ssb oscillators

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Oscillators are not peculiar to single-sideband. They exist in all ham-radio equipment. Nor does single-sideband use oscillators that are any different, except that they should be extremely stable; the sideband relationships (to one another) have to be maintained consistently throughout a transmitter or receiver. Likewise, when the carrier is re-inserted by the bfo, that oscillator must be steady as a rock and right on frequency, or the recovered voice modulation won't sound much like the original.

There is another reason why you should understand oscillators in single-sideband. There are simply more of them. One fairly elaborate ssb receiver has five oscillators. In a typical exciter there may be that many, too, depending on how many frequency translations there are. At the very least, there will be two or three in a transmitter, and the same in a receiver.

The block diagram in **fig. 1** illustrates a transmitter that uses four different oscillators. Another, of similar design, also has an audio oscillator for A2 transmission and for testing. In **fig. 2** you see a receiver design that uses five different oscillators. In a transceiver, you may find some of the oscillators shown in **figs. 1** and **2** are combined, so that the overall transceiver may have only six or seven oscillators—maybe even fewer.

Somehow, oscillators have gained a reputation for being hard to understand. They are not, provided you are aware of certain principles. When you're trying to make one work that won't, you can simplify your trouble-shooting by understanding what makes an oscillator tick.

Fig. 3 shows the four things it takes to make an oscillator. They are: amplification, dc power, feedback, and tuning. The differences among all the many oscillators that exist are in how each of these four jobs is accomplished. You can learn to classify the oscillator type by noticing how each function takes place. For example, a Colpitts oscillator, even though crystal controlled, derives feedback from a capacitive divider network—two capacitors in series, with a feedback tap-off between them. A Pierce crystal oscillator, on the other hand, has the crystal connected between plate (or screen grid) and control grid, providing feedback and tuning simultaneously. The Hartley uses a tapped coil for feedback.

Amplification is handled by a tube or a transistor. The **dc power** is merely to keep the transistor (or tube) working. The method by which these operating voltages are applied is usually the chief consideration whenever you think about or describe an oscillator.

The most important factor, so far as oscillation is concerned, is the **feedback.** Without

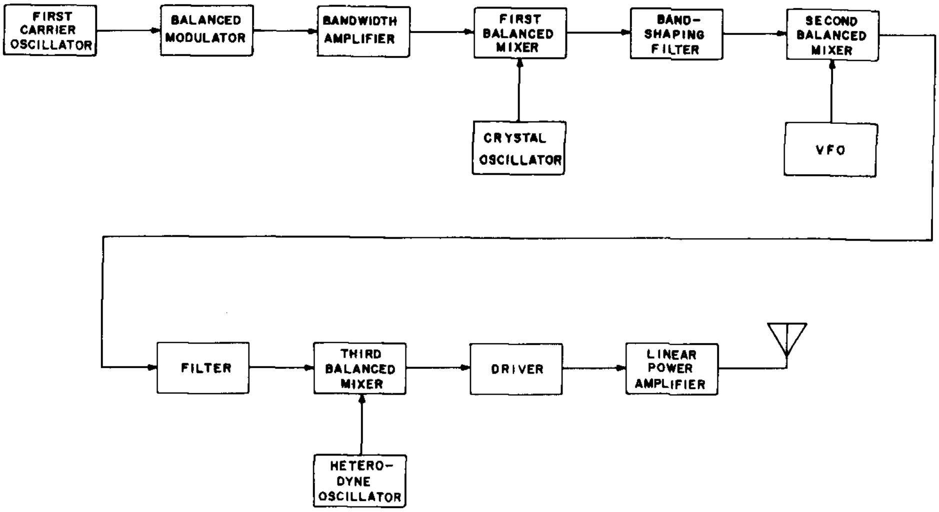


fig. 1. Block diagram of a ssb transmitter with four separate oscillator stages.

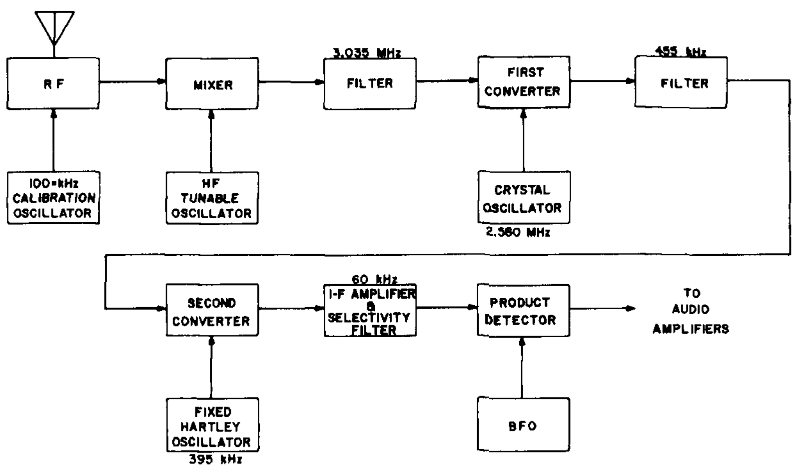
it, the tube and its dc operating voltages would form nothing more than another amplifier. The feedback takes some of the output **signal** voltage of the amplifier stage and feeds it back to the input in such phase that it is *re-amplified*. The signal is thus self-sustaining. You wouldn't want this action in a normal amplifier tube, but it is the essence of oscillator action.

Finally, the matter of **tuning.** It is of little value to have a circuit oscillate unless it is at some frequency you can use. The form of tuning in the oscillator often determines what kind of oscillator it is—what name it goes by. Tuning also affects how efficient or stable the oscillator is.

Keep in mind, then, that you can learn to recognize any oscillator by its characteristics in each of these four factors: the type of amplification, the method of applying dc operating voltages, the way feedback is developed and applied, and how the oscillator is tuned.

Rather than go into all the different possible combinations of these four requisites, it's more practical to examine typical circuits that use them. We'll begin with the most popular oscillator in all of single-sideband equipment—the Colpitts.

fig. 2. This communications receiver uses five different oscillators.



Colpitts—crystal and variable

The uses for this versatile oscillator are many. In different brands, you'll find it in one form or another as a vfo, as the carrier generator in a transmitter, and as a linear master oscillator (LMO) for transceivers. You'll find it both crystal-controlled and variable in frequency.

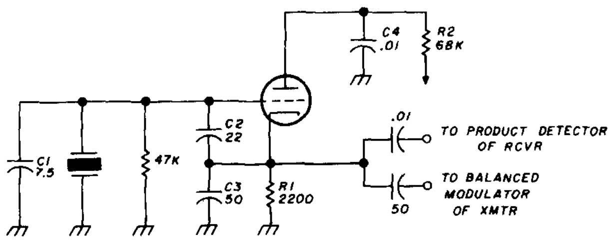
There are several reasons why the Colpitts oscillator is so popular. Mainly, it is stable over a wide range of frequencies. Because a capacitive divider is used, the ratio of feedback voltage remains approximately constant, since the reactance **ratio** between the two capacitors stays the same regardless of frequency change.

Fig. 4 shows the common crystal-controlled version. A triode tube is the amplifying device, although a pentode tube or a transistor could be used just as well. Feedback is developed in capacitive divider C2–C3, and fed to the cathode. The dc connection is typical. Voltage is applied to the plate through R2; the plate is grounded for rf by capacitor C4. If the tube is a pentode, a dc screen supply is provided.

The tube is grid-driven, and output is taken from the cathode. This offers lower output impedance than a plate-output arrangement. In a few models, particularly if a pentode is used, which offers better isolation between input and output circuits, you'll find conventional tuned-tank output arrangements. In the Heathkit linear master oscillator, for example, output is taken from a broadly tuned rf transformer. B+ is fed to the tube through the primary winding of the transformer.

As in all crystal-controlled oscillators, the tuning is accomplished by the crystal itself. The feedback arrangement can easily be designed to force the crystal into operation on an overtone (harmonic), which is desirable in some transmitters and receivers. Sometimes, where cathode bias isn't needed, an rf choke is used in place of the cathode resistor R1. This offers a high impedance to rf, and yet almost no resistance to dc plate current.

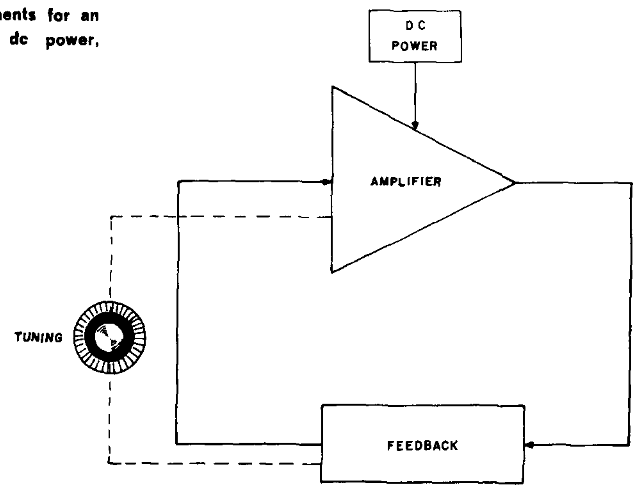
fig. 4. Crystal-controlled Colpitts oscillator.



In some transmitters, the frequency of the crystal is "warped" onto precise frequency by a capacitor—C1 in **fig. 4.** This is done only where frequency is critical, since the "raw" accuracy of a crystal is usually enough for ham work. The capacitor may even be adjustable.

Colpitts oscillators of the tunable variety

fig. 3. The four requirements for an oscillator: amplification, dc power, feedback and tuning.



generally use pentode tubes, which offer better input-output isolation. **Fig. 5** shows one of the most elaborate. Besides the basic tunable Colpitts oscillator, special innovations make this crcuit doubly interesting. The exceptional stability and linear operation of this particular circuit over a range of frequencies makes it particularly attractive for linear master oscillator (LMO) service in transceivers.

The pentode is generally a high-mu type with remote cutoff characteristics—the kind used frequently in television-set i-f strips. The 6CB6 and 6BZ6 are popular for this. In one version, the tube is operated as a tetrode, with positive voltage applied to both screen and suppressor grids.

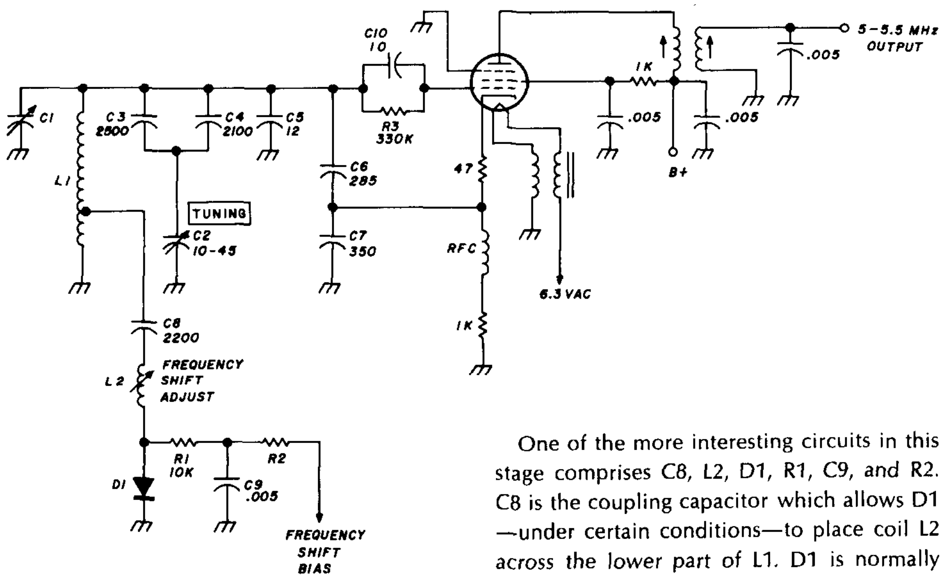
Despite all the elaborate devices for tuning, retuning, coupling, and decoupling, the basic Colpitts configuration is easy to recognize. Capacitors C6 and C7 between grid and ground develop the feedback voltage. The tap to the cathode is the giveaway. An rf choke keeps the cathode well above rf ground, so the feedback can be applied.

An unusual form of grid bias is used in this example, although not in most similar Colpitts circuits. Grid-leak bias is developed in RC network C10–R3.

Capacitor C2 is the main tuning capacitor, and C1 is the trimmer. C3, C4, and C5 are temperature-compensating capacitors; they make sure the oscillator stays at whatever frequency it's set for. To make sure the oscillator does not interact with other rf stages, elaborate decoupling is included. Besides the usual screen-grid and plate-supply decoupling, the filament lead has a bifilar-wound choke. Even when one side of all filaments is grounded, a choke is placed in series with the hot filament lead, with a capacitor to ground.

Output from this version is through a bandpass transformer in the plate circuit. Others use cathode-follower output, and one (in Collins equipment) uses a tapped plate coil and a coupling capacitor.

fig. 5. Variable-frequency oscillator using the Colpitts circuit.



One of the more interesting circuits in this stage comprises C8, L2, D1, R1, C9, and R2. C8 is the coupling capacitor which allows D1 —under certain conditions—to place coil L2 across the lower part of L1. D1 is normally reverse biased and therefore offers a high impedance. When frequency-shift bias is applied at the end of R2, however, the positive voltage makes D1 conduct. While it is conducting, it effectually grounds the lower end of coil L2, thus placing it across L1. This change in inductance shifts the oscillator frequency just enough to switch the receiver or transmitter to the other sideband. Normally, the oscillator runs at a frequency that produces upper-sideband operation. When the frequency-shift voltage is applied, oscillator frequency is lowered and operation switches to the lower sideband.

In practically all versions of the tunable Colpitts oscillator, frequency determination is in the grid circuit. The output is broad-banded. In most cases you'll find the frequency range covered by the oscillator is limited, particularly in ssb equipment. The way output frequencies are developed in single-sideband transmitters (by translation) makes it unnecessary for the carrier-generator oscillator to cover a very wide range.

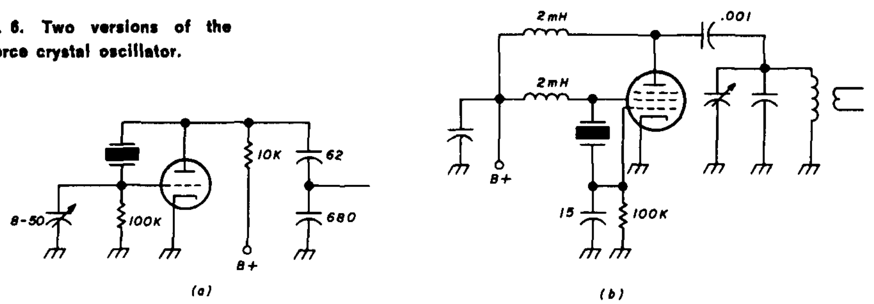
Summarizing, then, you can see that factor No. 1, amplification, is provided by a triode tube in most crystal-controlled Colpitts oscillators and by a pentode tube in most variable-tuned Colpitts circuits. Factor No. 2, dc power, is generally applied to the plate through a resistor or a transformer winding, even in stages that use cathode-follower outputs. Grid bias may be either by a cathode resistor or by grid-leak bias; in a few it is developed by natural grid current in a high grid resistance. Factor No. 3, feedback, is invariably developed in a Colpitts by a capacitive divider from grid to ground, with the cathode tapped in between the two capacitors. The cathode is kept above rf ground by a resistor or an rf choke. Factor No. 4, tuning, is either by a crystal or a tuned circuit from grid to ground. In the latter case, always keep in mind that the feedback capacitors are in parallel with, and form part of, the tuned circuit. The value of any replacement capacitor in the grid circuit of a Colpitts is quite critical.

second most popular—the Pierce

This oscillator is popular because of its simplicity and stability. It uses a triode or a pentode, connected normally, with a crystal providing both feedback and tuning. The crystal is connected from plate to grid with a triode, and from screen grid to control grid with a pentode. Because of the accuracy and resonant efficiency of a crystal, a Pierce oscillator holds its frequency well over wide variations of dc input voltage. It isn't likely to drop out of oscillation unless plate or screen voltage becomes **extremely** low.

You'll find the Pierce in both transmitters and receivers; it's often used as a heterodyne oscillator for raising frequency in transmitters, and as a frequency-conversion oscillator in receivers. The simplest version, a triode, is shown in **fig. 6A.** The only elaboration is a frequency-warping capacitor connected between the grid end of the crystal and ground.

fig. 6. Two versions of the Pierce crystal oscillator.



It permits fine adjustments of the crystal's resonating frequency.

The output of a Pierce oscillator is usually rather strong. This is the reason for the capacitive-divider output network, which gives a ten-to-one reduction in rf voltage fed from this particular oscillator. This version is used in some receivers as a frequency-control oscillator, with output fed to the second mixer, and in at least one transmitter as a heterodyning (frequency-translation) oscillator.

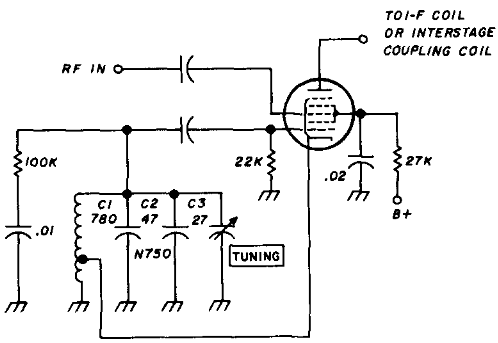
Fig. 6B shows a pentode version of the Pierce oscillator. The dc supply is conventional; some versions use cathode bias while others have the cathode grounded. In either case, the cathode is always kept grounded for rf.

Output is from the plate. Since the tube is a pentode, the plate is isolated from the frequency-control network. The output arrangement shown is a little off-beat; it is called impedance coupling. The choke from plate to B+ is the untuned plate load. A coupling capacitor feeds the rf voltage to the tuned circuit, part of a transformer. Coupling to the next stage is inductive. Another version uses simple RC coupling—a resistor supplies dc plate voltage and acts as output load, with a capacitor coupling the rf signal to the next stage.

Both plate and screen in this stage are fed through rf chokes, which offer some load for rf developed in the plate-current stream of the tube. The screen grid may sometimes have a capacitor tying it to ground, but is very seldom completely grounded for rf; if it were, feedback couldn't take place from the screen grid to the control grid through the crystal. In the version shown, the screen is not bypassed at all; only a small stabilizing capacitor is connected between the control grid and ground.

There is one version that operates as a cathode follower, with the output tuned circuit in the cathode circuit. Output arrangements have no bearing on the "type" of oscillator. The Pierce gets its identification from the fact that it is controlled by a crystal between the plate and grid. In pentode versions, the screen grid is operating as a plate, not as a screen grid in the usual sense. (That's why it's not thoroughly bypassed for rf.)

fig. 7. Although this Hartley oscillator is part of a pentagrid converter, the same circuit may be used with an electron-coupled oscillator.



the tapped-coil Hartley

This oscillator is distinctly recognizable because the tube's cathode always goes to ground through a tap on a coil (see **fig.** 7). The other end of the coil almost invariably is connected through a capacitor to the grid. The Hartley oscillator is uncomplicated and stable and is used extensively for tunable applications. There is a crystal-controlled version, but it is rarely used in modern ssb equipment.

The version in **fig. 7** is part of a pentagrid converter; the same circuit can be used as an electron-coupled oscillator. The Hartley is found in both receivers and transmitters. In one transmitter, it is the first carrier generator, operating at 60 kHz; in another, the second conversion oscillator, operating at 395 kHz.

The oscillator plate in the tube of **fig. 7** is the double grid, grids 2 and 4. This oscillator plate doesn't have to be left ungrounded for rf, since the control grid modulates the entire electron stream. The rf from the previous stages—from a station or a transmitter stage—is fed in at grid 3. Grid 4 (part of the double grid) acts as a shield for the rf input grid, very much like the screen grid in an ordinary pentode.

The tapped coil that sets up the feedback is always a part of the tuning circuit. The tank capacitors include tuning capacitor C3, temperature-compensating capacitor C2, and main frequency-determining capacitor C1. All affect frequency. In some circuits, C1 may be a trimmer, and occasionally the temperature-compensating capacitor is omitted.

the rest of them

Another simple oscillator used in single-sideband equipment is the tuned-plate-crystal-grid oscillator, sometimes called simply **tpxg.** This one commonly appears as the first receiver oscillator in double- or triple-conversion receivers—named, in that application, the heterodyne oscillator.

Triodes are always used, because tpxg oscillators depend on interelectrode capacitance for feedback. The screen grid in a pentode would shield out this Miller effect and keep the tube from oscillating. The crystal is connected from grid to ground. A frequency-warping capacitor or coil can be used with the crystal, although it seldom is.

The dc voltages for the tube are conventional. The cathode may be either grounded or above ground (for cathode bias). In most tpxg oscillators, bias is in the form of grid-leak or "contact" bias across a fairly large-value grid resistor.

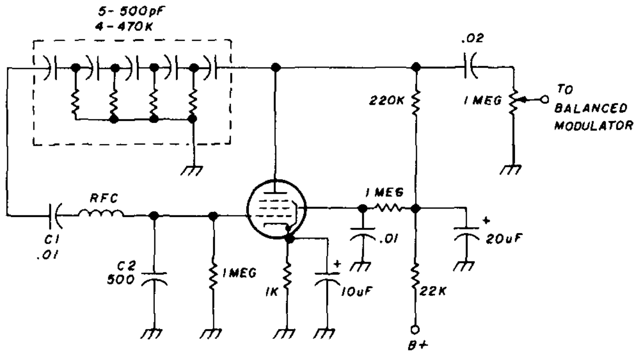
Output circuits vary just as much as with any other oscillator. Sometimes a broadband coil is used as the load, with a small capacitor coupling the oscillator output. Occasionally, inductive coupling is used, again with a broadband transformer.

This kind of oscillator is especially suitable for overtone operation—running the crystal at (usually) three times its normal frequency. This kind of operation may be necessary in the front end of a ham receiver, and that's why this circuit is not at all uncommon as the up-front heterodyne oscillator. Sometimes, particularly when cathode bias is used, the crystal is separated from the grid by a blocking capacitor. If grid-leak bias is used, there is no need for this.

Occasionally, there is reason to use a tone in a single-sideband transmitter—for testing or for A2 code transmission. **Fig. 8** shows an 800-Hz phase-shift oscillator. There are any number of other audio oscillators that can be used, but this one is exceptionally stable and its frequency is independent of output load. This latter characteristic makes it excellent for tone keying.

Feedback is via a printed component circuit (PEC) consisting of five capacitors and four resistors. As they are arranged, they give a phase shift that is almost adequate to sustain oscillation at 800 Hz. Capacitors C1 and C2 and the rf choke complete the job. The result is extremely stable audio oscillation. The output is RC-coupled to a buffer amplifier via a volume control that determines how much modulation will be developed.

fig. 8. An 800-Hz audio phase-shift oscillator.



what to look for next month

That's the story of oscillators in single-sideband equipment. There are other circuits just as interesting, and often more difficult to understand. We plan to cover most of them in this series on single-sideband.

The method of single-sideband generation in most of today's ssb transmitters is the **filter** method. A balanced modulator, which has already been explained, forms a double-sideband suppressed-carrier signal which is then pushed through a filter that removes one or the other of the sidebands. However, there's another way, called the **phase-shift** method.

Although the phase-shift method is almost never used in commercial ham gear, many readers have wondered about the principles behind it. It is sometimes less expensive than the filter method—particularly at high frequencies, because there is no need for stages of frequency translation. If the suppression ratios were improved, and the circuits made easier to adjust, phase-shift ssb might catch on. Next month, we'll explain how the method works, and give some pointers on making adjustments to this type of ssb generator.

ham radio