WHAT ARE ALL THOSE EXTRA COMPONENTS FOR?

They have practical reasons for being in the circuit.

BY JIM HUFFMAN

STUDENTS of electronics are often confused by how much more complex a practical circuit often turns out to be when it is compared to the classical circuit from which it was derived. Under such circumstances, the most often asked question is: "What are all those extra components for?"

Let us first assume that, in practical manufacturer circuits, every component used is there for very good reasons, specifically to obtain proper operation from the circuit. It then remains only to understand the function of each component and how it aids in the operation of the circuit.

If proper understanding of classical and typical circuits is achieved, little difficulty should be encountered in analyzing the operation of practical circuits. Knowing the function and/or mode of operation of the circuit can provide the key to why a particular component or components are used in any given circuit.

Classical vs. Practical. In Fig. 1 is shown a typical common-emitter amplifier stage. The thing to remember with "classical" circuits used in textbook theory—and this circuit is such an example—is that an absolute minimum of components is ever shown.

Transistor *Q1* serves as a current amplifier. A small current applied to the base initiates and controls a much larger current flow in the collector circuit. The current applied through biasing resistor *R1* to the base of *Q1* is supplied by *Eb*. In the absence of an input signal at *C1*, the bias current is a function of the voltage level of *Eb* and the resistance value of *R1*.

Capacitors *C1* and *C2* couple the signal into and out of the circuit, respectively, while blocking dc to prevent upset of the bias on this stage and the next. Resistor *R2* is the collector load that allows the ouput signal to be developed between the collector of *Q1* and ground.

While the functions of the components in Fig. 1 are easy to see, a different frame of reference must be used when you are

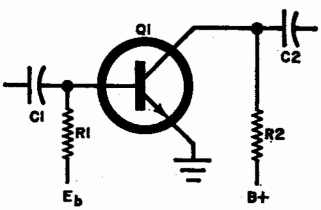

Fig. 1. Classical common-emitter circuit with basic, essential components.

confronted with the practical circuit in Fig. 2. The key here is that this is an *r-f* amplifier stage of a type commonly used in radio receivers.

Once this is known, it is fairly easy to explain the existence of *L1*, *T1*, and *T2* as having something to do with providing proper operation at radio frequencies. But what about the extra capacitors and resistors?

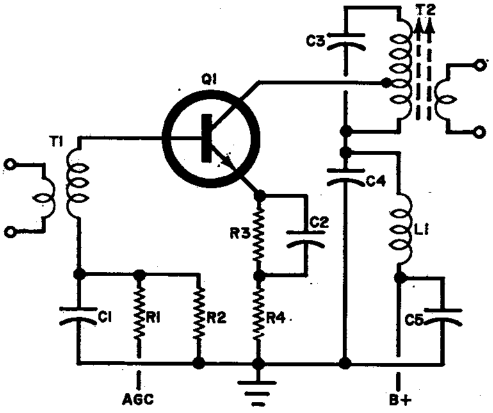

Fig. 2. Practical r-f amplifier has much more complexity when compared to the circuit from which it was derived.

By using some logic, you can see that the *R1*/*R2* combination performs essentially the same function as that performed by *R1* in Fig. 1. Note also that *R2* is grounded at one end and that *R1* is a special input for an automatic gain control (agc) signal. The agc is a voltage, the value of which depends on the level of the input signal at *T1*. When the agc voltage increases, bias on *Q1* increases and stage gain decreases. Consequently, the agc voltage is similar to biasing voltage *Eb* in the classical circuit.

Capacitor *C1* in Fig. 2 functions in a manner similar to *C1* in Fig. 1. That is, it blocks dc bias voltages. Also, it places one side of *T1*'s secondary at *r-f* ground, allowing the full output from the transformer to be impressed on the base of *Q1*. If *C1* were not in the Fig. 2 circuit, *R1* and *R2* would reduce signal level and diminish stage gain.

Although it is more complex, the output section of Fig. 2 corresponds in performance to the two-component output section of Fig. 1. Transformer *T2* provides dc isolation and matches the output impedance of *Q1* to the input impedance of the next stage. So, the primary of *T2* functions as the collector load for *Q1*. The tap on the primary of *T2* is for matching the low output impedance of *Q1* to the higher impedance of the transformer's primary. This is done so that a practical value for *C3* (which forms a tuned circuit with the primary of *T2*) can be selected to provide a reasonable Q for the tuned circuit.

Capacitor *C4* is used to connect the lower end of *T2's* primary to r-f ground and block dc. Coil *L1* has a large reactance to r-f and "chokes" any r-f that might get past *C4* into the power supply. A large value of capacitance for *C5* insures against variations in the output signal caused by agc action. These are low-frequency variations which, if they got into sensitive stages via the power supply leads, can really mess up the sound from the receiver.

There is one more circuit to call attention to—the emitter circuit of *Q1*. Here we see components that do not even exist in the classical circuit in which the emitter goes directly to ground. The differences in bias arrangements account for the extra components in the practical circuit. The classical circuit employs a separate biasing supply (*Eb*), but our practical circuit is self-biased. Resistors *R3* and *R4* should be treated as a single emitter resistor. Capacitor *C2* is there to by-pass r-f around *R3* so that it does not affect the circuit during biasing.

Resistor *R4* carries both dc and r-f. This is done to introduce negative feedback to the r-f signal. Some of the current flowing between the emitter and collector of *Q1* causes a voltage to be dropped across *R4*. This drop is wasted; so the presence of *R4* in the circuit decreases stage gain, a form of negative feedback. The obvious reason

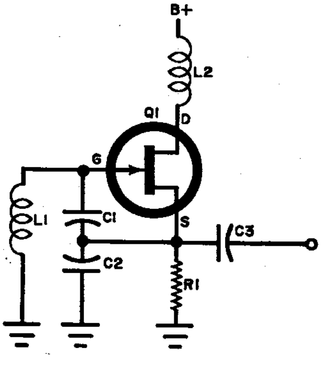

Fig. 3. Typical textbook VFO circuit has little practical use as it stands.

for *R4* being where it is, then, is to provide the circuit with a measure of overload protection. Enough gain can be obtained from later stages to cancel the losses introduced by *R4*.

Rules of the Thumb. From the foregoing, we can establish some "rules of the thumb" that can help us in analyzing any circuit and clear up doubts about extra components. The first of these is that coupling capacitors are usually in series with the signal path. Also, in connection with capacitors, bypass capacitors route signals around a component or circuit. Next, coils without parallel capacitors are usually just chokes. Transformers represent output loads and perform the dc blocking function of capacitors. There are other rules you can add to this list as you become more proficient in analyzing circuits.

Let us take one more example of classical-versus-practical circuits. In Fig. 3, you see the classical representation of a FET variable-frequency oscillator (VFO). It is fairly easy to understand the function of each component in this circuit. The drain and gate signals of FET *Q1* are 180° out of phase with each other. Coil *L1* is center-tapped by the *C1/C2* arrangement. Since *L1* is tapped, the signal from the drain of *Q1* undergoes another inversion in the coil, and actual feedback to the gate of *Q1* is in-phase with the output signal. The in-phase condition causes the output to reinforce the input and oscillation occurs at a frequency determined by the values of *C1, C2,* and *L1.*

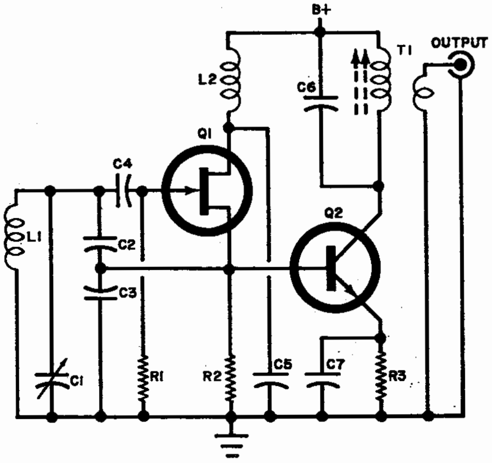

Fig. 4. Practical VFO uses an extra stage (Q2) for buffering and extra components to give stability.

Coil *L2* serves as the drain load for *Q1* and its high reactance prevents the output signal from the FET from feeding into the power supply. Resistor *R1* provides source bias. Capacitor *C3* is a signal coupler that passes the output signal into the next stage while blocking dc.

The practical VFO circuit shown in Fig. 4 bears little resemblance to the classical circuit. Probably the most confusing part of this circuit is the addition of an extra transistor stage. Obviously, to obtain good results, the Fig. 3 circuit needs some isolation; not to mention extra drive. For this reason, the buffer stage (*Q2* and its associated components) were added to the circuit in Fig. 4.

Now, let us analyze the rest of the circuit as we did in the previous example. Variable capacitor *C1* provides a means for accurately adjusting the output frequency of the oscillator. Resistor *R1* connects the gate to the source of *Q1*, providing both bias and a means for developing a signal voltage. Capacitor *C4* and resistor *R1* keep dc out of the tuned circuit, thus aiding in operational stability.

Capacitor *C5* serves as a bypass that routes the signal on the drain of *Q1* to ground. Note that *Q1* is set up in a common-drain configuration. The gate is used for an input and the source for an output. Thinking of the oscillator in this light, you can see that the ground connection is the same as the connection in the classical circuit that led from the drain to the gate. Alternatively, *C5* can be viewed as a coupler in series with the signal flow.

One more point on the circuit. There is no coupling capacitor between the source of *Q1* and the base of *Q2*. In this case, *Q2* obtains bias from *Q1* and *R2* with both components serving as the bias resistance. Hence *Q1* and *R1* in Fig. 4 correspond to *R1* and *R2* in Fig. 2.

As we have demonstrated, classical or typical circuits are not always—and, in fact, rarely are—the same as the practical working circuits. But if you work on the assumption that every extra component used is there to aid in circuit performance in some way and you apply a few rules of thumb, you will be able to interpret a circuit's diagram quickly and be better prepared when it comes to troubleshooting and repair. ◆