Simple RF Signal Generator

Add this handy piece of test gear to your bench.

J. Frank Brumbaugh W4LJD
P.O. Box 30 - c/o Defendini
Salinas PR 00751-0030

A good RF signal generator covering from below the 160 meter band to above the 10 meter band with no skips in coverage is a very handy piece of test equipment for the service bench in the shack. Top quality, very well shielded signal generators can cost upward of $1,000, but such extremes are not needed in the usual ham shack.

There are a number of commercial signal generators that are quite adequate but start at around $150. That is too much money, especially when you can easily build a signal generator that is as good or better for no more than $10 or $15 in parts, not including the air dielectric tuning capacitor and enclosure. However, you can build from pieces of unetched printed circuit board a better shielded enclosure than you can buy, and you can do it for pennies.

The signal generator described here is at least as useful as a $150 commercial model, yet it is very simple, easy to construct, and (best of all) requires very few common parts. The only difficult (read: expensive) component needed is the air dielectric tuning capacitor. As this is being written, many sizes are available from: Dan's Small Parts and Kits, P.O. Box 3634, Missoula MT 59806.

I designed this signal generator to use a 150 pF tuning capacitor. Danny lists one at $7.50. However, if you can find a 365 pF tuning capacitor from an old tube radio or at the bottom of some ham's junk box, it can be used in series with a 330 pF NPO disc capacitor in place of the specified 150 pF capacitor. Other combinations of variable and fixed series capacitors will also work. Or, you could tailor the four toroid inductances to cover the desired frequency ranges with whatever tuning capacitor you have available.

This signal generator (see **Figs. 1** and **2**) uses a Franklin oscillator at its heart. Although this oscillator requires two FETs, it is not only foolproof—it *has* to oscillate—but it is also the most stable wide range oscillator I have ever found.

Further, the Franklin oscillator uses no tapped coils, no capacitive voltage dividers, and no special parts. The parallel tank circuit is grounded, making band-switching simple, and the four toroid inductances are switched in individually to provide full coverage with overlaps between bands. There are only four resistors, four capacitors, and two diodes needed to complete this two-FET oscillator, in addition to the tank circuit.

The oscillator is followed by an FET source follower for buffering, which drives an NPN bipolar broadband amplifier. This, in turn, feeds amplified RF through an impedance matching transformer and a -6 dB 50 ohm attenuator, providing RF at 50 ohms impedance, either direct or through a built-in switched attenuator, to a BNC output connector on the panel.

Fig. 2 illustrates the attenuator. RF from the -6 dB attenuator, which terminates the active circuits, is fed through RG-174/U coax to one wiper of a dual wafer switch having at least seven positions. Attenuator resistors are wired onto the two wafers to provide from zero to -30 dB attenuation of the RF available from the signal generator. In addition, position 7 on this switch provides only a 51 ohm shielded resistance, which is applied across the receiver antenna connector when measuring internal receiver noise. This is not normally a part of a signal generator and is therefore optional. It is provided so a shielded 51 ohm

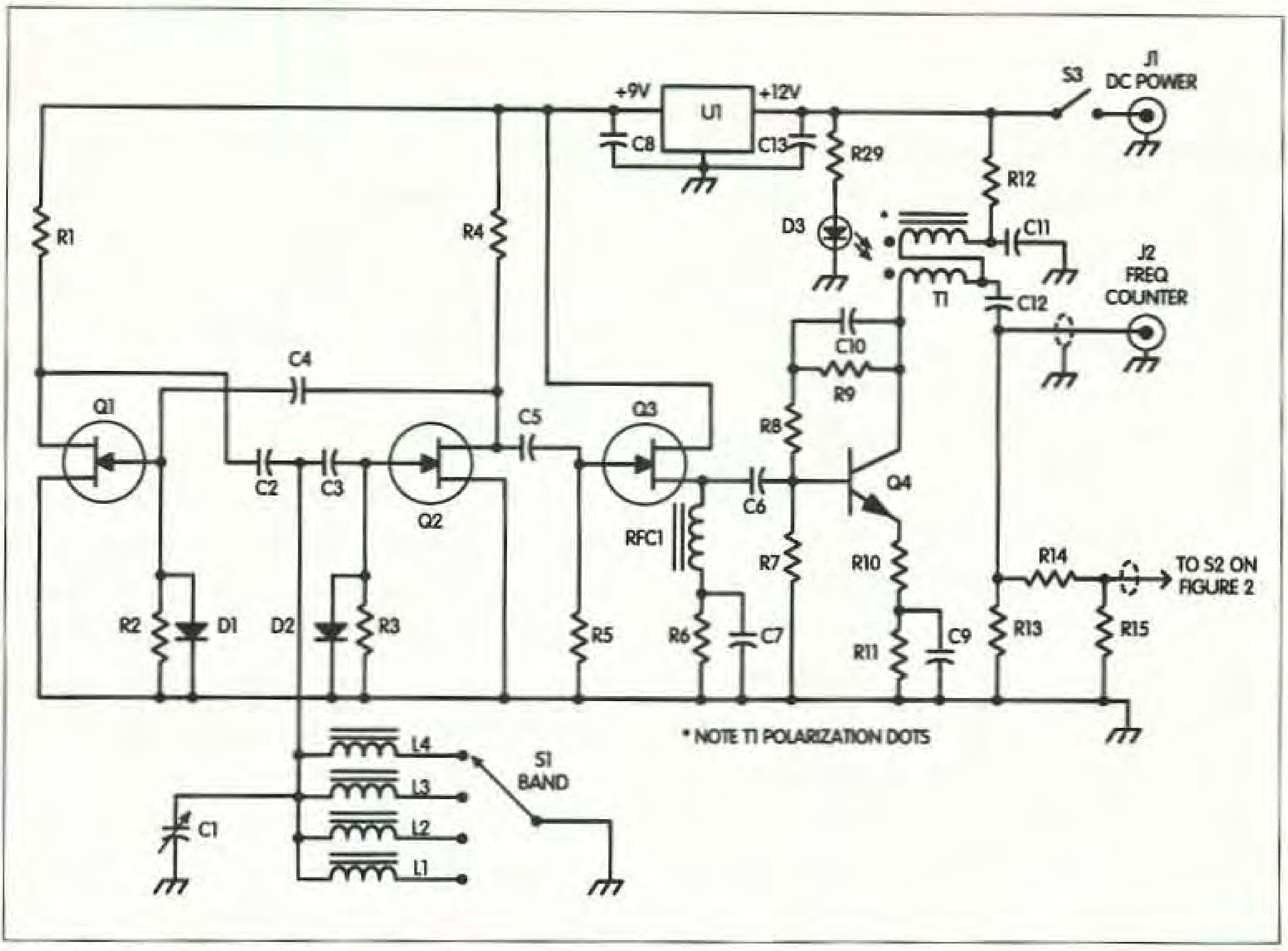

Fig. 1. Schematic diagram.

termination will be readily available whenever needed.

The wafer switch I used for the attenuator does not have a grounded shield between wafers, which would have been preferable. Because of this, there is bound to be some leakage between wafers that will affect the actual attenuation level. Still, it does provide different levels of attenuation and maintains the RF output at 50 ohms impedance.

Specifications

Power supply: 12 to 15 VDC. At 13.8 VDC, current drain is 42 mA.

Frequency range: 1.6 to 32 MHz in four bands, as follows: band A, 1.6 to 3.43 MHz; band B, 3.4 to 7.4 MHz; band C, 7.3 to 17 MHz; and band D, 15.5 to 32 MHz.

RF output: At 50 ohms impedance, output is remarkably level. Band A: low end 1.47 Vp-p. At high end, 1.7 Vp-p. Band B: At low end, 1.98 Vp-p. At high end, 2 Vp-p. Band C: At low end, 2 Vp-p. At high end, 2.6 Vp-p. Band D: At low end, 2.8 Vp-p. At high end, 2.26 Vp-p. Note: These levels were measured as RMS voltages and calculated for peak-to-peak equivalents.

Attenuator (decibels): 0, -3, -6, -10, -20, -30.

Stability: Worst case measured at 30 MHz from a cold start, ambient temperature 82° F. Frequencies were measured at ten-minute intervals to an

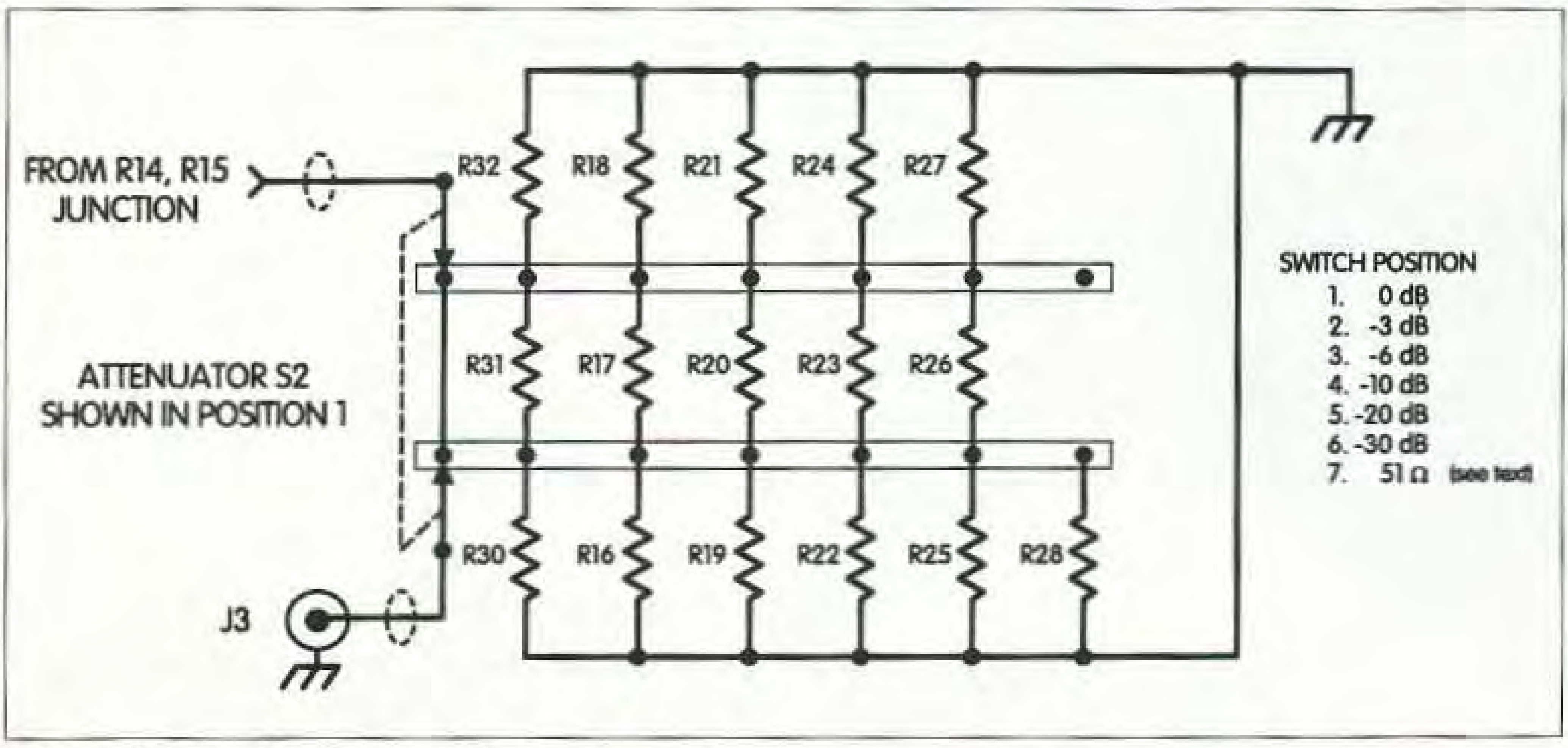

Fig. 2. Schematic diagram of step attenuator.

Photo A. Front panel view.

accuracy of ± 100 Hz and rounded off to the nearest kHz. After 30 minutes, the frequency had drifted down 72 kHz, or less than one quarter of one percent.

Stability is a result not only of the Franklin oscillator but also because of the very small amount of heat generated by the circuit. With 42 mA at 13.8 VDC, 0.58 watts of heat is generated, so once the signal generator has warmed up, there will be very little heat-induced drift. Aiding in thermal stability is the thermal inertia of the relatively large tuning capacitor, and the fairly large toroid cores in inductances L1 through L4. Because C1 and any one of the inductances are the only frequency determining components, only they can be affected by the small amount of heat generated by transistors and resistors.

How it works

Q1 and Q2 are asymmetrically cross-connected in a way similar to an astable multivibrator. Because of tolerances in resistors and slight differences in the FETs, the latter will draw slightly different current when power is applied. The capacitive cross-connections ensure that oscillation will begin immediately and be maintained as long as power is applied.

The parallel tuning tank, C1, and one of the inductances, L1 through L4, is lightly coupled to the oscillator at the junction of capacitor C2 and C3.

RF is coupled from the drain of Q2 to the gate of Q3, configured as a source follower. Operating voltage for the oscillator and source follower are provided by U1, a 9 volt regulator.

RF developed across RFC1 is capacitively coupled to the base of Q4, an NPN bipolar broadband RF amplifier essentially flat over the range of the signal generator and beyond. Negative feedback and emitter degeneration are incorporated to provide broadband amplification. The output impedance of Q4 is approximately 200 ohms. T1, a 4:1 impedance matching transformer, injects RF at about 50 ohms impedance to a -6 dB attenuator to provide a stable and solid 50 ohm RF output.

RF from the -6 dB attenuator is directed through RG-174/U coax to a connector on the rear of the enclosure for use in monitoring exact output frequency. Another short length of RG-174/U coax takes RF from the -6 dB attenuator to one wiper of a wafer on the attenuator switch. See **Fig. 2.** This switch selects from 0 dB (the output from the -6 dB internal attenuator) to -30 dB in steps at -3, -6, -10, -20, or -30 dB. The wiper of the second wafer connects to the BNC RF connector on the panel. (The next switch position, number 7, selects only the shielded 51 ohm resistive termination for measuring receiver noise, if included.)

Construction

I recommend using a small general purpose printed circuit board for greatest ease in wiring. I used a Radio Shack 276-150 PC board that provides more than enough room for all the circuitry as well as all four toroid inductances. Of course, you can build it "dead bug"–style if you wish. Just remember that frequencies as high as 30 MHz are present, so follow good engineering practice with short leads, and use the types of components specified in the parts list. When the inductances are trimmed to cover the exact ranges desired and wired into the circuit, use a non-acid containing "goop" or beeswax to secure them to the PC board so that they will not shift or break the fine wire used to wind them.

I used a 365 pF tuning capacitor from my junk box (the last one), with a 300 pF NPO capacitor in series with it for tuning. This method, while providing the desired capacitive range, tends to compress the high frequency ends of the dial. I bent up a bracket to mount the capacitor and added a Jackson Brothers vernier salvaged from an ancient Eico sweep generator. I used a circular dial plate left over from cutting a meter hole in another project, with white card stock adhered to one side, and arcs drawn and calibration added after construction. (These are not stipulated in the parts list, because each instrument is going to be a little different.)

I used a Ten-Tec TG-34 enclosure, about 4" x 4" x 3" high, for my own signal generator, although a case made of unetched printed circuit boards would allow discretion in the size of the panel (which determines how large a dial can be used) as well as provide better shielding. However, because I bolted my PC board with all circuitry on the left end of my tuning capacitor,

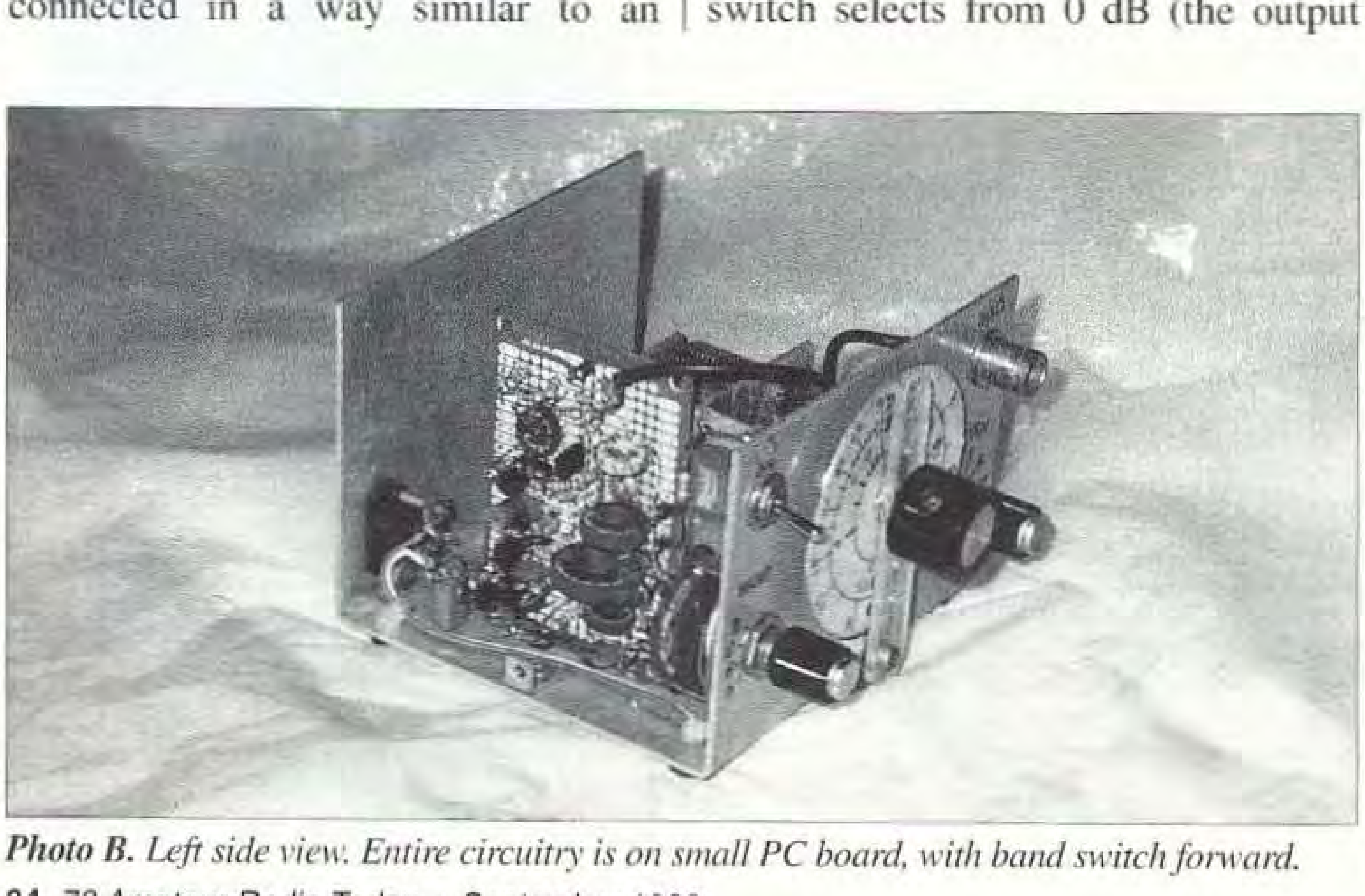

Photo B. Left side view. Entire circuitry is on small PC board, with band switch forward.

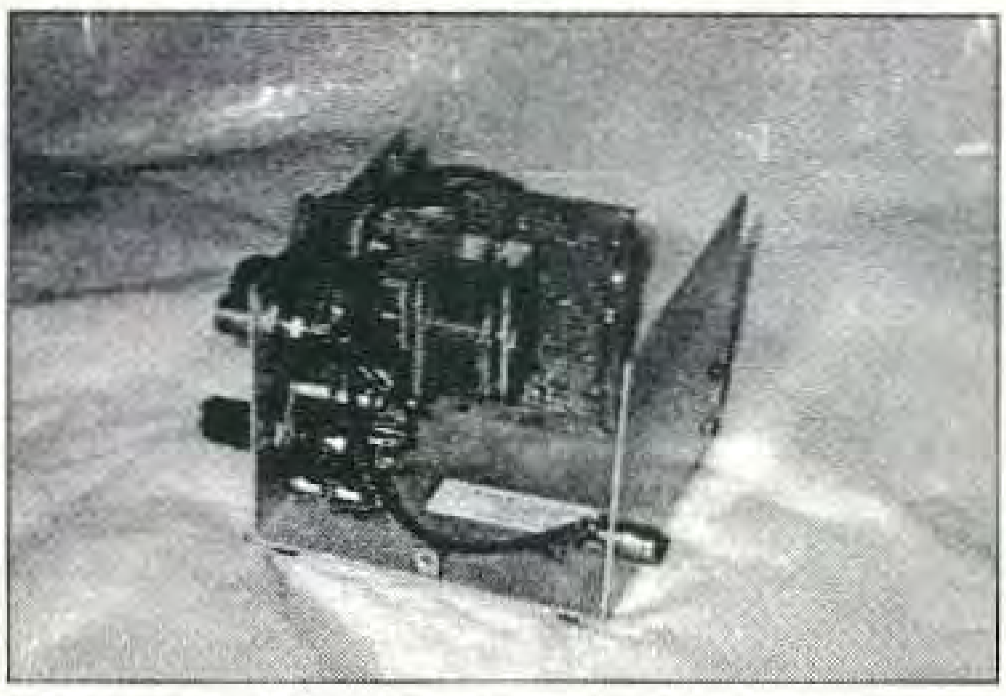

Photo C. *Right side view showing attenuator switch and frequency counter connector.*

and the inductances are all on toroidal forms, there is a little stray RF inside my enclosure. Probably only the stator of the tuning capacitor could be a source of stray RF in the enclosure, so I expect it is at least as well shielded as a $150 commercial generator, and probably a bit better, especially considering the low level of RF being generated.

Because of tolerances—no two toroid cores of the same type are identical, and no two tuning capacitors rated identically are ever quite the same—the winding data given for L1 through L4 are what worked for me with my specific cores and particular tuning capacitor and series capacitor. Because your parts will be somewhat different, you may have to adjust the number of turns on each tuning inductance to get the proper frequency coverage and adequate overlap between bands.

I suggest using the winding data given, but adding a few turns before checking the frequency range of each band. Thus, I suggest you start with L1 on Band A, getting the low frequency limit a bit below 1.8 MHz, the low end of 160 meters, and then check the high frequency end. This becomes the frequency a bit higher than what you will set the low frequency end of L2 at to provide overlap. Continue in this manner with L3 and L4. Your actual bands will, no doubt, be somewhat different from mine, but as long as you can generate RF from less than 160 meters to more than 10 meters with no skips between bands, you will have a stable and very useful instrument.

General comments

In the parts list, resistors R13 through R27 and R30 through R32 are first listed with the standard 1% resistance values for the attenuator, and then followed by a suggested 5% 1/4 watt resistor. Actually, little will be lost in an instrument this simple if you use the nearest 5% resistors in these locations.

However, for the purists out there, it is possible to make resistors of the exact values by carefully filing the bodies of lower value resistors while monitoring the value of resistance with an ohmmeter. To exclude dampness from the filed portions of resistors, apply some Q-Dope®, clear fingernail polish, or a product called "Hard As Nails" (used to overcoat nail polish). When all toroids are checked and cover the desired frequencies, use one of these products to coat them and hold the winding in place as well as to keep out moisture.

Q1 and Q2 *must* be the same type, and it is probably preferable that the same type be used for Q3. I used J309s, but 2N4416 or J308 should work as well. The 2N4400 I used for Q4 can be just about any small signal NPN transistor as long as the F_t is at least 300 MHz (and preferably higher).

Do not change the values or types of C2, C3, C4, C5, and C6, although if you cannot locate 18 pF NPO capacitors for C2 and C3, you can substitute 15 pF or 22 pF. However, both capacitors must be marked with the same value and be NPO. If you don't have an FT37-43 ferrite toroid for T1, you can use an FT50-43 with no change in windings.

Where a 0.1 µF capacitor is shown in **Fig. 1** in parallel with a resistor, use a monolithic capacitor, axial if possible, and solder it across the resistor before adding them to the circuit.

For most casual use around the shack, it will not be necessary to use the built-in attenuator. You can just wire a potentiometer between the junction of R14 and R15 to ground and connect the wiper to the BNC RF output connector on the panel. Adjusting the pot will change the RF level, but the impedance will no longer be 50 ohms. Or, if you have constructed the switched attenuator described in the *ARRL Hand-*

Continued on page 36

Parts List	
Part	**Description**
R1, R4, R7	1k
R2, R3, R5	1 meg
R6, R11	100 ohms
R8	560 ohms
R9	3.3k
R10	10 ohms
R12	47 ohms
R13, R15-16, R18	150.5 ohms 1% (use 150)
R14, R17	37.3 ohms 1% (use 36)
R19, R21	96.2 ohms 1% (use 100)
R20	70.7 ohms 1% (use 68)
R22, R24	61 ohms 1% (use 62)
R23	247.5 ohms 1% (use 240)
R25, R27	53.2 ohms 1% (use 51)
R26	789.7 ohms 1% (use 820)
R28	51 ohms
R29	2.7k
R30, R32	292 ohms 1% (use 300)
R31	17.6 ohms 1% (use 18)
All resistors 1/4 W 5% unless otherwise noted.	
C1	150 pF air dielectr. tuning cap (see text)
C2-3	18 pF NPO disc (15 or 22 pF acceptable)
C4-5	100 pF COG monolithic capacitor
C6	56 pF COG or NPO disc
C7-13	0.1 μF monolithic, axial
D1-2	1N914, 1N4148, etc., silicon small signal diode
D3	LED, your choice
J1	DC connector, your choice
J2	connector for freq counter, your choice
J3	BNC panel-mount coax female connector
L1	FT37-61, 29T #30 (see text)
L2	T68-2, 45T #30 (see text)
L3	T50-2, 18T #30 (see text)
L4	T37-6, 11T #30 (see text)
Q1-3	J309 (see text)
Q4	2N4400, 2N4401, 2N2222, etc.
RFC1	1 mH RFC
S1	SP4T rotary switch
S2	2P dual wafer, 7 or more pos. Should have grnded shield between wafers.
S3	SPST toggle or slide switch
T1	FT37-43 12 bifilar turns #30
U1	78L09 regulator

book, you can use it outboard and not build-in the specified attenuator.

Changes you might want to make

Frequency coverage can easily be extended above and below the specified ranges by adding additional inductances and positions on the band switch. Within reason, of course. It probably won't work at UHF!

If a higher level of RF output is desired, one or two MMIC wideband amplifiers can be added to maintain the 50 ohms output impedance. Or, for really higher RF output, you could build and install the four-stage RF amplifier described on page 135 of W1FB's *QRP Notebook*. It is flat from 1 to 40 MHz and provides 40 dB gain at 50 ohms impedance, but this may be too high for the internal attenuator.

As designed, this signal generator can also be operated portable with either a 9 V or 12 V battery. If a 9 V battery is used, eliminate U1. In this case, RF output will be lower and will decline as the battery ages.

If you desire, you could install an LCD frequency dial such as the "K1MG Digital Clock/Counter" available from Blue Sky Engineering Company, 400 Blossom Hill Road, Los Gatos CA 95032. Write for the current price—but be forewarned that this will probably cost about twice as much as the rest of the instrument. 73