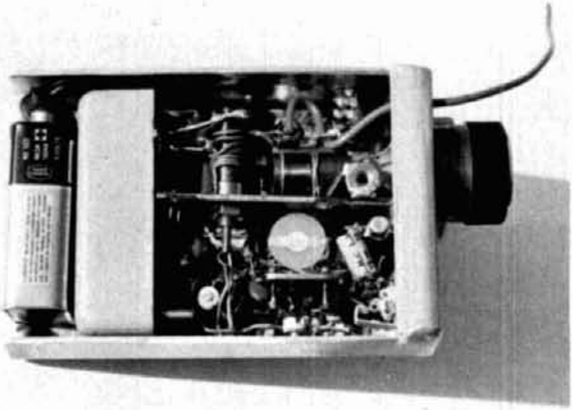
14-MHz superhet uses inexpensive ICs



build a pocket-portable SSB receiver

This article describes the design and construction of a very small, portable 20-meter single sideband receiver. Because some of the more demanding performance requirements can be relaxed in favor of small size and reduced component count, the project also represents an interesting design exercise in value engineering.

For example, reference 1 states that performance limitations are the principal drawbacks of integrated circuit mixers. Yet for a portable receiver in use in a remote location — say on a camping trip — small size and high gain may be more important than strong signal performance. Reduced complexity is also attractive to inexperienced builders; using ICs simplifies the design, since they can be considered as building blocks already designed by the manufacturer's specification sheets. The only real work, then, is selecting the best ICs and connecting them together.

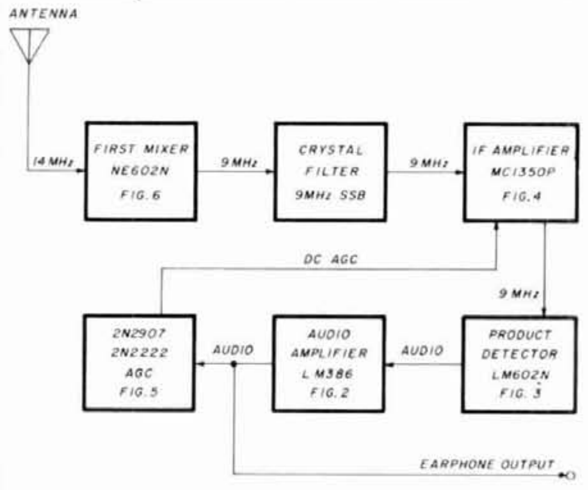


fig. 1. 20-meter receiver block diagram.

circuit description

Figure 1 shows that the receiver is a conventional single conversion superheterodyne design with a 9-MHz i-f. Major circuit blocks are represented by IC part numbers with the exception of the AGC. The following circuit theory of operation is presented in a sequence beginning at the output and proceeding toward the input, which is the recommended sequence for construction. Dividing a large project into several small tasks makes the work seem easier, and the completed output stages can be used as a test aid to align and troubleshoot preceding stages assembled later.

audio amplifier

Figure 2 shows the National Semiconductor LM386 Low-Voltage Audio Power Amplifier, which is used to drive an earphone. The main advantage of this component is low battery drain and operation from a 9-volt

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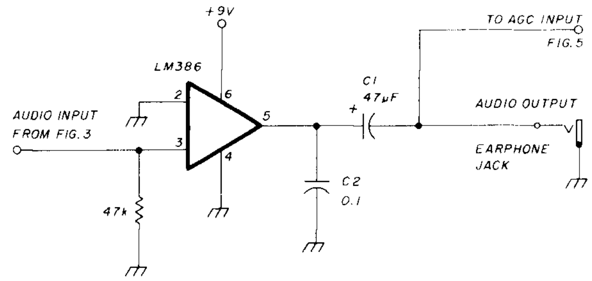

fig. 2. Audio amplifier.

battery. The 9-volt power source was considered essential for convenience in obtaining batteries while traveling.

Peripheral components increase circuit complexity, but provide an opportunity to shape the receiver audio frequency response. Signal frequencies below a few hundred Hz and above a few kHz should be attenuated by selecting audio coupling and bypass capacitor values carefully. Each capacitor (and associated resistance) provides a 6-dB per octave rolloff beyond the break point. The half-power break frequency is:

$$F = \frac{0.159}{RC}$$

where F is in Hz, R is in ohms, and C is in farads. For example, the output coupling capacitor, C1 of **fig. 2**, gives a low-frequency rolloff frequency calculated as 160 Hz. This is assuming that the LM386 output impedance is very low and the earphone offers the principal resistance in the circuit. I actually measured the earphone impedance to be 21 ohms at 1000 Hz when the calculations gave confusing results. The earphone is presumably 16 ohms, but it could have been 8 ohms. The following data was taken for selected capacitors using one-half voltage for the measurement point, which resulted in slightly lower frequencies (6 dB down):

330 μF	10 Hz
100 μF	70 Hz
47 μF	120 Hz

These results suggest that it may be better to substitute capacitors and sweep the frequencies with an audio oscillator than perform calculations when circuit resistance may be inconvenient to determine. In fact, components were selected experimentally, but the equation is helpful for awareness of circuit operation and to provide a starting point. A bypass capacitor (0.047 μF) in the product detector output provides a similar function for high frequencies, and the equation is the same.

C2, added to cure a high-frequency oscillation, may not be necessary in all cases. A large capacitor bypassing the audio power amplifier wastes power and may cause instability.

Tests showed that a 30-millivolt, 1000-Hz input signal provided a 600-millivolt output for a gain of 20. Current drain was 5 milliamperes at 9 volts.

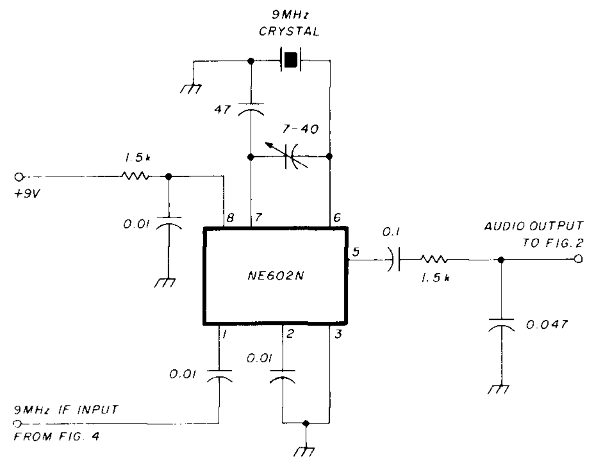

fig. 3. Product detector. Pins 4 and 5 are push-pull outputs, and either may be used.

product detector

The Signetics NE602 shown in **fig. 3** is used for the product detector as well as the first mixer. One of the more popular Gilbert Cell mixers, it also contains a voltage regulator and bias, an oscillator, and an rf amplifier. These features are implemented with an absolute minimum of external components. Pin 7, the oscillator emitter, can be used as a test point for checking oscillator operation. 350 millivolts of 9-MHz sine wave signal is a typical value. The capacitors connected to pin 7 must be adjusted for the correct operating carrier frequency to match the crystal filter. Power voltage for the NE602 is 6 volts, which is supplied to pin 8 through the 1.5k resistor. Application of a 400-microvolt 9-MHz i-f input signal to pin 1 gives a 150-millivolt peak-to-peak earphone output when connected to the audio amplifier **see fig. 2**. The current drain is an economical 2.5 milliamperes. More information on the NE602 is provided in the first mixer circuit description.

The resistor/capacitor network connected to pin 5 shapes the audio frequency response as described in the previous section. The 0.1 μF capacitor provides low frequency rolloff to complement C1 of **fig.1**. The 0.047 μF capacitor bypasses high frequencies.

i-f amplifier

A Motorola MC1350P television i-f amplifier was used for the 9-MHz i-f amplifier **fig. 4**. This popular IC features high gain, excellent stability, and a very handy AGC input terminal. The MC1350P was intended for a 12-volt power supply, but works well on 9 volts with a current drain measured at 12 milliamperes. No particular effort was expended to wind T1 with a 14-turn primary (center tapped) and a 14-turn secondary on an FT 37-61 ferrite toroid core with No. 27 AWG wire. It seemed to resonate with about 15 pF of capacitance provided by a 9- to 20-pF variable, but it also works without the capacitor. Be sure to ground the AGC input, pin 5, for maximum gain while testing. Performance testing now shows that only 0.7 microvolts RMS 9-MHz input is required to produce a 100-millivolt peak-to-peak earphone audio output. The MC1350 gain was 50 dB with a 200 microvolt i-f output for the 0.7 microvolt input. Total receiver current drain at this point was 20 milliamperes.

crystal filter

The crystal filter is the largest and potentially most expensive item. The price of a new crystal filter would make it impractical for so simple a project. I first considered the crystal filter as an optional or less critical item, but the obvious performance improvement made it a necessity. The filter and BFO crystal can be a junk box or surplus item. The 9-MHz filter used for this project was purchased for about $20 from a *ham radio* advertiser a few years ago, but swap meets and hamfests are also good sources. Be sure to get a BFO crystal with the filter, but if several filters are available inexpensively it may be better to break apart a filter to get an oscillator crystal. With luck it may be possible to tune the BFO to the right frequency with the oscillator capacitors and avoid the expense of ordering a crystal. At this point, a substantial effort may be required to sweep the filter with a signal generator while monitoring the receiver audio output and adjusting the BFO frequency for the desired frequency response.

automatic gain control

AGC is a truly optional feature that could be substituted with a potentiometer voltage divider connected to the MC1350 AGC input. Some experience using this method showed that the "two-knob" tuning method required was somewhat inconvenient considering the small controls and lack of panel space. Also, eliminating the manual gain control provided additional space for an AGC circuit.

The AGC characteristics of the MC1350 used were measured and tabulated as follows:

Pin 5 voltage	4.50 volts max gain
	4.77 volts min gain

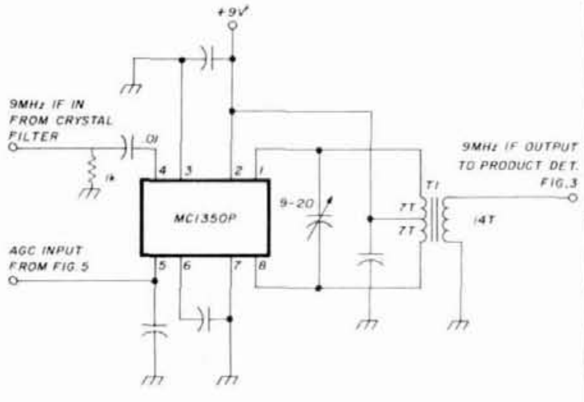

fig. 4. I-f amplifier. All capacitors are 0.01 disc except the 9-20 pF variable.

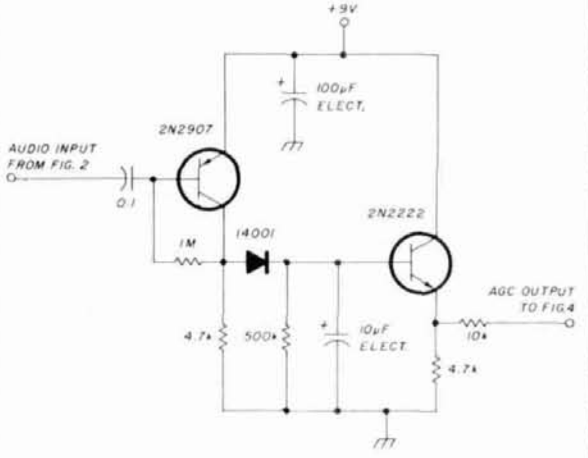

fig. 5. Automatic gain control.

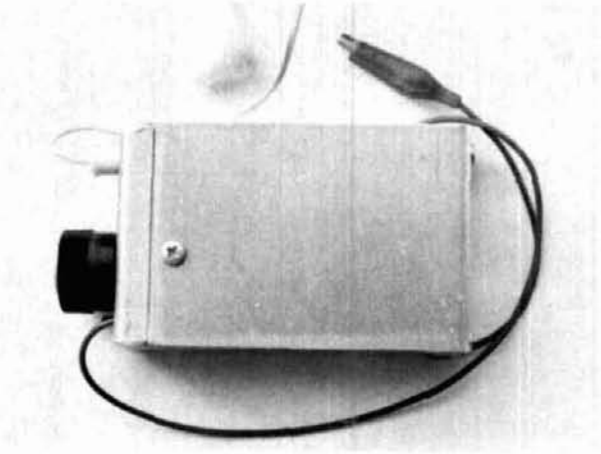

Photo A. The receiver is housed in a sheet aluminum enclosure. The aluminum was bent in a brake and the corners were TIG (Tungsten Inert Gas) welded. The clip lead is the antenna connector.

Pin 5 with a 10-k series resistor	4.00 volts max gain 6.30 volts min gain

Pin 5 is essentially a current sink. Adding a 10-k resistor in series makes a convenient voltage range for the AGC circuit to drive.

Figure 5 shows the AGC circuit, an unfortunate departure from the use of ICs. The Plessey SL621C would have provided an excellent AGC IC, but I felt that it was too sophisticated (and expensive) for this simple application. The 2N2907 amplifies the earphone audio, which is half-wave rectified by the 1N4001. The time constant circuit uses a 10-μF capacitor and a 500-k resistor. The 2N2222 is a dc amplifier that drives the MC1350. A 100-μF electrolytic capacitor was required to bypass the 9-volt power line to prevent a low-frequency oscillation.

The addition of this AGC circuit holds the earphone audio output to 100 millivolts peak-to-peak and consumes 2 milliamperes of current drain. Performance could be described as very aggressive but slightly slow on attack time. A slow attack time prevents the receiver from being muted for the RC time constant period when only a brief noise pulse is received. A full wave AGC rectifier would improve attack time but would also add to complexity. The circuit has more gain than is required to keep the audio ouput leveled, but I prefer this compression effect to eliminate the need for any other gain control.

mixer

The NE602N is used in the receiver first mixer (**fig. 6**). Two LC-tuned circuits are used in this circuit; L3 tunes the 14-MHz input and L1 is the 5-MHz local oscillator (LO) frequency control. L2 is a small rf choke added to restrict the L1 tuning range to 5.000 to 5.375 MHz. It's difficult to find a small vernier dial and variable capacitor, so a knob was attached to L1 for a tuning control. L1 was a 0.375-inch iron slug-tuned coil wound with 17 turns of No. 27 AWG wire. Many different L and C combinations could probably be used in this oscillator circuit. Pin 7 is the emitter and pin 6 is the base of the oscillator transistor. Reference 2 cautions against using too low a circuit Q and suggests connecting a 22-k resistor from pin 7 to ground if the oscillator won't start. Increasing the 300-pF capacitor values in **fig. 6** reduced the oscillator output, which was measured at pin 7 to be about 300 millivolts peak-to-peak. L3 is a 0.250-inch iron slug tuned form with 14 turns of No. 27 AWG wire. The input coupling link used five turns of hook-up wire. Don't try to use capacitor coupling for the NE602N input without a parallel choke or coil winding to ground. Low-frequency noise ("hum") will be coupled to the input amplifier, modulating all signals received.

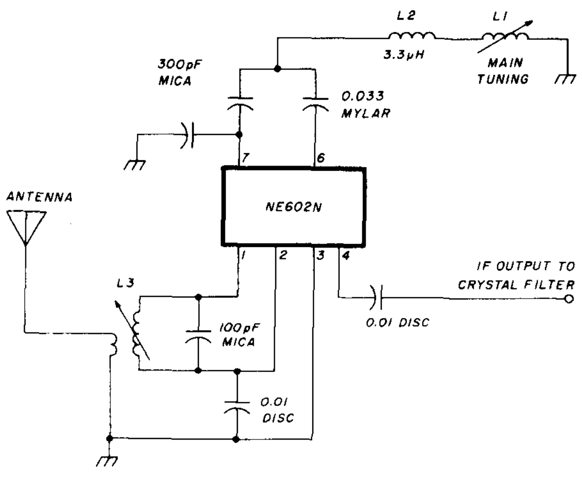

fig. 6. First mixer. The value of the 300-pF capacitors must be adjusted for alignment.

construction notes

I started out soldering components together by their leads as sort of a breadboard without the board to test the circuits. It was soon obvious that the most compact construction technique is to cut the leads as short as possible and solder them together on a double-clad unetched circuit board. The board serves as a ground plane as well as a structural mount. This mounting method is really quite strong, considering the light weight of the parts. A dab of epoxy would really add to strength, but it hasn't been necessary. Most of the parts were junk box selections so only general descriptions of the parts required will be given. This is especially the case for the tuning control, L1. The tuning slug screw must have a friction lock to prevent backlash. Since wear is a problem, select the largest screw size slug available and lubricate it with automotive wheel bearing grease. In this case, I found a short spacer with a tapped hole that fit on the tuning slug screw and locked it with a jam nut the same size. A knob can fit easily over the outside diameter of the spacer. The obvious disadvantage is lack of calibration markings, so it's important to limit the L1 tuning range to reduce confusion.

It may be desirable to enclose L1 and other oscillator components with circuit board since flexing the external cabinet will cause frequency changes. The double-clad printed circuit board is quite rigid when soldered together to make a box. After all the components were assembled and tested on the circuit board, I made a small aluminum box to fit around them. It's probably better to plan ahead and buy a small box, but at the beginning I wasn't sure what the final size or shape would be. (See **Photo A.**)

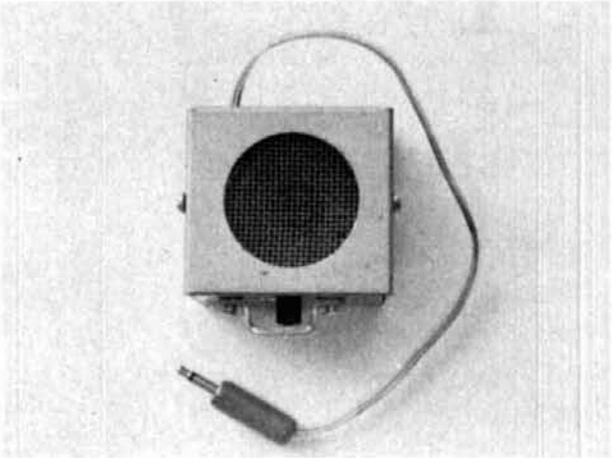

Photo B. This small box contains an amplifier and a speaker. The amplifier is the same as shown in fig. 2. No volume control is required when used with the receiver.

Soldering the components together does pose some problems, however. As can be seen in the photographs, it's very difficult to see some of the components. Repairs seem impossible. Don't solder to the crystal can near any of its solder seals; doing so may cause a vacuum leak, spraying molten solder on the quartz.

The electronic aspects of construction require use of an oscilloscope with a high impedance (x10) probe, an audio oscillator, and an rf signal generator. A frequency counter is handy but not essential. The x10 probe allows monitoring the oscillators with a minimal amount of frequency shift due to loading by the probe. I connect my frequency counter to the oscilloscope channel 1 output for checking the oscillator frequency. This is especially handy for setting up the BFO when the exact frequency is known, but the BFO frequency is subject to adjustment later "by ear" when listening to SSB signals. The first mixer oscillator can be adjusted with a receiver or signal generator, and will also require considerable adjustment to obtain the right frequency range.

conclusion

This receiver has enough gain to be used with almost any metal object as an antenna. I used a clip lead as an antenna connector. It's handy to carry a convenient length of insulated flexible wire for those times when there's a chance to rig a makeshift antenna in a tree or bush. Twenty meters provides good listening most times of the day or night, with some DX in the early morning.

This article presented a few applications of some simple but versatile integrated circuits. My intent was to present a few circuits that might inspire the reader to develop new applications. For example, I mounted an LM386 with a battery and speaker in a small box to carry with the receiver. (See **Photo B**.) Future projects for the NE602 might include a tunable shortwave converter for an a-m car radio, or an aircraft band receiver with an MC1350 i-f amplifier.

references

1. Gary A. Breed, "Mixers: Making the Right Choice," *rf design*, August, 1986.

2. "Applying the Oscillator of the NE602 in Low-Power Mixer Applications," Signetics Applications Note No. AN1982, October, 1985. (Signetics Corporation, 811 East Arques Avenue, Sunnyvale, California 94088-3409.)

ham radio