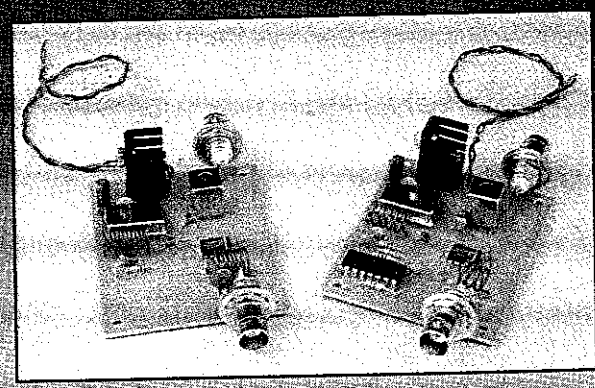
By Rod Kreuter, WA3ENK

Junk-Box Converters for 6 and 2 Meters



These simple 6 and 2-meter converters are enjoyable projects that don't take much time to assemble, use a minimum number of parts and won't give you "wallet wince." The 6-meter converter is on the left, the 2-meter unit (with a few more parts) is to the right. A small finned heat sink (the black, vertical object) keeps the voltage regulator cool. Each board has an oscillator module—the flat, horizontal, silver-colored rectangle. The silver-colored vertical object is the IF-output transformer.

These easy-to-build hearing aids use a common PC board and are a snap to build!

Bob Auraud, K3VOT, a friend of mine, has been working on some 6-meter homebrew gear. While checking different transmitters, Bob and I did some on-the-air testing. We discovered that, sometimes, saying the transmitted audio "sounds a little funny" isn't quite enough to pinpoint a problem. Anyone who has tried this knows what I mean.

Bob doesn't have much ham gear now, but he does own a general-coverage 0.5 to 30-MHz receiver. I decided that I'd throw together a simple 6-meter to 10-MHz converter to help him monitor his transmitter. Simple converters are much easier to make today than they were years ago. The one I made for Bob works so well, he suggested other hams might like to build one. So encouraged, I worked up a companion 2-meter to 16-MHz converter. Each converter can be built for less than $30. A good bit of that cash outlay will be for the enclosure, on/off switch and connectors. If you have a well-stocked junk box, you'll spend less.

I call these "junk-box" converters because *I* didn't have to buy anything to build them. Of course, my wife, Joyce, KA3SWK, feels few hams have a four-bedroom junkbox. your situation may be different, but let's take a look at the circuits.

Overview

Four technologies have made simple VHF converters easier to build than ever. These include readily available:

- General-coverage (100-kHz to 30-MHz) receivers

Years ago, you d probably have to own *two* receivers to have general coverage capability. Most ham-shack receivers then covered the ham bands only. (Nowadays, most MF/HF ham transceivers have built-in general-coverage receivers—and transmitters). HF-band-only coverage limited our choice of IF and LO frequencies when using VHF-to-HF converters. Many times, odd-frequency crystals (such as 43.333 MHz) were needed. Even then, an entire amateur VHF band couldn't be covered easily because it's much wider than the HF-band amateur assignments. As an extreme example, take an HF radio that tunes 14 to 14.35 MHz: Both 6 meters and 2 meters are 4 MHz wide. With an HF-band tuning range of only 350 kHz on 20 meters, we need *12 crystals* to tune the entire 6 and 2-meter bands—and lots of switching!

- Low-cost (less than $5) oscillator modules

The microprocessor and digital world provides us with dozens of easy-to-use, low-cost oscillator modules. A glance through almost any electronic parts catalog will disclose many modules (costing as little as $2 each) operating at various frequencies. Often, you can find the oscillator module you need sitting on a scrap computer video card or motherboard. For $2, I've bought such boards holding as many as six oscillators!

Such oscillators are quite stable, and it doesn't take much to get them running: You simply hook them up to +5 V and ground and they oscillate. On the other hand, they're not fantastically accurate (their output may not be the frequency marked on their enclosure).

- Low-cost (less than $3) IC mixers

The NE602 has become a staple of the RF world. It sure makes it pretty easy to throw together a mixer/oscillator. Other diode mixers could also be used but it's hard to beat a '602 for simplicity.

- Easy-to-make PC boards

I've been using the DynaArt[1] "sugar paper" method for about two years. I find it's very easy to produce single-sided PC boards.

About the Converters

These converters *are*: low-cost and easy to duplicate. Because the oscillator is already built, it is fairly easy to get these converters working without any test equipment. These converters *are not*: state-of-the-art, low-noise EME converters and high-dynamic-range pileup busters.

Refer to Figure 1A and B. Each converter has an LO (U2) and a mixer (U1, the NE602). For the sake of simplicity, neither converter has an additional RF or IF amplifier. U1 combines the LO signal and the desired incoming signal from J1, to produce a third—*intermediate*—frequency, or IF, output at J2 to the HF receiver. The LO operates at a frequency *lower* than the incoming frequency (*low-side* injection). U3, a 7805 voltage regulator, ensures that the circuit receives a steady 5 V dc. U3 is equipped with a heat sink.

The NE602

The heart of each converter is a Signetics NE602 mixer/oscillator IC. The workings of the NE602 have been covered in other articles.[2] These circuits differ from other NE602 designs in that I don't use the IC's internal oscillator.

In the NE602 is an emitter follower, intended for use as an oscillator. The transistor's base and emitter are readily available at pins 6 and 7, respectively. Energy from the LO (U2) is coupled to the transistor's base via a low-value capacitor (C9). The data book recommends a drive of 200 to 300 mV RMS (570 to 850 mV P-P) as optimum. Measuring the oscillator drive to the NE602 is difficult because of the small-value coupling capacitor used. Almost any scope probe exhibits more capacitance than the

[1]Notes appear on page 34.

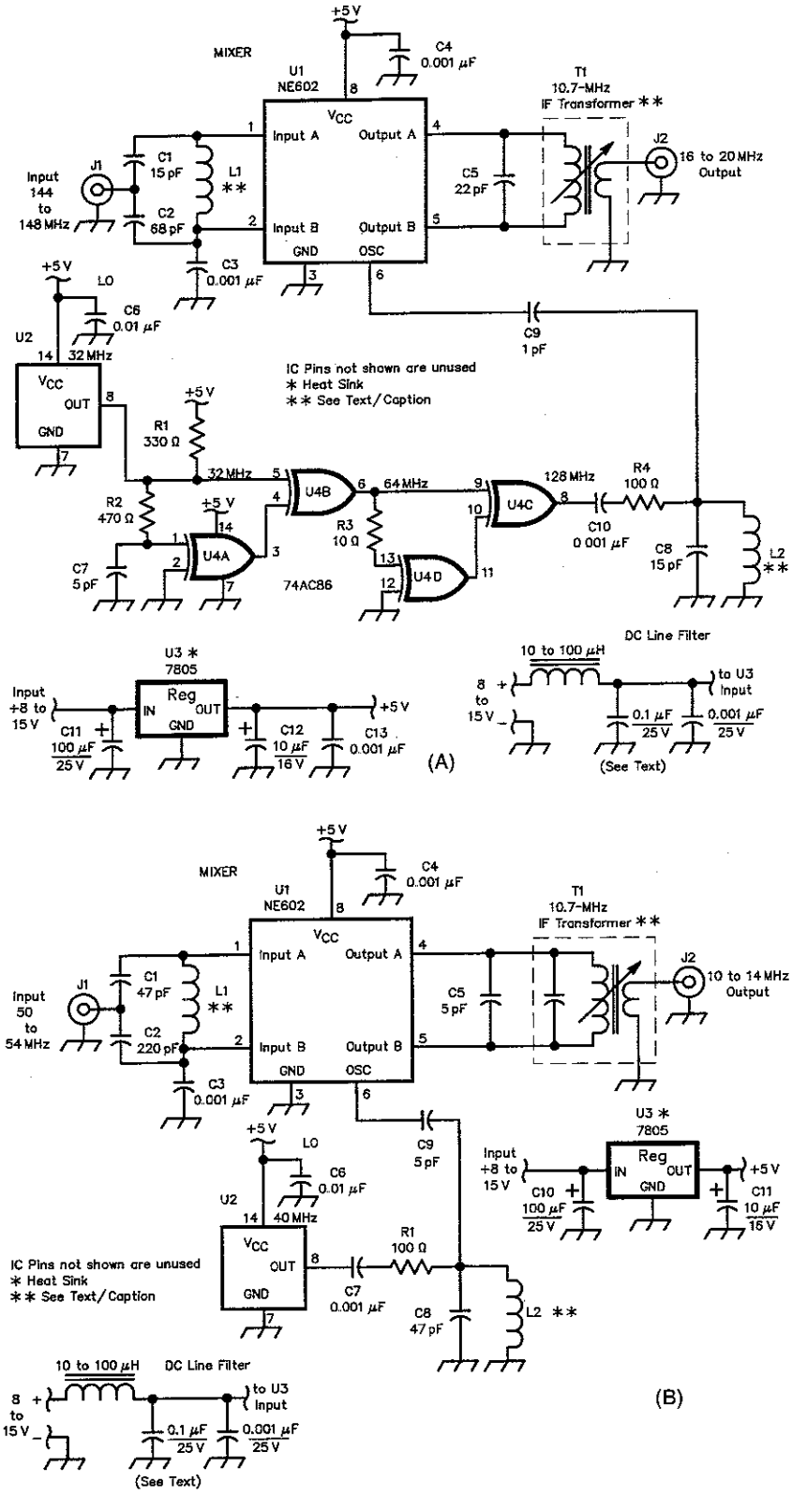


Figure 1—Schematics of the 2-meter (A) and 6-meter (B) converters. The insert shows a simple method of providing some dc-line filtering. Equivalent parts can be substituted. Unless otherwise specified, resistors are 1/4-W, 5%-tolerance carbon-composition or film units. Parts are available from these and other distributors: DC Electronics, PO Box 3203, Scottsdale, AZ 85257, tel 800-467-7736, 602-945-7736; fax 602-994-7707 (DC). Digi-Key Corp, 701 Brooks Ave S, Thief River Falls, MN 56701-0677, tel 800-344-4539, 218-681-6674; fax 218-681-3380, **http://www/digikey.com** (DK). Mouser Electronics, 2401 Hwy 287 N, Mansfield, TX 76063-4827, tel 800-346-6873, 817-483-4422; fax: 817-483-0931, **http://www.mouser.com** (ME). Hosfelt Electronics, Inc, 2700 Sunset Blvd, Steubenville, OH 43952-1158, tel 800-524-6464, 614-264-6464; fax 800-524-5414 (HEI). Ocean State Electronics, 6 Industrial Dr, Westerly, RI 02891, tel 800-866-6626, 401-596-3080, fax 401-596-3590 (OS), and Radio Shack (RS).

J1, J2—BNC or other connector
L1—6 meters: 8 turns 0.25 inch diam #20 enameled wire, 0.4 in. long; 2 meters: 4 turns 0.25 inch diam #20 enameled wire, 0.4 inch long
L2—6 meters: 10 turns 0.25 in. diam #20 enameled wire 0.55 in. long; 2 meters: 5 turns 0.25 inch diam #20 enameled wire, 0.55 in. long
T1—10.7-MHz IF transformer; 15-kΩ pri, 300-Ω sec (ME 42IF122); for the 2-meter converter, modify per text.
U1—NE602A mixer/oscillator (DC, OS)
U2—TTL oscillator module, 14-pin DIP; 32 MHz for 2 meters, 40 MHz for 6 meters; (DK, HEI, ME, OS)
U3—7805 3-terminal, 5-V, 1-A voltage regulator; equip with heat sink (DK, HEI, ME, OS, RS)
U4—74AC86 quad 2-input **XOR** gate (DK 74AC86PC)
Misc: TO-220 heat sink, PC board, enclosure, solder lugs for BNC connectors, assorted hardware

coupling capacitor, so connecting a probe to the '602 is a waste of time. The best way to check the drive is to assume it's okay and test the converter!

2-Meter Converter

I was lazy (and perhaps a bit cocky) when I designed the 2-meter converter. I wanted to use the 40-MHz oscillator circuit that I had used in the 6-meter converter and simply tune the LC tank to its third harmonic at 120 MHz (square waves have lots of energy at their odd harmonics). That went fairly well, but I hadn't stopped to think about what I had done. As I tuned down from the local repeaters toward the SSB portion of the band, all I could hear were commercial FM stations! I'd forgotten to consider the *image* frequency! Recall that at least two frequencies can mix with the LO and produce an output at the IF. What I wanted was:

144 MHz (input) –120 MHz (LO) = 24 MHz (output)
148 MHz (input) –120 MHz (LO) = 28 MHz (output)

What I forgot to consider was:

120 MHz (LO) – 96 MHz (input) = 24 MHz (output)
120 MHz (LO) – 92 MHz (input) = 28 MHz (output)

Therefore, commercial FM stations on frequencies between 92 and 96 MHz appeared at the output of the 2-meter converter. Worst of all, the stations in that range run a *lot* of power and use big antennas. Back to the proverbial drawing board.

There seemed to be three ways to get

around the image problem: (1) Use an image-reject mixer. Possible, but it takes quite a bit of circuitry; (2) put a *really good* filter in front of the converter.[3] Again it's possible, but it would be hard to tune, etc; (3) use an LO that produces an image that falls outside the FM band. The latter seemed like the logical path, but a little math showed that the lowest-frequency LO that could be used that didn't produce an image in the FM broadcast band was 128 MHz. I know of no one selling oscillator modules whose third, fifth, or seventh harmonic is close enough to 128 MHz. I decided on a different approach.

Most commercial oscillator modules are designed to work in the digital world and therefore produce a square wave at the output. A square wave contains a fundamental frequency and a series of odd harmonics (third, fifth, seventh, etc). The higher the order, the less energy the square wave contains. For example, there is more third-harmonic energy in a square wave than there is seventh-harmonic energy.

If you want energy at the third harmonic—say 120 MHz from a 40-MHz oscillator—you simply tune an LC tank to 120 MHz and filter out the unwanted frequencies. This is a little understated, perhaps, but not much.

But what about obtaining *even-order* products, such as deriving 128 MHz from a 32-MHz oscillator? That's not as easy to do. Because there is no even-order energy in a 50% duty cycle waveform, I had to devise a way to produce some. The traditional approach is to build two stages of transistor amplifiers with tuned outputs. The first stage doubles the 32-MHz energy to 64 MHz, and the second stage doubles again to 128 MHz. But then, who goes traditional anymore?

The nontraditional method involves the use of digital gates: **XOR**, to be exact. The fundamental signal is applied to one input, a delayed signal is applied to the second input and *voilà* a ×2 signal! No tuning, no muss. It works.

One of the few logic families that will do the job is AC CMOS; in this case, a 74AC86 (U4). These devices have good drive capability and can work in the 150-MHz neighborhood. Don't try substituting a member of the slower logic families for use at U4.

The IF output of the 2-meter converter ranges from 16 to 20 MHz. A modified 10.7-MHz IF transformer is used for the tuned output circuit. The transformer's internal capacitor (mounted underneath the coil) is removed so that a smaller-value capacitor can be connected externally. Don't try to remove the capacitor in one piece—just get it out.

6-Meter Converter

The 6-meter converter uses a 40-MHz oscillator for the LO and an NE602 for the mixer. The IF output ranges from 10 to 14 MHz. A 10.7-MHz IF transformer with some added capacitance is used for the tuned output circuit. You could probably omit the capacitor (C5) since the tuning range of the transformer alone should reach 10 MHz. If you're interested in receiving the upper part of 6 meters, omit C5. The 6-meter converter doesn't need the 74AC86, so a PC-board jumper from U4's pin 5 to pin 8 locations is required to complete the signal path.

Construction

There really isn't much to say about assembling these converters. Although you can build them without a PC board,[4] I can't recommend doing so. Today, it's very easy to make small quantities of PC boards using any of several toner-transfer processes that use a laser printer or photocopier.[5] I've been using the toner-transfer process for about two years now and produce good-quality boards with 10-mil traces. Try it—I'm sure you'll like it!

I must admit that the first trials of the converters found PC boards balanced on a stack of books and connected to a power source with clip leads. Because these converters use frequencies that are occupied by high-power shortwave stations, it's imperative that you house them in RF-tight metal boxes. If you don't, you'll probably do what I did: Think there's a rare 2-meter opening because you hear Spanish stations coming through.....

Keep the leads from the antenna input and IF output connectors to the PC board short. How short? Use the rule of thumb taught to me by an old RF engineer: If you can measure the lead length, it's too long.

Make tuned-circuit adjustments by stretching or compressing the air-wound inductors while listening to a weak station. Simply tune for "max smoke." It's a crude approach, but it's cost-effective—and it works. Use a nonmetallic tuning tool to adjust the slug in T1 for maximum output.

It's a good idea to add RF bypassing to the power-supply leads. An inductor in series with the dc line and a couple of bypass capacitors to ground (mounted off-board) should do the trick (see the insert of Figure 1). The 2-meter converter uses more current that the 6-meter converter, so U3 will run warm. Be sure to use a heat sink. If you're really conservative, attach the regulator leads to the PC-board pads from the bottom, leaving the leads long. This enables you to secure the regulator to the enclosure and use it as a heat sink (the 7805 regulator case is at ground potential).

Tuning In

As I mentioned earlier, the output frequency of the oscillator modules is not necessarily right on target. And because they're sealed, there's no way to "tweak" them. This means that the converter output may not wind up exactly on the calculated frequency (input frequency – LO = IF). I've found that by the time you multiply a 32-MHz oscillator by four (for 2-meter use), the received frequency (at the IF) can be off by as much as 12.8 kHz. But that's not a big problem. Because most CW and SSB stations don't operate on a precise frequency, any frequency offset doesn't make a whole lot of difference when you're listening to such stations. On the other hand, if you're trying to listen to a repeater on 146.85 MHz, you should realize it might come in at 146.83 or 146.86 on "your radio dial." Remember: These are junk-box converters!

Summary

I've used two of the converters and find them to be a lot of fun. I've even discovered a couple of repeaters that I didn't know existed. It seems it's a lot easier to tune around using a knob rather than thumbwheel switches. The sensitivity of each converter measured about 1 μV.[6]

Build a couple! Have some fun! Get on 6 and 2 meters so I can have someone to talk to!

Acknowledgments

Thanks to Bob, K3VOI, for his ideas and for the use of his extensive test equipment during testing; Tom, KC4YMB, and Kathy, KC4YHI, for their review of a prototype and early text; and my wife Joyce, KA3SWK, for her ideas and patience.

When he was 15, Rod Kreuter got his Technician class license and "worked lots of 6-meter AM." Rod currently holds an Extra class license. Amateur Radio led Rod to a career in electrical engineering. He holds a BSEET from The Pennsylvania State University. He's worked in the fields of fiber optics, signal processing and satellite communications systems, primarily for defense contractors. Rod is now the Director of Research Instruments for Penn State's Chemistry Department. Rod describes himself as a "hardware bum." He enjoys biking, backpacking, tinkering and ragchewing. You can contact Rod at 319 McBath St, State College, PA 16801; e-mail **jek160@psu.edu**.

Notes

[1]DynaArt PC board-making process materials are available from Digi-Key Corp, 701 Brooks Ave S, Thief River Falls, MN 56701-0677, tel 800-344-4539, 218-681-6674; fax 218-681-3380 (DK TTS-5 and DK TTS-10, 5 and 10 transfer-sheet packages, respectively).

[2]John Dillon, WA3RNC "The Neophyte Receiver," *QST*, Feb 1988, pp 14-18; Bob Zavrel, W7SX, "Using the NE602," Technical Correspondence, *QST*, May 1990, pp 38-39; Michael Covington, "Single-Chip Frequency Converter," *Radio-Electronics*, Apr 1990, pp 49-52.—*Ed.*

[3]To learn a bit more about image response, IMD and related subjects, see Ed Hare, KA1CV, "'Intermod—A Modern Urban Problem,'" *QST*, Aug 1996, pp 40-43.—*Ed.*

[4]PC boards and kits are available from Q-Sat, PO Box 110, Boalsburg, PA 16827; e-mail **jek160@psu.edu**. Charge cards are not accepted; telephone number not available. PC board only for either converter, $5 plus $1.50 shipping and handling; kit (includes PC board, but no connectors or enclosure): 6 meters, $18; 2 meters, $21. Add $3 for shipping and handling for each kit. Pennsylvania residents add state tax. Please allow 4 to 5 weeks for delivery. A PC-board template package is available from the ARRL for $2 for members, $4 for nonmembers. Send your request for the KREUTER VHF CONVERTERS TEMPLATE to the ARRL Technical Department Secretary, 225 Main St, Newington, CT 06111-1494.

[5]See Glenn Elmore, N6GN, "Better Iron-On PC Patterns," Correspondence, *QEX*, Jun 1993, p 21; John Grebenkemper, KI6WX, "Ironing Out Your Own Printed-Circuits Boards," *QST*, Jul 1993, pp 42-43.

[6]The converters' sensitivity was confirmed by ARRL Lab measurements.—*Ed.*