Radio and Electronic LABORATORY HANDBOOK

M G SCROGGIE

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Preface

During the more than thirty years since the first edition of this book the situation has changed drastically. Whereas in 1938 there was so little choice of ready-made equipment that the experimenter had to construct much of what he wanted, now the variety offered by the instrument trade is embarrassingly large. Both the instruments and the ways in which they are used have become much more sophisticated. Experimenting is a good deal less light-hearted than it used to be, and far more people are doing it—mostly as professionals rather than as amateurs.

So this eighth edition is hardly recognizable, either in size or content, as a descendant of the first. Even the title is slightly different, in recognition of the fact that the techniques are now applied far beyond the field of radio. But all the editions have had the same basic aim—to provide the experimenter with guidance on means and methods, without assuming unlimited funds and space at his disposal, or substantial qualifications and experience. Certain chapters—notably 3, 8 and 12—deal with the underlying principles of experimenting and the approach to it, seldom discussed or considered, but vitally important. It is hoped, too, that the book will not disappoint those readers who have been good enough to say they liked the original style—aimed to be a shade less solemn than the more advanced text-books. Students—and, in these days, sixth-formers—and sometimes even their teachers, seem to appreciate this.

Possessors of previous editions may need to be convinced that it is going to be worth while getting this one. It should be enough to remind them that when the last was written transistors had made only a rather tentative appearance in instrumentation. By now transistors and many other semiconductor devices are the norm. The use of valves, with their bulk, heating-up delays, and large power dissipation with consequent temperature-coefficient problems, needs to be justified by special circumstances. Even transistors, as separate units, are tending to be displaced by integrated circuits—in general, microelectronics. Aided by these developments, a rapid trend is in progress towards digital instead of analogue (pointer) instruments. Commercially, instrument making has become highly competitive, so manufacture in small quantities by skilled craftsmen whose products were almost as individualistic as themselves has had to give place to designing for uniform production in large lots with as little skill as possible. Therefore the chapters on instruments and many sections of those on measurements have been largely rewritten.

The usual never completely successful attempt has been made to keep the book down to the same size, by deletion and by selecting from the vast range of instruments and methods those likely to be most generally useful and best value for money, and presenting the information as concisely as possible consistent with the aim of helping those with limited experience and learning. More than ever, references to the literature for details have been regrettably necessary. Microwaves have been excluded; they now have a large literature of their own.

To avoid having to repeat details of apparatus in every method employing it, the chapters on apparatus come first. General principles and reference material are stored at the end in Chapter 13. Any necessary link-up is facilitated by cross-references: all sections, figures and tables are numbered, the number of the chapter being given first; e.g., Sec. 13.23 is the 23rd section in Chapter 13. But the index and table of contents should not be forgotten; they are there to be used.

The basic units are those of the SI, which is an expansion of the rationalized m.k.s. system (Sec. 13.1). Whenever other units are used they are specified in square brackets; e.g.,

$$C = \frac{25\,330}{f_r^2 L} \text{ [pF; } \mu\text{H; MHz]}$$

This example illustrates also the change-over from c/s to Hz, now generally accepted. There is no change in meaning! Symbols and abbreviations are British Standard, set out in detail in Secs 13.1 and 2. The time-wasting practice of specifying component values in a separate list instead of on the circuit diagram itself continues to be rejected. The only necessary indications of unit are the multipliers (p, n, μ, k, M, etc.), and by using these so as to avoid unnecessary noughts, and leaving the circuit symbol to denote the main unit (F, H, or Ω), the values can be shown clearly on the most complicated circuit diagram. Quantities are denoted by italics; e.g., *R* for resistance, in distinction from R for a resistor.

In drawing circuit diagrams, the 'positive up' convention has been followed.

Another usage, which may not even yet be familiar to everyone, is the abbreviation 'z.f.', meaning 'zero frequency'. Attempts to do without it result in absurdities such as 'd.c. current' and 'at d.c.'.

References to literature are admittedly not in standard form as laid down in B.S. 1629 : 1950. This is because it is believed that the first concern of most readers is not the author but the subject, and secondly that the date of a paper is more helpful than the volume number. Any injustice to authors in this arrangement has, it is hoped, been removed by placing all their names in the index. The titles of books and periodicals are given in italics; most of the latter are abbreviated as shown on page 8. Publishers of books are indicated in brackets, and their full names and addresses in Britain are shown on page 14.

There are now quite a number of publications providing information on what instruments and components are available and from whom they can be bought. Most of the technical periodicals have a 'New Products' section. Among the reference volumes there are the *British Instruments Directory* (Scientific Instrument Manufacturers' Association), *Instruments: Electronics: Automation, Purchasing Directory* (Morgan), *Eurolec* (David Rayner Associates), and *Electronic Engineering Index* (Technical Indexes Ltd., Index House, Ascot, Berks) which is brought up to date monthly.

Thanks are due to the firms (named in the captions) which have contributed photographs illustrating technical features of equipment, and to those that have supplied information on their products.

Considerable help has been given in the preparation of this eighth edition by Mr. D. E. O'N. Waddington.

Finally, the author will much appreciate reasoned criticisms or the pointing out of any errors that may have occurred.

Bromley, Kent M.G.S.
1971.

Full Titles of Journals

B.C. & E.	*British Communications and Electronics
E. & P.	Electronics & Power (J.I.E.E.)
E. & R.E.	*Electronic & Radio Engineer
E.E.	Electronic Engineering
E.T.	*Electronic Technology
G.R.E.	General Radio Experimenter
I.E.	Industrial Electronics
J. Brit. I.R.E.	*Journal of the British Institution of Radio Engineers
J.I.E.E.	*Journal of the Institution of Electrical Engineers
J. Sci. Inst.	Journal of Scientific Instruments
M.I.	Marconi Instrumentation
M.T.C.	Mullard Technical Communications
Proc. I.E.E.	Proceedings of the Institution of Electrical Engineers
Proc. I.R.E.	*Proceedings of the Institute of Radio Engineers (New York)
Proc. Wireless Section I.E.E.	*Proceedings of the Wireless Section of the Institution of Electrical Engineers
P.T.R.	Philips Technical Review
R. & E.E.	Radio & Electronic Engineer
R.C.	Radio Constructor
S.R. & R.	*Sound Recording and Reproduction (Journal of the British Sound Recording Association)
Trans. I.R.E.	Transactions of the Institute of Radio Engineers
W.E.	*Wireless Engineer
W.W.	Wireless World

*No longer published as such

Publishers

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Contents

(Key subjects are shown in bold type)

CHAPTER 1

The End and the Means

1.1. PURPOSE OF A LABORATORY

The way a laboratory is equipped and carried on depends very largely on what it is for. It can have a number of quite distinct purposes, which perhaps may conveniently be identified by the words Demonstration, Research, Design, Test and Maintenance.

Demonstration

This is to repeat the results of others and so get first-hand knowledge. While this suggests school with its set experiments, it is a still more valuable object for private work. An ounce of practice is worth a ton of theory, we are told. While this exact numerical ratio does not appear to have been rigorously proved, there is no doubt that personally confirming experiments does give one a mastery of the subject that can never be derived from books and lectures only. Moreover it may lead to

Research

or finding out more about how things work and so possibly discovering something new. Some of the most valuable discoveries have been made as a result of *not* confirming the findings of others. 'Take nothing for granted' is too strict a rule to observe literally, but the spirit of it is sound. Many lines of research accidentally grow out of and perhaps dwarf the importance of the original work. Others, again, are deliberately planned and (sometimes!) carried through. Turning from these heights that are so fascinating to contemplate and often so tedious to climb, we find

Design

Work under this heading really falls into two divisions: obtaining data for design, and checking the designs when they have materialized. This is the main purpose of most of the laboratories in manufacturing concerns, and on a smaller scale the same object is pursued by keen amateurs.

Test

The private experimenter ought to make a practice of testing all the parts he obtains for his work. It is better to start doing this voluntarily than to be driven to it, sad but belatedly wise. In large organizations this work falls to the Test Room, but there are usually special tests that cannot or ought not to be done there. Tracing obscure faults in apparatus may be included in this division. Lastly comes

Maintenance

This is probably common to all laboratories, from least to greatest; for there is always plenty of work to be done in keeping the instruments and other equipment in perfect order, making and checking calibrations—electronic voltmeters, for example, ought to be checked quite often—and setting up new apparatus. Nothing is more exasperating, when carrying out an experiment, than continually having to digress in order to locate and cure faults in the apparatus, or (worse still) failing to notice such faults until one has taken a long series of readings, all of which must then be condemned as unreliable. Under this rather humble heading, too, come those expensive Standards Laboratories that only the larger organizations can afford. Their object is to maintain the accuracy of all the rest of the concern's equipment.

1.2. THE QUESTION OF EQUIPMENT

The foregoing list, drawn up to help clarify ideas, is intended mainly for the experimenter who is setting up his own laboratory: the paid worker is generally not in a position to choose. When equipping a laboratory, one can save money by first considering rather carefully what one wants to do. The most lavishly-equipped plant without inspiration may be less truly a laboratory than the corner of a living-room with a few simple home-made instruments. At the same time, one cannot set out to experiment on long-wave directional aerial arrays in a small flat. But it is possible to make what might prove most valuable observations with little more than an ordinary receiver. The 'Luxembourg Effect' (or ionospheric intermodulation, as it was called when it was admitted to serious science) was not discovered by means of elaborate and costly apparatus, nor was it predicted as a result of intricate mathematical calculations; the equipment was a receiver and slightly more than average observation. Yet there was a discovery that gave the scientists a valuable new line of approach to the problems of the ionosphere.

So far nothing very suggestive of laboratory apparatus has been mentioned. But even when the chosen experimental work can be carried on with only a receiver it is at least desirable to have something of the nature of a laboratory, if only for ensuring the very highest degree of reliability in that receiver. Work is very restricted without some means of producing an artificial signal when required, and measuring frequencies and component values. Meters for checking circuits and taking experimental readings, oscillators of various types, and controllable power supplies are constantly needed whenever more general experimental work is undertaken. And so one goes on. The question is how to lay out limited funds to the best advantage.

1.3. SELECTING FOR MINIMUM COST

Cost will be taken into account when equipment is described in detail in subsequent chapters; but in the meanwhile it is possible to make some general observations.

Assuming that experimental work is not a fleeting passion, there are certain instruments that will be practically essential, both now and in the future, of a kind that does not quickly become obsolete. For these it is false economy to go in for the very cheapest that will just do at the time. What are loosely but very conveniently termed 'meters' certainly come into this category. So do standards of resistance, capacitance, and so forth. Good workmanship now more than ever costs money, and in the ordinary way a high-grade instrument by a famous firm always commands a good price. In the *ordinary* way; but one does sometimes pick up exceptional bargains second-hand. And of course releases of Government surplus stocks are a great attraction to the bargain hunter. But in bargain hunting one must never forget the legal maxim '*caveat emptor*' 'Let the buyer beware!' As bargains do not generally carry any guarantee, such buying calls for discrimination, and it is advisable to be able to check them against standards. Unless one can get something much better this way than could be afforded otherwise, it is perhaps wiser to be on the safe side and buy a new instrument. Sometimes, however, the original makers, or a reputable agent, can supply used instruments that have been reconditioned and recalibrated and are practically equivalent to new, except that perhaps they are not of the latest pattern. But of course one cannot in this way expect to save a very large proportion of the cost of a new instrument.

If some expensive equipment would be a valuable aid in a particular project, but uneconomical to buy, the best thing may be to hire it from a firm providing such a service.

1.4. TRUE ECONOMY

Decide, then, what apparatus is likely to be of permanent value, and get something of higher quality than appears to be justified, even if it means postponing other purchases. In doing so do not overlook the possibility of unit instruments, consisting of a nucleus to which accessories may be added as required. For example, an oscilloscope that accepts a range of 'plug-ins' can be made to fulfil many requirements.

Versatility is an important feature to be considered. Careful choice may enable a few instruments to take the place of many. But do not let catalogue descriptions rush you into buying a jack of all trades and master of none. And remember, too, that one instrument, however versatile, cannot be in more than one place in the circuit at a time.

With regard to more specialized types of equipment, of which there is now such a vast and rapidly increasing variety—waveform generators, distortion meters, transistor testers, and so on—more caution is necessary. They are constantly changing in design, are generally expensive, and tend to become obsolete fairly rapidly. This is not to say that a good signal generator, for example, is a bad investment; it is just that one needs to exercise foresight. People who a few years ago bought expensive television signal generators that stopped short of Band V find them very restricted today. It is bad policy to spend a lot on a splendidly finished and symmetrical instrument if the development of technique makes it necessary after a short time to disfigure it with some makeshift alteration.

1.5. MAKING ONE'S OWN APPARATUS

It is hereabouts that we enter the field of things that it may be advisable to make rather than buy. One should not run away with the idea that it is necessarily much cheaper to do so. When the time spent on experimenting has been taken into account it may be quite an expensive way. But a private worker does not often rate his time very highly, and he learns all the time; and a technical department is often able to present the cost of construction to the directors in a less disturbing form than that of an outright purchase. Slack time of mechanics can be employed, for instance. The advantage, too, of being able to suit one's own needs may amply compensate for what may possibly be a limited standard of workmanship. As a matter of fact, there are comparatively few items that really need be made up in permanent form—much of the work can be more efficiently, economically and adaptably carried out on temporarily mounted wiring boards such as are described in the next chapter. This is especially true of circuits using semiconductors.