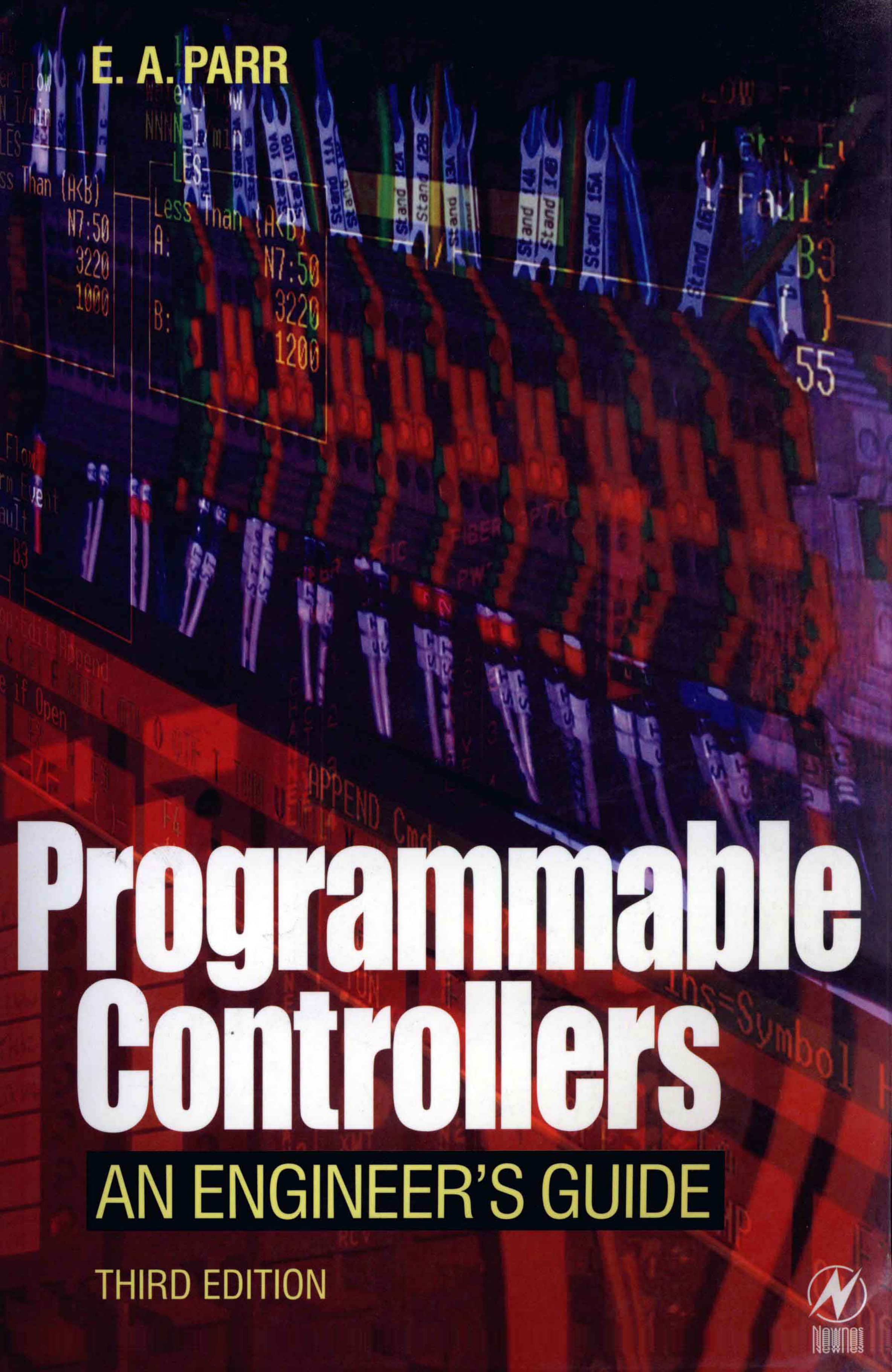

E. A. PARR

Programmable Controllers

AN ENGINEER'S GUIDE

THIRD EDITION

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Programmable Controllers

In memory of Arthur Parr, 1913–1992.

Man is still the most extraordinary computer of all.

John F. Kennedy
21 May 1963

Preface

All industrial processes need some form of control system if they are to run safely and economically. In recent years a specialist control computer, called a programmable controller, has evolved and revolutionized control engineering by combining computing power and immense flexibility at a reasonable price.

This book is concerned with the application and use of programmable controllers. It is not an instructional book in programming, and is certainly not a comparative guide to the various makes of machine on the market.

To some extent, choosing a programmable controller is rather like choosing a word processor. You ask people for their views, try a few simple examples in a shop, and buy the cheapest that you think meets your requirements. Only after several months do you really know the system. From then on, all other word processors seem awkward.

Programmable controllers are similar. Unless there are good reasons for a particular choice (ready experience in the engineering or maintenance staff, equipment being supplied by an outside contractor and similar considerations), there are good and bad points with all (the really bad machines left the market years ago).

At the Sheerness Steel Company where I work, the plant control is based on about sixty programmable controllers consisting of Allen Bradley PLC 2s and 5s, GEC (now CEGELEC) GEM-80s, ASEA (now ABB) Masters and Siemens SIMATIC S5s, with small machines primarily from Mitsubishi. These controllers are somewhat like the trees at Galleons Lap in Winnie the Pooh; there never seems to be the same number on two successive days, even if you tie a piece of string around each one!

As with most plants, the background to this distribution of controllers is largely historical chance (the original Mitsubishi came on a small turn-key plant from an outside contractor, for example), but the ready access to these machines is the reason for their prominence in this book.

Even within this range of PLC families, the coverage in this book is not complete. The PLCs have been chosen to cover the application points I wish to make, not as a complete survey of a manufacturer's range.

In 'previous lives' I have worked with PLCs from AEG, GE, Landys and Gyr, Modicon, Telemecanique, Texas Instruments and many other companies. To these manufacturers I offer my sincere apologies for not giving them more coverage, but to do so would have made a tedious book and masked the application points I have tried to make. I could happily use any of these machines, and there is not a major difference in style or philosophy between them (the manufacturers would no doubt disagree!).

The guideline is therefore choose a machine that suits *you*, and do not change manufacturers for purely economic reasons. Knowledge, consistency of spares and a good relationship with a manufacturer are very valuable.

A book like this requires much assistance, and I would like to thank Peter Bark and Dave Wilson of ABB, Adrian Bishop, Bob Hunt, Julian Fielding, John Hanscombe, Hugh Pickard, Jennie Holmes and Hennie Jacobs of Allen Bradley, Peter Backenist, David Slingsby and Stuart Webb of GEC/CEGELEC, Peter Houldsworth, Paul Judge, Allan Norbury, Dickon Purvis, Paul Brett and Allan Roworth of Siemens, and Craig Rousell who all assisted with information on their machines, commented constructively on my thoughts and provided material and photographs.

My fellow engineers at Sheerness Steel also deserve some praise for tolerating my PLC systems (and who will no doubt compare my written aims with our actual achievements!).

A book takes some time to write, and my family deserve considerable thanks for their patience.

Andrew Parr
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Note for second edition

This revision incorporates additional material covering recent developments, and reflects the increasing importance of health and safety legislation.

Notes for third edition

This edition includes a new chapter giving example ladder rungs for common industrial problems. Screen shots of Windows based programming software have been included to show how programs are entered. Health and Safety issues, particularly the introduction of IEC 61508, have been updated.

Contents

1 Computers and industrial control

1.1 Introduction

Very few industrial plants can be left to run themselves, and most need some form of control system to ensure safe and economical operation. Figure 1.1 is thus a representation of a typical installation, consisting of a plant connected to a control system. This acts to translate the commands of the human operator into the required actions, and to display the plant status back to the operator.

At the simplest level, the plant could be an electric motor driving a cooling fan. Here the control system would be an electrical starter with protection against motor overload and cable faults. The operator controls would be start/stop pushbuttons and the plant status displays simply running/stopped and fault lamps.

At the other extreme, the plant could be a vast petrochemical installation. Here the control system would be complex and a mixture of technologies. The link to the human operators will be equally varied, with commands being given and information displayed via many devices.

In most cases the operator will be part of the control system. If an alarm light comes on saying 'Low oil level' the operator will be expected to add more oil.

1.2 Types of control strategies

It is very easy to be confused and overwhelmed by the size and complexity of large industrial processes. Most, if not all, can be simplified by considering them to be composed of many small sub-processes. These sub-processes can generally be considered to fall into three distinct areas.

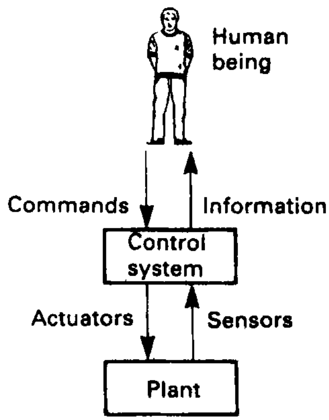

Figure 1.1 *A simple view of a control system*

1.2.1 Monitoring subsystems

These display the process state to the operator and draw attention to abnormal or fault conditions which need attention. The plant condition is measured by suitable sensors.

Digital sensors measure conditions with distinct states. Typical examples are running/stopped, forward/off/reverse, fault/healthy, idle/low/medium/high, high level/normal/low level. Analog sensors measure conditions which have a continuous range such as temperature, pressure, flow or liquid level.

The results of these measurements are displayed to the operator via indicators (for digital signals) or by meters and bargraphs for analog signals.

The signals can also be checked for alarm conditions. An overtravel limit switch or an automatic trip of an overloaded motor are typical digital alarm conditions. A high temperature or a low liquid level could be typical analog alarm conditions. The operator could be informed of these via warning lamps and an audible alarm.

A monitoring system often keeps records of the consumption of energy and materials for accountancy purposes, and produces an event/alarm log for historical maintenance analysis. A pump, for example, may require maintenance after 5000 hours of operation.

1.2.2 Sequencing subsystems

Many processes follow a predefined sequence. To start the gas burner of Figure 1.2, for example, the sequence could be:

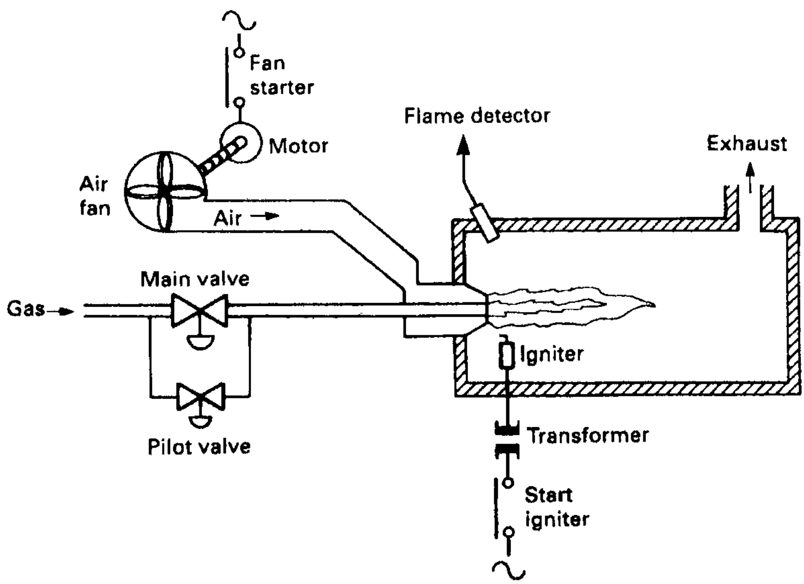

Figure 1.2 *Gas-fired burner, a sequence control system*

(a) Start button pressed; if sensors are showing sensible states (no air flow and no flame) then sequence starts.
(b) Energize air fan starter. If starter operates (checked by contact on starter) and air flow is established (checked by flow switch) then
(c) Wait two minutes (for air to clear out any unburnt gas) and then
(d) Open gas pilot valve and operate igniter. Wait two seconds and then stop igniter and
(e) If flame present (checked by flame failure sensor) open main gas valve.
(f) Sequence complete. Burner running. Stays on until stop button pressed, or air flow stops, or flame failure.

The above sequence works solely on digital signals, but sequences can also use analog signals. In the batch process of Figure 1.3 analog sensors are used to measure weight and temperature to give the sequence:

1 Open valve V1 until 250 kg of product A have been added.
2 Start mixer blade.
3 Open valve V2 until 310 kg of product B have been added.
4 Wait 120 s (for complete mixing).
5 Heat to 80 °C and maintain at 80 °C for 10 min.
6 Heater off. Allow to cool to 30 °C.
7 Stop mixer blade.
8 Open drain valve V3 until weight less than 50 kg.

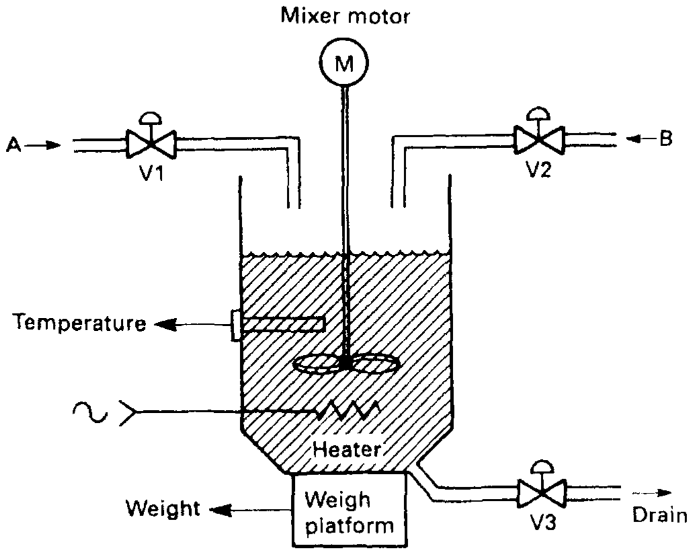

Figure 1.3 *A batch process*

1.2.3 Closed loop control subsystems

In many analog systems, a variable such as temperature, flow or pressure is required to be kept automatically at some preset value or made to follow some other signal. In step 5 of the batch sequence above, for example, the temperature is required to be kept constant to 80 °C within quite narrow margins for 10 minutes.

Such systems can be represented by the block diagram of Figure 1.4. Here a particular characteristic of the plant (e.g. temperature) denoted by PV (for process variable) is required to be kept at a preset value SP (for setpoint). PV is measured by a suitable sensor and compared with the SP to give an error signal

$$\text{error} = SP - PV \tag{1.1}$$

If, for example, we are dealing with a temperature controller with a setpoint of 80 °C and an actual temperature of 78 °C, the error is 2 °C.

This error signal is applied to a control algorithm. There are many possible control algorithms, and this topic is discussed in detail in Chapter 4, but a simple example for a heating control could be 'If the error is negative turn the heat off, if the error is positive turn the heat on.'

The output from the control algorithm is passed to an actuator which affects the plant. For a temperature control, the actuator could be a heater, and for a flow control the actuator could be a flow control valve.

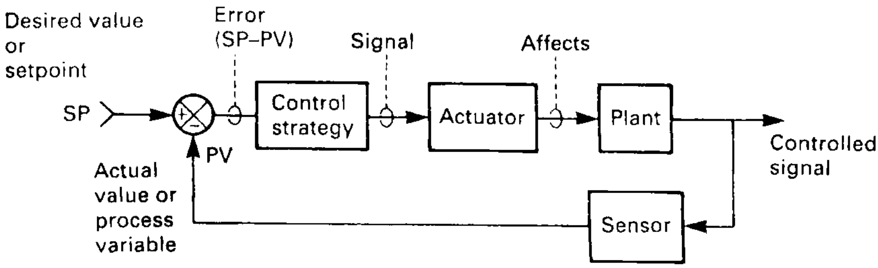

Figure 1.4 *A closed loop control system*

The control algorithm will adjust the actuator until there is zero error, i.e. the process variable and the setpoint have the same value.

In Figure 1.4, the value of PV is fed back to be compared with the setpoint, leading to the term 'feedback control'. It will also be noticed that the block diagram forms a loop, so the term 'closed loop control' is also used.

Because the correction process is continuous, the value of the controlled PV can be made to track a changing SP. The air/gas ratio for a burner can thus be maintained despite changes in the burner firing rate.

1.2.4 Control devices

The three types of control strategy outlined above can be achieved in many ways. Monitoring/alarm systems can often be achieved by connecting plant sensors to displays, indicators and alarm annunciators. Sometimes the alarm system will require some form of logic. For example, you only give a low hydraulic pressure alarm if the pumps are running, so a time delay is needed after the pump starts to allow the pressure to build up. After this time, a low pressure causes the pump to stop (in case the low pressure has been caused by a leak).

Sequencing systems can be built from relays combined with timers, uniselectors and similar electromechanical devices. Digital logic (usually based on TTL or CMOS integrated circuits) can be used for larger systems (although changes to printed circuit boards are more difficult to implement than changes to relay wiring). Many machine tool applications are built around logic blocks: rail-mounted units containing logic gates, storage elements, timers and counters which are linked by terminals on the front of the blocks to give the required operation. As with a relay system, commissioning changes are relatively easy to implement.

Closed loop control can be achieved by controllers built around DC amplifiers such as the ubiquitous 741. The 'three-term controller'