VHF and Above Operation

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A Safe LED Optical Transceiver System — Part 3

Well, this month let's wrap up the LED transceiver and get on with the remaining photo optical receiver circuitry. By the way, the LED used in the transmitter circuit covered last month is a Radio Shack 260 nM 5000 Mcp high-output-power LED, part #276-086, costing just less than $3 apiece.

Basically, the receiver is a sensitive photo diode with a large cross-section area and 4-transistor amplifier that we obtained in surplus. Alternately, a diode can be obtained from commercial sources for under $5, and an alternate amplifier using an op amp could be used here to replace the 4-transistor circuit that we built from used surplus components.

The photo diode and amp assembly is placed in the exact center of the first forward facing pipe cap assembly and has light focused on its surface by the Fresnel lens in the splice union. Again, just like the LED transmitter, the assembly is quite identical for both receiver and transmitter circuitry. The rear cap (of the two caps cemented back-to-back) houses the local oscillator and mixer circuit that converts the 35 kHz (or 45 kHz) received FM from the photo diode amplifier to a frequency in the 2 meter ham band for reception only on my 2 meter HT.

We used a synthesizer at 145 MHz to accomplish this conversion. However, other frequencies are possible depending on what you have on hand to serve as a local oscillator as well as your choice of FM receivers for reception. A scanner will function just as well as the 2 meter HT I used. While an FM broadcast receiver would seem to function here, its FM bandwidth is too wide for narrowband FM reception, making this an unlikely choice. With the LED being switched at a rate above 50 or so kHz, efficiency drops off, making wider modulation schemes impossible with this design.

Photo A. *Front view of entire system showing spotting scope on top, centered between the receiver and transmitter 4-inch assemblies. Visible just inside the front of each tube is the Fresnel lens in the splice union coupling.*

In our system, we used a synthesizer to produce an LO of 145 MHz for injection into the LO port, pin 8, and ground of a SBL-1 mixer to convert the 35 kHz IF to 145.035. The output of the converted photo diode detector amplifier assembly feeds the IF port, pins 3 and 4 tied together, and common ground of the SBL-1 mixer directly. The RF port of the mixer, pin 1 (blue pin), and ground is the coaxial connection to the HT's RF connector. The SBL-1 mixer has pins 2-5-6 and 7 all tied to common ground. Again, pin 8 is LO input, pin 1 is RF output, and pins 3 and 4 are the common IF input.

I have used many different other agile sources of RF for LO injection to the mixer, replacing the synth on a trial basis. Any good signal generator that is stable enough to be held on frequency for narrowband FM work would do for a bench test. It would seem that a simple crystal oscillator circuit that is used for a 2 meter converter could be duplicated here to replace the synthesizer circuit. The frequency of the circuit needs to be changed from the original circuit that appears in almost any *ARRL Handbook* on VHF 2 meter converters. Just the crystal oscillator circuit needs to be built with a suitable crystal for the frequency desired.

In another test, I tried a TTL oscillator at 78 MHz and coupled it to a MMIC amplifier. Not only did it amplify the 78 MHz, but it also proved to be a good 2nd harmonic generator at 156 MHz. Using 156 MHz unfiltered for other harmonics and 78 MHz I tried readjusting my wide coverage HT to the commercial FM band (150 to 174 MHz). I set it to 156.035 MHz and it worked as well as using the synthesizer and 2 meter portion of the HT frequency range. Harmonic output of this 78 MHz crystal oscillator was quite good, giving full scale S-meter reading in my back yard with just the crystal oscillator powered up on my workbench. Stability on my FM HT at 156 MHz was quite good.

The TTL oscillator is powered from +5 volts DC at a few mA, and puts out .8 volts p-p or just about zero dBm as measured on my 432 HP power meter. Duplicating pin pattern for a standard 14-pin IC, pin 1 is DC ground, pin 6 is signal RF ground (can be common ground connected). Pin 7 is +5 volts DC, and pin 14 is 78 MHz RF output.

Whatever circuit you use, be it the 2 meter converter crystal oscillator circuit or the TTL crystal and MMIC design, either one will work well for you. This simplification of the circuitry and component parts required will help to hold down parts count, eliminating the more complex synthesizer. The reason I tried the 78 MHz TTL crystal oscillator is that I came across a quantity of 78 MHz TTL oscillators and they seem to work well. If you have any TTL oscillators in the junk box, give them a whirl — it might work. Remember, this is just a suggestion, as there are many other frequency combinations that will work just as well. Put the junk box to use if at all possible.

The TTL oscillator is a quite simple 4-lead device looking much like a IC that fits into a standard IC socket. They are a complete oscillator circuit and crystal all enclosed in a miniature metal can. Mount the oscillator dead-bug upside down on a small piece of PC board next to the MMIC amp capacitor coupled to the MMIC input. A DC supply resistor and output coupling capacitor complete the LO TTL oscillator. A short section of miniature coax couples RF out of the MMIC amp harmonic generator to the LO port of a SBL-1 or similar mixer.

The photo detector we used was obtained from surplus and had a four-transistor amplifier as part of the assembly. The photo detector/amplifier was chosen because it had a large surface of active light detection area about 3/16 of a inch square. This assembly used a detector that was not obscured with a dark red infrared filter. If the detector you obtain is covered with a molded IR filter on the detector, a suitable replacement photo diode can be obtained from Newark Electronics (see **Photo C** caption).

The surplus photo detector/amplifier assembly we obtained was not filtered (for IR), making it very usable over the LED visible frequency range. The units with a IR diode and IR filter (very dark red) are not usable as far as the photo diode is concerned. See **Fig. 1**. The photo diode should be clear in appearance, allowing you to see the dark photo sensitive element in the device. See **Fig. 2** for the reverse-engineered schematic of the photo detector amplifier and the conversion to the output transistor amplifier circuit. This converts

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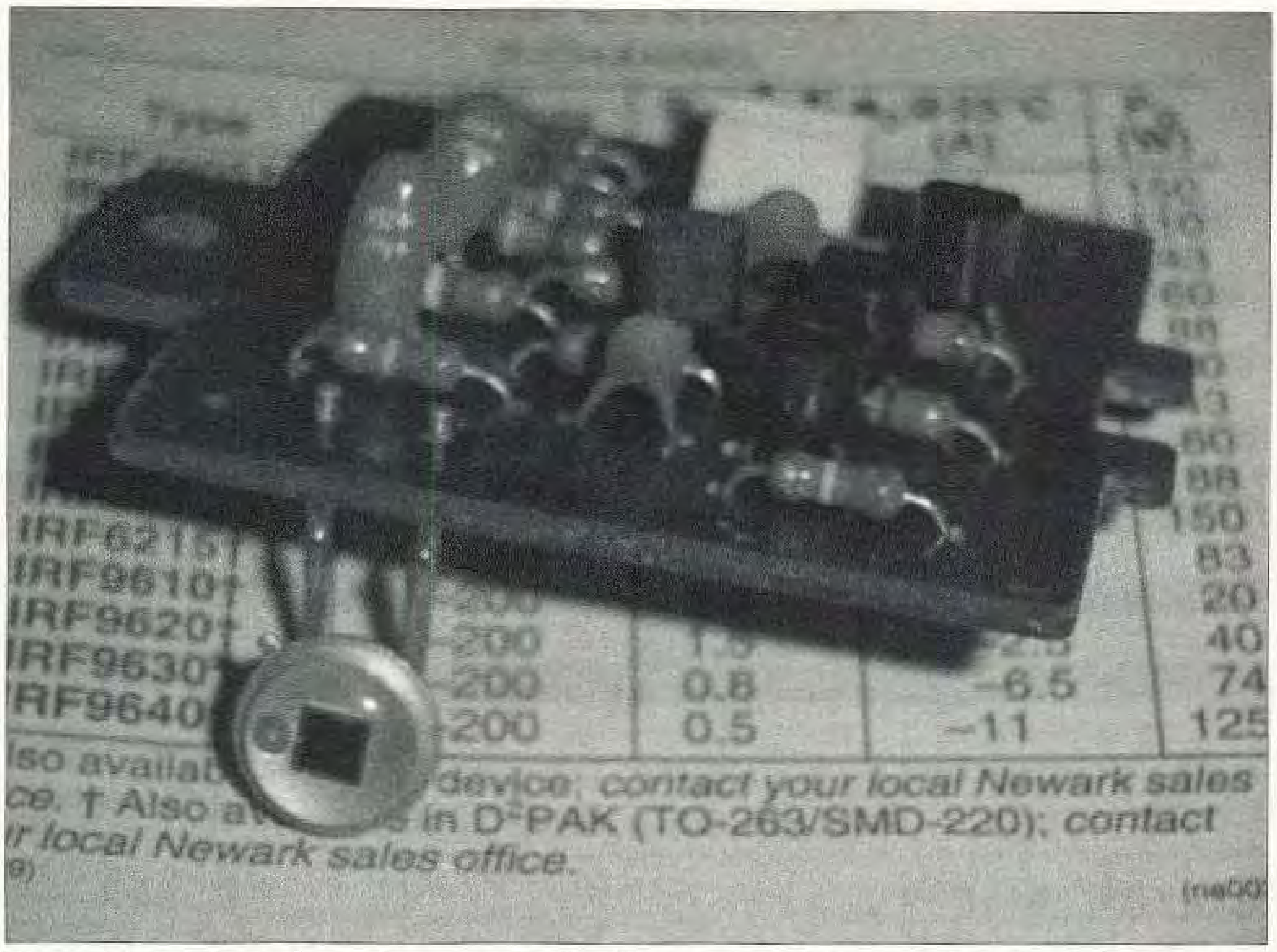

Photo B. *Original photo detector obtained in surplus. Note the photo diode near bottom left. You can see active element for photo detect in visible light. If it were for IR use only, it would be obscured with a very deep-colored RED lens.*

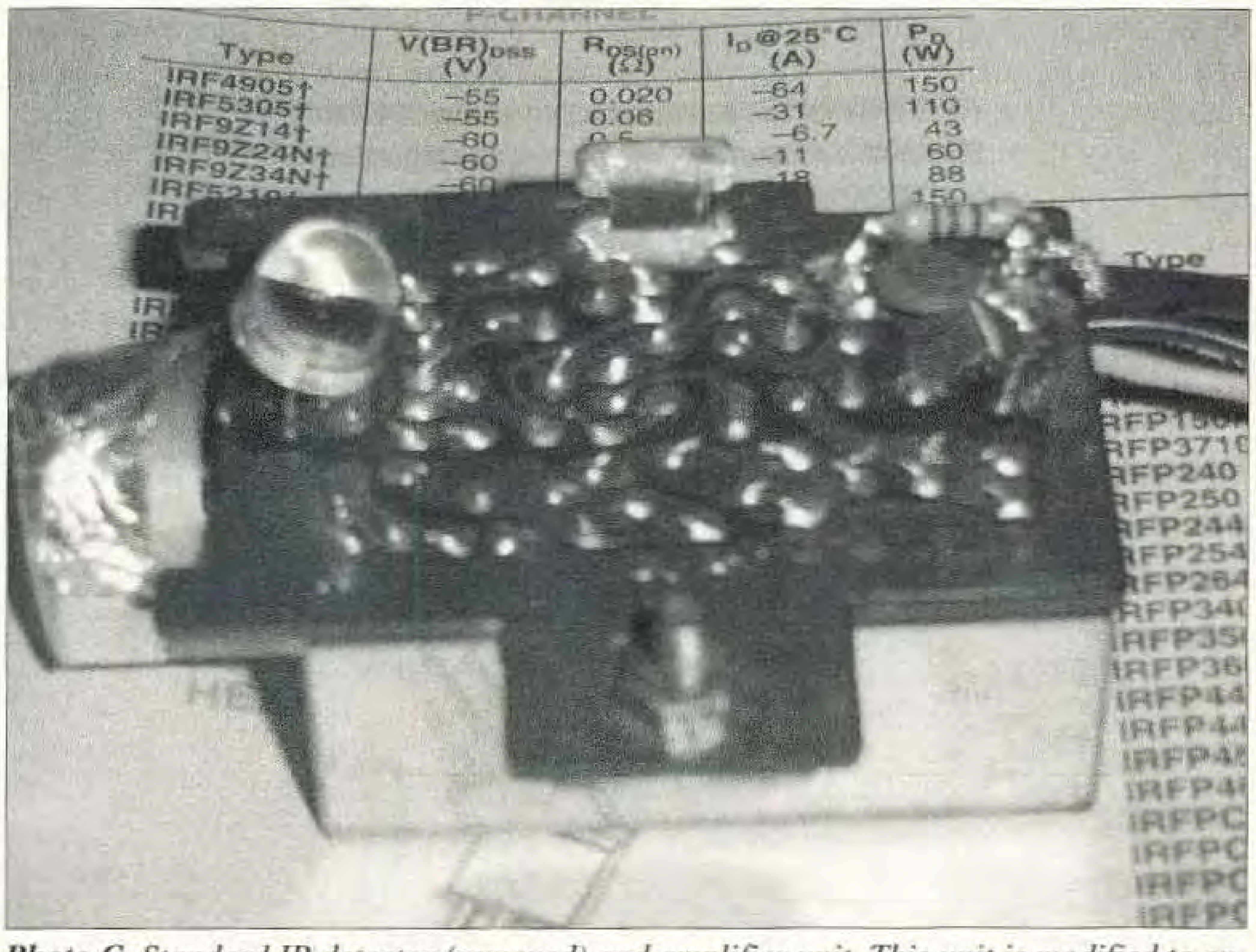

Photo C. *Standard IR detector (removed) and amplifier unit. This unit is modified to experiment with the Newark Electronics photo diode (#95F9029, p. 583, Newark Electronics cat. #117). As you can see, the Newark Electronics replacement photo diode has a clear white plastic lens. The Newark photo diode replaced the IR diode as received in surplus. Same 1k emitter mod on final transistor amplifier stage.*

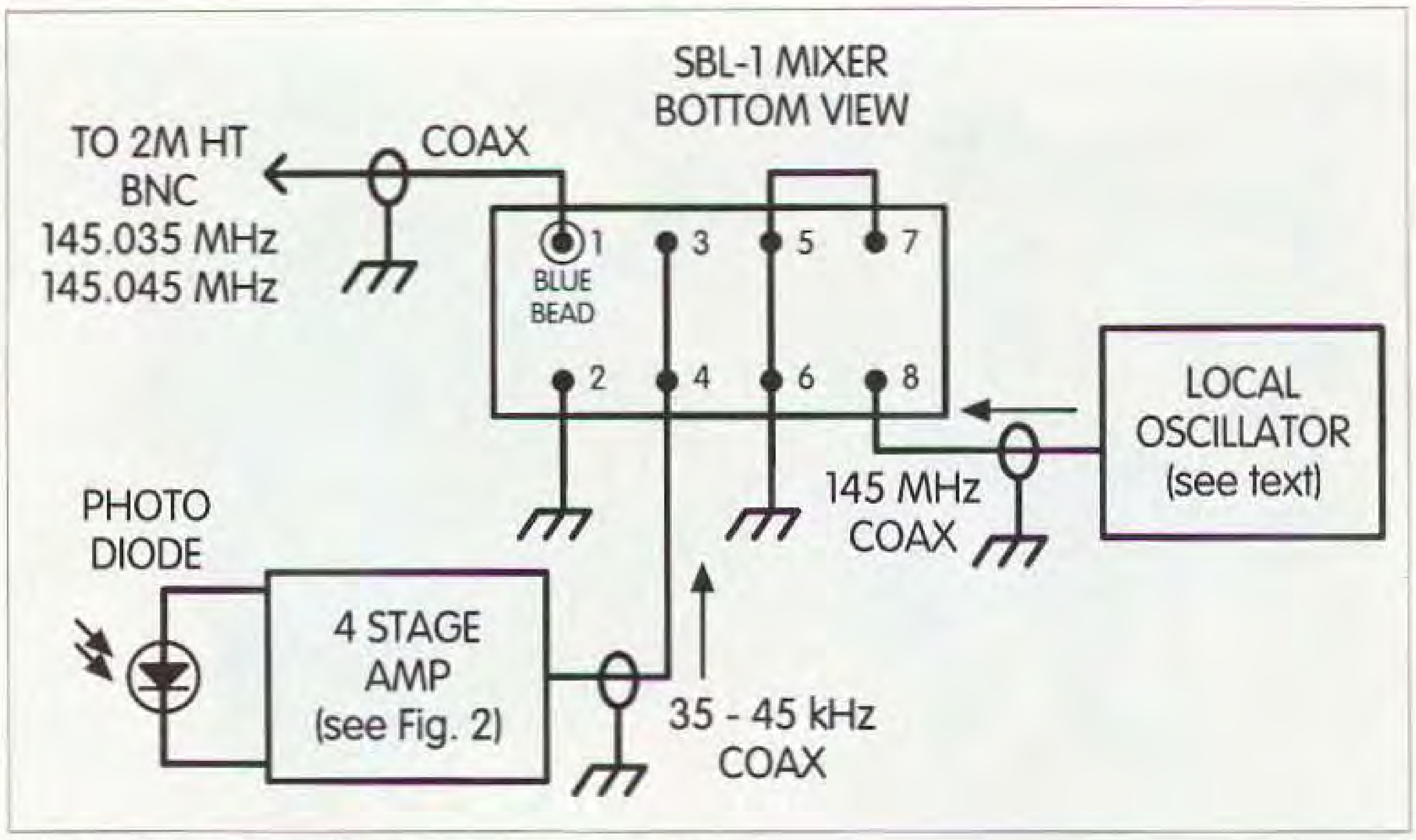

Fig. 1. Optical receiver/converter schematic.

Above & Beyond

continued from page 45

from digital to analog for use with our FM application.

The conversion is simple, as the original transistor emitter is grounded and needs to have ground broken to the emitter, to be replaced with a 1k resistor. Output is not the collector as in the original circuit, but converted to an emitter follower by coupling out of this last stage on top of the 1k emitter resistor coupled with a .001 μF capacitor.

Alternately, if you can't locate an IR detector assembly, an alternative could be a suitable photo diode and constructing an amplifier using a common op amp. While improved designs use high performance op amps, most of these amps are hard to locate. The op amp design is not critical — it's your choice. See what you can come up with from the junk box. A good junk box will cut costs.

With this design, I hope you don't follow exactly what I used, but rather use it as a guide. I used what I was able to find in my scrap metal and surplus dealers for low cost assembly. You're quite welcome to follow exactly but try where possible to use alternatives from locally available components to reduce your construction costs. In that way, you should use this as a guide not as an absolute to-follow-at-all-costs design.

The output .001 μF capacitor of the photo detector amplifier is coupled to the IF port of an SBL-1 mixer. Now, amplifying light might not seem proper using common RF components, but remember what we are actually amplifying is the LED's light output chopped at 35 kHz rate. That's the RF carrier with the FM modulation superimposed on this carrier frequency. That's why we had to modify the transistor amplifier output stage to analog to pass without distortion the carrier and its FM modulation.

The local oscillator, be it a signal generator, synthesizer, or TTL crystal oscillator MMIC amplifier, is injected to the local oscillator port (LO) of the same mixer. The HT antenna is connected to the RF port via miniature flexible coax cable.

Startup tests were performed inside a garage, focusing the LED transmitter on the inside of the garage door and setting the TX optics for best spot focus. Turn on the receiver and connect the HT tuned to your receive frequency (RF carrier + local oscillator injection frequency). The RF carrier is either 35 or 45 kHz and your LO is 145 MHz with the synthesizer or 156 MHz if you used the 78 MHz TTL crystal source. If all is functioning, you should have a full quieting signal of the HT receiving your RF being generated from the LED transmitter. For best return signal, you might have to target a plastic bag or some reflective surface to give a return reflection.

Further tests include peaking up the system using a remote reflector mounted quite a distance away, say, 200 or so feet distant. Auto rear backup light reflectors make a great target also. Aim the LED transmitter at the reflector, and when the transmitter is being reflected (very noticeable) by the remote reflector, signal strength on the HT should be nearly or completely full S-meter deflection. Align the spotting scope and target in the scope's crosshairs first for a coarse adjustment. Then peak up system performance using an attenuator in the HT path to reduce overloading. Use the S-meter to peak up on. At the same time, the final rifle spotting scope adjustment is done by slightly loosening the vertical and horizontal calibration screws on the scope mount. Then, move the scope and position the scope crosshairs, aligning the scope on target with the LED transmitter being reflected by the reflector target.

If all is well after this initial alignment, re-verify mount rigidity, as it will be subjected to some stress when the whole unit is moved to a remote location for further tests. I suggest moving out the distance attempted from a modest test at relative short ranges to greater and greater ranges as system sensitivity suggests. Try across a school or park open space first or up and down a city block first before trying a greater distance. If S-meter readings are still way up there, go for a greater distance. We tried 2 miles and made it on our first attempt. This,

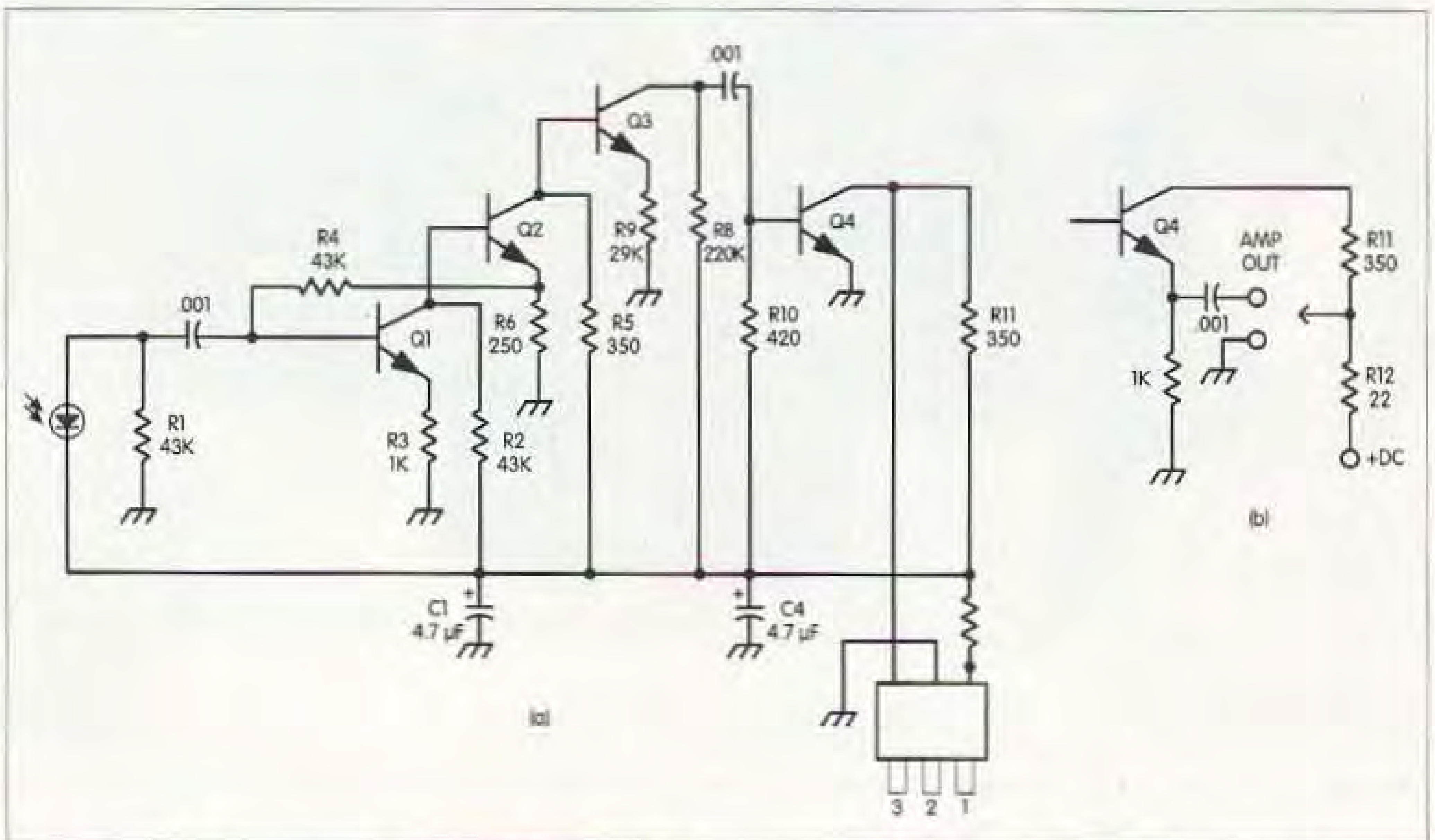

*Fig. 2. **(a)** Reverse-engineered drawing of converted surplus IR diode detector and 4-transistor amplifier. **(b)** We converted the output stage by removing ground on the emitter and coupled out of the emitter with a .001 μF capacitor.*

after great care was given to align the LED and detector diodes in the center of the respective housings and making a careful focus of the Fresnel lenses for best focus sensitivity.

These tests were made at night and from nearly black background areas. To locate each other, a very bright flashlight was blinked on and off. Just like using microwaves, if you are using a narrow or few-degrees dish antenna and you're not pointed at the correct heading, you won't make contact.

When you have contact, you can visually observe the LED transmitter at the remote location. The LED system looks like a bright porch light — colored red, of course. Not overly bright, as observed at a 2 mile distance. You immediately wonder if this thing will function at this distance at all, being as dim as you optically observe this light at this distance. In practice, these units can still have detection (noisy) when slightly off direct aiming. If you use an SSB HT for lineup, this allows you to detect a CW tone from the carrier and use this tone to peak up the pointing angle as compared to relative tone strength. This tone can be fed back to the transmitting location to facilitate alignment using the SSB receiver feeding back this tone over the communications liaison system. We use 450 MHz simplex frequencies to prevent having anything locally in the VHF 2 meter IF band used in this optical transceiver.

Did I forget to mention using a good tripod for the system? We use the same tripods for this system that we use for our microwave dish antenna mounts. Whatever tripod you use, we suggest a heavy one — much heavier than a standard camera unit. Camera tripods could be used; however, they are not as sturdy as a microwave tripod.

Also when setting up at night, be sure to bring a small flashlight for local use to check setup in the dark. A useful light is an old military signal flashlight with red colored filters over the flashlight bulb to retain some of your night vision, allowing you to look through the spotting scope. It's not a necessary item, but a thought. For a liaison radio, we used our 450 MHz FM HTs on a simplex channel for communications setup as they're much better than arm and hand signals.

A nice addition to this liaison communications setup is a Radio Shack VOX headset boom mic, part #19-312. The cost is $50 — much less than others on the market. Its use allows hands-free operation for work on the optical system and communications over the liaison channel while setting up. The VOX operation is very nice, and it seems to be able to be used on many different HTs that not only include a whole series of Icom radios, but also Alinco, Yaesu, and Standard models, according to Radio Shack catalog details.

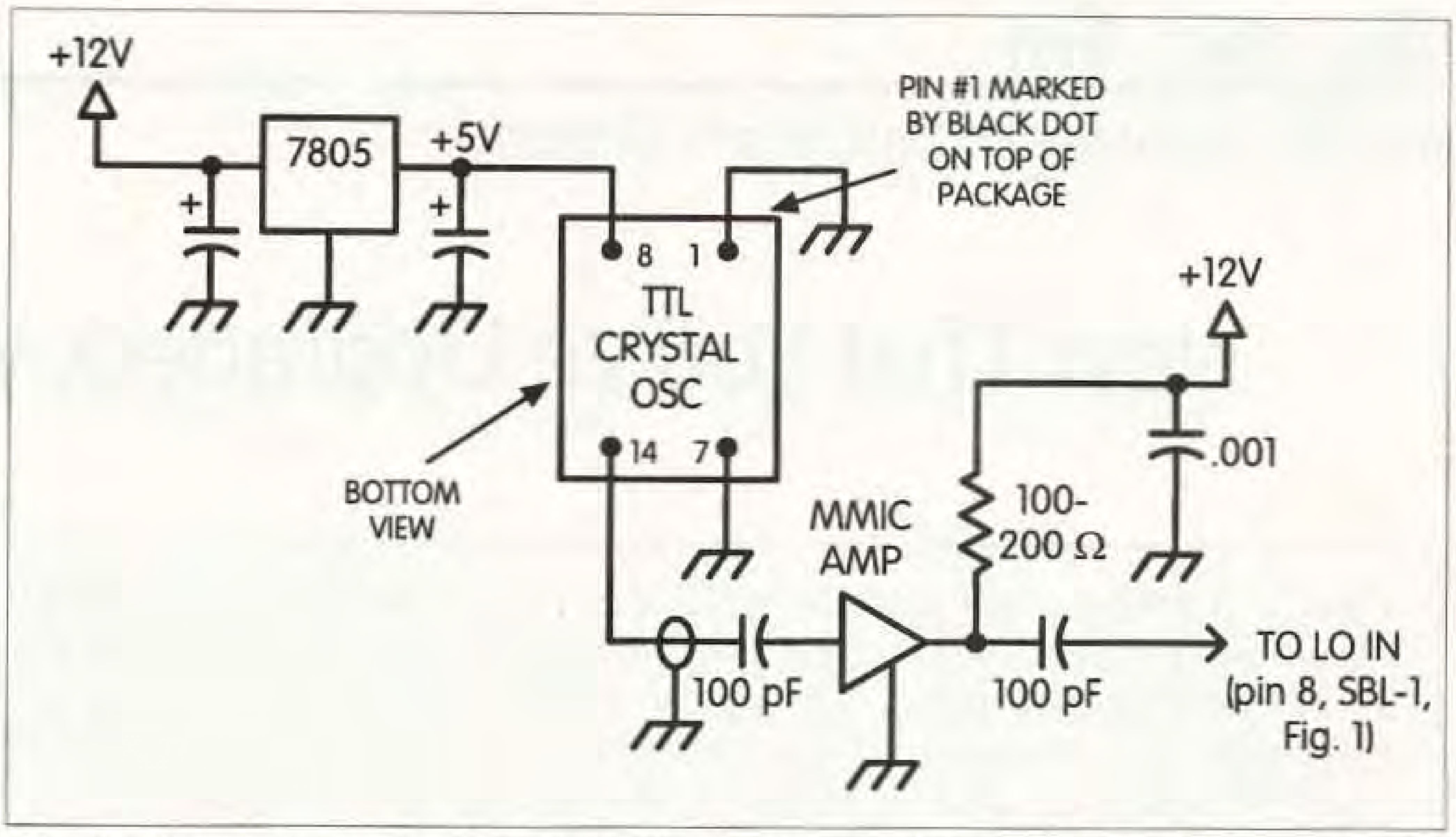

Fig. 3. *LO constructed from 78 MHz TTL crystal oscillator and MMIC (driven hard to produce harmonics) used for LO injection at 2nd harmonic for 156 MHz reception of the LED transmitter, 35 or 45 kHz modulation.*

Don't forget to bring along some of the creature comforts like a lawn chair. You might have a wait for total setup and there is nothing like being comfortable.

Well, there is the entire system that Kerry N6IZW and I constructed.

Of course, there are improvements that can be constructed and added on to this system. The tripod head we used had a return spring that somewhat argues with the manual positioning of the tripod in fine positioning settings. Just could not set on to a spot but near it. It was like there was backlash in the mechanism. I suppose in its original use this tripod that we used was in reality a TV camera tripod. The return spring was a great device with such a heavy camera. For our system it was removed, and we use the horizontal and vertical locking screws. This made life easier for finer pointing when using the rifle scope crosshairs to align scope and target together.

Well, that's it for the system. I hope you have as much enjoyment as Kerry and I have had in this project. It just goes to show you that some things that seem impossible are just not so. They might be, but until you give them a whirl, you will never know. I have located a quantity of 78 MHz TTL crystal oscillators and will make them available for $2 postpaid.

For laser topics and lots of information and suppliers check out Web address [http://www.qsl.net/k3pgp/opening.htm]. Our final plan is to use the system during the ARRL 10 GHz and up contest for fun, should my KNEES allow me to do so. Best 73 for now, Chuck WB6IGP.

Depression is merely anger without enthusiasm.