Low Power Two Meter FM Transmitter

Inexpensive, lightweight and expendable!

by Carl Lyster WA4ADG

After my balloon flight honoring the 20th anniversary of Apollo 11, I decided to design a simple 2 meter FM transmitter that could be built cheaply enough to be considered expendable. It needed to be lightweight, to provide a few hundred milliwatts output at best and be reproducible with few headaches. The circuit described here meets all of these requirements and performs better than my expectations. The complete unit measures 2" x 4", weighs under two ounces, provides 225 mW of output and is rugged and stable over a voltage range of 9 to 12 VDC.

When designing this device I chose several components that I knew from previous experience would perform well at 2 meters: a 2N3866 transistor for a final, 2N5179s for the multipliers, double-tuned toroidal forms for the tanks, and an X12 frequency multiplication scheme that would allow the use of Drake TR-22 type transmit crystals (low-cost and easy to order).

The circuit went through many revisions as I attempted to simplify the test equipment needed to tune up the transmitter. I spent many days in front of a spectrum analyzer trying to optimize the values of the tuned circuits to prevent accidental generation of spurs. The value of each resonant inductance was chosen so that the associated trim cap would be unlikely to resonate on the wrong multiple. This transmitter is not foolproof but it should be easily adjustable by anyone with patience and some good luck!

Audio Section

The transmitter requires a 6 Vp-p audio input level to obtain 5 kHz deviation. It was originally designed to interface directly with my digitized voice ID circuit in *Ham Radio*, Feb. '89. However, if you want to use a microphone or other low level audio source, use the circuit in Figure 1. This audio amplifier provides the necessary 6 Vp-p output while consuming only 2 mA from the 12 volt supply. Two sections of an LM324 quad op-amp are used to implement the amplifier. The first stage is set for a gain of 40 and is capacitively coupled by C2 to potentiometer VR1 which controls the overall amplifier gain. The second stage is set for a gain of 6 and its output is fed directly to the transmitter through a low-pass filter externally mounted between the audio amplifier and the transmitter input (C12 and R9 in Figure 4). The gain of these two stages was chosen so that the last stage could be used by itself if a higher level source of audio is available. By opening the trace from pin 8 to C2, an external signal of about 1 volt or better can be injected into the positive terminal of C2. If you experience low frequency rolloff in your transmitter with this amplifier, you might try increasing the value of C11, the DC blocking capacitor in the external low-pass filter (Figure 4.)

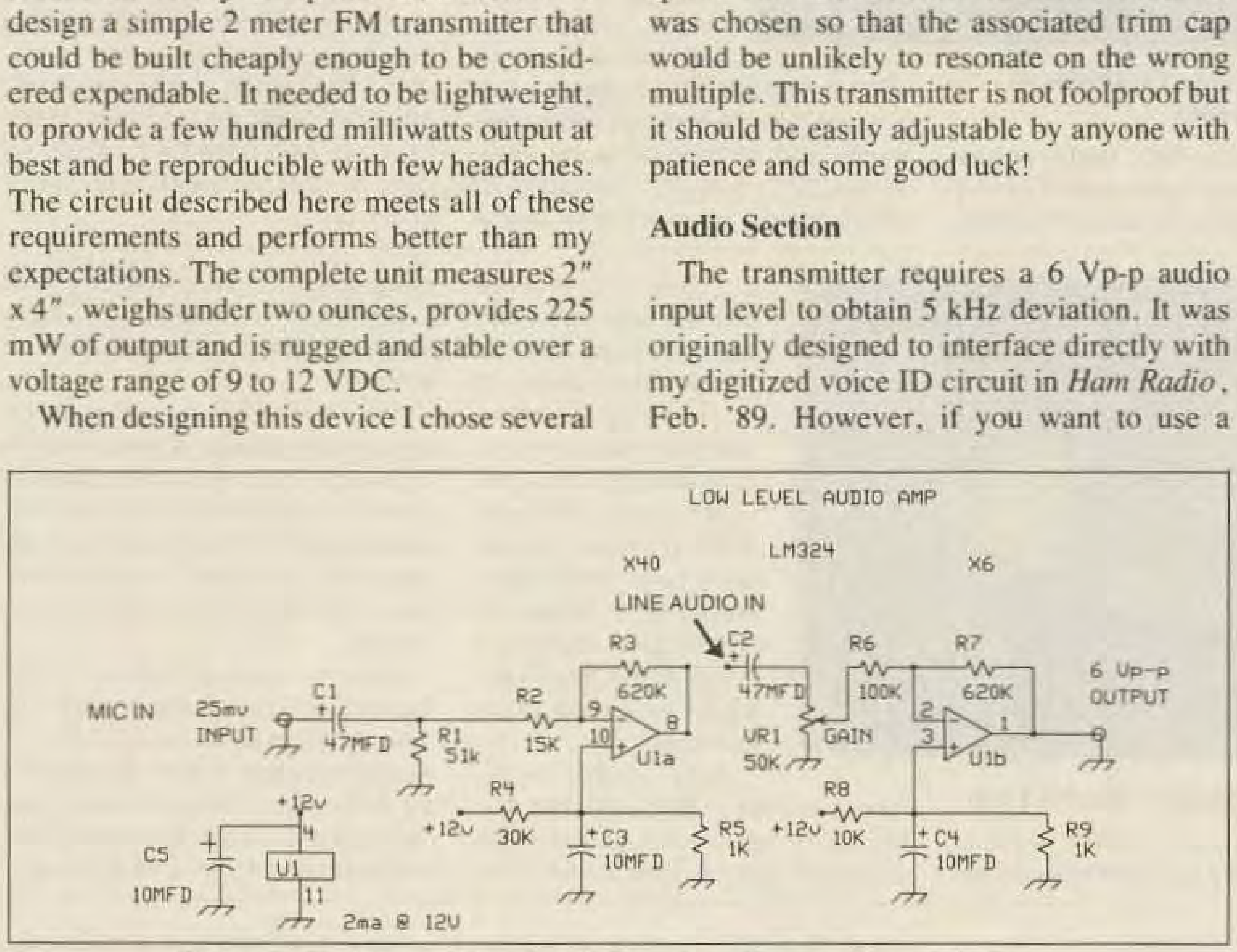

Figure 1. Audio amplifier circuit for microphone or line audio input.

The Transmitter Circuit

Transistor Q1 forms the 12 MHz oscillator and crystal Y1 is set on frequency by trim cap C1 (Figure 4). Zener diode D1 regulates the

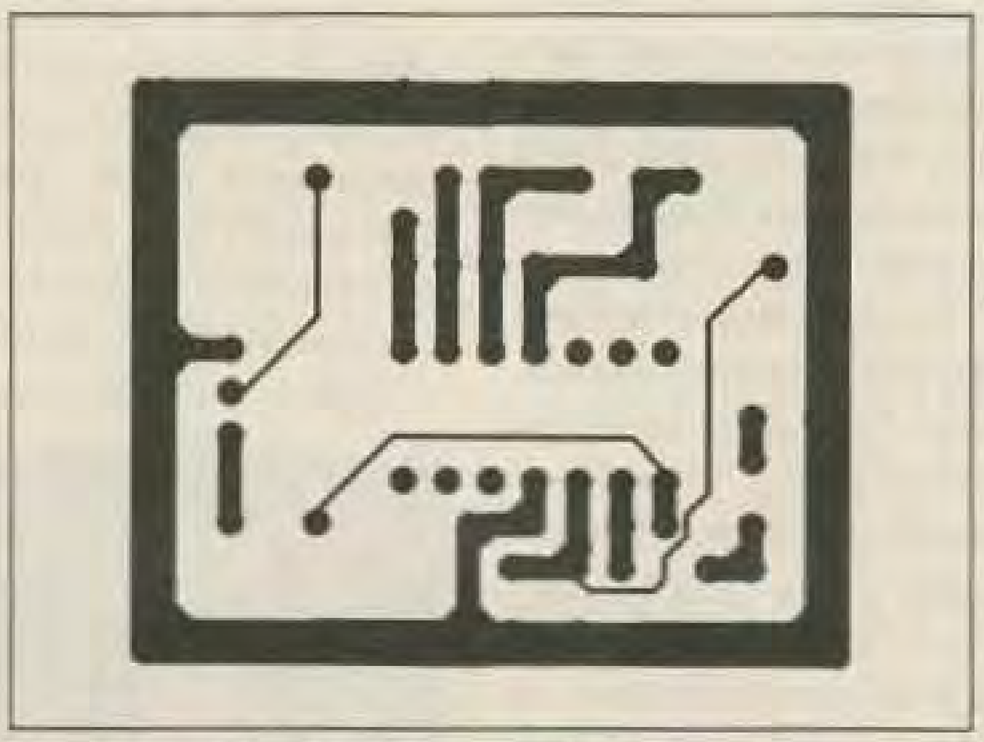

Figure 2. Audio amplifier foil pattern.

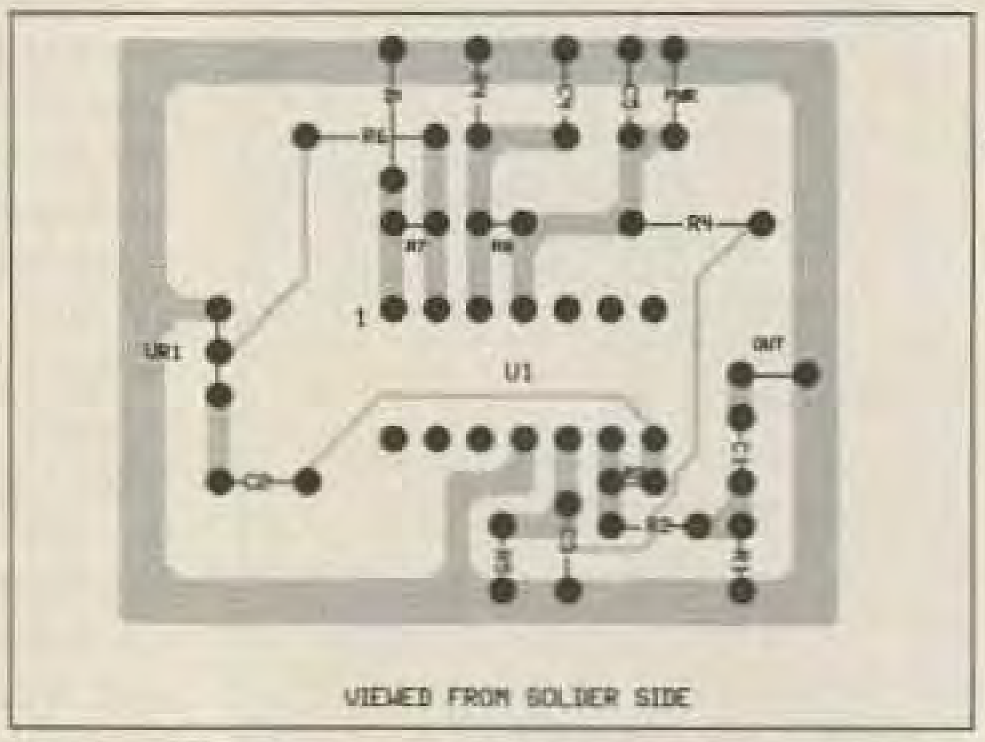

Figure 3. Audio amplifier parts placement.

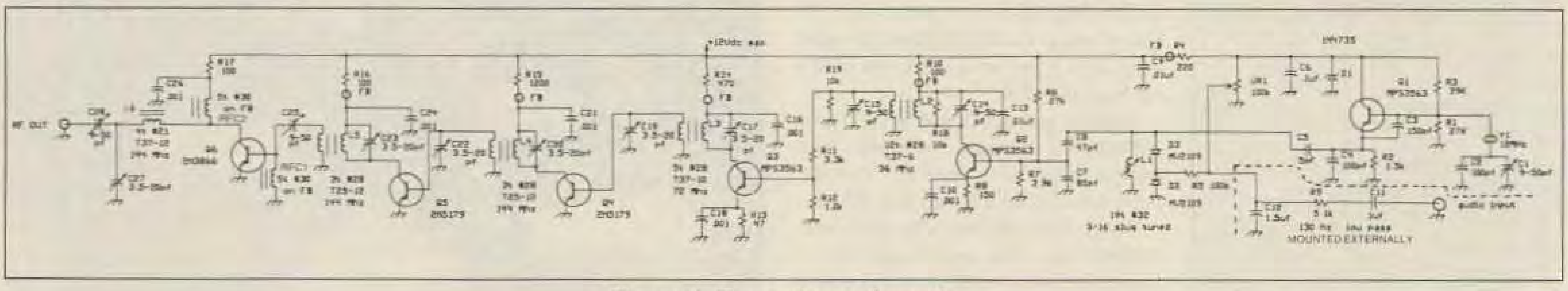

Figure 4. Transmitter schematic.

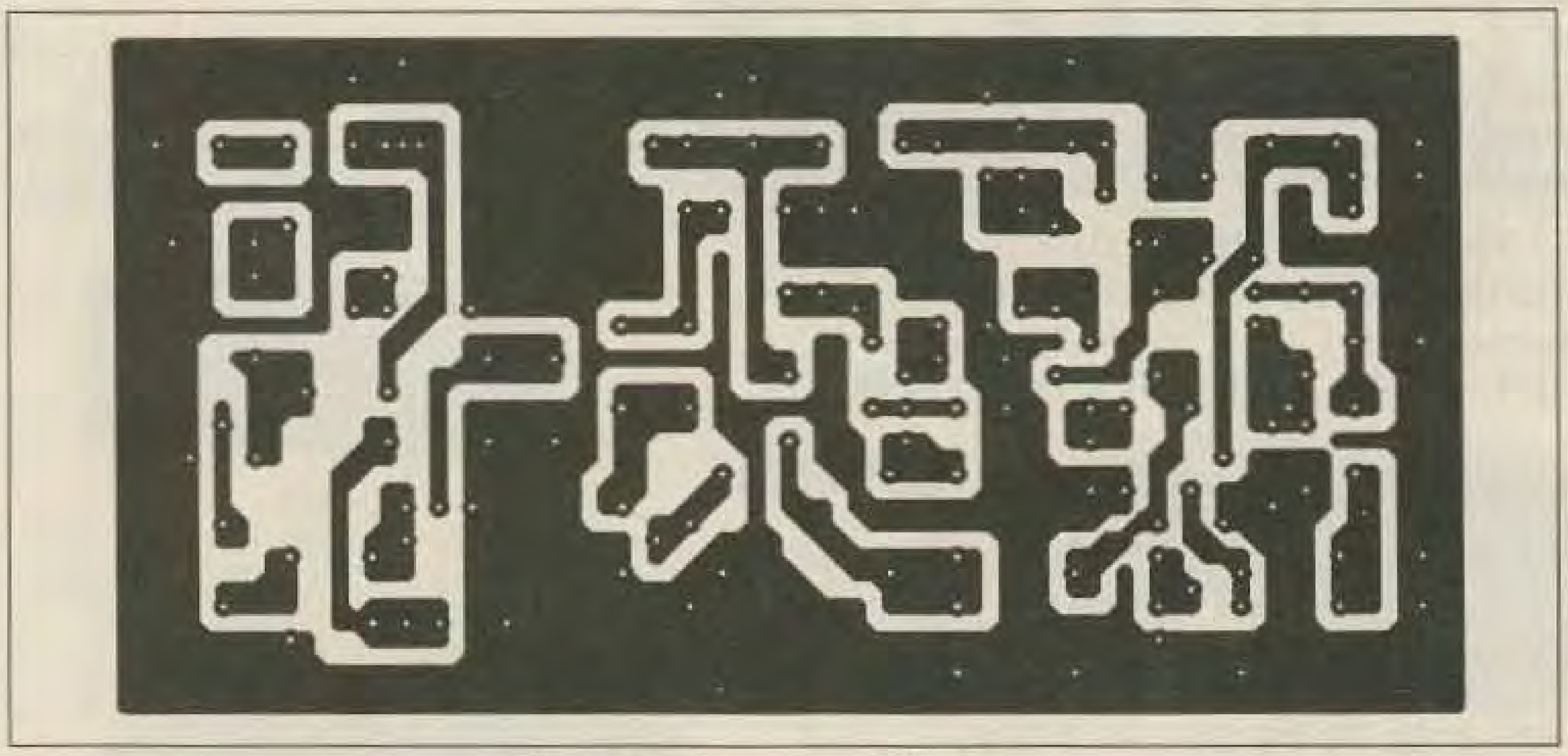

Figure 5. Transmitter foil pattern.

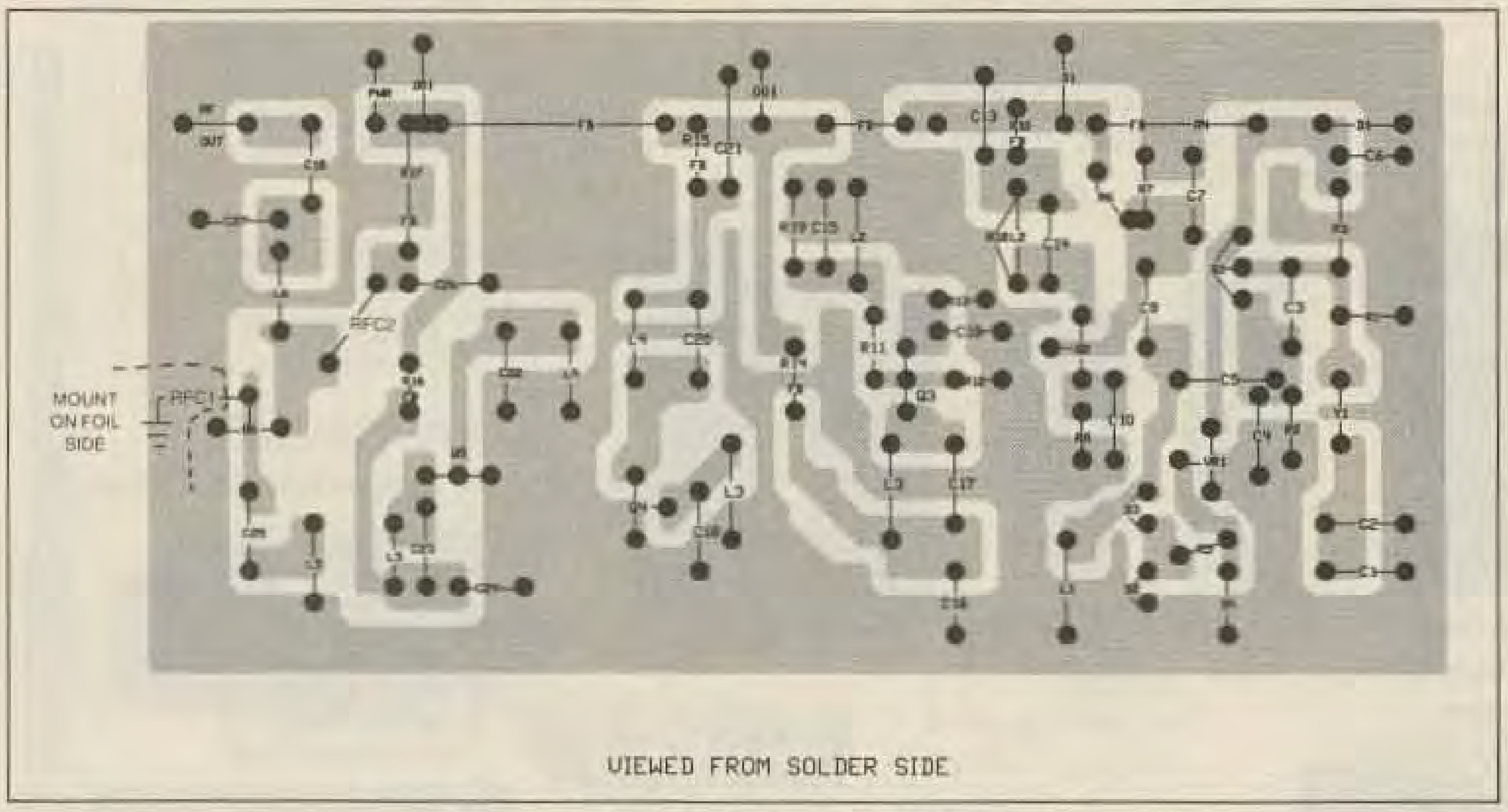

Figure 6. Transmitter parts placement.

power supply for the oscillator to 6.2 VDC for frequency stability. C5 couples the output of the oscillator to the phase modulator composed of L1 and varactor diodes D2 and D3. Pot VR1 sets the DC operating point for the diodes and is summed with the audio input to provide the modulation signal for the varicaps. Since phase modulators are sensitive to both modulation amplitude and frequency, audio is fed into the transmitter through a DC blocking capacitor C11 and an externally mounted low-pass filter composed of C12 and R9. Components C11, C12 and R9 are connected externally between the audio amplifier (or 6 Vp-p audio source) and the transmitter due to the fairly large size of C12. This filter provides the 6 dB per octave rolloff needed to maintain an equal deviation versus frequency response. About 6 Vp-p of audio is required to give 5 kHz of deviation.

The modulated 12 MHz signal is applied to Q2 where it is tripled to 36 MHz. Tank L2 is composed of 12 turns of wire on both primary and secondary and has its Q dampened by 10k ohm resistors on each.

The trim caps on this tank (C14 and C15) tune very sharply and must be adjusted with care. Q2 produces excessive 36 MHz energy so a voltage divider, composed of R11 and R12, drops the 36 MHz level applied to the base of Q3, the first class-C multiplier.

Tank L3 resonates at 72 MHz and is composed of 5 turns of #28 on each winding. Q4 is the first 2N5179 multiplier. The MPS3563 transistors don't perform well above 100 MHz so they are used only for the low frequency multipliers. Q4's tank resonates at 144 MHz and is composed of 3 turns each of #28 wire. There is an output of about 5 mW here but it lacks spectral purity.

Q5 is a low power amp that adds greatly to the purity of the final output. Its tank is also composed of 3 turns of #28 on each winding. About 20 mW of output is available here. Q6 is the final and is limited to just over 200 mW output by resistor R17. I do not recommend attempting to get higher power output by changing this resistor because you're bound to get instability.

Trim caps C28 and C27 match the output to a 50 ohm load and tune somewhat broadly. Two RF chokes composed of 5 turns of #30 wire on a small ferrite bead are used as a DC collector supply and a DC path to ground for the base of Q6. Other ferrite beads are used throughout the circuit for supply isolation.

Tune-Up

You need some basic test equipment to get any home-brew transmitter up and running. I would recommend a grid dip meter and a frequency counter as a bare minimum. Start by installing a crystal of your choice and a low-power 50 ohm dummy load at the output. Apply +12 volts and check for oscillation at Q1. This can be done by connecting a counter across L1.

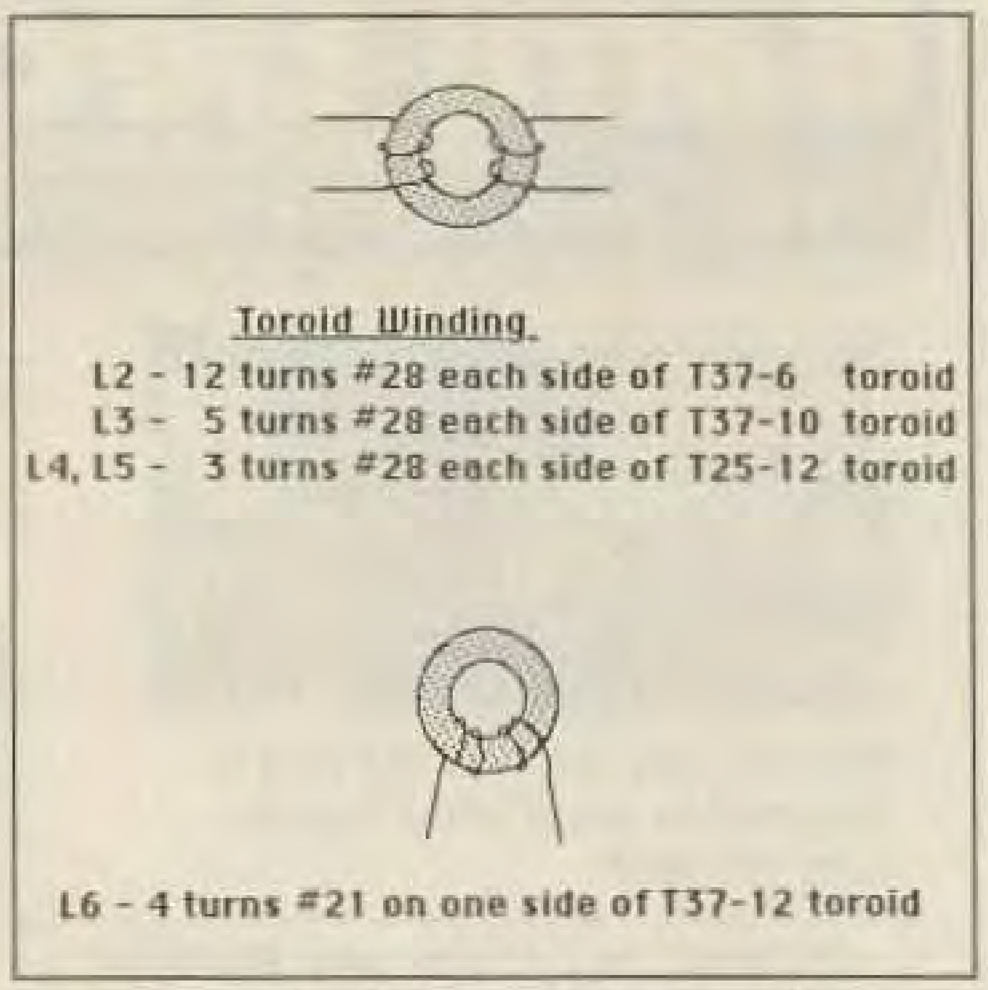

Figure 7. Toroid winding details.

Transmitter Parts List

C1,C14,C15,C28, C17,C19,C20,C25	9–50 pF trim cap
C22,C23,C27	3.5–20 pF trim cap
C3	150 pF disk cap
C4	100 pF disk cap
C5	5 pF disk cap
C6,C11	0.1 MFD monolithic cap
C12	1.5 MFD cap
C9,C13	0.01 MFD disk cap
C8	47 pF disk cap
C7	82 pF disk cap
C10,C16,C18, C21,C24,C26	0.001 µF disk cap
Q1,Q2,Q3	MPS3563
Q4,Q5	2N5179
Q6	2N3866
D1	1N4735 zener
D2,D3	MV2109 varicap
R1,R6	27k ¼ watt
R2	1.5k ¼ watt
R3	39k ¼ watt
R4	220Ω ¼ watt
R5	100k ¼ watt
R7	3.9k ¼ watt
R8	150Ω ¼ watt
R9	5.1k ¼ watt
R10,R16,R17	100Ω ¼ watt
R11	3.3k ¼ watt
R12	1.0k ¼ watt
R13	47Ω ¼ watt
R14	470Ω ¼ watt
R15	1.2k ¼ watt
R18,R19	10k ¼ watt
VR1	100k trimpot
L1	19T #32 on 3/16" slug-tuned form
L2	12T each winding of #28 on T37-6
L3	5T each winding of #28 on T37-10
L4,L5	3T each winding of #28 on T25-12
L6	4T of #21 on T37-12 core
RFC1,RFC2	5T of #30 wound on Ferrite Bead
FB	6 Ferrite Beads
Y1	Drake TR-22 xmit crystal

Audio Amplifier Parts List

U1	LM324 op-amp
C1,C2	0.47 µF/35V Elect.
C3,C4,C5	10 µF/35V Elect.
VR1	50k trimpot
R1	51k ¼ watt
R2	15k ¼ watt
R3,R7	620k ¼ watt
R4	30k ¼ watt
R5,R9	1k ¼ watt
R6	100k ¼ watt
R8	10k ¼ watt

Blank PC Boards are available from FAR Circuits, 18N640 Field Court, Dundee, IL 60118. Toroid cores and ferrite beads are available from Radiokit, P.O. Box 973-C, Pelham NH 03076. Phone: (603) 635–2235. Crystal Y1 can be obtained from KW Crystals, P.O Box 508, Prague OK 74864. Phone: (405) 567–2285 or JAN Crystals, P.O. Box 6017, Fort Myers FL 33906-6017. Phone: (813) 936–1404. All other components can be obtained from Circuit Specialists, P.O. Box 3047, Scottsdale, AZ 85271-3047. Phone: (800) 528–1417.

An alternative for the slug-tuned coil L1 is J.W. Miller part # 23A336RPC (2.40-4.10 µH) also available from Circuit Specialists.

Once oscillation is confirmed, loosely couple a grid dipper adjusted to 36 MHz to L2. Adjust L1 with VR1 in center position for a maximum reading on the dipper being used as a tuned RF voltmeter. Adjust C14 for maximum reading. About 1.1 VDC should be present at the emitter of Q2. Set the dipper for 72 MHz and couple it to L3. Adjust C15 and C17 for maximum indication on the dip meter. About 0.05 VDC should be at the emitter of Q3. Move the dipper to L4 and adjust C19 and C20 for maximum energy at 144 MHz. Move the dipper to L5 and adjust C22 and C23 for maximum signal at 144 MHz. You should be able to see some output at the 50 ohm load by now. Adjust C25, C27 and C28 for maximum output. Go back and retouch C14 through C28 for maximum. There should be a minimum of 100 mW output. Apply 6 Vp-p of 1000 Hz audio to the input of the low-pass filter.

Use a 2 meter rig as a monitor and adjust L1 to VR1 for the best-sounding audio. If possible, use an oscilloscope to monitor the shape of the received sine wave and adjust L1 and VR1 for best reproduction. These two adjustments interact quite a bit so jockey back and forth to obtain the best possible signal. Also, set the transmitter on frequency by adjusting C1.

If you monitor the unmodulated transmitter on a nearby receiver you can detect spurious outputs from a maladjusted transmitter. It is always a good idea to have a 2 meter rig on when making these adjustments. Any bizarre chirps or fluctuations in the received signal are a sure indication that a stage is in oscillation and needs to be rechecked. If at all possible, have your transmitter checked on a spectrum analyzer to be absolutely sure that no unwanted spurs are being emitted. Most of the units that I have built have no detectable spurs 50 dB down from the main carrier. Your particular transmitter may require additional filtering to meet FCC specs. The average weight for these transmitters is about 1.5 oz. with 170 mW of output at 12 VDC. The current consumption is about 100 mA.

Good tinkering! 73

Number 11 on your Feedback card

UPDATES

Two Meter Portable Quad —Correction

Charles W. Pearce, Ph.D., K3YWY, author of the above article in the June 1990 issue, has sent us a correction.

Refer to Table 2 on page 24. The spacers listed as 3.5" should be 4.5". Thank you, K3YWY, for the update. 73