An NE-602 RF Signal Generator

Useful test equipment from a versatile IC.

by Julian Kerr

The Signetics NE-602 chip has intrigued many people, partly because it is versatile and partly because it is well behaved. What does "well behaved" mean? It means that the chip does what it's supposed to do with little effort on your part. It is an RF device, so you have to be careful with matters such as component selection and layout, but it will work well for you if you just follow a few simple rules. I experienced no problems in a weekend of experimentation in preparation for this article.

Another of the NE-602's attractions is that it is easy to get. As an electronics hobbyist, I am frequently distressed at published circuits that work wonders, but require chips that aren't available through most distributors. Furthermore, major industrial distributors will normally deal with individuals on a cash-up-front basis only (some will do COD), and have a minimum order of $50 or $100. Fortunately, the NE-602 is available by mail from Digi-Key at P.O. Box 677, Thief River Falls MN 56701-0677; (800) 344-4539.

The NE-602 is an 8-pin mini-DIP integrated circuit double-balanced mixer with a built-in oscillator (see Figure 1a). The mixer works up to 500 MHz, while the oscillator works up to 200 MHz. There are two balanced inputs (labeled "Input-A" and "Input-B") and two balanced outputs (labeled "Output-A" and "Output-B"). Both the inputs and the outputs can be used in a single-ended, rather than balanced, configuration. The pinouts of the NE-602 (see Figure 1b) are listed in Table 1.

Much of what has been written thus far about the NE-602 has centered around its uses as a receiver or a frequency converter. Indeed, the NE-602 makes a dandy little single-chip RF front end and will provide a high degree of sensitivity and a low noise figure in that application. In addition, because it is a double-balanced mixer, the LO and RF signals are suppressed in the outputs, so only the sum and difference IF frequencies (LO ± RF) exist in the output. In this article we are going to examine the largely-overlooked oscillator function of the NE-602.

NE-602 Oscillator Circuits

In normal receiver or frequency converter applications, the local oscillator signal generated inside the NE-602 is suppressed in the output. This is an excellent feature to have in a receiver front-end, accounting for the use of double-balanced mixer circuits in high priced communications receivers. But if we unbalance the RF input (pins 1 and 2), then the LO signal will appear on the two output terminals of the NE-602 (pins 4 and 5).

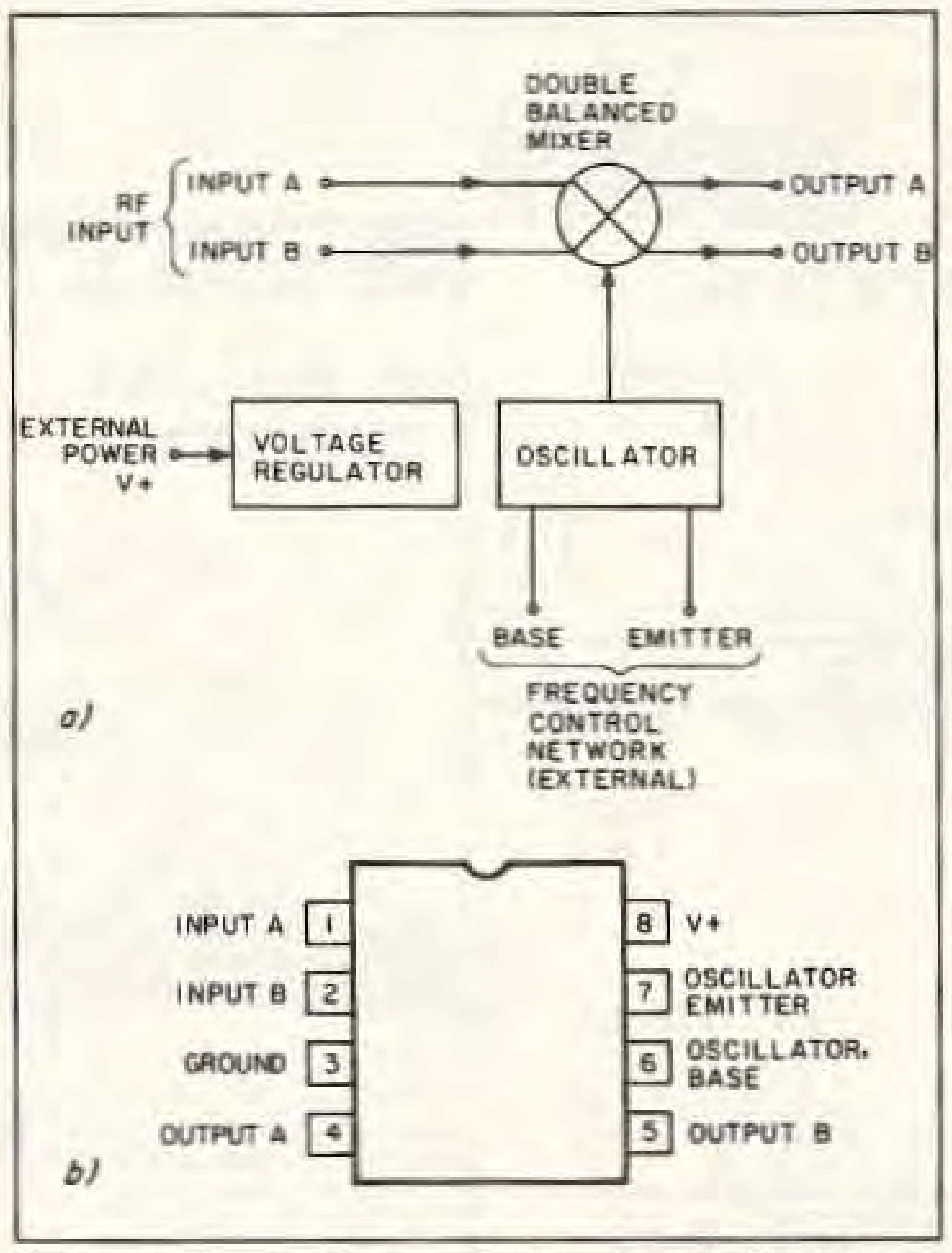

Figure 1. a) Internal circuit of NE-602 in block form; b) pinouts of the NE-602.

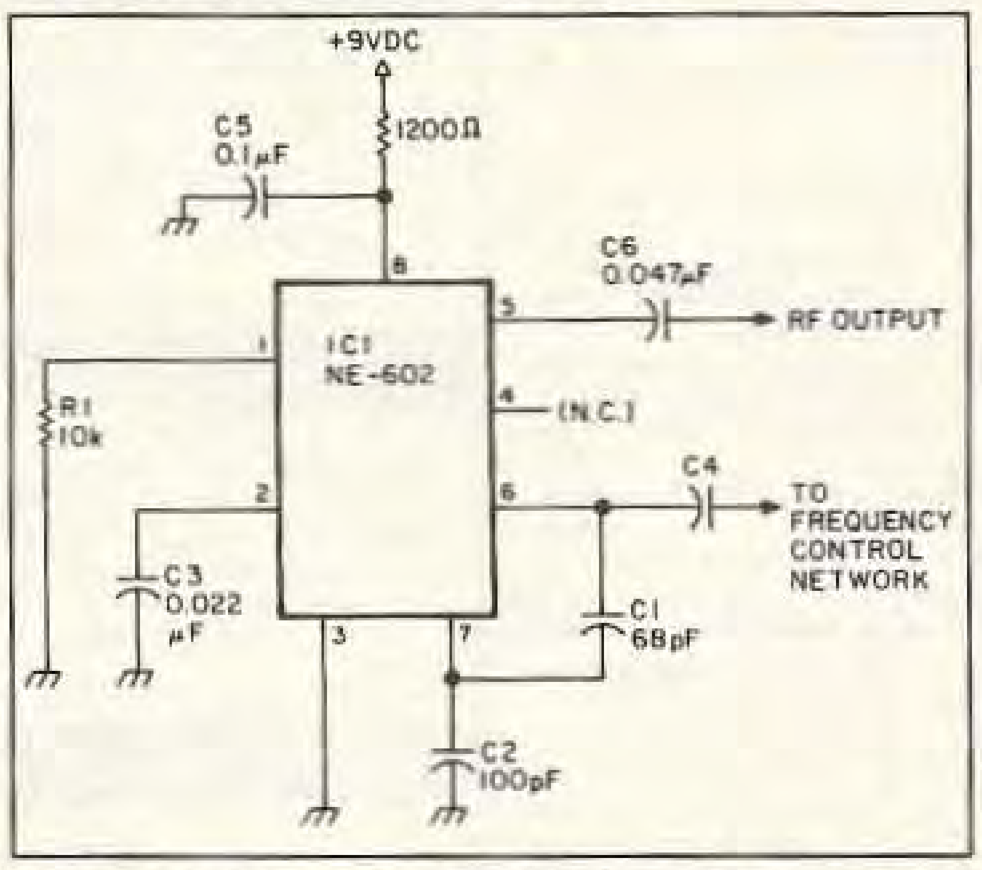

Figure 2. Generic NE-602 oscillator circuit.

Figure 2 shows the basic configuration of the NE-602 in oscillator mode. Input-A is grounded through a 10k ohm resistor, while Input-B is bypassed to ground for RF signals through a capacitor (C3). The value of this capacitor is dependent on the operating frequency. The value shown will work nicely in the HF and low VHF range, but for lower frequencies use a higher value. In general, the capacitor should be 0.001 µF to 0.01 µF for VHF, 0.01 µF to 0.05 µF for HF, and 0.05 µF to 0.33 µF for VLF through low HF frequencies.

As is true for all bypass capacitors, mount C3 as close to the body of the NE-602 as possible. Use disk ceramic, mica or other capacitor types that work well at the frequency of operation. Not all capacitor types that work well in audio or other low frequency circuits will work at RF. The catalog description of the capacitor will tell you its intended uses.

The NE-602 works from DC power supplies in the +4.5 to +8 volt range, and draws 2.4 to 2.7 mA of current. If higher voltage operation is required, then you must use one of two tactics. For +9 volt DC power supplies (meaning battery operation is possible), insert a 1000 to 1500 ohm resistor in series between the V+ power supply and the V+ terminal (pin no. 8) on the NE-602. For even higher voltages, use a three-terminal IC voltage regulator that drops the voltage to 5, 6 or 9 volts. In the latter case, use the 1000 ohm series resistor as well.

The V+ pin is bypassed to ground for RF by a capacitor (C5). The same approximate value ranges described above for C3 are also valuable for this application. Again, mount the capacitor as close as possible to the body of the NE-602.

The output signal can be taken from either pin no. 4 or pin no. 5. I used pin no. 5 because of layout considerations on the perforated board that I used.

The NE-602 oscillator circuit contains an NPN transistor and supporting circuitry, and can be used in all of the normal oscillator configurations that don't require access to the collector terminal. Two examples are the Colpitts oscillator and the Hartley oscillator. For the purposes of illustrating NE-602 oscillator circuits, all but one example will be of the Colpitts oscillator configuration because the Colpitts oscillator uses a tapped capacitor voltage divider (C1/C2) for feedback, while the Hartley configuration uses a tapped inductor. The latter is a little harder to build; the Colpitts works well for most applications.

The values of C1 and C2 determine the stability of the oscillator, and indeed whether or not the circuit will oscillate at all. The approximate values are as follows:

Equation 1: $$C1 = \frac{100\ \text{pF}}{\sqrt{F_{MHz}}}$$

Equation 2: $$C2 = \frac{1000\ \text{pF}}{F_{MHz}}$$

In terms of standard capacitor values, these equations translate to the approximate values shown in Table 2. These values are not absolute, and I found it possible to make good oscillator circuits with values different from these, including the project at the end of this article.

An example of the output signal from the circuit of Figure 2 is shown in Photo A. This signal is from a 10 MHz crystal oscillator (see below), and appeared on both pins 4 and 5. It had an amplitude of about 180 mV, which is more than is normally needed for a signal generator.

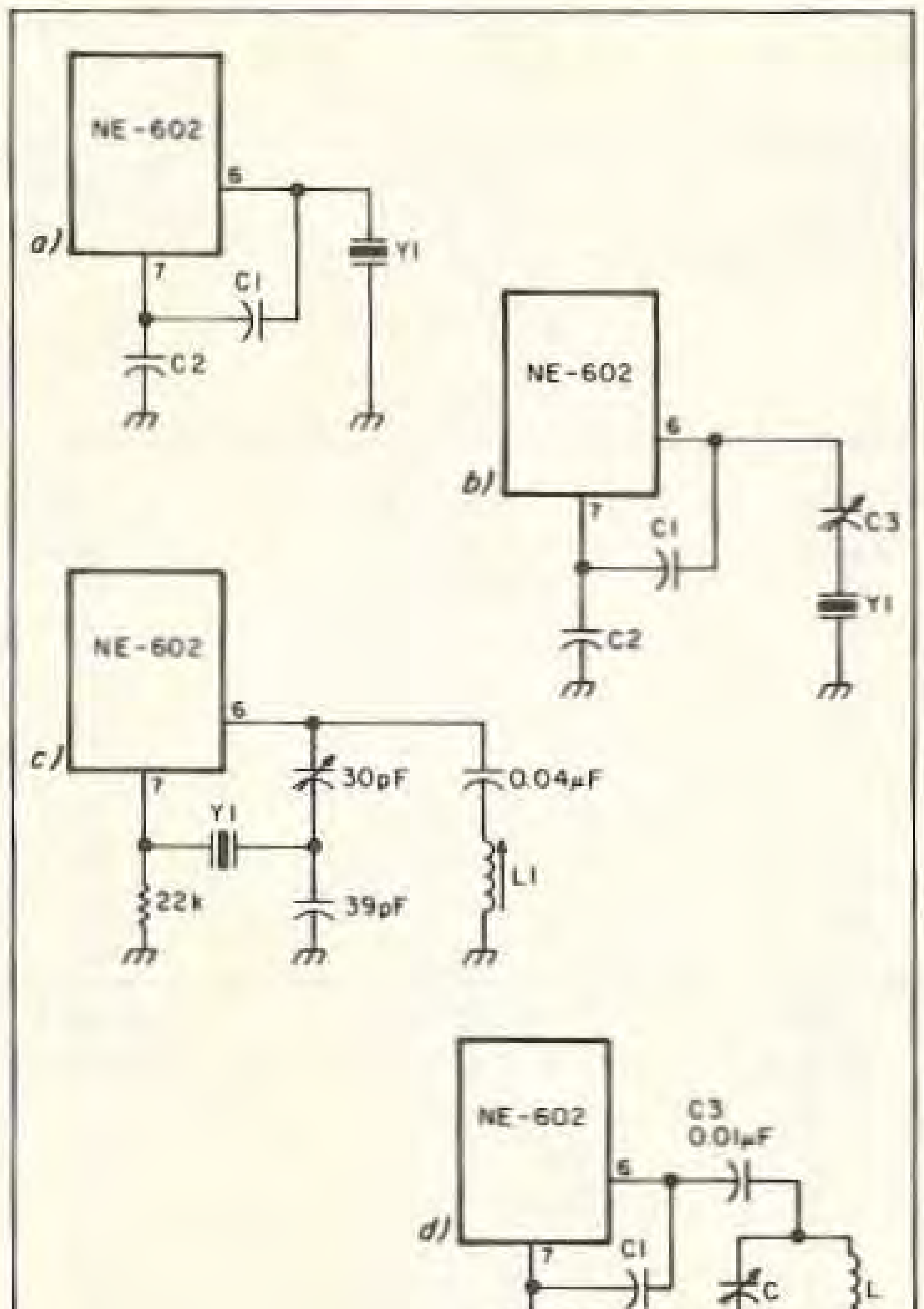

Figure 3. Oscillator frequency control networks: a) simple fundamental mode crystal oscillator; b) adjustable fundamental mode crystal oscillator; c) Butler third overtone oscillator; d) LC tuned VFO; e) series tuned voltage variable VFO; f) parallel tuned voltage variable VFO.

NE-602 Oscillator Frequency Control Networks

The rest of the oscillator circuit consists of the frequency control network (not shown in Figure 2). This network can be a piezoelectrical quartz crystal resonator, a ceramic crystal resonator, or an inductor-capacitor (LC) network. Figure 3 shows several possible variations on the frequency control network.

Figure 3a shows a crystal oscillator circuit. The piezoelectric quartz crystal (Y1) is operated in the parallel fundamental mode, so it is connected in parallel with the oscillator circuit. Because a crystal has an extremely high resistance to DC, there is no need for a DC blocking capacitor between the NE-602 and the crystal.

One problem with the circuit of Figure 3a is that the frequency is not adjustable. The frequency of any crystal resonator is a function of, among other things, the capacitance of the load seen by the crystal (most crystals are calibrated for 20 or 32 pF loads). Because of tolerances in the crystal manufacture, and the values of the external capacitor network (plus stray capacitance, which is significant in RF circuits), the actual frequency and the marked frequency might be different. By placing a variable trimmer capacitor in series or parallel with the crystal (Figure 3b), we can make the actual oscillating frequency adjustable. You can use an insulating tuning wand (a.k.a. "diddle stick") to adjust C3 for the correct operating frequency.

The non-Colpitts oscillator circuit referred to above is the Butler overtone crystal oscillator shown in Figure 3c. The previous two crystal oscillators operate in the fundamental mode, while in Figure 3c the crystal oscillates in the third overtone (similar to harmonic) mode. A fundamental mode crystal is only good to about 20 MHz because the crystal slab becomes too thin above that frequency and is therefore likely to fracture. But, in the overtone mode we can accommodate high HF and VHF frequencies without making the crystal too thin for safe operation.

A variable frequency oscillator (VFO) circuit is shown in Figure 3d. In this circuit the resonator is replaced with an inductor-capacitor (LC) network that tunes the oscillator. Because the inductor has a low resistance and is connected to ground, a DC block capacitor (C3) is used between the LC network and the NE-602. A variation on this theme is the Clapp oscillator in which the inductor and capacitor are in series rather than parallel.

Figures 3e and 3f show voltage-tunable oscillator circuits. The series-tuned version is shown in Figure 3e; Figure 3f shows the parallel-tuned version. In both cases, the tuning element is a voltage-variable capacitance diode (varactor). In these diodes, the junction capacitance of the diode changes as a function of the applied reverse bias voltage (Vt). In this configuration, Vt is a positive voltage between 0.5 and some maximum limit (+9, +18, +30 or +40 volts depending on the diode).

The voltage-tunable oscillators can be used to make signal generators in which the operating frequency is set by a DC power supply and a potentiometer. Alternatively, the same circuit can be used to make a sweep generator or FM generator, or be used to generate the FM signal in a transmitter.

Signal Generator Project

The signal generator that I needed was a crystal-controlled circuit that would operate on the HF ham bands as well as 10 MHz (for use as a frequency standard). Although I selected an adjustable fundamental mode crystal oscillator similar to Figure 3b, you can use any of the standard oscillator configurations, depending on your own needs. Another requirement for my own signal generator was

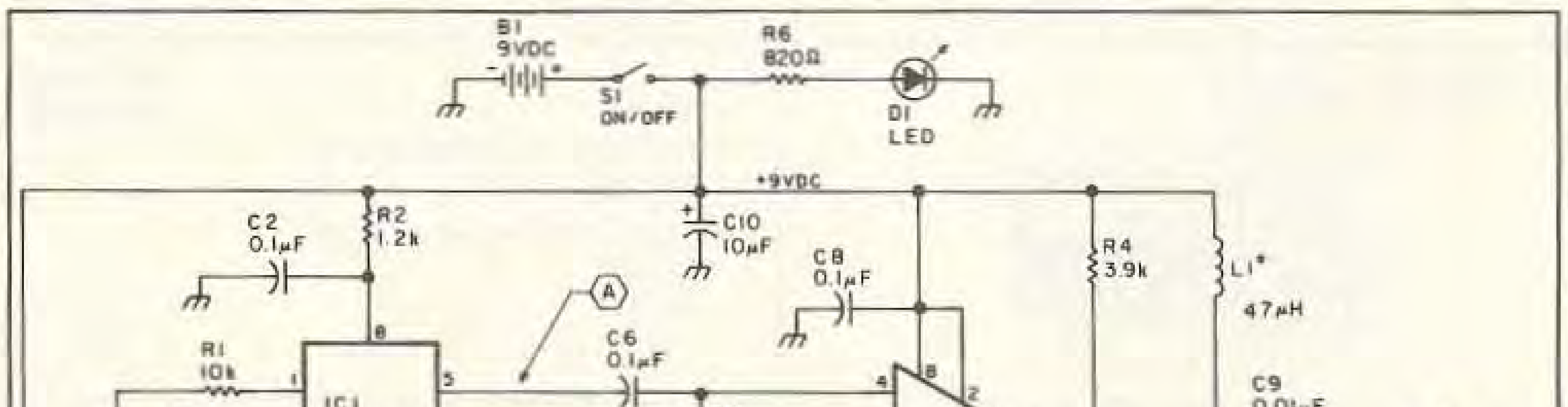

Figure 4. Circuit diagram for the signal generator.

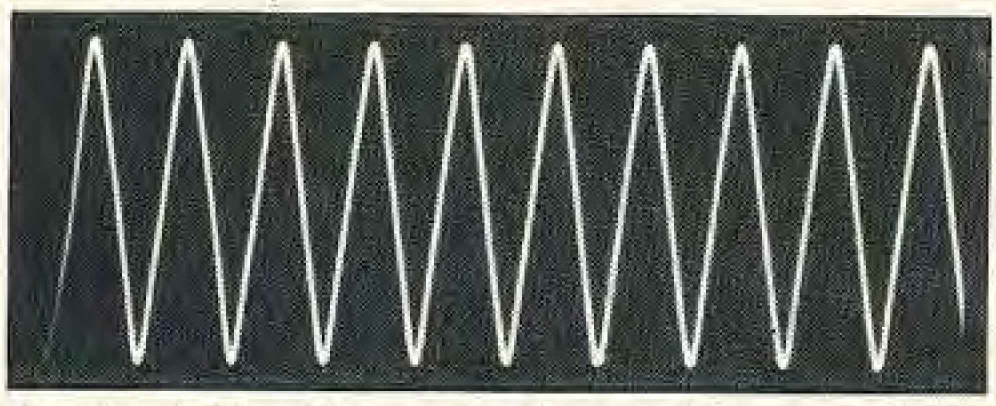

Photo A. Oscilloscope photo of the waveform from the output signal at pin no. 5 (see the circuit shown in Figure 2).

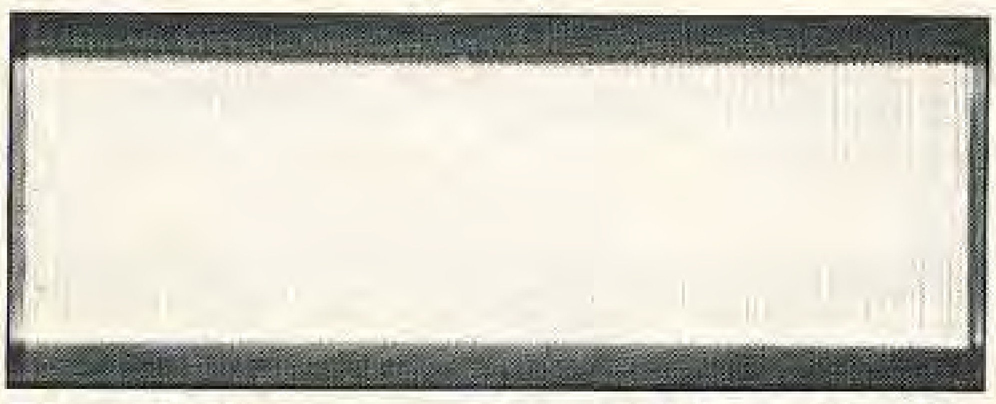

Photo B. Output waveform: RF from NE-602.

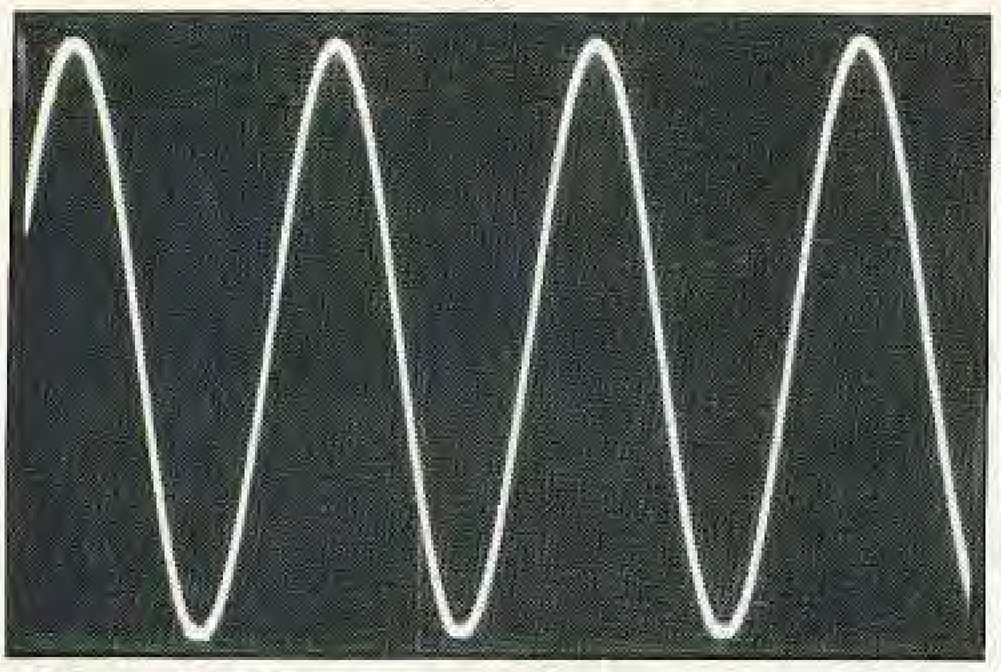

Photo C. Output waveform: AF from 741.

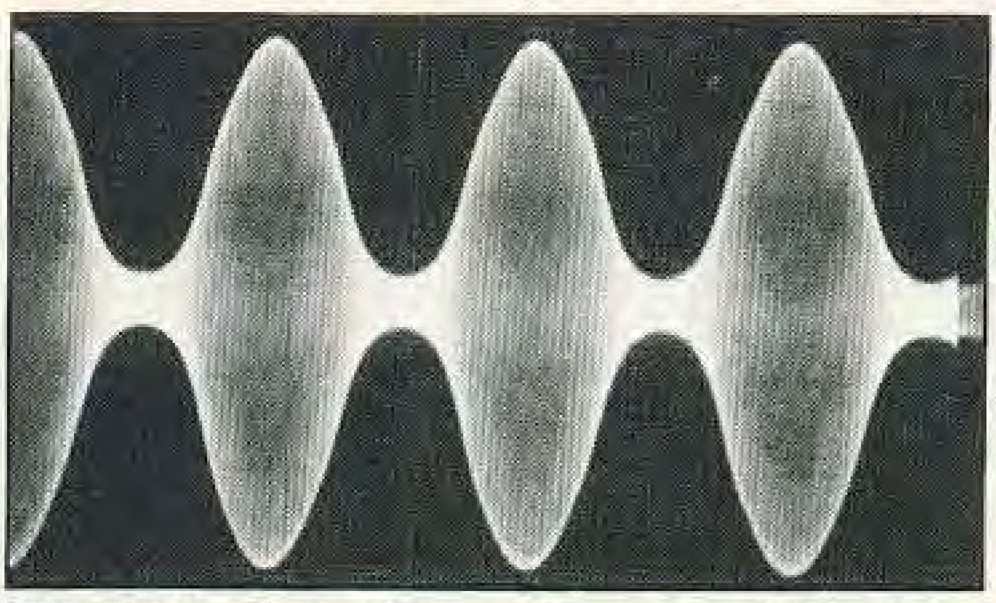

Photo D. Output waveform: modulated RF from MC-1350P.

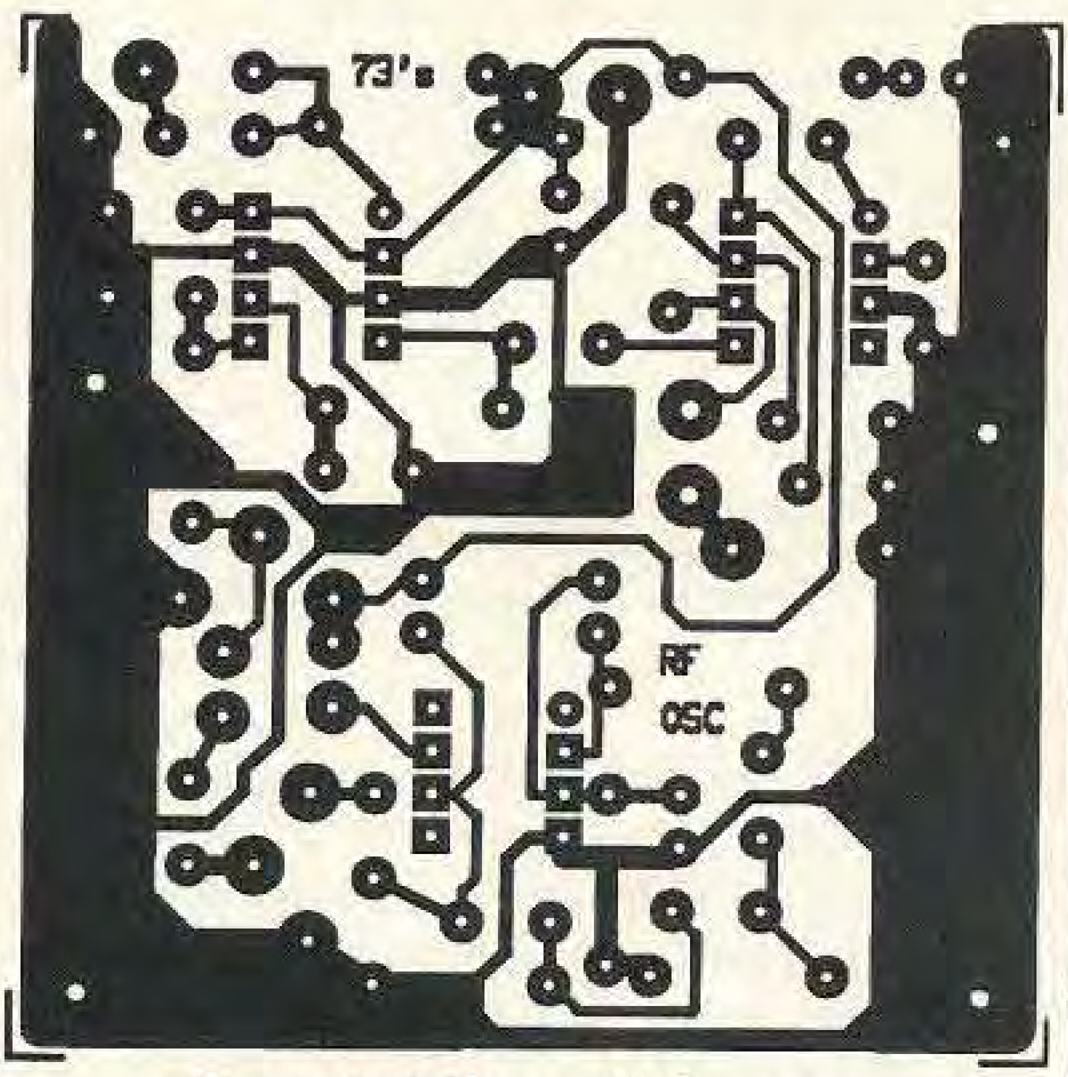

Figure 5. PC board foil pattern.

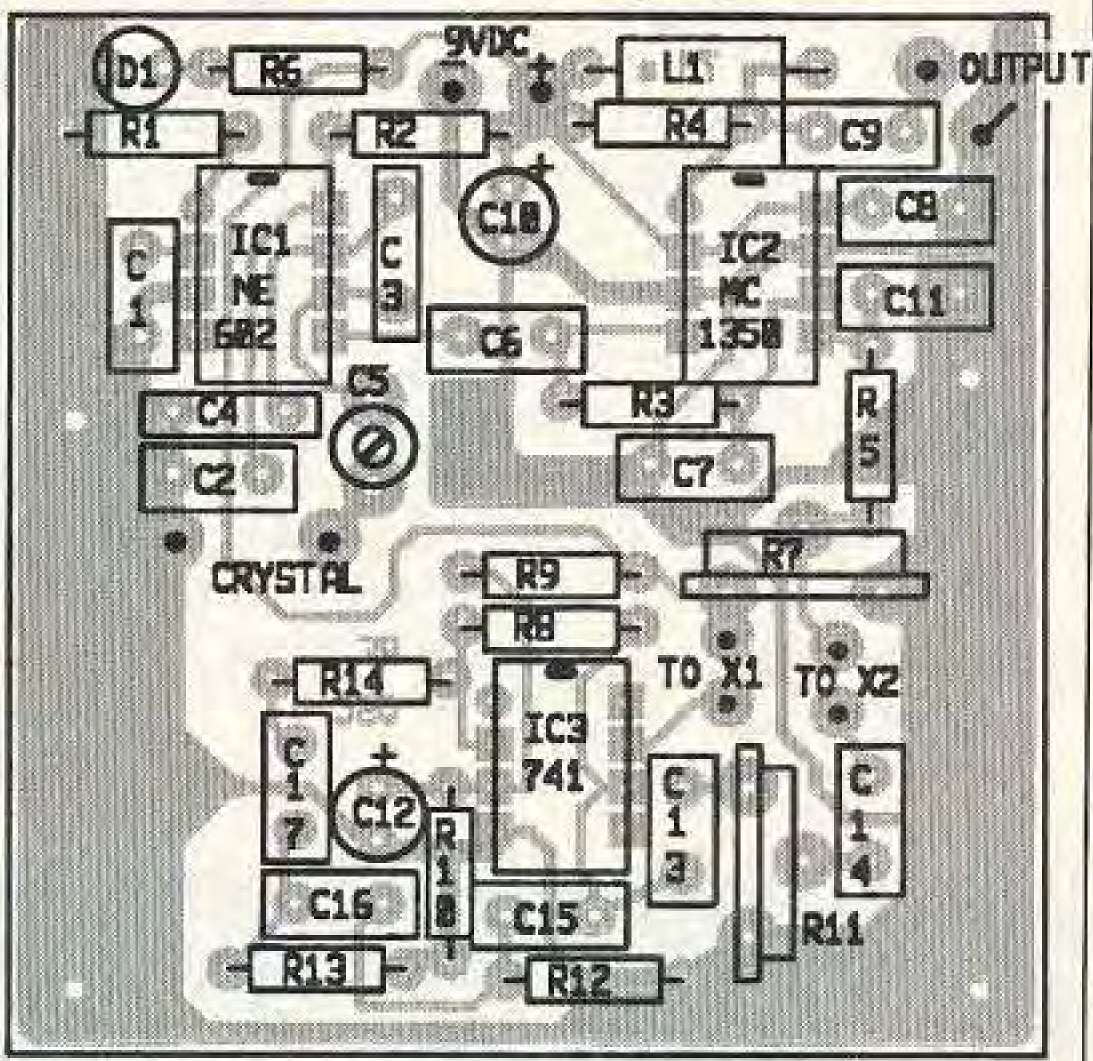

Figure 6. Parts placement.

that it be amplitude-modulated at some frequency between 300 and 1500 Hz (the exact AF frequency was not important). The final circuit is shown in Figure 4.

The crystal oscillator is an NE-602 (IC1) connected in a fundamental mode circuit with a trimmer capacitor for varying the oscillating frequency of the crystals. Because a number of different crystals will be used, and I didn't want to switch them in and out of the circuit (too complex), I used a panel-mounted crystal socket (SK1).

The crystal should be a fundamental mode crystal cut for 3 to 18 MHz operation, and calibrated for 32 pF. Suitable crystals, as well as sockets, can be ordered from a number of sources. Limited selections (with predetermined frequencies) can be found at mail order computer dealers, or the parts houses that support them. But custom (as well as standard) crystals can be ordered from Jan Crystals at P.O.B. 06017, Fort Myers FL 33906; (800) JAN-XTAL; or in Florida, (813) 936-2397.

Integrated circuit IC2 serves as both an output buffer amplifier for the oscillator and an amplitude modulator. It is the MC-1350P (also available as the NTE-746 from replacement part dealers), and is billed as an IF/RF gain block. It is frequently used in the IF amplifier stages of FM and communications receivers. It is an 8-pin mini-DIP IC.

This chip is especially useful for three reasons. First, it will operate at the desired frequencies. Second, it is also fairly well behaved, although it seems a little more touchy than the NE-602 device in the circuits that I've tried. This touchiness is probably due to the very high gain that is possible when the output terminal (pin no. 1) is tuned to the input frequency. Third, it has a single terminal that makes it really useful as an amplitude modulator: the AGC terminal (pin no. 5).

The AGC terminal on the MC-1350P is intended for gain control applications. A DC potential applied to this pin will change the gain of the circuit. Two voltages are applied to the AGC terminal in this project: a DC level set by potentiometer R7, and the modulating audio signal. The latter signal is set by potentiometer R11. The DC voltage is normally supposed to be between 3 and 9 volts, so the DC level control is used to set the value at some midpoint that will allow the audio signal to go through positive and negative excursions without exceeding either limit.

The modulating signal is produced by IC3, a 741 operational amplifier connected in the RC phase shift oscillator configuration. Because only a single DC power supply is used, the 741 is operated with a bias voltage applied

Pin. No.	Function
1	Input-A
2	Input-B
3	Ground
4	Output-A
5	Output-B
6	Oscillator Base
7	Oscillator Emitter
8	V+

Table 1. The NE-602's pinouts.

to the noninverting input (+IN) through a voltage divider (R9/R10).

The oscillating frequency of the 741 is set by a 180 degree phase shift network consisting of C15, C16, C17, R12, T13 and R14. When combined with the 180 degree phase shift caused by connecting the 741 in the inverting follower manner, the network will produce the 360 degrees needed for oscillation. The oscillating frequency is set by:

$$\text{Equation 3:} \quad F_{Hz} = \frac{1}{2\pi\sqrt{6}\,RC}$$

where R = R12 = R13 = R14, and C = C15 = C16 = C17. With the values shown in Figure 4, the circuit oscillates at a frequency just under 400 Hz. The feedback resistor (R8)

Frequency (MHz)	C1 (pF)	C2 (pF)
0.5	150	2000
1.0	68	470
5.0	45	220
10.0	32	100
20.0	22	50
30.0	18	47
50.0	14	22

Table 2. Capacitor values for oscillator circuits.

should have a value that is at least 29 times the value of R used in Equation 3.

If you want to be able to turn the modulation on and off, then insert the switch shown in the inset to Figure 4 at the points marked "X1" and "X2."

Results

As the old proverb says, the proof of the pudding is in the eating. Photos B, C and D show oscilloscope photos of the waveforms in this circuit. The 10 MHz RF carrier is shown in Photo B (although at a different time base than Figure 2); this signal appears at point "A" in Figure 4. The audio modulating signal appears at point "B," and is shown in Photo C. Finally, the modulated RF signal from the output of IC2 (point "C") is shown in Photo D.

Parts List

IC1	NE-602
IC2	MC-1350P (or NTE-746)
D1	Red LED
Y1	Crystal frequency of your choice
R1,R9,R10	10k resistor
R2	1.2k
R3,R4	3.9k
R5	4.7k
R6	820 ohm
R7,R11	20k potentiometer
R8	82k
R12,R13	2.7k
C1	0.022 µF capacitor
C2,C8	0.1 µF
C3	68 pF
C4	100 pF
C5	8-80 pF variable
C6,C9,C14	0.01 µF
C7,C15,C16,C17	0.068 µF
C10	10 µF/35V electrolytic
C11,C13	0.05 µF
C12	3.3 µF electrolytic
S1	SPST switch
L1	47 µH Digi-Key TK-3922
SK1	Crystal socket
B1	9-volt battery

Misc: Battery clip, case, PC board. A blank PC board is available for $4.50 + $1.50 shipping from FAR Circuits, 18N640 Field Court, Dundee IL 60118.