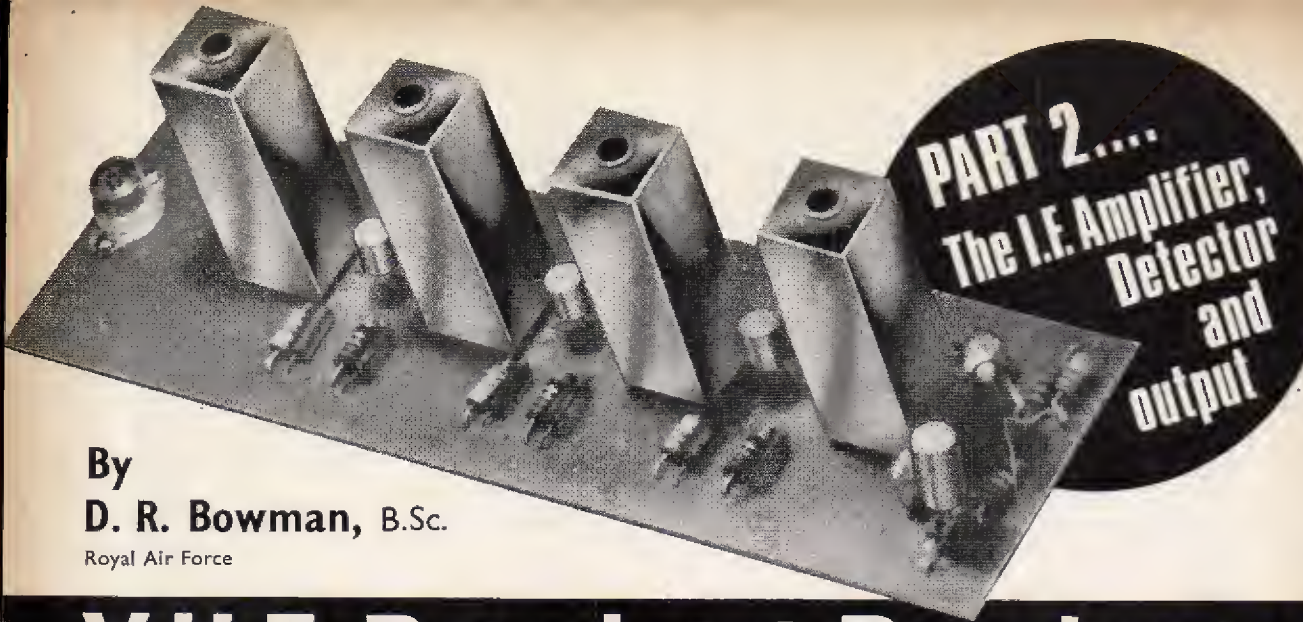

PART 2.... The I.F. Amplifier, Detector and output

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V.H.F. Broadcast Receiver

THREE stages of i.f. amplification (at 10·7Mc/s) are employed, and these are followed by a ratio detector.

It is worth mentioning at this point that although some hi fi people would regard this with some surprise, the decision to use a ratio detector is backed by sound principles. Eyebrows may be lowered. The ratio detector is capable of just as linear a response as the Foster-Seeley or the earlier Rond-Travis discriminators, and although the Foster-Seeley has been the "standard" for valve users for a good many years, nowadays more and more designers are using the ratio detector.

For transistor circuits the Foster-Seeley has notable disadvantages unless a relatively low i.f. is used, and the bandwidth needed has to be obtained by a much more critical i.f. amplifier set-up.

The theoretical man will appreciate that the mathematics of either type of discriminator show just the same opportunities for distortion, and that this can be minimised by using an i.f. amplifier whose response curve is "gaussian"—that is, bell-shaped—giving the most linear phase change through resonance point. Any reasonably advanced text book on electric circuit analysis may be consulted on this point, for example M.I.T. Radiation Laboratory Series Vol. 18—Vacuum Tube Amplifier (Valley & Wallman; McGraw-Hill Book Co.).

What is very important is to see that the i.f. amplifier and detector overall response is a smooth curve, rising steadily (though rapidly) to a peak at resonance and dropping off thereafter in an equally steady and rapid way. Any bumps or spikes on this curve are reflected in irregularities of phase-change, and consequent kinks in the phase characteristic. Fig. 13 illustrates a good and a bad type of response curve, with the appropriate phase characteristic.

To ensure that the i.f. amplifier has the proper response fixed neutralisation has been abandoned, and variable neutralising capacitors are used instead, TC3, 4, and 5. These have to be adjusted, when the i.f. amplifier has been built, to get the proper response curve.

CRITICAL WINDINGS

The construction of the i.f. amplifier transformers is also somewhat critical, especially as regards the gauge of wire used and the spacing between primary and secondary. (Refer to data and Fig. 8 in last month's article.) Coupling has been arranged to be a little less than "critical", except in the detector stage where joint critical coupling is employed.

If any difficulty exists in deciding the spacing, one should err on the generous side, rather than bring the windings even fractionally too close. Also the wire must be wound close, that is, with the adjacent turns touching. Any systematic gap will increase the winding length unacceptably. This is not usually a bother when coils are wound by hand, but if a winder is used the coils should be carefully inspected after construction.

Correct spacing is best obtained by cutting a strip of drawing paper the exact width required, and with it winding a spacer centrally on the former. The windings can then be started from the centre, hard up against the spacer; the latter may be removed later, when the fixing cement is hard and dry, but there is no real need to do this.

With regard to the detector transformer T7, particular care is necessary here, since a number of associated components have to be fitted inside the screening can in addition to the actual transformer assembly. Provided the smallest size of components is used, the "long" can specified will accommodate all items shown inside the dotted line which represents the can in Fig. 11. Details of the assembly of these components on the coil former are given in Fig. 12.

THE ETCHED CIRCUIT BOARD

The etched circuit is set out on a piece of copper clad laminate measuring 2¾in by 8in, as shown in Fig. 10.

The conductors are relatively few, and may be drawn direct on to the laminate surface with an acid resist. Thinner cellulose paint may be used for this quite successfully, but the vapour is dangerous to inhale and the process should be done in the open—or at the least, in an extremely well-ventilated room.

The best resist the writer has discovered is a proprietary french polish type of fluid known and marketed as "Glitseal", which is obtainable from "do-it-yourself" shops. This has to be diluted with about one-third of its volume of methylated spirit, as it is too thick for accurate small work, and for visibility it is dyed with a few crystals of crystal violet, obtainable from any dispensing chemist.

The conductors may be drawn with this mixture, using a ruling pen preferably as a small brush cannot readily be set against a straight edge. It should be noted that the conductors N, P, Q, and R are the earthing strips for the i.f. transformer cans, and conductor S is the earth point for the coaxial socket output to the i.f. strip. The conductor A is the common "earth" connection, and is best made quite wide as several component leads have to be soldered to it.

When the "conductors" are dry and hard, a careful check should be made to see that all is well. Then the etching process may be carried out, using 30 per cent ferric chloride solution in the usual way—see last month's article.

The theoretical circuit of the i.f. amplifier, detector, and pre-amplifier is given in Fig. 11, and during the wiring-up procedure this diagram should be consulted frequently to ensure that no errors occur. When wiring is complete the circuit board should be given a coating of varnish—the "Glitseal" is excellent for this purpose—to protect the copper laminate against corrosion.

ALIGNMENT OF THE I.F. STAGES

To set up the i.f. amplifier the following method should be followed. This will enable a stable and well-tuned amplifier to be achieved, which is then trimmed for the correct response curve.

A multimeter is needed, and a signal generator capable of supplying a signal of 10·7Mc/s, amplitude modulated or unmodulated at will. The leads from the multimeter should be decoupled at the ends by means of 5 kilohm resistors, and these soldered lightly to tags 3 and 11 (across the stabilising capacitor of the ratio detector). The leads must be arranged to lie well away from the i.f. stages.

Set the multimeter to the 50μA or 100μA range, and the signal generator to high output.

Set the neutralising capacitors TC3, 4, and 5 to minimum. Disconnect the two 100Ω decoupling resistors R17, R21 from the B− line; this leaves only the ratio detector driver transistor and the pre-amplifier transistor in operation. The battery supply is now connected.

Most likely at this stage the microammeter will show a reading, indicating the stage is oscillating. Rotate the adjustment of TC5. Two positions will be found at which the stage breaks into oscillation, with a space between when no oscillations occur. Obtain the centre setting. Switch on the signal generator and bring the "live" lead near the base of TR6. Rotate both cores of T7 until maximum deflection of the meter is obtained, reducing the signal generator output if necessary. It may well happen that as the transformer is brought into line TC5 will require re-adjustment, but there is no difficulty at all in tuning up this stage and neutralising it.

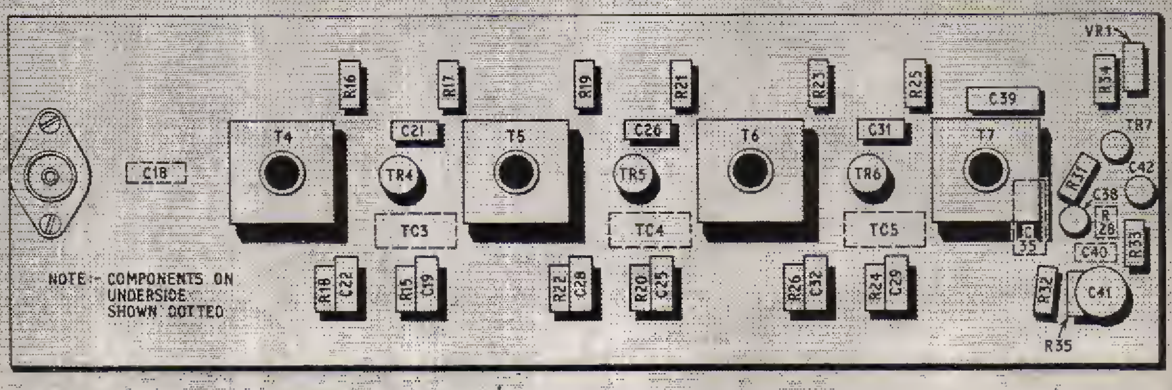
Next tune the secondary of T5 until maximum meter deflection is reached, once again adjusting TC5 as necessary to recover stability. No contact should be necessary between the signal generator lead and the base of TR6, but if the signal generator output is small the lead may be connected via a small capacitor to the primary of T6 at the collector terminal of TR5.

Next transfer the signal generator lead to the base of TR5, again without physical contact, and re-tune the transformer T6. As the transistor for this stage is not working yet, a small reading only will be obtained unless the signal generator output is increased. Connect up the decoupling resistor of this stage (R21), to bring the stage into operation. Again, oscillation will probably result, and in the absence of an input signal a meter reading will be obtained. Adjust TC4 to stabilise the circuit, and tune the secondary of T5.

Couple in R17, and repeat the above adjustments with T4, T5, and TC3. At this stage it may well be found that *very small* adjustments of TC4 and TC5 are required to retain overall stability. These will amount only to a fraction of a turn—10 degrees or so of adjustment is usually enough.

Now that the i.f. amplifier is stable and roughly tuned the signal generator output lead should be plugged into the coaxial socket SK2, and the output reduced to a few microamps r.f. Re-tune the entire receiver for maximum output at the meter. It should

Fig. 9. A top view of the i.f. printed board showing component layout



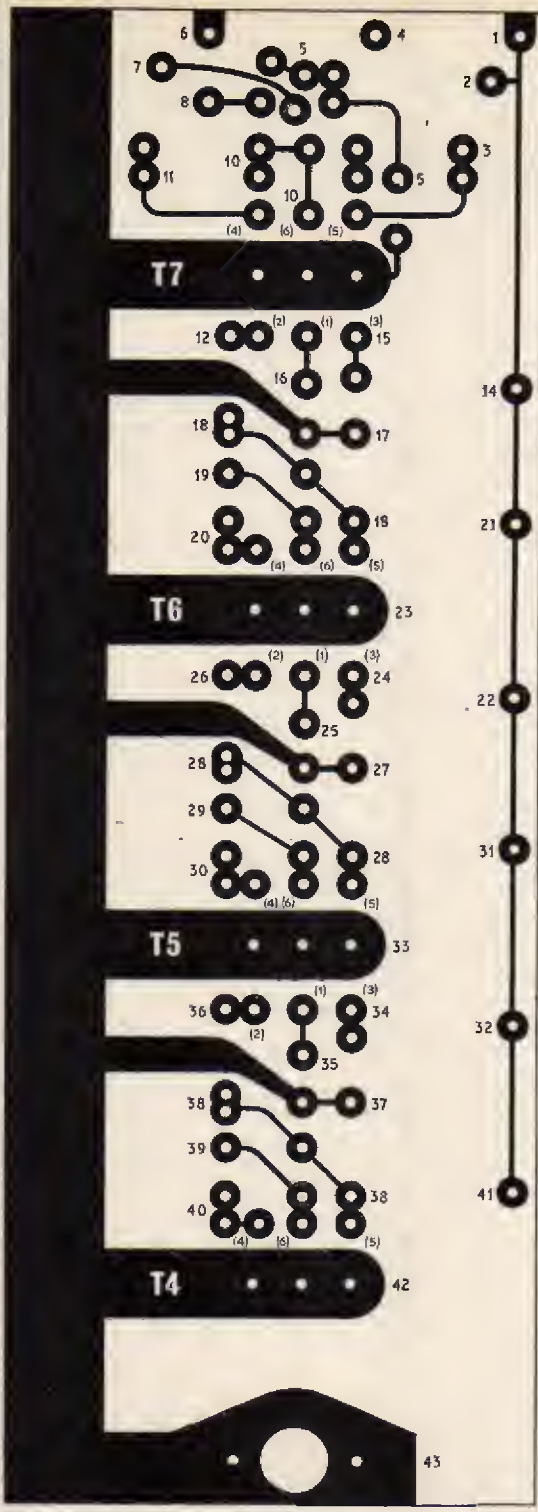


Fig. 10. Printed board. The small numerals refer to similarly numbered points on the circuit. The small numbers in brackets are the pin numbers of the coils. See Fig. 11. The common earthing strip on the left-hand side is referred to as "A" in the text

be found that the stages tune quite independently. If not, neutralisation is not exact. *Very slight* adjustments of all three neutralising capacitors are now needed, with re-tuning of the transformers as necessary, until the transformers tune independently, and a change in the setting of one core does not affect the timing of the next stage.

VISUAL ALIGNMENT

If a wobbulator (i.e. frequency modulated oscillator) and an oscilloscope are available it is possible to align for the best response curve.

For this, deviation is set to the maximum; and the stabilising capacitor C38 temporarily disconnected from points 3 and 11, and the oscilloscope connected to these points. If necessary, one of these points may be earthed temporarily. Extremely slight adjustment of transformer tuning and of the neutralising capacitors will permit a smoothly-rounded curve to be obtained.

THE DETECTOR

The next step is to adjust the ratio detector. Re-attach the stabilising capacitor C38 between points 3 and 11, and connect a pair of headphones (or audio amplifier) to detect the modulated output. Connect the signal generator output to the coaxial input socket SK2. Switch on the modulation in the signal generator. Maximum sound output will not be obtained, but there should be some. Rotate the core of the secondary of the discriminator transformer T7 until *zero output* is obtained. This will be quite sharp.

Next, if a wobbulator is available set to 25kc/s deviation and connect its r.f. output to the input socket and the oscilloscope between points 5 and earth. While listening to the output, tune the wobbulator gently so that its output frequency slowly reaches the intermediate frequency to which the i.f. amplifier is tuned.

As the wobbulator comes into tune, the harsh-sounding third harmonic should disappear completely, leaving a pure tone. Meanwhile the trace should show a straight line inclined to the X axis. Increasing now the deviation to a large extent will reveal all or part of the phase response curve. If all has gone well, the trace should closely resemble Fig. 9a. If not, very slight further adjustments may be made until the perfect characteristic is approached.

If exceptionally high fidelity is not the aim, the wobbulator test may be omitted, the final check being to tune the signal generator gently through the i.f. with the meter connected across the stabilising capacitor C38 as before, and the amplitude modulation switched on. The output should be monitored aurally.

As resonance is approached the meter reading should rise steadily, in the same way as the amplitude characteristic of Fig. 9a, as the sound output increases. As resonance is approached the sound should die away to zero as the meter approaches maximum. A check should be made that the peaks of the most intense sound are equally spaced about the zero point. Also, by connecting a meter between point 10 or 13 and chassis, check that a zero reading is obtained at the zero sound output point and that equal positive and negative readings are obtained at equal frequencies off resonance.

The conditions necessary for this are that the ratio detector transformer should be absolutely symmetrical, and that it should be matched each side. The 470 ohm and 6·8 kilohm load resistors R29, R30, R31, and R32 should therefore be matched as exactly as possible from stock; for "hi fi" results, match should be to 1 per cent or better. In such a case a matched pair of OA79 diodes is useful, and if they differ (as supplied) by more than 10 per cent it may be advisable to increase the 470 ohm resistors to 680 ohms—also carefully matched.

The two 500pF capacitors C36 and C37 should also be close in value, but this is less important. It is better to get a close match between the load resistors than to be very precise about the actual numerical value.

OUTPUT ARRANGEMENTS

The pre-amplifier stage TR7 is arranged for pre-set output. If this receiver is to be used in association with a sensitive power amplifier (such as the 5W Integrated Amplifier currently appearing in our pages) it may be feasible to dispense with the gain of this stage and instead employ the transistor TR7 as an emitter-follower. This is recommended for the highest quality reproduction.

To effect this change, remove VR1 and connect the collector of TR7 direct to the B− rail. Change the value of R35 to 1·8 kilohm, and remove C41. Output at a few ohms impedance is then taken from the emitter of TR7.

If a coupling capacitor is to be used between this and the next audio stage, a 500μF capacitor should be used. It will be preferable however to use direct coupling into the base of the next stage if d.c. conditions can be achieved correctly.

I.F. INTERFERENCE

The author has found that in certain locations interference can be obtained from transmissions on the intermediate frequency of 10·7Mc/s if any r.f. signal finds its way into the i.f. amplifier. Provided the interfering signal is not so strong as to cause cross-modulation with the desired signal, direct r.f. pick-up can be avoided by good screening and by adequate selectivity in the r.f. stages.

However, in this receiver unit construction is employed, and connecting cables may cause a certain amount of pick-up at i.f.; added to which is the possibility of direct pick-up on the circuit wiring of the i.f. amplifier, unless an earthed screening box for the whole unit is made. Usually, however, it is possible to find a quiet spot within a few hundred kc/s of the nominal i.f., and this is the recommended procedure if interference is experienced.

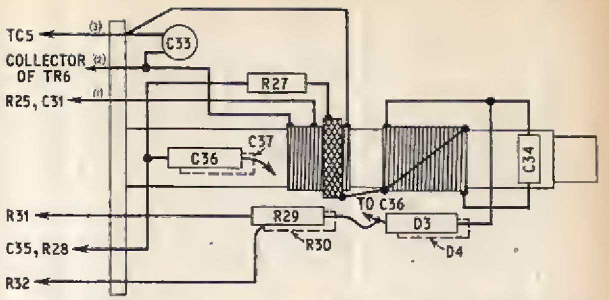


Fig. 12. Wiring of ratio detector circuit. D4, R30, C37 are behind D3, R29, C36, and are similarly wired. When assembled all components should be wrapped in a layer of thin polythene to ensure insulation from the can. For coil connections see Fig. 8 in last month's article

ALIGNMENT OF THE R.F. UNIT

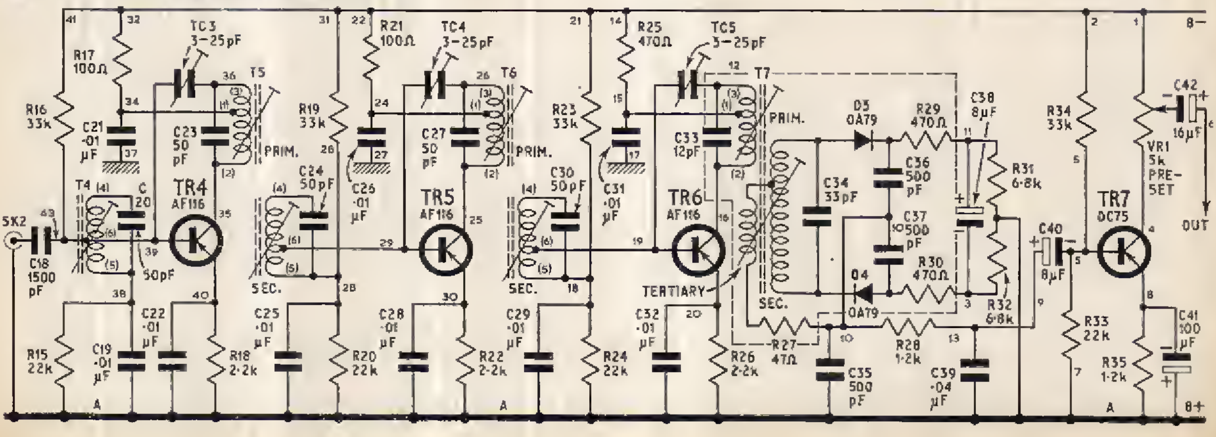
Having roughly ascertained that the oscillator is working in the correct frequency band—in the way previously mentioned—all that remains is to effect a careful alignment using a meter. Either phones or a small loudspeaker may be connected between C42 and B+, or an a.f. amplifier may be attached.

A test oscillator or signal generator is required capable of giving a modulated output (preferably f.m.) over the range 85–100Mc/s. This is set to 87·5Mc/s, and connected to the aerial socket of the receiver; moderate output will be required, say 10mV. The volume control should be adjusted so that the receiver does not emit too much noise. Set the ganged capacitors to maximum (full interleaved) and rotate the core of the oscillator inductor (L2) until a signal is heard. If too loud reduce the signal generator output. Tune the oscillator for peak signal by means of the core. If the signal can be heard at two settings of the core, select the position corresponding to the smaller value of inductance.

Set the signal generator to 100Mc/s and the ganged capacitor to minimum. Adjust the oscillator trimming capacitance until maximum signal is heard. Next set the gang to the half-way position, and tune the signal generator for maximum output in the receiver. Rotate the core of the aerial coupling inductor and of the r.f. interstage transformer for maximum volume.

During the above procedure it will be found that when exact tuning with the signal generator is achieved the modulation disappears, unless the signal generator

Fig. 11. Circuit diagram of the i.f. unit



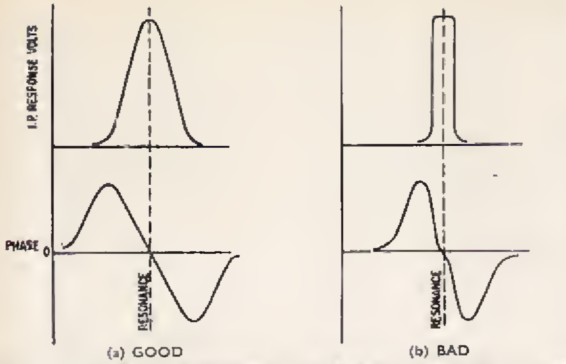


Fig. 13. The i.f. amplifier and detector response curve showing good (a) and bad (b) characteristics

is frequency-modulated. However, a slight mistuning one way or the other will bring in the modulation sufficiently well for the output to be estimated. The following procedure, however, should be carried out with an f.m. signal, or failing this with an extremely small input. The latter can be achieved by attaching the aerial to the receiver—using the signal generator as a low-power transmitter. The signals when received should be barely above the noise level, so that the limiting effect of the ratio detector is at its minimum. Alternatively, the broadcast stations themselves may be used for alignment, but this method is not as accurate and may take more time.

The procedure given in the above paragraphs should now be repeated, except that the aerial π-coupling should not be re-adjusted. Further repetition will give more accurate alignment, but it is seldom necessary to perform the operation more than three times in all.

If a meter is used for the alignment, it should be connected across the capacitor C38. The voltage developed, with an aerial input of $10\mu V$, will be about 1V, but the response is highly non-linear and when the receiver is aligned the BBC transmissions may not give much more than this. Provided the signal generator output is kept as low as will give a reasonable meter deflection there should be no difficulty in achieving correct alignment. ★

COMPONENTS . . .

*Items marked * are not required if an emitter-follower output stage is employed.*

Resistors

R15	15kΩ	R22	2·2kΩ	R29	470Ω
R16	22kΩ	R23	22kΩ	R30	470Ω
R17	100Ω	R24	15kΩ	R31	6·8kΩ
R18	2·2kΩ	R25	470Ω	R32	6·8kΩ
R19	22kΩ	R26	2·2kΩ	R33	22kΩ
R20	15kΩ	R27	47Ω	R34	33kΩ
R21	100Ω	R28	1·2kΩ	*R35	1·2kΩ
	All ¼W carbon			R35	1·8kΩ

*VR1 5kΩ preset carbon potentiometer

Capacitors

C18	1,500pF	C30	50pF
C19	0·01μF paper	C31	0·01μF paper
C20	50pF	C32	0·01μF paper
C21	0·01μF paper	C33	12pF
C22	0·01μF paper	C34	33pF
C23	50pF	C35	500pF
C24	50pF	C36	500pF
C25	0·01μF paper	C37	500pF
C26	0·01μF paper	C38	8μF elect. 15V
C27	50pF	C39	0·04μF paper
C28	0·01μF paper	C40	8μF elect. 15V
C29	0·01μF paper	*C41	100μF elect. 15V

All silver mica or high quality ceramic, unless otherwise indicated

TC3, TC4, TC5 3–25pF

Transformers

T4, T5, T6 I.F. transformers—see text
T7 Detector transformer—see text

Transistors

TR4	AF116	TR6	AF116
TR5	AF116	TR7	OC75

Diodes

D3	OA79	D4	OA79

Miscellaneous

SK2 coaxial socket

OFFICE WORK MADE EASY . . .

ELECTRONICS is playing an important part in automation of office methods and it was evident from the Business Efficiency Exhibition, held at Olympia on 5–14 October, that the modern business establishment is finding new ways of speeding up office work and reducing the risk of error.

Among new developments there was the new electronic calculator, on show for the first time by Friden, which displays four rows of numbers and answers, including the decimal point and function signs, on a small c.r.t.

The decimal point can be positioned to give 0, 2, 5, 7, or 11 decimal place working, and any number of calculations can be made instantaneously by operating a simple 10-key keyboard.

The emphasis on quick and simple operation of dictating machines has been further enhanced by automatic tape threading and coupling to the take-up spool by the operation of a simple lever. The operator of one particular model, made by Philips, need not and indeed cannot touch the tape himself once the cassette is on the machine.

Another new dictating machine, developed by Grundig, uses foil, instead of the more conventional oxide coated plastic tape.

This unique museum piece, thought to be the earliest idea of an acoustically operated chain driven dictating machine, was on the Aga stand at the B.E.E. Let us hope it does not cause redundancy among shorthand typists !