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Data Acquisition and Control of a 22 L B. Braun Fermenter Using LabVIEW

HANJING HUANG
TINGYUE GU

Department of Chemical Engineering,
Ohio University,
Athens, Ohio

MURRAY MOO-YOUNG

Department of Chemical Engineering,
University of Waterloo,
Waterloo, Ontario, Canada

The flexible and automatic monitoring and control of a 22 L B. Braun Biostat C fermenter using LabVIEW software were achieved by establishing a serial interface between the fermenter's control unit and a personal computer. This setup was also used for the on-line monitoring of the DO change in a custom-made 50 L airlift bioreactor.

Keywords: Bioreactor control; Data acquisition; LabVIEW; Airlift bioreactor

Introduction

Fermentation is a very complicated process, and feedback control of fermentation is a useful strategy to guarantee a successful run. LabVIEW software is a powerful software program for data acquisition and control with increasing popularity. It supports IEEE488 (GPIB), RS232/422, and VXI, as well as plug-in A/D, D/A, and digital I/O boards (Jamal, 1994). This work utilized LabVIEW to achieve flexible monitoring and control of a 22 L (15 L working volume) B. Braun Biostat C fermenter (B. Braun Biotech International, GmbH, Melsungen, Germany).

Experimental Setup

LabVIEW Software and Personal Computer

The graphical programming environment LabVIEW (LabVIEW for Windows, Version 4.1, National Instruments, Austin, Tex.) ran on a Pentium personal computer with Microsoft Windows 95 operating system. User-written LabVIEW

programs are called "virtual instruments" (VIs). VIs have three main parts: the front panel, block diagram, and icon/connector. The front panel provides the user an interface for data inputs and outputs. The user operates the front panel by using the computer's keyboard and mouse. Behind the front panel is the block diagram that is responsible for the actual data flow between the inputs and outputs. The icon/connector defines data flow between subroutines (Wells, 1994). The LabVIEW programs in this work can also be used in newer versions (such as Version 6) of the LabVIEW software.

Fermenter Settings

In the 22 L B. Braun Biostat C fermenter, pH, stirring speed, temperature, and airflow rate are controlled by a DFC-2 hardware process control unit equipped with on-off and Proportion integral derivative (PID) controllers. The pO_2 is measured by a steam sterilizable electrode. Agitation and airflow rates are controlled by internal PID boards, according to the set point values addressed by the pO_2 controller. Without additional software and hardware, flexible scheduling of fermentation events and automatic data acquisition cannot be achieved. LabVIEW is an ideal tool in this case to improve the situation. The fermenter's control unit has to be set up for a computer connection. To do this, the user goes to the MAINTENANCE menu on the control unit's display and steps down to the HOST setup, and then sets the following parameters: ADR = 1, SPEED = 9600 bd, DATA = 7 bit, STOP = 1 bit, PARTY = EVEN.

Communication Port Setting

The connection between the fermenter and the computer was established through a non-powered RS-232 to RS-422 signal converter (Model 263F, Telebyte, Inc., Greenlawn, N.Y.) connected to the computer's serial port 2 (RS-232 port 2). No additional power supply was needed for the converter due to the short distance between the fermenter and the computer. Serial port 1 was used for the mouse. The RS-422 interface is not as sensitive to interfering signals as the common RS-232 interface. The RS-232 to RS-422 signal converter is equipped with a nine-pin connector on one end and an RJ-11 phone jack at the other end. A four-wire telephone cable was used to connect the converter and RS-422 connector on the fermenter's control unit.

The Model 263F non-powered RS-232 to RS-422 signal converter is equipped with a DTE/DCE switch selectable for reversing TD (transmit data) and RD (receive data). It was set to DCE in this work. The assignments of the telephone wires to the corresponding pins of the RS-422 connector on the fermenter's control unit are shown in Table I.

Results and Discussion

Serial Communication

The data are transmitted between the computer and the fermenter's control unit according to the master-slave principle. The computer can control the data transmission to a substation (i.e., the fermenter's control unit) via commands in the form

Table I Assignments of telephone wires to the corresponding pins of the 9-pin RS-422 connector on the fermenter's control unit

| Pin and function	Telephone wire color and function
3 T × D −	Yellow R+
4 R × D −	Red T+
8 T × D +	Black R−
9 R × D +	Green T−

of a telegram. A telegram mainly consists of command, value, and checksum. Commands are available as:

- DR, "data request": requests for process data from the substation.
- DS, "data set": sends process data to the substation.
- SU, "setup": subsystem initialization.

Before sending data to the substation or requesting data from it, the host computer must initialize the corresponding substation: the initialization command sends parameters to the substation and thus adapts the data transmission to the requirements. Without initialization, the substation sends back an error telegram. The interpretation of the telegram was given by B. Braun's technical manual entitled "Description of Serial Interface between Host and Control Units of the B. Braun Biotech International GMBH" (Rev. 09/96, Sept. 1996). Calc Chk Sum.VI is given as an example here to calculate the checksum of the telegram. Figures 1 and 2 are the front panel and block diagram of Calc Chk Sum.VI, respectively. Test 1.VI performs bidirectional serial communication using a serial port on the computer. It first initializes the COM 2 port to the specified settings (such as port number, baud rate, data bit, stop bits, parity), then writes a string to the port. It finally performs a read string with timeout. Figures 3 and 4 are the front panel and block diagram of Test 1.VI, respectively. Below are two more VI examples used in this work.

Process Value.VI

Process value.VI provides a more straightforward interface for data request as compared to Test 1.VI. On the front panel are the numeric indicators for the corresponding process values as shown in Figure 5. In Figure 6, a conversion of a corresponding process value in data transmission range to true value is performed.
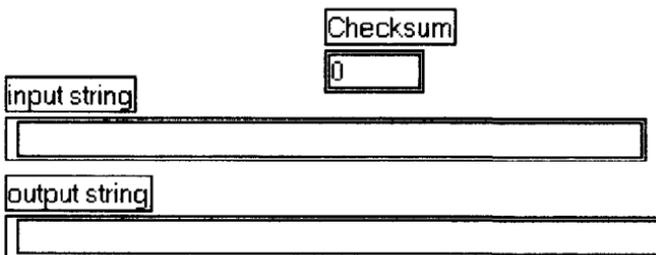
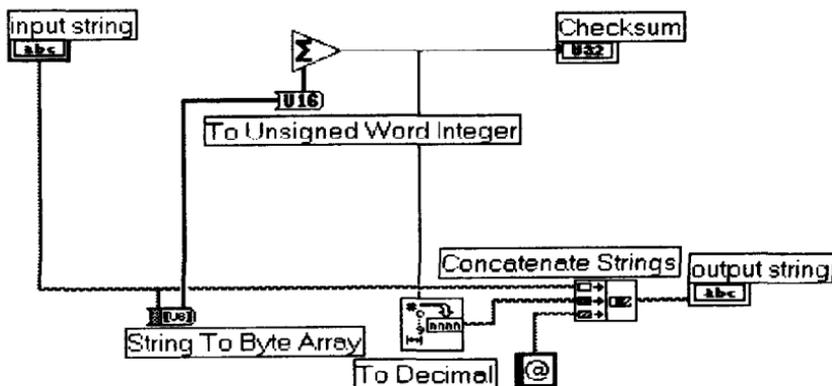
Figure 1. Front panel of Calc Chk Sum.VI.

Figure 2. Block diagram of Calc Chk Sum.VI.

DO.VI

In Figure 7, the user can set the time interval (seconds) for each data request, and the indicator will show the dissolved oxygen (DO) value for each data request. In the graph's window, x-axis represents the time elapse (seconds), y axis represents the DO (%) value; the x-axis and y-axis are set to autoscale by default, so the graph can autoscale continuously with the change of data. In Figure 8, it displays the DO value in the graph and saves the DO values to a text or spreadsheet file.
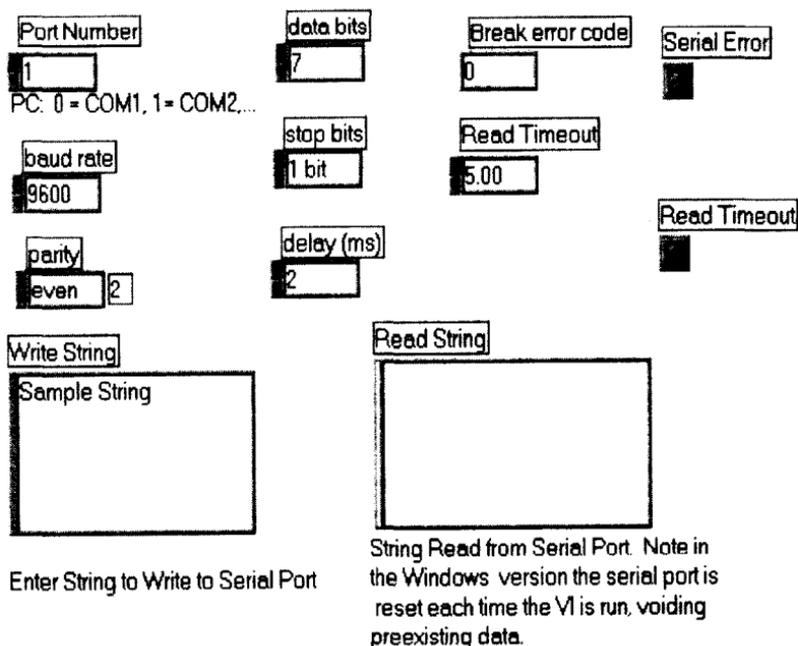
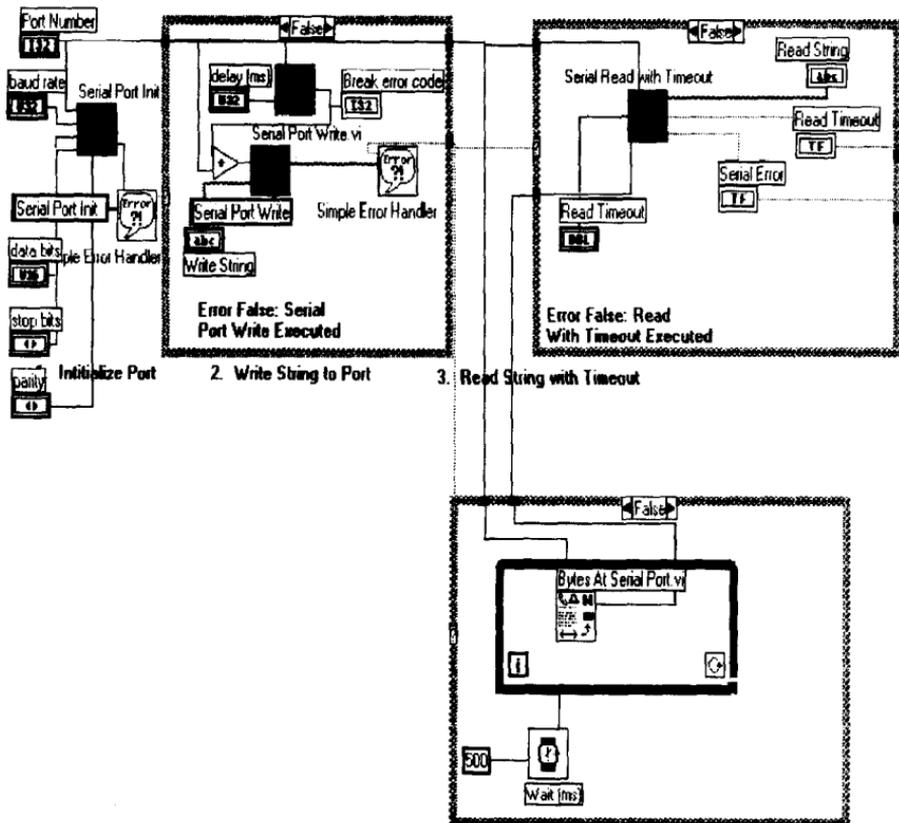**Figure 3.** Front panel of Test 1.VI.

Figure 4. Block diagram of Test 1.VI.

a Measurement in a 50 L Airlift Bioreactor Using the Dynamic Method

he DO probe of a custom-made 50 L (41 L working volume) airlift bioreactor was
nnected to the B. Braun fermenter's control unit, so the Model 4300 dissolved oxy-
n microprocessor transmitter (Mettler-Toledo, Wilmington, Mass.) for the airlift
oreactor was controlled by the B. Braun fermenter's control unit. The dynamic
ethod of measuring the oxygen transfer coefficient was carried out (Bai et al.,
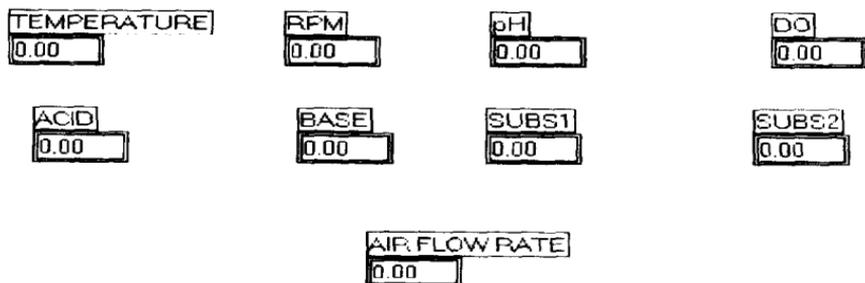01). Upon the drop of DO to zero by nitrogen gassing, the DO.VI program started
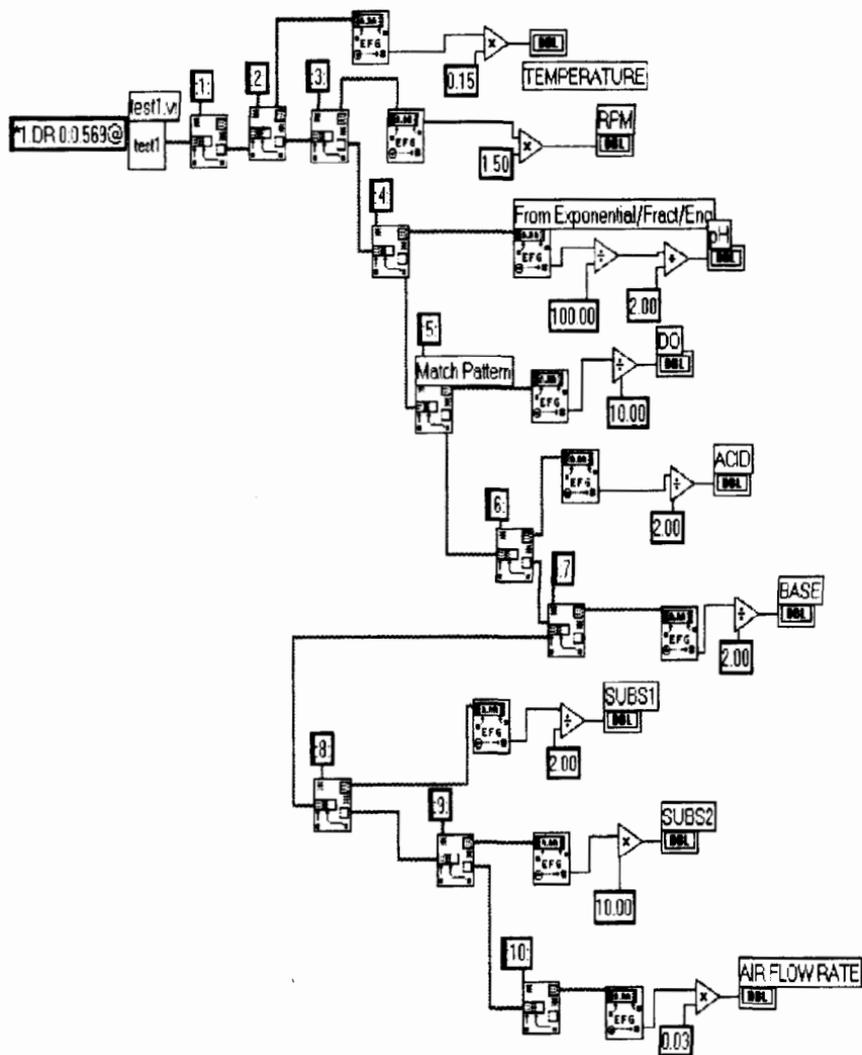

Figure 5. Front panel of Process value.VI.

Figure 6. Block diagram of Process value.VI.

to run, and the air was sparged into the airlift reactor. The DO reached saturation state within minutes. By switching the button of the front panel from on to off position, the file dialog box will pop up to prompt the user to save the DO data to a Microsoft Excel file. This is very convenient and accurate when DO changes dramatically with time.

Figure 9 is an on-line plot of DO change in the 50 L airlift reactor (Bai et al., 2001). The equation for calculating $k_L a$ is as follows:

$$\ln(1 - C/C^*) = -k_L a \bullet t$$

From the data stored in the Excel file, a plot of $\ln(1 - C/C^*)$ versus t was generated to calculate $k_L a$ conveniently.
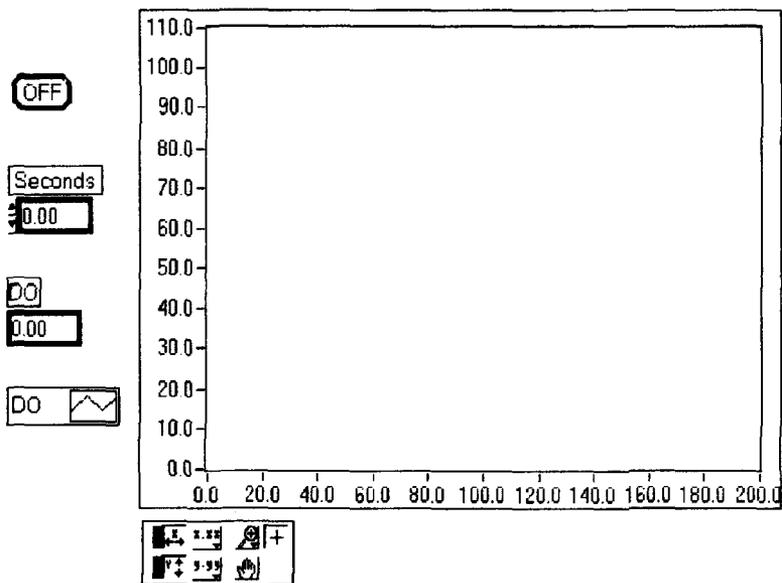
Figure 7. Front panel of DO.VI.

Conclusions

A successful serial communication interface between a 22 L B. Braun Biostat C fermenter and a personal computer was achieved using an RS-232 to RS-422 converter and the LabVIEW software. The LabVIEW software was powerful in fulfilling the data acquisition and flexible control tasks during fermentation. This automated control system was also applied to monitoring and data logging of DO change in a 50 L airlift bioreactor. The B. Braun family of fermenters such as the one used in this work is very common in academic research and industrial applications. This work helps users set up the control of a bioreactor with LabVIEW easily by interfacing its existing controller with a personal computer. It allows convenient data logging
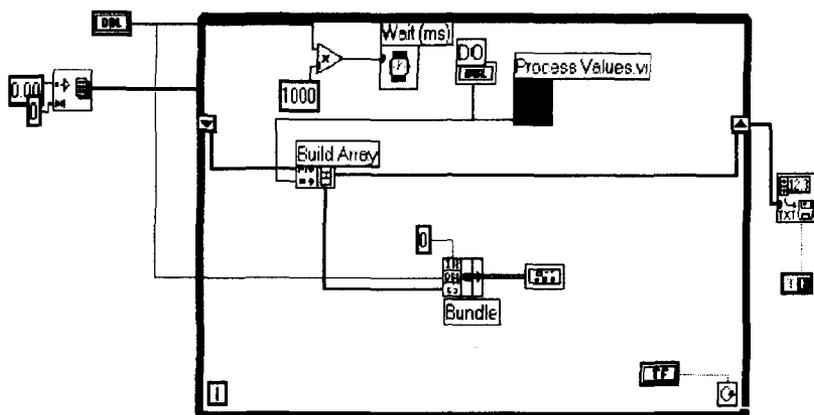

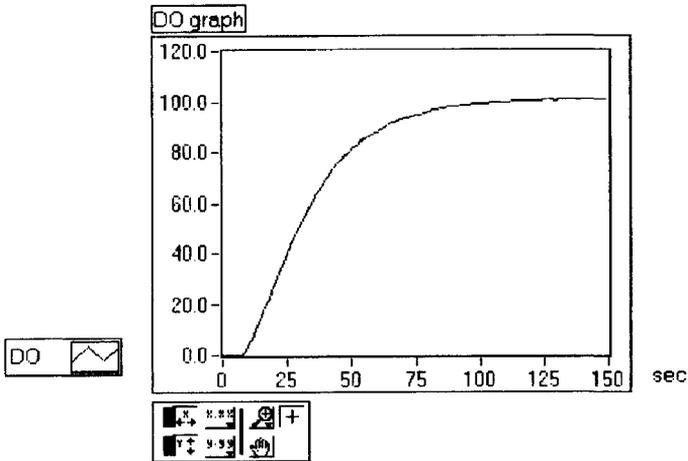**Figure 8.** Block diagram of DO.VI.

Figure 9. Real time DO (%) versus time in the 50 L airlift bioreactor with an airflow rate of 2.2 L/min.

and flexible scheduling of a complicated fermentation process such as fed-batch fermentation.

Nomenclature

C dissolved oxygen tension, %
C^* saturated dissolved oxygen tension, %
$k_L a$ oxygen mass transfer coefficient, s^{-1}
t time, s

References

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