 FREQUENCY CONVERTERS ARE BASIC building blocks of RF equipment. You'll find them wherever there's a need to shift the RF carrier of a signal from one frequency to another, such as in any modern radio receiver.

Frequency conversion, or heterodyning, is the process of mixing an incoming signal with that of a Local Oscillator (LO), as shown in Fig. 1. Two signals result from mixing, their frequencies being the sum and difference of those of the originals. Thus, a 9-MHz input and a 2-MHz LO yield outputs of 7 and 11 MHz.

Building a frequency converter is easier now than it's ever been because of a new IC, the Signetics NE602. The NE602 contains an LO and double-balanced mixer in an 8-pin DIP, as shown in Fig. 2, a block diagram of the IC. The NE602 was originally designed for VHF receiver front ends, since the LO works up to 200 MHz, and the mixer to 500 MHz. However, it has plenty of uses at lower frequencies as well, and this article will explore them.

Circuit description

The NE602 uses a double-balanced mixer, producing only the sum and difference frequencies, not that of the RF input or LO. You can thus connect the output of an NE602 directly to a receiver without overloading it. With a conventional mixer, you'd have to add a tuned LC circuit to eliminate the LO output. The NE602 LO is also well isolated from its RF input; you can thus connect a receiving antenna directly to the RF input terminals of the IC without worrying about radiating the LO signal back out through the antenna. This is important in direct-conversion receivers, where the LO frequency is so close to that of the input, that the two can't be isolated by a tuned LC circuit.

The combination of the differential amplifier and mixer in the NE602 is known as a Gilbert cell. The mixer has on-board voltage regulation, and draws 2.5–3 mA at 4.5–8 volts. For best performance, bypass the power supply with a 0.04-µF capacitor as close to the IC as possible. The absolute maximum supply voltage is 9.0 volts, but a 9-volt battery often exceeds that, and 9-volt wall transformers often deliver as much as 11 volts. For safety, use 1000-ohm dropping resistor R1 as shown in Fig. 3; using a Zener diode, you can use automotive power supplies up to 18 volts.

The RF input and mixer output can be either single-ended or balanced as shown in Figs. 4 and 5. Using a balanced input reduces harmonics, while a balanced output gives better suppression of the input RF and LO signals. However, even in the simplest single-ended configuration, the NE602 gives much better performance than the one-transistor mixer commonly found in receivers.

The input and output impedances of the NE602 are about 1.5K at low frequencies, and decrease with increasing frequency. The input signal should be weak to prevent harmonics; the third-order intercept point is for a -15 dBm input, but the recommended
The input signal is amplified prior to mixing; the voltage gain is about 10. Thus, a receiving converter built with the NE602 can increase a receiver's sensitivity. The NE602 LO is a transistor with connections to its base and emitter, with biasing handled on the chip. That makes it easy to build many different oscillator types with few external components.

Figure 6 shows some of the main versions; there are many others. The NE602 can be used as an oscillator without the mixer. One way is to sample the LO output at pin 7; a better way is to unbalance the mixer and use it to amplify the LO signal, as shown in Fig. 7. The unbalance is created by a 10K resistor from one input pin to ground, which changes the bias voltage slightly. The output level of such an oscillator is about 0.5 VAC P-P.

**Basic crystal oscillator**

Many frequency converters are crystal-controlled; Fig. 8 shows the most basic version. The low side of XTAL1 and C2 can be returned either to ground or to VCC; the latter is more compact, because pins 6 and 7 are adjacent to VCC (pin 8). The values of C1 and C2 are important. If C1 is too large, or C2 is too small, there's too much feedback and the oscillator waveform is distorted, with a strong third harmonic. If C1 is too small or C2 is too large, oscillation doesn't occur.

Some suggested values for C1 and C2 are shown in Fig. 6 along with formulae for calculating them. At high frequencies, C1 can be somewhat than the value shown because stray capacitance does some of the work. The values shown are for the best sinusoid. If you want to be sure that a relatively inactive crystal will oscillate and don't mind harmonics, make C1 three times larger. The third harmonic from such a circuit could be used for VHF. There's also a lower frequency limit; the unmodified circuit will oscillate with a 455-kHz ceramic resonator, but not a 100-kHz crystal. Adding 22K from pin 7 to ground will increase the oscillator gain, and improve your chances with low-frequency crystals.

**Precise frequency control**

A crystal won't necessarily oscillate at its exact rated frequency. There are two kinds, series- and parallel-resonant. They're electrically identical, the only difference being that series-resonant crystals are cut to an exact frequency, whereas parallel-resonant crystals are cut slightly longer, so as to resonate independently slightly below their rated frequency. For that reason, parallel-resonant
FIG. 5.—OUTPUT CONFIGURATIONS. Here, (a) is the simplest single-ended approach without impedance matching, (b) is a single-ended approach for a tuned LC circuit load, and (c) is for a balanced approach for better suppression of input and LO signals.

FIG. 6.—BASIC NE602 OSCILLATOR CIRCUITS; (a) is Colpitts crystal-controlled, (b) is Colpitts LC-tank-controlled, (c) is Hartley LC-tank-controlled, and (d) is controlled by an external oscillator. Many other configurations are possible.

FIG. 7.—THIS IS A GENERAL CONFIGURATION for an NE602. To make an LO signal appear at OUT A (pin 4) and OUT B (pin 5), IN A (pin 1) is grounded through R1.

crystals need external capacitors (usually 32 pF) to increase their actual frequency of oscillation to their rated value. In Fig. 8, C1 is this capacitor, but it’s usually larger than 32 pF and has less effect than the one depicted here.

Thus, at 10 MHz, parallel-resonant crystals oscillate about 100 parts per million (ppm) below their rated frequency, while series crystals resonate about 300 ppm above. A parallel-resonant crystal can be pulled up to its rated frequency using a small variable capacitor in series with it, as in Fig. 9, letting you adjust the oscillator as desired. However, even without this capacitor, the frequency error won’t be more than 300 ppm (0.03%).

Overtone crystal oscillator

Above 20 MHz, crystals oscillate in overtone mode, and the oscillator

data sheet recommends a modified Colpitts oscillator for overtone crystals, but the Butler oscillator in Fig. 10 gives much better results. Its crystal is series-resonant, and L1 and C1 are tuned to the crystal frequency.

This circuit is reliable to at least 60 MHz. Just adjust L1 and C1 until oscillation occurs. By adjusting this tuned LC circuit, you can trim the frequency by about 50 ppm; for greater variation, use a parallel-resonant crystal in series with a variable capacitor for adjustments.

Frequency doubler

Figure 11 shows a crystal-controlled frequency doubler with no tuned LC circuits. That circuit is useful in the 20-40 MHz range, but the same method could be used with overtone crystal oscillators for even higher output frequencies.

The doubling is achieved by feeding the LO from pin 7 into the mixer. The output is $2 \times f$ (where $f$ is the oscillator fundamental frequency), while the difference frequency is zero (or DC), disappearing due to capacitive coupling. The output still contains some energy at the LO frequency and isn’t pure, but is good enough for hobbyist purposes. A tuned LC circuit can easily provide pure output. Of the oscillators shown here, this is the only one that can’t be used with the mixer, because one mixer input is occupied (although you could feed a signal to the other mixer input).

Figure 12 shows a Colpitts LC oscillator using coils and capacitors. Here, L1 forms a resonant circuit with C1 and C2 in series, plus C4 in parallel. Also, C3 blocks DC from pin 6 to $V_{cc}$ or ground; it has little effect on the resonant frequency. Figure 12 also gives formulas for component values. At very high frequencies, a 22K resistor from pin 7 to ground (not $V_{cc}$) will change the bias point and increase gain.
Longwave receiver converter

Figure 13 shows a frequency converter front end for a shortwave receiver to receive longwave signals (350–500 kHz) up to 4.35–4.5 MHz, enabling them to be received via a shortwave receiver plugged into J1.

Direct-conversion receiver

A frequency converter can shift frequencies up or down. However, if you shift an RF signal down to audio, you get an audio signal. This is called direct-conversion reception, and can demodulate Single-Sideband (SSB) and Morse code Continuous-Wave (CW) transmissions. It demodulates AM, but there’s a whine if the tuning isn’t perfect.

Figure 14 shows such a direct-conversion receiver for the 40 meter band (7.5 MHz), that was able to receive several amateur radio stations using a 3-foot whip antenna. The design could be refined; tuning would be easier with a variable capacitor instead of an adjustable coil.

Conclusion

There are basically three RF circuit types—amplifiers, oscillators, and frequency converters. The NE602 makes frequency conversion easier than ever. Both it and related IC’s will eventually become basic building blocks of RF design. This article has only scratched the surface of the possibilities for the NE602. In an IF section, it makes a good product detector. By mixing audio with RF, it can act as an AM or DSB modulator. By mixing audio with audio, the

NE602 can be the heart of an ultrasonic listener (by down-converting high-frequency audio) or a speech scrambler to add security to telephone conversations.

You can get NE602’s at $2.00 each, plus $2.50 per order postage and handling per order, from the Small Parts Center, 6818 Meese Drive, Lansing, MI 48911, (517) 882-6447; there’s no minimum order. They’re are also available from Arrow Electronics, Schweber Electronics, and many other Signetics distributors, with $25.00 typical minimum orders. Be sure to specify whether you want the NE602N (8-pin DIP) or NE602D (surface mount package).

You also may prefer to order the NE602A, which will be replacing the NE602 imminently; it has somewhat improved intercept characteristics, resulting in less harmonic generation and intermodulation distortion. To specify the desired package type, you’d refer to the NE602AN or NE602AD. We would like to thank Phil Anzalone, Ali Fotowat, and Craig Hirtz of Signetics for their invaluable assistance in preparing this article.

POWER LINE GLITCHES

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13–16. Figure 13 shows a normal power sinusoid, Fig. 14 shows harmonic distortion, Fig. 15 shows a brief glitch, and Fig. 16 shows a brief power outage.

Conclusion

Those graphs shown in Figs. 8–16 show only a few of many possible disturbances. Power glitches are common and readily identified. Most are easily fixed, the culprit often being poor wiring, bad grounding, or load switching—all can be corrected cheaply. The most common, practical countermeasure is to install a separate power line from the circuit-breaker box involved to the device being interfered with, like a PC.

Power monitors make identification easy, but they’re generally too expensive, and would be needed too infrequently, to warrant purchase by the average hobbyist. They can, however, be rented for short periods, on an as-needed basis, letting you derive the benefits of their technology without making a major investment.