# APPLICATION OF COMPUTER IN DIRECT PROCESS CONTROL

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## ABSTRACT

Automation in the process industries has been under way for many years. Early applications tended to be single analog loop feedback control. As the control problem becomes complicated, more advanced control concepts, such as inferential, feed forward, and cascade are used. However, for those control situations where combinations of interactions with the control loops, non-linearities, very long process delays, compute variables which are not directly measurable, make usual analog controllers relatively useless. The advent of digital process control computer has provided an alternative approach – Direct Digital Control. This paper describes the control concept of using computing, monitoring, information storage, and analytical ability of direct digital control computer.

## INTRODUCTION

The hardware of Process Control Computer consists of processor, memory, and interfaces for peripheral devices, and micro controller for master and I/O stations. To illustrate the general hardware structure of process control computer, a functional diagram of the Foxboro FOX-300 is outlined in Figure 1.

Programmable Processor:

- Random Access Memory 256 K words,
- Diskette Interface,
- FOXNET communication Ports, connect to a total of 100 stations,
- Processor Service Unit, is used for examining and changing processor register and memory contents,
- Status Panel, displays computer status
- Peripheral Interface Logic, provides interface to peripheral devices,
- Peripheral Devices:
  - Keyboard/ Printers
  - Video Terminal
  - Printers
  - Operator Consoles

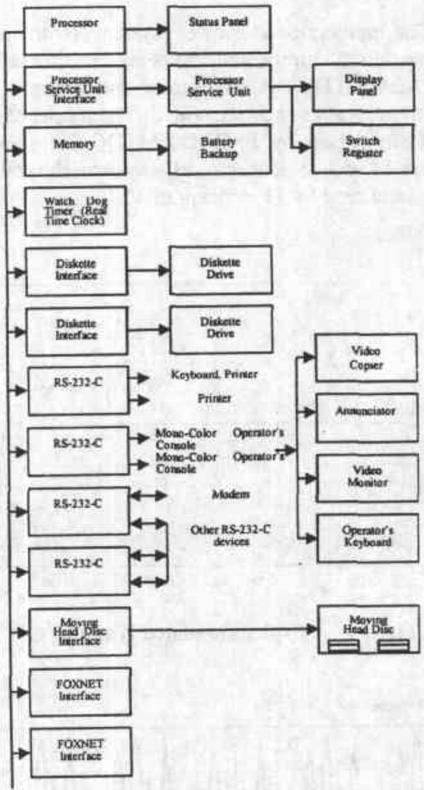

Figure 1. Functional Diagram of the Fox 300 System and its Peripheral Device.

Network Stations:

- Master Stations, can initiate and respond to communications,
- Process Control Stations,
- Unit Control Module (UCM), a process control device which operates on a block-processing principle,

- Controller Communication Module (CCM), a control device that interfaces with 16 analog controllers, allowing the master station to read measurements and read/write set points.

Process I/O Interface Stations:

- Analog Input Module (AIM), supplies the master station to read analog/digital data and write output values to 240 field devices,
- Universal Field Multiplexer (UFM), provides data to master station from 768 process points.

The general structure for a process control software is illustrated in Figure 2. The operating system is responsible for scheduling various other portions of the software system, maintaining communications between the various programs in use, and handling real-time input and output. The application software is divided into four levels.

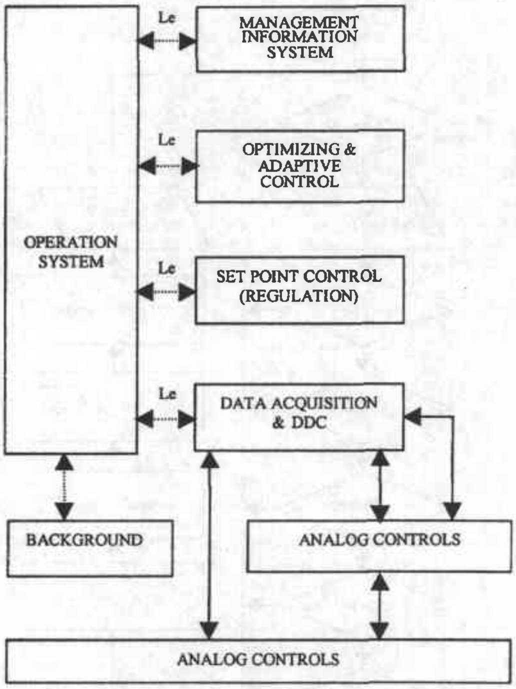

Figure 2. Process Control Software System.

Level 1 is a data acquisition and direct digital control (DDC) software package. It controls the input of data from the process into the computer, and control of the process (instead of analog control equipment). The response time is in the order of seconds or one minute.

Level 2 is the software which effects set point control. This software examines the measurements and calculate from these measurement according to some predefined algorithm, to define the set points of analog controllers. The set point control is done at intervals of several minutes.

Level 3 is the optimisation or adaptive control algorithms. These algorithms operate by varying the parameters of the algorithm used in level 3 to calculate set points. The main objective of the optimising control is to improve the performance of the processes according to some predetermined criteria.

The top level is a management information system. It generates operation information for management of control, or scheduling production over long period time intervals.

The background is a time sharing sub system which allows user to process non-real time computing, such as compiling of software, program testing etc.

## APPLICATION OF DIGITAL COMPUTER TO PROCESS CONTROL

Digital Computers are of significant interest to the industrial process control field due to their ability to store data, program, calculate simple and complex control relationships, compute variables which are not directly measurable, monitor the process and take action according to a preplanned schedule. The digital computer easily performs tasks that the analog system finds difficult; it can be programmed to adapt the overall control system to changes in process dynamics, materials, equipment and production demands. Because of this versatility, digital computers are being designed and installed in continuous process plants. Many of the installations use direct digital control techniques on all provide other additional advantages. It could make feed forward, cascade and inferential calculations which would optimise control set points for economics or production considerations,. Economic constraints relating to material balance, throughput, inventory etc., could be developed. In general, in addition, it provides auxiliary functions to assist process operators and engineers.

- Digital Analog Control (DAC)

DAC or Supervisory Control system is an extension of a computer data logging system. As various loads in a process change, it is often advantageous to alter set points in certain loops to increase efficiency or to maintain operation within certain precalculated limits. In general, the choice of set point is a function of many other parameters in the process. In fact, a decision to alter one set point may necessitate the alteration of many other loop set points as interactive effects are taken into account. Given the number of loops, interactions, and calculations required in such decision, a computer can perform the operation under program control.

- Direct Digital Control (DDC)

In a DAC system, the control mode (Proportional, Integration, Differentiation) is performed by an analog controller, with the set point defined by digital computer. The operations of summing, proportioning, integrating, and differentiating can also be performed by a digital computer. Data associated with a process can be provided as input and output of a digital computer through a multiplexer and AD or DA converters. A natural consequence is that, given the variable inputs from a process, the computer compares these internally to the set points values, solve the controller mode equations, and output any necessary signals to the final control elements.

- Auxiliary Functions

In additions, the on-line process computer performed other useful work to aid operators, plant supervisors and process engineers. A list of secondary functions of an on-line process computer is given in the following steps

- Log operating data periodically in engineering units
- Calculate and display operator guides
- Integration of material flow
- Report on process statistics, material user, fuel used, throughput etc.,
- Calculate and display or record unmeasurable variables such as heat rate, mass flow,
- Monitor and alarm process limits,
- Record process events during unusual disturbances,
- Monitor and record changes in set points, alarm limits etc.,
- Provide on demand operator information such as trend recording, alarm status report, loop set point and parameter data.

EXAMPLES

- Digital Analog Computer

Example 1:

The process specifications are;

1. Reactants A and B combine such that one part to two parts B produce one part C,
2. Volume production of C varies as the square root of A and B flow rate product,
3. The operating temperature must be linearly decreased with C volume production rate
4. For stability, the reaction must occur with the pressure maintained below a critical value. The cont

The process equipments are illustrated in Figure 3. To increase the production of C;

Step (1): Increase the flow rate of A by a change of set point,

Step (2): Set point of B flow must be set to 2x of setpoint A,

Step (3): Set point of C flow must be increased by the square root of new A and B flow rates,

Step (4): The temperature set point must be decreased by a proportion of the new C set point.

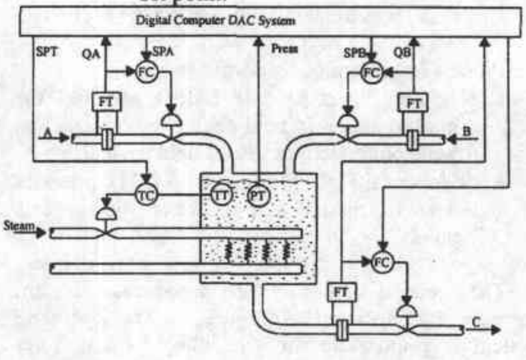

Figure 3. A Physical Process for Example 1.

The DAC system to accomplish such a process is demonstrated by a event flow diagram in Figure 4.

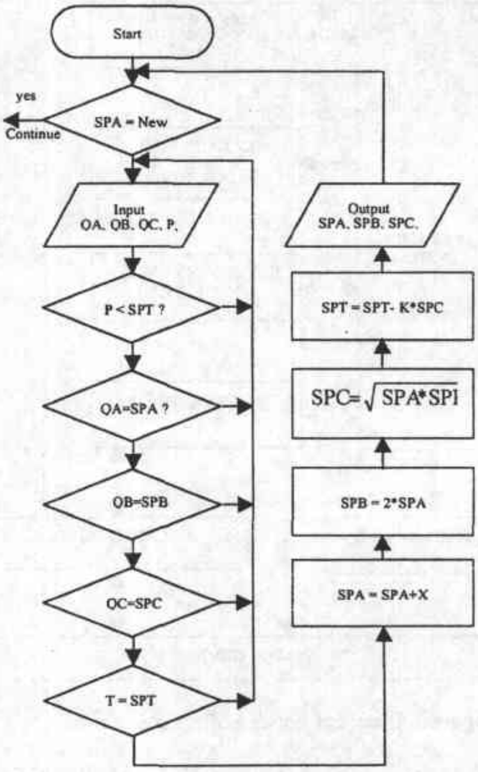

Figure 4. Event Flow Diagram for Example 1.

The control computer obtain the current values of flow rate A, B, C, pressure and temperature. New set points for flow rate A, B, C and temperature are calculated and output to the analog controller. The response time to give a set of new set points will be in 100us. Most of the adjustment time is spent waiting for the loops to stabilise. The instant such stabilisation occurs, the next increment of set points is made.

- Direct Digital Control

Example 2:

Figure 5 shows a simplified fuel system of an oil air heater as an example for DAC. The system will use DDC PI control with 40% PB, 0.5%/min integration time, and a 0.75 minute sample time. The input is to be average of five temperatures, and the output will be a control signal to the fuel control valve.

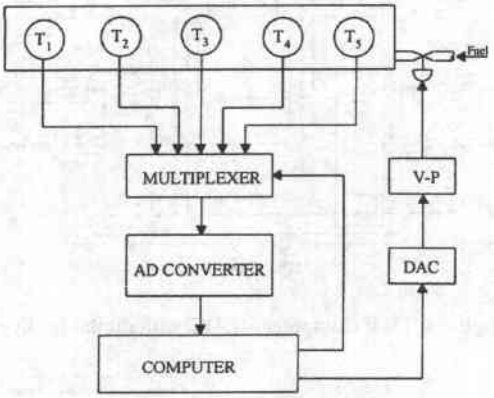

Figure 5. A Simplified Fuel System.

1. A temperature measurement device is available which provides a voltage from the temperature transducer with the following relationships;

   $V= 0.075*T+0.0004*T*T;$

2. Temperature range is 0 degree C to 90 degree C with a 57 degree C set point,
3. For initial start up, the output signal to the valve should be 5 volts. The valve is driven directly from a D/A converter, adjusted so that 0 (hex) is 0 volts and FF (hex) is 10 volts,
4. A data acquisition system is available with five channels and a A/D converter which converts 0 volts to 0 (hex) and 10 volts to FF (hex).

The general flow diagram of the above system is shown in Figure 6. The output signal to drive the fuel valve is calculated as follow;

1. Voltage to temperature conversion
   $V= 0.075*T+0.0004*T*T$
   $T=-93.75+(8789+2500*V)^{0.5}$
2. Calculate the error
   $Ep=(Tavg-57)/90*100$
   Tavg: average temperature
3. Calculate the proportional gain
   PB=40%→error changes by 40% the output changes by 100%
   Kp=100/40=2.5%/%
4. Calculate the integration term
   Integral gain=0.5%/min →1% error contribute 0.5% change
   Sampling time is 0.75 min
   Integral gain is actually →(0.5%/min)/0.75 min/sample= 0.375%/sample
5. Calculate output
   Output signal to DDC;
   $P=2.5*Ep+0.9375*SUM$
   and adjust no of pulse output so that 100% equal to 255 (FF hex)
   $Pout=2.55*P$

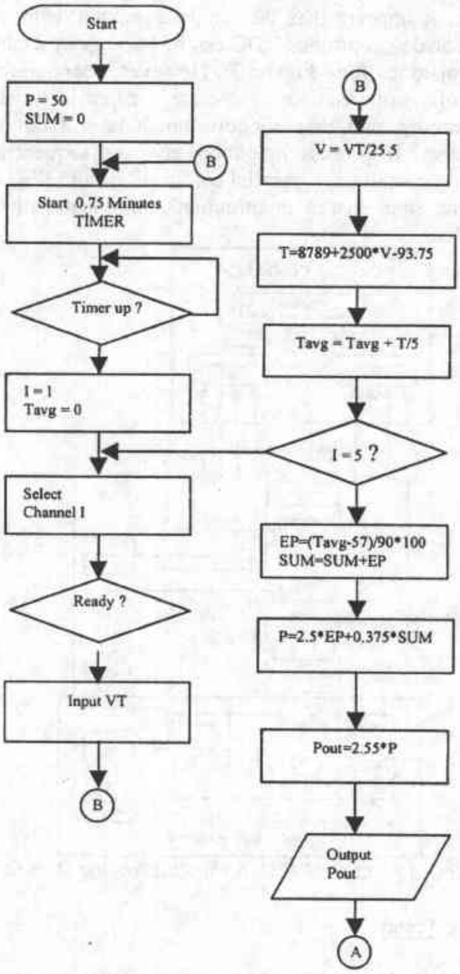

Figure 6. Event Flow Diagram for Example 2.

## DISCUSSION AND CONCLUSION

### General

This paper presents a discussion of the general features of computer application in process control. The important features are;

1. Digital Analog Control lets the computer to adjust process-loop set points for optimum process performance even through standard analog control loops are still used for control,
2. Direct Digital Control eliminates the analog controller and replaces the mode implementation by programs within the computer,
3. Auxiliary functions, such as logs, data trending, alarm reports, background job processing are also available.

## Backup Equipments

A digital computer may sometimes fail, therefore control security must always be considered on any process installation contemplating a digital computer.

For continuous processes, involving less than 150 loops, it appears that the single computer with set point analog control or DDC can be back up by analog control loops (See Figure 7). However, economic of control optimisation, advance control, event sequencing, and user support functions will not be available. If process operation involves sequencing and logic analysis, a parallel computer system (Figure 8) with time shared input/output equipment will be suitable.

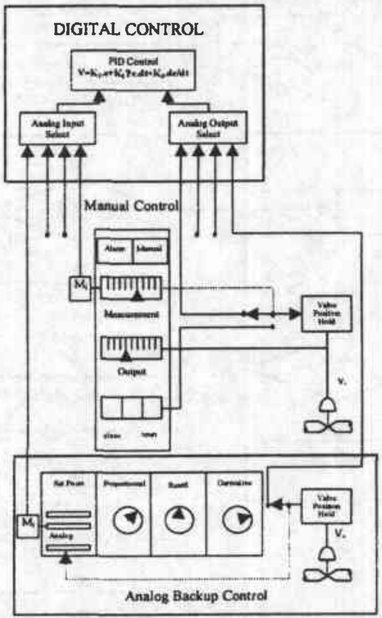

Figure 7. Direct Digital Control with Analog Backup.

## Future Trend

Manufacturing system of any process or plant can be viewed as a pyramid structure as shown in Figure 9. The first level is the process control functions which include single or multivariable control activities, usually associated with the control of process units. Production control at the second level is the guidance for the utilisation of production facilities; it covers such activities as scheduling, inventory Control, cost control, maintenance planning etc. The management control at the third level include the setting objectives to be achieved by the system within the constraints of policy. The availability of on-line process control computers makes it possible to affect in real-time the entire information network of the production process and to implement integrated systems that will perform control functions at all levels of the hierarchy.

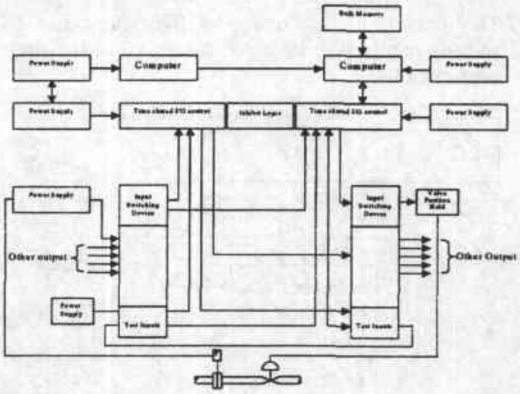

Figure 8. Dual Computer – DDC with digital backup

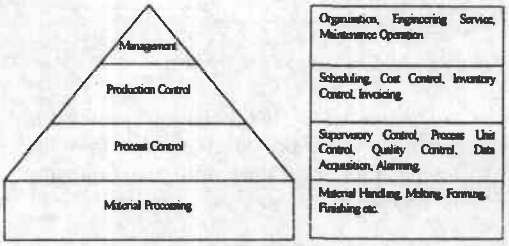

Figure 9. Plant Function.

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