Defining Moments: The Book That Launched A Career

by Brian Austin, G0GSF

When I look back on my career as an electronics engineer, both in industry and in the academic world, I am struck by the fact that the major influence on my choice of what I might do with my life came not from any single person or event – even though there were many of those that were extremely influential – but from a book. And again, though there were many books that confirmed in my mind that electronic engineering is what I wanted to do, there was one that stood out as the defining light. And it was written in South Africa.

The world during the late 1950s was on the brink of an electronics revolution. The transistor, invented just ten years before, was now available to engineers, technicians and technologists to use in a myriad of applications. Soon, amateur enthusiasts joined their professional colleagues in using these miniature marvels and together they turned the world of electronics on its head. And all this happened even in places a long way from the hotbeds of science and technology.

South Africa: Gold, Diamonds And Semiconductors

Growing up at the southern end of the African continent during that immediate post-war decade, meant that there was something of a time lag between what happened in Europe and North America and those other parts of the world well to the south of them. Of course, news travelled quickly thanks to the radio but it took somewhat longer to actually lay one's hands on the technology that we heard and read about in newspapers and magazines. For example, the latest models of Mr Ford's motorcars, and those of all his many rivals and competitors, only arrived in South African showrooms some months after they had appeared at Olympia,

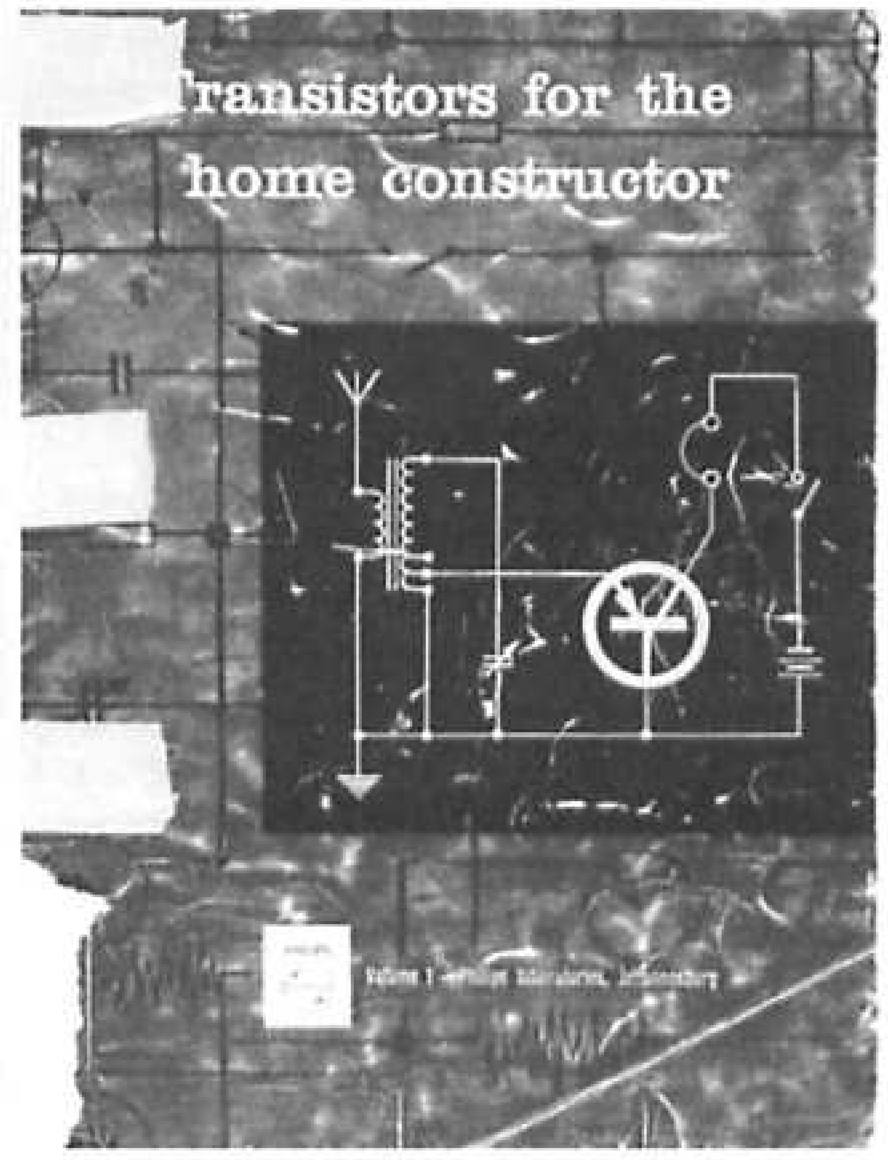


Fig. 1. A dog-eared and much repaired front cover of Transistors for the Home Constructor *Volume 1*

and wherever else the latest Edsel, or similar marques, were unveiled to a clambering public. And so too, the latest developments in electronics only filtered through sometime after our colleagues well to the north of us had got their teeth into them. But, by 1958, the semiconductor revolution was about to explode well south of the equator, or at least in Johannesburg and the other major centres of human enterprise in South Africa.

That city was not only the centre of the country's fabulously rich mining industry but it was the industrial, financial and business hub of the country. Its engineering base was strong with both local and foreign companies turning out sophisticated machinery, equipment and devices to meet the nation's needs. Likewise, the country's universities and technical colleges were educating and training scientists, engineers and technicians to cover the spectrum of specialities that were evolving very rapidly thanks, as is always the case, to the momentum that had been established to meet the needs of the military during the war not long ended, and the industries that now underpinned the economy of the country.

Narrowing our focus to the electrical and electronics world we find such international names as Marconi, Philips, General Electric and Westinghouse, amongst many others, operating significant manufacturing, and in some cases even research and development, facilities in and around Johannesburg with some further afield in Cape Town, Durban and other smaller cities. And there too were local organisations, much smaller on the scale of such things, but nonetheless important in terms of producing equipment specifically geared to local needs. Perhaps the most important of those (and here I'm likely to be shot down in flames by those who will name a host of others!) was the Durban-based electronics manufacturer SMD which emerged from its pre-war predecessor, the Radio-Electro-Equipment Co. (Pty) Ltd. (See *RB106* for far more details) to become, not long afterwards, Racal-SMD when that famous British company, now sadly no longer with us, became the major shareholder in SMD. By 1965, when that merger took place, the South African electronics industry was more than a sturdy stripling, it was, as we say today, very much up and running. But I'm getting ahead of myself.

The Dutch Giant

Philips of Holland opened its first office in South Africa not long after the Union of South Africa came into being in 1910 when the previous enemies from the Boer War joined hands to forge a country from two British colonies and two fiercely independent Dutch/Afrikaner republics. Naturally, since electric light bulbs were what launched

Philips upon the world, that's what they turned out in South Africa too, at least to start with. But soon SA Philips, as it became, was a major supplier of electrical and electronic goods and equipment, and its radio manufacturing facility in Johannesburg was one of the largest, if not the largest, in the country. It did not take them long to set up an R&D department to address their own as well as a variety of local needs. Thus, transistors, all manufactured by Philips in Holland and their associate company Mullard in England, and bearing their distinctive OA (for diodes) and OC (for transistors) prefixes, were at the forefront of all that SA Philips did.

In 1958, the manager of the SA Philips Electronic Application Laboratories in Johannesburg, Dr J C R Heydenrych, announced the publication of a book written by his engineering colleagues in the lab. It was called (**Figure 1**) *Transistors for the Home Constructor*. My father bought us a copy. His interest in radio had been stirred in the late 1920s when a lodger installed a large wireless set and horn speaker on the balcony outside his bedroom and proceeded to entertain all and sundry within earshot. Then, crystal sets using the bed springs as an aerial, allowed my father and other boys at boarding school to listen to the local SABC transmitter in Grahamstown long after lights-out. But the war soon intervened and other more pressing priorities, such as service in the SAAF, prevented him from taking that nascent interest any further until my tinkering reignited his fascination for the subject some two decades later.

The Home Constructor

Two things were striking about *Transistors for the Home Constructor*. The first was that we, those aspirant home constructors, suddenly had a book that acknowledged our existence; the second was that it was full of circuits. Until then, all textbooks and handbooks on radio and electronics had looked daunting and *Wireless World*, the magazine for the cognoscenti, did too. Fortunately there was *Practical Wireless* magazine for the hobbyist. Without it we could easily have felt ignored.

A glance at the list of contents of this SA Philips book, more than half a century after its publication, is revealing. One immediately realises that we are (still) living in an analogue world even though the present-day explosion of everything 'digital' occasionally suggests otherwise. In addition, in those very early days of the electronics revolution there were no such things as integrated circuits. All components were what we would now call 'discrete' and not only could you easily read their particular values but you didn't need a visor equipped with a magnifying lens to make it possible to solder them in place. And pliers still had a role to play in doing everyday electronic things (**Figure 2**).

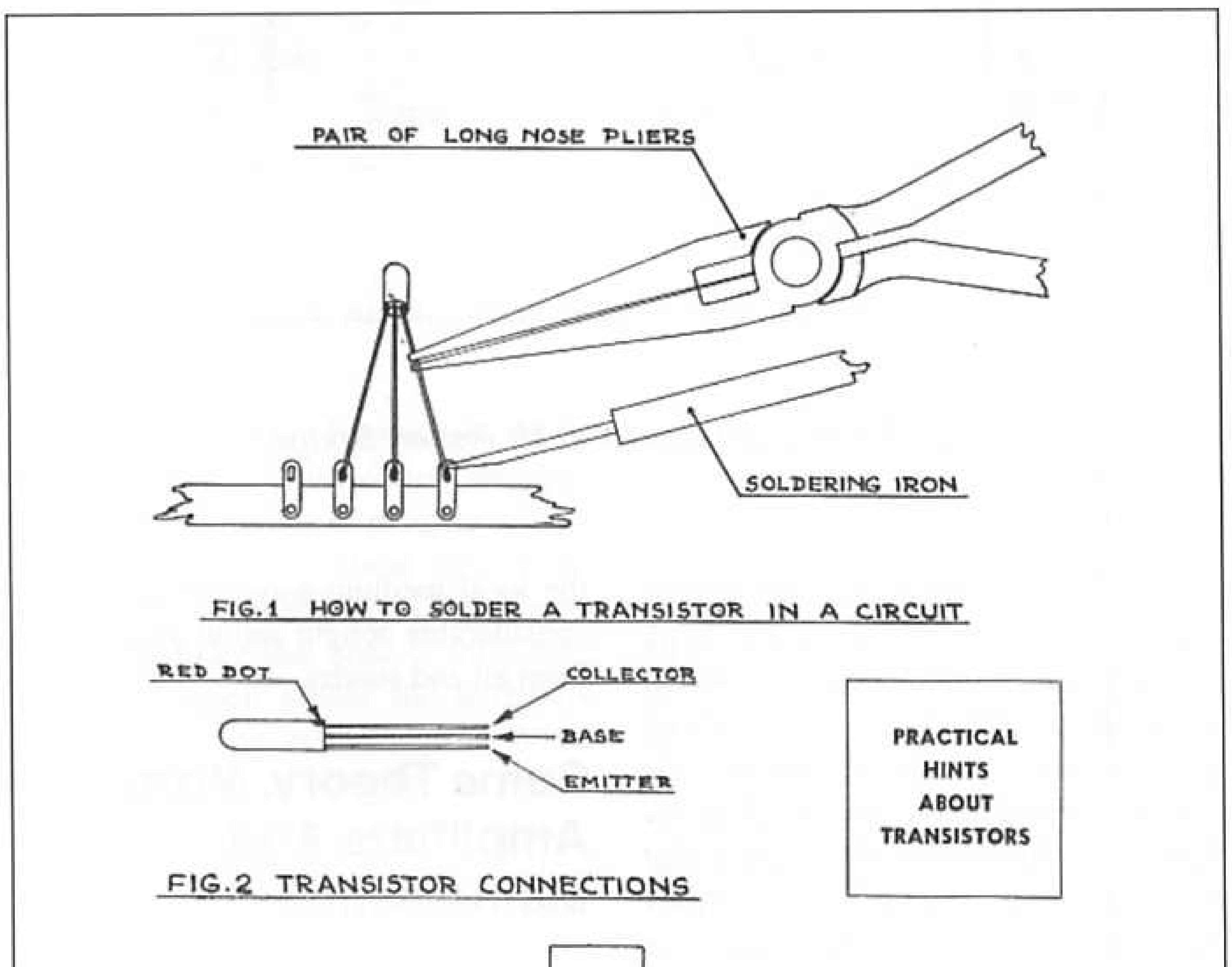


Fig.2. Practical hints about transistors

Dr Heydenrych set the scene in his preface. Electronics, he wrote, is the silent helper of the scientist but soon it would be the assistant in both the factory and the office. 'The application of transistors to a variety of new uses is now taking place' and this book 'will provide the young experimenter, the casual hobbyist, the amateur and even perhaps the serious technician, with a variety of circuits which he can construct at very low cost'. We, those young experimenters, were even invited to write to SA Philips to tell them of our successes (and even failures) and he stressed that his staff would be more than willing to assist us with any problems. He even promised a second volume 'dealing with more applications and more advanced circuits' if there was a demand. Sure enough, three years later, Volume II appeared.

And we even learnt who the brilliant designers of those circuits were: Mr Robert Bridgen, B.Sc.(Eng.), D.I.C. and Mr A.A. Dubbelman, M.T.S. To someone aged 13 these gentlemen were clearly both geniuses with qualifications one could only dream about.

Circuits, Circuits, Circuits ...

After two short sections that told readers how the relatively new subject of 'electronics' was now vital to the progress of the world and, more specifically, that the amount of money involved in electronics sales and services in the United States exceeded

$12 billion in 1957, the circuits then appeared and they were described by the designers themselves.

Robert Bridgen opened the proceedings with what anyone who'd ever dabbled with radio would expect: a crystal set. But this one didn't have a cat's whisker and a lump of galena, instead it used an OA85 germanium diode as its detector. And the tuning coil was wound on a ferrite rod. That was a leap forward from the almost regulation cardboard toilet-roll holder that had served that function almost since time immemorial. And, to add a bit of African flavour to the circuit diagram, the aerial wire was supported at the far end by a palm tree – see **Figure 3**.

The first transistor appeared in the next circuit. As you might expect, it was a one-transistor amplifier for the crystal set and the 'active device', as they're always called, was one of the most famous of the OC series: the OC71, a PNP germanium transistor in its distinctive black-painted glass encapsulation with a red dot indicating the collector wire with the base being the one in the middle. Today's reader might be a little surprised at the symbol Mr Bridgen used for his transistor because it looks rather like a triode valve, but we should appreciate that at that early stage in the development of solid-state devices even their symbols were still evolving – see **Figure 4**.

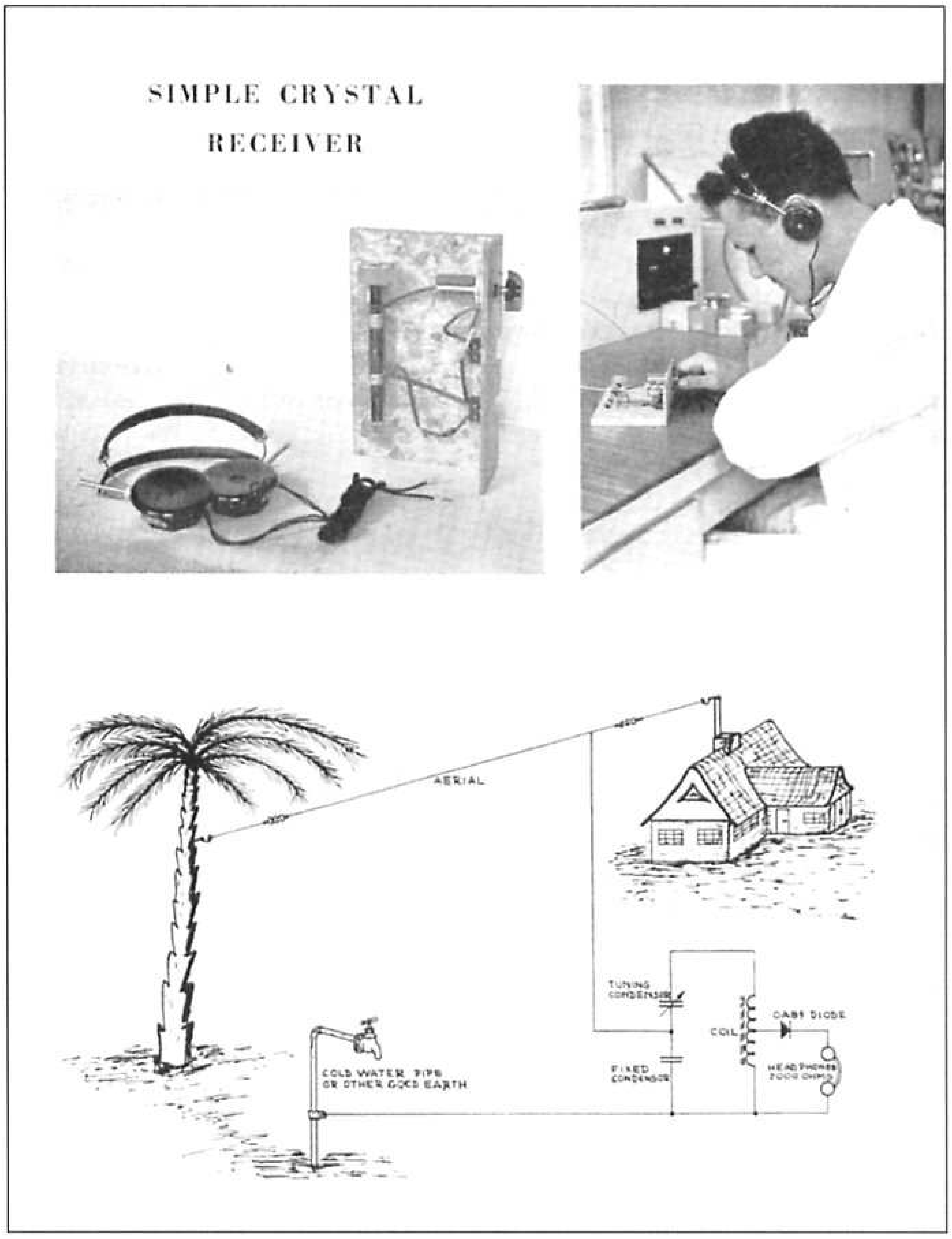


Fig. 3. The crystal set and Mr Robert Bridgen

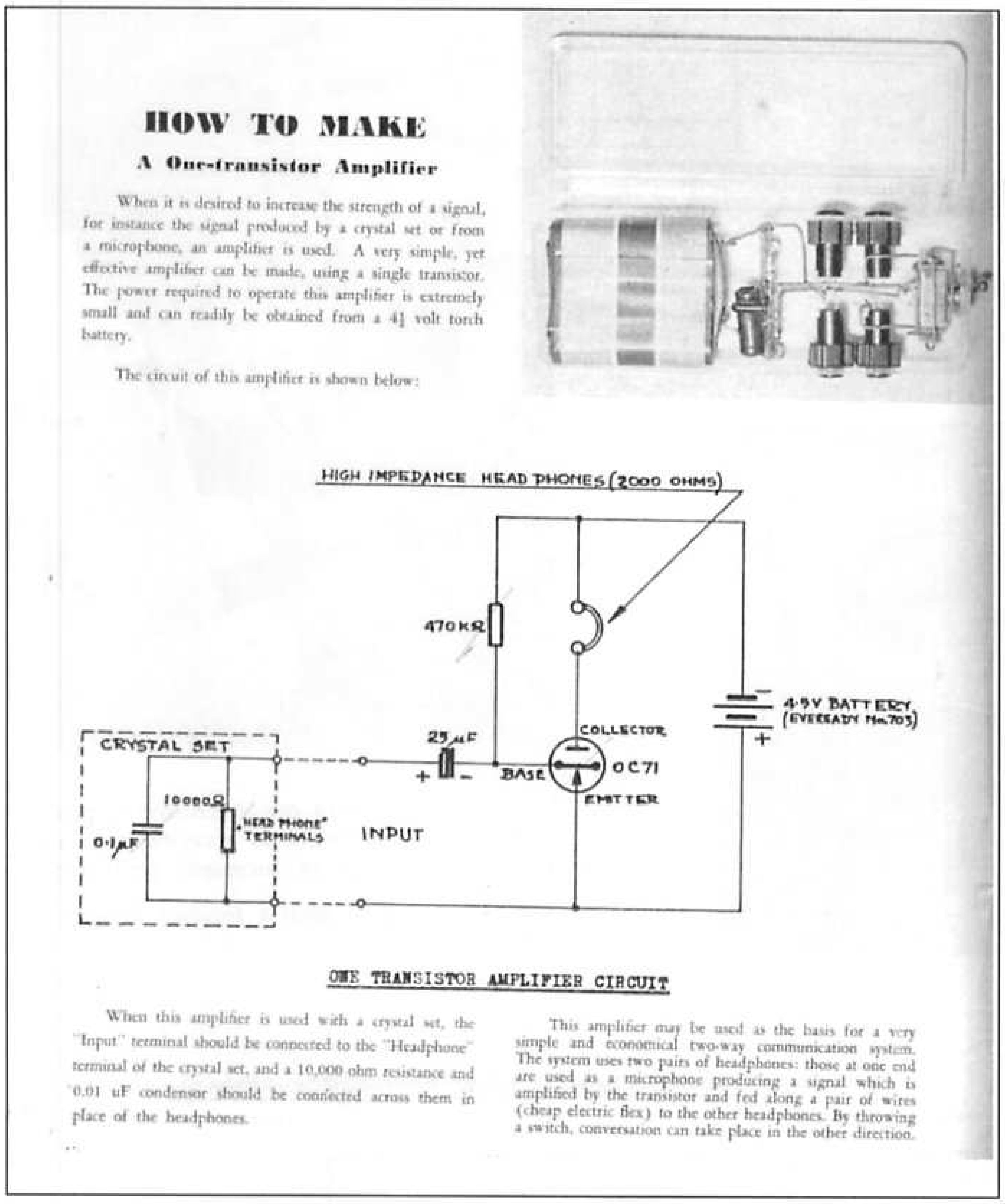
An intercom amplifier and a Morse code oscillator, both using just a single OC70 or OC71, followed and then came the real McCoy, a one-transistor regenerative receiver. Since I was already something of a radio aficionado this was the highpoint, so far, for me. The transistor used was an OC45 and being in a regenerative circuit meant that there was a feedback winding on the same ferrite rod as the tuned circuit (**Figure 5**). This was serious stuff because success all depended on that winding being connected the right way round. But what Mr Bridgen's description of the circuit didn't explain (and which I only cottoned onto years later) was that the receiver was even more subtle than that.

The single OC45 transistor functioned in two different ways in this circuit. It behaved as a self-oscillating regenerative detector and also as a reflex audio amplifier. Careful examination of the circuit diagram will show that the emitter of the transistor is not decoupled but, unconventionally, it is connected back to the base via a 25µF electrolytic capacitor (or condenser, as the book still referred to them), and yet another winding on the ferrite rod whose primary function was to transfer the incoming signal from the aerial to the base of the transistor. This meant that the detected audio signal from the highly sensitive regenerative stage would be re-amplified by that same transistor but now it was acting, in reflex-mode, as an AF amplifier that drove a pair of high-impedance headphones.

I built the receiver, and probably had winding 'C' the wrong way round to start with, but once the connections had been reversed the regeneration control brought the circuit smoothly to the point of oscillation where it was at its most sensitive. And then, after adjusting the 150pF tuning capacitor, in came all the local medium-wave stations to my considerable delight and to much praise from all and sundry.

Some Theory, More Amplifiers And Mathematics

Like all good books, this one kept the readers' interest alive. Never too much of the same thing was the simple formula. So, an early dose of interesting circuits was followed by a burst of very relevant and equally interesting theory. And then came another batch of fascinating circuits to build, all of which made use of the theory just covered. What a way to learn! The inner-workings of a transistor were all revealed with electrons, holes, P-type and N-type



HOW TO MAKE

A One-transistor Amplifier

When it is desired to increase the strength of a signal, for instance the signal produced by a crystal set or from a microphone, an amplifier is used. A very simple, yet effective amplifier can be made, using a single transistor. The power required to operate this amplifier is extremely small and can readily be obtained from a 4½ volt torch battery.

The circuit of this amplifier is shown below:

ONE TRANSISTOR AMPLIFIER CIRCUIT

When this amplifier is used with a crystal set, the "Input" terminal should be connected to the "Headphone" terminal of the crystal set, and a 10,000 ohm resistance and 0.01 uF condensor should be connected across them in place of the headphones.

This amplifier may be used as the basis for a very simple and economical two-way communication system. The system uses two pairs of headphones: those at one end are used as a microphone producing a signal which is amplified by the transistor and fed along a pair of wires (cheap electric flex) to the other headphones. By throwing a switch, conversation can take place in the other direction.

Fig. 4. An OC71 amplifier and its circuit diagram

material – and the doping needed to cause them – all sandwiched into just a few pages with lots of pictures to help the digestion of all these new facts. And there was maths too. That was a timely reminder that none of this could possibly happen unless the designers also did the necessary sums. When you're 13 years old, and maths at school can sometimes seem rather pointless, there is nothing better to focus the mind than a wonderful example of electronics to emphasise just how important the mathematics is (**Figure 6**).

Mr Dubbelman was the multi-transistor amplifier designer. From one transistor performing one function (or two in the reflexed regenerative receiver) we now moved to multiple transistors connected in cascade that provided much more amplification; sufficient, in fact, to drive a loudspeaker. Mr Dubbelman's transistors were drawn using the symbol that has now become the international standard (**Figure 7**). And this was good because the last thing one wanted when just starting out was to confuse transistors with triodes!

The subtleties of electronic circuit design immediately began to emerge. Biasing of transistors, the need for decoupling, the role of feedback and even the characteristics of transformers when used for interstage coupling lurked somewhere within those circuits as did the fact that transistors were very sensitive to excessive heat so good thermal dissipation, in the form of heatsinks, was vital. And though it didn't occur to me at the time, the frequency response of the amplifier depended not only on the transistors used but also very much on the reactances of the coupling capacitors (or condensers as they were called then), and even on the characteristics of those transformers.

It was only years later, when I was immersed in electronic theory as a university student, that I realised that the 'topology' of that audio frequency amplifier was exactly the same as that of a solid-state high frequency linear power amplifier used at the output of SSB transmitters. The only difference being the values of the components and the construction of the transistors and those transformers. But, of course, no one had heard of SSB in 1958!

A Transmitter...

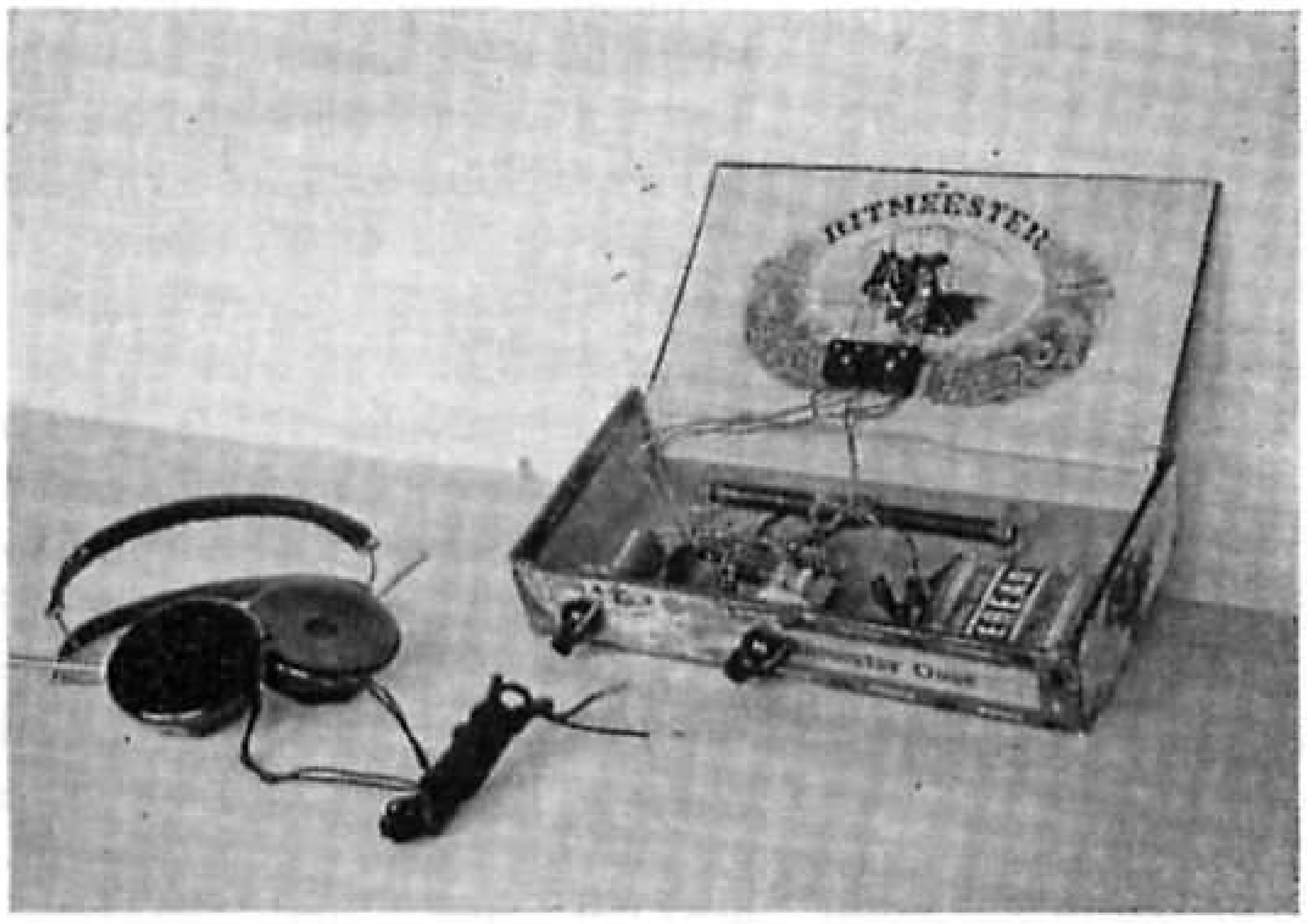
Amateur radio had come into my world by then, thanks to two things. The first was the wonderful old HMV 141 receiver that occupied an important position in the family lounge. The other was Sunspot Cycle number 19 that reached its peak – the highest yet recorded – around 1957/8, the very time that my interest in radio began to emerge. Signals from all over the world roared in on that HMV receiver owing to superb ionospheric propagation. And for that one had to thank all those sunspots. From then on I was hooked on amateur radio. To my delight, I discovered that *Transistors For the Home Constructor* contained the circuit diagram for a transmitter that would work on the 80m amateur band!

The fact that I did not have an amateur radio licence, being five years too young (as the rules were then in South Africa), was not really an issue that dwelt long on my mind. The mere fact that one could actually send a voice-modulated signal over some distance, which would then be received on the HMV, was the magical bit. Closer reading of the article indicated that 'long-range' was certainly not what Philips had in mind when they included that transmitter in their wonderful compendium.

The circuit diagram showed an OC44 as an oscillator. Modulation came from the carbon microphone used in a standard telephone handset of those days. Even more careful reading also revealed that the OA85 diode had an important part to play in this process. By varying the voltage across the diode in sympathy with the voice – the function of the telephone handset – would cause the capacitance of the diode to change. Now that capacitance *C*, when combined with the inductance *L* wound on a ferrite rod, plus a couple of other capacitors, constituted a tuned circuit whose resonant frequency would vary with the voice. So this combination of *L* and *C*, plus the necessary biasing resistors and two semiconductors, was my first transmitter (**Figure 8**).

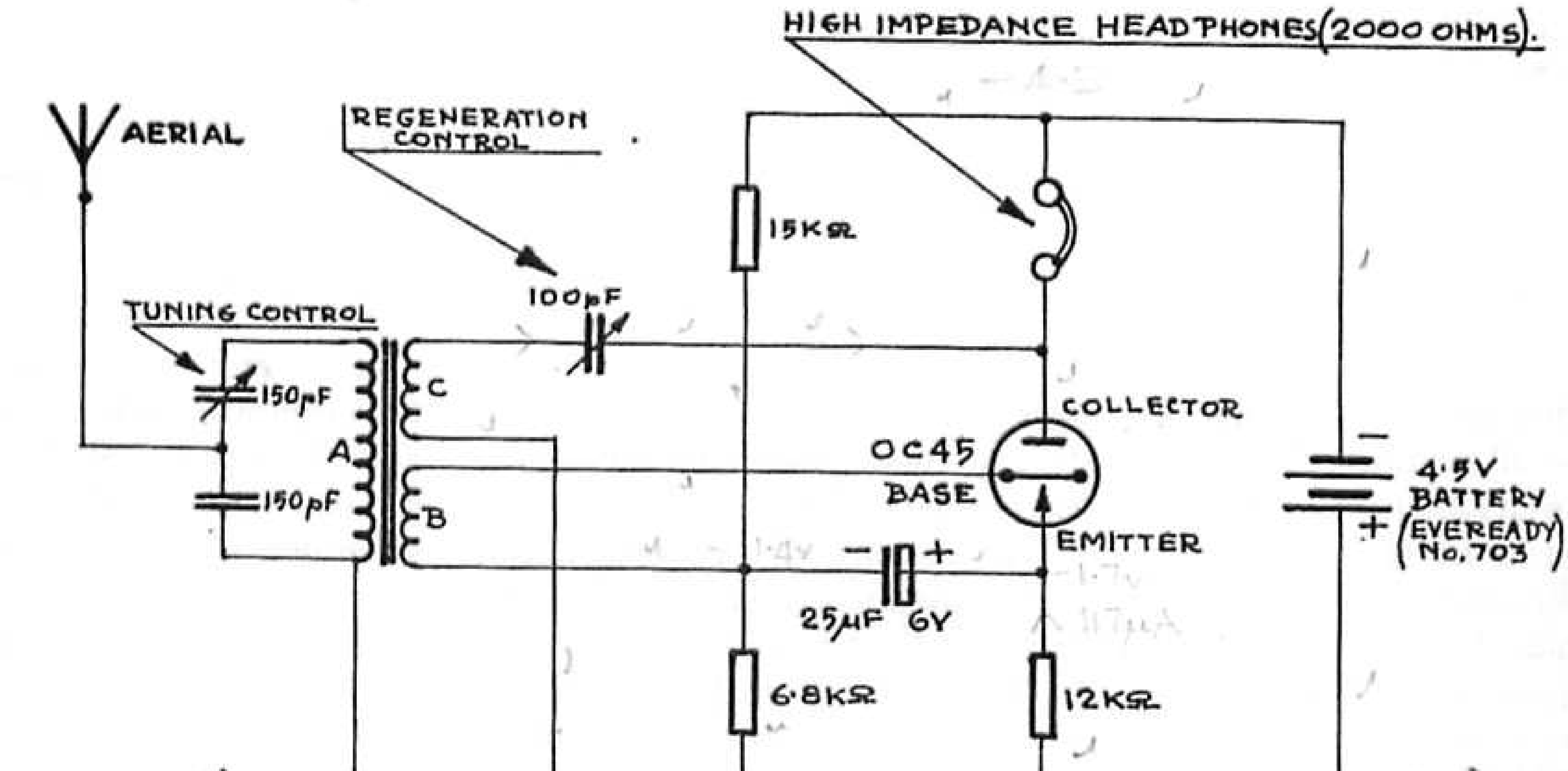
HOW TO MAKE

A One-transistor Regenerative Receiver



A receiver using one transistor is practically as easy to build as a crystal set, but has the advantage of increased sensitivity.

The circuit of such a receiver is shown below:

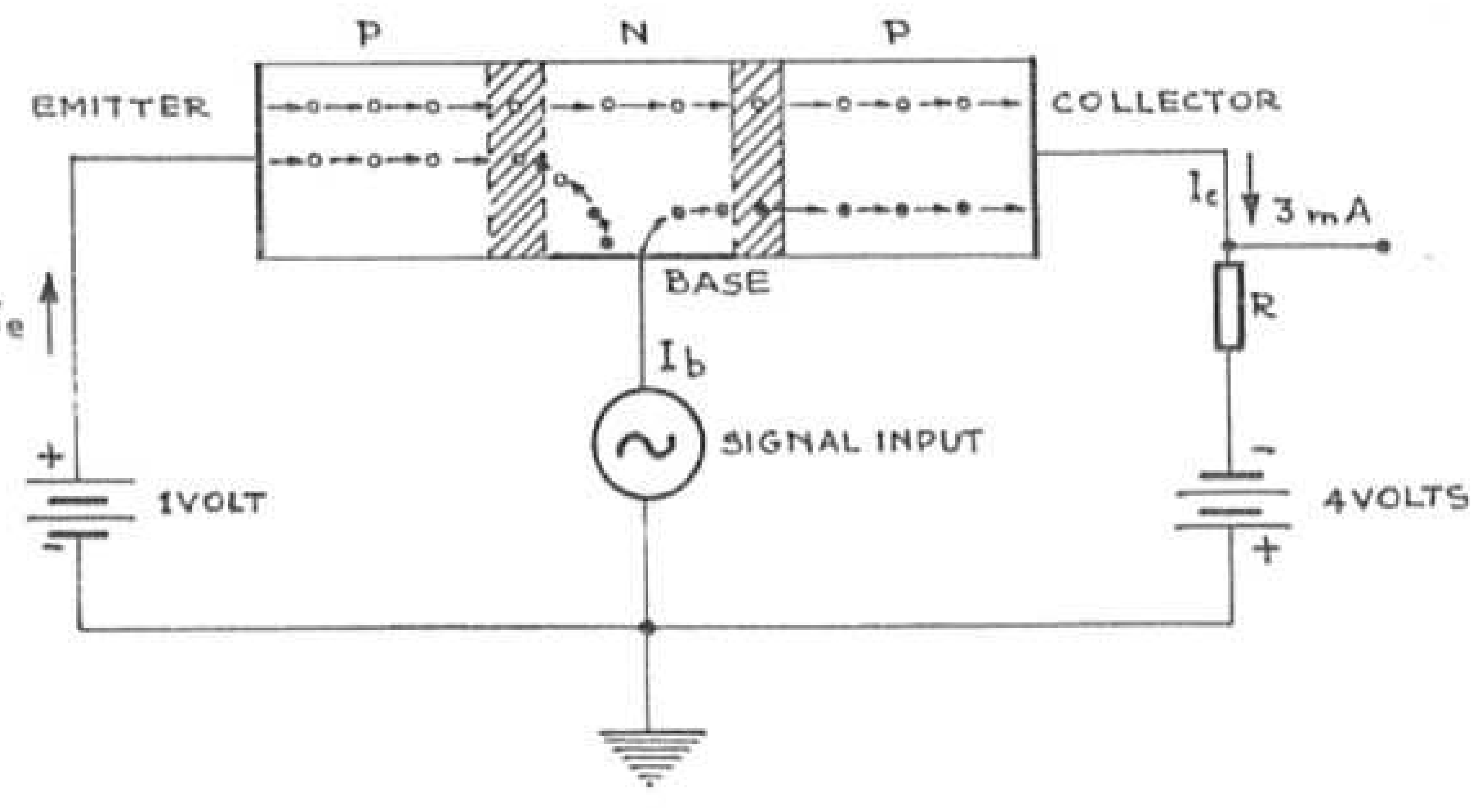


The coil is wound on a 14 x 1 cm. Ferroxcube 4B rod using 29 S.W.G. enamel wire. Winding "A" has 120 turns; winding "B", wound at the earthy end of winding "A", has 7 turns; while winding "C", wound close to winding "B", has 10 turns.

To make the receiver function properly, the regenerative winding, winding "C", must be connected into the circuit the right way round. If this has been done the receiver will start oscillating at some setting of the regeneration control, indicated by a hissing sound in the headphones.

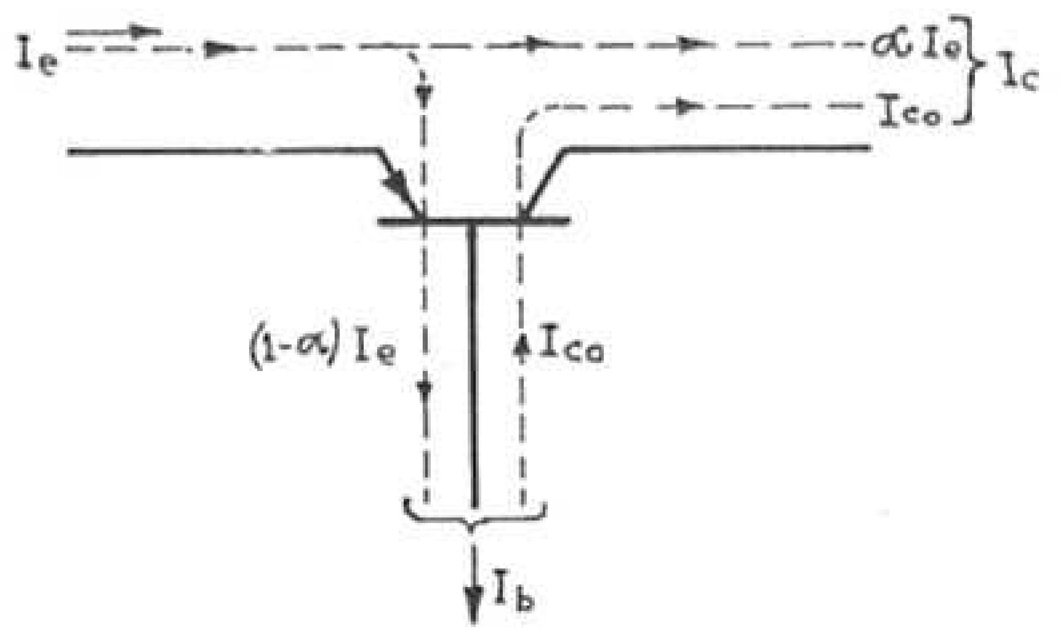
The receiver should be connected to a good aerial and earth. The aerial should have a length of at least 25 yards and be as high up as possible, while the earth connection may be made either to a cold water pipe or to a metal rod buried in the ground.

Fig. 5. The regenerative and reflex receiver built in a cigar box



Transistor Amplification Process.

FIG. 5A



V_c = collector voltage (relative to base)
V_e = emitter voltage (relative to base)
I_e = emitter current
I_b = base current
I_c = collector current
I_{co} = collector cut-off current (I_c with I_e = 0)

FIG. 5B

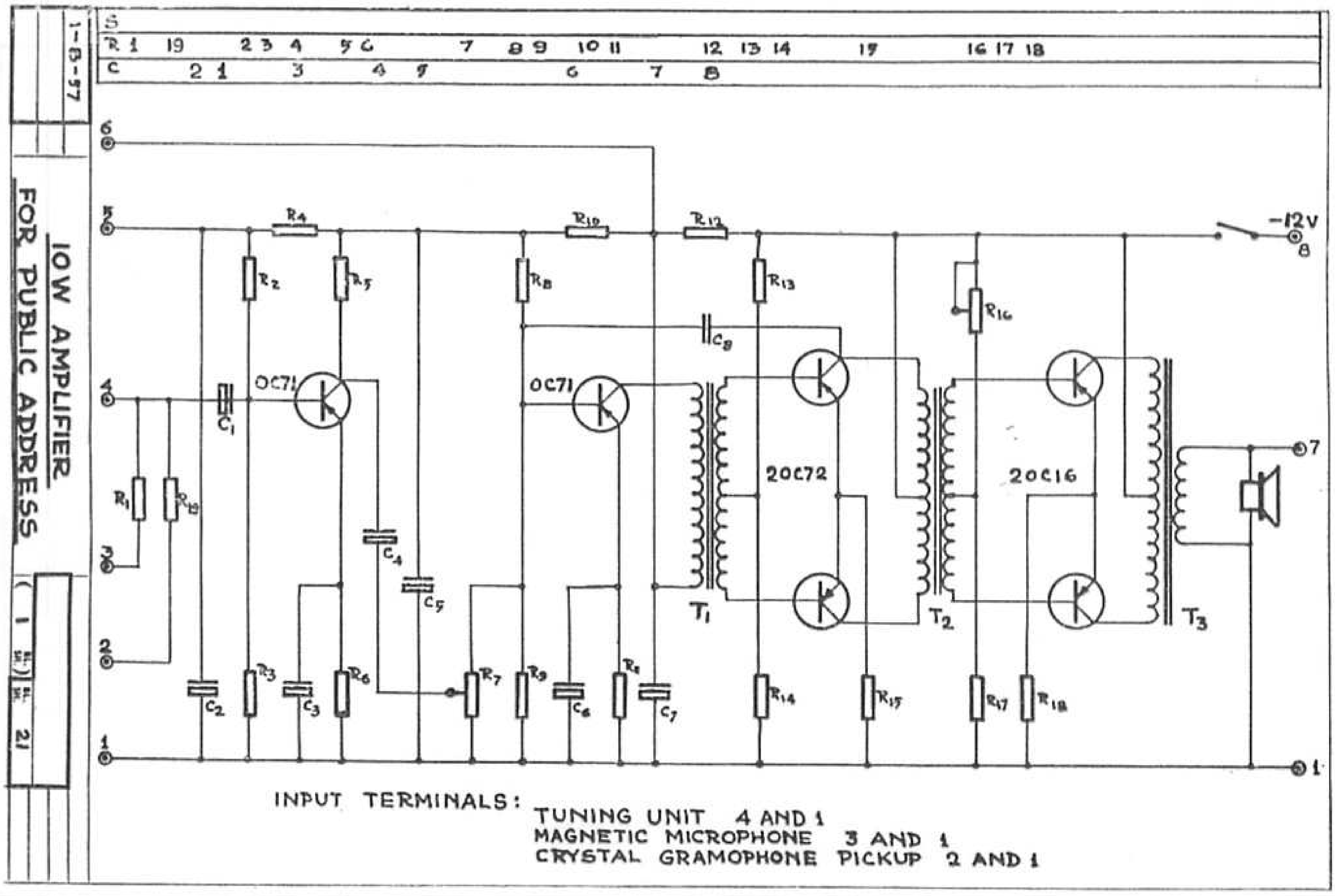
Fig. 6. Theory of operation of a PNP transistor

It will be noted, of course, that the modulation produced was FM rather than AM. This inconvenience, since the HMV receiver in the lounge was only intended for AM reception in the broadcast and short-wave bands, was addressed in my new Philips bible. It said the following: 'The receiver must not be tuned "spot on" the carrier of the transmitter, but somewhat off-frequency so that it can detect the frequency modulated signal of the transmitter'. This was slope-detection at work, though the term meant nothing to me then. And, yes, it was only a short-range device. The book said about 50 yards and that's what it did. But what an achievement!

And Another Receiver

Chapter IX of this mine of electronic information was entitled *How to build a Transistor Superhet receiver*. What constituted a 'Superhet' took up a good few pages to explain but they were liberally illustrated with drawings and

Fig.7. (below) The archetypical broadband transistor amplifier



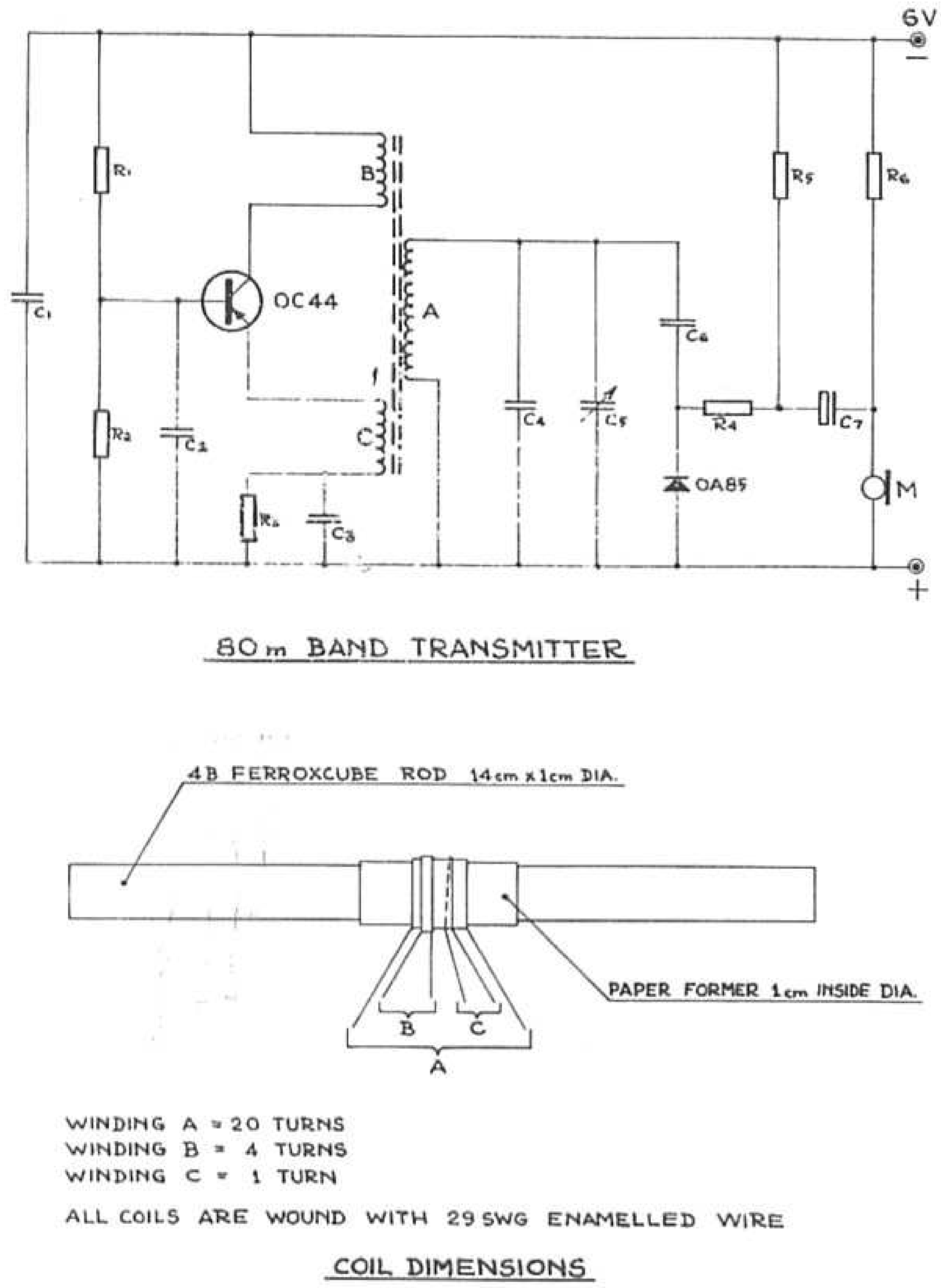


Fig. 8. A one-transistor 80m band FM transmitter

that certainly helped. Then came two circuit diagrams, since two receiver options were available to the constructor. The first contained four transistors configured as a self-oscillating mixer (OC44), followed by a single IF stage around 455kHz (the book called it Kcs), using an OC45, and then came two stages of audio amplification with an OC71 driving the OC72 power amplifier and its 60Ω loudspeaker. Detection was taken care of by an OA79 diode.

The second receiver had two stages of IF amplification plus an additional audio stage and then a push-pull pair of OC72s transformer-coupled to a 3Ω speaker. And that receiver also contained some AGC, which I discovered was the feedback loop providing automatic gain control (**Figure 9**).

My youthful enthusiasm to construct the simpler of the two receivers was reined in, to some extent, by the realisation that such things require a bit of planning. For example, neither my father nor I had heard of printed circuit boards in 1958 and, apparently neither had SA Philips because the photographs accompanying the receivers showed them to be built on tag boards mounted on an aluminium chassis. And then there were the mechanical things like mounting the IF transformers, the variable condenser and the volume control, and even arranging the dial drive and where to put the loudspeaker

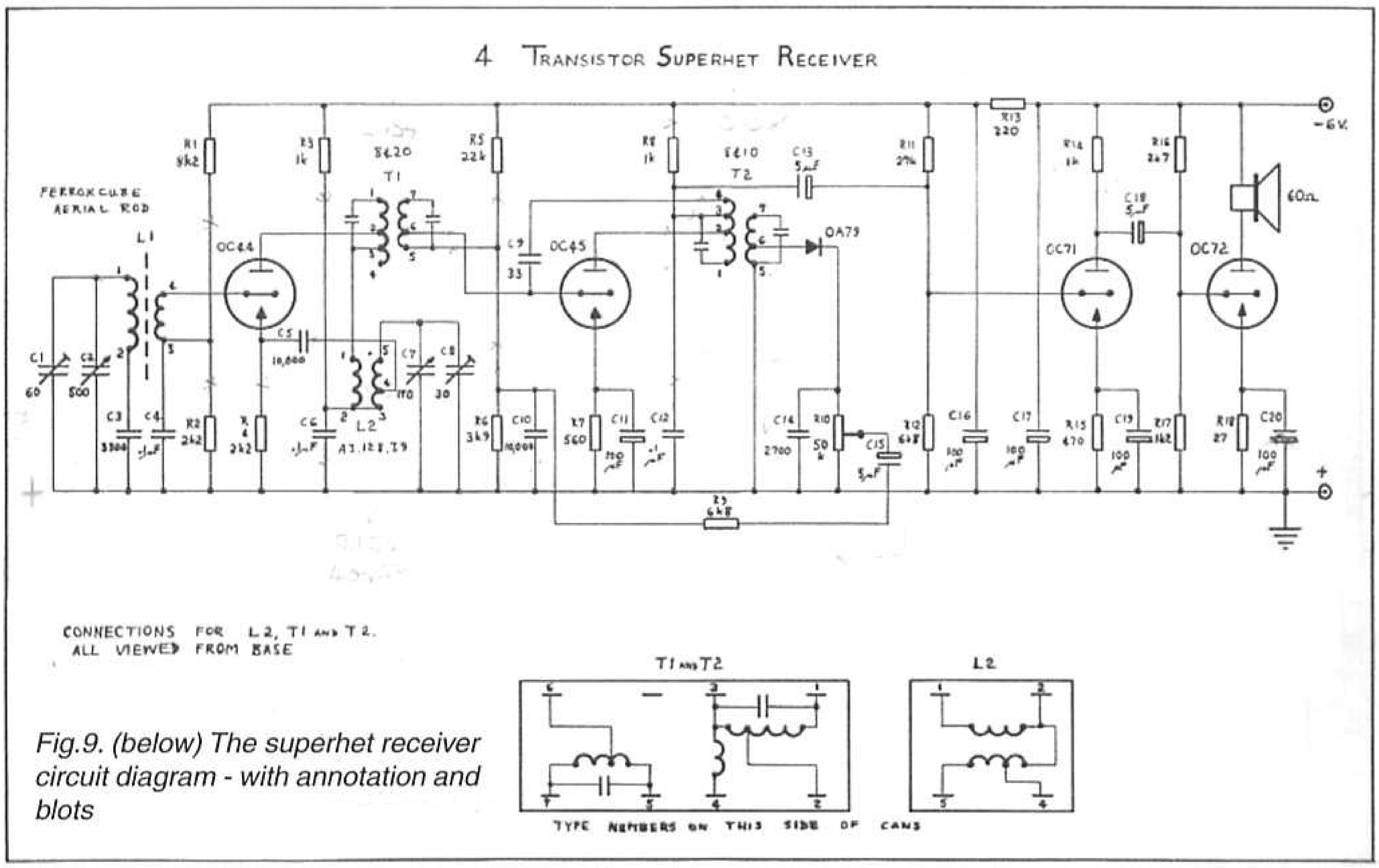


Fig.9. (below) The superhet receiver circuit diagram - with annotation and blots

and so on. Those things couldn't be rushed. As we would say today, I was on a 'learning curve'.

We soon found we had to take up Dr Heydenrych's kind offer of assistance when we hit an apparently insoluble problem. Now, nearly sixty years later, I cannot remember what it was but a telephone call to the Philips laboratory 'in town' was soon routed through to none other than Mr Bridgen himself. He listened attentively as my father explained the problem as we saw it. Perhaps it was something to do with the fact that we didn't have a signal generator, so adjusting the IF stage so that its passband was centred on 452kHz (as the book said it should be) was rather like painting in the dark. But I do remember our going back to the 'shack' and setting the tuning condenser around about mid-range. Then, presumably, we adjusted the oscillator (the OC45 stage) until – and lo and behold – the sound of music issued, though perhaps somewhat weakly, from the loudspeaker. There was our test signal which enabled the IF transformers to be tweaked until the best-sounding signal was heard. After that it was probably 'just' a case of adjusting the condenser and trimmer of the local oscillator until all the local stations were tuneable across the medium-wave band. Our superhet was working.

The Future Beckons

With such a start it wasn't too surprising that my career was beginning to be mapped out. Within a couple of years the 'space race' between the Russians and the Americans had begun. By then other books on the subject of radio, especially an old copy of the ARRL *Radio Amateur's Handbook* had found its way into our home from the bookshelves of a local school fête. I soon built another receiver, also regenerative but this time using a double-triode valve, and with its collection of plug-in coils, all wound on plastic formers, the short-wave bands came alive.

I heard the launch, from the *Voice of America* (VOA) transmitters, of the *Mercury* capsule that took Alan Shepard on his sub-orbital flight in 1961 that made him the first American in space. I also listened to the launch and subsequent communications between mission-control in Houston and every one of the subsequent NASA missions, all relayed by the VOA. And best of all was that I'd built the receiver on which those transmissions made such indelible memories and which, undoubtedly, launched me on my career.

The Philips Legacy

Volume II of *Transistors for the Home Constructor* was published in 1961. It took the art of electronic design to a new level, and far above me as a schoolboy. But just a few years later, at university, it turned out to be very useful when I was grappling with small signal models of transistors and other equally esoteric things. Dr Heydenrych, in its preface, remarked at how well Volume I had been received, even prompting publication of a second edition within a year. And a special batch of a thousand copies was sent to New Zealand to meet an unexpected but not unsurprising request from there.

I'm sure there's no doubt that I wasn't the only 'home constructor' whose choice of a future career was so influenced by that wonderful book. ***RB***