Simple novice transmitter for the 3.5MHz amateur band

Here is a simple transmitter design for those who hope to have their Novice Licence shortly. Using only four readily available valves, it will enable you to get on the air with a minimum of time and effort. A matching modulator and power supply will be described next month.

by IAN POGSON

The idea of a Novice Amateur Licence is one which has been under consideration for a number of years and at the time of writing it is almost a reality. Let us hope that by the time this appears in print candidates will have some definite information as to when they will be able to get going.

Meanwhile, we have been giving the matter some careful thought regarding the presentation of a suitable transmitter for the Novice Licensees. Although Novices will be licensed to operate on certain segments of the 3.5MHz, 21MHz and 27MHz bands, on CW, AM, SSB and narrow band FM, we considered that it would be rather too complex a project to attempt to cover too much in one hit. We have chosen a rather simple transmitter for use on 3.5MHz only catering for CW and AM. This unit is straightforward and should be quite easy for the novice to get going.

In addition to frequency restrictions for novices, the power input to the final is restricted to 10 watts and the transmitter must also be crystal controlled. All of these points can be met without any problems. The next question we faced was how we should go about designing a transmitter of this type—what physical form should it take, should it use solid state devices or should it use valves?

Perhaps the most important decision related to the use of solid state techniques versus valves. We settled for the latter, as valves are far more tolerant and easy to get going in transmitter applications. But the choice of valves was a harder one to decide, as a wide range of possibilities suggest themselves. Within reasonable limits, there are many valves which will do the functions required. More will be said about possible alternatives later on.

For the transmitter proper, that is, the crystal oscillator and final stages, we considered that two valves common to many television receivers would be suitable: a 6BX6 for the crystal oscillator and a 6CM5 line output valve for the final. We had already used the 6BX6 as an oscillator in the past, but we had not seen the 6CM5 used in the role of an RF amplifier. The characteristics of the 6CM5 appeared to be attractive for this application, being quite rugged with regard to dissipation ratings, compared with the power which we would be asking it to handle.

Having arranged a rough lash-up of a 6BX6 crystal oscillator and a 6CM5 RF amplifier, we soon had over 1.5mA of grid drive to the 6CM5, without any HT applied to the plate or screen. Further investigation led to suitable screen grid and plate circuit constants and we had no trouble in loading the 6CM5 up to 10 watts plate input. In short, the 6CM5 turned out to be an excellent valve for the application. Of course this investigation was restricted to the 3.5MHz band, and it remains to be seen just how well it would perform at higher frequencies. This can come later should the need arise.

The same question arises as to what should be used for a speech amplifier and modulator—solid state or valves. For similar reasons already stated, we decided that it would be best to use valves. What valves? For the speech amplifier, there are a number of alternative choices but we settled for a 12AX7. This consists of two high gain triodes and when used in cascade, these give enough gain for a microphone input to drive a pentode or beam power amplifier.

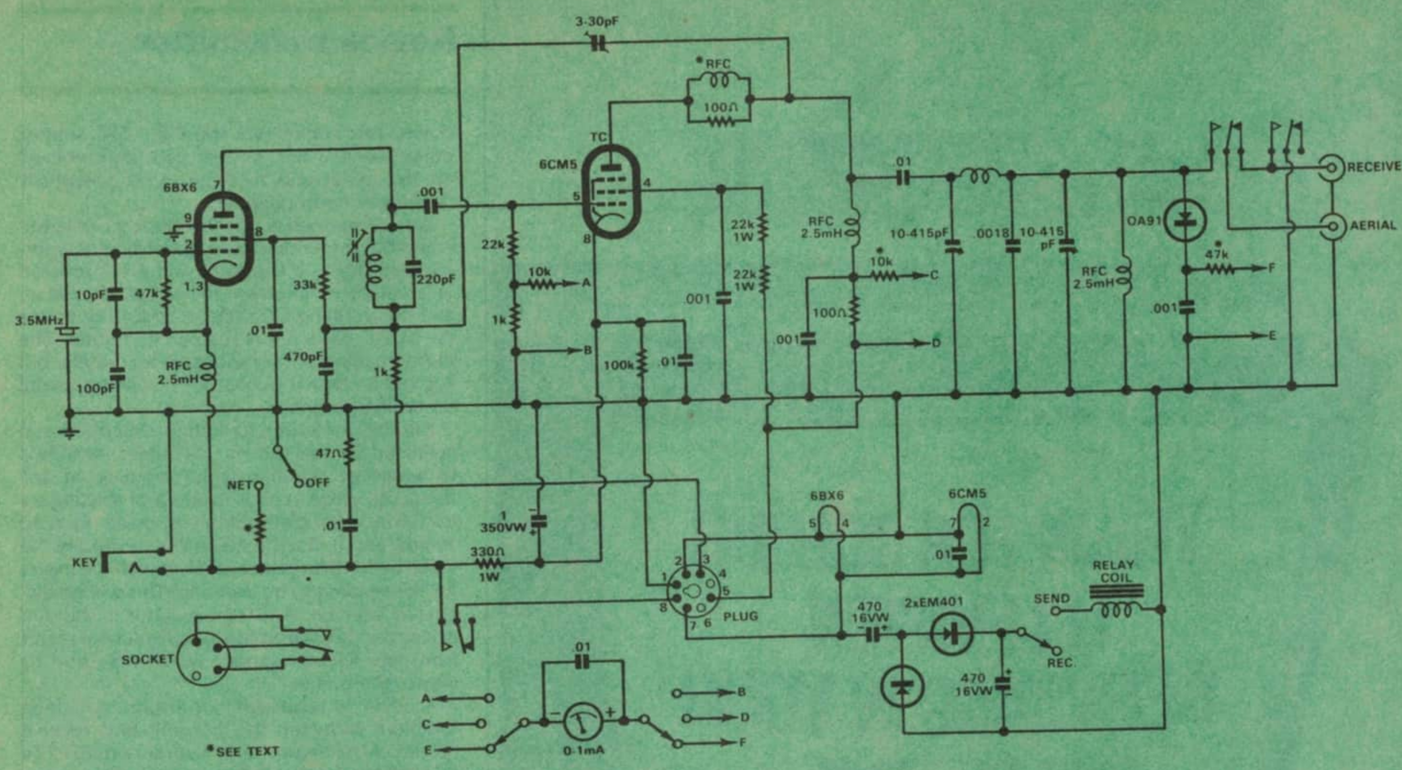
At first sight it may seem that there may be many power valve types which could be used as a modulator. However, this is not so. The need is for a single ended stage, operated in class A and which will give 5 watts output to the secondary of a modulation transformer. Also, to keep costs down, we elected to use a power transformer as a modulation transformer and this leads to further restrictions with regard to impedance matching between the modulator valve and the modulated RF amplifier. A 6V6 or similar, will give a maximum of 4.5 watts and by the time this is used to modulate the RF amplifier, there will be even less than 4.5 watts, resulting in inefficient use of the 10 watts of input to the RF amplifier.

The 6L6, big brother of the 6V6, will give sufficient power to modulate the RF amplifier but it is a high current device and requires a fairly low plate load impedance, points which are not compatible with our setup. The 6CA7 is very similar and so it is not suitable either.

Possibly the most suitable valve for our purpose is the 6BQ5 (EL84). This valve is rated to give 6 watts output with a plate current of just under 50mA. This suits our purpose nicely and it is the obvious choice. More will be said later on regarding the possibility of using other valve types.

The question as to whether the whole system would be contained in one complete case, or broken into two or more separate assemblies also had to be decided. While there is a lot to be said for including everything in one assembly, there are also arguments for separating some of the functions. It is desirable to keep the RF and audio sections separate,

At left is the completed prototype, built into a standard metal case. Full circuit details are shown on the facing page.



3.5MHz NOVICE TRANSMITTER

to avoid the possibility of RF getting into the audio circuits, with attendant problems such as distortion and RF feedback.

A fairly logical choice would be to make the RF sections into one assembly and combine the audio and power supply into another assembly. This is the method which we have adopted. Apart from the power supply requirement, the RF section is a complete CW transmitter and we will describe this part first, leaving the modulator and power supply to be described next month.

The circuit of the transmitter is conventional but for the benefit of novices it may be worth while to have a closer look at it. The crystal oscillator is a Colpitts, with the normal L-C tuned circuit replaced by a crystal. A pentode valve is used, with the screen-grid being bypassed and so grounded to RF so that it actually performs the normal function of the plate or anode.

The plate proper is "electron-coupled" to the oscillator part of the circuit and there is a tuned circuit in the plate which is resonated at the same frequency as the crystal. It may be of interest to note that the plate tuned circuit of such an oscillator may be resonated to a harmonic of the crystal frequency, so the complete stage could be used as a frequency multiplier in a more elaborate transmitter.

In order to achieve oscillation, a characteristic of the Colpitts oscillator is to use two capacitors in a voltage divider arrangement, with the capacitances selected so as to give the correct amount of feedback. This is achieved in this case with the 10pF and 100pF capacitors in series. A 47k grid leak is connected from the control grid to the cathode, which is also connected to the junction of the capacitor divider. An RF choke is used between the cathode and earth return, to provide a DC path for the cathode current and to keep the cathode at its correct RF potential.

Output from the plate of the oscillator is fed via a .001uF capacitor to the control grid of the power amplifier. In this grid circuit we have a 22k resistor for the grid leak. It will also be noted that there is a 1k resistor in series with the grid leak. This is for metering the amount of grid current passing through the grid resistor, by virtue of the RF drive from the previous stage. The current through the 1k resistor may be read off as a voltage drop. A 10k resistor from the junction of the 22k and 1k resistors is run to a 0-1mA meter, making it a 0-10 voltmeter. Thus, if a current of 1mA is flowing through the 1k resistor, it will read as 1V on the meter.

The cathode of the power amplifier is normally grounded to DC and RF. But in order to achieve certain transmitter controls and functions this circuit is here somewhat more complex. We will leave this for the moment and return to it a little later on.

The screen grid of the power amplifier is fed from the modulated high tension supply, via two 22k, 1W resistors in series. The screen is bypassed to RF but the value of this capacitor must be such that it bypasses the RF while not affecting the higher audio frequencies. A value of .001uF meets this requirement.

The plate of the power amplifier is also fed from the modulated high tension supply, via a 2.5mH RF choke. This choke passes the plate current and also allows the RF output voltage to be developed across it. It may also be seen that there is another RF choke, shunted with a 100 ohm resistor, right at the plate of the RF amplifier. This combination is inserted as a precaution against parasitic oscillations, although we did not find it to be necessary.

Metering for the power amplifier plate circuit is done in a similar manner to that for the control grid. As the current will be much greater in this case, instead of a 1k resistor, we have used 100 ohms. A 10k resistor is connected in series with the same meter as before, and the voltage drop across the 100 ohm resistor is read on the meter, in terms of current (0-100mA).

From the junction of the RF choke, 100 ohm and 10k resistors is an RF bypass capacitor. As was the case with the screen grid bypass, this capacitor must bypass the RF at this point but as it is in the modulated HT line, it must not affect the audio frequencies. Again, a value of .001uF meets the need.

While it may be possible to avoid neutralising the power amplifier, it is quite a simple addition and one which we consider well worth while. Neutralisation is achieved by the series-capacitance method. A 3-30pF neutralising capacitor is connected back to a 470pF capacitor at the "cold" end of the crystal oscillator tuned circuit. The complete neutralising circuit is in the form of a bridge. Neutralising is correct when the ratio of the neutralising capacitance to the 470pF is equal to the ratio of plate-to-grid capacitance to the input capacitance to the control grid. This latter also includes the output capacitance of the previous stage, plus strays.

Returning now to the plate circuit of the power amplifier, the RF energy at the plate is fed via a .01uF coupling capacitor to a "pi-network". The coupling capacitor is necessary to block off the DC voltage from the tuned circuit, but at the same time passing the RF component.

The pi-network consists essentially of a tuned circuit, with a coil and two capacitors. Both capacitors are variable and one functions as a "tuning" capacitor and the other for "loading". The complete circuit is an impedance matching device, transferring the RF energy from a high impedance plate circuit, to a low impedance feedline to the aerial. The tuning capacitor is a somewhat lower value than that for loading, thereby achieving the required impedance transformation. To obtain sufficient capacitance for the loading element, a fixed capacitor is connected in parallel with the smaller variable capacitor.

It may be seen that there is a 2.5mH RF choke connected across the loading capacitor. This does not contribute to the functioning of the circuit but it is included as a safety device. Should the .01uF coupling capacitor break down, this choke will short the DC supply, otherwise it would appear as a high voltage on the aerial and feedline, with potentially dangerous consequences.

Also connected across the loading capacitor is another metering circuit, consisting of a germanium diode, a capacitor and a 47k resistor. This circuit rectifies a little of the RF output, and the resulting DC voltage appearing across the .001uF capacitor is read on the meter. The meter reading is not calibrated accurately, but it gives a relative output level reading useful for tuning purposes.

All the metering functions described are achieved by the use of one meter, switched to whatever circuit may be required at any time. The grid circuit is capable of reading up to 10mA. The plate circuit is made to read 100mA and it may be necessary to modify the value of the 10k resistor in series with the meter for this reading to be accurate. This will be discussed later on. A .01uF capacitor is shunted across the meter terminals to protect the meter from any RF component which may find its way to the meter.

A relay is required to perform switching functions between the transmit and receive modes. A miniature relay with a nominal 12V DC winding and with four sets of changeover contacts is needed. The circuit shows one set changing the aerial connection between the receiver and transmitter, with a second set used to short-circuit the aerial lead to the receiver when the transmitter is on. A third set of contacts is used for the function involving switching between the phone and CW modes, while the fourth set is reserved for use in receiver muting during transmitting.

A special power supply is required for the relay coil. This supply is derived from the transmitter valve heater 6.3V AC supply. A half-wave voltage-doubler circuit using two silicon power diodes and two 470uF electrolytic capacitors give approximately 12V DC under load. This voltage rises somewhat off load.

As mentioned earlier, the cathode circuits are somewhat more than a simple arrangement. This is brought about by the need for a satisfactory keying arrangement for CW transmission. The classical method of achieving keying with this type of transmitter is to tie the two cathode circuits together and key both stages. A study of this part of the circuit will show that this is how we have done it.

Under "key-up" conditions, there is practically no cathode current at all. To stop the cathode potential from rising too high above earth potential, with the danger of heater-cathode breakdown, a 100k resistor is connected permanently between the power amplifier cathode and earth. This limits the voltage to about 150V between cathode and heater/ground.

A 330 ohm resistor in the cathode of the power amplifier performs two functions. In the event of loss of grid drive, this resistor acts as a bias resistor and limits the plate current of the valve to a safe value. This resistor is also part of the keying filter circuit, working with the 1uF electrolytic capacitor to soften the keying characteristic. The 1uF electrolytic and a .01uF capacitor in parallel function as RF and audio bypass for the power amplifier cathode.

Another part of the keying filter is a 47 ohm resistor in series with a .01uF capacitor, directly across the key. This is to reduce sparking at the key contacts and so avoid key clicks.

A "net" facility is also included in the cathode circuits. A resistor is connected in series with a "net" switch, the two also being across the key. By operating this switch, the resistor limits the current to both stages but the oscillator will still give enough output to be heard in the receiver, which may be set correctly to the crystal frequency. The value of the resistor must be determined experimentally.

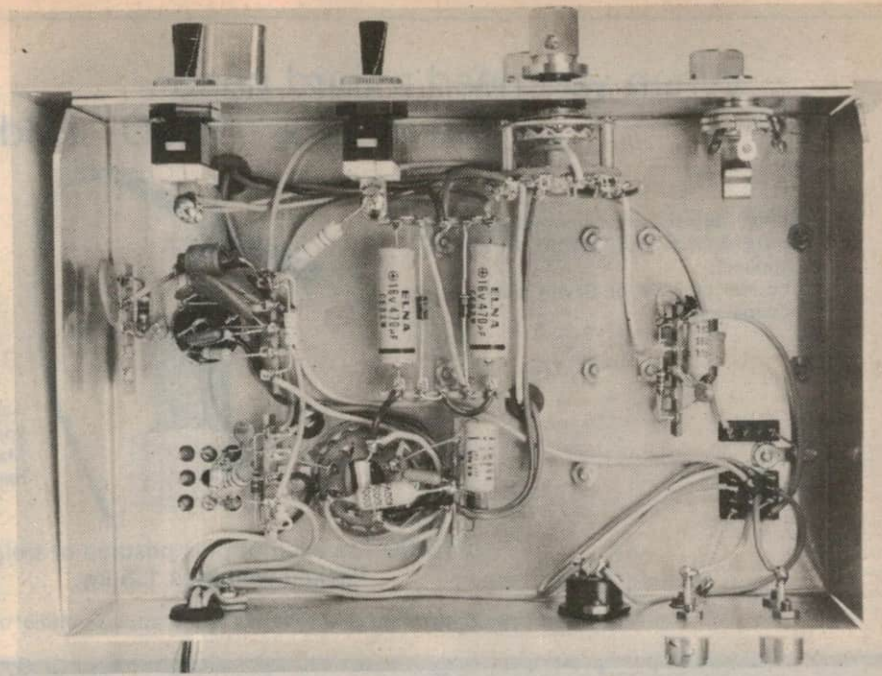
Having looked over the circuit, perhaps some comments on components may be helpful.

Resistors should present no problems at all. The only point to watch is that although most resistors may be ½ watt types, some must be 1 watt rating as indicated on the circuit and the parts list.

Some of the capacitors are reasonably critical and substitutions should be avoided unless readers have good reason for doing so. The two variables are quite standard and are made by Roblan. Although the spacing is fairly close, especially for the tuning capacitor, in practice we have found that it presents no problems with regard to flashover on modulation peaks. The 3-30pF neutralising capacitor used on the prototype is one of the older Philips "beehive" type. We suggest that you use this type if you can get one. Otherwise a substitute, such as the newer Philips trimmer with solid dielectric should suffice, although we have not tried them in this application.

The .01uF coupling capacitor between the power amplifier and the pi tuning network should ideally be a stacked foil mica type. Unfortunately these are very difficult to come by these days and so most builders will have to content themselves with some other type. We used a ceramic disc type rated at 630V and this has proved quite satisfactory in operation. At this rather low frequency, it may be possible to use one of the polycarbonate types, also rated at 630V, in this position. We used one of this type across the loading capacitor.

The crystal must be within the frequency range 3.525MHz and 3.575MHz. We used two crystals provided by courtesy of Bright Star Crystals Pty. Ltd., 35 Eileen Road, Clayton, Victoria. The frequencies which we selected were on 3.530MHz and 3.565MHz, but frequency selection will be up to individual choice, within the limits laid down. You may order crystals from Bright Star Crystals Pty. Ltd., from another manufacturer of your choice, or you may even have one of the old FT243 types. In point of fact, we did our initial development with one of these old crystals on 3.540MHz and it functioned very well.



This under-the-chassis view clearly shows the layout of the major components. Note the relative positions of the various tagstrips used to facilitate construction.

The meter is a readily available type and there should be no problems here. The knobs used on the prototype came from Messrs Watkin Wynne Pty. Ltd. These knobs are of machined aluminium and are quite attractive.

The rotary switch used for meter switching is readily available and we used an "Oak", made by MSP, on the prototype. We understand that Watkin Wynne are also able to supply a suitable switch under the Jabel brand. The toggle switches which we used were supplied by McMurdo (Aust) Pty. Ltd. These switches are rugged, have an easy to use paddle and are readily available.

The relay is a miniature type, with a 12V coil and four sets of changeover contacts. There are a number of different brands available and the one which we used was made by Varley.

There are two coil formers used in the transmitter, one in the plate circuit of each stage. The oscillator output coil is wound on a Neosid 7.6mm former, 32mm long and tuned with a grade 900 slug. The former is housed in a square aluminium can. The power amplifier coil is wound on a former which is 1¼in (32mm) diameter and 2⅝in (67mm) long. The former which we used was supplied by R.C.S. Radio and we understand that there are ample stocks of these formers. There are two types available, one with the standard 6-pin valve base and the other without pins. We used one without pins.

Three RF chokes are required and we found that in all cases a standard 2.5mH, single pi winding type was adequate. This applied also to the RF choke in the plate circuit of the power amplifier where an RF choke would normally need to be a more elaborate one and one which had an ample current rating. However this transmitter only has to operate on one frequency band and the plate current is only of the order of 40mA. The simple RF choke has been found to be very efficient, with no signs of overheating.

The subject of valves has been given quite a lot of thought. The types which we chose for the initial prototype are those which we feel should be readily available to many builders without even having to go out and buy them. Both the 6BX6 and the 6CM5 have been used in large quantities in black and white television receivers. Old receivers of this type may well be a source of valves for this project. Even if you are not that fortunate, then they are still available from most component houses.

LIST OF COMPONENT PARTS

1 Metal case, 9in wide x 6⅝in high x 5½in deep
1 Chassis, 8in x 5¼in x 2⅛in
1 Meter, 0-1mA, 65mm x 60mm
1 Crystal, selected frequency, HC-6/U, 30pF, ambient temperature, tolerance .003%
1 Socket for crystal
2 Toggle switches, SPST, McMurdo
1 Rotary switch, 2-pole, 5-position, Oak or Jabel
1 Jack socket, 6.4mm
3 Knobs, Jabel etc
1 4-pin miniature speaker socket
2 Coaxial sockets, McMurdo, Belling & Lee
1 9-pin miniature valve socket
1 Octal valve socket
1 Octal plug
2 ¼in flexible couplings
1 Relay, 12V winding, 4 sets changeover contacts
1 Socket for relay
1 Coil former, Neosid, 7.6mm x 32mm with can and grade 900 slug
1 Coil former, R.C.S. Radio, 32mm diameter x 67mm long
1 Valve, 6BX6
1 Valve, 6CM5
2 Silicon diodes, EM401 or similar
1 Germanium diode, OA91 of similar
3 2.5mH RF chokes
8 Miniature 5-tag strips
4 Rubber grommets
1 Anode clip for 6CM5 valve

RESISTORS (½W unless stated otherwise)
1 47 ohms
2 100 ohms
1 330 ohms
2 1k
2 10k
1 10k 1W (see text)
1 22k
2 22k 1W
1 33k
2 47k
1 100k

CAPACITORS
1 10pF NPO ceramic
1 3-30pF Philips trimmer (see text)
1 100pF NPO ceramic
1 220pF 630V polystyrene
2 10-415pF single gang variable, Roblan
1 470pF 630V polystyrene
4 .001uF 630V polycarbonate or ceramic
1 .0018uF 630V polycarbonate
5 .01uF 400V polycarbonate or ceramic
1 .01uF 500V ceramic (see text)
1 1uF 350VW electrolytic
2 470uF 16VW electrolytics

MISCELLANEOUS
Hookup wire, solder, solder lugs, screws, nuts, cable clamp.

Novice transmitter

There are a number of alternative valves which may be used in this transmitter, although we have not tried any at this stage. It is hoped that in the not too distant future we may be able to get time to investigate at least some of the alternatives. Such types as the 6EH7, 6AU6, 6AM6 come to mind as being possibilities for the crystal oscillator. In place of the 6CM5, such types as the 2E26, 6146, 807, etc., may be tried. These are all double ended types, in common with the 6CM5 but it may be possible to use some single ended types. Here the possibilities are numerous and such types as the 6V6, 6L6, 6BW6, 6AQ5 and 6M5 may be suitable.

The transmitter is built into a metal case, 230mm wide x 170mm high x 140mm deep, including a chassis 200mm x 130mm x 50mm. This metalwork is made by Wardrope & Carroll Fabrications Pty Ltd and should be available through most components houses. The metalwork is not drilled and this means that builders will have to do the necessary drilling and punching themselves. If required, copies of the metalwork drawings may be obtained from the Information Centre.

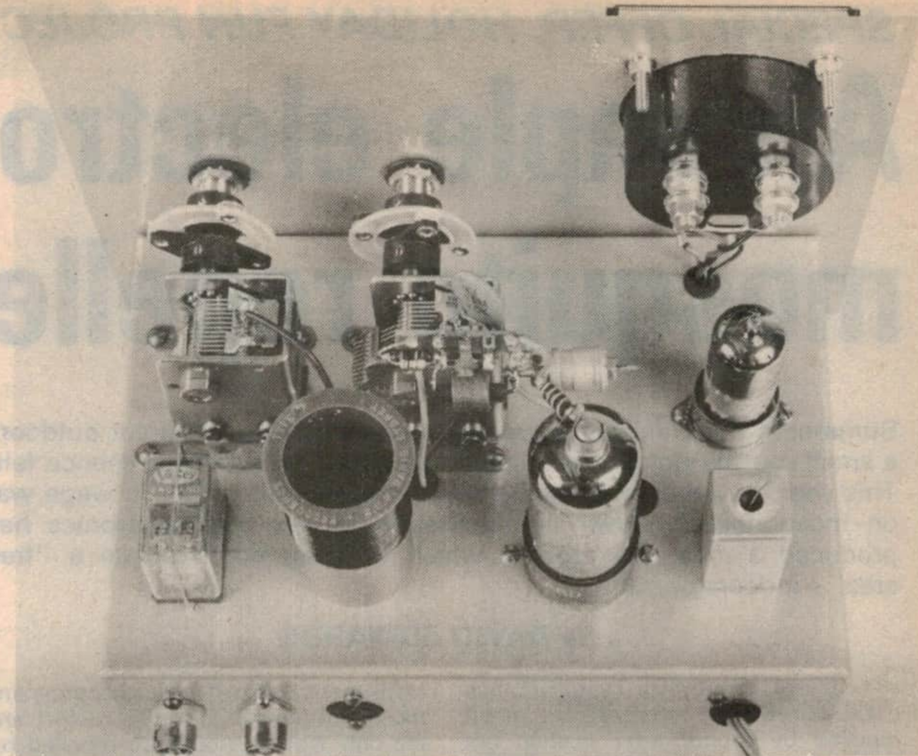
Before proceeding with the main assembly and wiring, it is a good idea to wind the coils. The oscillator plate coil consists of 50 turns of 28B&S enamel wire, close wound on the Neosid former. Each end of the winding may be anchored with a piece of good electrical tape, making sure that the winding is firm and not free to move. A spot or two of lacquer or paraffin wax could be used to advantage. The grade 900 slug should be stabilised with a short piece of thin shirring elastic, obtainable from haberdashery stores. The cotton should be removed before use. The coil winding should be terminated at the lugs which make for the shortest leads when the coil is wired into circuit. The aluminium can is fitted after the coil is completed.

The final tank coil is wound on the 1¼in diameter former, using about 20B&S enamel wire, 20 turns wound to 16 turns per inch, making the winding 1¼in long. Each end of the winding is anchored by drilling two holes about ¼in apart and threading the wire through. The winding must be firmly wound and carefully spaced and again, a small quantity of lacquer or paraffin wax may be used to ensure that the windings remain in place. A hole is drilled in the bottom of the former for fixing purposes later on.

The parasitic suppressor in the plate circuit of the power amplifier consists of four turns of about 20B&S tinned copper wire, wound over a 100 ohm ½ watt resistor. The leads of the resistor are cut off very short. The plate cap is soldered to one end and a short piece of hookup wire is soldered to the other end.

The process of assembly could conveniently start with the valve sockets. The oscillator valve socket should be orientated with pins 4 and 5 facing towards the centre of the chassis. The key of the power amplifier valve socket should point towards the position for its tank coil. The relay socket should be orientated as may be seen from the photograph. The three sockets on the back skirt of the chassis present no problems.

Before mounting the two variable capacitors, make sure that you solder a lead on the underneath lug for the stators of the loading capacitor. The oscillator coil is fixed with two 6BA screws and the tank coil may be held with one screw and nut and with the leads facing between the two variable capacitors. Grommets are fitted to the hole on the back skirt of the chassis, one behind the tuning capacitor, one in front of the oscillator valve and one between the power amplifier valve and the oscillator plate coil.



A topside view of the chassis, as seen from the rear.

Underneath the chassis, there are seven 5-tag strips. There is one fixed under each of the valve socket screws of each socket. Two more in about the middle of the chassis are held under screws fixing the tuning capacitor. The seventh one is located under a screw fixing the loading capacitor and close to the lead from its stators. The eighth tag strip is located on the body of the tuning capacitor. We fixed it with a self-tapping screw and the location may be seen from the photograph.

Turning now to the front panel, the crystal socket, meter and the two ¼in bushes may be fixed. Slip the flexible couplings on to each of the variable capacitor spindles. Now the front panel is assembled on to the chassis by means of the two toggle switches, the rotary switch and the jack socket. Two short pieces of ¼in diameter rod are required to be run through the bushes on the panel. The rods need to be long enough to be fixed to the flexible coupling and with enough protruding to take a knob. Suitable pieces of rod may be salvaged from offcuts of potentiometer spindles.

With the assembly complete, we are now in a position to do the wiring. Quite a lot of the wiring detail may be gleaned from the photographs but some comments touching on some of the more obscure points may be helpful.

All wiring which does not involve actual signal paths may be run as desired, keeping in mind the idea that leads should never be unnecessarily long and that they should be run neatly. Where earth points are involved, it is always best and indeed at times, essential, to make them as short and direct as possible. Where leads have to run between the top and bottom of the chassis, the hole through which it should run will be quite obvious.

All wiring around the sockets of both valves is done between the actual socket lugs and the lugs on the adjacent tag strips. Neatness and short, direct leads will result in a satisfactory job. Remember to earth the centre spigot of the oscillator valve socket, along with other points which must be earthed.

The electrolytics and diodes for the relay DC supply are strung between the two tag strips in the middle of the chassis. The tag strip to the right contains the items on the output end of the tank coil and across the loading capacitor. Care needs to be taken when wiring the relay, to identify the socket lugs correctly. One set of changeover contacts is run to lugs on the 4-pin socket on the back skirt of the chassis. These are for use in muting the receiver and the connections will be determined by individual requirements.

When wiring to the coaxial sockets, to avoid melting the insulation a plug should be inserted into the socket while soldering. The six leads running from the transmitter chassis are run through the grommet provided and the leads are clamped adjacent to the grommet. The leads should be long enough to run between the transmitter and modulator chassis but they should not be excessively long. We made those on the prototype about 50cm. An octal plug is fitted to the far end.

Most of the wiring above the chassis involves the final tuning circuits. The bottom end of the coil is terminated on the top rotor lug of the loading capacitor and the top end is terminated similarly on the tuning capacitor. The RF choke, resistor and .001uF capacitor are mounted on the tag strip. One lug of the neutralising capacitor is also soldered to the tag strip and a lead runs to the under-chassis from the other lug. The coupling capacitor is run directly between the tag strip and the top lug of the tuning capacitor. Note that the stopper is connected directly to the valve anode clip.

By the time you have completed the wiring of the transmitter, I imagine that the next issue of the magazine will be about due and we expect to be able to give details of the other unit, which includes the modulator and power supply. All necessary information will be included for adjustments and getting the complete transmitter operational.