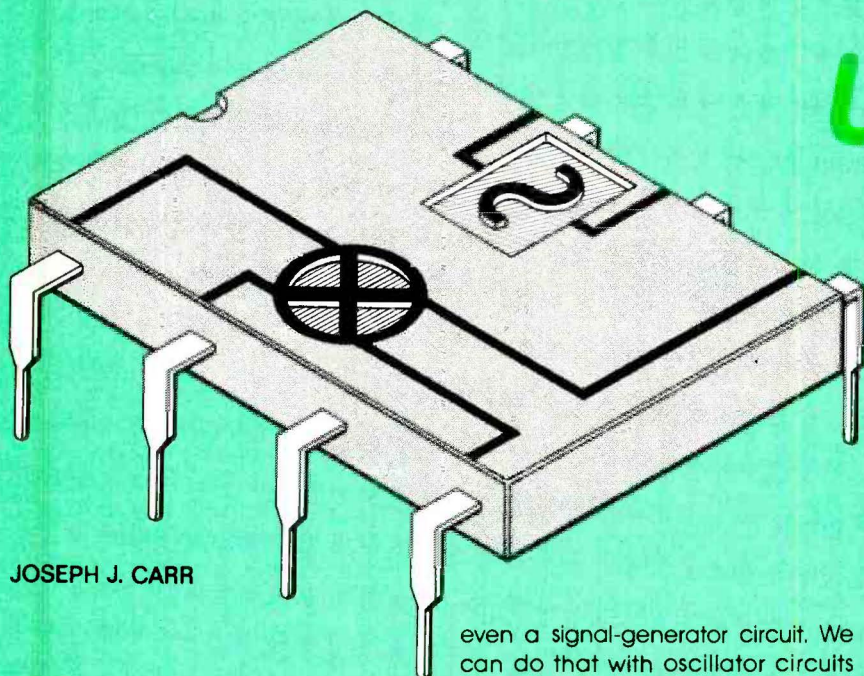


*The NE602 could very well become the RF experimenter's "555" chip.
Learn about this fascinating and versatile device for your next RF project.*



JOSEPH J. CARR

Every now and then a chip comes along that strikes the public imagination, so it gets used in a lot of projects. The 741 operational amplifier was like that in the early 1970s. Also reaching a high pitch of popularity was the 555 IC timer chip. Both of those chips reached such heights because they were both useful and well-behaved (i.e. they did what they did with little fuss or fuss). The radio frequency (RF) hobbyist, however, only recently found a chip that meets those requirements: the NE602 from Signetics.

The NE602 device is a monolithic integrated circuit containing a double-balanced mixer (DBM) and an internal oscillator circuit. The DBM has balanced inputs (pins 1 and 2), balanced outputs (pins 4 and 5), and can operate at up to 500 MHz. The internal oscillator circuit provides an emitter connection and a base connection to the outside world. Figure 1-a shows the block diagram, and Fig. 1-b the pinouts for the NE602 device.

The NE602 is meant to be used as the receiver front-end in VHF portable telephones, but a lot of amateur radio and electronics enthusiasts have used the chip for a wider variety of applications, some of which we'll talk about here. The NE602 is a strong candidate whenever you want to build a frequency converter or translator, or

even a signal-generator circuit. We can do that with oscillator circuits consisting of inductor-capacitor (L-C) variable-frequency oscillators, or piezoelectric crystals in either voltage-tuned or swept-frequency arrangements. We're going to explore some of the various configurations of circuits for the NE602 device, including the DC-power-supply connections, the RF-input configurations, the local-oscillator circuits, and the output circuits.

The NE602 version of the device operates over a temperature range of 0- to +70°C, while the related SA-602 device operates over an extended temperature range of -40- to +85°C. The most common form of the NE602, and most useful for the hobbyist and experimenter, is the NE602N, which is in an eight-pin mini-DIP package. An eight-lead surface-mount package (NE602D) is also available.

Heart of the NE602. Because the NE602 contains both a DBM and a local oscillator (LO), it can be used as the entire front-end of a radio receiver. Figure 2 shows a partial view of the internal circuit of the heart of the NE602: the double-balanced mixer stage. That configuration is known as a Gilbert transconductance cell. It consists of a pair of cross-coupled differential amplifiers. One feature of the design is that it offers a very good

USING THE NE602

noise figure, which is typically 5 dB at 45 MHz. The third-order intercept point is -15-dBm referenced to a matched input. Unfortunately, the dynamic range is not what it could be, so a good idea is to be sure that the input signal levels do not exceed -25 dBm (≈ 3.16 mW). That signal level is similar to about 12.6 mV into a 50-ohm load, or 68 mV into the 1,500-ohm input impedance of the NE602. The NE602 is capable of providing 0.2- μ V sensitivity without the need for external RF amplification. Although the straight NE602 suffers from dynamic range problems, the improved NE602A is said to solve that problem.

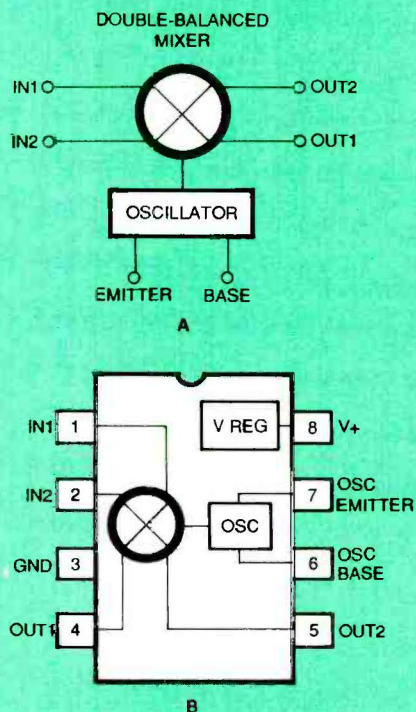


Fig. 1. The NE602 contains a double-balanced mixer and local oscillator. Here are its block diagram (A) and pinouts (B).

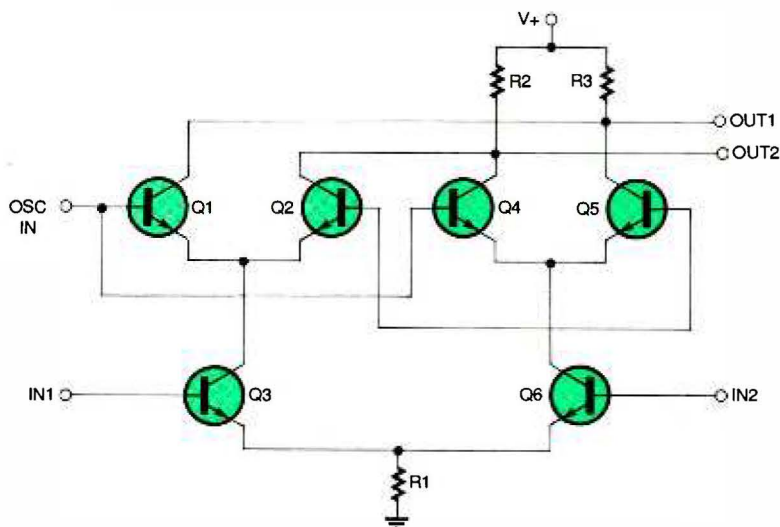


Fig. 2. The heart of the NE602: a Gilbert transconductance cell used for the double-balanced mixer.

Frequency Translation. The process of frequency translation or conversion is called heterodyning. When two frequencies (F_1 and F_2 in Fig. 3) are mixed together in a nonlinear circuit, a collection of different frequencies will appear at the output. Those frequencies are characterized as $mF_1 \pm nF_2$, where n and m are integers or zero (0, 1, 2, 3...). For the sake of simplicity, we normally consider only the cases where m and n are either 0 or 1, so the output frequencies are F_1 , F_2 , $F_1 - F_2$ (difference), and $F_1 + F_2$ (sum). To make a super-heterodyne receiver (the most common modern form), select either the sum ($F_1 + F_2$) or difference ($F_1 - F_2$) frequency as the receiver's intermediate frequency (IF). The NE602 contains a double-balanced mixer, so when it is properly impedance matched, it suppresses the two input frequencies (F_1 and F_2) at the output, and only produces the sum and difference frequencies.

In order to provide frequency translation by heterodyning, it is necessary to provide an LO circuit. The LO circuit inside the NE602 consists of a transistor

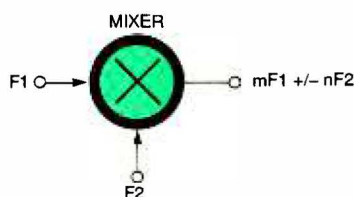


Fig. 3. In a basic mixer circuit, the sum ($F_1 + F_2$) and difference ($F_1 - F_2$) of two input frequencies appear at the output.

with its base and emitter elements available to the outside world. Oscillators using that circuit will operate up to 200 MHz. Any form of oscillator can be built, as long as the circuit does not need a connection to the collector of the oscillator transistor. Because of that restriction, both L-C and crystal variants of the Colpitts, Clapp, Hartley, Butler and other oscillator circuits can be built, while the Pierce and Miller circuits are not possible.

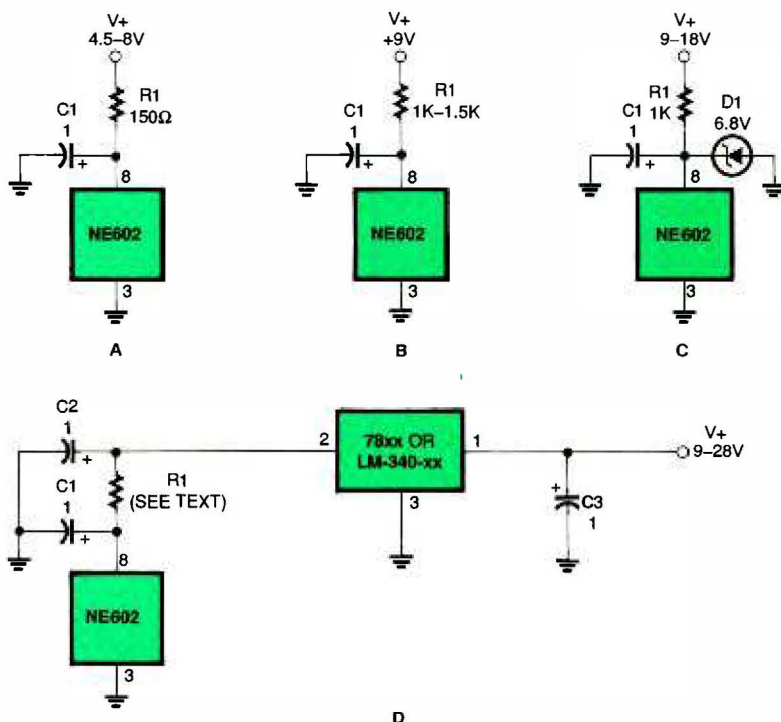


Fig. 4. There are several ways to power the NE602. A resistor should be placed in series between the power supply and the NE602 (a and b). A Zener diode (c) or a voltage regulator (d) can also be used.

DC Power Supply Connections.

The power is applied to the NE602 between pins 3 (ground) and 8 (V_+). The DC power supply voltage range is +4.5- to +8-volts DC, with a current drain ranging from 2.4 to 2.8 mA.

The DC power supply terminal (pin 8) must be decoupled with a 0.01- to 1- μ F capacitor (0.1 μ F is most common). The bypass capacitor must be mounted as close as possible to the body of the NE602, and must be capable of good performance at RF frequencies (some capacitors act like complex RLC networks at RF).

Figure 4 shows several possible DC power-supply configurations for the NE602. In Fig. 4-a, the DC power supply voltage is between +4.5 and +8-volts DC, which is the normal operating range of the device. A resistor, usually 100 to 180 ohms, is placed in series with the V_+ line to the NE602. If the circuit is operated from a 9-volt DC power supply (e.g. a 9-volt DC transistor-radio battery), then the resistor should be increased to a value between 1,000 and 1,500 ohms, as in Fig. 4-b.

If the DC power supply voltage is either unstable, or at a value higher than 9-volts DC, you might want to use some form of voltage regulation. In

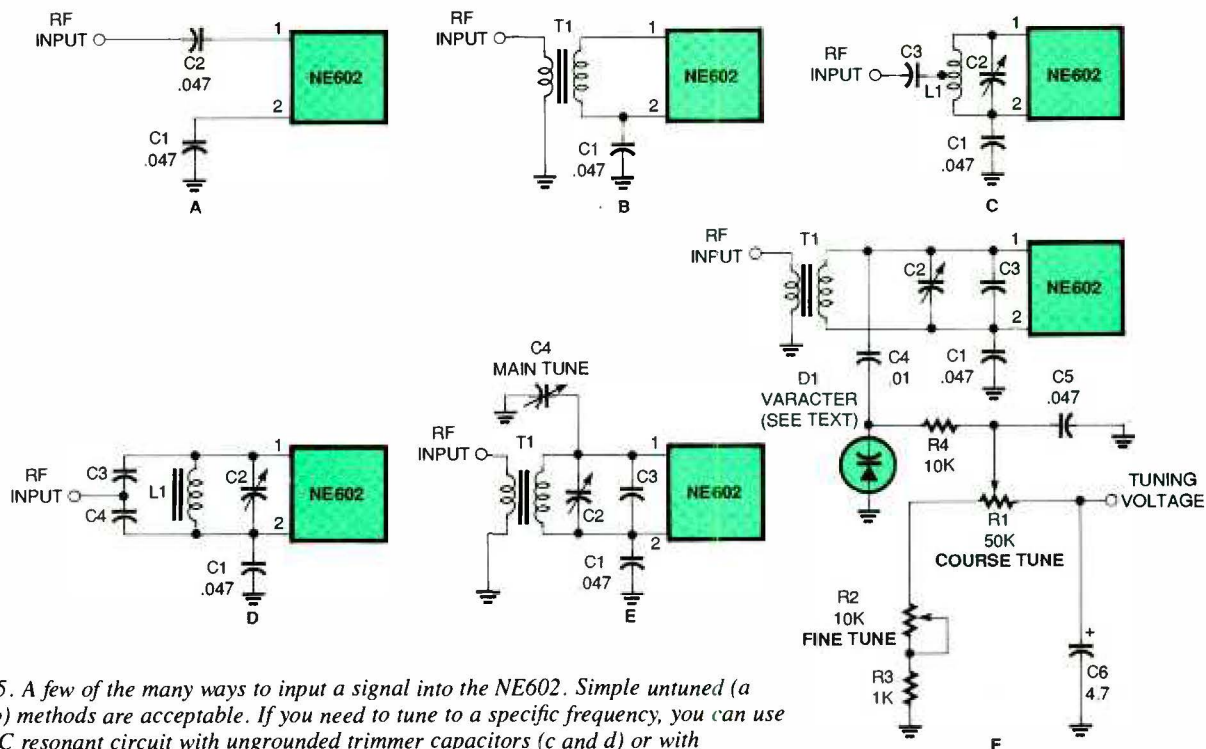


Fig. 5. A few of the many ways to input a signal into the NE602. Simple untuned (a and b) methods are acceptable. If you need to tune to a specific frequency, you can use an L-C resonant circuit with ungrounded trimmer capacitors (c and d) or with grounded variable capacitors (e). You can even use a tuning voltage in connection with a varactor (f).

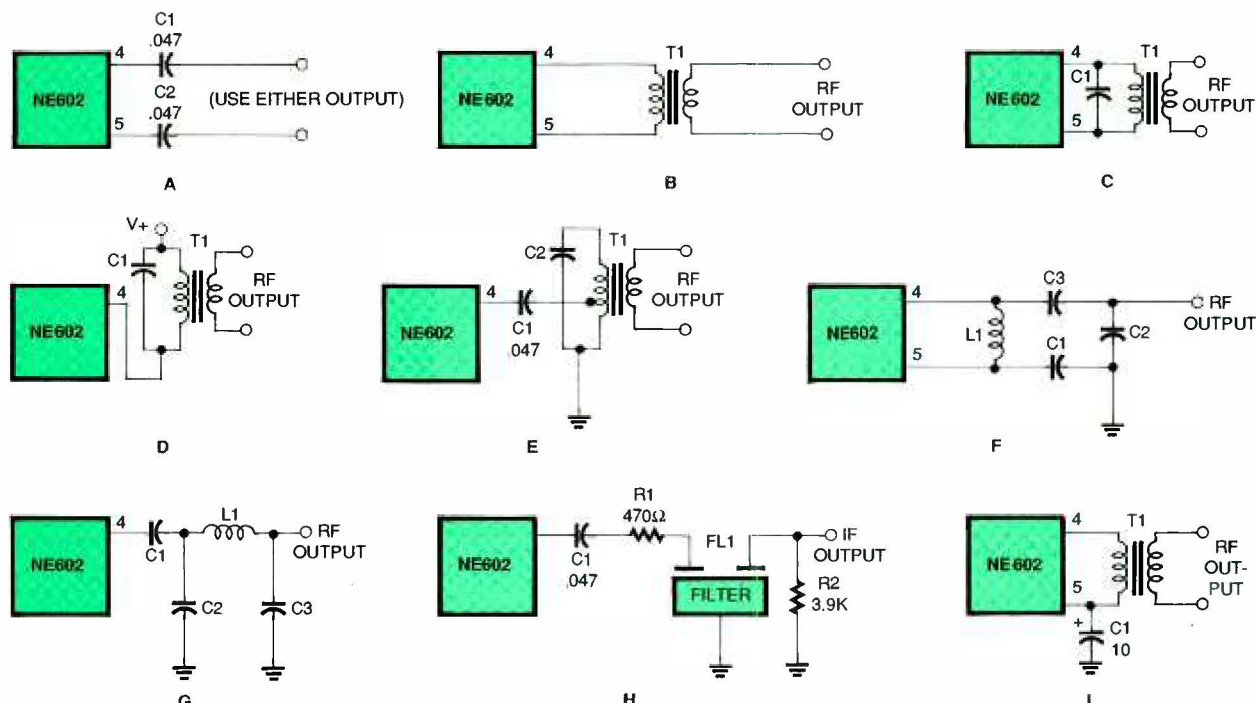


Fig. 6. The various output circuits shown here demonstrate how to either pass all the frequencies from the NE602, or allow only the sum or difference frequencies through, depending on which circuit is used.

fact, that's highly recommended. Figure 4-c shows the use of a Zener diode, rated at 6.8-volts DC, which keeps the supply voltage seen by the NE602 at that level even though the source power supply voltage might

vary from 9 to 18 volts, or so.

The use of a three-terminal voltage regulator is shown in Fig. 4-d. Those devices provide a constant output voltage for a wide range of DC input voltages. A typical voltage regulator

can accept input voltages from a minimum of about 2.5-volts higher than its rated output voltage, up to a maximum of about 30 to 38 volts. Almost any positive voltage regulator can be used in the circuit of Fig. 4-d if it

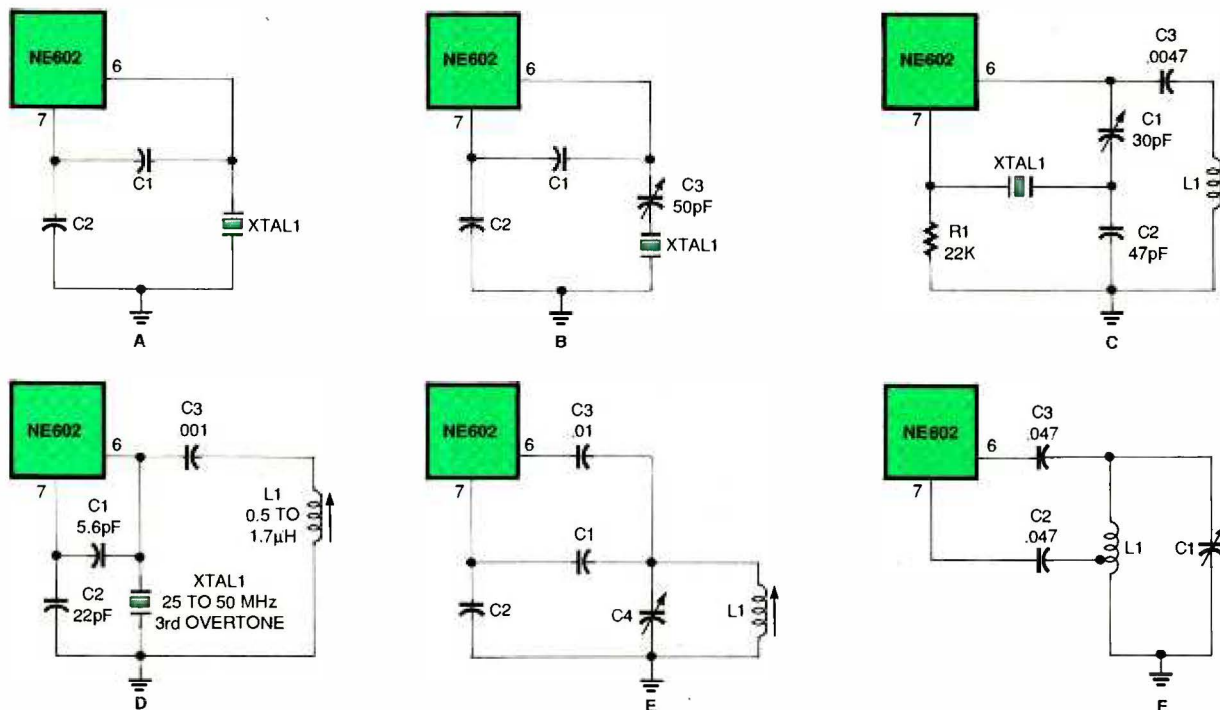


Fig. 7. The local oscillator for the NE602 can take the form of either a crystal-controlled (a through d) or a resonant-tank circuit (e and f).

has the correct output-voltage rating. The 78xx series and the LM-340-xx are essentially the same devices, with the "xx" replaced by the voltage rating. For example, the 7805 is a +5-volt DC voltage regulator. Because the NE602 device has such a low current requirement, it's possible to use the low-powered 78Lxx series. Good candidates are the 78L05, 78L06, 78L08 or 78L09 devices, with the first three preferred. The value of R1 in Fig. 4-d should follow the same rules as for Figs. 4-a and 4-b.

NE602 Input Circuits. The RF input side of the NE602 uses pins 1 and 2 (IN1 or IN2), which form a differential pair. The input impedance of the NE602 at lower frequencies is about 1,500 ohms shunted by 3 pF of capacitance, while at higher frequencies it drops to about 1,000 ohms. Both balanced and unbalanced input circuits can be used on the NE602. Unless a true differential configuration is used, the signal is usually applied to pin 1, and pin 2 is bypassed to ground.

Figure 5-a shows the simplest form of input circuit. A single capacitor (0.047- μ F typical) couples the signal from the outside world to pin 1 of the NE602. The other input pin (pin 2) is bypassed to ground with another

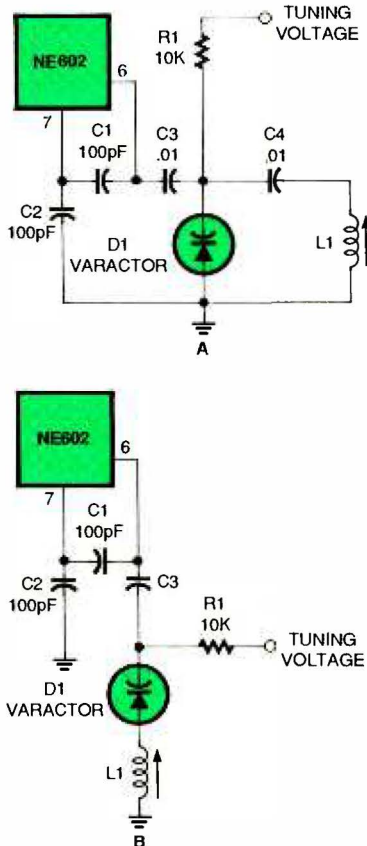


Fig. 8. The LO circuit for the NE602 can also be voltage-controlled. Here are two different methods of accomplishing that.

0.047- μ F capacitor. With that configuration, the input signal should be kept around -25 dBm, or 180-mV peak-to-peak.

The use of a wideband RF transformer is shown in Fig. 5-b. In that configuration, the secondary of a wideband transformer is connected across pins 1 and 2 of the NE602, while the primary is connected between the antenna and ground. The turns ratio of the transformer is set to transform the 1,000- to 1,500-ohm input impedance of the NE602 to the system impedance (usually 50 ohms). A general rule for the transformer is to set the inductance of the secondary winding to provide four times the NE602 input impedance at the operating frequency, or about 4,000 to 6,000 ohms. Either conventional- or toroid-wound transformers can be used for T1 in that application. As we've seen before, one input of the NE602 is decoupled to ground through a capacitor.

The circuits shown in Fig. 5-c and 5-d are tuned to a single frequency, but use different methods to provide impedance matching between the source and the input of the NE602. Of course, a capacitor could also be used to resonate the secondary of the transformer in Fig. 5-b. In Fig. 5-c, we do just that by resonating coil L1 with

variable capacitor C2. The input signal is coupled to coil L1 through an impedance-matching tap on L1 via capacitor C2. As with the other circuits, pin 2 is bypassed to ground.

The circuit in Fig. 5-d shows the use of a capacitor voltage divider (C3 and C4) to match the impedances. The resonant frequency is set by tuning L1 with variable capacitor C2, plus the series capacitance of C3 and C4. The tuning capacitance is:

$$C_{\text{tune}} = C2 + C3 \times C4 / C3 + C4$$

The circuits shown in Figs. 5-c and 5-d are used when the source impedance to be matched is less than the 1,500-ohm input impedance of the NE602 device. When a transformer input such as Figs. 5-b and 5-e are used, then the source impedance can be either higher or lower than 1,500 ohms, provided that we have the correct transformer turns ratio. One difficulty with the resonant circuits discussed earlier is the fact that the capacitor is connected across L1, which means that it must be ungrounded. That's fine as long as you can use trimmer capacitors, or somehow insulate a normally grounded variable capacitor. But it's not always practical to do that, so you can use the circuit of Fig. 5-e instead. Three tuning capacitors are used in that circuit: C2, C3 and C4. Capacitor C4 is effectively across the secondary winding of T1, provided that the value decoupling capacitor C1 is very large compared to the value of C4. In that instance, the value of the series combination of C1 and C4 is very nearly the value of C4. Capacitor C4 is used as the main tuning capacitor, while C2 is an optional trimmer capacitor for fine tuning. Also optional is C3, which is used to make up any extra capacitance required to meet a minimum value. If $C1 \gg C4$, the effective capacitance across the secondary of T1 is $C2 + C3 + C4 + 3 \text{ pF}$.

A voltage-tuned variant of the input

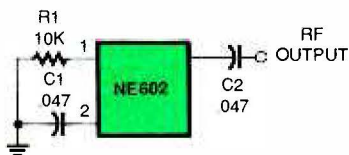


Fig. 9. If LO signal of the NE602 is sent directly to the output pins, the device can be used as a low-cost, high-frequency oscillator.

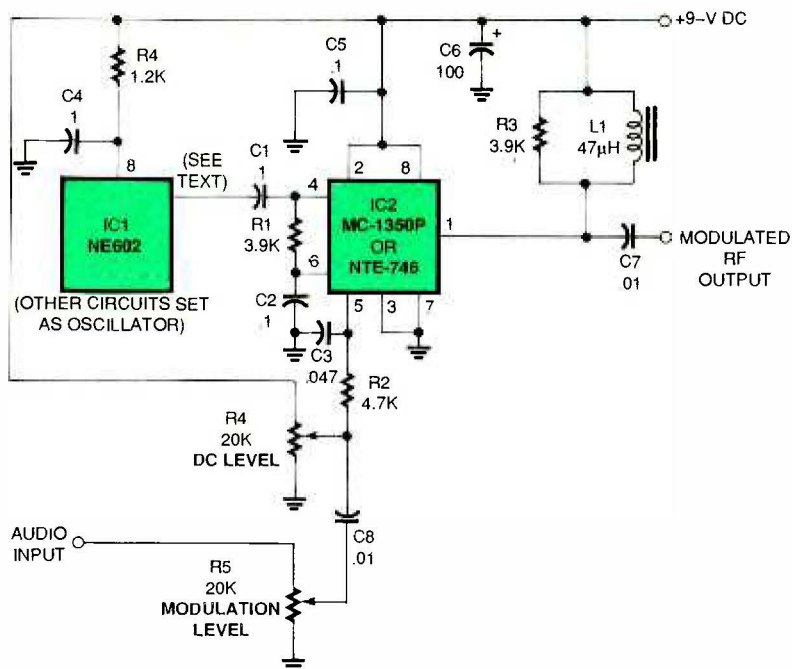


Fig. 10. By using an MC-1350P modulator IC, the output of the NE602 can easily be amplitude modulated.

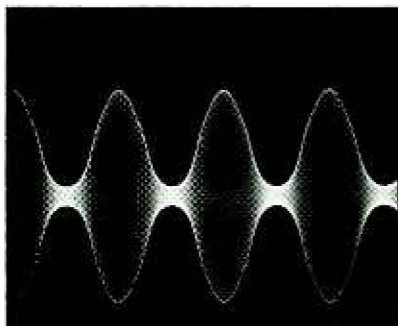


Fig. 11. This is the waveform of the circuit in Fig. 10, ready to be transmitted as an AM-radio signal.

circuit is shown in Fig. 5-f. That circuit is similar to Fig. 5-e, except that the variable "main tuning" capacitor (C4 in Fig. 5-e) is replaced with a voltage variable-capacitance (varactor) diode, D1. Those diodes provide a capacitance that drops as you increase the reverse voltage across the diode's terminals. As long as C4 is very much larger than the capacitance of D1 at any voltage, the tuning capacitance is that of D1. Resistor R1 is used to isolate the tuning voltage from the diode, so that it doesn't load the capacitance. Although a single "main tuning" potentiometer could be used, the circuit uses both coarse tune (R1) and fine tune (R2) potentiometers.

NE602 Output Circuits. The NE602

has two outputs that can be used as a balanced pair, or alone as single-ended outputs. Either pin 4 or pin 5 can be used alone for single-ended circuits, or pins 4 and 5 are used together as a balanced, or differential, output. The simplest form of output circuit is shown in Fig. 6-a. Either pin 4 or pin 5 can be used. The output signal is coupled through a 0.01- to 0.1-µF capacitor to whatever circuit the NE602 is to drive. The circuit of Fig. 6-a is a wideband configuration and cannot tell which signals are the sum ($F1 + F2$) or difference ($F1 - F2$) signals.

A wideband balanced-output circuit is shown in Fig. 6-b. The transformer is used to change the 1,500-ohm output impedance of the NE602 to the impedance of whatever circuit is being driven. If both input and output system impedances are the same, then the same type of transformer can be used for both input and output, although reversed relative to each other. As in the case of the input circuit, either standard or toroidal transformers can be used for T1.

Tuned-output circuits are shown in Figs. 6-c through 6-e. The circuit of Fig. 6-c is balanced. The primary of the transformer is connected across pins 4 and 5, and is resonated by capacitor C1. A single-ended variation is shown in Fig. 6-d. In that case, the parallel-tuned circuit consists of C1

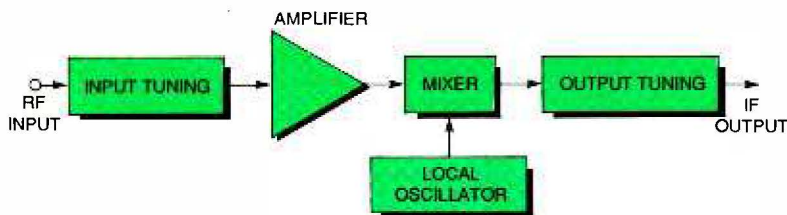


Fig. 12. If we add input and output tuning to the basic block diagram of Fig. 1-a, we can use the NE602 as a frequency translator.

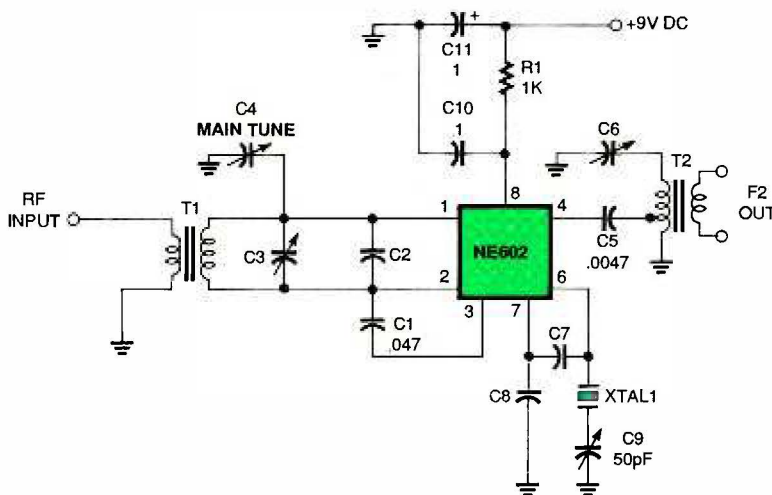


Fig. 13. This basic frequency translator/converter circuit is based on the block diagram of Fig. 12. It is useful as a demodulator in radio receivers.

and the primary of T1 as before, but the tank circuit is connected to either pin 4 or 5 and the DC-power-supply line. Another variation is shown in Fig. 6-e. There, impedance matching is provided between a higher impedance transformer primary and the output of the NE602 by using a tap on the transformer. Capacitor C1 (0.047- μ F) is used to provide DC isolation between the output and the coil. That capacitor is needed because the coil is grounded. Still another variation (not shown) connects the capacitor to the top of T1, rather than a tap. That would be a grounded version of Fig. 6-d.

Still another single-ended output configuration is shown in Fig. 6-f. The inductor (L1) is connected across the balanced outputs, pins 4 and 5, but the pin 5 end is bypassed to ground through capacitor C1. The inductor is resonated by the series combination C2/C3, which also serves as a capacitor voltage divider for impedance transformation.

The output network in Fig. 6-g is an L-C low-pass filter circuit. That configuration will select the difference IF frequency ($F1 - F2$) if the -3-dB point of

the filter is set correctly. If you want to select the sum IF frequency ($F1 + F2$), then use a high-pass L-C filter. That is done by replacing C2 and C3 with inductors, and L1 with a capacitor. The values of those components can be found using the normalized method in The ARRL Radio Amateur's Handbook (any recent edition), or by using the software FilterMaker for Windows (available from the author at P.O. Box 1099, Falls Church, VA, 22041 for \$20. VA residents should add appropriate sales tax).

The network in Fig. 6-h is for use with fixed-frequency filters such as a crystal, ceramic, or mechanical types. Such filters are used to provide the IF-bandpass characteristic in receivers, and are available with characteristics from "sorta decent" for a few bucks, to real good for \$100 and up. The center frequency of the filter is set to either the sum or difference IF, and its bandwidth is set according to application (e.g. 500 Hz for CW, 2.8 kHz for SSB, or 5 to 6 kHz for AM). An output circuit for a direct-conversion receiver is shown in Fig. 6-i. A direct-conversion receiver is similar to a superheterodyne, except that the LO and RF frequencies are

very close to each other, so that the difference is the recovered audio. For example, to receive SSB, set the LO 2.8-kHz from the RF, or to receive CW set it 400- to 1,000-Hz (depending on the tone you'd like to hear). To receive an AM signal, set the LO to exactly the same frequency as the RF. Transformer T1 in Fig. 6-i is an audio transformer. It can be a 1,000:1,000-ohm transformer if the next stage has a high impedance input, or it can be a 1,000:8-ohm audio-output transformer.

NE602 Local Oscillator Circuits.

There are two general methods for controlling the frequency of the LO in any oscillator circuit: inductor-capacitor (LC) resonant tank circuits, and piezoelectric-crystal resonators. We'll talk about both methods, starting with the crystal oscillator.

Figure 7-a shows a basic Colpitts crystal oscillator. It will operate with fundamental-mode crystals on frequencies up to about 20 MHz. The feedback network consists of a capacitor voltage divider (C1/C2). The values of those capacitors are critical, and should be approximately:

$$C1 = 100/\sqrt{F(\text{MHz})}$$

$$C2 = 1000/F(\text{MHz})$$

The values predicted by these formulas are approximate, but work well under circumstances where external stray capacitance does not dominate the total. However, the practical truth is that capacitors come in standard values and those may not be exactly the values calculated. When the capacitor values are correct, oscillation will be consistent. If you pull the crystal out, and then reinsert it, the oscillator will restart immediately. Alternatively, if the power is turned off and then back on again, the oscillator will always restart. If the capacitor values are incorrect, then the oscillator will either fail to run at all, or will operate intermittently. Generally, an increase in the capacitances will suffice to make operation consistent.

A problem with the circuit of Fig. 7-a is that the crystal frequency is not controllable except by replacing the crystal. The actual operating frequency of any crystal depends, in part, on the circuit capacitance seen by the crystal. Most crystals are designed for load capacitances of 20 or 32 pF, but

that can be specified if crystals are being ordered directly from a manufacturer. In Fig. 7-b, a variable, or "trimmer" capacitor is placed in series with the crystal in order to set the frequency. The trimmer capacitor can be adjusted to set the oscillator to the desired frequency.

The two previous crystal oscillators operate in the fundamental mode of crystal oscillation. The resonant frequency in the fundamental mode is set by the dimensions of the slab of quartz used for the crystal; the thinner the slab, the higher the frequency. Fundamental-mode crystals work reliably up to about 20 MHz, but at higher frequencies the slabs become too thin for safe operation; at that point, the thinness of the slabs of fundamental-mode crystal causes them to fracture easily. An alternative is to use overtone-mode crystals. The overtone frequency of a crystal is not necessarily an exact harmonic of the fundamental mode, but is close to it. The overtones tend to be close to odd

integer multiples of the fundamental (3rd, 5th, 7th, etc.). Overtone crystals are marked with the appropriate overtone frequency, rather than the fundamental.

Figures 7-c and 7-d are overtone-mode crystal-oscillator circuits. The circuit in Fig. 7-c is a Butler oscillator. The overtone crystal is connected between the oscillator emitter of the NE602 (pin 7) and a capacitive voltage divider that is connected between the oscillator base (pin 6) and ground. There is also an inductor in the circuit (L1) that must resonate with C1 to the overtone frequency of crystal XTAL1. Figure 7-c can use either 3rd- or 5th-overtone crystals up to about 80 MHz. The circuit in Fig. 7-d is a third-overtone crystal oscillator that works from 25 to about 50 MHz, and is simpler than Fig. 7-c.

A pair of variable-frequency oscillator (VFO) circuits are shown in Fig. 7-e and 7-f. The circuit in Fig. 7-e is a Colpitts-oscillator version, while Fig. 7-f is a Hartley-oscillator version. In both

oscillators, the resonating element is an inductor-capacitor (LC) tuned-resonant circuit. In Fig. 7-e, however, the feedback network is a tapped-capacitor voltage divider, while in Fig. 7-f it is a tap on the resonating inductor. In both cases, a DC-blocking capacitor to pin 6 is needed in order to prevent the oscillator from being DC grounded through the resistance of the inductor.

Voltage Tuned NE602 Oscillator Circuits.

Figure 8-a and 8-b show a pair of VFO circuits in which the capacitor element of the tuned circuit is a voltage-variable capacitance diode, or varactor (D1 in Fig. 8-a and 8-b). Those diodes exhibit a junction capacitance that varies in direct response to the reverse-bias voltage applied across the diode. Thus, the oscillating frequency of those circuits is controlled by a tuning voltage. The version shown in Fig. 8-a is a parallel-resonant Colpitts oscillator, while Fig. 8-b is a series-tuned Clapp oscillator.

Using the NE602 as a Signal Generator.

The NE602 is normally used as a receiver front-end or as a frequency converter. It can also be used as a signal generator. Figure 9 shows the basic configuration for providing the LO signal at output pins 4 and 5; place a 10,000-ohm resistor (R1) between pin 1 and ground, while bypassing pin 2 to ground through a 0.047- μ F capacitor. The output signal is taken from either pin 4 or 5 through another 0.047- μ F capacitor.

The output signal of Fig. 9 will be a sinewave at the frequency of oscillation for the oscillator circuit connected to pins 6 and 7. That signal can be swept or frequency modulated by using one of the varactor LO circuits shown in Fig. 8. To sweep the frequency, make the tuning voltage a sawtooth waveform, while to frequency-modulate it, use a sinewave. If you want to amplitude-modulate the signal, then use a circuit such as Fig. 10.

The signal source is any of the NE602 oscillators (IC1 in Fig. 10), while the modulator is IC2, an MC-1350P chip. That chip is also available from the service-repair industry replacement lines as the NTE-746 or ECG-746. It is an RF-gain block with a gain-control terminal (pin 5), and that gain-control terminal can be used for the

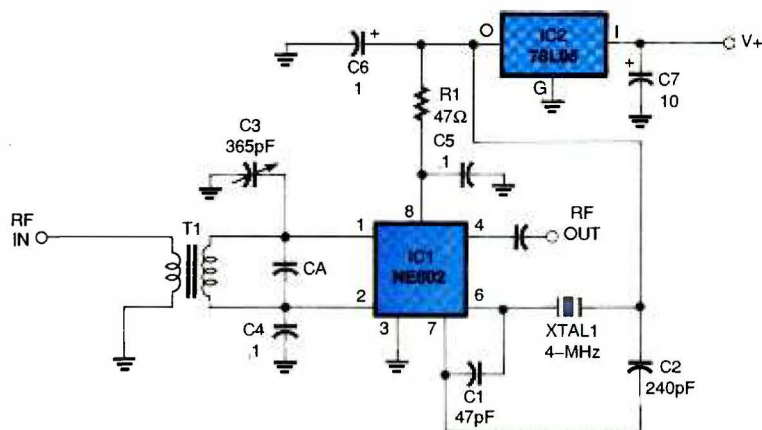


Fig. 14. Here is another simple frequency translator circuit; it does not select which frequency appears at the output.

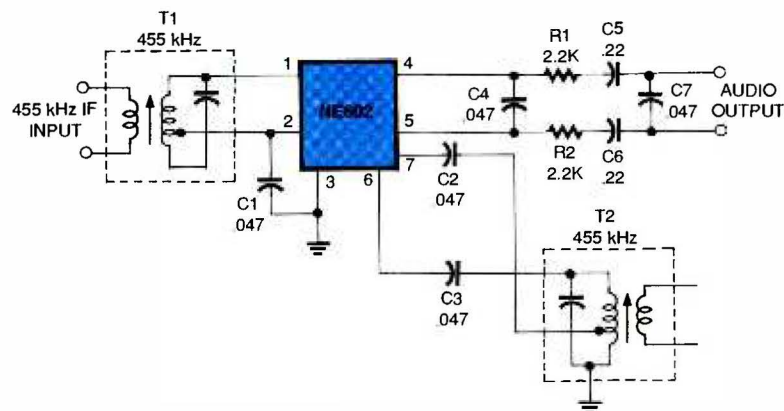


Fig. 15. After you've tuned in a particular radio frequency and demodulated it, this product-detector circuit can be used for Morse code (CW) or single-side band (SSB) reception.

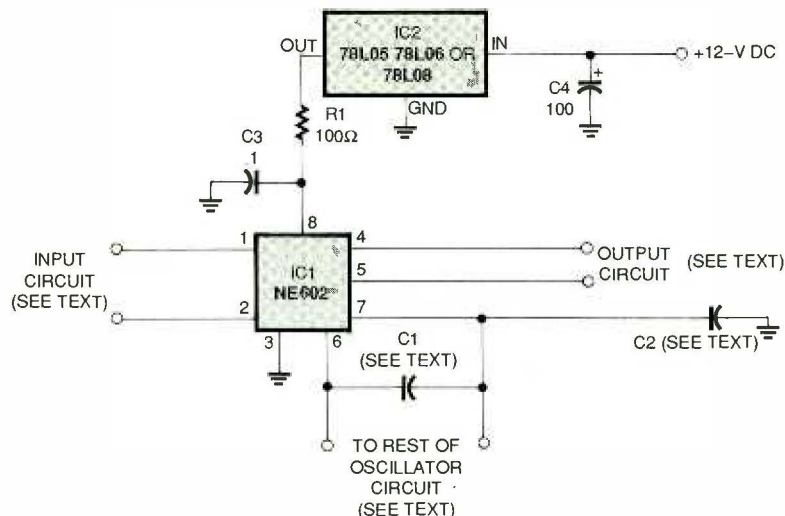


Fig. 16. There is just enough circuitry on the universal project board for NE602 to get you up and running with many different projects.

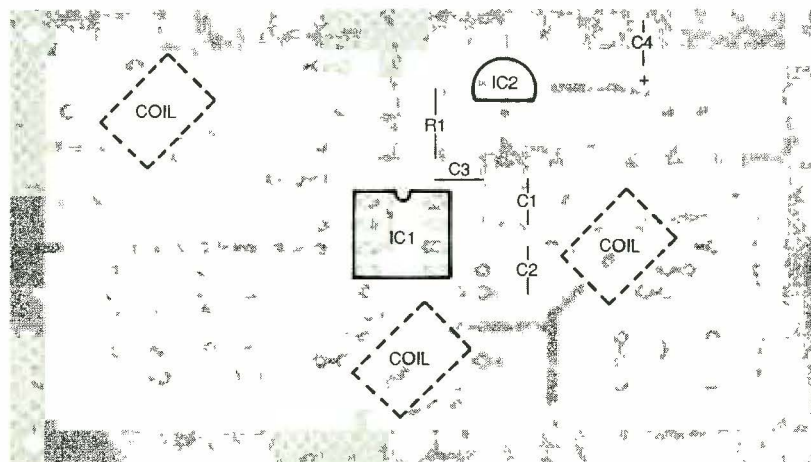
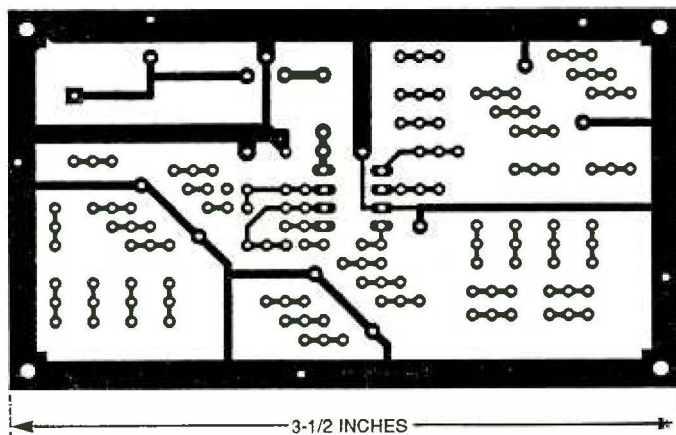


Fig. 17. Component placement on the universal project board leaves plenty of room for your own circuitry.



Here's the foil pattern for the NE602 universal project board. Many stand-alone pads are included to hold your circuitry.

amplitude-modulation function. Two signals are applied to the gain-control terminal as shown in Fig. 10; a DC level from potentiometer R4, and the

audio signal from the MODULATION LEVEL control (R5). Adjust both DC LEVEL and MODULATION LEVEL until the output signal, as viewed on an oscilloscope, looks

like Fig. 11. There should be good symmetry and no clipping of the peaks.

Using the NE602 in Converter Projects.

The basic frequency converter was shown in block form back in Fig. 1-a; now it is time to expand upon that as shown in Fig. 12. The NE602 and its supporting circuitry might be used as the mixer and local oscillator. The amplifier is optional, and should only be used when sensitivity is poor. Poor sensitivity might be caused when insertion loss of the input tuning network is high.

The input and output tuning networks are used to segregate the signals. The input tuning selects the desired RF-input frequency (F_1), and rejects all other frequencies. The output tuning network selects either $F_1 - F_2$ (difference), or $F_1 + F_2$ (sum) signals. Those filters can be L-C resonant-tank circuits, low-pass filters, high-pass filters, or band-pass filters as needed for the specific application.

Figure 13 shows a basic NE602 frequency-converter circuit. The input circuit consists of a transformer with a secondary winding resonated by C2, C3, and C4. The LO circuit is a crystal Colpitts circuit that uses a trimmer capacitor (C9) for adjusting the oscillation frequency over a small range. The output circuit is a variant of the parallel-resonant tank circuit in which the primary of the transformer (T2) is tapped to match the impedance of the NE602 output to the coil.

Another variant is shown in Fig. 14. That circuit is similar, except that the output is not tuned. The reason for that approach is that the frequency converter is used to drive the antenna input of a radio receiver, which performs the frequency selection (sum vs. difference) function.

Using the NE602 as a Product Detector.

Figure 15 shows the circuit for a product detector based on the NE602. A product detector is a frequency converter that sets the LO frequency close enough to the RF or IF signal so a single-sideband (SSB) or CW signal is demodulated. For example, a 455-kHz IF signal from a receiver can be converted to an 800-Hz CW audio output ("beep-beep") by using an LO at 455.8 kHz or 454.2 kHz. The difference tone is found in the output.

(Continued on page 79)

BUILD THE PCDRILL

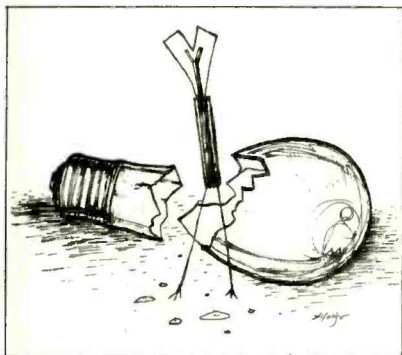
(Continued from page 46)

the compiled version. (Look for PCDRILL.ZIP on the Gernsback FTP site —ftp.gernsback.com/pub/EN).

Select each of the first four options in turn. The table and the drill should move in the selected direction. The test program moves the table and caddy in "slow motion," but real applications (like the one that will be presented next time) produce quicker and smoother movement. If either motor stalls and the table or drill does not move, the associated guide is probably jamming against the track. Adjust the guide and try again. Repeat the process until both table and caddy move smoothly throughout the entire range of travel.

Several tweaks can improve the performance of PCDrill. For instance, apply paste wax to all moving wooden surfaces, including the drill caddy sides and drill slides. All moving metal surfaces should get a thin coat of light oil. That includes the driver nuts, threaded rods, and aluminum angle tracks. Those lubrication efforts will decrease friction and make for smoother operation.

Next time we'll align PCDrill, and introduce the application program and all of its functions. We'll also look at the application's data file and explain each of its entries, including the Speed entry that maximizes speed of movement. We'll also provide details for building a 5.75-volt power supply from scratch, and use PCDrill to fabricate its own PC board. To round things out, we'll provide an AC wiring option that allows you to energize the drill only during actual drilling, as opposed to having the drill run continuously. See you then. Ω



CONDUCTANCE ADAPTER

(Continued from page 63)

keep the input leads short to avoid 60-Hz line pickup. Although the ICs used in the Conductance Adapter are ESD protected, you should avoid letting any static discharges into J1 or J2.

Connect a 1-megohm resistor to J1 and J2 and the output on a DVM will be 1.000 volts, which is equal to 1.00 micromho or 1000 nanomhos. A 300-megohm resistor will read 3.33 millivolts, which is equal to 3.33 nanomhos. A diode (shown as D_x in Fig. 1) might show a reading of 2.55 millivolts when reverse biased. That is equal to a leakage current of 2.55 nanoamps. Leakages can be measured down to 10 picoamps. If you need a voltage greater than -1.00 volt for your tests, do not make any connection to J1. Apply an external voltage between the ground jack (J3) and the free lead of the device being tested. Do not let any voltages applied to J2 exceed 3 volts, or IC2 will be destroyed. Ω



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USING THE NE602

(Continued from page 54)

If the signal is an SSB signal, then the LO is set at a frequency of 2.5- to 2.8-kHz higher or lower than the IF, depending on whether you want to demodulate an upper-sideband (USB) or lower-sideband (LSB) signal.

The input signal circuit in Fig. 15 uses a 455-kHz IF transformer of the sort used for transistor radios (see Digi-Key or Mouser catalogs for suitable types). The transformer that you want to use for T1 is the type that has a resonant secondary with a tapped inductance. The LO circuit uses the same type of transformer as the input, but configured as a Hartley oscillator.

The output signal is at audio frequencies, and is filtered by an R-C network. The audio output is balanced, so it should be fed to a differential audio amplifier such as an op-amp.

NE602 "Universal" Project Board.

We've included a printed circuit pattern for a "universal" project board based on the NE602. The on-board circuitry (Fig. 16) is limited to the DC power connection, which is regulated by a three-terminal IC voltage regulator. All other functions can be set by you to make any project that you want. There are a large number of multi-pad stand-alone connections for various components depending on the circuit that you want to make, as well as positions for three six-pin standard shielded coils of the sort manufactured by Toko and sold by Digi-Key. You can also use these same holes for mounting home-brew toroid inductors. Figure 17 shows the parts placement of the universal project board. The universal NE602 board can be bought from FAR Circuits, 18N640 Field Court, Dundee, IL, 60118 for \$4 plus \$1.50 shipping for every four boards ordered (i.e. 1 to 4 boards shipped for \$1.50). IL residents will have to add appropriate sales tax.

Now you've seen how well-behaved the NE602 is. Here is an RF chip that will function in a variety of applications from receivers, to converters, to oscillators, to signal generators. With the universal project board, the task of testing a new design based on the NE602 becomes "duck soup." Ω