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Converting from Analogue to Fieldbus — The Latest Upgrade

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Abstract

This paper will describe the processes involved, engineering through commissioning, associated with migrating a conventional control system to one using Foundation Fieldbus. Topics to be covered include device selection, documentation, engineering, commissioning, and post project support. The author will share his experience from a completed project of this type.

Why Convert?

There are at least as many reasons to convert an existing analogue field device to Fieldbus, as there are reasons to convert to Fieldbus in the first place. This paper will only highlight a few of the more common reasons a person may want to consider replacing an otherwise ‘perfectly good’ device, including an already “smart” transmitter with a Fieldbus version.

Cable Savings

How many of older plants are finding that they do not have sufficient spare wires in their facility?

How many projects or operations requests have had to be ‘cancelled’ because it would cost too much to install the necessary increase in infrastructure represented by lack of cable capacity?

Is your facility like most plants, discovering that the first place to run out of these spares is in the most remote part of the plant?

Fieldbus is the answer to these questions. Fieldbus is the only standard multiplexer available on the market. By converting from analogue to Fieldbus, a person can 'automatically' at least triple the number of signals on existing cables in a facility, and if the facility does not use Intrinsic Safety (I.S.) circuits, this factor is even better, closer to a six-fold increase in signal capacity.

Never mind the "old" wiring savings stories associated with Fieldbus, this represents real savings, since for a grass roots facility, the project will be installing cables anyway. Everyone knows that at least 75 — 80 percent of cable installation costs are related to labour and cable tray, the cable itself is only a fraction of the cost. Therefore, if you have an existing facility that needs new cable and this "new" cable can be found without the associated labour costs, management will quickly see the economics, even if they are not engineers.

Information

Due to their all-digital design, fieldbus systems are capable of providing an abundance of information between the field and central computer system(s). Some of the information that is of most importance includes:

Device diagnostics — All fieldbus devices contain diagnostic information, The various 'flavours' of fieldbus do this to varying degrees. But all of them due to their bi-directional communications have some form of diagnostics. Foundation Fieldbus, which uses the Device Description (DD) language similar to that used by HART,[a] is much richer in its information content. It can therefore assist the user in diagnosing and in many cases remedying the problem remotely over the network.

HART has two levels of AMS support. Generic devices allow users to: read universal commands (such as manufacturer, model and revision) and read and write common practice commands (such as range and units). The generic DD does not allow access to device specific commands, such as material of construction. To obtain full HART support one must ensure they have an 'AMS –aware' device.[1]

Device status — Again, due to their bi-directional communication, fieldbus systems provide information to the host system about their operational condition. Foundation Fieldbus, integrates this seamlessly into the host system and provides status information, typically Good, (MAN (manual) and AUTO (automatic)), or bad (O/S (out of service)). This alone is justification to use a fieldbus system since it is now possible to inform panel operators, in real time, whether the signal being used for control is actually valid or requires work by an instrument technician. This same status information can be used to insure that any applications controlling the process only use valid data to make changes to the operation.

and

Remote calibration — Fieldbus has the ability to remotely change the range and calibration of a device, without requiring a maintenance technician to remove it from service and bring it into the shop. Experience has in fact shown that in most cases, removing a digital

[a] Highway Addressable Remote Transducer

transmitter and calibrating it on a shop bench actually decreases its accuracy versus the original factory settings.

Foundation Fieldbus devices also have the following capabilities:

Field based control — Foundation Fieldbus is capable of migrating regulatory control from the host system to the field devices themselves. There are some ‘restrictions’ necessary to implement this feature but they are fairly simple and not much different than the industry is used to applying from its beginnings in the days of pneumatic loops.

This means Fieldbus provides a means to achieve control and diagnostics at the lowest level, which represents a return to single loop integrity.

“Plug and Play” configuration — The Device Description and Capabilities Files which come with every Fieldbus certified device insure that when a device is added to a Fieldbus network, it will be ‘automatically’ recognised and visible on the host /configuration system. There is no need to set dipswitches or other mechanical settings to install a new device on the network, while the network is operating. In many cases, all that will be required is to rename the device with its actual system tag name so the operators can associate it with the service to which it is applied.

Foundation Fieldbus through its certification and testing programs insures truly interoperable devices from diverse manufacturers.

Function Blocks — These blocks of memory in the device, determine it characteristics and since they are memory based, they can be configured and updated as additional features are defined for the device.

and

High Speed Ethernet (HSE) connection — Fieldbus is introducing devices this year that will enable integration of the H1 31.25 kbit/second network into an Ethernet based High Speed network. This network called HSE, operates at 100 Mbit/sec using commercial off the shelf technology to connect ‘best in class’ devices for each layer of a corporation’s computer environments.

Integrated System

As just mentioned, H1 and HSE, together offer an integrated environment from the plant floor to the data historian layer of the enterprise. In addition, since HSE is based on standard Ethernet products and protocols, it will also integrate well with the corporate information layer, which also typically uses an Ethernet backbone. Installing a data server on the HSE network provides a low overhead method of integrating all plant information with minimal equipment and overhead.

H1 and HSE also have plug and play interoperability making it possible to control processes over extended distances without intervention of a central control (host) system.

Host Loading

Foundation Fieldbus supports regulatory control in the field, which means that the computing resources used by the host system to perform this task can be reallocated to another use such as advanced, multivariable, or optimisation control.

As an alternate, Fieldbus can also be configured for bumpless transfer of control to or from the host system or another device on the segment in the event of a failure on the network. This increases system reliability by reducing the potential for a single point of failure causing an entire plant to ‘crash.’

Experience

Installing a “small scale” Foundation Fieldbus system of only a few loops ‘at the end of the line’ and if desired for indication only tags, will also provide a facility with experience on Fieldbus in a non-critical application. The lessons learned from this first installation, and the associated opportunity for all site personnel to become familiar with the technology will then make it easier to install additional systems in the future.

The experience in almost every facility to date that has installed a Foundation Fieldbus system is that within a short period of time, they are “back for more.” It seems the hardest part of the process is getting the first project approved and operating.

The above has presented some of the reasons why to install Fieldbus and how to justify doing so, now comes the fun part — how to do it?

How do I convert?

As with any engineered project, a sequence of steps and activities must be performed to ensure success. Since this is a conversion project, and thus will use existing infrastructure, it is vitally important that the quality and integrity of that infrastructure be confirmed prior to proceeding too far along the project path. The major components that need to be checked, are the cable and device.

Device Selection

Not all manufacturers support conversion of their devices without complete device change out so be sure to ask the supplier of the device already installed in the field if it is possible to convert the ‘electronics end’ of the device only. Each of the manufacturers that support this change has different requirements.

Rosemount (Emerson Process Management) require the changing of the electronics communication card and that the device be no older than mid-1999, so be sure to check the serial number. When going this route, it will also be necessary to check with the local electrical approval authorities, since changing the electronics can also result in a change in approval. Therefore, unless a certified and trained professional does the conversion the device will no longer be approved for service.

Yokogawa Corporation changes the entire electronics, including the housing, though the sensor remains in place. This allows them to match the electronics to the device, rather than just the communications, resulting in tighter integration of the transducer and output signal.

Other manufacturers have different processes, but the author is not familiar with all of them.

If your present device supplier does not support an upgrade path, it will be necessary to either purchase a new device, or connect it to a current to Fieldbus converter.

Cable Testing

Foundation Fieldbus has as part of their standards conservative estimates on lengths of cables for various configurations and cable types. It is therefore important that the cable being proposed for conversion be tested using networking tools from Relcom Inc.

Two devices are used in together when testing a signal cable, a signal generator – the FBT-5, Fieldbus Wiring Validator, and the FBT-3 Fieldbus Network Monitor. The cable under test **MUST** have the terminators already installed at **BOTH** ends of the cable prior to starting the test. The FBT-5 is connected to the wire pair at one end, and the FBT-3 can then be used to confirm there is sufficient voltage, signal level, and continuity (no shorts) as well as confirmation that the noise level is below a certain threshold. Full information on the required operational levels is contained in the documentation that comes with the validator and monitor.

It is unlikely that if a conventional analogue device is functioning properly, that the same cable will not work for a Fieldbus installation but the above tests MUST be done. Assuming the cable test passes, it is time to start the engineering process proper.

Documentation

There are a number of different requirements for documentation associated with a Fieldbus installation. Despite the fact these changes are minor, they are important.

One change is related to the traditional loop diagram, and the other is with the device data sheet.

Data sheets need to be updated to capture the information associated with the additional fieldbus parameters of a device. This includes information such as function blocks present and used, power requirements, capacitance, if the device is polarity sensitive or not, and software / firmware revision information.

The traditional loop diagram, which represents the flow of current through the instrument loop from the host system to the device and back again, in the Fieldbus environment is replaced with a network diagram. Figure 1, shows the differences between a loop diagram and network diagram. Fieldbus is a parallel network, so though it is not technically accurate, a network diagram continues represent the flow of current between the host and the devices it powers. Figure 1 is simply a representation of a typical loop and therefore does not show items such as Intrinsically Safe (IS) barriers or Marshalling Cabinets.

Notice the main differences between the two systems.

- Multiple devices on a single pair of wires from the field junction box to the host system signal conditioner
- Terminator (shown in grey) at the field end of the ‘home run’ cable. A similar terminator is required at the host end and is not shown, as it is often part of the host signal conditioning termination assembly.[b]

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[b] Power Supply is not shown for clarity, but it too is often contained within the host signal conditioning system.

- Potential for significantly fewer terminations, and certainly reduced ‘real estate’ in the host rack room.

Engineering

There are a number of design differences in the communications aspects of a Fieldbus system versus that of a conventional analogue system and many papers have been presented on this topic already, so this one will merely summarise the issues that need to be considered.

The Fieldbus network design items required are:

- Network topology — Spur, Star (also known as Chicken foot or Tree), Daisy Chain (not recommended), or a combination of the above. Remember in order to implement control in the field and have the desired single loop integrity, all the devices for the control loop must be on the same segment.
- Number of devices per network — This is a function of network length as well as the power requirement for each device on the network, so the design process can be iterative. A good conservative rule of thumb is to use 15—20 mA/device for a transmitter (temperatures are normally less than 15 mA) and 20—25 mA for each valve.
- Network length calculations — Verify total network length does not exceed the limits defined in the Fieldbus standard.
- Voltage calculations — Confirm sufficient power will be available to all devices. The Fieldbus specification states that a device should continue to operate with a 9 volt supply, but it is better to err on the safe side and design for 12 volts to allow room for either additional capacity or power inrush currents at device start-up.
- Capacitance calculations — Provide an indication of how susceptible the system will be to attenuation errors.
- Bandwidth calculations — Another iterative process, in which the designer must balance the cycle time or how fast the loop responds, against the number of devices the host can support during that same period.
- Virtual Communications Resources — This is normally a non-issue, but some host systems and devices have insufficient memory to maintain a large enough “buffer” to “map” the registers needed for communications across the network. Newer devices no longer have this ‘problem’ but for completeness, it is better that it be checked.

It is critical to remember, despite the fact that Fieldbus offers a significant number of enhancements to the information available via the host system, the sensor/transducer technologies used to make the actual measurement are unchanged from today. Therefore, instrumentation and control engineers will continue to need to develop, use and apply their skills and knowledge to properly specify the correct instrument for the measurement required, **AND** be sure it is installed properly. Just like today.

Commissioning

The commissioning process for the Fieldbus devices is relatively straightforward. What follows is a generic description of the process since it may deviate slightly for each host system.

1. Load the Device Description (DD) and Capabilities File (CFF) on the host system, verifying the revision numbers is the same for the software on the host and the firmware in the device.[c]
2. Confirm the network parameters in the host, especially the slot time, Minimum Inter PDU delay (≥ 12), and Maximum Response Delay.
3. Use the host system configuration tools and complete the network configuration. This step is host specific but determines how each element on the network interacts with each other. It is during this step that items such as:
   - Link Active Scheduler placement is determined. The default is normally to have the Master in the host system and the Backup in the least 'loaded' device.
   - Control — will control be done "in the field" or remain in the host?
   - Cycle Time — how fast will the "loop" be 'polled'? It is recommended that 70% of each cycle be left unscheduled (Acyclic) for sharing of non-process data across the network.
4. Connect the devices to the network. They should appear on the configuration screen "live list" almost as soon as power is applied and then a few minutes later, once full communications and the associated 'hand shakes' have been established the system will be operational.

What happens if the devices do not appear on the "live list"?

1. Check the wiring (all this can be done with a traditional Multimeter)
   - Verify proper terminal connections
   - Check the voltage at the terminals of the device(s)
   - Verify the device current draw against the manufacturer's specifications
   - Verify there are no shorts in the network and that the shield is grounded only once.
2. Verify the network parameters are the "largest' of the ones specified by the combination of vendors. For example, if one manufacture specifies a slot time of 8 and another requires 10, ensure the slot time is set for 10.
3. Verify the software revisions are the same in the device as the host.
4. Block Errors
   - Configuration error — verify the proper Ltype, Channel and XDScale are being used and the units for the XDScale are correct.
   - Confirm the network schedule (item 3 above) has been downloaded.
   - Verify that the Resource and Transducer blocks are in "Auto"

What happens now that Fieldbus is operational?

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[c] Device Description files for all ITK certified devices are available from the Foundation Fieldbus web site at www.fieldbus.org

Post Project Support

One word best describes what must happen now — Education. Process technicians, maintenance technicians, engineers, and managers will be watching this ‘new technology’ like the proverbial hawk. If anything different than what happened in the past occurs, the culprit will be sure to be the new fieldbus stuff, even if the fieldbus stuff is doing what it is supposed to be doing. For example, should a device fail, and an alarm be propagated to the host system, and the process or maintenance technicians are unaware that diagnostics and status information are now part of what they can expect, be prepared to do lots of explaining. It is always easier to prepare people before something happens than explain it later.

Along the same lines, it may be a good idea to install a Fieldbus “mini-system” so technicians and engineers have a place to maintain their skills with the technology. Today’s control system components are so reliable, that they rarely require servicing, so all the more reason to have a place to maintain skills for when they are needed.

Can I convert?

Provided you meet the conditions for the devices listed above, and your device supplier supports an on-line conversion, moving to Fieldbus can be done today. In fact, the author has done this with a number of devices in his facility over a year ago and hopes to convert more devices this same way in the future.

If, on the other hand, your present device and host suppliers do not fully support Fieldbus and device migration there are alternatives.

The most obvious alternative is to change out the device for one from another manufacturer. The only difficulty here is that not all devices are interchangeable. Fieldbus makes devices interoperable and interchangeable electronically, but not all devices have the same process connection dimensions. ISA, the Instrumentation, Systems and Automation Society has a Standards Committee in the process of addressing this need. ISA S-97 hopes to issue a draft standard for face-to-face dimensions of vortex meters in early 2002. The IEC already has a standard for magnetic flow meters, and fortunately, pressure transmitters already meet a de facto standard of 58 mm.

The second method is to use a pair of devices available from Smar International. Smar have developed a current to Fieldbus (I/F) and Fieldbus to current (F/I) converter. Figure 1 shows how they might be used with a Fieldbus host system while Figure 2 shows how they could be used as a multiplexer/de-multiplexer pair on a non-Fieldbus system. The current to Fieldbus converter is the model IF132 and FF to current device is model FI302.

Are there conditions?

As alluded to above, there are a number of conditions associated with a successful Fieldbus conversion. To repeat some of the key conditions are:

- Not all suppliers have a path that provides an upgrade of field devices on line so the conversion may require planning to either coincide with a plant outage opportunity, or a second device must be installed in parallel on an alternate process connection.
- If installed host system does not support fieldbus then the options shown in Figure 2 are possible

    - Use a multiplexer /de-multiplexer combination in the field and at the host or central control system.
    - Use a complete Fieldbus system and then connect from it to the existing control system using some alternate protocol such as High Speed Ethernet (HSE) to a server compatible with the control system and its Ethernet network ports.
- The infrastructure must meet the Fieldbus design conditions for the Physical Layer.

Another feature that the host system should have to support the migration to Fieldbus, is incremental back build. This allows the addition or removal of a device from the network without having to reload the entire segment or network. Loading normally requires that all the devices on that portion of the network be "off line" and hence in manual, for in some cases up to 20-30 minutes, depending on the complexity of the network. Incremental back build is done during the acyclic times and only affects the device being changed.

Conversion Complete?

Fieldbus is becoming the standard control network protocol. It is only a matter of time. As Dick Caro, Vice President, Automation Research Corporation has stated, "For Profibus-PA, the experience in savings has been very positive and this is the third year of a five year acceptance cycle. For Foundation Fieldbus, this is only the second year of that same five year cycle."

Now that you have seen how easy it is. Are you ready to convert?

Bibliography

[1] "Open Communications essential for successful asset management" James Masterson, www.thehartbook.com/articles/h8ams.asp

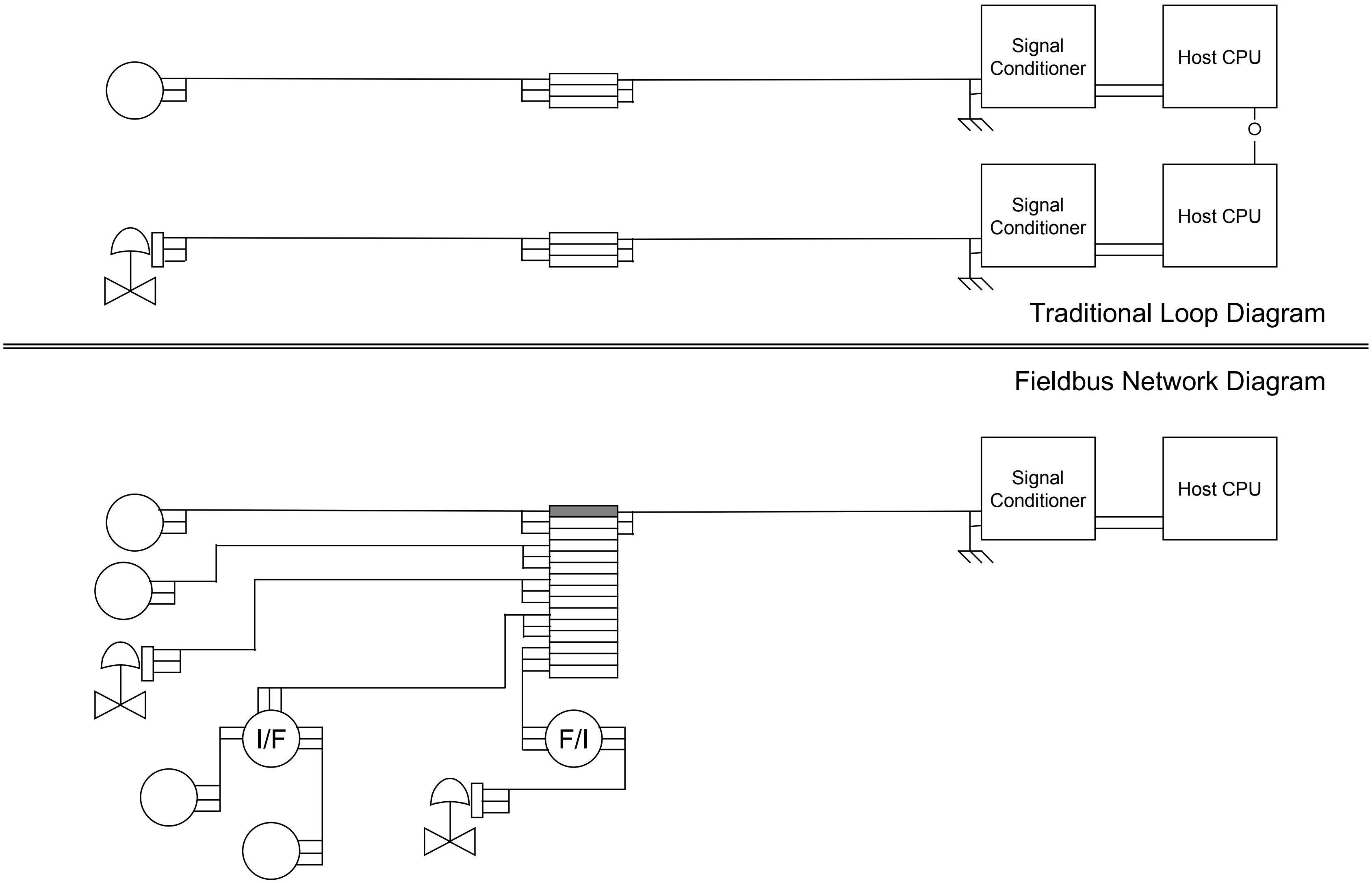

Figure 1: Loop versus Segment Diagram comparison

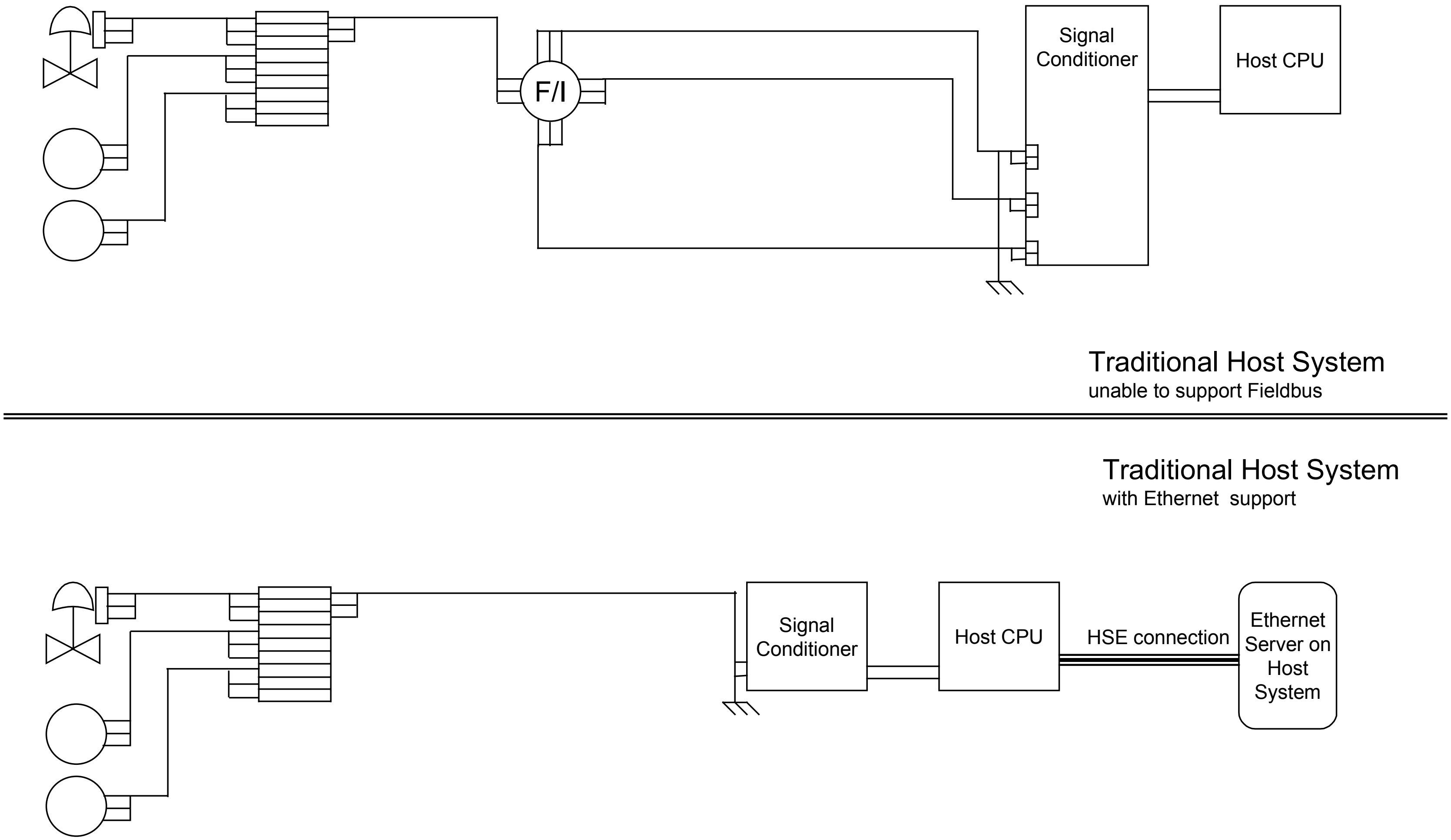

Figure 2: Installation Options for Hosts without Fieldbus Support