' from happening ('controlled long distance' see 'Theory', 5).

Observing these guidelines allows the unproblematic transition to larger networks. Bus Terminators, Tuners, Repeaters, and Advanced Repeaters can be combined. The details of the system define the optimum configuration. Figure 4 lists the most important criteria:

- Total length
- Segment length
- Position and protection class of master, power supply, extender, and Repeater
- Power consumption of the slave
- Costs

Fig. 4: Criteria for selecting a configuration

*Total and segment length* are the basic data for every system (see fig. 5-9 below). While designing a network it must be remembered that the possible length for a network using Bus Terminator and Tuner are given as 'up to'-values: for instance 'up to 200 m' or 'up to 300 m'. For most networks these values are correct. But there are cases where a Tuner must replace a Bus Terminator before reaching the 200 m mark and where a (Advanced) Repeater must replace a Tuner before getting to 300 m. This is the logical conclusion when the true limits of the system are approached in a safe and unproblematic fashion. The limits now depend on the details of the specific network (see 'Theory', 5).

*Selection and placement* depend on the protection class and position of the components: power supplies usually offer protection class IP20 and need to be installed in a cabinet or junction box. Masters and Repeaters are offered in both protection classes. When installed close to the power supply, IP20 devices lend themselves to mounting in a single junction box. While master and power supply can be freely placed, Bus Terminator and Tuner must be positioned far from the power supply, possibly at a distant branch of the network. Hence, Bus Terminator and Tuner are always constructed to meet protection class IP65.

To minimize cable losses when individual *high current consumption* slaves are used it may be necessary to connect the power supply in close proximity to the slave. This can lead to the separation of master and power supply.

3. AS-Interface Analyser: Fieldbus diagnosis for all cases. SPS Magazin, issue 5+6, May 2005, p. 32-34

The costs for different configurations depend on the selected devices, the design, and the protection measures for the devices. They can vary considerably even for similar network lengths. Costs are discussed in the following chapter.

**Typical cases**

**Networks with a length of up to approximately 200 m**

If the 100 m standard network (fig. 1) is exceeded four alternatives can be suggested: splitting into sub-networks (fig.5), Repeater (fig. 6), Bus Terminator (fig. 7), or using a Tuner. The standard solution, as described above, is splitting the network into 2 sub-networks employing a Double Master (in the middle of the application) or using two separately installed single masters.

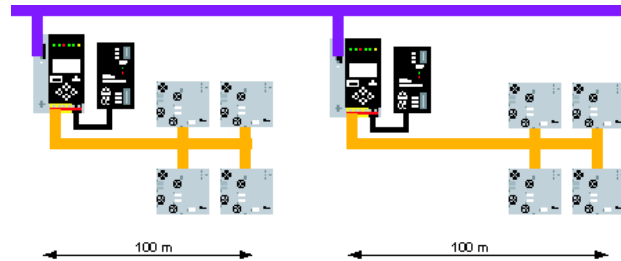


Fig. 5: Splitting into sub-networks

Bus Terminators result in the lowest device costs. It only costs about 8 % of an additional gateway with power supply or 15 % of a Tuner or a combination of Repeater and power supply, respectively. In this case the network should be examined with an Analyzer during the start-up phase. If a Tuner or an Advanced Tuner is employed this examination is performed constantly.

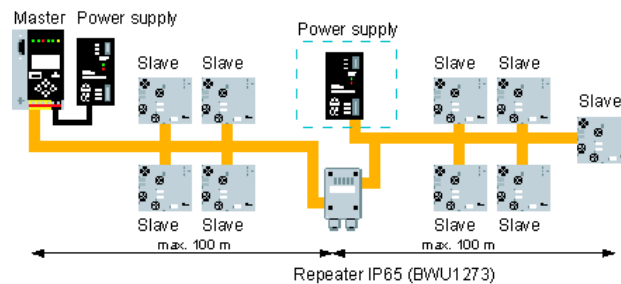
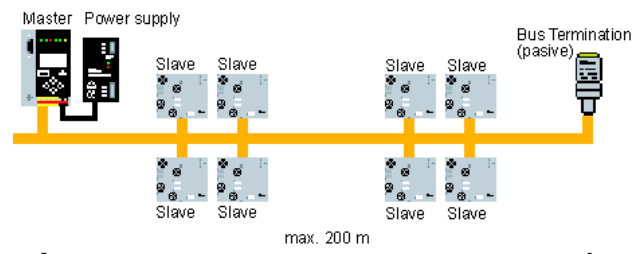


Fig. 6: Signal refreshing with classic repeater

A design with Repeater is only suggested in the following two cases: either if the network runs through an environment with extreme EMC conditions or if users with high current consumption are placed in the first and second segment.



**Networks with a length of up to about 300 m**

The same considerations apply to networks up to about 300 m with the only difference that instead of a Bus Terminator a Tuner or two Repeaters with additional power supplies must always be used. A solution using a Tuner costs about 50 % of the design with a Repeater. A solution '1 Repeater plus 1 Bus Terminator' is possible with the disadvantage, that the continuous monitoring of the network is then omitted.

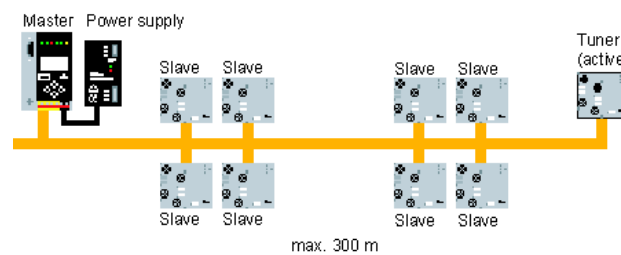


Fig. 7: Signal correction with bus termination (up to 200 m) or with tuner (up to 300 m)

**Networks with a length of more than 300 m**

To span a network of more than 300 m at least 1 Repeater and an additional power supply as well as a Tuner or Bus Terminator or one additional Repeater, depending on the length of the system, is necessary.

**Getting AS-Interface ready for the long distance**

*Automatisierungstechnik*

More than two daisy-chained classical Repeaters or three 300 m segments separated by two classical Repeaters are not permitted. Signal delay times in the Repeater and in the extended segment exceed the permitted time-out duration between master call and slave response at the location of the master (see above). By using the classical Repeater the network extension cannot exceed 600 m.

**Networks of more than 300 m with Advanced Repeater**

This is the primary field of operation for the Advanced Repeater. Its delay times are short enough to permit the design of three 300 m networks with two Advanced Repeaters. This is also applicable for Safety at Work applications: In this case the resulting delay times of less than 60 µs are short compared to the guaranteed Safety-at-Work response time of 40 ms.

This makes AS-Interface a genuine long distance network. Fig. 9 shows an extended network of up to 1500 m linear extension (using Tuners) that can be further expanded as a two-dimensional network if star shaped branches are added. One specific feature must be observed for the start-up of such a system: During the teaching process each Tuner can only affect its own segment but evaluates the information of all slaves. Consequently, this may necessitate starting up the network segment by segment.

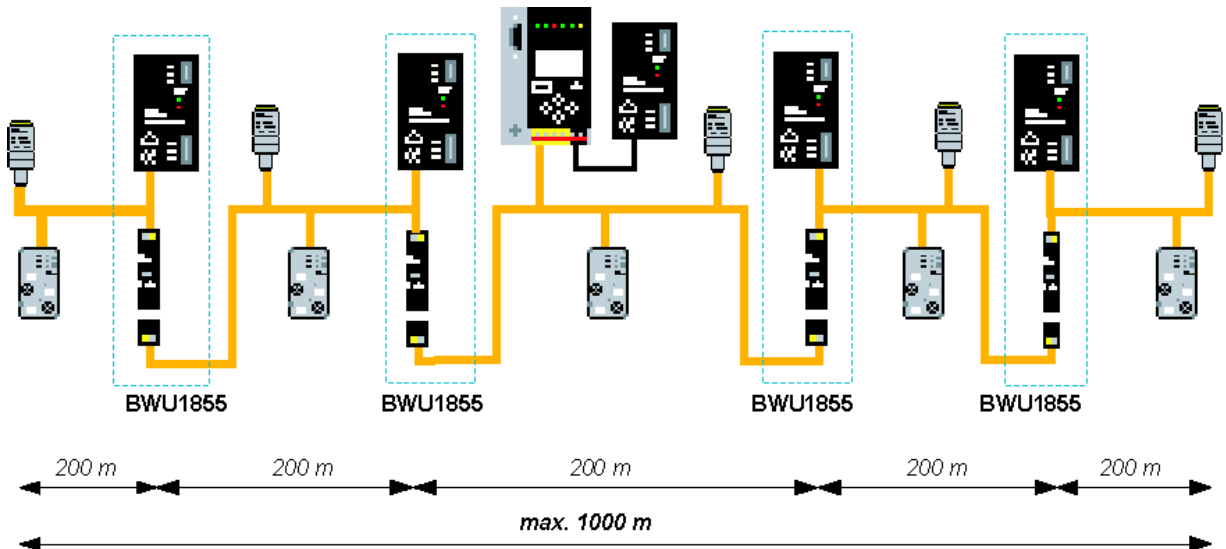


Fig. 8: Large network with two double daisy-chained Advanced Repeaters and Bus Terminations.

Final remarks: In spite of the original length limitation of 100 m for AS-Interface, today a network extension by more than one order of magnitude is easily possible with thorough planning. This includes monitoring the communication quality to obtain the number of telegram repetitions. Is this number sufficiently low ('green' LED light on Tuner and Analyzer) there is no reason to refrain from using large, extended AS-Interface networks, for instance for conveyor applications and in plant construction.