Development of Optical Fieldbus Systems

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1. Introduction

In the areas of such fundamental materials as oil and chemical fields, the search for world-wide innovation and high added value products has risen year by year, driven by intense international competition.

As a result, highly functional flexible and inexpensive systems have become expected through the use of open technologies such as instrumentation control and information systems. Fieldbus system is expected as one of the solution to these issues.

Fuji Electric has aggressively developed open systems in the field of instrumentation control and promoted the establishment of international standards. Optical fieldbus physical layer specification was decided as IEC international standard in November 1996.

To establish a international standard for fieldbus systems, the Fieldbus Foundation was founded in September 1994 and has more than 100 enterprises world-wide. As a director of the Fieldbus Foundation, from the beginning Fuji Electric has been working on certain specifications, hardware development, promoting increased usage, and public relations.

The Fieldbus Foundation tested the communication protocol for a low-speed fieldbus and completed final specifications in January and June 1996 respectively in the USA. Fuji Electric has started the fiber optic fieldbus working group, and now the results of the working was finalized as final specification in the Fieldbus Foundation.

This paper describes the specifications and features of Fuji Electric's fieldbus system that satisfies both the IEC standard and specifications of the Fieldbus Foundation.

2. Outline and Configuration of the Optical Fieldbus System

2.1 Outline of the optical fieldbus system

The fieldbus replaces the conventional analog current signal (4 to 20 mA) with digital communication that connects each field device and control device that make up an instrumentation and control system. The optical fieldbus uses optical fibers to transfer the fieldbus signal, and therefore has excellent transfer characteristics such as anti-noise and stable operation.

The standard physical layer of the optical fieldbus has been introduced in IEC 1158-2 Optical Medium (clause 15 to 18) and the host layer has been introduced in the Fieldbus Foundation specifications (same as for the electric fieldbus).

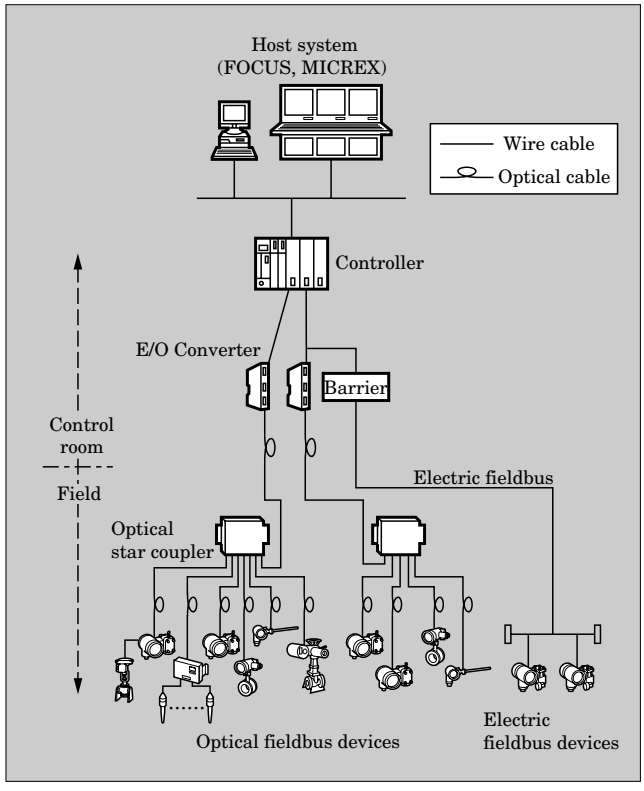
2.2 Configuration of the optical fieldbus system

The optical fieldbus system is composed of 4 main devices: field devices such as a sensor and actuator, an optical star coupler, an E/O converter and a host system. These are connected to an optical fiber or electric cable. Figure 1 shows the system configuration.

2.2.1 Field devices

Field device of the optical fieldbus include optical

Fig.1 Configuration of optical fieldbus system



parts known as “optical units” in addition to ordinary sensors and actuators.

An optical unit has a monolithic construction and consists of an LED, a photo diode and an optical connector for transferring and detecting receipt of the optical signal. Bidirectional communication is possible with one optical fiber.

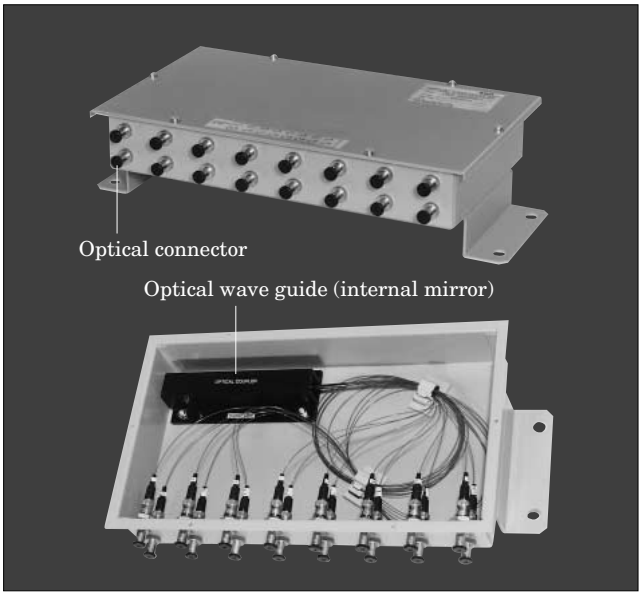
Most of the power sources for field devices are built-in lithium batteries. As a result, since a external power line is unnecessary for each device, the field devices are insulated.

2.2.2 Optical star coupler

An optical star coupler is an optical device used in the field without power. The role of the optical star coupler is to transfer multi-channeled signals from each device to the host device through one optical fiber, and on the other hand, to distribute signals from the host device to the field devices. Figure 2 shows the external and internal construction of the optical star coupler.

The optical star coupler has 16 optical connectors and it can connect a maximum of 16 field or host devices. The optical signals input from each optical connector are reflected by the internal mirror and then are output from all the optical connectors.

Fig.2 External and internal construction of the optical star coupler



2.2.3 Electro/Optical fieldbus converter

The E/O fieldbus converter mutually converts electric and optical signals of the fieldbus. The external view is shown in Fig. 3.

Power is supplied to the converter together with an electric fieldbus signal. The converter is mounted in the control room with the host device and acts as an interface between the field device and the host. The converter has been developed by Fuji Electric and MTL (Measurement Technology Limited) which is a barrier manufacturer in the UK.

2.2.4 Host device

The host device is a distributed control system (DCS) or a personal computer. An interface unit for transferring and detecting the fieldbus signal is mounted on the host device. The host device is common to both electrical and optical signals from the field device.

2.2.5 Optical fiber cable

In addition to the required transfer characteristics and economics for practical applications, it is also important that the optical fiber for the optical fieldbus have a large diameter for easy handling and easy assembling of the connector in the field.

As a result, the fiber and the connector use two

Fig.3 External view of E/O fieldbus converter

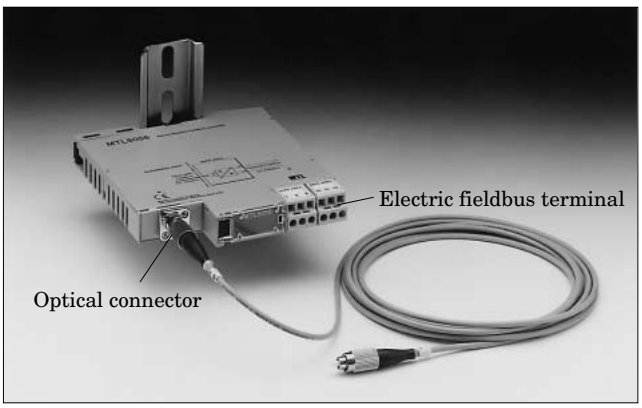
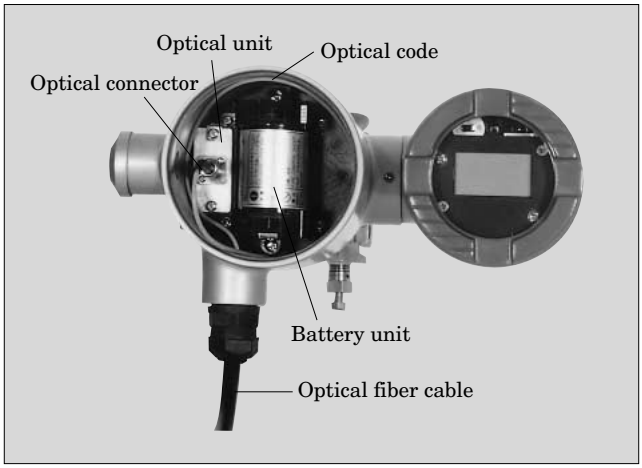


Table 1 Optical fiber cable for optical fieldbus

Optical fiber		Optical loss and transmission distance	Assembly ease of optical connector	Use and remarks
Type	Core/cladding			
Silicate optical fiber	50/125μm	Optical loss : low Transmission distance : long	Difficult	○ Computer communications ○ LAN, PLC communications for control system
Silicate optical fiber	62.5/125μm			
Silicate optical fiber	100/140μm			Utilized for optical fieldbus (optical loss of 4dB/km at max. distance of 1.2km)
Plastic cladding fiber (PCF)	200/230μm	Optical loss : high Transmission distance : short	Easy	Introduced for optical fieldbus (optical loss of 6dB/km at max. distance of 0.7km)
Optical connector : FC connector or ST connector Cable type : optical cord assembly type				

Fig.4 Example connection of optical fiber



types of silicate and plastic cladding as shown in Table 1, and two types of FC and ST connectors.

The fiber has an optical cord assembly type construction and is connected to an optical connector in the terminal box of the field device. Figure 4 shows a connection diagram of the optical fiber.

3. Features of the Optical Fieldbus

The optical fieldbus system has optical transmission features in addition to features of the fieldbus.

3.1 Digital communication

The fieldbus is the infrastructure technology of an instrument control system which is able to connect to and communicate with field devices as a DCS (distributed control system) host device. The fieldbus is expected to realize various intelligent functions which are impossible to achieve with the conventional 4 to 20 mA analog communication.

Communication among the field devices enables signal detection and control operations that will make possible the realization of field distributed control and a high-level device maintenance function.

3.2 Multi-drop connection

The conventional 4 to 20 mA analog communication requires a pair of cables for each field device, due to a point-to-point connection structure between the field and host devices.

Because multiple field devices can be connected with one bus, the fieldbus has the advantage of eliminating the signal cable and making the wiring more efficient. The topology (connection configuration) is based on the bus configuration and can also incorporate tree or split type configurations for the electric fieldbus.

3.3 Excellent transfer characteristics

In order to transfer the digital communication properly, the fieldbus uses software techniques such as error control to prevent noise or distortion of the signal waveform. Since the signal transmission medium for the electric fieldbus is wire, there is no method to completely eliminate external electromagnetic noise.

However, a suitable cable has been selected and the cable route has been designed to reduce the noise. Because it uses optical signal transmission, the optical fieldbus is not affected by external noise.

3.4 Resistance to lightning

Since the electric fieldbus is connected to multiple field devices on every bus, damage by lightning is considered more serious than with analog transmission. In addition to connecting a lightning arrester as before, the type and number of connecting devices for each bus are limited in the system design stage.

On the other hand, many devices of the optical fieldbus are electrically insulated and well protected against lightning.

3.5 Intrinsic safety

To satisfy the intrinsic safety (IS) of the electric fieldbus, one barrier is connected to each bus.

Although the fieldbus standard specifies that a maximum of 32 devices can be connected to each bus, that number is limited due to the limited input current. Moreover, the state of actual connections must be estimated to decide whether to satisfy the IS. Therefore, the number of devices that can be connected to the fieldbus depends on the manufactures and types of devices.

When using optical devices, no limitation is imposed on the number of connectable devices, recognition that each device satisfies IS. Most of the devices are able to satisfy IS without barriers, as they are activated by internal batteries with no external power supplies.

3.6 Duplexed transfer line

In the case of the optical fieldbus, it is possible to duplicate the optical cable trunk line (optical cable between the optical star coupler and control rooms) and the host device by using two channels of the optical star coupler connector. The connection of multiple fieldbus devices is an economical advantage that is compatible with improved reliability.

Figure 5 shows the construction of a duplex optical fieldbus system.

4. Development and Features of the Optical Fieldbus

4.1 Development

A summary and specifications of the fieldbus being developed are listed below.

4.1.1 Pressure and differential pressure transmitter

The gauge which measures various fluids is a fine precision, electrostatic capacitance type and is a differ-

ential pressure transmitter (Fig. 6).

The transmission protocol is based on the Fieldbus Foundation Standard, and on the function block that realizes interoperability between devices.

The gauge is designed for low power consumption by using a power management controller which controls each device by regulating the power supply and supply clock.

(1) Configuration

The device consists of a sensing unit for pressure measurement, an amplifier unit for signal processing and communication of the pressure output, an optical unit for transferring and detecting the optical signal, a display unit for pressure, and a power unit for stabilizing the power source. These are all driven by a built-in lithium battery (Fig. 7).

(2) Specifications

(a) Accuracy rating: ±0.1%

(b) Ambient temperature: –30 to +70°C

(c) Power source:
built-in lithium battery (1 battery)

(d) Measuring range:
gauge pressure; 1.6 to 50,000 kPa
differential pressure; 0.1 to 3,000 kPa

(e) Explosion-proof: intrinsic safety

Fig.5 Configuration of optical fieldbus duplexed system

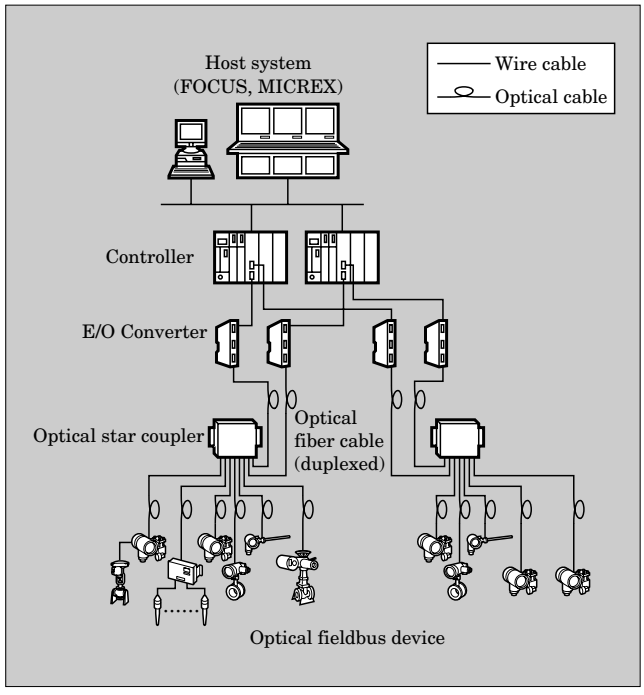


Fig.6 Exterior of pressure transmitter

4.1.2 Temperature converter and multi-point temperature converter

The temperature converter (for 1 point) and multi-point converter (for max. 8 points) connect to an optical fieldbus system which detects signals from 1 or a maximum of 8 measuring points by a thermocoupler or resistance bulb sensor. An external view of the multi-point temperature converter is shown in Fig. 8.

The multi-point temperature converter has a diagnostic function that detects sensor disconnections and processes alarms for the function block. The multi-point temperature converter multiplexes temperature data of a maximum of 8 points and is able to transfer that data through a single optical fiber to the host.

(1) Configuration

The input signal is detected by a standard AI function block (Fieldbus Foundation Standard) after conversion by the high precision A-D converter in the built-in microprocessor. Single point and multi-point

Fig.7 Internal configuration of optical fieldbus transmitter

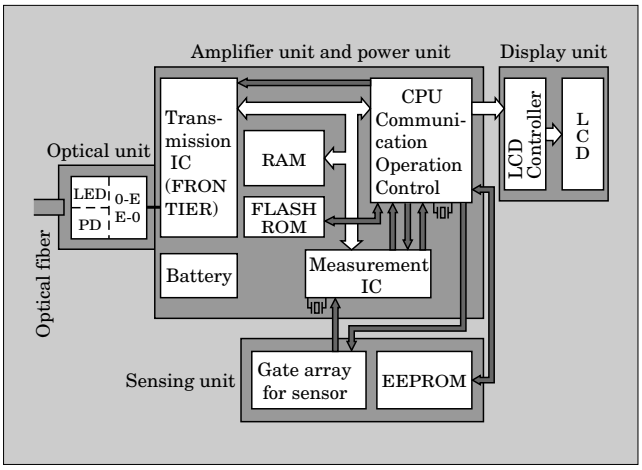
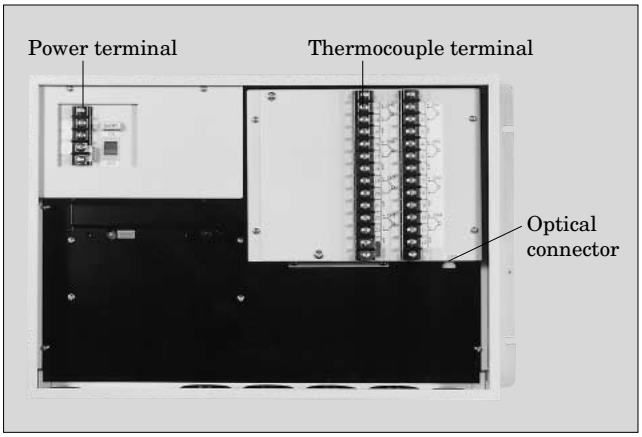


Fig.8 Configuration of multi-point temperature converter



temperature conversion is powered by a built-in battery and an external power source respectively.

(2) Specifications

(a) Power source:

single point temperature converter;
built-in lithium battery (1 battery)

multi-point temperature converter;
24VDC, 100/115/220VAC

(b) Measuring range: –200 to +1,200°C

(c) Applied sensor:
thermocouple or resistance bulb

(d) Explosion-proof: intrinsic safety

4.1.3 Optical-pneumatic converter

The converter drives a diaphragm type control valve pneumatically (20 to 100 kPa) in response to the indicator input through the optical fieldbus (Fig. 9).

As the converter needs no external power source, it is able to realize the IS structure by itself and has a burn out function if the input fails and a function to read back the output.

(1) Configuration

The converter is composed of a control unit for communication and control, an electric-pneumatic pressure converter unit that pneumatically converts the output and a feedback sensor to measure the output pressure. All of these units can be driven by the internal lithium battery.

(2) Specifications

(a) Pneumatic output: 20 to 100 kPa

(b) Power source: built-in lithium battery (1 or 2 batteries)

(c) Explosion-proof: intrinsic safety

Fig.9 Exterior of optical-pneumatic converter

4.1.4 Optical signal repeater

In the case of long transfer distance between the field device and receiving unit, the repeater is used as an optical amplifier.

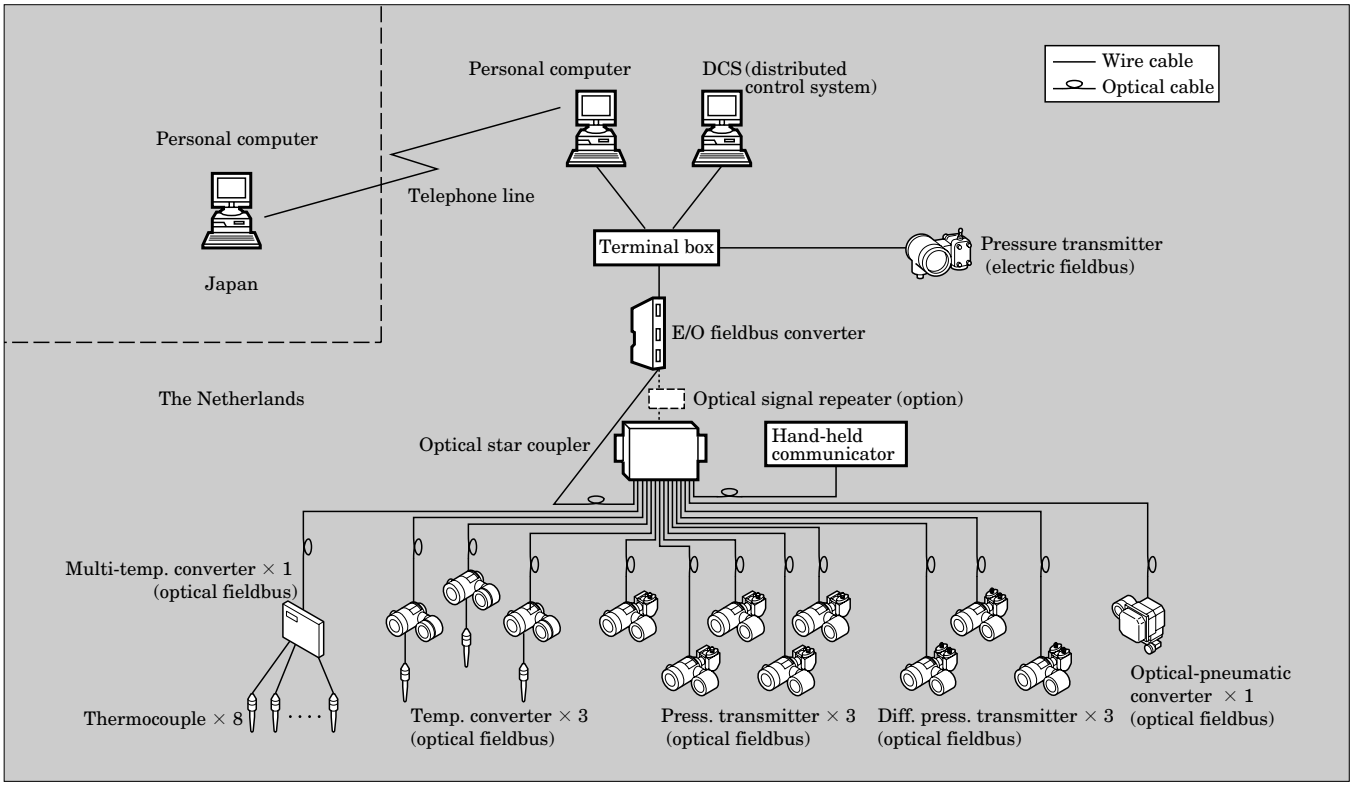
In addition to improving distorted signals, the repeater sends out an amplified optical signal with standard intensity (–40dBm to +13.5 dBm) that decreases due to the long transmission length.

(1) Configuration

The optical signal repeater is composed of following three functional parts.

(a) An O/E converter that converts optical signal input to an electric signal

Fig.10 Configuration of field demonstration test system



(b) A logic circuit that improves the quality of converted electric signal.
(c) An E/O converter that converts the output signal back to an optical signal

(2) Specifications
(a) Input and output signal:
optical fieldbus digital signal
(b) Transfer distance:
Max. 7km between fieldbus and host device
(c) Power source: 24 VDC (20 to 30 VDC)
(d) Ambient temperature: –10 to +50°C
(e) Explosion-proof: intrinsic safety

4.2 Future developments

The devices introduced in this paper are fundamental for plant construction and will be arranged into a product series. A signal converter to convert the conventional signal (4 to 20mA, 1 to 5V) to optical fieldbus signals and a HHC (hand held communicator) will be considered in future products.

Future goals include developing an optimal maintenance tool to operate these functions completely, to accumulate the know how and maintenance for communication analysis, and to "build-up" the operator. Promoting the wide use of the fieldbus is one means to achieve the quick and practical use of these functions.

5. Field Trial for the Optical Fieldbus

At present, plans are progressing for a field trial of the optical fieldbus with Chiyoda Corporation and Shell, a major oil company, at SRTCA (Shell Research and Technology Center in Amsterdam, Shell International Oil Products B.V.). Figure 10 shows the construction of the evaluation system. The ease of setting up field devices, optical cable characteristics, system functionality and reliability, and practical applications for users will be evaluated more thoroughly from October 1997 to June 1998.

6. Conclusion

This paper describes features of the configuration and specifications developed for the optical fieldbus system.

Fuji Electric presented the fieldbus at the ISA TECH/97 exhibition in the USA in October 1997 and at INTERMAC/97 in Japan. The practical field test of the optical fieldbus system is the last stage before production. Fuji Electric will continue to develop the fieldbus for practical applications.

References:

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