• *Beginner's Bench*

The Principles and Building of SSB Gear

Part 2: This month, we'll examine the speech amplifier, balanced modulator, filter, IF amplifier and carrier generator of an SSB generator. Practical circuits are offered for the amateur builder.

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How many times have you heard SSB signals that contained distortion, RF-energy-caused squeals or hum? Chances are that you could tune across one of the phone bands at this moment and find several "dirty" signals. Generally, when a clean SSB signal does not appear at the transmitter output the cause is at the operator end of the line. Most commercial rigs are capable of delivering quality SSB signals, but too many operators feel compelled to use excessive mic-gain levels—they may shout into the microphone or operate improperly adjusted speech processors. In other instances, the transmitter audio section generates howls and squawks because poor transmitter grounding permits RF energy to enter the speech-amplifier stages. There are situations, however, in which poor circuit design can lead to these maladies. Too many audio "highs" or "lows" can also be attributed to faulty design, assuming the mic is capable of passing the desired speech frequencies. Let's consider a practical speech amplifier.

An IC Speech Channel

Good circuits can be developed using transistors, ICs or tubes as speech amplifiers. The choice is up to the designer, and the available parts in our personal project inventory may dictate the design we adopt. Our circuit will use an op-amp (operational amplifier) IC. It provides high gain, requires few components and is inexpensive. A practical circuit is shown in Fig. 1.

Last month, we acknowledged a need for some type of RF filtering at the mic-input terminal of the speech stage. RFC1 and the two 560-pF bypass capacitors in Fig. 1 provide filtering for unwanted RF energy that can enter the transmitter by way of the mic cable. This brute-force low-pass filter is effective through 30 MHz, and helps to prevent "unworldly screeching" during the transmit period.

Care must be taken to minimize the passage of 60-Hz hum through the speech amplifier. The values chosen for the coupling capacitors will restrict all frequencies below approximately 200 Hz. This blocks out the 60-Hz energy that could be picked up on the mic cord.

We need to match the characteristic impedance of the mic to the input of U1 if we are to preserve the frequency response and ensure maximum transfer of power from the mic. R1 has been added to make the input of U1 look like low impedance for the 500-ohm mics we have today. To use a high-impedance mic, such as a D-104, we may remove R1 from the circuit. The amplifier may be used for either type of mic.

It is important to keep low-frequency noise to a minimum when dealing with the first stage of an audio amplifier. Op amps are characteristically noisier than FETs or low-noise bipolar transistors. This variety of inherent noise (caused by current flow in the input section of the op amp) is known as popcorn noise among engineers.

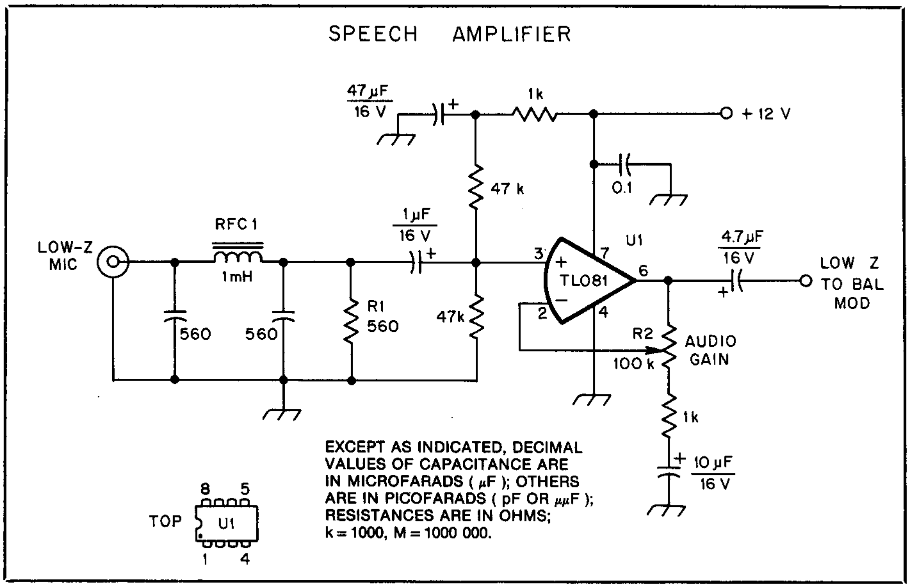


Fig. 1—Schematic diagram of a practical speech amplifier. Capacitors are disc ceramic or mylar, except those with polarity marked, which are electrolytic or tantalum. Fixed-value resistors are ¼-W carbon composition. R1 is used when a low-impedance mic is employed. R2 is a linear-taper, carbon-composition control suitable for panel mounting. RFC1 is a miniature RF choke (value not critical within 20%). Op amp U1 can be obtained at a Radio Shack store.

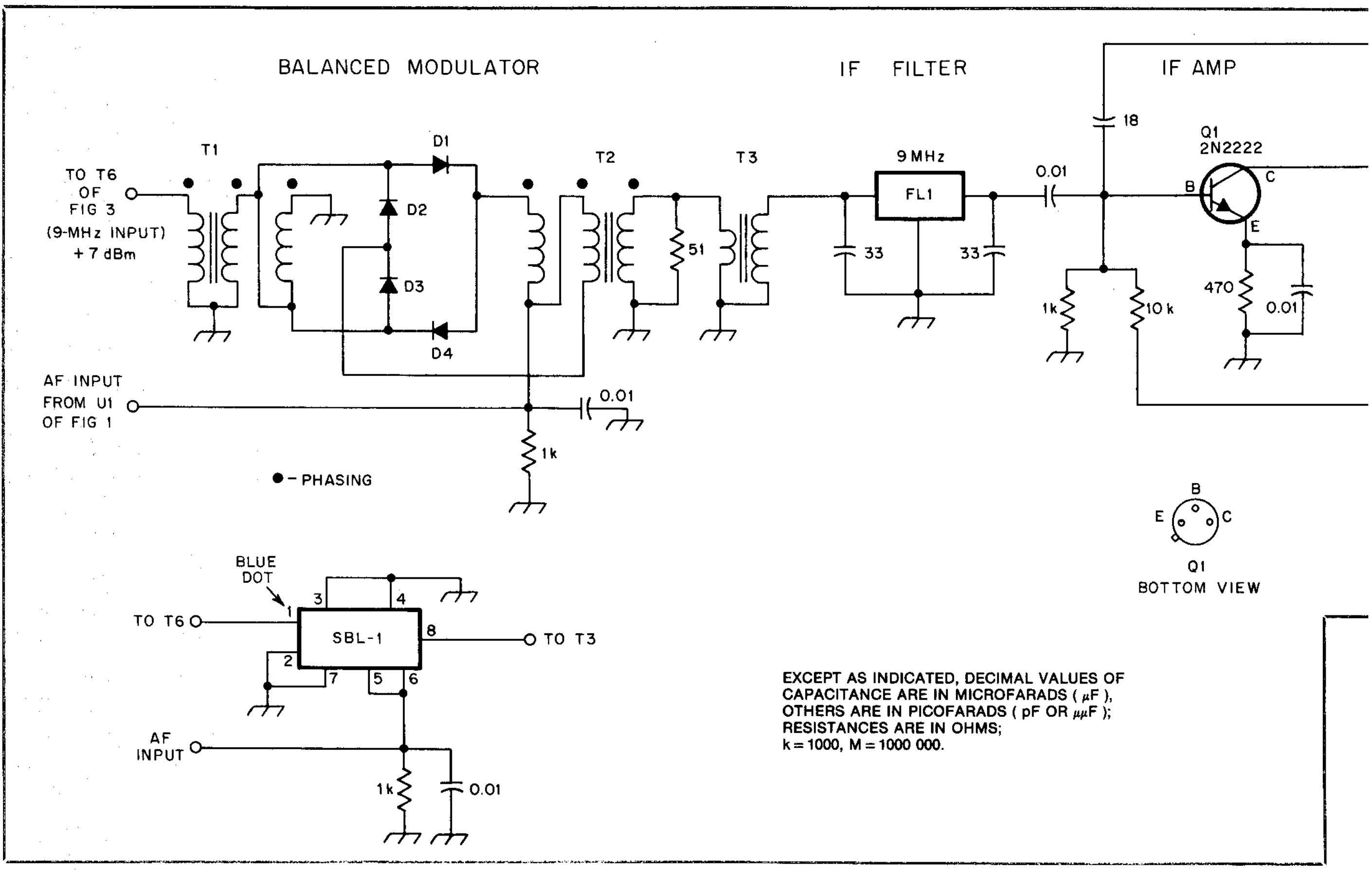


Fig. 2—Circuit diagram of a practical balanced modulator, IF filter and post-filter IF amplifier. The lower inset drawing shows the terminal connections for a commercial DBM module that may be used in place of D1-D4, T1 and T2 (see note 2). Fixed-value capacitors are disc ceramic. Resistors are ¼-W carbon composition, 10% tolerance or better.

C1—Miniature trimmer, 100 pF maximum.
D1-D4, incl.—Matched set of 1N914 or equiv. silicon small-signal diodes (see text).
FL1—9-MHz crystal filter, 2.4-kHz bandwidth (see note 2).
T1, T2—Trifilar broadband transformer. Use 15 turns of no. 30 enam. wire on an Amidon Assoc. FT-37-43 toroid core. Observe phasing of windings, as indicated by dots.
T3—Broadband toroidal transformer, 3:1 turns ratio. Secondary has 15 turns of no. 30 enam. wire on a FT-37-43 ferrite core. Primary contains 5 turns of no. 30 wire.
T4—Narrow-band tuned transformer. Primary is 3.8 μH. Use 28 turns of no. 26 enam. wire on an Amidon Assoc. T50-2 powdered-iron toroid core. Secondary winding has 8 turns of no. 26 wire (see text).

The low-cost family of op amps (741 group) are especially noisy. Such popcorn, if allowed to prevail, would be amplified and passed through the SSB generator, thereby appearing in the RF output signal. The TL081 op amp is a low-noise type that uses FETs at the input.

The larger the value of the input and output coupling capacitors in Fig. 1 (1 μF and 4.7 μF), the more pronounced the low-frequency response of the amplifier. Excessive highs can be rolled off by adding small-value bypass capacitors (0.01 to 0.47 μF) from pins 3 and 6 of U1 to ground. You can, through experimentation, shape your speech-amplifier response to suit your mic and voice characteristics. Maximum gain from U1 of Fig. 1 is roughly 40 dB.

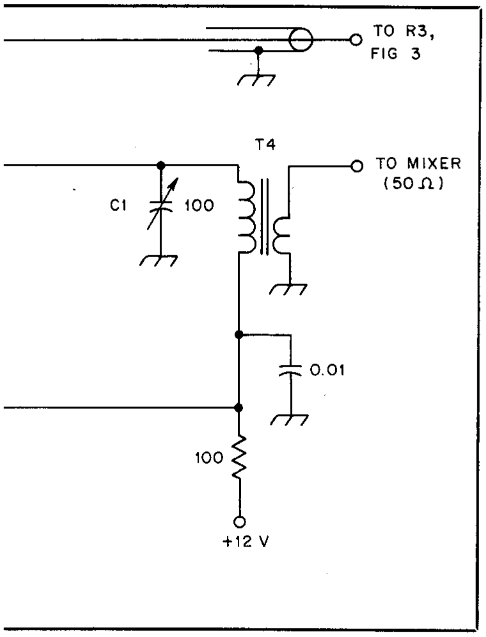
Modulator and Filter Section

We have chosen a diode-ring balanced modulator for our practical SSB generator. We could have used an IC balanced modulator, or combined bipolar or field-effect transistors in a balanced circuit. The diode-ring configuration is a *passive* circuit (no operating voltages required), whereas the other devices form *active* circuits. The active devices provide a signal increase called *conversion gain*. The diode modulator has a loss of approximately 8 dB. This is called *conversion loss*. The circuit of Fig. 2 illustrates the balanced modulator with its two broadband transformers and four matched diodes. D1 through D4, inclusive, can be generic style 1N914 high-speed silicon diodes. If they are used, a matched set should be selected from a group of diodes by measuring the forward and back resistances with an ohmmeter. The forward resistance is the most important when you are seeking a matched set. Typically, it will be on the order of 8-10 ohms. Back resistances are generally 1 megohm or greater. The more carefully we match the diodes, the greater the carrier null (desirable). If you have access to a matched set of hot-carrier diodes, use them. They offer somewhat better performance in this circuit than is available with small-signal silicon diodes.

We need not build our own balanced modulator if we are willing to purchase a ready-made doubly balanced mixer (DBM) module. The Mini-Circuits SBL-1 is a low-cost unit enclosed in a metal case and is suitable for PC-board mounting.[1] If you construct your own balanced modulator, try to follow a symmetrical layout while keeping all leads as short as possible. A DIP header makes a fine plug-in foundation for a homemade balanced modulator.

The diode modulator was selected because of its excellent balancing traits. Also, it is more resistant to unwanted IMD (intermodulation distortion products) than is an active balanced modulator. The Motorola MC1496 balanced-modulator chip is good for active circuits, provided the input-signal levels are kept low enough to prevent IMD problems. The diodes,

[1] Notes appear on page 30.



however, permit substantially more leeway in applied signal levels.

Coupling into and out of the balanced modulator of Fig. 2 is accomplished by means of trifilar (three windings) broadband transformers. They are easy to wind and do not cost very much. Small ferrite toroid cores are used for T1 and T2. The terminal impedances of the modulator (inclusive of T1 and T2) are approximately 50 ohms.

Filter Details

If you reviewed the *QST* paper by W7ZOI in May 1982 *QST*, pp. 21-27, you learned how to build your own ladder filter for a small investment. If you are not interested in developing a homemade filter, you may purchase a 9-MHz SSB filter for FL1 of Fig. 2.[2] The unit specified in Fig. 2 has input and output impedances of 500 ohms. T3 matches the 50-ohm modulator impedance to the 500-ohm impedance of FL1. A 51-ohm resistor is used between T2 and T3 to force a more precise impedance transformation. It also provides a termination for the balanced modulator: This tends to reduce IMD.

The input and output ports of FL1 need to be tuned to 9 MHz. The 33-pF capacitors at each end of FL1 serve this purpose. Proper tuning and filter termination ensure minimum ripple (see Part 1). The characteristic input impedance of Q1, plus the base-bias resistors, ensure a 500-ohm load for the filter output.

IF Amplifier

The combined signal loss through the balanced modulator and FL1 is approximately 13 dB. We need to recover this lost signal by adding an IF amplifier (Q1) after FL1. Practically, we will gain a few dB in the process of amplifying the output of FL1: Stage gain for Q1 should be on the order of 15 to 18 dB if all is as it should be. The IF amplifier operates in class A, which makes it a linear "gain multiplier." A tuned output transformer, T4, helps to "launder" the signal, and it provides an impedance match between Q1 and the mixer stage that will be described in the next installment.

Note the shielded RF input line above Q1. This is used to route some of the carrier-generator energy *around* FL1 and the balanced modulator if we wish to operate CW or AM with our SSB generator. We could, on the other hand, disturb the balance of the circuit by applying a dc potential between D1 and D4, thereby causing a carrier to appear at the transmitter output. The method indicated in Fig. 2 is perhaps a bit simpler, all things considered.

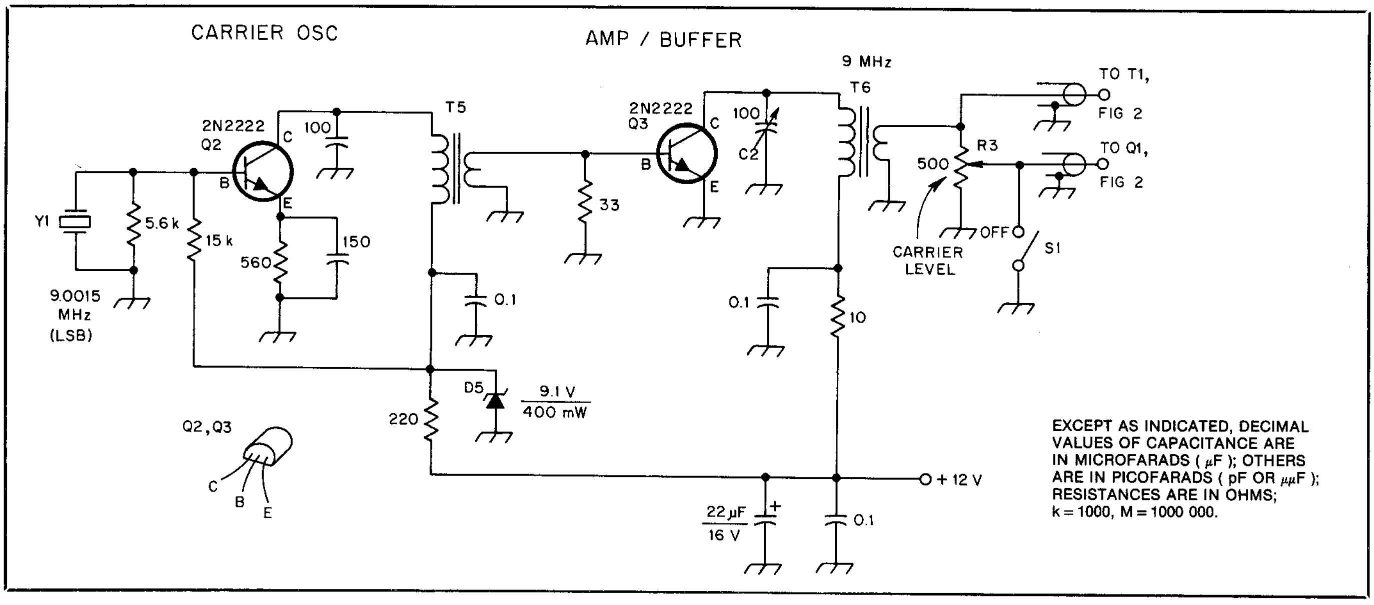
Carrier Generator

To produce an SSB signal, we must generate a 9-MHz carrier, then get rid of it in the balanced modulator. As ridiculous as this may seem, it is necessary! Fig. 3 shows the circuit we have adopted for our project.

Q2 is the oscillator. A 9.0015-MHz crystal (available from the supplier in note 2) is needed for lower-sideband (LSB) operation. Two crystals and a selector switch may be employed if both USB and LSB are desired: An 8.9985-MHz crystal is necessary for USB operation.

As we learned in Part 1, the frequency of Y1 should fall about 20 dB below the peak (center frequency) response of the filter (FL1). In order to "rubber" the carrier-oscillator crystal for precise placement of the carrier frequency, we may insert a 60-pF trimmer capacitor between the lower end of Y1 and ground. If this does not provide natural voice quality, try placing the trimmer in parallel with Y1, then adjust the capacitor while monitoring your SSB signal.

D5 provides a regulated operating voltage for Q2. This will aid stability, particularly if mobile operation is planned. A



EXCEPT AS INDICATED, DECIMAL VALUES OF CAPACITANCE ARE IN MICROFARADS (µF); OTHERS ARE IN PICOFARADS (pF OR µµF); RESISTANCES ARE IN OHMS; k = 1000, M = 1000 000.

Fig. 3—Schematic diagram of a practical carrier generator. Fixed-value capacitors are disc ceramic. Resistors, other than R3, are ¼-W carbon composition.

C2—Miniature trimmer, 100 pF maximum capacitance.
D5—Zener diode, 9.1 V at 400 mW.
R3—Linear-taper carbon-composition control, panel mount.
S1—Part of R3 assembly, SPST.
T5—Narrowband RF transformer, 3.0-µH primary. Use 24 turns of no. 26 enam. wire on a T50-2 toroid core. Secondary has 5 turns of no. 26 wire.
T6—Same as T4 of Fig. 2.
Y1—See text and note 2.

fixed-tuned output transformer, T5, is used to couple the Q2 signal to the input of buffer-amplifier Q3. The primary turns of T5 may be spread or compressed to tune the Q2 collector for peak output.

We must amplify the oscillator output to a proper level for the balanced modulator of Fig. 2. The correct injection level is +7 dBm. The term *dBm* refers to the power level, as referenced to 1 mW. Hence, +7 dBm is roughly 6 mW, or 0.006 W. This being the case, and with the balanced modulator presenting a 50-ohm load for Q3, the RMS voltage across the T6 secondary winding (when terminated in 50 ohms) should be close to 0.55, as observed with a scope or RF probe and VTVM. The P-P voltage reading on a scope would be 1.55. The number of secondary turns on T6 may be adjusted to provide the desired injection level.

R3 of Fig. 3 is a carrier-injection level control for CW work or transmitter tuning purposes. S1 is a part of R3. It shorts the output line from R3 during SSB operation. This discourages unwanted leakage of the 9-MHz energy to the output side of FL1 of Fig. 2. Miniature shielded cable (RG-174) should be used for both output lines from R3. This will help prevent stray-signal leakage that could cause an excessive carrier level during SSB operation. The shield braids of these lines must be grounded at each end of the cables.

C2 is adjusted for peak output from the class-C amplifier, Q3. The 33-ohm resistor from the base of Q3 to ground is used to stabilize the output amplifier. Without it, self-oscillation may occur.

Parting Comments

If you enjoy laying out your own PC boards, there is no reason you can't combine the circuits of Figs. 1 and 2 in a common module. The carrier generator of Fig. 3 should be on a separate PC board, and it would be wise to enclose this assembly in a small shield box, perhaps a homemade one fashioned from PC-board stock. The shielding will discourage 9-MHz energy from wandering about in other parts of the SSB-generator circuit. Circuit boards, parts or a complete kit for the 75-meter SSB transmitter will be available by mail from A & A Engineering at the conclusion of this series.[3] Some of you may wish to delay your workshop project until that time.

Next month, we will discuss operation and practical circuits for the mixer and subsequent amplifier stages. CW keying methods will be treated later on. Meanwhile, why not breadboard these circuits and discover what your 9-MHz SSB signal sounds like? PC-board artwork and a parts-placement guide for these circuits will be presented later in this series.

Notes

[1] Mini-Circuits, P.O. Box 166, Brooklyn, NY 11235, tel. 718-934-4500. Minimum order is 10 units for the SBL-1, but the SBL-1X can be substituted and is available in single-lot quantity.

[2] Spectrum International, Inc., P.O. Box 1084, Concord, MA 01742, tel. 617-263-2145. Filter model XF-9A (2.4 kHz) suggested.

[3] 7970 Orchid Dr., Buena Park, CA 90620, tel. 714-521-4160.

Feedback

☐ The carrier-generator for the SSB series by W1FB Fig 3 (Oct 1985 *QST,* p 29) may require a series trimmer for netting the crystal, depending on the crystal traits. A wide netting range can be had by placing a 4.7-μH miniature RF choke between the series trimmer and ground. Also, should oscillation be weak when using series crystal tuning, make sure Q2 has ample gain. A 2N2222A is better than a 2N2222 or PN2222 device.