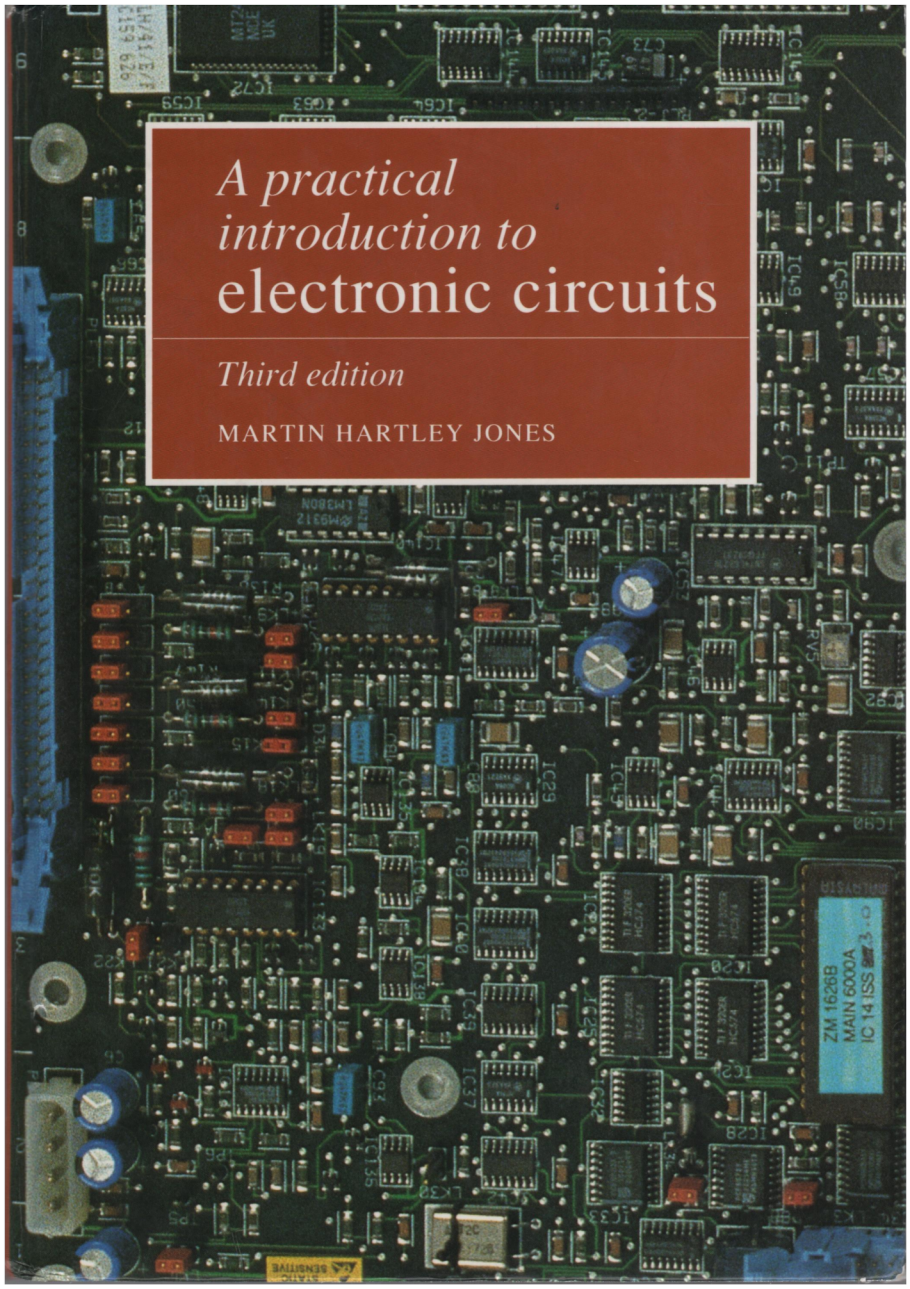

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Cover illustration from radar processing circuit.
Courtesy Kelvin Hughes Ltd.

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11

Integrated circuit analogue building bricks

11.1 Introduction

The integrated circuit (IC) is clearly the building brick of electronic circuits. We have already had a flavour of IC applications when looking at power supply regulators. Now we turn towards the full range of IC capabilities. A glance through a component distributor's catalogue reveals a seemingly limitless range of ICs for virtually every conceivable function. An IC may contain from a dozen transistors to a million depending on the application, together with all necessary resistors, diodes etc. The intimate thermal connection achieved by fabricating all the components on one chip of silicon generally leads to excellent stability and predictability in use.

The understanding of discrete components gained from earlier chapters will be found essential to the proper interfacing of ICs: in fact even today very few analogue circuit applications dispense totally with discrete semiconductors. However, the IC designer has today relieved the circuit designer of much of the 'donkey work'. In addition, the small size and low power consumption of ICs has made possible products like the Camcorder and hand-held GPS position-fixing satellite receiver.

This chapter deals with applications of linear ICs. They are designed to handle *analogue* signals, which carry their information in terms of amplitude and waveshape. Most audio and radio signals come into this category; they are distinct from the standard binary pulses of digital circuits which are discussed in chapter 13. To give an idea of the scope of this chapter, fig. 11.1 includes many of the basic building bricks which will be discussed and provides a quick reference to the outline circuits.

11.2 The operational amplifier

11.2.1 Simplifying assumptions

All the circuits of fig. 11.1 make use of an *operational amplifier* (op amp). The term 'operational' is generally used nowadays to describe a high-gain voltage amplifier, particularly one in IC form; the name is derived from the original use of such amplifiers in analogue computing *operations*. The characteristics of an op amp are such that the following simplifying assumptions can be made in most practical circuits:

infinite open-loop voltage gain, A_{VOL} (typically 2×10^5)
infinite input impedance (typically 2 MΩ)
zero output impedance (typically 75 Ω)

The parameter values quoted above refer to the popular 741 type IC amplifier which is used in many of the practical circuits in this book.

11.2.2 Input bias current and offset voltage

The input terminals of an op amp connect to internal transistor bases or gates which must be given some d.c. reference and be able to draw a small bias current if the amplifier is to function (there are no coupling capacitors on the chip). Input bias current in the 741 amplifier is about 100 nA. The first design consideration, therefore, is that each input of any IC amplifier must have some sort of d.c. path to earth, even if it is through a high-value resistor.

Ideally, both the inverting and non-inverting inputs should 'see' the same resistance to earth; otherwise, as fig. 11.2 shows, an effective input offset voltage will appear. We can assume that the two input bias currents are equal, i.e.

$$I_1 = I_2.$$

Hence, if $R_1 = R_2$, V_1 and V_2 will be equal and there will be zero effective differential offset voltage $(V_2 - V_1)$ at the amplifier inputs. In most circuits, the inverting input will normally have a feedback resistor R_f connected through to the output as in fig. 11.3 and therefore a proportion of the bias current will be drawn from the output through R_f. Now, if our circuit is designed correctly so that the offset voltage is zero, then the output will be at 0 V level under quiescent conditions. This means that, as far as the input bias current is

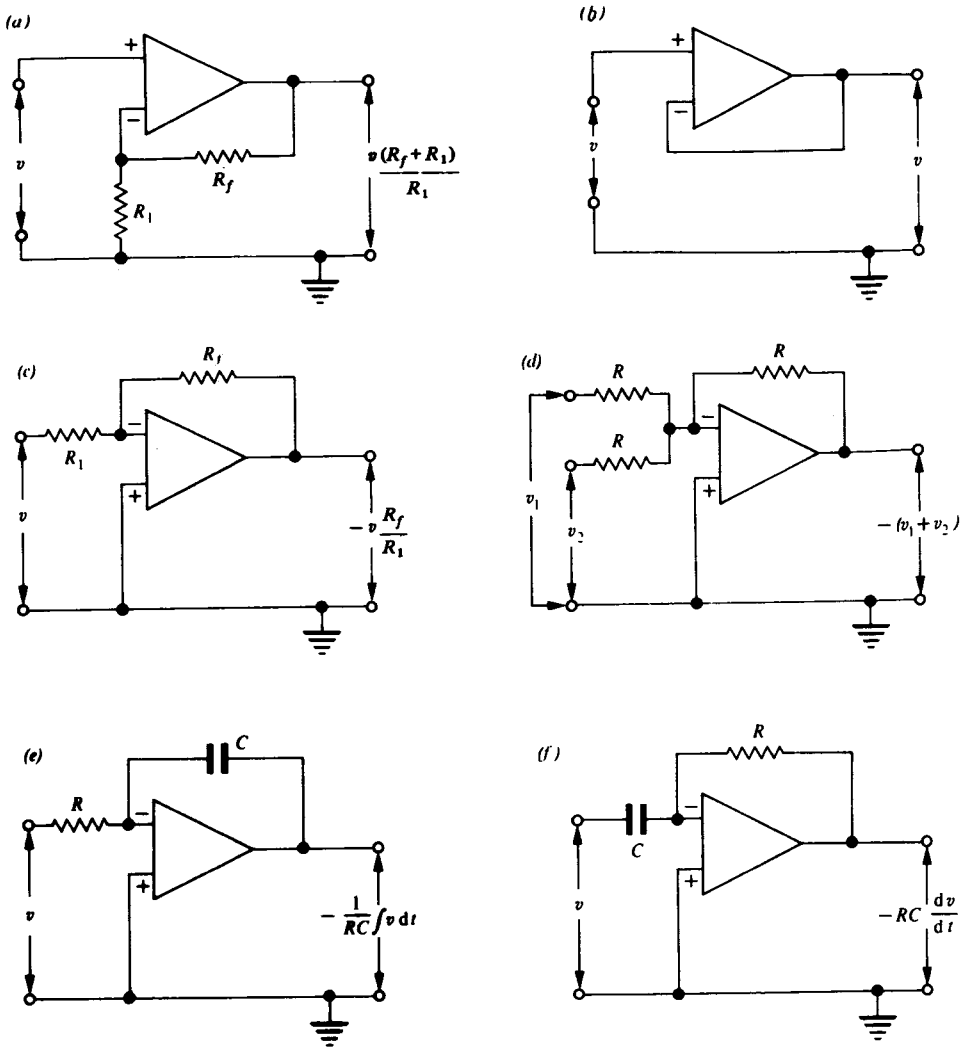

Fig. 11.1. (*a*) Non-inverting amplifier. (*b*) Voltage follower. (*c*) Inverting amplifier. (*d*) Adder. (*e*) Integrator. (*f*) Differentiator.

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