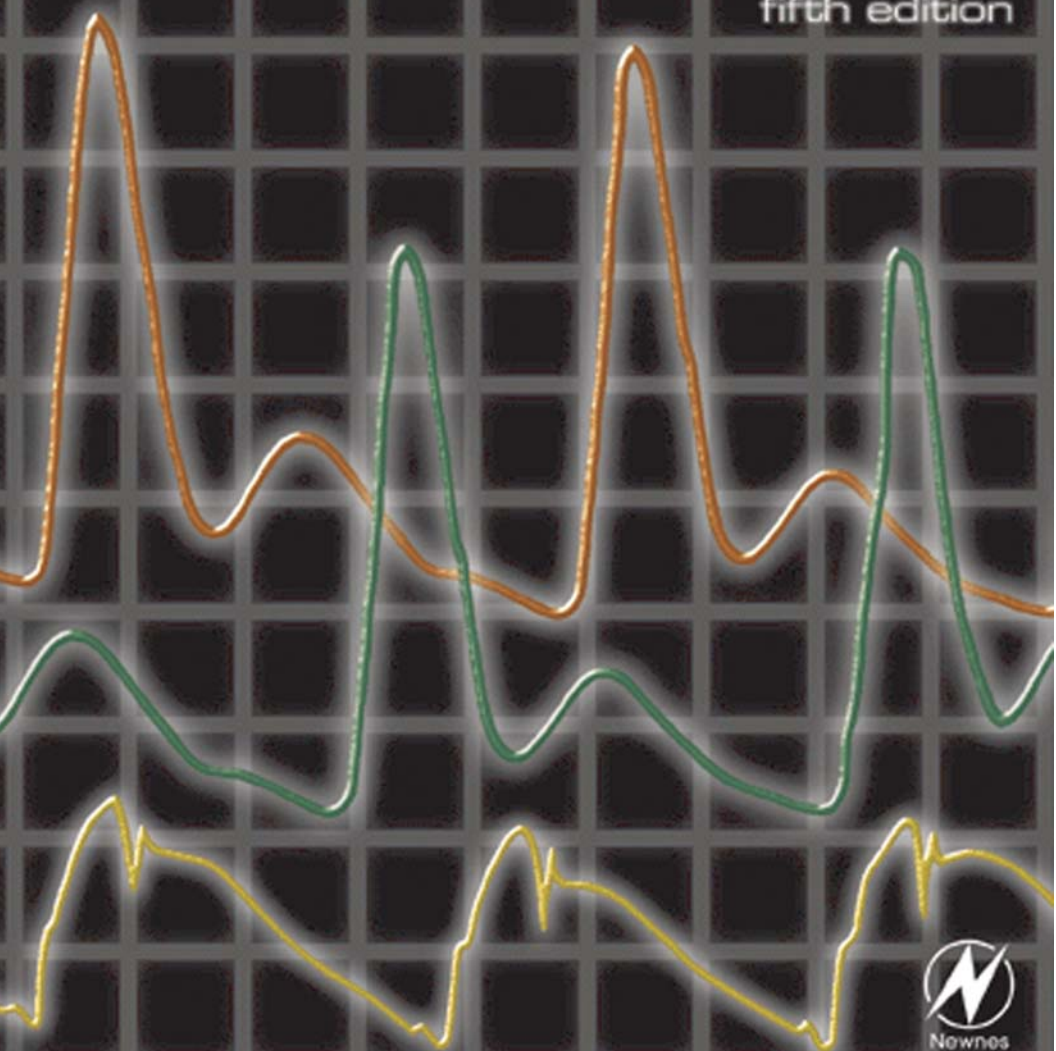


ian hickman

oscilloscopes

fifth edition



Oscilloscopes

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Oscilloscopes

How to use them, how they work

Fifth Edition

Ian Hickman

BSc (Hons), CEng, MIEE, MIEEE



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Preface

Who is this book meant for? It is for anyone who is interested in oscilloscopes, how to use them and how they work, and for anyone who might be if he or she knew a little more about them.

It is easy to say what the book is not: it is not a textbook of any sort, and particularly not a textbook on how to design oscilloscopes. Nevertheless, besides describing a great variety of oscilloscopes, their particular advantages and how to use them, the book explains briefly how these instruments work, on the basis that the best drivers have at least some idea of what goes on under the bonnet. This takes us into electron physics and circuit theory – but not too far. Formulae and results are simply stated, not derived or proved, and those with only the haziest knowledge of mathematics will find nothing to alarm them in this book. Consequently, readers in their earliest teens will be able to learn a lot from it; Chapter 1 is written especially for anyone with no prior knowledge of the subject. Sixth-formers and students on ONC and HNC courses should all find the book useful. Even many degree students will find it of considerable help (though they may choose to skip Chapter 1!); electronic engineering undergraduates have plenty of opportunity to learn about oscilloscopes, but many graduates come into electronic engineering from a physics degree course, and will welcome a practical introduction to oscilloscope techniques.

Technicians and technician engineers in the electronics field will of course be used to oscilloscopes, but the following chapters should enlarge their understanding and enable them to use the facilities of an oscilloscope to the full. Finally, I hope that those whose interest in electronics is as a hobby, including many amateur radio hams and radio-controlled-model enthusiasts, will find the book valuable, especially if they are considering buying or even constructing their own oscilloscopes.

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Preface to fifth edition

Keeping this book up to date is rather like painting Edinburgh's famous bridge over the Firth of Forth – no sooner do they get to the end than it's time to start all over again at the beginning. In the same way, no sooner does a new edition of this book come out than one or other of the oscilloscopes illustrated or featured will go out of production, usually to be replaced by a later, improved model. And as for Appendix 2, one can more or less guarantee that by the time a new edition is in the offing, at least 50 per cent of the manufacturers or their agents will have changed their address or telephone number.

As ever, the performance and value for money offered by the current models have advanced considerably since the appearance of the last (fourth) edition. This is a continuing source of mild surprise and quiet satisfaction for anyone who has been interested in the oscilloscope scene for any length of time – which in my case amounts to nigh on fifty years.

My first scope, home built for cheapness of course, was a home-brew conversion of an ex-RAF Indicator Unit Type 182A, which incorporated a VCR517C cathode ray tube. The unit was available on the post-war military equipment surplus market for a few pounds, a lot of money in those days – especially for a lad still at school. Even so, it was considerably cheaper than units containing the more popular VCR97 cathode ray tube, with its short-persistence green phosphor. So, for reasons of financial stringency, my first oscilloscope had a long persistence cathode ray tube with a blue 'flash' and yellow 'afterglow'. In its original role as a radar display, a glass filter tinted deep yellow in front of the screen suppressed the flash, but I removed this, making the tube rather less inappropriate for oscilloscope duty. Nevertheless, the afterglow was always a nuisance except for single shot applications or during extended observation of a stable triggered waveform – unfortunately I never thought of putting a deep blue filter in front of the screen. (A subsequent conversion to TV use was even less

satisfactory. Apart from blurred lips, the newsreader was not too bad but a football match was a disaster. The blue ball with its long curved yellow tail looked like a comet, and when the camera panned from one end of the ground to the other, confusion reigned supreme.)

A scope with a long-persistence screen is still very useful in certain applications, where it can form a very much cheaper option than a variable-persistence storage oscilloscope or a DSO (digital storage oscilloscope) of similar bandwidth. Oscilloscopes offering the option of a cathode ray tube with a long-persistence screen in place of a standard one are by now unobtainable, but many long-persistence scopes are still in regular use. Thus in the world of the oscilloscope, the old and the new both continue to be useful, each in its appropriate sphere.

Another example of this is the 'second user market', an area of steadily growing importance. As Government Departments and Agencies and large firms re-equip themselves with the latest and best in oscilloscopes, large quantities of used but perfectly serviceable equipment are released. Most of this finds its way onto the second user market, where dealers specializing in this trade offer it for resale. The more reputable dealers will have had the equipment overhauled and recalibrated to good-as-new condition, and it then represents excellent value for the smaller company, the independent consultant and even the keen electronics enthusiast. In this way, an excellent oscilloscope, spectrum analyser or other instrument (admittedly of a model often no longer in production) can be obtained for somewhere between a tenth and a fifth of the price of its current new equivalent. The major manufacturers continue to support such instruments for some eight to ten years after the model was discontinued. So a bargain scope can be repaired and maintained as necessary, giving many years of faithful service, especially if returned to the maker for a complete overhaul just before the period of support expires.

This fifth edition of the book, which was first published in 1981 and has never been out of print since, has been extensively revised. Chapter 11, describing how storage cathode ray tubes work, has been retained. It was added at the third edition when 'analogue' storage scopes (i.e. those using direct-view storage c.r.t.s) were

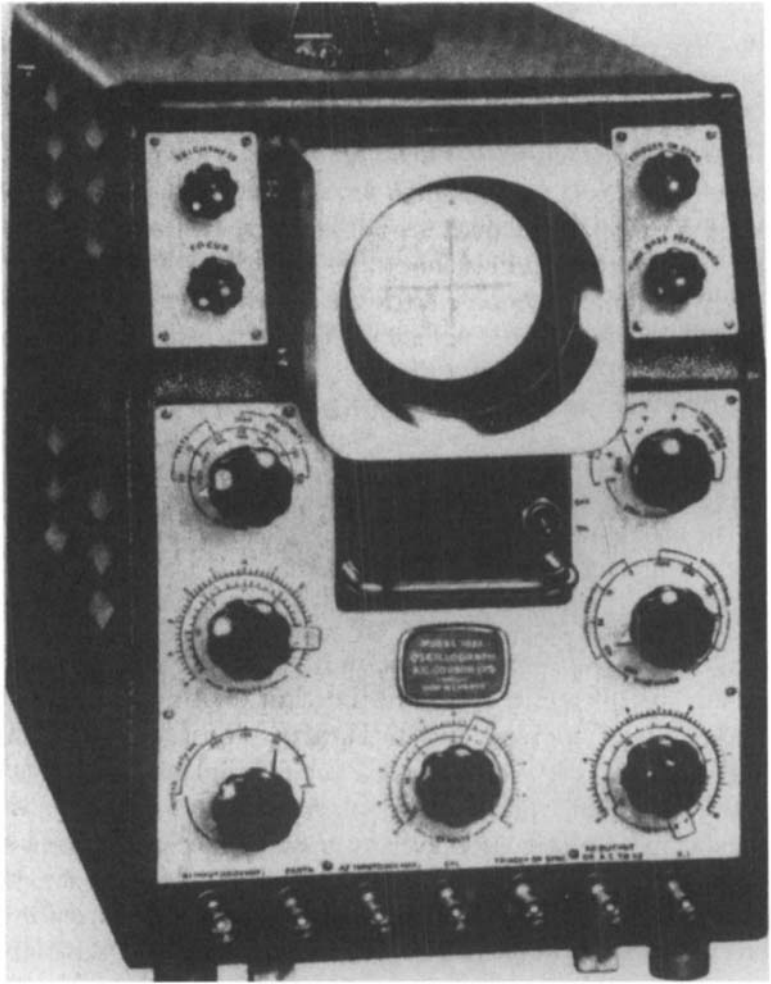
available from a number of manufacturers. This is no longer the case, so perhaps the logical move might seem to be the omission of the chapter in its entirety. But it has been retained, for a number of reasons. Firstly, the description of the operation of storage c.r.t.s illustrates some interesting aspects of electron optics, a branch of physics on which all c.r.t.s depend for their operation. Secondly, with the march of time, sources of information on the modus operandi of storage cathode ray tubes will become rarer and rarer. Thirdly and more importantly, many analogue storage scopes are still in use, and some guidance on their advantages, limitations and quirks may not come amiss. And while oscilloscopes using a storage cathode ray tube no longer seem to be available (except on the second user market), one of the major oscilloscope manufacturers still produces analogue storage oscilloscopes, using a 'scan converter tube'. The principle of operation of these is also touched on in Chapter 11. The chapter has therefore been retained, but with the substantial pruning carried out at the previous (fourth) edition, while still covering all the fundamentals of the subject.

The book now includes photographs of later models of some of the instruments which were illustrated in the fourth edition, plus details and photographs of instruments from various manufacturers whose product lines were not previously represented in these pages, whilst illustrations of models no longer available have, with but one or two exceptions, been removed.

The author gratefully acknowledges the many manufacturers and their agents who have assisted by providing information on, and pictures of, their products. From these, a selection of photographs has been included illustrating real-time oscilloscopes, both storage and non-storage, sampling and digital storage oscilloscopes and their accessories. In each case, the caption at least gives brief details of the performance of the instrument, whilst in several cases it has been possible to give a more extensive account of its performance in the text. My special thanks are due to Tektronix UK Ltd for providing material upon which I have drawn freely in Chapters 6 and 11 and elsewhere, and for other valued assistance.

I.H.

October 2000



An advanced oscilloscope of the 1940s. The Cossor model 1035 Mk11A was a true dual beam oscilloscope with a maximum bandwidth of 7 MHz (Y1 amplifier), 100 kHz (Y2 amplifier) and a fastest sweep rate of 15 μ s per scan, with repetitive, triggered and single-stroke operation (courtesy Cossor Electronics Ltd)

Introduction

The cathode ray oscilloscope is an instrument designed to display the voltage variations, periodic or otherwise, that are met with in electronic circuits and elsewhere.

The word is an etymological hybrid. The first part derives from the Latin, to swing backwards and forwards; this in turn is from *oscillum*, a little mask of Bacchus hung from the trees, especially in vineyards, and thus easily moved by the wind. The second part comes from the Classical Greek *skopein*, to observe, aim at, examine, from which developed the Latin ending-*scopium*, which has been used to form names for instruments that enable the eye or ear to make observations. For some reason the subject of the design and use of oscilloscopes is generally not called oscilloscopy but oscillography, from *oscillo-* and *graphein*, to write.

There are other types of oscilloscope besides those using cathode ray tubes. For example, pen recorders, ultra-violet chart recorders and XY plotters are all oscilloscopes or oscillographs of a sort, as indeed is 'Fletcher's Trolley' of school physics fame. However, this book is concerned mainly with cathode ray oscilloscopes, together with the increasing number of similar instruments using LCD (liquid crystal display) technology.

Representing a varying voltage

The basic principle of oscillography is the representation, by graphical means, of a voltage that is varying. The voltage is plotted or traced out in two-dimensional Cartesian coordinates, named after Descartes, the famous French seventeenth-century philosopher and mathematician.

Figure 1.1 shows the general scheme for the representation of any two related variables. Both positive and negative values of each variable can be represented. The vertical axis is called the Y axis, and the horizontal the X axis. The point where the axes cross, where both $X = 0$ and $Y = 0$, is called the 'origin'.