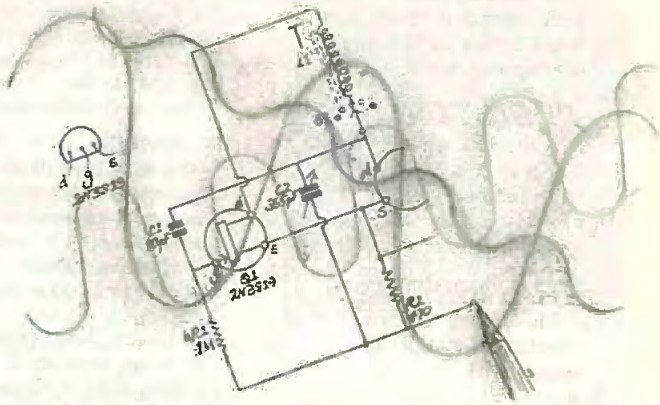
Special Series

PRACTICAL OSCILLATOR DESIGNS



RAYMOND HAIGH

This new series is prepared with the electronics enthusiast and experimenter very much in mind and is intensely practical. Tried and tested circuits are fleshed out with component values, and their vices and virtues are exposed.

PART 2: COLPITTS OSCILLATOR AND ITS VARIANTS

LAST month's article dealt with the history and general principles of oscillators, and covered the Hartley circuit in some detail. This month, frequency stability is considered, and the Colpitts oscillator and its variants are explored.

FREQUENCY STABILITY

Above 5MHz or so, drift becomes an increasing problem with LC oscillators, and above 10MHz frequency stability is almost impossible to achieve without recourse to complex circuitry.

The main causes of drift are mechanical instability, variations in supply voltage, excessive loading on the oscillator tuned circuit, and changes in temperature. Temperature changes can be externally imposed, or they can arise from the consumption of power by the oscillator.

Sound construction, a regulated power supply and the use of a buffer amplifier, will do much to overcome the first three causes. The problem of temperature fluctuations, which modify the characteristics of all of the oscillator's components, is more difficult to overcome.

REDUCING DRIFT

Whether mounted on printed circuit board (p.c.b.), stripboard, or tagstrips, oscillator components and wiring must be rigidly fixed in position. Completed assemblies can be protected against vibration, and made more rigid, by a liberal application of beeswax or by attaching components to the board and to one another by a viscous non-water-based adhesive.

Avoid double-sided printed circuit boards for oscillators. The two layers of foil can form capacitors which vary with temperature and shift the frequency of oscillation. If unscreened coils are mounted on the board, etch away the area of foil beneath them to avoid any possible capacitance effects.

Oscillators should be isolated in a separate metal "screening" enclosure. Again, if unscreened coils are used, make the case sufficiently large for the sides and ends of the coils to be spaced from it by at least one coil diameter in order to limit the reduction in the Q factor caused by the metal screening. Locate the box away from draughts and sources of heat.

INDUCTORS

In the quest for low drift, air-cored coils are the first choice followed, in order of preference, by coils with dust iron cores, then ferrite cores, ferrite cups, dust iron toroids and, least preferred, ferrite toroids. However, the ability to adjust inductance often overrides the desire to minimise drift, and slug and cup tuned coils are widely used. Similarly, the high Q factors and minimal external fields of toroidal coils are advantages which frequently dictate their use.

Coil formers must be rigid and have good dielectric properties. The range of commercially produced items available to the home constructor is now very limited, but plastic pipes used in the plumbing and electrical industries can be pressed into service. P.V.C. electrical conduit is of particular interest, as its thick walls impart rigidity.

Single layer coils should be tightly wound. When adjoining turns are touching, the entire winding can be held in place by the application of a thin coat of clear cellulose without unduly affecting the performance of the coil.

Spaced windings of heavy gauge wire can be secured by applying cyanoacrylate adhesive (Superglue) along the turns of the coil. Piled coils should be held within bobbins and wound with only a light tension on the wire. Unless they are to be exposed to wide humidity changes, it is best not to impregnate them.

Beeswax can be used to lock cores in position, but the effects of dimensional and permeability changes caused by shifts in temperature have to be minimised by the compensating action of the capacitors in the tuned circuit.

CAPACITORS

Variable tuning capacitors should be air-spaced and of good quality. Silver plated brass vanes are to be preferred to aluminium (they are usually only available in values up to 150pF), and double bearing rotors are more stable than the single bearing type.

In the early days of radio, silvered mica components were the first choice when a fixed capacitor had to be connected into a tuned circuit. Their temperature coefficient is, however, rather unpredictable, and modern practice tends towards the use of polystyrene dielectric capacitors, which have a slight negative temperature coefficient. (This can compensate for the positive coefficient of dust iron toroids).

Ceramic capacitors, which are manufactured in a range of positive and negative coefficients, including zero change types, are available in close increments of value from 1pF to 220pF. Avoid, in tuned circuits, ceramic capacitors intended for coupling and

Frequency Stability

Drift becomes an increasing problem in all *LC* oscillators as the frequency of operation rises through the h.f. spectrum. Its main causes are:

(1) Mechanical instability.
(2) Power supply voltage variations.
(3) Excessive and variable oscillator loading.
(4) Temperature variations, externally imposed or internally generated.

However well constructed, simple *LC* oscillators cannot, by themselves, be made sufficiently drift free for use in transmitters radiating much above 10MHz. They will, however, give a more than adequate performance in receivers operating up to 30MHz.

decoupling. The lower Q and uncertain temperature coefficient of these components is likely to impair performance.

When all the rules of good construction have been followed, the only simple means of reducing residual drift is to substitute different fixed capacitors until the temperature coefficient has been optimised. The Colpitts oscillator, where several capacitors are wired, directly or indirectly, across the tuned circuit, is ideal for this treatment.

RESISTORS

Although quarter-watt resistors are usually adequate for most low-powered oscillator circuits, the greater bulk of higher rated types reduces the heating effect and the resistance changes which this causes. Increasing the power rating of gate and base bias resistors to one or two watts can prove beneficial.

TRANSISTORS

The internal capacitances and port impedances of transistors are affected by changes in temperature, supply voltage and signal voltage. These effects can be minimised by keeping the supply voltage, and the amplitude of oscillation, as low as possible consistent with reliable operation.

It is usually easier to obtain good results with field-effect transistors (f.e.t.s). Their high gate impedance, and the simpler biasing arrangements which result, are largely responsible for this. However, f.e.t. gate impedance falls as the frequency of operation rises through the h.f. and v.h.f. spectrum, and the advantage is a diminishing one.

With care, bipolar transistors can give very acceptable results. Circuits based on the use of semiconductors of this type have, therefore, been included.

Whether using a f.e.t. or a bipolar transistor, always choose a type with the highest transconductance (Y_{fs}) or gain (h_{fe}) for a given f_T. Whilst transistors will often oscillate up to their rated upper frequency limit or f_T (the frequency at which gain falls to unity), it is good practice to select a device with an f_T at least three times, and preferably four or five times, as high as the maximum operating frequency. These measures will ensure reliable starting and oscillation, and permit supply voltages to be kept low to minimise drift.

OSCILLATOR LOADING

Some energy has to be taken from the oscillator, and the resultant loading affects the Q factor and operating frequency of its tuned circuit. The loading must, therefore, be constant and as light as possible in order to maximise frequency stability.

A buffer amplifier, placed between the oscillator and the load, is essential if high performance is to be achieved. Even when the oscillator incorporates isolating circuitry (e.g., the Dow variant, see Part 1) it is still desirable for additional buffering measures to be provided.

BUFFER AMPLIFIER

A buffer amplifier should have a high input impedance to minimise damping on the oscillator circuit. Its output impedance should be low to enable it to maintain a reasonably constant signal level over a range of load impedances. The signal voltage produced by a few of the oscillators is modest and some gain is, therefore, desirable.

Readers may wish to use one of the oscillator circuits to form a signal generator, and provision for modulating the r.f. output will also be useful. A buffer amplifier capable of meeting these requirements, and of modification to suit the needs of individual constructors, is detailed in Fig.1.

A two-stage circuit, where transistor TR1 is a dual-gate MOSFET configured as a source follower, is shown in Fig.1a. Arranged in this way, it presents a very high impedance to the oscillator, and an appropriately low impedance feed for the bipolar, common emitter amplifier TR2. Although the dual-gate MOSFET does not yield any voltage gain in this mode, it does provide a significant power gain.

INPUT CIRCUIT

Oscillator input to the MOSFET TR1 is via d.c. blocking capacitor C1. This component should have the lowest possible value consistent with sufficient output being obtained from the buffer amplifier. It is best selected by experiment, and for this reason no provision is made for it on the buffer amplifier p.c.b. Its value will range from 1pF to 100pF. Gate resistor R2 ensures correct biasing.

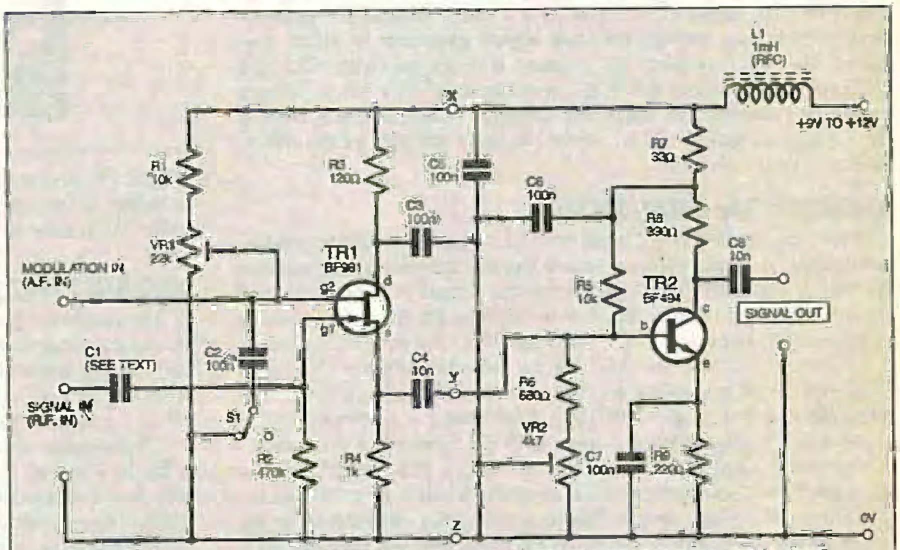
The gain of TR1 is controlled by preset potentiometer VR1 which sets the voltage on gate 2. The r.f. signal can be modulated, on its way through TR1, by varying the gate 2 voltage at audio frequencies. A suitable modulation oscillator is described later.

Switch S1 connects bypass capacitor C2 into circuit when modulation is not being applied. This switch should be ganged with the

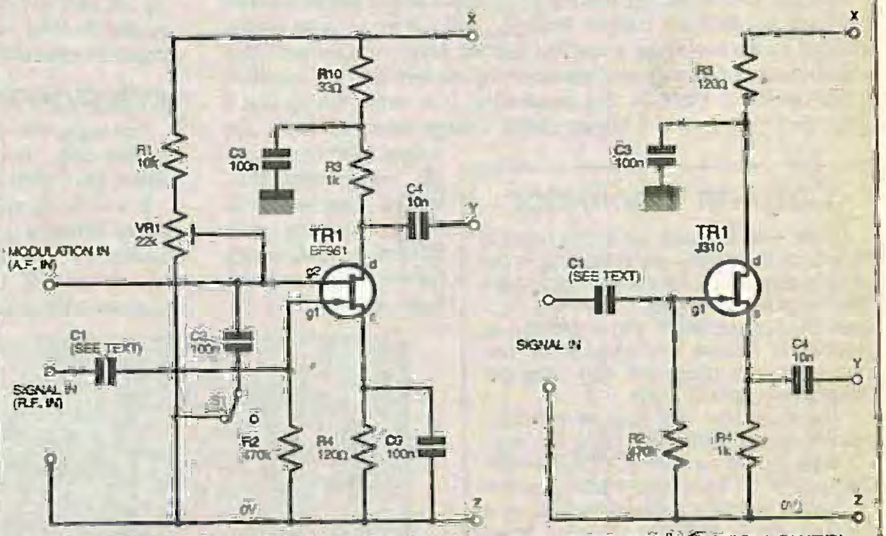
Buffer Amplifiers

A buffer amplifier is essential if drift is to be reduced to a minimum, and a circuit diagram which can be widely adapted to suit individual needs is given in Fig.1. All versions feature a high input and low output impedance.

The full circuit has a voltage gain of approximately 26dB, an output of 2V r.m.s., and a reasonably flat response from 100kHz to 100MHz. Provision is made for gain adjustment and the application of audio modulation.



a) WITH DUAL-GATE MOSFET IN COMMON DRAIN (SOURCE FOLLOWER) MODE



b) DUAL-GATE MOSFET (COMMON SOURCE)

c) F.E.T. (SOURCE FOLLOWER)

Fig.1. Circuit diagram for a buffer amplifier with alternative front ends.

switch which connects the power supply to the modulation oscillator. Resistor R3 and capacitor C3 decouple the input stage from the supply line, and the signal output, developed across source (s) resistor R4, is coupled to the base of transistor TR2 by d.c. blocking capacitor C4.

OUTPUT CIRCUIT

Bipolar transistor TR2 is arranged as a common emitter stage. Bias is applied to the base (b) by a resistor chain formed by R5, R6 and preset potentiometer VR2. The inclusion of VR2 enables the voltage to be optimised for a wide range of transistor types. Emitter (e) bias is provided by R9, and C7 functions as a bypass capacitor.

The buffer circuit output is developed across TR2 collector (c) load resistor R8. The value of this component has been chosen to ensure a reasonably constant gain over a 100kHz to 100MHz frequency range, and an acceptably low output impedance. Its value can be reduced in order to lower output impedance, but this will be at the expense of signal voltage. Capacitor C8 acts as a d.c. blocker.

Resistor R7 and capacitor C6 decouple the stage, and the r.f. choke, L1, and capacitor C5, isolate the entire buffer amplifier from the power supply. The inclusion of a radio frequency (r.f.) choke is very much a good-practice measure in circuitry of this kind and, in almost every case, a low value resistor (10 to 100 ohms) could be substituted without any deterioration in performance.

With a 12V power supply, the output from this circuit (Fig.1a), just before the onset of overload, is 2V r.m.s. (almost 6V peak-to-peak): more than enough for most signal generator or mixer purposes. The input required to produce this output (with VR1 and VR2 set for maximum gain), is approximately 0·1V r.m.s. Voltage gain of the amplifier is, therefore, some 20 times, or 26dB. Setting the voltage on gate 2 of TR1 to zero reduces the gain of the unit to around 6 times, or 15dB.

COMMON SOURCE

If desired, MOSFET TR1 can be made to provide voltage gain by configuring it in the common source mode. The circuit arrangement for this is depicted in Fig.1b, where the output is now developed across drain load resistor R3. Source resistor R4 has a lower value in this circuit, and resistor R10 and capacitor C3 decouple the stage.

This configuration should only be adopted when a dual-gate MOSFET stage is used on its own, or when the gain (h_{fe}) of transistor TR2 is *low* (e.g., a BF199). Combining a common source input with a high gain output stage is likely to result in instability.

The buffer amplifier also works well with a j.f.e.t. arranged as a source follower input stage, and a suitable circuit is given in Fig.1c. It will not, of course, be possible to apply audio modulation to the buffer in the same way if this circuit is used, nor will it be possible to adjust the gain of the amplifier.

The dual gate MOSFET and the j.f.e.t. input stages can be used on their own as oscillator buffers. Isolation will not be as great as that afforded by the two-stage amplifier, and the output voltage available with the source follower configuration will be less than that supplied by the oscillator itself. In this connection, it is worth noting that a J310 j.f.e.t. will deliver a higher output voltage than a 2N3819. The output from these simple, single stage f.e.t. buffers can be varied by substituting a 1 kilohm potentiometer for the drain or source load resistor.

Colpitts Oscillator

With the Colpitts oscillator circuit, feedback is applied via a tapping in the tuning capacitor. Like the Hartley (where the inductor is tapped – see Part 1), it can be configured in either parallel or series fed modes, and simplified circuit diagrams depicting the two arrangements are given in Fig.3.

The shunting of the ports of the maintaining device with fairly large amounts of capacitance contributes to the circuit's reputation for frequency stability, and it is widely used by radio amateurs as a narrow band oscillator. Output does, however, tend to vary with the setting of the tuning capacitor to a greater extent than with other *LC* circuits.

The basic Colpitts oscillator has, perhaps more than any other, been modified and developed by a succession of designers who have all attempted to reduce even further its already low level of drift.

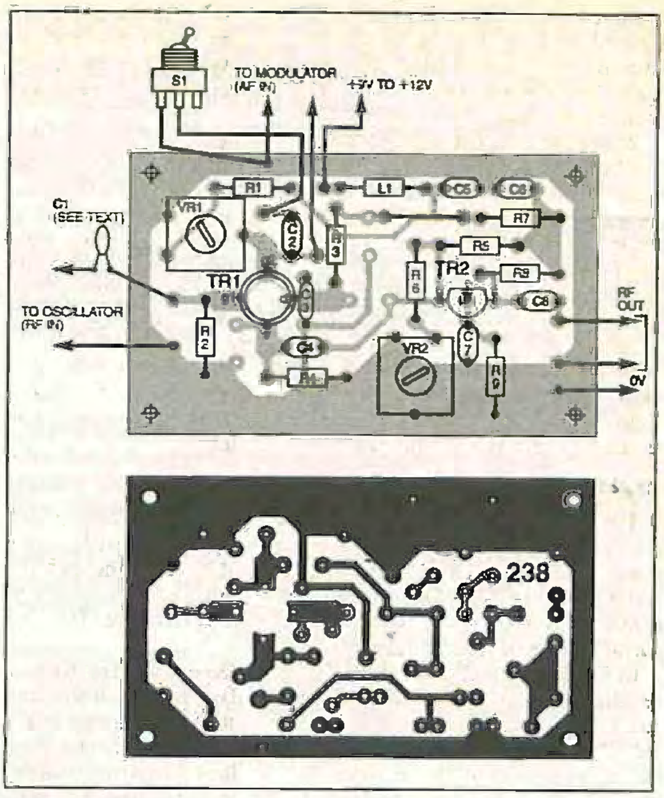


Fig.2. Printed circuit board component layout and full-size foil master for a dual-gate MOSFET buffer amplifier. The p.c.b. also caters for different front ends. (See EPE PCB Service.*)*

CONSTRUCTION – BUFFER AMP

The two-stage buffer amplifier is best assembled on a small p.c.b. A suitable component layout, based on Fig.1a, together with a full size copper track master is given in Fig.2. This board is available from the *EPE PCB Service*, code 238. Provision has been made for all of the alternative front-end arrangements described earlier.

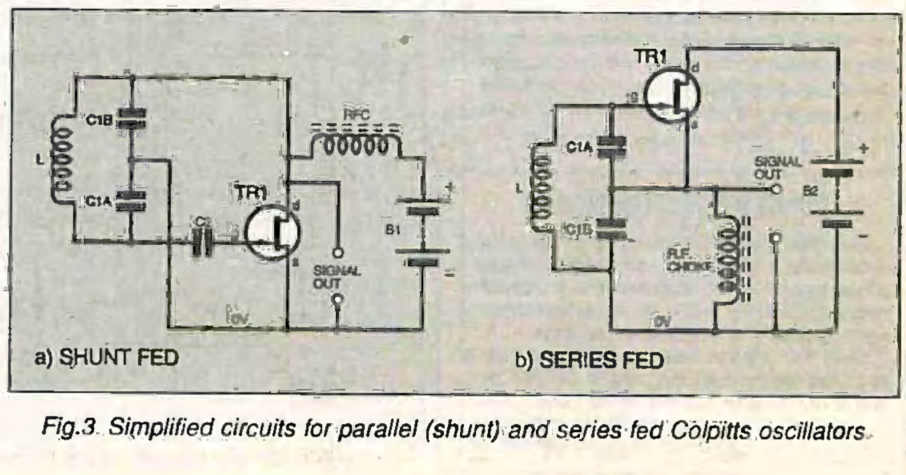
Construction should be fairly straightforward and should start with the smallest components working up to the largest. It is probably best to leave the transistors until last. Check the finished board against the circuit diagram. Note that capacitor C1 is off-board and do not forget the single link wire.

Connect the buffer to its own regulated output from the power supply, and house it in a separate metal enclosure, which should be located as close as possible to the oscillator in order to minimise the length of connecting leads.

COLPITTS OSCILLATOR

Having covered the measures which have to be taken in order to combat drift, we can now consider the next oscillator circuit in the series, the Colpitts and its variants.

It will be recalled that feedback was applied to a tapping on the tuning inductor in the case of the Hartley circuit. With the Colpitts, feedback is applied via a tapping in the tuned circuit capacitance. Because of this, untapped, single winding coils can be used, and band switching is even simpler than with the Hartley.



a) SHUNT FED

b) SERIES FED

Fig.3. Simplified circuits for parallel (shunt) and series fed Colpitts oscillators

Moreover, the transistor ports connected to the tuned circuit are shunted by fairly large amounts of capacitance, and this tends to swamp temperature related capacitance changes within the device itself. The Colpitts and its variants can, therefore, be made less prone to drift than other circuits.

With most (but not all) Colpitts arrangements, the need to have fixed capacitors across the tuned circuit in order to maintain oscillation restricts the frequency coverage produced by a variable capacitor. Whilst this can be an advantage in circuits designed to cover a narrow band of frequencies, it is a drawback when wide coverage is required. Moreover, the signal output from the Colpitts oscillator is more dependant upon the tuning capacitor setting than some circuits, and this also militates against wide coverage.

Despite these drawbacks, the opportunity to minimise drift has made the Colpitts and its variants popular when narrow frequency bands (e.g., the amateur bands) have to be covered. It is adopted almost universally when a simple variable frequency oscillator is required in receivers operating at v.h.f. and u.h.f.

BASICS

The commonly encountered versions of the basic Colpitts circuit are shown in Fig.3. In Fig.3a, the tuned circuit formed by inductor *L* and capacitors *C1A* and *C1B* is connected between the gate (g) and drain (d) of TR1. The source (which is grounded) is, in effect, connected to the tapping in the tuned circuit capacitance. This is a *parallel* or *shunt* fed arrangement.

In Fig.3b one end of the coil *L* is grounded and the feedback is developed across an r.f. choke. The drain (d) is connected into circuit via the power supply, and this circuit is, therefore, termed *series* fed. The impedance of the tapping point can be varied by changing the relative values of the two capacitors. Reducing *C1A* and increasing *C1B* will lower the impedance presented to the feedback connection and the damping on the tuned circuit.

The capacitors are often of equal value, especially with the version depicted in Fig.3a. However, when the oscillator is used for more demanding applications, better performance can usually be achieved by making the relative value of *C1B* as large as possible consistent with reliable operation.

SPOT-ON COLPITTS

A Colpitts circuit suitable for generating a 1kHz spot frequency is given in Fig.4. Bipolar transistor TR1 is used as the maintaining device in this shunt fed arrangement, and the tuned circuit formed by L1, C1 and C2 determines the frequency of oscillation.

Bias is applied to the base (b) of TR1 by resistor R1, and the signal is developed across R2, the collector (c) load resistor. C3, C4 and C6 are d.c. blocking capacitors, and potentiometer VR1 permits the adjustment of the output voltage. Bypass capacitor C5 makes the unit immune to changes in supply impedance (ageing batteries), and its value is related to the low operating frequency of the circuit.

The unit is suitable for applying modulation to an r.f. signal generator, and it works well with the buffer circuit described previously. When used in this way, VR1 sets the modulation depth.

Output voltage falls as the load impedance is reduced, but frequency remains pretty constant. (The signal level is 0·25V r.m.s. when the load is reduced to 1k). Because of this there is some interaction between the output control potentiometer and the buffer amplifier (Fig.1) gain control preset VR1.

The circuit oscillates vigorously, and can be used to generate spot frequencies with a tolerably good waveform from below 100Hz up to 10MHz. Above 10MHz, operation becomes erratic.

WIDE RANGE COLPITTS

A Colpitts oscillator with fixed feedback capacitors is not particularly suitable when wide and continuous frequency coverage is required. A version of the shunt fed circuit, in which feedback is applied to a tapping in the variable tuning capacitor, is, however, sometimes used as a wide coverage oscillator, and this arrangement is depicted in Fig.5.

Because of the grounded feedback connection, a twin-gang variable capacitor, VC1a and VC1b, can provide the feedback tapping and also tune the switched inductors. The moving vanes, connected by the spindle, form the tap, which is conveniently connected to ground. The fixed vanes are connected to either end of the inductor.

The effective swing of a 360pF unit is, of course, reduced to 180pF, but continuous coverage from 150kHz to 15MHz can be obtained with five switched inductors (six Toko coils will probably be required if coverage between 300kHz and 500kHz is included).

A high input impedance f.e.t., TR1, has to be used in order to ensure reliable starting and oscillation over the full swing of the tuning capacitor V1 on all ranges. C2 is a d.c. blocking capacitor, resistor R1 ensures correct biasing, and diode D1 limits oscillation

Parallel or Shunt Fed Colpitts Oscillators

Two examples of the shunt fed Colpitts oscillator arrangement are given. The first, depicted in Fig.4, generates a 1kHz audio tone and can be used for modulating an RF signal generator or for providing a test signal.

A good output voltage is developed with a waveform of reasonable purity. The circuit has the virtue of great simplicity, and an untapped, single winding inductor is all that is required.

It could, with advantage, be substituted for the Hartley oscillator in the metal detector circuit given in Part 1. With appropriate tuned circuit components, it will oscillate from below 100Hz to above 10MHz. However, above 10MHz its operation becomes erratic.

How the basic Colpitts oscillator can be configured to give continuous coverage from 150kHz to 15MHz is shown in Fig.5. Although this arrangement generates a near perfect waveform, the Hartley (last month), Butler and Franklin (next month) circuits are to be preferred when a simple, wide coverage oscillator is required. Output from these circuits is more constant over the tuning capacitor swing, and they will operate up to 30MHz and beyond.

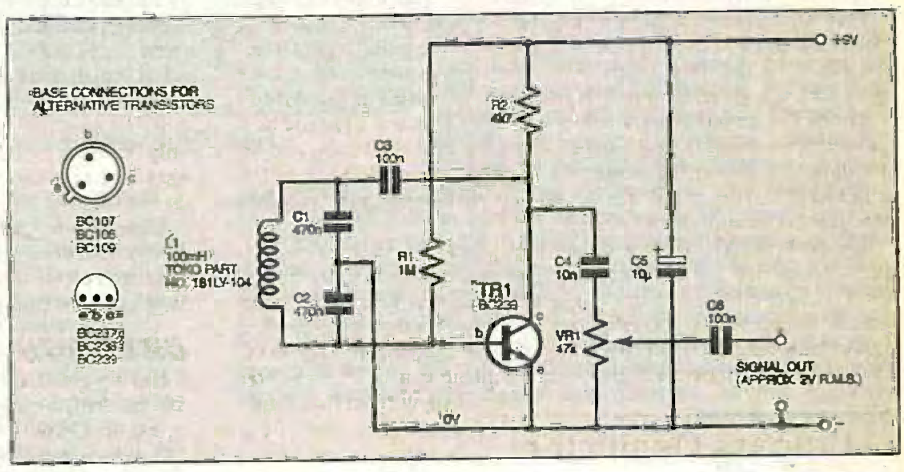


Fig.4. Circuit diagram for a Colpitts 1kHz a.f. oscillator for modulating an r.f. signal generator.

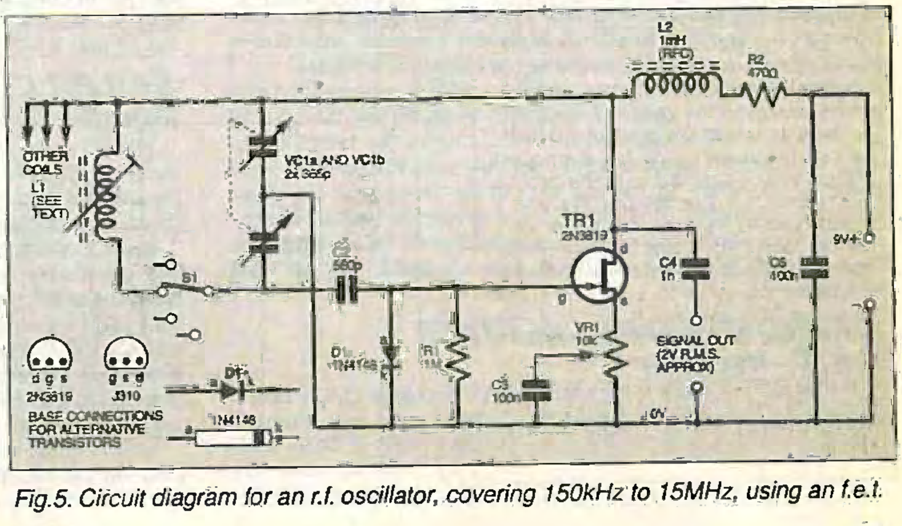


Fig.5. Circuit diagram for an r.f. oscillator, covering 150kHz to 15MHz, using an f.e.t.

amplitude in order to prevent forward conduction of the f.e.t.'s gate. An output is developed across L2, a radio frequency choke, and resistor R2 functions as a *Q* spoiler preventing erratic operation being triggered by its natural resonances. C4 is a d.c. blocking capacitor.

Potentiometer VR1 acts as the source bias resistor, and its slider (moving contact) is connected to the r.f. bypass capacitor C3. Moving the slider towards earth (0V) leaves an increasing portion of the resistor unbypassed. The resulting negative feedback reduces the gain of TR1 and improves the output waveform.

By this means the circuit can be adjusted to produce a near perfect sinewave, but this is at the expense of output voltage. Signal output also varies with the setting of the tuning capacitor (it reduces by approximately 60 per cent as the vanes are rotated from half mesh to fully open). The quoted output voltage is with the tuning capacitor set at half mesh and VR1 adjusted to give the best waveform.

Above 15MHz, the circuit will not oscillate over the full swing of the tuning capacitor, and operation becomes increasingly erratic as frequency is raised. More refined versions of the circuit could, no doubt, be persuaded to give coverage up to, and beyond, 30MHz.

Wide coverage can be obtained with much less bother with the Hartley, Butler and Franklin oscillators, and new twin-gang capacitors are expensive. The circuit has, however, been included for the sake of completeness.

NARROW BAND COLPITTS – Bipolar Transistor Version

In the bipolar transistor version of the narrow band Colpitts oscillator, shown in Fig.6, the tuning capacitance is made up of a pair of series connected feedback capacitors, C3 and C4; and two capacitors, C1 and C2, which limit the effect of variable tuning capacitor VC1. By restricting coverage in this way, the full 180 degree swing of the variable capacitor is required in order to traverse the band, and this ensures the lowest possible tuning rate (a very desirable feature when attempting to resolve weak, amateur single-sideband transmissions).

Capacitor C5 acts as the d.c. blocking capacitor (because of the comparatively high value of this component, the circuit cannot be regarded as the Seiler variant, which is covered later), and resistors R1 and R2 bias transistor TR1. Resistor R3 and capacitor C6 are decoupling components, and C6 also ensures that TR1 collector (c) is connected directly into the feedback circuit rather than via the power supply. Output and feedback voltages are developed across emitter (e) load resistor R4 and the r.f. signal is extracted via the low-value d.c. blocking capacitor C7.

Every port of the transistor is shunted by a capacitor, and this helps to minimise the effect of small changes in capacitance within the device itself. The values of C3 and C4 should, therefore, be as high as possible consistent with reliable starting and oscillation, but they may have to be tailored to ensure that the desired frequency coverage can be obtained with a particular coil and variable capacitor combination.

START-UP

Tuned circuit components for this standard Colpitts arrangement, are listed in Table 1. The values quoted for C3 and C4 will ensure reliable starting and operation with a wide range of transistor types. However, the use of a BF494 r.f. transistor limits the reduction in output which occurs as the frequency of operation increases.

Individual constructors may find it possible to improve the output waveform and/or further reduce drift by increasing the value of one or both of these capacitors. If this is done, the values of the other tuned circuit capacitors (and possibly the inductor) may need changing in order to restore the stated frequency coverage. Increasing the values of C3 and C4 will reduce the output voltage.

On ranges where swing reducing capacitor C1 is not fitted, the fixed vanes of VC1 must, of course, be connected to the "hot" end of inductor L1.

NARROW BAND COLPITTS – F.E.T. Version

A Colpitts oscillator with a field-effect transistor (f.e.t.) as the maintaining device is shown in Fig.7. The tuning and feedback capacitor arrangements are the same as those listed in Table 1 for the bipolar version.

Table 1: Narrow band Colpitts oscillators

Tuned circuit components for bipolar and f.e.t. versions.
(See Fig.6 and Fig.7 for circuit diagrams.)

Band MHz	Toko coil L1	Base wiring	C1 pF	C2 pF	C3 pF	C4 pF
1·8	154FN8A6438EK	A	–	–	180	470
3·5	154FN8A6439EK	B	–	–	180	470
7	KXNK3767EK	B	22	–	180	470
10	KXNK3767EK	A	27	–	180	470
14	KXNK3767EK	A	22	–	82	270
18	8·5 turn type S18	–	10	18	82	270
21	8·5 turn type S18	–	15	–	56	180
24-28	5·5 turn type S18	–	–	–	39	82

Notes: (1) The type S18 coils have ferrite cores. (2) See Fig.17 for base wiring details. (3) When a swing reducing capacitor, C1, is not provided, the fixed vanes of tuning capacitor VC1 must be connected directly to the "hot" end of the inductor.

The gate (g) of the f.e.t. is grounded (0V) through coil L1 and the usual gate bias resistor is not required. Diode D1 should, however, be wired into circuit to limit oscillation amplitude and prevent forward conduction of the gate.

A radio frequency choke, L2, has to be used as a source (s) load in order to ensure reliable oscillation with the f.e.t. version of the circuit. Resistor R2 spoils the *Q* of the choke and avoids any tendency for its resonances to affect the operation of the circuit.

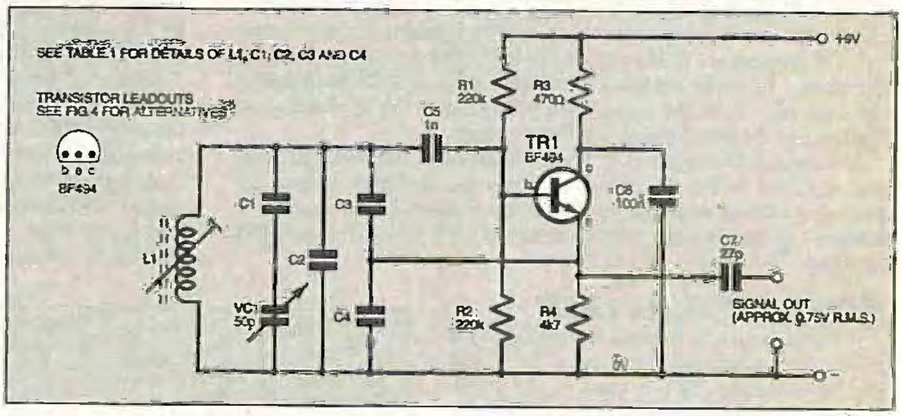


Fig.6. Circuit diagram for a narrow band Colpitts oscillator

Resistor R1 and capacitor C5 decouple the circuit from the power supply, and C5 also ensures that the drain (d) of the transistor is effectively connected into the feedback circuit. (This is a series fed oscillator, and feedback would otherwise depend entirely upon the drain being connected through the power supply.)

Output is taken from the source of TR1 via d.c. blocking capacitor C6. In order to minimise loading on the oscillator, this component should have the lowest possible value consistent with sufficient voltage being supplied to the accepting circuit.

Signal output from this oscillator is significantly higher on the two lower frequency ranges (approximately 2·5V r.m.s.). Making the value of C6 small will, therefore, also have the desirable effect of evening out the signal level, as it will impede the lower frequencies more. (Output is greater because the values of feedback capacitors, C3 and C4, have been reduced in order to ensure coverage of the 1·8 and 3·5MHz bands with a 50pF variable capacitor.)

SEILER COLPITTS VARIANT – Bipolar Transistor Version

A radio amateur, E. O. Seiler, published a variant of the Colpitts oscillator in 1941. Developed during the valve era, he originally described it as a "Low-C Electron-Coupled Oscillator". Two updated semiconductor versions are given in Fig.8 and Fig.9.

Seiler's modification provided for the "grid" of the valve (now the base (b) of a bipolar transistor or the gate (g) of a f.e.t.) to be tapped down the tuned circuit by adding another capacitor, C3, to the feedback chain connected across the coil L1. In the original valve version, this is a 100pF preset component which can be reduced until oscillation is only just maintained. By this means, the isolation of the valve, from the tuned circuit, is made as great as possible, thereby enhancing the frequency stability of the basic Colpitts circuit.

It can be likened to the Lampkin variant of the Hartley oscillator (see last month), where the base or gate of the maintaining

Table 2: Narrow band Seiler oscillator
Tuned circuit components for bipolar transistor version.
(See Fig.8 for circuit diagram.)

Band MHz	*Toko coil L1*	*Base wiring*	*C1 pF*	*C2 pF*	*C4 pF*	*C5 pF*
1·8	154FN8A6438EK	B	–	–	120	270
3·5	154AN7A6440EK	D	–	–	82	270
7	154FN8A6439EK	A	27	–	120	270
10	KXNK3767EK	B	15	–	120	270
14	KXNK3767EK	A	47	–	120	270
18	8·5 turn type S18	–	47	–	120	270
21	5·5 turn type S18	–	–	–	82	180
24-28	5·5 turn type S18	–	–	–	56	56

Notes: (1) S18 coils for the 18MHz and 21MHz bands have ferrite cores. The coil for the 24MHz and 28MHz bands has an aluminium core. (2) A parallel, fixed tuning capacitor, C2, is not required on any range with the bipolar version. (3) See Fig.17 for base wiring details.

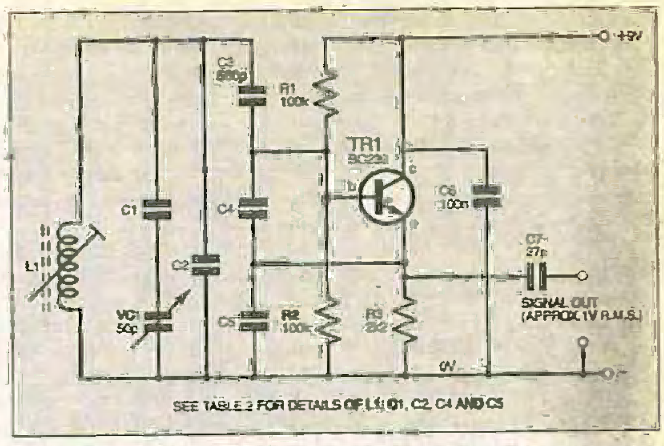


Fig.8. Circuit diagram for a narrow band Seiler variant of Colpitts oscillator.

device is tapped down the tuning inductor to achieve the same result.

Because of their low base impedance, bipolar transistors do not lend themselves as readily as f.e.t.s to this circuit, and reducing the value of C3 below 500pF excessively attenuates the signal available at the base and inhibits oscillation. In the interests of consistent performance with a range of transistor types, the value of the additional capacitor has, therefore, been fixed at 560pF for the bipolar version of the circuit.

This is only a modest improvement over the 1nF capacitor specified for the basic Colpitts oscillator. However, any reduction in tuned circuit damping is worthwhile, and constructors interested in experimenting with the bipolar version can use this value as a starting point and reduce it until reliable oscillation is only just maintained. Table 2 gives the values for the remaining tuning capacitors when C3 is 560pF. One or more of them will, of course, need increasing if C3 is reduced in order to restore the stated coverage.

SEILER VARIANT – F.E.T. Version

The valve-like characteristics of field-effect transistors (f.e.t.s) makes them more suitable for the Seiler variant. A circuit diagram is given in Fig.9, and the functions of the various components have already been described in connection with other f.e.t. maintained oscillators. There is no d.c. path between the gate of TR1 and ground, and resistor R1 has to be provided in order to ensure correct biasing.

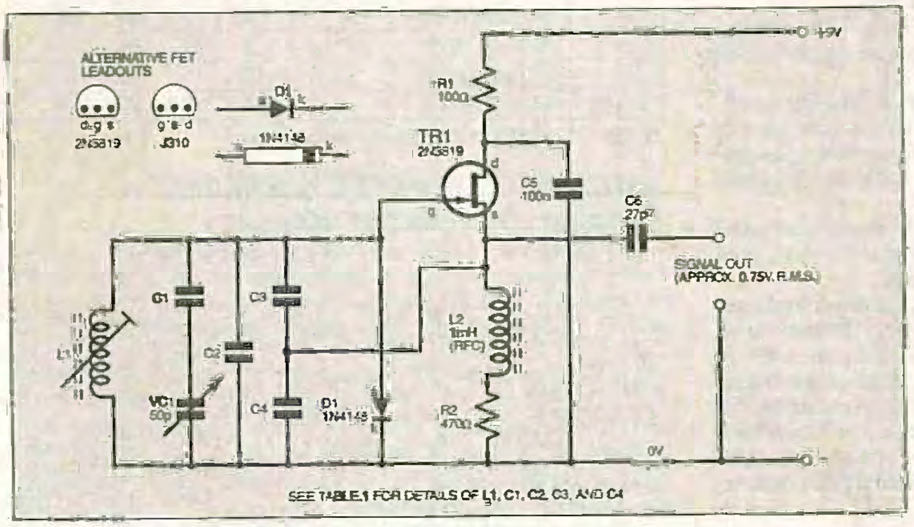


Fig.7. Narrow band Colpitts oscillator using an f.e.t.

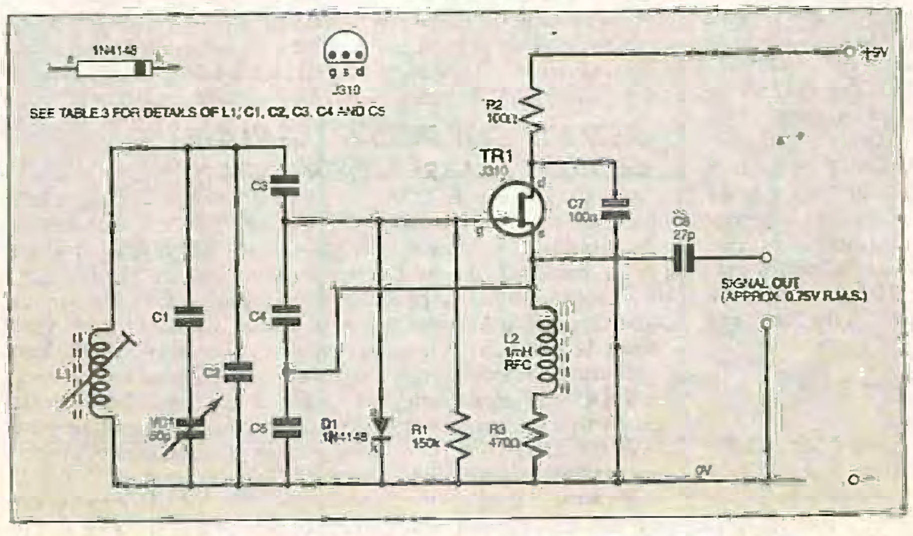


Fig.9. Narrow band Seiler variant of Colpitts oscillator using an f.e.t.

Narrow Band Oscillators

The Colpitts oscillator is widely used for coverage of the h.f. amateur bands. Bipolar and f.e.t. versions of a basic Colpitts circuit are illustrated in Fig.6 and Fig.7.

Seiler's adaptation, which attempts to further improve frequency stability by tapping the grid, base or gate of the maintaining device down the chain of feedback capacitors, is depicted in Fig.8 and Fig.9.

Clapp tried to improve on the basic circuit by adopting a series tuned, as opposed to a parallel tuned, *LC* network. Bipolar and f.e.t. versions of Clapp's modification (sometimes known as the Gouriet-Clapp circuit) are given in Fig.10 and Fig.11.

Another variant which attempts to improve on the basic Colpitts oscillator by modifying the tuning arrangements is the Vackar. Alternatives are given in Fig.12 and Fig.13, where a π network has been substituted for the original parallel tuned circuit.

The various Colpitts arrangements all have their advocates. Performance differences between them are slight, but they have probably been listed above in ascending order of improvement, with the Vackar as the most drift free. They must, however, be buffered, well constructed, and the tuning and feedback capacitors selected with care, if the claimed low levels of drift are to be achieved.

Table 1 to Table 5 list the values of tuning components for all of the narrow band Colpitts variants. These circuits will, however, cover wider bands if desired, oscillating over the full swing of a 365pF variable capacitor, and down to 100kHz and below, if appropriate inductors and feedback capacitors are fitted.

Table 3: Narrow band Seiler oscillator
Tuned circuit components for field-effect transistor version.
(See Fig.9 for circuit diagram.)

Band MHz	*Toko coil L1*	*Base wiring*	*C1 pF*	*C2 pF*	*C3 pF*	*C4 pF*	*C5 pF*
1·8	154FN8A6438EK	B	–	82	47	120	270
3·5	154FN8A6438EK	A	56	–	47	120	270
7	154FN8A6439EK	B	10	27	47	120	270
10	KXNK3767EK	B	15	15 (56)	560 (47)	82 (120)	120 (270)
14	KXNK3767EK	A	22 (27)	18 (56)	560 (47)	82 (120)	120 (270)
18	8·5 turn type S18	–	22	120 (47)	560 (120)	82 (120)	120 (270)
21	5·5 turn type S18	–	82 (47)	82 (39)	560 (120)	82 (120)	120 (180)
24-28	5·5 turn type S18	–	82 (120)	– 56'	560 (82)	39 (82)	82 (120)

Notes: (1) The S18 type coils all have ferrite cores. (2) The figures in brackets are the component values for the Dow and Goral versions. (3) On the 24MHz to 28MHz bands, the '56pF capacitor, C2, is required only for the Goral version. (4) See Fig.17 for base wiring details.

The ubiquitous 2N3819 is likely to prove too docile for this circuit with the capacitor values specified in Table 3, so a J310 is strongly recommended. If difficulty is encountered in obtaining this particular f.e.t., a dual-gate MOSFET (e.g., a BF981) with its gates strapped together will probably perform well.

Dow and Goral versions of Seiler's modification are discussed later. These variants oscillate more vigorously than the basic f.e.t. arrangement, and enable the value of C3 to be kept low.

CLAPP'S COLPITTS VARIANT

Our next modification to the Colpitts oscillator is the Clapps' variant. Depicted in Fig.10 and Fig.11, it was also conceived during the valve era.

An American engineer, J. K. Clapp was the first to publish the circuit. However, a British inventor, Geoffrey Gouriet, had already developed it during the early 1940's, but wartime restrictions prevented him making his findings known. Strictly speaking, therefore, it should be called the Gouriet-Clapp variant.

It involves the substitution of a series tuned for the parallel tuned circuit used in the original design. Advocates of the arrangement claim that it displays improved frequency stability.

The formulae relating frequency, inductance and capacitance are the same as those used for parallel tuned circuits. However, with series tuned circuits, maximum Q is realised when the ratio of inductance to capacitance is as high as possible (with parallel tuned circuits, capacitance should be kept high in order to maximise Q). The series tuned circuit presents a low impedance to the base or gate of the maintaining device, and this results in a better match, especially when a bipolar transistor is used (parallel tuned circuits present a high impedance at resonance).

CLAPP'S VARIANT – Bipolar Version

A bipolar version of the Clapp circuit is given in Fig.10, where C3 and C4 are the feedback capacitors, and the series tuned circuit is formed by L1, C1, VC1 and C2.

Transistor TR1 is biased by resistors R1, R2 and preset potentiometer VR1. Preset VR1 allows adjustment of the base voltage to suit individual devices. Details of the tuned circuit components are given in Table 4.

CLAPP'S VARIANT – F.E.T. Version

The circuit diagram of a f.e.t. maintained Clapp oscillator is given in Fig.11. There is no d.c. path between the gate of TR1 and ground, and resistor R1 must be provided to ensure the correct biasing of the transistor.

The functions of the other passive components have been described in connection with earlier circuits. The inductors and capacitors scheduled in Table 4 also apply to the f.e.t. version.

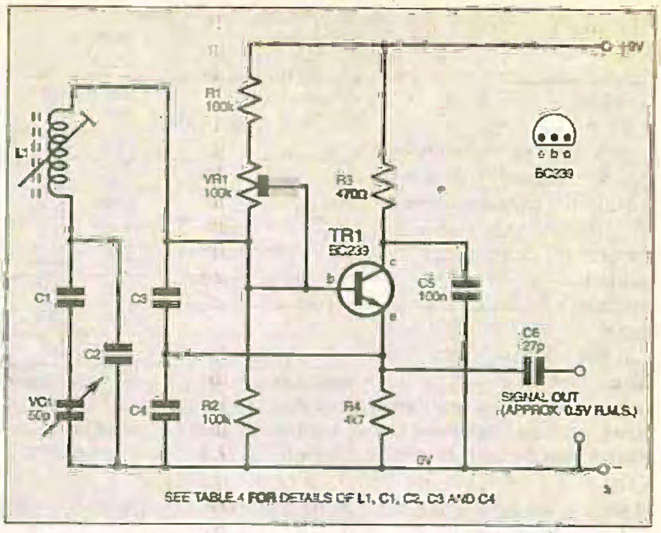


Fig.10. Circuit diagram for a narrow band Clapp variant of Colpitts oscillator.

Table 4: Narrow band Clapp oscillators
Tuned circuit components for bipolar and f.e.t. versions.
(See Figs.10 and 11 for circuit diagrams.)

Band MHz	*Toko coil L1*	*Base wiring*	*C1 pF*	*C2 pF*	*C3 pF*	*C4 pF*
1·8	154FN8A6438EK	B	–	100	680	1500
3·5	154FN8A6438EK	A	–	56	270	470
7	154FN8A6439EK	B	27	82	270	470
10	154FN8A6439EK	A	27	68	180	270
14	154FN8A6439EK	A	10	22	120	180
18	KXNK3767EK	B	10	27	82	120
21	KXNK3767EK	B	10	15	82	100
24-28	KXNK3767EK	A	18	15	47	82

Notes: (1) See Fig.17 for base wiring details.

VACKAR COLPITTS VARIANT – Bipolar Transistor Version

First published in 1945, the Vackar oscillator, like the Clapp, is a Colpitts variant involving a modification to the original tuning arrangements. With the Vackar, a π-section tuned circuit is used to achieve the necessary 180 degree phase reversal in the feedback loop.

A circuit designed around a bipolar transistor is given in Fig.12, where the combination of capacitors C1, C2 and variable capacitor VC1, together with L1 and C4, comprise the π-section tuned circuit. Trimmer capacitor VC2 and C3 form an attenuation network, limiting the amount of feedback applied to the base of TR1. Keeping feedback as low as possible, consistent with reliable starting and oscillation, does much to ensure a good, harmonic-free waveform, minimal loading on the tuned circuit, and reduced drift.

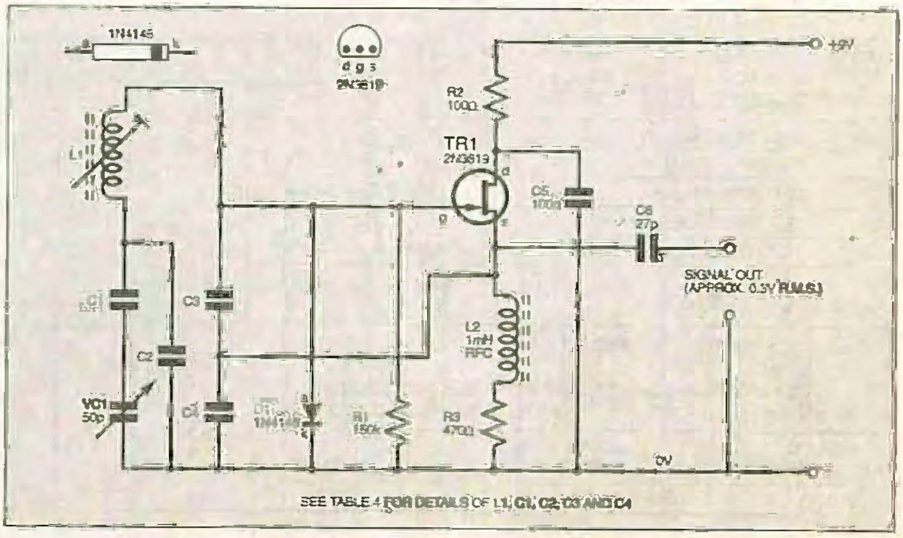


Fig.11. Circuit diagram for a narrow band Clapp oscillator using an f.e.t.

Feedback coupling capacitor VC2 is traditionally a high quality air-spaced trimmer. These components are expensive and no longer so readily available, and constructors may wish to try substituting a modern (and inexpensive) miniature preset capacitor with a film-dielectric. A component of this kind would not be suitable for permanent inclusion in the circuit, but it could be used to determine the minimum amount of capacitance needed to maintain oscillation and then be replaced by a fixed capacitor with an appropriate temperature coefficient.

In the original Vackar oscillator, the relative values of the two capacitors which form the "legs" of the π-section tuned circuit are maintained, as closely as possible, at a 6:1 ratio (the capacitor at the collector (c) end of inductor L1 is the larger of the two). The two capacitors which act as the attenuation network are also kept at approximately this ratio (the capacitor between base or gate and ground is the larger).

Ensuring reliable oscillation and securing the desired frequency coverage with a particular coil and variable capacitor combination tends to shift the relationships away from this ideal. Nevertheless, even compromised versions of the circuit are capable of good frequency stability and of producing a waveform of excellent purity.

The emitter and base biasing components shown in Fig.12 should ensure satisfactory operation with a wide range of bipolar transistors. In this design, the output signal is developed across L2, the radio frequency choke which forms the collector load for TR1.

Tuned circuit and feedback attenuation components are scheduled in Table 5.

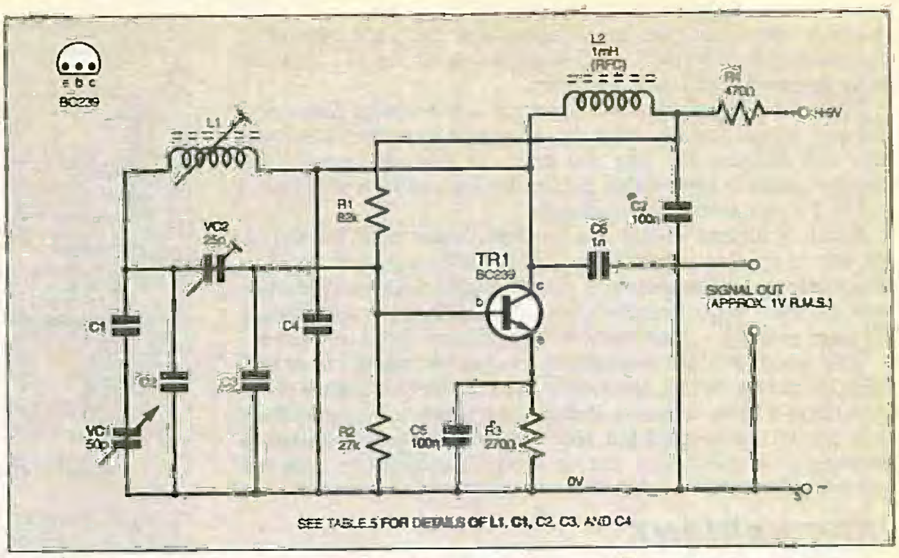


Fig.12. Circuit diagram for a narrow band Vackãr variant of Colpitts oscillator.

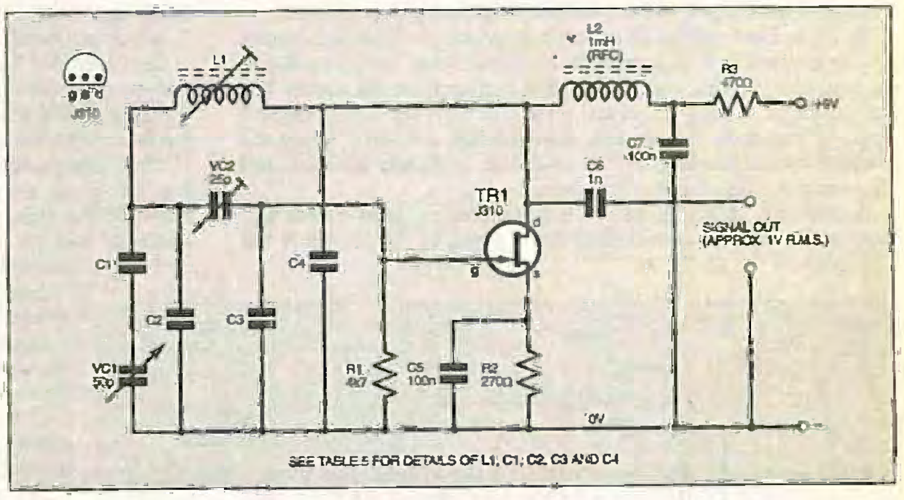


Fig.13. Narrow band Vackar oscillator using an f.e.t.

VACKAR VARIANT – F.E.T. Version

An f.e.t. version of the Vackar oscillator circuit is given in Fig.13. The source bias resistor R2 and its bypass capacitor C5 must be provided when a J310 f.e.t. is used or the circuit will not oscillate. They can be dropped when a 2N3819 is the active device.

The tuned circuit and attenuation network components listed in Table 5 are also suitable for this version.

EXTENDING FREQUENCY COVERAGE – Using Colpitts at V.H.F.

The Colpitts oscillator is often encountered in equipment working at v.h.f. and u.h.f. Indeed, it is almost a standard feature in the front-ends of VHF-FM receivers.

Table 5: Narrow band Vackar oscillators
Tuned circuit components for bipolar and f.e.t. versions.
(See Figs.12 and 13 for circuit diagrams.)

Band MHz	*Toko coil L1*	*Base wiring*	*C1 pF*	*C2 pF*	*C3 pF*	*C4 pF*
1·8	154FN8A6438EK	B	–	82	47	800
3·5	154FN8A6438EK	D	–	82	47	800
7	154FN8A6439EK	A	–	100	47	800
10	154FN8A6439EK	D	33	100	27	470
14	KXNK3767EK	A	47	82	10	470
18	KXNK3767EK	A	47	82	10	220
21	KXNK3767EK	A	47	56	10	220
24-28	KXNK3767EK	A	–	27	10	100

Notes: (1) See Fig.17 for base wiring details.

Table 6: Colpitts oscillator for V.H.F. operation
Tuned circuit components. (See Fig.14 for circuit diagram.)

Frequency range MHz	*Toko coil L1*	*Core material*
30-50	8·5 turn type S18	ferrite
50-85	3·5 turn type S18	no core
85-120	1·5 turn type S18	no core

A basic Colpitts circuit where the component values have been chosen to ensure reliable oscillation between 30MHz and 120MHz or more is shown in Fig.14. It is very similar to the narrow band bipolar circuit given in Fig.6, but here the value of the feedback capacitors, C1 and C2, is lower, the variable tuning arrangements are simpler, and the emitter resistor has been replaced by a radio frequency choke in order to ensure sufficient feedback.

Many v.h.f. versions of the Colpitts circuit are often configured in the parallel, or shunt fed, mode depicted earlier in Fig.4, and the internal capacitances of the transistor can function as the tapped

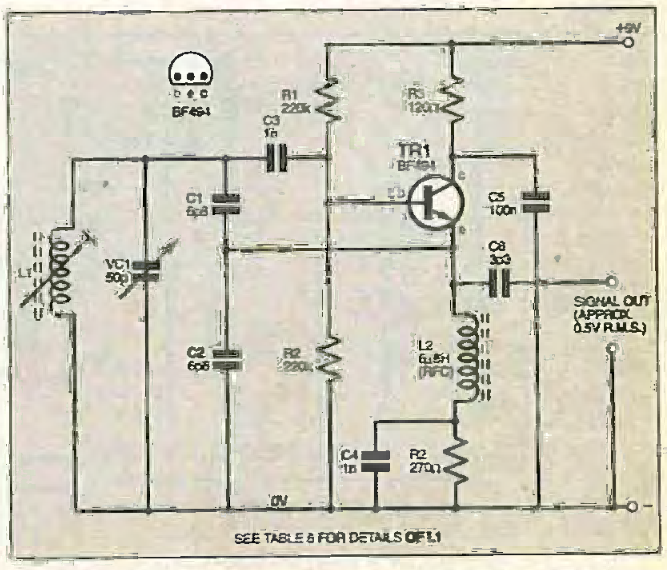


Fig.14. Circuit diagram for a v.h.f. Colpitts oscillator.

feedback capacitor (the base/emitter and the collector/emitter capacitances replace the C1/C2 combination of Fig.14). This can make the circuit difficult to recognise.

When the internal capacitances of the active device function in this way, and particularly when the tuning coil is connected between base and collector (or gate and drain, or grid and anode), this Colpitts variant is often called an ultra-audion oscillator after one of Lee de Forest's earliest valve circuits.

Inductors for this circuit can be hand-wound with 18s.w.g. to 22s.w.g. enamelled copper wire, and be self-supporting. Readers who prefer to use commercially produced coils could use inductors from the Toko range. Suitable types, together with the approximate coverage given by a 50pF variable capacitor, are listed in Table 6.

Stray inductance and capacitance have an increasing effect with rising frequency, and connections must be as short as possible or the upper limit will be curtailed. Frequency stability leaves something to be desired (the simplest f.m. receivers incorporate drift correction measures), but the circuit can be used, in conjunction with the buffer amplifier described earlier, as a simple signal generator.

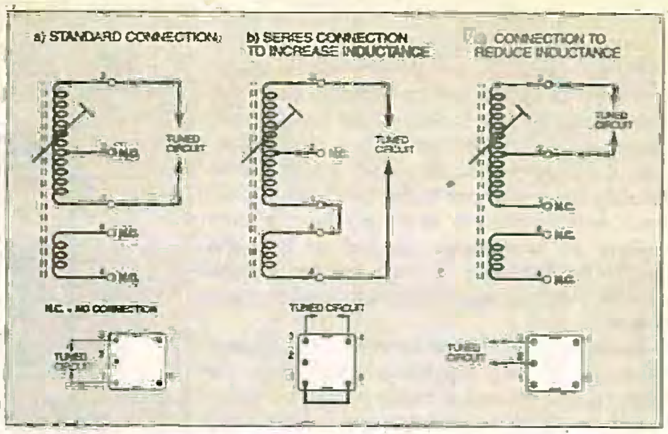


Fig.17. Base connection details for Toko Coils.

DOW VARIANT

Dow's system of electron coupling was described last month in connection with the Hartley oscillator. The technique can also be applied to the Colpitts circuit and its Seiler and Clapp variants.

In 1931, Dow published a circuit in which the cathode, control grid and screen grid of a pentode or tetrode valve are connected in an oscillatory circuit, and the signal is extracted via the anode. The only medium linking the actual oscillator with the signal take-off point is, therefore, the electron flow through the valve, hence the circuit's name. Loading on the oscillator is greatly reduced, and frequency stability thereby improved.

A dual-gate MOSFET can be used to simulate Dow's modification, and a suitable circuit diagram is given in Fig.15 where the technique has been applied to a Colpitts/Seiler oscillator. The tuned circuit arrangements are identical to those already described and depicted in Fig.9. Here, however, a double-gate MOSFET, TR1, has been substituted for the j.f.e.t., and the output is developed across drain load resistor R4. Resistors R2 and R3 fix the potential on gate 2, which is grounded at r.f. by capacitor C6.

The dual-gate MOSFET oscillates more readily than the j.f.e.t., and the values of C3, C4 and C5 can be modified in order to reduce damping on the tuned circuit and improve impedance matching at the feedback injection point. Alternative values are quoted in Table 3.

The isolation afforded by the structure of a solid-state device is not likely to equal that achieved with an evacuated valve. Nevertheless, this circuit is superior to the basic bipolar and f.e.t. versions, and the reduced tuned circuit damping improves frequency stability and makes output level more constant.

Solid-state Dow circuits can display a tendency towards frequency doubling. This problem was not encountered when the modification shown in Fig.15 was made to the basic Colpitts circuit (Fig.7), or to the Seiler and Clapp variants (Fig.9 and Fig.11).

If frequency problems do arise, try reducing the supply voltage. If this fails to effect a cure, change the radio frequency choke to one of different inductance, and/or increase the value of the *Q* spoiling resistor R5.

GORAL VARIANT

The Goral oscillator circuit development involves the insertion of an emitter follower stage into the feedback loop and is shown in Fig.16, where the modification has been made to the Clapp/Colpitts oscillator. It can also be applied, with equal success, to the basic Colpitts circuit, and to the Seiler variant.

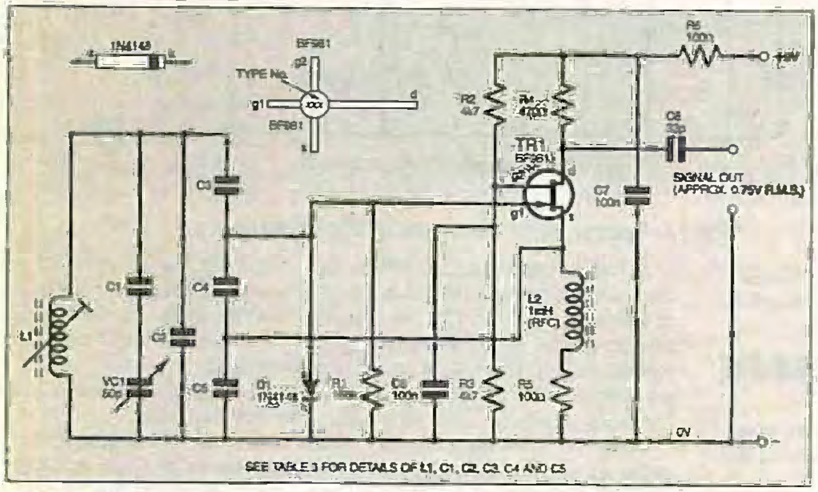
The improved power gain of the two transistor combination makes the circuit much more ready to oscillate, and the values of feedback capacitors, C3 and C4, can be optimised for minimum tuned circuit damping and drift. This process is further assisted by the low impedance of the feedback connection from the emitter (e) of TR2, via potentiometer VR1.

Signal output is developed across collector (c) load resistor R5, and the isolation, although slight, of the take-off point, from the tuned circuit, also helps to reduce damping and drift.

Resistor R4 and capacitor C6 decouple the additional stage, and C7 functions as a d.c. blocking capacitor. Potentiometer VR1, which forms the emitter load for TR2, enables the level of feedback to be set as low as possible. Minimising feedback improves the output waveform (it can be made near-perfect with this arrangement), reduces its harmonic content, and improves the frequency stability.

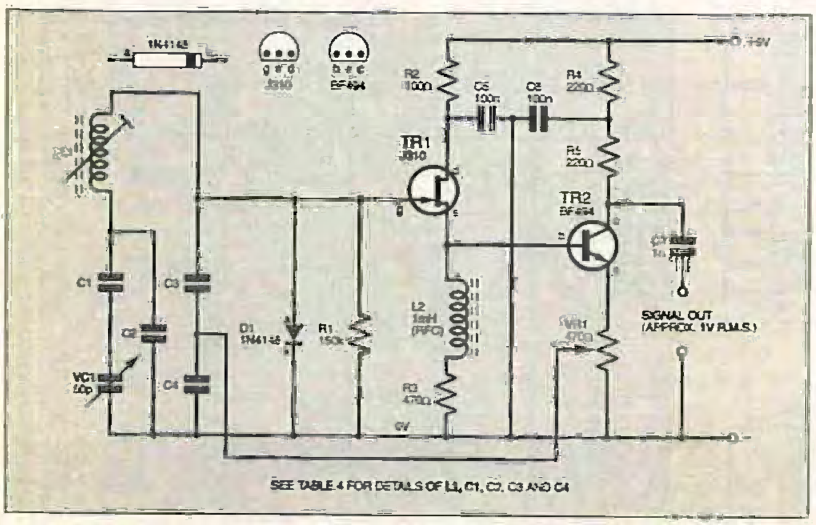
Although a 2N3819 f.e.t. will function in this circuit, the J310 specified enhances performance and is very much to be preferred.

Next month: The construction of a stabilised power supply, simple probes to enable r.f. voltages to be measured with ordinary test meters, and the Armstrong, Butler, Franklin and Meissner oscillators will be described.



SEE TABLE 3 FOR DETAILS OF L1, C1, C2, C3, C4 AND C5

Fig.15. Circuit diagram for a narrow band Dow/Seiler variant of Colpitts oscillator.



SEE TABLE 4 FOR DETAILS OF L1, C1, C2, C3 AND C4

Fig.16. Circuit diagram for a narrow band Goral/Clapp variant of Colpitts oscillator.