

YEFLO VORTEX FLOWMETER WITH FIELDBUS COMMUNICATION

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A new model that is compatible with FOUNDATION™ Fieldbus has been developed as an enhanced product of the YEFLO Vortex Flowmeter series. A single YEFLO unit can measure fluid flow, gas flow and steam flow over a wide range of temperature and pressure. YEFLO flowmeters cater for pipelines with a nominal diameter of 15 to 300 mm. The product lineup has been extended to include flowmeters that provide fieldbus-based output for bidirectional high-speed digital communication, as well as the conventional BRAIN-based 4-20 mA analog output and pulse output. This paper describes the characteristics of the new YEFLO*E compatible with the fieldbus communication protocol.*

INTRODUCTION

The operating principle of the vortex flowmeters YEFLO series, which first became commercially available in 1979, is based on the phenomenon in which the frequency of a Kàrmàn vortex train that occurs from a vortex shedder placed in a fluid flow, is proportional to the speed of that flow. Following its release, the advantages of these economical in-line flowmeters that were capable of measuring both gases and fluids, received high acclaim from the market. Since then, the YEFLO has achieved dramatic sales growth in the market of process flowmeters.

In 1992, we released a style 'E' YEFLO (YEFLO*E) that featured an even higher degree of versatility, including increased vibration resistance, a converter free from fluid-type constraints, and a simplified method of parameter setting. Recently, we have successfully developed a converter that is based on the industry-proven YEFLO*E and also supports the standards of the Fieldbus Foundation, thereby constituting a significant reinforcement to our converter line-up. Figure 1 shows an external view of the flowmeter models that support the fieldbus standard.

OPERATING PRINCIPLE OF VORTEX FLOWMETERS

Kàrmàn vortex trains are formed in the downstream of a bluff body (vortex shedder) placed in a flow of fluid. The frequency f of the Kàrmàn vortex train is proportional to the volumetric flow rate Q , as shown in the following formula.

$$f = K_T * Q \quad (K_T = K \text{ factor})$$



Figure 1 External View

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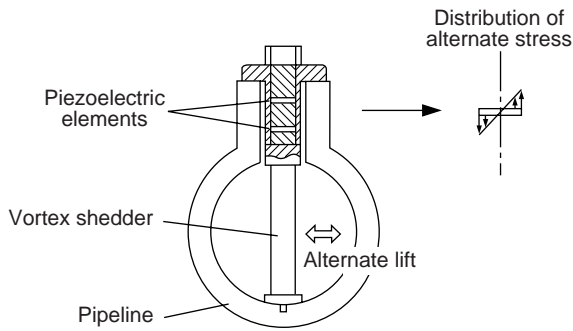


Figure 2 Sensor Structure

The K factor varies according to the meter's Reynolds number. It does however, remain roughly constant over a broad range of Reynolds numbers, if a vortex shedder having the optimum shape and dimensions is selected. As a result, the flow rate Q can be determined by measuring the frequency f.

The fluctuant lift F_{Lf} having a frequency appropriate for the resulting Kàrmàn vortex train applies to the vortex shedder. As a result, alternate stress σ_{Lf} arises within the vortex shedder. The YEFWLO's vortex shedder contains piezoelectric elements that induce alternating charge q_{Lf} according to this stress. The frequency of the vortexes can be determined from the alternating charge, as shown in the following formula:

$$q_{Lf} \propto \sigma_{Lf} \propto F_{Lf} \propto C_L \rho v^2 \text{ where, } C_L = \text{alternate lift coefficient.}$$

In actual piping, the vortex shedder is subject to the alternate stress caused by the Kàrmàn vortexes as well as any disturbance resulting from the vibrating pipeline at the same time. Therefore, two piezoelectric elements of differing levels of sensitivity for stress and disturbance are assembled into the vortex shedder to add and subtract the outputs of these two elements so that any output component resulting from the vibrating pipeline is eliminated. This structure makes it possible to detect the alternate stress without any disturbance effects from pipeline vibration (Figure 2).

FIELDBUS-COMPATIBLE CONVERTER

Figure 3 shows the circuit diagram of the converter.

The primary objectives in the design of a fieldbus-enabled device are:

- (1) ability to transmit and receive 31.25-Kbps communication signals - relatively fast signals for such a field device;
- (2) ability to respond to commands given by the fieldbus within a time frame appropriate for the given control cycle;
- (3) ability to measure and process input signals precisely and securely even while engaged in high-speed communication processing;
- (4) minimization of current consumption so that a sufficient number of units can be connected and the requirements for intrinsically safe explosion-proof equipment satisfied.

Accordingly, objectives (1) to (3) require a high-speed processor, while objective (4) requires a limit to be placed on the processor's speed. The fieldbus-compatible YEFWLO*E comprises two microprocessors, one serving as a signal processing CPU that determines the vortex frequency and calculates the output and the other serving as a communication processing CPU that deals with communications through a fieldbus. The purpose of the dual-processor configuration is to reduce the total current consumption and properly handle the loads on fieldbus communication.

1. Hardware Configuration

An alternating charge occurring in the piezoelectric elements due to Kàrmàn vortexes is converted into an AC voltage signal using the two charge amplifiers. In the next stage, the signal passes through an adder and filter to eliminate any disturbances resulting from variations in the fluid pressure and pipeline vibration. The Schmidt trigger (TLA) detects only those signals having a specific amplitude so that it does not pick up small-vibration signals that are superposed on the vortex signal. Thus, the Schmidt trigger outputs a pulse-train signal appropriate for the given vortex frequency. This pulse-train signal is fed to the

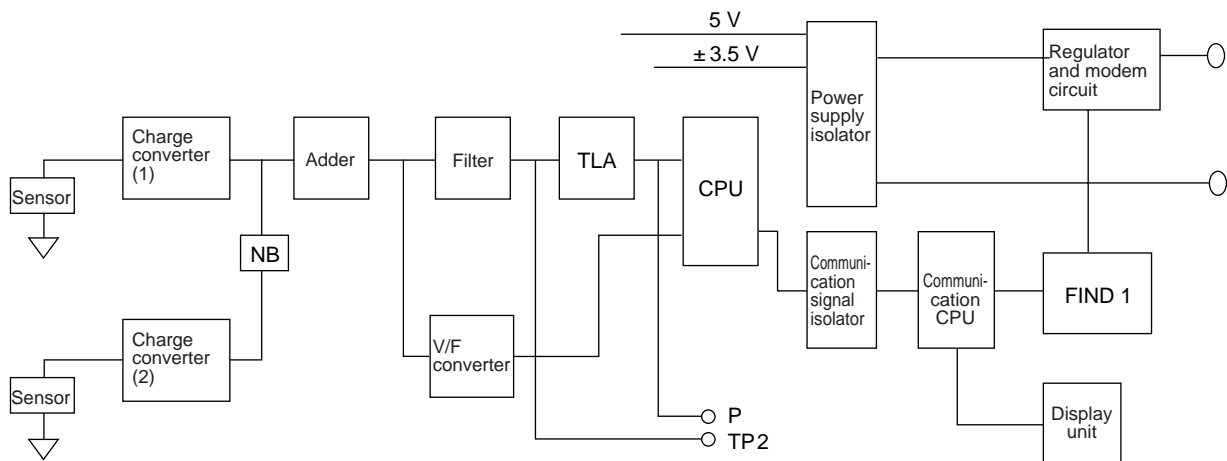


Figure 3 Circuit Diagram of the Converter

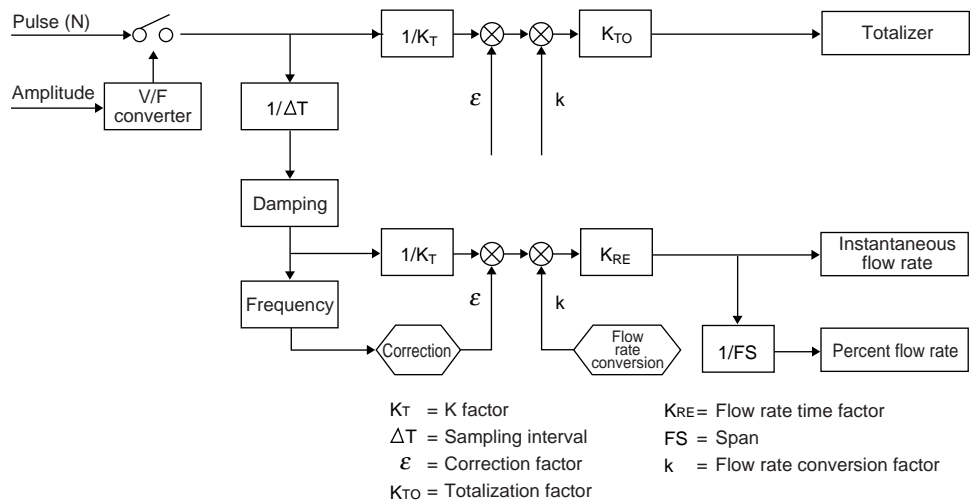


Figure 4 Diagram of the Computing Block

microprocessor, where the signal is weighted by the K factor and the pipe diameter in order to calculate the flow rate.

Concurrently, the vortex signal is converted to obtain a DC voltage signal in the full-wave rectifier. The signal is then converted to a frequency signal by the V/F converter and fed to the microprocessor. From the frequency and amplitude of the vortex signal, the microprocessor determines whether the signal is merely noise due to disturbances resulting from pipeline vibration or an actual flow-rate signal. This stabilizes the zero point when there is no fluid flow.

The output of the signal processing block is transferred to the fieldbus CPU by serial communication, where the output is further transferred to a higher-order equipment as requested by the fieldbus.

2. Software Configuration

Figure 4 is a diagram of the computing block.

The number of input pulses N is scaled using the K factor K_T . The error coefficient ϵ , which represents a variety of corrections, such as the correction of Reynolds number, the correction of errors arising from the effects of neighboring pipelines, and the correction of the compression factor, and a flow rate time factor K_{RE} are multiplied to calculate the instantaneous flow rate.

3. Support of Fieldbus Standard

(1) Standard Blocks

The Fieldbus Foundation stipulates that a fieldbus-compatible device should consist of three functional building blocks:

- Resource block
 - For controlling the common data of a device as well as its operating condition.
- Transducer block
 - For processing signals from sensors and converting them to process quantities such as flow rate or pressure.
- Function block
 - For filtering the above mentioned process quantities and

raising alarms, such as upper- and lower-limit alarms.

The YEWFLO*E vortex flowmeter serves as the analog input device (AI function block) specified in the fieldbus standard. The flowmeter has all of the functions required for an AI function block that comply with the standard.

(2) Expansion of Function Block

The AI function block standardized by the Fieldbus Foundation does not include any totalizer function. A totalizer function block is presently being researched by the Fieldbus Foundation as a completely new function block, though no standard has yet been issued.

Since it was not considered a good idea to eliminate the totalizer function that is available on conventional devices, we expanded the AI function block to include the totalizer function. When adding the function, we tried to minimize any diversion away from the standard and coordinate an equivalent function for conventional devices. Accordingly, we added the same totalization parameters as used on the conventional flowmeters with style code E to the standard AI function block, enabling the new YEWFLO to output digital totalizer values and show them on an LCD display.

(3) Access to Added Parameters

The added parameters are described in the Device Description Language (normally abbreviated as DDL) and compiled to a binary file using Tokenizer. The compiled device description file (normally abbreviated as a DD file) is installed in higher-order equipment (such as DCSs or PCs) so that the parameters can be accessed in the same way as standard parameters.

(4) Self-diagnosis

Like the new YEWFLO, the conventional models of the YEWFLO series were also capable of diagnosing failures in the amplifiers and flow velocity overloads. However, these models did not have any means of transferring the diagnosis

information to higher-order equipment, such as DCSs; they could only show the information on their LCD display. The new fieldbus-compatible model carries out prescribed diagnoses on the function block, such as a check of the upper and/or lower-limit alarms, in addition to the conventional diagnosis. The results of these diagnoses are constantly transferred as status information along with process quantities to higher-order equipment.

ADVANTAGES OF FIELDBUS

1. Reduction in Installation Costs and Other Advantages

The advantages of a fieldbus most often acknowledged include:

- (1) Reduction in the cost of cables by means of multidrop wiring
- (2) Improvement in accuracy by means of digital output
- (3) Compatibility among devices by standardization

Once the fieldbus standard is supported, these advantages can be realized for all devices.

2. Precision Bidirectional Digital Communication

The operating principle of the YEWFLO*E vortex flowmeter supports operation over wide ranges of temperature, pressure and flow rate and thereby places fewer restrictions on the type of fluid measured. In fieldbuses with which the new YEWFLO is compatible, the flowmeter output is transmitted in digital values. Consequently, there are no factors that limit the measurement resolution, such as D/A conversion at the converter's output stage and A/D conversion at the input stage of receiving equipment (e.g., a DCS), as seen in conventional flowmeters having a 4-20 mA output. As a result, users can obtain precision measurement regardless of the flow rate being measured once they set the constants relating to the particular fluid measured, such as the fluid type, temperature, pressure and kinematic viscosity, and the sensor related parameters, such as the pipe diameter and K factor. This means there is no need to reconfigure the span parameter even if the flow rate changes. Thus, the new YEWFLO is considered to be one of the optimum devices for fieldbus-based systems.

CHANGE FROM OPERATION ON AN LCD DISPLAY TO OPERATION ON A CRT DISPLAY

As discussed earlier, the fieldbus-enabled model has been developed with the primary focus on maintaining the functionality and operability of the existing YEWFLO*E and optimizing the use of digital communication.

The LCD display, which is mounted on the new YEWFLO and driven at high voltages, has no backlight because the minimum operating voltage specified for devices in a two-wire system that derive power from the fieldbus, is too low. In addition, fieldbus-enabled devices have too many parameters for

the AI function block. This makes the conventional method of parameter setting using switches on an LCD display so difficult that it is no longer practicable.

Fieldbus technology has enabled high-speed, bidirectional digital communication, which has made it possible to set parameters graphically on the CRT display of a DCS or personal computer equipped with technology that supports parameter setting and control tools providing advanced operability.

FIELD TRIAL

Our development of the fieldbus-enabled model almost coincided with the standardization of the fieldbus specifications by the Fieldbus Foundation. One particularly noteworthy event during this development was the field trial conducted from November 1995 to April 1996 at Monsanto Company, USA. It was during this field trial that the model was recognized as a flowmeter capable of in-line measurement of high-temperature, high-pressure fluids. It was then adopted as a flowmeter for measuring the flow rate of boiler feed water and continued to operate correctly without failure during the whole test period, thus proving to be an excellent general-purpose in-line flowmeter.

CONCLUDING REMARKS

The newly developed fieldbus-compatible model in the YEWFLO*E series is considered to be the top-end model in the YEWFLO family. This model succeeds the features offered by conventional 4-20 mA output (BRAIN communication) models, such as simplified communication-based parameter tuning, standardization of the liquid/gas conversion block, and various correction functions.

In addition to these features, the fieldbus-based bidirectional digital communication makes the new model capable of 1) full-range precision output transfer regardless of the measuring range, and 2) continuous transfer of the results from the self-diagnosis of alarms and failures. With these features, we expect the new model to become more widely used than conventional models in process lines where, for example, the variation in flow rate is relatively large or where a high degree of reliability is required.



* YEWFLO is a registered trademark of Yokogawa Electric Corporation.

REFERENCE

- (1) Ito I., & Miyata T., "Intelligent Vortex Flowmeters," Yokogawa Technical Report, Vol. 36, No. 4, pp. 165-168 (1995).