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HART PROTOCOL ANALYSER BASED IN LABVIEW

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Abstract: *Analysis of Highway Addressable Remote Transducer (HART) protocol is important in reliability evaluation of HART based systems. The present work proposes a virtual instrument based solution for HART signal analysis that includes a digital oscilloscope with GPIB interface, a HART modem, a PC with a GPIB interface board and a RS232 port, and a software component developed in LabVIEW. The HART analyser permits the visualisation of signals that correspond to the HART protocol, gives access to data coming from field instruments and has the ability to analyse and modify field instrument performance.*

Keywords: *Protocol analyser, instrumentation and control network signalling, intelligent instrumentation*

1. INTRODUCTION

Highway addressable remote transducer (HART) systems seem to be one of the best transition solutions between the old current loop instrumentation systems, based on 4-20 mA signalling [1], and the fully digital instrumentation and control fieldbus systems [2]. HART devices can be considered a hybrid solution because they preserve the 4-20 mA signalling together with digital transmission signalling based on frequency shift keying (FSK). Two frequencies, with values equal to 1200 Hz and 2200 Hz, are used to represent digital data with a throughput equal to 1200 baud (bits per second).

The specifications of the HART protocol were established by the HCF (HART Communication Foundation) [3][4][5] and several instrumentation manufacturers offer today intelligent instrumentation devices with HART transmission capability [6][7].

This paper presents a HART protocol analyser (HPA) based on a personal computer (PC), or laptop, that can be used for centralised or field maintenance of HART instrumentation and control systems.

2. SYSTEM DESCRIPTION

2.1. HARDWARE

Figure 1 represents the block diagram of the HPA and its interconnection to the HART transmission line. The main elements of the system are: a PC or laptop equipped with a GPIB interface board (NI-PCIIA), a digital oscilloscope (Yokogawa, DL1200A) [8] and a HART interface (HI 311) [9] that provides the hardware connection between the serial communication port (RS232) and the HART transmission line.

The main features of the HI 311 include: no need of external power supply, easy installation, very low leakage current to or from the process network (lower than 10 µA) and interconnection to the PC through a standard DB9 serial port, as represented in Fig. 2.

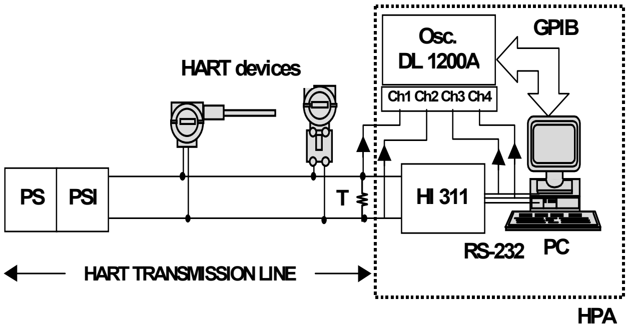


Fig. 1 - Block diagram of the HART protocol analyser and interconnection to the HART transmission line: PS- power supply, PSI- power supply impedance, Osc.- digital oscilloscope, PC- personal computer, HI 311- HART serial interface, GPIB- general purpose interface bus, T- terminator (250 Ω/0.25 W resistor).

Oscilloscope channels 1 and 2 are used in differential mode to acquire the FSK signalling. Channels 3 and 4 are used to capture the digital information associated with the RS232 received signal and transmitted signals, respectively.

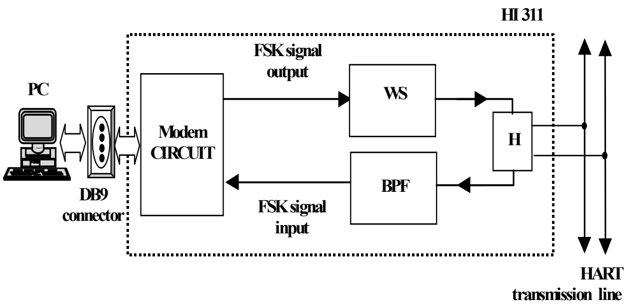


Fig. 2 - Interconnection between the PC and the transmission medium: WS-wave shaper, BPF- band-pass filter, H- hybrid interface circuit.

Data acquisition from the oscilloscope is made through GPIB by binary transfer from the display memory (vector with 1001 elements for each channel). The main characteristics of the oscilloscope include an input sensitivity of 2 mV/div, a vertical resolution of 8 bits and a time base accuracy of ± 0.01% of the display time interval. These specifications are more than sufficient to obtain an accurate measurement of HART signal parameters.

2.2. SOFTWARE

The system software uses the graphical programming language LabVIEW 6.1 [10], which enables an easy and flexible software development and, if necessary, a remote TCP/IP operation by using the Internet toolbox functions library.

The main functions of the program include data communication with processing tasks. The communication with the digital oscilloscope and the HART transmission line uses the GPIB and HI 311 interfaces, respectively.

A fundamental task of the data communication software is the synchronisation of the HART signal that must consider the standardised HART frame format represented in Fig. 3.

P	SC	AD	CN	BC	S	D	CS

Fig. 3 - HART frame format: P-preamble, SC- start character, AD-address, CN- command number, BC- byte count, S- status, D- data, CS- checksum.

Triggering of frame acquisition is provided by the preamble field of the HART frame that contains a sequence between five and twenty hexadecimal "FF" characters.

3. RESULTS

To evaluate some capabilities of the proposed HPA, a simple flow control system is considered. The system includes a remote Coriolis effect based flow transmitter (Micromotion RFT9712), a PID controller (Onneywell UDC3000) and a pneumatic valve (Honneywell SCR ½"). The remote flow transmitter is a microprocessor-based mass flow transmitter that simultaneously measures flow rate, temperature, density and total flow.

Figure 4 represents the HART frame data for a flow measurement of 30 kg/minute. The message from the slave to master is of the short format type (SC=06), the flow transmitter address is equal to 86, the command

number associated with the measurement of the primary variable is 01, the status or response code is zero, which means that no communication, command or field errors are present. Finally, it is important to note that the measured data (30 kg/min.) uses the standardised IEEE 754 single-precision floating-point format, as defined by HCF.

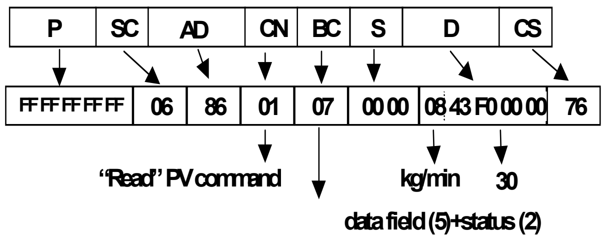
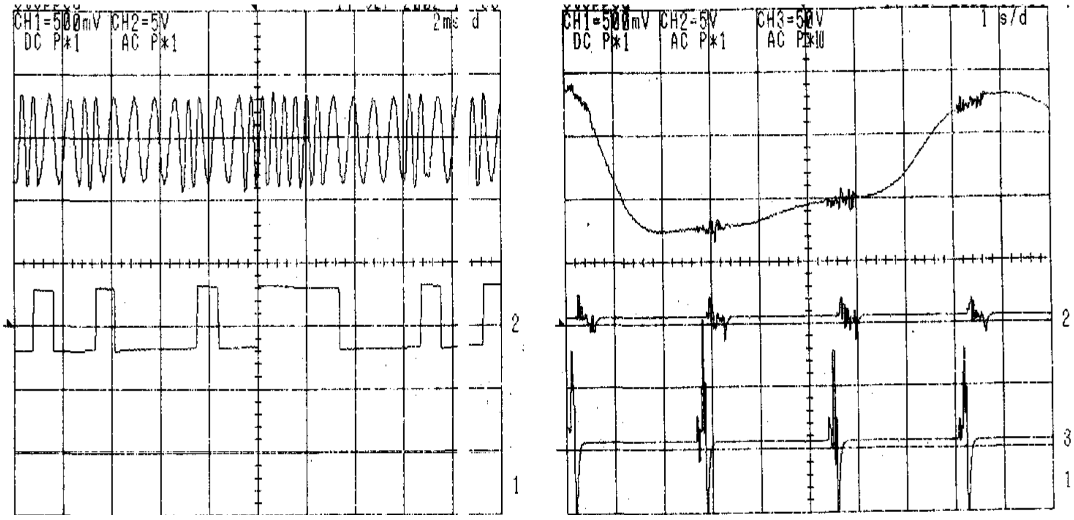


Fig. 4 - HART frame data for a flow measurement of 30 kg/minute.

Figure 5 represents data captured from the digital oscilloscope. The graph on the left side refers to the HART signal and correspondent digital data received by the HART interface (HI 311). Amplitude and base time settings of the oscilloscope (CH1- 500mV/div, CH2- 5V/div, time/div=2 ms) allow us to measure near 750 mV for the amplitude of the FSK signal, 5 V for the amplitude of the digital received signal and a baud rate approximately equal to 1176.5 bits/s.

The graph on the right side refers to the HART signal and correspondent digital received and transmitted data. However, this graph uses a larger time scale (1s/div) in order to observe long-term variations of the HART signal. The upper curve represents the HART transmission signal that contains the 4-20 mA information superimposed to the digital FSK signal. The 4-20 mA signal variation is directly related with the flow rate measurement, whose variation was easily obtained by opening and closing a manual valve, and the FSK signal, represented by the signal bursts, contains the digital information associated with the HART commands and responses. In this case, the digital measured data contains information about the



(a) (b)

Fig. 5 - Digital oscilloscope captured data: (a) HART and digital received signal with a time scale of 2 ms/div (b) HART and digital received and transmitted signals with a time scale of 1 s/div.

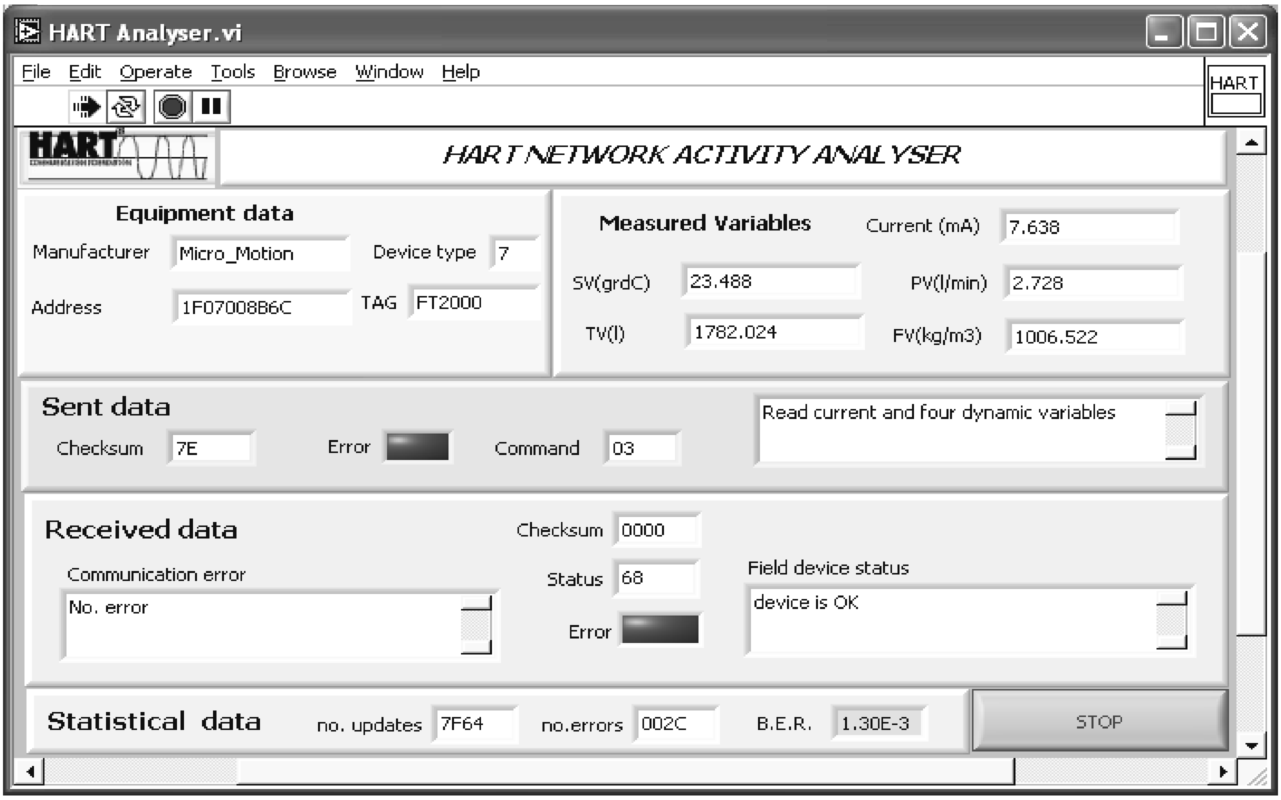


Fig. 6 - LabVIEW front panel of the HART network activity analyser (PV- primary variable, SV- secondary variable, TV- third variable, FV- fourth variable, B.E.R.- bit error rate).

multiple parameters processed by the HART flowmeter (RFT9712), namely: flow rate, total flow, density and temperature. From this figure it can also be verified that the delay between the command transmission (channel 3) and the response reception (channel 2) is negligible but the number of digital measurements per second (updates) is only about 0.4 s^{-1}.

Referring to the HART protocol analysis capabilities, the LabVIEW program decodes sent and received data and presents the following information (see Fig. 6 representing the front panel of the system): equipment data, measured variables values, sent data command and checksum bytes and received data checksum, error and status information. Some statistical data can also be accessed, including the bit error rate (BER), which is one of the most important transmission parameters because it gives a direct measurement of channel transmission quality.

4. CONCLUSION

The proposed protocol analyser includes, among others, the following main characteristics: capability to trace HART messages between devices; remote and local operation modes; flexible programming; capability to identify system faults and transmission overloads and delays; centralised maintenance without need of handheld communicators and user-friendly man-machine interface.

Network performance can also be evaluated using character and messages transmission errors detected by analysing parity and frame check sequence (CS) bits, respectively.

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