Foundation Fieldbus End Users Council Australia Inc.

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# OPEN ARCHITECTURE PHYSICAL LAYER DIAGNOSTICS SPEED INSTALLATION AND REDUCE DOWNTIME

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**Hand-held test tools have been used routinely on the world's major fieldbus installations to speed the installation process by diagnosing wiring errors prior to start-up. In response to end-user feedback, recent enhancements have delivered better features such as noise measurement in multiple frequency bands and the ability to store field measurements before downloading them in the maintenance shop. Now, with the advent of continuous, on-line monitoring of the fieldbus physical layer, diagnostic information can be integrated into the asset and alarm management environments of today's fieldbus control systems. The paper will describe how the use of Foundation fieldbus as the protocol for communicating diagnostic information delivers an open architecture that is independent of control system choice. The key benefits of physical layer diagnostics will be explained, such as the ability to detect deterioration of segment performance before it affects the process, and improved use of maintenance resources during commissioning, hand-over and long-term operation.**

**Keywords: Physical Layer; Diagnostics; Hand-held tools; Monitoring**

# 1. Diagnostics drive fieldbus growth

One of the driving forces behind the rapid growth of FOUNDATION™ fieldbus has been the availability of the digital network to transmit high quality diagnostic information, alongside the input and output variables required for control. Users have therefore been able to reduce life-cycle costs by replacing scheduled maintenance programmes with activities that are in response to diagnostic information provided by the field instruments. By providing key parameters, the instruments indicate if and when re-calibration or repair will be necessary. This ‘predictive’ regime reduces the number of unnecessary visits to the field and reduces trouble-shooting time.

## *1.1. The fieldbus physical layer*

However, the overall health of a fieldbus network depends not only on the measuring instruments and output devices, but also on the electrical network that interconnects them. In Foundation Fieldbus terms, this network is described as the ‘physical layer’, being one of the seven layers that are defined in the OSI model for digital networks. For H1 systems operating at 31.25 kbits/s over wire medium, the physical layer components include the conditioned fieldbus power supply, the wiring ‘hub’ that provides a means of connecting fieldbus devices to the bus, and the cable itself. Figure 1 illustrates a typical fieldbus segment, constructed according to the ‘chicken foot’ topology that is commonly adopted.

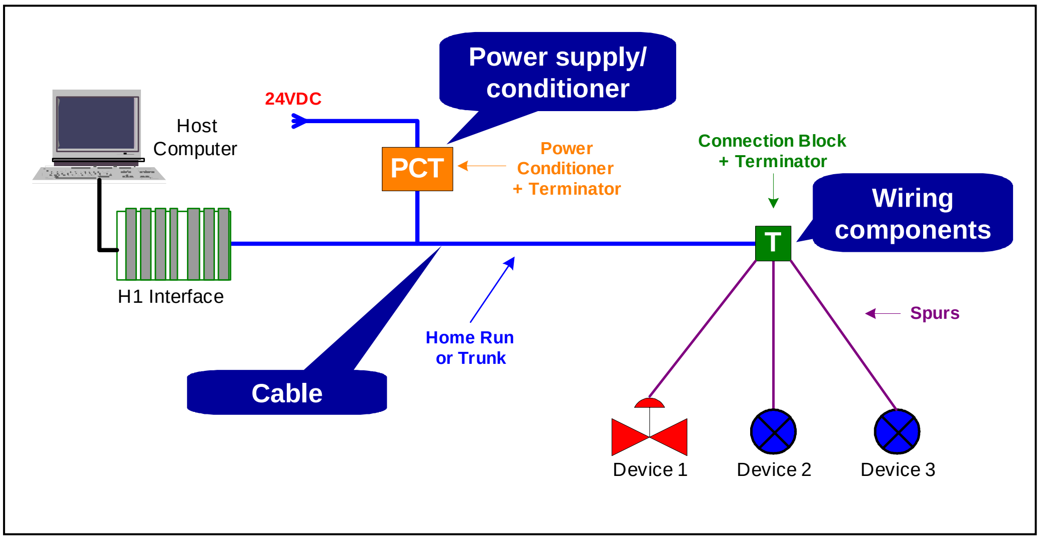


Fig 1. The Fieldbus Physical Layer

## *1.2. Designing for reliability*

The design of an H1 fieldbus segment should take into account the possible failure modes that can affect its availability. For example, if high reliability is required, the conditioned power supply may be of a redundant format such that any single point of failure in the source of power will not remove power from the entire bus. In addition, some form of protection is normally included in the wiring hub to prevent the network from failing in the event of short-circuits in the spur wiring. But even with these precautions in place, the physical layer is still vulnerable to faults that can affect its reliability and ultimately cause failure if undetected.

## 2. What can go wrong?

Physical layer faults can be divided into two main categories: those that result from inadequate materials or poor installation practice, and those that occur during operation.

The long-term reliability of a fieldbus system is heavily influenced by the quality of the initial installation and the choice of components. Faults that commonly occur at this stage are:

- Wiring errors, including wrong connections, open or short circuits, intermittent connections and reversed polarity
- Too many or too few terminators on each segment
- Faulty 'out of the box' physical layer components or fieldbus instruments
- Inadequate grounding, such as multiple grounds in field, or the absence of any clear grounding strategy

The lack of proper training for installation personnel can result in poor workmanship, especially if they have no previous experience of fieldbus systems. For example, are the ferrules that are used for wire termination compatible with the cable cross-sectional area, and with the screw terminal entries? Is the ferrule crimp tool properly specified? Are the screw terminals adequately tightened with a suitable torque screwdriver? Are proper conventions followed for signal polarity and grounding practice? Failure to address these issues can result in an unreliable installation.

Once the faults that occurred during the installation stage have been eliminated and the bus is operational, other factors contribute to its reliability:

- Environmental damage, such as water ingress, corrosion, exposure to light and vibration
- Manually inflicted damage
- Surge damage resulting from lightning or on-site welding
- Electrical noise, due to faulty or improperly grounded electrical apparatus
- In-service failure of physical layer components or fieldbus devices

## 3. Periodic monitoring

To date, the detection of faults in fieldbus networks has been assisted by the use of hand-held test equipment that is specifically designed to measure the parameters of a functioning bus. These devices can provide much more information than a simple multi-meter, such as:

- Short-circuits between the fieldbus + or – and the cable shield

- The signal level of each participant on the bus. A minimum level is specified by Foundation fieldbus specifications. Low or high levels on all devices suggest incorrect bus termination, but if the faulty signal level is only on one device, there is possibly a problem on a single spur
- DC voltage on the bus, indicating correct functioning of power supply/conditioner.
- Noise: A maximum level is specified by Fieldbus specification
- Retransmissions. This provides a good measurement of physical layer health; re-tries can obscure faulty device or network

These features are particularly suitable for diagnosing the installation errors already described, but the usefulness of hand-held devices continues throughout the life of an installation. Maintenance may then take the form of periodic measurements, but use of such tools is more likely to be in response to suspected network faults.

Note that the measured parameters are carefully chosen to provide information that is both easy to understand and actionable. The interpretation of results should not require extensive training or expert knowledge. The use of built-in thresholds to provide ‘Good/Bad’ status is particularly useful.

## 4. Further enhancements

In response to requests from users, more recent designs have incorporated additional features, such as the measurement of noise in multiple frequency bands (to assist in tracing its source), and the ability to store sets of measurements in the field for subsequent ‘upload’ to an Excel™ spreadsheet on a computer in the control room or maintenance shop (Figure 2). Proprietary spreadsheet commands may then be used to manipulate the data, such as graphical trending of consecutive sets of readings. In addition to providing a convenient way to store and archive the network diagnostic data, this tool goes some way to providing a similar capability to the integrated diagnostics that are available for fieldbus instruments within the control system.

Figure 2: Typical hand-held fieldbus monitor

## 5. Continuous monitoring

A logical progression from periodic monitoring using a portable device is some form of permanently-connected diagnostic monitor. This has the potential to align the quality and accessibility of physical layer diagnostics with those of the fieldbus instruments. A logical place for the diagnostic monitor to reside is at the fieldbus power supply, because a single unit can then have access to a number of separate segments, thereby spreading the cost of the monitoring hardware. If the monitor is able to perform the same measurements as a typical hand-held device, then it will be able to build a constantly updated database of parameters for a number of fieldbus segments. This will be available for analysis without the labour overhead associated with manual measurements, and - more importantly - supervisory software can automatically analyse the harvested data and trigger alarms if key parameters go beyond pre-defined limits.

A key consideration of any permanent monitor is how it is to report its measurements to the fieldbus host control system. One solution suggests itself, which is to make the monitor a fieldbus device, so that it can be a participant on one of the segments that it is monitoring. The possible objection that access to the diagnostic information will be lost if the reporting segment fails altogether is not a serious drawback, since this would require a catastrophic and unlikely event such as a trunk short-circuit or coincident loss of both redundant power supplies.

A typical arrangement for a diagnostic module capable of monitoring eight fieldbus segments is shown in Figure 3. Since the module is itself a fieldbus device, it is essentially an ‘open’ solution that does not require any additional communication network or integration into the host control system.

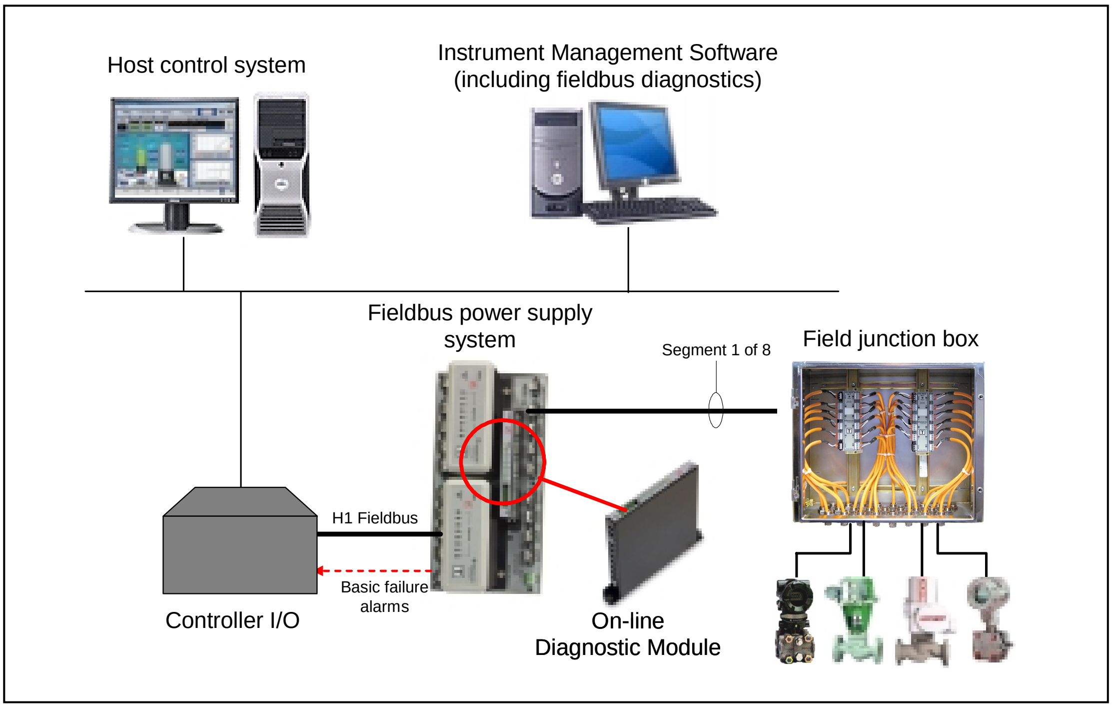


Figure 3: Permanently-installed diagnostic module

A further advantage of this approach is that the physical layer diagnostic information has access to the control system's own features, such as historian and trending software. Fieldbus Device Type Managers (DTMs) and Enhanced Device Description Language (eDDL) can also be written to provide enhanced graphical interfaces.

## 6. References

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