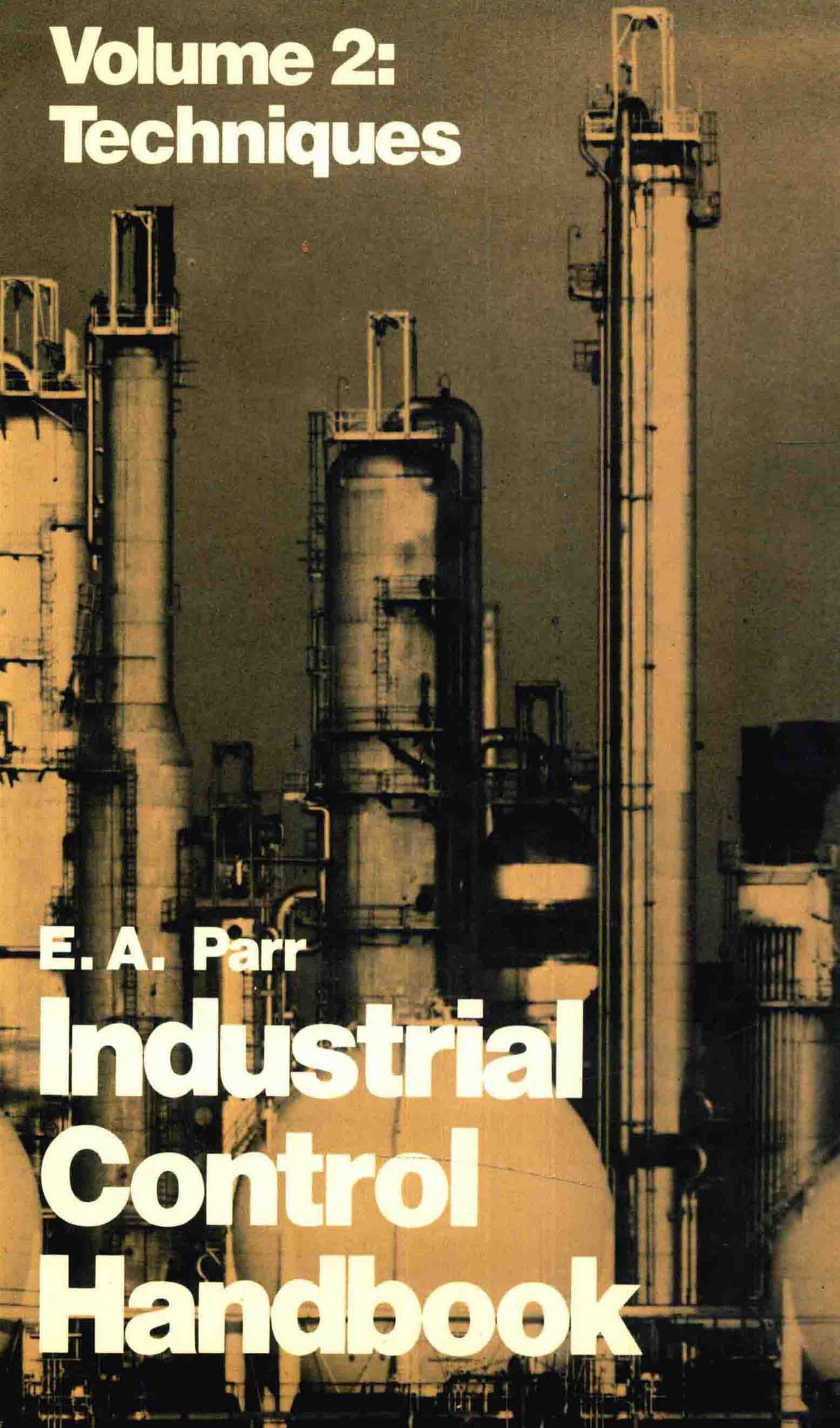

Volume 2: Techniques

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Industrial Control Handbook

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Industrial Control Handbook

Volume 2: Techniques

For Alison

Technology has brought meaning to the life of many technicians.

Ed Bluestone

Preface

This book is the second in a three-volume series on the topic of industrial process control. The aim of the series is to present the subject in a practical manner that reflects the way industry works. Volume 1 covers the vital sensors and transducers that gather information from the plant. Volume 3 gives the background theory and mathematics normally associated with process control, and provides the link between theory and practice. The series should be of value to both the newly qualified engineer (for whom the bridge from theory to practice is often difficult to cross) and the practising engineer who wishes to widen his base of knowledge.

The process control engineer has to be competent in a wide range of technologies–power electronics, pneumatics, hydraulics and computing to name a few. This volume is concerned with these and other techniques, and gives sufficient detail for the engineer to use and apply the equipment described.

Many people have helped in the preparation of this book, particularly my fellow engineers at the Sheerness Steel Company who have given helpful suggestions and advice. Special thanks are due to my long-suffering family for the ever increasing backlog of work that remains unfinished about the house. Apologies are due to a very patient Bernard Watson of Collins who tolerated a deadline that seemed to follow the pattern of suppliers' delivery dates and slip further and further back! Many companies have provided information and photographs. These are acknowledged at the relevant places in the text.

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Kent

June 1987

Contents

Chapter 1
DC amplifiers

1.1. Introduction

1.1.1. DC amplifier requirements

Signals in instrumentation and process control are generally represented digitally, pneumatically or as an analog voltage or current. Digital signals are covered in chapter 3, and pneumatics in chapter 6. This chapter is concerned with the manipulation of signals represented as an electrical voltage or current.

Instrumentation signals are essentially static for long periods, and as such require amplifiers with predictable characteristics down to 0 Hz, i.e. DC amplifiers. A typical AC audio amplifier, for comparison, would have little gain below about 20 Hz, and would 'droop' on low-frequency signals as fig.1.1a. The lower frequency limit in AC amplifiers is usually determined by the impedance of coupling capacitors between stages and emitter decoupling capacitors. In fig.1.1b, the impedances of C1 to C5 will all increase with decreasing frequency, causing the gain to fall. DC amplifiers therefore use direct coupling between stages.

Direct coupling, however, brings its own problems. Figure 1.2a shows a possible design for a simple direct coupled amplifier. Unfortunately almost all transistor parameters vary with temperature and from device to device. V_{be}, for example, changes by 2 mV per °C, and collector/emitter leakage current doubles every 10°C. These, and similar effects, will cause the output of fig.1.2a to vary in a manner which is indistinguishable from changes caused by the signal itself.

Most DC amplifiers are based on the so-called long tailed pair circuit of fig.1.2b. TR1 and TR2 are identical transistors maintained at the same temperature (both conditions being ensured by constructing the circuit on a single integrated

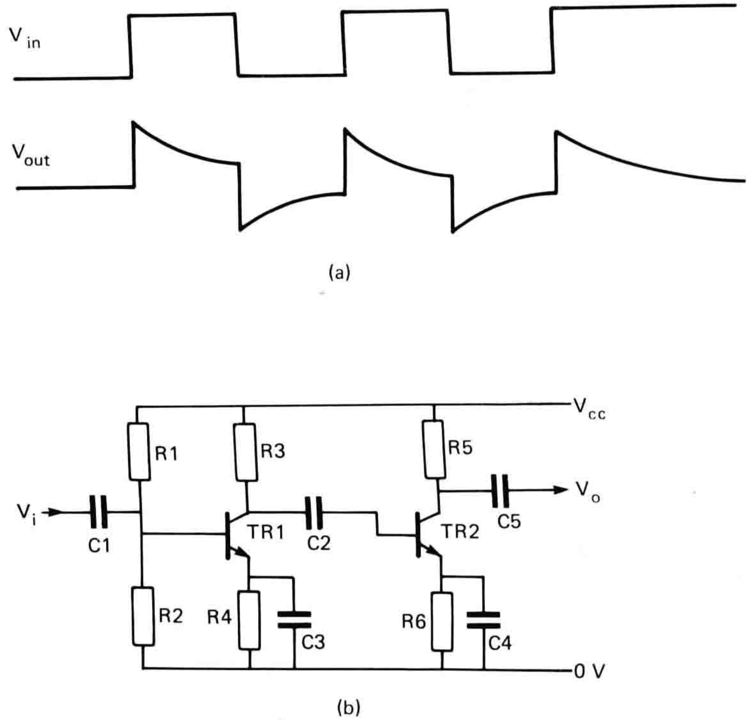

Fig. 1.1 The effect of AC amplifiers on low frequency signals. (a) The effect of poor low frequency response on a signal. (b) A simple AC amplifier. The low frequency response is determined by capacitors C1–C5.

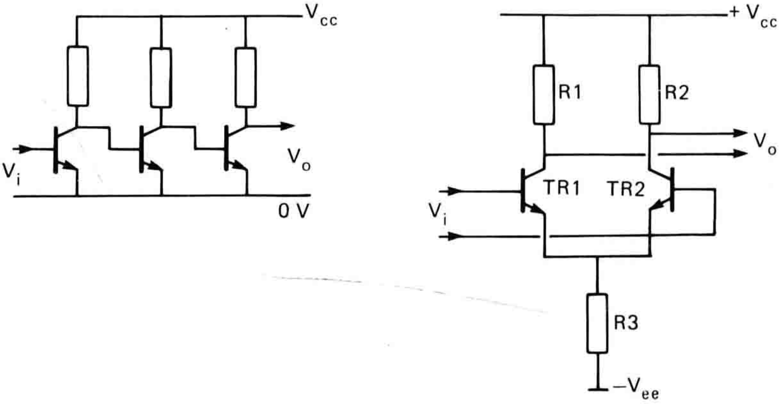

Fig. 1.2 DC amplifier circuits. (a) Simple DC amplifier. (b) The long tail pair.

circuit–IC–silicon wafer). Resistor R3 acts as a constant current sink, with the current being split between TR1/TR2. Because the two transistors are identical and at the same temperature, leakage currents and offsets will cancel and the current split between TR1, TR2 will depend solely on V_{in}. The output voltage is therefore an amplified version of V_{in}, and is unaffected by temperature changes. Note that fig.1.2b is, in effect, a *differential* amplifier because it amplifies the voltage difference between its two inputs.

1.1.2. Integrated circuit DC amplifiers

It is exceedingly rare nowadays for DC amplifiers to be constructed of individual transistors. The requirements of fig.1.2b are identical components and a uniform circuit temperature. These conditions are best met by fabricating the entire circuit as an IC. There are many IC DC amplifiers available with different characteristics, but by far the commonest is the ubiquitous 741, arguably the most successful IC ever designed. Other DC amplifiers are similar in principle, differing only in, say, greater or lesser gain or perhaps frequency response. DC amplifier specifications are described in section 1.2.

A DC amplifier can be represented by fig.1.3a; this has two inputs, two power supply connections (usually symmetrical 15 volts positive and negative) and the output. Note that all voltages (including the power supplies) are referred to the 0V rail, even though the DC amplifier itself does not need an 0V connection. The output voltage is given by:

$$V_o = A\,(V1 - V2) \qquad (1.1)$$

where A is the amplifier gain.

Input 1 is usually called the non-inverting input and input 2 the inverting input, for reasons that can be seen by linking each input to 0V in turn. With input 2 linked to 0V, and a signal applied to input 1, $V_o = AV1$; the output moves in the same sense as the input signal. With input 1 linked to 0V, and a signal applied to input 2, $V_o = -AV2$; the output moves in the opposite sense to the input signal. Often a + sign is used for the non-inverting input and a − sign for the inverting input; these should not be confused with the power supply connections.