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Above & Beyond

VHF and Above Operation

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10 GHz fun, 1999 update, part 2: the Gunn diode modulator power supply

Last time, we covered construction of the Ramsey FR-10 30 MHz FM IF system for our microwave transceivers for use on both 10 GHz and 24 GHz. This month, I want to complete the construction of the transceiver package, with discussion about the additional circuitry required in the transmitter portion of the system.

The power supply modulator in a wideband FM system is quite simple in that DC voltage is used to power a Gunn diode in a microwave cavity. The 24 GHz Gunn-varactor-controlled transceiver can be obtained from SHF Microwave Supply [arutz@shfmicro.com]; phone: (123) 456-789; FAX: (123) 456-789. The 30 MHz receiver was obtained from Ramsey Electronics, 793 Canning Parkway, Victor NY 14564; 1 (800) 446-2295 will get you the order desk for the FR-10 30 MHz receiver.

A little review is in order due to differences between 10 and 24 GHz Gunn oscillators. For 10 GHz, the Gunn voltage is in the 5 to 10 V range. Current requirements depend on the power output of the Gunn device. Ten milliwatt Gunn sources draw about 50 to 100 mA of current, while 100 mW devices can draw as much as 600 mA. 24 GHz Gunn diodes require lower voltages to function than the 10 GHz devices do. Nominal voltage for a 24 GHz Gunn device is in the 3 to 6 V range, with requirements similar to those of the 10 GHz devices with regard to power and current drawn.

The power supply/modulator for either circuit is quite the same. In each case, the power supply is constructed from a single LM317 adjustable voltage regulator. For systems that use a varactor diode, the Gunn diode voltage is set at a fixed value near its maximum voltage of around +5 V, depending on diode specifications for that particular diode. Then, to adjust frequency, another variable resistor varies voltage on the varactor to adjust frequency of operation.

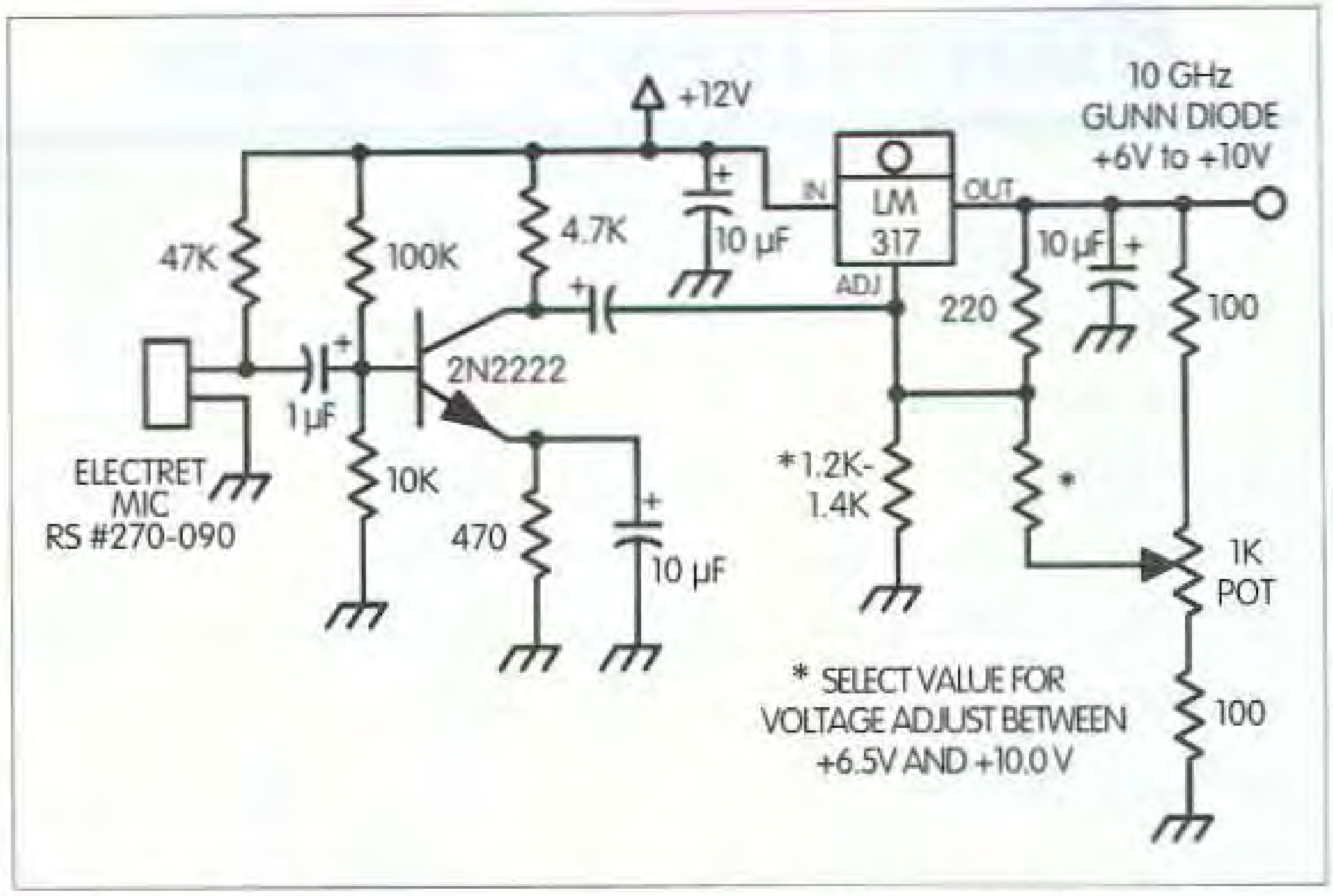

Fig. 1. Schematic for power supply modulator for 10 GHz Gunn diode source requiring +10 volts without varactor control. You must use an LM317 adjustable regulator for the circuit to function with modulation. A 7810 voltage regulator will not function as a regulator, having only in/out and ground, and no reference terminal.

The modulator mike amplifier of the circuit can be a single transistor or an op amp. In the case of varactor cavities, the mike amp is connected to the adjust terminal of the varactor regulator. Audio from the mike is a small-value AC component now riding on the regulator adjust terminal of the variable voltage regulator.

When the mike audio (a small-value AC voltage) is added to the fixed DC voltage on the regulator, it causes the output voltage to vary at the audio rate, producing a change in frequency varying at the audio rate. This produces FM (frequency modulation) on the transmit signal. The amount of audio when increased affects the deviation of the transmitter FM. The audio voltage (very small AC voltage) rides on top of the DC varactor control voltage that is used to set the RF frequency of operation.

Quite a simple scheme, mike audio to FM in a voltage regulator circuit. In the Gunn diode without varactor frequency control, the audio is connected to the Gunn diode voltage regulator adjust terminal to function much the same as in the varactor scenario. The non-varactor cavity setup is hampered with less frequency agility than varactor cavities allow. Frequency agility is quite good with varactor cavities, making them more expensive and desirable. In any event, both work—it's just that the varactor cavity is like a Lincoln in comparison with an economy car. See **Fig. 1** for the power supply modulator circuit for a basic Gunn oscillator cavity without varactor control.

A simple circuit uses a single 2N2222 NPN transistor for the audio amplifier mike amp, as shown in **Fig. 2.** The LM317 circuit is similar for all applications, whether with 10 or 24 GHz Gunn sources. The only differing factor is the voltage required for the Gunn diode—approximately 10 volts for a 10 GHz diode and a value of about five volts for a 24 GHz diode.

With most systems operating from +12 volts DC, a direct connection to the LM317 will be sufficient, with a modest heat sink to dissipate heat. For higher-current operation for high-current diodes, use a bootstrapping NPN pass transistor to increase the regulator's current handling ability. Almost any NPN transistor will work. I used a TO-220-case 2N3055, as it was in my junk box. Any modest current device with work, too. Use an insulating mount to secure the transistor to a chassis, as the back of the device is the collector and needs to be insulated on the heat sink. See **Fig. 4** for circuit details.

Bypass the emitter of the NPN pass transistor with a 10 µF or more cap (value not critical) to minimize noise on the DC line from the regulator. By looking on a scope, I found that at this emitter output point I had quite an AC oscillation when the regulator was combined. I eliminated the oscillation with a 40 µF capacitor between the emitter of the 2N3055 and ground. I just grabbed the first tantalum out of the junk box—I suspect that a 10 µF would work just as well.

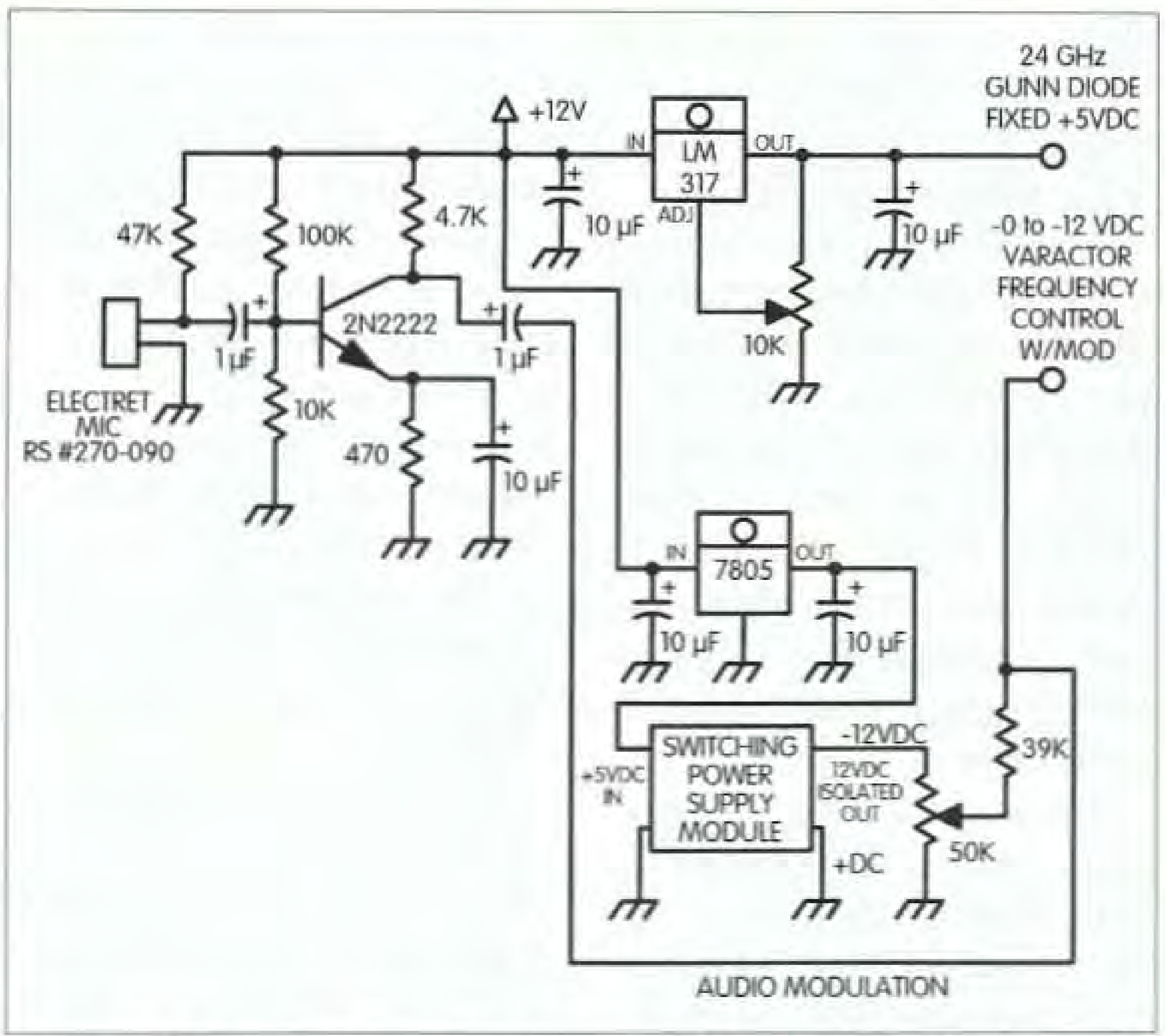

Fig. 3. Schematic changes when using 24 GHz Gunn diode source and varactor tuning arrangements. Note that on the 24 GHz cavity the varactor uses a negative voltage for control of frequency adjustment. Gunn diode voltage must be reduced to the required 5 to 6 V range. Verify your diode's maximum voltage before applying power. Note the addition of a small isolated switching PC-board-mount power supply added to obtain the inverted negative output for varactor tuning voltage. The power supply can be very small, as current required is less than 1 mA.

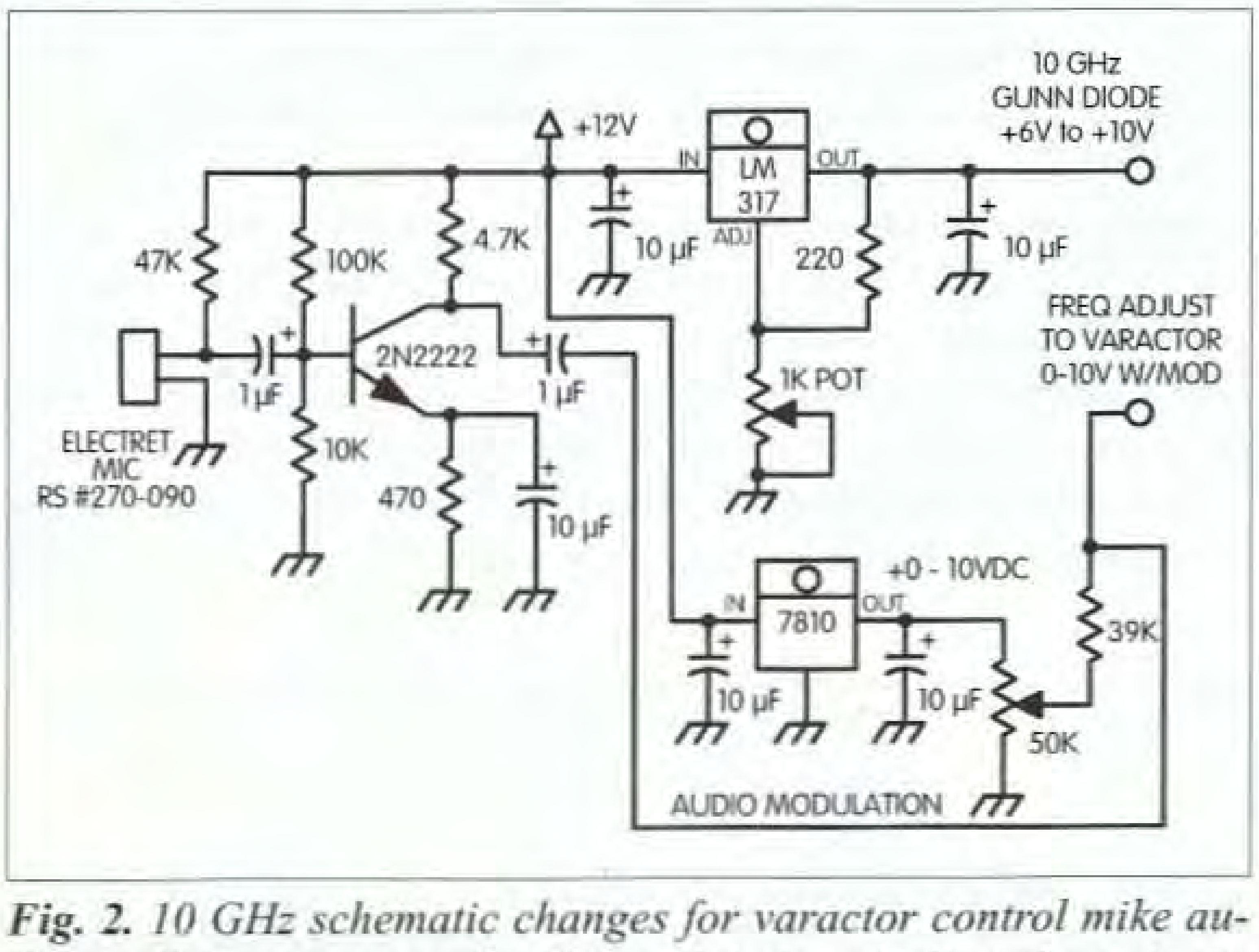

Fig. 2. 10 GHz schematic changes for varactor control mike audio applied to varactor for FM modulation. Audio voltage is superimposed on top of varactor DC control voltage that is used for frequency tuning. The LM317 could be replaced here by a fixed 7810 voltage regulator and used for both Gunn and varactor supply. Two regulators are used in this example for demonstration purposes.

Check out the power supply modulator using a basic scope if you have one. Look at the DC voltage output and set the LM317 up for whatever voltage is required—in the case of our varactor-controlled 10 GHz system, this will be +10 volts nonvariable. The varactor is driven with a positive voltage and is DC-adjustable from zero to +12 volts. Verify voltage operation and then use the scope to verify modulation on the AC-coupled scope. A few millivolts is all that is required of AC modulation superimposed on the varactor DC voltage for proper FM modulation.

In operation with the completed system, check all your power supply connections and voltage requirements twice before you connect up the wrong polarity or wrong voltage to the precious Gunn diode and its associated detector diode. The diode can be bypassed with both a small- and large-value capacitor to lower frequency oscillations. You will find that 0.001 and 10 µF capacitors will do just fine.

The detector diode needs a DC return to draw a little current to bias it slightly on. Most any value small RF choke near 30 µH or so will suffice. Run shielded leads to both the Gunn and detector diodes. I used miniature coax (RG-174) that was

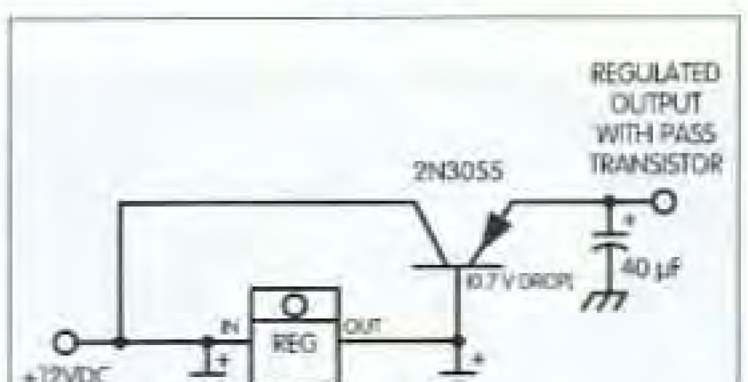

Fig. 4. Bootstrap 2N3055 or similar NPN pass transistor is added to voltage regulator circuit to increase current handling capabilities of voltage regulator. Note: There will be a 0.7 volt drop in regulated voltage out of the regulator due to voltage drop in the base emitter of the pass transistor. Set voltage regulator slightly higher to overcome voltage drop in use.

about one-eighth of an inch in diameter. Coax type is not critical; it's just required for shielding to prevent stray pickup.

Again, I stress: Use different connectors for the connections to feed voltage and detection, to prevent making connections to the wrong lead. If you, for instance, put the detector diode into the 10-volt source, it will destroy the costly detector diode. Use different connectors and you can't make an error in connections.

The detector diode connection is made directly to the 30 MHz input of the Ramsey FR-10 receiver. With the modifications described last month, the receiver should tune over a 400 kHz range of frequencies, making 30 MHz exactly the center of tuning. Normally, you will not have to make any receiver adjustment in frequency. For other stations that might be slightly off-frequency from 30 MHz, you may need to adjust slightly for received clarity.

Operation on microwave is full duplex, just like talking on a telephone. With simple horn antennas, you can communicate over many miles, depending on terrain and path conditions. By adding a small (12 inches in diameter) dish antenna, you can increase available gain by 28 dB (vs. a small horn, whose gain is about 12 dB). Quite an increase in gain with such a small dish antenna. The same comparison is true for 24 GHz operation. However, a one-foot dish at 24 GHz would have about 35 dB of gain because of its smaller wavelength. As frequency increases, wavelength becomes smaller, and you get more gain for the same area than at lower frequencies. Of course, that's for a dish antenna optimized at frequency.

Well, there you go. The package of the Ramsey FR-10 receiver and the transmitter modulator power supply control circuits should get you on the air with simple wideband FM operation. I tested my circuits using the Ramsey receiver, which proved quite sensitive and of great quality. The frequency I used was 24 GHz, because I knew from past experience that if it worked here it will perform on 10 GHz just as well.

Why pick 24 GHz for a test?

We wanted to complete project testing in time for participation in the ARRL 10 GHz and up contest. I used my 10 GHz narrowband station at home and made several contacts, but I really wanted to try 24 GHz for pure fun and to see if both Kerry N6IZW and I could get operational. I constructed and modified the receivers and obtained some small medical receivers to use for a shielded housing after removing all junk from the cabinet except the fuse and on/off switch. A simple conversion of the cases sure beat the prices of new metal cabinets (hams are frugal at times).

Kerry N6IZW constructed the modulator power supplies, and one evening two days prior to the contest we sat down, bench-tested both units, and got them operational. Kerry fashioned his 10 GHz dish with a small C-clamp, to fix the 24 GHz diode assembly near focus, and that allowed him to obtain quite a bit of gain in his system, possibly as much as 45 dB. I did not have time to haul out the dish feed due to commitment to our grandson's soccer game that Saturday morning, so I used a simple miniature horn antenna less than an inch in area for my antenna. Still, I made contact with Kerry over a short test range of about two to three miles, from Mt. Helix to Kerry's front yard.

Then Kerry and I met on top of Mt. Helix and communicated with Ed W6OYJ again on 24 GHz wideband FM. He was on top of San Miguel, where there are several television stations and FM radio stations, besides commercial FM repeaters—all co-located near his operation point. We made contact on 24 GHz, but signals were so strong from an interference point that Ed's S-meter was pinned, with or without 24 GHz signals. Both Kerry and I were able to hear sync buzz from the very powerful video UHF transmitter, even at some 12 miles distance. All in all, it made for a very interesting day and lots of enjoyment.

In retrospect, I can't give enough praise to the Ramsey FR-10 receiver. It delivered in many areas, including the most important one, cost. It is very inexpensive at $35, and outperforms similar systems. It comes with all component parts, a quality PC board, and easy assembly instructions. In field tests that we ran, it proved to be a very important player, and worked far better than I had hoped. If you haven't picked one up yet, do so if you intend at all to get on wideband FM. You should not pass up this fine bargain.

Next time, I want to get into the test equipment that was constructed to allow our testing at 24 GHz. I will bet your work bench is in the same boat mine was, with nothing above 18 GHz in the testing arena. Well, my old 8551 20-year-old (or older) spectrum analyzer goes to blue light with external mixers, but in reality, it's not very good with regard to what it sees. Next time we'll describe what circuitry was assembled to do quality testing at 24 GHz. The approach is not limited to only this frequency but can be applied to others as well—even lower ones—depending on your testing needs.

The main ingredient needed is a spectrum analyzer that can cover up to a GHz or so. We'll let you in on the plot next month and describe what we came up with. 73 for now, Chuck WB6IGP.

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