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.

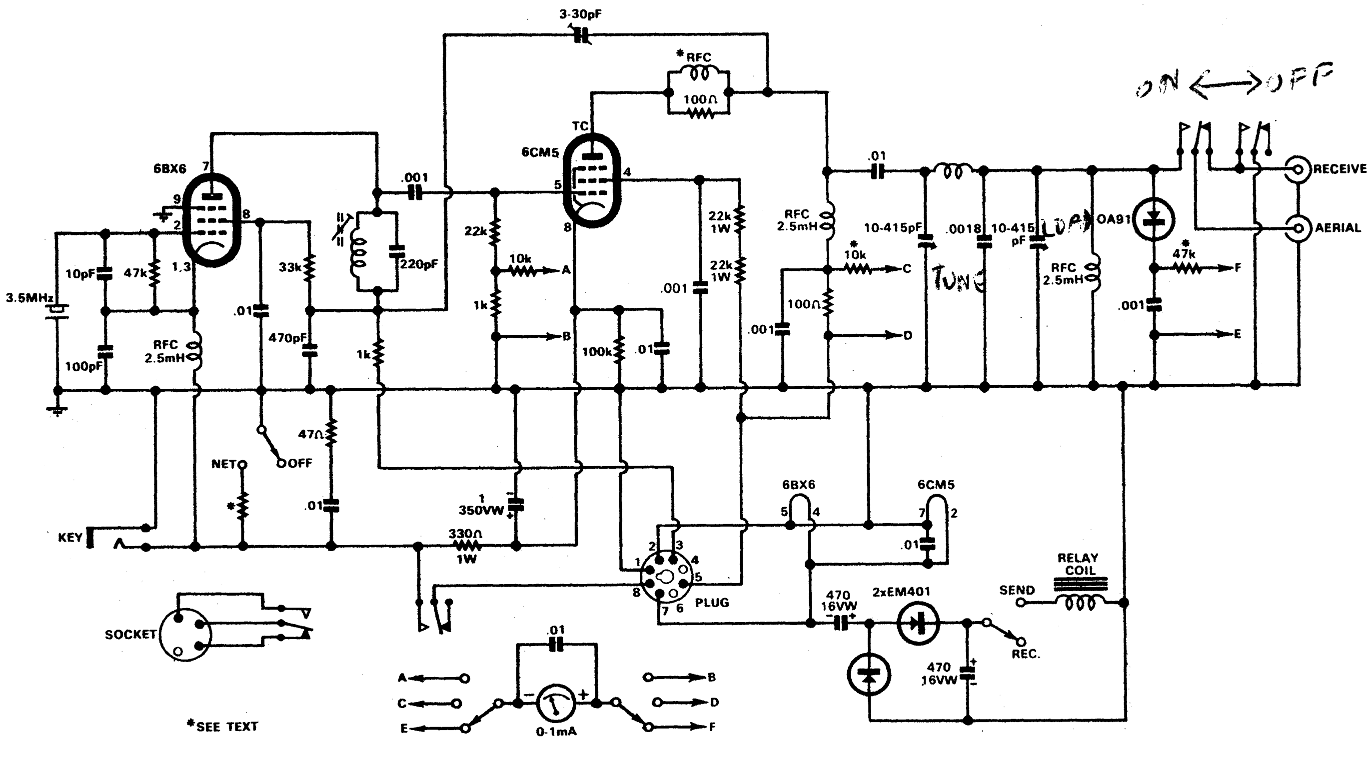
At first sight it may seem that there may be many power valve types which could be used as a modulator. However, this is not so. The need is for a single ended stage, operated in class A and which will give 5 watts output to the secondary of a modulation transformer. Also, to keep costs down, we elected 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

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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.

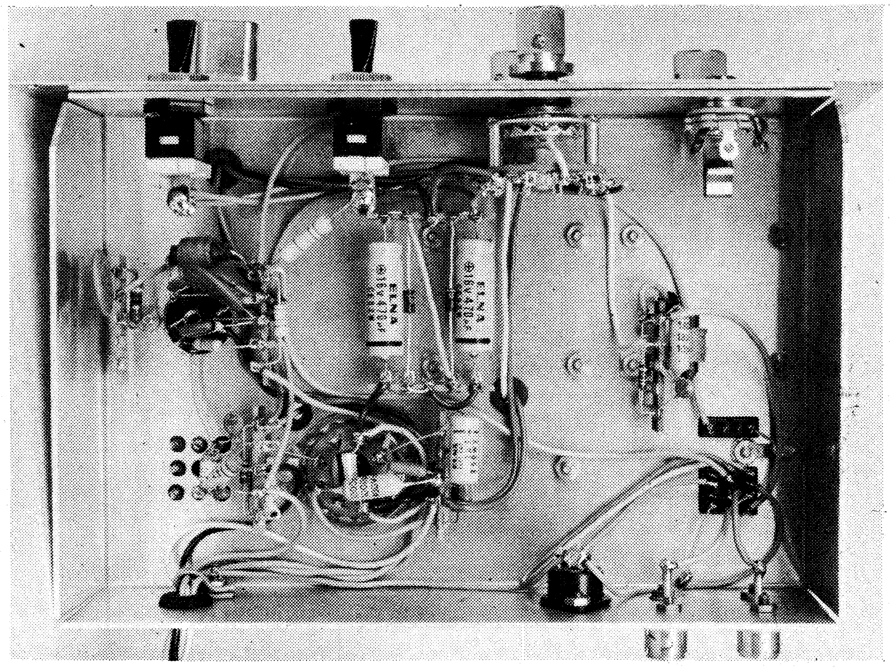
Another part of the keying filter is a 47 ohm resistor in series with a .01uF capacitor, directly across the key. This is to reduce sparking at the key contacts and so avoid key clicks.

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.



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 .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.

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.

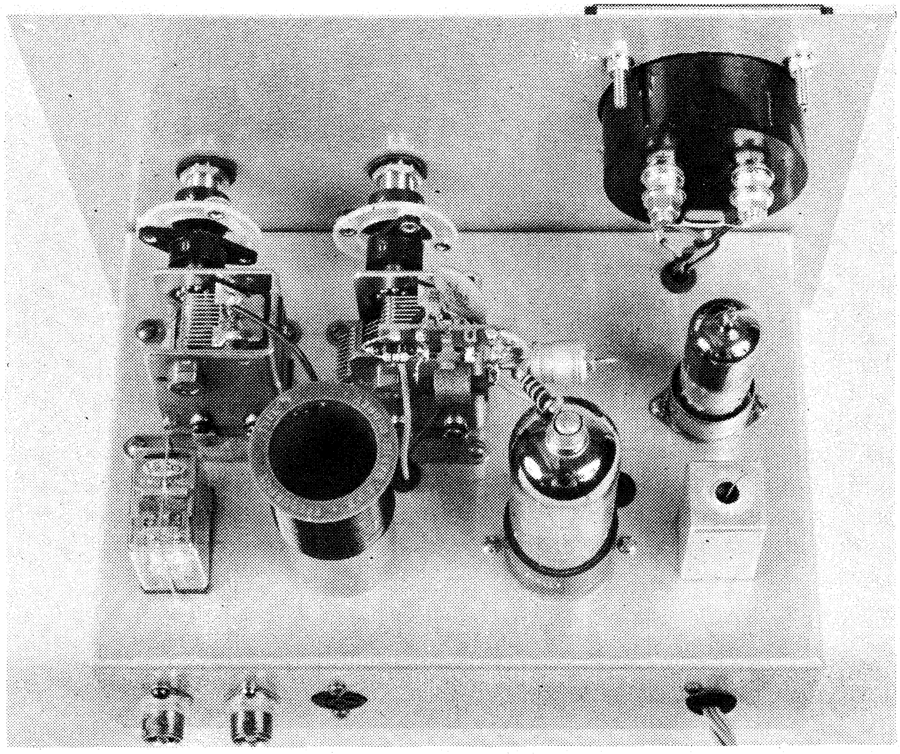
Before proceeding with the main assembly and wiring, it is a good idea to wind the coils. The oscillator plate coil consists of 50 turns of 28B&S enamel wire, close wound on the Neosid former. Each end of the winding may be anchored with a piece of good electrical tape, making sure that the winding is 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.

Modulator & power supply for the novice transmitter

Here is the second article describing our Novice Transmitter, and it gives details of the power supply and modulator unit. While designed to go with the transmitter described last month, it would be equally suitable for use with other small transmitters.

by IAN POGSON

Last month we described the transmitter proper of our new 3.5MHz Novice Transmitter and we come now to the power supply, with the speech amplifier and modulator integrated on the same chassis. Those of you who may have built the transmitter already, will find this second part somewhat easier to make.

Before proceeding with other aspects of this part of the project, let us have a look at the circuit. The speech amplifier is split into two stages, each using one half of a 12AX7 twin triode. The first half takes its input from the microphone and to make the input as versatile as possible with respect to microphone types, the grid resistor has been kept to a high value of 2.7M. This means that crystal, ceramic, or dynamic microphones could be used. Bias for the valve is obtained with a 3.3k cathode resistor, bypassed with a 10uF electrolytic capacitor. The plate load is a 220k resistor.

Output from the plate of the first stage is fed via a .0068uF coupling capacitor to a 470k potentiometer, which serves as the audio level control and in turn sets the modulation depth. The rotor of the potentiometer feeds into the grid of the second stage, with bias and plate load conditions the same as the first stage. HT supply to both stages is decoupled via a 10k resistor and 8uF 300VW electrolytic capacitor.

Output from the second stage is fed via another .0068uF coupling capacitor to the grid of the 6BQ5 modulator valve. Cathode bias is obtained with a 180 ohm 1W resistor bypassed with a 10uF capacitor. The plate load is one winding of the modulation transformer and the screen grid is supplied directly from the HT line. The .001uF capacitor shunting the transformer winding restricts the audio high frequency response. Low frequency response is restricted by the two coupling capacitors and the three cathode bias resistor bypass capacitors.

The secondary winding of the modulation transformer has one end connected to the HT side of the primary winding. The HT supply is fed to this common point via one pole of a DPDT toggle switch. This switch selects either the "Phone" or "CW" mode of transmission. The other end of the secondary winding is routed to the modulated RF amplifier in the transmitter assembly, via pin 5 on the outlet socket. It may also be seen that there is an ordinary power diode connected in series with the secondary circuit just referred to and that there is a connection from the cathode of the diode to the mode switch. This arrangement is adopted to avoid transients being developed across the secondary of the modulation transformer when the transmitter is keyed for CW.

The other pole of the mode switch runs via pin 8 of the socket and connects to a set of relay contacts on the transmitter chassis. Pin 3 of the socket is the HT line to the crystal oscillator of the transmitter, while pins 2 and 7 carry the 6.3V AC heater supplies to the transmitter valves.

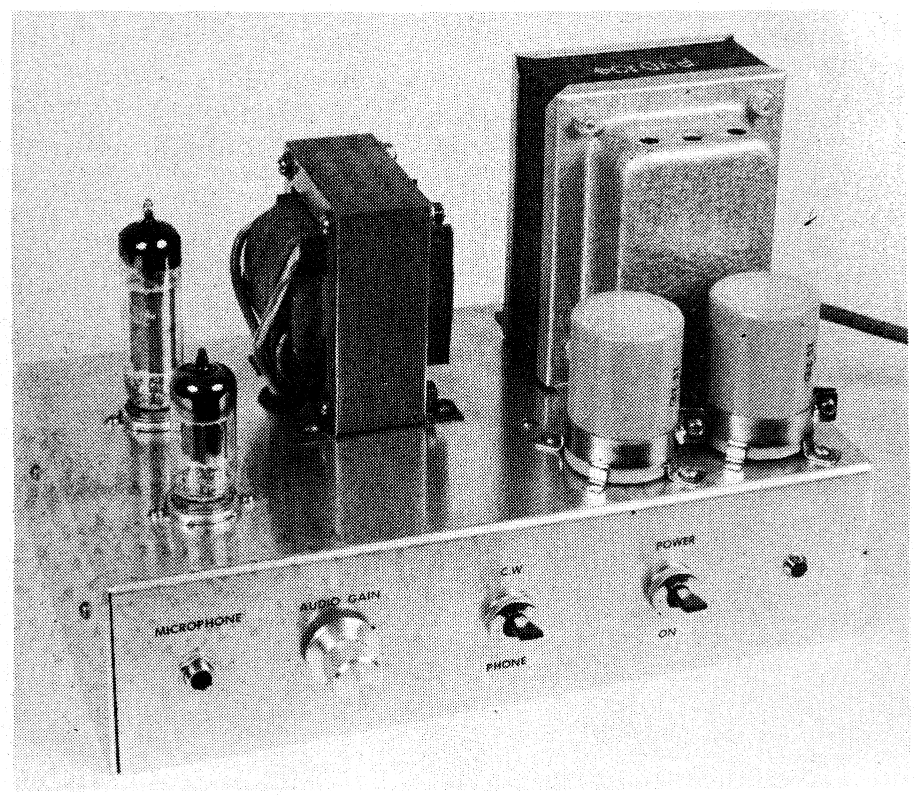
The power supply is very simple but adequate for the job. The high tension voltage is derived from the transformer secondary winding in a full wave voltage doubler arrangement and with a current rating of 125mA. There are two 6.3V heater windings, each rated at 3A, one being used for the RF part of the transmitter and the other for the audio section. To reduce the hum level to an economical minimum, a 47uF electrolytic capacitor is added across the HT line. Also, a bleed consisting of three 15k 1W resistors in series is added across the HT line. This discharges the capacitors after switching off, thus avoiding the possibility of electric shock from storage.

All of the components used on this unit are fairly straightforward and no difficulty should be experienced in this regard. However, a few comments on some of the components used may be useful.

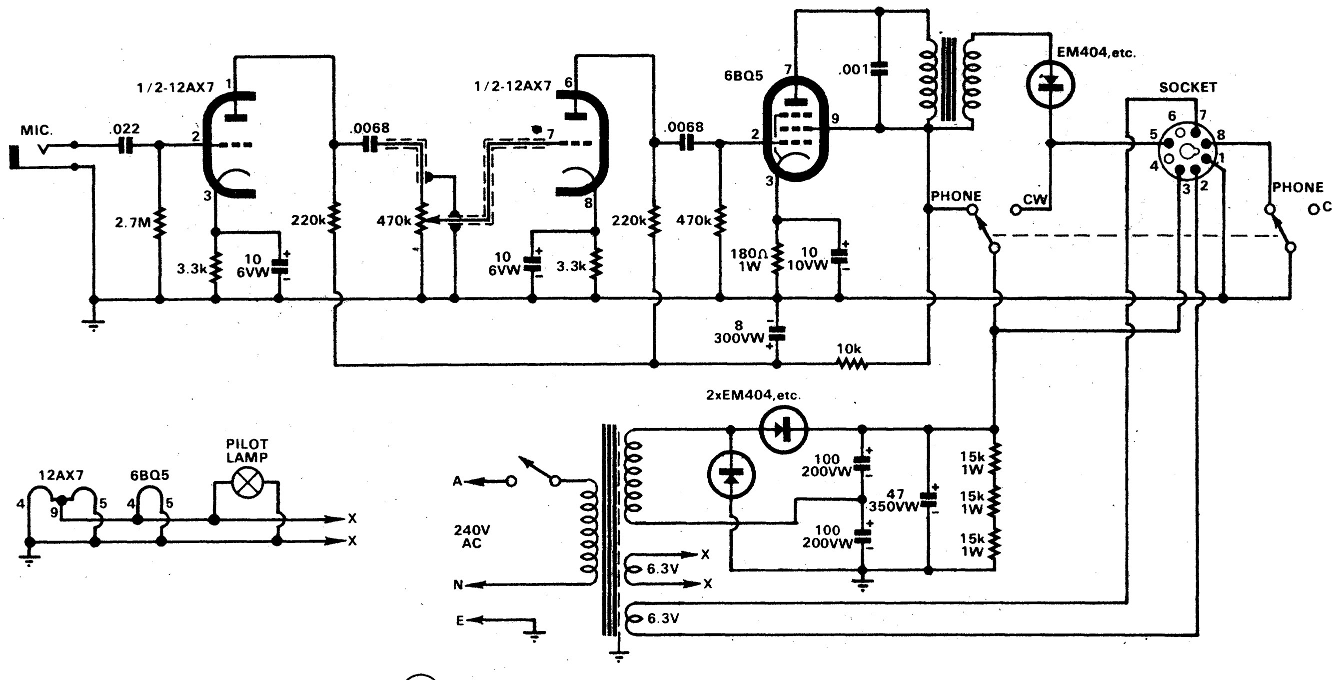
Resistors and capacitors are commonly used types and there should be no problems here. The toggle switches, in common with those used on the RF section described last month, are made by McMurdo and this particular design is ideal for our purpose. The knob is the same as used on the RF section.

The indicator lamp is one which we have used before on a number of projects and should be readily available. It may be seen that we have specified a lamp rated at 14V. This is used across one of the 6.3V supplies and obviously the lamp will not glow very brightly. However, it gives sufficient light as an indicator and it should last almost indefinitely under these conditions.

The power transformer which we used is type PVD104, made by Ferguson. An equivalent transformer in another brand should be all right. Indeed, if you have a transformer in your junk box which will give about 275 volts DC at about 125mA and it has two 6.3V heater windings capable of delivering the current required in each case, then this could be used.



At left is the completed prototype, designed around a simple dish-shaped chassis. Circuit details are shown on the facing page.



3.5MHz NOVICE TRANSMITTER
(MODULATOR AND POWER SUPPLY)

The modulation transformer which we used is a power transformer. It is also one made by Ferguson, type PF201. It has two windings of interest—the usual 240V primary winding and a secondary winding giving 225V each side of a centre tap. As we will see in a moment, these windings can be used such that they give quite a good impedance match between the modulator (6BQ5) and the modulated amplifier (6CM5).

To find the load which the modulated amplifier presents to the modulator, we take the plate supply voltage and divide it by the combined plate and screen current of the valve. We will consider the voltage between the supply line and the cathode of the modulated amplifier to be 250V and the combined plate and screen current to be 42mA. Now 250 x 1000/42 results in a load of near enough to 6000 ohms. On consulting the characteristics and operating conditions for the 6BQ5 modulator valve, we find that the required load is 5200 ohms. Under some conditions this amount of mismatch may be tolerated but we do not have much audio power to spare, so we must take steps to get a closer match.

The circuit shows that each of these valves is fed through a separate winding on the modulation transformer. By manipulating the transformer turns ratio between the two windings, we can obtain the proper match. The impedance ratio is 6000/5200, which is equal to 1.15. Now the turns ratio is proportional to the square root of the impedance ratio, and the square root of 1.15 is just about 1.07.

The voltage ratio given for the windings of a transformer is proportional to their turns ratio. Let us see what our transformer can offer. The ratio of 240/225 is just a little under 1.07—just about as close as we could possibly hope for. This means then, that if we use the 240V winding to feed the modulated amplifier and one of the 225V windings for the feed to the 6BQ5, we will have achieved our matching objective.

The example just given for our particular purpose shows how the calculation is made and if you have the need to find the transformer ratio for another set of circumstances, then it is only necessary to follow the example given.

Before leaving the subject of modulation transformers and matching, there is an old trick which may be used where circumstances permit. In days gone by, there were many power transformers about which had a centre-tapped secondary, not unlike the one which we have used. Instead of using the primary winding, this is left unused and both halves of the centre-tapped secondary winding are used. The centre-tap would be connected to the common high tension power supply and one side feeds the modulator valve and the other side feeds the modulated amplifier.

This idea may be used where the impedance ratio required is exactly one, or very close to it, or in cases where a certain amount of mismatch could be tolerated. The idea also has the advantage that the two lots of DC flowing through the windings are such that their magnetic effects cancel in the core, or very nearly so.

The chassis in blank form is available from at least some components stores and if the correct size is not readily available to you, then one close to the wanted size should not be difficult to come by. We drilled and punched the holes in the chassis for the prototype.

As may be seen from the photographs, we have not fitted the modulator and power supply into a case as was done for the transmitter. There is no particular need for a case for the modulator, whereas the transmitter must be covered for safety reasons, as well as for shielding against unwanted radiation directly from the transmitter. However, if you wish to fit the modulator into a case to match the transmitter, then there is no reason why this should not be done.

Construction of this unit is fairly straightforward but there are some points which could be discussed and which should make the job that much easier.

We will assume that you have a ready drilled chassis and all the components. It is always a good idea to assemble the small and light components first. These include the valve sockets, microphone jack, indicator lamp, volume control, switches, electrolytic capacitors and mains terminating strip.

Before attempting to fix the two transformers, make sure that you have the rubber grommets in place. When the transformers are screwed in place, all the flying leads will be left sticking through the holes and vertical to the chassis. The next job is to get rid of these leads as soon as possible. As may be seen from the underneath picture, we used a miniature tag strip with 16 pairs of tags in about the middle of the chassis. All of the tags are not used. We fitted this tag strip mainly to terminate the transformer flying leads. In addition to terminating these leads, we also mounted the three 15k 1W resistors, the three EM404 silicon diodes and the 47uF electrolytic capacitor. This is not a complex job and so we are leaving it to the individual to wire it as he sees fit.

Before leaving this board, there is one point which we observed and which we think it would be wise to include in your wiring. We brought all earth connections involving the power supply to one tag on the board, near the electrolytics. This point is later wired to another point on the chassis and near the microphone input. The mains earth lead is connected to the chassis to a solder lug under one of the electrolytic fixing screws.

Having disposed of the transformer flying leads and having done the rest of the wiring on the terminating board, we are now in a position to extend the terminated leads to their destination. These include heater wiring, both to the audio valves on the chassis and the other heater circuit to pins 2 and 7 on the octal outlet socket. The high voltage supply and modulation transformer wiring completes this part of the job.

By now you may have already done the heater wiring to the two valves. This circuit will still be floating and it should now be earthed to a solder lug under one of the valve socket screws for the 12AX7. The centre spigot for both sockets should also be earthed, that for the 6BQ5 to another lug at its socket.

Most of the components for the two valves are mounted on a piece of miniature tag board with 15 pairs of tags. All of the tags are not used but we made the strip long enough so that components could be placed to keep leads as short as possible. No drawing has been made for this board either but to help the builder, this is the order of the components from the input end. 2.7M resistor, 10uF capacitor with its 2.2k resistor underneath, 220k resistor, .0068uF capacitor, 10uF capacitor with its 2.2k resistor underneath, 220k resistor, .0068uF capacitor, 470k resistor, two blanks, 10uF capacitor, 180 ohm resistor, .001uF capacitor, 8uF capacitor and 10k resistor.

With the components mounted, interconnecting wiring is done. We kept the components to be earthed such that all items for the 6BQ5 are kept together and an earth lead run direct to the earth lug on the 12AX7 valve socket. Similarly, all items to be earthed and associated with the 12AX7 were connected together and another separate lead run to the common earth lug. Other leads are run to the respective valve socket pins. The two leads from the volume control are run in light coaxial cable. The braid of each cable is connected to the earth lug on the volume control and the braid is cut short and not terminated at the other end. A lead from the volume control earth lug is run to the common earth point. Similarly, the earth lug on the microphone input socket is earthed to the common point.

You may notice that we have used a .022uF coupling capacitor between the microphone input socket and the grid of the valve. This is not strictly necessary and under most circumstances it may be omitted. It may also be noted that we have not taken any precautions against RF getting into the audio amplifier. This was found not to be necessary on the prototype. However, if you wish, or find it necessary, a small capacitor of 100pF or so may be shunted across the 2.7M resistor. A 47k resistor may also be connected in series with the lead between the microphone and the grid of the valve. Another method which is sometimes used, is to slip a ferrite bead over the lead right at the valve grid pin.

Having completed the wiring, before proceeding with tests, it is essential to make a thorough check to make sure that there are no errors or omissions in the wiring. Care should be taken to make sure that all pin connections on valve sockets are correct. The polarity of diodes and electrolytics should also be checked.

We are now in a position to test the complete transmitter and put it into operation. While there may be many ways of going about this, I will run through a procedure which should make the task quite straightforward.

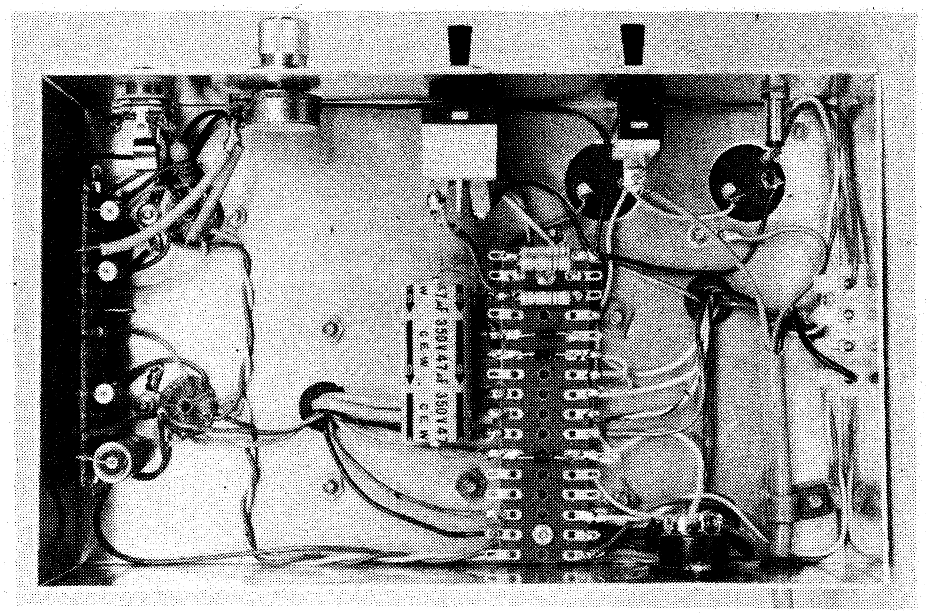
The transmitter should be left out of its case for testing and the valves may be left out of the modulator chassis for the initial stages. Connect up the cable between the units and connect a dummy load to the transmitter output, equal to the characteristic impedance of the feedline which you intend to use e.g., 50 or 75 ohms. Set the "power" and "net" switches to the off position and the other two switches to "receive" and "phone". The audio gain should be turned off, the meter switch set to "grid" and the "tune" and "load" capacitors set right in. The crystal which you intend to use should be plugged in.

Break the HT lead feeding the plate and screen of the 6CM5 valve and make sure that the lead is kept out of harm's way. Turn on the power switch and wait for about half a minute for the valves to warm up. Now throw the switch to "send". The relay should operate and you should get a small reading of grid current. Adjust the slug in the oscillator plate coil for maximum grid current reading. This should be about 1.5mA. Switch back to "receive" and switch off the power; then connect up the HT lead which you just disconnected.

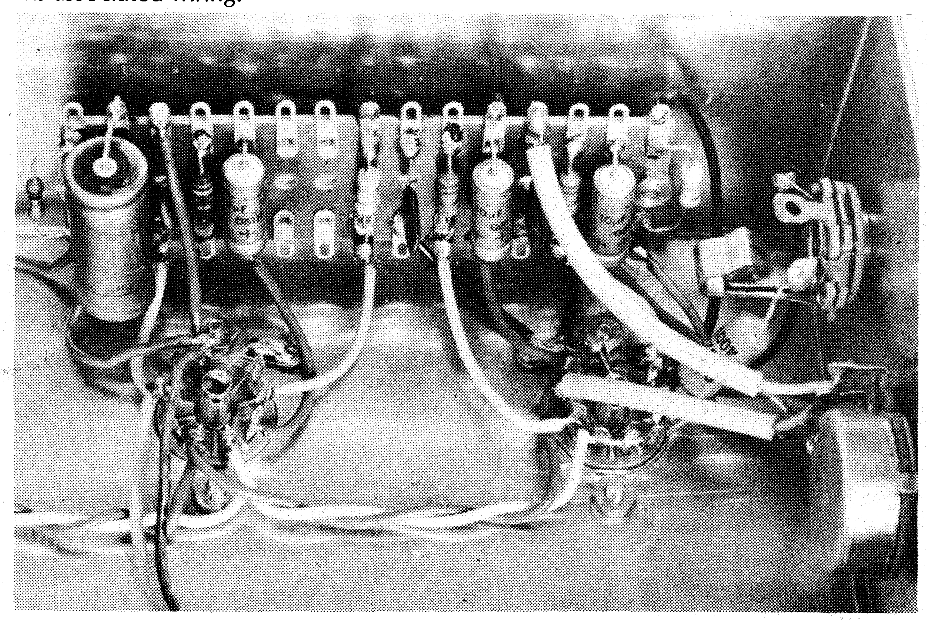
Switch on again and wait for warm-up. Set the neutralising capacitor to minimum capacitance. Set the meter switch to "plate", and switch to "send". The plate current will rise to a high value of about 80mA or so and this condition should not be allowed to persist. Carefully rotate the "tune" control until a dip is obtained in the plate current reading. Tune for maximum dip. This should be somewhat less than 40mA. Now rotate the "load" control which will cause the plate current to rise again. Stop at 40mA and touch up the "tune" control for dip again. It may not have altered very much. If you are unable to load up to 40mA then the .0018uF capacitor needs to be reduced. If you cannot get down to 40mA then the capacitor will have to be increased.

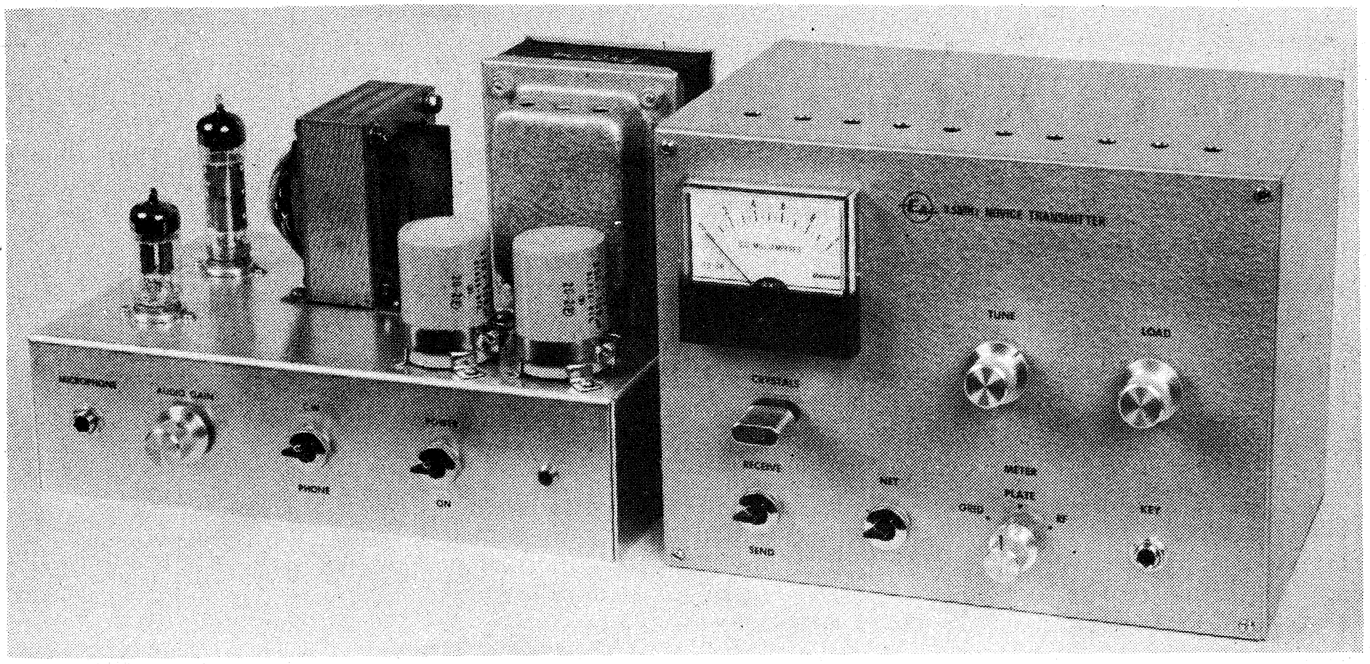
You now have the transmitter running with about 10 watts input to the final, which is the power authorised. We will come back to this a little later on to make more precise adjustments to the HT voltage and the meter reading accuracy. Meanwhile, we will neutralise the final and this is an interesting operation. If you have a wavemeter, or a GDO which can be used as a wavemeter, then this can be used as an aid to neutralising. If you do not have one, then we can do without it.

Switch to "receive" and switch off the power. Again disconnect the HT line to the plate and screen of the final as before. Do not touch the "tune" or "load" settings. Switch on again and after warm-up, switch to "send". Bring the coil of the wavemeter near to the final tank coil and adjust the wavemeter to the frequency of the crystal, such that an indication is given on the wavemeter. Adjust the neutralising capacitor for minimum indication on the wavemeter. Now slightly adjust the "tune" control for an increase in the wavemeter reading and adjust the neutralising capacitor for a minimum reading. Repeat this process until the minimum possible reading has been obtained on the wavemeter.



View at top shows the simple nature of the under-the-chassis layout. Below is a detailed view of the tagboard mounted on one side of the chassis, together with its associated wiring.





The modulator and power supply unit together with the transmitter described last month.

At this point the final is neutralised for all practical purposes but this can be checked and indeed, there is a second method which may be used by those builders who do not have a wavemeter.

To check the latest adjustment for correct neutralisation, or to actually carry out the process from the beginning, the following procedure is suggested. Before starting however, the HT lead to the final which was disconnected must be restored.

Switch on and tune for a precise dip in plate current as previously described. Now set the meter switch to "grid". To carry out this procedure it will be necessary to switch the meter from "grid" to "plate" as required. With the final correctly dipped, carefully watch the grid current reading and slowly detune the "tune" control in one direction. The grid current should fall. Now dip the plate current again and repeat the procedure, this time turning the "tune" control in the opposite direction. If neutralising is "spot on", the grid current will fall again, and you have a properly neutralised transmitter.

Should the grid current rise and then fall as you slowly tune away from resonance in one direction, then the stage is not properly neutralised and the neutralising capacitor should be given a slight adjustment in one direction. If a subsequent check shows that the situation is worse, then you have moved the neutralising capacitor the wrong way. Pursue this course until the grid current falls on both sides of resonance.

If you have not made any preliminary neutralising adjustments using a GDO as previously discussed, then follow the subsequent procedure just described. The only difference this time is the possibility that the neutralising capacitor will have to be adjusted by a greater amount than if you had made the preliminary adjustment.

Having neutralised the transmitter, before we go on to the modulator, we hinted that the meter plate current readings may be somewhat in error. This may be checked by making a comparison with a multimeter of known accuracy. The HT line will have to be broken say between the 100 ohm resistor and the 22k screen resistor and the multimeter inserted in series with the line. With the transmitter switched on, the multimeter should indicate approximately 40mA and this should be compared with the reading on the transmitter meter. If the reading is low, then the 10k resistor must be shunted with a high value of resistor such that the reading is correct. On the prototype, we shunted the 10k resistor with a 100k resistor. If the meter reads high, then the 10k resistor will need to be increased.

So far, we have not checked the HT voltage. Ideally, this should be about 265 to 270V. If not, and the transformer has some taps which will allow you to effect a voltage adjustment, then we suggest that you aim for this voltage. If your transformer does not allow for any adjustment, then the voltage should be taken between the HT point and the cathode of the 6CM5, with the transmitter properly adjusted. The plate current of 40mA which we quote is on the assumption that the effective plate voltage is 250. If it deviates in either direction from this value, then the plate current should be adjusted accordingly, to give an input power to the plate of 10 watts.

With the transmitter adjusted, the valves may now be fitted to the modulator chassis. Switch on and bring up the transmitter and still with the dummy load attached, tune into the signal on a receiver, preferably fitted with a pair of headphones. Turn the volume control off, plug in the microphone and slowly advance the volume control while speaking into the microphone. Your voice should be heard in the headphones. Continue to advance the volume control until the plate current meter on the transmitter starts to kick and then back off a little. This should give about the right setting for the audio level.

If you have a CRO or some other means of checking modulation, then it is a good idea to check for depth of modulation. This done, and with your Novice licence in one hand, pull out the cable to the dummy load and plug in the aerial feedline with the other hand. Switch on the transmitter. It may be necessary to readjust the "load" and "tune" controls a little to get the right value of plate current again. You are now "on the air", and I wish you good DX!

LIST OF COMPONENT PARTS

1 Chassis, 10in x 6in x 2½in
1 Transformer, primary 240V, secondaries 120V, tapped 110V, 100V at 125mA, 6.3V at 3A, 6.3V at 3A. PVD104 or similar
1 Transformer, primary 240V, secondary 225V-CT-225V. PF201 or similar (see text)
1 Switch, SPST, McMurdo
1 Switch, DPDT, McMurdo
1 Jack socket, 6.4mm
1 Indicator lamp, 14V type BFB-6G, Rodan
1 Knob, Jabel etc
1 4-way mains terminal strip
1 Miniature tag board, 16 prs tags
1 Miniature tag board, 15 prs tags
2 Valve sockets, 9-pin miniature
1 Valve socket, octal
4 Rubber grommets
1 Valve, 12AX7
1 Valve, 6BQ5
3 Silicon diodes, EM404 or similar

RESISTORS (½W unless stated otherwise)

1 180 ohms 1W	*2 220k*
2 3.3k	*1 470k*
1 10k	*1 470k log pot*
3 15k 1W	*1 2.7M*

CAPACITORS
1 .001uF 630V ceramic
2 .0068uF 400V polycarbonate
1 .022uF 400V polycarbonate
1 8uF 300VW electrolytic
2 10uF 6VW electrolytics
1 10uF 10VW electrolytic
1 47uF 350VW electrolytic
2 100uF 200VW electrolytics

MISCELLANEOUS
Hookup wire, solder, solder lugs, screws, nuts, 3-core power flex, 3-pin plug, cable clamp, 15cm shielded or light coaxial cable.