The Origins and Growth of Electronic Engineering – a Personal View

by

Maurice V. Wilkes

Computer Laboratory, University of Cambridge, England

Before the First World War radio was in its infancy. During the war, it made great strides, being used by both sides for military purposes. The vacuum tube triode came into widespread use and was to form a solid bases for radio engineering during peacetime. As time went on, vacuum tubes of the type developed for use in radio receivers began to be used in applications that did not involve the use of radio waves or, if they did, were not concerned with the sending of messages from one place to another. A need was felt for a new term to cover these applications and the term *electronics* emerged.

Electronics was a hi-jacked term. It had been in use for a long time to denote the internal physics of a vacuum tube. The hi-jacking, quite naturally aroused resentment among vacuum tube physicists. I shall return to this.

The word itself came into prominence in 1930 when it was adopted as the title for a new monthly magazine published by McGraw-Hill. The early issues contained, in addition to articles on the technically more interesting aspects of radio and related subjects, articles on various applications of vacuum tubes in industry. Typical of the latter were the control of temperature in welding equipment and the use of photocells for counting objects and for other purposes. However, as the years went by, industrial applications became more elaborate and came to dominate the magazine. It has been suggested, very plausibly, that this was a major factor in giving the word electronics its present meaning[1]

My Personal Involvement

I lived through much of this period and my account will therefore necessarily be something of a personal one. I have checked what I can against written sources, but this account is primarily an informal and personal one.

I was nine years old in 1922 when broadcasting started in the UK. It was not long before I had successfully built a crystal set and was saving up for my first vacuum tube. I used this to build a simple receiver and followed it up, as my resources grew, by a series of more elaborate receivers. I built my first transmitter when I was still a schoolboy and operated it under a school license. As a graduate student, I worked on

ionospheric research at the Cavendish Laboratory and, later, during the war, I worked on radar engineering of various kinds. After the war, I built my first computer.

The Radio Industry

At the end of the Second World War, there was in existence a large worldwide radio industry. Few of the technical people working in it were trained in university engineering departments which, apart from a few honorable exceptions, were only just beginning to teach radio engineering. Many of the people had a physics background or had been introduced to radio while in war service; others had just picked it up.

As far as professional bodies went, radio engineers were better catered for in the United States than in the UK. The Institute of Radio Engineers (IRE) formed in 1912 existed alongside the older American Institute of Electrical Engineers (AIEE), and had rapidly gained strength. On the other hand, in the United Kingdom the Institution of Electrical Engineers (IEE) had no comparable competitor. An attempt to create one was made in 1925, when the British Institution of Radio Engineers was formed. Unfortunately, the BritIRE, as it was known, received very little support from senior radio engineers, who remained loyal to the IEE. In consequence, while it did good work, the BritIRE was never a significant challenge to the IEE.

In retrospect, this is a pity since a strong professional body devoted to light current electrical engineering would have had great value. In particular it would have been appreciated by computer pioneers, who felt frustration with the way that the IEE was dominated by heavy electrical engineers. I still have painful memories of being a member of the program committee for a computer conference organized by the IEE in 1956; not only were the heavy electrical engineering stalwarts very rigid in their views about how the conference should be run, but they committed the further offence of being on the average 10 years older than we were. I hope that historians will recognize that electronics was a young person's activity and will explain how this came about.

In 1945, while there was a large radio industry, my impression is that there is little that could be described as an electronics industry. On the other hand a lot of people had acquired knowledge of electronics during the War. This was especially true in the United Kingdom where so many young people—many of them of very high quality—were engaged in radar and its offshoots. After the War, some of these people found ready employment in the electronics industry which began to expand rapidly. Others joined universities or went back to the universities from which they had obtained leave of absence for war service. They were scattered through the various university scientific departments, biological as well as physical, and many of them put what they had learned about electronics to good use, especially in laboratory instrumentation.

The rapid growth in the electronics industry soon led to the term *electronics engineering* or *electronic engineering* coming in as a more formal alternative to electronics. The latter term had been familiar in the UK since 1941 when a journal, up to then known as T*elevision and Short Wave World,* changed its name to *Electronic Engineering*.

The growth of electronics engineering as a major activity is illustrated by the fact that, when on 1 January 1963 the AIEE and the IRE eventually merged, the resulting combined body was called *The Institute of Electrical and Electronics Engineers,* the word 'radio' having disappeared. Before the merger took place there was some discussion as to whether the reference in the title should be to *electronics* engineers or to *electronic* engineers. A laudable concern for linguistic purity led to the former being chosen, but since then the stronger pull of euphony has led to the latter coming in. When reading and commenting on the older literature it is important that the historian should note and observe the distinction.

The above terms, along with radio engineering, have never been authoritatively defined. It is better to regard them as convenient names by which differently placed groups of people are known, or choose to describe themselves, rather than as denoting distinct disciplines. Some aspects of radio engineering are not naturally described as electronics. An example is antenna design, whose affinity lies with physical optics, in particular with diffraction gratings.

The feeling of resentment over the hi-jacking of the term electronics lasted at least until the mid 1950s. Documentary support for this statement will be found in the editorial to the first issue of a new journal, called *Journal of Electronics,* published in the UK in 1955 by Taylor and Francis and intended to cover the behavior of electrons in the free state or in states where the binding energy is low. The editors state that several of their scientific colleagues were unhappy with this use of the word *electronics* and that they had therefore added a subtitle 'devoted to electron sciences' in an Endeavour to meet their objection. They went on to say that what was more serious was that the word electronics was being loosely used to describe application of electronic devices in equipment. When they said *loosely used* they clearly meant *mis-used* or *wrongly used,* and the sense of resentment comes through. They assumed that their readers would feel as they did, and they hastened to assure them that they had no intention of publishing papers dealing 'solely with equipment'.

Ionosphere Research

Perhaps the earliest non-communication use of radio was the use of radio waves for exploring the upper atmosphere. In 1925, Appleton and Barnett in the UK and Breit and Tuve in the US independently obtained experimental proof that radio waves were reflected from the upper atmosphere [2]. Their work inaugurated the study of the physics of the atmosphere by radio methods.

Appleton borrowed a broadcasting station and performed a frequency shift experiment. Bright and Tuve used pulse methods, and for this reason there work is more interesting from the present point of view. From it stems the ionospheric echo sounder, a device from studying radio waves reflected from the ionosphere. This was in routine use when I joined the ionosphere research group of the Cavendish Laboratory under J. A. Ratcliffe in 1934.

In an ionospheric echo sounder, time is divided into a series of fixed intervals—or time slots—usually locked to the mains. At the beginning of each interval a pulse is transmitted. Echoes of the pulse received from the ionosphere are picked up on a receiver and displayed along with the transmitted pulse on a CRT. Since all the echoes are received within a few milliseconds after the transmission of the original pulse, it is only necessary to display a corresponding portion of the received signal. This was one of the first uses of the CRT as a display device.

Television and Radar

From the above beginnings, a series of important applications of the CRT have come into existence; these include radar and television. In all these, time is divided into slots in the above manner, although not necessarily for the same reason.

Without the CRT, electronics would hardly have been possible. It is in universal use, both as an imbedded display device and also as the basis of the *cathode ray oscilloscope,* an essential piece of test gear. What a pair of headphones is to ordinary radio, the cathode ray oscilloscope is to electronics.

Television gave a great stimulus to electronics. Circuits for generating and handling the waveforms for setting up a raster, synchronization, extracting information from the received signal etc, are all properly described as electronics. Compared with television, early radar sets were relatively simple, emphasizing radio rather than electronics, but as time went on they became more sophisticated electronically. Some of the later systems could track a target automatically. This involved the use of a *strobe* waveform for sampling part of the signal.

Analog Computers and Control Engineering.

Analog computers, mainly mechanical, came into prominence in the late 1930s. Most important was the mechanical differential analyzer pioneered by V. Bush for solving ordinary differential equations. The electronic differential analyzer emerged as an alternative. It was not quite as general or as accurate as the mechanical version, but it was useful for many applications. Next in importance to differential analyzers were linear algebraic equation solvers based on networks of various kinds, most commonly resistor networks.

What I have just described were devices which, within their capability, could be used to solve differential or algebraic equations arising in a wide range of subjects. There were other analog computers designed for specific application, for example to model modes of oscillation in aircraft wings. In some applications, analog computers were perhaps better described as simulators rather than computers.

Analog computers constituted a significant subdivision of the electronic field and many major systems were built. They depended on the use of linear circuits, in particular on the use of the operational amplifier, Further information will be found in Early History

of the Monolithic Operational Amplifier, by K. Lundberg [3]. Inevitably during the 1960's analog computers were swept away as digital computers became more mature and more generally available; see A Great Disappearing Act: The Electronic Analog Computer, by C. Bissel [4].

At about this time control engineering departments began to appear in universities. These departments were both users of electronics and contributors to it. At the time this resulted in the perception that a closer connection existed between computers and control than has actually proved to be the case. Electronic methods did not have a monopoly in control engineering. For example, pneumatic controllers were much used for the low level control of chemical plants. This was mainly because they worked at a higher power level and were better adapted to the operation of mechanical devices, such as valves for the control of the flow of fluids.

Late in 1944, when an end to hostilities was in sight, much thought was given in Britain to post-war planning. The contribution of the BritIRE to this discussion was made in a report published in October 1944. It contains an interesting analysis of the current status of industrial electronics and its potential as then perceived. [5]

Growth of Digital Methods

Up to the end of WW2 virtually everything was analog with an emphasis on linear circuits. The use of pulse code modulation for telephony had been proposed by A. H. Reeves in 1937 but it was much ahead of its time and had so far made little impact. Otherwise there were two major excursions into digital electronics, Colossus and the ENIAC.

At the time I knew nothing about Colossus and I still only know what has been released. The high degree of secrecy surrounding Colossus led to it having little discernable influence on the development of digital computers. In the ordinary way I would have done no more than mention it; however since I am speaking at Bletchley I will make a few remarks.

Colossus was developed under the direction of Professor M.H.A Newman, a Cambridge mathematician, and designed by T. Flowers, a post office engineer. The first version became operational in June 1944. The extent of Turing's involvement with Colossus is obscure. He had played a significant part in the breaking of the ENIGMA code and in developing the Bomb, but it is not clear how much he was involved with work at Bletchley after he had been sent on a mission to the United States in 1942. In 1944 Turing was working at Haslope Park. There is an interesting paper by R. W. Addie in the IEEE Annals of the History of Computing describing his work there [6].

One should be careful how one describes Colossus to ordinary people. If you tell them that it was a computer, they will immediately think of a PC and of Windows and get entirely the wrong idea. They will assume that one could run a spread sheet on Colossus and work out one's income tax.

Colossus was in fact a special purpose digital signal processor designed to be an aid in decrypting certain enemy signals of interest at the time. The operations it would perform were logical in nature. This was for the very good reason that the algorithms that Newman and his group—along with other cryptanalysts—were interested in were logical, not arithmetical.

If Flowers had been asked to provide an arithmetical capability, he would no doubt have been willing to try. However, later experience with digital computers suggests that both the cost and duration of the project would have been much greater. The increased duration would probably have ruled it out as a war time project

It is sometimes suggested that the fact that Colossus was not designed to do arithmetic is a trivial distinction. This makes an interesting mathematical point, but it is not true in an engineering sense.

The ENIAC

The ENIAC was a general purpose digital computer, it was supported by the US Army Ordinance Department, who proposed to use it to compute artillery firing tables.

In historical terms, the main achievement of the ENIAC group was not the ENIAC itself, but the development of the advanced architectural ideas to which it led them and on which modern stored program computers are based. The term stored program computer is, of course a technical term, and does not simply mean that the program is stored in some way in the computer. One should take care not to apply the term to any computer proposed or built at an earlier period.

The handful of electronic engineers—of which I was on—who took up the challenge of building the early stored program computers were a mixed bunch. We had one thing in common, namely, that we had complete confidence that the state of the art in electronic engineering was fully up to the job. This proved to be the case. We realized of course that we would be exploiting the non-linear properties of vacuum tubes rather than their linear properties.

As far as circuits for implementing computing logic was concerned, we found ourselves with various choices. For example, we could use diode gates, as we did in the EDSAC, or pentodes with control signals on both grids, a system widely used elsewhere. This sort of choice persisted and the term *families of logic* came into use. Those who have worked with transistors, will remember TTL and ECL as well as the now dominant CMOS.

However, the stored program compute presented one entirely new requirement. It was memory based, and depended on the availability of a central memory capable of holding a large number of words, either numbers or instructions, and giving access to them at high speed. Fortunately Presper Eckert, the principal designer of the ENIAC, had proposed one way in which such a memory could be realized within the limits of available technology. He proposed basing it on *ultrasonic delay units,* otherwise known as *mercury tanks,* in which trains of pulses were continuously circulated.

At the beginning no other memory system had been shown to be practicable and several early computers used mercury tanks. These were far from ideal and we could not expect to be able to store more than about a thousand words in them, although it was obvious that we really needed vastly more than that. Nevertheless the availability of the mercury memory meant that engineers could go ahead and build something.

In retrospect, it seems remarkable how little the coming of transistors to replace vacuum tubes affected the development of electronics. More important was the later switch from discrete transistors to very large scale integrated circuits. E*lectronic engineering* remains appropriate as a term to distinguish light current electrical engineering from the heavy current variety. Whether we now also need the term electronics to describe a subject area is perhaps a matter for debate

Acknowledgments

I am indebted to Ms Victoria Hill of the Library of Congress for providing me with copies of the list of contents of the first issues of Electronics and to Dr William Wulf, President of the National Academy of Engineering, and his staff for kindly making the contact. I am also indebted to Mr Alan Hughes, Associate Editor of the Oxford English Dictionary, for a useful exchange of email messages on the lexicographical aspects of the words 'electronics' and 'electronic' and for drawing my attention to the paper referred to in endnote 1.

---

[1] See C. Süsskind IEEE Spectrum May 1966 p 72

[2] Appleton and Barnett. Proc. Roy. Soc. A vol 109 p 621 1925
Breit and Tuve . Terr. Mag. vol 30 p 15 1925

[3] IEEE History Center conference June 2004 [reference to be inserted]

[4] IEEE History Center conference June 2004 [reference to be inserted]

[5] Journal of the BritIRE vol 4 (new series) p 135 Oct-Dec 1944 ; see pp 143-147

[6] vol 15 p 59 Jan 1993