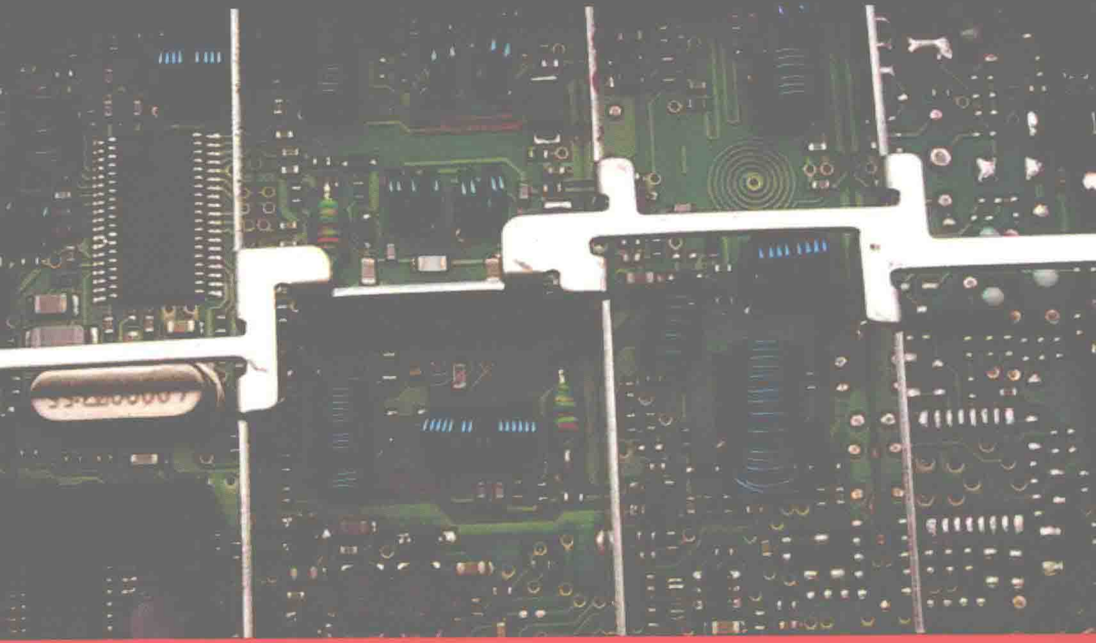
FOURTH EDITION

Starting Electronics



KEITH BRINDLEY

Newnes

Starting Electronics

Fourth Edition

Keith Brindley

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Starting Electronics

For Jane – it's not much,
but it's mine, and it's all because of you …

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Preface

This book originated as a collection of feature articles, previously published as a series of magazine articles in the, then, leading hobbyist electronics magazine in the UK. They were chosen for publication in book form later, not only because they were so popular with readers in their original magazine appearances, but also because they are so relevant in the field of introductory electronics – a subject area in which it is evermore difficult to find information of a technical, knowledgeable, yet understandable nature for anyone wanting to "get into" electronics. This book – hopefully – is exactly that.

Since its original publication, and with each successive new edition, I have added significant new material to make sure it is all still highly relevant and up to date. Without doubt, electronics is a rapidly moving area to study, but where this book has always been and still is firmly aimed – right at the very introduction to electronics – it manages to provide one of the best entries to the subject a reader can make.

I hope you will agree that the practical nature of the book lends itself to a self-learning experience that readers can follow in a logical and easily manageable manner. I also hope that you enjoy your journey into electronics, because even though it is a highly technical and quite demanding subject, it should also be fun.

Enjoy *Starting Electronics*! That's what I intended when I wrote it, and what I continue to believe you should do.

Keith Brindley, 2011

Contents

Chapter 1

The Very First Steps

Most people look at an electronic circuit diagram, or a printed circuit board, and have no idea what they are. One component on the board, and one little squiggle on the diagram, looks much as another. For them, electronics is a black art, practiced by weird techies, spouting untranslatable jargon and abbreviations that make absolutely no sense whatsoever to the rest of us in the real world.

But this needn't be! Electronics is not a black art – it's just a science. And like any other science – chemistry, physics, or whatever – you only need to know the rules to know what's happening. What's more, if you know the rules you're set to gain an awful lot of enjoyment from it because, unlike many sciences, electronics is a practical one, more so than just about any other science. The scientific rules that electronics is built on are few and far between, and many of them don't even have to be considered when we deal in components and circuits. Most of the things you need to know about components and the ways they can be connected together are simply mechanical and don't involve complicated formulae or theories at all.

That's why electronics is a hobby that can be immensely rewarding. Knowing just a few things, you can set about building your own circuits. You can understand how many modern electronic appliances work, and you can even design your own. I'm not saying you'll be an electronics whizz-kid, of course – it really does take a lot of studying, probably a university degree, and at least several years' experience to be that – but what I am saying is that there's lots you can do with just a little practical knowledge. That's what this book is all about – starting electronics. The rest is up to you.

WHAT YOU NEED

Obviously, you'll need some basic tools and equipment. Just exactly what these are and how much they cost depends primarily

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on quality. But some of these tools, as you'll see in the next few pages, are pretty reasonably priced, and well worth having. Other expensive tools and equipment that the professionals often have can usually be substituted with tools or equipment costing only a fraction of the price. So, as you'll see, electronics is not an expensive hobby. Indeed, its potential reward in terms of enjoyment and satisfaction can often be significantly greater than its cost.

In this first chapter I'll give you a rundown of all the important tools and equipment: the ones you really do need. There's also some rough guidelines to their cost, so you'll know what you'll have to pay. The tools and equipment described here, however, are the most useful ones you'll ever need and chances are you'll be using them as long as you're interested in electronics. For example, I'm still using the side-cutters I got over 20 years ago. That's got to be good value for money.

TOOLS OF THE TRADE

Talking of cutters, that's the first tool you need. There are many types of cutters but the most useful sorts are side-cutters. Generally, buy a small pair – the larger ones are OK for cutting thick wires but not for much else. In electronics most wires you want to cut are thin so, for most things, the smaller the cutters the better.

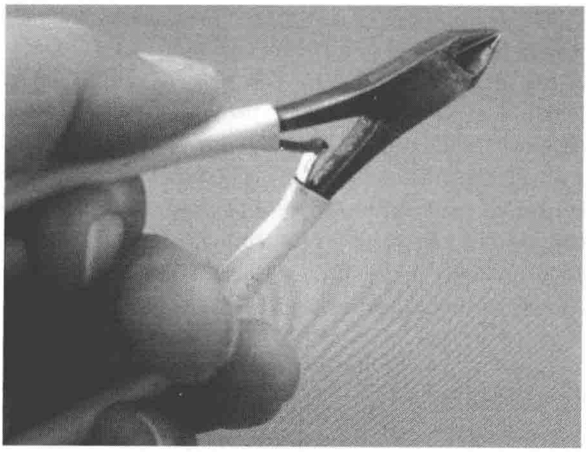

PHOTO 1.1 Side-cutters like these are essential tools – buy the best you can afford.

Hint

If you buy a small pair of side-cutters (as recommended), don't use them for cutting thick wires, or you'll find they won't last very long and you'll have wasted your money.

You can expect to pay from £4 up to about £50 or so (about US $7–85) for a good-quality pair, so look around and decide how much you want to spend.

You can use side-cutters for stripping insulation from wires too, if you're careful. But a proper wire-stripping tool makes the job much easier, and you won't cut through the wires underneath the insulation (which side-cutters are prone to do) either. There are many different types of wire strippers ranging in price from around £3 to (wait for it!) over £100 (about US $5–165). Of course, if you don't mind paying large dentist's bills you can always use your teeth – but certainly don't say I said so. You didn't hear that from me, did you?

A small pair of pliers is useful for lightly gripping components and the like. Flat-nosed or, better still, snipe-nosed varieties are preferable, costing between about £4 and £50 or so (around US $7–85). Like side-cutters, however, these are not meant for heavy-duty engineering work. Look after them and they'll look after you.

The last essential tool we're going to look at now is a soldering iron. Soldering is the process used to connect electronic

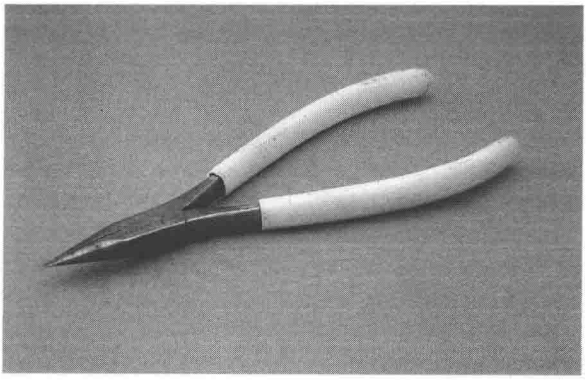

PHOTO 1.2 Snipe-nosed pliers – ideal for electronics work and another essential tool.

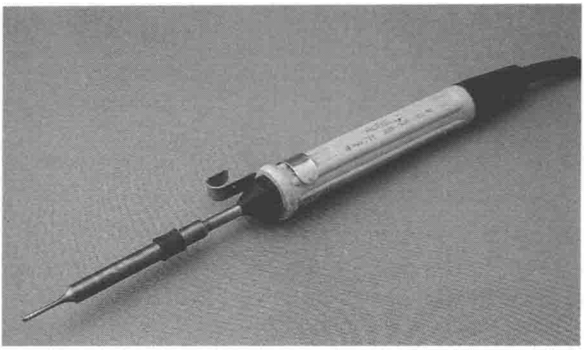

PHOTO 1.3 Low-wattage soldering iron intended for electronics.

components together, in a good permanent joint. Soldering irons range in price from about £10 to (gulp!) about £150 (about US $15–250), but – fortunately – the price doesn't necessarily reflect how useful they are in electronics. This is because irons used in electronics generally should be of pretty low power rating, because too much heat doesn't make any better a joint where tiny electronic components are concerned, and you run the risk of damaging the components too. Power rating will usually be specified on the iron or its packing and a useful iron will be around 25 watts (which may be marked 25 W).

It's possible to get soldering irons rated up to and over 100 watts, but these are of no use to you as a beginner – stick with an iron with a power rating of no more than 30–40 watts. Because of this low power need, you should be able to pick up a good iron for around £20 (about US $35).

These are all the tools we are going to look at in this chapter (I've already spent lots of your money – you'll need a breather to recover), but later on I'll be giving details of other tools and equipment that will be extremely useful to you.

IDEAS ABOUT ELECTRICITY

Electricity is a funny thing. Even though we know how to use it, how to make it do work for us, to amplify, to switch, to control, to create light or heat (you'll find out about all of these aspects of electricity over the coming chapters), we can still only guess at what it is. It's actually impossible to see electricity: we only see what it does! Sure, everyone knows that electricity is a flow

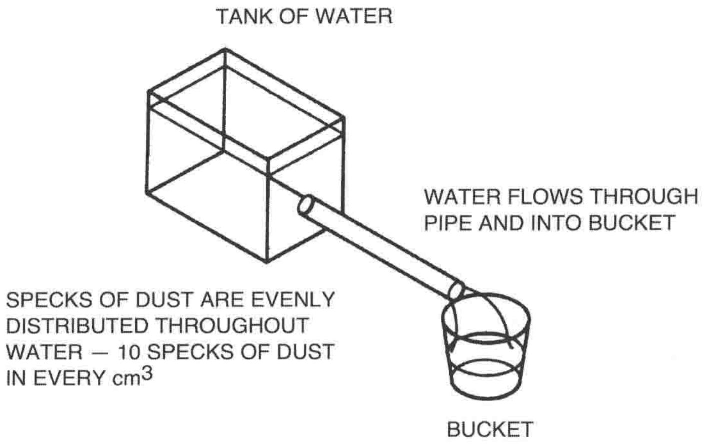

FIGURE 1.1 Water flowing in a pipe is like electricity in a wire.

of electrons, but what are electrons? Have you ever seen one? Do you know what they look like?

The truth of the matter is that we can only hypothesize about electricity. Fortunately, the hypothesis can be seen to stand in all of the aspects of electricity and electronics we are likely to look at, so to all intents and purposes the hypothesis we have is absolute. This means we can build up ideas about electricity and be fairly sure they are correct.

Right then, let's move on to the first idea: that electricity is a flow of electrons. To put it another way, any flow of electrons is electricity. If we can measure the electricity, we must therefore be able to say how many electrons were in the flow. Think of an analogy – say, the flow of water through a pipe (Figure 1.1). The water has an evenly distributed number of foreign bodies in it. Let's say there are 10 foreign bodies (all right then, 10 specks of dust) in every cm^3 of water.

Now, if 1 liter of water pours out of the end of the pipe into the bucket shown in Figure 1.1, we can calculate the number of specks of dust that have flowed through the pipe. There's, as near as dammit, $1000\,cm^3$ of water in a liter, so:

$$10 \times 1000 = 10{,}000$$

water-borne specks of dust must have flowed through the pipe.

Alternatively, by knowing the number of specks of dust which have flowed through the pipe, we can calculate the volume of water. If, for example, 25,000 specks of dust have flowed, then 2.5 liters of water will be in the bucket.

Charge

It's the same with electricity, except that we measure an amount of electricity not as a volume in liters, but as a charge in coulombs (pronounced koo-looms). The foreign bodies that make up the charge are, of course, electrons.

There's a definite relationship between electrons and charge: in fact, there are about 6,250,000,000,000,000,000 electrons in one coulomb. But don't worry, it's not a number you have to remember – you don't even have to think about electrons and coulombs because the concept of electricity, as far as we're concerned, is not about electron flow, or volumes of electrons, but about flow rate and flow pressure. And as you'll now see, electricity flow rate and pressure are given their own names which – thankfully – don't even refer to electrons or coulombs. Going back to the water and pipe analogy, flow rate would be measured as a volume of water that flowed through the pipe during a defined period of time, say 10 liters in 1 minute, 1000 liters in 1 hour, or 1 liter in 1 second.

With electricity, flow rate is measured in a similar way, as a volume that flows past a point during a defined period of time, except that volume is, of course, in coulombs. So, we could say that a flow rate of electricity is 10 coulombs in 1 minute, 1000 coulombs in 1 hour, or 1 coulomb in 1 second.

We could say that, but we don't! Instead, in electricity, flow rate is called current (and given the symbol I, when drawn in a diagram).

Electric current is measured in amperes (shortened to amps, or even further shortened to the unit: A), where 1 amp is defined as a quantity of 1 coulomb passing a point in 1 second.

Instead of saying 10 coulombs in 1 minute we would therefore say:

$$\frac{10}{60} \text{ coulombs per second} = 0.167 \text{ A}$$

Similarly, instead of a flow rate of 1000 coulombs in 1 hour, we say:

$$\frac{1000}{3600} \text{ coulombs per second} = 0.3 \text{ A}$$

The other important thing we need to know about electricity is flow pressure. Returning to our analogy with water and pipe,

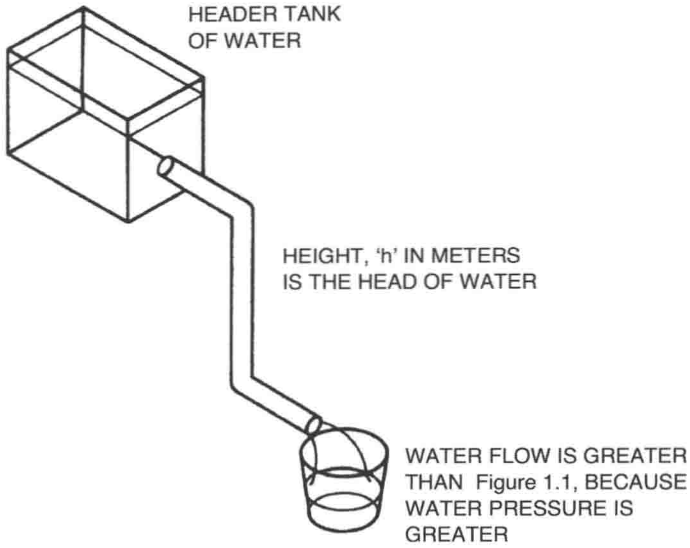

FIGURE 1.2 A header tank's potential energy forces the water with a higher pressure.

Figure 1.2 shows a header tank of water at a height, *h*, above the pipe. Water pressure is often classed as a head of water, where the height, *h*, in meters, is the head. The effect of gravity pushes down the water in the header tank, forming a flow pressure, forcing the water out of the pipe. It's the energy contained in the water in the header tank due to its higher position – its potential energy – that defines the water pressure.

With electricity the flow pressure is defined by the difference in numbers of electrons between two points. We say that this is a potential difference, partly because the difference depends on the positions of the points and how many electrons potentially exist. Another reason for the name potential difference comes from the early days in the pioneering of electricity, when the scientists of the day were making the first batteries. Figure 1.3 shows the basic operating principle of a battery, which simply generates electrons at one terminal and takes in electrons at the other terminal. Figure 1.3 also shows how the electrons from the battery flow around the circuit, lighting the bulb on their way round.

Under the conditions of Figure 1.4, on the other hand, nothing actually happens. This is because the two terminals aren't joined and so electrons cannot flow. (If you think about it, they are joined by air, but air is an example of a material that doesn't allow electrons

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