10 GHz Fun

Easy way to get on the 3cm band.

by C.L. Houghton WB6IGP

Want a cheap and easy way to get on 10 GHz? This 30 MHz IF strip and modulator allows you to put together a very inexpensive system for 3 cm operation. Combine this transceiver with a Gunn oscillator and a Polaplexer mount attached to a small dish antenna, and you are ready to go! (See the October 1987 issue of *73 Magazine* to learn how to build the Polaplexer mount.)

Overview

Let's look at what is required for a complete system operating on 10 GHz. The October article describes the Polaplexer detector and circular waveguide to which is coupled a Gunn oscillator. I used the Solfan alarm type available from many burglar alarm companies. *[Ed. note: Solfan, now defunct, also had a broad line of passive infrared detectors used in intrusion detectors and as actuators for door openers. Don't try to convert an infrared detector using these techniques.]* Being inexpensive, it is not varactor controlled. Adding just a power supply modulator and IF amplifier operating at our IF of 30 MHz complete the package! Figure 1 is a block diagram of the complete 10 GHz system.

Transmitter Circuitry

The transmitter consists of a single Gunn oscillator unit. Many different types exist. The best known unit is made by Solfan, and it can be found throughout the US and Canada.

The output power of an unmodified Gunn oscillator cavity runs about 10 mW. (I recently modified these cavities with high power Gunn diodes that have a power output of about 100 mW. I will make these available soon.) The Gunn oscillator is supplied with about 10 VDC (positive for the Solfan) from a variable voltage regulator. This regulator is modulated by a single CA-3130 op-amp serving a microphone amplifier. (The LM-386 and CA-3130 are available from Jameco.)

Now see Figure 2. The output of the microphone amplifier is capacitively coupled through a deviation control (variable resistor) to the voltage-adjust terminal of the power supply regulator. A small variation in audio voltage on this adjust terminal varies the voltage of the power supply which in turn varies the operating frequency of the Gunn oscillator, providing FM. An option on the PC board allows use of Gunn oscillators that have varactor frequency control.

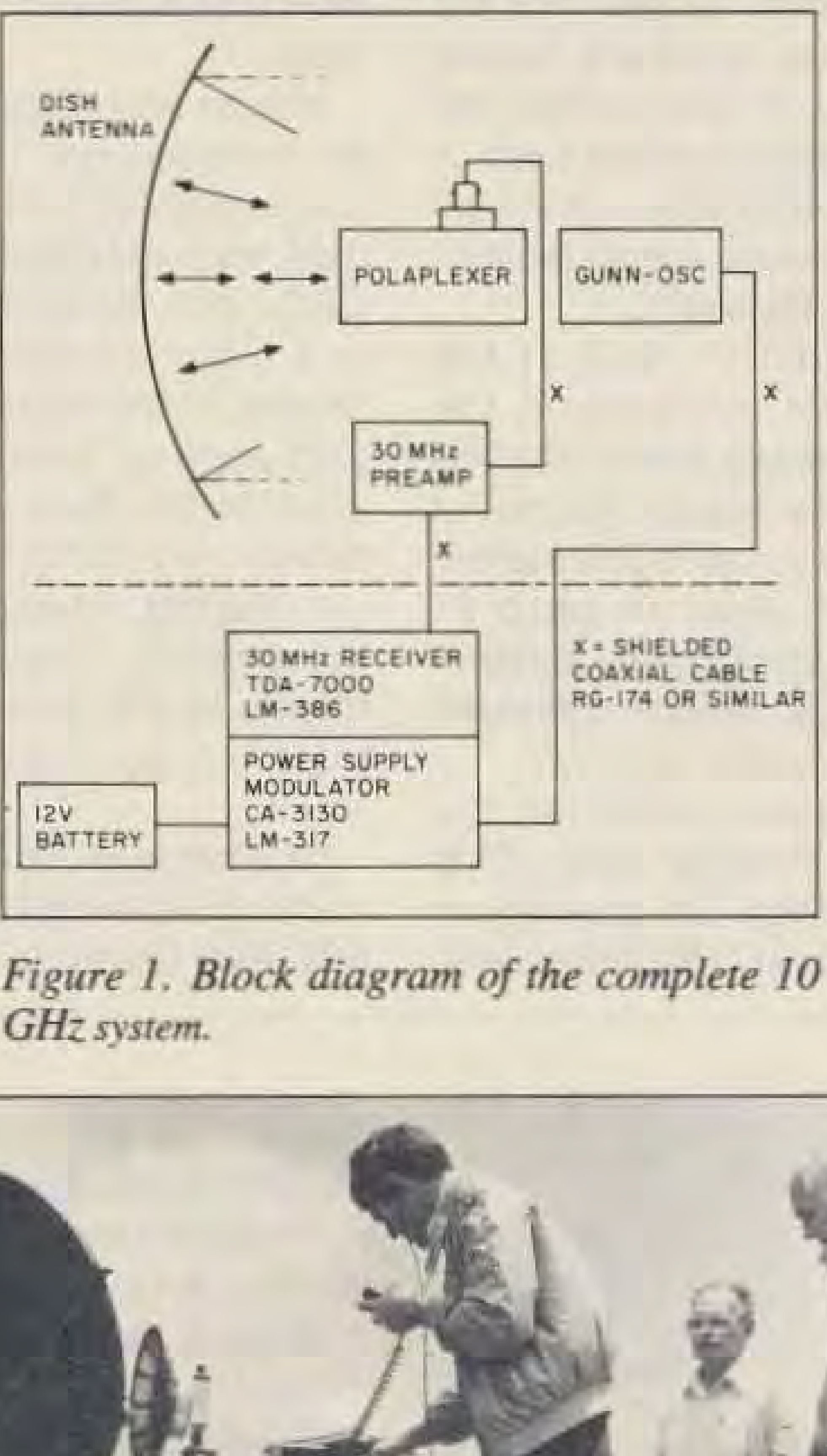

Figure 1. Block diagram of the complete 10 GHz system.

Receiver Circuitry

Figure 3 shows the WA6EXV 30 MHz 40673 FET preamp. The output of the Polaplexer detector diode (MA/COM 1N23WE) is coupled to the input of the single chip receiver system, operating at 30 MHz. For first-time operation, the detector and receiver can be connected together. You can improve operation, however, by adding an IF preamplifier between the detector diode and the 30 MHz IF amplifier-receiver. I tried several types of preamplifiers and use either a U-310 grounded gate FET or a 40673 FET. When the full system was tested on a noise meter at 10 GHz, the system noise figure was about 12 to 14 dB.

The heart of the IF amplifier is a Signetics TDA-7000 single-chip receiver. This chip has an input sensitivity of 5 microvolts for full quieting and is capable of operation directly to about 120 MHz. I am really impressed with this chip in that it operates with very few external components and does its job so well. It's hard to believe that this one chip converts the 30 MHz IF signal direct to headset level audio. This unit is an improved version of my original receiver IF amplifier that appeared in *73 Magazine* in October 1986. Operation of the unit was quite good and provided the vehicle to easy construction and operation on the 10 GHz "X" band or other microwave frequencies.

Kelly N6IZW operating the W6OYJ Polaplexer and 10 GHz SSB transceiver from the top of Mt. Soledad in California, while several other members of the San Diego Microwave Group look on. The transceiver drives a 10W traveling wave tube (TWT) amplifier. They made a contact over a 174 mile path, to a receiving system on Mt. Pinos. [Photo by author.]

This article updates the original unit and adds several unique features. Before, when operating the IF amplifier with several stations on 10 GHz, there was no easy way to offset the 30 MHz IF strip to allow for incremental tuning. This was needed, however, to keep the Gunn transmitters on frequency and compensate for small frequency errors in the receiver IF amplifier. This

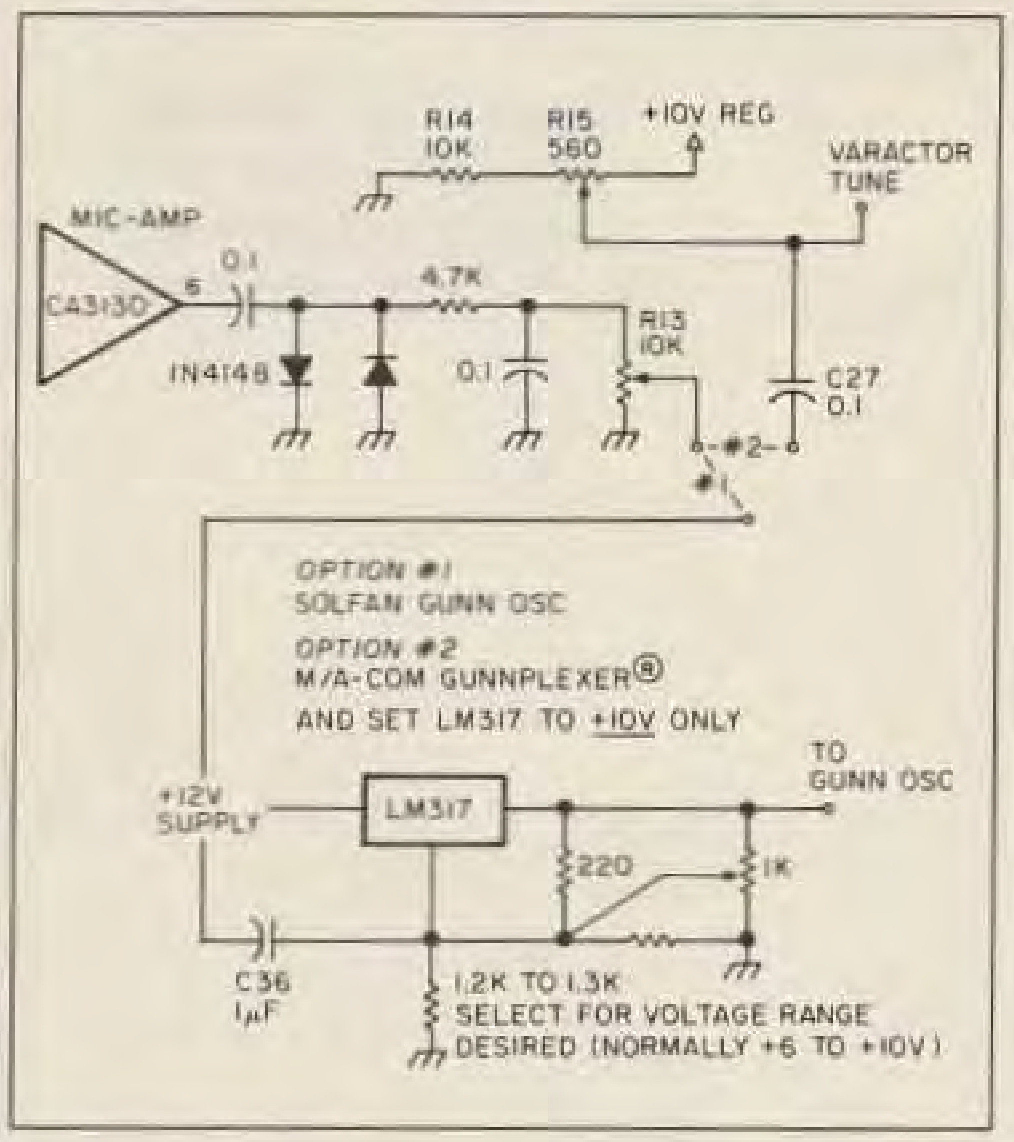

Figure 2. Microphone input modulation circuit.

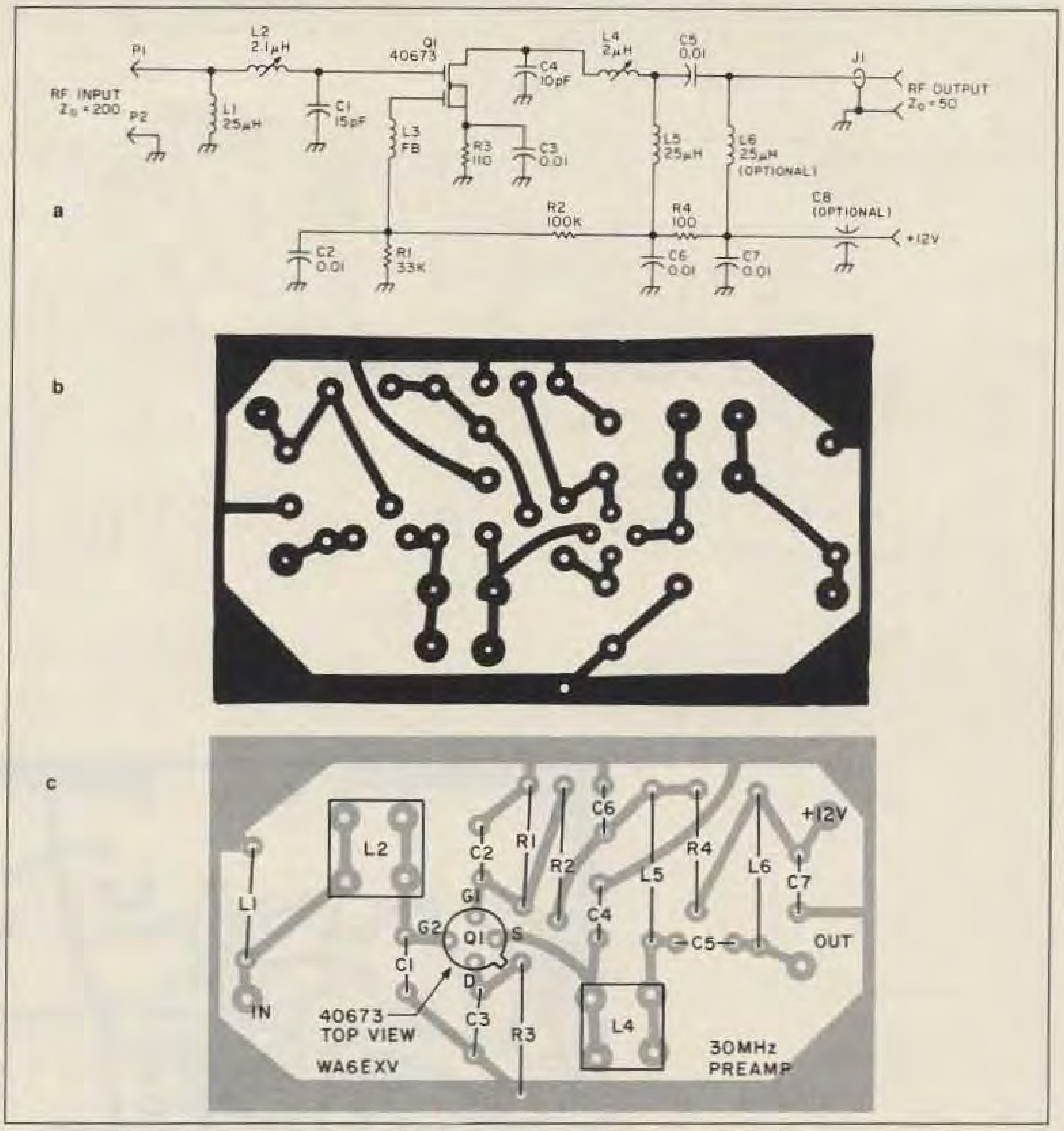

Figure 3. (a) Schematic, (b) PCB foil diagram, and (c) parts placement for the 30 MHz preamp.

was due to the 30 MHz IF not being exactly centered on 30 MHz on all units. Without it, you would continually adjust your Gunn's voltage slightly to improve reception clarity and both stations would soon "walk" each other out of sight, in continually adjusting frequency to make up for this difference. To compensate for this, a varactor diode was installed on the oscillator coil of the IF amplifier and adjusted by a pot on the front panel to change the IF frequency for a RIT offset. This allowed fine frequency netting of both stations and removed one drift problem from this transceiver's operation.

Users also soon begin to want a smaller PC board to make a more compact system. Additionally, there was no provision for making the unit adaptable to the very fine MA/COM Gunnplexers available from Microwave Associates. In this updated version, I wanted to make this unit useful for home-brew construction. After all, the main object is to have a lot of fun operating a home-constructed, inexpensive 10 GHz transceiver.

The Signetics TDA-7000 chip is really very simple. All that is required to put the chip into operation is setting the oscillator coil to the desired frequency. The low power output from this circuit is not easily detected by a grid dip meter, so I usually set receivers up by injecting a signal at the desired IF of 30 MHz.

If you live in an area with modest power FM broadcast stations nearby, as I do here in San Diego, you can touch the input pin with any metal object and hear a multitude of FM broadcast stations that are harmonically related to the oscillator frequency. Proper shielding and limiting the input to 30 MHz solves this problem.

The remaining functions are supported by fixed values of capacitors tied from the chip's pins to +5 volts not grounded. This might seem odd to most, but I assure you, it is proper. The circuitry on board the chip has an internal oscillator, mixer, IF limiter-amplifier, and a demodulator with a frequency locked loop operating at an IF of 70 kHz. Toss in about a dozen external capacitors, a few resistors, and a coil, and you have a complete basic system with operation to over 100 MHz. By selecting various values for a few components, the bandwidth can be changed from 4.5 kHz to about 75 kHz. The unit as shown in the schematic (Figure 4a) is set up for 25 kHz bandwidth. Table 1 shows the component values for different bandwidths.

Reliability

Of over 100 units locally home-brewed, fewer than 5% failed. Only two had defective ICs; most of the other failures were simple oversights in building.

There is always one unit that defies gravity. Such a unit was shipped to me for repair after I could not isolate the trouble over the telephone. It drove me nuts! I replaced quite a few suspicious components, including the TDA chip, and it still did not work. All voltages seemed proper, but the chip just would not function at RF. In desperation, I used the chip in another receiver board. This proved the chip good, so the trouble was on the board. On detailed inspection, I found that the unit had been put together with *acid-core* solder. This is a paramount no-no! It looked good but had high leakage all over the board. After giving the board a complete cleaning, resoldering with rosin solder, and degreasing with lacquer thinner, it performed quite well.

PC Description

In addition to the IF 30 MHz receiver, the printed circuit board contains a small audio amplifier, S-meter circuitry, and a microphone amp (see Figure 4b). This makes for a crowded PC board. Additionally, there are the power supply regulator chips for the 5 volt, 10 volt, and Gunn diode supplies. The circuit board is double-sided: the top foil acts as a ground plane, the bottom foil is the actual circuit. I prepared the printed circuit board by first drilling all holes that do not require grounding to the top ground foil surface. (I used a #65 bit, about 0.035 inch. Drill bits costing about 50¢ are available from model train (HO) hobby stores.)

After drilling all holes that are not to be grounded, I reamed out the top ground foil with a larger drill, 3/16" or so, giving a clearance around the component leads when inserted on the board. Once the reaming for the non-grounding holes was completed, I drilled the remaining holes. These were not reamed out allowing the grounding leads to be soldered to the top *and* bottom foils. This gives the very short low inductance ground leads, making for very stable operation.

PC Board Assembly

I usually install the resistors first to get the lay of components on the PC board. Once a few parts have been placed on the board, the

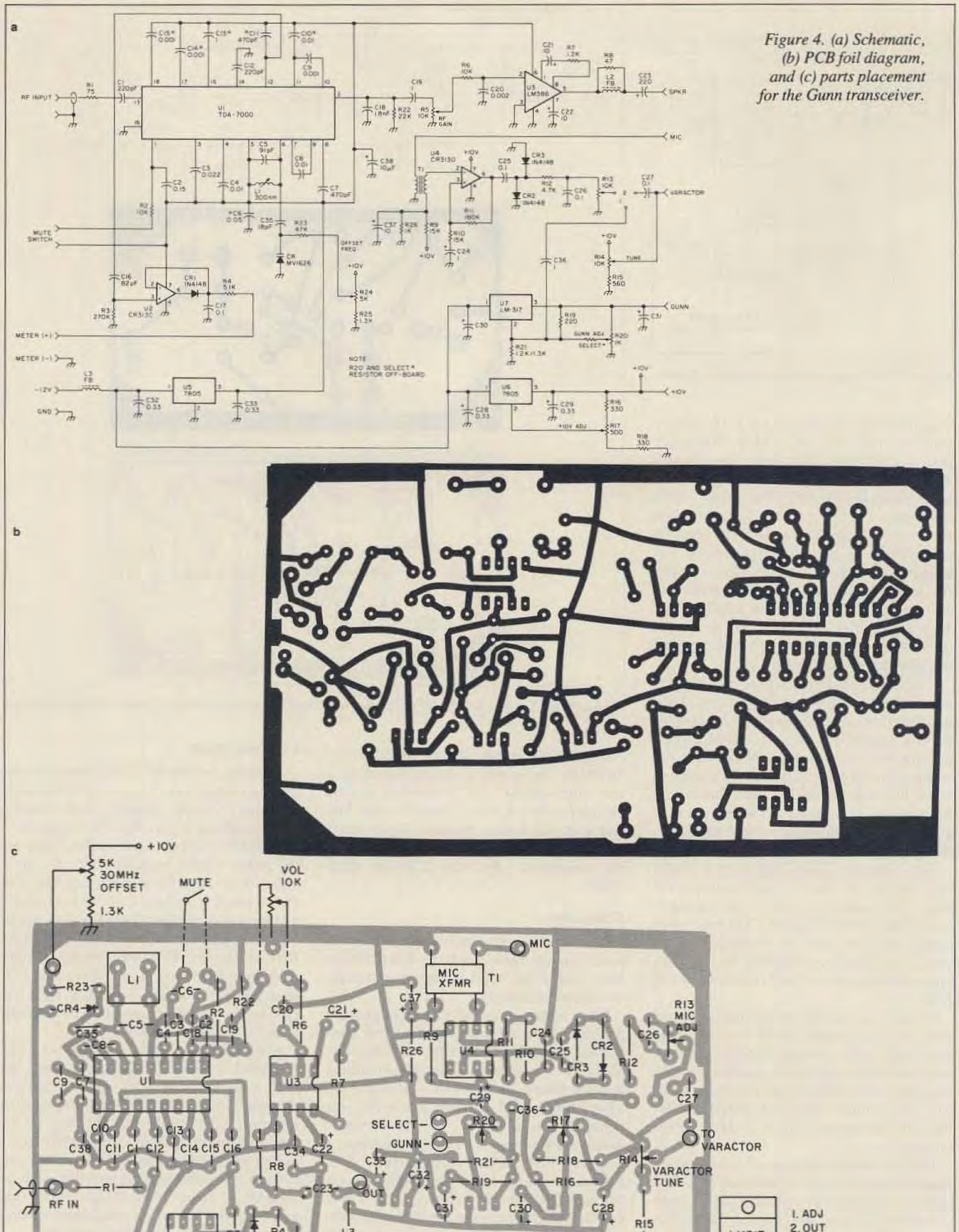

Figure 4. (a) Schematic, (b) PCB foil diagram, and (c) parts placement for the Gunn transceiver.

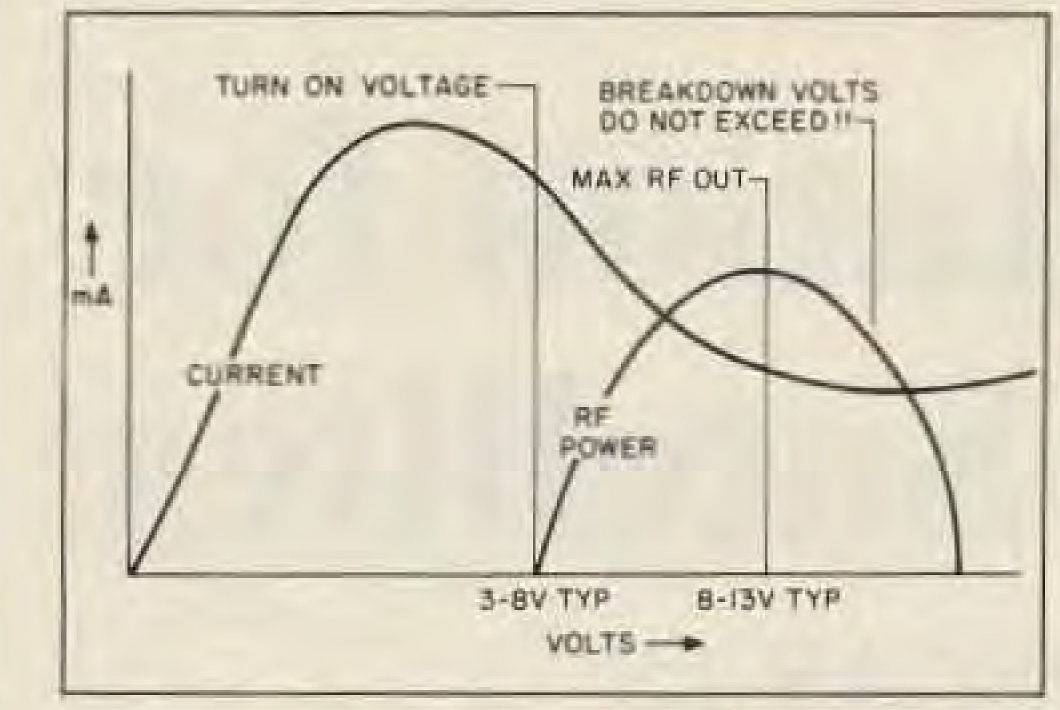

Figure 5. Gunn diode I/V curve.

rest is simpler. After most of the components are assembled on the PC board, check the power supplies for proper operation before mounting the chips. (I mount the TDA-7000 last.) Primary power for the unit is provided by either an external or internal 12 volt battery. I hooked a five-foot-long connecting cord to a surplus 2½ Ah lead-acid battery similar to the size of a motorcycle battery. The capacity allows many hours of continuous operation without recharge.

The 5 V supply is standard with a 7805 +5 V regulator. The Gunn power supply uses a LM-317 adjustable voltage regulator, providing 6 to 10 V adjustable for frequency control, and has audio modulating its adjust terminal. The 1k adjust pot (R20) and its fixed limit (select) resistor are mounted off-board, allowing front-panel frequency adjust for use with non-varactor cavities. In its use as supply to a varactor-type cavity, the voltage of the LM-317 is fixed at 10 V and the microphone output deviation control is coupled to the varactor voltage tune line for transmitter modulation. See Figure 2. The main reason for using fixed resistors in the adjust circuit of the LM-317 is that more than 12 V may destroy your Gunn diode. In the event of high battery voltage, the LM-317 limits the voltage to a level that is safe for the Gunn diode.

The 1k tuning pot is set with the series resistor (select) to limit the voltage range to a maximum of about 10 V. You can omit the two extra resistors, using just the 220Ω, and replace the fixed adjust resistor with a single variable. The +10 V supply uses a 7810 fixed regulator. However, you could use a single 7805, referenced above ground, allowing it to provide other than its normal +5 V. It holds down costs and doesn't provide high currents, so it works very well in this application. Most of the regulators can be obtained at Radio Shack. The 7805 is RS #276-1770, and the LM-317 is RS #276-1778.

Alignment

After power supply check-out, give the PC board a once-over, and when satisfied all is proper, apply power. The slug in the core of the ⅛" coil form of the TDA-7000 oscillator circuit will be adjusted first. You might want to enable/disable the mute line by connecting +5 V to the mute line 10k resistor. Connect a signal generator to the input of the IF amplifier receiver and find out where the device is tuned to. Once you have found the point where the receiver is operating, adjust the slug in the core to alignment at 30 MHz. If you can't obtain operation at 30 MHz, you might have to pad your coil with a capacitor on the bottom of the PC board to bring it to frequency. (I used a ⅛" adjustable coil form with 12 turns of #24 wire.) This adjustment is done with the varactor in place and the tune (RIT) control set to approximately mid-position. I used a 1N5141/1N5142 varactor, 12/15 pF respectively. Any similar low-capacitance varactor diode will work here.

Frequency Calibration

When the final frequency calibration is completed, you should obtain a signal that is full-quieting from about 5 µV. I do not have an FM generator, so I use a surplus URM-26 (AM generator) for check-out on my work bench. Operation of the S-meter circuit can be checked and calibrated with your signal generator for an indication of what µV sensitivity is indicated on the S-meter for future reference. You might want to connect your preamp for these measurements.

Gunn Safety

After the receiver is performing as needed, fire up the Gunn oscillator. A Gunn oscillator can be checked out without any complex instruments, to at least determine if it produces RF. One word of caution: Don't look into the open end of any waveguide system when it is radiating; the microwave radiation can injure your eyes. With low power devices, the safe distance is a few feet, but always use caution. Others might not know about the dangers. Safety first!

Again, it's easy to tell when a Gunn oscillator is oscillating. Connect a current meter in series with the power supply line and turn on the power. Preset the output voltage to about 5–6 volts, as the Gunn devices draw maximum current at very low voltages. With the normal Solfan 10 mW diode in place, use 9–10 volts. Wave your hand in front of the cavity opening and watch the current meter. This detunes the cavity and changes the operating point of the Gunn diode. It should affect the current being drawn. A crude method, yes, but it works on the bench, giving a quick indication of Gunn operation.

Gunn Diode Notes

Gunn devices draw maximum current at low voltages, so avoid these voltages. A Gunn's resistance does not read like a standard diode front-to-back ratio, but looks more like a 2–3Ω resistor. (Caution: Gunn diodes are voltage-polarity sensitive.) As the voltage slowly rises, a point is reached where oscillation starts. Further increase in voltage produces an increase in output, up to a point. Beyond this point (maximum RF output), increasing voltage produces a decrease in RF output. Going much above this point destroys the Gunn device. See the I/V curves in Figure 5.

Transmitter Operation

The transmitter (Gunn oscillator) connects to the Polaplexer detector mount, and the detector output connects to the input of the 30 MHz IF amplifier. If you use coax connectors to break the cables, use different types, or mark the coax cables to prevent supplying 10 volts to the mixer diode and destroying it. When powered up, you should see about 0.8 mA of current on the mixer diode when the injection screw is set for proper mixer injection. All that is required to use the system is another unit to put into full duplex 10 GHz operation.

In the Field

The Polaplexer/transceiver system has gone on countless outings, and performed very well. One advantage to the Polaplexer system is that you can quickly change—in just a few seconds—the polarization for either vertical or horizontal operation. Our organization, the San Diego Microwave Group, has settled on a vertical mode of operation.

On a recent DXpedition to a nearby hilltop, several transceivers were set up and many contacts made. Our Big Gunn system was in operation using narrowband SSB on 10.368 GHz, feeding to a traveling wave tube (TWT) and producing several watts of power on 10 GHz. Our group's best SSB DX contact to date is 174 miles. About 10 days later, Don WB6FWE on Mt. Pinos and Jack N6XQ on Mt. Soledad made contact using Solfan Gunn units and our transceiver board, for a wideband FM contact over the same SSB path—174 miles. I think that sets a record for Solfan use that will be hard to beat, considering the very modest units involved.

Parts Kit

I have a kit of new parts available with a PC board etched and ready for drilling. The parts kit includes the TDA-7000 chip, some Mylar™ capacitors, and the ferrite bead used in the audio circuit. I usually include a few other parts I have on hand as well. The basic kit cost with PC board is $10 postpaid. I will supply varactors, if needed, for $1 each. I also have a supply of high-output Gunn diodes providing 50 to about 100 mW at 10 GHz. Six and 18 GHz devices are also available. I test all devices prior to shipment and furnish specs. Cost of the Gunn diodes is $5 each; $10 each for premium devices with power out of 100 mW and up. I will be glad to answer any questions concerning this project or any other related microwave subject. For a prompt reply, include an SASE. Chuck WB6IGP, San Diego Microwave Group, 6345 Badger Lake Dr., San Diego CA 92119. ■

Component	Bandwidth		
	75 kHz	25 kHz	4.5 kHz
C8	3300 pF	0.01 µF	0.1 µF
C7	180 pF	500 pF	2200 pF
C9	330 pF	1000 pF	4700 pF
C10	3300 pF	0.01 µF	0.1 µF
C11	150 pF	470 pF	3300 pF
C14	330 pF	1000 pF	4700 pF
C15	220 pF	620 pF	3900 pF
Bypass			
C6	0.01 µF	0.1 µF	0.1 µF
C15	0.1 µF	1 µF	4.7 µF

Table 1. Values for changing bandwidth of TDA-7000. Compiled by WA6EXV.